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Evaluation of the effectiveness of intake wedgewire screens

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Abstract

The Logan Generating Plant (LGP), owned and operated by US Generating Company, is located on the shore of the Delaware River in New Jersey. It withdraws make-up water from the river to replace evaporative water losses from its closed-cycle cooling tower system. The intake is equipped with two intake conduits that are situated perpendicularly to the current and terminate on the river bottom at depth of approximately 3 m. The intake terminuses are covered by cylinders constructed of 1-mm wedgewire screen.

The LGPs intakes are located in an area of the river where striped bass spawn and rear. Previous studies determined that without screening, the plant would withdraw less than 0.03% of the study area's striped bass. LGP was required to conduct an intake screen performance test to document the plant's entrainment of striped bass eggs and larvae.

Entrainment samples were collected from water filtered through the wedgewire screens. Source water body samples were collected from three transects in the river: one upriver, one down river, and one directly in front of the plant. Sampling at the transect in front of the intake was coordinated to occur at the same time as entrainment sampling.

The densities of striped bass larvae in the source water body and in entrainment samples were used to estimate proportional withdrawal. The study found that the wedgewire screens performed better than expected. The average proportional withdrawal of striped bass larvae was 0.003%, an order of magnitude less than the estimate for an unscreened intake.

Keywords: Wedgewire screens; Entrainment; Proportional withdrawal; Delaware River; Larval fishes

1. Introduction

The Logan Generating Plant (LGP), formerly Keystone Cogeneration Power Plant, is situated on the Delaware River in Logan Township, Gloucester County, New Jersey (Fig. 1). It is located in an area of the river used by striped bass for spawning and rearing purposes. The Logan Plant uses water withdrawn from the river to replace evaporative water losses from its closed-cycle cooling tower system.

The plant was designed using the best available technology to minimize entrainment and impingement impacts. Closed-cycle cooling towers were built to reduce the amount of river water needed to operate the plant. The underwater intake (Fig. 2) utilizes cylindrical screens constructed of 1-mm wedgewire. These screens were placed parallel to the current to provide continuous flushing of the screens, thereby eliminating impingement concerns and reducing entrainment losses. The intake screen openings were designed to limit screen approach velocity to a maximum of 0.15 m/s (0.5 fps).

Pre-construction studies were conducted to determine the densities and distribution of fish eggs and larvae in the vicinity of the power plant (Biosystems Analysis, Inc., 1990a,b). Three sampling transects were established: one was located upriver of LGP, one was aligned with the plant's fuel loading dock, and one was located down river of the plant. Each of the three

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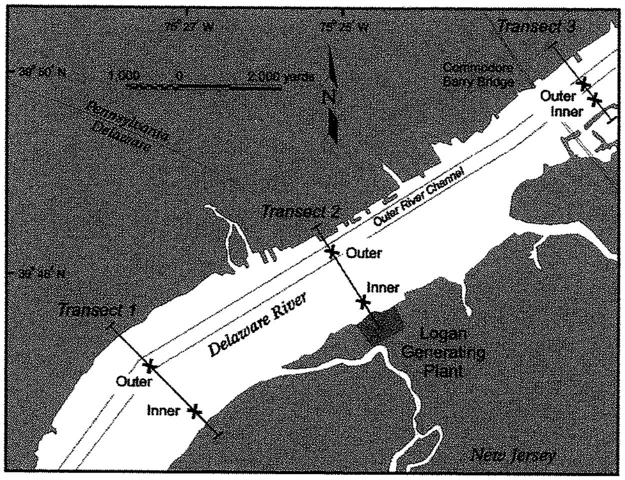

Fig. 1. Location of Logan Generating Plant and study areas.

transects had an inner (shallow) and outer (channel) sampling station. Results of this study estimated that an unscreened intake would entrain approximately 0.03% of the local striped bass larvae (Biosystems Analysis, Inc., 1990a).

LGP was required to conduct an intake screen performance study. The purpose of the study was to document the plant's entrained striped bass densities. The study also sought to verify that the operational larval striped bass entrainment rate was less than or equal to that predicted in the 1990 study. In order to accomplish this, samples would have to be collected from both the source water and also from water that had passed through the wedgewire screens at the plant. The only method to sample entrainment at LGP was to pump water from the plant's intake wet well. Source water samples were most effectively collected by towing a plankton net at varying, representative water depths of 10, 8.5, and 6.5 m.

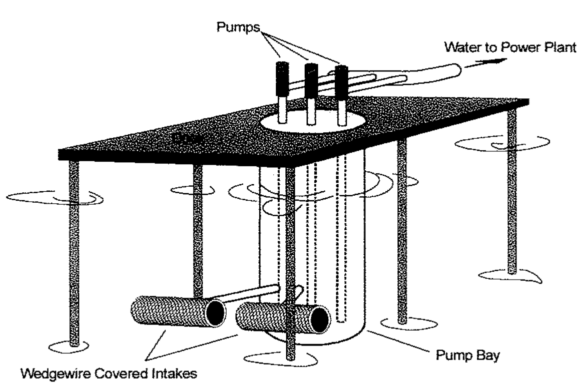

Fig. 2. Artist rendition of the Logan Generating Plant's intake structure.

2. Gear comparison study

A gear comparison study was designed to investigate the possibility of differences between the sampling efficiencies of towing and pumping. The study was conducted in May and June 1993 during the period of peak striped bass spawning. Samples were collected as synchronously as possible to assure temporal representation in a comparative analysis of the intake and source water larval densities. Pumped samples were collected with a centrifugal trash pump mounted on a boat deck. The plankton tows were collected by towing a 30 cm diameter 335 μm mesh plankton net. These paired samples were collected from one boat traveling at a constant speed. Since the time necessary to collect a sample of equal volume was approximately twice as long for a pumped sample than for a towed net sample, the pumped sample was collected from a slightly different water mass. Sampling locations were the same as those used in the 1990 pre-construction study (Fig. 1).

All eggs and larval fishes were removed from the samples and identified to the lowest taxonomic level possible. All ichthyoplankton specimens were counted, and the life stage and condition of specimens were recorded. The densities of fish eggs and larvae were used to compare the performance of the pump vs towed nets.

3. Results and discussion

The results from 30 trials of towed net vs pump were compared using a single-sample, repeated-measures t-test. The mean ichthyoplankton density from the towed net samples was 0.98/m^3 (sd 1.64), with an upper 95% limit of the confidence interval of 1.59 and a lower limit of 0.36. The mean ichthyoplankton density sampled by the pump was 0.88/m^3 (sd 1.47), with an upper 95% limit of 1.44 and a lower limit of 0.32. The t-value from the comparison of the two means (0.53) was not significant at the 99% CL. The power of the one sample t-test was 8.8%, making this a relatively weak test.

Results of the gear comparison study also provided information on the density and composition of ichthyoplankton. The most abundant species collected in the deep (9 m) stations were striped bass, constituting 39% of the total catch, followed by white perch (28%), minnows/carps and suckers (19%), and herrings (13%). In the shallow 1 m deep stations herrings dominated the catch (80%), followed by white perch (17%), striped bass (2%), and minnows/carps and suckers (1%).

4. Intake screen performance study

In 1994, LGP began commercial operation and the intake screen performance study was scheduled to occur during the striped bass spawning season of 1995. The operational study sought to verify that the larval striped bass entrainment rate was less than or equal to 0.03% of the average density of larval striped bass found in the study area during the May–June striped bass egg and larval season.

Samples of entrained ichthyoplankton were collected at the intake from the plant's wet well (pump bay) after the water had flowed through the wedgewire screens. The same centrifugal pump used in the gear comparison study was used in the intake screen performance study. Pumped water volumes were measured by an inline flowmeter located in the discharge line of the sampling pump. The water emptied into a 335 μm mesh plankton net that was suspended in a water filled plastic tank which lessened abrasion of the larvae. Every hour the material in the net was rinsed into a screen-walled collection container. This material was put into labeled jars and preserved.

Samples of source water ichthyoplankton were collected by towing a plankton net at three transects in the river. The transects were the same ones sampled in both the pre-construction and the gear comparison studies (Fig. 1). Each of the three transects had an inner shallow and outer (channel) shallow and deep sampling stations. Samples were collected from approximately a 1 m depth at the shallow location for both the inner and outer stations of each transect. Samples at the shallow stations were collected by towing the net at the prescribed depth for a total of 5 min. Deep samples were collected at each of the outer sampling locations from a combination of three depths: 10, 8.5, and 6.5 m. All samples were collected with a 30-cm diameter, 335 μm mesh plankton net equipped with an close-open-close system designed to allow for the collection of samples at discrete depths. The net was towed in the direction of the prevailing current for 1.6 min at each of the depths listed above, resulting in a total collection time of 5 min per tow. The closed net was first lowered to 10 m then opened and towed for the prescribed time. The open net was then raised and this procedure was followed for the other two depths. The net was then closed and retrieved. The samples from each tow were labeled and preserved.

Sampling was scheduled to occur during the period of peak larval striped bass activity. A total of six weekly surveys were conducted between 4 May 1995 and 8 June 1995. Entrainment samples were collected from eight, 1-hour sampling periods. River sampling was scheduled so that Transect 2, located directly offshore of the plant, was sampled simultaneously with entrainment sampling. A total of four surveys per day was completed at Transect 2 and two surveys were completed on both Transects 1 and 3. Transects 1 and 3 were sampled in between the entrainment sample collection times.

Striped bass eggs and all larval fishes were identified and enumerated. When possible, all fishes were identified to the species level. A determination of the condition (live or dead) upon collection of the striped bass eggs was noted at the time of sorting. This information was then used to compute the estimated daily average density of striped bass eggs and all fish larvae for both entrainment and river samples.

The larval striped bass density estimates were employed in a similar formulation of proportional withdrawal estimated in the pre-construction study of the generating plant's predicted impact on the source water striped bass larvae (Biosystems Analysis, Inc., 1990a). The formula was modified slightly because the earlier study did not have an estimate of the larvae entrained.

$$P = \frac{\mathrm{sum}(A_{\mathrm{p}}Q_{\mathrm{p}})}{\mathrm{sum}(A_{\mathrm{r}}Q)}$$

P is the proportion of larvae withdrawn (entrained), A_{p} is the daily average density of the striped bass larvae entrained, A_{r} is the cross-sectional daily average abundance of larvae, Q_{p} is the flow rate into the plant, and Q is the freshwater flow in the river. A_{r} was determined by multiplying the cross-sectional area of the river in front of the plant in the shallow depth (to 1 m) by the average density of the striped bass larvae in all of the shallow samples collected on each day. A similar value was calculated for the deeper depth, using the cross-sectional area in the deeper depth and the average larval density in the deeper samples. The shallow and deep values were combined to estimate the abundance of larvae passing by the plant. The values of Q_{p} and Q were estimates of the water flow.

Table 1
Estimated proportional withdrawal of larval striped bass during this study

Date	Proportional withdrawals (%)
4/5/1995	0.0053
11/5/1995	0.0079
18/5/1995	0.0030
25/5/1995	0
1/6/1995	0
8/6/1995	0

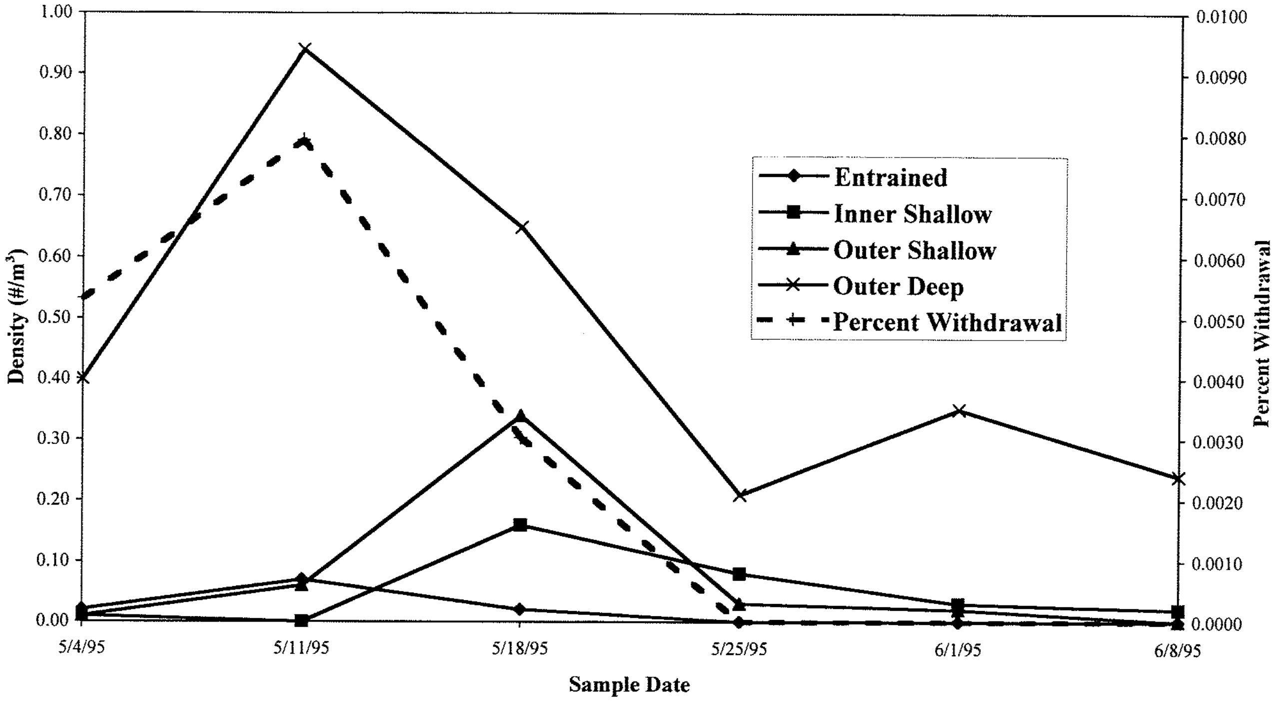

Fig. 3. Percentage withdrawal and mean densities of striped bass larvae from entrainment samples and collected from Transects 1–3 during the 1995 study.

5. Results and discussion

The densities of striped bass larvae measured in the Delaware River source water and those sampled in the plant's makeup water were used to estimate the proportional withdrawal of striped bass larvae from the river (Table 1). The original formulation assumed that the plant's withdrawal rate would be 0.32 m^3/s and the

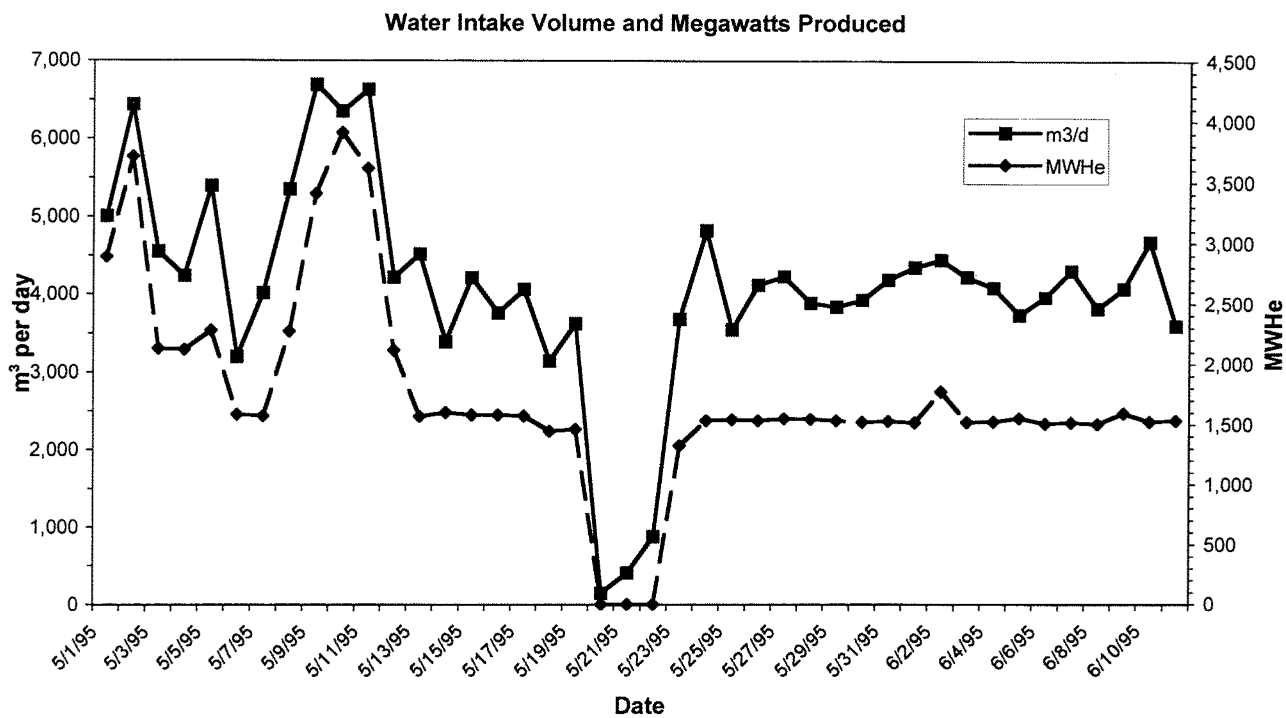

Fig. 4. Logan Generating Plant daily water withdrawal and electrical generation.

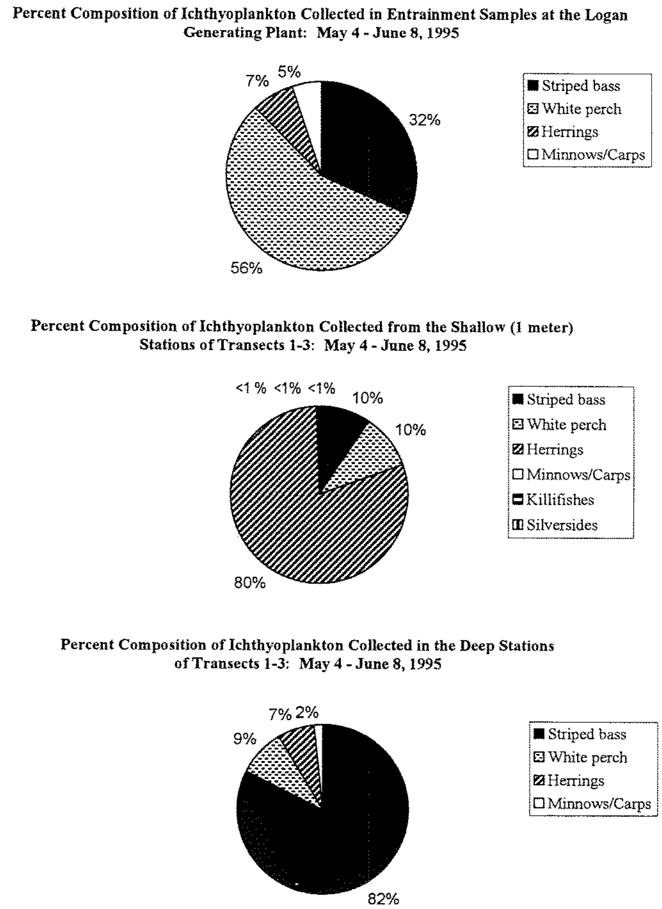

Fig. 5. Species composition of ichthyoplankton entrained and collected on the transects.

river flow would average 332 m^3/s. Based on the preconstruction ichthyoplankton survey of striped bass larvae, it was estimated that the generating plant would withdraw less than 0.03% of the supply of source water body striped bass larvae even without the intake screens. The intake screens were expected to exclude up to 90% of the striped bass larvae.

The results of the 1995 intake screen performance study demonstrated that the plant's intake screens performed as well as, or better than, expected. The entrainment tests found that the plant's average proportional withdrawal of striped bass larvae was at least an order of magnitude below the predicted licensing and permitted level of 0.03%. The calculated proportional withdrawal of striped bass larvae summed over the 6 weeks during the intake screen performance study was 0.003%.

The proportional withdrawal among surveys varied with the deep channel densities of striped bass larvae, as illustrated in Fig. 3. The proportional withdrawal increased, as density of the striped bass larvae increased in the channel depths, to a peak of 0.9/m^3 in the 11 May survey and then declined with the density of striped bass larvae in the channel depths during the 18 May and 25 May surveys. These results suggest a relationship between the deep water densities of striped bass larvae and the entrainment of larvae; seemingly a contradiction in the generally observed pattern of low shallow-water densities of larval striped bass, including the shallow area of the generating plant's intake. The general pattern of increasing striped bass larval densities, from shallow to deep habitat in the study area, had been observed in other ichthyoplankton studies (Biosystems Analysis, Inc., 1990a,b; Army Corp of Engineers, 1992; Versar, Inc., 1992; Tenera, Inc., 1996). This finding may be a consequence of deepening the area in front of the intakes as a result of dredging for a coal barge basin. It is not known whether the effect has been that deeper water is drawn from the channel opposite the shoreline of the intake, or larvae, that apparently prefer the deeper water habitat, are attracted to it. In either case, the studies have demonstrated that the generating plant has easily met its proportional withdrawal objective and is protective of the area's larval striped bass resources. This condition was also apparent when the actual 1995 river flows and planned makeup water usage were used in an estimate of the plant's percent proportional withdrawal of the Delaware River's striped bass larvae.

The potential influence of the plant's varying intake velocities on entrainment rates of larval fishes was tested. The ratio of the larval fish density in the area of the intake to the densities of entrained striped bass larvae was compared to the generating plant's daily cooling water intake volumes. The plant's cooling-tower makeup-water withdrawals from 1 May to mid-June 1995 are presented in Fig. 4. There was no significant correlation between the average density of larval fishes or larval striped bass entrained by survey and the daily volumes of cooling water withdrawn on the survey dates. On three of the six survey dates the den-

Table 2
Range of total ichthyoplankton densities (#/m^3) from the Delaware River samples. The dates of peak abundance are in parentheses

Location	Channel deep	Channel shallow	Inner shallow
Transect 1	0.15–0.50/m^3 (18 May)	0.03–0.60/m^3 (25 May)	0.00–0.79/m^3 (1 June)
Transect 2	0.24–2.10/m^3 (11 May)	0.02–1.22/m^3 (1 June)	0.02–1.59/m^3 (8 June)
Transect 3	0.22–0.91/m^3 (18 May)	0.00–2.32/m^3 (25 May)	0.00–1.07/m^3 (8 June)

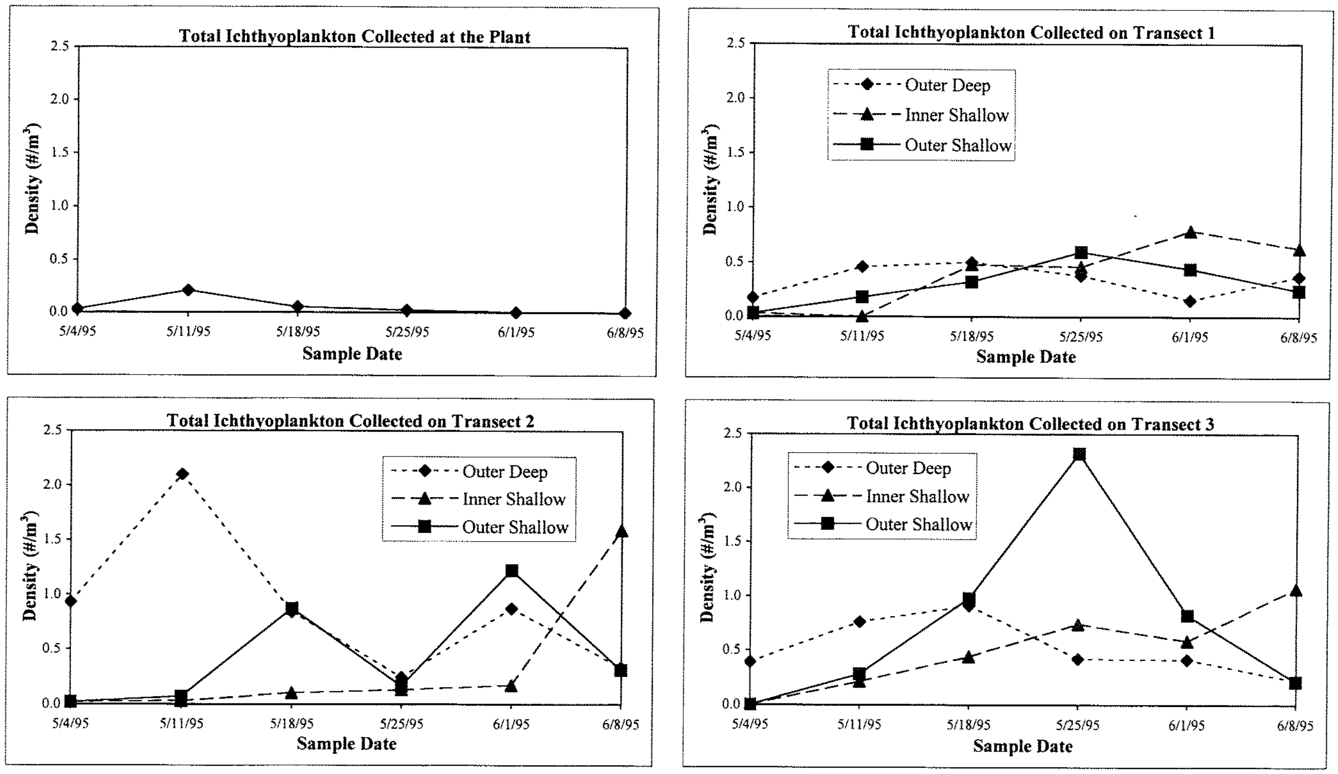

Fig. 6. Density of total ichthyoplankton entrained and collected from transects.

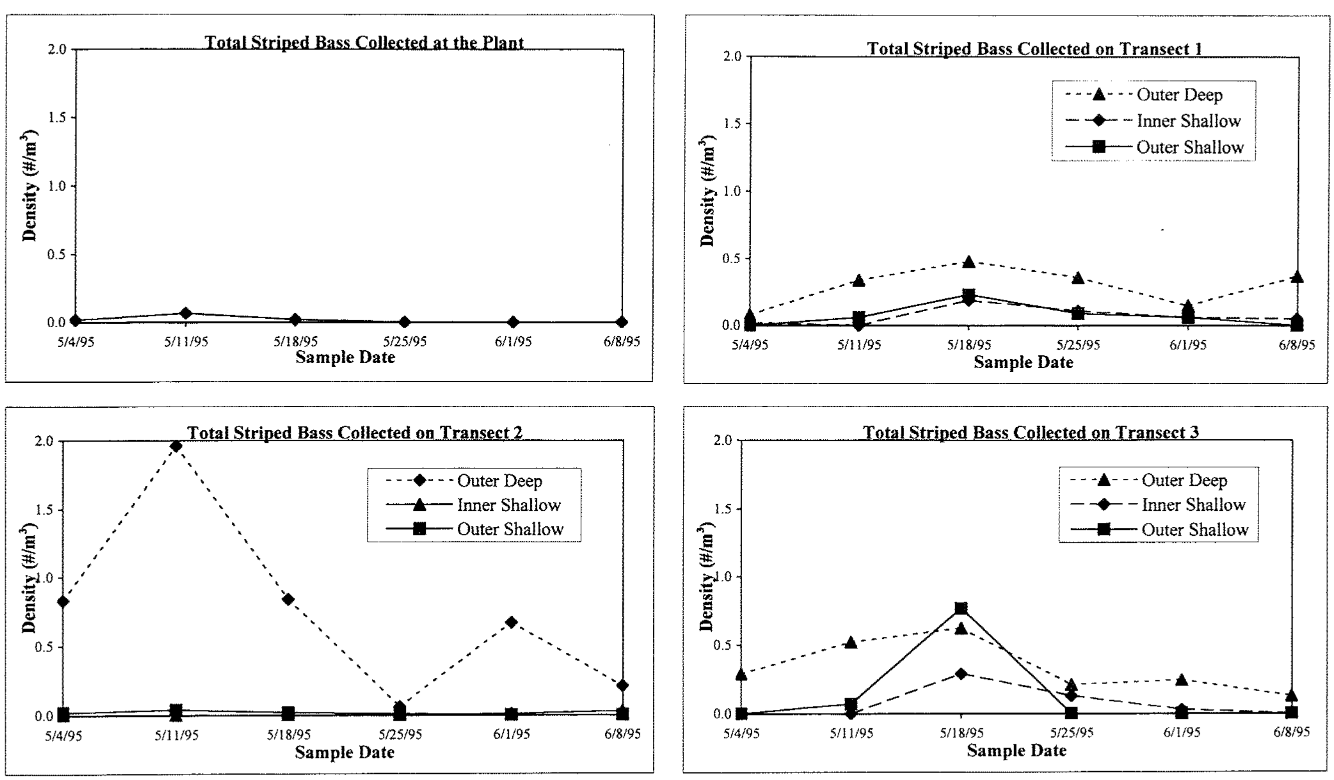

Fig. 7. Density of striped bass entrained and collected on the transects.

Table 3
Range of striped bass density (♯/m^3) from the Delaware River samples. The dates of peak abundance are in parentheses

Transect	Channel deep	Channel shallow	Inner shallow
Transect 1	0.08–0.48/m^3 (18 May)	0.00–0.23/m^3 (18 May)	0.00–0.19/m^3 (18 May)
Transect 2	0.06–1.96/m^3 (11 May)	0.00–0.04/m^3 (11 May)	0.00–0.03/m^3 (8 June)
Transect 3	0.13–0.62/m^3 (18 May)	0.00–0.77/m^3 (18 May)	0.00–0.29/m^3 (18 May)

sity of entrained striped bass larvae was zero, although they were present in the samples collected in the river. The plant was essentially off-line, with respect to makeup-water usage, from 21 May to 23 May. During the entrainment study period, the plant was operated at an average of 25% capacity due to generally low electricity demand at that time of the year. During the same period of time, the daily amounts of makeup-water withdrawals, as illustrated in Fig. 4, were also 25% or less of the generating plant's permitted maximum amount of 26,460 m^3/day (7 million gallons/day).

Results of the screen performance study also provided information on the density and composition of ichthyoplankton. A total of 1315 larval fishes were collected in the 1995 study: 435 from the deep channel stations, 839 from the shallow stations, and 41 from the entrainment samples. Species composition is presented in Fig. 5. Striped bass were the most abundant taxa collected in the deep stations, constituting 82% of the total catch, followed by white perch (9%), herrings (7%), and minnows/carps (2%). In the shallow stations, herring dominated the catch (80%), followed by white perch (10%) and striped bass (10%). Minnows/carps, killifishes, and silversides represented less than 0.5% of the total catch. White perch were the most abundant taxa entrained (56%), followed by striped bass (32%), herrings (7%), and minnows/carps (5%). White perch, striped bass, and members of the Clupeidae (herrings) and Cyprinidae (minnows and carps) families were the most commonly collected larval fishes in the 1995 study. Densities of total ichthyoplankton for the entrainment collections and the plankton tows are presented in Fig. 6. Generally higher densities of larval fishes were found at Transects 2 and 3, and the lowest densities were found at the entrainment location. A summary of the range of densities at the sampling locations on the three transects is shown in Table 2.

The plant's entrainment samples contained fish larvae in only the first 4 weeks of the sampling period. No entrained larval fishes were observed in the last 2 weeks of the study, even though larval fishes were collected in the river samples. Densities of total ichthyoplankton in the entrainment samples ranged from 0.02/m^3 to 0.21/m^3 during the first four surveys.

Densities of striped bass were calculated for the river samples. Sampling results showed that striped bass were only entrained in the first 3 weeks of sampling (Fig. 7). No striped bass were found in the entrainment samples during the last 3 weeks, but they were present in the river samples. Table 3 presents the range of striped bass densities at the sampling locations on the three transects.

6. Conclusion

The study's findings showed the densities of striped bass larvae in the vicinity of the generating plant were generally higher in the deep channel water than in the shallow, corroborating earlier reports and the findings of other investigators. The density and distribution of larval fish species in the study also corresponded well to other researcher's findings that larvae, other than those of striped bass, were more common in the study area's shallow water habitat than in the deep channel habitat. The timing of the peak egg and larval abundance of striped bass in the study generally agreed with the expected beginning and end of the species spawning season in the Delaware River.

The Logan Generating Plant's cooling water intake facility has proven to be effective in meeting its original design criteria to reduce the entrainment of striped bass. This study has shown that the use of wedgewire screens were effective at reducing the proportional withdrawal of striped bass larvae by an order of magnitude less than the estimate for an unscreened intake. The successful performance of the generating plant's intake screen technology, when combined with the shallow water location of the intakes, has achieved a high level of resource protection for the power plant's use of river water.

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