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John S. Howard
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April 3, 2014

VIA ELECTRONIC FILING

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: FirstLight Hydro Generating Company, FERC Project Nos. 2485-063 and 1889-081
Information Relevant to U.S. Fish and Wildlife Service Notice of Study Dispute

Dear Secretary Bose:

On March 18, 2014, FirstLight Hydro Generating Company (FirstLight), licensee of the Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project, filed a 1993 LMS report that was referenced in the U.S. Fish and Wildlife Service's notice of study dispute, filed March 13, 2014 in the above-captioned dockets. FirstLight believes that two reports related to the 1993 LMS report also may be relevant to the dispute resolution panel's consideration of the study dispute. Accordingly, FirstLight encloses for filing the following two documents pursuant to section 5.14(i) of the Commission's regulations:[1]

- "Northfield Mountain Pumped Storage Project 1990 Field Sampling Program." The draft report, dated February 1991, was prepared by Harza Engineering Company for Northeast Utilities Service Company and is enclosed as Attachment A.

- "Impact of the Northfield Mountain Pumped Storage Facility on Atlantic Salmon and American Shad." The draft report, dated March 1993, was prepared by Lawler, Matusky & Skelly Engineers for Northeast Utilities Service Company and is enclosed as Attachment B.

If you have any questions, or need additional information, please feel free to contact me.

Sincerely,

John Howard

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1 FirstLight reserves the right to file additional comments and information regarding the dispute by April 7, 2014, as permitted by 18 C.F.R. § 5.14(i).

ATTACHMENT A

Northfield Mountain
Pumped Storage Project
1990 Field Sampling Program

<u>DRAFT</u>

Prepared for

Northeast Utilities Service Company

Prepared by

Harza Engineering Company

with

BioSonics, Inc.
and
Environmental Research and Consulting, Inc.

February 1991

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INTRODUCTION

Northfield Mountain Pumped Storage Project (Northfield) is located on the Connecticut River in north-central Massachusetts (Figure 1). The project uses four Francis-type pump-turbines, each pump-turbine has the capacity to generate 250 MW or pump 3,000 cfs. As part of the Memorandum of Agreement between Northeast Utilities Service Company (NUSCO) and various regulatory agencies, NUSCO has agreed to conduct studies to determine the impact of Northfield on the anadromous fish (Atlantic salmon, American shad, and blueback herring) populations of the Connecticut River. During the fall of 1990, a pilot study was conducted to identify and evaluate methods to collect juvenile clupeids in the immediate vicinity of the lower reservoir intake and to evaluate the effectiveness of various gear types in capturing juvenile clupeids in different types of habitat. The feasibility of using hydroacoustics to monitor fish entrainment rates was evaluated, and the upper reservoir, in conjunction with a scheduled maintenance drawdown, was surveyed to determine if juvenile clupeids had been entrained.

OBJECTIVES

There were three objectives of the fall 1990 Northfield field sampling program:

- Evaluate the effectiveness of various sampling techniques to collect juvenile clupeids at the lower reservoir intake during the pumping phase; and, determine the feasibility of using hydroacoustics to monitor fish entrainment rates.

- Determine the types of gear that are most effective in capturing juvenile clupeids in a variety of habitat types; and, determine the distribution of juvenile clupeids in Turners Falls Pool.

- Sample the upper reservoir to determine if juvenile clupeids were entrained into the upper reservoir.

STUDY AREA

Turners Falls pool is comprised of a 21.5-mile reach of the Connecticut River, from Vernon Dam in southeast Vermont to Turners Falls Dam in northern Massachusetts (Figure 1). A variety of habitat types exist in this area, including shallow runs below Vernon Dam, narrow deep areas such as the French King Gorge, and calm, lacustrine areas, such as Bartons Cove (Figures 2-6).

The Northfield pumping intake is located in a small cove on the east side of the river, approximately six miles upstream of Turners Falls Dam (Figure 3). A plan and a section of the intake are shown in Figure 7A. A boat boom, consisting of 17 tubular floats, each about 15 feet long, extends across the mouth of the intake cove (Figure 7B). The floats are separated by approximately three feet and are attached to a common cable. Sufficient slack exists in the cable to allow the boat boom to bow out during the generating phase and bow in during the pumping phase. The center of the boat boom travels in excess of 100 feet between the maximum bowing positions. Water depths at the intake can fluctuate as much as four feet from the generating phase to the pumping phase.

Water velocity characteristics of the intake area depend on daily operations of the facility. Facility operators can use any number of four pump/generator units; each pump has a capacity of 3,000 cfs at rated head. The water is pumped through the intake/tailrace to a 6,790-ft long tunnel leading to the upper reservoir. The average gross head of Northfield is 772 feet. When one pump was operating, velocities three feet below the center of each boat boom float were all less than 0.7 feet per second (fps). When three pumps were operating, velocities at the boat boom ranged from zero or 0.0 fps (in an eddy area near the downstream end of the boat boom) to 2.6 fps (Table 1). During the sampling period, September 12 through September 29, the total pumping time was 113 hours (Table 2). Four pumps were in simultaneous operation

Because this study was primarily directed towards gear evaluation, no attempt was made to standardize effort with each gear or to systematically sample specific locations (excluding the intake boat boom). Sampling effort was conducted throughout the Turners Falls pool (Figures 2-6). However, the portion of the pool immediately downstream of Vernon Dam (Sector 5; Figure 6) was used as the primary location for gear evaluation because considerable numbers of clupeids were observed dimpling the surface in that area at dusk.

Gill Nets

Intake Area. Sampling of the intake area was conducted with 100-ft long by 12-ft deep, vertical gill nets with one-inch stretch mesh. The nets were suspended from the boat boom. Due to the high velocities at the intake area, 17-ft long lines with 20-pound depressors (droppers) were suspended from the boat boom shackles between the gill net and the intake. This allowed the net to be pushed back into the droppers and remain vertical without having an excess amount of weight on the net.

Initially, attempts were made to set the gill nets from outside the floating boat boom (for safety and logistical reasons). The first attempt to set the nets from outside the boat boom was made when the pumps were operating, resulting in the nets being pushed back between the droppers and into the boat boom shackles, tangling the net before the lead line could pull it down. Additional weights (10-pound pieces of reinforcing steel) were attached to the lead line at approximately 17-ft intervals to make the lead line sink before it became tangled. After these attempts failed to effectively deploy the gill nets, a joint decision was made by Harza, ERC, and NUSCO to attempt to deploy the nets from inside the boat boom.

Setting the net from inside the boat boom required two boats, a small row boat that could be pulled over the boat boom and a larger boat that could carry the droppers and nets. The net was attached to the boat boom shackles at 10-ft intervals (this was later used after drawdown and fish were concentrated in a small area, each net was only fished for 2.5 hours to 3 hours.

Electrofishing

The electrofishing system was comprised of a Coffelt Manufactured VVP-2C-2000 variable voltage pulsator powered by a 2.7-kw generator. A 16-ft flat bottom aluminum boat, powered by a 50-hp jet pump equipped outboard engine, was used for electrofishing. A single 24-inch diameter Wisconsin ring, mounted on a boom extending approximately eight feet in front of the boat, served as the anode and the boat hull served as the cathode. Pulsed-DC current was used to minimize fish mortality. Stunned fish were netted at the bow and placed in a holding tank. Electrofishing was conducted primarily after dark to maximize efficiency. Most electrofishing was conducted near shore with occasional samples in open water. Thirty-eight electrofishing samples, lasting 0.08 to 0.55 hours (0.24 hours average) in duration, were collected for a total of 9.13 hours of effort.

Trawling

Trawling with otter and frame trawls was conducted from an 18-ft fiberglass boat powered by a 175-hp outboard engine. The otter trawl was a 16-ft semi-balloon "shrimp try net" obtained from Marinovich Trawl Company, Inc. (Biloxi, Mississippi). The body mesh size was 1.5-inch stretched mesh; the cod-end was 1.25-inch stretched mesh; and the cod-end inner liner was 0.5-inch stretched mesh. Sixteen otter trawl samples, 0.01 to 0.45 hours in duration (averaging 0.21 hours) were taken for a total of 3.35 hours of effort. The frame trawl consisted of the otter trawl attached to a 4-ft x 6-ft frame. Seven frame trawl samples, 0.17 to 0.25 hours in duration (averaging 0.23 hours) were taken for a total of 1.6 hours of effort.

The otter trawl was progressively modified throughout the study (based on the results) and fished using a variety of techniques. Initially, no modifications were made to the trawl. Towing speeds varied from 5 fps to 7 fps. The towing line lengths were adjusted to fish the bottom and the surface. Two bottom trawls were attempted at dusk. In both instances, the equipment became entangled by submerged logs, aborting the efforts. Subsequently, only surface trawls were made, all of which were conducted after dark. Trawling within three feet of the surface with the unmodified trawl was accomplished using short, 25-foot tow lines. Because no fish were captured, it was hypothesized that the boat or propwash may have frightened the fish, allowing them to avoid the trawl. To eliminate this possibility, a frame trawl was constructed.

The frame trawl consisted of modifying the 16-ft semi-balloon otter trawl bag (mesh sizes previously described) to fit to a 6-ft by 4-ft aluminum frame. This trawl was equipped with floats and/or depressors and sampled the water between two and ten feet deep. It was fished 110-feet to 180-feet behind the boat so that the net was beyond the direct influences of the propwash. The otter trawl and the frame trawl were towed in large circular patterns to keep the nets out of the boat wake. These techniques also proved unsuccessful in catching fish and the frame trawl was subsequently equipped with electrofishing electrodes.

It was assumed that the electrofishing gear would attract and/or stun juvenile clupeids in front of the net. A small metal cylinder, attached to the towing harness approximately three feet in front of the net, served as the positive electrode and the frame served as the negative electrode. Power was supplied to the electrodes through 300-ft cables connected to the electrofishing system described above. This technique also proved unsuccessful.

Finally, the 16-ft otter trawl was modified to fish the surface while being pulled between two boats. Modifications included changing the angle of the otter boards, increasing the length of the float line, and putting brails in the mouth of the net to hold it open. These modifications allowed the net to fish 4-ft deep, with the top three inches of the net above the surface. This modification also proved unsuccessful. Because all of these modifications to the trawl net failed to capture any fish, no further modifications were attempted and the technique was abandoned.

Seining

Nylon and monofilament nets were used for beach seining. Both seines were flat nets (i.e. without a bag). The nylon net seine was 300-ft long by 12-ft deep, with 3/8-inch ace mesh. The monofilament seine was a 200-ft long by 12-ft deep 1-inch stretch mesh gill net, fitted with brails to allow for efficient seining. A total of 22 seine samples were taken by anchoring one end of the seine to the shore and pulling the other end with a boat in a semicircle into the current, then pulling the whole net onto shore.

Hydroacoustics

Fixed structures to attach transducer mounts above or in front of the intake opening were not available, consequently, floating transducer mounts were used. The mounts were attached to guylines spanning the intake channel (Figure 9). Two 6 x 12 degree elliptical-beam 420 kHz transducers were deployed at a distance of 105 feet from the center of the intake at a depth of 19" below the surface. The two transducer mounts were located 45 feet apart, centered on the intake axis. The transducers were aimed at an 83-degree vertical aiming angle (i.e. 7 degrees down from horizontal) toward the intake opening (Figure 10).

These transducer orientations were chosen to maximize acoustic sample volumes at the intake opening. The transducers were aimed with the beam axis approximately parallel with flow vectors into the intake. This maximized fish detectability and provided information regarding fish direction of movement as the fish moved through the long-axis of the transducer beam.

Based on the nominal beamwidths, each transducer ensonified adjacent elliptical regions on either side of the center of the intake, each 23 feet wide by 11.5 feet high. The top of the ensonified zone began approximately 10 feet below the surface to a depth of 21.5 feet.

The 500-ft long transducer cables were routed to shore along the guylines to the hydroacoustic instruments, located in a secure metal box on the intake gate structure. The hydroacoustic system consisted of a BioSonics Model 101 Echo Sounder, Model MPX Multiplexer, Model 111 Thermal Chart Recorder, BioSonics Model 281 Echo Signal Processor (ESP), and a Hitachi Oscilloscope. Transducer, cable and echo sounder combinations were calibrated against a US Naval standard transducer of known sensitivity at BioSonics calibration facility in Seattle prior to shipment to the study site. This ensured that the minimum on-axis fish detectability was uniform at any sample location, regardless of the transducer used. A complete description of the operational characteristics and function(s) of each component is described in Appendix A.

Hydroacoustic data collection began September 12 at 1730 hr and continued through September 27 at 1745 hr. The data were recorded simultaneously to the Model 111 Chart Recorder and Model 281 ESP. The recorder provided a paper strip chart recording or "echogram" showing fish passage through the ensonified area. The ESP measured the parameters of each returning echo including amplitude, range and pulse widths, writing these data to a computer file. It also has the capability of tracking individual fish targets based on up to 20 user-specified criteria and recording these records to disk.

A transducer sampling rate of 10 pings/second was used during the study. A transmit pulse width of 0.4 mS and a receiver bandwidth of 5 kHz were employed. The on-axis minimum detection threshold was -56 dB. The BioSonics MPX Multiplier automatically switched between the two transducers, sampling each for a period of 15 minutes, such that each sample location was monitored 30 minutes per hour.

The ESP was programmed to write fish passage data once per hour. A technician monitored the hydroacoustic system once per day, verifying hydroacoustic system performance, down loading the ESP data files as necessary and replacing the chart recorder paper.

Chart recorder echograms were used as the preliminary data source for calculating fish passage estimates. A test data set was also processed using the ESP to evaluate the system's capability to track individual fish under representative site conditions.

Echogram traces had to satisfy three criteria to be classified as entrained fish: (1) the strength of the target echoes had to exceed the predetermined -56 dB threshold based on the ambient noise level; (2) fish had to be detected by consecutive pulses (redundancy); and (3) fish had to show consistent movement into the intake and be observed within 30 feet of the trash rack opening.

The data collection system was calibrated so that the chart recorder would mark targets with target strengths greater than twice the observed ambient noise level (50 mV) when passing the center of the beam of the transducer. This corresponded to a chart recorder threshold of 100 mV.

At least eight successive ensonifications were required for a target to be classified as a fish. Most of the fish observed were sequentially detected more than eight times. The reasons for this high redundancy were (1) the beamwidths and orientations of the transducers (most fish moved along the beam axis and were observed for several seconds or more); (2) the high pulse repetition rates; and (3) the behavior of the fish (fish typically appeared to be moving at about the same velocity as the flow). This redundancy criterion enhanced fish detectability in the presence of background interference and was necessary to obtain sufficient change-in-range information to determine direction of fish travel.

The transducers were oriented at aiming angles that were not perpendicular to the direction of fish travel to distinguish direction of movement. Fish moving toward the intake could be readily discerned from those moving away or remaining generally stationary. As the fish passed through the ensonified volume, a succession of echoes on the echogram indicated the fish's change-in-range relative to the transducer. Since the transducer's position was known, this change-in-range information expressed the fish's direction of movement (Figure A1, Appendix A).

Further details of fish detection criteria for fixed-location hydroacoustics can be found in Carlson et al. (1981).

IBM - PC compatible microcomputers were used for data storage analysis. Data from individual fish observations recorded on the echograms were marked, then entered into numeric data files. Only fish exhibiting continuous movement into the intake observed within 30 feet of the intake opening during pumpback were considered to be entrained.

After completion of data entry, the data files were loaded into Microsoft EXCEL spreadsheets, then weighted to account for unsampled time within the hour. Only fish passing through the cross-sectional area immediately in front of the trash racks were included in the entrainment counts. Expansion of observed fish passage into unsampled areas of the intake was not done, because information on the vertical distribution of entrained fish at the intake was not collected. Based on site drawings of the intake structure, the area across the face of the intake opening was estimated at 4,000 square feet, or 2,000 square feet per sample area (each side). Transducer X1, on the north shore of the intake channel, sampled a 111.8-square foot area of the intake. Transducer

X2, nearest to the south shore, ensonified a 157.3-foot area. The differences in sample areas between the two transducers are due to variations in total sampling range and nominal beamwidths. The extrapolation factor used for each transducer can be expressed as:

$$E_i = F*(60/S)$$

where: E_i = extrapolated observation of fish (i)
F = number of entrained fish observed
S = minutes sampled within the hour

Each 30-minute count was extrapolated using the above formula to estimate total observed entrainment within the sample area for that hour. The formula assumes that entrainment rates were uniform within the hour (i.e. the 30 minute sample time was representative of the hour). All subsequent analyses were based on these estimated fish detections.

RESULTS AND DISCUSSION

Common and scientific names of fish collected by conventional net sampling during the Northfield study are given in Table 3. Over 1,627 specimens representing 23 taxa of fish were collected by all methods combined (Table 4). The various gear types were evaluated on the basis of their respective catches. The species and numbers of fish captured by each sampling method are reported in Table 5. Because no one gear type was expected to be effective in all habitats and the objective of the study was to effectively sample various habitats, the results are presented according to sampling area.

Intake Area

Trawling. No fish were captured by 5.67 hours of trawling, suggesting the technique is ineffective. On several occasions, trawling equipment was used in areas where numerous clupeids could be seen dimpling the surface. On all of these occasions no clupeids were collected. Therefore, it was suspected that gear avoidance and escape through the sides of the net in the upstream end were responsible for the lack of success. A smaller mesh size at the upstream end of the trawl might reduce escapement; however, it would increase drag and turbulence that could increase gear avoidance.

Gill Nets. The gill nets used in this study were not especially effective in capturing clupeids in the intake area. High velocities at the intake combined with apparent size selectivity of the nets decreased the effectiveness of the gill nets at that location. Although the gill nets suspended from the boat boom captured 77 American shad in 100.3 hours of fishing (Table 6), the nets did not appear to be fishing effectively when more than one pump was in operation.

With one pump operating, the net hung vertically and appeared to fish very well. With two pumps operating, the net fished at approximately 30 degrees to the surface. In this position, the net was stretched tight and the integrity of the net was compromised. With three pumps operating, the upper eight feet of the net were parallel to the surface and the bottom four feet curled down. In this position, only the top four feet of the water column were sampled. The net was not observed with four pumps operating, but it is assumed that the higher water velocities would position the net nearly parallel to the surface.

The one-inch stretch mesh gill nets appear to be size selective, capturing only clupeids greater than 100 mm. Of 75[1/] shad taken in the boat boom gill net samples, 73 were larger than 100 mm. In contrast, of the 123 shad captured by electrofishing and nylon haul seine in Turners Falls pool, only 40 were greater than 100 mm (Table 7).

The mesh size used in the 1990 studies was the smallest mesh commercially available in a timely manner. Nets of smaller mesh size are available for purchase with sufficient lead time. Harza has confirmed the availability of 3/4-inch and 1/2-inch stretch mesh. However, the ability of the 1/2-inch stretch mesh monofilament to capture fish is questionable due to the net's rigidity. (The monofilament in a 1/2-inch mesh net is twice as dense as that in a 1-inch mesh net, thus increasing its rigidity.)

Because the gill nets only fished satisfactorily when one pump was operating, and because one pump operated only 15.4% of the total pumping time; either further modifications to the gill net deployment will be required or the nets should be used in conjunction with a technique that is more effective than gill nets at high velocities, such as hydroacoustic monitoring.

Boat Electrofishing. Although electrofishing directly in front of the intake captured 11 shad in three hours of sampling, all of the shad were captured during periods when one or two pumps were operating. With three or four pumps operating, some fish were captured while others were swept through the electrofishing field by high velocities. Shad were also observed passing under the front of the boat at a depth of approximately three feet and were unaffected by the electroshocker. It may be possible to increase the effectiveness of the electroshocker by increasing the amount of current in the water. This could be accomplished by increasing the number of droppers on the anode (the Wisconsin ring).

[1/] A total of 77 fish were captured. However, only the heads of two of these fish were found in the gill net.

Hydroacoustic Sampling. Fish movement near the Northfield pumpback intake was clearly affected by plant operations. During generation, fish were generally observed either moving away from the intake or milling in front of it. An example of an echogram showing typical fish movement during generation is presented in Figure 11.

The initiation of pumpback operations was evidenced by an increase in the numbers of observed fish and their directional vectors. Under pumpback, the majority of fish observed were moving toward the intake, apparently entrained with flow. Greater numbers of targets were observed, consistent with net inshore movement toward the intake. An example of an echogram showing typical fish movement during pumpback is presented in Figure 12.

Upon termination of pumpback operation, fish immediately ceased moving into the intake. After approximately one minute, large numbers of fish were observed exiting the intake opening and dispersing. The tailrace tunnel appeared to "backflush", draining water and entrained fish into the intake channel. An example of an echogram showing this movement is presented in Figure 13.

Hourly and nightly estimates of fish entrainment into the Northfield Mountain pumpback intake for the study period are presented in Tables 8 - 12. Hourly total entrainment rates during full pumpback operation varied between 34 and 346 fish/hour.

Total entrainment and plant pumping volume on a nightly (pumpback cycle) basis is shown in Figure 14 and in Tables 8 - 12. The highest total entrainment (1,628 fish) was observed on September 26-27, the last night of the study. Lowest total entrainment (674 fish) occurred on September 18-19. The estimate of 260 fish on the night of September 13-14 is due to missing data for that period, due to overturned transducer mounts. Total observed entrainment varied between approximately 700-1,400 fish per pumpback cycle during most of the study, then increased to 1,562 and 1,628 fish on the last two days of the study. Over the entire study period, September 12-27, a total of 14,556 entrained fish were observed during pumpback operation, an average of 1,040 fish per pumpback cycle.

The trace types and peak voltage strengths recorded by the hydroacoustic system were consistent with smaller size fish. However, because the study was conducted using single-beam (rather than dual-beam) transducers, the actual acoustic size distributions of these fish are unknown. Further, because of the problems encountered with conventional sampling at the intake, the species composition of these fish is also unknown. Nonetheless, because juvenile clupeids were captured at the intake during pumpback and in the upper reservoir, it is reasonable to assume that some portion of the entrained fish were clupeids.

A general correlation was expected between pumpback volume and fish entrainment rates. To test this hypothesis, Spearman rank correlation coefficients were calculated for two variable sets. The first data set consisted of daily observed entrained fish vs. daily pumping volume (in acre feet) (Figure 14). The second data set compared daily observed entrained fish vs. the ratio of daily average pumping volume to average natural river flow volume (Figure 15).

Both Spearman rank test coefficients were essentially zero (0.0725 for the first comparison, and -0.011 for the second), indicating that fish entrainment was not correlated with either pumping volume or with percent river diversion during the study period. The abundance of fish in the proximity of the intake is likely more significant in determining entrainment rates.

A diel distribution showing mean hourly fish entrainment rates during the study period is given in Figure 16. Mean entrainment rates appeared to be generally consistent throughout the pumpback cycle over the hydroacoustic sampling period. A slight increase in mean entrainment was generally observed between 0300-0400 hr. The decreased entrainment rates at 2300 and 0600 hr are artifacts of the variable pumpback startup and shutdown times.

To verify that significant ($P \leq 0.05$) differences did not exist in mean hourly entrainments rates throughout the pumpback cycle, a sign test was performed, comparing the first and last three complete hours of the pumpback cycle. The sign test determines if paired data are significantly different by comparing the occurrence of differences between the paired data sets (Zar 1974). In this case, the number of fish observed during the first three hours of pumpback cycle was compared with the number observed during the last three hours of the same cycle. Either a positive, negative, or null difference was recorded. The test stastistic, calculated by summing the number of positive differences, was 7 (critical value $\leq$ 3.26 or $\geq$ 10.26). Thus, within a 95% confidence bound, significant differences in mean entrainment rates were not observed between the two time periods.

Entrainment rates appeared to vary horizontally across the face of the intake opening (Figure 17). The numbers of fish observed moving into the intake were consistently higher on Transducer X2, which monitored the south half of the intake opening. On average, Transducer X2 observed five times as many entrained fish as X1, located on the northern shore. This may have been due to the intake channel configuration. The southern half of the intake channel was deeper and appeared to direct the majority of flow into the intake.

The general equipment deployment and sampling design used during the Northfield Mountain hydroacoustic entrainment study provided good sample coverage of the pumpback intake and appears suitable for long term monitoring. Ambient noise levels at the site were not limiting at the study's -56 dB minimum detection threshold.

Upper Reservoir

Sampling in the upper reservoir resulted in the capture of 962 specimens representing 13 species (Table 13). The most abundant species captured in the upper reservoir for all gear types combined were white perch (259 specimens), American shad (184 specimens), eastern silvery minnow (171 specimens), blueback herring (141 specimens), and spottail shiner (138 specimens). Additionally, eight other species were collected, all represented by less than 25 specimens. In earlier surveys (1973-1976) of the upper reservoir (Massachusetts Division of Fish & Game 1978), white perch was the dominant species for three of the four years surveyed; spottail shiner was the most abundant in 1973 (Table 14). Clupeids were not collected in the upper reservoir in any of the earlier surveys, even though more than 6,000 clupeids were released into the Turners Falls Pool during this time period (Layzer 1978). A total of 22 species of fish have been collected combining all studies in the upper reservoir.

In addition to the clupeids captured during the sampling effort, NUSCO personnel reported dead clupeids stranded in the penstock and tailrace areas after the drawdown. The penstock could not be investigated for safety reasons, but in seven randomly selected 100-ft sections of the 5,200 foot-long tailrace tunnel, 17 dead clupeids were observed.

Seine Net. At full pool, no suitable sites exist for seining in the upper reservoir. One seine haul was attempted prior to drawdown at the only site shallow enough for sampling. However, this area contained submerged terrestrial vegetation and only two cyprinids were captured (Table 15). During drawdown, seining was possible, but deep silt deposits made seining difficult. Three seine hauls after drawdown resulted in the capture of 117 specimens (two of which were American shad), representing six species (Table 16). A one-inch stretch monofilament net was used during these studies. A smaller mesh net should be used in future efforts because many fish were able to escape through the mesh. As noted above, one-inch stretch mesh is apparently not effective for clupeids less than 100 mm total length.

Boat Electrofishing. Large rapid daily fluctuations in water levels make boat access difficult. In accordance with a request from NUSCO, boat electrofishing was confined to Mondays, when the water level was typically high enough to safely reach the access site. Electrofishing for 1.6 hours in the upper reservoir conducted prior to drawdown captured 37 specimens, representing eight species (Table 17). None of these fish were clupeids. During the five year maintenance drawdown, electrofishing was very effective; Electrofishing for 0.7 hours after drawdown resulted in the capture of 628 specimens representing nine species (Table 18). Of these, 323 were clupeids (182 American shad and 141 blueback herring). The effectiveness of the electrofishing gear after drawdown is likely due to the fish being concentrated in a small area.

Gill Nets. The experimental gill nets (mesh sizes for all nets ranged from one to eight inches in one-inch increments) anchored in the upper reservoir were successful in capturing many species of fish having a total length greater than 100 mm. The floating experimental gill nets captured 178 specimens, representing six species, none of which were clupeids (Table 19). If a smaller size mesh were used, this technique is expected to be successful in capturing clupeids.

Turners Falls Pool

The distribution of clupeids in Turners Falls Pool was more difficult to assess. Harza personnel seining with a 280-ft long, 10-ft deep net having 1/4-inch mesh for a separate study made several collections at Bartons Cove and the Turners Falls Rod and Gun Club (Table 20). On September 13, two haul seine collections at the Bartons Cove boat ramp yielded a total of 319 clupeids. Fourteen collections at the Rod and Gun Club Cove on September 14 and 15 resulted in a combined catch of 1,010 clupeids. The mean catch of juvenile clupeids for both locations combined was 83.1 specimens per collection. Many of these fish were blueback herring. During the present study, collections with larger haul seines (18 hauls) farther upstream in the Turners Falls pool averaged 2.8 specimens per collection. Although no blueback herring were captured during this study in Turners Falls Pool, 141 blueback herring were captured in the upper reservoir (Table 21). Clupeids were also observed on the surface on several occasions below Vernon Dam, indicating they were also dense in that area.

As indicated on Figures 2-6 and Table 22, occasional fish were caught throughout the pool by several methods. Anchored gill nets caught fish at low numbers throughout the pool (Table 23) as did electrofishing (Table 24) and haul seines (Tables 22, 23, and 24). Stretching a gill net between two boats and drifting with the current showed potential of being a successful technique (see Table 25). However, stretching the net tight might make it even more size selective (the mesh would be stretched beyond the rated one-inch opening). Trawling equipment proved to be ineffective; no fish were collected in 26 samples at various locations using several different modifications of the technique (Tables 26 and 27).

Seine Net. Seining was the most consistent sampling technique to capture juvenile clupeids in Turners Falls Pool (Tables 28 and 29). Suitable seine sites existed in the pool from the intake upstream to Vernon Dam (Figures 1 - 6). No adequate sites were found from the intake area downstream to the Turners Falls Rod and Gun Club (Figure 2). In addition, areas with high velocities are difficult to seine with the ace mesh minnow seine. A larger mesh net is recommended. However, the mesh size must be small enough (< one inch) to prevent escapement of fish.

Boat Electrofishing. Electrofishing success in capturing juvenile clupeids was sporadic. Although some fish were collected, others were observed swimming outside the effective range of the electrofisher. Nonetheless, this technique could be used to determine shad distribution.

Gill Nets. Anchored gill nets captured fish sporadically and were size selective to fish greater than 100 mm. This problem may be resolved by using a smaller mesh (as discussed above). The fact that very little effort is needed to use this technique makes it attractive. Drifting a gill net between two boats also showed promise.

SUMMARY AND CONCLUSIONS

Summary

The 1990 field sampling program at Northfield demonstrated the effectiveness of several conventional methods for the collection of juvenile clupeids in the vicinity of this project as well as the effectiveness of hydroacoustic monitoring to assess entrainment during the pumpback operation. Collections in the upper reservoir, combined with hydroacoustic data, showed that clupeids are entrained into the upper reservoir. The distribution of juvenile clupeids in Turners Falls Pool is highly variable. The distribution of schooling pelagic species is often dependent on school behavior and water quality parameters as much as on the morphological characteristics of the area. This appears to be the case for juvenile clupeids in Turners Falls Pool.

Conventional Sampling Methods

It was found that a program combining several conventional methods is preferable to any single method for obtaining a better understanding of the fish populations affected by Northfield. Electrofishing and haul seining with the 300- x 12-ft nylon net were the most effective and least size selective methods for capturing juvenile clupeids. However, the number of juvenile clupeids collected by these methods in the present study was generally low. This is likely the result of low abundance rather than gear avoidance or selectivity. Shoreline electrofishing and haul seining (with a 60-ft x 8-ft nylon net) were proven to be very effective collection techniques in a study of juvenile alosids conducted on the Connecticut River near Hartford during the summer and fall of 1990. Individual catches exceeding several hundred juvenile shad and/or blueback herring were common in this study (Environmental Research and Consulting, Inc., unpublished data).

Fine mesh gill nets, whether anchored, towed, or used as a haul seine, were only effective in collecting American shad greater than 100 mm TL.

No fish were collected by either otter trawl or frame trawl in the present study. It is suspected that this was due to net avoidance. Similar types of trawl nets have been used to effectively collect juvenile shad and river herring in other systems. Loesch et al. (1982) collected juvenile alosids in the Mattaponi River, Virginia using a 31-foot semi-balloon bottom trawl and a 4.9- x 4.9-foot Cobb surface trawl. PSE&G (1984a, b, and c) reported capture of juvenile American shad, blueback herring, and alewife in the Delaware River and Delaware Bay with a 16-foot semi-balloon trawl (the same net used in the present study) and a 3.9- x 5.9- foot fixed-frame trawl. Davis and Cheek (1966) collected large numbers of juvenile clupeids in the Cape Fear River, North Carolina with a 4-foot x 12-foot frame trawl pulled by two boats powered by 18-horse power motors.

In the present study, juvenile American shad were collected throughout the Turners Falls pool, though generally in low numbers. Large numbers of specimens were, however, collected by haul seine (28- x 8-ft) in Bartons Cove and Turners Falls Rod and Gun Club Cove for a concurrent study at the Hadley Falls Project. These coves provide a unique habitat in the Turners Falls pool. Both coves are broad, relatively shallow, low current areas, with extensive beds of submerged aquatic vegetation. Low current velocities provide an energetically efficient environment for the juvenile clupeids. It is also possible that prey species attractive to juvenile clupeids occur in greater density in these coves than in the adjacent river.

The catch of American shad in electrofishing collections in the Turners Falls pool evidenced a diel pattern. Collections made during daylight averaged 1.3 specimens per sampling hour, whereas those at night (including dusk) averaged 13.2 specimens per sampling hour. This suggests that American shad moved upward in the water column and/or inshore at night. Outmigrating juvenile shad sampled by haul seine in the Delaware River evidenced a similar pattern of movement (Environmental Research and Consulting, Inc., unpublished data). Loesch et al. (1982) reported significantly higher catches of non-migrating juvenile American shad, blueback herring, and alewife by surface trawl at night and bottom trawl during the day. Loesch (1987) attributed this phenomena to general negative phototaxic behavior of juvenile alosids or the prey they follow. However, Buckley and Kynard (1985), studying the vertical distribution of outmigrating juvenile shad in the First Level Canal at Holyoke Dam, found no evidence of diel vertical migration and reported a strong orientation to surface waters.

Hydroacoustic Sampling

Elliptical-beamwidth transducers scanning obliquely at the trashrack openings were found to be very effective in monitoring at the Northfield Mountain pumpback intake. This deployment arrangement maximizes sample volumes in the area of interest. Water velocities at the intake opening during pumpback appear adequate to positively entrain fish, eliminating the need to determine entrainment based on behavioral criteria, such as echogram trace type. Because the fish transit a relatively large ensonified-volume as they approach the intake, this orientation provides good fish detectability levels.

The complete hydroacoustic monitoring program at the Northfield Mountain pumpback intake would incorporate one transducer per trash rack face, for a total of four transducers. This would allow greater spatial coverage of the intake bay, as well as increased resolution near each trash rack. To provide vertical distribution information, dual-beam transducers would be attached to the top of the intake structure and aimed down along the trashrack face. This arrangement would also provide estimates of fish target strength that could be used to calculate the effective sampling volume of the transducer array and to evaluate changes in mean size of the entrained population.

To minimize transducer mount movement with flow, the offshore transducers should be located on clump mounts located on the bottom of the intake channel. These would provide a solid mounting structure and be less subject to damage than floating mounts. An additional transducer scanning offshore would be incorporated to assess how fish densities in the river affect entrainment rates. During initial deployment, a BioSonics rotator assembly would be used to optimize the transducer orientation and minimize structural interference. The transducers should be fast-multiplexed, allowing two sample locations to be sampled simultaneously, maximizing temporal sampling efficiency.

Conclusion

Hydroacoustic monitoring of clupeid entrainment was shown to be feasible at Project intakes, although the inability of this method to identify the species being detected and other problems related to the location and orientation of the transducers need to be overcome. This method, in conjunction with conventional sampling techniques to verify its results, should be considered for use in future studies of the impact of the Project on American shad and blueback herring.

Three conventional sampling methods (electrofishing, seining, and gill netting) were found to be effective for sampling juvenile clupeids in the Turners Falls pool. Although the results of the present study did not delineate the distribution of juvenile clupeids in the Turners Falls pool, these methods should be adequate to accomplish that task in the future.

Sampling in the upper reservoir using seines, electrofishing and gill nets captured 962 specimens representing 13 species. Among the specimens collected were 184 American shad and 141 blueback herring.

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TABLES

Table 1. Current velocity and direction measured along the Northfield Mountain intake boom.

Float No. (South ---> North)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Water depth (ft)[1/]		0	2.0	3.1	3.6	4.7	8.0	11.6	17.1	23.5	30.8	33.2	35.0	33.5	33.8	27.2	13.1	56
Current velocity (fps)[1/]	-	<0.7	<0.7	1.2	1.8	2.1	2.1	2.2	2.3	2.4	2.5	2.6	2.5	1.6	1.5	0	-1.0	

Current direction[1/]:
Intake (east) side
-------NET--------
River (west) side

[1/] Recorded on 9/28/90, 0100-0130 hrs while 3 units were pumping back.

TABLE-T

Table 2. Northfield Mountain Pumped Storage Project pumping hours, September 12 - 29, 1990.

DATE	FIRST PUMP START	LAST PUMP STOP	TOTAL HOURS PUMPED	NUMBER OF PUMPS OPERATING ON AN HOURLY BASIS 4	3	2	1
12/13	2319	0604	6.75		5.93	0.42	0.40
13/14	2331	0607	6.60		5.55	0.82	0.23
/15	0104	0725	6.35			5.68	0.67
15/16	2333	0732	7.99		6.27	1.02	0.70
16/17	2347	0641	6.90	0.05	5.23	0.58	1.03
17/18	2340	0550	6.17		4.35	0.91	0.90
18/19	2306	0544	6.63		3.42	1.52	1.70
19/20	2257	0633	7.60		5.05	1.65	0.90
20/21	2351	0635	6.73		4.48	0.85	1.40
21/22	2313	0704	7.85			6.97	0.88
22/23	2259	0748	8.82	5.02	1.55	1.67	0.58
23/24	2302	0604	7.03		5.88	0.77	0.38
/25	0058	0543	4.75			3.83	0.92
25/26	2339	0550	6.18		3.67	1.30	1.22
/27	0012	0550	5.63		4.00	0.80	0.83
27/28	2307	0604	6.95		5.83	0.73	0.38
/29	0123	0541	4.30				4.30
		Totals	113.23	5.07	61.21	29.52	17.42
		Percent	100%	4.5%	54.1%	26.1%	15.4%

Table 3. Common and scientific names of fishes collected during the Northfield Mountain study, September-October 1990.

Common Name	Scientific Name
Lamprey	Petromyzontidae
Sea lamprey	*Petromyzon marinus*
Freshwater eel	Anguillidae
American eel	*Anguilla rostrata*
Herring	Clupeidae
Blueback herring	*Alosa aestivalis*
American shad	*Alosa sapidissima*
Gizzard shad	*Dorosoma cepedianum*
Pike	Esocidae
Chain pickerel	*Esox niger*
Carp and Minnow	Cyprinidae
Common carp	*Cyprinus carpio*
Eastern silvery minnow	*Hybognathus regius*
Golden shiner	*Notemigonus crysoleucas*
Spottail shiner	*Notropis hudsonius*
Fallfish	*Semotilus corporalis*
Sucker	Catostomidae
White sucker	*Catostomus commersoni*
Bullhead catfish	Ictaluridae
Channel catfish	*Ictalurus punctatus*
Killifish	Cyprinodontidae
Banded killifish	*Fundulus diaphanus*
Temperate bass	Percichthyidae
White perch	*Morone americana*
Sunfish	Centrarchidae
Rockbass	*Ambloplites rupestris*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
Perch	Percidae
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum vitreum*

TABLE-J

Table 4. Fishes collected during the Northfield Mountain study, September-October 1990.

Location	Intake	Turners Falls Pool	Northfield Mountain Reservoir	Total
Species				
Sea lamprey	0	1	0	1
American eel	0	7+	0	7+
Blueback herring	0	0	141	141
American shad	77	158	184	419
Gizzard shad	1	0	0	1
Chain pickerel	0	1	0	1
Common carp	0	1	0	1
Eastern silvery minnow	0	53+	171	224+
Golden shiner	0	1	0	1
Spottail shiner	0	151+	138	289+
Fallfish	0	19	0	19
Unidentified minnows	0	5	2	7
White sucker	0	36+	14	50+
Channel catfish	0	0	1	1
Banded killifish	0	10	0	10
White perch	0	0	259	259
Rockbass	0	27+	0	27+
Pumpkinseed	0	1	5	6
Bluegill	0	22	2	24
Smallmouth bass	0	45+	15	60+
Largemouth bass	0	9	1	10
Yellow perch	0	37+	24	61+
Walleye	0	3	5	8
Total taxa	2	19	14	23
Total specimens	78	587+	962	1,627+

+ = Indicates minimum number of specimens collected.

TABLE-K

Table 5. Fishes collected at the Northfield Mountain intake and in the Turners Falls pool, by gear type, September-October 1990.

	Intake	Turners Falls Pool						
Gear type	Gill net	Electrofisher	Haul seine (nylon)	Haul seine (monofilament)	Gill net (anchored)	Gill net (towed)	Trawl (frame & otter)	
No. of collections	14	29	18	3	12	6	28	
Species								Total
Sea lamprey	0	1	0	0	0	0	0	1
American eel	0	7+	0	0	0	0	0	7+
American shad	77	81	51	13	8	5	0	235
Gizzard shad	1	0	0	0	0	0	0	1
Chain pickerel	0	1	0	0	0	0	0	1
Common carp	0	1	0	0	0	0	0	1
Eastern silvery minnow	0	41+	12+	0	0	0	0	53+
Golden shiner	0	1	0	0	0	0	0	1
Spottail shiner	0	108+	43+	0	0	0	0	151+
Fallfish	0	3	0	16	0	0	0	19
Unidentified minnows	0	2	3	0	0	0	0	5
White sucker	0	36+	0	0	0	0	0	36+
Banded killifish	0	8	2	0	0	0	0	10
Rockbass	0	17+	10	0	0	0	0	27
Pumpkinseed	0	1	0	0	0	0	0	1
Bluegill	0	19	3	0	0	0	0	22
Smallmouth bass	0	38+	5	1	1	0	0	45+
Largemouth bass	0	9	0	0	0	0	0	9
Yellow perch	0	37+	0	0	0	0	0	37+
Walleye	0	3	0	0	0	0	0	3
Total taxa	2	19	8	3	2	1	0	20
Total specimens	78	414+	129+	30	9	5	0	665+

TABLE-M.NMS

Table 6. Fishes collected by gill net at the Northfield Mountain intake, September 1990.

Date	9/14/90	9/16-17/90	9/17-18/90	9/18-19/90	9/20/90	9/20-21/90	9/21-22/90	9/22-23/90
Time	0330-0500	2350-0650	2300-0630	2345-0630	0001-0630	2330-0640	2350-0630	2330-0800
Set duration (hrs)	1.50	7.00	7.50	6.75	6.48	7.17	6.67	8.50
Water temperature (°C)								
Set	23.5	-	19.2	19.5	-	17.8	17.4	-
Retrieve	-	20.0	-	18.5	18.0	-	17.2	17.0
Dissolved oxygen (mg/l)								
Set	9.0	-	-	-	-	-	9.2	-
Retrieve	-	-	-	-	-	-	9.3	-
Length of net (ft)	100	100	200	200	200	200	200	200
Net location								
(boom float no.)	6-9	-	6-15	5-14	4-11	6-13	7-14	6-15
No. of units pumping	3	4	3	3	3	3	2	4
No. pumping hrs.	4.50	18.05	15.67	14.33	17.76	16.54	13.39	27.92
Species								
American shad	0	0	0	2	1	1	12	6
Gizzard shad	0	0	1	0	0	0	0	0
Total species	0	0	1	1	1	1	1	1
Total specimens	0	0	1	2	1	1	12	6
No. fish/pumping hr	0	0	0.0638	0.1396	0.0563	0.0605	0.8962	0.2149

Table 6. Continued.

Date	9/23-24/90	9/24-25/90	9/25-26/90	9/26-27/90	9/27-28/90	9/28-29/90	
Time	2300-0630	2325-0630	2230-0630	2250-0630	2340-0840	2200-0700	
Set duration (hrs)	7.50	7.58	8.0	7.67	9.0	9.0	
Water temperature (°C)							
Set	17.3	17.7	16.6	16.4	15.7	15.9	
Retrieve	16.5	15.5	15.3	15.3	15.5	15.9	
Dissolved oxygen (mg/l)							
Set	9.3	9.1	9.5	9.5	10.3	10.2	
Retrieve	9.5	9.7	9.7	9.7	10.1	10.4	
Length of net (ft)	200	200	200	200	200	200	
Net location							
(boom float no.)	6-15	6-15	6-15	6-15	6-15	6-15	Total
No. of units pumping	3	2	3	3	3	1	
No. pumping hrs.	19.56	7.75	14.66	14.43	18.41	4.30	207.27
Species							Total
American shad	1	12	22	4	1	15	77
Gizzard shad	0	0	0	0	0	0	1
Total species	1	1	1	1	1	1	2
Total specimens	1	12	22	4	1	15	78
No. fish/pumping hr	0.0511	1.5484	1.5007	0.2772	0.0543	3.4883	0.3763

TABLE-C

Table 7. Length-frequency distribution of American shad collected at the Northfield Mountain intake and in the Turners Falls pool, September-October 1990.

Location	Intake	Turners Falls Pool					
Gear Type	Gill net	Electrofisher	Haul seine (nylon)	Haul seine (Monofilament)	Gill net (Anchored)	Gill net (Towed)	
Length Increment (mm TL)							Total
66-70		2					2
71-75	1	4	1				6
76-80		4	4				8
81-85		1	9				10
86-90		7	6				13
91-95		9	10				19
96-100	1	14	9	1			25
101-105	17	21	12	8	1	3	62
106-110	19	8		3	3	2	35
111-115	11	1		1	1		14
116-120	9				3		12
121-125	8	1					9
126-130	6						6
131-135	2						2
136-140	1						1
Total measured	75	72	51	13	8	5	224
Total taken	77	81	51	13	8	5	235
Mean length	112.5	96.0	92.3	104.5	111.8	105.0	101.9

TABLE-L

Table 8. Estimated hourly fish entrainment into the pumpback intake, Northfield Hydroelectric Station, September 12-15, 1990.

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/12	2200						
	2300	10	130	140	23:19/ON		
9/13	0	14	166	180			
	100	18	76	94			
	200	18	76	94			
	300	0	62	62			
	400	8	116	124			
	500	16	164	180			
	600				06:04/OFF		
	700						
DAILY TOTAL		84	790	874		5209	6.7

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/13	2200						
	2300	8	32	40			
9/14	0	24	196	220	00:21/ON		
	100	NO DATA					
	200						
	300						
	400						
	500						
	600				06:02/OFF		
	700						
DAILY TOTAL		32	228	260		4866	7.5

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/14	2300						
9/15	0	32	36	68			
	100	50	82	132	01:04/ON		
	200	36	100	136			
	300	18	88	106			
	400	12	98	110			
	500	30	50	80			
	600	36	40	76			
	700	10	66	76	07:25/OFF		
DAILY TOTAL		224	560	784		3392	4.8

Table 9. Estimated hourly weighted fish entrainment into the pumpback intake, Northfield Hydroelectric Station, September 15-18, 1990.

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/15	2300	2	2	4	23:33/ON		
9/16	0	32	36	68			
	100	50	26	76			
	200	36	150	186			
	300	14	330	344			
	400	16	56	72			
	500	10	128	138			
	600	8	226	234			
	700	0	134	134	07:32/OFF		
DAILY TOTAL		168	1088	1256		5726	6.2

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/16	2200						
	2300	4	8	12	23:47/ON		
9/17	0	14	88	102			
	100	38	0	38			
	200	34	62	96			
	300	26	138	164			
	400	32	70	102			
	500	30	130	160			
	600	14	74	88	06:41/OFF		
	700						
DAILY TOTAL		192	570	762		4679	5.9

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/17	2200						
	2300	20	2	22	23:40/ON		
9/18	0	52	20	72			
	100	34	154	188			
	200	22	132	154			
	300	14	82	96			
	400	10	88	98			
	500	6	52	58	05:50/OFF		
	600						
	700						
DAILY TOTAL		158	530	688		4162	5.9

Table 10. Estimated hourly fish entrainment into the pumpback intake, Northfield Hydroelectric Station, September 18-21, 1990.

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/18	2200						
	2300	34	14	48	23:06/ON		
9/19	0	30	24	54			
	100	18	62	80			
	200	34	108	142			
	300	38	104	142			
	400	24	100	124			
	500	20	64	84	05:44/OFF		
	600						
	700						
DAILY TOTAL		198	476	674		4003	5.3

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/19	2200				22:57/ON		
	2300	54	68	122			
9/20	0	72	176	248			
	100	54	140	194			
	200	24	60	84			
	300	34	48	82			
	400	24	64	88			
	500	26	116	142			
	600	14	102	116	06:33/OFF		
	700						
DAILY TOTAL		302	774	1076		5316	6.0

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/20	2200						
	2300	10	2	12	23:51/ON		
9/21	0	62	24	86			
	100	64	140	204			
	200	56	118	174			
	300	28	110	138			
	400	32	174	206			
	500	20	154	174			
	600	6	46	52	06:35/OFF		
	700						
DAILY TOTAL		278	768	1046		4626	5.8

Table 11. Estimated hourly fish entrainment into the pumpback intake, Northfield Hydroelectric Station, September 21-24, 1990.

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/21	2200						
	2300	36	56	92	23:13/ON		
9/22	0	26	198	224			
	100	16	150	166			
	200	28	102	130			
	300	16	82	98			
	400	16	90	106			
	500	28	56	84			
	600	12	106	118	06:33/OFF		
	700						
DAILY TOTAL		178	840	1018		4096	4.7

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/22	2200				22:59/ON		
	2300	86	24	110			
9/23	0	68	104	172			
	100	40	40	80			
	200	44	40	84			
	300	44	0	44			
	400	34	0	34			
	500	26	0	26			
	600	26	72	98			
	700	16	194	210	07:48/OFF		
DAILY TOTAL		384	474	858		7751	7.3

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/23	2200						
	2300	18	112	130	23:02/ON		
9/24	0	86	166	252			
	100	74	172	246			
	200	56	136	192			
	300	32	150	182			
	400	34	100	134			
	500	40	226	266			
	600				06:04/OFF		
	700						
DAILY TOTAL		340	1062	1402		4990	2.5

Table 12. Estimated hourly fish entrainment into the pumpback intake, Northfield Hydroelectric Station, September 24-27, 1990.

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/24	2200						
	2300						
9/25	0	8	6	14	00:58/ON		
	100	12	22	34			
	200	24	140	164			
	300	24	266	290			
	400	36	272	308			
	500	8	110	118	05:37/OFF		
	600						
	700						
DAILY TOTAL		112	816	928		2085	3.8

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/25	2200						
	2300				23:39/ON		
9/26	0	70	180	250			
	100	62	188	250			
	200	34	216	250			
	300	24	294	318			
	400	40	256	296			
	500	8	190	198	05:50/OFF		
DAILY TOTAL		238	1324	1562		4012	5.5

DATE	HR	DETECTED FISH X1	DETECTED FISH X2	HOURLY TOTAL	PUMPS ON/OFF	PUMPED VOLUME (ACRE FT)	DAILY PUMPBACK/RIVERFLOW RATIO
9/26	2200						
	2300						
9/27	0	248	12	260	00:12/ON		
	100	82	184	266			
	200	48	166	214			
	300	34	266	300			
	400	16	226	242			
	500	34	312	346	05:50/OFF		
DAILY TOTAL		462	1166	1628		3929	6.1

Table 13. Fishes collected in Northfield Mountain Reservoir, by gear type, September-October 1990.

Gear Type	Electrofisher	Haul seine (nylon)	Haul seine (monofilament)	Gill net	
No. of Collections	9	1	3	3	
Species					Total
Blueback herring	141	0	0	0	141
American shad	182	0	2	0	184
Eastern silvery minnow	171	0	0	0	171
Spottail shiner	86	0	52	0	138
Unidentified minnows	0	2	0	0	2
White sucker	13	0	0	1	14
Channel catfish	0	0	0	1	1
White perch	43	0	55	161	259
Pumpkinseed	5	0	0	0	5
Bluegill	2	0	0	0	2
Smallmouth bass	13	0	1	1	15
Largemouth bass	1	0	0	0	1
Yellow perch	7	0	5	12	24
Walleye	1	0	2	2	5
Total taxa	12	1	6	6	14
Total specimens	665	2	117	178	962

TABLE-B

Table 14. Fishes by percent species composition collected in Northfield Mountain Reservoir. Data for 1973 through 1976 were obtained from Massachusetts Division of Fisheries and Game (1978).

Species	1973	1974	1975	1976	1990
Blueback herring					15
American shad					19
Atlantic salmon	0.6				
Brown trout				trace	
Brook trout	0.6			0.3	
Chain pickerel	1.3	0.6	2.0		
Golden shiner	0.6	0.6		trace	
Eastern silvery minnow					18
Spottail shiner	34.6		1.3	11.8	14
Fallfish				trace	
Unidentified minnows					
White sucker	15.7	31.7	30.9	13.8	1.4
Brown bullhead	0.6	0.6		0.2	
Channel catfish					0.1
White perch	17	26.1	32.2	54.6	27
Rock bass				0.2	
Pumpkinseed	1.3	5	0.7	0.9	0.5
Bluegill	0.6			1.2	0.2
Smallmouth bass	3.3	3.7	5.3	10.5	1.5
Largemouth bass	7.2			0.4	0.1
Black crappie		0.6		0.2	
Yellow perch	15	23	23.7	5.4	2.5
Walleye	1.3	8.1	3.3	0.5	0.5

Table 14. **Fishes by percent species composition collected in Northfield Mountain Reservoir. Data for 1973 through 1976 were obtained from Massachusetts Division of Fisheries and Game (1978).**

Species	**1973**	**1974**	**1975**	**1976**	**1990**
Blueback herring					15
American shad					19
Atlantic salmon	0.6				
Brown trout				trace	
Brook trout	0.6			0.3	
Chain pickerel	1.3	0.6	2.0		
Golden shiner	0.6	0.6		trace	
Eastern silvery minnow					18
Spottail shiner	34.6		1.3	11.8	14
Fallfish				trace	
Unidentified minnows					
White sucker	15.7	31.7	30.9	13.8	1.4
Brown bullhead	0.6	0.6		0.2	
Channel catfish					0.1
White perch	17	26.1	32.2	54.6	27
Rock bass				0.2	
Pumpkinseed	1.3	5	0.7	0.9	0.5
Bluegill	0.6			1.2	0.2
Smallmouth bass	3.3	3.7	5.3	10.5	1.5
Largemouth bass	7.2			0.4	0.1
Black crappie		0.6		0.2	
Yellow perch	15	23	23.7	5.4	2.5
Walleye	1.3	8.1	3.3	0.5	0.5

Table 15. **Fishes collected by nylon haul seine in Northfield Mountain Reservoir prior to drawdown, September 24, 1990.**

Collection No.	S1
Location	Boat launch area
Time	1310-1330
Water temperature (°C)	17.0
Dissolved oxygen (mg/l)	10.6
Water depth (ft)	0-52
<u>Species</u>	
Unidentified minnows	2

TABLE-R

Table 16. **Fishes collected by monofilament haul seine in Northfield Mountain Reservoir after drawdown, October 5, 1990.**

Collectio No.	S'1	S'2	S'3	
Location	Cofferdam area	Cofferdam area	Cofferdam area	
Time	1316-1330	1700-1720	1730-1749	
Water temperature (°C)	16.0	-	-	
Dissolved oxygen (mg/l)	6.4	-	-	
Water depth (ft)	0-4	0-6	0-4	
Species				Total
American shad	2	0	0	2
Spottail shiner	27	0	25	52
White perch	10	7	38	55
Smallmouth bass	1	0	0	1
Yellow perch	2	0	3	5
Walleye	0	1	1	2
Total species	5	2	4	6
Total specimens	42	8	67	117

TABLE-S

Table 17. **Fishes collected by electrofisher in Northfield Mountain Reservoir prior to drawdown, September 24, 1990.**

Collection No.	E1	E2	E3	E4	E5	
Location	From boat launch to W. shore	Along W. shore	Along N. shore	Near water supply tower	Intake/ discharge canal	
Time	1004-1024	1049-1109	1121-1144	1154-1204	1211-1233	Total
Duration (hrs)	0.33	0.33	0.38	0.17	0.37	1.58
Water temperature (°C)	15.5	15.5	-	16.4	16.5	
Dissolved oxygen (mg/l)	9.9	9.9	-	-	-	
pH	7.5	7.5	-	-	-	
Conductivity (umhos)	115 @ 16°C	115 @ 16°C	-	-	-	
Water depth (ft)	1-8	-	-	56-101	5-101	
Species						Total
Spottail shiner	1	2	2	0	0	5
White sucker	2	4	1	0	4	11
White perch	0	0	1	0	0	1
Pumpkinseed	5	0	0	0	0	5
Bluegill	2	0	0	0	0	2
Smallmouth bass	0	3	2	0	1	6
Largemouth bass	1	0	0	0	0	1
Yellow perch	2	2	2	0	0	6
Total species	6	4	5	0	2	8
Total specimens	13	11	8	0	5	37

TABLE-O

Table 18. **Fishes collected by electrofisher in Northfield Mountain Reservoir after drawdown, October 9, 1990.**

Collection No.	E'1	E'2	E'3	E'4	
Location	Near cofferdam	Along N. shore	Near water supply tower, along S. shore	Mid-pool, near water supply tower	
Time	1739-1749	1829-1839	1917-1927	2004-2014	Total
Duration (hrs)	0.17	0.17	0.17	0.17	0.67
Water temperature (°C)	16.0	-	-	-	
Dissolved oxygen (mg/l)	7.4	-	-	-	
Conductivity (umhos)	-	-	132 @ 16°C	-	
Water depth (ft)	1-7	0-8	-	6-23	

Species					Total
American shad	61	105	9	7	182
Blueback herring	29	61	44	7	141
Eastern silvery minnow	0	0	170	1	171
Spottail shiner	23	23	35	0	81
White sucker	0	0	2	0	2
White perch	5	20	11	6	42
Smallmouth bass	0	5	2	0	7
Yellow perch	1	0	0	0	1
Walleye	0	1	0	0	1
Total species	5	6	7	4	9
Total specimens	119	215	273	21	628

TABLE-P

Table 19. **Fishes collected by gill net in Northfield Mountain Reservoir after drawdown, October 5, 1990.**

Collection No.	G1	G2	G3	
Location	SW. of water supply tower	W. of water supply tower	N. of water supply tower	
Time	1150-1415	1205-1500	1245-1545	Total
Set duration (hrs)	2.42	2.92	3.00	8.34
Water temperature (°C)	15.2	15.0	15.2	
Dissolved oxygen (mg/l)	-	5.8	-	
pH	6.9	6.9	6.9	
Conductivity (umhos)	120 @ 15°C	120 @ 15°C	120 @ 15°C	
Water depth (ft)	14	14	13-20	
Mesh size (in)	1-4	1-4	5-8	

Species	G1	G2	G3	Total
White sucker	1	0	0	1
Channel catfish	1	0	0	1
White perch	70	91	0	161
Smallmouth bass	1	0	0	1
Yellow perch	6	6	0	12
Walleye	0	2	0	2
Total species	5	3	0	6
Total specimens	79	99	0	178

TABLE-Q

Table 20. Clupeids collected by haul seine in Turners Falls Pool during a separate study, September 1990.

Collection No.	*S19	*S20	*S21
Sector	1	1	1
Location	Barton Cove boat landing	Turners Falls Rod and Gun Club	Turners Falls Rod and Gun Club
Date	9/13	9/14	9/15
No. of Clupeids	319	225	785

* Number of seine attempts unknown.

SEINE

Table 21. **Length-frequency distribution of American shad and blueback herring collected in Northfield Mountain Upper Reservoir, October 1990.**

Gear Type	Electrofisher	Haul Seine (monofilament)	
Length Increment (mm TL)			Total
American shad			
61-65	2		2
66-70	4		4
71-75	19		19
76-80	38	1	39
81-85	35	1	36
86-90	17		17
91-95	8		8
96-100	6		6
Total			
Measured	129	2	131
Taken	182	2	184
Mean Length	81.3	80.5	81.2
Blueback herring			
56-60	1		1
61-65	5		5
66-70	18		18
71-75	50		50
76-80	34		34
81-85	25		25
86-90	1		1
Total			
Measured	134	0	134
Taken	141	0	141
Mean Length	75.1	-	75.1

TABLE-A

Table 22. Juvenile American shad collected in Turners Falls pool using all gear types.

Collection No.[1/]	E7	E10	E11	E13	E21	E23	E24	E25	E26	E27	S3
Sector	1	4	4	5	2	2	2	2	5	5	2
Location	Rod & Gun Club Cove	S. of abandoned RR br. piers, W. shore	S. of Shell br., W. shore	Vernon Dam E. shore cove	Intake Area	Intake area	Intake area	Intake area	Vernon Dam boat ramp	Near Stebbins Island	Otter Run Beach
Date	9/17	9/18	9/18	9/19	9/28	9/29	9/29	9/29	10/1	10/1	9/22
Time	0255-0305	0225-0235	0330-0340	1044-1054	0550-0610	0317-0350	0433-0503	0540-0610	1823-1829	1825-1910	1930-1938
Duration (hrs)	0.17	0.17	0.17	0.17	0.33	0.55	0.5	0.5	0.1	0.58	-
Water temperature (°C)	19.5	19.5	22	18	15.5	16	16	15.4	16.2	16	17
Dissolved oxygen (mg/l)	-	-	-	9.5	10	10	10	10	9.9	9.8	10.8
pH	7.5	7.1	7.7	7.9	-	-	-	-	-	7.8	7.5
Conductivity (umhos/cm)	122	122	115	25	110	-	110	110	-	118	-
Water depth (ft)	2-5	2-15	-	0-15	-	5-34	-	-	5-13	6-38	0-15
Net length (ft)	-	-	-	-	-	-	-	-	-	-	300
American shad	1	2	19	1	2	6	2	1	4	35	1

Collection No.	S5	S6	S8	S13	S14	S15	S'1	S'3	G2	G7	G8
Sector	5	5	5	3	4	4	5	5	2	2	2
Location	S. of Vernon Dam S. end of island	S. of Vernon Dam, E. shore	Vernon Dam boat ramp	S. of Rt. 10 Br., W. shore	S. of Central Vermont RR Br., W. shore	N. of Shell Br., E. shore	S. of Vernon Dam	S. of Vernon Dam	N. of intake E. side	N. of intake E. side	N. of intake E. side
Date	9/25	9/25	10/2	10/3	10/3	10-3	10-4	10-4	9/21-22	9/26-27	9/28
Time	1815-1830	2055-2110	1015-1030	1120-1140	1212-1225	1240-1400	1520-1525	1623-1633	2145-0745	2037-0814	0035-0800
Duration (hrs)	-	-	-	-	-	-	-	-	10	11.6	7.4
Water temperature (°C)	16	15.5	15.7	-	-	-	16	16	17.5	15.8	15.9
Dissolved oxygen (mg/l)	10	10	10.2	-	-	-	-	-	9.9	-	10.2
pH	7.6	-	7.3	-	-	-	-	-	-	-	-
Conductivity (umho/cm)	-	-	-	-	-	-	-	-	-	-	-
Water depth (ft)	0-10	0-19	0-15	-	-	-	0-14	0-12	12-20	-	11-21
Net length (ft)	300	300	300	300	300	300	200	200	150	200	200
American shad	11	22	2	9	3	3	5	8	1	3	2

[1/] The gear type used for each individual collection can be determined by the collection number: E = electrofisher; S = Seine Net; and G = Gill Net.

Table 22. Continued.

Collection No.	G10	G11	G'3	G'4	* S19	* S20	* S21
Sector	5	5	5	5	1	1	1
Location	SW. of Stebbins Island, S. side	S. of Vernon Dam N. side	W. of Stebbins Island	W. of Stebbins Island	Barton Cove Boat Landing	Turners Falls Rod & Gun Club	Turners Falls Rod & Gun Club
Date	10/1	10/2	10/8	10/8	9/13	9/14	9/15
Time	1610-2030	1430-1930	1820-1830	1840-1855			
Duration (hrs)	4.33	5	-	-			
Water temperature (°C)	16.4	16	15	15			
Dissolved oxygen (mg/l)	9.4	-	10	10			
pH	-	-	-	-			
Conductivity (umhos/cm)	-	-	-	-			
Water depth (ft)	9-32	14-16	-	-			
Net length (ft)	100	100	200	200			
American shad	1	1	1	1	** 319	**225	**785

* = number of seine samples unknown
** = American Shad and Blueback Herring combined

SHAD

Table 23. Fishes collected by anchored gill net in the Turners Falls pool, September-October 1990.

Collection No.	G1	G2	G3	G4	G5	G6	G7
Sector	2	2	2	2	2	4	2
Location	S. of Dry Brook, W. side	N. of intake, E. side	N. of intake, W. side	N. of intake, E. side	N. of intake, E. side	N. of Schell Br., E. side	N. of intake, E. side
Date	9/21	9/21-22	9/22-23	9/24-25	9/25	9/25	9/26-27
Time	1827-2114	2145-0745	1753-0637	2200-0800	0810-1604	1700-2020	2037-0814
Set duration (hrs)	2.78	10.0	12.70	10.00	7.90	3.33	11.62
Water temperature (°C)							
Set	18.0	17.5	17.0	16.3	15.7	17.0	15.8
Retrieve	-	17.0	-	-	16.2	15.5	-
Dissolved oxygen (mg/l)							
Set	9.6	9.9	8.9	9.9	9.9	9.7	-
Retrieve	-	9.3	-	-	6.7	9.3	-
pH							
Set	7.2	-	7.2	-	-	7.6	-
Retrieve	-	-	-	-	7.4	-	-
Net Length (ft)	150	150	200	200	200	200	200
Water depth (ft)	10-25	12-20	11-12	12-18	12-18	11-13	-
Species							
American shad	0	1	0	0	0	0	3
Smallmouth bass	0	0	0	0	0	0	1
Total species	0	1	0	0	0	0	2
Total specimens	0	1	0	0	0	0	4

Table 23. Continued.

Collection No.	G8	G9	G10	G11	G12	
Sector	2 [1/]	2 [1/]	5 [1/]	5 [1/]	5 [1/]	
Location	N. of intake, E. shore	N. of intake, E. side	SW. of Stebbins Island, S. Side	S. of Vernon Dam, N. Side	SW. of Stebbins Island, S. Side	
Date	9/28	9/28	10/1	10/4	10/4	
Time	0035-0800	0900-2345	1610-2030	1430-1930	1507-1945	Total
Fishing time (hrs)	7.42	14.75	4.33	5.00	4.63	95.13
Water temperature (°C)						
Set	15.9	15.9	16.4	16.0	16.0	
Retrieve	15.5	-	-	-	-	
Dissolved oxygen (mg/l)						
Set	10.2	10.2	9.4	-	-	
Retrieve	10.0	-	-	-	-	
pH						
Set	-	-	-	-	-	
Retrieve	-	-	-	-	-	
Net Length (ft)	200	200	100	100	100	
Water depth (ft)	11-21	-	9-32	14-16	12-21	

<u>Species</u>						Total
American shad	2	0	1	1	0	8
Smallmouth bass	0	0	0	0	0	1
Total species	1	0	1	1	0	2
Total specimens	2	0	1	1	0	9

[1/] nets rigged with brails

TABLE.E

Table 24. Fishes collected by electrofisher in the Turners Falls pool, September-October 1990.

Collection No.	E1	E2	E3	E4	E5	E6	E7	E8
Sector	2	2	2	2	1	1	1	1
Location	N. of intake, E. shore	N. of intake, W. shore	Intake, W. shore	Intake, mid-river	Miller River	Rod & Gun Club Cove	Rod & Gun Club Cove	Rod & Gun Club Cove
Date	9/16	9/16	9/17	9/17	9/17	9/17	9/17	9/17
Time	2130-2140	2210-2220	0023-0033	0040-0050	0105-0115	0210-0220	0255-0305	0330-0340
Duration (hrs)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Water temperature (°C)	19.0	20.0	19.0	19.0	23.0	19.5	19.5	20.0
Dissolved oxygen (mg/l)	-	-	-	-	-	-	-	-
pH	7.3	7.1	-	-	7.1	7.5	7.5	7.5
Conductivity (umhos)	122 @ 19°C	122 @ 20°C	122 @ 19°C	122 @ 19°C	163 @ 23°C	122 @ 19°C	122 @ 19.5°C	122 @ 20°C
Water depth (ft)	0-6	0-6	6-24	20-50	1-15	0-5	2-5	2-6
Species								
Sea lamprey	0	0	0	0	1	0	0	0
American eel	3	0	0	0	2	0	0	1
American shad	0	0	0	0	0	0	1	0
Chain pickerel	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	0	1	0	0
Eastern silvery minnow	0	6	0	0	0	10	3	1
Golden shiner	0	0	0	0	0	1	0	0
Spottail shiner	2	49	0	0	0	10	39	7
Fallfish	0	0	0	0	0	0	0	0
Unidentified minnows	0	0	0	0	1	0	1	0
White sucker	18	0	1	0	1	7	0	3
Banded killifish	0	0	0	0	0	6	0	0
Rockbass	7	1	0	0	1	1	1	0
Pumpkinseed	0	0	0	0	0	0	1	0
Bluegill	0	0	0	0	0	8	3	8
Smallmouth bass	8	7	0	0	10	1	0	1
Largemouth bass	0	0	0	0	0	3	4	2
Yellow perch	0	0	0	0	1	5	11	17
Walleye	0	0	0	0	0	0	1	1
Total taxa	5	4	1	0	7	11	10	9
Total specimens	38	63	1	0	17	53	65	41

Table 24. Continued.

Collection No.	E9	E10	E11	E12	E13	E14	E15	E16
Sector	4	4	4	4	5	5	5	5
Location	N. of abandoned RR br. piers, mid river	S. of abandoned RR br. piers, W. shore	S. of Schell br., W. shore	S. of abandoned RR br. piers, E. shore	Vernon Dam E. shore cove	Vernon Dam boat ramp	SW. of Stebbins Island	NE. of Stebbins Island
Date	9/18	9/18	9/18	9/18	9/19	9/19	9/19	9/19
Time	0110-0120	0225-0235	0330-0340	0420-0430	1044-1054	1122-1132	1150-1200	1200-1205
Duration (hrs)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.08
Water temperature (°C)	19.0	19.5	22.0	-	18.0	18.0	-	-
Dissolved oxygen (mg/l)	-	-	-	-	9.5	9.3	-	-
pH	7.7	7.1	7.7	-	7.9	-	-	-
Conductivity (umhos)	122 @ 19°C	122 @ 19.5°C	115 @ 22°C	-	25 @ 18.5°C	-	-	-
Water depth (ft)	20-45	2-15	-	5-30	0-15	0-6	-	-
Species								
Sea lamprey	0	0	0	0	0	0	0	0
American eel	0	0	0	0	0	0	0	0
American shad	0	2	19	0	1	0	0	0
Chain pickerel	0	0	0	0	0	1	0	0
Common carp	0	0	0	0	0	0	0	0
Eastern silvery minnow	0	16	1+	0	2	0	0	0
Golden shiner	0	0	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0
Fallfish	0	1	0	0	0	2	0	0
Unidentified minnows	0	0	0	0	0	0	0	0
White sucker	0	2	1	0	0	0	0	0
Banded killifish	0	0	0	0	2	0	0	0
Rockbass	0	3	1	0	1	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	0	0
Smallmouth bass	0	6	2	0	2	0	0	0
Largmouth bass	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	0	0	0	0	0	0	0
Total taxa	0	6	4	0	4	2	0	0
Total specimens	0	30	24+	0	8	3	0	0

Table 24. **Continued.**

Collection No.	E17	E18	E19	E20	E21	E22	E23	E24	E25
Sector	4	2	2	2	2	2	2	2	2
Location	N. of Schell Br., W. shore	Intake area	Intake area	Intake area	Intake area	Intake area	Intake area	Intake area	Intake area
Date	9/19	9/28	9/28	9/28	9/28	9/29	9/29	9/29	9/29
Duration (hrs)	0.17	0.18	0.25	0.18	0.33	0.52	0.55	0.50	0.50
Time	1250-1300	0219-0230	0232-0247	0252-0303	0550-0610	0010-0041	0317-0350	0433-0503	0540-0610
Water temperature (°C)	18.0	15.3	16.0	16.0	15.5	15.9	16.0	16.0	15.4
Dissolved oxygen (mg/l)	8.7	10.0	10.0	10.0	10.0	10.2	10.0	10.0	10.0
pH	7.6	-	-	-	-	-	-	-	-
Conductivity (umhos)	124 @ 18.5°C	-	-	-	110 @ 16°C	-	-	110 @ 16°C	110 @ 16°C
Water depth (ft)	3-10	1-27	3-34	0-7	-	1-34	5-34	-	-
<u>Species</u>									
Sea lamprey	0	0	0	0	0	0	0	0	0
American eel	0	1+	0	0	0	0	0	0	0
American shad	0	0	0	0	2	0	6	2	1
Chain pickerel	0	0	0	0	0	0	0	0	0
Common carp	0	0	0	0	0	0	0	0	0
Eastern silvery minnow	0	1+	0	0	1	0	0	0	0
Golden shiner	0	0	0	0	0	0	0	0	0
Spottail shiner	0	1+	0	0	0	0	0	0	0
Fallfish	0	0	0	0	0	0	0	0	0
Unidentified minnows	1	0	0	0	0	0	0	0	0
White sucker	0	1+	0	0	0	0	0	0	0
Banded killifish	0	0	0	0	0	0	0	0	0
Rockbass	0	1+	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	0	0	0
Smallmouth bass	0	1+	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	0	0
Yellow perch	0	1+	0	0	2	0	0	0	0
Walleye	0	1+	0	0	0	0	0	0	0
Total taxa	1	8	0	0	3	0	1	1	1
Total specimens	1	8+	0	0	5	0	6	2	1

Table 24. Continued.

Collection No.	E26	E27	E28	E29	
Sector	5	5	5	5	
Location	Vernon Dam boat ramp	Near Stebbins Island	Near Stebbins Island	S. of Vernon Dam	
Date	10/1	10/1	10/1	10/1	Total
Duration (hrs)	0.10	0.58	0.17	0.22	6.83
Time	1823-1829	1835-1910	1932-1942	2008-2021	
Water temperature (°C)	16.2	16.0	16.0	16.0	
Dissolved oxygen (mg/l)	9.9	9.8	9.8	9.8	
pH	-	7.8	7.8	7.8	
Conductivity (umhos)	-	118 @ 16°C	118 @ 16°C	118 @ 16°C	
Water depth (ft)	5-13	6-38	4-21	7-31	

Species					Total
Sea lamprey	0	0	0	0	1
American eel	0	0	0	0	7+
American shad	4	35	0	8	81
Chain pickerel	0	0	0	0	1
Common carp	0	0	0	0	1
Eastern silvery minnow	0	0	0	0	41+
Golden shiner	0	0	0	0	1
Spottail shiner	0	0	0	0	108+
Fallfish	0	0	0	0	3
Unidentified minnows	0	0	0	0	2
White sucker	1+	0	0	0	36+
Banded killifish	0	0	0	0	8
Rockbass	0	0	0	0	17+
Pumpkinseed	0	0	0	0	1
Bluegill	0	0	0	0	19
Smallmouth bass	0	0	0	0	38+
Largemouth bass	0	0	0	0	9
Yellow perch	0	0	0	0	37+
Walleye	0	0	0	0	3+
Total taxa	2	1	0	1	19
Total specimens	5+	35	0	8	414+

+ = Indicates minimum number of specimens collected.

TABLE-N

Table 25. Fishes collected by towed gill net in the Turners Falls pool, October 1990.

Collection No.	G'1	G'2	G'3	G'4	G'5	G'6	
Sector	5	5	5	5	1	1	
Location	At base of Vernon Dam	At base of Vernon Dam	W. of Stebbins Island	W. of Stebbins Island	N. of French King Br.	N. of French King Br.	
Date	10/4	10/4	10/8	10/8	10/9	10/9	
Time	1847-1900	1905-1915	1820-1830	1840-1855	0933-0937	0945-1009	
Water temperature (°C)	-	-	15.0	15.0	15.0	15.0	
Dissolved oxygen (mg/l)	-	-	10.0	10.0	9.6	9.6	
Net length	200	100	200	200	200	200	
Water depth (ft)	16-44	-	-	-	16-40	16-40	
Species							Total
American shad	2	1	1	1	0	0	5
Total species	1	1	1	1	0	0	1
Total specimens	2	1	1	1	0	0	5

TABLE-F

Table 26. Frame net samples in the Turners Falls pool, September-October 1990.

Collection No.	F1	F2	F3	F4	F5	F6	F7	
Sector	2	2	2	2	3	1	2	
Location	N. of Intake	N. of Intake	Dry Brook	Kidds Island	Munns Ferry	S. of French	N. of French King Br.	King Br.
Date	9/20	9/20	9/20	9/20	9/20	9/20	9/20	
Time	1759-1809	1821-1836	1849-1904	1913-1928	1936-1951	2024-2039	2048-2058	
Water temperature (°C)	17.5	17.5	17.8	-	-	-	-	
Dissolved oxygen (mg/l)	9.2	9.2	9.2	-	-	-	-	
pH	7.1	7.1	7.1	-	-	-	-	
Trawl speed (ft/sec)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Volume filtered (m^3)	2,499	3,218	3,230	3,260	3,317	3,443	3,789	
Water depth (ft)	12-22	12-18	12-26	-	13-45	17-101	12-40	

---------------------------- NO FISH COLLECTED ------------------------

Collection No.	F8	F9	F10	F11	F12	
Sector	2	2	5[1/]	5[1/]	5	
Location	Intake area	Intake area	S. of Vernon Dam	S. of Vernon Dam	S. of Vernon Dam	
Date	9/26	9/26	10/3	10/3	10/3	
Time	2047-2100	2115-2128	1802-1812	1818-1821	1833-1842	
Water temperature (°C)	15.7	15.7	15.6	15.6	15.6	
Dissolved oxygen (mg/l)	-	-	10.1	10.1	10.1	
pH	-	-	7.4	7.4	7.4	
Trawl speed (ft/sec)	6.5	6.0-6.5	5.0-6.0	5.0-6.0	6.0	Total
Volume filtered (m^3)	4,394	3,399	-	-	-	30,549
Water depth (ft)	12-30	12-32	10-61	10-61	9-39	

------------------ NO FISH COLLECTED -----------------

[1/] Electrofishing electrodes used (see text).

TABLE-H

Table 27. Otter trawl samples in the Turners Falls pool, September-October 1990.

Collection No.	T1	T2	T3	T4	T5	T6	T7	T8	T9
Sector	2	2	2	2	2	2	1	1	2
Location	S. of intake	N. of intake	Intake area	Intake area	Intake area	Intake area	S. of French King Br.	The Narrows	Intake area
Date	9/13	9/13	9/14	9/14	9/14	9/26	9/26	9/26	9/26
Time	1100-1110	1128-1138	0030-0044	0056-0110	0119-0132	1726-1746	1755-1805	1818-1833	1844-1852
Water temperature (°C)	22.0	21.0	21.0	21.0	23.0	16.0	-	-	-
Dissolved oxygen (mg/l)	8.3	8.7	9.0	9.0	9.2	9.9	-	-	-
pH	7.6	7.5	7.5	7.5	7.5	7.1	-	-	-
Trawl speed (ft/sec)	4.5	6.0	5.0	5.0	5.0	6.0	6.0	6.0-7.0	6.5
Depth (ft)									
fishing	5.6	4.8	5.2	5.2	5.2	4.8	10.4	9.5	9.5
water	14-22	9-17	11-31	9-31	7-31	16-30	12-80	24-71	17-32

------------------------------------- NO FISH COLLECTED -------------------------------------

Collection No.	T10	T11	T12	T13	T14	T15	T16
Sector	2	2	2	5	5[1/]	5[1/]	5[1/]
Location	Intake area	S. of Kidds Island	Intake area	S. of Vernon Dam	E. of Stebbins Island	E. of Stebbins Island	W. of Stebbins Island
Date	9/26	9/26	10/3	10/3	10/8	10/8	10/8
Time	1901-1914	1934-2001	1719-1724	1730-1736	1627-1638	1655-1706	1727-1741
Water temperature (°C)	-	-	-	-	15.0	15.0	15.0
Dissolved oxygen (mg/l)	-	-	-	-	9.9	9.9	9.9
pH	-	-	-	-	-	-	-
Trawl speed (ft/sec)	6.5	6.5	6.0	6.0	5.0-6.5	5.0-6.0	5.0-6.0
Depth (ft)							
fishing	9.5	9.5	8.7	8.7	ca. 4.0	ca. 3.0	ca. 3.0
water	13-22	13-30	12-43	12-43	6-14	9-13	-

---------------------------------- NO FISH COLLECTED ----------------------------

[1/] Towed by 2 boats with net brails and extra flotation.

Table 28. Continued.

Collection No.	S10	S11	S12	S13	S14	S15	S16	S17	S18	
Sector	5	2	3	3	4	4	5	5	5	
Location	S. of Vernon Dam, S. end of island	Otter Run Beach	N. of Munns Ferry, W. shore	S. of Rt. 10 Br., W. shore	S. of Central Vermont RR Br., W. shore	N. of Schell Br., E. shore	Near Dole Junction, E. shore	E. of Stebbins Island, S. shore	S. of Vernon Dam, E. shore	
Date	10/2	10/3	10/3	10/3	10/3	10/3	10/3	10/3	10/3	
Time	1145-1200	1000-1015	1050-1108	1120-1140	1212-1225	1240-1400	1335-1350	1400-1420	1440-1456	
Water temperature (°C)	15.7	15.3	-	-	-	-	-	15.5	-	
Dissolved oxygen (mg/l)	10.2	10.0	-	-	-	-	-	10.0	-	
pH	7.3	7.3	-	-	-	-	-	7.3	-	
Net length (ft)	300	300	300	300	300	300	200	300	300	
Water depth (ft)	-	0-15	0-14	-	0-13	0-18	-	0-10	-	
Species										Total
American shad	0	0	0	9	3	3	0	0	0	51
Eastern silvery minnow	0	0	0	0	0	2	0	0	0	12+
Spottail shiner	0	0	0	0	1	0	0	3	0	43+
Unidentified minnows	0	0	0	0	0	0	0	0	0	3
Banded killifish	0	0	0	0	0	2	0	0	0	2
Rockbass	0	0	0	0	0	0	0	0	0	10
Bluegill	0	0	0	0	0	0	0	0	0	3
Smallmouth bass	0	0	0	0	0	3	0	0	0	5
Total taxa	0	0	0	1	2	4	0	1	0	8
Total specimens	0	0	0	9	4	10	0	3	0	129+

+ = Indicates minimum number of specimens collected.

TABLE-D

Table 29. **Fishes collected by monofilament haul seine in the Turners Falls pool, October 4, 1990.**

Collection No.	S'1	S'2	S'3	
Sector	5	5	5	
Location	S. of Vernon Dam	E. of Stebbins Island	S. of Vernon Dam	
Time	1520-1525	1548-1558	1623-1633	
Water temperature (°C)	16.0	16.0	16.0	
Water depth (ft)	0-14	0-10	0-12	
<u>Species</u>				Total
American shad	5	0	8	13
Fallfish	0	16	0	16
Smallmouth bass	0	1	0	1
Total species	1	2	1	3
Total specimens	5	17	8	30

TABLE-I

FIGURES

Figure 1. Northfield Mountain Pumped Storage Project and Turners Falls Pool, Connecticut River.

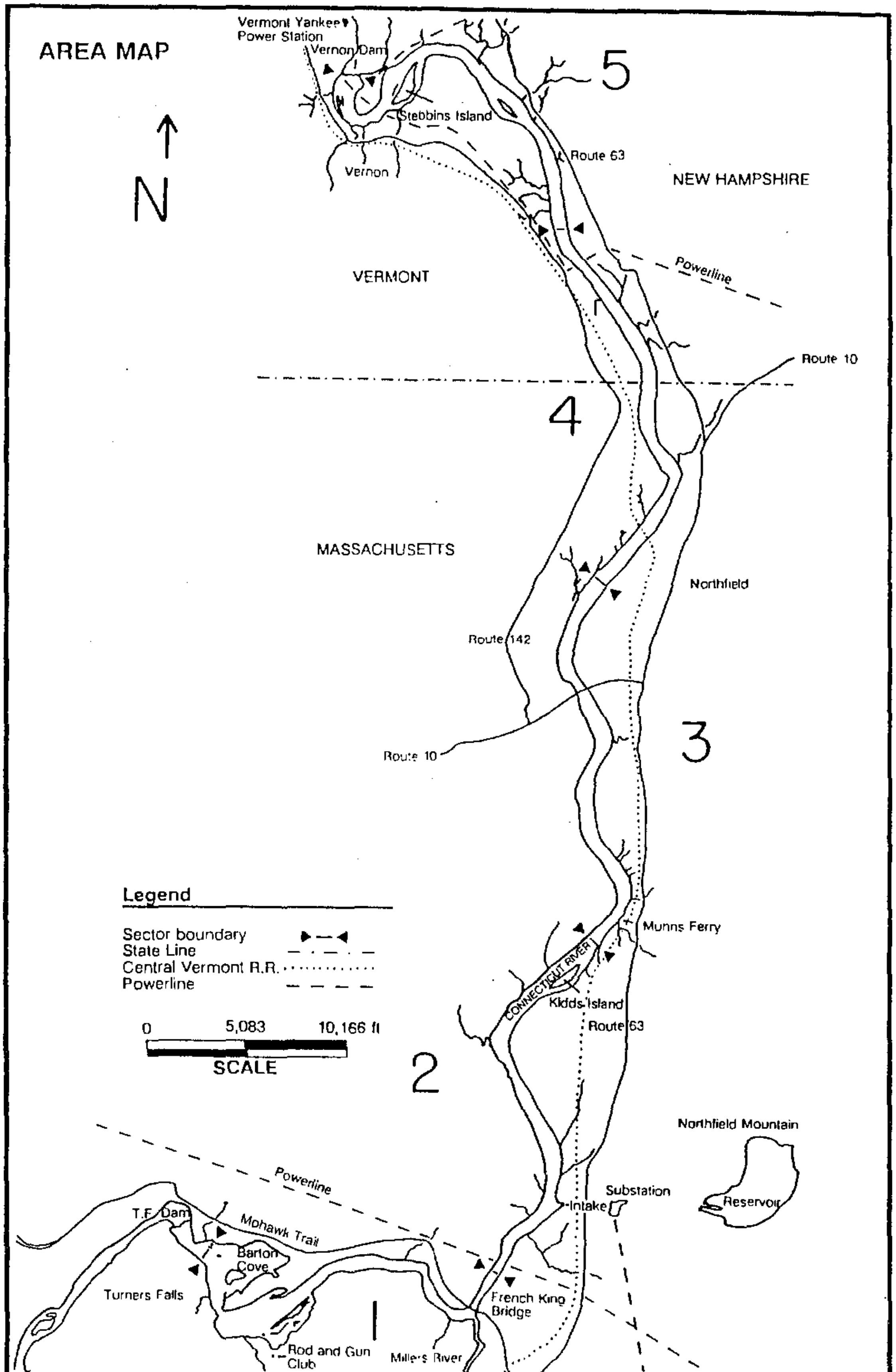


Figure 2. The Connecticut River, Study area Sector 1.

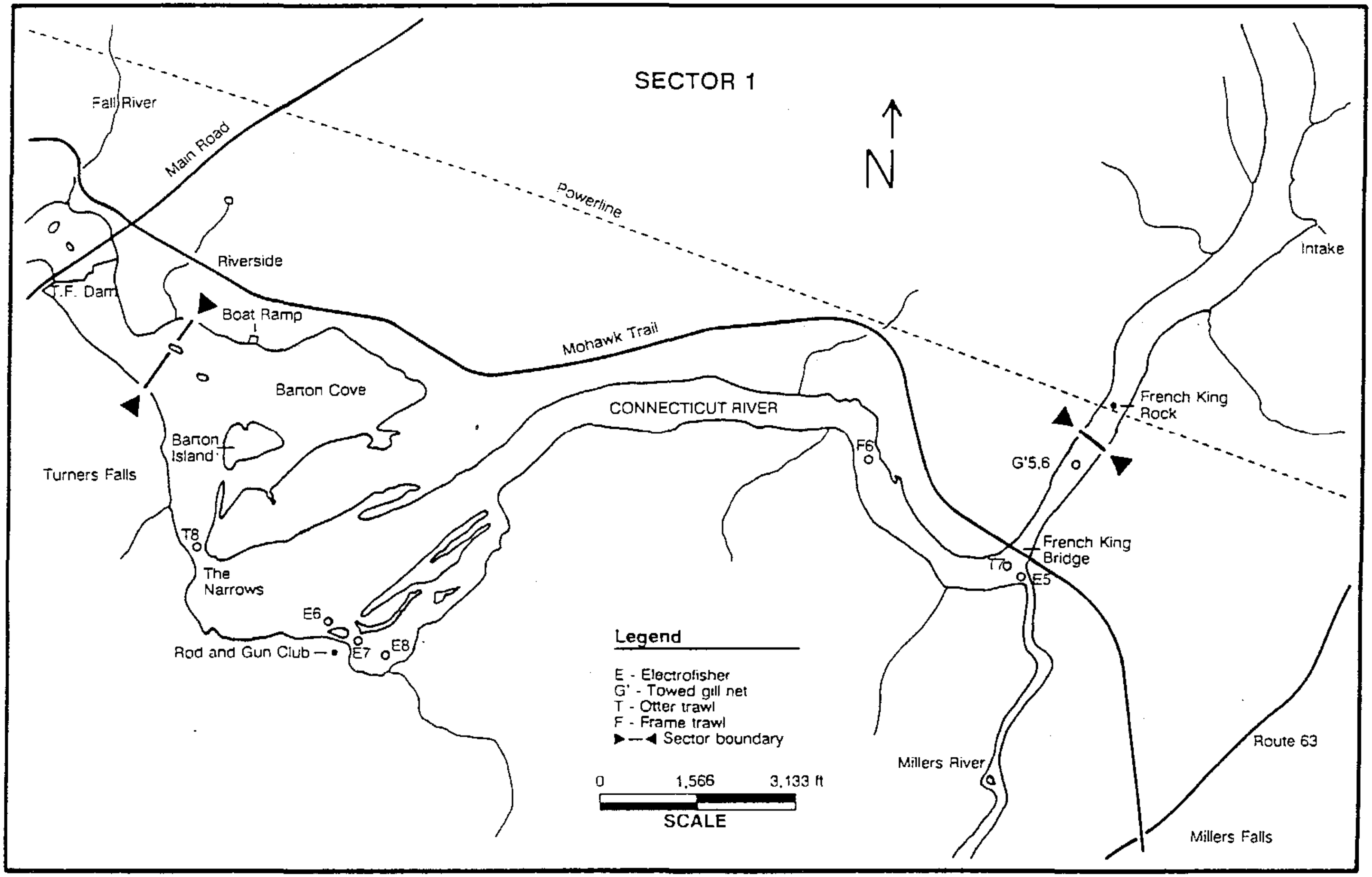


Figure 3. The Connecticut River, Study area Sector 2.

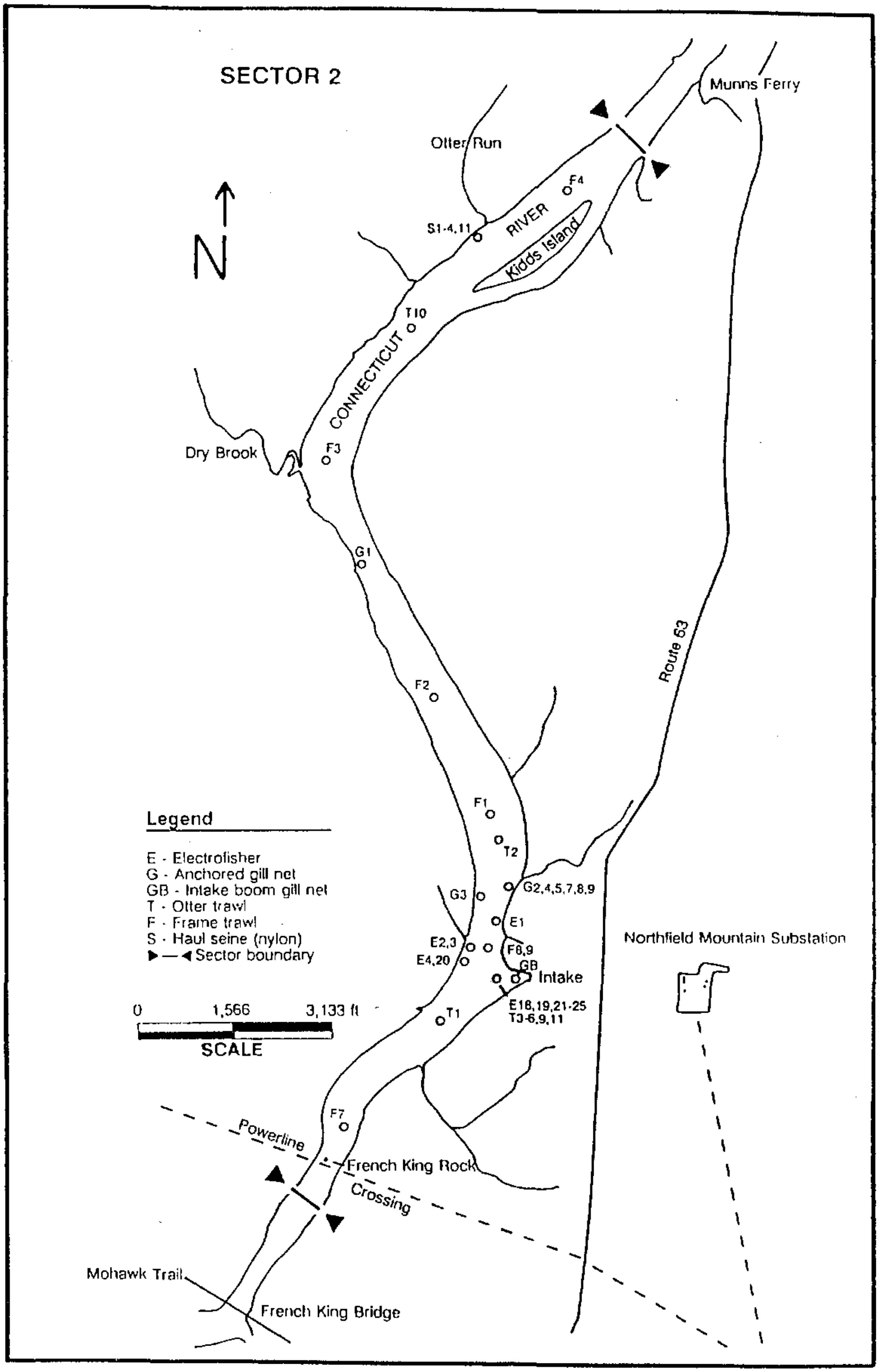


Figure 4. The Connecticut River, Study area Sector 3.

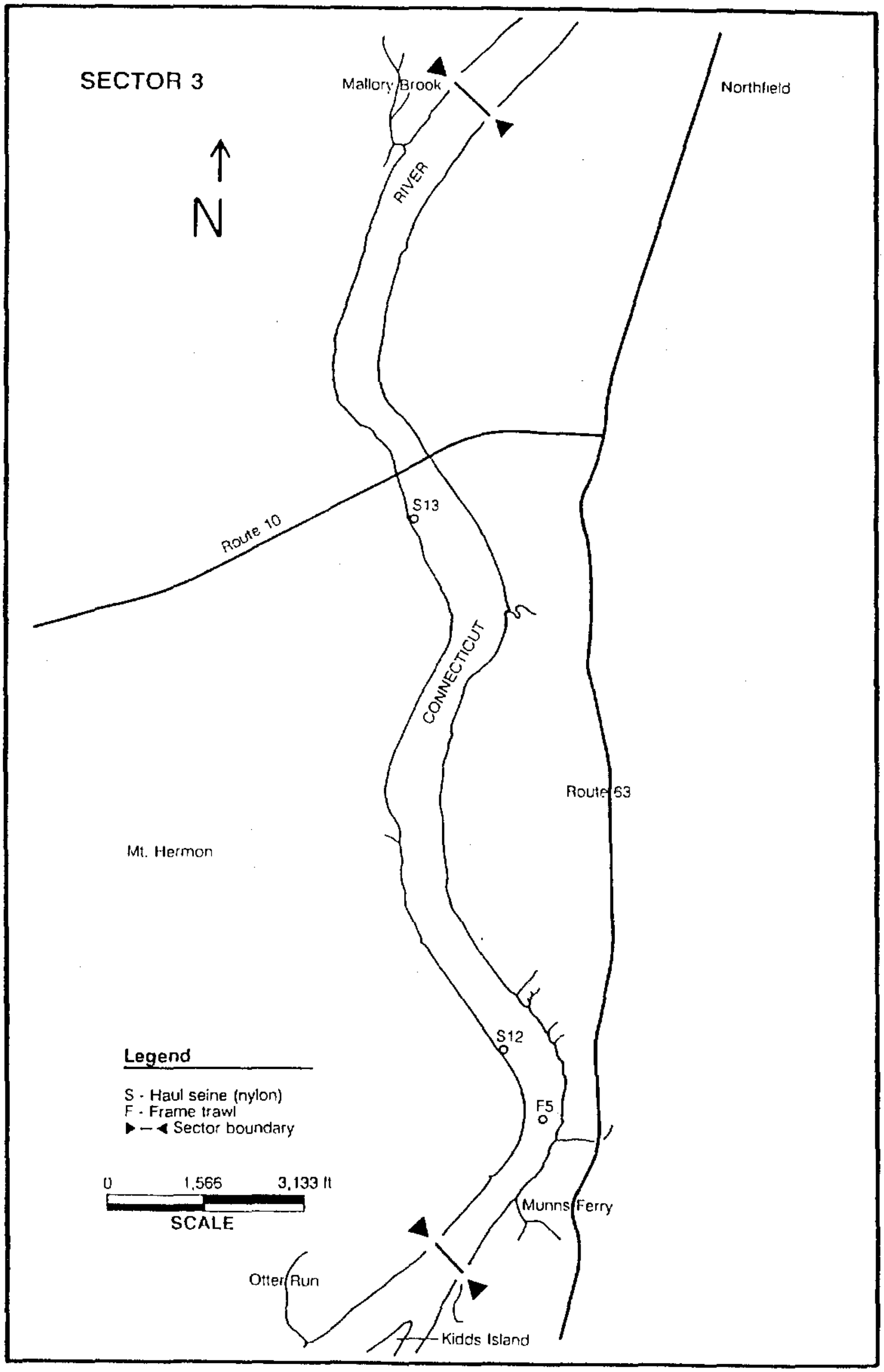


Figure 5. The Connecticut River, Study area Sector 4.

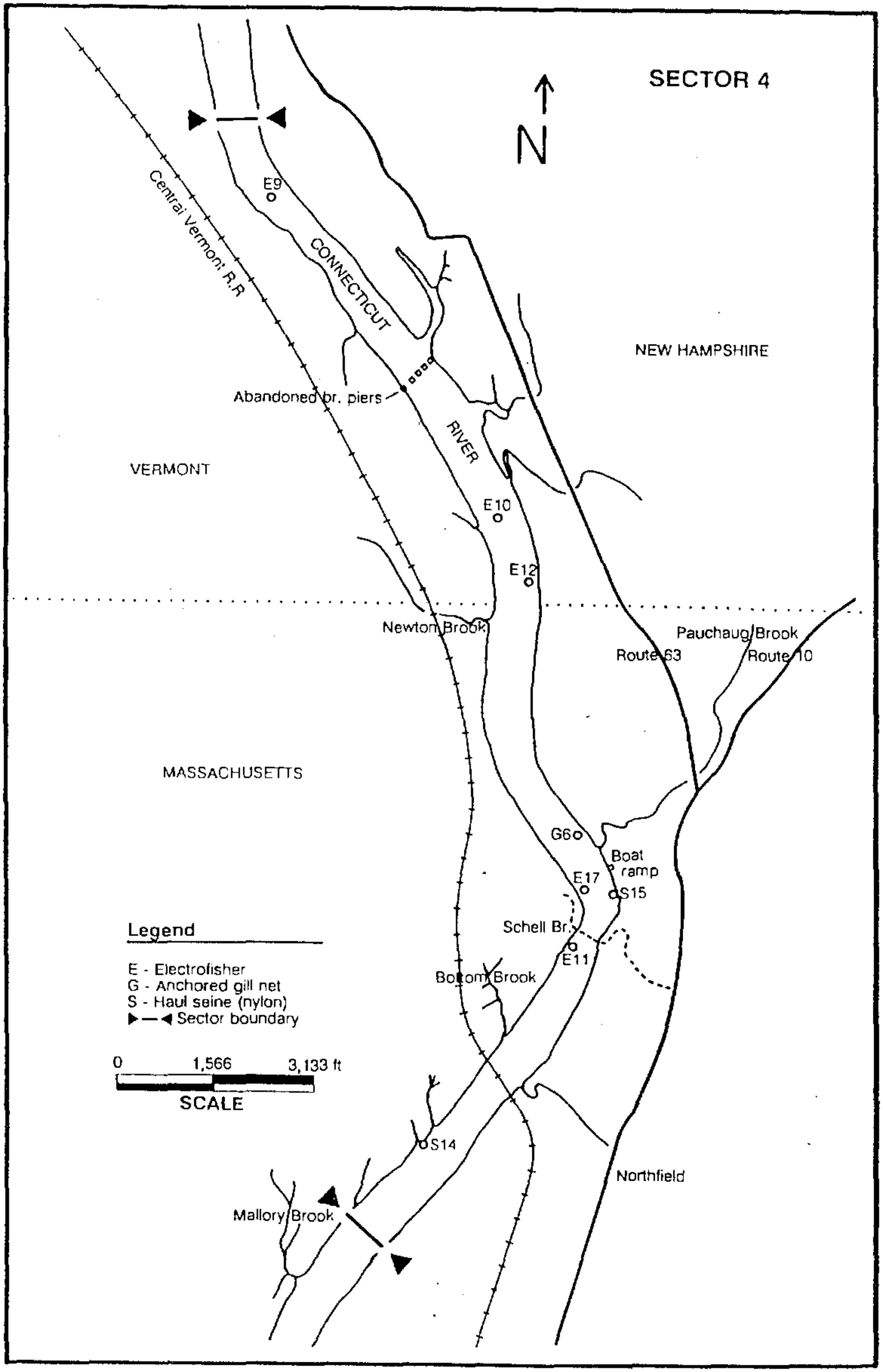


Figure 6. The Connecticut River, Study area Sector 5.

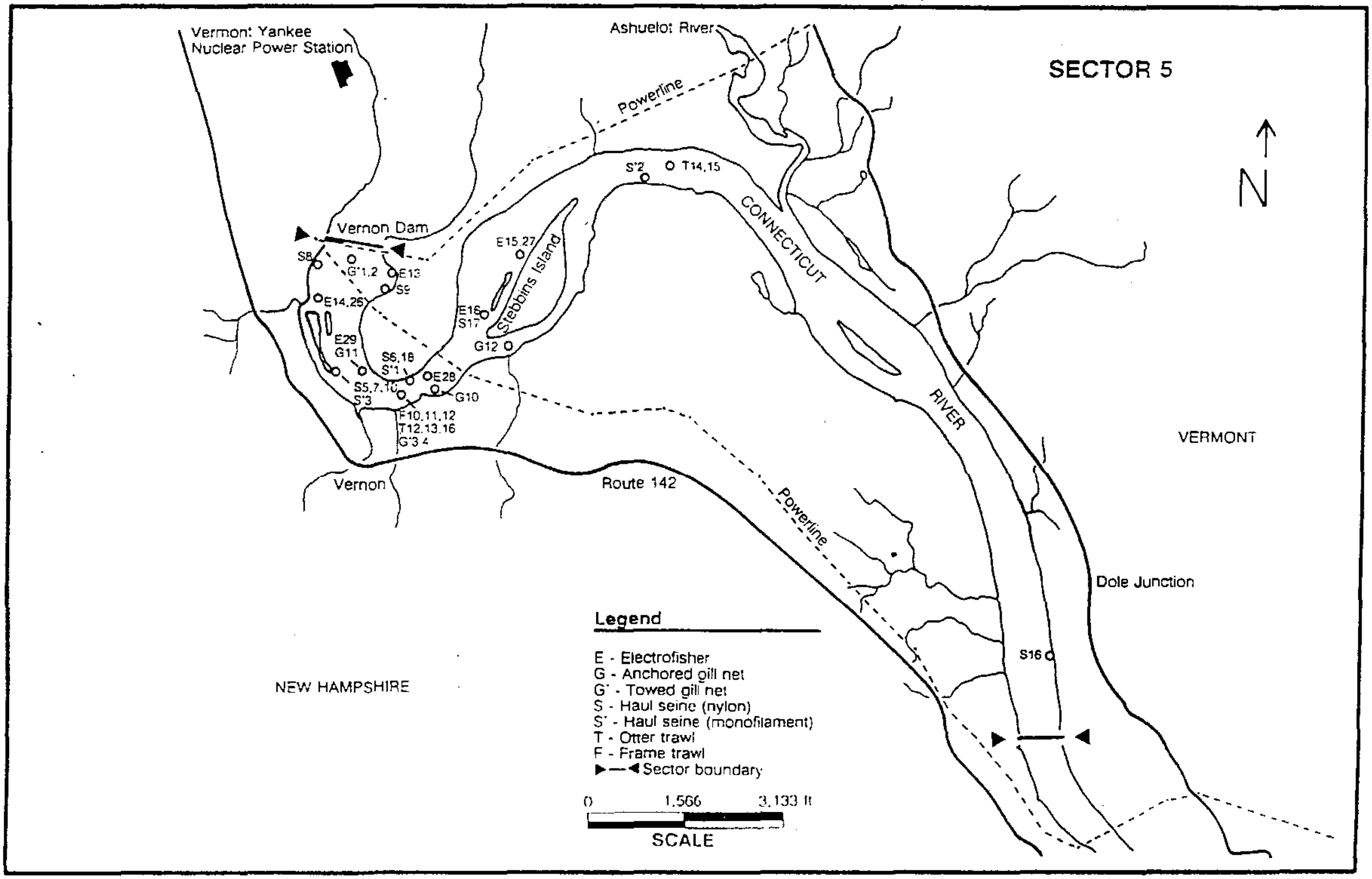


Figure 7A. A plan and section of the Northfield Mountain Pumped Storage Project intake.

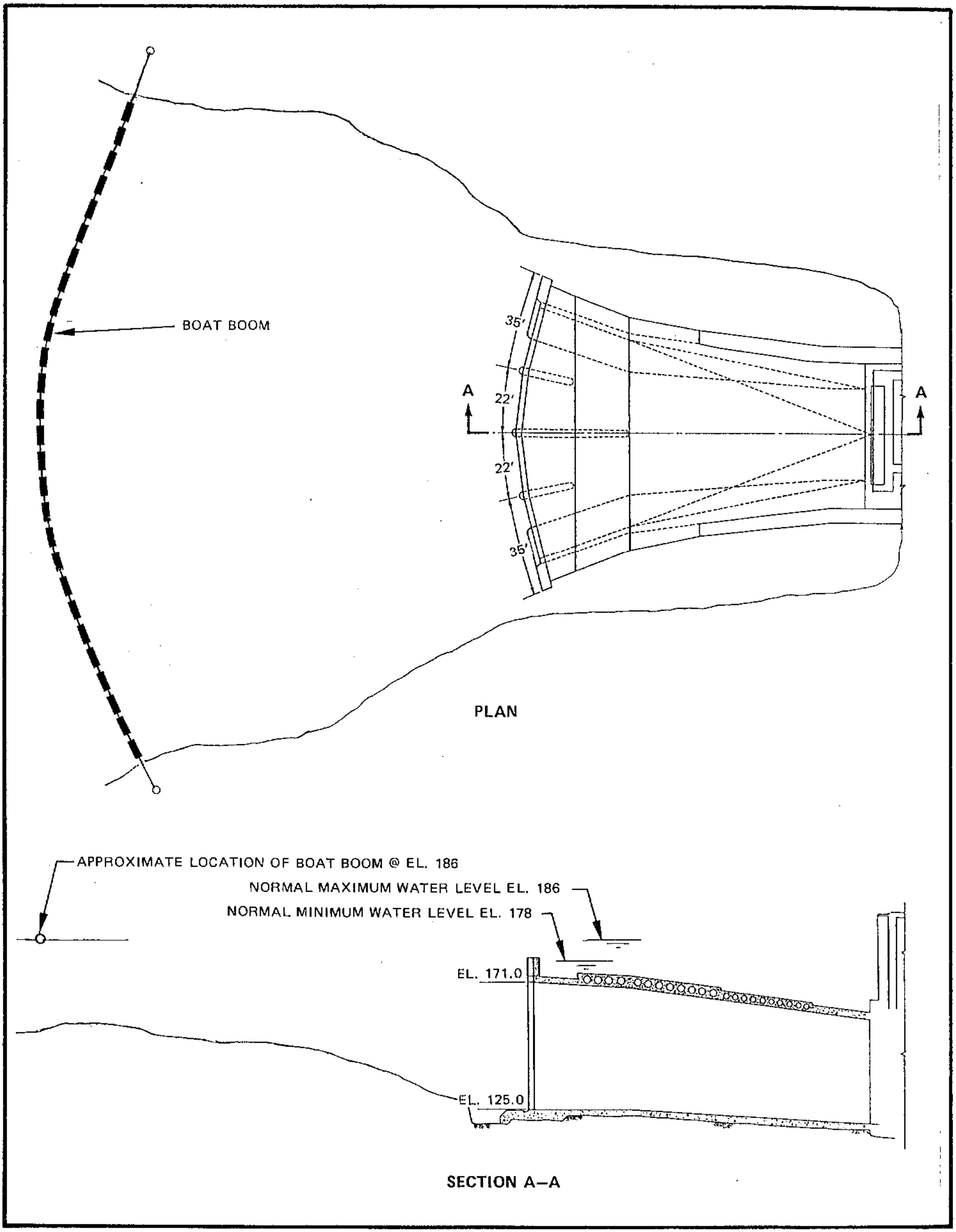


Figure 7B. Northfield Mountain Pumped Storage Project intake, Connecticut River, Massachusetts.

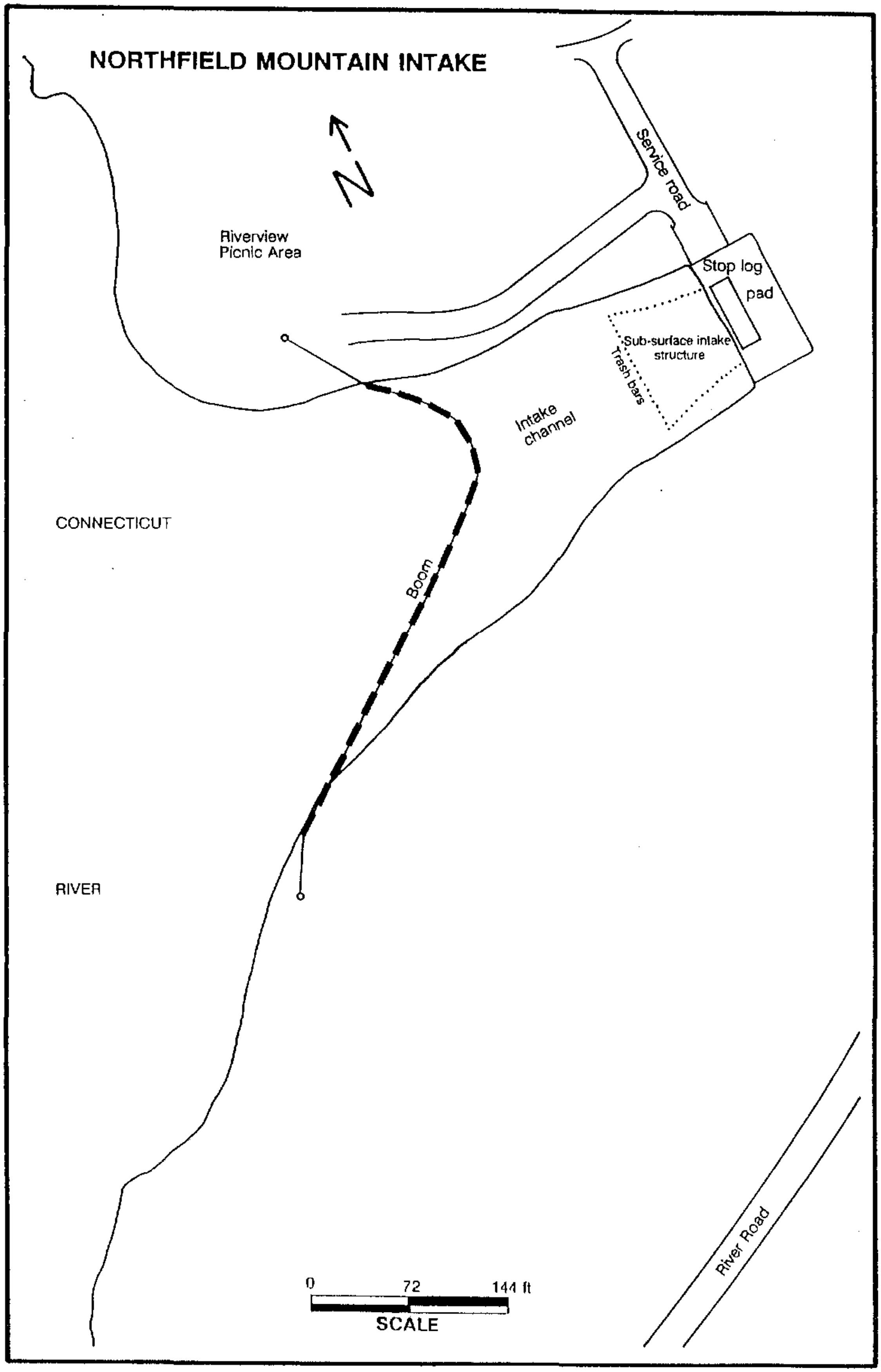


Figure 8. The upper reservoir of the Northfield Mountain Pumped Storage Project, Connecticut River, Massachusetts.

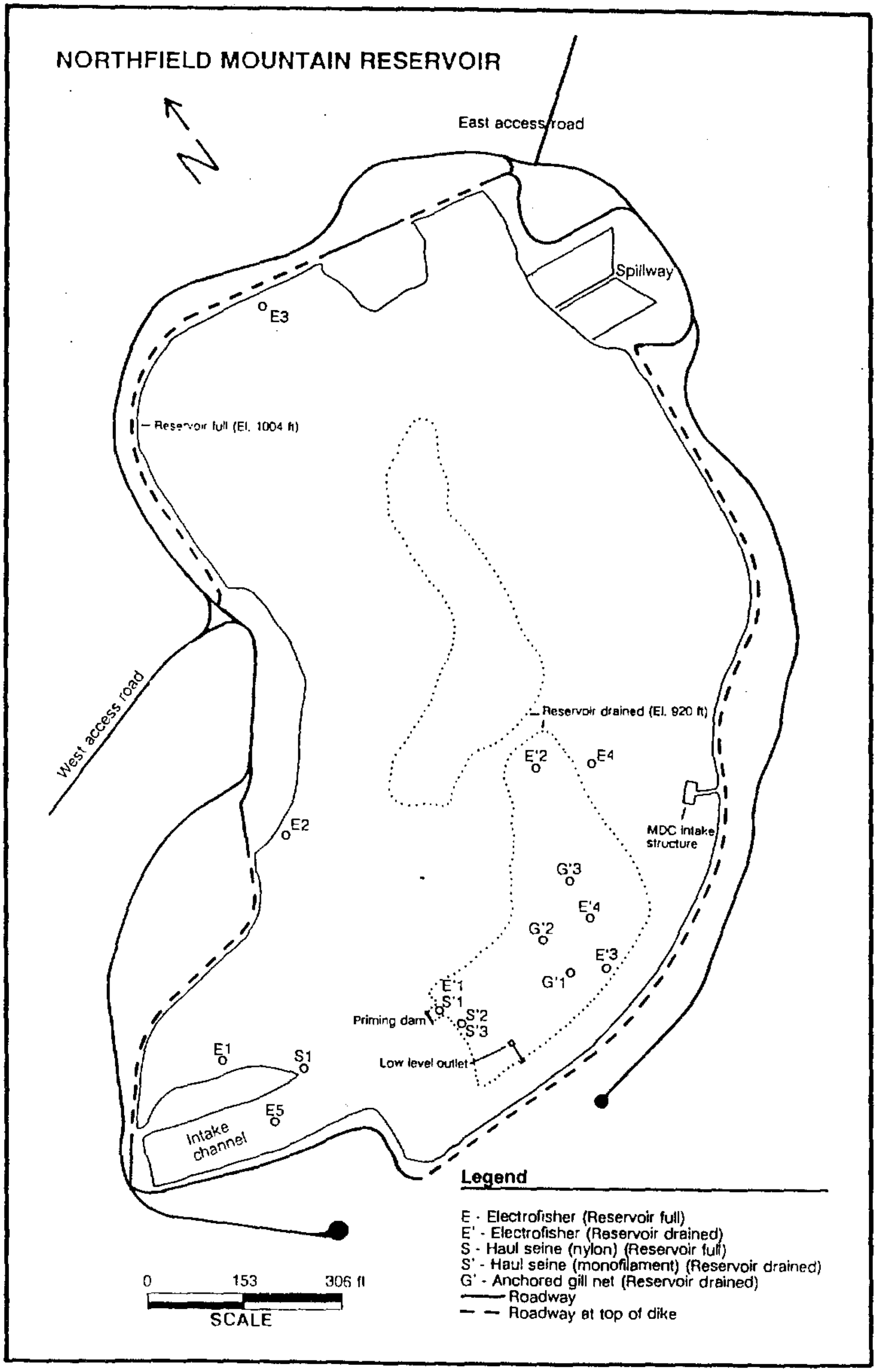


Figure 9. **Top view showing transducer beam placement used during hydroacoustic sampling, Northfield Mountain Hydroelectric Station, September 12-27, 1990.**

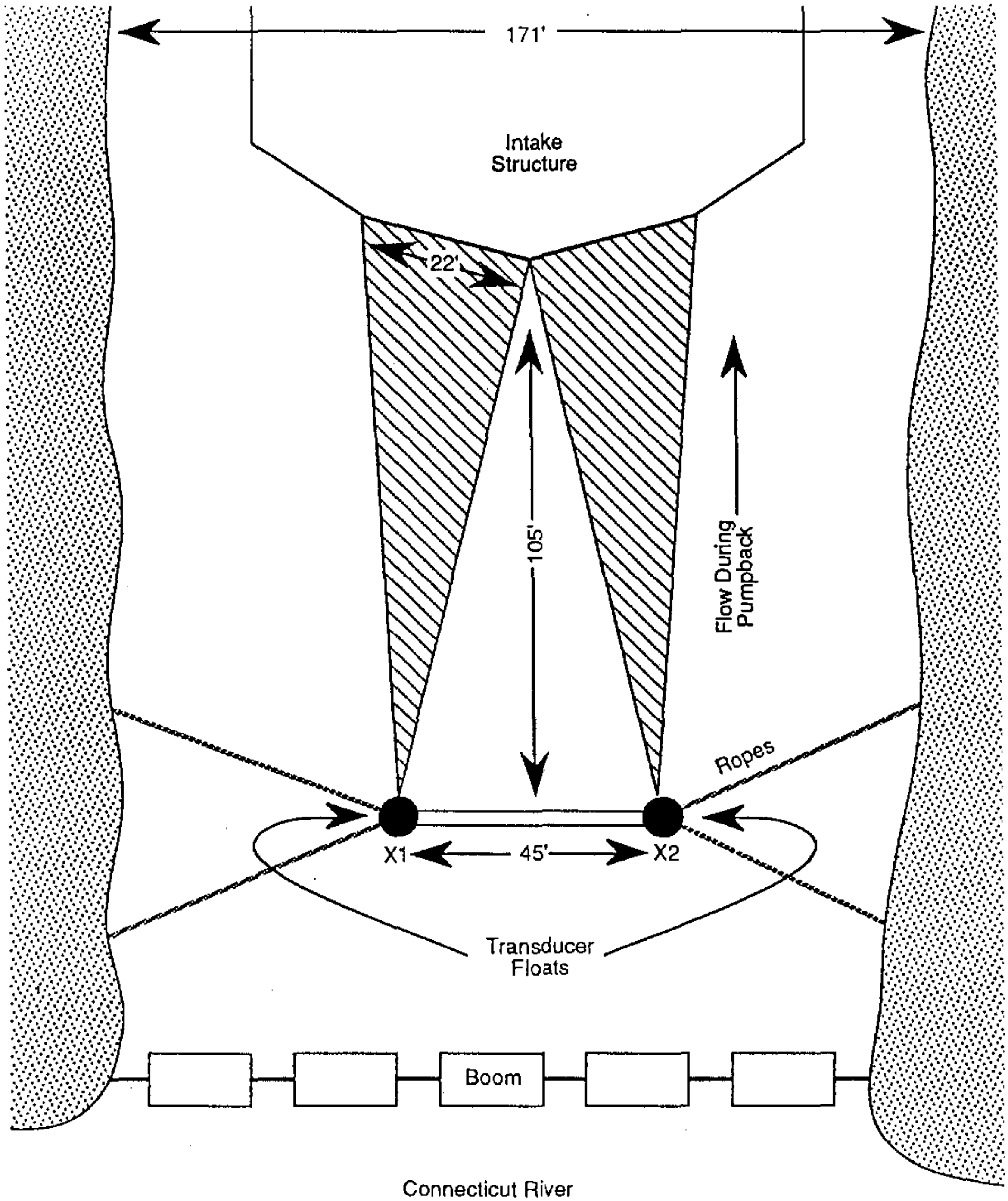


Figure 10. Side view showing transducer beam placement used during hydroacoustic sampling, Northfield Mountain Hydroelectric Station, September 12-27, 1990.

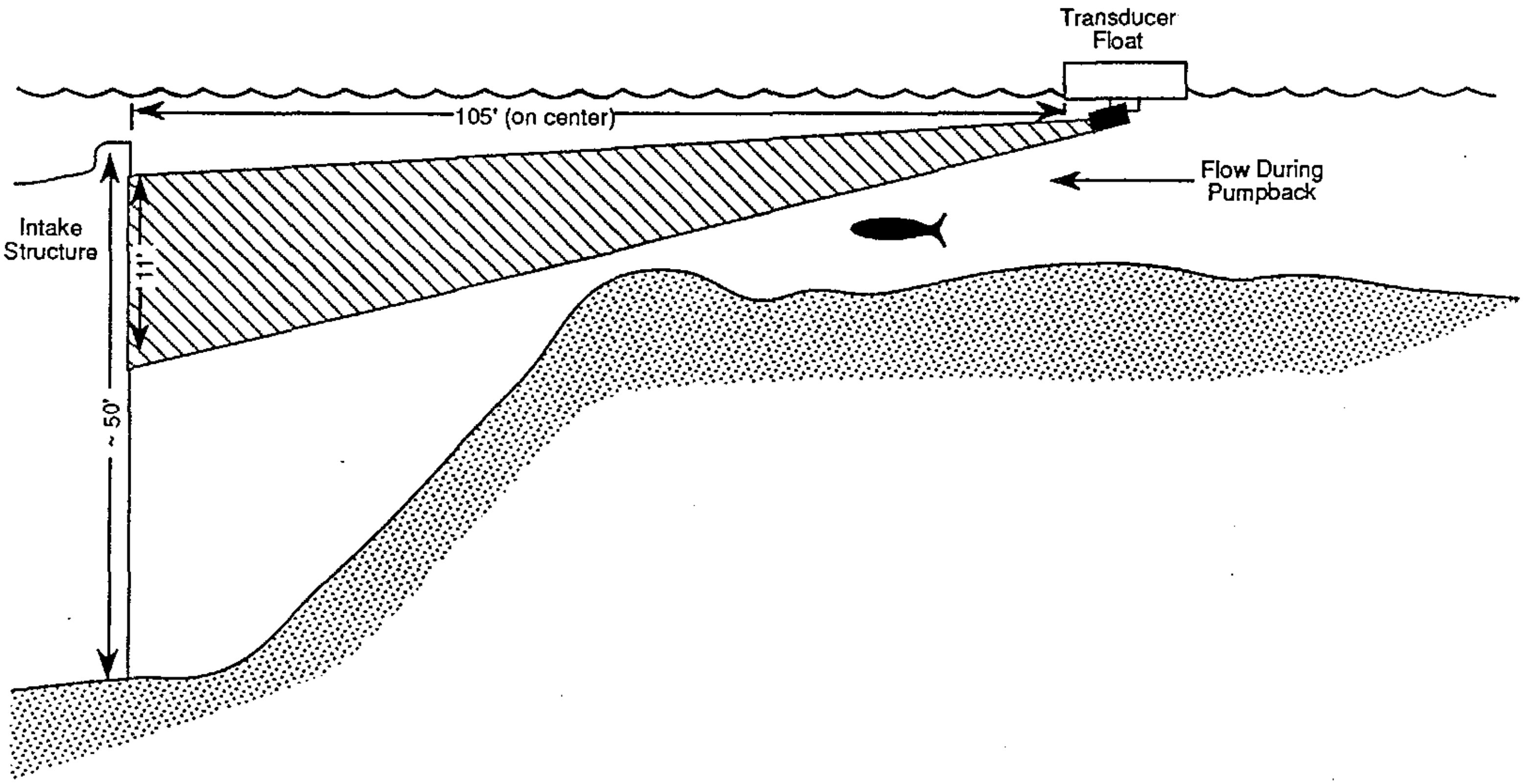


Figure 11. **Typical echogram showing fish behavior during generation, Northfield Mountain Hydroelectric Station, September 12-27, 1990.**

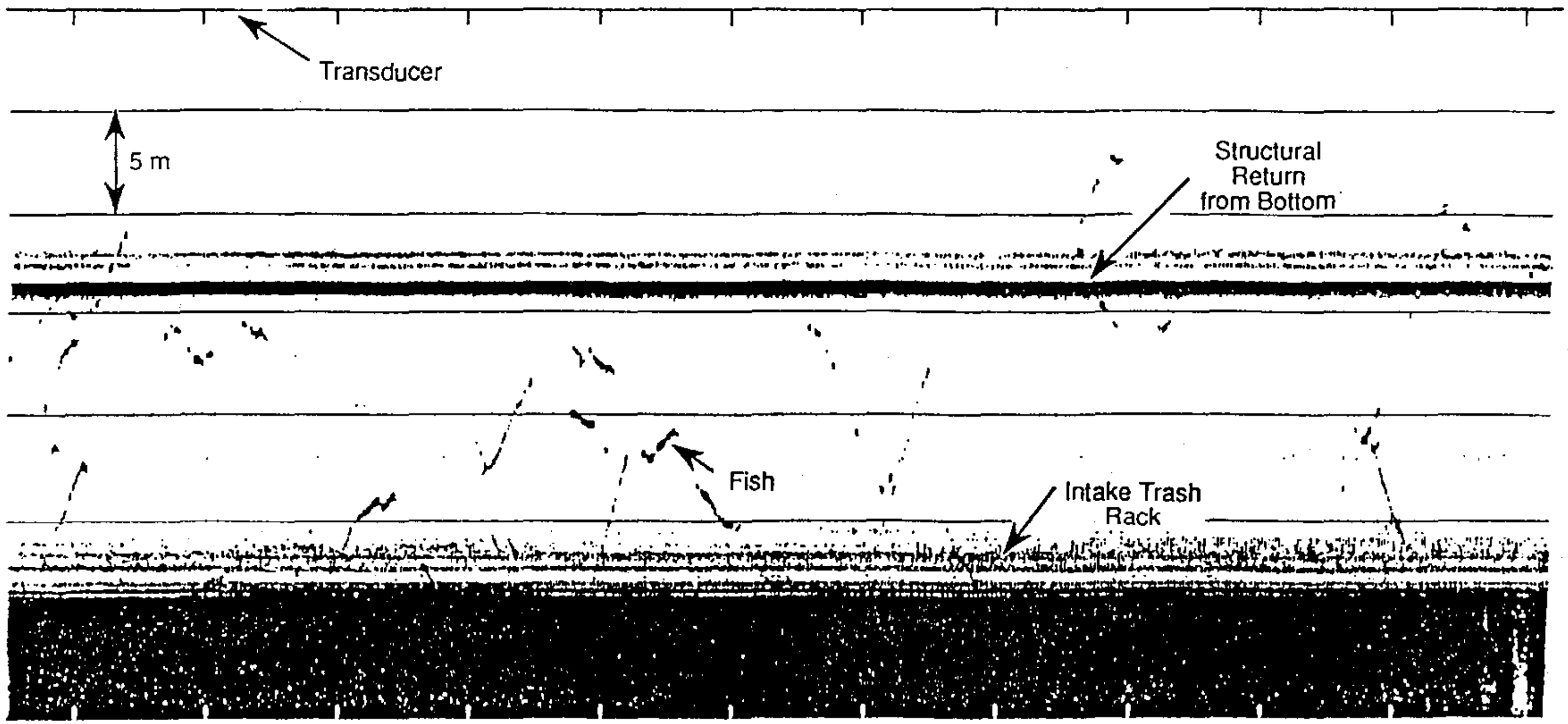


Figure 12. **Typical echogram showing entrained fish moving into the intake during pumpback, Northfield Mountain Hydroelectric Station, September 12-27, 1990.**

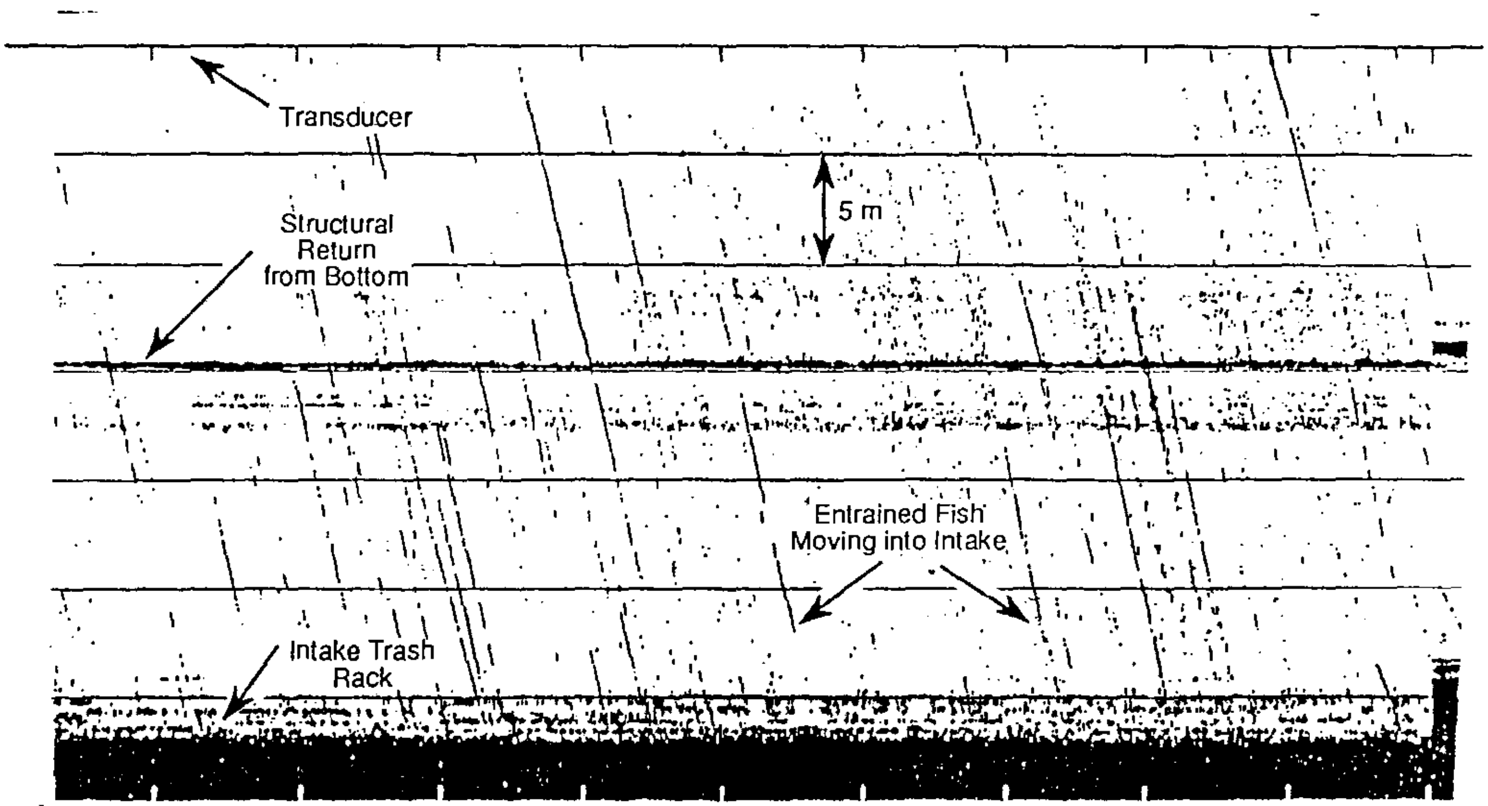


Figure 13. **Typical echogram showing fish behavior during termination of pumpback activity, Northfield Mountain Hydroelectric Station, September 12-27, 1990.**

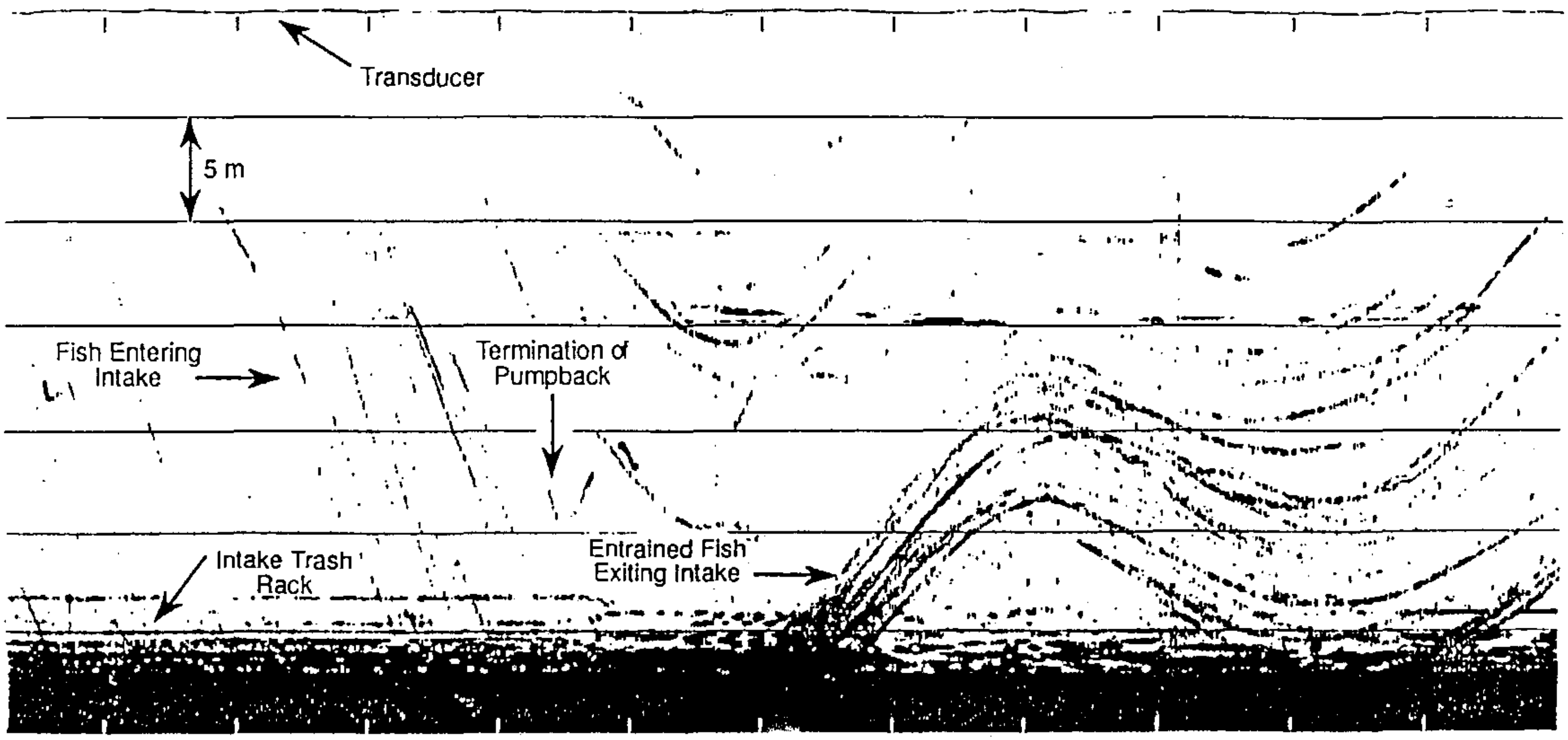


Figure 14. **Nightly estimated total fish entrainment vs. pumping volume, Northfield Mountain Hydroelectric Station, September 12-27, 1990.**

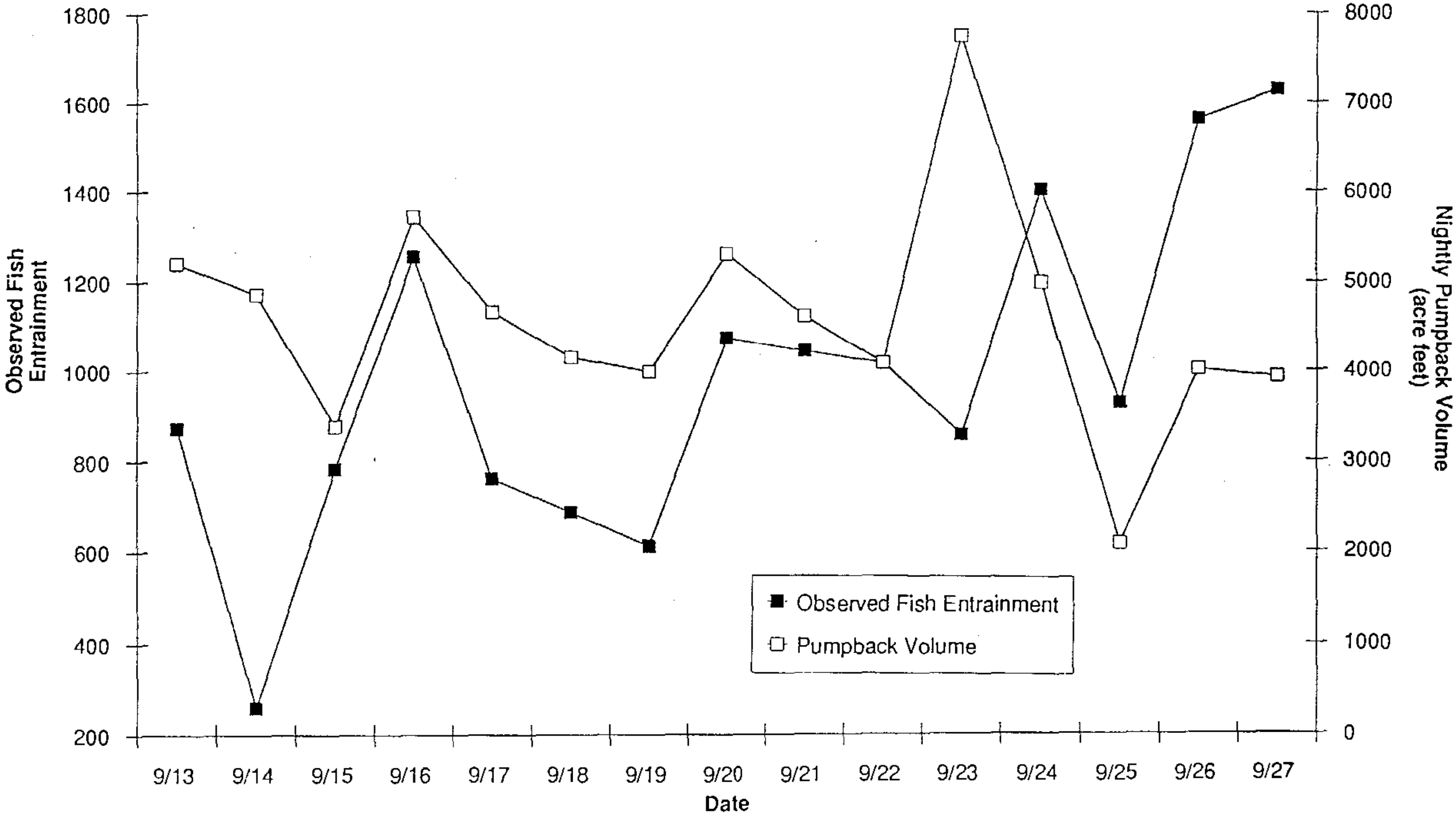


Figure 15. **Nightly estimated total fish entrainment vs the ratio of total pumpback volume/natural river flow, Northfield Mountain Hydroelectric Station, September 12-27, 1990.**

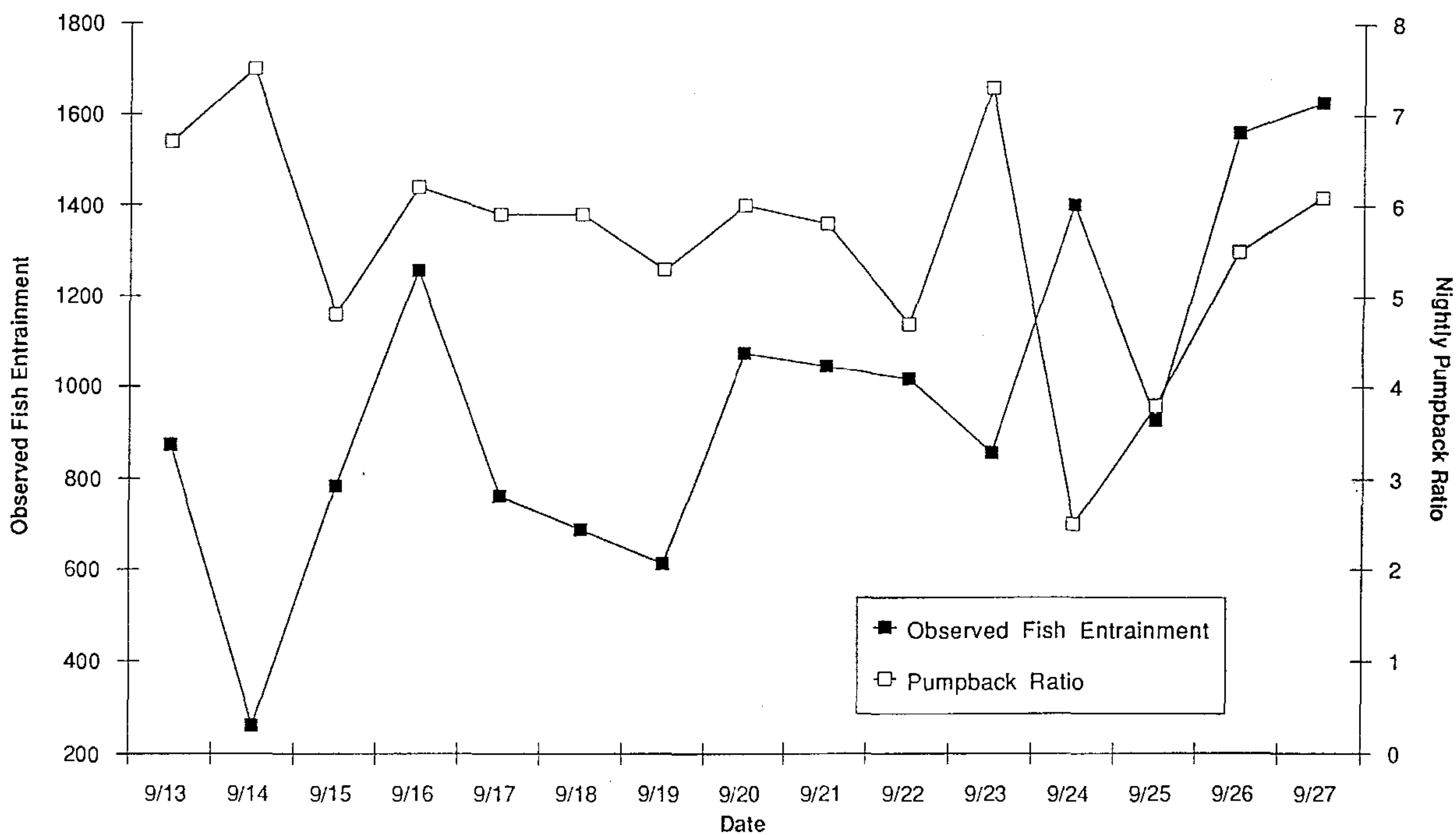


Figure 16. **Mean hourly estimated fish entrainment over the study period, Northfield Mountain Hydroelectric Station, September 12-27, 1990.**

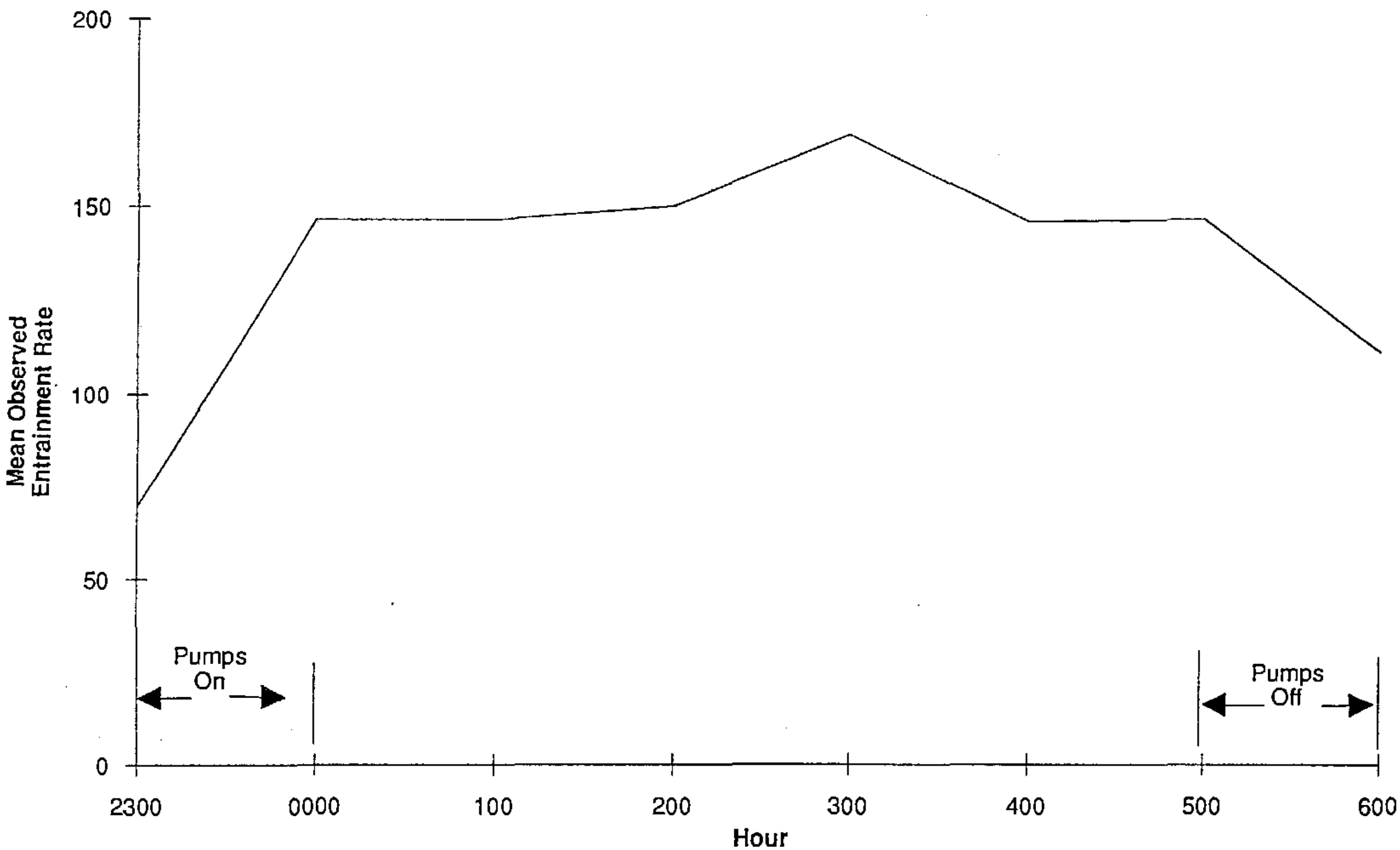
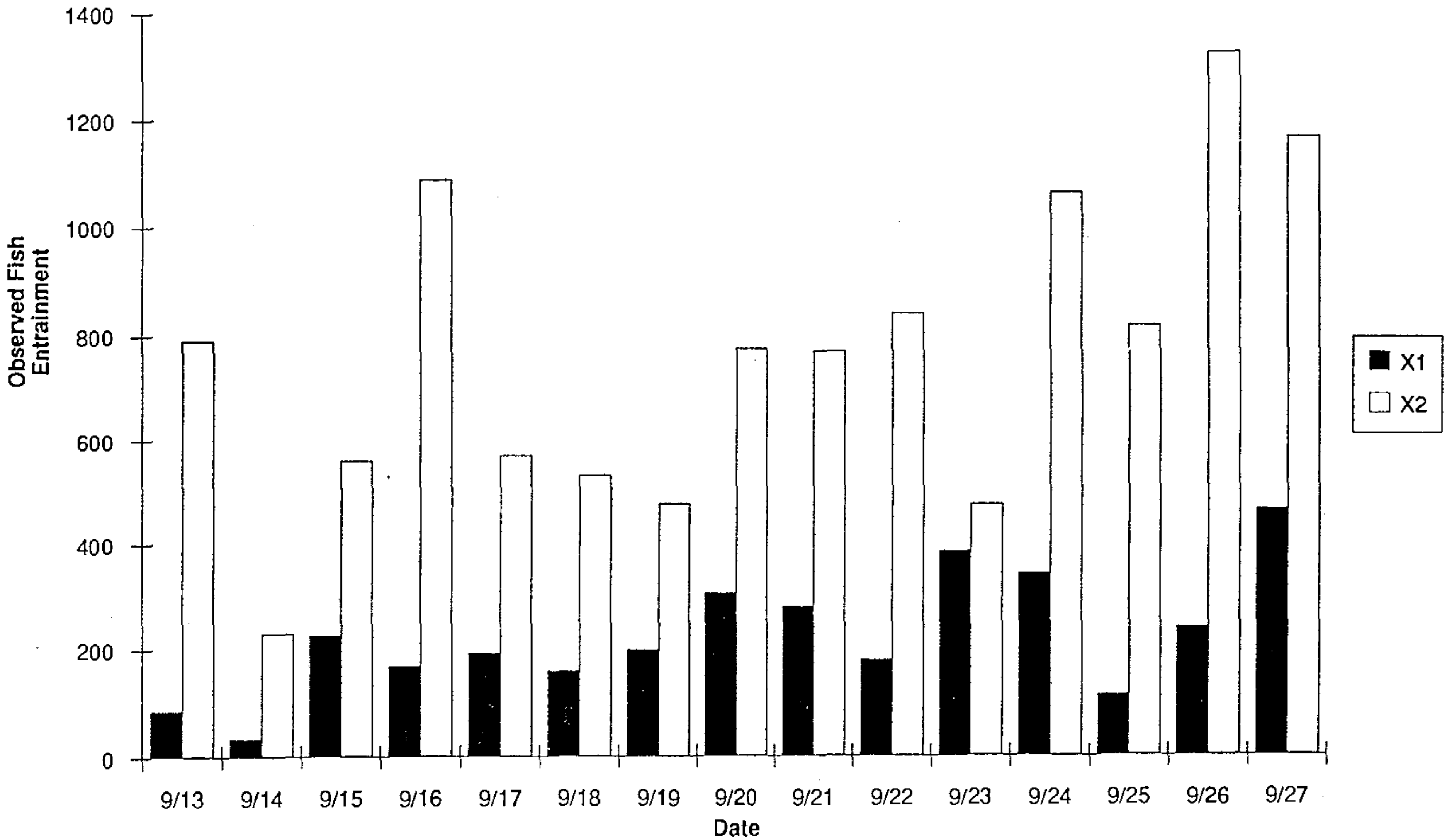


Figure 17. **Nightly estimated total fish entrainment by sampling location, Northfield Mountain Hydroelectric Station, September 12-27, 1990.**



APPENDIX A

APPENDIX A. Hydroacoustic System Equipment, Operation and Calibration

A1. Equipment Description

The hydroacoustic feasibility studies at Northfield Mountain Hydroelectric Station in 1990 used a BioSonics hydroacoustic data collection system consisting of the following components: 420 kHz elliptical-beam transducers, an echo sounder/transceiver, an echo signal processor, a thermal chart recorder and an oscilloscope. A block diagram of the basic system is shown in Figure E1. Table E1 lists specific manufacturers and model numbers of the electronic equipment used. The specific functions and applications of each instrument are discussed below.

Echo Sounder

The BioSonics Model 101, 102 and 105 Echo Sounders are designed for scientific hydroacoustic assessments in lakes, rivers, reservoirs and marine environments. Their stable power output, highly accurate time-varied-gains (TVG's) and numerous operating features provide replicable, verifiable outputs and results. The TVG, which precisely compensates for the loss of signal strength due to absorption and acoustic beam spreading with distance, allows fish of a given size to return the same signal amplitudes out of the echo sounder regardless of their range from the transducer. The ability of the BioSonics' echo sounders to be calibrated against a known standard ensures that minimum fish detection thresholds can be determined and are uniform, regardless of transducer or cable used. It also allows accurate estimates of fish acoustic size to be determined, as well as the effective transducer sample volume. These are some of the primary features that differentiate a scientific echo sounder from commercial units and allow quantitative fishery estimates that are legally and scientifically defendable.

The Model 105 is a smaller, more portable unit that can be operated on either 12 volt DC or 110 volt AC power. It has fewer user-selectable parameters and a lower power output than the Model 101 or 102, but uses the same quality TVG circuitry. The Model 102 offers greater parameter selectability and also incorporates the ability to multiplex between two transducers of the same or different frequencies, effectively sampling both simultaneously. It incorporates adjustable near-range and far-range blanking of the received signal, as well as adjustable band width and pulse width.

Multiplexer/Equalizer

The Model 151 Multiplexer/Equalizer is a programmable switching device that can connect a single echo sounder with up to 16 transducers, 3 chart recorders and 2 other data recording or analysis instruments. Up to 9 hourly sampling sequences can be programmed via the front panel keypad. A sampling sequence consists of up to 24 separate intervals, each programmable for transducer number, chart recorder number, ping rate, and sampling time. The transducers may be sampled one at a time with the returned echo signals directed to a single chart recorder, or two at a time, with the signals directed to two chart recorders (fast multiplexing). An equalization level (additional receiver gain) can be specified for each transducer/cable combination in 0.1 dB increments to precisely match the minimum detection sensitivities of all transducers in the sampling array.

The Model 151 can multiplex at very high pulse repetition rates, up to 40.0 pings per second. It also automatically writes the transducer number sampled, the current time, the total number of pings in the sample and the chart recorder number onto the chart paper at the end of each sample interrogation. A multiplexer/equalizer is indicated for surveys where repetitively sampled multiple transducer arrays are required to sample a region of interest.

Chart Recorder

A chart recorder is used to create a permanent data record by transferring the returned acoustic signal to a moving paper strip chart, or "echogram". An adjustable print voltage threshold can be applied to eliminate noise or smaller size fish targets, if desired. For many types of fixed-aspect hydroacoustic studies, echograms are the primary data source. Fish moving through the area of interest create distinctive marks on the chart record, which are manually tabulated and entered into a computer database for analysis.

As chart recorders are electro-mechanical devices, they are usually the most subject to failure of the hydroacoustic components. Most commercial chart recorders use belt-driven styli moving at high speed over the paper surface to transfer the image to the echogram. These components frequently break and interrupt data collection, generally requiring that a technician constantly attend the hydroacoustic system.

For these reasons, a BioSonics Model 111 Thermal Chart Recorder was used during the Northfield hydroacoustic study and is recommended for any future surveys using the echograms as a data record. The Model 111 uses a thermal print head to produce detailed recordings on heat-sensitive paper. It operates quietly and with no moving parts, with the exception of the paper transport mechanism. Due to the reliability of these instruments, they can run unattended for extended periods, requiring only a chart paper change 1 or 2 times per day, depending on sample ping rate and paper speed.

Oscilloscope

An oscilloscope is essential to monitor the hydroacoustic signal during equipment set-up and data collection. It allows exact measurements of background noise, fish echo amplitude, chart recorder mark thresholds and sample ranges. Using the system calibration data, expected peak voltages can be calculated for fish of given acoustic sizes and also for standard calibration targets. Comparing these expected values to the voltages observed on the oscilloscope during data collection allows *in-situ* verification of the system calibration, ensuring consistent performance over the study period. A Hitachi Oscilloscope was used during the Northfield hydroacoustic study. Several other manufacturers also offer suitable units of similar quality.

Transducers

The cone-shaped sampling volume (acoustic beam) of a transducer is determined by its beam width, which is typically expressed in degrees. The larger the beam width, the larger the sampling volume.

The *nominal* beam width is defined as the full angle at which the transmitted acoustic intensity is one-half (3 dB less, one way) of the on-axis intensity. Generally, a transducer is classified by its nominal beam width. The actual *effective* beam width of a transducer is a function of the target strength (acoustic size) of the target being detected; i.e. for a given detection threshold, larger size targets can be detected further away from the acoustic beam axis than smaller targets. For many quantitative studies, it is important to measure fish target strengths to accurately determine the effective beam width and actual sampling volume. The relationship between system threshold, target strength, and effective beam width is discussed in greater detail in Ehrenberg (1984).

The transducer beam width chosen is dependent on the dimensions of the site to be sampled and the study objectives. In shallow, wide environments, such as in canals, elliptical beam transducers scanning sideways provide greatest sampling coverage. Typical beam widths available include 2x10, 3x10, 4x15 and 6x12 degrees. Near structure, such as inside an intake, narrow beam transducers between 2 - 6 degrees nominal beam width generally have better spatial resolution and can be aimed within restricted areas. Elliptical transducers aimed vertically also perform well. To monitor fish passage in relatively unrestricted areas, such as open water or in front of an intake, wider beam widths, typically around 15 degrees, are used to maximize sampling coverage.

The location and aiming angle of each transducer is chosen so that the wider part of the acoustic beam (with its greater sampling power) is positioned in the area of primary interest. To detect the direction of fish movement, the transducer should be aimed at an angle non-perpendicular to the fish's trajectory.

Transducer mount location is dependent on the configuration of the sample site. The transducer should be placed at a sufficient distance from the area of interest to maximize the sample volume (in open water or unrestricted areas) or cross-sectional coverage (in intakes and restricted areas). Surface-mounted transducers have been affixed to poles, concrete structures, guy wires, and buoys. Bottom-mounted transducers have been attached to various underwater structures, concrete anchors, and gimbal mounts.

Echo Signal Processor

The BioSonics Model 221/281 Echo Signal Processor (ESP) is used to collect, process and analyze echo signal output from the hydroacoustic data collection system. It consists of a digital signal processing circuit card installed inside of an IBM-PC compatible computer. The ESP digitally samples each returning echo and records its amplitude, range, pulse widths, and other parameters characterizing the acoustic signal. Once installed, the ESP hardware is entirely software driven. Depending on the BioSonics program being run, the ESP can function as an echo integrator, returning biomass estimates in high density situations, or as a dual-beam processor, providing estimates of mean acoustic fish size and passage.

The ESP software also supports real-time fish tracking capabilities, which allow the instrument to track and group acoustic echo returns into individual fish targets based on user-defined criteria. This ability is particularly valuable for long-term fixed-location hydroacoustic studies, as it minimizes manpower and chart recorder expenses. Real-time fish tracking incorporates a wide range of fish selection criteria including fish direction, slope (change in range divided by time in the acoustic beam), range from the transducer, inflection, linearity, target strength (acoustic size) and other factors. This flexibility allows the user to strictly define acceptance or exclusion criteria based on fish behavior, automating the fish detection and counting process. Based on these selections, the ESP will uniformly track and record the fish targets of interest, eliminating echogram interpretation as a source of error. The system can be configured to generate periodic fish passage estimates and to automatically transfer these data via modem, to a home office on a defined periodic basis.

Other features of the ESP include the ability to present the hydroacoustic data in real-time on the resident computer via an on-screen oscilloscope and density or target strength graphics. New or improved functions are easily added by merely upgrading the software package. The computer environment gives the ESP the future capability to read and control the hydroacoustic equipment settings of the echo sounder, multiplexer/equalizer, rotator, and other devices. These parameters could also be remotely monitored and changed using a modem, if desired. The hydroacoustic data can be written to a variety of formats that can be directly read by most commercial software spreadsheet and analysis programs, such as Microsoft EXCEL ™, Lotus 1-2-3 ™, D:Base ™ and R:Base ™. As the ESP software runs under the Microsoft WINDOWS ™ environment, other applications, such as data analysis or word processing programs, can be run simultaneously with ESP data collection.

A2. Equipment Operation

The hydroacoustic data collection system operates as follows: When triggered by a BioSonics Echo Sounder, the high-frequency 420 kHz transducer emits short sound pulses in a cone-shaped pattern aimed toward an area of interest. As these sound pulses encounter fish or other targets, echoes are reflected back to the transducer which then reconverts the sound energy to electrical signals. The returning signals are then amplified at a 40 log R (range) time-varied-gain (TVG) by the echo sounder to compensate for losses in signal strength due to absorption and geometric spreading of the beam with distance from the transducer. Thus, on-axis targets of equal size will produce the same signal amplitude at the echo sounder output regardless of their distance from the transducer. A target's range from the transducer is determined by the timing of its echo return relative to the transmitted pulse.

The echo sounder relays the returning TVG amplified signals to the chart recorder, oscilloscope, digital tape recording system and/or Echo Signal Processor. The oscilloscope provides a real-time display of echo amplitude and duration. It can be used by the operator to count targets or monitor the system. Individual fish traces are recorded on the chart recorder's strip chart or "echogram" for permanent display and for later analysis. The chart recorder's threshold circuit eliminates signals which are less than the echo levels of the fish of interest. Echoes from debris, small organisms and other targets smaller than the minimum size fish to be observed are excluded from the data record. The digital tape recording system does not impose a signal threshold. It records the full echo sounder signal output for later analysis. The taped data can be used to recreate echograms at various thresholds or they can be processed to obtain fish size and density information. The Echo Signal Processor processes each returning echo in real time and writes these data to a computer file. It can be programmed to provide fish passage estimates, acoustic size and background noise measurements, or biomass values.

A BioSonics Model 151 Multiplexer/Equalizer is used for fixed-location studies employing multiple transducers at different sampling locations. The Model 151 can be programmed to sample up to 16 transducers in any sequence over a one-hour period. The user can select specific ping rates, sample durations, and transducer equalizations for each location.

The transducers were used to monitor the Northfield site were placed with the transducer beam axis at a non-perpendicular angle with respect to flow. This configuration provided information about fish direction and movement (flux) at each site. Figure A1 shows how fish direction can be determined through an angled transducer beam.

A3. System Calibration

Prior to the study, each transducer was calibrated for use with the Model 101 Echo Sounder. Calibration assured that an echo from a target of known acoustic size passing through the acoustic axis of any of the transducers produced a known output voltage at the echo sounder. This information was used to equalize the receiving sensitivity of all transducers used in the Northfield hydroacoustic study, so that fish detectability was uniform regardless of the specific transducer used. Once system calibration values were established, an accurate estimate of the actual beamwidth over which fish are detected (or "effective" beamwidth) for a given target strength could be calculated for each transducer based on beam pattern plots. These target strength values can be related to a minimum fish detection size using an empirical equation established by Love (1971, 1977). A detailed description of the calibration of hydroacoustic systems can be found in Albers (1965) and Urich (1975).

Table A1. Hydroacoustic data collection equipment used, Northfield Hydroacoustic Entrainment Study, September 12 - 27, 1990.

Qty.	Model No.	Manufacturer	Equipment	Serial Number
1	101	BioSonics	Echo sounder 420 kHz	101-83-037
1	111	BioSonics	Thermal chart recorder	111-85-007
1	221/281	BioSonics	Echo signal processor	221/281-89-016
2	141	BioSonics	500' transducer cables	141-89-548 141-89-549
1	386S	Compaq	Computer with 70mB hard drive	452506182679
2	6x12	BioSonics	6x12 elliptical-beam transducer	420-6x12-029
1	V-422	Hitachi	Oscilloscope	8203175

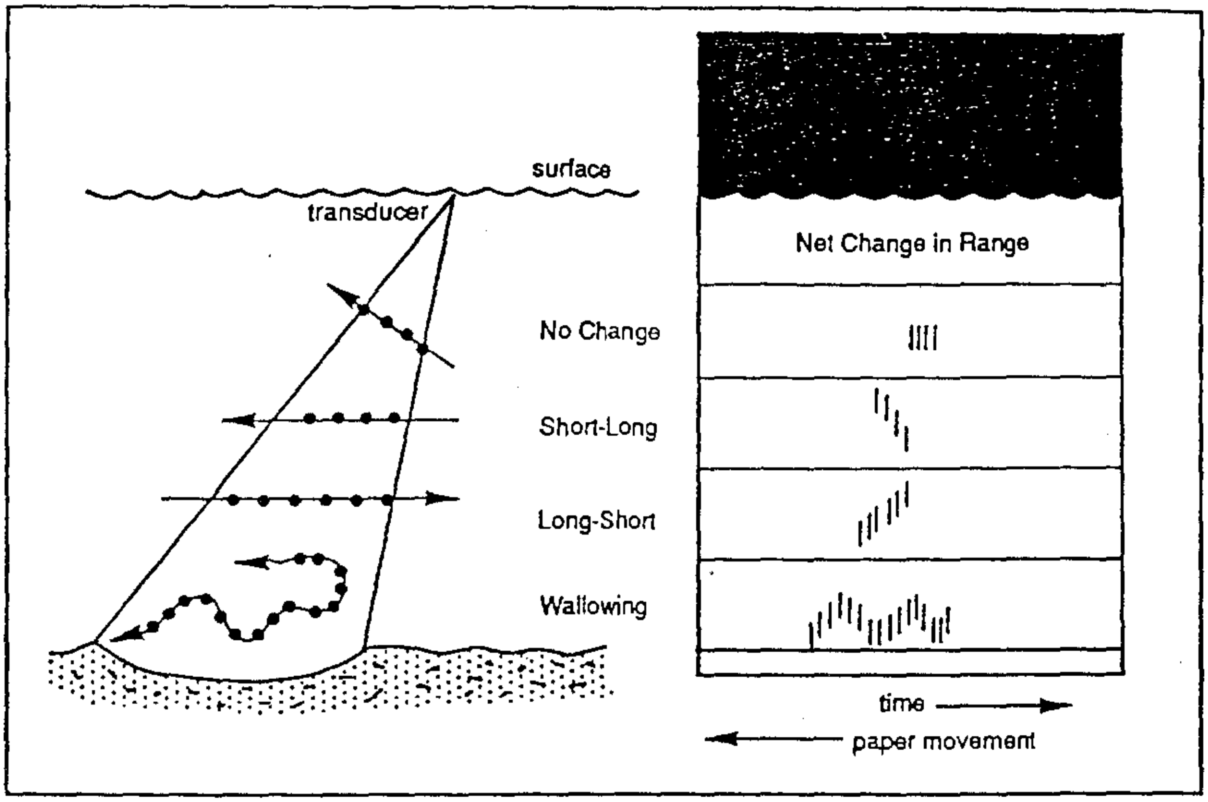


Figure A1. Fish behavior in the acoustic beam of a transducer (left) results in distinct traces on the chart recorder, or echogram (right). The change in range on the echogram traces indicates changing distance of the fish from the transducer. Arrows indicate the path ensonifications, or "pings," each leaving a mark on the echogram.

ATTACHMENT B

Prepared for

NORTHEAST UTILITIES SERVICE COMPANY
Berlin, Connecticut

IMPACT OF THE NORTHFIELD MOUNTAIN PUMPED-STORAGE FACILITY ON ATLANTIC SALMON (*Salmo salar*) AND AMERICAN SHAD (*Alosa sapidissima*)

DRAFT REPORT

March 1993

Prepared by
LAWLER, MATUSKY & SKELLY ENGINEERS
Environmental Science & Engineering Consultants
One Blue Hill Plaza Pearl River, New York

IMPACT OF THE NORTHFIELD MOUNTAIN PUMPED-STORAGE FACILITY ON ATLANTIC SALMON *(SALMO SALAR)* AND AMERICAN SHAD *(ALOSA SAPIDISSIMA)* IN THE CONNECTICUT RIVER

Prepared For

NORTHEAST UTILITIES SERVICE COMPANY
Berlin, Connecticut

DRAFT REPORT

March 1993

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Project No. 298-016

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CHAPTER 1

INTRODUCTION

On July 26, 1990 the Northeast Utilities Service Company (NUSCo) and resource agencies responsible for the management of anadromous fish in the Connecticut River, entered into a Memorandum of Agreement (MOA), which provided for a two year study of the effect of the Northfield Mountain Pumped-Storage Facility (NMPSF) on anadromous fish. The purpose of the study was to conduct an impact assessment of the operation of the NMPSF on juvenile Atlantic salmon (*Salmo salar*) and American shad (*Alosa sapidissima*) in the Connecticut River. NUSCo conducted studies in 1991 and 1992 to collect data necessary to assess impact at the NMPSF. Results of these studies can be found in separate technical reports (Atlantic salmon: Harza 1992a; LMS 1993a (Attachment I); American shad: Harza 1992b; LMS 1993b (Attachment II)).

The purpose of this report is to synthesize those data into estimates of plant impact as defined in the original scope of study accompanying the MOA and the 1992 study plans presented to the resource agencies for Atlantic salmon (LMS 1992a) and for American shad (LMS 1992b). The assessment of impact includes a discussion which qualifies the analysis in terms of seasonal river flow during the study, sampling biases that may have affected the results, and other factors which need to be considered along with each species specific measure of impact.

CHAPTER 2

ATLANTIC SALMON

2.1 INTRODUCTION

Because of the problems associated with directly measuring salmon smolt entrainment, the impact of the NMPSF on juvenile Atlantic salmon was evaluated by releasing a surrogate population of tagged salmon smolts upstream of the facility and estimating the number entrained. Radiotelemetry was the methodology for marking and tracking smolts in the river and into the plant. Wild smolts were the focus of the study, because hatchery smolt entrainment at the facility had previously been evaluated (Layzer and O'Leary 1978) and for the foreseeable future a portion of the salmon smolts emigrating from the upper basin will be wild individuals produced from fry stocking (LMS 1992a). The resource agencies had requested the use of wild smolts in order to incorporate their natural behavior in the study.

Several key elements of this plan were identified in the study scope: (1) tagged smolts would be released far enough upstream of the NMPSF to allow them, as much as possible, to proceed downstream according to their own behavioral mandate; and (2) tagged smolts would be released at several times a day to account for the effect of release time on entrainment or downstream passage.

No means of censusing the salmon smolt population originating above the NMPSF was available at the time of the development of the MOA. The entrainment rate of the tagged population was expected to define a rate that could be applied directly to the salmon smolt population that emigrated past the plant.

2.2 IMPACT ASSESSMENT METHODOLOGY

The impact of the NMPSF on Atlantic salmon was defined as the reduction in the number of smolts leaving Turners Pool due to smolt entrainment at Northfield. This approach assumes entrainment results in mortality. Given this definition, impact (I) can be computed as follows:

$$I_{ATS}=\frac{M}{T} \qquad (2\text{-}1)$$

where:

M = the estimated number of tagged smolts entrained

T = the total number of tagged smolts passing the NMPSF

2.3 STUDY RESULTS

A total of 173 tagged salmon smolts (89 wild and 84 hatchery) were released upstream of the NMPSF in May and June of 1992. Seventy tagged smolts reached the plant and provided data for impact analysis; 42 passed the plant while it was pumping, 25 while it was generating or non-operational, and 3 at an unknown time. Twenty-one tagged smolts entered the plant and one exited the plant and was recorded downstream of the intake. Six of the 20 tagged smolts that remained in the plant were recorded in the upper reservoir.

Values for the impact equation variables defined above are:

M = 20

T = 70

2.4 CALCULATION OF PLANT IMPACT

The impact (I) of the NMPSF on Atlantic salmon smolts based on the tagged population is:

$$I_{ATS}=\frac{M}{T}=\frac{20}{70}=0.286$$

2.5 DISCUSSION OF IMPACT

Layzer and O'Leary (1978) reported a general relationship between salmon smolt entrainment at the NMPSF and the percentage of the volume of river flow diverted by the plant. However, a volume based relationship may not be appropriate for salmon smolt entrainment, because smolts are known to be concentrated near the water surface (Ducharme 1972) and not distributed uniformly in the water column. A relationship between the percent of river flow pumped by the plant and the rate of salmon smolt entrainment will exist only if the distribution of river flow pumped into the plant is proportional to the distribution of smolts in the river at the plant intake. Hydrodynamic modeling of the flow in the NMPSF nearfield area showed that even under high (e.g., 67%) percent flow diversions, the distribution of river flow provided avenues for salmon smolts to safely pass the plant (**Figure 2-1**). Moreover, even though the plant diverted a significant percentage of the river flow on a daily basis during the 1992 study period (**Figure 2-2**), some tagged smolts in the vicinity of the NMPSF during high percent diversions were able passed the plant.

The longterm mean daily flow was exceeded on several dates in early June in 1992 (**Figure 2-3**). However, for most of the salmon smolt entrainment study period, daily mean river flow in Turners Pool was below average when compared to the longterm mean daily flow record from 1980 to 1991. Sixteen of the tagged smolts that were in the vicinity of the plant while it was pumping, were present on dates when the mean daily river flow was below the longterm average (**Figure 2-4**). As a result, the rate of salmon smolt entrainment in 1992 may have been higher than would occur under average or high river flow conditions.

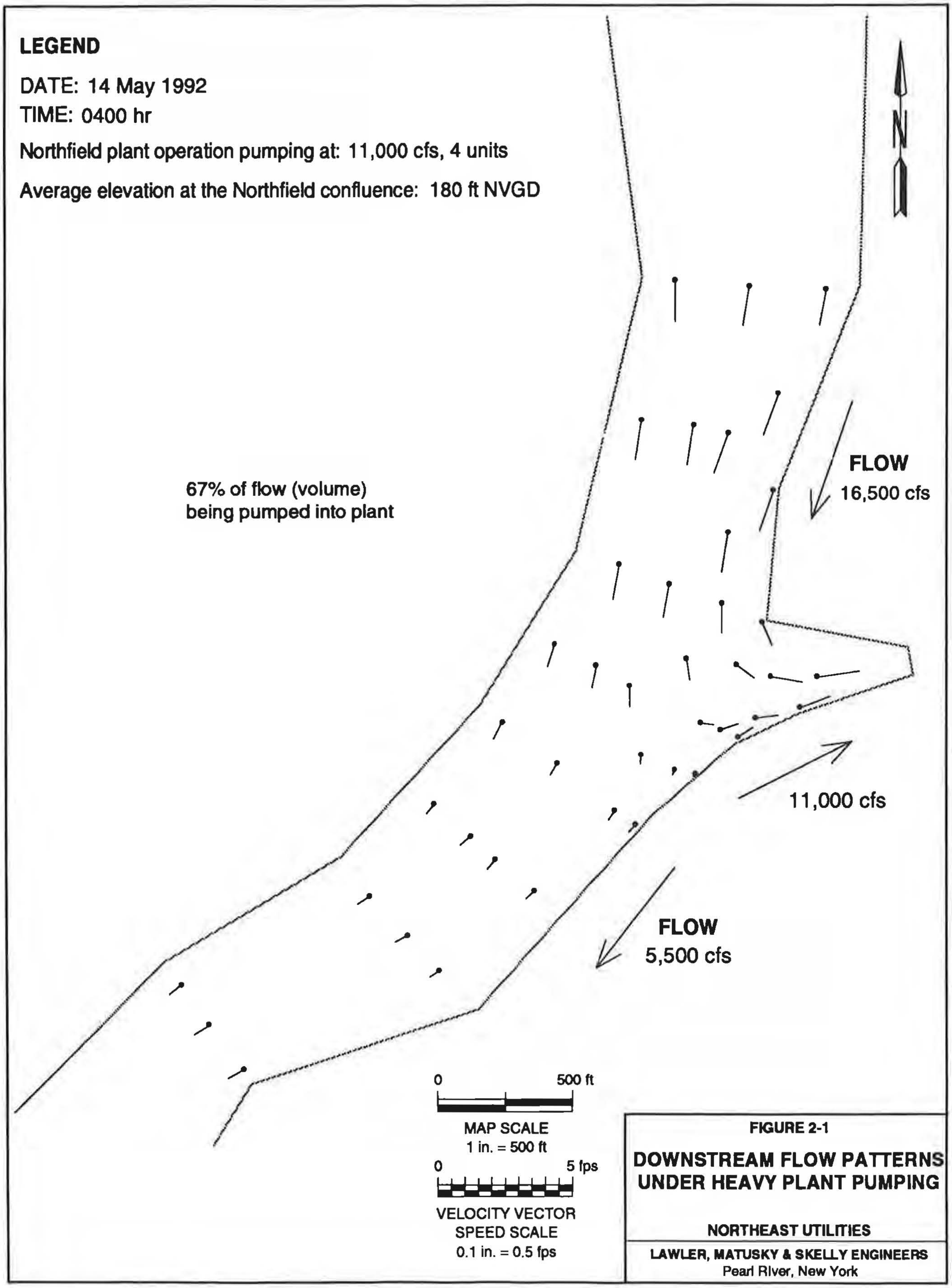


FIGURE 2-1

DOWNSTREAM FLOW PATTERNS UNDER HEAVY PLANT PUMPING

NORTHEAST UTILITIES

LAWLER, MATUSKY & SKELLY ENGINEERS
Pearl River, New York

Figure 2-2
Percent River Flow Diverted by the Plant: May 1 to June 10, 1992
Dates Tagged Smolts at Intake: No. Entering Intake / Total at Intake

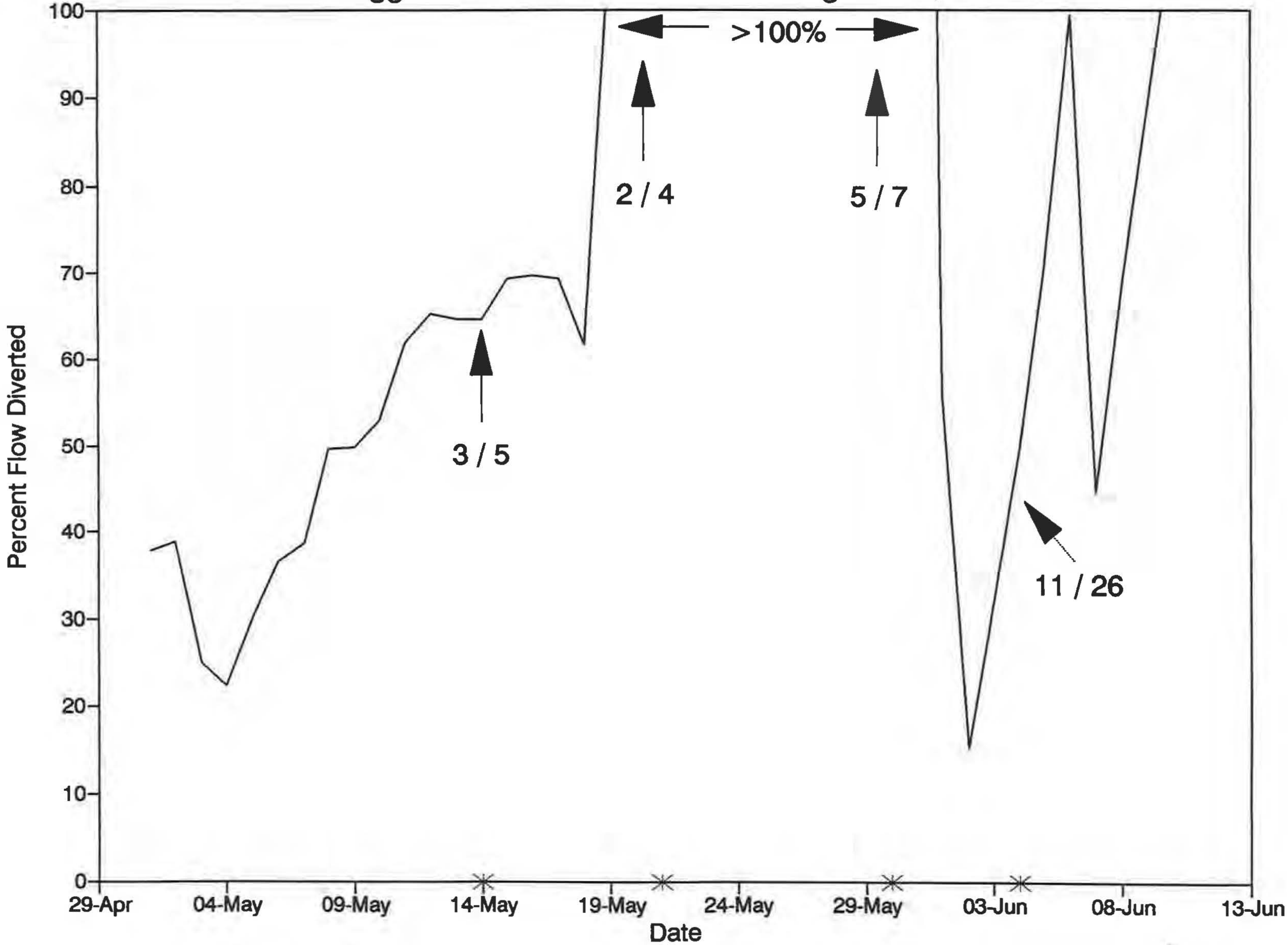


Figure 2-3

Longterm (1980-1991) vs 1992 Flow: April 1 to June 30

Connecticut River (Turners Falls Pool)

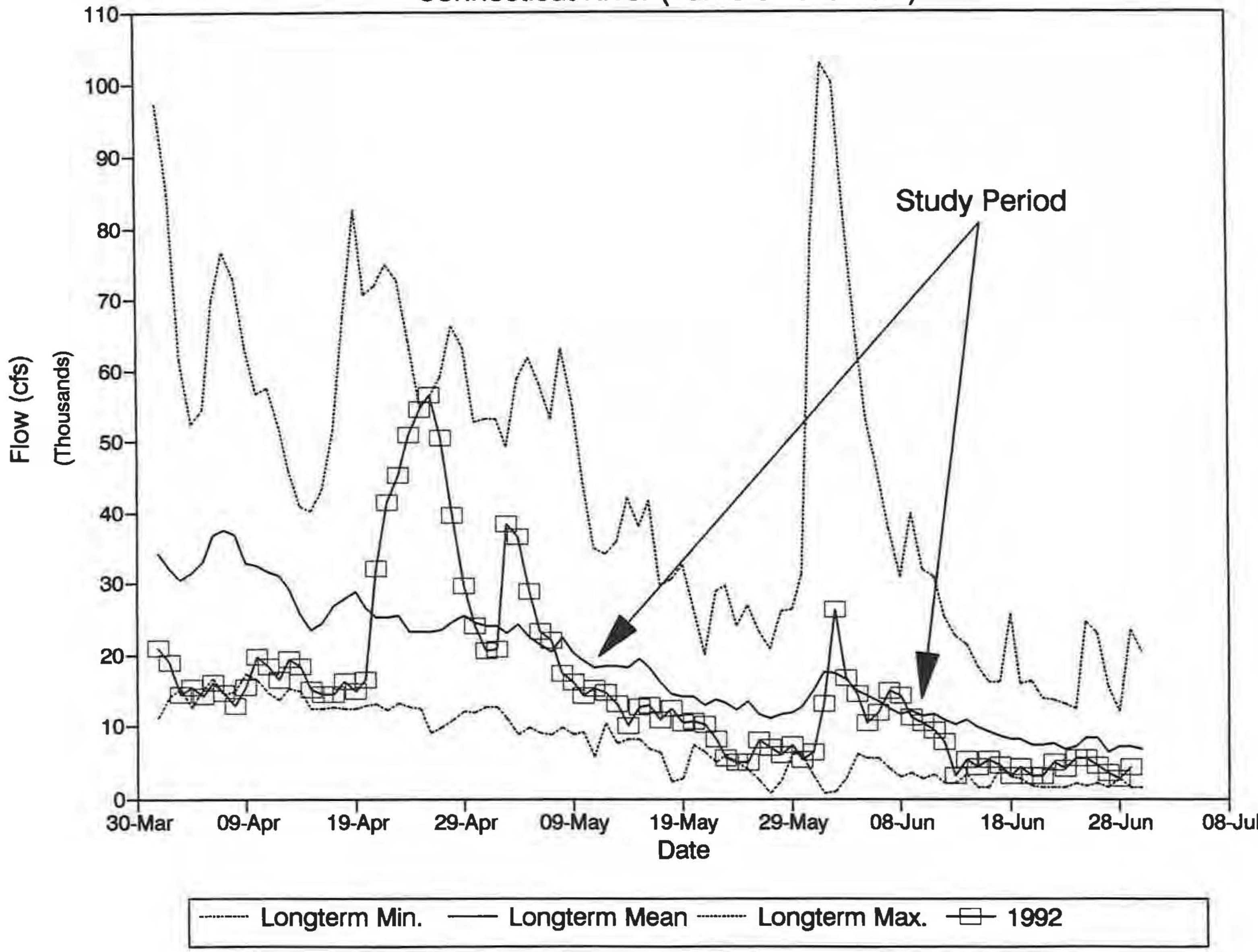
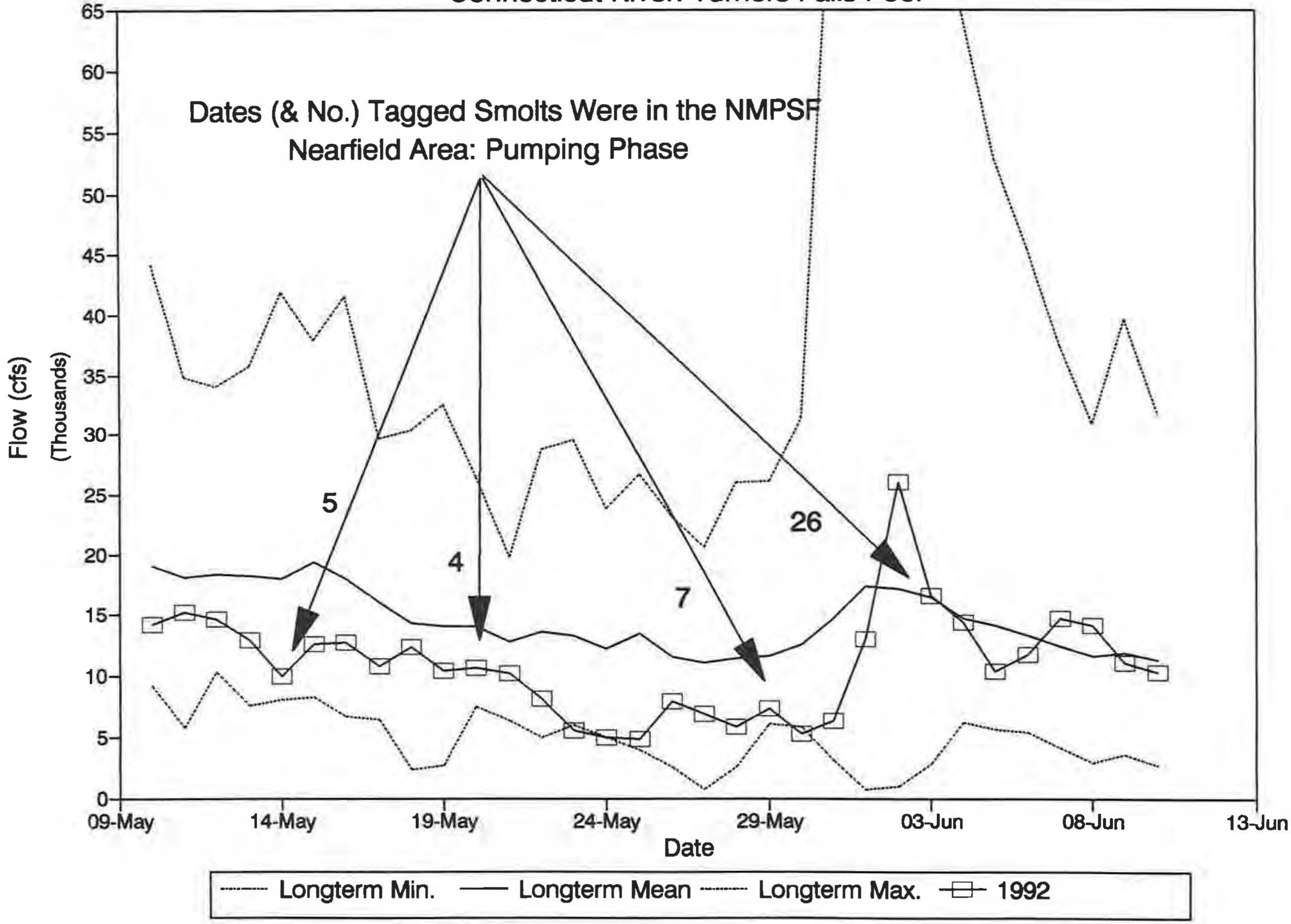


Figure 2-4

Longterm (1980-1991) vs 1992 Flow: May 10 to June 10

Connecticut River: Turners Falls Pool



Several assumptions were detailed in the discussion of the derivation of impact for Atlantic salmon smolts: (1) smolts would be released far enough upstream of the NMPSF to allow them, as much as possible, to proceed downstream according to their own behavioral mandate; and (2) tagged smolts would be released at several times a day to account for the effect of release time on entrainment or downstream passage.

During the 1992 study, tagged smolt releases were made at four different times per day: 00:00, 06:00, 12:00, and 18:00. Releases from the 10 mile point produced few returns to the intake and all but one of them were from the 18:00 or 00:00 release time. It was discovered that tagged salmon smolts released from 10 miles above the plant could pass the plant within the same evening; thus the time that a tagged smolt was released could have influenced its subsequent entrainment. Since no entrainment or downstream passage data from the 06:00 and 12:00 release times were available for comparison, it was not possible to determine whether the entrainment rate of the tagged smolts released at 18:00 and 00:00 was unbiased and representative of the population. Similar results were garnered from the release of hatchery smolts 6 miles above the intake. A number of tagged smolts released in the evening passed the NMPSF in the following early morning hours during the pumping cycle and a number of tagged smolts released during the day passed the plant in the following early evening hours when the plant was generating.

An independent measure of the timing of smolt movement through Turners Pool produced inconclusive results. Trap netting in the mainstem of Turners Pool was undertaken to evaluate the diel periodicity of smolt movements to determine what percentage of the population of smolts would be exposed to entrainment. The majority (76.8%) of the smolts were collected during hours that the plant was pumping. However, gear efficiency may have been low due to visual avoidance of the trap nets during the daytime and reduced river velocities that existed during daytime periods of plant generation. These factors may have biased the results toward greater catches during periods of nighttime pumping. Portable boat tracking of tagged smolts confirmed that some smolts moved downstream during the day when the plant is normally non-operational or generating.

The estimated level of impact (0.286) includes a portion of smolts that passed the facility during the day. Because some tagged smolts passed the facility at a time that was related to when they were released, it is not known whether the allowance for daytime movement in the level of impact is representative of the natural population. Because of biases between release time and entrainment, there still is a general inability to relate the probability of salmon smolt entrainment to the population at large. This relationship is essential for developing an impact estimate that is both rigorous and representative of the level of impact that the salmon population will experience at the NMPSF.

In addition to biases related to release time, there are other factors that may have affected the results of the 1992 study and thus the estimate of impact. A significant percentage of the tagged wild smolts did not reach the plant and did not provide data for impact analysis. This may have been an indication that the radiotagging procedure and the radiotag itself encumbered or affected the behavior of the smolts or the behavior of predators towards them. The estimate of plant impact could have been affected if the behavior and swimming ability of the smolts was affected by the tag or tagging procedure.

Most smolts providing entrainment data in 1992 (LMS 1993a), and all of the salmon smolt entrainment data from previous NMPSF studies (Layzer and O'Leary 1978), were obtained using hatchery smolts. Behavioral differences between hatchery and wild salmon smolts specific to the potential for entrainment at the NMPSF that could cause the disproportionate entrainment of one or the other of these groups have not been identified. Entrainment data acquired from hatchery smolts may not be applicable to wild smolts, which also represent a proportion of the smolt population that annually emigrates past the NMPSF.

CHAPTER 3

AMERICAN SHAD

3.1 INTRODUCTION

The assessment of the impact of the NMPSF on American shad focused on the entrainment of eggs, larvae, and juveniles resident in Turners Pool, as well as migratory juveniles, produced in and upriver of Turners Pool. Densities of shad eggs and larvae vulnerable to entrainment were estimated with oblique tows of a sled mounted plankton net during the occurrence of the early life stages at multiple stations in the NMPSF nearfield area. The entrainment of pre-migratory and migratory juvenile shad was determined with a netting program in the plant's upper storage reservoir, which included multiple net calibration tests.

The plan for evaluating the impact of the NMPSF on American shad was to relate the estimated number of individuals entrained (i.e., for all life stages through migratory juveniles) to the theoretical population of shad juveniles produced in and upriver of Turners Pool. The theoretical number of juvenile shad produced was developed by first computing the number of eggs spawned upstream of the NMPSF based on counts of adults and their sex ratio from fishway sampling at Turners, Vernon, and Bellows dams and an estimate of egg retention (Lehman 1953). Natural mortality rates for eggs, larval, and juvenile shad (Crecco and Savoy 1987) were applied to the initial egg number to estimate the number of later life stages. A more detailed treatment of the assumptions and application of this methodology can be found in the 1992 Study Plan for the Impact of Project Operations on American Shad (LMS 1992b). See Appendix A (Part I) for the step by step procedures used in the population modeling analysis for this report.

Three basic assumptions were required for including ichthyoplankton into the analysis of plant impact on American shad: (1) the entrainment of shad eggs and larvae results in their removal from the system, which assumes 100% mortality through the plant; (2) sampling gear used to enumerate ichthyoplankton densities was efficient for all ichthyoplankton stages included in the analysis; and (3) shad larvae are planktonic and are susceptible to entrainment proportional to their concentration in the water column. Assumptions for pre-migratory juveniles from Turners Pool and migratory juveniles from Turners Pool and upriver in the impact equation included: (1) sampling gear was efficient at retaining the size range of juveniles sampled and (2) catch rates were representative of the number of juveniles entering the plant.

3.2 IMPACT ASSESSMENT METHODOLOGY

The general impact model proposed in the scope of work to estimate the proportion of the juvenile shad population lost due to project operation (I) was:

$$I_{ASD}=1-(1-E_r)\times(1-E_m) \qquad (3\text{-}1)$$

where:

- E_r - proportional reduction of the emigrating population due to the entrainment of pre-migratory YOY
- E_m - proportional reduction of the emigrating population due to the entrainment of emigrating YOY

Based on this general model, impact can be computed in several different ways:

Method-1: Because larval shad stages are heavily influenced by environmental factors such as flow and water temperature (Crecco and Savoy 1987), recruitment is generally considered to occur at the juvenile stage. Thus, impact on the juvenile stage is perhaps the most relevant. Impact can be computed by relating the estimated number of juvenile shad entrained to the total theoretical number of juvenile shad produced in areas in and upriver of Turners Pool:

$$I_{ASD}=\frac{J_{NF}}{(N_B+N_V+N_T)} \qquad (3\text{-}2)$$

where:

J_{NF} - the estimated number of juvenile shad entrained at the NMPSF

N_B - the theoretical number of juvenile shad produced in Bellows Pool

N_V - the theoretical number of juvenile shad produced in Vernon Pool

N_T - the theoretical number of juvenile shad produced in Turners Pool

In 1992, an extensive sampling program at the Cabot Station was undertaken to enumerate the fall out-migration of juvenile shad from Turners Pool and upriver areas (Harza 1993). The number of juvenile shad counted at Cabot provides a juvenile shad population estimate for areas upriver of Turners, that already includes the effect of Northfield. If the effect of Northfield, expressed as the estimated number of juvenile shad entrained, is added to the counts of juvenile shad from Cabot, this sum can be substituted in equation 3-2 for the juvenile shad production estimate garnered from population modeling:

$$I_{ASD}=\frac{J_{NF}}{(N_C+J_{NF})} \qquad \textbf{(3-3)}$$

where:

J_{NF} - the estimated number of juvenile shad entrained at the NMPSF

N_C - the extrapolated number of American shad juveniles counted at the Cabot Station

Methods associated with the derivation of the extrapolated number of American shad enumerated at the Cabot Station can be found in Harza (1993).

Method-2: The impact of the NMPSF on American shad can also be considered through a comparison between the theoretical number of shad juveniles produced in and upriver of

Turners Pool garnered from population modeling and the number of juvenile shad counted at the Cabot Station in 1992. As noted, the counts at the Cabot Station include the effect of Northfield. The effect of Northfield can be isolated from the counts at Cabot by:

$$I_{ASD} = \frac{(N_B + N_V + N_T) - N_C}{(N_B + N_V + N_T)} \qquad (3\text{-}4)$$

where:

N_B - the theoretical number of juvenile shad produced in Bellows Pool

N_V - the theoretical number of juvenile shad produced in Vernon Pool

N_T - the theoretical number of juvenile shad produced in Turners Pool

N_C - the extrapolated number of American shad juveniles counted at the Cabot Station

Method-3: Impact was also evaluated by computing the theoretical equivalent number of juvenile shad that would have been produced from the eggs, yolk-sac and post yolk-sac larvae that were estimated to have been entrained. (See Appendix A (Part II) for a description of the equivalent juvenile calculation.) Combining the theoretical equivalent number of lost juveniles from the analysis of egg and yolk-sac and post yolk-sac larval entrainment with the estimated number that were entrained during the fall entrainment sampling program, gives the total estimated number of juveniles lost due to the operation of the NMPSF. Impact is derived by relating this number to the total theoretical number of juvenile shad produced in and upriver of Turners Pool:

$$I_{ASD} = \frac{(E_{eq} + YS_{eq} + PYS_{eq}) + J_{NF}}{(N_B + N_V + N_T)} \qquad (3\text{-}5)$$

where:

- E_{eq} - is the theoretical equivalent number of juveniles lost through the entrainment of eggs
- YS_{eq} - is the theoretical equivalent number of juveniles lost through the entrainment of yolk-sac larvae
- PYS_{eq} - is the theoretical equivalent number of juveniles lost through the entrainment of post yolk-sac larvae
- J_{NF} - the estimated number of juvenile shad entrained at the NMPSF
- N_B - the theoretical number of juvenile shad produced in Bellows Pool
- N_V - the theoretical number of juvenile shad produced in Vernon Pool
- N_T - the theoretical number of juvenile shad produced in Turners Pool

Method-4: An independent measure of impact using equivalent juveniles can be derived by replacing juvenile counts at Cabot in the denominator of equation 3-5 for the numbers estimated through population modeling. Since the juvenile counts from Cabot include the effect of Northfield, the equivalent number of juveniles plus the estimated number of juvenile shad entrained at Northfield must be added to the Cabot count to complete the denominator:

$$I_{ASD}=\frac{(E_{eq}+YS_{eq}+PYS_{eq})+J_{NF}}{N_C+((E_{eq}+YS_{eg}+PYS_{eq})+J_{NF})} \quad \text{(3-6)}$$

where:

- E_{eq} - is the theoretical equivalent number of juveniles lost through the entrainment of eggs
- YS_{eq} - is the theoretical equivalent number of juveniles lost through the entrainment of yolk-sac larvae

PYS_{eq} - is the theoretical equivalent number of juveniles lost through the entrainment of post yolk-sac larvae

J_{NF} - the estimated number of juvenile shad entrained at the NMPSF

N_C - the extrapolated number of American shad juveniles counted at the Cabot Station

3.3 STUDY RESULTS

Estimates based on field sampling and population modeling for the various variables defined above were:

E_{eq} - 4,630

YS_{eq} - 14,150

PYS_{eq} - 134,700

J_{NF} - 37,260

N_B - 2,113

N_V - 629,299

N_T - 903,968

N_C - 1,654,000

3.4 CALCULATION OF PLANT IMPACT

For ***Method-1*** the NMPSF impact estimate is:

$$I_{ASD}=\frac{37{,}260}{(2{,}113+629{,}299+903{,}968)}=0.0243$$

and using counts at the Cabot Station:

$$I_{ASD}=\frac{37{,}260}{1{,}654{,}000+37{,}260}=0.0220$$

For ***Method-2*** the NMPSF impact estimate is:

$$I_{ASD}=\frac{1{,}535{,}000-1{,}654{,}000}{1{,}535{,}000}=0.00$$

For ***Method-3*** the NMPSF impact estimate is:

$$I_{ASD}=\frac{(4{,}630+14{,}150+134{,}700)+37{,}260}{(2{,}113+629{,}299+903{,}968)}=0.124$$

For ***Method-4*** the NMPSF impact estimate is:

$$I_{ASD}=\frac{(4{,}630+14{,}150+134{,}700)+37{,}260}{1{,}654{,}000+((4{,}630+14{,}150+134{,}700)+37{,}260)}=0.103$$

3.5 DISCUSSION OF IMPACT

Three basic assumptions were made when including ichthyoplankton in the analysis of plant impact on American shad: (1) the entrainment of shad eggs and larvae results in their removal from the system (i.e., none survive plant passage); (2) the sampling gear used to enumerate ichthyoplankton densities was efficient for all ichthyoplankton stages included in the analysis; and (3) shad larvae are planktonic and are entrained in proportion to their concentration in the water column.

The assumption that none of the ichthyoplankton survive plant passage most likely results in an overestimate of impact, because it is possible that some shad ichthyoplankton pumped to the upper reservoir may survive and be returned to the river during generation (Cada 1991). Due to their size, the probability of death due to turbine injury is very low for ichthyoplankton (Cada 1991).

Results from the shad ichthyoplankton sampling program indicated that the sampling gear was not likely as effective in the collection of shad eggs and yolk-sac larvae as it was in the collection of post yolk-sac larvae (LMS 1993b). It is possible that the entrainment of shad eggs and yolk-sac larvae may have been underestimated if the observed densities in the NMPSF nearfield area were lower than the true densities. However, shad eggs are heavier than water (Chittenden 1969) and yolk-sac larvae remain near the bottom after hatching (Maxfield 1953 and Cave 1978 in Crecco and Savoy 1987). Thus, shad eggs and yolk-sac larvae may not be susceptible to entrainment in proportion to their concentration in the water column, an effect which would offset the effect of underestimating their densities due to sampling biases. Two other factors could make post yolk-sac larvae less susceptible to entrainment than their proportional representation in the water column. Crecco and Savoy (1987) noted that early post yolk-sac larvae are entirely planktonic and they may be carried in the river current and eventually deposited in low velocity areas such as eddies. In addition, post yolk-sac larvae leave the planktonic stage very soon after first feeding, as evidenced by the sharp increase in the daily rate of survival after this transition, an indication as Crecco and Savoy (1987) noted, of their better ability to "locate food and avoid predators". Thus, considering post yolk-sac larvae to be planktonic in the impact analysis and entrainable in proportion to their concentration in the water column, may lead to an overestimation of plant impact.

For pre-migratory juveniles from Turners Pool and migratory juveniles from both Turners Pool and upriver, the assumptions were that: (1) the sampling gear was efficient at retaining the size range of juveniles sampled and (2) catch rates were representative of the number of juveniles entering the plant. Based on multiple tests of net efficiency, it was clear that the net used to collect juvenile shad entrained though Northfield was highly efficient (73.65%) (LMS 1993b). Also, entrainment catch rates were greatest during early to mid-October when water temperatures were in the 14-15°C range, which are water temperatures where American shad migrations are known to peak in the Connecticut River (O'Leary and Kynard 1986). The fact that entrainment catch rates peaked concurrently with the time when shad migrations are known to peak, strongly suggests that entrainment catch rates were related to the number of juveniles passing the plant.

The temporal pattern of downstream movement of juvenile shad may have played a role in the relatively low level of juvenile shad entrainment observed at the NMPSF. According to O'Leary and Kynard (1986), juvenile shad have been observed to exhibit peak movement between 18:00 and 22:00, which is earlier than the 01:00 to 07:00 periods of heaviest pumping by the NMPSF.

CHAPTER 4

CONCLUSION

4.1 ATLANTIC SALMON

The relationship between the magnitude of entrainment and the population of wild smolts emigrating from the basin upstream of the NMPSF could not be reliably established, because of biases that may have affected the study results used to calculate impact. Even without the biases, there still remains a need to quantify the rate of Atlantic salmon smolt entrainment at the NMPSF in a manner that will enable the results to be applicable to the population at large. The net sampler used in the upper reservoir for shad in 1992 and the new by-pass sampler at the Cabot Station presents an opportunity for a more direct estimate of impact than through a surrogate population approach based on radiotelemetry. Direct netting of the upper reservoir pump-back flow coupled with the enumeration of the salmon smolt run at Cabot Station, could provide data that would be relatable to the population at large, as well as provide an independent check on the 1992 entrainment estimate. A plan based on this approach has been developed and is scheduled to be implemented in 1993.

4.2 AMERICAN SHAD

The various estimates of shad impact show a distinct difference depending on whether or not the ichthyoplankton stages are included in the analysis. Including shad ichthyoplankton into the impact assessment increases the level of impact on American shad. Several of the assumptions which were made to include ichthyoplankton sampling data into the impact model could have a major effect on the estimates if they overestimate early life stage abundance. Based primarily on life history information, there is strong evidence that considering the probability of entrainment to be proportional to the concentration of eggs or larvae in the water column results in an overestimation of shad entrainment and thus plant impact. Moreover, the recruitment of shad in the Connecticut River population is known to occur at the juvenile stage, which supports the argument that the entrainment of juveniles rather than larval shad is the appropriate life stage for impact analysis. Considering juveniles in the impact analysis reveals that the impact of the NMPSF on American shad in the Connecticut River is negligible, which is supported by the fact that in spite of this low level of entrainment, the Connecticut River American shad population has continued to expand with the Northfield plant in operation.

No spill was recorded at Turners Dam during the juvenile shad out-migration period in 1992. Since river flows were near average, they were not especially advantageous for juvenile shad downstream passage at Northfield. Because river flows were moderate in 1992, the impact estimate using juvenile shad entrainment at Northfield and the estimated number of juvenile shad produced (**Method-1**) is likely similar to what occurs in an average year. The low level of juvenile shad entrainment was likely due to the fact that the period of greatest shad activity does not coincide with periods of heaviest plant pumping. The similarity between the predicted juvenile shad production (1,535,000) and empirically determined, extrapolated catch at the Cabot Station (1,654,000), further confirms that the level of impact is low.

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APPENDIX A

SUPPORT DOCUMENTATION OF THE STEPS TAKEN IN THE POPULATION MODELING EXERCISE

PART I. METHODS USED IN THE CALCULATION OF THE THEORETICAL NUMBER OF JUVENILE SHAD PRODUCED IN TURNERS, VERNON, AND BELLOWS POOLS

The theoretical number of juvenile shad produced in Turners, Vernon, and Bellows pools is a valve used in several of the methods employed to compute impact, which are detailed in Chapter 3. The population modeling exercise which resulted in the calculation of the number of juvenile shad produced in and upriver of Turners Falls Pool involved a number of steps. The action taken in each of these steps as well as data and equations used (where appropriate) are presented below for reference purposes.

Step-1: The number of shad remaining in Turners, Vernon, and Bellows pools was determined from adult shad counts made at each dam (**Figure A-1**). The female ratio and length at age data for virgin female shad that migrated above Turners was acquired from sampling conducted by the State of Massachusetts at Turners. These data were used to calculate the number of eggs produced in each pool (**Table A-1**), based on the fork length (mm) and individual fecundity relationship for Connecticut River American shad (Leggett 1969).

Step-2: A 6.75% egg retention adjustment was applied to the total number of eggs produced in each pool to account for incomplete egg discharge (Lehman 1953).

Step-3: From the total number of eggs released in each pool, their seasonal distribution was estimated from the seasonal distribution of shad eggs in the NMPSF nearfield area acquired from ichthyoplankton sampling in 1992 (LMS 1993b) (**Figure A-2**). The seasonal distribution of shad eggs served as the basis for the construction of daily cohorts used in the population modeling exercise.

Step-4: Only a portion of the eggs discharged are fertilized, yet no estimates for percent egg fertilization are available. This percentage is likely to vary yearly and be location specific. The portion of the eggs discharge that are fertilized has a significant effect on the ultimate juvenile shad production estimate for Turners and upriver areas. The egg fertilization rate was estimated after factors for fertilized egg hatching success and daily larval survival were applied to the egg population. The development of the egg fertilization rate estimate is discussed in detail in **Step-7**.

Step-5: The hatching success of fertilized eggs was determined from relationships between water temperature and daily egg instantaneous mortality (Crecco and Savoy 1987) (**Figure A-4**) and incubation days (PSE&G 1982). An egg hatching success model based on the effect of river water temperature on daily mortality and the number of incubation days was developed (**Figure A-5**) and hatching success estimates were applied to the number of eggs portioned in each daily cohort. Steps used in the development of the hatching success model are detailed in **Table A-2**.

Step-6: The number of larvae hatched for each daily cohort was decayed using daily larval survival rates developed by Crecco and Savoy (1987) (**Table A-3**). Each daily cohort was decayed to 3 October, which was the mid-point in the seasonal distribution of American shad counts made at Cabot in 1992 (Harza 1993a) (**Figure A-6**).

Step-7: A relationship between the total number of juvenile shad produced in above Turners (based on methods described in ***Step-5*** and ***Step-6***) and the egg fertilization rate was developed (**Figure A-7**). A fertilization rate of 50% was used for the impact analysis. **Figure A-7** is presented to show how the total theoretical number of juveniles produced above Turners is affected by the egg fertilization rate.

A summary of values used in the derivation of the theoretical number of juvenile shad produced in and upriver of Turners are presented in **Table A-4**.

PART II. DESCRIPTION OF STEPS TAKEN DURING THE CALCULATION OF THE THEORETICAL NUMBER OF EQUIVALENT JUVENILES PRODUCED IN AND UPRIVER OF TURNERS FALLS POOL

Step-1: A general daily distribution of the number of shad eggs and yolk-sac and post yolk-sac larvae entrained was developed from the weekly estimates of the number of these life stages entrained by week and a seasonal entrainment mid-point was calculated for each life stage

(**Figure A-8**). The seasonal entrainment mid-point for each life stage was used as the starting date for the calculation of the theoretical equivalent number of juveniles.

Step-2: The yolk-sac and post yolk-sac larval stages encompass a range of days. The equivalent juvenile analysis was initiated on the first day of each life stage on the dates defined in Figure A-8. Natural larval mortality rates for Connecticut River American shad from Crecco and Savoy (1987) were applied as detailed in ***Step-6***, Part I of this appendix. The analysis was run to 3 October, which as noted above, was the mid-point of the seasonal distribution of shad counts made at the Cabot Station.

A summary of values used in the equivalent juvenile calculation are presented in **Table A-5**.

TABLE A-1

TOTAL NUMBER OF SHAD EGGS PRODUCED IN TURNERS, VERNON, AND BELLOWS POOLS BASED ON AGE COMPOSITION DATA AND THE FORK LENGTH-FECUNDITY RELATIONSHIP FOR CONNECTICUT RIVER AMERICAN SHAD

AGE	PERCENT COMPOSITION[a]	NO. FEMALES[b]	FORK LENGTH (mm)[a]	INDIVIDUAL FECUNDITY (NO. EGGS/FEMALE)[c]	NO. EGGS PRODUCED
TURNERS					
IV	39	3,670	447.7	227,860	836,312,911
V	51	4,800	471.2	270,122	1,296,478,486
VI	10	941	493.6	310,405	292,122,048
Total:		9,411			2,424,913,445
VERNON					
IV	39	2,555	447.7	227,860	582,157,675
V	51	3,341	471.2	270,122	902,479,074
VI	10	655	493.6	310,405	203,346,247
Total:		6,551			1,687,982,996
BELLOWS					
IV	39	9	447.7	227,860	1,955,040
V	51	10	471.2	270,122	3,030,765
VI	10	2	493.6	310,405	682,891
Total:		22			5,668,696

[a]Percent age composition and fork length estimates are from 1992 sampling performed at Turners.

[b]Sex ratio sampling conducted at Turners and Vernon in 1992 was used to derive the number of females remaining in each pool. The number of females remaining in Bellows Pool was estimated from the female ratio observed at Vernon.

[c]Individual fecundity estimates were based on the fork length-fecundity relationship for Connecticut River American shad (Leggett 1969).

TABLE A-2

STEPS AND EQUATIONS USED TO DERIVE A HATCHING SUCCESS ESTIMATE FOR FERTILIZED SHAD EGGS BASED ON RIVER WATER TEMPERATURE

DESCRIPTION	EQUATION	No.
From Crecco and Savoy (1987), the relationship between the daily instantaneous egg mortality rate (Z_t) and the mean June river water temperature (T) (**Figure A-4**) is:	$Z_t = -0.1068 \times (T) + 2.599$	1
From PSE&G (1982), the relationship between shad egg incubation time in days (D) and water temperature (T) is:	$D = 1594.218 \times (T)^{-1.973}$	2
The total percentage of the fertilized eggs that successfully hatch (H) is a function of the number of days (D) shad eggs incubate before they hatch and the daily rate of survival (S) for each of those days:	$H = (S)^{D}$	3
From Ricker (1975), survival (S) is:	$S = e^{-Z_t}$	4
Hatching success (H) can then be expressed as:	$H = (e^{-Z_t})^{D}$	5
Expressing both "Z_t" from equation 1 and "D" from equation 2 in terms of "T" and substituting them into equation 5 gives a general model for relating river water temperature to the hatching success of fertilized shad eggs (**Figure A-5**)[a]:	$H = (e^{-(-0.1068 \times (T) + 2.599)})^{1594.218 \times (T)^{-1.973}}$	6

[a]The mean daily river water temperature was used to derive a fertilized egg hatching success estimate for each daily cohort.

TABLE A-3

DAILY SURVIVAL RATES AND ASSOCIATED TIME INTERVALS USED IN THE CALCULATION OF THE NUMBER OF JUVENILE SHAD PRODUCED IN TURNERS, VERNON, AND BELLOWS POOLS

DAY RANGE	DAILY SURVIVAL RATE APPLIED[a]
0 to 9	79%
10 to 18	91%
19 to 29	94%
30 to 3 October[b]	98%

[a]Daily survival rates were calculated from daily American shad larval mortality estimates for Holyoke Pool (Crecco and Savoy 1987).

[b]October 3 was the seasonal mid-point in the counts of American shad at Cabot (Harza 1993a) and was thus considered as the endpoint for the population modeling analysis.

TABLE A-4

SUMMARY OF VALUES USED IN THE POPULATION MODELING EXERCISE OF THE THEORETICAL NUMBER OF JUVENILE SHAD PRODUCED ABOVE TURNERS

	MAINSTEM POOL			
	TURNERS	VERNON	BELLOWS	TOTAL
Number of Shad counted:	60,089	31,155	103	
Number of Shad Remaining:	28,934	31,052	103	60,089
Number of Female Shad:	9,411	6,551	22	15,984
Theoretical Number of Eggs Produced:	2.425×10^9	1.688×10^9	5.669×10^6	4.119×10^9
Number of Eggs Released Including the 6.75% Egg Retention Adjustment:	2.261×10^9	1.574×10^9	5.286×10^6	3.840×10^9
Number of Juveniles as of 3 October (50% Egg Fertilization Rate):	903,968	629,299	2,113	1.535×10^6
Number of Juveniles as of 3 October Adjusted for 10% Mortality at Each Mainstem Dam:	905,968	566,369	1,712	1.472×10^6

TABLE A-5

SUMMARY OF THE THEORETICAL EQUIVALENT NUMBER OF JUVENILE SHAD PRODUCED FROM THE ESTIMATED NUMBER OF EGGS AND YOLK-SAC AND POST YOLK-SAC LARVAE ENTRAINED AT THE NMPSF

	LIFE STAGE			
	EGGS	**YOLK-SAC**	**POST YOLK-SAC**	**TOTAL**
Estimated No. Entrained:	1.176e+06	2.744e+06	1.053e+07	
Mid-Point Date (Date Analysis Was Begun):	5 June	7 June	18 June	
Theoretical No. Juveniles That Would Have Been Produced (As of 3 October):	4,630	14,150	134,700	153,480

Figure A-1

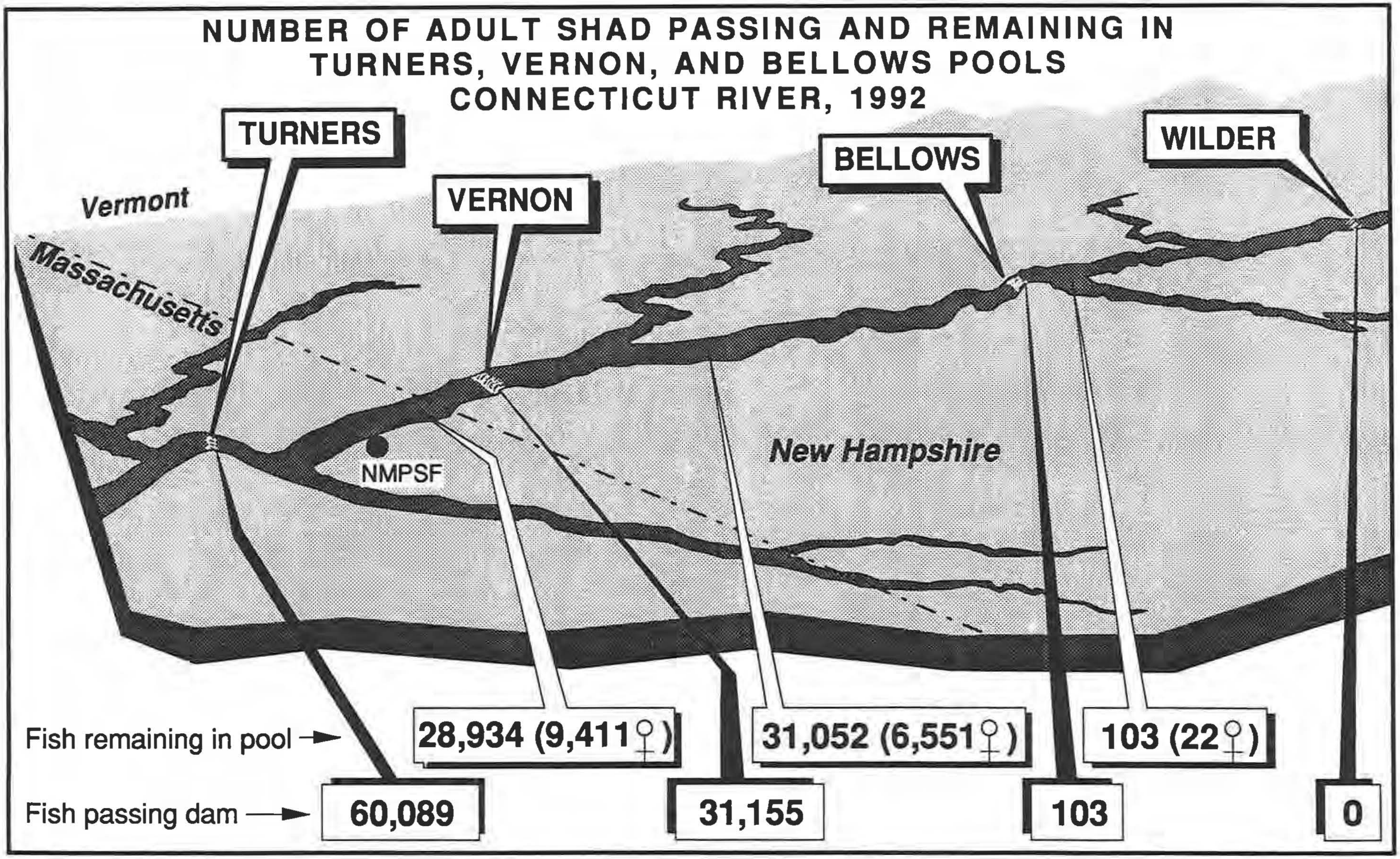
NUMBER OF ADULT SHAD PASSING AND REMAINING IN
TURNERS, VERNON, AND BELLOWS POOLS
CONNECTICUT RIVER, 1992
TURNERS
VERNON
BELLOWS
WILDER
Vermont
Massachusetts
New Hampshire
NMPSF
Fish remaining in pool
28,934 (9,411♀)
31,052 (6,551♀)
103 (22♀)
Fish passing dam
60,089
31,155
103
0

Figure A-2
Fork Length-Fecundity Relationship for Connecticut River American Shad
From Leggett (1969)

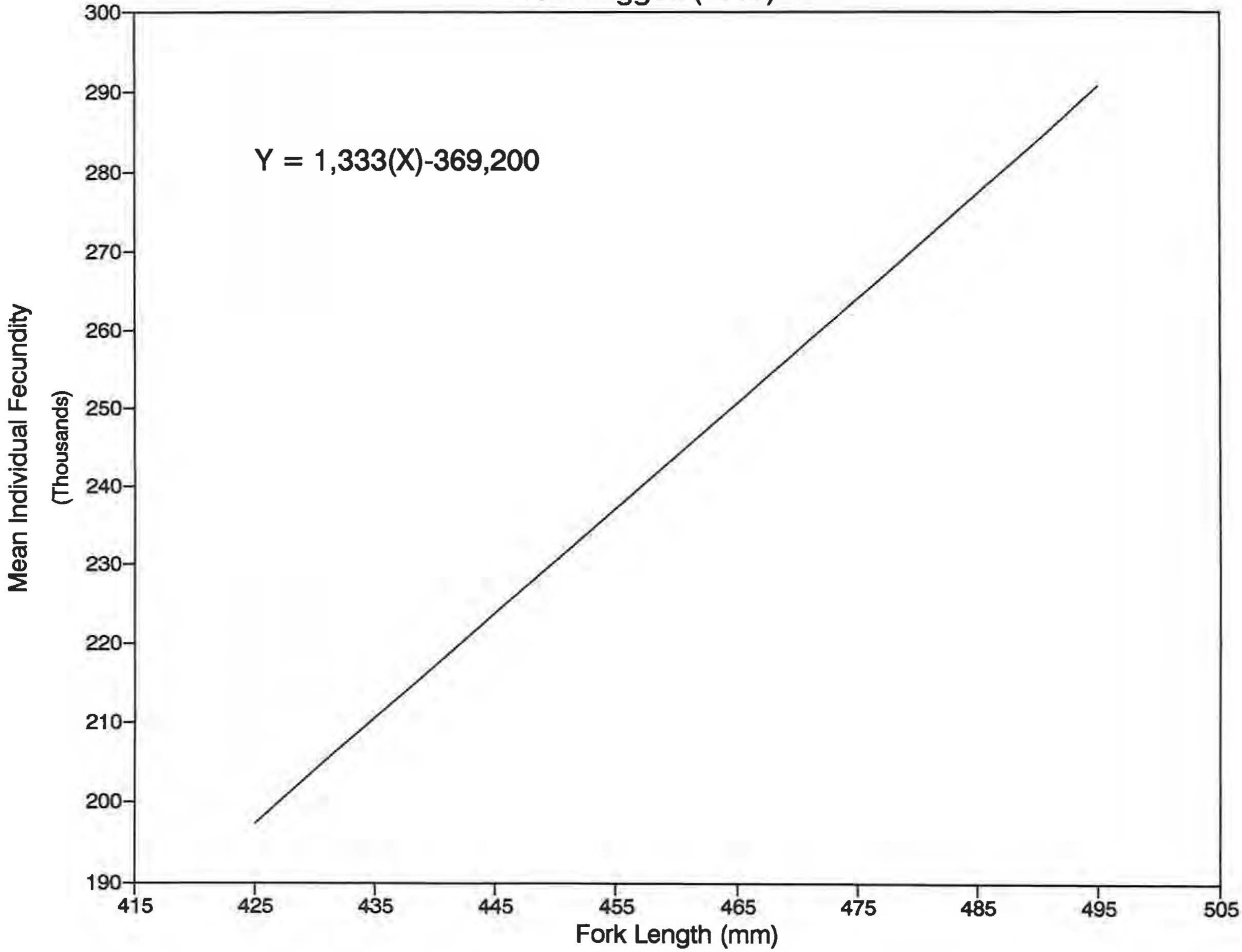

Figure A-3
Seasonal Distribution of Shad Eggs in Turners, Vernon, and Bellows Pools
Based on 1992 Ichthyoplankton Sampling in the NMPSF Nearfield Area

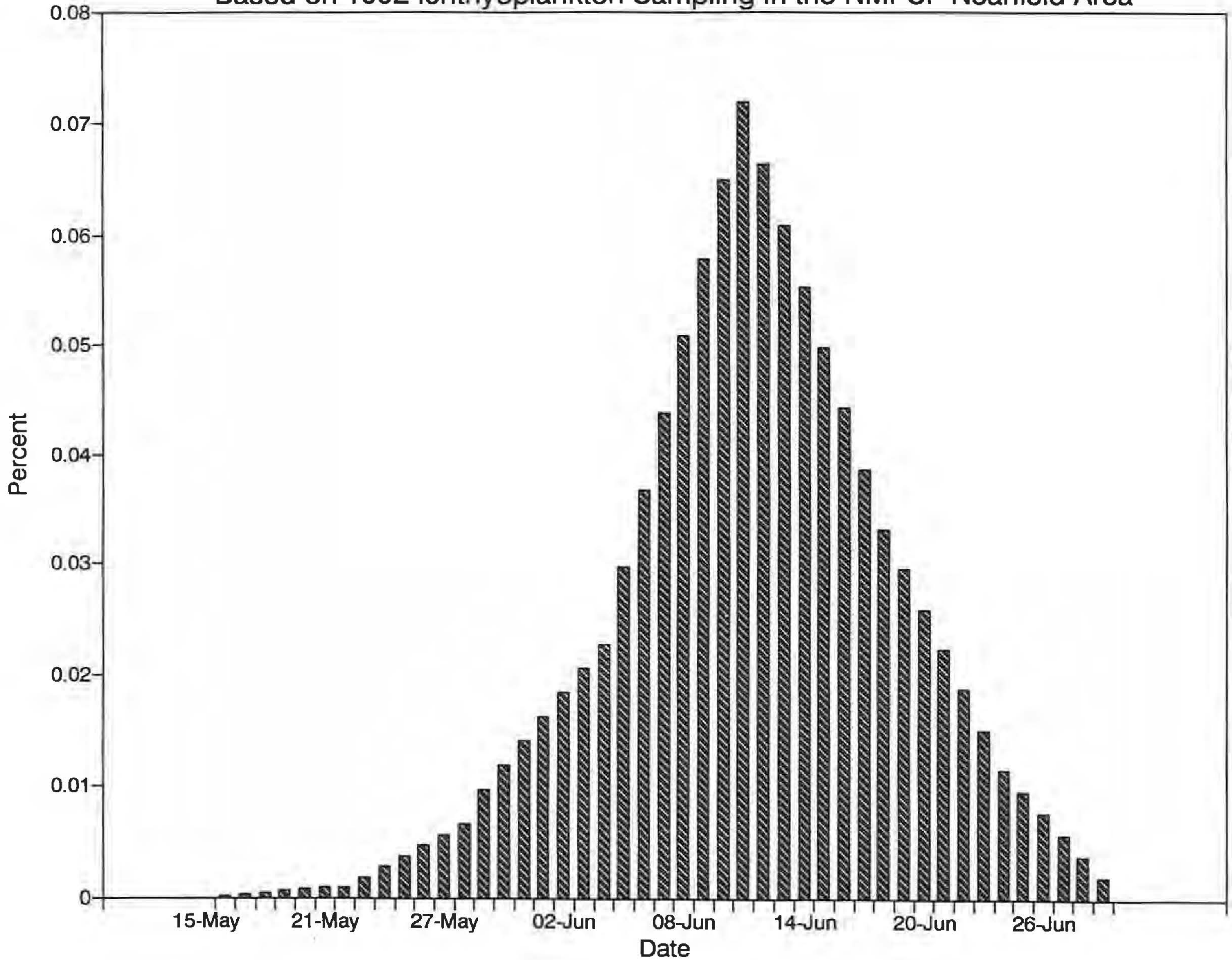

Figure A-4

Instantaneous Daily Mortality Rate (Egg) vs Mean June Water Temperature

From Crecco and Savoy (1987)

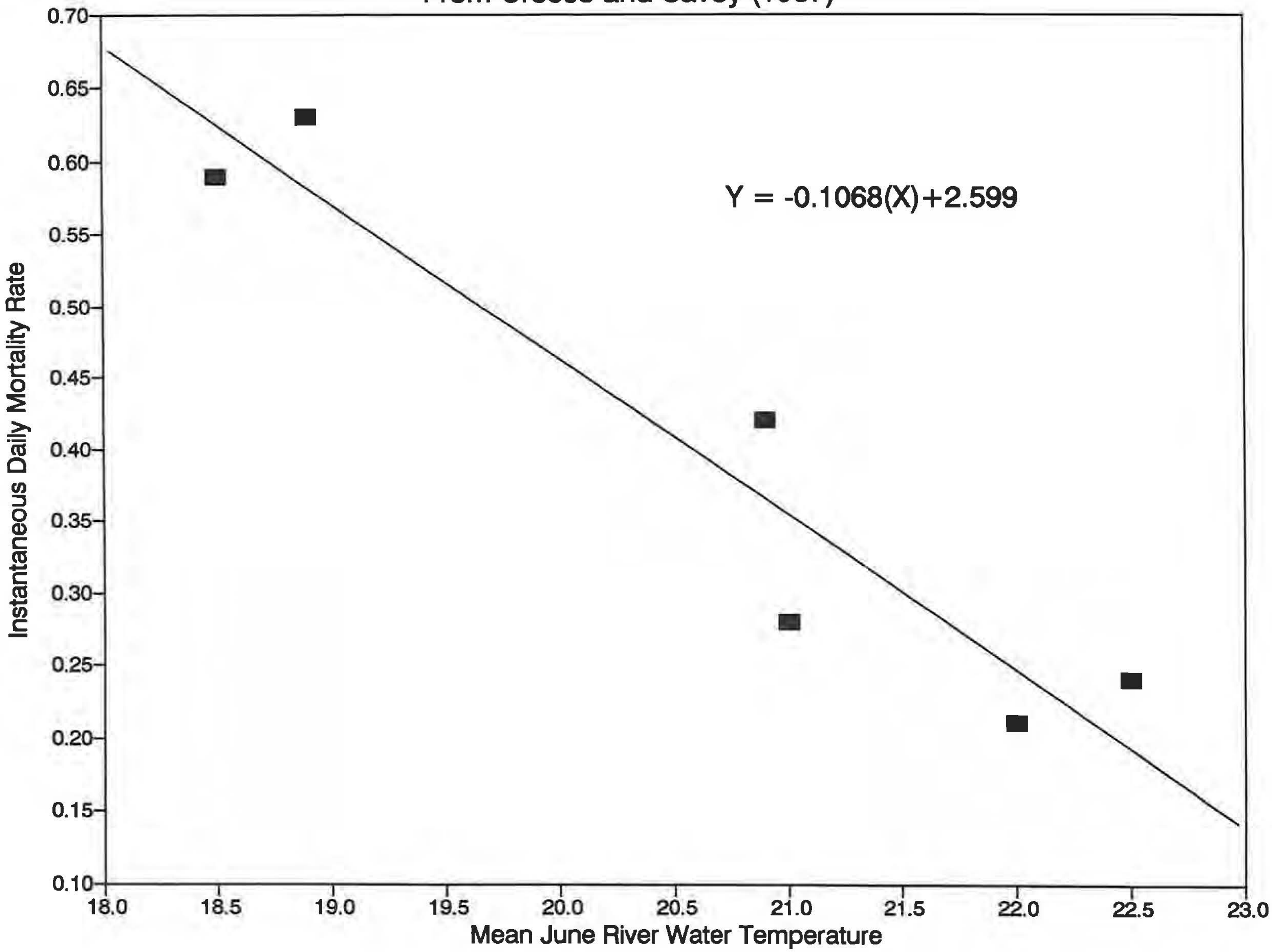

Figure A-5

Shad Fertilized Egg Hatching Success vs River Water Temperature

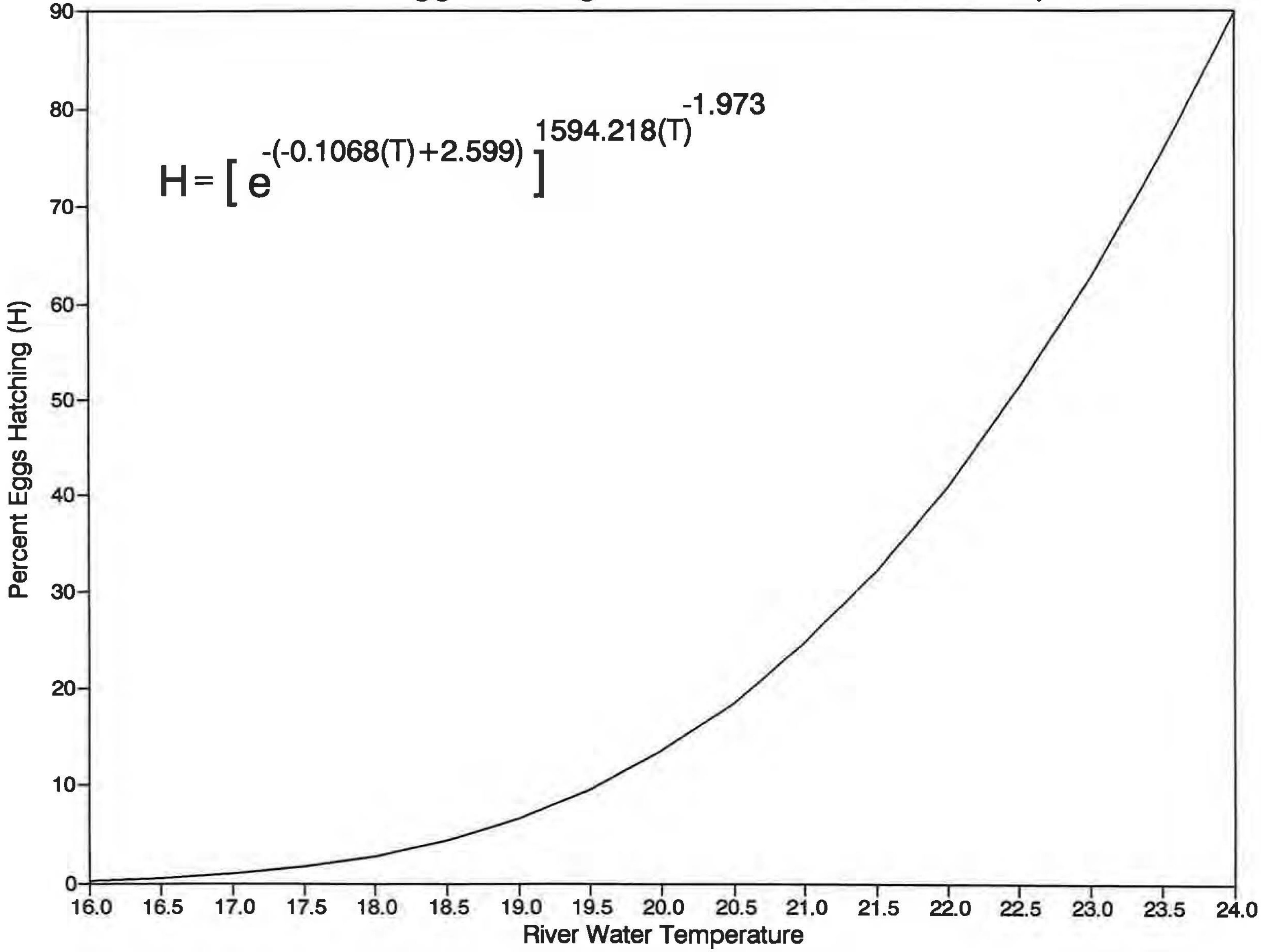

Figure A-6
1992 Seasonal Distribution of American Shad Extrapolated Counts at Cabot
Harza (1993)

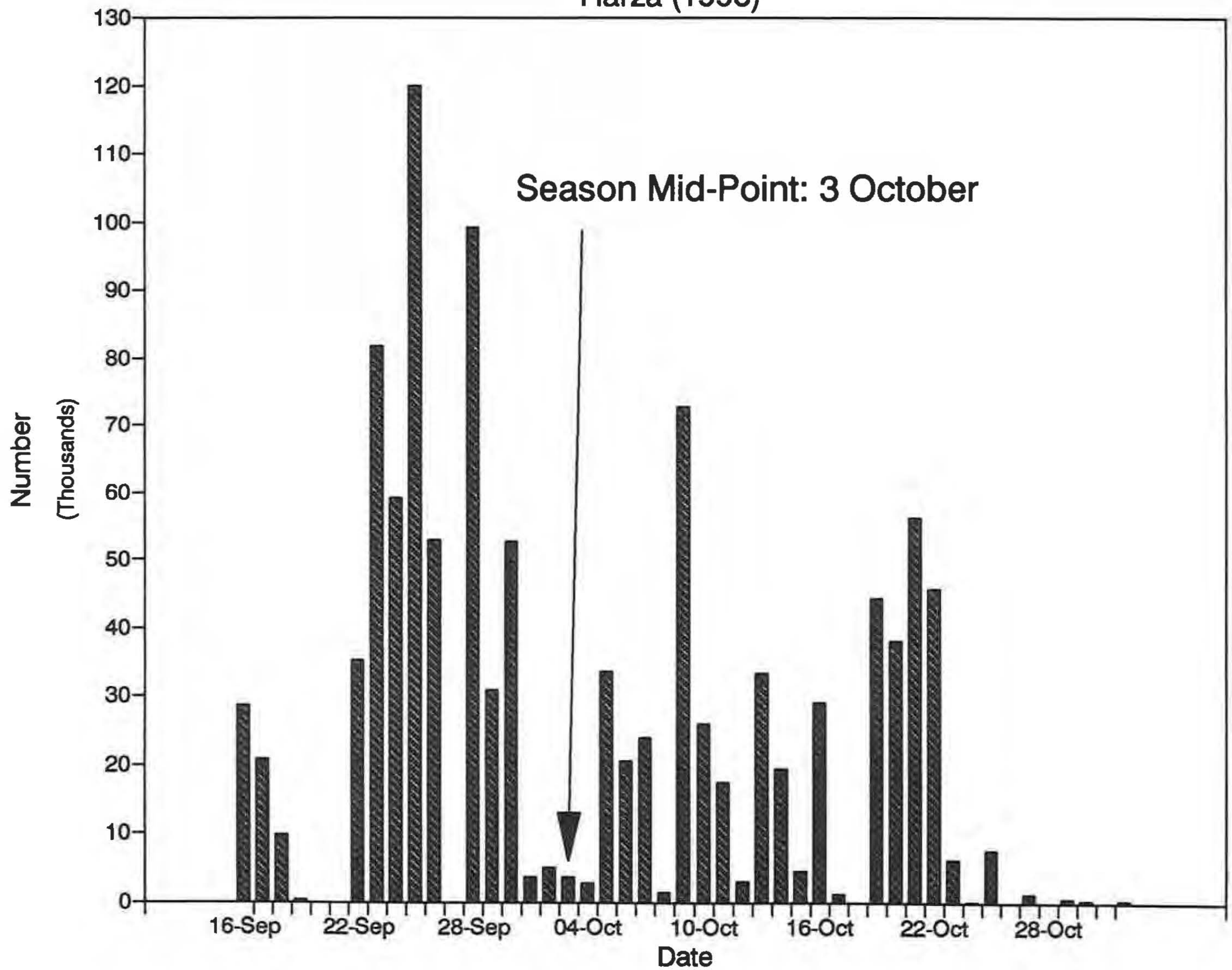

Figure A-7

Effect of Fertilization Rate on the Total No. of Juvenile Shad Produced Upriver of Turners

Connecticut River 1992

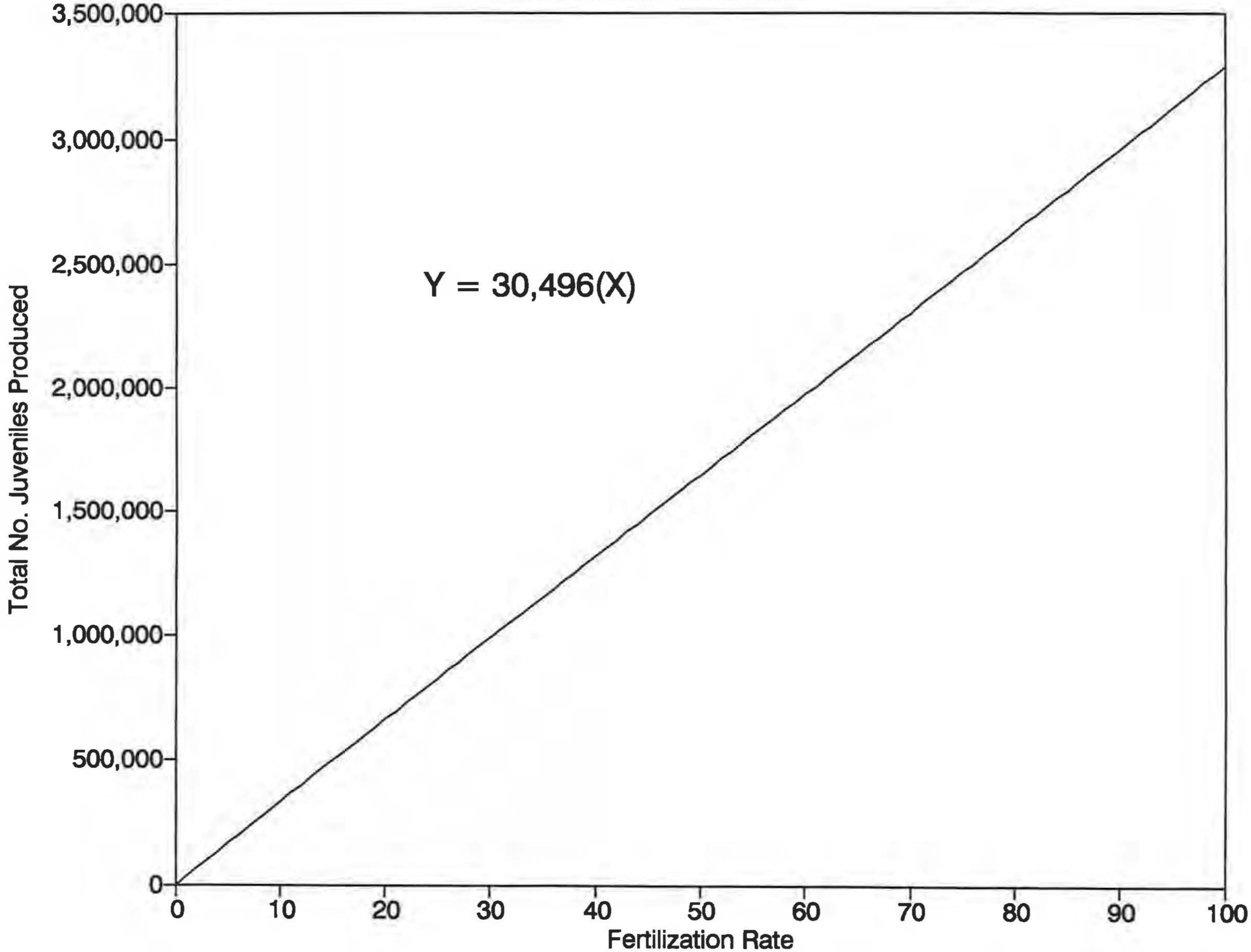

Figure A-8
Distribution of Numbers Entrained