3.6 Fish

3.6 FISH

3.6.1 AFFECTED ENVIRONMENT

For purposes of this Supplemental Environmental Impact Statement (EIS)/Overseas EIS (Supplemental EIS/OEIS), the Region of Influence for fish remains the same as that identified in the March 2011 Gulf of Alaska (GOA) Navy Training Activities Final EIS/OEIS and includes the Temporary Maritime Activities Area (TMAA) (the Study Area).

3.6.1.1 Existing Conditions

The following provides an overview of the predominant fish species and habitat types known to occur in the TMAA. Two fish categories are described: anadromous salmonids (genus *Oncorhynchus*; hereafter referred to as salmonids) and groundfishes. The TMAA is over 12 nautical miles offshore, and includes primarily offshore habitats such as pelagic (open ocean), continental shelf, slope, and abyssal plain, which are influenced by both the Alaska Coastal Current and the Alaska Gyre.

3.6.1.1.1 Salmonid and Groundfish Species

The life histories of the dominant species of salmonids and groundfishes occurring in the Gulf of Alaska are described in the 2011 GOA Final EIS/OEIS. Salmonids present in the GOA include Chinook (*O. tshawytscha*), coho (*O. kisutch*), chum (*O. keta*), pink (*O. gorbuscha*), sockeye (*O. nerka*), and steelhead (*O. mykiss*). Groundfish species in the GOA include the flatfishes, rockfishes, roundfishes, skates, sharks, and chimeras. Neither the species nor the species status of salmonids and groundfishes has changed since it was last described in the 2011 GOA Final EIS/OEIS. Therefore, the information and analysis presented in the 2011 GOA Final EIS/OEIS remains valid.

3.6.1.1.1.1 Summary of Fisheries Management

The historical accounts for Pacific halibut (*Hippoglossus stenolepis*) management occurring prior to the 2011 GOA Final EIS/OEIS are fully described in the 2011 GOA Final EIS/OEIS. Following a review of recent stock assessment reports, the Pacific halibut fishery commercial catch decreased 6 percent between 2009 and 2010 with only a 1 percent decrease in effort in the Gulf of Alaska (International Pacific Halibut Commission 2013). Figure 3.6-1 shows the groundfish and halibut harvests within the GOA and TMAA, most of which are concentrated on the western edge of the TMAA. However, the overall trend does not indicate declines in abundance throughout the Gulf of Alaska. Additionally, no new or additional United States (U.S.) Department of the Navy (Navy) training activities are being proposed in this Supplemental EIS/OEIS that would affect fish resources in the Study Area. Since the changes presented in the Pacific halibut stock assessment reports relate to landings, catch-per-unit-effort, and variable abundance across the GOA, the information and analysis presented in the 2011 GOA Final EIS/OEIS remains valid.

3.6.1.1.2 Fish Habitat in the Gulf of Alaska Temporary Maritime Activities Area and Offshore Habitats

Habitat characteristics, which include geomorphic, physical, biological, and chemical parameters, as well as islands, biogenic habitats, benthic habitats, and the water column variables, are described in the 2011 GOA Final EIS/OEIS. Additionally, offshore areas, which include corals, sponges, benthic, and artificial habitats, as well as the water column, are also described in the 2011 GOA Final EIS/OEIS. These habitat descriptions and locations within the TMAA, as listed in the 2011 GOA Final EIS/OEIS, have not changed due to their intrinsic static nature. Since the habitats types have remained the same, the information and analysis presented in the 2011 GOA Final EIS/OEIS remains valid.

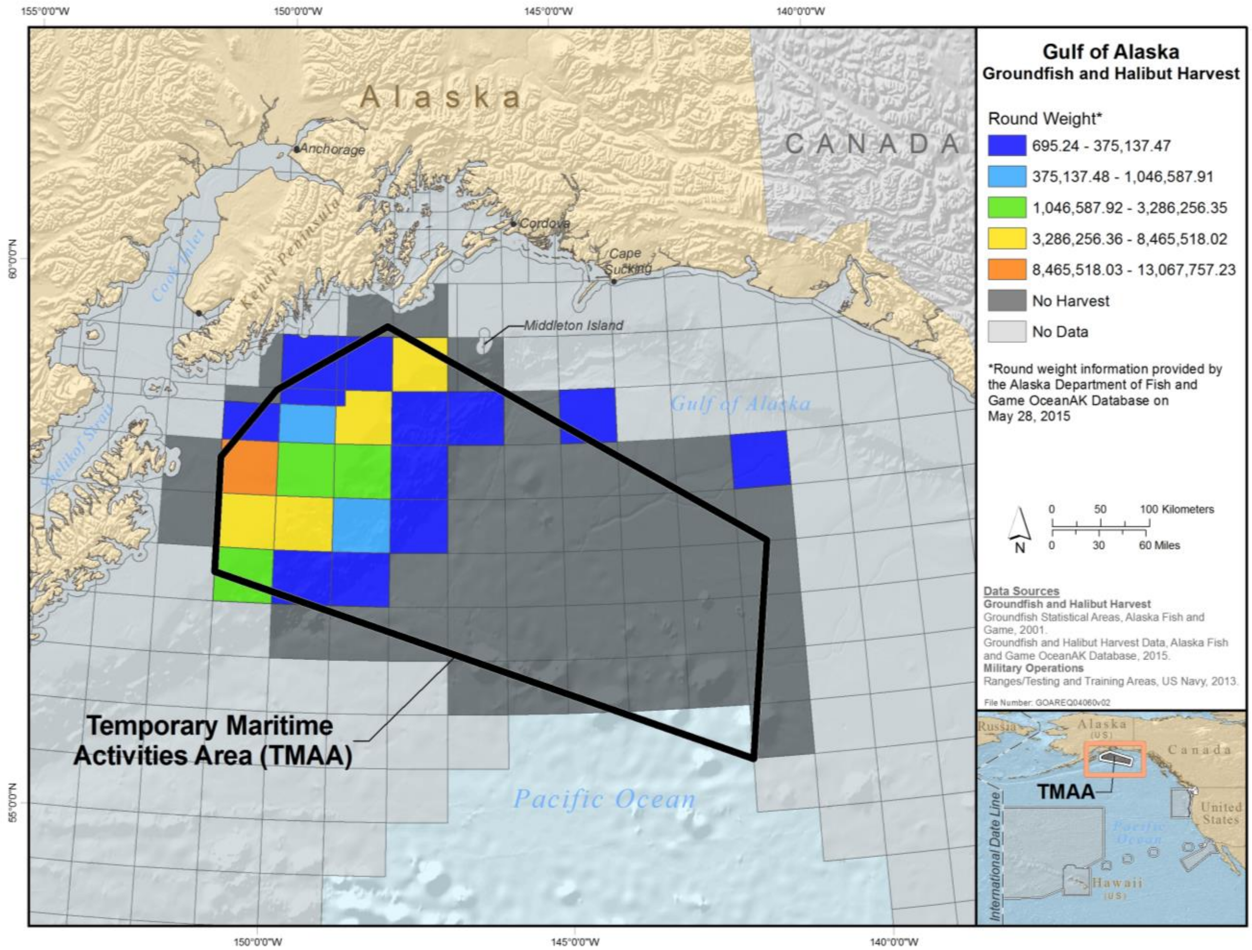

Figure 3.6-1: Groundfish and Halibut Harvest in the Gulf of Alaska

3.6.1.2 Essential Fish Habitat

Descriptions of Essential Fish Habitat (EFH) were presented in the 2011 GOA Final EIS/OEIS. This Supplemental EIS/OEIS addresses the same activities within the TMAA as did the 2011 GOA Final EIS/OEIS. The North Pacific Fishery Management Council has three Fishery Management Plans (FMP) in effect for the scallop, groundfish, and salmon fisheries in the Gulf of Alaska, which are described below. Although a few updates have occurred to the FMPs since the 2011 GOA Final EIS/OEIS, none have changed or affected the previous information or analyses. As such, the general description of the EFH within the TMAA in the 2011 GOA Final EIS/OEIS has not changed; thus, the information presented remains valid. However, the updates to each FMP are presented below, by species group.

3.6.1.2.1 Scallop Fishery Management Plan

As presented in the 2011 GOA Final EIS/OEIS, there is a Scallop FMP for the Gulf of Alaska. A recent review of the FMP and associated documents indicated that the National Marine Fisheries Service (NMFS) approved Amendment 13 to the Scallop FMP on September 30, 2011 (76 Federal Register [FR] 61996). NMFS also approved Amendment 15 on October 31, 2012 (77 FR 66564). Amendment 13 implemented an annual catch limit and accountability measures to prevent overfishing. Since Amendment 13 was included to facilitate support for a sustainable scallop fishery and did not include changes to fishable habitat area or impose new environmental baseline restrictions, the information presented in the 2011 GOA Final EIS/OEIS remains valid. Amendment 15 revised Amendments 7 and 9 based on the outcome of the 2010 EFH 5-year review. The amendment revised EFH descriptions and identifications by species, and updated life history, distribution, and habitat association information; updated descriptions of EFH impacts from non-fishing activities, and EFH conservation recommendations for non-fishing activities; revised the timeline associated with the Habitat Areas of Particular Concern process to a 5-year timeline; and updated EFH research priority objectives. The Navy has reviewed the information presented in Amendment 13 and Amendment 15 and has determined that no changes are necessary to the 2010 EFH and the information presented in the 2011 GOA Final EIS/OEIS remains valid. Therefore, no additional update to the 2011 GOA Final EIS/OEIS is required.

3.6.1.2.2 Groundfish Fishery Management Plan

As presented in the 2011 GOA Final EIS/OEIS, there is a Groundfish FMP for the Gulf of Alaska. A recent review of the FMP and associated documents indicated that NMFS issued several amendments to the plan. Amendments 76 through 102 have been implemented following the completion of the 2011 GOA Final EIS/OEIS, and focused on stricter regulations on quotas, licenses, gear, annual catch rates, implementation of an observer program for the commercial halibut sector, the removal of the dusky rockfish (*Sebastes ciliates*) from federal management, authorized the establishment of halibut prohibited species catch limits, removed the size restriction on blocks of sablefish quota share, established a salmon bycatch reduction incentive program in the non-pollock trawl fisheries in the Western and Central GOA, corrected an omission regarding vessel length limits, and revised observer requirements (81 FR 17403). NMFS also has proposed Amendment 103 that will allow NMFS to reapportion unused Chinook prohibited species catch within and among specific trawl sectors (81 FR 39237). Since these amendments were included to help facilitate a sustainable groundfish fishery by reducing overall catch and did not impose new environmental baseline restrictions, the information in the 2011 GOA Final EIS/OEIS remains valid. Therefore, no additional update to the 2011 GOA Final EIS/OEIS is required.

3.6.1.2.3 Salmon Fishery Management Plan

As presented in the 2011 GOA Final EIS/OEIS, there is a Salmon FMP for the Gulf of Alaska. A recent review of the FMP and associated documents showed that NMFS had issued Amendments 10 through 12 to the management plan. Amendment 10 allows NMFS to recover administration costs associated with processing permit applications. Amendment 11 extended the time period to solicit proposals for habitat areas of particular concern from 3 to 5 years. Amendment 12 revises the plan in order to better facilitate the State of Alaska salmon management (77 FR 75570). Since these amendments were administrative (e.g., permit cost recovery and proposal review period) and resource management related and did not propose any new restrictions on the habitat or the species, the information and analyses presented in the 2011 GOA Final EIS/OEIS remains valid. Therefore, no additional update to the 2011 GOA Final EIS/OEIS is required.

3.6.1.3 Threatened and Endangered Species

3.6.1.3.1 Salmonids

Following a review of literature published since the 2011 GOA EIS/OEIS (including, but not limited to National Marine Fisheries Service 2016a), as well as a review of the National Marine Fisheries Office of Protected Resources website, Federal Registrar publications, and online scientific journal databases (such as BIOSIS), the most recent information pertaining to threatened, endangered, candidate, and species of concern salmonids is presented in Table 3.6-1. Candidate species are any species that are undergoing a status review that NMFS has announced through an FR notice (71 FR 61022). Species of

Concern are identified by NMFS when there is concern regarding species status, but for which insufficient information is available to indicate a need to list the species (69 FR 19975). Candidate species and Species of Concern do not carry any procedural or substantive protections under the Endangered Species Act (ESA) (71 FR 61022). Chinook, coho, chum, pink, and sockeye salmon and steelhead that originate from Alaskan rivers are not listed under the ESA and thus are absent from the table. Table 3.6-1 describes listed salmonid species that originate from rivers in California, Oregon, and Washington that may be present in the Study Area during certain times of their life cycle.

Table 3.6-1: Pacific Salmonid Evolutionarily Significant Units and Distinct Population Segments in the Temporary Maritime Activities Area and Vicinity

Species	ESU[1]/DPS[2]	Federal Status	Critical Habitat in the TMAA
Chinook	Sacramento River Winter-run ESU	Endangered	No
	Upper Columbia River Spring-run ESU	Endangered	No
	Snake River Spring/Summer-run ESU	Threatened	No
	Snake River Fall-run ESU	Threatened	No
	Central Valley Spring-run ESU	Threatened	No
	California Coastal ESU	Threatened	No
	Puget Sound ESU	Threatened	No
	Lower Columbia River ESU	Threatened	No
	Upper Willamette River ESU	Threatened	No
	Central Valley Fall, Late Fall ESU	Species of Concern[3,4]	No
Coho	Central California Coast ESU	Endangered	No
	Southern Oregon/Northern California Coasts ESU	Threatened	No
	Lower Columbia River ESU	Threatened	No
	Oregon Coast ESU	Threatened	No
	Puget Sound/Strait of Georgia ESU[3]	Species of Concern[3,4]	No[3]
Chum	Hood Canal Summer-run ESU	Threatened	No
	Columbia River ESU	Threatened	No
Sockeye	Snake River ESU	Endangered	No
	Ozette Lake ESU	Threatened	No
Steelhead	Southern California DPS	Endangered	No
	Upper Columbia River DPS	Threatened	No
	Snake River Basin DPS	Threatened	No
	Middle Columbia River DPS	Threatened	No
	Lower Columbia River DPS	Threatened	No
	Upper Willamette River DPS	Threatened	No
	South-Central California Coast DPS	Threatened	No
	Central California Coast DPS	Threatened	No
	Northern California DPS	Threatened	No
	California Central Valley DPS	Threatened	No
	Puget Sound DPS	Threatened	No
	Oregon Coast DPS	Species of Concern[3,4]	No

[1] ESU is a population of organisms that is considered distinct for purposes of conservation.
[2] A species with more than one DPS can have more than one ESA listing status, as individual DPSs can be either not listed under the ESA or can be listed as endangered, threatened, or a candidate species.
[3] New/updated information differing from the 2011 GOA Final EIS/OEIS.
[4] National Marine Fisheries Service 2016b.
Notes: DPS = Distinct Population Segment, ESA = Endangered Species Act, ESU = evolutionarily significant unit, TMAA = Temporary Maritime Activities Area

3.6.1.3.1.1 Chinook Salmon

There are nine evolutionarily significant units (ESUs) listed under the ESA; two are listed as endangered and seven as threatened (National Marine Fisheries Service 2016a). There is one additional ESU that is a species of concern. Critical habitat for nine Chinook salmon ESUs has been designated (National Marine Fisheries Service 2016a), although there is no critical habitat designated in Alaska. Most of the ESUs have a low abundance relative to historical levels (National Marine Fisheries Service 2016a). NMFS has reported population sizes from individual ESUs, but because Chinook school while at sea, it is difficult to accurately estimate the marine life stage population. NMFS references specific population estimates based on freshwater adult returns within each of the ESUs in Good et al. (2005). With the exception of this additional information about the variability of the adult population, the information regarding Chinook salmon presented in the 2011 GOA Final EIS/OEIS remains valid. Therefore, no additional update to the 2011 GOA Final EIS/OEIS is required.

3.6.1.3.1.2 Coho Salmon

There are four ESA-listed coho ESUs, one is listed as endangered and three as threatened (National Marine Fisheries Service 2016a). There is one additional ESU that is a species of concern. The ESUs have a low abundance relative to historical levels and have seen decreases in recent years (National Marine Fisheries Service 2016a). NMFS has reported population sizes from individual ESUs, but because coho likely school while at sea, it is difficult to accurately estimate the marine population. Specific population numbers, based on freshwater adult returns, within each of the ESU can be found in Good et al. (2005). With the exception of this additional information citing population decreases, the information regarding coho salmon presented in the 2011 GOA Final EIS/OEIS remains valid. Therefore, no additional update to the 2011 GOA Final EIS/OEIS is required.

3.6.1.3.1.3 Chum Salmon

There are two ESA-listed chum ESUs, both are listed as threatened. NMFS's salmon population trends indicate that the overall population trend for the Hood Canal summer-run chum is increasing and the Columbia River chum population is unknown due to lack of data (Good et al. 2005, National Marine Fisheries Service 2016c, National Marine Fisheries Service 2016d). The information regarding chum salmon presented in the 2011 GOA Final EIS/OEIS remains valid. Therefore, no additional update to the 2011 GOA Final EIS/OEIS is required.

3.6.1.3.1.4 Sockeye Salmon

There are two ESA-listed sockeye ESUs, both are listed as threatened. NMFS's salmon population trends indicate that the Snake River ESU is increasing (National Marine Fisheries Service 2016e). Data collection practices for the Ozette Lake ESU makes differentiating between the number of hatchery and natural spawners difficult; however, the size of the population is small, though possibly growing (National Marine Fisheries Service 2016f). NMFS has reported population sizes from individual distinct population segments (DPSs), but because sockeye school while at sea, it is difficult to estimate the marine population. NMFS uses specific population numbers, based on freshwater adult returns, within each of the DPSs from Good et al. (2005). With the exception of this additional information regarding the fluctuating population and apparent need to implement new ways to distinguish hatchery stock from wild stocks, the information presented in the 2011 GOA Final EIS/OEIS remains valid. Therefore, no additional update to the 2011 GOA Final EIS/OEIS is required.

3.6.1.3.1.5 Steelhead Trout

There are 11 ESA-listed steelhead DPSs, two as endangered and nine as threatened (National Marine Fisheries Service 2016a). There is one additional ESU that is a species of concern. Critical habitat for

10 west coast steelhead DPSs was designated in 2005, although none occur in the Study Area (National Marine Fisheries Service 2016a). Most of the DPSs have a low abundance relative to historical levels, and there is widespread occurrence of hatchery stock spawning with natural populations (Good et al. 2005; National Marine Fisheries Service 2016). NMFS has reported population sizes from individual DPSs, but because steelhead likely school while at sea, it is difficult to accurately estimate the population during their ocean phase. NMFS uses specific population numbers based on freshwater adult returns within each of the DPSs from Good et al. (2005). No new or additional information or analyses on steelhead has been developed, hence the information regarding steelhead presented in the 2011 GOA Final EIS/OEIS remains valid. Therefore, no additional update to the 2011 GOA Final EIS/OEIS is required.

3.6.1.4 Hearing and Vocalization in Fish

The 2011 GOA Final EIS/OEIS described the hearing and vocalization capabilities of fish using best available science. Since 2011, researchers have continued to investigate hearing and vocalization capabilities of fish. Popper et al. (2014) provided a consolidated review of the literature and proposed three groups of fishes based on their anatomical structures and how they detect and use sound. By categorizing fishes into functional hearing groups, it allows for better organization of the existing literature and clearer conclusions when describing effects from sound exposure. Functional hearing groups for fish are not new, have been previously discussed in the literature, and were evaluated in the 2011 GOA Final EIS/OEIS. The work of Popper et al. (2014) has further refined the previously known functional hearing groups which will be described in this section. Since the 2011 GOA Final EIS/OEIS already evaluated effects to fish based on their anatomy and other factors, this information does not change the previous analysis, the effects from the activities, nor the conclusions. However, it may provide a clearer path for understanding the effects or lack thereof. Following a recent review of technical documents and scientific literature, additional relevant information pertaining to fish hearing and vocalization is presented below.

As discussed in the 2011 GOA Final EIS/OEIS, all fish have two sensory systems which can detect sound in the water: the inner ear, which functions very much like the inner ear in other vertebrates, and the lateral line, which consists of a series of receptors along the fish's body (Popper and Schilt 2008). The lateral line system is sensitive to particle motion relative to the fish that arises from sources within a few body lengths of the animal. The lateral line detects particle motion at low frequencies from below 1 Hertz (Hz) up to at least 200 Hz (Hastings and Popper 2005, Coombs and Montgomery 1999, Webb et al. 2008).

Although many researchers have investigated hearing and vocalizations in fish species (as reviewed in the 2011 GOA Final EIS/OEIS and subsequently in Ladich and Fay 2013, Popper 2008, and Popper et al. 2014), hearing capability data only exist for more than 100 of the over approximately 33,000 currently known marine and freshwater fish species. However, past literature has grouped fish based on their anatomical structures for the purpose of analyzing effects from sound. Fish with specialized adaptations connecting the swim bladder to the inner ear had traditionally been called "hearing specialists," while fish that do not possess specialized structures or swim bladders have been referred to as "generalists" (Popper et al. 2003). However, these terms are no longer used to describe fish hearing groups as fish contain a continuum of different anatomical features which result in varying degrees of hearing sensitivity (Popper and Fay 2010).

The traditional categories of "hearing generalist" and "hearing specialist" have been further defined based on Popper et al. (2014) as the following:

- Fishes with a swim bladder that is involved in hearing (hearing up to a few kilohertz [kHz]) (e.g., herring and previously called a hearing specialist).
- Fishes with a swim bladder that is not involved in hearing (hearing generally below 1 kHz]) (e.g., salmon, steelhead, trout and previously called a hearing generalist).
- Fishes without a swim bladder (hearing limited to particle motion detection—well below 1 kHz) (e.g., flatfishes such as halibut and previously called a hearing generalist).

The inner ears of fish are directly sensitive to acoustic particle motion rather than acoustic pressure. Although a propagating sound wave contains pressure and particle motion components, particle motion is most significant at low frequencies (up to at least 200 Hz) and occurs within close proximity to the sound source. Fish species may actually possess a continuum of anatomical specializations that can enhance their sensitivity to sound pressure (Astrup 1999; Popper and Fay 2010). Some species of fish have a gas-filled swim bladder, which can enhance sound detection by converting acoustic pressure into localized particle motion, which may then be detected by the inner ear (Radford et al. 2012). Fish with swim bladders generally have better sensitivity and better high-frequency hearing than fish without swim bladders (Popper and Fay 2010) (Popper et al. 2014).

Data suggest that most species of fish detect sounds from below 50 up to 1,000 Hz, with few fish hearing sounds above 4 kHz (Popper 2008) (Mann et al. 1997, 2001). It is believed that most fish have their best hearing sensitivity from 100 to 400 Hz (Popper 2003). Marine fish in the families Holocentridae (squirrelfish and soldierfish), Pomacentridae (damselfish), Gadidae (cod, hakes, and grenadiers), and Sciaenidae (drums, weakfish, and croakers) have some members that can potentially hear sound up to a few kHz. Some fish in the subfamily Alosinae (i.e., shad and menhaden) possess ultrasonic hearing, which means they are able to detect sounds above 4 kHz to over 180 kHz (Mann et al. 2001). The anatomy of the ear, presence of a swim bladder, and connections or proximity of these two organs can help guide assumptions about the hearing capabilities of a species, although these assumptions should generally be verified by hearing measurements (Popper et al. 2014). Some fishes, such as deep sea species in the family Myctophidae, may have structural adaptations to enhance hearing capabilities (Deng et al. 2011; Popper 1977, 1980). Since it has not been possible to collect actual measures of hearing on fish from great depths, the suspected hearing capabilities of these fishes are based on the structure of the ear, the relationship between the ear and the swim bladder, and the presence of highly developed areas of the brain related to inner ear and lateral line functions (Buran et al. 2005; Deng et al. 2011, 2013).

As discussed above, most marine fish species investigated to date lack higher-frequency hearing (i.e., greater than 1,000 Hz). This notably includes sturgeon species tested to date that can detect sound up to about 400 or 500 Hz (Lovell et al. 2005a, Meyer et al. 2010) and Atlantic salmon that can detect sound up to about 500 Hz (Hawkins and Johnstone, 1978, Kane et al. 2010). Sawfish and sharks are cartilaginous fish (i.e., elasmobranchs), which available data suggests can detect sounds from 20 to 1,000 Hz, with best sensitivity at lower ranges (Casper et al. 2003; Casper and Mann 2006; Casper and Mann 2009; Myrberg 2001). As part of the family Serranidae, Nassau grouper may have a similar hearing range to the leopard coral grouper (*Plectropomus leopardus*), with sounds detected by larvae from 100 to 2,000 Hz (Wright et al. 2008; Wright et al. 2010).

Bony fish can produce sounds in a number of ways and use them for a number of behavioral functions (Ladich 2008). Over 30 families of fish are known to use vocalizations in aggressive interactions, and over 20 families are known to use vocalizations in mating (Ladich 2008). Sounds generated by fish as a means of communication are generally below 500 Hz (Slabbekoorn et al. 2010). The air in the swim bladder is vibrated by the sound producing structures (often muscles that are integral to the swim bladder wall) and radiates sound into the water (Zelick et al. 1999). Sprague and Luczkovich (2004) calculated that silver perch can produce drumming sounds ranging from 128 to 135 decibels referenced to 1 micropascal (dB re 1 µPa). Female midshipman fish apparently detect and locate the “hums” (i.e., approximately 90 to 100 Hz, up to 400 Hz) of vocalizing males during the breeding season (McIver et al. 2014) (Sisneros and Bass 2003). Sciaenids produce a variety of sounds, including calls produced by males on breeding grounds (Ramcharitar et al. 2001), and a “drumming” call produced during chorusing by reef fish (McCauley and Cato 2000). Other sounds produced by chorusing reef fish include “popping,” “banging,” and “trumpet” sounds; altogether, these choruses produce sound levels 35 decibels above background levels, at peak frequencies between 250 and 1,200 Hz, and source levels between 144 and 157 dB re 1 µPa (McCauley and Cato 2000). Figure 3.6-2 shows the hearing ranges for common fish groups in the TMAA along with the range for the AN/SQS-53 hull mounted sonar proposed for use in the GOA. Of the species presented, only herring have the capability to detect sound in the range of the Proposed Action activities. Sivle et al. (2015) modeled possible population-level effects to Atlantic herring (*Clupea harengus*) from active naval sonar using data collected by Doksæter et al. (2009; 2012) and Sivle et al. (2012). Doksæter et al. (2009; 2012) and Sivle et al. (2012; 2015) studied the reactions of both wild and captive Atlantic herring to the Royal Netherlands Navy’s experimental mid-frequency active sonar ranging from 1 to 7 kHz. The source levels used within each study varied across all studies and exposures with a maximum received sound pressure level of 181 dB re 1 µPa and maximum cumulative sound exposure level (SEL_{cum}) of 184 decibels referenced to 1 micropascal-second (dB re 1µPa^2·s). No avoidance or escape reactions were observed. Instead, significant reactions were noted at lower received sound levels of killer whale feeding sounds at received sound pressure levels of ~150 dB re 1 µPa (Sivle 2012). Startle responses were seen when the cages for captive herring were hit with a wooden stick and with the ignition of an outboard boat engine at a distance of one meter from the test pen (Doksaeter 2012). Each of these reactions demonstrates that the experimental design was sensitive to noting changes in behavior. It is possible that the herring either were not bothered by the sonar or were motivated to continue other behaviors such as feeding.

Based on these results (Sivle et al. 2012; Doksæter et al. 2009, 2012), Sivle et al. (2015) created a model for reporting on the possible population-level effects on Atlantic herring from active Naval sonar. The authors concluded that the use of naval sonar poses little risk to populations of herring regardless of season, even when the entire population of herring are aggregated during sonar exposure. Therefore, no additional update to the 2011 GOA Final EIS/OEIS is required.

This additional information does not contribute to nor conflict with the information regarding fish hearing presented in the 2011 GOA Final EIS/OEIS. Additionally, no new relevant studies have produced data to initiate the re-analysis of the environmental impacts presented in the 2011 GOA Final EIS/OEIS.

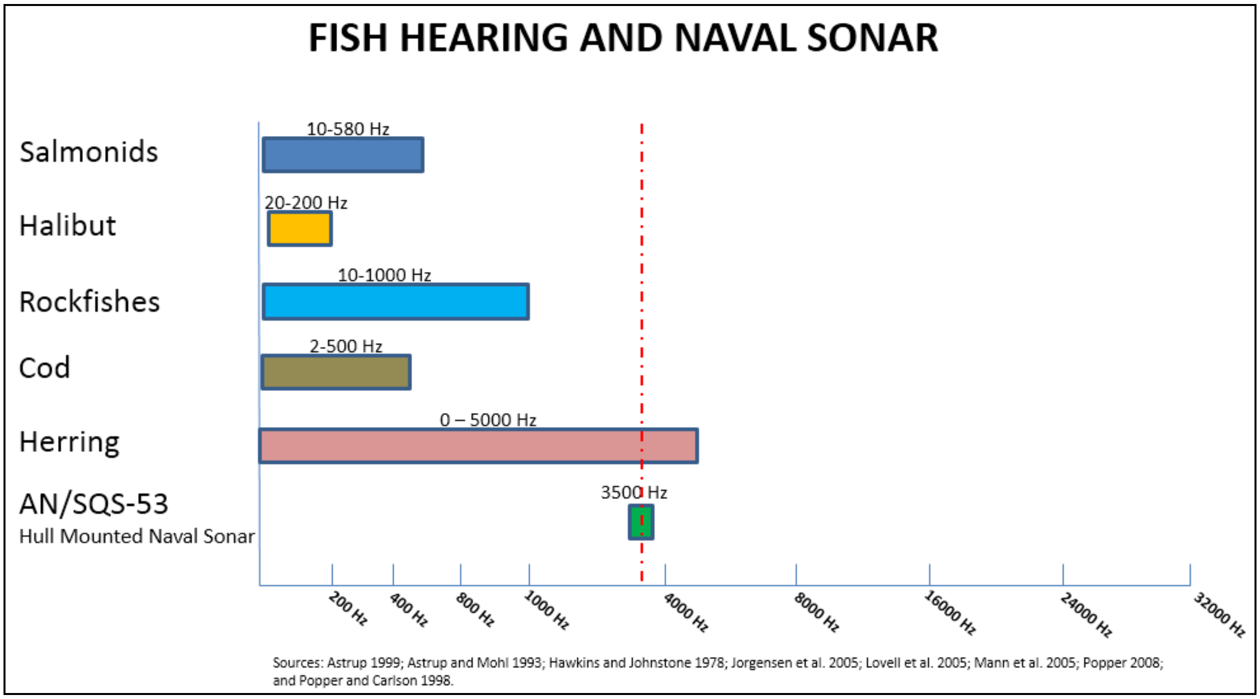

Figure 3.6-2: Hearing Ranges of Select Fishes and Naval Sonar

3.6.1.5 Current Requirements and Practices

As stated in the 2011 GOA Final EIS/OEIS, the comprehensive suite of protective measures and standard operating procedures implemented by the Navy to reduce impacts to marine mammals and sea turtles, also offer protections to habitats associated with the fish assemblage and communities. Mitigation is discussed in more detail in Chapter 5 (Standard Operating Procedures, Mitigation, and Monitoring) of this Supplemental EIS/OEIS.

3.6.2 Environmental Consequences

3.6.2.1 Criteria and Thresholds for Assessing Acoustic and Explosive Impacts on Fish

In late 2015, through the ESA consultation process, the Navy, NMFS, and the USFWS jointly developed criteria and thresholds to quantitatively assess the impacts of sonar and explosive sources on ESA-listed fish. The studies from which these criteria and thresholds were developed were previously discussed and considered in the 2011 GOA Final EIS/OEIS, and effects were evaluated qualitatively and quantitatively as the data allowed. However, a more detailed level of analysis is required under the ESA, including the quantification of take down to the level of individual fish (or their surrogate) from which to make the jeopardy determination.

In a technical report, Popper et al. (2014) evaluated the sound detection capabilities for a wide range of fishes based on how sound is detected, and presented exposure guidelines for assessing how natural and anthropogenic sound sources may affect fishes. The criteria below were largely derived from the extensive review provided in Popper et al. (2014). Thresholds within that technical report are generally presented at the lowest level at which the effect occurred. In some cases the thresholds presented in Popper et al. (2014) did not show any effect, but are the only data available for that stressor. Therefore, these guidelines may be overly conservative.

3.6.2.1.1 Criteria and Thresholds for Sonar and Other Active Acoustic Sources

Threshold criteria were not developed high-frequency sonar sources. Only a few species of shad within the Clupeidae family (herrings) are known to be able to detect high-frequency sonar and other active acoustic sources greater than 10,000 Hz. The species considered within the Study Area would not detect these sounds and would therefore experience no stress, behavioral disturbance, or auditory masking. High-frequency sonar is not anticipated to cause mortality or injury due to the lack of fast rise times, lack of high peak pressures, and the lack of high acoustic impulse. Also, similar to low- and mid-frequency sonar, mortality or injury has not been shown to occur from exposure to high-frequency sonar sources. For these reasons, the potential effects of high-frequency active sonar on fish will not be discussed further in this document. Table 3.6-2 provides the sound exposure criteria for sonar and other active acoustic sources.

Table 3.6-2: Criteria and Thresholds for Sonar and Other Active Acoustic Sources

Low-Frequency Navy Sonar (< 1 kHz)					
	Mortality and mortal injury	**Recoverable injury**	**TTS**	**Masking**	**Behavior**
Fish – no SB (swim bladder)	>> 218 dB SEL_{cum}	> 218 dB SEL_{cum}	> 218 dB SEL_{cum}	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
Fish w/SB not involved in hearing (particle motion detection)	>> 218 dB SEL_{cum}	> 218 dB SEL_{cum}	210 dB SEL_{cum}	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
Fish w/SB used in hearing (pressure detection)	>> 218 dB SEL_{cum}	> 218 dB SEL_{cum}	210 dB SEL_{cum}	(N) Mod (I) Low (F) Low	> 197 dB SPL_{rms}
Mid-Frequency Navy Sonar (1–10 kHz)					
	Mortality and mortal injury	**Recoverable injury**	**TTS**	**Masking**	**Behavior**
Fish – no SB	>> 221 dB SEL_{cum}	> 221 dB SEL_{cum}	N/A	N/A	N/A
Fish w/SB not involved in hearing (particle motion detection)	>> 221 dB SEL_{cum}	> 221 dB SEL_{cum}	N/A	N/A	N/A
Fish w/SB used in hearing (pressure detection)	>> 221 dB SEL_{cum}	> 221 dB SEL_{cum}	220 dB SEL_{cum}	(N) Low (I) Low (F) Low	200 dB SPL_{rms}

Notes: dB = decibels; kHz = kilohertz; N/A = not applicable; SEL_{cum} = cumulative sound exposure level; SPL_{rms} = sound pressure level, root mean square; TTS = Temporary Threshold Shift

3.6.2.1.1.1 Mortality, Mortal Injury, and Recoverable Injury

Sonar has not been known to cause mortality, mortal injury, or recoverable injury in the wild due to lack of fast rise times, lack of high peak pressures, and lack of high acoustic impulse. These types of effects are associated with some impulsive sounds (e.g., explosives).

Low-Frequency Sonars

Long duration exposures (up to 2 hours) of low-frequency sonar to fish in laboratory settings has caused stunning and mortality in some cases, but these exposures were much longer than any exposure a fish would normally encounter in the wild due to proposed activities. In addition, the subjects exposed in the lab were held in a cage for the duration of the exposure, unable to avoid the source (Hastings 1991, Hastings 1995). Exposure to low-frequency sonar has been tested at sound pressure levels of up to 193 dB re 1μPa (root mean square [rms]) for 324 seconds (equivalent to an SEL_{cum} of 218 dB re $1μPa^2·s$) and has not been shown to cause mortality or any injury in fish with swim bladders (Popper et al. 2007, Kane et al. 2010). Lesser potential for injurious effects would be expected for fish without air cavities (i.e., swim bladders). Therefore, the recommended threshold would be >> 218 dB re $1μPa^2·s$ for mortality and cumulative SEL_{cum} of > 218 dB re $1μPa^2·s$ for recoverable injury.

Mid-Frequency Sonars

Exposure to mid-frequency sonar has been tested and has not been shown to cause mortality or any injury in fish with swim bladders (Popper et al. 2007, Kane et al. 2010). Lesser potential for injurious effects would be expected for fish without air cavities (i.e., swim bladders). Therefore, the recommended threshold would be an SEL_{cum} >> 221 dB re $1μPa^2·s$ for mortality and > 221 dB re $1μPa^2·s$ for recoverable injury.

3.6.2.1.1.2 Temporary Threshold Shift

Low-Frequency Sonars

Exposure to low-frequency sonar has not been shown to induce Temporary Threshold Shift (TTS) in fish species without swim bladders (Popper et al. 2014). Exposure to sonar above 1 kHz has been known to induce TTS in some fish species with swim bladders (Popper et al. 2007, Halvorsen et al. 2013). Subjects from Popper et al. (2007) may have undergone varying husbandry treatments or possessed different genetics, which may have resulted in higher than normal shifts. Criteria provided in Popper et al. (2014) were reported in SPL dB re 1μPa (rms). This criteria was converted to sound exposure level (SEL) based on the signal durations reported in Popper (2007) and Halvorsen et al. (2013) (i.e., 193 dB re 1μPa + 10 * log (324 sec) = 218 dB re $1μPa^2·s$) and was rounded down (from 218 dB to 210 dB re $1μPa^2·s$) from the lowest SEL as a conservative measure.

Mid-Frequency Sonars

Exposure to mid-frequency sonar has not been known to induce TTS in fish species without swim bladders or in fish with swim bladders that are not involved in hearing (Halvorsen et al. 2012). In addition, fish without swim bladders involved in hearing (i.e., close connections to the inner ear) do not sense pressure well and cannot hear at frequencies above 1 kHz.

Exposure to mid-frequency sonar has been known to induce TTS in some fish species with swim bladders and better hearing capabilities (Halvorsen et al. 2012). Criteria form Popper (2014) was originally listed as > 210 dB SPL, root mean square. As previously stated, TTS criteria reported as SEL_{cum} accounts for the duration of the exposure as well. Therefore, the criteria originally presented in the technical report was converted to this metric using the duration of the signal reported from the experiments (i.e., 210 dB re 1μPa + 10 * log (15 sec) = 221 dB re $1μPa^2·s$) and was rounded down (from 221dB to 220 dB re $1μPa^2·s$) as a conservative measure (Halvorsen et al. 2012).

3.6.2.1.1.3 Masking

Low-Frequency Sonars

No data are available on masking by sonar, but it is unlikely that sonar would mask important sounds for fish. For fish without swim bladders or whose swim bladders are not involved in hearing, the risk of significant masking occurring within any distance from the source is low (Popper et al. 2014). For fish with swim bladders used in hearing, the risk is moderate near the source and low at intermediate and far distances from the source (Popper et al. 2014); The narrow bandwidth of most sonar would result in only a limited range of frequencies being masked (Popper et al. 2014). Furthermore, most sonars are intermittent (i.e., low duty cycle) which further lowers the probability of any masking effects.

Mid-Frequency Sonars

Most mid-frequency sonars are above the hearing range of most fish species and almost all marine fish species (including salmonids). Therefore, for fish without swim bladders or whose swim bladders are not involved in hearing, the potential for masking is not considered possible. There is no data available on masking by mid-frequency sonar for fish with swim bladders used in hearing, but it is unlikely that sonar would mask important sounds for fish. The risk is considered low within any distance from the source (Popper et al. 2014). The narrow bandwidth of most sonar would result in only a limited range of frequencies being masked (Popper et al. 2014). Furthermore, most sonars are intermittent (i.e., low duty cycle) which further lowers the probability of any masking effects.

3.6.2.1.1.4 Behavioral Responses

Low-Frequency Sonars

No data are available on behavioral reactions to low-frequency sonar. Fish without a mechanism to sense pressure are unlikely to sense sound beyond the near-field (i.e., within a few tens of meters from the sound source). The risk that sonar would result in a behavioral response within near, intermediate, or far distances from sonar is low (Popper et al. 2014). For fish with swim bladders involved in hearing, no reactions were seen in fish exposed to 1–2 kHz, sonar which is categorized as mid-frequency sonar, not low-frequency sonar. Criteria used for behavioral reactions to low-frequency sonar was set at > 197 dB re 1µPa, as derived in Popper et al. (2014) from Doksaeter et al. (2009, 2012).

Mid-Frequency Sonars

Fish without swim bladders or without swim bladders involved in hearing would not be able to hear mid-frequency sonar; therefore, behavioral reactions would not occur. For fish with swim bladders involved in hearing, no reactions were seen in herring exposed to 1–2 and 6–7 kHz sonar (Doksaeter et al. 2009, 2012). Therefore, this criterion was set to 200 dB re 1µPa as a conservative measure. This criterion only applies to mid-frequency sonars up to 2.5 kHz since even fish with swim bladders with connections to the inner ear cannot hear above these frequencies, with the exception of fish in the genus *Alosa* (e.g., herring). While improbable (see Doksaeter et al. 2009, 2012), *Alosa* spp. could have behavioral reactions over the full bandwidth of mid-frequency sonar (1–10 kHz).

3.6.2.1.2 Criteria and Thresholds for Explosive and Other Impulsive Sound Sources

Table 3.6-3 provides the sound exposure criteria for explosive and other impulsive sound sources.

Table 3.6-3: Criteria and Thresholds for Explosive and Other Impulsive Sound Sources

	Mortality and mortal injury[1]	TTS	Masking	Behavior
Fish – no SB (swim bladder)	229 dB SPL_{peak} and N/A[2]	>>186 dB SEL_{cum}	N/A	(N) High (I) Mod (F) Low
Fish w/SB not involved in hearing (particle motion detection)	229 dB SPL_{peak} and Range equation	>186 dB SEL_{cum}	N/A	(N) High (I) High (F) Low
Fish w/SB used in hearing (pressure detection)	229 dB SPL_{peak} and Range equation	186 dB SEL_{cum}	N/A	(N) High (I) High (F) Low

[1] 1% Mortality and No Injury = Survivability Curve equation is presented in Young (1991) and adjusted using data from Yelverton et al. (1975). 'No injury' relates to data in which no injuries were observed; onset of injury (i.e., LD1) would be at some higher exposure. These criteria are based on the acoustic impulse metric with units (Pa-s).

[2] Sufficient data to derive 1% mortality and no injury thresholds for fish without swim bladders is not available. Fish without swim bladders are very resistant to underwater explosions. 10% mortality for charges up to 1,000 pound trinitrotoluene (TNT) equivalent are about 20 feet for small flatfish (e.g., flounder and sole) based on Young (1991).

Notes: (1) n/a = No data available or threshold is not applicable to fish, (N) = near (i.e., tens of meters from the source), (I) = intermediate (i.e., hundreds of meters from the source), (F) = far (thousands of meters form the source), High, Mod (moderate), and Low = Probability of the effect occurring. For any cell containing these designations please see Popper et al. (2014) for meaning. (2) SEL_{cum} units are dB re 1µPa^2·s. (3) SPL_{peak} units are dB re 1µPa. (4) dB = decibel(s), SEL_{cum} = cumulative sound exposure level, SPL_{peak} = peak sound pressure level

3.6.2.1.2.1 Mortality and Mortal Injury

The proposed criteria is from Popper et al. (2014) which stated that the guidelines are based on Hubbs and Rechnitzer (1952) which represents the lowest amplitude that caused consistent mortality. Hubbs and Rechnitzer (1952) used dynamite as a source on a variety of marine species and showed minimum amplitude of 40–70 psi (peak pressure) that resulted in mortality. This is equivalent to 276–482 kPa or 229–234 dB re 1 µPa. Debusschere et al. (2014) was reviewed with regard to mortality from pile driving events; however, the levels tested did not reach those of the proposed criteria (a peak sound pressure level of 210–211 dB re 1µPa, or an SeL_{cum} of 215–222 dB re 1µPa2·s) and largely confirmed mortality results of previous lab experiments.

Maximum range to effect at any depth is provided in Young (1991) for 10 percent mortality (i.e., 90 percent survivability) based on O'Keeffe (1984). Yelverton et al. (1975) shows the relationship between impulse and percent mortality or no injury; Young's equation is modified to predict ranges to the 1 percent Mortality and No Injury zones based on the relationships between fish mass, impulse, and injury found in Yelverton et al. (1975).

Therefore, the Navy is using a dual criteria to predict onset mortality in fish: a peak sound pressure level of 229 dB re 1µPa or an equation using acoustic impulse based on Young (1991) and modified using data from Yelverton et al. (1975). The criteria for 'no injury' is an equation using acoustic impulse based on Young (1991) and modified using data from Yelverton et al. (1975).

3.6.2.1.2.2 Temporary Threshold Shift

Data on TTS from explosions are not available. The threshold for assessing TTS is based upon data from Popper et al. (2005) which examined the effects of exposure to a seismic airgun array on three species of fish—a fish with hearing specializations, the lake chubb (*Couesius plumbeus*), and two fishes without known hearing specializations, the northern pike (*Esox lucius*), and the broad whitefish (*Coregonus nasus*). Fish were exposed to either 5 or 20 seismic pulses from a 730 cubic inch airgun array and their hearing was measured immediately post-exposure to determine changes in sensitivity. The cumulative 186 dB re 1µPa^2·s threshold value was accumulated over five seismic pulses within about 5 minutes and resulted in up to 20 dB of TTS in the lake chub at different frequencies (Popper et al. 2014). About 20 dB of TTS also occurred in the adult northern pike, but only at 400 Hz. TTS did not occur at other frequencies, nor at any frequencies testing in juvenile northern pike. Broad whitefish showed no TTS to sounds after exposure at the same level. In all cases, fish that showed TTS recovered to normal hearing levels within 18–24 hours (Popper et al. 2014). Therefore, the Navy is using 186 dB re 1µPa^2·s as the threshold to determine onset of TTS in fish due to explosions, although this threshold should be much higher for fishes without hearing specializations and for fishes without swim bladders (e.g., halibut and sharks).

3.6.2.1.2.3 Masking

Explosive sounds are brief in duration, lasting for only fractions of a second. Those generated by Navy training are intermittent and infrequent in a given location. Therefore, auditory masking is unlikely due to explosive sounds from Navy training.

3.6.2.1.2.4 Behavioral Responses

Explosive sounds are brief in duration, lasting for only fractions of a second. Those generated by Navy training are intermittent and infrequent in a given location. No data are available on behavioral reactions to explosives. The risk that explosives would result in a behavioral response decreases as the distance from the source increases. Popper et al. (2014) describes the probability of a behavioral response from a fish with no swim bladder exposed to an explosive at near ranges (tens of meters) as high, intermediate ranges (hundreds of meters) as moderate, and at far ranges (>1000 m) as low. Popper et al. (2014) describes the probability of a behavioral reaction by fish with swim bladders to explosives at near ranges (tens of meters) as high, intermediate ranges (hundreds of meters) as high, and at far ranges (>thousands of meters) as low. This would be highly dependent on the size of the explosive charge and the resulting magnitude of the sound. However, any behavioral reactions that would occur, such as startle responses, are anticipated to brief and minor due to the transient and infrequent nature of Navy explosive activities.

3.6.2.2 Impacts from Sonar and Other Active Acoustic Sources

Non-impulsive sources from the Proposed Action include sonar and other active acoustic sources. Potential acoustic effects to fish from these sources may be considered in four categories: (1) direct injury, (2) hearing loss, (3) auditory masking, and (4) physiological stress and behavioral reactions.

As discussed above and in the 2011 GOA Final EIS/OEIS, mortality or direct injury to fish from sonar has not been reported in the scientific literature to date (Popper et al. 2007; Kane et al. 2010). While criteria for mortality, mortal injury, and recoverable injury are presented from exposure to low- and mid-frequency sonar, these effects are extremely unlikely to occur. The values presented in Table 3.6-2 represent the highest SELs which have been tested to date, none of which have resulted in any injury (or mortality) to fish with swim bladders involved in hearing, which would be the types of fish most sensitive to the effects of sonar. Sonar is not anticipated to cause mortality or injury due to the lack of fast rise times, lack of high peak pressures, and lack of high acoustic amplitude.

Table 3.6-4 shows the predicted range to effects for each sonar source bin used in the GOA Study Area, based on the criteria and thresholds previously outlined. The distances for mortality and recoverable injury are based on the highest levels tested; although, as discussed above, no injury (or mortality) was demonstrated at those levels. Given the extremely small sizes of these zones and that injury or mortality have never been documented at levels that would occur at these distances, the potential for these effects to occur is so unlikely as to be discountable. Therefore, mortality or direct injury to fish as a result of exposure to sonar and other active acoustic sources is not discussed further in this analysis.

Table 3.6-4: Predicted Range to Effects for Sonar Source Bins used in the Gulf of Alaska TMAA (distances in meters)

Sonar Bin	No Swim Bladder			Swim Bladder (Not involved in hearing)			Swim Bladder (Involved in hearing)			
	Mortality and Injury	Recoverable Injury	TTS	Mortality and Injury	Recoverable Injury	TTS	Mortality and Injury	Recoverable Injury	TTS	Behavioral Harassment
MF1	<<12	<12	CH	<<12	<12	CH	<<12	<12	14	138
MF3	<<2	<2	CH	<<2	<2	CH	<<2	<2	2	24
MF4	0	0	CH	0	0	CH	0	0	0	8
MF5	0	0	CH	0	0	CH	0	0	0	0
MF6	0	0	CH	0	0	CH	0	0	0	0
MF11	<<6	<6	CH	<<6	<6	CH	<<6	<6	7	69
ASW2	0	0	0	0	0	1	0	0	1	6
ASW4	<<1	<1	CH	<<1	<1	CH	<<1	<1	1	15

Notes: (1) Range is maximum expected range. All distances are in meters. A value of "0" indicates that the source level is below the criteria threshold even after accumulation of multiple pings. (2) For mortality and recoverable injury, the effect occurs at a distance either much less than the number provided or less than the number provided, respectively. (3) CH = cannot hear, TMAA = Temporary Maritime Activity Area, TTS = temporary threshold shift

There are no range to effects provided for bins ASW3 and TORP2 since the sound produced by these sources is outside the hearing range of most if not all fish species in the TMAA.

Research previously analyzed indicates that exposure of fish to transient, non-impulsive sources is unlikely to result in any hearing loss. Most sonar sources are outside of the hearing range of most marine fish, and noise sources such as vessel movement and aircraft overflight lack the duration and intensity to cause hearing loss. Furthermore, permanent hearing loss has not been demonstrated in fish as they have been shown to regenerate lost sensory hair cells. Table 3.6-4 shows the predicted range to effects based on the criteria and thresholds previously outlined for each sonar source bin used in the GOA TMAA Study Area. The distances presented are where the onset TTS could theoretically occur. Given the extremely small sizes of these zones and that the loudest sources move at a speeds of 10–14 knots, the potential for these effects to occur is so unlikely as to be discountable. Therefore, hearing loss as a result of exposure to sonar and other active acoustic sources is not discussed further in this analysis.

The potential for auditory masking and physiological stress and behavioral reactions in fishes due to exposure to sonar and other active acoustic sources is discussed below.

3.6.2.2.1 Mid-Frequency Sonar

Most marine fish species are not expected to be able to detect sounds in the mid-frequency range of operational sonar. The fish species that are known to detect mid-frequencies (some sciaenids [drum], most clupeids [herring, sardines], and potentially deep-water fish such as myctophids [lanternfish]) do not have their best sensitivities in the range of operational sonar. Thus, these fish may only detect the most powerful systems, such as hull-mounted sonar, within a few kilometers, and most other, less powerful mid-frequency sonar systems, for a kilometer or less. Due to the limited time of exposure due to the moving sound sources, most mid-frequency active sonar used in the Study Area would not have the potential to substantially mask key environmental sounds or produce sustained physiological stress or behavioral reactions. Furthermore, although some species may be able to produce sound at higher frequencies (greater than 1 kHz), vocal marine fish, such as sciaenids, largely communicate below the frequency ranges used by mid-frequency sonars. Other marine species probably cannot detect mid-frequency sonar (1,500–10,000 Hz) and therefore behavioral impacts are not expected for these fish (Popper 2008, Popper et al. 2014). However, any such effects on behavior would be temporary and infrequent as a vessel operating mid-frequency sonar transits an area. Long-term population level impacts due to exposure to mid-frequency sonar and other active acoustic sources are not expected.

3.6.2.2.2 Low-Frequency Sonar

A large number of marine fish species, including cartilaginous fish, may be able to detect low-frequency sonar and other active acoustic sources. However, the potential for masking would only occur within a limited range of frequencies due to the narrow bandwidth of most sonar signals as well as the short, intermittent duration of the signal itself. Behavioral or physiological stress responses to sonar have not been observed in recent literature. The best scientific judgment (Popper et al. 2014) indicates the potential for masking and behavioral effects from low-frequency sonar is expected to be low at all distances from the source for fish without swim bladders or fish whose swim bladders is not involved in hearing. The potential for masking and behavioral effects for fish whose swim bladder is used in hearing is moderate within a few tens of meters from the source, but low at any distances beyond that (Popper et al. 2014).

Low-frequency active sonar usage is rare and most low-frequency training activities are conducted in deeper waters, usually beyond the continental shelf break. The majority of fish species, including those that are the most highly vocal, exist on the continental shelf and within nearshore, estuarine areas, outside of the TMAA. Fish within a few tens of kilometers around a low-frequency active sonar could experience brief periods of masking, physiological stress, and behavioral disturbance while the system is used, with effects most pronounced closer to the source. However, overall effects would be localized and infrequent. Furthermore, there are no high power low-frequency active sonar systems in the Navy's GOA TMAA Study Area.

3.6.2.3 Impacts from Explosives and Other Impulsive Sound Sources

Table 3.6-5 shows the predicted range to effects for each explosive source bin used in the GOA TMAA, based on the criteria and thresholds previously outlined. Explosions and other impulsive sound sources include explosions from underwater detonations and explosive ordnance, and noise from weapons firing, launch, and impact with the water's surface. Potential acoustic effects to fish from impulsive sound sources may be considered in four categories: (1) direct injury, (2) hearing loss, (3) auditory masking, and (4) physiological stress and behavioral reactions.

Table 3.6-5: Predicted Range to Effects for Explosive Bins used in the Gulf of Alaska TMAA (distances in meters)

Explosive BIN	Representative depth of charge[1]		Chinook		Coho		Chum		Sockeye		Steelhead	
		Life Stage	Juveniles	Adult	Juveniles	Adult	Juveniles	Adult	Juveniles	Adult	Juveniles	Adults
		Weight (g)	NA	3,020	14.91	1,468	3.87	399	15.09	440	31	355
E5	1	1% Mort	140	71	136	75	160	89	136	88	124	90
		Onset injury	231	133	228	137	263	155	288	153	208	157
E6	1	1% Mort	N/A	N/A	N/A	91	N/A	108	N/A	106	148	109
		Onset injury	N/A	N/A	N/A	162	N/A	185	N/A	183	250	188
E7	1	1% Mort	N/A	N/A	N/A	123	N/A	145	N/A	144	203	148
		Onset injury	N/A	N/A	N/A	215	N/A	247	N/A	244	335	251
E8	1	1% Mort	N/A	N/A	N/A	143	N/A	168	N/A	166	230	170
		Onset injury	N/A	N/A	N/A	540	N/A	281	N/A	277	381	285
E9	1	1% Mort	N/A	N/A	N/A	182	N/A	215	N/A	212	298	218
		Onset injury	N/A	N/A	N/A	304	N/A	354	N/A	250	487	360
E10	1	1% Mort	N/A	N/A	N/A	217	N/A	259	N/A	256	361	263
		Onset injury	N/A	N/A	N/A	356	N/A	419	N/A	414	582	426
E11	35	1% Mort	N/A	N/A	N/A	700	N/A	700	N/A	700	860	700
		Onset injury	N/A	N/A	N/A	863	N/A	1,017	N/A	1,004	1,404	1,032
E12	1	1% Mort	N/A	N/A	N/A	263	N/A	314	N/A	310	435	319
		Onset injury	N/A	N/A	N/A	427	N/A	506	N/A	500	703	514

Source: Swisdak 1978

[1]Energy loss into air for surface detonations is considered.

[2]Range to effects were not presented where there is not expected to be co-occurrence between the explosive bin and the species/life stage.

Notes: N/A = not applicable

Ranges to effects were species-specific and varied with fish size. Ranges to effect were developed for ESA-listed fish. Ranges to effects are not presented for some explosive bins where the species or life-stage considered is not expected to co-occur in space or time.

Concern about potential fish mortality associated with the use of at-sea explosives led military researchers to develop mathematical and computer models that predict safe ranges for fish and other animals from explosions of various sizes (e.g., Yelverton et al. 1975, Goertner 1982, Goertner et al. 1994). Young (1991) provides equations that allow estimation of the potential effect of underwater explosions on fish possessing swim bladders using a damage prediction method developed by Goertner (1982). Young's parameters include the size of the fish and its location relative to the explosive source, but are independent of environmental conditions (e.g., depth of fish and explosive shot frequency). An example of such model predictions is shown in Table 3.6-6, which lists estimated explosive effects ranges using Young's (1991) method for fish possessing swim bladders exposed to explosions that would typically occur during training exercises. Fish without swim bladders are very resistant to underwater explosions, with a 10 percent mortality for charges up to 1,000 pounds. The TNT equivalent is about 20 feet for small flatfish (e.g., flounder and sole) based on Young (1991). The 10 percent mortality range is the distance beyond which 90 percent of the fish present would be expected to survive.

Table 3.6-6: Estimated Explosive Effects Ranges for Fish with Swim Bladders

Representative Ordnance	Explosive Bin[1]	Depth of Explosion (ft.)	10% Mortality Range, ft.(m)		
			1 oz. Fish	1 lb. Fish	30 lb. Fish
SUS Buoy	E3 (> 0.5–2.5 lb. NEW)	98	483 (147)	337 (103)	216 (66)
Torpedo (MK-46/54)	E8 (> 60–100 lb. NEW)	115	1405 (428)	980 (299)	630 (192)

[1] Range for maximum NEW in bin shown, which may be greater than the NEW of the representative ordnance shown.
Notes: NEW = Net Explosive Weight, lb. = pound, ft. = foot/feet, m = meter(s), oz. = ounce, UNDET = underwater detonation

Fish not killed or driven from a location by an explosion might change their behavior, feeding pattern, or distribution. Changes in behavior of fish have been observed as a result of sound produced by explosives, with effect intensified in areas of hard substrate (Wright 1982). Stunning from pressure waves could also temporarily immobilize fish, making them more susceptible to predation.

The number of fish killed by an underwater explosion would depend on the population density in the vicinity of the blast, as well as factors discussed above such as net explosive weight, depth of the explosion, depth of the fish, and fish size. For example, if an explosion occurred in the middle of a dense school of menhaden, herring, or other schooling fish, a large number of fish could be killed.

Sounds from explosions could cause hearing loss in nearby fish (dependent upon charge size). Table 3.6-7 shows example predicted range to TTS for explosives used in Navy training activities based on criteria thresholds presented in Popper et al. (2014). Permanent hearing loss has not been demonstrated in fish, as lost sensory hair cells can be replaced unlike in mammals. However, fish that do experience hearing loss could miss opportunities to detect predators or prey, or reduce interspecific communication. If an individual fish were repeatedly exposed to sounds from underwater explosions that caused alterations in natural behavioral patterns or physiological stress, these impacts could lead to long-term impacts for the individual such as reduced survival, growth, or reproductive capacity. However, the time scale of individual explosions is very limited, and training exercises involving explosions are dispersed in space and time. Consequently, repeated exposure of individual fish to sounds from underwater explosions is not likely and most acoustic effects are expected to be short-term and localized. Long-term population level impacts would not be expected.

Table 3.6-7: Average Approximate Range to Temporary Threshold Shift from Explosions for Fish

Criteria Threshold	Average Approximate Range (meters) to Effects for Sample Explosive Bins			
	Bin E3 (>0.5–2.5 lb. NEW)	Bin E5 (>5–10 lb. NEW)	Bin E10 (>250–500 lb. NEW)	Bin E12 (>650–1,000 lb. NEW)
186 SEL (dB re $1\mu Pa^2\cdot s$)	172	35	280	394

Notes: dB re $1\mu Pa^2\cdot s$ = decibels referenced to 1 micropascal-second, lb. = pound(s), NEW = net explosive weight, SEL = sound exposure level

3.6.3 ALTERNATIVES ANALYSIS

All three alternatives (No Action Alternative, Alternative 1, and Alternative 2), as discussed in the 2011 GOA Final EIS/OEIS, remain the same for this Supplemental EIS/OEIS. The Navy conducted a review of existing federal and state regulations and standards relevant to fishes, as well as a review of new literature, to include laws, regulations, and publications pertaining to fish. Although additional information relating to existing conditions was found, the new information does not indicate an appreciable change to the existing environmental conditions as described in the 2011 GOA Final EIS/OEIS. Because the existing conditions have not changed appreciably, and no new Navy training activities are being proposed to occur in the TMAA in this Supplemental EIS/OEIS, re-analysis of the alternatives with respect to fish is not warranted. Subsequently, the conclusions made for the alternatives analyzed in the 2011 GOA Final EIS/OEIS remain unchanged in this Supplemental EIS/OEIS. The 2011 GOA Final EIS/OEIS determined that the effects on fishes from the proposed training activities in the TMAA would be minimal and would not have a population level impact.

3.6.4 CONCLUSION

As described above, there is new information on existing environmental conditions as well as updated fish stock assessment reports and information on fish hearing. However, this new information does not change the affected environment, which forms the environmental baseline of the fish analysis in the 2011 GOA Final EIS/OEIS. Additionally, no new Navy training activities are being proposed in this Supplemental EIS/OEIS that would affect fishes in the TMAA. Therefore, conclusions for fish species impacts made for the alternatives analyzed in the 2011 GOA Final EIS/OEIS remain unchanged in this Supplemental EIS/OEIS, and training activities do not compromise productivity of fishes or impact their habitats. For a summary of effects of the No Action Alternative, Alternative 1, and Alternative 2 on fishes under both the National Environmental Policy Act and Executive Order 12114, please refer to Table 3.6-11 (Summary of Effects by Alternative) in the 2011 GOA Final EIS/OEIS.

According to 50 Code of Federal Regulations (C.F.R.) Section 600.920(a), a supplemental consultation for EFH is required for renewals, reviews, or substantial revisions of actions if these actions may adversely affect EFH. There are no changes to Navy activities or designated EFH in the TMAA that are substantial in nature and that may adversely affect EFH previously analyzed. The analysis previously captured in Appendix C of the 2011 GOA Final EIS/OEIS (U.S. Navy, August 2010, Gulf of Alaska (GOA) Navy Training Activities Essential Fish Habitat Assessment) remains unchanged.

As part of the SEIS, the Navy is consulting under Section 7 of the ESA with NMFS for the ESA-listed fishes, but will continue to rely on the prior analysis from the 2011 GOA Final EIS/OEIS, as reviewed and amended by this Supplement, and Biological Evaluation, as they remain valid. Specifically, there has not been an exceedance of incidental take for listed fishes under the current Biological Opinion; there is no new information that reveals new effects to listed fish species or critical habitat for listed fishes that were not previously considered; Navy training activities in the TMAA are not being substantially modified in a manner that would cause effect to listed fish species or their critical habitat that was not previously considered; and there has not been a new species of fish listed or critical habitat for other fish species created within the TMAA.

REFERENCES CITED AND CONSIDERED

Astrup, J. (1999). Ultrasound detection in fish—a parallel to the sonar-mediated detection of bats by ultrasound-sensitive insects? Comparative Biochemistry and Physiology Part A 124: 19–72.

Astrup, J., and Møhl, B. (1993). Detection of intense ultrasound by the cod *Gadus morhua*. Journal of Experimental Biology 182:71–80.

Buran, B. N., Deng, X., and Popper, A. N. (2005). Structural variation in the inner ears of four deep-sea elopomorph fishes. Journal of Morphology. 265(2):215–225.

Casper, B., Lobel, P. and Yan, H. (2003). The hearing sensitivity of the little skate, *Raja erinacea*: A comparison of two methods. *Environmental Biology of Fishes, 68*, 371-379.

Casper, B. M., and Mann, D. A. (2006). Evoked potential audiograms of the nurse shark (*Ginglymostoma cirratum*) and the yellow stingray (*Urabatis jamaicensis*). *Environmental Biology of Fishes, 76*, 101-108. 10.1007/s10641-006-9012-9.

Casper, B. M. and Mann, D. A. (2009). Field hearing measurements of the Atlantic sharpnose shark *Rhizoprionodon terraenovae*. *Journal of Fish Biology, 75*, 2768-2776. doi:10.1111/j.1095-8649.2009.02477.x

Coombs, S., and J. C. Montgomery. (1999). The Enigmatic Lateral Line System. In R. R. Fay and A. N. Popper (Eds.), Comparative Hearing: Fish and Amphibians (pp. 319–362). New York: Springer-Verlag.

Debusschere, E., B. De Coensel, A. Bajek, D. Botteldooren, K. Hostens, J. Vanaverbeke, S. Vandendriessche, K. Van Ginderdeuren, M. Vincx, and S. Degraer. (2014). In situ mortality experiments with juvenile sea bass (*Dicentrarchus labrax*) in relation to impulsive sound levels caused by pile driving of windmill foundations. PLoS ONE, 9(10), e109280.

Deng, X., Wagner, H.-J., and Popper, A. N. (2011). The inner ear and its coupling to the swim bladder in the deep-sea fish *Antimora rostrata* (Teleostei: Moridae). Deep-Sea Research, part I. 58(1): 27–37.

Deng, X., H. J. Wagner, and A. N. Popper. (2013). Interspecific variations of inner ear structure in the deep-sea fish family melamphaidae. The Anatomical Record, 296(7), 1064–1082.

Doksæter, L., Godø, O. R., Handegard, N. O., Kvadsheim, P. H., Lam,A. F. P., Donovan, C., and Miller, P. J. O. (2009). Behavioral responses of herring (*Clupea harengus*) to 1–2 and 6–7 kHz sonar signals and killer whale feeding sounds. Journal of the Acoustical Society of America, 125: 554–564.

Doksæter, L., Handegard, N. O., Godø, O. R., Kvadsheim, P. H., and Nordlund, N. (2012). Behavior of captive herring exposed to naval sonar transmissions (1.0–1.6 kHz) throughout a yearly cycle. Journal of the Acoustical Society of America, 131: 1632–1642.

Goertner, J.F. (1982). Prediction of Underwater Explosion Safe Ranges for Sea Mammals. Research and Technology Department. NSWC TR 82-188.

Goertner, J. F., Wiley, M. L., Young, G. A. and McDonald, W. W. (1994). Effects of underwater explosions on fish without swimbladders. (NSWC TR 88-114). Silver Spring, MD: Naval Surface Warfare Center.

Good, T. P., Waples, R. S., and Adams, P. (2005). Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. (NOAA Technical Memorandum NMFS-NWFSC-66, pp. 598) U.S. Department of Commerce.

Halvorsen, M. B., Casper, B. M., Woodley, C. M., Carlson, T. J., and Popper, A. N. (2012). Threshold for onset of injury in Chinook salmon from exposure to impulsive pile driving sounds. Plos One, 7(6), e38968.

Halvorsen, M. B., Zeddies, D. G., Chicoine, D., and Popper, A. N. (2013). Effects of low-frequency naval sonar exposure on three species of fish. The Journal of the Acoustical Society of America, 134(2), EL205–EL210.

Hastings, M. C. (1991). Effects of Underwater Sound on Bony Fishes. Paper presented at the 122nd Meeting of the Acoustical Society of America.

Hastings, M. C. (1995). Physical effects of noise on fishes. Presented at the Proceedings of INTER-NOISE 95, The 1995 International Congress on Noise Control Engineering.

Hastings, M. C. and Popper, A. N. (2005). Effects of Sound on Fish. (Contract No. 43A0139, Task Order 1). 2600 V Street Sacramento, CA 9581: California Department of Transportation. Prepared by P. C. Jones and Stokes.

Hawkins, A. D. and Johnstone, A. D. F. (1978). The hearing of the Atlantic salmon, *Salmo salar*. Journal of Fish Biology. 13(6): 655–673.

Hubbs, C., and Rechnitzer, A. (1952). Report on experiments designed to determine effects of underwater explosions on fish life. California Fish and Game 38, 333-336.

Jørgensen, R., Olsen, K. K., Falk-Petersen, I. B., and Kanapthippilai, P. (2005). Investigations of potential effects of low frequency sonar signals on survival, development and behaviour of fish larvae and juveniles. The Norwegian College of Fishery Science, University of Tromsø, N-9037 Tromsø Norway.ne, A.S., Song, J., Halvorsen, M.B., Miller, D.L., Salierno, J.D., Wysocki, L.E., Zeddies, D., and Popper, A.N., (2010). Exposure of fish to high-intensity sonar does not induce acute pathology. Journal of Fish Biology. 76(7): 1825–1840.

Kane, A. S., Song, J., Halvorsen, M. B., Miller, D. L., Salierno, J. D., Wysocki, L. E., Popper, A. N. (2010). Exposure of fish to high intensity sonar does not induce acute pathology. [Uncorrected Proof]. *Journal of Fish Biology*.

Ladich, F. (2008). Sound communication in fishes and the influence of ambient and anthropogenic noise. [Journal Article]. *Bioacoustics, 17*, 35-37.

Ladich, F., and R. R. Fay. (2013). Auditory evoked potential audiometry in fish. Reviews in Fish Biology and Fisheries, 23(3), 317–364.

Lovell, J., Findlay, M., Moate, R., Nedwell, J.R., and Pegg, M. (2005). The inner ear morphology and hearing abilities of the Paddlefish (*Polyodon spathula*) and the Lake Sturgeon (*Acipenser fulvescens*). Comparative Biochemistry and Physiology, Part A, 142(3):286–296.

Mann, D. A., Popper, A. N., and Wilson, B. (2005). Pacific herring hearing does not include ultrasound. Biology Letters 1: 158–161.

Mann, D. A., Lu, Z. and Popper, A. N. (1997). A clupeid fish can detect ultrasound. *Nature, 389*, 341.

Mann, D., Higgs, D., Tavolga, W., Souza, M. and Popper, A. (2001). Ultrasound detection by clupeiform fishes. *Journal of the Acoustical Society of America*, 3048-3054.

McCauley, R. D. and Cato, D. H. (2000). Patterns of fish calling in a nearshore environment in the Great Barrier Reef. *Philosophical Transactions: Biological Sciences, 355*, 1289-1293.Meyer, M., Fay, R. R., and Popper, A. N. (2010). Frequency tuning and intensity coding of sound in the auditory periphery of the lake sturgeon, *Acipenser fulvescens*. Journal of Experimental Biology. 213 (9), 1567–1578.

McIver, E. L., Marchaterre, M. A., Rice, A. N., & Bass, A. H. (2014). Novel underwater soundscape: acoustic repertoire of plainfin midshipman fish. Journal of Experimental Biology, 217(13), 2377-2389.

Miller, J. D. (April, 1974). Effects of noise on people. Journal of the Acoustical Society of America. 56(3): 729–764.

Myrberg, A. A. (2001). The acoustical biology of elasmobranchs. *Environmental Biology of Fishes, 60*, 31-45.

National Marine Fisheries Service. (2016a). 2016 Status review updates for Pacific salmon and steelhead listed under the Endangered Species Act. Available: http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016_status_review.html Accessed: 13 July, 2016.

National Marine Fisheries Service. (2016b). Proactive Conservation Program: Species of Concern. Available: http://www.nmfs.noaa.gov/pr/species/concern/NMFS. Updated: 4 January, 2016. Accessed 12 July, 2016.

National Marine Fisheries Service. (2016c). Salmon population trend summary: Hood Canal Summer chum (1998-2007). Northwest Fisheries Science Center, December 2009. https://www.nwfsc.noaa.gov/trt/trt_documents/hood_canal_chum.pdf. Accessed July 13, 2016.

National Marine Fisheries Service. (2016d). Salmon population trend summary: Lower Columbia chum (2004-2008). Northwest Fisheries Science Center, December 2009. https://www.nwfsc.noaa.gov/trt/trt_documents/lcolumbia_chum.pdf. Accessed July 13, 2016.

National Marine Fisheries Service. (2016e). 2016 5-year Review: Summary and Evaluation of Snake River Sockeye, Snake River Spring-Summer Chinook, Snake River Fall-Run Chinook, and Snake River Basin Steelhead. NMFS West Coast Region, Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_snake-river.pdf

National Marine Fisheries Service. (2016f). 2016 5-year review: Summary and Evaluation of Lake Ozette Sockeye. NMFS West Coast Region, Portland, OR. http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_lake_ozette.pdf

O'Keeffe, D. J. (1984). Guidelines for predicting the effects of underwater explosions on swimbladder fish (pp. 1-28). Dahlgren,Virginia: Naval Surface Weapons Center.

Popper, A. N. (1977). A scanning electron microscopic study of the sacculus and lagena in the ears of fifteen species of teleost fishes. Journal of Morphology. 153(3): 397–418.

Popper, A. N. (1980). Scanning electron microscopic studies of the sacculus and lagena in several deep sea fishes. American Journal of Anatomy. 157(2): 115–136.

Popper, A. N. and Carlson, T. J. (1998). Application of sound and other stimuli to control fish behavior. Transactions of the American Fisheries Society 127: 673–707.

Popper, A. (2003). Effects of Anthropogenic Sounds on Fishes. *Fisheries, 28*(10), 24-31. Retrieved from www.fisheries.org

Popper, A. N. (2008). Effects of Mid- and High-Frequency Sonars on Fish. Naval Undersea Warfare Center Division. Newport, Rhode Island. Contract N66604-07M-6056.

Popper, A. N. and Fay, R. R. (2010). Rethinking sound detection by fishes. *Hearing Research*. doi: DOI: 10.1016/j.heares.2009.12.023 Retrieved from http://www.sciencedirect.com/science/article/B6T73-4Y0KWGD-1/2/7a2c622709c6199f8a4051cbbbffbd8c

Popper, A. N. and Fay, R. R. (2011). Rethinking sound detection by fishes. Hearing Research. 273: 25–36. DOI: 10.1016/j.heares.2009.12.023.

Popper, A. N., Fay, R. R., Platt, C. and Sand, O. (2003). Sound detection mechanisms and capabilities of teleost fishes S. P. Collin and N. J. Marshall (Eds.), *Sensory Processing in Aquatic Environments*. New York: Springer-Verlag.

Popper, A. N., Halvorsen, M. B., Kane, A., Miller, D. L., Smith, M. E., Song, J., Wysocki, L. E. (2007). The effects of high-intensity, low-frequency active sonar on rainbow trout. *Journal of the Acoustical Society of America, 122*(1), 623–635.

Popper, A., A. Hawkins, R. Fay, D. Mann, S. Bartol, T. Carlson, S. Coombs, W. Ellison, R. Gentry, M. Halvorsen, S. Løkkeborg, P. Rogers, B. Southall, D. Zeddies, and W. Tavolga. (2014). Classification of Fishes and Sea Turtles with Respect to Sound Exposure Risk. Pages 15-16 in ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Springer International Publishing.

Popper, A. N. and C. R. Schilt. (2008). Hearing and acoustic behavior (basic and applied). In: in Fish Bioacoustics. J. F. Webb, R. R. Fay, and A. N. Popper, ed. Springer Science + Business Media, LLC, New York.

Popper, A. N., Smith, M. E., Cott, P. A., Hanna, B. W., MacGillivray, A. O., Austin, M. E. and Mann, D. A. (2005). Effects of exposure to seismic airgun use on hearing of three fish species. *Journal of the Acoustical Society of America, 117*(6), 3958-3971. Retrieved from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=16018498

Radford, C. A., J. C. Montgomery, P. Caiger, and D. M. Higgs. (2012). Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. The Journal of experimental biology, 215(Pt 19), 3429–3435.

Ramcharitar, J., Higgs, D. M. and Popper, A. N. (2001). Sciaenid inner ears: a study in diversity. *Brain, Behavior and Evolution, 58*, 152-162.

Sisneros, J. A. and Bass, A. H. (2003). Seasonal Plasticity of Peripheral Auditory Frequency Sensitivity. *The Journal of Neuroscience, 23*(3), 1049-1058.

Sivle, L. D., Kvadsheim, P. H., and Ainslie, M. A. (2015). Potential for population-level disturbance by active sonar in herring. ICES Journal of Marine Science: Journal du Conseil, 72(2), 558–567.

Sivle, L. D., Kvadsheim, P. H., Ainslie, M. A., Solow, A., Handegard, N. O., Nordlund, N., and Lam, F. P. A. (2012). Impact of naval sonar signals on Atlantic herring (*Clupea harengus*) during summer feeding. ICES Journal of Marine Science: Journal du Conseil, fss080.

Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C. and Popper, A. N. (2010). A noisy spring: The impact of globally rising underwater sound levels on fish. Trends in Ecology and Evolution, 25(7), 419-427. doi: 10.1016/j.tree.2010.04.005.

Sprague, M. W. and Luczkovich, J. J. (2004). Measurement of an individual silver perch *Bairdiella chrysoura* sound pressure level in a field recording. *Journal of the Acoustical Society of America, 116*(5), 3186-3191.

Swisdak, M. (1978). Explosion effects and properties, Part II: Explosion effects in water. Naval Surface Warfare Center/ White Oak Laboratory (NSWC/WOL) Technical Report TR 76-116.

Webb, J. F., J. C. Montgomery, and J. Mogdans. (2008). Bioacoustics and the Lateral Line of Fishes Fish Bioacoustics (pp. 145–182). New York, NY: Springer.

Wright, D. G. (1982). A Discussion Paper on the Effects of Explosives on Fish and Marine Mammals in the Waters of the Northwest Territories *Canadian Technical Report of Fisheries and Aquatic Sciences*. (pp. 1-16). Winnipeg, Manitoba: Western Region Department of Fisheries and Oceans.

Wright, K. J., Higgs, D. M., Belanger, A. J., & Leis, J. M. (2008). Auditory and olfactory abilities of larvae of the Indo-Pacific coral trout *Plectropomus leopardus* (Lacepède) at settlement. Journal of Fish Biology, 72(10), 2543-2556.

Wright, K. J., Higgs, D. M., Cato, D. H. and Leis, J. M. (2010). Auditory sensitivity in settlement-stage larvae of coral reef fishes. Coral Reefs, 29, 235-243. doi:10.1007/s00338-009-0572-y

Yelverton, J. T., Richmond, D. R., Hicks, W., Saunders, K. and Fletcher, E. R. (1975). The relationship between fish size and their response to underwater blast. (Defense Nuclear Agency Topical Report DNA 3677T, pp. 39 pp.). Washington, DC: Lovelace Foundation for Medical Education and Research, Defense Nuclear Agency.

Young, G. A. (1991). Concise Methods for Predicting the Effects of Underwater Explosions on Marine Life. (NAVSWC MP 91-220, pp. 19). Dahlgren, VA: U.S. Department of the Navy, Naval Surface Warfare Center.

Zelick, R., Mann, D. and Popper, A. N. (1999). Acoustic communication in fishes and frogs R. R. Fay and A. N. Popper (Eds.), *Comparative Hearing: Fish and Amphibians* (pp. 363-411). New York: Springer-Verlag.

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