Institute of Environmental Medicine

MORTALITY OF STRIPED BASS EGGS AND LARVAE IN NETS

A SPECIAL REPORT

to

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

PREPARED BY

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MORTALITY OF STRIPED BASS EGGS AND LARVAE IN NETS

Introduction

The Hudson River has a number of steam electric generating stations in zones inhabited or used by important sport and commercial fishes. This has spurred intensive monitoring programs of Hudson River biota and the development of sophisticated mathematical models to predict the environmental impact of power plants. Most attention has been paid the striped bass (*Morone saxatilis*) because of its value as a ~~sport and commercial~~ fishery.

New York University has been conducting ichthyoplankton entrainment studies for Consolidated Edison Company of New York at the Indian Point Nuclear Power Plant since 1971. There has been found in these studies a significantly higher mortality of striped bass eggs and larvae in the discharge canal (after passage through the plant's cooling system) compared to the plant's intake (NYU, 1973, 1974). These viability estimates were based on the assumption that survival of the organisms, when captured by nets, was the same in the discharge canal as in the intakes, and that the mortality caused by nets was of no significance.

In past power plant entrainment studies little attention was paid the damage to organisms from the sampling gear; however, since failure to account for net-induced mortality may result in excessively high impact assessments, a number of workers have recently devised sampling gear designed to minimize net mortality. Mathiesson (pers. comm.) attempted to sample fish eggs and larvae in the vicinity of the Pilgrim Nuclear station using an air-life pump mechanism designed to minimize the velocity at which ichthyoplankton would impact with the filtering surface of nets. Preliminary results indicated no increase in survival for ichthyoplankton collected by this method. Lawler, Matusky and Skelly Engineers, studying entrainment of ichthyoplankton at Hudson River power plants, constructed a larval sampling device based upon the concept of progressive separation of suspended particulates. This technique, under study since 1974, has proven successful in reducing net-induced mortality. Studies undertaken in our own laboratory in 1974 (NYU, 1976) were directed toward decreasing the volume of water filtered by a 0.5 m plankton net sampling in the Indian Point discharge canal, where velocities between 3 feet per second (61 to 91 cm per second) may occur. Sheet-metal cones were designed to reduce the volume of water entering the plankton net, thereby reducing velocity at the filtering surface and ameliorating damage to ichthyoplankton in the net. Although field-tests of velocity reduction cones were not conclusive in relation to reduction of velocity or to increase of survival, velocity reduction cones were used in entrainment studies at Indian Point throughout 1974 and 1975 since preliminary test results showed no increase in mortality of ichthyoplankton due to the cones.

Consolidated Edison, through contract with the Alden Research Laboratory of Worcester Polytechnic Institute, constructed an experimental flume for the express purpose of evaluating the efficacy of devices designed to reduce fish impingement at the Indian Point generating station (Stone and Webster, 1975). The dimensions and controlled flow characteristics of the experimental flume allowed for the design and implementation of a program to test the critical assumptions associated with field programs to determine cross-plant survival of ichthyoplankton entrained at Indian Point. This study has been designed to test parameters crucial to impact studies: net mortality; velocity effects on mortality; net retention of organisms; stage differences in net survival; and the effect of time in the net on short-term and latent viability.

Methods and Materials

The experimental work was carried out during May and June, 1975, in Consolidated Edison's water flume, located at the Alden Research Laboratories, Holden, Massachusetts. Nets were set in the 40-foot long canal section which was 6 feet wide and 6 feet deep (Figure 1). For full details of the flume design see Stone and Webster (1975). Flow was found to be uniformly distributed in the canal at the point of testing by measurement with an Ott flowmeter. The desired water velocity for testing was controlled by varying the speed of a diesel-drive bow-thruster pump. Velocities of approximately 15, 45, and 91 cm sec, (0.50, 1.50, and 3.00 feet per second (fps)) were used throughout the study.

Sampling gear used in tests at the flume were identical to the gear employed in gathering ichthyoplankton samples for viability estimates at the Indian Point intake and discharge stations (NYU; 1973, 1974). The geometry of intake and discharge nets differed due to the limited space available for sampling in the Unit 2 intake forebays; intake nets were 4 feet (1.22 m)

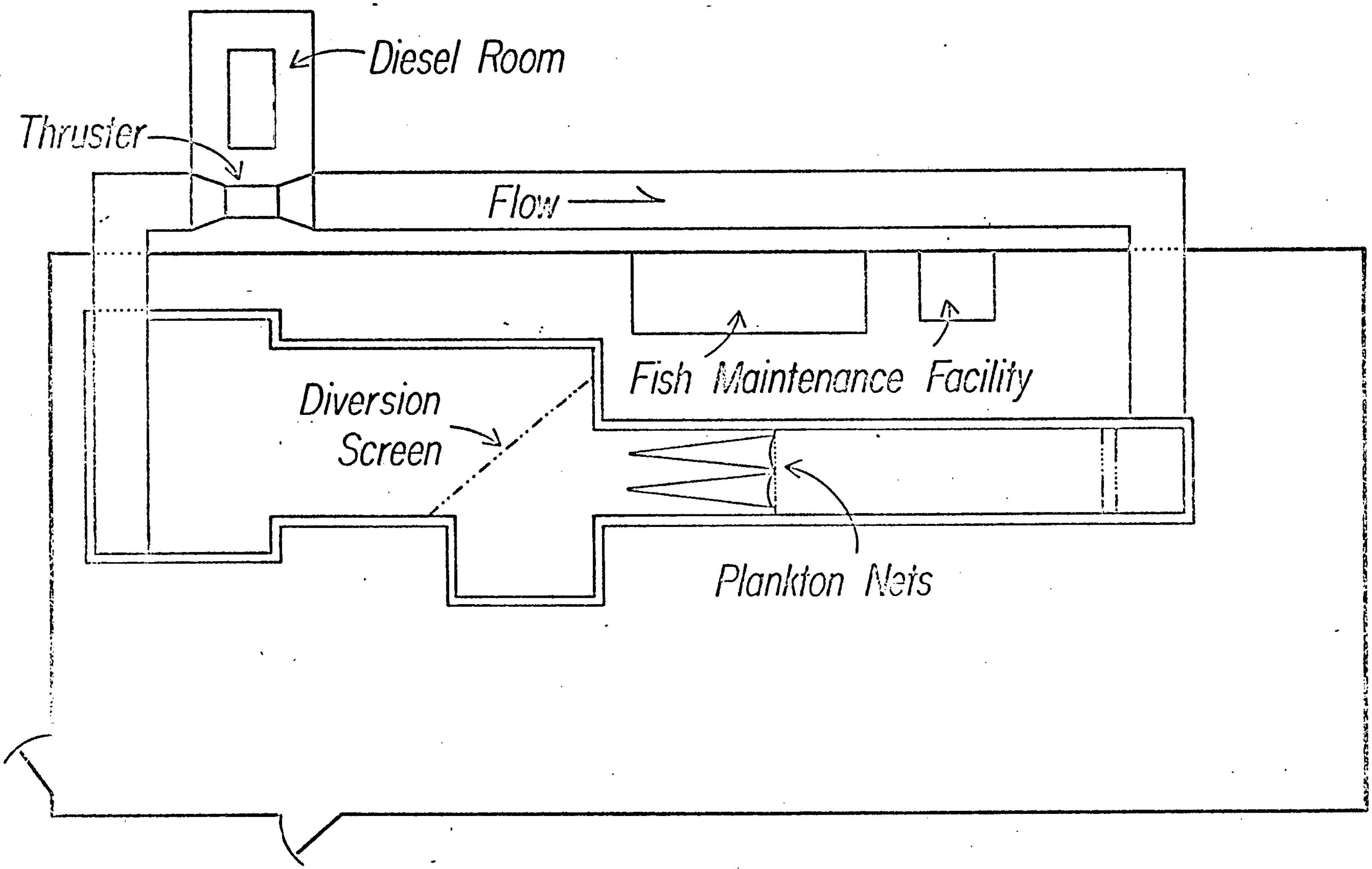

Figure 1. Plan view of the Consolidated Edison experimental flume located at Alden Research Laboratories, Holden, Massachusetts.

from mouth-to-cod end whereas discharge nets were 6 feet (1.83 m) from mouth-to-cod end. Intake and discharge nets both had a mouth opening of 1.6 feet (0.5 m) and most testing was carried out using a conical net constructed of 0-gauge nylon (mesh size = 571μ). Some testing was carried out using nets constructed of silk mesh (500μ mesh). The objective in testing silk-fiber nets was to determine whether the natural fiber would reduce net mortality. Preliminary testing, however, indicated no difference in survival between nylon and silk nets. ~~The majority of the~~ testing, therefore, was carried out using nylon nets, since they are used in entrainment sampling.

Studies of entrainment mortality at Indian Point (NYU, 1973) revealed that the differential in velocity of water flow at intake sampling stations and discharge stations may have some effect on ichthyoplankton survival in the nets.[1] In-plant studies in 1974, therefore, employed velocity reduction cones on discharge nets in an effort to reduce the velocity of water across the sampling surface to approximately 0.5 fps (15 cm/sec). The cones were fabricated from 0.75 gauge galvanized sheet metal and were tapered from 0.5 m (1.6 feet) to 0.35 m (14 in.) for use in the intakes, or from 0.5 m (1.6 feet) to 0.17 m (6.75 in.) for use in discharge flows of varying velocity. The cones used in the present study were primarily those having the 0.5 to 0.35 m taper (Figure 2). The choice of intake cones (0.5 to 0.35 m taper) for use in

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1. Intake velocities ∿0.1 to 0.7 fps (∿3.0 to 21.0 cm/sec). Discharge velocities under normal operating conditions ≥ 1.7 fps (52 cm/sec).

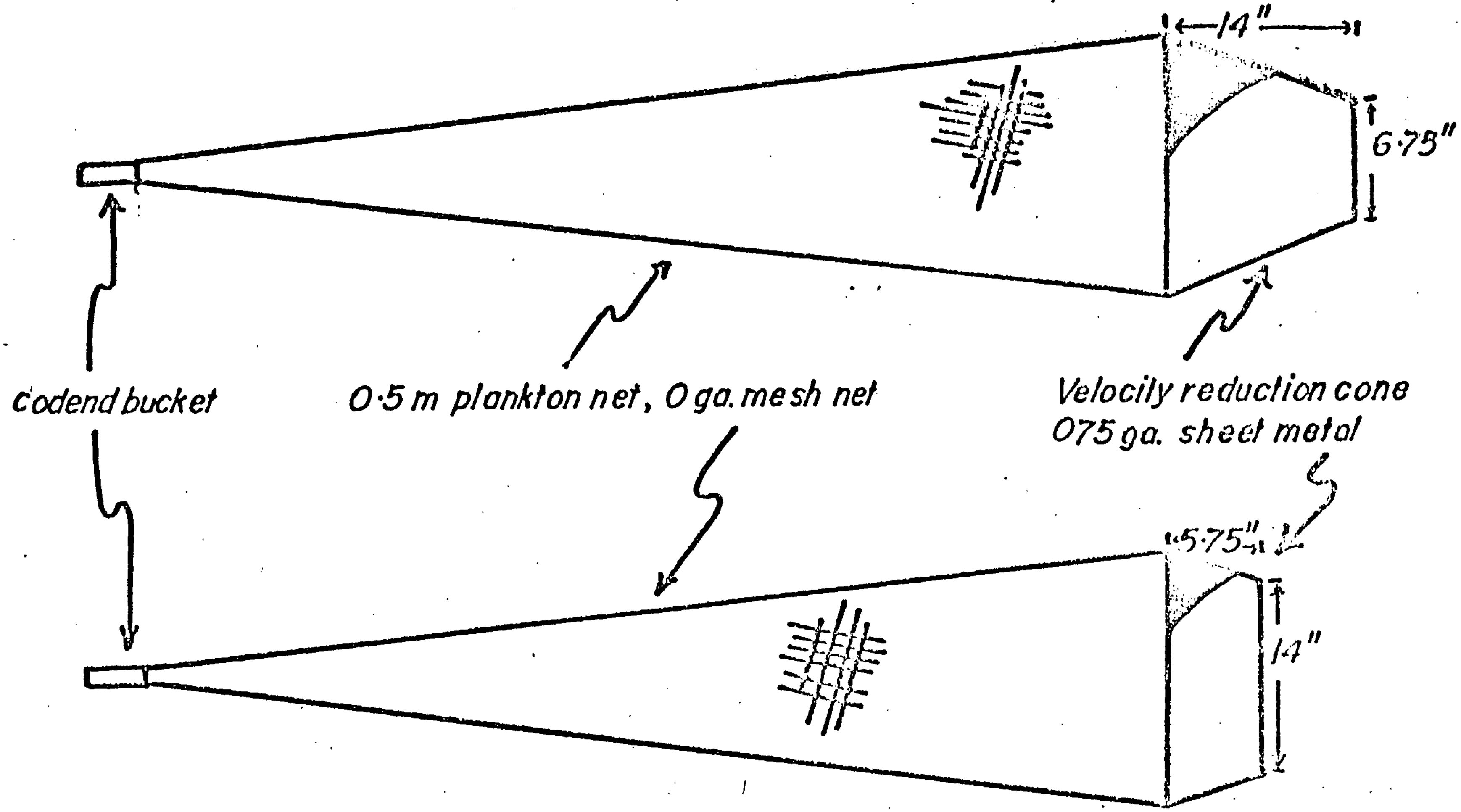


Figure 2. Schematic diagram of plankton nets equipped with velocity reduction cones of 14" and 6.75" mouth openings.

the present study was based upon the availability of cones which could be spared from the in-plant entrainment studies which were in progress at the time of the flume work.

The striped bass were obtained from Consolidated Edison's Verplanck Hatchery; all stages used in the flume study were derived from hatchery females number 12 and 16. Organisms were transported to the flume site in sealed 1-gallon plastic containers half filled with air-saturated water supplemented with oxygen. These containers were then placed in a plastic lined incubated chest to maintain a constant temperature. Upon arrival at the flume site the organisms were acclimated to local water conditions over a period of 3 to 6 hours and then transferred to brood-cages which were suspended in filtered recirculating water at 20° (72°F) ± 2°C. Mortality of life-stages maintained at the flume did not differ from that observed at the hatchery (total mortality from egg to juvenile 77% for female 12, 80% for female 16; data obtained from Texas Instruments).

The method used to examine the combined effects of our sampling gear and water velocity on striped bass eggs and larvae was to release living organisms directly into nets submerged in a water flow and observe the survival. Immediate and latent observations of the organisms' mortality were recorded along with retention of fish and eggs in the nets. Velocity measurements were taken with a digital flowmeter outside and inside the net in order to assess water flow characteristics to which the test organisms may be exposed.

The time-duration of sampling and velocities tested were chosen to reflect conditions representative of the intake and discharge sampling at Indian Point. Tests with each net were run at each of three velocities (0.5, 1.5 and 3.0 fps) for sampling times of 5 and 10 min. duration, with and without velocity reduction cones using, in independent tests, hatchery-reared striped bass eggs, yolk-sac larvae and larvae. Each test was replicated.

For each test the flume was adjusted to the desired velocity (measured prior to and during each test using an Ott digital current meter; A. Ott, Kempton, Germany). The nets were lowered into the water until the hoop was 8-12 inches below the water's surface. Test organisms, varying in number from 25 to 50 depending upon supply, were introduced into the nets underwater by release at the center of the mouth opening. A control group of organisms was held in a plastic bucket in 8 ℓ of flume water for the duration of each test.

Sample retrieval was carried out in a manner similar to that employed during in-plant entrainment studies. The nets were raised from the water, rinsed down by hose, and the cod-end bucket was placed in a bucket of flume water. The contents of the sample bucket were then emptied into a glass tray and counted; the numbers of live and dead organisms in the sample were recorded according to the following criteria:

live egg- chorion complete and clear; oil globule and/or embryo intact.

dead egg - chorion ruptured and/or opaque; oil globule and/or embryo ruptured.

live larva- swimming vigorously to some twitching or opecular movement.

dead larva- no vital life signs, no body or opecular movement, no response to gentle probing.

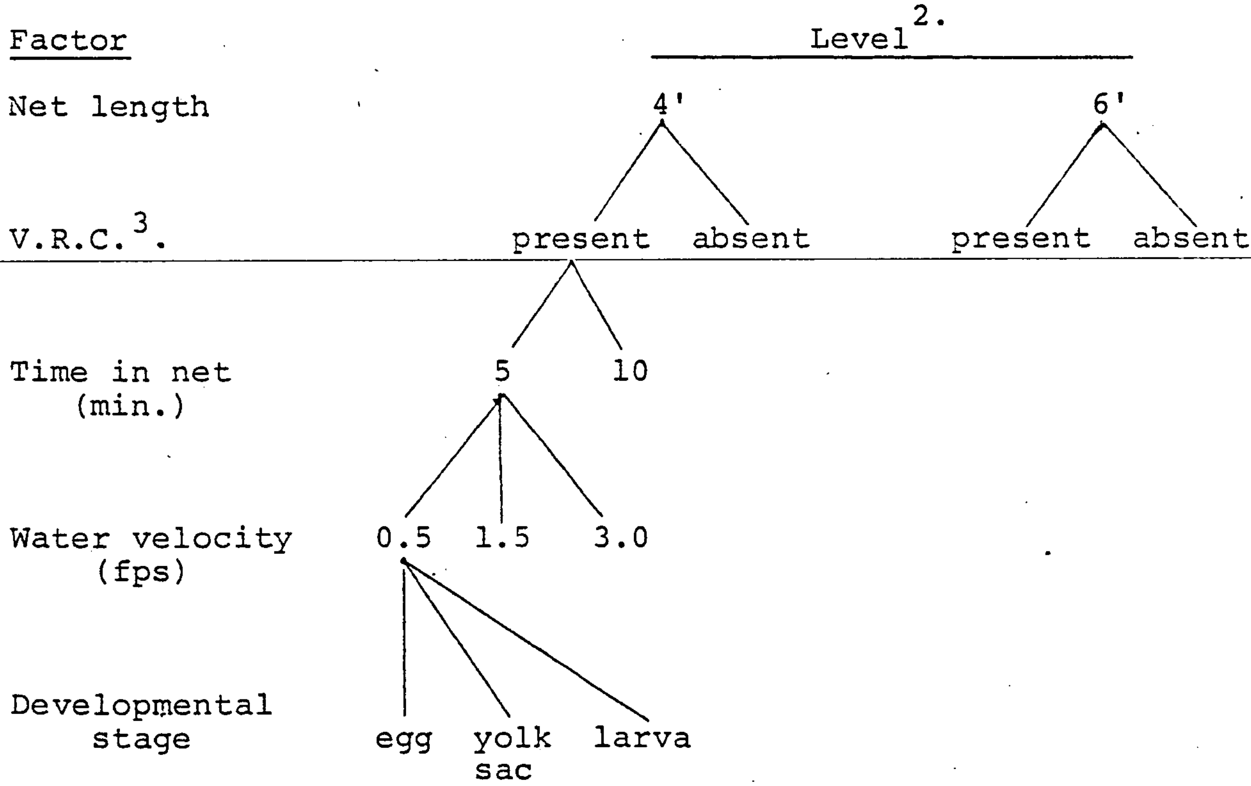
The organisms alive at the end of a test were held in filtered, recirculating water for periods up to 96 hr. for determination of latent mortality. Observations were made two times each day; any dead organisms were removed upon observation. The latent mortality experiments continued until either all the test fish died or until the 4-day period elapsed.

The experimental design was based on an hierarchical model of analysis of variance (ANOVA) in which each test parameter was considered nested within each level of all other parameters (Table 1; Simpson, Roe and Lewontin, 1960). Individual comparisons of paired factors, such as net length, time duration and cone vs. no cone, were tested by one-way ANOVA to determine whether data groups could be paired for inclusion in tests of survival effects due to velocity alone.

Results

The retention efficiency of gear tested in the experimental flume, determined by comparing numbers retained vs. numbers added in each test, was between 89 and 98% for all life history stages (Table 2), including special tests run with dead organisms to determine if dead organisms (presumably having attained some level of decomposition) were more subject to extrusion or washing out of the nets than live organisms.

Table 1. Experimental design for net mortality studies at the Con Edison flume, Alden Research Laboratories, Holden, Mass.[1]



1. Final test design. Considerations of silk-fiber nets were discarded after preliminary tests; see text for explanation.

2. Levels indicated are for purposes of illustration. Each factor was tested for each level in the excution of the design.

3. Velocity Reduction Cone.

Table 2. Summary of organism retention during flume studies. All speeds combined. Values presented are proportional retention ± 1 standard devistion

Life stage	no. experiments	Number placed in net	Number retained	Retention
Eggs	24	1177	1132	0.96±0.07
Yolk-sac larvae	24	1222	1092	0.89±0.11
Larvae (14-days)	30	1245	1175	0.95±0.06
Larvae (23-days)	19	593	584	0.98±0.03

Preliminary tests with eggs collected by silk nets showed that the natural fiber net caused mortality equal to or greater than the synthetic fiber (nylon) nets ($F_{7,7} = 1.53 \times 10^{-3}$; $P > 0.05$). Sufficient numbers of organisms in other developmental stages were not available for further evaluation of silk nets within the experimental design. Further testing was discontinued as it was deemed non-productive to evaluate the performance of gear not being used in actual entrainment work.

STRIPED BASS SURVIVAL

Striped bass egg survival was most strongly affected by the velocity of water (Table 3). At 0.5 and 1.5 fps, survival was approximately 80% with no difference in survival at the two velocities ($F_{11,3} = 1.4 \times 10^{-3}$; $P > 0.05$). At 3.0 fps, however, mortality was complete (Figure 3). Partitioning of the data to analyze for differences due to time ($F_{5,3} = 3.09$; $P > 0.05$) and net length ($F_{7,7} = 0.01$; $P > 0.05$) showed no differences. Tests for the effect of differing time in the net and different net geometry were not run at 3.0 fps.

YOLK-SAC LARVAE

Yolk-sac larvae (3 days post hatching) were found to be sensitive to velocity effects (Table 3), whereas other factors such as length of time in the net, net geometry and the effect of velocity reduction cones had no additional effect on survival ($P > 0.05$). At 0.5 fps mortality of test organisms was approximately 50%. Increasing velocity to 1.5 fps resulted in almost complete mortality, with a mean survival of 7%. No data were obtained at 3.0 fps for yolk-sac larvae.

Table 3. Survival of striped bass eggs, yolk-sac larvae, and larvae at 0.5, 1.5 and 3.0 feet per second velocity. Data for each velocity represents combined data for all experiments in which sampling time, net geometry and cone effects were non-significant.

		Velocity					
		0.5 fps		1.5 fps		3.0 fps	
		mean±	$s_{\bar{x}}$	mean±	$s_{\bar{x}}$	mean±	$s_{\bar{x}}$
Eggs	Experimental	79.58	±2.90	79.50	±10.58	0.00	±0.00
	Control	98.00	±1.04	100.00	±0.00	90.00	±5.29
Yolk-sac larvae	Experimental	52.70	±9.88	6.94	±2.15	No data	
	Control	94.80	±1.85	95.25	±1.77		
Larvae (14 days)	Experimental	63.75	±4.46	27.25	±4.68	0.00	±0.00
	Control	86.50	±5.12	96.17	±0.91		
Larvae (23 days)	Experimental	40.53	±2.70	20.25	±6.20	0.00	±0.00
	Control	89.75	±3.79	83.00	±5.00	87.14	±4.83

POST-YOLK-SAC LARVAE

Post yolk-sac larvae of two ages were tested independently. The first age group (14 days post-hatching) was divided in two, one group being subjected to a thermal shock of 11°C ΔT for 30 sec. prior to testing by immersion in a beaker of heated water and the other group not being subject to thermal shock prior to testing in the flume. Survival of shocked and non-shocked groups did not differ ($F_{7,7} = 0.60$; $P > 0.05$). As in the egg and yolk-sac stages, survival was dependent primarily upon water velocity (Table 3). The same was true for older larvae (23 days post-hatching; Table 3) although percentages of organisms surviving were slightly different.

Survival at 0.5 fps for 14-day-old fish was about 74%, but was reduced to 27% at 1.5 fps. There was no survival at 3.0 fps. Survival of control post-yolk-sac larvae was slightly less than for eggs and yolk-sac larvae (Table 3).

Slightly older fish (23 days post-hatching) showed reduced survival at 0.5 fps over 14-day-old fish (40.6% vs. 63.7%) and approximately the same survival (20.2% vs. 27.1%) at 1.5 fps (Figure 3). For both groups of post yolk-sac larvae there occurred no differences in survival due to the duration of time in the net.

LATENT EFFECTS

The latent effects of sampling gear on net-captured striped bass early developmental stages were determined only for 14-day-old larvae. Survival estimates of all other stages beyong 24-hr. from the time of testing were complicated by significant mortality

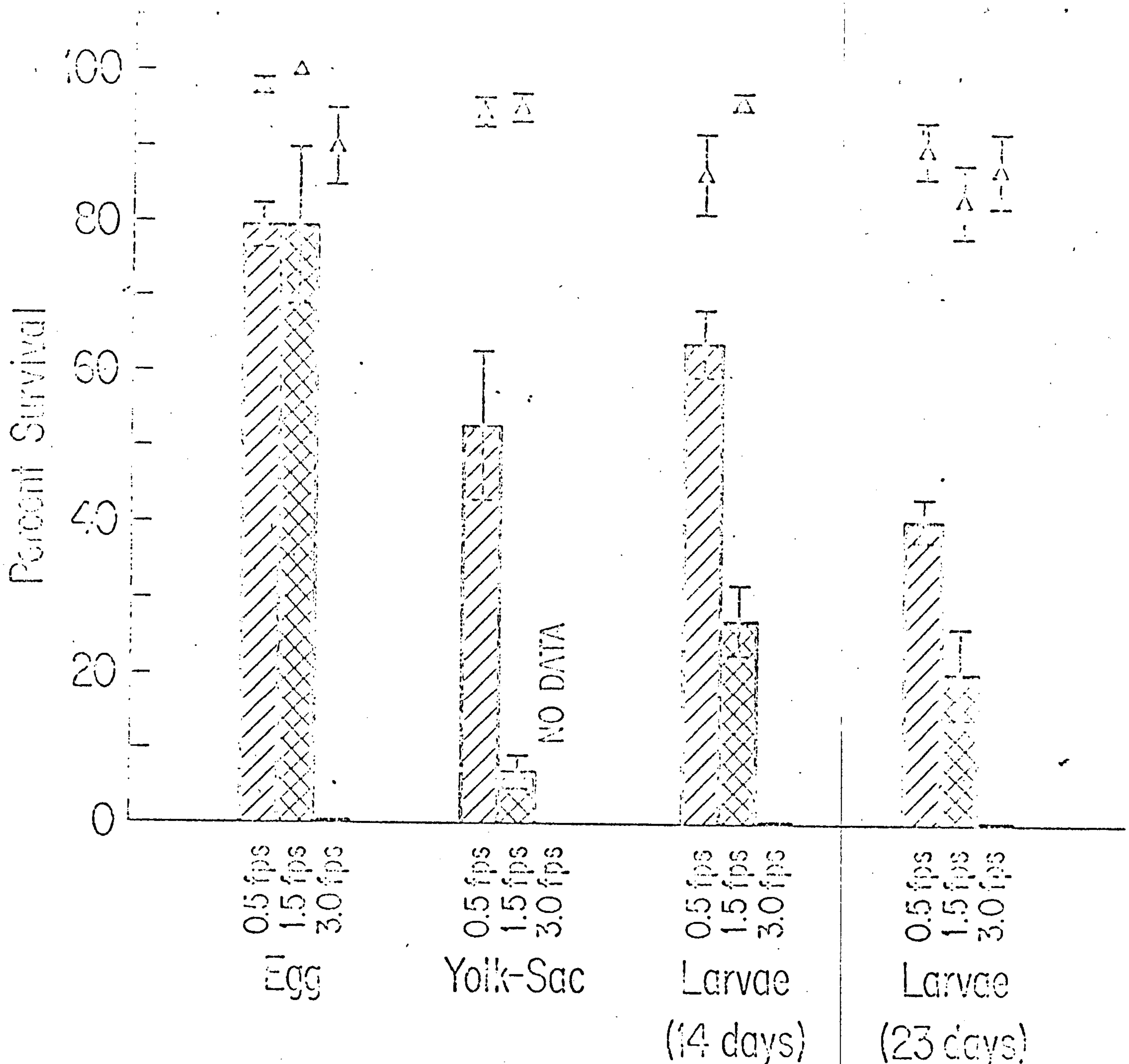


Figure 3. Immediate survival of eggs, yolk-sac larvae (4 days old) and larvae (14 and 23 days old) of striped bass following exposure to plankton nets in velocities of 0.5, 1.5 and 3.0 fps. Histograms represent experimental data; solid triangles are control survival.

in the control group, possibly due to nutritional deficiency in the organisms.

For 14-day-old larvae there occurred a significantly greater rate of mortality in fish exposed to 1.5 fps than in fish exposed to 0.5 fps (Figure 4). Thereas control groups showed between 57 and 78% survival over 24-hr. and between 50 and 60% survival over 48-hr., the experimental fish exposed to 1.5 fps velocity showed only 1.43% survival in 24-hr. Fish exposed to the lower velocity of 0.5 fps had a survival percentage of 33% after 24 hr.; 15% after 48 hr. and 7.5% after 72 hr. The absolute differences between control and experimental fish (Figure 4) were about 30% for fish exposed to 0.5 fps and about 80% for fish exposed to 1.5 fps.

Discussion

These results, determined in prototype sampling gear under controlled conditions in the Con Edison experimental flume, provide the first critical test to evaluate whether standard sampling procedures employed at Indian Point provide true estimates of cross-plant survival of ichthyoplankton.

It may be concluded from these experiments that, of the many factors tested, only the velocity of the water being sampled had a significant effect on the survival of net-captured ichthyoplankton. It is significant to note that the lethal effects of water velocity on ichthyoplankton differed according to the life-history stage tested and, for 14-day old larvae, exerted a measureable effect on latent mortality. These results are of particular

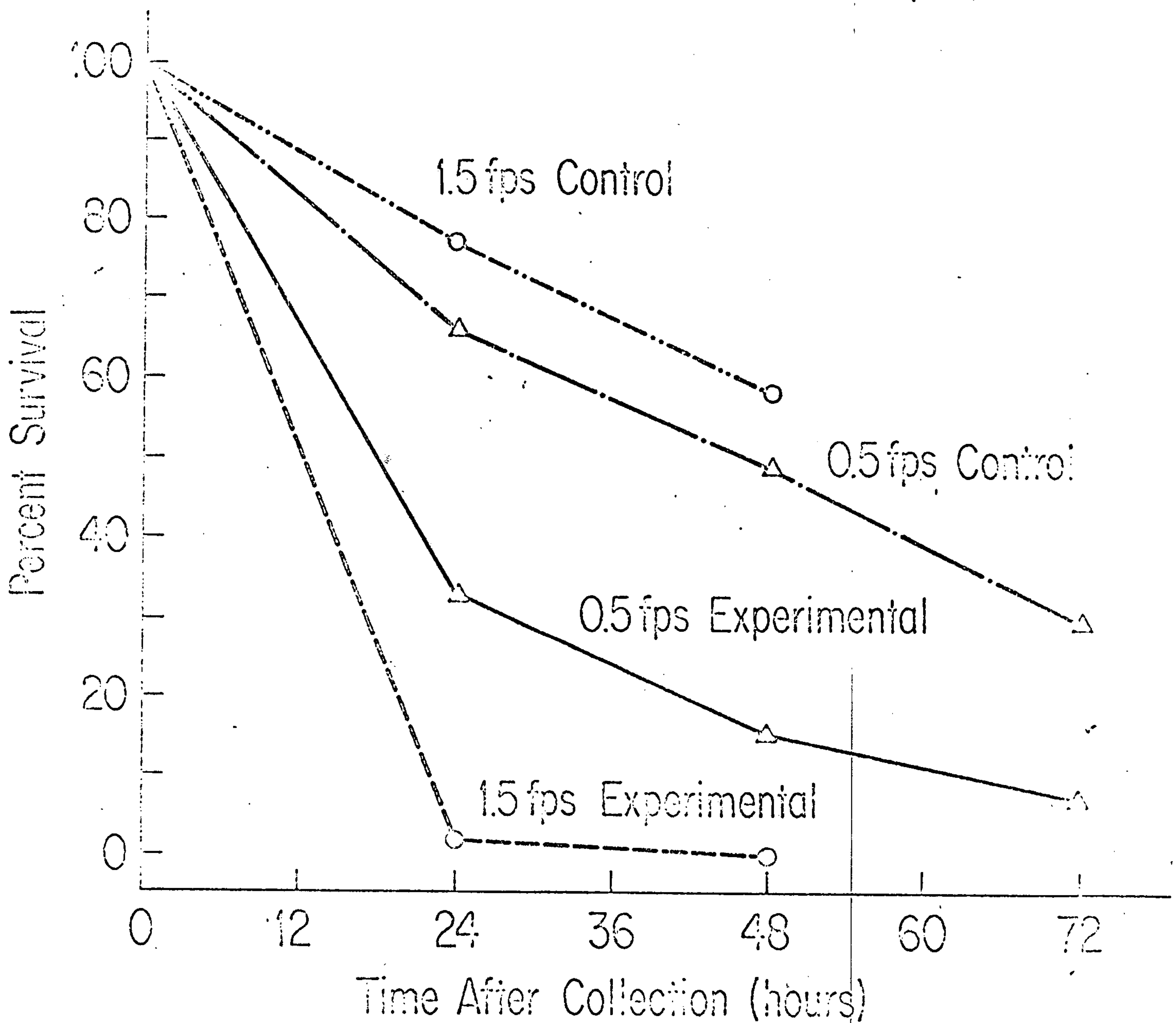


Figure 4. Latent survival of 14 day old striped bass larvae which had previously survived exposure to nets at 0.5 and 1.5 fps in the experimental flume.

importance when one considers that effective estimates of immediate cross-plant survival have, in the past, typically relied upon comparison of data collected under differing conditions, usually an intake forebay of low approach velocity and a discharge area of high velocity. Entrainment mortality was assumed to be a factor one could derive by simply subtracting the percentage of dead organisms in intake samples from the percentage of dead organisms in discharge samples. This study has shown that such data are dependent upon water velocity and stage of development of the fish under study. For striped bass it is apparent that velocities in excess of 1.5 fps cause net mortality greater than 20% in eggs and 73% or greater in yolk-sac larvae and larvae. Velocities approaching 3.0 fps may be assumed to cause complete mortality.

It would be imprudent to apply the results of these laboratory studies directly to the field situation without detailed knowledge of the velocity of water in the intake forebays and discharge canal at the time of sampling, and a firm understanding of the proportion of alive and dead organisms in the river population from which plant samples may be drawn. It is necessary, however, for proper appraisal of the flume study, to examine field data in light of the experimental results with which it might be compared if a rigorous statistical analysis were undertaken.

Striped bass eggs tested in the flume study had immediate survivals of 79.58 and 79.50% at 0.5 and 1.5 fps (15 and 46 cm/sec), respectively. Data collected at the Indian Point intakes in May and June of 1974 showed egg survival ranging from 39±9% to 55±11% (NYU, 1976). Current meters tested at the Indian Point intakes indicated velocities between 0.4 and 0.7 fps (12 to 21 cm/sec) during April of the same year. There appears, then, to be a disagreement of 24 to 40 percent in field and laboratory data for egg survival.

Among yolk-sac larvae 1974 plant data showed intake survival (alive plus stunned) to be 40%. In comparison, flume tests showed yolk-sac survival at 0.5 fps (12 cm/sec) to be 52.7%. The agreement in this case is quite good, the disparity (12%) falling within ± two standard errors of the mean of laboratory data.

Larval survival at 0.5 fps in the flume ranged from 40.6% (23-day larvae) to 63.75% (14-day larvae). Combined larval survival (all larvae undistinguished as to age by size) at the plant intake in 1974 was 57%, intermediate to the laboratory data points.

Velocity measurements for the discharge canal in April of 1974 indicated flows between 2.5 and 3.0 fps (76 to 91 cm/sec). Survival of eggs at the Indian Point discharge station D-1 (see NYU, 1976) was 19%. In the flume survival decreased from 79.5% to 0 between 1.5 and 3.0 fps.

Yolk-sac survival at the plant discharge was 27%. The flume test showed that approximately 7% of yolk-sac larvae survived at 1.5 fps. At stations further downstream in the discharge canal, however, survival was zero.

Larval survival at 1.5 fps in the flume (27.25% and 20.25% for 14-day and 23-day larvae, respectively) differed from 1974 field data by a very small margin.

Net mortality is a complex phenomenon which may not lend itself to complete control under in-plant sampling conditions due to the variability of intake and discharge flow and the differential response of different life history stages to net capture. Using the results of the present flume study, one may hypothesize that mortality of ichthyoplankton in power plant discharges is a combination of net mortality and plant-induced stress. This hypothesis may be tested in controlled conditions such as at the Con Edison experimental flume. If the contribution of net mortality to total mortality is ignored, power plant impact on ichthyoplankton populations may be greatly overestimated.

Assuming the necessity of using plankton nets for ichthyoplankton studies in at least some power plants, it is imperative to develop a sufficient understanding of net-induced mortality to adjust field data to avoid confounding sampling mortality with plant-induced mortality, making field data a more accurate representation of power plant effects. Estimates of cross-plant survival of ichthyoplankton for use in impact assessment are probably best made through a combination of laboratory studies and field sampling, the laboratory data serving as a "correction factor" to be applied to field data, thus providing the best available data for use in predictive models of entrainment effects.

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