DATA DOCUMENTATION
FOR
INFORMATION PROVIDED TO
U.S. NUCLEAR REGULATORY COMMISSION
IN RESPONSE TO
9/26/14 REQUEST FOR ADDITIONAL INFORMATION

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1 INTRODUCTION

On September 26, 2014, the U.S. Nuclear Regulatory Commission (NRC) sent Entergy Nuclear Operations (Entergy) a request for additional information (RAI) pertaining to potential aquatic environmental impacts of continued operation of Indian Point Nuclear Generating Units 2 and 3. The information requested in the RAI was intended to update information previously provided to NRC, specifically to allow extension of the environmental analysis from 2007 to 2011, and to allow NRC to evaluate alternative analyses provided by Entergy in February, 2014.

This report documents the information provided to NRC in response to the RAI.

2 REQUEST FOR ADDITIONAL INFORMATION

The information requested by NRC is provided in the two formats in the RAI as described below. All information conforms to the specifications provided in Table 1 and Table 2.[1]

Table 1 Fish taxa included in RAI.

Taxon Code	Species
1	Alewife
2	Bay anchovy
3	American shad
4	Bluefish
13	Hogchoker
19	Atlantic Menhaden
22	Blueback herring
25	Rainbow smelt
27	Shortnose sturgeon
28	Spottail shiner
29	Atlantic Sturgeon
30	Striped bass
32	Atlantic Tomcod
34	White catfish
35	White perch
45	Weakfish
75	Gizzard shad

Table 2 Region designations for information requested in RAI.

Region	Name	RM*
1	YK – Yonkers	12-23
2	TZ – Tappan Zee	24-33
3	CH – Croton-Haverstraw	34-38
4	IP – Indian Point	39-46
5	WP – West Point	47-55
6	CW – Cornwall	56-61
7	PK – Poughkeepsie	62-76
8	HP – Hyde Park	77-85
9	KG – Kingston	86-93
10	SG – Saugerties	94-106
11	CS – Catskill	107-124
12	AL – Albany	125-152
13	All	12-152

***** River mile measured upstream from Battery Park

Format 1 Data: Please provide the following data from the Fall Shoals Survey (FSS), Beach Seine Survey (BSS) and Long River Survey (LRS):

(1) the unstandardized River Segment 4 annual densities (if AKRF calculated these as in the FSEIS as the 75th percentile of the weekly densities--if AKRF used some other measure, then please submit both that measure and the 75th percentile of the weekly densities) for each survey (FSS, BSS, and LRS);
(2) the unstandardized River Segment 4 annual CPUE (catch per unit effort) used in the AKRF analysis for each survey (FSS and LRS);
(3) the unstandardized Riverwide CPUE for each survey (FSS, BSS, and LRS); and
(4) the Riverwide unstandardized abundance index (with an indication for each taxon of which sampling program was used for its construction) used by AKRF for trends analysis for each year and taxon listed in Table 1.

[1] The data provided on the enclosed compact disc cover the same species for which Entergy provided data to NRC staff prior to the development of the SFEIS. We note and agree with NRC staff's conclusion that the rates of entrainment and impingement observed at Indian Point for Atlantic menhaden, Atlantic and shortnose sturgeon, gizzard shad, and blue crab were very low and compelled a finding of Low for the strength of connection metric. *See* SFEIS, Appendix H, p. H-47 ("NRC staff could not model the strength of connection for Atlantic menhaden, Atlantic and shortnose sturgeon, gizzard shad, and blue crab, but concluded that the connection was Low because of the low rate of entrainment and impingement observed at IP2 and IP3 (Table H-16)."). We also note that sturgeon have been fully addressed during the Endangered Species Act consultation process, resulting in a final BiOp and ITS.

Format 2 Data: The NRC staff requests the weekly YOY density; weekly YOY catch; weekly total catch; weekly number of samples; and weekly volume sampled, all by year, region, and taxon for each sampling program (FSS, BSS, and LRS). Please provide the units for each measurement. Note, Region 13 as used in the tables of weekly catch is the total weekly catch from regions 1 – 12 as defined in Table 2.

3 SAMPLING PROGRAMS

3.1 SAMPLING DESIGN

Several fishery techniques were employed in three separate sampling surveys to obtain comprehensive information on the abundance and distribution of selected larval, juvenile or young-of-year (YOY), and adult fish species in the Hudson River estuary. Temporally, the monitoring program encompassed the spring through fall season of each year 1979 through 2011, the period of greatest biological activity in northern U.S. temperate waters. The surveys were designed to sample the full range of Hudson River habitat toward a representative assessment of species-specific spatial distribution patterns.

The scope and objectives of the three sampling surveys comprising the overall monitoring program are summarized as follows.

1. **Longitudinal River Ichthyoplankton Survey** (LRS or Long River Survey)— Sampling currently encompasses the entire length of the Hudson River estuary, from River Mile (RM) 1 at the Battery in Manhattan to RM 152 at the Federal Dam in Troy, however in the early years of the program sampling did not extend below RM 12. The LRS yields ichthyoplankton data to support calculations of standing crop, temporal and geographic indices, and growth rates for selected Hudson River fish species. The primary species were Atlantic tomcod (*Microgadus tomcod*), American shad (*Alosa sapidissima*), striped bass (*Morone saxatilis*), white perch (*M. americana*) and bay anchovy (*Anchoa mitchilli*), but all species captured are identified and recorded. LRS sampling has been weekly or every other week during the spring, summer, and early fall when eggs and larvae of the primary species have historically been abundant, but the starting and ending weeks of sampling has varied over the years of the study. (See Appendix Table 2-1.) Sampling effort varies from approximately 100 to 212 samples per week, with the fewest samples collected in the fall weeks.

2. **Fall Shoal Survey** (FSS)—Samples are collected every other week from the Battery (since 1996) to the Troy Dam in mid-summer and fall. The objective was to provide data on YOY fish to support calculation of standing crop and temporal and geographic indices for selected Hudson River fish species. The target species were Atlantic tomcod, American shad, striped bass, and white perch, but all species captured are identified and recorded. The survey has typically been conducted from mid-June through October, when YOY of these species were typically abundant in the shorezone nursery areas but the starting and ending weeks of sampling has varied over the years of the study. (See Appendix Table 2-2.) Sampling effort is approximately 200 samples per week.

3. **Beach Seine Survey** (BSS)—Beach seine samples are collected in alternate weeks relative to the FSS at randomly selected fixed stations ranging from the George Washington Bridge (RM 12) to the Troy Dam (RM 152). The objective is to obtain distribution and relative abundance information on YOY American shad, Atlantic tomcod, striped bass, and white perch during periods when these species are concentrated primarily in the shallow, near-shore areas, but all species captured are identified and recorded. The survey has typically been conducted from mid-June through October, when YOY of these species were typically abundant in the shorezone nursery areas but the starting and ending weeks of sampling has varied over the years of the study. (See Appendix Table 2-3.) Sampling effort is 100 samples per week.

Sampling for all surveys is conducted according to a stratified random design in which the Hudson River estuary from the Battery (RM 1) to the Federal Dam at Troy (RM 152) was divided into 13 regions (Figure 2-1). Each region was further divided into "strata" on the basis of river depth:

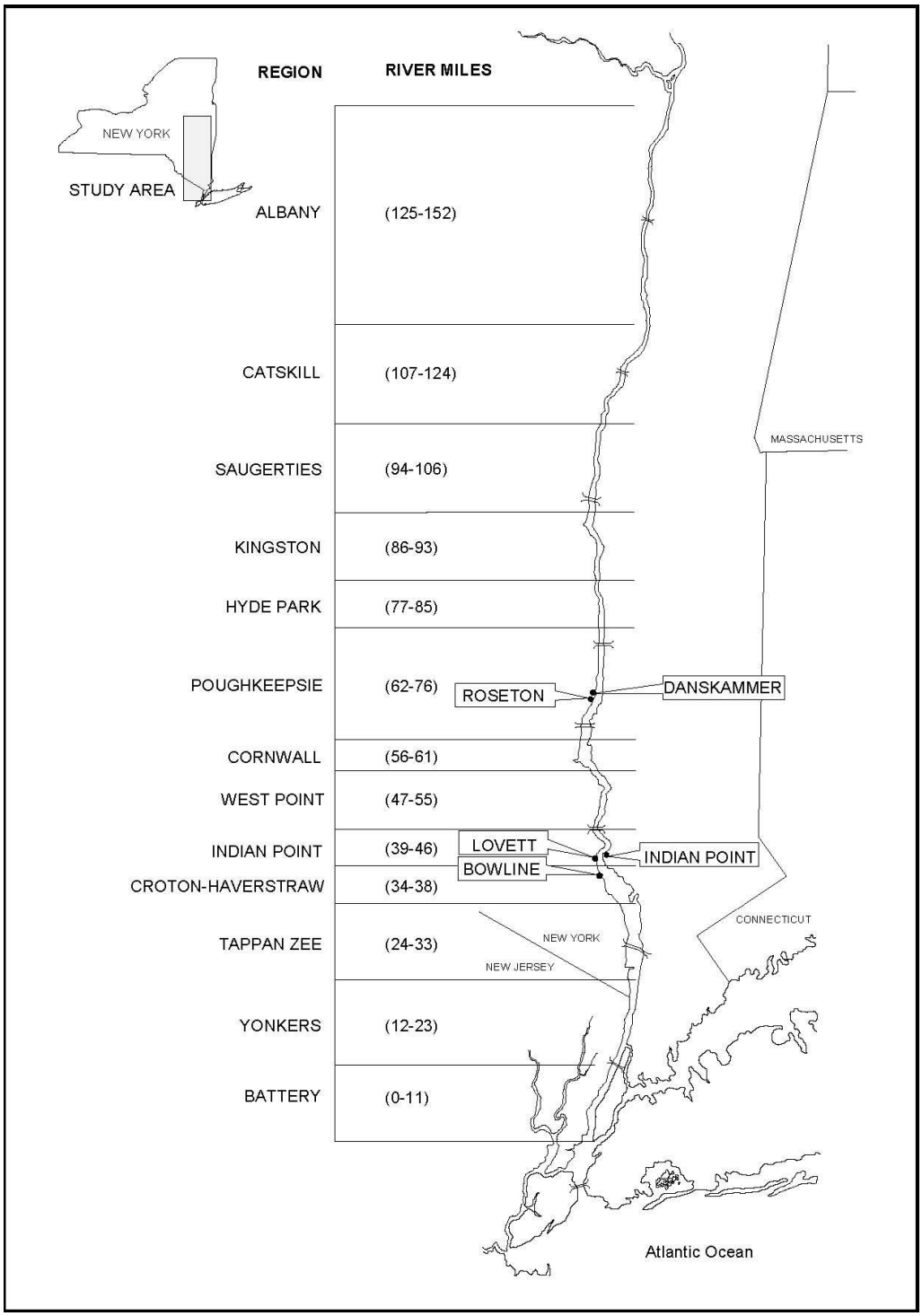


Figure 1 Location of river regions in the Hudson River Environmental Monitoring Program.

Shore—That portion of the Hudson River estuary extending from the shore to a depth of 10 ft (the stratum defined only for BSS).

Shoal— That portion of the Hudson River estuary extending from the shore to a depth of 20 ft at mean low tide.

Bottom—That portion of the Hudson River estuary extending from the bottom to 10 ft above the bottom where river depth is greater than 20 ft at mean low tide.

Channel—That portion of the Hudson River estuary not considered bottom where river depth is greater than 20 ft at mean low tide.

The relative area and configuration of the shoal, bottom, and channel strata vary over the length of the Hudson River estuary (Table 3). In upriver regions, the shoal stratum is not sampled due to its limited extent and potential for problems sampling close to shore in larger vessels.

3.2 SAMPLING METHODS

Abbreviated descriptions of the typical sampling methods are provided in this section. Some variation in methods, and sampling intensity, has occurred through the 40+ years of the monitoring program. More complete descriptions of the methods are available for each year in the annual Year Class Reports and in the survey-specific annual Standard Operating Procedures (SOPs).

3.2.1 LRS

Two distinct gear types are used for field sampling during the LRS: 1.0-m^2 Tucker trawl (Figure 2) to sample the shoal and channel strata (non-bottom), and 1.0-m^2 epibenthic sled (Figure 3) to sample the bottom-only shoal and channel strata.

Both gear types are fitted with 1 m by 8 m nets made from 0.5 mm mesh Nytex and are towed against the prevailing current for 5 minutes. Tows start with the remote opening of the net and terminate with its remote closing. If the river depth is 20 ft or less, an open set and retrieval of the net is performed. The tow speed for the Tucker trawl is adjusted to maintain a towing wire angle of approximately 45° at a velocity through the water of 0.9 m/second. The tow speed for the epibenthic sled-mounted net is maintained at approximately 1.0 m/second. An electronic flowmeter mounted along the side of the research vessel and equipped with an on-deck readout display is used to establish and maintain tow speed. A calibrated digital flowmeter mounted in the center of the net mouth is used to calculate the volume of water filtered for each sample.

Following deployment and retrieval of the sampling gear, net washing is performed to concentrate the sample into the codend bucket. The samples are then examined for yearling and older fish which are identified, enumerated, and returned to the Hudson River estuary. Special care is taken to observe sturgeon species for physical condition and for the presence of marks and/or tags. All yearling and older sturgeon are processed in accordance with Incidental Take Permits from NMFS and NYSDEC. After yearling and older fish are removed, the remaining sample is placed in container(s) so that the sample occupied no more than 25 percent of the container volume. The containers are filled with a 10 percent aqueous formalin solution.

Table 3 Sampling regions for Hudson River Environmental Monitoring Program, with strata volumes (m^3) and shorezone surface area (m^2) for each region and stratum.

Geographic Region	Channel Volume	Bottom Volume	Shoal Volume	Region Volume	Shorezone Surface Area
0 Battery	141,809,822	48,455,129	18,747,833	209,012,784	Undetermined
1 Yonkers	143,452,543	59,312,978	26,654,767	229,420,288	3,389,000
2 Tappan Zee	138,000,768	62,125,705	121,684,992	321,811,465	20,446,000
3 Croton-Haverstraw	61,309,016	32,517,633	53,910,105	147,736,754	12,101,000
4 Indian Point	162,269,471	33,418,632	12,648,163	208,336,266	4,147,000
5 West Point	178,830,022	25,977,862	2,647,885	207,455,769	1,186,000
6 Cornwall	94,882,267	36,768,629	8,140,123	139,791,019	4,793,000
7 Poughkeepsie	228,975,052	63,168,132	5,990,260	298,133,444	3,193,000
8 Hyde Park	131,165,041	32,012,000	2,307,625	165,484,666	558,000
9 Kingston	93,657,021	35,479,990	12,332,868	141,469,879	3,874,000
10 Saugerties	113,143,296	42,845,077	20,307,338	176,295,711	7,900,000
11 Catskill	83,924,081	42,281,206	34,526,456	160,731,743	8,854,000
12 Albany	32,025,080	13,517,183	25,606,842	71,149,105	6,114,000
13 Total	1,603,443,480	527,880,156	345,505,257	2,476,828,893	76,555,000

Shaded strata are not sampled. Volumes are added to adjacent sampled strata within the same region when calculating standing crops and regional densities.

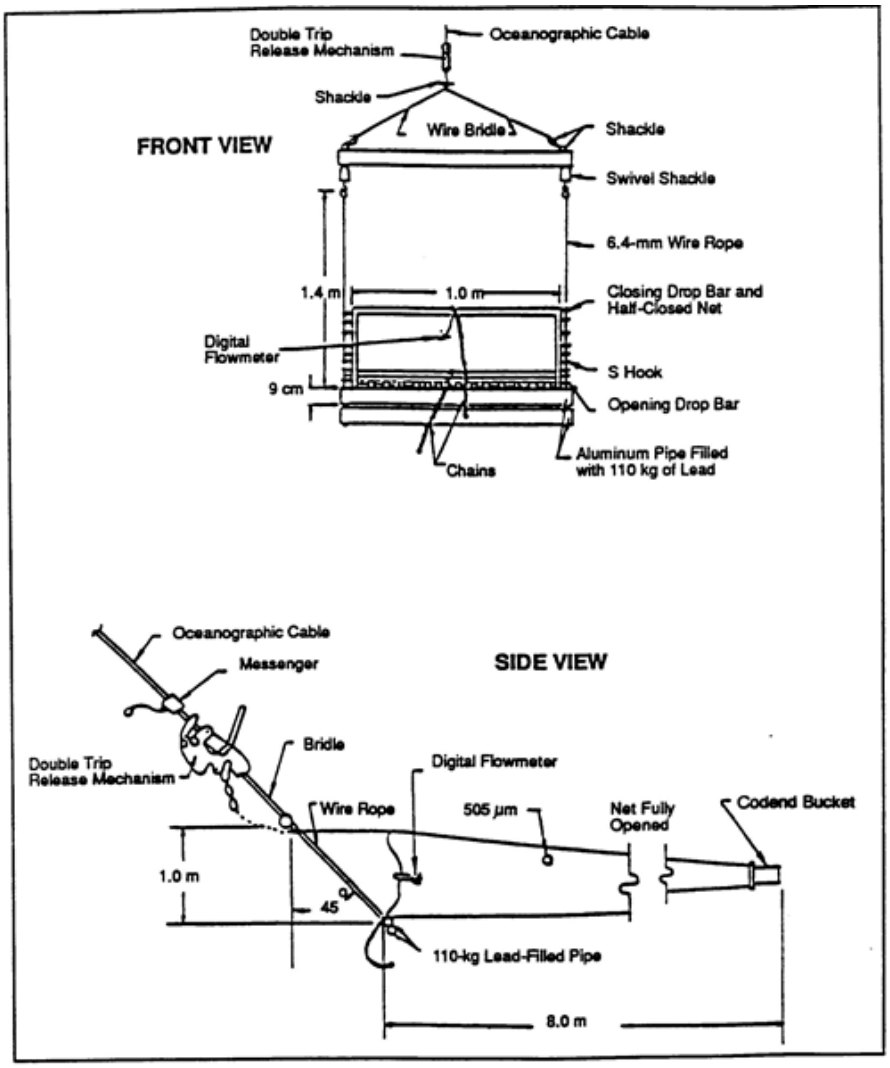


Figure 2 Dimensions of Tucker trawl used to sample channel and shoal strata in LRS and FSS programs.

In situ measurements of water temperature (°C), dissolved oxygen (mg/L), and specific conductance (microsieman/cm at 25°C) are taken with calibrated meters at fixed river mile and strata stations in conjunction with the biological sampling.

Typically, approximately 70 percent of the regular LRS samples are selected for laboratory analysis. Selection of samples for laboratory analysis begins with the grouping of samples according to river run (i.e., sampling week), region, and strata. Based on these groupings, samples are selected based on one of the following criteria:

1. If there were less than 6 samples in the group, then all are selected for analysis.

2. If there were between 6 and 12 samples in the group, then 50 percent of the samples are randomly selected for analysis.

3. If there were more than 12 samples in the group, then 20 percent of the samples are randomly selected for analysis.

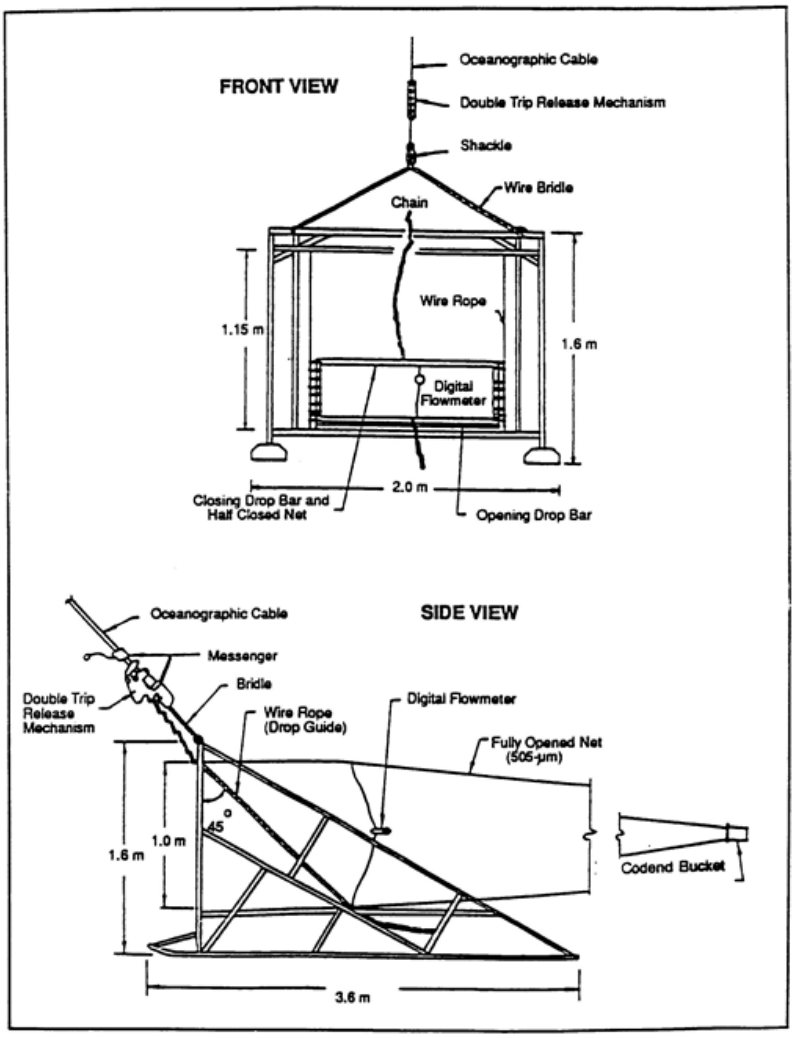


Figure 3 Dimensions of epibenthic sled used to sample bottom and shoals strata in LRS program and FSS program prior to 1985.

Splitting (or subsampling) of samples with a large number of organisms is permitted. A trained technician first determines, by visual inspection, if the sample needs splitting. Samples containing large numbers of eggs may be split so that eggs are only sorted from one or more aliquots containing a total of at least 250 eggs (all species combined).

Two different sets of criteria are used for subsampling of larval stages, depending on the river run. Beginning with the river run in which striped bass PYSL first appear, and for the next 8 river runs (a total of 9 consecutive river runs), a minimum of 500 *Morone* larvae (i.e., the combined total of YSL, PYSL, and YOY of striped bass, white perch, and unidentified *Morone*) are sorted from the entire sample and a minimum of 50 non-*Morone* larvae is also sorted. Because some of the more difficult distinctions between species (e.g., striped bass versus white perch) or between life stages cannot be made reliably during sorting, samples from these 9 river runs are typically sorted in their entirety for larvae (i.e., YSL, PYSL, and YOY combined) of all species combined.

An exception to this may be made, at the discretion of the laboratory supervisor, under the following circumstances: when extremely large numbers of non-*Morone* larvae occur in the sample and a qualified identifier has verified that sufficient numbers of both *Morone* larvae and non-*Morone* larvae are sorted to meet their respective subsampling quotas. The purpose of this exception is to allow splitting before sorting of taxa such as clupeids which could readily be distinguished from *Morone* by sorters.

The second set of criteria for subsampling larvae applies to the river runs not covered in the previous paragraph (before and after the period of striped bass abundance). Any sample from these river runs may be subsampled so that larvae are sorted from one or more splits containing at least 100 larvae (i.e., YSL, PYSL, and YOY combined) of all species combined.

To eliminate bias, some steps in the splitting procedure are performed by an assistant so that the sorter has no prior knowledge of which splits will to be used for the analysis. Randomness of the splitting procedure is monitored and demonstrated by testing selected samples to determine whether splits from the same sample differ by more than random variation. Samples are selected to test for randomness by a continuous sampling plan.

Eggs and larvae and YOY are separated from detrital material, sorted by major taxonomic group and life stage, counted, and placed in vials containing 5 percent formalin or in ethyl alcohol. Sorted samples are evaluated by a trained technician under magnification and all organisms are identified and enumerated. The following life stage designations are used in identification:

Life Stage	Description
Egg	Embryonic stage from spawning to hatching,
YSL	From hatching to development of a complete and functional digestive system,
PYSL	From development of a complete digestive system to transformation to juvenile
YOY	From completed transformation to Age 1.

Whenever possible, a maximum of 30 striped bass, 30 white perch, 30 American shad, 30 Atlantic tomcod, and 30 bay anchovy per sample were measured. Organisms were chosen at random from each taxon regardless of life stage until the required numbers were obtained; life stages to be included were YSL, PYSL, and YOY. The total length of YSL and PYSL was measured to the nearest 0.1 mm and to the nearest 1 mm for YOY.

Continuous sampling Quality Control (QC) inspection is employed during the sort and identification procedures to ensure an average outgoing quality limit of 10 percent or better.

3.3 FALL SHOAL SURVEY

This survey, which began in 1974, initially sampled only in shoal stratum. It was named the Fall Shoal Survey, but was extended to sample shoal, bottom, and channel strata and samples both before and after the fall season. It is also known as the Fall Juvenile Survey. A 1.0-m^2 Tucker trawl (Figure 2), 1.0-m^2 epibenthic sled from 1974-1984 (Figure 3), and a 3.0-m beam trawl from 1985-present (Figure 4) are used to collect YOY fish in the FSS. The Tucker trawl with 3.0-mm mesh is used to collect samples in the channel stratum, while the beam trawl with 3.8-cm (stretch) mesh in the body, 3.2-cm (stretch) mesh in the cod-end, and 1.3-cm mesh (stretch) liner (Figure 2-8), is currently used to sample the shoal and bottom strata. The latter gear was first used in this capacity in the 1985 FSS; prior to 1985, an epibenthic sled-mounted Tucker trawl was used. In

later weeks (mid-October and later) the sampling effort is reduced by collecting no Tucker trawl samples and only beam trawl samples in the shoal and bottom strata.

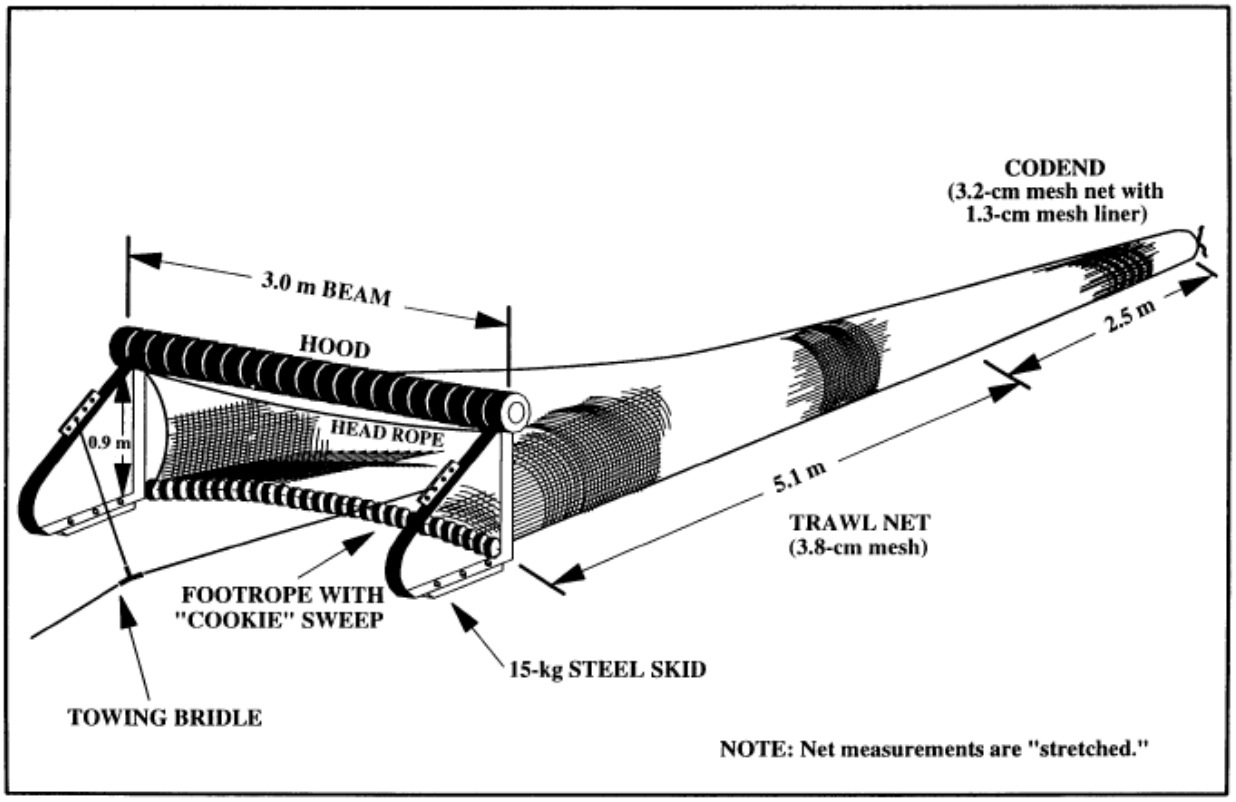


Figure 4 Dimensions of beam trawl used to sample bottom and shoal strata in FSS program.

Both gear types are towed against the prevailing current for approximately 5 minutes. For the Tucker trawl, vessel speed is adjusted as necessary to achieve and maintain a 45° wire angle; the resultant tow speed (through the water) is recorded. The beam trawl is towed at a speed of approximately 1.5 m/second. Tow speed is established and maintained by use of an electronic flowmeter mounted along the side of the research vessel and equipped with an on-deck readout display. Tucker trawl samples taken in greater than 20 ft of river depth are remotely opened and closed at sampling depth. A calibrated digital flowmeter mounted in the center of the net mouth is used to calculate the volume of water filtered for each sample.

Calibrated water quality instruments are used to measure water temperature (°C), dissolved oxygen (mg/L), and specific conductance (microsieman/cm at 25°C) at fixed river mile and strata stations in conjunction with field sampling.

Because of the difficulty in differentiating some species, especially YOY *Morone* (striped bass, white perch) and *Alosa* (alewife, blueback herring), samples collected during the first three sampling periods (River Runs 1 through 3) are preserved with 10 percent formalin at the time of collection and returned to the laboratory for analysis. Before preservation, samples are examined for fish determined to be yearling or older, based on length categorization; live fish are returned to the river after count data are determined. Beginning with the fourth biweekly sampling period, samples were evaluated in the field. Only fish required to fill length measurement and food habit

quotas are returned to the laboratory.

All fish not returned to the laboratory are identified and enumerated into length classes :

Length Class 1—Less than or equal to the YOY total length limit ("Division 1"), which was determined by the field contractor on a weekly basis for each species.

Length Class 2—Greater than Division 1 and less than or equal to the yearling total length limit ("Division 2"); set at 150 mm for most species. From 1 January through 31 May, Division 2 represents the upper length limit for yearling fish for all species. From 1 June through 31 December, Division 2 is assigned a static value of 150 mm total length for all species except alewife, American shad, blueback herring, striped bass, Atlantic tomcod, and white perch. For these species, Division 2 is maintained as a dynamic upper length limit for yearling fish throughout the year.

Length Class 3—Greater than Division 2 and less than or equal to 250 mm.

Length Class 4—Greater than 250 mm.

3.4 BEACH SEINE SURVEY

BSS samples are collected during daylight hours on alternate weeks from the FSS. A total of 100 samples are allocated in a stratified random manner to identified beach habitats in each region (1-12). The BSS utilizes a 30.5-m (nominal 100 ft) total length beach seine with 1-cm mesh (bar) in the wings and 0.5-cm mesh (bar) in the bag, to collect YOY fish in the shorezone of each region, except the Battery region. One end of the net is held on shore and the other end towed perpendicularly away from the shore by boat. The seine is then hauled, clockwise if possible, in a semicircular path toward shore. The complete beach seine deployment sweeps an area of approximately 450 m^2 (TI 1981).

Measurements of water temperature (°C), dissolved oxygen (mg/L), and specific conductance (microsieman/cm at 25°C) are taken with each beach seine sample using *in-situ* water quality instrumentation. Physical/chemical measurements are taken 1 ft below the water surface and approximately 50 ft from the shoreline.

As in the FSS program, YOY fishes collected during the first few beach seine river runs are processed in the laboratory because of the difficulty in distinguishing species at the YOY life stage. Field and laboratory sample processing are conducted similar to the FSS program.

4 CALCULATION METHODS

4.1 CALCULATIONS FOR FORMAT 1 DATA

(1) Unstandardized River Segment 4 annual densities were computed as the 75th percentile of the weekly density estimates listed in the Format 2 data files. For the FSS and LRS, the units of Format 1 Unstandardized River Segment 4 annual densities are numbers per 1000 m^3. For the BSS, the units of Format 1 Unstandardized River Segment 4 annual densities are numbers per beach seine haul.

(2) Unstandardized River Segment 4 annual CPUEs were computed as the 75th percentile of the weekly density estimates listed in the Format 2 data files. For the FSS and LRS, the units of Format 1 Unstandardized River Segment 4 annual CPUEs are numbers per 1000 m^3.

(3) For the FSS and LRS, the Format 1 Unstandardized Riverwide annual CPUEs were computed as the sum of counts divided by the sum of volume sampled from the Format 2 data files. Counts and sample volumes were summed over the selected weeks of sampling and over River Segments 1 through 12. For the FSS and LRS, the units of Format 1 Unstandardized Riverwide annual CPUEs are numbers per 1000 m^3.

For the BSS, the Format 1 Unstandardized Riverwide annual CPUEs were computed as the sum of counts divided by sum of the number of samples from the Format 2 data files. Counts and numbers of samples were summed over the selected weeks of sampling and over River Segments 1 through 12. For the BSS, the units of Format 1 Unstandardized Riverwide annual CPUEs are numbers per beach seine haul.

(4) The Riverwide unstandardized abundance indices were taken from Appendix F of the 2011 Year Class Report. The methods used to calculate those indices of abundance are described in the documentation for the Format 2 data files. For the FSS the units of the Riverwide unstandardized abundance indices are numbers per 1000 m^3, and for the LRS, numbers per m^3. For the BSS, the units of the Riverwide unstandardized abundance indices are numbers per beach seine haul.

4.2 CALCULATIONS FOR FORMAT 2 DATA

4.2.1 Density tables

Estimates of population densities were made for the LRS and FSS. For the LRS and FSS, the number of fish (by species and life stage) captured in individual samples was first converted to density (number per m^3 of water sampled).

$$d_{ikrw} = \frac{c_{ikrw}}{v_{ikrw}} \quad [1]$$

Where

d_{ikrw} = Density (for a life stage and species) per m^3 for sample i in stratum k in region r during week w
c_{ikrw} = Number of fish caught (of a life stage and species) in sample i in stratum k in region r during week w
v_{ikrw} = Volume (m^3) of sample i in stratum k in region r during week w

The mean density (per m^3) for stratum k in region r in week w and the standard error of the mean were calculated using Equations 2a and 2b.

$$\overline{D}_{krw} = \frac{1}{n_{krw}} \sum_{i=1}^{n_{krw}} d_{ikrw} \quad [2a]$$

$$SE(\overline{D}_{krw}) = \sqrt{\frac{\sum_{i=1}^{n_{krw}} (d_{ikrw} - \overline{D}_{krw})^2}{n_{krw}(n_{krw}-1)}} \quad [2b]$$

$\overline{D}_{krw}$ = Average density per m^3 in stratum k in region r in week w
n_{krw} = Number of samples taken (or analyzed) in stratum k in region r in week w
$SE(\overline{D}_{krw})$ = Standard error of the average density in stratum k in region r during week w

To obtain a mean regional density and its standard error for each region during each sampling week, the stratum densities were weighted by the proportion of the regional river volume found in the stratum, V_{kr} (Table 3):

$$\overline{D}_{rw} = \frac{\sum_k D_{krw} V_{kr}}{\sum_k V_{kr}} \quad [3a]$$

$$SE(\overline{D}_{rw}) = \sqrt{\frac{\sum_k SE(\overline{D}_{krw})^2 V_{kr}^2}{(\sum_k V_{kr})^2}} \quad [3b]$$

If a stratum was not sampled, its volume was added to the volume of an adjacent stratum that was sampled. Stratum volume substitutions were made according to the following rules:

Stratum Not Sampled	Volume Added to Stratum
Shoal	Bottom
Bottom	Channel
Channel	Bottom

For the BSS, there is no volume or area swept recorded for each sample, therefore the region-week mean density (actually catch per haul) and standard error are calculated as:

$$\overline{D}_{rw} = \frac{1}{n_{rw}} \sum_{i=1}^{n_{rw}} c_{irw} \quad [4a]$$

$$SE(\overline{D}_{rw}) = \sqrt{\frac{\sum_{i=1}^{n_{rw}} (dc_{irw} - \overline{D}_{rw})^2}{(n_{rw} - 1)}} \quad [4b]$$

Density tables (BSSdensity, FSSdensity, LRSdensity) are provided as requested in the RAI:

TAXON: Taxon number of selected species (See Table 1)
REGION: Defined sampling region (1-12)
PROGRAM: Sampling program (either LRS, FSS, or BSS)
LIFESTAGE: Life stage selected (YOY only)
YEAR: Year of sampling (1979-2011)
START_DATE: First sampled date in the week
END_DATE: Last sampled date in the week
WEEK: Week number calculated from first Monday of each year. [In some weeks including a holiday, sampling was initiated on Sunday. The Sunday samples were assigned to the same week as the samples taken on the next day, Monday.]
DENSITY: Mean number of YOY captured per m^3 sampled (mean catch per sample for BSS)
SEDENSITY: Standard error of mean region-week density
NSAMPLES: Number of samples taken in region-week

4.2.2 CPUE tables

CPUE tables are provided as requested in the RAI. Sample catch (*c*), and sample volume (*v*) were summed within each region and week:

LRS & FSS:

$$Count_{rw} = \sum_k \sum_{i=1}^{n_{rw}} c_{irw} \quad [5]$$

$$Volume_{rw} = \sum_k \sum_{i=1}^{n_{rw}} v_{irw} \quad [6]$$

BSS:

$$Count_{rw} = \sum_{i=1}^{n_{rw}} c_{irw} \quad [7]$$

Weekly riverwide totals, indicated as region 13 were summed over the entire river.

$$Count_w = \sum_{r=1}^{12} Count_{rw} \quad [8]$$

$$Volume_w = \sum_{r=1}^{12} Volume_{rw} \quad [9]$$

Counts were calculated for YOY, and for YOY plus all fish older than YOY (Total Catch) combined. Variable definitions for the CPUE tables (BSScount, FSScount, LRScount) are:

PROGRAM: Sampling program (either LRS, FSS, or BSS)
YEAR: Year of sampling (1979-2011)
WEEK: Week number calculated from first Monday of each year. [In some weeks including a holiday, sampling was initiated on Sunday. The Sunday samples were assigned to the same week as the majority of samples.]
REGION: Defined sampling region (1-12), or total river (regions 1-12 combined = 13)
RIVERREGION: Name of river region (e.g. Tappan Zee, Indian Point, Albany)
TAXON: Taxon number of selected species (See Table 1)
COMMON_NAME: Name of taxon (See Table 1)
COUNT_YOY: Number of YOY of selected species
COUNT_TOTAL: Count of YOY, Yearling, and older fish of selected species
NSAMPLES: Number of samples collected in the region in the week
VOLUME_M3: Sum of individual sample volumes in the region and week (m^3)

4.2.3 Abundance Index tables

Although NRC requested index values for the same species list (Table 1) as for the other data summaries, not all species requested are effectively captured by these programs. In the annual Year Class Reports, an annual abundance index is developed for 13 of the 17 requested species, using sampling programs that are effective for particular life stages of each. The data previously provided to NRC included indices for these 13 taxa.

Annual indices of abundance for 13 species of finfish were computed from data from the LRS, FJS and BSS from 1979 through 2011. For each of the 13 species, one or more sampling programs were selected to be the basis for the index of abundance. The selections considered when and where each species was expected to be present in the Hudson River based on life-history characteristics of each species in relation to the times and places that sampling gear was deployed by each program. The selections were also based on observed catch rates from each of the three sampling programs. The sampling programs on which the indices of abundance were based as well as the life stages and weeks selected for analysis are summarized in Table 4.

The statistical methods used to estimate the annual indices of abundance are described in the following sections.

Table 4 Parameters for Indices of Annual Abundance Based on Data from the Beach Seine Survey (BSS), Fall Juvenile Survey (FJS), and Longitudinal River Survey (LRS)

		Weeks Used in Sampling Program		
Species	Life Stage	BSS	FJS	LRS
Striped bass	Egg, YSL, and PYSL			Variable[1]
Striped bass	YOY	33-40		
White perch	Egg, YSL, and PYSL			Variable[1]
White perch	YOY and Yearling	33-40		
Atlantic tomcod	PYSL and YOY combined			19-22
Bay anchovy	YOY		33-40 (Channel)	
American shad	Egg, YSL, and PYSL			Variable[1]
American shad	YOY	33-40		
Alewife	YOY	33-40	33-40 (Channel)	
Blueback herring	YOY	33-40	33-40 (Channel)	
Rainbow smelt	YOY		33-40 (Channel)	20-27
Hogchoker	YOY		40-43 (Bottom)	
Spottail shiner	YOY	33-40		
White catfish	Yearling and older	33-40		
Weakfish	YOY		33-40 (Channel)	
Bluefish	YOY	33-40		

[1] 7 weeks beginning with the first week in which 5% of annual total is achieved

4.2.3.1 Longitudinal River Survey

Indices of abundance using data from the LRS were calculated for striped bass, white perch, American shad, Atlantic tomcod and rainbow smelt. For striped bass, white perch and American shad, the indices are based on the egg, yolk-sac larvae (YSL), and post yolk-sac larvae (PYSL) life stages and the weeks selected depend on the period of abundance. For Atlantic tomcod the index was based on PYSL and juveniles combined over weeks 19 through 22 and for rainbow smelt the index was based on the juvenile life stage in weeks 20 through 27. The Long River Survey Index of abundance (*L*) for each year and species is a measure of average density and is calculated according to the following formula:

$$L = \sum_{w=firstwk}^{lastwk} \left[\frac{\sum_{i=1}^{12}\sum_{s=1}^{5} V_{is} \left(\frac{\sum_{j} Ct_{jisw}}{\sum_{j} v_{jisw}} \right)}{\sum_{i=1}^{12}\sum_{s=1}^{5} V_{is}} \right],$$

where

L = the LRS index for any species in any year;
Ct_{jisw} = the count of a species in sample *j*, region *i*, stratum *s*, and week *w*;
v_{jisw} = the volume of sample *j* from in region *i* , stratum *s*, and week *w*;
V_{is} = the volume of stratum *s* in river region *i*;
firstwk = the first week included in the annual index of abundance:
striped bass, American shad, and white perch egg, YSL, and PYSL -- the first week of the year in which the sum of weekly density estimates (from the initial week of sampling in the year through the current week) exceeds 5% of the sum of densities over all weeks of sampling,
Atlantic tomcod PYSL and juveniles combined -- week 19, and
rainbow smelt juveniles -- week 20; and
lastwk = the last week included in the annual index of abundance:
striped bass, American shad, and white perch egg, YSL, and PYSL -- *firstwk* +7;
Atlantic tomcod PYSL and juveniles combined -- week 22; and
rainbow smelt juveniles -- week 27.

The above equation can be expressed in terms of average sample density as follows:

$$L = \sum_{w=firtswk}^{lastwk} \overline{Y}_{w} = \sum_{w=firstwk}^{lastwk} \left[\frac{\sum_{i=1}^{12}\sum_{s=1}^{5} V_{si}\overline{Y}_{isw}}{\sum_{i=1}^{12}\sum_{s=1}^{5} V_{si}} \right],$$

where

$\overline{Y}_{isw}$ = the average density of a species in samples from region *i*, stratum *s*, and week *w* [Note: for strata and regions that were not sampled, predicted densities (based on regression predictors and densities in adjacent strata) were used] and
$\overline{Y}_{w}$ = the weighted average density of a species in samples collected during week *w.*

Variance of the index was estimated using the following equation:

$$\mathrm{var}(L) = \sum_{w=firstwk}^{lastwk} \left[\frac{\sum_s \sum_i V_{is}^2 \left(\frac{n_{si} \left(\sum_j \frac{\left(Ct_{jisw} - \overline{Ct}_{isw} \right)^2}{n_{si} - 1} \right)}{\left(\sum_j v_{jisw} \right)^2} \right)}{\left(\sum_s \sum_i V_{is} \right)^2} \right],$$

where

V_{is} = the total volume in region *i* and stratum *s*.

Then:

std. err.(L) = (var(L))$^{1/2}$.

As indicated in Heimbuch et al. (1992), for indices based on LRS sampling, the volume of water between the beach and 10 ft deep was divided into two substrata: beach and shore. The beach stratum, defined from the beach to water five ft deep, corresponds with the shallow waters sampled in the BSS. The shore stratum, defined as water greater than five ft deep and less than 10 ft deep, is an unsampleable region. Densities in these substrata were estimated based on fixed ratios to the densities in adjacent strata.

4.2.3.2 Fall Shoal Survey

Indices of abundance using data from channel sampling by the FSS (also known as the Fall Juvenile Survey or FJS) were calculated for juvenile blueback herring, alewife, bay anchovy, weakfish, and rainbow smelt for the years 1979 through 2011, the years that the channel was sampled. In addition, indices of abundance based on bottom sampling by the FSS were calculated for juvenile hogchoker. Weeks 33 to 40 were selected as the only period consistently sampled in the FSS for channel sampling and weeks 40 to 43 for bottom sampling. The Fall Shoal Survey Index of abundance (F) for each year and species sampled in gear specific for either the channel or the bottom is a measure of average density and is calculated according to the following formula:

,

$$F_g = \frac{1}{n} \sum_{w=33}^{40} \left[\frac{\sum_{i=1}^{12} \sum_{s=1}^{3} V_{is} \left\{ \frac{1000 \sum_j Ct_{jiswg}}{\sum_j v_{jiswg}} \right\}}{\sum_{i=1}^{12} \sum_{s=1}^{3} V_{is}} \right] X_w$$

where

F_g = the FSS index (for gear *g*) for a species in a year;
Ct_{jiswg} = the count of a species in sample *j* from gear *g*, region *i*, stratum *s*, and week *w*;
X_w = 1 if week *w* was sampled during the year, 0 otherwise;
n = the number of weeks sampled in the year,
= $\sum_{w=33}^{40} X_w$;
v_{jiswg} = the volume of sample *j* from gear *g* in region *i* , stratum *s*, and week *w*; and
V_{isg} = the volume of stratum *s*, sampled by gear *g*, in river region *i*.

The above equation can be expressed in terms of weighted average sample densities as follows:

$$F_g = \frac{1}{n}\sum_{w=33}^{40}\overline{Y}_{wg}X_w = \frac{1}{n}\sum_{w=33}^{40}\left[\frac{\sum_{i=1}^{12}\sum_{s=1}^{3}V_{si}\overline{Y}_{iswg}}{\sum_{i=1}^{12}\sum_{s=1}^{3}V_{si}}\right]X_w,$$

where

$\overline{Y}_{iswg}$ = the average density (number per 1000 m^3) of a species in samples from region *i*, stratum *s*, week *w*, and gear *g* and
$\overline{Y}_{wg}$ = the weighted average density of a species in samples from week *w*, and gear *g*.

Because not all weeks within the period of week 33 to 40 (or 40 to 43 for bottom sampling) were sampled by the FSS in each year, the variance of the FSS index of abundance in any year is calculated as the sum of two components. The primary unit in the first stage is weeks, and the design is assumed to be simple random sampling (i.e., weeks of sampling are construed to be a random sample of weeks within the period from week 33 through week 40 or from week 40 through week 43). The sampling units in the second stage are region-(habitat) strata, and the design is stratified random where region-(habitat) strata are the statistical strata. The variance is calculated using a two-stage estimator based on equation 11.24 in Cochran (1977, p. 303):

$$\mathrm{var}\left(F_g\right) = \frac{\left(1-\frac{n}{N}\right)}{n}S_{1,g}^2 + \frac{1}{Nn}\sum_{w}S_{2,gw}^2,$$

where

$S_{1,g}^2$ = the first stage variance (temporal, among weeks),
$S_{2,gw}^2$ = the second stage variance (spatial) in week w, and
N = the number of weeks (8 or 4) within the selected period, i.e., weeks 33 through 40 or weeks 40 through 43.

The first stage variance component is calculated as:

$$S_{1,g}^2 = \frac{1}{n-1}\sum_{w=33}^{40}\left(\overline{Y}_{wg} - F_g\right)^2 .$$

The second stage variance is calculated as:

$$S_{2,gw}^2 = \frac{\sum_{i=1}^{12}\sum_{s=1}^{3}\left[V_{isg}^2 \frac{\left(\frac{h_{iswg}\sum_j\left(Ct_{jiswg} - \overline{C}t_{iswg}\right)^2}{h_{iswg}-1}\right)}{\left(\sum_j v_{ijswg}\right)^2}\right]}{\left(\sum_{i=1}^{12}\sum_{s=1}^{3}V_{isg}\right)^2},$$

where

V_{isg} = the total volume of (habitat) stratum, *s*, and region, *i*, sampled by gear *g*.

Then:

std. err. (F_g) = (var(F_g))$^{1/2}$.

4.2.3.3 Beach Seine Survey

Indices of abundance using data from the BSS were calculated for juvenile striped bass, white perch, American shad, alewife, blueback herring, bluefish, and spottail shiner; for yearling white perch; and for yearling and older white catfish. Weeks 33 to 40 were selected as the only period consistently sampled in the BSS. The Beach Seine Survey Index of abundance (*B*) for each year and species is a measure of catch per haul and is calculated according to the following formula:

$$B = \frac{1}{n}\sum_{w=33}^{40}\left[\frac{\sum_{i=1}^{12}W_i\left(\frac{\sum_j Ct_{jiw}}{h_{iw}}\right)}{\sum_{i=1}^{12}W_i}\right]X_w ,$$

where

B = the BSS index for a species in a year;
Ct_{jiw} = the count of a species in sample *j*, region *i*, and week *w*;

X_w = 1 if week *w* was sampled during the year, 0 otherwise;
n = the number of weeks sampled in the year,
= $\sum_{w=33}^{40} X_w$;
h_{iw} = the number of seine hauls in region *i* and week *w*; and
W_i = the number of beaches in the sampling design in river region *i*.

The above equation can be expressed in terms of a weighted average catch per haul (CPH) as follows:

$$B = \frac{1}{n}\sum_{w=33}^{40}\bar{Y}_w X_w = \frac{1}{n}\sum_{w=33}^{40}\left[\frac{\sum_{i=1}^{12} W_i \bar{Y}_{wi}}{\sum_{i=1}^{12} W_i}\right] X_w ,$$

where

$\bar{Y}_{wi}$ = the average CPH in week *w* and region *i* and
$\bar{Y}_w$ = the weighted average CPH in week *w.*

Because not all weeks within the period of week 33 to 40 were sampled by the BSS in each year, the variance of the BSS index in any year is calculated as a two-stage variance. The primary sampling unit in the first stage is weeks, and the design is assumed to be simple random sampling (i.e., weeks of sampling are construed to be a random sample of weeks within the period from week 33 through week 40). The sampling units in the second stage are regions, and the design is stratified random where regions are the statistical strata. The variance is calculated using a two-stage estimator based on equation 11.24 in Cochran (1977, p. 303):

$$\mathrm{var}\left(B\right) = \frac{\left(1-\frac{n}{N}\right)}{n} S_1^2 + \frac{1}{Nn}\sum_w S_{2,w}^2 ,$$

where

S_1^2 = the first stage variance (temporal, among weeks),
$S_{2,w}^2$ = the second stage variance (spatial) in week w, and
N = the number of weeks (8) within the selected period, i.e., weeks 33 through 40.

The first stage variance component is estimated as:

$$S_1^2 = \frac{1}{n-1}\sum_{w=33}^{40}\left(\bar{Y}_w - B\right)^2 .$$

The second stage variance component is estimated as:

$$S^2_{2,w} = \frac{\sum_{i=1}^{12} W_i^2 \left[\frac{\sum_j \left(Ct_{jiw} - \frac{1}{h_{iw}} \sum_j Ct_{jiw} \right)^2}{(h_{iw})(h_{iw}-1)} \right]}{\left(\sum_{i=1}^{12} W_i \right)^2}.$$

Then:

std. err.(B) = (var(B))$^{1/2}$.

Abundance index tables are provided as requested in the RAI (BSSindex, FSSindex, LRSindex). Variable definitions for the abundance index are:

YEAR: Year of sampling (1979-2011)
PROGRAM: Sampling program (either LRS, FSS, or BSS)
LIFESTAGE: Life stage selected (Egg, YSL, PYSL, YOY)
TAXON: Taxon number of selected species (See Table 1)
INDEX: Annual abundance index value
SEINDEX: Standard error of annual index

APPENDICES

APPENDIX 1

Common and Scientific Names

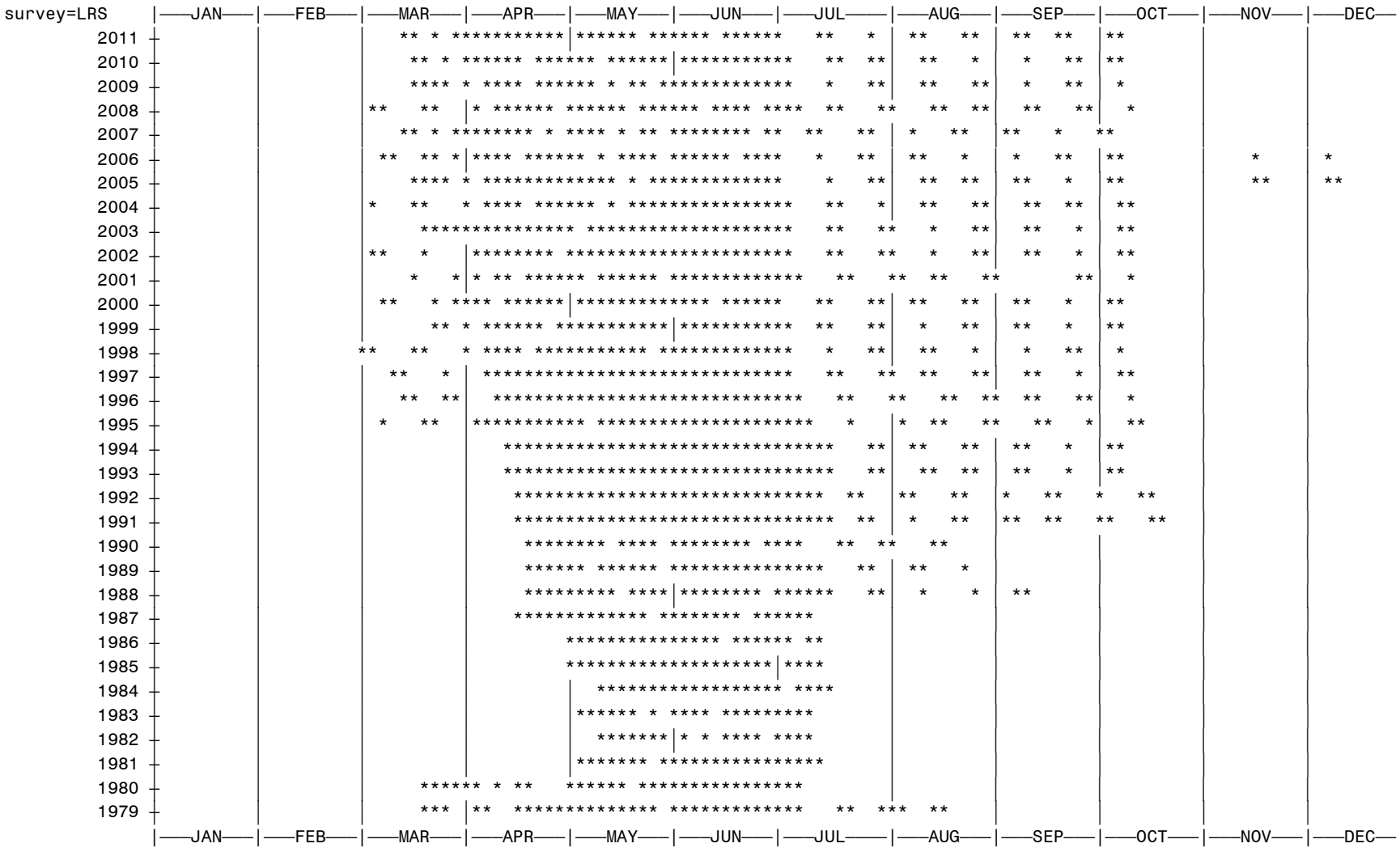
Appendix Table A-1. Common and Scientific Names of Fish Species

Taxon Code	Common Name	Scientific Name
1	Alewife	*Alosa pseudoharengus*
2	Bay anchovy	*Anchoa mitchilli*
3	American shad	*Alosa sapidissima*
4	Bluefish	*Pomatomus saltatrix*
13	Hogchoker	*Trinectes maculatus*
19	Atlantic Menhaden	*Brevoortia tyrannus*
22	Blueback herring	*Alosa aestivalis*
25	Rainbow smelt	*Osmerus mordax*
27	Shortnose sturgeon	*Acipenser brevirostrum*
28	Spottail shiner	*Notropis hudsonius*
29	Atlantic Sturgeon	*Acipenser oxyrhynchus*
30	Striped bass	*Morone saxatilis*
32	Atlantic Tomcod	*Microgadus tomcod*
34	White catfish	*Ictalurus catus*
35	White perch	*Morone americana*
45	Weakfish	*Cynoscion regalis*
50	River herring (or Alosa)	*Alosa spp.*
75	Gizzard shad	*Dorosoma cepedianum*

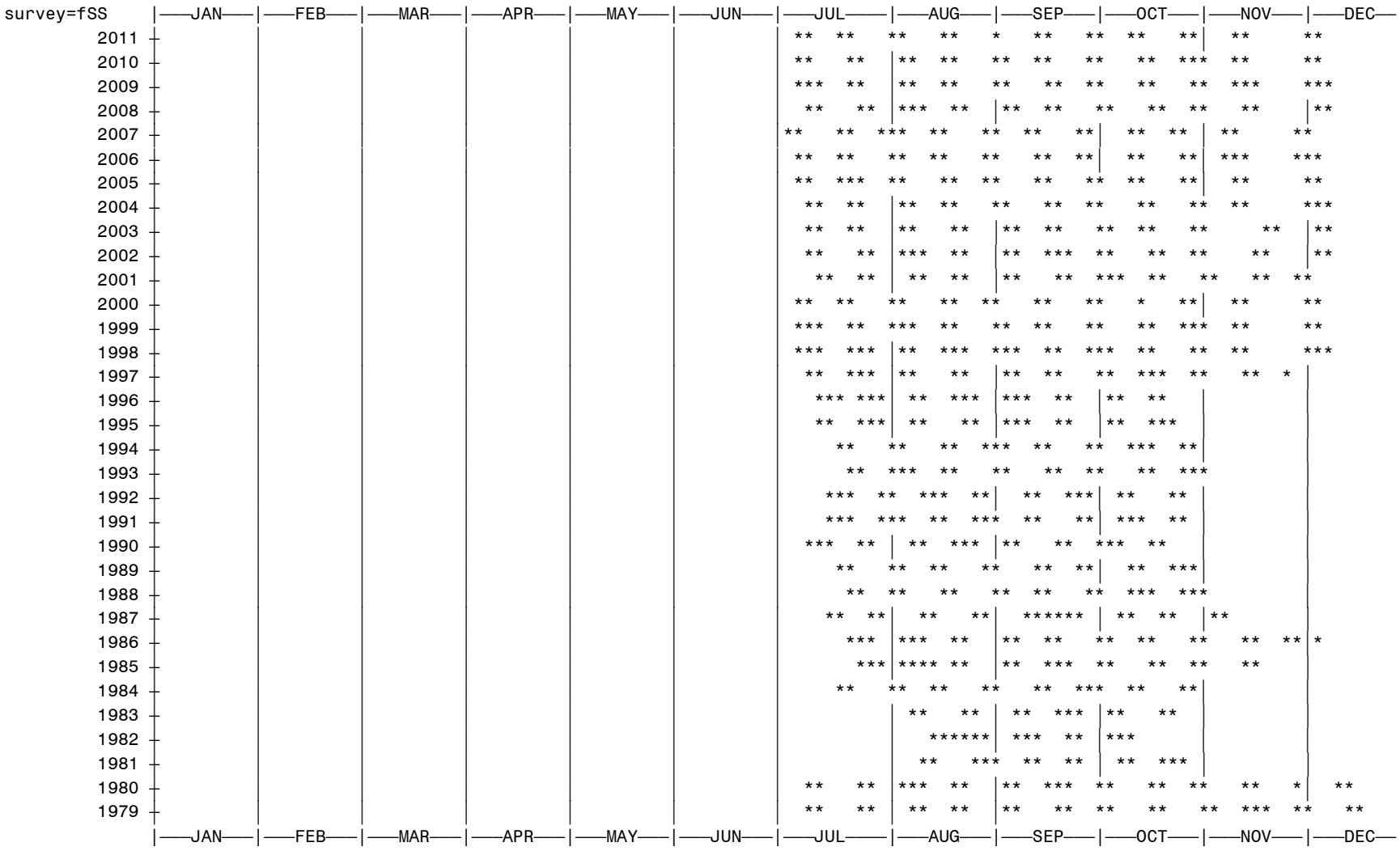
APPENDIX 2

Survey Sample Dates

Appendix Table 2-1 Sample dates for Long River Survey Program, 1979-2011.



Appendix Table 2-2 Sample dates for Fall Shoal Survey Program, 1979-2011.



Appendix Table 2-3 Sample dates for Beach Seine Survey Program, 1979-2011.