CHAPTER 2 MATERIALS AND METHODS

2.1 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, 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. During 2000, survey-specific techniques were employed which were consistent with previous Hudson River Monitoring Programs.

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

- Longitudinal River Ichthyoplankton Survey (LRS or Long River Survey)— Sampling encompassed 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. The LRS yielded 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*). LRS sampling was concentrated during the spring, summer, and early fall when eggs and larvae of the primary species have historically been abundant.
- Fall Shoals Survey (FSS or Fall Juvenile Survey)—Samples were collected every other week from the Battery 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.
- 3. **Beach Seine Survey** (BSS)—Beach seine samples were collected in alternate weeks relative to the FSS at stations ranging from the George Washington Bridge (RM 12) to the Troy Dam. The objective was to obtain distribution and relative abundance information on YOY American shad, Atlantic tomcod, striped bass, and white perch during periods when these species were concentrated primarily in the shallow, near-shore areas. The survey was conducted from mid-June through October, when YOY of these species were typically abundant in the shorezone nursery areas.

Sampling for all surveys was 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. The strata, based on river depth, are graphically presented in Figure 2-2 and defined below:

- **Shore**—That portion of the Hudson River estuary extending from the shore to a depth of 10 ft (the stratum defined only for BSS).
- **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 but may be characterized using the three cross section views presented in Figure 2-2. For example, the low relief sectional is characteristic of the Tappan Zee and Croton-Haverstraw regions, the high relief sectional is exemplified by the Yonkers and Poughkeepsie regions, and the fjord relief sectional represents the West Point region.

A minimum of two samples was assigned to each stratum in most regions for the LRS. However, no samples were allocated in the Poughkeepsie through Albany regions during the first three sampling weeks of the LRS (6 March - 2 April) nor in the Hyde Park through Albany regions during the final seven sampling weeks of the LRS (10 July - 8 October) because few organisms of the target species were historically present in these regions during these weeks. A minimum of two samples was assigned to each stratum in each region for the FSS except no channel samples were allocated during the final three sampling weeks (23 October – 3 December). A minimum of three samples was allocated in each region for the BSS. Shoal strata samples were not assigned in upriver regions nor were shoal or shore strata samples assigned in the Battery region. The strata actually sampled in each region during the 2000 survey period are presented in Table 2-1.

A general summary of the three sampling surveys for the annual monitoring program is presented in Table 2-2. The field and laboratory methods used for each survey are described in detail in the following sections.

2.2 LONGITUDINAL RIVER ICHTHYOPLANKTON SURVEY

2.2.1 Field Methods

The 2000 LRS was performed over a period of 31 weeks from 6 March to 6 October (Table 2-2 and Figure 2-3). For the first four weeks, sampling was conducted on three of the four weeks between RM 1 and RM 61 with all samples collected during the day. For the next four weeks beginning 3 April, weekly sampling encompassed RM 1 to RM 152 with samples continuing to be collected during the day. Beginning the week of 1 May for nine consecutive weeks sampling was conducted at night between RM 1 and RM 152. In the final phase of sampling from 10 July through 5 October, sampling was conducted biweekly between RM 1 and RM 76 with all samples collected at night. Between 15 May and 7 September, approximately 10 additional trawl (channel strata) samples were collected per week. The samples were specially preserved so that aging of striped bass larvae could be conducted.

The allocation of sampling effort among river regions and strata was temporally adjusted in response to the projected presence and distribution of target species and life stages. The 2000 LRS sampling program was scheduled as 6 separate multi-week efforts. The first sampling effort, performed in March, focused on the collection of Atlantic tomcod post yolk-sac larvae (PYSL). The second effort, performed during early April, focused on the collection of American

shad eggs. The third effort, from late April to mid-May, was designed to collect eggs of *Morone* spp. and American shad. The fourth effort, performed from mid-May through the beginning of June, targeted *Morone* spp. and American shad yolk-sac larvae (YSL). The fifth effort, in June, was designed to collect *Morone* spp. and American shad PYSL. The LRS sampling program concluded with a 13-week period, sampled biweekly, from the middle of July to early October. The final sampling effort was designed to collect all life stages of bay anchovy.

The allocation of sampling effort among regions and strata is presented in Table 2-3. Of the 3,647 ichthyoplankton samples (including 125 striped bass otolith aging samples) scheduled for collection during 2000, 3,646 samples were collected, accounting for nearly 100 percent of the scheduled total.

Two distinct gear types were used for field collections during the 2000 LRS:

- 1.0-m² Tucker trawl (Figure 2-4 and Table 2-4) to sample the shoal and channel strata (non-bottom), and
- 1.0-m² epibenthic sled (Figure 2-5 and Table 2-4) to sample the bottom-only shoal and channel strata.

Both gear types were towed against the prevailing current for 5 minutes. The tow started with the remote opening of the net and terminated with its remote closing. If the river depth was 20 ft or less, an open set and retrieval of the net was performed. The tow speed for the Tucker trawl was adjusted to maintain a towing wire angle of approximately 45° averaging approximately 0.9 m/second. The tow speed for the epibenthic sled-mounted net was 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 was used to establish and maintain tow speed. A calibrated digital flowmeter mounted in the center of the net mouth was used to calculate the volume of water filtered for each sample.

Following deployment and retrieval of the sampling gear, net washing was performed to concentrate the sample into the codend bucket. The samples were then examined for yearling and older fish which were identified, enumerated, and returned to the Hudson River estuary. Special care was taken to observe sturgeon species for physical condition and for the presence of marks and/or tags. All yearling and older sturgeon were measured to the nearest millimeter, weighed to the nearest gram, and, if alive, returned to the river or, if dead, frozen and saved for the NYSDEC. After yearling and older fish were removed, the remaining sample was placed in container(s) so that the sample occupied no more than 25 percent of the container volume. The containers were filled with a 10 percent aqueous formalin solution.

In situ measurements of water temperature (°C), dissolved oxygen (mg/L), and specific conductance (microsieman/cm at 25°C) were taken with calibrated meters at fixed river mile and strata stations in conjunction with the biological sampling. The number of physical/chemical sampling locations, by river mile and strata, are presented in Table 2-5 for the 2000 LRS. Physical/chemical measurements were recorded from surface, mid-depth, and bottom water depth at channel stations and from the surface and bottom water depth at shoal stations. During the 23 collection weeks of the 2000 LRS, 3,520 physical/chemical measurements were scheduled, with 3,509 measurements actually recorded, accounting for 99.7 percent of the scheduled total.

Ichthyoplankton samples collected for striped bass otolith aging were handled in the same manner as regularly scheduled LRS samples except that a 95 percent ethanol preservative was substituted. Within 48 hours, the samples were drained and placed in fresh 95 percent ethanol.

2.2.2 Laboratory Methods

In 2000, approximately 70 percent of the regular LRS samples were selected for laboratory analysis. Selection of samples for laboratory analysis began with the grouping of samples according to river run, region, and strata. Based on these groupings, samples were selected based on one of the following criteria:

- 1. If there were less than 6 samples in the group, then all were selected for analysis.
- 2. If there were between 6 and 12 samples in the group, then 50 percent of the samples were randomly selected for analysis.
- 3. If there were more than 12 samples in the group, then 20 percent of the samples were randomly selected for analysis.

The allocation of samples for laboratory analysis among regions, strata, and gear types based on these criteria is listed in Table 2-6. The total number of analyzed samples was 2,435, comprising 69.2 percent of the collected samples (excluding those collected for otolith analysis).

In 2000, as in previous years, splitting (or subsampling) was permitted. A trained technician first determined, by visual inspection, if the sample needed splitting. Samples containing large numbers of eggs may have been split so that eggs were only sorted from one or more aliquots containing a total of at least 250 eggs (all species combined).

Two different sets of criteria were used for subsampling of larval stages, depending on the river run. Beginning with the river run in which striped bass PYSL first appeared, 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*) was sorted from the entire sample and a minimum of 50 non-*Morone* larvae was also sorted. Because some of the more difficult distinctions between species (e.g., striped bass versus white perch) or between life stages could not be made reliably during sorting, samples from these 9 river runs were typically sorted in their entirety for larvae (i.e., YSL, PYSL, and YOY combined) of all species combined. An exception to this may have been made, at the discretion of the laboratory supervisor, under the following circumstances: when extremely large numbers of non-*Morone* larvae occurred in the sample and a qualified identifier had verified that sufficient numbers of both *Morone* larvae and non-*Morone* larvae were sorted to meet their respective subsampling quotas. The purpose of this exception was 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 applied to the 13 other river runs not covered in the previous paragraph (before and after the period of striped bass abundance). Any sample from these river runs may have been subsampled so that larvae were 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 were performed by an assistant so that the sorter had no prior knowledge of which splits were to be used for the analysis. This procedure is explained in Figure 2-6. Randomness of the splitting procedure was monitored and demonstrated by testing selected samples to determine whether splits from the same sample differed by more than random variation. Samples were selected to test for randomness

by a continuous sampling plan, shown in Figure 2-7 (CSP-V from MIL-STD-1235, AOQL = 10 percent).

For each split sample evaluated, three fractions of the same aliquot size were sorted and compared by the chi-square test according to the following procedure. The counts of the three splits (including any quality control [QC] finds) were averaged to obtain the expected value for the sample. Chi-square was calculated as:

chisquare =
$$\frac{(O_1 - E)^2}{E} + \frac{(O_2 - E)^2}{E} + \frac{(O_3 - E)^2}{E}$$

where

 O_1 , O_2 , and O_3 = Observed counts for splits 1, 2, and 3.

E = Expected value for the sample (average of O_1 , O_2 , and O_3).

If the calculated value for chi-square was less than 5.99, then the splits of that sample were considered random, and the sample passed the split QC (5.99 was the critical value of chi-square with two degrees of freedom at an alpha level of 0.05). If a sample was split for both eggs and larvae, then both stages were tested separately. The sample passed the split QC only if chi-square was below the critical value for both life stages.

Eggs and larvae were 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 were evaluated by a trained technician under magnification and all organisms were identified and enumerated. The following life stage designations were 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 form, and							
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. Measurements were recorded on the laboratory data sheet. Selection of specimens for measuring was randomized by spreading them uniformly in a gridded container, selecting a starting point in the grid by means of a random number table, and then measuring the first 30 measurable specimens encountered in a predetermined pattern commencing at the starting point. Every grid space had an equal probability of being selected as the starting point, so every specimen had an equal probability of being included in the subsample.

Continuous sampling inspection was employed during the sort and identification procedures to ensure an average outgoing quality limit of 10 percent or better. Two sampling modes were required in the continuous sampling plan (CSP-1):

Mode 1—The first eight samples sorted or analyzed for larval identification by an individual are subject to 100 percent QC reanalysis. If all eight pass the reanalysis, i.e., if \leq 10 percent of the ichthyoplankton are missed or misidentified per sample, the individual is placed in CSP Mode 2. If any sample fails during Mode 1, then Mode 1 is continued until eight consecutive samples pass. For example, if a sample with QC No. 7 fails, then samples with QC Nos. 8 through 15 are subject to QC resorting.

Mode 2—Lots of seven consecutive samples per individual are assigned for identification QC and per laboratory facility for sort QC. One sample from each lot is randomly chosen for QC analysis. If a sample fails (>10 percent of organisms missed or misidentified) during Mode 2, the individual is placed back into Mode 1. For example, if a sample with QC No. 6 fails in a lot of seven samples, then samples with QC Nos. 7 through 14 are subject to QC reanalysis. If samples 7 through 14 pass, the individual is again placed in Mode 2.

Results of the 2000 CSP-1 Quality Control Program are contained in Appendix A.

2.3 FALL SHOALS SURVEY

2.3.1 Field Methods

The 2000 FSS biweekly sampling program extended from RM 1 to 152 and covered 22 weeks from 5 July to 30 November (Figure 2-3). Samples were collected at night for the first 8 river runs from 5 July through 12 October, and during the day for last 3 river runs from 23 October through 30 November. These last river runs, which were conducted with a modified sampling design, were intended to examine Atlantic tomcod distribution. Table 2-7 presents the distribution of the FSS sampling effort among the 13 river regions by stratum. Of the 2,130 samples scheduled for collection, 2,113 were actually collected, yielding 99.2 percent completion.

A 1.0-m² Tucker trawl and a 3.0-m beam trawl were used to collect YOY fish in the 2000 FSS. The Tucker trawl with 3.0-mm mesh was used to collect samples in the channel stratum, while the beam trawl (Figure 2-8) was 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. With the modified sampling design of the last 3 river runs from 23 October through 30 November, no channel samples or Tucker trawl samples were scheduled for collection. Only beam trawl samples in the shoal and bottom strata were taken during these river runs. Design specifications for FSS gear currently in use are listed in Table 2-8.

Both gear types were towed against the prevailing current for approximately 5 minutes. For the Tucker trawl, vessel speed was adjusted as necessary to achieve and maintain a 45° wire angle; the resultant tow speed was recorded. The beam trawl was towed at a speed of approximately 1.5 m/second. Tow speed was established and maintained by use of an electronic flowmeter mounted along the side of the research vessel and equipped with an ondeck readout display. Tucker trawl samples taken in greater than 20 ft of river depth were

remotely opened and closed at sampling depth. A calibrated digital flowmeter mounted in the center of the net mouth was used to calculate the volume of water filtered for each sample.

Calibrated water quality instruments were 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. Sampling locations were the same as those used for the 2000 LRS sampling program (Table 2-5). Measurements of physical/chemical parameters were recorded from surface, mid-, and bottom water depths at channel stations and from surface and bottom water depths at shoal stations. During the 2000 FSS, of the 2,002 samples scheduled for collection, 1,984 were actually collected, yielding 99.1 percent completion.

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) for the 2000 FSS program were preserved with 10 percent formalin at the time of collection and returned to the laboratory for analysis. Before preservation, samples were examined for fish determined to be yearling or older, based on length categorization; live fish were returned to the river after count data were determined.

Beginning with the third biweekly sampling period, samples were evaluated in the field; only fish required to fill length measurement and food habit quotas were returned to the laboratory. The quota was to be 20 specimens of a selected species from each river region per river run; because of the necessity of returning fish to the river alive, the first 20 specimens of a selected species were brought to the laboratory for length measurements. The Hyde Park through Albany regions were considered one region for the purpose of filling length measurement quotas during the entire FSS and during River Runs 4 through 10 of the BSS. Also for the BSS during River Runs 1 through 3, the Yonkers through West Point regions were considered as one region for the same purpose. In river regions where fewer than 10 samples were collected per survey, no more than 10 specimens of each selected species from an individual sample were used to fill the length measurement quota. This criterion was used in the following surveys for the specified river regions:

Sampling Program	Region
BSS	YK, IP, WP, CW, PK
FSS	WP, PK

In all other regions, when the sample schedule resulted in 10 or more samples per survey, no more than 5 specimens per species in a sample were used to fill the length measurement quotas. If more specimens of a species were collected than needed, the individuals used to fill the quotas were randomly selected.

All fish not returned to the laboratory were identified and enumerated into length classes as described in the following section. All Atlantic sturgeon, shortnose sturgeon, and striped bass were examined for external and internal magnetic tags. All sturgeon were measured to the nearest millimeter, weighed to the nearest gram, and, if alive, returned to the river or, if dead, frozen and saved for the NYSDEC. All striped bass with external streamer tags were measured and a scale sample was taken.

2.3.2 Laboratory Methods

Fish from the FSS in both the field and laboratory were identified and enumerated into the following length classes:

Length Class 1—Less than or equal to the YOY 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 length limit ("Division 2"); set at 150 mm for most species, also determined weekly by the field contractor. 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.

Twenty specimens of the following selected species collected in each river region per river run were measured for total length (nearest millimeter) in the laboratory (except for sturgeon species which were measured in the field):

- Alewife
- American shad
- Atlantic sturgeon
- Atlantic tomcod
- Bay anchovy
- Blueback herring
- Shortnose sturgeon
- Spottail shiner
- Striped bass
 Weakfish
 White catfish
 White perch.

2.4 BEACH SEINE SURVEY

2.4.1 Field Methods

The 2000 BSS utilized a 30.5-m (nominal 100ft) total length beach seine to collect YOY fish in the shorezone of each region, except the Battery region. Table 2-9 presents specifications for the beach seine. One end of the net was held on shore and the other end was towed perpendicularly away from the shore by boat. The seine was then hauled, clockwise if possible, in a semicircular path toward shore. The complete beach seine deployment swept an area of approximately 450 m² (TI 1981). All BSS samples were collected on a diurnal schedule during alternate weeks of the FSS.

The 2000 BSS biweekly sampling program was conducted from 13 June through 18 October (Figure 2-3). Ten of the 19 weeks in this time period were collection weeks with 100 beach seine samples per week scheduled for collection. Allocation of the total number of samples by river region collected for the 2000 BSS is presented in Table 2-10. All of the 1,000 samples projected for collection in 2000 were collected, yielding 100 percent completion.

Measurements of water temperature (°C), dissolved oxygen (mg/L), and specific conductance (microsieman/cm at 25°C) were taken with each beach seine sample using *in-situ* water quality instrumentation. Physical/chemical measurements were taken 1 ft below the water surface and approximately 50 ft from the shoreline. During the 10 collection weeks of the 2000 BSS, all 1,000 scheduled water quality samples were collected.

YOY fishes collected during the first four beach seine river runs in 2000 were processed in the laboratory because of the difficulty in distinguishing species at the YOY life stage; adults were processed in the field. Beginning with River Run 5, all samples were field processed; 20 specimens of the selected species from each region per run were collected (as described in Section 2.3.1) for length determination in the laboratory. Samples maintained for laboratory analysis were preserved using 10 percent formalin. Fish from the BSS in both the field and laboratory were identified and enumerated into length classes as described in Section 2.3.2. Any sturgeon collected during the BSS were measured to the nearest 1 mm and weighed to the nearest 1 g. Fish that remained alive were returned to the Hudson River estuary; dead fish were frozen and held for NYSDEC. All sturgeon and striped bass were examined for external and internal magnetic tags. Striped bass with external tags were measured and a scale sample was taken.

2.4.2 Laboratory Methods

All fish returned to the laboratory were measured for total length to the nearest 1.0 mm. Laboratory analysis was conducted in the same manner as described for samples collected during the FSS.

2.5 ANALYTICAL METHODS

2.5.1 Physical/Chemical Parameters

To display the spatial and temporal patterns of temperature, salinity, and dissolved oxygen, a mean of each parameter for each sampling location and sampling week, weighted by stratum volume, was calculated. Equation 1 was used to compute these means for the standard physical/chemical stations sampled in conjunction with the LRS and FSS. Equation 2 was used for data collected in conjunction with the BSS. Salinity data were computed from conductivity data (microsieman/cm at 25°C) using Equation 3 (TI 1976). This equation differs from that used in some of the previous Year Class reports in that pressure data are not required. The maximum deviation between this equation and the previous equation is 0.1 percent (TI 1976).

$$W_{lw} = \sum_{k=1}^{n_{lw}} P_{kr} \left[1/n_{klw} \sum_{d=1}^{n_{klw}} \left(1/n_{dklw} \sum_{i=1}^{n_{dklw}} W_{idklw} \right) \right]$$
(1)

where

W_{Iw} = Weighted mean of a physical/chemical parameter at sampling location I during week w of the LRS and FSS.

- n_{dklw} = Number of sites at which measurements were made at depth d in stratum k at sampling location I during week w.
- n_{klw} = Number of depths sampled in stratum k at sampling location I during week w.
- n_{Iw} = Number of strata sampled at sampling location I during week w.

$$W_{rw} = 1/n_{rw} \sum_{i=1}^{n_{rw}} W_{irw}$$
 (2)

where

W _{rw}	=	Mean of a physical/chemical parameter at river mile r during biweek w of the BSS.	
W _{irw}	=	Physical/chemical measurement for location i at river mile r during biweek w.	
n _{rw}	=	Number of physical/chemical measurements taken at river mile r during biweek w.	
Salinity	=	-100 <i>In</i> (1 - C ₂₅ /178.5)	(3)

where

 C_{25} = Conductivity (millisieman/cm at 25°C).

2.5.2 Spatiotemporal Distribution Indices

2.5.2.1 Density and Catch-Per-Unit-Effort Estimates

Estimates of population densities were made for the LRS and FSS. For these two surveys the number of fish (by species and life stage) captured in individual samples was first converted to density (no./m³ of water sampled) using Equation 4. The mean density and the standard error of the mean were calculated for each stratum, region, and sampling week using Equations 5 and 6. To obtain a mean density and 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 (Equations 7 and 8). If a stratum was not sampled, its volume was added to the volume of an adjacent stratum that was sampled. Stratum volume adjustments were made according to the following rules:

If This Stratum Its Volume Was Added

	Was Not Sampled	To This Stratum	
	Shoal	Bottom	
	Bottom	Channel	
	Channel	Bottom	
	0		
ר	_ C _{ikrw}		

$$D_{ikrw} = \frac{O_{ikrw}}{V_{ikrw}}$$
(4)

where

D _{ikrw}	=	Density (for a life stage and species)/m ³ for sample i in stratum k in region r during week w.			
C _{ikrw}	=	Number of fish caught in sample i in stratum k in region r during week w.			

 V_{ikrw} = Volume sampled (m³) by sample i in stratum k in region r during week w.

$$D_{krw} = \frac{1}{n_{krw}} \sum_{i=1}^{n_{krw}} D_{ikrw}$$
(5)

where

D _{krw}	=	Average density in stratum k in region r during week w.

- D_{ikrw} = Sample density calculated in Equation 4.
- n_{krw} = Number of samples taken in stratum k in region r during week w.

$$SE(D_{krw}) = \sqrt{\frac{\sum_{i=1}^{n_{krw}} (D_{ikrw} - D_{krw})^2}{(n_{krw})(n_{krw} - 1)}}$$
(6)

where

SE(D _{krw})	=	Standard error of the average density in stratum k in	
		region r during week w.	

- D_{ikrw} = Sample density calculated in Equation 4.
- D_{krw} = Average stratum density calculated in Equation 5.

$$D_{rw} = \sum_{k=1}^{n_{rw}} (D_{krw})(P_k)$$
(7)

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k=1

where

$$D_{krw}$$
 = Average stratum density calculated in Equation 5.

$$P_k^*$$
 = Proportion of the regional river volume found in stratum k (Table 2-11).

n_{rw} = Number of strata sampled in region r during week w.

$$SE(D_{rw}) = \sqrt{\sum_{k=1}^{n_{rw}} \left[SE(D_{krw})^{2} (P_{k})^{2} \right]}$$
(8)

where

- SE(D_{rw}) = Standard error of average density in region r during week w.
- $SE(D_{krw})$ = Standard error of the average stratum density calculated in Equation 6.

Catches from the BSS were reported as number caught per seine haul (catch-per-unit-effort [CPUE]) by life stage and species. The average CPUE for a region and its standard error were calculated using Equations 9 and 10:

$$C_{rw} = \frac{1}{n_{rw}} \sum_{i=1}^{n_{rw}} C_{irw}$$
 (9)

where

- C_{rw} = Average CPUE in region r during week w.
- C_{irw} = CPUE for sample i in region r during week w.
- n_{rw} = Number of samples taken in region r during week w.

When a stratum is missing, P_k for the sampled stratum is equal to the sum of the P_k for the sampled stratum and the P_k for the unsampled stratum.

$$SE(C_{rw}) = \underbrace{\sum_{i=1}^{n_{rw}} (C_{irw} - C_{rw})^2}_{n_{rw}(n_{rw} - 1)}$$
(10)

where

- SE(C_{rw}) = Standard error of average CPUE in region r during week w.
- C_{rw} = Average regional CPUE calculated in Equation 9.

2.5.2.2 Standing Crop Estimates

An index of standing crop (the number of fish in an area at a particular time) was estimated by life stage and species for each of the three surveys. Standing crop indices and the associated standard errors were calculated for each stratum in a region by taking the product of the average stratum density (or the standard error) and the volume of water contained in that stratum (Equations 11 and 12 for the LRS and FSS) (Table 2-11). The regional standing crop index was then estimated as the sum of the stratum index values (Equations 13 and 14). Similarly, an estimate of the standing crop index for the Hudson River estuary for each week was calculated by summing the standing crops for the 13 (12 for the BSS) river regions (Equations 15 and 16). This value is an index rather than an absolute standing crop value because no adjustment was applied for collection efficiency.

$$SC_{krw} = (V_{kr})(D_{krw})$$
(11)

where

	SC _{krw}	=	Standing crop index for stratum k in region r during week w.	
	V _{kr}	=	River volume contained by stratum k in region r.	
	D _{krw}	=	Average stratum density calculated in Equation 5.	
	SE(SC _{krw})	=	(V _{kr})[SE(D _{krw})]	(12)
whe	ere			
	SE(SC _{krw})	=	Standard error of the standing crop index for stratum k in region r during week w.	
	SE(D _{krw})	=	Standard error of average stratum density calculated	

in Equation 6.

$$SC_{rw}^{**} = \sum_{k=1}^{3} SC_{krw}$$
 (13)

where

$$SC_{rw}$$
 = Standing crop index for region r during week w.

 SC_{krw} = Stratum standing crop index calculated in Equation 11.

$$SE(SC)_{rw}^{**} = \sqrt{\sum_{k=1}^{3} [SE(SC_{krw})]^2}$$
 (14)

where

- SE(SC_{rw}) = Standard error of standing crop index for region r during week w.
- $SE(SC_{krw})$ = Standard error of stratum standing crop index calculated in Equation 12.

$$SC_{w} = \sum_{r=1}^{12} SC_{rw}$$
(15)

where

SCw	=	Standing crop index for week w. For the LRS and FSS,
		regional standing crop indices include the Battery Region
		(r=0).

SC_{rw} = Regional standing crop index calculated in Equations 13 or 17.

$$SE(SC_w) = \sqrt{\sum_{r=1}^{12} [SE(SC_{rw})]^2}$$
 (16)

where

SE(SC_w) = Standard error of standing crop index for week w. For the LRS and FSS, regional standing crop indices include the Battery Region (r=0).

^{**} Volumes of unsampled strata were added to the volumes of an adjacent stratum according to the rules for stratum volumes in Section 2.5.2.

 $SE(SC_{rw})$ = Standard error of regional standing crop index calculated in Equations 14 or 18.

An index of regional standing crop (and standard error) for the BSS was obtained by multiplying CPUE and the surface area of the shorezone and dividing by the empirically derived estimate of the area sampled by the 30.5-m beach seine (Equations 17 and 18). The weekly index of standing crop for the shorezone was calculated as the sum of the 12 regional standing crops (Equations 15 and 16).

$$SC_{rw} = (C_{rw} A_r) / A$$
(17)

where

SC_{rw} = Standing crop index for the shorezone in region r during week w.

$$A_r$$
 = Surface area (m²) of the shorezone in region r.

A = Surface area (m^2) sampled by the beach seine (450 m²) (TI 1981).

$$SE(SC_{rw}) = [SE(C_{rw})] (A_r)$$
(18)

where

- SE(SC_{rw}) = Standard error of standing crop index for the shorezone in region r during week w.
- $SE(C_{rw})$ = Standard error of average regional CPUE calculated in Equation 10.

2.5.2.3 Temporal and Geographic Distribution Indices

Distribution indices were computed to facilitate presentation of changes in distribution of selected species and life stages through time and space. To allow comparisons of 2000 data with historical data, only data from samples collected from Weeks 18 to 27 (where Week 1 begins with the first Monday in January) were used for LRS (except for bay anchovy which used Weeks 18-40); data from Weeks 33 to 40 were used for the FSS and BSS. In all cases, data were used only when Regions 1-12 were sampled (except for bay anchovy which included Region 0).

The LRS was used for calculating the temporal and geographic indices for early life stages of striped bass, white perch, Atlantic tomcod, bay anchovy, American shad, *Alosa* spp., and rainbow smelt. The FSS was used to calculate geographical distribution indices for hogchoker, white catfish, and weakfish. The BSS was used to calculate geographical distribution indices for striped bass, white perch, bay anchovy, American shad, alewife, blueback herring, gizzard shad, spottail shiner, and bluefish.

The periods used for the LRS and BSS spanned 1974-2000, whereas the time period for the FSS extended from 1979 (when the FSS sampled the river from RM 12 to RM 152) through 2000. Temporal and geographic indices for bay anchovy from the LRS used the period from 1988 to 2000, when the sampling design included the Battery region.

A geographic index that collapses data over weeks was calculated for LRS, FSS, and BSS data as the relative standing crop in each region. This geographic index was calculated as follows:

$$G_{ry} = \frac{\sum_{w=1}^{n_y} SC_{rwy}}{\sum_{r=1}^{12} \sum_{w=1}^{n_y} SC_{rwy}}$$
(19)

where

$$G_{ry}$$
 = Geographic index for region r in year y.

$$n_y$$
 = Number of weeks sampled in year y.

A temporal index that collapses data for the entire Hudson River estuary was computed for early life stages from LRS standing crop indices (Equation 20):

$$T_{wy} = \frac{SC_{wy}}{\sum_{w=1}^{n_y} SC_{wy}}$$
(20)

where

 T_{wy} = Temporal index for week w in year y.

SC_{wy} = Weekly standing crop index in year y calculated in Equation 15.

n_y = Number of weeks sampled in year y.

Link to Chapter 3



Figure 2-1. Location of 13 geographic regions (with river mile boundaries) sampled during the 2000 biological monitoring program in the Hudson River estuary.



Figure 2-2. Cross sections of the Hudson River estuary showing locations and typical proportional relationships of the shoal, bottom, and channel strata.



Figure 2-3. Completed sampling schedule for 2000.



Figure 2-4. Design and dimensions of 1.0-m² Tucker trawl.



Figure 2-5. Design and dimensions of 1.0-m² Tucker trawl mounted on an epibenthic sled.



Figure 2-6. Conceptual diagram of the splitting process.

When nine consecutive samples are found within the	olerance.
The QC inspector is released from 100% inspection where the samples are selected in a random manne	n and inspects a fraction, $1/7$ of the samples, π .
If one defective sample is found before nine more samples have been inspected,	If nine consecutive QC samples are within tolerance,
Y	
	₩
The QC inspector continues to inspect fraction 1/1	of the randomly selected samples.
When the QC inspector finds one defective sampl	с,
	<u> </u>
	ne samples.
The QC inspector begins inspection of 100% of the	
The QC inspector begins inspection of 100% of the life one defective sample is found before three more samples have been increased.	If three consecutive QC samples are within tolerance.

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Figure 2-7. Inspection plan for evaluation of splitting precision.



Figure 2-8. Design and dimensions of the 3.0-m beam trawl.

			River	2000 Survey				
Region	Abbreviation	River Miles	Kilometers	<u>Shore</u>	<u>Shoal</u>	Channel	Bottom	
Battery	ВТ	1-11	1-19			Х	Х	
Yonkers	YK	12-23	19-39	Х	х	х	Х	
Tappan Zee	ΤZ	24-33	39-55	Х	х	х	Х	
Croton-Haverstraw	/ CH	34-38	55-63	Х	х	х	Х	
Indian Point	IP	39-46	63-76	Х	х	х	Х	
West Point	WP	47-55	76-90	Х		х	Х	
Cornwall	CW	56-61	90-100	Х	х	х	Х	
Poughkeepsie	PK	62-76	100-124	Х		х	Х	
Hyde Park	HP	77-85	124-138	Х		х	Х	
Kingston	KG	86-93	138-151	Х		х	Х	
Saugerties	SG	94-106	151-172	Х		х	Х	
Catskill	CS	107-124	172-201	Х		х	Х	
Albany	AL	125-152	201-246	Х		х	Х	

NOTE: Dashes (--) indicate no sampling scheduled.

Table 2-2 Summary of 2000 Hudson River Surveys

		Sample Number							
	Start	End	Number of	Sampling	Strata	Collec	tion	Lab	
Program Phase	<u>Week</u>	<u>Week</u>	River Runs	Frequency	Sampled	Projected	<u>Actual</u>	<u>Analysis</u>	Sampling Gear
Longitudinal River Ichthyoplankton Survey	6 MAR	2 OCT	23	Weekly/ Biweekly	Shoal	588	588	554	1.0-m ² net on epibenthic sled, or 1.0-m ² Tucker trawl
					Channel	1,670 ^a	1,669	955	1.0-m ² Tucker trawl
					Bottom	1,389	1,389	926	1.0-m ² net on epibenthic sled
Fall Shoals Survey	3 JUL	27 NOV	11	Biweekly	Shoal	427	426		3.0-m beam trawl, or 1.0-m ² Tucker trawl
					Channel	648	640		1.0-m ² Tucker trawl
					Bottom	1,055	1,047		3.0-m beam trawl
Beach Seine Survey	12 JUN	16 OCT	10	Biweekly	Shore	1,000	1,000		30.5-m beach seine

^a Includes 125 samples collected for striped bass otolith analysis.

TABLE 2-3 SUMMARY OF 2000 SAMPLE COLLECTION INFORMATION BY RIVER REGION AND STRATUM FOR THE LONGITUDINAL RIVER ICHTHYOPLANKTON SURVEY

	4-We	4-Week Period from 6 MAR to 31 MAR					ek Period	d from 3 A	PR to 21	I APR	3-Week Period from 24 APR to 12 MAY				
	Sh	noal	Bottom	Channel		S	noal	<u>Bottom</u>	Channe	el	Sho	oal	<u>Bottom</u>	Channel	
Region	Sled	Trawl	Sled	Trawl	Total	Sled	Trawl	Sled	Trawl	Total	Sled	Trawl	Sled	Trawl	Total
Battery			15	15	30			24	18	42			18	18	36
Yonkers	6	6	18	18	48	6	6	21	15	48	6	6	21	15	48
Tappan Zee	9	6	18	18	51	18	12	12	12	54	18	12	12	12	54
Croton-Haverstraw	9	6	18	18	51	12	10	12	12	46	12	9	12	12	45
Indian Point	6	6	18	18	48	6	6	12	12	36	6	6	18	30	60
West Point			15	15	30			15	15	30			18	45	63
Cornwall	6	5	12	12	35	9	6	9	9	33	9	6	24	15	54
Poughkeepsie								9	9	18			30	30	60
Hyde Park								9	21	30			27	33	60
Kingston								24	18	42			18	21	39
Saugerties								24	18	42			9	15	24
Catskill								48	21	69			9	15	24
Albany								60	30	90			15	15	30
Total	36	29	114	114	293	51	40	279	210	580	51	39	231	276	597

	<u>3-We</u>	eek Perio	od from 15	5 MAY to 2	4-We	ek Perioo	<u>d from 5 J</u>	UN to 30	JUN	<u>13-</u> W	<u>13-Week Period from 11 JUL to 6 OCT</u>				
	S	hoal	Bottom	Channe	<u> </u>	S	hoal	Bottom	Channe	el	Sh	noal	Bottom	Channel	
Region	Sled	Trawl	Sled	Trawl	Total	Sled	Trawl	Sled	Trawl	Total	Sled	Trawl	Sled	Trawl	Total
Battery			24	15	39			24	20	44			42	50	92
Yonkers	6	3	18	15	42	8	8	24	32	72	14	14	42	37	107
Tappan Zee	12	6	12	15	45	8	8	20	24	60	21	21	28	38	108
Croton-Haverstraw	12	6	12	15	45	12	8	24	28	72	21	21	28	36	106
Indian Point	6	6	18	39	69	12	8	20	68	108	21	21	28	33	103
West Point			21	51	72			32	104	136			28	33	61
Cornwall	9	6	24	17	56	8	8	48	52	116	14	14	21	26	75
Poughkeepsie			36	57	93			28	64	92			21	26	47
Hyde Park			21	33	54			20	40	60					
Kingston			12	18	30			16	24	40					
Saugerties			15	9	24			16	8	24					
Catskill			9	9	18			12	12	24					
Albany			9	9	18			12	12	24					
Total	45	27	231	302	605	48	40	296	488	872	91	91	238	279	699

NOTE: Dashes (--) indicate no sampling scheduled.

TABLE 2-4SPECIFICATIONS OF SAMPLING GEAR USED DURING THE 2000LONGITUDINAL RIVER ICHTHYOPLANKTON SURVEY

1.0-m² Tucker Trawl

- Length8.0 mMouth (width)1.0 mMouth (height)1.4 mMesh size500 μmNet materialNytex (monofilament nylon)Collection cup
- Length Length with net-retaining ring Mesh size Net material

30 cm 37 cm 500 μm Nytex (monofilament nylon)

1.0-m² Net Mounted on Epibenthic Sled

Length Mouth (width) Mouth (height) Mesh size Net material 8.0 m 1.0 m 1.4 m 500 μm Nytex (monofilament nylon)

Collection cup Length Length with net-retaining ring Mesh size Net material

30 cm 37 cm 500 μm Nytex (monofilament nylon)

	Schedule	ed Sampling Locations (RM)	Number of Water Quality Samples Scheduled Per Region Per River Run							
River Region	Shoals ^a	Channel	LRS River Runs 1-3	LRS River Runs 4-16	LRS River Runs 17-23	FSS River Runs 1-11				
Battery		1, 3, 6, 9	12	12	12	12				
Yonkers	19	12, 14, 17, 19, 22	19	19	19	19				
Tappan Zee	29	25, 27, 29, 32	16	16	16	16				
Croton- Haverstraw	36	35, 36, 37, 38	16	16	16	16				
Indian Point	43	40, 42, 43, 46	16	16	16	16				
West Point		49, 51, 53, 55	12	12	12	12				
Cornwall	59	56, 57, 59, 61	16	16	16	16				
Poughkeepsie		63, 67, 71, 75		12	12	12				
Hyde Park		78, 80, 82, 84		12		12				
Kingston		87, 89, 91, 93		12		12				
Saugerties		96, 99, 102, 105		12		12				
Catskill		109, 114, 118, 122		12		12				
Albany		126, 131, 135, 138, 142		15		15				
Total per River Run			107	182	119	182				

TABLE 2-5 WATER QUALITY SAMPLING LOCATIONS DURING THE 2000 LONGITUDINAL RIVER ICHTHYOPLANKTON AND FALL SHOALS SURVEYS

NOTE: Dashes (--) indicate no sampling scheduled. ^a Sample collected from east and west shoals at designated river mile.

TABLE 2-6 SUMMARY OF 2000 SAMPLE ANALYSIS INFORMATION BY RIVER REGION AND STRATUM FOR THE LONGITUDINAL RIVER ICHTHYOPLANKTON SURVEY

	4-Week Period from 6 MAR to 31 MAR				3-We	ek Period	I from 3 A	PR to 21	APR	3-We	3-Week Period from 24 APR to 12 MAY				
	Sh	noal	Bottom	Channel	_	SI	noal	Bottom	Channe	el	Sh	oal	Bottom	Channe	
Region	Sled	Trawl	Sled	Trawl	Total	Sled	Trawl	Sled	Trawl	Total	Sled	Trawl	Sled	Trawl	Total
Battery			15	15	30			12	9	21			9	9	18
Yonkers	6	6	9	9	30	6	6	12	15	39	6	6	12	15	39
Tappan Zee	8	6	8	9	31	9	12	12	12	45	9	12	12	12	45
Croton-Haverstraw	9	6	9	9	33	12	9	12	12	45	12	9	12	12	45
Indian Point	6	6	9	9	30	6	6	12	12	36	6	6	9	15	36
West Point			15	15	30			15	15	30			9	9	18
Cornwall	6	5	12	12	35	9	6	9	9	33	9	6	12	15	42
Poughkeepsie								9	9	18			15	15	30
Hyde Park								9	12	21			15	18	33
Kingston								12	9	21			9	12	21
Saugerties								12	9	21			9	15	24
Catskill								9	12	21			9	15	24
Albany								12	15	27			15	15	30
Total	35	29	77	78	219	42	39	147	150	378	42	39	147	177	405

	<u>3-We</u>	ek Perio	od from 15	5 MAY to 2	4-We	4-Week Period from 5 JUN to 30 JUN					13-Week Period from 11 JUL to 6 OCT				
	S	hoal	Bottom	Channe	-	S	hoal	Bottom	Chanr	nel	Sh	oal	Bottom	Channe	<u>el</u>
Region	Sled	Trawl	Sled	Trawl	Total	Sled	Trawl	Sled	Traw	<u>/I_Total</u>	Sled	Trawl	Sled	Trawl	Total
Battery			12	12	24			13	15	28			20	22	42
Yonkers	6	3	9	12	30	8	8	12	16	44	14	13	20	28	75
Tappan Zee	12	6	12	12	42	8	8	20	20	56	15	21	28	28	92
Croton-Haverstraw	12	6	12	12	42	12	8	13	11	44	20	21	28	28	97
Indian Point	6	6	9	18	39	12	8	20	12	52	15	21	27	28	91
West Point			12	9	21			16	20	36			28	28	56
Cornwall	9	6	12	14	41	8	8	24	24	64	14	14	21	21	70
Poughkeepsie			18	12	30			16	12	28			21	21	42
Hyde Park			12	15	27			20	20	40					
Kingston			11	9	20			16	12	28					
Saugerties			15	9	24			16	8	24					
Catskill			9	9	18			12	12	24					
Albany			9	9	18			12	12	24					
Total	45	27	152	152	376	48	40	210	194	492	78	90	193	204	565

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NOTE: Dashes (--) indicate no sampling scheduled.

TABLE 2-7 SUMMARY OF 2000 SAMPLE COLLECTION BY RIVER REGION AND STRATUM FOR THE FALL SHOALS SURVEY

	15-	15-Week Period from 5 JUL to 12 OCT						6-Week Period from 23 OCT to 30 NOV					
	Sho	oal	<u>Bottom</u>	<u>Channel</u>			Sh	oal	<u>Bottom</u>	<u>Channel</u>			
Region	<u>Beam</u>	Tucker	Beam	Tucker	<u>Total</u>		<u>Beam</u>	<u>Tucker</u>	Beam	Tucker	<u>Total</u>		
Battery			56	41	97				36		36		
Yonkers	16	16	64	48	144		15		33		48		
Tappan Zee	48	48	48	48	192		15		24		39		
Croton-Haverstraw	40	40	48	48	176		15		18		33		
Indian Point	31	32	56	57	176		15		30		45		
West Point			80	96	176				36		36		
Cornwall	40	40	48	48	176		15		30		45		
Poughkeepsie			88	88	176				29		29		
Hyde Park			64	47	111				30		30		
Kingston			33	48	81				25		25		
Saugerties			32	16	48				30		30		
Catskill			24	24	48				30		30		
Albany			31	31	62				24		24		
Total	175	176	672	640	1663		75		375		450		

NOTE: Dashes (--) indicate no sampling scheduled.

TABLE 2-8	SPECIFICATIONS OF SAMPLING GEAR USED DURING THE 2000 FAL	L
	SHOALS SURVEY	

	1.0-m ² Tucker Trawl
Length	8.0 m
Mouth (width)	1.0 m
Mesh size	3.0 mm
Collection cage (codend)	
Length	81 cm
Diameter	41 cm
Mesh size	3.0 mm
	3.0-m Beam Trawl
Length	7.6 m
Beam width	3.0 m
Net body	3.8-cm mesh (stretch)
Codend	3.2-cm mesh (stretch) net with 1.3-cm mesh (stretch) liner
Hood	3.8-cm mesh (stretch)
Footrope	Equipped with 5.1-cm rollers
Headrope	Equipped with three floats
Mouth area	2.7 m^2

TABLE 2-9 SPECIFICATIONS OF SAMPLING GEAR USED DURING THE 2000 BEACH SEINE SURVEY

30.5-m Beach Seine	
Number of wings	2
Length of wings	12.0 m
Depth of wings	2.4 m
Wing mesh (bar)	1.0 cm
Length of bag	6.1 m
Depth of bag	3.0 m
Bag mesh (bar)	0.5 cm
Sampling area	450 m ²

Region	5-Week Period from 13 JUN to 14 JUL	13-Week Period from _24 JUL to 20 OCT	<u>Total</u>
Yonkers	9	35	44
Tappan Zee	33	168	201
Croton-Haverstraw	21	98	119
Indian Point	9	35	44
West Point	9	35	44
Cornwall	9	42	51
Poughkeepsie	24	35	59
Hyde Park	24	35	59
Kingston	24	35	59
Saugerties	45	63	108
Catskill	57	70	127
Albany	36	49	85
Total	300	700	1000

TABLE 2-10 SUMMARY OF 2000 SAMPLE COLLECTION BY RIVER REGION FOR THE BEACH SEINE SURVEY

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

TABLE 2-11 STRATUM AND REGION VOLUMES (m³) AND SURFACE AREAS (m²) USED IN ANALYSIS OF 2000 HUDSON RIVER ESTUARY DATA

a. Shorezone surface area is unknown and not used in data analysis as no beach seine sampling is performed in the Battery region.