# CORNELL UNIVERSITY LAKE SOURCE COOLING FACILITY

## PROPOSED WORK PLAN FOR
## AN ENTRAINMENT CHARACTERIZATION STUDY

**Prepared for**

**New York State Department of Environmental Conservation**
**Division of Fish, Wildlife and Marine Resources,**
**Bureau of Habitat, Steam Electric Unit**
**625 Broadway, 5th Floor**
**Albany, NY 12233**

**Prepared by**

**Cornell University**
**Energy and Sustainability, Utilities Section**
**Humphreys Service Building**
**Ithaca, NY 14850**

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# 1.0 INTRODUCTION

The Cornell Lake Source Cooling (LSC) facility is designed to withdraw up to 2 cubic meters per second (46 million gallons per day) of water from Cayuga Lake at a depth of approximately 76 m to cool campus buildings. Lake water at that depth is approximately 4 °C year round. The cold water pumped from the lake bottom is passed through heat exchangers located on shore, which absorb some of the heat in water used to cool the Cornell Campus and Ithaca High School. The system began operation in 2000.

The LSC facility operates under State Pollutant Discharge Elimination System (SPDES) permit number NY 0244741, with an Effective Date (EDP) of May 1, 2013. The *Special Conditions: Biological Monitoring Requirements* section of the permit calls for Cornell University to submit an approvable plan for an *Entrainment Characterization Study* at the LSC facility. The study plan must include a schedule for implementation, standard operating procedures for data collection, and a final report. At a minimum, the study must include:

a) Duration – April through August during 2014
b) Intensity – at least one 24 hour collection made in every seven calendar day period through the study duration
c) All samples will be analyzed for ichthyoplankton and juvenile fish
d) Concurrent samples shall also be collected in the near shore area so as to provide a baseline density of ichthyoplankton, and basis for comparison with entrainment samples.
e) The final report shall be submitted within 9 months of completion of data collection and include a summary table of the total number of fish entrained by species and life stage based upon continuous operation of all pumps at full rated flow and actual operation and cooling water volume over the study period. All data collected during the entrainment study must be provided to the department in an agreed upon electronic format.

This document presents Cornell University's entrainment characterization study plan to satisfy the aforementioned special condition of the LSC facility SPDES permit.

## 1.1 Background

### 1.1.1 Project Location and Description

The LSC facility is located at the southern end of Cayuga Lake in the City of Ithaca, Tompkins County, NY. The structure housing the heat-exchange facility is located along the east shore near the extreme south end of the lake. The facility's intake structure is located on the lake bottom approximately 3.2 km north-northwest, approximately 1.4 km from the east shore, and in approximately 76 m of water. The intake is an octagonal structure made up of 2.0 mm wedge-

wire screen panels, positioned 3 m above the lake bottom. Each screen panel is 2.4 m high by 1.2 m wide. The intake has a solid cap so that water is withdrawn from the horizontal plane only. The design intake velocity is 0.15 m/s (0.50 feet per second) with 50% of the area of the slots plugged (velocity = 0.08 m/s or 0.25 fps when clean). A 1.6-m diameter HDPE pipe extends from the structure along the lake bottom for a distance of approximately 3.2 kilometers, connecting to the on-shore heat exchange facility. Cleaning of the screen panels is done manually, but this has seldom been necessary.

Within the shore-based facility, the cold lake water circulates through heat exchangers, where it absorbs heat from water in the closed-loop pipeline extending from Cornell's central cooling system to the LSC facility. The system is designed so that Cayuga Lake water does not mix with the closed-loop campus chilled water system, as the two water loops are separated by the stainless steel plates of the heat exchangers. The chilled water then circulates back to the Cornell campus through 3.9 km of buried pipeline. The warmed lake is returned to Cayuga Lake via a 152-m outfall pipe that extends off-shore from the facility, terminating with a 23-m diffuser submerged at a depth of 2.7 m.

### 1.1.2 Source Water Body

Cayuga Lake is situated in a steep-sided, glacially carved valley in the Oswego River drainage basin of Central New York. The lake is long and narrow, extending 61.4 km north from Ithaca to the lake's outlet into the Seneca River. Maximum lake width is 6.4 km and maximum depth is 132.6 m. With a total lake volume is 9.4 billion $m^3$ and a mean depth of 54.5 m, Cayuga Lake has a large volume of deep water that remains cold year round.

Cayuga Lake supports both warm-water and cold-water fish communities. The cold-water fish community, which includes water column (pelagic) and bottom-oriented (benthic) species has lake trout (*Salvelinus namaycush*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and Atlantic salmon (*Salmo salar*) as the primary sportfish. Dominant cool-/warm-water sportfish include smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), chain pickerel (*Esox niger*), northern pike (*Esox lucius*), yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*) and various sunfish (*Lepomis* spp.). Important forage species include alewife (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax*), and white sucker (*Catostomus commersonii*). A list of fish species known from the lake is provided in Table 1.

## 1.2 Objectives

The objective of this investigation is to characterize the near-shore ichthyoplankton community of Cayuga Lake in the vicinity of the LSC facility and document current levels of ichthyoplankton entrainment at the LSC facility. The ichthyoplankton community will be

characterized with regard to species composition, density, and life stage. Similar information for entrained ichthyoplankton will be collected during concurrent sampling of the LSC facility intake water. These data will be provided to the New York State Department of Environmental Conservation (NYSDEC) in order to determine if the current location, design, construction, and capacity of the LSC facility water intake structure meet BTA standards thereby satisfying the requirements of 6 NYCRR Part 704.5

## 2.0 METHODS

### 2.1 Near-shore Ichthyoplankton Community Sampling

#### 2.1.1 Sampling Location and Frequency

Sampling of the near-shore ichthyoplankton community will occur along the east side of Cayuga Lake in the vicinity of the LSC facility. A single "station" will be sampled during each event, with a station consisting at a minimum of the distance covered during a 5-minute net tow averaging approximately 1 m/s (for a minimum distance of 300 m). An individual sampling effort will consist of one tow of a bongo-style two-net array at a depth of 2 m below the surface. The station will follow a constant depth contour to the extent possible given aquatic macrophyte growth and other obstacles. The target depth contour will be 3 m so that the 2-m depth tow will be sampling just above the lake bottom. However, as submerged macrophytes grow up through the water column during the summer, it is anticipated that station location will shift off-shore and northward to avoid clogging the nets with vegetation. This will result in an increase in water depth at the station, but the actual sampling depth will be maintained at approximately 2 m regardless of total water depth. GPS coordinates will be recorded at the beginning and end of each tow.

At least one 24-hour collection will be made weekly from the first week in April through August 2014. A 24-hour collection will be comprised of three daytime and three nighttime sampling efforts within a 24-hour period. The daytime sampling efforts will begin at 1000 hr, 1200 hr, and 1400 hr. The nighttime sampling efforts will begin at approximately 2200 hr, 0000 hr, and 0200 hr. This sampling scheme will result in collection of 12 samples (six duplicate bongo-style net tows) during each 24-hour collection. If conditions arise due to weather, lake conditions, or gear malfunction that preclude conducting a sampling event as originally scheduled, the sampling event will be conducted as soon as possible thereafter within the scheduled week once the issue preventing sampling has been resolved. If a 24-hour sampling event cannot be completed within its scheduled week, the sampling event will not be conducted so as to maintain the regular weekly sampling schedule. Reasons for the omission of a sample will be fully documented and reported to the NYSDEC within one week of the sample being missed.

### 2.1.2 Sampling Gear and Protocol

Near-shore ichthyoplankton samples will be collected onboard a 17-ft center-console motor boat equipped with a transom-mounted GPS/sonar unit. Two bongo-style conical plankton nets (designed for oblique tows) will be used. Each net will be 2.0 m long with a mouth opening of 0.3-m, 500-μm mesh, and a detachable cod-end bucket. A mechanical flow meter will be attached in the center of the mouth of one of the nets to determine the amount of water filtered through the nets during each tow. A 5-kg depressor and/or floats will be used to maintain the desired depth. The net array will be deployed from the stern of the boat.

Tow speed of the sampling gear will be maintained at approximately 1 m/s and be monitored using a GPS unit with a stern-mounted transducer. Before net deployment, the mechanical flow meter will be checked for correct operation and beginning numbers will be recorded. Once deployed, the sample start time will begin when the nets reach the desired depth. The length of time for each tow will be measured with a stopwatch, and GPS coordinates will be recorded at the beginning and end of each tow. During the sample, tow velocity, depth, and tow-line angle will be monitored to ensure the net is fishing properly and at the correct depth. The estimated maximum volume of water that would be sampled by an individual net during a 5-minute tow, assuming a net efficiency of 100%, is 84 $m^3$. Actual sampled volume is expected to be less due to back-pressure on the towed net, which will increase as organisms and other material are collected during the course of a tow.

At sample completion, the net will be retrieved and the number of revolutions of the mechanical flow meter will be recorded. Any tow for which there was apparent net damage, loss of sample, or improper deployment will be considered invalid and will be repeated. If a tow is considered acceptable, the nets will be washed down from the outside to concentrate the sample in the detachable cod-end bucket. The sample contents of each net will then be transferred to a labeled, 1-L sample jar and preserved with 95% ethanol with Rose Bengal stain. Samples containing large amounts of organic material may be preserved in 10% formalin solution prior to being transferred to ethanol.

In summary, the proposed near-shore ichthyoplankton sampling program will involve conducting six sampling efforts during each weekly 24-hour sampling event from April through August 2014. Sampling will occur at a depth of 2 m, and two samples (side-by-side bongo-style nets) will be collected during each tow. This will result in the collection of a total of 264 near-shore ichthyoplankton samples over the course of the sampling program.

### 2.1.3 Water Quality Measurements

Water-quality conditions will be recorded prior to the start of every sampling effort. Parameters to be measured will include water temperature (°C), dissolved oxygen concentration (mg/L), and specific conductance (μS/cm). Each parameter will be measured *in situ* at the 2-m depth from the surface using hand-held, portable meters calibrated to the manufacturers' specifications.

## 2.2 Ichthyoplankton Entrainment Monitoring

### 2.2.1 Sampling Location and Frequency

Sampling of the ichthyoplankton entrained at the LSC facility intake will occur at a pre-existing, integrated sampling system inside the facility. Water traveling through the main intake pipe from the facility's wet well will be withdrawn from the main intake pipe via an integrated sampling line. This is the same sampling system that was used for biological monitoring for the entrainment of ichthyoplankton at the facility from 2000-2005.

In-plant ichthyoplankton entrainment sampling will be conducted concurrently with near-shore ichthyoplankton community sampling. At least one 24-hour collection will be made weekly from April through August 2014. A 24-hour collection will be comprised of three 8-hour sampling efforts. The first sampling effort will begin at 0800 hr and end at approximately 1600 hr. The second sampling effort will begin at approximately 1600 hr and continue to approximately 0000 hr of the following day. The third sampling effort will begin at approximately 0000 hr and end at approximately 0800 hr. If conditions arise that preclude conducting a sampling event as originally scheduled, the sampling event will be conducted as soon as possible thereafter within the scheduled week once the issue preventing sampling has been resolved. If a 24-hour sampling event cannot be completed within its scheduled week, the sampling event will not be conducted so as to maintain the regular weekly sampling schedule. Reasons for the omission of a sample will be fully documented and reported to the NYSDEC within one week of the sample being missed.

### 2.2.2 Sampling Gear and Protocol

Water withdrawn from the main intake pipe via the integrated sampling line will be split into two equal-sized sample pipes, each of which in turn will discharge into a 2.0-m long plankton net with a mouth opening of 0.3-m, 500-μm mesh, and a detachable cod-end bucket. The two plankton nets will be suspended vertically, mouth end up, in a water-filled tank to reduce damage to collected ichthyoplankton. Sampled flow will be controlled and monitored by a flow meter and recorded after each sample collection. The integrated sampling line will divert approximately 1% of the plant flow to the net array.

At sample completion, each net will be inspected for net damage, loss of sample, or improper deployment. Any sample for which there was apparent net damage, loss of sample, or improper deployment will be considered invalid and discarded. If a sample is considered acceptable, the net will be washed down from the outside to concentrate the sample in the detachable cod-end bucket. The sample contents of each net will then be transferred to a labeled, 1-L sample jar and preserved with 95% ethanol with Rose Bengal stain.

In summary, the proposed in-plant entrainment sampling program will involve deploying two nets simultaneously during each weekly 24-hour sampling event from April through August 2014, concurrent with the near-shore in-lake sampling. Each 24-hour sampling event will be comprised of three contiguous 8-hour sampling efforts. This will result in the collection of a total of 132 in-plant entrainment samples over the course of the sampling program.

### 2.2.3 Water Quality Measurement

Water quality conditions of facility intake water will be measured at the start of each sampling effort. Parameters to be measured will include water temperature (°C), dissolved oxygen concentration (mg/L), and specific conductance (μS/cm). Each parameter will be measured *in situ* at the 1-m depth from the surface in the plant's wet well using hand-held, portable meters calibrated to the manufacturers' specifications.

## 2.3 Laboratory Analysis

All preserved near-shore and in-plant ichthyoplankton samples will be transported to a laboratory on Cornell University's campus and be analyzed as follows.

### 2.3.1 Sample Sorting

Each sample will be rinsed through a 500-μm sieve in a sink under a fume hood to remove all traces of preservative. Ichthyoplankton will be sorted from sample debris by placing the sample in a tray and using a magnifying lamp to systematically search the sample for ichthyoplankton. All such organisms will be removed, sorted into like groups, placed in labeled vials, and preserved in 95% ethanol. Samples that are estimated to contain more than 400 fish eggs or 400 fish larvae may be subsampled using a plankton splitter.

### 2.3.2 Sample Identification and Measurement

After sorting, the fish larvae and eggs will be identified to the lowest practical taxon (with a target level of species) and enumerated. Fish larvae life stage will be categorized as yolk-sac,

post-yolk-sac, or juvenile. Only whole larvae, parts of larvae with a head, or pieces of larvae with a substantial portion (more than half) of the body present will be counted. Total length will be recorded for all fish life stages (excluding eggs) identified to species for up to 25 specimens for each life stage. If more than 25 specimens of an individual species life stage are present in a sample, a random sub-sample of no more than 25 specimens per life stage will measured in order to further characterize sizes in a life stage. All ichthyoplankton will be preserved and archived following identification.

### 2.4 Data Analysis

The *Special Conditions: Biological Monitoring Requirements* of the LSC facility SPDES permit specify that the results of the *Entrainment Characterization Study* should include "a summary table of the total number of fish entrained by species and life stage based upon continuous operation of all pumps at full rated flow and actual operation and cooling water volume over the study period." These data will be generated using the following calculations. Examples of these calculations are provided in Appendices A and B.

#### 2.4.1 Density Calculations

Density (number of organisms per 100 $m^3$) of ichthyoplankton in the near-shore area of Cayuga Lake in the vicinity of the LSC facility and in the intake water of the facility and will be calculated for each fish species and life stage for each sample (i.e., each individual net collection). Density will be calculated by dividing the sum of the total number of a fish species life stage collected by the total sample volume in $m^3$ and multiplying this by 100. The mean density for each fish species and life stage for a 24-hour sampling event will be calculated by averaging the density values from the individual net samples collected over the 24-hour period. A mean density value for the 12 in-lake net samples and a mean density value for the six in-plant net samples will be calculated for each 24-hour sampling event.

#### 2.4.2 Full-rated Flow Entrainment Estimate

An estimate of ichthyoplankton entrainment for the period of the study assuming all pumps were operated at the full-rated flow will be calculated by multiplying the mean density (no./100 $m^3$) of each fish species life stage for a given 24-hour sampling event by the total volume of the full-rated flow expressed in units of 100 $m^3$ per day. This will yield an estimate of the total number of each fish species life stage potentially entrained under full-rated flow conditions during the 24-hour sampling event. This value will then be multiplied by 7 to obtain an estimate of the total number of fish entrained by species and life stage for the week (7-day period) encompassing the 24-hour sampling event. This weekly estimate of entrainment under full-rated flow will be calculated for each weekly 24-hour sampling event using each of the mean density estimates

obtained via the in-lake sampling and the in-plant sampling. Summing the weekly estimates over the 22-week sampling program will provide estimates of the total number of fish entrained by species and life stage based upon continuous operation of all pumps at full rated flow during the course of the study (April through August).

The estimate derived from the in-plant data will represent potential entrainment resulting from operation of the plant at full-rated flow with the current intake location and technology. The estimate derived from the in-lake data will represent the entrainment calculation baseline, which is the potential entrainment that would occur at the LSC facility assuming that: the cooling water system were to have been designed as a once-through system and; the opening of the cooling water intake structure were located at and oriented parallel to the shoreline and near the surface of the lake; and the intake were operated at its full rated capacity.

### 2.4.3 Actual Operation Flow Entrainment Estimate

An estimate of ichthyoplankton entrainment for the period of the study under actual operation flows will be calculated in the same manner as for the full-rated flow entrainment estimate except the mean density (no./100 $m^3$) of each fish species life stage for a given 24-hour sampling event will be multiplied by the actual operation flow expressed in units of 100 $m^3$ per day rather than the by the full-rated flow. The estimate derived from the in-plant data will provide an estimate of actual entrainment resulting from operation of the plant during the period of study with the current intake location and technology. The estimate derived from the in-lake data will represent the potential entrainment that would occur at the LSC facility assuming that: the cooling water system were to have been designed as a once-through system; the opening of the cooling water intake structure were located at and oriented parallel to the shoreline and near the surface of the lake; and the intake is operated at actual flow levels occurring during the course of the study.

## 3.0 REPORTING

A final report will be prepared and submitted to the NYSDEC within nine months of completion of data collection. This report will include a detailed description of all methods and materials used and a summary table of the total number of fish entrained by species and life stage based upon continuous operation of all pumps at full-rated flow and actual operation and cooling water volume over the study period. In addition, all data collected during the entrainment study will be provided to the NYSDEC in an agreed upon electronic format.

## 4.0 SCHEDULE, LOGISTICS, AND CONTINGENCIES

Sampling of the near-shore ichthyoplankton community and in-plant entrainment will commence during the first week of April 2014 and continue weekly through the end of August 2014. This schedule will be adhered to as closely as possible under the constraints of safety, weather, functionality of sampling gear, and LSC facility operation. Given the extensive and intensive nature of the field sampling program, it is possible that unworkable/unsafe weather or lake conditions may preclude sampling at a regularly scheduled time. Similarly, equipment malfunction or an unforeseen LSC facility shutdown could potentially result in an inability to conduct a regularly scheduled sampling event. In such cases, sampling will be resumed as soon as conditions are appropriate to do so. Any such occurrences will be thoroughly documented as to why regularly scheduled sampling did not occur and what steps, if any, were taken to remedy the situation in a timely manner. Documentation of any deviations in the sampling schedule, reasons for such deviations, and associated corrective actions will be provided in the final report. If a 24-hour sampling event cannot be completed within its scheduled week, the sampling event will not be conducted so as to maintain the regular weekly sampling schedule. Reasons for the omission of a sample will be fully documented and reported to the NYSDEC within one week of the sample being missed. If conditions arise that may result in an inability to conduct sampling over an extended period of time (two or more weeks), the NYSDEC will be notified as soon as possible and consulted regarding how such a condition might best be addressed.

## 5.0 LITERATURE CITED

Chiotti, T.L. 1980. A strategic fisheries management plan for Cayuga Lake. Bureau of Fisheries, Division of Fish and Wildlife, New York State Department of Environmental Conservation, Albany, NY. 56 pp.

HDR. 2010a. AES Cayuga Generating Station 2006-2007 juvenile and adult entrainment study. Prepared for AES Cayuga, LLC, Lansing, NY by Henningson, Durham and Richardson Architecture and Engineering, P.C., Pearl River, NY. 55 pp. + appendices.

HDR. 2010b. AES Cayuga Generating Station 2006-2007 finfish community and waterbody studies. Prepared for AES Cayuga, LLC, Lansing, NY by Henningson, Durham and Richardson Architecture and Engineering, P.C., Pearl River, NY. 55 pp. + appendices.

**Table 1.** Scientific and common names of fish species reported from Cayuga Lake, NY. (Sources: Chiotti 1980; HDR 2010a, 2010b)

| SCIENTIFIC NAME | COMMON NAME |
|---|---|
| **Petromyzontidae--lampreys** | |
| *Petromyzon marinus* | Sea lamprey |
| **Acipenseridae--sturgeon** | |
| *Acipenser fulvescens* | Lake sturgeon |
| **Lepisosteidae--gars** | |
| *Lepisosteus osseus* | Longnose gar |
| **Amiidae--bowfins** | |
| *Amia calva* | Bowfin |
| **Anguillidae--freshwater eels** | |
| *Anguilla rostrata* | American eel |
| **Clupeidae--herrings** | |
| *Alosa pseudoharengus* | Alewife |
| *Dorosoma cepedianum* | Gizzard shad |
| **Ictaluridae--bullhead catfishes** | |
| *Ameiurus nebulosus* | Brown bullhead |
| *Ictalurus punctatus* | Channel catfish |
| *Noturus flavus* | Stonecat |
| *Noturus insignis* | Margined madtom |
| *Noturus miurus* | Brindled madtom |
| **Catosotmidae--suckers** | |
| *Catostomus commersoni* | White sucker |
| *Hypentelium nigricans* | Northern hog sucker |
| *Moxostoma* sp. | Redhorse |

Table 1. Continued.



| SCIENTIFIC NAME | COMMON NAME |
|---|---|
| **Cyprinidae--carps and minnows** | |
| *Cyprinus carpio* | Common carp |
| *Cyprinella analostana* | Satinfin shiner |
| *Luxilus cornutus* | Common shiner |
| *Notropis hudsonius* | Spottail shiner |
| *Notemigonus crysoleucas* | Golden shiner |
| *Rhinichthys atratulus* | Blacknose dace |
| *Rhinichthys cataractae* | Longnose dace |
| *Scardinius erythrophthalmus* | Rudd |
| *Semotilus atromaculatus* | Creek chub |
| *Semotilus corporalis* | Fallfish |
| **Salmonidae--trouts** | |
| *Coregonus artedi* | Cisco |
| *Coregonus clupeaformis* | Lake whitefish |
| *Oncorhynchus mykiss* | Rainbow trout |
| *Salmo salar* | Atlantic salmon |
| *Salmo trutta* | Brown trout |
| *Salvelinus fontinalis* | Brook trout |
| *Salvelinus namaycush* | Lake trout |
| **Osmeridae--smelts** | |
| *Osmerus mordax* | Rainbow smelt |
| **Esocidae--pikes** | |
| *Esox lucius* | Northern pike |
| *Esox niger* | Chain pickerel |
| **Percopsidae--trout-perches** | |
| *Pecopsis omiscomaycus* | Troutperch |
| **Fundulidae--killifishes** | |
| Fundulus diaphanus | Banded killifish |

Table 1. Continued.



| SCIENTIFIC NAME | COMMON NAME |
|---|---|
| **Atherinidae--silversides** | |
| *Labidesthes sicculus* | Brook silversides |
| **Gasterosteidae--sticklebacks** | |
| *Culaea inconstans* | Brook stickleback |
| **Percichthyidae--temperate basses** | |
| *Morone americana* | White perch |
| *Morone chrysops* | White bass |
| **Centrarchidae--sunfishes** | |
| *Ambloplites rupestris* | Rock bass |
| *Lepomis auritus* | Redbreast sunfish |
| *Lepomis gibbosus* | Pumpkinseed |
| *Lepomis macrochirus* | Bluegill |
| *Micropterus dolomieu* | Smallmouth bass |
| *Micropterus salmoides* | Largemouth bass |
| *Pomoxis nigromaculatus* | Black crappie |
| *Pomoxis annularis* | White crappie |
| **Percidae--perches** | |
| *Etheostoma nigrum* | Tesselated darter |
| *Perca flavescens* | Yellow perch |
| *Percina caprodes* | Logperch |
| **Cottidae--sculpins** | |
| *Cottus bairdii* | Mottled sculpin |
| *Cottus cognatus* | Slimy sculpin |
| **Gobiidae--gobies** | |
| *Neogobius melanostomus* | Round goby* |

* - confirmed present by NYSDEC staff in 2013

## APPENDIX A

### Example of Density Calculation (No./100 $m^3$) for Near-shore Ichthyoplankton Samples

Density of Species A, post-yolk sac larvae life stage for a 24-hour sampling event:

The number of Species A post-yolk sac larvae per 100 $m^3$ is determined for each net tow. The daily mean density for Species A post-yolk sac larvae is determined by averaging the density value obtained for each individual net sample.

Catch for a 24-hour Sampling Event

| Net No. | Time (hours)* | Vol. Sampled (m3) | No. collected | No./$m^3$ | No./100 $m^3$ |
|---|---|---|---|---|---|
| 1 | 1000 | 60 | 1 | 0.017 | 1.67 |
| 2 | 1000 | 60 | 2 | 0.033 | 3.33 |
| 1 | 1200 | 55 | 0 | 0.000 | 0.00 |
| 2 | 1200 | 55 | 3 | 0.055 | 5.45 |
| 1 | 1400 | 65 | 2 | 0.031 | 3.08 |
| 2 | 1400 | 65 | 1 | 0.015 | 1.54 |
| 1 | 2200 | 60 | 1 | 0.017 | 1.67 |
| 2 | 2200 | 60 | 3 | 0.050 | 5.00 |
| 1 | 0000 | 55 | 0 | 0.000 | 0.00 |
| 2 | 0000 | 55 | 2 | 0.036 | 3.64 |
| 1 | 0200 | 60 | 1 | 0.017 | 1.67 |
| 2 | 0200 | 60 | 2 | 0.033 | 3.33 |
| Mean | | | | 0.025 | 2.53 |

* - Time at initiation of sampling

### Full-rated Flow Entrainment Estimate for Near-shore Ichthyoplankton Samples

Estimated daily entrainment of Species A post yolk-sac larvae under full rated flow conditions is calculated by multiplying the daily mean density of 2.53/100 $m^3$ by the full-rated flow of the LSC facility (172,800 $m^3$) and dividing by 100.

(2.53 x 172,800)/100 = 4,372 post yolk-sac larvae of Species A entrained per day

Estimated weekly entrainment of Species A post yolk-sac larvae under full rated flow conditions is calculated by multiplying the daily estimate by 7.

4,372 x 7 = 30,604 post yolk-sac larvae of Species A entrained per week.

Estimated total entrainment of Species A post yolk-sac larvae under full rated flow conditions for the duration of the study period (April-August) is calculated by summing the 22 individual weekly estimates derived from the weekly 24-hour sampling events.

**Actual Operation Flow Entrainment Estimate for Near-shore Ichthyoplankton Samples**

Estimated daily entrainment of Species A post yolk-sac larvae under actual operation flow conditions is calculated by multiplying the daily mean density of 2.53/100 $m^3$ by the actual operation flow that occurred during the 24-hour period during which a sampling event occurred and dividing by 100. In this example, an actual operation flow of 138,240 $m^3$ (80% of full-rated flow) is used.

(2.53 x 138,240)/100 = 3,497 post yolk-sac larvae of Species A entrained per day

Estimated weekly entrainment of Species A post yolk-sac larvae under actual operation flow conditions is calculated by multiplying the daily estimate by the daily actual operation flow for each day of the week represented by that sample. Calculation for a hypothetical week in which flow ranged from 80-100% of full-rated flow would be as follows.

| Day | Daily Mean Density (No./$m^3$) | Daily Actual Flow ($m^3$) | Est. Daily Entrainment |
|---|---|---|---|
| 1 | 2.53 | 138,240 (80%)* | 3,497 |
| 2 | 2.53 | 138,240 (80%) | 3,497 |
| 3 | 2.53 | 146,880 (85%) | 3,716 |
| 4 | 2.53 | 172,800 (100%) | 4,372 |
| 5 | 2.53 | 155,520 (90%) | 3,935 |
| 6 | 2.53 | 155,520 (90%) | 3,935 |
| 7 | 2.53 | 138,240 (80%) | 3,497 |
| | | | |
| Total | | | 26,449 |

* - Represents percentage of full-rated flow

Estimated total entrainment of Species A post yolk-sac larvae under actual operation flow conditions for the duration of the study period (April-August) is calculated by summing the 22 individual weekly estimates derived from the weekly 24-hour sampling events.

## APPENDIX B

### Example of Density Calculation (No./100 $m^3$) for In-plant Ichthyoplankton Samples

Density of Species A, post-yolk sac larvae life stage for a 24-hour sampling event:

The number of Species A post-yolk sac larvae per 100 $m^3$ is determined for each net. The daily mean density for Species A post-yolk sac larvae is determined by averaging the density value obtained for each individual net sample.

Catch for a 24-hour Sampling Event

| Net No. | Time (hours)* | Vol. Sampled ($m^3$)** | No. collected | No./$m^3$ | No./100 $m^3$ |
|---|---|---|---|---|---|
| 1 | 0800 | 288 | 1 | 0.003 | 0.35 |
| 2 | 0800 | 288 | 2 | 0.007 | 0.69 |
| 1 | 1600 | 288 | 0 | 0.000 | 0.00 |
| 2 | 1600 | 288 | 3 | 0.010 | 1.04 |
| 1 | 0000 | 288 | 2 | 0.007 | 0.69 |
| 2 | 0000 | 288 | 1 | 0.003 | 0.35 |
| Mean | | | | 0.005 | 0.52 |

* - Time at initiation of sampling

** - Example assumes 1% of full-rated flow is sampled by both nets combined. Actual operation flow from the biomonitoring station flow meter will be used.

### Full-rated Flow Entrainment Estimate for In-plant Ichthyoplankton Samples

Estimated daily entrainment of Species A post yolk-sac larvae under full rated flow conditions is calculated by multiplying the daily mean density of 0.52/100 $m^3$ by the full-rated flow of the LSC facility (172,800 $m^3$) and dividing by 100.

(0.52 x 172,800)/100 = 899 post yolk-sac larvae of Species A entrained per day

Estimated weekly entrainment of Species A post yolk-sac larvae under full rated flow conditions is calculated by multiplying the daily estimate by 7.

899 x 7 = 6,293 post yolk-sac larvae of Species A entrained per week.

Estimated total entrainment of Species A post yolk-sac larvae under full rated flow conditions for the duration of the study period (April-August) is calculated by summing the 22 individual weekly estimates derived from the weekly 24-hour sampling events.

**Actual Operation Flow Entrainment Estimate for In-plant Ichthyoplankton Samples**

Estimated daily entrainment of Species A post yolk-sac larvae under actual operation flow conditions is calculated by multiplying the daily mean density of 0.52/100 $m^3$ by the actual operation flow that occurred during the 24-hour period during which a sampling event occurred and dividing by 100. In this example, an actual operation flow of 138,240 $m^3$ (80% of full-rated flow) is used.

(0.52 x 138,240)/100 = 719 post yolk-sac larvae of Species A entrained per day

Estimated weekly entrainment of Species A post yolk-sac larvae under actual operation flow conditions is calculated by multiplying the daily estimate by the daily actual operation flow for each day of the week represented by that sample. Calculation for a hypothetical week in which flow ranged from 80-100% of full-rated flow would be as follows.

| Day | Daily Mean Density (No./$m^3$) | Daily Actual Flow ($m^3$) | Est. Daily Entrainment |
|---|---|---|---|
| 1 | 0.52 | 138,240 (80%)* | 719 |
| 2 | 0.52 | 138,240 (80%) | 719 |
| 3 | 0.52 | 146,880 (85%) | 764 |
| 4 | 0.52 | 172,800 (100%) | 899 |
| 5 | 0.52 | 155,520 (90%) | 809 |
| 6 | 0.52 | 155,520 (90%) | 809 |
| 7 | 0.52 | 138,240 (80%) | 719 |
| | | | |
| Total | | | 5,438 |

* - Represents percentage of full-rated flow

Estimated total entrainment of Species A post yolk-sac larvae under actual operation flow conditions for the duration of the study period (April-August) is calculated by summing the 22 individual weekly estimates derived from the weekly 24-hour sampling events.