

## **FINAL EIR UNDERWATER NOISE ANALYSIS**

The section augments the detailed analysis of noise effects in the Draft EIR with a discussion of the behavioral responses of different marine species to underwater sound from Project construction (pile driving) and operation. First, the hearing bandwidth and auditory thresholds of different marine species are presented. Next, a calculation of species-specific hearing threshold ( $\text{dB}_{\text{ht}}$ ) sound levels for construction and operation sound is presented. Finally, the zone of behavioral response is provided for each species, and conclusions are drawn regarding the Project's effect on marine mammals, sea turtles, and fish. Underwater construction sound from the Project is in the low frequency bands. Vessel underwater sound has its energy peak well below 1,000 Hz<sup>1</sup>, and pile driving sound for the Project is concentrated in the very low frequencies below 250 Hz.

### **1.0 MARINE SPECIES HEARING THRESHOLDS AND BANDWIDTH**

The hearing threshold is the minimum sound level in a 1/3-octave band that can be perceived by an animal in the absence of significant background noise. The hearing bandwidth for an animal is the range of frequencies over which an animal can perceive sound. The existing data on these two items are presented below for the following families of marine animals:

- Toothed Whales
- Baleen Whales
- Hair Seals
- Sea Turtles
- Finfish

To the extent possible, data were developed for all federally listed and state-protected marine species (see Sections 5.5.3.1 and 5.5.3.2, Draft EIR) as well as marine mammals and finfish common to Nantucket Sound (see Section 5.5.3.3, Draft EIR). Where no information is available for a certain species, data for other similar animals in that family serve as a best estimate. Hearing threshold data are

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<sup>1</sup> Richardson, W., et al., Marine Mammals and Noise, Academic Press, 1995.

summarized in Tables 1 through 5 and displayed as audiograms in Figures 1 through 3. The frequency range in which underwater construction noise is concentrated (< 1,000 Hz) is shaded in the tables.

### **1.1 Toothed Whales (Odontocetes)**

Extensive study has been done on the hearing thresholds of toothed whales (odontocetes), using a variety of methods. In general, toothed whales have a hearing bandwidth of 100 Hz to over 100 kHz, with the most sensitive hearing in the high-frequency range of 10 kHz to 65 kHz where their hearing threshold is 45 to 85 dB re 1  $\mu$ Pa.<sup>2</sup> Communication among these mammals occurs primarily in the lower end of this high-frequency band, and echolocation for navigation uses the upper end. In the low frequencies below 1 kHz where construction sound is concentrated, toothed whales have a very high hearing threshold of 80 to 130 dB re 1  $\mu$ Pa. Hearing thresholds and bandwidths for three toothed whales species (Harbor Porpoise, Striped Dolphin, Bottlenose Dolphin) are summarized in Table 1, in which data from 13 research studies<sup>3</sup> have been combined to produce maximum likelihood estimates. For the other species without data (White-Sided Dolphin, Pilot Whale, Minke Whale), the results for the Bottlenose Dolphin are recommended as a best estimate.

### **1.2 Baleen Whales (Mysticetes)**

Baleen whales (mysticetes) have very different, and less sensitive hearing capabilities, than toothed whales. Due to their immense size, these mammals cannot be kept in captivity for study like toothed whales. In the limited studies done, baleen whales reacted primarily to sounds at low frequencies below 1 kHz, which is consistent with the fact these whales usually communicate at frequencies in the 20 Hz to 500 Hz range.<sup>4</sup> While this is their most sensitive hearing range, the hearing bandwidth for baleen whales is thought to range from 5 Hz to 20 kHz. The hearing threshold for baleen whales at low frequencies is limited by the relatively high background noise in the ocean under quiet weather conditions without any nearby industrial activity. Those levels range from 82 dB re 1  $\mu$ Pa at

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<sup>2</sup> Richardson, W., et al., Marine Mammals and Noise, Academic Press, 1995.

<sup>3</sup> Nedwell, J.R., et al., "Fish and Marine Mammal Audiograms: A summary of available information," Subacoustech Report No. 534R0214, September 2004.

<sup>4</sup> Richardson, W., et al., Marine Mammals and Noise, Academic Press, 1995.

500 Hz to 88 dB re 1  $\mu$ Pa at 20 Hz.<sup>5</sup> It is reasonable to assume that baleen whale hearing thresholds are no lower than these quiet ocean background levels. With that assumption and the limited research data available, a single set of hearing thresholds for baleen whales similar in shape to those for other marine mammals but shifted to their low frequency range was constructed and is given in Table 2. These data are applicable to the Humpback Whale, Fin Whale and North Atlantic Right Whale.

The vocalization frequency of baleen whales ranges from the tens of Hz for “moans” to kHz for “songs”.<sup>6</sup> Source levels have been estimated as ranging from 130 to 190 dB re 1  $\mu$ Pa @ 1 m.<sup>7</sup> In a study conducted by the Western Australian Division of Minerals and Energy, baleen whales were tested for their threshold levels to low-frequency underwater air gun noise.<sup>8</sup> Humpback Whales exhibited a significant behavioral reaction at sound levels above 179 dB re 1  $\mu$ Pa, or roughly 90 dB above the minimum hearing threshold of 90 dB re 1  $\mu$ Pa listed in Table 2 for baleen whales. This is consistent with NOAA/NMFS guidelines<sup>9</sup> on low-frequency impulse sound below 250 Hz that define the zone of behavioral response (i.e., annoyance, disturbance) for marine mammals as a sound pressure level 80 to 100 dB above the animal’s hearing threshold.

### **1.3 Hair Seals (Pinnipeds)**

Hair seals (pinnipeds) have a similar hearing bandwidth to toothed whales, 100 Hz to 100 kHz, but their most sensitive hearing is at middle frequencies of 1 kHz to 30 kHz where their hearing threshold is 60 to 80 dB re 1  $\mu$ Pa.<sup>10</sup> In the low frequencies below 1kHz where construction sound is concentrated, hair seals have a high hearing threshold of 80 to 100 dB re 1  $\mu$ Pa. Hearing thresholds

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<sup>5</sup> Nedwell, J.R., et al., “Fish and Marine Mammal Audiograms: A summary of available information,” Subacoustech Report No. 534R0214, September 2004, p.90.

<sup>6</sup> Cummings, W. and Holliday, D., “Sounds and source levels from bowhead whales off Point Barrow, Alaska,” in *J. of Acoust. Soc. Am.*, **82**:814-821, 1987.

<sup>7</sup> Medwin, H. and Clay, C., *Fundamentals of Acoustical Oceanography*, Academic Press, 1997.

<sup>8</sup> Western Australian Division of Minerals and Energy, “Appendix F: The environmental effects of air gun noise,” [http://www.isr.gov.au/resources/petr\\_envr/Review](http://www.isr.gov.au/resources/petr_envr/Review).

<sup>9</sup> Reported by University of California at San Diego, Ocean Acoustic Observatories, “Alternate Source Test-Office of Naval Research Pilot Project,” <http://atoc.ucsd.edu/ASTpg.html>.

<sup>10</sup> Richardson, W., et al., *Marine Mammals and Noise*, Academic Press, 1995.

and bandwidths by species are summarized in Table 3, and data from 11 sources<sup>11</sup> have been combined to produce maximum likelihood estimates. For the one species without data (Hooded Seal), the results for the Harp Seal should be used as it is the most similar species.

#### **1.4 Sea Turtles**

While very little published data on hearing thresholds for sea turtles exist, unpublished research results from an Office of Naval Research hearing threshold study being done at New England Aquarium on Green Turtles were obtained<sup>12</sup> and these data were combined with other information<sup>13</sup> to present the hearing thresholds for sea turtles found in Table 4. These are the best estimates available for the Green Turtle, Loggerhead Turtle, Kemp's Ridley Turtle, and Leatherback Turtle. The hearing bandwidth for turtles is relatively narrow, 50 to 1,000 Hz with maximum sensitivity around 200 Hz. And these animals have very high hearing thresholds (over 100 dB re 1  $\mu$ Pa) in the low frequencies where construction sound is concentrated.

#### **1.5 Finfish**

Finfish have a relatively narrow hearing bandwidth, in the range of 16 to 1,600 Hz, in which their hearing threshold is 80 to 130 dB re 1  $\mu$ Pa. Data from nine sources<sup>14</sup> have been combined to produce maximum likelihood estimates of hearing thresholds, summarized in Table 5 for Tautog, Bass, Cod and Atlantic Salmon.

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<sup>11</sup> Nedwell, J.R., et al., "Fish and Marine Mammal Audiograms: A summary of available information," Subacoustech Ltd. Report No. 534R0214, September 2004.

<sup>12</sup> Personal communication, Ms. Kathy Streeter, New England Aquarium, Boston, June 2005.

<sup>13</sup> Ruggero, M. and Temchin, A., "The roles of the external, middle and inner ears in determining the bandwidth of hearing," Proceedings of the National Academy of Sciences, October 2002.

<sup>14</sup> Nedwell, J.R., et al., "Fish and Marine Mammal Audiograms: A summary of available information," Subacoustech Report No. 534R0214, September 2004 and Hastings, M. and Popper, A., "Effects of Sound on Fish," California DOT, Sacramento, January 2005.

## **2.0 HEARING THRESHOLD SOUND LEVELS (dB<sub>ht</sub>)**

As part of a recent COWRIE (Collaborative Offshore Wind Research into the Environment) study of underwater wind farm sound and its effects, Nedwell<sup>15</sup> developed a decibel scale to estimate the behavioral effects on marine species – finfish and marine mammals. The hearing threshold sound level (dB<sub>ht</sub>) for a given species is calculated by passing the frequency spectrum of underwater sound produced by a source through a filter that mimics the frequency-dependent hearing thresholds of that species. The benefit of this approach is that it enables a single number to describe the effects of sound on that species. The process to calculate dB<sub>ht</sub> is similar to that used to calculate dBA, which is the standard measure of noise in air perceived by humans. Research shows marine animal avoidance reactions occur for 50% of individuals at 90 dB<sub>ht</sub> re 1 μPa, occur for 80% of individuals at 98 dB<sub>ht</sub> re 1 μPa, and occur for the single most sensitive individual at 70 dB<sub>ht</sub> re 1 μPa.<sup>14</sup> The 90 dB<sub>ht</sub> re 1 μPa threshold for significant behavioral response is consistent with NOAA/NMFS guidelines defining a zone of influence (i.e., annoyance, disturbance) for marine mammals as a sound pressure level 80 to 100 dB above an animal’s hearing threshold.<sup>16</sup> For estimating the zone of injury for marine mammals, a sound pressure level of 130 dB<sub>ht</sub> re 1 μPa (i.e. 130 dB above an animal’s hearing threshold) is recommended.<sup>15</sup> Of the five groups of marine animals considered in this analysis, toothed whales have the lowest hearing thresholds in the frequency range where construction sounds would occur (below ultrasonic), and those thresholds are around 50 dB re 1 μPa, and 130 dB above that hearing threshold level is a sound level of 180 dB re 1 μPa, which is the present NMFS guideline for preventing injury or harassment to all marine mammals.<sup>17</sup>

Note that since the NMFS 180 dB re 1 μPa guideline is designed to protect all marine species from high sound levels at any point in the frequency spectrum, it is a very conservative criterion. The dB<sub>ht</sub> calculated for each combination of Project activity and marine species is a more accurate measure of acoustic effects than simply comparing the sound level to the NMFS 180 dB criterion because the dB<sub>ht</sub>

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<sup>15</sup> Nedwell, J. and Howell, D., “A review of offshore wind farm related underwater noise sources,” Subacoustech Ltd. Report No. 544R0308, October 2004.

<sup>16</sup> Reported by University of California at San Diego, Ocean Acoustic Observatories, “Alternate Source Test-Office of Naval Research Pilot Project,” <http://atoc.ucsd.edu/ASTpg.html>.

<sup>17</sup> Kurkul, P., NMFS Regional Administrator, Letter to Christine Godfrey, U.S. Army Corps of Engineers, June 27, 2002.

method takes into account the frequency distributions of both the sound source and the receiving animal's hearing thresholds.

Using the hearing threshold data from Tables 1 through 5, species-specific  $dB_{ht}$  sound levels were calculated for the project's loudest construction noise (pile driving) and for project operation, and the results are given in Tables 6 and 7, respectively. In Table 6, construction noise results are given for the NMFS safety radius of 500 m and two closer distances, 320 m and 30 m, where source measurements were made at the Utgruden wind park used in the Project's acoustic analysis (see Section 2.3.1 of Appendix 5.11-A, Draft EIR). Pile driving sound levels cannot be reliably estimated for distances closer than 30 m due to near-field effects. In Table 7, operation sound results are given for the two distances where source measurements were made in the Utgruden and Gotland wind parks, 20 m and 100 m, used in the Project's acoustic analysis (see Section 2.3.2 of Appendix 5.11-A, Draft EIR). Operation sound levels cannot be reliably estimated for distances closer than 20 m due to near-field effects. The  $dB_{ht}$  sound levels reported in Tables 6 and 7 represent the sound as perceived by each group of animals at varying distances. These levels can then be directly compared to the 90  $dB_{ht}$  re 1  $\mu$ Pa threshold for avoidance and the 130  $dB_{ht}$  re 1  $\mu$ Pa threshold for injury.

### **3.0 DISCUSSION OF RESULTS**

#### **3.1 Construction Sound**

As discussed in Section 5.11.2.6 of the Draft EIR, the principal sound from construction would be pile driving of monopiles, one monopile at a time. Using the  $dB_{ht}$  data in Table 6, the zone of behavioral response for pile driving at the project site was calculated. The results, summarized in Table 8, give the distance from the monopile where a significant avoidance reaction will occur for each species, i.e., where  $dB_{ht} = 90$  dB re 1  $\mu$ Pa. Avoidance by a minority of individuals would be expected at lower levels and hence at slightly greater distances than those listed in Table 8.

The results in Table 6 show that no injury to marine mammals, sea turtles or fish are predicted even if an individual were to approach as close as 30 m to the pile driving because all  $dB_{ht}$  values at this minimum distance are well below 130 dB re 1  $\mu$ Pa. This confirms the conclusion in Section 5.5.6.1.1 of the Draft EIR that construction of the Project is not expected to cause physical harm to

marine mammals or sea turtles. If marine animals are in the Project construction area, they are likely to temporarily avoid the zone of behavioral response around the monopile being driven. Table 8 reveals that behavioral effects (avoidance) would occur at a range of 250 to 1,400 m by marine mammals, at a range of less than 30 m by sea turtles, and at a range of 60 to 350 m by finfish.

### **3.2 Operation Sound**

The results in Table 7 show that no behavioral effects to marine mammals, sea turtles or fish are predicted even if an individual were to approach as close as 20 m to a monopile when the Project is operating at the design wind speed because all  $dB_{ht}$  values at this minimum distance are well below 90 dB re 1  $\mu$ Pa. In fact, Project operation will be inaudible for all toothed whales, hair seals, and sea turtles and would be only slightly audible to baleen whales and finfish at the extremely close distance of 20 m ( $dB_{ht}$  values in Table 7 are only 14-21 dB re 1  $\mu$ Pa). This confirms the conclusion in Section 5.5.6.1.1.1 of the Draft EIR that operation of the Project will produce no adverse effect to marine mammals or sea turtles.

### **3.3 Vessel Sounds**

The sound source level for a tug and barge traveling at low speed, the typical construction and maintenance vessels for this Project, is 162 dB re 1  $\mu$ Pa @ 1 m (3.3 feet) (Malme et al. 1989). Whalewatching guidelines for the Northeast region prohibit a vessel from approaching within 100 feet (30.5 m) of any whale (NMFS and NOS, 2006). NOAA Seal Watching Guidelines recommend staying at least 50 yards (45.7 m) away from any resting seal (NMFS and NOS, 2006). While no similar restriction applies for other marine animals, a minimum vessel approach distance of 100 feet (30.5 m) was assumed for whales, sea turtles, porpoises and dolphins and a minimum approach distance of 50 yards (45.7 m) was assumed for seals. Using the reported sound source level for tugs and barges, the maximum perceived underwater sound level was evaluated at 100 feet (30.5 m) for whales, sea turtles, porpoises and dolphins and 150 feet (45.7 m) for seals using the hearing-threshold data presented in Tables 1 through 4. This is conservative for right whales since federal law prohibits approaching within 1,500 feet (460 m) of a right whale. In addition, it is likely that vessel operators will make best efforts to maintain an even greater distance from any sighted whales, dolphins, porpoises, or sea turtles as suggested in guidelines implemented for the Gulf of Mexico oil and gas lease industry (MMS, 2003). Following these guidelines, vessel operators would maintain a

distance of 90 m (295 feet) or greater from a whale and 45 m (148 feet) or greater from a sea turtle or small cetacean.

To represent a possible worst-case scenario, the maximum hearing-threshold sound levels ( $\text{dB}_{\text{ht}}$  re 1  $\mu\text{Pa}$ ) for a Project vessel were calculated at 100 feet (30.5 m) and 150 feet (45.7 m) (seals only) and results were as follows: 42  $\text{dB}_{\text{ht}}$  for whales, 45  $\text{dB}_{\text{ht}}$  for toothed whales, 17  $\text{dB}_{\text{ht}}$  for sea turtles, and 44  $\text{dB}_{\text{ht}}$  for seals. In all cases, the animal would be able to hear the vessel but the sound levels are safely below the 130  $\text{dB}_{\text{ht}}$  re 1  $\mu\text{Pa}$  threshold for preventing injury or harassment to marine animals and the 90  $\text{dB}_{\text{ht}}$  re 1  $\mu\text{Pa}$  threshold for significant behavioral response (i.e., annoyance, disturbance). Therefore, Project vessels will not cause physical harm or behavioral effects in marine mammal or sea turtle species.

Using the reported sound source level for tugs and barges, the maximum perceived underwater sound level was evaluated at 10 feet for finfish using the hearing-threshold data presented in Table 5. The maximum hearing-threshold sound level ( $\text{dB}_{\text{ht}}$  re 1  $\mu\text{Pa}$ ) for finfish at a distance of 10 feet from a Project vessel was calculated as 73  $\text{dB}_{\text{ht}}$  re 1  $\mu\text{Pa}$ . Finfish would be able to hear the vessel but the sound levels are safely below the 130  $\text{dB}_{\text{ht}}$  re 1  $\mu\text{Pa}$  threshold for preventing injury or harassment. Therefore, Project vessels that are 10 feet or greater from finfish should not cause physical harm. The 73  $\text{dB}_{\text{ht}}$  re 1  $\mu\text{Pa}$  sound level at 10 feet is above the 70  $\text{dB}_{\text{ht}}$  re 1  $\mu\text{Pa}$  threshold for avoidance by the most sensitive finfish individual, and thus finfish in the Project vicinity may display avoidance behaviors to vessels. These behaviors, however, would be short-term and would likely be similar to the behaviors observed during activities that regularly occur in Nantucket Sound such as pleasure boat use, ferry traffic, and fishing.



**TABLE 1**

**HEARING THRESHOLDS AND BANDWIDTHS FOR TOOTHED WHALES**

Hearing Bandwidth 1/3 Octave Band (Hz)	Hearing Threshold		
	Harbor Porpoise (dB re 1 $\mu$ Pa)	Striped Dolphin (dB re 1 $\mu$ Pa)	Bottlenose Dolphin (dB re 1 $\mu$ Pa)
80			132
100			108
125			104
160			99
200			94
250	115		91
315	109		87
400	101		83
500	92	121	81
630	89	119	82
800	85	116	83
1,000	81	113	101
1,250	78	110	102
1,600	74	106	101
2,000	69	102	99
2,500	67	100	102
3,150	64	97	77
4,000	61	93	80
5,000	59	88	78
6,300	57	82	74
8,000	55	73	73
10,000	48	71	85
12,500	50	69	83
16,000	52	66	82
20,000	50	61	82
25,000	50	56	79
31,500	49	50	76
40,000	52	48	72
50,000	54	46	70
63,000	57	45	67
80,000	60	46	64
100,000	63	48	74
126,000	64	50	89
160,000	65	116	

**TABLE 2**  
**HEARING THRESHOLDS AND BANDWIDTHS**  
**FOR BALEEN WHALES**

<b>Hearing Bandwidth 1/3 Octave Band (Hz)</b>	<b>Hearing Threshold Baleen Whales (dB re 1 <math>\mu</math>Pa)</b>
4	134
5	130
6	126
10	110
13	104
16	98
20	90
25	90
31	90
40	90
50	90
63	90
80	90
100	90
125	90
160	91
200	91
250	91
315	91
400	92
500	92
630	92
800	93
1,000	93
1,250	94
1,600	94
2,000	95
2,500	96
3,150	97
4,000	100
5,000	104
6,300	110
8,000	117
10,000	125
12,500	130
16,000	137
20,000	145

**TABLE 3**  
**HEARING THRESHOLDS AND BANDWIDTHS**  
**FOR HAIR SEALS**

Hearing Bandwidth 1/3 Octave Band (Hz)	Hearing Threshold		
	Harbor Seal (dB re 1 $\mu$ Pa)	Harp Seal (dB re 1 $\mu$ Pa)	Grey Seal (dB re 1 $\mu$ Pa)
80	101		
100	96		
125	93		
160	89		
200	84		
250	84		
315	84		
400	84		
500	83		
630	82		
800	80	77	
1,000	79	78	
1,250	77	72	
1,600	74	69	83
2,000	73	69	84
2,500	72	68	83
3,150	71	70	83
4,000	70	75	83
5,000	69	74	81
6,300	66	73	80
8,000	64	69	78
10,000	63	69	77
12,500	63	70	73
16,000	63	71	69
20,000	63	68	64
25,000	64	68	63
31,500	65	74	71
40,000	74	75	82
50,000	87	79	91
63,000	108	103	103
80,000	117	110	118
100,000	122	156	128
126,000	126		145

**TABLE 4**  
**HEARING THRESHOLDS AND BANDWIDTH**  
**FOR SEA TURTLES**

<b>Hearing Bandwidth 1/3 Octave Band (Hz)</b>	<b>Hearing Threshold Sea Turtle (dB re 1 <math>\mu</math>Pa)</b>
50	149
63	142
80	131
100	119
125	118
160	117
200	115
250	119
315	123
400	130
500	136
630	144
800	154
1,000	166

**TABLE 5**

**HEARING THRESHOLDS AND BANDWIDTHS FOR FINFISH**

Hearing Bandwidth 1/3 Octave Band (Hz)	Hearing Threshold			
	Tautog (dB re 1 $\mu$ Pa)	Bass (dB re 1 $\mu$ Pa)	Cod (dB re 1 $\mu$ Pa)	Salmon(dB re 1 $\mu$ Pa)
16	91			
20	90		84	
25	89		82	
31	87		85	108
40	85		86	108
50	86		83	107
63	88		83	106
80	90		82	103
100	89	98	82	100
125	87	99	84	98
160	87	99	84	96
200	93	100	87	102
250	100	100	88	108
315	104	100	91	112
400	115	102	101	132
500	128	106	111	
630		107		
800		106		
1,000		107		
1,250		112		
1,600		119		

**TABLE 6**

**PREDICTED UNDERWATER SOUND LEVELS PERCEIVED BY MARINE ANIMALS  
(HEARING THRESHOLD SOUND LEVELS) FROM PROJECT CONSTRUCTION**

Marine Animal	Perceived Sound of Pile Driving (Hearing Threshold Sound Levels - dB <sub>ht</sub> re 1 μPa)		
	At 500 m	At 320 m	At 30 m
Toothed Whales			
Harbor Porpoise	99	103	123
Striped Dolphin	94	98	118
Bottlenose Dolphin	93	97	117
White-Sided Dolphin	93	97	117
Pilot & Minke Whales	93	97	117
Baleen Whales			
All Species	86	90	110
Hair Seals			
Harbor Seal	97	101	121
Gray Seal	84	88	108
Harp & Hooded Seals	97	101	121
Sea Turtles—All Species	56	60	80
Finfish			
Tautog	81	85	105
Bass	76	80	100
Cod	87	91	111
Atlantic Salmon	72	76	96

Note: Research shows marine animal avoidance reactions occur for 50% of individuals at 90 dB<sub>ht</sub> re 1 μPa, occur for 80% of individuals at 98 dB<sub>ht</sub> re 1 μPa, and occur for the single most sensitive individual at 70 dB<sub>ht</sub> re 1 μPa. The 90 dB<sub>ht</sub> re 1 μPa threshold for significant behavioral response is consistent with NOAA/NMFS guidelines defining a zone of influence (i.e., annoyance, disturbance) for marine mammals as a sound pressure level 80 to 100 dB above an animal’s hearing threshold. For estimating the zone of injury for marine mammals, a sound pressure level of 130 dB<sub>ht</sub> re 1 μPa (i.e., 130 dB above an animal’s hearing threshold) is recommended.

**TABLE 7**

**PREDICTED UNDERWATER SOUND LEVELS PERCEIVED BY MARINE ANIMALS  
(HEARING THRESHOLD SOUND LEVELS) FROM PROJECT OPERATION**

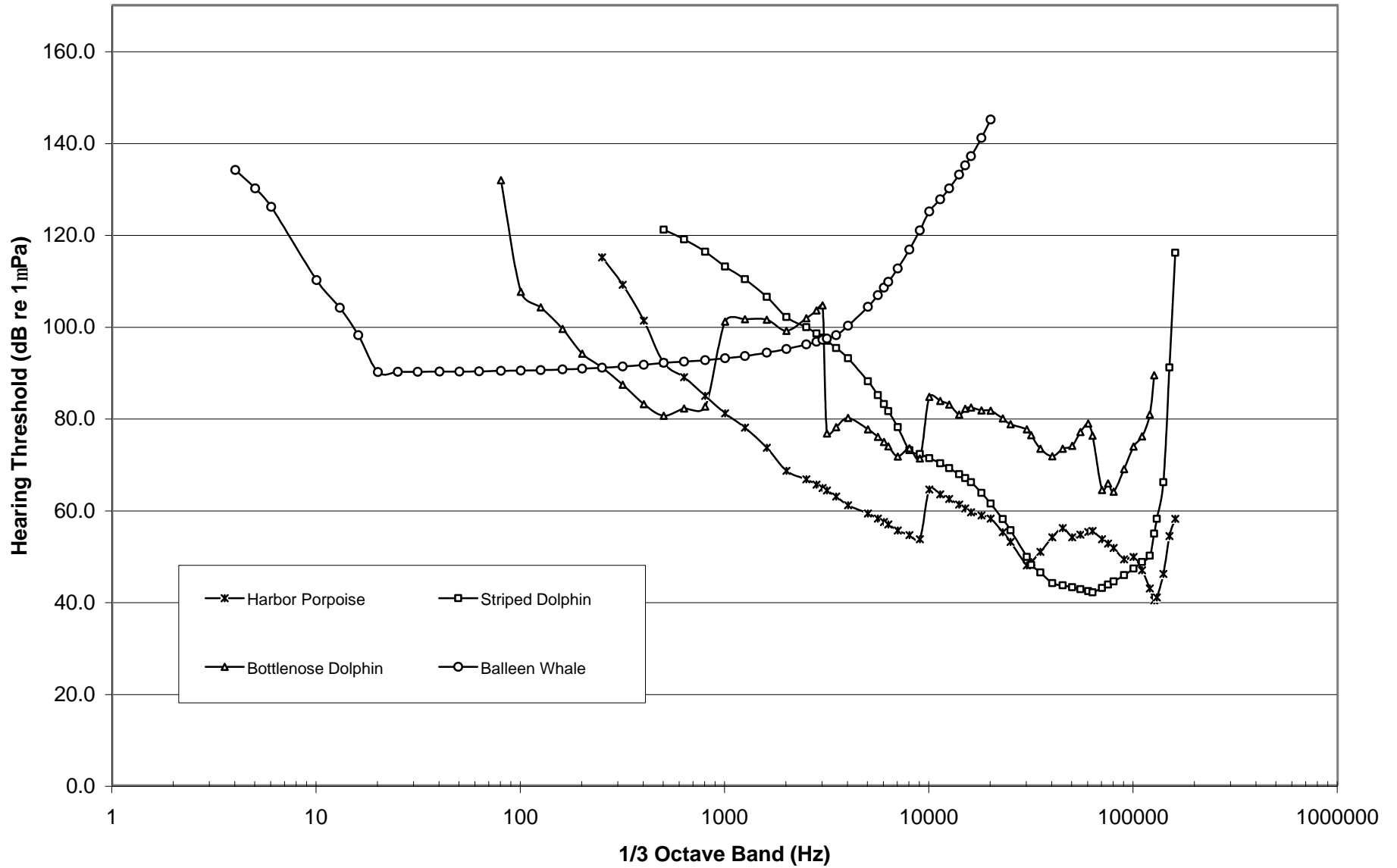
Marine Animal	Perceived Operational Sound Level (Hearing Threshold Sound Levels - dB <sub>ht</sub> re 1 μPa)	
	At 100 m	At 20 m
Toothed Whales All Species	<0	<0
Baleen Whales All Species	0	14
Hair Seals All Species	<0	<0
Sea Turtles All Species	<0	<0
Finfish All Species	7	21

**TABLE 8****CALCULATED ZONE OF BEHAVIORAL RESPONSE FOR  
SIGNIFICANT AVOIDANCE REACTION TO PILE DRIVING**

<b>Marine Animal</b>	<b>Distance Where <math>dB_{ht} = 90</math> dB re 1 <math>\mu</math>Pa and Avoidance Reaction May Occur (meters)</b>
Toothed Whales Harbor Porpoise Striped Dolphin Bottlenose Dolphin, White-Sided Dolphin, Pilot & Minke Whales	1,410 790 710
Baleen Whales All Species	320
Hair Seals Harbor Seal Gray Seal Harp & Hooded Seals	1,120 250 1,120
Sea Turtles—All Species	< 30
Finfish Tautog Bass Cod Atlantic Salmon	180 100 350 60



**FIGURE 1. AUDIOGRAMS FOR TOOTHED AND BALEEN WHALES**





**FIGURE 3. AUDIOGRAMS FOR FINFISH**

