3 SPECIES EFFECTS ANALYSIS

Effects to species are project-specific; however, certain effects are predictably associated with different types of work. The purpose of this section is to describe the effects of construction activities on listed species, and provide necessary analysis for making effects determinations on a project-by-project basis. Table 3-1 outlines the nature and severity of potential effects that could occur from certain types of construction. The life histories and other information on these species are described in Appendix B.

Effects to listed fish species are expected to be similar and are therefore grouped together in Section 3.1. Additional species specific information is provided where appropriate. Effects to listed marine mammal and bird species discussed seperately.

3.1 Listed Fish Species Effects

Potential effects to fish are similar, therefore this section addresses all listed species. Studies of Chinook are more common, which is reflected in the discussion below. Rockfish presence is depth specific, so is discussed separately at the end of this section.

3.1.1 In-water Noise

NMFS has set underwater noise injury and disturbance thresholds for fish as shown in Table 3-2. Impact pile driving of steel and concrete piles can produce sound that exceeds injury and disturbance levels. Impact driving of timber piles, and vibratory driving/removal of all types of piles do not exceed injury levels, but can exceed disturbance levels.

The ESA listed species effect determinations for any individual project will depend on a combination of factors including site-specific sediment conditions, use of attenuation devices, duration of exposure, and shoreline configuration that may limit sound propagation (for example, an enclosed bay as opposed to an open shoreline). For a full discussion of in-water noise, pile driving and removal noise data, and impact pile driving attenuation data, see Section 7.2 of the WSDOT Biological Assessment Manual (WSDOT 2019a).

Table 3-1
Effects Associated with Project Activities

Type of Work	Associated Effects			
	Noise	**Turbidity**	**Change in Overwater/Benthic Coverage**	**Other Potential Effects**
Pile repair		Short-term, localized turbidity may occur		Metal leaching (from ACZA-treated wood)
Impact pile driving	Potential for injury and disturbance effects for fish, murrelet and marine mammals.	Short-term, localized turbidity may occur	If benthic footprint increased, may result in lowerproductivity and/or altered predator-prey relationships. If decreased, may result in increased benthic productivity .	
Vibratory pile driving and removal	Potential for disturbance effects for fish and murrelet. Potential injury and disturbance effects for marine mammals.	Short-term, localized turbidity may occur	If benthic footprint increased, may result in lowerproductivity and/or altered predator-prey relationships. If decreased, may result in increased benthic productivity.	Resuspension of contaminants[1]
Rock anchors	Potential for underwater noise above ambient levels but below the behavioral effects threshold			Elevated pH if concrete grouting is used
Cast-in-place concrete				Elevated pH
Dredging		Short-term turbidity with significant plume possible; severity depends partly on sediment conditions		Temporary loss of benthic productivity
New or replacement structures	Noise associated with pile driving; can reach injury or disturbance thresholds underwater and in air	Short-term, localized, turbidity associated with pile removal and/or installation	If overwater/benthic footprint increased, may result in lower benthic productivity and/or altered predator-prey relationships. If decreased, may result in increased benthic productivity Some water temperature effects possible with large changes	
Shoreline armoring		Short-term, localized turbidity, especially if excavation is part of the work	May increase shoreline productivity if bulkhead is removed or modified	Elevated pH if concrete is used

Table 3-2
Fish Sound Injury and Disturbance Threshold

	Pulse
Single Strike Injury (fish of all sizes)	206 dB_{PEAK}
Cumulative Sound Injury	--
<2 grams	183 dB_{SEL}
≥2 grams	187 dB_{SEL}
Disturbance	150 dB_{RMS}

Source: Fisheries Hydroacoustic Working Group 2008

3.1.2 Temporary Turbidity

Work involving sediment disturbance, including pile removal and installation, dredging, and other in-water activities, has the potential to cause turbidity. The potential effects of increased turbidity on salmonids have been investigated in a number of dredging studies (Servizi and Martens 1987 and 1992; Emmet et al. 1988; Noggle 1978; Simenstad 1988; Redding et al. 1987; Mortensen et al. 1976; Berg and Northcote 1985). Dredging activities would generate much greater turbidity than pile removal activities because smaller amounts of material are removed during pile removal activities. Pile removal activities disturb far less sediment and have less potential impact on water quality than dredging.

The most important factor in resistance to turbidity effects is the availability of "turbidity refugia," areas of clear water outside the turbidity plume that are accessible to fish (Bash et al. 2001). All the WSF terminals are in areas of open water large enough to provide turbidity refugia outside the affected area.

Very little data exists regarding sediment plumes and turbidity caused by pile removal. Roni and Weitkamp (1996) monitored water quality parameters during a pier replacement project in Manchester, Washington. The study measured water quality before, during, and after pile removal, dredging, and pile replacement. Construction activities occurred from mid-February 1991 to March 1993. The study found that construction activity at the site had "little or no effect on DO (dissolved oxygen), water temperature, and salinity." Turbidity (measured in nephelometric turbidity unit [NTU]) at all depths nearest the construction activity was typically less than 1 NTU higher than stations farther from the construction area throughout construction. Only during dredging in 1991 did turbidity exceed background levels by more than 1 NTU.

In September 2004, water quality monitoring conducted at the Friday Harbor Ferry Terminal during three pile removal events of creosote-treated structures showed turbidity levels did not exceed 1 NTU over background conditions and were generally less than 0.5 NTU over background levels. In October 2005, water quality monitoring conducted at the Eagle Harbor Maintenance Facility during four pile removal events of creosote and steel piles showed turbidity levels did not exceed 0.2 NTU over background levels (WSF 2005a). In December 2005, water quality monitoring conducted during 28 pile removal events of steel piles at the Friday Harbor Ferry Terminal showed turbidity levels did not exceed 0.61 NTU over background levels (WSF 2005b).

The U.S. Environmental Protection Agency (EPA) indicates that turbidity is localized around piling to about a 25-foot radius during pile installation. Because there is so little information available on turbidity and pile removal and installation, studies on the effects to fish from suspended sediments from dredging are summarized for this discussion. Turbidity from dredging greatly exceeds turbidity levels measured during pile removal because dredging involves the removal and disturbance of greater amounts of sediment than pile removal.

There are several mechanisms by which suspended sediment can affect juvenile salmonids, including direct mortality, gill tissue damage, physiological stress, and behavioral effects. Each is discussed in Sections 3.1.2.1 through 3.1.2.4.

3.1.2.1 *Direct Mortality*

Direct mortality from extremely high levels of suspended sediment has been demonstrated at concentrations far exceeding those caused by typical dredging operations. Laboratory studies have consistently found that the 96-hour median lethal concentration (LC_{50}) for juvenile salmonids occurs at levels above 6,000 milligrams per liter (mg/L) (Stober et al. 1981; Salo et al. 1980; LeGore and DesVoigne

1973). However, typical samples collected adjacent to dredge sites (within approximately 150 feet) contain suspended sediment concentrations between 50 and 150 mg/L (Havis 1988; Salo et al. 1979; Palermo et al. 1990). Based on an evaluation of seven clamshell dredge operations, LaSalle (1988) determined that suspended sediment levels of 700 mg/L and 1,100 mg/L at the surface and bottom, respectively, would represent the upper limit concentration expected adjacent to the dredge source (within approximately 300 feet). Concentrations of this magnitude could occur at sites with fine silt or clay substrates. Much lower concentrations (50 to 150 mg/L at 150 feet) are expected at sites with coarser sediment. Because direct mortality occurs at turbidity levels that far exceed typical dredging operations, and because levels of suspended sediment from dredging far exceed levels generated by pile removal and installation, direct mortality from suspended sediment is not expected to occur during pile removal or installation activities.

3.1.2.2 *Gill Tissue Damage*

Studies also indicate that suspended sediment concentrations occurring near dredging activity will not cause gill damage in salmonids. Servizi and Martens (1992) found that gill damage was absent in underyearling coho salmon exposed to concentrations of suspended sediments lower than 3,143 mg/L. Redding et al. (1987) also found that the appearance of gill tissue was similar for control fish and those exposed to high, medium, and low concentrations of suspended topsoil, ash, and clay. Based on the results of these studies, juvenile and sub-adult salmonids, if any are present, are not expected to experience gill tissue damage even if exposed to the upper limit of suspended sediment concentrations expected during dredging, and therefore, are not expected to experience gill tissue damage from suspended sediment caused by pile removal or installation activities.

There is some evidence that fish may be more susceptible to gill tissue damage during the summer months when protective mucous secretions are generally lower (Bash et al. 2001).

3.1.2.3 *Physiological Stress*

Suspended sediments have been shown to cause stress in salmonids, but at concentrations higher than those typically caused by dredging. Underyearling coho salmon exposed to suspended sediment concentrations above 2,000 mg/L were physiologically stressed, as indicated by elevated blood plasma cortisol levels (Redding et al. 1987). Exposure to approximately 500 mg/L of suspended sediment for 2 to 8 consecutive days also caused stress, but to a much lesser degree (Redding et al. 1987; Servizi and Martens 1987). At 150 to 200 mg/L of glacial till, no significant difference in blood plasma glucose concentrations were observed. These results indicate that upper limit suspended sediment conditions near dredging activity (700 to 1,100 mg/L) can cause stress in juveniles if exposure continues for an extended period of time. Continued exposure is unlikely, however, due to the tendency for unconfined salmonids to avoid areas with elevated suspended sediment concentrations (Salo et al. 1980). Typical sediment plumes (50-150 mg/L) caused by dredging do not create suspended sediment concentrations high enough to cause stress in juvenile salmonids. Therefore, it is concluded that the even lower concentrations of suspended sediment caused by pile removal and other in-water activities will not have physiological impacts on salmonids in the project area.

3.1.2.4 *Behavioral Effects*

Behavioral responses to elevated levels of suspended sediment include feeding disruption and changes in migratory behavior (Servizi 1988; Martin et al. 1977). Several studies indicate that salmonid foraging behavior is impaired by high levels of suspended sediment (Bisson and Bilby 1982; Berg and Northcote 1985). Redding et al. (1987) demonstrated that yearling coho and steelhead exposed to high levels (2,000 to 3,000 mg/L) of suspended sediment did not rise to the surface to feed. Yearling coho and steelhead exposed to lower levels (400 to 600 mg/L); however, actively fed at the surface throughout the experiment. In these instances, the thresholds at which feeding effectiveness was impaired greatly exceeded the upper limit of expected suspended solids during dredging. Pile installation is expected to result in even lower levels of sediment suspension.

Adult migration could also be subject to disruption from suspended sediment. Adult salmonids are not closely associated with the shoreline and are less vulnerable to adverse impacts should they avoid turbid conditions. Whitman et al. (1982) used volcanic ash from the eruption of Mount St. Helens to recreate highly turbid conditions faced by returning adult salmon. This study showed that, despite very high levels of ash, adult male Chinook salmon were still able to detect natal waters through olfaction even when subjected to 7 days of total suspended sediment levels of 650 mg/L. Since suspended sediment levels are not expected to reach those of dredging, migratory or feeding disruptions are not likely to occur from pile removal or installation activities.

3.1.3 Change in Overwater Coverage

The effects of overwater structures on outmigrating juvenile salmonids are not well understood. Some literature suggests that overwater structures have the potential to affect juvenile salmonids through habitat changes, increased predation, and disruption of migration patterns (Nightengale and Simenstad 2001). These issues have been studied to varying degrees but have not yielded conclusive results. Sections 3.1.3.1 through 3.1.3.3 discuss the potential effects of additional overwater cover, including migration disruption, the potential for increased predation, and primary and epibenthic productivity.

3.1.3.1 Migration Disruption

Juvenile salmonids are reliant on shallow water nearshore habitats for food and refuge. Recent studies suggest that the movement of juvenile salmonids is affected by sharp shadows and dark/light interfaces cast by overwater structures (Nightengale and Simenstad 2001; NOAA Fisheries 2004; USFWS 2004a; Southard et al. 2006). Studies have shown that juvenile salmonids may follow the edge of a shadow along piers, rather than pass under the pier. A 2005 study conducted by Pacific Northwest National Laboratory (PNNL) at 10 WSF ferry terminals found it to be probable that overwater structures are temporary impediments to juvenile salmonid movement during specific times of day (depending on light level, sun angle, and cloud cover) or under specific environmental conditions (depending on current magnitude and direction, and tidal stage). The study also found that "juvenile chum remained on the light side of a dark/light shadow line when the decrease in light level was approximately 85% over a shore horizontal distance (e.g., five meters)" (Southard et al. 2006). However, another study conducted by PNNL at the existing Mukilteo Ferry Terminal found that "salmon fry moved freely under the relatively narrow, shaded portion of the Mukilteo Ferry Terminal where mean light levels in water were reduced by over 97%" (Williams et al. 2003). The observers concluded that "during the day, fry moved freely under the relatively narrow (33 feet wide), shaded portion of the ferry terminal and did not appear to be inhibited by the differences in light levels detected here…the terminal structure did not appear to act as barriers to fry movement at this location…" (Williams et al. 2003).

A 2008-2009 WSDOT sponsored research study by the University of Washington School of Aquatic and Fishery Sciences/Batelle Marine Science Laboratory on the effectiveness of under dock lighting as mitigation for shading was carried out at the Port Townsend Ferry Terminal. This study found that juvenile salmon seldom swam underneath the terminal but instead stayed 2 to 5 meters away from the dock, even in the afternoon when the shadow line moved underneath the dock. In addition to avoiding the dock's shading, juvenile salmon also appeared to avoid the overwater structure itself. Shoals of juvenile salmon observed in this study did not swim under the dock during daylight hours even when the shadow line moved some distance beneath the terminal. The study concluded that there is a high probability that small juvenile pink salmon experience more than 9 hours of migration delay per dock encounter, during high tides, on a sunny day. Unfortunately, there are no data to allow generalization of this finding to other overwater structures and other salmon species. Artificial light was used to mitigate the dock shadow edge, and the study concluded fish were more likely to come closer to the dock edge. This raises the possibility that a properly designed lighting system may allow for fish passage under the dock (Ono et al. 2010).

Bull trout enter Puget Sound at a later stage of development than most salmonids and are not as dependent on the shoreline environment (Goetz 2004). Therefore, bull trout migration may be less affected by nearshore overwater coverage.

3.1.3.2 *Potential for Increased Predation*

Studies have suggested that migrating salmonids may not pass under an overwater structure and may be forced to move farther offshore where they may become more susceptible to predation from birds, mammals, and fish. However, no conclusive evidence has been found to suggest that marine overwater structures contribute to increased predation on juvenile salmonids. According to Simenstad et. al. (1999), "despite considerable speculation about the effects of overwater structures increasing predation on juvenile salmonids, evidence supporting this contention scientifically is uncertain at best."

Williams et al. (2003) conducted bird/mammal surveys at six north-central Puget Sound WSF terminals and paired reference sites between April 1 and May 10, 2002. In addition, intensive surveys for potential predators of juvenile salmonids were conducted at the Mukilteo Ferry Terminal and reference sites in May 2002. The studies included SCUBA transects (benthic predatory fishes), snorkel transects (pelagic fishes), bird and marine mammal predatory surveys, salmon fry abundance surveys, documentation of nearshore fish assemblages during all diel phases using boat-deployed beach seines, collection of live potential fish predators and stomach content analysis, documentation of light measurements, and the use of Dual-frequency Identification Sonar (DIDSON) to document potential predators associated with the water column and terminals at night. According to Williams et al. 2003:

> Observational surveys at six locations suggest that potential salmon predators were statistically more abundant at WSF terminals with unmodified shorelines. Piscivorous birds were observed more often than expected at ferry sites as compared with reference sites. However, large aggregations of piscivorous birds were not observed at WSF terminals during any survey. Predatory fish surveys, which were conducted only at the Mukilteo ferry terminal and paired reference sites, produced similar findings…We found no evidence that avian or marine mammal predators consumed more juvenile salmon near WSF terminals along shorelines without overwater structures…our analysis of fish diets at the Mukilteo ferry terminal provides one piece of conclusive evidence that juvenile salmon were observed in the diet of a single staghorn sculpin collected at the reference site; these salmon were undigested and likely consumed in the bag of the beach seine. Our interpretation of the abundance, distribution patterns, and diets of potential predators suggest that juvenile salmon did not experience biologically

significant levels of predation near the ferry terminals studied during the spring of 2002.

The body of available research on the effects of overwater structure related to predation is inconclusive. Each project must be evaluated, considering the water depth where overwater structure is being added, the estimated light penetration under the structure, and any other available information.

3.1.3.3 *Primary and Epibenthic Productivity*

A research report by Haas et al. (2002) studied the relationship between the large overwater structures associated with ferry terminals and abundance of epibenthic prey species. Although results were variable, the differences in epibenthic assemblages indicated negative effects from the terminals. The results demonstrated that significant differences in epibenthic assemblages do exist around the ferry terminals. Adjusted in-water photosynthetically active radiation (PAR) was generally close to zero under the existing structure at Bainbridge Island. Substrate composition for all three terminals studied (Bainbridge Island, Clinton, and Southworth) was noticeably different around the terminal structures, with higher gravel, shell, and cobble proportions as compared to sand, the dominant component. This was attributed to a combination of sea star foraging on piling and in substrate and the decomposition of shells from large numbers of bivalves in the sediments under and near the terminals. The Haas et al. (2002) study suggested that propeller wash may contribute to differences in epibenthic productivity at Bainbridge Island.

The Haas et al. (2002) study concluded that ferry terminal structures induce decreases or changes in epibenthos density, diversity, and assemblage composition, but attributed it to a combination of four interacting factors rather than to overwater coverage alone:

1. Direct disturbance and/or removal by regular vessel disturbance
2. Reduced benthic vegetation or compromised benthic vegetation function due to shading and physical disturbance
3. Physical habitat alterations (e.g., altered grain-size distribution from propeller wash or piling effects)

4. Biological habitat alterations (e.g., increased shell hash from sea star foraging and reduced eelgrass density due to benthic macrofauna disturbance)

The dominant factors will vary by project and should be discussed at the project level. A significant change in the configuration of an overwater structure could cause changes in local currents and sediment transport; this would need to be identified and evaluated at the individual project level.

3.1.4 Creosote Exposure and Effects

WSF is systematically replacing creosote-treated timber structures with steel or concrete. This is resulting in a reduction in polycyclic aromatic hydrocarbon (PAH) exposure in Puget Sound. The amount any one project contributes to this effort depends on the number of piles or board feet of timber removed from the aquatic environment. Removal of creosote-treated timber results in a reduction in long-term chronic exposure to fish and aquatic life. Removal of creosote-treated piles may result in a short-term increase in PAH exposure during removal activities, which is discussed below.

Existing creosote-treated piles are a source of hydrocarbon contamination to marine sediments in the form of PAHs. Concerns have been raised about the potential for resuspension of contaminants during removal of creosote-treated piles. As with all potentially toxic chemicals, the risk is a function of exposure, which can be highly variable and subject to modifying factors in the natural environment.

The bioavailable fraction of non-polar organic chemicals (i.e., PAHs) is a function of the sediment chemistry, including the amount and type of organic carbon, and the nature of the source material. Resident benthic species can come in contact with sediment-associated PAHs through three primary pathways: 1) through ingestion of sediment in their diet; 2) through direct contact, ingestion, and ventilation of interstitial water in the benthic mixed layer; and 3) through direct contact with contaminated sediment. This can lead to direct effects, primarily from non-polar narcosis (disruption of cellular function resulting in disorientation), as well as bioaccumulation in some benthic invertebrates.

The primary exposure pathway for PAHs in most vertebrate species is through the food chain. Marine fish that prey on benthic infauna can be exposed to PAHs via the dietary pathway (USFWS 2004a). The effects of ingesting PAHs accumulated in prey species includes the following, as noted in the Edmonds Crossing Biological Opinion (BO) (USFWS 2004a):

> Vertebrate organisms are able to quickly metabolize some of the lighter PAH compounds and readily excrete a percent of the hydrophobic parent compound along with the polar water-soluble metabolites (James et al. 1991; McElroy et al. 1991) which can be passed on to consuming marine fish. While PAHs do not bioaccumulate in vertebrates, some of the heavier, more carcinogenic PAH compounds and metabolites may persist and are known to cause sub-lethal effects to fish exposed in laboratory studies (NTP 1999) and field studies (Moore and Myers 1994; Myers et al. 1998a and 1998b; O'Neill et al. 1998).

Exposure to PAHs in juvenile salmon has been linked to immunosuppression and increased disease susceptibility (Arkoosh et al. 1998). However, Palm et al (2003) concluded that their controlled laboratory experiments suggest that dietary exposure to an environmentally relevant mixture of PAH compounds does not alter the immunocompetence or growth of juvenile Chinook salmon. Other effects of exposure to PAHs have been described in the Edmonds Crossing BO (USFWS 2004a):

> The general mode of effect associated with acute exposure to PAHs is non-polar narcosis (van Brummelen et al. 1998). Other major effects include biochemical activation/adduct formation (carcinogenesis), phototoxicity (acute and chronic exposure), and disturbance of hormone regulation. The role of PAHs in endocrine disruption is not well documented. Immunotoxicity as a mode of PAH toxicity has been investigated (Varanasi et al. 1993, Karrow et al. 1999). PAHs have induced tumors in laboratory animals exposed by inhalation and ingestion (Germain et al. 1993). The presence of hepatic (liver) tumors in English sole (Parophrys vetulus), a benthic marine fish, has been linked to PAH contamination in sediments collected from industrialized areas around Puget Sound (Johnson 2002, Meyers et al. 1990, Stein et al. 1990, Krahn et al. 1986).

3.1.4.1 *Fate and Transport of PAHs from Pile Removal*

There are two mechanisms by which pile removal can reintroduce PAH contamination. The first route of contamination is through the water column as piles are being extracted. The second route of contamination is through the settling of resuspended PAHs on the surface sediments as residuals. PAHs are heavier than water and can sink to the bottom floor. Though undetectable in the water column, marine species could be directly or indirectly exposed to creosote through the food chain (USFWS 2004a).

At some terminal sites, the presence of crabs and shellfish and an accumulation of years of barnacles (*Balanus glandula*) attaching themselves to the dock piles, dying, and sloughing off to the bottom has created a thick layer of shell hash on the bottom. Theoretically, this shell hash will be pulled by the natural vacuum that is created during pile extraction and will further bury the contaminated sediment. The suction pulling the shell hash in the hole could counteract much of the sediment plume entering the water column during extraction. This natural cap should form a layer that may help isolate the contaminated sediment from the marine environment.

Field studies from dredging operations indicate that remobilization of PAHs from pile removal is not expected to affect salmonids that might be in the surrounding areas. A summary of the mechanisms by which contaminants could be mobilized and become bioavailable during an activity that disturbs bottom sediments and the frequency with which this has been observed during various dredging events is provided below. The dredging information comes from a literature review documenting the effects of resuspended sediments due to dredging operations (Anchor 2003b). It is expected that dredging activities lead to a larger amount of resuspended sediments and disturbance to the sediments than pile pulling and driving; therefore, this information is conservative for this application.

Non-polar organic compounds, like PAHs, are heavier than water and are not likely to dissolve in the water column. Organic compound contaminants become mobilized during dredging in the following ways: 1) through the release of porewater containing dissolved chemicals; 2) by desorption from sediment particles; and 3) through loss of particulate bound contaminants (Averett et al. 1999 *cited in* Anchor 2003a). Once mobilized, organic compound contaminants may become bioavailable as dissolved and particulate bound forms. The dissolved fraction available can be predicted using equilibrium partitioning modeling (EPA 2003). The dissolved form of chemicals can be toxic or can contribute to bioaccumulation of chemicals in an organism's tissue.

Theoretically, the releases of non-polar organic contaminants (including PAHs) can occur during dredging of contaminated sediments and increase water column concentrations above ambient levels. However, field studies show that PAH releases were small in comparison to the dilution from the receiving waters and that there were minimal changes in water quality, even when heavily contaminated sediments were dredged (Ludwing and Sherrard 1988; Brannon 1978; both *cited in* Anchor 2003a). Additional studies indicate that the concentrations of PAHs measured in the water column during dredging operations have been minimal and, in many instances, below detection limits. For example, dredge monitoring at the Port of Los Angeles showed PAH concentrations in the water column were four to six orders of magnitude lower than the concentrations measured in the sediments (MBC 2001a-f; all *cited in* Anchor 2003a).

Overall, the studies included in the literature review did not find a significant increase in concentration of organic compounds in the water column from suspended sediment resulting from dredging activities. Pile removal activities are generally less disruptive to bottom sediment than dredging. Sediments disturbed by pile removal will be suspended for only a short duration before particles settle out. Because of this, it is expected that pile removal would cause even less of an increase in contaminants dissolved in the water column than dredging.

The long-term benefit of removing creosote-treated wood from the aquatic environment is greater than the short-term impacts of removal. The short-term impacts generally result in an effect determination of "may affect, not likely to adversely affect," unless individual project conditions make a different effect determination appropriate.

3.1.5 ACZA Exposure and Effects

Research has shown that ACZA presents a far smaller relative hazard than creosote in the marine environment. While piling over 40 years of age still contain diffusible amounts of creosote that migrate from the piling to the environment, ACZA leaching lasts only up to a few weeks. The shorter leaching period is due in part to the pressure treatment and washing process that ACZA treated pilings must go through before being installed in marine environments. The leaching period may be slightly longer in overwater structures that are not constantly exposed to the water column. After several weeks, the metal compounds fuse to the wood and leaching no longer occurs (Poston 2001).

During the short leaching period, ACZA treated timbers may be a source of trace metals (primarily copper) to the aquatic environment by leaching into the water column and surrounding sediments.

The primary effect to salmonids of increased copper concentrations in water is olfactory disruption (Brooks 2004). Salmonids depend on olfaction to determine their migration route and to find food. A relationship between olfactory inhibition and diminished alarm response to predators has also been established (Sandahl et al. 2007). Chronic effects to salmonids occur when copper concentrations rise above the level the fish are acclimated to. These effects are detectable at levels of 2.0 μg/L above the acclimated level (Sandahl et al. 2007). Salmonids recover from these chronic effects when concentrations are lowered.

However, when ACZA piles are installed, increases in sediment metal concentrations are generally limited to within 10 feet or less of small treated wood structures in both marine and freshwater habitats. This can result in the food chain being exposed to copper, but not at potentially toxic levels (Poston 2001). In addition, the overwhelming conclusion of studies (Poston 2001) indicates that the effect from the use of ACZA treated wood can be greatly minimized if the wood is treated properly. As presented in Poston 2001, the reviewed studies and model results applied to projects to predict environmental responses to ACZA treated wood indicate the following:

- The use of treated wood in projects with less than 100 piling and in areas with normal tidal flushing does not produce metal concentrations that exceed Washington State's regulatory levels (measured in parts per billion [ppb]).

- The use of treated wood is unlikely to result in detectable increases in dissolved copper in water. The predicted amounts are a few tens of parts per trillion and are a thousand times less than the several ppb increase that might cause effects in even the most sensitive species.
- Models indicate that loss rates decline exponentially with time and reach background levels within 1 week after installation. Model results indicate that if water and sediment concentrations of copper are maintained below federal and state water and sediment quality standards, zinc or arsenic will not reach levels of concern and will be below the thresholds associated with stress or disease.
- Metal accumulation associated with ACZA-treated wood structures is relatively minor in most settings. Metal accumulation is limited spatially (within 10 feet or less of the structure), has not been associated with significant biological effects, and is not high enough to pose ecological risks in moderate to well-mixed waterbodies.
- Impacts of metals in sediments are localized and tests have shown that the sediment concentrations are lower than state Water Quality Criteria (WQC) by a factor of 22 within 2 centimeters of the pile and lower than the Sediment Quality Standards (SQS) by a factor of up to 26 within 30 centimeters of a pile. These concentrations decrease rapidly with time and reach background levels within 2 weeks.
- Metal losses reach low values in less than 2 weeks, losses are very small after 1 or 2 weeks, and ACZA and other treated wood provide excellent protection in most aquatic environments.
- Leaching rates are not sufficiently high to pose ecological risks in mixed waterbodies, and the duration of biological effects appears to be attenuated within several months of construction.
- No adverse biological impacts were reported in the studies reviewed. The most probable route of exposure to contaminants is through consumption of contaminated prey if a species is feeding in low flow areas adjacent to treated wood structures.

Further information on listed fish species can be found in Appendix B.

3.1.6 Prey Species

Prey species for all listed fish are discussed in Appendix B. Effects to prey species are expected to be similar to effects to listed fish species.

For WSF projects, any adverse effects to prey species occur during project construction and are short term. Given the large numbers of prey species in Puget Sound, the short term nature of effects, and extensive MMs to protect prey species during construction, WSF projects are not expected to have measurable effects on the distribution or abundance of listed fish prey species.

3.1.7 Rockfish Species

Bocaccio and yelloweye rockfish adults are found in deep water, usually more than 150 feet deep, and are very unlikely to occur within the immediate project areas because of ferry facility shallower depths (64 ft. MLLW maximum depth). Larvae and juveniles are found in the water column closer to the surface.

Adults are unlikely to be affected by localized temporary turbidity because of the distance from the terminal areas to very deep water where adults are found. Pelagic juveniles could be affected by turbidity, but the turbidity associated with WSF projects is localized, affecting a small area that could be avoided by juvenile rockfish.

3.2 Killer Whale (*Orcinus orca*)

For WSF projects, underwater noise, water quality effects, and adverse effects on the whales' food supply (i.e., potential direct effects to salmonids) have the most potential to affect killer whales. Further information on killer whales can be found in Appendix B.

3.2.1 Noise

For cetaceans, sound is perhaps the most critical sensory pathway of information. Killer whales communicate with each other over short and long distances with a variety of clicks, chirps, squeaks, and whistles. They also use echolocation to find prey and to navigate. Killer whales are mid-frequency cetaceans, with hearing in the range of 150 Hz to 20 kHz (Southall et al. 2007). Natural and anthropogenic sounds have the potential to impact the use of biologically important acoustic signals by killer whales (NOAA 2008). Long-term impacts from noise pollution would not likely show up as noticeable behavioral changes in habitat use, but rather as sensory damage or a gradual reduction in population health (Whale Museum 2005).

For most free-ranging cetaceans, behavioral responses are difficult to observe, and interpretation of observed results is limited by uncertainty as to what does and does not constitute a response (Southall et al. 2007; NOAA 2008). Additionally, precise measurements of received noise exposure and other relevant variables can be difficult to obtain. Only a few disturbance studies have been undertaken that estimate received sound levels, and only a very small number have measured received levels at the subject. Thus, behavioral reactions to acoustic exposure in cetaceans are generally more variable, context-dependent, and less predictable than effects of noise exposure on hearing or physiology (Southall et al. 2007).

The majority of the research on underwater noise impacts to killer whales is associated with vessel and navy sonar disturbances and does not address impacts from pile driving. The NMFS 2004 Status Review of Killer Whales released in December 2004 and the WDFW status report released in March 2004 indicate that the threshold levels at which underwater noise becomes harmful to killer whales are unknown (Krahn et al. 2004). There are several short-term and long-term effects that have been hypothesized and untested, including impaired foraging efficiency due to noise and its potential effects on movements of prey, as well as harmful physiological conditions, energetic expenditures, and temporary hearing threshold shifts due to chronic stress from noise (Krahn et al. 2004).

NMFS has implemented Technical Guidance for assessing the potential impacts of sound on marine mammals (NMFS 2018). All projects with pile driving or removal are required to use this guidance when assessing potential impacts. For a full discussion of in-water noise, pile driving and removal noise data, and impact pile driving attenuation data, see Section 7.2 of the WSDOT Biological Assessment Manual (WSDOT 2019a).

3.2.2 Water Quality

Short-term turbidity can result from in-water work. Turbidity was not raised as an issue in the proposed or final listings for Southern Resident killer whales, nor is it mentioned in the Recovery Plan for Southern Resident Killer Whales (NMFS 2008a). In addition, WSF must comply with state water quality standards that limit the extent of turbidity to the immediate project area and killer whales are not expected to come close to WSF facilities during construction. Therefore, turbidity is not expected to affect Southern Resident killer whales in any significant way.

Existing creosote-treated piles are a source of hydrocarbon contamination to marine sediments in the form of PAHs. Long-term water quality improvements in the Puget Sound will result from WSF's systematic replacement of creosote-treated timber structures with steel and concrete. Because killer whales are at the top of the food chain and have a long life expectancy, bioaccumulation of toxins is of high concern (NMFS 2008a). Removal of creosote from the aquatic environment has a beneficial effect on Southern Resident killer whales.

The NMFS (2008a) Recovery Plan lists the classes of environmental contaminants that are of concern to killer whales. They are:

- Organochlorines (polychlorinated biphenols [PCBs], pesticides, dioxins, and furans)
- Polybrominated diphenyl ethers/biphenyls (PBDEs/PBBs), used as flame retardants
- PAHs, from fuel combustion and other sources
- Other chemical compounds including perfluorinated compounds, polychlorinated paraffins (PCPs), polychlorinated naphthalenes (PCNs), polychlorinated terphenyls (PCTs), tributyltin/dibutyltin (TBT/DBT), perfluro-octane sulfonate (PFOs), endocrine disruptors (e.g., synthetic estrogens, steroids, and some pesticides), pharmaceuticals, and personal care products (e.g., diagnostic agents and cosmetics)
- Toxic elements—most importantly, mercury, cadmium, and lead

3.2.3 Prey Species

Chinook salmon is the dominant component of the Southern Resident killer whales' summer diet, while steelhead and a wider variety of species are used for forage in other seasons (Hanson et al. 2010). For most WSF projects, any adverse effects to salmonids occur during project construction and are short term.

Given the large numbers of salmonids in Puget Sound, the short term nature of effects to salmonids, and extensive MMs to protect salmonids during construction, WSF projects are not expected to have measurable effects on the distribution or abundance of potential killer whale prey species.

3.2.4 Passage Conditions

WSF terminal structures are located at the shoreline and extend a few hundred feet (to a maximum of approximately 800 feet) into the water. Water depths at the outer limit of the terminals range from 40 to 100 feet. Most WSF projects involve repair or replacement to existing facilities. In the event of a project that introduces new passage barriers, that project will be evaluated to determine effects to passage conditions.

If the underwater injury or disturbance thresholds from impact or vibratory pile driving for killer whales are exceeded within designated critical habitat, then passage conditions may be impeded. Areas with water less than 20 feet deep relative to the extreme high water mark are not included in the critical habitat designation (Federal Register 2006).

3.3 Humpback Whale (*Megaptera novaeangliae*)

For WSF projects, underwater noise, water quality effects, and adverse effects on the whales' food supply (especially herring) have the most potential to affect humpback whales. Further information can be found in Appendix B.

3.3.1 Noise

For cetaceans, sound is perhaps the most critical sensory pathway of information. Humpback whales sing long, complex songs lasting 10 to 20 minutes. Humpbacks are also thought to communicate with gestures involving tail and flipper slapping

(American Cetacean Society 2009). Humpback whales are low-frequency cetaceans, with hearing in the range of 7 Hz to 22 kHz (Southall et al. 2007). It is not known whether humpback whales that tolerate chronic noise exposure undergo stress or are otherwise deleteriously affected (NPS 2009).

NMFS has implemented Technical Guidance for assessing the potential impacts of sound on marine mammals (NMFS 2018). All projects with pile driving or removal are required to use this guidance when assessing potential impacts. For a full discussion of in-water noise, pile driving and removal noise data, and impact pile driving attenuation data, see Section 7.2 of the WSDOT Biological Assessment Manual (WSDOT 2019a).

3.3.2 Water Quality

Humpback whales are affected by the same bioaccumulating toxins described for Southern Resident killer whales in Section 3.2.2. WSF's systematic removal of creosote-treated wood from all its terminals is consistent with regional creosote removal efforts and will contribute to long-term water quality improvements.

3.3.3 Prey Species

The most significant prey item for humpback whales in Puget Sound is herring (American Cetacean Society 2009). A large herring holding area exists in the south Sound near the southern tip of Vashon Island (WDFW 2005c). WSF repair and maintenance activities would not affect this holding area. Herring spawn on macroalgae, mainly eelgrass and kelp (WDFW 2005c). Most of the work at WSF terminals is in deeper water, away from suitable spawning substrate.

3.4 Marbled Murrelet (*Brachyramphus marmoratus*)

Potential effects on marbled murrelets are primarily related to noise from construction, specifically from pile driving activities, and physical disturbance during foraging. Of all WSF facilities, murrelet sightings are most common at Port Townsend, Coupeville, Anacortes, Mukilteo and the San Juan Island terminals (PSAMP and WDFW 1994). Further information on marbled murrelet can be found in Appendix B.

3.4.1 *Noise*

Because murrelets are diving sea birds, both in-air and underwater noise effects must be considered.

3.4.1.1 *In-air Noise Potential Effects on Foraging*

Marbled murrelets can be affected by project noise, most notably impact driving of steel piles. In-air noise measurements are often recorded in dBA using the A-frequency weighing scale. The A-weighted rating of noise is used because it relates to human interpretation of noise. Peak sound emitted from a source is called Lmax. Sound levels averaged during a measured period of time are referred to as Leq.

All WSF terminals experience regular human activity to some extent; therefore, murrelets in those areas are expected to be somewhat acclimated to the normal activity levels. Noise studies were conducted at several WSF terminals to determine in-air noise from vessel operation in January 2005. Based on the noise data from the Bremerton Ferry Terminal, which is situated in a semi-urban area, in-air noise from ferry operations had approximate Lmax recordings of 65.5 dBA for arrival, 72.5 dBA during unloading of vehicles, 67.5 dBA during loading of vehicles, and 67.5 dBA during departure. From arrival to the next departure, noise recordings ranged from a low of 56 dBA during departure to a high of 72.5 dBA during unloading. Ambient noise recordings ranged from approximately 54 to 61 dBA at the terminal (McMullen Associates, Inc. 2005).

According to the Mukilteo test pile project noise results, a marbled murrelet on the surface of the water 300 feet from the pile driving location would experience noise levels within the Lmax range of 93.4 to 99.3 dBA (WSF 2007a).
USFW evaluated the effects of sound-related disturbance in the terrestrial environment and determined that murrelets could be adversely affected by sounds higher than 92 dBA (USFW 2003). USFW considers 92 dBA to be a disturbance threshold guideline, not criteria, for the foraging marbled murrelet (Fisheries Hydroacoustic Working Group 2008). There are no known studies or data available on the likely response of murrelets (or other alcids) to in-air sound in the marine environment. For projects in the marine environment, it is assumed that murrelet

response to above-ambient sounds on the water would be similar to those expected in the terrestrial environment (USFW 2010b).

In 2013, USFW implemented in-air masking thresholds for impact driving of steel piles, and in some cases for impact driving of concrete piles (Table 3-4). Monitoring of the appropriate masking zone takes place during the April 1-September 23 nesting season, to reduce disturbance of foraging murrelet pair communication. Shutdown of pile driving is implemented when a murrelet approaches the zone to prevent masking effects.

Table 3-3
Murrelet In-Air Masking Masking Zones

	Meters
Piles < 36-inch	42
Piles ≥ 36-inch	168

Source: WSDOT 2019a.

3.4.1.2 *In-air Noise Potential Effects on Suitable Nesting Habitat*

Construction and pile driving noise can have disturbance effects on occupied murrelet nests. According to USFW guidance (WSDOT 2014b):

- If marbled murrelet suitable habitat is present within 328 feet, then construction noise from heavy equipment or pile driving (within 368 feet) could result in behavioral disruption and harassment.
- If suitable habitat is present farther than 328 feet, but within 0.25 miles (1,320 feet), then murrelet may be disturbed by construction noise.
- If suitable habitat is present farther than 0.25 miles (1,320 feet), no effect to murrelet is expected from construction noise.

A WSF biologist has reviewed habitat conditions near all WSF facilities, using a combination of Google Maps, GIS orthophotos, the USFW habitat suitability index (WSDOT 2019a), and site visits. Suitable murrelet habitat is present farther than 328 feet, but within 0.25 miles of the Anacortes, Coupeville, Lopez and Shaw terminals (Table 3-5) (Figures 3-1/3-2/3-3/3-4). Therefore, there is potential to disturb marbled murrelet if the suitable habitat is occupied.

However, there is considerable disturbance from ferry vessel noise and other activities near this suitable habitat. Table 3-4 notes the number of planned vessel trips for Fiscal Year 2017-2018 (July 2017-June 2018), and the number of trips during the April 1 – September 23 nesting season when murrelet may be occupying suitable habitat (WSDOT 2018a). Table 3-4 also provides the nearest documented murrelet nesting (WSDOT 2018b), and prey presence (WSDOT 2018c). Additional disturbance factors present at the four terminals with suitable habitat are listed after each Figure (3-1/3-2/3-3/3-4).

Table 3-4
Marbled Murrelet Disturbance/Habitat/Nesting/Prey

Facility	WSF Vessel Trips FY 2017/2018	WSF Vessel Nesting Season Trips FY 2017/2018	Suitable Habitat Present within 0.25 miles	Nearest Documented Nesting (miles/direction)	Documented Prey Species Spawning Presence
Anacortes	5,430	3,010	**Yes**	39 SW	**Surf Smelt**
Bainbridge	16,520	8,290		27 W	**Surf Smelt**
Bremerton	10,900	5,465		22 NW	
Clinton	13,400	6,798		29 SW	**Surf Smelt**
Coupeville	4,465	2,596	**Yes**	21 SW	
Eagle Harbor	N/A*	N/A*		27 W	
Edmonds	8,605	4,315		34 SW	
Fauntleroy	14,040	7,080		34 SW	**Sand Lance**
Friday Harbor	4,920	2,570		38 S	
Kingston	8,605	4,315		42 SW	
Lopez	5,980	2,910	**Yes**	42 SW	**Surf Smelt**
Mukilteo	13,400	6,798		27 NE	**Sand Lance**
Orcas	4,990	2,650		42 SW	
Point Defiance	6,985	3,505		37 NW	
Port Townsend	4,465	2,596		15 SW	**Surf Smelt**
Seattle	27,420	13,755		35 NW	
Shaw	4,900	2,540	**Yes**	42 SW	
Southworth	8,560	4,325		29 NW	**Surf Smelt**
Tahlequah	6,985	3,505		35 NW	
Vashon	18,200	9,260		31 NW	**Surf Smelt**

*Infrequent ferry vessel traffic – only when repair or maintenance required

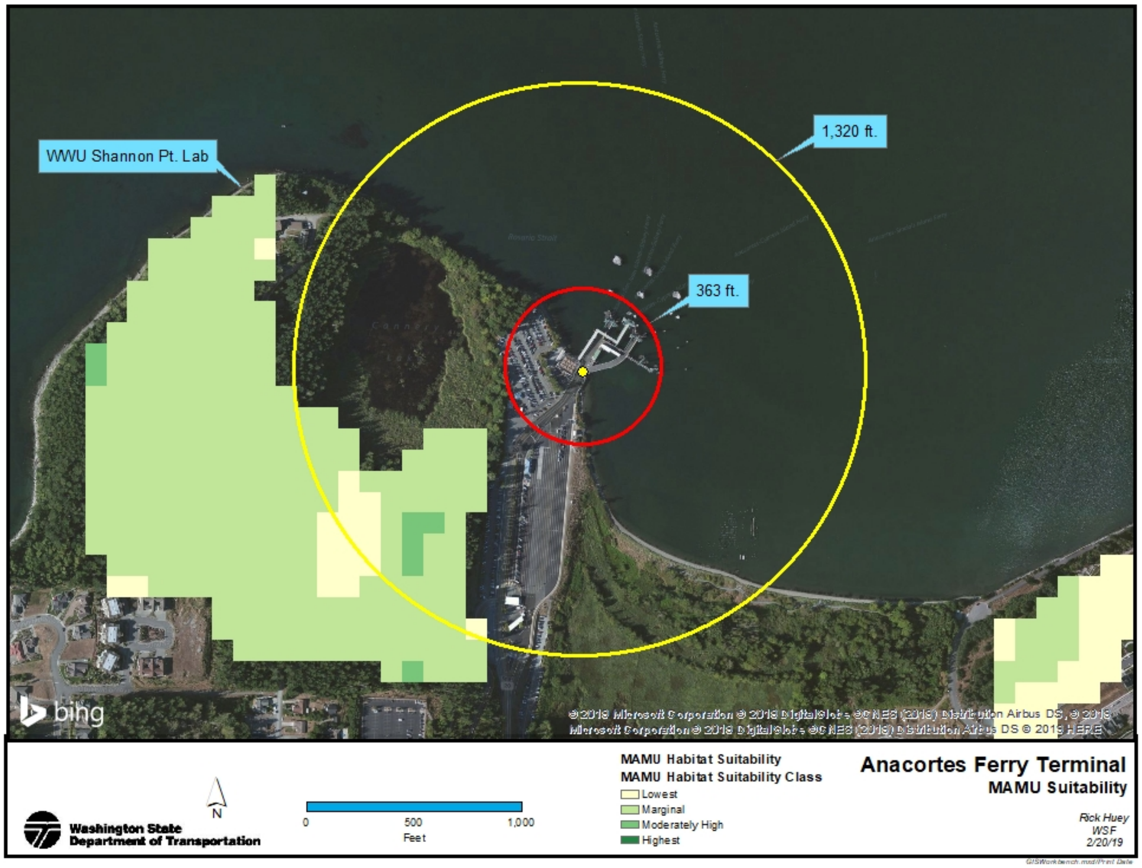

Figure 3-1
Anacortes MAMU Suitability and Potential In-air Disturbance Zone

3.4.1.3 *Anacortes Murrelet Disturbance Factors:*

- ✓ The WSF upper parking lot is open for Spring/Summer use mid-May to mid-September. This lot is closer to suitable habitat, and vehicle traffic and pedestrian use generates increased noise; especially during the April 1-Sept. 23 nesting season.
- ✓ The adjacent neighborhood and the WWU Shannon Point Marine Lab are present near suitable habitat; and vehicle, pedestrian and homeowner power tool use generates increased noise.
- ✓ An informal trail system is present within suitable habitat, which increases the chance for disturbance, especially during the April 1-Sept. 23 nesting season.

- ✓ Corvid presence in the area increases predation risk, making this habitat less suitable for murrelet use.

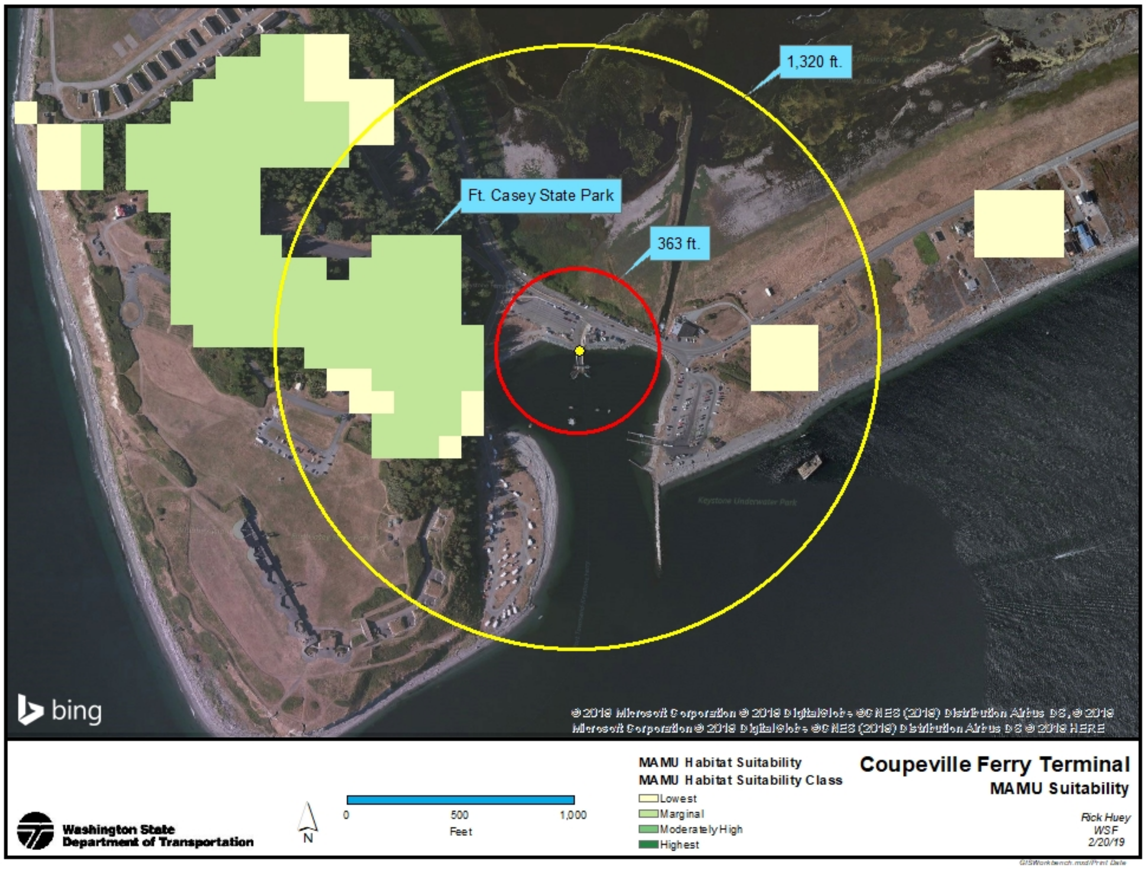

Figure 3-2
Coupeville MAMU Suitability and Potential In-air Disturbance Zone

3.4.1.4 *Coupeville Murrelet Disturbance Factors:*

- ✓ Suitable habitat near the terminal is within Ft. Casey State Park, which is disturbed by campers, vehicles and pedestrians; especially during the April 1-Sept. 23 nesting season.
- ✓ Corvid presence in the area increases predation risk, making this habitat less suitable for murrelet use.

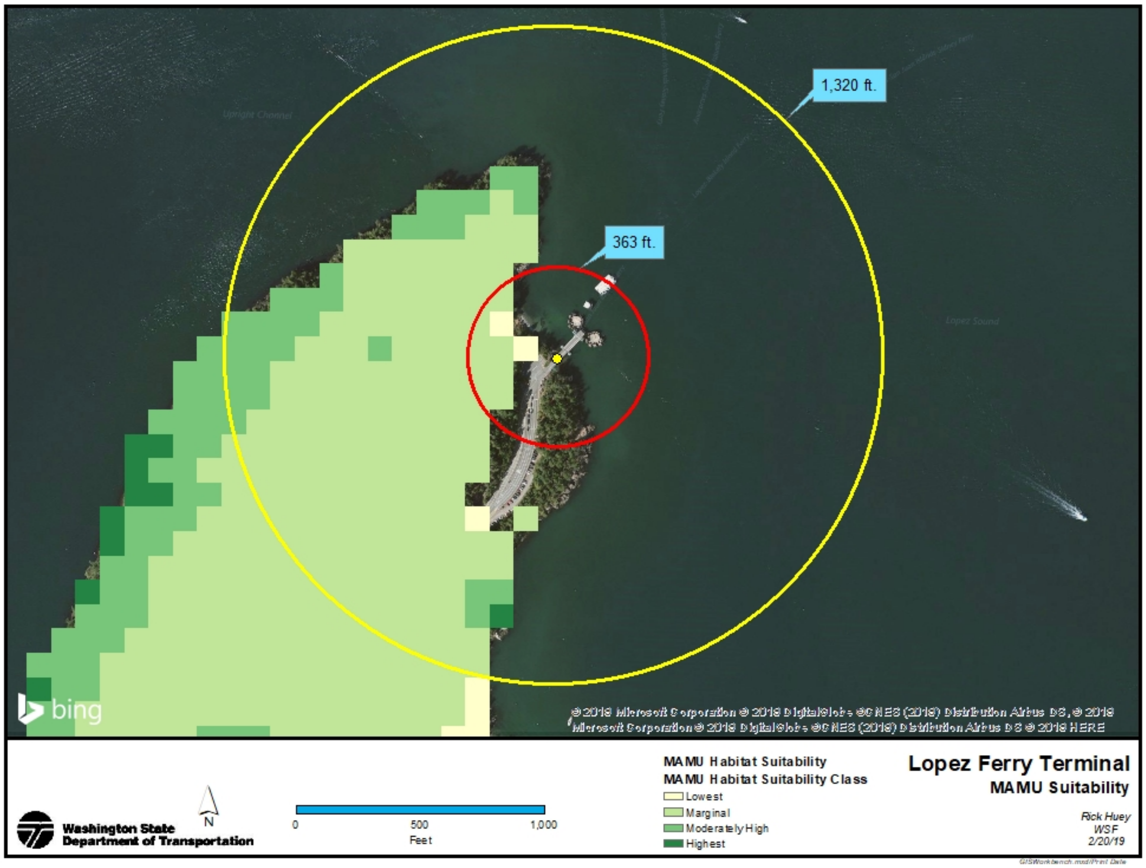

Figure 3-3
Lopez MAMU Suitability and Potential In-air Disturbance Zone

3.4.1.5 *Lopez Murrelet Disturbance Factors:*

- ✓ Suitable habitat near the terminal is within the San Juan Co. Land Bank's Upright Head Preserve, which includes a trail system that has heavier day hiker use during the April 1-Sept. 23 nesting season.

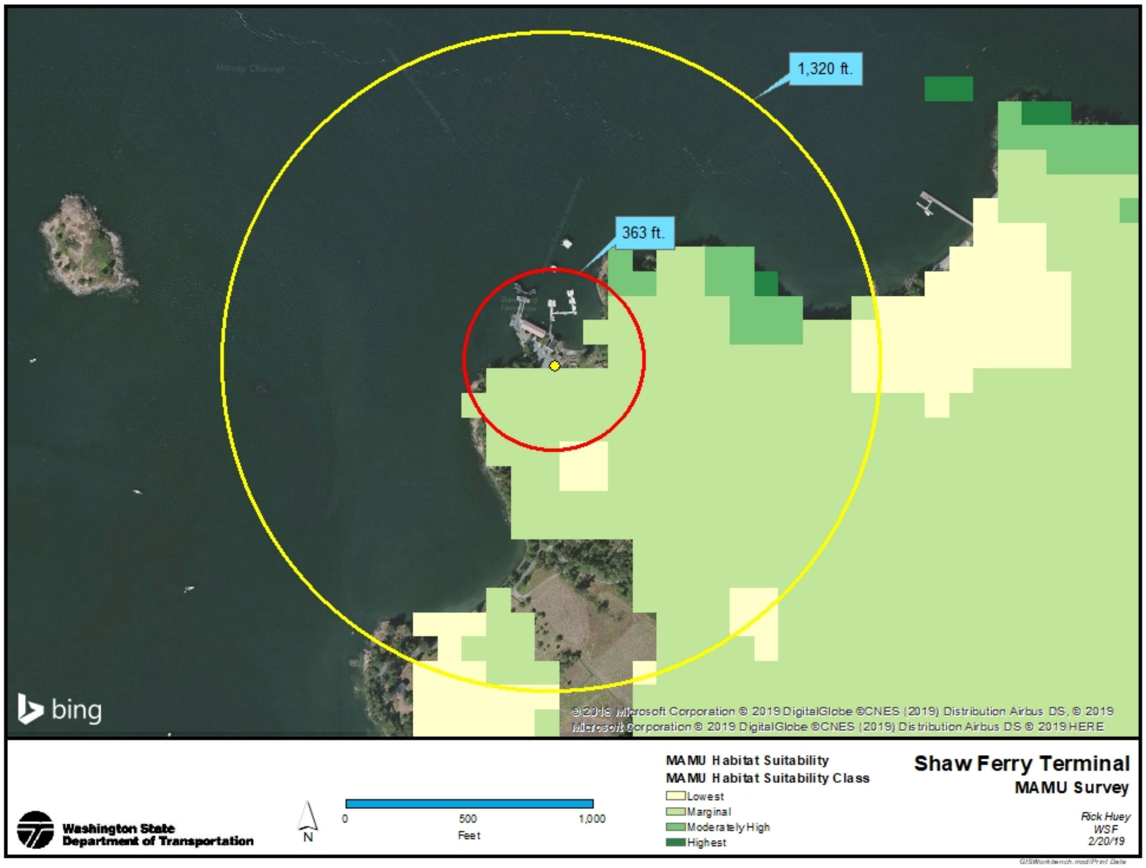

Figure 3-4
Shaw MAMU Suitability and Potential In-air Disturbance Zone

3.4.1.6 *Shaw Murrelet Disturbance Factors:*

- ✓ A marina and private properties are adjacent to suitable habitat, which increases the likelihood of disturbance.
- ✓ An informal trail system is present within suitable habitat, which increases the chance for disturbance, especially during the April 1-Sept. 23 nesting season.

3.4.1.7 *Underwater Noise*

Physical harm and behavioral modifications could result from elevated underwater SPLs caused by impact installation of steel piles. Pile driving noise, particularly during impact hammer installation, could temporarily disrupt or displace foraging murrelets, or cause direct harm via elevated SPLs, particularly if a murrelet was foraging underwater during impact pile installation (USFWS 2003).

USFWS has set thresholds for physical injury and a disturbance guideline (Table 3-5). No injury or disturbance thresholds for vibratory pile driving are set by USFWS.

Table 3-5
Murrelet Undewater Sound Injury and Disturbance Threshold

	Pulse
Barotrauma	208 dB_{SEL}
Auditory Injury	203 dB_{SEL}
Disturbance	150 dB_{RMS}

Source: WSDOT 2019a.

For a full discussion of in-water noise, pile driving and removal noise data, and impact pile driving attenuation data, see Section 7.2 of the WSDOT Biological Assessment Manual (WSDOT 2019a).

3.4.1.8 *Potential Physical Disturbance of Foraging Murrelet*

Foraging murrelet near WSF terminals may be disturbed by frequent ferry vessel arrivals and departures. Table 3-5 (above) notes the number of planned vessel trips for Fiscal Year 2017-2018 (July 2017-June 2018) that may disturb foraging murrelet. Table 3-5 also notes the number of trips during the April-September 23 nesting season, when murrelet may be foraging to feed new chicks (WSDOT 2018a). Table 3-5 also provides documented prey presence (WSDOT 2018c).

3.4.2 Prey Species

Marbled murrelet feed on fish, small crustaceans, and invertebrates. Murrelets prefer to forage near kelp beds and at stream mouths, and feed on a variety of prey including sand lance, Pacific herring, and northern anchovy. For WSF projects, any adverse effects to prey species occur during project construction and are short term. Given the large numbers of prey species in Puget Sound, the short term nature of effects to salmonids, and extensive MMs to protect prey species during construction, WSF projects are not expected to have measurable effects on the distribution or abundance of potential murrelet prey species.

4 TERMINAL SPECIFIC INFORMATION

This chapter provides a summary of the baseline information and distribution of ESA-listed species and critical habitat at each terminal. The chapter begins with three tables summarizing the chemical, physical, and biological indicators for the 19 ferry terminals and one ferry maintenance facility. The chapter is then organized alphabetically by ferry terminal, with more detailed descriptions of the environmental baseline followed by the ESA-listed species and critical habitat distributions for each terminal.