April 19, 2018

**VIA ELECTRONIC FILING**

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

Re: FirstLight Hydro Generating Company, Turners Falls Hydroelectric Project (FERC No. 1889) and Northfield Mountain Pumped Storage Project (FERC No. 2485). Submittal of RMC 1994 Report.

Dear Secretary Bose:

On April 6, 2018, FirstLight Hydro Generating Company (FirstLight) filed a letter with the Federal Energy Regulatory Commission (FERC or the Commission), which included the following four reports as requested by FERC in its March 16, 2018 letter to FirstLight.

- Harza Engineering Company (Harza) & RMC Environmental Services (RMC). (1992). Turners Falls downstream fish passage studies: Downstream passage of juvenile clupeids, Fall 1991. Report to Northeast Utilities Service Company. Berlin, CT.
- Harza & RMC. (1993). Turners Falls downstream fish passage studies: Downstream passage of juvenile clupeids, Fall 1992. Prepared for Northeast Utilities Service Company. Berlin, CT.
- RMC. (1994). Emigration of juvenile clupeids and their responses to light conditions at the Cabot Station, Fall 1993. Prepared for Northeast Utilities Service Company. Berlin, CT.
- RMC. (1995). Log sluice passage survival of juvenile clupeids at Cabot hydroelectric station Connecticut River, Massachusetts. Drumore, PA. Report to Northeast Utilities Service Company.

In its filing, FirstLight mistakenly omitted the third report above (RMC, 1994). Please find attached the requested report. If you have any questions regarding this filing, please feel free to contact me at the number below.

Sincerely,

Douglas Bennett
Plant General Manager

Attachment: RMC 1994 Report

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# EMIGRATION OF JUVENILE CLUPEIDS AND THEIR RESPONSES TO LIGHT CONDITIONS AT THE CABOT STATION, FALL 1993

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**December 1994**

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## EXECUTIVE SUMMARY

As part of Northeast Utilities Service Company's continuing cooperation with state and federal resource agencies and their desire to afford safe downstream passage to emigrating fishes at their dams, a study was proposed for Cabot Station during fall 1993 to continue investigations of measures to enhance downstream migration of clupeids. Due to an outage of Unit 1 during the emigration time period, the proposed study was limited to determination of the timing of the 1993 clupeid emigration and the investigation of the effects of lighting on clupeid passage through the log sluice.

The log sluice sampling device at Cabot Station was operated generally three days a week from September 8 through November 12, 1993. All clupeids which passed through the sluice were enumerated and subsamples were measured and identified to species. During each weekly sample period, the effects of three discrete lighting conditions on passage rates were evaluated; one lighting condition per daily sample was investigated. Ambient light condition was normal Station lighting, the sluice light condition was sluice light and near forebay light on continuously with the far forebay light off, and the 20 min interval condition was sluice light on continuously with far forebay light off and the near forebay light cycled on and off every 20 min. During the 20 min interval testing, clupeids were enumerated every 20 min; during the other light conditions, clupeids were enumerated every hour.

On September 8, the first day of sampling, 88 juvenile clupeids were collected. Water temperature was 24°C (75.2°F) and canal flows were 2,591 - 3,507 cfs. Abundance generally increased to a peak between October 5 and 7 with water temperatures of 14 - 14.5°C (57.2-58.0°F); secondary peaks occurred between October 19 - 28. Numbers generally declined thereafter and the total clupeid catch on November 12 numbered 2,654. Water temperature was 6.5°C (43.7°F). Most clupeids (88.4%) were collected between 1900 and 2200 hr.

Clupeid passage was 168 times greater at the sluice light condition and 233 times greater at the 20 min interval condition than during ambient conditions. Statistically, the passage at ambient conditions was significantly lower ($P<0.05$). Passage rates between sluice light and intermittent lighting conditions were not significantly different ($P>0.05$). Differences between passage rates when the near forebay light was on vs off, within the 20 min interval tests, were not statistically significant ($P>0.05$).

## 1.0 INTRODUCTION

The restoration of anadromous fishes, primarily American shad (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*), and Atlantic salmon (*Salmo salar*), to the Connecticut River has been a priority of state and federal agencies for more than 20 years. Fishways and lifts installed at dams on the River have generally been successful in providing a means for upstream migration of these fishes. Concern now has been focused on safe, efficient downstream passage for both adult and juvenile fish.

A Memorandum of Agreement (MOA) was signed in 1990 between Northeast Utilities Service Company (NUSCO), The United States Fish and Wildlife Service (USFWS) and the Connecticut River Atlantic Salmon Commission (CRASC), and its member agencies, which designated that NUSCO would provide safe and efficient downstream passage facilities at all of their dams by 1994 (NUSCO et al. 1990). In response to the MOA, NUSCO has conducted studies at Hadley Falls, Holyoke Canal, Cabot Station, and Northfield Mountain Pumped Storage Station since 1990 to determine measures required to enhance downstream passage through existing structures and to investigate means to prevent or limit passage through turbines. At Cabot Station, a pre-feasibility study (Ruggles 1990) evaluated various techniques that had been used at other sites to divert emigrating fish away from turbine intakes. In the fall of 1991, a study was conducted to determine the proportion of emigrating clupeids which passed the Station by the log sluice and trash trough (Harza and RMC 1992). This study was generally repeated in the fall of 1992 with more emphasis placed on the determination of the proportion of clupeids using available routes to pass Cabot Station, the determination of approximate numbers of clupeids passed via the log sluice, and an evaluation of the trash trough as a viable downstream passage route (Harza and RMC 1993). During the performance of this study, general observations suggested that forebay lighting may play a role in the apparent reluctance of clupeids to readily pass down the log sluice. Preliminary experimentation with a mercury vapor light positioned under the walkway at the sluice entrance indicated that further study of lighting regimes was warranted (Harza and RMC 1993).

This report presents findings of a limited study conducted at Cabot Station during fall 1993. Originally, the proposed study was to be a confirmation of the 1992 results with the objectives of determining the proportion of clupeids passed through the trash trough openings and log sluice versus the turbines; further evaluation of trash trough passage; and to conduct a more formalized study to determine the effect of above water lights on passage through the log sluice. A mechanical failure and projected extended outage of turbine 1, however, precluded the possibility of achieving reliable, comparable results of the 1992 study due to the lack of attraction flows generated by the operation of Unit 1. Consultations between NUSCO and CRASC resulted in the approval of a study limited in scope. The objectives of the new proposed study were to determine the timing of the juvenile clupeid emigration past Cabot Station and to determine the effect of above water lights on downstream passage through the sluice.

## 2.0 STUDY SITE

The Turner's Falls Project generation facilities were built between 1905 and 1915. The Project consists of Turners Falls Dam, a canal gate house structure, a 2.1 mile long canal, Turners Falls No. 1 Station and Cabot Station (Figure 2-1). The Dam is located at River Mile 117 on the Connecticut River, Massachusetts.

Turners Falls Dam consists of the Montague Spillway and Gill Dam. The Montague Spillway has four 120-ft long by 13.5-ft high Bascule gates for pond elevation control. The Gill Dam includes a non-overflow section and three tainter gates. Water is typically either stored or spilled over the dam when river flows exceed approximately 15,000 cfs, the combined hydraulic capacity of Turners Falls Station No. 1 and Cabot Station. The canal gate house structure, situated on the east side of the river, is capable of directing up to approximately 15,000 cfs into the power canal.

Turners Falls No. 1 Station is located approximately 0.5 miles downstream from the gate house, on a Branch Canal (Figure 2-1). The station houses five Francis turbines with a total nameplate rating of 5.6 MW at a head of 43 ft. The total hydraulic capacity of the units at Turners Falls No. 1 Station is 2,500 cfs. The station is operated primarily when daily river flows exceed 12,500 cfs.

Cabot Station is an integral-intake powerhouse and is located at the downstream end of the power canal (Figure 2-2). The station has six Francis turbines with a total nameplate rating of 51 MW at a nominal head of 60 ft. Water flows to each of the turbines through three-bay intakes joined to the respective penstocks. The total hydraulic capacity of the station is 12,500 cfs.

A log sluice adjacent to Cabot Station is used as an alternate route for downstream migrating fish during emigration periods (Figure 2-2). During downstream migrations, the log sluice gate is lowered 2.0 - 2.5 ft below the forebay water level to produce a surface discharge of 150 to 220 cfs. A bulkhead insert was designed to enhance the number of fish using the log sluice. It was constructed to narrow and deepen the gate opening while maintaining the same discharge capacity. The insert fits into the stoplog slots of the log sluice, and has a 4 ft deep by 11 ft wide opening. The effect of the bulkhead insert on enhancing the use of the log sluice by downstream migrating fish was initially tested in the spring of 1992 (Harza and RMC 1992b).

An ice and trash trough, behind the top of the Cabot Station trash racks, is aligned perpendicular to the flow of water and discharges into the log sluice. In 1991, three openings were cut into the wall of the ice and trash trough to provide an alternative route for downstream movement of fish past Cabot Station. The maximum flow through any one opening is 123 cfs. If more than one slot is open at the same time, the flow through each slot is correspondingly less than 123 cfs. Each opening can be configured in two ways: 2.8 ft wide and 6 ft deep or 2.8 ft wide and 3 ft deep.

## 3.0 METHODS AND MATERIALS

### 3.1 Study Design

In order to determine the timing of the juvenile clupeid emigration, clupeids passing through the log sluice were enumerated prior to and after the expected daily movement peak of the run (O'Leary and Kynard 1986). Each sampling day consisted of six hourly samples, commencing at 1600 hr and ending at 2200 hr. The log sluice sampler was generally operated for three consecutive days during each week in September and October 1993. Canal wall repairs, which required draw down of the Canal, prevented sampling during the weeks of 12 - 18 September and 11 - 16 October. During the week prior to 11 October, the sampler operated for six consecutive days. All fish entering the sampler were enumerated and identified as clupeids or other (non alosids were identified to at least genus level) during each hourly sample. Subsamples of 100 clupeids were collected randomly over each hourly sample, identified to species, and measured to the nearest 5 mm fork length.

The effect of above water lighting on the passage of juvenile clupeids through the log sluice was evaluated by testing three distinct lighting regimes during each week's sampling. Each daily sample was conducted under normal lighting conditions (ambient), near forebay flood light on with sluice light on (sluice light), or near forebay light cycled on and off in 20 min intervals with sluice light on continuously (20 min interval). The light condition to be tested on a particular sampling day was chosen randomly prior to the onset of the study. During sampling under the 20 min interval light regime, clupeids were enumerated for each 20 min light condition i.e. light on or off.

Data were analyzed using the General Linear Model Procedures (GLM) of the Statistical Analysis System (SAS Institute, Inc., Version 6.03). These analyses consisted of analysis of variance and multiple range tests. Analyses were conducted on both non-transformed and transformed (log $x+1$) data; log transformation of the data improved the model fit. Thus interpretation is based on the results of log transformed data analysis. Differences in abundance of juvenile clupeids under the three test conditions were considered significant at $P \leq 0.05$. For the purpose of delineating the effects of light on juvenile passage only data collected between 1900 and 2200 h were statistically compared, a time when light effects would be manifested. A separate analysis was also conducted for data collected between 1600 and 1900 h. The outputs of all the statistical analyses conducted are provided in Appendix I.

### 3.2 Sampling

The log sluice sampling device consisted of a 27.5 ft long stainless steel profile wire screen that diverted fish into a flume while shedding the majority of water which flowed onto the screen (Figure 3-1). The sampler was positioned immediately downstream of the log sluice gate. The screen was 11 ft wide at the mouth of the sampler narrowing to 6.4 ft at the downstream end. The screen consisted of 0.06 in wide bars, spaced 0.04 in apart, which provided an open area that was 40% of the total screen area. The sampler was framed in steel with 4.5 ft high wooden side-walls.

Prior to commencement of each daily sample, the log sluice gate was closed, and a bulkhead insert which had an 11 ft wide by 4 ft deep opening was lowered into framework behind the skimmer gate. The inclined plane screen was lowered to a horizontal position with the upstream end of the screen resting on the bulkhead insert. The downstream end of the screen was attached to a fixed pivot point so that the screen and bulkhead could be lifted, allowing passage of water under the sampling device during non-sampling periods. Once the screen was in place, the sluice skimmer gate was lowered to approximately 30% open ( 2.0 to 2.5 ft, depending upon Canal level) and the sample commenced. Water and fish diverted by the screen flowed through a 31 ft long, 1 ft wide flume onto a sorting table. The flume had an initial depth of 3.0 ft and at the downstream end, a final depth of 3.75 ft. An inclined section of profile wire screen at the end of the flume diverted fish up to the sorting table and allowed a portion of water to flow through to a regulated release valve. The remaining water and fish flowed across the sorting table and returned back into the log sluice through a 12 in diameter PVC pipe. The sorting table was equipped with a divider, installed length-wise, and gates installed at the point where water flowed onto the table (Figure 3-1). The gates allowed fish to be diverted to either side of the divided table. Removable screens at the end of the table retained fish on the table while water flowed into the drain pipe. During each hourly sample, all fish collected were identified, enumerated, and released. A subsample of up to 100 clupeids from each hourly collection was retained to determine species composition and length distribution. The species of each juvenile clupeid was determined by peritoneum coloration. At the end of each hourly sample, a crowder (constructed of two wooden poles and nylon mesh) was used to force fish that were residing in the flume onto the sorting table so they would be included in that collection.

Each daily collection consisted of six hourly samples, commencing on the hour from 1600 hr to 2100 hr (final hourly collection ended at 2200 hr). Prior to the opening of the sluice skimmer gate for each daily sampling, a light reduction profile of the water column immediately in front of the sluice was conducted. Light measurements were taken in 1 ft increments down to a 10 ft depth with a Li-Cor Model 185B Photometer. The proportional degradation of light intensity for each 1 ft of depth was determined and called the light attenuation coefficient. The sluice gate was opened and sampling commenced. At the beginning of each hourly sample, light measurements were taken at nine locations in the forebay (Figure 3-2) at depths of 1 ft and 3 ft with a LI-Cor Model LI-1000 Datalogging Photometer. At the end of each daily collection, the log sluice skimmer gate was closed, the inclined screen was raised, and the bulkhead insert was removed. The gate was then opened again.

### 3.3 Light Experiments

Three lighting conditions were evaluated and are termed: ambient lighting, sluice light, and 20 min interval lighting. Ambient lighting was the condition of normal Station lights operation. The forebay was illuminated primarily by two high pressure sodium lamps, initiated by photo cells, located on each side of the intake area (Figure 3-2). The sluice light condition consisted of the near sluice forebay light on continuously, the far forebay light off, and the sluice light on continuously. The sluice light was a 400 watt mercury vapor unit suspended approximately 4 ft above water level immediately in front of the sluice under the walkway (Figure 3-2). This light was turned on at 1600 hr and remained on until 2200 hr during all daily sampling under this condition. Sampling procedures during these light conditions followed methods described above. The 20 min interval light condition utilized the sluice light on continuously, the far forebay light off, and the near sluice forebay light cycled on and off every 20 min after it was energized. During Daylight Savings Time (Sept.-Oct.), this light generally turned on near 1800 hr; during Eastern Standard Time, it generally came on near 1700 hr. Sampling under this light condition generally followed the same procedures as the other two conditions except that during each hourly sample, the flume leading to the sorting table was cleared of fish every 20 min, coinciding with the cycling of the forebay light, and numbers of clupeids were enumerated for each 20 min cycle.

Only the two November samples were conducted during Eastern Standard Time, thus, the time change did not affect protocol for the light condition experiments.

## 4.0 RESULTS

### 4.1 Timing and Emigration

Sampling to determine the timing of emigration of juvenile clupeids was initiated on September 8, 1993 (Table 4-1; Figure 4-1). Some 88 fish were collected on that date indicating that juvenile clupeids may have arrived at Cabot Station prior to September 8, 1993. The average water temperature was 23.7-24.0°C (74.7-75.2°F) and canal flows averaged 2,485-3,220 cfs during the first week of sampling. The highest peak abundance occurred between October 6 and 8, coincident with average water temperatures of 14.4-15.0°C (57.9-59°F) and average canal flows of 7,836-12,040 cfs. Abundance of juvenile clupeids declined somewhat after that and other smaller peaks occurred on October 19-21 and October 27-28. Intensive sampling ceased on October 28, when the abundance of juvenile clupeids was still relatively high. Limited sampling continued until November 12, 1993, when the abundance of juvenile clupeids had declined considerably and water temperatures were 6.5°C (43.7°F). The Cabot forebay was visited November 19 between 1900 and 2000 h to observe juvenile clupeid density. Water temperature was 6.0°C (42.8°F). Although juvenile clupeids were still present in the forebay, their numbers were substantially less than those observed the prior week. These data suggest that the emigration period, as determined by the presence of juvenile clupeids at Cabot Station, lasted for at least two months, with peaks occurring over a much shorter time when water temperature averaged 10.7-15.0°C (51.3-59.0°F) and canal flows averaged approximately 4,600-12,040 cfs.

The passage rate of clupeids differed between time periods over the hours sampled (Table 4-2 and Figure 4-2). Under the non-ambient conditions, most (88.4%) passed the sluice between 1900 and 2200 h. In contrast, of those passing the sluice under the ambient condition, 92.5% (7,017 of 7,590) did so prior to 1900 h. Of the 138,687 juvenile clupeids using the sluice during the intermittent condition, 96.3% (133,549) did so between 1900-2200; under the continuous light condition, 84.3% (96,445 of 114,473) did so during this period.

### 4.2 Responses to Light Conditions

A total of 230,567 juvenile clupeids was collected between 1900-2200 h over the seven weeks of light testing (Table 4-3); the overall averages were 27.3 fish/hr at the ambient light condition, 4,592.6 fish at the sluice light test condition, and 6,359.5 fish at the 20 min interval test condition (Table 4-4). Though some variation occurred among weeks, the overall passage of juvenile clupeids between 1900-2200 h was nearly 168 to 233 times higher at the sluice light or 20 min light interval condition than at the ambient condition; only 0.2% of the total clupeids were collected at ambient and the remainder at the other two light conditions. Within the seven weeks of light testing, the sluice light condition was responsible for over 50% of the total weekly clupeid catch during two weeks and the 20 min interval lighting condition provided over 50% of the catch during the other five weeks. The passage rate at the ambient condition was consistently less than 8% of the weekly passage rate.

A correlation analysis was performed, as a screening process, to detect relationships between individual measured variables and daily juvenile clupeid catch between 1900-2200 h under each light condition. The resulting correlation matrices are given in Table 4-6. Correlations differed under the three test conditions. Under the intermittent light conditions clupeid catch was significantly correlated ($P < 0.05$) with date, average canal flow, and average water temperature. As the season progressed the catch increased as it did with an increase in flow. The catch was negatively correlated with water temperature. Under the sluice light condition clupeid catch was correlated with average canal flow (positive) and water temperature (negative). None of the variables were correlated with clupeid catch under the ambient condition.

Data were further analyzed to evaluate the effects of light on the clupeid passage rate by a General Linear Model Procedure (GLM) using sampling week as a block. Two analyses were conducted; one on data collected between 1900-2200 h and the other using analysis data gathered at non-peak abundance periods (1600-1900 h). Abundance data were logarithmically transformed ($\log x+1$).

The analysis for 1900-2200 h showed significant ($P<0.01$) differences in clupeid catch among test conditions (Table 4-7). The Duncan's multiple range test showed that the passage rate at the ambient light condition was significantly ($P<0.05$) less than at the other two conditions. However, the passage rates were not different ($P>0.05$) between the sluice lights on and intermittent light condition. Similar statistical analyses on data gathered between 1600-1900 h did not show significant ($P>0.05$) differences among the test conditions indicating that the effects of light were more pronounced after 1900 h.

The data were further analyzed to detect effects of intermittently turning the near forebay light on and off (Table 4-5). This analysis was conducted to determine if the assumption that cycling the near forebay light at 20 minute intervals may enhance the passage rate of juvenile clupeids through the log sluice. Though the clupeid passage rate was 16% higher during light off than light on condition, this difference was not significant ($P>0.05$).

## 4.3 Light Measurements

Light measurements taken at nine locations in the forebay (Figure 3-2) showed great variability in illumination throughout the study period (Table 4-8). The areas in front of Unit 1 through 5 were generally the brightest areas during times of daylight. After dark, during the ambient light conditions, illumination in front of the sluice and in front of Unit 1 was generally similar. Light intensity generally decreased along Units 2 through 4, then increased from Unit 5 to 6. Light readings during the sluice light condition (after dark) in front of the sluice and Unit 1 were generally similar. Intensity decreased steadily from Unit 2 through Unit 6. This pattern was noted during times with the near forebay light on, during the 20 min interval test condition, however, during periods with the forebay light off, readings were extremely low in front of all the Units. The area in front of the sluice was also dim, but measurements were from 2 to 4 times greater than those recorded in front of the Units.

Light attenuation measurements were taken virtually every day of sampling in front of the sluice gate during daylight hours. Daily variability in intensity and attenuation coefficients were noted throughout the study period (Table 4-9). The overall average light intensity attenuation coefficient was 0.240.

## 4.4 Species Composition

A total of 15 non-alosid species (681 specimens) was captured during the log sluice sampling (Table 4-10). In order of abundance, American eel, white perch, and smallmouth bass were most common.

Two alosid species, American shad and blueback herring, were captured. Of these, American shad comprised 93.1% of the sub-sampled catch (Table 4-11) and blueback herring comprised 6.9%. The length distribution of these alosids is shown in Table 4-12. Most American shad measured between 71 and 90 mm with a range of 56 to 141 mm; most blueback herring measured between 71 and 90 mm with a range of 51 to 101 mm.

## 5.0 DISCUSSION

The primary objectives of the study were to 1) delineate the timing of emigration of juvenile clupeids; and 2) evaluate the responses of juvenile clupeids to different light conditions. Based on the 1993 capture data, the timing of the emigration, daily peak movement, and water temperature over which these movements occurred at Cabot Station can be established as follows. The emigration of juvenile clupeids began in September at water temperatures greater than 20.0°C (68°F), peaked in October, and tapered off in late October to early November. Water temperatures ranged from 14.4-15°C (57.9-59.0°F) during the peak emigration. The timing of the peak daily movements differed among the test conditions. Only 7.5% of all juveniles that utilized the sluice under ambient light condition passed between 1900-2200 h; under the 20 min interval light regime, 96.3% passed during this period, and 84.3% passed during these hours under the sluice light regime. O'Leary and Kynard (1986) reported that at the Holyoke Project (approximately 36 miles downstream of Cabot Station) daily peak movement occurred between 1800-2200 h; emigration began when water temperature declined to 19.0-21.0°C (66-69.8°F) in September, peaked at 9-15°C (48.2-59.0°F) and ended in late October or early November.

The second objective of the study was to evaluate the responses of juvenile clupeids to three light conditions (ambient, sluice lights on, and 20 min interval cycling of the near overhead forebay light). Clupeid passage rate was influenced by light conditions between 1900-2200 h. Passage was 168 and 233 times greater during sluice light and 20 min interval test conditions, respectively, than it was during the ambient condition. This difference was statistically significant ($P < 0.05$) which strongly implies that the lighting conditions tested enhanced clupeid passage relative to ambient conditions. Within the 20 min interval light test, however, the passage rate with the near forebay light off was not significantly different ($P > 0.05$) from that observed when the light was on; the overall passage rate was only 16% higher at light off than at light on and the variability was large between test dates.

Field observations indicated that the shadow cast at the entrance to the sluice by the walkway (Figure 3-1) under ambient conditions may have induced an avoidance response in clupeids present in the forebay. Fish appeared to be attracted to the lighted areas. They tended to school upstream of and avoid the shadow area. Both of the tested light conditions (sluice light and 20 min interval) included the use of the sluice light, which virtually eliminated the walkway shadow, and in turn, the avoidance response of the fish. It is not known whether the sluice light simply minimized the avoidance response or actually attracted juvenile clupeids. Although results have not been consistent, attraction of juvenile clupeids to underwater mercury vapor lights has been noted elsewhere (EPRI 1990).

Despite the lack of statistically significant passage rates between light conditions during the interval tests, observations at the site indicated that clupeids responded to changes in the light conditions. Fish became startled when the light was turned off; less so than when it was turned on since the forebay light, when energized, slowly increased to maximum intensity over a 2-3 min period. In addition, it was observed that once the forebay light was on, juvenile clupeids tended to be more dispersed throughout the areas of the sluice entrance and Unit 1 intake. During the light off period, most juveniles appeared to concentrate near the sluice entrance, where the sluice light was located.

The net benefit of instituting one of the experimental lighting conditions as the standard condition during future out migrations is difficult to assess. Previous sluice and turbine passage studies (Harza and RMC 1993) were conducted predominately under the ambient light condition and indicated that 88% of the juvenile clupeids passed through the sluice. This sampling, however, was conducted primarily between 1700 and 2100 hr. Data from 11 diel samples during 1992 indicated that 94.4% of all fish passing through the sluice between the hours of 1600-2200 h were collected during the period of 1600-1900 h. This is similar to the results of the 1993 ambient lighting condition tests where 92.5% of the total passage between 1600-2200 h occurred during the period of 1600-1900 h. Under the test lighting conditions, this ratio changed dramatically. For the combined test conditions, only 9.2% of all clupeids captured during the 1600-2200 h period were collected between 1600-1900 h. Most (90.8%) passage occurred after dark under light test conditions.

The difference between the 1992 and 1993 results may have been due to the experimental light conditions. It is possible that the dominance of daytime migration during 1992 may have been due to the walkway shadow inhibiting sluice passage at night. Once the shadow was eliminated by the sluice light in 1993, nighttime migration may have been enhanced.

Another explanation may be that the presence of the sluice light induced the fish to migrate at night when they otherwise may not have, and that the walkway shadow under the ambient condition had no effect on migration. This is not supported by the differences noted between 1992 and 1993, however. Furthermore, studies at the Holyoke Project have indicated an evening/early night peak in clupeid passage rates (O'Leary and Kynard 1986; Harza and RMC 1993).

It is most likely that both the reduction of the walkway shadow effect and the apparent attraction of the clupeids to lighted areas contributed to the observed difference between the ambient and test conditions.

## 6.0 CONCLUSIONS

The emigration of juvenile clupeids (American shad and blueback herring), as measured at the Cabot Station log sluice, began in early September and lasted through early to mid November. The peak occurred in October. The water temperature ranged from 6.5-24.0°C (43.7-75.2°F); water temperature during the emigration peaks ranged from 10.7-17.4°C (51.3-63.3°F). The canal flows were 4,597 to 10,998 cfs. American shad comprised 93.1% of the clupeid catch; the remainder were blueback herring.

Significantly more ($P < 0.05$) juvenile clupeids passed the log sluice during the lighted conditions than at ambient lighting. There were, however, no significant differences ($P > 0.05$) in passage rates between continuous sluice lighting and intermittent near forebay lighting, nor between near forebay light on and off condition.

## 7.0 LITERATURE CITED

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**Table 4-1. Daily juvenile clupeid passage, average water temperature and canal flow at Cabot Station, September - November 12, 1993.**

| DATE | TOTAL CATCH | AVERAGE WATER TEMPERATURE C | AVERAGE CANAL FLOW cfs |
|---|---|---|---|
| 8-Sep-93 | 88 | 24.0 | 2,876.3 |
| 9-Sep-93 | 629 | 23.7 | 3,219.8 |
| 10-Sep-93 | 405 | 24.0 | 2,485.2 |
| 22-Sep-93 | 233 | 19.0 | 3,981.5 |
| 23-Sep-93 | 1,288 | 18.7 | 4,187.0 |
| 24-Sep-93 | 128 | 18.7 | 3,540.3 |
| 27-Sep-93 | 7,352 | 18.0 | 8,822.7 |
| 28-Sep-93 | 4 | 17.9 | 9,030.0 |
| 29-Sep-93 | 15,605 | 17.4 | 9,283.0 |
| 5-Oct-93 | 2,605 | 14.7 | 6,274.5 |
| 6-Oct-93 | 53,189 | 14.6 | 7,836.5 |
| 7-Oct-93 | 44,926 | 14.4 | 10,998.7 |
| 8-Oct-93 | 32,695 | 15.0 | 12,040.0 |
| 9-Oct-93 | 7,542 | 15.4 | 4,597.0 |
| 10-Oct-93 | 3,964 | 14.4 | 4,597.5 |
| 19-Oct-93 | 18,792 | 12.3 | 8,461.2 |
| 20-Oct-93 | 204 | 12.0 | 8,906.3 |
| 21-Oct-93 | 24,702 | 12.0 | 8,771.8 |
| 26-Oct-93 | 597 | 11.1 | 8,343.5 |
| 27-Oct-93 | 26,746 | 10.8 | 7,366.5 |
| 28-Oct-93 | 19,056 | 10.7 | 10,546.5 |
| 5-Nov-93 | 2,441 | 8.3 | 8,776.8 |
| 12-Nov-93 | 2,654 | 6.5 | 9,933.3 |
| **TOTAL** | **265,845** | **15.4** | **7,168.5** |

Table 4-2. Variation in hourly catches of juvenile clupeids under three test conditions (ambient light, sluice light, and 20 min interval near forebay light) at Cabot Station, September-October 1993.

| | Time of Day | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1600-1700 | 1700-1800 | 1800-1900 | Subtotal 1600-1900 | 1900-2000 | 2000-2100 | 2100-2200 | Subtotal 1900-2200 | Totals |
| Ambient | 1,270 | 2,620 | 3,127 | 7,017 | 282 | 203 | 88 | 573 | 7,590 |
| Sluice | 1,363 | 4,373 | 12,292 | 18,028 | 44,254 | 25,641 | 26,550 | 96,445 | 114,473 |
| 20 min Interval | 399 | 890 | 3,849 | 5,138 | 43,584 | 47,999 | 41,966 | 133,549 | 138,687 |
| **TOTAL** | **3,032** | **7,883** | **19,268** | **30,183** | **88,120** | **73,843** | **68,604** | **230,567** | **260,750** |

Table 4-3. Comparison of daily juvenile clupeid catches under three test conditions (ambient light, sluice light, and 20 min interval near forebay light) at Cabot Station, September-October 1993. Only observations after 19:00 used.

| Date | Ambient | Sluice Light | 20 min interval | Total |
|---|---|---|---|---|
| 8-10 September | 87 | 629 | 405 | 1,121 |
| 22-24 September | 128 | 233 | 1,281 | 1,642 |
| 27-29 September | 4 | 15,572 | 7,350 | 22,926 |
| 5-7 October | 64 | 43,304 | 52,436 | 95,804 |
| 8-10 October | 155 | 4,144 | 30,027 | 34,326 |
| 19-21 October | 76 | 15,224 | 23,978 | 39,278 |
| 26-28 October | 59 | 17,339 | 18,072 | 35,470 |
| **TOTALS** | **573** | **96,445** | **133,549** | **230,567** |

Table 4-4. Comparison of juvenile clupeid catches (number per hourly collection) at three test conditions (ambient light, sluice light and 20 min interval near forebay light) at Cabot Station sluice, September-October 1993. Only observations after 19:00 used.

| Date | Ambient | Sluice Light | 20 min interval |
|---|---|---|---|
| 8-10 September | 29.0 | 209.7 | 135.0 |
| 22-24 September | 42.7 | 77.7 | 427.0 |
| 27-29 September | 1.3 | 5,190.7 | 2,450.0 |
| 5-7 October | 21.3 | 14,434.7 | 17,478.7 |
| 8-10 October | 51.7 | 1,381.3 | 10,009.0 |
| 19-21 October | 25.3 | 5,074.7 | 7,992.7 |
| 26-28 October | 19.7 | 5,779.7 | 6,024.0 |
| OVERALL | 27.3 | 4,592.6 | 6,359.5 |

Table 4-5. Comparison of daily juvenile clupeid catches (number per 20 minute collection) during 20 minute interval lighting (off and on) at the sluice gate of Cabot Station, September-October 1993. N=36 observations when lights were off and 33 when lights were on during the study period.

| | Light | | Ratio |
|---|---|---|---|
| Date | Off | On | Off:on |
| 10 September | 53.8 | 38.0 | 1.41 |
| 23 September | 138.8 | 146.8 | 0.95 |
| 27 September | 383.0 | 1,358.8 | 0.28 |
| 6 October | 4,514.2 | 7,466.3 | 0.60 |
| 8 October | 2,885.2 | 3,900.3 | 0.74 |
| 21 October | 3,393.0 | 681.3 | 4.98 |
| 28 October | 2,553.5 | 621.2 | 4.11 |
| OVERALL | 2,097.2 | 1,802.8 | 1.16 |

Table 4-6. Correlation matrix of environmental variables with log(catch + 1) from Cabot Bypass Canal, 1993. Only start times from 19:00 on used.

CORRELATION ANALYSIS
4 'VAR' Variables: LOGCATCH DATE AVGFLOW AVGWATER

LIGHTING = AMB

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| LOGCATCH | 7 | 1.77496 | 0.497978 | 12.424722 | 0.69897 | 2.193125 |
| DATE | 7 | 12330 | 16.267116 | 86313 | 12304 | 12352 |
| AVGFLOW | 7 | 6547.238095 | 2772.765365 | 45831 | 2924.333333 | 9182.333333 |
| AVGWATER | 7 | 15.957143 | 4.477339 | 111.7 | 11 | 24 |

Pearson Correlation Coefficients / Prob > \|R\| under Ho: Rho=0 / N = 7

| | LOGCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| LOGCATCH | 1<br>0 | 0.06365<br>0.8922 | -0.58872<br>0.1643 | -0.08098<br>0.863 |
| DATE | 0.06365<br>0.8922 | 1<br>0 | 0.6819<br>0.0915 | -0.98468<br>0.0001 |
| AVGFLOW | -0.58872<br>0.1643 | 0.6819<br>0.0915 | 1<br>0 | -0.68726<br>0.088 |
| AVGWATER | -0.08098<br>0.863 | -0.98468<br>0.0001 | -0.68726<br>0.088 | 1<br>0 |

LIGHTING = INT

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| LOGCATCH | 7 | 3.916684 | 0.780767 | 27.416786 | 2.608526 | 4.719638 |
| DATE | 7 | 12331 | 16.469308 | 86315 | 12306 | 12354 |
| AVGFLOW | 7 | 8038.714286 | 3624.076395 | 56271 | 2527.666667 | 12716 |
| AVGWATER | 7 | 16.02381 | 4.561746 | 112.166667 | 10.5 | 24 |

Pearson Correlation Coefficients / Prob > \|R\| under Ho: Rho=0 / N = 7

| | LOGCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| LOGCATCH | 1<br>0 | 0.78463<br>0.0367 | 0.87108<br>0.0107 | -0.85846<br>0.0134 |
| DATE | 0.78463<br>0.0367 | 1<br>0 | 0.77521<br>0.0406 | -0.97895<br>0.0001 |
| AVGFLOW | 0.87108<br>0.0107 | 0.77521<br>0.0406 | 1<br>0 | -0.78825<br>0.0352 |
| AVGWATER | -0.85846<br>0.0134 | -0.97895<br>0.0001 | -0.78825<br>0.0352 | 1<br>0 |

LIGHTING = SL

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| LOGCATCH | 7 | 3.7196 | 0.839633 | 26.037198 | 2.369216 | 4.636638 |
| DATE | 7 | 12331 | 16.226081 | 86314 | 12305 | 12353 |
| AVGFLOW | 7 | 7120.047619 | 3025.991288 | 49840 | 2985.333333 | 11077 |
| AVGWATER | 7 | 15.957143 | 4.363176 | 111.7 | 10.666667 | 23.5 |

Pearson Correlation Coefficients / Prob > \|R\| under Ho: Rho=0 / N = 7

| | LOGCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| LOGCATCH | 1<br>0 | 0.70945<br>0.0742 | 0.95274<br>0.0009 | -0.75613<br>0.0492 |
| DATE | 0.70945<br>0.0742 | 1<br>0 | 0.62987<br>0.1295 | -0.98841<br>0.0001 |
| AVGFLOW | 0.95274<br>0.0009 | 0.62987<br>0.1295 | 1<br>0 | -0.71577<br>0.0705 |
| AVGWATER | -0.75613<br>0.0492 | -0.98841<br>0.0001 | -0.71577<br>0.0705 | 1<br>0 |

Table 4.7 ANOVA for week and lighting as main effects for log(clupeid catch + 1) at Cabot Station, Fall 1993. Only start times from 19:00 on used.

General Linear Models Procedure
Class Level Information

| Class | Levels | Values |
|---|---|---|
| LIGHTING | 3 | 20 MIN. INTERVAL AMBIENT SLUICE LIGHT |
| WEEKOF | 7 | 1 2 3 4 5 6 7 |

Number of observations in data set = 21

General Linear Models Procedure

Dependent Variable: LOGCATCH

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 8 | 24.17504078 | 3.0218801 | 7.53 | 0.0011 |
| Error | 12 | 4.81770524 | 0.40147544 | | |
| Corrected Total | 20 | 28.99274603 | | | |

| R-Square | C.V. | Root MSE | LOGCATCH Mean |
|---|---|---|---|
| 0.833831 | 20.19778 | 0.63362089 | 3.137081 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHTING | 2 | 19.6173686 | 9.8086843 | 24.43 | 0.0001 |
| WEEKOF | 6 | 4.55767218 | 0.75961203 | 1.89 | 0.1635 |

| Source | DF | Type II SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHTING | 2 | 19.6173686 | 9.8086843 | 24.43 | 0.0001 |
| WEEKOF | 6 | 4.55767218 | 0.75961203 | 1.89 | 0.1635 |

Duncan's Multiple Range Test for variable: LOGCATCH

NOTE: This test controls the type I comparisionwise error rat, not the experimentwise error rate.

Alpha= 0.05 df=12 MSE= 0.401475

| Number of Mean | 2 | 3 |
|---|---|---|
| Critical Range | 0.737 | 0.772 |

Means with the same letter are not significantly different

| Duncan Grouping | Mean | N | LIGHTING |
|---|---|---|---|
| A | 3.917 | 7 | 20 MIN. INTERVAL |
| A | | | |
| A | 3.72 | 7 | SLUICE LIGHT |
| B | 1.775 | 7 | AMBIENT |

Least Squares Means

| LIGHTING | LOGCATCH LSMEAN | Std Err LSMEAN | Pr > \|T\| H0:LSMEAN=0 | i/j | Pr > \|T\| H0: LSMEAN(i)=LSMEAN(j) 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| 20 MIN INTERVAL | 3.91668372 | 0.2394862 | 0.0001 | 1 | . | 0.0001 | 0.5714 |
| AMBIENT | 1.77496033 | 0.2394862 | 0.0001 | 2 | 0.0001 | . | 0.0001 |
| SLUICE LIGHT | 3.71959976 | 0.2394862 | 0.0001 | 3 | 0.5714 | 0.0001 | . |

NOTE: To ensure overall protectioon level, only probabilities associated with pre-planned comparisions should be used.

**Table 4-8. Light intensity measurements (lux) in Cabot Forebay, fall 1993.**

**Forebay Lights on:** **Near:** 1922 **Far:** off

| Date | Time | Depth | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep-09 | 1708 | 1 ft | 2841 | 2450 | 2635 | 3640 | 4677 | 5944 | 5174 | 5295 | 4515 |
| | | 3 ft | 1450 | 1428 | 1525 | 2233 | 3393 | 3475 | 3120 | 3190 | 2641 |
| | 1900 | 1 ft | 660 | 545 | 524 | 440 | 399 | 356 | 358 | 325 | 248 |
| | | 3 ft | 305 | 312 | 263 | 246 | 222 | 226 | 212 | 193 | 142 |
| | 2000 | 1 ft | 54 | 54 | 61 | 49 | 12 | 3 | 1 | 0.5 | 0.2 |
| | | 3 ft | 29 | 31 | 36 | 32 | 7 | 1 | 0.8 | 0.2 | 0 |
| | 2100 | 1 ft | 47 | 30 | 52 | 46 | 12 | 1 | 1 | 0.5 | 0.3 |
| | | 3 ft | 28 | 26 | 31 | 31 | 8 | 0.5 | 0.8 | 0.3 | 0.3 |

**Forebay Lights on:** **Near:** 1908 **Far:** off

| Date | Time | Depth | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep-10 | 1715 | 1 ft | 5154 | 4860 | 5151 | 5456 | 4069 | 4530 | 5154 | 4535 | 4275 |
| | | 3 ft | 2897 | 2568 | 2802 | 3274 | 3271 | 3185 | 3067 | 2766 | 2442 |
| | 1900 | 1 ft | 240 | 214 | 207 | 203 | 191 | 192 | 183 | 173 | 168 |
| | | 3 ft | 190 | 180 | 171 | 171 | 169 | 167 | 161 | 152 | 150 |
| | 2000 | 1 ft | 140 | 137 | 125 | 114 | 111 | 129 | 127 | 130 | 133 |
| | | 3 ft | 129 | 124 | 123 | 113 | 128 | 143 | 128 | 125 | 128 |
| | 2100 | 1 ft | 164 | 172 | 165 | 162 | 126 | 113 | 113 | 114 | 113 |
| | | 3 ft | 142 | 146 | 142 | 148 | 122 | 112 | 113 | 113 | 112 |

Table 4-8. cont.

Forebay Lights on: Near: 1855 Far: off

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep-22 | 1614 | 1 ft | 5400 | 6211 | 5800 | 7370 | 7696 | 7749 | 7934 | 7621 | 5200 |
| | | 3 ft | 3300 | 3014 | 2936 | 4795 | 4809 | 5099 | 4898 | 5012 | 3494 |
| | 1705 | 1 ft | 5000 | 4900 | 4139 | 5300 | 5125 | 5194 | 5120 | 4962 | 3665 |
| | | 3 ft | 2530 | 2344 | 2118 | 3175 | 3005 | 3184 | 3090 | 3020 | 2640 |
| | 1802 | 1 ft | 1494 | 1462 | 1335 | 1708 | 1643 | 1535 | 1453 | 1372 | 902 |
| | | 3 ft | 745 | 699 | 667 | 939 | 909 | 835 | 818 | 795 | 544 |
| | 1902 | 1 ft | 77 | 68 | 70 | 65 | 27 | 18 | 15 | 13 | 11 |
| | | 3 ft | 44 | 50 | 37 | 45 | 21 | 13 | 11 | 10 | 9 |
| | 2005 | 1 ft | 60 | 65 | 61 | 56 | 28 | 12 | 9 | 8 | 7 |
| | | 3 ft | 37 | 45 | 45 | 43 | 18 | 10 | 9 | 7 | 7 |
| | 2106 | 1 ft | 60 | 60 | 52 | 54 | 17 | 9 | 8 | 7 | 8 |
| | | 3 ft | 35 | 46 | 33 | 40 | 13 | 9 | 7 | 7 | 8 |

Forebay Lights on: Near: 1850 Far: off

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep-23 | 1610 | 1 ft | 3225 | 2219 | 1870 | 2074 | 1782 | 1430 | 1382 | 1530 | 1200 |
| | | 3 ft | 1422 | 970 | 921 | 1100 | 975 | 890 | 874 | 1020 | 754 |
| | 1712 | 1 ft | 1460 | 1518 | 1540 | 1381 | 680 | 642 | 590 | 572 | 410 |
| | | 3 ft | 855 | 895 | 870 | 450 | 407 | 384 | 375 | 364 | 260 |
| | 1804 | 1 ft | 360 | 342 | 297 | 278 | 296 | 387 | 420 | 388 | 218 |
| | | 3 ft | 182 | 180 | 151 | 165 | 181 | 246 | 254 | 206 | 131 |
| | 1905 * | 1 ft | 14 | 12 | 13 | 9 | 8 | 6 | 6 | 5 | 4 |
| | | 3 ft | 11 | 11 | 11 | 7 | 4 | 6 | 4 | 4 | 3 |
| | 2004 | 1 ft | 53 | 70 | 70 | 52 | 15 | 8 | 5 | 5 | 3 |
| | | 3 ft | 34 | 36 | 46 | 39 | 13 | 7 | 5 | 5 | 3 |
| | 2110 * | 1 ft | 8 | 8 | 7 | 2 | 1 | 2 | 2 | 2 | 2 |
| | | 3 ft | 7 | 7 | 6 | 2 | 0.5 | 1 | 2 | 2 | 1 |

* [illegible] light off

Table 4-8. cont.

Forebay Lights on: Near: 1903 Far: 1909

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep-24 | 1600 | 1 ft | 4669 | 4869 | 5160 | 5387 | 5082 | 5040 | 4717 | 4901 | 3296 |
| | | 3 ft | 2431 | 2478 | 2428 | 3101 | 2952 | 2827 | 2629 | 2721 | 1882 |
| | 1700 | 1 ft | 4381 | 3815 | 3503 | 4147 | 4050 | 4125 | 4027 | 3871 | 2964 |
| | | 3 ft | 2191 | 2152 | 1988 | 2548 | 2422 | 2459 | 2342 | 2261 | 1826 |
| | 1800 | 1 ft | 2682 | 2590 | 2450 | 2442 | 2520 | 2381 | 2350 | 2250 | 1786 |
| | | 3 ft | 1150 | 1320 | 1140 | 1486 | 1451 | 1440 | 1402 | 1340 | 1058 |
| | 1900 | 1 ft | 31 | 27 | 23 | 23 | 20 | 18 | 16 | 14 | 10 |
| | | 3 ft | 13 | 13 | 10 | 11 | 11 | 9 | 8 | 7 | 6 |
| | 2000 | 1 ft | 50 | 62 | 44 | 52 | 14 | 6 | 7 | 25 | 90 |
| | | 3 ft | 27 | 25 | 33 | 33 | 9 | 4 | 4 | 17 | 57 |
| | 2100 | 1 ft | 50 | 64 | 52 | 51 | 13 | 5 | 6 | 23 | 87 |
| | | 3 ft | 24 | 28 | 28 | 32 | 8 | 1 | 3 | 17 | 53 |

Forebay Lights on: Near: 1830 Far: off

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep-27 | 1605 | 1 ft | 3953 | 4990 | 4390 | 5166 | 5230 | 5510 | 4050 | 4250 | 5344 |
| | | 3 ft | 2314 | 2225 | 1992 | 3092 | 3073 | 2369 | 3199 | 3128 | 3056 |
| | 1700 | 1 ft | 2950 | 2880 | 2950 | 3352 | 3371 | 3265 | 2578 | 3424 | 3678 |
| | | 3 ft | 1675 | 1500 | 1599 | 2015 | 2018 | 2038 | 1840 | 2016 | 2241 |
| | 1800 | 1 ft | 250 | 229 | 201 | 225 | 239 | 254 | 198 | 270 | 295 |
| | | 3 ft | 137 | 118 | 102 | 135 | 150 | 151 | 151 | 155 | 172 |
| | 1900 * | 1 ft | 9 | 6 | 5 | 2 | 1 | 1 | 1 | 1 | 1 |
| | | 3 ft | 8 | 6 | 5 | 1 | 0.8 | 1 | 0.8 | 0.5 | 0.8 |
| | 2240 | 1 ft | 123 | 149 | 135 | 144 | 100 | 94 | 93 | 97 | 99 |
| | | 3 ft | 119 | 121 | 111 | 123 | 94 | 90 | 89 | 91 | 90 |

* - Near forebay light off

Table 4-8. cont.

Forebay Lights on: Near: 1854 Far: 1859

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep-28 | 1600 | 1 ft | 5464 | 6093 | 5802 | 6898 | 6536 | 6131 | 4220 | 5972 | 5886 |
| | | 3 ft | 2662 | 2322 | 2417 | 3729 | 3932 | 3977 | 2919 | 3234 | 3547 |
| | 1700 | 1 ft | 3900 | 4360 | 4272 | 4892 | 4630 | 4395 | 3371 | 4577 | 4356 |
| | | 3 ft | 1806 | 2008 | 1789 | 2765 | 2690 | 2785 | 2450 | 2311 | 2453 |
| | 1800 | 1 ft | 2266 | 1885 | 1670 | 2107 | 2070 | 1933 | 1682 | 1804 | 1908 |
| | | 3 ft | 957 | 765 | 692 | 1152 | 1072 | 1039 | 1039 | 947 | 963 |
| | 1900 | 1 ft | 62 | 42 | 41 | 60 | 22 | 10 | 11 | 24 | 80 |
| | | 3 ft | 31 | 23 | 25 | 39 | 12 | 7 | 8 | 21 | 47 |
| | 2004 | 1 ft | 52 | 67 | 53 | 55 | 17 | 9 | 9 | 25 | 83 |
| | | 3 ft | 34 | 35 | 34 | 41 | 11 | 7 | 7 | 19 | 52 |
| | 2104 | 1 ft | 47 | 61 | 50 | 58 | 20 | 7 | 11 | 26 | 78 |
| | | 3 ft | 26 | 21 | 27 | 46 | 12 | 6 | 9 | 20 | 49 |

Forebay Lights on: Near: 1851 Far: off

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep-29 | 1603 | 1 ft | 4510 | 4105 | 3876 | 5543 | 5216 | 5127 | 5040 | 4834 | 3759 |
| | | 3 ft | 2100 | 1780 | 1886 | 2913 | 2668 | 2643 | 2481 | 2358 | 1881 |
| | 1700 | 1 ft | 3344 | 4365 | 3321 | 4239 | 4342 | 4007 | 4016 | 4222 | 2950 |
| | | 3 ft | 1569 | 1633 | 1341 | 2202 | 2218 | 2019 | 2125 | 1984 | 1516 |
| | 1801 | 1 ft | 2117 | 1775 | 1783 | 2135 | 1980 | 1961 | 1883 | 1733 | 1465 |
| | | 3 ft | 787 | 853 | 890 | 1202 | 1025 | 983 | 946 | 915 | 773 |
| | 1900 | 1 ft | 53 | 71 | 56 | 53 | 12 | 4 | 1 | 1 | 1 |
| | | 3 ft | 28 | 28 | 32 | 32 | 7 | 2 | 1 | 0.5 | 0 |
| | 2010 | 1 ft | 48 | 61 | 52 | 52 | 9 | 4 | 1 | 1 | 1 |
| | | 3 ft | 28 | 35 | 32 | 34 | 8 | 2 | 1 | 0 | 0 |
| | 2206 | 1 ft | 50 | 63 | 60 | 51 | 11 | 4 | 1 | 1 | 0 |
| | | 3 ft | 25 | 30 | 30 | 33 | 9 | 2 | 1 | 1 | 0 |

Table 4-8. cont.

Forebay Lights on: Near: 1838 Far: 1844

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-05 | 1602 | 1 ft | 11590 | 9678 | 8451 | 10310 | 9806 | 10270 | 10850 | 10930 | 7482 |
| | | 3 ft | 5067 | 4400 | 4157 | 5682 | 5459 | 5787 | 6249 | 6152 | 4286 |
| | 1700 | 1 ft | 5296 | 5512 | 4638 | 6482 | 6270 | 6298 | 6328 | 5960 | 3608 |
| | | 3 ft | 4417 | 2595 | 1929 | 3845 | 3714 | 3412 | 3591 | 3465 | 2123 |
| | 1807 | 1 ft | 699 | 750 | 637 | 768 | 722 | 713 | 648 | 610 | 417 |
| | | 3 ft | 262 | 314 | 326 | 434 | 412 | 371 | 363 | 307 | 226 |
| | 1908 | 1 ft | 47 | 63 | 63 | 51 | 17 | 10 | 80 | 30 | 66 |
| | | 3 ft | 20 | 26 | 27 | 30 | 10 | 3 | 4 | 12 | 35 |
| | 2000 | 1 ft | 48 | 62 | 56 | 50 | 14 | 6 | 8 | 34 | 73 |
| | | 3 ft | 20 | 15 | 23 | 32 | 8 | 3 | 4 | 17 | 39 |
| | 2105 | 1 ft | 46 | 56 | 57 | 51 | 18 | 5 | 6 | 20 | 69 |
| | | 3 ft | 23 | 27 | 26 | 31 | 8 | 4 | 3 | 15 | 37 |

Forebay Lights on: Near: 1842 Far: off

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-06 | 1600 | 1 ft | 4093 | 3764 | 3351 | 5459 | 5232 | 5056 | 4928 | 4791 | 3270 |
| | | 3 ft | 2143 | 1756 | 1628 | 2818 | 2575 | 2448 | 2246 | 2433 | 1533 |
| | 1700 | 1 ft | 2802 | 2754 | 2704 | 3862 | 3776 | 3608 | 3613 | 3402 | 3520 |
| | | 3 ft | 1008 | 1039 | 874 | 1960 | 1820 | 1710 | 1780 | 1696 | 1213 |
| | 1810 | 1 ft | 861 | 788 | 745 | 833 | 792 | 708 | 673 | 618 | 468 |
| | | 3 ft | 387 | 395 | 325 | 418 | 375 | 389 | 343 | 315 | 270 |
| | 2115 * | 1 ft | 5 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 3 ft | 4 | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2124 | 1 ft | 52 | 71 | 60 | 66 | 11 | 3 | 2 | 0.5 | 0.3 |
| | | 3 ft | 25 | 34 | 34 | 30 | 7 | 0.8 | 1 | 0 | 0 |

* - Near forebay light off

Table 4-8. cont.

Forebay Lights on: Near: 1841 Far: off

| Date | Time | Depth | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-07 | 1600 | 1 ft | 5607 | 5367 | 5414 | 6350 | 6651 | 6254 | 6190 | 6374 | 3854 |
| | | 3 ft | 3307 | 2192 | 2347 | 2827 | 3075 | 2314 | 2738 | 2473 | 1955 |
| | 1709 | 1 ft | 3210 | 2925 | 2948 | 3977 | 3954 | 3857 | 3826 | 3890 | 3699 |
| | | 3 ft | 1323 | 1306 | 1318 | 2000 | 1866 | 1852 | 2049 | 1844 | 1887 |
| | 1806 | 1 ft | 1028 | 896 | 905 | 1039 | 1040 | 940 | 941 | 888 | 647 |
| | | 3 ft | 438 | 361 | 313 | 503 | 503 | 447 | 445 | 436 | 387 |
| | 2000 | 1 ft | 42 | 55 | 54 | 47 | 11 | 4 | 1 | 1 | 0.5 |
| | | 3 ft | 21 | 21 | 17 | 26 | 8 | 2 | 0.5 | 0.3 | 0.3 |
| | 2108 | 1 ft | 45 | 62 | 45 | 45 | 13 | 7 | 2 | 0.5 | 0.5 |
| | | 3 ft | 21 | 24 | 22 | 28 | 8 | 1 | 0.5 | 0.3 | 0.3 |

Forebay Lights on: Near: 1839 Far: off

| Date | Time | Depth | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-08 | 1600 | 1 ft | 8602 | 11017 | 11062 | 11334 | 11222 | 7005 | 11050 | 11127 | 11112 |
| | | 3 ft | 4898 | 5016 | 5055 | 7019 | 6559 | 5114 | 5024 | 5648 | 5808 |
| | 1710 | 1 ft | 5194 | 5026 | 4917 | 6477 | 5854 | 4458 | 5261 | 5654 | 5704 |
| | | 3 ft | 2325 | 2078 | 2033 | 3285 | 2796 | 2746 | 2719 | 2908 | 3022 |
| | 1806 | 1 ft | 850 | 780 | 844 | 877 | 790 | 590 | 624 | 680 | 680 |
| | | 3 ft | 370 | 368 | 310 | 440 | 350 | 290 | 310 | 333 | 331 |
| | 1908 * | 1 ft | 7 | 5 | 4 | 3 | 0 | 0 | 0 | 0 | 0.2 |
| | | 3 ft | 4 | 4 | 4 | 0.1 | 0 | 0 | 0 | 0 | 0 |

* - Near forebay light off

Table 4-8. cont.

Forebay Lights on: Near: 1826 Far: off

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-09 | 1601 | 1 ft | 13000 | 11100 | 10560 | 12130 | 11060 | 6868 | 8548 | 9411 | 8156 |
| | | 3 ft | 5157 | 5046 | 4906 | 6605 | 6325 | 3958 | 4742 | 5604 | 6008 |
| | 1700 | 1 ft | 3779 | 3843 | 3693 | 4786 | 4457 | 3282 | 3815 | 3941 | 3798 |
| | | 3 ft | 1638 | 1790 | 1979 | 2827 | 2657 | 1914 | 2163 | 2188 | 1665 |
| | 1808 | 1 ft | 170 | 123 | 111 | 102 | 96 | 79 | 101 | 110 | 118 |
| | | 3 ft | 75 | 62 | 52 | 57 | 53 | 48 | 60 | 64 | 59 |
| | 1912 | 1 ft | 49 | 52 | 43 | 40 | 11 | 4 | 0.2 | 1 | 0.5 |
| | | 3 ft | 25 | 26 | 26 | 30 | 7 | 3 | 0 | 0.8 | 0.3 |
| | 2010 | 1 ft | 42 | 61 | 47 | 46 | 13 | 4 | 1 | 0.5 | 0.5 |
| | | 3 ft | 19 | 20 | 23 | 24 | 7 | 2 | 0.8 | 0 | 0 |
| | 2109 | 1 ft | 44 | 59 | 53 | 46 | 13 | 3 | 1 | 0.8 | 0.3 |
| | | 3 ft | 22 | 18 | 21 | 29 | 7 | 2 | 0.8 | 0.2 | 0.1 |

Forebay Lights on: Near: 1837 Far: 1842

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-10 | 1607 | 1 ft | 4000 | 3617 | 3036 | 4598 | 4200 | 3268 | 3290 | 3801 | 1065 |
| | | 3 ft | 1525 | 1415 | 1403 | 1926 | 1960 | 1054 | 1592 | 1678 | 1497 |
| | 1709 | 1 ft | 2676 | 2520 | 2453 | 3148 | 2990 | 2350 | 2880 | 3014 | 3036 |
| | | 3 ft | 973 | 871 | 917 | 1588 | 1377 | 1139 | 1460 | 1568 | 1503 |
| | 1810 | 1 ft | 572 | 452 | 405 | 476 | 462 | 401 | 404 | 406 | 397 |
| | | 3 ft | 221 | 170 | 154 | 221 | 220 | 207 | 191 | 190 | 179 |
| | 1900 | 1 ft | 47 | 63 | 55 | 55 | 14 | 5 | 7 | 27 | 75 |
| | | 3 ft | 20 | 20 | 31 | 31 | 8 | 2 | 3 | 14 | 41 |
| | 2000 | 1 ft | 45 | 41 | 42 | 52 | 13 | 5 | 7 | 25 | 70 |
| | | 3 ft | 18 | 15 | 18 | 29 | 6 | 2 | 3 | 13 | 36 |
| | 2104 | 1 ft | 46 | 46 | 39 | 51 | 12 | 6 | 7 | 23 | 70 |
| | | 3 ft | 21 | 18 | 20 | 30 | 7 | 3 | 4 | 14 | 40 |

Table 4-8. cont.

Forebay Lights on: Near: 1818 Far: off

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-19 | 1604 | 1 ft | 2696 | 2454 | 2528 | 4085 | 4214 | 4080 | 3868 | 3842 | 2414 |
| | | 3 ft | 1106 | 1033 | 891 | 1803 | 1842 | 2227 | 2155 | 1610 | 1322 |
| | 1702 | 1 ft | 1565 | 1404 | 1201 | 1920 | 1834 | 1601 | 1539 | 1599 | 1283 |
| | | 3 ft | 475 | 490 | 401 | 725 | 666 | 657 | 698 | 661 | 505 |
| | 1803 | 1 ft | 196 | 169 | 142 | 160 | 122 | 102 | 99 | 90 | 64 |
| | | 3 ft | 74 | 66 | 52 | 68 | 56 | 51 | 40 | 37 | 27 |
| | 1941 | 1 ft | 46 | 61 | 51 | 47 | 8 | 2 | 0.5 | 0 | 0.3 |
| | | 3 ft | 21 | 25 | 28 | 24 | 3 | 1 | 0.3 | 0 | 0 |
| | 2106 | 1 ft | 48 | 64 | 54 | 45 | 10 | 2 | 1 | 0.3 | 0.3 |
| | | 3 ft | 21 | 25 | 27 | 23 | 4 | 1 | 0.5 | 0 | 0 |

Forebay Lights on: Near: 1758 Far: 1808

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-20 | 1600 | 1 ft | 1584 | 1461 | 1322 | 1850 | 1770 | 1729 | 1759 | 1744 | 1434 |
| | | 3 ft | 718 | 624 | 530 | 823 | 729 | 791 | 866 | 816 | 693 |
| | 1706 | 1 ft | 735 | 574 | 576 | 632 | 699 | 751 | 762 | 692 | 540 |
| | | 3 ft | 270 | 235 | 215 | 371 | 351 | 335 | 338 | 312 | 255 |
| | 1810 | 1 ft | 52 | 52 | 46 | 49 | 15 | 9 | 9 | 19 | 65 |
| | | 3 ft | 11 | 11 | 15 | 22 | 6 | 3 | 4 | 16 | 28 |
| | 1910 | 1 ft | 42 | 48 | 38 | 45 | 12 | 7 | 6 | 16 | 64 |
| | | 3 ft | 15 | 11 | 12 | 22 | 6 | 2 | 3 | 10 | 24 |
| | 2000 | 1 ft | 54 | 40 | 34 | 39 | 11 | 6 | 6 | 19 | 65 |
| | | 3 ft | 18 | 9 | 13 | 20 | 5 | 2 | 3 | 11 | 25 |
| | 2100 | 1 ft | 41 | 48 | 39 | 45 | 12 | 5 | 6 | 17 | 57 |
| | | 3 ft | 20 | 9 | 17 | 23 | 6 | 3 | 3 | 11 | 27 |

Table 4-8. cont.

Forebay Lights on: Near: 1755 Far: off

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-21 | 1600 | 1 ft | 1226 | 1207 | 1215 | 1470 | 1445 | 1203 | 1452 | 1508 | 1622 |
| | | 3 ft | 558 | 571 | 550 | 742 | 724 | 615 | 708 | 760 | 833 |
| | 1712 | 1 ft | 864 | 712 | 726 | 614 | 532 | 384 | 413 | 444 | 427 |
| | | 3 ft | 330 | 320 | 256 | 295 | 248 | 191 | 203 | 202 | 205 |
| | 2125 | 1 ft | 85 | 95 | 73 | 78 | 43 | 34 | 27 | 28 | 26 |
| | | 3 ft | 53 | 51 | 48 | 54 | 36 | 30 | 25 | 26 | 25 |
| | 2143 * | 1 ft | 63 | 59 | 54 | 41 | 35 | 33 | 41 | 46 | 38 |
| | | 3 ft | 58 | 53 | 47 | 37 | 33 | 31 | 41 | 41 | 35 |

Forebay Lights on: Near: 1801 Far: 1808

| Date | Time | | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-26 | 1550 | 1 ft | 7984 | 9418 | 8966 | 9864 | 10210 | 9935 | 9884 | 9758 | 8558 |
| | | 3 ft | 3644 | 3477 | 3787 | 5143 | 4952 | 4848 | 5090 | 4962 | 4560 |
| | 1708 | 1 ft | 2623 | 2445 | 2224 | 2642 | 2667 | 2464 | 2302 | 2383 | 2047 |
| | | 3 ft | 1030 | 1040 | 852 | 1275 | 1170 | 1143 | 1167 | 1121 | 1032 |
| | 1803 | 1 ft | 55 | 61 | 72 | 65 | 27 | 15 | 13 | 26 | 87 |
| | | 3 ft | 26 | 33 | 25 | 35 | 13 | 8 | 7 | 19 | 47 |
| | 1904 | 1 ft | 42 | 59 | 47 | 46 | 13 | 6 | 6 | 26 | 69 |
| | | 3 ft | 20 | 24 | 24 | 26 | 8 | 3 | 4 | 15 | 46 |
| | 2005 | 1 ft | 44 | 61 | 45 | 47 | 13 | 5 | 7 | 25 | 68 |
| | | 3 ft | 18 | 22 | 14 | 26 | 6 | 2 | 4 | 12 | 40 |
| | 2107 | 1 ft | 51 | 74 | 40 | 50 | 11 | 4 | 5 | 25 | 66 |
| | | 3 ft | 20 | 23 | 26 | 26 | 6 | 2 | 3 | 13 | 38 |

Table 4-8. cont.

Forebay Lights on: Near: 1801 Far: off

| Date | Time | Depth | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-27 | 1602 | 1 ft | 3976 | 3050 | 3117 | 4375 | 4518 | 4757 | 4728 | 4769 | 4275 |
| | | 3 ft | 1651 | 1342 | 1304 | 2176 | 2216 | 2561 | 2425 | 2367 | 2319 |
| | 1705 | 1 ft | 1208 | 1098 | 935 | 1358 | 1285 | 1272 | 1225 | 1181 | 1046 |
| | | 3 ft | 541 | 476 | 405 | 683 | 668 | 631 | 611 | 566 | 506 |
| | 1811 | 1 ft | 44 | 33 | 35 | 49 | 15 | 6 | 3 | 2 | 1 |
| | | 3 ft | 20 | 20 | 17 | 25 | 6 | 3 | 1 | 0.5 | 0.5 |
| | 1905 | 1 ft | 46 | 51 | 35 | 44 | 11 | 4 | 2 | 0.8 | 0.5 |
| | | 3 ft | 17 | 19 | 16 | 25 | 6 | 1 | 0.5 | 0 | 0 |
| | 2000 | 1 ft | 45 | 21 | 36 | 44 | 10 | 4 | 1 | 0.5 | 0.3 |
| | | 3 ft | 21 | 18 | 19 | 26 | 7 | 2 | 0.5 | 0.3 | 0 |
| | 2107 | 1 ft | 48 | 30 | 37 | 45 | 12 | 4 | 1 | 0.5 | 0.3 |
| | | 3 ft | 22 | 24 | 16 | 23 | 6 | 1 | 0.3 | 0.3 | 0 |

Forebay Lights on: Near: 1805 Far: off

| Date | Time | Depth | Location 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-28 | 1600 | 1 ft | 4966 | 4763 | 4013 | 5782 | 5876 | 5718 | 5454 | 5756 | 5335 |
| | | 3 ft | 1904 | 1820 | 1754 | 2805 | 2902 | 2874 | 2885 | 2807 | 2729 |
| | 1705 | 1 ft | 2869 | 2618 | 2246 | 2481 | 2411 | 2525 | 2347 | 2260 | 1944 |
| | | 3 ft | 1247 | 1203 | 772 | 1238 | 1146 | 1164 | 1118 | 1062 | 869 |
| | 1805 | 1 ft | 39 | 47 | 54 | 56 | 22 | 16 | 10 | 8 | 6 |
| | | 3 ft | 18 | 24 | 18 | 29 | 11 | 5 | 4 | 3 | 3 |
| | 2008 | 1 ft | 43 | 56 | 37 | 49 | 13 | 3 | 2 | 0.8 | 0 |
| | | 3 ft | 19 | 20 | 16 | 25 | 6 | 2 | 0.5 | 0.3 | 0 |

## Table 4-9. Light intensity (lux) vs. depth at the log sluice gate, Cabot Station, fall 1993.

| Date | Time | 1 ft | | 2 ft | | 3 ft | | 4 ft | | 5 ft | | 6 ft | | 7 ft | | 8 ft | | 9 ft | | 10 ft | Average coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sep-22 | 1645 | 390 | | 292 | | 250 | | 203 | | 162 | | 130 | | 104 | | 85 | | 67 | | 56 | 0.193 |
| coefficient | | | 0.251 | | 0.144 | | 0.188 | | 0.202 | | 0.198 | | 0.200 | | 0.183 | | 0.212 | | 0.164 | | |
| Sep-23 | 1545 | 410 | | 340 | | 280 | | 210 | | 170 | | 150 | | 100 | | 90 | | 70 | | 60 | 0.189 |
| coefficient | | | 0.171 | | 0.176 | | 0.250 | | 0.190 | | 0.118 | | 0.333 | | 0.100 | | 0.222 | | 0.143 | | |
| Sep-24 | 1549 | 43 | | 36 | | 28 | | 23 | | 18 | | 13 | | 11 | | 8 | | 7 | | 5 | 0.211 |
| coefficient | | | 0.163 | | 0.222 | | 0.179 | | 0.217 | | 0.278 | | 0.154 | | 0.273 | | 0.125 | | 0.286 | | |
| Sep-27 | 1555 | 420 | | 320 | | 210 | | 150 | | 110 | | 95 | | 80 | | 70 | | 60 | | 50 | 0.207 |
| coefficient | | | 0.238 | | 0.344 | | 0.286 | | 0.267 | | 0.136 | | 0.158 | | 0.125 | | 0.143 | | 0.167 | | |
| Sep-28 | 1543 | 53 | | 41 | | 37 | | 27 | | 22 | | 18 | | 13 | | 10 | | 8 | | 6 | 0.213 |
| coefficient | | | 0.226 | | 0.098 | | 0.270 | | 0.185 | | 0.182 | | 0.278 | | 0.231 | | 0.200 | | 0.250 | | |
| Sep-29 | 1530 | 625 | | 500 | | 375 | | 300 | | 210 | | 170 | | 135 | | 110 | | 90 | | 70 | 0.215 |
| coefficient | | | 0.200 | | 0.250 | | 0.200 | | 0.300 | | 0.190 | | 0.206 | | 0.185 | | 0.182 | | 0.222 | | |
| Oct-05 | 1541 | 1300 | | 800 | | 650 | | 500 | | 400 | | 300 | | 200 | | 200 | | 150 | | 100 | 0.241 |
| coefficient | | | 0.385 | | 0.188 | | 0.231 | | 0.200 | | 0.250 | | 0.333 | | 0.000 | | 0.250 | | 0.333 | | |
| Oct-06 | 1540 | 49 | | 31 | | 21 | | 11 | | 11 | | 9 | | 7 | | 6 | | 4 | | 3 | 0.255 |
| coefficient | | | 0.367 | | 0.323 | | 0.476 | | 0.000 | | 0.182 | | 0.222 | | 0.143 | | 0.333 | | 0.250 | | |
| Oct-07 | 1548 | 600 | | 420 | | 335 | | 230 | | 165 | | 120 | | 92 | | 75 | | 55 | | 40 | 0.259 |
| coefficient | | | 0.300 | | 0.202 | | 0.313 | | 0.283 | | 0.273 | | 0.233 | | 0.185 | | 0.267 | | 0.273 | | |
| Oct-08 | 1555 | 980 | | 740 | | 620 | | 470 | | 298 | | 205 | | 145 | | 120 | | 100 | | 78 | 0.242 |
| coefficient | | | 0.245 | | 0.162 | | 0.242 | | 0.366 | | 0.312 | | 0.293 | | 0.172 | | 0.167 | | 0.220 | | |
| Oct-09 | 1543 | 120 | | 90 | | 80 | | 60 | | 50 | | 40 | | 30 | | 25 | | 20 | | 15 | 0.205 |
| coefficient | | | 0.250 | | 0.111 | | 0.250 | | 0.167 | | 0.200 | | 0.250 | | 0.167 | | 0.200 | | 0.250 | | |
| Oct-10 | 1550 | 410 | | 280 | | 210 | | 150 | | 110 | | 80 | | 60 | | 40 | | 35 | | 25 | 0.265 |
| coefficient | | | 0.317 | | 0.250 | | 0.286 | | 0.267 | | 0.273 | | 0.250 | | 0.333 | | 0.125 | | 0.286 | | |
| Oct-19 | 1537 | 555 | | 300 | | 255 | | 182 | | 130 | | 95 | | 65 | | 45 | | 35 | | 25 | 0.287 |
| coefficient | | | 0.459 | | 0.150 | | 0.286 | | 0.286 | | 0.269 | | 0.316 | | 0.308 | | 0.222 | | 0.286 | | |
| Oct-20 | 1550 | 205 | | 150 | | 115 | | 85 | | 60 | | 48 | | 35 | | 25 | | 20 | | 15 | 0.251 |
| coefficient | | | 0.268 | | 0.233 | | 0.261 | | 0.294 | | 0.200 | | 0.271 | | 0.286 | | 0.200 | | 0.250 | | |
| Oct-21 | 1550 | 275 | | 190 | | 140 | | 95 | | 70 | | 55 | | 35 | | 25 | | 15 | | 10 | 0.306 |
| coefficient | | | 0.309 | | 0.263 | | 0.321 | | 0.263 | | 0.214 | | 0.364 | | 0.286 | | 0.400 | | 0.333 | | |
| Oct-26 | 1540 | 1100 | | 885 | | 620 | | 450 | | 335 | | 230 | | 175 | | 125 | | 90 | | 65 | 0.269 |
| coefficient | | | 0.195 | | 0.299 | | 0.274 | | 0.256 | | 0.313 | | 0.239 | | 0.286 | | 0.280 | | 0.278 | | |
| Oct-27 | 1550 | 55 | | 40 | | 31 | | 23 | | 17 | | 11 | | 8 | | 6 | | 5 | | 4 | 0.251 |
| coefficient | | | 0.273 | | 0.225 | | 0.258 | | 0.261 | | 0.353 | | 0.273 | | 0.250 | | 0.167 | | 0.200 | | |
| Oct-28 | 1540 | 950 | | 650 | | 512 | | 375 | | 265 | | 197 | | 150 | | 110 | | 80 | | 60 | 0.264 |
| coefficient | | | 0.316 | | 0.212 | | 0.268 | | 0.293 | | 0.257 | | 0.239 | | 0.267 | | 0.273 | | 0.250 | | |
| Average coefficient | | | 0.274 | | 0.214 | | 0.269 | | 0.239 | | 0.233 | | 0.256 | | 0.210 | | 0.220 | | 0.247 | | 0.240 |

**Table 4-10. Non-alosids collected during sampling at Cabot Station, fall, 1993.**

| Common Name | Scientific Name | Number |
|---|---|---|
| American eel | *Anguilla rostrata* | 406 |
| White perch | *Morone americana* | 146 |
| Smallmouth bass | *Micropterus dolumieu* | 42 |
| Bluegill | *Lepomis macrochirus* | 21 |
| Sea lamprey | *Petromyzon marinus* | 18 |
| Rock bass | *Ambloplites rupestris* | 17 |
| Spottail shiner | *Notropis hudsonius* | 16 |
| Largemouth bass | *Micropterus salmoides* | 3 |
| Black crappie | *Pomoxis nigromaculatus* | 3 |
| Redbreast sunfish | *Lepomis auritus* | 2 |
| Yellow perch | *Perca flavescens* | 2 |
| Walleye | *Stizostedion vitreum* | 2 |
| Brown trout | *Salmo trutta* | 1 |
| Common carp | *Cyprinus carpio* | 1 |
| Pumpkinseed | *Lepomis gibbosus* | 1 |

**Table 4-11. Number and percent composition by day of American shad and blueback herring collected during sampling at Cabot Station, fall 1993.**

| Date | American shad | | Blueback herring | |
|---|---|---|---|---|
| | # | % | # | % |
| 08 Sep | 86 | 97.73 | 2 | 2.27 |
| 09 Sep | 196 | 90.32 | 21 | 9.68 |
| 10 Sep | 206 | 96.26 | 8 | 3.74 |
| 22 Sep | 178 | 98.34 | 3 | 1.66 |
| 23 Sep | 300 | 96.46 | 11 | 3.54 |
| 24 Sep | 126 | 98.44 | 2 | 1.56 |
| 27 Sep | 304 | 99.35 | 2 | 0.65 |
| 28 Sep | 4 | 100.00 | 0 | 0.00 |
| 29 Sep | 337 | 99.41 | 2 | 0.59 |
| 05 Oct | 263 | 97.05 | 8 | 2.95 |
| 06 Oct | 446 | 91.39 | 42 | 8.61 |
| 07 Oct | 527 | 93.77 | 35 | 6.23 |
| 08 Oct | 584 | 92.99 | 44 | 7.01 |
| 09 Oct | 572 | 91.81 | 51 | 8.19 |
| 10 Oct | 322 | 76.85 | 97 | 23.15 |
| 19 Oct | 608 | 97.12 | 18 | 2.88 |
| 20 Oct | 178 | 99.44 | 1 | 0.56 |
| 21 Oct | 566 | 94.18 | 35 | 5.82 |
| 26 Oct | 297 | 99.33 | 2 | 0.67 |
| 27 Oct | 534 | 85.03 | 94 | 14.97 |
| 28 Oct | 422 | 87.37 | 61 | 12.63 |
| 05 Nov | 469 | 91.42 | 44 | 8.58 |
| 12 Nov | 403 | 99.26 | 3 | 0.74 |
| **Total** | **7928** | **93.12** | **586** | **6.88** |

**Table 4-12. Length frequency distribution (5mm total length groups) of American shad and blueback herring collected during sampling at Cabot Station, fall 1993.**

| Length (mm) | American shad | Blueback herring |
|---|---|---|
| 51 - 55 | 0 | 1 |
| 56 - 60 | 3 | 3 |
| 61 - 65 | 33 | 26 |
| 66 - 70 | 343 | 57 |
| 71 - 75 | 1477 | 82 |
| 76 - 80 | 2342 | 106 |
| 81 - 85 | 1972 | 143 |
| 86 - 90 | 784 | 106 |
| 91 - 95 | 340 | 33 |
| 96 - 100 | 259 | 7 |
| 101 - 105 | 169 | 1 |
| 106 - 110 | 96 | 0 |
| 111 - 115 | 46 | 0 |
| 116 - 120 | 22 | 0 |
| 121 - 125 | 19 | 0 |
| 126 - 130 | 4 | 0 |
| 131 - 135 | 2 | 0 |
| 141 - 145 | 1 | 0 |
| **Total** | **7912** | **565** |

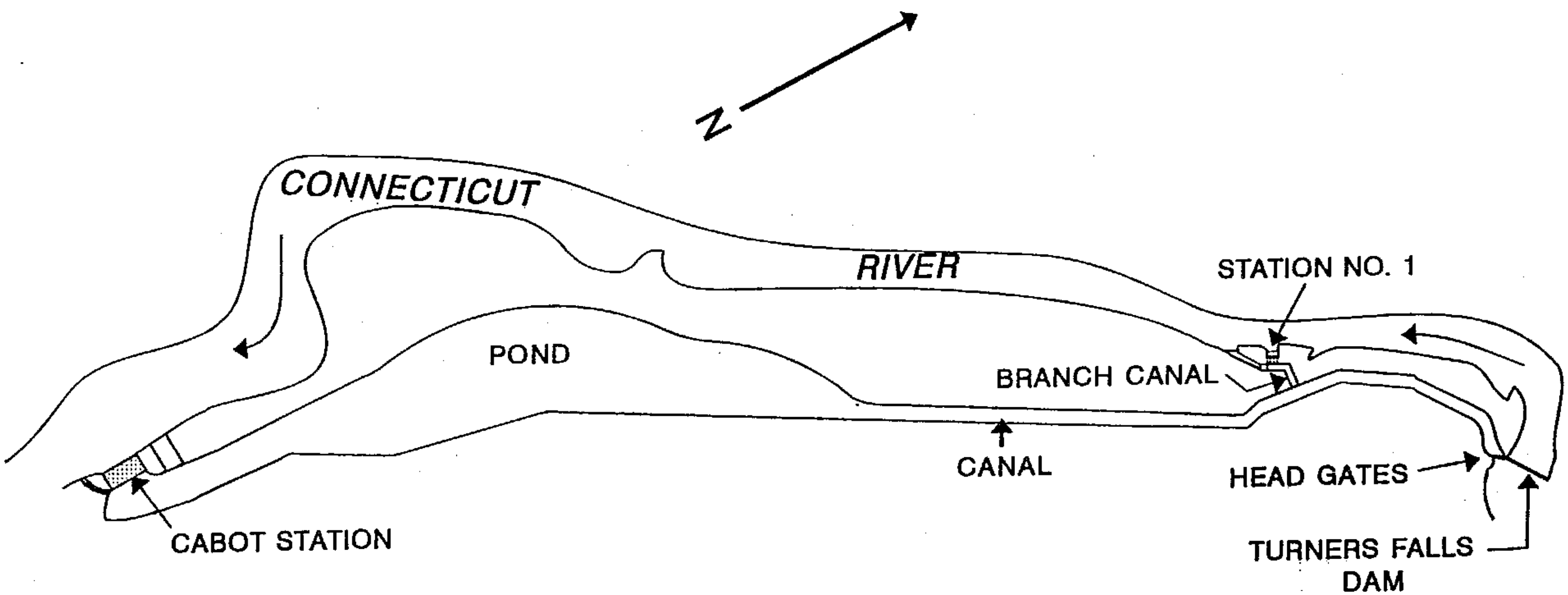



Figure 2-1. Schematic of Turner's Falls System.

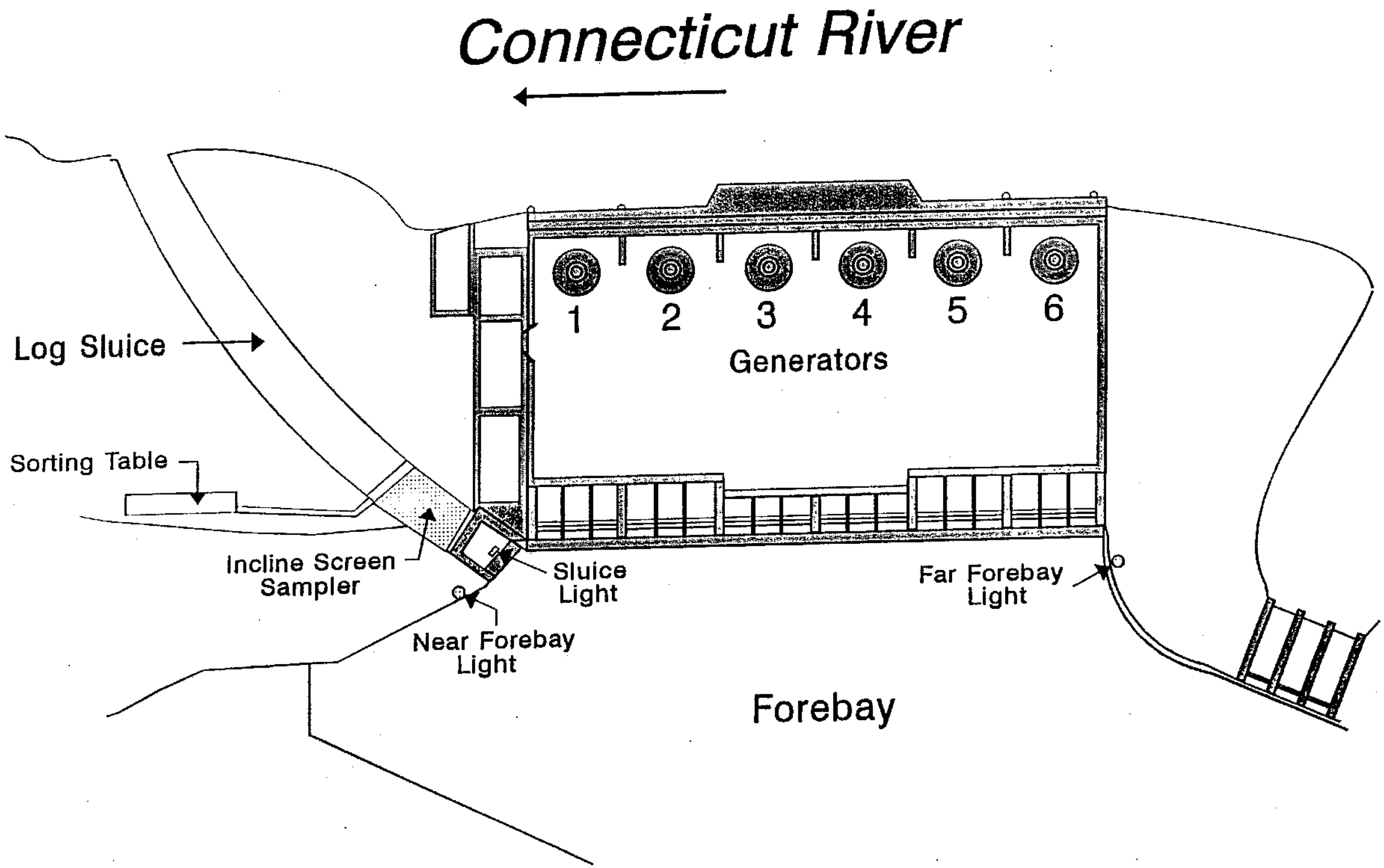



Figure 2-2. Schematic of Cabot Station.

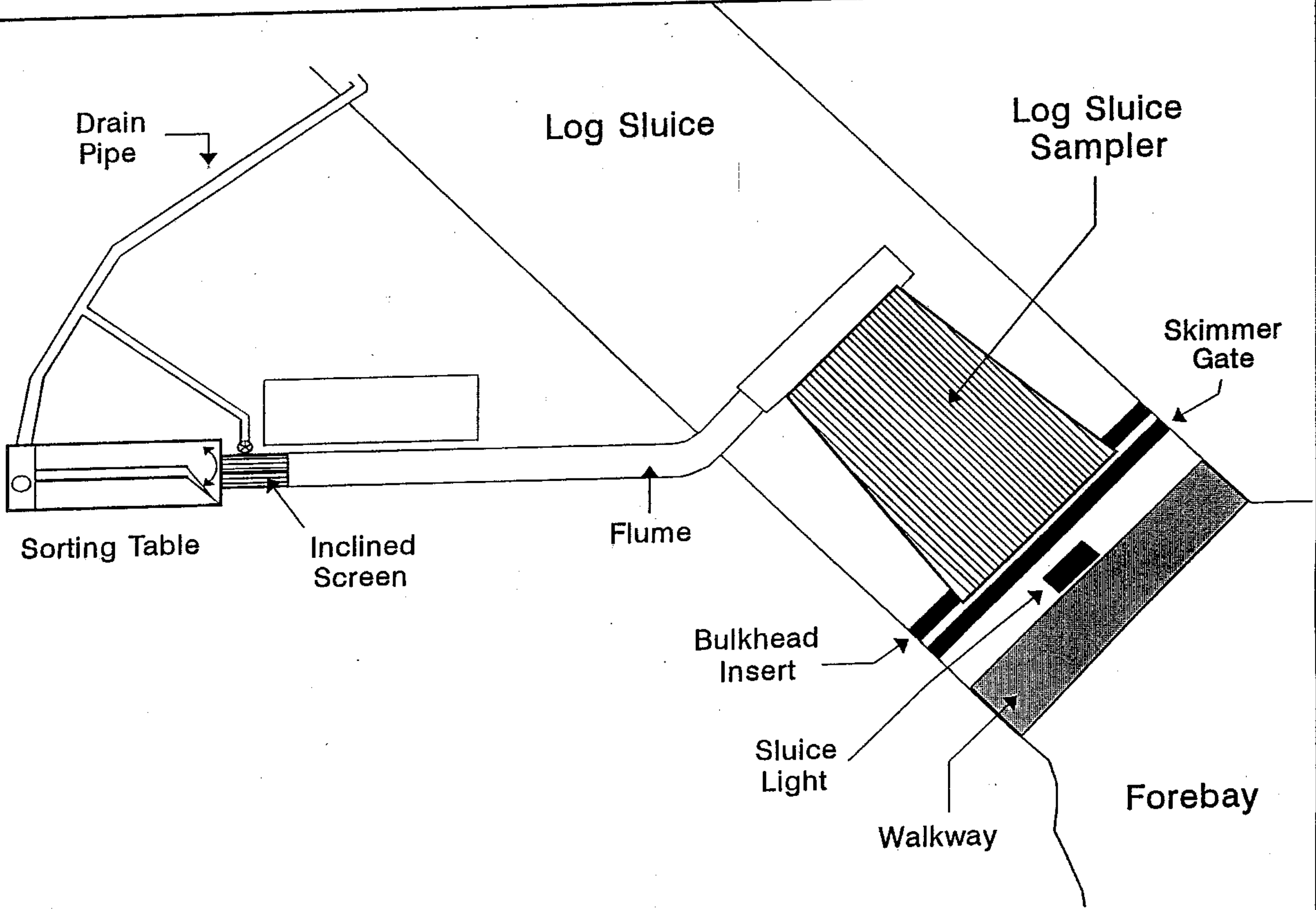



Figure 3-1. Schematic of the log sluice sampler.

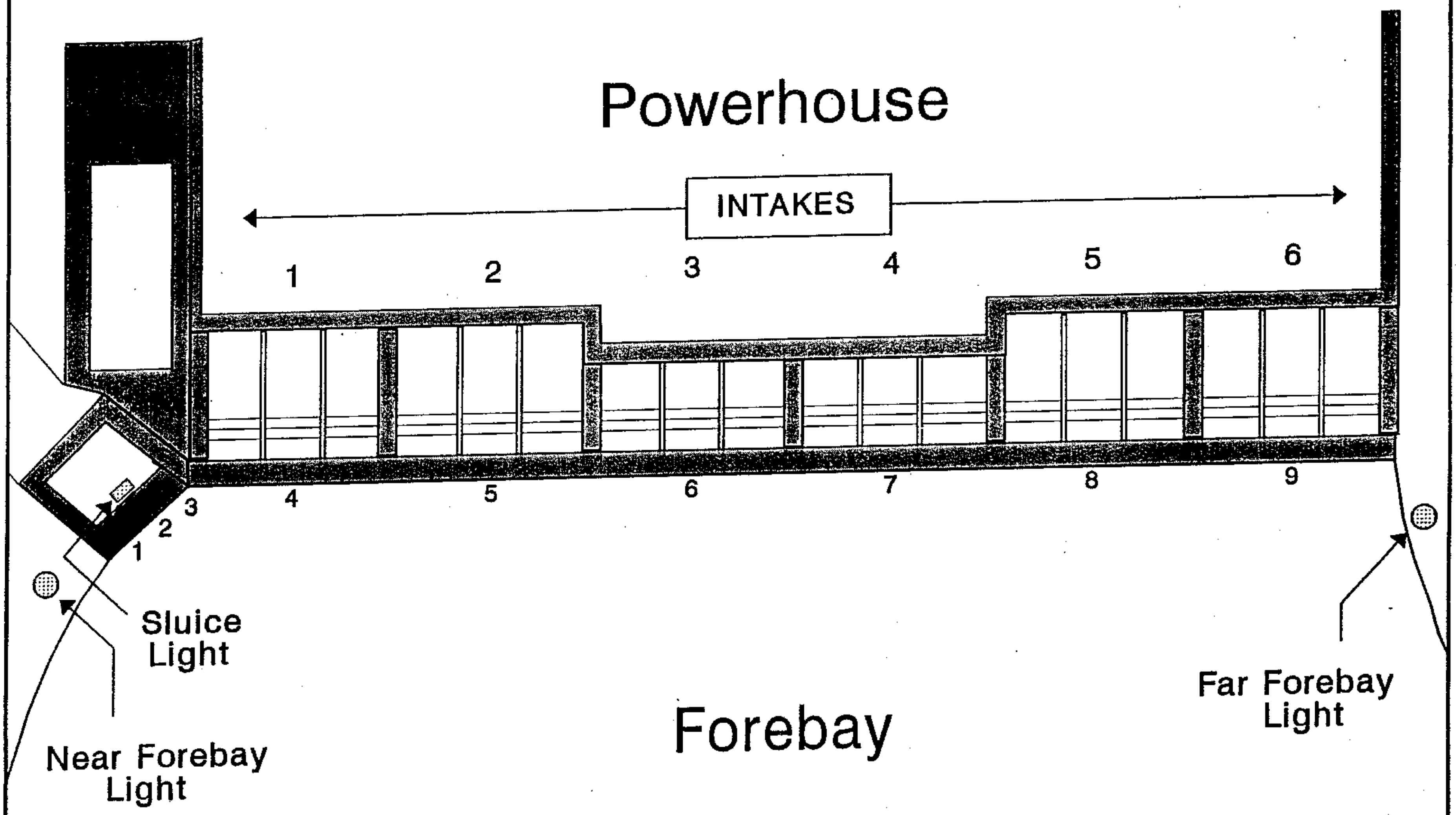



Figure 3-2. Schematic of Cabot Station forebay showing 9 light measurement stations.

FIGURE 4-1. DAILY CLUPEID CATCH WITH MEAN WATER TEMPERATURE (C) AND CANAL FLOW (cfs) AT CABOT STATION, 1993.

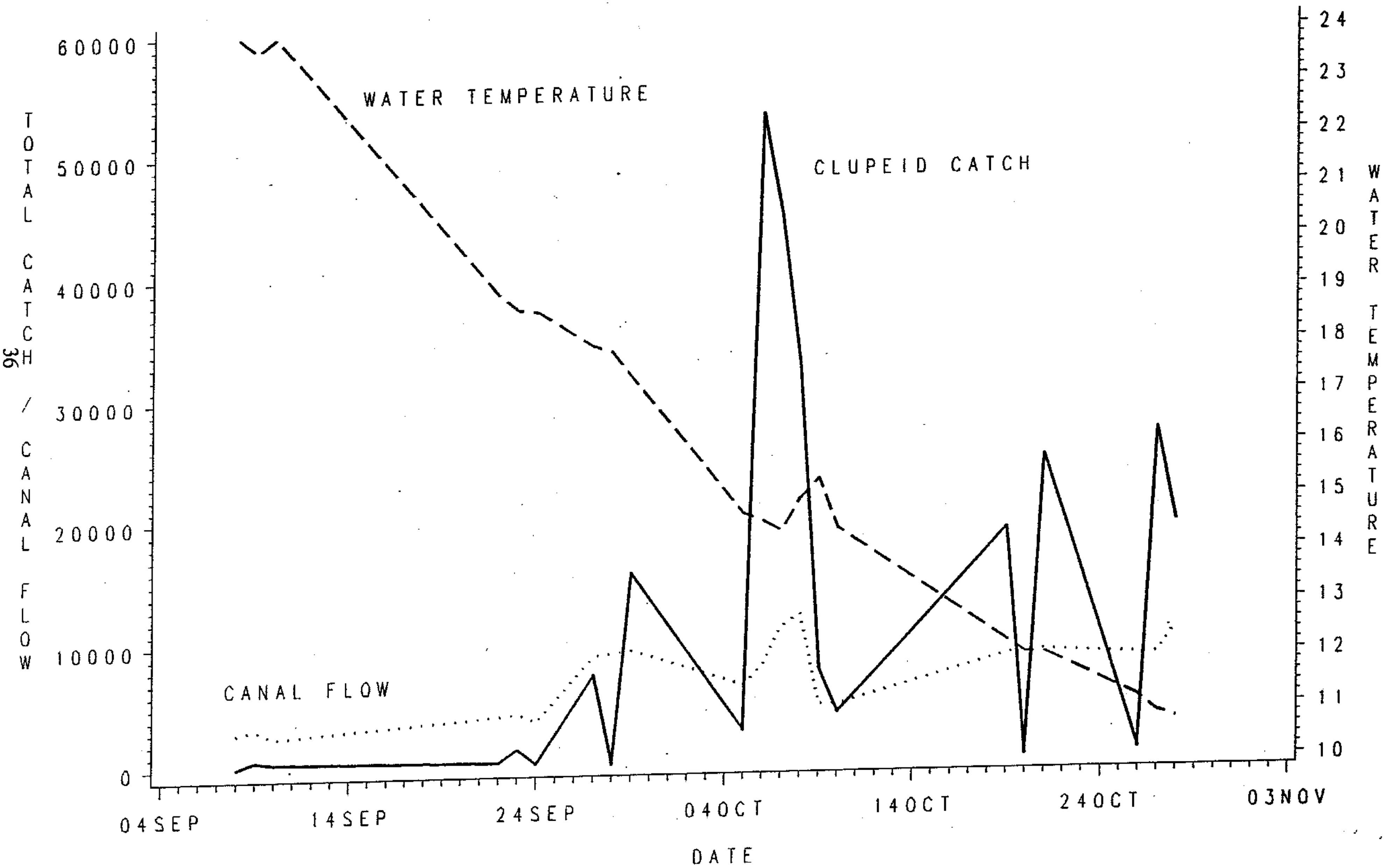
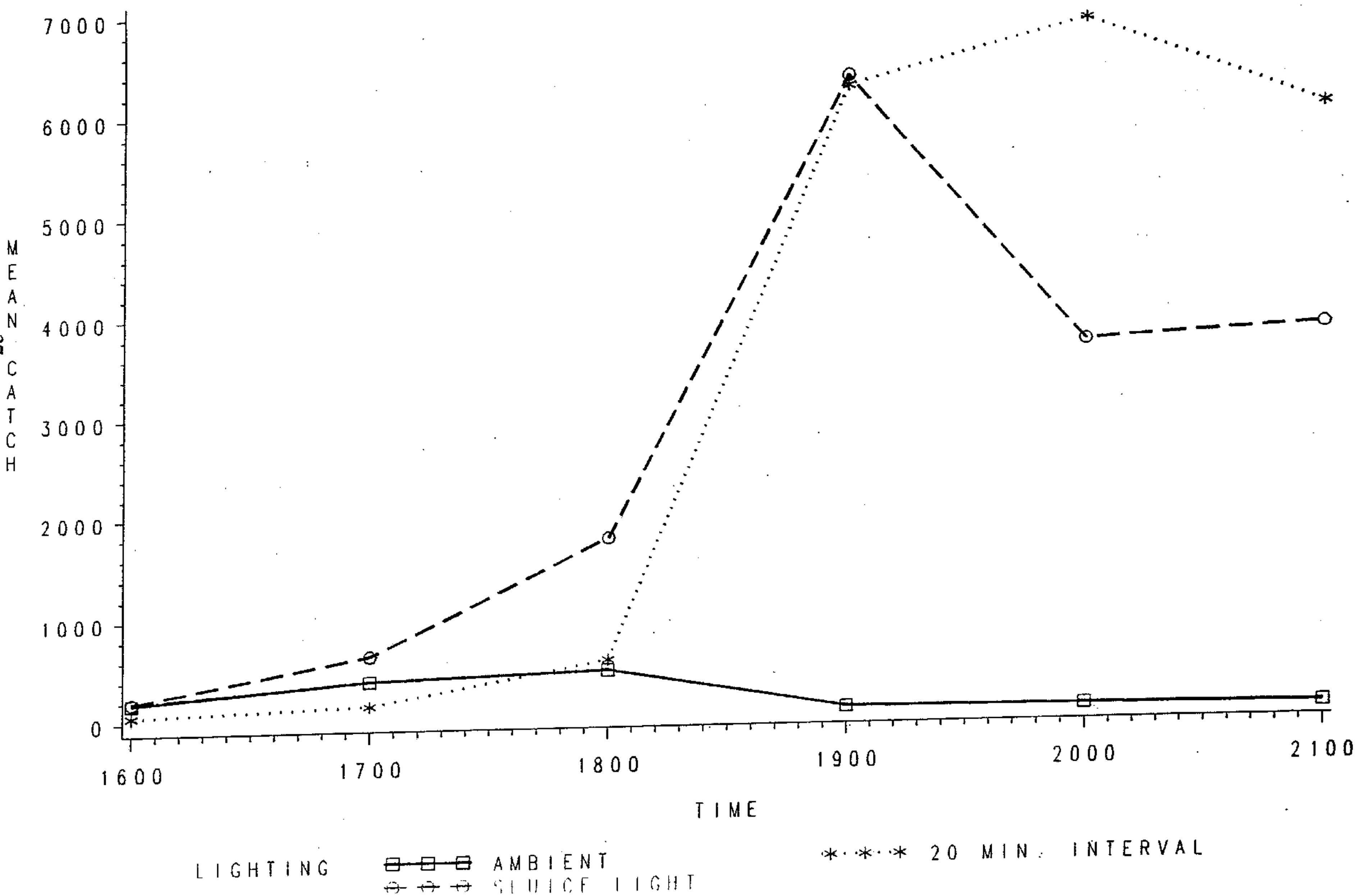


FIGURE 4-2. MEAN CLUPEID CATCH BY TIME OF DAY FOR EACH LIGHTING SCHEME USED AT CABOT STATION, 1993.



# APPENDIX I

List of Statistical Tables

Table A-1. Correlation matrix of environmental variables with catch from Cabot Bypass Canal, 1993. Only start times from 19:00 on used.

CORRELATION ANALYSIS

4 'VAR' Variables: TOTCATCH DATE AVGFLOW AVGWATER

LIGHTING=AMB

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| TOTCATCH | 7 | 81.857143 | 49.062642 | 573 | 4 | 155 |
| DATE | 7 | 12330 | 16.267116 | 86313 | 12304 | 12352 |
| AVGFLOW | 7 | 6547.238095 | 2772.765365 | 45831 | 2924.333333 | 9182.333333 |
| AVGWATER | 7 | 15.957143 | 4.477339 | 111.7 | 11 | 24 |

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 7

| | TOTCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| TOTCATCH | 1<br>0 | -0.06339<br>0.8926 | -0.70271<br>0.0783 | 0.02586<br>0.9561 |
| DATE | -0.06339<br>0.8926 | 1<br>0 | 0.6819<br>0.0915 | -0.98468<br>0.0001 |
| AVGFLOW | -0.70271<br>0.0783 | 0.6819<br>0.0915 | 1<br>0 | -0.68726<br>0.088 |
| AVGWATER | 0.02586<br>0.9561 | -0.98468<br>0.0001 | -0.68726<br>0.088 | 1<br>0 |

LIGHTING=INT

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| TOTCATCH | 7 | 19078 | 18532 | 133549 | 405 | 52436 |
| DATE | 7 | 12331 | 16.469308 | 86315 | 12306 | 12354 |
| AVGFLOW | 7 | 8038.714286 | 3624.076395 | 56271 | 2527.666667 | 12716 |
| AVGWATER | 7 | 16.02381 | 4.561746 | 112.166667 | 10.5 | 24 |

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 7

| | TOTCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| TOTCATCH | 1<br>0 | 0.48911<br>0.2653 | 0.58175<br>0.1706 | -0.59836<br>0.1558 |
| DATE | 0.48911<br>0.2653 | 1<br>0 | 0.77521<br>0.0406 | -0.97895<br>0.0001 |
| AVGFLOW | 0.58175<br>0.1706 | 0.77521<br>0.0406 | 1<br>0 | -0.78825<br>0.0352 |
| AVGWATER | -0.59836<br>0.1558 | -0.97895<br>0.0001 | -0.78825<br>0.0352 | 1<br>0 |

LIGHTING=SL

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| TOTCATCH | 7 | 13781 | 14939 | 96469 | 233 | 43304 |
| DATE | 7 | 12331 | 16.226081 | 86314 | 12305 | 12353 |
| AVGFLOW | 7 | 7120.047619 | 3025.991288 | 49840 | 2985.333333 | 11077 |
| AVGWATER | 7 | 15.957143 | 4.363176 | 111.7 | 10.666667 | 23.5 |

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 7

| | TOTCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| TOTCATCH | 1<br>0 | 0.43098<br>0.3344 | 0.88431<br>0.0082 | -0.52793<br>0.2232 |
| DATE | 0.43098<br>0.3344 | 1<br>0 | 0.62987<br>0.1295 | -0.98841<br>0.0001 |
| AVGFLOW | 0.88431<br>0.0082 | 0.62987<br>0.1295 | 1<br>0 | -0.71577<br>0.0705 |
| AVGWATER | -0.52793<br>0.2232 | -0.98841<br>0.0001 | -0.71577<br>0.0705 | 1<br>0 |

Table A-2. ANOVA for week and lighting as main effects for clupeid catch at Cabot Station, Fall 1993. Only start times earlier than 19:00 used.

General Linear Models Procedure
Class Level Information

| Class | Levels | Values |
|---|---|---|
| LIGHTING | 3 | 20 MIN. INTERVAL AMBIENT SLUICE LIGHT |
| WEEKOF | 7 | 1 2 3 4 5 6 7 |

Number of observations in data set = 21

General Linear Models Procedure

Dependent Variable: TOTCATCH

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 8 | 57199483.43 | 7149935.429 | 1.91 | 0.1503 |
| Error | 12 | 44886283.14 | 3740523.595 | | |
| Corrected Total | 20 | 102085766.6 | | | |

| R-Square | C.V. | Root MSE | TOTCATCH Mean |
|---|---|---|---|
| 0.560308 | 134.6693 | 1934.043328 | 1436.142857 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHTING | 2 | 13798988.86 | 6899494.429 | 1.84 | 0.2002 |
| WEEKOF | 6 | 43400494.57 | 7233415.762 | 1.93 | 0.1559 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHTING | 2 | 13798988.86 | 6899494.429 | 1.84 | 0.2002 |
| WEEKOF | 6 | 43400494.57 | 7233415.762 | 1.93 | 0.1559 |

Duncan's Multiple Range Test for variable: TOTCATCH

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 3740524

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | 2248 | 2355 |

Means with the same letter are not significantly different.

| Duncan Groupin | Mean | N | LIGHTING |
|---|---|---|---|
| A | 2572 | 7 | SLUICE LIGHT |
| A | | | |
| A | 1002 | 7 | AMBIENT |
| A | | | |
| A | 734 | 7 | 20 MIN. INTERVAL |

Least Squares Means

| LIGHTING | TOTCATCH LSMEAN | Std Err LSMEAN | Pr > \|T\| HO:LSMEAN=0 | Pr > \|T\| H0: LSMEAN(i)=LSMEAN(j) i/j | 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| 20 MIN. INTERVA | 734 | 730.99967 | 0.3351 | 1 | . | 0.7995 | 0.1007 |
| AMBIENT | 1002.42857 | 730.99967 | 0.1954 | 2 | 0.7995 | . | 0.1548 |
| SLUICE LIGHT | 2572 | 730.99967 | 0.0042 | 3 | 0.1007 | 0.1548 | . |

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table A-3. Correlation matrix of environmental variables with log(catch + 1) from Cabot Bypass Canal, 1993. Only start times earlier than 19:00 used.

CORRELATION ANALYSIS

4 'VAR' Variables: LOGCATCH DATE AVGFLOW AVGWATER

LIGHTING=AMB

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| LOGCATCH | 7 | 1.732758 | 1.602491 | 12.129309 | 0 | 3.580925 |
| DATE | 7 | 12330 | 16.267116 | 86313 | 12304 | 12352 |
| AVGFLOW | 7 | 5900.904762 | 2674.752815 | 41306 | 2828.333333 | 8942 |
| AVGWATER | 7 | 16.280952 | 4.415036 | 113.966667 | 11.266667 | 24 |

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 7

| | LOGCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| LOGCATCH | 1<br>0 | 0.67599<br>0.0955 | -0.0078<br>0.9868 | -0.71098<br>0.0733 |
| DATE | 0.67599<br>0.0955 | 1<br>0 | 0.64817<br>0.1154 | -0.98946<br>0.0001 |
| AVGFLOW | -0.0078<br>0.9868 | 0.64817<br>0.1154 | 1<br>0 | -0.61634<br>0.1405 |
| AVGWATER | -0.71098<br>0.0733 | -0.98946<br>0.0001 | -0.61634<br>0.1405 | 1<br>0 |

LIGHTING=INT

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| LOGCATCH | 7 | 1.933958 | 1.415579 | 13.537705 | 0 | 3.426349 |
| DATE | 7 | 12331 | 16.469308 | 86315 | 12306 | 12354 |
| AVGFLOW | 7 | 7586.904762 | 3180.729463 | 53108 | 2442.666667 | 11364 |
| AVGWATER | 7 | 16.266667 | 4.467993 | 113.866667 | 10.933333 | 24 |

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 7

| | LOGCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| LOGCATCH | 1<br>0 | 0.83631<br>0.019 | 0.74443<br>0.055 | -0.86745<br>0.0114 |
| DATE | 0.83631<br>0.019 | 1<br>0 | 0.76829<br>0.0436 | -0.98571<br>0.0001 |
| AVGFLOW | 0.74443<br>0.055 | 0.76829<br>0.0436 | 1<br>0 | -0.79925<br>0.031 |
| AVGWATER | -0.86745<br>0.0114 | -0.98571<br>0.0001 | -0.79925<br>0.031 | 1<br>0 |

LIGHTING=SL

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| LOGCATCH | 7 | 2.256869 | 1.725701 | 15.798083 | 0 | 3.972388 |
| DATE | 7 | 12331 | 16.226081 | 86314 | 12305 | 12353 |
| AVGFLOW | 7 | 6853.571429 | 3090.385004 | 47975 | 3363.333333 | 10920 |
| AVGWATER | 7 | 16.32381 | 4.364915 | 114.266667 | 11 | 23.933333 |

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 7

| | LOGCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| LOGCATCH | 1<br>0 | 0.9241<br>0.0029 | 0.5002<br>0.2529 | -0.91127<br>0.0043 |
| DATE | 0.9241<br>0.0029 | 1<br>0 | 0.53121<br>0.2198 | -0.98669<br>0.0001 |
| AVGFLOW | 0.5002<br>0.2529 | 0.53121<br>0.2198 | 1<br>0 | -0.59693<br>0.1571 |
| AVGWATER | -0.91127<br>0.0043 | -0.98669<br>0.0001 | -0.59693<br>0.1571 | 1<br>0 |

Table A-4. ANOVA for week and lighting as main effects for log(clupeid catch + 1) at Cabot Station, Fall 1993. Only start times earlier than 19:00 used.

General Linear Models Procedure
Class Level Information

| Class | Levels | Values |
|---|---|---|
| LIGHTING | 3 | 20 MIN. INTERVAL AMBIENT SLUICE LIGHT |
| WEEKOF | 7 | 1 2 3 4 5 6 7 |

Number of observations in data set = 21

General Linear Models Procedure

Dependent Variable: LOGCATCH

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 8 | 43.37375681 | 5.4217196 | 22.4 | 0.0001 |
| Error | 12 | 2.9042653 | 0.24202211 | | |
| Corrected Total | 20 | 46.27802211 | | | |

| R-Square | C.V. | Root MSE | LOGCATCH Mean |
|---|---|---|---|
| 0.937243 | 24.91519 | 0.49195743 | 1.97452645 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHTING | 2 | 0.97870437 | 0.48935219 | 2.02 | 0.1751 |
| WEEKOF | 6 | 42.39505243 | 7.06584207 | 29.2 | 0.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHTING | 2 | 0.97870437 | 0.48935219 | 2.02 | 0.1751 |
| WEEKOF | 6 | 42.39505243 | 7.06584207 | 29.2 | 0.0001 |

General Linear Models Procedure

Duncan's Multiple Range Test for variable: LOGCATCH

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.242022

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | 0.572 | 0.599 |

Means with the same letter are not significantly different.

| Duncan Groupin | Mean | N | LIGHTING |
|---|---|---|---|
| A | 2.257 | 7 | SLUICE LIGHT |
| A | | | |
| A | 1.934 | 7 | 20 MIN. INTERVAL |
| A | | | |
| A | 1.733 | 7 | AMBIENT |

General Linear Models Procedure
Least Squares Means

| LIGHTING | LOGCATCH LSMEAN | Std Err LSMEAN | Pr > \|T\| HO:LSMEAN=0 | Pr > \|T\| HO: LSMEAN(i)=LSMEAN(j) i/j | 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| 20'MIN. INTERVA | 1.93395791 | 0.18594243 | 0.0001 | 1 | | 0.459 | 0.243 |
| AMBIENT | 1.73275843 | 0.18594243 | 0.0001 | 2 | 0.459 | | 0.0695 |
| SLUICE LIGHT | 2.25686902 | 0.18594243 | 0.0001 | 3 | 0.243 | 0.0695 | |

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table A-5. Correlation matrix of environmental variables with catch from Cabot Bypass Canal, 1993. Only start times earlier than 19:00 used.

CORRELATION ANALYSIS

4 'VAR' Variables: TOTCATCH DATE AVGFLOW AVGWATER

LIGHTING=AMB

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| TOTCATCH | 7 | 1002.428571 | 1540.39766 | 7017 | 0 | 3809 |
| DATE | 7 | 12330 | 16.267116 | 86313 | 12304 | 12352 |
| AVGFLOW | 7 | 5900.904762 | 2674.752815 | 41306 | 2828.333333 | 8942 |
| AVGWATER | 7 | 16.280952 | 4.415036 | 113.966667 | 11.266667 | 24 |

Pearson Correlation Coefficients / Prob > \|R\| under Ho: Rho=0 / N = 7

| | TOTCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| TOTCATCH | 1<br>0 | 0.24108<br>0.6025 | -0.38852<br>0.3891 | -0.2984<br>0.5157 |
| DATE | 0.24108<br>0.6025 | 1<br>0 | 0.64817<br>0.1154 | -0.98946<br>0.0001 |
| AVGFLOW | -0.38852<br>0.3891 | 0.64817<br>0.1154 | 1<br>0 | -0.61634<br>0.1405 |
| AVGWATER | -0.2984<br>0.5157 | -0.98946<br>0.0001 | -0.61634<br>0.1405 | 1<br>0 |

LIGHTING=INT

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| TOTCATCH | 7 | 734 | 949.247597 | 5138 | 0 | 2668 |
| DATE | 7 | 12331 | 16.469308 | 86315 | 12306 | 12354 |
| AVGFLOW | 7 | 7586.904762 | 3180.729463 | 53108 | 2442.666667 | 11364 |
| AVGWATER | 7 | 16.266667 | 4.467993 | 113.866667 | 10.933333 | 24 |

Pearson Correlation Coefficients / Prob > \|R\| under Ho: Rho=0 / N = 7

| | TOTCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| TOTCATCH | 1<br>0 | 0.47272<br>0.2841 | 0.71606<br>0.0703 | -0.49703<br>0.2565 |
| DATE | 0.47272<br>0.2841 | 1<br>0 | 0.76829<br>0.0436 | -0.98571<br>0.0001 |
| AVGFLOW | 0.71606<br>0.0703 | 0.76829<br>0.0436 | 1<br>0 | -0.79925<br>0.031 |
| AVGWATER | -0.49703<br>0.2565 | -0.98571<br>0.0001 | -0.79925<br>0.031 | 1<br>0 |

LIGHTING=SL

Simple Statistics

| Variable | N | Mean | Std Dev | Sum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| TOTCATCH | 7 | 2572 | 3382.390723 | 18004 | 0 | 9383 |
| DATE | 7 | 12331 | 16.226081 | 86314 | 12305 | 12353 |
| AVGFLOW | 7 | 6853.571429 | 3090.385004 | 47975 | 3363.333333 | 10920 |
| AVGWATER | 7 | 16.32381 | 4.364915 | 114.266667 | 11 | 23.933333 |

Pearson Correlation Coefficients / Prob > \|R\| under Ho: Rho=0 / N = 7

| | TOTCATCH | DATE | AVGFLOW | AVGWATER |
|---|---|---|---|---|
| TOTCATCH | 1<br>0 | 0.85252<br>0.0148 | 0.26002<br>0.5734 | -0.78237<br>0.0376 |
| DATE | 0.85252<br>0.0148 | 1<br>0 | 0.53121<br>0.2198 | -0.98669<br>0.0001 |
| AVGFLOW | 0.26002<br>0.5734 | 0.53121<br>0.2198 | 1<br>0 | -0.59693<br>0.1571 |
| AVGWATER | -0.78237<br>0.0376 | -0.98669<br>0.0001 | -0.59693<br>0.1571 | 1<br>0 |

Table A-6. ANOVA for week and lighting as main effects for clupeid catch at Cabot Station, Fall 1993. Only start times earlier than 19:00 used.

General Linear Models Procedure
Class Level Information

| Class | Levels | Values |
|---|---|---|
| LIGHTING | 3 | 20 MIN. INTERVAL AMBIENT SLUICE LIGHT |
| WEEKOF | 7 | 1 2 3 4 5 6 7 |

Number of observations in data set = 21

Dependent Variable: TOTCATCH

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 8 | 57199483.43 | 7149935.429 | 1.91 | 0.1503 |
| Error | 12 | 44886283.14 | 3740523.595 | | |
| Corrected Total | 20 | 102085766.6 | | | |

| R-Square | C.V. | Root MSE | TOTCATCH Mean |
|---|---|---|---|
| 0.560308 | 134.6693 | 1934.043328 | 1436.142857 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHTING | 2 | 13798988.86 | 6899494.429 | 1.84 | 0.2002 |
| WEEKOF | 6 | 43400494.57 | 7233415.762 | 1.93 | 0.1559 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHTING | 2 | 13798988.86 | 6899494.429 | 1.84 | 0.2002 |
| WEEKOF | 6 | 43400494.57 | 7233415.762 | 1.93 | 0.1559 |

General Linear Models Procedure
Duncan's Multiple Range Test for variable: TOTCATCH

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 3740524

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | 2248 | 2355 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | LIGHTING |
|---|---|---|---|
| A | 2572 | 7 | SLUICE LIGHT |
| A | | | |
| A | 1002 | 7 | AMBIENT |
| A | | | |
| A | 734 | 7 | 20 MIN. INTERVAL |

General Linear Models Procedure
Least Squares Means

| LIGHTING | TOTCATCH LSMEAN | Std Err LSMEAN | Pr > \|T\| H0:LSMEAN=0 | Pr > \|T\| H0: LSMEAN(i)=LSMEAN(j) i/j | 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| 20 MIN. INTERVA | 734 | 730.99967 | 0.3351 | 1 | . | 0.7995 | 0.1007 |
| AMBIENT | 1002.42857 | 730.99967 | 0.1954 | 2 | 0.7995 | . | 0.1548 |
| SLUICE LIGHT | 2572 | 730.99967 | 0.0042 | 3 | 0.1007 | 0.1548 | . |

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table A-7. Analysis of variance for log(clupeid catch + 1) at Cabot Station, Fall 1993. Catch during intermittent lighting used.

General Linear Models Procedure
Class Level Information

| Class | Levels | Values |
|---|---|---|
| LIGHT | 2 | OFF ON |

Number of observations in data set = 69

Dependent Variable: LOGCATCH

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 1 | 0.0447816 | 0.0447816 | 0.05 | 0.8182 |
| Error | 67 | 56.33092791 | 0.84076012 | | |
| Corrected Total | 68 | 56.3757095 | | | |

| R-Square | C.V. | Root MSE | LOGCATCH Mean |
|---|---|---|---|
| 0.000794 | 33.45184 | 0.91692972 | 2.74104433 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHT | 1 | 0.0447816 | 0.0447816 | 0.05 | 0.8182 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHT | 1 | 0.0447816 | 0.0447816 | 0.05 | 0.8182 |

General Linear Models Procedure
Least Squares Means

| LIGHT | LOGCATCH LSMEAN | Std Err LSMEAN | Pr > \|T\| H0:LSMEAN=0 | Pr > \|T\| H0: LSMEAN1=LSMEAN2 |
|---|---|---|---|---|
| OFF | 2.76543541 | 0.15282162 | 0.0001 | 0.8182 |
| ON | 2.71443588 | 0.15961698 | 0.0001 | |

General Linear Models Procedure

Duncan's Multiple Range Test for variable: LOGCATCH

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 67 MSE= 0.84076
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 34.43478

Number of Means 2
Critical Range 0.441

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | LIGHT |
|---|---|---|---|
| A | 2.765 | 36 | OFF |
| A | | | |
| A | 2.714 | 33 | ON |

Table A-8. Analysis of variance for clupeid catch at Cabot Station, Fall 1993. Catch during intermittent lighting used.

General Linear Models Procedure
Class Level Information

| Class | Levels | Values |
|---|---|---|
| LIGHT | 2 | OFF ON |

Number of observations in data set = 69

Dependent Variable: CATCH

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 1 | 1492295.68 | 1492295.68 | 0.23 | 0.6327 |
| Error | 67 | 433835121.1 | 6475151.062 | | |
| Corrected Total | 68 | 435327416.8 | | | |

| R-Square | C.V. | Root MSE | CATCH Mean |
|---|---|---|---|
| 0.003428 | 130.0657 | 2544.631813 | 1956.42029 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHT | 1 | 1492295.68 | 1492295.68 | 0.23 | 0.6327 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| LIGHT | 1 | 1492295.68 | 1492295.68 | 0.23 | 0.6327 |

General Linear Models Procedure
Least Squares Means

| LIGHT | CATCH LSMEAN | Std Err LSMEAN | Pr > \|T\| H0:LSMEAN=0 | Pr > \|T\| H0: LSMEAN1=LSMEAN2 |
|---|---|---|---|---|
| OFF | 2097.22222 | 424.1053 | 0.0001 | 0.6327 |
| ON | 1802.81818 | 442.96354 | 0.0001 | |

General Linear Models Procedure

Duncan's Multiple Range Test for variable: CATCH

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 67 MSE= 6475151
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 34.43478

Number of Means 2
Critical Range 1225

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | LIGHT |
|---|---|---|---|
| A | 2097.2 | 36 | OFF |
| A | | | |
| A | 1802.8 | 33 | ON |