Appendix F: Ecology

F-6 Methodology for Estimating Potential Hydroacoustic Impacts to Abundant Hudson River Fish Species and Shortnose Sturgeon from Pile-driving Activities during Construction of the Tappan Zee Bridge Replacement Project and a Summary of Analysis Results

APPENDIX F-6

Methodology For Estimating Potential Hydroacoustic Impacts To Abundant Hudson River Fish Species And Shortnose Sturgeon From Pile-Driving Activities During Construction Of The Tappan Zee Hudson River Crossing Project, And A Summary Of Analysis Results

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METHODOLOGY FOR ESTIMATING POTENTIAL HYDROACOUSTIC IMPACTS TO ABUNDANT HUDSON RIVER FISH SPECIES AND SHORTNOSE STURGEON FROM PILE-DRIVING ACTIVITIES DURING CONSTRUCTION OF THE TAPPAN ZEE BRIDGE REPLACEMENT PROJECT, AND A SUMMARY OF ANALYSIS RESULTS.

Underwater noise created by pile-driving activities during construction of the Tappan Zee Crossing has the potential to impact the local fish community by exposing fishes to cumulative noise. At low levels, the cumulative sound exposure may cause behavioral avoidance of the ensonified area or, at higher levels, physical injury and mortality.

Different approaches were used to assess these potential impacts., The first approach (**Trawl Approach**) used biological data collected with trawl nets during annual utilities-sponsored fish surveys from 1998-2007 throughout the Hudson River, including the Tappan Zee region. This approach was used to estimate the potential impacts as a percentage of the total riverwide standing crop of fish, as well as the potential impacts to the seven most abundant species. The second approach (**Gill-Net Approach**) was used to examine potential impacts specifically for shortnose sturgeon and used data collected by the project's consultants from 2007-2008 during gill-net sampling at the project site immediately upstream of the existing Tappan Zee Bridge. This approach was considered appropriate for assessing shortnose sturgeon because gill nets are one of the more effective gears for sampling sturgeon and because sampling was conducted recently at the project site.

Both the Trawl Approach and Gill-Net Approach provide an estimate of the number of fish that are likely to occur within an ensonified area with a cumulative sound exposure level ($SEL_{cum)}$ of 187dB re 1μPa^2-s during the onset of construction. For these analyses the $SEL_{cum)}$ of 187dB re 1μPa^2-s was selected as a threshold for the onset of physiological effects to fish based on the interim West Coast criteria agreed to in a Memorandum of Agreement (MOA) by FHWA, USFWS, NMFS, CalTrans, and the Washington Department of Transportation on June 12, 2008. However, recent research strongly suggests that the onset for physiological effects actually occurs at SEL_{cum} levels considerably higher than 187 dB re 1μPa^2-s (See Biological Assessment Appendix F-4).

Due to behavioral avoidance of the ensonified area by fishes during pile-driving activities, it is likely that fish densities will be temporarily reduced in the ensonified area relative to surrounding areas, particularly when pile driving occurs on consecutive days over the course of the first several months of construction. However it is likely that fish that temporarily avoided the area or new fish migrating through the area would return to the previously ensonified areas following the end of the day's construction. A more detailed description of analytical methods used for each of these approaches is given below.

A. Trawl Approach

A hydroacoustic model was developed by JASCO (JASCO 2011) to delineate the spatial extent of noise impacts generated during pile-driving activities over each week of construction. Noise isopleths were superimposed on bathymetric data of the project area collected by NOAA and the State University of New York at Stony Brook (NYS GIS Clearinghouse 2011) to estimate the water volumes contained by the 187dB isopleths during driving of 4, 6, 8 and 10-foot diameter piles. To account for depth-related differences in habitat use by various fish species, three-dimensional volumes were partitioned into habitats that corresponded to those recognized by the Hudson River Utilities Monitoring Program (ASA 2009). These habitats included:

- **Shoal** (0-20-ft depth),
- **Bottom** (0-10-ft from the bottom where water is >20-ft deep), and
- **Channel** (water column above the bottom where water is >20-ft deep).

For each bridge pier to be constructed (each containing a series of piles), the number of fish potentially affected can be estimated using the mean fish density during the weeks of construction and the volume of each habitat contained within the 187dB re 1μPa^2-s acoustic isopleths during those weeks.

The Hudson River Utilities Monitoring Program provides the most comprehensive available spatial and temporal database on Hudson River fish resources. This database includes over three decades of monitoring data with considerable sampling within the Tappan Zee region. Fish community data collected as part of the Hudson River Utilities Fall Shoals Monitoring Program between 1998 and 2007 were used to estimate the number of fish by habitat within the 187dB isopleths. To do this, mean fish densities in the Tappan Zee region (river miles 24-33) were first calculated by habitat and sampling event for each of the 11 sampling events that typically occurred every other week from July through November, using the equations provided in the Utilities Year Class Reports (ASA 2009). Briefly, density was calculated per-unit volume sampled by the trawl for each region, habitat and sample event by dividing the number of fish caught by sample volume in cubic meters. Mean density per week was derived by averaging densities by the number of samples collected in each region, habitat and week during a given sample year. Riverwide weekly standing crop was calculated as the sum of the weekly regional standing crops, which were estimated as the product of weekly fish density and the regional volume.

Using the actual observed densities, densities were interpolated for “off” weeks during the survey year (July through November) when samples were not collected, as well as for weeks between survey years (December through June). Interpolations were performed for weeks during the survey year by averaging fish densities from the previous and following week. For weeks between survey years, a linear interpolation was performed based on the final measured density of the current survey year and the initial measured density of the following survey year. The resulting dataset included the mean density of fishes by habitat in the Tappan Zee region for each of the 52 weeks during the calendar year.

Mean weekly fish densities were then applied to the water volumes affected by the $\mathrm{SEL}_{\mathrm{cum}}$ 187dB re 1μPa^2-s noise isopleths during each week of the proposed construction schedule to estimate the total number of fish expected to be impacted by pile-driving activities on a weekly basis over the course of bridge construction. Impacted volumes were determined following the proposed construction schedule, which outlines the month, week and year during which specific piles are to be driven and allows fish-density estimates to be linked to the habitat and volume impacted by pile driving over the course of construction. This approach allowed us to account for the various combinations of pile sizes that will be driven simultaneously, their location along the span and their depth within the River. Fish numbers were expressed in terms of the Hudson River standing crop for all fish species combined. We then assessed the species composition of the fish community to determine those species most likely to be present in the project area by calculating proportional abundances for all species. Number of fish within the ensonified area were estimated at the species-level for the seven most abundant species, which included bay anchovy (*Anchoa mitchilli*), hogchoker (*Trinectes maculatus*), white perch (*Morone americana*), weakfish (*Cynoscion regalis*), striped bass (*Morone saxatilis*), Atlantic croaker (*Micropogonias undulatus*), and Atlantic menhaden (*Brevoortia tyrannus*).

Upper and lower bounds for the number of fish potentially impacted were estimated by first assuming that the Hudson River standing crop exists in a closed system (i.e., there is no immigration or emigration). Under this assumption, the same individual fish can be observed multiple times and the number of fish vulnerable to noise impacts can not exceed the maximum weekly average number of fish observed.

Therefore, the lower bounds were calculated as:

$$\mathrm{Impacted}_{\mathrm{max}} / \mathrm{SC}_{\mathrm{max}} \ \mathrm{X}\ 100$$

where,

$\mathrm{Impacted}_{\mathrm{max}}$ = the maximum weekly number of fish within the isopleth for $\mathrm{SEL}_{\mathrm{cum}}$ at 187dB re 1μPa^2-s

$\mathrm{SC}_{\mathrm{max}}$ = the maximum weekly standing crop of the Hudson River.

To estimate the upper bounds, it was assumed that the Hudson River standing crop exists in an open system with fish moving throughout the River. In this case, fish are never observed more than once and every fish observed within the project area is counted as a different individual. Under these assumptions, the number of fish within the ensonified area each week was summed across all weeks and divided by the number of weeks of pile driving. This average weekly number of fish was then multiplied by 52 weeks in a year to determine the number of impacted fish during an average construction year.

Therefore, the upper bounds are calculated as:

$$(\sum \text{Impacted}_{\text{weekly}} / \text{n}_{\text{weeks}}) * 52 / \text{SC}_{\text{max}} \text{ X } 100$$

where,

$\text{Impacted}_{\text{weekly}}$ = the weekly number of fish within the isopleth for SEL_{cum} at 187dB re $1\mu\text{Pa}^2$-s

n_{weeks} = the number of weeks of pile driving during construction

Table 1 inidcates the percentage of the Hudson River standing crop within the SEL_{cum} at 187 dB re $1\mu\text{Pa}^2$-s ensonified area during an average construction year for the seven most abundant fish species and for all fish species combined.

B. Gill-Net Approach

As with the Trawl Approach, the results of the hydroacoustic model produced by JASCO (JASCO 2011) were used to delineate the spatial extent of noise impacts generated during pile-driving activities during each week of construction. For the Gill-Net Approach, the width of the 187dB re $1\mu\text{Pa}^2$-s isopleths was measured to scale sturgeon catch rates from 125-ft wide gill nets to isopleths widths.

Using abundance estimates for shortnose sturgeon (“sturgeon”) from a 1-year gill-net sampling project conducted by AECOM (Appendix E-3), the encounter rate of sturgeon in the study area was estimated as the number of sturgeon collected per gill net per hour. From June 2007 – May 2008, 476 gill nets were deployed just upstream of the existing Tappan Zee Bridge (and within the project area) for a total sampling time of 679 hours. During this time, 12 sturgeon were collected: 7 in September and October, 4 in May and June and 1 in August. Based on the observed number of sturgeon collected over 647 gill-net hours, the encounter rate for sturgeon in the project area is 0.02 sturgeon encountered per hour.To estimate the potential number of sturgeon occurring within the 187dB re $1\mu\text{Pa}^2$-s ensonified area, it was necessary to scale gill-net encounter rates from a single gill-net sample to the width encompassed by the isopleth bounding the 187dB SEL_{cum}, which is used as the threshold for physical injury to fish (reviewed in Stadler and Woodbury 2009). To do this, isopleths widths derived from hydroacoustic modeling conducted for representative construction scenarios (JASCO 2011) were used to determine the number of sturgeon that might have been collected if multiple gill nets were deployed side-by-side across the width of the 187dB isopleth. The length of the gillnet is 125-ft. The widths of the 187-dB re $1\mu\text{Pa}^2$-s isopleth for each of the pile sizes ranges from 1,020 to 9,324 ft. Therefore, it would require 8 to 75 gill nets to span the width of the isopleths depending on the size of the pile being driven. Movement by shortnose sturgeon has been shown to be strongly oriented into or with river currents (McCleave et al. 1977). This is supported by data collected during the 2007-2008 gill net study, in which shortnose sturgeon were collected with greater frequency in gill nets deployed across the river current than in those placed with the current (Appendix E-2).

Based on these results, it was assumed that sturgeon moved in an upstream or downstream direction through the project area and at a constant rate and would thus be intercepted by gill nets spanning the width of the noise isopleth. it was also assumed that catch rates are proportional to sturgeon abundance, which is a central assumption of most fish-sampling gears, and that sturgeon were uniformly distributed throughout the Tappan Zee region. Under these assumptions, each gill net would encounter sturgeon at the same rate allowing the estimates of sturgeon number to be scaled to the width of the isopleth. The assumption of uniform sturgeon distribution provides a conservative estimate of encounter rate. This is because the high frequency of single sturgeon collected in the gill-net study suggests that sturgeon are distributed randomly (rather than uniformly or aggregated) and thus would actually be encountered at a lower rate than if they were uniformly distributed (i.e., adjacent gill nets should not each collect the same number of sturgeon when sturgeon are randomly distributed).

Tables 2 and 3 draws from the project's construction schedule and indicates the number of shortnose sturgeon that would encounter the 187 dB re 1μPa^2-s ensonified area during the construction period for the Short Span (482 shortnose sturgeon) and Long Span (365 shortnose sturgeon) Options.

The percentage of the total river width occupied by the 187dB re 1μPa^2-s ensonified width was plotted by week for both the Short Span Option and the Long Span Options over the proposed construction period. The results are shown in Figures 1 and 2.

Table 1
Percentage of Hudson River Fish Standing Crop Within the 187 dB Ensonified Area During an Average Construction Year for the Short Span and Long Span Design Options

Species	Option	Lower-bound estimate for number of fish in the 187 dB ensonified area	Upper-bound estimate for number of fish in the 187 dB ensonified area	Maximum standing crop	Lower bound (%)	Upper bound (%)
Bay anchovy	Long-span	1,320,249	6,002,479	283,753,295	0.47	2.12
Bay anchovy	Short-span	1,320,249	5,169,451	283,753,295	0.47	1.82
Hogchoker	Long-span	23,645	106,569	6,692,813	0.35	1.59
Hogchoker	Short-span	23,645	83,499	6,692,813	0.35	1.25
White perch	Long-span	26,892	146,274	6,235,262	0.43	2.35
White perch	Short-span	26,892	123,641	6,235,262	0.43	1.98
Weakfish	Long-span	8,494	65,430	9,237,259	0.09	0.71
Weakfish	Short-span	6,806	64,590	9,237,259	0.07	0.70
Striped bass	Long-span	12,383	156,084	21,191,428	0.06	0.74
Striped bass	Short-span	16,431	151,874	21,191,428	0.08	0.72
Atlantic croaker	Long-span	130,287	500,261	21,792,473	0.60	2.30
Atlantic croaker	Short-span	130,287	364,209	21,792,473	0.60	1.67
Atlantic menhaden	Long-span	35,035	66,005	6,130,635	0.57	1.08
Atlantic menhaden	Short-span	35,035	51,038	6,130,635	0.57	0.83
All fish species	Long-span	1,536,851	7,956,076	346,334,109	0.44	2.30
All fish species	Short-span	1,536,851	7,021,955	346,334,109	0.44	2.03

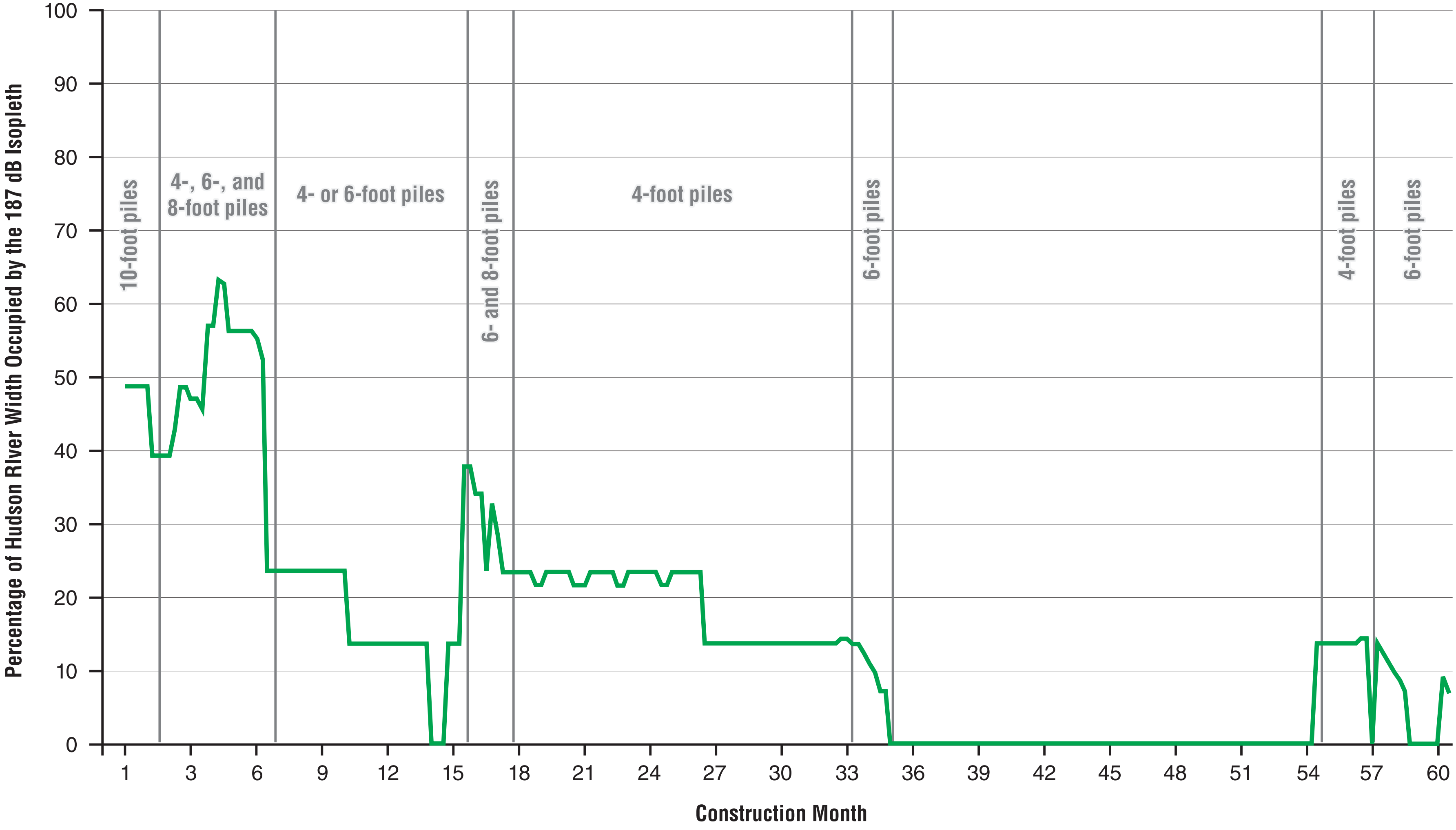

Figure 1

Percent of the Hudson River Width Occupied by the 187dB Isopleth During Pile Driving at the Proposed Tappan Zee Crossing Short Span Option

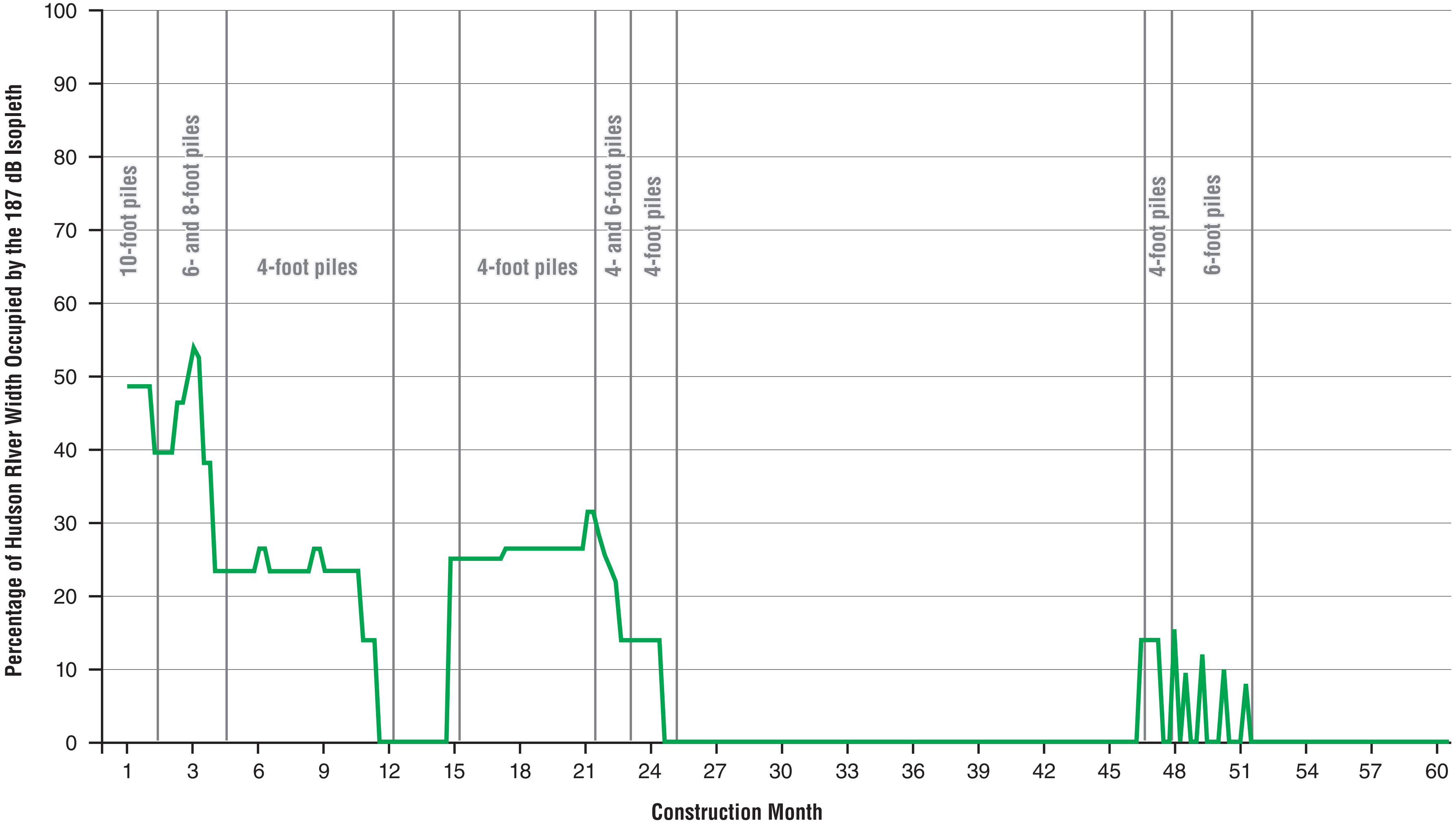

Figure 2

Percent of the Hudson River Width Occupied by the 187dB Isopleth During Pile Driving at the Proposed Tappan Zee Crossing Long Span Option

Table 2

Number of Shortnose Sturgeon Estimated to be Within the 187 dB Ensonified Area During the Construction Period for the Short Span Option

Year	Week	Diameter (feet)	Number of piles	Number of piles driven/day	Pile driving time (hours/pile)	Number of concurrently driven piles	Estimated pile driving time (hours)	With 10 dB BMPs			
								Width of isopleth for 187-db cSEL (ft)	Number of gill nets to span width of isopleth	Sturgeon encounter rate (fish/hr)	Number of shortnose sturgeon potentially affected by pile driving
1	40-44	10	50	4	1.55	2	38.75	7186	57	0.02	44.55
	45-48	6,8	20	7	1.11	2	11.1	5807	46	0.02	10.32
	49	6,8	8	7	1.11	2	4.44	6336	51	0.02	4.50
	50-51	4,8	20	6	1.14	2	11.4	7170	57	0.02	13.08
	52	4,8	10	6	1.14	2	5.7	6952	56	0.02	6.34
2	1	4,8	10	6	1.14	2	5.7	6952	56	0.02	6.34
	2	4,8	10	6	1.14	2	5.7	6735	54	0.02	6.14
	3-4	4,6,8	30	10	1.14	3	11.4	8418	67	0.02	15.36
	5	4,6,8	15	10	1.14	3	5.7	9324	75	0.02	8.50
	6	4,6,8	15	10	1.14	3	5.7	9253	74	0.02	8.44
	7	4,6,8	15	10	1.14	3	5.7	8312	66	0.02	7.58
	8-12	4,6,8	75	10	1.14	3	28.5	7732	62	0.02	35.25
	13	6,8	12	7	1.14	2	6.84	7732	62	0.02	8.46
	14-28	4,4	160	6	1.14	2	91.2	3490	28	0.02	50.9
	29-49	4	95	3	1.14	1	108.3	2024	16	0.02	35.15
	50-51	4,4,6	30	10	1.14	3	11.4	5581	45	0.02	10.18
	52	4,4,6	15	10	1.14	3	5.7	5036	40	0.02	4.59
3	1	4,4,6	15	10	1.14	3	5.7	5036	40	0.02	4.59
	2	4,4	10	6	1.14	2	5.7	3490	28	0.02	3.18
	3	4,4,6	15	10	1.14	3	5.7	4836	39	0.02	4.41
	4	4,4,6	16	10	1.14	3	6.08	4217	34	0.02	4.10
	5-10	4,4	65	6	1.14	2	37.05	3461	28	0.02	20.51
	11-12	4,4	22	6	1.14	2	12.54	3197	26	0.02	6.42

Table 2 (con't)
Number of Shortnose Sturgeon Estimated to be Within the 187 dB Ensonified Area During the Construction Period for the Short Span Option

								With 10 dB BMPs			
Year	**Week**	**Diameter (feet)**	**Number of piles**	**Number of piles driven/day**	**Pile driving time (hours/pile)**	**Number of concurrently driven piles**	**Estimated pile driving time (hours)**	**Width of isopleth for 187-db cSEL (ft)**	**Number of gill nets to span width of isopleth**	**Sturgeon encounter rate (fish/hr)**	**Number of shortnose sturgeon potentially affected by pile driving**
3 (con't)	13-17	4,4	53	6	1.14	2	30.21	3461	28	0.02	16.73
	18-20	4,4	30	6	1.14	2	17.1	3197	26	0.02	8.76
	21-25	4,4	55	6	1.14	2	31.35	3461	28	0.02	17.35
	26-27	4,4	20	6	1.14	2	11.4	3197	26	0.02	5.84
	28-33	4,4	60	6	1.14	2	34.2	3461	28	0.02	18.96
	34-35	4,4	20	6	1.14	2	11.4	3197	26	0.02	5.84
	36-41	4,4	60	6	1.14	2	34.2	3461	28	0.02	18.96
	42-52	4	60	3	1.14	1	68.4	2024	16	0.02	22.2
4	1-14	4	70	3	1.14	1	79.8	2024	16	0.02	25.9
	15-16	6	12	4	0.33	1	3.96	2120	17	0.02	1.34
	17-18	6	6	4	0.33	1	1.98	2019	16	0.02	0.64
	19	6	6	4	0.33	1	1.98	1821	15	0.02	0.58
	20	6	6	4	0.33	1	1.98	1624	13	0.02	0.51
	21	6	4	4	0.33	1	1.32	1440	12	0.02	0.30
	22-23	6	8	4	0.33	1	1.64	1060	8	0.02	0.44
5	50-52	4	15	3	1.14	1	17.1	2024	16	0.02	5.55
6	1-5	4	25	3	1.14	1	28.5	2024	16	0.02	1.85
	6-7	6	12	4	0.33	1	3.96	2120	17	0.02	1.34
	9	6	6	4	0.33	1	1.98	2019	16	0.02	0.64
	10	6	6	4	0.33	1	1.98	1821	15	0.02	0.58
	11	6	6	4	0.33	1	1.98	1624	13	0.02	0.51
	12	6	4	4	0.33	1	1.32	1440	12	0.02	0.30
	13	6	4	4	0.33	1	1.32	1280	10	0.02	0.27
	14	6	4	4	0.33	1	1.32	1060	8	0.02	0.22
	21	6	6	4	0.33	1	1.98	1346	11	0.02	0.43
	22	6	6	4	0.33	1	1.98	1020	8	0.02	0.32
Potential number of sturgeon affected											
Shortnose sturgeon affected											**482**
Percentage of shortnose sturgeon standing crop (60,000 fish)											**0.80**

Table 3
Number of Shortnose Sturgeon Estimated to be Within the 187 dB Ensonified Area During the Construction Period for the Long Span Option

Year	Week	Diameter (feet)	Number of piles	Number of piles driven/day	Pile driving time (hours/pile)	Number of concurrently driven piles	Estimated pile driving time (hours)	With 10 dB BMPs			
								Width of isopleth for 187-db cSEL (ft)	Number of gill nets to span width of isopleth	Sturgeon encounter rate (fish/hr)	Number of shortnose sturgeon potentially affected by pile driving
1	40-44	10	50	4	1.55	2	38.75	7186	57	0.02	44.55
	45-48	6,8	20	7	1.11	2	11.1	5866	47	0.02	10.42
	49-50	6,8	16	7	1.11	2	8.88	6862	55	0.02	9.75
	51	6,8	12	7	1.11	2	6.66	7387	59	0.02	7.87
	52	6,8	14	7	1.11	2	7.77	7965	64	0.02	9.90
2	1	6,8	10	7	1.11	2	5.55	7767	62	0.02	6.90
	2-3	8	12	3	1.11	1	13.32	5648	45	0.02	12.04
	4-11	4,4	88	6	1.14	2	50.16	3458	28	0.02	27.76
	12-13	4,4	20	6	1.14	2	11.4	3910	31	0.02	7.14
	14-21	4,4	80	6	1.14	2	45.6	3458	28	0.02	25.2
	22-23	4,4	22	6	1.14	2	12.54	3910	31	0.02	7.84
	24-30	4,4	73	6	1.14	2	41.61	3458	28	0.02	23.01
	31-33	4	45	3	1.14	1	51.3	2064	17	0.02	16.95
	47-52	4,4	60	6	1.14	2	34.2	3712	30	0.02	20.34
3	1-4	4,4	40	6	1.14	2	22.8	3712	30	0.02	13.56
	5-18	4,4	160	6	1.14	2	91.2	3910	31	0.02	57.1
	19	4,4,6	21	10	1.14	3	7.98	3910	31	0.02	4.99
	20-21	4,6	34	7	1.14	2	19.38	4653	37	0.02	14.43
	22	4,6	22	7	1.14	2	12.54	4200	34	0.02	8.43
	23	4,6	16	7	1.14	2	9.12	3784	30	0.02	5.52
	24	4,6	11	7	1.14	2	6.27	3512	28	0.02	3.52
	25	4,6	11	7	1.14	2	6.27	3240	26	0.02	3.25
	26-33	4	40	3	1.14	1	45.6	2064	17	0.02	15.04
5	17-20	4	20	3	1.14	1	22.8	2064	17	0.02	7.52
	23	6	6	4	0.33	1	1.98	2282	18	0.02	0.72
	25	6	4	4	0.33	1	1.32	1395	11	0.02	0.29
	28	6	6	4	0.33	1	1.98	1759	14	0.02	0.56
	32	6	6	4	0.33	1	1.98	1469	12	0.02	0.47
	36	6	6	4	0.33	1	1.98	1178	9	0.02	0.37
Potential number of sturgeon affected											
Shortnose sturgeon affected											**365**
Percentage of shortnose sturgeon standing crop (60,000 fish)											**0.61**

II. REFERENCES

ASA Analysis and Communications (ASA). 2009. 2007 Year Class Report for the Hudson River Estuary Monitoring Program. February 2009.

JASCO Applied Sciences (JASCO). 2011. Tappan Zee Bridge Construction Hydroacoustic Noise Modeling. Final report. Submitted March 2011. 69pp.

McCleave, J.D., S.M. Fried, and A.K. Towt. 1977. Daily movements of shortnose sturgeon, Acipenser brevirostrum, in a Maine estuary. Copeia 1977: 149-157.

New York State Geographic Information Systems (NYSGIS) Clearinghouse. 2011. Hudson River Estuary Bathymetry 30-m grid dataset. Available from the NYSGIS Clearinghouse website (http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=1136). Accessed December 2, 2011.

Stadler, J. H. and D. P. Woodbury. 2009. Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria. Inter-Noise 2009, Ottawa, Ontario, Canada. ftp://167.131.109.8/techserv/Geo-Environmental/Biology/Hydroacoustic/References/Literature%20references/Stadler%20and%20Woodbury%202009.%20%20Assessing%20the%20effects%20to%20fishes%20from%20pile%20driving.pdf (February 2011).