Appendix F: Ecology

F-1 Aquatic Sampling Program

Aquatic Sampling Program

AECOM

April 2011

Introduction

In support of the DEIS, this appendix contains aquatic ecological studies by AECOM and their subconstultants. Studies for fish, benthos, oysters and submerged aquatic vegetation were performed for the project from 2006 to 2009. This appendix is organized into the following three sections:

- Section 1 – Study Area Fisheris Resources;
- Section 2 – Benthic Macroinvertebrates; and
- Section 3 – Submerged Aquatic Vegetation

1 Study Area Fisheries Resources

It is important to recognize the configuration of bridge piers and their influence on river conditions in the study area. The placement of the bridge piers is not uniform, which is reflective of the dramatic changes in river bathymetry. Thus, the bridge habitat can be divided into three broad zones, as follows:

- Piers 1 to 168 - The water depths vary between 10 and 18 feet (3.05 and 5.5 m) Mean High Water (MHW). The bridge piers are spaced 50 (15.24 m) feet apart. Except for periods of slack tides, currents are present between the piers. The velocity of the current is increased by the presence of the pier caps and footings and the proximity to the main river channel. Currents are less pronounced at the shoreline.

- Piers 168 to 180 – These piers are spaced 50 to 200+ feet (15.24 to 61+ m) apart. Water depths vary between 20 and 50+ feet. Observations performed during the sampling program determined that the pier's influence on surface water velocity during ebb tides can be considerable.

- Piers 180 to 190 – The piers are spaced approximately 75 feet (22.9 m) apart. The water depths vary between 1 and 20 feet (0.3 and 6 m). Observations performed during the sampling program determined that the pier's influence on water velocity is minor.

1.1 Sampling Program

A year-long fish survey was conducted to document the seasonal variations in fish populations in the study area. Fish sampling was conducted every other month over a two-week period between April 2007 and May 2008. Prior to the start of the sampling program, the sampling plan was provided to the regulatory agencies for their comments. Agencies that reviewed and commented on the plan included the USEPA, NMFS, USFWS, NYSDEC, and the New York State Department of State (NYSDOS). In addition, due to the potential for encountering the endangered shortnose sturgeon, research permits were obtained from NMFS and NYSDEC.

As shown on Figure F-1-1, fish sampling occurred within the current bridge alignment and within the anticipated alignment of the proposed bridge. Fish sampling was accomplished by three methods: acoustic surveys, gill nets, and fish traps. Descriptions of these sampling methods are provided below.

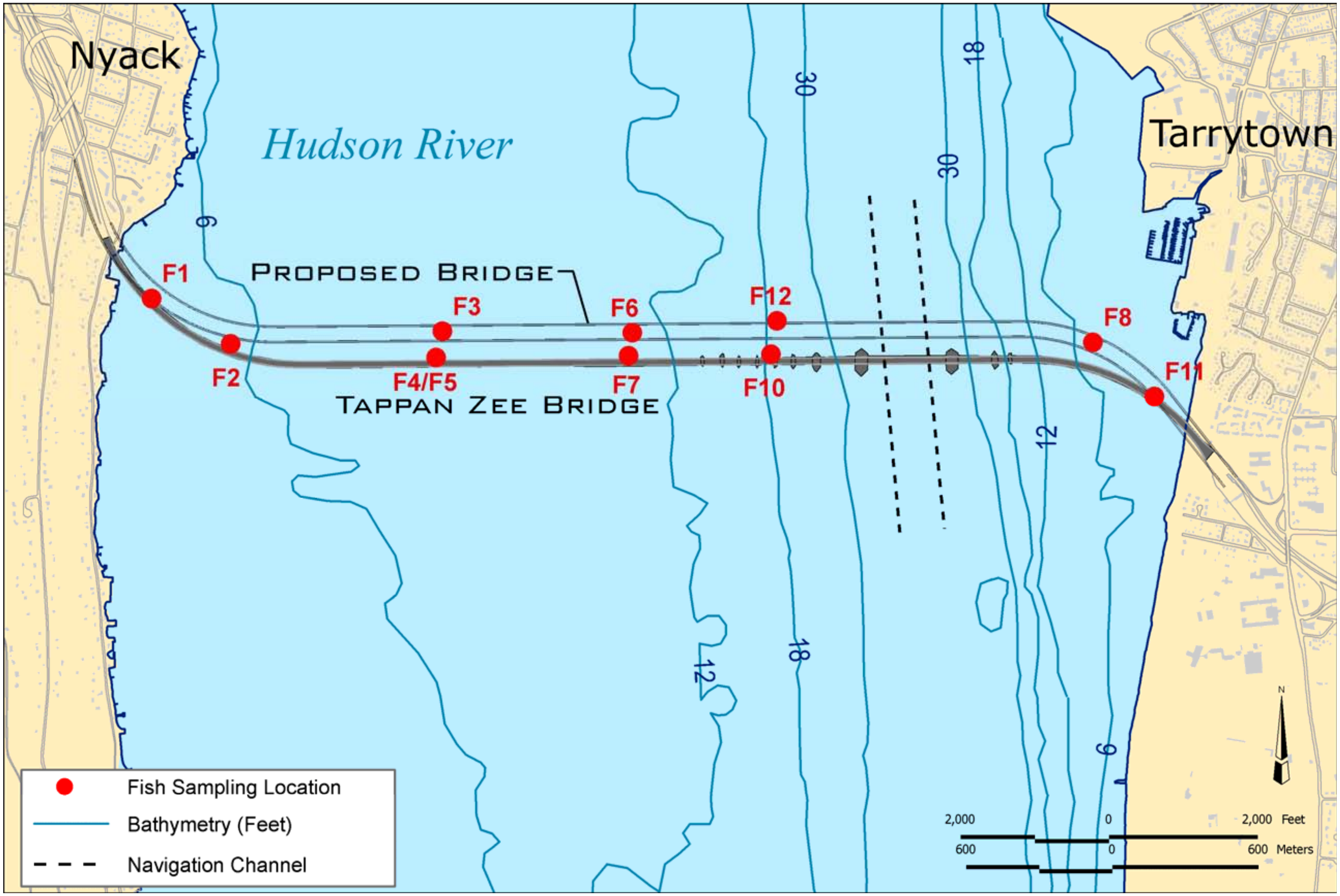


Figure F-1-1 Fish Sampling Locations

Hydroacoustic Survey

A mobile hydroacoustic survey to assess fish populations in the Hudson River was conducted using two 420-kiloHertz (-kHz) split-beam digital transducers (Figure F-1-2). The transducers were mounted on the starboard side of the survey vessel, approximately amidships, one mounted vertically along the side of the vessel and the second mounted horizontally. The transducers were controlled by an echosounder that was connected to a GPS and a data-collection computer. Data-collection parameters were 7 pings per second with a pulse duration of 0.4 milliseconds (ms). The data-collection threshold was set at 90 decibels (dB). Vessel speed was maintained at approximately 4.0 knots during the survey.

A total of 6 systematically located transects were surveyed (Figure F-1-3). Transect locations are labeled as follows:

- Transect 100S – located 100 feet (30.5 m) south of the existing bridge.
- Transect 50S – located 50 feet (15.24 m) south of the existing bridge.
- Transect 50N – located 50 feet (15.24 m) north of the existing bridge.
- Transect 100N – located 100 feet (30.5 m) north of the existing bridge.
- Transect 200N – located 200 feet (61 m) north of the existing bridge.
- Transect 400N – located 400 feet (122 m) north of the existing bridge.

Gill Nets

Experimental gill nets (Photo F-1-1) were deployed to capture and determine which fish species utilize the study area. The gill nets measured 8 feet (2.4 m) high by 125 feet (38.1 m) long and consisted of 5 gill net panels (each 25 feet (7.6 m) long) with mesh sizes ranging between 1 and 5 inches (2.5 and 12.7 cm). In order to keep the nets vertical in the water column, the gill nets are manufactured with a float line on the top of the net and a lead line on the bottom. Additional large surface floats (Photo F-1-2) were added to assist in keeping the net vertical in the water and to act as marker buoys to provide a warning to navigation. The gill nets were set in place using either 10- or 15-pound (4.5- or 6.8-kilogram [kg]) anchors placed at either end of the net. The attached lead line and anchors kept the bottom of the net on the river bottom. Gill nets were generally set perpendicular to the river flow, although some nets were set parallel to the flow when wind and tides did not allow for the net deployment and retrieval parallel to the flow.

To reduce fish mortality, the time each gill net was deployed (soak time) was based on a strict set of temperature criteria. These criteria were as follows:

- For temperatures below 59˚F (15˚C), the net could be deployed for a maximum of 4 hours.
- For water temperatures between 59 and 68˚F (15 and 20˚C), the net could be deployed for a maximum of 2 hours.
- For water temperatures between 68 and 80.6˚F (20 and 27˚C), the net could be deployed for a maximum of 1 hour.
- Nets were not deployed when water temperatures were above 80.6˚F (27˚C).

These soak times are consistent with *A Protocol for Use of Shortnose and Atlantic Sturgeons* (Moser et al. 2000). Upon retrieval of the net, all captured fish were identified by species and their lengths recorded (Photo F-1-3). The fish were then returned to the water.

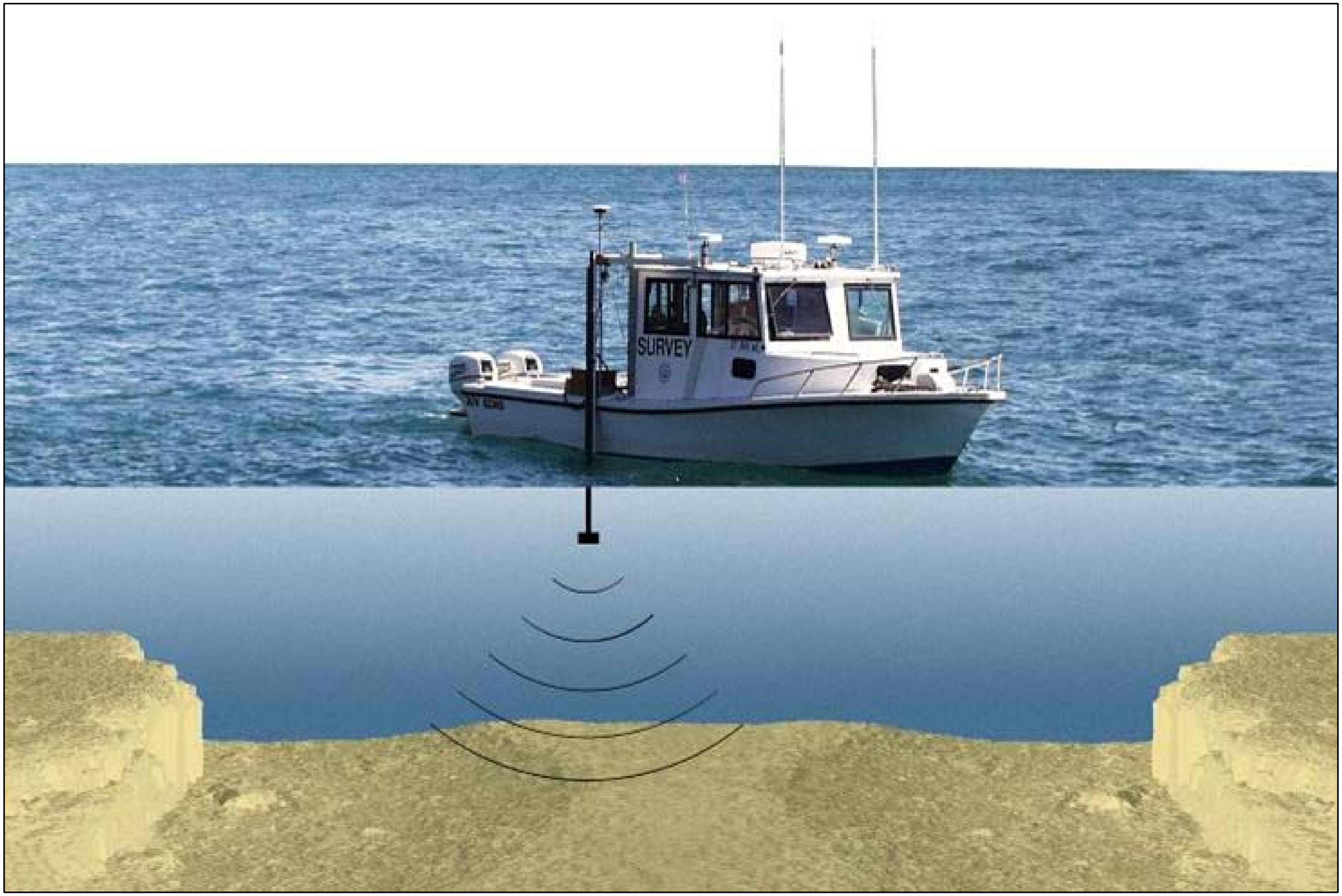


Figure F-1-2 Illustration of the Hydroacoustic Device

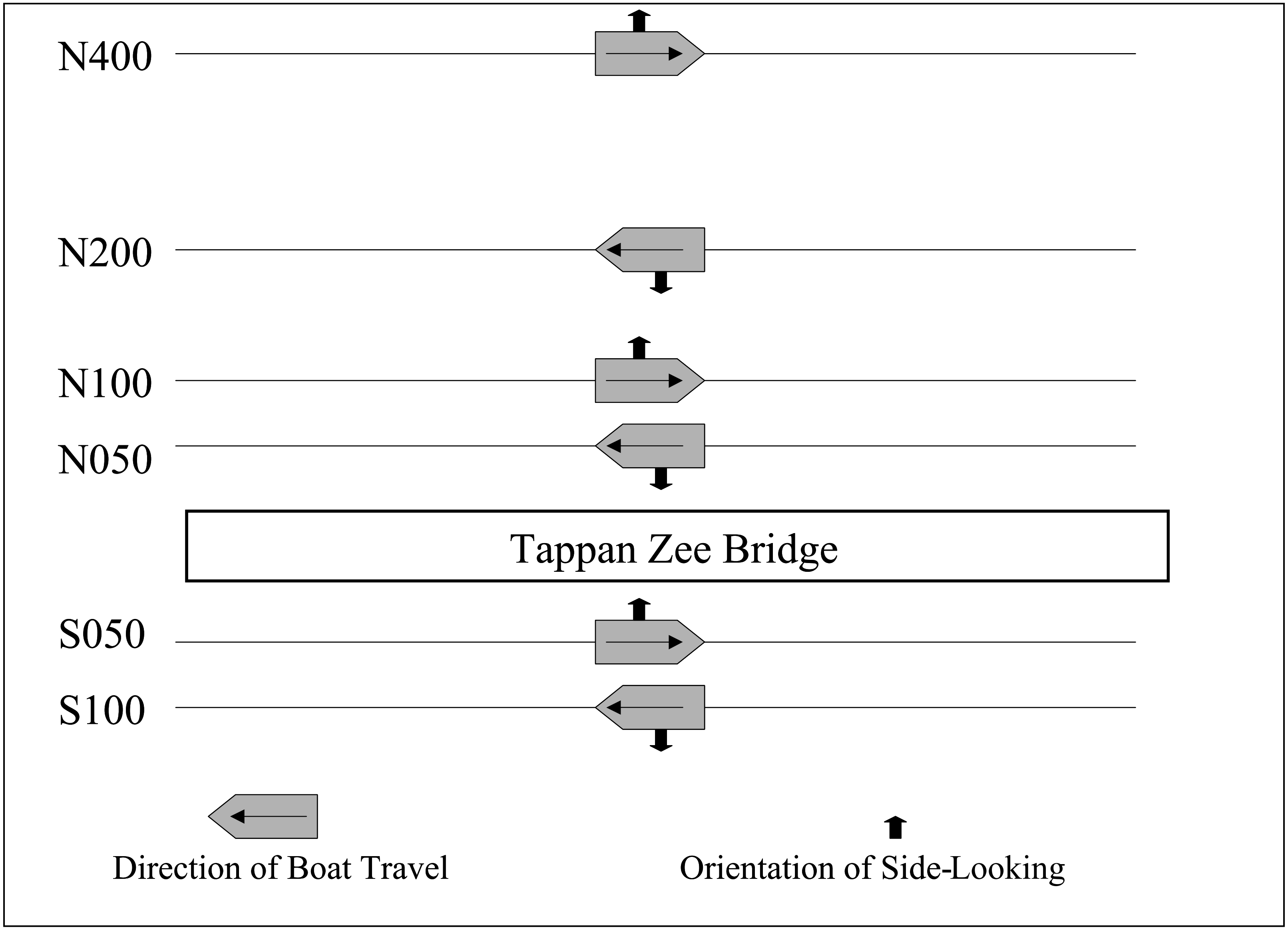


Figure F-1-3 Acoustic Transect Locations

Photo F-1-1 Experimental Gill Net Retrieval

Photo F-1-2 Surface Floats Depicting Gill Net Endpoints

Photo F-1-3 Captured Fish on Measuring Board

All personnel involved in the fish-sampling program were trained by NYSDEC in the proper handling of the endangered shortnose sturgeon and the Atlantic sturgeon. The Atlantic sturgeon is a candidate species for placement on the Threatened and Endangered Species List. Upon capture, the sturgeons were removed from the net and placed in a floating live well (Photo F-1-4) with ambient river water conditions. The floating net pen measured approximately 4 feet by 2 feet by 3 feet (1.2 m by 0.6 m by 0.9 m), with netting on all sides. The pen allowed for the sturgeon to be secured in ambient river conditions, to reduce the stress on the fish. The sturgeons were scanned both visually and electronically for the presence of identification tags. For tagged fish, the information was recorded and provided to the regulatory agencies. The sturgeons were also weighed and measured. The sturgeons were placed in a saline electrolyte bath to reduce stress and restore slime coat. When handling the fish, the scientists donned surgical gloves to further reduce stress on the fish. All sturgeons were handled for less than 15 minutes and returned to the river unharmed. Individuals of all other species of fish were placed within the pen after capture. Each individual was identified to species and measured for length and then returned to the river.

Photo F-1-4 Floating Live Well

Sampling Locations

A total of nine fish-sampling sites were utilized for the gill nets and fish traps. Sampling occurred between the 6-foot (1.8-m) and 35-foot (10.7-m) bathymetric contours. In order to determine the habitat conditions around the existing bridge, six sites were directly adjacent to and/or underneath the bridge. In addition, three sites were selected as reference locations within 500 and 600 feet (152.4 and 182.9 m) north of the bridge. The reference sites were selected to provide locations similar in depth, bathymetry, and sediment characteristics to the bridge pier locations. These locations were also comparable in depth and bottom type to that of the possible replacement bridge locations.

Nets were not deployed in water depths greater than 35 feet (10.7 m), as that would have required the deployment of the nets in an active ship channel. Also, very strong currents are encountered at water depths greater than 30 feet (9.1 m). Descriptions of the nine fish-sampling locations are provided below.

- **Bridge Sampling Sites**

  Site F1, approximately 462 ft (140.8 m) from the western shoreline. The water depths ranged from 7 to 11 feet (2.1 and 3.4 m) and the benthic habitat consisted of soft silt.

  Site F2, located approximately 0.34 mi (0.55 km) from the western shoreline. The water depths ranged between 10 and 14 ft (3.0 and 4.3 m) and the benthic habitat consisted of soft silt.

  Site F4/F5, located approximately 0.86 mi (1.38 km) from the western shoreline. The water depths ranged between 11 and 15 ft (3.4 and 4.6 m) and the benthic habitat consisted of soft silt with some shell material.

Site F7, located approximately 1.35 mi (2.17 km) from the western shoreline. The water depths ranged between 13 and 17 feet (4.0 and 5.2 m) and the benthic habitat consisted of silt with shell material. Oyster shells were periodically encountered in this location.

Site F10, located approximately 1.08 mi (1.74 km) from the eastern shoreline. The water depths ranged between 25 and 34 feet (7.6 and 10.4 m) and the benthic habitat consisted of scoured sediments and oyster reefs.

Site F11, located approximately 481 ft (146.61 m) from the western shoreline. The water depths ranged between 6 and 10 feet (1.8 and 3.0 m) and the benthic habitat consisted of soft silt.

In April and June 2007, two other sampling sites were utilized – Sites F5 and F9. Site F5 was originally located approximately 1.0 mile (1.61 km) from the western shoreline in approximately 12 feet (3.7 m) of water. However, in June 2007, sampling site F5 was removed in order to create the deep-water sampling site F10. Site F9 was moved closer to the east bank of the river and renamed Site F11.

- **Reference Sampling Sites**

Site F3, located approximately 0.86 mi (1.38 km) from the western shoreline and approximately 500 feet (152.4 m) north of the bridge. The water depths ranged from 10 to 14 feet (3.0 and 4.3 m) and the benthic habitat consisted of soft silt.

Site 8, located approximately 0.27 mi (0.43 km) from the eastern shoreline and approximately 500 feet (152.4 m) north of the bridge. The water depths ranged between 9 and 13 feet (2.7 and 4.0 m) and the benthic habitat consisted of soft silt.

Site 12, located approximately 1.09 mi (1.75 km) from the eastern shoreline and approximately 500 feet (152.4 m) north of Site 10. The water depths ranged between 24 and 32 feet (7.3 and 9.8 m) and the benthic habitat consisted of scoured clays with oyster reefs.

In April and June 2007, reference sampling Site F6, located approximately 1.35 mi (2.17 km) from the western shoreline, was utilized. This location was in approximately 14 feet (4.3 m) of water. This location was abandoned to create the deep-water reference sampling site F12.

Fish Traps

Fish traps were deployed to identify the young-of-the-year (YOY) fish resources in the area of the bridge. The traps were designed to have an opening of 1 inch or less, to prevent predation by larger fish or crabs.

In April 2007, two unbaited fish nets sized for small YOY fish were deployed at each location; each net measured 35.9 x 18.1 x 11.8 inches (91 x 46 x 30 centimeters [cm]), with 2-mm mesh stretched over the frame with a single V-shaped 1 x 18.1-inch (2.5 x 46-cm) throat and a 0.12-inch (F-1-mm) nylon mesh cod end. These traps were weighted and marked with buoys for easy retrieval. However, the traps often fouled and ripped due to strong currents and debris around the bridge. Also, on several occasions the weighted traps were swept away by strong currents encountered during winter conditions. Due to the multiple problems encountered with these traps, in June 2007 through May 2008, smaller traps – standard minnow traps (Photo F-1-5) – were placed along the bridge piers and at reference locations at various depths. The traps were baited and secured to the piers so that they would not be dislodged by river currents. Approximately 20 traps were deployed day and night for each two-week sampling period. The traps were deployed at various depths from 2 to 15 feet (0.6 to 4. 6 m) below mean low water (MLW).

Photo F-1-5 Standard Minnow Trap

1.2 Results

Hydroacoustic Survey

A description of each monthly sampling effort is provided below. For each sampling event, the water-quality data did not reveal any water-quality parameters that would significantly limit fish distributions, such as depleted oxygen levels or excessive temperatures.

April 2007

A total of 656 fish were identified during the April 2007 hydroacoustic survey. The greatest abundance of fish occurred south of the existing bridge structure (Figure F-1-4). As can be observed in the figure, approximately 155 fish were observed at Transect 100S. There were progressively fewer fish observed on the northern transects. The survey was conducted between one hour before low tide and four hours after low tide. Transect 100S was conducted at approximately one hour before low tide. Transects 50S and 50N were conducted at slack low water. Transects 100N, 200N, and 400N were conducted on a rising tide, approximately two hours, three hours, and four hours, respectively, after low tide.

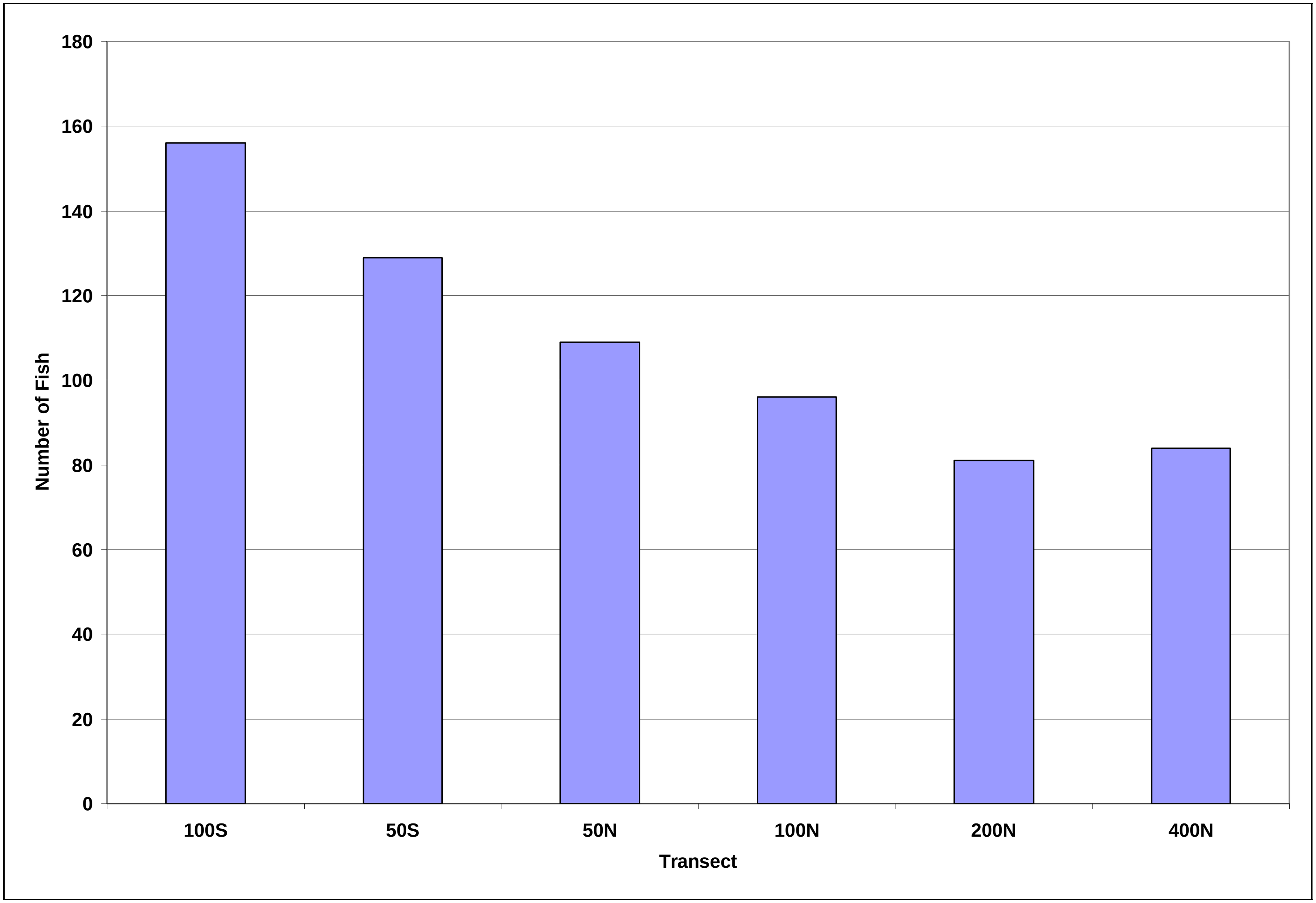


Figure F-1-4 Number of Fish Recorded on Each Acoustic Transect (April 2007)

The horizontal distribution showed that the fish were concentrated in the main channel of the river, with relatively few fish observed in the shallow water that extends from each shoreline. Figure F-1-5 illustrates the distribution of fish identified across the river at transects 100S and 50S. As can be observed in the figure, the majority of fish are located within the deep channel.

The hydroacoustic and water-quality survey conducted in April 2007 suggested that the main environmental parameter governing fish distribution in the Hudson River is salinity. The greatest number of fish was observed in the main channel at depths below the halocline (approximately 19.7 feet [6 m]).

The hydroacoustic results indicate that the field sampling program may be underestimating the number of smaller fish (<5.9 inches [15 cm] total length) in the area. The hydroacoustic results indicated the presence of a large number of smaller fish that were absent from the April 2007 gill net survey.

June 2007

A total of 122 fish were identified during the June 2007 hydroacoustic survey. The greatest abundance of fish occurred north of the existing bridge structure. Figure F-1-6 illustrates the number of fish identified per transect. As can be observed in the figure, relatively similar numbers of fish were observed at transects 50N, 100N, and 200N, with substantially fewer fish observed at the other three transects. The survey was conducted throughout the tidal cycle. Transect 400N was conducted approximately three hours before high tide. Transects 100S and 50S were conducted at high tide and one hour after high tide, respectively. Transects 200N, 100N, and 50N were conducted on a falling tide, approximately two hours, three hours, and four hours after high tide, respectively.

The horizontal distribution of fish showed that they were concentrated in the main channel of the river, with relatively few fish observed in the shallow water that extends from each shoreline.

August 2007

A total of 555 fish were identified during the August 2007 hydroacoustic survey. The greatest abundance of fish occurred north of the existing bridge structure. Figure F-1-7 illustrates the number of fish identified per transect. As can be observed in the figure, approximately 195 fish were observed at transect 200N. The survey was conducted throughout the tidal cycle. Transect 50S was conducted at the end of low tide. Transects 100S, 100N, and 50N were conducted at three hours, two hours, and one hour, respectively, before high tide. Transects 200N and 400N were conducted at high tide and one hour after high tide. The horizontal distribution of fish showed that they were concentrated in the main channel of the river, with relatively few fish observed in the shallow water that extends from each shoreline.

In the absence of any water-column structure (i.e., thermoclines or haloclines) the fish did not appear to exhibit any spatial aggregations vertically. Horizontal distributions were centered on the main channel.

October 2007

A total of 321 fish were identified during the October 2007 hydroacoustic survey. The greatest abundance of fish occurred south of the existing bridge structure. Figure F-1-8 illustrates the number of fish identified per transect. As can be observed in the figure, approximately 115 and 100 fish were observed at transects 100S and 50S, respectively. The survey was conducted throughout the tidal cycle. Transect 50S was conducted at the end of low tide. Transects 100S, 50N, and 100N were conducted at one hour, two hours, and three hours after high tide, respectively. Transects 200N and 400N were conducted at one hour before high tide and at high tide, respectively.

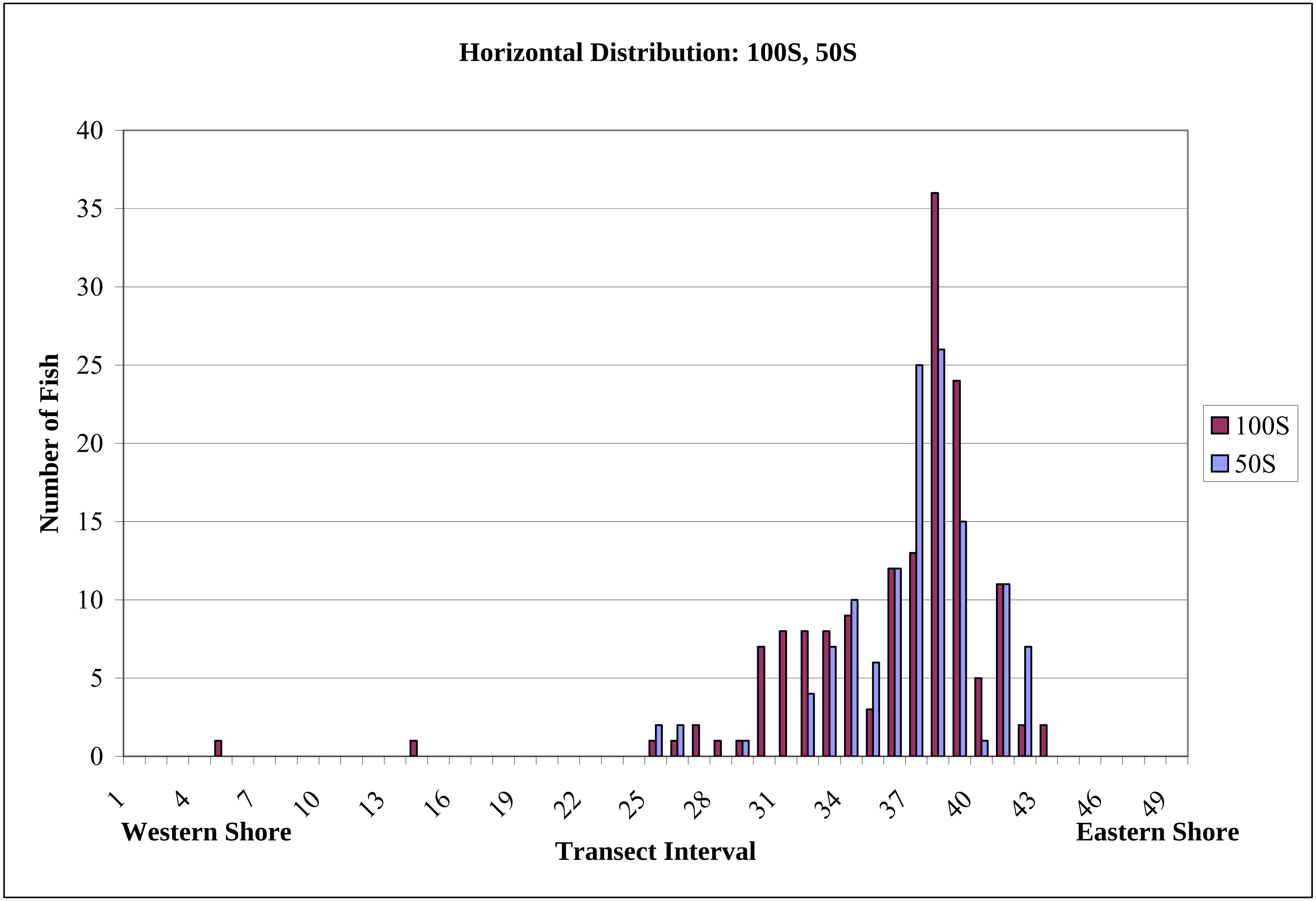


Figure F-1-5 Horizontal Distribution of Fish from West to East across the River (April 2007)

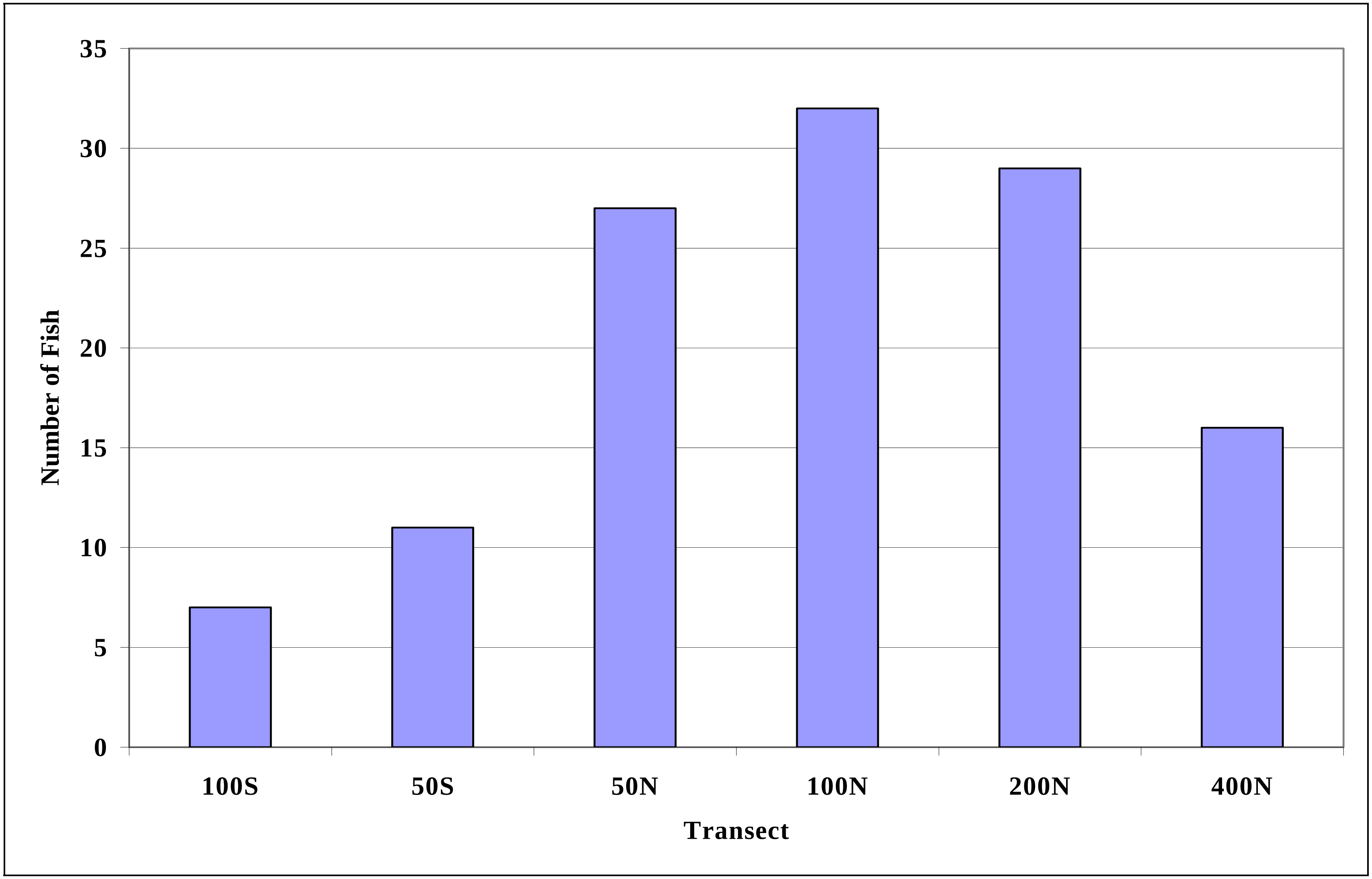


Figure F-1-6 Number of Fish Recorded on Each Acoustic Transect (June 2007)

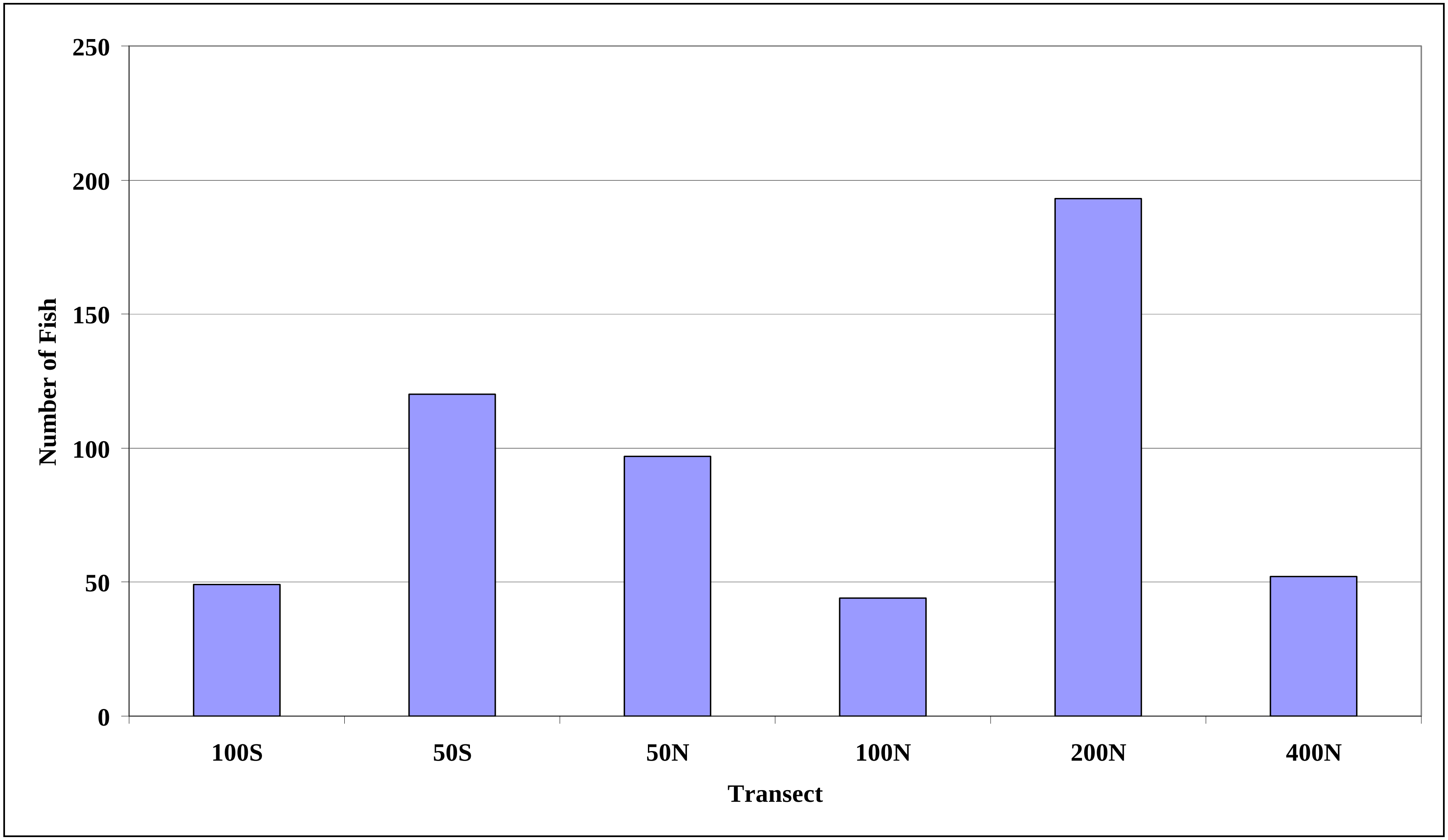


Figure F-1-7 Number of Fish Recorded on Each Acoustic Transect (August 2007)

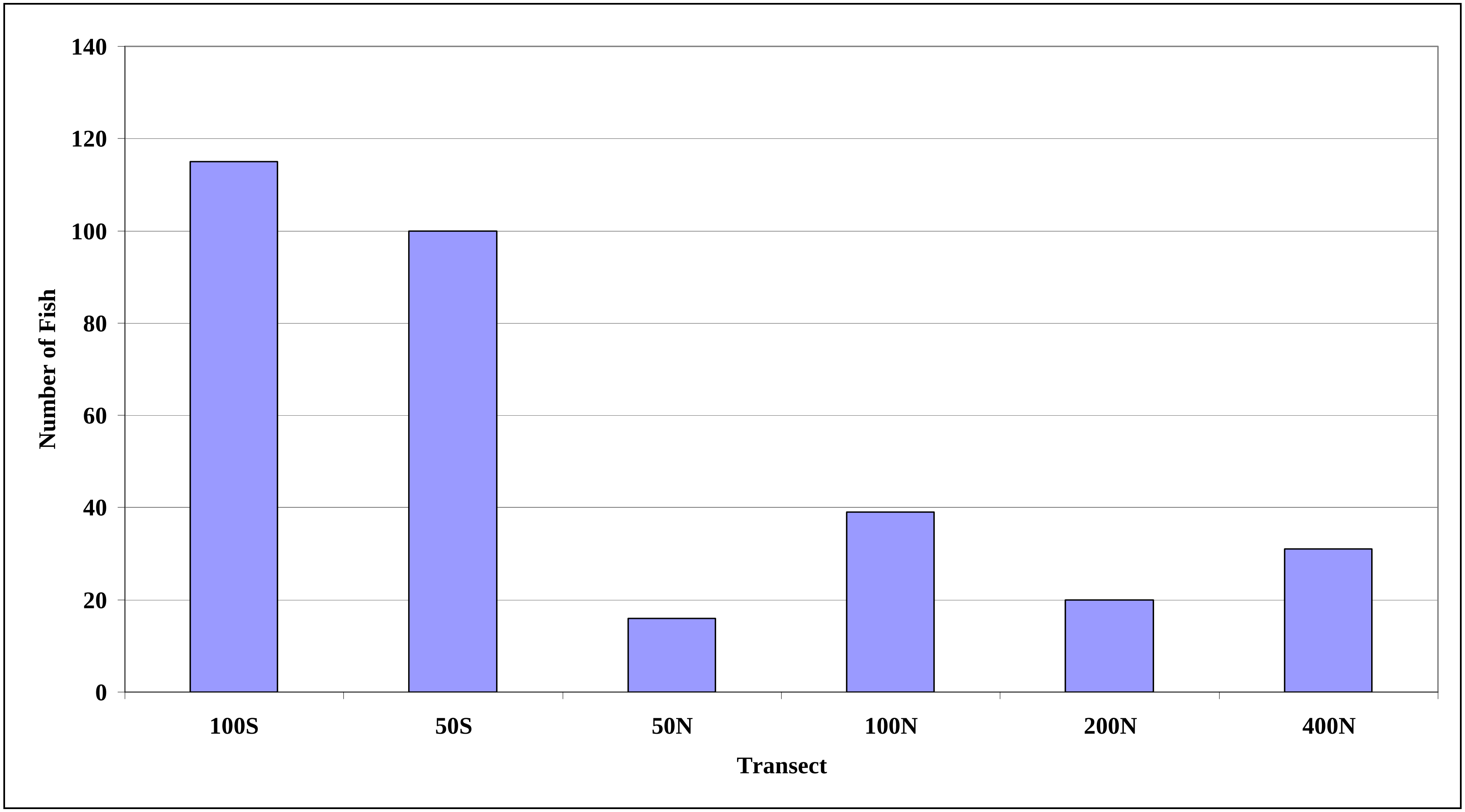


Figure F-1-8 Number of Fish Recorded on Each Acoustic Transect (October 2007)

Figure F-1-9 illustrates the horizontal distribution of fish identified across the river. As can be observed in the figure, the majority of fish are located within the deep channel; although more fish were recorded in shallower locations. The increased number of fish in shallow water is likely the result of warmer more saline waters in shallower locations and utilization of these areas by marine summer residents. Several fish schools were observed during the survey; all were presumed to be schools of bay anchovy.

In the absence of any water-column structure (i.e., thermoclines or haloclines) the fish did not appear to exhibit any spatial aggregations vertically. Horizontal distributions were centered on the main channel.

December 2007

A total of 300 fish were identified during the December 2007 hydroacoustic survey. The greatest abundance of fish occurred away from the existing bridge structure. Figure F-1-10 illustrates the number of fish identified per transect. As can be observed in the figure, a majority of the fish was observed at the 200S and 400N transects. The survey was conducted from three hours before high tide to two hours after high tide. Transects 400N, 100S, and 50S were conducted at three hours, two hours and one hour before high tide, respectively. Transects 50N, 100N, and 200N were conducted at high tide, one hour, and two hours after high tide, respectively. The horizontal distribution of fish showed that they were concentrated in the main channel of the river, with relatively few fish observed in the shallow water that extends from each shoreline.

In the absence of any water-column structure (i.e., thermoclines or haloclines) the fish did not appear to exhibit any spatial aggregations vertically. Horizontal distributions were centered on the main channel.

February 2008

A total of 520 fish were identified during the February 2008 hydroacoustic survey. The fish were relatively evenly distributed among the transects, with the exception of 400N, where roughly 50 percent fewer fish were observed. Figure F-1-11 illustrates the number of fish identified per transect. The survey was conducted throughout the tidal cycle. Transects 100S and 50S were conducted at high tide and one hour after high tide, respectively. Transects 50N, 100N, 200N, and 400N were conducted at three hours, two hours, one hour before low tide, and at low tide, respectively. The horizontal distribution of fish showed that they were concentrated in the main channel of the river, with relatively few fish observed in the shallow water that extends from each shoreline. Both water temperatures and salinities were low and constant vertically and horizontally throughout the study area.

In the absence of any water-column structure (i.e., thermoclines or haloclines) the fish did not appear to exhibit any spatial aggregations vertically. Horizontal distributions were centered on the main channel.

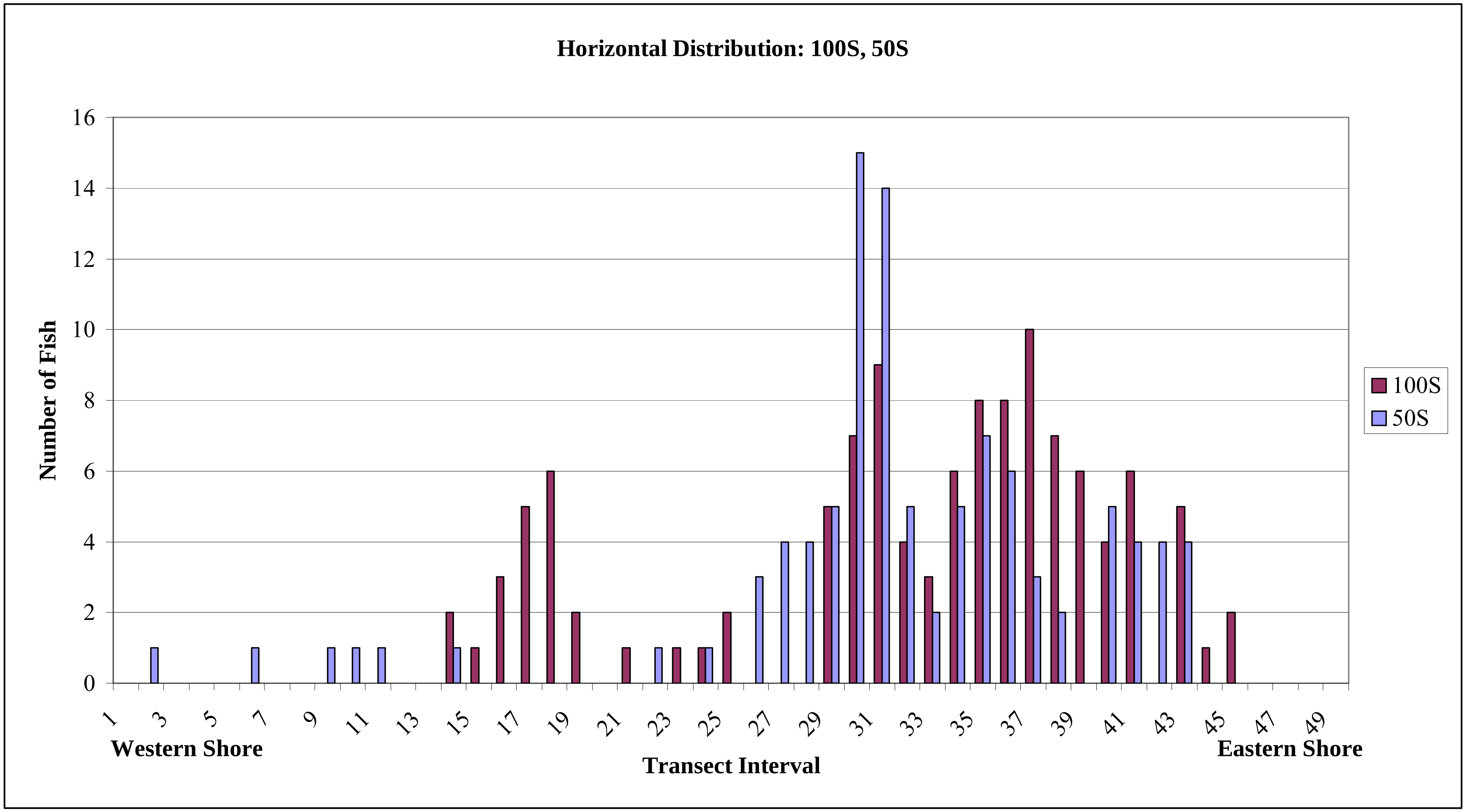


Figure F-1-9 Horizontal Distribution of Fish From West to East (October 2007)

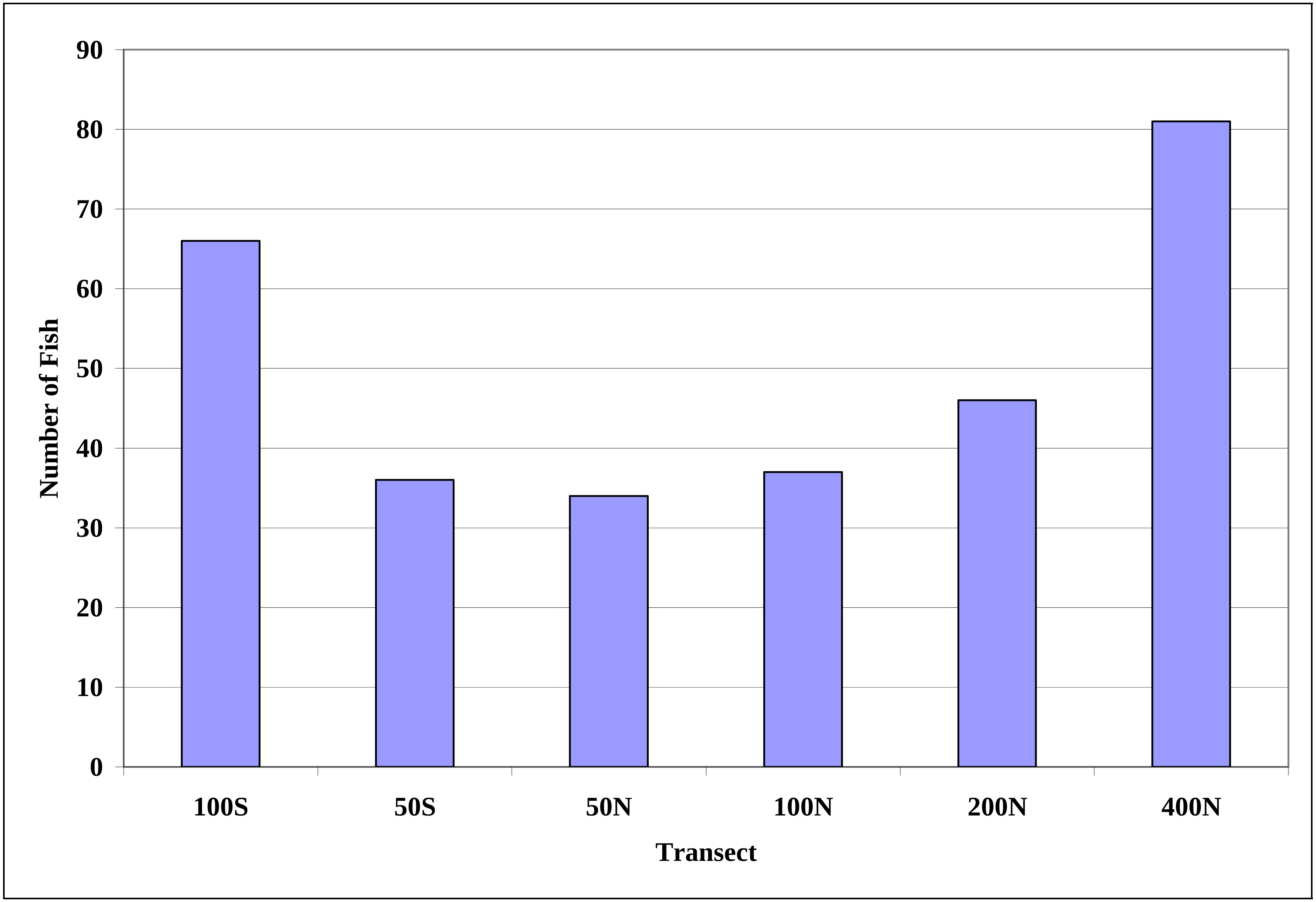


Figure F-1-10 Number of Fish Recorded on Each Acoustic Transect (December 2007)

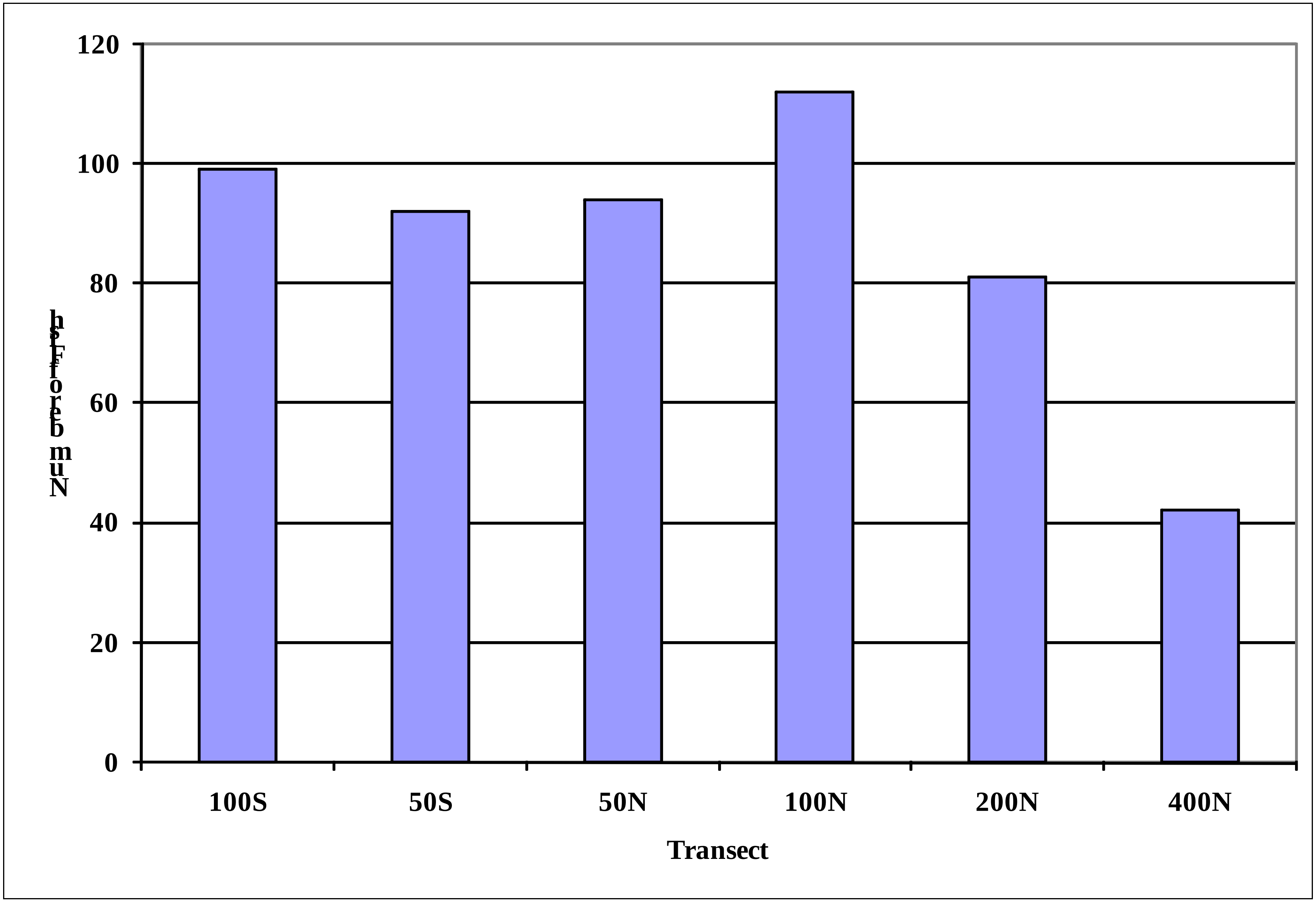


Figure F-1-11 Number of Fish Recorded on Each Acoustic Transect (February 2008)

May 2008

A total of 703 fish were identified during the May 2008 hydroacoustic survey. The greatest abundance of fish occurred on the northern side of the existing bridge structure. Figure F-1-12 illustrates the number of fish identified per transect. The survey was conducted throughout the tidal cycle. Transects 400N, 200N, and 50N were conducted five hours, four hours, and three hours before low tide and at low tide, respectively. Transects 50N, 50S, and 100S were conducted at one hour before low tide, at low tide, and one hour after high tide, respectively. The horizontal distribution of fish showed that they were concentrated in the main channel of the river, with relatively few fish observed in the shallow water that extends from each shoreline. Although fish were distributed throughout the water column, the majority of fish appeared to aggregate below the halocline.

Summary of Hydroacoustic Sampling

The hydroacoustic survey studied the horizontal, vertical, and geographic distribution of fish in the Hudson River. The horizontal distribution of fish in the river showed that they concentrate primarily in the deep water portion of the channel. The study also concluded that salinity is a major factor in determining the vertical distribution of fish. In the late winter and early spring, a distinct halocline is present near a depth of 19.7 feet (6 m). As the water column becomes stratified, with higher salinities at depth, the fish are concentrated in the deeper portions of the channel. As the water temperature warms, the halocline dissipates and fish are more likely to appear in shallow waters. The geographical distribution showed that in the colder months of the year, the fish tend to concentrate south of the bridge. In the warmer portions of the year, greater numbers of fish tend to be concentrated north of the bridge. Presumably these concentrations reflect several factors:

- In the winter, waters with higher salinities occur south of the bridge (towards New York Harbor and the Atlantic Ocean).
- In the warmer months (June through October), the salinity increases throughout the Tappan Zee Reach and the fish utilize the entire reach as a habitat resource.
- For no sampling event did the water-quality data reveal any water-quality parameters that would significantly limit fish distributions, such as depleted oxygen levels or excessive temperatures. Also, no discernible patterns with respect to fish populations could be attributed to the tide stage.

Results (Gill Nets and Traps)

Gill nets were deployed for more than 800 hours during the study. The nets captured 2,004 fish and hundreds of blue crabs. Fish that were captured in the nets were identified to species and measured for length. If a fish fell out of the net during net retrieval, the species was recorded and the length estimated. All captured sturgeons were handled in accordance with NOAA and NYSDEC regulations, measured for length, weighed, and scanned both visually and electronically for identification tags.

Figures F-1-13 through F-1-21 show the deployment locations and directional orientation of each individual net.

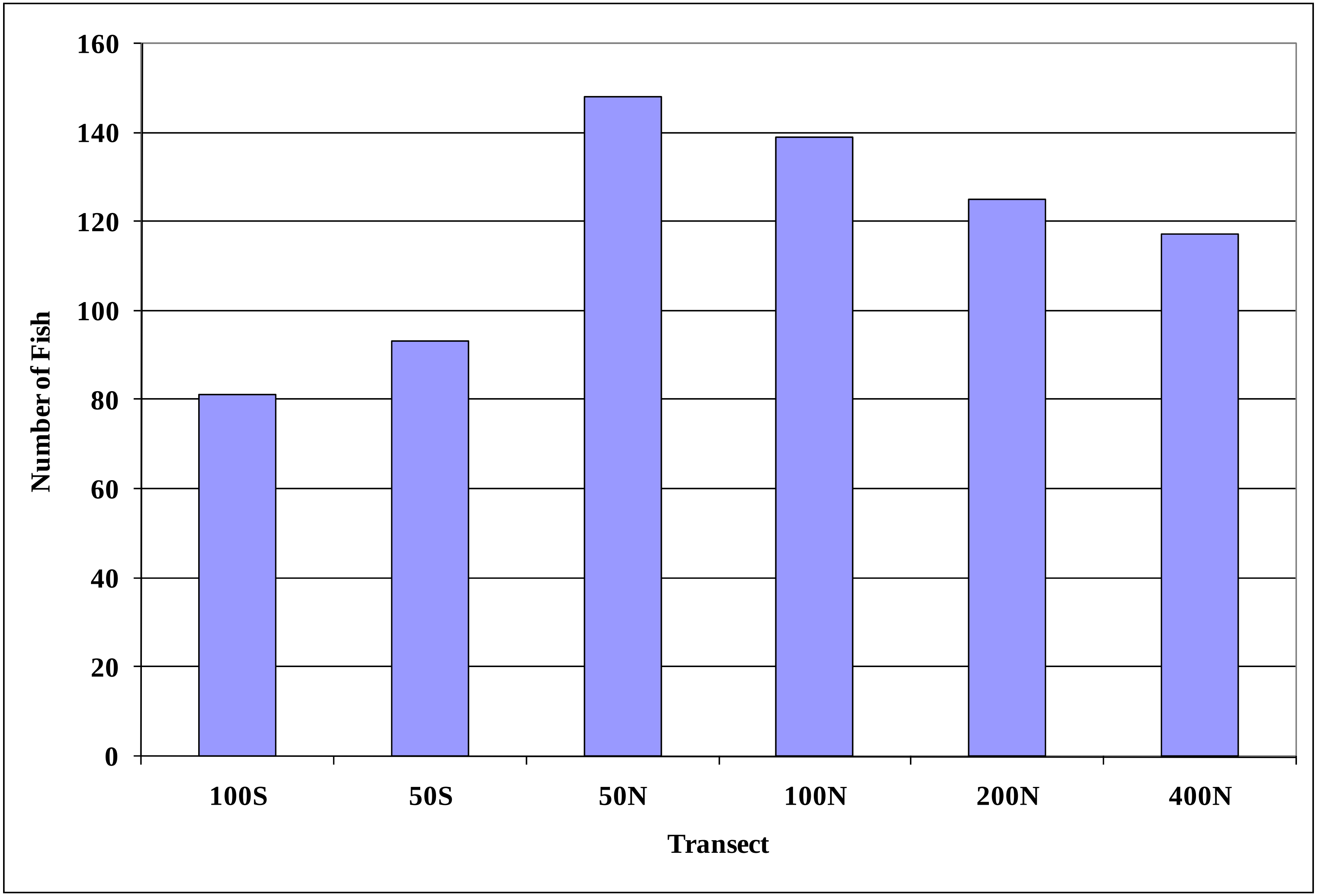


Figure F-1-12 Number of Fish Recorded on Each Acoustic Transect (May 2008)

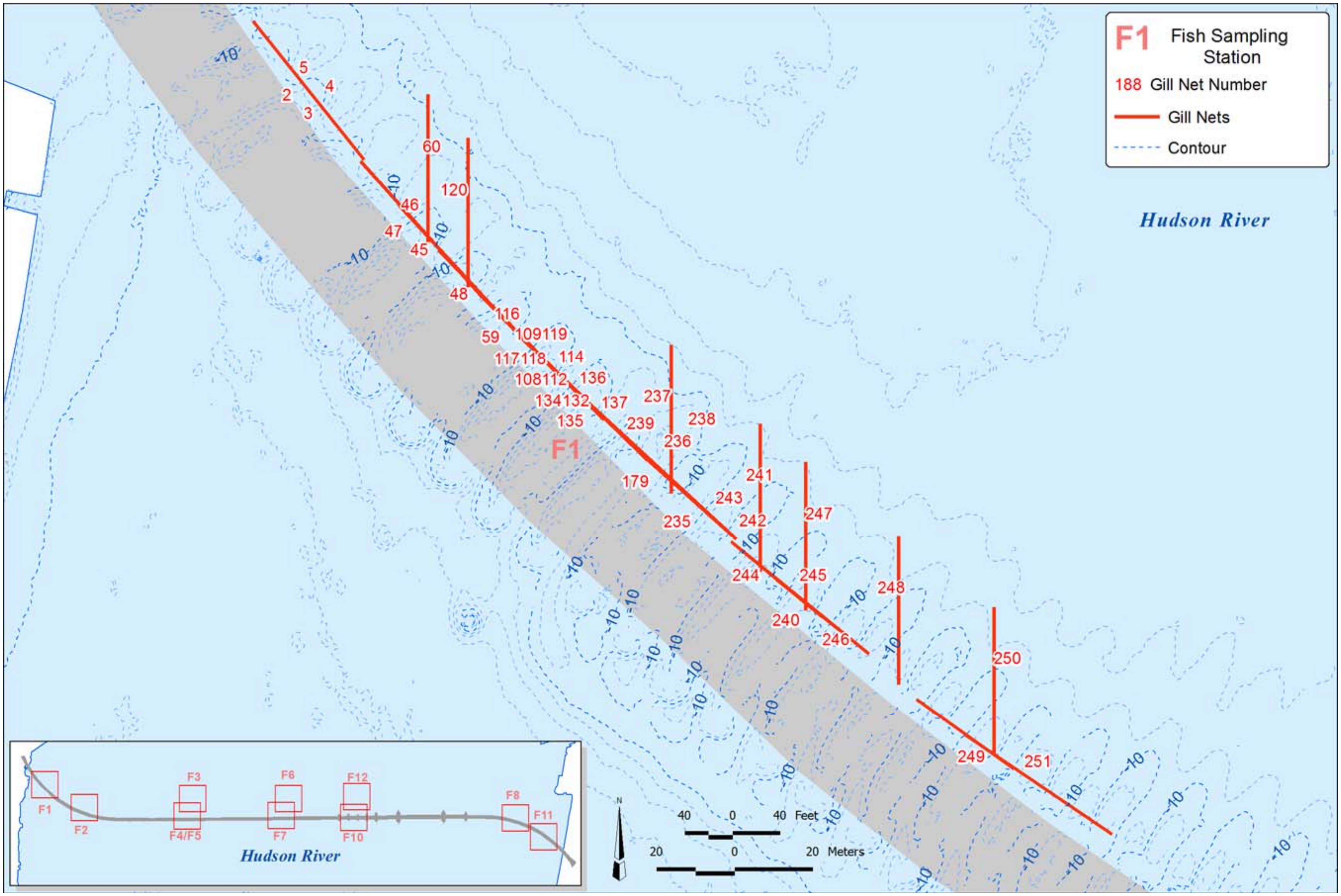


Figure F-1-13 Gill Net Deployment Locations at F1

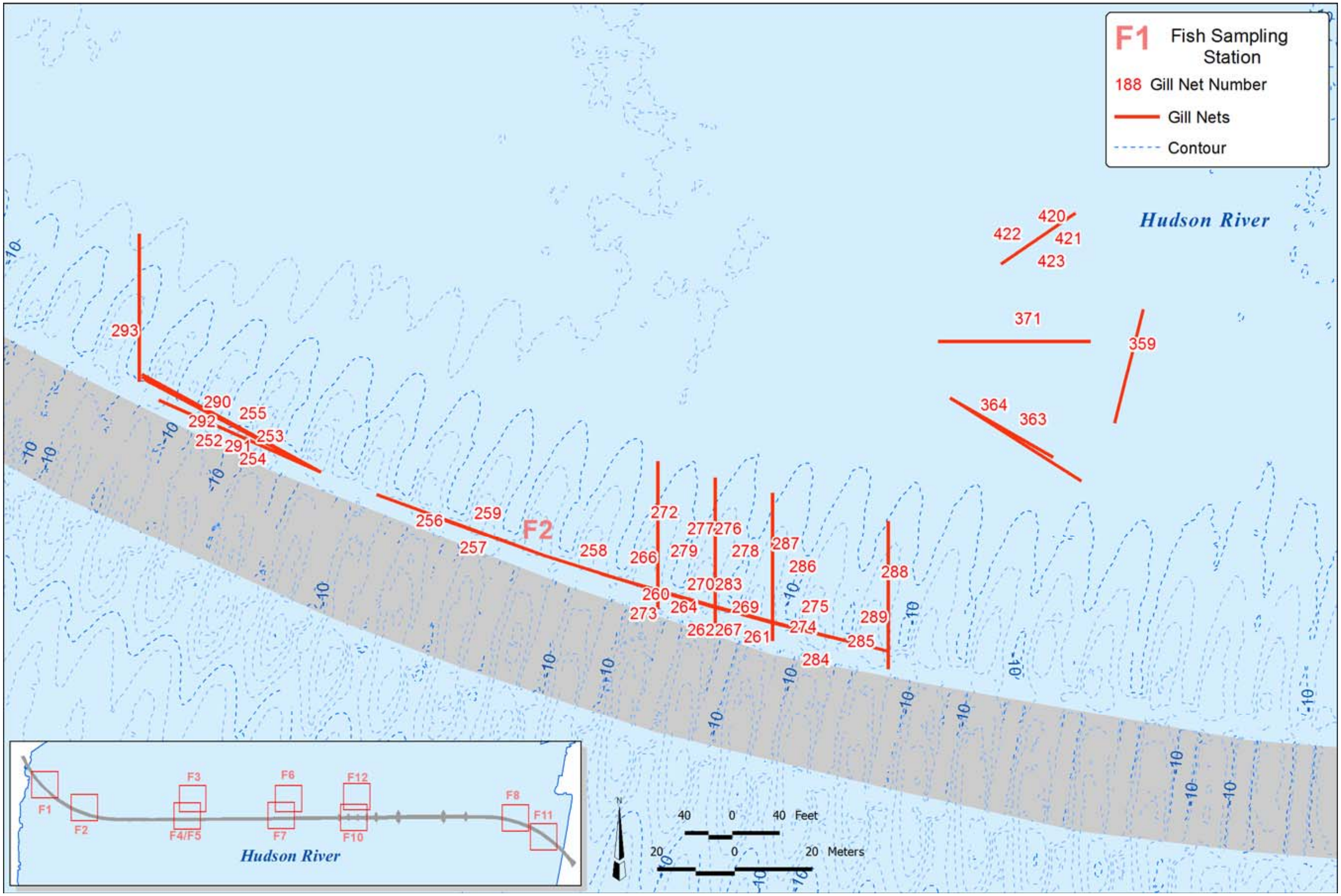


Figure F-1-14 Gill Net Deployment Locations at F2

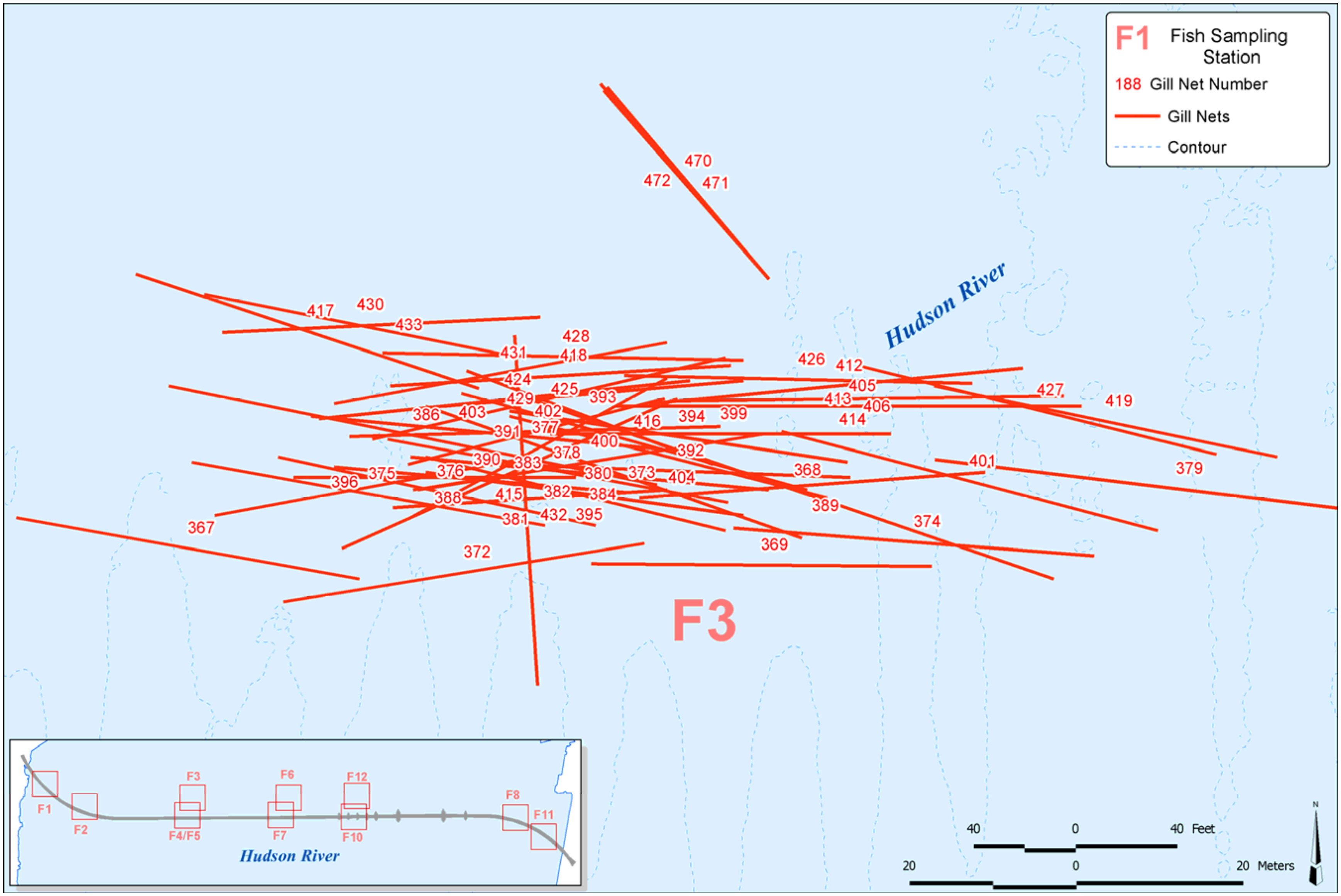


Figure F-1-15 Gill Net Deployment Locations at F3

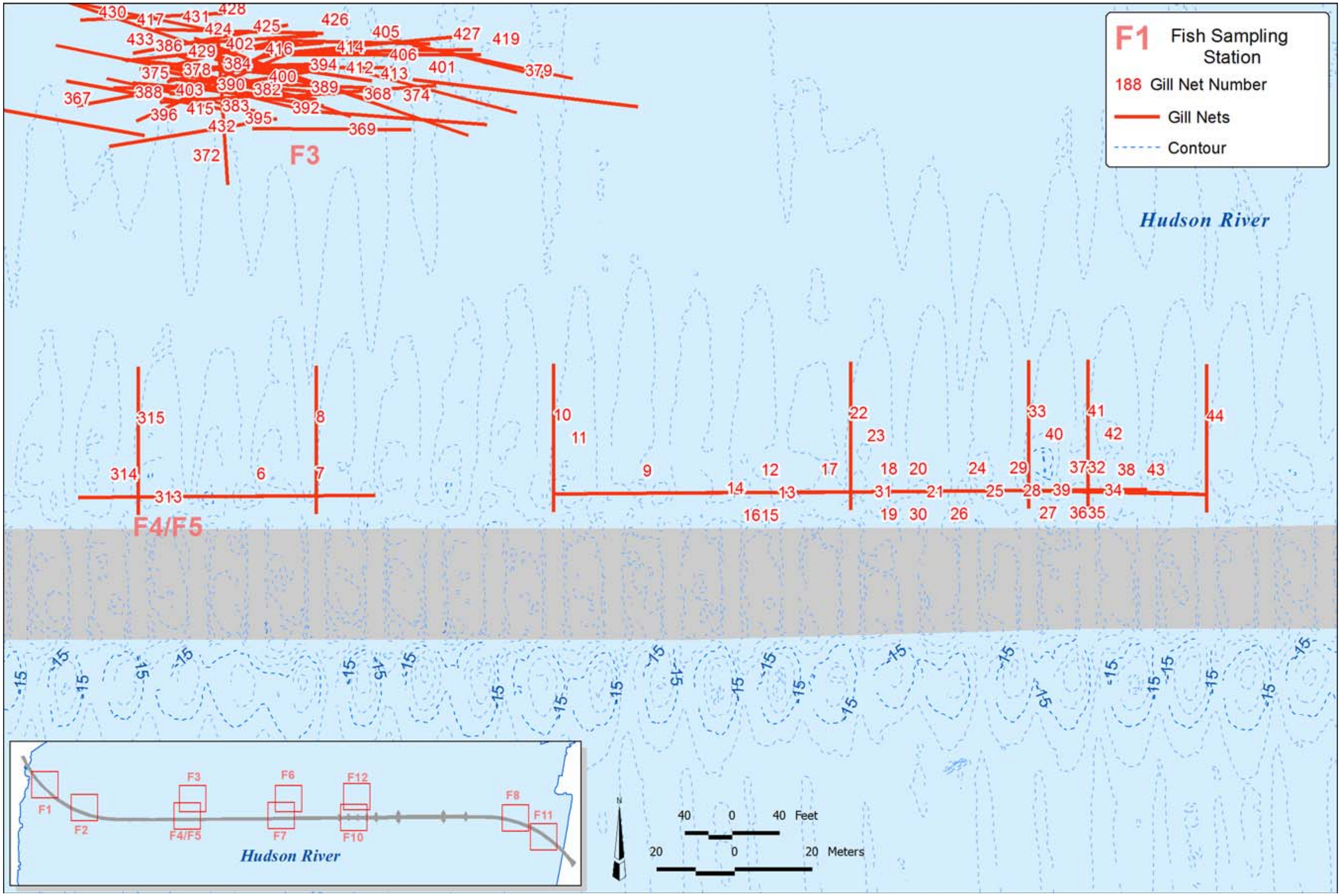


Figure F-1-16 Gill Net Deployment Locations at F4/5

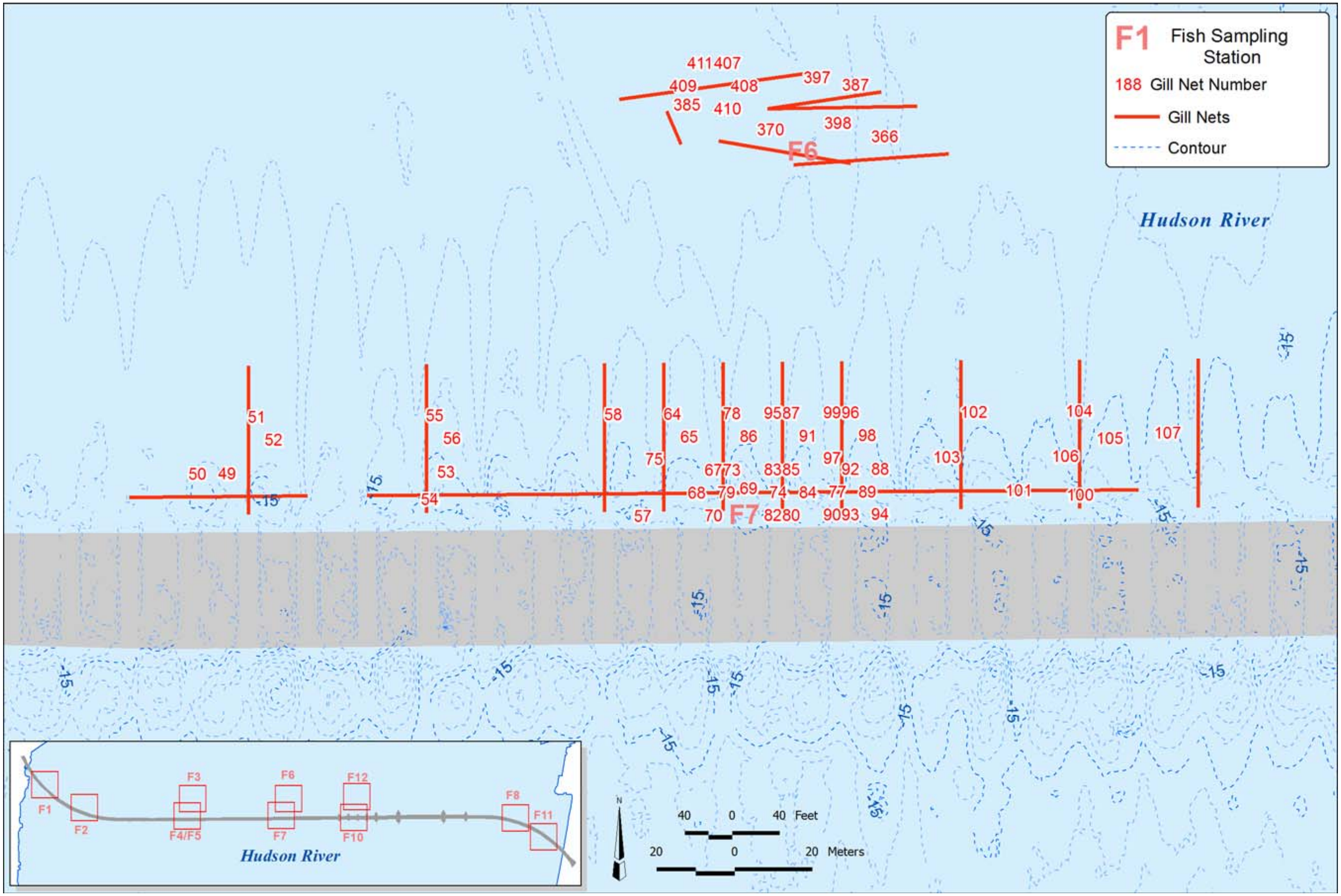


Figure F-1-17 Gill Net Deployment Locations at F6 and F7

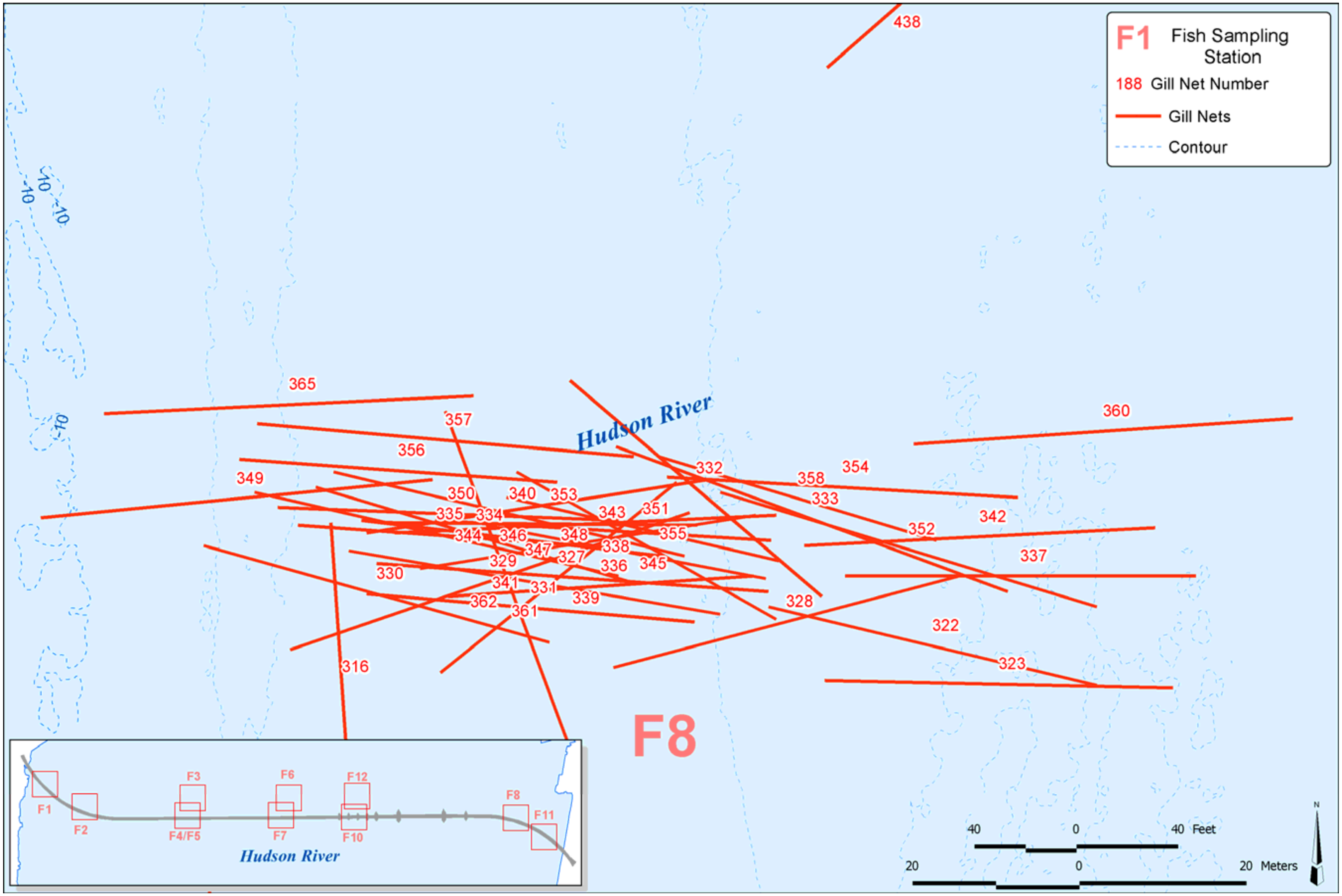


Figure F-1-18 Gill Net Deployment Locations at F8

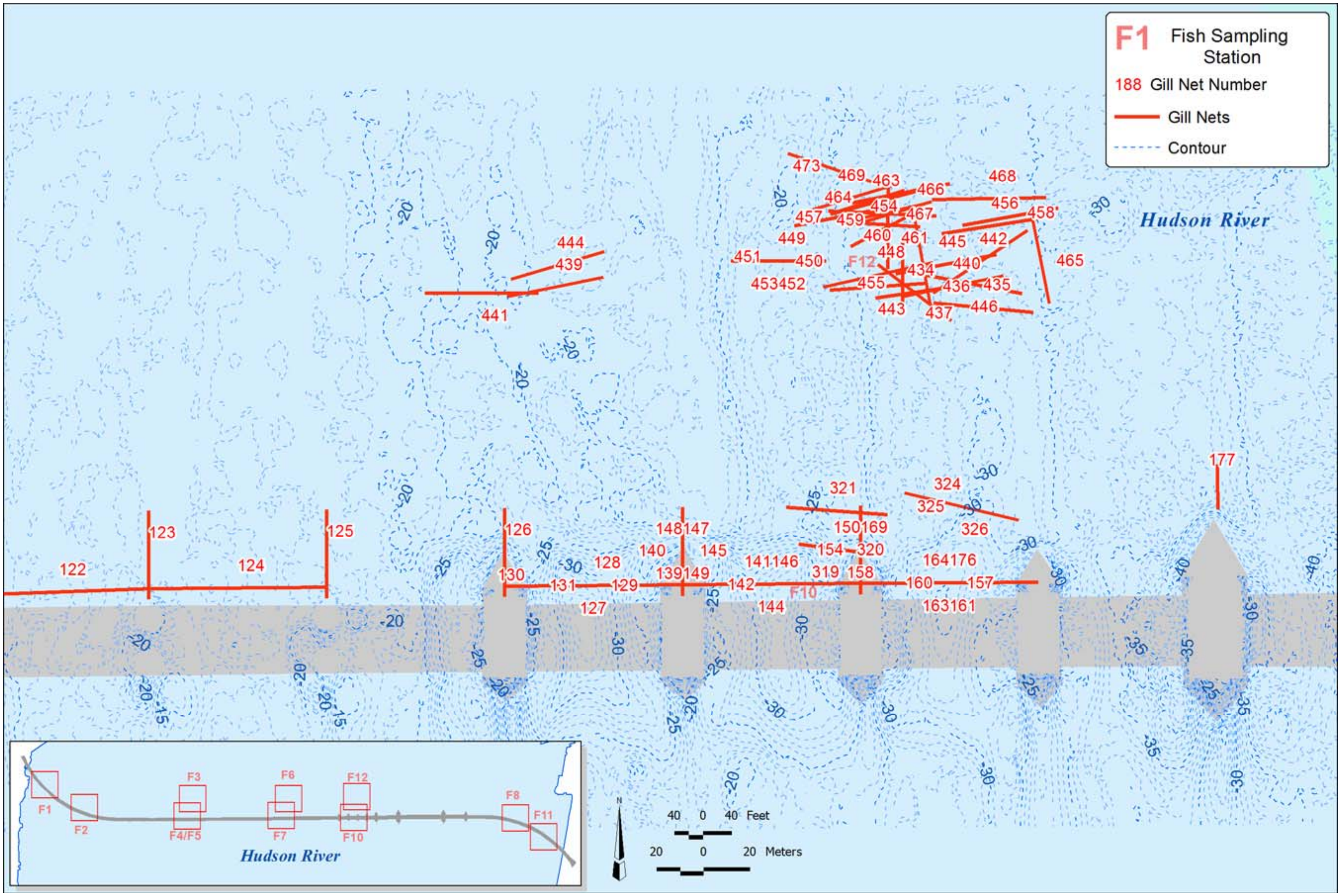


Figure F-1-19 Gill Net Deployment Locations at F10 and F12

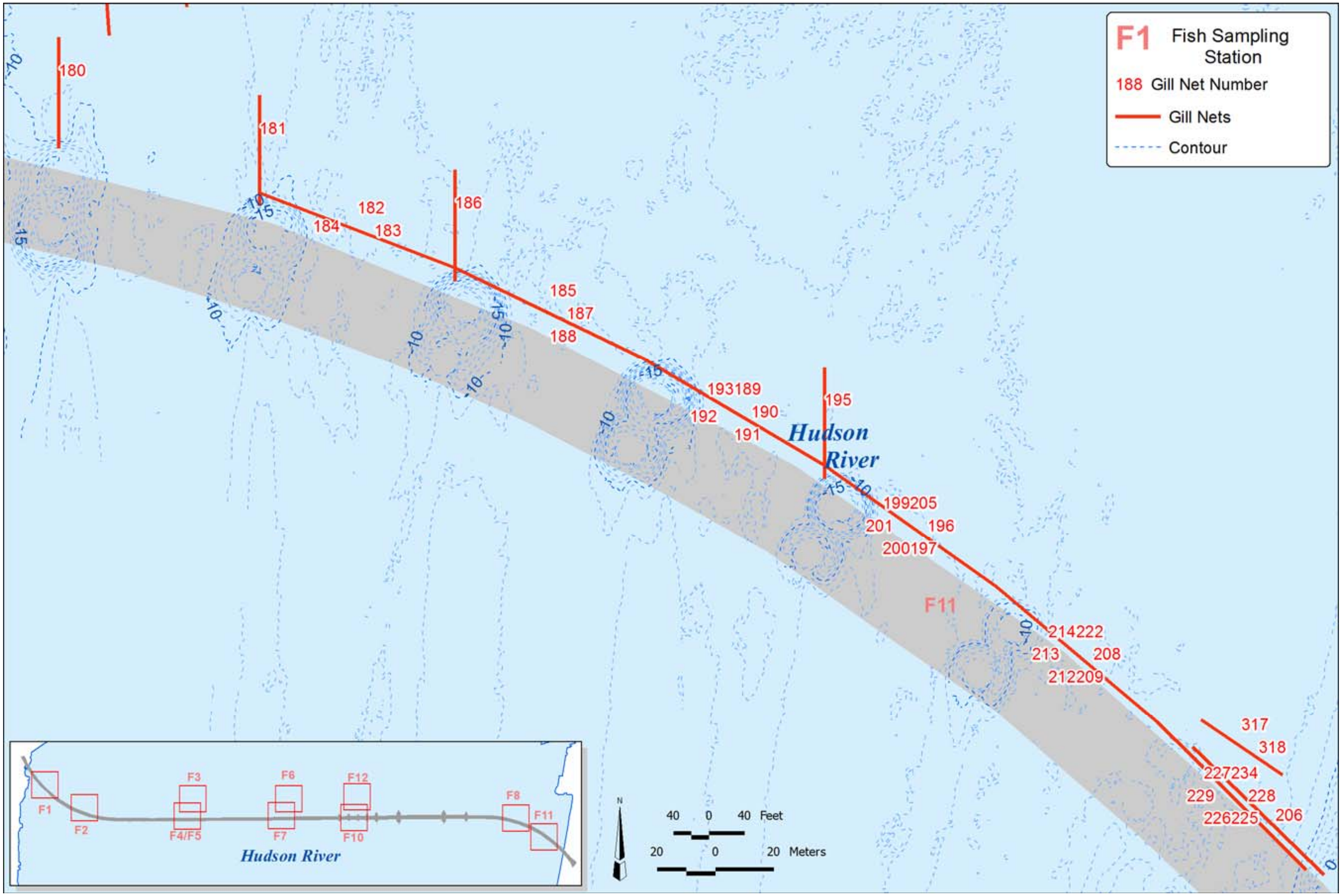


Figure F-1-20 Gill Net Deployment Locations at F11

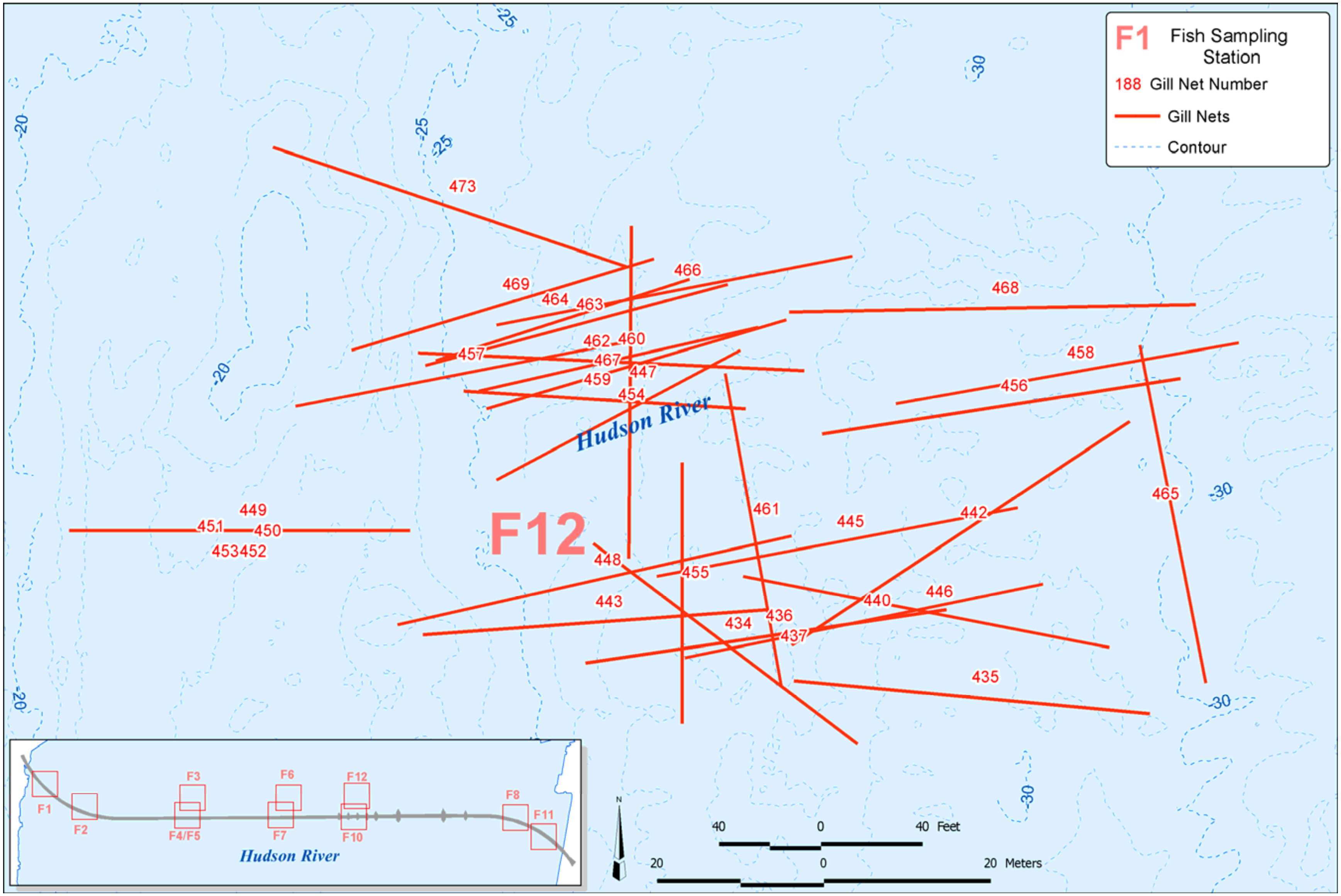


Figure F-1-21 Gill Net Deployment Locations at F12

Sampling Totals and Catch per Unit Effort

Fish Caught by Location

Fish were caught at all sampling locations throughout the year. In the colder months of the year, the total numbers of fish caught at all locations were markedly lower than the numbers of fish caught during the warmer months of the year. Moreover, there were higher numbers of fish caught at the sampling locations with greater water depths. Table F-1-1 provides the number of fish caught per location each month.

Table F-1-1
Monthly Fish Catch Totals by Location April 2007 – May 2008

Sample Location		Monthly Fish Catch Totals							Totals
		2007					2008		
		April	June	Aug	Oct	Dec	Feb	May	
Bridge	F1	5	16	76	107	2	1	31	*238*
	F2	2	6	51	101	1	1	13	*175*
	F4/F5	4	58	123	57	7	1	78	*328*
	F7	15	22	22	77	10	3	36	*185*
	F9	1	4	n/a	n/a	n/a	n/a	n/a	*5*
	F10	n/a	48	74	35	3	19	15	*194*
	F11	n/a	5	84	27	2	1	41	*160*
	Totals	*27*	*159*	*430*	*404*	*25*	*26*	*214*	*1,285*
Reference Area	F3	13	78	97	86	13	6	19	*312*
	F6	29	42	10	n/a	n/a	n/a	n/a	*81*
	F8	1	2	26	15	6	0	45	*95*
	F12	n/a	24	69	38	9	20	15	*175*
	Totals	*43*	*146*	*202*	*139*	*28*	*26*	*79*	*663*
GRAND TOTALS		70	305	632	543	53	52	293	*1,948*

Note: n/a = not applicable (These locations were not sampled within the respective months).

Sampling Effort

Table F-1-2 shows the number of gill net deployment hours (i.e., soak time) per location, per month. Due to concerns of injuring the shortnose sturgeon, the gill net soak times were limited by water temperatures. For temperatures below 59˚F (15˚C), the maximum soak time was 4 hours; for temperatures between 59 and 68˚F (15 and 20˚C), the soak times were limited to 2 hours. For temperatures between 68 and 80.6˚F (20 and 27˚C), the soak times were limited to 1 hour. No netting was permitted when the water temperatures exceeded 80.6˚F (27˚C).

Table F-1-2
Total Soak Time April 2007 – May 2008

Sample Locations		Hours Per Sampling Location							*Totals*
		April	June	Aug	Oct	Dec	Feb	May	
Bridge	F1	11.25	3	9	8.75	23.4	21.4	17.4	*94.2*
	F2	4	2	6	8.5	18.5	27.75	4.3	*71.05*
	F4	8.5	14	10.75	8.75	20.25	20.4	16.5	*99.15*
	F7	9.6	8	6.25	9.15	24.25	30.45	12	*99.7*
	F10	-	9	10.25	6	12.75	24.25	15	*77.25*
	F11	-	2	13.35	9.25	22.75	34	24.5	*105.85*
	Totals	*33.35*	*38*	*55.6*	*50.4*	*121.9*	*158.25*	*89.7*	*547.2*
Reference Area	F3	12	7	10	6	20.75	37.25	17	*110*
	F8	7.5	1	7	8.15	22.5	25.45	25	*96.6*
	F12	-	5	7.5	7	12.5	23	14.8	*69.8*
	Totals	*19.5*	*13*	*24.5*	*21.15*	*55.75*	*85.7*	*56.8*	*276.4*
GRAND TOTALS	*Totals*	*52.85*	*51*	*80.1*	*71.55*	*177.65*	*243.95*	*146.5*	*823.6*

Generally, in the warmer portions of the year a total of two nets were deployed in the river. The nets were set at 0.5-hour intervals. The scientists would retrieve one net; identify the fish species captured, remove the fish, re-deploy the net, and travel to another location to repeat the process. In the warmer months up to 12 nets were set and deployed each day.

In the winter months (December and February), the colder water temperatures allowed for longer soak times and the placement of additional nets.

CPUE, the metric that identifies the number of fish caught per effort (i.e., gill net deployment), is calculated by the number of fish caught per gill net hour. Thus, if six fish were captured in a gill net that was deployed for three hours, the CPUE would be 2. Table F-1-3 identifies the CPUE for each sample location in the study area.

Review of the data shows that there was minor variation of total CPUE between reference and bridge locations of similar depth and substrate. For the mid-depth locations on the west side of the river, the reference location (Sample Site F3) usually had a slightly higher CPUE than did the bridge locations (Sample Sites F1, F2, F4, and F7); although the difference was substantial for the month of June, when the reference location CPUE was double that of the bridge locations.

Table F-1-3

CPUE for each Sample Location

Sample Location		Apr	Jun	Aug	Oct	Dec	Feb	May
Bridge	F1	0.44	5.33	8.44	12.23	0.09	0.05	1.78
	F2	0.50	3.00	8.50	11.88	0.05	0.04	3.02
	F4	0.47	4.14	11.44	6.51	0.35	0.05	4.73
	F7	1.56	2.75	3.52	8.52	0.41	0.10	3.00
	F10	-	5.33	7.22	5.83	0.24	0.78	1.00
	F11	-	2.50	6.22	2.92	0.09	0.03	1.67
	Totals	*0.78*	*4.08*	*7.72*	*8.04*	*0.21*	*0.16*	*2.39*
Reference Area	F3	0.92	11.14	9.70	14.33	0.63	0.16	6.41
	F8	0.13	2.00	4.00	1.84	0.27	0.00	1.80
	F12	-	4.80	9.20	5.14	0.72	0.87	1.01
	Totals	*1.05*	*17.94*	*22.90*	*21.32*	*1.61*	*1.03*	*9.23*

Identified Fish Populations

A total of 25 fish species were collected during the fish-sampling activities between April 2007 and May 2008. A list of these species is presented in Table F-1-4.

In order to determine the use of the study area by the fish populations, each species identified in Table F-1-4 was assigned to one of the five assemblages (anadromous, catadromous, estuarine, freshwater, marine) based on the species' migratory habits and salinity preferences. As noted earlier, the grouping of species in this manner is a common way to identify the ecology of a specific study area in an estuarine environment. The assemblages are the same as those identified in the utilities' annual Year Class Reports. Table F-1-5 identifies the fish species comprising each assemblage.

Table F-1-6 identifies the numbers of fish captured each month, by assemblage. As can be observed in the table, for each month there is a similar distribution of anadromous, estuarine, and marine fish between the bridge and the reference locations. There is also no perceivable difference between the bridge and the reference area as habitat for freshwater fish. Although no freshwater fish were captured in the reference area, only four fish were captured in the bridge location. This likely reflects the fact that there were twice as many bridge sampling locations as there were reference locations.

Only two catadromous fish were captured (using traps) in the bridge location. It should be noted that fish traps were deployed overnight and for considerably longer periods at the bridge locations. (Traps could not be left overnight at reference locations as they would pose a hazard to navigation.)

Anadromous and estuarine fish were captured in every sampling event. Marine fish were only captured in the warmer months of the year when salinities permitted their presence in the study area.

Table F-1-4
Species Identified During Sampling

Common name	Scientific Name
Alewife	*Alosa pseudoharengus*
American eel*	*Anguilla rostrata*
American shad	*Alosa sapidissima*
Atlantic butterfish	*Peprilus triacanthus*
Atlantic menhaden	*Brevoortia tyrannus*
Atlantic tomcod	*Microgadus tomcod*
Bluefish	*Pomatomus saltatrix*
Blueback herring	*Alosa aestivalis*
Blue runner	*Caranx crysos*
Common carp	*Cyprinus carpio*
Gizzard shad	*Dorosoma cepedianum*
Hickory shad	*Alosa mediocris*
Hogchoker	*Trinectes maculatus*
Naked goby*	*Gobiosoma bosci*
Northern kingfish	*Menticirrhus saxatilis*
Northern sea robin	*Prionotus carolinus*
Oyster toad fish*	*Opsanus tau*
Porgy sp.	Order Perciformes
Shortnose sturgeon	*Acipenser brevirostrum*
Spot	*Leiostomus xanthurus*
Striped bass	*Morone saxitalis*
Summer flounder	*Paralichthys dentatus*
Weakfish	*Cynoscion regalis*
White catfish	*Ameiurus catus*
White perch	*Morone Americana*
Note: * Species only captured in fish traps.	

Table F-1-5

Captured Fish Species by Identified Assemblage

Assemblage	Species
Anadromous	Alewife American shad Atlantic tomcod Blueback herring Hickory shad Striped bass
Catadromous	American eel
Estuarine	Hogchoker Shortnose sturgeon White catfish White perch
Freshwater	Common carp Gizzard shad
Marine	Atlantic butterfish Atlantic menhaden Bluefish Blue runner Naked goby Northern kingfish Northern sea robin Oyster toad fish Porgy Spot sp. Summer flounder Weakfish

Table F-1-6

Numbers of Fish Captured each Month by Assemblage

Location	Assemblage	Apr	Jun	Aug	Oct	Dec	Feb	May	Totals
Bridge	Anadromous	39	8	30	29	4	10	38	158
	Catadromous*	0	0	0	1	0	0	1	2
	Freshwater	1	0	0	1	2	0	0	4
	Estuarine	16	124	202	266	19	16	64	707
	Marine	0	69	207	112	0	0	72	460
	Totals	56	201	439	408	25	26	174	1,331
Reference Area	Anadromous	13	3	29	10	7	8	40	110
	Catadromous	0	0	0	0	0	0	0	0
	Freshwater	0	0	0	0	0	0	0	0
	Estuarine	1	46	85	79	21	18	63	313
	Marine	0	55	77	50	0	0	68	250
	Totals	14	104	191	139	28	26	171	673
GRAND TOTALS		70	104	191	139	28	26	171	2,004
Note: Catadromous fish were only captured in fish traps.									

Analysis of Captured Species

The utilities' annual Year Class Reports provide detailed information on 16 key species within the Hudson River. Individuals of 12 of these 16 species were captured during the bi-monthly sampling effort. An analysis of those 12 species is provided below.

Alewife

A total of 39 alewives were captured, with 37 individuals captured in the May event, one in the April event, and one in the October event. Alewives varied in length between 3.5 and 10.4 inches (9 and 26.3 cm). Alewives were only captured at Sample Sites F1, F2, F3, F4 and F8. The capture of alewives in May, April, and October is likely reflective of the anadromous nature of the species. In the spring the species migrates through the Tappan Zee Reach upstream to spawn, and in the fall it migrates through the reach towards the ocean.

American Shad

A total of five American shad were captured during the study. Four shad were captured in April and one in May. They varied in length between 6.3 and 21.7 inches (16 and 55.2 cm). The capture of shad in May and April is likely reflective of the anadromous nature of the species. In the spring the species migrates through the Tappan Zee Reach upstream to spawn, and in the fall it migrates through the reach towards the ocean.

Atlantic Tomcod

A total of 11 tomcod were captured during the survey, all of them in the May sampling event. The tomcod varied in length from 8.6 to 11.6 inches (21.9 to 29.5 cm); all individuals were captured in the deep-water sampling locations (Sample Sites F10 and F12). It is unclear whether the captured tomcod were migrating back towards the ocean in the spring or were part of a resident population of the Hudson River. In December and February, when tomcod are most prevalent in the lower estuary, gill nets were deployed for more than 420 hours and yielded no individuals of this species.

Blueback Herring

One blueback herring was captured during the May sampling event. The fish measured 9.4 inches (24 cm) and was captured at Site F8. The capture of the blueback herring in May is likely reflective of the anadromous nature of the species. In the spring the species migrates through the Tappan Zee Reach upstream to spawn, and in the fall it migrates through the reach towards the ocean.

Gizzard Shad

A total of six gizzard shad were captured during the sampling program. The shad were caught in the months of April, May, October, and December. They were primarily captured at the sampling sites closest to the shoreline (F1 and F11), but one was caught at Site F5. The shad varied in length between 7.1 and 19.7 inches (18 and 50.1 cm). Gizzard shad are a resident estuarine fish, so their capture during all four seasons was not unanticipated.

Hogchoker

A total of 15 hogchokers were captured. Hogchokers were recorded at both shallow and deep-water sampling stations. Hogchokers were captured during the months of June, August, and October, when the salinity in the Tappan Zee Reach was higher.

Sturgeons – Atlantic and Shortnose

A total of 12 shortnose sturgeons (Photo F-1-6) were captured during the bi-monthly fish-sampling effort. The sturgeons were captured in the warmer months of the year – between May and October – at both the bridge and reference locations in water depths between 6 and 30 feet (1.8 and 9.1 m). Table F-1-7 lists the sturgeons caught, giving their length, weight, and location. No Atlantic sturgeons were captured, although in May 2008 the carcass of an Atlantic sturgeon was observed floating approximately 500 feet (152.4 m) north of the bridge.

No discernible trend regarding the presence or absence of shortnose sturgeons can be inferred from the data. Although no individuals were captured during the December, February, and April sampling events, it is possible that the species is present within the Tappan Zee Reach but that the cold waters slowed its movements.

Photo F-1-6 Shortnose Sturgeon Captured at the F1 Sampling Location. Note the bridge in the background.

Table F-1-7

Sturgeons Caught During the Fish Survey

Date	Station	Water Depth in Feet	Water Temperature		Species	Length		Weight	
			C°	F°		M	Feet	Kg	Lbs
06/13/07	F1	10.5	22.41	72.3	Shortnose sturgeon	0.99	3.02	5.2	11.65
06/14/07	F11	6	21	69.8	Shortnose sturgeon	0.86	2.61	3.6	8.07
08/21/07	F8	7.5	23.92	75.1	Shortnose sturgeon	0.88	2.67	4.25	9.52
09/04/07	F4	12	23.53	74.4	Shortnose sturgeon	0.45*	1.37	-	-
09/06/07	F7	15	24.68	76.4	Shortnose sturgeon	0.71	2.16	2.9	6.50
10/02/07	F5	14	21.02	69.8	Shortnose sturgeon	0.77	2.35	4.2	9.41
10/03/07	F10	32	22.12	71.8	Shortnose sturgeon	0.89	2.72	3.9	8.74
10/08/07	F7	15	22.82	73.1	Shortnose sturgeon	0.75	2.29	3	6.72
10/08/07	F7	15	22.82	73.1	Shortnose sturgeon	0.83	2.53	4.1	9.19
10/09/07	F10	30	22.92	73.3	Shortnose sturgeon	0.65*	1.98	-	-
5/7/08	F12	28	14.18	57.5	Shortnose sturgeon	0.69	2.10	3.25	7.28
5/16/08	F8	8	15.58	60.0	Shortnose sturgeon	0.81	2.47	3.3	7.39
5/16/08	F3	12	15	59.0	Atlantic sturgeon**	2.50 **	7.62	-	-

Notes:

* Length estimated. Fish fell out of net during retrieval.

** Carcass was observed floating on the surface. The carcass was scanned both visually and electronically for identification tags, but none were found. Total length was estimated, as the carcass was exhibiting signs of decomposition and disarticulation (its head was missing).

Striped Bass

A total of 185 striped bass were captured during the fish survey. The length of a striped bass is correlated with its age. For purposes of this study, YOY fish are those less than 4.7 inches (12 cm) in length. Fish larger than 17 inches (43 cm) in length are potentially sexually mature males or egg-bearing females. Fish of lengths between these two values are classified as sub adults. Of the 185 individual fish sampled, 48 were YOY, 83 were sub adult, and 54 were capable of bearing young.

The striped bass were captured throughout the river during the year, with their numbers and sizes varying by season and location. Table F-1-8 displays the total number of individual striped bass captured each month and the average length, minimum length, and maximum length of individuals captured at each location each month.

During the colder months (December and February) and the month of June, the number of fish captured was low, and fish were segregated by size and depth. YOY and sub adults were generally located in the shallow shoals, while larger fish were captured in the deeper portion of the river. During the spawning period (April and May), larger fish were captured within the shallow shoals. Also, in the May sampling event, 18 of the 32 individuals captured were YOY fish. In June, August, and October, most of the fish captured were sub adults. The fish were caught throughout the river at different depths, although during these months as well, larger fish were caught at the deeper-water sites.

Weakfish

A total of 19 weakfish were captured during the study. The weakfish varied in length between 3.9 and 15.7 inches (10 and 40 cm). Weakfish were only captured during August and October and the large majority of them (16 of the 19) were captured at the deep-water locations (Sites F10 and F12). Weakfish are marine species and were captured during the portions of the year when salinity in the study area was at its highest.

White Catfish

White catfish were captured during the March, May, June, August, and October sampling periods. A total of 37 were captured, and varied in total length between 5.9 and 17.7 inches (15 and 45 cm). During the June sampling period, white catfish were only captured at the deep-water sampling locations (Sites F10 and F12). In other months of the year, they were captured in both shallow and deep-water locations. White catfish are a resident estuarine fish, so their capture during all four seasons was not unanticipated.

White Perch

Roughly 50 percent (983) of all the fish captured in gill nets during the sampling program were white perch. Sampling events in warmer water temperatures had dramatically higher captures of white perch than months with colder water temperatures. White perch were most abundant during the October sampling (335 individuals captured) and least abundant during the April sampling event (only 17 individuals). The average length of fish captured each month generally was fairly constant, except for the May sampling event, which likely reflects an increase in the number of captured YOY fish. Table F-1-9 shows the number of white perch captured and average lengths each month.

Table F-1-8
Striped Bass Captured During the Sampling Effort

Month	Sample Site	Fish Length in centimeters		
		Average	Minimum	Maximum
All months (N* = 186)	All	30.2	7.6	83.0
February (N = 17)	All sites combined	39	10.0	80.0
	F1	10	10	10
	F3	11.0	10	12
	F10	53.6	42	80
	F11	20	20	20
	F12	41.4	10	56.4
April (N = 46)	All sites combined	45.8	17	76
	F1	57.5	57.5	57.5
	F3	45.65	27	76
	F4	45.4	41.8	47.3
	F6	46.5	33	61
	F7	44.3	17	56
May (N= 33)	All sites combined	22.4	9	83
	F1	11.5	11	12
	F2	22	22	22
	F3	23.8	9	83
	F4	23.4	9	48.1
	F7	42.4	21.2	57
	F8	26	10	11
	F10	61	61	61
	F11	11	10	12
	F12	11.75	11	12
June (N =8)	All sites combined	12.6	7.6	24.4
	F3	15.8	15.6	15.8
	F5	9.2	n/a	n/a
	F6	10.0	n/a	n/a
	F7	12.2	12.2	12.2
	F10	17.3	10.2	24.4
August (N =37)	All sites combined	23.9	8	60
	F1	9.8	9.5	10
	F2	20.0	10	30
	F3	21.2	10	31.5
	F4	19.6	10	26.5
	F7	14.9	10.1	22.5
	F8	14.5	10	19
	F10	36.3	20	60
	F11	21.5	21.5	21.5
	F12	22.2	15	27

Table F-1-8 (con't)

Striped Bass Captured During the Sampling Effort

Month	Sample Site	Fish Length in centimeters		
		Average	Minimum	Maximum
Oct (N =34)	All sites combined	24.1	10	52.5
	F1	21.1	10	38.1
	F2	14.5	11	23
	F3	17.9	11	24.3
	F4	16.8	10	23.5
	F7	21.3	12	27
	F10	39.7	23.5	52.5
	F11	-	-	-
	F12	35.5	25	46
Dec (N =10)	All sites combined	28.0	12.0	59.0
	F1	37.5	37.5	37.5
	F3	35.2	19.8	50.5
	F5	12.0	12.0	12.0
	F7	22.5	21.9	23
	F8	22.3	20.5	24.1
	F12	59.0	59.0	59.0

Notes: "N" refers to the number of individuals.
n/a = not applicable.
A total of 185 striped bass were captured during the survey.

Table F-1-9

Number and Average Length of White Perch Captured by Month

Month	Number Captured	Average Length in centimeters
April	17	18.3
May	146	15.0
June	151	18.9
August	263	19.7
October	335	19.9
December	40	19.8
February	31	19.1
TOTAL	983	18.67

Review of the data shows that there is a slight correlation of average fish length to water depth. Shallow-water sampling sites (F1, F8, and F11) had the smallest average fish lengths and deeper-water sampling sites had greater fish lengths, although there was wide variation in lengths at all sites. Average fish length per sample site is shown in Table F-1-10.

Table F-1-10
Average Length of White Perch Captured by Location

Sample Site	Number	Average Length in centimeters
F1	95	18.4
F2	92	19.1
F3	163	18.3
F4	163	19.1
F6	30	19.4
F7	97	19.7
F8	32	16.8
F10	120	20.0
F11	96	18.2
F12	95	19.0

American Eel, Atlantic Menhaden, Bluefish, and Hickory Shad

The American eel, Atlantic Menhaden, Bluefish, and Hickory Shad are four species that occur seasonally within the Hudson River.

- American eel – This catadromous species utilizes the lower Hudson estuary. Eels are predatory fish, but they also serve as prey species for larger predatory fish. Only two American eels were captured (in the fish traps) during the sampling period. This low number of capture likely underrepresents the eel population, as the sampling program’s objective and gear was not designed to capture eels.

- Atlantic Menhaden – This marine species is present within the estuary during the warmer months of the year when salinity levels are at their highest. Menhaden are a prey species for many of the predatory fish, especially striped bass. Both the Atlantic menhaden and bluefish (see below) generally swim in large schools. Between the months of May and October, large schools of both species were observed swimming in the Tappan Zee Reach. During the fish survey, 382 Atlantic Menhaden were captured. Menhaden were captured at all sampling locations.

- Bluefish – This marine species is present in the Tappan Zee Reach during the warmer months when salinity levels are at their highest. Bluefish are voracious predators. During the fish survey, 151 bluefish were captured. Bluefish were captured at all sampling locations.

- Hickory Shad – This anadromous species is in the same family as alewives, American shads and herrings. The hickory shad is one of the species that make up the “shad runs” during the spring. Five hickory shad were captured during the survey, all during the months of June and August at Sites F4 and F5.

Other Species Captured

Nine other marine species of fish were captured during the sampling program, including the Atlantic butterfish, blue runner, naked goby, northern king fish, northern sea robin, oyster toadfish, porgy, spot, and summer flounder. These marine species were either gill netted or trapped during the June, August, and October sampling periods. During the warmer summer months, the increase in river salinity permits the utilization of the Lower Hudson River by typical marine fish or species adapted to live in polyhaline conditions. The number of captured individuals of each species was minimal.

The naked goby and the oyster toad fish are common species within the Hudson River estuary and New York Harbor. Both of these species are cryptic and live on the bottom within dark recesses, under ledges, or on oyster reefs. These two species may use the bridge piers as a habitat resource.

The common carp is a freshwater species. One individual was captured during the May sampling event after a very large rain event. It is likely that the fish was washed out of a nearby stream and does not reside in the study area. The fish was captured at Sample Site F11 along the shoreline.

Essential Fish Habitat Species

Of the 13 EFH species identified, only two – the bluefish and the summer flounder – were captured during the sampling program. These marine species were captured in the warmer months of the year when higher salinities are present within the study area. It should be noted that the winter flounder (*Pleuronectes americanus*), designated as an EFH species by NMFS, was not captured or observed during the sampling program. This is important to note, as winter flounders lay their eggs over softer sediments (silty sand) in shallow waters during the winter months. Soft sediments in shallow waters dominate the western side of the river.

Fish Traps

Despite being deployed for hundreds of hours throughout the year-long survey, the fish traps yielded limited catches. Two American eels and one dozen naked gobies were captured in the traps. The low catch is likely a result of the strong currents present around the bridge piers and the resulting limited numbers of small fish that utilize the piers as habitat. Also, commercial crab traps deployed as part of the benthic invertebrate survey incidentally captured an oyster toadfish and numerous white perch.

Fish Utilization of the Study Area

As stated previously, the Hudson River Estuary is a dynamic environment. The presence of a particular species is often dependent on water temperature, migratory patterns, salinity, and other ecological factors. Table F-1-11 provides a brief synopsis of notable species, their lifestages, and biomass that occur within the Tappan Zee Reach throughout the year.

The combination of hydroacoustic surveys and gill nets and traps identified fish populations and distributions in and around the study area. Except for a few common cryptic species, the surveys determined that fish populations do not solely utilize the bridge as a refuge or foraging area.

Table F-1-11

Seasonal Presence of Biomass and Species in the Tappan Zee Reach

Hudson River Location	Bathymetric Contour (feet)	Biomass Abundance			Notable Species and Life Stages Present in the Study Area		
					Water Temps Below 5°C	Water Temps Above 5°C	
		Dec - Mar	Apr - May	Jun - Nov	Dec -Mar	Apr-May	Jun - Nov
West Side	0-6	Low	Low	Low (although large schools may transit through the shallow waters)	Atlantic Tomcod and its early life stages (e.g., eggs and larvae- more prevalent in March.) Striped Bass (mid-March)	Striped Bass Shad and Herring Early life stages (e.g., eggs and larvae)of various species begin to appear in May (striped bass, shad, white perch)	Blue Crabs Shortnose Sturgeon Shad and Herring* Large schools baitfish and summer marine species (e.g., bluefish, menhaden) Early life stages for many species (e.g., eggs and larvae) Numerous YOY (e.g., striped bass, shad, tomcod, and white perch).
	6-12	Low	Moderate	Moderate	Atlantic Tomcod and its early life stages (e.g., eggs and larvae - more prevalent in March.) Striped Bass (mid-March)	Striped Bass Shad and Herring Early life stages (e.g., eggs and larvae) of various species begin to appear in May (striped bass, shad, white perch)	Blue Crabs Shortnose Sturgeon Shad and Herring* Large schools baitfish and summer marine species (e.g., bluefish, menhaden) Early life stages for many species (e.g., eggs and larvae) Numerous YOY (e.g., striped bass, shad, tomcod, and white perch).

Table F-1-11 (con't)

Seasonal Presence of Biomass and Species in the Tappan Zee Reach

Hudson River Location	Bathymetric Contour (feet)	Biomass Abundance			Notable Species and Life Stages Present in the Study Area		
					Water Temps Below 5°C	Water Temps Above 5°C	
		Dec -Mar	Apr - May	Jun – Nov	Dec -Mar	Apr-May	Jun - Nov
West Side (cont'd)	12-18	Low	Moderate	Moderate	Striped Bass (mid-March)	Atlantic Sturgeon Striped Bass Shad and Herring Early life stages (e.g., eggs and larvae) of various species begin to appear in May (striped bass, shad, white perch)	Blue Crabs Shortnose Sturgeon Shad and Herring* Large schools baitfish and summer marine species (e.g., bluefish, menhaden) Early life stages for many species (e.g., eggs and larvae) Numerous YOY (e.g., striped bass, shad, tomcod, and white perch).
	18-24	Low-Moderate	Moderate	Moderate	Striped Bass (mid-March)	Atlantic Sturgeon Shortnose Sturgeon Striped Bass Early life stages (e.g., eggs and larvae) of various species begin to appear in May (striped bass, shad, white perch)	Blue Crabs Shortnose Sturgeon Shad and Herring* Tomcod Weakfish Large schools baitfish and summer marine species (e.g., bluefish, menhaden) Early life stages for many species (e.g., eggs and larvae)

Table F-1-11 (con't)

Seasonal Presence of Biomass and Species in the Tappan Zee Reach

Hudson River Location	Bathymetric Contour (feet)	Biomass Abundance			Notable Species and Life Stages Present in the Study Area		
					Water Temps Below 5°C	Water Temps Above 5°C	
		Dec -Mar	Apr - May	Jun – Nov	Dec -Mar	Apr-May	Jun - Nov
Deep Channel	24+	Moderate - High	Moderate - High	High	Shortnose Sturgeon Striped Bass (mid-March)	Atlantic Sturgeon Atlantic Tomcod Shortnose Sturgeon Striped Bass Early life stages (e.g., eggs and larvae) of various species begin to appear in May (striped bass, shad, white perch)	Blue Crabs Shortnose Sturgeon Tomcod Weakfish Large schools baitfish and summer marine species (e.g., bluefish, menhaden) Early life stages for many species (e.g., eggs and larvae)
East Side	18-24	Low-Moderate	Moderate	Moderate	Striped Bass (mid-March)	Atlantic Sturgeon Shad and Herring Shortnose Sturgeon Striped Bass Early life stages (e.g., eggs and larvae) of various species begin to appear in May (striped bass, shad, white perch)	Blue Crabs Shortnose Sturgeon Shad and Herring* Tomcod Weakfish Large schools baitfish and summer marine species (e.g., bluefish, menhaden) Early life stages for many species (e.g., eggs and larvae)

Table F-1-11 (con't)

Seasonal Presence of Biomass and Species in the Tappan Zee Reach

Hudson River Location	Bathymetric Contour (feet)	Biomass Abundance			Notable Species and Life Stages Present in the Study Area		
					Water Temps Below 5°C	Water Temps Above 5°C	
		Dec -Mar	Apr - May	Jun – Nov	Dec -Mar	Apr-May	Jun - Nov
East Side (con't)	12-18	Low	Low	Moderate	Striped Bass (mid-March)	Atlantic Sturgeon Shad and Herring Shortnose Sturgeon Early life stages (e.g., eggs and larvae) of various species begin to appear in May (striped bass, shad, white perch)	Blue Crabs Shortnose Sturgeon Shad and Herring* Large schools baitfish and summer marine species (e.g., bluefish, menhaden) Early life stages for many species (e.g., eggs and larvae) Numerous YOY, especially striped bass and white perch after mid-July through September.
	6-12	Low	Low	Moderate	Atlantic Tomcod and its early life stages (e.g., eggs and larvae- more prevalent in March.)	Shad and Herring Early life stages (e.g., eggs and larvae) of various species begin to appear in May (striped bass, shad, white perch)	Blue Crabs Shortnose Sturgeon Shad and Herring* Large schools baitfish and summer marine species (e.g., bluefish, menhaden) Early life stages for many species (e.g., eggs and larvae) Numerous YOY, especially striped bass and white perch after mid-July through September.

Table F-1-11 (con't)

Seasonal Presence of Biomass and Species in the Tappan Zee Reach

Hudson River Location	Bathymetric Contour (ft)	Biomass Abundance			Notable Species and Life Stages Present in the Study Area		
					Water Temps Below 5°C	Water Temps Above 5°C	
		Dec -Mar	Apr-May	Jun – Nov	Dec -Mar	Apr-May	Jun - Nov
East Side (con't)	0-6	Low	Low	Low (although large schools may transit through the shallow waters)	Atlantic Tomcod and its early life stages (e.g., eggs and larvae- more prevalent in March.)	Shad and Herring Early life stages (e.g., eggs and larvae) of various species begin to appear in May (striped bass, shad, white perch)	Blue Crabs Shortnose Sturgeon Shad and Herring* Large schools baitfish and summer marine species (e.g., bluefish, menhaden) Early life stages for many species (e.g., eggs and larvae) Numerous YOY, especially striped bass and white perch after mid-July through September.
Notes: * Shad and herring present during the fall migration (September – October).							

The horizontal, vertical, and geographical distribution of fish within the Tappan Zee Reach and the study area is substantially influenced by temperature and salinity. In the colder months of the year (December through April), the fish populations are concentrated in deeper waters with higher salinities. In the late winter and early spring, a distinct halocline was observed at a depth of approximately 19.7 feet (6 m). Fish concentrations increased below this depth. As the water warms in the late spring, the halocline dissipates and there is a notable increase in salinity in the shallower depths. Also observed is a marked increase in fish populations at those depths, although, the greatest numbers of fish continue to occur in the deepest portion of the channel. In the warmer months of the year, early life stages of many species are present within the Tappan Zee Reach.

Within the study area, fish do not appear to utilize the bridge structure in a significant way compared to the reference areas. The hydroacoustic survey determined that there was no clear pattern of habitat preference (bridge vs. reference area) by the fish species. Moreover, review of the CPUE data indicates that slightly higher populations of fish were captured at the reference area in the western portion of the river. This may be a result of three factors:

1) The increased water velocities near the bridge during certain portions of the tidal cycle and shading from the bridge during daylight hours are unattractive habitat characteristics for fish.

2) A large percentage of the individuals that were captured are members of large schooling species. The presence of the bridge piers restricted the potential approach direction to the gill net, resulting in slightly lower catches.

3) Sample Site F3 is the closest sampling location to historical oyster beds north of the bridge and is in close proximity to new oyster beds that were mapped in 2009. Oyster reefs and beds serve as attractive foraging areas for fish. It is likely that due to the presence of these oyster beds, more fish congregate near F3 that at other locations.

The endangered shortnose sturgeon was not determined to utilize the bridge structure in a significant way. The sturgeons were captured in the warmer months of the year at different depths. Only two EFH species, bluefish and the summer flounder, were captured during the fish survey. The winter flounder, another EFH-listed species, whose spawning area preferences match the conditions in the western portion of the study area, was not captured during the fish survey.

2 Benthic Macroinvertebrates

2.1 Area-Wide Macrobenthic Data

In 2000 and 2001, Versar (NYSDEC, 2009) collected 130 benthic community samples between RMs 11 and 40 within the study area. These samples were collected over a surface area of 0.43 sq feet (399.4 square centimeters [sq cm]) to a depth of 3.94 inches (10 cm). The benthic abundance and biomass data are summarized by calculating the total number of species per sample and the total biomass (grams ash free dry weight) per sample, respectively.

The highest numbers of species per sample are generally located in the lower region of the study area (south of the Tappan Zee Bridge), while the lowest numbers of species per sample are located primarily in the upper region of the river (north of the Tappan Zee Bridge). The highest benthic biomass occurs in the shallow-water regions of the river in Croton Bay and north of the Piermont Pier on the western side of the river.

The densities of benthic species – the number of individuals per sq m – were derived by summing all occurrences throughout the study area, dividing by the sample area (399.4 sq cm), and converting this value to an area in sq m (Table F-1-12). The species with the three highest densities are as follows:

- The species with the greatest density was the oligochaete worm *Tubificoides* spp., at 522/sq m, with the highest-density samples found near Hastings-on-Hudson, on the eastern shore of the river near RM 19.
- The species with the second-highest density was the small clam *Rangia cuneata*, at 401/sq m, with the samples of greatest density occurring near RM 31, Upper Nyack.
- The species having the third-highest density was the amphipod *Leptocheirus plumulosus*, at 263/sq m, with the samples of greatest density occurring near RM 35, near Croton Point.

2.2 Project-Specific Data

Benthic macro-invertebrate sampling locations were linked to the construction and demolition activities that may be evaluated in the EIS. As shown on Figure F-1-22 benthic sampling occurred in locations anticipated to be disturbed from proposed construction and/or rehabilitation.

For purposes of evaluating the potential ecological impacts of the removal of the existing bridge, the benthic community sampling occurred at 11 stations along a transect within 50 feet (15.24 m) of the existing bridge. In addition to the sampling near the bridge, 11 benthic sampling stations were placed along two transects within 150 feet (45.7 m) north of the existing bridge for the replacement bridge, at four locations along the southeast shoreline, and at two locations each on the southeast and southwest sides of the existing bridge for potential temporary causeways. Benthic sample locations were located within both scour and depositional areas near bridge piers and, where possible, based on boat safety restrictions, under the bridge itself. Sampling sites were selected in consultation with NYSDEC Region 3 using results of both the hydrographic surveys (described further below) and geophysical surveys conducted by LDEO.

Sampling was conducted bimonthly over a one-year period concurrent with the fish sampling. Sampling methods included use of a modified Van Veen grab (Photo F-1-7). Three replicates per location were collected. Samples were sieved in the field through a No. 35 mesh (0.5 mm), preserved in 70 percent ethyl alcohol and rose bengal and shipped to a laboratory for identification to the lowest practicable taxon (Photo F-1-8). Species identifications were verified by a third party. *In situ* water-quality measurements – of temperature, dissolved oxygen, and salinity – were collected at each station.

2.2.1 Sampling Locations

A total of 41 benthic invertebrate sediment sampling locations and six benthic invertebrate bridge pier sampling locations were utilized for this project.

Table F-1-12

Benthic Density of Species in the Study Area

Phylum	Species	Total Abundance	Density per sq m
Arthropoda	*Leptocheirus plumulosus*	1,506	263
	Balanus improvisus	1,096	192
	Cyathura polita	497	87
	Coelotanypus spp.	402	70
	Leucon americanus	291	51
	Neanthes succinea	187	33
	Rheotanytarsus spp.	97	17
	Ameroculodes species complex	68	12
	Chironomidae pupae	43	7.5
	Rhithropanopeus harrisii	37	6.5
	Leitoscoloplos spp.	36	6.3
	Edotea triloba	33	5.8
	Polypedilum halterale group	31	5.4
	Apocorophium lacustre	28	4.9
	Parachironomus hirtalatus	24	4.2
	Synidotea laticauda	18	3.1
	Parachironomus monochromus/tenuicadatus grp.	16	2.8
	Ampelisca abdita	10	1.7
	Melita nitida	10	1.7
	Cricotopus spp.	9	1.6
	Dicrotendipes spp.	9	1.6
	Cryptochironomus spp.	9	1.6
	Almyracuma proximoculi	3	0.5
	Procladius spp.	3	0.5
	Thienemannimyia grp.	3	0.5
	Ampelisca spp.	2	0.3
	Gammarus spp.	2	0.3
	Nais communis	2	0.3
	Neomysis Americana	2	0.3
	Crangon septemspinosa	1	0.2
	Harnischia spp.	1	0.2
	Monocorophium spp.	1	0.2
	Orthocladius spp.	1	0.2
Ampharetidae	Ampharetidae	1	0.2

Table F-1-12 (con't)

Benthic Density of Species in the Study Area

Phylum	Species	Total Abundance	Density per sq m
Annelida	*Tubificoides* spp.	2,986	522
	Marenzelleria viridis	1,209	211
	Heteromastus filiformis	1,090	191
	Hobsonia florida	621	109
	Boccardiella ligerica	575	101
	Polydora cornuta	539	94
	Streblospio benedicti	379	66
	Sabellaria vulgaris	237	41
	Immature Tubificid without capiliform chaetae	108	19
	Tubificidae without capiliform chaetae	61	11
	Mediomastus ambiseta	27	4.7
	Eteone heteropoda	24	4.2
	Aulodrilus limnobius	22	3.8
	Aulodrilus limnobius	22	3.8
	Laeonereis culveri	15	2.6
	Manayunkia aestuarina	15	2.6
	Limnodrilus hoffmeisteri	7	1.2
	Pectinaria gouldii	6	1
	Incisocalliope aestuarius	5	0.9
	Spiophanes bombyx	5	0.9
	Asabellides oculata	4	0.7
	Glycera Americana	4	0.7
	Nephtyidae	1	0.2
	Podarke obscura	1	0.2
	Podarkeopsis levifuscina	1	0.2
	Turbellaria	1	0.2
Chordata	*Molgula manhattensis*	131	23
Cnidaria	Anthozoa	38	6.6
Hepatophyta	*Mytilopsis leucophaeata*	12	2.1

Table F-1-12 (con't)

Benthic Density of Species in the Study Area

Phylum	Species	Total Abundance	Density per sq m
Mollusca	*Rangia cuneata*	2,292	401
	Mulinia lateralis	273	48
	Mya arenaria	149	26
	Macoma balthica	148	26
	Littoridinops tenuipes	104	18
	Odostomia engonia	51	8.9
	Crassostrea virginica	39	6.8
	Acteocina canaliculata	21	3.7
	Dreissena polymorpha	10	1.7
	Tellinidae	6	1
	Gastropoda	2	0.3
	Mytilus edulis	1	0.2
	Mytilidae	1	0.2
Nemertea	*Carinoma tremaphoros*	330	58
	Amphiporus bioculatus	3	0.5
	Micrura leidyi	1	0.2
Platyhelminthes	*Stylochus ellipticus*	5	0.9
Source: Densities calculated from data presented by Versar in 2003 *as cited in* NYSDEC, 2009.			

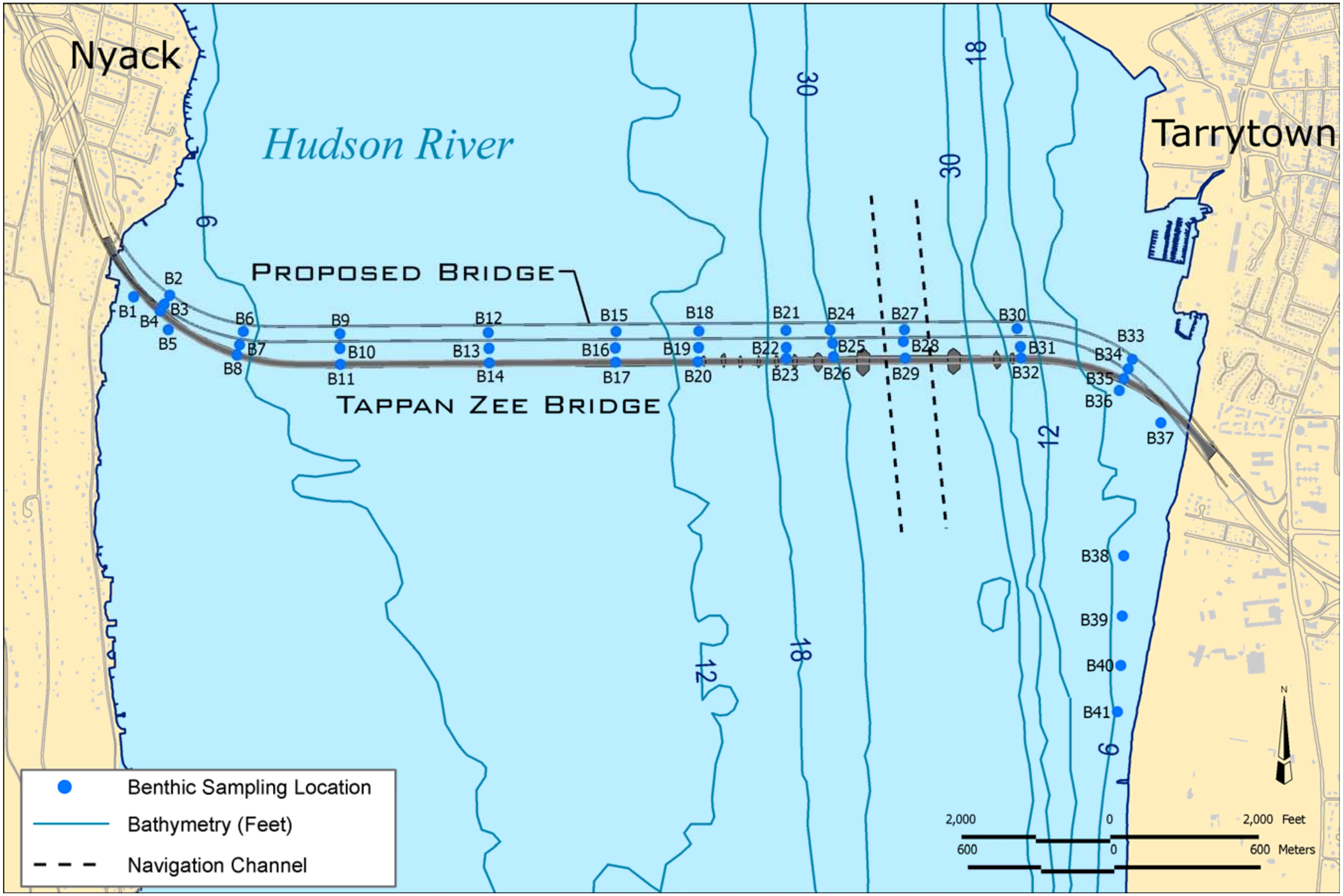


Figure F-1-22 Benthic Invertebrate Sampling Locations

Photo F-1-7 A Van Veen Grab Used for Benthic Sampling. Note glove for scale.

Photo F-1-8 Scientists processing benthic invertebrate samples.

Soft Sediment Sampling Locations

Benthic invertebrate samples were collected in five general geographical areas. Descriptions of these areas are as follows:

- Bridge Span – Sediment sampling sites within this area were located directly beneath the footprint of the current alignment.

- Mid Span – Sediment sampling sites within this area were located 50 feet (15.2 m) north of the current alignment.

- New Span – Sediment sampling sites within this area were located 150 feet (45.7 m) north of the current alignment. This area is presumed to be the alignment of the new bridge.

- South – Sediment sampling sites within this area were located in the areas of the potential alignments of southerly approaches to a new bridge.

- Shoreline – Sediment sampling sites within this area were in four locations south of the bridge along the eastern bank of the river.

In order to accurately describe the distribution of benthic invertebrates in the study area, the benthic habitat has been broken down into five broad categories with respect to the composition of the benthic substrate: fine sediments; sediments with shell hash; oyster shells/reef; scoured; and shoreline. Descriptions of each of these habitats follow:

- Fine Sediment Habitat. This habitat is comprised of thick deposits of soft, fine-grained sediments. Silt environments often occurred in shallow waters near the river banks where the river flow is attenuated by the shallow depth and bridge piers, which permits the buildup of soft sediments. The silt environment had limited shell material within the matrix.

- Sediment with Shell Hash Habitat. This habitat likewise contains very fine-grained sediments, but there is a marked increase in the number of shells and shell fragments (i.e. shell hash) in the matrix.

- Oyster Shells with Sediment. A majority of the matrix consisted of live oysters, oyster shells, and shell fragments. Sediments associated with this habitat were generally comprised of coarser-grained materials.

- Scoured. This habitat is limited to the deeper river channel. The presence of strong currents has affected the sediments, which generally consist of densely-packed, scoured clays with pockets of shells.

- Shoreline Habitat. This habitat was present south of the bridge on the eastern bank of the river. The sediments here are coarse-grained, with some gravel in the matrix. The sediments are influenced by previous Shoreline construction and outwash from small brooks and rivulets that empty into the river. There was often a limited recovery of sediment material in these locations.

Table F-1-13 provides a description of the each sediment sample.

Table F-1-13

Benthic Invertebrate Soft Sediment Sampling Locations

Sample Point	Geographical Area	Depth in feet	Habitat Category	Sediment Description
B-1	South	5	Fine Sediment	Silt
B-2	New Span	6	Fine Sediment	Very fine silt
B-3	Mid	7	Fine Sediment	Very fine silt with organic material
B-4	Bridge	10	Fine Sediment	Very fine silt
B-5	South	11	Fine Sediment	Very fine silt with organic material
B-6	New Span	7	Fine Sediment	Very fine silt with organic material and shells
B-7	Mid	9	Fine Sediment	Very fine silt with organic material and shells
B-8	Bridge	10	Fine Sediment	Silt with high amounts of shell hash
B-9	New Span	12	Sediment with Shell Hash Habitat	Clayey silt with shells
B-10	Mid	12	Sediment with Shell Hash Habitat	Clayey silt with shells
B-11	Bridge	12	Sediment with Shell Hash Habitat	Shells, gravel, and silt
B-12	New Span	11	Sediment with Shell Hash Habitat	Silty Material with shells
B-13	Mid	13	Sediment with Shell Hash Habitat	Oyster shells with clayey-silt
B-14	Bridge	12	Sediment with Shell Hash Habitat	Rocks, shells, and gravels
B-15	New Span	13	Sediment with Shell Hash Habitat	Silt material with organic matter
B-16	Mid	14	Sediment with Shell Hash Habitat	Silt material with shells
B-17	Bridge	14	Sediment with Shell Hash Habitat	Oyster shells with sand and gravel
B-18	New Span	20	Oyster Shells with Sediment	Oyster Shells with Silt
B-19	Mid	20	Oyster Shells with Sediment	Oyster Shells with Silt
B-20	Bridge	21	Oyster Shells with Sediment	Oyster Shells with Silt
B-21	New Span	24	Oyster Shells with Sediment	Oyster Shells with Silt
B-22	Mid	25	Oyster Shells with Sediment	Oyster Shells with Silt
B-23	Bridge	37	Oyster Shells with Sediment	Oyster Shells with Silt
B-24	New Span	37	Oyster Shells with Sediment	Oyster Shells with Silt
B-25	Mid	40	Oyster Shells with Sediment	Oyster Shells with Silt
B-26	Bridge	42	Oyster Shells with Sediment	Oyster Shells with Silt
B-27	New Span	50	Scoured	Rocks, shells, and gravels
B-28	Mid	49	Scoured	Rocks, shells, and dense clays
B-29	Bridge	48	Scoured	Rocks, shells, limited sediment
B-30	New Span	12	Oyster Shells with Sediment	Silty material with organic matter

Table F-1-13 (con't)

Benthic Invertebrate Soft Sediment Sampling Locations

Sample Point	Geographical Area	Depth in feet	Habitat Category	Sediment Description
B-31	Mid	20	Oyster Shells with Sediment	Oyster shells, very low recovery of material
B-32	Bridge	22	Oyster Shells with Sediment	Gravel, pebbles, with shells
B-33	New Span	9	Oyster Shells with Sediment	Oyster Shells
B-34	Mid	10	Oyster Shells with Sediment	Oyster Shells and silt
B-35	Bridge	9	Sediment with Shell Hash Habitat	Silt with Shells
B-36	South	9	Fine Sediment	Very fine silt with shell hash
B-37	South	7	Fine Sediment	Very fine silt with shells
B-38	Shoreline	5	Shoreline Habitat	Sand and Silt
B-39	Shoreline	11	Shoreline Habitat	Sand and Silt
B-40	Shoreline	6	Shoreline Habitat	Sandy material, with shells
B-41	Shoreline	10	Shoreline Habitat	Sandy material

Bridge Pier Sampling Locations

To obtain data regarding the benthic flora and fauna that colonized the bridge pier structures, Self Contained Underwater Breathing Apparatus (SCUBA) divers performed visual observations and collected specimens for analysis. Six piers were selected for the study, conducted in October 2007; their locations are shown in Figure F-1-23.

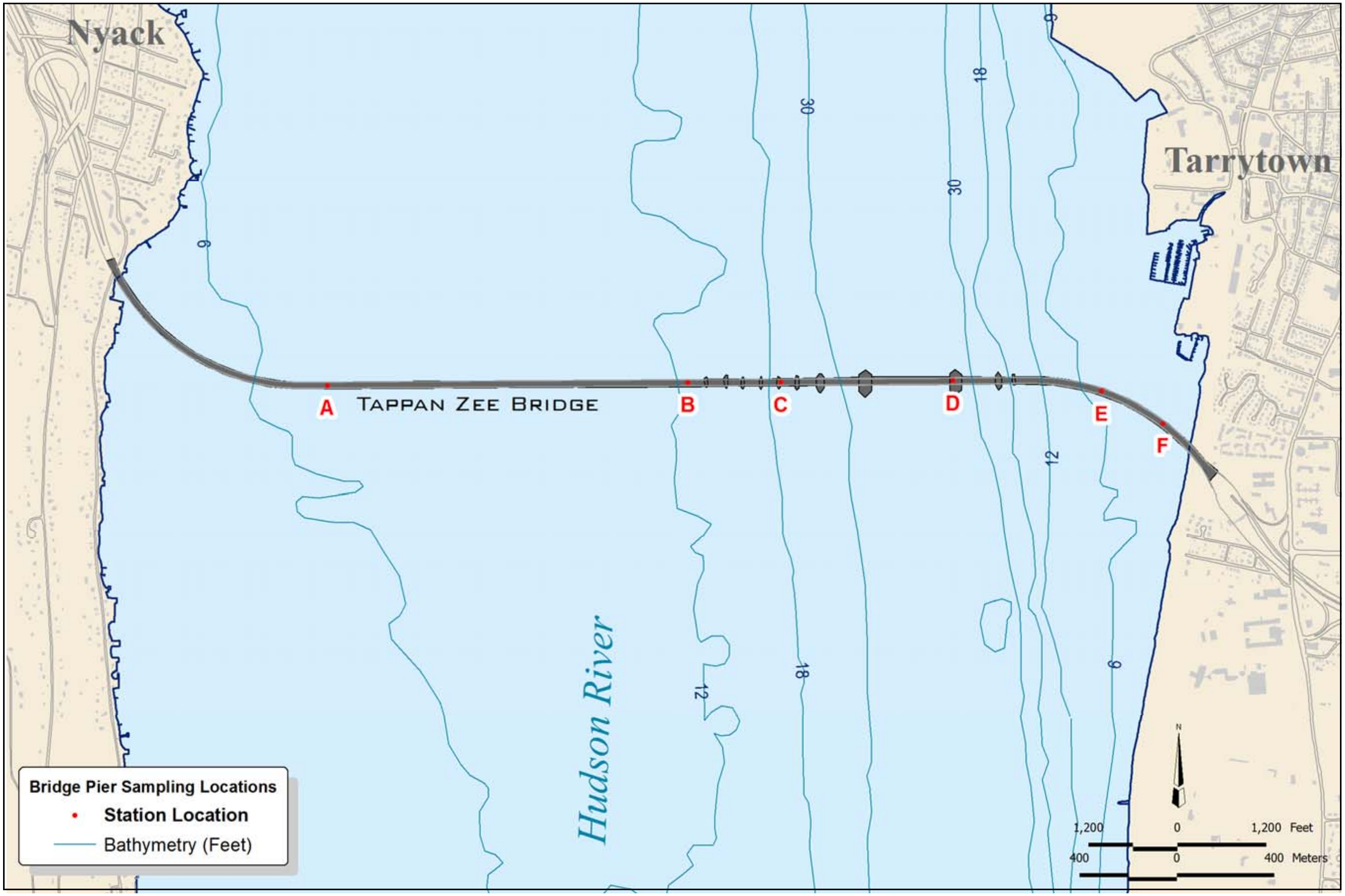


Figure F-1-23 Bridge Pier Sampling Locations

Six locations on different bridge piers were inspected by remote video methods to develop an understanding of the extent to which fish use these structures as habitat. Also, twenty 0.5-meter quadrants were sampled by divers by scraping off any attached organisms into sampling containers. The flora and fauna samples collected by the diver at each pier were combined in a labeled plastic jar containing a 70 percent concentration of isopropyl alcohol (a preservative) with rose bengal (a biological stain). Organisms in the sample jars were identified by Earth Tech staff to the lowest practical taxonomy.

Table F-1-14 provides a brief description of each of the six bridge pier sampling locations; some information on the piers themselves is given immediately below.

- Location A – In a shallow-water area along the west side of the river; water depth 12 feet (3.7 m) below mean sea level (MSL). The substructure of this pier consists of a concrete pile cap supported by numerous timber piles.
- Location B – In a mid-depth area along the western side of the river; water depth 18 feet (5.5 m) MSL. The substructure of this pier consists of a concrete pile cap supported by a concrete-filled steel cofferdam and timber piles (below the mudline).
- Location C – In a slope area near the main channel; water depth 25 feet (7.6 m) MSL. The substructure of this pier consists of a concrete pile cap supported by a steel caisson and timber piles (below the mudline).
- Location D – In the main channel area; water depth 40 feet (12.2 m) MSL. The substructure of this pier consists of a concrete pile cap supported by a steel caisson and timber piles (below the mudline).
- Location E – In shallow water along the eastern side of the river; water depth 12 feet (3.7 m) MSL. The substructure of this pier consists of a concrete pile cap supported by a concrete-filled steel cofferdam and timber piles (below the mudline).
- Location F – In a near-shore area along the eastern side of the river; water depth 10 feet (3 m) MSL. The substructure of this pier consists of a concrete pile cap supported by a concrete-filled steel cofferdam and timber piles (below the mudline).

Table F-1-14

Description of Pier Habitats

Pier Location	Depth of River in feet at Pier Location	Description
A	10	Shallow-water environment near the river’s west bank.
B	15	This pier represents the start of the slope from the western shoal to the deep channel.
C	25	This pier is in the lower portion of the slope.
D	50	This pier represents benthic organisms inhabiting the deepest portion of the river.
E	12	Shallow-water environment along the eastern side of the river.
F	6	Shallow-water environment near the river’s east bank.

2.2.2 Results of Sediment Sampling and Bridge Pier Sampling Programs

In what follows, the results of the sediment sampling program are discussed first, followed by the results of the bridge pier sampling program. At the end of this chapter, an analysis of the benthic invertebrate community within the study area is provided.

Sediment Sampling Program

A total of 48 species and 213,000 individual organisms were collected during the sediment sampling program. Generally, the species richness and numbers of individuals were lower in the late winter and early spring and higher in the summer and the fall. Species diversity remained relatively constant throughout the year, with slightly higher numbers during the July sampling event. Table F-1-15 shows the numbers of individuals, species richness, and total diversity (calculated using the Shannon-Weiner Index) for each of the six sample months. The Shannon Weiner Index is a measure of uncertainty. The higher the value of H, the greater is the probability or uncertainty that the next individual chosen at random from a collection of species will not belong to the same species as the previous one (Smith, 1990). The index is expressed by the following equation:

$$H = -\sum_{i=1}^{s} (pi)(\log pi)$$

where

H = diversity index

s = number of species

i = species number

pi = proportion of individuals of the total sample belonging to the *i*th species

Source: Smith, 1990

Table F-1-15

Sediment Sampling Program Results

Sampling Month	Abundance (Number of Individuals)	Species Richness	Total Diversity
January	30,182	34	0.505514
March	17,382	32	0.537161
May	23,700	27	0.5209935
July	66,271	38	0.6282055
September	34,840	39	0.514145
November	41,003	38	0.5209843

In Table F-1-15, the total diversity for each month is a relative measure. The data presented in the table show that July is the month with the highest species diversity and that January the month with the lowest diversity.

Species

Review of the entire sample collection shows a variety of benthic organisms that comprises taxonomic groups. A description of the taxonomic groups collected is provided below:

- Phylum Annelida. Commonly referred to as annelids, this is a large phylum of animals comprising the segmented worms, with about 15,000 modern species, including the well-known earthworms, leeches, and marine worms.

  Class Oligochaeta – Oligochaeta means "few bristles," which refers to the small bundles of hair-like bristles that occur on each body segment. These worms have long been recognized as pollution-tolerant because of their ability to thrive in poor water quality conditions.

  Class Polychaeta – Meaning "many hairs," referring to the many bristles (parapodia) that extend from the side of the species. Polychaetes are a major prey species for a variety of marine organisms. These worms live in a variety of depths and habitats throughout the lower Hudson River and New York Harbor.

- Phylum Arthropoda – Arthropods comprise over three quarters of living creatures. They vary from spiders and scorpions to shrimp and lobsters. Common characteristics of arthropods are an exoskeleton and the necessity to molt. In the marine environment arthropods comprise a major portion of the food chain, and larger arthropods (e.g., blue crabs, shrimp, and lobsters, etc.) are commercially harvested.

  Class Amphipoda – These are small crustaceans that number about 4,000 species. Amphipods have a vertically thin body and one set of legs for jumping or walking and another set for swimming. Examples of amphipods include beach fleas, sand hoppers, and water lice.

  Class Cripedia – The only species of crustaceans whose adults are wholly sessile (e.g., barnacles).

  Class Diptera – Diptera are true flies. Diptera species in the samples were often represented by larvae.

  Class Decapoda – Decapods are ten-legged crustaceans. These species (crabs and lobsters are examples) are familiar species and are commercially harvested.

  Class Isopoda – These are benthic invertebrates that comprise a portion of the diet of many estuarine species.

- Phylum Chordata – This phylum consists of species with a spinal column.

  Class Osteichthyes – This is a class of bony fish. Two species of this class were found in the samples.

- Phylum Mollusca – This phylum consists of shellfish common to northeast estuaries.

  Class Bivalvia – Clams and oysters.

  Class Gastropoda – Gastropod is derived from Greek and means "stomach foot." Whelks are examples of species in this class.

- Phylum Platyhelminthes

  Class Polycladida – Species in this class are generally referred to as flatworms.

Table F-1-16 provides a listing of species collected during each sampling month and comments about each species within the study area.

Review of the data collected during the bi-monthly sampling shows that two species – *Balanus* spp. and *Leptocheirus plumulosus* – were predominant during each sampling event. Often these two species combined comprised over 50 percent of the total individuals recorded. *Hypaniola grayi*, *Chironomidae* spp. (larvae), *Hydrobia minuta* (juvenile), and *Capitellidae* spp. comprised the third- highest percentage of individuals in the combined monthly samples; however, these percentages were often much smaller that barnacles and *Leptocheirus plumulosus*. Table F-1-17 shows the three species with the highest abundance in each monthly sample. All of the species are common within estuaries of the northeast United States.

In order to determine habitat value and species usage within the benthic communities that occupy the various benthic habitat types – Fine Sediment, Sediment with Shell hash, Oyster Shells with Sediment, Scoured, and Shoreline – sampling locations were grouped by habitat and separated by the four geographical areas – i.e., existing span [bridge], mid span, new span, and southern locations. Sampling locations south of the bridge (i.e., the shoreline) are separated as the benthic substrate is markedly different within that portion of the study area. Tables 1-18, 1-19, and 1-20 show the total numbers of individuals, species richness, and diversity, by month, habitat, and location.

Findings

As can be seen in Table F-1-18, for all alignments, the total numbers of individuals was correlated with seasons. The months of March and May had the lowest numbers of individuals and the month of July had the highest numbers of individuals. Benthic invertebrate communities in estuaries typically have a higher number of individuals in the summer. The higher populations are a result of recruitment and changes to water quality parameters.

In order to determine what, if any, statistically significant difference existed between the benthic communities of the bridge – the new, mid, and proposed bridge alignments and the southern approaches – an analysis of variance (ANOVA) test was applied to the findings. Due to the limited number of sampling locations and markedly different benthic habitat, statistical analysis was not performed on the shoreline samples. In addition, southern locations were only used for comparison with bridge alignment locations whose benthic communities comprised fine sediments.

The results of the fine-sediment habitats for each alignment were compared using a two-way ANOVA for each sampled month. Table F-1-21 displays the statistical data for comparison of benthic communities between alignments (bridge, mid, new span), bottom habitat, and interaction effects between the two. The analysis shows that there is generally no statistically significant difference in benthic communities between the alignments (i.e., existing bridge alignment, mid-span, or new replacement bridge alignment). There was no statistically significant difference among individuals, except for the month of November. There was a statistically significant difference regarding species richness (the number of identifiable taxa) in March, September, November, and January samplings, but not in May and July.

Table F-1-16
Occurrence of Species Collected during the Sediment Sampling Program

PHYLUM / Class	Species	Jan	Mar	May	Jul	Sep	Nov	Comments
ANNELIDA Oligochaeta	*Oligochaete* spp.	✓	✓	✓	✓	✓	✓	Samples collected each month had very low numbers of oligochaete worms.
Polychaeta	*Capitellidae* spp.	✓	✓	✓	✓	✓	✓	A common prey species for fish and marine invertebrates. *Capitellidae* species were observed every month at benthic stations throughout the study area.
	Eteone heteropoda	✓				✓	✓	A common prey species for fish and marine invertebrates. This species was observed in marine samples associated with deep-water habitats. Abundance was low for this species.
	Goniadidae sp.						✓	This species was observed at one location and in very low abundance.
	Hypaniola grayi	✓	✓	✓	✓	✓	✓	A common prey species for fish and marine invertebrates. This species was observed every month at benthic stations throughout the study area.
	Nereis diversicolor	✓	✓	✓	✓	✓	✓	A prey species for fish and marine invertebrates. This species was observed every month, although its distribution and abundance were limited throughout the study area.
	Nereis succinea	✓	✓	✓	✓	✓	✓	A common prey species for fish and marine invertebrates. This species was observed every month at benthic stations throughout the study area.
	Pectinaria gouldii	✓				✓	✓	This species is a tube worm that was observed in only a handful of samples and in very low abundance.
	Polydorids (Boccardia spp. *& Polydora* spp.*)*	✓	✓	✓	✓	✓	✓	Referred to as "oyster worms" these species commonly live among oyster reefs. These species were observed during each bi-monthly sampling event. Their distribution was mostly limited to deeper-water stations where oysters were present. They were recorded in high abundance.
	Sabellaria viridis						✓	Also commonly referred to as "oyster worms" this species also lives among oyster reefs. This species had a limited distribution and abundance in the study area.
	Scolecolepides viridis	✓	✓	✓	✓	✓	✓	This species is a burrowing worm. It was found throughout the study area and in every month, although abundance was low.
	Scoloplos sp.	✓				✓		This species had limited distribution and abundance.
	Streblospio benedicti	✓			✓	✓	✓	This small worm (less than one-half inch long) had a limited distribution and abundance in the study area.
ARTHROPODA Amphipoda	*Ampelisca vadorum*				✓	✓		This amphipod had an extremely limited abundance and distribution in the study area.
	Corophium sp.	✓	✓	✓	✓	✓	✓	This species' abundance and distribution was limited in the study area
	Gammarus daiberi	✓	✓	✓	✓	✓	✓	This species' abundance and distribution was limited in the study area

Table F-1-16 (con't)

Occurrence of Species Collected during the Sediment Sampling Program

PHYLUM / Class	Species	Jan	Mar	May	Jul	Sep	Nov	Comments
ARTHROPODA Amphipoda (con't)	*Leptocheirus plumulosus*	✓	✓	✓	✓	✓	✓	This burrowing amphipod is often found in estuarine and marine communities with strong currents. This species was well-distributed throughout the study area and was in very high abundance.
	Melita nitida	✓	✓	✓	✓	✓	✓	This species had limited distribution and abundance in the study area.
	Monoculodes sp.	✓	✓	✓	✓	✓	✓	This species had limited-to-moderate distribution and abundance in the study area.
	Pleusymtes glaber (variant)				✓	✓	✓	This species had very limited distribution and abundance in the study area.
Cirripedia	*Balanus* spp.	✓	✓	✓	✓	✓	✓	Barnacles are sessile marine organisms that are common throughout the world. The species affixes itself to hard substrates in shallow estuarine and marine waters. Barnacles are prevalent throughout the Lower Hudson river and New York Harbor.
Decapoda	*Callinectes sapidus*						✓	
	Caridea zoea				✓	✓		Larval stage of shrimp that is a prey for many species within the estuary.
	Crangon septemspinosa		✓	✓	✓	✓		This species of shrimp is highly motile and can be difficult to catch with the sampling device that was employed. Many species of fish feed on shrimp.
	Neomysis americana	✓		✓	✓	✓	✓	This species of shrimp is highly motile and can be difficult to catch with the sampling device that was employed. Many species of fish feed on shrimp.
	Palaemonetes vulgaris	✓	✓		✓	✓	✓	This species of shrimp is highly motile and can be difficult to catch with the sampling device that was employed. Many species of fish feed on shrimp.
	Rhithropanopeus harrisii	✓	✓	✓	✓	✓	✓	This species is a small mud crab. The distribution of this species was limited to shallow-water locations. The abundance was limited in the study area.
	Rhithropanopeus harrisii (mega)				✓			This species is a small mud crab. The distribution of this species was limited to deep-water locations. The abundance was very limited in the study area.
	Rhithropanopeus harrisii (zoe)				✓			This species is a small mud crab. The distribution of this species was limited to deep-water locations. The abundance was very limited in the study area.
Diptera	*Chironomidae* spp. *(larvae)*	✓		✓	✓	✓	✓	Larvae of a small fly that is a prey for many species within the estuary.
Isopoda	*Chiridotea* sp.		✓	✓				Isopods are aquatic crustaceans with seven pairs of legs adapted for crawling. Isopods are often preyed upon by various fish and other benthic invertebrates.
	Cyathura polita	✓	✓	✓	✓	✓	✓	
	Edotea triloba	✓	✓	✓	✓	✓	✓	
	Sphaeromatidae sp.		✓				✓	
	Synidotea sp.				✓	✓		
CHORDATA Osteichthyes	*Gobiosoma bosci*	✓	✓		✓	✓	✓	This species is a small fish that is common to estuarine benthic habitats.
	Trinectes maculatus		✓					This species, commonly referred to as a hogchoker, is a small species of flounder that is common in estuarine environments.

Table F-1-16 (con't)

Occurrence of Species Collected during the Sediment Sampling Program

PHYLUM / Class	Species	Jan	Mar	May	Jul	Sep	Nov	Comments
MOLLUSCA Bivalvia	*Congeria leucopheata*	✓	✓	✓	✓	✓	✓	A mussel species that usually inhabits the less-saline waters of an estuary.
	Crassostrea virginica	✓	✓	✓	✓	✓	✓	Oysters were not present in environments with high amounts of silt (sampling sites B1 through B8 and B35 through B39). Oysters were densely concentrated in the sampling sites located in the middle of the river (sites B-12 through B33 and B-40). Juvenile and adult individuals were identified in each sample. The total number of oysters collected ranged from 289 (March) to a high of 789 (November)
	Macoma balthica	✓			✓	✓	✓	A small clam approximately 1.5 inches in size that is usually buried in mud.
	Modiolus demissus	✓	✓	✓	✓	✓	✓	A mussel species that is very common to the New York Harbor area; a filter feeder.
	Mulinia lateralis	✓				✓	✓	Referred to a "surf clam". A small bivalve that is approximately 1 inch in length that inhabits subtidal, muddy bottoms.
	Mya arenaria	✓			✓	✓	✓	A clam approximately 4 inches long that inhabits subtidal benthic sediments.
	Rangia cuneata	✓	✓	✓	✓	✓	✓	A clam approximately 2.5 inches long that is common in estuaries in the northeast US.
	Tellina agillis						✓	A small clam approximately 0.5 inches in length that is usually buried in mud.
	Bivalvia spp. *(juvenile clams)*	✓	✓	✓	✓	✓	✓	Bivalvia are small clams that were not identified to species.
Gastropoda	*Hydrobia minuta (juvenile)*	✓	✓	✓	✓	✓	✓	Commonly referred to as "seaweed snails" this 0.2-inch bivalve inhabits grass beds or muddy bottoms in estuaries.
PLATYHELMINTHES Polycladida	*Stylochus ellipticus*	✓			✓	✓	✓	An aquatic worm that is a major predator of barnacles.

Note: ✓ indicates that individuals of the listed species were collected in the given month.

Table F-1-17

The Three Dominant Species Collected during each Bi-Monthly Sampling Event

Month and Year	Species	Percentage of Total Sample
January 2008	*Balanus* spp.	25.5
	Leptocheirus plumulosus	22
	Hypaniola grayi	7.3
March 2007	*Balanus* spp.	39.9
	Leptocheirus plumulosus	24.8
	Chironomidae spp. (larvae)	6
May 2007	*Balanus* spp.	39.5
	Leptocheirus plumulosus	17.6
	Hydrobia minuta (juvenile)	8.2
July 2007	*Leptocheirus plumul*osus	35.4
	Balanus spp.	32.9
	Hydrobia minuta (juvenile)	15.1
September 2007	*Balanus* spp.	42.5
	Leptocheirus plumulosus	17.2
	Capitellidae spp.	8.5
November 2007	*Balanus* spp.	28.6
	Leptocheirus plumulosus	25.9
	Capitellidae spp.	14.2

Table F-1-18

Total Numbers of Individuals Collected by Benthic Habitat and Proposed Bridge Alignments and Approaches

Month	Benthic Habitats Within Existing and Proposed Bridge Alignments and Approaches													Shore-line*
	Fine Sediments				Sediment with Shell Hash			Oyster Shells/Reefs			Scoured			
	New	Mid	Bridge	South	New	Mid	Bridge	New	Mid	Bridge	New	Mid	Bridge	
Jan	1,038	919	684	970	841	653	639	826	848	715	135	338	600	476
Mar	659	800	247	421	538	397	533	416	478	508	274	196	209	114
May	750	628	402	909	457	316	839	620	689	584	228	391	798	311
Jul	2,497	3,073	1,555	1,933	1,425	1,440	1,407	842	1,094	1,462	1,187	1,462	2,698	2,148
Sep	881	598	942	537	693	672	746	882	1,088	1,177	794	1,019	818	875
Nov	1,434	1,005	805	928	1,057	1,208	916	920	759	900	444	1,681	1,468	1,158

Notes:

*The data for the four locations that represent the shoreline sampling stations are presented as an average.

New refers to the proposed bridge alignment, approximately 150 feet north of the existing bridge alignment.

Mid refers to the alignment that is 50 feet north of the existing bridge.

Bridge refers to the existing alignment.

South refers to several locations south of the existing bridge, near the east and west banks.

Shoreline refers to the locations along the shoreline south of the bridge.

Table F-1-19

Species Richness by Benthic Habitat and Proposed Bridge Alignments and Approaches

Month	Benthic Habitats Within Existing and Proposed Bridge Alignments and Approaches														Shoreline
	Fine Sediments				Sediment with Shell Hash			Oyster Shells/Reefs			Scoured				
	New	Mid	Bridge	South	New	Mid	Bridge	New	Mid	Bridge	New	Mid	Bridge		
Jan	16.0	15.5	14.5	16.3	13.3	16.0	13.3	17.6	17.8	14.4	7.0	21.0	13.0		18
Mar	12.0	15.5	17.5	10.5	18.3	18.3	18.3	16.4	14.0	15.4	10.0	14.0	13.0		15
May	13.0	9.5	13.0	12.8	13.7	16.0	13.3	13.2	16.2	14.6	9.0	13.0	16.0		13
Jul	11.0	15.5	16.0	13.3	16.7	17.7	14.7	18.0	16.0	16.2	18.0	11.0	11.0		15
Sep	15.0	15.5	15.5	17.3	13.7	13.3	13.7	19.4	18.0	14.2	23.0	15.0	20.0		20
Nov	15.5	15.0	14.5	14.8	17.3	17.7	11.3	19.2	19.0	15.4	19.0	21.0	19.0		19

Notes:
*The data for the four locations that represent the shoreline sampling stations are presented as an average.
New refers to the proposed bridge alignment, approximately 150 feet north of the existing bridge alignment.
Mid refers to an alignment that is 50 feet north of the existing bridge.
Bridge refers to the existing alignment.
South refers to several locations south of the existing bridge, near the east and west banks.
Shoreline refers to the locations along the shoreline south of the bridge.

Table F-1-20

Species Diversity by Benthic Habitat and Proposed Bridge Alignments and Approaches

Month	Benthic Habitats Within Existing and Proposed Bridge Alignments and Approaches													
	Fine Sediments				Sediment with Shell Hash			Oyster Shells/Reefs			Scoured			
	New	Mid	Bridge	South	New	Mid	Bridge	New	Mid	Bridge	New	Mid	Bridge	Shoreline*
Jan	0.530	0.578	0.611	0.552	0.497	0.390	0.292	0.491	0.482	0.404	0.477	0.544	0.291	0.494
Mar	0.612	0.596	0.525	0.412	0.555	0.528	0.274	0.399	0.415	0.411	0.446	0.512	0.490	0.534
May	0.595	0.617	0.560	0.574	0.533	0.530	0.388	0.459	0.508	0.565	0.576	0.465	0.450	0.580
Jul	0.659	0.565	0.593	0.623	0.462	0.324	0.437	0.544	0.367	0.542	0.656	0.629	0.610	0.367
Sep	0.546	0.553	0.499	0.533	0.585	0.403	0.282	0.535	0.412	0.376	0.555	0.478	0.438	0.544
Nov	0.485	0.562	0.282	0.564	0.569	0.582	0.192	0.551	0.547	0.482	0.522	0.445	0.522	0.531

Notes:
* The data for the four locations that represent the shoreline sampling stations are presented as an average.
New refers to the proposed bridge alignment, approximately 150 feet north of the existing bridge alignment.
Mid refers to an alignment that is 50 feet north of the existing bridge.
Bridge refers to the existing alignment.
South refers to several locations south of the existing bridge, near the east and west banks.
Shoreline refers to the locations along the shoreline parallel to the south of the bridge.

Table F-1-21
Statistical Comparison of Species Richness and Individuals

Month	Source	Individuals	Richness
March	Alignments	0.767	0.470
	Habitat	0.460	**0.028**
	Alignment X Habitat	0.647	0.526
May	Alignments	0.636	0.244
	Habitat	0.895	0.096
	Alignment X Habitat	0.469	0.161
July	Alignments	0.722	0.696
	Habitat	0.032	0.255
	Alignment X Habitat	0.411	0.341
September	Alignments	0.878	0.216
	Habitat	0.298	**0.008**
	Alignment X Habitat	0.963	0.197
November	Alignments	0.636	**0.022**
	Habitat	0.463	**0.007**
	Alignment X Habitat	0.278	0.420
January	Alignments	0.139	0.178
	Habitat	0.950	**0.016**
	Alignment X Habitat	0.831	0.115
Note: Values <0.05 are statistically significant and are indicated by numbers in boldface.			

To further elucidate the findings, a one-way ANOVA analysis was applied to the data (divided by sampled month and habitat type) to determine the difference, if any, between the existing and proposed spans in diversity, richness, and numbers of individuals (Table F-1-22) for fine sediment, silt with shell hash, and oyster shells. (Due to low sample size, the scoured and shoreline habitats could not be statistically analyzed.) Following every significant (or near-significant) finding, a Tukey HSD post-hoc test is done to examine which alignments are significantly different from each other. The table displays a matrix of pairwise comparison probabilities between alignments, after every significant (or near-significant) statistical result; (any value <0.05 is considered significantly different). Data that were excessively skewed, or showed high kurtosis, were transformed, as was most effective, prior to analysis. If data failed the F-test, a Krustal-Walis Non-Parametric test was used instead. Data analysis was carried out using SYSTAT 9.

There was no statistically significant difference in benthic diversity, total numbers of individuals, or richness between the current and proposed bridge alignments. There was a difference between the current bridge alignment and approaches to the south; however, the habitat south of the bridge is different than both the bridge alignment and proposed locations north of the bridge. Habitats north of the bridge are influenced by marinas and active barge traffic associated with the maintenance yard. There is little development or benthic disturbance south of the bridge. Also, locations south of the bridge normally accumulate thick sediment deposits, which may cause changes to the benthic community structure.

Table F-1-22

Results of Statistical Tests on Benthic Invertebrate Populations

Month	Habitat	Parameter	Alignments	Alignments			
				Bridge	Mid	New Span	Southern
March	Fine Sediments (Silt)	**Diversity p=0.002**	Bridge	1			
			Mid	0.289	1		
			New Span	0.171	0.969	1	
			Approach	**0.039**	**0.004**	**0.003**	1
		Richness p=0.013	Bridge	1			
			Mid	0.673	1		
			New Span	0.70	0.278	1	
			Approach	**0.014**	**0.058**	**0.755**	1
		Individuals p=0.020	Bridge	1			
			Mid	0.289	1		
			New Span	0.171	0.969	1	
			Approach	**0.039**	**0.004**	**0.003**	1
	Sediment With Shell Hash	Diversity	p=0.061*				
		Richness	p=1.000				
		Individuals	p=0.804				
	Oyster Shells With Sediment	Diversity	p=0.984				
		Richness	p=0.387*				
		Individuals	p=0.997*				
May	Fine Sediments (Silt)	**Individuals p=0.045**	Bridge	1			
			Mid	0.519	1		
			New Span	0.218	0.860	1	
			Approach	**0.036**	0.258	0.659	1
	Sediment With Shell Hash	Diversity	p=0.150				
		Richness	p=0.187*				
		Individuals	p=0.180*				
	Oyster Shells With Sediment	Diversity	p=0.512*				
		Richness	p=0.264				
		Individuals	p=0.641				
July	Fine Sediments (Silt)	Diversity	p=0.269*				
		Richness	p=0.343*				
		Individuals	p=0.546				
	Sediment With Shell Hash	Diversity	p=0.725				
		Richness	p=0.422				
		Individuals	p=0.977				
	Oyster Shells With Sediment	Diversity	p=0.066				
		Richness	p=0.485				
		Individuals	p=0.336				
September	Fine Sediments (Silt)	Diversity	p=0.557				
		Richness	p=0.294				
		Individuals	p=0.443				
	Sediment With Shell Hash	Diversity	p=0.148*				
		Richness	p=0.977				
		Individuals	p=0.980				
	Oyster Shells With Sediment	Diversity	p=0.288				
		Richness p=0.057	Bridge	1			
			Mid	0.177	1		
			New Span	0.054	0.765	1	
		Individuals	p=0.546				

Table F-1-22 (con't)

Results of Statistical Tests on Benthic Invertebrate Populations

Month	Habitat	Parameter	Alignments	Alignments			
				Bridge	Mid	New Span	Southern
November	Fine Sediments (Silt)	**Diversity p<0.001**	Bridge	1			
			Mid	0.001	1		
			New Span	0.003	1.86	1	
			Approach	**0.000**	1.00	0.112	1
		Richness	p=0.963				
		Individuals	p=0.154				
	Sediment With Shell Hash	**Diversity p=0.003**	Bridge	1			
			Mid	0.004	1		
			New Span	0.005	0.980	1	
		Richness p=0.055	Bridge	1			
			Mid	0.071	1		
			New Span	0.087	0.986	1	
	Oyster Shells With Sediment	Diversity	p=0.452				
		Richness p=0.018	Bridge	1			
			Mid	0.036	1		
			New Span	0.028	0.986	1	
		Individuals	p=0.932*				
January	Fine Sediments (Silt)	Diversity	p=0.341				
		Richness	p=0.842				
		Individuals	p=0.639				
	Sediment With Shell Hash	Diversity	p=0.367				
		Richness	p=0.089				
		Individuals	p=0.749				
	Oyster Shells With Sediment	Diversity	p=0.478				
		Richness	p=0.188				
		Individuals	p=0.800*				

Note: * p-value calculated via Krustal-Walis Non-Parametric Test

Oyster Reefs

Oysters (*Crassostrea virginica*) are reef-building organisms found in the intertidal and subtidal zones along the east coast of the US in muddy bays and harbors. The juvenile oysters attach (with a glue-like substance) themselves to adult oysters already attached to rocks, shell or other oysters (NYSDEC, 2011). The number of species found on any given oyster reef varies according to location, temperature, and salinity, but all oyster reefs have a diversity of species on, within, and around them. Because they are filter feeders, oysters (Photo F-1-9) can greatly influence nutrient cycling in estuarine systems, maintain the stability of the ecosystem, and may have significant effects on phytoplankton biomass in an area (NOAA, 2009).

Photo F-1-9 Live Oysters Collected During the Benthic Invertebrate Sampling.

Several historical oyster beds were identified in the area of the study. Figure F-1-24 identifies the presence of historical reefs near the study area. North of the bridge and west of the navigation channel, oyster reefs have been mapped within 1,000 ft (305 m) of the Tappan Zee Bridge. Benthic sampling results showed that oysters comprised a portion of the samples in the deeper portions of the western shoals.

In September and October of 2009, oyster beds were mapped approximately 2 miles (3.2 km) north and south of the bridge. They were accomplished through the use of side scan sonar and physical grab samples to confirm the findings of the sonar.

A Klein Model 3000 dual frequency (100 and 500 KHz) digital side scan sonar was used to image the river bottom to locate potential oyster beds. The system was operated at 500 kHz with a 75m range per channel. The side scan sonar revealed a bottom with varying characteristics, dependent on depth and geology. Along the west bank of the river, mud flats were seen to extend nearly two miles eastward to the main channel of the river. Within the channel, sand and till were present, comprising large, undulating ripples. The eastern bank featured a combination of mud and gravel, with outwash deposits noted at the mouth of tributary streams.

Distributed throughout the survey area at differing depths was a distinct bottom texture somewhat like gravel. This texture was tentatively identified as oyster shells based on its initial appearance in what was noted as an historical oyster bed. Figure F-1-25 identifies the mapped oyster beds.

In the southern block, seven potential oyster beds were identified. The most southern of the seven, denoted as S1, appeared to abut against the edge of an old channel about 9,000 ft south of the bridge

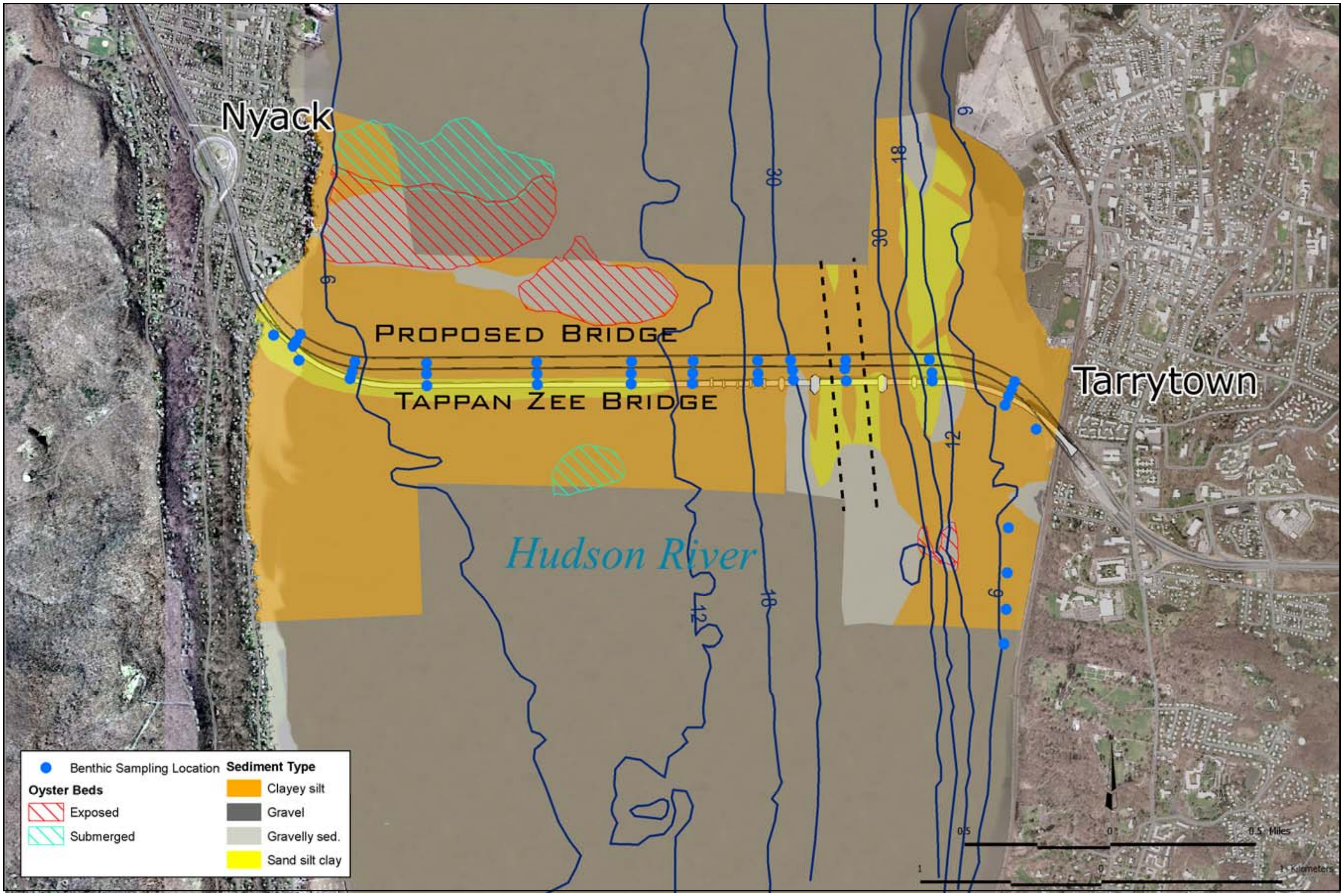


Figure F-1-24 Oyster Reefs and Substrate Types within Proximity of the Benthic Invertebrate Sampling Locations

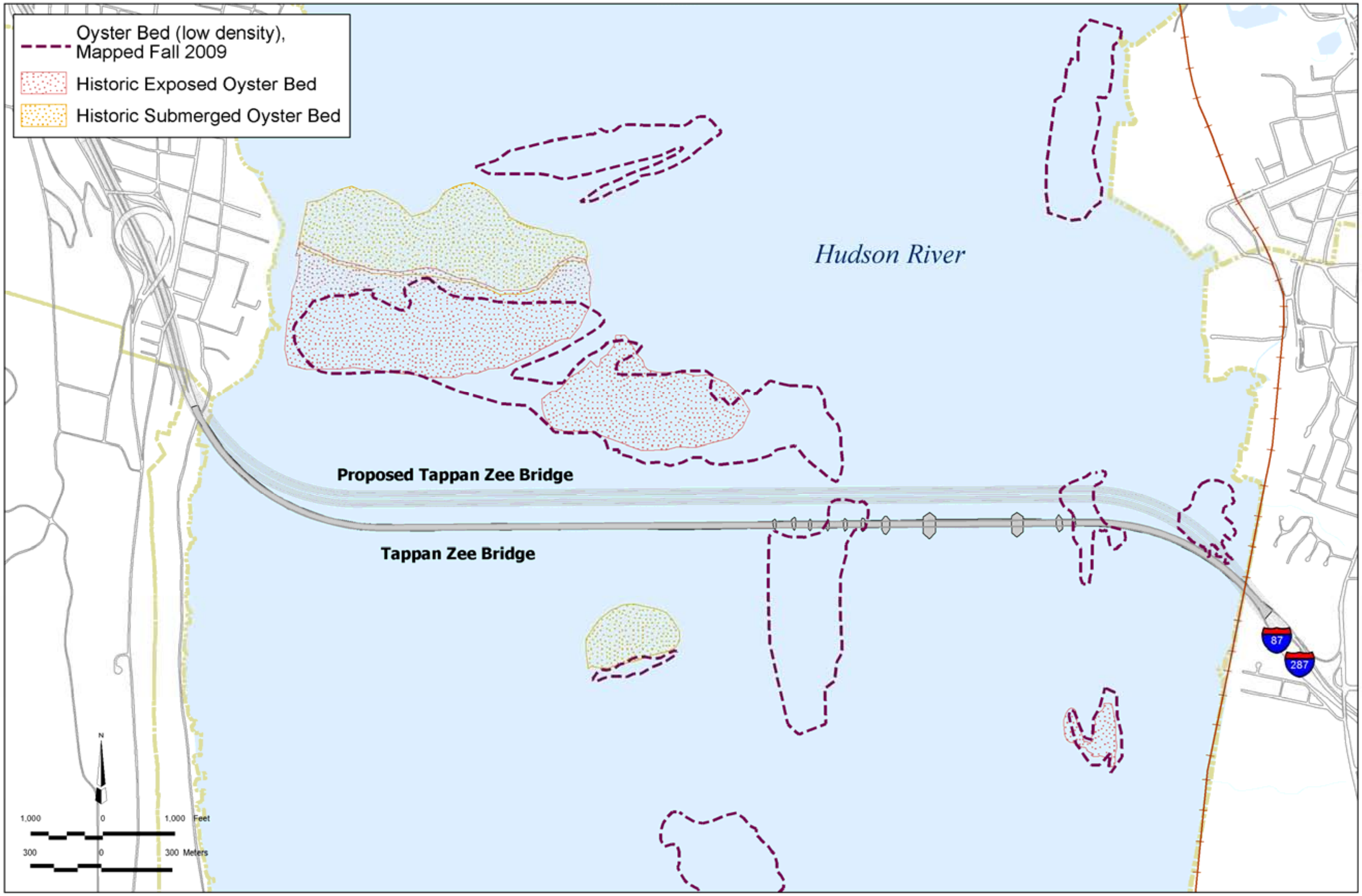


Figure F-1-25 Mapped Oyster Beds - 2009

along the north side of Piermont Pier. The bed seemed somewhat diffuse in terms of density. S2, located northwest of S1 along the channel about 8,500 ft south of the bridge, appeared to be a diffuse, clumpy bed. S3 appeared to be a dense bed located near the middle of the flats 5,000 ft south of the bridge. S4 and S5 were two thin but dense strips located about 2,000 ft south of the Tappan Zee Bridge causeway. S6 appeared diffuse and was positioned along the slope of the channel leading up to and under the western main support columns of the Tappan Zee Bridge's central truss. S7 was located about 2000 ft south of the Tappan Zee's eastern approach, along the edge of the channel. It appeared to be rather dense.

Six potential beds were identified in the north. Adjacent to the bridge, along the eastern side of the channel, was N1. Due east of N1, near the shore, was N2. These beds appeared to have a somewhat diffuse density. Along the shore, 2,500 ft north of N1, was N3. N3 appeared to have some oyster-like texture, but for the most part the area appeared very rocky/gravelly. On the flats west of the channel there were three beds that had been previously delineated. These were N4 (10,000 ft north of bridge), N5 (5,000 ft north of bridge), and N6 (2,000 ft north of bridge). All of these beds appeared to be dense.

The side scan sonar revealed a bottom with varying characteristics, dependent on depth and geology. Along the west bank of the river, mud flats were seen to extend nearly two miles eastward to the main channel of the river. Within the channel, sand and till were present, comprising large, undulating ripples. The eastern bank featured a combination of mud and gravel, with outwash deposits noted at the mouth of tributary streams.

Distributed throughout the survey area at differing depths was a distinct bottom texture somewhat like gravel. What was unique about this texture was that its reflectivity was particularly strong and uniform, sometimes causing the return echo to become chaotic at the edge of the sonar's range. This texture was tentatively identified as oyster shells based on its initial appearance in what was noted as an historical oyster bed.

Photo F-1-10, Side Scan Sonar in Flashlight Mode, shows the side scan sonar image as seen in 'flashlight mode', which makes more acoustically reflective areas appear lighter and more absorptive areas appear darker. The bottom half of the image shows the edge of a confirmed oyster bed, while the top half shows the bed tapering off into mud.

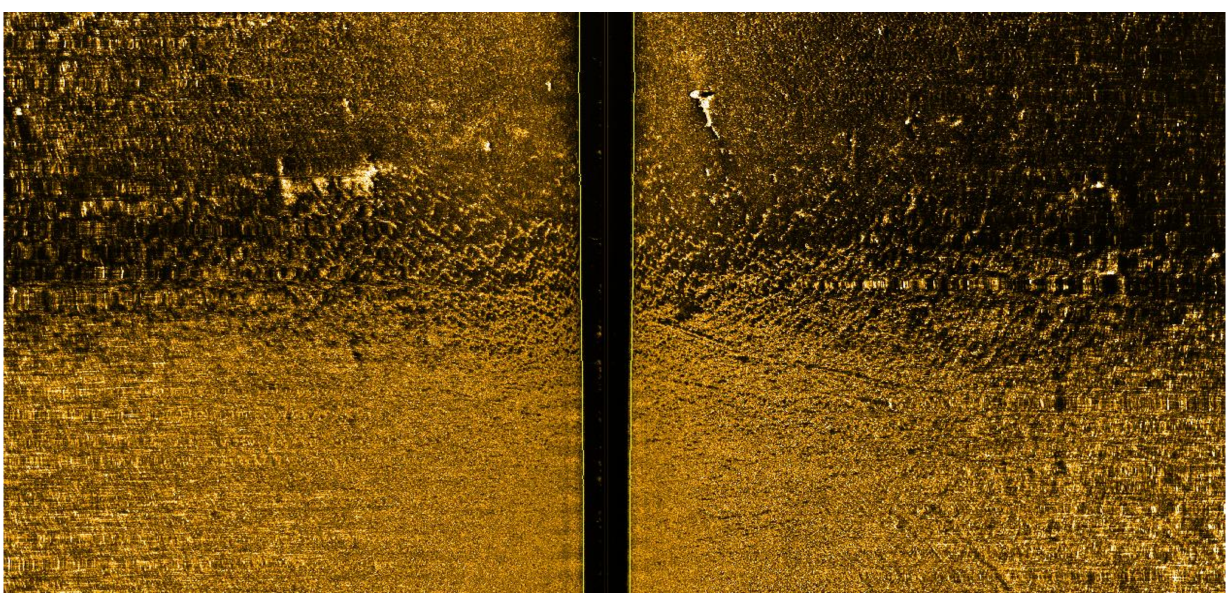


Photo F-1-10 Side Scan Sonar in Flashlight Mode

Photo F-1-11, Typical Oyster Bed of the Eastern Bank, shows a flashlight mode image of mud (in the upper right) adjacent to the bed. In the lower right quadrant of the image, the bed appears clumpy, probably overlying a more gravelly/till-laden terrain.

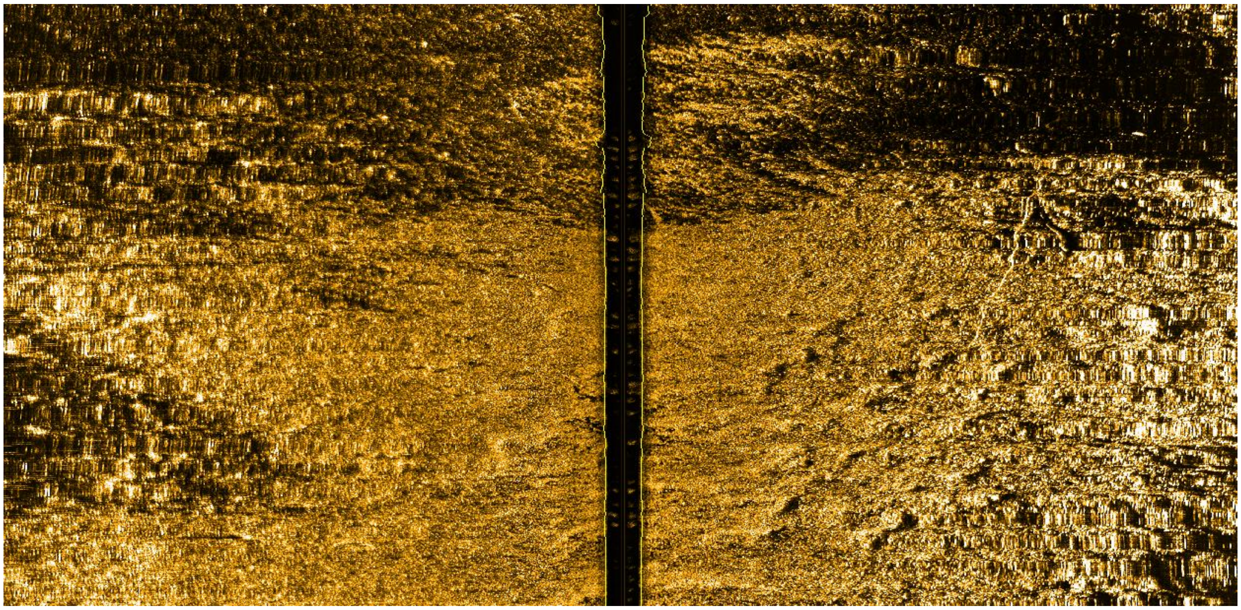


Photo F-1-11 Typical Oyster Bed of the Eastern Bank

In the southern block, seven potential oyster beds were identified. The most southern of the seven, denoted as S1, appeared to abut against the edge of an old channel about 9,000 ft south of the bridge along the north side of Piermont Pier. The bed seemed somewhat diffuse in terms of density. S2, located northwest of S1 along the channel about 8,500 ft south of the bridge, appeared to be a diffuse, clumpy bed. S3 appeared to be a dense bed located near the middle of the flats 5,000 ft south of the bridge. S4 and S5 were two thin but dense strips located about 2,000 ft south of the Tappan Zee Bridge causeway. S6 appeared diffuse and was positioned along the slope of the channel leading up to and under the western main support columns of the Tappan Zee Bridge's central truss. S7 was located about 2000 ft south of the Tappan Zee's eastern approach, along the edge of the channel. It appeared to be rather dense. Six potential beds were identified in the north. Adjacent to the bridge, along the eastern side of the channel, was N1. Due east of N1, near the shore, was N2. These beds appeared to have a somewhat diffuse density. Along the shore, 2500 ft north of N1, was N3. N3 appeared to have some oyster-like texture, but for the most part the area appeared very rocky/gravelly. On the flats west of the channel there were three beds that had been previously delineated. These were N4 (10000 ft north of bridge), N5 (5000 ft north of bridge), and N6 (2,000 ft north of bridge). All of these beds appeared to be dense.

Oyster Bed Grab Sampling Results

Grab sampling on the oyster beds began at site S1, proceeding northward. At S1, the grabs sampler failed to retrieve live oysters, but upon recovering the boat anchor, live oysters were found. The oysters appeared to be clustered around a piece of wooden debris. At S2, oysters were again recovered on the anchor, this time clinging to a large fragment of red sandstone. S3 produced live oysters in the grab, but none on the anchor. At S4, only shell hash was recovered, but at S5 live oysters were recovered both on the anchor and in the grab. Photo F-1-12, Live Oysters Recovered from S2 and S5, shows oyster encrusted block of sandstone recovered from the anchor at area S2 on the left and a live oyster recovered from the grab at S5 is opened on the right.

Photo F-1-12 Live Oysters Recovered from S2 and S5

Grabs were taken at three separate locations along S6, at the center of the site, and just north and south of the bridge. At the center, live oysters were recovered both in the grab and on the anchor. For the other two grabs adjacent to the bridge, oysters were recovered only on the anchor. The last of the southern sites, S7, produced live oysters from the grab.

The northern sites were sampled starting with N1. Despite a strong current at N1, which made staying in position difficult, oysters were successfully recovered on the anchor in the area north of the bridge. Live oysters were later recovered in the grab in the area of N1 south of the bridge. At N2, live oysters were recovered from the anchor along the southern edge of the bed. Additional live oysters were noted upon anchoring at a more central location within the bounds of N2. N3 produced live oysters on both the anchor and in the grab. It should be noted that the grab on N3 was unique due to the large quantity of gravel also recovered. Taking into consideration the results of the side scan imagery, the bed at this location is likely scattered and diffuse, intermixed heavily with gravel. N4, N5, and N6 produced small to medium-sized live oysters with a large amount of shell hash. These beds, which were apparently previously identified, are likely remnants, containing only a small fraction of the living oysters they once held.

Side scan sonar imagery indicated the presence of potential oyster beds throughout the survey area, including under the Tappan Zee Bridge, in depths ranging from 8 ft to 30 ft. Grab sampling on the beds delineated using the side scan sonar data confirmed the presence of live oysters at all survey locations, except one location south of the bridge, S4.

Oyster beds were delineated north, south, and under the bridge, occupying depths between 8 ft and 30 ft. All identified oyster beds, except for one bed south of the bridge, were confirmed to contain live oysters. Oyster beds were of differing character, being dense, diffuse, or remnant, and sometimes containing gravel or sandstone fragments.

Oyster Bed Findings

Side scan sonar imagery indicated the presence of potential oyster beds throughout the survey area, including under the Tappan Zee Bridge, in depths ranging from 8 ft to 30 ft. Grab sampling on the beds

delineated using the side scan sonar data confirmed the presence of live oysters at all survey locations, except one location south of the bridge, S4.

Oyster beds were delineated north, south, and under the bridge, occupying depths between 8 ft and 30 ft. All identified oyster beds, except for one bed south of the bridge, were confirmed to contain live oysters. Oyster beds were of differing character, being dense, diffuse, or remnant, and sometimes containing gravel or sandstone fragments.

BRIDGE PIER SAMPLING RESULTS

In total, eight species from three phyla of fauna and two species from two phyla of flora were collected by SCUBA divers (Photo F-1-13). The collected species are identified in Table F-1-23. The differences in the organisms collected at the piers as presented in the table is likely due to the manner in which the samples were collected. As an example, barnacles were collected at four of the piers but review of the video footage collected by the SCUBA divers clearly showed barnacles present at the other two piers. It is likely that all of the organisms identified in the table live within the habitat of all of the bridge piers. As indicated in the note to the table, the species of isopod that was collected may be *Synidotea laevidorsalis*, which has been identified as an invasive species.

Photo F-1-13 SCUBA Diver Entering the River to Perform Bridge Pier Analysis

The entire surface of the piers was covered with fauna and flora from the high water line to the bottom of the pier. The surfaces of the pier substructure consist of timber, concrete, and areas of steel sheeting. In general, the fauna and flora equally colonized these three different growth surfaces.

Green algae growth was found on all of the piers between the high-water lines to the low-water line. The mean tidal range of the Hudson River at the Tappan Zee Bridge is 3.2 feet (0.98 m). The growth was observed to generally be denser on the south side of the structures due to increased exposure to sunlight.

Below the low-tide line, barnacles colonize the structure; they reach their highest density about 3 feet (0.9 m) below the low-water line. Below this depth, the barnacles gradually diminish in size and density and are no longer found at depths greater than 15 feet (4.6 m) below the low-water line. Red algae growth starts at about 4 feet (1.2 m) below the low-water line and reaches its greatest density at about 10 feet (3 m) below the low-water line. Oyster shells were found attached to the pier starting at a depth of about 8 feet (2.4 m) below the low-water line and were found to increase in density to the bottom of the pier. Mussels were not common and. when found, were generally limited to cavities beneath the steel sheeting.

- **Location A** – Fauna and flora on the pier were observed to correspond to the general conditions identified above.
- **Location B** – At a depth of 10 feet (3 m) below MLW, oysters were observed at a density of about ten shells per square foot.
- **Location C** – In 2004, the Self Contained Underwater Breathing Apparatus (SCUBA) survey leader was involved in the installation of a polyvinyl chloride (PVC) plastic pipe at Pier 171 to carry electrical cable to pumps associated with the pier caissons. It was observed that the growth of the fauna and flora on the plastic pipe was very similar in variety and density to the organisms on the adjacent concrete and steel surfaces. This observation would indicate that the colonization of new surfaces takes place rapidly (within three years) in this environment.
- **Location D** – Fauna and flora on the pier were observed to correspond to the general conditions identified above.
- **Location E** – All of the underwater surfaces observed were steel sheeting; there was no exposed concrete. The northern side of the pier had less red algae and more oysters than the other sides of the pier.
- **Location F** – There was a much lower density of red algae than at the other piers. It was observed that there was a greater density of mussels than at the other piers.

The survey of the underwater portions of the bridge piers indicated that the pier surfaces were completely covered with various fauna and flora. The fauna consisted of eight species from three phyla; flora consisted of two species from two phyla. The fauna and flora attached to the pier surfaces were found at similar depths on each of the six piers surveyed. The results of the analysis are shown in Table F-1-23.

Table F-1-23

Species Collected on Bridge Piers

Taxonomy	Scientific Name	Common Name	Pier Locations					
			A	B	C	D	E	F
ANNELIDA	Polychaeta *Nereis* spp.	clam worm			✓		✓	✓
ARTHROPODA	*Gammarus* spp.	scuds	✓	✓	✓			
	Cirripedia *Balanus* spp.	barnacles		✓	✓	✓	✓	
	Palaemonetes vulgaris	common shore shrimp		✓		✓		
	Rhithropanopeus spp.	mud crab	✓	✓	✓	✓	✓	✓
	Isopoda *Synidotea* spp.	isopod	✓	✓	✓	✓	✓	✓
MOLLUSCA	*Crassostrea virginica*	oyster	✓	✓		✓	✓	✓
	Modiolus demissus	ribbed mussel	✓	✓	✓	✓	✓	✓
RHODOPHYTA	*Rhodymenia* spp.	red algae	✓	✓	✓	✓	✓	✓
CHLOROPHYTA	*Entromorpha* spp.	green algae	✓	✓	✓	✓	✓	✓
Notes: ✓ indicates presence in sample. *Synidotea* spp. may be *Synidotea laevidorsalis* which is identified as an invasive species.								

The underwater pier structures consisted of three types of surfaces – concrete, steel and timber. At the same water depth, these surfaces were colonized by the same flora and fauna in approximately similar densities. The PVC pipe installed in 2004 at Location C was found to have a similar diversity and density of flora and fauna as the adjacent concrete and steel surfaces.

2.2.3 Summary of Benthic Community in the Study Area

Within the study area there is a robust benthic community. Both the bridge piers and sediments are well colonized by sessile and motile benthic invertebrates. The bridge piers are also well colonized with algal growth. Statistical analysis shows that there is no significant difference in populations between the existing and proposed bridge alignments. Also, benthic populations markedly increase in the warmer months and decrease in the colder months.

3 Submerged Aquatic Vegetation

Submerged Aquatic Vegetation (SAV) beds are subtidal plant communities that occur in water as much as six feet below low tide (Sea Grant, 2011). SAV beds act as nurseries for numerous larval and juvenile fish, such as alewife, banded killifish, and white perch and produce organic matter that is an integral part of the Hudson River food web (Sea Grant, 2011). The SAV beds improve the clarity of the river by filtering suspended sediments (Sea Grant, 2011). A number of diving ducks, such as the canvasback, bufflehead, common goldeneye, merganser and scaup, feed on the SAV and the fish and invertebrates that inhabit SAV beds.

Using NYSDEC mapping as a guide, surveys were conducted in late summer of 2006 to confirm the extent and characteristics of SAV in the study area. These surveys were performed in the bridge study area along both shorelines (Figure F-1-26). The investigations were conducted during late summer, and included sediment grabs in locations where visibility was poor. The grabs were brought to the surface and inspected for the presence of SAV and the range of species present.

The surveys covered the shoreline to a depth of approximately 8 feet (2.4 m) from 3,000 feet (914 m) south of the existing bridge to 8,000 feet (2,438 m) north of it. Transects were run in a north-south direction with ponar grab collected every 50 to 100 feet (15.2 to 30.5 m). Only two locations north of the existing bridge were found to contain SAV. On the eastern shore, SAV was found within Tarrytown Marina along the shoreline; on the western shore – approximately 1 mile north of the bridge – SAV was encountered within the 2-foot (0.61-m) contour.

Based on these survey results, no significant areas of SAV were found within the area of potential impact from either the construction of the replacement bridge or the demolition of the existing bridge.

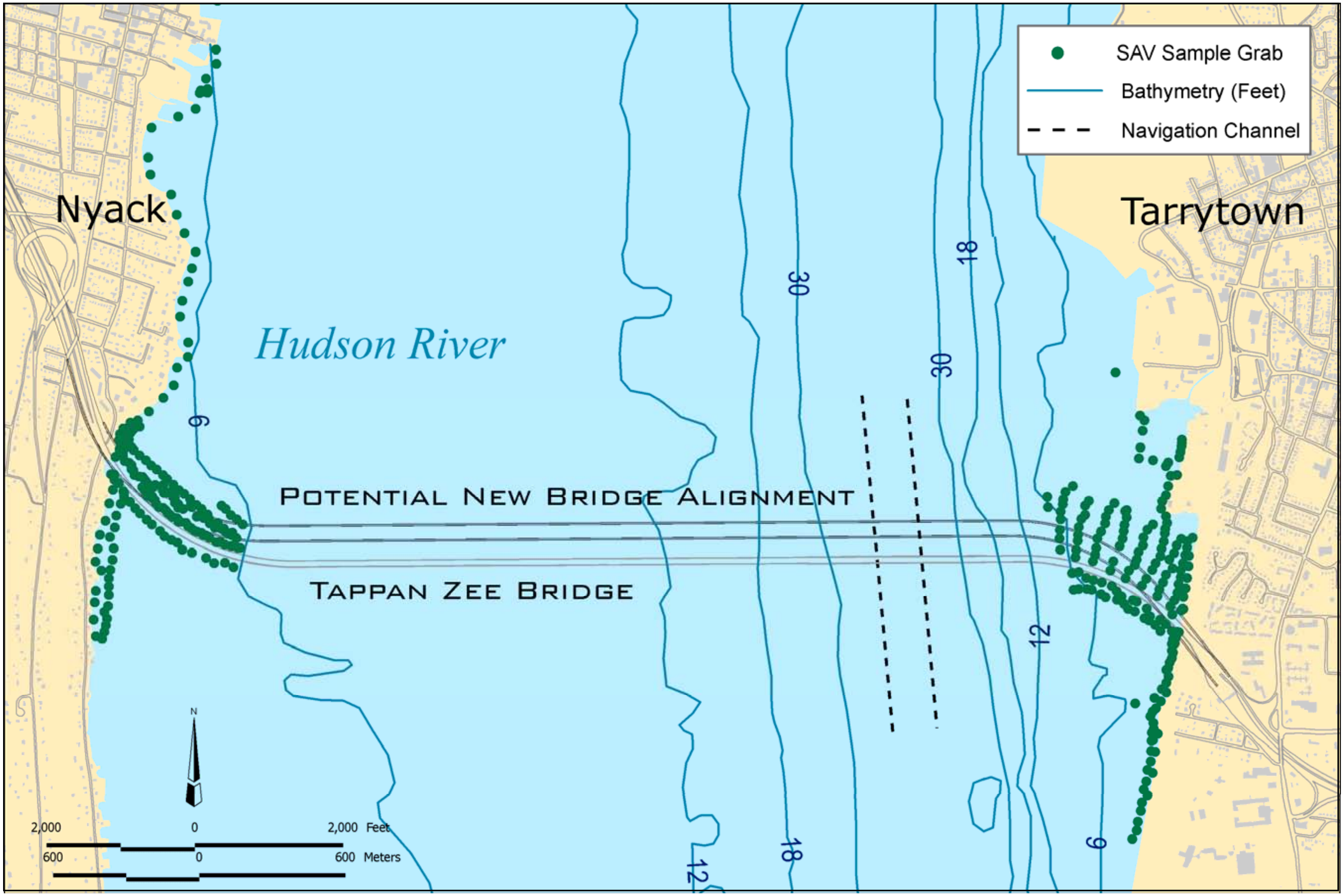


Figure F-1-26 SAV Sampling Locations

In September 2009, previous SAV mapping data were obtained from the NYSDEC. SAV beds are mapped using aerial photo interpretation every five years by the NYSDEC. The mapped polygons are later field confirmed. The available SAV mapping is from years 1997 and 2002. These data are depicted on Figure F-1-27. Results of the 2007 mapping are considered preliminary and are not available for the public; however, preliminary review of the data shows that no new SAV beds near the Tappan Zee Bridge were identified. As part of this project, field studies in Fall 2009 confirmed the presence of the SAV beds depicted on Figure F-1-26.

In September 2009, previous SAV mapping data were obtained from the NYSDEC. SAV beds are mapped, using aerial photo interpretation, every five years by the NYSDEC. The first stage of the investigation involved obtaining the available SAV mapping through the NYSDEC from years 1997 and 2002. These data are depicted on Figure F-1-26. The second part was to ground truth each mapped SAV bed. This involved traversing the Tappan Zee via boat to each location and taking one (1) to three (3) Van Veen grab samples at each location.

If the grab sample confirmed the presence of SAV during the first sample, then the investigators would identify the SAV species, count the number of individual shoots for each species, document the recovery and move to the next location. Otherwise, up to three samples were taken at various locations within the site to confirm the presence or absence of the SAV beds. SAV grab samples were divided into four regions, comprised of the bank north and west of the bridge (WBN), south and west of the bridge (WBS), north and east of the bridge (EBN), and south and east of the bridge (EBS). On the WBN, eleven (11) targets were explored using the Van Veen grab sampling technique. Of those 11 targets, 10 were confirmed to have SAV beds. This confirmation came in the form of grab sampling the general area as shown on Figure F-1-26. The sampling program produced grabs of *Vallisneria* sp. (water celery) shoots that were rooted in the sediment, as shown in Photo F-1-14.

Photo F-1-14 *Vallisneria* sp. sample taken from EBN5.

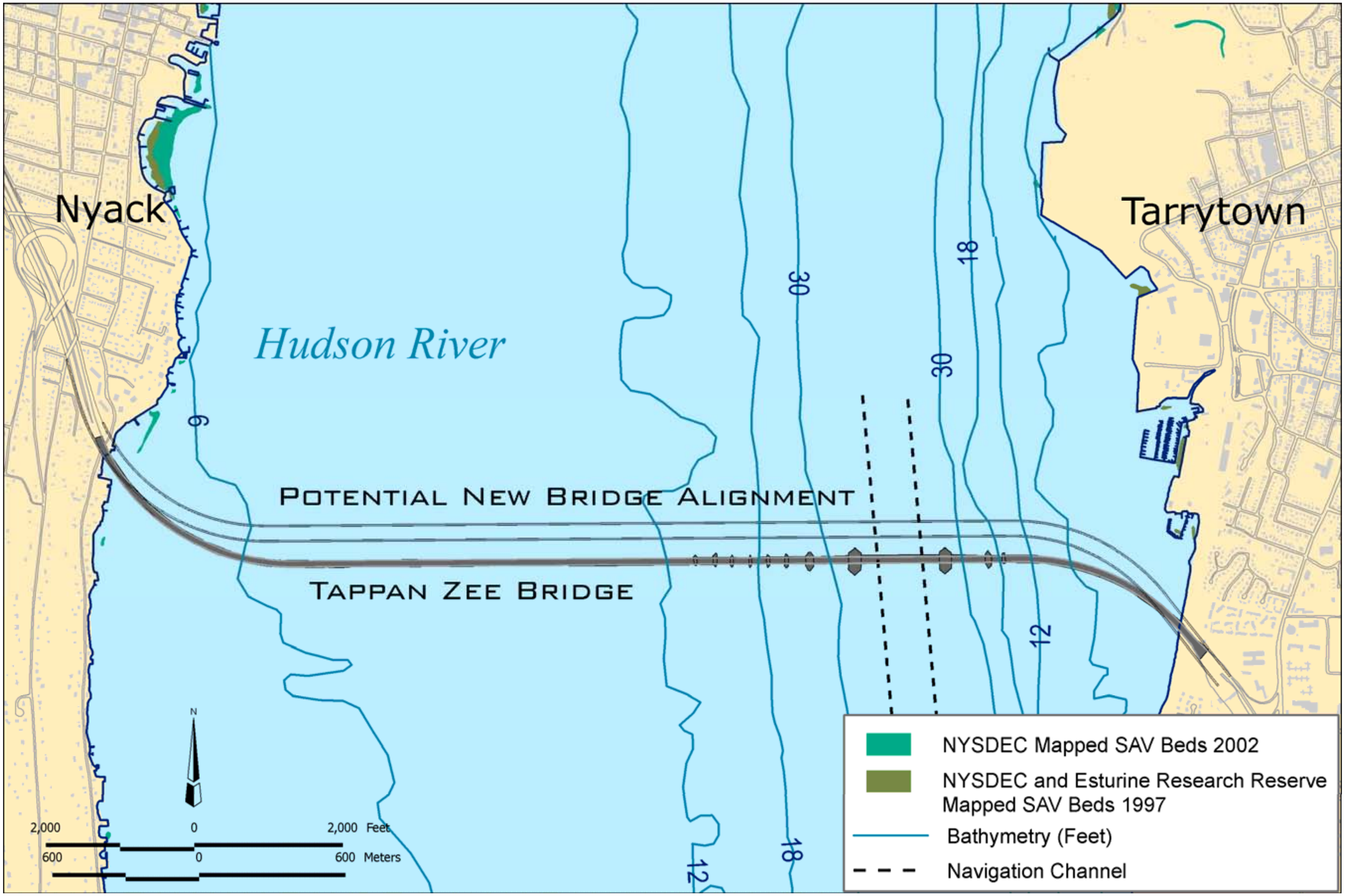
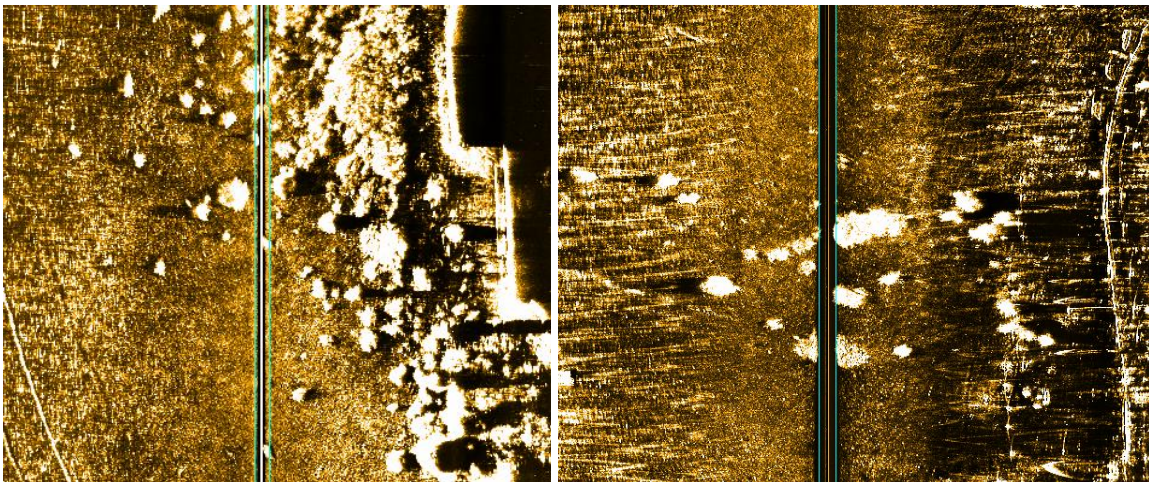


Figure F-1-27 NYSDEC Mapped SAV Beds 1997 and 2002

Visual surveys were also conducted to determine the presence of floating vegetation, specifically *Trapa natans* (water chestnut) *Myriophyllum spicatum* (Eurasian milfoil) and *Potamogeton pectinatus* (Sago pondweed). On the WBS, one (1) target was explored, in which an SAV bed was confirmed and is depicted in Photo F-1-15. Vegetation in this image appears as cloudy, whitish spots, often casting black acoustic shadows. The same cloudy, whitish features noted in the image of WBS-1 can be seen, although the apparent density of possible vegetation is not as great. For scale, the left channel on both images is approximately 55 meters wide.

On the EBN, six (6) targets were explored. The sampling program produced 5 SAV beds. On the EBS, three (3) targets were explored, none of which yielded any confirmed SAV beds.



Note: Left: Confirmed SAV bed imaged at WBS-1. *Right*: Tentative SAV bed imaged by side scan sonar.

Photo F-1-15 WBS-1 Side-scan Sonar Survey SAV Bed

SAV Findings

SAV was found at all previously delineated beds along the west bank. On the east bank, SAV was found only north of the bridge. In addition to the oyster beds that were delineated (see details below), a tentative SAV bed was seen on the side scan sonar in an area not noted in prior studies. The possible vegetation was located in a shallow cove north of the landward section of Piermont Pier in the area around 653474.88 E, 805316.77 N (NAD83 NY State Plane East). Grab sampling in areas previously known to harbor SAV confirmed the presence of vegetation in all sites along the west bank of the study area. Side scan sonar imagery may have also identified an additional area of SAV adjacent to the northern side of Piermont Pier on the west bank. Along the east bank, SAV was only found north of the bridge.