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MERRIMACK RIVER THERMAL STUDY

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MERRIMACK RIVER THERMAL POLLUTION STUDY

by

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Job Completion Report for Federal Aid Project F-22-R

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ABSTRACT

A three year study was conducted in the Bow to Manchester section of the Merrimack River to determine the effects increased thermal discharges had upon the biological and chemical parameters of the area.

On the basis of data accumulated, it appears an acclimation to increased temperatures occurred to the fishery population of the area for the most part. There was some evidence of a largemouth bass population increase after the plant became operational, as well as an indication the planktonic population is affected to some degree by the heated effluent. Movement of the fishery population from areas affected by the heated discharge was insignificant as was the general water chemistry of the area in comparison to the normal river condition. There was some evidence of better growth to the smallmouth bass in the unaffected area of the river, while redbreast sunfish showed a better growth rate in the area subjected to thermal flow. Whether this was due to the thermal discharge effects, further study is necessary to fully substantiate.

INTRODUCTION

Electrical power production has increased at a rate of 7.2% annually for almost a half-century. This trend is likely to continue and possibly accelerate as the future needs of customer demands are met. The remaining sites suitable for hydroelectric stations are limited, creating a need for more fuel fired stations to meet power generation demands. At the present time such plants produce approximately 81% of the electricity generated in the United States. Future predictions indicate this figure may reach 92% by the year 2000. With this increase in electrical generating facilities, the demand for water as a coolant will increase proportionately creating vast amounts of heated waters to be absorbed by our existing rivers and streams. The result could be a rise in temperature of such water courses to the degree where the existing aquatic populations would be severely affected, and in some cases annihilation of certain species could occur.

Because of the expansion of power facilities on the Merrimack River, it was felt a study to prevent such occurrence should be conducted to determine the effects of the heated effluent on the biota in the Bow section of the Merrimack River.

Although construction had started on the larger generating unit, a cooperative agreement between the Public Service Company and the New Hampshire Fish and Game Department resulted in a study being initiated in 1967, a year before the unit became operational. This study was designed to include detailed studies of the biological, chemical and physical parameters associated with sections of river subjected to temperature increases.

The chemical and physical aspects were obtained and determined by the Public Service Company under the direction of Dr. Normandeau while the fishery aspects of the study were under the direction of the New Hampshire Fish and Game Department.

The objectives of the study were to determine and evaluate ecological changes in the Merrimack River before and after operation of increased power generating facilities using water for cooling purposes at Bow, New Hampshire.

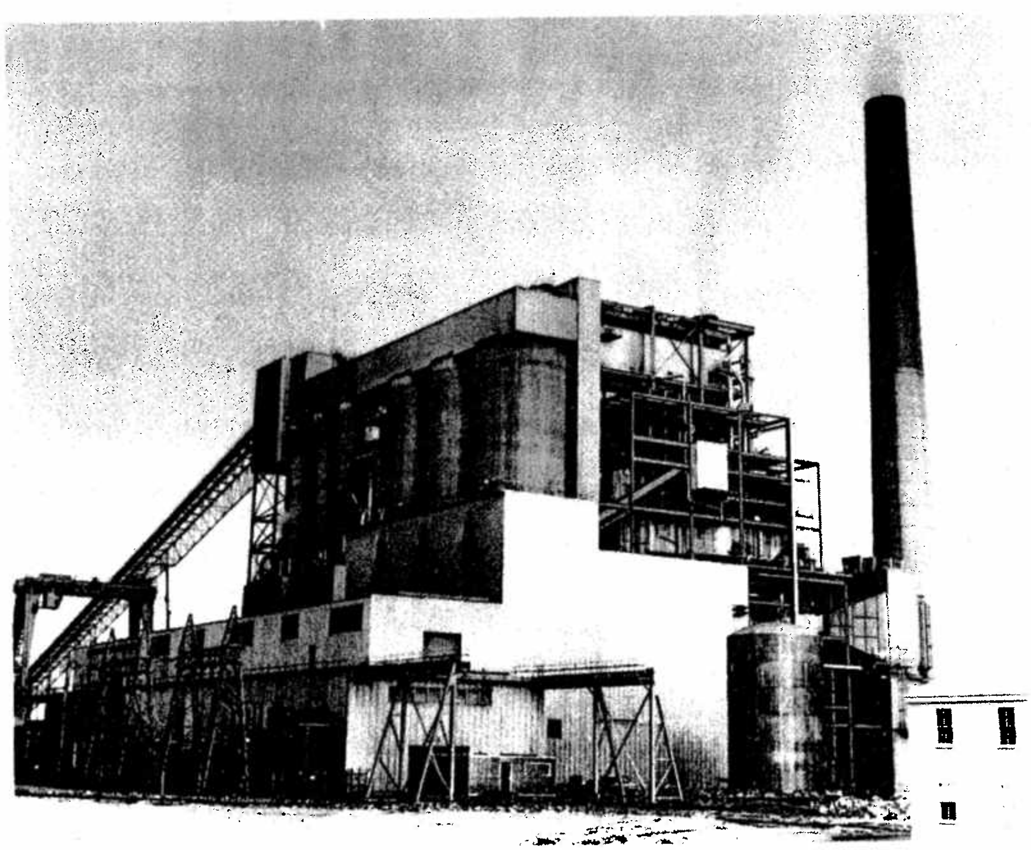
There are two fossil fuel base load electric generating units at Bow. Merrimack 1, or MK-1 is a 120 megawatt steam generating facility using approximately 60,000 gallons of cooling water per minute and has been in operation since late 1960. Merrimack II, or MK-11 is a 350 megawatt steam generating facility and uses approximately 140,000 gallons of cooling water per minute. Completion of this unit was finalized in May of 1968. Both units are designed for a 20 - 25° F. rise in temperature of the condenser cooling waters before release back into the river via a 1500' canal. There are times when the heat differential is greater than 25° F. due to a build up of sand and silt at the plant intake and a resulting decrease in the intake volume of cooling waters.

The volume of water which is subjected to temperature increase is 200,000 gallons per minute (444 cfs) or 286,560,000 gallons per day when both units are at full operation.

As can be determined by the above figures, this is a substantial volume of water, and as a result, a considerable portion of the river during low flows is subjected to use for condenser cooling purposes. There are times when the total flow of the river through regulation by hydro facilities upstream is less than the required intake for full production at the Bow plant. Because there was no consideration for any cooling device during the construction of the power facility, temperatures downstream from the effluent show a significant increase especially during the summer months when flows are at a minimum and seasonal temperatures are highest. There is a marked stratification of the heated waters in the upper three feet during the summer, although some heat conduction occurs to all depths when bottom temperatures are compared with normal river temperatures. Effects of the heated effluent are visibly evident during the winter months by the ice cover on the river upstream of the plant and the lack of ice for many miles below the power facility.

Originally this project was designed to be a long-term study, however, the recent Water Supply and Pollution Control Commission requirements that cooling facilities be constructed as a safeguard against the indiscriminant use of the state's water resources resulted in the construction of such facilities at Bow. At the time of this writing, a spray-type cooling system is being tested at the Bow plant and, if determined to be feasible, will become operational in 1972.

Because of this change in developments, it was felt continuation of the study would be academic, and as a result the study was terminated after three years. The following contents of this report pertain to the portion of the study which was completed from 1967 to 1969 (Figure 1).



Bow Plant (Figure 1)

I. Summary:

As a result of studies conducted for the three year period from 1967 to 1969, it appears that the resident adult fish population was not adversely affected by increased thermal flows from the Bow Steam Plant.

The similarity of composition of the population of fishes between the affected areas of the south and the unaffected area of the north seems to indicate an acclimation to temperature increases occurred. Because it is known fish can adapt to increases in temperatures providing such change is gradual, it appears such was the case in water subjected to maximum temperature increase.

Certain trends were in evidence during electro-fishing, which may be indicative of heated effects to the future fishery composition of the area. Such trends were as follows:

In 1968 and 1969, the southern section of the study showed an increase of largemouth bass after increased thermal flows occurred. Whether this was due to increased temperatures cannot be conclusively stated. However, it is known this species has a higher temperature tolerance than other species collected and the factor of temperature cannot be ruled out.

In 1969, a similar increase in this species occurred in the northern section. Again, whether this is the result of movement from the heated area to the north section as competition for space and food occurred is not fully known.

It appears the Amoskeag section of the study area follows an independent course of its own due to it being a separate impoundment.

The fact gill netting indicated similar numbers of walleyes in the area of Hooksett Falls during the study period, would appear to substantiate the theory that acclimation to temperatures has occurred in this section. Other species sampled gave no consequential evidence of thermal effects in this area.

Netting and electro-fishing in the canal gave evidence that the canal supported a greater abundance of fish-life prior to power plant expansion due to heated water stratification and lower velocities.

Movement based on fin-clip and jaw tag returns showed escapement from areas of temperature stress was of a vertical or cross-stream movement rather than displacement from one area to another.

Age growth studies show very little variation in the growth of yellow perch and pumpkinseeds in the areas involved. Smallmouth bass gave an indication of better growth rates in the unaffected area of the north in 1969, while redbreast sunfish indicated a similar affect in the southern section. Whether this variation was due to thermal effects or is a natural occurrence is not fully known.

Temperature characteristics showed stratification of heated water occurs in the southern section to a greater degree during periods of low flows in the late summer. Although stratification occurs, there is some heat conduction to the lower depths. Because this conduction is especially evident in the forebay of the Hooksett Falls dam, it is likely a detrimental effect would occur to future anadromous fish migrations in this sector.

There was a significant heat dissipation in the southern area prior to mixing of the water in the Amoskeag Pool, which resulted in a maximum temperature difference of approximately 6°F. compared to the northern section, although generally temperatures are not as great.

Comparisons of DO values between the north and south show DO values are comparable; however, because temperatures are higher in this section and more oxygen is needed for metabolic processes, it is felt flows should be increased to combat periods of low oxygen concentrations in the southern section.

Chemical data collected indicated that the effects of the power plant on these parameters is negligible and their effects to the biota is not significant at this time.

A comparison of zooplankton and phytoplankton effects by the thermal discharge indicated some reduction occurs to organisms south of the plant. Although the situation is not critical, the fact a change did occur may be of some consequence during periods of low flows and high seasonal temperatures, as well as to future fisheries in the area.

II. Background:

The study was initiated to determine the effects additional heated flows would have on existing fisheries when power facilities were expanded.

Determination of the fishery composition in the study area, as well as movement and growth characteristics before and after such flows, has been analyzed and tabulated for determination of effects.

A study regarding the physical, chemical and biological changes within the river was conducted by the Public Service Company of New Hampshire as a further determination of thermal effects. As per terms of a cooperative agreement, the data collected by this organization was forwarded to us and the interpretation of said data is included in this report.

III. Objectives:

Determination of the effects additional heated effluents will have on the biota in the Hooksett-Amoskeag impoundment, as well as the tributaries as it pertains to growth, movement and species composition.

IV. Watershed Description:

The Merrimack River Basin lies in central New England and extends from the White Mountains of New Hampshire southward into the east-central portion of Massachusetts. This basin is the fourth largest of those lying wholly within New England and has a maximum length of 134 miles. The mainstem of the Merrimack River is formed by the confluence of the Pemigewasset and Winnipesaukee Rivers at Franklin, New Hampshire. Topography of the basin varies from high, rugged mountains in the north (elevation 4,000-5,000 feet) and west to low plains in the southeast. The study area is located on approximate river miles 73-90 between Garvins Falls, Bow, New Hampshire and the Amoskeag dam, Manchester, New Hampshire.

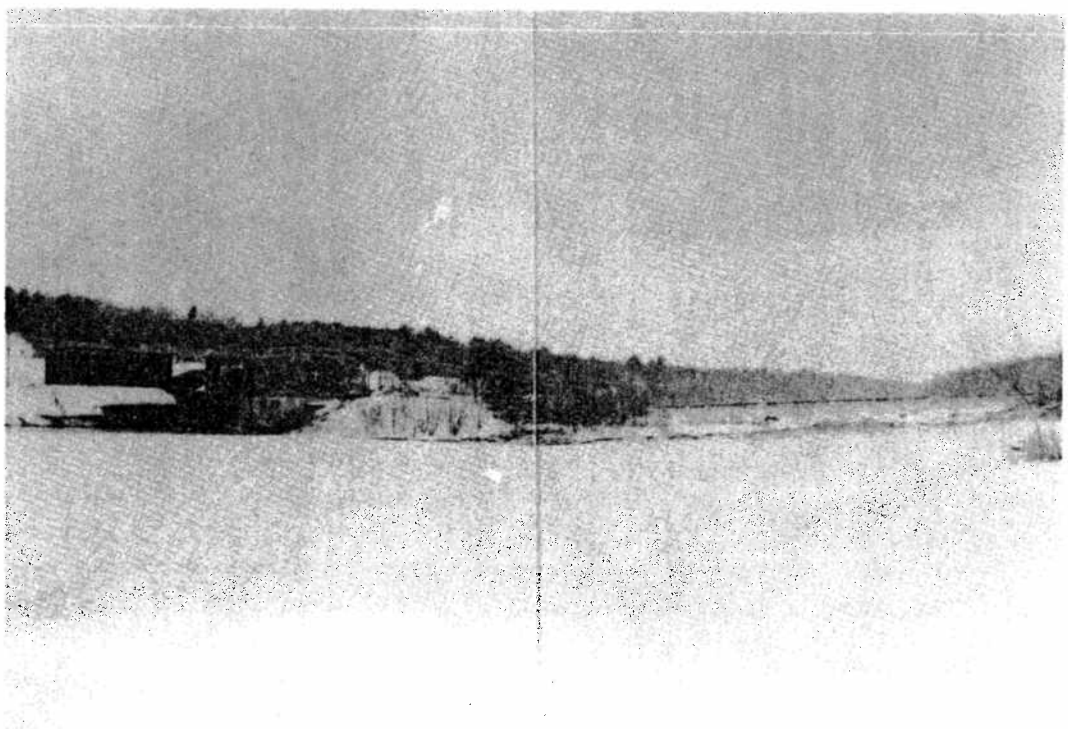
The watershed comprises an area of 5,010 square miles of which 3,800 are in New Hampshire and the remainder in Massachusetts.

In the 94 miles above tide water, the river descends a total of 254 feet at a fairly uniform rate of about 2.7 feet per mile.

The average annual runoff in the basin varies from less than 18 inches (1.3 cfs/square mile) in the lower portion of the basin to over 30 inches (2.2 cfs/square mile) in the area above Plymouth, New Hampshire. The average annual runoff for the watershed is 21 inches (1.5 cfs/square mile) or approximately one-half the annual precipitation. About 50 percent of the annual runoff occurs in the spring from March to May with the remainder being rather uniformly distributed throughout the year with the lowest flows occurring in September.

In the entire river, flows are regulated by hydroelectric dams. A description of the dams in the study area is as follows:

Garvins Falls at the upper end of the study area is a run-of-the-river type plant with the four units having a name plate rating of 7,200 kw. or an annual output of 40 million kw/hr. The drainage area upstream of the site is 2,427 square miles. The dam itself is constructed of granite blocks and concrete on ledge having an overall length of 525 feet and a gross head of 30 feet (Figure 2).



Garvins Falls (Figure 2)

The Hooksett Falls impoundment is approximately seven miles downstream from Garvins Falls and is also a run-of-the-river type generating station. The single unit has a name plate rating of 1,600 kw. and an annual output of 10.8 million kw/hr. The impoundment created by this facility is

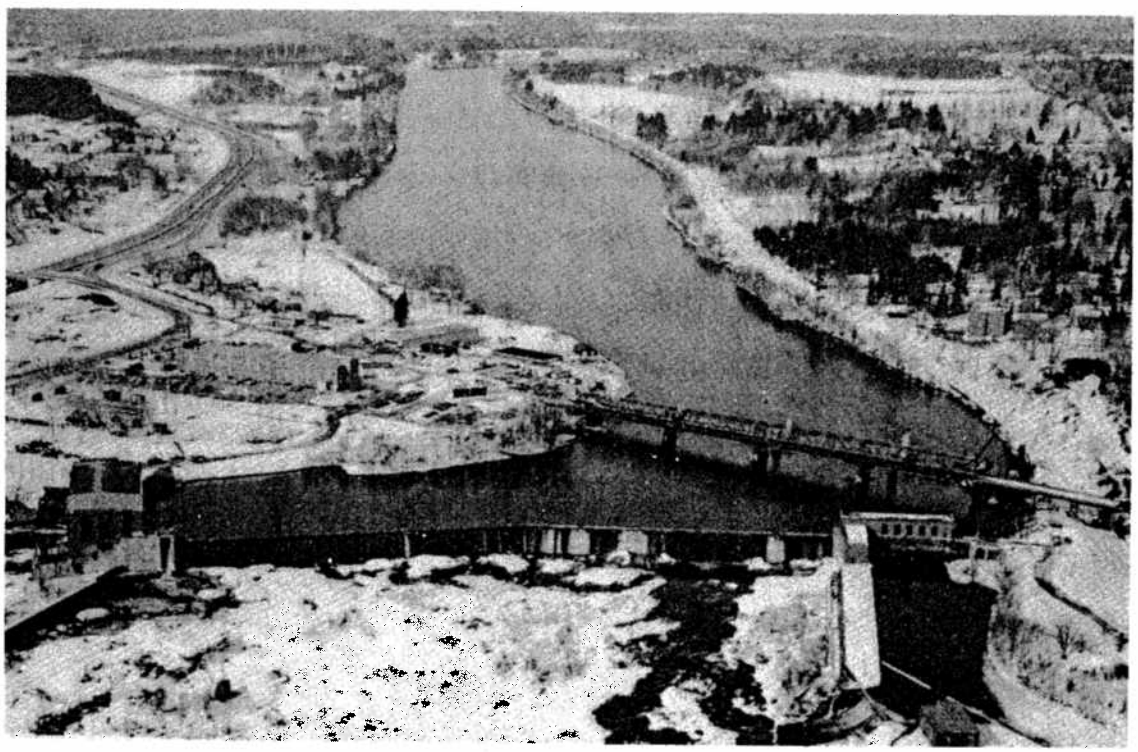
405 acres in size having a drainage area of 2,805 square miles. Daily fluctuations in water levels are not extreme in this section due to the type of power generation, with a normal daily drawdown of approximately one foot.

The dam itself is constructed of granite blocks and concrete on ledge. Its overall length is approximately 638 feet with a gross head of 14 feet. It is within this impoundment the Bow Steam plant is located, which was described in detail in the introduction of this report (Figure 3).

Hooksett Falls (Figure 3)

The Amoskeag impoundment is approximately seven miles in length comprising approximately 478 acres and having a drainage area of 2,854 square miles. The generating facilities are operated as a peaking plant, except when sufficient water is available to operate as a base load plant.

Fluctuations in the water levels are more extreme in this impoundment with fluctuations of 2-4 feet occurring daily. The facility has three generating units with a name plate rating of 16,000 kw. and an annual output of 82.7 million kw/hr. The dam itself is a concrete gravity structure having a length of approximately 1,100 feet and a gross head of 46 feet. A minimum instantaneous release of 50 cfs is made when the turbines are not operating primarily for the benefit of the downstream fishery (Figure 4).



Aerial View of the Amoskeag (Figure 4)

The Merrimack River, within the project area, is fairly uniform in width with the average width being between 500 to 700 feet. Although there are some areas of depth greater than twenty feet the river, for the most part, is relatively shallow with most sections being less than ten feet deep. The bottom type in the area is primarily fine to coarse sand with some variations along the edges of the river where silt to coarse rock is in evidence. Silt and decaying matter is particularly evident in the forebays of the dams due to pollution load sedimentation.

Normal river temperatures are between 70-80^{o} F. during the summer months of July and August, with a decline into the low 30's during the winter months.

Pollution in the form of domestic, industrial and thermal effluent occurs in the areas studied. The thermal effects are from the Bow Steam Plant while the industrial and domestic sewage is from Concord, Suncook, Hooksett and part of Manchester within the study area. The area supports a warm-water fishery which includes smallmouth and largemouth bass, white and yellow perch, brown and yellow bullheads, walleyes, white suckers, golden shiners, chain pickerel and sunfish.

Fishing pressure is light in the area due to the quality of the water which exists at present. Plans to restore anadromous fish such as Atlantic salmon and American shad to the watershed are presently in progress, and with present pollution abatement legislation,the recreational demands on the watershed should increase.

Because of the recreational potential of the watershed, it is of great importance that the natural environment of the river be maintained as much as possible against the encroachment of technological uses which would have an adverse effect on the ecology of the area.

V. Procedure:

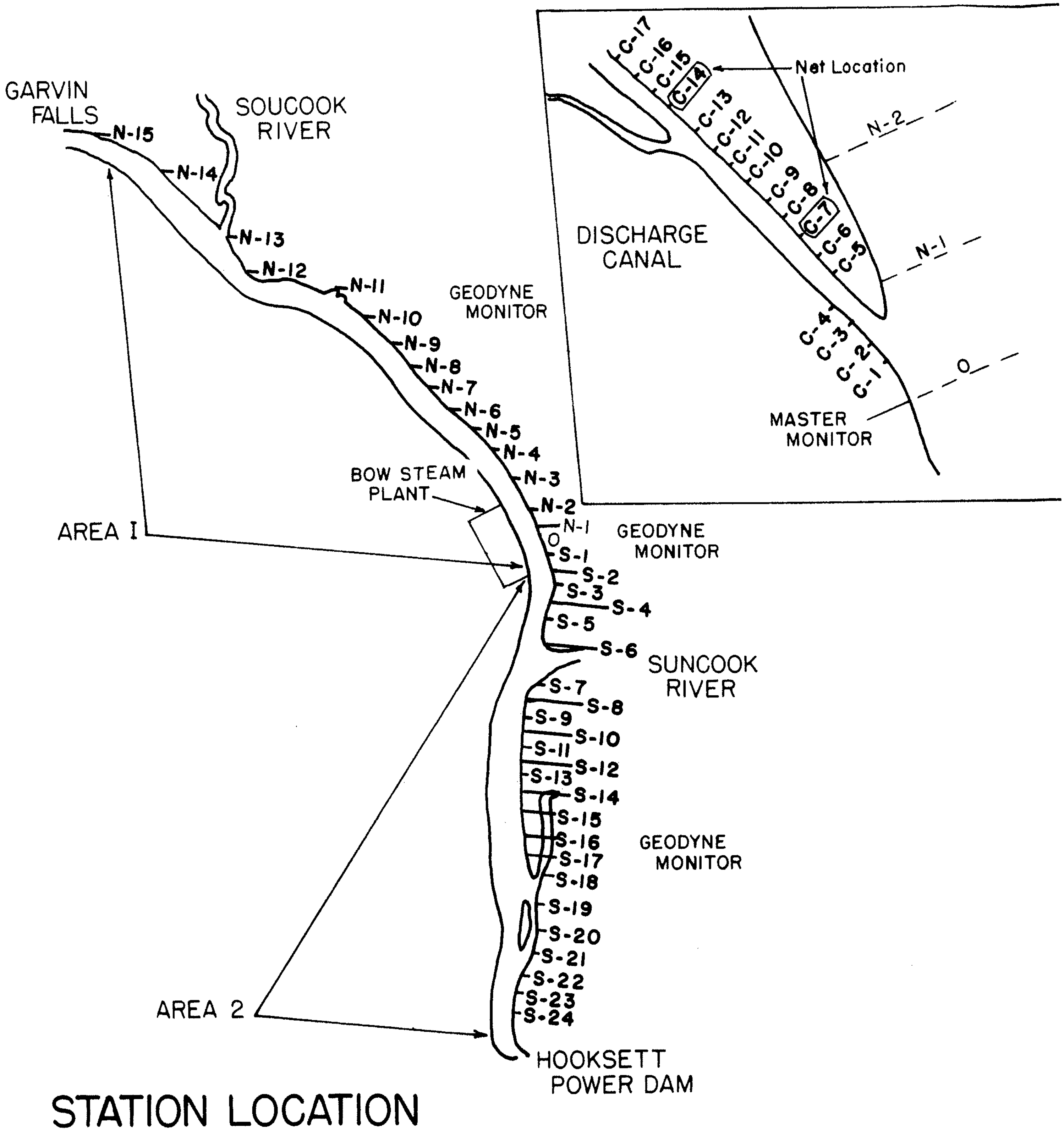
Due to the increased thermal flows from expansion of a fossil fuelled steam electric station in Bow, New Hampshire, a study to determine the effects on the resident fish population as well as the ecology of the immediate area was initiated.

Population studies were conducted during the summer months of mid-June to mid-September from 1967 to 1969, utilizing fyke nets, gill nets and electro-fishing gear. The study area was divided into three sections. The northern section or Area 1, consisted of the river from Garvins Falls to the discharge canal below the plant comprising approximately 3.3 miles of river (Figure 5). The southern section or Area 2, approximately 2.7 miles in length consisted of the area from the heated effluent to the Hooksett Falls dam (Figure 5). The third area commenced below the Hooksett dam and comprised the area from this location to the Amoskeag dam in Manchester (Figure 6). This impoundment is approximately seven miles in length.

Netting sites were delineated by numbered marker posts in Sections 1 and 2 to insure similar net sets during the course of the study, while Area 3 net sites were plotted on aerial photographs to insure similar positioning in this area. Netting was done extensively in the three sections in 1967 and 1968 to determine what the immediate effects of the increased flows would be while 1969 netting was less extensive due to the primary purpose being for age growth data. It was felt 1969 netting was representative of the study area and was treated as such.

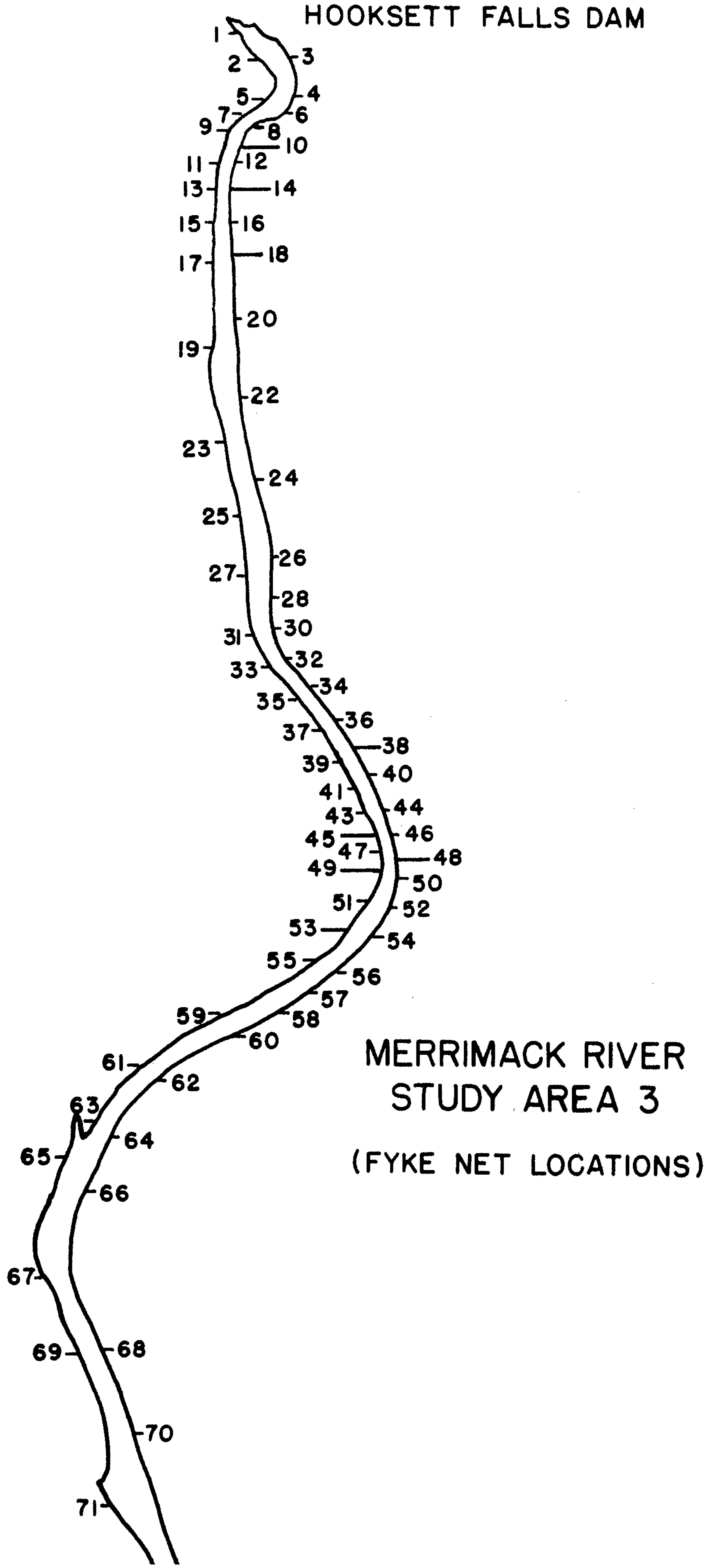
All fish captured by netting were fin-clipped according to the area in which original capture took place. The purpose for this technique was to determine re-captures as well as movement from one area to

FIGURE 5



STATION LOCATION
HOOKSETT POND & DISCHARGE CANAL
MERRIMACK RIVER

FIGURE 6


HOOKSETT FALLS DAM
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MERRIMACK RIVER
STUDY AREA 3
(FYKE NET LOCATIONS)

another. A representative sample of larger fish such as bass, chain pickerel and walleye were given numbered monel jaw tags for similar purposes.

Scales were obtained from a representative sample of the four major species in each area for age growth determination.

Electro-fishing was conducted in the heated canal as well as Areas 1 2, and 3. Area 1, the north section, was shocked on both sides as far north as N-10 (Figure 5), while Area 2 was shocked in its entirety all years of the study. Area 3 was shocked in 1968 and 1969, a distance of 3/4 miles below the Hooksett dam (Figure 6).

Two tributaries were electro-fished in the north section in 1967 and 1968 to determine any change in the fishery population due to possible crowding effects in the mainstem.

Gill netting was conducted on a limited scale in the deeper waters of the river in 1967 and 1968, however, results were inconclusive and it was discontinued in 1969.

Fyke netting was conducted on a limited scale in the winter of 1968, 1969 and 1970 in the canal area, the canal/river confluence, as well as downstream to determine fish movement into the canal during the winter months.

Procedures for determination of values in the Public Service Company study are stated at the beginning of each specific study subject.

Table 1 shows the common and scientific names of fish species encountered during the population studies on the Merrimack River and its tributaries.

Table 1. Common and scientific names of fish species encountered during the population studies on the Merrimack River and its tributaries.

Common Name	Scientific Name
Walleye	Stizostedium vitreum
Largemouth bass	Micropterus salmoides
Smallmouth bass	Micropterus dolomieui
Chain pickerel	Esox niger
Yellow perch	Perca flavescens
Yellow bullhead	Ictalurus natalis
White perch	Morone americana
Brown bullhead	Ictalurus nebulosus
Pumpkinseed	Lepomis gibbosus
Fallfish	Semotilus corporalis
White sucker	Catostomus commersoni
Golden shiner	Notemigonus crysoleucas
American eel	Anquilla rostrata
Blacknose dace	Rhinichthys atratulus
Longnose dace	Rhinichthys cataractae
Eastern madtom	Notorus sp.
Burbot (cusk)	Lota lota
Landlocked salmon	Salmo salar
Redfin shiner	Notropis umbratilis
Redbreast sunfish	Lepomis auritus

The above mentioned data was derived from American Fisheries Society Special Publication Number Six.

VI. Findings:

Fyke Netting

Fyke netting was conducted in Areas 1, 2, and 3 during the summer months of 1967 through 1969. Areas 1 and 2 were netted concurrently during the months of June and July to prevent a seasonal bias in results, while the Amoskeag area or Area 3 was netted during August.

Netting during the 1969 season was not as extensive as previous years, due to the fact the primary purpose was for age growth data.

Although netting was not as extensive in 1969, it is felt a representative sample was derived and data obtained was treated as such.

The following table pertains to net days per year in each section:

Table 2. Net days per year in each section.

	Year	Net Days	Year	Net Days	Year	Net Days
Area 1, North	1967	161	1968	195	1969	78
Area 2, South	1967	193	1968	230	1969	90
Area 3, Amoskeag	1967	382	1968	421	1969	51

An attempt was made to keep netting effort equal in Areas 1 and 2 during the 1968 season, however, high waters caused a suspension of netting activities twice during this period due to nets fouling. In all phases of the study, a reduction in the numbers of fish captured occurred during the 1968 field season indicating a change took place in the river through natural effects rather than thermal effects only.

In Areas 1 and 2 this could be attributed to the higher flows which continued into mid-July (Figure 28, Flow data sheet), while visual observations in the Amoskeag area during netting seemed to indicate more water impounded than the previous year. This circumstance would cause less concentration of fish due to more water area and the netting catch would be lessened. Also of prime consideration is the fact populations of the river are in a constant state of flux and such changes will occur regardless of environmental variations such as thermal pollution. Because of the variations in netting efforts due to adverse water conditions, changes in netting results will be based on percentage of catch rather than total numbers for species.

A summary of the fyke net catch during the study period is depicted in Tables 3, 4, and 5 while the graphic illustrations of change is portrayed in Figures 7, 8, and 9.

Fyke Netting Results - North Section

On the basis of fyke netting in the north, which is the area unaffected by the thermal flows, the following results were derived during the study period.

The predominant species in this section varied each year of the study with pumpkinseeds predominating in 1967, yellow perch in 1968 and white suckers in 1969 (Figure 7).

This fact tends to point out that the river itself is in a constant state of change within its ecological boundaries through natural effects as well as man's intrusion on the environment.

Pumpkinseeds, which were the most abundant species in 1967, showed declines each successive year of the study decreasing from a peak abundance of 33.5% in 1967 to 14.3% of the catch in 1969.

Yellow perch, although declining slightly in 1969, were still within 4% of 1967 values and should be considered as fairly constant in abundance during the course of the study in this section.

White suckers showed an inverse pattern compared to pumpkinseeds as they gave evidence of increases each year of the study increasing from 11.6% of the catch in 1967 to 29% in 1969.

A similar pattern of increase was evidenced by the golden shiner population with an increase noted each successive year of the study rising from 2.9% of the catch in 1967 to 10.5% in 1969.

Brown bullheads, which appeared in significant numbers, showed varying trends from a high of 14.3% in 1967, decreasing to 7.7% in 1968 and then increasing in abundance to 10.1% in 1969. Yellow bullheads, which constitute a smaller portion of the catch, appear to give indications of inverse catch frequency to brown bullheads.

Smallmouth bass remained constant at 3.2% of the catch in 1967 and 1968 while 1969 results showed an increase in this species to 5.4%. A similar pattern of consistency was evidenced by the other centrarchids of the area namely redbreast sunfish.

Chain pickerel seem to be increasing slightly in the area, although their numbers constitute only a small proportion of the catch.

Other species were captured such as fallfish, eels, white perch, walleyes and madtom but, due to insignificant numbers, have little bearing on trends (Figure 7).

Fyke Netting Results - South Section

Netting results in the south section, which is the section subjected to maximum heated effects from the Bow Steam Plant, showed a similar correlation in frequency of abundance to those encountered in the north (Figure 8).

Of the five most abundant species: pumpkinseeds, yellow perch, white suckers, brown bullheads and golden shiners, four showed trends similar to those which resulted in the north. The exception to this trend was the golden shiner population, which showed a decline in 1969 while northern results showed a continued increase.

Table 3 - 1967 Summer fyke netting results indicating number of fish, weight and re-caps in each area.

	BBHD		YP		P. SEED		CWS		EEL		SMB		ECP		RBSF		EGS		Y. BHD		WP		WE-P		LMB		Cusk		Madtom	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
EA 1 161 net-days) Totals	971	284.9	1810	291.4	2266	317.2	784	856.0	34	37.4	217	172.4	75	77.9	276	39.5	199	31.7	105	26.9	6	4.2	2	2.0	-	-	-	-	-	-
-caps	22	7.5	62	12.3	67	9.3	11	8.7	-	-	20	13.3	2	1.9	22	3.6	-	-	4	1.4	-	-	-	-	-	-	-	-	-	-
EA 2 193 net-days) Totals	2056	590.3	1668	288.1	2977	414.4	953	1054.6	39	43.4	159	109.0	90	92.2	380	51.3	704	110.1	146	36.9	2	1.6	-	-	-	-	-	-	-	-
-caps	108	26.5	39	6.8	120	21.1	19	17.2	-	-	32	23.6	-	-	36	5.9	1	.2	7	1.4	-	-	-	-	-	-	-	-	-	-
EA 3 382 net-days) Totals	749	405.5	780	172.6	3290	774.1	261	336.8	61	90.6	657	423.2	36	41.1	290	69.6	41	10.1	44	18.3	4	3.1	85	75.1	9	6.0	2	.7	1	.1
-caps	33	17.8	28	7.6	110	22.0	7	6.3	-	-	60	44.6	-	-	16	4.0	-	-	4	1.8	-	-	1	.7	-	-	-	-	-	-

KEY TO SPECIES OF FISH

BBHD - brown bullhead
YP - yellow perch
P. SEED - pumpkinseed
CWS - white sucker
SMB - smallmouth bass
ECP - chain pickerel
RBSF - redbreast sunfish
EGS - golden shiner
Y. BHD - yellow bullhead
WP - white perch
WE-P - walleye pike
LMB - largemouth bass

All Species	Total Number	Total Weight
Area 1	6,745	2,141.8
Area 2	9,174	2,791.9
Area 3	6,310	2,426.9
Grand Total	22,229	7,360.6

Table 4 - 1968 Summer fyke netting results indicating number of fish, weight and re-caps in each area.

	BBHD		YP		P. SEED		CWS		EEL		SMB		ECP		RBSF		EGS		Y. BHD		WP		WE-P		LMB		REDFIN		MADTOM		FALLFISH	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
…1 (…5 net-…ys) …tals	307	112.6	1181	170.0	980	151.7	713	763.4	9	9.9	128	124.3	78	76.5	221	50.5	238	39.1	102	33.5	6	5.0	1	1.2	-	-	1	.1	-	-	8	5.4
…caps	42	20.6	52	9.4	171	28.8	8	9.9	-	-	29	25.1	3	4.4	79	14.4	14	2.1	5	1.8	-	-										
…2 (…0 net-…ys) …tals	427	138.3	1064	147.5	1438	223.7	545	621.8	13	10.8	44	22.3	50	34.2	253	37.5	626	108.6	53	18.5	9	6.4	-	-	2	1.8	2	.2	-	-	-	-
…aps	33	14.0	30	4.8	367	65.3	19	24.1	-	-	21	21.1	3	2.0	26	4.0	32	5.1	7	2.7	-	-	-	-	3	2.6						
…3 (…1 net-…ys) …tals	262	180.8	833	177.5	2501	589.1	125	215.7	39	53.8	217	141.5	27	16.9	151	38.7	16	5.0	47	23.8	5	4.7	33	51.5	6	.3	-	-	-	-	-	-
…aps	24	15.1	44	10.4	317	78.4	4	7.5	-	-	134	109.8	-	-	22	6.3	1	.2	1	2	-	-	-	-	-	-	-	-	-	-	-	-

All Species	Total Number	Total Weight
Area 1	3,976	1,543.5
Area 2	4,527	1,371.6
Area 3	4,262	1,499.3
Grand Total	12,765	4,414.4

Table 5 - 1969 Summer fyke netting results indicating number of fish, weight and re-caps in each area.

	BBHD		YP		CSF		CWS		EEL		SMB		ECP		RBSF	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
REA 1 (78 net-days) Totals	156	71.6	353	63.0	220	43.8	446	546.6	7	14.9	83	104.9	33	36.0	33	7.1
e-caps	27	17.1	12	3.25	67	12.7	23	28.0	-	-	26	30.3	-	-	11	2.4
REA 2 (90 net-days) Totals	259	114.3	309	42.7	401	75.6	280	372.7	5	7.3	57	36.9	41	31.3	61	12.1
e-caps	40	22.1	11	2.7	136	29.1	16	21.2	8	9.8	-	-	-	-	15	3.4
REA 3 (51 net-days) Totals	72	48.5	170	37.5	284	63.6	78	105.3	2	5.5	77	44.6	5	3.4	34	9.2
e-caps	1	1.0	8	1.8	31	7.3	3	5.9	-	-	15	19.7	-	-	1	.2

	EGS		Y. BHD		WP		WE-P		LMB		REDFIN		MADTOM		FALLFISH	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
REA 1 (78 net-days) Totals	162	43.1	35	18.0	3	2.4	1	3.3	-	-	-	-	-	-	5	4.3
e-caps	11	1.4	1	.3	-	-	-	-	-	-	-	-	-	-	-	-
REA 2 (90 net-days) Totals	161	34.9	49	37.0	13	5.7	-	-	10	12.7	-	-	-	-	3	2.3
e-caps	20	4.7	3	2.6	-	-	-	-	-	-	-	-	-	-	-	-
REA 3 (51 net-days) Totals	1	.2	19	8.3	5	3.7	13	28.8	-	-	-	-	-	-	-	-
e-caps	1	.2	1	.5	-	-	-	-	-	-	-	-	-	-	-	-

All Species	Total Number	Total Weight
Area 1	1,537	959.0
Area 2	1,649	785.5
Area 3	760	358.6
Grand Total	3,946	2,103.1

FIGURE 7

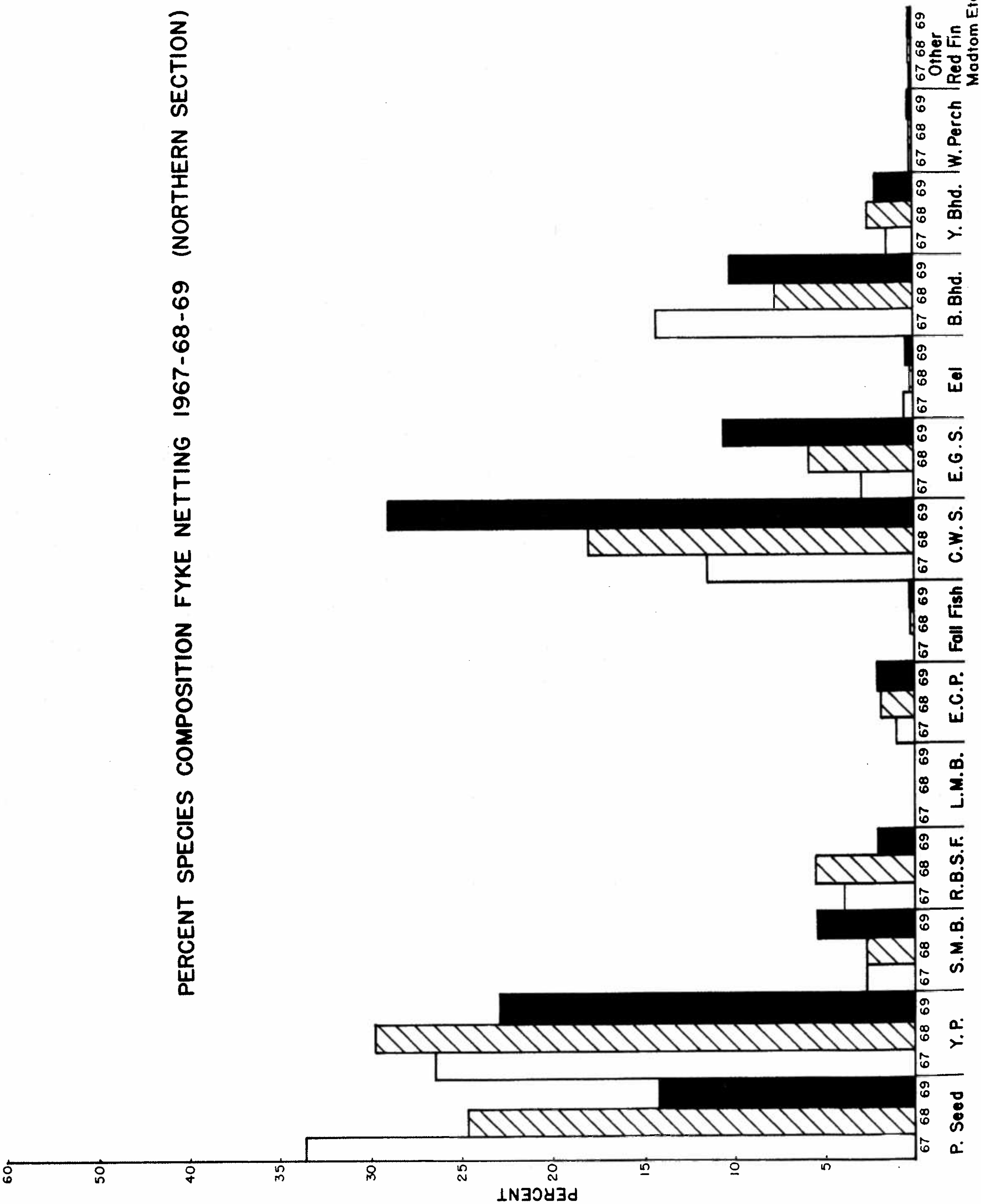
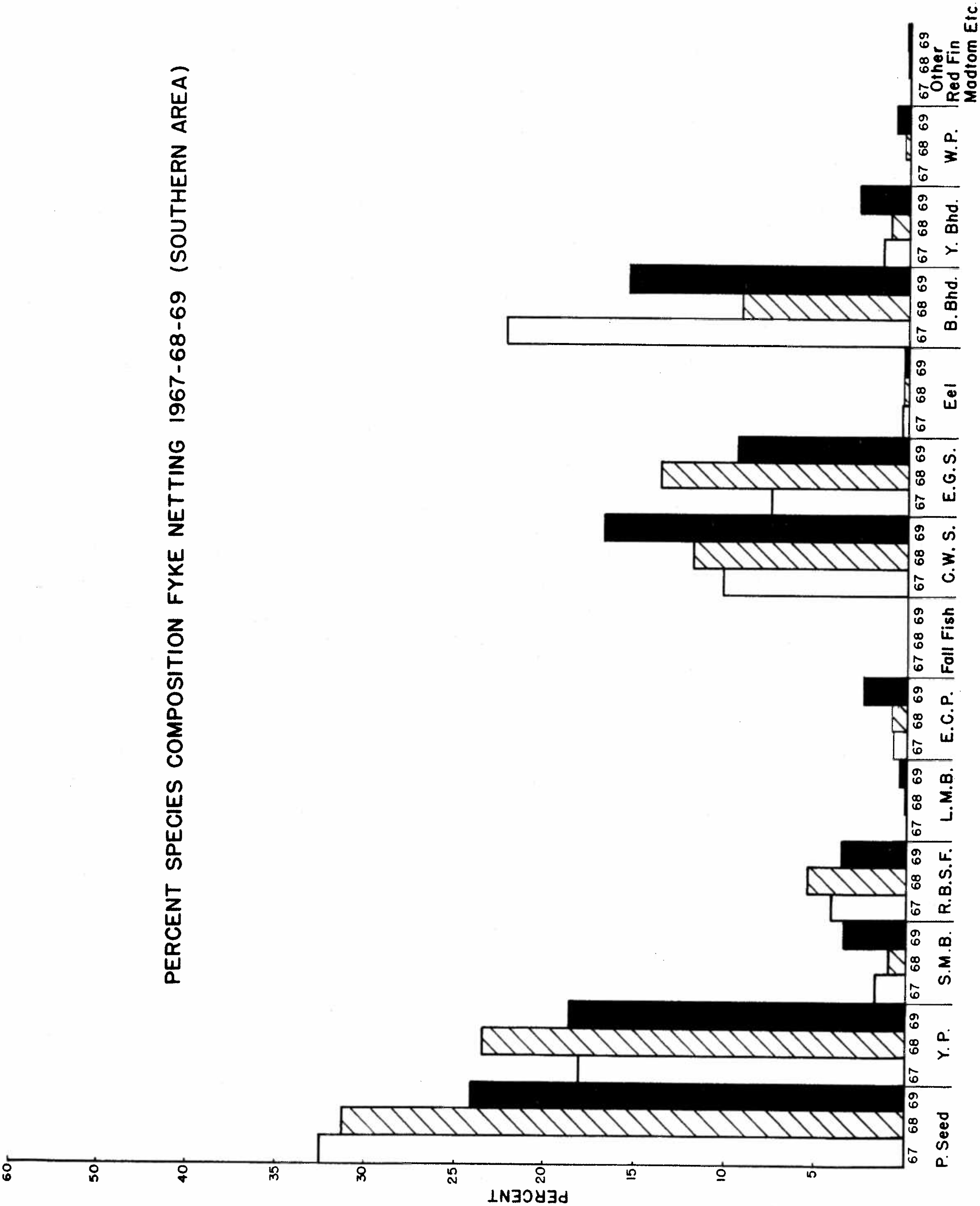

PERCENT SPECIES COMPOSITION FYKE NETTING 1967-68-69 (NORTHERN SECTION)
PERCENT
60
50
40
35
30
25
20
15
10
5
67 68 69
P. Seed
Y. P.
S.M.B.
R.B.S.F.
L.M.B.
E.C.P.
Fall Fish
C.W.S.
E.G.S.
Eel
B. Bhd.
Y. Bhd.
W. Perch
Other
Red Fin
Madtom Etc

FIGURE 8


PERCENT SPECIES COMPOSITION FYKE NETTING 1967-68-69 (SOUTHERN AREA)
PERCENT
5
10
15
20
25
30
35
40
50
60
67 68 69
P. Seed
Y. P.
S.M.B.
R.B.S.F.
L.M.B.
E.C.P.
Fall Fish
C.W. S.
E.G.S.
Eel
B. Bhd.
Y. Bhd.
W.P.
Other
Red Fin
Madtom Etc.

Although a decline was evident in the pumpkinseed population each year from 1967 to 1969, the species still maintained itself as the predominant fish in the southern area throughout the study. This is contrary to northern area results where yellow perch and white suckers were the predominant species in 1968 and 1969 respectively.

Other species included in the catch showed the following trends: Smallmouth bass declined in 1968 but increased above 1967 values in 1969; Redbreast sunfish showed an opposite trend from those of the same species in the north increasing in 1968 and then declining to 1967 levels in 1969; Chain pickerel and largemouth bass showed slight increases each year of the study; while yellow bullheads, although in limited numbers, seem to parallel brown bullheads in increases and decreases. This trend is contrary to northern results where an inverse trend was evidenced between brown and yellow bullhead catch frequencies.

Other species captured in this section but of insignificant numbers to establish any trends were white perch, fallfish, eels, madtoms and redfin shiners (Figure 8).

Fyke Netting Results - Amoskeag Section

Fyke netting in the Amoskeag area revealed this section is less productive than the northern and southern sections of the Hooksett pool. Although there is a complete mixing of the heated waters in this section due to water flows through Hooksett Falls, it is felt other factors such as greater daily water fluctuation compared to the upstream pools must be considered in the reduction. The fact that netting efforts took place here during August when seasonal temperatures are higher and fish activity is less, might also account for the reduced catch in the nets. Of the species captured, pumpkinseeds were the most abundant species comprising over 50% of the catch in 1967 and 1968 before declining to 37% in 1969 (Figure 9). The predominance of pumpkinseeds is similar to the results encountered in the southern area.

Yellow perch, the second most abundance species in the area, showed an increase each year of the study increasing from 12.3% in 1967 to 22.3% of the catch in 1969, a trend which is contrary to that of the north and south section where a decrease was the rule in these sections during 1969.

Smallmouth bass make up a larger portion of the catch in this section than was evident in the upper two sections with 1967 and 1969 results indicating a 10% frequency occurrence, while a decrease to 5.1% resulted in 1968. A similar trend occurred in the redbreast sunfish population, although the decrease in 1968 was not as pronounced due to the fewer numbers of this species involved.

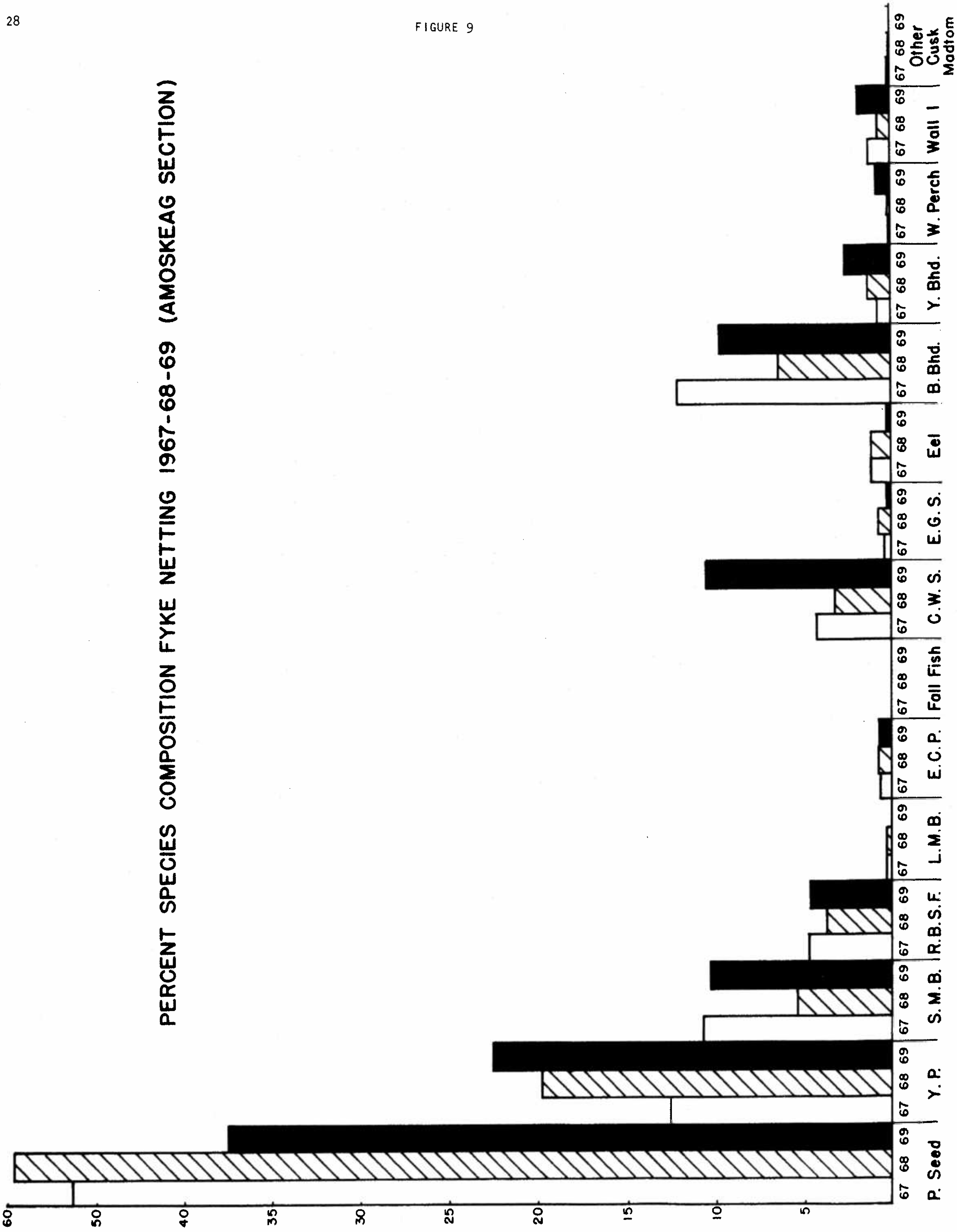
White suckers showed a decrease in 1968 but increased in 1969 to a considerable degree above 1967 results, a trend which appears in all sections sampled.

Brown bullheads had a trend similar to that derived in the upper sections, while yellow bullheads set a pattern of increase each year which is contrary to north or south results.

Walleye, which are more numerous in this area, showed an increase over previous years data in 1969. It is possible predation by this species could account for the low number of golden shiners in this area compared to the upper sections.

Other species captured in insignificant numbers were cusk, madtom, white perch, eels and largemouth bass.

FIGURE 9



PERCENT SPECIES COMPOSITION FYKE NETTING 1967-68-69 (AMOSKEAG SECTION)

Based on fyke netting results, it appears the Amoskeag impoundment follows a more independent population pattern than was evident in north and south section comparisons (Figure 9).

Discussion: Fyke Netting - North, South and Amoskeag

Based on data accumulated from fyke netting results it appears there is a marked similarity in the population trends in the north and south area. This continuity is probably due to the fact the north and south sections are in the same impoundment complex while the Amoskeag area is a separate entity. Of the more numerous species sampled in the north and south section, only golden shiners and yellow bullheads showed a dissimilar trend among the two sections. This would seem to indicate the heated effluent is not having the effect that was feared, at least during the first year of operation. However, the fact the most abundant species in the southern and Amoskeag section remained pumpkinseed, while the northern section varied from pumpkinseeds to yellow perch and white suckers, might be an indication the warmer water is allowing this species to remain predominant in spite of natural effects. It is fairly well documented the sunfish have a greater tolerance than yellow perch or white suckers; because of this factor it is possible the predominance of pumpkinseed could be the result of heated effects. Further study is necessary to substantiate this theory, however, in view of the present data it appears the northern section does not favor the domination of a single species as much as the lower two sections, whether due to pool characteristics or thermal flows is not fully known.

As was stated earlier in the report, the similarity of the Amoskeag impoundment is not as great as that of the north and south sections due to it being a separate impoundment. Although the stratified heated water is mixed in this section causing some warming to the entire cross section of water, it does not appear to be causing undue stress to the present adult fish population. This observation is based on returns derived from species such as yellow perch, walleyes, smallmouth bass and white suckers, which are not as temperature tolerant as other species.

In all cases regarding these species, an increase in catch percentage was noted in 1969 over 1968 returns after increased thermal flows had been in effect for one year.

On this basis, it is felt that an acclimation to the increased temperatures has occurred in the sections affected by warmer waters. What the effects to the physiological make-up behavioral aspects and biological rhythms of these fish are, the study did not entail and further work is necessary to determine.

In summary, it appears on the basis of fyke netting, thermal effects did not create as rapid a change in the fishery composition as was feared. This does not imply that over a long period of time that some effect to the fish population will not occur. This portion of the study pertains to what would, in a sense, be the end of the food chain. Because the duration of the study covers only one year of increased thermal conditions, 1968-1969, it is felt the overall effect to the fishery will not be evident for several years hence.

For these reasons based on fyke netting results to date, it can only be stated there is little evidence of thermal effects to the existing fishery during the first year of increased plant production.

Fyke Netting Canal - Summer and Winter

Fyke nets were placed in the heated effluent canal during the summer of 1967, 1968 and 1969. In 1967 the heated flows were approximately 132 cfs while in 1968 flows had increased to approximately 440 cfs due to the increased production of power plant facilities.

Before the advent of increased flows, stratification was evident in the canal with the following summer temperatures existing during canal netting (38.5°C on the surface and 24.8°C on the bottom). This stratification varied from one foot to four feet depending on the distance from the plant effluent to the confluence of the canal and river. No stratification was evident after increased power production occurred, as indicated by the following temperatures obtained during canal netting in 1968 and 1969. Canal temperatures in 1968 were 38.9°C on the surface and 38.5°C on the bottom, while in 1969, temperatures were 38.9°C on the surface and 38.0°C on the bottom.

It appears that a combination of the increased flows and lack of stratification prevented any escapement from the heated water and resulted in a reduced fish population in the canal.

Summer Fyke Netting - Canal

Fyke netting was conducted at Stations C-7 and C-14 (Figure 5) in late July and early August during each year of the study. In 1967 during eight fyke net days, five different species totaling 230 fish and weighing 31.0 pounds were captured. Of the total number, pumpkinseed comprised 83.4% with brown bullheads comprising 14.3% of the catch. Other species appearing in limited numbers were yellow perch, largemouth bass and smallmouth bass (Table 6).

Table 6 - Summer and Winter Netting Results Canal and Immediate Area Downstream - Merrimack River Study 1967-68-69-70

		BBHD		YP		P. SEED		CWS		LMB		SMB		ECP		Y. BHD		BKT		EGS	
		No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Canal Summer	1967	33	10.7	1	0.3	192	17.4	-	-	2	2.2	2	0.4	-	-	-	-	-	-	-	-
	1968	-	-	-	-	16	1.7	-	-	1	0.1	2	0.2	-	-	-	-	-	-	2	0.1
	1969	1	1.0	2	.3	2	.1	-	-	-	-	-	-	-	-	-	-	-	-	2	.3
Re-caps	1967	2	0.4	-	-	6	0.5	-	-	-	-	1	0.3	-	-	-	-	-	-	-	-
	1968	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1969	-	-	-	-	2	.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Canal Winter	1968	3120	1230.6	11	2.8	270	37.5	5	5.5	-	-	-	-	-	-	52	18.2	-	-	-	-
	1969	5	2.4	3	0.7	19	4.7	2	3.5	-	-	-	-	1	.8	-	-	-	-	-	-
	1970	55	35.8	40	15.4	170	39.4	4	12.4	-	-	1	0.7	4	3.2	9	9.8	-	-	-	-
Re-caps	1968	138	-	1	-	27	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-
	1969	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1970	3	2.0	-	-	21	4.6	1	1.3	-	-	-	-	5	-	-	-	-	-	-	-
Downstream Winter -S-1-W	1968	48	20.1	7	2.2	-	-	11	13.7	-	-	-	-	3	2.6	-	-	1	1.1	-	-
	1969	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Confluence of River & Canal Winter	1968	12	5.7	-	-	1	-	2	2.0	-	-	-	-	-	-	-	-	-	-	-	-
	1969	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Summer Temp:
1967 - Surface 38.5° - Bottom 24.8°
1968 - Surface 38.9° - Bottom 38.5°
1969 - Surface 38.9° - Bottom 38°

Winter Temp:
1968 - Surface 68° - Bottom 45°
1969 - Surface 59° - Bottom 55.4°
1970 - Surface 43° - Bottom 43°

1967 - Canal - Summer - 8 net days
1968 - Canal - Summer - 6 net days
1969 - Canal - Summer - 1 net day
1968 - Canal and Downstream - Winter - 12 net days
1969 - Canal and Downstream - Winter - 10 net days
1970 - Canal - 10 net days

KEY:

BBHD - brown bullhead
YP - yellow perch
P. SEED - pumpkinseed
CWS - white sucker
LMB - largemouth bass
SMB - smallmouth bass
ECP - chain pickerel
Y. BHD - yellow bullhead
BKT - brook trout
EGS - golden shiner

In 1968, six fyke net days yielded only 21 fish of five species weighing two pounds. As was the case in 1967, pumpkinseeds were the predominant species numbering sixteen and comprising 76.1% of the total catch. Smallmouth bass, golden shiner and largemouth bass appeared in limited numbers totaling two each for smallmouth bass and golden shiners and one largemouth bass. Netting during this period indicated that the net closest to the plant effluent at C-14 yielded only pumpkinseeds, which seems to indicate the extreme temperatures at this location preclude survival of other species in this area.

In 1969 a fyke net was placed in the canal at C-7. As was the case in 1968, some fish were existing in the canal although not in the numbers prior to increased flows. The catch consisted of two each of pumpkinseed, yellow perch and golden shiners, plus one bullhead.

Visual observations during the field season indicated pumpkinseeds existed in the canal during June and early July in 1968 and 1969. However, upon the advent of increased seasonal temperature, as well as the lack of stratification, the majority of these individuals apparently dropped back into the main river resulting in reduced numbers during fyke netting efforts.

Winter Fyke Netting - Canal

Winter fyke netting was conducted at C-7 and C-14 in the canal at the canal river confluence and at S-1-W in late January of 1968 and 1969, while in 1970, nets were placed only in the canal portion.

As was the case during summer netting, a greater abundance of fish life wintered in the canal prior to increased generating capacity, rather than after.

Winter temperatures during 1968 netting ranged from 20° C on the surface to 7° C on the bottom, while 1969 temperatures were 15° C at the surface and 13° C on the bottom. The netting for 1970 showed lower temperatures existing in the canal with temperatures of 11° C and 6° C being recorded on separate days and very little stratification occurring. This reduction in temperature was probably due to a decrease in the generating output at the Bow Steam Plant and is not indicative of maximum or normal temperatures during the winter months.

In 1968, during six net days, a total of 3,458 fish were captured utilizing fyke nets; brown bullheads were the predominant species comprising 90.4% of the catch. Pumpkinseeds comprised 7.80% with yellow bullheads, yellow perch and white suckers appearing in descending abundance (Table 6).

Results during the 1969 winter fyke netting showed a pronounced reduction in fish captured with only 26 fish representing five different species being taken during four net days. To insure the fyke nets were not fouling, two gill nets were placed at the same locations across the entire canal with the result being four fish taken by this means. As was the case during summer months, pumpkinseeds were the most abundant species comprising 63.3% of the catch followed by brown bullheads at 16.6% with yellow perch, white suckers and chain pickerel completing the catch in this order.

Results of winter netting in 1970 indicated an increase of fish in the canal compared to 1969 netting totals, but still far below the figures derived during 1968 netting efforts with a total of 283 fish being captured. Pumpkinseeds continued to be the most abundant species comprising 60.0% of the catch followed by brown bullheads and yellow perch at 19.4% and 14.1% respectively. Yellow bullheads, chain pickerel, white suckers and smallmouth bass completed the catch in descending order of abundance.

In 1968 and 1969 nets were also placed at the confluence of the canal/river and at S-1-W. As occurred with nets placed in the canal, there was a marked decrease in fish captured in 1969 compared to the previous year when heated flows were less.

In 1968 a total of 85 fish were captured at these locations compared to no fish in 1969. Brown bullheads were the most abundant, as was the case in the canal during this period, followed by white sucker, yellow perch, chain pickerel, pumpkinseed and brook trout. Temperatures during the netting period were 17^{o} C on the surface, 2^{o} C two feet below the surface and 1^{o} C at the bottom. It appears white suckers prefer the temperature existing in this area to those in the canal, while pumpkinseeds exhibited an inverse tendency appearing in greater numbers in the canal itself. The brook trout was the only trout caught during the entire study, seeming to indicate that a limited number do exist in the river under present conditions.

<u>Discussion</u>: <u>Fyke Netting</u> - <u>Canal</u>

On the basis of netting the canal, it appears conditions prior to increased plant capacity were more conducive to fish life than was the case after increased effluent flows occurred. This was probably due to the absence of stratification in the canal upon the advent of increased flows which afforded no relief from the effluent temperatures. Pumpkinseeds appear to be the most tolerant species to the warmer temperatures, being observed in the canal proper as far as the outlet pipe during June and early

July. Upon the increase in seasonal temperatures, however, the majority of these individuals either die or are displaced back to the mainstem where temperatures are not as extreme.

It is interesting to note smallmouth bass appeared in small numbers during 1968 summer netting when extremely high temperatures existed. How long these individuals existed in the canal is unknown, however, the fact juveniles did appear in the net gives evidence some fish will swim into and exist in hot water although it is of a lethal temperature.

Although 1969 and 1970 winter netting results were far below 1968 results, the reason for discrepancy between 1969 and 1970 netting totals can only be theorized. A chemical check of the area shortly after 1969 netting did not show any condition which would cause distress to fish, however, it is possible an overdose of cleansing reagents could have occurred during daily algicide treatment at the plant. An occurrence such as this could have caused a movement of fish out of the canal area.

Also to be considered is the fact a burst boiler pipe caused an emergency shutdown of MK-II in the late fall. Whether reverse thermal shock occurred to fish when this malfunction occurred or the fact the heated attraction was reduced after winter dormancy occurred is not known. It is apparent the ability of a fish to temperatures above 20° C (Doudoroff, 1942 and Brett, 1944). Conversely the loss in this increased tolerance, and the gain in resistance to low temperatures are inherently slower processes, requiring up to 20 days in some species to approach completion. These rates appear to be governed by the rate of metabolism which if depressed by low environmental temperature automatically reduces the rate of acclimation. Whether such an occurrence took place in the canal during the malfunction and resulted in the reduction of fish cannot be verified, however, the fact remains a marked decrease did take place.

Because breakdowns do occur and abrupt temperature gradients could take place the question as to what effect this has upon fish life in the canal and river proper is raised.

In view of these unanswered questions, it is felt future cases of emergency power plant shutdowns should be investigated to determine the effects to the fishery in the area.

Electro-fishing

Electro-fishing was conducted in the same areas in 1967 through 1969 to determine what changes occurred before and after additional heated flows occurred. Area 1, or the northern section above the plant was shocked as far north as Station N-10, while Area 2 was electro-fished from the steam plant effluent to the Hooksett dam. Two tributaries, Bow Bog Brook and the Soucook River, in the northern area were shocked to determine if any fish movement from the main stem occurred due to thermal flows and possible resulting crowding conditions. A small portion of the Amoskeag pool below Hooksett dam was shocked during the 1968 and 1969 seasons.

On the basis of electro-fishing results from 1967 to 1969 in the north and south areas, a reduction in numbers of fish captured occurred during 1968 and 1969 seasons in comparison to 1967 results. Reductions of 75% and 70% respectively in fish captured in the north occurred during the 1968-1969 electro-fishing efforts, while the southern area showed a reduction of 58% and 70% during the same period.

The Amoskeag area showed a similar trend during 1968 and 1969 efforts with a reduction of approximately 73% occurring in 1969.

Again, the fact some change occurred in the river itself, other than thermal pollution, seems to be the most likely explanation for the reduction of fish numbers in all phases of work.

Electro-fishing - North Section

Electro-fishing results in the north section during the three years of the study show no definite trend being established by the most abundant species, namely pumpkinseeds and yellow perch (Figure 10). It appears pumpkinseeds, which were the predominant species during 1967 and 1968 electro-fishing efforts, suffered a decline in 1969. Yellow perch on the other hand appeared to increase after declining to 12.7% in 1968, as they comprised 38.5% of the total catch in 1969 and were the predominate species.

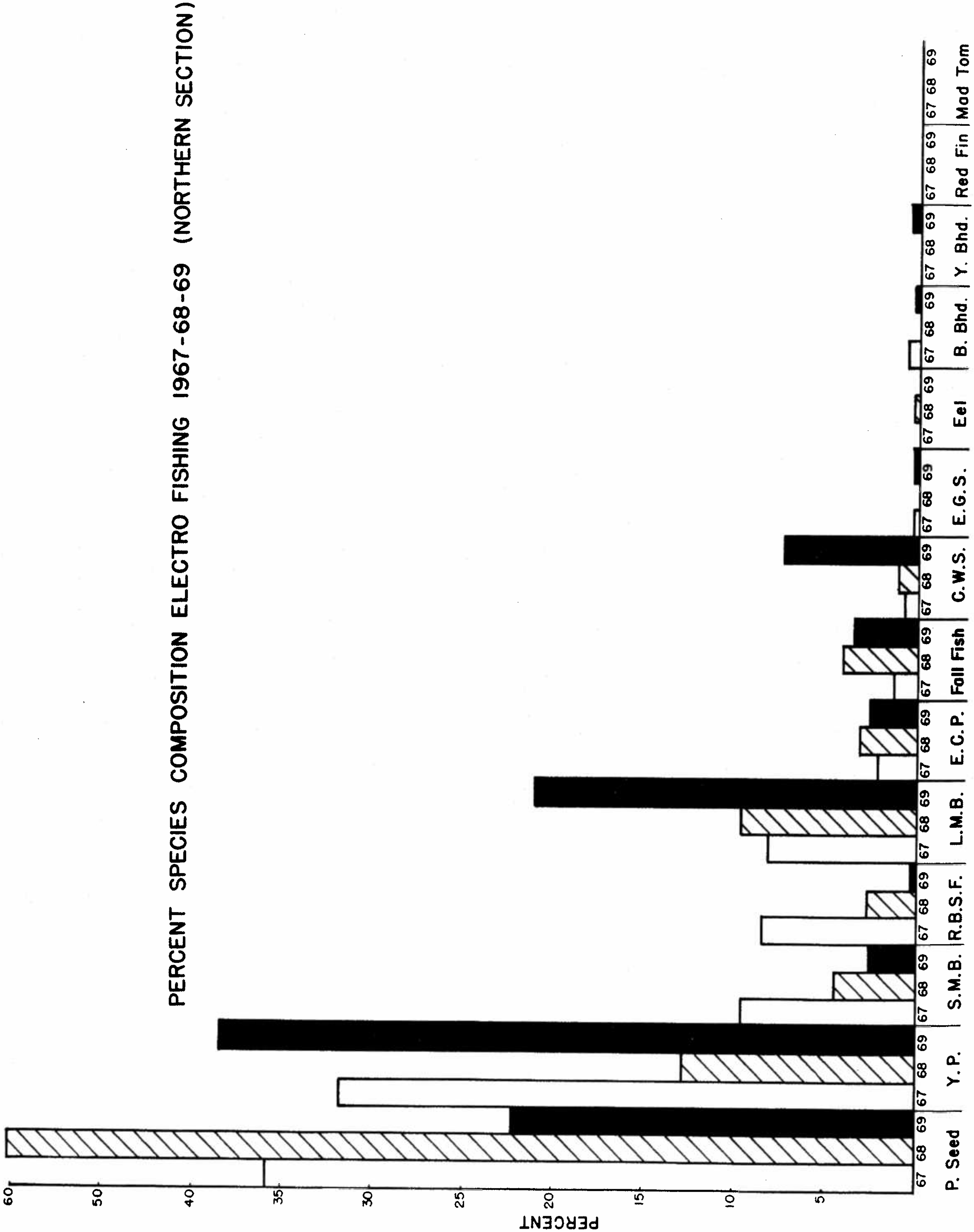
Smallmouth bass show an inverse trend compared to largemouth bass as the former showed decreases each successive year while largemouth bass showed a slight increase of 1.5% in 1968 and then increased to 20.2% of the catch in 1969, a rise of 12% over 1967 results. This would seem to indicate the increase of largemouth bass in the south is also occurring to a lesser degree in the north as will be pointed out later in the report.

Redbreast sunfish, a centrarchid showed a decrease in numbers each succeeding year as did the smallmouth bass.

Fallfish and chain pickerel appear to be remaining fairly constant, while white suckers appear to be on the increase, an occurrence which was borne out by fyke netting results.

Other species which were captured during electro-fishing, but in insignificant numbers to represent a trend were golden shiners, eels, brown and yellow bullheads.

FIGURE 10



PERCENT SPECIES COMPOSITION ELECTRO FISHING 1967-68-69 (NORTHERN SECTION)
PERCENT
60
50
40
35
30
25
20
15
10
5
67 68 69
P. Seed
Y. P.
S.M.B.
R.B.S.F.
L.M.B.
E.C.P.
Fall Fish
C.W.S.
E.G.S.
Eel
B. Bhd.
Y. Bhd.
Red Fin
Mad Tom

Electro-fishing - South Section

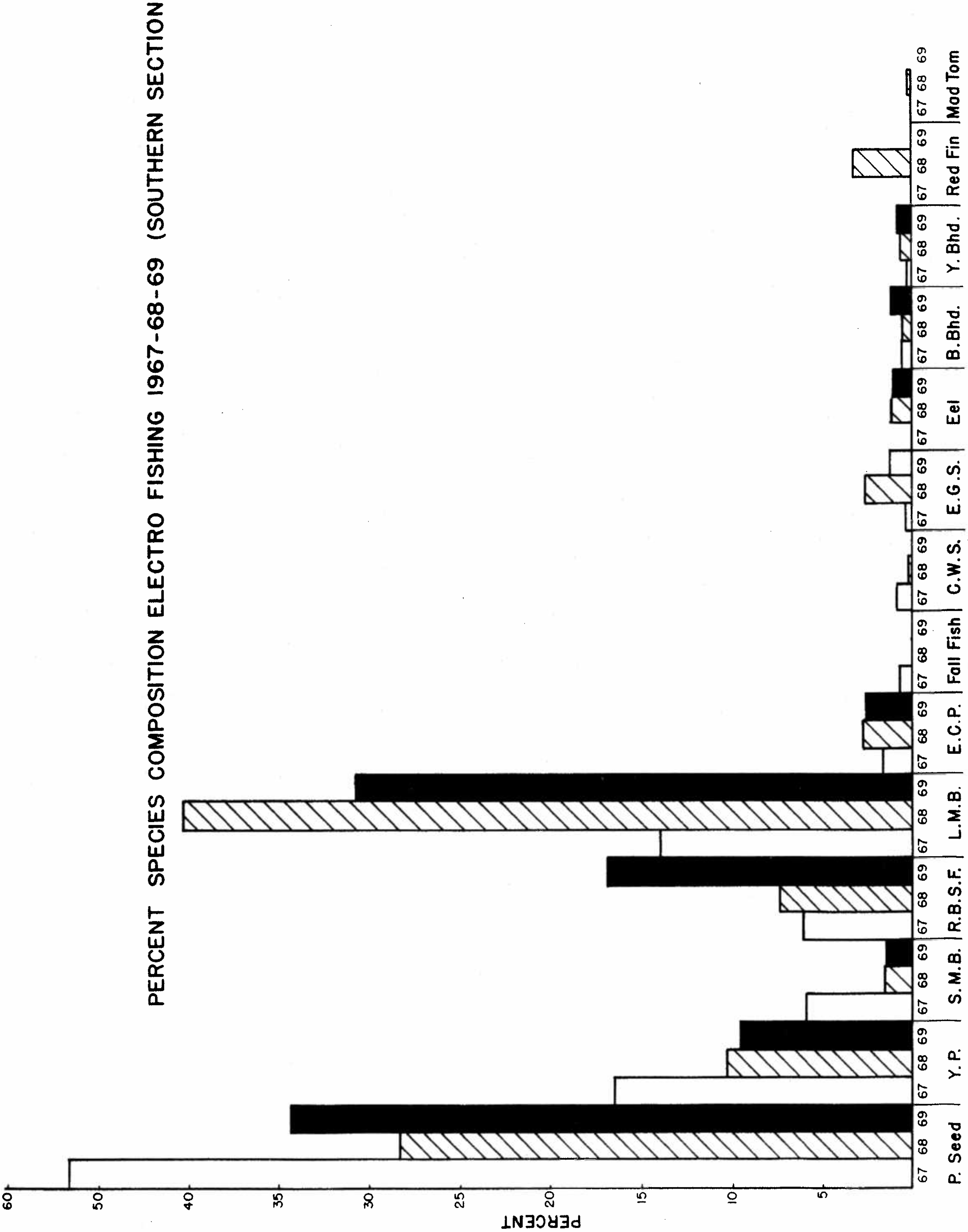
Contrary to fyke netting results variations in species composition trends were more pronounced between the north and south sections during electro-fishing efforts, especially among the pumpkinseed and yellow perch populations (Figure 11).

In this area, pumpkinseeds showed inverse trends to the north during the 1968 and 1969 season, while yellow perch showed a decrease each year of the study in the south compared to a decrease and then an increase in the north.

Smallmouth bass showed a similar trend of decline in both sections, although the decline of 1969 was very slight in the south.

Redbreast sunfish indicated an increase each year in the southern section which compares inversely to northern results for this species. It is interesting to note the other centrarchid, the pumpkinseed, showed a similar pattern of inverse change compared to the northern area.

Probably the most significant result of the electro-fishing data is the indication of a significant largemouth bass population appearing in this section. Because largemouth bass prefer warmer waters and are more heat tolerant then smallmouth bass, it is possible future increases will occur to the former at the expense of the smallmouth bass population. Although it was not possible to determine movements of largemouth bass, due to their lack of susceptability to netting, the fact a substantial increase of largemouth bass occurred in the north in 1969 may have been an indication they are migrating to this section as competition for food and space takes place in the south.


PERCENT SPECIES COMPOSITION ELECTRO FISHING 1967-68-69 (SOUTHERN SECTION)
PERCENT
60
50
40
35
30
25
20
15
10
5
67 68 69
P. Seed
Y. P.
S. M. B.
R. B. S. F.
L. M. B.
E. C. P.
Fall Fish
C. W. S.
E. G. S.
Eel
B. Bhd.
Y. Bhd.
Red Fin
Mad Tom

Further study will be necessary to provide proof of this occurrence and its cause; however, the fact certain trends appear to be becoming established may be an indication of a change which will occur in the future.

Chain pickerel remained relatively constant in this section, although a slight increase did occur in 1968 and 1969 over 1967 results.

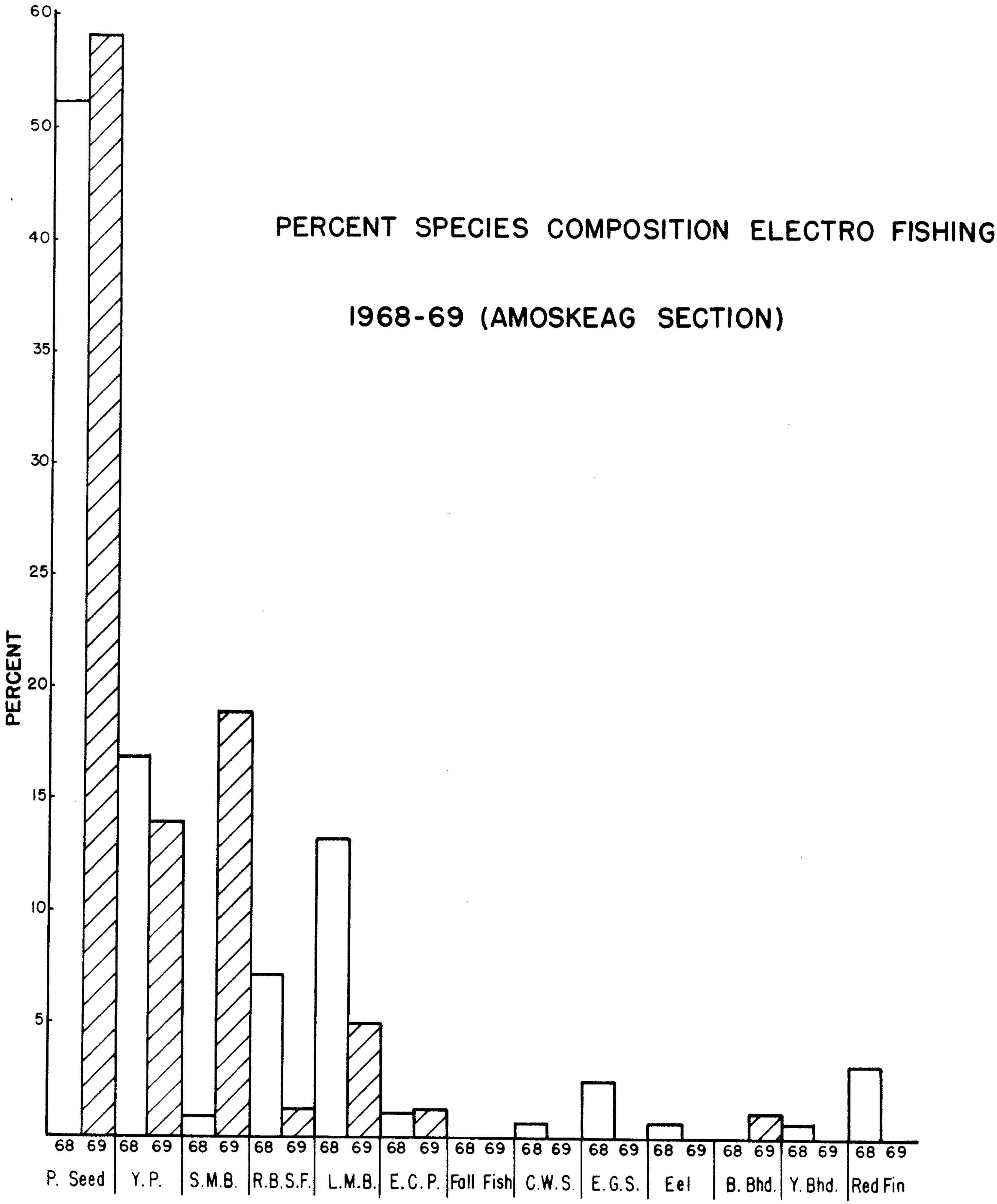
In 1969, white suckers did not appear to be as abundant in the shallow waters of the south section as they were in the north. It is known white suckers are primarily a deep or cool water fish, however, because they did appear in significant numbers in the north during 1969 electro-fishing as well as during fyke netting efforts in all areas, it is possible some change in their behavioral patterns has resulted due to temperature effects. Further study is necessary to conclusively determine if this assumption is valid; however, the fact no suckers showed in the catch during this phase of the study may have more significance than appears at first glance.

A breakdown of the other species captured is depicted in Figure 11.

Electro-fishing - Amoskeag Section

Electro-fishing results in the Amoskeag Pool provided very little evidence of any significant change to the species in this area due to thermal effects. As was the case during fyke netting efforts, it is apparent this area follows an independent course compared to the upper two sections (Figure 12).

Pumpkinseeds and yellow perch followed trends similar to those encountered in the south section.



PERCENT SPECIES COMPOSITION ELECTRO FISHING
1968-69 (AMOSKEAG SECTION)
PERCENT
60
50
40
35
30
25
20
15
10
5
68 69
P. Seed
Y. P.
S.M.B.
R.B.S.F.
L.M.B.
E.C.P.
Fall Fish
C.W.S.
E.G.S.
Eel
B. Bhd.
Y. Bhd.
Red Fin

Smallmouth bass, contrary to the results of the upper two sections, showed a significant increase from 1968 to 1969, while the other centrarchids - redbreast sunfish and largemouth bass showed a decline. The decline of largemouth bass in this area tends to dispute the claim of largemouth bass migrating to the northern area (refer to southern results, page 39). However, it must be remembered sampling was done in September when flows were at a minimum and any movement from the southern area to the Amoskeag pool would entail movement over the dam during high water or through the turbines during low flows. Because there are flows in the river most of the time in which fish can orientate themselves, it is felt a movement upstream into the northern section would be more likely than movement downstream to the Amoskeag area. The closer proximity of the northern area from the area of maximum heated effects could also be a significant factor as to why the north showed an increase of this species and the Amoskeag did not.

White suckers, as was the case in the south, did not appear in Amoskeag results during the electro-fishing efforts in 1969. This again raises the question as to why fyke netting results indicated an increase of this species in all sections studied, but only the north showed an increase during electro-fishing.

It is possible a displacement of young suckers is occurring in the shallow waters of these two areas due to heating effects creating temperature conditions too high for habitation by this species.

Chain pickerel appear to be unaffected by environmental changes as they remained fairly constant in this section as was true in all areas studied.

Other species which appeared in insignificant numbers are depicted in Figure 12.

Electro-fishing - Canal

Electro-fishing in the canal during September, 1967, indicated several species of fish existed in the canal itself. Pumpkinseed were the most numerous species followed by largemouth bass, smallmouth bass, yellow and brown bullheads, as well as redbreast sunfish (Table 7).

Table 7. Length frequency from electro-fishing results in the canal.

Length	RBSF	P. SEED	LMB	SMB	BBHD	Y. BHD
2.0 - 2.4		2				
2.5 - 2.9			5	2		
3.0 - 3.4			6	2		
3.5 - 3.9		2	2			
4.0 - 4.4		3				
4.5 - 4.9		10	1			
5.0 - 5.4		10	1			
5.5 - 5.9	1	5	1	1		
8.0 - 8.4						2
8.5 - 8.9					1	
Weight (lb.) 4.6	2	3.0	.5	.3	.3	.3
Numbers - 57	1	32	16	5	1	2

RBSF - redbreast sunfish
P. SEED- pumpkinseed
LMB - largemouth bass
SMB - smallmouth bass
B. BHD - brown bullhead
Y. BHD - yellow bullhead

Subsequent shocking in the canal in September 1968 and 1969 resulted in no fish being captured by this means, although pumpkinseeds were observed swimming ahead of the electrodes during this phase of the study. Again it appears that the canal stratification which existed in

1967 (31.9° C surface and 20.3° C bottom) but not in 1968 (surface 36.6° C and bottom 35.3° C), as well as the increase of heated flows from 132 cfs to 440 cfs, created conditions non-conducive for fish life upon completion of the increased power facilities.

Discussion: Electro-fishing

It is interesting to note the variations which occurred during fyke netting did not necessarily continue to occur during electro-fishing efforts.

This is probably due to the fact electro-fishing equipment evaluates the shallow area habitat of young fish populations while fyke nets evaluate the fishery biota in the waters of greater depths. Also to be considered is the fact certain species such as largemouth bass do not net as readily as smallmouth bass. This is most apparent when comparing fyke netting with electro-fishing results.

The most significant result indicated by electro-fishing is the fact largemouth bass are on the increase in both the north and south section. In the south section a yearly increase of 26% and 16% occurred over 1967 results, while the northern section showed an increase of less than 2% in 1968 and then increased to 12% over 1967 results during 1969 studies. It appears largemouth bass are increasing in the south with a possible movement into the northern section as competition increases. Smallmouth bass, on the other hand, showed a decline in the north and south section each year of the study, although the decline in the south was slight in 1969.

Ferguson states the preferred temperature for largemouth bass is 80° F to 82° F, while Brett listed the upper lethal temperature for largemouth bass acclimated at 86° F to be 97.5° F. Smallmouth bass tolerances are lower with field observations indicating 68.5° F to 70.3° F the preferred temperatures. Acclimation to increased temperatures would raise this tolerance to a higher degree, but the maximum temperature of survival would still be less than largemouth bass.

Because of the temperature tolerance difference between the two species, it is highly feasible the increased temperature in the south is creating a more desirable environment for largemouth bass, while the smallmouth bass will maintain their numbers for a time before encroachment of largemouth bass numbers will cause a further decline in the smallmouth bass population.

The Amoskeag impoundment on the other hand in 1969 showed an increase of smallmouth bass over 1968 results while the largemouth bass showed a decline which is the opposite of the upper sections. Because the waters in this section are not exposed to the warming which occurs in the south, it is possible the largemouth bass have not become established as quickly in the Amoskeag section. As to movement, it is felt the proximity of the north section to the southern areas, which are exposed to maximum heated effect, is much closer than escapement to the Amoskeag area. The fact a 10% increase of this species occurred in the north compared to a 10% decrease in the south seems to be more than a coincidence.

Other centrarchids such as pumpkinseed and redbreast sunfish showed varying trends. Redbreast sunfish in the northern and Amoskeag area showed declines in their populations, while the southern area shows an increase each year. On this basis due to the high temperature tolerance of redbreast sunfish, it is possible the warmer waters in the southern section are creating an increased population; however, if this was the case, it is felt the pumpkinseed would have shown a similar trend. This is not apparent as the highest percentage occurrence of this species occurred before increased thermal flows began in the southern section.

Yellow perch showed considerable fluctuation in the northern section with the lowest order of abundance occurring in 1968 and the highest incidence in 1969. The two southern sections showed declines all years of the study. The fact yellow perch have a thermal death point of 73-77° F (Erickson Jones) could have some bearing on this decline.

This is not to imply the fish died but rather escapement to the deeper waters may have resulted and a subsequent decrease in the capture of individuals inhabiting the heated shallow water occurred. It is felt a similar situation might have occurred to the white suckers as an increase was evidenced in all areas fyke netted, as well as electro-fishing results in the north during 1969. The fact no white suckers were captured in the shallow areas during 1969 efforts where heated effects occurred may be due to behavorial change because of temperatures, however, further study is necessary to determine the reason for this. Chain pickerel appear to be remaining fairly constant in all sections sampled.

Electro-fishing results in the canal showed fish existed in the canal prior to the steam plant expansion. In 1968 and 1969, after flows increased and stratification was not evident, no fish were captured by electro-fishing methods. Visual observation during this period indicated fish were surviving in the canal although in limited numbers. The fact fish were surviving although temperatures were extreme 35.3° C to 36.6° C indicates acclimation to high temperature is possible providing it is a gradual process.

In summary, although certain trends appear to be occurring, whether increased temperatures are causing these trends or some other factor is involved is not fully known.

The fact the normal river populations are changing through natural processes tends to obscure the true impact of thermal effects in this area and only further study will resolve such questions.

Electro-fishing: Soucook River

Electro-fishing in the Soucook River was done in the same 500-foot area in 1967 and 1968 to determine if any movement occurred from the main stem to the tributaries. The 1968 work points out such was not the case, as very little movement occurred from one area to another. However, because effort was expended in case a change did occur, the following pertains to the result of 1967 and 1968 electro-fishing in the Soucook River.

Twelve species, totaling 146 fish, were captured in 1968 compared to a total of 13 species and 115 fish in 1967. Species absent in 1968, but caught in 1967 were one landlocked salmon and one golden shiner, while one largemouth bass appeared in the 1968 total and not in the 1967 results. In all cases only one fish is involved, so the change is not significant. The capture of landlocked salmon indicated some adult salmon survive in the Merrimack River and reproduction to a limited degree is occurring.

The greatest increase in numbers was evidenced by Eastern madtom and longnose dace; this could be attributed to the habitat of the Soucook River rather than a movement from the main stem. Other individuals showed an increase in numbers, but because of the paucity of numbers, the results are insignificant. Table 8 shows results of two years electrofishing in the Soucook River as it pertains to numbers, species and length frequency.

The Bow Bog Brook was shocked for 250 feet during 1967 and 1968. However, in 1968, a beaver dam had been built across the mouth of the brook and any change caused by thermal flows was negated by this dam. For this reason, data obtained in this area will not be included in this report.

Movement:

To determine if there was a migration of fish from one section to another due to increased thermal effects, all fish caught in the fyke nets were fin-clipped according to the area of original capture.

For similar reasons, numbered monel jaw tags were placed on a representative sample of larger fish such as bass, walleyes and chain pickerel. On the basis of fin clips and jaw tag returns, it appears very little movement is occurring from one area to another. Based on netting results of 1968 and 1969, of the 608 fish recaptured in the Amoskeag pool only 11 had fin clips indigenous to Area 2. In the southern section of the 790 fish recaptures, only 37 gave evidence of being captured in the northern section, while the northern section produced 581 fish recaptured, of which 49 had been originally captured in the south. Of this total, 20 fish were recaptured in the section of 0 Station and N-2, which is exposed to considerable thermal loading during low flows in the main stream.

Jaw tags, which can be used more effectively to determine capture and recapture location, also showed very little movement from the

Table 8 - Species and Numbers of Fish Captured by Electro-fishing in the Soucook River, 1967 and 1968.

	Species												
Length	White Sucker	Smallmouth Bass	Yellow Perch	Golden Shiner	Pumpkin-seed	Madtom	Redbreast Sunfish	Blacknose Dace	Longnose Dace	American Eel	Landlocked Salmon	Largemouth Bass	Fallfish	Redfin Shiner
1.0 - 1.4								1						
1.5 - 1.9								1					1	
2.0 - 2.4						3 (2)							2 (2)	1
2.5 - 2.9						3 (3)			(2)				1 (8)	
3.0 - 3.4	1 (1)			1		3 (7)			(6)				9 (5)	2
3.5 - 3.9						4 (11)		1	6 (7)			(1)	4 (11)	1
4.0 - 4.4	1		1		(1)	7 (6)	1		(1)				6 (8)	2 (1)
4.5 - 4.9	1					3 (6)							8 (2)	
5.0 - 5.4	2 (1)	1			1	3 (5)	1						1	
5.5 - 5.9			(1)			2 (3)							2	
6.0 - 6.4	(1)	(1)					1 (2)	(2)						
6.5 - 6.9	1 (1)	(1)	(1)				(1)	(1)					1	
7.0 - 7.4	6 (1)	1	1 (1)				1				1		1	
7.5 - 7.9	2												1 (1)	
8.0 - 8.4	3		(1)											
8.5 - 8.9	(3)													
9.0 - 9.4	(3)													
9.5 - 9.9	(2)													
10.0 -10.4	(4)													
10.5 -10.9	1 (1)													
11.0 -11.4	(1)													
11.5 -11.9	1 (3)													
12.0 -12.4	1 (1)													
12.5 -12.9														
13.0 -13.4	(1)													
13.5 -13.9		(1)												
14.0 -14.4														
14.5 -14.9														
15.0 -15.4														
15.5 -15.9		(1)												
Totals	20 (24)	2 (4)	2 (4)	1 (0)	1	28 (43)	4 (3)	3 (5)	6 (16)	4 (7)	1	(1)	37 (37)	6 (1)

* 67 results are without ( )
* 68 results with ( )

southern area to northern area and vice-versa. Two individual bass were captured three and four times respectively in the south section with all recaptures in the vicinity of the original capture.

There were exceptions to the rule in which some individual fish showed a tendency to travel downstream a considerable distance. In 1967 a smallmouth bass, which was captured in the Hooksett dam area, was captured in the same year, a distance of approximately six miles downstream. Another smallmouth bass, tagged above the Hooksett dam, was caught by an angler in the Amoskeag section while one walleye netted at Hooksett Falls was captured below Amoskeag dam.

On the basis of recapture results, it appears vertical and horizontal movement is the most likely way in which fish are avoiding the heated flows rather than movement upstream or downstream. Because the warmer water tends to remain on the surface, it is felt that escapement is possible in the lower depths. If such stratification did not occur, it is felt more movement would have taken place.

Table 9 shows the recapture areas of fish fin-clipped in other areas, as well as movement based on jaw tag returns.

Gill Netting - North, South and Amoskeag

Gill netting was conducted for nine net days in a representative cross-section of each study area in 1967 and 1968. Although nets were placed in the same locations each year, a pronounced reduction in total numbers of fish resulted in 1968. Because this occurrence took place in all sections sampled, it becomes more apparent that a natural change took place in the river itself.

Table 9 - Tag Return Locations for Fish Captured During Merrimack Thermal Studies, Showing Distance Traveled.

te and Area of Original Capture			Date and Area of Recapture by Nets and Anglers		Distance Traveled
iallmouth Bass	7/5/67	S-1-	7/13/68	S-3	Approx. 1,000 ft. dwnstrm.
	7/6/67	S-17	6/7/68	Below Hooksett Falls	4,500 ft. dwnstrm.
	7/18/67	N-6	7/30/68	N-10	4,000 ft. upstrm.
*	7/18/67	S-3	8/5/68 8/29/69	0 S-6	68 - 1,500 ft. upstrm. 69 - 3,000 ft. dwnstrm.
	7/18/67	S-22	8/24/67 7/17/68	A58 S-1	Approx. 6 miles dwnstrm. 1,000 upstrm.
	7/5/67	S-3	6/7/70	Angler did not specify	------------------
	7/6/67	N-14	7/10/69	N-14	0
*	7/6/67	S-17	6/27/68 7/15/68 7/27/68	S-19 S-20 S-19	1,000 ft. dwnstrm. 500 ft. dwnstrm. 500 ft. upstrm.
	7/5/67	N-13	7/30/68	N-14	1,500 ft. upstrm.
*	7/10/67	S-19	6/25/68	S-21	1,000 ft. dwnstrm.
			7/9/68	S-19	500 ft. upstrm. point of original capture
			7/22/68 8/7/68	S-17 S-20	1,000 ft. upstrm. 1,500 ft. dwnstrm.
	7/13/67	N-15-W	7/31/68	Garvin Falls	1,500 ft. upstrm.
	7/9/67	N-13	8/12/70	Angler did not specify	------------------
	8/14/68	A-11	8/69	A-11	0
	8/14/68	A-10	7/69	A-3	2,500 ft. upstrm.
	8/9/68	A-8	7/30/69	A-6	500 ft. upstrm.
argemouth Bass	7/25/68	S-19	7/29/68	S-20	500 ft. dwnstrm.
alleye	9/7/67	A-1	6/21/68	Hooksett Dam	0
	9/8/67	A-6	5/4/68	Hooksett Dam	2,500 ft. upstrm.
	8/19/68	A-31	5/9/70 (Angler)	Hooksett Dam	Approx. 13,000 ft. upstrm.
	8/12/68	A-1	7/69 (Angler)	Below Amoskeag Dam	Approx. 39,000 ft. dwnstrm.
. C. Pickerel	7/7/67	N-14	7/68	N-13	1,500 ft. dwnstrm.
	7/9/68	S-8	7/15/68	S-20	6,000 ft. dwnstrm.

* Length of movement of fish captured more than once is figured on point of

In the three sections netted, a reduction of 45% occurred in the Amoskeag area while the northern and southern areas showed a decrease of 43% and 36% respectively.

During the 1967 gill netting, yellow perch were the predominant species in the Amoskeag pool and southern area, while white suckers predominated in the north.

In 1968, yellow perch continued to be the predominant species in Amoskeag while white suckers were most frequent in the north and south areas, with increases of 20% and 32% respectively.

Probably the most significant finding during this portion of the study was the fact walleyes in the Amoskeag section remained constant in numbers compared to 1967 results. This would seem to indicate the thermal effects are not causing a change in this species on the basis of limited data to date. It must be stressed, however, that this portion of the study deals with adult walleyes only and the effects, if any, on reproduction and juveniles will not be known for several years. Overall, there appears to be less fluctuation in the percentage of catch in the Amoskeag area in comparison to the north and south section which is probably due to the separate entity of the two impoundments.

Redbreast sunfish, although appearing in limited numbers during netting in 1967, did not appear in any of the sections during 1968. Pumkinseeds showed a similar characteristic in 1968 as they appeared only in Amoskeag nets. Because gill nets were set to determine the species inhabiting the deeper water, it would appear that sunfish are inhabiting the shallow shoreline waters in spite of thermal effects due to their tolerance for higher temperature.

Smallmouth bass showed an increase in the percentage of catch in the Amoskeag and northern areas while southern results showed an absence of this species captured. Because of the limited numbers involved, this probably has little significance; however, it is possible this species is staying closer to shore than was expected.

Discussion: Gill Netting

In summary, very little data of significance was derived from gill netting efforts.

The fact adult walleyes maintained their numbers in the Hooksett Falls area after increased temperatures occurred, is probably the only significant aspect of gill netting.

A breakdown of gill netting results is depicted in Figures 13, 14, and 15 and Tables 10 and 11.

Age Growth Studies:

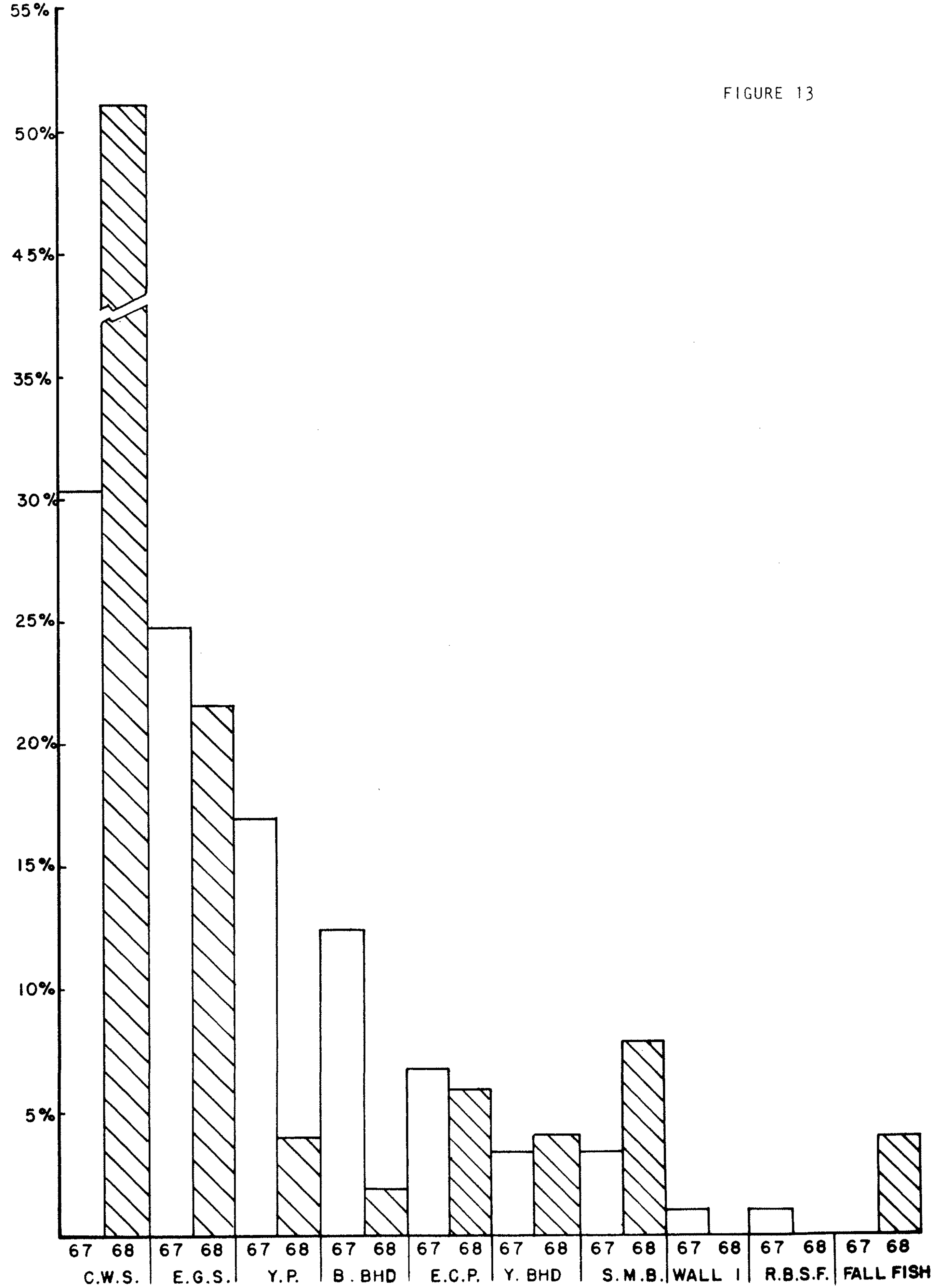
A total of 1,717 fish representing four different species were aged and back calculated from each section during each year of the study.

Scale samples were taken from pumpkinseed, redbreast sunfish, smallmouth bass and yellow perch. All suitable scale samples were utilized and impressions made of three to six scales on each plastic slide. An Eberbach scale projector was used for magnification purposes.

The generally accepted procedure for age growth studies by the age scale method was followed. After the fish had been aged, back calculation to each annulus was employed.

The following pertains to the data derived from this method by species:

NORTH GILL NETTING 1967-68



SOUTH GILL NETTING 1967-68

FIGURE 14

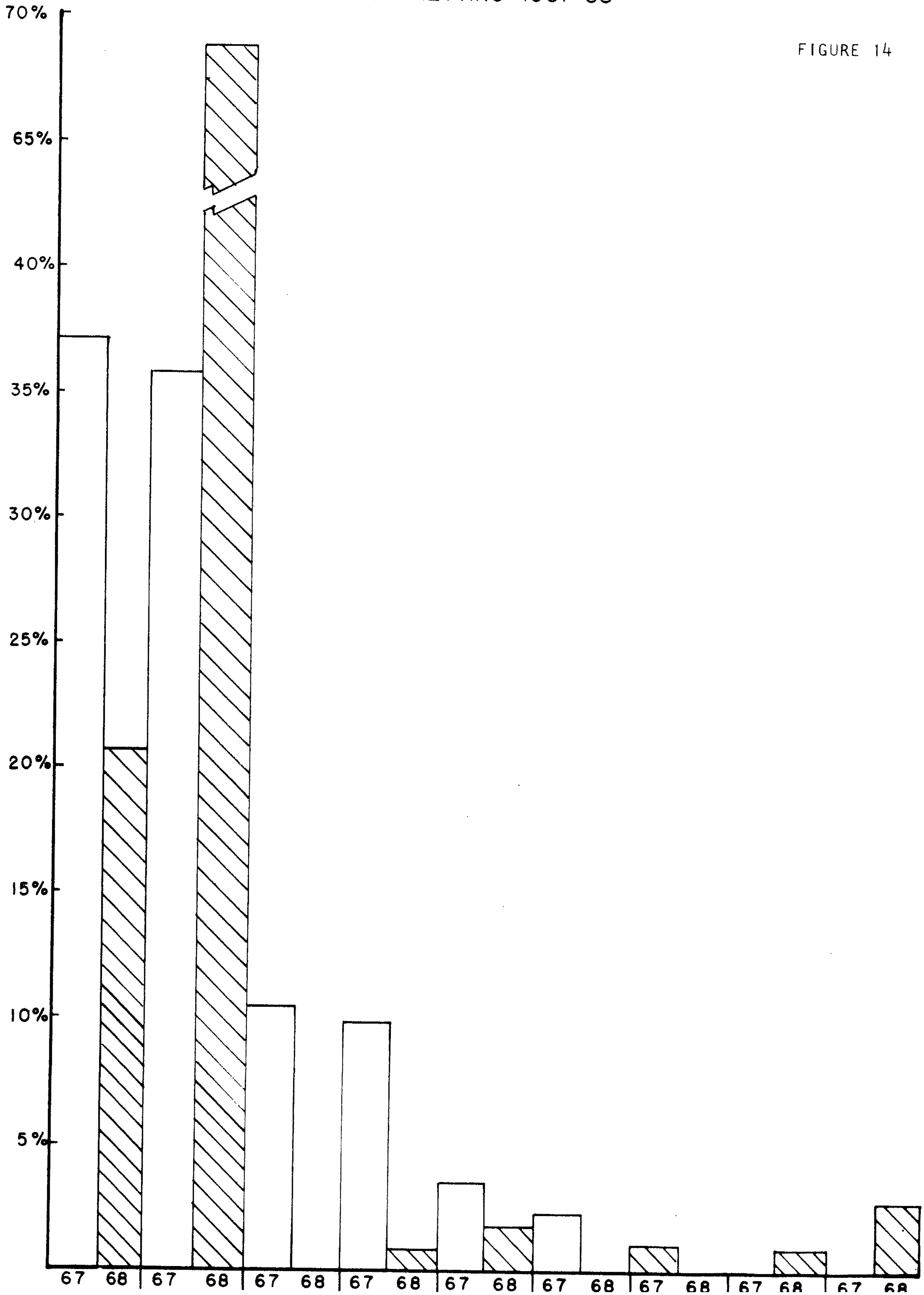


Table 11 - Gill Netting Results, 1968

	ECP	YP	CWS	WE-P	SMB	EGS	P.SEED	RBSF	B.BHD	Y.BHD	WP	FALLFISH	TOTAL
MOSKEAG POOL													
2 net-days)													
Weight (lbs.)	1.0	3.2	15.0	19.2	5.5	-	.3	-	1.0	4.8	.9	-	50.9
umber	2	15	11	12	6	-	1	-	2	7	1	-	57
ercent of total catch	3.50	26.31	19.29	21.05	10.52	-	1.75	-	3.50	12.2	1.75	-	
ORTH SECTION													
3 net-days)													
eight (lbs.)	1.9	.3	31.5	-	3.7	2.2	-	-	.1	.5	-	.8	41.0
umber	3	2	26	-	4	11	-	-	1	2	-	2	51
ercent of total catch	5.88	3.92	50.98	-	7.84	21.56	-	-	1.96	3.92	-	3.92	
OUTH SECTION													
4 net-days)													
'eight (lbs.)	6.2	5.2	95.7	-	-	.3	-	-	1.1	3.1	.8	-	112.4
iumber	3	23	77	-	-	1	-	-	2	5	1	-	112
'ercent of total catch	2.67	20.53	68.75	-	-	.89	-	-	1.78	4.46	.89	-	

Yellow perch

On the basis of growth data derived on yellow perch in the study areas, it appeared that growth in the Amoskeag area was slightly better than that of the north section at least during the early stages of life. Two years of the study (1968 and 1969) revealed equal growth characteristics during the third year annulus between these two areas.

The southern area showed a slight lag in growth during all years of the study. Because this discrepency in growth manifested itself before the additional heated flows occurred, it is felt, based on the limited data obtained, yellow perch growth rates are not effected by the thermal change at this point.

A reduction in the lengths beyond three and four years of age was apparent in 1968 and 1969 in all sections when compared to 1967 data. This is a continuation of the fact something occurred in the river itself rather than thermal effects. Figures 16, 17 and 18 depict the age growth trends of yellow perch.

Pumpkinseed

Pumpkinseeds exhibited very little growth variation in the three sections studied. In 1968 and 1969, the southern area displayed slightly better growth than the Amoskeag and northern sections of the age two and three year fish. The strong two year class of the southern area in 1967 prevailed each successive year of the study with better growth in this section being the result. As was indicated in the growth patterns of the other species, there appeared to be no disconcernable effect from the increased thermal flows during the 1968 to 1969 period.

Figures 19, 20 and 21 depict the age growth data of this species from 1967 to 1969.

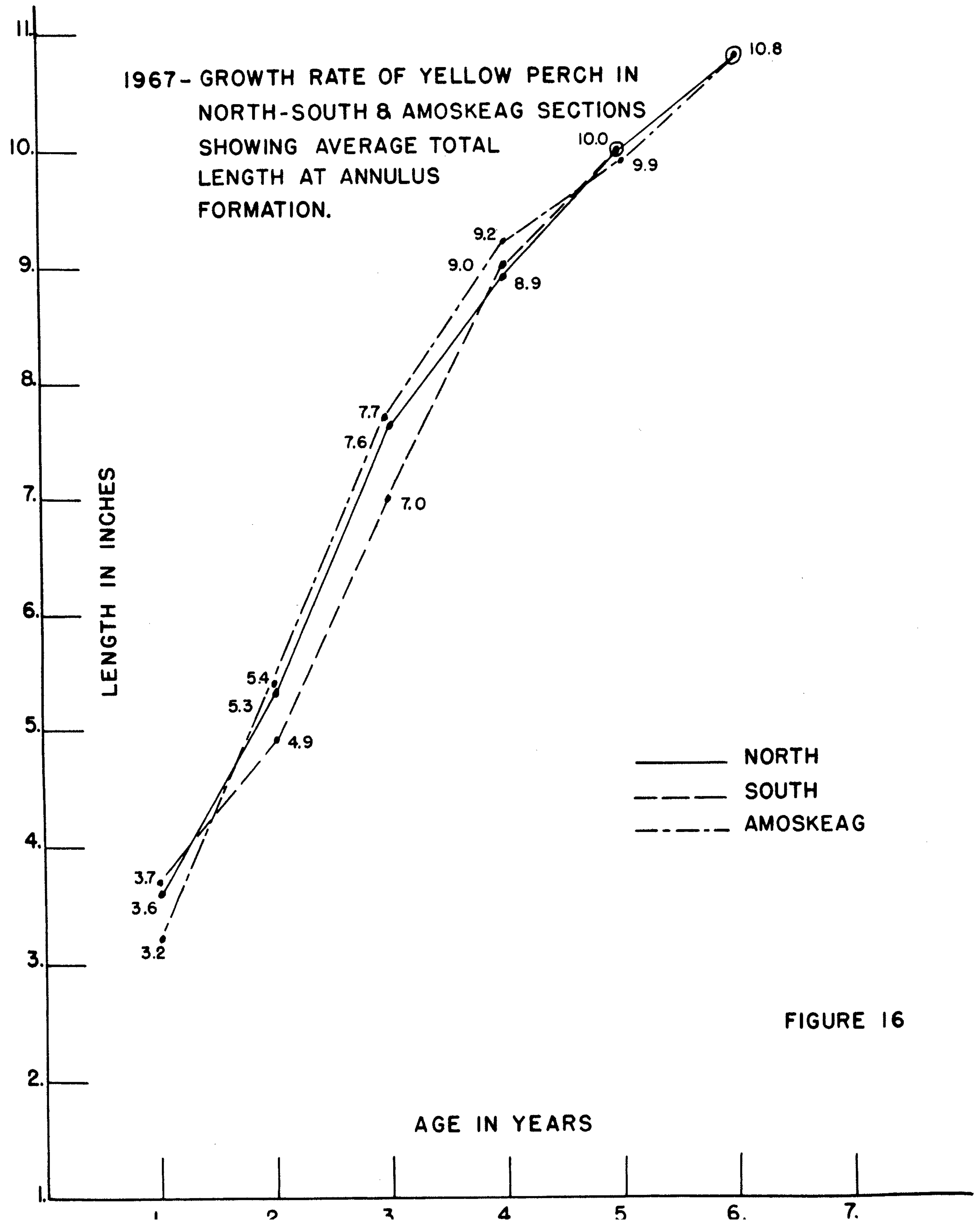

1967 - GROWTH RATE OF YELLOW PERCH IN NORTH-SOUTH & AMOSKEAG SECTIONS SHOWING AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.
LENGTH IN INCHES
AGE IN YEARS
NORTH
SOUTH
AMOSKEAG
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
1
2
3
4
5
6.
7.
3.7
3.6
3.2
5.4
5.3
4.9
7.7
7.6
7.0
9.2
9.0
8.9
10.0
9.9
10.8

FIGURE 16

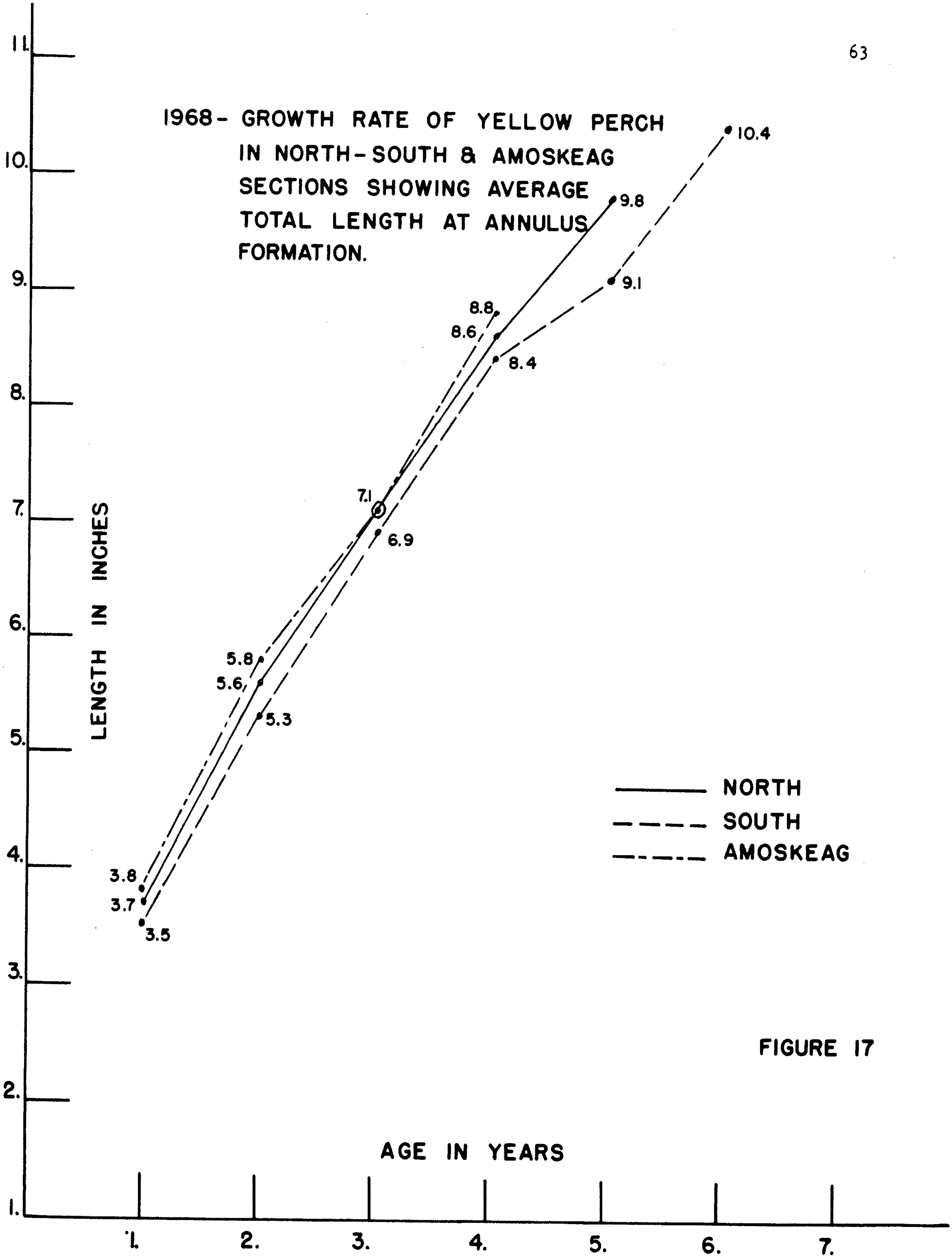

1968- GROWTH RATE OF YELLOW PERCH
IN NORTH-SOUTH & AMOSKEAG
SECTIONS SHOWING AVERAGE
TOTAL LENGTH AT ANNULUS
FORMATION.
LENGTH IN INCHES
AGE IN YEARS
NORTH
SOUTH
AMOSKEAG
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11.
1. 2. 3. 4. 5. 6. 7.
3.8
3.7
3.5
5.8
5.6
5.3
7.1
6.9
8.8
8.6
8.4
9.8
9.1
10.4

FIGURE 17

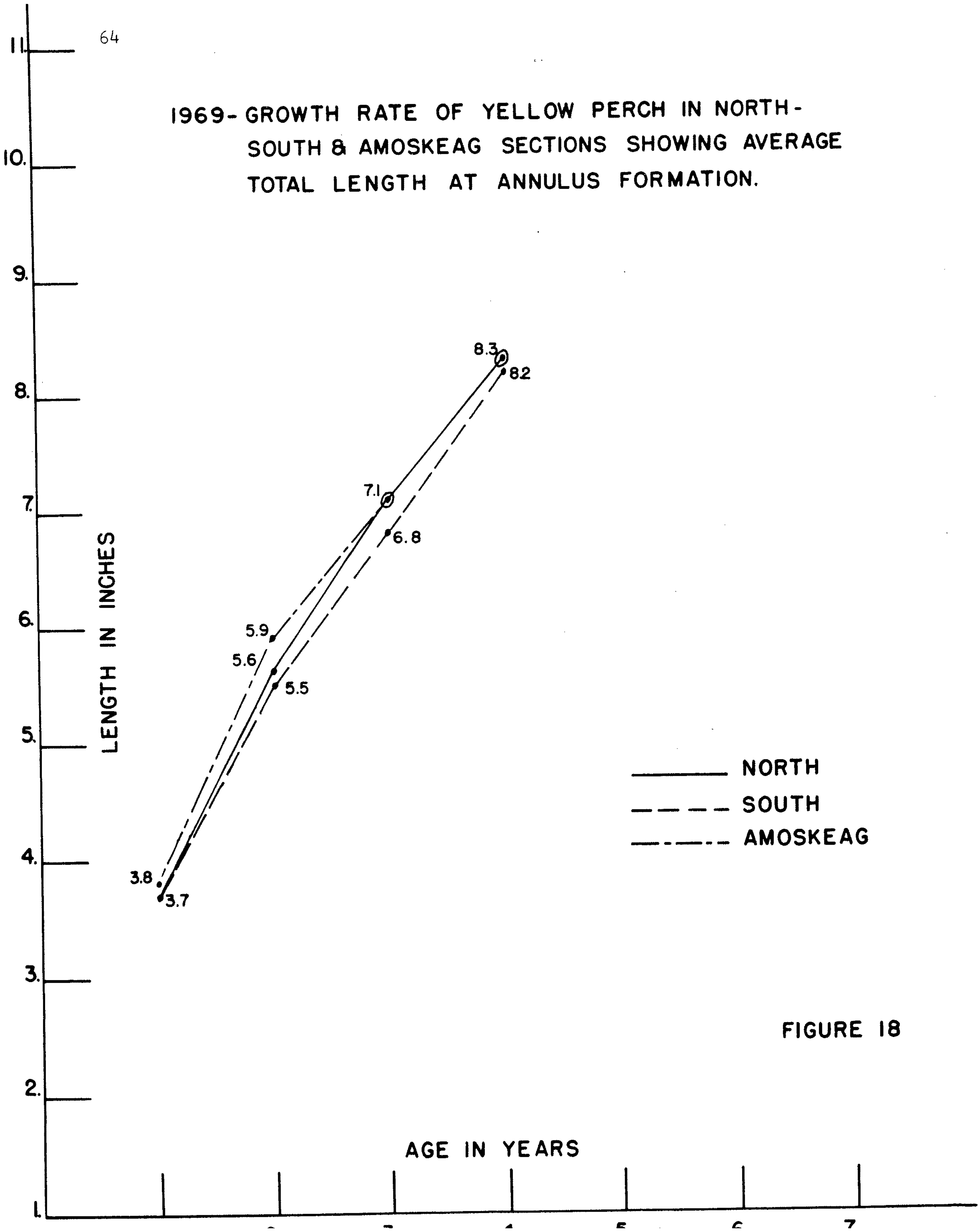

1969- GROWTH RATE OF YELLOW PERCH IN NORTH-SOUTH & AMOSKEAG SECTIONS SHOWING AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.
LENGTH IN INCHES
AGE IN YEARS
NORTH
SOUTH
AMOSKEAG
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
3.8
3.7
5.9
5.6
5.5
7.1
6.8
8.3
8.2

FIGURE 18

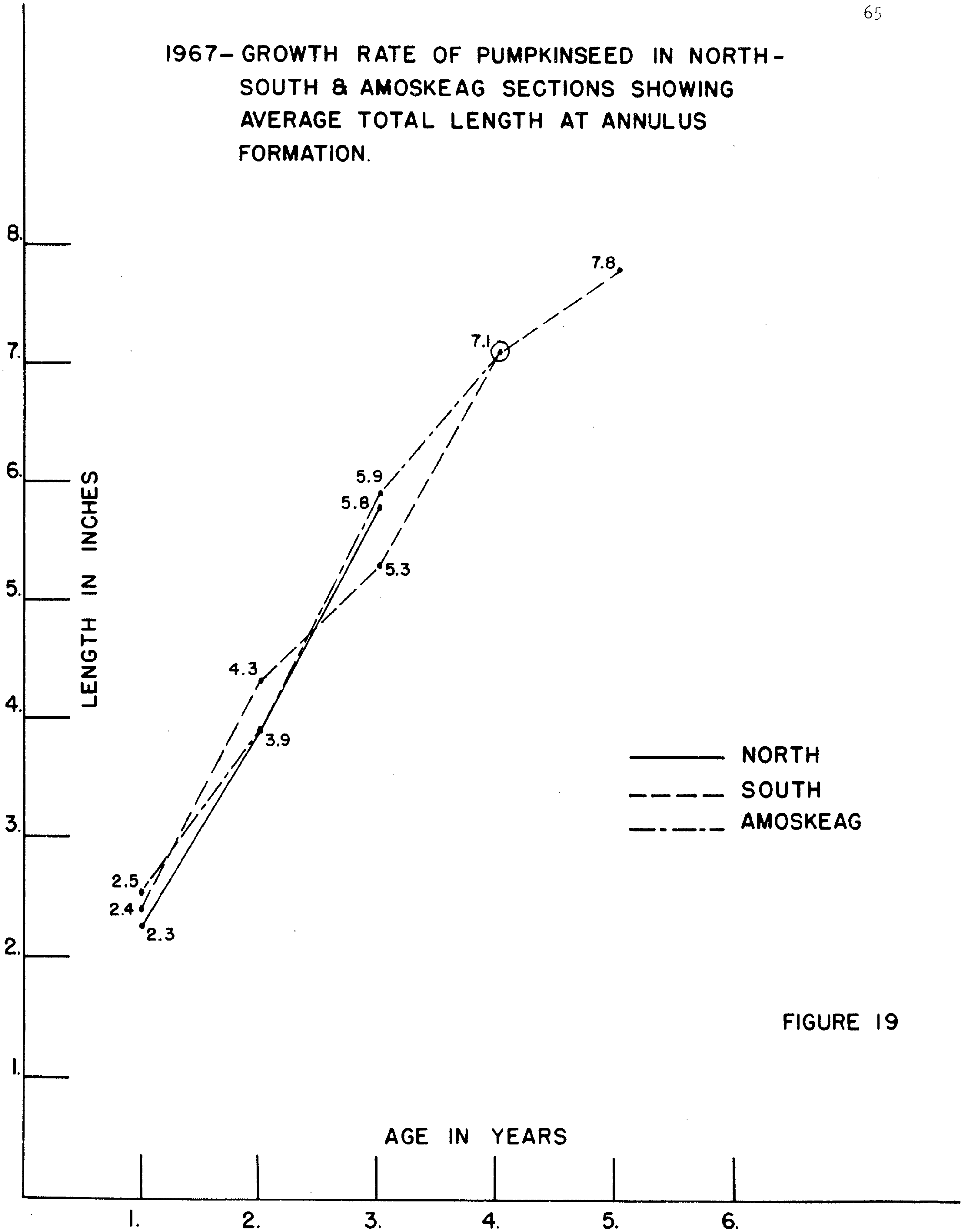

1967- GROWTH RATE OF PUMPKINSEED IN NORTH-SOUTH & AMOSKEAG SECTIONS SHOWING AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.
LENGTH IN INCHES
8.
7.
6.
5.
4.
3.
2.
1.
7.8
7.1
5.9
5.8
5.3
4.3
3.9
2.5
2.4
2.3
NORTH
SOUTH
AMOSKEAG
AGE IN YEARS
1.
2.
3.
4.
5.
6.

FIGURE 19

1968-GROWTH RATE OF PUMPKINSEED IN NORTH-SOUTH & AMOSKEAG SECTIONS SHOWING AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.

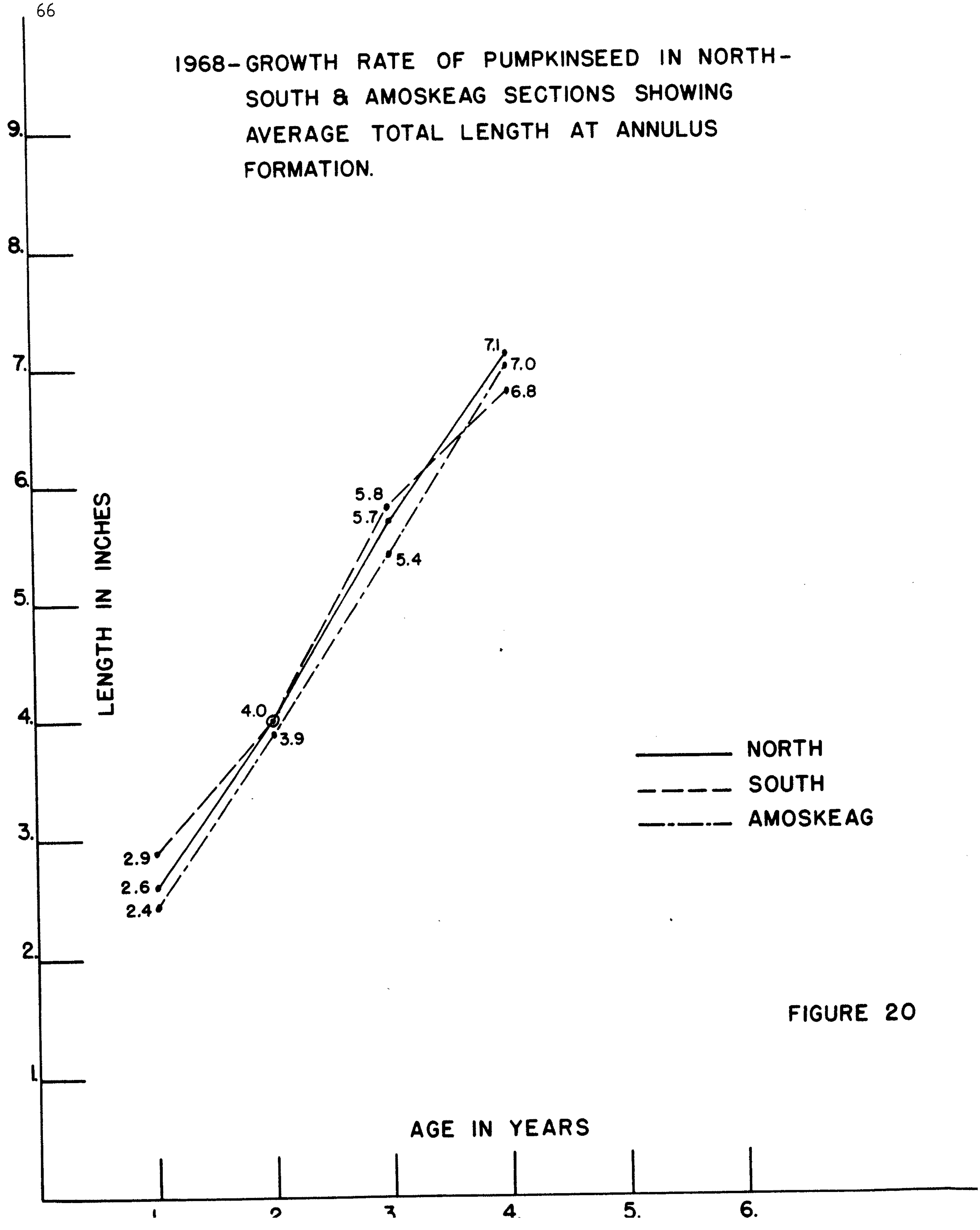


FIGURE 20

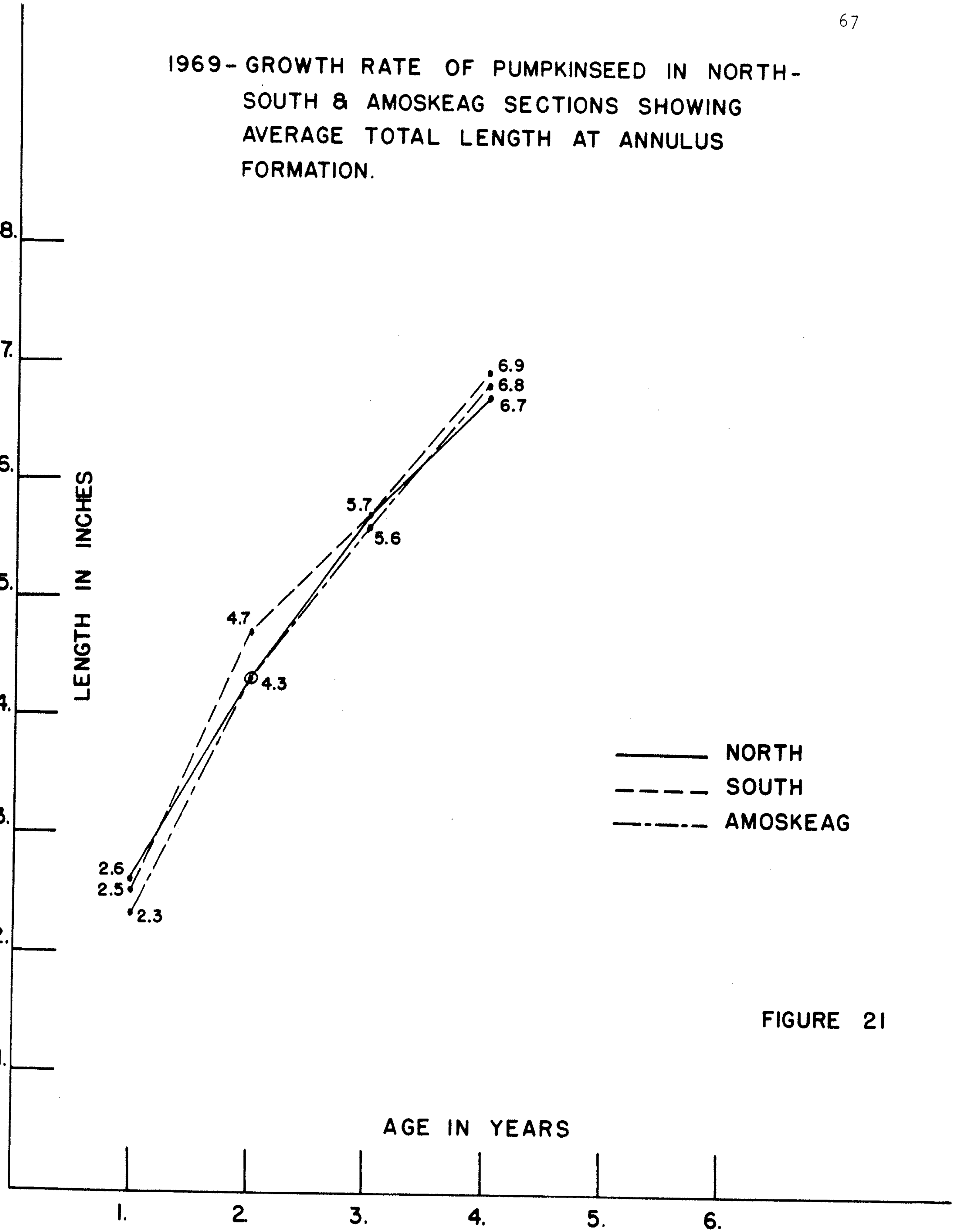

1969 - GROWTH RATE OF PUMPKINSEED IN NORTH-SOUTH & AMOSKEAG SECTIONS SHOWING AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.
LENGTH IN INCHES
8.
7.
6.
5.
4.
3.
2.
1.
6.9
6.8
6.7
5.7
5.6
4.7
4.3
2.6
2.5
2.3
NORTH
SOUTH
AMOSKEAG
AGE IN YEARS
1.
2.
3.
4.
5.
6.

FIGURE 21

Smallmouth Bass

Age growth studies of smallmouth bass show varying trends during the course of the study. In 1967 it appears that Amoskeag and southern sections had a slightly greater rate than the northern area in all age groups except during the fifth year when the northern section prevailed.

In 1968 the southern and Amoskeag areas continued to show better growth rates with the exception of the north surpassing the growth of the southern section in the two and five year age-class. The south showed a strong three year-class during this period when it rose above the Amoskeag sample.

The results in 1969 showed a reversal of previous growth data with the north section exhibiting a slightly higher growth rate of the two, three and four year old fish compared to the sections below the plant. The six year age-class, however, reverted to previous patterns of better growth in the southern section, as was the case throughout the study. Whether this occurrence is due to thermal effects or natural causes is not known (Figures 22, 23 and 24).

Redbreast Sunfish

Redbreast sunfish appear to be growing slightly faster in the southern and Amoskeag section of the river compared to those of the north. Of the three sections studied, the Amoskeag area seems to demonstrate greater growth rates all years of the study for this species.

At the age of three years there is a close proximity of growth rates between the northern and southern section; however, at age four to five the northern section declines while the Amoskeag and south section show a better growth rate.

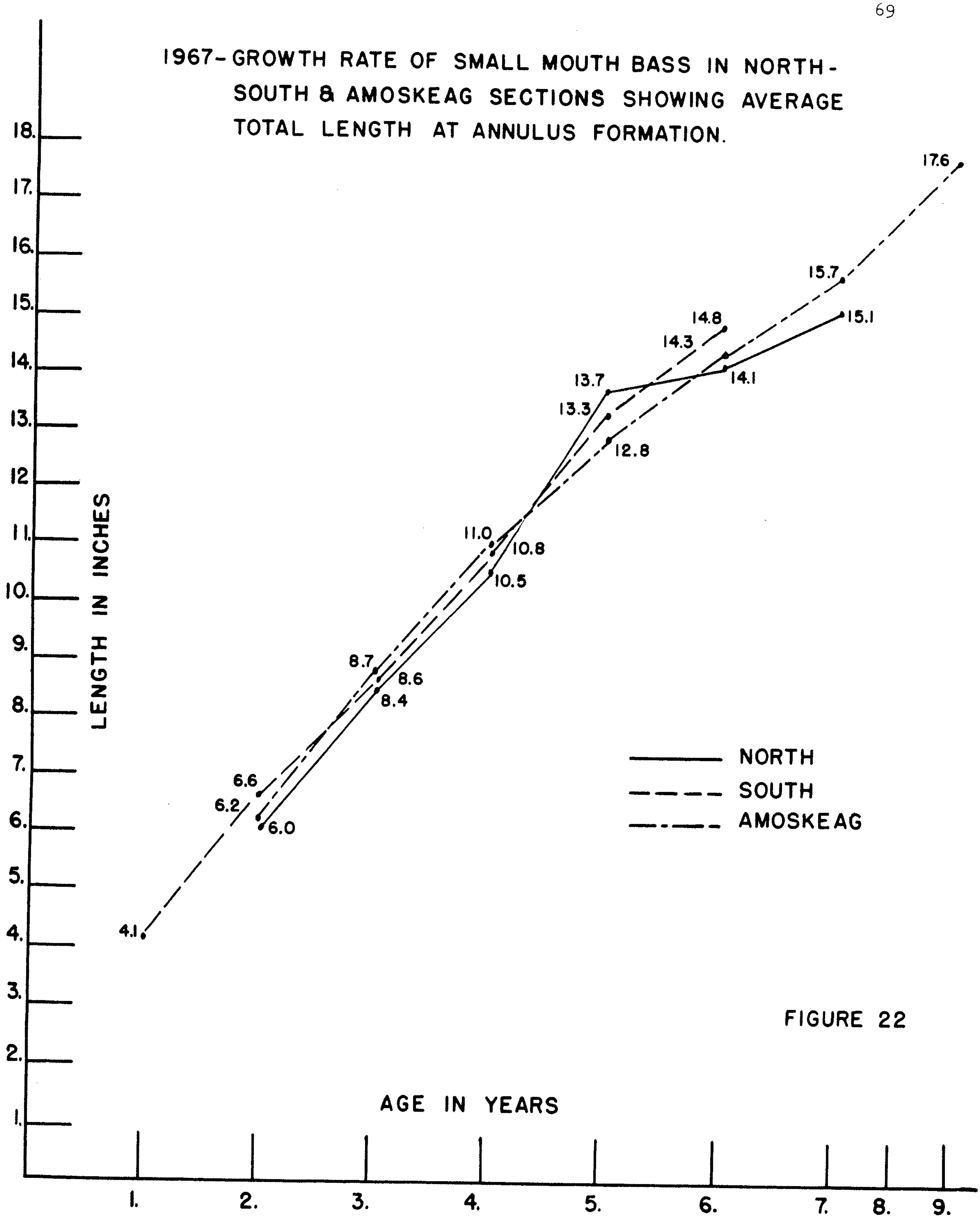

1967-GROWTH RATE OF SMALL MOUTH BASS IN NORTH-SOUTH & AMOSKEAG SECTIONS SHOWING AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.
LENGTH IN INCHES
AGE IN YEARS
NORTH
SOUTH
AMOSKEAG
4.1
6.6
6.2
6.0
8.7
8.6
8.4
11.0
10.8
10.5
13.7
13.3
12.8
14.8
14.3
14.1
15.7
15.1
17.6
18.
17.
16.
15.
14.
13.
12
11.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
1.
2.
3.
4.
5.
6.
7.
8.
9.

FIGURE 22

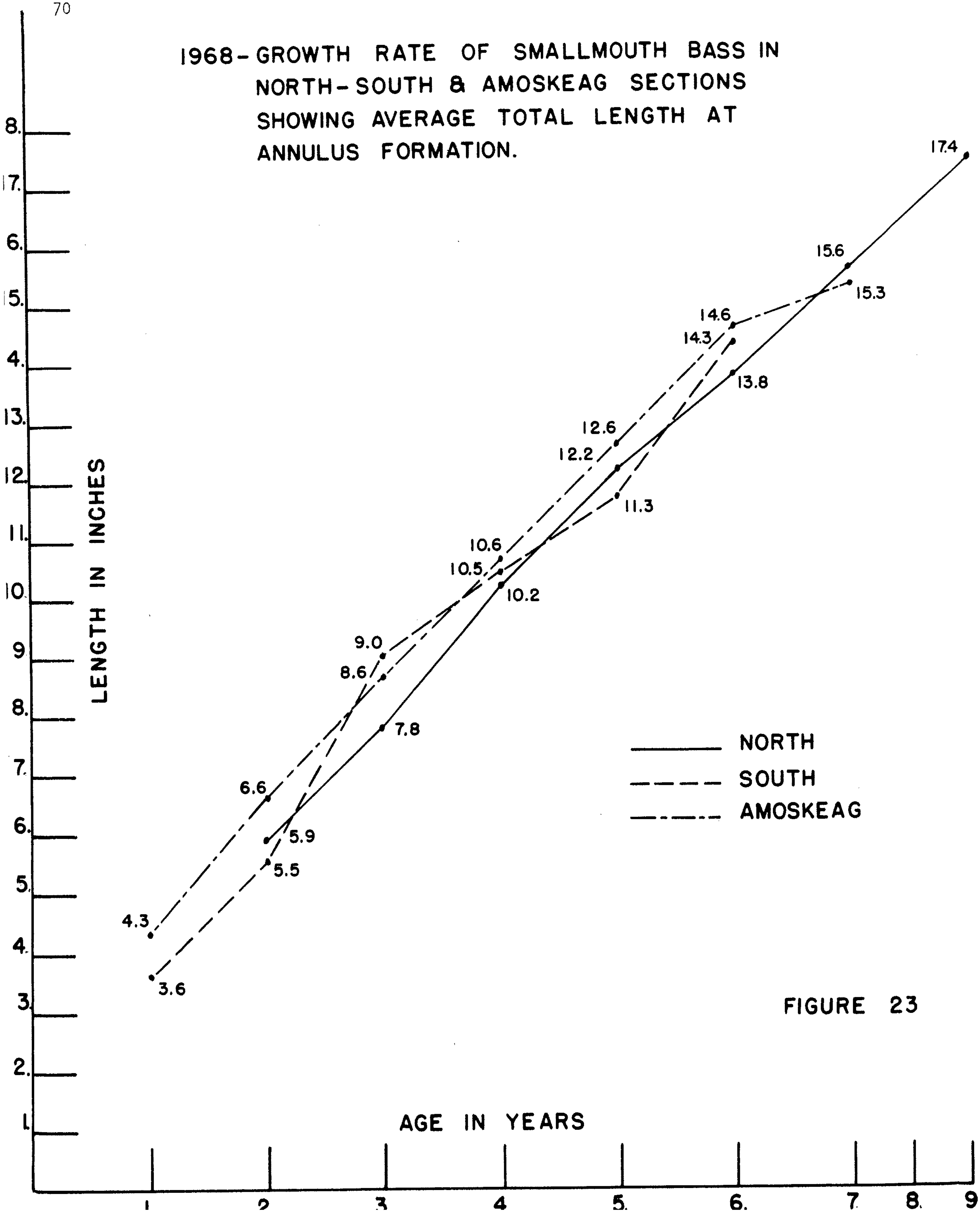

1968 - GROWTH RATE OF SMALLMOUTH BASS IN NORTH-SOUTH & AMOSKEAG SECTIONS SHOWING AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.
LENGTH IN INCHES
AGE IN YEARS
NORTH
SOUTH
AMOSKEAG
17.4
15.6
15.3
14.6
14.3
13.8
12.6
12.2
11.3
10.6
10.5
10.2
9.0
8.6
7.8
6.6
5.9
5.5
4.3
3.6

FIGURE 23

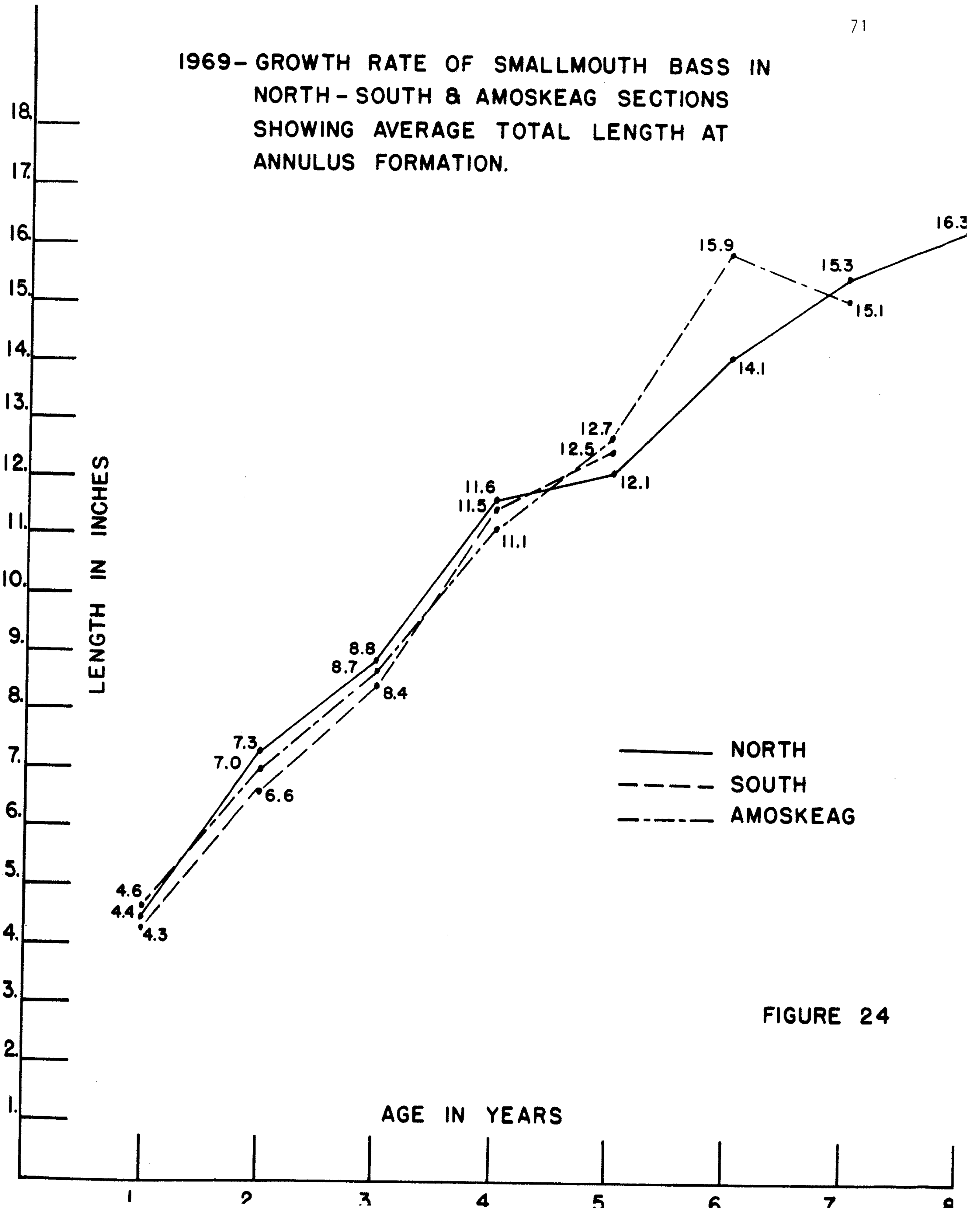

1969 - GROWTH RATE OF SMALLMOUTH BASS IN NORTH - SOUTH & AMOSKEAG SECTIONS SHOWING AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.
LENGTH IN INCHES
AGE IN YEARS
NORTH
SOUTH
AMOSKEAG
18.
17.
16.
15.
14.
13.
12.
11.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
4.6
4.4
4.3
7.3
7.0
6.6
8.8
8.7
8.4
11.6
11.5
11.1
12.7
12.5
12.1
15.9
14.1
15.3
15.1
1
2
3
4
5
6
7

FIGURE 24

A reduction in the rate of growth during the four to five year age class was apparent in all sections during 1969 compared to 1967 values, which again points to a natural change in the river itself during 1968.

Overall, it appears very little effect to the redbreast sunfish is occurring from thermal conditions with some indication of slightly better growth in the areas south of the plant. Figures 25, 26 and 27 depict the age growth data of this species from 1967 to 1969.

Discussion: Age Growth Studies

It appears, on the basis of the limited data obtained during this study, that immediate effects from the heated water on growth of fish in each section is not apparent. Various factors such as increased river flows during mid-summer the latter two years of the study, probably had as much effect as any one condition to disguise the total effect to the fisheries from thermal effects. The fact that the study was of a short duration contributed greatly to the insignificance of the age growth study.

It appears the species of yellow perch and pumpkinseed had very little immediate effect from the heated flows.

The redbreast sunfish and smallmouth bass seem to give some indication of a change in growth patterns, however, because other phases of the study point towards a change in the river itself, it is rather dubious to say the thermal effects are creating this change. It is possible such is occurring, but to make a blanket statement that this is the absolute cause could not be validated.

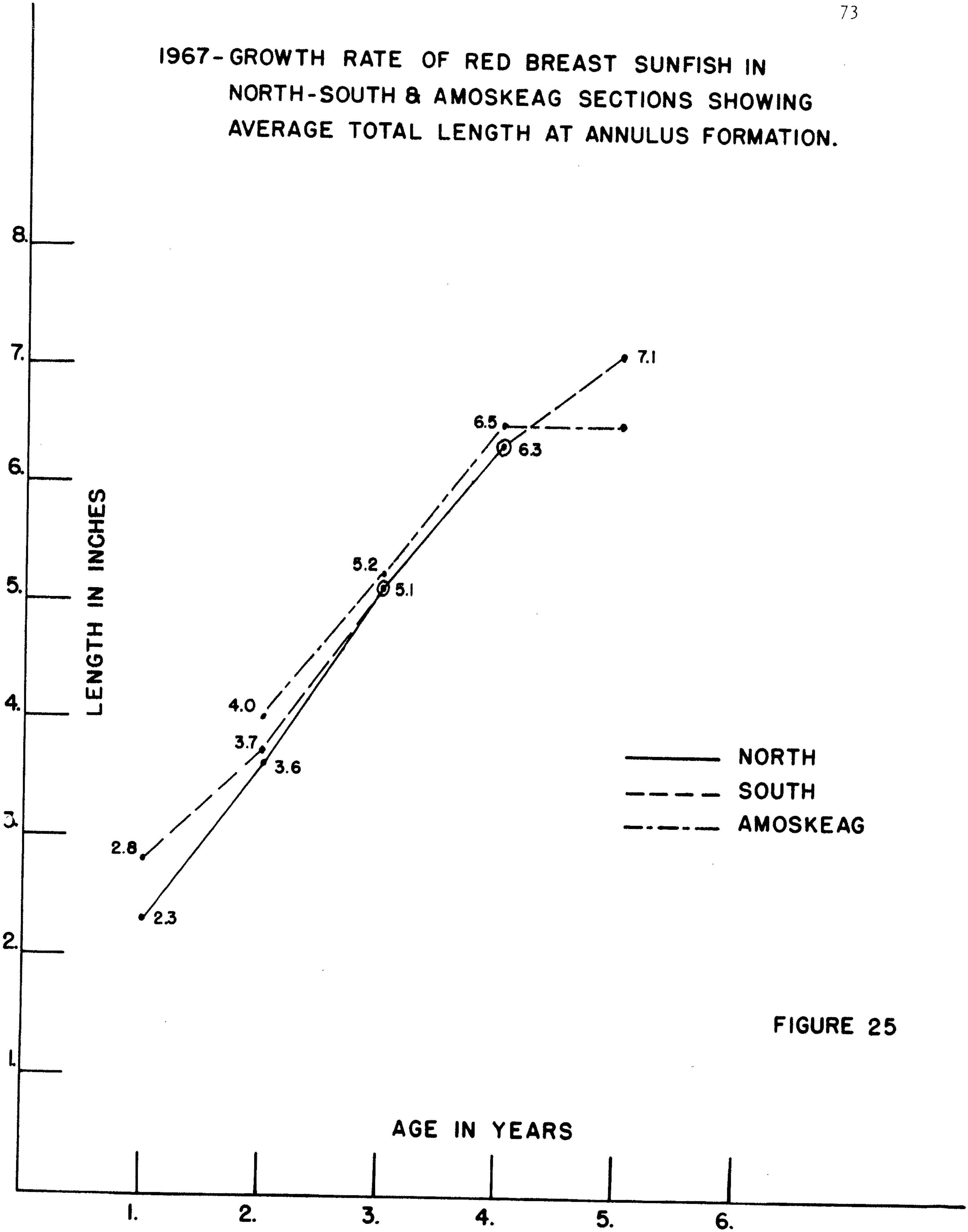

1967 - GROWTH RATE OF RED BREAST SUNFISH IN
NORTH-SOUTH & AMOSKEAG SECTIONS SHOWING
AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.
LENGTH IN INCHES
AGE IN YEARS
1. 2. 3. 4. 5. 6.
1. 2. 3. 4. 5. 6. 7. 8.
2.8
2.3
4.0
3.7
3.6
5.2
5.1
6.5
6.3
7.1
NORTH
SOUTH
AMOSKEAG

FIGURE 25

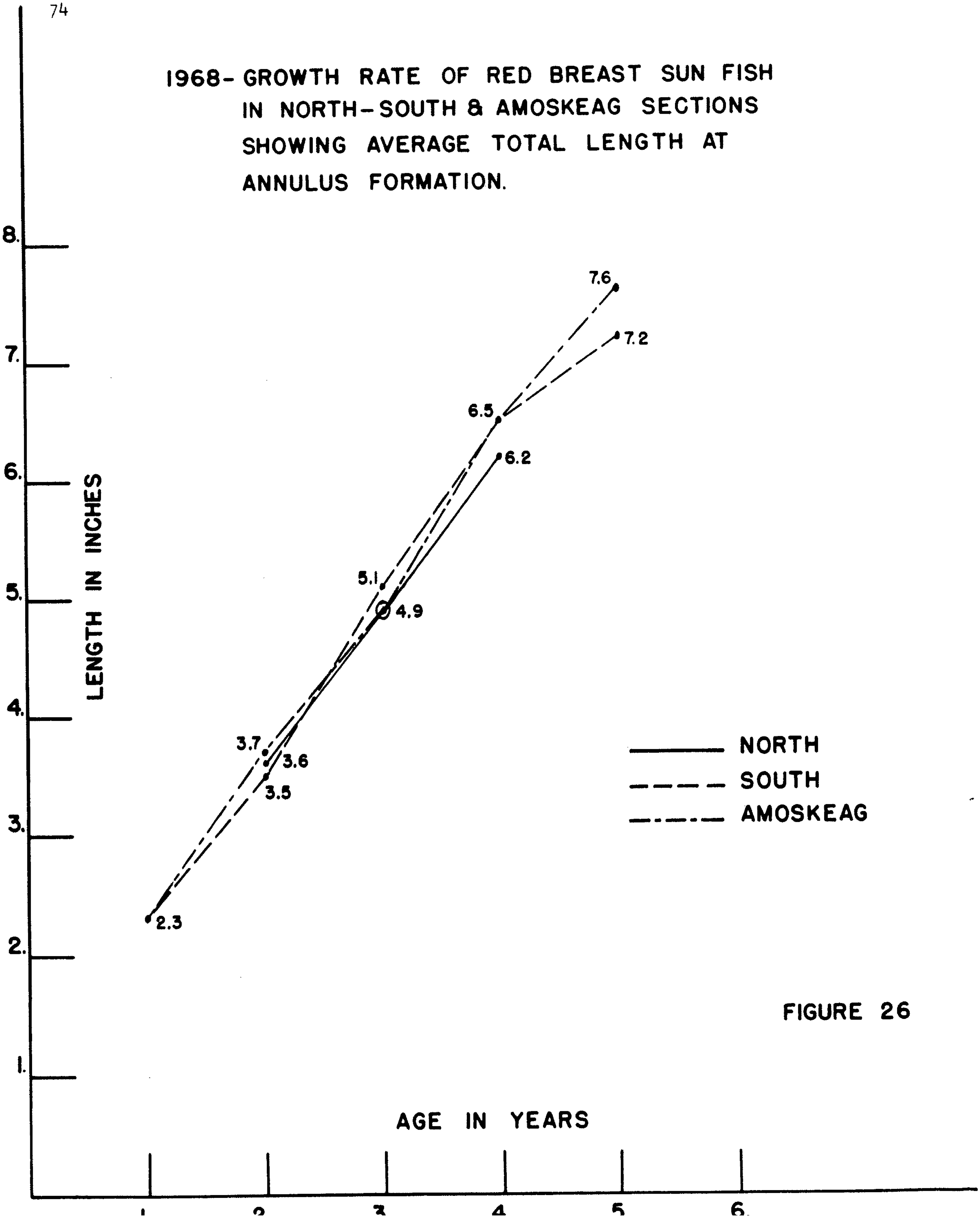

1968- GROWTH RATE OF RED BREAST SUN FISH IN NORTH-SOUTH & AMOSKEAG SECTIONS SHOWING AVERAGE TOTAL LENGTH AT ANNULUS FORMATION.
LENGTH IN INCHES
AGE IN YEARS
NORTH
SOUTH
AMOSKEAG
8.
7.
6.
5.
4.
3.
2.
1.
7.6
7.2
6.5
6.2
5.1
4.9
3.7
3.6
3.5
2.3
1
2
3
4
5
6

FIGURE 26

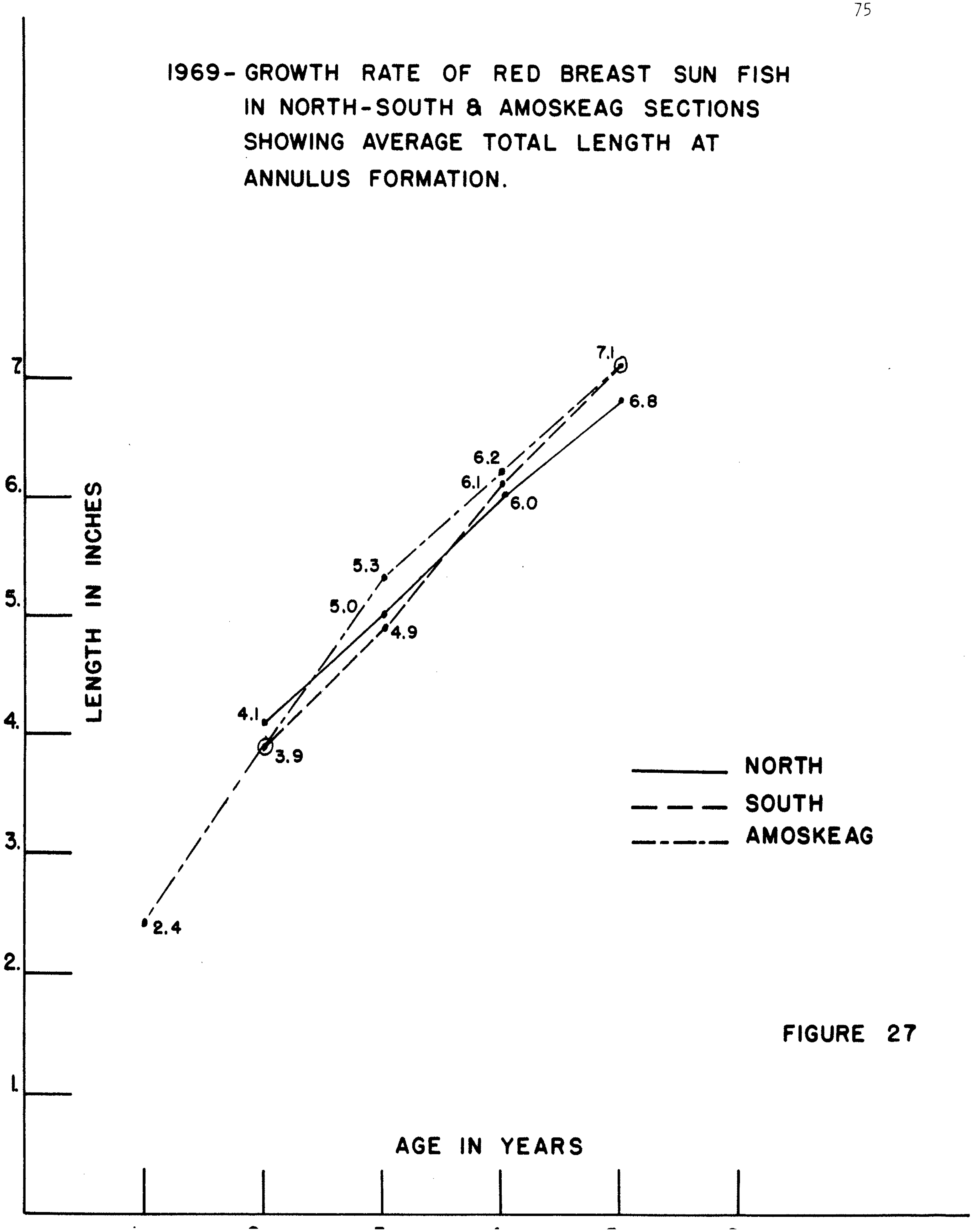

1969- GROWTH RATE OF RED BREAST SUN FISH
IN NORTH-SOUTH & AMOSKEAG SECTIONS
SHOWING AVERAGE TOTAL LENGTH AT
ANNULUS FORMATION.
LENGTH IN INCHES
7.
6.
5.
4.
3.
2.
1.
7.1
6.8
6.2
6.1
6.0
5.3
5.0
4.9
4.1
3.9
2.4
NORTH
SOUTH
AMOSKEAG
AGE IN YEARS

FIGURE 27

Flows

Flow data on the Merrimack River was obtained by gauging equipment installed at Garvins Falls Hydro station. Although the Garvins Falls station and Hooksett station are run-of-the-river type plants, it is felt the flows at Hooksett are higher than indicated on the gauging equipment due to the supplimentary flows from the Soucook and Suncook Rivers.

No attempt was made to determine flow data on these two rivers except for a measurement made for one day on the Suncook River. On the day of measurement, it was determined a flow of 275 cfs was occurring in the Suncook River. Applying this volume of flow to that of the mainstem on the same day, it appears that at times, the Suncook River could supplement the main river flow by 14%. This volume of flow could have significant effect on the cooling characteristics of the main river as well as the biota therein.

A comparison of flows in 1967 and 1968 indicates water conditions were more favorable in June to mid-July of 1968, than was the case in 1967. From mid-July on, however, flows were generally lower in 1968. As can be seen by Figure 28 the period of lowest flows occurs in late summer and early fall after high seasonal temperatures have passed.

Because Figure 28 deals with flows on a twenty-four hour basis, there are times when hourly flows are significantly reduced from those obtained on a twenty-four hour period.

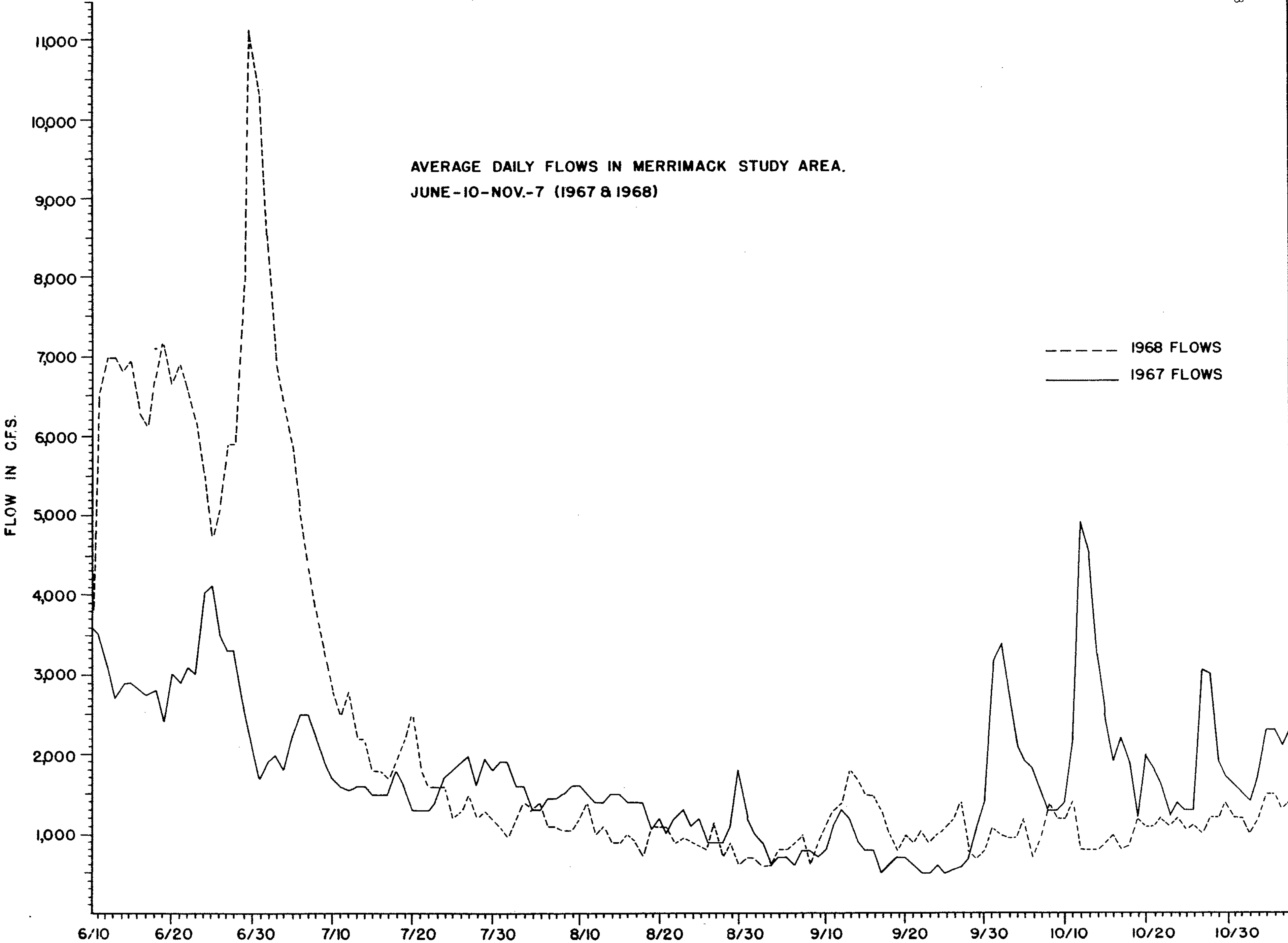
This was particularly evident during September, 1967 when there was no record of flows through Garvins Falls for up to six hours. Although this circumstance took place before MK-11 became operational, the fact such an occurrence does happen points to the need for a minimum sustained flow to prevent excessive thermal loading in the downstream area.

In 1967, there were twenty-eight days with average daily flows of less than 1,000 cfs. Of this number, four days occurred in late August and the remaining twenty-four in September. When one considers the number of days in September, it becomes apparent this month is critical in regards to minimum sustained flows (Figure 28).

Fortunately in 1968, after MK-11 became operational, minimum flow extremes were not as great as those which occurred in 1967. During the 1968 field season there was only one instance of zero flow, which occurred on July 14 for a one hour time period. Other periods of low flows were evident in late August and September when flows of 400-600 cfs were sustained for lengthy periods on some days. The lowest daily average flow was on September 8, 1968 when the twenty-four hour average was 556 cfs. During this date there were several hours when flows were 428 cfs. Considering the power plant needs are approximately 440 cfs, it is obvious thermal conditions could be extreme if full power production is occurring. In 1968, there was a total of 41 days during the August and October period when daily average flows were less than 1,000 cfs.

In view of the fact 1968 was considered a wet year, it becomes obvious that a cycle of dry years, as was the case in the northeast during the early and mid-60's could have significant effect on the cooling water supply, as well as the impact thermal conditions would have on the river during a period of drought.

FIGURE 28



BASED ON DATA RECEIVED FROM PUBLIC SERVICE CO RE: MERRIMACK RIVER THERMAL STUDY.

Discussion - Flows

Data obtained indicates during periods of low flows and high air temperatures there is more heat conduction in the entire cross-section of the river south of the plant to Amoskeag dam.

It appears the present facilities are approaching the maximum demand for cooling water the river can support in late summer when flows are at their minimum. Because electrical demands will increase with the resulting need for additional generating plants, a foregone conclusion, it is questionable if the river can support such units without significant effect to the present and future potential of the river. For this reason it is felt necessary to forestall additional power facilities until the present unit is fully proven to have little or no effect over a long-term period. If additional facilities are constructed in the watershed with no concern to thermal effects as was the Bow plant, it is felt problems of considerable magnitude are going to result not only during periods of low flows but during periods of normal flows which would have considerable impact on the fishery potential of the Merrimack Watershed.

Temperature

Due to the effect temperatures have on the aquatic environment, as well as its biota, it was necessary to evaluate the characteristics of the heated waters from the power plant upon its return to the normal river flow pattern. This phase of the study entailed a great deal of effort on the part of personnel connected with Public Service Company under the direction of Dr. Normandeau. Data was obtained by a variety of instruments which included the following: portable field thermistor systems (Yellow Spring Model 44); a Geodyne Model A-775 digitizer, digital temperature and D.O. recorder with thermistor sensors.

Geodyne monitoring equipment was positioned at Station N-10, 0 (effluent and river confluence) and S-17 with temperature sensors positioned at the surface, 2.0, 3.5, 5.0, 6.5 and 7.0 feet below the surface.

Temperature profiles were taken at various stations north and south of the plant utilizing the Yellow Springs Model 44 telethermometer with an attached hand-held pole having thermistors at one-foot intervals. Temperatures were from surface to bottom at three to five sub-stations of each station sampled. Isotherms were plotted on river cross-section profiles at each station sampled with a fairly complete picture of heat characteristics resulting. The following data is derived from the results of the mobile unit Yellow Springs thermistor systems. In some cases, the lower thermistors on the profile probe are inaccurate, resulting in some misleading temperature readings. However, an attempt is made to differentiate these from actual readings in order to provide an accurate description of thermal characteristics.

The following isotherms show the characteristics of the heated plume from its origin at the canal and river confluence to the forebay of the Hooksett dam. As a matter of comparison, each set of isotherms has a profile of normal river temperatures upstream of the plant. Although profiles were taken at every other station below the power facility, not all stations are included in this phase of the report due to the repetition of the thermal effects in the river cross section.

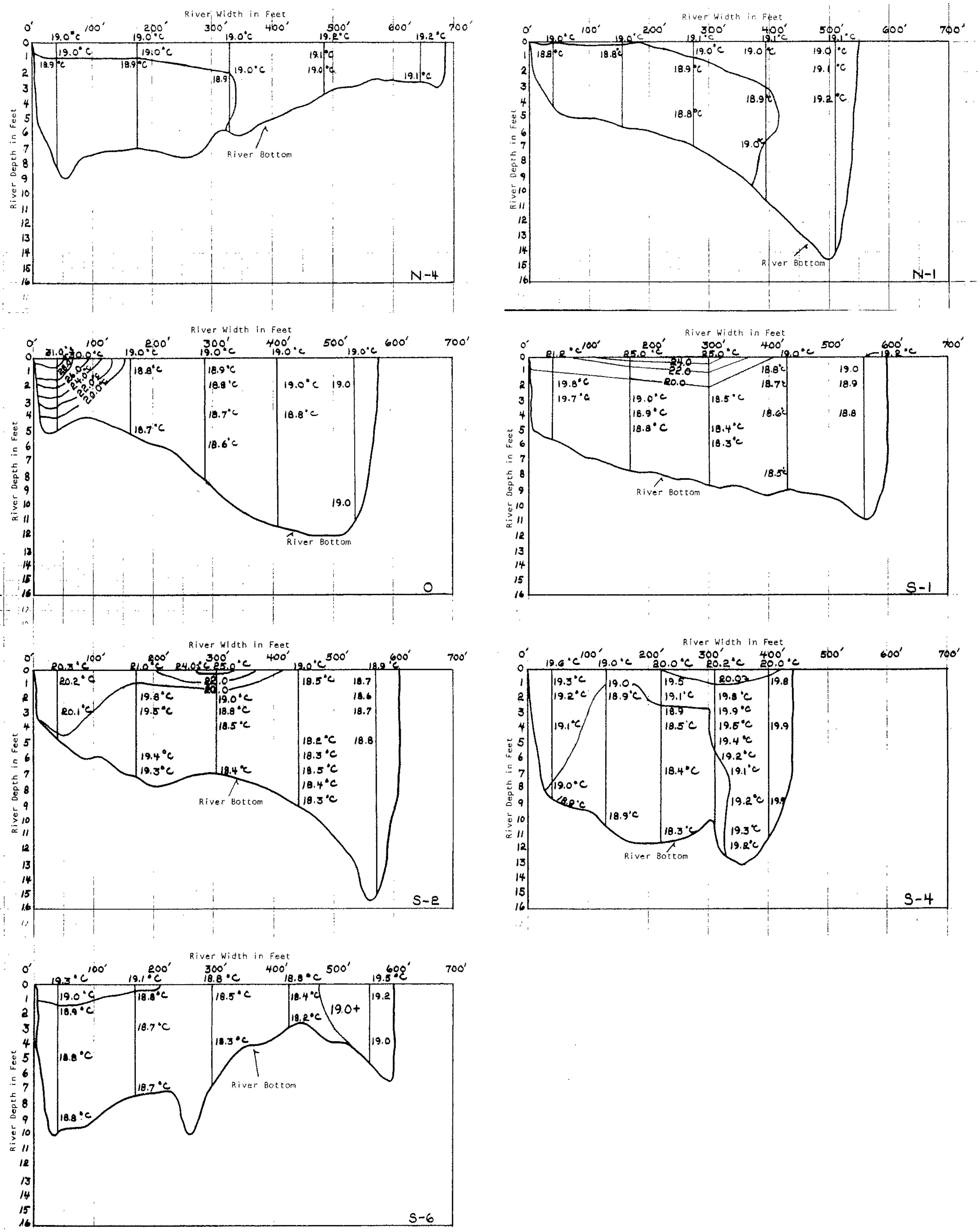
Meteorological data and power plant production is included before each set of temperature profile graphs for further information on the day of profile data taking.

Stations in which the profile data was obtained is located in the lower right hand corner. Data obtained represents a single day sampled each week of the study. For this reason, results should be treated as conditions which generally occur during the summer and do not represent extreme conditions encountered.

The following tables and figures pertain to the weather and plant production at the time of temperature profiles. This information is derived from Public Service data forwarded to this department.

Temperature Profile of June 6, 1968

Figure 29



TEMPERATURE PROFILE OF JUNE 13, 1968

Time - 1730

Station: N-2 - Accuracy of bottom thermistor questionable as there appears to be some inversion at lower depths. Temperatures at N-6 show temperatures similar to those recorded at this section with 17°C water on surface only. Major portion of river has water in 16°C range.

Time - 1600

Station: 0 - Maximum temperature of 29°C at canal effluent, temperature effects restricted to confluence of river and canal.

Time - 1550

Station: S-2 - 18°C temperature extends to four foot depth. Considerable heat loss in evidence with maximum temperature slightly above 22°C.

Station: S-4 - Very little evidence of 16°C temperatures which existed in the northern section at this sample station due to total mixing.

Time - 1520

Stations:
S-6 & S-10 - All water in the 17°C temperature range, none in the 16°C range.

Time - 1400

Stations:
S-18 & S-24 - Buildup of heated water on western bank with 18° C temperatures appearing at station S-24. This is apparently due to heat conduction of water held back by the dam.

Table 12

June 13 - Meteorological Data and Power Plant Production

River Flows 6,954 cfs, 24 hr. average - Min. flow 6,539 cfs - Max. flow 7,337 cfs

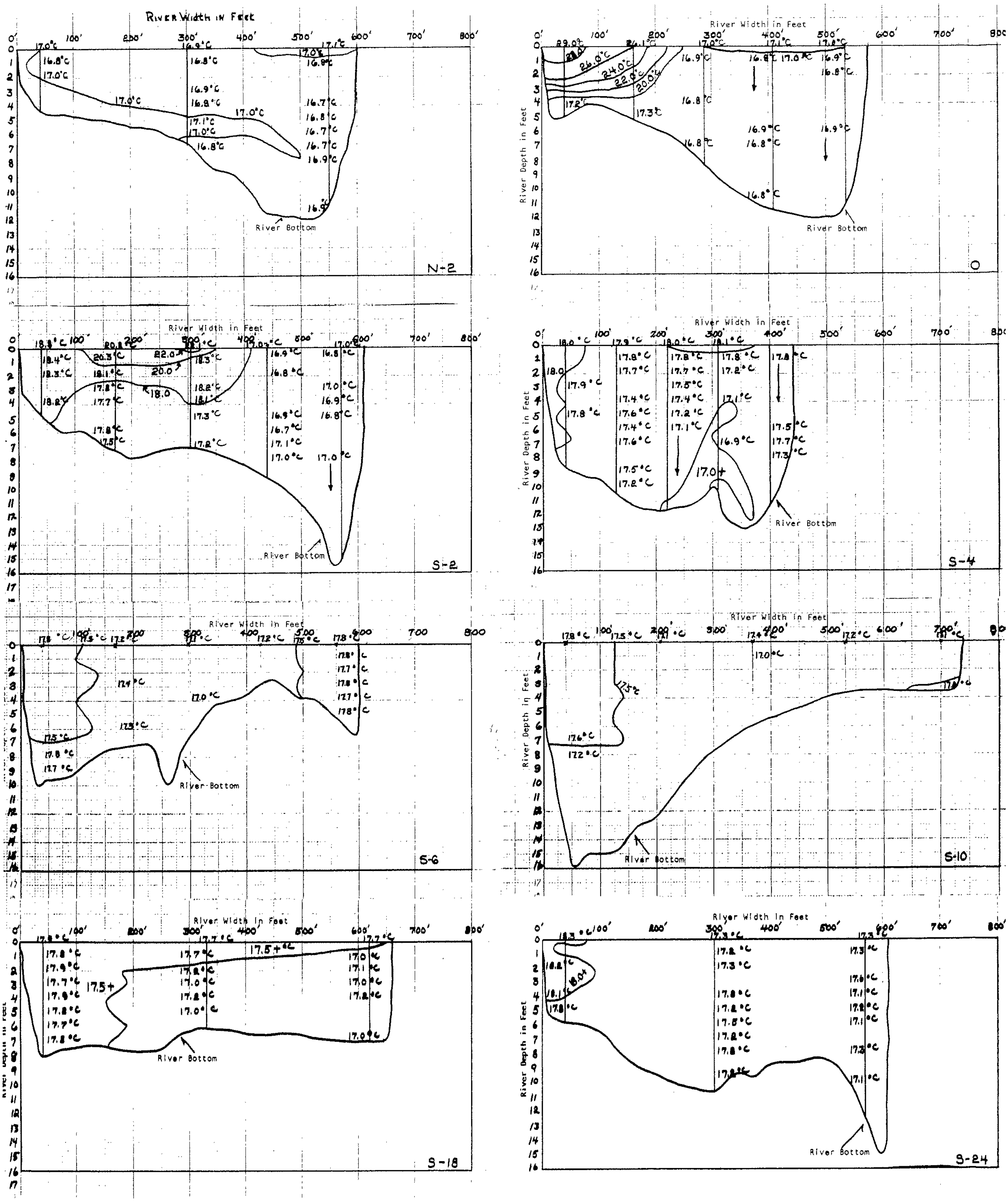
Normal River Temperature 16.9° C

Time	8 A.M.	Noon	4:30 P.M.
Air Temperature	17° C	22.5° C	27.0° C
Max./Min. Temperature	28.0 - 12.5° C	-	-
Barometric Pressure	29.54	29.54	29.54
Relative Humidity	98%	86%	71%
Sky Cover	100%	100%	60%
Wind Speed	1 mph	1 mph	2 mph
Precipitation	-	-	-

	Hourly Output MK-I and MK-II in Megawatts	
Time	MK-I	MK-II
9:00	91.0	354.0
10:00	90.0	353.0
11:00	91.0	356.0
12:00	90.0	355.0
13:00	90.0	352.0
14:00	90.0	351.0
15:00	90.0	351.0
16:00	89.0	352.0
17:00	91.0	353.0

Temperature Profile of June 13, 1968

Figure 30



TEMPERATURE PROFILE OF JUNE 27, 1968

Time - 1600

Station: N-1 - Temperatures of 17.0°C at all levels, no evidence of thermal effects due to magnitude of river flows.

Time - 1554

Station: 0 - Temperatures from canal significantly lower than temperatures occurring later in the summer. Temperatures during this period do not extend completely across the river as in the case later in the summer.

Time - 1525

Station: S-2 - 18°C water extends to four foot depth while major portion of thermal effect is restricted to upper two feet. No evidence of 17°C water at any depth.

Station: S-4 - Magnitude of flows creating very little stratification as 19°C water extends to bottom on eastside of river, while 18°C water extends to bottom on westside.

Time - 1500

Station: S-8 - 18°C water prevails in eastern half of river and small portion on western shore.

Time - 1425

Station: S-12 - No evidence of 17° C water during sample period.

Time - 1355

Station: S-20 - Reappearance of 17° C water, 18° C water appears on east bank to all depths.

Time - 1330

Station:S-24 - 18° C water at all depths very small amount of water in 17° C range.

Table 13

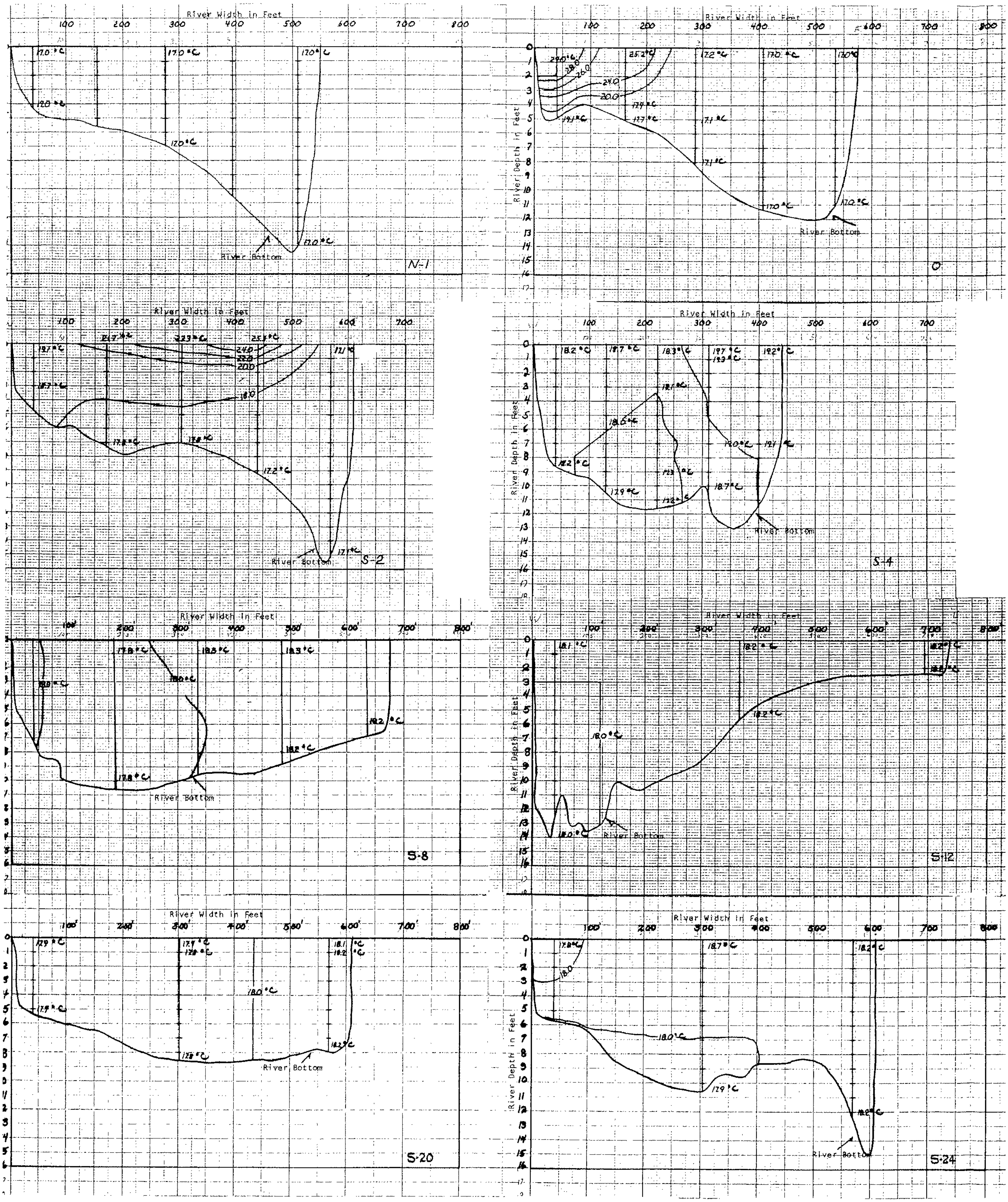
June 27 - Meteorological Data and Power Plant Production

River Flows 5,805 cfs, 24 hr. average - Min. flow 5,645 cfs - Max. flow 6,081 cfs

Normal River Temperature 17.0° C

Time	8 A.M.	Noon	4:30 P.M.
Air Temperature	13.0° C	13.0° C	15.0° C
Max./Min. Temperature	15.0 - 12.0° C	-	-
Barometric Pressure	29.78	29.87	29.90
Relative Humidity	87%	96%	87%
Sky Cover	100%	100%	100%
Wind Speed	2 mph	2 mph	2 mph
Precipitation	-	Light	-

	Hourly Output MK-I and MK-II in Megawatts	
Time	MK-I	MK-II
9:00	101.0	352.0
10:00	102.0	352.0
11:00	114.0	353.0
12:00	116.0	352.0
13:00	116.0	352.0
14:00	116.0	352.0
15:00	116.0	353.0
16:00	116.0	353.0
17:00	116.0	352.0


River Width in Feet
River Depth in Feet
River Bottom
N-1
O
S-2
S-4
S-8
S-12
S-20
S-24

TEMPERATURE PROFILE OF JULY 11, 1968

Time - 1732-1711

Stations:
N-6-5-4 - Uniform temperature of 22.1°C

Time - 1614

Station: N-1 - Evidence of slight temperature increase along both shores.

Station: 0 - Temperature of 34.8°C appearing at confluence of canal and river. Bottom temperature readings slightly higher than those recorded in the northern section. This is probably due to an inaccurate sensor on temperature probe rather than a result of thermal effects.

Time - 1539

Station: S-2 - Heat decay is evident as 34°C water has cooled to 30°C with extreme temperatures on eastern surface level. Thermal warming has penetrated to eight-foot depth on eastside, not as pronounced on the western side.

Station: S-4 - Maximum thermal effects have shifted to western side of river. 30°C temperatures are non-existent at this station, with 29.2°C maximum temperature recorded. Considerable portion of the river shows some temperature increase to nine-foot depth.

Time - 1504

Stations:

S-6 & 8 - Evidence of a leveling out of heated strata with primary effects being limited to upper three feet. Supplemental flows of Suncook River at S-8 probably aiding in further temperature decrease.

Time - 1415

Station: S-16 - Slight warming effect occurring to bottom depths.

Time - 1355-1329

Stations:

S-20 & 24 - Heated effects are marginal with limited effect appearing on western side of the river. Temperature buildup in dam forebay unlike June 27 sample. Possibility of generating pattern having some effect in temperature variation from east to west of river cross section.

Table 14

July 11 - Meteorological Data and Power Plant Production

River Flows 2,548 cfs, 24 hr. average - Min. flow 1,605 cfs - Max. flow 2,990 cfs

Normal River Temperature 22.1° C

Time	8 A.M.	Noon	4:30 P.M.
Air Temperature	14° C	24.5° C	27.5° C
Max./Min. Temperature	32 - 12° C	-	-
Barometric Pressure	30.00	30.03	30.01
Relative Humidity	63%	63%	81%
Sky Cover	75%	100%	60%
Wind Speed	1	3	2
Precipitation	-	-	-

	Hourly Output MK-I and MK-II in Megawatts	
Time	MK-I	MK-II
9:00	80.3	340.4
10:00	103.7	341.4
11:00	103.1	340.4
12:00	103.1	339.5
13:00	100.1	340.4
14:00	103.4	339.4
15:00	99.8	339.4
16:00	94.1	342.4
17:00	94.1	342.3

Temperature Profile of July 11, 1968

Figure 32

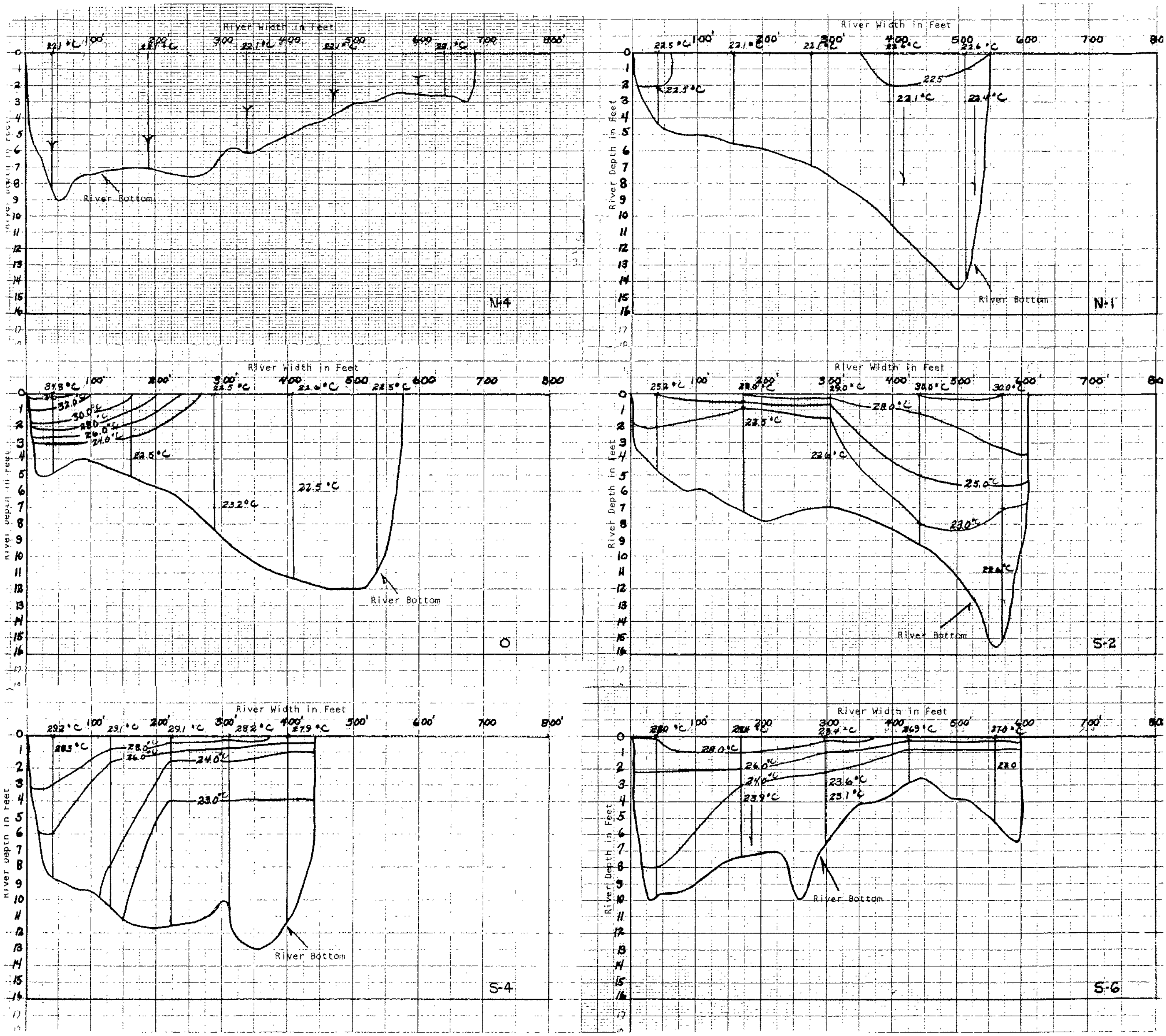
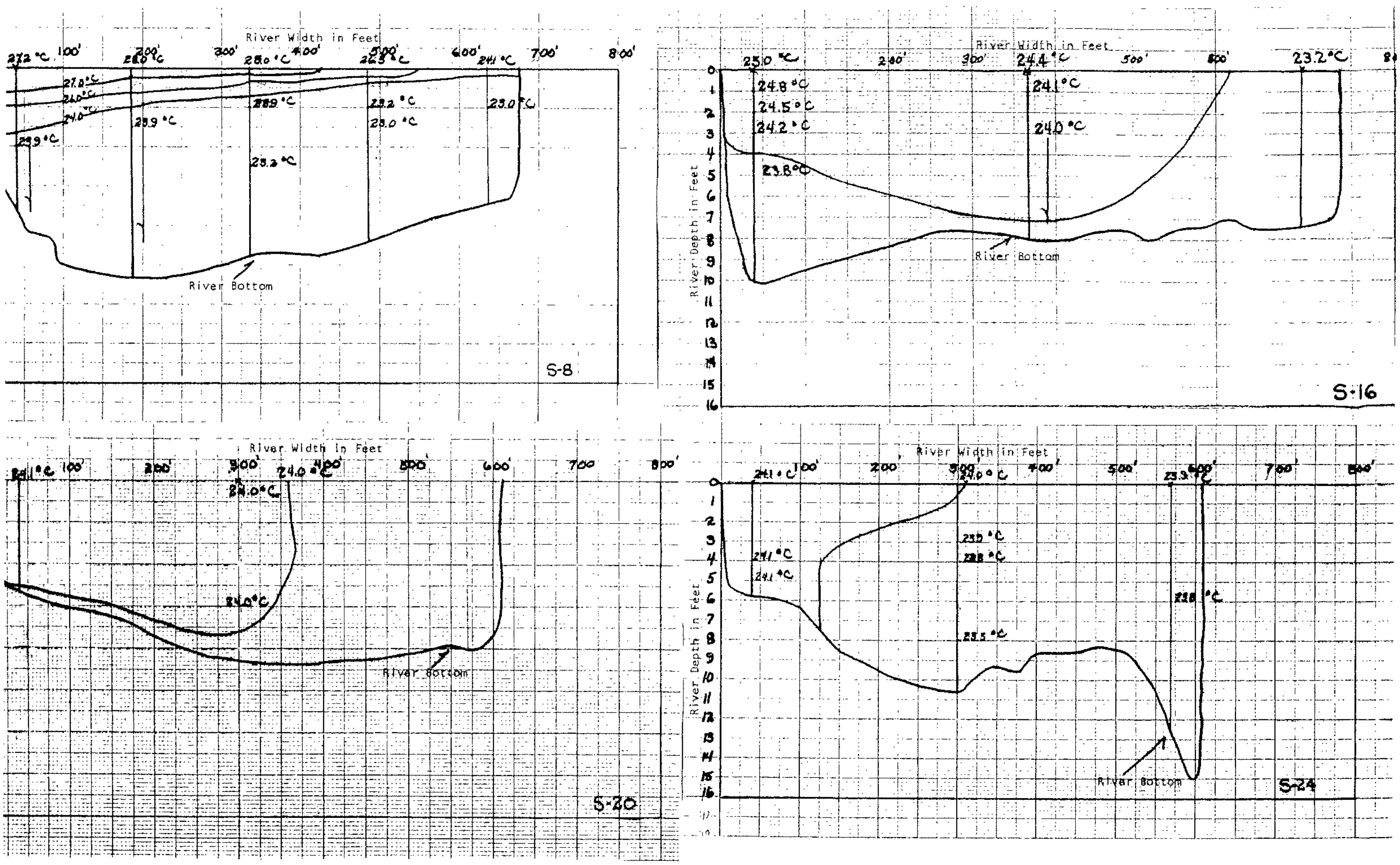


Figure 33 Temperature Profile of July 11, 1968



TEMPERATURE PROFILE OF JULY 18, 1968

Time - 1226

Station: N-4 - Temperatures above 27.0° C appearing on eastern and western shore. This is apparently due to the movement of the heated effluent upstream from recirculating effects and wind direction.

Time - 1239

Station: N-2 - Effects of heated effluent quite evident at this station with an approximate rise of 5.4° C in evidence on the eastern shore. Less marked heat rise on western shore.

Time - 1330

Station: N-1 - Thermal effects indicated in upper three feet of surface water. Difference of approximately 7° C apparent in area of greatest heated effect.

Time - 1255

Station: 0 - Extreme temperatures of 39.1° C at the canal and river confluence. Some warming of water to three and four-foot depths primarily, although eastern shore indicates 28° C temperature extends to six-foot depth.

Time - 1341

Station: S-2 - Temperatures of 28° C extending from three-foot depth on western shore to approximately five-foot on eastern shore. Maximum temperatures on surface primarily on eastern half of river with 9° C rise in temperature extending to three-foot depth.

Time - 1409-1439

Stations:
S-6 & S-10 - Temperatures of 28° C continuing down to three-foot depth. Surface layer gives evidence of 7-8° C temperature variation from bottom temperatures.

Time - 1503-1511

Stations:
S-14 & S-16 - 28° C temperatures continue at approximately three-foot layer. Temperature difference of nearly 8° C evident on eastern shore in comparison to bottom temperatures.

Time - 1530-1339

Stations:
S-20 & S-24 - 28° C temperature between two-foot and three-foot depth at S-20, descends to five-foot depth at S-24 as backup effects of the dam become apparent. Similar depth increase of 32° C temperatures at this station. Heat dissipation very slow on the date of this sample.

It appears that high air temperatures on this date (up to 37^{o} C) caused a reduction in heat dissipation from the heated waters in the impoundment.

Table 15

July 18 - Meteorological Data and Power Plant Production

River Flows 1,854 cfs, 24 hr. average - Min. flow 1,506 cfs - Max. flow 2,809 cfs

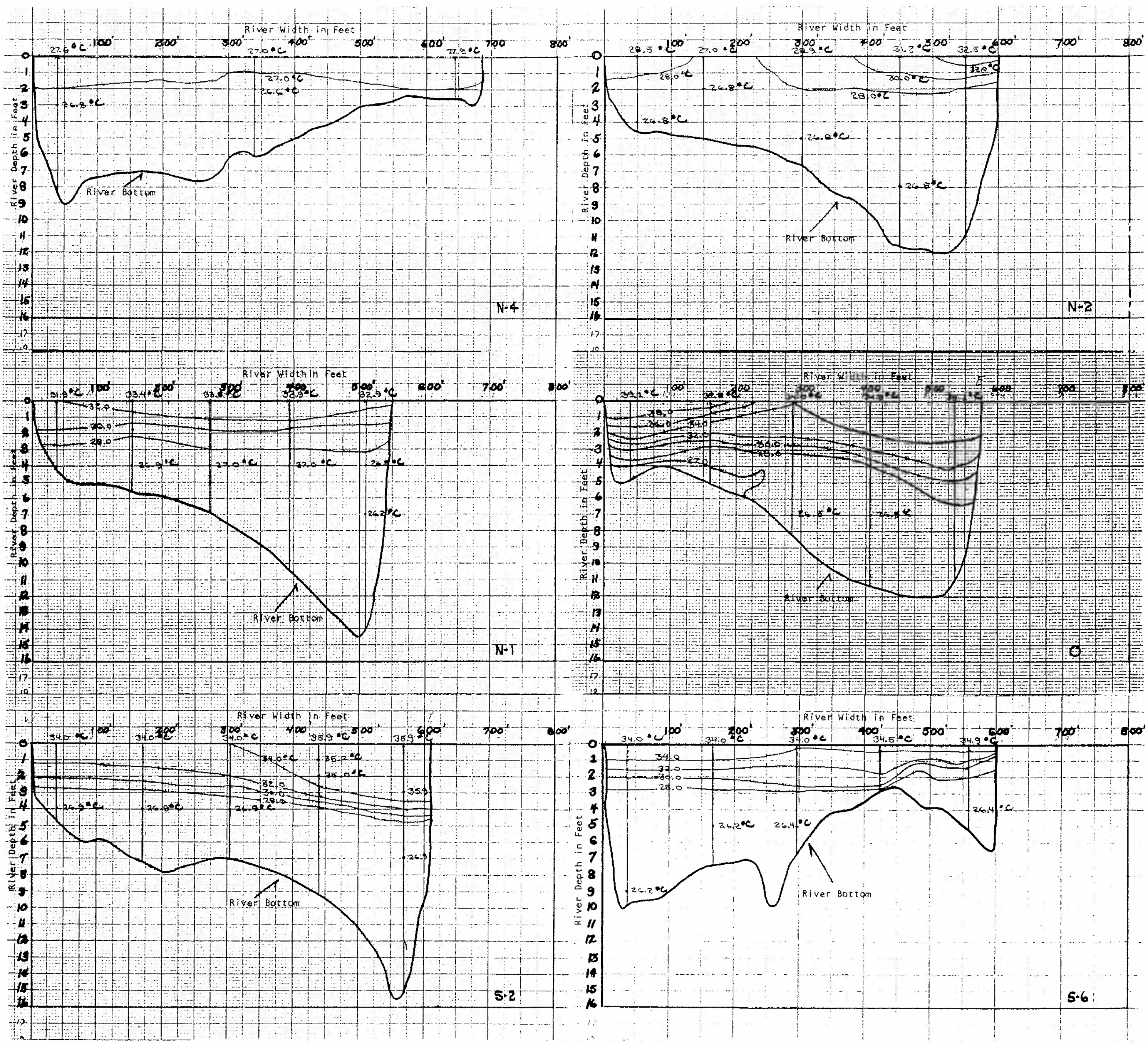
Normal River Temperature 26.8° C

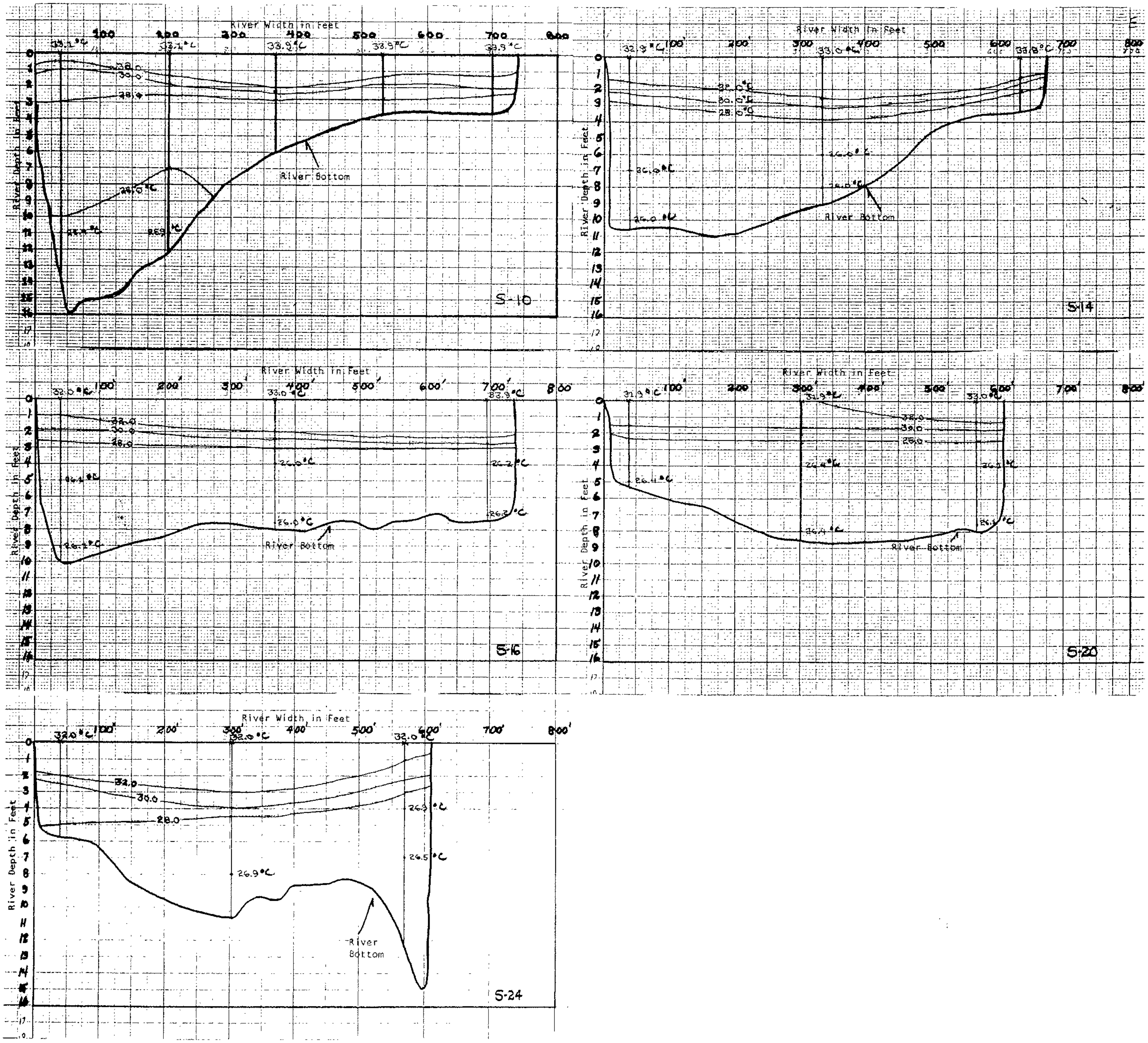
Time	8 A.M.	Noon	4:30 P.M.
Air Temperature	20° C	30° C	37° C
Max./Min. Temperature	37 - 16° C	-	-
Barometric Pressure	29.90	29.92	29.83
Relative Humidity	90%	73%	70%
Sky Cover	100% Haze	0	10%
Wind Speed	1 mph	1 mph	2.3 mph
Precipitation	-	-	-

	Hourly Output MK-I and MK-II in Megawatts	
Time	MK-I	MK-II
9:00	112.3	334.3
10:00	112.3	338.3
11:00	111.9	336.2
12:00	111.8	335.3
13:00	110.8	335.3
14:00	111.9	332.4
15:00	111.4	330.5
16:00	111.3	332.4
17:00	112.4	333.3

Temperature Profile of July 18, 1968

Figure 34




River Width in Feet
River Depth in Feet
River Bottom
S-10
S-14
S-16
S-20
S-24
32.0
30.0
28.0
26.0°C
33.0°C
32.0°C

TEMPERATURE PROFILE OF AUGUST 2, 1968

Time - 1501

Station: N-4 - 24° C temperatures comparable to N-6 station appears to be more radiational warming to surface waters due to low flows and high air temperatures. Slight amount of heated water on eastern side.

Time - 1448

Station: N-1 - Backup of heated water evident at three-foot depth, significant increase in temperature on surface.

Time - 1422

Station: 0 - Rapid stratification of thermal load due to low flows on this date - 26° - 31°C temperatures encompass entire river surface.

Time - 1402

Station: S-2 - Thermal effects increasing in depth with a large amount of 30° water extending to four-foot depth on eastern side.

Time - 1336

Station: S-6 - Conditions similar to station S-4 with 30°C water extending nearly across the river in upper two feet of surface water.

Time - 1307

Station: S-16 - Evidence of heating effect in upper two and three feet of surface waters as 26^{o} C water extends across river.

Time - 1250-1239

Stations:
S-20 & 24 - Loss of 28^{o} C thermal layer but still evident of heating effect which extends to greater depths in forebay of the dam, due to backup conditions.

Table 16

August 2 - Meteorological Data and Power Plant Production

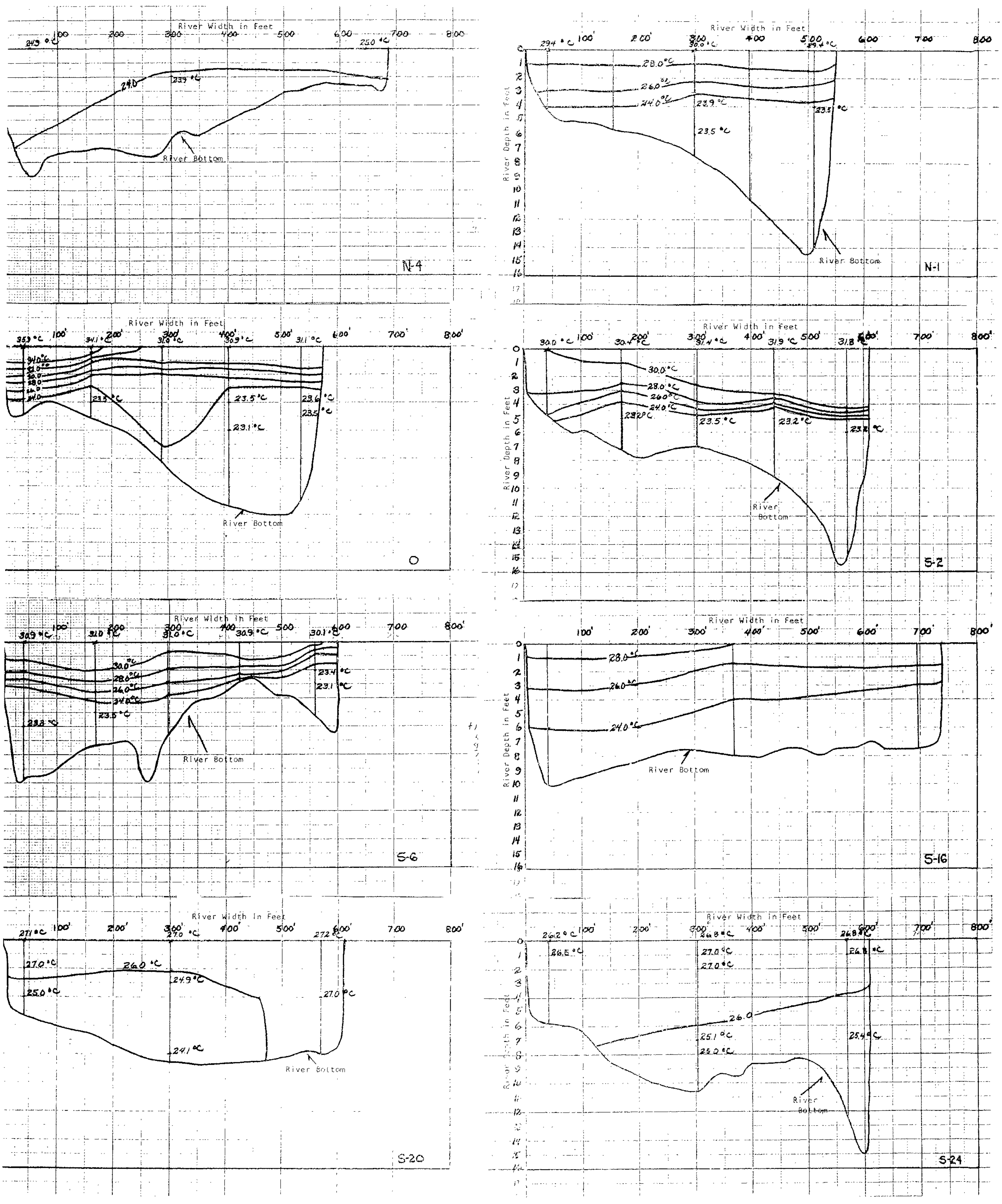
River Flows 1,177 cfs, 24 hr. average - Min. flow 995 cfs - Max. flow 1,271 cfs

Normal River Temperature 24.1° C

Time	8 A.M.	Noon	4:30 P.M.
Air Temperature	17° C	24° C	29° C
Max./Min. Temperature	32 - 14° C	-	-
Barometric Pressure	29.88	29.90	29.92
Relative Humidity	96%	76%	65%
Sky Cover	100%	100%	80%
Wind Speed	1 mph	2 mph	1 mph
Precipitation	-	-	-

	Hourly Output MK-I and MK-II in Megawatts	
Time	MK-I	MK-II
9:00	111.9	331.3
10:00	111.5	331.3
11:00	111.9	330.3
12:00	111.7	330.3
13:00	111.7	331.2
14:00	112.0	332.2
15:00	112.3	333.2
16:00	112.2	329.4
17:00	112.4	330.2

Figure 36 Temperature Profile of August 2, 1968



TEMPERATURE PROFILE OF AUGUST 27, 1968

Time - 1835

Station: N-4 - Bottom sensors appear to be inaccurate, however, it is estimated normal river temperature is approximately 22.8° C.

Time - 1751

Station: N-1 - Considerable backup of heated water at this station with nearly 5° C increase in surface temperature.

Station: 0 - Stratification evident at this station completely across river to three-foot depth. Maximum canal temperature 35° C.

Time - 1715

Station: S-2 - Thermal effects extend to greater depths than was apparent in previous samples.

Time - 1555

Station: S-8 - Thermal effects extend to four-foot depth, middle portion of surface water has 28° C+ to a depth of two feet.

Time - 1537

Station: S-12 - Definite buildup of thermal effects to significant depths, 28^{o} C water extends to four-foot depth and covers large amount of surface area.

Time - 1451

Station: S-14 - Compare with following graphs as to thermal buildup at lower depths as Hooksett dam effects are felt. Also make note of bottom temperature.

Time - 1435

Stations:
S-18 - S-24 - Temperature increase to all depths of 3-4^{o} C over normal river temperature. Temperature buildup especially evident during this sample period in forebay.

Table 17

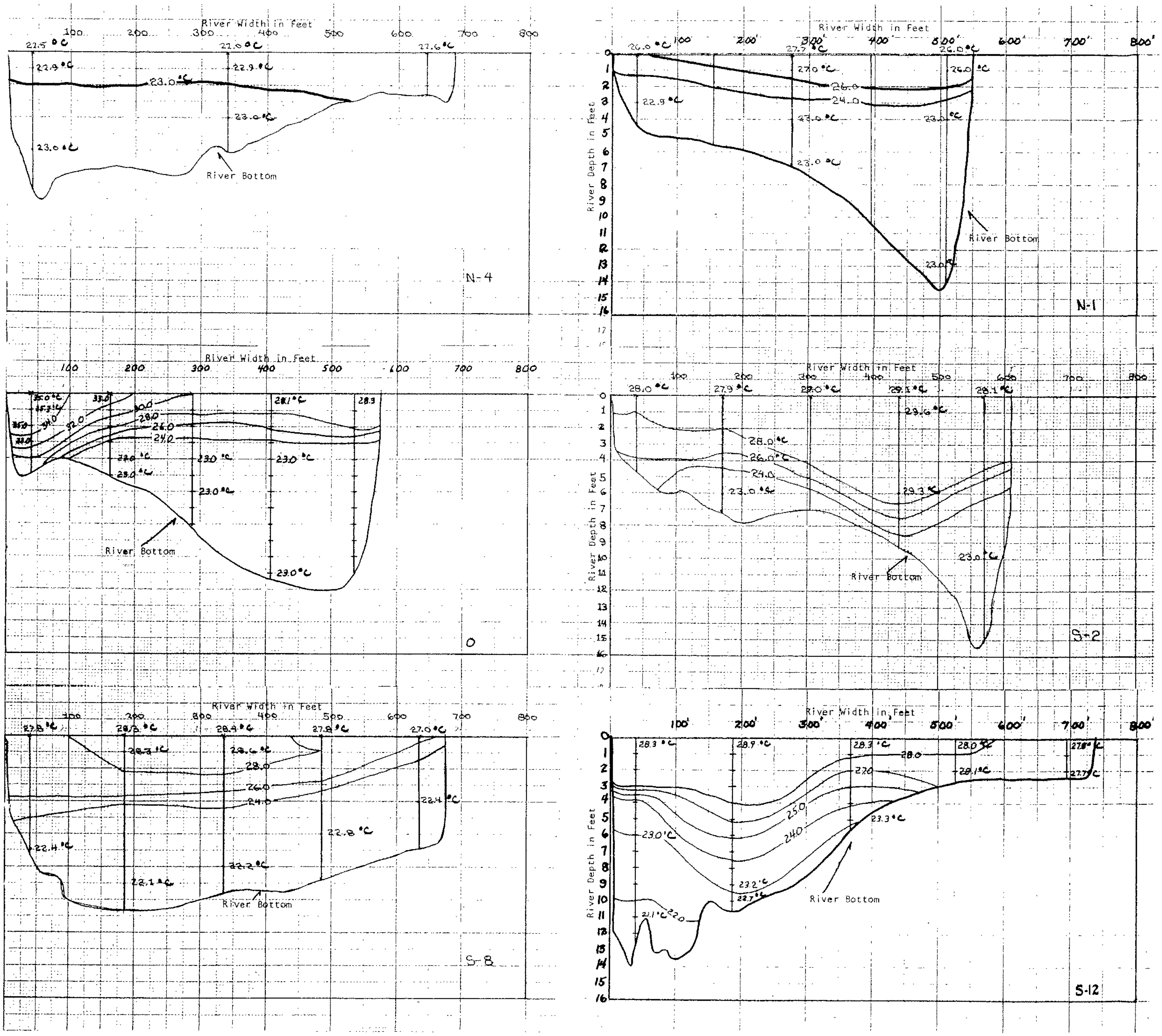
August 27 - Meteorological Data and Power Plant Production

River Flows 1,153 cfs, 24 hr. average - Min. flow 963 cfs - Max. flow 1,391 cfs

Normal River Temperature 22.8° C

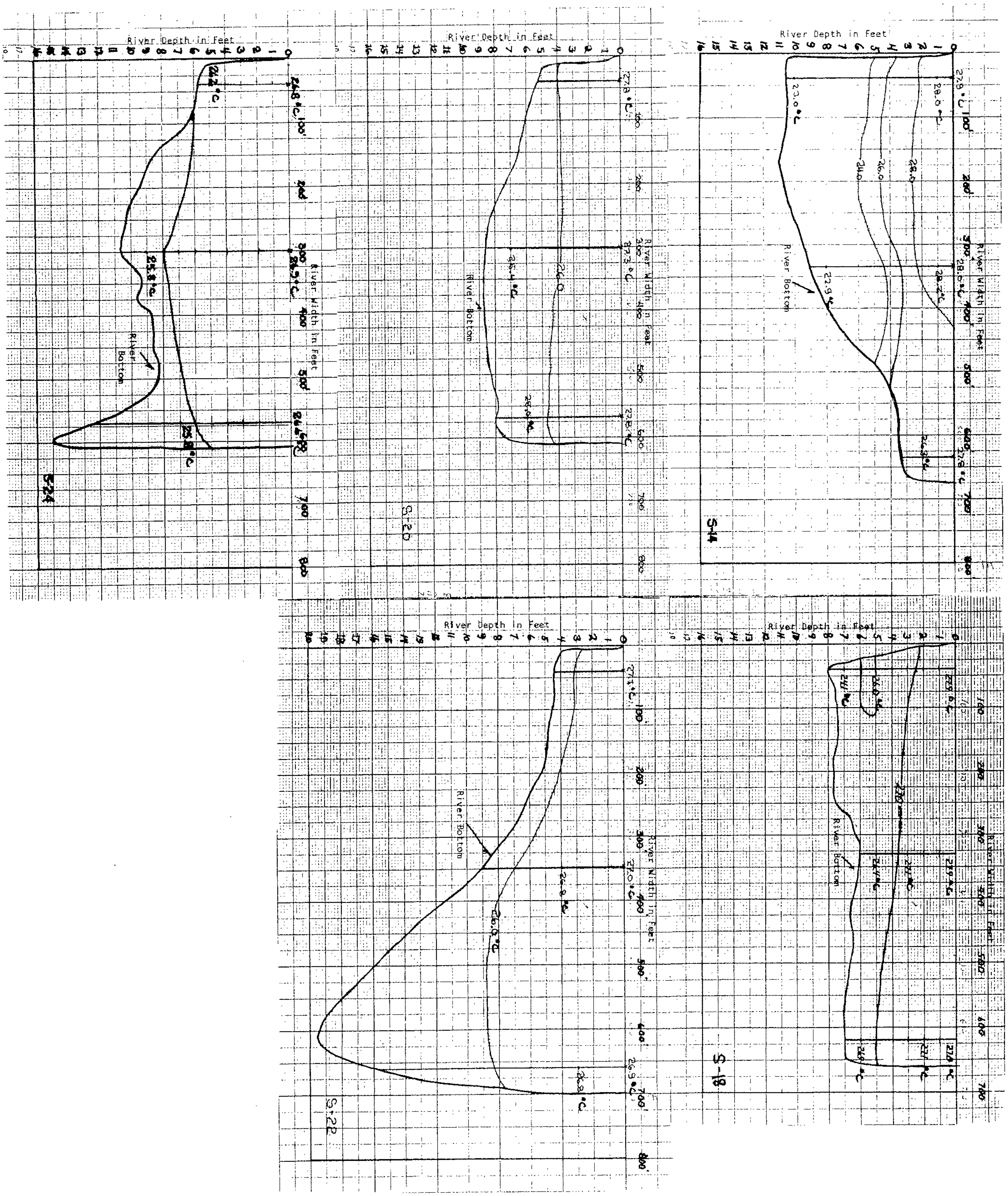
Time	8 A.M.	Noon	4:30 P.M.
Air Temperature	15° C	-	17.5° C
Max./Min. Temperature	27 - 6° C	-	-
Barometric Pressure	29.82	-	29.86
Relative Humidity	55%	-	51%
Sky Cover	0	-	100%
Wind Speed	1 mph	-	3 mph
Precipitation	None	-	None

	Hourly Output MK-I and MK-II in Megawatts	
Time	MK-I	MK-II
9:00	112.7	320.5
10:00	112.6	320.4
11:00	111.7	319.5
12:00	112.6	319.5
13:00	111.6	319.5
14:00	112.9	320.3
15:00	111.6	320.5
16:00	112.6	320.3
17:00	111.8	319.5


River Width in Feet
River Depth in Feet
River Bottom
N-4
N-1
O
S-2
S-8
S-12
23.0°C
22.9°C
26.0
24.0
28.0
27.0
25.0
23.0°C

Temperature Profile of August 27, 1968

Figure 38



TEMPERATURE PROFILE OF SEPTEMBER 4, 1968

Time - 1651

Station: N-4 - Some warming on surface from plant effluent station N-6 shows temperature of 22.2^{o} C at all depths.

Time - 1605

Station: 0 - Thermal effect extends completely across river, temperature increase to four-foot depths.

Time - 1533

Station: S-2 - Thermal effects of 24^{o} C extend to four and five-foot depths. Temperatures of 30^{o} C or better - vary from one-foot depth westside to four-foot depth on eastside.

Time - 1519

Station: S-8 - 30^{o} C temperature evident on surface with 24^{o} C evident to five-foot depth.

Time - 1451

Station: S-12 - Significant warming in shallow water on east bank - 30^{o} C temperatures still existing with thermal effects to five-foot depth.

Station:S-18 - 30° C water non-existent, 24° C isotherm has risen closer to surface - 28° C water on east bank.

Time - 1233

Station:S-22 - 24° C water has increased in depth as well as a slight warming trend at all depths. 22° C water in bottom layer non-existent at this sample station.

Time - 1245

Station:S-24 - Significant buildup of 27° C water, 24° C water at a maximum depth of nine feet. Reappearance of 22° C water at this station. Backup of warm water especially pronounced at this station.

Table 18

September 4 - Meteorological Data and Power Plant Production

River Flows 793 cfs, 24 hr. average - Min. flow 642 cfs - Max. flow 1,087 cfs

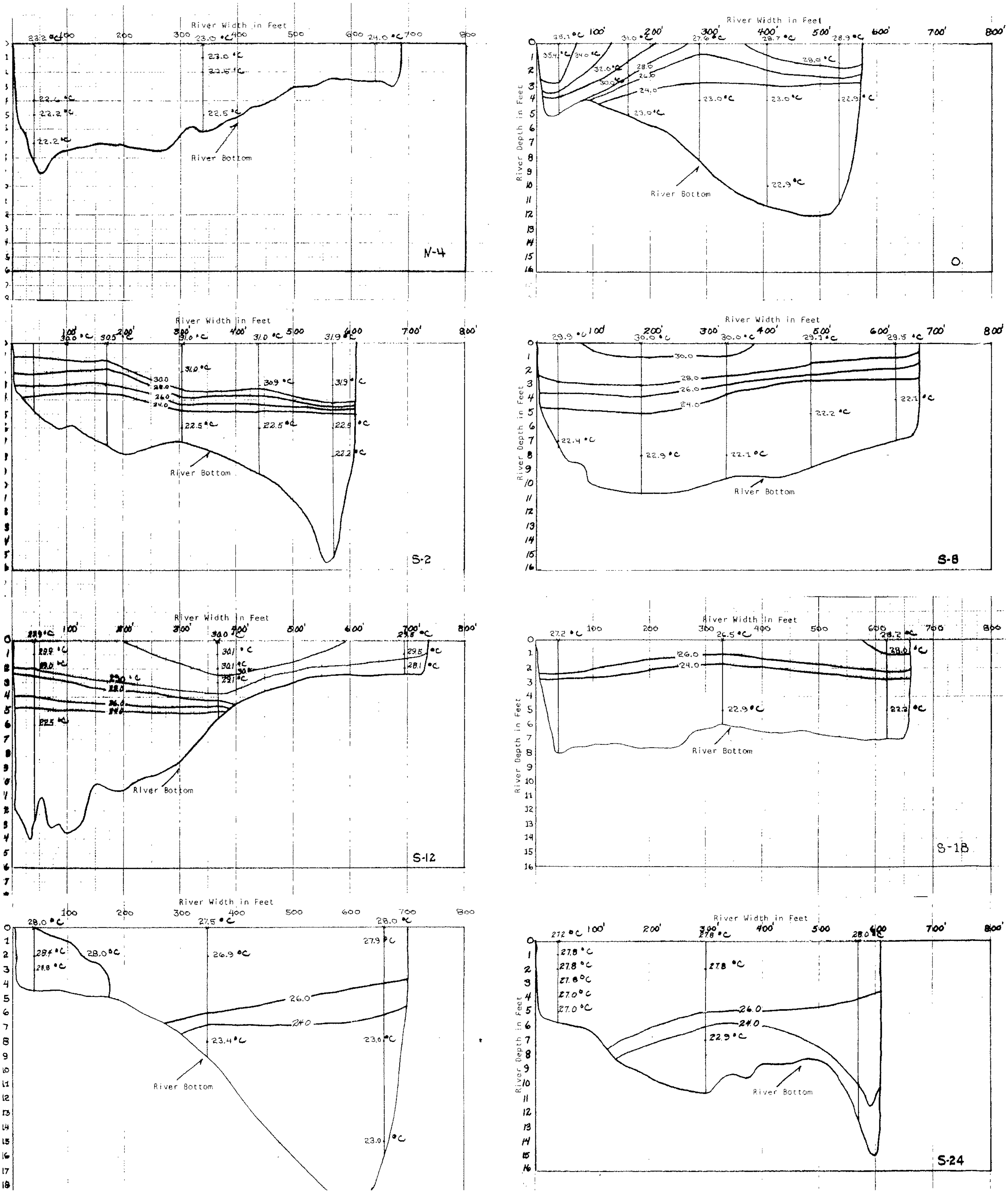
Normal River Temperature 22.2° C

Time	8 A.M.	Noon	4:30 P.M.
Air Temperature	13° C	24° C	21° C
Max./Min. Temperature	29 - 11° C	-	-
Barometric Pressure	29.80	30.06	30.04
Relative Humidity	96%	69%	73%
Sky Cover	100%	100%	100%
Wind Speed	1 mph	1 mph	2 mph
Precipitation	None	-	None

	Hourly Output MK-I and MK-II in Megawatts	
Time	MK-I	MK-II
9:00	111.8	338.1
10:00	112.4	340.1
11:00	111.7	341.1
12:00	111.9	341.0
13:00	112.6	341.0
14:00	112.7	341.1
15:00	112.6	341.0
16:00	112.8	340.0
17:00	111.5	339.1

Temperature Profile of September 4, 1968

Figure 39



Temperature - Amoskeag

Table 19 shows the results of temperature profiles taken below the Hooksett Dam after complete mixing of the water occurs. (Reference to station locations is shown in Figure 6). It should be noted that the temperature data accumulated in this section of the river was obtained during the morning hours between 9:45 a.m. and 12:05 p.m., whereas the ambient temperatures used for comparison were obtained later in the day when diurnal effects were greater. In the case of the September 4 sample, a time difference of six hours had transpired before the northern section temperatures were obtained. For this reason, although data obtained indicates a maximum difference of 4° C occurred on August 27 at Station A-13, it is felt the variation in temperature was greater than is indicated due to the time difference.

On a seasonal basis the temperature variation in June is less than the succeeding months due to normal water temperatures and the dilution effect of the greater flows. This is especially evident as flows decrease in the summer months and seasonal temperatures increase resulting in a greater heat differential. An exception to this pattern was during August 15 when MK-II was operating considerably below maximum output during the sampling period.

Heat decay and thermal stratification occurs to a lesser degree in the Amoskeag impoundment compared to the area between the plant and Hooksett dam due to complete mixing of the water from the dam effects.

This results in temperatures generally warmer to all depths in comparison to normal river temperatures (Table 19).

Table 19 Comparison of Ambient River and Amoskeag Pool Temperatures During 1968

Date	Amoskeag Pool			Ambient River Temp.			Avg. Temp. Amoskeag Pool °C	Avg. Ambient Temp. °C
	Time	Station	Temp. Range	Time	Station	Temp. Range		
6/27/68	1115	A-6	17.7 - 17.9	1605	N-4	16.9 - 17.1	17.8	17.1
	1051	A-13	17.3 - 17.8				17.7	
	-	A-23	17.2 - 17.9				17.6	
	1015	A-39	17.2 - 18.0				17.9	
	-	A-63	17.5 - 18.4				18.1	
7/11/68	1121	A-6	23.3 - 23.4	1732	N-4	22.1 - 23.0	23.4	22.2
	-	A-13	23.5 - 23.8				23.7	
	1055	A-23	23.9 - 24.0				23.9	
	-	A-39	23.8 -				23.8	
	1005	A-63	23.9 - 24.0				23.9	
7/18/68	1036	A-6	28.0 -	1226	N-4	26.5 - 27.9	28.0	26.9
	1011	A-13	28.2 - 29.2				28.6	
	1022	A-23	28.8 - 29.0				28.9	
	0935	A-39	28.2 - 28.9				28.4	
	1000	A-63	28.2 - 29.0				28.5	
8/2/68	1009	A-6	26.4 - 27.0	1507	N-4	23.8 - 25.0	26.8	24.1
	0949	A-13	26.9 - 27.1				27.1	
	0958	A-23	26.9 - 27.2				27.0	
	0919	A-39	25.1 - 25.9				25.5	
	0937	A-63	24.2 - 25.0				24.9	
8/15/68	1007	A-6	23.8 - 24.0	1357	N-4	23.0 - 23.6	24.0	23.1
	0939	A-13	23.8 - 24.0				24.0	
	0947	A-23	23.0 - 23.8				23.7	
	0912	A-39	23.2 - 23.8				23.7	
	0922	A-63	23.5 - 23.9				23.9	
8/27/68	1145	A-6	25.8 - 25.9	1835	N-4	22.0 - 23.0	25.9	22.8
	1123	A-13	26.6 - 26.8				26.7	
	1111	A-23	26.0 - 26.5				26.2	
	1035	A-39	25.5 - 25.9				25.6	
	1018	A-63	25.1 - 25.8				25.4	
9/4/68	1034	A-6	26.1 - 26.9	1630	N-4	22.2 - 24.0	26.3	22.8
	1004	A-13	26.1 - 26.9				26.4	
	1018	A-23	26.0 - 26.4				26.1	
	0922	A-39	25.0 - 25.5				25.0	
	0945	A-63	24.6 - 25.0				24.8	

<u>Temperatures - North and South - Geodyne data</u>

Maximum daily temperatures which occurred during July and August of 1968 are shown in Figures 40, 41, 42 and 43. This data represents maximum bottom and surface temperatures as monitored by Geodyne equipment on a twenty-four hour basis at Stations N-10, 0 and S-17. Data was monitored from June to October, however, the following data pertains to only the critical temperature period of July and August.

No data was forwarded to this office regarding Geodyne data from the period of late August through September, however, observations of the report of Dr. Normandeau for Public Service Company show that surface temperatures declined to the 70's and 60's°F in the north and south with the difference of the two sections comparable to previous months results. Peak ambient temperatures for both years of the study were recorded during the July 16-23 period.

In 1968, at N-10, the extreme bottom temperature of 27.2°C (80.9°F) was recorded on July 17 and 18 during the 1500-1900 time period while surface temperatures peaked at 28.1°C (82.5°F) on July 17 and 27.5°C (81.5°F) the following day (Figures 40 and 42).

Station 0 showed peaks of 40.5°C (104.9°F) on July 16, with four days exhibiting peaks of 39°C (102.2°F) or more during the time period of July 14 to July 18. Bottom temperatures were greatest on July 18, 1968, when a temperature of 27.4°C (83.1°F) was recorded. Fortunately, these temperatures did not cover the entire cross-section of the river where normal flows create reduced temperatures. They do, however, indicate the temperate impact of the canal on the river. Maximum surface temperatures of 33.4°C (91.1°F) were recorded at S-17 on July 18 with temperatures of 32.4°C (90.3°F) occurring on July 19 and 32.7°C (91.2°F) on July 17.

1968 - COMPARISON OF DAILY MAXIMUM SURFACE TEMPERATURES AT STATIONS N-10, O, S-17.

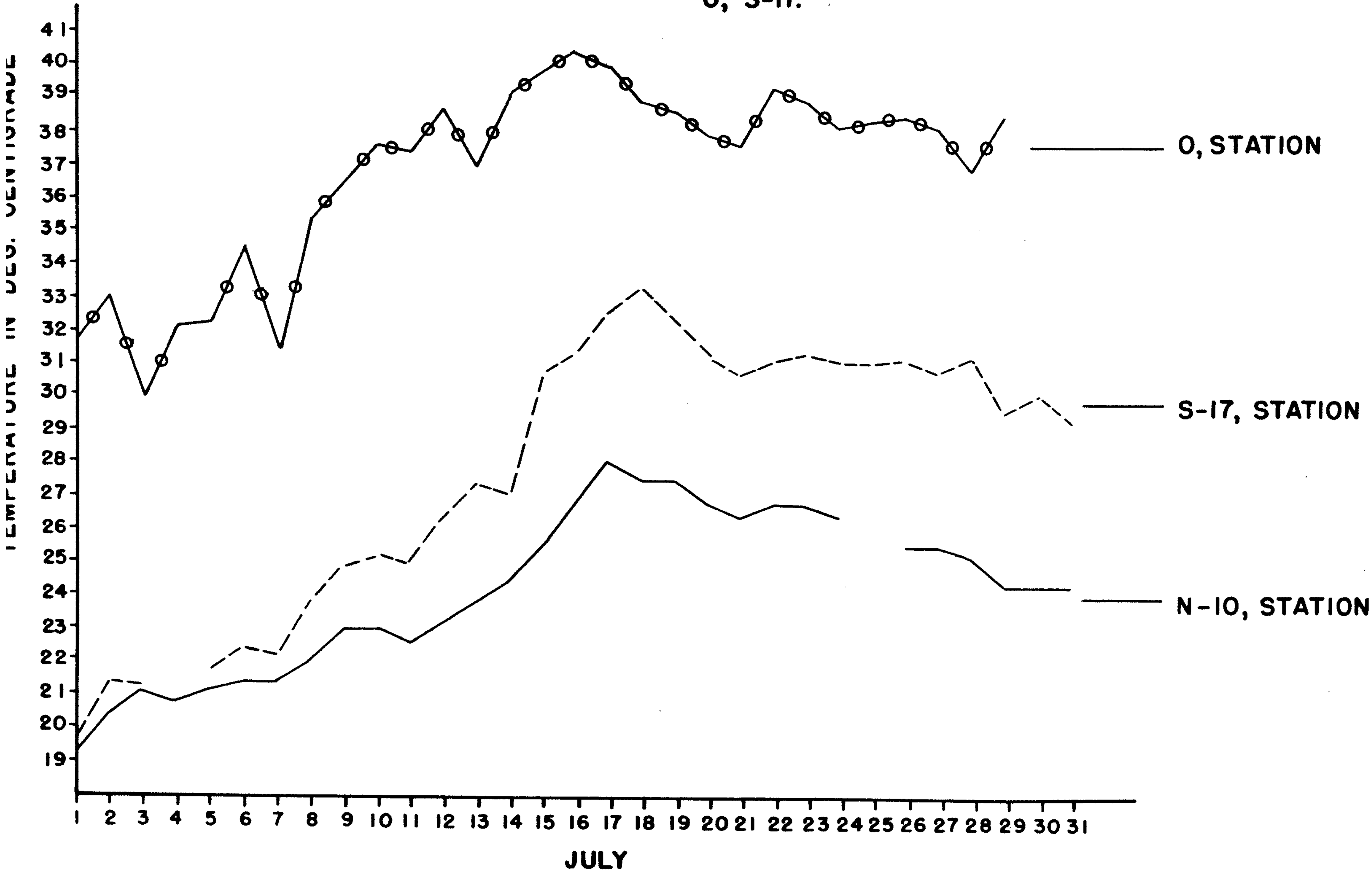


FIGURE 40 - BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO. RE: MERRIMACK RIVER THERMAL STUDY. (GEODYNE DATA)

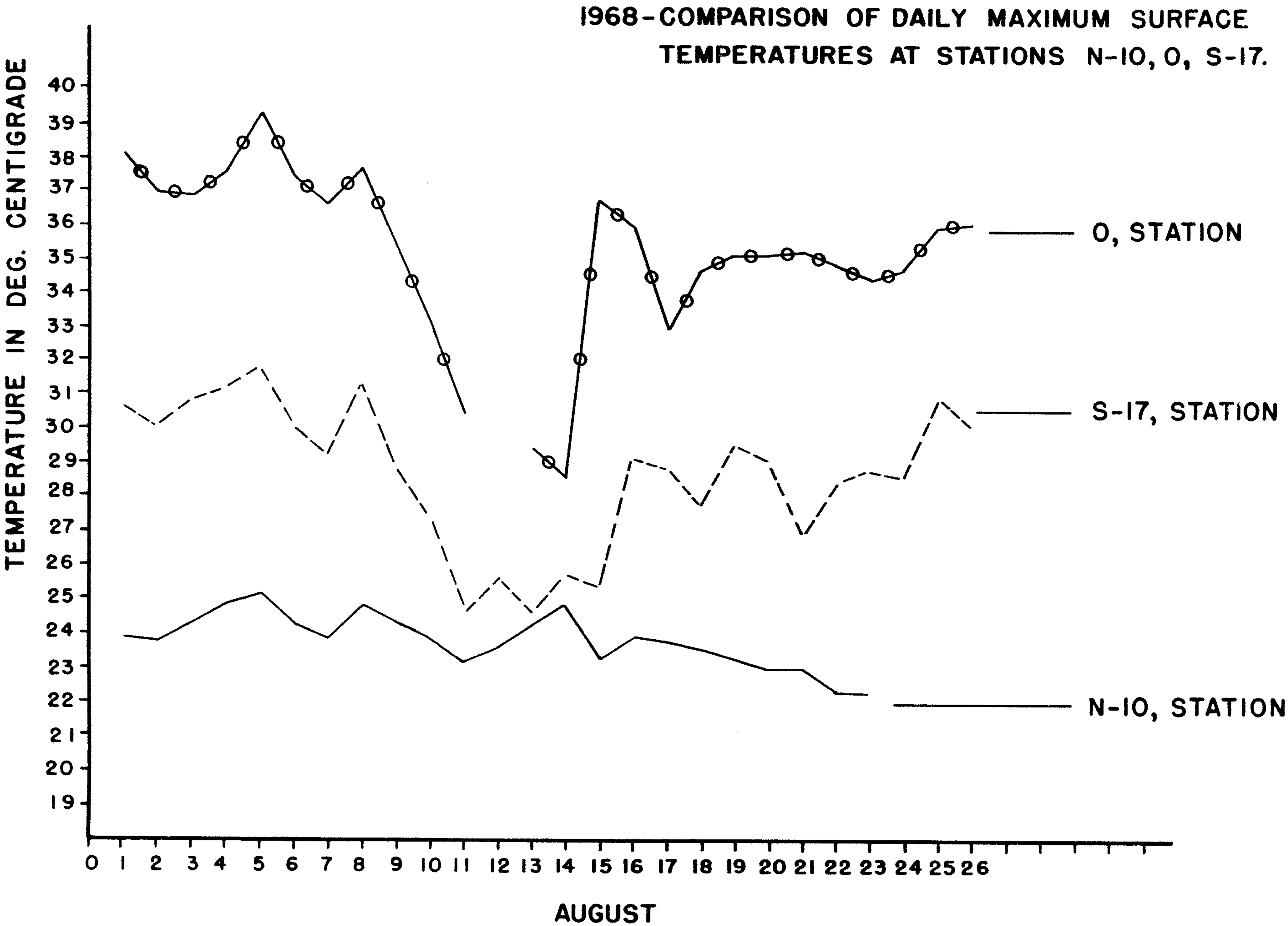


FIGURE 41- BASED ON DATA RECEIVED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY. (GEODYNE DATA)

1968-COMPARISON OF DAILY MAXIMUM BOTTOM TEMPERATURE AT STATIONS N-10, O, S-17.

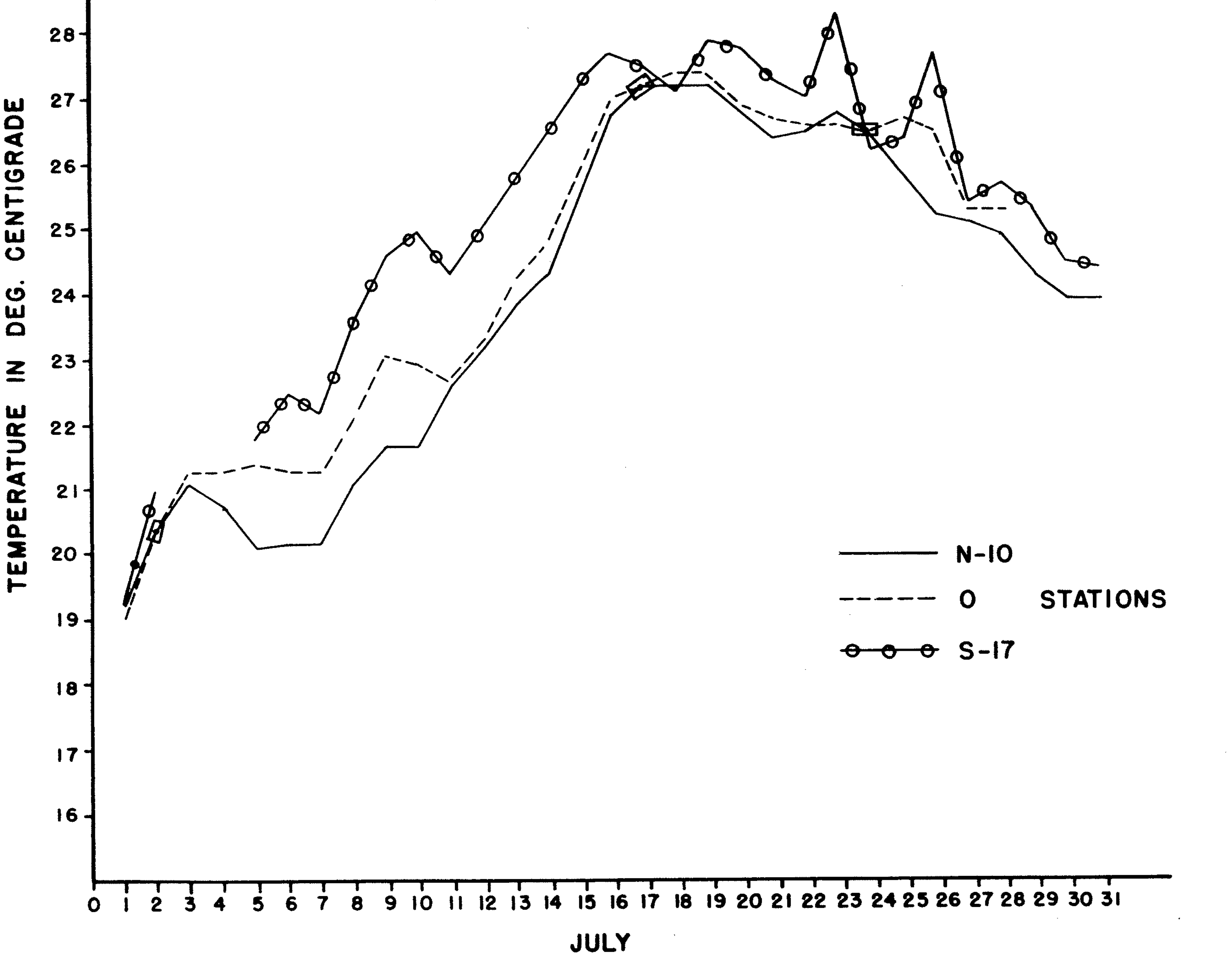


FIGURE 42-BASED ON DATA RECEIVED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY (GEODYNE DATA)

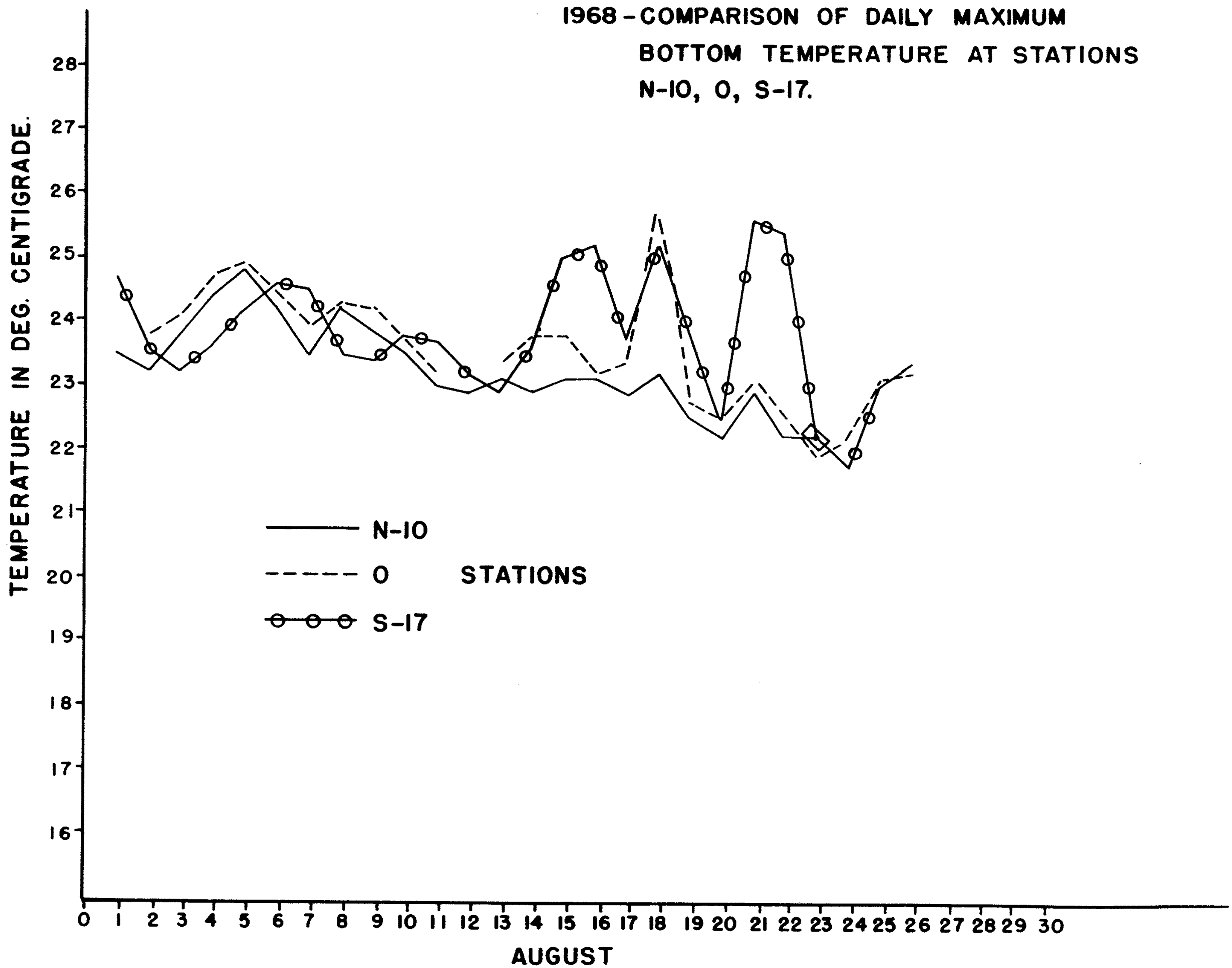


FIGURE 43-BASED ON DATA RECEIVED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY. (GEODYNE DATA)

Extremes in the bottom temperatures at this station were evident with temperatures of 27°C (80.6°F) or better occurring from July 15-23 with a peak of 28.4°C (83.1°F) being recorded on July 23.

It is interesting to note that the period of greatest warming occurred in the north station during the hours of four to seven p.m. when diurnal effects were greatest, while at S-17 bottom temperature extremes occurred during the hours of ten p.m. to two a.m. in six of the nine days of maximum bottom temperature readings due to generating patterns.

Although surface temperatures at Stations 0 and S-17 were significantly higher than at Station N-10, bottom temperatures did not show a corresponding increase due to stratification of the heated flows.

A comparison of the maximum bottom temperatures (Figures 42 and 43) as recorded at N-10 and S-17 show such temperatures are generally higher in the southern section with a maximum variation of 3.3°C occurring on July 10 and August 21. There are some instances when bottom temperatures are less in the south compared to the north due to the reduced generation output and the cooling effect of the Suncook River.

Discussion - Temperatures

Based on results to date it appears that, although temperature stratification is quite evident in the surface waters, especially during periods of low flows, there is still heat conduction to the lower depths due to power plant production.

Surface temperatures show considerable heat decay from stations 0 to S-17 depending on atmospheric and flow conditions; however, because temperatures tend to be higher in the shallow areas of littoral zones, which are the most biologically productive part of a river system, it is felt the inhabitants of this area such as young fish could suffer from this heating effect.

Ferguson (1958) states the final upper temperature preferenda for largemouth bass and pumpkinseeds is 86-89.6°F respectively, while the upper lethal temperature for white suckers was listed as 86°F (Black, 1955) and yellow perch acclimated to 77°F was 85.5°F (Lezzi, Filson and Myers, 1952).

If this is the case, temperatures of 90°F or better in these areas is going to cause such species to seek refuge in the cooler depths where temperatures are not as extreme. When these temperatures occur, it is not unrealistic to foresee considerable predation by the larger fish inhabiting the deeper waters.

Admittedly, the northern section at times shows temperatures close to the final preferendum of fish such as smallmouth bass which Ferguson states has a final preferendum of 82.4°F; however, the point which cannot be overlooked is that a rise in a few degrees in temperatures may mean the difference of survival of a species or severe reduction in the same when temperatures become critical.

It is known species exist over a wide range of temperatures with temperature requirements for any individual species varying at different stages of its life. Such requirements differ for migration, spawning, maturation of the ova and development of the egg and fry.

Temperatures which may favor a competitor, predator or disease organism may have profound effect on a desired species. Because higher temperatures favor the coarse or less desirable fish, a glance at the numbers of white suckers fyke netted may be an indication that such a change is occurring due to thermal effects.

The fact temperature recordings indicated a build-up of heated water in the forebay of the Hooksett dam may have serious effects to the anadromous fish program in the Merrimack River. Because a fishway will have to be constructed at Hooksett, it is felt the heated water will create considerable problems at this location. It is widely documented that anadromous fish are quite selective in the streams they will ascend during their spawning migration. If water temperatures are of a critical nature, a thermal block could result with migrations ceasing altogether. Even if migrations were not deterred, the fact temperatures have such an effect on the metabolism of migrating fish, it is entirely possible the selected spawning areas would never be reached and the egg survival would be insignificant to perpetuate the species.

For these reasons, it is felt that temperatures which exist in the river are going to have significant effect to the resident and future fish of the area. Admittedly, it does not appear conditions are critical for the existing fishery as it pertains to adult fish during the time the thermal flows have been studied. As to what the long-term effects of such temperatures will be on the biota, only time will provide answers. Because it is a distinct advantage to have temperature conditions that favor species most desired, it is hope cooling facilities under construction will provide these temperatures.

Benthos (General Survey)

Two species found in significant abundance to satisfy requirements for study as indicator species of benthic organisms were Elliptio complanatus, a fresh water mussel and Campeloma decisum, a snail. Two other species of Unionids, Alasmidonta and Anodonta were found in limited numbers, however, due to the paucity of numbers these two organisms will not be utilized to establish trends but will be included as a matter of interest.

Bottom samples were obtained at each station and five substations across the river at these points utilizing a 9 x 9 inch Ponar grab (Figure 44). Samples were then screened and placed in containers to be identified by species and numbers obtained at each substation at the laboratory facilities of St. Anselms College. In 1967, sampling was conducted from July 7 to August 28 while two samples were obtained in 1968. The first survey was conducted in June of 1968, while the second commenced in August and was completed in September. Stations N-11, N-15 were not sampled during the second survey in 1968.

Of the four species sampled, Elliptio complanatus was the most abundant species comprising 51.3% of the organisms sampled in 1967, whereas, an occurrence of 52.7% and 50.6% resulted from surveys one and two respectively during 1968 (Figure 45). Campeloma decisum which was the second most abundant organism, comprised 42.9% of the organisms during 1967 and varied from 36.2% and 47.0% during surveys one and two respectively in 1968.

Benthos Sampling Schedule (General)

Date	(North Sampling Stations) 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	(South Sampling Stations) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ly-August, 1967	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X		X		X		X	
ne, 1968 I	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
gust-September, 1968 II						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

All substations (1-5) were sampled in all cases.

F I G U R E 44

Percent Composition of Pelecypoda and Gastropoda in Study Area

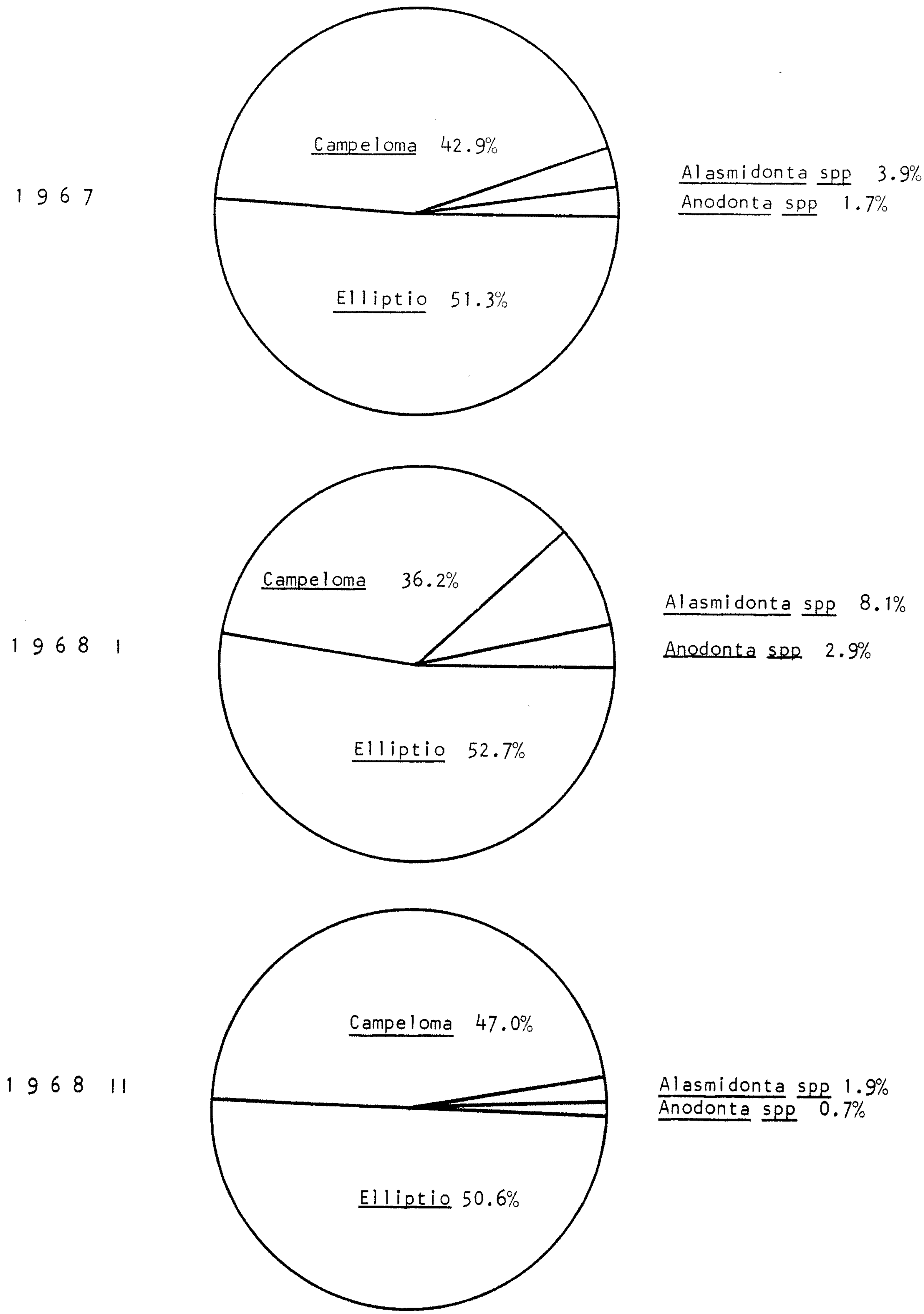


FIGURE 45

RELATIVE ABUNDANCE OF ELLIPTIO COMPLANATUS.
1967-MERRIMACK RIVER.

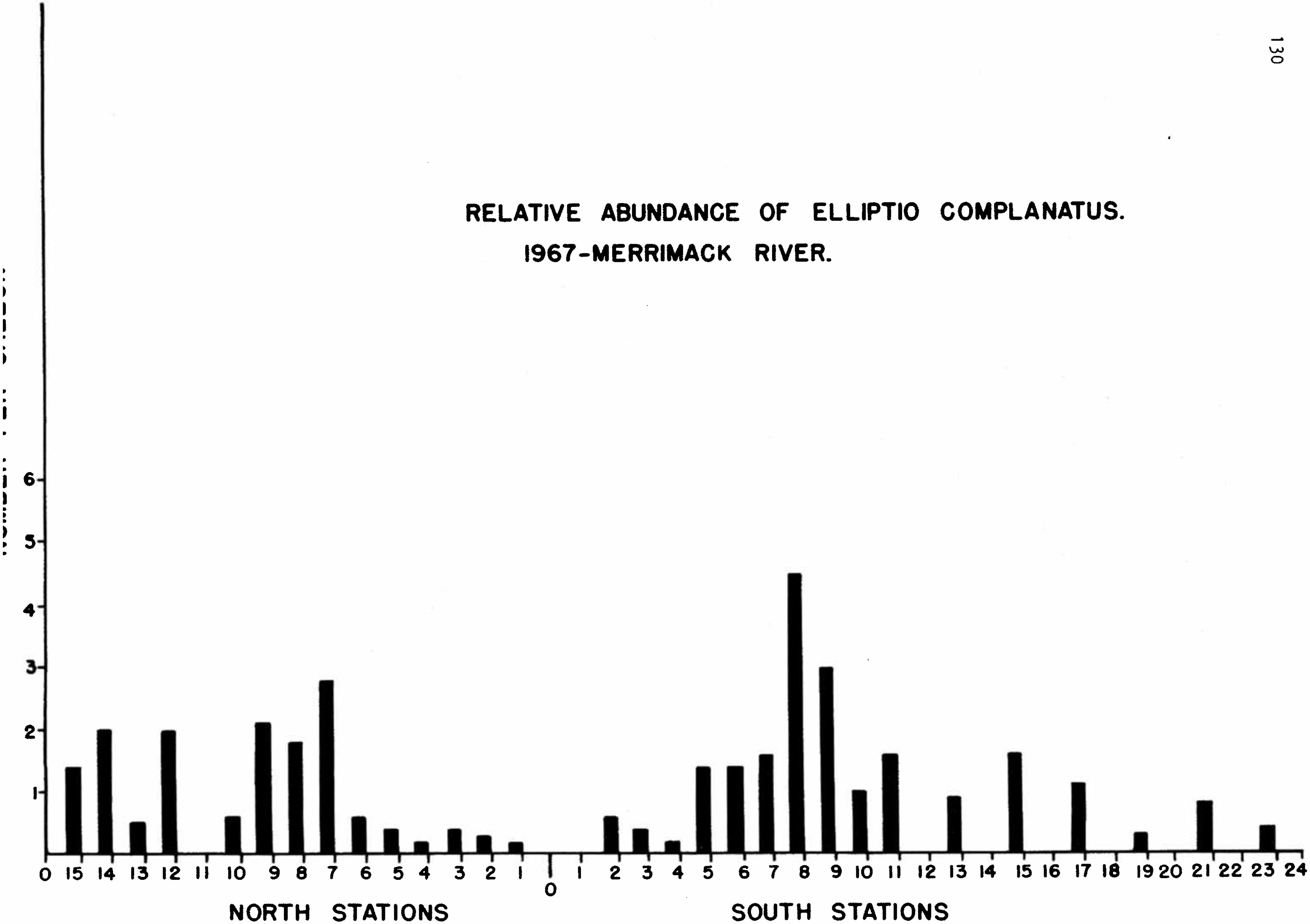


FIGURE 46- BASED ON DATA RECEIVED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

Alasmidonta, which was the most frequent of the two lesser species, comprised 3.9% of the 1967 total, increased to 8.1% in June of 1968, and then dropped to 1.9% in the August through September sample period. Anodonta, which was the least numerous species, comprised 1.7% in 1967, showed an increase to 2.9% of the total sample in June of 1968, and then decreased to 0.7% in the August through September survey. The percent totals of all samples is depicted in Figure 45.

Elliptio Complanatus

Based on 1967 sample results (Figure 46), it was found the peak densities of Elliptio complanatus occurred downstream of tributaries which enter the Merrimack River at stations N-10 and S-6 (Figure 5). In the north section the most abundant sampling areas were located below Bow Bog Brook at station N-9 and N-7 where collections of 2.8 to 2.1 organism per gallon resulted. From this area downstream to station S-5, a decrease in Elliptio complanatus is evident before the Suncook River, with its nutrient effects, causes an increase in organism abundance. The effects of this tributary appeared most evident at station S-8 where a peak Elliptio complanatus occurrence of 4.5 organism per gallon were found. Station S-9 showed the second greatest abundance of this organism with a decline in productivity exhibited to varying degrees from this point to the forebay of the Hooksett dam. On the basis of this survey, it appears the area in the vicinity of the power plant intake to S-4 has the least number of organisms. The reason for this decline could be attributed in some part to construction activities at the power plant site for the building of intake facilities. This is only theorizing and other effects such as natural occurrences probably had greater effect on the limited abundance of _Elliptio complanatus_ in the above area in question. It appears the effects of thermal conditions before the advent of increased power facilities were minimal except in the confluence area of the heated canal and the main river.

In 1968, sampling surveys showed a disimilar trend from the previous year's results as peak abundance did not occur in the vicinity of tributary effects (Figure 47).

Station S-8, which was the area of highest _Elliptio complanatus_ abundance in 1967, showed a complete reversal of organisms abundance and was nearly devoid of _Elliptio complanatus_ during 1968 sampling.

Significant reductions in numbers also occurred at stations N-9 and N-7 during both 1968 surveys.

The stations with the highest incidence of _Elliptio complanatus_ during the June sample were stations S-13 and S-17, while peak northern densities were found in the upper portion of the study area near Garvins Falls.

Stations 0 and S-2 immediately below the heated effluent, which had limited numbers during the 1967 survey, showed a slight increase during both 1968 surveys. While Stations S-3 and S-9 exhibited variations of decrease during both surveys in 1968. A marked increase was indicated at stations N-2 and 0 during the late sampling period.

Campeloma decisum

Similar patterns of population abundance were exhibited by _Campeloma decisum_. As was the case in 1967 with _Elliptio complanatus_,

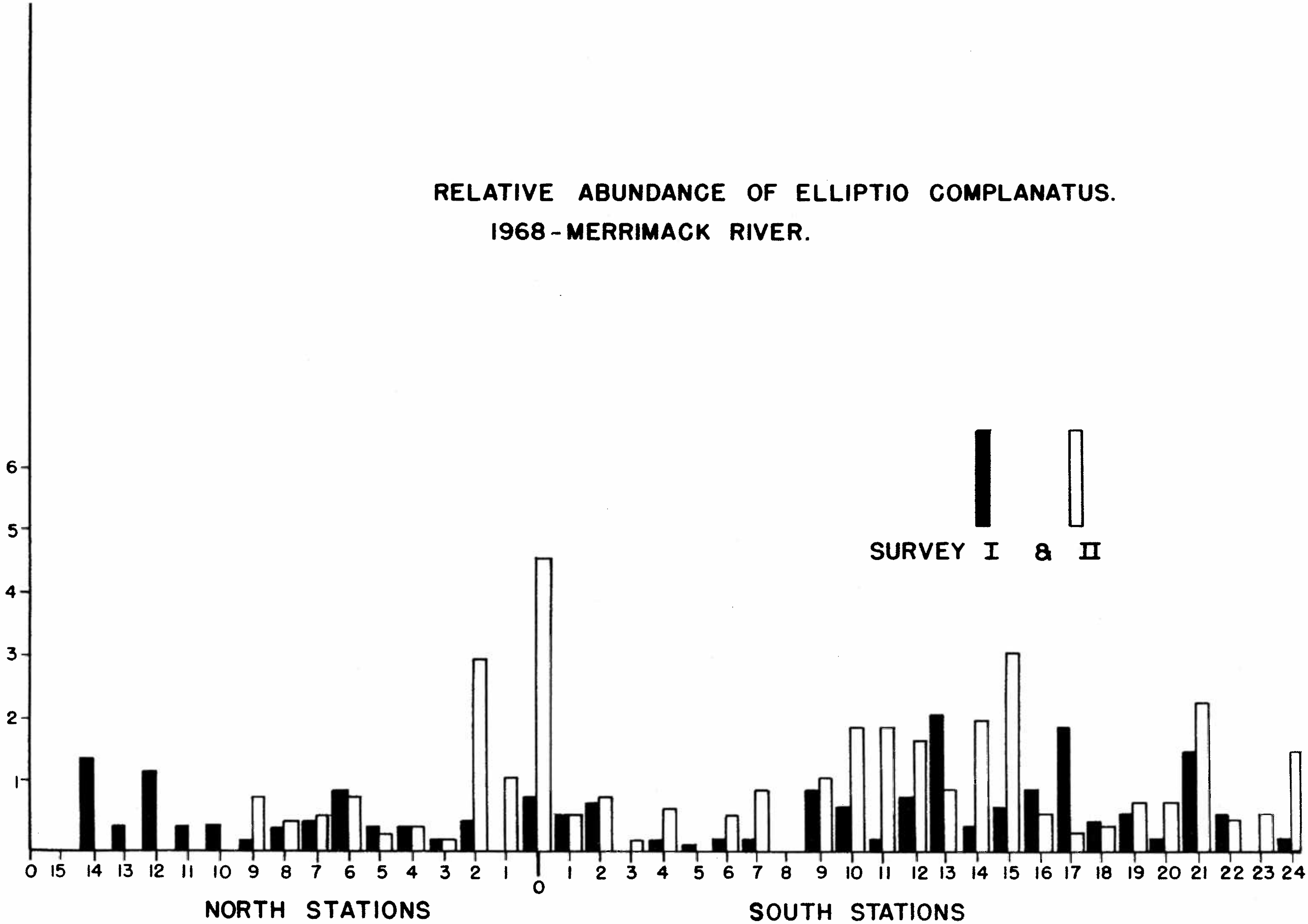


FIGURE 47 - BASED ON DATA RECEIVED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

the areas of greatest abundance occurred where the tributaries of Bow Bog Brook and the Suncook River flow into the Merrimack River (Figure 48). A reduction in organisms occurred during both 1968 surveys in the north section seeming to indicate something has happened in the main river through natural causes rather than from thermal effects. Although the June survey showed a decrease in numbers in the south section, the August and September survey showed the densities increased beyond previous sample results below the areas effected by the Suncook River. A slight drop occurred to organisms directly downstream of the heated effluent during the late summer survey (Figure 49).

It appears the southern section exhibits a greater seasonal variation than the northern section with the August and September samples showing an increase in organisms over June sampling efforts.

Discussion: Benthic Studies

Due to sampling the variations in 1967 and 1968, it is rather difficult to ascertain the effects, if any, to benthic organisms in the study area due to thermal flows.

Data obtained indicates primarily that a downstream movement from the effluent areas of Bow Bog Brook and the Suncook River occurred in 1968 compared to 1967 data in regards to *Elliptio complanatus*.

In 1968, the northern populations showed peak abundance just upstream of the heated effluent mainly at stations N-2 through 0 compared to peak densities at stations N-9 and N-7 in 1967.

The southern area showed a shift of population abundance from S-5 to S-11 in 1967 and S-9 to S-15 in 1968. Station S-8, which showed peak abundance of this organism in 1967, had the lowest abundance in 1968.

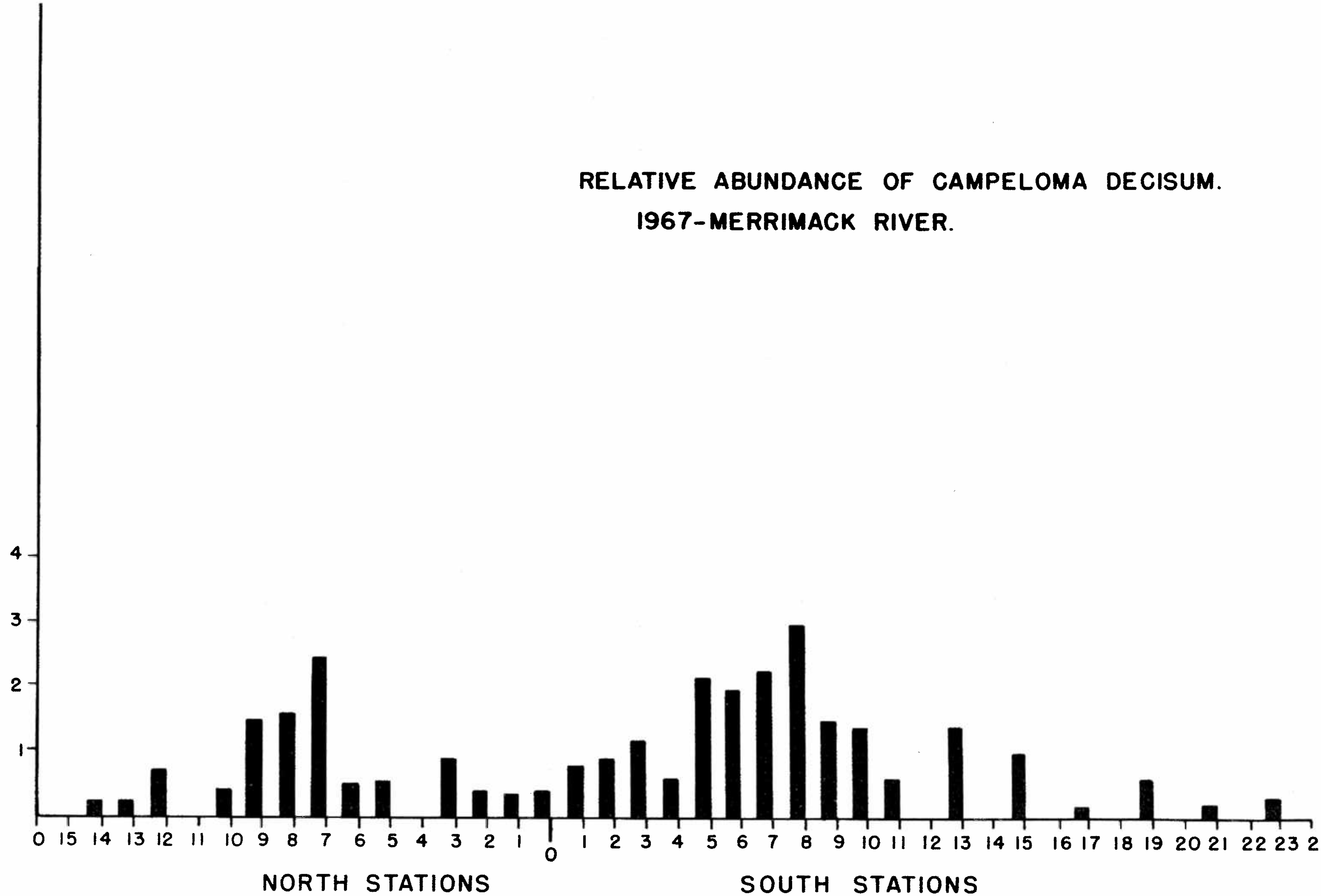


FIGURE 48 - BASED ON DATA RECEIVED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

RELATIVE ABUNDANCE OF CAMPELOMA DECISUM.
1968 - MERRIMACK RIVER.

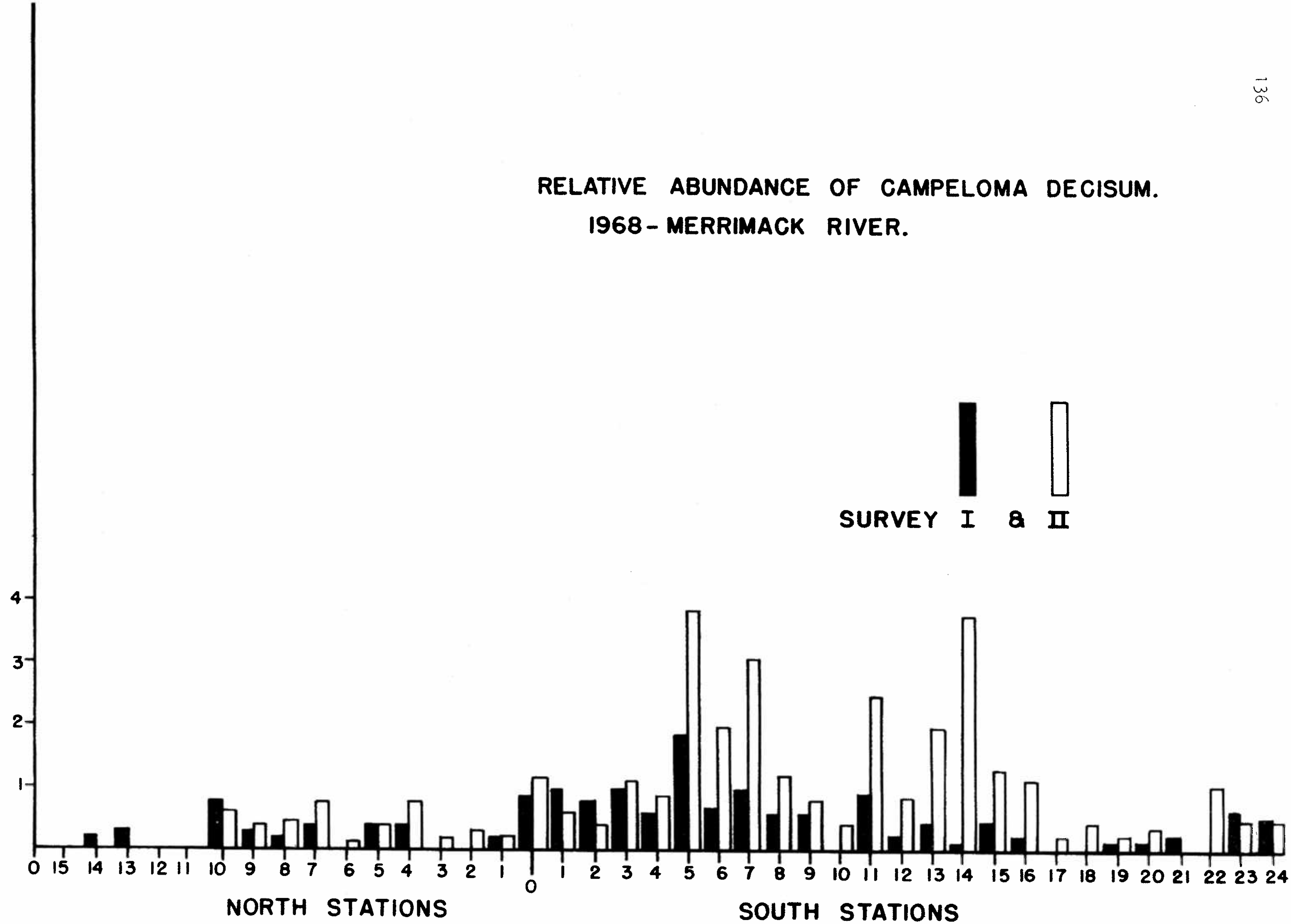


FIGURE 49 - BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

In the case of Campeloma decisum, similar densities were exhibited in the areas of the tributaries in 1967 with stations N-9, N-7 and S-5 to S-8 showing the highest densities. In 1968, a reduction in this organism occurred in the northern tributary of Bow Bog Brook during both sampling periods.

Southern results showed a decline in the tributary area during the June sampling period but late summer sample results showed similar results in this area to those of 1967. It appears that seasonal variation is more pronounced in the southern section with greater population abundance indicated during the late summer sampling period. This is not so apparent in the northern section. It appears the ecological niche inhabited by these organisms is below the full effect of the heated water and variations in numbers i due to seasonal or natural fluctuations rather than power plant effects.

There also seems to be some reduction in the organism abundance of 1968 compared to 1967 sampling results. Whether this is due to the sampling technique which had a time period variation, or due to natural effects, I cannot say. In short very little can be derived from this phase of the study.

Special Benthic Study

A special benthic study was conducted to determine changes in biota of the Merrimack River before and after additional heated effects occurred. Data obtained was collected and determined by Professor Lawrence of St. Anselm's College under the general direction of Dr. Normandeau.

Samples were collected with a 9 x 9 inch Ponar grab. Single grabs were made at three substations at the stations indicated in Tables 20 and 21. The contents of the grab were placed in a container

Table 20

Qualitative Sampling
(*Data is shown in Organisms per gallon)

Data Summary Sheet *1967 Hooksett Pool

Sampling Station	N - 8			N - 4			S - 4			S - 8			S - 12			S - 16			S - 20			S - 21		
	Substation			Substation			Substation			Substation			Substation			Substation			Substation			Substation		
Benthic Organism	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
Oligochaetes		2.0				550.0																		
Diptera larvae				4.0		2.0																		
Entomostraca																								
Hirudinea																								
Hydrachna																								
Ephem. larvae																								
Isopoda																								
Pelecypoda	1.6		2.0	2.0		2.0																		
Gastrapoda	8.1		4.0		2.0																			
Nematoda																								
Amphipoda																								
Trichoptera larvae	1.6																							
Oligochaetes	8.0	4.2	2.7				68.8	24.0		70.0	36.2	112.7												
Diptera larvae	1.3	5.3	1.3				3.2	6.0		2.0	2.9	2.3												
Entomostraca																								
Hirudinea																								
Hydrachna																								
Ephem. larvae								2.0	1.8															
Isopoda																								
Pelecypoda		1.1	1.3				1.6		1.8															
Gastrapoda							1.6	2.0		2.0	1.4													
Nematoda																								
Amphipoda																								
Trichoptera larvae									1.8															
Oligochaetes													224.0	124.0	289.8	61.6	19.8	74.0	6.4	56.0	76.8			
Diptera larvae														8.0	20.7	4.0	4.4	8.0	1.6	6.0	1.6			
Entomostraca																								
Hirudinea													48.0		13.8									
Hydrachna																								
Ephem. larvae																	2.2							
Isopoda																								
Pelecypoda													24.0		6.9					2.0	1.6			
Gastrapoda													16.0			1.3								
Nematoda																								
Amphipoda																								
Trichoptera larvae																								

Table 21

Qualitative Sampling
(*Data is shown in Organisms per gallon)

Data Summary Sheet *1968 Hooksett Pool

	Sampling Station	N - 8			N - 4			S - 4			S - 8			S - 12			S - 16			S - 20			S - 21		
		Substation			Substation			Substation			Substation			Substation			Substation			Substation			Substation		
	Benthic Organism	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
June	Oligochaetes	9.3	3.2	2.9							140.0	16.0	97.8									481.6	4.2		1720.0
	Diptera larvae	1.3	9.6	2.9							20.0	8.0	7.1									15.2			57.2
	Entomostraca																								
	Hirudinea																					15.2			11.4
	Hydrachna																					5.1	2.1		
	Ephem. larvae											2.3													11.4
	Isopoda											1.2										5.1			11.4
	Pelecypoda		3.2																			5.1			
	Gastrapoda												8.9												11.4
	Nematoda																								11.4
	Amphipoda																								11.4
	Trichoptera larvae		1.6																						
July	Oligochaetes	24.3	16.0	59.6							31.0	6.5	56.0									600.6	152.0		688.8
	Diptera larvae	24.3	20.0	23.0							16.6	8.1	20.0									22.7	38.0		
	Entomostraca												4.0												16.0
	Hirudinea			9.2																		4.6	9.5		
	Hydrachna	8.1											4.0												
	Ephem. larvae			4.6																					8.0
	Isopoda																								
	Pelecypoda										1.3											2.0			
	Gastrapoda																								
	Nematoda																						9.5		
	Amphipoda																								
	Trichoptera larvae																								
August	Oligochaetes	5.7	7.7	37.0							32.4	42.4	58.6									387.0	71.8		964.0
	Diptera larvae	17.2	28.2	23.6								49.8	29.3									27.6	7.7		47.1
	Entomostraca		15.3	3.4							1.7	10.0	14.7									6.9	15.4		
	Hirudinea												4.9									27.6			58.8
	Hydrachna		5.1	3.4									4.9										2.6		
	Ephem. larvae											2.5													
	Isopoda																								11.8
	Pelecypoda												2.0												
	Gastrapoda																								
	Nematoda																								
	Amphipoda																								
	Trichoptera larvae																								11.8

and taken to the laboratory within one hour for identification. Contents were placed in a #20 mesh sieve and washed in tap-water to remove the fine particles. The residual was placed in a white enameled pan and observed for organisms which in turn were identified.

Sampling operations took place during the months of June through August; both years with 24 grabs analyzed in 1967 and 27 grabs in 1968.

In 1967, the pattern of sampling stations was more random than in 1968 (Tables 20 and 21). For this reason, the value of comparisons before and after the advent of heated flows is questionable. Because of this problem, the major portion of the data obtained in this portion of the study has been applied towards a fauna list of the study area.

An attempt was made to derive some information from Oligocheates and Diptera data; however, because of the sampling technique, information derived is questionable and should be treated as such.

Bottom Fauna - Qualitative Sampling

Relative Abundance:

The qualitative composition of the bottom fauna, given in the percentage of the total number of individuals for every main group, is as follows:

Oligochaetes are the dominant group of organisms. They represent 88% of the total number of organisms collected in 1967 and 86% of the total number of organisms collected in 1968.

Diptera larvae ranked second in abundance. They constituted 4% and 8% respectively, of the total number of organisms collected in 1967 and 1968. The Diptera made up approximately 90% of insects collected.

Hirudinea ranked third in relative abundance in 1967 and 1968, constituting 3% and 2%, respectively, of the bottom fauna collected.

Pelecypoda and Gastropoda, ranking fourth in abundance, constituted no more than 2% of the total number of organisms collected in 1967 and in 1968.

Composition

The composition of the bottom fauna consisted of a sample species of Platyhelminthes, nine species of Oligochaetes in six genera, seven species of Hirudinea in five genera, and a single species of Amphipoda. It consists of one genera of Ephemeroptera, two families of Trichoptera and one family of Diptera. It consists of one genera of Arachnida, (two species of Gastropoda in two genera and five species of Pelecypoda in five genera).

Faunal List - Benthos (Merrimack River, 1967-1968)

Phylum - Platyhelminthes (Flatworms)

Class Turbellaria

Order Tricladida

Family Planariidae

Dugesia tigrina (Girard)

Phylum - Annelida (Sigmented worms)

Class Oligochaeta

Family Naididae

Pristina osborni (Walton, 1906)

Pristina schmiederi (Chen, 1944)

Stylaria lacustris (Linnaeus, 1767)

Slavina appendiculata (d'Udekem, 1855)

Allonais paraguayensis (Michaelsen, 1905)

Nais simplex (Piguet, 1906)

Nais pseudobtusa (Piguet, 1906)

Nais sp.

Family Tubificidae

Limnodrilus claparedianus (Ratzel, 1869)

Class Hirudinea

Order Rhynchobdellida

Family Glossiphoniidae

Glossiphonia heteroclita (Linnaeus, 1758)

Helobdella stagnalis (Linnaeus, 1758)

Helobdella fusca (Castle, 1900)

Family Pisicolidae

Pisicola sp.

Family Erpobdellidae

Erpobdella punctata (Leidy, 1870)

Dina fervida

Dina microstoma

Phylum Arthropoda

Class Crustacae

Order Amphipoda

Family Talitridae

Hyalella azteca (Saussure, 1858)

Class Insecta

Order Ephemeroptera

Family Polymitarcidae

Ephoron sp.

Order Trichoptera

Family Limnephilidae

Family Leptoceridae

Mystacides sp.

Order Diptera

Family Tendipedidae

Class Arachnida

Order Acari

Family Hydrochnidae

Hydrachna sp.

Phylum Mollusca

Class Gastropoda

Order Mesogastropoda

Family Viviparidae

Campeloma decisum (Say)

Family Bulimidae

Lyrogyrus sp.

Class Pelecypoda

Order Eulamellibranchia

Family Unionidae

Elliptio complanatus

Alasmidonta undulata (Say)

Anodonta sp.

Family Sphaeriidae

<u>Sphaerium partumeium</u>

<u>Pisidium variable</u>

Because Oligochaetes and Diptera appear to be the only organisms in sufficient numbers to establish a trend, the following data is derived from the substation samples taken during the 1967 and 1968 surveys.

At station N-8, 1968 sampling results show an increase of Oligochaetes over 1967 results during the months of June and July.

At station S-8, one sample was taken in July of 1967. In comparing this with July of 1968, it appears a reduction of Oligochaetes occurred in this area at all substations across the river. Keeping in mind that this area is below the heated effluent, it is rather difficult to ascertain whether this is the result of thermal loading due to the fact effects of the Suncook River are considerable in this section and should negate thermal effects to some extent.

The only other section possible for comparison during the two years of study is substation 5 at Station S-20. In this area a marked increase in numbers occurred from 1967 to 1968. Whether this is the result of thermal loading is questionable due to the distance from that effluent and/or back-up effects in the forebay of the dam. The possibility of a yearly fluctuation seems to be more likely as some increase was noted at stations N-8 over S-12, 1967 results. The 1968 sampling showed the areas of greatest organism density were in the areas of S-20 and S-21. However, because these areas were not sampled in 1967, it is impossible to make any comparison.

Due to the random sampling in 1967, the determination of seasonal trends is difficult; however, 1968 data exhibits the following characteristics. At station N-8, July results exhibited the greatest numbers of Oligochaetes per gallon with June being the period of the least numbers. At station S-8, the period of peak abundance occurred during June, with the succeeding samples fairly equal in numbers, but to a lesser degree. Station S-20 exhibited a trend similar to the northern section with the period of greatest abundance occurring during July; however, August was the period of fewest numbers.

On the basis of this, it would appear July is the peak month in organism abundance in the areas furthest removed from the heated effluent with the area nearest the effluent declining in July and August. Again, the writer would like to state the data collected is insufficient for definite conclusions and only generalities can be made until further study occurs.

Based on the limited data available, it appears the following could be occurring.

A slight increase in Oligochaetes occurred in the North during 1968 sampling. Some change is occurring below the power effluent at S-8 due to thermal loading or the effect of the Suncook pollution load during periods of higher temperatures and low flows. The abundance of Oligochaetes is greatest in the southern stations of the Hooksett Pool where the effects of the Hooksett dam has created a mud and silt build-up.

Diptera larvae, which were the second most abundant organisms collected, exhibited the following characteristics. At all stations in which a yearly comparison could be made, an increase in numbers occurred during 1968 sampling. The limited numbers involved do not show any evidence of thermal loading effects. As the summer advanced, seasonal changes showed an increase in numbers at all stations.

Hirudinea, which are closely related to the Oligochaetes, appeared only in the station S-12 sample area in 1967. Sampling results in 1968 showed a higher incidence of these organisms occurring than was the case in 1967 with the greatest numbers of these organisms appearing in the lower section of the river at stations S-20 to S-21, as was the case with Oligochaetes, although a small number of these organisms occurred during July sampling efforts at station N-8.

Other organisms collected comprised such a small amount of the total sample, that any trend exhibited would be of questionable value. Organisms which make up this lesser quantity are scuds, aquatic sow bugs, ostracods, copepods, water fleas. (Tables 20 and 21)

Plankton Studies

Studies to determine the relative abundance and composition of zooplankton and phytoplankton in the area of the Bow steam plant were conducted during the summer months of 1967 and 1968. Plankton samples were taken north and south of the power plant and the discharge canal during periods of maximum temperatures, as well as minimum flows. The samples were obtained utilizing a plankton net hauled behind a boat for a distance of 1,000 feet or 500 feet, as was the case on September 4 and 5 of 1968. All samples obtained were placed in vials and transported to the laboratory for examination and identification within three hours of procurement. The contents were mixed and two drops of the mixture were placed on a microscopic slide. A 22 mm square cover slip was placed over the mixture and five scans of each slide was made. This procedure was repeated four or five times for each sample resulting in twenty to twenty-five scans for each plankton sample. The results were reported as the number of scans in which an organism or group of organisms was found over the total numbers of scans. This was represented in the percent of frequency of occurrence.

Samples taken in 1967 are given a numerical value as follows: 5=90%-100%, 4=65%-89%, 3=31%-64%, 2=10%-30% and 1=1%-9% due to the fact percentages were not supplied in the raw data obtained from the institute (Table 22).

In 1968, numerical percentages were supplied in the raw data and such values are indicated in Table 23.

Samples taken south or below the power plant discharge were subjected to the maximum effect of heated flows on the surface water. No attempts were made to determine organism abundance at water levels other than the surface.

Comparison of heated water effects to plankton was carried out in the summer of 1967 at stations 1 to 3 in the north and stations 0 to 2 in the south.

Data obtained during 1967 indicates the effect to the biota of the mainstem was not as extensive as that of 1968 when the volume of heated flows increased.

Because general values were used during this period of sampling, instead of specific values as in 1968, it is difficult to derive any conclusions. It does appear that in 1967 organism abundance was fairly uniform both north and south with some seasonal variation except in the case

Table 22

Frequency of Occurrence of Plankton During 1967

Plankton Studies North - South Comparison

Based on Data Received from Public Service Company Regarding Merrimack River Thermal Study

	7/28/67		8/2/67	
Stations	N-1-3	S-2-0	N-1-3	S-2-0
Flagellates	2	1	4	2
Ciliates	3	3	3	3
Rotifers	3	4	4	3
Cladocera	3	3	3	3
Copepod	2	3	3	3
Insect Larvae			0	1
Sarcodina			1	1
Fungi	4	4	4	3
Desmids	3	4	3	3
Yellow-Green Algae	3	4	4	3
Diatoms	5	5	5	5
Green Algae	5	5	3	3
Blue-Green Algae	3	3	3	3

Categories of Organism Frequency

5 = 90-100%

4 = 65-89%

3 = 31-64%

2 = 10-30%

1 = 1-9%

Table 23

Frequency of Occurrence of Plankton in the Northern and Southern Areas of the Hooksett Impound
(Northern section is under normal conditions)
(Southern section is under heated effect)

Based on Data Received from Public Service Company Regarding Merrimack River Thermal Study

	6/20/68			7/24/68			8/22/68			Sept. 4		Sept. 5		
	N-10-11	S-4-6	S-20-22	N-10-11	S-4-6	S-20-22	N-10-11	S-4-6	S-20-22	N-2-3	S-2-1	S-4-5	S-8-9	N-2-1
Other Green Algae	84	60-	76-	100	100 eg	100 eg	100	100 eg	100 eg	100	95-	65-	100+	95
Desmids	8	10+	16+	68	40-	0-	65	35-	95+	90	85-	35-	25-	40
Fungi	4	15+	16+	52	75+	12-	90	100+	80-	50	-	5+	25+	
Yellow-Green Algae	40	20-	8-	4	10+	0-	20	10-	65+	45	25-	5-	20+	15
Diatoms	52	30-	44-	100	60-	32-	65	0-	10-	15	-	5-	15 eg	15
Blue Green Algae	8	30+	36+	100	80-	32-	25	20-	60+		5+		15+	5
Flagellates	32	100+	52+	96	75-	68-	50	0-	35-	70	60-		10+	
Rotifers	20	5-	0-	32	20-	12-	20	10-	5-	65	25-	20-	30-	55
Cladocera	12	5-	4-	0	0 eg	4+	50	20-	25-	5	15+	10-	10-	55
Ciliates	36	70+	20-	80	20-	24-	50	5-	20-				15+	
Copepoda	16	5-	12-	4	0-	0-	25	15-	10-	35	20-	15 eg		15
Dinoflagellates	4	0-	4 eg	0	15+	0 eg	0	5+	10+	10	-	5+	-	
Sarcodina	0	0	0	5	0-	4-	0	5+	5+	35	-		5-	
Insect Larvae	8	0-	0	4	0-	0-	5	0	0		5+			
Watermites	0	0	0	0	0	0 eg	5	0	0			5+		
Nematodes										5				

+ = Increase over normal river organism numbers
- = Decrease over normal river organism numbers
eg = Equal to normal river organism numbers

of flagellates where the northern section shows greater abundance during both months of comparison. It should be realized, however, that sampling was not as extensive in 1967 as 1968 and a statement that this decrease is a result of the heated effluent is difficult to ascertain due to sampling inconsistency. In 1968, sampling was conducted at stations N-10 and N-11 whereas stations S-6, S-4 and S-22 to S-20 were used as indicators of southern organism abundance. The data obtained indicated changes do occur to varying degrees during summer sampling in the north and south sections.

Table 23 depicts the percent frequency occurrence of plankton in the sampling areas in 1968.

Results obtained in June of 1968 when maximum river and air temperatures had not occurred showed variable effects appearing in the areas of study. Organisms at stations S-4 and S-6, such as desmids, fungi, blue-green algae, flagellates and ciliates exhibit a greater abundance than those of the north section with ciliates and flagellates showing the greatest increase. Declines in the south from the north frequencies were indicated by green algae, diatoms, as well as lesser species such as rotifers, cladocera and copepoda.

Partial recovery or an increase is evident in six of the twelve most abundant organisms sampled at stations S-20 and S-22. Significant declines occurred in flagellates and ciliates in comparison to stations S-4 and S-6 results with cibrates declining below northern abundance during this sample period.

In July, when river flows are usually lowest and water temperatures are at their maximum, a reduction in numbers at stations S-6 and S-4 appears to occur compared to northern figures. Exception to this trend is green algae, which is of equal abundance at all three sample areas, along with fungi, yellow green algae and dinoflagellates. Results indicate this decline continues into the S-22 and S-20 stations with organisms showing practically no recovery, as was the case in the June sampling, with some organisms exhibiting further decrease. Cladocera and ciliates were the only organisms to show an increase and this comprised a value of only four percent frequency occurrence.

August sampling showed similar trends with a decreased organism frequency occurring at stations S-6 through S-4. Exceptions were green algae which tended to remain unaffected throughout sampling efforts and fungi which appeared more numerous in the southern areas. Two organisms, sarcodina and dinoflagellates, which appeared in sparse amounts, were more frequent in the south than the north in August.

Recovery at stations S-2 and S-20 was more pronounced than the previous month with several organisms, fungi, yellow green algae, blue green algae, dinoflagellates and sarcodina appearing more numerous than the north samples. September sampling stations were changed to N-2 to N-1, N-2 to N-3 and S-1 to S-2, S-4 to S-5, S-8 to S-9, with downstream hauls occurring at N-2 to N-1, S-4 to S-5 and S-8 to S-9, while N-2 to N-3 and S-2 to S-1 plankton hauls were upstream.

In order to keep continuity, a comparison has been made with N-2 to N-3 and S-2 to S-1 results and the north downstream hauls in the other sequence. As was the case in previous samplings, a decrease in frequency occurrence appears to be true of the southern areas with the exception of organisms of limited abundance (less than 15% frequency).

Sampling at station S-8 to S-9 indicates the recovery effects of the Suncook River is a possibility, with some increases in numbers over upstream stations being noted. In 1968, samples were taken in the effluent canal (Table 24), however, due to a tributary entering the canal at station C-13, it is felt a true representation of canal biota is impossible due to the character of the plankton tows. Data obtained in the canal area does appear to indicate plankton survival occurs to some extent during the heated route of condensor water. Questions of damage or degree of mortality after exposure to the extreme heat and then cooler environmental conditions encountered in the river, remain unanswered. There is also some effect to the organisms from the algicidal treatment of the condensors to combat slime buildup. Because this is a daily treatment, it would appear that some effect could result, although the scope of the study did not delve into this effect.

Discussion: Plankton Studies

There appears to be a reduction in the frequency of occurrence of plankton in the surface waters south of the Bow Steam Plant.

Because data to date pertains only to surface waters which have been subjected to the heating effect of the steam plant, it is not known how extensive the affliction is.

Zooplankton such as ciliates, rotifers, flagellates and cladocera appear to be adversely affected by the heated effluent while desmids, diatoms and blue green algae indicated similar effects among the phytoplankton. Green algae and fungi appear least susceptible to changes in

Table 24

Percent Frequency of Occurrence of Plankton in Canal Section Below Plant Effluent (1968)

Station Organism	C-2 to C-7 (Sept.)	C-1 to C-5 (Sept.)	C-10 to C-15 (Sept.)
Flagellates	30%	70%	25%
Rotifers	35	40	30
Cladocera	15	25	15
Ciliates	30	-	40
Copepoda	25	30	20
Dinoflagellates	2	20	10
Sarcodina	5	5	5
Insect Larvae	--	5	5
Green Algae	100	100	100
Diatoms	35	25	15
Desmids	50	95	75
Fungi	25	25	35
Yellow-green Algae	60	15	65
Blue-green Algae	5	10	10

Based on Data Obtained from Public Service Co.
Regarding Merrimack River Thermal Study

water temperatures. Because blue green algae is more heat tolerant than green algae, it is felt other effects such as the use of chlorine for slime control treatment may have had some effect on these organisms rather than temperatures alone. Further study is necessary to determine the limiting factor on the biota in the southern section; the following work cited indicates temperature is probably the deciding element in plankton decrease. Welch states, "that temperature acts directly and indirectly in influencing the vertical distribution of plankton which are sensitive to difference in temperature change."

Direct effects are usually manifested through either (1) selection by motile plankton of certain favorable temperatures or (2) inability of some non-motile forms to exist in levels having certain temperatures. Indirect effects are changes in the density and viscosity of water; such changes alter the floatation levels of certain plankters which are delicately adjusted to floatation.

Also to be considered is diurnal movements; it seems well established that temperature cannot be regarded as either the direct or indirect cause of diurnal movement, however, it has been shown that temperatures may effect the nature of light response. One important modification being that a high temperature increases the negative phototropism, while a low temperature lessens or even reverses it.

Based on this data and the fact only the surface layers were sampled, it is within the realm of possibility that such has occurred in the area below the steam plant.

Further evidence that temperatures may be having an effect on the biota of the area is based on the results of a study by Trembly in Pennsylvania in which he states the following, "As temperatures increase there is a decrease in the number of organisms. As temperature increases to 80-87° F., the number decreases by 54% and when the temperature increases from 87-93° F., there is a 24% loss."

Although data compiled to date does not indicate a critical level has been reached in the study area, the importance of plankton to survival of certain species of fish at some stage in life must not be overlooked. Fortunately, there is a partial recovery effect in the lower section due to the natural river flows and biota enrichment from the Suncook River. This, however, slowed considerably during periods of low flows and high seasonal temperatures.

In summary, although the Bow Steam Plant appears to have had some effect to the plankton of the area, the supplementary flows of the Suncook River and the mainstem provide a recovery effect to such organisms. Whether organism reduction will have any effect on the fish life of the area as it exists at present is doubtful. Because some reduction did occur, the fact that as more generating capacity is needed to meet future electrical demands, further deleterious effects could occur. For this reason it is felt future plants should have cooling facilities incorporated in their initial plans as a protective measure to maintain the ecological balance.

Periphyton Studies

A limited study was made of periphyton organisms to determine species composition and abundance in the Merrimack River study area.

Slide racks containing several microscopic slides were suspended approximately two feet below the surface at stations N-10, C-16 and S-17. The racks were positioned on July 5 and removed on July 24.

The slides were transported to the laboratory where they were viewed under a compound microscope.

Determination of frequency of occurrence was similar in technique to previous plankton study procedure.

The results of the periphyton study is indicated in Table 25.

At station N-10 the dominant groups of plankton were blue-green algae and diatoms while the zooplankton dominance was exhibited by tendipidae larvae. At station S-17 similar organism abundance was observed for the most part, although three species found in the north section were absent. These species were flatworms, rotifers and water-mites.

The dominant fauna at station S-17 was tendepidae larvae while the dominant flora was blue-green algae and diatoms as was found at station N-10.

Reductions in abundance appeared to occur to ciliates and green algae in comparison to northern results.

At the C-16 station, a definite reduction in organism abundance was observed with only flagellates and ciliates being represented and these organisms were in limited numbers. It is apparent that the two factors of extreme temperatures and high water velocities have a deterrent effect on the periphyton in the canal area. Water velocities are quite swift at this station especially as the heated condensor water erupts from the underground pipe into the open canal, while temperatures were quite extreme with a range of 88-101° F. being recorded during the sampling duration.

Table 25

Periphyton Frequency of Occurrence[1] at Three Sampling Stations

Sampling Station	N-10	Canal 16	S-17
Temperature Range	70-82^{o}F	88-107^{o}F	70-88^{o}F
Algal Groups			
Cyanophyta	5	-	5
Chlorophyta	3	-	2
Desmids	2	-	2
Diatoms	5	-	5
Protozoa			
Mastigophora	4	1	4
Cilliata	5	1	4
Turbellaria	1	-	-
Rotatoria	2	-	-
Hydracarina			
Hydrachnellae	2	-	-
Insecta[2]	5	-	5

[1] The numbers 1 through 5 denote the percent of the samples examined that the groups were recorded as present. (1 = 1-9%; 2 = 10-30%; 3 = 31-64%; 4 = 65-89%; and 5 = 90-100%).

[2] The Insecta were primarily Tendipedidae Larvae.

Based on Data Obtained From Public Service Co.
Regarding Merrimack River Thermal Study

It would seem the extreme temperatures alone would cause a deletion in the frequency of occurrence of organisms while a combination of extreme temperatures and high water velocities would definately cause a reduction in abundance. Because of the limitation effects of these two factors, it is difficult to ascertain the direct result of the decrease in the canal. Also another factor which cannot be discounted is what effect chlorine treatment of the condensors for slime control has at this station. It is without doubt of considerable significance in the decline of organisms at this locale due to the exposure concentrations at this station. The following statement regarding chlorine treatment effects was taken from research data at Martin's Creek (1956-1959) by the Institute of Research, Lehigh University. "The use of chlorine in the cooling water to remove slimes from the condenser tubes has a depressing effect upon the periphyton in the immediate area of the discharge structure and, at some times and to a limited extent, in the river below the entrance of the discharge canal into the river."

Because of these limiting factors, it is apparent as to why a reduction of organism abundance occurred in the canal area.

In the area of the main river, namely stations N-10 and S-17, the decrease in organism abundance below the steam plant is, in all probability, due primarily to temperatures although chlorine could have some limitation to growth. The following statement from Welch as to temperature effects probably explains the reason for the organism decline in the southern portion. "The occasional rise of surface water temperatures to unusual heights (although only a few degrees above the usual summer maximum) in protected bays in times of clear, hot weather and dead, calm water promptly leads to a dying off of surface plankton and certain other shallow water organisms."

Because of the limited scope of this portion of the study, it cannot be determined with any clarity the overall effect the heated effluent has or will have on the biota of the area under study. One thing does appear to be occurring, there is a reduction in organisms both sessile and motile in the area below the heated effluent. Although such effects do not appear to be critical at this date, the fact changes are taking place should not be treated lightly. One of the most outstanding features in the aquatic complex is the partial or complete food dependence direct or indirect of the higher nonplankton animals, such as fish upon the plankton. Some fish are plankton feeders throughout their life, others are plankton feeders at some particular stage of the life cycle. Even within the plankton assemblage itself, two general strata of life occurs, the cholrophyll bearing organisms and the nonchlorophyll bearing organisms. For the most part, the latter depends on the former. Within the plankton there is a series of organisms which leaves potential food stuffs to different levels of availability, beginning with the inorganic materials and culminating in the small but highly organized plankton animals such as Cladocera which, in turn becomes food for fish.

It is, therefore, imperative that close watch is maintained on heated water conditions such as exists in Bow to prevent a link in this chain of life from being broken causing irrepairable damage to the ecology of the watershed. The fact some change has occurred to the section below the steam plant might be the beginning of such a circumstance.

Chemistry - Dissolved Oxygen

Due to the major importance associated with dissolved oxygen content to the survival of most aquatic organisms, a study to determine values above and below the power plant was conducted.

It is known, as water increases in temperature, the solubility of oxygen or retention is decreased resulting in less oxygen for metabolic requirements. Also to be considered is the fact the Merrimack River is heavily polluted. Because of this organic load, considerable biochemical oxygen demand occurs through the consumption of oxygen by the bacteria associated with decomposition of this organic material. Because of these two factors, it was feared significant oxygen deficiencies would occur south of the Bow Steam Plant.

Oxygen content was determined by a Yellow Springs Model 54 oxygen meter and a Geodyne A775 digitizer at stations N-10, 0 and S-17.

Utilization of the Yellow Springs meter was by manual means with the D.O. readings taken on the surface and lowered to just off the bottom at the described stations. These measurements were taken several times each week from June to September during the 1967 through 1968 study period.

The Geodyne equipment was a continuous recording device used to measure dissolved oxygen concentrations every hour. Malfunctions rendered the data from this equipment insignificant in 1967, although in 1968 this problem was rectified and usuable data did result except at station 0, where instrument failure occurred during the major part of the summer from July 19 to August 30, 1968.

Normal dissolved oxygen values as determined manually in 1967 indicated a range of six ppm to 8.5 ppm in the northern section while southern values during the same period were similar (Figures 50 and 51.) Results of this data indicate that the D.O. values in the south were slightly higher than the northern section. This is probably the result of supplementary flows from the Suncook River which was found to have a higher oxygen content than the main river.

It should be indicated these results are indicative of day time D.O. values only and, in all probability, are not as low as encountered in the morning hours when the metabolic processes of organisms through respiration and photosynthesis caused a reduction in the D.O. content.

In 1968, sampling indicated a greater variation in D.O. content with D.O. concentrations of 10.5 ppm to 4.8 ppm occurring. Flows during the early season probably account for the increased content in June as there was a pronounced increase in flows early in the season compared to 1967. Similar factors can be attributed to the minimum readings which occurred in September when flows were less than 500 cfs for a considerable portion of September 8 and 9 (Figures 52 and 53.)

Dissolved oxygen in percent saturation, as monitored on a twenty-four hour basis utilizing Geodyne data, shows a value of 38% of 3.4 ppm on the same date at station N-10. Because erratic instrumentation occurred at the effluent (station 0), it is not known the value at this station, however, based on manual results, it is assumed values were lower. Data obtained from this equipment also indicated D.O. pulses were at a minimum in the early morning hours due to metabolic functions of organisms.

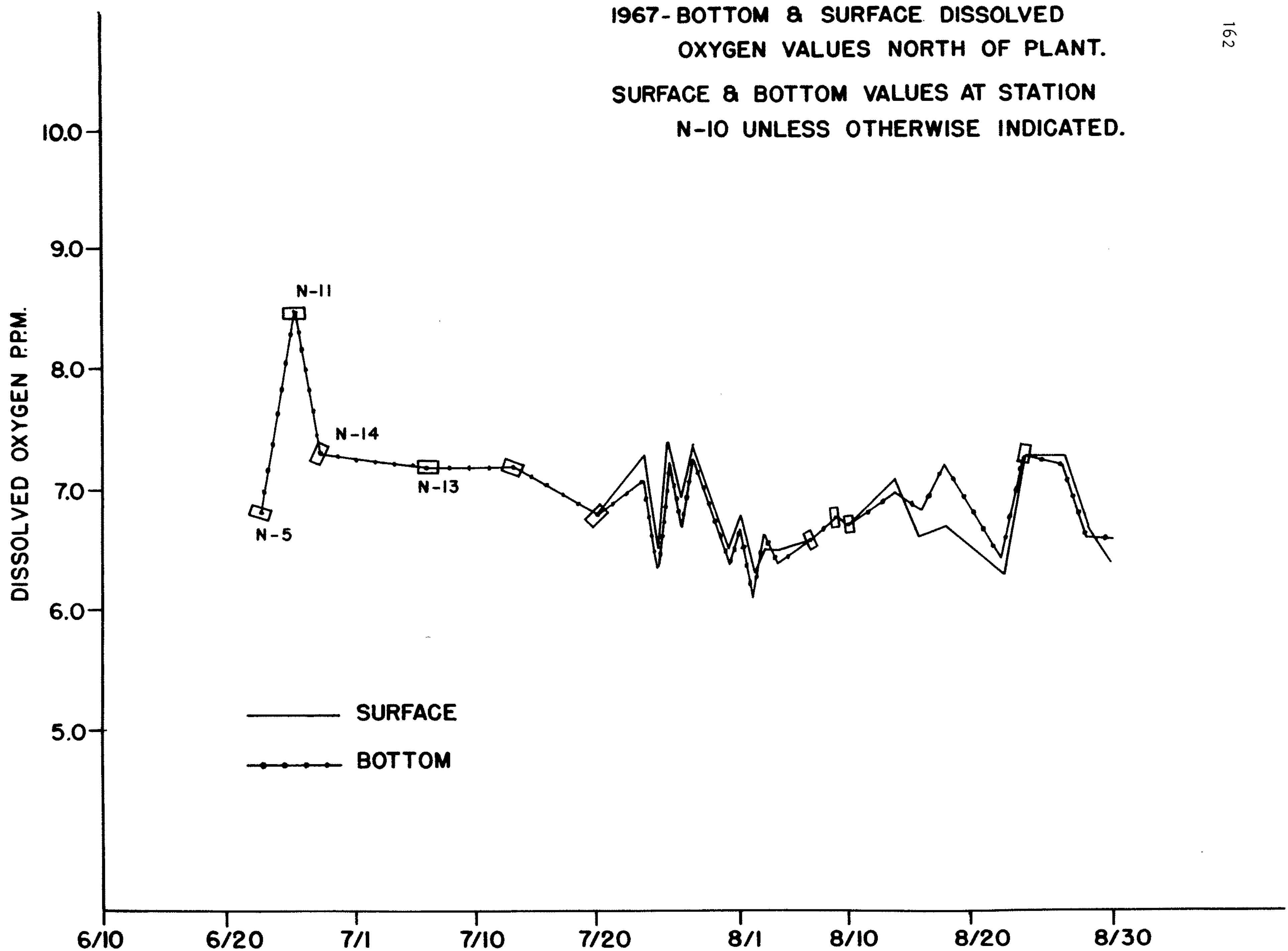


FIGURE 50- BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

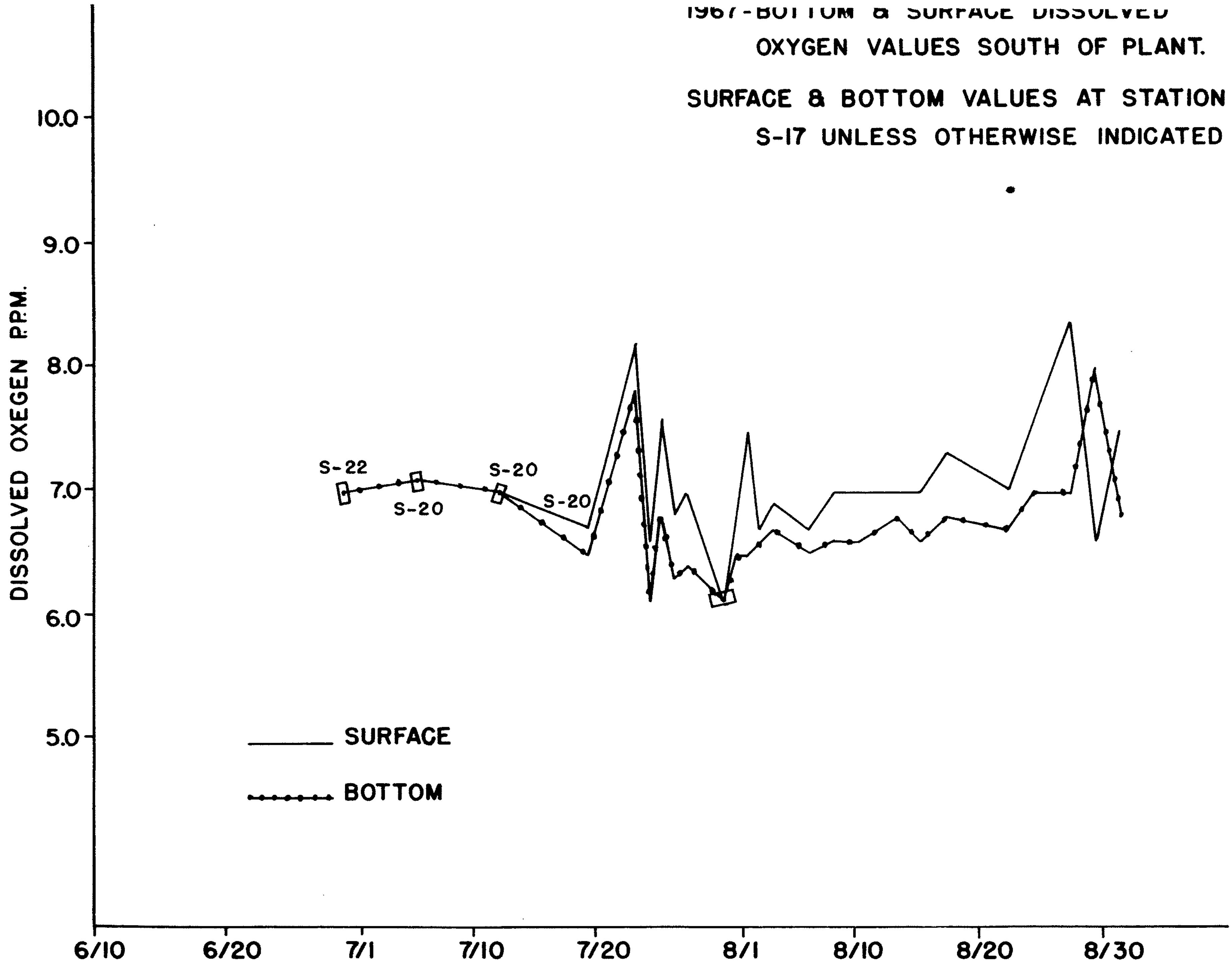


FIGURE 51-BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

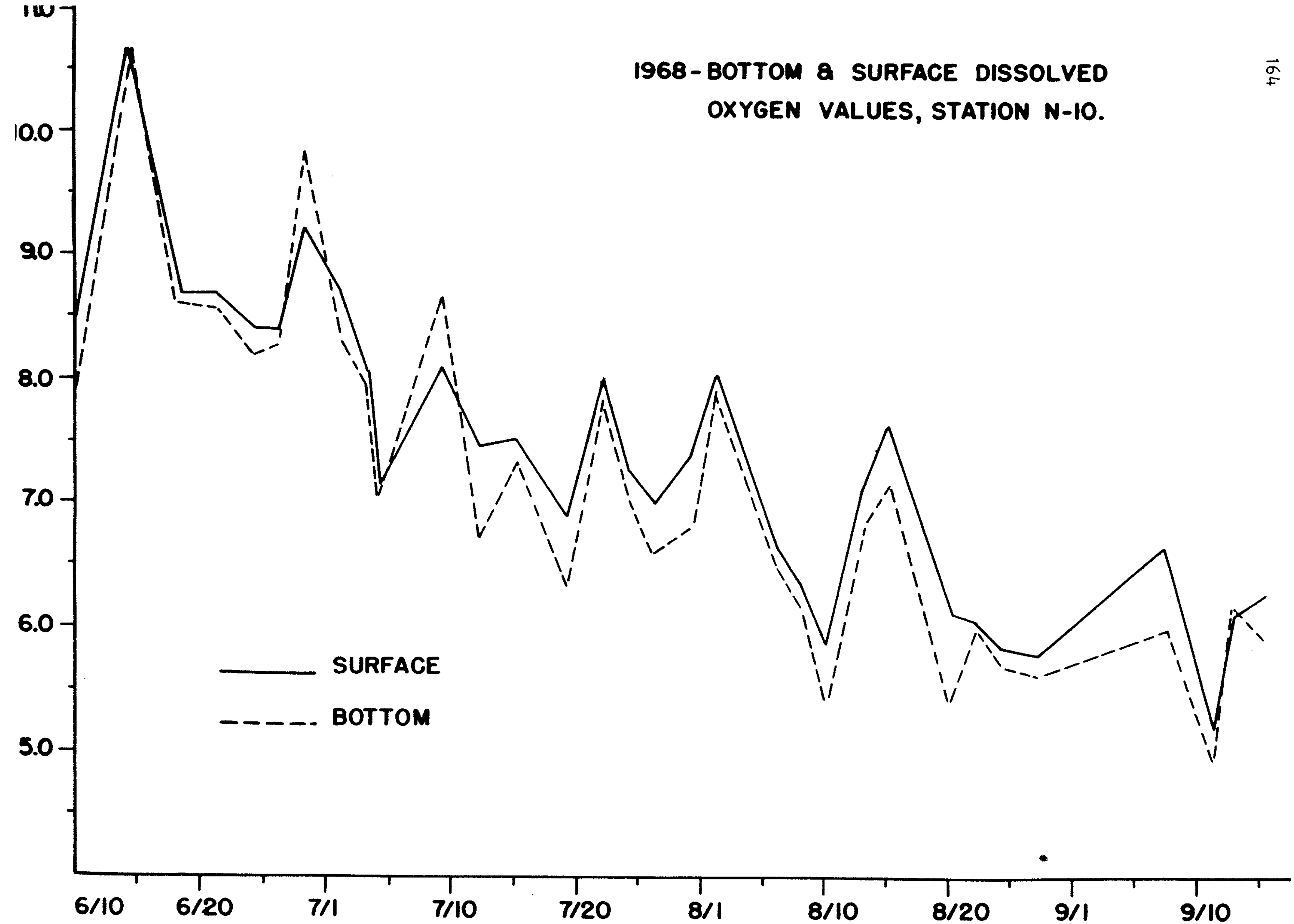


FIGURE 52 - BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO
RE: MERRIMACK RIVER THERMAL STUDY.

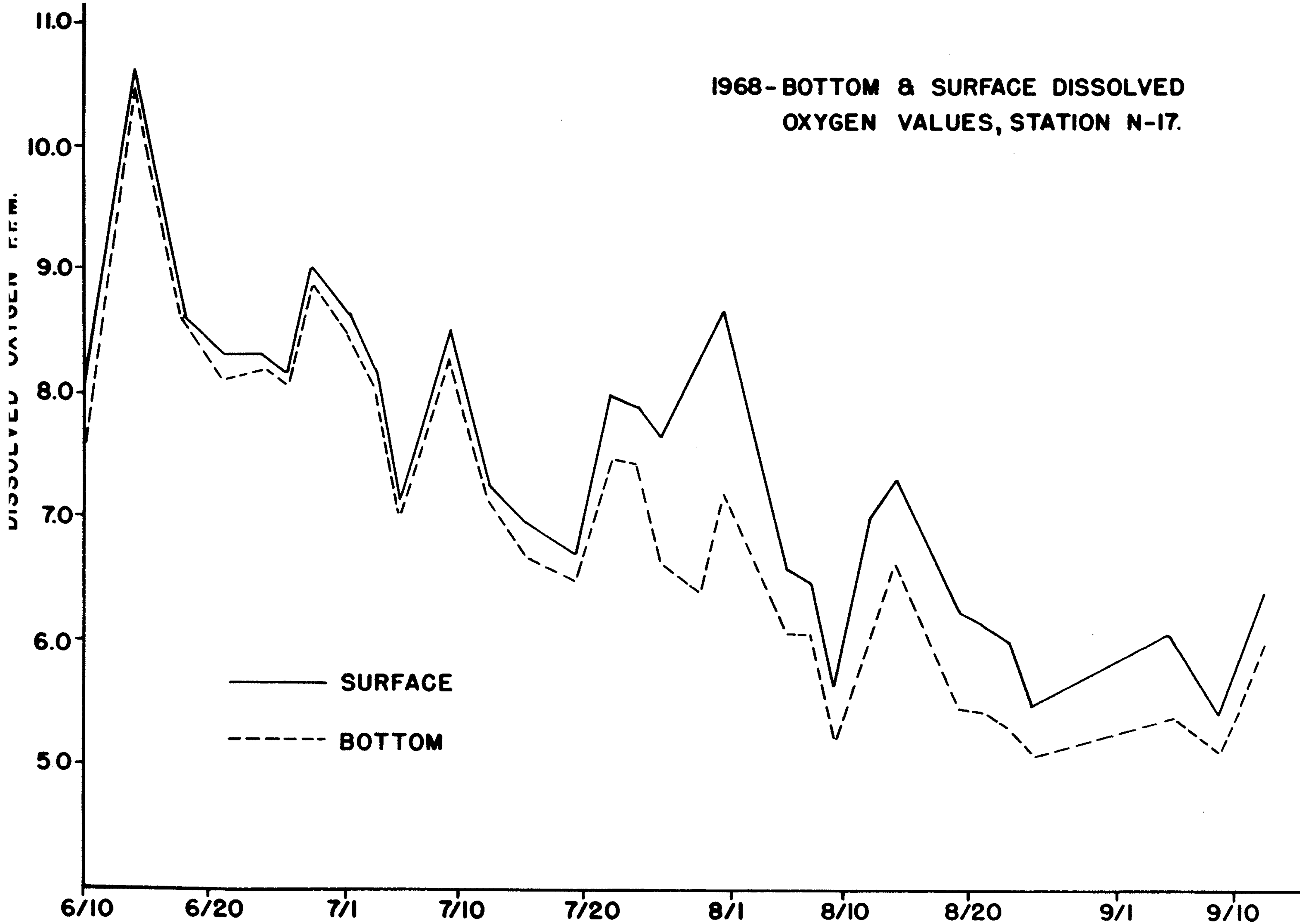


FIGURE 53-BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

Manual D.O. values collected at station 0 indicate greater variation at this station than those encountered at stations N-10 and S-17 (Figure 54 through 57.)

Variations of 5.2 to 7.9 ppm were evident on September 10 while August 14 and August 21 data showed a range of 6.2 to 8.4 and 5.4 to 7.6 ppm respectively.

The fact the effluent discharge consistently had lower oxygen content explains why the minimum values were less than the other stations. There are times when maximum oxygen content was greater than stations N-10 or S-17 in the entire river cross section at this station, although data obtained on the west side where effluent flows were concentrated were invariably lower.

Comparisons of surface and bottom D.O. values at stations N-10 and S-17 show greater variation in the dissolved oxygen content in the surface and bottom at S-17 than was encountered in the N-10 sample station (Figures 52 and 53).

There are times when the southern D.O. content is greater than encountered in the north. Also fluctuations in percent saturation oxygen were not as extreme in the south. The reason for this reduced fluctuation again points to the fact the Suncook River contributes significantly to the D.O. content of the lower section, which would explain the variation during the daytime and stabilizing effect during the night when photosyntheses and respiratory effects are greatest. Further evidence of the Suncook River contribution of D.O. is evident in 1967 results, which indicated higher D.O. values south of the plant compared to northern results.

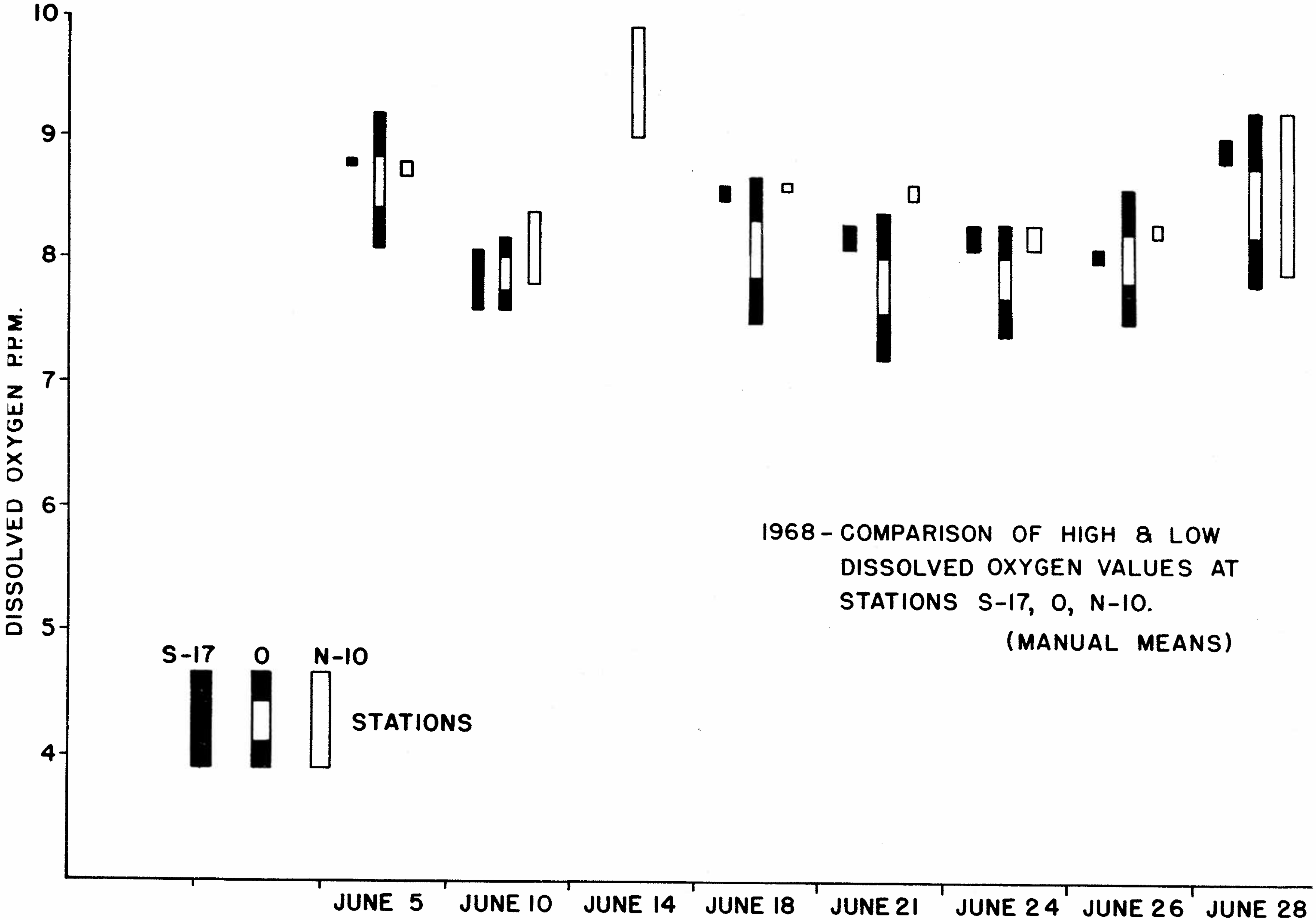


FIGURE 54 - BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

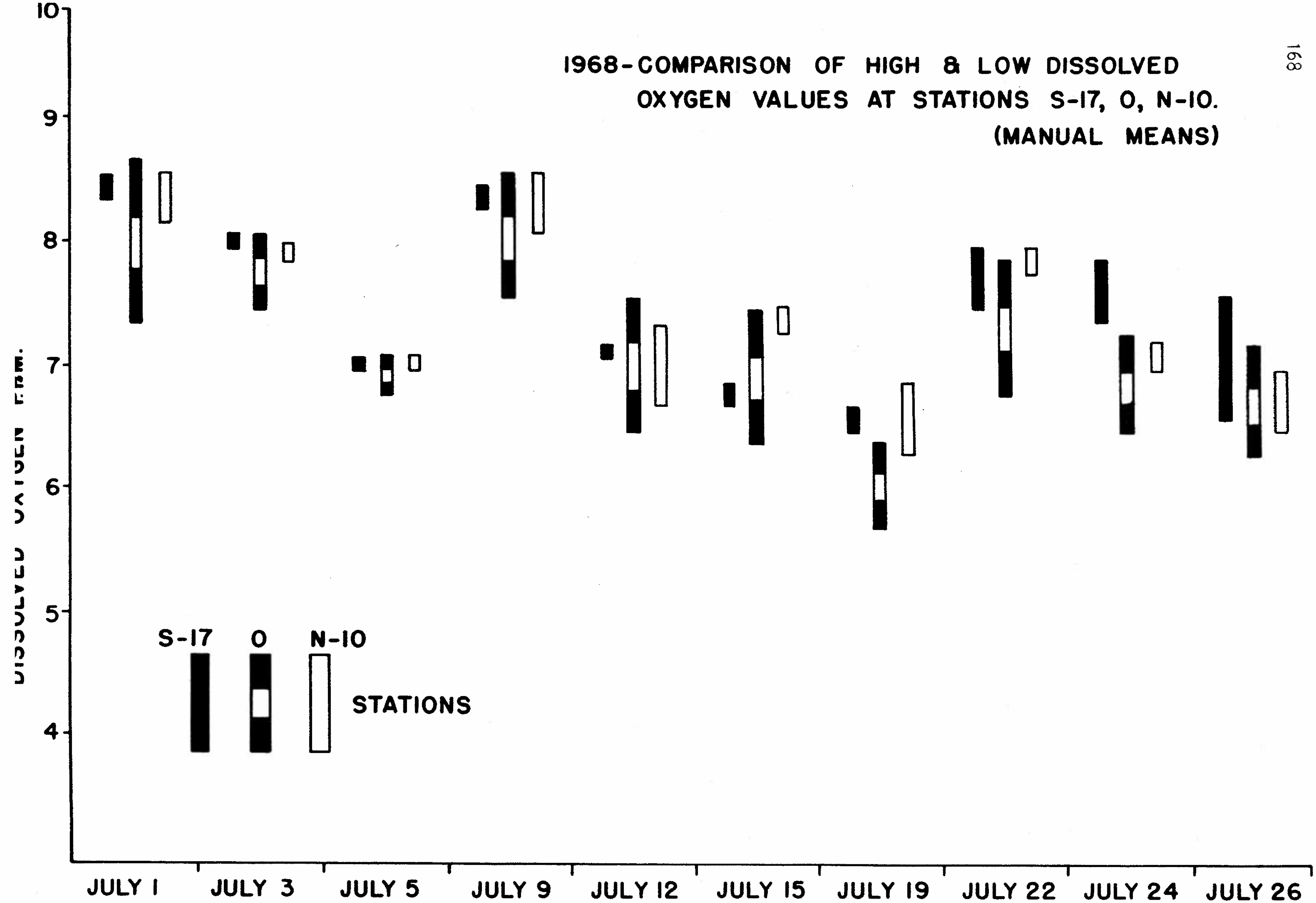


FIGURE 55 - BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

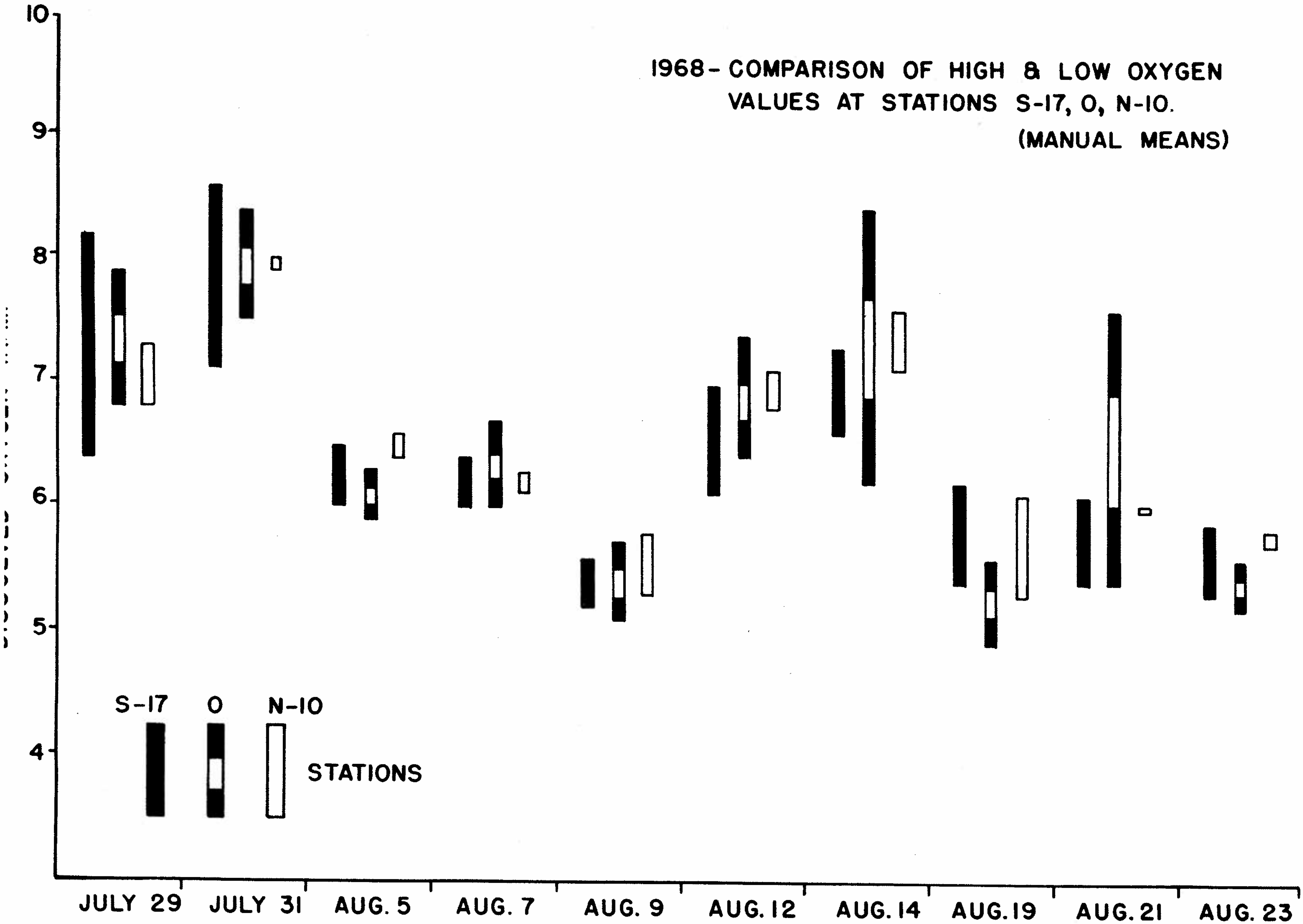


FIGURE 56- BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

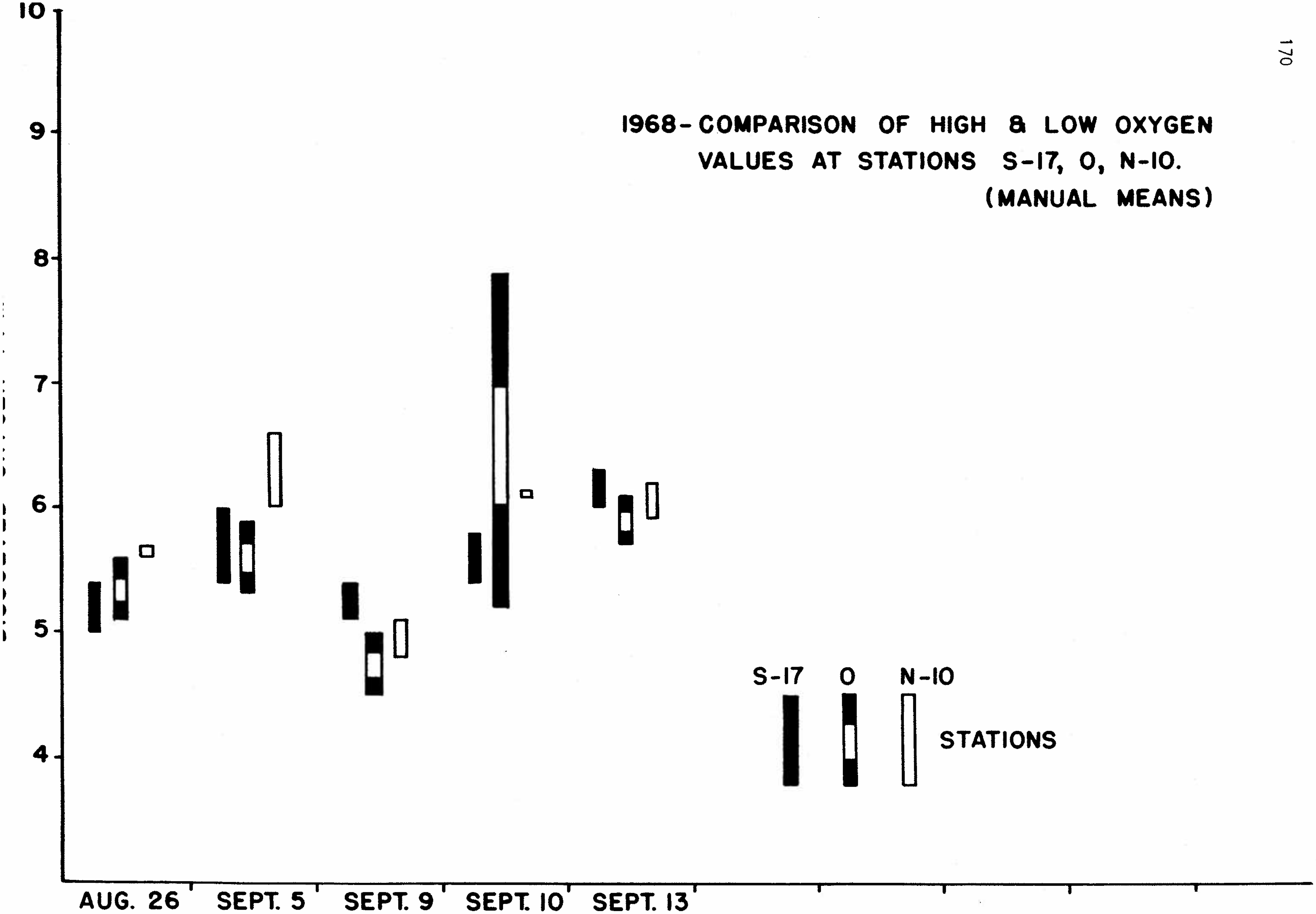


FIGURE 57 - BASED ON DATA OBTAINED FROM PUBLIC SERVICE CO.
RE: MERRIMACK RIVER THERMAL STUDY.

Limited samples obtained below Hooksett dam show a higher oxygen level in this section due, in all probability, to aeration effects of the dam as it flows into this pool.

Discussion: Dissolved Oxygen

In summary it appears that the following is occurring in regard to D.O. content between the northern and southern sections. There is some reduction in the D.O. content due to the heated effluent, however, supplementary effects from the Suncook River tend to restore and improve this condition. Dissolved oxygen values at S-17 are generally comparable to those encountered in the north with some instances of higher dissolved oxygen content.

Station 0, although having reduced oxygen on the westside at the effluent outfall, did not give any indication of critical conditions due to the supplementary effect of the main river. Limited data obtained below Hooksett dam indicates higher oxygen levels due to aeration effects at the dam.

Data obtained regarding D.O. values above and below the Bow Steam Plant indicate the effects of the Bow Steam Plant are not as critical as had been feared. The fact the Suncook River supplies a significant amount of D.O. to the southern section, creates a condition which is probably of considerable benefit to D.O. values obtained at S-17, as at times the oxygen content is greater in the south section than the north. However, a point which cannot be taken lightly is that a fish uses considerably more oxygen as temperatures increase, also asphyxia concentration is proportionately greater the higher the temperature. Because temperatures tend to be higher in the southern section, the fact of D.O. values are comparable to the north is a little misleading. More oxygen is needed in the southern section to maintain life. Also activity plays an important role; fish must be active to forage for food, avoid capture by predators and maintain their position against the current.

A combination of high temperatures and low oxygen could cause a decrease in such activity. Also the metabolic rate (oxygen demand) of juvenile fish is greater than adults. The combination of the previously described condition could result in the loss of a year-class if periods of extreme stress occurred.

In rivers which receive sewage and industrial wastes, as well as heated effluents such as the Merrimack River, the indirect effects of increased temperatures on dissolved oxygen should be considered in the following statement: The toxicity of poisons and the lethal effects of low concentrations of dissolved oxygen increase with temperature and the concentration of dissolved oxygen in solution is, in turn, determined by its solubility and an equilibrium between rates of oxidation, respiration, photosynthesis and aeration, all of which are temperature dependent. Of the fishes, the small free swimming fish are mainly affected, the larger fish are able to swim away to safety.

Rough fish are better able to cope with such environmental conditions than are game fish which could conceivably cause a predominance of such fish at the expense of preferred species over a long period of time.

In conclusion, although dissolved oxygen values are comparable in the two sections, the effect of higher temperatures and similar dissolved oxygen conditions creates a dissimilar situation than exists in the north. To combat this situation, flows should be increased in and out of the Hooksett Pool as well as a continuation of monitoring in the area of study to determine situations which might cause deoxgenation.

Chemistry pH

Because of the effect changes in the pH of an aquatic environment would have to the organisms therein, a study to determine the influence on this parameter by the generating plant was conducted.

Samples were obtained, utilizing an Orion specific ion meter Model 401, periodically from June to September in 1967 and again in 1968. All sections of the study area were sampled at top and bottom to determine variation of pH values above and below the plant.

The normal range of pH samples in 1967 was generally from 6.0 to 6.8 ppm. A low of 5.5 ppm was recorded at N-10 on August 2,1967, whereas, no pH value of seven or higher was recorded in 1967.

No evidence of any significant difference between surface and bottom values occurred during 1967 samples. In 1968, a low of 5.6 ppm occurred at stations 0 and S-17 on June 28, as well as a high of 7.3 ppm at station S-17 on July 19.

Doudoroff & Katz (1950) concluded that most, if not all fully developed freshwater fish can live indefinitely in water with a pH value of above 5.0 ppm and up to at least 9.0. The pH values outside the tolerable range and persisting long enough to be fatal to fish are unusual. Very young fish may be somewhat more sensitive to extremes of pH than adults. Overall, 1968 pH values varied only slightly from the north and south section. Because of this, it is felt the effect of the steam plant on this parameter is insignificant with little effect occurring to the fish life.

Conclusions

It does not appear pH values in the study area below the Bow Steam Plant are injurious to existing fish life on the basis of 1968 data.

Chemistry

The following chemical levels were analyzed by personnel and facilities of St. Anselm's College under the direction of Dr. Normandeau. The analysis included the following parameters:

Turbidity	Chloride
Calcium	Total phosphate
Biological Oxygen Demand	Orthophosphate
Sulfates	Nitrite
Hardness	Nitrate
Polyphosphate	pH
	Organic Ammonia Nitrogen

Sampling stations were located at N-4, the discharge canal and at S-17, for the most part, with some other stations sampled for added information.

Since the purpose of the study was to determine water quality prior to increased plant operations, as well as after, the mean and standard deviations were determined at the IBM center at St. Anselm's College. The numbers of samples falling within the standard deviation was compared for both years.

It was found that no significant changes occurred in the samples north of the plant compared to the area affected by the plant effluent.

Some loading effects occurred in the chloride, hardness and calcium properties in 1968 during periods of low flows. Based on data collected and correlated by Dr. Normandeau and staff it appears the effects of the power facility to these parameters is negligible.

VIII. Conclusions:

On the basis of data obtained to date regarding thermal effects on the adult fish life in the area of the Bow Steam Plant, it appears the effects were not as great as had been anticipated. Although there is evidence of some changes taking place, the fact the river is in a constant change though normal processes tends to obscure the total effect of the warmer water.

Fyke netting results between the southern and northern areas indicate similarities in yearly species composition, which rules out any significant effect to the adult fish populations as it exists at present. Because of this similarity, it is felt an acclimation effect has occurred to the fishery population which has enabled most species to adapt to increased temperatures and the resulting effects south of the plant.

There are some changes regarding certain species which may be indicative of thermal effects, although the duration of the study tends to limit a blanket statement that these changes were the result of the thermal flows. The fact largemouth bass are on the increase in the southern section of the study area could be an indication that this species, being more tolerant of temperatures, are going to increase in numbers as the heated conditions continue. Because northern section showed significant increase in 1969, it is possible some movement is occurring from the south to the north as competition for food and space occurs. Although movement studies did not indicate movement of any significant magnitude of adult fish, it must be emphasized the majority of fish constituting this largemouth bass increase were not adults and the possibility of such movement due to competition effects must not be ruled out.

Another species which may be affected by the environmental change could be white suckers. Based on electro-fishing results, white suckers were absent in the 1969 electro-fishing capture in the southern and Amoskeag area, although they did appear in previous years efforts to a limited degree.

In view of the fact the northern section showed evidence of this species during electro-fishing each year it was conducted, the question of their absence in the southern sections is raised. It is obvious the littoral zone is warmed to some degree by the heated effects. Because electro-fishing concentrates on this zone, it is possible the resultant temperatures are causing a movement of this species into the cooler water through temperature displacement.

Of the four species sampled for growth effects from the heated flows yellow perch and pumpkinseeds showed very little change in growth characteristics.

Smallmouth bass gave evidence of slightly better growth in the north section in 1969 in the two and four year age class; whether this is due to thermal effects is questionable, however, it is known smallmouth bass are less heat tolerant then some of the other species sampled and some effect could have resulted.

Redbreast sunfish on the other hand showed a slightly better growth in the southern sections compared to the north which could be an indication temperatures are benefiting this species to some extent.

Movement results on the basis of recaptured, tagged, and fin-clipped adult fish reveals little movement from one section to another. It appears the adult fish are surviving temperature extremes by vertical and cross-stream movement rather than displacement from one section to another.

Conditions in the canal section where effluent temperatures are the greatest showed a greater abundance of fish existed in the canal prior to increased flows and resulting temperatures. This occurrence held true during both winter and summer sampling efforts, which is contrary to some publications which state power plant effluents supply a significant fishery during the winter months; such is not the case in the Bow area.

It is felt water velocities plus increased temperature with little or no stratification resulted in the decline in fish numbers during sampling periods in the canal sector.

Gill netting results indicated adult walleyes are not avoiding the area below Hooksett Falls where the effects of the mixed waters are greatest.

Because the data obtained to date dealt mainly with adult fish, the overall effect, if any, to juvenile fish and reproduction of the species studied is not known. At present there does not appear to be any significant effect to the fishes of the area except perhaps in the case of largemouth bass and white suckers, as was stated previously, however, because the fishery is in a sense the end of the food chain, it is felt the overall effect to the resident species will not be known for several years.

In view of the fact at present a program has been initiated toward restoration of American shad and Atlantic salmon in the Merrimack Watershed, the effect the increased temperature will have on their life cycle such as spawning and migration could pose severe limitations to the future of the anadromous program. For this reason, it is felt cooling facilities will be necessary upon successful establishment of these species.

Results of temperature data collected show stratification occurs in the southern section to a greater degree during the late summer months when flows are reduced. Although such stratification occurs, there is still marginal heating to the lower depths in the forebay of the dam at Hooksett Falls.

The effect of temperatures in the Amoskeag impoundment is lessened somewhat by evaporation and dilution processes from the main river and its tributaries. There is, however, less stratification in this section due to mixing of heated water as it spills over Hooksett Dam. This mixing effect results in a warming water trend appearing at all depths of the impoundment with reduced heat dissipation due to the entire river cross-section being warmed. Flow demands in the area appear to be one of the most critical aspects of this study. It is quite evident that the existing flows are being subjected to close to the maximum demands which power facilities can expect to use for condenser cooling water. Because flows are so low in late summer, there are times when the plant cooling water demands exceed the flow of the river. The effects of these demands are reflected in the resulting temperature increase and dissolved oxygen content downstream of the plant. Because flows are so critical to the existing biota of the river, it is felt the study area would suffer irreparable damage if additional power plants are constructed in the area.

Benthic organisms do not appear to be adversely affected by the thermal effects at this writing, however, sampling techniques left much to be desired in this phase of the study and the results were inconclusive.

In regards to the phytoplankton and zooplankton of the area, it appears some reduction is occurring to these organisms due to increased temperatures from the generating facilities; how extensive the affliction is in terms of depth is unknown as sampling was restricted to the surface waters. Because of the importance of these organism to certain species of fish during all or part of their life cycle, it is felt these findings are of significant value. Although conditions at present have not reached a critical level, it is felt monitoring of some type should continue in this area of study to determine fully the effects to these populations over a long term period.

Dissolved oxygen values do not appear to reach critical proportions downstream of the plant as had been feared due to supplementary oxygen content from the Suncook River. It is evident that flows play an important part in the oxygen content of the entire river as evidenced by September data.

Although D.O. values are similar above and below the plant in terms of ppm, the fact temperatures are higher below the plant creates a situation where the metabolic rate is increased. This increase in metabolism creates an increased demand on the D.O. content for life sustenance in the area. Because of this factor and the fact D.O. values do become quite low, it is felt increased flows during the late fall period would alleviate this situation.

Again, I would like to emphasize this study was of too short a duration to provide any conclusive evidence of biological changes due to thermal effects. It does appear that certain changes could be in the process, but as to their overall long-term effect, the results of this study cannot answer.

Recommendations

Due to the fact a change resulted in the plankton abundance downstream of the power plant, it is recommended some type of a study be continued in the Hooksett impoundment to determine the long-term effects of these organisms exposed to heated water.

In view of the trends which appear to be resulting among the fishery population from thermal effects, it is felt a study of the Hooksett impoundment should continue utilizing electro-fishing equipment during the fall of each year for a ten year period.

Because emergency shutdowns do occur to generating facilities creating abrupt changes in the water temperatures, it is felt in cases of such breakdown the Fish and Game Department be contacted to evaluate any evidence of fish distress if such malfunctions occur.

In view of the low flows which occur in the watershed during late summer and the fact existing facilities at times could be using more than the total flow of the river for cooling purposes, that additional flows be released in the fall to safeguard the biota of the river from such occurrence.

In view of the demands which would be placed on the watershed if additional power plants were constructed, even with cooling facilities, it is recommended that future plants be placed elsewhere rather than in the watershed.

Because of possible temperature effects and the possible deterrent to resident and anadromous fish programs, it is recommended that construction and operation of cooling facilities be considered at this plant as soon as possible to safeguard this river resource.

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