POWER AUTHORITY OF THE STATE OF NEW YORK
JAMES A. FITZPATRICK NUCLEAR POWER PLANT

316(a) DEMONSTRATION SUBMISSION

PERMIT NO. NY0020109

LMSE-76/0301&260/002

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

SUMMARY OF FINDINGS

The major findings of this document in regard to the effect of thermal discharge from the James A. FitzPatrick Nuclear Power Plant (JAF) on the aquatic community in the vicinity of Nine Mile Point are summarized below. Discharge effects on major trophic levels and representative important species were assessed. The demonstration follows the procedures provided in the draft document "316(a) Technical Guidance - Thermal Discharges," dated September 30, 1974 and is a Type III Demonstration.

1. The James A. FitzPatrick Plant Nuclear Power Plant (JAF) has a flow of 22.23 m^3/sec (785 cfs) and a maximum plant temperature rise of 17.5°C (31.5°F). The heated water is discharged through a multiport, high velocity diffuser at a depth of 8 m (25 ft) directly offshore from the plant.

2. JAF operated at a 50% power level or greater from July through October 1975 and was placed in commercial operation on July 28, 1975. The power levels sustained throughout the summer of 1975 combined with the operation of Nine Mile Point Nuclear Station Unit 1 (NMP-1) were sufficient to produce observable effects on the trophic levels being studied had any occurred.

3. The JAF diffuser was designed to produce rapid dilution of the thermal effluent and to minimize the surface area which experiences significant temperature increases. Mathematical analysis of the near-field plume (before plume surfacing) indicates a decrease in temperature above intake temperatures from 31.5 to 13.5°F (17.5 to 7.5°C) in one second and a further decrease to 9°F (5°C) four seconds after discharge.

4. Hydrothermal field surveys confirmed the rapid dilution of the thermal effluent and indicated a maximum surface area extent of the 3°F (1.7°C) isotherm of 1,196 x 10^3 ft^2 when the isotherm was present. Most of the year the areal extent of the surface 3°F isotherm will be reduced (at times to zero) because of natural temperature differences between the surface and bottom near the outfall. Interaction of the JAF plume with that of NMP-1 was documented. Under conditions causing near field plume interaction, JAF's discharge was found to reduce surface temperatures due to the NMP-1 discharge.

5. An analysis of the abundance of major phytoplankton groups in 1975 yielded no evidence of plant-induced depression or enhancement of total phytoplankton, diatoms, green algae, or blue-green algae. Analysis of primary production and chlorophyll a concentrations from entrainment samples indicated that primary production was

increased somewhat in the plume during the period of study and that it was not possible to detect trends in chlorophyll a concentrations. The lack of trends in chlorophyll a indicates that plant operation is not affecting phytoplankton standing crop and mortality due to plume entrainment is not indicated in the data.

6. Comparisons of abundances of microzooplankton between plant and control transects in 1975 indicated neither statistical nor observable differences in abundances. The mortality data for microzooplankton collected at the plant intake, from the plume, and from exposure to simulated plume conditions did not show an increase in mortality attributable to temperature increases encountered during plume entrainment.

7. The abundances of the macrozooplankters Leptodora kindtii and Gammarus fasciatus were compared for plant and control transects in 1975. No differences in abundance attributable to plant operation were found.

8. Ichthyoplankton in the study area was low in abundance with the exception of alewife larvae. This low abundance of larvae of most species suggests that the area around JAF's discharge is not a major spawning ground.

9. Local scouring and deposition due to the action of the high velocity diffuser has been observed in the discharge area. The area of scour and deposition was estimated to be 44.9×10^3 m^2. Benthic habitat has been lost in the area of scour, while in the area of deposition, recolonization and benthic production will resume. The loss of benthic habitat is small and unimportant in relation to benthic production in the Nine Mile Point vicinity.

10. The fish community at Nine Mile Point has a species composition typical of Lake Ontario and a seasonal pattern of distribution and abundance that is not influenced by the presence of the thermal discharge.

11. Voluntary exposure to the thermal plume by representative important species of fish will not cause mortalities because the velocity field of the plume will not permit species to maintain themselves in an area of elevated temperature above their upper incipient lethal temperature. Avoidance responses to unsuitable temperatures by representative species of fish will insure that mortalities will not occur.

12. Exposure to the thermal plume due to entrainment could result in mortality of the juveniles and adults of some representative species if it is assumed that individuals do not avoid the plume

and that they are entrained into the plume at the point of discharge. It was demonstrated that representative important species entrained at the point of discharge would be in safe temperature increases in less than one second which makes the possibility of plume entrained mortality for all life history stages very remote.

13. The velocity field of the JAF diffuser will preclude acclimation to temperatures above ambient which could produce a cold shock situation.

14. The lethal thresholds for Gammarus spp. are well above any time/temperature regimes they will experience if entrained into the JAF plume, therefore, no mortalities will occur.

15. The effects of shear forces, reduced dissolved oxygen levels, pressure changes, and temperature/chemical interactions in the plume were analyzed and found to have no effect on organisms.

16. The analyses in this document demonstrate that the current mode of discharge at JAF, which is the alternative thermal effluent limitation previously requested, will not harm the biological community in the vicinity of Nine Mile Point.

I. INTRODUCTION

On May 22, 1974, the staff for Region II of the U.S. Environmental Protection Agency (EPA) issued a draft National Pollutant Discharge Elimination System (NPDES) permit for the James A. FitzPatrick Nuclear Power Plant (JAF). On June 30, 1974 the Power Authority of the State of New York (PASNY), pursuant to Section 316(a) of the Federal Water Pollution Control Act (FWPCA), requested the Regional Administrator impose alternative thermal effluent limitations to those designated in the draft permit. On February 27, 1975, EPA issued a final NPDES Permit for the FitzPatrick Plant which did not contain the requested alternative thermal effluent limitations.

In the memorandum transmitted with the Final Permit, EPA deferred a decision on PASNY's request for alternative thermal effluent limitations until a demonstration is made pursuant to 316(a) of FWPCA that those alternative thermal effluent limitations are sufficient to protect the balanced indigenous community. In meetings and correspondence between PASNY and EPA subsequent to issuance of the Final Permit, the scope for a 316(a) Demonstration was discussed and a Type III Demonstration was confirmed in a letter dated November 9, 1976 from Mr. Gerald Hansler (EPA) to Mr. Scott Lilly (PASNY). The Representative Important Species for JAF were indicated in a letter dated August 11, 1975 from Mr. Gerald Hansler (EPA) to Mr. George Berry (PASNY).

This document follows the procedures presented in the draft document entitled "316(a) Technical Guidance Thermal Discharges," dated September 30, 1974 and addressed specific points discussed at meetings between PASNY and EPA. Extensive references are made to study results previously submitted to EPA. This document includes descriptions of the plant and the site baseline hydrography. The baseline biological community description summarizes available data from the site and includes biological data for the various trophic levels while the plant was in operation. More specific impact evaluations based on both site data and published literature are provided for the designated representative important species to support conclusions made in this document.

Appended to this document are the temperature data available for the representative important species and a description of the thermal bioassay conducted for this demonstration. Also included in the Appendix are the relevant water quality communications.

II. PLANT DESCRIPTION

A. LOCATION AND GENERAL FEATURES

The James A. FitzPatrick Nuclear Power Plant (JAF) is located in the Town of Scriba, New York on the south shore of Lake Ontario (Figures II-1 and II-2). The plant is a single generating unit with a boiling water reactor producing 821 MWe (net output). It is located approximately 3000 ft east of the Nine Mile Point Nuclear Power Station and approximately 7 mi east of the Oswego Steam Station.

B. CIRCULATING WATER SYSTEM

JAF uses once-through cooling to dissipate waste heat from the main condensers and auxiliary cooling systems. Circulating water is withdrawn from Lake Ontario through a submerged inlet, circulated through the main condensers and auxiliary systems, and returned to the lake through a submerged jet diffuser (Figure II-3).

When operating to maximum power output, the plant requires a total flow of 23.36 m^3/sec (825 cfs). Of the total flow, 22.23 m^3/sec (785 cfs) are for the main condensers which raise the temperature 18.0°C (32.4°F), and 1.13 m^3/sec (40 cfs) are for service water requirements which produce a 7.5°C (13.5°F) rise in temperature. The combined condenser and service water discharge flow has a temperature rise of 17.5°C (31.5°F). These cooling water characteristics remain essentially the same throughout the year. The seasonal temperature variation of the cooling water flow at the intake is approximately 0°C (32°F) to 25°C (77°F).

The total heat rejected to the lake is a function of electrical load; heat rejection increases with an increase in electrical load. With the exception of NRC imposed limitations, the Power Authority expects to operate the plant at full load except when maintenance or refueling is required. The heat rejection rate at 100% load is calculated to be 5.714×10^9 Btu/hr.

1. Intake Structure

The intake structure is located on the lake bottom 274.3 m (900 ft) offshore of the plant in 7.9 m (26 ft) of water at the average controlled lake surface level of 75 m (246 ft). The structure is 20.9 m (68.5 ft) across at its widest point and 4.3 m (14 ft) high (Figure II-4). There are four intake openings on the south side of the structure and a solid wall on the north side. This configuration was designed to prevent any recirculation of heated water from the discharge structure located 82.3 m (270 ft) farther out in the lake.

FIGURE II-1

GENERAL LOCATION MAP

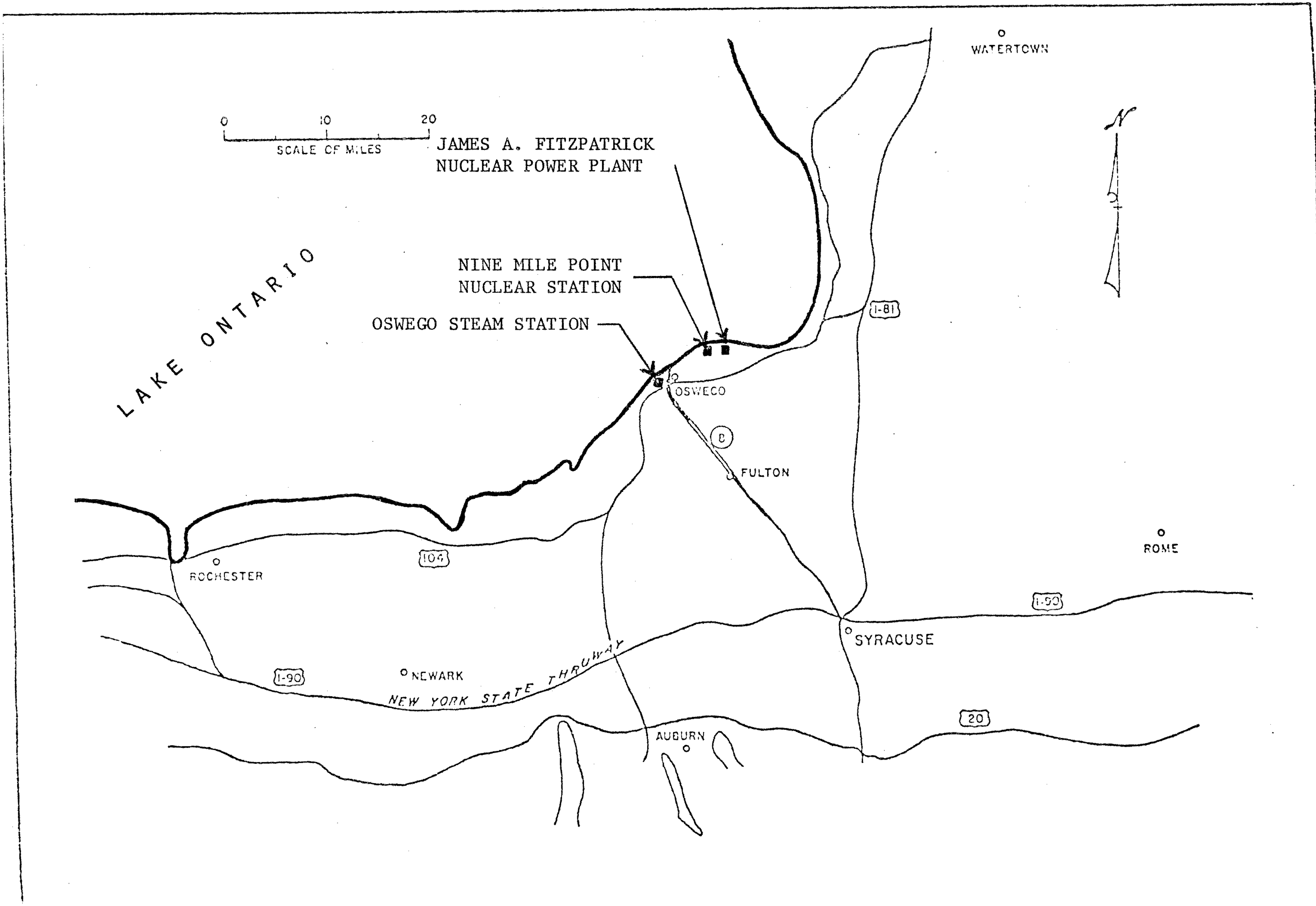
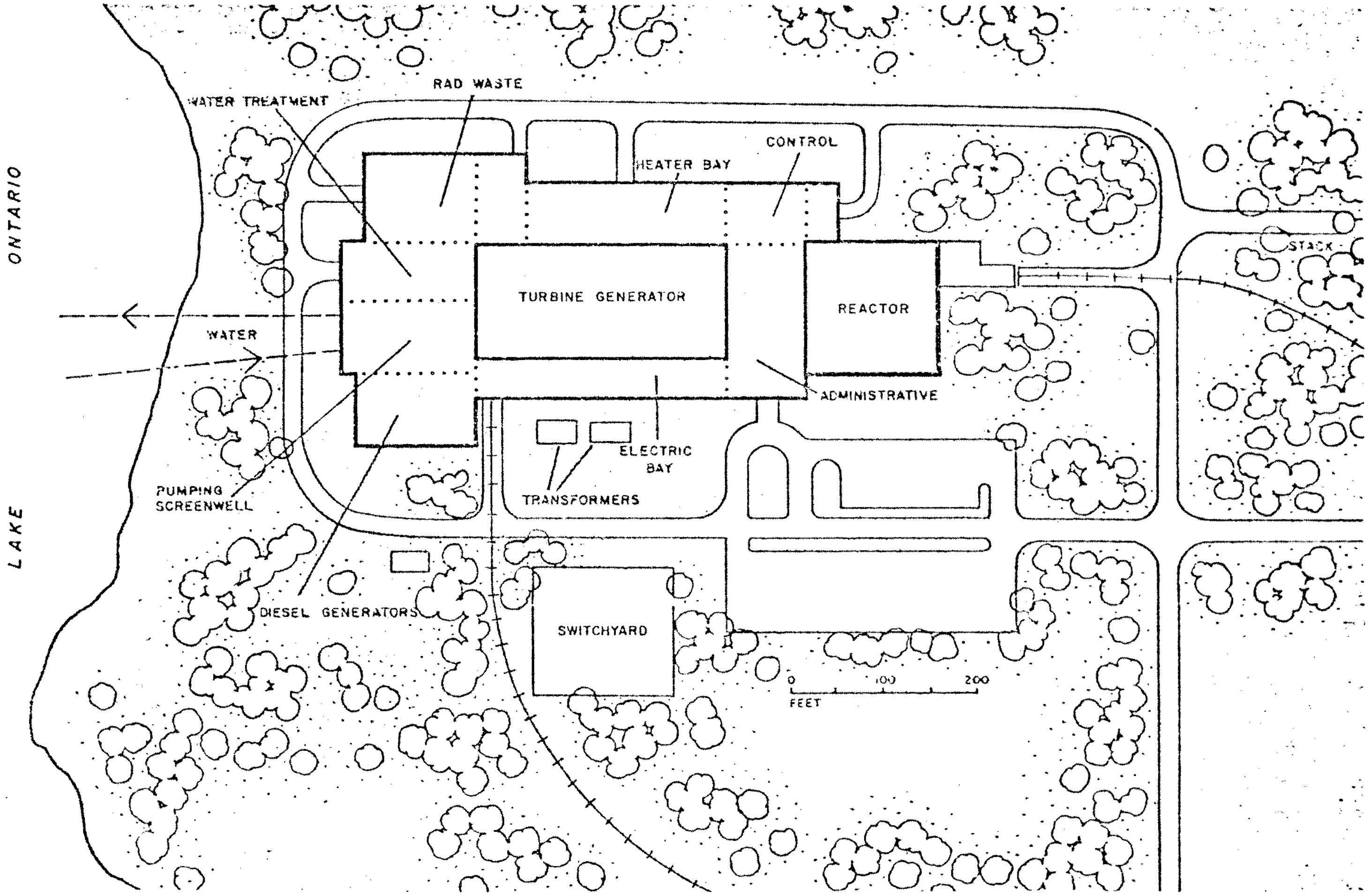


FIGURE II-2

PLOT PLAN

JAMES A. FITZPATRICK
NUCLEAR POWER PLANT



WATER INTAKE AND DISCHARGE ARRANGEMENT

JAMES A. FITZPATRICK NUCLEAR POWER PLANT

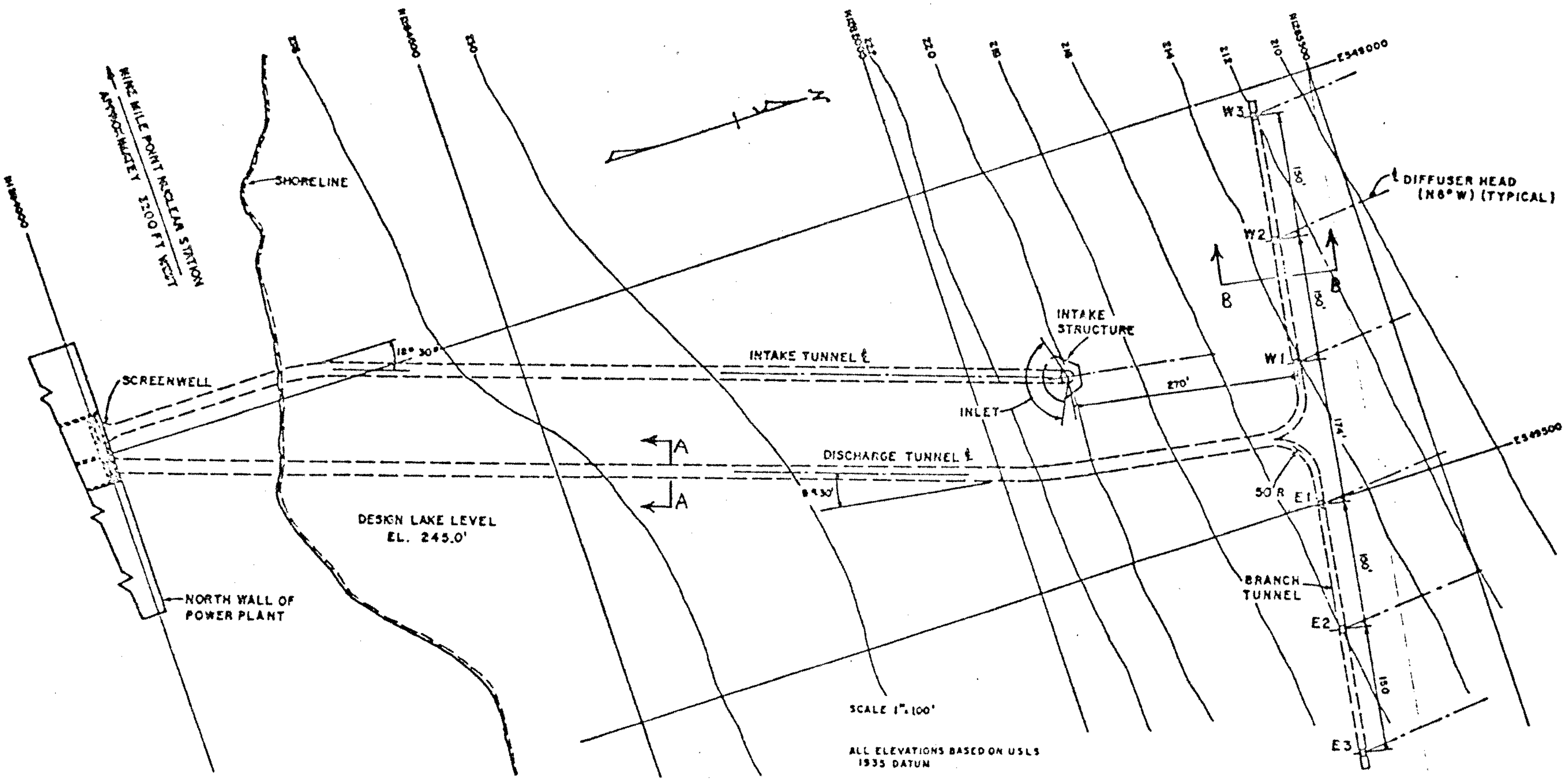
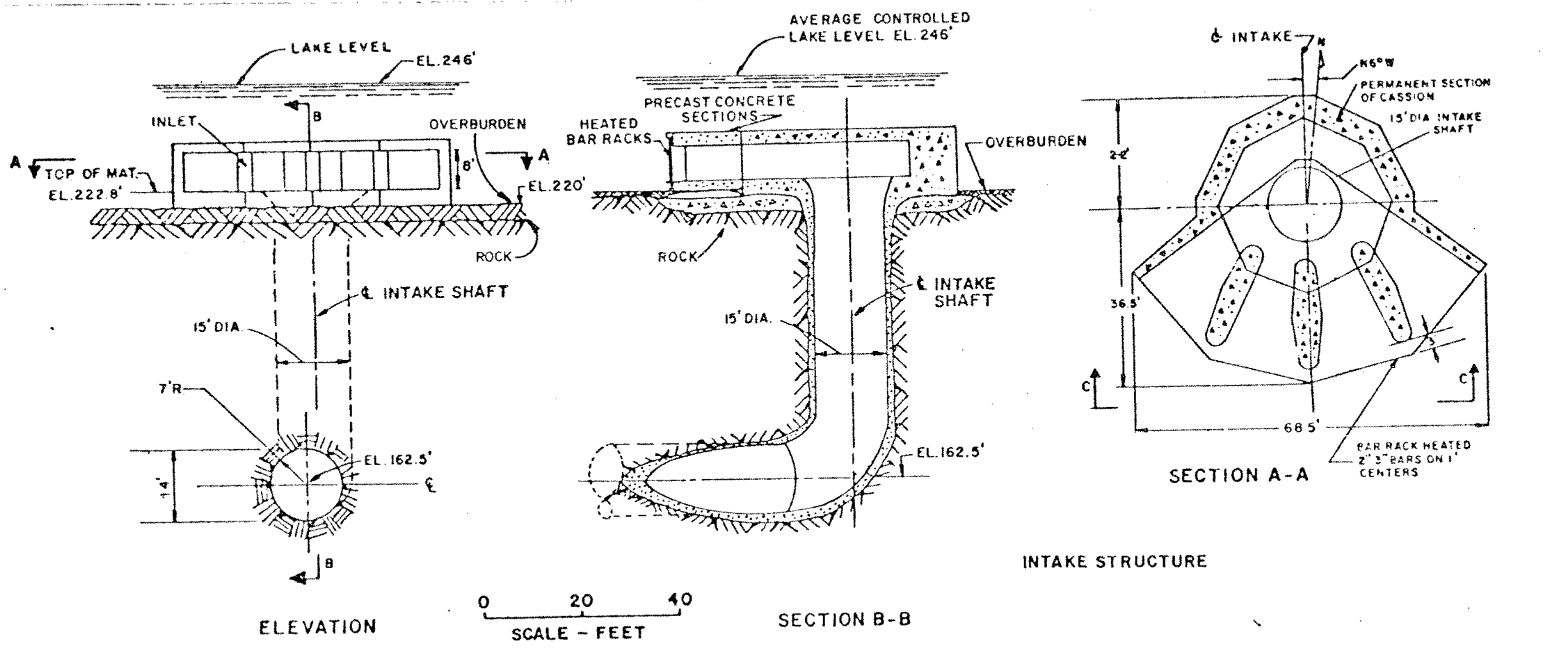


FIGURE II-3

FIGURE II-4

INTAKE STRUCTURE

JAMES A. FITZPATRICK NUCLEAR POWER PLANT



The four intake openings are 2.4 m (8 ft) high with a maximum width of 6.7 m (22 ft) at the bar racks. There is a total horizontal clear opening of 21.3 m (70 ft). The intake openings are 0.9 m (2.8 ft) above the lake bottom and the entire structure is covered by a solid roof. The intake cover restricts flow to a primarily horizontal direction. A bar rack system covers the entire open area of the intake structure to prevent the entry of large debris. In addition, the bar racks are heated to prevent ice formation. The calculated intake velocity through the bar racks is 0.43 m/sec (1.4 ft/sec).

After passing through the intake openings the water flows down a 4.6 m (15 ft) diameter vertical shaft to a horizontal tunnel 18.3 m (60 ft) below the lake bottom (Figure II-5). The water passes through the tunnel at 1.4 m/sec (4.7 ft/sec) and then rises in a vertical shaft to the onshore screenwell forebay. In the forebay the water passes through three separate bays, each equipped with bar racks and vertical traveling screens. The vertical traveling screens have 0.95 cm (0.375 in) square wire mesh. Behind the traveling screens is a well from which the main circulating pumps withdraw water.

2. Discharge Structure

The multiport discharge structure is located 356.6 m (1170 ft) offshore of the plant (Figure II-5). The discharge tunnel extends from the onshore screenwell to two branch tunnels positioned approximately parallel to the shoreline. Each branch tunnel has three diffuser heads spaced 45.7 m (150 ft) apart, with two discharge nozzles at each head, directed away from the shoreline. The submergence of the diffuser heads varies from 7.0-8.5 m (23-28 ft); depth of submergence increasing from east to west along the branch tunnels. The nozzles of each pair are separated by a horizontal angle of 42° and each nozzle has a 0.76 m (2.5 ft) diameter opening (Figure II-6). The circulating water system is designed to produce a 4.3 m/sec (14 ft/sec) exit velocity.

The NPDES permit for JAF places the following limitations on the discharge effluent:

(1) The discharge temperature shall not exceed 44.5°C (112°F).

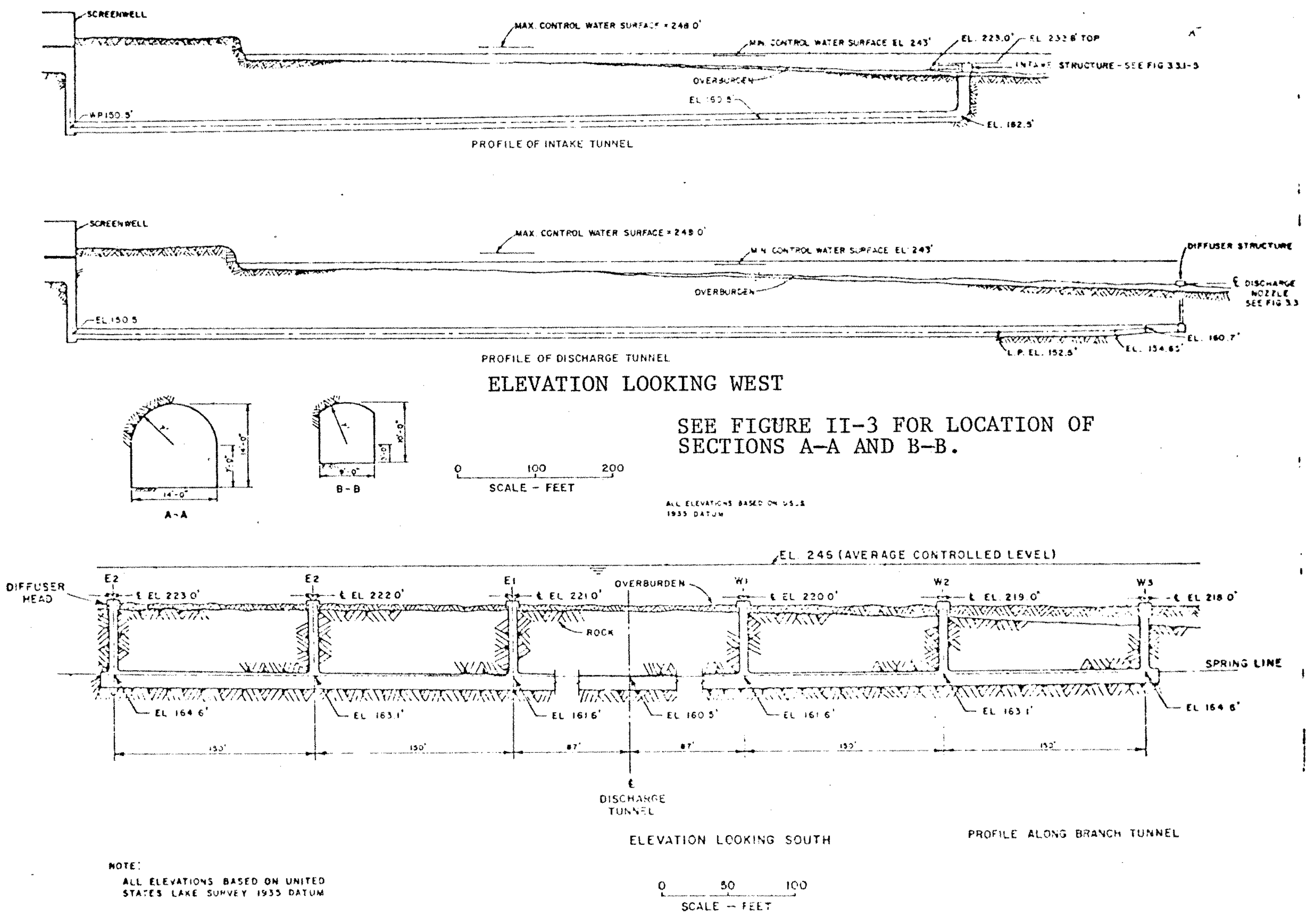
(2) The discharge-intake temperature* difference shall not exceed 17.8°C (32.4°F).

---

*During those periods when intake water tempering occurs, the intake temperature shall be considered that temperature existing after tempering.

INTAKE AND DISCHARGE TUNNELS

JAMES A. FITZPATRICK NUCLEAR POWER PLANT



SEE FIGURE II-3 FOR LOCATION OF SECTIONS A-A AND B-B.

NOTE:
ALL ELEVATIONS BASED ON UNITED STATES LAKE SURVEY 1935 DATUM

FIGURE II-5

DISCHARGE STRUCTURE TYPICAL DIFFUSER HEAD

JAMES A. FITZPATRICK NUCLEAR POWER PLANT

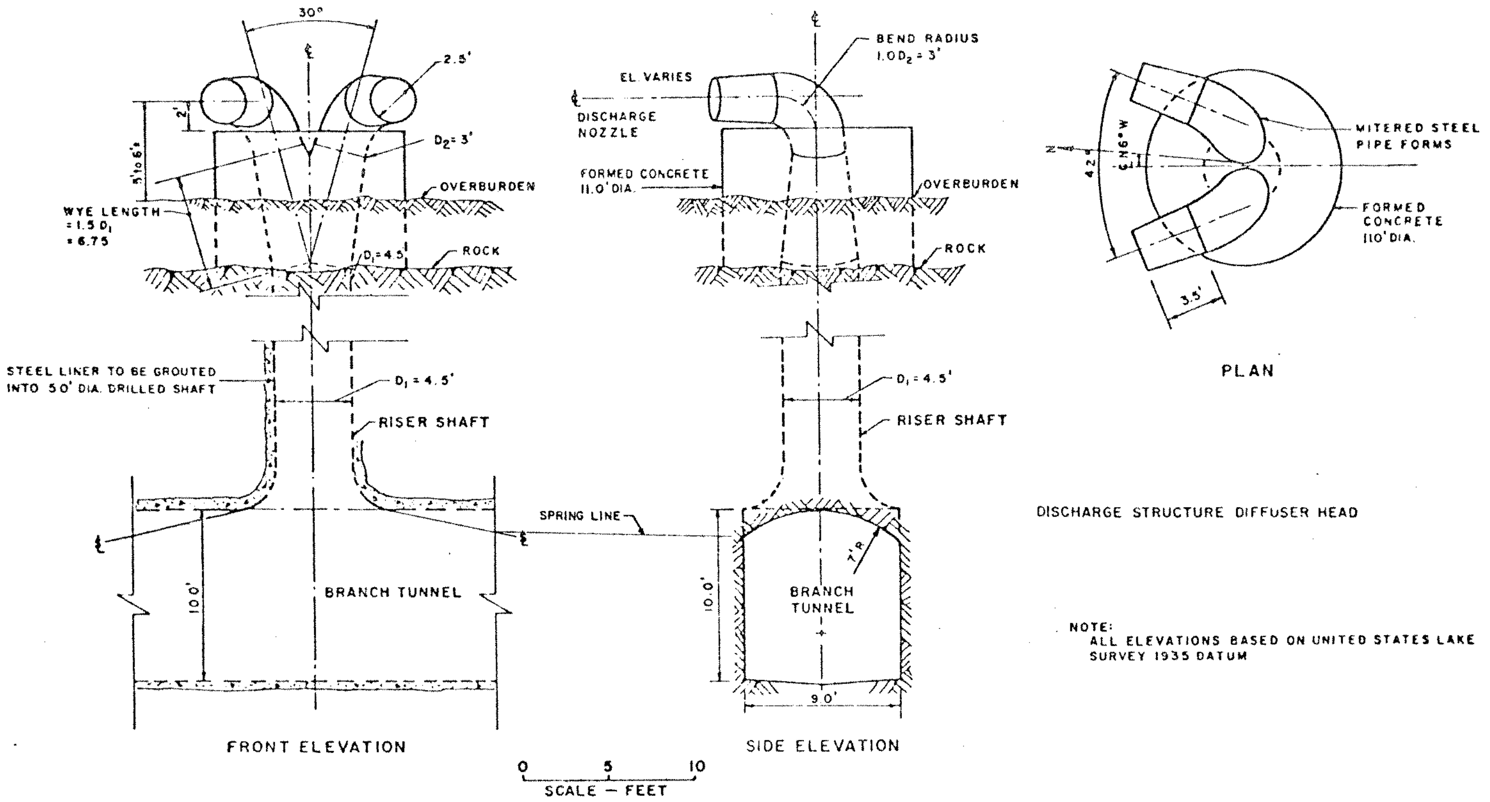


FIGURE II-6

(3) The net rate of addition of heat to the receiving water shall not exceed 1.44 billion Kcal/hr. (5.72 billion BTU/hr.).

(4) The pH shall not be less than 6.5 nor greater than 8.5 at any time.*

(5) No algicides shall be added to the condenser and auxiliary cooling water.

C. OPERATING HISTORY

JAF achieved criticality in November, 1974 and began commercial operation on July 28, 1975. Between these dates the plant went through a period of start-up testing during which there was intermittent operation at increasingly higher power levels.

Table II-1 summarizes the plant electrical output (gross MWe) from July 1, 1975 to September 30, 1976. During this interval the plant was consistently above 500 MWe gross output when the unit was on line. Figure II-7 provides a frequency histogram of daily average discharge temperatures for the fall of 1975 and the spring and summer of 1976. There were a total of 18 outages with durations ranging from less than 24 hrs to all or part of 68 days (Table II-2). During two outages there was a brief resumption of generation. However, each outage was counted as a single event because the plant did not reach a high power level for a sustained period. The circulating water systems were in operation during outages, and except for 7 days during the outage in December 1975, the average flow was at least 8.7 m^3/sec (307.5 cfs) averaged over one day periods.

---

*The pH of the discharge shall not exceed 8.5 unless the pH of the intake water is greater than this value; in this case, the pH of the discharge shall not exceed the pH of the intake by more than 0.1 pH unit.

TABLE II-1

PLANT ELECTRICAL OUTPUT*

JAMES A. FITZPATRICK NUCLEAR POWER PLANT - JULY 1, 1975-SEPTEMBER 30, 1976

DATE	1975																	
	JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER		
	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
1			126			638			0	0	0	0	0	0	0	675	749	718
2			191			645			0	0	498	180	0	0	0	757	780	773
3			194			572			0	496	632	541	0	0	0	770	776	773
4			201			0			0	596	633	622	0	492	303	771	801	779
5			201			163			0	624	631	625	504	590	543	799	814	805
6			254			402			0	625	633	625	595	700	658	796	801	797
7			322			480			157	624	628	624	705	780	744	800	802	688
8			6			548			363	625	627	626	771	779	774	0	0	0
9			8			622			525	626	632	628	772	778	775	0	0	0
10			326			672			524	629	633	631	775	780	776	0	0	0
11			467			665			161	266	636	512	0	779	350	0	0	0
12			542			674			0	480	521	483	0	382	102	0	0	0
13			607			686			0	528	538	535	0	0	0	0	348	237
14			635			693			0	549	629	612	0	0	0	0	451	314
15			592			696			0	611	628	620	0	0	0	0	0	0
16			460			175			28	626	639	633	0	0	0	0	0	0
17			0			471			387	623	641	633	0	0	0	0	0	0
18			21			492			541	636	641	635	0	0	0	0	0	0
19			361			607			628	639	661	638	0	295	65	0	0	0
20			462			680			702	653	755	702	295	561	443	0	0	0
21			565			701			742	682	794	773	534	584	555	0	0	0
22			622			498			743	0	795	457	557	563	560	0	0	0
23			617			517			739	0	168	24	560	562	561	0	0	0
24			616			520			748	175	590	446	560	563	563	20	290	115
25			607			521			750	594	706	658	554	567	562	60	370	278
26			611			515			749	705	796	770	556	559	558	10	330	103
27			614			511			609	384	792	761	553	559	554	330	780	398
28			616			509			719	562	794	765	554	557	555	510	620	547
29			624			515			748	0	793	692	550	583	558	620	690	660
30			633			553			418	0	0	0	613	692	670	680	690	687
31			634			434				0	0	0				540	690	598

*Gross MWe

TABLE II-1 (Continued)

PLANT ELECTRICAL OUTPUT*

	1976																	
	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE		
DATE	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
1	548	560	550	0	0	0	0	0	0	410	590	509	530	690	665	770	780	775
2	440	570	498	0	0	0	0	0	0	520	620	582	690	750	722	770	780	771
3	480	530	514	0	0	0	0	0	0	500	630	553	730	750	743	770	780	771
4	510	520	514	0	0	0	0	0	0	200	600	361	670	750	728	0	770	351
5	510	610	560	0	0	0	0	0	0	200	570	459	730	750	741	0	0	0
6	580	600	585	0	0	0	0	0	0	590	620	604	740	760	747	30	430	295
7	570	590	580	0	0	0	0	0	0	590	610	601	740	760	751	430	500	480
8	570	590	580	0	0	0	0	0	0	590	660	614	740	760	750	490	600	516
9	579	657	618	0	0	0	0	0	0	640	700	671	730	750	747	640	750	693
10	654	726	687	0	0	0	0	0	0	680	720	706	730	750	743	740	780	764
11	730	783	755	0	0	0	0	0	0	700	730	716	730	750	739	750	780	767
12	788	805	799	0	0	0	0	0	0	710	720	715	730	740	737	770	780	776
13	797	805	801	0	0	0	0	0	0	690	720	712	0	750	315	780	780	780
14	798	803	801	0	0	0	0	0	0	690	710	700	0	0	0	770	790	778
15	799	803	800	0	0	0	0	0	0	560	710	684	30	160	13	780	800	785
16	0	803	473	0	0	0	0	0	0	640	700	671	240	420	353	770	790	782
17	0	0	0	0	0	0	0	0	0	680	700	690	420	580	513	770	790	775
18	0	0	0	0	0	0	0	0	0	680	690	688	590	680	631	0	780	139
19	0	0	0	0	0	0	0	0	0	680	700	687	680	740	719	0	460	198
20	0	0	0	0	0	0	0	0	0	680	700	697	730	750	741	460	630	554
21	0	0	0	0	0	0	0	0	0	500	710	676	730	760	746	640	760	710
22	0	0	0	0	0	0	0	0	0	490	600	558	600	770	727	760	780	773
23	0	0	0	0	0	0	0	0	0	580	690	648	680	740	704	0	783	446
24	0	0	0	0	0	0	101	180	29	700	720	707	740	790	770	0	681	505
25	0	0	0	0	0	0	90	310	184	700	720	712	780	790	781	670	760	714
26	0	0	0	0	0	0	310	360	331	710	730	718	780	790	781	770	780	774
27	0	0	0	0	0	0	350	450	408	710	730	723	770	790	782	750	760	753
28	0	0	0	0	0	0	450	510	466	720	740	733	770	790	778	740	760	751
29	0	0	0	0	0	0	510	540	430	720	740	726	770	780	776	740	760	755
30	0	0	0	0	0	0	220	580	507	520	730	692	770	780	776	0	500	215
31	0	0	0	0	0	0	280	550	501				770	780	778			

*Gross MWe

TABLE II-1 (Continued)

PLANT ELECTRICAL OUTPUT*

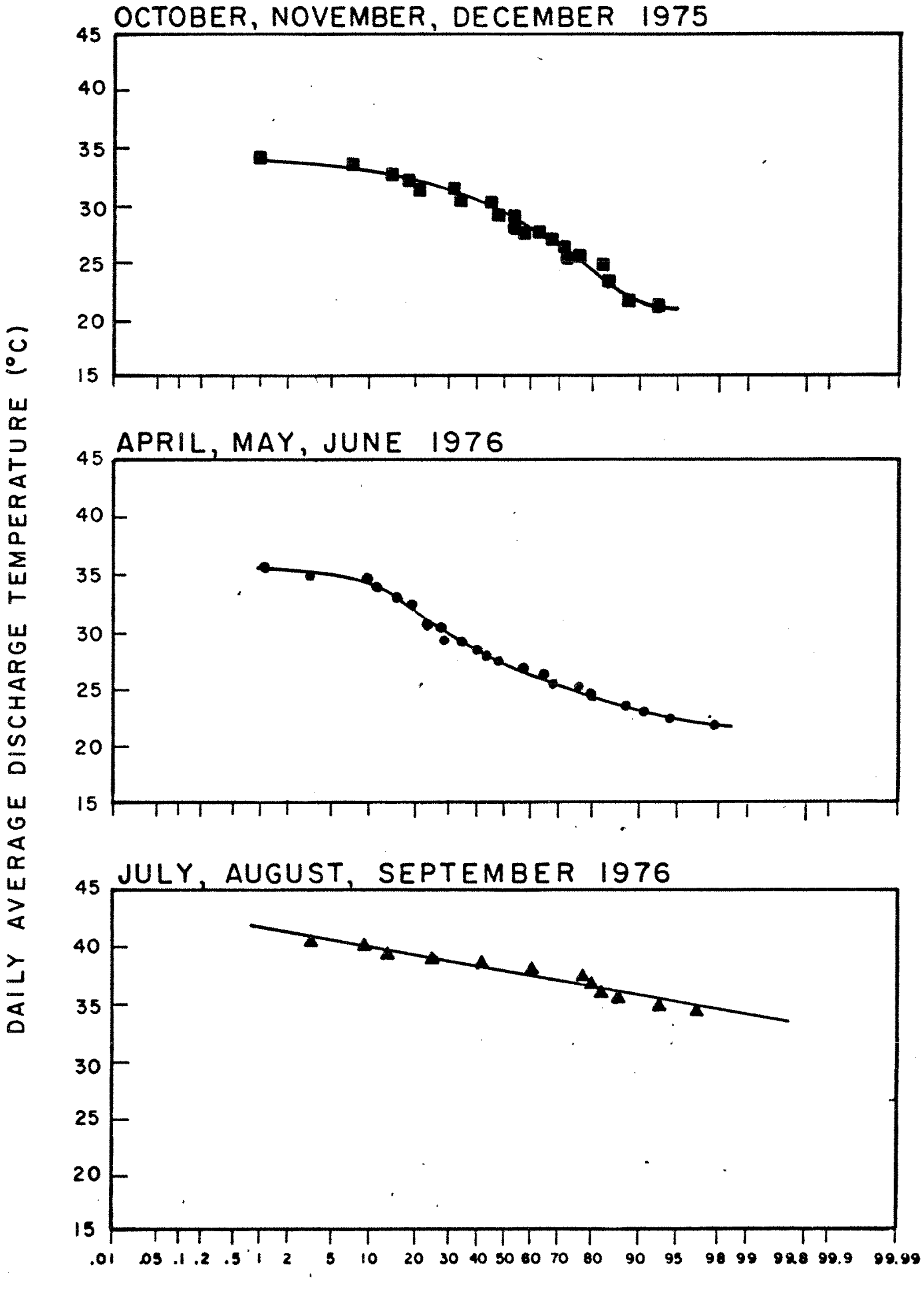
	1976								
	JULY			AUGUST			SEPTEMBER		
DATE	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
1	150	580	248	740	760	750	470	680	603
2	580	690	633	740	760	751	680	760	723
3	700	770	743	740	760	748	760	780	772
4	750	770	762	740	750	747	780	790	780
5	760	770	767	740	750	747	770	790	779
6	760	780	771	560	750	725	770	790	782
7	760	780	773	560	680	632	780	790	786
8	740	780	769	670	750	718	780	790	785
9	770	600	750	750	780	769	770	790	782
10	690	770	751	760	780	771	590	790	723
11	760	780	765	760	780	771	710	740	735
12	750	780	765	770	790	783	720	740	735
13	0	780	715	620	800	777	730	740	735
14	0	0	0	760	790	785	730	740	731
15	0	0	0	780	790	788	720	740	733
16	0	0	0	780	790	788	720	740	731
17	0	330	113	780	790	788	620	740	724
18	350	600	503	780	800	792	720	740	733
19	596	672	637	780	800	791	720	740	729
20	678	759	721	690	800	785	730	740	730
21	0	780	462	770	800	788	730	740	732
22	0	0	0	780	800	786	730	740	730
23	0	0	0	780	800	786	730	740	735
24	0	0	0	780	800	792	650	740	730
25	0	0	0	780	800	789	720	740	733
26	0	0	0	780	790	786	720	740	733
27	0	0	0	600	790	763	730	740	733
28	0	400	73	600	730	622	730	740	733
29	420	620	543	730	790	775	730	740	730
30	610	660	635	0	790	650	730	740	730
31				670	730	695	0	430	157

*Gross MWe

FIGURE II-7

FREQUENCY HISTOGRAM OF DAILY AVERAGE DISCHARGE TEMPERATURES UNDER CONSTANT FULL FLOW OPERATION*

JAMES A. FITZPATRICK NUCLEAR POWER PLANT —1975-1976


OCTOBER, NOVEMBER, DECEMBER 1975

APRIL, MAY, JUNE 1976

JULY, AUGUST, SEPTEMBER 1976

* Discharge Temperatures Calculated by Addition of 17.8°C to 1975-76

TABLE II-2

OUTAGES BETWEEN JULY 1, 1975 AND SEPTEMBER 30, 1976

JAMES A. FITZPATRICK NUCLEAR POWER PLANT

NUMBER	START DATE	END DATE	DURATION IN DAYS*
1	17 JUL	17 JUL	< 1
2	4 AUG	4 AUG	< 1
3	1 SEP	6 SEP	6
4	12	15	4
5	1 OCT	2 OCT	< 2
6	22	23	< 2
7	29	4 NOV	< 7
8	11 NOV	19	< 9
9	8 DEC	23 DEC	16
10	16 JAN	23 MAR	<68
11	13 MAY	14 MAY	< 2
12	4 JUN	5 JUN	< 2
13	18	19	< 2
14	23	24	< 2
15	30	30	< 1
16	13 JUL	17 JUL	< 5
17	21	28	< 8
18	30 AUG	31 AUG	< 2

*Dates are inclusive in the outage. An outage could span two consecutive dates but have a total duration ranging from less than three hours to more than 45 hours. Incident number 8, for example, could be a little more than 7 days but could not exceed 9 days.

III. BASELINE HYDROGRAPHIC CHARACTERISTICS

A. INTRODUCTION

The discharge of JAF is designed to minimize the impact of the plant's thermal discharge on the biological and thermal characteristics of Lake Ontario in the vicinity of Nine Mile Point. Lake Ontario temperature characteristics, general circulation and local current patterns, lake bed topography, and existing water uses were the important design criteria used in the development of the circulating water system. The selection of a water body segment for multiplant impact analysis was based on hydrographic characteristics of the southeast section of Lake Ontario. The baseline hydrographic characteristics of Lake Ontario relevant to the assessment of the thermal discharge from the FitzPatrick Plant are discussed in the following sections.

B. GENERAL FEATURES OF LAKE ONTARIO

1. Seasonal Temperature Structure

a. Spring Warming and the Thermal Bar

Lake Ontario is a large temperate lake which experiences seasonal changes in its thermal structure. Natural warming of the lake begins in mid-March and continues until mid-September. At the onset of warming the surface water temperature in the shallow littoral zone rises more rapidly than in regions just offshore. By May this difference has created a sharp horizontal temperature gradient with inshore water temperatures above 4°C (39°F) and the offshore water below 4°C (39°F). There is a convergence zone where water from the relatively warm inshore region mixes with the cold offshore water (Rodgers, 1966). As a consequence of the nonlinear temperature/density relationship of fresh water, the mixed water produced in this transition zone is heavier than the water on either side and sinks, setting up a bar that may reduce free exchange of water between the shallow littoral zone and the deeper part of the lake. The thermal bar moves gradually and steadily offshore with spring warming of the lake until it dissipates in late June. It is estimated that the spring thermal bar may exist for as long as 8 weeks (Sweers, 1969).

As the thermal bar moves offshore, the inshore water continues to warm and a thermocline develops which separates the warm surface water from the cold deep water. The thermocline restricts vertical mixing to the epilimnion, but in mid-lake on the offshore side of the thermal bar mixing extends from surface to bottom. About four weeks after emergence of the bar the inshore area constitutes approximately half the area of the lake (Sweers, 1969).

b. Summer Stratification

The disappearance of an offshore surface temperature of 4°C (39.2°F) in late June defines the start of the summer season in the lake. In general, vertical stratification is established over the entire basin by the combined effects of lake warming and the advection of the warmer, nearshore water. The sporadic appearance of surface temperature minima during summer are related to upwellings. As warming continues, stratification intensifies and the thermocline is more sharply defined, with vertical temperature gradients in excess of 1°C/m (0.6°F/ft). As a consequence of stratification, heat transfer and mixing are confined largely to the epilimnion. The lake's mean surface temperature reaches 21°C (69.8°F), and the hypolimnion temperature varies with depth, ranging between 3.8 and 4.0°C (38.0° and 39.2°F) (Sweers, 1969). The thermocline forms near the surface in early summer but descends due to continued warming and reaches a characteristic depth of approximately 21 m (70 ft) (Casey et al., 1965).

c. Fall Cooling

In late September the warming process ends, the lake's mean surface temperature rapidly drops below 17°C (62.6°F) and the rate of descent of the thermocline increases. The vertical temperature gradient decreases as the surface layer and deeper water effectively mix. Mixing is the consequence of convection caused by cooling at the surface and is enhanced by the weakening of the thermocline which permits wind-induced turbulence to extend to greater depths.

The fall cooling process resembles spring warming. When nearshore water cools below the temperature of maximum density, a "reverse" thermal bar develops separating colder inshore water from warmer offshore water. The fall thermal bar has a weaker thermal gradient than the spring thermal bar.

d. Winter Cooling

The breakdown of stratification throughout the lake marks the onset of the winter season. The offshore water mass is well mixed, attaining a nearly isothermal condition. The date of overturn differs from year to year depending on the occurrence of storms. The lake surface is cooled below 4°C(39°F) and surface isotherms tend to be parallel to shore. As cooling continues and surface temperatures drop below 4°C (39°F), vertical stratification is again produced with colder buoyant water above the warmer 4°C (39°F) water at depth. Vertical circulation at times extends as deep as 100 m (328 ft) (Sweers, 1969). With continued cooling ice forms in the nearshore region. Under normal climatic conditions the greatest extent of ice cover is found in the east end of the lake in mid-March, while in a severe winter ice covers about 25% of the lake surface (U.S. Army Corps of Engineers, 1975).

2. Lake Circulation

The large scale circulation of Lake Ontario is counter-clockwise (cyclonic flow) with flow to the east along the south shore in a relatively narrow band and a somewhat less pronounced flow to the west along the north shore. The conceptual model that explains this general circulation is presented here as follows.

A cool mound of water extends from surface to bottom in spring and from below the thermocline to the bottom in summer and fall (Sweers, 1969). The baroclinic flow resulting from the horizontal temperature differences is initially directed outward from mid-lake towards the shore. Although the Coriolis effect is acting to turn the flow to the right (clockwise), its effect is diminished due to bottom friction. This outward flow brings water to the inshore area where it begins to pile up. A surface slope, higher inshore than in mid-lake, develops into a barotropic current initially directed lakeward. The barotropic current tends to the right because of the Coriolis effect. The result is that Coriolis effect and the barrier effect of the coastline trap the flow against the shoreline. The flow continues along the shoreline in a counter-clockwise direction as long as the surface slope is maintained.

Inflow from the Niagara River causes the western end of the lake surface to be higher than the eastern end (on the average). The resulting flow down the gradient is held against the lake's south shore by the Coriolis effect, thereby enhancing the already existing barotropic flow along the south shore. Wind stress averaged over the year tends further to accelerate the flow to the east and decelerate the flow to the west.

The general circulation in winter is less well documented. In late fall after overturn has occurred, the lake is essentially isothermal, thereby permitting a free exchange of water from surface to bottom. Wind direction in winter is primarily from the west-northwest. The net surface flow that results is eastward with westward return flow developing below the surface. The surface layer in the western end is advected to the east and is replaced by subsurface water (Sweers, 1969). This large scale upwelling at the upwind end of the lake and downwelling at the downwind end mixes the surface and subsurface water on a scale that is not likely to occur during the rest of the year.

3. Perturbations of the General Circulation Pattern

The general circulation described above is documented by observations collected over long periods (months). The circulation patterns that are observed at any given time, however, are more complex as a result of the lake's response to the shifting winds. At times a major wind shift can alter the currents in a matter of hours, while at other times some features of the current pattern have continued even with an opposing wind (Csanady, 1972). The response time of the currents to a shift in wind distribution is partially related to the scale of the current; large offshore longshore currents respond sluggishly and with longshore currents nearer to shore the response is more rapid, six hours or less. In addition, the deeper the current, the more slowly it responds.

Two important examples of wind-induced changes in the general circulation are upwelling and internal oscillations. Upwelling occurs when a water mass is forced from depth to the surface, and is observed to some degree in all lakes during all seasons (Mortimer, 1971); however it is more conspicuous during seasons of stratification when the upwelled water is much colder than the surface water that it displaces. Wind stress and associated currents depress the thermocline to below equilibrium level at the downwind end of the basin, while at the upwind end the thermocline is displaced upward and may intersect the surface. Upwelling motions are strongly influenced by the Coriolis force. Depression of the thermocline is greatest to the right of the downwind end of a basin and upwelling is strongest to the left of the upwind end (Mortimer, 1971). For example, in Lake Ontario, a west wind causes upwelling along the northwest shore, and the thermocline is deepest along the southeast shore.

A variety of mechanisms have been proposed to account for the observed periodic displacement of the thermocline. The most direct explanation is that an upwelling event displaces the thermocline from equilibrium by converting kinetic energy of the wind to potential energy of the thermocline position. When the wind stress is removed, internal waves are set in motion and contribute to the dissipation of this energy. Internal waves incease in amplitude after storms, and in Lake Ontario the oscillations have a period near 17.5 hours, roughly three complete oscillations every two days. These oscillation events are a common feature of lake temperature records and are prominent in the intake temperature records at many power plants.

C. SITE FEATURES

1. Bottom Sediments

A number of observations of the bottom sediments have been made along the south shore of Lake Ontario. Sutton et al. (1970) made observations of nearshore bottom sediments (0-33 m, 0-108.3 ft) in 1968 and 1969 between Rochester and Stony Point. Among their conclusions the following are relevant to the FitzPatrick site:

a. There is generally a west-to-east transport of sediment.

b. Sites of sediment accumulation occur in nearshore shallow areas where the shoreline is irregular and where there are local deviations from the above transport pattern.

c. In general, the coarser sands, boulders, pebbles, and cobbles lie in the beach or nearshore area, and finer sediments are found lakeward.

d. Several small patches of sand occur offshore between Oswego and Mexico Bay, and it is hypothesized that these originate from the Oswego River.

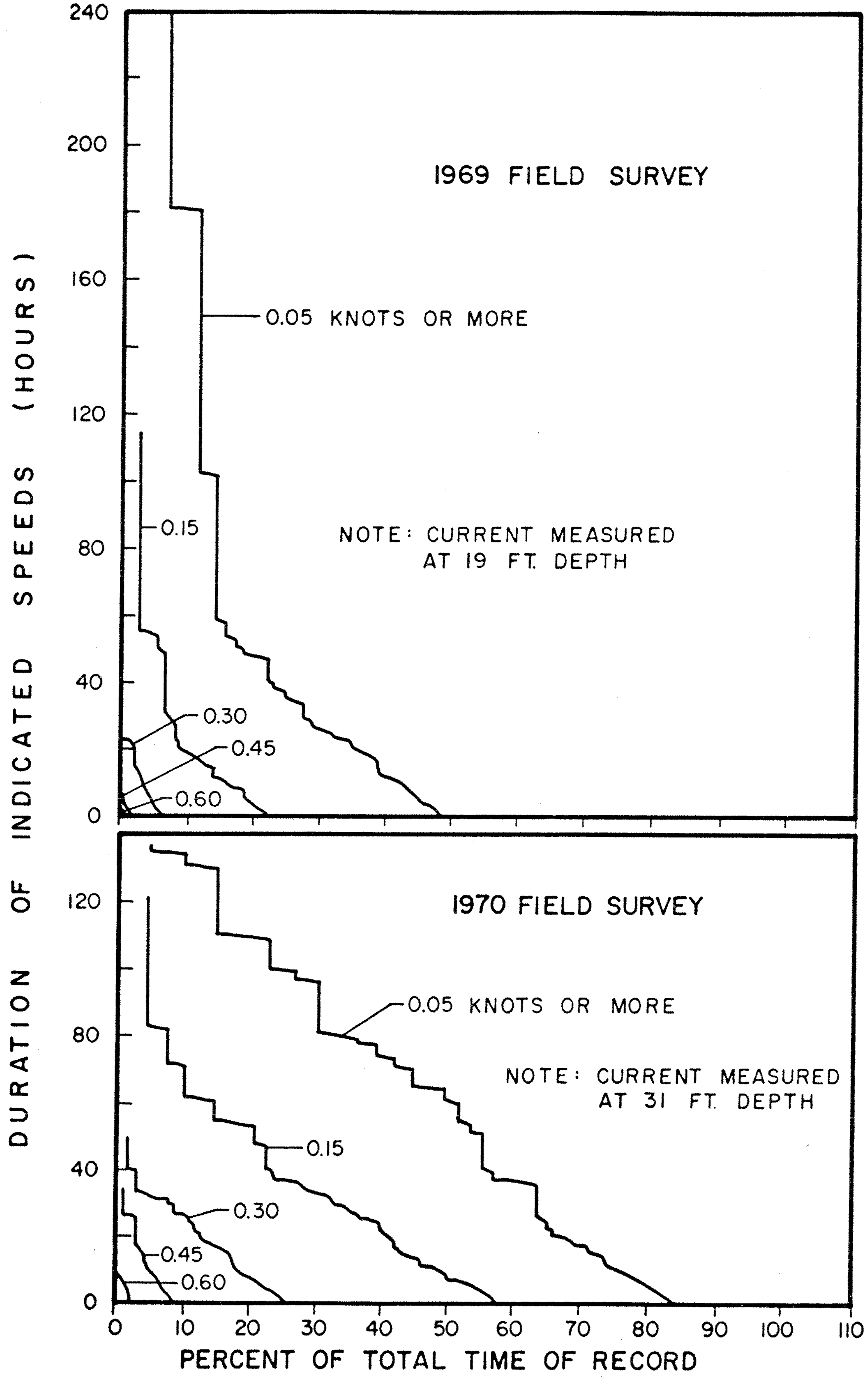
Visual observations made in the Nine Mile Point vicinity during the 1974 sampling period corroborate some of the earlier observations of Sutton et al. (1970). The two western transects, NMPW and NMPP, are dominated by more bedrock and rubble than sand and silt, whereas the FITZ and NMPE transects have bedrock and rubble near shore with sand and silt prevalent beyond the 6.1 m (20 ft) depth contour. The presence of a finer grained sediment to the east probably corresponds to the dominance of patchy sand deposits in Mexico Bay. The irregularity of the shoreline at Nine Mile Point could possibly be the cause of minor sand and silt deposition at that point and eastward. In general, finer grained sediments are more dominant farther offshore.

2. Local Currents

In the course of preoperational studies for JAF, current measurements were made off the Nine Mile Point promontory from May to October 1969, and from July to October 1970. Two fixed underwater towers were placed in the lake, one in 7.3 m (24 ft) of water, and one in 14.0 m (46 ft) of water, and provided average hourly current speed and direction. In addition, two drogue surveys were conducted in 1969 to obtain the overall current pattern at the site. These studies were reported by Gunwaldson et al. (1970) and the Power Authority of the State of New York (PASNY) (1971). Figure III-1 presents frequency-duration data derived from these studies. The data obtained are consistent with wind-induced current frequencies reported by Palmer and Izatt (1970) for a similar water depth near Toronto.

The field data clearly illustrate a correlation between summer currents

DURATION OF LAKE ONTARIO CURRENT



and wind speed. The correlation is an accepted principle of hydrodynamics as theorized by Ekman (1928) and subsequently verified by numerous oceanographers (Neumann and Pierson, 1966). Measurements of wind currents at lightships (Haight, 1942) have been analyzed to determine the ratio of current speed to wind speed. Reported values of this ratio, commonly called the "wind factor," range between .005 and .030.

The wind speed frequency data indicate that over the year a speed in excess of 32 km/hr (20 mph) occurs 21.6% of the time, based on readings averaged over a 6-hour period. For the summer months, June through September, winds in excess of 32 km/hr (20 mph) occur 13.9% of the time. The current speed of 6 hour duration exceeded with comparable frequency in 14 m (46 ft) of water is about 15 cm/sec (0.5 fps) (see Figure III-2). For a persistence of 24 hours, the current speed exceeded 13.9% of the time is 13.7 cm/sec (0.45 fps).

The predominant direction of currents in the studies described above is alongshore, as dictated by continuity. On those occasions when onshore or offshore currents were observed, their magnitudes were substantially less than those for alongshore currents. The reported frequencies of various current directions during the summer are presented in Figure III-2. This figure indicates that currents alongshore from the west or east are equally frequent at 35% of the time for each. Onshore and offshore currents each account for 5% of the observations. The remaining 30% of the observations were below the meter threshold, 0.05 knots (2.5 cm/sec, 0.09 fps). At the 6.4 m (21 ft) depth in 14.0 m (46 ft) of water, the mean onshore current speed was 3.0 cm/sec (0.09 fps) and the mean offshore current speed was 6.0 cm/sec (0.2 fps). On the other hand, alongshore currents from the west and east averaged 9 cm/sec (0.3 fps).

Vertical profiles of currents have been recorded in several lake studies. Current profiles with depth, however, are sensitive to the turbulent momentum exchange coefficient and ambient stratification. A theoretical profile was computed for the homogeneous shallow waters found near the Nine Mile Point site and indicates the absence of any significant Ekman spiral.

Lake currents were measured at selected locations in the immediate vicinity of the Oswego Steam Station on five days between 12 October and 19 November 1970. These surface current velocities were mostly alongshore with speeds that ranged from very low (less than 2.5 cm/sec, 0.08 fps) up to 15 cm/sec (0.50 fps). This is in general agreement with the measurements at Nine Mile Point.

3. Local Lake Thermal Structure

Data on the thermal structure of the lake in the vicinity of Nine Mile

LAKE ONTARIO CURRENT DIRECTIONS

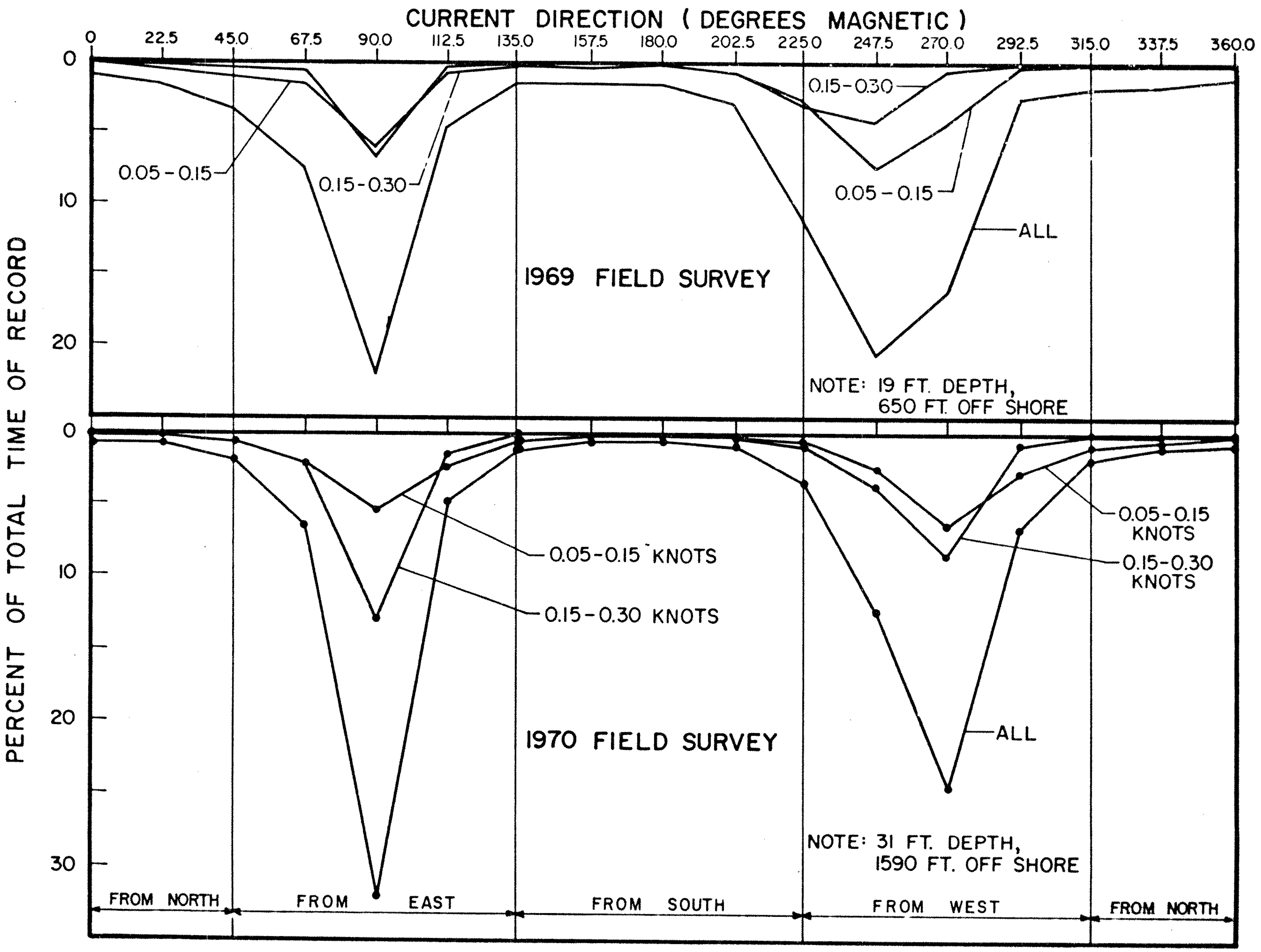


FIGURE III-2

Point are available from studies conducted offshore of JAF 1969 and 1970, from temperature data recorded in the existing intake for Oswego Units 1-4 (see Figure III-5 for location) from 1968 through 1972, and from studies conducted offshore of the Oswego-Nine Mile Point area during 1973. A short description of each of these studies is presented in subsequent paragraphs. These data were used to determine the vertical temperature variations and the surface temperatures in the vicinity of JAF.

In conjunction with the lake current studies carried out in 1969 and 1970 as part of the preoperational surveys for JAF (PASNY, 1971), water temperatures were also recorded. Three types of temperature measurements were made:

a. intermittent vertical profiles obtained in 18.3 and 30.5 m (60 and 100 ft) of water,

b. continuous temperature recordings, using seven self-contained underwater instruments mounted on the two underwater towers, obtained at various depths,

c. surface temperatures measured by airborne infrared radiometry.

The 1970 studies offshore of Oswego consisted of the collection of weekly temperature data at four locations near the discharge of Oswego Unit 6. Temperatures were measured at 1-meter increments from surface to lake bottom for seventeen consecutive weeks from July through November 1970 (QLM, 1972).

Temperature data in the Oswego-Nine Mile Point area were obtained during 1973 from west of Oswego to east of Nine Mile Point. Vertical temperature profiles were obtained weekly from June through mid-December 1973 along five transects (QLM, 1974).

Data from these studies were used to evaluate the vertical temperature structure and to determine whether or not persistent stratification exists in this area. Vertical temperature profiles revealed the existence of transient thermal gradients equal to or greater than 1°C per meter (1.6°F per 3.2 ft) throughout the study area. The gradients appeared to be seasonal since they existed primarily in the summertime. They were not "seasonally stable," since they were generated and destroyed by surface heating and cooling and mixing within the water column over periods dependent upon meteorological conditions. Although gradients were observed on sequential weeks for up to a three week period, the gradients observed were at different temperatures and at different depths from week to week and, therefore, were not persistent. In addition, when the gradients were observed, they appeared to be uniform from station to station. A more complete discussion is presented in the documents previously submitted to the EPA (LMS, 1976).

These data were also used to determine the surface temperature in the area. During 1970 the maximum surface temperature recorded was 25.5°C (77.9°C). The temperature data recorded in the existing intake of the Oswego Steam Station were statistically analyzed and are shown in Figure III-3. Since the lake is generally isothermal in the top 6 m (20 ft), the temperature obtained at the intake depth of 4.9 m (16 ft) can be considered to be representative of the surface water teperatures. The analysis shows that temperatures in excess of 23.3°C (74°F) occurred only 10% of the time during the summer months and less than 1% of the time on an annual basis.

Figure III-4 shows the average surface temperature throughout the 1973 survey period for the stations in water depths of 6 and 30.5 m (20 and 100 ft.). As shown in this figure, temperatures at both stations were approximately 12°C (54°F) on 4 June, rose to a maximum temperature of approximately 24°C (75.2°F) on 13 August, and then declined to approximately 6°C (43°F) on December. A drop in the average surface temperatures of between 3 and 5°C (5.4 and 9°F) seems to have occurred during the week between 11 and 18 June. This drop in temperature can be attributed to "upwelling" generated by wind from the south.

D. EXISTING THERMAL DISCHARGES IN THE FITZPATRICK VICINITY

1. Oswego Steam Station Units 1-4, 5 and 6

The Oswego Steam Station's Units 1-4, which were constructed during the period 1938 to 1959, have a maximum generating capacity of 407 megawatts. The combined cooling water flow for these units is 21.58 m^3/sec (762 cfs) when they are operating at maximum capacity. The common intake of the circulating water systems is located 76.2 m (250 ft) north of the northwestern tip of the Oswego Harbor breakwater (see Figure III-5 for location of intake and discharge structures at Oswego). The cooling water flow for Units 1-4 is discharged to the "western leg" or turning basin of Oswego Harbor at a maximum temperature of 6.8°C (12.4°F) above intake temperature.

The circulating water systems for Oswego Units 5 and 6 are independent of the Units 1-4 systems, each having submerged intake and discharge structures in the lake offshore of the station (See Figure III-5 for location of intake and discharge structures at Oswego). Oswego Unit 5 began operation in 1975 and has a maximum net output of 850 MWe. Its maximum cooling water flow of 17.98 m^3/sec (635 cfs) is taken from the lake approximately 414.5 m (1360 ft) offshore of the site. The flow

FIGURE III-3

FREQUENCY DISTRIBUTION FOR LAKE ONTARIO WATER TEMPERATURE MEASURED AT OSWEGO FOR SUMMER (JUNE, JULY, AUG., SEPT.) 1968 – 1972

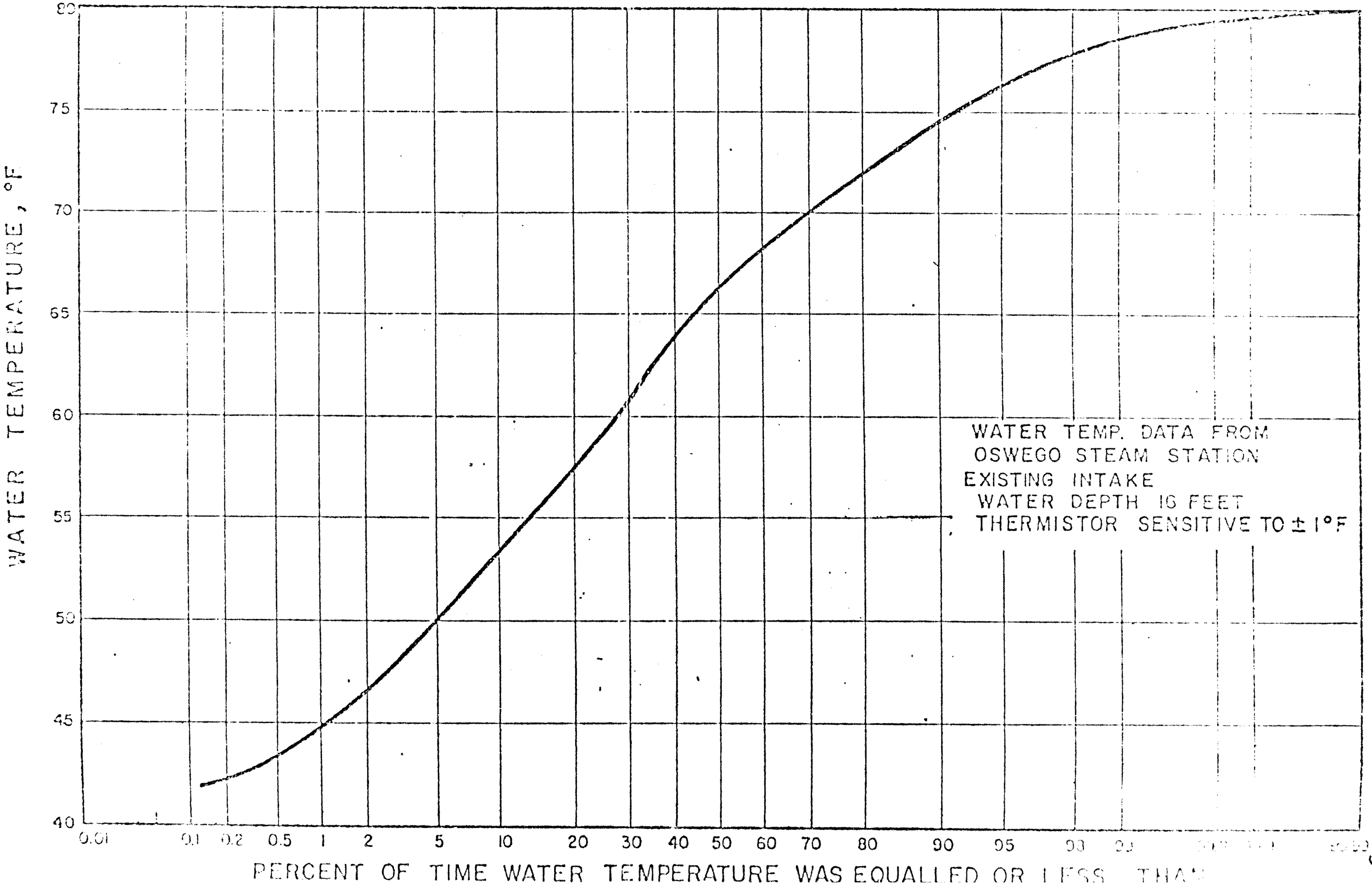


FIGURE III-4

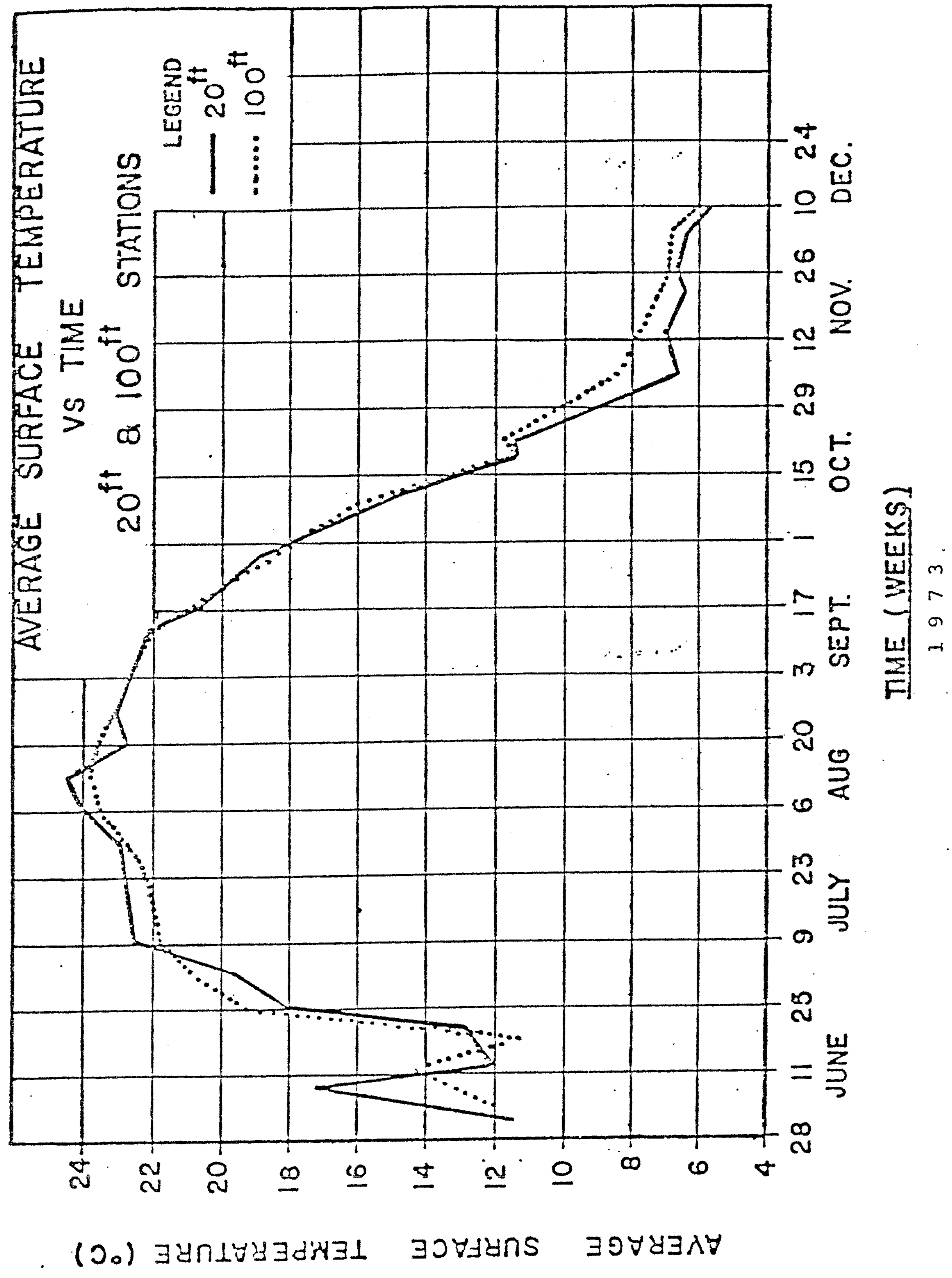
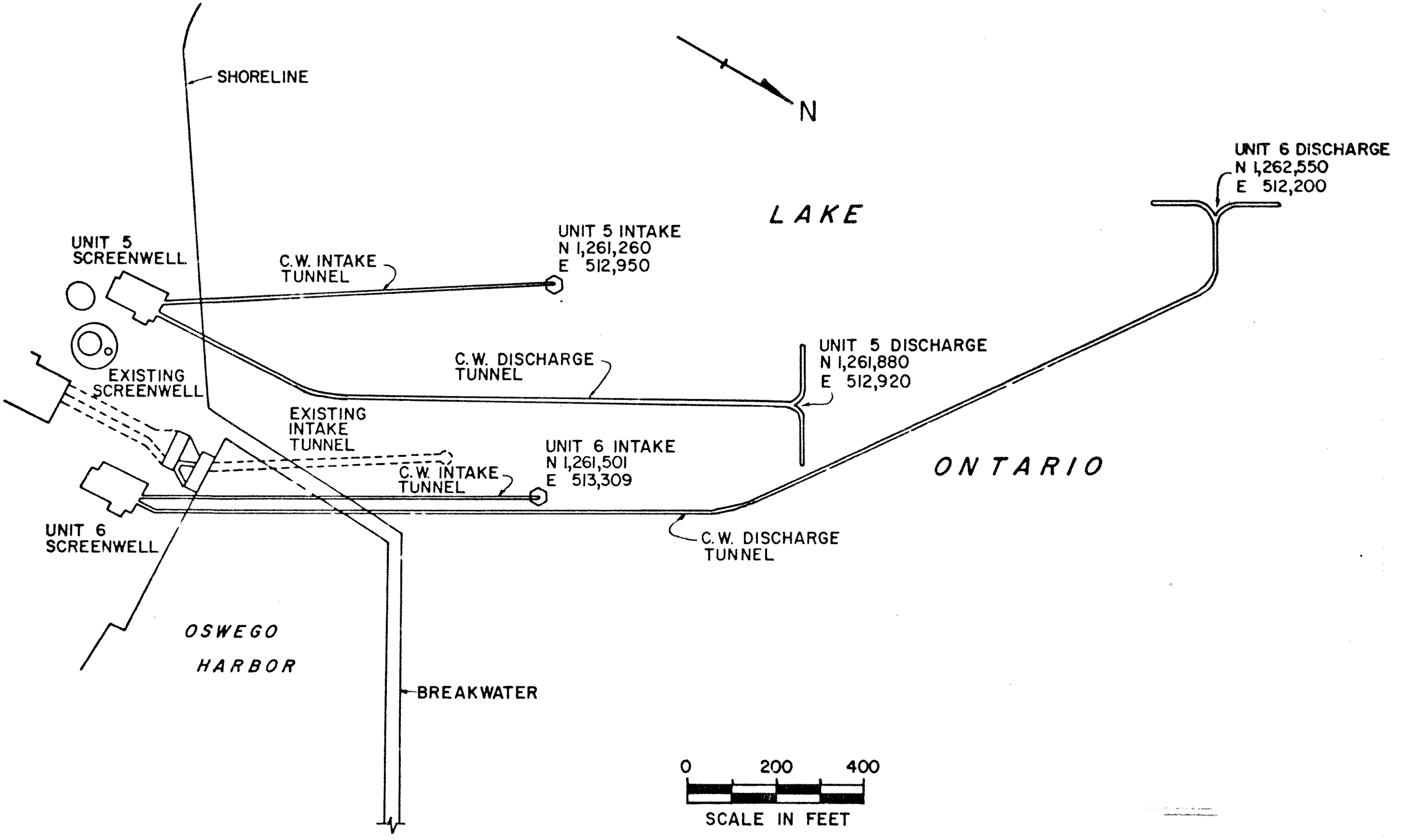

AVERAGE SURFACE TEMPERATURE
VS TIME
20ft & 100ft STATIONS
LEGEND
20ft
100ft
24
22
20
18
16
14
12
10
8
6
4
AVERAGE SURFACE TEMPERATURE (°C)
28
11
25
9
23
6
20
3
17
1
15
29
12
26
10
24
JUNE
JULY
AUG
SEPT.
OCT.
NOV.
DEC.
TIME (WEEKS)
1973

FIGURE III-5

LOCATION OF INTAKE AND DISCHARGE STRUCTURES
OSWEGO STEAM STATION-UNIT 6



is returned to the lake at a temperature increase up to 15.9°C (28.6°F) above intake temperature through a high-speed, submerged difuser designed to achieve rapid dilution.

Oswego Unit 6, presently under construction, will have a maximum net output of 850 MWe, a maximum cooling water flow of 17.98 m^3/sec (635 cfs) and a maximum temperature increase over intake temperature of 15.9°C (28.6°F). Table III-1 indicates the hydraulic and thermal characteristics of generating units in the vicinity of the FitzPatrick plant.

The plant flows and temperature rises presented for the units at Oswego are maximum conditions for full generating capacity, however, these units will operate at less than full capacity much of the time. Therefore, an assessment of impact should be based on an estimate of actual plant loads. Seasonal plant operating loads have been estimated for Oswego Units 5 and 6 and are presented in Table III-2. A similar estimate is not available for Oswego Units 1-4, but because these are relatively old units, it is anticipated that they will operate at substantially less than maximum rated capacity.

2. Nine Mile Point Nuclear Station Unit 1

Nine Mile Point Nuclear Station Unit 1 (NMP-1) has been in operation since 1969 and has a maximum net capacity of 610 MWe. The maximum cooling water flow of 16.94 m^3/sec (597 cfs) for this unit is taken from the lake approximately 259.1 m (850 ft) offshore of the site. This flow is returned to the lake at temperatures up to 17.3°C (31.2°F) higher than intake temperature through a submerged discharge in the lake. The discharge is located approximately 11.3 km (7 mi) east of the Oswego Steam Station and approximately 914.4 m (3000 ft) west of JAF discharge. Monthly capacity factors for Nine Mile Unit 1 are presented in Table III-3.

3. Oswego River

The Oswego River discharges an annual average flow of 174.2 m^3/sec (6137 cfs) (based on the 33-year period, 1933-1967) into Oswego Harbor from the south, where the river flow mixes with the Oswego Units 1-4 discharge and waste treatment plant discharges, and enters Lake Ontario at the harbor mouth.

The maximum flow on record was 1064.2 m^3/sec (37,500 cfs), which occurred on 28 March 1936. The minimum daily flow of 10.02 m^3/sec (353 cfs) was recorded on 14 August 1949, but the minimum average seven-consecutive-day flow, having a once-in-ten-year frequency (MA7CD/10) is 20.43 m^3 (720 cfs).

TABLE III-1

DISCHARGE CHARACTERISTICS FOR OSWEGO UNITS 1-6 NINE MILE UNIT 1, AND FITZPATRICK UNIT

	OSWEGO UNITS 1-4	OSWEGO UNIT 5	OSWEGO UNIT 6	NINE MILE UNIT 1	FITZPATRICK UNIT
Length of main tunnel from existing shoreline	-	414.5 m 1360 ft	688.8 m 2260 ft	160.9 m 528 ft	384 m 1260 ft
Tunnel velocity	-	-	-	8 fps 2.44 m/sec	4.7 fps 1.43 m/sec
Length of diffuser	-	79.3 m 260 ft	81.4 m 267 ft	-	235.9 m 774 ft
Number of duffuser ports	-	12	12	-	12
Number of diffuser ports/riser		2	2	-	2
Inside diameter of diffuser ports	-	0.61 m 2 ft	0.61 m 2.0 ft	-	0.76 m 2.5 ft
Port spacing	-	12.2 m 40 ft	12.2 m 40 ft	-	45.7 m 150 ft
Initial discharge velocity	-	5.12 m/sec 16.8 fps	16.8 fps 5.12 m/sec	1.22 m/sec 4 fps	4.27 m/sec 14 fps
Angle between ports	-	20°	20°	-	42°
Total diffuser flow	21.58 m^3/sec 762 cfs	17.98 m^3/sec 635 cfs	17.98 m^3/sec 635 cfs	16.94 m^3/sec 597 cfs	23.36 m^3/se 825 cfs
Average depth of port centerline below mean low water	-	6.4 m 21 ft	10.4 m 34 ft	4.9 m 16 ft	7.62 m 25 ft
Average depth of lake bottom below mean low water at discharge	-	7.92 m 26 ft	11.9 m 39 ft	5.5 m 18 ft	9.14 m 30 ft
Maximum Port temperature rise above lake ambient	6.9°C 12.4°F	15.9°C 28.6°F	15.9°C 28.6°F	17.3°C 31.2°F	17.5°C 31.5°F

- Does not apply

TABLE III-2

ANTICIPATED MAXIMUM SEASONAL LOADS

OSWEGO STEAM STATION UNITS 5 AND 6 - 1981*

UNIT 5

SEASON	PERCENTAGE MAX. LOAD	UNIT OUTPUT (MWe)	HEAT DISCHARGE (BBtu/hr)	CONDENSER ΔT (°F)	DISCHARGE ΔT (°F)
SUMMER	53.4	453.9	2.244	18.3	16.4
FALL	70.2	596.7	2.765	22.5	20.0
WINTER	48.7	414.9	2.052	17.4	15.7
SPRING	30.0	255.0	1.443	11.8	10.8

UNIT 6

SEASON	PERCENTAGE MAX. LOAD	UNIT OUTPUT (MWe)	HEAT DISCHARGE (BBtu/hr)	CONDENSER ΔT (°F)	DISCHARGE ΔT (°F)
SUMMER	53.4	453.9	2.244	18.3	16.4
FALL	70.2	596.7	2.765	22.5	20.0
WINTER	48.7	414.9	2.052	17.4	15.7
SPRING	30.0	255.0	1.443	11.8	10.8

*Anticipated year of maximum usage.

TABLE III-3

RECORD OF MONTHLY CAPACITY FACTORS*

NINE MILE POINT NUCLEAR STATION UNIT 1

MONTH	1970	1971	1972	1973	1974	1975	MEAN
JAN	-	79.3	77.9	94.8	94.9	70.3	83.4
FEB	-	98.4	89.0	60.8	93.9	56.8	79.8
MAR	-	100.0	82.6	94.6	77.2	79.2	86.7
APR	-	6.4	0.8	30.8	0.0	83.7	24.3
MAY	-	1.9	0.0	0.0	0.0	88.5	18.1
JUN	-	51.3	22.5	27.9	0.0	86.9	37.7
JUL	45.8	75.7	75.2	81.9	69.8	-	69.7
AUG	86.1	88.0	80.1	83.6	91.1	-	85.8
SEP	87.0	52.6	54.6	84.4	94.1	-	74.5
OCT	64.8	12.7	68.9	66.6	78.8	-	58.4
NOV	89.4	93.3	77.2	68.0	90.4	-	83.7
DEC	44.8	94.6	95.2	89.0	47.1	-	74.1
MEAN		62.8	60.3	65.2	61.4		64.7

*Based on 500 MWe prior to July 1971 and 610 MWe after July 1971.

Previous investigations have shown that temperatures in the Oswego River are normally higher than those at the surface of the lake. The 1970 survey data indicate that the river warms more rapidly than the lake and is warmer throughout the summer months. The National Field Investigations Center (Anonymous, 1975) report of a thermal survey conducted by infrared radiometry demonstrates a plume in the lake that results from the river discharge.

REFERENCES CITED

CHAPTER III

Anonymous. 1975. Remote sensing report, Lake Ontario: A study of thermal discharges from Ginna Nuclear Power Station, Oswego Steam Power Station, and Nine Mile Point Nuclear Power Station. National Field Investigation Center, U.S. Environmental Protection Agency. 88p.

Casey, D.J., W. Fisher, and C.O. Klevano. 1965. Lake Ontario environmental summary - 1965. U.S. Environ. Protection Agency, Region II (Rochester, New York) EPA-902/9-73-002.

Csanady, G.T. 1972. The coastal boundary layer in Lake Ontario. II. The summer-fall regime. J. Physical. Oceanogr. 2:168-176.

Ekman, V.W. 1928. Eddy viscocity and skin friction in the dynamics of winds and ocean currents. Mem. Roy. Met. Soc. 2(20).

Gunwaldsen, R.W., B. Brodfeld, and G.E. Hecker. 1970. Current and temperature surveys in Lake Ontario for James A. FitzPatrick Nuclear Power Plant. Proc. 13th Conf. Great Lakes Res. 1970: 914-926.

Haight, F.J. 1942. Coastal currents along the Atlantic Coast of United States. Dept. of Commerce, Coast and Geodetic Survey, Special Publ. 230.

Lawler, Matusky and Skelly, Engineers. 1976. 1975 Nine Mile Point Aquatic Ecology Studies. Report to Niagara Mohawk Power Corporation, May 1976.

Mortimer, C.H. 1971. Large scale oscillatory motions and seasonal temperature changes in Lake Michigan and Lake Ontario. I. Center for Great Lakes Res., Univ. of Wisconsin-Milwaukee Spec. Rept. 12: 111p.

Neumann, G., and W.J. Pierson. 1966. Principals of physical oceanography. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Palmer, M.D., and J.B. Izatt. 1970. Lakeshore two-dimensional dispersion. Proc. 13th Conf. Great Lakes Res. 1970(1):495-507.

Power Authority of the State of New York. 1971. Environmental report for James A. FitzPatrick Nuclear Power Plant. Prepared for United States Atomic Energy Commission.

REFERENCES CITED (Continued)

Quirk, Lawler and Matusky Engineers. 1972. Effect of circulating water system on Lake Ontario: water temperature and aquatic biology. [Oswego Steam Station Unit 6]. Prepared for Niagara Mohawk Power Corp.

Quirk, Lawler and Matusky Engineers. 1974. 1973 Nine Mile Point aquatic ecology studies. Prepared for Niagara Mohawk Power Corp. and Power Authority of the State of New York.

Rodgers, G.K. 1966. The thermal bar in Lake Ontario, spring 1965 and winter 1965-66. Great Lakes Res. Div. Publ. [Proc. 9th Conf. Great Lakes Res. (1965)] 15:369-374.

Sutton R.G., T.L. Lewis, and D.L. Woodrow. 1970. Near shore sediments in Southern Lake Ontario, their dispersal patterns and economic potential. Proc. 13th Conf. Great Lakes Res:308-318.

Sweers, H.E. 1969. Structure, dynamics and chemistry of Lake Ontario: investigations based on monitor cruises in 1966 and 1967. Mar. Sci. Branch, Dept. of Energy, Mines and Resources, Ottawa, Canada. Manuscript Rept. Ser. 10: 227p.

U.S. Army Corps of Engineers. 1975. Great Lakes-St. Lawrence Seaway navigation season extension program: demonstration program, fiscal year 1976 [draft]. U.S. Army District, Detroit.

IV. JAMES A. FITZPATRICK THERMAL DISCHARGE CHARACTERISTICS

A. INTRODUCTION

This chapter describes the characteristics of the thermal plume resulting from the JAF plant discharge which are pertinent to the evaluation of biological impact. Information on the characteristics of the plume resulting from the thermal discharge is available from three sources: 1) hydraulic model results; 2) analytical model results; and 3) the results of three hydrothermal field surveys conducted during the summer and fall of 1976.

The hydraulic model tests were conducted primarily to evaluate, prior to construction, the performance of the diffuser system in the near-field vicinity of the discharge. A combination of the hydraulic model results and an analytical far-field model was used to predict temperature distributions outside the near-field area. The hydrothermal field surveys were designed to measure the three-dimensional temperature distributions resulting from the joint operation of NMP-1 and the JAF plants and to evaluate the performance of JAF diffuser based on the dilution of dye released into the discharge.

B. REVIEW OF PHYSICAL AND MATHEMATICAL MODELS

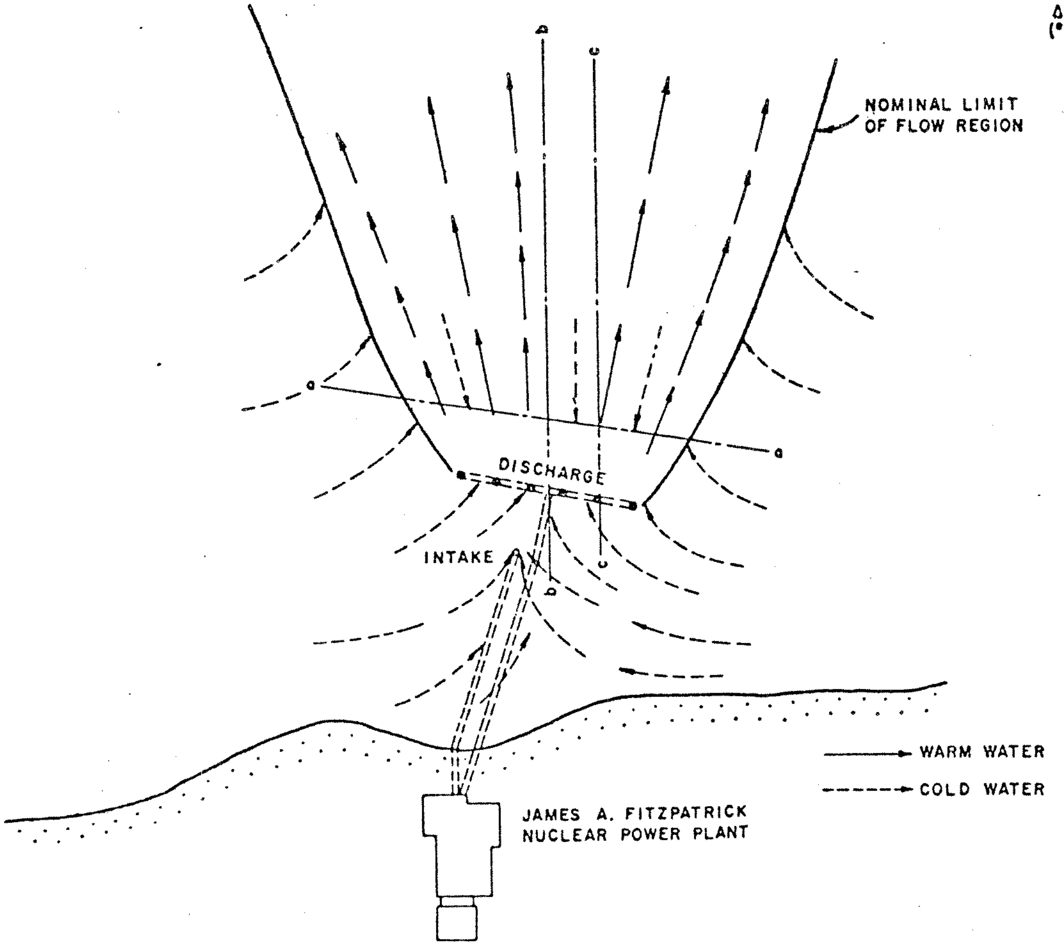
A total of five different hydraulic models were constructed and tested in order to select the final diffuser configuration and evaluate its performance (PASNY, 1971). Models 1 and 2 were used primarily to select the optimum diffuser configuration and orientation. Models 3 and 4 were undistorted models of the diffuser structure at scales of 1/50 and 1/81, respectively, and were used to evaluate the diffuser performance under various ambient lake conditions. Model 5 was constructed to assist in determining the thermal effects produced by NMP-1 at the site of JAF discharge.

Figures IV-1, IV-2, and IV-3 show surface flow patterns and excess temperature contours in the vicinity of the discharge resulting from hydraulic model tests with no lake current, 0.8 fps eastward lake current, and 0.7 fps westward lake current, respectively. The maximum excess surface temperatures measured during the three test conditions were 2.8°F with no lake current, and 4.0 and 4.4°F for the eastward and westward current conditions, respectively. These temperature rises correspond to dilutions of the discharge flow by ambient water of 11.6:1, 8.1:1, and 7.4:1. The near-field hydraulic model results indicated that the dilution of the discharge achieved at the lake surface decreased with increasing ambient cross currents. It should be noted, however, that the lake current conditions simulated in the above model tests (0.8 and 0.7 fps) have both a low probability of occurrence

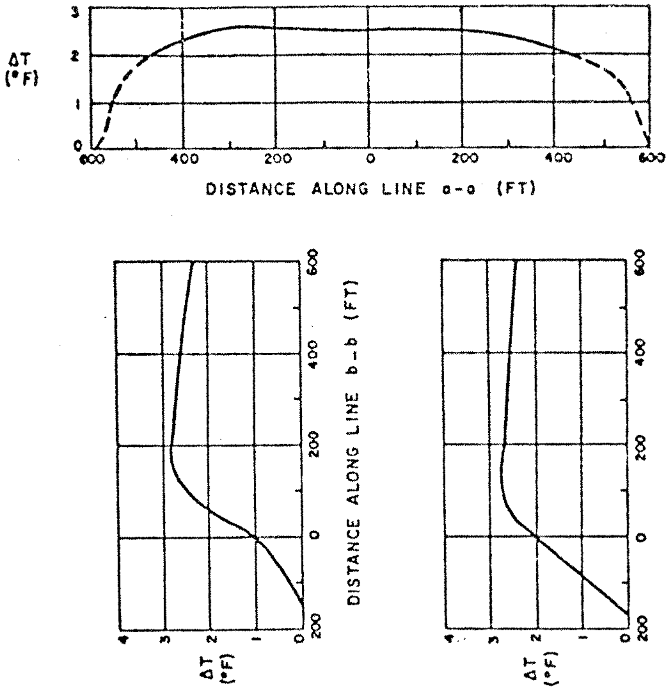
FIGURE IV-1

SURFACE FLOW PATTERN AND TEMPERATURE PROFILES WITH NO NATURAL LAKE CURRENT — MODEL TESTS*

JAMES A. FITZPATRICK NUCLEAR POWER PLANT



FLOW PATTERN



SURFACE TEMPERATURE PROFILES

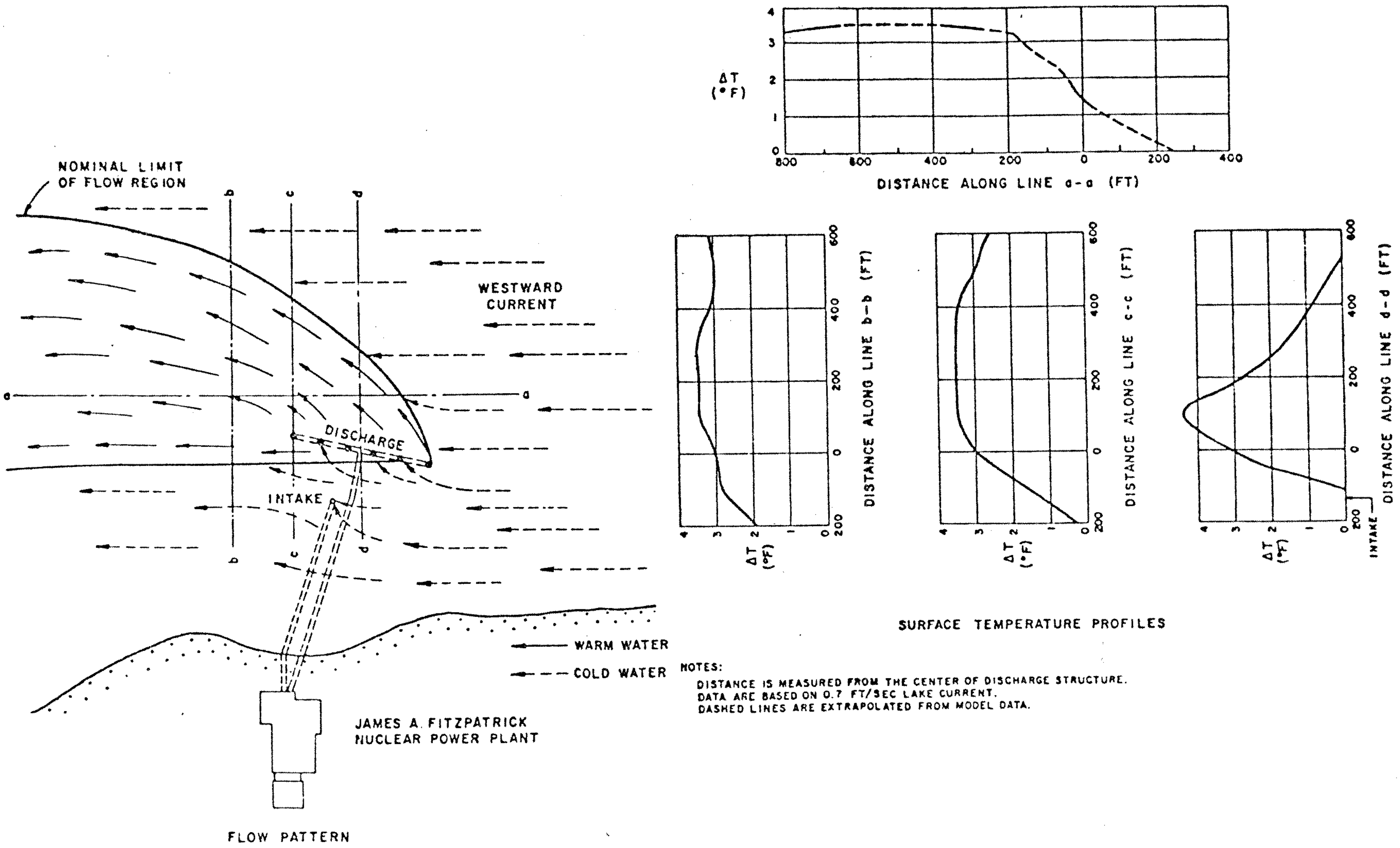
NOTES:

DISTANCE IS MEASURED FROM THE CENTER OF DISCHARGE STRUCTURE.
DASHED LINES ARE EXTRAPOLATED FROM MODEL DATA.

*PASNY, 1971

FLOW PATTERN AND TEMPERATURE PROFILES WITH WESTWARD LAKE CURRENT - MODEL TESTS*

JAMES A. FITZPATRICK NUCLEAR POWER PLANT



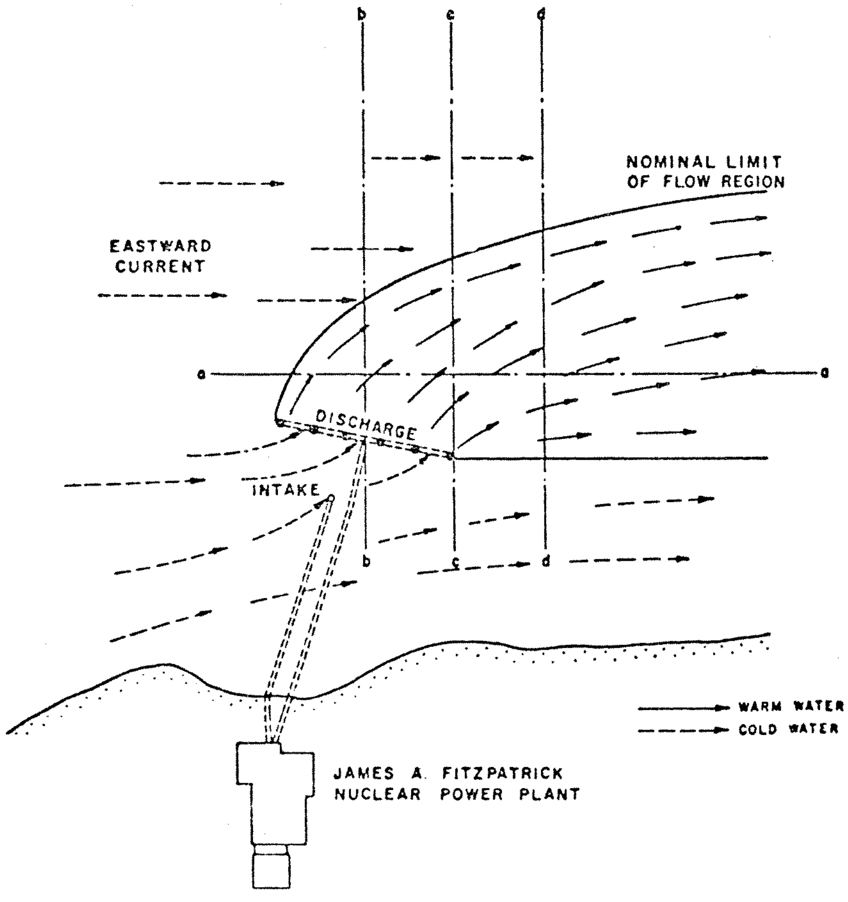
NOTES:

DISTANCE IS MEASURED FROM THE CENTER OF DISCHARGE STRUCTURE.
DATA ARE BASED ON 0.7 FT/SEC LAKE CURRENT.
DASHED LINES ARE EXTRAPOLATED FROM MODEL DATA.

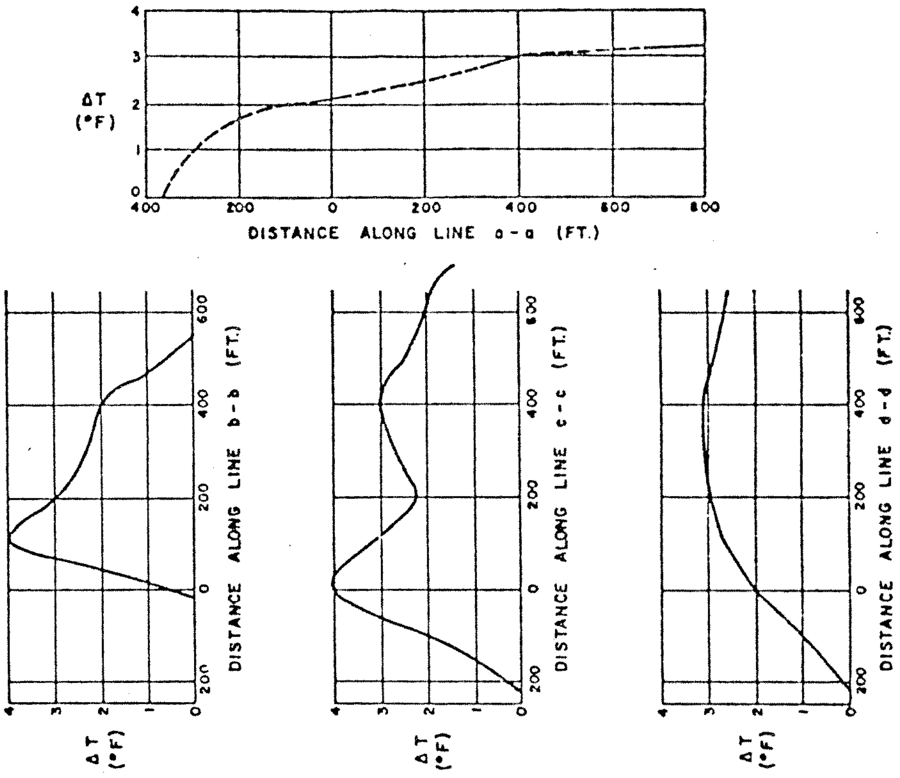
*PASNY 1971

FLOW PATTERN AND TEMPERATURE PROFILES WITH EASTWARD LAKE CURRENT - MODEL TESTS*

JAMES A. FITZPATRICK NUCLEAR POWER PLANT



FLOW PATTERN



SURFACE TEMPERATURE PROFILES

——→ WARM WATER
- - - → COLD WATER

NOTES:
DISTANCE IS MEASURED FROM THE CENTER OF DISCHARGE STRUCTURE.
DATA ARE BASED ON 0.8 FT/SEC LAKE CURRENT.
DASHED LINES ARE EXTRAPOLATED FROM MODEL DATA.

*PASNY 1971

and short duration time in the lake (Figures III-1 and III-2). The 0.8 fps speed has a frequency of occurrence of less than 5% at 12 hours duration. Figures IV-2 and IV-3, which illustrate the maximum excess temperatures of 4.0 and 4.4°F, respectively, show that those temperature rises decrease rapidly within approximately 200 ft of the discharge, indicating the occurrence of additional rapid dilution of the discharge waters in that region.

Temperature distributions outside the near-field area were predicted by an analytical model which used the near-field hydraulic model results to define a line source for the intermediate and far-field plume. Surface temperature distributions were predicted for ambient currents ranging from no lake current to 0.8 fps eastward current and 0.7 fps westward current. The results obtained from the analytical model studies indicated that as the ambient lake current increased, dilution along the plume centerline occurred less rapidly, and the surface area bounded by a given isotherm increased. Geometrically, the plumes became increasingly elongated in the direction of the simulated current as the velocity increased, with the far-field plume centerline approximately paralleling the shoreline at the higher along shore velocities. Plumes resulting from easterly currents were found to be similar to plumes resulting from westerly currents, outside of the near-field zone.

It should be noted that all of the above hydraulic and analytical modeling was done under conditions that would be expected to render the results conservative. The hydraulic model tests did not simulate certain field conditions usually associated with lake currents, such as the presence of winds and waves, which would induce some additional heat dissipation and mixing in the prototype. The model tests used an earlier estimated plant temperature rise of 32.4°F, which is 0.9°F above the design value. In addition, the model tests did not evaluate the effect of ambient lake stratification on the temperature rises produced by the diffuser in the near field. The initial colder dilution waters entrained into the jets from the lower depths under stratified ambient conditions would reduce the excess surface temperatures relative to surface ambient. Hence, since the nearshore waters of Lake Ontario are stratified during most of the spring, summer and early fall months, the effect of the JAF discharge on surface temperatures during these seasons would be reduced from those predicted under isothermal conditions.

C. REVIEW OF HYDROTHERMAL FIELD SURVEYS TO DATE AND INTERACTION OF THE NINE MILE POINT AND JAMES A. FITZPATRICK NUCLEAR PLANT THERMAL PLUMES

Triaxial hydrothermal field surveys of JAF thermal plume were conducted during June, August and October of 1976 (Stone and Webster, 1976a, 1976b, 1976c). Briefly, the surveys included simultaneous triaxial measurements of temperature and dye concentration along fixed transects in the vicinity of the JAF and NMP-1 plants. Lake currents at three depths, lake level, and wind speed and direction were also continuously monitored before and during each survey. The following represents a summary of the triaxial surveys.

Table IV-1 contains a summary of the pertinent plant operating data and prevailing lake conditions during each of the 13 triaxial surveys, along with measurements of the observed surface plumes. The surveys were conducted under plant generating loads ranging between 725 and 793 MWe (88 and 97% of capacity), with a mean of 773 MWe (94% of capacity). Lake currents during the surveys were predominantly westward, with only the two 7 October surveys conducted during eastward currents. Current velocities were generally low, as evidenced by the fact that currents exceeded 0.5 fps during only one of the 13 surveys.

The presence of natural thermal gradients (both horizontal and vertical) in the vicinity of the discharge, as well as possible interaction with NMP-1 plume, complicate the determination of an ambient temperature from which plume temperature rises can be calculated. The vertical stratification observed at the JAF intake (Table IV-1) during each of the surveys is an example of such a complicating factor. In those cases where an ambient temperature was determined, it was obtained by averaging temperatures in the vicinity of the diffuser along transects outside the dye plume. The degree of natural temperature variation and the presence of NMP-1 plume in the vicinity of JAF discharge prevented the determination of ambient temperature by this method for all but one of the August surveys (Table IV-1).

The ambient temperature determined for the single 4 June survey was 53.3°F while ambient on the 13th of June decreased during the day from 51.7 to 47.3°F. The maximum surface temperature rise observed during the June surveys was 2.3°F, and thus no 3°F temperature rise isotherm was present. The minimum dilution of the dye observed at the surface during the June surveys (Table IV-1) would yield maximum surface temperature rises between 3.4 and 4.2°F if applied to the plant T under isothermal lake conditions. However, the vertical stratification in the vicinity of the discharge reduces the observed surface temperature rise since the dilution water entrained by the jet is from the lower depth, which is cooler than surface water. The degree to which surface temperature rises are affected by vertical stratification is dependent on both the magnitude and the distribution of vertical temperature differences.

The sizes of the observed dye plumes during the June surveys increased with increasing current velocity, the largest areal extent of the 10:1 dilution being observed on 4 June when lake currents were approximately 0.25 fps. Substantial reductions of the areal extent of the same dilution contour were observed on 13 June, under low (< 0.1 fps) lake currents.

TABLE IV-1

SUMMARY OF HYDROTHERMAL FIELD SURVEY DATA

JAMES A. FITZPATRICK NUCLEAR POWER PLANT - 1976

DATE OF SURVEY	TIME	PLANT LOAD (MWe)	PLANT ΔT (°F)	DISCHARGE TEMP (°F)	LAKE CURRENT[a]		VERTICAL ΔT AT INTAKE[b] (°F)	MAXIMUM OBSERVED ΔT AT SURFACE (°F)	MAXIMUM OBSERVED DILUTION FACTOR AT SURFACE[c]	SURFACE AREA OF 3°F ISOTHERM ($ft^2 x 10^3$)	SURFACE AREA OF 10 TO 1 DILUTION FACTOR[c] ($ft^2 x 10^3$)
					VELOCITY (fps)	DIRECTION					
4 JUN	0657-0818	779	29.0	81.0	0.25	SW	3.0	2.3	7.1	NO	1398
13 JUN	0638-0801	782	29.0	78.5	<0.05	W	3.0	0.8	8.6	NO	44
	1032-1152	782	28.8	75.5	<0.05	W	2.1	1.7	6.9	NO	164
	1446-1623	780	28.5	74.0	0.08	SW	1.7	2.2	7.4	NO	312
19 AUG	0856-0949	788	29.5	99.0	0.46	WSW	1.1	2.6	8.5	NO	28
	1229-1338	793	29.5	100.0	0.33	W	5.1	ND	7.5	ND	226
	1603-1743	791	28.5	101.3	0.26	SW	5.4	ND	9.6	ND	27
20 AUG	0818-0949	793	29.5	100.0	0.17	SW	4.2	ND	8.9	ND	6
	1231-1344	792	27.5	100.0	0.24	W	2.5	ND	8.2	ND	888
	1610-1722	791	29.0	101.0	0.25	W	2.9	ND	8.4	ND	15
7 OCT	0826-1004	726	26.5	89.0	0.74	E	2.1	4.3	5.5	139	818
	1502-1615	726	26.0	89.0	<0.10	E	4.0	4.2	NA	1196	NA
8 OCT	1642-1759	725	26.0	87.5	0.50	W	0.0	3.6	5.9	232	989

[a] Lake current at 10 ft depth
[b] Difference between top 2 ft and bottom 2 ft of water column
[c] Based on dye concentration measurements

NO - Not observed
ND - Ambient temperature not determined
NA - Not available

The ambient temperature determined for the first 19 August survey was 68.9°F, and the corresponding maximum surface temperature rise was 2.6°F. The degree of thermal stratification in the discharge area was low during the first survey period, as indicated by the 1.1°F difference between surface and bottom temperatures (Table IV-1). It is of interest to note that the minimum observed dye dilution of 8.5 at the surface would produce a 3.5°F temperature rise under isothermal conditions, and that the maximum observed temperature rise (2.6°F) plus the observed vertical ΔT (1.1°F) yields a similar temperature rise of 3.7°F. This indicates that the main portion of the entrained dilution water originated in the cooler bottom waters. No 3°F surface isotherm was observed during the first August survey.

The influence of the NMP-1 plume in the vicinity of the JAF discharge (note the increase in vertical ΔT) prevented the determination of an ambient temperature for the remainder of the August surveys. The minimum dye dilution values applied to the existing plant T's would yield maximum surface temperature rises between 3.0 and 3.9°F under isothermal conditions. The calculated maximum temperature rises based on the dye data were less than the observed vertical T at the intake in three of the five August surveys for which ambient temperature could not be determined in the near field. This would indicate that the JAF discharge actually had a cooling effect on the surface waters in the vicinity of the discharge during the three surveys. The plume chartings (Stone and Webster, 1976b) also showed this effect. Thus, the interaction of the NMP-1 plume with the JAF plume under these conditions resulted in a reduction of the temperature in the NMP-1 plume through dilution with the cooler JAF plume. The maximum temperature rise attributable to the JAF discharge during the last two August surveys (Table IV-1) would be 3.4°F based on dye dilution, but the temperature rise relative to the surface waters in the vicinity would be reduced by the observed vertical stratification during these surveys.

The surface areal extents of the 10:1 dilution factor contours observed during the August surveys are given in Table IV-1. These would correspond to the approximate extents of the 3°F isotherm under capacity operation (plant ΔT equal to 31.5°F) and isothermal lake conditions.

The survey results listed in Table IV-1 show that both the highest maximum surface temperature (4.3°F) and lowest minimum dilution factor (5.5) for all 1976 surveys occurred during the October surveys. Both of these values were recorded during the first 7 October survey which had the highest observed current velocity of all surveys and was also the only survey during which significant easterly currents were observed. A low minimum dilution (5.9) was also observed during the 8 October survey at a current velocity of 0.5 fps to the west.

In summary, the field survey results show maximum surface temperature rises of 4.3°F based on recorded temperature data and 4.8°F based on dye dilution and assuming isothermal lake conditions. During periods of vertical stratification in the vicinity of the discharge resulting from either natural causes or the influence of the NMP-1 discharge, the surface temperature rises attributable to the JAF discharge are reduced and it may, under conditions of NMP-1 plume interaction, actually reduce temperatures in the NMP-1 plume. The survey data do indicate that increasing lake velocities can decrease the dilution achieved by the diffuser, and can increase the areal extent of the intermediate field isotherms.

D. PLUME TIME-TEMPERATURE HISTORY AND VELOCITY PROFILES

In order to determine the time-temperature history of plume waters it is necessary to know the spatial distribution of velocities and temperatures in the plume. The time of travel through the temperature distribution can then be determined by integrating the velocity distribution over distance. The high velocities and high levels of turbulence in the near-field jet region of a submerged discharge preclude the measurement of these distributions in the submerged jet region, thus necessitating a theoretical determination using the known discharge velocity and temperature (u_o and T_o, respectively) and measured values from field data at the point of jet surfacing. Abramovich ([1963]) has shown that the dissipation of velocity is related to the dilution of temperature. A variety of expressions are available to describe this relationship, but one that is in common usage is,

$$\frac{u_o}{u} = \left(\frac{T_o}{T}\right)^b \qquad \text{(IV-1)}$$

If b = 1, the temperature and velocity are diluted equally. However, usually b>1, as evidenced by plume deflection in an ambient current, until the plume no longer shows the effect of discharge momentum, although noticeable temperature elevations remain. This is explained by the fact that the discharge momentum has gone to increase the level of turbulent motion in the plume, while the decay of heat is primarily a result of exchange to the atmosphere; that is, the decay of heat and momentum are distinctly different processes.

It remains then to describe the temperature dilution distribution. Previous studies (LMS, 1975) have indicated that the dilution of temperature along the centerline of the plume is proportional to the centerline distance raised to same power or,

$$\frac{T(s)}{T_o} = \frac{1}{S^a} \qquad \text{(IV-2)}$$

By substitution of Equation IV-2 into Equation IV-1 and integration of the resulting expression for velocity over centerline distance, a time/temperature relationship can be determined. Substitution of the initial discharge conditions and conditions at some centerline distance downstream yields values of a and b of 0.41 and 1.12 respectively. The substitution values selected for this determination were the initial discharge velocity of 14.0 fps, the initial ΔT of 31.5°F, and the velocity and temperature at a centerline distance of 300 ft of 1.0 fps and 3.0°F, respectively. The resulting time/temperature distribution for travel along the plume centerline is shown in Figure IV-4. Figure IV-4 applies only to the near-field portion of the plume where discharge momentum dominates the hydrodynamics of the plume. Figure IV-4 illustrates the rapid dilution of the discharge temperature achieved by the diffuser in the near field, with the initial temperature rise of 31.5°F being reduced to less than a 7°F temperature rise within ten seconds of discharge to the lake. It should be noted that since the time/temperature relationship shown in Figure IV-4 is along the centerline of the plume, it represents the maximum exposure. Waters flowing in the plume but not at the centerline would be diluted more quickly and therefore would be subjected to smaller temperature rises.

The velocity (u) versus distance (s) can be derived from the temperature distribution using Equation IV-1. The resulting estimated centerline velocity is described by Figure IV-5 for the near-field region.

In the far-field plume, velocities are dominated by lake currents; thus the centerline time of travel can be computed by dividing the centerline distance to a specified isotherm by the magnitude of lake current. The far-field model results for lake currents between 0.2 and 0.8 fps indicate that the maximum travel time to the 2°F isotherm would be 2.5 hours and would occur at lake currents of 0.5 fps. Lake currents less than 0.5 fps would yield lower travel times since dilution along the centerline occurs more rapidly. The use of lake current to compute far-field travel time is conservative in that the average velocities along the centerline would be higher than the lake currents due to convective spreading and discharge momentum.

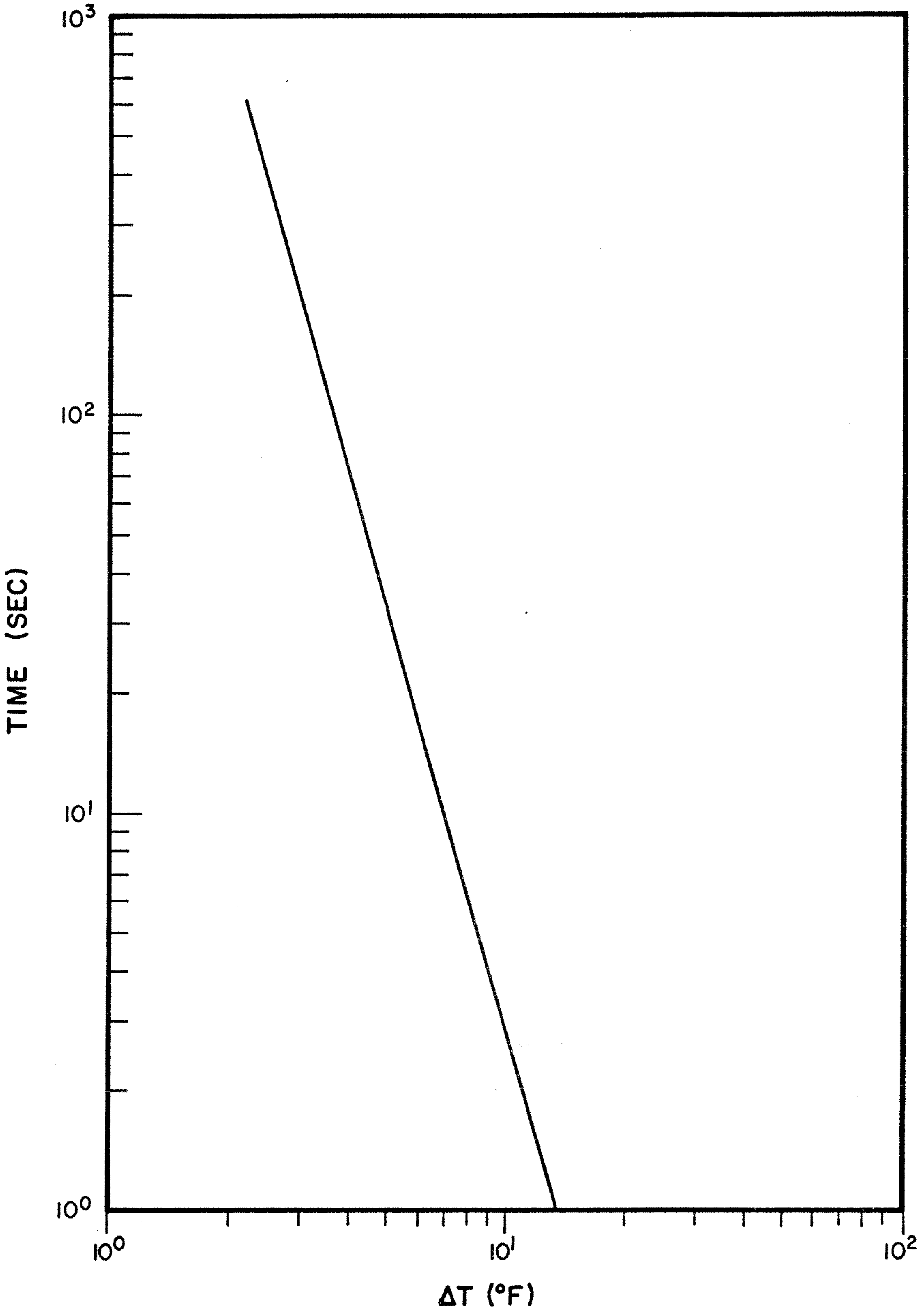
It should be pointed out that a distribution of possible time/temperature exposures exists which could be experienced by an entrained organism; these exposures range from a low temperature rise for a short time period to the maximum exposures given above. Only a small percentage of the organisms would experience either the maximum or minimum exposures.

E. WATER BODY SEGMENT FOR MULTI-PLANT EFFECTS

A water body segment encompassing the discharges of Oswego Units 1-6, Nine Mile Point Unit 1, the James A. FitzPatrick Plant and the Oswego

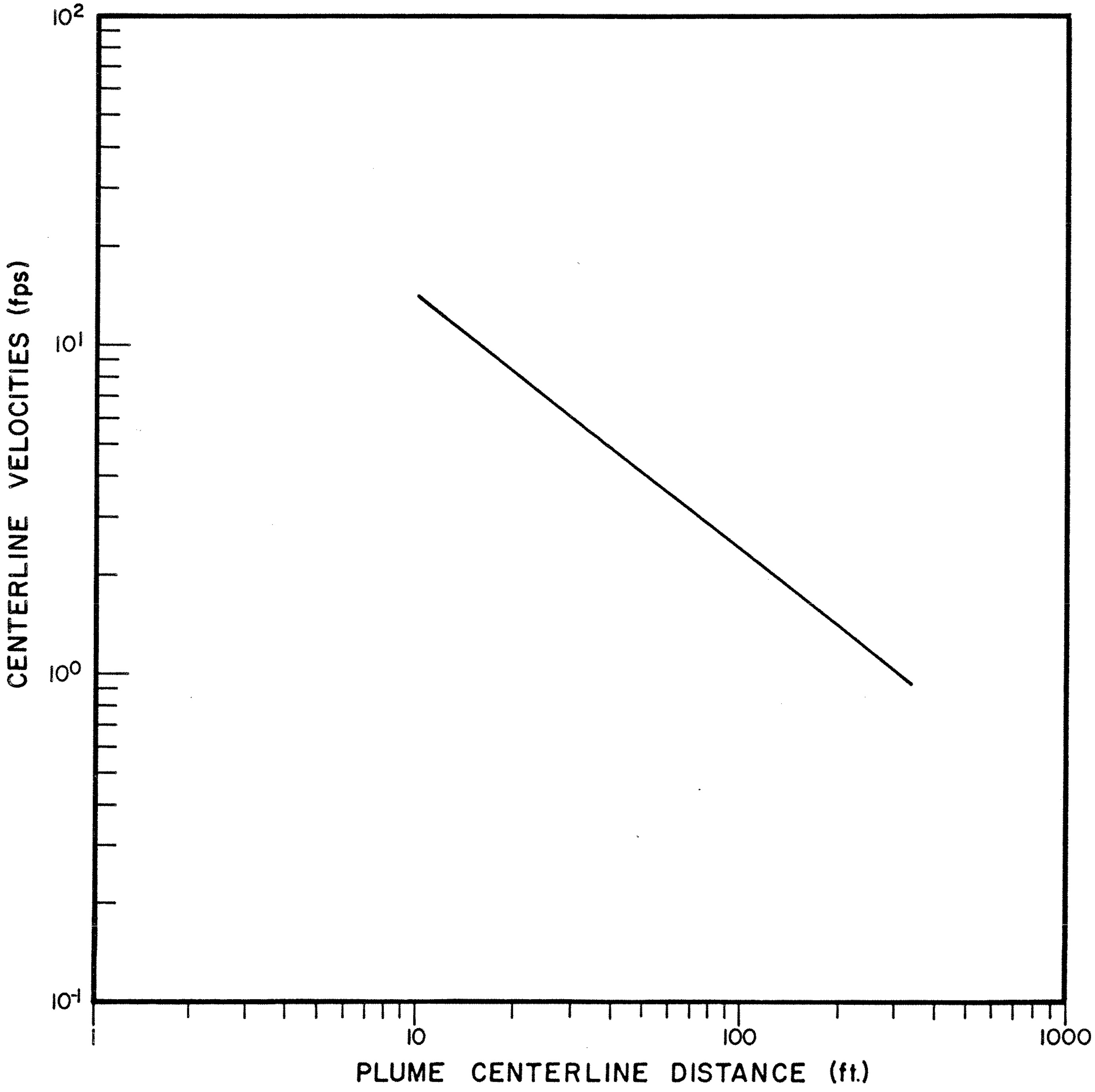
TIME-TEMPERATURE HISTORY FOR THE NEAR FIELD PLUME

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY



VELOCITY AT PLUME CENTERLINE
VS.
DISTANCE FROM DIFFUSER

JAMES A. FITZPATRICK NUCLEAR POWER PLANT



River was chosen for consideration of multi-plant effects. Based on an analysis of ambient lake current persistences, it is expected that 95% of the currents of 0.1 knots will have an excursion distance shorter than half the water body segment length. That is, for the characteristic speed, a persistence in excess of 96 hours would be required before a floating organism would leave the water body segment, which extends approximately 10.6 km (6.6 mi) offshore and stretches along the shore for a distance of 36 km (22.5 mi). The volume of water contained in this segment is 9.6×10^9 m^3 (3.4×10^{11} ft^3). The cross-sectional area normal to the longshore flow is approximately 2.7×10^5 m^2 (2.9×10^6 ft^2) (see Table IV- 2). The selected segment includes 0.59% of the volume of Lake Ontario.

F. PLUME ENTRAINMENT VOLUME RATIOS

In order to evaluate the effect of the thermal discharge on the water body segment, it is desirable to quantify the fraction of the total flow through the water body that is entrained into the plume at selected temperature rises.

It has been shown by many investigators that a Gaussian distribution is a good approximation of the horizontal and vertical temperature variations for submerged and surface jets. Therefore, it can be assumed that temperature in a cross section, normal to the plume centerline, decreases exponentially with the square of the horizontal distance, r, and vertical distance, z, from the centerline. This temperature, T(s,r,z) is described by:

$$T(s,r,z) = T^* (s) \operatorname{Exp} - \left[\left(\frac{z^2}{2\sigma_z^2} + \frac{r^2}{2\sigma_r^2} \right) \right] \qquad \text{(IV-3)}$$

Where σ_z and σ_r are the standard deviations of the temperature distributions and T*(s) is the centerline temperature. If σ_r is assumed to be different for both the left and right side of the plume cross section, plume asymmetry is also accounted for.

Equation IV-3 describes a full elliptical cross section for each isotherm in the submerged portion of the jet and a half elliptical section for the plume after jet surfacing ($z \geq 0$). The cross-sectional area within any isotherm of value T after jet surfacing can be shown to be:

$$A = \pi \sigma_r \ \sigma_z \ln \ \frac{T^*(s)}{T} \qquad \text{(IV-4)}$$

TABLE IV-2

CHARACTERISTICS OF THE WATER BODY SEGMENT

Water Body Segment		
Distance to offshore boundary	10.6 km	6.6 mi
Depth at offshore boundary	~140 m	~450 ft
Distance along shore	36 km	22.5 mi
Surface area	382 km^2	147.5 mi^2
Volume within bounds	9.6×10^9 m^3	3.4×10^{11} ft^3
Cross sectional area	2.7×10^5 m^2	2.9×10^6 ft^2

Solving Equation IV-4 for temperature as a function of area enclosed yields:

$$T = T^*(s)\ \mathrm{Exp} - \left[\frac{A}{\pi \sigma_r \sigma_z}\right] \qquad \text{(IV-5)}$$

and by substitution from Equation IV-1:

$$u = u_o \left(\frac{T^*(s)}{T_o}\right)^b \mathrm{Exp} - \left[\frac{bA}{\pi \sigma_r \sigma_z}\right] \qquad \text{(IV-6)}$$

The principle of heat conservation dictates that under steady-state conditions the heat flux at any plume cross section be equal to the total flux at the diffuser ports or:

$$H = \int_0^\infty \rho C_p T_u \, dA = H_o = \rho C_p n \pi r^2 u_o T_o \qquad \text{(IV-7)}$$

Where: H = heat flux at any plume cross section
H_o = heat at diffuser ports input
= density of water
C_p = heat capacity of water
n = number of diffuser ports
r = radius of diffuser ports

Substitution for T and u from Equations IV-5 and IV-6 and evaluation of the integral in Equation IV-7 yields:

$$\sigma_r \sigma_z = n r_o^2 (b + 1) \left(\frac{T_o}{T^*(s)}\right)^{b + 1} \qquad \text{(IV-8)}$$

as a necessary condition for heat conservation at any cross section after jet surfacing. A similar analysis for the submerged portion of the jet yields the necessary condition:

$$\sigma_r \sigma_z = r_o^2 \left(\frac{b + 1}{2}\right)\left(\frac{T_o}{T^*(s)}\right)^{b + 1} \qquad \text{(IV-9)}$$

The total flow through an isotherm T with area A(T) is defined by:

$$Q = \int_0^{A(T)} u(A)\, dA \qquad \text{(IV-10)}$$

which after substitution for (A) from Equation IV-6 and evaluation of the integral yields:

$$Q(T) = u_o \left(\frac{T^*(s)}{T_o}\right)^b \frac{\pi \sigma_r \sigma_z}{b} \left[1 - \left(\frac{T}{T^*(s)}\right)^b\right] \qquad \text{(IV-11)}$$

where the $\sigma_r \sigma_z$ product is specified by equation IV-8.

Substitution for $\sigma_r \sigma_z$ from Equation IV-11 yields:

$$Q = \frac{Q_o T_o}{T^*(s)} \left(\frac{b + 1}{b} \right) \left[1 - \left(\frac{T}{T^*(s)} \right)^b \right] \qquad \text{(IV-12)}$$

for the flow through the cross section bounded by isotherm T, after jet surfacing. Similar analysis for the submerged portion of the jet also leads to Equation IV-12. Differentiating equation IV-12 with respect to T*(s), solving for T*(s) when Q is maximum, and back substitution into Equation IV-12 yields:

$$Q_{MAX} \ (T) = \frac{Q_o T_o}{T(b + 1)^{1/b}} \qquad \text{(IV-13)}$$

for the maximum flow through the isotherm T.

The beauty of equation IV-13 is that it allows the maximum flow to be computed without requiring prior determination of where in the plume it occurs. It should be noted that the Q_{MAX} resulting from equation IV-13 is a conservative estimate of the entrained flow since it is the sum of some portion of the discharged flow and the entrained flow contained within the particular isotherm. Thus, the actual maximum flow entrained through the particular isotherm would be less than Q_{MAX} by the portion of the original discharge flow still inside the isotherm at the location where Q_{MAX} occurs.

Equation IV-13 was used to calculate the maximum flows within the 2°F and 3°F isotherm for the JAF plume and for the other generating stations in the selected water body segment. The results of the analysis and a comparison of the entrained flows with the total flow in the water body segment are given in Table IV-3. All flow rates shown in Table IV-3 are based on capacity operation of all stations. If seasonal load factors were applied in the analysis the given isotherm flows would be substantially reduced.

TABLE IV-3

MAXIMUM HEATED WATER FLOW WITHIN 3 AND 2°F ISOTHERMS

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY

PLANT	ISOTHERM (°F)	Q_{MAX} (cfs)	RATIO OF Q_{MAX} TO Q IN WATER BODY SEGMENT[a]
FITZPATRICK	3	5001	0.0103
	2	7502	0.0154
ALL PLANTS[b]	3	15576	0.0320
	2	23365	0.0479

[a] Q in water body segment equals 13800 m^3/sec

[b] Includes Oswego Units 5 and 6, Nine Mile Point Unit 1, FitzPatrick

REFERENCES CITED

CHAPTER IV

Abramovich, G.N. [1963]. The theory of turbulent jets. [Translated by Scripta Tech.] Edited by Leon H. Schindel. Massachusetts Inst. Tech. Press, Cambridge.

Lawler, Matusky and Skelly Engineers. 1975. 316(a) demonstration submission: Oswego Unit 5, NPDES Permit #070 0X2 2 000632 NY (0003212). Prepared for Niagara Mohawk Power Corp.

Power Authority of the State of New York. 1971. Environmental report: Environmental statement to the United States Atomic Energy Commission pursuant to the National Environmental Policy Act - James A. FitzPatrick Nuclear Power Plant. AEC Docket No. 50-333.

Stone and Webster. 1976a. June 1976 postoperational hydrothermal survey for James A. FitzPatrick Nuclear Power Plant. Prepared for Power Authority of the State of New York.

Stone and Webster. 1976b. August 1976 postoperational hydrothermal survey for James A. FitzPatrick Nuclear Power Plant. Prepared for Power Authority of the State of New York.

Stone and Webster. 1976c. October 1976 postoperational hydrothermal survey for James A. FitzPatrick Nuclear Power Plant. Prepared for Power Authority of the State of New York.

V. BIOLOGICAL COMMUNITY

1. Introduction

The occurrence of such changes in the aquatic community that may result from the addition of heat by the condenser cooling system to the receiving waters is determined in part by assessing the abundance and diversity, distribution, trophic relationships and the dynamic aspects of the aquatic biota of the receiving water bodies. Studies of composition, diversity and type of community associations in natural and artificially heated aquatic regions are used to delineate the degree of response of the aquatic organisms to thermal addition. In this chapter, an assessment of four major biological groups present in the vicinity of JAF will be provided along with a discussion on the integrity of the biological community of the ecosystem.

Aquatic ecological studies have been conducted in the vicinity of JAF and NMP-1 since 1969; aquatic monitoring programs continue in accordance with the NRC requirements. The programs conducted by LMS (QLM, 1973; 1974; LMS, 1975; 1976) in the Nine Mile Point area have consisted of surveys of plankton (phytoplankton, zooplankton, and ichthyoplankton), benthos, and fish populations during the spring through fall periods at various depths and transect locations. Sampling by LMS has been relatively consistent since 1972 and sample locations are indicated in Figure V-1 to V-3. Impingement and entrainment of nektonic and planktonic populations were also monitored at the station's intake. Water quality was investigated by LMS in the vicinity of Nine Mile Point (QLM, 1973; 1974; LMS, 1975; 1976), including monthly determinations of the concentrations of inorganic nutrients, heavy metals, dissolved oxygen (DO), temperature, pH, and biochemical oxygen demand (BOD). Each trophic level of the community within the vicinity of Nine Mile Point is discussed in the following sections. Other studies were conducted in the study area by McNaught and Fenlon (1972), McNaught and Buzzard (1973) Storr (1973) and Lake Ontario Environmental Laboratory (LOTEL) (RGE, 1974).

The following analysis, with the exception of entrainment studies, is restricted to data collected through 1975. In 1975 JAF was in operation from July through December and load factors for this period were presented in Chapter II. It is important to point out that the plant averaged greater than 50% capacity from July through October when major thermal effects, if any, would be expected due to high ambient temperatures. Also, NMP-1, located 3000 ft west of JAF, began operation in 1969 and these studies can be used to indicate combined effects at JAF.

FIGURE V-1

FISH SAMPLING STATIONS
NINE MILE POINT VICINITY - 1975

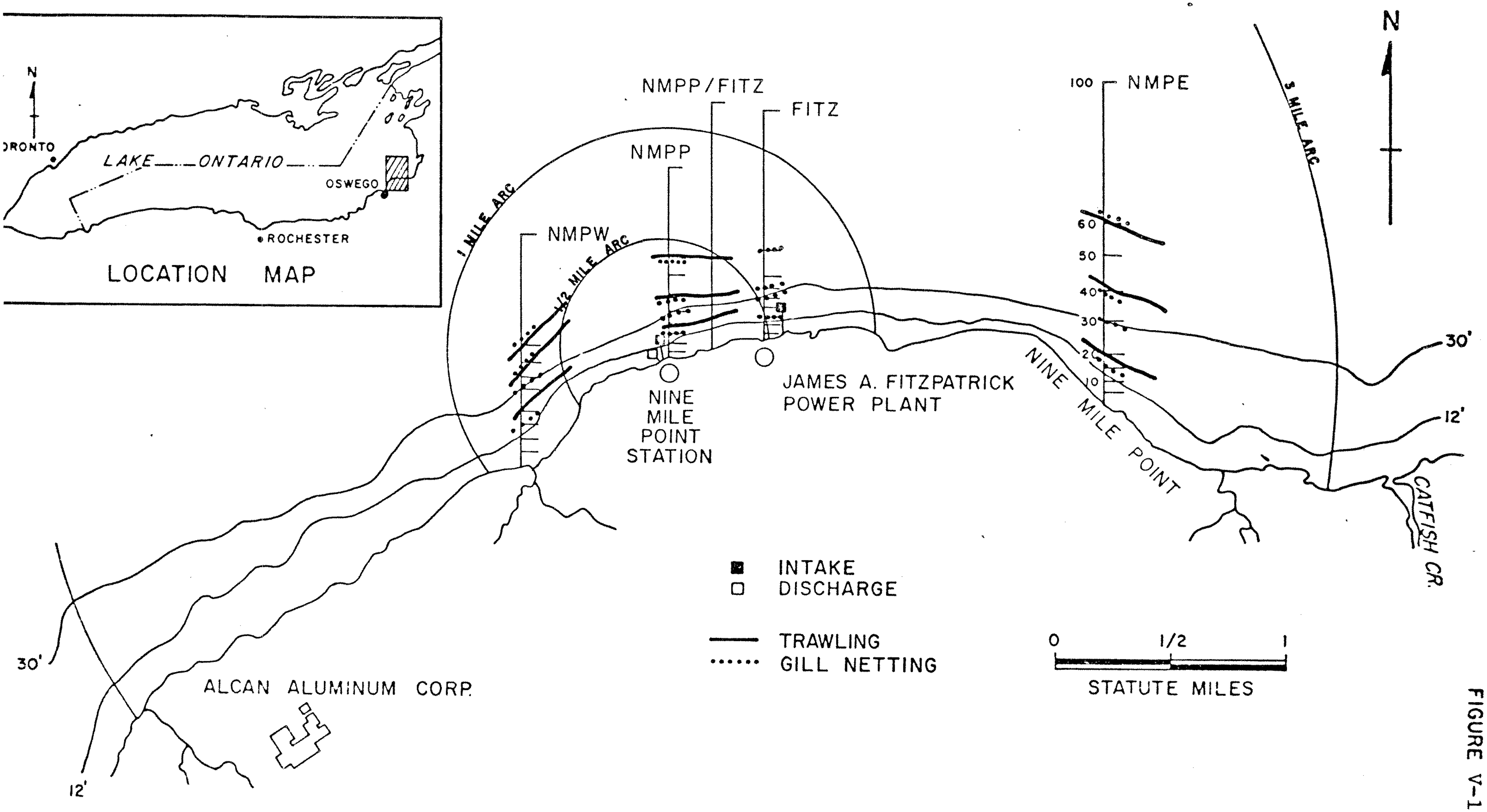


FIGURE V-2

BENTHOS SAMPLING STATIONS
NINE MILE POINT VICINITY - 1975

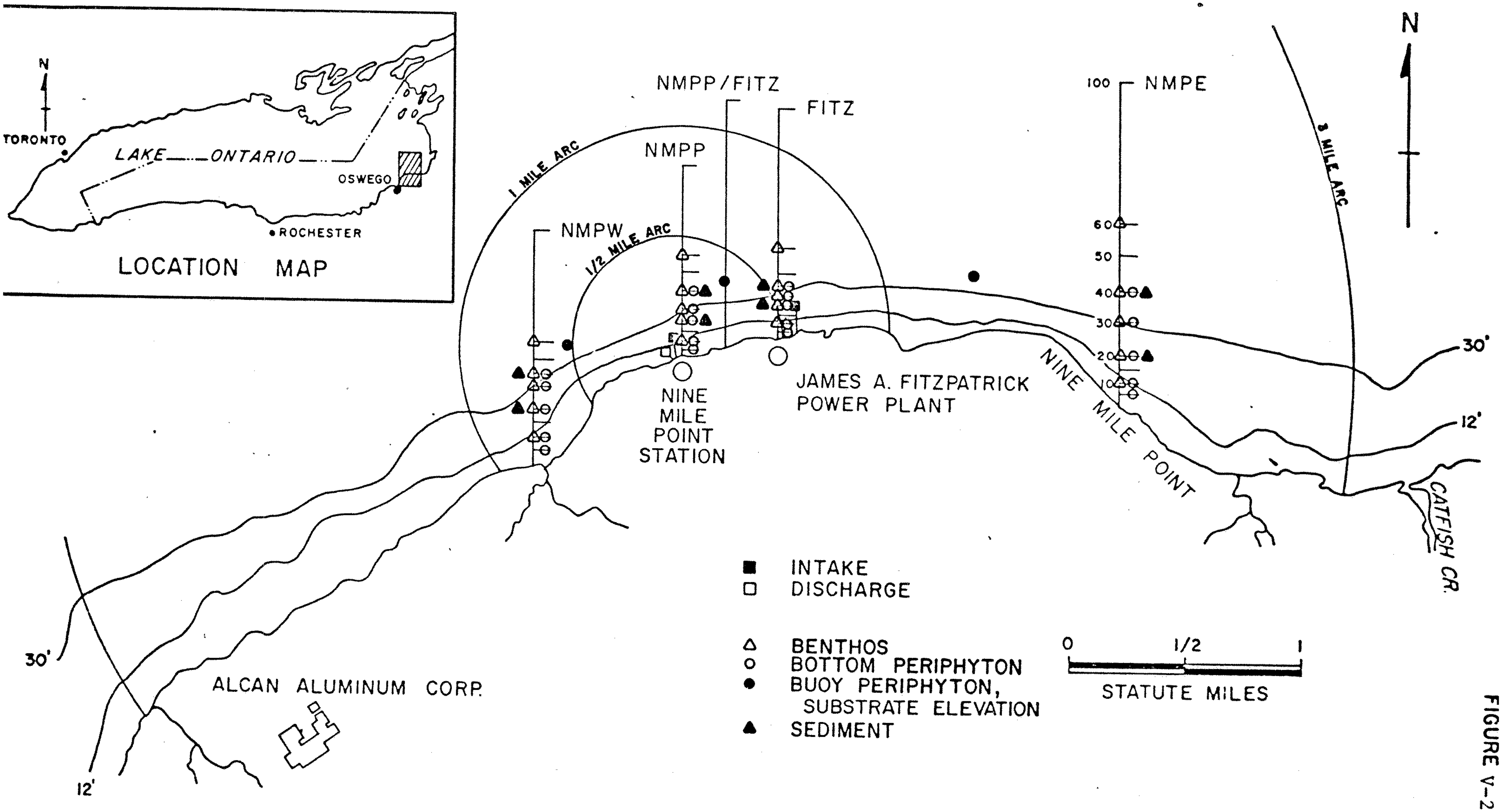
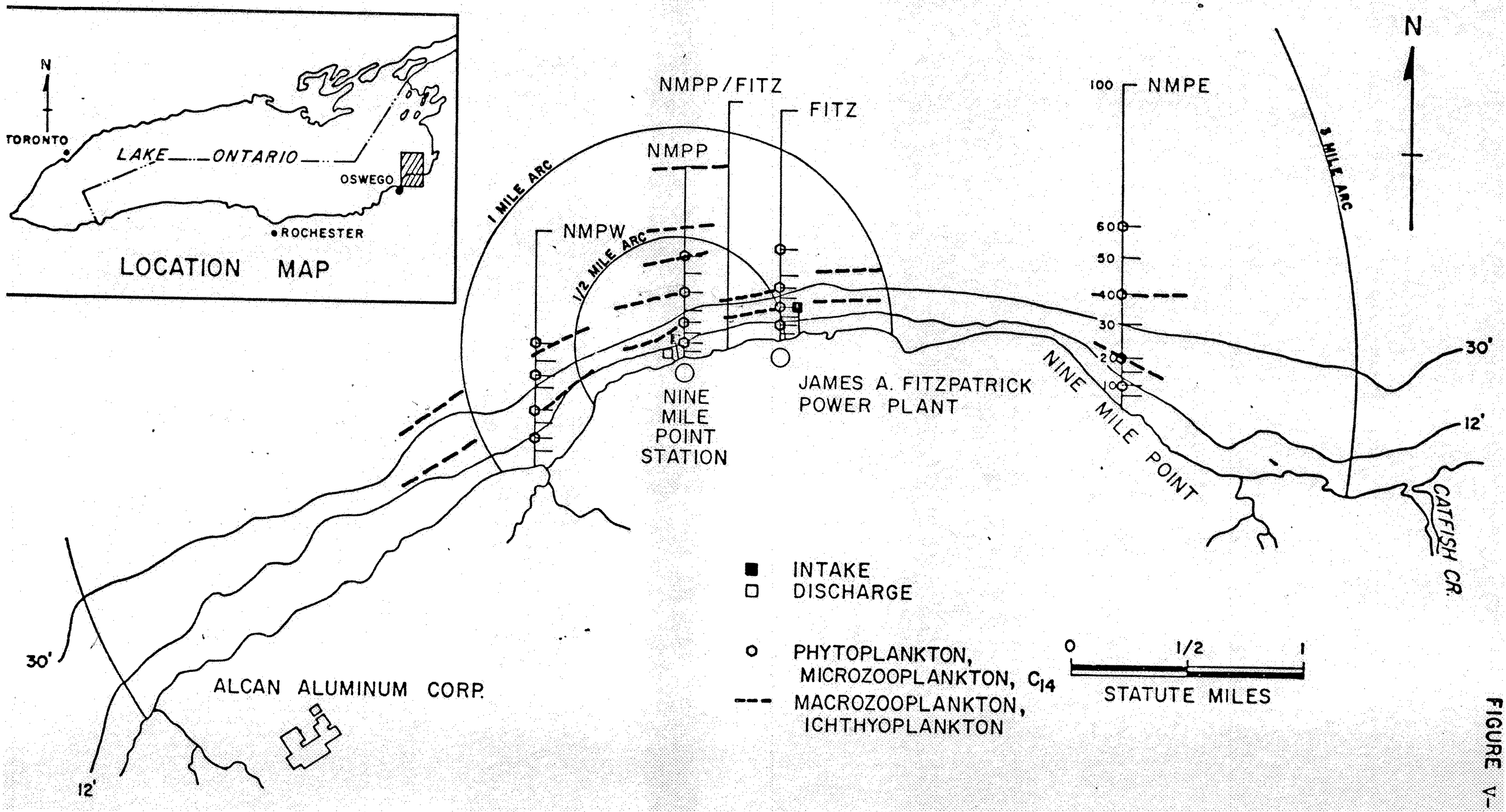


FIGURE V-3

PLANKTON SAMPLING STATIONS
NINE MILE POINT VICINITY - 1975



2. Phytoplankton

The species of phytoplankton collected during 1974 and 1975 in the vicinity of Nine Mile Point are grouped at the class level according to the classification scheme of Prescott (1962) and are shown in Table V-1. Green algae composed the majority of genera identified in both 1974 (42 genera) and 1975 (51 genera; 41 genera were identified in 1973). Of the other groups, 20 and 18 genera of diatoms (19 genera in 1973) were identified in 1974 and 1975, respectively, as well as 14 and 16 genera of blue-green algae (18 genera in 1973). For those two years, 10-23 genera were identified among the other classes of phytoplankton.

Seasonal changes in the abundance of phytoplankton were evident in the vicinity of the NMP-1 and JAF. These seasonal changes also varied among years depending on the lake conditions (QLM, 1973; LMS, 1974). Munawar and Nauwerck (1971) reported that green algae tended to be the dominant component of the phytoplankton in Lake Ontario during late summer and that blue-green algae were dominant during the fall bloom. Reinwand (1969) found that Asterionella, Fragilaria and Tabellaria were major genera of diatoms in Lake Ontario. Findings of LMS (1974) for the Nine Mile Point vicinity are in agreement with the findings for the lake as a whole.

The following evaluations are restricted to comparing data collected at the 40-ft depth contour in 1975 when JAF was operating part of the year. We cannot compare preoperational-operational abundances because improvements in collection and laboratory techniques in each of the years which makes these comparisons very difficult to interpret. Changes in techniques are indicated in Table V-2.

The 40-ft depth contour was selected for this analysis after review of hydrothermal studies at JAF which demonstrate that this contour is affected the greatest by JAF's discharge. In addition, NMP-1 discharge affects this depth contour which makes it particularly suitable for an intensive evaluation to determine effects from both plants.

3. Total Phytoplankton

The total phytoplankton abundance (number/ml) showed a biomodal periodicity in 1975. The two maxima observed in 1975 occurred on 8 July and 24 August; however, phytoplankton abundance also increased sharply on 10 and 24 June 1975 (Table V-3*).

The ANOVA includes data from the period April-June when JAF was not operating and thus absence of significant main effects (average of

---

*This increase is attributed to the improved technique. (See the conclusion at the end of the section.)

TABLE V-1

PHYTOPLANKTON SPECIES INVENTORY

NINE MILE POINT VICINITY - 1974-1975

MYXOPHYCEAE
- Anabaena sp.
- A. flos-aquae
- A. macrospora
- Anacystis sp.
- A. aeruginosa
- A. incerta
- Aphanizomemnon flos-aquae
- Aphanocapsa sp.
- A. delicatissima
- A. elachista
- A. pulchra
- A. rivularis
- Aphanothece sp.
- A. nidulans
- A. saxicola
- Chroococcus sp.
- C. dispersus
- C. dispersus v. minor
- C. limneticus
- C. minutus
- Coelosphaerium dubium
- C. kuetzingianum
- C. naegelianum
- C. pallidum
- Dactylococcopsis smithi
- Gloecapsa sp.
- Gomphosphaeria lacustris
- Lyngbya limnetica
- Merismopedia glauca
- M. tenuissima
- Oscillatoria sp.
- O. agardhii
- O. geminata
- O. limnetica
- O. minima
- O. tenuis
- Phormidium sp.
- Plectonema sp.
- Polycystis aeruginosa
- P. incerta
- Rhabdoderma lineare
- R. minima
- Rhaphidiopsis sp.
- UID Chroococcales

CHLOROPHYCEAE
- Actinastrum gracillimum
- A. Hanzschii
- Akistrodesmus falcatus
- A. falcatus v. tumidus
- A. nanoselene
- A. spirotaenia
- Asterococcus limneticus
- Botryococcus sudeticus
- Carteria sp.
- C. cordiformis
- C. klebsii
- Characium ornithocephalum
- Chlamydomonas sp.
- C. globosa
- C. pseudopertyi
- Chlorogonium sp.
- Chodatella sp.
- C. ciliata
- C. citriformis
- C. longiseta
- C. quadriseta
- C. subsalsa
- C. wratislawiensis
- Chlorella sp.
- Closterium sp.
- C. aciculare
- C. monoliferum
- C. venus
- Coelastrum cambricum
- C. microporum
- C. reticulatum
- Coranastrum aestivale
- Cosmarium sp.
- Crucigenia sp.
- C. apiculata
- C. crucifera
- C. lauterbornii
- C. quadrata
- C. rectangularis
- C. tetrapedia
- Dictyosphaerium ehrenbergianum
- D. puchellum
- Dispora crucigenoiodes
- Echinosphaerella limnetica
- Elaktothrix genatinosa

TABLE V-1 (Continued)

PHYTOPLANKTON SPECIES INVENTORY

CHLOROPHYCEAE (Continued)
- *Errerella bornhemiensis*
- *Eudorina elegans*
- *Franceia droescheri*
- *F. ovalis*
- *F. tuberculata*
- *Gloecystis* sp.
- *G. ampla*
- *G. gigas*
- *G. planktonica*
- *G. vesiculosa*
- *Gloeotila curta*
- *Golenkinia paucispina*
- *G. radiata*
- *Kirchneriella contorta*
- *K. lunaris*
- *K. obesa*
- *K. subsolitaria*
- *Lobomonas* sp.
- *L. ampla*
- *Micractinium pusillum*
- *Mougeotia* sp.
- *Nephrocytium agardhianum*
- *N. limneticum*
- *N. lunatum*
- *Oedogonium* sp.
- *Oocystis* sp.
- *O. borgei*
- *O. lacustris*
- *O. parva*
- *O. pusilla*
- *O. solitaria*
- *O. submarina*
- *Pandorina morum*
- *Pediastrum boryanum*
- *P. duplex*
- *P. simplex*
- *P. tetras*
- *Pedinomonas minutissima*
- *Phacotus lenticularis*
- *Polyedriopsis spinulosa*
- *Polytoma* sp.
- *Quadrigula* sp.
- *Q. chodatii*
- *Q. closteroides*
- *Q. lacustris*
- *Radiococcus nimbatus*

CHLOROPHYCEAE (Continued)
- *Scenedesmus* sp.
- *S. abundans*
- *S. acuminatus*
- *S. acutiformis*
- *S. arcuatis*
- *S. bijuga*
- *S. bijugatus*
- *S. brasiliensis*
- *S. denticulatus*
- *S. dimorphus*
- *S. incrassatulus*
- *S. intermedius*
- *S. longus*
- *S. obliquus*
- *S. opoliensis*
- *S. quadricauda*
- *Schroederia judayi*
- *S. setigera*
- *Selenastrum minutum*
- *S. westii*
- *Sphaerocystis schroeteri*
- *Spirogyra* sp.
- *Staurastrum* sp.
- *S. gracile*
- *Tetradesmus* sp.
- *Tetraedron caudatum*
- *T. minimum*
- *T. muticum*
- *T. pentaedricum*
- *T. regulare*
- *T. trigonum*
- *Tetraspora lacustris*
- *T. lamellosa*
- *Tetastrum elegans*
- *T. heteracanthum*
- *T. staurogeniaforme*
- *Treubaria setigerum*
- *T. triappendiculata*
- *Trochiscia* sp.
- *Ulothrix* sp.
- *U. subconstricta*
- *Westella linearis*
- *UID Chlorophyceae*
- *UID colony*
- *UID single cell*
- *UID germling*

TABLE V-1 (Continued)

PHYTOPLANKTON SPECIES INVENTORY

EUGLENOPHYCEAE
Euglena sp.
Lepocinclis sp.
Phacus sp.
Trachelomonas sp.

CHRYSOPHYCEAE
Chromulina sp.
Chrysamoeba sp.
Chrysarachinion insidians
Chrysochromulina parva
Chrysoephaerella longispina
Dinobryon sp.
D. bavaricum
D. divergens
D. sociale
D. sociale v. *americanum*
Kephyrion sp.
Mallomonas sp.
Ochromonas sp.
Rhizochrysis sp.
Stelexmonas sp.
Uroglena sp.
UID Chrysomonadales

BACILLARIOPHYCEAE
Amphiprora sp.
Amphora ovalis
Asterionella formosa
Cocconeis sp.
Coscinodiscus lacustris
C. Rothii
C. subtilis
Cyclotella sp.
C. atomus
C. glomerata
C. meneghiniana
C. pseudostelligera
C. stelligera
Cymbella sp.
Diatoma elongatum
D. tenue v. *elongatum*
D. vulgare
Eunotia curvata
Fragilaria capucina
F. crotonensis
F. vaucheriae

BACILLARIOPHYCEAE (Continued)
Gomphonema sp.
G. olivaceum
Gyrosigma sp.
G. attenuatum
Melosira sp.
M. binderana
M. granulata
M. granulata v. *angustissima*
M. islandica
M. italica
M. italica v. *subarctia*
M. varians
Navicula sp.
N. cryptocephala
N. tripunctata
Nitzschia sp.
N. acicularis
N. dissipata
N. gracilis
N. holosatica
N. palea
N. sigmoidea
Rhoicosphenia curvata
Stephanodiscus sp.
S. astrea
S. astrea v. *minutulus*
S. hantzschii
S. hantzschii v. *pusilla*
S. niagarae
S. tenuis
Surirella sp.
Synedra sp.
S. acus
S. rumpens
S. ulna
Tabellaria fenestrata
T. flocculosa

CRYPTOPHYCEAE
Chroomonas sp.
C. acuta
Cryptaulax rhomboidea
Cryptomonas sp.
C. erosa
C. erosa v. *reflexa*
C. marsonii

TABLE V-1 (Continued)

PHYTOPLANKTON SPECIES INVENTORY

- CRYPTOPHYCEAE (Continued)
  - *Cryptomonas obovata*
  - *C. ovata*
  - *C. phaseolus*
  - *C. platyuris*
  - *C. pusilla*
  - *C. reflexa*
  - *C. rotrata*
  - *Katablepharis ovalis*
  - *Rhodomonas minuta*
  - *R. minuta* v. *nannoplanctica*
  - *Sennia parvula*
  - UID Chryptophyte
- DINOPHYCEAE
  - *Amphidinium* sp.
  - *Ceratinum hirundinella*
  - *Glenodinium* sp.
  - *G. pulvisculus*
  - *Gymnodinium* sp.
  - *G. helveticum*
  - *G. ordinatum*
  - *G. varians*
  - *Peridinium* sp.
  - *P. aciculiferum*
  - *P. cinctum*
  - *P. cunningtonii*
  - *P. inconspicuum*

TABLE V-2

COLLECTION AND ANALYSES METHODS FOR PHYTOPLANKTON AND MICROZOOPLANKTON

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1973-1975

YEAR	TYPE	SAMPLING METHOD	ANALYSIS METHOD
1973	MICRO-lake	Vertical tows (12 cm net) 2 reps 76 µ net	Sedgewick-Rafter
	PHYTO-lake	1) 20 liters surf. water thru 28 µ net 2) Whole water (June-December)	Palmer-Maloney
1974	MICRO-lake	Vertical tows (76 µ Wisconsin Net)	Sedgewick-Rafter
	PHYTO-lake	Whole water	Palmer-Maloney
1975	MICRO-lake	Clarks-Bumpus 76 µ mesh	Sedgewick-Rafter
	PHYTO-lake	Whole water	Utermohl

TABLE V-3

ABUNDANCE AND BIOMASS OF WHOLE WATER PHYTOPLANKTON* AT 40-FT DEPTH CONTOUR BY TRANSECT

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1975

I. TOTAL PHYTOPLANKTON

DATE	NMPW		NMPP		FITZ		NMPE	
	No./ml	mg/m^3	No./ml	mg/m^3	No./ml	mg/m^3	No./ml	mg/m^3
29 APR	2517	1253.92	3443	2445.11	2670	1302.48	2279	1395.42
6 MAY	2593	418.20	2624	610.04	1937	416.20	3939	644.50
20 MAY	2667	532.09	4028	1527.01	4355	1299.81	3803	2095.35
10 JUN	42423	1924.82	30212	1186.02	16942	780.57	18037	908.94
24 JUN	36919	2060.78	30164	3019.80	17945	2198.33	14277	1276.12
8 JUL	71273	1165.04	50983	795.80	36125	598.94	23195	700.98
29 JUL	2847	566.50	9682	2091.33	13483	2223.00	9325	2538.28
4 AUG	17347	2945.92	12386	1524.61	5567	1213.91	6558	753.94
24 AUG	31342	2504.18	12799	314.47	15967	655.46	32501	1169.92
18 SEP	7672	394.76	6940	464.08	7043	831.83	5831	614.03
27 OCT	7414	1456.18	9008	1550.54	6635	1389.25	8656	1226.32
17 NOV	2171	612.25	2916	807.39	3060	594.34	2509	624.56
12 DEC	1796	413.35	1672	395.43	1855	429.47	1646	372.34
MEAN	17605	1249.84	13604	1287.05	10276	1071.74	10197	1101.59

II. DIATOMS

29 APR	1502	933.88	1667	2011.22	1298	871.21	920	826.57
6 MAY	377	162.36	473	237.38	339	286.63	414	206.00
20 MAY	448	127.99	2076	941.12	1835	984.33	1442	868.44
10 JUN	2483	738.06	408	236.95	525	351.32	763	239.44
24 JUN	300	167.65	125	111.76	113	115.74	75	45.93
8 JUL	173	238.39	85	57.86	93	47.73	25	3.43
29 JUL	62	45.44	1502	1120.20	1555	988.28	1050	697.65
4 AUG	405	338.47	324	207.85	4	2.94	32	9.26
24 AUG	208	166.49	45	11.37	40	15.29	430	165.43
18 SEP	250	61.06	169	34.11	308	147.48	235	82.84
27 OCT	522	371.49	420	275.49	361	289.01	529	264.88
17 NOV	219	249.90	263	203.01	318	203.51	134	106.01
12 DEC	123	205.24	230	172.12	183	199.77	144	154.36
MEAN	544	292.80	599	432.34	536	346.40	476	282.33

*Mean of original and replicate samples

TABLE V-3 (Continued)

ABUNDANCE AND BIOMASS OF WHOLE WATER PHYTOPLANKTON* AT 40-FT DEPTH CONTOUR BY TRANSECT

III. GREEN ALGAE

DATE	NMPW		NMPP		FITZ		NMPE	
	No./ml	mg/m^3	No./ml	mg/m^3	No./ml	mg/m^3	No./ml	mg/m^3
29 APR	382	28.80	645	29.20	394	34.97	377	35.63
6 MAY	432	21.64	374	36.81	285	12.40	336	14.23
20 MAY	1128	77.79	1506	82.46	1649	148.89	1453	102.27
10 JUN	4490	180.07	1170	70.88	828	48.72	1460	75.20
24 JUN	2040	121.30	2345	212.81	1743	153.66	615	63.71
8 JUL	1843	262.63	1545	182.35	920	153.77	795	191.47
29 JUL	429	40.74	2777	269.04	3097	316.46	2550	287.84
4 AUG	2334	420.44	2036	244.51	1379	175.00	2075	197.27
24 AUG	4055	386.38	1553	152.25	2338	225.76	3948	306.60
18 SEP	1012	92.50	1390	159.98	904	156.06	1310	182.85
27 OCT	1109	454.15	821	264.72	824	232.09	641	341.85
17 NOV	157	92.44	230	199.61	144	31.52	177	104.49
12 DEC	180	58.19	179	29.92	207	56.45	155	47.92
MEAN	1507	172.08	1275	148.81	1132	134.29	1222	150.10

IV. BLUE-GREEN ALGAE

29 APR	200	9.59	305	15.51	160	4.74	175	1.98
6 MAY	200	2.27	489	23.22	261	7.61	464	8.95
20 MAY	545	12.94	294	12.31	667	15.94	626	30.07
10 JUN	28740	112.80	23852	86.94	12500	64.68	11194	37.14
24 JUN	21267	42.11	9836	58.14	1848	10.70	2675	9.36
8 JUL	66218	28.26	47443	26.28	33198	21.95	19578	15.90
29 JUL	1460	0.70	4263	58.77	7547	65.89	3536	41.33
4 AUG	13132	195.91	8178	222.97	2465	43.25	2447	29.03
24 AUG	23414	100.05	8981	46.86	11199	50.13	23303	100.82
18 SEP	5616	43.76	4281	40.00	4023	27.27	2954	35.05
27 OCT	3767	75.00	5283	87.16	3626	41.65	5149	57.47
17 NOV	1126	21.66	1617	31.21	1814	46.73	1461	36.84
12 DEC	1036	8.88	867	6.65	1049	9.73	973	8.93
MEAN	12825	50.30	8899	55.08	6181	31.56	5733	31.76

*Mean of original and replicate samples

sample locations over the year) should be approached with caution for JAF. However, there is no trend for the FITZ transect for operational months when abundance was consistently high or low (Table V-3).

There was no significant difference in either the abundance (Table V-4) or the biomass (Table V-5) of the total phytoplankton among the four 40 ft sample locations, thus indicating the lack of any significant plant effect, in the operational year from JAF and NMP-1.

4. Diatoms

In 1975 there was no significant difference among the four sample locations (Table V-3), nor did the FITZ or NMPP locations exhibit trends of consistently high or low abundances. This demonstrates that operation of both NMP-1 and JAF did not measurably affect diatom abundances. Differences that exist in monthly abundances between locations is attributed to natural variability and patchiness in the light of definable trends.

There was a significant difference ($\alpha = .01$) in diatom biomass among transects in 1975 (Table V-5). The average diatom biomass at NMPP 40 ft stations exceeded those at the other transects. This difference was significant only on 29 April (Table V-5). A second peak in biomass occurred on 29 July at NMPP, FITZ and NMPE 40-ft stations (Table V-3).

April is the month of maximum diatom biomass and abundance at the NMPP transect was approximately two fold higher than at any of the other sample locations. This difference almost equals the next highest biomass of the year. Because biomass for the rest of the year at NMPP is not consistently high or low, we attribute the April difference to the patchy nature of phytoplankton. We also note that differences of the magnitude discussed above frequently occur between the two control or reference locations, NMPW and NMPE.

5. Green Algae

Green algal abundance was highest in July/August 1975 (Table V-3). The presence of large numbers of green algae in late summer is characteristic of algal populations in Lake Ontario (Ogawa, 1969; Munawar and Nauwerck, 1971), and has also been reported by Schelske et al. (1971) for Lake Michigan populations.

The biomass (mg/m^3) of green algae increased from April to May, fluctuated during the summer and declined in November and December 1975 (Table V-3). This pattern of green algal growth has been reported for those organisms by Patrick (1969).

TABLE V-4

STATISTICAL ANALYSIS OF PHYTOPLANKTON ABUNDANCE AT 40 FT STATIONS

JAMES A FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1975

I. TOTAL PHYTOPLANKTON

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	12	18.8468	1.5706	30.56**
TRANSECTS	3	0.1203	0.0401	0.78
ERROR	36	1.8519	0.0514	
WITHIN SAMPLES	52	0.5127	0.0099	
TOTAL	103	21.3317		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

	8	10	24	24	4	29	27	18	20	29	6	17	12		
Largest:	JUL	JUN	JUN	AUG	AUG	JUL	OCT	SEP	MAY	APR	MAY	NOV	DEC	:	Smallest

II. DIATOM

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	12	19.1972	1.5998	4.28**
TRANSECTS	3	0.5129	0.1710	0.46
ERROR	36	13.4425	0.3734	
WITHIN SAMPLES	52	2.6623	0.0512	
TOTAL	103	35.8149		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

	20	29	10	29	27	6	18	17	24	12	24	4	8		
Largest:	MAY	APR	JUN	JUL	OCT	MAY	SEP	NOV	AUG	DEC	JUN	AUG	JUL	:	Smallest

TABLE V-4 (Continued)

STATISTICAL ANALYSIS OF PHYTOPLANKTON ABUNDANCE AT 40 FT STATIONS

III. GREEN ALGAE

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	12	15.4986	1.2916	17.27**
TRANSECTS	3	0.1429	0.0476	0.64
ERROR	36	2.6912	0.0748	
WITHIN SAMPLES	52	1.0159	0.0195	
TOTAL	103	19.3486		

**Significant at α= .01

TUKEY T TEST - DATES (α= .05)

Largest: 24 AUG 29 JUL 4 AUG 10 JUN 24 JUN 20 MAY 8 JUL 18 SEP 27 OCT 29 APR 6 MAY 12 DEC 17 NOV : Smallest

IV. BLUE-GREEN ALGAE

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	12	46.0918	3.8410	41.43**
TRANSECTS	3	0.3066	0.1022	1.10
ERROR	36	3.3355	0.0927	
WITHIN SAMPLES	52	2.4413	0.0469	
TOTAL	103	52.1752		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

Largest: 8 JUL 12 JUN 24 AUG 24 JUN 4 AUG 27 OCT 18 SEP 29 JUL 17 NOV 12 DEC 20 MAY 6 MAY 29 APR : Smallest

TABLE V-5

STATISTICAL ANALYSIS OF PHYTOPLANKTON BIOMASS AT 40 FT STATIONS

JAMES A FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1975

I. TOTAL PHYTOPLANKTON

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	12	4.6639	0.3887	4.82**
TRANSECTS	3	0.0270	0.0090	0.11
ERROR	36	2.9007	0.0806	
WITHIN SAMPLES	52	0.3537	0.0068	
TOTAL	103	7.9453		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

	24	29	4	29	27	20	10	24	8	17	18	6	12	
Largest:	JUN	JUL	AUG	APR	OCT	MAY	JUN	AUG	JUL	NOV	SEP	MAY	DEC :	Smallest

II. DIATOM

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	3	0.6123	0.2041	0.40
TRANSECTS	12	21.5992	1.7999	3.51**
ERROR	36	18.4515	0.5125	
WITHIN SAMPLES	52	5.8904	0.1133	
TOTAL	103	46.5534		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

	29	20	29	10	27	6	17	12	4	24	24	8	18	
Largest:	APR	MAY	JUL	JUN	OCT	MAY	NOV	DEC	AUG	JUN	AUG	JUL	SEP:	Smallest

TABLE V-5 (Continued)

STATISTICAL ANALYSIS OF PHYTOPLANKTON BIOMASS AT 40 FT STATIONS

III. GREEN ALGAE

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	12	12.9641	1.0803	11.13**
TRANSECTS	3	0.0751	0.0250	0.26
ERROR	36	3.4966	0.0971	
WITHIN SAMPLES	52	1.3216	0.0254	
TOTAL	103	17.8574		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

	27	24	4	29	8	18	24	17	20	10	12	29	6	
Largest:	OCT	AUG	AUG	JUL	JUL	SEP	JUN	NOV	MAY	JUN	DEC	APR	MAY:	Smallest

IV. BLUE-GREEN ALGAE

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	12	16.4145	1.3679	4.89**
TRANSECTS	3	0.9954	0.3318	1.19
ERROR	36	10.0764	0.2799	
WITHIN SAMPLES	52	5.0044	0.0962	
TOTAL	103	32.4907		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

	4	10	24	27	29	18	17	24	8	20	6	12	29	
Largest:	AUG	JUN	AUG	OCT	JUL	SEP	NOV	JUN	JUL	MAY	MAY	DEC	APR:	Smallest

There were no significant differences in biomass or abundances at the 40 ft locations in 1975 (Tables V-4 and V-5). Also, there were no trends of consistently high or low abundances. These two considerations lead us to conclude that operation of both plants has not effected green algae abundance.

6. Blue-green Algae

Blue-green algae are characterized as having rapid growth in warm and nutrient-rich waters. They were abundant at the 40-ft stations in June, July and August (Table V-3) throughout the summer in 1975.

Blue-green algae were reported to be the dominant phytoplankton in Lake Michigan in late August and early September (Schelske et al., 1971), a pattern similar to that found in the study area. These authors attributed the blue-green algal peaks to increased nutrient concentrations.

There was no significant difference among the four sample locations in either abundance (Table V-4) or biomass (Table V-5) of blue-green algae. This indicates that neither the NMP-1 discharge nor the JAF discharge significantly influenced the abundance of blue-green algae at the 40 ft stations of any of the transects. This conclusion, with the reservation that JAF was not operating early in the year, is none the less very important in that the plant was operating at greater than 50% capacity July, August and September when a stimulatory effect on blue-green algae and inhibition of other phyla could occur.

a. Effect of Plume Entrainment on Phytoplankton Productivity

If plume entrainment was measurably affecting the algal community, both primary production and/or standing stock could be atlered; increases, decreases, or no change in these parameters is possible. The effect of plume entrainment was tested by comparing production rates (mg C assimilated/m^3/hr) and standing stock (μg chlorophyll a/1) in the plume, both actual and simulated, to values at the intake. In that chlorophyll a is rapidly reduced to phaeopigments on cell death, this parameter can also be used to estimate phytoplankton assemblage viability. These experiments were conducted from May through September 1976 according to the following design.

Whole water intake samples for plume and plant entrainment analyses were obtained by submerged pump from the intake forebay and discharge aftbay during the entire sampling period, May through September (Table V-6). Samples for determination of plume effects were either obtained from the surface waters within the approximate 3 and 2°F isotherms of the plume (2 and 3°F lake samples) with a Van Dorn

TABLE V-6

PLANT LOAD AND TEMPERATURE RISE AT TIME OF SAMPLING

JAMES A. FITZPATRICK NUCLEAR POWER PLANT - 1976

DATE	HOUR	AVERAGE LOAD/DAY (MWe)	ΔT (°C) AT TIME OF INTAKE OF SAMPLE
12 MAY	0958	737	14.4
26 MAY	1012	781	15.5
9 JUN	1021	693	12.9
23 JUN	1018	446	15.8
20 JUL	1019	721	14.2
29 JUL	1016	543	13.6
11 AUG	0951	771	15.1
25 AUG	0950	789	15.0
8 SEP	1000	785	15.8
22 SEP	1038	730	14.4

*Samples for chlorophyll a analysis were taken at night under similar ΔT conditions on each date, except that the June night sample was taken on 28 June.

water sampler or were simulated by dilution of discharge samples, obtained from the discharge aftbay, with intake sample water to represent both plant and plume entrainment to the 3 and 2°F isotherms. During the period May through June the dilution ratios used in the simulations were designed to reduce the measured temperature difference between intake and discharge to 3 and 2°F, depending on the plume effect being simulated. The dilution during this period was done with a single instantaneous addition of intake water to the discharge sample. For the period July through September, the dilution scheme was changed to a time series of dilutions, designed to simulate the time-temperature regime of plume organisms. The times of travel to the temperature rises above 2°F were doubled (see Chapter IV), to insure maximum exposure of the organisms. Due to the length of the estimated time interval to the 2°F isotherm, a time period of 5 minutes was allowed between the 3 and 2°F simulated temperature rises.

After simulation on lake collection, samples were transported back to the laboratory where they were incubated at 1000 ft/candles for four hours. Primary production rates and chalorophyll a concentrations at the experimental locations (3 and 2° isotherms) were divided by the control (intake forebay) rates to provide an index of entrainment effects. When the index equals one, no effects are noted and rates in excess of one suggests a stimulatory effect.

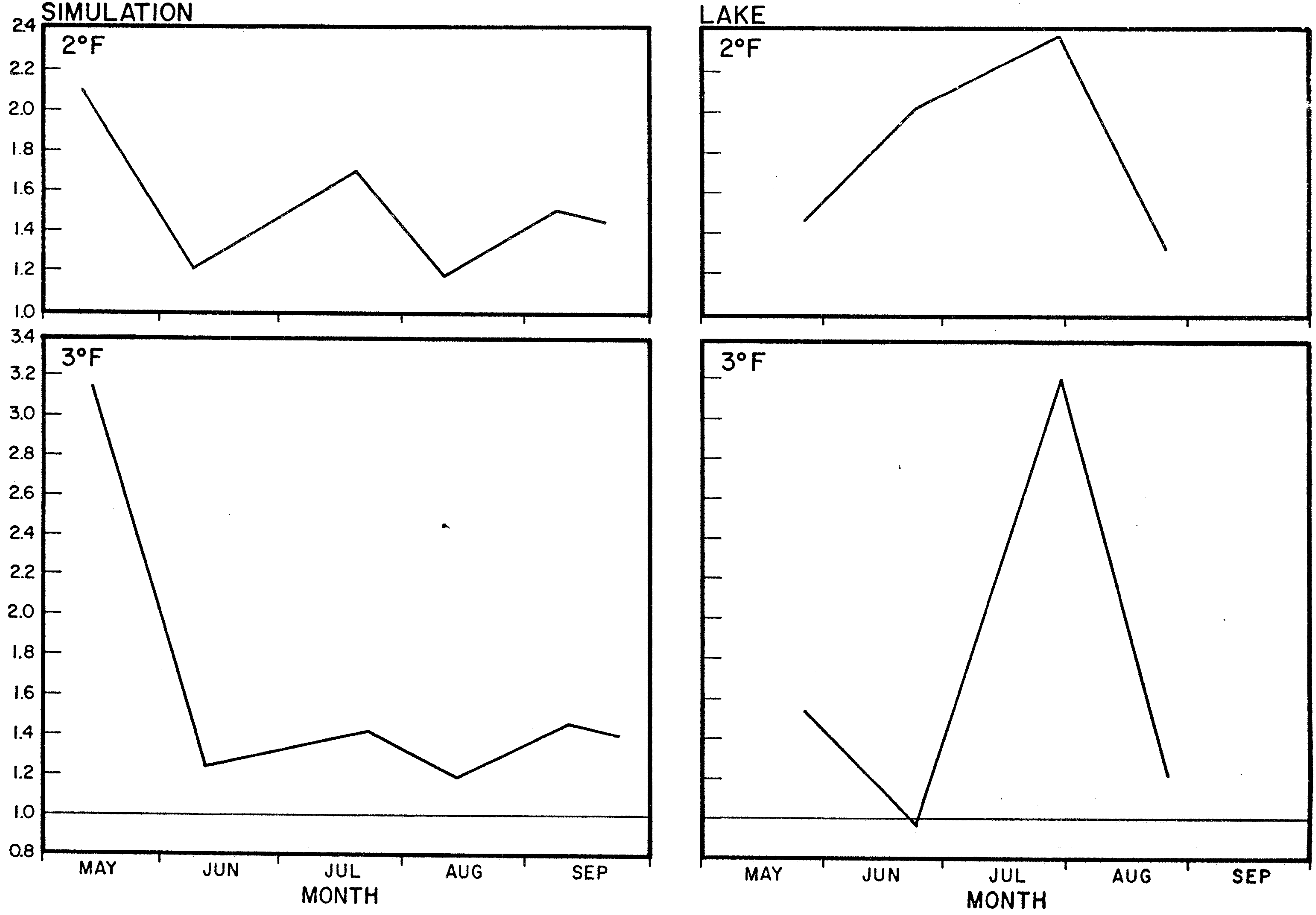
Since all discharge samples used in the simulations were held at discharge temperature for the travel time from the discharge bay to the lake discharge, the only possible effects that are not simulated are those effects, if any, caused by pressure change and mechanical damage in the discharge tunnel system.

With one exception, primary production rates in the plume were greater than at the intake (Figure V-4) for both actual and simulation experiments, indicating that during the warmer months of the year the net effect of phytoplankton entrainment is stimulation of primary production. The mean stimulation factors were similar (between 1.5 and 1.8) among the four treatments over comparable months, suggesting that the variation in ΔT's and ambient had little influence on the results. Lake samples exhibited more variability and increased stimulation than simulated samples which suggests that there may be natural differences between intake and surface samples, since intake water is withdrawn from near the bottom in 25 ft of water. This implies that the simulation studies may be more representative of plume entrainment effects.

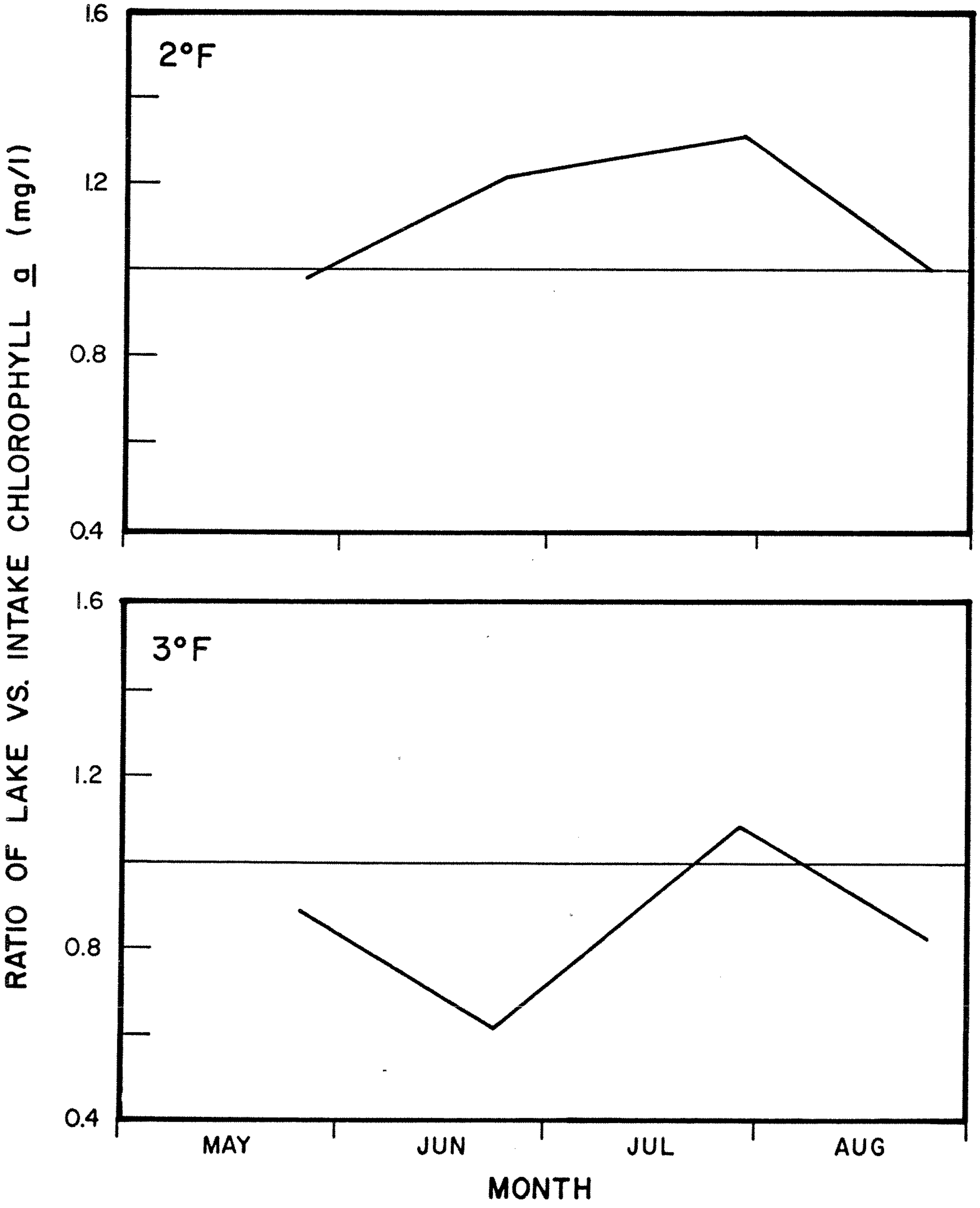
Chlorophyll a values tended to be equal or greater at the 2°F isotherm in the lake than at the intake, but lower at the 3°F than at the intake (Figure V-5). The magnitudes, of difference were,

FIGURE V-4

RATIO OF PLUME VS. INTAKE PRIMARY PRODUCTION
JAMES A. FITZPATRICK NUCLEAR POWER PLANT — MAY-SEPTEMBER 1976



RATIO OF LAKE
VS.
INTAKE CHLOROPHYLL a
JAMES A. FITZPATRICK NUCLEAR POWER PLANT — MAY-AUGUST 1976



however, generally less than ±20%. The simulation experiments showed similar results except there was no consistent trend in plume to intake ratios (Figure V-6).

Overall, then the data indicate net stimulation of primary production, primarily in the plume. No consistent change in standing stock was noted along with no substantive mortality during the warmer months of the year. Chlorophyll a concentrations suggest that it will not be possible to detect differences in standing crop outside the immediate discharge area.

Conclusion

The preceding analyses yielded no evidence of plant-induced depression or enhancement of total phytoplankton, diatoms, green algae or blue-green algae in 1975. Results of the entrainment studies support this conclusion in that it was determined that it will probably not be possible to detect changes in chlorophyll a outside the immediate discharge area. There is, however, an increase in primary production in the plume.

7. Zooplankton

For the purposes of this study the zooplankton community is divided into two subcategories according to the size of the organisms. Those collected by and retained in a 76µ mesh net are microzooplankton, while macrozooplankton are defined as those zooplanktonic organisms retained by a 571µ mesh net. Two different mesh sizes were used to facilitate the collection of organisms of different sizes.

a. Microzooplankton

The species constituting the microzooplankton assemblage in the vicinity of JAF in 1974 and 1975 are listed in Table V-7. Four major taxonomic groups - rotifers, cladocerans, copepods and protozoans - made up the bulk of the microzooplankton community in the study area in both 1974 and 1975 (LMS, 1975; LMS, 1976).

Total abundance, species composition and patterns of distribution of the four major groups followed a seasonal cycle that was most influenced by meteorological parameters. The highest densities of total microzooplankton were observed during the June-July period, with a maximum concentration of 1,000,000 organisms/m^3 reached on 8 July 1975 (Table V-8).

Rotifers were abundant at all depth contours, increasing from 20,000 organism/m^3 in May 1975 to 700,000 organism/m^3 in July

RATIO OF PLUME VS. INTAKE CHLOROPHYLL a

JAMES A. FITZPATRICK NUCLEAR POWER PLANT — MAY-SEPTEMBER 1976

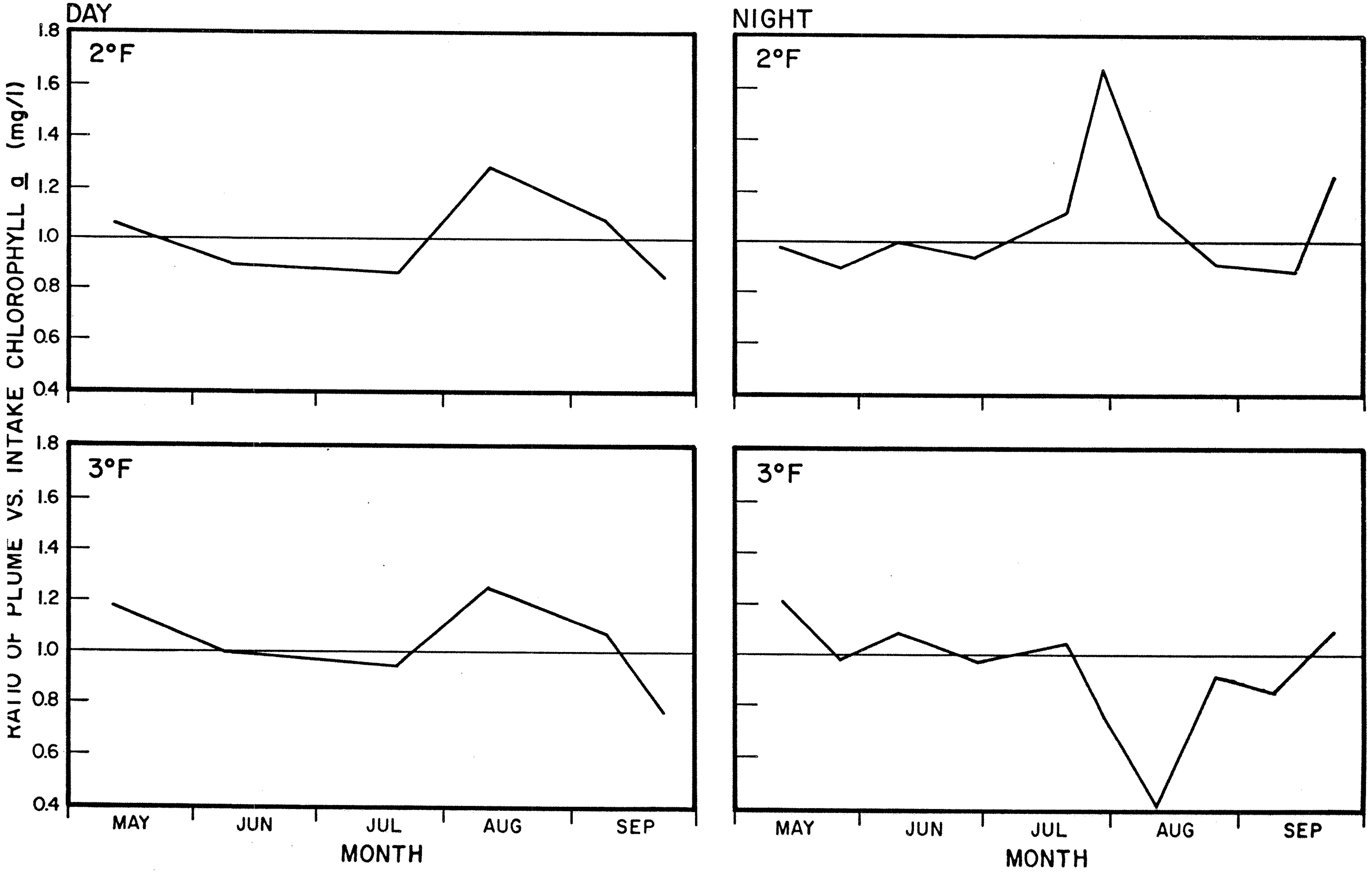


FIGURE V-6

TABLE V-7

MICROZOOPLANKTON SPECIES INVENTORY[a]

NINE MILE POINT VICINITY - 1974-1975

- PROTOZOA
  - Lobosa
    - Testacealobosa
      - Difflugiidae
        - *Difflugia* sp.
  - Suctoria
    - Tentaculiferida
      - Acinetidae
        - *Acineta* sp.
        - *Thecacineta* sp.
        - *Tokophyra* sp.
      - Dendrosomidae
        - *Staurophyra elegans*
      - Podophryidae
        - *Paracineta* sp.
  - Ciliata
    - Spirotrichida
      - Tintinnidae
        - *Codonella cratera*
    - Peritrichida
      - Epistylidae
        - *Epistylis* sp.
      - Vaginocolidae
      - Vorticellidae
        - *Vorticella* sp.
    - Holotrichida
      - Gymnostomina[b]

- ROTIFERA
  - Bdelloidea
  - Monogononta
    - Ploima
      - Brachionidae
        - *Brachionus* sp.
        - *B. angularis*
        - *B. budapestinensis*
        - *B. calyciflorus*
        - *B. caudatus*
        - *B. havanaenis*
        - *B. quadridentatus*
        - *B. urceolaris*
        - *Euchlanis* sp.
        - *E. dilatata*
        - *Kellicottia bostoniensis*
        - *K. longispina*
        - *Keratella* sp.

- ROTIFERA (Continued)
        - *K. cochlearis*
        - *K. crassa*
        - *K. earlinae*
        - *K. quadrata*
        - *K. valga*
        - *Lepadella* sp.
        - *Notholca* sp.
        - *N. acuminata*
        - *N. squamula*
        - *N. striata*
        - *Platyas patulus*
        - *Trichotria* sp.
      - Lecanidae
        - *Lecane* sp.
      - Notommatidae
        - *Cephalodella* sp.
        - *Monostyla* sp.
      - Trichocercidae
        - *Ascomorpha* sp.
        - *A. eucaudis*
        - *Trichocerca* sp.
        - *T. cylindrica*
        - *T. multicrinis*
        - *T. porcellus*
        - *T. similis*
      - Gastropidae
        - *Chromogaster ovalis*
      - Asplanchnidae
        - *Asplanchna* sp.
        - *A. priodonta*
      - Synchaetidae
        - *Ploesoma* sp.
        - *P. hudsoni*
        - *P. lenticulare*
        - *P. truncatum*
        - *Polyarthra* sp.
        - *P. dolichoptera*
        - *P. euryptera*
        - *P. major*
        - *P. remata*
        - *P. vulgaris*
        - *Synchaeta lackowitziana*
        - *S. pectinata*
        - *S. stylata*
        - *S. tremula*

TABLE V-7 (Continued)

MICROZOOPLANKTON SPECIES INVENTORY [a]

- ROTIFERA (Continued)
  - Testudinellidae
    - *Filinia longiseta*
  - Hexarthridae
    - *Hexarthra* sp.
  - Conochilidae
    - *Conochiloides* sp.
    - *Conochilus* sp.
    - *C. unicornis*
  - Collothecidae
    - *Collotheca mutabilis*

- ARTHROPODA
  - Crustacea
    - Cladocera
      - Bosminidae
        - *Bosmina* sp.
        - *B. coregoni*
        - *B. longirostris*
      - Chydoridae
        - *Alona affinis*
        - *Chydorus sphaericus*
      - Daphnidae
        - *Ceriodaphnia lacustris*
        - *C. quadrangula*
        - *Daphnia* sp.
        - *D. galeata mendotae*
        - *D. longiremus*
        - *D. retrocurva*
      - Holopedidae
        - *Holopedium gibberum*
      - Sididae
        - *Diaphanosoma leuchtenbergianum*
    - Copepoda[c]
      - Copepoda nauplii
      - Calanoida
        - Diaptomidae
          - *Diaptomus* sp.
          - *D. minutus*
        - Centropagidae
          - *Limnocalanus macrurus*
        - Temoridae
          - *Eurytemora affinis*

- ROTIFERA (Continued)
  - Calanoida juvenile
  - Cyclopoida
    - Cyclopidae
      - *Acanthocyclops vernalis*
      - *Diacyclops bicuspidatus thomasi*
      - *Mesocyclops edax*
      - *Tropocyclops prasinus mexicanus*
    - Cyclopoida juvenile
  - Harpacticoida
    - Harpacticoida juvenile

---

[a] Subject to corrections

[b] Suborder

[c] Subclass

TABLE V-8

ABUNDANCE* OF MICROZOOPLANKTON AT FITZ-40 FT STATION

JAMES A FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1973-1975

I. TOTAL MICROZOOPLANKTON

1973		1974		1975	
DATE	No./m^3	DATE	No./m^3	DATE	No./m^3
		26 APR	76170	29 APR	NS
		11 MAY	272470	6 MAY	81304
16 MAY	3165	22 MAY	NS	20 MAY	704490
		6 JUN	380900	10 JUN	1261076
15 JUN	631	28 JUN	322930	24 JUN	478066
20 JUL	1489338	15 JUL	1285810	8 JUL	1488990
26 JUL	1792795	29 JUL	421770	29 JUL	232052
13 AUG	290541	8 AUG	583880	4 AUG	906602
23 AUG	428819	22 AUG	476790	24 AUG	48032
20 SEP	189843	27 SEP	99410	18 SEP	225810
25 OCT	348154	24 OCT	266550	27 OCT	157612
20 NOV	200273	27 NOV	78790	17 NOV	110064
		12 DEC	72320	12 DEC	NS
MEAN	527062		361483		517646

II. ROTIFERA

1973		1974		1975	
		26 APR	65960	29 APR	NS
		11 MAY	180260	6 MAY	26372
16 MAY	3165	22 MAY	NS	20 MAY	600458
		6 JUN	250915	10 JUN	1157090
15 JUN	631	28 JUN	291685	24 JUN	406878
20 JUL	886510	15 JUL	887000	8 JUL	1131100
26 JUL	50686	29 JUL	503650	29 JUL	100406
13 AUG	147271	8 AUG	446050	4 AUG	374318
23 AUG	316752	22 AUG	239600	24 AUG	37232
20 SEP	123909	27 SEP	15585	18 SEP	50216
25 OCT	87685	24 OCT	194550	27 OCT	101496
20 NOV	40202	27 NOV	49485	17 NOV	34456
		12 DEC	46800	12 DEC	NS
MEAN	184090		264295		365456

III. CLADOCERA

1973		1974		1975	
		26 APR	310	29 APR	NS
		11 MAY	355	6 MAY	0
16 MAY	0	22 MAY	NS	20 MAY	0
		6 JUN	3130	10 JUN	6732
15 JUN	0	28 JUN	10540	24 JUN	20490
20 JUL	330509	15 JUL	147800	8 JUL	260028
26 JUL	983561	29 JUL	42865	29 JUL	30634
13 AUG	36281	8 AUG	144250	4 AUG	183360
23 AUG	59350	22 AUG	13165	24 AUG	2418
20 SEP	3828	27 SEP	26190	18 SEP	95954
25 OCT	214539	24 OCT	35350	27 OCT	28830
20 NOV	116817	27 NOV	10960	17 NOV	35236
		12 DEC	2495	12 DEC	NS
MEAN	249269		36451		60334

*Mean of original and replicate samples
NS - No sample

TABLE V-8 (Continued)

ABUNDANCE* OF MICROZOOPLANKTON AT FITZ-40 FT STATION

IV. COPEPODA

1973		1974		1975	
DATE	No./m^3	DATE	No./m^3	DATE	No./m^3
		26 APR	8970	29 APR	NS
		11 MAY	1185	6 MAY	2824
16 MAY	0	22 MAY	NS	20 MAY	10564
		6 JUN	40705	10 JUN	23768
15 JUN	0	28 JUN	9640	24 JUN	26772
20 JUL	113504	15 JUL	37880	8 JUL	49584
26 JUL	302449	29 JUL	59275	29 JUL	75152
13 AUG	106990	8 AUG	58290	4 AUG	226704
23 AUG	52717	22 AUG	129900	24 AUG	8382
20 SEP	62107	27 SEP	54255	18 SEP	58736
25 OCT	45931	24 OCT	48840	27 OCT	18872
20 NOV	43279	27 NOV	17420	17 NOV	36282
		12 DEC	14330	12 DEC	NS
MEAN	103854		40058		48876

*Mean of original and replicate samples
NS - No sample

of the same year before they declined throughout the rest of the year. Copepod abundance increased from less than 10,000 organisms/m^3 in May 1975 to more than 50,000 organisms/m^3 in August 1975. Cladocerans, represented primarily by Bosmina longirostris, increased in abundance at all depths from 1,000 organism/m^3 in April and May to 100,000 organism/m^3 in July 1975 (Table V-8).

Of the four major taxonomic groups rotifers, composed the largest portion of the microzooplankton community in the area in 1974 and 1975. The same observation was made during the studies conducted in 1973 (QLM, 1974). Rotifer abundance varied from 6 to 97% of the total organisms collected on a given sampling date and they were represented by as many as 50 species (LMS, 1976). Keratella, Polyarthra and Synchaeta were the most abundant rotifer genera, and rotifer species occurring throughout the 1975 sampling period were Brachionus angularis and Kellicottia longispina. Seasonal shifts in the dominant rotifer taxa were evident, however; for example, from April through May 1975, Synchaeta tremula was dominant, while from 10 June through 8 July Keratella quadrata, Asplanchna priodonta and Ploesoma truncatum were dominant.

Cladocerans made up the second highest percentage of the total microzooplankton community present in the study area, being represented by 9 genera in 1974 and 8 genera in 1975 (9 genera in 1973). A species which occurred throughout the 1975 sampling program was Bosmina longirostris. The seasonal pattern of cladoceran abundance was bimodal, the first mode occurring in July while the second was observed in the October-November period (LMS, 1975). Bosmina longirostris was dominant between 10 June and 8 July 1975, and from 29 July through 18 September 1975. Storr (1971) found B. longirostris to be the dominant cladoceran in Lake Ontario with peak abundance in the late summer/early fall period. Daphnia was the most abundant cladoceran during the spring of 1974 in the Nine Mile Point vicinity.

Copepods, adult forms and nauplii were abundant in spring and late summer, respectively. Copepods in the study area exhibited a cyclic distributional pattern similar to that reported for cladocerans (LMS, 1975). Copepods made up 10-20% of total microzooplankton community abundance (LMS, 1975). The copepod Diacyclops bicuspidatus was collected throughout the sampling period in 1975.

Protozoa, represented by 8-10 genera in 1974-1975, showed higher variability in abundance and species composition than the other three major groups found in the vicinity of JAF. Protozoa were present in highest abundance in summer and lowest abundance in winter (LMS, 1975); the protozoan Codonella cratera was collected throughout the 1975 sampling program (LMS, 1976) while Staurophyra elegans showed a seasonal cycle, being abundant in spring/early summer.

The abundance and distribution of rotifers, copepods, cladocerans and protozoans is largely dependant on seasonal meteorological factors, particularly wind as it effects lake currents and upwellings. The seasonal patterns of abundance of microzooplankton in the Nine Mile Point vicinity were similar to those described by Gachter et al. (1974) and Glooschenko et al. (1972) for Lake Ontario communities. There was no apparent changes in the microzooplankton community composition between 1973 and 1975 in the study area.

Because of the elevated water temperature induced by JAF discharge, the major components of the microzooplankton community collected at the 40-ft stations were analyzed for differences within 1975 and at the FITZ 40-ft location only for differences between years (1973-1975). Differences in collection techniques occurred over the years. However, net size remained constant and thus differences were not considered to be as significant as for phytoplankton where similar analyses were not undertaken.

(i) Total Microzooplankton

Strong similarities existed in total microzooplankton abundance (number/m^3) among years (Table V-8). Peak abundance occurred in July of all three years, and the mean annual abundance of total microzooplankton was similar among years, although there was some seasonal variability. The maximum abundance of microzooplankton reported in 1973 occurred on 20-26 July (Table V-8). The peak abundance observed for microzooplankton in 1975 occurred on 8 July at NMPW, NMPP and FITZ 40-ft stations and on 24 June at NMPE transect (Table V-9). The magnitudes of the maxima at NMPW, NMPP and NMPE in 1975 were similar but greater than that of FITZ transect. However, an analysis of variance (ANOVA) indicated that there was no significant difference in the average abundance of microzooplankton among transects (Table V-10).

(ii) Rotifera

Annual peaks in rotifer density (number/m^3) at the FITZ 40-ft station occurred in July of 1973, 1974 and 1975 (Table V-8), although they were observed on slightly different dates among years (20, 15 and 8 July in 1973, 1974 and 1975, respectively). The magnitude of the 1973 peak was greater than that of 1974 but lower than that of 1975. Mean annual rotifer densities in 1973 and 1974 were smaller than those found in

TABLE V-9

ABUNDANCE OF MICROZOOPLANKTON* AT 40-FT DEPTH CONTOUR BY TRANSECT

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1975

I. TOTAL MICROZOOPLANKTON

DATE	NMPW No./m^3	NMPP No./m^3	FITZ No./m^3	NMPE No./m^3
29 APR	46958	49176	NS	88685
6 MAY	50867	45393	40652	34501
20 MAY	254598	180016	352245	384163
10 JUN	341774	416761	630538	320418
24 JUN	380295	337113	239033	1041265
8 JUL	1128360	1386429	744495	599855
29 JUL	250015	180853	116026	239986
4 AUG	545086	915776	453301	324883
24 AUG	115773	63442	24016	56120
18 SEP	65782	83720	112905	132598
27 OCT	54015	116253	78806	94017
17 NOV	57001	72055	55032	52874
12 DEC	NS	NS	NS	24445
MEAN	274210	320582	258823	261062

II. ROTIFERA

29 APR	8484	10780	NS	28171
6 MAY	15777	19297	13186	17101
20 MAY	190744	125204	300229	299320
10 JUN	306735	405049	578545	311705
24 JUN	311868	304766	203439	906712
8 JUL	914138	1103426	565550	451162
29 JUL	61898	81325	50203	108435
4 AUG	309432	460621	187159	126110
24 AUG	94431	43706	18616	39122
18 SEP	12542	19782	25108	43662
27 OCT	32161	66247	50748	42896
17 NOV	24157	23800	17228	16005
12 DEC	NS	NS	NS	7853
MEAN	190197	222000	182728	184481

*Mean of original and replicate samples; multiply each number by 2 for correction factor

NS - No sample

TABLE V-9 (Continued)

ABUNDANCE OF MICROZOOPLANKTON* AT 40-FT DEPTH CONTOUR BY TRANSECT

III. CLADOCERA

DATE	NMPW No./m^3	NMPP No./m^3	FITZ No./m^3	NMPE No./m^3
29 APR	0	0	NS	690
6 MAY	109	265	0	252
20 MAY	0	0	0	247
10 JUN	2477	519	3366	384
24 JUN	12175	9778	10245	25709
8 JUL	152290	243985	130014	110854
29 JUL	42850	40669	15317	53426
4 AUG	90697	231881	91680	46928
24 AUG	4416	3108	1209	1987
18 SEP	8789	19956	47977	29979
27 OCT	9514	24040	14415	23739
17 NOV	15654	23263	17618	11348
12 DEC	NS	NS	NS	3822
MEAN	28248	49789	30167	23797

IV. COPEPODA

29 APR	984	2456	NS	8233
6 MAY	1699	2251	1412	4064
20 MAY	6494	1671	5282	11665
10 JUN	8050	5097	11884	6167
24 JUN	15118	13063	13386	39147
8 JUL	49231	35195	24792	14298
29 JUL	31998	41736	37576	45596
4 AUG	106433	161901	113352	71554
24 AUG	16926	14500	4191	10091
18 SEP	36561	30413	29368	34421
27 OCT	9635	19562	9436	18676
17 NOV	15731	19220	18141	19352
12 DEC	NS	NS	NS	12632
MEAN	24905	28922	24438	22761

*Mean of original and replicate samples; multiply each number by 2 for correction factor

NS - No sample

1975 due to the use of Clarke Bumpus nets in 1975 instead of Wisconsin nets in 1973-1974 (Table V-2).

The rotifer abundance at 40-ft stations at all transects in the Nine Mile Point vicinity exhibited a multi-modal distribution in 1975 (Table V-9), with peaks in June, July and August. Analysis of variance (Table V-10) indicated the lack of any significant difference in average abundance of rotifers at 40-ft stations of all transects in 1975.

(iii) Cladocera

Cladocera were abundant during the July-August period of 1973, 1974 and 1975 (Table V-8). These organisms followed the same seasonal pattern of abundance as the rotifers, with July peaks observed during for 1973, 1974 and 1975. This observation is similar to the finding of Murarka (1976) regarding peak abundance of cladocerans in Lake Michigan.

The July maxima in cladoceran abundance among years were not of comparable magnitude; more cladocerans were collected at FITZ 40-ft stations in July 1973 than in July of either 1974 or 1975 (Table V-8). LMS (1976) found that temporal variations in zooplankton distribution were more pronounced than spatial variation.

On the average, there was an increase in the number of cladocerans from 1974 to 1975. This increase in connection with higher abundances in 1973 implies that differences between years is due to natural variation.

Abundance data from 1975 for all 40-ft stations showed that the maximum annual density at all transects occurred on 8 July (Table V-9). The heights of the peaks varied slightly, being greater at NMPW and NMPP than at FITZ and NMPE transects. The difference in the average abundance of cladocerans among transects in 1975 was examined statistically (ANOVA) in order to detect any significant effect that could have resulted from the plant-heated plume. The results indicated that there was no significant difference in cladocera density among the four transects (Table V-10). Thus, any effects induced by the JAF discharge were undetectable statistically. An examination of the data also shows no trends for either the NMPP or FITZ locations in which abundance was consistently high or low. This conclusion supports the previous contention that differences between years is due to natural variation.

TABLE V- 10

STATISTICAL ANALYSIS OF MICROZOOPLANKTON ABUNDANCE AT FITZ-40 FT STATION

JAMES A FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1975

I. TOTAL MICROZOOPLANKTON

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	10	16.7465	1.6747	27.10**
TRANSECTS	3	0.1243	0.0414	0.67
ERROR	30	1.8534	0.0618	
WITHIN SAMPLES	44	0.0623	0.0014	
TOTAL	87	18.7865		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

```
            8   4  24  10  20  29  18  27  17  24   6
Largest:  JUL AUG JUN JUN MAY JUL SEP OCT NOV AUG MAY :  Smallest
          ---------------
              ---------------
                  ---------------
                              -----------
                                  -------------------
```

II. ROTIFERA

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	10	27.5752	2.7575	36.05**
TRANSECTS	3	0.1582	0.0527	0.69
ERROR	30	2.2963	0.0765	
WITHIN SAMPLES	44	0.0902	0.0021	
TOTAL	87	30.1199		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

```
            8  10  24   4  20  29  27  24  18  17   6
Largest:  JUL JUN JUN AUG MAY JUL OCT AUG SEP NOV MAY :  Smallest
          ---------------
              ---------------
                          -------
                              -----------
                                  -------------------
```

TABLE V-10 (Continued)

STATISTICAL ANALYSIS OF MICROZOOPLANKTON ABUNDANCE AT FITZ-40 FT STATION

III. CLADOCERA

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	10	188.1013	18.8101	29.24**
TRANSECTS	3	0.4668	0.1556	0.24
ERROR	30	19.3000	0.6433	
WITHIN SAMPLES	44	16.3024	0.3705	
TOTAL	87	224.1705		

**Significant at α= .01

TUKEY T TEST - DATES (α= .05)

```
            8   4  29  18  27  17  24  24  10   6  20
Largest:  JUL AUG JUL SEP OCT NOV JUN AUG JUN MAY MAY :  Smallest
          ---------------------------
                  -----------------------
                                      -------
                                          -------
                                              -------
```

IV. COPEPODA

NESTED ANALYSIS OF VARIANCE
(Log Transformed)

SOURCE	DF	SS	MS	F
BETWEEN SAMPLES				
DATES	10	17.4566	1.7457	21.45**
TRANSECTS	3	0.2006	0.0669	0.82
ERROR	30	2.4417	0.0814	
WITHIN SAMPLES	44	0.3636	0.0083	
TOTAL	87	20.4625		

**Significant at α = .01

TUKEY T TEST - DATES (α = .05)

```
            4  29  18   8  24  17  27  24  10  20   6
Largest:  AUG JUL SEP JUL JUN NOV OCT AUG JUN MAY MAY:  Smallest
          -------
              -----------------------
                      -------------------
                          -------------------
                                  ---------------
                                              -------
```

(iv) Copepoda

Copepoda (adults and nauplii) made up a sizable portion of the zooplankton community at the 40-ft stations of FITZ transect in 1973, 1974 and 1975. A July abundance maximum can be seen in 1973, but not in 1974-1975 (Table V-8). In the latter two years, maximum abundance occurred in August (22 and 4 August in 1974 and 1975, respectively); however, in both 1974 and 1975, copepod density (number/m^3) increased sharply in late July (on 29 July). The fall peak, which was smaller in magnitude, was observed in 1973 (20 November), 1974 (27 November) and 1975 (17 November). It follows that there was no apparent shift in the time of occurrence of the fall peak between preoperational and operational periods for JAF.

Maximum copepod density occurred on 4 August 1975 at the plants transects (NMPP and FITZ), as well as at the control transects (NMPW and NMPE) (Table V-9). No significant differences were found in mean copepod density (Table V-10).

b. Cluster Analysis of Microzooplankton Distribution

The spatial and temporal distribution of selected taxa including total copepods, total rotifers, Bosmina longirostris (a cladoceran), as well as, total microzooplankton was examined using cluster analysis to determine if their distributions among sampling stations reflects the influence of the thermal plume. The stations near the power plant discharge variously had higher, lower and similar abundances with stations distant from the discharge. There was no consistently recurring distribution pattern which might suggest plant effects. The variations in abundance were attributed primarily to seasonal factors and meteorological conditions (LMS, 1976).

c. Effect of Plume Entrainment on Microzooplankton Survival

Microzooplankton mortality was measured for intake forebay samples, and discharge aftbay samples collected with a pump (1.26 liter/sec capacity at a 6.4 m head) discharged into a 1/2 meter 76µ mesh net. Pumping time ranged from 5 to 15 minutes per sample. From May through June 1976 some microzooplankton samples collected at the discharge were immediately diluted to 2 or 3°F above intake temperature with intake forebay water after a holding time representing discharge tunnel transit time. Microzooplankton samples were also collected monthly in the lake at the approximate 3 and 2°F isotherms. Beginning in July this procedure was changed and intake samples were added to filtered discharge water by means of several serial dilutions to represent only plume entrainment mortality. The dilution occurred over an interval that was twice the predicted time of entrainment in case the model did not correctly estimate the actual time-temperature relationship. This change in procedure was necessary because in the original experimental design concentrated microzooplankton discharge samples were diluted with unconcentrated intake water. This technique resulted in high densities of plant entrained organisms in comparison to simulated plume entrained organisms which effectively precluded any evaluation of plume entrainment.

The percent mortality for the various sampling collections and simulations were plotted for the study period for total zooplankton and protozoa, rotifera, total copepods and cladoceran. Day and night collections and simulations were plotted separately. A comparison of the percent mortality for the intake samples with various simulation and lake conditions provides a measure of the affect of plume and plume plus plant entrainment. One would expect that if there were significant mortality due to plume or plant entrainment, the percent mortality for the simulations and lake collections would exceed the percent mortality in the intake collections.

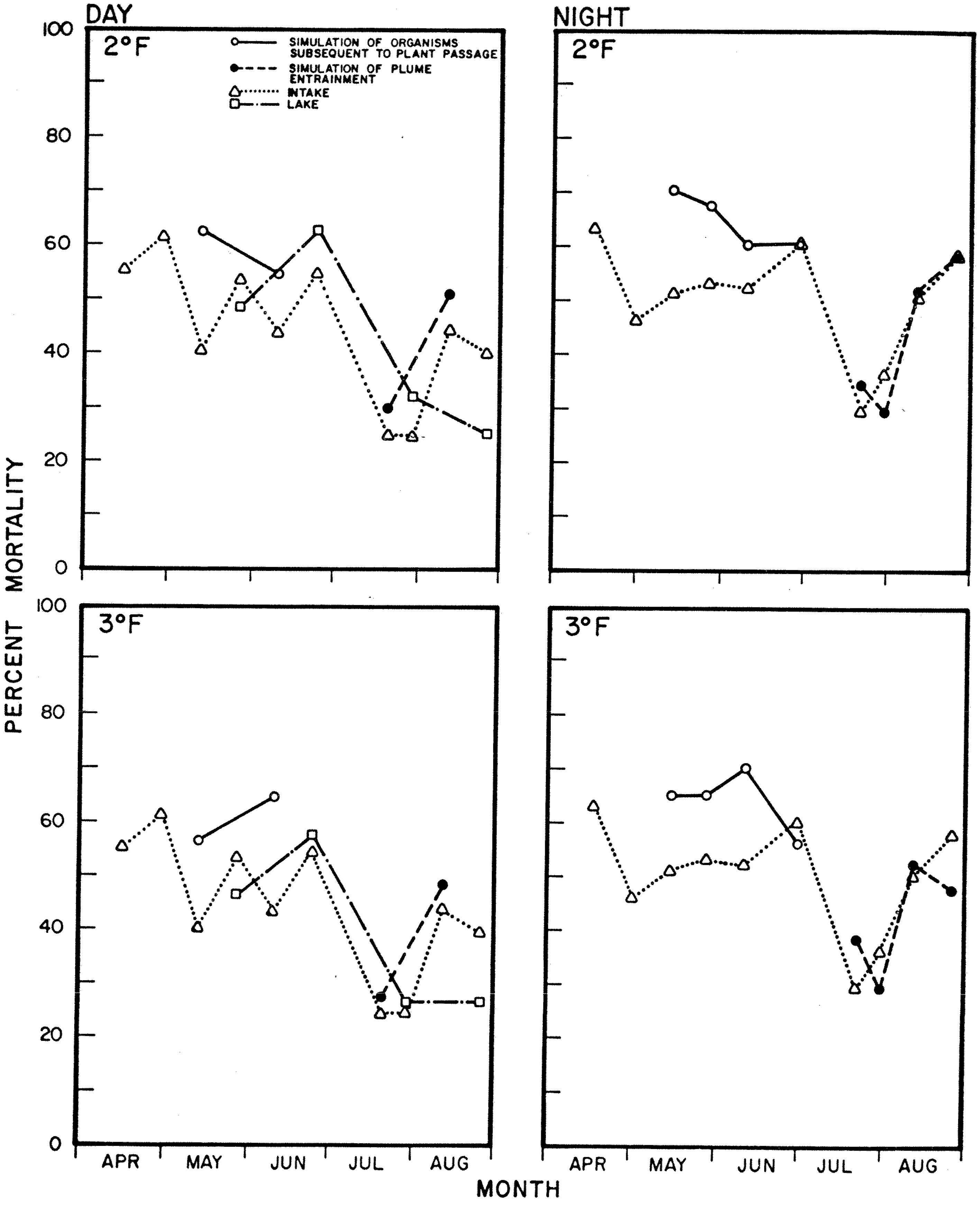
The percent mortality for total microzooplankton in the intake sample was quite varied throughout the study period (April through August) (Figure V-7). The percent mortality for simulations without plant passage and the lake collections show a similar variability and are generally close to intake values. This indicates that plume entrainment does not inflict any substantial mortality on zooplankton. The percent mortality in simulations following plant passage tended to be slightly greater than corresponding intake percentages. This suggests that the additional stresses of plant entrainment are killing a small percentage of the microzooplankton passing through the plant.

In the plots of major microzooplankton groups (Figures V-8 through V-11), the pattern observed for total microzooplankton was less distinct, but there was a tendency for the percent mortalities in the simulations and lake collections to follow the magnitude and direction of change in the intake sample percentages. There were many instances, however, when corresponding values were quite far apart, but no consistent pattern in the difference between intake and simulation or lake collection percentages was evident. The differences are thus attributed to the experimental techniques and it is clear that plume entrainment has no obvious effect on microzooplankton viability.

FIGURE V-7

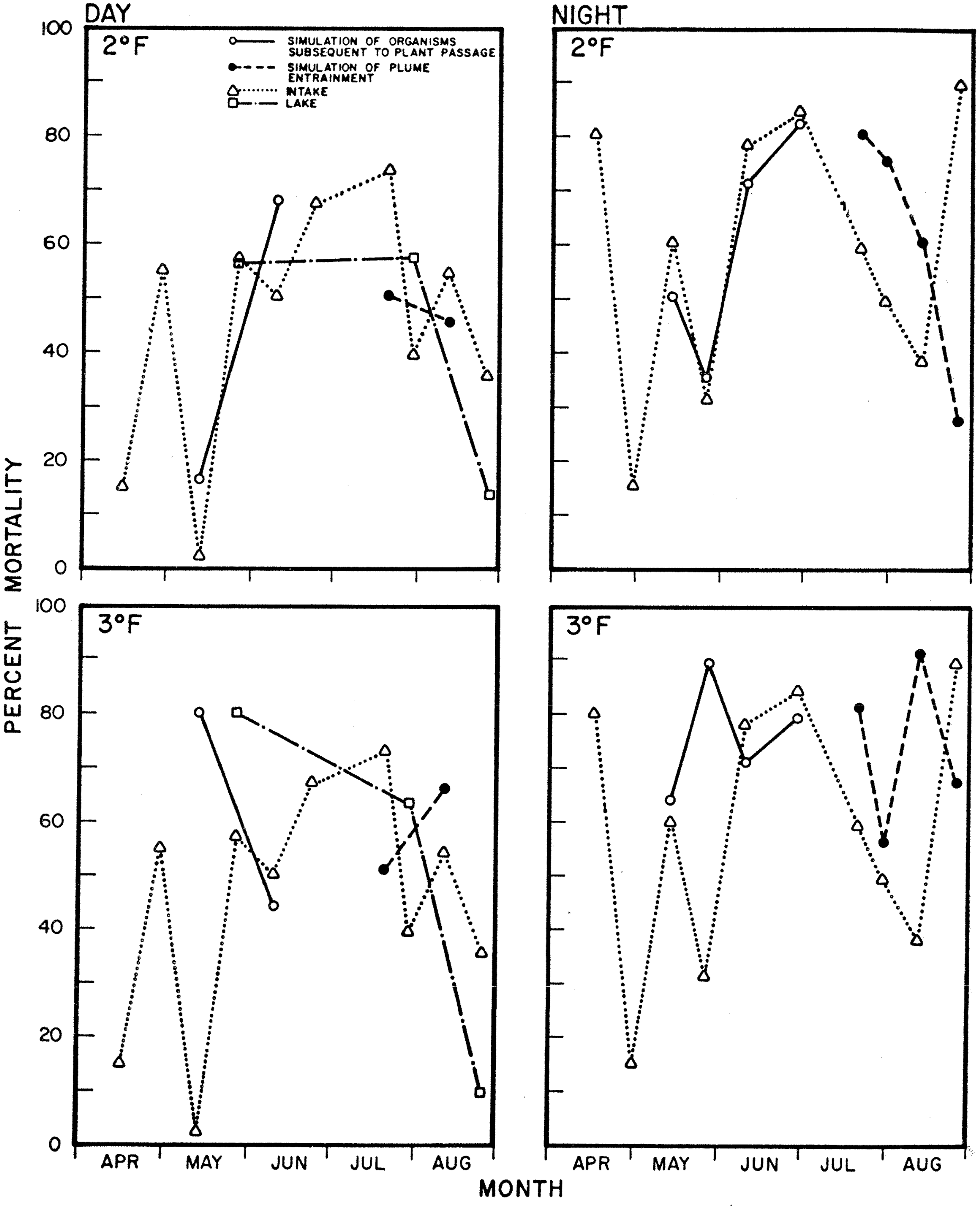
INTAKE AND PLUME SIMULATION MORTALITY OF TOTAL MICROZOOPLANKTON

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY – 1976



INTAKE AND PLUME SIMULATION MORTALITY OF PROTOZOA

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY – 1976



INTAKE AND PLUME SIMULATION MORTALITY OF ROTIFERA

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY – 1976

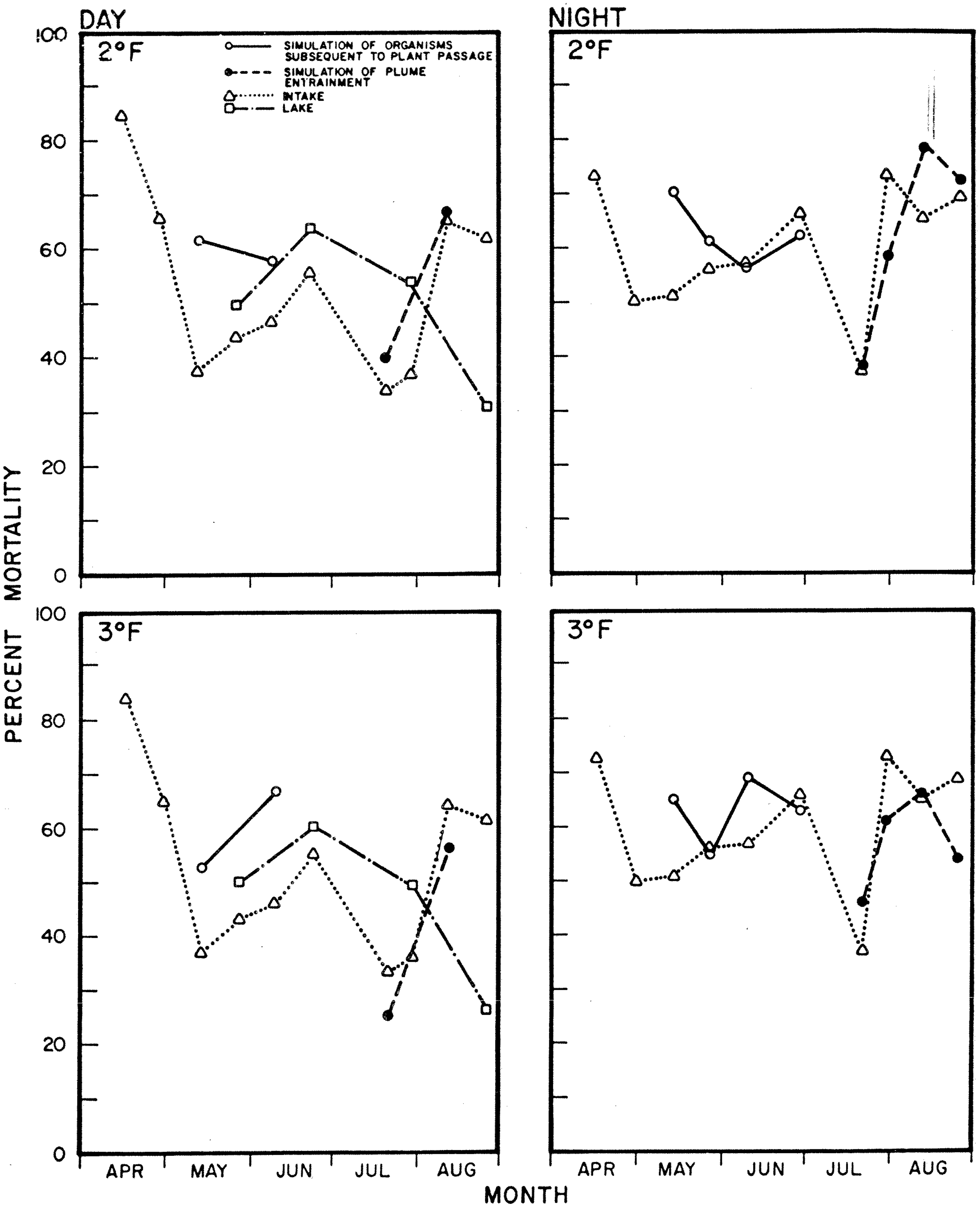
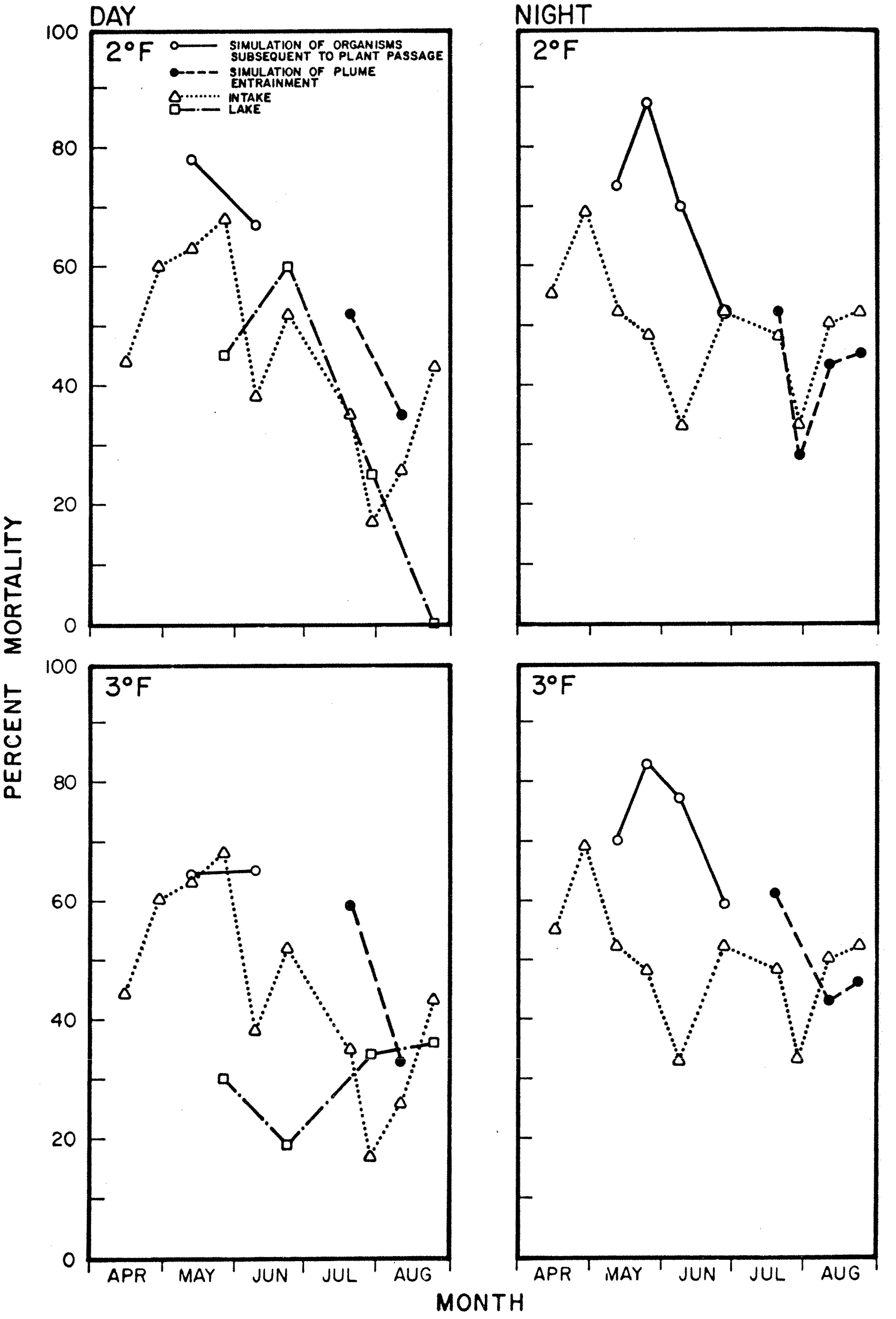


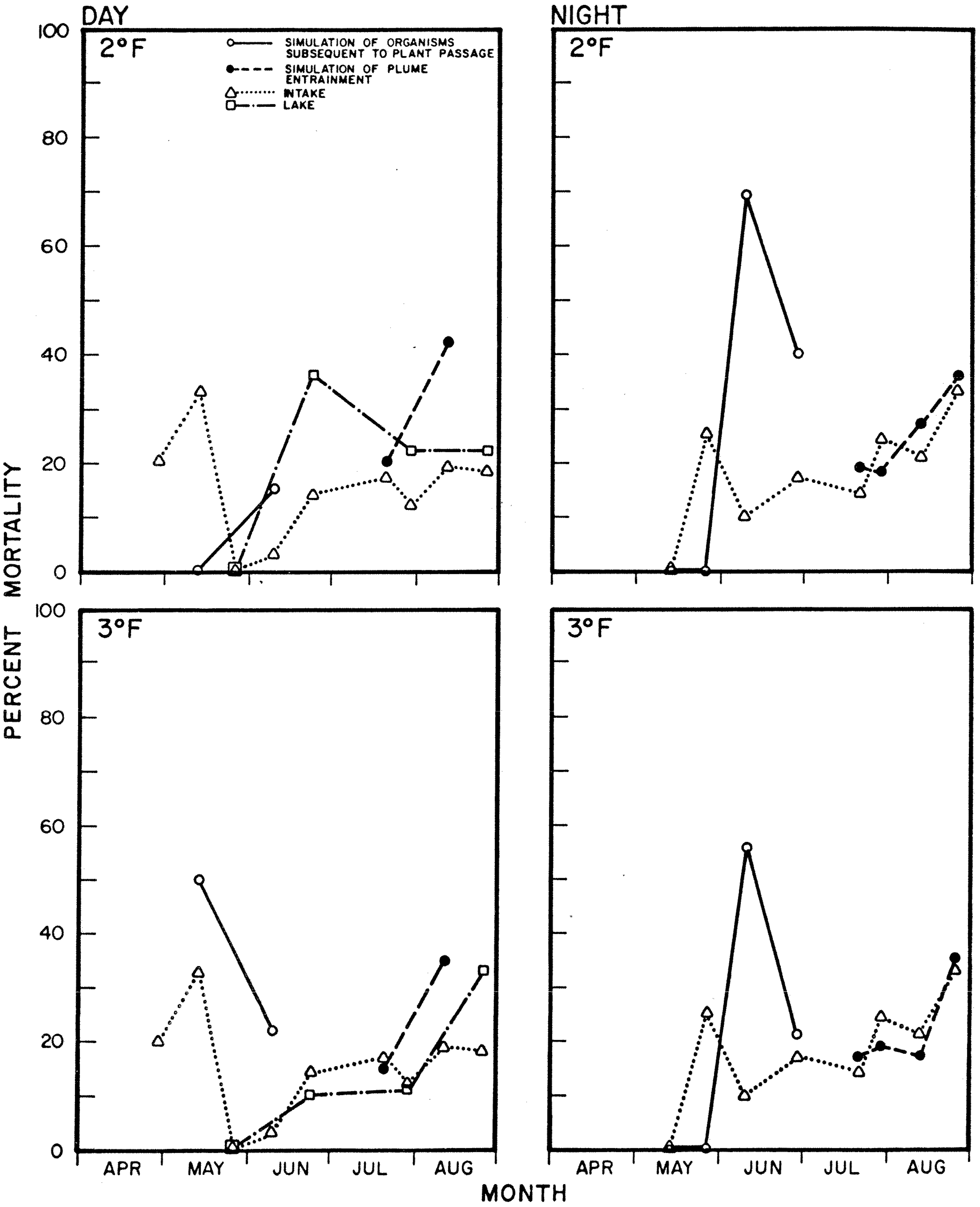
FIGURE V-10

INTAKE AND PLUME SIMULATION MORTALITY
OF TOTAL COPEPODA
JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY – 1976



INTAKE AND PLUME SIMULATION MORTALITY OF CLADOCERA

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY – 1976



Conclusion

The analyses presented above do not show any significant impact that can be attributed to the operation of the JAF in conjunction with operation of NMP-1 in 1975. Comparisons between transects (plants vs. control) in the same year (1975) indicated no statistical or empirical difference in the abundance of planktonic organisms among transects.

It is recognized that the conclusions reached here were based on analyses of data collected in 1973, 1974 and 1975 even though some collection (and analysis) procedures may have been changed. This may have influenced the magnitude of abundances among years, but did not affect the timing of peaks. The mortality data for microzooplankton collected at the plant intake, from the plume and exposed to simulated plume conditions did not show an increase in mortality attributable to temperature increases encountered during plume entrainment.

c. Macrozooplankton

Macrozooplankton are defined as those invertebrate zooplankters retained in a 571μ mesh plankton net. However, invertebrate crustaceans of the same species may be found in both the macrozooplankton and the microzooplankton groups due to wide range of sizes encompassed by the developmental stages of these organisms.

Cladocerans, copepods and amphipods were the dominant macrozooplankters encountered in 1973 and 1974 collections. The cladoceran *Leptodora kindtii* and the amphipod *Gammarus fasciatus* (*G. fasciatus* is the most abundant of two *Gammarus* species present) were the two dominant species in 1975, while other zooplankters, including *Mysis relicta*, dipteran larvae and pupae, hydroids, hydracarinids, and isopods, occurred in small numbers throughout the sampling program. Members of the Nematoda and Gastropoda were occasionally observed in the macrozooplankton collections.

The species of macrozooplankton identified in the vicinity of JAF during 1974 and 1975 are shown in Table V-11. The cladoceran *Leptodora kindtii* was the numerically dominant macrozooplankter enumerated in 1974; the amphipod *Gammarus fasciatus* was the second most abundant species followed by members of Hydroida and Diptera, mostly larvae and pupae (LMS, 1975). *Pontoporeia affinis* (Amphipoda) and *Mysis oculata relicta* (Mysidacea) were less abundant,

TABLE V-11

MACROZOOPLANKTON SPECIES INVENTORY*

NINE MILE POINT VICINITY - 1974-1975

- COELENTERATE
  - Hydrozoa
    - Athecata
      - *Cordylophora lacustris*
      - *Hydra americana*
- PLATYHELMINTHES
  - Turbellaria
- ASCHELMINTHES
  - Nematoda
- MOLLUSCA
  - Gastropoda
  - Bivalvia (Pelecypoda)
- ANNELIDA
  - Polychaeta
    - Sabellida
      - *Manayunkia speciosa*
  - Oligochaeta
  - Hirudinea
- ARTHROPODA
  - Arachnida
    - Acari
      - Limnesiidae
        - *Limnesia* sp.
      - Hygrobatidae
        - *Hygrobates* sp. A
        - *Hygrobates* sp. B
      - Unionicolidae
        - *Huitfeldtia rectipes*
        - *Unionicola* sp. A
        - *Unionicola* sp. B
      - Pionidae
        - *Forelia* sp.
        - *Piona* sp.
      - Lebertiidae
        - *Lebertia* sp.
  - Insecta
    - Odonata
    - Ephemeroptera
    - Hemiptera
    - Trichoptera
    - Diptera

- ARTHROPODA (Diptera Continued)
      - Culicidae
        - *Chaoborus albipes*
      - Simuliidae
      - Chironomidae
        - *Chironomus* sp.
        - *Cricotopus* sp.
        - *Cryptochironomus* sp.
        - *Demicryptochironomus* sp.
        - *Dicrotendipes* sp.
        - *Endochironomus* sp.
        - *Glytotendipes* sp.
        - *Micropsectra* sp.
        - *Orthocladius* sp.
        - *Parachironomus* sp.
        - *Paracladopelma* sp.
        - *Paratendipes* sp.
        - *Phaenopsectra* sp.
        - *Polypedilum* sp.
        - *Potthastia* sp.
        - *Procladius* sp.
        - *Psectrocladius* sp.
        - *Pseudochironomus* sp.
        - *Rheotanytarsus* sp.
        - *Tanytarsus* sp.
    - Coleoptera
    - Lepidoptera
    - Neuroptera
  - Crustacea
    - Cladocera
      - *Leptodora kindtii*
    - Branchiura
      - *Argulus* sp.
    - Isopoda
    - Amphipoda
      - Gammaridae
        - *Crangonyx* sp.
        - *Gammarus fasciatus*
      - Haustoridae
        - *Pontoporeia affinis*
    - Mysidacea
      - Mysidae
        - *Mysis oculata relicta*
    - Ostracoda
    - Podocopa

---

*Subject to corrections

each composing less than 1% by number of all macrozooplankters analyzed. These two species are cold-water inhabitants and were observed primarily during periods of cold-water upwelling. L. kindtii, G. fasciatus and dipterans exhibited a diel pattern of movement, being more abundant at night and in the subsurface areas.

The macrozooplankton L. kindtii, G. fasciatus, and dipterans were abundant in both day and night collections during 1975 (LMS, 1976). More organisms were collected at night at surface and mid-depths than near the bottom, but there was no consistant pattern. On the other hand, more organisms were collected near the bottom during daylight hours.

(i) Leptodora kindtii

The seasonal distribution of Leptodora was characterized as exhibiting an upward trend from April and May, when it was absent or scarce at all transects, to August 1975, when it reached its maximum; a sharp decline was then noted through December. Generally there was no persistent pattern of abundance in either longshore direction: west-east or east-west direction.

The distribution of Leptodora at the 40-ft depth contour was scarce to absent in April-May, increasing gradually toward midsummer, reaching a peak in August and then declining sharply toward December. The annual average (number/1,000 m^3) density of Leptodora was similar among the five transects (3-NMPW, 1-NMPW, .5 NMPW, 1-NMPE and 3-NMPE) but was drastically lower than that of FITZ transect (.5-NMPE); due to a single high monthly value (Table V-12). There is thus no consistent differences in Leptodora abundances due to operation of JAF.

(ii) Gammarus fasciatus

Gammarus collected in the 1975 study were much more abundant at night than during the daylight hours (LMS, 1976), similar to the pattern reported for Gammarus in 1974 (LMS, 1975). As was the case in 1974, Gammarus appeared first in April collections but was represented by very few organisms. Seasonal trends were not evident in either year due to large fluctuations among sampling dates and stations. The 1975 collections indicated that Gammarus were relatively abundant at night in July and August at all transects, but were abundant in August in day collections at the western transects (3-NMPW, 1-NMPW and .5-NMPW) only.

TABLE V-12

ABUNDANCE[a] OF SELECTED MACROZOOPLANKTON AT 40-FT DEPTH CONTOUR[b]

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1975

I. LEPTODORA KINDTII

MONTH	3-NMPW	1-NMPW	.5-NMPW	FITZ[c]	1-NMPE	3-NMPE
APR[d]	0	0	0	0	0	0
MAY[d]	5	15	0	6	16	6
JUN	1075	925	1934	880	3350	3102
JUL	37146	40305	31810	30383	19079	22447
AUG	246476	160877	172128	436800	164747	144933
SEP[d]	76731	83285	79356	133614	85524	106214
OCT[d]	9556[f]	7761	6964	6673	7023	9138
NOV[d]	839	889	2321	2219	2098	1940
DEC[d]	67	40	38	87	37	47
MEAN[e]	54451	41350	41702	89894	39088	38192

II. GAMMARUS FASCIATUS

APR[d]	0	0	0	1	0	0
MAY[d]	0	0	0	4	0	4
JUN	174	150	202	40	243	208
JUL	330	302	1135	1168	716	1044
AUG	120	179	3172	196	352	566
SEP[d]	43	16	4	2	2	0
OCT[d]	0[f]	0	0	45	0	0
NOV[d]	0	0	1	0	0	0
DEC[d]	0	0	2	11	0	0
MEAN[e]	108	106	752	239	219	303

---

[a] Number of organisms/1000^3; mean of sample depths; mean of day and night collections

[b] NMPP transect is not included (not sampled at 40-ft depth contour)

[c] Same as .5-NMPE

[d] Day sample only

[e] Weighted mean

[f] Surface and bottom sample only

Moreover, Gammarus were found only near the bottom in July and in mid-depths in August at FITZ, 1-NMPE and 3-NMPE (LMS, 1976).

The seasonal distributional pattern of Gammarus in 1975 at the 40-ft depth contour of all transects (no samples were taken at NMPP) is shown in Table V-12. The maximum abundance was reached in July at all transects except at .5-NMPW, which exhibited a maximum density in August. However, the abundance of Gammarus at the .5-NMPW transect in July was also characterized as similar to or greater than the maxima shown by the rest of the transects (Table V-12). The data in Table V-12 indicates that JAF is not affecting water column Gammarus abundance in that abundance at FITZ in July, August, September, October and November when JAF was operating at greater than 50% capacity indicates no differences that are indicative of trends, either high or low, exist.

d. Ichthyoplankton

Fish eggs and larvae were collected from the vicinity of JAF in 1974 and 1975. A species inventory of ichthyoplankton collected during the two-year period is presented in Table V-13. Eighteen, 17 and 20 species of fish larvae were collected in 1973, 1974 and 1975, respectively. Fish larvae were generally collected from April through September, and were most abundant in June and July, declining in number toward the end of September.

Of all larval species identified during the study period, alewives were the most abundant. Larvae of johnny darter and white perch were collected in smaller numbers, and a very few yellow perch larvae and a number of other species were occasionally caught.

Differences in species composition of fish larvae among years were attributed to the scattered distribution of the larvae in the study area. Moreover, the area of larval sampling is characterized as having sandy to bedrock/rubble substrata and lacking extensive vegetation, conditions which make it undesirable for spawning by many fish species collected from the area.

Larval alewives were found from June through early September in the Nine Mile Point area (LMS, 1975). Seasonal abundance patterns for alewife larvae reflected a late spring abundance peak followed by a second higher peak in August. Length frequency data and abundance

TABLE V-13

ICHTHYOPLANKTON SPECIES INVENTORY

NINE MILE POINT VICINITY - 1974-1975

FAMILY	SCIENTIFIC NAME	COMMON NAME
Clupeidae	*Alosa pseudoharengus*	Alewife
	Dorosoma cepedianum	Gizzard shad*
Salmonidae	*Coregonus artedii*	Cisco or Lake herring
Osmeridae	*Osmerus mordax*	Rainbow smelt
Cyprinidae	*Carassius auratus*	Goldfish
	Cyprinus carpio	Carp
	Notropis sp.	UID shiner
	N. atherinoides	Emerald shiner
	N. cornutus	Common shiner
	N. hudsonius	Spottail shiner
	Pimephales notatus	Bluntnose minnow
	UID Cyprinidae	-
Percopsidae	*Percopsis omiscomaycus*	Trout-perch
Gadidae	*Lota lota*	Burbot
Gasterosteidae	*Gasterosteus aculeatus*	Threespine stickleback
Percichthyidae	*Morone americana*	White perch
Centrarchidae	*Lepomis* sp.	UID sunfish
	L. gibbosus	Pumpkinseed
	Micropterus dolomieui	Smallmouth bass
	UID Centrarchidae	-
Percidae	*Etheostoma* sp.	UID darter
	E. nigrum	Johnny darter
	Perca flavescens	Yellow perch
	Stizostedion vitreum vitreum	Walleye*
Cottidae	*Cottus bairdi*	Mottled sculpin

*Eggs only
- Not applicable

of eggs suggest that alewife spawning reached peak levels during the first half of July. The abundance of alewife larvae in night collections from late June through early August was usually an order of magnitude greater than the abundance of these fish larvae in day collections. Norden (1968) and Scott and Crossman (1973) point to a nocturnal behavior pattern for this species.

The seasonal patterns of total larval abundance reflected the seasonal patterns of larval alewife abundance at most stations (LMS, 1974).

Rainbow smelt, johnny darter, carp, and mottled sculpin formed small percentages of the total fish larvae population during the early summer, along with the larvae of white perch, common shiner, yellow perch, emerald shiner, and pumpkinseed. Spottail shiner larvae and unidentified shiner larvae were also collected on at least one sampling date (LMS, 1974). Larvae of yellow perch were present in two collections in 1975 (4 June and 25-28 June), but were very few in numbers (LMS, 1976).

Most fish larvae were found in samples collected between late June and late August; however, rainbow smelt larvae were collected during mid-May, and mottled sculpin and rainbow smelt larvae were found in early November collections in 1974.

Larvae of the burbot and Coregonus sp. were collected during the earliest sampling dates in 1974, reflecting the cold-water spawning of the burbot and late fall spawning of coregonid species (Scott and Crossman, 1973).

The pattern of fish egg distribution was similar for day and night collections in 1974 and 1975 (Figure 12). Daytime egg collections in the Nine Mile Point vicinity exhibited a bimodal pattern in both years, with maxima occurring in mid-June and mid-July. Night collections showed a single mode, with the peak occurring in July of both years. Magnitudes of both day and night abundance peaks were similar between years.

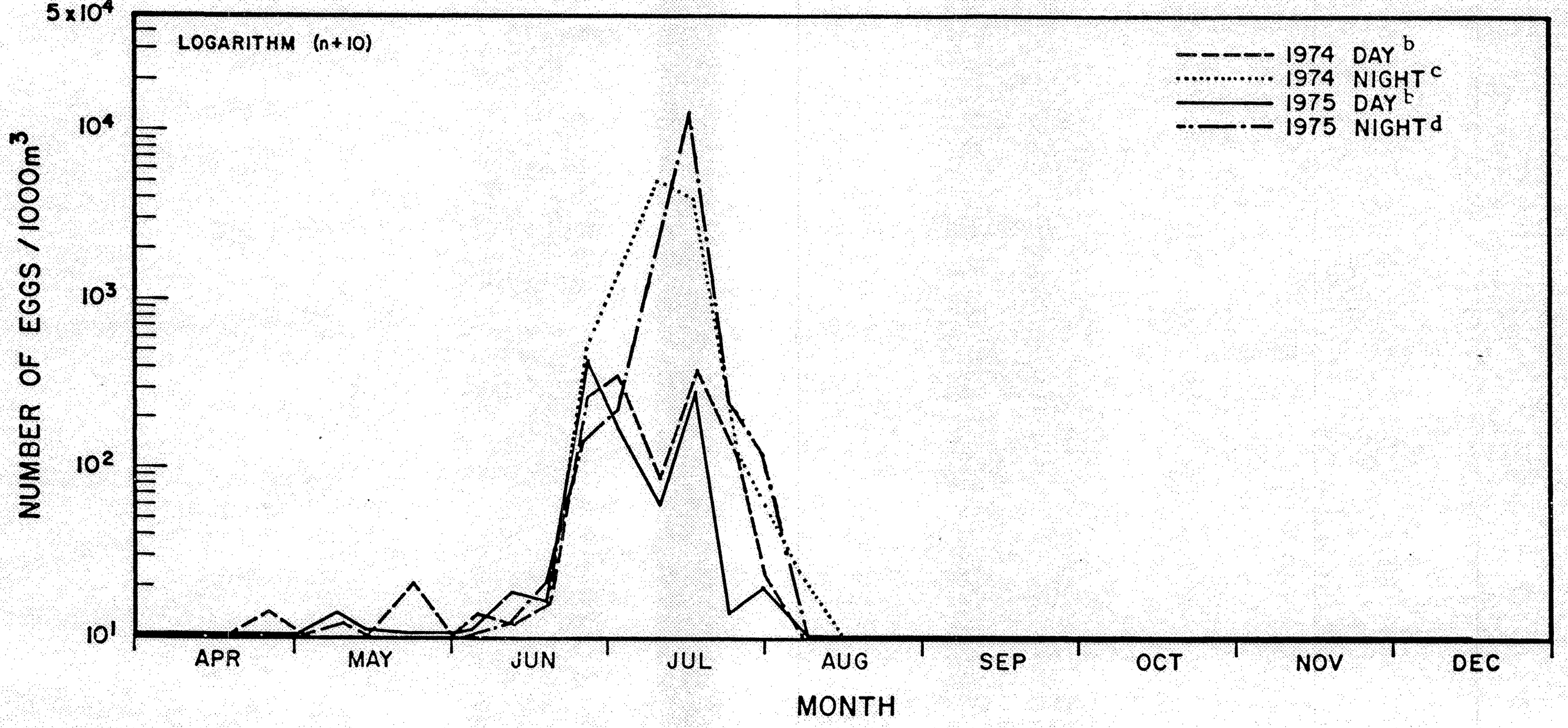
By contrast to egg abundance, diel distributions of larvae in 1974 and 1975 were different; more larvae were collected at night in 1974 than in 1975 (Figure V-13).

In general, the ichthyoplankton community in the vicinity of JAF is characterized as having low larval abundance except for alewife larvae. The low concentrations of most larval species, combined with the type of bottom habitats, indicate that the area is not a major spawning ground.

FIGURE V-12

ABUNDANCE OF FISH EGGS[a]

NINE MILE POINT VICINITY — 1974-1975



[a] Mean of all stations and sample depths; number of eggs/m^3

[b] Sampling continued until 13 Dec, no eggs were collected after Aug.

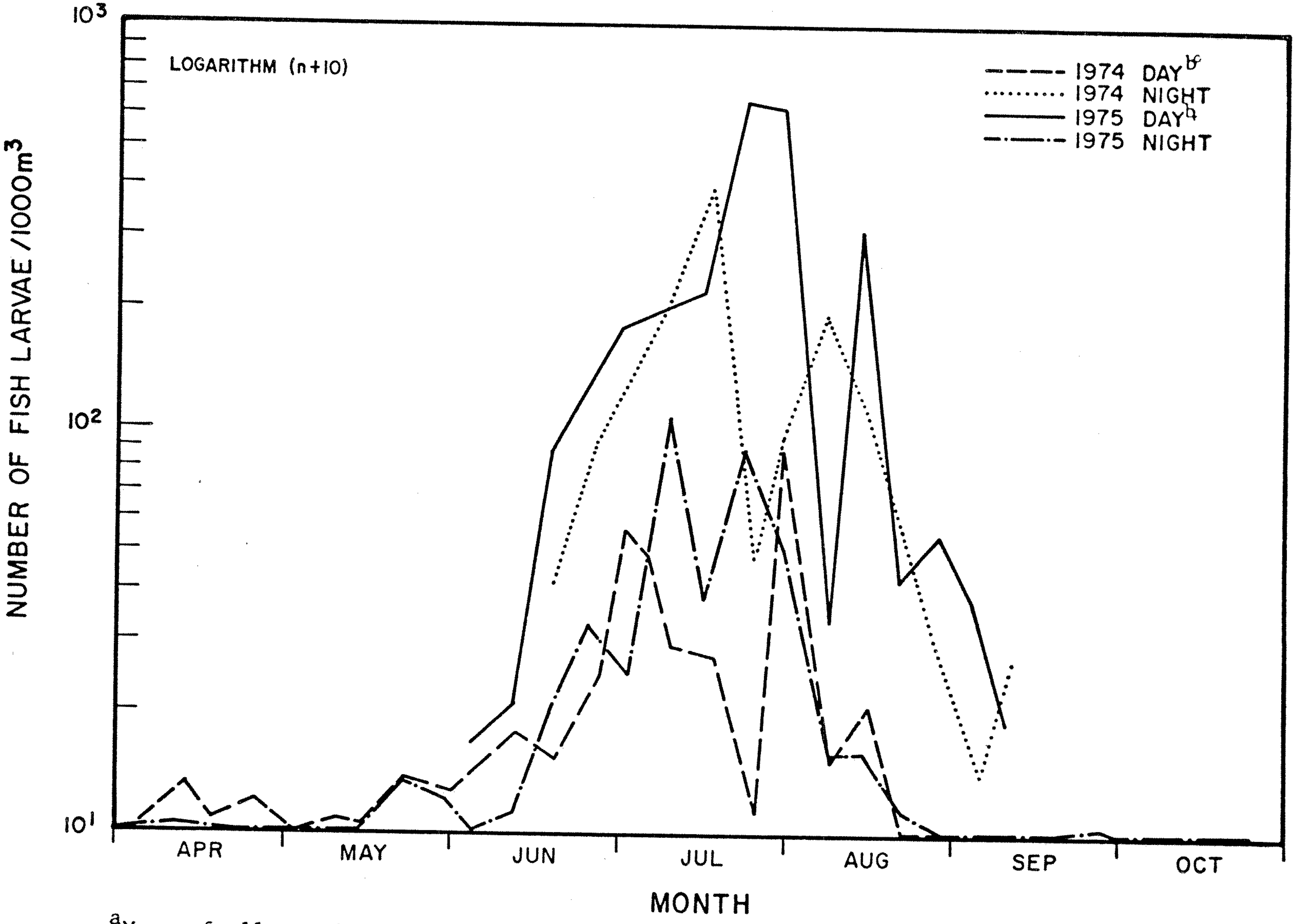
[c] Sampling continued until 11 Sep, no eggs were collected after Aug.

[d] Sampling continued until 10 Sep, no eggs were collected after Aug.

FIGURE V-13

ABUNDANCE[a] OF TOTAL FISH LARVAE

NINE MILE POINT VICINITY — 1974-1975



[a] Mean of all stations and sample depths; number of larvae/1000 m^3

[b] Sampling continued unitl 13 Dec, no larvae were collected after Sep.

8. Benthos

a. Introduction

Substrate structure and currents are among the important factors influencing diversity in benthic communities and which are of particular importance in this analysis. Certain species are strictly confined to well-defined types of substrata and exist at a certain current velocity. Moreover, the species composition and abundance of benthic macroinvertebrates has been shown to vary with depth in Lake Ontario. For example, the benthic fauna was reported to increase in abundance and diversity with increasing depth (Judd and Gemmel, 1971) and Brinkhurst (1969) reported the presence of eutrophic species in the inshore area of the lake.

b. Bottom Structure

During the study program, visual observation of the type of substratum in the vicinity of the Nine Mile Point was determined along the four transects (NMPW, NMPP, FITZ and NMPE) by divers following defined criteria (LMS, 1976). The divers' observations indicated that two transects (NMPW and NMPP) were dominated by more bedrock and rubble than sand and silt. The FITZ and NMPE transects were characterized as having bedrock and rubble in the inshore areas with sand and silt prevalent beyond the 20-ft depth contour. In general, finer particles are dominant in the offshore areas.

Results of 1975 diver observations (LMS, 1976) indicated little or no sedimentation at NMPW or NMPP/FITZ transects. At NMPE, both sedimentation and scouring alternately occurred, indicating sediment instability in that area. Scouring was also confirmed by LMS special study conducted in 1976 at the FITZ transect in the area near the diffuser (40 ft station).

c. Community Structure

Species of seven phyla - Nematoda, Mollusca, Platyhelminthes, Arthropoda, Annelida, Coelenterata and Nemertea - constituted the benthic community in the Nine Mile Point vicinity (Table V-14). These phyla included 81-85 genera identified during the 1973-1975 period. Species of Nemertea and Coelenterata (*Hydra* and *Cordylophora*) were collected in 1973 but recorded in the years that followed.

Phylum Arthropoda, represented by 33-45 species, included the most abundant organisms in the area, including *Gammarus fasciatus*, which was the most single dominant species collected. Members of the order Oligochaeta were relatively abundant in the April-December

TABLE V-14

BENTHOS SPECIES INVENTORY*

NINE MILE POINT VICINITY - 1974-1975

- COELENTERATA
  - Hydrozoa
    - *Cordylophora caspia*
    - *Hydra* sp.
    - *H. americana*
- PLATYHELMINTHES
  - Turbellaria
    - Tricladida
      - Planariidae
        - *Dugesia* sp.
- NEMERTEA
- NEMATODA[a]
  - *Alaimus* sp.
  - *Anonchus* sp.
  - *Butlerius* sp.
  - *Dorylaimus* sp.
  - Bastianiidae
    - Genus A
    - Genus B
    - Genus C
  - UID
- BRYOZOA
- ANNELIDA
  - Polychaeta
    - Sabellidae
      - *Manuyunkia speciosa*
  - Oliochaeta
    - Prosopora
      - Lumbriculidae
        - *Stylodrilus heringianus*
    - Plesiopora
      - Tubificidae
        - IWOC-immature without chaetae
        - IWC-immature with chaetae
        - *Aulodrilus americanus*
        - *A. limnobius*
- ANNELIDA (Cont)
        - *A. piqueti*
        - *A. pluriseta*
        - *Ilyodrilus templetoni*
        - *Limnodrilus claparedianus*
        - *L. hoffmeisteri*
        - *L. profundicola*
        - *L. spiralis*
        - *L. udekemianus*
        - *Peloscolex ferox*
        - *P. freyi*
        - *P. multisetosus multisetosus*
        - *P. m. longidentus*
        - *Potamothrix moldaviensis*
        - *P. vejdovskyi*
        - *Tubifex newaensis*
        - *T. tubifex*
      - Enchytraeidae
      - Naididae
        - *Areteonais lomondi*
        - *Chaetogaster diaphanus*
        - *C. limnaei*
        - *Nais barbata*
        - *N. bretscheri*
        - *N. communis*
        - *N. elinquis*
        - *N. pseudobtusa*
        - *N. simplex*
        - *Ophidonais serpentina*
        - *Paranais littoralis*
        - *P. simplex*
        - *Piquetiella michiganensis*
        - *Pristina* sp.
        - *Specaria josinae*
        - *Stylaria fossularis*
        - *S. lacustris*
        - *Uncinais uncinata*
        - *Vejdovskyella* sp.
        - *V. comata*
        - *V. intermedia*
  - Hirudinea

TABLE V-14 (Continued)

BENTHOS SPECIES INVENTORY*

- ANNELIDA (Continued)
  - Rhynchobdellida
    - Piscicolidae
      - *Piscicola* sp.
- ARTHROPODA
  - Arachnoidea
    - Hydracarina
      - Hygrobatidae
        - *Hygrobates* sp. 1
        - *Hygrobates* sp. 2
        - *Hygrobates* sp. 3
        - *Hygrobates* sp. 4
      - Limnesiidae
        - *Limnesia* sp.
      - Unionicolidae
        - *Huitfeldtia rectipes*
        - *Koenikia* sp.
        - *Neumania* sp.
        - *Unionicola* sp.
        - *Unionicola* sp. 1
        - *Unionicola* sp. 4
      - Lebertiidae
        - *Lebertia* sp.
    - Torrenticollidae
      - Pionidae
        - *Forelia* sp.
        - *Piona* sp.
  - Crustacea
    - Ostracoda[b]
      - Podocopa-UID
    - Malacostraca[b]
      - Mysidacea
        - *Mysis oculata relicta*
      - Isopoda
        - Asellidae
          - *Asellus* sp.
      - Amphipoda
        - Gammaridae
          - *Gammarus fasciatus*
        - Crangonycidae
          - *Crangonyx* sp.
        - Haustoriidae
          - *Pontoporeia affinis*
      - Decapoda
        - Astacidae
        - Cambarinae[c]
- ARTHROPODA (Cont)
          - *Cambarus bartoni*
          - *C. robustus*
          - *Orconectes propinquus*
  - Insecta
    - Ephemeroptera
      - Heptageniidae
        - *Stenonema* sp.
      - Baetidae-UID
    - Hemiptera-UID
    - Neuroptera
      - Sisyridae
        - *Climacia areolaris*
    - Trichoptera
      - Hydroptilidae
        - *Agraylea* sp.
      - Leptoceridae
        - *Athripsodes* sp.
        - *Oecetis* sp.
      - Psychomyiidae
        - UID pupa
    - Lepidoptera-UID
    - Diptera
      - Chironomidae
      - Chironomini[d]
        - *Chironomus* sp.
        - *Cryptochironomus* sp.
        - *Cryptocladopelma* sp.
        - *Demicryptochironomus* sp.
        - *Dicrotendiptes* sp.
        - *Glyptotendiptes* sp.
        - *Microtendiptes* sp.
        - *Parachironomus* sp.
        - *Paracladopelma* sp.
        - *Paralauterborniella* sp.
        - *Paratendiptes* sp.
        - *Phaenopsectra* sp.
        - *Pseudochironomus* sp.
        - *Polypedilum* sp.
        - *Stictochironomus* sp.
        - *Xenochironomus* sp.
      - Tanytarsini[d]
        - *Calopsectra* sp.
        - *Cladotanytarsus* sp.
        - *Microsectra* sp.[e]
        - *Paratanytarsus* sp.
        - *Rheotanytarsus* sp.

TABLE V-14 (Continued)

BENTHOS SPECIES INVENTORY*

ANNELIDA (Continued)
    Tanytarsus sp.[e]
  Tanypodinae[e]
    Anatopynis sp.
    Procladius sp.
    Psectrocladius sp.
  Orthocladinae
    Cardiocladius sp.
    Cricotopus spp.
    Heterotrissocladius sp.
    Orthocladius sp.
    Trichocladius sp.
    Trissocladius sp.
    UID pupae
  Diamesinae[c]
    Potthastia sp.
   Ceratopogonidae-UID
   Empididae-UID
   Stratomyidae-UID

---

*Subject to corrections

[a] Only Genera are listed; taxonomy is under revision.

UID = Unidentified form.

[b] Subclass

[c] Subfamily

[d] Tribe

[e] Genera identification tentative

period; tubificid worms (Family Tubificidae) were abundant in all seasons and at most transects.

Differences observed in the distribution and species abundance of benthic invertebrates between stations and transects are attributed to animal-substrate relationships. For example, Gammarus and Manayunkia were dominant and associated with bedrock substrata while the nematode Dorylaimus, tubificids and the dipteran Cryptochironomus were abundant where substrata were mostly sand and silt. In general, more organisms were found in deep areas in association with Cladophora beds, and abundance and biomass increased eastwards, i.e., at FITZ and NMPE.

Benthic invertebrates in the Nine Mile Point vicinity have a seasonal growth and reproduction pattern similar to that reported by Fretwell (1972) and Odum (1971) for temperate zones (LMS, 1975). Seasonally the abundance of macroinvertebrates was as follows: the polychaete Manayunkia and the gastropods Valvata perdepressa and Amnicola limosa were dominant in April, the oligochaetes (in particular Nais bretscheri) and the ostracods in June, the amphipod Gammarus fasciatus and the polychaete Manayunkia in August, Gammarus fasciatus and oligochaetes in October, and Gammarus fasciatus in December. Benthic organisms were most abundant in June 1973, 1974 and in June-August 1975.

The trend of greater benthic invertebrate abundance during the spring and fall periods is mainly due to the presence of actively growing Cladophora, a filamentous green alga which provides food and refuge for many invertebrate populations. Cladophora exhibited a maximum seasonal abundance in June of 1974 and 1975 (LMS, 1976). Cladophora biomass decreased rapidly with depth, and was either scarce or nonexistent at depths of 30 and 40 ft. This was previously noted by Neil and Owen (1964). Christie (1974) attributes the increased productivity observed in Lake Ontario during recent years to the growth of Cladophora and its associated fauna. This was confirmed by the studies at Nine Mile Point in which the greatest abundance and biomass of benthic invertebrates were found at the shallow 10 ft stations, while both these parameters generally decreased with increasing depth.

(i) Phylum Platyhelminthes (Order Tricladida)

Abundance and biomass of Tricladida collected at the 40-ft depth contour at the four transects were low in April, June and August 1975 (Table V-15). In October, their numbers (and biomass) increased to a maximum of 95 and 45 organism/m^2 at NMPW and NMPP, respectively, however, remained relatively unchanged at FITZ and NMPE transects.

TABLE V- 15

ABUNDANCE[a] AND BIOMASS[b] OF SELECTED MACROINVERTEBRATES AT 40-FT DEPTH CONTOUR BY TRANSECT[c]

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1975

I. TRICLADIDA

TRANSECT	APRIL		JUNE		AUGUST		OCTOBER	
	No./m^2	mg/m^2	No./m^2	mg/m^2	No./m^2	mg/m^2	No./m^2	mg/m^2
NMPW	0	0.000	2	0.001	0	0.000	50	0.027
NMPP	4	0.011	0	0.000	2	<0.001	24	0.009
FITZ	0	0.000	10	0.002	0	0.000	4	0.005
NMPE	0	0.000	3	0.002	0	0.000	6	0.004
MEAN	1.0	0.003	3.8	0.001	0.5	-	21.0	0.011

II. NEMATODA

NMPW	0	0.000	4	<0.001	0	0.000	0	0.000
NMPP	0	0.000	0	0.000	2	<0.001	3	<0.001
FITZ	7	<0.001	411	0.016	77	0.003	2	<0.001
NMPE	32	0.002	335	0.013	127	0.005	46	0.002
MEAN	9.8	-	187.5	-	51.5	-	12.8	-

III. GASTROPODA

NMPW	0	0.000	0	0.000	4	0.100	141	0.320
NMPP	0	0.000	2	0.085	105	0.458	10	0.004
FITZ	17	0.079	140	0.717	141	0.526	98	0.263
NMPE	404	1.091	490	1.177	1303	1.412	773	2.328
MEAN	105.2	0.292	158.0	0.495	388.2	0.624	255.5	0.729

IV. BIVALVA (PELECYPODA)

NMPW	0	0.000	0	0.000	2	0.001	3	0.002
NMPP	0	0.000	0	0.000	17	0.002	4	0.002
FITZ	23	0.021	26	0.014	66	0.030	115	0.049
NMPE	356	0.168	574	0.309	729	0.435	1058	1.224
MEAN	94.8	0.047	150.0	0.081	203.5	0.117	295.0	0.319

[a] For total number multiply by 1.89

[b] For total biomass multiply by 5.09

[c] Based on subsamples

\- Averages were not calculated where abundance values were <0.0001.

TABLE V-15 (Continued)

ABUNDANCE[a] AND BIOMASS[b] OF SELECTED MACROINVERTEBRATES AT 40-FT DEPTH CONTOUR BY TRANSECT[c]

V. POLYCHAETA

TRANSECT	APRIL		JUNE		AUGUST		OCTOBER	
	No./m^2	mg/m^2	No./m^2	mg/m^2	No./m^2	mg/m^2	No./m^2	mg/m^2
NMPW	0	0.000	6	<0.001	3	<0.001	2	<0.001
NMPP	2	<0.001	0	0.000	0	0.000	171	0.006
FITZ	0	0.000	11	<0.001	0	0.000	0	0.000
NMPE	0	0.000	11	0.001	7	<0.001	11	0.001
MEAN	0.5	-	7.0	-	2.5	-	46.0	-

VI. OLIGOCHAETA

NMPW	4	<0.001	5	0.002	0	0.000	9	0.007
NMPP	0	0.000	0	0.000	8	0.006	5	0.004
FITZ	552	0.387	1223	1.306	438	0.498	268	0.234
NMPE	686	0.742	849	0.931	34	0.024	260	0.229
MEAN	310.5	-	519.2	0.560	120.0	0.132	135.5	0.118

VII. ACARI

NMPW	20	0.002	326	0.036	55	0.006	311	0.035
NMPP	10	0.001	418	0.047	52	0.006	634	0.071
FITZ	0	0.000	58	0.007	14	0.002	2	<0.001
NMPE	0	0.000	15	0.002	83	0.010	50	0.005
MEAN	7.5	0.001	204.2	0.023	51.0	0.006	249.2	0.028

VIII. DIPTERA

NMPW	6	0.001	37	0.006	13	0.006	2	0.001
NMPP	2	<0.001	46	0.026	20	0.004	6	0.001
FITZ	31	0.012	170	0.049	29	0.013	58	0.026
NMPE	92	0.047	147	0.024	80	0.037	96	0.039
MEAN	32.8	-	100.0	0.026	35.5	0.015	40.5	0.017

[a] For total number multiply by 1.89

[b] For total biomass multiply by 5.09

[c] Based on subsamples

- Averages were not calculated where abundance values were <0.0001.

TABLE V-15 (Continued)

ABUNDANCE[a] AND BIOMASS[b] OF SELECTED MACROINVERTEBRATES AT 40-FT DEPTH CONTOUR BY TRANSECT[c]

IX. AMPHIPODA

	APRIL		JUNE		AUGUST		OCTOBER	
TRANSECT	No./m^2	mg/m^2	No./m^2	mg/m^2	No./m^2	mg/m^2	No./m^2	mg/m^2
NMPW	7	0.006	20	0.010	24	0.019	228	0.045
NMPP	6	0.023	0	0.000	10	0.008	1079	0.186
FITZ	53	0.027	885	0.265	335	0.117	737	0.238
NMPE	136	0.087	613	0.122	632	0.309	749	0.284
MEAN	50.5	0.036	379.5	0.099	250.2	0.113	698.2	0.188

X. OSTRACODA

NMPW	8	0.001	71	0.006	54	0.004	221	0.017
NMPP	2	<0.001	76	0.006	72	0.006	8	0.001
FITZ	4	<0.001	5913	0.440	127	0.010	22	0.002
NMPE	43	0.003	2590	0.076	61	0.005	167	0.013
MEAN	14.2	-	2162.5	0.132	78.5	0.006	104.5	0.008

[a] For total number multiply by 1.89

[b] For total biomass multiply by 5.09

[c] Based on subsamples

- Averages were not calculated where abundance values were <0.0001.

Tricladida, in general, declined in abundance from 1973 to 1974 in all Nine Mile Point benthic collections (LMS, 1975). However, collections at NMPW had a substantially increased percentage of triclads in 1974 (36%) compared to 1973 (8%); the percentage at NMPE and FITZ decreased in 1974, but remained unchanged at NMPP. The NMPP and FITZ transects did not consistently show higher or lower abundance of triclads than the other two transects during the sampling period (LMS, 1975).

(ii) Phylum Nematoda

In 1975, nematodes were abundant at the 40-ft depth contour of FITZ and NMPE transects, but scarce to absent at NMPW and NMPP transects (Table V-15). They were most abundant in June, after which their numbers and biomass continued to decline toward the end of the summer.

In 1974 nematodes were abundant throughout the sampling period at both FITZ and NMPE (LMS, 1975), and also at NMPP in April due probably to the abundance of the genus *Dorylaimus* (LMS, 1975); their numbers then declined in June, August and October. Nematode abundance is attributed essentially to two genera, *Alaimus* and *Dorylaimus*, which alternately dominated the collections; i.e., *Dorylaimus* was dominant in April and August while *Alaimus* was abundant in June (LMS, 1975).

(iii) Phylum Mollusca (Class Gastropoda)

The gastropods collected from Nine Mile Point vicinity were dominated by pulmonates and prosobranchs. The prosobranchs *Valvata perdepressa* and *Amnicola limosa* were dense at NMPE in 1974 and 1975, scattered at NMPP and NMPW, and present in moderate abundance at FITZ transect. In general, gastropods were most abundant in August and October in 1974-1975 and least abundant in December 1974.

The seasonal distribution of gastropods at the 40-ft depth contour in 1975 was in agreement with the above observations; average numbers and biomass exhibited an upward trend from April to August (Table V-15) and the organisms remained relatively abundant in October. Abundance and biomass of gastropods at the two eastern transects FITZ and NMPE were greater on the average than those at the same sampling depth of NMPW and NMPP. Except for NMPP in August and NMPW in October, gastropods were scarce or not present at the NMPW and NMPP 40-ft depth contour.

(iv) Phylum Mollusca (Class Pelecypoda)

Pelecypods (Bivalvia) in the Nine Mile Point vicinity are represented primarily by members of two families: Sphaeriidae, the most abundant bivalves dominated by the genera Sphaerium and Pisidium, and Unioniidae, which was seldom represented in the study area. Bivalves were abundant in midsummer (LMS, 1975, 1976) and increased in numbers in the west-to-east direction.

The occurrence of maximum bivalve abundance at NMPE was related to the type of substratum at that transect. Bivalved molluscs are known to be associated with sand or to live attached to rocks and submerged objects.

Bivalve distribution at the 40-ft depth contour was generally similar to the distribution found along the transects in 1974 and 1975: more organisms at FITZ and NMPE than at NMPW and NMPP (Table V-15), with the highest average numbers and biomass at the NMPE transect. The general pattern of west-to-east increase in density (number/m^2) found in 1974 was also evident here (Table V-15); the maximum density of organisms occurred in October at both FITZ and NMPE transects.

(v) Phylum Annelida (Class Polychaeta)

Only one species of polychaete, Manayunkia speciosa (Family Sapellidae), was observed in any collection during 1973, 1974 and 1975. This species is a domiculous species (Pennak, 1953) living in tubes constructed from mud, detritus or mucus secretion. Polychaetes reached their maximum abundance in August 1974 and were equally abundant in August and October 1975. They declined in numbers toward the end of the year.

Polychaetes were abundant at NMPW and NMPP (LMS, 1975); they were abundant at NMPE in 1973, but numbers there dropped off sharply in 1974, unlike NMPP transect, where they were more numerous in 1974. This pattern seems to change with the month of collection. Samples taken at 40-ft depth contour in 1975 indicated that polychaetes were more abundant at NMPE than NMPW in June, August and October (Table V-15); they were found at FITZ transect only in June, while they were numerous at NMPP transect in October.

(vi) Phylum Annelida (Class Oligochaeta)

In contrast to polychaetes, the oligochaetes were represented by as many as 33 species in 1974 and were abundant at NMPP and NMPW

(LMS, 1975). Tubificid worms, whose presence has been used as an indicator of organic pollution (Howmiller and Beeton, 1970; Goodnight, 1973), were abundant in the area.

Oligochaetes were highly abundant at the 40-ft depth contour at FITZ and NMPE transects in 1975 (Table V-15), reaching a maximum there in June. These organisms were scarce to absent at the 40-ft depth contour of NMPW and NMPP (Table V-15).

(vii) Phylum Arthropoda (Order Acari)

A comparison of the relative abundance of Acari (water mites) between 1973 and 1974 indicated a shift in the period of peak water mite abundance from August in 1973 to June in 1974. NMPW transect contributed the greatest percentage of Hydracarina for both years (44% in 1973; 46.1% in 1974). The abundance at FITZ transect was relatively low for both years; however, the proportion of total abundance at NMPE transect dropped from 20% in 1973 to 9.2% of the Hydracarina population in 1974.

In 1975, water mites were least abundant at the 40-ft depth contour of the FITZ and NMPE transects (Table V-15), and most abundant at both NMPW and NMPP. Their numbers were greater in June and October, but declined in April and August (Table V-15), following a bimodal pattern.

(viii) Phylum Arthropoda (Order Diptera)

Dipterans were abundant and diversified in the study area, as shown in 1973, 1974 and 1975 studies. Dominant genera were Chironomus, Cryptochironomus and Cricotopus. There was an upward trend in abundance of dipterans among years, and distribution generally followed a west-east pattern of increase in abundance.

Dipterans are abundant in the early midsummer period, and they decline in number and biomass in late summer/early fall as a result primarily of emergence, which is temperature-dependent, and also of cropping by fish. In 1974, dipterans reached a peak in August, with NMPE exhibiting the greatest abundance (LMS, 1975). Abundance then declined toward October, particularly populations in shallow areas. For example, Chironomus sp. larvae were abundant at the 60-ft depth contour of FITZ and NMPW transects in October, at the same time as a decline in standing crop was noted at the 10, 20 and 30-ft depth contours.

The seasonal abundance and biomass of dipterans collected at the 40-ft depth contour in 1975 are shown in Table V-15. These indicate the presence of a west-to-east trend of increased abundance during the April-October period. Average number and biomass of dipterans reached a maximum in June and then drastically declined in August and October. These organisms were more abundant at both FITZ and NMPE than at NMPW and NMPP transects during all 1975 collections.

(ix) Phylum Arthropoda (Order Amphipoda)

Two species of amphipods were collected from the Nine Mile Point area in 1973, 1974 and 1975: Gammarus fasciatus and Pontoporeia affinis. G. fasciatus is generally considered a littoral species, although it has been recorded from depths up to 33 m in Lake Ontario (Hiltunen, 1964). G. fasciatus was more abundant than P. affinis and played a major role in the food chain of the representative important species in the area (LMS, 1975, 1976).

G. fasciatus was abundant in August (its peak) and October in 1975 (LMS, 1976); its abundance in 1974 was characterized by a minor peak in August followed by a major peak in December (December collections were not available for 1975). In 1973, the peak abundance occurred in June and numbers declined toward October (QLM, 1974). In general, the distribution of Gammarus did not follow a definite pattern among transects, but the littoral habit of the species was evident in that more organisms were collected from the 10 and 20-ft depth contours in 1974 and 1975.

Pontoporeia affinis was less abundant than Gammarus and was encountered at the 40 and 60-ft depth contours. This was substantiated by 1973 (QLM, 1974) and 1974 (LMS, 1975) data which indicated the presence of 90% of the species at these two depths.

The density distribution of amphipods at the 40-ft depth contour at the four transects in 1975 is shown in Table V-15. These data indicated that amphipods were abundant at FITZ and NMPE transects in April, June and August. In October, however, all transects displayed high values in both number and biomass.

(x) Phylum Arthropoda (Order Ostracoda)

Seasonal distribution of ostracods was similar in 1973 (QLM, 1974), 1974 (LMS, 1975) and in 1975 (LMS, 1976). The abundance at all transects increased from relatively low numbers in April to a maximum in June, followed by a sharp decline through December 1973-1974 and through October 1973.

NMPE provided the maximum contribution to ostracod abundance in the 1973-1975 period, followed by FITZ transect, where abundance was unchanged between 1973 and 1974. Ostracod abundance declined at NMPP transect in 1974, where it was least in 1975. In general, NMPW and NMPP had fewer ostracods than FITZ and NMPE throughout the study period.

Ostracod distribution at the 40-ft depth contour (Table V-15) was similar to that described above, reaching maximum abundance in June and declining in abundance toward October. FITZ and NMPE had more ostracods, on the average, than NMPW and NMPP, especially in June when ostracods were abundant.

9. Scouring

The high-velocity jet discharge at JAF has created a depression 3-9 ft deep near the center of the diffuser. The scouring in the vicinity of the discharge caused sand and bottom substratum to be transported from an area approximately 50 ft from the center of the diffuser and extending to about 180 ft lakeward. The scouring of this area has also created a "mound" north of it as a result of the deposition of the transferred materials as the plume velocity declines. It is thus most likely that this scouring process has displaced part of the benthic community occupying an area roughly 488 x 92 m and some damage may have occurred. The deposition area, even though it is expected to be recolonized, is included in the area of impact of the scouring.

10. Nekton

The fish community in the plant vicinity was sampled from March through December 1973, and from April through December of 1974 and 1975 by gill nets, trawls, and seines. Samples were collected from the shoreline to the 60-ft depth contour along four transects - NMPW, NMPP, FITZ, and NMPE. The two transects, NMPW and NMPE, served as control transects because, for the most part, they were not influenced by the heated discharge from the two plants. It should be noted, however, that on very few occasions the 2°C isotherm may have occurred at either transect. Description of the gears used and methods of sampling are in QLM (1974) and LMS (1976).

An ascending trend in the number of species collected was noted during the period 1973-1975. The number varied from 37 species in 1973 to 42 species in 1974 and 53 species in 1975 (Table V-16).

The alewife was the dominant species collected, making up 73, 74 and 75% of the total number of fish collected in 1973, 1974, and 1975, respectively. Rainbow smelt was the second most abundant species in 1974

TABLE V-16

FISH SPECIES INVENTORY

NINE MILE POINT VICINITY - 1974-1975

FAMILY	SCIENTIFIC NAME	COMMON NAME
Petromyzontidae	*Petromyzon marinns*	Sea Lamprey
Lepisosteidae	*Lepisosteus osseus*	Longnose gar
Amiidae	*Amia calva*	Bowfin
Anguillidae	*Anguilla rostrata*	American eel
Clupeidae	*Alosa pseudoharengus*	Alewife
	Dorosoma cepedianum	Gizzard shad
Salmonidae	*Coregonus artedii*	Cisco or Lake herring
	Oncorhynchus kisutch	Coho salmon
	O. tshawytscha	Chinook salmon
	Salmo gairdneri	Rainbow trout
	S. trutta	Brown trout
	Salvelinus fontinalis	Brook trout
	S. namaycush	Lake trout
	S. namaycush x fontinalis	Splake trout
Osmeridae	*Osmerus mordax*	Rainbow smelt
Esocidae	*Esox americanus americanus*	Redfin pickerel
	E. lucius	Northern pike
Cyprinidae	*Corassius auratus*	Goldfish
	Conesius plumbens	Lake chub
	Cyprinus carpio	Carp
	Hybognathus nuchalis	Silvery minnow
	Notemigonus crysolencas	Golden shiner
	Notropis atherinoides	Emerald shiner
	N. bifrenatus	Bridle shiner
	N. cornutus	Common shiner
	N. hudsonius	Spottail shiner
	Pimephales promelas	Fathead minnow
	Rhinichthys cataractae	Longnose dace
Catostomidae	*Catostomus catostomus nannonyzon*	Dwarf longnose sucker
	C. commersoni	White sucker
	Erimyzon sucetta	Lake chubsucker
	Hypentelium nigricans	Northern hogsucker

TABLE V-16 (Continued)

FISH SPECIES INVENTORY

FAMILY	SCIENTIFIC NAME	COMMON NAME
Ictaluridae	*Ictalurus nebulosus*	Brown bullhead
	I. puntatus	Channel catfish
	Notarus flavus	Stonecat
	N. gyrinus	Tadpole madtom
Percopsidae	*Percopsis omiscomaycus*	Trout-perch
Gadidae	*Lota lota*	Burbot
Cyprinodontidae	*Fundulus diaphanus*	Banded killifish
Atherinidae	*Labidesthes sicculus*	Brook silverside
Gasterosteidae	*Culaea inconstans*	Brook stickleback
	Gasterosteus aculeateus	Threespine stickleback
Percichthyidae	*Morone americana*	White perch
	M. chrysops	White bass
	M. mississippiensis	Yellow bass
Centrarchidae	*Ambloplites rupestris*	Rock bass
	Lepomis gibbosus	Pumpkinseed
	L. macrochirus	Bluegill sunfish
	Micropterus dolomieni	Smallmouth bass
	M. salmoides	Largemouth bass
	Pomoxis nigramaculatus	Black crappie
Percidae	*Etheostoma nigrum*	Johnny darter
	Perca flavescens	Yellow perch
	Percina caprodes	Logperch
	Stizostedian vitreum vitreum	Walleye
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum
Cottidae	*Cottus bairdi*	Mottled sculpin

(11.7% of the total catch), but represented only 2% in 1973 and 2.5% in 1975. The latter difference is attributed to variations in April fishing efforts between 1974 and 1975 (April is the spawning time for rainbow smelt). Spottail shiner (the second most abundant species in 1975), threespine stickleback, yellow perch, white perch and gizzard shad were relatively abundant at one time or another during the collection periods. White perch was the second most abundant species in 1973 (7% of all fish collected).

The catch per unit effort for salmonids probably reflects the rate of stocking in Lake Ontario and growth to catchable size of these species. Both the brown trout and the coho salmon were caught in greater numbers in 1975 than in either 1973 or 1974. The brown trout was represented by 182 specimens in 1975 as compared to 75 in 1974; and the coho salmon by 57 individuals in 1975 and by 13 in 1974. Lake trout catch increased from 4 in 1974 to 28 in 1975. Other salmonids were captured in similar low numbers over the last two years.

Fluctuations in the seasonal abundances of various species are evident (LMS, 1975, 1976). The greatest number of fish were collected in the spring months, corresponding to the spawning of rainbow smelt and the inshore migration of alewife. The fish abundance then declined during the summer months due to the lakeward (post spawning) migration of these two abundant species (LMS, 1975).

The Shannon-Weaver diversity index (H), applied to bottom gill net collections (few fish were caught in surface gill nets) in 1974, indicated higher diversity at FITZ and NMPE transects and lowest diversity at NMPW transect, which with NMPP, generally had lower diversity values throughout the year (LMS, 1975). The fairly distinct west-to-east increase in diversity that occurred in 1974 was not found in 1975 when JAF was operating. Averages (and ranges) of diversity values based on 1975 bottom gill nets data were similar for the four transects.

Monthly station data for bottom gill nets were subjected to a clustering regime using group-average strategy in an attempt to discern patterns in the spatial and temporal distribution indicative of effects of the thermal plume (LMS, 1976). The transects were found not to differ among themselves, thus there is no apparent differences between stations close to and distant from the discharge. There was an apparent difference between inshore and offshore stations that was not the result of the presence of the thermal discharge.

The relative abundance and species composition of fish collected in surface and bottom gill nets in 1975 was different from that found in 1974. More alewife were collected near the surface in 1975 than in 1974 and fewer alewife were caught in the bottom gill nets in 1975 than in 1974. Moreover, 13 more species were collected in bottom gill nets than in surface gill nets in 1975. These two factors may have contributed to the changes in the diversity which is illustrated as follows: when 1974 data for species diversity were calculated, excluding alewife, the west-to-east assending trend was absent, i.e., more alewife inhabitated the western part of the study area in terms of their relative contribution to the nekton community.

The distribution and relative abundance of fishes observed in the Nine Mile Point vicinity is similar to the general pattern for the entire lake. The seasonal occurrence of fishes in the Nine Mile Point area follows the known seasonal behavior of the abundant species and no unusual concentrations or depletions in the vicinity of the discharge have been observed. A comparison of the life history data for the representative important species collected at Nine Mile Point is compared with the literature on each species in Chapter VI.

This conclusion is verified by the work of Storr (1974) who conducted tagging studies in the vicinity of NMP-1 and found that normal seasonal movements were not effected by operation of NMP-1. Preliminary results from 1976 indicate that this conclusion can be extended to JAF.

11. Conclusions

The biological community in the vicinity of Nine Mile Point shows high diversity at all trophic levels. The distribution, abundance and seasonal changes in groups and individual species are typical of Lake Ontario and follow the expected values and patterns found in the literature. There is a normal seasonal cycle of changing species composition and abundance in phytoplankton and zooplankton.

Phytoplankton zooplankton species abundance was found not to be affected by combined operation of NMP-1 and JAF. Measurement of photosynthetic rate suggested a stimulatory effect by the heated water, however, the increase is probably insignificant in terms of phytoplankton population dynamics due to the short period of stimulation. Microzooplankton samples from the plume and simulations of plume entrainment indicate percentage mortalities similar to simultaneous intake samples. There was no indication in these data of thermal induced mortality.

for all groups?
I doubt

The high velocity discharge of the JAF has scoured an area of the lake bottom immediately north the discharge ports and created an area of deposition beyond the area of scour. In both areas the benthic invertebrate community has been disturbed and a loss of productive benthic habitat has probably occurred in the scour area; productivity can be expected in the depositioned area when it becomes stabilized. The loss of benthic productivity is restricted to a small area and is unimportant in relation to benthic production in the Nine Mile Point Area.

The fish community at Nine Mile Point has a species composition typical of Lake Ontario and a seasonal pattern of distribution and abundance that is not influenced by the presence of the thermal discharge. The information on representative important species presented in Chapters VI and VII provides details on the effects of the thermal discharge on fishes.

REFERENCES CITED

CHAPTER V

Brinkhurst, R.O. 1969. Benthos, problems and techniques. In Proceedings of the conference on changes in the biota of Lake Erie and Ontario. Bull. Buffalo Soc. Nat. Sci. 25(1):76-82.

Christie, W.J. 1974. Changes in the fish species of the Great Lakes. J. Fish. Res. Bd. Canada 31(5):827-854.

Fretwell, S.D. 1972. Population in a seasonal: monographs on population biology -5. Princeton, New Jersey. 217p.

Gachter, R., R.A. Vollenweider, and W.A. Glooshenko. 1974. Seasonal variations of temperature and nutrients in the surface waters of Lake Ontario. J. Fish. Res. Bd. Canada 31:275-290.

Glooschenko, W.A., J.E. Moore, and R.A. Vollenweider. 1972. The seasonal cycle of phaeo-pigments in Lake Ontario with particular emphasis on the role of zooplankton grazing. Limnol. Oceanogr. 17(2):597-605.

Goodnight, C.J. 1973. The use of aquatic macroinvertebrates as indicators of stream pollution. Trans. Amer. Micros. Soc. 92(1):1-13.

Howmiller, R.P., and A.M. Beeton. 1970. The oligochaete fauna of Green Bay, Lake Michigan. Proc. 13th Conf. Great Lakes Res. 1970: 15-46.

Judd, J.H., and D.T. Gemmel. 1971. Distribution of benthic macrofauna in the littoral zone of southeastern Lake Ontario. Presented at Midwest Benthological Soc., 10th Annual Meet., Contrib. State Univ of N.Y. at Oswego. [Lake Ontario Environ. Lab. Contrib. 3: 9p.]

Lawler, Matusky and Skelly Engineers. 1975. 1974 Nine Mile Point aquatic ecology studies. Prepared for Niagara Mohawk Power Corp. and Power Authority of the State of New York.

Lawler, Matusky and Skelly Engineers. 1976. 1975 Nine Mile Point aquatic ecology studies. Prepared for Niagara Mohawk Power Corp. and Power Authority of the State of New York.

McNaught, D.C. and M. Buzzard. 1973. Changes in zooplankton populations in Lake Ontario (1939-1972). Proc. 16th Conf. Great lakes Res. 1973:76-86.

REFERENCES CITED (Continued)

McNaught, D.C., and M. Fenlon. 1972. The effects of thermal effluents upon secondary production. Verh. Int. Verein. Limnol. 18:204-212.

Munawar, M., and A. Nauwerck. 1971. The composition and horizontal distribution of phytoplankton in Lake Ontario during the year 1970. Proc. 14th Conf. Great Lakes Res. 1971:69-78.

Murarka, I.P. 1976. An evaluation of Environmental Data Relating to selected Nuclear power plant sites: The Kewaunee Nuclear power plant site. Argonne National Laboratory, Division of Environmental Impact Study; Argonne, Illinois.

Neil, J.H., and G.E. Owen. 1964. Distribution, environmental requirements and significance of Cladophora in the Great Lakes. Great Lakes Res. Div. Publ. [Proc. 7th Conf. Great Lakes Res. (1964)] 11:113-121.

Norden, C.R. 1968. Morphology and food habits of the larval alewife, Alosa pseudoharengus (Wilson) in Lake Michigan. Proc. 11th Conf. Great Lakes Res. 11:103-110.

Odum, E.P. 1971. Fundamentals of ecology. 3rd ed. W.B. Saunders Co., Philadelphia. xiv + 574p.

Ogawa, R.E. 1969. Lake Ontario phytoplankton, September 1964, p. 27-38. In Limnology study of Lake Ontario, 1964. Great Lakes Fish. Comm. Tech. Rept. 14: 59p.

Patrick, R. 1969. Some effects of temperature on freshwater algae, p. 161-185. In: P.A. Krenkel and F.L. Parker (eds.), Biological aspects of thermal pollution: proceedings of the National Symposium on Thermal Pollution. Vanderbilt University Press, Nashville, Tenn. 407p.

Pennak, R.W. 1953. Freshwater invertebrates of the United States. The Ronald Press Co., New York. 769p.

Prescott, G.W. 1962. Algae of the western Great Lakes. William Brown company, Dubuque, Iowa. 977p.

Quirk, Lawler and Matusky Engineers. 1973. Nine Mile Point Aquatic Ecology Studies 1972.

Quirk, Lawler and Matusky Engineers. 1974. 1973 Nine Mile Point aquatic ecology studies - Nine Mile Point Generating Station. Prepared for Niagara Mohawk Power Corp.

REFERENCES CITED (Continued)

Reinwand, J.F. 1969. Planktonic diatoms of Lake Ontario. *In* Limnological survey of Lake Ontario, 1964. Great Lakes Fish. Comm. Tech. Rept. 14:19-26.

Rochester Gas and Electric (RGE). 1974. The Sterling power project. [August 1973, Revised January 1974]. Rochester, N.Y.

Schelske, C.L., E.F. Stoermer, and L.E. Feldt. 1971. Nutrients, phytoplankton productivity and species composition as influenced by upwelling in Lake Michigan. Proc. 14th Conf. Great Lakes Res. 1971:102-113.

Storr, J.F. 1971. Ecological studies of cooling water discharge. Rochester Gas and Electric Corp.

Storr, J.F. 1973. Summary of studies to evaluate ecological effects from the introduction of a thermal discharge into Lake Ontario in the area of the Nine Mile Point Nuclear Station Unit one. Niagara Mohawk Power Corp.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Canada Bull. 184: 966p.

VI. SELECTION OF IMPORTANT REPRESENTATIVE SPECIES

A. RATIONALE

The purpose of selecting important representative species is to permit an assessment of plant effects on the ecosystem without resorting to a study of numerous species at each trophic level. The species selected are considered characteristic of the ecosystem, and therefore, an assessment of plants effects on these species provides an assessment of ecosystem effects.

The Regional Administrator, after consulting with the Commissioner of New York State Department of Environmental Conservation, the Secretary of Commerce and the Secretary of Interior, selected the following species as Representative Important Species for the James A. FitzPatrick Nuclear Power Plant (letter from Mr. Gerald Hansler to Mr. George Berry dated August 11, 1975).

1.	Alewife	*Alosa pseudoharengus*
2.	Brown trout	*Salmo trutta*
3.	Coho salmon	*Oncorhynchus kisutch*
4.	Rainbow smelt	*Osmerus mordax*
5.	Smallmouth bass	*Micropterus dolomieui*
6.	Threespine stickleback	*Gasterosteus aculeatus*
7.	Yellow perch	*Perca flavescens*
8.	*Gammarus fasciatus*	

Four criteria were used to aid in the selection of important representative species as required for the 316(a) demonstration for the James A. FitzPatrick Plant. The criteria were: (1) the species is important for a recreational or commercial fishery, (2) the species is numerically abundant or represents a major portion of the biomass of its trophic level, (3) the species is important because its existence in the lake is endangered or it is a nuisance, (4) the species has an important functional role in the ecosystem.

The sources of information which were used include: (1) published literature regarding the biology of a given species; (2) determinations of importance to the ecosystem based on biological and plant monitoring programs which have been conducted in the Nine Mile Point/ Oswego area since 1963; and (3) design features, location, and predicted plumes of the thermal discharge which may impact on the distribution and abundance of the selected species. The important representative species are listed below with the rationale for inclusion of each species in the list.

1. Alewife

The alewife was selected as a representative species because it is numerically abundant, a major portion of the total fish biomass, an important forage species for valuable recreational fishes, at times a nuisance, and a potentially important commercial species. Alewife was the dominant species in the vicinity of Nine Mile Point and in impingement sampling from 1973 to 1975. In 1975, it made up 75% of the annual lake catch (all gears combined) and 79.6% of the total number of fish collected during annual impingment monitoring. This species is the forage base for a number of recently introduced salmonids and constitutes a portion of the diet of all large piscivorous fishes in Lake Ontario. Annual spring and summer die-offs of alewives have clogged water intake systems and fouled shoreline areas with rotting carcasses. The alewife is not commercially exploited in Lake Ontario.

56.7
89.9 %

2. Brown Trout and Coho Salmon

The brown trout and coho salmon were selected because they are important recreational species, and are among several salmonids being stocked in large numbers by the State of New York and the Province of Ontario. These two species, along with other salmonids, feed heavily on alewives and thereby convert a nuisance species into a useful resource. In addition, salmonids are "coldwater" species that could be impacted by thermal discharges. Although salmonids are presently collected in low numbers in lake and impingement sampling, their recreational value, as well as their relationship to the alewife, has led to their inclusion as representative species.

3. Rainbow Smelt

The rainbow smelt was selected for the representative species list because it is numerically abundant and represents a major portion of the total fish biomass of the lake. Smelt are harvested commercially in Lake Ontario and formerly supported a sport fishery on the Canadian side of the lake. The rainbow smelt increased in abundance dramatically in the late 1940's and may have important ecological relationships with other lake species. It is collected in substantial numbers in lake and impingement sampling at Nine Mile Point.

4. Smallmouth Bass

The smallmouth bass in an important sport fish and an important piscivore in the nearshore area of the lake. Smallmouth bass were collected in small numbers compared to alewife, although they are found in the nearshore area and in impingement collections.

5. Threespine Stickleback

The threespine stickleback is listed as a representative species because it is important as forage for many piscivores, very abundant in the nearshore area, and collected in relatively large numbers in impingement collections at Nine Mile Point. Threespine stickleback spawn in the Nine Mile Point area.

6. Yellow Perch

The yellow perch was chosen as a representative species because it is important for sport and commercial fisheries and abundant in the nearshore area. Christie (1973) felt that the increased commercial catch of this species indicates a substantial increase in its abundance in the eastern end of Lake Ontario. It is collected in substantial numbers in lake and impingement sampling at Nine Mile Point, and there is evidence of a minimal amount of spawning in the Nine Mile Point area.

7. *Gammarus* sp.

Gammarus sp., an amphipod, is considered representative of the benthic invertebrates that are important forage for the young and adults of many fish species. Several species of *Gammarus* are found in Lake Ontario with *Gammarus fasciatus* the most abundant. Unlike most benthic invertebrates, *Gammarus* is quite mobile and migrates upward away from the bottom. It is thus entrained into the cooling system of the Nine Mile Point plant (LMS, 1975) and into the discharge plume.

8. Threatened and Endangered Species

Lists of threatened and endangered species are published by the U.S. Department of the Interior. A review of these publications, current issues of the Federal Register, and technical literature indicates that the following species from Lake Ontario are considered threatened, endangered, or rare:

1. Lake sturgeon (*Acipenser fulvescens*)
2. Blue pike (*Stizostedion vitreum glaucum*)
3. Kiyi (*Coregonus kiyi*)
4. Blackfin cisco (*Coregonus nigripinnis prognathus*)
5. Shortnose cisco (*Coregonus reighardi*)

None of these fishes have been collected in the vicinity of either Nine Mile Point or Oswego in the course of the extensive biological monitoring programs of the last four years (1972 to 1975). A discussion of the decline in abundance of the species listed above may be found in Christie (1973).

B. LIFE HISTORIES OF REPRESENTATIVE SPECIES

1. Alewife (*Alosa pseudoharengus*)

The alewife is an anadromous species that spends most of its adult life in marine waters and returns to fresh water to spawn. It occurs from Newfoundland to North Carolina (Scott and Crossman, 1973), and, in addition, is landlocked in many lakes along its range, including Lake Ontario.

- Abundance and Seasonal Distribution

In Lake Ontario, adult alewives reside in the open lake and migrate inshore during the spring and summer to spawn in streams or in nearshore shallow areas with sand and gravel bottoms. During the spring spawning season, great numbers of alewives move inshore at night; a decrease in alewife abundance in the spawning areas during the day indicates the occurrence of short diurnal migrations near the spawning grounds.

Alewife from Lake Michigan occupy all depths along the bottom as well as all vertical depths, depending on life stage and time of year (Wells, 1968). The inshore spawning migration of adults was reported to occur as early as March 11, and by April 15, the largest concentration of adult alewife was observed in the shallow areas of Lake Michigan (Wells, 1968). In the Bay of Quinte, Lake Ontario, the inshore migration of alewife reached a maximum in late June and ended in late July (Graham, 1956). The inshore movement of adult alewife in the FitzPatrick vicinity was observed to take place during April (LMS, 1975). Spawning activity began shortly after arrival, reaching a peak during the first half of July. Like the adults, juvenile alewife initiated their inshore movements in the spring; they tended to group in shallow areas at dark and to remain on the bottom, at 6 to 10 ft depth, during daylight hours.

The majority of alewife collected from the Nine Mile Point study area during the period 1973-1975 were caught by gill nets. In 1974, more alewife were caught in bottom gill nets than in surface gill nets; this trend, however, was reversed in 1975 (LMS, 1976). The 1974 gill net collections indicated that alewife abundance was not significantly different (based on catch/12 hours) at the FITZ transect than at the other three transects (LMS, 1975).

NO! backwards

who observed behavior?

Alewife in the Nine Mile Point area exhibited seasonal as well as diel variations in behavior. A three-way analysis of variance of 1974 gill net data (catch/12 hours) by sample depth among three seasons (Spring: April-June; Summer: July-September; and Fall: October-December) revealed that alewife were significantly more abundant in the evening and during the spring and summer periods than during fall (LMS, 1975). This is in agreement with observations of Graham (1956) and Scott and Crossman (1973) that alewife return to deep water after spawning, and was also confirmed by Wells (1968) for Lake Michigan alewife. More alewife were caught near the bottom during the daytime than near the surface, and conversely, near the surface at night.

Catch per effort (number/12 hrs) of alewives collected by surface and bottom gill nets at the 40 ft depth contour were estimated from April through December 1975 and compared among transects (Table VI-1). The 40 ft depth contour was chosen because it was most influenced by the thermal plume of the FitzPatrick plant. Surface gill net collections yielded significantly more alewives than bottom gill net collections, and the average catch per effort in April, May and July 1975 was significantly higher for collections during the rest of the sampling period (Table VI-2). The average catch per effort for surface gill nets at FITZ transect was similar to that of NMPW and NMPP, but higher than that of NMPE (Table VI-1). Catch per effort estimated from bottom gill net collections was higher at FITZ transect than the other three transects, primarily because of the large collection during July (Table VI-1). No significant difference existed in catch per effort among transects throughout the sampling period, and the difference between surface and bottom alewife abundance was significant in one month only, May, 1975 (Table VI-2).

- Age and Growth

The average calculated lengths at each annulus for male and female alewives are summarized in Table VI-3 and compared with these for fish collected in 1973 (QLM, 1974) and other populations from Lake Ontario and its vicinity (Table VI-4). Growth rate of alewife is characterized as rapid during the first two years of life. After the first and second years of life, alewife were 54 and 67%, respectively, of the length achieved after six years of growth. In a study of alewife growth in Lake Ontario, Graham (1956) noted that alewives experience an early period of rapid growth, the rate of which decreases with the onset of sexual maturity at age 2 for males and age 3 for females. Growth rates of male and female alewives were similar for age groups I and II, after which females exhibited a relatively faster growth rate than did males (Table VI-3). This is in agreement with Pritchard (1929) who reported that female alewives grow faster than males and attain a greater size.

The calculated growth of male and female alewife was plotted by age class (i.e., year spawned) so that differences or similarities among age classes could be observed (Figures VI-1 and VI-2). These graphs show (where comparisons are possible) that for fish spawned from 1969 to 1973, growth was similar for ages I, II, III, and IV. However, fish spawned in 1968 appeared to grow faster from ages III to VI. This

TABLE VI-1

CATCH PER EFFORT* OF SELECTED FISH SPECIES IN GILL NET COLLECTIONS AT 40-FT DEPTH CONTOUR

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1975

I. ALEWIFE

MONTH	SURFACE GILL NETS				BOTTOM GILL NETS			
	NMPW	NMPP	FITZ	NMPE	NMPW	NMPP	FITZ	NMPE
APR	45.1	127.9	88.8	16.8	27.0	14.5	26.3	3.0
MAY	202.7	133.3	90.4	60.5	4.6	4.9	2.2	1.6
JUN	67.3	24.5	57.4	42.4	1.4	3.4	6.0	12.0
JUL	154.0	85.7	91.9	68.0	19.0	49.1	188.9	8.6
AUG	16.9	27.0	2.4	4.0	4.4	1.9	9.1	24.5
SEP	2.8	17.3	7.7	2.6	8.0	10.7	18.8	6.8
OCT	10.8	17.5	NS	1.6	5.3	4.0	8.3	3.4
NOV	17.2	25.0	30.5	11.9	24.7	1.6	6.7	3.7
DEC	11.4	16.6	7.8	3.0	1.8	3.8	9.6	10.0
MEAN	58.7	52.8	47.1	23.4	10.7	10.4	30.7	7.2

II. RAINBOW SMELT

APR	1.6	3.6	26.2	8.6	4.3	1.9	15.0	5.3
MAY	0.0	0.1	0.1	0.1	0.4	0.0	0.1	0.1
JUN	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
JUL	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
AUG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEP	0.4	0.5	0.2	0.1	0.0	0.2	0.2	0.0
OCT	1.1	1.8	NS	0.1	0.4	0.2	1.6	0.4
NOV	0.8	1.3	0.5	0.6	1.3	0.6	2.2	2.6
DEC	0.2	1.3	0.7	0.0	0.4	0.0	1.2	0.0
MEAN	0.5	1.0	3.5	1.1	0.8	0.3	2.3	0.9

*Mean number of fish collected/12 hours

NS = No sample

TABLE VI-1 (Continued)

CATCH PER EFFORT* OF SELECTED FISH SPECIES IN GILL NET COLLECTIONS AT 40-FT DEPTH CONTOUR

III. YELLOW PERCH

MONTH	SURFACE GILL NETS				BOTTOM GILL NETS			
	NMPW	NMPP	FITZ	NMPE	NMPW	NMPP	FITZ	NMPE
APR	0	0.0	0.0	0	0.0	0.1	0.4	0.0
MAY	0	0.0	0.0	0	0.0	0.1	0.0	0.2
JUN	0	0.0	0.2	0	0.8	0.5	0.2	0.8
JUL	0	0.0	0.2	0	0.7	0.5	1.7	0.1
AUG	0	0.1	0.0	0	0.2	0.1	1.3	0.4
SEP	0	0.2	0.0	0	0.7	0.5	1.0	0.6
OCT	0	0.0	NS	0	1.0	0.2	2.0	1.1
NOV	0	0.0	0.0	0	0.5	0.2	0.4	0.2
DEC	0	0.0	0.0	0	0.4	0.0	0.0	0.0
MEAN	0	0.0	0.1	0	0.5	0.2	0.8	0.4

IV. SMALLMOUTH BASS

APR	0	0.0	0	0	0.0	0.0	0.6	0.2
MAY	0	0.0	0	0	0.2	0.1	0.2	0.0
JUN	0	0.0	0	0	0.0	0.0	0.0	0.0
JUL	0	0.0	0	0	0.1	0.5	0.7	0.7
AUG	0	0.0	0	0	1.9	1.8	0.7	1.6
SEP	0	0.5	0	0	0.8	1.8	3.4	0.4
OCT	0	0.0	0	0	0.1	0.0	0.0	0.0
NOV	0	0.0	0	0	0.5	0.0	0.1	0.0
DEC	0	0.0	0	0	0.0	0.0	0.0	0.0
MEAN	0	0.1	0	0	0.4	0.5	0.6	0.3

*Mean number of fish collected/12 hours
NS = No sample

TABLE VI- 2

STATISTICAL ANALYSIS OF SELECTED FISH SPECIES IN GILL NET COLLECTIONS AT 40-FT DEPTH CONTOUR

JAMES A FITZPATRICK NUCLEAR POWER PLANT - 1975

ALEWIFE

THREE-WAY ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F
MONTHS	7	44097.07	6299.58	6.72**
TRANSECTS	3	5120.33	1706.78	1.82
SAMPLE DEPTHS	1	16971.58	16971.58	18.10**
MONTH X TRANSECT	21	17216.77	819.85	0.87
MONTH X SAMPLE DEPTH	7	22616.92	3230.99	3.45*
TRANSECT X SAMPLE DEPTH	3	4787.95	1595.98	1.70
ERROR	21	19687.11	937.48	
TOTAL	63	130497.73		

*Significant at α = .05
**Significant at α = .01

ESTIMATED MEANS FOR MONTHS

MONTH	ESTIMATED MEAN
APR	43.7
MAY	62.5
JUN	26.8
JUL	83.2
AUG	11.3
SEP	9.3
NOV	15.2
DEC	8.0

TUKEY T TEST - MONTHS (α= .05)

Largest: JUL MAY APR JUN NOV AUG SEP DEC: Smallest

ESTIMATED MEANS FOR SAMPLE DEPTHS

SAMPLE DEPTH	ESTIMATED MEAN
SURFACE	48.8
BOTTOM	16.2

ESTIMATED MEANS FOR MONTHS AND DEPTHS

	DEPTH		
MONTH	SURFACE	BOTTOM	SIGNIFICANT DIFFERENCE[a]
APR	69.7	17.7	NO
MAY	121.7	3.3	YES
JUN	47.9	5.7	NO
JUL	99.9	66.4	NO
AUG	12.6	10.0	NO
SEP	7.6	11.1	NO
NOV	21.2	9.2	NO
DEC	9.7	6.3	NO

[a] Simultaneous tests using Bonferroni procedures (α= .05)

TABLE VI-3

AVERAGE CALCULATED TOTAL LENGTH AND STANDARD ERROR AT ANNULUS FORMATION OF ALEWIVES

NINE MILE POINT - 1974

YEAR CLASS	NUMBER OF FISH	AGE GROUP	I	II	III	IV	V	VI
			AVERAGE CALCULATED TOTAL LENGTH (mm) AND STANDARD ERROR AT ANNULUS FORMATION					
			MALES					
1973	44	I	98.40 ±2.02					
1972	13	II	81.63 ±3.83	138.42 ±3.65				
1971	18	III	86.14 ±3.25	139.17 ±3.01	155.42 ±3.28			
1970	48	IV	80.37 ±1.58	133.33 ±1.45	148.92 ±1.36	157.34 ±1.48		
1969	22	V	77.53 ±2.26	129.94 ±2.53	145.20 ±2.09	154.59 ±2.23	160.10 ±2.50	
1968	5	VI	76.33 ±7.35	131.08 ±10.59	164.60 ±7.79	179.87 ±9.88	190.49 ±10.42	198.80 ±11.53
		Grand average calculated length (weighted)	85.91	134.14	150.14	158.04	165.73	198.80
		Grand average increment of length (weighted)	85.91	53.41	16.60	9.16	6.46	8.31
		Sum of grand average increments	85.91	139.32	155.92	165.08	171.54	179.85
		Confidence interval of (α=0.05) grand calculated lengths	83.83 87.99	131.67 136.61	147.75 152.53	155.29 160.79	161.18 170.28	157.40 240.20
			FEMALES					
1973	44	I	98.40 ±2.02					
1972	8	II	82.00 ±5.84	140.38 ±3.94				
1971	28	III	88.54 ±2.98	142.26 ±2.80	160.38 ±2.27			
1970	48	IV	82.97 ±1.89	140.08 ±2.05	157.53 ±1.68	167.12 ±1.54		
1969	37	V	74.26 ±1.98	125.37 ±2.39	143.35 ±1.65	156.89 ±1.64	165.54 ±2.18	
1968	10	VI	74.23 ±4.56	129.80 ±10.22	160.20 ±8.91	170.53 ±8.53	182.67 ±8.45	198.20 ±9.79
		Grand average calculated length (weighted)	85.36	135.62	154.13	163.49	169.18	198.20
		Grand average increment of length (weighted)	85.36	54.65	18.82	11.21	9.39	5.53
		Sum of grand average increment	85.36	140.01	158.83	170.04	179.43	184.96
		Confidence interval of (α=0.05) grand calculated lengths	83.26 87.46	132.68 138.56	151.65 156.61	160.73 166.25	163.95 174.41	186.67 209.73

TABLE VI-4

COMPARISON OF GROWTH RATE OF ALEWIFE FROM LAKE ONTARIO AND ITS VICINITY[a]

NINE MILE POINT (LMS, 1975)	NINE MILE POINT (QLM, 1974)	PORT CREDIT LAKE ONTARIO (PRICHARD, 1929)	BAY OF QUINTE LAKE ONTARIO (PRICHARD, 1929)	LAKE MICHIGAN (NORDEN, 1967)	SENACA LAKE, N.Y. (ODELL, 1934)[b]
LENGTH (mm)	LENGTH (mm)	LENGTH (mm)	LENGTH (mm)	LENGTH (mm)	LENGTH (mm)
86 (44)	110 (2)	99 (7)		94 (147)	70 (113)
135 (21)	145 (28)	128 (5)	140 (1)	140 (177)	145 (89)
152 (46)	157 (83)	143 (11)	143 (2)	159 (1028)	154 (284)
		153 (34)	148 (14)	173 (502)	171 (49)
161 (96)	165 (145)	162 (35)	157 (17)		174 (15)
168 (59)	183 (31)	180 (3)	179 (9)		
198 (15)	204 (7)		187 (1)		
	217 (1)				

[a] Numbers which appear in parentheses represent the number of fish measured in determining average length.

[b] To convert standard length to total length multiply by 1.2513, based on Nine Mile Point alewives total length/standard length ratio.

FIGURE VI-1

COMPARISON OF THE CALCULATED GROWTH OF MALE ALEWIVES AMONG FIVE AGE CLASSES FOR FISH COLLECTED BY GILL NETS & TRAWLS*

NINE MILE POINT - 1974

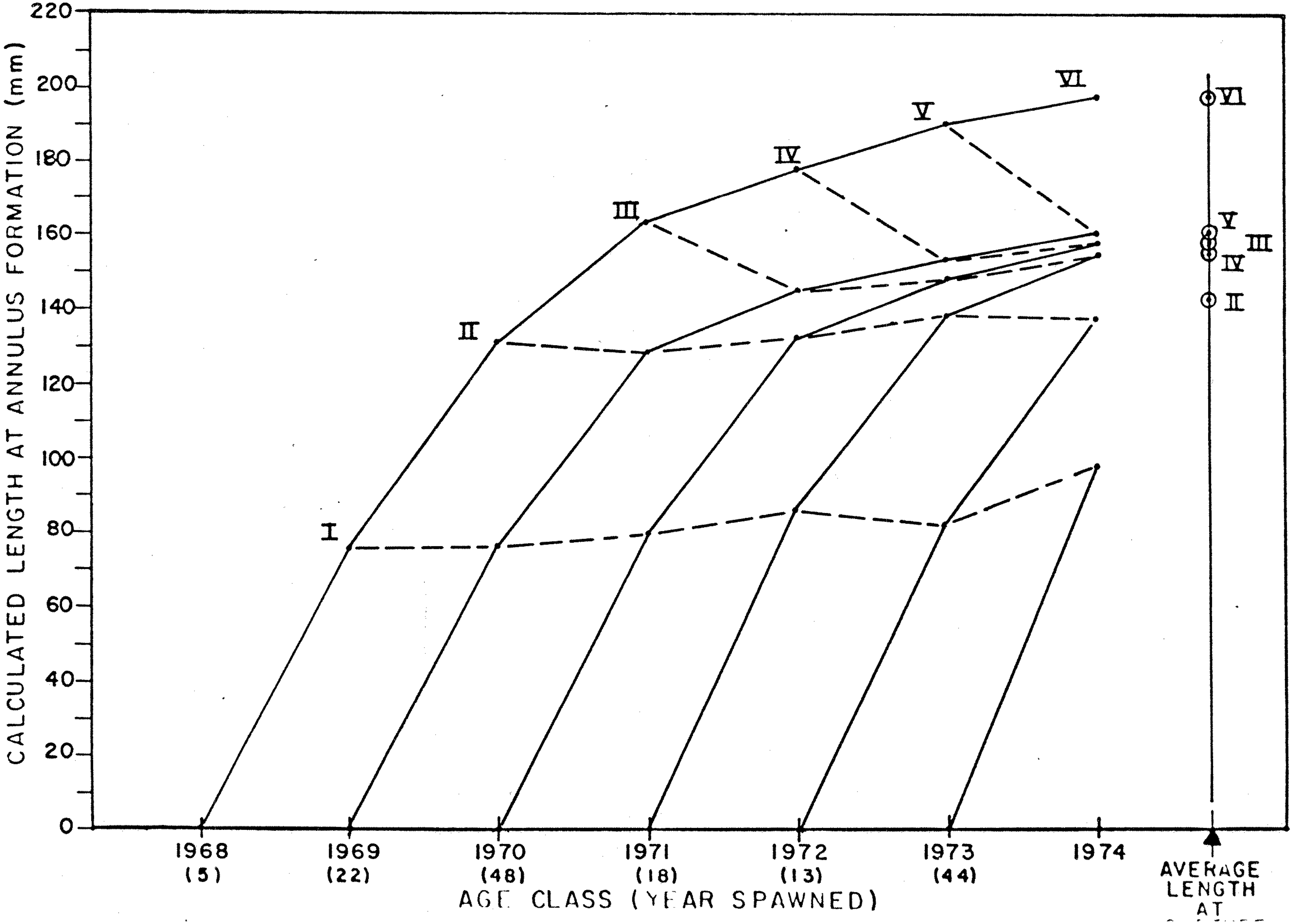
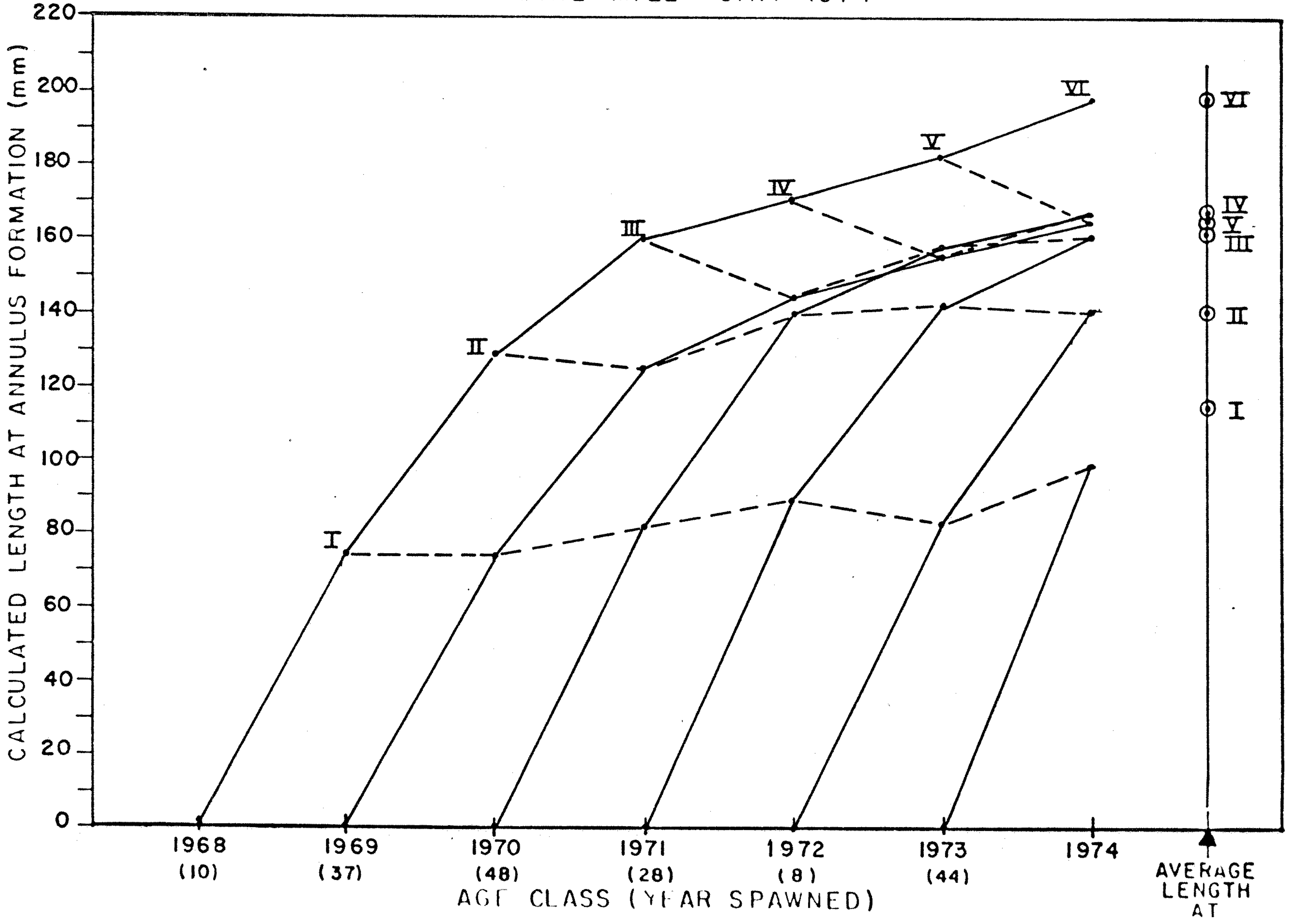


FIGURE VI-2

COMPARISON OF THE CALCULATED GROWTH OF
FEMALE ALEWIVES
AMONG SIX AGE CLASSES
FOR FISH COLLECTED BY GILL NETS & TRAWLS*
NINE MILE POINT-1974



phenomenon may be attributed to the small sample size or the fact that only larger, faster growing individuals survive for six years and are then available for capture.

Total alewife biomass and average biomass per fish were compared on a monthly basis among transects for the 1974 gill net collections (LMS, 1975). No observable pattern or difference among transects was observed in either the total or average fish biomass. Similarity of biomass distribution patterns suggests even distribution of comparable size (life stage) organisms in the Nine Mile Point vicinity.

Alewives from the Nine Mile Point vicinity of Lake Ontario generally appeared to grow more rapidly after the first year of life than fish from Port Credit and the Bay of Quinte, Lake Ontario (Pritchard, 1929) (Table VI-4). Graham (1956) reported that Atlantic alewife of both sexes mature one year later than landlocked Lake Ontario alewife, grow more quickly throughout their life, and attain a larger size than Lake Ontario alewife. He suggested that the freshwater environment hastens the onset of sexual maturity and that this results in an inhibition of growth.

- Reproduction

Landlocked alewives spend most of the year in deeper lake waters and move to shallow areas in spring for spawning. The inshore spawning migration is related to water temperature. The average water temperatures recorded in the Nine Mile Point vicinity at the onset of spawning were similar to those reported by Threinen (1958)(13-16°C) and Gross (1959)(17-19°C).

Alewives in the Nine Mile Point vicinity began spawning in late May/ early June and reach a peak spawning during the first two weeks of July when the water temperature is about 13.5-22°C.

Graham (1956) noted that peak spawning activity for alewives in the Bay of Quinte, on the north shore of eastern Lake Ontario, was near the end of July. Larvae were observed to remain in the shallow shore zone at least until late larval stages had been reached during the early fall period. Wells (1968) studied alewife distribution in Lake Michigan and found the greatest concentration located near the surface, with individuals gradually assuming a mid-depth to bottom preference with increased age.

Examination of alewife ovaries collected near the spawning peak revealed eggs at two distinct stages of development, distributed homogeneously throughout the ovary. Smaller, white eggs ranged in size from 0.2 to 0.4 mm with an average diameter of 0.3 mm; larger, yolk-laden eggs, which were those most likely to be spawned during the short spawning season, varied from 0.5 to 0.8 mm with an average diameter of 0.56 mm.

Total egg counts for fish in the 1974 study ranged from 8,981 to 50,274 eggs with a mean of 31,613 eggs. In 1973 (QLM, 1974), the total egg counts for 11 alewives from the Nine Mile Point vicinity of Lake Ontario ranged from 25,797 to 67,739 eggs, with a mean of 46,821 eggs.

A range in total egg production of 11,147 to 22,407 eggs per female was reported for alewives of similar size in Lake Michigan (Norden, 1967). Since only mature eggs are spawned during a season, total egg count may overestimate the actual fecundity of freshwater alewives.

Fecundity of alewives does not seem to be correlated with age, fish weight, ovary weight, or even fish length (LMS, 1975). Each of these parameters exhibited a poor correlation (r varied from 0.02 to 0.21 with fecundity). The fecundity estimates varied from 7,364 to 36,574 eggs (average 21,378 for 153-177 mm female alewives).

Alewife eggs were first observed in samples collected at Nine Mile Point on 19-20 June, and peak egg abundance was found during the second and third week of July, 1974 (LMS, 1975). This corresponds very closely to the observed time of spawning reported by Graham (1956). As expected, egg concentrations were higher in bottom samples since the alewife has demersal eggs which are broadcast at random (Mansueti and Hardy, 1967). The greatest concentration of alewife eggs was at the 20 ft depth contour stations of NMPP and the lowest numbers were observed at NMPE and at the deeper depth contour stations north of the point.

Alewife larvae were present in ichthyoplankton samples from the end of June through the middle of September, 1974. Peak abundance in the area around Nine Mile Point occurred during the last week in July and the first week of August. Length frequency information (LMS, 1975) suggests that the larvae averaged 10.8 mm during the period of peak abundance, and reached juvenile size before emigrating from the Nine Mile Point area in September. Collections made at Nine Mile Point had significantly greater numbers of larvae in surface samples compared to bottom samples, confirming the preference of the larvae for surface waters. Presence of larvae in samples from the end of June onward points to the prolonged spawning period by alewives in Lake Ontario.

The time required for egg hatching was cited (Scott and Crossman, 1973) to be six days at 15.6°C or three days at 22.2°C.

- Feeding

Alewives are size-selective zooplankton feeders preferring larger

- Feeding

Alewives are size-selective zooplankton feeders preferring larger cladocerans, calanoid and cylopoid copepods (Wells, 1970). Norden (1968) found that larval alewives in Lake Michigan had a definite food preference for cladocerans and copepods with incidental occurrences of diatoms and plant material in stomachs analyzed. Adult alewives from Lake Michigan, like the larvae, fed primarily on copepods and cladocerans (Rhodes and McCormish, 1975); however, during the summer, dipteran larvae were a preferred item and the deep-water amphipod, *Pontoporeia affinis*, was heavily utilized during the early fall. Wells (1970) noted heavy feeding pressure on *Leptodora kindtii*, which is one of the predominant macrozooplankters in the vicinity of Nine Mile Point.

Information on the feeding habits of alewives in the vicinity of Nine Mile Point is not currently available. All of the food items reported for alewives are abundant in the Nine Mile Point area (LMS, 1975).

2. Rainbow smelt (*Osmerus mordax*)

The original range of the rainbow smelt in eastern North America was the Atlantic coastal drainage from New Jersey to Labrador. Whether or not the smelt is native to Lake Ontario is uncertain; Hubbs and Lagler (1958) believe that it is, whereas Scott and Crossman (1973) are of the opposite opinion. In either case, the first report of rainbow smelt taken from Lake Ontario was in 1931 by Mason (1933), although they now occur in all of the Great Lakes and in many other Canadian and United States lakes. The smelt is an anadromous species, leaving the sea or large lakes in spring to spawn in freshwater streams.

- Abundance and Seasonal Distribution

The vast majority of rainbow smelt sampled from the Nine Mile Point area were collected by surface and bottom gill nets in both 1974 and 1975. Their representation declined from 1974, when rainbow smelt made up 11.7% of the total fish collected, to 1975, when they were only 2.5% of the total. The average catch per effort declined between years for both surface and bottom gill nets, dropping from 4.32 in 1974 to 1.06 in 1975 and from 3.63 in 1974 to 0.80 in 1975 for surface and bottom gill nets, respectively.

Trawl and seine nets produced little data on rainbow smelt in either 1974 or 1975. The absence of this species from the seine collections may indicate that spawning is not occurring in the littoral area. Scott and Crossman (1973) reported that rainbow smelt in the Great Lakes spawn in streams or, under adverse weather conditions, in the offshore areas on gravel shoals.

In 1974, the highest catch per effort was recorded at all transects in April, the reported time of the smelt spawning migration (LMS, 1975). The eastern transect, NMPE, yielded the greatest catch per effort, (40) while it was intermediate (39.8) at FITZ, and lower at NMPW (19.8) and NMPP (22.6).

In 1975, the number of rainbow smelt collected in April declined because of a reduction in the fishing efforts. Smelt were sampled on only three days in April 1975 compared to nine days in 1974. This explains the reduction in the percentage of the total for the two years since April is the time of peak abundance. Percent composition of rainbow smelt collected in bottom gill nets is summarized by season; Spring, Summer, and Fall 1975 (Table VI-5).

The catch per effort of rainbow smelt in surface and bottom gill nets in 1975 at the 40 ft depth contour was estimated and compared for all transects (Table VI-1). The average catch per effort during April-December 1975 was significantly higher at FITZ transect (= .01) than at the other three transects (Table VI-6). There was no significant difference between surface and bottom catch within transects, but the difference among transects was significant in April, with the FITZ catch exceeding that at all other transects combined, for both surface and bottom collections. Catch per effort in April, when JAF was not operating, was significantly higher than during the rest of the sampling period.

The larger number of rainbow smelt present at the FITZ 40 ft depth contour in April may be subject to the thermal discharge if the trend continues in the future. The majority of the fish are present in April when the average water temperature is about 6°C. The preferred temperature for smelt is about 7.0-7.2°C but they may enter waters as warm as 15.6°C for brief periods (Scott and Crossman, 1973). Catch per effort in October, November, and December was not significantly different at Fitz 40. Since smelt were present in the area, this implies that there is no attraction to the JAF discharge.

- Age and Growth

The growth history of rainbow smelt was based on the analyses of 101 male and 206 females (Table VI-7) collected in 1974 ranging in total length from 125 to 244 mm. Average back calculated lengths at each annulus, together with the standard error for each year of life, are summarized in Table VI-7.

Both male and female rainbow smelt grew faster in their early years of life, and growth increments declined with age. Both sexes exhibited similar growth rates during the first year of life, after which (i.e., at age two and older) female smelt grew significantly ($P = 0.5$, t-test)

TABLE VI-5

PERCENT COMPOSITION OF RAINBOW SMELT IN BOTTOM GILL NETS COLLECTIONS BY SEASON

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY - 1975

	TRANSECT			
SEASON	NMPW	NMPP	FITZ	NMPE
SPRING	2.47	2.70	9.41	3.71
SUMMER	0.48	1.02	0.24	0.08
FALL	6.47	2.54	5.14	5.05

TABLE VI-6

STATISTICAL ANALYSIS OF SELECTED FISH SPECIES IN GILL NET COLLECTIONS AT 40-FT DEPTH CONTOUR

RAINBOW SMELT

THREE-WAY ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F
MONTHS	7	459.8798	65.6971	28.31**
TRANSECTS	3	57.9642	19.3214	8.33**
DEPTHS	1	1.9252	1.9252	0.83
MONTH X TRANSECT	21	368.7796	17.5609	7.57**
MONTH X DEPTH	7	22.5261	3.2180	1.39
TRANSECT X DEPTH	3	5.0954	1.6985	0.73
ERROR	21	48.7383	2.3209	
TOTAL	63	964.9086		

**Significant at $\alpha = .01$

ESTIMATED MEANS FOR TRANSECTS

TRANSECTS	ESTIMATED MEAN
NMPW	0.6
NMPP	0.6
FITZ	2.9
NMPE	1.1

TUKEY T TEST - TRANSECTS ($\alpha = .05$)

Largest: FITZ NMPE NMPP NMPW: Smallest

ESTIMATED MEANS FOR MONTHS

MONTH	ESTIMATED MEAN
APR	3.3
MAY	0.1
JUN	0.0
JUL	0.0
AUG	0.0
SEP	0.1
NOV	0.8
DEC	0.2

TUKEY T TEST - MONTHS ($\alpha = .05$)

Largest: APR NOV DEC MAY SEP JUL JUN AUG: Smallest

ESTIMATED MEANS FOR MONTHS AND DEPTHS

	DEPTH		
MONTH	SURFACE	BOTTOM	SIGNIFICANT DIFFERENCE[a]
APR	10.0	6.6	YES
MAY	0.1	0.2	NO
JUN	0.0	0.0	NO
JUL	0.0	0.0	NO
AUG	0.0	0.0	NO
SEP	0.3	0.1	NO
NOV	0.8	1.7	NO
DEC	0.6	0.4	NO

[a] Simultaneous tests using Bonferroni procedures ($\alpha = .05$)

TABLE VI-7

AVERAGE CALCULATED TOTAL LENGTH AND STANDARD ERROR AT ANNULUS FORMATION OF RAINBOW SMELT

NINE MILE POINT - 1974

YEAR CLASS	NUMBER OF FISH	AGE GROUP	AVERAGE CALCULATED TOTAL LENGTH (mm) AND STANDARD ERROR ANNULUS FORMATION						
			I	II	III	IV	V	VI	VII
			MALES						
1972	29	II	79.35 ±2.25	128.56 ±2.41					
1971	67	III	75.97 ±1.19	118.69 ±1.42	147.72 ±1.47				
1970	3	IV	87.84 ±13.85	126.68 ±14.83	155.17 ±14.36	179.00 ±12.58			
1969	2	V	68.12 ±2.40	116.28 ±15.98	144.28 ±16.26	169.63 ±19.09	189.00 ±28.00		
		Grand average calculated length (weighted)	77.14	121.72	147.93	175.25	189.00		
		Grand average increment of length (weighted)	77.14	44.58	28.98	24.44	19.37		
		Sum of grand average increments	77.14	121.72	150.70	175.14	194.51		
		Confidence interval (α=0.05) grand average calculated lengths	74.95 79.33	119.16 124.26	144.85 151.00	124.38 226.12	166.76 544.17		
			FEMALES						
1972	8	II	85.70 ±2.87	145.27 ±3.88					
1971	107	III	80.69 ±1.03	128.48 ±1.20	157.47 ±1.49				
1970	49	IV	74.91 ±1.84	121.35 ±2.71	158.20 ±2.82	185.44 ±3.62			
1969	31	V	75.28 ±2.01	127.41 ±3.20	159.37 ±2.95	185.92 ±3.45	208.86 ±4.13		
1968	10	VI	73.25 ±3.10	132.07 ±3.07	160.24 ±3.26	183.73 ±4.47	199.26 ±5.25	217.09 ±4.72	
1967	1	VII	75.38	144.11	146.69	171.21	189.50	207.86	220.08
		Grand average calculated length (weighted)	78.31	127.38	158.03	185.26	206.11	216.25	220.08
		Grand average increment of length (weighted)	78.31	49.07	31.38	26.56	21.07	17.88	12.22
		Sum of grand average increment	78.31	127.38	158.76	185.32	206.39	224.27	236.49
		Confidence interval (α=0.05) grand average calculated lengths	76.76 79.86	125.30 129.46	155.69 160.36	180.26 190.06	199.09 213.13	204.93 227.56	

faster than males. This characteristic has been observed for female rainbow smelt in other waters.

McKenzie (1958) reported that female smelt in the Miramichi River, New Brunswick, Canada, were larger than males after the second year of growth. Bailey (1964) reported that age three and older female smelt in Lake Superior were larger than males. Burbidge (1969) found that female smelt in Lake Michigan attained a greater mean length than males after the second year of life, but that the female size advantage was significant only for the fourth year of life. The more rapid growth of female smelt was also reported by Van Oosten (1947) in Green Bay, Lake Michigan; by Baldwin (1950) in South Bay, Lake Huron; and by Hale (1960) in western Lake Superior.

The growth by each age class for males and females is plotted as a function of age in Figures VI-3 and VI-4. which show that growth has been uniform for fish spawned in the years 1967-1972.

The growth rate of rainbow smelt from the Nine Mile Point vicinity is greater than or similar to that of smelt collected from other areas in the vicinity of Lake Ontario (Table VI-8). The growth rate of Nine Mile Point smelt in the first year of life was greater than that of smelt from Lake Superior (Bailey, 1964) and Gull Lake, Michigan (Burbidge, 1969) and was comparable to the rate for smelt in Crystal Lake, Michigan (Beckman, 1942) (Table VI-8). Growth for the second through the seventh year of life for Nine Mile Point smelt appears lower than that for fish reported above (except age IV-VI for Gull Lake smelt). It should be noted that these analyses represent fewer smelt than those recorded in other studies.

- <u>Reproduction</u>

In Lake Ontario, spawning often occurs along the lake edge in shallow water on gravel shoals; Rupp (1965) believes that shore spawning may be as successful as stream spawning. Spawning runs of ripe smelt begin in March and continue through May (McKenzie, 1964).

Rainbow smelt spawning occurred in April in the Nine Mile Point area, as indicated by coefficient of maturity and the appearance of smelt eggs in the ichthyoplankton collections. The fecundity of rainbow smelt in the Nine Mile Point vicinity varied with fish length from 6,212 to 29,050 eggs, with a mean of 17,002 eggs. When allowance is made for the size of the fish, the estimates of Baldwin (1950) and Van Oosten (1940) are most nearly comparable to those of this study.

A listing of fecundity data from some other investigations performed on rainbow smelt in the Great Lakes follows:

COMPARISON OF THE CALCULATED GROWTH OF MALE RAINBOW SMELT AMONG FIVE AGE CLASSES FOR FISH COLLECTED BY GILL NETS & TRAWLS*

NINE MILE POINT-1974

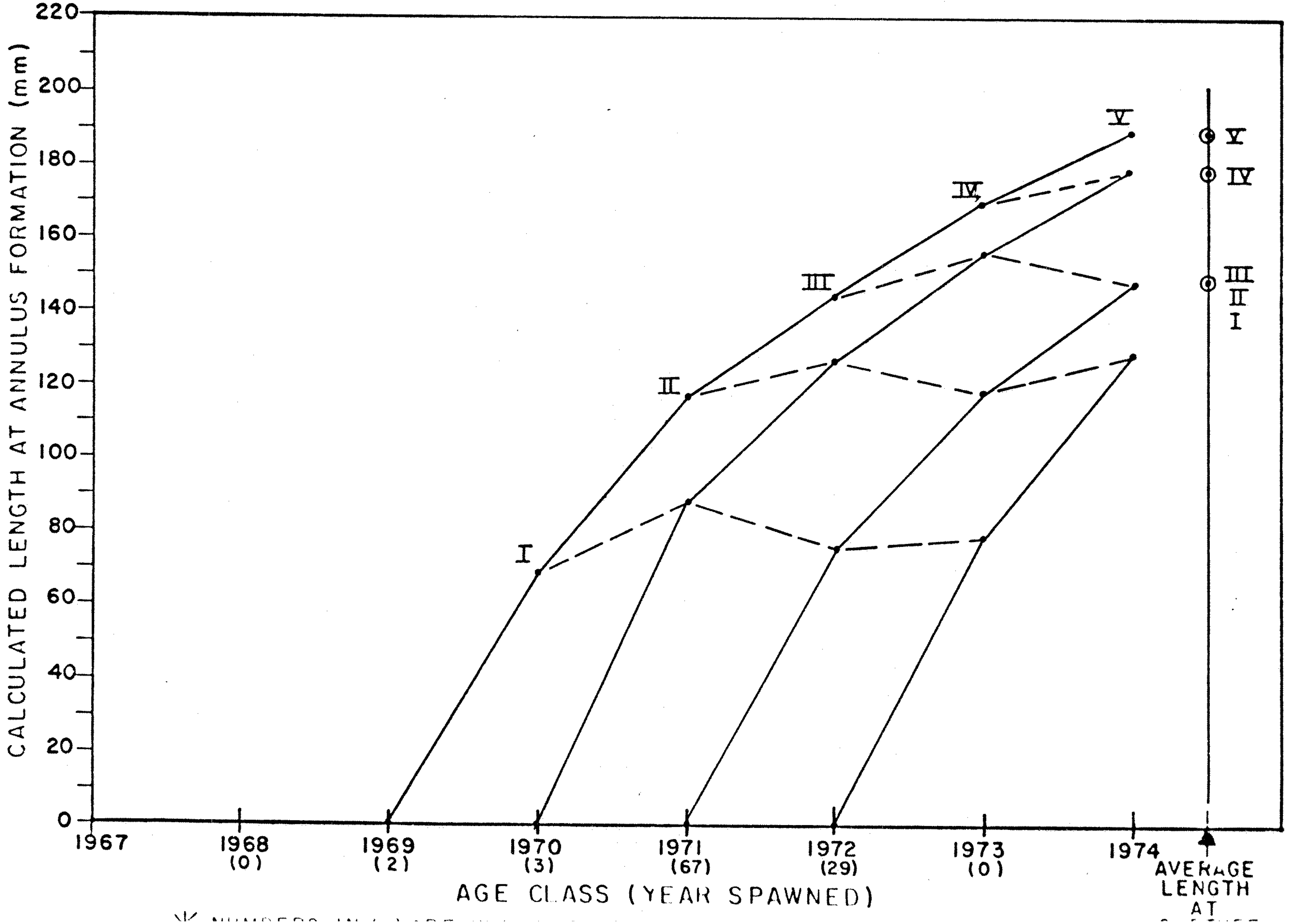


FIGURE VI-4

COMPARISON OF THE CALCULATED GROWTH OF FEMALE RAINBOW SMELT AMONG SIX AGE CLASSES FOR FISH COLLECTED BY GILL NETS & TRAWLS*

NINE MILE POINT-1974

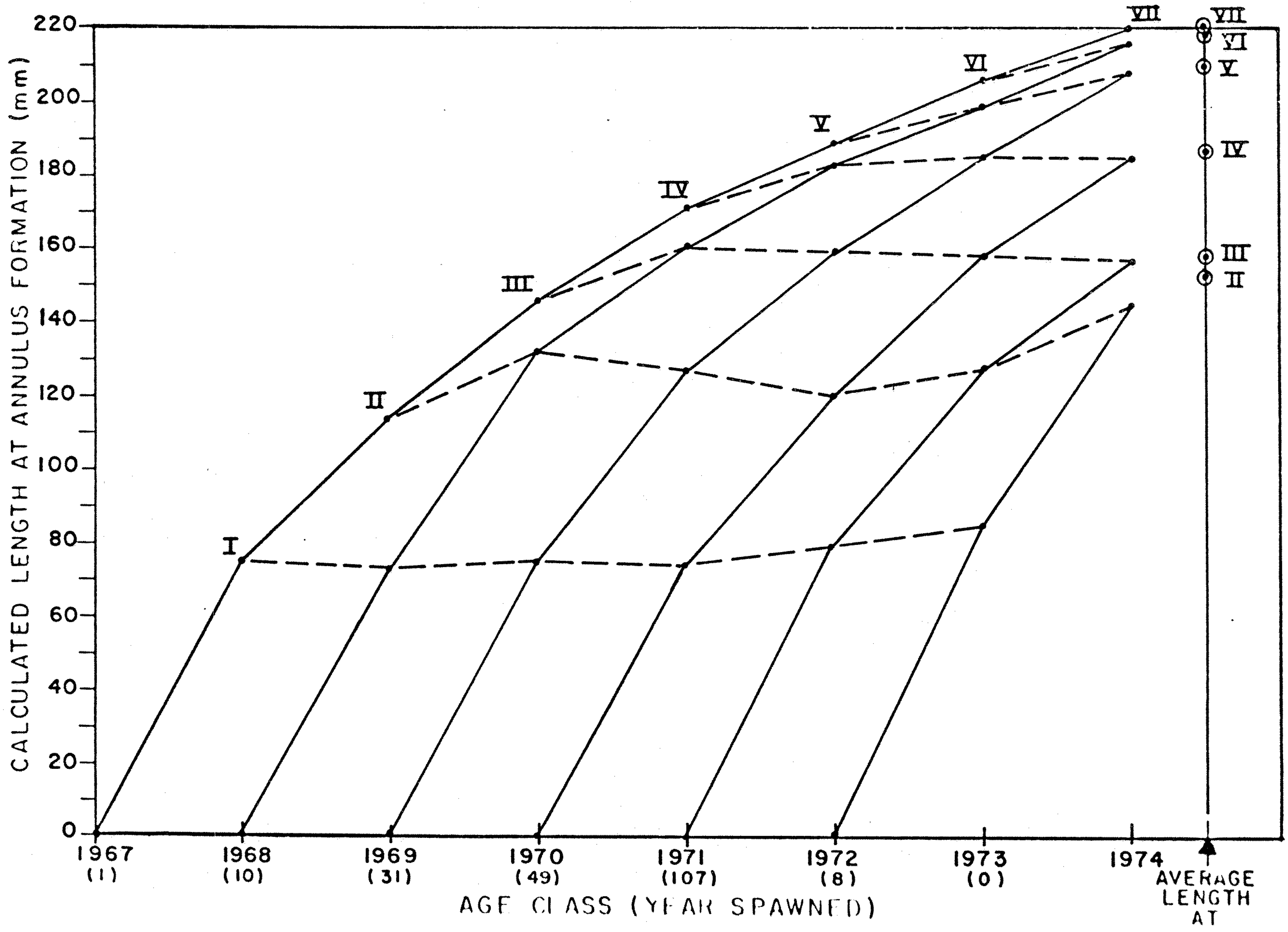


TABLE VI-8

COMPARISON OF GROWTH RATE OF RAINBOW SMELT FROM LAKE ONTARIO AND ITS VICINITY*

LAKE ONTARIO NINE MILE POINT (LMS, 1975)	LAKE ONTARIO NINE MILE POINT (QLM, 1974) 3	GULL LAKE, MICHIGAN (BURBRIDGE, 1969)	LAKE SUPERIOR (BAILEY, 1964)	CRYSTAL LAKE, MICHIGAN (BECKMAN, 1942)	LAKE MICHIGAN GREEN BAY (SCHNEBERGER, 1937)
LENGTH (mm)	LENGTH (mm)	LENGTH (mm)	LENGTH (mm)	LENGTH (mm)	LENGTH (mm)
78	103	60 (11)	66	112 (12)	
126 (37)	137	150 (141)	152 (307)	178 (92)	178
155 (174)	157	163 (123)	187 (256)	196 (100)	254
185 (52)	183	180 (24)	219 (121)	208 (35)	305
205 (33)	207	198 (7)	237 (39)	210	356
216 (10)	228	187 (2)	251 (10)		
220 (1)			309 (1)		

*Numbers which appear in parentheses represent the number of fish measured in determining average length.

Reference	Location	Size of Females	Number of Females	Mean No. of Eggs Per Female
Bailey (1964)	Lake Superior	188-224 mm	10	31,338
Baldwin (1950)	Lake Huron	140-224 mm	5	20,500
Van Oosten (1940)	Lake Michigan	185-196 mm	-	25,000
LMS (1975)	Lake Ontario	138-213 mm	24	17,002

The ratio of males to females is one indication of spawning activity. MacCullen and Regier (1970) found that males predominated in spawning areas during both the early and late parts of the spawning season. Of 5,542 rainbow smelt collected by trawls and gill nets from April to December 1974 (LMS, 1975), 50.3% were males and 49.7% were females; most were collected in April and May. During the remainder of the year (June-December), females predominated in the collections with 73 males and 410 females.

Adult rainbow smelt normally migrate from deeper offshore waters to the near shore area in late winter/early spring in preparation for spawning in tributary streams and along the lakes's shore (Scott and Crossman, 1973). At Nine Mile Point in 1974, rainbow smelt eggs were collected from 25 April through 22 May with the peak period occurring on 22 May. The small numbers of smelt eggs collected in 1974 were distributed evenly over the Nine Mile Point area.

Spawning occurs at night and the spawners move downstream to the lake during the day (Bailey, 1964; McKenzie, 1964). Smelt eggs are demersal, adhesive, and attach to bottom gravel. The number of eggs deposited is dependent upon the size of the female, ranging in number from approximately 8,000 to 30,000 (Scott and Crossman, 1973).

Rainbow smelt larvae were collected from 22 May to 25 July with the greatest concentration occurring in samples from 19-20 June. More larvae were collected at night, corresponding to the nocturnal activity of the species (Scott and Crossman, 1973). Generally, the shallower stations (20 ft depth contour) experienced the greatest abundance of rainbow smelt larvae during the spring and the average larval concentration then decreased with distance from shore. As the larvae matured, the deeper water stations became the preferred depth contour, corresponding to the offshore migratory pattern observed for the species (Wells, 1968).

Larval growth based on length frequency data suggest a period of rapid growth in the Nine Mile Point vicinity. Larvae on 22 May averaged 5.2 mm, while during the peak abundance period on 19-20 June they averaged 9.3 mm; growth had proceeded to approximately 20 mm by the end of July.

The correlation coefficients were determined for fecundity and age (r = .26), length (r = .76), body weight (r = .83) and weight of ovaries (r = .79). A positive correlation was found between fecundity and each of the above parameters. The low correlation between age and fecundity indicates that age is not a reliable indicator of fecundity.

The biomass data for rainbow smelt indicate a trend toward greater average weight per individual in April to June collections with lower average fish weight during July, indicative of the recruitment of young fish. The time of recruitment corresponds to the length frequency data discussed above. No observable trend was noted in either total biomass or average fish biomass among transects on a monthly basis.

- Feeding

Smelt are carnivorous and prey upon a variety of organisms including insects, oligochaetes, crustaceans, and other fish. Smelt are, in turn, preyed upon by lake trout, walleye, perch, and salmon.

Rainbow smelt are reported by Christie (1974) to feed on invertebrates when they are small, and to change to a piscivorous diet as they mature. Burbidge (1969) reported a seasonally varying diet with the dominant food item corresponding to the most abundant invertebrate, suggesting an opportunistic feeding pattern. O'Gorman (1974) reported definite predation by rainbow smelt on young alewives in the fall when both populations are located in the deeper offshore waters; however, Burbidge (1969) observed only the remains of young smelt in the stomachs of larger rainbow smelt. The common invertebrate organisms observed in smelt stomachs were dipterans, primarily *Chaoborus*, copepods, and cladocerans, all of which are abundant in the Nine Mile Point area.

3. Yellow perch (*Perca flavescens*)

Yellow perch have a circumpolar distribution in fresh water. In North America, the yellow perch occurs from Nova Scotia south along the Atlantic Coast, previously to South Carolina, but now apparently to Florida and Alabama.

The yellow perch is a commercially valuable species throughout its range, and consequently there is considerable literature on various aspects of its life history. These fish are considered very adaptable because of the wide range of habitats in which they are found, including warm to cooler areas from large lakes to ponds or quiet rivers. They are most abundant in the open water of large lakes with moderate vegetation (Scott and Crossman, 1973). Yellow perch are usually considered shallow water fish and are seldom collected in water depths below 9.2 m (30 ft).

Both the young and adults form loose aggregations of 50 to 200 individuals segregated by size. The groups of young are found in shallower water and nearer shore than adults. Individuals in schools of adults remain close together in summer and more separate in winter (Scott and Crossman, 1973).

- Abundance and Seasonal Distribution

The vast majority of yellow perch collected from the vicinity of Nine Mile Point in 1973, 1974 and 1975 were obtained in bottom gill nets. Yellow perch analyzed in 1974 were abundant in bottom gill nets during both day and night (LMS, 1975), and did not exhibit the diel vertical migration reported by Scott and Crossman (1973). Yellow perch were abundant in the vicinity of the FitzPatrick plant in July-August 1973 (highest catch per effort) and in July-September in 1974 and 1975. The timing of yellow perch abundance in the study area does not coincide with the timing of their reproductive behavior (April). This suggests that spawning does not take place in the area.

Bottom gill net data indicated that more yellow perch were caught at NMPE and FITZ transects than at NMPW transect. The catch per effort data on yellow perch collected in surface and bottom gill nets at 40-ft stations in 1975 (operational year) are summarized in Table VI-8. Data of Table VI-1 indicated a greater catch per effort of yellow perch in bottom gill nets than in surface gill nets. Moreover, there was a significant difference (= .01) in bottom gill net catches among transects (Table VI-9), with more fish collected at the FITZ transect.

Neill (1971) concluded that yellow perch (among other fish) avoided the outfall area of a steam electric power plant at Lake Monona, Wisconsin. In his laboratory experiments, Neill also found that yellow perch were attracted to a food-rich environment and suggested that this attraction did not override the species' behavioral thermoregulation.

In contrast to Neill's findings, Everest (1973) found that at the Hearn Generating Station in northern Lake Ontario, yellow perch, which were found only from June to November, were concentrated in the plume area as compared to a control area. This occurred especially during October, when these fish were collected at temperatures between 12-22°C, but when ambient temperatures were around 9-11°C.

- Age and Growth

The body length-scale length relationship for yellow perch was based on analyses of scales taken from 237 male and female fish ranging in total length from 81 to 323 mm (LMS, 1975). The back calculated lengths at previous ages and the standard error for each year of life are summarized in Table VI-10 for 102 male and 124 female yellow perch.

TABLE VI-9

STATISTICAL ANALYSIS OF SELECTED FISH SPECIES IN GILL NET COLLECTIONS AT 40-FT DEPTH CONTOUR

YELLOW PERCH

TWO-WAY ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F
MONTHS	8	3.7689	0.4711	3.49**
TRANSECTS	3	1.3872	0.4624	3.42*
ERROR	24	3.2403	0.1350	
TOTAL	35	8.3964		

*Significant at α = .05
**Significant at α = .01

ESTIMATED MEANS FOR TRANSECTS

TRANSECTS	ESTIMATED MEAN
NMPW	0.5
NMPP	0.2
FITZ	0.8
NMPE	0.4

TUKEY T TEST - TRANSECTS (α = .05)

Largest: FITZ NMPW NMPE NMPP: Smallest

ESTIMATED MEANS FOR MONTHS

MONTH	ESTIMATED MEAN
APR	0.1
MAY	0.1
JUN	0.6
JUL	0.8
AUG	0.5
SEP	0.7
OCT	1.1
NOV	0.3
DEC	0.1

TUKEY T TEST - MONTHS (α = .05)

Largest: OCT JUL SEP JUN AUG NOV APR DEC MAY: Smallest

TABLE VI-10

AVERAGE CALCULATED TOTAL LENGTH AND STANDARD ERROR AT ANNULUS FORMATION OF YELLOW PERCH

NINE MILE POINT - 1974

YEAR CLASS	No. of FISH	AGE GROUP	I	II	III	IV	V	VI	VII	VIII	IX
			MALES								
1972	19	II	68.60 ±2.05	132.42 ±3.54							
1971	22	III	64.29 ±1.78	117.37 ±2.56	158.98 ±4.13						
1970	33	IV	63.71 ±2.06	112.46 ±2.74	150.68 ±3.04	184.77 ±2.94					
1969	18	V	61.12 ±1.66	114.66 ±4.18	161.05 ±4.71	191.94 ±4.18	215.93 ±3.96				
1968	10	VI	62.90 ±4.06	112.32 ±8.85	157.86 ±7.84	185.40 ±8.77	205.77 ±9.38	224.26 ±8.76			
		Grand average calculated length (weighted)	64.25	117.61	155.99	186.99	212.30	224.26			
		Grand average increment of length (weighted)	64.25	53.36	41.77	32.07	22.70	18.49			
		Sum of grand average increments	64.25	117.61	159.38	191.45	214.15	232.64			
		Confidence interval of (α=0.05) grand average calculated lengths	62.23- 66.27	114.21- 121.01	151.62- 160.37	181.94- 192.04	203.38- 221.22	204.44- 244.08			
			FEMALES								
1973	4	I	77.54 ±4.00								
1972	32	II	68.27 ±2.27	130.12 ±2.84							
1971	32	III	69.43 ±1.75	118.37 ±2.21	150.15 ±2.10						
1970	23	IV	61.91 ±3.12	113.18 ±3.84	150.00 ±4.24	180.13 ±3.91					
1969	15	V	65.46 ±2.93	118.44 ±6.32	163.36 ±7.53	201.60 ±7.87	230.68 ±7.19				
1968	8	VI	65.49 ±3.09	113.12 ±4.00	155.04 ±8.66	184.44 ±10.93	212.21 ±12.76	232.24 ±12.79			
1967	7	VII	67.87 ±6.16	122.40 ±9.62	164.97 ±10.08	194.99 ±6.72	220.83 ±8.58	237.37 ±7.77	249.20 ±7.06		
1966	2	VIII	66.38 ±1.82	107.62 ±3.44	168.29 ±0.86	204.87 ±4.69	230.18 ±4.19	246.65 ±2.60	266.38 ±3.49	279.17 ±10.08	
1965	1	IX	56.24	101.49	169.99	233.58	256.83	272.73	286.18	303.28	317.18
		Grand average calculated length (weighted)	67.02	120.08	154.62	190.19	224.88	238.83	256.33	287.21	317.[illegible]
		Grand average increment of length (weighted)	67.02	53.41	38.19	33.01	27.67	18.05	13.57	14.23	14.70
		Sum of grand average increments	67.02	120.43	158.62	191.63	219.30	237.35	250.92	265.15	279.85
		Confidence intervals of (α=0.05) grand average calculated lengths	64.75 69.29	116.84 123.32	150.09 159.15	183.29 197.09	213.68 236.08	222.05 255.60	240.51 272.15	159.29 415.13	

The growth patterns for male and female yellow perch are similar; females appeared to be larger than males, but the differences in annual mean calculated lengths were not statistically significant (t-test, $p>0.05$). Female yellow perch are reported to grow faster than males and reach a greater ultimate size (Scott and Crossman, 1973). The growth rate of both male and female yellow perch from the Nine Mile Point vicinity is characterized as being rapid through the fourth year of life, after which it slows (Table VI-10).

Calculated growth of male and female yellow perch was plotted as a function of age (Figures VI-5 and VI-6). These graphs show that female yellow perch growth for the first three years of life has been similar for the past 9 years. After age four, females that spawned between 1966 and 1968 exhibited a progressively slower growth rate, while those which spawned in 1969 showed an increased rate of growth after four years of age. Male yellow perch appear to have grown uniformly from 1968 to 1972. No 1973 year class fish were collected during 1974, perhaps due to the selectivity of gill nets for larger fish. While statistical comparisons of Nine Mile Point yellow perch growth with that of other populations were not possible, a more general comparison (Table VI-11) indicates a great deal of variability between Nine Mile Point yellow perch and those from water bodies. However, the Nine Mile Point population does not appear to differ greatly from those in other collections.

- Reproduction

Muncy (1962) reported yellow perch movement to the spawning grounds in the Severn River, Maryland, from late February to early March, a period when water temperatures were 3.98-6.7°C (39-44°F). The time of spawning for yellow perch in the vicinity of Nine Mile Point was determined by examining the coefficient of maturity data for 351 males and 537 females collected from January through December 1974 (LMS, 1975). These data reveal that peak spawning occurred during the first two weeks in April, when water temperatures were 0.7-6.2°C (33.3-43.2°F) with a mean of 3.3°C (37.9°F). This observation corresponds very closely to that found by Muncy (1962).

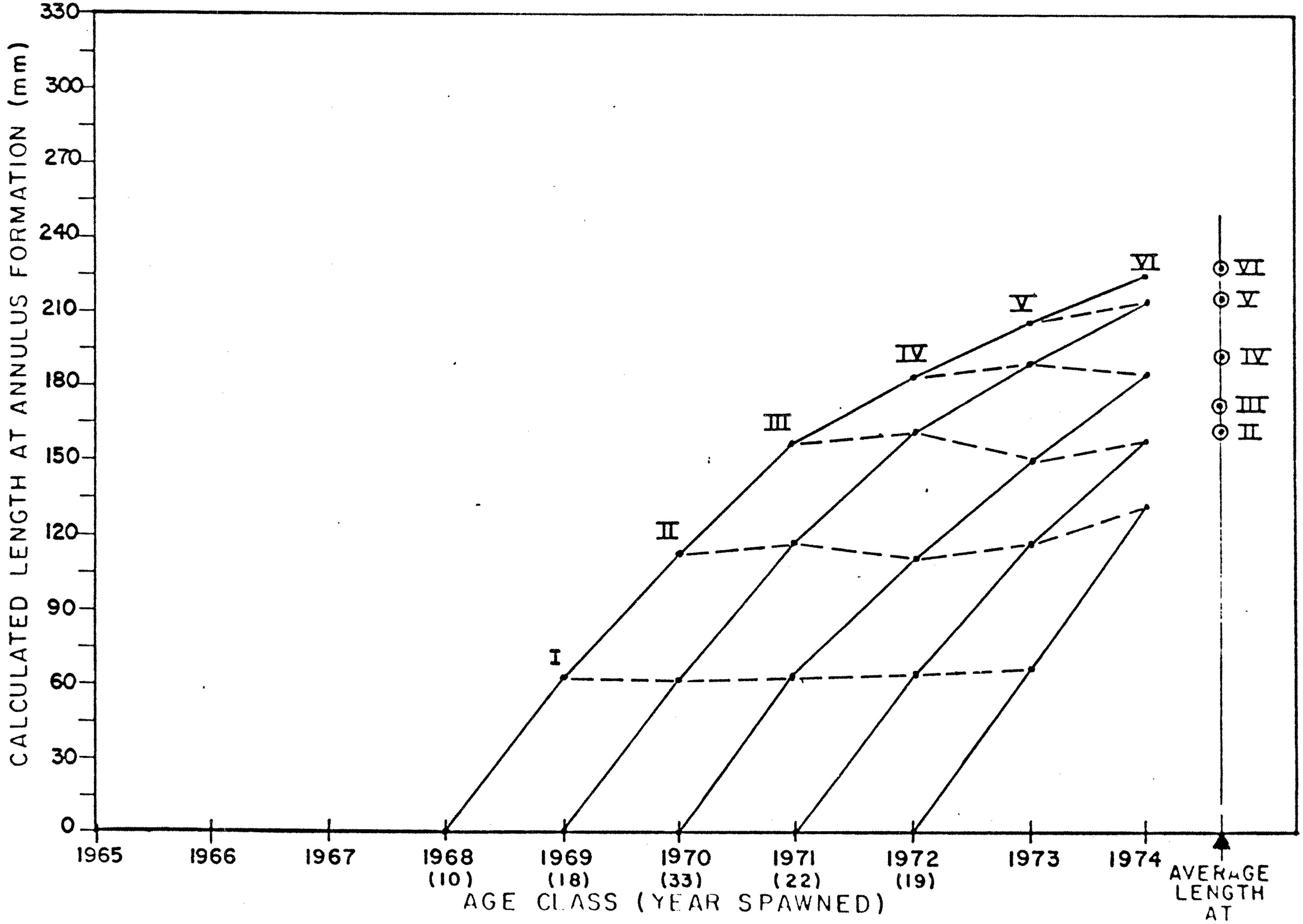
Sheri and Power (1969) estimated the fecundity of yellow perch in the Bay of Quinte, Lake Ontario, at 3,035 to 61,465 total eggs for fish 131-257 mm long. Muncy (1962) reported total egg counts of 5,900 to 109,000 for yellow perch 173 to 358 mm in length in the Severn River, Maryland. Mean egg production for 20 fish ranging in size from 173-295 mm was 17,940 eggs, while for five larger females (302-358 mm) it was 32,200 eggs (Muncy, 1962).

The ovaries of 18 sexually mature females (collected in the vicinity of Nine Mile Point) contained eggs ranging in diameter from 0.6 to 1.5

FIGURE VI-5

COMPARISON OF THE CALCULATED GROWTH OF MALE YELLOW PERCH AMONG FIVE AGE CLASSES FOR FISH COLLECTED BY GILL NETS & TRAWLS*

NINE MILE POINT-1974



* NUMBERS IN ( ) ARE NUMBERS OF FISH AGED

FIGURE VI-6

COMPARISON OF THE CALCULATED GROWTH OF FEMALE YELLOW PERCH AMONG NINE AGE CLASSES FOR FISH COLLECTED BY GILL NETS & TRAWLS*

NINE MILE POINT-1974

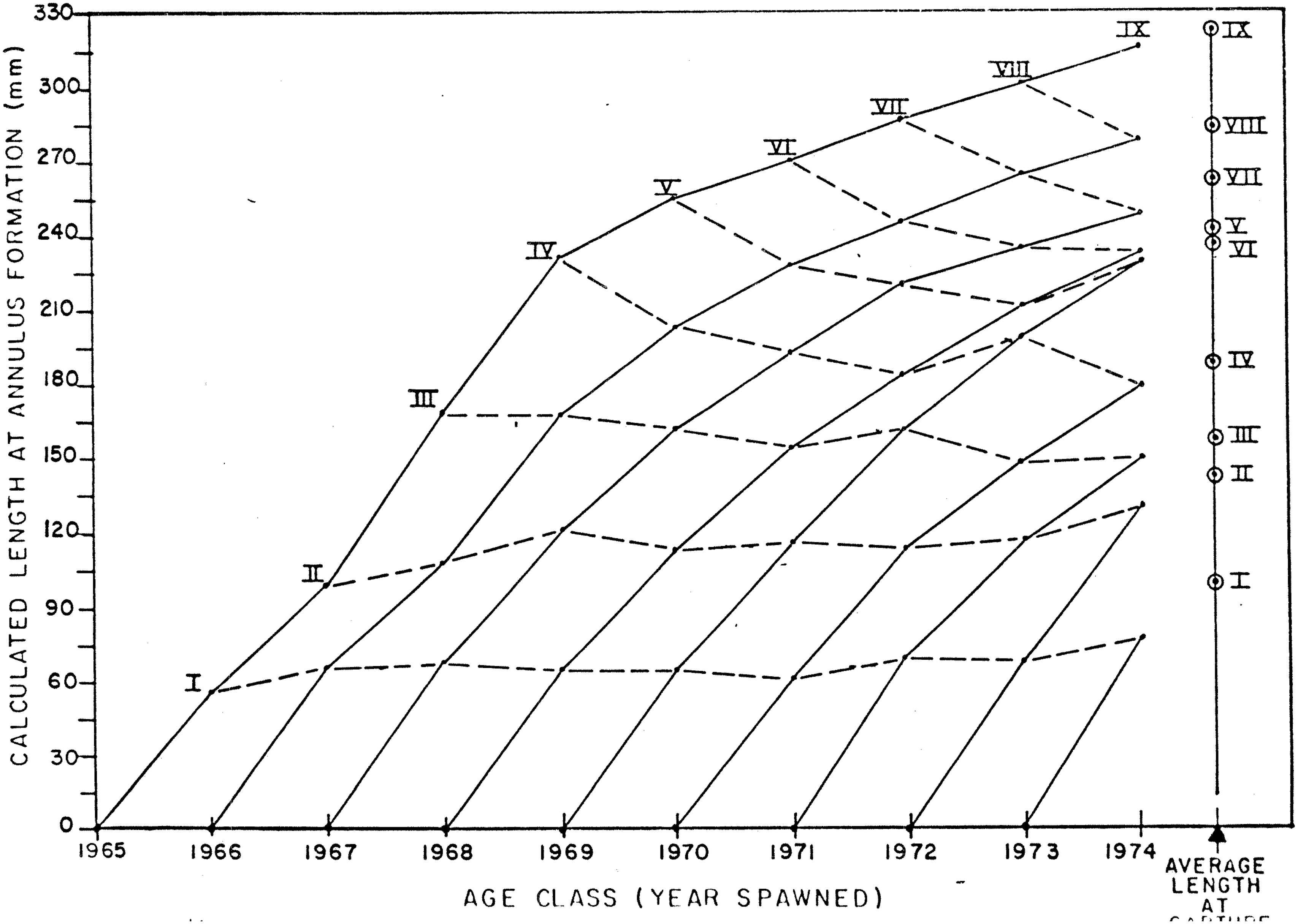


TABLE VI-11

COMPARISON OF GROWTH RATE OF YELLOW PERCH FROM LAKE ONTARIO AND ITS VICINITY*

AKE ONTARIO NE MILE POINT (LMS, 1975)	LAKE ONTARIO NINE MILE POINT (QLM, 1973)	GREEN BAY LAKE MICHIGAN (HILE AND JOBES, 1942)	SAGINAW BAY LAKE HURON (HILE AND JOBES, 1941)	LAKE ERIE (JOBES, 1952)	SAGINAW BAY LAKE HURON (EL-ZARKA, 1959)	THREE IOWA LAKES (PARSONS)	THREE WISCONSIN LAKES (SCHNEBERGER, 1935)		
							NEBISH LAKE	WEBER LAKE	SILVER LAKE
66 (4)	110	73 (2)	77	92	66 (18)	68 (74)	66 (159)	58 (3)	44
117 (51)	149	118 (58)	137 (20)	174	107 (565)	177 (86)	136 (306)	113 (389)	80 (148)
155 (54)	182	160 (128)	202 (308)	219	142 (1623)	235 (346)	175 (114)	145 (81)	113 (558)
189 (56)	211	198 (241)	248 (170)	248	178 (1006)	280 (16)	213 (39)	175 (278)	133 (239)
219 (48)	241	227 (212)	279 (137)	271	193 (173)	302 (39)		199 (248)	149 (93)
234 (18)	254	262 (98)	315 (17)	288	239 (12)			215 (69)	169 (21)
256 (7)	270	285 (8)	338 (5)		315 (3)			231 (13)	202 (2)
287 (2)		319 (4)			356 (1)			245 (3)	
318 (1)		360 (1)							

umbers which appear in parentheses represent the number of fish measured in determining average length.

mm with a mean of 0.93 mm. The fecundity estimates, based on total egg counts, ranged from 4,840 eggs (fish body length 150 mm, weight 42.2 g) to 50,000 eggs (290 mm length, 429.3 g weight), with a mean of 25,077 eggs (LMS, 1975).

When allowance is made for the size of the females among these studies, the estimates from the different areas evaluated appear to be comparable to those of yellow perch in the vicinity of Nine Mile Point during 1974 (LMS, 1975).

Scott and Crossman (1973) and Muncy (1962) state that males arrive on the spawning grounds before females and remain there longer; the females leave immediately after spawning. Therefore, more males will be found on the spawning grounds during the reproductive season. However, the sex ratio was biased toward females in the vicinity of Nine Mile Point during the yellow perch spawning season (April, May, June). This observation, in addition to the collection of few larvae from the area, indicates that yellow perch probably did not use the Nine Mile Point vicinity as a spawning ground (LMS, 1975). In addition, Storr (1973) showed that 40% of the yellow perch tagged and released in the Nine Mile Point vicinity moved eastward out of the area. The majority were recaptured at North Sandy Pond, an area which has been assumed to be the spawning grounds for the southern population of yellow perch in Lake Ontario. A few strands of yellow perch eggs were found by divers during the harvesting of buoy periphyton collections near Nine Mile Point, indicating some spawning in the area.

Larvae of the yellow perch were collected sporadically during 1973 and 1974 in the vicinity of Nine Mile Point beginning during the middle of May. Very few larvae were found, indicating very little use of the Nine Mile Point area as a nursery ground by this species.

- Feeding

The larvae feed on zooplankton and insect larvae, and when they grow to a length of 5.0 - 7.5 cm, their diet changes to larger zooplankton, insects, crayfish, snails, and small fish, including their own species (McClane, 1964). Tharatt (1959) found that alewives were the principal food of yellow perch in Saginaw Bay.

Stomach contents of yellow perch analyzed in 1975 indicated that perch consumed mostly fishes (54% of the diet by weight) and decapods (45% by weight). Dipterans (Family Chironomidae) were the only insects recovered from stomachs of yellow perch in 1975; other species found in yellow perch stomachs included Gammarus and oligochaetes. A mass of sculpin eggs was also found in the gut of a single perch, thus confirming the observation of Scott and Crossman (1973). Adult sculpins were also preferred food items for yellow perch analyzed in 1975.

The fish collected during the spring of 1974 (LMS, 1975) contained a greater variety of food items in their stomachs than did those recorded during the fall collection. Of the stomachs examined, 53.7% contained fish eggs and *Gammarus fasciatus*. During the fall sampling period, fish (alewife identified) and amphipods were the only identifiable materials in the stomachs of yellow perch. The results of the 1974 stomach content analysis agreed with results from a study conducted on fish collected during 1972 (Williams and Miller, 1973) and with those reported by Scott and Crossman (1973).

4. Smallmouth bass (*Micropterus dolomieui*)

The smallmouth bass is an important sport fish and an important piscivore in the nearshore area of Lake Ontario. Smallmouth bass were collected in small numbers compared to alewife, although they were found in the nearshore area and in impingement collections. Eggs and larvae of smallmouth bass were not represented in the 1975 ichthyoplankton collections. These eggs and larvae were not among the Nine Mile Point plant entrainment collections and thus the possibility of the lack of spawning grounds for smallmouth bass in the area exists. However, the lack of eggs in the collections could be partially attributed to the nesting habits of the species. Smallmouth bass eggs are demersal, adhesive, and attach to stones in the nest. Thus the presence or absence of smallmouth bass spawning grounds in the area could not be evidenced based on the current data. However the lack of eggs and larvae in the entrainment samples implies that large numbers of either life history stage will not be subjected to plume entrainment.

- Abundance and Seasonal Distribution

A total of 432 (0.54% of all collections) smallmouth bass were collected during 1975 in the Nine Mile Point vicinity. The vast majority (N = 413) were collected by bottom gill nets while only 15 specimens were collected from the surface. Like yellow perch, smallmouth bass seem to avoid the discharge area except perhaps ~~during feeding runs (LMS~~, 1975). In 1975, catch per effort of smallmouth bass at NMPP transect reached a maximum (average of 4.83 fish/12 hrs) during the summer. Catch per effort at the FITZ transect varied from an average of 2.45 in the summer to 0.07 in the fall of 1975; the NMPE and NMPW values did not differ significantly from those at the FITZ transect (LMS, 1976). Catch per effort was as high as 2.03 fish/12 hrs at NMPE in summer of 1975. The lowest catch per effort at all transects was recorded in the fall of 1975.

bull

Only 271 smallmouth bass were collected in 1974 (0.28% of the total annual catch) and these were collected exclusively in the bottom gill nets (N = 21), as occurred in 1975. The ANOVA comparing day-night differences indicated no significant differences among transects, probably because of the small sample size of the smallmouth bass collected.

The catch per effort of smallmouth bass collected in 1975 by surface and bottom gill nets at the 40 ft depth contours was estimated and compared among the transects by month (Table VI-1). The average catch per effort at NMPP and FITZ transects was slightly higher than at NMPW and NMPE; however, the differences were not statistically significant (Table VI-12).

- Age and Growth

Reynolds (1965) reported that annulus formation in smallmouth bass occurred in late May in the Des Moines River, Iowa; Suttkus (1955) observed that annulus formation for smallmouth bass was completed during May and June for a small stream population in Falls Creek, New York. Annulus formation began during May and June for smallmouth bass in the Nine Mile Point vicinity, peaked during July (52%), and was essentially complete by August.

The back calculated lengths were estimated for male (N = 59) and female (N = 71) smallmouth bass and are summarized in Table VI-13. The growth pattern for both male and female smallmouth bass was similar, but males appeared larger at all ages. A t-test of the differences between the grand average calculated lengths of male and female smallmouth bass for each year of life revealed that males were significantly larger at ages 1, 3, 5, 6, 8 and 9 ($p < 0.05$). In 1973, QLM (1974) reported that only five-year-old males were significantly larger than females. Stone et al. (1954) reported little difference in the growth of male and female smallmouth bass in the St. Lawrence region of Lake Ontario; Suttkus (1955) also found no difference in the growth between the sexes for smallmouth bass in Fall Creek, New York.

Calculated growth of male and female smallmouth bass was plotted as a function of age (Figures VI-7 and VI-8). These plots show that first-year growth was not uniform, with a 40 - 100% change occurring between any two year classes. In addition, there are year classes missing (not collected) for both sexes indicating a low abundance of these years' representatives. Female growth appears to be more regular than male growth, at least for age class I.

Based on the limitations of comparing data among growth studies described in LMS (1975), the following points are apparent. The difference between the estimated growth of smallmouth bass at Nine Mile Point for 1973 and 1974 was the greatest at ages 1 and 2, but decreased with increasing age; estimates of growth were similar at ages 6 to 8. The growth estimates at Nine Mile Point were similar to those at Tadenac

TABLE VI-12

STATISTICAL ANALYSIS OF SELECTED FISH SPECIES IN GILL NET COLLECTIONS AT 40-FT DEPTH CONTOUR

IV. SMALLMOUTH BASS

TWO-WAY ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F
MONTHS	8	13.0839	1.6355	6.07**
TRANSECTS	3	0.4733	0.1578	0.59*
ERROR	24	6.4717	0.2697	
TOTAL	35	20.0289		

**Significant at $\alpha = .01$

ESTIMATED MEANS FOR MONTHS

MONTH	ESTIMATED MEAN
APR	0.2
MAY	0.1
JUN	0.0
JUL	0.5
AUG	1.5
SEP	1.6
OCT	0.0
NOV	0.2
DEC	0.0

TUKEY T TEST - MONTHS ($\alpha = .05$)

Largest: SEP AUG JUL APR NOV MAY OCT JUN DEC: Smallest

TABLE VI-13

AVERAGE CALCULATED TOTAL LENGTH AND STANDARD ERROR AT ANNULUS FORMATION OF SMALLMOUTH BASS

NINE MILE POINT - 1974

YEAR CLASS	No. of FISH	AGE GROUP	I	II	III	IV	V	VI	VII	VIII	IX	X	
			FEMALE										
1973		I											
1972	2	II	89.60 ±6.52	148.95 ±10.95									
1971		III											
1970	5	IV	78.19 ±3.81	151.91 ± 8.33	220.33 ± 6.82	260.03 ± 9.44							
1969	3	V	62.33 ±5.29	124.07 ± 4.08	177.02 ± 3.48	238.24 ± 7.93	282.54 ± 5.25						
1968	2	VI	62.6 ± .21	118.55 ± 6.2	160.59 ± 2.56	198.20 ± 9.76	239. ± .99	264.5 ± 7.5					
1967	13	VII	80.47 ±6.83	145.32 ± 7.44	195.58 ± 7.32	236.54 ± 8.65	274.34 ± 9.3	309.6 ± 9.96	340.61 ± 9.66				
1966	14	VIII	75.95 ±5.7	130.91 ± 6.77	178.66 ± 7.38	220.93 ± 8.33	258.82 ± 8.49	288.6 ± 9.07	317.53 ± 7.78	341.06 ± 6.44			
1965	18	IX	73.66 ±3.62	128.14 ± 3.34	177.68 ± 5.91	219.29 ± 6.51	256.82 ± 7.09	283.31 ± 6.72	306.06 ± 6.56	329.55 ± 5.28	346.1 ± 4.17		
1964	11	X	77.49 ±5.23	140.06 ± 5.16	180.89 ± 5.08	216.27 ± 4.64	248.00 ± 3.83	276.52 ± 3.65	302.33 ± 5.17	323.50 ± 4.73	344.08 ± 4.57	337.45 ± 4.47	
1963	3	XI	62.44 ±2.89	109.37 ± 3.97	156.30 ± 7.22	194.54 ± 7.67	234.73 ± 5.89	269.21 ± 3.68	297.37 ± 5.37	326.90 ± 4.34	348.95 ± 3.14	364.52 ± 3.76	372.57 ± 2.9
1962		XII											
		Grand average calculated length (weighted)	75.44	134.703	199.365	224.48	275.892	287.592	315.257	331.433	345.672	358.965	372.57
		Grand average increment of length (weighted)	75.44	59.248	49.109	41.08	37.21	29.84	26.882	23.341	18.45	13.841	8.05
		Sum of grand average increments	75.44	134.588	183.797	224.877	262.87	291.927	318.809	342.15	360.6	374.441	382.491
		Confidence interval of (α=0.05) Grand average calculated lengths	74.14 76.75	133.24 136.16	193.74 204.99	218.231 230.729	268.525 283.259	280.18 295.00	308.005 322.51	325.17 331.43	344.06 347.3	350.94 366.99	357.89 387.89

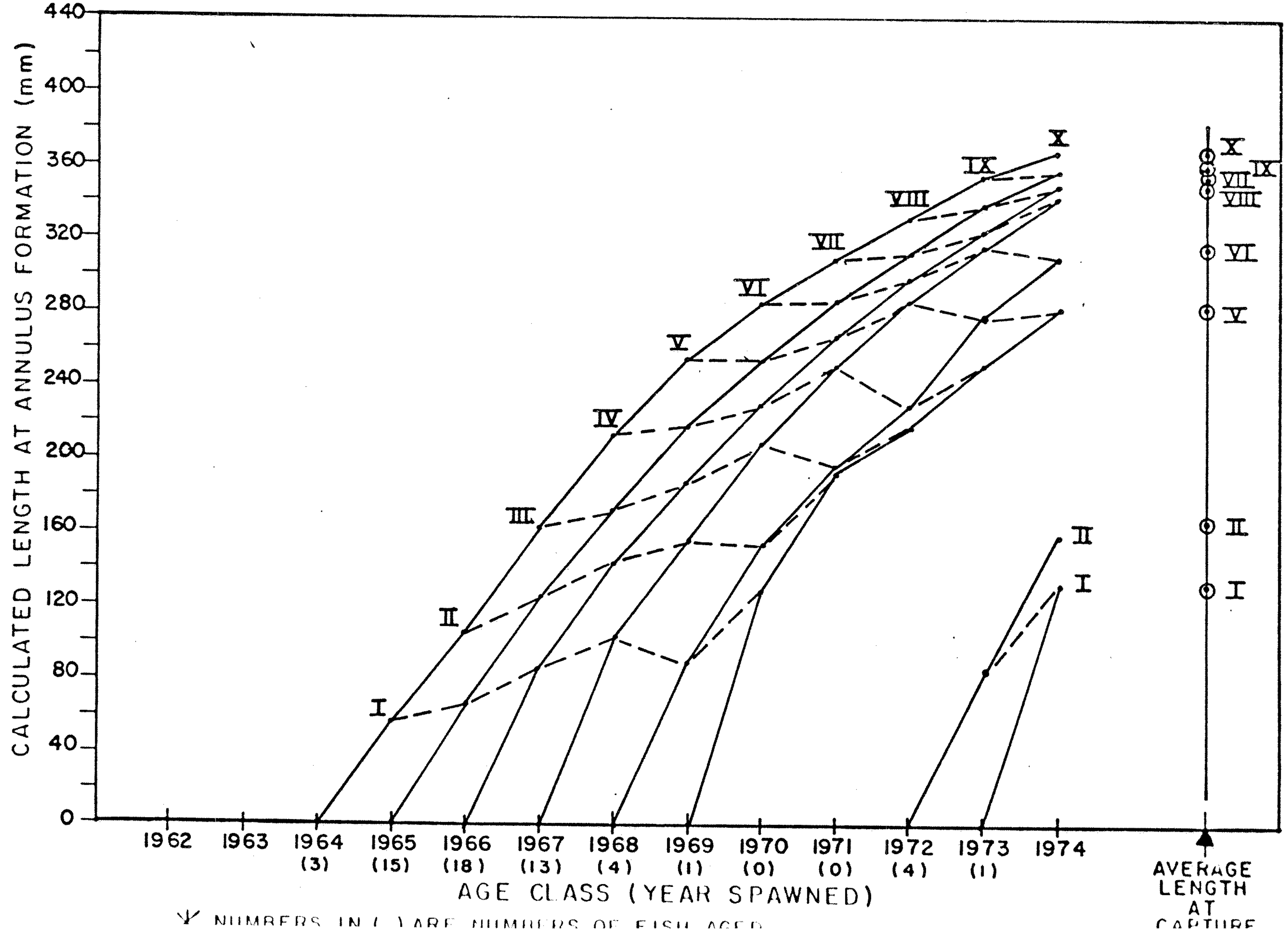
TABLE VI-13
(CONTINUED)

YEAR CLASS	No. of FISH	AGE GROUP	I	II	III	IV	V	VI	VII	VIII	IX	X
							MALES					
1973	1	I	131									
1972	4	II	85.95 ±5.19	158.17 ±4.92								
1971		III										
1970		IV										
1969	1	V	128.51	191.72	219.36	251.87	281.0					
1968	4	VI	93.28 ±20.72	153.99 ±31.44	193.11 ±30.30	229.54 ±28.32	279.51 ±21.29	309.22 ±18.08				
1967	13	VII	102.8 ±7.51	156.18 ±7.66	207.35 ±7.32	250.87 ±8.37	285.99 ±6.54	315.77 ±6.93	343.50 ±8.52			
1966	18	VIII	85.25 ±6.72	141.17 ±7.37	186.94 ±7.75	230.75 ±8.06	267.73 ±6.75	294.53 ±6.73	323.23 ±6.44	345.53 ±6.36		
1965	15	IX	66.43 ±2.22	124.89 ±3.55	173.69 ±4.8	219.36 ±5.79	255.03 ±6.13	285.74 ±6.50	311.48 ±6.04	337.06 ±4.33	355.64 ±4.64	
1964	3	X	57.99 ±3.49	114.85 ±7.48	163.37 ±11.69	215.45 ±18.37	255.77 ±13.73	283.90 ±12.62	308.58 ±11.76	331.64 ±8.77	353.61 ±7.05	366.00 ±5.69
1963		XI										
1962		XII										
		Grand average calculated length (weighted)	85.046	141.894	187.92	231.881	250.533	297.759	324.113	340.843	355.301	366
		Grand average increment of length (weighted)	85.046	56.662	47.176	43.96	37.17	28.932	27.29	23.73	19.145	12.39
		Sum of grand average increments	85.046	141.708	188.884	232.844	270.014	298.946	326.236	349.966	369.111	381.501
		Confidence interval of (α=0.05) grand average calculated lengths	78.70 91.38	134.39 149.39	179.63 196.21	223.01 240.75	243.067 258	290.289 305.229	316.36 331.87	333.21 348.47	346.67 363.92	341.5 390.5

FIGURE VI-7

COMPARISON OF THE CALCULATED GROWTH OF MALE SMALLMOUTH BASS AMONG EIGHT AGE CLASSES FOR FISH COLLECTED BY GILL NETS & TRAWLS*

NINE MILE POINT-1974

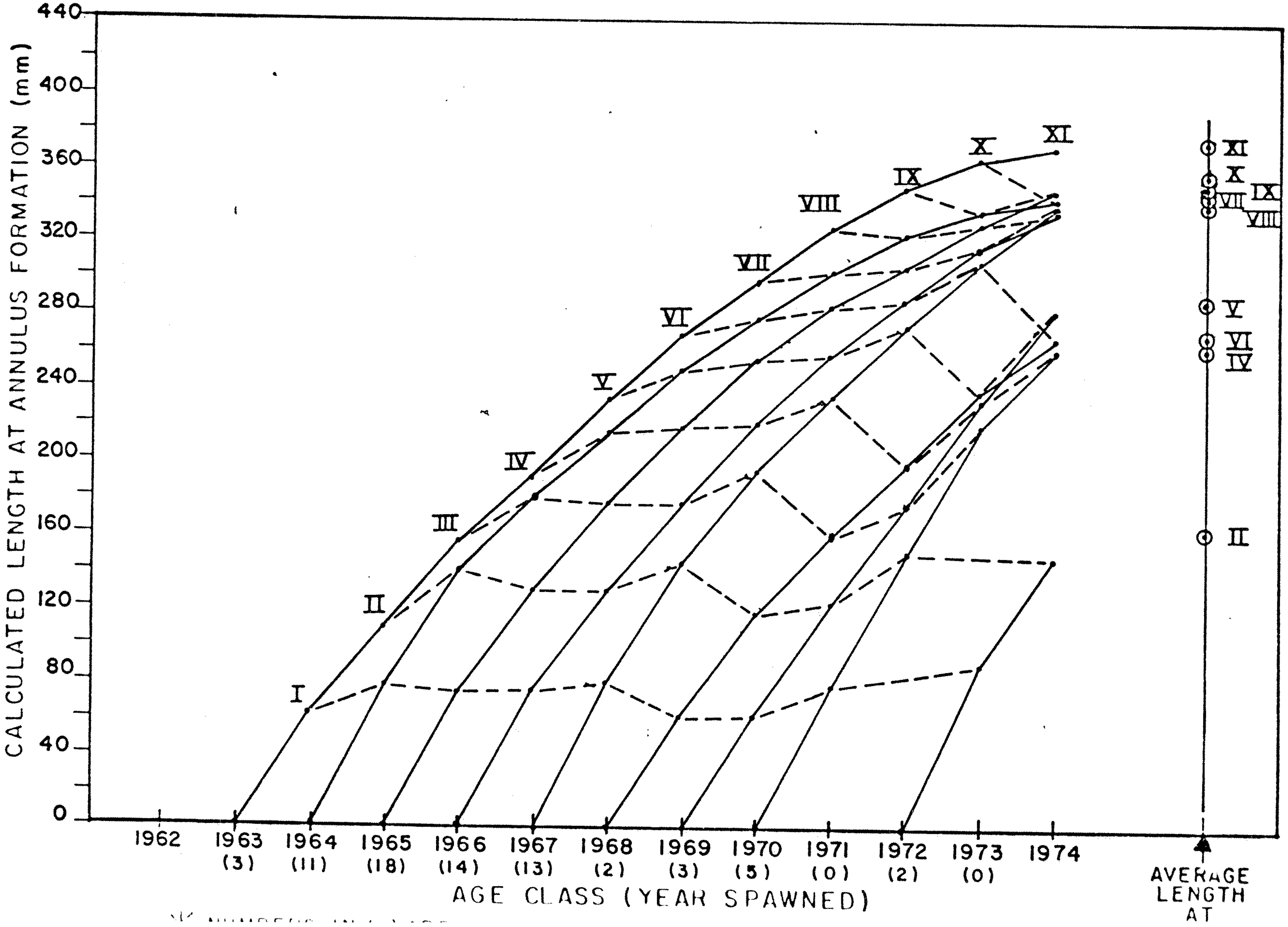


* NUMBERS IN ( ) ARE NUMBERS OF FISH AGED

FIGURE VI-8

COMPARISON OF THE CALCULATED GROWTH OF FEMALE SMALLMOUTH BASS AMONG NINE AGE CLASSES FOR FISH COLLECTED BY GILL NETS & TRAWLS*

NINE MILE POINT - 1974



* NUMBERS IN ( ) ARE

Lake, Ontario, for ages 1 to 4 and to the St. Lawrence River (Lake Ontario area) for ages 5 to 7. The growth estimates for fish in these two studies were greater than Nine Mile Point estimates for the remaining years of life. Smallmouth bass in Cayuga Lake, Lake Michigan, and the Des Moines River, Iowa appear to grow faster than smallmouth bass in the Nine Mile Point vicinity.

- Reproduction

Fecundity measurements were not performed on smallmouth bass because these fish were not present in collections during the spring, which was the expected time of spawning (Scott and Crossman, 1973). Male and female smallmouth bass were equally represented in gill net collections in the vicinity of Nine Mile Point during 1974 (LMS, 1975). Smallmouth bass spawn as pairs, and, therefore, it should be expected that in a spawning area individuals would be distributed equally between the sexes.

Eggs of the smallmouth bass are spawned in nests usually in shallow water areas during the late spring and early summer months. Adult males guard the nest through early larval development until when the larvae begin to leave the nest (Scott and Crossman, 1973). Eggs of the smallmouth bass have never been identified in collections at Nine Mile Point and during 1974 only one larva was collected. Presence of adults in the area strongly suggests that some spawning and larval development occur; however, the nesting habits preclude collection of the eggs and larval forms.

- Feeding

The diet of smallmouth bass varies with age. Young bass prey upon plankton and immature insects, whereas adult bass include crayfish and a variety of fish in their dietary spectrum. The food items consumed by individuals >301 mm (IV) in length are listed in Table VI-14. Rather than ingesting a wide variety of organisms from their habitat, larger bass apparently limit their feeding to essentially two types of prey: small fishes and decapod crustaceans. Although 25 specimens (one stomach was empty) is a small sample, previous studies support these results. Scott and Crossman (1973) describe the diet of smallmouth bass as including crayfish, fish, insects, and occasional frogs. Fish are believed to be the most important component, and in this study, they constituted 70% (by weight) of the gut contents.

Fish were present in the guts of 73% of the bass, whereas comparable values for crayfish were 30% by weight and 30% by occurrence. Two genera of crayfish were taken, Orconectes and Cambarus, with the former occurring in greater numbers (Table VI-14).

TABLE VI-14

GUT CONTENTS[a] OF SMALLMOUTH BASS

NINE MILE POINT VICINITY - 1975

LENGTH INTERVAL: >301 mm

TAXON	NO. PRESENT	DRY WT. (mg)	OCCURRENCE		% OF TOTAL ORGANISMS CONSUMED	% OF TOTAL DRY WT.
			NO. OF GUTS[b]	% OF GUTS[b]		
PISCES						
Etheostoma nigrum	3	432.8	2	7.6	8.1	2.6
Alosa pseudoharengus	2	4068.3	2	7.6	5.4	24.2
Notropis hudsonius	1	101.8	1	3.8	2.7	0.6
Notropis sp.	2	109.9	3	7.6	5.4	0.7
Cottus bairdi	1	43.0	1	3.8	2.7	0.3
Osmerus mordax	3	4562.2	3	11.5	8.1	27.1
UID Pisces	11	2455.3	9	34.6	29.7	14.6
TOTAL (Pisces)	23	11773.3	19	73.1	62.2	70.0
ARTHROPODA						
Crustacea						
Decapoda						
Orconectes sp.	6	3063.5	5	19.2	16.2	18.2
O. propinguus	1	87.0	1	3.8	2.7	0.5
Cambarus sp.	1	1027.7	1	3.8	2.7	6.1
UID crayfish	3	802.2	3	7.7	8.1	4.8
TOTAL (Decapoda)	11	4980.1	7	26.9	29.7	29.6
Insecta						
Orthoptera	3	63.0	1	3.8	8.1	0.4
TOTAL (All Prey Items)	37		-	-	100.0	100.0
Miscellaneous						
Oligochaete (setae)	-	-	1	3.8	-	-

---

[a] N = 25; does not include 1 additional gut containing oligochaete setae; empty = 10

[b] Includes those guts containing oligochaete setae; N = 26

5. Threespine stickleback (Gasterosteus aculeatus)

- Abundance and Seasonal Distribution

Although threespine stickleback are relatively abundant in impingement samples, they are not collected in large numbers with the fishing gear employed at Nine Mile Point; therefore, there is very limited life history data available for the FitzPatrick vicinity. During the 1973 sampling period, 78 threespine stickleback were collected, 50 specimens by surface trawl and 23 by seines. Threespine stickleback were most abundant in May and June at the NMPP and NMPE transects. The largest seine collection (N = 20) occurred in June at FITZ (N = 10) and NMPE (N = 10) transects (QLM, 1973).

The majority of threespine stickleback was collected by surface and bottom trawls in 1974 (21 out of a total of 29) and 1975. Seine collections were comparable to trawl collections in 1975, and in 1974, only two fish were gill netted.

More threespine stickleback were collected in 1975 than in 1973 and 1974 (LMS, 1976). Of the 160 specimens collected in 1975, 60% were collected by surface (N = 46) and bottom (N = 48) trawls, and 65 fish were collected by seines, as opposed to 6 fish in the preceding year. In general, however, the number of threespine stickleback collected in 1973-1975 from the Nine Mile Point vicinity was too small to permit drawing any definitive conclusions regarding differences among transects.

- Age and Growth

Growth is rapid during the first year, but slows during the second year of life, with a maximum size of 102 mm reached in fresh water. Sexual maturity is attained during the first year and individuals probably do not live longer than 3-1/2 years.

No data are available on the age and growth of the threespine stickleback in the vicinity of Nine Mile Point.

No data are available on the time of spawning or the fecundity of the threespine sticklebacks in the vicinity of Nine Mile Point. Eggs and larvae of the threespine sticklebacks were among the ichthyoplankton collections in 1975 but were few in number. Eggs were not collected in either 1973 or 1974, and very few larvae were found in 1973 collections. The threespine stickleback spawns during the summer (June - July) in fresh water, building its nest in shallow, sandy areas (Scott and Crossman, 1973). The male entices the female to the nest by a distinctive courtship display; eggs are then laid in clusters and are adhesive to each other. Breder and Rosen (1966) stated that hatching occurs in 7 days at 19°C (66.2°F). The males tend the eggs and the young for several days after hatching.

- Feeding

A voracious feeder, the threespine stickleback consumes various annelids, crustaceans, insects, and eggs and larvae of fish. They, in turn, are preyed upon by fish-eating birds as well as by larger fish including trout and salmon. The threespine stickleback, therefore, serves as an important forage species. Information on feeding habits of that species in the Nine Mile Point area is not available.

6. Coho salmon (Oncorhynchus kitsutch)

The coho salmon is an anadromous species which occurs naturally in the Pacific Ocean and in rivers and streams which drain northwestern North America. Attempts to establish the coho salmon in the Great Lakes were unsuccessful until the 1960's when there were reports of limited natural reproduction occurring in Michigan (Scott and Crossman, 1973). The New York State Department of Environmental Conservation annually stocks coho salmon in New York State tributary streams of Lake Ontario.

- Abundance and Seasonal Distribution

Coho salmon were caught in greater numbers in 1975 (57 fish) than in 1974 (13 fish); none was caught in 1973. The majority were collected by gill nets in both years, and no differences were noted in coho salmon distribution among transects due to the small sample size. The increase in the coho salmon abundance in the lake collections is attributed to the success of the salmonid stocking program in Lake Ontario.

- Age and Growth

Because of the scarcity of coho salmon in the study area, age and growth of that species were not analyzed.

- Reproduction

The spawning runs of the coho in the Great Lakes take place from September to early October, although actual time of the spawning occurs from October to January, depending upon the spawning run (Scott and Crossman, 1973). Swift-running tributaries with gravel bottoms are selected as the spawning site. Populations of salmon in the Lake Ontario are maintained through stocking of hatchery-reared fingerlings.

The number of eggs deposited by the female varies with size of the female, location, and year. The adults die shortly after they spawn, and eggs hatch during the early spring in 35-50 days, depending upon the water temperature. The yolk sac is absorbed by the alevins during a 2-3 week period the eggs remain on the gravelly stream bottom. When fry emerge, which may occur from March to July, some individuals will migrate to the sea or open lake, although most fry remain in freshwater streams or tributaries for a one-year period.

No data are available on the time of spawning or the fecundity coho salmon in the vicinity of Nine Mile Point. Lake Ontario stocks of the coho salmon first introduced in 1968-1969 are currently being maintained through extensive stocking programs. At present no information is available on any natural reproduction by the introduced fish. Coho are riverine spawners and would not be expected to spawn in the FitzPatrick vicinity.

- Feeding

In fresh water, the young cohos feed upon aquatic insects and oligochaetes. Schools of salmon migrate to the ocean or lake during the spring of the year following emergence. The majority of the migratory population spends about 18 months in the lake or at sea, and returning to spawn at age 3 or age 4 during the fall (Scott and Crossman, 1973). Large coho salmon prey primarily upon rainbow smelt and alewives. Information on coho salmon feeding in the Nine Mile Point vicinity is not presently available.

7. Brown trout (Salmo trutta)

The brown trout is a native of Europe, western Asia, and northern Africa. It was introduced into North American waters during the 1800's and may be found throughout the Great Lakes region and the northeast coast of the United States (Scott and Crossman, 1973). This species is annually stocked in the New York portion of Lake Ontario by the New York State Department of Environmental Conservation.

- Abundance and Seasonal Distribution

As in the case of other salmonids, brown trout were caught in greater numbers in 1975 than in either of the two previous years, due to stocking. The brown trout was represented by 182 specimens in 1975 as compared to 75 in 1974 and 31 fish in 1973. All of the brown trout caught in 1975 were collected by surface (N = 116) and bottom (N = 66) gill nets. No differences were found among transects.

- Age and Growth

Age and growth studies of Lake Ontario brown trout indicated that individuals of this species may live for 13 years (Marshall and MacCrimmon, 1970); brown trout have been reported to reach a length of 427 mm at age 4 (Mansell, 1966).

No data are available on age and growth of brown trout from the Nine Mile Point vicinity.

- Reproduction

Brown trout usually spawn during late autumn/early winter; in one study, Mansell (1966) noted that brown trout spawned during mid-October through early November in Ontario Province when water temperatures ranged from 6.7-8.9°C (44.1-48.0°F). Spawning usually takes place in the shallow headwaters of streams over a gravel bottom, although Eddy and Surber (1960) observed that many trout spawned on rocky reefs along the shore of Lake Superior. The number of eggs deposited by a spawning female brown trout is proportional to her size: the larger females deposit more eggs.

No data are available on the fecundity or time of spawning of brown trout in the vicinity of Nine Mile Point. No eggs or larvae of the brown trout have been collected in the Nine Mile Point vicinity.

- Feeding

Brown trout feed on a wide variety of organisms ranging from insects, molluscs and amphibians to decapods and fish. The wide range of food items consumed would not preclude brown trout from the area of Nine Mile Point; however, no information on feeding habits is currently available.

8. *Gammarus fasciatus*

Gammarus was among the most abundant species in both macrozooplankton (>571) and benthic collections in the 1973-1975 period. Abundance and distribution of *Gammarus* in the study area have been discussed earlier in the plankton and benthos sections.

Summary

The population parameters including abundance and distribution, age and growth, reproduction and feeding of the representative important species in the vicinity of Nine Mile Point have been discussed in this section. In addition, distributional trends among years (1973-1975) and within years (1975) encompassing preoperational (1973-1974) and post operational (1975).

REFERENCES CITED

CHAPTER VI

Baily, M. M. 1964. Age growth, maturity, and sex composition of the American smelt, Osmerus mordax (Mitchill), of western Lake Superior. Trans. Amer. Fish. Soc. 93(4):382-395.

Baldwin, N. S. 1950. The American smelt, Osmerus mordax (Mitchell), of South Bay, Manitoulin Island, Lake Huron. Trans. Amer. Fish. Soc. 78(1948):176-180.

Beckman, W. C. 1942. Length-weight relationship, age, sex ratio and food habits of the smelt from Crystal Lake, Benzie County, Michigan. Copeia. 1942(2):120-124.

Brender, C. M., Jr. and D. E. Rosen. 1966. Modes of reproduction in fishes. Natural History Press, New York. 941p.

Burbidge, R. G. 1969. Age, growth, length-weight relationship, sex ratio, and food habits of American smelt, Osmerus mordax (Mitchill), from Gull Lake, Michigan. Trans. Amer. Fish. Soc. 98(4):631-640.

Christie, W. J. 1973. A review of the changes in the fish species composition of Lake Ontario. Great Lakes Fish. Comm. Tech. Rept. 23: 65 p.

Christie, W. J. 1974. Changes in the fish species of the Great Lakes. J. Fish. Res. Bd. Canada. 31(5):827-854.

Eddy, S. and T. Surber. 1960. Northern fishes with special reference to the upper Mississippi Valley. (Revised ed). Charles T. Branford Co., Mass. 276p.

Everest, G. 1973. Some effects of heated effluents on fish populations at three thermal generating stations. M. S. Thesis, Univ. Toronto, Canada. 157p.

Graham, J. J. 1956. Observations on the alewife, Pomolobus pseudoharengus (Wilson), in freshwater. Univ. Toronto Biol. Ser. 62, Publ. Ont. Fish. Res. Lab. 74: 43p.

Gross, R. W. 1959. A study of the alewife, Alosa pseudoharengus (Wilson), in some New Jersey lakes with special reference to Lake Hoptchona. M. S. Thesis, Rutgers Univ., New Brunswick, N. J. 52p.

REFERENCES CITED (Continued)

Hale, J. 1960. Some aspects of the life history of the smelt (Osmerus mordax) in western Lake Superior. Minnesota Fish Game, Invest., Ser. 2:25-41.

Hubbs, C. L. and K. F. Lagler. 1958. Fishes of the Great Lakes region. Univ. Michigan Press, Ann Arbor. xv+213p.

Lawler, Matusky and Skelly Engineers. 1975. 1974 Nine Mile Point aquatic ecology studies. Prepared for Niagara Mohawk Power Corp. and Power Authority of the State of New York.

Lawler, Matusky and Skelly Engineers. 1976. 1975 Nine Mile Point aquatic ecology studies. Prepared for Niagara Mohawk Power Corp. and Power Authority of the State of New York.

MacCullen, W. R. and M. A. Regier. 1970. Distribution of smelt, Osmerus mordax and the smelt fishery in Lake Erie in the early 1960's. J. Fish. Res. Bd. Canada. 27:1823-1846.

Mansell, W. D. 1966. Brown trout in sothern Ontario. Ont. Fish. Wildl. Rev. 5(2):3-8.

Mansueti, A. J. and J. D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay region: An atlas of eggs, larval, and juvenile stages. I. Natural Res. Inst., Univ. Maryland. 202p.

Marshall, T. L. and H. R. MacCrimmon. 1970. Exploitation of self-sustaining Ontario stream populations of brown trout (Salmo trutta) and brook trout (Salvelinus fontinalis). J. Fish. Res. Bd. Canada. 27(6):1087-1102.

Mason, E. J. R. 1933. Smelts in Lake Ontario. Copeia. 1933(1):34.

McClane, A. J. 1964. McClane's standard fishing encyclopedia. Holt, Reinhart, and Winston, New York.

McKenzie, R. A. 1958. Age and growth of smelt, Osmerus mordax (Mitchell), of the Miramichi River, New Brunswick. J. Fish. Res. Bd. Canada. 15(6):1313-1327.

McKenzie, R. A. 1964. Smelt life history and fishery in the Miramichi River, New Brunswick. Fish. Res. Bd. Canada. 144: 77p.

Muncy, R. J. 1962. Life history of the yellow perch, Perca flavescens, in estuarine waters of the Severn River, a tributary of Chesapeake Bay, Maryland. Chesapeake Sci. 3(3):143-159.

REFERENCES CITED (Continued)

Norden, C. R. 1967. Age, growth and fecundity of the alewife, *Alosa pseudoharengus* (Wilson), in Lake Michigan. Tran. Amer. Fish. Soc. 96(4):387-393.

Norden, C. R. 1968. Morphology and food habits of the larval alewife, *Alosa pseudoharengus* (Wislon) in Lake Michigan. Proc. 11th Conf. Great Lakes Res. 1968:102-110.

O'Gorman, R. 1974. Predation by rainbow smelt (*Osmerus mordax*) on young-of-the-year alewives (*Alosa pseudoharengus*) in the Great Lakes. Prog. Fish. Cult. 36(4):223-224.

Pritchard, A. L. 1929. The alewife (*Pomolobus pseudoharengus*) in Lake Ontario. Univ. of Toronto Stud. Biol. Ser. 33:39-54.

Quirk, Lawler and Matusky Engineers. 1973. Nine Mile Point aquatic ecology studies 1972.

Quirk, Lawler and Matusky Engineers. 1974. 1973 Nine Mile Point aquatic ecology studies - Nine Mile Point Generating Station. Prepared for Niagara Mohawk Power Corp.

Reynold, J. B. 1965. Life history of the smallmouth bass, *Micropterus dolomieui*, in the Des Moines River, Boone County, Iowa. Iowa State J. Sci. 39:417-436.

Rhodes, R. J. and T. S. McComish. 1975. Observations on the adult alewife's food habits (Pisces: Clupeidae: *Alosa pseudoharengus*) in Indiana's waters of Lake Michigan in 1970. Ohio J. Sci. 75(1): 50-55.

Rupp, R. S. 1965. Shore-spawning and survival of eggs of the American smelt. Trans. Amer. Fish. Soc. 94(2): 160-168.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Canada Bull. 184: 966p.

Sheri, A. N. and G. Power. 1969. Fecundity of the yellow perch, *Perca flavescens* Mitchell, in the Bay of Quinte, Lake Ontario Canada J. Zool. 47(1):55-58.

Stone, U. B., D. G. Pasko, and R. M. Roecker. 1954. A study of Lake Ontario-St. Lawrence River smallmouth bass. N. Y. Fish Game J. 1(1):1-26.

REFERENCES CITED (Continued)

Storr, J. 1973. Fish tagging program, Nine Mile Point. August 1972 to September 1973. A program report to Niagara Mohawk Power Corp.

Suttkus, R. D. 1955. Age and growth of a small-stream population of 'stunted' smallmouth black bass, Micropterus dolomieui dolomieui (Lacepede). N. Y. Fish Game J. 2(1):83-94.

Tharratt, R. C. 1959. Food of yellow perch, Perca flavescens (Mitchell) in Saginaw Bay, Lake Huron. Trans. Amer. Fish. Soc. 88(4):330-331.

Threinen, C. W. 1958. Life history, ecology, and management of the alewife Pomolobus pseudoharengus (Wilson). Publ. Wisc. Conserv. Dept. 223: 8p.

Van Oosten, J. K. 1940. The smelt, Osmerus mordax (Mitchell). Michigan Dept. Conserv. 13p. [Revised 1942].

Van Oosten, J. K. 1947. Mortality of smelt, Osmerus mordax (Mitchell), in Lakes Huron and Michigan during the fall and winter of 1942-1943. Trans. Amer. Fish. Soc. 24(1944):310-337.

Wells, L. 1968. Seasonal depth distribution of fish in southern Lake Michigan. Fish. Bull. 67(1):1-15.

Wells, L. 1970. Effects of alewife predation on zooplankton populations in Lake Michigan. Limnol. Oceanogr. 15(4):556-565.

Williams, R. W. and G. Miller. 1973. Summer and fall feeding preferences of selected fishes from Lake Ontario. Paper presented at 16th Conf. Great Leakes Res.

VII. IMPACT OF THE THERMAL DISCHARGE

A. INTRODUCTION

In this Chapter, the potential direct and indirect effects of JAF thermal discharge are discussed and then followed by an assessment of these effects on the representative species. Although emphasis is placed on the thermal component of the discharge, physical and chemical components of the discharge are also discussed. For the purpose of this discussion, direct effects are defined as those resulting from contact by individual organisms with a potentially injurious component of the discharge. Indirect effects are those which result from an interaction of the discharge with other potentially stressful conditions in the environment or an ecosystem imbalance initiated through direct effects.

Ecosystem effects are initiated at the individual organism level and become important when a substantial proportion of the individuals experience deleterious effects of the discharge. This chapter evaluates potential effects on individual organisms and the subsequent ecosystem effects that may occur.

B. POTENTIAL EFFECTS

1. Thermal Effects Conceptual Framework

The behavioral and physiological capabilities of fish and the temporal and spatial gradients of temperature within thermal plumes allow for a range of response to thermal exposure from death to no effect. In order to evaluate the effects of the exposure of organisms to changes in temperature, a conceptual framework has been developed within which organism response can be tested in the laboratory for specific thermal regimes, and extrapolated to the multi-dimensional thermal regimes of an actual discharge. This conceptual framework is briefly discussed to provide a background for a subsequent discussion of the thermal characteristics of the representative important species. (For a detailed exposition of the following concepts see Coutant, 1970 and Warren, 1971.)

The response of an organism to temperature is divided into two zones: the zone of tolerance and the zone of resistance. An organism may live indefinitely in the zone of tolerance because the temperature level does not exceed the incipient lethal level (lethal threshold) for that species. The incipient lethal temperature is the highest (or lowest) temperature at which a given percentage of test individuals (usually 50%) will survive indefinitely for a given acclimation temperature. The higher the acclimation temperature, the higher the incipient lethal level until the ultimate incipient lethal level is reached. At this level, an increase in acclimation temperature will not raise the incipient lethal level.

In the zone of resistance an organism's survival is time-dependent. At temperatures well above the incipient lethal level, resistance time is very short, while at temperatures close to the incipient lethal level, resistance times are greater. A temperature can ultimately be reached which produces instantaneous death.

Another important concept related to the thermal responses of fish is that of the Critical Thermal Maximum (CTM). The CTM is the thermal point at which the locomotor activity becomes disorganized and the fish loses its ability to escape from conditions that may cause death. The point of equilibrium loss is of particular importance in the evaluation of effects of exposure to thermal plumes in the natural environment. Standard thermal bioassays, while providing a rather precise demarcation of lethal temperatures, do not permit evaluation of sub-lethal effects on behavior which can culminate in death. Coutant (1970) has shown that sub-lethal exposures to lethal temperatures resulted in increased predation on juvenile salmonids in controlled laboratory experiments. Increases in predation rate occurred at thermal doses well below those causing equilibrium loss visible to the experimenter.

The thermal history of an organism, or its acclimation temperature, has a profound influence on the physiological and behavioral response of fish to a change in temperature. The ability of a fish to tolerate and adjust to a change in temperature varies with its acclimation temperature.

In addition to the physiological response of death and loss of equilibrium, fish can respond behaviorally to temperature changes by avoiding or gravitating to the change. For example, when presented with a gradient of temperature in the laboratory, fish will show a preference for a temperature regime. When presented with a series of choices between two temperatures, fish will show an avoidance response when an unsuitable temperature is presented. A series of experiments can be conducted which will produce preferred and avoidance temperatures over a broad range of acclimation temperatures. Preferred and avoidance temperatures are important in the assessment of thermal plume effects in that they permit an evaluation of fish behavior in relation to the thermal gradient of the plume.

Laboratory determinations of preferred and avoidance temperatures eliminate the influence of other factors on fish behavior. In a natural situation fish may respond to many factors, and therefore, the prediction of fish behavior from laboratory results must be approached with caution.

C. EVALUATION OF POTENTIAL EFFECTS ON REPRESENTATIVE IMPORTANT SPECIES

1. Direct Thermal Effects

The evaluation of potential effects is based on thermal data for each species, field data collected in the vicinity of the JAF, and literature on the effect of thermal discharges. The tabulated data of thermal characteristics includes selected representative species as well as other Great Lakes species. The thermal characteristics of the other species are presented to show that the selected species are representative in regard to the analysis of thermal effects. Thermal data of Otto et al. (1973), for specimens collected in Lake Michigan, are particularly useful because they provide thermal characteristics relative to an acclimation temperature in each case.

The assessment of the effect of the JAF discharge on representative important species and closely related species draws together and evaluates evaluates the factors that determine the likelihood of exposure, duration of exposure, and consequences of exposure to the plume for each species. The probable ecological consequences of the projected lethal and sub-lethal effects are discussed in terms of the representative species and the overall biological community data presented in Chapter V.

a. Lethal Effects

The thermal plume can be potentially lethal in two ways: fish can voluntarily swim into an increasing temperature gradient until lethal conditions are met and organisms can be entrained into the plume at temperatures that are lethal. The temperature distributions in the plume, described in Chapter IV, indicate a very sharp gradient of temperature due to the rapid dilution produced by the high velocity discharge. Although the temperature at the point of discharge exceeds the upper incipient lethal temperature (Tables VII-1 and VII-2) for all the representative species, the likelihood of a fish intentionally experiencing the full temperature increase is very remote.

Otto et al. (1973) studied the swimming ability of yellow perch, rainbow smelt and other species from Lake Michigan(Figure VII-1). The maximum sustained swimming speeds (speeds which a fish can maintain for time intervals up to 45 minutes) over a range of acclimation temperatures from 5 to 20°C were 14-28 cm/sec for yellow perch and 34-45 cm/sec for rainbow smelt. Their ranges of sustained swim speeds probably encompass the capabilities of the other species on the representative list.

TABLE VII-1

SUMMER LETHAL THRESHOLD TEMPERATURES FOR REPRESENTATIVE IMPORTANT SPECIES

JAMES A. FITZPATRICK NUCLEAR POWER PLANT AND VICINITY

SPECIES	SUMMER LETHAL THRESHOLD*
Alewife	23.0-32.2°C
Brown trout	23.5-25.0°C
Coho salmon	24.0-25.0°C
Rainbow smelt	21.5-28.5°C
Smallmouth bass	35.0°C
Threespine stickleback	25.8-33.0°C
Yellow perch	29.0-32.0°C
Gammarus fasciatus	34.0-37.0°C

*Upper lethal threshold temperatures based on the highest acclimation temperatures presented in Appendix A.

TABLE VII-2

A SUMMARY OF UPPER INCIPIENT LETHAL TEMPERATURES (°C) FOR FISH[a]

LAKE MICHIGAN

SPECIES	ACCLIMATION TEMPERATURE (°C) 5	10	15	20	25
Alewife (Adult)*	-	23.3	23.8	24.5	-
Alewife (Young-of-the-Year)*		26.3	-	30.3	32.1
Bloater[b]	22.6	23.8	24.8	26.6	27.0
Brook Trout[c]	23.7	24.4	25.0	25.3	25.3
Chinook Salmon[b]	21.5	24.3	25.0	25.1	-
Cisco[c]	21.6	24.3	-	26.6	26.0
Coho Salmon[d]*	21.3	22.5	23.1	23.9	-
Emerald Shiner[f]	23.2	26.7	28.9	30.7	30.7
Fathead Minnow[f]	-	28.2	-	31.7	33.2
Golden Shiner[g]	-	29.3	30.5	31.8	32.2
Largemouth Bass[g]	-	-	-	32.5	34.5
Rainbow Trout (Yearling)	23.4	24.7	25.7	25.7	-
Slimy Sculpin	18.5	22.5	23.5	-	-
Yellow Perch*	22.2	24.7	27.7	29.8	31.2

[a] Otto et al., 1973

[b] Edsall et al., 1970

[c] Fry et al., 1946

[d] Brett, 1952

[e] Edsall and Colby, 1970

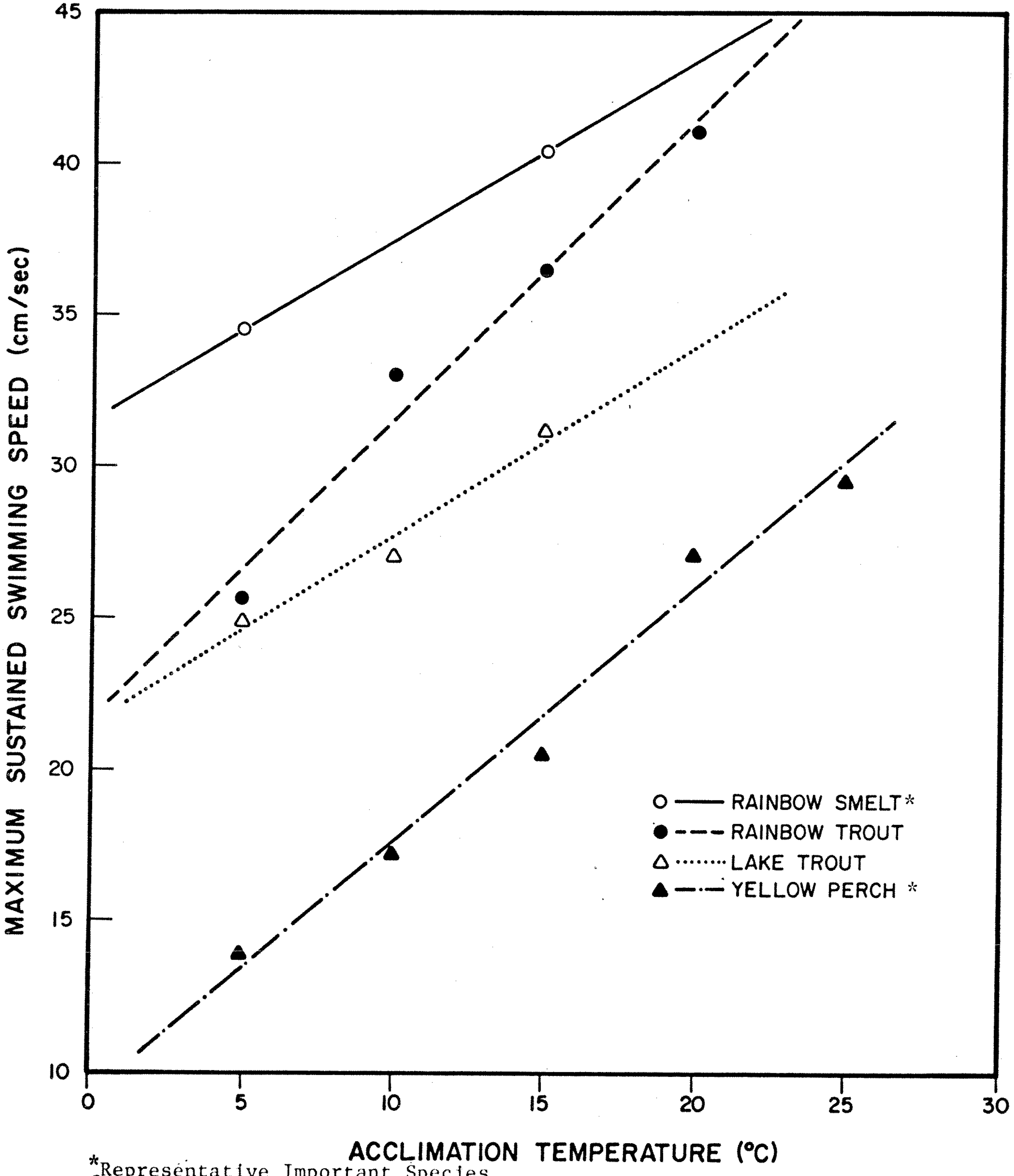
[f] Hart, 1947

[g] Hart, 1952

*Representative Important Species

MAXIMUM SUSTAINED SWIMMING SPEEDS OF FISH[a] ACCLIMATED TO CONSTANT TEMPERATURES[b]

LAKE MICHIGAN



* Representative Important Species

[a] Mean standard lengths of test fish (cm): rainbow smelt, 13.4 cm; lake

The velocity of water exiting from the discharge ports is 426.7 cm/sec and decreases to 30.48 cm/sec at a distance of 91.4 m from the ports. Over this same distance dilution of the discharge water has reduced the temperature increase from 17.5°C to temperatures of 1.7-2.8°C above ambient. It is clear from a comparison of discharge velocities and maximum sustained swim speeds that it is impossible for any of the representative species to swim against the discharge flow and maintain themselves in the hottest portion of the plume. Therefore, the evaluation of lethal effects resulting from voluntary exposure to the plume should be based on the temperatures which exist in the area of the velocity field where a fish could theoretically maintain itself.

Most of the representative species could maintain themselves in the area of water velocity of 30.5 cm/sec during the summer months when their swimming ability is at a maximum, particularly for specimens larger than those tested. Temperature increases of 1.7-2.8°C are expected in the area where plume velocities are approximately 30.5 cm/sec. Upper incipient lethal levels for all representative species at low to moderate ambient lake temperatures are well above temperatures in the 30.5 cm/sec area of the plume. During high ambient conditions the upper incipient lethal levels for five of the representative species - adult alewife, brown trout, coho salmon, rainbow smelt and threespine stickleback - are exceeded or very close to temperatures in the area of 30.5 ft/sec velocities. Summer lethal thresholds for remaining representative important species, smallmouth bass, yellow perch and Gammarus sp., are above the plume temperatures under consideration.

Brown trout, coho salmon, and rainbow smelt are cold-water species which normally leave the warm surface waters of the lake during the summer months and reside in the cool waters in the depths of the lake. This distribution pattern, an expression of their avoidance of warm water, effectively removes them from contact with the plume during the period of high ambient temperatures.

Adult alewives are less tolerant of high temperatures than young-of-the-year alewives. While the upper incipient lethal level may be exceeded for adult alewives during the summer, young-of-the-year alewives can apparently tolerate the same conditions. Adult alewives move to the cool depths of Lake Ontario following spawning in the spring. This movement would remove them from contact with the plume.

The threespine stickleback is an inshore species throughout the year and is, therefore, susceptible to lethal conditions. The area of the plume under consideration is restricted to the surface during the summer. The stickleback nests on the bottom in late spring and early summer, which would isolate it from the thermal plume, but at other times during the summer it could be exposed to lethal conditions.

The above considerations preclude mortality to fish due to their voluntary contact with the plume. Plume temperatures in an area where a species maintains itself never exceed the upper incipient lethal temperature when that species can be expected to be in the vicinity of the discharge. There is, however, another consideration which supports the conclusion that voluntary excursion into the plume cannot result in mortality.

Avoidance of potentially harmful temperatures by fish has been demonstrated in the laboratory many times and is observable in nature in the seasonal changes in distribution made by salmonids. Table VII-3 lists laboratory-determined avoidance temperatures for some Lake Michigan fishes, which include four of the representative species (Otto et al., 1973). Except for yellow perch, there is a trend through the range of acclimation temperatures available which shows the avoidance temperature to be below the critical thermal maximum (Table VII-4) at each acclimation temperature. The CTM's which are substantially greater than upper incipient lethal temperatures, permit a greater excursion into the plume and thus a fish has a substantial temperature differential which permits avoidance of the plume.

These data demonstrate that the representative species, with the exception of yellow perch, have avoidance behavior of potentially harmful conditions. Yellow perch may not avoid conditions which would ultimately be lethal. However, this condition will not occur because the upper incipient lethal level is not exceeded in the area of the plume to which yellow perch have access.

The foregoing discussion was directed to potential mortalities when an organism moves under its own power into the thermal plume. A second mode of contact with the thermal plume is through entrainment with the surrounding water mass. As the condenser water exits from the discharge ports at high speed, surrounding lake water is drawn into the jet stream and mixed with the condenser water. The velocity of the surrounding water entering the jet stream near a discharge nozzle was estimated to be 15.24 cm/sec (0.5 ft/sec) in the hydraulic model. Organisms with limited motility will be entrained with the water mass, and actively swimming organisms will be entrained if they do not resist the flow.

Figure IV-4 shows the decay of temperature with time in the JAF plume. Because of the complex hydraulics associated with the mixing of the jet and the surrounding water it is difficult to define the

TABLE VII-3

AVOIDANCE TEMPERATURES OF FISH AS DETERMINED IN A +/- CHOICE APPARATUS[a]

LAKE MICHIGAN

SPECIES	ACCLIMATION TEMPERATURE (°C)				
	5	10	15	20	25
Brook Trout	20.0	22.0	21.5	24.0	-
Brown Trout*	-	21.5	-	-	-
Chinook Salmon	20.0	21.5	23.5	-	-
Coho Salmon*	19.5	22.0	24.5	23.5	-
Lake Trout	17.5	18.0	22.0	-	-
Rainbow Smelt*	10.5	16.0	-	-	-
Rainbow Trout	20.5	21.5	23.5	24.5	-
Slimy Sculpin	15.0	19.0	23.0	-	-
Yellow Perch	26.0	30.0	31.0	31.0	33.0

[a] Otto et al., 1973

*Representative Important Species

TABLE VII-4

A SUMMARY OF CRITICAL THERMAL MAXIMA (°C) FOR FISH ACCLIMATED TO CONSTANT TEMPERATURES[a]

LAKE MICHIGAN

SPECIES	ACCLIMATION TEMPERATURE (°C)					
	5	10	15	20	25	30
Alewife (Adult)*	24.7	28.7	29.9	31.9	32.8	-
Alewife (Young-of-the-Year)*	24.7	26.7	29.5	31.9	34.3	36.7
Brook Trout (Yearling)	27.5	28.8	30.0	-	-	-
Brown Trout (Yearling)*	-	27.8	-	-	-	-
Chinook Salmon (Yearling)	26.4	28.5	29.5	30.2	-	-
Coho Salmon (Yearling)*	26.1	27.3	28.2	29.9	-	-
Fathead Minnow	28.5	31.9	32.7	35.7	36.7	38.5
Golden Shiner	27.9	30.3	33.0	35.0	37.6	39.0
Longnose Dace	28.4	30.5	31.4	33.9	35.4	36.7
Lake Trout (Yearling)	26.3	25.9	27.9	-	-	-
Rainbow Smelt*	23.5	24.4	-	-	-	-
Rainbow Trout (Yearling)	27.9	28.4	29.7	31.1	-	-
Slimy Sculpin	23.4	25.0	27.1	29.4	-	-
Spottail Shiner	27.7	30.2	31.2	33.3	35.5	37.7
White Sucker	27.8	28.7	30.5	32.9	-	-
Yellow Perch (Adult)*	26.6	29.3	31.6	33.8	35.4	-
Yellow Perch (Young-of-the-Year)*	27.5	28.6	30.3	32.6	35.1	-

[a] Otto et al., 1973

*Representative Important Species

thermal regime that a plume-entrained organism might experience. If an organism were entrained next to the discharge nozzle and entered the core of the jet it would theoretically experience the time/temperature relationship of a water particle exiting from the discharge ports. This would represent the worst situation for an entrained organism.

The other extreme would be for organisms which briefly encounter the periphery of the plume and only experience a small temperature increase for a short time. Therefore, plume entrainment results in a broad spectrum of time/temperature exposures. For this analysis the worst-case conditions will be emphasized which consist of entrainment into the plume at the point of discharge and exposure to temperatures diminishing from 17.5°C above ambient to surface ambient. The effect of plume entrainment on representative species will be assessed separately for larvae and early life stages and for older life stages.

An attempt to simulate the time/temperature regime of the FitzPatrick plume on larvae collected in the intake was conducted from June through August 1976. Because of initial high mortality in the intake samples, apparently due to the collection process, and very low numbers of larvae available for testing, no substantive results were obtained. On a few occasions live larvae were obtained and survived the simulation process. This demonstrates that larvae can survive plume entrainment. However, it is not possible to quantify survival percentages and this requires extrapolation from other sources.

Laboratory studies simulating the temperature effects of condenser entrainment are useful for evaluating plume entrainment of larvae and early life stages of fish because the time/temperature exposures incurred during passage through a cooling system are considerably more severe than the worst case of time/temperature exposures in the JAF plume. Although data are not available on the representative species, data from a few closely related species are available, while the data from a variety of species provide a general picture of the effect of thermal shock on early life stages of fish.

Schubel et al. (1975) exposed larvae of blueback herring (Alosa aestivalis), American shad (Alosa sapidissima) and striped bass (Morone saxatilis) to time/temperature histories typical of currently operating power plants for acclimation temperatures of 20°C.

The study of Schubel et al. consisted of exposing eggs and larvae of various sizes to temperature increases for periods of time representing plant passage and then decreasing temperature over several different time intervals to represent various time/temperature histories in the plume. LMS restricted their comment to the holding times representing plant passage, since time temperature histories of Schubel et al (1975) are longer than those at JAF and are thus conservative. The holding times representing plant passage are also extreme in that the shortest time of exposure to maximum temperature increases are substantially longer than time of exposure to the near field temperature increase at JAF.

For eggs of the three selected species, Schubel et al. found no significant increase in mortality for temperature increases of 10°C for 20 minute exposure. Eggs of striped bass survived temperature increases of 15°C for 3 minutes exposures, but eggs of the other two species exhibited a significant increase in mortality for the same temperature increase and exposure. Schubel et al (1975) did not indicate the percentage increase in mortality for Alosa eggs at 15°C exposures.

Similar results were found for larvae in that no significant increase in mortality occurred for increased temperatures of 10°C for 20 minutes exposure for striped bass and blueback herring. There was a significant increase in mortality for American shad but the increase was only 3% (average of difference in control and D1 mortalities; Table 6 of Schubel et al.). For a 15°C increase at a 3 minute exposure, there was no significant increase in mortality for blueback herring, but there was for the other two species. The increase in mortality was, however, less than 50% (average of difference in mortality between control and experiment classification E in Tables 5 and 6 of Schubel et al.).

Hoss et al. (1973) exposed larvae of Atlantic menhaden (Brevoortia tyrannus), spot (Leiostomus xanthurus), pinfish (Lagodon rhomboides) and three species of flounder (Paralicthys albigutta, P. lethostigma and P. dentatus) to thermal shocks simulating the time/temperature exposures that could be encountered in the cooling systems of operating power plants. Each species was maintained at a range of acclimation temperatures and exposed to temperature increases of 12, 15 and 18°C for 10, 20, 30 and 40 minutes. With the exception of menhaden, no significant increased mortality was observed for the 12°C increase over a 40-minute exposure at maximum ambient (15 or 20°C depending on the species). Menhaden exhibited increased mortality with a temperature increase of 12°C at a 15°C acclimation temperature, but no increased mortality with an increase of 10°C at the same acclimation temperature. Increased mortality was observed for temperature increases above 12°C for all species, particularly at the high acclimation temperatures.

Hoss et al. (1973) did not find persistent (long-term) effects of thermal shock on oxygen consumption and growth rate. In addition, exposure of larvae to a 12°C increase in temperature did not cause visible signs of distress in most cases. Subtle changes in behavior, however, may be difficult for an observer to see in these small specimens.

Chadwick (1974) obtained high survival of striped bass larvae after exposure to 10°C temperature shocks for up to 6 minutes at acclimation temperatures of 15.5 and 21.1°C. Temperature increases which brought the maximum to 32°C or above resulted in significant mortality, regardless of exposure time for this species.

The foregoing results of larval entrainment simulations indicate that the worst case of plume entrainment at JAF is far less severe than the time/temperature regimes for which there was substantial survival for a variety of species. These studies exposed eggs and larvae to temperature increases for a minimum of 3 minutes. At JAF an organism entrained exactly at the point of discharge is down to 5°C above ambient in less than 2 seconds for the worst case condition. In general, these other studies found that a 10°C increase did not affect survival while a 15°C increase resulted in some mortality, less than 50%. Since these studies were done for exposure periods that were substantially longer than comparable exposure at JAF, it is expected that plume entrainment of JAF will have a minimal effect on survival of eggs and larvae.

The analysis of plume entrainment of juvenile and adult fish presents a more complex situation because these life stages have the ability to resist entrainment into the plume or to leave the plume if they encounter unsuitable temperatures. The velocity component of the discharge will assist entrained organisms to escape potentially harmful temperatures because the plume momentum is carrying organisms away from the warmest temperatures. This analysis will be based on the worst case entrainment situation described for larval life stages. The evaluation will be based almost entirely on contents of Otto et al. (1973). However, unlike the larval evaluation, the Otto et al. report addressed all of the representative important species except smallmouth bass and threespine stickleback. All of the Lake Michigan species they studied are found in Lake Ontario.

At the beginning of this section it was indicated that the upper incipient lethal level was exceeded during summer for five species in the area of the plume velocities of 30.48 cm/sec. It was also shown that these species are distributed in cooler waters when exposure to lethal temperatures in the plume would be possible. The other representative species could be entrained in the plume during the summer months, while all species could be entrained at one or all of the other seasons.

When the 17.5°C temperature increase at the point of discharge is added to the acclimation temperatures shown in Table VII-2, the upper incipient lethal levels generally approximate the maximum discharge temperature for 5°C acclimation and exceed the upper incipient lethal temperatures for all other acclimation temperatures. In other words, at acclimation temperatures of 5°C and above, fish in the worst-case entrainment situation have entered the zone of resistance and their survival is dependent on the time of exposure.

There are no data available on the effect of extremely short exposures to temperature increases such as would occur in the Fitz-Patrick plume. A thermal bioassay was conducted in which juvenile yellow perch acclimated to 25°C (maximum intake temperature recorded at JAF in summer, 1976) were exposed to temperature increases of 4.4, 8.8, 13.2, and 17.5°C for 6 seconds. A median tolerance limit of 38.5°C was established. Behavior was, however, noticeably altered for the lowest test temperature. There was no equilibrium loss at an increase of 4.4°C, but there was a depression of activity which lasted up to 15 minutes. Because no other temperature tolerance information exists for very short exposure times, CTM temperatures will be used as an indication of survival in JAF's discharge for plume entrained nekton.

CTM's as pointed out previously, are determined by exposing a fish to gradually increasing temperatures until there is an equilibrium loss. Otto et al. used 1°C increase per minute. Determination of an upper incipient lethal temperature takes a minimum of several hours exposure. The Critical Thermal Maximum (CTM) temperatures in Table VII-4 are in the zone of resistence and can be used as an indication of the temperature increase that a species can survive for very short exposure periods. This can be verified by comparing the CTM and upper incipient lethal temperature for yellow perch as determined by Otto et al., and the 6 second exposure lethal temperature determined as part of this study. Juvenile yellow perch have an upper incipient lethal temperature of 31.2, a CTM 35.1 and a 6 sec lethal temperature of 38.5°C. Using the 2°C safety factor advocated by EPA (1973), the 6 sec exposure safe temperature is 36.5°C or approximately 1.5°C higher than the CTM.

Use of the CTM rather than the upper incipient lethal temperature indicated that the 17.5°C temperature increase will be at or near the lethal level for a few species at 10°C acclimation, while some limited mortality may occur at 15°C. At a water temperature of 20°C, it is expected that the salmonids and rainbow smelt would have migrated and only the warm water nekton species would be exposed to potentially lethal temperatures. At 20°C plume temperatures, 12°C above ambient would be potentially lethal while at 25°C, plume temperatures above 10°C could be potentially lethal. At 25°C, it is expected that adult alewives have left the area since this temperature exceeds their upper incipient lethal temperature. This analysis does not address smallmouth bass and threespine stickleback. Since the smallmouth bass is the most temperature tolerant of all representative important species, it is expected that no plume related mortality will occur for this species (Table VII-1). Since yellow perch and threespine stickleback have similar temperature tolerances (Table VII-1), the conclusion made above for yellow perch would be appropriate for threespine stickleback.

While the above analysis suggests that some mortality may occur for the worst case condition, particularly at 20 and 25°C acclimation temperatures, it needs to be emphasized that the bioassay studies which support this conclusion are atypical of the conditions which exist for plume entrainment. Bioassays exposed fish to gradually increasing temperatures for CTM's or to a sudden increase in temperature for upper lethal temperatures. At JAF the worst case condition occurs at 25°C acclimation; which is the maximum intake temperature recorded in 1976. For this case, fish are down to 10°C above ambient in less than 1 second. It takes 1 sec to traverse to the 7.5°C isotherm, a drop of 10°C. After this point, plume related mortality cannot occur.

In summary, it appears that any plume entrained mortality will be minimal, if it occurs at all, and this is predicated on the assumption that fish will not avoid the highest velocity component of the discharge. Observations in the discharge area support this contention in that dead fish have not been seen despite the fact that studies around the discharge are conducted several times a month.

The Critical Thermal Maximum is defined in terms of equilibrium loss, a readily observable effect. However, as Coutant showed, increased predation occurred at shock temperatures less than those producing observable changes in behavior. Therefore, although plume entrainment probably will not cause mortality to juvenile and adult fish even at the worst case condition of highest lake ambient and maximum temperature exposure in the plume, fishes so exposed could be susceptible to increased predation.

Mortality of fish due to "cold shock," i.e., abrupt exposure of organisms acclimated to a warm effluent to very low ambient temperatures, has occurred at a number of power plants. Acclimation to warmer than ambient temperatures is a precondition for cold shock mortality and the diffuser at JAF will preclude acclimation to high temperature increases. Otto et al. (1973) reported that it takes approximately 6 days for alewife and yellow perch to acclimate to 90% of a 10°C increase in temperature.

Maximum sustained swim speeds for low acclimation temperatures presented by Otto et al. (1973) indicate that strong swimmers such as salmonids could not maintain themselves in plume velocities above 35 cm/sec. Plume temperature rises corresponding to this velocity are in the range of 1.7 to 2.8°C. Maximum sustained swim speeds are defined as the speed a fish can maintain for a moderate length of time, generally less than 45 minutes. Maximum sustained speeds are greater than speeds that can be maintained for extended periods (days). Therefore, a velocity field in which representative species could maintain themselves for extended periods, the time these organisms would require to become thermally acclimated would have temperature increases on the order of 1°C. The velocity field of the FitzPatrick plume is such that the representative species will be unable to maintain themselves in a temperature sufficiently above ambient to produce a shock effect if it were removed by a plant shutdown. Because fish are effectively excluded from the plume by the velocity field, cold shock cannot occur at FitzPatrick.

In regard to plume entrainment of Gammarus sp. at JAF, Lauer et al. (1974) found that individuals from an estuarine population of Gammarus sp. could tolerate a 10°C temperature increase for 60 minutes at an ambient temperature of 25°C and 15 minute exposures of 12°C at the same acclimation temperature. At absolute temperatures above 37°C mortality after 24 hr increased significantly. Alterations in behavior indicating stress were not observed at temperature shocks of 10°C or less for exposure times of 60 minutes.

Simulations of plume entrainment of Gammarus sp. at JAF conducted in the summer of 1976 are in agreement with Lauer's results. In these simulations, Gammarus collected in the intake were placed in full plant ΔT and 1/2ΔT discharge water and then serially diluted with intake water to simulate the rate of cooling in the plume. Individuals exposed to the full ΔT were diluted to a final temperature of 3°C above ambient and 1/2ΔT exposures were diluted to 2°C above ambient. The mean percentage dead (of two replicates) did not exceed two on four test dates and was similar to the mean percentage dead in the intake samples on the same date.

The simulations conducted at JAF and by Lauer indicate that Gammarus sp. can tolerate the worst time/temperature regimes in the plume, and that therefore, there will be no mortality to Gammarus sp. due to plume entrainment.

b. Sub-lethal Effects

Sub-lethal effects may manifest themselves as a change in behavior or physiology of the organism. Behavioral changes involve almost immediate responses by fish, while physiological changes require an extended period of exposure to increased water temperatures. Life history data on selected representative species are presented in this section to show that the utilization of the NMP-1 area by these species has not resulted in altered reproductive or feeding behavior and physiology.

The velocity field of the JAF plume is such that fishes are excluded from all but the lowest temperatures above ambient. Based on the preferred temperatures of Table VII-5, fish are excluded from areas where they may concentrate at various seasons if they had access. Therefore, the velocity field of the FitzPatrick plume is the factor which establishes the area of exclusion in the vicinity of the discharge. The area of exclusion, the estimated 2 to 3 surface acres inside the 30-48 cm/sec velocity isopleth, is extremely small in relation to the water body segment discussed in Chapter IV and is not a crucial area for the life history of any representative species or other species in Lake Ontario.

Sub-lethal effects involving a physiological response are precluded due to the exclusionary effect of the plume velocity. The time required for a fish to acclimate to a change in water temperature is days or weeks, depending on the magniture of change. Based on maximum sustained swim speeds, fish can maintain themselves only on the periphery of the plume and then only for short periods of time.

The potential for a sub-lethal effect due to a brief exposure to an elevated temperature, such as would occur in the worst case entrainment situation, has not been studied exclusively. The results of Hoss et al. (1973) cited earlier indicated no persistent effects on oxygen consumption or growth rate for thermally shocked fish lavae.

There was no increased mortality after 10 days to Gammarus spp. exposed to a 8.3°C temperature increase over an ambient of 25.5°C for 60 minutes (Ginn et al., 1976). An 11.1°C increase caused significant mortality after ten days for the same ambient temperature and exposure time, while a five minute exposure to an 11.1°C increase did not cause increased mortality. The 8.3°C, 60 minute exposure did not effect subsequent reproductive behavior, nor the release of young from ovigerous females.

There are many physiological mechanisms which could be affected by brief sub-lethal exposure to elevated temperature. While only a few of these physiological responses have been examined in a few species, it appears that the sub-lethal exposures that organisms could experience in the FitzPatrick plume will not cause latent effects that are debilitating or ultimately fatal to the organism.

TABLE VII-5

A SUMMARY OF PREFERRED TEMPERATURES FOR FISH ACCLIMATED TO CONSTANT TEMPERATURES[a]

LAKE MICHIGAN

SPECIES	ACCLIMATION TEMPERATURE (°C)				
	5	10	15	20	25
Fathead Minnow	-	21.2	-	26.5	-
Golden Shiner	18.6	22.2	25.6	25.8	27.2
Lake Trout	9.0	8.7	10.8	-	-
Rainbow Trout	12.2	13.5	14.9	16.0	-
Slimy Sculpin	8.5	-	11.1	-	-
Yellow Perch	16.9	19.7	20.0	25.2	26.4

[a] Otto et al., 1973

The ecological studies in the vicinity of Nine Mile Point and Oswego, which have been in progress for several years, provide a data base of information on the representative important species. While the foregoing analyses indicate little potential effect of the plume on the representative species, life history data on alewife, rainbow smelt, yellow perch and smallmouth bass are summarized below to indicate observed effects compared to the theoretical considerations of the preceding analyses. These four species were chosen for detailed discussion because of the large amount of data available on them. The majority of these studies were conducted prior to JAF operation. However, both the Oswego and NMP-1 stations were operating and, thus, the results can be used to evaluate potential JAF impacts. Also, before continuing, it should be pointed out that concerns related to long term sublethal effects assume that some portion of a population is residing for long periods in the discharge area.

Work conducted by Storr (1974) indicates the extent of movement of fish in the Nine Mile Point vicinity. From 1972 to 1974 almost 10,000 individuals of 22 species of fish were tagged in the vicinity of Nine Mile Point. Tag returns were obtained primarily from anglers, therefore, there was a differential rate of return depending on the popularity of a species with anglers and relative ease of capture for each species. Yellow perch and smallmouth bass, two representative species, were among the species whose tags were returned in greatest numbers.

There was a continuous dispersal of fish from the tagging area which suggests that there may not be long term residence in the discharge area. Tagged fish were recovered from a wide area, indicating on approximate 70 mile range of movement around Nine Mile Point. There was a general pattern of movement to the east of Nine Mile Point during the summer and fall and westward movement in the spring. Storr's findings are supported by the results of LMS's studies (cited throughout this document) that normal onshore-offshore seasonal migrations have been found not to be effected by the presence of the thermal discharges.

(i) Fecundity and Time of Spawning

Spawning of alewife, rainbow smelt and yellow perch was determined by examining the coefficient of maturity (LMS, 1975) of the males and females of these species. The period of maximum spawning for alewife in the study area occurred during the first half of July (LMS, 1975) at a time when the average surface and bottom water temperatures were 20.6 (range of 13.5-22°C) and 16.8°C, respectively. Similar spawning temperatures have been reported for freshwater alewife in Maine (13-21°C; Rounsefell and Stringer, 1943) and in New Jersey (17-19°C; Gross, 1959). Scott and Crossman (1973) cited hatching temperatures for alewife eggs as 15.6-22.2°C. These water temperatures are not exceeded in the area during the period of alewife spawning.

Fecundity of alewife studied in 1973 (QLM, 1974) in the area varied from 25,798 to 67,739 eggs (average of 46,821) per female, for females ranging from 156 to 181 mm in total length. The total egg counts conducted in 1974 (LMS, 1975) varied from 8,981 to 50,274 eggs (average of 31,613) per female, for females ranging from 153 to 177 mm in total length. Fecundity did not differ significantly for different age classes. The total egg production for alewife taken from Lake Michigan (in July 1965) varied from 11,147 to 22,407 eggs per female of a size similar to those analyzed in this study (Norden, 1967). The number of eggs per female alewife cited by Scott and Crossman (1973) varied from 10,000 to 12,000. The values reported in this study seem to be relatively high, which is attributed to the fact that total egg count overestimates the actual number of eggs to be spawned in one season. Therefore, these figures clearly show that the alewife fecundity in the area varied from 25,798 to 67,739 eggs (average of 46,821) per female, for females ranging from 156 to 181 mm in total length. The total egg counts conducted in 1974 (LMS, 1975) varied from 8,981 to 50,274 eggs (average of 31,613) per female, for females ranging from 153 to 177 mm in total length. Fecundity did not differ significantly for different age classes. The total egg production for alewife taken from Lake Michigan (in July 1965) varied from 11,147 to 22,407 eggs per female of a size similar to those analyzed in this study (Norden, 1967). The number of eggs per female alewife cited by Scott and Crossman (1973) varied from 10,000 to 12,000. The values reported in this study seem to be relatively high, which is attributed to the fact that total egg count overestimates the actual number of eggs to be spawned in one season. Therefore, these figures clearly show that alewife fecundity in the area is not depressed and it is similar to that of other alewife populations reported elsewhere.

Rainbow smelt spawning migration begins in March when water temperature is 13.5°C and continues through May when water temperature is 18.3°C (McKenzie, 1964). During this study, maximum spawning for rainbow smelt was observed during April, when water temperature in the Nine Mile Point vicinity varied from 0.7-6.2°C (LMS, 1975). Trawl collections in April contained mature females, while smelt eggs and larvae were present in ichthyoplankton collections during the same month. This may indicate that appropriate spawning conditions for rainbow smelt occurred during the March-May period at temperatures from less than 10°C. McKenzie recognized two spawning populations of smelts in the Miramichi River system. One group of smelt spawned at temperatures less than 10°C (early spawners) and a second group spawned at temperatures 15°C or less (late spawners).

Rainbow smelt collected from the area during 1974 exhibited a fecundity of 6,212 to 29,050 eggs for females 138 to 213 mm, respectively, in total length (average 17,002 eggs)(LMS, 1975).

Fecundity was not dependent on fish age, but showed good correlations to length (r = .76), body weight (r = .83) and weight of ovaries (r = .79). The fecundity of smelt from Lake Ontario, as reported by Bailey (1964), averaged 31,338 eggs for females ranging in length from 188 to 224 mm. Lake Michigan (Van Oosten, 1940) and Lake Huron (Baldwin, 1950) female rainbow smelt showed comparable values. It is evident that maturity coefficient, time of spawning and fecundity of smelt collected from the vicinity of the JAF are similar to those exhibited by smelt in other natural bodies of water.

As in the case of alewife and rainbow smelt, yellow perch in the study area showed a coefficient of maturity, time of spawning, and spawning temperature, similar to those cited in the literature. Coefficient of maturity of yellow perch from Nine Mile Point area revealed a peak spawning activity during the first half of April (LMS, 1975) when water temperature ranged from 0.7 to 6.2°C (average 3.3°C). A temperature range of 3.9-6.7°C was reported by Muncy (1962) for spawning yellow perch in the Severn River, Maryland. In 1973 (QLM, 1974) yellow perch from Nine Mile Point spawned earlier, in mid-March, but at a similar water temperature, 3.3-6.8°C.

Yellow perch from the vicinity of the plant showed fecundity values of 4,840-5,000 eggs per female ranging 150-290 mm in total length and an average of 25,077 eggs per female (LMS, 1975). Sheri and Power (1969) estimated the fecundity of yellow perch in the Bay of Quinte, Lake Ontario as 3,035-61,465 eggs per female ranging in total length from 131 to 257 mm. Muncy (1962) reported that fecundity values for female yellow perch in Maryland (173-295 mm) were similar to those found in this study.

Alewife, rainbow smelt and yellow perch, as representative of the important species, showed that reproduct activity proceeds normally and is similar to the same parameters in fish studied in other natural environments.

(ii) Time of Annulus Formation

The time of annulus formation is the result of simultaneous processes, both internal and external (Nikolsky, 1963), and is more or less similar among years, i.e., rings, or annuli, are formed at the same time every year in a given species. This process takes place presumably when the natural environmental factors do not alter. It should be noted that the annuli are not formed directly as a result of water temperature (Nikolsky, 1963), but that water temperature can influence other factors (e.g., food abundance) which in turn influence the formation of annuli.

For fish observed from the study area, annuli were formed on scales of 36% of the alewife captured in June, 43% in July, and 100% in August 1974 (LMS, 1975). At Nine Mile Point during 1973, annulus formation began in April, reached 29 and 42% for the alewife collected in May and June, respectively, and peaked in July and August with 66 and 65%, respectively (QLM, 1974). Norden (1967) reported that 15% of alewife collected from Lake Michigan had formed annuli in June while the remainder showed annuli in July. These results are similar to the time of annulus formation for alewife collected from the vicinity of Nine Mile Point.

Fourteen percent of rainbow smelt collected in this study area during April 1974 (LMS, 1975) showed annuli on their scales; the proportion in May was 12%, and increased to 72% in June 1974, after which all smelt sampled had formed annuli. Similar results were found in 1973 (QLM, 1974), when 89% of the rainbow smelt sampled in July and 100% of those in August had formed annuli. This is in agreement with data for older smelt collected from Lake Superior (Bailey, 1964); annuli were formed earlier in younger fish. Annulus formation was complete in some yellow perch collected in this study area in April and May 1974, peaked in June and was complete for all fish examined in July (LMS, 1975). Yellow perch collected in 1973 (QLM, 1974) exhibited a similar pattern. These data are also in agreement with those of Jobes (1952), who reported the formation of annuli in yellow perch from Lake Erie in early April to mid-July.

Annulus formation for smallmouth bass collected from Nine Mile Point in 1974 (LMS, 1975) started in May, peaked in July and was essentially complete by August. Reynolds (1965) reported that annulus formation in smallmouth bass occurred in late May in the Des Moines River, Iowa; Suttkus (1955) found that annulus formation for smallmouth bass was completed in May-June for a small stream population in Falls Creek, New York. A slightly later time of annulus formation would be expected in the more northerly population of Lake Ontario.

The above discussion indicates that for alewife, rainbow smelt, yellow perch and smallmouth bass collected from Nine Mile Point area the time of annulus formation which is indirectly dependent on water temperature was similar to times observed for the same species collected from other waters. Additionally, the annuli for the above species were formed at comparable times in both years, 1973 and 1974.

(iii) Feeding

Feeding behavior of fish is governed by many factors including relative abundance of prey, behavior of predator and prey, spatial and temporal distribution of food items, and intensity of competition. These factors are directly or indirectly affected by increased (or decreased) water temperature. The influence of temperature is evident as altered predator-prey relationships.

This section describes the predator-prey relationship of representative important species in the study area. Such feeding relationships will be compared to those of the same species inhabiting natural waters which receive no heated discharges.

Smallmouth bass and yellow perch, two of the representative important species, were considered for studies of food habits. Stomach contents of these two species were analyzed in 1973 (QLM, 1974) and in 1975 (LMS, 1976). Additionally, stomach contents of yellow perch were also analyzed in 1974 (LMS, 1975).

- Yellow Perch

A total of 114 yellow perch varying in length from 130 to 275 mm and collected mostly during morning hours in August-November 1973 were examined for food preference. At the JAF 15-ft station, Gammarus fasciatus contributed more than 70% (by volume) of the total food ingested of all fish averaging in length from less than 84 to 279 mm. Pontoporeia made up only 1.3% of the stomach contents (QLM, 1974). In addition, small yellow perch (84 mm) fed on dipterans to a large degree (12.8% of their diet) while larger fish (141-186 mm) showed a tendency to consume the gastropod Physa sp. and preyed intensively on Gammarus.

Yellow perch (141-186 mm) collected at the 15-ft depth contour of NMPP transect tended to show great preferences for the amphipod Pontoporeia sp. (abundant in benthic collections), while dipterans made up a small part of their diet. Amphipods and fish were the major part of the diet of yellow perch (141-236 mm) collected at the end of August, while older fish (237-279 mm) preferred the gastropods Valvata sp. and Amnicola sp. Fish items also composed a sizable portion of their diet (QLM, 1974). At the NMPE 15-ft station yellow perch (141-186 mm) fed exclusively on Gammarus in September (QLM, 1974), whereas, the diet of those collected at NMPW 15 and 30-ft stations in October consisted mainly of fish.

Stomach contents of 48 yellow perch collected in bottom gill nets at the 15-ft depth contour (all transects combined) were examined in 1974 (LMS, 1975). These fish ranged in size from 160 to 268 mm during the spring and from 186 to 274 mm during the fall. The fish collected during the spring contained a greater variety of food items in their stomachs than those recorded from the fall collection. Of the stomachs examined, 53.7% contained fish (mottled sculpin and alewife) and 26.8% contained fish eggs and Gammarus fasciatus (LMS, 1975).

Scott and Crossman (1973) report that in general large yellow perch (>150 mm) feed primarily on decapod crustaceans, small fish and Odonata nymphs. In addition, they frequently ingest the eggs of a wide variety of fishes. McClane (1964) reported that larvae feed on zooplankton and insect larvae, and when they grow to a length of 50 to 75 mm, their diet changes to larger zooplankton, insects, crayfish, snails and small fish, including those of their own species.

Seaburg and Moyle (1964) studied summer food preference of yellow perch in Minnesota, and concluded that 66% (by volume) of stomach contents of fish larger than 127 mm was made up of fish.

Muncy (1962) examined the stomach contents of 209 yellow perch and found the major food items to be small crustaceans and insects, especially chironomid larvae. Stomachs of larger fish (89-92 mm total length) contained fish.

Yellow perch in the Nine Mile Point vicinity have a basic diet of fish and crustaceans (particularly amphipods), in addition to gastropods and dipterans, with the amount and types of food consumed depending on available food items and feeding location. The food items selected by yellow perch in the vicinity of Nine Mile Point are typical of the food preferences reported for this species in the literature. The Nine Mile Point food habit studies indicate that a diverse food base is available to yellow perch and that their food habits and feeding behavior is probably unaltered in the vicinity of the thermal discharge.

- Smallmouth Bass

In all smallmouth bass stomachs collected from August through October 1973 in the Nine Mile Point vicinity, for fish ranging in size from 167 to 415 mm total length, fish and decapod crustaceans (crayfish) were the bulk of all food present. Twenty five adult smallmouth bass over 301 mm total length analyzed in 1975 fed almost exclusively on fish and crayfish. In the 1975 samples fish were present in 73% of the stomachs and were 70% of the weight of stomach contents, while crayfish were 30% by occurrence and 30% by weight in the stomachs.

Dendy (1946) concluded that crayfish and fish are the most significant foods for smallmouth bass, and Scott and Crossman (1973) described the diet of smallmouth bass as including fish, crayfish, insects and occasionally frogs, with fish believed to be the most important component.

As with yellow perch, it is evident that the presence of JAF has neither resulted in adverse effects on food habits nor altered the normal predator-prey relationships of smallmouth bass.

c. Indirect Thermal Effects

Indirect effects are those which are secondary to contact of the thermal component of the discharges by individual organisms.

The JAF does not treat the cooling system piping to control biological growth; therefore, there are no biocides present to interact with the thermal component of the discharge.

Studies have been conducted at NMP-1 to quantify the reduction in DO after passage of the cooling water through the power plant. Analyses of the 1973 data indicated that the reduction averaged 0.3 mg/l when the inlet water was supersaturated. The mean percent DO saturation value recorded in 1975 was 108% in surface water and 104% in bottom waters; it was never below 74% and occasionally reached as high as 144%.

DO concentrations in the study area remained relatively unchanged throughout the 1973-1975 period and were consistently above the minimum value necessary for growth and development of even the most sensitive species (5.0 mg/l for salmonids). Despite spring-summer fluctuation in DO, the lowest mean DO concentration, 7.1 mg/l recorded in bottom waters in 1975 (LMS, 1976), is well above the minimum criterion for the protection of aquatic life (USEPA, 1973).

Coutant (1970) reviewed the theoretical aspects and field studies of the change in dissolved oxygen levels in water passing through power plant condensers. He presented abundant evidence to show that reductions in dissolved oxygen below saturation values do not occur when water is passed through power plant cooling systems.

The studies at NMP-1, field studies in the vicinity of Nine Mile Point and the literature indicate that there will be no significant change in dissolved oxygen levels due to passage through the JAF cooling system. Therefore, there will be no interaction of the thermal component of the discharge and reduced dissolved oxygen levels.

d. Other Effects

(i) Shear Forces

Shear forces produced by the differential current movements may result in an additional stress on fish eggs and larvae. The maximum shear force expected to occur between the 2.5°C isotherm and the ambient temperature water is about 1.33 dynes/cm^2. The shear between the 0.3°C isotherm and the ambient water is 0.09 dynes/cm^2. Morgan et al. (1973) have reported that striped bass larvae could withstand shear of 3.4 dynes/cm^2 for 1 minute in a specialized apparatus with laminar flow. Although this species is not present in Lake Ontario, the shear stress it can withstand before injury is applicable to the species in the vicinity of JAF. Therefore, it appears that little or no adverse impact can be expected to occur as a result of shear forces within the thermal plume.

(ii) Pressure Change

At the JAF discharge, as the heated water rises to the surface, carrying with it plankton and possibly eggs and larvae, a sudden drop in pressure is expected, from 2 atmospheres at 34 ft to one atmosphere near the surface. This process, which takes place in about 30 seconds, subjects the entrained organisms to an abrupt change in pressure without sufficient time for gradual adjustment at a rate of 0.03 atmos/sec.

Tsvetkov et al. (1972), after studying the effects of hydrostatic pressure changes on fish, concluded:

1. acclimation of fish to a pressure is critical in determining mortalities resulting from rapid changes in pressure
2. for fish survival, the rate of pressure change is more important than the magnitude of the pressure applied
3. injury and mortality, especially in physoclists (fish without connection between air bladder and gut), occurs when the pressure release rate is greater than the normal decompression rate for fish
4. rapid pressure changes can affect physostomous fish (fish with functional connection between gut and swim bladder)
5. sensitivity to rates and magnitudes of pressure changes is greater for the young of fish with developed swim bladder than for older fish.

Most investigations of the effects of pressure on fishes have dealt with the lethal thresholds of increasing pressure while little has been published on the effects of a reduction of pressure toward atmospheric pressure.

Tsvetkov et al. (1972) exposed both physostomous and physoclistous fishes to modeled changes in the magnitude and rates of change of hydrostatic pressure during passage through turbines. Pressures from 1-6 atmospheres were applied by air pressure to the surface of the water in order to acclimate the fish, which were allowed to adapt to neutral buoyancy. The perch (_Perca fluviatilis_), a physoclist, required 23-27 hours to acclimate to neutral buoyancy at one atmosphere, and at least 72 hours at 3 atmospheres. The physostomous fishes were unable to acclimate, when access to an air-water interface was restricted. To observe possible delayed mortalities, all surviving fish were maintained up to four days.

Swim bladder injury and gas disease were the causes of pressure-induced mortalities. Death occurred within 10 seconds to 15 minutes after rapid release from the acclimation pressure, when rupturing of the swim bladder wall occurred. In the physostomous fishes, no swim bladder damage was observed when the rate of pressure release was retarded, but rupturing of other internal organs did occur as the swim bladder expanded, compressing the other organs. Fingerlings of the roach, _Rutilus rutilus_

(L.), [a physostome] displayed 100% mortality at a pressure release rate of 3 atm/sec, 40-72% mortality at 0.1-0.5 atm/sec, and 10% mortality when the rate was below 0.1 atm/sec.

Generally, the physostomes, including the alewife and rainbow smelt, will not be adversely affected by the reduction of 0.03 atm/sec expected to occur within the rising discharge waters. In addition, it is unlikely that this rate of pressure reduction would adversely affect the physoclists.

(iii) Effects of Turbulence on Benthos

The high velocity discharge of JAF creates turbulence near the point of discharge which has disturbed bottom sediments. The analysis of the effect of scouring on benthic life, including Gammarus spp., was discussed in Chapter V.

(iv) Multiplant Effects in the Water Body Segment

Within the water body segment (defined in Chapter IV) there are seven operating generating units and one unit under construction. Oswego Units 1-4 discharge into Oswego harbor, therefore Oswego Unit 5, NMP-1, and the JAF discharges are the major sources of artificial heat into the water body segment. The contribution of heat from Oswego Units 1-4 to the Oswego River varies seasonally depending on river flow, but generally has a small effect on the temperature differential between the river and lake.

Previous analyses of the impact of the thermal component of the discharge of Oswego Units 5 and 6 and NMP-1 (see 316(a) Demonstrations for these units) have indicated that potential effects on representative species (including the same representative species discussed here) were minimal. Many of the basic considerations which limit the probability of effects discussed previously in this document were found to limit potential effects at the other discharges.

In regard to long term effects on representative species, the temperature distributions of the existing thermal plumes are fixed by design, therefore, the impact on representative species and the biological community, which is currently assessed as minimal should not change. The thermal component of the discharge does not alter the physical habitat of the lake and because heat is not retained in the lake, there is no progressive decline in water quality. These characteristics of the thermal plumes preclude the possibility of long term effects on representative important species.

REFERENCES CITED

CHAPTER VII

Baldwin, N.S. 1950. The American smelt, *Osmerus mordax* (Mitchill), of South Bay, Manitoulin Island, Lake Huron. Trans. Amer. Fish. Soc. 78(1948):176-180.

Bailey, M.M. 1964. Age, growth, maturity, and sex composition of the American smelt, *Osmerus mordax* (Mitchill), of western Lake Superior. Trans. Amer. Fish. Soc. 93(4):382-395.

Brett, J.R. 1952. Temperature tolerance in young pacific salmon, genus *Oncorhynchus*. J. Fish. Res. Bd. Canada 9:265-323.

Coutant, C.C. 1970. Biological aspects of thermal pollution. I. Entrainment and discharge canal effects. CRC Crit. Rev. Environ. Cont. 1(3):341-381.

Dendy, J.S. 1946. Food of several species of fish, Norris Reservoir, Tennessee. J. Tenn. Acad. of Sci. Vol 21, No. 1:105-127.

Environmental Protection Agency. 1973. Cooling water intake structures, a proposal regarding minimizing adverse environmental impact. Federal Register 38(239):34410-34412.

Edsall, T.A. and P.J. Colby. 1970. Temperature tolerance of young-of-year cisco *Corengonus artedii*. Trans. Am. Fish. Soc. 99:526-531.

Edsall, T.A., D.V. Rottiers and E.H. Brown. 1970. Temperature tolerance of bloater *Coregonus hoyi*. J. Fish. Res. Bd. Canada 27:2047-2052.

Fry, F.E.J., J.S. Hart, and K.F. Walker. 1946. Lethal temperature relations for a sample of young speckled trout, *Salvelinus fontinalis*. Univ. Toronto Biol. Ser. 54, Ontario Fish Res. Lab. Publ. 66:1-35.

Ginn, T.C., W.T. Waller, and G.J. Lauer. 1976. Survival and reproduction of *Gammarus* spp. (Amphipoda) following short-term exposure to elevated temperature. Chesapeake Sci. 17(1):8-14.

Gross, R.W. 1959. A study of the alewife, *Alosa pseudoharengus* (Wilson) in some New Jersey lakes, with special reference to Lake Hopatcong. M.S. Thesis, Rutgers Univ. 52p.

Hart, J.S. 1947. Lethal temeprature relations of certain fish in the Toronto region. Trans. Roy. Soc. Can., Sec. 5. 41:57-71.

REFERENCES CITED (Continued)

Hart, J.S. 1952. Geographic variation of some physiological and morphological characters in certain freshwater fish. Univ. Toronto Biol. Ser. 60, Ontario Fish Res. Lab. Publ. 72: 79p.

Hoss, D.E., W.F. Hettler, and L.C. Coston. 1973. Effects of thermal shock on larval estuarine fish - ecological implications with respect to entrainment in power plant cooling system, p. 357-371. In J.H.S. Blaxter (ed.), The early life history of fish. Proc. Int. Symp. Dunstaffnage Mar. Res. Lab., Scottish Mar. Biol. Assoc., Oban, Scotland. [Springer-Verlay, Berlin.]

Jobes, F.W. 1952. Age, growth and production of yellow perch in Lake Erie. U.S. Fish Wildl. Serv. Fish. Bull. 52:205-266.

Lawler, Matusky and Skelly Engineers. 1975. 1974 Nine Mile Point aquatic ecology studies. Prepared for Niagara Mohawk Power Corp. and Power Authority of the State of New York.

McClane, A.J. 1964. McClane's standard fishing encyclopedia. Holt, Reinhart and Winston, New York.

McKenzie, R.A. 1964. Smelt life history and fishery in the Miramichi River, New Brunswick. Fish. Res. Bd. Canada Bull. 144: 77p.

Morgan, R.P., II., et al. 1973. Effects of water movement on eggs and larvae of striped bass and white perch. Appendix XII. In Final report on hydrographic and ecological effects of enlargement of the Chesapeake and Delaware Canal. U.S. Army Corps of Engineers, Philadelphia District. Contract DACW 61-71-C-0062.

Muncy, R.J. 1962. Life history of the yellow perch, Perca flavescens, in estuarine waters of the Severn River, a tributary of Chesapeake Bay, Maryland. Chesapeake Sci. 3(3):143-159.

Nikolsky, G.V. 1963. The ecology of fishes. (Translation by L. Birkett). Academic Press, New York. 352p.

Norden, C.R. 1967. Age, growth and fecundity of the alewife, Alosa pseudoharengus (Wilson), in Lake Michigan. Tran. Amer. Fish. Soc. 96(4):387-393.

Quirk, Lawler and Matusky Engineers. 1974. 1973 Nine Mile Point aquatic ecology studies - Nine Mile Point Generating Station. Prepared for Niagara Mohawk Power Corp.

REFERENCES CITED (Continued)

Reynolds, J.B. 1965. Life history of the smallmouth bass, Micropterus dolomieui, in the Des Moines River, Boone County, Iowa. Iowa State J. Sci. 39:417-436.

Rounsefell, G.A. and L.D. Stringer. 1943. Restoration and management of the New England alewife fisheries with species reference to Maine. U.S. Fish Wildl. Serv. Fish. Leafl. 42: 33p.

Schubel, J.R., T.S.Y. Koo and C.F. Smith. 1975. Thermal effects of power plant entrainment on survival of fish eggs and larvae: a laboratory assessment. Chesapeake Bay Institute, The Johns Hopkins University and Marine Sciences Research Center, State University of New York.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Canada Bull. 184: 966p.

Seaburg, K.G. and J.B. Moyle. 1964. Feeding habits, digestive rates and growth of some Minnesota warmwater fishes. Trans. Amer. Fish. Soc. 93(3):269-285.

Sheri, A.N. and G. Power. 1969. Annulus formation on scales of white perch, Morone americana (Gmelin), in the Bay of Quinte, Lake Ontario. Trans. Amer. Fish. Soc. 98(2):322-326.

Storr, J. 1974. Nine Mile Point fish tagging program, 1974 Annual Report. Report to Niagara Mohawk Power Corporation.

Suttkus, R.D. 1955. Age and growth of a small-stream population of 'stunted' smallmouth black bass, Micropterus dolomieui dolomieui (Lacepede). N.Y. Fish Game J. 2(1):83-94.

Tsvetkov, V.I., D.S. Paulov, and V.K. Nezdoliy. 1972. Changes of hydrostatic pressure lethal to the young of some freshwater fish. J. Ichthyol. 12:307-318.

Van Oosten, J.K. 1940. The smelt, Osmerus mordax (Mitchill). Michigan Dept. Conserv. 13p. [Revised 1942.]

✓ Warren, C.E. 1971. Biology and water pollution control. W.B. Saunders Co., Philadelphia. 434p.