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DETERMINATION OF COMPLIANCE WITH PL 92-500 SECTION 316(b) FOR THE DONALD C. COOK NUCLEAR POWER PLANT OF THE INDIANA AND MICHIGAN POWER COMPANY

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Argonne, Illinois

for

U. S. Fish and Wildlife Service
Region III
Twin Cities, Minnesota

April 1980

DISCLAIMER

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by

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ABSTRACT

Region III of the U.S. Fish and Wildlife Service contracted with the Division of Environmental Impact Studies, Argonne National Laboratory, to make the 316(b) determination for the Donald C. Cook Nuclear Power Plant of the Indiana and Michigan Power Company and to make recommendations for improvement in intake design to facilitate compliance. To conduct this assessment, appropriate literature on screening systems and reports furnished by the applicant on intake design and operation and on ecological studies at the site were reviewed. Modifications of the location and design of the existing intake and possibilities of retrofitting with fine-mesh screening to screen larval forms of fishes were examined. It was determined that currently there is no dictated need for fine-mesh screening of intake flow at the D.C. Cook Nuclear Power Plant. Recommendations were made for generic demonstration studies for engineering feasibility and biological effectiveness of various fine-mesh screening options as a coordinated effort among industry and interested state and federal agencies. These demonstration studies would be intended to advance the state-of-the-art such that various options may be implemented should the need for fine-mesh screening become apparent in the future.

CONTENTS

FIGURES

TABLES

Determination of Compliance with PL 92-500 Section 316(b) for the Donald C. Cook Nuclear Power Plant of the Indiana and Michigan Power Company

INTRODUCTION

It is required in Section 316(b) of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) that "the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impacts." The U.S. Environmental Protection Agency (USEPA) is charged with the responsibility of ensuring compliance with the provisions of PL 92-500, and under Section 402 of the same Act, the USEPA can delegate assessment authority to appropriate state agencies, with the regional USEPA Administrator still retaining the power to veto the state findings.

The Fish and Wildlife Service of the U.S. Department of the Interior also has a vested interest in the enforcement of Section 316(b) because of the agency's responsibility to protect the country's fish and wildlife resources. The agency can conduct its own independent assessment of compliance with Section 316(b) and make recommendations to the USEPA and/or other agencies for appropriate action for compliance. Such an assessment does not in any way obviate need for a 316(b) determination by the USEPA or by state agencies to which assessment authority has been delegated.

Region III of the Fish and Wildlife Service has chosen to make such an independent 316(b) determination relative to the cooling-water intake of the Donald C. (D.C.) Cook Nuclear Power Plant of the Indiana and Michigan Power Company. The agency contracted with the Division of Environmental Impact Studies, Argonne National Laboratory, to make the 316(b) determination for the plant and to make recommendations for improvements in intake design to facilitate compliance.

There is no uniform procedure for determining compliance with Section 316(b) for operating power plants. An applicant seeks 316(b) compliance approval (1) on an ecological basis by contending that no significant damage to fish and other important aquatic biota has occurred or will occur from continued operation, (2) on an engineering basis by contending that no water-intake screening system better than the one in operation can be installed at the site, or (3) on the basis that any modification of the existing screening structures will not be cost-effective (i.e., the cost of modifications will significantly outweigh the benefits to be derived by increased protection of impacted biota). The applicant submits a report to USEPA (or the designated state agency) containing information on intake design, ecological monitoring programs, fish impingement data, and a discussion of various water-screening procedures considered for use at the plant. In the case of the D.C. Cook plant, the applicant's report was submitted to the State of Michigan and was made available to the Fish and Wildlife Service and to the Argonne National Laboratory.

The judgments made by the applicant or the regulatory agencies regarding potential ecological damage and best available technology for screening of cooling water at a site are largely subjective. The ecological processes are often little understood, and any predictions as to what levels of impact could lead to significant changes in the ecosystem have very wide margins of error. Therefore, a concensus on determination of the significance of various levels of ecological impact does not exist. Also, there is no clear choice of an intake-screening system that can alleviate or minimize impacts on aquatic biota at all sites. The geological and hydrological features of sites vary, and screening methods suitable for one location may not be suitable for another. Judgment varies even among experts as to what is or is not a suitable intake design for a given site. For the new screening technologies being developed, there is no adequate operating experience to justify any strong recommendation for their deployment.

The important variables that affect fish impingement or larval entrainment are the density and distribution of fish and larvae in the general vicinity of the intake structure. If large numbers of organisms are present in the vicinity of the intake, a correspondingly large number may be impinged or entrained by a given type of screening system. Conversely, where fish density is low in the general vicinity of the intake, fewer fish will be expected to be impinged or entrained by the same screening system. Therefore, the number of fish impinged or larvae entrained does not necessarily provide a suitable basis for assessment of the effectiveness of a screening system.

The approach taken here for determining a suitable intake design for the D.C. Cook plant relies on assessment of the favorable and unfavorable characteristics of intakes in reference to the site. The present intake system has been evaluated and recommendations for modifications have been made on the basis of engineering feasibility and protection of biota. The main objective has been to determine whether the present intake can be modified to reduce entrainment and impingement losses at the plant.

To conduct this assessment, we* reviewed (1) appropriate literature on screening systems,[1-3] (2) the reports submitted by the applicant as part of its 316(b) demonstration,[4-6] and (3) annual progress reports on ecological studies conducted by the applicant, as summarized in the applicant's 1978 Annual Report.[7] In addition, we met with representatives of USEPA (Region V), U.S. Fish and Wildlife Service (Region III and the National Power Plant Team), State of Michigan (Department of Natural Resources), applicant (Indiana and Michigan Power Company and American Electric Power), and the applicant's consultant (University of Michigan, Great Lakes Research Division). We also visited the D.C. Cook Nuclear Power Plant to observe the operation of the existing intake.

SITE CHARACTERISTICS

The D.C. Cook plant occupies a 650-acre site in Lake Township, Berrien County, Michigan, on the eastern shore of Lake Michigan (Fig. 1). It is about two miles northeast of Bridgman, Michigan.[7] The site includes 4350 feet

*Throughout this document, "we" refers to the Argonne National Laboratory scientists who prepared this report.

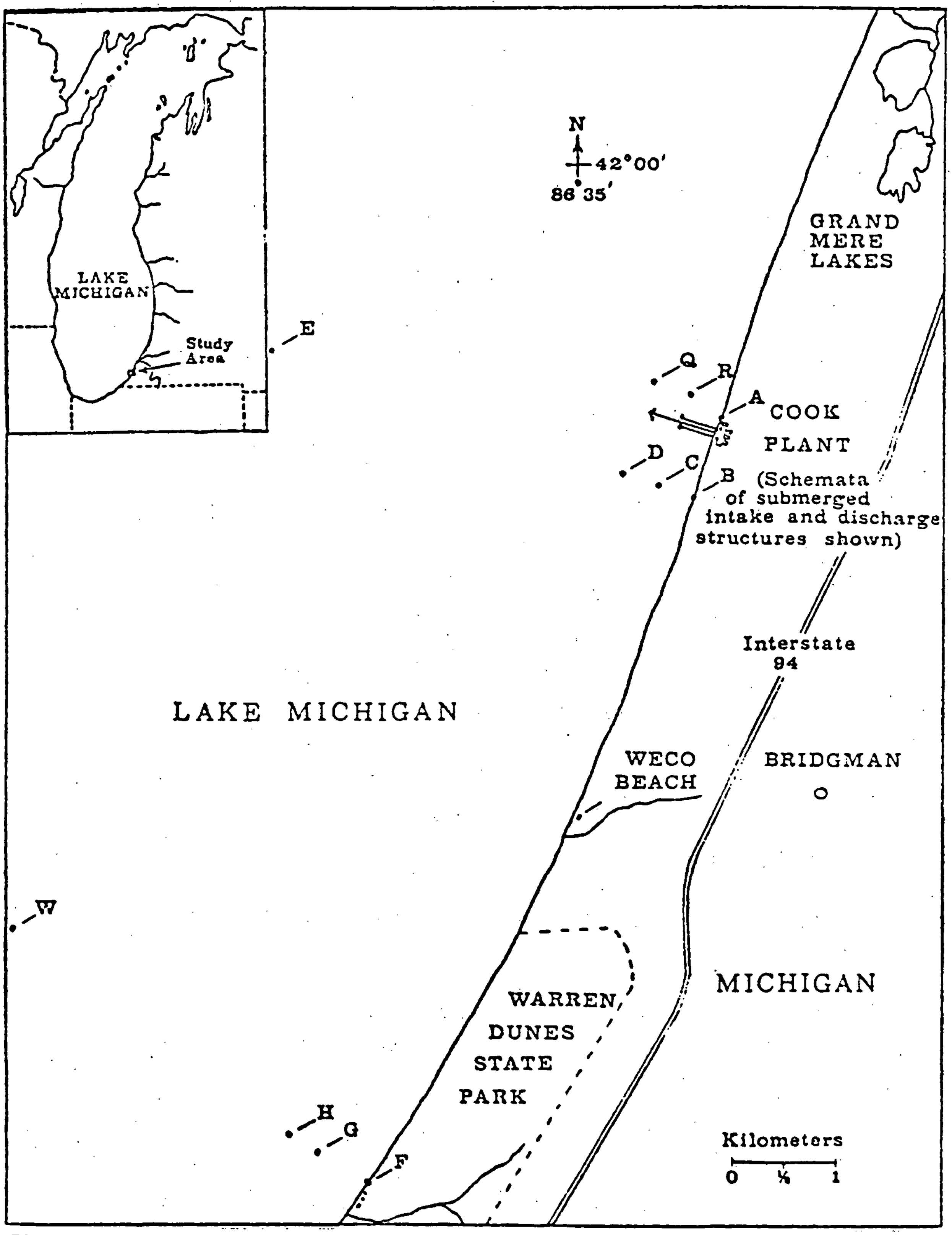

Figure 1. Map Showing General Location of D.C. Cook Nuclear Power Plant and Locations of Fish-Sampling Stations at the D.C. Cook Plant and the Warren Dunes Study Areas. *(For details of the sampling program at each lettered station, see "Donald C. Cook Nuclear Plant Units No. 1 and 2, Indiana and Michigan Power Company Annual Environmental Report, January 1 through December 31, 1978.")*

of shoreline and is contiguous to residential Rosemary Beach on the north and to land zoned for agriculture on the south.

The 30-foot depth contour lies about one-half mile offshore. The major surface-water currents along the shore at the site flow north or south under the influence of surface winds. The mean surface-water temperature of the lake at the plant ranges from 32°F (December through February) to 70°F (July) and to 77°F (August).

INTAKE DESIGN AND OPERATION

The D.C. Cook Nuclear Power Plant consists of two units, each employing a pressurized water reactor that generates about 1100 MWe gross. The plant utilizes a once-through system for condenser cooling. The cooling water is drawn through three intake cribs located about 2250 feet offshore in 24 feet of water (Figs. 2 and 3). The intake cribs consist of smoothly rounded intake elbows set in the lake bottom, surrounded by sacked concrete and riprap to prevent erosion. Each elbow is surrounded by an octagonal frame of heavy structural steel. The steel frame is provided with bar racks and guides on all sides. These bar racks and guides form an 8-inch-square grill; the top of the structural frame is provided with a steel-plate roof to prevent vortex formation. The trash racks are made of 3/4-inch-thick by 4-inch-deep bars on 3-inch centers, with openings of 2-5/8 inches.

Water is pumped through three submerged parallel pipes to the screenhouse located on the beach in front of the station. There are 14 vertical traveling

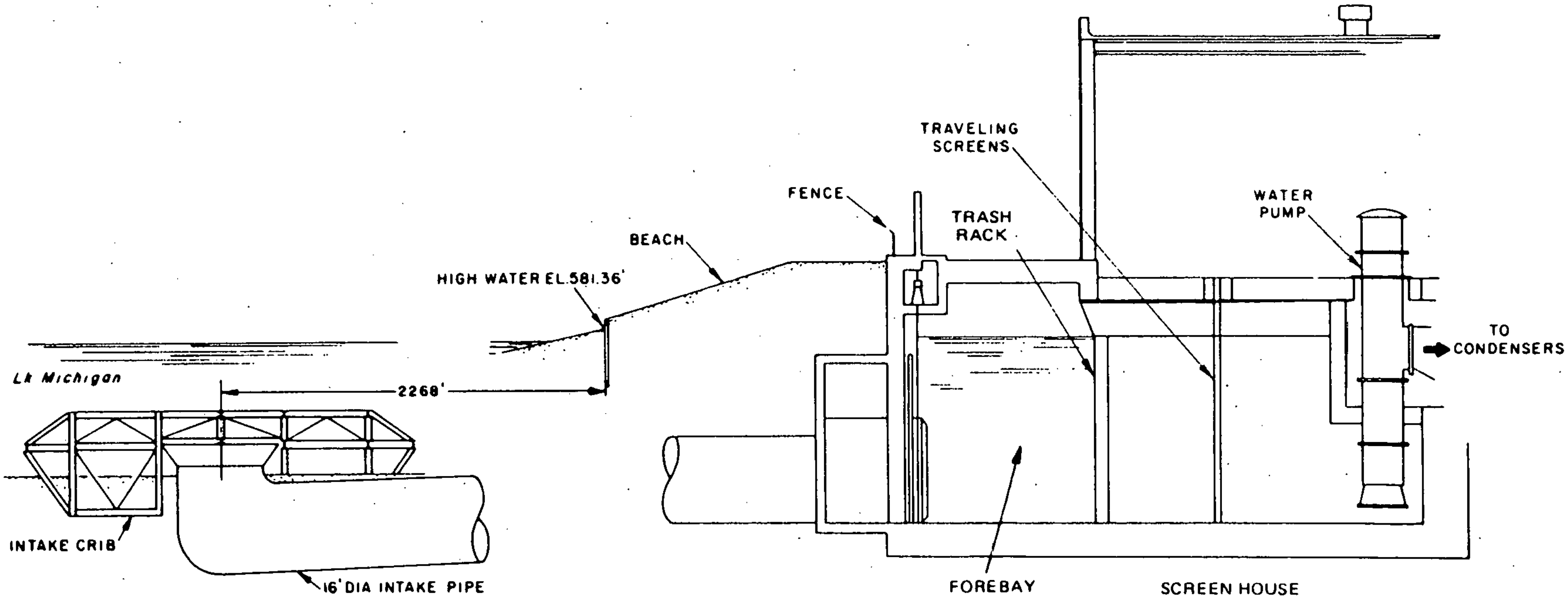

Figure 2. Intake Crib and Screenhouse. *(From R.K. Sharma and R.F. Freeman III. "Survey of Fish Impingement at Power Plants in the United States," Vol. I, "The Great Lakes." Argonne National Laboratory, ANL/ES-56, March 1977.*

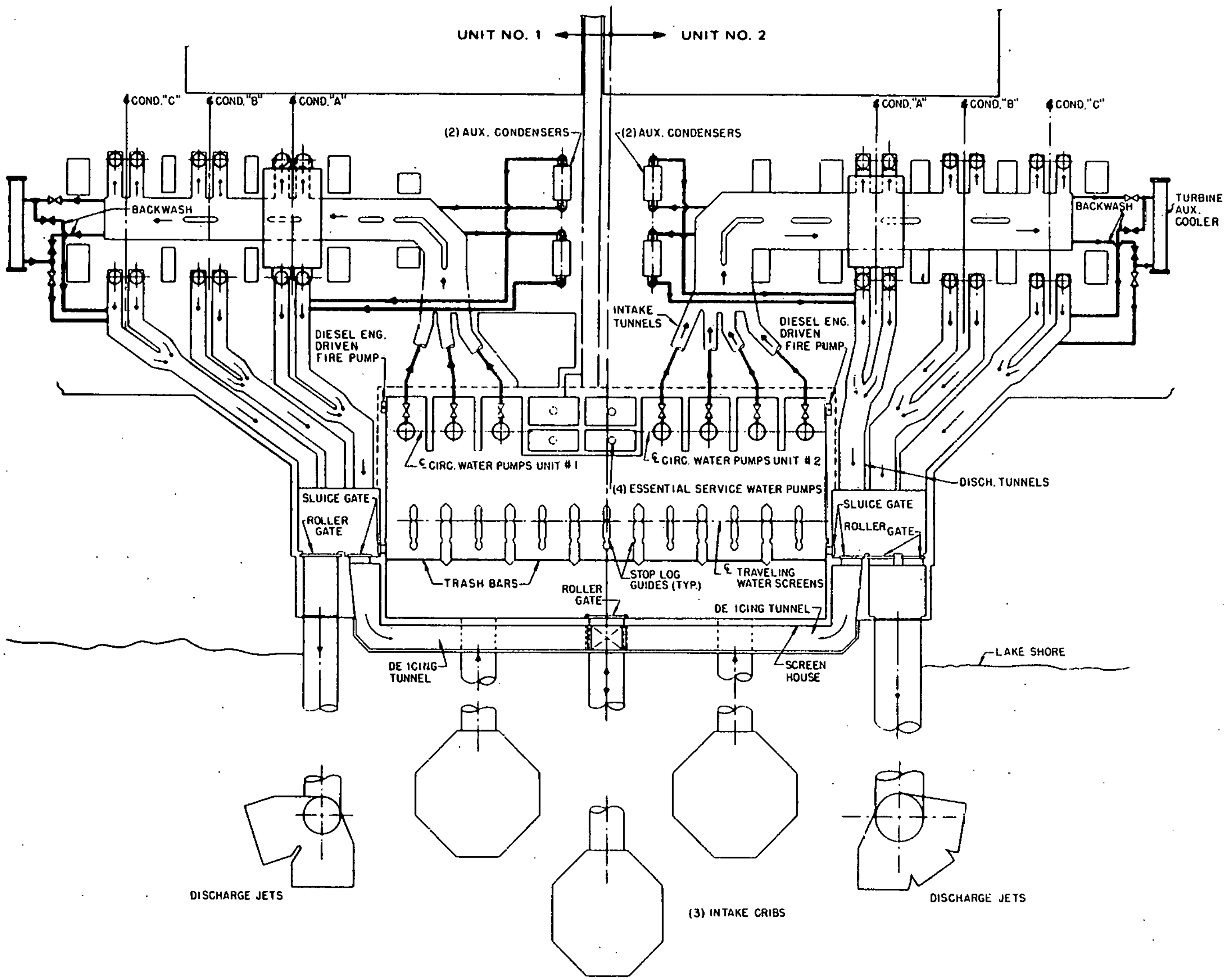

Figure 3. Condenser and Cooling-Water System. *(From R.K. Sharma and R.F. Freeman III. "Survey of Fish Impingement at Power Plants in the United States," Vol. I, "The Great Lakes." Argonne National Laboratory, ANL/ES-56, March 1977.)*

screens, seven for each unit. The traveling screens have 3/8-inch-square openings. The maximum condenser flow rate for the two units is 1,645,000 gpm. The screenhouse is common to both reactors, but each has separate pumpwells. There are three circulating water pumps for Unit 1 and four for Unit 2. Intake velocities at various locations in the system are estimated as follows:

- 1.27 fps through the 8-inch-square intake grills
- 1.9 fps through the 8-inch-square intake grills during deicing
- 6.0 fps through the intake pipes
- 1.0 fps through the trash racks
- 2.0 fps through the traveling screens (at lowest expected water level in the screenhouse forebay)

During winter deicing operations, cooling water is drawn through only two of the three intake pipes, and heated water is discharged through the third. This increases the intake velocity through the outermost intake grill by 50%.

Total cooling-water transit time from intake to discharge is about ten minutes; transit time through each condenser is about six seconds. Debris and fish impinged on the traveling screens are washed off by water sprays and flushed into troughs to be disposed of offsite.

ECOLOGICAL MONITORING PROGRAM

The applicant has conducted studies of the aquatic ecosystem in the vicinity of the site to comply with regulatory requirements. These studies include sampling of phytoplankton, zooplankton, periphyton, benthos, fish eggs and larvae, and adult fish. In addition, entrainment and impingement studies were also conducted to assess impacts of the cooling water flow through the plant. For determination of 316(b) compliance, the entrainment studies of fish eggs and larvae and impingement monitoring of fish are of particular interest. Details of the complete monitoring program can be found in annual reports prepared by the applicant, such as that for 1978.[7]

Entrainment Studies for Fish Eggs and Larvae

During the study period, 1974 through 1976, fish larvae and eggs were collected by pumping water from the intake forebay for four 6-hour segments during a 24-hour period once a week during June through August each year and twice a month during the remainder of each year. A 50-gpm stream of water from a sampling pump was filtered through a plankton net suspended in a barrel of water. These collections were timed to catch any brief runs of particular species. Such runs are most likely during the summer months. Fish larvae were sorted by species and counted. Because it was not possible to determine whether a larva was alive or dead at the time of sampling, 100% mortality was assumed. Fish eggs collected were simply counted. No attempt was made to differentiate between live and dead eggs. Based on the numbers of larvae and eggs collected during the sampling periods, the applicant then made estimates of total entrainment.[5] The results, taken from the applicant's 1978 Annual Report,[7] are summarized below and in Table 1.

Fish egg entrainment was most common May through July, usually peaking in mid-July. Estimates of numbers of fish eggs entrained each year during the period 1974-1976 were 6.49×10^8, 9.42×10^8, and 27.4×10^8, respectively.

Table 1. Estimated Numbers and Mean Weights of Pro and Post Larvae Entrained at the D.C. Cook Nuclear Power Plant Between 1974 and 1976

Species	Year	Estimated Total	75% Chebyshev Interval		Class of Larvae	Mean Weight, mg	Estimated Number	Estimated Biomass, g
			Lower	Upper				
Alewife	1974	6.4603×10^7	3.6×10^7	9.371×10^7				
					Pro	0.03	4.9680×10^7	1.490×10^3
					Post	4.45	1.492×10^7	6.64×10^4
	1975	1.05357×10^8	1.94184×10^7	1.92467×10^8				
					Pro	0.03	1.017×10^8	3.05×10^3
					Post	4.45	3.687×10^6	1.64×10^4
	1976	6.12407×10^7	3.10853×10^7	9.23769×10^7				
					Pro	0.03	4.458×10^7	1.337×10^3
					Post	4.45	1.666×10^7	7.413×10^4
Rainbow Smelt	1974	8.97×10^6	1.88×10^6	1.61×10^7				
					Pro	0.17	5.597×10^6	9.51×10^2
					Post	8.71	3.373×10^6	2.938×10^4
	1975	1.22×10^6	1.87×10^5	2.53×10^6				
					Pro	0.17	3.489×10^5	5.932×10^1
					Post	8.71	8.711×10^5	7.587×10^3
	1976	7.881×10^5	0	1.82×10^6				
					Pro	0.71	7.881×10^5	1.340×10^2
					Post	8.71	0	
Yellow Perch	1974	0	0	0				
	1975	7.63×10^4	0	2.288×10^5				
					Pro	0.91	7.63×10^4	6.943×10^1
					Post	-	0	0
	1976	0	0	0				
Spottail Shiner	1974	1.227×10^5	0	3.683×10^6				
					Pro	0.82	5.99×10^4	4.91×10^1
					Post	0.91	3.217×10^4	2.927×10^1
	1975	4.9639×10^6	1.1725×10^6	8.907×10^6				
					Pro	0.82	3.941×10^6	3.23×10^3
					Post	0.91	1.023×10^6	9.305×10^2
	1976	1.0429×10^6	1.14×10^4	2.6265×10^4				
					Pro	0.82	7.843×10^5	6.431×10^2
					Post	0.91	2.586×10^5	2.354×10^2

From "On the Calculation of Production Foregone Due to Entrainment and Impingement of Fishes of the Donald C. Cook Nuclear Plant," Great Lakes Research Division, Univ. of Michigan, Ann Arbor, November 1978.

Of the fish larvae entrained, alewife were the most commonly occurring species, making up 90% of the total (Table 1). Alewife larvae were entrained from May through September of each year but were most common in June and July (peaking in mid-July). Rainbow smelt were the second most common fish larvae entrained, accounting for about 4% of total estimated larval entrainment during the three-year period. Smelt entrainment was most common in early May. Spottail shiners made up 3% of the total larvae entrained, occurring most commonly from mid-June through July. Yellow perch were not entrained in 1974, and were not commonly encountered in 1975 and 1976 entrainment samples. For the three-year period this species made up less than 0.1% of the total estimated larval entrainment. Small numbers of yellow perch larvae were entrained in mid-June and mid-July of 1975 and 1976.

The total numbers of unidentified fish larvae entrained annually from 1974 through 1976 were estimated to be 9.56×10^5, 9.59×10^5, and 1.97×10^5, respectively. Many entrainment samples in 1975 contained unidentified fish larvae, but only two samples contained larvae of undetermined species during 1976.

Impingement of Adult Fish

The numbers and weights of impinged fish were periodically sampled. Total impingement has been estimated using the following formula:

$$\text{Total} = \text{Number (or weight) of fish collected in a given month} \times \frac{(\text{\# of days in the month})}{(\text{\# of days sampled})}$$

The results of these extrapolations for the four most abundantly impinged species are summarized in Tables 2 through 5 for 1975 through 1978. During

Table 2. Estimated Impingement of the Four Most Abundant Species at the D.C. Cook Plant, 1975[a]

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Alewife													
Number	243	1	1,624	47,183	22,681	81,836	11,638	1,906	614	2,424	1,005	1,721	172,876
Biomass[b]	9.40	0.01	64.05	1,775.63	794.24	2,036.55	288.33	46.96	11.03	12.53	23.23	71.26	5,133.22
Rainbow smelt													
Number	10	11	75	1,113	1,020	156	44	223	42	793	198	222	3,907
Biomass[b]	0.19	0.2	0.7	22.84	17.07	1.73	0.42	0.98	0.25	1.22	1.41	2.37	49.38
Yellow perch													
Number	265	152	246	1,192	45	309	388	492	420	4,067	1,744	2,155	11,475
Biomass[b]	3.66	7.36	14.15	71.69	2.05	38.77	58.75	48.78	15.42	56.79	49.04	19.91	386.37
Spottail shiner													
Number	103	259	820	952	746	685	122	47	318	1,831	1,929	2,501	10,313
Biomass[b]	1.22	3.37	7.55	13.77	7.20	7.38	1.16	0.48	2.64	15.26	14.96	17.96	92.95
Days/month sampled	25	28	31	30	31	30	31	31	30	31	30	31	
Total													
Number	807	577	3,171	53,874	26,368	84,655	12,794	3,139	2,310	16,087	10,217	8,028	222,027
Biomass[b]	33.53	15.57	93.91	1,936.34	848.06	2,117.06	355.27	106.05	39.25	157.38	187.55	168.10	6,058.07

[a] *Total impingement was estimated by the following formula:*

Total number (or weight) = number (or weight) collected in a given month $\times \frac{\text{days in the month}}{\text{days sampled}}$.

[b] *Biomass is given in kilograms.*

Based on data presented in "Donald C. Cook Nuclear Plant Units No. 1 and 2, Indiana and Michigan Power Company, Annual Environmental Report, January 1 through December 31, 1978."

Table 3. Estimated Impingement of the Four Most Abundant Species at the D.C. Cook Plant, 1976[a]

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Alewife													
Number	184	3	16,151	1,942	7,124	31,492	28,012	3,826	3,228	2,356	4,294	174	98,786
Biomass[b]	9.56	0.11	701.02	79.30	215.89	761.86	713.12	90.56	23.67	12.28	99.81	4.38	2,711.56
Rainbow smelt													
Number	232	75	410	270	609	45	193	84	7	112	43	100	2,180
Biomass[b]	2.54	1.27	5.36	7.79	5.34	0.54	1.73	1.73	0.12	0.59	0.60	1.39	29.00
Yellow perch													
Number	1,660	111	461	146	289	330	2,030	1,523	5,310	4,123	99	1,194	17,276
Biomass[b]	14.01	8.21	17.18	4.54	8.61	33.95	234.4	149.76	112.94	81.63	3.26	71.8	740.29
Spottail shiner													
Number	2,318	1,863	11,652	888	137	2,588	426	275	2,245	2,953	1,059	1,821	28,225
Biomass[b]	27.02	19.12	110.01	9.45	1.13	43.99	3.82	2.48	22.86	30.53	9.81	21.08	301.3
Days/month sampled	31	29	8	8	6	8	8	7	8	8	7	8	
Total													
Number	6,020	2,314	30,194	4,239	11,659	32,671	33,046	6,435	14,301	10,463	5,841	3,623	160,806
Biomass[b]	107.58	73.21	886.95	118.34	298.55	833.05	981.09	259.00	177.14	137.53	133.63	175.80	4,081.87

[a]Total impingement was estimated by the following formula:

$$\text{Total number (or weight)} = \text{number (or weight) collected in a given month} \times \frac{\text{days in the month}}{\text{days sampled}}.$$

[b]Biomass is given in kilograms.

Based on data presented in "Donald C. Cook Nuclear Plant Units No. 1 and 2, Indiana and Michigan Power Company, Annual Environmental Report, January 1 through December 31, 1978."

Table 4. Estimated Impingement of the Four Most Abundant Species at the D.C. Cook Plant, 1977[a]

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Alewife													
Number	7	0	567	1,935	2,918	9,579	2,507	124	570	6,413	341	444	25,405
Biomass[b]	0.14	0.0	23.08	72.02	94.32	245.43	62.12	3.61	6.49	39.33	3.33	17.50	567.37
Rainbow smelt													
Number	8	109	124	225	85	73	496	5	11	469	64	45	1,714
Biomass[b]	0.13	1.11	0.81	2.44	0.62	0.72	1.86	0.03	0.03	3.77	0.81	0.58	12.91
Yellow perch													
Number	10	126	1,151	473	39	111	5,510	186	94	558	488	403	9,149
Biomass[b]	2.59	6.78	22.13	27.77	1.76	58.37	507.74	20.53	6.35	7.59	16.51	8.70	686.82
Spottail shiner													
Number	4	109	2,201	1,166	167	43	465	21	45	496	263	210	5,190
Biomass[b]	0.06	1.71	28.98	15.15	1.95	0.94	4.44	0.27	0.36	3.68	2.58	1.82	61.94
Days/month sampled	31	8	7	8	8	7	8	6	8	7	8	9	
Total													
Number	68	410	4,339	4,985	3,605	10,106	10,939	413	882	11,476	1,519	1,338	50,080
Biomass[b]	23.85	27.14	112.24	148.18	144.85	309.4	588.00	26.21	19.35	115.72	212.45	167.83	1,895.22

[a]*Total impingement was estimated by the following formula:*

$$\text{Total number (or weight)} = \text{number (or weight) collected in a given month} \times \frac{\text{days in the month}}{\text{days sampled}}.$$

[b]*Biomass is given in kilograms.*

Based on data presented in "Donald C. Cook Nuclear Plant Units No. 1 and 2, Indiana and Michigan Power Company, Annual Environmental Report, January 1 through December 31, 1978."

Table 5. Estimated Impingement of the Four Most Abundant Species at the D.C. Cook Plant, 1978[a]

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Alewife													
Number	0	0	0	13	4,805	49,710	109,620	8,634	2,240	4,665	3,675	1,382	184,744
Biomass[b]	0.0	0.0	0.0	0.62	188.61	1,220.42	2,674.36	199.51	30.97	59.21	128.85	55.62	4,558.17
Rainbow smelt													
Number	105	32	1,341	86	3,720	1,032	19,588	13,632	355	39	0	66	39,996
Biomass[b]	1.95	0.80	23.98	1.85	24.75	4.63	65.30	65.52	2.91	1.16	0.0	0.31	193.16
Yellow perch													
Number	488	56	442	544	62	198	14,437	4,270	1,060	457	3,300	239	25,553
Biomass[b]	26.06	7.27	56.33	69.03	5.06	9.93	451.67	345.97	62.59	45.73	58.5	16.43	1,154.57
Spottail shiner													
Number	2,577	300	1,166	3,536	666	1,086	104,939	5,491	2,880	3,856	675	1,847	129,019
Biomass[b]	31.18	3.15	15.49	52.92	6.74	7.68	327.95	38.18	20.27	32.5	5.55	19.44	561.05
Days/month sampled	8	7	8	7	6	5	7	8	6	8	4	7	
Total													
Number	3,444	488	3,187	4,499	10,455	53,508	319,955	35,117	7,805	11,179	7,973	4,592	462,202
Biomass[b]	78.12	98.63	196.11	208.94	291.72	1,308.91	4,017.58	714.41	181.94	359.21	629.63	496.22	8,581.42

[a] *Total impingement was estimated by the following formula:*

$$\text{Total number (or weight)} = \text{number (or weight) collected in a given month} \times \frac{\text{days in the month}}{\text{days sampled}}.$$

[b] *Biomass is given in kilograms.*

Based on data presented in "Donald C. Cook Nuclear Plant Units No. 1 and 2, Indiana and Michigan Power Company, Annual Environmental Report, January 1 through December 31, 1978."

this period, the alewife was the most abundantly impinged species in terms of both numbers and biomass, with the exception of 1977, when yellow perch biomass exceeded that of alewife. Although entrainment of yellow perch larvae was not common in 1975 and 1976, the biomass of impinged yellow perch was second to alewife in both years. Spottail shiner and rainbow smelt ranked third and fourth in terms of biomass impinged. The estimated number of spottail shiner impinged exceeded that of yellow perch in 1976 and 1978; however, the estimated biomass of perch was greater than that of spottail shiner for all four years. The percentages of total impingement for both numbers and biomass of alewife, rainbow smelt, yellow perch, and spottail shiner are summarized in Table 6.

Table 6. Percentage of Total Impingement for Four Most Abundantly Impinged Species, 1975-1978

	Alewife		Rainbow Smelt		Yellow Perch		Spottail Shiner	
	Number	Biomass	Number	Biomass	Number	Biomass	Number	Biomass
1975	78%	85%	1.7%	0.8%	5.2%	6.4%	4.6%	1.5%
1976	61	65	1.3	0.7	11	18	17	7.2
1977	51	30	3.4	0.7	18	36	10	3.3
1978	40	53	8.7	2.3	5.5	13	28	6.5

Calculated from data presented in Tables 2 through 5.

Field Sampling of Fish Eggs and Larvae

The applicant's 1978 Annual Report contains summary data on temporal and spatial differences in the distribution of fish larvae collected (and methods of collection) in field sampling in the vicinity of the D.C. Cook plant for the period 1973-1976.[7] Larval concentrations among depth strata ranging from surface to near bottom for a particular area and time were not found to be significantly different. Alewives were the most frequently captured fish larvae, occurring in both the beach zone and open water, depending on water temperature. Disregarding the sampling bias due to net avoidance, more larvae were captured in the beach zone during the day and in the open water at night. More larvae also were captured at the 6-m depth than at the 9-m depth. More smelt larvae were collected during the day at 6 m and at night at 9 m.

Field Sampling of Juvenile and Adult Fish

Juvenile and adult fish were collected in the vicinity of the D.C. Cook plant with trawls, seines, and gill nets at various sampling stations (Fig. 1).[7] The fish species captured in the vicinity of the plant are listed in Table 7.

The alewife was the most abundant species for the sampling period 1973 through 1978. Spottail shiner, the second most abundant species, usually was caught from April through November, with adults and yearlings being most abundant in spring and summer and young-of-the-year predominating in late summer and fall. Large numbers of spottails in seine samples indicated their abundance in shallow, inshore waters. Spottails were not abundant in the beach zone during winter and were not abundant during periods of high wave conditions at 6- and 9-m depths during spring and fall--periods coinciding with inshore-offshore migrations.

Yearling rainbow smelt occupied the nearshore zone (6-m and 9-m contours) during April through June. By July, they moved farther offshore. The young-

Table 7. Scientific and Common Names of Fishes Found in the Vicinity of the D.C. Cook Plant

Family	Scientific Name	Common Name
Acipenseridae		
	Acipenser fulvescens	Lake sturgeon
Clupeidae		
	Alosa pseudoharengus	Alewife
	Dorosoma cepedianum	Gizzard shad
Salmonidae		
	Coregonus artedii	Lake herring or Cisco
	Coregonus clupeaformis	Lake whitefish
	Coregonus hoyi	Bloater
	Oncorhynchus kisutch	Coho salmon
	Oncorhynchus tshawytscha	Chinook salmon
	Salmo gairdneri	Rainbow trout
	Salmo trutta	Brown trout
	Salvelinus namaycush	Lake trout
Osmeridae		
	Osmerus mordax	Rainbow smelt
Esocidae		
	Esox lucius	Northern pike
Cyprinidae		
	Cyprinus carpio	Carp
	Notemigonus crysoleucas	Golden shiner
	Notropis atherinoides	Emerald shiner
	Notropis heterodon	Blackchin shiner
	Notropis hudsonius	Spottail shiner
	Notropis spiloterus	Spotfin shiner
	Notropis stramineus	Sand shiner
	Pimephales notatus	Bluntnose minnow
	Pimephales promelas	Fathead minnow
	Rhinichthys cataractae	Longnose dace
Catostomidae		
	Carpiodes cyprinus	Quillback
	Catostomus catostomus	Longnose sucker
	Catostomus commersoni	White sucker
	Moxostoma anisurum	Silver redhorse
	Moxostoma erythrurum	Golden redhorse
	Moxostoma macrolepidotum	Shorthead redhorse
Ictaluridae		
	Ictalurus melas	Black bullhead
	Ictalurus punctatus	Channel catfish
Percopsidae		
	Percopsis omiscomaycus	Trout-perch
Gadidae		
	Lota lota	Burbot
Antherinidae		
	Labidesthes sicculus	Brook silverside
Gasterosteidae		
	Pungitius pungitius	Ninespine stickleback

Table 7. continued

Family	Scientific Name	Common Name
Centrarchidae		
	Ambloplites rupestris	Rock bass
	Lepomis cyanellus	Green sunfish
	Lepomis gibbosus	Pumpkinseed
	Lepomis macrochirus	Bluegill
	Micropterus dolomieui	Smallmouth bass
	Micropterus salmoides	Largemouth bass
Percidae		
	Etheostoma nigrum	Johnny darter
	Percina caprodes	Logperch
	Perca flavescens	Yellow perch
Sciaenidae		
	Aplodinotus grunniens	Freshwater drum
Cottidae		
	Cottus bairdi	Mottled sculpin
	Cottus cognatus	Slimy sculpin

of-the-year used the nearshore zone as a nursery area. Young-of-the-year were caught in larval sampling through May; by the period July-August they were large enough to be retained by trawls. Adult smelt were captured in gill nets only during spring, when they moved inshore for spawning. Yellow perch were caught in large numbers during various sampling years; however, there were large variations from year to year and for the same fishing gear.

DISCUSSION

Ecological Significance

The concern expressed by the regulatory agencies charged with the responsibility of enforcing Section 316(b) compliance is that entrainment of alewife larvae at the D.C. Cook plant will result in decline of alewives in Lake Michigan.[8] An exotic species in the lake, the alewife was considered a nuisance until the introduction of coho salmon by the State of Michigan; now the alewife is an important food species for the coho. Perhaps success of the coho salmon fishery and the continuation of the economic benefits that resource generates depend on survival of a healthy population of alewives. Therefore, there is emphasis on prevention of entrainment of alewife larvae in the cooling-water flow at the D.C. Cook plant. It is important to note, however, that the problem is not unique to that plant. There are other large power plants and municipal water intakes withdrawing water from Lake Michigan. Impingement of alewives and entrainment of their larvae occur at all these facilities.

P.J. Rago of the Great Lakes Research Division, the University of Michigan, in consulting capacity to the applicant, has conducted analyses to estimate how many adult alewife equivalents are lost (production foregone) by impingement and entrainment at the D.C. Cook plant.[5] (Such estimates also were made for spottail shiner, rainbow smelt, and yellow perch.) To make these calculations where "real" data or information was lacking, it was necessary for Rago to make certain assumptions and to select certain parameter values on the basis of "best available estimates." No matter how reasonable the assumptions and how precise the estimates of parameters may seem, there is no way of proving that they are correct. Thus, such analyses can be easily supported or criticized depending on personal bias. Regardless of this bias factor, the effort by Rago provides sharp focus on the issues, and the calculations made and estimates presented appear credible. However, such estimates should not be used as the only basis for estimating production foregone. Rago has expressed adequate reservations in this regard in his report. We agree with his conclusion that "The ... ecological effects of the removal of these fish, if any, would probably be masked by the immensity and complexity of the Lake Michigan communities." If the alewife population were to decline in the lake, the decline would not be attributable solely to entrainment or impingement at the D.C. Cook plant.

In the absence of any defensible lakewide population estimates for various fish species, it is difficult to put the impingement and entrainment losses at D.C. Cook plant in perspective. Comparison of such losses to commercial catch data, where available, is one approach. Such a comparison made by Rago for alewives, smelt, and perch is convincing of the fact that fish losses due to D.C. Cook plant operation amount to a rather insignificant fraction of commercial catches (p. 62, Table 25 of Ref. 5). However, such a fraction may not be insignificant when fish losses at all power plant and municipal water intakes on the lake are considered. Therefore, for a more meaningful analysis, concerns for a healthy coho salmon sport fishery should not be limited to the D.C. Cook plant alone for its contribution of a relatively insignificant fraction of forage fish killed, but should include consideration of losses from other impacts as well. On an ecological basis or on the basis of importance of alewives to the coho salmon fishery, it is difficult to prove that impingement or entrainment at the D.C. Cook plant alone will have any significant adverse impacts.

The available data indicate that impingement of alewife, slimy sculpin, spottail shiner, and yellow perch at the D.C. Cook plant is not significantly greater than at other power plants on Lake Michigan.[1] However, only a lake-wide assessment of populations of these species and their mortality from all other sources may provide some indication of the level of impingement and entrainment at D.C. Cook plant that can be considered acceptable. One alternative to such an assessment is to reduce impingement and entrainment by modifications of intake location, design, and operation in a cost-effective manner.

Existing Intake

The cooling-water intake of the D.C. Cook plant was designed almost ten years ago, before the passage of PL 92-500. Design of the intake incorporated features which at that time were considered suitable for reduction of entrapment and impingement of adult fish or other biota that would not pass through a 3/8-inch-square mesh. The offshore intake was designed with a velocity cap, intended to induce horizontal rather than vertical currents in the vicinity of the intake pipe openings. It has been claimed that fish sense the horizontal currents more readily than vertical currents and thus can avoid being drawn into the intake flow. The rest of the design features of the intake system incorporated conventional technology, including vertical traveling screens with 3/8-inch-square mesh. Reduction of intake velocity through the traveling screens, generally believed to be a desirable feature, would not be of much advantage in case of D.C. Cook plant intake design. Once the fish are entrapped at the offshore intake, they end up in the forebay onshore. The only way to get the entrapped fish out of the forebay is to have a high intake velocity through the traveling screens with screens rotating continuously. By this procedure, fish would impinge on the screens and then could be removed as the screen rotates. Although the D.C. Cook plant intake is designed with a 2-fps intake velocity through the vertical traveling screens at the lowest expected water level, no system to return fish to the lake in an ecologically acceptable manner was included in the design.

If protection of adult fish continues to be the only concern (as it was when the plant was originally designed) only minor modifications may be required to further reduce fish mortality on the screens. Some provision will have to be made for impinging the entrapped fish in the forebay without much delay between entrapment and impingement and rotating the traveling screens continuously and sluicing the fish (hopefully still alive) back to the lake. Use of fish "baskets" in place of screen panels on the vertical traveling screens would aid in the survival and safe washing of the impinged fish. Such a system is currently in use at the Surry Nuclear Power Plant of the Virginia Electric Power Company.

Intake Location and Design Alternatives

During the last few years, emphasis in intake location and design has shifted from protection of adult fish alone to protection of their larval forms as well. But because of the lack of proven larval screening systems, the only method for reducing impacts on fish larvae has been by reducing cooling-water intake by use of closed-cycle cooling. The effectiveness of this option in reducing entrainment impacts has been questioned, however. There is some survival of larval forms even after passage through the power plant with once-through cooling, but no survival can be expected after entrainment in a closed-cycle-cooling system.

Various technological options that possibly could be used to screen fish eggs and larvae were brought into focus at the Workshop on Larval Exclusion Systems for Power Plant Cooling Water Intakes held at San Diego, California, in February 1978.[2] Findings of the workshop are relevant to this discussion.

Currently, there is no screening system that combines proven engineering design and demonstrated biological effectiveness for screening fish larvae from large water intakes such as that of the D.C. Cook plant. Such systems either have been deployed only at smaller water intakes, such as those for closed-cycle cooling, or are in various stages of research and development. Several engineering and biological factors must be considered in designing any system to protect fish larvae. The system must employ proven engineering technology requiring no more than reasonable maintenance. A power plant cannot operate in a cost-effective manner if it has to be shut down excessively for maintenance. From a biological standpoint, the system must be demonstrated to operate in such a way that a reasonably high percentage of larvae are screened without damage and that these screened larvae survive in the source water body in appreciably high numbers. Installation of unproven technology with questionable gains in larval protection is likely to generate debate similar to that arising over use of the closed-cycle cooling option (i.e., whether or not the system is in fact biologically effective).

Placement of the water intake often can be nearly as important as the screening system used in reducing entrainment. The screening systems and location alternatives that merit consideration for the D.C. Cook plant are as follows:

1. <u>Use fine-mesh screening panels on existing vertical traveling screens</u>. With this system the screens would have to be rotated continuously during the expected larval entrainment season. A new screen wash system with gentle sprays would be required, and the existing sluiceway would have to be modified and extended to return the larvae (and adults) to the lake. Provision also would have to be made for adequate flow in the sluiceway to keep the larvae submerged. A bladeless impeller type of pumping installation might be needed if it was decided to pump larvae back to the lake.

2. <u>Replace the existing vertical traveling screens with Passavant screen with fine-mesh panels</u>. With this system also the screens would have to be

rotated continuously during the expected larval entrainment season. The modifications of the spray system, extension of sluiceway, and need for pumping discussed for alternative 1 also would be needed for this system.

3. Replace the existing vertical traveling screens with an offshore network of wedge-wire Johnson screens. Such a system would require installation of an elaborate backwash system using compressed air.

4. Extend the existing intake opening farther offshore where larval density may be lower than at the present location. With this alternative, the existing vertical screens may be left as they are or replaced as discussed for alternatives 1 and 2 above. Obviously, new construction in the lake farther offshore would be required.

In its 15 September 1979 report to the Michigan Water Resources Commission,[6] the applicant considered location, capacity, and design alternatives for minimizing entrainment of fish larvae for the D.C. Cook plant cooling-water intake. These alternatives have been discussed in adequate detail in that report. Our analysis of these alternatives is given below.

Fine-Mesh Screening Systems. The fine-mesh screening systems, which include the conventional vertical traveling screens and the Passavant screens, offer advantages of proven technology. The screening elements available for use on either the conventional traveling screen system or the Passavant screens will do a satisfactory job of physically screening larvae. Operating experience and testing of various screening materials indicates that a polyester or nylon screen, usually with 1/2-mm or 1-mm openings, is preferable. The vertical traveling screen is considered a standard off-the-shelf item for power plant intakes. Passavant screens, although only recently introduced in the United States, have been in use for several years in Europe, South America, and other locations for power plants and various other kinds of installations. However, both systems originally were designed for intermittent operation. Use for larval screening implies a continuous operating mode at least during larval season, which necessitates more than average maintenance.

Low- and high-velocity wash sprays have been used at some installations and will perhaps be adequate to wash fish larvae off the screens. Designing a sluiceway does not seem to be an insurmountable problem; however, one has not yet been designed and operated with a high degree of success. The biggest uncertainty in fine-mesh screening is survival of larvae after screening under field conditions. To better assess the effectiveness of a fine-mesh screening system coupled with wash sprays and a sluiceway to return larvae to the lake, data are needed for various points in the entire cycle, from impingement of larvae on the screens to their survival in the source water body. Some data are available on survival of larvae after various durations of impingement;[9,10] however, it is not known what levels of mortality occur during washing and sluicing operations. Furthermore, the chances of survival of larvae in the source water body and their subsequent behavior after having gone through the stress of impingement, washing, sluicing, and possibly pumping are entirely matters of speculation.

<u>Wedge-Wire Screening</u>. The cylindrical wedge-wire screens, or the Johnson screens, with fine mesh adequate for screening fish larvae can be considered a proven technology where water demands do not exceed those comparable to

closed-cycle cooling. These screens have been used successfully at many industrial water intakes requiring flows up to 125,000 gpm and at several power plants with relatively small makeup water requirements. This system, however, has not been used for once-through cooling flows comparable to the D.C. Cook plant (1,625,000 gpm). Elaborate hydrological modeling would be needed before the system could be expanded to accommodate such large flows. Because of the large volume of water required for the D.C. Cook plant, a wedge-wire system would take up considerably more area in the lake than the present intake. The applicant has calculated that approximately 210 individual screens would be required at the D.C. Cook plant, assuming 1-mm openings and an intake velocity of 0.5 fps.[6]

For successful operation, the system requires adequate flow or currents across the screening elements to carry away the larvae. The lake currents in the vicinity of the D.C. Cook plant do not seem to be adequate for this. To prevent clogging, bypass currents of at least 1.5 times the intake velocity are recommended. A wedge-wire system with 1-mm openings and an intake velocity of 0.5 fps thus would require a bypass current of 0.75 fps. Such bypass currents are often lacking in lacustrine systems. In absence of such currents, larvae will most likely impinge on the screens and die. The Johnson screens also require a backwash system to clean off debris. The compressed air system may be the most logical choice. Whether such a large system can be operated successfully without undue maintenance problems is again a matter of speculation.

A wedge-wire screening system may reduce entrainment of larvae; however, it is doubtful that mortality would be significantly reduced. Preliminary, unpublished test results of sustained swimming speeds of larval fish indicate that few, if any, larvae can avoid an intake approach velocity of 0.5 fps. Thus, entrainment would probably decrease but larval impingement would increase. Such a screening system would also be very susceptible to clogging by debris. Protection from floating ice may also be necessary because of the thickness of such ice in Lake Michigan. The applicant has had problems in safeguarding the existing intake even with a grid of eight-inch "I" beams. Any fine-mesh screens in the lake will also be susceptible to fragile ice formation.

Intake Location. Another possible alternative to decrease larval mortality is to move the existing intake farther offshore. However, the biological effectiveness of this alternative is not certain. The existing intake can be moved to 4000 feet offshore before screen-house modifications must be made to accommodate gravitational flow. The water depth at 4000 feet offshore is approximately 50 feet. Data on alewife larval density were collected on 15 July 1976 and 10-11 August 1976 (unpublished). The day samples (15 July and 10 August) do indicate that fewer alewife larvae are present in deeper water (50 feet) than in the vicinity of the intake (24 feet); however, the night sample (11 August) indicated essentially no difference in alewife larval density between the deeper water station and the location of the existing intake. Therefore, it is not possible to predict the reduction of entrainment of fish larvae that would result from locating the existing intake farther offshore. However, based on data collected at the J. H. Campbell Power Plant (Fig. 4), it appears that abundance of *Pontoporeia affinis* is greatest at about 50 feet.[11] Therefore, entrainment of *Pontoporeia* might become a problem if the existing intake were to be relocated in deeper water. Given the variability of ecological data, the staff does not feel confident in passing

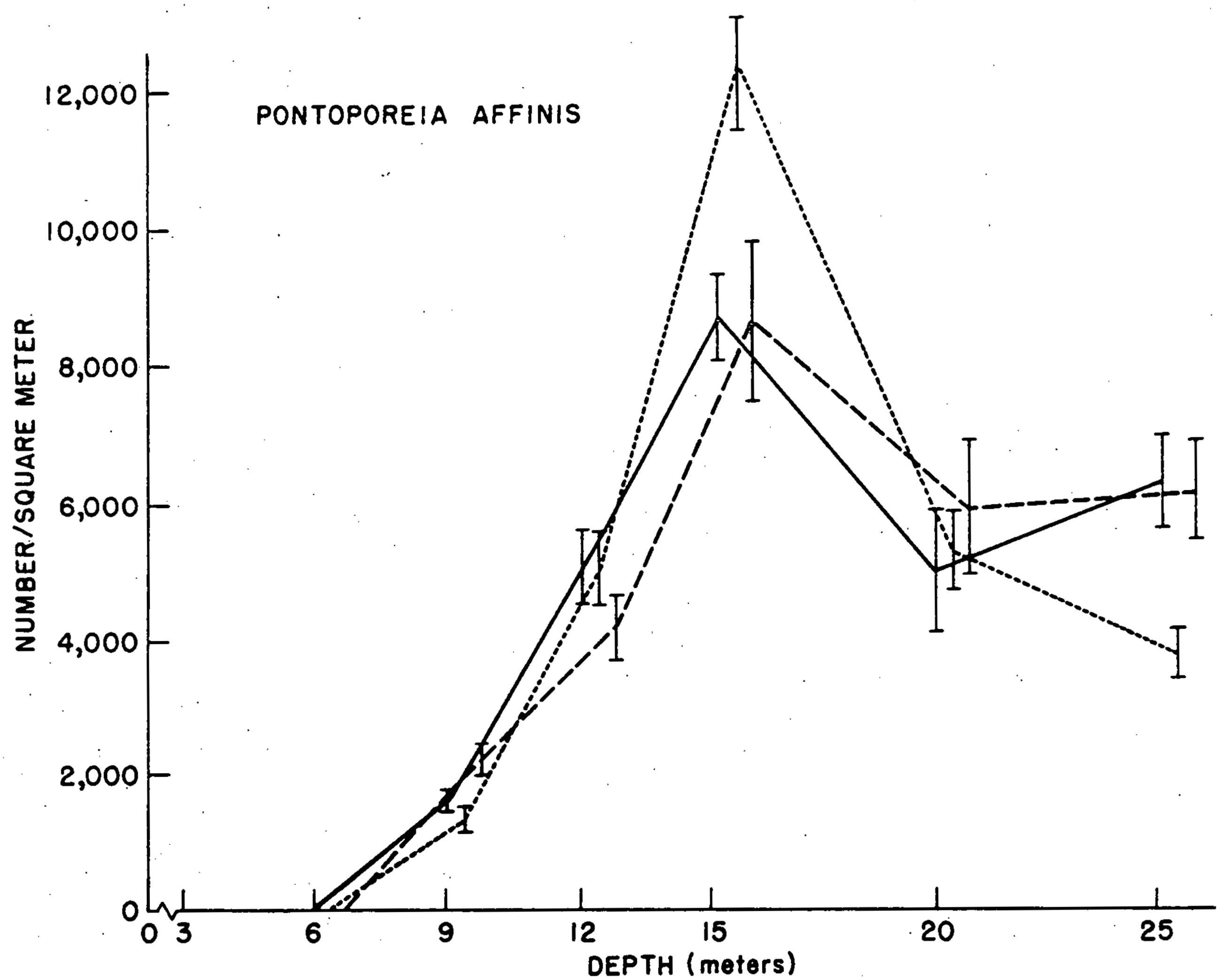

Figure 4. Density of *Pontoporeia* vs. Depth for Open-Water Lake Michigan Stations near the J.H. Campbell Plant in the Northern (——), Middle (---) and Southern (– – –) Regions, Eastern Lake Michigan. *(Taken from D.J. Jude et al., "Adult and Juvenile Fish, Ichthyoplankton and Benthos Populations in the Vicinity of the J.H. Campbell Power Plant, Eastern Lake Michigan, 1977," University of Michigan, Great Lakes Research Division, Special Report Number 65.)*

judgment on the desirability of relocating the intake openings farther offshore. A decision to undertake such a relocation should be made only on the basis of the analysis of data collected consistently over a long period for all biota of important trophic status. Even then, relocation of the intake by 1000 or 2000 feet farther offshore may not be adequate because changes in the lake's thermal and/or hydrological regimes on a local scale can nullify such a relocation by redistributing larvae to areas in which they formerly were less dense.

CONCLUSIONS AND RECOMMENDATIONS

1(a) On an ecological basis we are not convinced that entrainment and impingement of larvae and adults of alewife and other fish species at the D.C. Cook power plant alone constitute a threat to the coho salmon fishery of Lake Michigan. However, we do believe that it is important to examine the impacts on fish populations from all sources of mortality on the lake. The losses from several sources of mortality that individually might appear insignificant could possibly add up to a significant impact on the fishery resources of the lake.

(b) Screening of larvae from the once-through cooling system of the D.C. Cook power plant is feasible by use of fine-mesh screening panels on conventional vertical traveling screens or Passavant screens. Modifications of the existing intake bays would be necessary to install Passavant screens, and for either of the systems, modifications of the sluiceways and screen-wash systems would be required. However, there are no data which indicate that the screened larvae would have an appreciable rate of survival on return to the source water body.

(c) Wedge-wire (Johnson) screens have not been used for once-through cooling water flows comparable to the D.C. Cook power plant. Also, the success of the screens depends on the larvae's being swept away by the ambient currents, thus preventing impingement; such currents are lacking in a lacustrine system. Maintenance, operation, and protection of 1- or 2-mm screens in several feet of water 2000 to 4000 feet offshore is not a demonstrated technology. In addition, there are no experimental data on survival rates of impinged and screened larvae in the source water body for the wedge-wire screens.

2(a) We recommend that a lakewide assessment be undertaken to determine on a generic basis the need for enhanced protection of larval fishes.

(b) We recommend that demonstration studies be undertaken on a generic basis for engineering feasibility and biological effectiveness of various fine-mesh screening options for the Great Lakes. We do not believe that such generic demonstration studies should be made the responsibility of a single utility. Steps should be undertaken for a coordinated effort among industry and interested state and federal agencies. Recommendation of demonstration studies does not imply a dictated need for fine-mesh screening at all water intake installations. It is intended to advance the state-of-the-art such that various options may be implemented if such a need becomes apparent in the future.

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