Diurnal Movement of Fish Larvae and Invertebrates into a Power Plant Intake

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Introduction

Kelso and Milburn (1979) analyzed the impingement and entrainment occurring during 1975 or 1976, as a result of the once-through cooling process, to attempt to determine the relevance of this loss to the Great Lakes fishery. They determined that impingement losses, when combined with entrainment losses will affect recruitment to some unknown degree and will likely constitute a significant undesirable impact upon the Great Lakes fishery. They indicated data were. available for only about 24% of existing plants and few sources provided acceptable data sets with identification of major species and year-round sampling. They did not discuss diurnal or depth differences in entrainment rates for fish larvae or invertebrate groups.

While complying with the National Pollutant Discharge Elimination System (NPDES), Part 1B(8), Permit Program, The Detroit Edison Company, Detroit, Michigan, undertook an intake entrainment study at their Monroe Power Plant. One aspect of the study was to determine if any differences existed in entrainment rates of fish larvae and invertebrates between periods of daylight and darkness and the 1 and 3 m levels in the intake channel. This paper will present the results of sampling from December 1975 to December 1976 to determine diurnal and depth differences in entrainment rates of fish larvae and invertebrate groups.

Study Location

The Monroe Power Plant is a 4 unit, coal-fired electric generating station with a maximum expected net capacity of 3,150 Mwe (megawatts). It is located on the western shore of Lake Erie just south of the confluence of the Raisin River between Brest and LaPlaisance bays. The plant is approximately 61 km southwest of Detroit, Michigan, and 27 km northeast of Toledo, Ohio. Water used for the once-through cooling is drawn from the Raisin River through a 213 m long, 11 to 33 m wide, intake canal. The canal branches to provide water to two identical 8 bay screen houses each servicing 2 units (Figure 1). The depth of the intake canals varied with normal, high and low water flow and low wind tide from 6.9 m, 5.3 m and 3.1 m, respectively.

Methods and Materials

Eight 530 1/min Kenco Model 139 submersible sump pumps were fitted with 5.1 cm diameter flexible hoses and water was pumped through a 1-x-3 m oceanographic plankton net with mesh size of 571μ. The samples were collected from 6 AM to 6 PM and 6 PM to 6 AM from pump locations B, C, D, E, F and G (Figure 1). A 1.5 m head was usually maintained and provided a measured flow of approximately 530 1/min. This flow yielded a 381,600 liter sample for each 12-hour period. The samples were removed after 12 hours, preserved with 10 percent formalin and returned to the laboratory for sorting and identification.

All entrained fish were categorized as egg-larvae, yolksac larvae, larvae or prejuveniles. To facilitate data reduction the first category was considered as
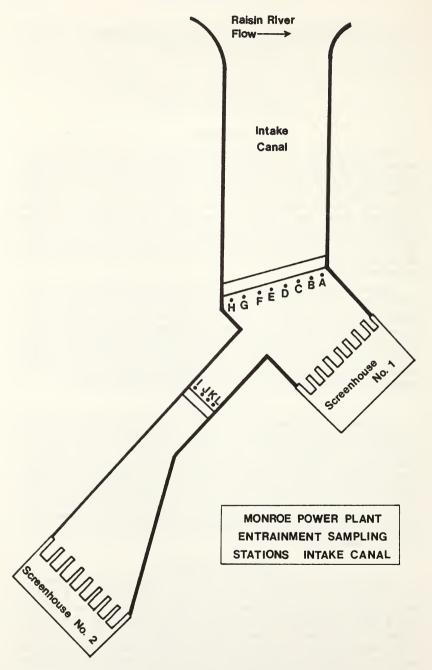
FIGURE 1.

"eggs", and the last two as "larvae". Yolksac larvae were retained as a separate category.

The SAS statistical package GLM analysis of variance program and Duncan/Waller multiple comparison test was used to determine if significant diurnal periods and diurnal period x depth interaction differences occurred for fish larvae and invertebrate groups.

Results and Discussion

Table 1 presents the difference in mean 12 hour collections for combined land 3 m samples. There were significant differences in collections for 6 of 11 categories of fish larvae. In these categories there were significantly higher numbers of yolksac larvae and larvae collected during the 6 PM and 6 AM period than the 6 AM to 6 PM period. Although significantly more perch, *Perca flavescens*, yolksac larvae were collected between 6 AM to 6 PM there was no significant difference between periods for perch larvae. There were also no significant differences between periods for Clupeidae (alewife, *Alosa pseudoharengus*, and gizzard shad, *Dorosoma cepedianum*), yolksac larvae smelt, *Osmerus mordax*, walleye, *Stizostedion canadense*, carp, *Cyprinus carpio*, and channel catfish, *Ictalurus punctatus* yolksac larvae and larvae.

TABLE 1. *Comparison of diurnal differences in mean 12 hour entrainment rates for fish larvae and invertebrate groups at the Monroe Power Plant, Monroe, Michigan. (PM and AM represent 6 PM to 6 AM and 6 AM to 6 PM, respectively).*

	Total yolksac larvae		Total invertebrates	
Time period	PM	AM	PM	AM
Number of samples	57	33	108	105
Mean	15.3	6.8	105.5	15.5
	Total larvae		Chironomid larvae	
Time period	PM	AM	PM	AM
Number of samples	60	39	93	76
Mean	31.9	11.5	9.6	6.2
	Total yolksac larvae and larvae		Chironomid pupae	
Time period	PM	AM	PM	AM
Number of samples	66	48	97	84
Mean	44.2	14.0	96.1	9.3
	Clupeidae larvae		*Gammarus* spp.	
Time period	PM	AM	PM	AM
Number of samples	51	29	68	37
Mean	36.0	13.5	4.6	2.1
	Perch yolksac larvae		*Chaoborus* spp.	
Time period	PM	AM	PM	AM
Number of samples	16	9	26	11
Mean	5.4	2.8	16.7	3.2
	Perch larvae		Ephemeroptera	
Time period	PM	AM	PM	AM
Number of samples	10	20	42	20
Mean	2.5	2.0	3.0	1.6
	Carp yolksac larvae		Trichoptera	
Time period	PM	AM	PM	AM
Number of samples	50	25	32	31
Mean	14.7	6.8	3.6	3.6

There were significant differences in collections for 6 of 8 categories of invertebrates. In these categories there were significantly higher numbers of invertebrates collected during the 6 PM to 6 AM period than the 6 AM to 6 PM period. There were no significant differences between periods for Trichoptera and Odonata groups.

Table 2 presents the differences in mean 12 hour collections for diurnal period x depth interaction. Significant differences are displayed utilizing underscoring of the same or different mean values. In the category total yolksac larvae *17.4 13.4 8.1 5.1* indicates *17.4* and *13.4* are significantly different from each other and from 8.1 and 5.1 (at P ≤ 0.05 level). The single underscore beneath *8.1 5.1* indicates that although the values are significantly different from *17.4* and *13.4* they are not significantly different from each other. In all categories of yolksac larvae and larvae, significantly greater numbers were collected during the 6 PM to 6 AM period. Total yolksac larvae showed significantly larger numbers were collected in the 3 m samples while for total larvae significantly higher numbers were collected in the 1 m samples. When both these categories were combined there was no significant difference between depths. There were no significant differences in col-

TABLE 2. *Comparison of diurnal x depth interaction differences in mean 12 hour entrainment rates for fish larvae and invertebrate groups at the Monroe Power Plant, Monroe, Michigan. (PM and AM represent 6 PM to 6 AM and 6 AM to 6 PM, respectively).*

	Total yolksac larvae				Total invertebrates			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	3	1	3	1	3	1	3	1
Number of samples	27	30	19	14	54	54	53	52
Mean	17.4	13.4	8.1	5.1	120.5	90.5	19.9	10.9
	Total larvae				Chironomid larvae			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	1	3	3	1	3	1	3	1
Number of samples	29	31	19	20	48	39	45	37
Mean	38.0	26.1	12.1	11.0	12.1	7.6	7.0	4.8
	Total yolksac larvae and larvae				Chironomid pupae			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	1	3	3	1	3	1	3	1
Number of samples	34	32	23	25	47	50	43	41
Mean	44.3	39.9	16.6	11.6	107.3	85.6	11.9	6.7
	Clupeidae larvae				*Gammarus* spp.			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	1	3	1	3	3	1	3	1
Number of samples	25	26	14	15	38	30	23	14
Mean	42.5	29.7	14.8	12.3	6.0	2.8	2.3	1.7
	Carp yolksac larvae				*Chaoborus* spp.			
Time period	PM	PM	AM	AM	PM	PM	AM	AM
Depth (m)	3	1	3	1	3	3	1	1
Number of samples	23	27	14	11	11	6	15	5
Mean	15.9	13.7	7.3	5.5	34.6	4.5	3.6	1.6
					Ephemeroptera			
Time period					PM	PM	AM	AM
Depth (m)					3	1	3	1
Number of samples					26	16	14	6
Mean					3.3	2.4	1.7	1.3

lections for diurnal period x depth interaction for smelt, walleye and channel catfish yolksac larvae or larvae and carp larve.

In all categories of invertebrates significantly greater numbers of invertebrates were collected during the 6 PM to 6 AM period and, except for Ephemeroptera, the 3 m depth samples collected significantly higher numbers of invertebrates than the 1 m depth. There were no significant differences for Trichoptera and Odonata groups.

Conclusions

Kelso and Milburn (1979) estimated annual entrainment rates for each Laurentian Great Lake based upon a derived regression formula between power plant size and number of larvae entrained and found it to be relatively strong (r = 0.63). They stated that it is apparent that numbers entrained increased with increasing power plant size and although local deviations may exist, entrainment is in direct relation to plant size and consequently cooling water volume. While I don't dispute this rationale, I suggest that based upon the data presented in this paper concerning differences in diurnal periods and diurnal periods x depth sampling that the use of annual entrainment rates for a single plant, much less for an entire lake, could be misleading unless these local deviations are taken into consideration during the calculations.

Literature Cited

1.   KELSO, J. R. M., and G. S. MILBURN. 1979. Entrainment and impingement of fish by power plants in the Great Lakes which use the once-through cooling process. J. Great Lakes Res., Internat. Assoc. Great Lakes Res. 5(2):182-194.