**AN EVALUATION OF ENVIRONMENTAL DATA
RELATING TO SELECTED NUCLEAR POWER
PLANT SITES**

THE NINE MILE POINT NUCLEAR POWER STATION SITE

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October 1976

MASTER

DIVISION OF ENVIRONMENTAL IMPACT STUDIES

ARGONNE NATIONAL LABORATORY

Argonne, Illinois

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AN EVALUATION OF ENVIRONMENTAL DATA
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PLANT SITES

THE NINE MILE POINT
NUCLEAR POWER STATION SITE
UNIT 1

by

Ishwar P. Murarka

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Preface

The Office of Regulatory Research, U. S. Nuclear Regulatory Commission, is supporting a program at the Argonne National Laboratory for the evaluation of the data collected by field studies at a number of operating nuclear power plants. The objective is to analyze data from both a disciplinary and a statistical standpoint. Each of the plants chosen is required, by the terms of the licenses granted, to conduct certain monitoring programs. Some plants are running additional programs to serve their own interests. Do such programs meet the interests of ecologists concerned with the protection of biota? What is the precision and accuracy of the results? What decisions are made on the basis of the field data and how valid are such decisions? Answers to such questions would be of great value in establishing the most cost-effective programs for future plants and redesigning the programs for existing plants.

Through the cooperation of the companies operating the plants, the staff is obtaining the data from a number of installations. As the results were compiled the Laboratory prepared an informal report such as this to present the analysis pertaining to each plant chosen. A summary and intercomparison of data, together with the Laboratory's recommendations, will be presented in one or more reports to the NRC.

This, the seventh of the informal reports, pertains to the Nine-Mile Point Nuclear Power Plant.

Other reports in this series are:

ANL/EIS-1 *The Kewaunee Nuclear Power Plant Site.*

ANL/EIS-2 *The Quad-Cities Nuclear Power Station Site.*

ANL/EIS-3 *The Duane Arnold Energy Center Site.*

ANL/EIS-4 *The Three Mile Island Nuclear Station Site.*

ANL/EIS-5 *The Zion Nuclear Power Station Site.*

ANL/EIS-6 *The Prairie Island Nuclear Generating Plant Site.*

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AN EVALUATION OF ENVIRONMENTAL DATA RELATING
TO SELECTED NUCLEAR POWER PLANT SITES

THE NINE MILE POINT NUCLEAR POWER STATION SITE-UNIT 1

Abstract

Fish impingement monitoring data for the years 1974 and 1975 pertaining to the Nine Mile Point Unit One, which began commercial operation in December 1969, were analyzed by the most practical qualitative and quantitative methods. The mathematical models used in describing the fish kill rates showed a marked improvement over the previous assumptions that fish kills (by species) can be considered as random events independent over time. However, with more accurate estimates on fish kills now available, it is still not possible to determine the significance of these fish kills. The results showed that predictions were higher than those observed.

The data acquired, method of analysis, and results obtained are presented in detail along with our recommendations and conclusions.

THE PLANT

LOCATION

The station is located on a 900-acre site in an area known as Nine Mile Point on the south shore of Lake Ontario in Oswego County, New York. The site has two reactors. Unit 1 has a net capacity of 610 MWe and Unit 2 has a net capacity of about 1100 MWe. Immediately east of Nine Mile Point (NMP) is the James A. Fitzpatrick Nuclear Power Plant owned by the Power Authority of the State of New York. Figure 1 shows the relative locations of the generating stations.

Fig. 1. Map of the Vicinity of the Nine Mile Point Nuclear Power Station. From the Applicant's Environmental Report.

The NMP site is about eight miles east of Oswego, 36 miles northwest of Syracuse and 135 miles east of Buffalo, New York.

The land area within five miles of the station is primarily rural. Much of the land was formerly farmed but is now covered with second-growth trees and other woody vegetation. Some land is farmed but there is a rapid decline in farming in this area.

The land is a relatively flat plain which rises gently from Lake Ontario to the Appalachian Uplands. The site itself is a generally flat and featureless plain. It has an elevation of 260 feet above mean sea level (MSL) rising to 310 feet above MSL one mile away at its southern extremity.

PLANT FEATURES AND INTERACTION WITH THE ENVIRONMENT

The station uses once-through cooling to dissipate waste heat from the main condensers and auxiliary cooling systems. The circulating water for the station Unit 1 is drawn from Lake Ontario into a submerged inlet, circulated through the condensers and returned to the lake through a submerged discharge structure. At maximum power output for Unit 1, there is a total flow of 268,000 gpm composed of 250,000 gpm for the main condenser and 18,000 gpm for service-water. A maximum cooling water temperature rise of 32°F, corresponding to a heat rejection rate of 4.0×10^9 Btu/hr, is expected.

Cooling water is taken from the lake about 850 feet from the shoreline into a hexagonal intake structure located at a water depth of approximately 18 ft. The six water inlets located in the lake are each 5 ft high by 10 ft

long. Figures 2-5 show the schematics of the intake-discharge locations and structural details.

The discharge tunnel, ten feet in diameter and about 78 square feet in cross-section takes the heated water from the screenwell to the discharge structure located about 335 ft offshore.

From the intake structure the water flows at 8 fps maximum velocity. Two circulating pumps (total capacity 250,000 gpm) take the water through trash racks and traveling screens and thence to the condenser at a velocity up to 0.85 fps maximum. The discharge tunnel flow velocity is also about 8 fps maximum.

OPERATING HISTORY

Nine Mile Point Unit 1 attained initial criticality on September 5, 1969, but did not start commercial operation until December, 1969. Since the plant began commercial power production, daily power generation levels have been reported to the U. S. Nuclear Regulatory Commission (NRC), formerly the Atomic Energy Commission. The data for Unit 1 for the years 1974 and 1975 (obtained from the NRC gray book) are plotted in Figure 6. It is evident that the daily power generation fluctuates over the full range from zero output to the maximum level of 610 MWe (net).

This operating characteristic influences the environmental measurements and the determination of changes in the biota, water chemistry, and thermal regime in the vicinity of the station.

Fig. 2. Plan of Intake and Discharge Structure Locations.

ALL ELEVATIONS ARE REFERENCED TO USLS 1935 DATUM

Fig. 3. Intake and Discharge Structures.

Fig. 4. Diagram of the Screenwell.

INTAKE TUNNEL (LOOKING EAST)

DISCHARGE TUNNEL (LOOKING EAST)

SECTION 1-1

0 5 10
SCALE - FEET

SECTION 2-2

0 5 10
SCALE - FEET

NOTES:

ALL ELEVATIONS ARE REFERENCED TO USLS 1935 DATUM

0 100 200
SCALE - FEET
EXCEPT WHERE SHOWN

Fig. 5. Profile of the Circulating-Water System.

Fig. 6. Daily Power Generation by Nine Mile Point Unit 1, 1974-1975.

AQUATIC ASSESSMENT

POTENTIAL AND PREDICTED IMPACTS

One of the most visible effects of power plant operation is the observed fish kills due to impingement at the cooling water intakes. Fish losses of various species in varying quantities are assumed to have an effect on the fisheries of the water body. The nature and extent of the fish losses and the resultant stress on the fisheries are not well understood. The effects are variable from one aquatic system to another, and a generalized conclusion defining fish kills per se, and relating them to a particular effect on the local fisheries is very difficult. Case by case analysis and conclusions might be needed to determine the effect of impingement on the fisheries of the region. There is a potential ecological impact in a long-term period. The number of fish kills during any short period is insignificant, except as it relates to the dynamics of the fish populations in the natural water body.

At the time of final environmental impact statement writing, data collected by the applicant were available for the period May, 1972, to June, 1973, for a total of 32 sampling days. Inasmuch as the sampling design for data collection was not considered satisfactory, a gross approximation was made about the annual fish kill at the Nine Mile Point 1 site. On the basis of available data it was observed that the fish kills at the Nine Mile Point 1 intake are dominated by large numbers of alewives collected during spring. Disregarding the peak alewife mortality during spring, it was estimated that roughly one million fish of other species would have been killed at the NMP-1 site. Inclusion of the alewives increased the estimate to between 2 to 4 million fish a year.

An elaborate discussion in the FES essentially ascertained that no interpretation of the effect of these fish kills on the ecology can be made without substantial years of ecological data. It was, however, concluded that the fish kills at NMP 1 are considered undesirable and might act to lower the threshold value, thus diminishing the margin for future developments of the lake. The staff required that the applicant collect fish impingement data three times per week and continue a comprehensive ecological survey program. An evaluation after June, 1975, is to be made by the staff to determine if significant fish mortality occurs at NMP 1 and if there will be a need for modification of existing intakes or development and implementation of other preventive methods or a combination of both.

OBSERVED FISH IMPINGEMENT

Fish impingement monitoring at a frequency of three times a week was done at the Nine Mile Point 1 during the years 1974 and 1975, in accordance with the NRC staff requirements. Some data were also collected during 1972 and 1973. However, the 1974-1975 data were more complete and were utilized in this evaluation. Data on intake water temperature and intake water flow rates corresponding to available impingement dates were also obtained. Throughout the monitoring period fish kills of various species have been observed. We selected alewives, rainbow smelt and total daily impingement values for our examination in this study. The two selected species account for most of the fish killed at NMP 1. Figures 7-9 show the observed daily fish kills for the period 1974-75. In these figures, natural logarithmic transformation of the impingement rates is plotted against time. Table 1 shows the fish impingement and plant environmental variables data for 1974 and 1975 which were used in this analysis.

Fig. 7. Plot of Total Fish Impingement for the Years 1974-1975 for NMP Unit 1.

Fig. 8. Plot of Alewife Impingement for the Years 1974-1975 for NMP Unit 1.

Fig. 9. Plot of Rainbow Smelt Impingement for the Years 1974-1975 for NMP Unit 1.

Table 1. Fish Impingement and Plant Environmental Data
for NMP, Unit 1, 1974-1975

MONTH	DAY	YEAR	TOTIMP	ALEWIFE	SMELT	INTEMP	INFLOW
1	2	74	1817	92	1573	33.96	250
1	7	74	500	66	122	31.98	250
1	9	74	738	21	652	32.72	250
1	11	74	224	13	177	33.88	250
1	14	74	576	41	343	35.53	250
1	16	74	465	9	335	32.87	250
1	18	74	46	10	14	35.39	250
1	21	74	69	6	40	37.92	250
1	23	74	235	3	164	36.93	250
1	25	74	131	1	60	35.90	250
1	28	74	378	2	147	35.55	250
1	30	74	417	41	270	38.59	250
2	1	74	504	59	214	36.16	250
2	4	74	435	30	109	31.91	250
2	6	74	125	2	88	35.78	250
2	8	74	223	6	106	37.26	250
2	11	74	663	42	258	32.53	250
2	13	74	711	2	523	33.93	250
2	15	74	493	7	325	32.08	250
2	18	74	280	2	118	32.40	250
2	20	74	313	2	160	32.73	250
2	22	74	1082	13	330	33.42	250
2	25	74	539	1	193	32.93	250
2	27	74	1690	1	1098	33.40	250
3	1	74	1349	1	624	32.93	250
3	4	74	339	3	167	37.61	250
3	6	74	248	12	107	38.58	250
3	8	74	203	29	81	35.78	250
3	11	74	545	153	159	35.94	250
3	13	74	469	94	142	35.06	250
3	15	74	277	32	123	35.01	250
3	18	74	2293	46	825	32.86	250
3	20	74	1108	12	342	33.28	250
3	22	74	2888	12	817	33.31	250
3	25	74	3293	21	1355	33.57	250
3	27	74	2763	1	1382	32.61	250
3	29	74	994	20	592	32.38	250
4	2	74	2777	70	1299	37.40	250
4	4	74	1525	259	990	40.00	250
4	6	74	596	68	439	40.10	250
4	9	74	2622	1782	670	39.40	250
4	11	74	4850	3752	744	39.60	250
4	16	74	3999	2563	935	45.80	125
4	18	74	7996	7372	433	48.50	125
4	20	74	6897	5743	889	42.70	125
4	23	74	1804	1641	133	46.60	125
4	25	74	11301	10303	788	44.10	125
4	27	74	20532	19816	556	47.30	125
4	28	74	4788	4524	209	46.20	125
4	30	74	6370	5931	337	47.50	125
5	2	74	19794	17559	1757	47.70	250
5	3	74	2971	2829	108	44.10	250
5	4	74	8811	8521	207	47.60	250
5	7	74	18706	18244	352	46.50	250
5	8	74	279735	276060	3431	49.90	250

Table 1. Continued

MONTH	DAY	YEAR	TOTIMP	ALEWIFE	SMELT	INTEMP	INFLOW
5	9	74	30052	27646	2206	47.8	250
5	10	74	6768	6162	587	44.2	250
5	11	74	9989	9334	610	48.5	250
5	14	74	131880	130931	860	47.0	250
5	15	74	55373	54714	520	48.6	180
5	16	74	4944	4722	158	50.8	125
5	17	74	10386	10000	336	51.2	125
5	18	74	59084	57242	1244	49.5	180
5	19	74	22226	21696	294	47.0	250
5	21	74	19116	18500	526	48.7	125
5	23	74	6598	6092	274	56.5	250
5	25	74	21106	20346	332	54.9	250
5	26	74	12684	11982	182	54.7	180
5	28	74	7096	6864	128	53.9	250
5	30	74	33188	32664	220	54.2	250
5	31	74	18494	17908	300	55.4	250
6	1	74	8166	8054	66	53.1	250
6	4	74	5112	4950	112	54.3	250
6	6	74	7612	7476	90	54.1	250
6	8	74	6578	6524	31	48.9	250
6	11	74	3228	3156	49	59.1	250
6	13	74	5094	4635	234	57.1	250
6	15	74	14496	14112	255	53.2	250
6	18	74	5860	5684	72	57.8	250
6	20	74	4497	4277	94	60.1	250
6	22	74	3353	3229	86	59.3	250
6	25	74	6672	6492	83	56.4	250
6	27	74	4254	4041	121	58.5	250
6	29	74	2447	2291	106	50.7	250
7	2	74	5827	5750	45	61.7	250
7	4	74	3644	3524	56	65.3	250
7	6	74	7369	7122	33	66.8	250
7	9	74	7622	7460	9	68.1	250
7	11	74	8061	7404	17	70.5	250
7	13	74	9445	9338	5	68.7	250
7	16	74	8261	8158	1	70.7	250
7	18	74	5789	5743	3	71.7	250
7	20	74	5355	5163	2	71.3	250
7	23	74	1535	1520	1	71.1	250
7	25	74	909	899	1	69.6	250
7	27	74	1156	1134	1	68.8	250
7	30	74	1896	1869	13	68.8	250
8	1	74	2381	2362	2	70.0	250
8	3	74	1657	1652	1	67.2	250
8	6	74	3092	3067	2	68.4	250
8	8	74	669	656	1	69.0	250
8	10	74	680	659	1	65.7	250
8	13	74	21772	21746	15	67.8	250
8	14	74	10164	10152	1	69.6	250
8	15	74	18258	18203	17	57.4	250
8	16	74	34044	33933	99	55.3	250
8	17	74	15842	15831	7	66.8	250
8	20	74	8959	8956	1	70.1	250
8	22	74	7409	7409	1	70.6	250
8	24	74	5762	5760	1	72.4	250

Table 1. Continued

MONTH	DAY	YEAR	TOTIMP	ALEWIFE	SMELT	INTEMP	INFLOW
8	27	74	2955	2950	1	72.2	250
8	29	74	1043	1037	1	72.6	250
8	31	74	610	602	2	71.8	250
9	3	74	637	620	1	70.2	250
9	5	74	1811	1728	54	52.5	250
9	7	74	5453	5444	6	58.1	250
9	10	74	2709	2702	1	66.7	250
9	12	74	2555	2548	1	68.5	250
9	14	74	10287	9954	2	67.8	250
9	17	74	1651	1623	9	66.5	250
9	19	74	1019	962	42	65.9	250
9	21	74	982	973	2	65.8	250
9	24	74	570	562	1	63.7	250
9	26	74	549	543	2	63.2	250
9	28	74	641	635	5	62.4	250
10	1	74	2468	1267	155	60.4	250
10	3	74	632	534	7	58.3	250
10	5	74	514	475	8	57.8	250
10	8	74	880	846	7	57.5	250
10	10	74	1626	1604	16	56.3	250
10	12	74	693	650	21	54.8	250
10	15	74	468	451	3	50.6	250
10	17	74	950	914	8	53.3	250
10	19	74	655	619	10	51.8	250
10	22	74	536	508	11	50.6	250
10	24	74	1025	996	9	51.6	250
10	26	74	871	846	12	51.1	250
10	29	74	1032	1010	11	49.5	250
10	31	74	988	973	4	49.7	250
11	1	74	1012	1001	2	49.6	250
11	4	74	535	521	8	49.2	250
11	6	74	692	673	17	48.4	250
11	8	74	632	615	13	48.0	250
11	11	74	987	981	3	47.6	250
11	13	74	579	566	7	46.6	250
11	15	74	5470	5349	56	43.5	250
11	18	74	635	596	22	44.4	250
11	20	74	883	855	13	44.8	250
11	22	74	585	536	25	43.8	250
11	25	74	665	642	8	43.6	250
11	27	74	781	763	12	43.3	250
11	29	74	68	66	1	42.2	224
12	2	74	6855	6741	21	41.1	250
12	4	74	208	192	7	40.6	250
12	6	74	344	267	44	38.1	250
12	9	74	6253	5856	128	34.1	250
12	11	74	763	360	289	37.7	250
12	13	74	2293	2172	92	38.4	250
12	16	74	384	310	49	37.4	250
12	18	74	4671	4095	364	33.9	250
12	20	74	3271	3163	61	35.9	250
12	23	74	3632	3394	166	34.8	250
12	25	74	1042	886	141	34.9	250
12	27	74	797	614	150	34.0	250
12	30	74	557	234	258	33.2	250

Table 1. Continued

MONTH	DAY	YEAR	TOTIMP	ALEWIFE	SMELT	INTEMP	INFLOW
1	1	75	273	88	145	36.3	250
1	3	75	456	213	222	35.3	250
1	6	75	674	300	356	35.7	250
1	8	75	865	636	158	38.6	250
1	10	75	1037	847	163	34.6	250
1	13	75	1405	876	298	32.7	250
1	15	75	837	109	481	31.8	250
1	17	75	451	94	260	37.0	250
1	20	75	244	13	190	34.6	250
1	22	75	328	39	258	32.8	250
1	24	75	196	16	137	37.0	250
1	27	75	384	9	295	32.1	250
1	29	75	205	12	86	32.9	250
1	31	75	528	6	227	32.8	250
2	3	75	459	1	264	30.6	250
2	5	75	234	45	157	32.0	250
2	7	75	508	5	261	29.6	250
2	10	75	476	3	251	31.4	250
2	12	75	286	11	177	31.7	250
2	14	75	673	14	166	31.1	250
2	17	75	162	15	69	37.7	250
2	19	75	447	4	160	31.0	250
2	21	75	119	25	30	34.2	250
2	24	75	268	100	107	36.1	250
2	26	75	584	7	199	32.4	250
2	28	75	2792	518	905	32.0	250
3	3	75	1310	32	363	30.2	250
3	5	75	1383	78	419	32.2	250
3	7	75	857	25	255	31.1	250
3	10	75	4570	105	702	31.1	250
3	12	75	978	376	206	36.6	250
3	14	75	351	77	137	33.8	250
3	17	75	483	145	217	37.4	250
3	19	75	322	169	95	36.7	250
3	21	75	523	289	149	37.6	250
3	24	75	1176	892	120	39.0	250
3	26	75	3064	1333	481	36.4	250
3	28	75	1059	724	136	40.2	250
3	31	75	1334	941	158	34.5	250
4	2	75	3014	1072	583	35.4	250
4	4	75	1274	318	474	34.2	250
4	7	75	2976	463	1118	34.1	250
4	9	75	4006	966	1553	34.4	250
4	11	75	5395	845	1638	34.6	250
4	14	75	7244	1454	1409	37.6	250
4	16	75	3147	1494	698	37.8	250
4	18	75	5658	3633	400	40.7	250
4	21	75	32650	19904	4185	42.1	250
4	22	75	53024	33352	3191	42.6	250
4	23	75	23108	21086	933	42.7	250
4	24	75	21660	20439	610	42.4	250
4	25	75	32365	31803	610	44.4	250
4	26	75	23371	20604	904	46.7	250
4	27	75	26164	24167	1283	44.7	250
4	28	75	19958	19014	689	43.7	250

Table 1.. Continued

MONTH	DAY	YEAR	TOTIMP	ALEWIFE	SMELT	INTEMP	INFLOW
4	30	75	6181	5565	406	42.7	250
5	2	75	9645	9206	257	45.2	250
5	5	75	11041	10503	229	43.0	250
5	7	75	3448	3187	143	42.6	250
5	9	75	17075	16437	264	46.0	250
5	12	75	19071	18677	248	47.1	250
5	14	75	12581	12243	206	48.5	250
5	16	75	17246	16938	157	48.0	250
5	19	75	11721	11497	108	52.0	250
5	21	75	5555	5312	93	52.6	250
5	23	75	7203	6989	102	56.5	250
5	26	75	3076	2972	47	51.5	250
5	28	75	3698	3418	47	52.5	250
5	30	75	9854	9714	36	54.8	250
6	2	75	2488	2366	20	56.1	250
6	4	75	1835	1735	25	56.5	250
6	6	75	3126	3066	21	56.3	250
6	9	75	3253	3186	25	57.0	250
6	11	75	2789	2755	11	54.7	250
6	13	75	4470	4411	16	59.0	250
6	16	75	1770	1749	1	58.7	250
6	18	75	2147	2121	5	60.0	250
6	20	75	1258	1252	0	60.2	250
6	23	75	1143	1119	0	65.2	250
6	25	75	1908	1872	14	61.5	250
6	27	75	1394	1378	4	62.4	250
6	30	75	1004	797	137	44.7	250
7	2	75	2391	2155	180	60.2	250
7	4	75	1483	1456	3	72.0	250
7	7	75	641	620	0	73.2	250
7	9	75	736	694	0	74.1	250
7	11	75	313	283	0	72.8	250
7	14	75	39	19	0	73.5	250
7	16	75	43	21	0	72.9	250
7	18	75	22	13	0	73.9	250
7	21	75	42	25	0	75.2	250
7	23	75	8	4	0	74.6	250
7	25	75	133	45	1	73.2	250
7	28	75	49	32	1	72.9	250
7	30	75	31	18	0	73.9	250
8	8	75	31	11	0	49.6	250
8	11	75	7	7	0	71.7	250
8	13	75	193	20	162	72.6	250
8	15	75	18	11	0	71.9	250
8	18	75	19	17	0	71.9	250
8	20	75	20	15	0	71.4	250
8	22	75	12	10	0	71.0	250
8	25	75	6	5	0	73.2	250
8	27	75	88	74	0	73.7	250
8	29	75	2		0	71.4	250
9	1	75	208	142	22	50.1	250
9	3	75	205	49	78	56.3	250
9	5	75	17	8	3	64.5	250
9	8	75	18	10	1	62.3	250
9	10	75	11	5	0	63.8	250

Table 1. Continued

MONTH	DAY	YEAR	TOTIMP	ALEWIPE	SMELT	INTEMP	INFLOW
9	12	75	5	3	0	63.5	250
9	15	75	9	2	0	62.2	250
9	17	75	16	8	3	62.6	250
9	19	75	0		0	61.3	250
9	22	75	14	10	0	61.6	250
9	24	75	11	9	0	62.7	250
9	26	75	13	12	0	61.3	250
9	29	75	27	18	3	58.9	250
10	1	75	75	24	16	60.4	250
10	3	75	62	11	7	59.0	250
10	6	75	42	9	2	59.4	250
10	8	75	69	55	8	58.2	250
10	10	75	18	12	1	56.0	250
10	13	75	9	6	1	58.6	250
10	15	75	12	8	0	58.3	250
10	17	75	37	27	1	57.5	250
10	20	75	38	26	1	55.1	250
10	22	75	19	17	0	58.6	250
10	24	75	20	17	1	54.9	250
10	27	75	11	9	0	55.4	250
10	29	75	4	2	1	55.9	250
10	31	75	23	16	1	52.1	250
11	3	75	13	8	0	56.8	250
11	5	75	16	13	3	56.7	250
11	7	75	25	21	2	54.8	250
11	10	75	2114	813	3	53.2	250
11	12	75	119	60	27	53.7	250
11	14	75	107	29	22	50.8	250
11	17	75	450	351	6	50.8	250
11	19	75	261	235	4	51.7	250
11	21	75	632	571	1	48.7	250
11	24	75	43	23	8	49.8	250
11	25	75	12	7	3	48.4	250
11	28	75	28	12	7	48.0	250
12	1	75	1868	1352	101	47.2	250
12	3	75	389	252	62	45.0	250
12	5	75	135	94	14	46.0	250
12	8	75	168	109	16	43.6	250
12	10	75	148	104	5	43.3	250
12	12	75	417	372	20	43.4	250
12	15	75	129	100	7	41.9	250
12	17	75	735	495	6	40.8	250
12	19	75	368	332	17	37.9	250
12	22	75	172	155	10	38.3	250
12	23	75	100	84	9	39.9	250
12	26	75	108	62	16	38.9	250
12	29	75	75	21	6	39.0	250
12	30	75	61	20	26	39.9	250

Like the Lake Michigan plants, NMP 1 on Lake Ontario shows that alewives and rainbow smelt are the most dominating species impinged. In examining the plots of these two species and the total impingement rates at NMP 1 (Figs. 7-9), we can see that there is a distinct seasonality in the dominant fish kills. The alewife impingement rate rises in spring, starting in March and rapidly reaches a high impingement rate by the end of April. A very gradual and slow decline follows during the summer and fall before reaching to a minimum (or no impingement) in winter. The pattern of alewife fish kills differs for the two years examined. Even though the first half of each calendar year shows almost identical fish impingement rates, the second half is quite different. For the year 1975, rapid decline to essentially no alewife impingement is found as early as August, and practically no alewife impingements were found in the following three or so months.

The rainbow smelt fish impingement rate curves for 1974 and 1975 are the same. However, the total impingement rate curve, which is weighted in dominance by the alewife impingements, shows the characteristic of the difference in behavior for the two years (i.e. 1974 and 1975).

There are two likely explanations for the differences in the observed alewife impingement rate patterns for the years 1974 and 1975. During the second half of the year 1975, the neighboring plant, James Fitzpatrick, started commercial operation. The additional nuclear power plant may have cropped some of the fish in the area and thus may have reduced the number of fish available for impingement at NMP 1. The operation of other power plants in the area may also have reduced the local fish abundance and thereby decreased fish impingement at NMP 1. Unavailability (to the author) of fish impingement data from the

other plants in the locality rendered it impossible to make a comprehensive analysis on the nature and extent of environmental impact from fish kills at NMP 1.

The 1974 and 1975 fish impingement data were analyzed statistically. On the basis of graphical analysis and statistical pattern recognition, it can be said that the daily impingement rate is a time-dependent function, and the parameters can be estimated from the data. However, it is apparent that an annual mean value is not a proper statistic to represent the time-dependent function of a variable such as fish impingement. Instead, the species-specific impingement rate function may be represented by three linear segments which may represent the expected impingement rates for a yearly cycle.

In the statistical analysis, multiple regressions were carried out by using cubic order variables in time and quadratic order variables in temperature as the independent variables, and logarithmically transformed impingement values for alewife and smelt as the dependent variables. The selection of independent variables for the multiple regression was made after a careful study of several other regression models. Because of near constant flow rate as a function of time, this independent variable was not used in the regression model. Table 2 gives the result of various regressions fitted to the 1974 and 1975 fish impingement data collected at NMP 1.

A study of the regressions reveals that the 1974 and 1975 impingement rates are nearly the same for rainbow smelt but different for the alewife species. The estimated impingements on the total yearly numbers of alewives, smelts, and all species combined are given in Table 3. One can see that the observed fish

Table 2. Regression Analysis Results for Alewife and Rainbow Smelt Impingements at Nine Mile Point Unit 1

For Alewife Impingement				R ²
Model I	$y = -6.2899 + 0.15072 * \text{Time} - 0.001138 * \text{Time}^2 + 0.00000234 * \text{Time}^3$ (3.29) ^b (0.016) (0.000085) (0.00000019) + 0.37446 * Temperature - 0.003473 * Temperature ² (0.1295) (0.00101) (for 1974 year, n = 165)			0.808
Model II	$y = -15.3807 + 0.0974 * \text{Time} - 0.001208 * \text{Time}^2 + 0.00000304 * \text{Time}^3$ (2.8767) (0.0156) (0.0000899) (0.00000002) + 0.8402 * Temperature - 0.0074 * Temperature ² (0.11568) (0.00092) (for 1975 year, n = 158)			0.771
Model III	$y = -2.2827 + 0.1703 * \text{Time} - 0.0013 * \text{Time}^2 + 0.00000259 * \text{Time}^3$ (2.97) (0.0159) (0.000093) (0.00000021) + 0.2800 * Temperature - 0.003448 * Temperature ² (0.11868) (0.000953) (for 1974 and 1975 years, n = 323)			0.543
For Smelt Impingement				
Model IV	$y = 7.7393 + 0.0710 * \text{Time} - 0.00064 * \text{Time}^2 + 0.00000135 * \text{Time}^3$ (2.4883) (0.0124) (0.000064) (0.00000014) - 0.03165 * Temperature - 0.00102 * Temperature ² (0.0978) (0.00076) (for the year 1974, n = 165)			0.811
Model V	$y = 8.5555 + 0.0443 * \text{Time} - 0.000418 * \text{Time}^2 + 0.00000085 * \text{Time}^3$ (2.3786) (0.01287) (0.0000744) (0.00000016) - 0.0641 * Temperature - 0.00077 * Temperature ² (0.0956) (0.00076) (for the year 1975, n = 158)			0.815
Model VI	$y = 9.2469 + 0.0659 * \text{Time} - 0.000555 * \text{Time}^2 + 0.00000108 * \text{Time}^3$ (1.64) (0.0088) (0.000051) (0.00000012) - 0.0883 * Temperature - 0.000673 * Temperature ² (0.0656) (0.00053) (for the years 1974 and 1975, n = 323)			0.789

^ay = Natural logarithmic value of alewife or rainbow smelt impingement observations.

^bParenthetical quantity is the standard error of the coefficient.

Table 3. Estimated Fish Kills for the Years 1974
and 1975 Based on the Monitored Data

	1974	1975
<u>Method 1</u> (Integrated value with linear interpolation for days between successive observations)		
Alewife	1,884,507	674,941
Smelt	82,509	65,235
Other species	65,063	119,980
All species		
Total	2,032,080	860,157
<u>Method 2</u> (mean value $\times$ 365)		
Alewife	2,612,876	882,551
Smelt	91,345	76,830
Other species	62,727	147,880
All species		
Total	2,766,948	1,107,262

kills are substantially less than the predictions in the FES (a difference of a magnitude or more for other species). If a mean value rate model is assumed and fish kills are recalculated, the estimated observed fish kills are about the same as those predicted in the FES. The results are shown in Table 3.

From this analysis, it is apparent that the estimation and prediction methods need to be properly developed. The sampling requirements will accordingly be reduced with gains in precision and cost effectiveness of the monitoring schemes.

Of all the models fitted, the best results are obtained by fitting the same structural model to the 1974 and 1975 data separately in the case of alewives. We have plotted the fitted (expected) value curves in Figures 10-17 along with the data scatter around the regression lines for alewife and rainbow smelt species. Examination of the coefficients (shown in Table 2) shows the stability and consistency of the results. The linear parts show that there is an overall increasing trend in fish impingement rates within a year. This trend is modified by a strong quadratic part and is further changed by a statistically significant cubic part. The effects of temperature, linear and quadratic portions, are statistically significant only when the time variables are already in the regression model. The amount of variation accounted for by the fitted model is about 81%. Residuals from the fitted models appear to meet the assumptions on the error term. Some autocorrelation still appears to be present in the residuals and may require additional considerations.

Even though an apparently satisfactory regression model has been found, there are a number of deficiencies in this model. This model should be considered

Fig. 10. Observed Values of Alewife Impingement and Plot of Expected Values Obtained by Use of Model I.

Fig. 11. Observed Values of Alewife Impingement and Plot of Expected Values Obtained by Use of Model II.

Fig. 12. Observed Values of Alewife Impingement and Plot of Expected Values Obtained by Use of Model III.

Fig. 13. Observed Values of Alewife Impingement and Plot of Expected Values by Use of Model I for 1974 and Model II for 1975.

Fig. 14. Observed Values of Smelt Impingement and Plot of Expected Values Obtained by Use of Model IV.

Fig. 15. Observed Values of Smelt Impingement and Plot of Expected Values Obtained by Use of Model V.

Fig. 16. Observed Values of Smelt Impingement and Plot of Expected Values Obtained by Use of Model VI.

Fig. 17. Observed Values of Smelt Impingement and Plot of Expected Values Obtained by Use of Model IV for 1974 and Model V for 1975.

only the beginning of an effort which will probably give rise to a final satisfactory methodology.

CRITIQUE, CONCLUSIONS AND RECOMMENDATIONS

The fish impingement studies are conducted at various cooling water intakes on the Great Lakes. The main objective of such studies is to provide an estimate of fish killed at the screening structures. Incidental to these studies is the important information on various aspects of fish and fisheries of the waters concerned. It is important to determine the impact of fish kills so that the environment may be protected from undue abuses.

The fish impingement as a function of time can be estimated and the estimate can be modified according to the environmental and plant-operating conditions if proper data are collected. Complete records of all daily observations are not needed. A high precision estimate can be obtained through the use of statistically sound sampling schemes. Adequate sampling frequency will vary from site to site because of the differences in the site-specific, time-dependent, fish impingement rate functions. As soon as the deterministic part is functionally represented and the residual values are defined, a sample size determination can be made. The theory and implementation of these methods are undertaken at this laboratory. The sampling designs, estimation methods, and the associated computer software will be made available upon completion of the work.

On the basis of this study, the following conclusions, specific to the Nine Mile Point 1 site, can be drawn:

(1) Impingement predictions made in FES are quite different from those observed. It is quite likely that the state-of-the-art at that time was such that accurate predictions were not possible.

(2) Now, with the available ecological and fish impingement data for NMP 1, it is still not possible to determine the ecological significance of these fish kills. The major reason for this inability seems to be a lack of knowledge as to what constitutes a significant impact.

(3) The lake-wide fisheries are very large and are subjected to a variety of pollution pressures due to the presence of multiple industrial plants using the lake waters. Our restricted ability in estimating fish populations of the lake precludes the use of data related to impingement losses at NMP-1 (locally and regionally) as a means of determining significant effect. Much research work is needed in the development of mathematical models and other criteria which can be utilized to determine the significance of fish kills. Some work is in progress at Argonne to obtain solutions which would provide a basis for determining the significance of fish kills.

(4) The sampling scheme currently in use appears to be ad-hoc and arbitrary. There is no defined approach to make use of data for the determination of significance of the fish kills at NMP 1. As mentioned earlier, we are working out the statistical details to make the process of sample size determination theoretically sound and practical.