# United States Department of the Interior

FISH AND WILDLIFE SERVICE

Washington Fish and Wildlife Office
510 Desmond Dr. SE, Suite 102
Lacey, Washington 98503


In Reply Refer To:
**13410-2008-F-0160**

Mr. Daniel Mathis
Division Administrator
Federal Highway Administration - Washington Division
711 South Capitol Way, Suite 501 Evergreen Plaza
Olympia, Washington 98501-1284

Attn:Wendy McAbee

Dear Mr. Mathis:

This document transmits the U.S. Fish and Wildlife Service's Biological Opinion (Opinion) based on our review of the proposed Manette Bridge Replacement Project, in Kitsap County, Washington, and its effects on the bull trout (*Salvelinus confluentus*) and the marbled murrelet (*Brachyramphus marmoratus*) in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

Your request for initiation of formal consultation, dated January 24, 2008, was received in our office on January 25, 2008. The request included information supporting a "may affect, likely to adversely affect" determination for the marbled murrelet and a "may affect, not likely to adversely affect" determination for the bull trout. We concur with these effect determinations. We subsequently received additional information via submittals from your office on April 30, 2008, November 4, 2008, and April 13, 2009. At that point, we determined that the information required to initiate formal consultation on the project was adequate. On May 7, 2009, we sent your office a letter noting that we were initiating formal consultation as of April 13, 2009.

The proposed project involves replacement of the structurally deficient, and functionally obsolete, Manette Bridge over the Port Washington Narrows in Bremerton. A new concrete bridge will be built parallel to, and just south of, the existing bridge, with roadway connections to existing city street intersections.

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The enclosed Opinion addresses the proposed action's adverse effects to the marbled murrelet and includes mandatory terms and conditions intended to minimize certain adverse effects. If you have any questions regarding the Opinion or your responsibilities under the Endangered Species Act, please contact Brooke Hamilton at (360) 753-9073 or Emily Teachout at (360) 753-9583, of my staff.

Sincerely,

Ken S. Berg, Manager
Washington Fish and Wildlife Office

cc:
WSDOT, Olympic Region, Olympia, WA (C. Ward)
WSDOT, Olympic Region, Olympia, WA (J. Sawyer)
WSDOT, ESO, Olympia, WA (P. Wagner)
NOAA, Sand Point, WA (M. Grady)

Endangered Species Act - Section 7 Consultation

# BIOLOGICAL OPINION

USFWS Log # 13410-2008-F-0160

## Manette Bridge Replacement Project

## Kitsap County, Washington

Agency:

Federal Highway Administration
Olympia, Washington

Ken S. Berg, Manager
Washington Fish and Wildlife Office

Date

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## CONSULTATION HISTORY

The Washington State Department of Transportation (WSDOT) and Federal Highway Administration (FHWA) proposes to replace the structurally deficient and functionally obsolete Manette Bridge in Bremerton, Kitsap County, Washington. Federal funding from FHWA establishes a nexus requiring consultation under section 7(a)(2) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*)(Act).

The U.S. Fish and Wildlife Service (USFWS) based this Biological Opinion (Opinion) on the following sources of information: the Biological Assessment (BA), dated January 24, 2008 and received on January 25, 2008, a field review of the project site and meeting with the WSDOT project team on March 18, 2008, and WSDOT and FHWA responses to our requests for additional information (written correspondence received on April 30, 2008, November 4, 2008, and April 13, 2009). In December 2008 and March 2009 several meetings were held to discuss the recommended USFWS marbled murrelet monitoring protocol. After the March 2009, meeting attended by WSDOT biologists, biologists from the U.S. Department of Agriculture Forest Service Pacific Northwest Research Station, Hamer Environmental, and USFWS staff, a modified, site-specific monitoring protocol was agreed upon by all parties. On April 13, 2009, a complete package of information was received in our office that included the site-specific, revised, marbled murrelet monitoring protocol. On May 7, 2009, the USFWS sent a letter to FHWA to formally initiate the consultation as of April 13, 2009. A complete record of this consultation is on file in the Washington Fish and Wildlife Office in Lacey, Washington. A chronological summary of important consultation events follows:

January 25, 2008 – The FHWA submits a BA and request for formal consultation with an effect determination of "may affect, likely to adversely affect" for the bull trout (*Salvelinus confluentus*) and also requests informal consultation with an effect determination of "may affect, not likely to adversely affect" for marbled murrelet (*Brachyramphus marmaratus*) (murrelet).

February 27, 2008 – Telephone conversations with WSDOT occurred to discuss the appropriateness of the effect determination of "may affect but not likely to adversely affect" for murrelet. The USFWS advised that the effect analysis should factor in an assumption that murrelets will be exposed to underwater sound from pile driving.

February 27, 2008 – The WSDOT project biologist sent an email to inform the USFWS of a design change regarding routing of stormwater discharge.

March 18, 2008 – The USFWS staff attended a site visit and meeting with WSDOT project office and other stakeholders. An overview of the project and draft BA was presented. The USFWS along with the National Marine Fisheries Service (NMFS) (collectively referred to as the "Services") provided the WSDOT biologist with a joint request for additional information.

April 30, 2008 – The WSDOT submitted a response to our request for additional information that included a revised effect determination for murrelets.

September 9, 2008 – The WSDOT requested this consultation be put on hold in order to meet more urgent timelines for another consultation and asked the USFWS to reprioritize consultation work. The USFWS agreed to stop working on this project and to focus on the Lofall Passenger Only Ferry Terminal project associated with the Hood Canal Bridge Replacement consultation.

October 14, 2008 – Work resumed on this consultation. The USFWS requested more information regarding pile driving, the sound analysis associated with the pile driving, timing of the in water work, as well as some basic elements of construction. This information helped clarify some missing pieces in the project description.

October 29, 2008 – The Services and WSDOT met to discuss the additional information request from October 14th. The WSDOT voiced concerns regarding the USFWS murrelet monitoring protocol and whether implementation of the protocol would be practical, economical, and effective for this project. The WSDOT informed the USFWS that they intended to have discussions with seabird survey experts from the U.S. Forest Service - Pacific Northwest Research Station and anticipated the need for revisions to the protocol. The USFWS requested inclusion in those conversations.

November 06, 2008 – The USFWS contacted the project biologist and advised WSDOT to reconsider the effect determination for bull trout. Based on discussions with the USFWS bull trout lead biologist, bull trout occurrence in the action area was expected to be extremely unlikely.

December 04, 2009 – The WSDOT met with USFWS to discuss implementation of the murrelet protocol. The outcome of the meeting was that USFWS and WSDOT would convene the appropriate murrelet/seabird surveying experts to determine whether site-specific modifications of the protocol would be appropriate and could accomplish the needs of both agencies.

January 06, 2009 – The Services met with WSDOT to discuss details of the planned pile driving.

March 12, 2009 – The USFWS met with staff from WSDOT regional and headquarters offices, the U.S. Forest Service - Pacific Northwest Research Station, and Hamer Environmental. A revised murrelet monitoring protocol with site-specific modifications was developed.

April 13, 2009 – WSDOT provided additional information that included an updated murrelet motoring protocol, revised effect determinations for bull trout and murrelets, and clarifications to the project description.

May 7, 2009 – The USFWS sent a letter to FHWA to acknowledge the receipt of the required information for initiating consultation.

May 21, 2009 - The Services met with WSDOT to discuss NMFS' draft Opinion. New in-water work windows specific to impact pile driving were agreed upon by NMFS and WSDOT. These timing restrictions are incorporated into the project description.

## CONCURRENCE

The FHWA determined that the activities associated with the proposed action "may affect, but are not likely to adversely affect" bull trout. Based on the supplemental information provided on April 13, 2009 and the BA, we concur with the effect determination for bull trout. Bull trout are unlikely to occur in the action area. There are no core populations nearby and the habitat is severely degraded. Due to the low numbers of bull trout that may use the action area, and the expected infrequent use of the action area, we expect bull trout are extremely unlikely to be exposed to effects from construction-related activities and operations. Potential effects are therefore discountable.

# BIOLOGICAL OPINION

## DESCRIPTION OF THE PROPOSED ACTION

The project proposes to replace the structurally deficient and functionally obsolete Manette Bridge with a new concrete bridge. The Manette Bridge is located in Bremerton, Kitsap County, Washington (Figure 1). The legal description of the location is Township 24N, Range 2E, Section 13. The bridge spans the Port Washington Narrows (PWN), a 3.5-mi-long and 0.25-mi-wide fjord connecting Dyes Inlet with Sinclair Inlet. The bridge links the eastern and western portions of Bremerton, on Point Herron and Point Turner, respectively.

The new Manette Bridge will be parallel to, and immediately south of, the existing bridge. It will be built with six in-water piers with a total footprint of 1,416 $ft^2$. This design will decrease the bridge footprint by 7,310 $ft^2$. Construction of the project is proposed to begin in 2010 and will continue for approximately 3 years. The project will occur in three main phases. First, the new bridge piers and central portion of the new bridge will be constructed. Second, the outermost spans of the existing bridge will be removed and the new bridge's outermost spans and abutments will be built. Finally, the remaining portions of the existing bridge will be demolished and removed.

Work will be conducted below the mean lower low water mark. This work will include installation and removal of 542, 24-to 36-inch piles, the construction of six new bridge piers, and demolition of the existing piers. Temporary work trestles will be built in PWN to support both the construction of the new bridge and demolition of the existing bridge.

In-water work of any kind will not occur from March 15 through June 14 of each construction year. Additionally, in-water impact pile driving will not occur from February 1 through June 30, or from August 21 through October 5, in each construction year.

Barges will be used extensively throughout the project to access work areas, support machinery, deliver and stage materials, and as a collection surface for spoils, construction debris, and materials from demolition. The actual number and dimensions of barges will be determined by the contractor. The WSDOT project office estimates that up to six barges will be used at one

time. A typical barge dimension is approximately 290 ft in length and 50 ft in width. Typical barge draft is 4 to 8 ft and a typical freeboard is 3 to 6 ft. The barges will be tethered with mooring lines and temporarily anchored buoys. Up to 12 steel piles may be impact driven to anchor the mooring buoys. Barges will be used throughout the 3-year construction period.

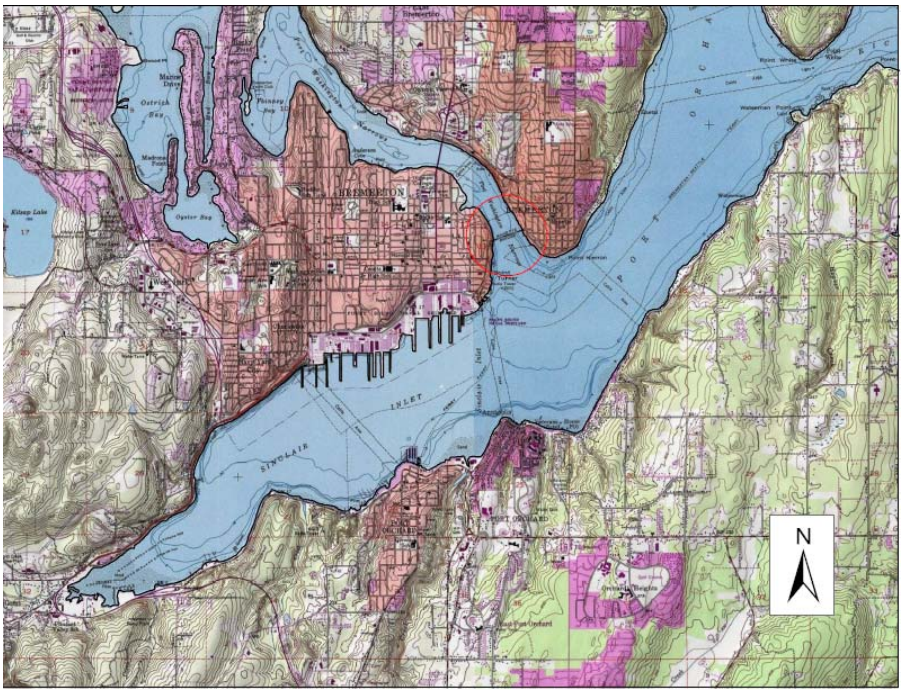


Figure 1. Manette Bridge Vicinity Map

## Construction Elements

The following details the primary components of the proposed project. The sequencing of construction elements and the machinery used will be determined by the contractor.

*Work Trestles and Falsework Towers*

Separate work trestles will be built to construct the new bridge and to demolish the existing bridge (Figure 2). The demolition trestle may be built after the construction trestles and stay in place for up to two years before it is used to disassemble the existing bridge. Falsework towers will be constructed on the trestles to allow access to the job site as the bridge is erected, support the new bridge until the final connections are made, and to support the existing bridge during demolition. The work trestles and falsework towers will be supported by a maximum of 360 steel piles (24-to 36-inch diameter) and could cover a maximum area of 40 $ft^2$. The bridge demolition trestles and falsework towers will be supported by a maximum of 170 steel piles (24-to 36-inch diameter) and could cover a maximum area of 15,900 $ft^2$. All piles will likely be driven with an impact hammer. The contractor may choose to use a vibratory hammer and then impact proof the piles to determine load-bearing capacity. The contractor may also choose to use two impact hammers simultaneously to install the piles more rapidly. WSDOT expects that the

impact pile drivers will be as far apart as possible and may be working on either side of the PWN. The likelihood that both impact hammers will strike a pile at the exact same time when both are in operation is very low (Ward, pers. comm. 2009a). The work trestles will be supported by steel girders attached to the piles. Timber decking will be attached to the girders. Construction of the work trestles is estimated to take up to 9 months. Work trestles and falsework towers will be in place throughout the project duration (approximately 3 years).

Figure 2. Estimated locations of work trestles for demolition of the existing bridge.

*New Piers*

The existing bridge has 13 piers: nine in the water and four upland. The new bridge will have eight piers: six in the water and two upland, with a total footprint of 1,416 $ft^2$. The proposed design will decrease the bridge footprint by 7,310 $ft^2$. Piers 1 and 8 are the bridge abutments and will be well above the mean high water line. Piers 2 through 7 are in the water. The construction of each pier will include the excavation of up to three, 10-or 12-foot-diameter shafts to support each pier, concrete pouring of each shaft, and the construction of piers.

Construction of the new concrete shafts will require installation of steel shaft casings, followed by excavation within the shaft, and then pouring of concrete. Shaft casings will be installed by a combination of sinking by their own weight, vibratory installation and drilling or oscillating (Ward, pers. comm. 2008). After excavation, steel reinforcement is placed into the hole. Concrete is then pumped into the hole using a tremie tube. As the concrete is pumped into the hole, slurry is displaced upward. The slurry is pumped from into tanks on the work trestle or barge, and is either re-used in the next shaft or transported from site. Spoils from shaft excavation will be contained in a steel box on a barge or work trestle and transported from the site.

After the shafts are completed, concrete forms will be stacked up to the crossbeam elevation. A steel reinforcing cage will be placed inside the concrete forms and the columns will be filled with concrete. A concrete crossbeam will be constructed on top of the columns. The construction of these in-water piers (2 through 7) will take up to 18 months.

*Installation of Girders and Decking*

Girders and decking will be installed using the work trestles, falsework towers, and cranes deployed on work barges. Girders will be fabricated off-site and will arrive at the site on barges.

The girders will be placed on the piers and falsework towers between piers 2 and 7. After girder placement, post-tensioning strands will be placed into the girders. The concrete roadway deck will be poured in place between piers 2 and 7. This work is expected to take 3 to 4 months.

*Reconfiguration of Abutments and Roadway Approaches*

The existing bridge abutments and retaining walls will be removed. New retaining walls and abutments piers (1 and 8) will be constructed. This will require the temporary disturbance of 0.75 acre and permanent removal of 0.15 acre of vegetation. Approximately 2,000 cubic yards of fill will be placed in upland areas. Once the abutments are complete, the new approach roadways will be constructed. This work will occur during the 3-month bridge closure period.

*Construction of Stormwater System*

The proposed project will create 1.79 acres of new pollution-generating impervious surface (PGIS) and will remove 1.13 acres of existing PGIS. This will result in a net increase of 0.67 acre of new PGIS. Stormwater from the proposed project will flow directly into underground treatments vaults, then flow to the City of Bremerton's stormwater system, and discharge to the Puget Sound. In addition to treating the all the stormwater from the new bridge, the new treatment system will treat an additional 0.81 acre of existing PGIS, currently discharging without treatment into Sinclair Inlet.

*Demolition of Existing Bridge*

Demolition of the existing bridge will occur over 18 months. After the central portion of the new bridge is constructed, the outermost spans and abutments of the existing bridge will be removed.

New abutments and outer spans will be constructed and the remaining bridge structure will be demolished. The bridge structure above the water line will be cut into manageable sections, using conventional concrete and metal cutting tools, and placed on barges for transport to approved waste or recycling sites. Pavement will be removed using a hoe ram. The portions of the piers below the water line will be cut off at the ground level and cut into pieces using a wire saw. All slurry from wire cutting operations above the water line will be contained; below the water line it will be dispersed by the current. WSDOT estimates that approximately 12,000 cubic yards of riprap will be removed from the existing bridge footings. Once the bridge demolition is complete, the falsework towers and work trestles will be removed. This is expected to occur over 4 to 6 months.

## Best Management Practices and Minimization Measures

The best management practices and minimization measures below are proposed by WSDOT and are considered part of the project:

- The contractor will develop and implement a temporary erosion and sediment control (TESC) plan consistent with WSDOT standards. The TESC plan will be designed to control sediments from all construction activities including site preparation, excavation, roadway and bank protection construction, transportation of materials, vegetation removal, and/or ground-disturbing activities.
- All exposed soils will be stabilized during the first available period, and will not be untreated for more than 7 days without receiving the erosion control specified in the TESC plan.
- Construction equipment will be inspected daily for leaks of hydraulic fluids, fuel, lubricants, or other petroleum products, and any necessary repairs will be completed prior to commencing work.
- No paving, chip sealing, or stripe painting will occur during periods of rain or wet weather.
- The contractor will prepare a spill prevention, control, and countermeasures (SPCC) plan prior to beginning construction. The SPCC plan will identify the appropriate spill containment materials, which will be available at the project site at all times.
- The contractor will designate at least one employee as the erosion and spill control lead. The erosion and spill control lead will be responsible for the implementation and monitoring of the TESC and SPCC plans and compliance with all local, state, and federal erosion and sediment control requirements.
- A WSDOT inspector will be on site during construction. The role of the inspector will be to ensure contract and permit requirements.
- All equipment used for construction activities will be cleaned and inspected prior to arriving at the project site to ensure no potentially hazardous materials are exposed, no leaks are present and the equipment is functioning properly.
- All concrete will be poured in the dry and will be allowed to cure a minimum of seven days before contact with surface water, per WSDOT standards. Water used to cure the concrete shall not be allowed to run off and enter surface waters.
- A concrete truck chute cleanout area shall be established to properly contain wet concrete.
- All Best Management Practices (BMPs) will be installed according to WSDOT standards and will be inspected and maintained throughout the life of the project.
- There will be no discharge of oil, fuels, or chemicals to surface waters, or onto land where there is a potential for reentry into surface waters.

- No cleaning solvents or chemicals used for tools or equipment cleaning will be discharged to ground or surface waters.
- The disposal of waste, construction or any materials into the waters of natural water bodies or groundwater will be prohibited.
- Sediment-laden water generated during construction will be pumped to an upland site to infiltrate, or to a containment tank for disposal at a permitted site.
- The contractor will be required to retrieve any floating debris generated during construction. Debris will be disposed of at an upland location.
- Barges will not be allowed to ground out during construction.
- In-water work of any kind will not occur during the months of March 15 through June 14. Impact pile driving in water will not occur February 1 through June 30 and August 21 through October 5 of all years of construction to minimize impacts to salmonids.
- A bubble curtain meeting specifications outlined by the Services will be employed for all piles installed with an impact hammer to reduce the transmission of underwater sound pressure levels.
- The murrelet monitoring protocol (Appendix B) will be implemented during all in-water impact pile driving to detect murrelets within a zone of potential physical injury.
- During the murrelet breeding season (April 1 through September 15), impact pile driving will not begin until 2 hours after sunrise and will end 2 hours before sunset during each year the project is in construction.
- Marine vegetation restoration and shoreline enhancement on the east shore of the PWN will be completed by WSDOT.
- A WSDOT biologist will re-evaluate the project for changes in design and potential impacts associated with those changes, as well as the status and location of listed species, every 6 months until project construction is completed. Consultation with the Services will be reinitiated if there are changes in project design or changes in listed species that result in effects beyond those considered in this Opinion.

## Action Area

The action area includes all areas affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR § 402.02). In delineating the action area, we evaluated the farthest reaching physical, chemical, and biotic effects of the action on the environment.

The action area is delineated by assessing the greatest extent of in-air noise and underwater sound. The loudest single construction activity is anticipated to be the placement of 36-inch steel piles using an impact hammer.

Noise is transmitted through air when an object moves, like water flowing over rocks, or air passing through vocal cords. This movement causes air waves, similar to ripples in water.

When these waves reach an animal's ears, they are perceived as noise. Noise is usually measured in decibels (dB). A decibel is a relative measure, not an absolute measure, that is accompanied by a reference scale (dB = 20 * log (P1/Pr), where P1 is the measured noise pressure and Pr is the reference pressure) to denote the Sound Pressure Level (SPL). In-air noise (which commonly is frequency-weighted to approximate human hearing) is measured on an A-weighted scale, denoted as dBA. The A-weighted decibel scale begins at zero, which represents the faintest noise that humans can hear.

The extent of in-air noise was calculated based on the distance construction noise attenuates to ambient levels. The loudest construction activity is expected to be the placement of 36-inch steel piles using an impact hammer. Construction noise was estimated based on the three loudest pieces of equipment and activities associated with the project (WSDOT 2006). In-air sound levels are expected to reach 115 dBA at 50 ft during impact pile driving (WSDOT 2008). Sound levels during other construction activities are expected to reach 101 dBA when more than one piece of equipment is used simultaneously. The baseline ambient sound levels for the project area are 51 dBA on average and 75 dBA at a maximum. Project related sound is expected to attenuate to ambient sound levels within 1,750 ft assuming soft site conditions and could possibly extend as far 18,000 ft before attenuating to baseline conditions when considering hard site conditions.

The aquatic portion of the action area consists of the underwater extent of sound produced by construction (primarily pile driving) to the point where the sound intersects a land mass or where it attenuates to background levels. Estimating the propagation of a sound wave through water is extremely complicated. The study of sound propagation has been given considerable attention (Richardson et al. 1995; Gausland 1998) and sophisticated models have been developed. Most models require site specific data and it is often not feasible to obtain the appropriate data prior to a project's implementation. In the absence of site specific data, it is possible to make predictions based on physical principles and field measurements.

Temporarily elevated underwater SPLs resulting from pile installation are expected to have the farthest reaching effects in the aquatic environment (Figure 3). Based on the supplemental information (Ward, pers. comm. 2009b), SPLs at 10 m from the pile are expected to be a maximum of 214 dB. To estimate the geographic area in which effects are expected, the distance at which transmission loss (TL) attenuates the pressures to below the thresholds must be estimated. Calculating TL is extremely complicated, and is likely to be site-specific. In the past, the USFWS has relied on a cylindrical spreading model [TL = 10*Log (R), where R = range or distance from the source] or spherical spreading model [TL = 20*Log(R)] to estimate TL. However, Reyff (2003) provided hydroacoustic monitoring data which suggest that the actual spreading loss may be intermediate between cylindrical and spherical spreading. Therefore, a practical spreading model, as described by Davidson (2004) [TL = 15*Log(R)] is more appropriate. The practical spreading model is used to estimate the distances at which injury and behavioral disruption are expected. This model assumes that SPLs decrease at a rate of 4.5 dB per doubling distance. Based on the practical spreading model, underwater SPLs associated with the proposed project are expected to extend 1.8 miles before either attenuating to ambient levels or contacting land. In the case of this project, however, due to its geographic position, we expect underwater sound produced during construction will reach the shorelines of south Sinclair Inlet and northwest to Anderson Cove before attenuating to background levels or

terminating because of land contact. As such, the aquatic action area is defined by adjacent land masses rather than by predicted levels of transmission loss.

The WSDOT BA states that turbidity will be generated during installation and removal of work trestles, and removal of the existing piers and surrounding rip rap. The WSDOT BA states that turbidity is expected to remain fairly localized and settle out within 300 ft (WSDOT 2008).

Figure 3. Depiction of the action area with the extent of in-air sound shown in red and underwater SPLs shown in blue.

## ANALYTICAL FRAMEWORK FOR THE JEOPARDY AND ADVERSE MODIFICATION DETERMINATIONS

### Jeopardy Determination

In accordance with policy and regulation, the jeopardy analysis in this Opinion relies on four components: (1) the *Status of the Species*, which evaluates the murrelet's rangewide condition, the factors responsible for that condition, and its survival and recovery needs; (2) the *Environmental Baseline*, which evaluates the condition of the murrelet habitat in the action area, the factors responsible for that condition, and the relationship of the action area to the survival and recovery of the murrelet; (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on the murrelet; and (4) *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the murrelet.

In accordance with policy and regulation, the jeopardy determination is made by evaluating the effects of the proposed Federal action in the context of the murrelet's current status, taking into account any cumulative effects, to determine if implementation of the proposed action is likely to

cause an appreciable reduction in the likelihood of both the survival and recovery of the murrelet in the wild.

The jeopardy analysis in this Opinion places an emphasis on consideration of the range-wide survival and recovery needs of the murrelet and the role of the action area in the survival and recovery of the murrelet as the context for evaluating the significance of the effects of the proposed Federal action, taken together with cumulative effects, for purposes of making the jeopardy determination.

## STATUS OF THE SPECIES (range wide)

The status of murrelets within their listed range is provided in Appendix A.

## ENVIRONMENTAL BASELINE (in the action area)

Regulations implementing the Act (50 CFR 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions and other human activities in the action area. Also included in the environmental baseline are the anticipated impacts of all proposed Federal projects in the action area that have undergone section 7 consultation, and the impacts of State and private actions which are contemporaneous with the consultation in progress.

### Existing Conditions: Setting

The project occurs in Water Resource Inventory Area (WRIA) 15 East. East WRIA 15 includes the streams and marine waters on the Puget Sound side of Key Peninsula, Gig Harbor Peninsula, South Puget Sound Islands, and Kitsap Peninsula. This WRIA is dominated by numerous short, low order, low gradient streams flowing into the Puget Sound. This WRIA is unique for this region because its streams do not receive any water from either the Olympic Mountains or the Cascade Range as their flows are supported almost entirely by precipitation and groundwater.

The WRIA drains an area of 27,492 acres, including the creeks that flow into Sinclair Inlet (primarily along the southern shore) and the Beaver Creek watershed to the east. The WRIA includes 57 miles of saltwater frontage, approximately 46 lakes with 9.7 miles of shoreline, and greater than 62 miles of streams. Gorst and Blackjack creeks are the main sources of freshwater into Sinclair Inlet (PSCRBT 1990). While several small streams occur in the action area, there are no streams in the vicinity of construction.

Sinclair Inlet and Dyes Inlet are large, partially enclosed embayments that have been significantly modified by humans. Modifications to the nearshore include loss and alteration of shallow water habitats, degradation of sediment quality, degradation of water quality, and loss of riparian vegetation along the shoreline. Nearshore habitat has been significantly altered due to extensive armoring and alteration of the marine shoreline. Roadways across or along the mouths of streams and marine shorelines have significantly altered or eliminated estuarine and nearshore

function. Extensive upland development and armoring of the shoreline has reduced the quality of intertidal habitat in the action area. Modifications to the nearshore include loss and alteration of shallow water habitats, degradation of sediment quality, degradation of water quality, and loss of riparian vegetation along the shoreline. Washington State ShoreZone Inventory (WDNR 2001) indicates that more than 95 percent of the shoreline on the north side of the bridge is modified and between five and 35 percent of the shoreline on the south side of the bridge is modified.

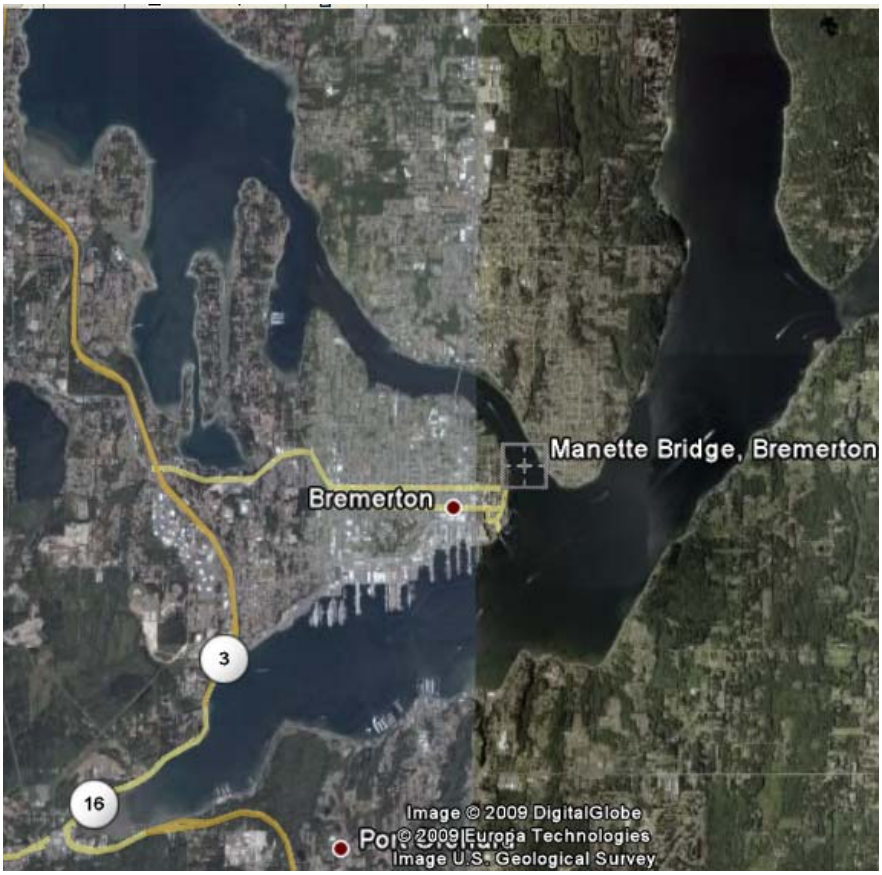


Figure 4. Water bodies in the action area.

Steep slopes on the west side of the bridge with multi-family homes built on the top are at risk for mass wasting events (WSDOT 2008). There is a lack of any functional shoreline riparian vegetation. These impacts are associated with the development of the U.S. Naval Shipyard and Intermediate Maintenance Facility, and the commercial and residential development associated with the cities and ports of Bremerton and Port Orchard (WSCC 2000). The habitat quality and natural physical processes of estuarine and nearshore environments have been severely impacted throughout much of East WRIA 15.

The main basin of Sinclair Inlet is deepest (130 ft) near the eastern end, south of Point Herron, but the head of the inlet is less than 10 ft deep. Mean higher high water in the shipping channel under the bridge is at 10.8 ft. Tideflats at the head of the inlet are exposed during low tides. The

tidal currents of Sinclair Inlet are relatively weak, at only 0.8 knots (PSCRBT 1990). However, tidal currents in the portion of the PWN adjacent to the project area range as high as 4 knots (NOAA 2008). Gravel and sand substrates are the primary substrate type in Sinclair Inlet. Mud substrates are found in the shallow west end of the Inlet. The sediments of Sinclair Inlet are considered highly degraded. Sinclair Inlet is listed as impaired by total polychlorinated biphenyls (PCBs) for 1,4-Dichlorobenzene, 2,4-Dimethyophenol, Aldrin, Arsenic, Benz(a)anthracene, Benzo(ghi)perylene, Benzoic acid, Bis(2-ethylhexyl)phthalate, Butylbenzyl phthalate, Cadmium, Chrysene, Copper, Dieldrin, Fluoranthene, Indeno(1,2,3-cd)pyrene, Lead, Mercury, PCB- 1254, PCB-1260, Phenanthrene, Zinc, and exceedance of the fecal coliform standards on Ecology's 303(d) list (Ecology 2006).

The tidal flats in Sinclair inlet adjacent to the action area are highly productive benthic habitats. The west end of Sinclair Inlet is very shallow, with excellent production of prey for fish and seabirds (WSDOT 2008). The Washington State ShoreZone Inventory (WDNR 2001) shows kelp is continuous along the PWN shoreline. Seaweed is documented in patches on the east side of the bridge. There is no eelgrass documented near the bridge but is present on the southeast shoreline of Sinclair Inlet. There are also important local spawning beaches for surf smelt (*Hypomesus pretiosus*) and Pacific sand lance (sand lance)(*Ammodytes dubius*) in Sinclair Inlet (and along much of the East Kitsap shoreline), and Pacific herring (herring) (*Clupea pallasii*) in Port Orchard (from Agate Pass to the Illahee area) (WDFW 2009a).

Upland vegetation in the project area consists primarily of small patches of mixed native and exotic species, in a landscape dominated by buildings, roads and other built environments. Scattered trees also occur in these areas. Within the clearing limits of the project, vegetation is dominated by Himalayan blackberry (*Rubus armeniacus*), Scot's broom (*Cytisus scoparius)*, English ivy (*Hedera helix*), oceanspray (*Holodiscus discolor)*, and beaked hazelnut (*Corylus cornuta*) Douglas fir (*Pseudotsuga menziesii*), Pacific madrone (*Arbutus menziesii*) and big-leafed maple (*Acer macrophyllum*) also occur along the shoreline.

The WSDOT determined ambient sound levels for in-air and underwater. The average in-air sound levels ranged from 56.7 dBA to 57.1dBA in the action area. The peak level was 75.7 dBA. Underwater sound measurements were taken from a dock just southeast of the bridge and were determined to average 136 dB. Peak levels were between 145dB and 147dB. The action area experiences recreational and commercial use by boats, ships and ferries resulting in high underwater ambient sound levels.

## Status of the Marbled Murrelet (in the action area)

### Conservation Needs of the Marbled Murrelet in the Action Area

The Marbled Murrelet Recovery Plan (U.S. Fish and Wildlife Service 1997) outlines the conservation strategy for the murrelet. Of the primary recovery plan recommendations, the following are most pertinent to the needs of murrelets within the action area.

1. Protect the quality of the marine environment essential for murrelet recovery.

2. Reduce adult and juvenile mortality in the marine environment.

The proposed project is located within Conservation Zone 1 (Puget Sound) and includes primarily marine habitat. The recovery plan has identified all waters of Puget Sound as essential for murrelet foraging and loafing.

**Likelihood of Species Presence in the Action Area**

During the breeding season, murrelets tend to forage in well-defined areas along the coast in relatively shallow marine waters (Strachan et al. 1995). Murrelets forage at all times of the day, and in some cases at night (Strachan et al. 1995).

During the pre-basic molt flightless murrelets must select foraging sites that provide adequate prey resources within swimming distance (Carter and Stein 1995). During the non-breeding season, murrelets typically disperse and are found farther from shore (Strachan et al. 1995).

The proposed action is located within Conservation Zone 1 (Puget Sound). Murrelet presence in the action area is documented by several sources. The U.S. Forest Service and the Washington Department of Fish and Wildlife (WDFW) have conducted at-sea surveys for murrelets and other seabirds in Washington for many years. However, murrelet use of the action area is not well understood because there have not been surveys conducted specifically to determine murrelet use of the action area.

The U.S. Forest Service, Pacific Northwest Research Laboratory conducts boat surveys to determine population size and trends under the Northwest Forest Plan Marbled Murrelet Effectiveness Monitoring Program. The action area for this project occurs in Conservation Zone 1 (Washington Inland Marine Waters) within stratum 3 (Puget Sound). Stratum 3 does not include the San Juan Islands, Saratoga Passage, the south side of Admiralty Inlet or northern Hood Canal. Each stratum is divided into "Primary Sampling Units" or PSUs. Each PSU is a rectangular area approximately 20 km long composed of inshore and offshore subunits. PSUs are sampled between May 15 and July 31 (Bentivoglio et al. 2002). Since 2000, the estimated population size for Conservation Zone 1 has ranged from a low of 5,500 murrelets in 2004 to a high of 9,700 in 2002. The most recent (2007) estimated population size for Conservation Zone 1 is 6,985 murrelets (4,105 - 10,382) (95 percent CI). Since 2000, the estimated murrelet density in Conservation Zone 1 has ranged from 1.56 to 2.78 murrelets per $km^2$. Specifically, in stratum 3, murrelet densities (Table 1) have ranged from 0.29 to 2.07 murrelets per $km^2$ (Huff et. al 2003).

Table 1. Marbled murrelet observations in Conservation Zone 1, Stratum 3, based on Effectiveness Monitoring for the Northwest Forest Plan (Falxa, pers. comm. 2008).

| Year | Density (birds/ $km^2$) Zone 1 Stratum 3 (Mean) |
|---|---|
| 2000 | 1.00 |
| 2001 | 2.07 |
| 2002 | 0.97 |
| 2003 | 0.79 |
| 2004 | 0.29 |
| 2005 | 2.02 |
| 2006 | 1.28 |
| 2007 | 1.80 |

The WDFW, in cooperation with the Puget Sound Ambient Monitoring Program conducts aerial surveys for seabirds in Puget Sound. These surveys are not specific to murrelets and probably underestimate murrelet presence; however, they provide useful information on the seasonal distribution of murrelets. Winter surveys were conducted in December and January from 1993 to 2006. During winter surveys, small numbers of murrelets were sighted in Sinclair Inlet near the U.S. Naval Shipyard. Densities averaged 0.5 murrelets per $km^2$.

Based on the information described above, we expect murrelets will be in the action area year-round in relatively low densities. Individuals may originate from either Conservation Zones 1 or 2.

*Forage Fish (Pacific Herring, Surf Smelt and Pacific Sand Lance)*

The status of forage fish is described here due to their importance to murrelets and their presence in the action area (figure 5). Forage fish play a key role in the food web of the marine environment and make up a significant proportion of the diets of murrelets. Forage fish are loosely defined as small, schooling fishes that form critical links between the marine zooplankton community and larger predatory fish, seabirds, and marine mammals in the marine food web (Penttila 2007; PSAT 2007). They feed mainly on zooplankton and phytoplankton and reside in the upper levels of the water column and nearshore areas (PSAT 2007). The three most common forage fish species in Puget Sound are herring, surf smelt, and sand lance. Forage fish species occupy every marine/estuary nearshore habitat in Washington State (Penttila 2007).

Within Puget Sound, each species appears to use approximately ten percent of the shoreline as spawning habitat. Some species tend to use the same beaches annually. All three species use near-shore habitats as nursery grounds (Penttila 2007). Populations of surf smelt and sand lance have not been monitored Puget Sound-wide and therefore we do not have annual abundance estimates or trends over time (Penttilla 2007). Monitoring for herring has been performed in the Puget Sound and provides a sense of abundance, trends over time and stock status. An important characteristic that forage fish populations have in common is a tendency for rapid change. Forage fish populations vary considerably, primarily due to environmental conditions (Bargmann 1998).

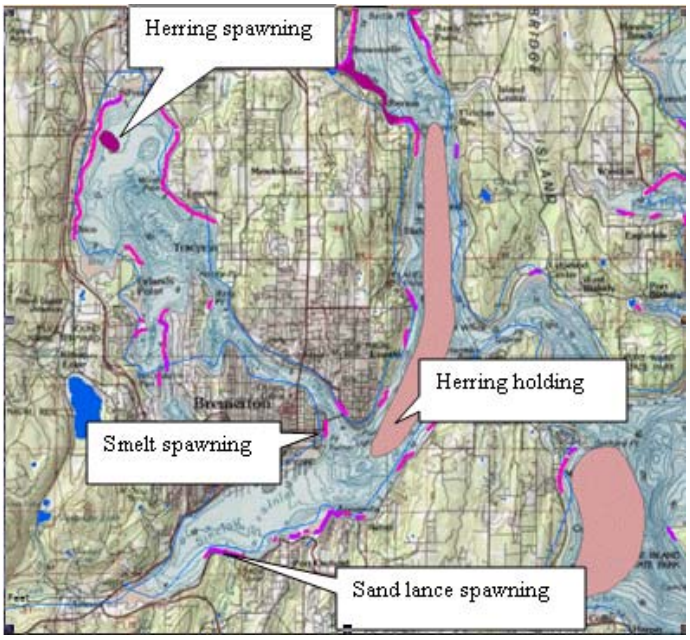


Figure 5. The polygons above represent herring holding and spawning areas.
The colored lines represent surf smelt and sand lance spawning beaches.

Pacific Herring

WDFW recognizes 19 different stocks of herring in Puget Sound, based on the timing and location of spawning activity (Stick 2005; PSAT 2007). Spawning grounds are well defined and the timing of spawning is very specific, seldom varying more than seven days from year to year (Bargmann 1998). Puget Sound herring are thought to be a mix of "resident" and "migratory" stocks, with the migratory populations cycling between winter spawning grounds in the inside waters and summer on the continental shelf off the mouth of the Strait of Juan de Fuca (Penttila 2007). It is not known which stocks are migratory and which are resident. It appears as though neither post-spawning adult herring nor pre-recruit herring persist in numbers in the immediate vicinity of any spawning ground during nonspawning times of year (Penttila 2007).

While herring spawning varies from year to year, most stocks in Puget Sound have declined since 2002 (PSAT 2007). The WDFW rates the herring stocks as either healthy, moderately healthy, depressed, critical, unknown, or extinct (Stick 2005). The stock rating is based on quality of data that WDFW indicates is either "poor," "fair to poor," "fair," or "good"(PSAT 2007). In 2008, approximately 48 percent of the herring stocks were rated as healthy or moderately healthy. This is a reduction from 2006 (Stick, pers. comm. 2009). Stock status, as defined by WDFW, is only one of several factors important to consider in our analysis.

Given the variation in data quality and the uncertainty regarding effects from stressors such as climate change, it is prudent to be conservative when predicting future trends and stock status from past data. Stock survey data have only been collected since the mid-1970's, and the size of herring populations prior to this time is unknown. Additionally, human population growth in the Puget Sound region has been significant over the last century, adding to the number and

increasing severity of stressors (e.g., degraded water and sediment quality, habitat loss/degradation) on herring and other fish species. Therefore, biomass data from 1975 to present only represents a snapshot of the health of forage fish populations during a time when perturbations may have already reduced their numbers.

Natural mortality for herring has increased significantly since the 1970s (WDFW 2009b). In addition, scientists have documented high polychlorinated biphenyls (PCBs) in herring from the central and southern basins of Puget Sound (PSAT 2007).

A portion of the pre-spawn holding area for the Port Orchard/Madison herring stock is located within the action area. The Port Orchard/Madison herring stock abundance has been fairly stable since a low point in the 1990s, with a mean spawning biomass of over 1,500 tons in the last ten years (Stick 2005). The Port Orchard/Madison stock currently has a healthy status. The estimated average Port Orchard herring stock biomass for 2001 through 2008 is approximately 417 metric tons. In 2008, 70 percent of the Port Orchard/Madison herring stock biomass was composed of two-year herring (Stick, pers. comm. 2009).

Spawning activity has been documented at the north end of Dyes Inlet (Stick 2005). However, spawning in Dyes Inlet has not been documented since then (Stick, pers. comm. 2009). Spawning occurs between early January and mid-April. Some months before the onset of spawning activity, fish begin to assemble adjacent to spawning sites in pre-spawning holding areas (Penttila 2007). Adult herring may stage in or migrate through the action area. Eggs incubate for 10-14 days before hatching. Following hatching the larvae drift in ocean currents (Bargmann 1998). Larval, juvenile, and adult herring maybe present in the action area.

Surf Smelt

Surf smelt are common, year-round residents in the nearshore waters of Puget Sound. They are a short-lived fish with most spawning populations comprised of 2-year old fish. They feed on plankton, macro-zooplankton (primarily arthropods), and are closely associated with the shoreline, spending their entire lives shoreward of the 10-fathom contour (60 ft). Surf smelt may be similar to herring in their predictable use of certain shorelines for spawning, at certain times of year. Though the specificity of spawning activities at certain sites and times suggests a degree of homing to their beaches of origin, this has not been proven (Penttila 2007). Their home ranges are unknown and there has been no assessment of stock status in Washington.

Spawning occurs during high tides on mixed-sand and gravel substrates in the upper tidal zone generally higher than plus 7 ft in tidal elevation. During spawning a single female maybe pursued by up to five males. Between 1,440 and 29,180 eggs are released during the spawning period by a single female (Schaefer 1936). Surf smelt eggs incubate for two to six weeks (WDFW 2000). Surf smelt larvae are planktonic drifters for several weeks after hatching and therefore at mercy of the currents and tides. Spawning beaches may produce larvae continuously for many months (Penttila 2007).

Known spawning locations occur in the action area along the PWN west and east shoreline adjacent to the bridge, on the southern and northern shorelines of Sinclair Inlet, north of the bridge, and in Dyes Inlet. Sinclair Inlet is heavily used (Waldbillig, pers. comm. 2009). There is

other suitable spawning habitat identified throughout the action area. Surf smelt are believed to spawn year-round in Sinclair Inlet with peak spawning in November through mid-January. Surf smelt spawn in Dyes Inlet starting around September 1 thru March 31st with the heaviest spawn occurring in mid October through December. We would expect more fish to congregating in the action area during the peak spawning time (Waldbillig, pers. comm. 2009). Adult, juvenile, and larval surf smelt are likely present in the action area year round.

Pacific Sand Lance

Sand lance are common, year-round residents in the nearshore waters of Puget Sound. They feed on macro-zooplankton, primarily arthropods. During spring and summer months, these fish are considered epibenthic, schooling pelagically during the day to forage and burrowing in the benthic substrate at night (Hobson 1986). Their home ranges are unknown and there has been no assessment of stock status in Washington.

Sand lance spawning in Puget Sound occurs from October 15 through March 1. Spawning times are not broken out by area. Spawnings may occur between November and February in multiple events without a specific peak (Bargmann 1998). Sand lance use the same stretches of beach as surf smelt at the same time of year (Bargmann 1998). Sand lance spawning is confined to the upper tidal zone, generally higher than plus five ft in tidal elevation. A single female releases around 1,400 to 16,080 eggs during the spawning period (AKNHP 2009). Eggs incubate for about four weeks. Upon hatching larvae are at the mercy of the currents and tides until they are about 22 mm in length (WDFW 2009b).

During the winter, these fish may remain buried in the sediment in a state of dormancy (Robards et al. 1999); however, sand lance may emerge from the sediments if oxygen conditions in the sediment become too low (Quinn 1999). Schools can be commonly encountered in waters over 100 ft deep. However, juveniles may be more closely associated with shorelines and protected bays, in mixed schools with herring and surf smelt of similar age and size.

Within the action area, sand lance spawning habitat has been identified on the southern shore of Sinclair Inlet. Spawning habitat is also documented in Dyes Inlet and in the surrounding vicinity. Adult, juvenile, and larval sand lance are likely present in the action area throughout the year.

## EFFECTS OF THE PROPOSED ACTION

The "effects of the action" are defined in the section 7 implementing regulations of the Act as "The direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline. Indirect effects are those that occur later in time but that are reasonably likely to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration" (50 CFR 402.02).

## Direct Effects

The primary direct effects of the proposed project derive from the nature, extent, and duration of the construction activities in the water. Negative effects may occur during the project from activities such as pile installation and removal and construction of in-water concrete piers. The installation of steel piles is expected to result in elevated underwater SPLs that will result in adverse effects to murrelets.

*Effects of Benthic Habitat Alteration*

Habitat alternation from the temporary placement and removal of 542, 36-inch piles across the PWN and the permanent placement of 18, 10-foot steel shaft casings below the mean lower low water mark could affect the prey base of murrelets. These activities will cover substrate and create temporary plumes of sediment in the water column. Direct disturbance of subtidal substrate by piles and shaft casings will result in the temporary loss of benthic and epibenthic organisms within the area affected. Approximately 3,710 $ft^2$ of benthic habitat will be disturbed for up to 3 years as a result of the installation and removal of 542 piles. However, drift of invertebrates from current is expected to rapidly recolonize the affected area once the pilings are removed (Barton 1977; Chisolm and Downs 1978; Waters 1995). Permanent displacement of benthic habitat will be limited to the 18 shafts (six piers) and a total of 1,416 $ft^2$. The proposed project will increase benthic habitat by 7,310 $ft^2$ by decreasing the bridge footprint. This will result in a recolonization of the area by benthic organisms and provide a benefit to the food web within the action area. A large amount of riprap is also being removed from the benthic floor and will not be replaced. This will increase the available benthic habitat for invertebrates and provide a benefit to the food web. The shaft casings will be advanced by a combination of their own weight (sinking into the mud), vibratory methods, and oscillating. Steel piles will be removed with a vibratory hammer. Material may be suspended by these activities but is expected to quickly dissipate or be transported away from the site by tidal currents. The time the particles remain in the water column depends on their size (small particles remain suspended longer than larger particles), the amount of mixing and lifting, and the water column speed (influenced by tide and tract location/bathymetry). The effects of suspended sediment and turbidity on fish are reported in the literature as ranging from beneficial to detrimental, though the vast majority of literature reports negative consequences from anthropogenic or naturally induced sediment regime changes. There is little literature documenting the effect of sediment on forage fish in the marine environment. Forage fish spawn and rear along naturally turbid shorelines and are frequently exposed to natural sediment plumes entering Puget Sound via freshwater tributary streams (Hamilton, pers. comm. 2008). We do not expect temporary turbidity or suspension of sediments and the permanent habitat alterations to impact the prey base to a measurable extent and therefore potential effects to murrelets are insignificant.

*Use of Barges*

Barges will be used extensively throughout the project duration to provide access to work areas, support machinery, deliver and stage materials, and as a collection surface for spoils, construction debris, and materials from demolition. The actual number and dimensions of barges to be used will be determined by the contractor. The project office has estimated that up to six barges will be used at one time. A typical barge dimension is approximately 290 ft in length and

50 ft in width. Typical barge draft is 4 to 8 ft and a typical freeboard is 3 to 6 ft. The barges will be tethered with mooring lines and temporarily anchored buoys. Barges will be used throughout the 3-year construction period. The proposed action will result in increased activity levels due to the use of barges. However, the action area likely experience significant boat traffic due to recreation, fishing, and commercial boating activities. Although the effects of human disturbance on murrelets at sea are not well documented, murrelets appear to habituate to heavy levels of boat traffic (Strachan et al. 1995). We do not anticipate that barges and other anthropogenic activities associated with the bridge replacement project will measurably affect murrelets. Therefore, effects to murrelets from this element of the project are expected to be insignificant.

*Effect of In-Air Sound Disturbance from Pile Installation*

The primary component of the proposed project that could potentially affect murrelets above the water is disturbance from construction. During construction, impact installation of steel piles is the activity that is expected to produce the highest levels of sound. Within the action area, ambient sound levels are expected to be at a range of 51 dBA - 79 dBA (WSDOT 2008). Based on sound measurements taken during installation of 36-inch diameter steel piles at the Mukilteo Test Pile Project, sound levels on the surface of the water approximately 91 m (300 ft) from impact pile driving would be approximately 89 to 92 dBA (Lmax) (WSF 2007).

Our office has previously 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 (U.S. Fish and Wildlife Service 2007). There are no known studies or data available that evaluate the response of murrelets (or other alcids) to sound in the marine environment. For projects in the marine environment, we assume that murrelet response to above-ambient sounds on the water would be similar to those expected in the terrestrial environment.

High sound levels generated by impact pile driving could mask vocalizations between murrelets. Murrelets tend to be more vocal at sea compared to other alcids (Nelson 1997). Individuals of a pair vocalize after surfacing apart from each other (Strachan et al. 1995). Vocalizations among pairs also occur after a disturbance (Strachan et al. 1995). When pairs are separated by boats, most will vocalize and attempt to reunite (Strachan et al. 1995). Strachan and others (1995) believe that foraging plays a major role in pairing and that some sort of cooperative foraging technique may be employed. This is evidenced by the fact that most pairs of murrelets consistently dive together during foraging and that they often swim towards each other before diving (Carter and Sealy 1990). Assuming vocalization plays a role in a cooperative feeding strategy, interruption of vocal communication could negatively impact foraging efficiency. Similarly, at-sea courtship could be negatively impacted. Courtship begins in early spring, continues through summer, and has also been noted in winter (Nelson 1997; Speckman et al. 2000).

We anticipate that noise levels will reach 91 dBA (source = 115 dBA at 50 ft) 243 m from impact pile driving and, therefore, the potential exists for disturbance of murrelets within this area. However, a murrelet monitoring protocol that is described in more detail below will be implemented in this area to avoid injury and mortality from underwater sound. The protocol

calls for impact pile driving to stop if a murrelet is spotted within a defined area. The potential disruption of foraging and masked vocalizations by murrelets from noise generated by impact pile driving will extremely unlikely because the protocol is designed to identify murrelet presence in the area and stop work to minimize exposure. Therefore, these effects are considered discountable.

*Effect of Piling Removal*

The project will install and remove 542 steel piles. Pile removal can potentially affect listed species via sound and vibration, and temporary turbidity. Once the piles are loosened with the vibratory hammer, they are usually pulled directly out of the water with a crane.

Vibratory and impact hammers produce underwater sound. Underwater sound can be described by instantaneous peak sound pressure level ($dB_{peak}$) and the Root Mean Square (RMS) ($dB_{RMS}$) pressure level during the impulse, sometimes referred to as the peak and RMS level respectively. The peak pressure is the instantaneous maximum overpressure or underpressure observed during each pulse and can be presented in Pascals (Pa) or SPL in decibels (dB) referenced to a pressure of 1 micropascal (dB re: 1 μPa). The RMS level is the square root of the energy divided by the impulse duration. This level is the mean square pressure level of the pulse.

Vibratory hammers produce underwater peak pressures that are approximately 17 dB lower than those generated by impact hammers (Nedwell and Edwards 2002). Not only are these sounds different in intensity, but they also differ in frequency and impulse energy (total energy content of the pressure wave), which may account for the fact that no fish kills have been associated with use of vibratory hammers. Most of the sound energy of impact hammers is concentrated between 100 and 800 Hz, the frequencies thought to be most harmful to aquatic animals, while the sound energy from the vibratory hammer is concentrated around 20 to 30 Hz. Additionally, during the strike from an impact hammer, the sound pressure rises much more rapidly than during the use of a vibratory hammer (Carlson et al. 2001; Nedwell and Edwards 2002) increasing the likelihood and severity of injury.

Depending on the location of the work, SPLs from vibratory installation and/or removal of piles may not exceed ambient sound levels. Vibratory installation of steel piles in a river in California resulted in SPLs that were not measurable above the background sound created by the current (Reyff 2006). WSDOT measured the ambient underwater sound levels just southeast of the bridge. The levels averaged 136 $dB_{rms}$. Peak levels were estimated at 147dB. Therefore, we expect underwater ambient sound levels to be relatively high.

We do not anticipate significant adverse effects to murrelets in the form of physical injury or mortality, or behavioral disruption from vibratory pile removal based on the differences, discussed above, in the underwater sounds produced by vibratory driving of piles. Therefore effects are considered insignificant.

*Effect of Impact Installation of Piles*

The proposed project will involve impact installation of steel piles. The BA indicates that impact installation will occur over 530 to 2120 hours. Five hundred and forty-two piles will be installed during 135 days of in-water work over 160 working days within a 3 year time period. The new bridge construction work trestle will be installed first and requires a maximum of 360, 36-inch diameter steel piles. The demolition work trestle will follow and be supported by 170, 36-inch diameter steel piles. Up to 12 steel piles will be installed to anchor mooring buoys. To minimize impacts to salmonids, impact pile driving will not be conducted during the months of February 1 through June 30 and August 1 through October 5. During the months of April 1 through September 15, impact pile driving will be restricted to work beginning 2 hours after sunrise and ending 2 hours before sunset to minimize impacts to murrelets during the breeding season.

High underwater SPLs are known to have negative physiological and neurological effects on a wide variety of vertebrate species including fishes and birds (Cudahy and Ellison 2002; Yelverton et al. 1973; Yelverton and Richmond 1981; Steevens et al. 1999; Fothergill et al. 2001; U.S. Department of Defense 2002). High underwater SPLs are known to injure and/or kill fishes by causing barotraumas (pathologies associated with high sound levels including hemorrhage and rupture of internal organs), as well as causing temporary stunning and alterations in behavior (Turnpenny and Nedwell 1994; Turnpenny et al. 1994; Popper 2003; Hastings and Popper 2005). In controlled experiments using underwater explosives, rapid change in SPLs caused internal hemorrhaging and mortality in submerged mallard ducks (*Anas platyrhnchos*) (Yelverton et al. 1973). Risk of injury appears related to the effect of rapid pressure changes, especially on gas-filled spaces in the bodies of exposed organisms (Turnpenny et al. 1994). In studies on ducks (*Anas spp.*) and a variety of mammals, all species exposed to underwater blasts had injuries to gas-filled organs, including eardrums (Yelverton and Richmond 1981). These data indicate that, at a coarse scale, physical responses may be similar across taxonomic groups.

High underwater SPLs can also cause a variety of behavioral responses that have not been well studied. Broadly, the effects of elevated underwater SPLs on organisms range from death to no effect. Over this continuum of effect, there is no easily identifiable point at which behavioral responses transition to physical effects. For the purposes of this analysis, we attempt to group the effects into these two categories as they are roughly correlated with key Endangered Species Act criteria for mortality and injury and significant behavioral changes. General literature and information on each category are described first, with the potential effects to murrelets described more specifically in subsequent sections.

*Effects from Impact Installation of Steel Piles Expected to Result in Mortality or Injury*

The injuries associated with exposure to high SPLs are referred to as barotraumas, and include hemorrhage and rupture of internal organs, hemorrhaged eyes, and temporary stunning (Yelverton et al. 1973; Yelverton et al. 1975; Yelverton and Richmond 1981; Turnpenny and Nedwell 1994; Hastings and Popper 2005). Death from barotrauma can be instantaneous, occurring within minutes after exposure, or several days later (Abbott et al. 2002).

Physical injury to aquatic organisms may not result in immediate mortality. If an animal is injured, death may occur several hours or days later, or injuries may be sublethal. Necropsy results from Sacramento blackfish (*Othodon microlepidotus*) exposed to high SPLs showed fish with extensive internal bleeding and a ruptured heart chamber were still capable of swimming for several hours before death (Abbott et al. 2002). Sublethal injuries can interfere with the ability to carry out essential life functions such as feeding and predator avoidance (Popper 2003).

There are no experimental data specific to impact pile driving and its effects on murrelets, or any other seabird. However, studies that have evaluated other types of underwater sounds on a variety of vertebrate species provide some basis for evaluating the effects of the high SPLs generated by pile driving on murrelets. Data related to seabirds is primarily limited to evaluations of the effects of underwater blasting and seismic testing (Yelverton and Richmond 1981; Cooper 1982; Stemp 1985; Flint et al. 2003; Lacroix et al. 2003).

Recent anecdotal information collected during monitoring of seabird response to pile driving for bridge and ferry terminal projects in Washington, have described potential behavioral responses to pile driving and documented behaviors that could be indicative of physiological effects. During replacement of the Hood Canal Floating Bridge, a pigeon guillemot (*Cepphus columba*) dove within 75 m of impact pile driving and quickly surfaced. It was then observed having difficulty getting airborne and shaking its head (Entranco and Hamer Environmental 2005). In January of 2007, WSDOT monitoring staff at the Anacortes Ferry Terminal replacement project detected a murrelet within 20 m of active pile driving. Although it was not actually observed underwater during pile driving, the murrelet was behaving aberrantly and monitoring staff followed it closely. For approximately 15 minutes it drifted very close to shore, was listing to one side, and was paddling with only one foot. The observers noted that while most seabirds were leaving the area during pile driving this individual did not dive or fly. After a few minutes the murrelet attempted to fly, but touched the water twice before landing again. Eventually it dove and was not observed again (WSF 2007, p. 4-5).

The potential for injury and/or mortality of any aquatic organism from underwater sound depends on the type and intensity of the sounds produced. These are greatly influenced by a variety of factors, including the type of hammer, the type of substrate, and the depth of the water. Firmer substrates require more energy for pile driving, and produce more intense sound pressures. Biologically, key variables that factor into whether an animal is affected include size, anatomical variation and location in the water column (Gisiner et al. 1998). Any gas-filled structure in an animal is particularly susceptible (Gisiner et al. 1998). Examples of gas-filled structures in vertebrates are swimbladders, bowel, sinuses, lungs, etc. As a sound travels from a fluid medium into these gas-filled structures, there is a dramatic drop in pressure that can rupture the hollow organs (Gisiner et al. 1998).

Sound energy from an underwater source readily enters the bodies of animals because the acoustic impedance of animal tissue nearly matches that of water (Hastings 2002). This has been demonstrated in fishes with swimbladders (such as salmonids). As a sound pressure wave passes through a fish, the swimbladder is rapidly compressed due to the high pressure and then rapidly expanded by the underpressure. At the SPLs associated with pile driving, the swimbladder may repeatedly expand and contract. This essentially hammers adjacent tissue and organs that are

bound in place near the swimbladder (Gaspin 1975). Exposure to this type of pneumatic pounding (resulting from pile driving) can rupture capillaries in the internal organs, as observed in fishes with blood in the abdominal cavity, and macerate tissues (Abbott et al. 2002; Stadler, pers. comm. 2002).

Yelverton and Richmond (1981) and Yelverton and others (1973) exposed many fish species, various birds, and terrestrial mammals to underwater explosions. Common to all the species that were exposed to underwater blasts were injuries to air and gas-filled organs, as well as eardrums. These studies identified injury thresholds in relation to the size of the charge, the distance at which the charge was detonated, and the mass of the animal exposed. Yelverton and others (1973) and Yelverton and Richmond (1981) found that the greater the fish's mass, the greater impulse level needed to cause an injury. Conversely, a fish with smaller mass would sustain injury from a smaller impulse.

At Bremerton, Washington, approximately 100 surfperch (*Cymatogaster aggregata, Brachyistius frenatus* and *Embiotoca lateralis*) were killed during impact driving of 30-inch diameter steel pilings (Stadler, pers. comm. 2002). The size of these fish ranged from 70 mm to 175-mm fork length. Dissections revealed that the swimbladders of the smallest of the fishes (80 mm fork length) were completely destroyed, while those of the largest individual (170 mm fork length) were nearly intact. Damage to the swimbladder of *C. aggregata* was more severe than to similar-sized *B. frenatus*. These results are suggestive of size and species-specific differences and are consistent with those of Yelverton and others (1975), who found size and/or species differences in injury from underwater explosions.

Another mechanism of injury and death resulting from high SPLs is "rectified diffusion", or the formation and growth of bubbles in tissue. Rectified diffusion can cause inflammation and cellular damage because of increased stress and strain (Vlahakis and Hubmayr 2000; Strotz et al. 2001) and blockage or rupture of capillaries, arteries, and veins (Crum and Mao 1996). Crum and Mao (1996) analyzed bubble growth underwater by rectified diffusion caused by sound signals at low frequencies (less than 5,000 Hz), long pulse widths, and atmospheric pressure. Their analysis indicated that SPLs exceeding 190 $dB_{peak}$ could cause bubble growth.

Due to differences between species and from variation in exposure type and duration, uncertainty remains as to the degree of potential adverse effects from SPLs between 180 and 190 $dB_{peak}$. Turnpenny and others (1994) exposed brown trout (*Salmo trutta*) to SPLs greater than 170 dB with pure tone bursts for a duration of 90 seconds. This resulted in a mortality rate of 57 percent after 24 hr in brown trout and 50 percent mortality occurring at 176 dB (95 Hz) in bass (*Dicentrarchus labrax*) and whiting (*Merlangius merlangus*). The authors suggest that the threshold for continuous sounds was lower than for pulsed sounds such as seismic air gun blasts. Sounds from pile driving are more similar to that of air guns than to pure tone bursts. As such, we conclude that the 170 dB threshold for injury to brown trout identified by Turnpenny is likely lower than the injury threshold level anticipated for pile driving from this project.

Based on the discussion above, we anticipate the potential for barotrauma to occur in aquatic organisms, including murrelets (when diving), at SPLs of greater than or equal to 190 $dB_{peak}$. We anticipate potential physical injury similar to those discussed above to occur above 180 $dB_{peak}$. The 180 $dB_{peak}$ threshold is probably conservative because most studies described

evaluated transmitted signals of longer duration that what is anticipated to result from pile driving. The potential adverse effects specifically anticipated for murrelets are described in more detail below.

*Measures to Reduce Exposure to Potentially Injurious Sound Pressure Levels*

In order to reduce the likelihood of injury to murrelets, WSDOT will use an air bubble attenuation system (bubble curtain) to reduce underwater sound during impact pile driving and they will implement a murrelet monitoring protocol (Appendix B).

Air bubbles are used to attenuate underwater sound (Gisiner et al. 1998). Air bubbles are most effective at moderate to high frequencies but are also useful for low frequency sounds and have been known to reduce SPLs at some frequencies by as much as 30 dB (Gisiner et al. 1998). During demolition of a dam on the Mississippi River, Keevin and others (Keevin et al. 1997) found a significant reduction in mortality of caged bluegill (*Lepomis macrochirus)* with use of a bubble curtain. Bubble curtains can also reduce particle velocity levels (MacGillivray and Racca 2005).

Bubble curtains are used on an increasing number of pile installation projects, primarily on the west coast. Designs have varied and are largely experimental. Effectiveness has also varied widely and is likely to be influenced by factors such as design, site conditions, and the ability for construction contractors to correctly implement the system. Improper installation and operation decreases effectiveness. Problems with implementation have been observed on a number of projects (Laughlin 2005; Pommerenck 2006).

Impact installation of large (2.4 m diameter) piles with an isolation casing combined with an air bubble curtain resulted in significant sound pressure attenuation on a project in California. During impact pile driving in the San Joaquin River an attenuation system consisting of an isolation casing with a bubble curtain on the inside achieved much less attenuation (between 6-9 dB) (Pommerenck 2006). This may have been due incorrect implementation. During impact installation of steel piles in an embayment on the Columbia River, a bubble curtain built according using the Longmuir and Lively (2001) design achieved a maximum reduction of 17 dB (Laughlin 2006). A test of bubble curtain effectiveness in Friday Harbor, Washington, noted improvements after the original design was modified to improve contact with the substrate. After modification, the bubble curtain was achieving a 12 dB reduction which equates to an 85 percent reduction in peak overpressure (Laughlin 2005). Use of a bubble curtain while installing 24-inch steel piles at a marina in Washington resulted in reductions of 10 to 15 dB (Houghton and Smith 2005). These examples illustrate the high degree of variability seen with use of air bubble attenuation systems and the influence of design, site conditions, and contractor implementation. When correctly implemented, however, bubble curtains significantly reduce the extent of potential adverse effects.

> According to the supplemental correspondence from WSDOT (Ward, pers. comm. 2008), the proposed project will implement an air bubble attenuation system capable of reducing SPLs by 10 dB and that is consistent with the specifications in the October 31, 2006, "Impact Pile Driving Sound Attenuation Specification" document prepared by USFWS and NMFS (Appendix C). The project expects that the contractor will deploy a confined

bubble curtain. Based on hydroacoustic monitoring conducted during impact installation of 36-inch piles, SPLs are expected to reach a maximum of 214 $dB_{peak}$ and 195 $dB_{rms}$ at 10 m from the pile without sound attenuation (Laughlin 2005). Accounting for the proposed attenuation, SPLs are not expected to exceed 204 $dB_{peak}$ and 187 $dB_{rms}$ at 10 m from the pile. In order to confirm this assumption, hydroacoustic monitoring will be conducted during impact pile driving activities. Recordings will be taken in various locations across the bridge according to the hydroacoustic monitoring plan (Appendix D).

To reduce the likelihood of exposure of murrelets to underwater sound, the project will implement a murrelet monitoring protocol (Appendix B). The protocol requires that qualified personnel survey the area where SPLs could exceed 180 $dB_{peak}$. To maximize effectiveness, an appropriate number of observers will be stationed on land and in boats to adequately cover the area and monitoring will only occur in weather conditions that allow good visibility. If murrelets are detected, pile driving will cease until the murrelet(s) leaves the zone of potential injury. However, due to challenges inherent in detecting and indentifying murrelets on the water, exposure to potentially harmful SPLs cannot be ruled out. Due to the small size, cryptic coloration, and diving behavior of murrelets, the survey protocol is not 100 percent effective. In a study of the effectiveness of on-water density survey protocols, single observers were found to be highly variable and 78 to 95 percent effective at detection of murrelets, while teams of paired observers were found to be less variable and 84 to 93 percent effective (Evans Mack et al. 2002 p. 872).

On-site reconnaissance and correspondence with local seabird survey experts indicated that for this site, due to its narrow restricted channel, there is a reasonable probability of detecting murrelets within 100 m when the sea state is at a Beaufort scale of 2 or better. This lead to a conclusion that this level of certainty can be obtained by the use of a boat containing a primary observer with backup coverage from the boat driver. Two additional observers will be stationed on land at advantageous spotting locations such as the bridge or work trestle. Evans Mack et al. (2002, p. 866) states that a single observer receiving back-up help from the boat driver worked well in small boats under many conditions when collecting murrelet density data. However, Evans Mack (2002, p.872) does not recommend using a single observer and cautions the use of a boat driver as an equivalent to a second observer because the driver will not be able to provide his/her complete attention to identifying murrelet presence. Our murrelet monitoring protocol generally requires two boat observers. In this site specific case, we concluded that because the monitoring area was in a narrow channel, one primary observer with back-up coverage from the boat driver would suffice. The boat will travel at 10 knots or less and cover a circuit that is 600 m long by 150 m wide. These site specific modifications to the USFWS murrelet monitoring protocol were determined appropriate due to the geographic setting of the project and familiarity with the site by murrelet surveying experts. The protocol in Appendix B specifies that observers must have completed a training session given by USFWS staff and meet other qualifications. Due to this requirement, the fact that surveying will be done continuously throughout the impact pile driving period, and the use of one primary boat observer supported by land observers, we expect monitoring efforts to be a conservative estimate of at least 78 percent effective at detecting murrelet presence.

In addition, potential adverse effects to breeding murrelets and nestlings will be minimized by the timing restriction that limits impact pile driving until 2 hours after sunrise and 2 hours before sunset during the breeding season (April 1 through September 15).

Impact pile driving will be limited during the breeding season due to the in-water work windows but will still occur in the months of July, late August, and September. The restriction will reduce the likelihood of aborted feeding attempts; however, some reduction in foraging efficiency is still expected to occur throughout the day when pile driving is occurring. Based on implementation of this diurnal timing restriction, we do not expect adverse effects to occur to nestlings.

*Estimating the Geographic Extent of Effect*

To estimate the geographic area in which effects are expected, we estimated the distance at which TL attenuates the sound pressures to below the levels where effects are expected. Calculating TL is extremely complicated, and is likely to be site-specific. The practical spreading model is used to estimate the distances at which injury and behavioral disruption are expected. This model assumes that SPLs decrease at a rate of 4.5 dB per doubling distance.

We expect that impact installation of 36-inch piles (the largest piles proposed to be used) will result in the highest SPLs and these will be a maximum of 214 $dB_{peak}$ at 10 m from the pile. Applying the practical spreading calculation (described above) allows us to estimate the distance at which SPLs will reach levels below those expected to create a likelihood of sublethal injury (Table 5). With a functioning sound attenuation system in place, SPLs above 180 $dB_{peak}$ will extend for approximately 0.25 mile (Figure 4) from the pile in each direction. The total area of effect is 0.41 $km^2$.

*Estimating the Number of Marbled Murrelets Subjected to Injury or Mortality*

We assessed the probability of exposure of foraging murrelets to high underwater SPLs in the action area by using a Bernoulli distribution probability model. The model estimates the random or chance behavior of the number of times an object in space, or event in time, occurs in a given number of trials (n). The event of interest here is the co-occurrence of murrelets and elevated underwater SPLs from impact pile driving. Since the number of trials (n) is very large and the chance of the event (p) is very small, use of an approximation of the Bernoulli distribution referred to as the Poisson distribution is appropriate because it is a better probability model for rare events. Rare events are those that occur only a few times in a very large number of potential trials. In the action area, murrelet density estimates are relatively low (0.8 to 1.2 birds/$km^2$). In Conservation Zone 1, Stratum 3, the likelihood of murrelet occurrence is rare within 500 m to 1000 m (1$km^2$) of any random point in the southern portion of Puget Sound (Falxa et al. 2008. in press). Poisson distribution models are particularly well suited for objects that occur randomly over time or space when all that is known is the average number of occurrences, in this case, murrelets per unit of time or space. The Poisson probability model assumes 1) the exposure of murrelets to underwater sound must be independent of any other exposure, 2) there is a zero-chance of two or more events occurring simultaneously, and 3) there are a constant average number of occurrences per unit of time or space.

From annual surveys summarized by Falxa and others (2008, in press), we determine the average annual murrelet density in a particular stratum by first computing the mean from the reported annual density estimates from 2000 to 2008 and dividing by the area of the stratum. We use this density for both summer and winter estimates.

Using the common forage group size of three individual murrelets (McShane et al. 2004), we calculate the average annual number of forage groups in a stratum. By assuming a random distribution of forage groups, the mean population density ($\mu$) of forage groups in a stratum is equal to the sample mean forage group density. This results in a forage group density estimate, prior to the murrelet monitoring surveys.

We then calculate the realized forage group density within the murrelet monitoring zone (zones up to 1 $km^2$), assuming the murrelet monitoring is at least 78 percent effective at detecting an individual murrelet or forage group.

In order to develop a biologically sensitive approach to quantifying murrelet exposure derived from probabilities of exposure less than 100 percent, we chose to use a probability of 10 percent as the break point at or above which we will consider one or more murrelets to occur and be subject to injury or mortality. For probabilities below 10 percent, we will assume zero murrelets to occur. This approach is consistent with a recent analysis USFWS completed on underwater noise (U.S. Fish and Wildlife Service 2008, p.99). The table below describes how the probability of exposure changes as a function of area. The probability is greater than 10 percent (Column 3) when the zone size exceeds 1.2 $km^2$, (Column 1), with application of the murrelet monitoring protocol with an estimated effectiveness of 78 percent. While the underwater sound attenuation system serves the valuable purpose of reducing the extent of the murrelet monitoring area, these estimates are independent of its effectiveness because of its variability and site specific results. Consequently, we assume zero attenuation for this analysis.

Table 2. Probability of murrelet forage group(s) within 1.2 $km^2$

| Area | mu | P(x=1) |
|---|---|---|
| 1 | 0.0868 | 0.0796 |
| 1.1 | 0.0954 | 0.0868 |
| 1.2 | 0.1041 | 0.0938 |
| 1.3 | 0.1128 | 0.1008 |
| 1.4 | 0.1215 | 0.1076 |
| 1.5 | 0.1301 | 0.1143 |
| 1.6 | 0.1388 | 0.1208 |
| 1.7 | 0.1475 | 0.1273 |
| 1.8 | 0.1562 | 0.1336 |

We calculated the probability of the number of forage groups (X) as a function of the size ($km^2$) of the murrelet monitoring area. If the probability P (X=1, 2, 3, etc.) is less than or equal to 0.10, then we assume the event is not reasonably certain to occur. The total area of potential injury/mortality as a result of impact pile driving for this project is 0.41 $km^2$. This is well under the 1.2 $km^2$ area that results in a probability of 10 percent or greater of exposure. Therefore, we do not anticipate injury or mortality of murrelets.

*Impact Installation of Steel Piles Expected to Result in Significant Disruption of Normal Behavior*

There are no experimental data available specific to the response of murrelets to underwater sound from pile driving. In fact, there is much uncertainty regarding the behavioral response of organisms in general to underwater sound. Most of the information on the behavioral effects of underwater sound is from studies using pure tone sounds. Sounds generated by pile driving, however, are impulsive sounds and are made up of multiple frequencies/tones, making comparisons with existing data difficult. Additionally, the few data that do exist are focused primarily on the response of humans, marine mammals, and fishes. With the exception of a few preliminary studies and limited anecdotal information, the following analysis draws heavily from the literature on fishes. Consequently, we make reasoned inferences from these data to assist us in evaluating potential effects to murrelets.

Behavioural response of seabirds, including murrelets, was monitored during construction of the Hood Canal Floating Bridge Replacement project (Entranco and Hamer Environmental 2005). Observers noted that at the beginning of the pile driving work the majority of seabirds in the vicinity responded by flushing, but that this response lessoned over time, indicating that there was some habituation. Their observations also noted that, despite ongoing construction disturbance, murrelets came within close proximity of the project and continued to dive and forage. In January of 2007, WSDOT monitoring staff at the Anacortes Ferry Terminal replacement project detected a murrelet within 20 m of active pile driving. The bird was behaving aberrantly and monitoring staff followed it closely while simultaneously communicating with the contractor to cease pile driving. For approximately 15 minutes the bird drifted very close to shore, was listing to one side, and was seen paddling with only one foot. The observers noted that while most seabirds were leaving the area during pile driving this bird did not dive or fly. After a few minutes the bird attempted to fly but touched the water twice before landing again. Eventually the bird dove and was not observed again (WSF 2007, pp. 4-5). These observations have noted disorientation in alcids (including one murrelet) as an apparent result of exposure to elevated SPLs from pile driving (Entranco and Hamer Environmental 2005; WSF 2007).

Exposure to elevated SPLs can result in temporary hearing damage referred to as temporary threshold shift (TTS). Most bioacoustic specialists consider TTS to be physiological fatigue, and not injury (Popper et al. 2006). However, an organism that is experiencing TTS may suffer the consequences of not detecting biologically relevant sounds such as approaching predators or prey, and/or mates attempting to communicate (Entranco and Hamer Environmental 2005). During monitoring of seabird responses to pile driving in Hood Canal, Washington, a pigeon guillemot (*Cepphus columba*) appeared disoriented and was observed having difficulty getting airborne after being exposed to underwater sound from impact pile driving (Entranco and Hamer Environmental 2005). Although it is impossible to know whether this individual was suffering from TTS, the behavior it was exhibiting likely made the individual more vulnerable to predators.

Turnpenny and others (1994) attempted to determine a level of underwater sound that would elicit behavioral responses in brown trout, bass, sole, and whiting. With brown trout, an avoidance reaction occurred above 150 $dB_{rms}$ and other reactions (e.g., a momentary startle), were noted at 170-175 $dB_{rms}$. The report references Hastings' "safe limit" recommendation of 150 $dB_{rms}$ and concludes that the Hastings' "safe limit" provides a reasonable margin below the lowest levels where fish injury was observed. In an associated literature review, Turnpenny and Nedwell (1994) also state that the Hastings' 150 $dB_{rms}$ limit did not appear overly stringent and that its application seemed justifiable. Additionally, observations by Feist and others (1992) suggest that sound levels in this range may also disrupt normal migratory behavior of juvenile salmon.

Fewtrell (2003) held fish in cages in marine waters and exposed them to seismic airgun impulses. The study detected significant increases in behavioral responses when SPLs exceeded 158 – 163 $dB_{rms.}$ Responses included alarm responses, faster swimming speeds, and tighter groups and movement toward the lower portion of the cage. It is difficult to discern the significance of these behavioral responses. The study also evaluated physiological stress response by measuring plasma cortisol and glucose levels and found no statistically significant changes. Conversely, Santulli and others (Santulli et al. 1999) found evidence of increased stress hormones after exposing caged European bass to seismic survey sound.

Clearly, there is a substantial gap in scientific knowledge on this topic. The most recent study by Fewtrell presents, at least, some experimental data on behavioral responses of fishes to impulsive sounds above 158 $dB_{rms}$. Given the large amount of uncertainty that lies in extrapolating from experimental data to the field, between sound sources (airguns vs. pile driving), and from one species to another, we believe it is appropriate to utilize a conservative threshold. As such, for the purposes of this analysis, we anticipate that SPLs in excess of 150 $dB_{rms}$ will cause significant behavioral changes in murrelets.

Impact pile driving will occur for a total of 24 weeks. A maximum of 135 days of pile driving will take place over 160 working days within a 690-day time period. Impact pile driving is expected to result in significant changes to the normal behaviour of murrelets. These changes in behaviour could result in adverse effects stemming from aborted feeding attempts, multiple delayed feeding attempts within a single day or across multiple days, and precluded access to suitable foraging habitat. These effects could result in an increased risk of predation and reduced fitness in adults, creating a likelihood of eventual injury. Although detecting effects of sub-lethal noise disturbance at the population level is hindered by the breeding biology of the murrelet, the effect of noise disturbance on murrelet fitness and reproductive success should be considered (McShane et al. 2004). In recently completed analyses, the Service concluded the potential for injury associated with disturbance (visual and sound) to murrelets in the terrestrial environment includes flushing from the nest, aborted feeding, and postponed feedings (U.S. Fish and Wildlife Service 2003). These responses by individual murrelets to disturbance stimuli can reduce productivity of the nesting pair, with consequences to the entire population (U.S. Fish and Wildlife Service 1997). Exposure to elevated SPLs underwater may result in all of the above responses for the duration of pile driving associated with this project.

*Measures to Reduce Exposure to Sound Pressure Levels that may Significantly Disrupt Normal Behavior*

As mentioned above, the proposed project will implement an air bubble attenuation system capable of reducing SPLs by 10 dB, consistent with the specifications in the October 31, 2006 "Impact Pile Driving Sound Attenuation Specification" document prepared by USFWS and NMFS (Appendix C).

*Estimating the Geographic Extent of Effect*

We used the practical spreading model to estimate the extent of potential behavioral disruption. This model assumes that SPLs decrease at a rate of 4.5 dB per doubling distance. With a functioning attenuation system in place, SPLs above 150 $dB_{rms}$ are expected to extend for 1.34 mi from impact pile driving (Figure 4), for a total area of 6.25 $km^2$.

*Estimating the Number of Marbled Murrelets Subjected to a Significant Disruption of Normal Behaviors*

To calculate the number of murrelets that will experience a significant disruption of normal behaviors we use habitat area as a surrogate. We use the same methods described above in *Estimating the Number of Marbled Murrelets to Injury/Mortality Area* to determine the number of birds we might expect, at a given time, within the area where SPLs will exceed 150 $dB_{rms}$ (including the area where murrelet monitoring will occur). Based on those methods, we expect that there is a significant (greater than or equal to 10 percent) likelihood of exposing four forage groups (12 individual birds) to SPLs above 150 $dB_{rms}$ at any moment in time in the 6.25 $km^2$ area. We expect that some of these birds will be new to the area and some will be exposed repeatedly as impact pile driving activities continue day after day. However, we do not know which conservation zones (1 or 2) these individual murrelets may originate from. Recent radio-telemetry data indicates murrelets move between zones 1 and 2 to forage (Bloxton and Raphael 2008).

It is difficult to determine at what point repeated exposures to high SPLs creates a likelihood of injury due to significant disruptions of behavior. However, we believe it is reasonable to assume that all murrelets in the 6.25 $km^2$ area will be adversely affected during the duration of impact pile driving. We use habitat area as a means for describing the extent of expected adverse effects. Exposure is expected to be temporary and murrelets are not expected to be precluded from foraging in the action area.

*Effects of Impact Installation of Steel Piles to Murrelet Prey Base*

Small schooling fish and large pelagic crustaceans are important components of the murrelet prey base. Sand lance, northern anchovy, immature herring, capelin, Pacific sardine, juvenile rockfishes (*Sebastas* spp.) and surf smelt are the most common forage fish species eaten by murrelets. Squid (*Loligo* spp.), euphausiids (krill), mysid shrimp, and large pelagic amphipods are the main invertebrate prey. Of particular importance are prey that provide higher lipid content, such as herring and sand lance.

Spawning habitat for sand lance, surf smelt and pre-spawning holding for herring are within and immediately adjacent to the action area. We expect that adult, juvenile, and larval forage fish, including surf smelt, sand lance, and herring, will be exposed to potentially injurious SPLs from impact pile driving.

High underwater SPLs are known to have negative physiological and neurological effects on a wide variety of vertebrate species, including fishes and birds (Yelverton et al. 1973, p. 9; Yelverton and Richmond 1981, p. 6; Steevens et al. 1999; Fothergill et al. 2001; Cudahy and Ellison 2002; U.S. Department of Defense 2002). High underwater SPLs can injure and/or kill fishes by causing barotraumas (pathologies associated with high sound levels including hemorrhage and rupture of internal organs), as well as causing temporary stunning and alterations in behavior (Turnpenny and Nedwell 1994; Turnpenny et al. 1994; Popper 2003; Hastings and Popper 2005). Death from barotrauma can be instantaneous, occurring within minutes after exposure, or several days later (Abbott et al. 2002). The severity of effects from high sound levels produced by impact-driving of steel piles depends on several factors, including the size of fish exposed. At Bremerton, Washington (location of the proposed project), approximately 100 surfperch (*Cymatogaster aggregata, Brachyistius frenatus* and *Embiotoca lateralis*) were killed during impact driving of 30-inch diameter steel pilings (Stadler, pers. comm. 2002). The size of these fish ranged from 70-mm to 175-mm fork length. Regardless of species, smaller fish appear to be far more sensitive to injury (Yelverton et al. 1975).

We expect that all life stages of forage fish, including sand lance, surf smelt, and herring, will suffer injury and mortality as a result of elevated SPLs caused by impact pile driving. Forage fish will be exposed to these effects during in-water work over the 3-year duration of the project. In the analysis conducted by NMFS for their Opinion on this project, they concluded that large numbers of larval, juvenile, and adult forage fish will be unavoidably exposed to elevated SPLs sufficient to cause injury or death (National Marine Fisheries Service 2009). They estimate that all fish using the action area during impact pile driving out to 541 m from a pile will be at risk of injury and mortality. The draft NMFS Opinion states that a temporary reduction in forage fish abundance will result in an adverse affect on the abundant forage element of chinook (*Oncorhynchus tshawytscha*) critical habitat Primary Constituent Elements #5. The proposed action is likely to cause adverse effects on juvenile and adult chinook and steelhead (*O. mykiss*) from injury or death caused by impact pile driving. In addition, NMFS also concluded that the proposed action will result in a temporary adverse effect to Essential Fish Habitat for Pacific salmon, west coast ground fish, and some coastal pelagic species as a result of high SPLs that will cause a localized decrease in forage fish abundance (National Marine Fisheries Service 2009).

Herring are found within Puget Sound throughout the year (Stout et al. 2001, Penttilla 2007). Herring in the action area are most likely from the Port Orchard/Madison stock. The Port Orchard/Madison herring stock abundance has increased since a low point in the 1990s. In recent years, spawn deposition was observed primarily in Hidden Cove (north Bainbridge Island) and Point Bolin (southeast of Poulsbo). Several separate pre-spawner holding areas are part of the Port Orchard/Madison stock, and a portion of the pre-spawn holding area for this stock is within the action area (WDFW, 2005). Spawning activity for this stock occurs from early

January through mid-April, with peak activity in late-February and early-March. Herring congregate in the general area of their spawning grounds 3 to 4 weeks prior to the beginning of spawning activities (Bargmann 1998). Herring have the greatest potential to be affected during this time as they will be congregating in, and may be migrating through, the action area. We expect adult pre-spawn herring may be exposed to elevated SPLs that cause injury and mortality.

Surf smelt are found in Puget Sound at all times of the year and spawn throughout the year (WDFW 2009b). Little is known about their adult life stage but they may stay near their spawning areas (Penttilla 2007). Surf smelt populations within the action area will be affected because known spawning locations occur along the PWN shoreline adjacent to the bridge on the east and west side, in the northern portion of the PWN, the southern and northern shores of Sinclair Inlet, and throughout Dyes Inlet. Even though surf smelt are shoreline oriented, they do migrate out to waters 60 ft in depth. The spawning period for surf smelt overlaps with proposed pile driving in every month. Impact pile driving will occur over a 3-month period at the same time we expect peak surf smelt spawning in the action area. Therefore, we expect all life stages of surf smelt will be exposed to elevated SPLs that cause injury and mortality.

Sand lance can be found within Puget Sound throughout the year (Pentilla 2007). Sand lance spawn in late fall and winter (Robards et al 1999). Within the action area, sand lance spawn in the same general locations as surf smelt on the southern shore of Sinclair Inlet and in Dyes Inlet and spawn mid-October through February. Impact pile driving will occur over a 3-month period at the same time we expect sand lance spawning in the action area. Therefore, we expect all life stages of sand lance will be exposed to elevated SPLs that cause injury and mortality.

<u>Estimating the Numbers of Forage Fish Subjected to Injury or Mortality</u>

It is difficult to discern the magnitude of effects that exposure to elevated SPLs will have on forage fish populations because of stock size fluctuations, their migratory nature, and lack of abundance data. Based on NMFS's analysis of the proposed project (National Marine Fisheries Service 2009), we expect that any fish migrating, spawning, foraging and/or rearing in the 541-m area around a pile during impact installation will be exposed to SPLs sufficient to cause injury and/or mortality. The consequence of these impacts to murrelets is described below.

*Surf Smelt and Pacific Sand Lance*

The project is located in a narrow channel that provides the only access to suitable spawning habitat in Dyes Inlet and PWN. Due to the duration, timing, and location of the project combined with the fact that surf smelt and sand lance must move through the project area to access, and disperse from spawning habitat, we expect that substantial numbers of these fish will encounter potentially injurious levels of underwater sound. Larvae and juveniles produced in Dyes Inlet will likely be carried into the zone of potential injury and mortality by the current. Over the months and years that impact pile driving occurs, successful surf smelt spawning at the two beaches adjacent to the Manette Bridge will be essentially precluded. At these two locations, we expect all life stages to be injured or killed, especially during the peak spawning period. As such, forage fish production in the action area will be eliminated for the duration of the project.

All life stages of sand lance and surf smelt that spawn in Sinclair Inlet will likely be exposed to elevated SPLs. Larvae are likely to be more susceptible because their movement is entirely dependent upon currents and tides. Juvenile and adult movements between spawning seasons are virtually unknown (WDFW 2009b). Therefore, we expect that schools of adults and juveniles produced in Sinclair Inlet are likely to use the PWN and enter the area of injury and mortality during impact pile driving.

Due to the timing and duration of impact pile driving, the severity of effects to small fish, and the documented presence of surf smelt and sand lance spawning habitat, we anticipate a measurable reduction in these two forage fish populations in Dyes Inlet, PWN, and Sinclair Inlet. This reduction is expected to last for at least 5 years because surf smelt spawn at year two and sand lance typically at year three.

*Pacific Herring*

A portion of the pre-spawn holding area for the Port Orchard herring stock is within the action area. Prior to spawning, two- to five-year old adults hold for up to five weeks before migrating to their spawning grounds. We believe that large schools of pre-spawning herring are likely to move into the area of elevated SPLs that cause injury and mortality based on the close proximity of the holding area to this area.

Natural mortality for herring is estimated to be 20-30 percent higher in Puget Sound than elsewhere in the world. However, good two-year-old recruitment in recent years has sustained most stocks in Puget Sound (WDFW 2009b). Recruitment is defined as an estimate of the biomass of new spawners in a particular year (Stick 2005). Recruitment failure, considering the high natural mortality, would lead to dramatic stock biomass declines (WDFW 2009b).

We anticipate that pre-spawn adult herring are likely to be injured or killed by exposure to elevated SPLs during the months of late December and January of each year of impact pile driving. Due to the duration of pile driving, we expect that some of the herring exposed to elevated SPLs will be new spawners. While larval herring could reach the area of harm and injury because their movement is subject to tides and currents, the timing of in-water pile driving limits the likelihood of their potential exposure. Based on the potential impacts to pre-spawn adults, however, we expect a local reduction in herring numbers and distribution over the life of the project that will create a temporary reduction in herring biomass.

In summary, SPLs resulting from impact pile driving, sufficient to injure and/or kill surf smelt, sand lance, and herring (as well as other forage fish) will occur within 541 m of each pile installed over the 3-year duration of the project. Additionally surf smelt spawning in the project vicinity will be affected to the extent that productivity could be precluded for the 3-year construction period. Forage fish produced in Sinclair and Dyes Inlet are also likely to utilize the action area, and are expected to be exposed to potentially injurious SPLs. As a result, we expect a measurable temporary reduction in forage fish numbers and biomass within Dyes Inlet, PWN, and Sinclair Inlet. This reduction in biomass is expected to last for at least 5 years.

*Effects to Murrelets from a Reduction in Prey Abundance*

Sand lance, northern anchovy (*Engraulis mordax*), immature herring, capelin (*Mallotus villosus*), pacific sardine, juvenile rockfishes (*Sebastas* spp.) and surf smelt are the most common fish species eaten by murrelets. Adults, sub-adults, and hatching-year murrelets feed primarily on larval and juvenile fish, and nestlings are commonly fed larger second-year fish. Sand lance is the most common food of the murrelet rangewide, and appears to be the most important prey in a chick's diet (U.S. Fish and Wildlife 1997). During the breeding season adults and chicks rely on schooling fish including surf smelt, herring, and sand lance as the main food sources. In the winter and spring, murrelets rely on crustaceans, capelin, surf smelt, and herring as the dominant prey (Nelson 1997).

Murrelet survival and reproduction is dependent upon an adequate quantity of high quality food throughout the year. Adequate food resources are necessary to survive winter, undergo molts, prepare for breeding in the spring, and to feed chicks during rearing. Wintertime distribution of murrelets appears to be related to concentrations of prey species (Dawson et al. 2007). Murrelets select foraging sites that provide adequate prey resources, such as consistent levels of higher trophic-level fishes (Becker 2001), and that are easily accessible during the pre-basic molt when they are flightless for up to 2 months. A complete pre-basic molt occurs from mid-July through December (Carter and Stein 1995; Nelson 1997). During this time, if prey are limiting murrelets swim to another more advantageous foraging location or increase dive attempts. Either outcome requires expending considerably more energy. This scenario is likely to be during the first year of pile driving activities. In subsequent years, murrelets may be displaced to other areas for the remainder of the project and prey recovery time. Murrelets can make substantial changes in foraging sites during the breeding season, but many birds routinely forage in the same general areas and at productive foraging sites (Carter and Sealy 1990, Whitworth et al. 2000, Becker 2001, Hull et al. 2001, Mason et al. 2002, and Piatt et al. 2007). Flexibility in foraging behaviors has been demonstrated widely for seabirds. However, thresholds likely exist where foraging flexibility can no longer buffer reproduction success against very low food availability (Dall and Boyd 2002 in Ronconi et al. 2008).

Breeding murrelet adults exercise more specific foraging strategies when feeding chicks, usually carrying a single, relatively large (relative to body size) energy-rich fish to their chicks (Burkett 1995; Nelson 1997), primarily around dawn and dusk (Nelson 1997; Kuletz 2005). Becker and others (2007) found murrelet reproductive success in California was strongly correlated with the abundance of mid-trophic level prey (e.g., sand lance, juvenile rockfish) during the breeding and post-breeding seasons. Prey quality can contribute substantially to the reproductive success or failure of seabirds. Dietary energy content is often the limiting factor for seabird breeding success (Litzow et al. 2002). Prey types are not equal in the energy they provide. For example, parents delivering fish other than age-1 herring may have to increase deliveries by up to 4.2 times to deliver the same energy value (Kuletz 2005). This can result in a substantial increase in energy expenditure by the parents, both in capturing prey and delivering it to the chick. Increases in prey capture and delivery efforts by the adults results in reduced adult body condition by end of the breeding season, and increases the predation risks to adults and chicks as more trips inland are required (Katherine Kuletz, U.S. Fish and Wildlife Service, *in litt.* 2006). Ronconi and Burger (2008) found that even though murrelets increased their foraging effort

during years of low prey availability, they were not able to maintain normal levels of reproductive success.

Impact pile driving activities may reduce an individual murrelet's foraging success or efficiency and/or reproductive success as a result of a reduction in high and mid-trophic level prey abundance. Any forage fish utilizing, or migrating through, the 541 m zone where injury and mortality is expected, will be affected. We expect that both high-and mid-trophic-level forage fish will be injured or killed during both murrelet molting periods and breeding seasons for three consecutive years.

Based on the expected reductions in forage fish biomass described above, it is likely that murrelets utilizing the action area will encounter reduced prey availability for the duration of the project and for multiple years after construction until forage fish populations rebound. It is reasonable to assume these reductions in prey will limit the ability of murrelets to undergo molt, survive winter, or reproduce successfully. Therefore, we expect that a temporary reduction in high-and mid-trophic-level prey abundance (high quality food) will create a likelihood if injury by significantly disrupting normal foraging and breeding behaviors of murrelets in the action area.

Estimating the Extent of Adverse Effects Related to a Reduction in Prey Abundance

It is difficult to quantify the number of murrelets that will be adversely affected by a reduction in prey abundance because of the natural variation in year to year prey abundance and the migratory nature of both murrelets and forage fish. As such, we used habitat area affected as a surrogate for describing the extent of these adverse effects. For this analysis we use the full extent of the action area (6.25km$^2$), because both forage fish and murrelets occur throughout the action area and depending on forage fish occurrence, murrelets could experience reduced foraging effectiveness anywhere within the action area in any given year. Therefore, we expect significant disruption of normal behaviors in all murrelets within the action area for 5 years of reduced fish abundance.

*Summary*

Elevated underwater SPLs associated with impact pile driving will cause adverse effects to murrelets. Several measures will be implemented to minimize the exposure to murrelets. The proposed sound attenuation system and murrelet monitoring protocol included as part of this project will substantially reduce the extent and/or severity of the potential impacts from pile installation to murrelets. Adverse effects to breeding murrelets will be minimized by restricting impact pile driving activities to the time from 2 hours after sunrise to 2 hours before sunset during the breeding season (April 1- September 15). Impact pile driving will be limited during the breeding season due to the in-water work windows but will still occur in the months of July, late August, and September. The timing restriction will reduce the likelihood of aborted feeding attempts by adult murrelets to nesting chicks, however some reduction in foraging efficiency may still occur throughout the day. We do not expect impact pile driving to result in mortality or injury of murrelets in a 0.41 km$^2$ area from a pile with the monitoring protocol implemented. We expect that the normal behaviors of all murrelets within 6.25 km$^2$ of pile installation will be adversely affected for the duration of impact pile driving. We estimate that at any moment in

time, four forage groups maybe present in this area. All murrelets that forage within the action area will encounter reduced prey abundance which is expected to lead to significant disruptions in normal behavior for up to 5 years.

## CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local or private actions that are reasonably certain to occur in the action area considered in this Opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act.

Current and future stressors are expected to adversely affect murrelets. Urban development and climate change are two stressors that are likely to affect conditions in the action area and the listed resources that occur there, including murrelets.

Urban development is reasonably certain to occur adjacent to the action area and will likely result in increased stormwater and wastewater discharges. Murrelets and their prey species are likely to be negatively affected as a result of degraded water quality from these discharges. The severity of effects to murrelets will depend on the amount and concentration of contaminants discharged, which is determined by many factors (e.g., existence of stormwater BMPs, maintenance of the stormwater BMPs, time between rain events), and is likely to be more severe in urbanized areas. Continued negative effects to prey abundance is of particular concern. Disruption of murrelet foraging due to high levels of boat traffic may also have adverse effects.

Climate change is anticipated to result in sea level rise, increased water temperatures, and decreases in the pH of marine waters in the action area. As sea level rises, a greater amount of shoreline will likely be armored to protect public property and reduce threats to public safety (Penttila 2007, p. 18). Current levels of shoreline armoring within Puget Sound have interfered with natural erosion of upland material (organic and inorganic debris) onto the beach and into the intertidal area, caused beach scouring, and resulted in changes in population structure of epibenthic and benthic organisms. A decrease in marine water pH is expected to affect marine organisms at the base of the food chain and those species that are temperature sensitive, such as forage fish species. Increased water temperatures will likely affect forage fish populations directly by influencing survival and growth, and indirectly by changing the predator/prey ratio (US Global Change Research Program 2003).

Increasing acidification of marine waters may have significant impacts on marine food-webs and is likely to adversely affect the forage fish food base. Calcifying species of plankton are expected to suffer serious negative impacts from increased ocean acidification. The negative impacts of increased acidity on plankton may cause negative impacts to many other species which are important food sources for juvenile salmon, herring, and cod (Ruckelshaus and McClure 2007, p. 55).

The anticipated future changes in water quality (pH and temperature) along with a loss or degradation of habitat from increased armoring and effects on prey are expected to add to the current stressors on murrelets.

## CONCLUSION

After reviewing the current status of the murrelet, the environmental baseline for the action area, the effects of the proposed Manette Bridge replacement and the cumulative effects, it is the USFWS's Biological Opinion that the project , as proposed, is not likely to jeopardize the continued existence of the murrelet. No critical habitat has been designated for this species in the action area, therefore, none will be affected.

- The population in Conservation Zone 1 (Washington Inland Marine Waters) is relatively large compared to other recovery zones, with an estimated population of 7,000 (4,100 - 10,400). However, the poor breeding success inferred from juvenile ratios determined through at-sea monitoring in Conservation Zone 1 and an adult survival estimate of 0.83 to 0.93, led investigators to conclude the murrelet population trend is negative (Ralph et al. 1995b; Cam et al. 2003; McShane et al. 2004b). We do not anticipate measurable adverse effects at the scale of the conservation zone because the action is temporal and will not reduce numbers, reproduction and distribution of murrelets.

- A number of conservation measures, including implementation of a murrelet monitoring protocol, the use of an air bubble attenuation system, and diurnal timing restriction are proposed as part of the project. These measures will greatly reduce the extent of adverse effects to murrelets.

- Direct injury or mortality of murrelets is not anticipated.

- All individuals in a 6.25 $km^2$ area will experience disruptions to their normal behaviors (including free movement and/or foraging throughout the action area) from elevated SPLs above 150 $dB_{rms}$ for 135 days of impact pile driving July 2010 through November 2013. These disruptions may displace and/or reduce the success of foraging attempts within the action area but we do not expect them to result in measurable reductions in numbers (abundance), reproduction (productivity), or distribution at the scale of the Conservation Zone. Murrelets will not be precluded from foraging and the fitness of exposed individuals is expected to recover over time.

- Exposure of forage fish to elevated SPLs will result in a measurable reduction of prey abundance. Forage fish reductions will occur during both murrelet molting periods and the murrelet breeding season, which is anticipated to significantly disrupt foraging behavior. Therefore, all murrelets foraging in the action area will be temporarily adversely affected by a significant disruption to their normal behaviors for five years. These disruptions may cause displacement and/or failed foraging attempts, but will not translate to measurable effects to numbers (abundance), reproduction (productivity), or distribution at the scale of the Conservation Zone. We do not anticipate a measurable reduction in population or reproduction (over the long term) at the scale of the conservation zone, even though murrelets may experience local shifts in foraging locations.

## INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound kill, trap, capture, or collect, or to attempt to engage in any such conduct. *Harm* is defined by the USFWS as an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 CFR 17.3). *Harass* is defined by the USFWS as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by the WSDOT so that they become binding conditions of any grant or permit issued, as appropriate, for the exemption in section 7(o)(2) to apply. The FHWA has a continuing duty to regulate the activity covered by this incidental take statement. If the FHWA 1) fails to assume and implement the terms and conditions or 2) fails to require the WSDOT to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the WSDOT must report the progress of the action and its impact on the species to the USFWS as specified in the incidental take statement [50 CFR 402.14(i)(3)].

### AMOUNT OF TAKE

The USFWS anticipates that all murrelets in a 6.25 $km^2$ area from impact pile driving activities could be taken as a result of this proposed action. The incidental take is expected to be in the form of harassment (significant disruption of normal behaviors) as described below:

- As a direct effect of exposure to elevated underwater SPLs resulting from impact pile driving. Approximately 542 steel piles will be installed between July 2010 and November 2013 (approximately 160 working days).

- As a result of a measurable reduction in prey abundance for 5 years caused by forage fish exposure to elevated SPLs.

The USFWS anticipates incidental take in the form of harassment of murrelets will be difficult to detect for the following reason(s): 1) the species' small body size and cryptic coloration; 2) the low likelihood of finding a dead or impaired specimen; and 3) the large area of impact. However, the following level of take of this species can be characterized by the maximum area

of exposure. The duration of the project, size of the area, and migratory nature of murrelets makes it difficult to quantify take by number of individuals and we therefore use area of impact as a surrogate.

## EFFECT OF THE TAKE

In the accompanying Opinion, we determined that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

The proposed action incorporates design elements and conservation measures that we expect will minimize impacts during construction. We assume WSDOT and FHWA will fully implement these measures and therefore they have not been specifically identified as Reasonable and Prudent Measures or Terms and Conditions.

## REASONABLE AND PRUDENT MEASURE

The USFWS believes the following reasonable and prudent measure (RPM) is necessary and appropriate to minimize the effect of incidental take of murrelets**.**

1. Minimize and monitor incidental take caused by elevated underwater SPLs from impact driving of steel piles.

## TERMS AND CONDITIONS

In order to be exempt from the prohibitions of section 9 of the Act, the (agency) must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

The following terms and conditions are required for the implementation of RPM 1:

1. Use a vibratory hammer to install steel piles until impact proofing is needed to establish load bearing or advancement through consolidated material. If vibratory driving is not possible given the substrate, then impact pile driving is acceptable.

2. Contact the USFWS within 24 hours if the hydroacoustic monitoring indicates that the SPLs will exceed the extent of take exempted in the Opinion. The FHWA shall consult with the USFWS regarding modifications to the proposed action in an effort to reduce the SPLs to the levels described in the Opinion and continue hydroacoustic monitoring.

3. Within 60 days of completing the hydroacoustic monitoring, a report shall be submitted to the Service (attn: Emily Teachout or Acting Transportation Team Lead). The contents of this report are specified in Appendix D.

The USFWS expects that the amount or extent of incidental take described above will not be exceeded as a result of the proposed action. The RPM, with its implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, this level of incidental take is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided. The FHWA and WSDOT must provide an explanation of the causes of the taking and review with the USFWS the need for possible modification of the reasonable and prudent measures.

The USFWS is to be notified within three working days upon locating a dead, injured or sick endangered or threatened species specimen. Initial notification must be made to the nearest U.S. Fish and Wildlife Service Law Enforcement Office. Notification must include the date, time, precise location of the injured animal or carcass, and any other pertinent information. Care should be taken in handling sick or injured specimens to preserve biological materials in the best possible state for later analysis of cause of death, if that occurs. In conjunction with the care of sick or injured endangered or threatened species or preservation of biological materials from a dead animal, the finder has the responsibility to ensure that evidence associated with the specimen is not unnecessarily disturbed. Contact the U.S. Fish and Wildlife Service Law Enforcement Office at (425) 883-8122, or the USFWS's Washington Fish and Wildlife Office at (360) 753-9440.

## CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

The implementation of Best Management Practices and Terms and Conditions will minimize murrelet exposure to harmful activities related to the Manette Bridge replacement project to the greatest extent practicable. However, given the status of the species and the amount of work that WSDOT conducts in marine waters and in or near murrelet terrestrial suitable and nesting habitat, we recommend that WSDOT create a long-term conservation strategy for murrelets that will contribute to biological goals for a stable or increasing population of murrelets and a population that is resilient to disturbance. The objective of this strategy should be to minimize threats to murrelets, of which underwater sound is one. The USFWS recommends that WSDOT conduct, support, and/or fund research on the effects of impulsive underwater sound on diving seabirds. Areas of research interest include how murrelets or alcids hear, exposure experiments with alcids or other surrogate species, behaviour studies, and any other level of research that would contribute to a better understanding of how elevated SPLs affect murrelets.

Further, we recommend that such a conservation strategy include ways to address the threats of habitat removal and disturbance in the terrestrial environment. Other elements of the strategy

could include producing a nesting and suitable habitat identification protocol, researching human disturbance on murrelets, surveying suitable habitat, etc.

In order for the USFWS to be kept informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the USFWS requests notification of the implementation of any conservation recommendations.

## REINITIATION NOTICE

This concludes formal consultation on the action(s) outlined in the (request/reinitiation request). As provided in 50 CFR ' 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

## LITERATURE CITED


Abbott, R.R., E. Bing-Sawyer, and R. Blizard. 2002. Assessment of pile driving impacts on the Sacramento blackfish (*Orthodon microlepidotus*). Administrative draft. Caltrans, Oakland, California, October 10, 2002.

AKNHP (Alaska Natural Heritage Program). 2009. Accessed website for scientific description for pacific sand lance. Environment and Natural Resources Institute, University of Alaska Anchorage. Description available at http://aknhp.uaa.alaska.edu/zoology/species_ADFG/ADFG_PDFs/Fishes/PacificSandLance_ADFG_web_060105.pdf

Bargmann, G. 1998. Forage fish management plan: A Plan for managing the forage fish resources and fisheries of Washington. Olympia, Washington, 66 pp.

Barton, B.A. 1977. Short-term effects of highway construction on the limnology of a small stream in southern Ontario. Freshwater Biology. 7:99-108.

Becker, B.H., S.R. Beissinger, and H.R. Carter. 2001. Effects of oceanographic variation on marbled murrelet diet and habitat selection. University of California at Berkeley, Berkeley, CA.

Becker, B.H. and S.R. Beissinger. 2006. Centennial decline in the trophic level of an endangered seabird after fisheries decline. Conservation Biology 20(2):470-79.

Becker, B.H., M.Z. Peery, and S.R. Beissinger. 2007. Ocean climate and prey availability affect the trophic level and reproductive success of the marbled murrelet, an endangered seabird. Inter-Research Marine Ecology Progress Series 329:267-79.

Bentivoglio, N., J. Baldwin, P.G.R. Jodice, D. Evans Mack, T. Max, S. Miller, S.K. Nelson, K. Ostrom, C.J. Ralph, M.G. Raphael, C.S. Strong, C.W. Thompson, and R. Wilk. 2002. Northwest Forest Plan marbled murrelet effectiveness monitoring 2000 Annual Report. U.S. Fish and Wildlife Service, Portland, Oregon, 73 pp.

Bloxton, T.D. and M.G. Raphael. 2008. Breeding ecology of the marbled murrelet in Washington State: project update 2004-2007. A report to the U.S. Fish and Wildlife Service and U.S. Forest Service, 32 pp.

Burkett, E.E. 1995. Marbled murrelet food habits and prey ecology. Pages 223-46. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report: PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Carlson TJ, Ploskey G, Johnson RL, Mueller RP, Weiland MA, Johnson PN. 2001. Observations of the Behavior and Distribution of Fish in Relation to the Columbia River Navigation Channel and Channel Maintenance Activities. Portland, Oregon: U.S. Army Corps of Engineers - Portland District. 38 p.

Carter, H.R., L.C. McAllister, and M.E. Isleib. 1995. Mortality of marbled murrelets in gill nets in North America. Pages 271-83. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Carter, H.R. and S.G. Sealy. 1986. Year-round use of coastal lakes by marbled murrelets. Condor 88(4):473-77.

Carter, H.R. and S.G. Sealy. 1990. Daily foraging behavior of marbled murrelets. Studies in Avian Biology 14:93-102.

Carter, H.R. and J.L. Stein. 1995. Molts and plumages in the annual cycle of the marbled murrelet. Pages 99-109. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Chisolm, J.L. and S.C. Downs. 1978. Stress and recovery of aquatic organisms as related to highway construction along Turtle Creek, Boone County, West Virginia. U.S. Geological Survey Water Supply Paper 2055, Washington, D.C. 40 p.

Cooper, J. 1982. Methods of reducing mortality of seabirds caused by underwater blasting. Cormorant 10:109-13.

Crum, L.A. and Y. Mao. 1996. Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety. Journal of the Acoustical Society of America 99(5):2898-907.

Cudahy, E. and W.T. Ellison. 2002. A review of the potential for in vivo tissue damage by exposure to underwater sound. Naval Submarine Research Laboratory, Department of the Navy, Groton, Connecticut, March 12, 2002, 6 pp.

Dall, S. and I.L. Boyd. 2002. Provisions under the risk of starvation. Ecol Res 4:853-863

Davidson, M. 2004. Transmission Loss. University of Plymouth, Institute of Marine Studies. Accessed February 2005. http://freespace.virgin.net/mark.davidson3/TL/TL.html

Day, R.H. and D.A. Nigro. 2000. Feeding ecology of Kittlitz's and marbled murrelets in Prince William Sound, Alaska. Waterbirds 23(1):1-14.

Ecology. 2006. Washington State's Water Quality Assessment 303(d) and 305(b) Reports, Final 2004 Submittal. Washington State Department of Ecology. Obtained on April 30, 2007 from agency website: http://apps.ecy.wa.gov/wats/WATSQBEHome.asp.

Ecology. 2007. WRIA 15 Watershed Description. Information obtained from Washington State Department of Ecology website on April 27, 2007: http://www.ecy.wa.gov/pubs/0610039/12.pdf.

Ecology. 2008. Washington Coastal Atlas. Information viewed from Washington State Department of Ecology website on October 9, 2008: http://www.ecy.wa.gov/programs/sea/sma/atlas_home.html.

Entranco, Inc. and Hamer Environmental, L.P. 2005. Marbled Murrelet Hazing Report - SR 104 Hood Canal Bridge east-half replacement and west-half retrofit project. Washington State Department of Transportation, 22 pp + appendices.

Evans Mack, D., W.P. Ritchie, S.K. Nelson, E. Kuo-Harrison, P. Harrison, and T.E. Hamer. 2003. Methods for surveying marbled murrelets in forests, a revised protocol for land management and research. Marbled Murrelet Technical Committee, Pacific Seabird Group.

Evans Mack, D., M.G. Raphael, and J.L. Laake. 2002. Probability of detecting marbled murrelets at sea: Effects of single versus paired observers. Journal of Wildlife Management 66(3):865-73.

Feist BE, Anderson JJ, Miyamoto R. 1992. Potential Impacts of Pile Driving on Juvenile Pink (*Onchorhynchus gorbuscha*) and Chum (*O. keta*) Salmon Behavior and Distribution. Seattle, Washington: University of Washington. 58 p.

Fewtrell, J.L. 2003. The response of marine finfish and invertebrates to seismic survey noise. Curtin University of Technology, Perth, Australia.

Flint, P., J.A. Reed, J.C. Franson, T.E. Hollmen, J.B. Grand, M.D. Howell, R.B. Lanctot, D.L. Lacroix, and C.P. Dau. 2003. Monitoring Beaufort Sea waterfowl and marine birds. OCS Study MMS 2003-037. U.S. Geological Survey, Alaska Science Center, Anchorage, AK, 125 pp.

Fothergill, D.M., J.R. Sims, and M.D. Curley. 2001. Recreational scuba diver's aversion to low-frequency underwater sound. Undersea and Hyperbaric Medicine 28(1):9-18.

Gaspin, J. 1975. Experimental investigations of the effects of underwater explosions on swimbladder fish, I: 1973 Chesapeake Bay Tests. NSWC/WOL/TR 75-58. White Oak Laboratory, Naval Surface Weapons Center, Silver Spring, Maryland, 76 pp.

Gausland, I. 1998. Physics of sound in water. *In*: Tasker, M.L. and C. Weir, eds. Proceedings of the Seismic and Marine Mammals Workshop. London. London.

Gisiner, R.C., E. Cudahy, G.V. Frisk, R. Gentry, R. Hofman, A.N. Popper, and J.W. Richardson. 1998. Workshop on the effects of anthropogenic noise in the marine environment. *In*: Gisiner, R.C., ed. Effects of Anthropogenic Noise in the Marine Environment. 141, February 10-12, 1998, Marine Mammal Science Program, Office of Naval Research, 141 pp.

Haring, Donald. 2000. Salmonid Habitat Limiting Factor: Water Resource Inventory Area 15 (East) Final Report. Washington State Conservation Commission. November 2000,

Hastings, M.C. 2002. Clarification of the meaning of sound pressure levels and the known effects of sound on fish. Ohio State University, Columbus, OH, August 26, 2002, 6 pp.

Hastings, M.C. and A.N. Popper. 2005. Effects of sound on fish. Contract No. 43A0139, Task Order, 1. California Department of Transportation, Sacramento, CA, January 28, 2005, 82 pp.

Hobson, K.A. 1990. Stable isotope analysis of marbled murrelets: evidence for freshwater feeding and determination of trophic level. The Condor 92:897-903.

Hobson, E.S. 1986. Predation on the Pacific sand lance, Ammodytes hexapterus (Pisces: Ammodytidae),during the transition between day and night in southeastern Alaska. Copeia 1:223-26.

Houghton, J.P. and K. Smith. 2005. 12th Street Marina construction - Preliminary pile monitoring results. 12021-102. Pentec Environmental, December 30, 2005.

Huff, M.H., P. Jodice, J. Baldwin, S. Miller, R. Young, K. Ostrom, C.J. Ralph, M. Raphael, C. Strong, C. Thompson, and G. Falxa. 2003. Marbled murrelet effectiveness monitoring - Northwest Forest Plan 2002 Annual Summary Report. 27 pp.

Huff, M.H., M.G. Raphael, S.L. Miller, S.K. Nelson, and J. Baldwin. 2006. Northwest Forest Plan - The first 10 years (1994-2003): Status and trends of populations and nesting habitat for the marbled murrelet. General Technical Report: PNW-GTR-650. U.S. Department of Agriculture, Forest Service, Portland, Oregon, 149 pp.

Hull, C.L., G.W. Kaiser, C. Lougheed, L. Lougheed, S. Boyd, and F. Cooke. 2001. Intraspecific variation in commuting distance of marbled murrelets (*Brachyramphus marmoratus*): Ecological and energetic consequences of nesting further inland. The Auk 118(4):1036-46.

Keevin, T.M., G.L. Hempen, and D.J. Schaeffer. 1997. Use of a bubble curtain to reduce fish mortality during explosive demolition of Locks and Dam 26, Mississippi River. Pages 197-206. *In*: Proceedings of the Twenty-third Annual Conference on Explosive and Blasting Technique. February 2-5, 1997, Las Vegas, NV. International Society of Explosives Engineers, Las Vegas, NV.

Kuletz, K.J. 1996. Marbled murrelet abundance and breeding activity at Naked Island, Prince William Sound, and Kachemak Bay, Alaska, before and after the Exxon Valdez oil spill. American Fisheries Society Symposium 18:770-84.

Kuletz, K.J. 2005. Foraging behavior and productivity of a non-colonial seabird, the marbled murrelet (Brachyramphus marmoratus), relative to prey and habit. Ph.D.

Kuletz, K.J. and J.F. Piatt. 1999. Juvenile marbled murrelet nurseries and the productivity index. The Wilson Bulletin 111(2):257-61.

Lacroix, D.L., R.B. Lanctot, J.A. Reed, and T.L. McDonald. 2003. Effect of underwater seismic surveys on molting male Long-tailed Ducks in the Beaufort Sea, Alaska. Canadian Journal of Zoology 81:1862-75.

Lance, M.M. 2004. Federal Aid Report - 2004 Marbled murrelet at-sea population monitoring. Washington Department of Fish and Wildlife, Olympia, WA, 7 pp.

Laughlin, J. 2005. Underwater sound levels associated with restoration of the Friday Harbor Ferry Terminal. Washington State Department of Transportation, Seattle, WA, 125 pp.

Laughlin, J. 2006. Underwater sound levels associated with pile driving at the Cape Disappointment Boat Launch Facility, Wave Barrier Project. Washington State Parks, April 24, 2006, 42 pp.

Litzow, M.A.; Piatt,J.F., Prichard,A.K.; Roby,D.D. 2002. Response of pigeon guillemots to variable abundance of high-lipid and low-lipid prey. Oecologia 132(2): 286-295.

Longmuir, C. and T. Lively. 2001. Bubble curtain systems for use during marine pile driving. Fraser River Pile and Dredge Ltd., New Westminster, British Columbia, Canada.

MacGillivray, A. and R. Racca. 2005. Sound pressure and particle velocity measurements from marine pile driving at Eagle Harbor maintenance facility, Bainbridge Island, WA. JASCO Research Ltd., Victoria, British Columbia, 13 pp.

Mason, A., A.E. Burger, and B. Hansen. 2002. At-sea surveys of marbled murrelets in Clayoquot Sound, 1996-2000. Pages 15-33. *In*: Burger, A. and T.A. Chatwin (eds). Multi-scale studies of populations, distribution, and habitat associations of marbled murrelets in Clayoquot Sound, British Columbia. Ministry of Water, Land, and Air Protection, Victoria, British Columbia.

Mathews, N.J.C. and A.E. Burger. 1998. Diving depth of a marbled murrelet. Northwestern Naturalist 79(2):70-71.

McShane, C., T.E. Hamer, H.R. Carter, R.C. Swartzman, V.L. Friesen, D.G. Ainley, K. Nelson, A.E. Burger, L.B. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation reports for the 5-year status review of the marbled murrelet in Washington, Oregon, and California. EDAW, Inc., Seattle, Washington, 370 pp.

Nedwell, J. and B. Edwards. 2002. Measurements of underwater noise in the Arun River during piling at County Wharf, Littlehampton. Report No. 513 R 0108. Subacoustech Ltd, August 1, 2002, 26 pp.

Nelson, S.K. 1997. The birds of North America, No. 276 - marbled murrelet (*Brachyramphus marmoratus*). Pages 1-32. *In*: Poole, A. and F. Gill (eds). The birds of North America: Life histories for the 21st century. The Academy of Natural Sciences & The American Ornithologists' Union, Philadelphia, PA; Washington, D.C.

National Marine Fisheries Service. 2009. Draft Biological Opinion. Manette Bridge Replacement Project. Unpublished. Seattle, Washington: National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

National Oceanic and Atmospheric Administration (NOAA). 2008. Tide and current predictions for the 'Port Washington Narrows, south entrance' tidal current station for year 2008. Data accessed on October 8, 2008. Available at: http://tidesandcurrents.noaa.gov/currents08/tab2pc2.html.

Penttila, D. 2000. Documented spawning seasons of populations of the surf smelt, Hypomesus, in the Puget Sound basin. Washington Department of Fish and Wildlife Marine Resources Division Briefing Report, October 2000. Olympia, Washington.

Penttila, D. 2007. Marine forage fishes in Puget Sound. Puget Sound Nearshore Partnership Report 2007-03. U.S. Army Corps of Engineers, Seattle, Washington, 30 pp.

Piatt, F.F., B.D. Roberts, W.W. Lidster, J.L. Wells, and S.A. Hatch. 1990. Effects of human disturbance on breeding least and crested auklets at St. Lawrence Island, Alaska. Auk 107:342-50.

Piatt, J.F., K.J. Kuletz, A.E. Burger, S.A. Hatch, V.L. Friesen, T.P. Birt, M.L. Arimitsu, G.S. Drew, A.M.A. Harding, and K.S. Bixler. 2007. Status review of the marbled murrelet *(Brachyramphus marmoratus)* in Alaska and British Columbia. U.S. Geological Survey Open-File Report 2006-1387. 258 pp.

Pommerenck, K. 2006. Results of underwater sound measurements for the construction of utility crossing at Stockton Regional Wastewater Control Facility. Illingworth and Rodkin, Inc., Petaluma, California, April 17, 2006, 12 pp.

Popper, A.N. 2003. Effects of anthropogenic sounds of fishes. Fisheries 28(10):24-31.

Popper, A.N., T.J. Carlson, A.D. Hawkins, B.L. Southall, and R. Gentry. 2006. Interim criteria for injury of fish exposed to pile driving operations: A white paper. May 13, 2006, 15 pp.

PSAT (Puget Sound Action Team). 2007. 2007 Puget Sound update: Ninth report of the Puget Sound assessment and monitoring program. PSAT 07-02. Puget Sound Action Team, Olympia, Washington, February, 2007, 276 pp.

PSNP and USGS. 2006. Coastal Habitats in Puget Sound: A Research Plan in Support of the Puget Sound Nearshore Partnership. Puget Sound Nearshore Partnership and U.S. Geological Survey, Technical Report 2006–1. Obtained on May 1, 2007 from website: http://www.pugetsoundnearshore.org/techical_papers/coastal_habitats.pdf

PSCRBT (Puget Sound River Basin Cooperative). 1990. Sinclair Inlet Watershed, King County, Washington. United States Department of Agriculture. April, 1990.

Quinn, T. 1999. Habitat characteristics of an intertidal aggregation of Pacific sand lance (Ammodytes hexapterus) at a north Puget Sound beach in Washington. Northwest Science 73(1):44-49.

Reyff, J.A. 2003. Draft: Underwater sound levels associated with seismic retrofit construction of the Richmond-San Rafael Bridge - Measurement results for the driving of temporary and permanent piles. Illingworth and Rodkin, Inc., January 31, 2003, 19 pp.

Reyff, J.A. 2006. Russian River Bridge at Geyserville: Underwater sound measurement data, driving of steel pipe piles for the construction of a temporary trestle. Illingworth and Rodkin, Inc., Petaluma, California, June 7, 2006, 10 pp.

Richardson, J. S. Davis, R. E. Harris, D. W. Owens, N. J. Patenaude, D. H. Thomson, R. C. Atkinson, and W. J. Marshall. 1995. Assessment of Potential Impact of Small Explosions in the Korea Strait on Marine Animals and Fisheries. Maritime Systems Technology Office. LGL Report TA2085. August 16, 1995, 144pp.

Richardson, J.W., C.R. Greene, C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego, California. 576 pp.

Robards, M.D., M.F. Willson, R.H. Armstrong, and J.F. Piatt. 1999. Sand lance: A review of biology and predator relations and annotated bibliography. Research Paper PNW-RP-521. USDA Forest Service Pacific Northwest Research Station, Portland, Oregon, September 1999, 189 pp.

Ronconi, R.A.; Burger, A.E. 2008. Limited foraging flexibility: Increased foraging effort by a marine predator does not buffer against scarce prey. Marine Ecology-Progress Series. 366: 245-258

Ruckelshaus, M.H. and M.M. McClure. 2007. Sound science: Synthesizing ecological and socioeconomic information about the Puget Sound ecosystem. NMFS, Northwest Fisheries Science Center, Seattle, Washington, January, 2007, 102 pp.

Santulli, A., A. Modica, C. Messina, L. Ceffa, A. Curatolo, G. Rivas, G. Fabi, and V. D'Amelio. 1999. Biochemical responses of European sea bass (*Dicentrarchus labrax* L.) to the stress induced by off shore experimental seismic prospecting. Marine Pollution Bulletin 38(12):1105-14.

Scheafer, M. 1936. Contribution to the life history of the surf smelt Hyponmesus pretousus in Puget Sound. Washington Department Fish Biology. 35B:1-45.

Steevens, C.C., K.L. Russell, M.E. Knafeic, P.F. Smith, E.W. Hopkins, and J.B. Clark. 1999. Noise-induced neurological disturbances in divers exposed to intense water-borne sound: Two case reports. Undersea and Hyperbaric Medicine 26(4):261-65.

Stemp, R. 1985. Observations on the effects of seismic exploration on seabirds. Pages 217-33. *In*: Workshop on Effects of Explosives Use in the Marine Environment. Halifax, Nova Scotia. Canada Oil and Gas Lands Administration,

Stick, K.C. 2005. 2004 Washington State herring stock status report. SS 05-01. Washington Department of Fish and Wildlife, Fish Program, Fish Management Division, Olympia, WA, May 2005, 86pp.

Strachan, G., M. McAllister, and C.J. Ralph. 1995. Marbled murrelet at-sea and foraging behavior. Pages 247-53. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. PSW-GTR-152. U.S. Department of Agriculture, Albany, CA. 420 pp.

Stotz, T., Colby J. 2001. January 2001 Dive Report for Mukilteo Wingwall Replacement Project. Seattle, WA: Washington State Ferries. 19 p.

Turnpenny, A. and J. Nedwell. 1994. The effects on marine fish, diving mammals and birds of underwater sound generated by seismic surveys. Fawley Aquatic Research Laboratories Limited, Marine and Freshwater Biology Unit, Southampton, Hampshire, UK, 40 pp.

Turnpenny, A., K.P. Thatcher, R. Wood, and J. Nedwell. 1994. The effects on fish and other marine animals of high-level underwater sound. Report FRR 127/94. Fawley Aquatic Research Laboratory, Ltd., Marine and Freshwater Biology Unit, Southampton, United Kingdom, 35 pp.

U.S. Department of Defense. 2002. Record of Decision for surveillance towed array sensor system low frequency active. Federal Register 67(141):48145-54.

U.S. Fish and Wildlife Service. 1997. Recovery Plan for the threatened marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. U.S. Department of the Interior, Portland, Oregon, 1997, 203 pp.

U.S. Fish and Wildlife Service. 2003. Biological opinion and letter of concurrence for effects to bald eagles, marbled murrelets, northern spotted owls, bull trout, and designated critical habitat for marbled murrelets and northern spotted owls from Olympic National Forest program of activities for August 5, 2003, to December 31, 2008. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Lacey, Washington.

U.S. Fish and Wildlife Services. 2008. Biological opinion for effects to bull trout, and marbled murrelets from the United States Navy Explosives Disposal Training Operations, Puget Sound ; Whidbey Island, Island County, Washington. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Lacey, Washington. 213pp.

US Global Change Research Program 2003, http://www.usgcrp.gov/usgcrp/nacc/education/alaska/ak-edu-4.htm; DFO and DOE 2008, http://www.pac.dfo-mpo.gc.ca/sci/herring/pages/indicator e.htm; both accessed on 1/14/09.

Vlahakis, N.E. and R.D. Hubmayr. 2000. Plasma membrane stress failure in alveolar epithelial cells. Journal of Applied Physiology 89:2490-96.

Wasser, S.K., K. Bevis, G. King, and E. Hanson. 1997. Noninvasive physiological measures of disturbance in the northern spotted owl. Conservation Biology 11(4):1019-22.

Watanuki, Y. and A.E. Burger. 1999. Body mass and dive durations in alcids and penguins. Canadian Journal of Zoology 77:1838-42.

Waters, T. F. 1995. *Sediment in Streams: Sources, Biological Effects, and Control.* American Fisheries Society Monograph 7.

WDFW. (Washington Department of Fish and Wildlife) 2005. 2004 Washington state herring stock status report. Washington Department of Fish and Wildlife, Fish Program, Fish Management Division, May 2005.

WDFW (Washington Department of Fish and Wildlife). 2005a. Marbled murrelet densities in the southern Puget Sound in winter with ferry routes.

WDFW (Washington Department of Fish and Wildlife). 2005b. Marbled murrelet densities in the Strait of Juan de Fuca and Puget Sound in summer with ferry routes.

WDFW. 2007. Washington Department of Fish and Wildlife Priority Habitats and Species (PHS) database information for S28/S34/S35/T21R02E. Data request dated March 19, 2007, data received March 29, 2007.

WDFW (Washington Department of Fish and Wildlife). 2000. Critical spawning habitat for herring, surf smelt, sand lance, and rock sole in Puget Sound, Washington. WDFW, Olympia, Washington.

WDFW. (Washington Department of Fish and Wildlife) 2009a. Forage fish database. Geographic information system digital data. Olympia, Washington.

WDFW. (Washington Department of Fish and Wildlife) 2009b. WDFW website access available at www.wdfw.wa.gov/fish/forage. June 15, 2009.

WDNR (Washington State Department of Natural Resources). 2001. Washington ShoreZone Inventory Data. Nearshore Habitat Program, Washington State Department of Natural Resources. February 2001. Olympia Washington.

Whitworth, D.L., S.K. Nelson, S.H. Newman, G.B. Van Vliet, and W.P. Smith. 2000. Foraging distances of radio-marked marbled murrelets from inland areas in southeast Alaska. The Condor 102(2):452-56.

Widermuth, D. 1993. Estimates of recreational harvest and spawn deposition for surf smelt (Hypomesus pretiosus pretiosus), at Ross Point, Washington in 1991 and 1992. Washington Department of Fish and Wildlife Progress Report 309. Olympia, Washington.

WSF (Washington State Ferries). 2007. Marbled Murrelet Monitoring Report: Anacortes Ferry Terminal Dolphin Replacement Project.

WSDOT. 2008. Biological Assessment - Manette Bridge Replacement Project. Washington State Department of Transportation. January 2008

WSDOT. 2006. Biological Assessment Preparation for Transportation Projects – Advanced Training Manual, Version 6. Part 3. Washington State Department of Transportation. Available online at http://www.wsdot.wa.gov/NR/rdonlyres/40DB4B7C-9C5B-4205-B06C-E1FFA3658E15/0/BA_ManualPt3.pdf.

Yelverton, J.T. and D.R. Richmond. 1981. Underwater explosion damage risk criteria for fish, birds, and mammals. *In*: 102nd Meeting of the Acoustical Society of America, 36,November 30 - December 04, Miami Beach, Florida. Department of Biodynamics, Lovelace Biomedical and Environmental Research Institute, Albuquerque, New Mexico. 36 pp.

Yelverton, J.T., D.R. Richmond, R.E. Fletcher, and R.K. Jones. 1973. Safe distances from underwater explosions for mammals and birds. Lovelace Foundation for Medical Education and Research, Albuquerque, NM, September 26, 1973, 64 pp.

Yelverton, J.T., D.R. Richmond, W. Hicks, K. Saunders, and R.E. Fletcher. 1975. The relationship between fish size and their response to underwater blast. AD-A015-970. Lovelace Foundation for Medical Education and Research, Albuquerque, NM, June 18, 1975, 39 pp.

### *In Litteris REFERENCES*

Dawson, N., M.A. Bishop, K. Kuletz, K. Brenneman, R. Thorne, and R. Crawford. The importance of juvenile pacific herring (Clupia pallasi) to wintering seabirds in Prince William Sound, Alaska. Poster presented at 2007 Pacific Seabird Group annual meeting.

Falxa, G. 2008. Northwest Forest Plan marbled murrelet effectiveness monitoring data. Data summarized in Falxa et al. 2008.

Kuletz, K. 2006. U.S. Fish and Wildlife Service. How many fish do murrelets need to raise a chick? Poster presented at Pacific Seabird Group Meeting, February 2006.

## PERSONAL COMMUNICATIONS

Falxa, G. 2008. Email to Martin Raphael, Lance, Monique, Pearson, Scott, Lynch, Deanna, Falxa, Gary, Nelson, Kim, Huff, Mark, Young, Rich, Bloxton, Thomas D., Bush, Jodi, Tuerler, Bridgette, Brown, Robin, Pereksta, David, Schmidt, Kristin, Flotlin, Kim, Burkett, E., McIver, Bill, Bond, James, Watkins, Jim H., Hoffman, Ken R., Roberts, Lynn M., Bosch, Ray, Hamlin, Robin, Olah, Ryan, Rabot, Theresa, Thomas, Darrin, Roy, Michael, Hensen, Paul, Young, Kristi, and Corbett, Miel, February 1 2008, Re: 2007 results of marbled murrelet at-sea populations surveys.

Hamilton, L. 2008. Interview with Dan Penttila re: forage fish.

Stadler, J.H. 2002. Notes from site visit, Winslow Ferry Terminal, to observe pile driving and monitoring of noise levels and effects to fishes.

Speckman SG, Springer AM, Piatt JF, Thomas DL. 2000. Temporal variability in abundance of marbled murrelets at sea in Southeast Alaska. Waterbirds 23(3):364-377.

Stick, K. 2009. Email to Brooke Hamilton. June 22, 2009. Port Orchard Herring Stock Biomass for 2001-2008 and Washington 2008 stock status.

Ward, C. 2008. Personal Communications. Supplemental information of the Manette Bridge Biological Assessment provided in October 29, 2008 meeting with WSDOT and NFMS and added to the project description.

Ward, C. 2009a. Personal communication. January 2009. The Services met with WSDOT to discuss pile driving.

Ward, C. 2009b. Personal Communications. Supplemental information of the Manette Bridge Biological Assessment added as an addition to the project description. Submitted April 13, 2009

Willdbligg, C. 2009. Phone conversation about forage fish biology and use in the action area. June 15, 2009.

# Appendix A: Status of the Species

## STATUS OF THE SPECIES: Murrelet

### Legal Status

The murrelet was federally listed as a threatened species in Washington, Oregon, and northern California effective September 28, 1992 (57 FR 45328 [October 1, 1992]). The final rule designating critical habitat for the murrelet (61 FR 26256 [May 24, 1996]) became effective on June 24, 1996. The Service recently proposed a revision to the 1996 murrelet critical habitat designation (71 FR 44678 [July 31, 2008]). A final rule is expected in 2009. The species' decline has largely been caused by extensive removal of late-successional and old-growth coastal forests which serve as nesting habitat for murrelets. Additional listing factors included high nest-site predation rates and human-induced mortality in the marine environment from gillnets and oil spills.

The Service determined that the California, Oregon, and Washington distinct population segment of the murrelet does not meet the criteria set forth in the Service's 1996 Distinct Population Segment policy (61 FR 4722 [May 24, 1996]; (Beissinger and Nur 1997 in USFWS 2004). However, the murrelet retains its listing and protected status as a threatened species under the Act until the original 1992 listing decision is revised through formal rule-making procedures, involving public notice and comment.

Critical habitat was designated for the murrelet to addresses the objective of stabilizing the population size. To fulfill that objective, the Marbled Murrelet Recovery Plan (USFWS 1997b) (Recovery Plan), focuses on protecting adequate nesting habitat by maintaining and protecting occupied habitat and minimizing the loss of unoccupied but suitable habitat (USFWS 1997b, p. 119). The Recovery Plan identified six Conservation Zones throughout the listed range of the species: Puget Sound (Conservation Zone 1), Western Washington Coast Range (Conservation Zone 2), Oregon Coast Range (Conservation Zone 3), Siskiyou Coast Range (Conservation Zone 4), Mendocino (Conservation Zone 5), and Santa Cruz Mountains (Conservation Zone 6).

As explained in the Endangered Species Consultation Handbook (USFWS and NMFS 1998) and clarified for recovery units through Memorandum (USFWS 2006), jeopardy analyses must always consider the effect of proposed actions on the survival and recovery of the listed entity. In the case of the murrelet, the Service's jeopardy analysis will consider the effect of the action on the long-term viability of the murrelet in its listed range (Washington, Oregon, and northern California), beginning with an analysis of the action's effect on Conservation Zones 1 and 2 (described below).

<u>Conservation Zone 1</u>

Conservation Zone 1 includes all the waters of Puget Sound and most waters of the Strait of Juan de Fuca south of the U.S.-Canadian border and extends inland 50 mi from the Puget Sound, including the north Cascade Mountains and the northern and eastern sections of the Olympic Peninsula. Forest lands in the Puget Trough have been predominately replaced by urban development and the remaining suitable habitat in Zone 1 is typically a considerable distance

from the marine environment, lending special importance to nesting habitat close to Puget Sound (USFWS 1997b).

Conservation Zone 2

Conservation Zone 2 includes waters within 1.2 mi of the Pacific Ocean shoreline south of the U.S.-Canadian border off Cape Flattery and extends inland to the midpoint of the Olympic Peninsula. In southwest Washington, the Zone extends inland 50 mi from the Pacific Ocean shoreline. Most of the forest lands in the northwestern portion of Zone 2 occur on public (State, county, city, and Federal) lands, while most forest lands in the southwestern portion are privately owned. Extensive timber harvest has occurred throughout Zone 2 in the last century, but the greatest loss of suitable nest habitat is concentrated in the southwest portion of Zone 2 (USFWS 1997b). Thus, murrelet conservation is largely dependent upon Federal lands in northern portion of Zone 2 and non-Federal lands in the southern portion.

## Life History

Murrelets are long-lived seabirds that spend most of their life in the marine environment, but use old-growth forests for nesting. Detailed discussions of the biology and status of the murrelet are presented in the final rule listing the murrelet as threatened (57 FR 45328 [October 1, 1992]), the Recovery Plan, Ecology and Conservation of the Marbled Murrelet (Ralph et al. 1995), the final rule designating murrelet critical habitat (61 FR 26256 [May 24, 1996]), and the Evaluation Report in the 5-Year Status Review of the Marbled Murrelet in Washington, Oregon, and California (McShane et al. 2004).

Physical Description

The murrelet is taxonomically classified in the family Alcidae (alcids), a family of Pacific seabirds possessing the ability to dive using wing-propulsion. The plumage of this relatively small (9.5 in to 10 in) seabird is identical between males and females, but the plumage of adults changes during the winter and breeding periods providing some distinction between adults and juveniles. Breeding adults have light, mottled brown under-parts below sooty-brown upperparts contrasted with dark bars. Adults in winter plumage have white under-parts extending to below the nape and white scapulars with brown and grey mixed upperparts. The plumage of fledged young is similar to the adult winter plumage (USFWS 1997b).

Distribution

The range of the murrelet, defined by breeding and wintering areas, extends from the northern terminus of Bristol Bay, Alaska, to the southern terminus of Monterey Bay in central California. The listed portion of the species' range extends from the Canadian border south to central California. Murrelet abundance and distribution has been significantly reduced in portions of the listed range, and the species has been extirpated from some locations. The areas of greatest concern due to small numbers and fragmented distribution include portions of central California, northwestern Oregon, and southwestern Washington (USFWS 1997b).

Reproduction

Murrelet breeding is asynchronous and spread over a prolonged season. In Washington, the murrelet breeding season occurs between April 1 and September 15 (Figure 1). Egg laying and incubation occur from late April to early August and chick rearing occurs between late May and late August, with all chicks fledging by early September (Hamer et al. 2003).

Murrelets lay a single-egg clutch (Nelson 1997), which may be replaced if egg failure occurs early (Hebert et al. 2003; McFarlane-Tranquilla et al. 2003). However, there is no evidence a second egg is laid after successfully fledging a first chick. Adults typically incubate for a 24-hour period, then exchange duties with their mate at dawn. Hatchlings appear to be brooded by an adult for one to two days and are then left alone at the nest for the remainder of the rearing period, except during feedings. Both parents feed the chick, which receives one to eight meals per day (Nelson 1997). Most meals are delivered early in the morning while about a third of the food deliveries occur at dusk and intermittently throughout the day (Nelson and Hamer 1995b). Chicks fledge 27 to 40 days after hatching. The initial flight of a fledgling appears to occur at dusk and parental care is thought to cease after fledging (Nelson 1997).

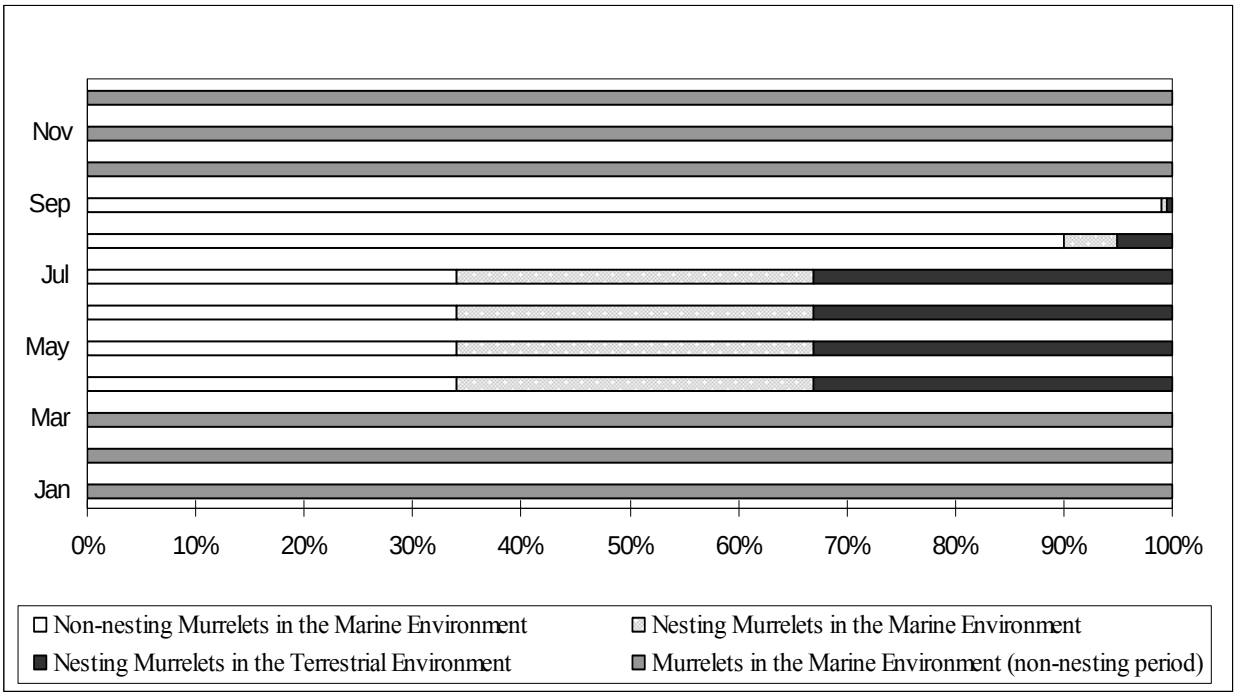


Figure 1. The seasonal changes in the relative proportion of breeding and non-breeding murrelets in the marine and terrestrial environments[1] within Washington State (Conservation Zones 1 and 2)

[1] Demographic estimates were derived from Peery et al. (2004) and nesting chronology was derived from Hamer and Nelson (1995) and Bradley et al. (2004) where April 1 is the beginning of the nesting season, September 15 is the end of the nesting season, and August 6 is the beginning of the late breeding season when an estimated 70 percent of the murrelet chicks have fledged.

Vocalization

Murrelets are known to vocalize between 480 Hertz and 4.9 kilohertz and have at least 5 distinct call types (Suzanne Sanborn, pers. comm. 2005). Murrelets tend to be more vocal at sea compared to other alcids (Nelson 1997). Individuals of a pair vocalize after surfacing apart from each other, after a disturbance, and during attempts to reunite after being separated (Strachan et al. 1995).

MURRELETS IN THE MARINE ENVIRONMENT

Murrelets are ususally found within 5 miles (8 kilometers) from shore, and in water less than 60 meters deep (Ainley et al. 1995; Burger 1995; Strachan et al. 1995; Nelson 1997; Day and Nigro 2000; Raphael et al. 2007). In general, birds occur closer to shore in exposed coastal areas and farther offshore in protected coastal areas (Nelson 1997). Courtship, foraging, loafing, molting, and preening occur in marine waters. Beginning in early spring, courtship continues throughout summer with some observations even noted during the winter period (Speckman 1996; Nelson 1997). Observations of courtship occurring in the winter suggest that pair bonds are maintained throughout the year (Speckman 1996; Nelson 1997). Courtship involves bill posturing, swimming together, synchronous diving, vocalizations, and chasing in flights just above the surface of the water. Copulation occurs both inland (in the trees) and at sea (Nelson 1997).

*Loafing*

When murrelets are not foraging or attending a nest, they loaf on the water, which includes resting, preening, and other activities during which they appear to drift with the current, or move without direction (Strachan et al. 1995). Strachan et al. (1995) noted that vocalizations occurred during loafing periods, especially during the mid-morning and late afternoon.

*Molting*

Murrelets go through two molts each year. The timing of molts varies temporally throughout their range and are likely influenced by prey availability, stress, and reproductive success (Nelson 1997). Adult (after hatch-year) murrelets have two primary plumage types: alternate (breeding) plumage and basic (winter) plumage. The pre-alternate molt occurs from late February to mid-May. This is an incomplete molt during which the birds lose their body feathers but retain their ability to fly (Carter and Stein 1995; Nelson 1997). A complete pre-basic molt occurs from mid-July through December (Carter and Stein 1995; Nelson 1997). During the pre-basic molt, murrelets lose all flight feathers somewhat synchronously and are flightless for up to two months (Nelson 1997). In Washington, there is some indication that the pre-basic molt occurs from mid-July through the end of August (Chris Thompson, pers. comm. 2003).

*Flocking*

Strachan et al. (1995) defines a flock as three or more birds in close proximity which maintain that formation when moving. Various observers throughout the range of the murrelet report flocks of highly variable sizes. In the southern portion of the murrelet's range (California,

Oregon, and Washington), flocks rarely contain more than 10 birds. Larger flocks usually occur during the later part of the breeding season and may contain juvenile and subadult birds (Strachan et al. 1995).

Aggregations of foraging murrelets are probably related to concentrations of prey. In Washington, murrelets are not generally found in interspecific feeding flocks (Strachan et al. 1995). Strong et al. (in Strachan et al. 1995) observed that murrelets avoid large feeding flocks of other species and presumed that the small size of murrelets may make them vulnerable to kleptoparasitism or predation in mixed species flocks. Strachan et al. (1995) point out that if murrelets are foraging cooperatively, the confusion of a large flock of birds could reduce foraging efficiency.

*Foraging Behavior*

Murrelets are wing-propelled pursuit divers that forage both during the day and at night (Carter and Sealy 1986; Gaston and Jones 1998; Henkel et al. 2003; Kuletz 2005). Murrelets typically forage in pairs, but have been observed to forage alone or in groups of three or more (Carter and Sealy 1990; Strachan et al. 1995; Speckman et al. 2003). Strachan et al. (1995) believe pairing enhances foraging success through cooperative foraging techniques. For example, pairs consistently dive together during foraging and often synchronize their dives by swimming towards each other before diving (Carter and Sealy 1990) and resurfacing together on most dives. Strachan et al. (1995) speculate pairs may keep in visual contact underwater. Paired foraging is common throughout the year, even during the incubation period, suggesting that breeding murrelets may temporarily pair up with other foraging individuals (non-mates) (Strachan et al. 1995; Speckman et al. 2003).

Murrelets can make substantial changes in foraging sites within the breeding season, but many birds routinely forage in the same general areas and at productive foraging sites, as evidenced by repeated use over a period of time throughout the breeding season (Carter and Sealy 1990; Whitworth et al. 2000; Becker et al. 2001; Hull et al. 2001; Mason et al. 2002; Piatt et al. 2007). Murrelets are also known to forage in freshwater lakes (Nelson 1997). Activity patterns and foraging locations are influenced by biological and physical processes that concentrate prey, such as weather, climate, time of day, season, light intensity, up-wellings, tidal rips, narrow passages between islands, shallow banks, and kelp (*Nereocystis* spp.) beds (Ainley et al. 1995; Strong et al. 1995; Burger 1995; Speckman 1996; Nelson 1997).

Juveniles are generally found closer to shore than adults (Beissinger 1995) and forage without the assistance of adults (Strachan et al. 1995). Kuletz and Piatt (1999) found that in Alaska, juvenile murrelets congregated in kelp beds. Kelp beds are often with productive waters and may provide protection from avian predators (Kuletz and Piatt 1999). McAllister (in litt. in Strachan et al. 1995) found that juveniles were more common within 328 ft of shorelines, particularly, where bull kelp was present.

Murrelets usually feed in shallow, near-shore water less than 30m (98 ft) deep (Huff et al. 2006), but are thought to be able to dive up to depths of 47 m (157 ft) (Mathews and Burger 1998). Variation in depth and dive patterns may be related to the effort needed to capture prey. Thick-

billed murres (*Uria lomvia*) and several penguin species exhibit bi-modal foraging behavior in that their dive depths mimic the depth of their prey, which undergo daily vertical migrations in the water column (Croll et al. 1992; Butler and Jones 1997). Jodice and Collopy's (1999) data suggest murrelets follow this same pattern as they forage for fish that occur throughout the water column but undergo daily vertical migrations (to shallower depths at night and back to deeper depths during the day). Murrelets observed foraging in deeper water likely do so when upwelling, tidal rips, and daily activity patterns concentrate the prey near the surface (Strachan et al. 1995).

The duration of dives appears to depend upon age (adults vs. juveniles), water depth, visibility, and depth and availability of prey. Murrelet dive duration ranges from 8 seconds to 115 seconds, although most dives last between 25 and 45 seconds (Thorensen 1989; Jodice and Collopy 1999; Watanuki and Burger 1999; Day and Nigro 2000).

Adults and subadults often move away from breeding areas prior to molting and must select areas with predictable prey resources during the flightless period (Carter and Stein 1995; Nelson 1997). During the non-breeding season, murrelets disperse and can be found farther from shore (Strachan et al. 1995). Little is known about marine-habitat preference outside of the breeding season, but use during the early spring and fall is thought to be similar to that preferred during the breeding season (Nelson 1997). During the winter there may be a general shift from exposed outer coasts into more protected waters (Nelson 1997), for example many murrelets breeding on the exposed outer coast of Vancouver Island appear to congregate in the more sheltered waters within the Puget Sound and the Strait of Georgia in fall and winter (Burger 1995). However, in many areas, murrelets remain associated with the inland nesting habitat during the winter months (Carter and Erickson 1992) and throughout the listed range, murrelets do not appear to disperse long distances, indicating they are year-round residents (McShane et al. 2004).

*Prey Species*

Throughout their range, murrelets are opportunistic feeders and utilize prey of diverse sizes and species. They feed primarily on fish and invertebrates in marine waters although they have also been detected on rivers and inland lakes (Carter and Sealy 1986); 57 FR 45328 [October 1, 1992]). In general, small schooling fish and large pelagic crustaceans are the main prey items. Pacific sand lance *(Ammodytes hexapterus)*, northern anchovy *(Engraulis mordax),* immature Pacific herring *(Clupea harengus)*, capelin *(Mallotus villosus)*, Pacific sardine (*Sardinops sagax*), juvenile rockfishes (*Sebastas* spp.) and surf smelt (Osmeridae) are the most common fish species taken. Squid (*Loligo* spp.), euphausiids, mysid shrimp, and large pelagic amphipods are the main invertebrate prey. Murrelets are able to shift their diet throughout the year and over years in response to prey availability (Becker et al. 2007). However, long-term adjustment to less energetically-rich prey resources (such as invertebrates) appears to be partly responsible for poor marbled murrelet reproduction in California (Becker and Beissinger 2006).

Breeding adults exercise more specific foraging strategies when feeding chicks, usually carrying a single, relatively large (relative to body size) energy-rich fish to their chicks (Burkett 1995; Nelson 1997), primarily around dawn and dusk (Nelson 1997; Kuletz 2005). Freshwater prey appears to be important to some individuals during several weeks in summer and may facilitate

more frequent chick feedings, especially for those that nest far inland (Hobson 1990). Becker et al. (Becker et al. 2007) found murrelet reproductive success in California was strongly correlated with the abundance of mid-trophic level prey (e.g. sand lance, juvenile rockfish) during the breeding and postbreeding seasons. Prey types are not equal in the energy they provide; for example parents delivering fish other than age-1 herring may have to increase deliveries by to up 4.2 times to deliver the same energy value (Kuletz 2005). Therefore, nesting murrelets that are returning to their nest at least once per day must balance the energetic costs of foraging trips with the benefits for themselves and their young. This may result in marbled murrelets preferring to forage in marine areas in close proximity to their nesting habitat. However, if adequate or appropriate foraging resources (i.e., "enough" prey, and/or prey with the optimum nutritional value for themselves or their young) are unavailable in close proximity to their nesting areas, marbled murrelets may be forced to forage at greater distances or to abandon their nests (Huff et al. 2006, p. 20). As a result, the distribution and abundance of prey suitable for feeding chicks may greatly influence the overall foraging behavior and location(s) during the nesting season, may affect reproductive success (Becker et al. 2007), and may significantly affect the energy demand on adults by influencing both the foraging time and number of trips inland required to feed nestlings (Kuletz 2005).

*Predators*

At-sea predators include bald eagles (*Haliaeetus leucocephalus*), peregrine falcons (*Falco peregrinus*), western gulls (*Larus occidentalis*), and northern fur seals (*Callorhinus ursinus*) (McShane et al. 2004). California sea lions (*Zalophus californianus*), northern sea lions (*Eumetopias jubatus*), and large fish may occasionally prey on murrelets (Burger 2002).

Murrelets in the Terrestrial Environment

Murrelets are dependent upon old-growth forests, or forests with an older tree component, for nesting habitat (Ralph et al. 1995; Hamer and Nelson 1995; McShane et al. 2004). Sites occupied by murrelets tend to have a higher proportion of mature forest age-classes than do unoccupied sites (Raphael et al. 1995). Specifically, murrelets prefer high and broad platforms for landing and take-off, and surfaces which will support a nest cup (Hamer and Nelson 1995). The physical condition of a tree appears to be the important factor in determining the tree's suitability for nesting (Ralph et al. 1995); therefore, presence of old-growth in an area does not assure the stand contains sufficient structures (i.e. platforms) for nesting. In Washington, murrelet nests have been found in conifers, specifically, western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), Douglas-fir (*Pseudotsuga menziesii*), and western red cedar (*Thuja plicata*) (Hamer and Nelson 1995; Hamer and Meekins 1999). Nests have been found in trees as small as 2.6 ft in diameter at breast height on limbs at least 65 ft from the ground and 0.36 ft in diameter (Hamer and Meekins 1999).

Murrelet populations may be limited by the availability of suitable nesting habitat. Although no data are available, Ralph et al. (1995) speculate the suitable nesting habitat presently available in Washington, Oregon, and California may be at or near carrying capacity based on: 1) at-sea concentrations of murrelets near suitable nesting habitat during the breeding season, 2) winter

visitations to nesting sites, and 3) the limitation of nest sites available in areas with large amounts of habitat removal.

Murrelets have been observed visiting nesting habitat during non-breeding periods in Washington, Oregon, and California (Naslund 1993; Nelson 1997) which may indicate adults are defending nesting sites and/or stands (Ralph et al. 1995). Other studies provide further insight to the habitat associations of breeding murrelets, concluding that breeding murrelets displaced by the loss of nesting habitat do not pack in higher densities into remaining habitat (McShane et al. 2004). Thus, murrelets may currently be occupying nesting habitat at or near carrying capacity in highly fragmented areas and/or in areas where a significant portion of the historic nesting habitat has been removed (Ralph et al. 1995).

Unoccupied stands containing nesting structures are important to the population for displaced breeders or first-time breeding adults. Even if nesting habitat is at carrying capacity, there will be years when currently occupied stands become unoccupied as a result of temporary disappearance of inhabitants due to death or to irregular breeding (Ralph et al. 1995). Therefore, unoccupied stands will not necessarily indicate that habitat is not limiting or that these stands are not murrelet habitat (Ralph et al. 1995) and important to the species persistence.

Radar and audio-visual studies have shown murrelet habitat use is positively associated with the presence and abundance of mature and old-growth forests, large core areas of old-growth, low edge and fragmentation, proximity to the marine environment, total watershed area, and increasing forest age and height (McShane et al. 2004). In California and southern Oregon, areas with abundant numbers of murrelets were farther from roads, occurred more often in parks protected from logging, and were less likely to occupy old-growth habitat if it was isolated (more than 3 miles or 5 km) from other nesting murrelets (Meyer et al. 2002). Meyer et al. (2002) also found at least a few years passed before birds abandoned fragmented forests.

Murrelets do not form dense colonies which is atypical of most seabirds. Limited evidence suggests they may form loose colonies or clusters of nests in some cases (Ralph et al. 1995). The reliance of murrelets on cryptic coloration to avoid detection suggests they utilize a wide spacing of nests in order to prevent predators from forming a search image (Ralph et al. 1995). However, active nests have been seen within 328 ft (100 m) of one another in the North Cascades in Washington and within 98 ft (30 m) in Oregon (Kim Nelson, Oregon State University, pers. comm. 2005). Estimates of murrelet nest densities vary depending upon the method of data collection. For example, nest densities estimated using radar range from 0.007 to 0.104 mean nests per acre (0.003 to 0.042 mean nests per ha), while nest densities estimated from tree climbing efforts range from 0.27 to 3.51 mean nests per acre (0.11 to 1.42 mean nests per ha) (Nelson 2005).

There is little data available regarding murrelet nest site fidelity because of the difficulty in locating nest sites and observing banded birds attending nests. However, murrelets have been detected in the same nesting stands for many years (at least 20 years in California and 15 years in Washington), suggesting murrelets have a high fidelity to nesting areas, most likely at the watershed scale (Nelson 1997). Use of the same nest platform in successive years as well as multiple nests in the same tree have been documented, although it is not clear whether the

repeated use involved the same birds (Nelson and Peck 1995; Divoky and Horton 1995; Nelson 1997; Manley 2000; Hebert et al. 2003). The limited observed fidelity to the same nest depression in consecutive years appears to be lower than for other alcids, but this may be an adaptive behavior in response to high predation rates (Divoky and Horton 1995). Researchers have suggested fidelity to specific or adjacent nesting platforms may be more common in areas where predation is limited or the number of suitable nest sites are fewer because large, old-growth trees are rare (Nelson and Peck 1995; Singer et al. 1995; Manley 1999).

Ralph et al. (1995) speculated that the fidelity to nest sites or stands by breeding murrelets may be influenced by the nesting success of previous rearing attempts. Although murrelet nesting behavior in response to failed nest attempts is unknown, nest failures could lead to prospecting for new nest sites or mates. Other alcids have shown an increased likelihood to relocate to a new nest in response to breeding failure (Divoky and Horton 1995). However, murrelets likely remain in the same watershed over time as long as stands are not significantly modified (Ralph et al. 1995).

It is unknown whether juveniles disperse from natal breeding habitat (natal dispersal) or return to their natal breeding habitat after reaching breeding age (natal philopatry). Natal dispersal distance can be expected to be as high or higher than other alcids given 1) the reduced extent of the breeding range, 2) the overlap between the wintering and breeding areas, 3) the distance individuals are known to move from breeding areas in the winter, 4) adult attendance of nesting areas during the non-breeding season where, in theory, knowledge of suitable nesting habitat is passed onto prospecting non-breeders, and 5) the 3-year to 5-year duration required for the onset of breeding age allowing non-breeding murrelets to prospect nesting and forage habitat for several years prior to reaching breeding age (Divoky and Horton 1995). Conversely, Swartzman et al. (1997 in McShane et al. 2004)) suggested juvenile dispersal is likely to be low, as it is for other alcid species. Nevertheless, the presence of unoccupied suitable nesting habitat on the landscape may be important for first-time nesters if they disperse away from their natal breeding habitat.

Murrelets generally select nests within 37 mi (60 kilometers (km) of marine waters (Miller and Ralph 1995). However, in Washington, occupied habitat has been documented 52 mi (84 km) from the coast and murrelets have been detected up to 70 mi (113 km) from the coast in the southern Cascade Mountains (Evans Mack et al. 2003).

When tending active nests during the breeding season (and much of the non-breeding season in southern parts of the range), breeding pairs forage within commuting distance of the nest site. Daily movements between nest sites and foraging areas for breeding murrelets averaged 10 mi in Prince William Sound, Alaska (McShane et al. 2004), 24 mi in Desolation Sound, British Columbia, Canada (Hull et al. 2001), and 48 mi in southeast Alaska. In California, Hebert and Golightly (2003) found the mean extent of north-south distance traveled by breeding adults to be about 46 mi.

Murrelet nests have been located at a variety of elevations from sea level to 5,020 ft (Burger 2002). However, most nests have been found below 3,500 ft. In Conservation Zone 1, murrelets have exhibited “occupied” behaviors up to 4,400 ft elevation and have been detected in stands up

to 4,900 ft in the north Cascade Mountains (Peter McBride, WDNR, *in litt*., 2005). On the Olympic Peninsula, survey efforts for nesting murrelets have encountered occupied stands up to 4,000 ft within Conservation Zone 1 and up to 3,500 ft within Conservation Zone 2. Surveys for murrelet nesting at higher elevations on the Olympic Peninsula have not been conducted. However, recent radio-telemetry work detected a murrelet nest at 3,600 ft elevation on the Olympic Peninsula in Conservation Zone 1 (Martin Raphael, USFWS, pers. comm. 2005).

**Population Status in the Coterminous United States**

Population Abundance

Research on murrelet populations in the early 1990s estimated murrelet abundance in Washington, Oregon, and California at 18,550 to 32,000 (Ralph et al. 1995). However, consistent population survey protocols were not established for murrelets in the coterminous United States until the late 1990s following the development of the marine component of the Environmental Monitoring (EM) Program for the NWFP (Bentivoglio et al. 2002). As a consequence, sampling procedures have differed and thus the survey data collected prior to the EM Program is unsuitable for estimating population trends for the murrelet (McShane et al. 2004).

The development of the EM Program unified the various at-sea monitoring efforts within the 5 Conservation Zones encompassed by the NWFP. The highest total population estimate for this area (20,500 +/- 4,600 birds at the 95 percent confidence interval) was in 2004 and the lowest total population estimate (17,400 +/- 4,600 birds at the 95 percent confidence interval) was in 2007 (Gary Falxa, *in litt*., 2008). The most recent population estimate for Conservation Zone 6 is 400 (+/- 140 birds at the 95 percent confidence interval) (Peery et al. 2008).

Population Trend

Estimated population trends within each Conservation Zone or for the entire coterminous population are not yet available from the marine survey data. Trend information will eventually be provided through the analysis of marine survey data from the EM Program (Bentivoglio et al. 2002) and from survey data in Conservation Zone 6 once a sufficient number of survey years have been completed. Depending on the desired minimum power (80 or 95 percent), at least 8 to 10 years of successive surveys are required for an overall population estimate and thus detection of an annual decrease, while 7 to 16 years are required for Conservation Zones 1 and 2 (Huff et al. 2003).

In the interim, demographic modeling has aided attempts to analyze and predict population trends and extinction probabilities of murrelets. Incorporating important population parameters and species distribution data (Beissinger 1995; Beissinger and Nur 1997 in USFWS 1997b; Cam et al. 2003; McShane et al. 2004), demographic models can provide useful insights into potential population responses from the exposure to environmental pressures and perturbations. However, weak assumptions or inaccurate estimates of population parameters such as survivorship rates, breeding success, and juvenile-to-adult ratios (juvenile ratios), can limit the use of models. Thus,

a cautious approach is warranted when forecasting long-term population trends using demographic models.

Most of the published demographic models used to estimate murrelet population trends employ Leslie Matrix modeling (McShane et al. 2004). Two other more complex, unpublished models (Akcakaya 1997 and Swartzman et al. 1997 in McShane et al. 2004) evaluate the effect of nest habitat loss on murrelets in Conservation Zone 4 (McShane et al. 2004). McShane et al. (2004) developed a stochastic Leslie Matrix model (termed "Zone Model") to project population trends in each murrelet Conservation Zone. The Zone Model was developed to integrate available demographic information for a comparative depiction of current expectations of future population trends and probability of extinction in each Conservation Zone (McShane et al. 2004). Table 1 lists rangewide murrelet demographic parameter values from four studies all using Leslie Matrix models.

Table 1. Rangewide murrelet demographic parameter values based on four studies all using Leslie Matrix models

| Demographic Parameter | Beissinger 1995 | Beissinger and Nur 1997* | Beissinger and Peery *in litt.* 2003 | McShane et al. 2004 |
|---|---|---|---|---|
| Juvenile Ratios | 0.10367 | 0.124 or 0.131 | 0.089 | 0.02 - 0.09 |
| Annual Fecundity | 0.11848 | 0.124 or 0.131 | 0.06-0.12 | (See nest success) |
| Nest Success | | | 0.16-0.43 | 0.38 - 0.54 |
| Maturation | 3 | 3 | 3 | 2 - 5 |
| Estimated Adult Survivorship | 85 % – 90% | 85 % – 88 % | 82 % - 90 % | 83 % – 92 % |

*in (USFWS 1997b)

Regardless of model preference, the overall results of modeling efforts are in agreement, indicating murrelet abundance is declining (McShane et al. 2004, p. 6-27). The rates of decline are highly sensitive to the assumed adult survival rate used for calculation (Steven R. Beissinger and M. Z. Peery *in litt*., 2003). The most recent modeling effort using the "Zone Model" (McShane et al. 2004) suggests the murrelet zonal sub-populations are declining at a rate of 3.0 to 6.2 percent per year.

Estimates of breeding success are best determined from nest site data, but difficulties in finding nests has led to the use of other methods, such as juvenile ratios and radio-telemetry estimations, each of which have biases. The nest success data presented in Murrelet Table 1 under McShane et al. (2004) was derived primarily from radio telemetry studies; however the nests sampled in these studies were not representative of large areas and specifically did not include Washington or Oregon. In general, telemetry estimates are preferred over juvenile ratios for estimating breeding success due to fewer biases (McShane et al. 2004), but telemetry data are not currently available for Washington or Oregon. Therefore, it is reasonable to expect that juvenile ratios derived from at-sea survey efforts best represent murrelet reproductive success in Washington, Oregon, and California.

Beissinger and Peery (Beissinger and Peery, *in litt*., 2003) performed a comparative analysis using data from 24 bird species to predict the juvenile ratios for murrelets of 0.27 (confidence intervals ranged from 0.15 to 0.65). Demographic models suggest murrelet population stability requires a minimum of 0.18 to 0.28 chicks per pair per year (Beissinger and Nur 1997 in USFWS 1997b). The lower confidence intervals for both the predicted juvenile ratio (0.15) and the stable population juvenile ratio (0.18) are greater than the juvenile ratios observed for any of the Conservation Zones (0.02 to 0.09 chicks per pair) (Beissinger and Nur 1997 in USFWS 1997b; Beissinger and Peery, *in litt*., 2003). Therefore, the juvenile ratios observed in the Conservation Zones are lower than predicted and are too low to obtain a stable population in any Conservation Zone. This indicates murrelet populations are declining in all Conservation Zones and will continue to decline until reproductive success improves.

Demographic modeling, the observed juvenile ratios, and adult survivorship rates suggests that the number of murrelets in Washington, Oregon, and California are too low to sustain a murrelet population. The rate of decline for murrelets throughout the listed range is estimated to be between 2.0 to 15.8 percent (Beissinger and Nur 1997 in USFWS 1997b; McShane et al. 2004).

Murrelets in Washington (Conservation Zones 1 and 2)

*Population estimates*

Historically, murrelets in Conservation Zones 1 and 2 were "common" (Rathbun 1915 and Miller et al. 1935 in USFWS 1997b), "abundant" (Edson 1908 and Rhoades 1893 in USFWS 1997b), or "numerous" (Miller et al. 1935 in McShane et al. 2004). Conservation Zone 1, encompassing the Puget Sound in northwest Washington, contains one of the larger murrelet populations in the species' listed range, and supports an estimated 41 percent of the murrelets in the coterminous United States (Huff et al. 2003). The 2007 population estimate (with 95 percent confidence intervals) for Conservation Zone 1 is 7,000 (4,100 – 10,400) and Conservation Zone 2 is 2,500 (1,300 – 3,800) (Falxa, *in litt.,* 2008). In Conservation Zone 2, a higher density of murrelets occurs in the northern portion of the Zone (Huff et al. 2003) where the majority of available nesting habitat occurs. In Conservation Zone 1, higher densities of murrelets occur in the Straits of Juan de Fuca, the San Juan Islands, and the Hood Canal (Huff et al. 2003), which are in proximity to nesting habitat on the Olympic Peninsula and the North Cascade Mountains.

Although population numbers in Conservation Zones 1 and 2 are likely declining, the precise rate of decline is unknown. The juvenile ratio derived from at-sea survey efforts in Conservation Zone 1 is 0.09. The juvenile ratios was not collected in Conservation Zone 2; however, the juvenile ratio for Conservation Zone 3 is 0.08. Therefore, it is reasonable to infer that the juvenile ratio for Conservation Zone 2 is likely between 0.08 and 0.09. These low juvenile ratios infer there is insufficient juvenile recruitment to sustain a murrelet population in Conservation Zones 1 and 2. Beissinger and Peery (Beissinger and Peery, *in litt*., 2003) estimated the rate of decline for Conservation Zone 1 to be between 2.0 to 12.6 percent and between 2.8 to 13.4 percent in Conservation Zone 3. It is likely that the rate of decline in Conservation Zone 2 is similar to that of Conservation Zones 1 and 3.

Juvenile ratios in Washington may be skewed by murrelets coming and going to British Columbia. At-sea surveys are timed to occur when the least number of murrelets from British Columbia are expected to be present. However, recent radio-telemetry information indicates 1) murrelets nesting in British Columbia forage in Washington waters during the breeding season (Bloxton and Raphael 2008) and could be counted during at-sea surveys; and 2) adult murrelets foraging in Washington during the early breeding season moved to British Columbia in mid-June and mid-July (Bloxton and Raphael 2008) and would not have been counted during the at-sea surveys. The movements of juvenile murrelets in Washington and southern British Columbia are unclear. Therefore, until further information is obtained regarding murrelet migration between British Columbia and Washington, we will continue to rely on the at-sea derived juvenile ratios to evaluate the population status in Conservation Zones 1 and 2.

**Habitat Abundance**

Estimates of the amount of available suitable nesting habitat vary as much as the methods used for estimating murrelet habitat. McShane et al. (2004) estimates murrelet habitat in Washington State at 1,022,695 acres, representing approximately 48 percent of the estimated 2,223,048 acres remaining suitable habitat in the listed range. McShane et al. (2004) caution about making direct comparisons between current and past estimates due to the evolving definition of suitable habitat and methods used to quantify habitat. As part of the ongoing pursuit to improve habitat estimates, information was collected and analyzed by the Service in 2005 resulting in an estimated 751,831 acres in Conservation Zone 1 and 585,821 acres in Conservation Zone 2 (Table 2).

Table 2. Estimated acres of suitable nesting habitat for the murrelet managed by the Federal and non-Federal land managers in Conservation Zones 1 and 2

| Conservation Zone | Estimated acres of suitable murrelet habitat by land management category * | | | | |
|---|---|---|---|---|---|
| | Federal | State | Private* | Tribal | Total |
| Puget Sound (Zone 1) | 650,937 | 98,036 | 2,338 | 520 | 751,831 |
| Western Washington Coast Range (Zone 2) | 485,574 | 82,349 | 9,184 | 8,714 | 585,821 |
| Total | 1,136,511 | 180,385 | 11,522 | 9,234 | 1,337,652 |

*Estimated acres of private land represents occupied habitat. Additional suitable nesting habitat considered unoccupied by nesting murrelets is not included in this estimate.

Estimated acreages of suitable habitat on Federal lands in Table 2 are based on modeling and aerial photo interpretation and likely overestimate the actual acres of suitable murrelet habitat because 1) most acreages are based on models predicting spotted owl nesting habitat which include forested lands that do not have structures suitable for murrelet nesting, and 2) neither modeling or aerial photo interpretation can distinguish microhabitat features, such as nesting platforms or the presence of moss, that are necessary for murrelet nesting. The amount of high quality murrelet nesting habitat available in Washington, defined by the Service as large, old, contiguously forested areas not subject to human influences (e.g., timber harvest or urbanization) is expected to be a small subset of the estimated acreages in Table 2. Murrelets nesting in high-

quality nesting habitat are assumed to have a higher nesting success rate than murrelets nesting in fragmented habitat near humans.

Other Recent Assessments of Murrelet Habitat in Washington

Two recent assessments of murrelet potential nesting habitat were developed for monitoring the Northwest Forest Plan (Raphael et al. 2006). This study provides a provincial-scale analysis of murrelet habitat derived from vegetation base maps, and includes estimates of habitat on State and private lands in Washington for the period of 1994 to 1996. Using vegetation data derived from satellite imagery, Raphael et al. (2006) developed two different approaches to model habitat suitability. The first model, or the Expert Judgment Model, is based on the judgment of an expert panel that used existing forest structure classification criteria (e.g., percent conifer cover, canopy structure, quadratic mean diameter, forest patch size) to classify forests into four classes of habitat suitability, with Class 1 indicating the least suitable habitat and Class 4 indicating the most highly suitable habitat. Raphael et al. (2006) found that across the murrelet range, most habitat-capable land (52 percent) is classified as Class 1 (lowest suitability) habitat and 18 percent is classified as Class 4 (highest suitability) habitat. In Washington, they found that there were approximately 954,200 acres of Class 4 habitat in between 1994 and 1996 (Table 3). However, only 60 percent of known nest sites in their study area were located in Class 4 habitat.

The second habitat model developed by Raphael et al. (2006) used the Biomapper Ecological Niche-Factor Analysis model developed by Hirzel et al. (2002). The resulting murrelet habitat suitability maps are based on both the physical and vegetative attributes adjacent to known murrelet occupied polygons or nest locations for each Northwest Forest Plan province. The resulting raster maps are a grid of 269 $ft^2$-cells (25 $m^2$-cells) (0.15 acres per pixel). Each cell in the raster is assigned a value of 0 to 100. Values closer to 100 represent areas that match the murrelet nesting locations while values closer to 0 are likely unsuitable for nesting (Raphael et al. 2006). These maps do not provide absolute habitat estimates, but rather a range of habitat suitability values, which can be interpreted in various ways. Raphael et al. (2006) noted that the results from the Ecological Niche Factor Analysis (ENFA) are not easily compared to results from the Expert Judgment Model because it was not clear what threshold from the habitat suitability ranking to use. Raphael et al. (2006) elected to display habitat suitability scores greater than 60 (HS >60) as a "generous" portrayal of potential nesting habitat and a threshold greater than 80 (HS >80) as a more conservative estimate. In Washington, there were over 2.1 million acres of HS >60 habitat, but only 440,700 acres of HS >80 habitat (Table 3). It is important to note that HS >60 habitat map captures 82 percent of the occupied nests sites in Washington, whereas the HS >80 habitat map only captures 36 percent of the occupied nests in Washington.

Table 3. Comparison of different habitat modeling results for the Washington nearshore zone (0 to 40 mi inland or Northwest Forest Plan Murrelet Zone 1)

| Murrelet Habitat Model | Habitat Acres on Federal Reserves (LSRs, Natl.Parks) | Habitat Acres on Federal, Non-Reserves (USFS Matrix) | Total Habitat Acres on Federal Lands | Total Habitat Acres on Non-Federal Lands (City, State, Private, Tribal) | Total Habitat Acres - All Ownerships | Percent of Total Habitat Acres on Non-Federal Lands | Percent of Known Murrelet Nest Sites in Study Area Occurring in this Habitat Classification |
|---|---|---|---|---|---|---|---|
| ENFA* HS >80 | 284,300 | 18,600 | 302,900 | 137,800 | 440,700 | 31% | 36% |
| EJM* Class 4 | 659,200 | 40,700 | 699,900 | 254,300 | 954,200 | 11% | 60% |
| EJM Class 3 and Class 4 | 770,600 | 54,700 | 825,300 | 535,200 | 1,360,500 | 16% | 65% |
| ENFA HS >60 | 927,000 | 85,300 | 1,012,300 | 1,147,100 | 2,159,400 | 53% | 82% |

*ENFA = Ecological Niche Facto Analysis. EJM = Expert Judgment Model. Results were summarized directly from Tables 4 and 5 and Tables 9 and 10 in Raphael et al (2005). All habitat estimates represent 1994-1996 values.

Because the HS >60 model performed best for capturing known murrelet nest sites, Raphael et al. (2006) suggest that the ENFA HS >60 model yields a reasonable estimate of potential murrelet nesting habitat. However, we found that large areas in southwest Washington identified in the HS >60 model likely overestimates the actual suitable habitat in this landscape due to a known lack of old-forest in this landscape. Despite the uncertainties associated with interpreting the various map data developed by Raphael et al. (2006), it is apparent that there is a significant portion of suitable habitat acres located on non-Federal lands in Washington, suggesting that non-Federal lands may play a greater role in the conservation needs of the species than has previously been considered. Using the most conservative criteria developed by Raphael et al. (2006) the amount of high-quality murrelet nesting habitat on non-Federal lands in Washington varies from 11 percent to as high as 31 percent (Table 3).

Raphael et al. (2006) note that the spatial accuracy of the map data are limited and that the habitat maps are best used for provincial-scale analysis. Due to potential errors in vegetation mapping and other potential errors, these maps are not appropriate for fine-scale project mapping.

Conservation Zone 1

The majority of suitable murrelet habitat in Conservation Zone (Zone) 1 occurs in northwest Washington and is found on Forest Service and National Park Service lands, and to a lesser extent on State lands. The majority of the historic habitat along the eastern and southern shores of the Puget Sound has been replaced by urban development resulting in the remaining suitable habitat further inland from the marine environment (USFWS 1997b).

Conservation Zone 2

Murrelet nesting habitat north of Gray's Harbor in Zone 2 occurs largely on State, Forest Service, National Park Service, and Tribal lands, and to a lesser extent, on private lands. Alternatively, the majority of habitat in the southern portion of Zone 2 occurs primarily on State lands, with a small amount on private lands.

**Threats**

Murrelets remain subject to a variety of anthropogenic threats within the upland and marine environment. They also face threats from low population numbers, low immigration rates, high predation rates, and disease.

Threats in the Marine Environment

Threats to murrelets in the marine environment include declines in prey availability; mortality associated with exposure to oil spills, gill net and other fisheries; contaminants suspended in marine waters; and visual or sound disturbance from recreational or commercial watercrafts (57 FR 45328 [October 1, 1992]; (Ralph et al. 1995; USFWS 1997b; McShane et al. 2004). Activities, such as pile driving and underwater detonations, that result in elevated underwater sound pressure levels may also pose a threat to murrelets.

*Prey Availability*

Many fish populations have been depleted due to overfishing, reduction in the amount or quality of spawning habitat, and pollution. As of 2004, only 50 percent of the Puget Sound herring stocks were classified as healthy or moderately healthy, with north Puget Sound's stock being considered depressed and the Strait of Juan de Fuca's stocks being classified as critical (WDFW 2005d). Natural mortality in some of these stocks has increased (e.g. the mean estimated annual natural mortality rate for sampled stocks from 1987 through 2003 averaged 71 percent, up from 20 to 40 percent in the late 1970s) (WDFW 2005c). There is currently only one commercial herring fishery which operates primarily in south and central Puget Sound (WDFW 2005b) where herring stocks are healthier. Unfortunately, the decline of some herring stocks may be affecting the forage base for murrelets in Puget Sound. There is limited information available for the coastal herring populations, but these populations appear to have relatively high levels of abundance (WDFW 2005a). There are herring fisheries in Willapa Bay and Grays Harbor, but no direct harvest is allowed in the coastal waters.

While there are commercial and recreational fisheries for surf smelt, the amount of harvest does not appear to be impacting the surf smelt stocks (Bargmann 1998). There are no directed commercial fisheries for sand lance (Bargmann 1998). Anchovies are taken commercially within coastal and estuarine waters of Washington. While the current harvest level doesn't appear to be impacting anchovy stocks, there is no current abundance information (Bargmann 1998).

In addition to fishing pressure, oceanographic variation can influence prey availability. While the effects to murrelets from events such as El Niño have not been well documented, El Niño events are thought to reduce overall prey availability and several studies have found that El Niño events can influence the behavior of murrelets (McShane et al. 2004). Even though changes in prey availability may be due to natural and cyclic oceanographic variation, these changes may exacerbate other threats to murrelets in the marine environment.

Shoreline development has affected and will continue to effect coastal processes. Shipping, bulkheads, and other shoreline developments have contributed to the reduction in eelgrass beds and other spawning and rearing areas for forage species.

*Oil Spills*

Murrelet mortality from oil pollution is a conservation issue in Washington (USFWS 1997b). Most oil spills and chronic oil pollution that can affect murrelets occur in areas of high shipping traffic, such as the Strait of Juan de Fuca and Puget Sound. There have been at least 47 oil spills of 10,000 gal or more in Washington since 1964 (WDOE 2004). However, the number of oil spills has generally declined since passage of the U.S. Oil Pollution Act in 1990. The estimated annual mortality of murrelets from oil spills in Washington has decreased from 3 to 41 birds per year (between 1977 and 1992) to 1 to 2 birds per year (between 1993 and 2003) (McShane et al. 2004).

Since the murrelet was listed, the amount of oil tanker and shipping traffic has continued to increase (USFWS 1997b; Burger 2002). Large commercial ships, including oil tankers, cargo ships, fish processing ships, and cruise ships, enter Washington waters more than 7,000 times each year, bound for ports in Puget Sound, British Columbia, Grays Harbor, and the Columbia River (WDOE 2004). Additionally, 4,500 tank-barge transits, 160,000 ferry transits, and military vessel traffic occur in these same waters each year (WDOE 2004). Individually these vessels may carry up to 33 M gal of crude oil or refined petroleum products, but collectively, they carry about 15.1 B gal across Puget Sound waters each year (WDOE 2004). These numbers are expected to increase as the human population and commerce continues to grow. Currently, there are State and Federal requirements for tug escorts of laden oil tankers transiting the waters of Puget Sound east of Dungeness Spit. However, the Federal requirements do not apply to double-hulled tankers and will no longer be in effect once the single-hull tanker phase-out is complete (WDOE 2005). Washington State is considering revising their tug escort requirements (WDOE 2005); however, the current tug escort requirements remain in place until the Washington State Legislature makes a change.

The U.S. Coast Guard rated the Dungeness area in the Strait of Juan de Fuca as being in the top five high-risk areas of the United States for being impacted by oil spills (USFWS 2003b). Therefore, even though the threat from oil spills appears to have been reduced since the murrelet was listed, the risk of a catastrophic oil spill remains, and could severely impact adult and/or juvenile murrelets in Conservation Zones 1 and 2.

*Gillnets*

Murrelet mortality from gillnet fishing has been considered a conservation issue in Washington (USFWS 1997b; Melvin et al. 1999). Murrelets can also be killed by hooking with fishing lures and entanglement with fishing lines (Carter et al. 1995). There is little information available on murrelet mortality from net fishing prior to the 1990s, although it was known to occur (Carter et al. 1995). In the mid 1990s, a series of fisheries restrictions and changes were implemented to address mortality of all species of seabirds, resulting in a lower mortality rate of murrelets (McShane et al. 2004). Fishing effort has also decreased since the 1980s because of lower catches, fewer fishing vessels, and greater restrictions (McShane et al. 2004), although a regrowth in gill net fishing is likely to occur if salmon stocks increase. In most areas, the threat from gill net fishing has been reduced or eliminated since 1992, but threats to adult and juvenile murrelets are still present in Washington waters due to gill net mortality (McShane et al. 2004).

Entanglement in derelict fishing nets, which are nets that have been lost, abandoned or discarded in the marine environment, may also pose a threat. Derelict gear can persist in the environment for decades and poses a threat to marine mammals, seabirds, shellfish, and fish. A recent survey estimated 3,900 derelict nets need to be removed from Puget Sound annually (Northwest Straits Foundation 2007) and each year the number of new derelict nets increases faster than the number removed. Over 50 percent of the derelict nets in Puget Sound occur in waters where murrelet densities are the highest in Washington. Derelict fishing gear also occurs along the Washington coast and the outer Straits of Juan de Fuca. While this high energy environment may reduce the time a derelict net remains suspended compared to a lower energy environment like the inner Puget Sound where gear may persist for years (NRC 2007), the amount of time a derelict net poses a threat to marine species depends on the length and type of the net and cause of entanglement.

*Marine Contaminants*

The primary consequence from the exposure of murrelets to contaminants is reproductive impairment. Reproduction can be impacted by food web bioaccumulation of organochlorine pollutants and heavy metals discharged into marine areas where murrelets feed and prey species concentrate (Fry 1995). However, murrelet exposure is likely a rare event because murrelets have widely dispersed foraging areas and they feed extensively on transient juvenile and subadult midwater fish species that are expected to have low pollutant loads (McShane et al. 2004). The greatest exposure risk to murrelets may occur at regular feeding areas near major pollutant sources, such as those found in Puget Sound (McShane et al. 2004).

*Disturbance*

In coastal and offshore marine environments, vehicular disturbance (e.g., boats, airplanes, personal watercraft) is known to elicit behavioral responses in murrelets of all age classes (Kuletz 1996; Speckman 1996; Nelson 1997). Aircraft flying at low altitudes and boating activity, in particular motorized watercraft, are known to cause murrelets to dive and are thought to especially affect adults holding fish (Nelson 1997). It is unclear to what extent this kind of disturbance affects the distribution, movements, foraging efficiency, and overall fitness of

murrelets. However, it is unlikely this type of disturbance has decreased since 1992 because the shipping traffic and recreational boat use in the Puget Sound and Strait of Juan de Fuca has continued to increase.

Marine projects that include seismic exploration, pile driving, detonation of explosives and other activities that generate percussive sounds can expose murrelets to elevated underwater sound pressure levels (SPLs). High underwater SPLs can have adverse physiological and neurological effects on a wide variety of vertebrate species (Yelverton et al. 1973; Yelverton and Richmond 1981; Steevens et al. 1999; Fothergill et al. 2001; Cudahy and Ellison 2002; U.S. Department of Defense 2002; Popper 2003). High underwater SPLs are known to injure and/or kill fish by causing barotraumas (pathologies associated with high sound levels including hemorrhage and rupture of internal organs), as well as causing temporary stunning and alterations in behavior (Turnpenny and Nedwell 1994; Turnpenny et al. 1994; Popper 2003; Hastings and Popper 2005). During monitoring of seabird response to pile driving in Hood Canal, Washington, a pigeon guillemot (*Cepphus columba*) was observed having difficulty getting airborne after being exposed to underwater sound from impact pile driving (Entranco and Hamer Environmental 2005). In controlled experiments using underwater explosives, rapid change in SPLs caused internal hemorrhaging and mortality in submerged mallard ducks (*Anas platyrhnchos*) (Yelverton et al. 1973). Risk of injury appears related to the effect of rapid pressure changes, especially on gas filled spaces in the bodies of exposed organisms (Turnpenny et al. 1994). In studies on ducks (*Anas spp.*) and a variety of mammals, all species exposed to underwater blasts had injuries to gas filled organs including eardrums (Yelverton and Richmond 1981). These studies indicate that similar effects can be expected across taxonomical species groups.

Physical injury may not result in immediate mortality. If an animal is injured, death may occur several hours or days later, or injuries may be sublethal. Sublethal injuries can interfere with the ability of an organism to carry out essential life functions such as feeding and predator avoidance. Diving birds are able to detect and alter their behavior based on sound in the underwater environment (Ross et al. 2001) and elevated underwater SPLs may cause murrelets to alter normal behaviors, such as foraging. Disturbance related to elevated underwater SPLs may reduce foraging efficiency resulting in increased energetic costs to all murrelet age classes in the marine environment and may result in fewer deliveries or lower quality food being delivered to nestlings.

Threats in the Terrestrial Environment

*Habitat*

Extensive harvest of late-successional and old-growth forest was the primary reason for listing the murrelet as threatened. Due primarily to extensive timber cutting over the past 150 years, at least 82 percent of the old-growth forests existing in western Washington and Oregon prior to the 1840s have been harvested (Teensma et al. 1991; Booth 1991; Ripple 1994; Perry 1995). About 10 percent of pre-settlement old-growth forests remain in western Washington (Norse 1990; Booth 1991). Although the Northwest Forest Plan has reduced the rate of habitat loss on Federal lands, the threat of continued loss of suitable nesting habitat remains on Federal and non-Federal

lands through timber harvest and natural events such as wildfire, insect outbreaks, and windthrow.

Natural disturbance has the potential to affect the amount and quality of murrelet nesting habitat. Wildfire and windthrow result in immediate loss of habitat and can also influence the quality of adjacent habitat. Global warming, combined with long-term fire suppression on Federal lands, may result in higher incidences of stand-replacing fires in the future (McShane et al. 2004). As forest fragmentation increases, the threat of habitat loss due to windthrow is likely to increase. In addition, insects and disease can kill complete stands of habitat and can contribute to hazardous forest fire conditions.

Between 1992 and 2003, the loss of suitable murrelet habitat totaled 22,398 acres in Washington, Oregon, and California combined, of which 5,364 acres resulted from timber harvest and 17,034 acres resulted from natural events (McShane et al. 2004). The data presented by McShane represented losses primarily on Federal lands, and did not include data for most private lands within the murrelets' range. Habitat loss and fragmentation is expected to continue in the near future, but at an uncertain rate (McShane et al. 2004). Raphael et al. (2006) recently completed a change analysis for marbled murrelet habitat on both Federal and non-Federal lands for the period from 1992 to 2003, based on stand disturbance map data developed by Healey et al. (2003). Raphael et al. (2006) estimated that habitat loss ranging from 60,000 acres up to 278,000 acres has occurred across the listed range of the species, with approximately 10 percent of habitat loss occurring on Federal lands, and 90 percent occurring on non-Federal lands. The variation in the acreage estimates provided by Raphael et al. (2006) are dependant upon the habitat model used (Table 3) to evaluate habitat change over time.

Gains in suitable nesting habitat are expected to occur on Federal lands over the next 40 to 50 years, but due to the extensive historic habitat loss and the slow replacement rate of murrelets and their habitat, the species is potentially facing a severe reduction in numbers in the coming 20 to 100 years (USFS and USBLM 1994a; Beissinger 2002). In addition to direct habitat removal, forest management practices can fragment murrelet habitat; this reduces the amount and heterogeneous nature of the habitat, reduces the forest patch sizes, reduces the amount of interior or core habitat, increases the amount of forest edge, isolates remaining habitat patches, and creates "sink" habitats (McShane et al. 2004). There are no estimates available for the amount of suitable habitat that has been fragmented or degraded since 1992. However, the ecological consequences of these habitat changes to murrelets can include effects on population viability and size, local or regional extinctions, displacement, fewer nesting attempts, failure to breed, reduced fecundity, reduced nest abundance, lower nest success, increased predation and parasitism rates, crowding in remaining patches, and reductions in adult survival (Raphael et al. 2002).

*Predation*

Predation is expected to be the principal factor limiting murrelet reproductive success and nest site selection (Ralph et al. 1995; Nelson and Hamer 1995a). Murrelets are believed to be highly vulnerable to nest predation compared to other alcids and forest nesting birds (Nelson and Hamer 1995a; USFWS 1997b). Murrelets have no protection at nest sites other than the ability to

remain hidden. Nelson and Hamer (1995a) hypothesized that small increases in murrelet predation will have deleterious effects on murrelet population viability due to their low reproductive rate (one egg clutches).

Known predators of adult murrelets in the forest environment include the peregrine falcon (*Falco peregrinus*), sharp-shinned hawk (*Accipiter striatus*), common raven (*Corvus corax*), northern goshawk (*Accipiter gentilis*), and bald eagle (*Haliaeetus leucocephalus*). Common ravens and Stellar's jays (*Cyanocitta stelleri*) are known to take both eggs and chicks at the nest, while sharp-shinned hawks have been found to take chicks. Common ravens account for the majority of egg depredation, as they appear to be the only predator capable of flushing incubating or brooding adults from a nest (Nelson and Hamer 1995a). Suspected nest predators include great horned owls (*Bubo virginianus*), barred owls (*Strix varia*), Cooper's hawks (*Accipiter cooperi*), northwestern crows (*Corvus caurinus*), American crows (*Corvus brachyrhynchos*), and gray jays (*Perisoreus canadensis*) (Nelson and Hamer 1995a; Nelson 1997; Manley 1999). Predation by squirrels and mice has been documented at artificial nests and these animals cannot be discounted as potential predators on eggs and chicks (Luginbuhl et al. 2001; Raphael et al. 2002; Bradley and Marzluff 2003).

Losses of eggs and chicks to avian predators have been determined to be the most important cause of nest failure (Nelson and Hamer 1995a; McShane et al. 2004). The risk of predation by avian predators appears to be highest in complex structured landscapes in proximity to edges and human activity, where many of the corvid (e.g., crows, ravens) species are in high abundance. Predation rates are influenced mainly by habitat stand size, habitat quality, nest placement (on the edge of a stand versus the interior of a stand), and proximity of the stand to human activity centers. The quality of murrelet nest habitat decreases in smaller stands because forest edge increases in relation to the amount of interior forest, while forest stands near human activity centers (less than 0.62 mi or 1 km), regardless of size, are often exposed to a higher density of corvids due to their attraction to human food sources (Marzluff et al. 2000). The loss of nest contents to avian predators increases with habitat fragmentation and an increase in the ratio of forest edge to interior habitat (Nelson and Hamer 1995a; McShane et al. 2004). For example, Nelson and Hamer (1995a) found successful nests were farther from edges (greater than 55 m) and were better concealed than unsuccessful nests.

The abundance of several corvid species has increased dramatically in western North America as a result of forest fragmentation, increased agriculture, and urbanization (McShane et al. 2004). It is reasonable to infer that as predator abundance has increased, predation on murrelet chicks and eggs has also increased, and murrelet reproductive success has decreased. It is also reasonable to assume that this trend will not be interrupted or reversed in the near future, as forest fragmentation, agriculture, and urbanization continue to occur.

Other Threats

Murrelets are subject to additional threats from diseases, genetics, low population numbers, and low immigration rates. To date, inbreeding (mating between close genetic relatives) and/or hybridizing (breeding with a different species or subspecies) have not been identified as threats to murrelet populations. However, as abundance declines, a corresponding decrease in the

resilience of the population to disease, inbreeding or hybridization, and other perturbations may occur. Additionally, murrelets are considered to have low recolonization potential because their low immigration rate makes the species slow to recover from local disturbances (McShane et al. 2004).

The emergence of fungal, parasitic, bacterial, and viral diseases has affected populations of seabirds in recent years. West Nile virus disease has been reported in California which is known to be lethal to seabirds. While the amount of negative impact this disease may bring is unknown, researchers agree that it is only a matter of time before West Nile virus reaches the Washington seabird population. Effects for murrelets from West Nile virus and other diseases are expected to increase in the near future due to an accumulation of stressors such as oceanic temperature changes, overfishing, and habitat loss (McShane et al. 2004).

Murrelets may be sensitive to human-caused disturbance due to their secretive nature and their vulnerability to predation. There are little data concerning the murrelet's vulnerability to disturbance effects, except anecdotal researcher observations that indicate murrelets typically exhibit a limited, temporary behavioral response (if any) to noise disturbance at nest sites and are able to adapt to auditory stimuli (Long and Ralph 1998; Golightly et al. 2002; Singer et al. 1995 in McShane et al. 2004). In general, responses to auditory stimuli at nests sites have been modifications of posture and on-nest behaviors (Long and Ralph 1998). While the unique breeding biology of the murrelet is not conducive to comparison of the reproductive success of other species, studies on other alcid and seabird species have revealed detrimental effects of disturbance to breeding success and the maintenance of viable populations (Cairns 1980; Pierce and Simons 1986; Piatt et al. 1990; Beale and Monaghan 2004).

Research on a variety of other species, including other seabirds, indicate an animal's response to disturbance follows the same pattern as its response to encountering predators, and anti-predator behavior has a cost to other fitness enhancing activities, such as feeding and parental care (Frid and Dill 2002). Some authors indicate disturbance stimuli can directly affect the behavior of individuals and indirectly affect fitness and population dynamics through increased energetic costs (Carney and Sydeman 1999; Frid and Dill 2002). Responses by murrelet adults and chicks to calls from corvids and other potential predators include no response, alert posturing, aggressive attack, and temporarily leaving a nest (adults only) (McShane et al. 2004). However, the most typical behavior of chicks and adults in response to the presence of a potential predator is to flatten against a tree branch and remain motionless (Nelson and Hamer 1995a; McShane et al. 2004). Therefore, researcher's anecdotal observations of little or no physical response by murrelets are consistent with the behavior they will exhibit in response to a predator. In addition, there may have been physiological responses researchers cannot account for with visual observations. Corticosterone studies have not been conducted on murrelets, but studies on other avian species indicate chronic high levels of this stress hormone may have negative consequences on reproduction or physical condition (Wasser et al. 1997; Kitaysky et al. 2001; Marra and Holberton 1998 in McShane et al. 2004).

Although detecting effects of sub-lethal noise disturbance at the population level is hindered by the breeding biology of the murrelet, the effect of noise disturbance on murrelet fitness and reproductive success should not be completely discounted (McShane et al. 2004). In recently

completed analyses, the Service concluded the potential for injury associated with disturbance (visual and sound) to murrelets in the terrestrial environment includes flushing from the nest, aborted feeding, and postponed feedings (USFWS 2003a). These responses by individual murrelets to disturbance stimuli can reduce productivity of the nesting pair, as well as the entire population (USFWS 1997b).

**Conservation Needs**

The Recovery Plan outlines the conservation strategy for the species. In the short-term, specific actions necessary to stabilize the population include maintaining occupied habitat, maintaining large blocks of suitable habitat, maintaining and enhancing buffer habitat, decreasing risks of nesting habitat loss due to fire and windthrow, reducing predation, and minimizing disturbance.

Long-term conservation needs include increasing productivity (abundance, the ratio of juveniles to adults, and nest success) and population size; increasing the amount (stand size and number of stands), quality, and distribution of suitable nesting habitat; protecting and improving the quality of the marine environment; and reducing or eliminating threats to survivorship by reducing predation in the terrestrial environment and anthropogenic sources of mortality at sea. The Service estimates recovery of the murrelet will require at least 50 years (USFWS 1997b).

The Recovery Plan states that four of the six Conservation Zones (Zones) must be functional in order to effectively recover the murrelet in the short- and long-term; that is, to maintain viable populations that are well-distributed. However, based on the new population estimates, it appears only three of the Zones contain relatively robust numbers of murrelets (Zones 1, 3, and 4). Zones 1 and 4 contain the largest number of murrelets compared to the other four Zones. This alone would seem to indicate a better condition there, but areas of concern remain. For example, the population in Zone 4 was impacted when oil spills killed an estimated 10 percent of the population (Bentivoglio et al. 2002; Ford et al. 2002), small oil spills continue to occur in Zone 1, and the juvenile ratios in both of these Zones continue to be too low to establish stable or increasing populations (Beissinger and Peery, *in litt*., 2003).

Murrelets in Zones 3, 5, and 6 have suffered variously from past oil spills which killed a large number of murrelets (Zone 3) (Ford et al. 2001), extremely small population sizes (Zones 5 and 6), and alarmingly low reproductive rates (Zone 6) (Peery et al. 2002). These factors have brought the status of the species to a point where recovery in Zones 5 and 6 may be precluded (Beissinger 2002). The poor status of murrelet populations in the southern Zones emphasizes the importance of supporting murrelet populations in Zones 1 and 2 in order to preserve the opportunity to achieve murrelet recovery objectives.

**Conservation Strategy**

<u>Marine Environment</u>

Protection of marine habitat is a component of the recovery strategy. The main threat to murrelets in the marine environment is the loss of individuals through death or injury, generally associated with oil spills and gill-net entanglements. The recovery strategy recommends

providing protection within marine waters in such a way as to reduce or eliminate murrelet mortality (USFWS 1997b). The recovery strategy specifically recommends protection within all waters of Puget Sound and Strait of Juan de Fuca, and within 1.2 mi of shore along the Pacific Coast from Cape Flattery to Willapa Bay. However, newer information indicates the majority of murrelet activity along the Washington Coast occurs within 5 mi (8 km) of shore (Raphael et al. 2007), suggesting that protections should be extended to encompass this area. Management strategies could include exclusion of vessels, stricter hull requirements, exclusion of net fisheries, or modification of fishing gear.

In Washington State, the Washington Fish and Game Commission requires the use of alternative gear (i.e., visual alerts within the upper 7 ft of a multifilament net), prohibits nocturnal and dawn fishing for all non-treaty gill-net fisheries, and closes areas to gill-net fishing in order to reduce by-catch of murrelets. The Olympic Coast National Marine Sanctuary was established in 1994 along the outer Washington coast from Cape Flattery south to approximately the Copalis River and extending between 25 mi and 40 mi offshore. Oil exploration and development are prohibited within this Sanctuary (NOAA 1993).

Terrestrial Habitat Management

The loss of nesting habitat (old-growth/mature forest) has generally been identified as the primary cause of the murrelet population decline and disappearance across portions of its range (Ralph et al. 1995). Logging, urbanization, and agricultural development have all contributed to the loss of habitat, especially at lower elevations.

The recovery strategy for the murrelet is contained within the Marbled Murrelet Recovery Plan (Recovery Plan) (USFWS 1997b) relies heavily on the Northwest Forest Plan (NWFP) to achieve recovery on Federal lands in Washington, Oregon, and California. However, the Recovery Plan also addresses the role of non-Federal lands in recovery, including Habitat Conservation Plans, State forest practices, and lands owned by Native American Tribes. The importance of non-Federal lands in the survival and recovery of murrelets is particularly high in Conservation Zones, where Federal lands, and privately held conservation lands (e.g., The Nature Conservancy Teal Slough, Ellsworth, Washington), within 50 mi of the coastline are sparse, such as the southern half of Conservation Zone 2.

Lands considered essential for the recovery of the murrelet within Conservation Zones 1 and 2 are 1) any suitable habitat in a Late Successional Reserve (LSR), 2) all suitable habitat located in the Olympic Adaptive Management Area, 3) large areas of suitable nesting habitat outside of LSRs on Federal lands, such as habitat located in the Olympic National Park, 4) suitable habitat on State lands within 40 mi of the coast, and 5) habitat within occupied murrelet sites on private lands (USFWS 1997b).

*Northwest Forest Plan*

When the U.S. Forest Service (USFS) and Bureau of Land Management incorporated the NWFP as the management framework for public lands, a long-term habitat management strategy for murrelets (USFS and USBLM 1994a; USFS and USBLM 1994b) was established. The NWFP

instituted pre-project surveys of murrelet habitat in areas planned for timber harvest and the protection of existing habitat at sites determined through surveys to be occupied by murrelets.

In the short-term, all known-occupied sites of murrelets occurring on USFS or Bureau of Land Management lands under the NWFP are to be managed as Late Successional Reserves (LSRs). In the long-term, unsuitable or marginally suitable habitat occurring in LSRs will be managed, overall, to develop late-successional forest conditions, thereby providing a larger long-term habitat base into which murrelets may eventually expand. Thus, the NWFP approach offers both short-term and long-term benefits to the murrelet.

Over 80 percent of murrelet habitat on Federal lands in Washington occurs within land management allocations that protect the habitat from removal or significant degradation. Scientists predicted implementation of the NWFP would result in an 80 percent likelihood of achieving a well-distributed murrelet population on Federal lands over the next 100 years (USFS and USBLM 1994a). Although the NWFP offers protection of known-occupied murrelet sites, concerns over the lingering effects of the historic widespread removal of suitable habitat will remain until the habitat recovers to late-successional characteristics. Habitat recovery will require over 100 years in many LSRs.

*Habitat Conservation Plans*

Four Habitat Conservation Plans (HCP) addressing murrelets in Washington have been completed for private/corporate forest land managers within the range of the murrelet: West Fork Timber Corporation (Murray Pacific Corporation 1993; Murray Pacific Corporation 1995; USFWS 1995) (Mineral Tree Farm HCP); Plum Creek Timber Company (Plum Creek Timber Company, L.P. 1996; USFWS 1996a; Plum Creek Timber Company, L.P. 1999; USFWS 1999) (Cascades HCP; I-90 HCP); Port Blakely Tree Farms, L.P. (Port Blakely Tree Farms, L.P. 1996; USFWS 1996b) (R.B. Eddy Tree Farm HCP); and Simpson Timber Company (Simpson Timber Company 2000; USFWS 2000b) (Olympic Tree Farm HCP). Habitat Conservation Plans have also been completed for two municipal watersheds, City of Tacoma (USFWS 2001; Tacoma Public Utilities 2001) (Green River HCP) and City of Seattle (USFWS 2000a; City of Seattle 2001) (Cedar River HCP), and the Washington Department of Natural Resources (WDNR 1997; USFWS 1997a). The HCPs which address murrelets cover approximately 500,000 acres of non-Federal (private/corporate) lands, over 100,000 acres of municipal watershed, and over 1.6 million acres of State-managed lands. However, only a portion of these lands contain suitable murrelet habitat.

The WDNR HCP addresses murrelets in Conservation Zones 1 and 2. All of the others address murrelets in Conservation Zone 1. Most of the murrelet HCPs in Washington employ a consistent approach for murrelets by requiring the majority of habitat to be surveyed prior to timber management. Only poor-quality marginal habitat (with a low likelihood of occupancy) is released for harvest without survey. All known occupied habitat is protected to varying degrees, but a “safe-harbor-like” approach is used to address stands which may be retained as, or develop into, suitable habitat and become occupied in the future. This approach would allow future harvest of habitat which is not currently nesting habitat.

*Washington State Forest Practices Regulations*

Under Washington Forest Practices Rules, which apply to all non-Federal lands not covered by an HCP (WFPB 2005), surveys for murrelets are required prior to the harvest of suitable nesting habitat. These criteria vary depending on the location of the stand. For stands found to be occupied or known to be previously occupied, the WDNR makes a decision to issue the permit based upon a significance determination. If a determination of significance is made, preparation of a State Environmental Policy Act Environmental Impact Statement is required prior to proceeding. If a determination of non-significance or mitigated determination of non-significance is reached, the action can proceed without further environmental assessment.

*Tribal Management*

The management strategy of the Bureau of Indian Affairs for the murrelet focuses on working with Tribal governments on a government-to-government basis to develop management strategies for reservation lands and trust resources. The Bureau of Indian Affairs' management strategy typically focus on avoiding harm to murrelets when feasible, to facilitate the trust responsibilities of the United States. However, other factors must be considered. Strategies must foster Tribal self-determination, and must balance the needs of the species and the environmental, economic, and other objectives of Indian Tribes within the range of the murrelet (Renwald 1993). For example, one of the Bureau of Indian Affairs' main goals for murrelet protection includes assisting Native American Tribes in managing habitat consistent with tribal priorities, reserved Indian rights, and legislative mandates.

**Summary**

Demographic modeling results indicate murrelet populations are declining within each Conservation Zone and throughout the listed range. The juvenile to adult ratios observed at sea in the Conservation Zones are too low to obtain a stable population in any Conservation Zone, which indicates murrelet abundance in all Conservation Zones will continue to decline until reproductive success improves. In other words, there is insufficient recruitment of juveniles to sustain a murrelet population in the listed range of the species.

Some of the threats to the murrelet population may have been reduced as a result of the species' listing under the Act, such as the passage of the Oil Pollution Act and implementation of the NWFP. However, no threats have been reversed since listing and in some areas threats, such as predation and West Nile Virus, may be increasing or emerging. Threats continue to contribute to murrelet population declines through adult and juvenile mortality and reduced reproduction. Therefore, given the current status of the species and background risks facing the species, it is reasonable to assume that murrelet populations in Conservation Zones 1 and 2 and throughout the listed range have little resilience to deleterious population-level effects and are at high risk of extirpation.

Considering the life history characteristics of the murrelet, with the aggregate effects of inland habitat loss and fragmentation and at-sea mortality, the species' capability to recover from lethal perturbations at the population or metapopulation (Conservation Zone) scale is extremely low.

The low observed reproductive rates make the species highly susceptible to local extirpations when exposed to repeated perturbations at a frequency which exceeds the species' loss-replacement rate. Also troublesome is the ineffectiveness of recovery efforts at reversing the ongoing lethal consequences in all demographic classes from natural and anthropogenic sources. Despite the relatively long potential life span of adult murrelets, the annual metapopulation replacement rates needed for long-term metapopulation maintenance and stability is currently well below the annual rate of individuals being removed from each metapopulation. As a result, murrelet metapopulations are currently not self-sustaining or self-regulating.

Accordingly, the Service concludes the current environmental conditions for murrelets in the coterminous United States appear to be insufficient to support the long-term conservation needs of the species. Although information is not sufficient to determine whether murrelets are nesting at or near the carrying capacity in the remaining nest habitat, activities which degrade the existing conditions of occupied nest habitat or reduce adult survivorship and/or nest success of murrelets will be of greatest consequence to the species. Actions resulting in the further loss of occupied nesting habitat, mortality to breeding adults, eggs, or nestlings will reinforce the current murrelet population decline throughout the coterminous United States.

## STATUS OF THE SPECIES: MARBLED MURRELET
## LITERATURE CITED


Ainley, D.G., S.G. Allen, and L.B. Spear. 1995. Offshore occurrence patterns of marbled murrelets in central California. Pages 361-69. *In*: Ecology and conservation of the marbled murrelet General Technical Report: PSW-GTR-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Bargmann, G. 1998. Forage fish management plan: A Plan for managing the forage fish resources and fisheries of Washington. Olympia, Washington, 66 pp.

Beale, C.M. and P. Monaghan. 2004. Human disturbance: People as predation-free predators? Journal of Applied Ecology 41(7):335-43.

Becker, B.H., S.R. Beissinger, and H.R. Carter. 2001. Effects of oceanographic variation on marbled murrelet diet and habitat selection. University of California at Berkeley, Berkeley, CA.

Becker, B.H. and S.R. Beissinger. 2006. Centennial decline in the trophic level of an endangered seabird after fisheries decline. Conservation Biology 20(2):470-79.

Becker, B.H., M.Z. Peery, and S.R. Beissinger. 2007. Ocean climate and prey availability affect the trophic level and reproductive success of the marbled murrelet, an endangered seabird. Inter-Research Marine Ecology Progress Series 329:267-79.

Beissinger, S.R. 1995. Population trends of the marbled murrelet projected from demographic analyses. Pages 385-93. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report: PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Beissinger, S.R. 2002. Analysis of the effects of a 10% reduction of population size on marbled murrelet population dynamics in Northern California. U.S. Fish and Wildlife Service, Arcata, CA, April 5, 2002, 10 pp.

Beissinger, S.R. and M.Z. Peery. 2003. Range-wide analysis of juvenile ratios from marbled murrelet monitoring programs: Implications for demographic analyses. University of California, Berkeley, CA. 30.

Bentivoglio, N., J. Baldwin, P.G.R. Jodice, D. Evans Mack, T. Max, S. Miller, S.K. Nelson, K. Ostrom, C.J. Ralph, M.G. Raphael, C.S. Strong, C.W. Thompson, and R. Wilk. 2002. Northwest Forest Plan marbled murrelet effectiveness monitoring 2000 Annual Report. U.S. Fish and Wildlife Service, Portland, Oregon, 73 pp.

Bloxton, T.D. and M.G. Raphael. 2008. Breeding ecology of the marbled murrelet in Washington state: project update 2004-2007. A report to the U.S. Fish and Wildlife Service and U.S. Forest Service, 32 pp.

Booth, D.E. 1991. Estimating pre-logging old-growth in the Pacific Northwest. Journal of Forestry 89(10):25-29.

Bradley, J.E. and J.M. Marzluff. 2003. Rodents as nest predators: Influences on predatory behavior and consequences to nesting birds. Auk 120:1180-87.

Burger, A.E. 1995. Marine distribution, abundance and habitat of marbled murrelets in British Columbia. Pages 295-312. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report.PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Burger, A.E. 2002. Conservation assessment of marbled murrelets in British Columbia, a review of biology, populations, habitat associations and conservation. Canadian Wildlife Service, Pacific and Yukon Region, 194 pp.

Burkett, E.E. 1995. Marbled murrelet food habits and prey ecology. Pages 223-46. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report: PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Butler, P.J. and D.R. Jones. 1997. Physiology of diving birds and mammals. Physiological Reviews 77(3):837-99.

Cairns, D. 1980. Nesting density, habitat structure and human disturbance as factors in Black Guillemot reproduction. The Wilson Bulletin 92(3):352-61.

Cam, E., L. Lougheed, R. Bradley, and F. Cooke. 2003. Demographic assessment of a marbled murrelet population from capture-recapture data. Conservation Biology 17(4):1118-26.

Carney, K.M. and W.J. Sydeman. 1999. A review of human disturbance effects on nesting colonial waterbirds. Waterbirds 22(1):68-79.

Carter, H.R. and R.A. Erickson. 1992. Status and conservation of the marbled murrelet in California, 1892-1987. Pages 92-108. *In*: Carter, H.R. and M.L. Morrison (eds). Status and conservation of the marbled murrelet in North America, 5th ed. Western Foundation of Vertebrate Zoology, Camarillo, CA.

Carter, H.R., L.C. McAllister, and M.E. Isleib. 1995. Mortality of marbled murrelets in gill nets in North America. Pages 271-83. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Carter, H.R. and S.G. Sealy. 1986. Year-round use of coastal lakes by marbled murrelets. Condor 88(4):473-77.

Carter, H.R. and S.G. Sealy. 1990. Daily foraging behavior of marbled murrelets. Studies in Avian Biology 14:93-102.

Carter, H.R. and J.L. Stein. 1995. Molts and plumages in the annual cycle of the marbled murrelet. Pages 99-109. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

City of Seattle. 2001. Final Cedar River Watershed Habitat Conservation Plan for the issuance of a permit to allow incidental take of threatened and endangered species. Seattle, Washington, 1034 pp.

Croll, D.A., A.J. Gaston, A.E. Burger, and D. Konoff. 1992. Foraging behavior and physiological adaptation for diving in think-billed murres. Ecology 73(1):334-56.

Cudahy, E. and W.T. Ellison. 2002. A review of the potential for in vivo tissue damage by exposure to underwater sound. Naval Submarine Research Laboratory, Department of the Navy, Groton, Connecticut, March 12, 2002, 6 pp.

Day, R.H. and D.A. Nigro. 2000. Feeding ecology of Kittlitz's and marbled murrelets in Prince William Sound, Alaska. Waterbirds 23(1):1-14.

Divoky, G.J. and M. Horton. 1995. Breeding and natal dispersal, nest habitat loss and implications for marbled murrelet populations. Pages 83-87. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Entranco, Inc. and Hamer Environmental, L.P. 2005. Marbled Murrelet Hazing Report - SR 104 Hood Canal Bridge east-half replacement and west-half retrofit project. Washington State Department of Transportation, 22 pp + appendices.

Evans Mack, D., W.P. Ritchie, S.K. Nelson, E. Kuo-Harrison, P. Harrison, and T.E. Hamer. 2003. Methods for surveying marbled murrelets in forests, a revised protocol for land management and research. Marbled Murrelet Technical Committee, Pacific Seabird Group.

Falxa, G. 2008. Email to Martin Raphael, Lance, Monique, Pearson, Scott, Lynch, Deanna, Falxa, Gary, Nelson, Kim, Huff, Mark, Young, Rich, Bloxton, Thomas D., Bush, Jodi, Tuerler, Bridgette, Brown, Robin, Pereksta, David, Schmidt, Kristin, Flotlin, Kim, Burkett, E., McIver, Bill, Bond, James, Watkins, Jim H., Hoffman, Ken R., Roberts, Lynn M., Bosch, Ray, Hamlin, Robin, Olah, Ryan, Rabot, Theresa, Thomas, Darrin, Roy, Michael, Hensen, Paul, Young, Kristi, and Corbett, Miel, February 1 2008, Re: 2007 results of marbled murrelet at-sea populations surveys.

Ford, R.G., G.K.H. Boor, B.E. Sharp, and J.L. Casey. 2002. Estimates of bird impacts resulting from the M/V Kure/Humboldt Bay oil spill of November 5, 1997. U.S. Fish and Wildlife Service, Sacramento, California, 71 pp.

Ford, R.G., G.K. Himes Boor, and J.C. Ward. 2001. Final Report: Seabird mortality resulting from the M/V New Carissa oil spill incident, February and March 1999. U.S. Fish and Wildlife Service, Portland, OR, 64 pp.

Fothergill, D.M., J.R. Sims, and M.D. Curley. 2001. Recreational scuba diver's aversion to low-frequency underwater sound. Undersea and Hyperbaric Medicine 28(1):9-18.

Frid, A. and L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology 6(1):1-11.

Fry, D.M. 1995. Pollution and fishing threats to marbled murrelets. Pages 257-60. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report: PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Gaston, A.J. and I. Jones. 1998. The Auks Alcidae. Oxford University Press, New York.

Golightly, R.T., P.N. Hebert, and D.L. Orthmeyer. 2002. Evaluation of human-caused disturbance on the breeding success of marbled murrelets (*Brachyramphus marmoratus*) in Redwood National and State Parks, California. 2001 Progress Report. U.S. Geological Survey, Humboldt State University, Arcata, CA, 61 pp.

Hamer, T.E., S.K. Nelson, and T.J. Mohagen II. 2003. Nesting chronology of the marbled murrelet in North America. Hamer Environmental and Oregon Cooperative Wildlife Research Unit, Portland, OR, February 6, 2003, 22 pp.

Hamer, T.E. and D.J. Meekins. 1999. Marbled murrelet nest site selection in relation to habitat characteristics in western Washington. Hamer Environmental, Mount Vernon, WA, 26 pp.

Hamer, T.E. and S.K. Nelson. 1995. Characteristics of marbled murrelet nest trees and nesting stands. Pages 69-82. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. U.S. Department of Agriculture Forest Service, Pacific Southwest Research Station, General Technical Report PSW-152, Albany, California. 420 pp.

Hastings, M.C. and A.N. Popper. 2005. Effects of sound on fish. Contract No. 43A0139, Task Order, 1. California Department of Transportation, Sacramento, CA, January 28, 2005, 82 pp.

Healey, S., W. Cohen, and M. Lefsky. 2003. Stand-replacing harvests and fires in Washington, 1984-2002. Laboratory for the Application of Remote Sensing in Ecology (LARSE), Pacific Northwest Research Station, U.S. Forest Service, USDA, Corvallis, Oregon.

Hebert, P.N., H.R. Carter, R.T. Golightly, and D.L. Orthmeyer. 2003. Radio-telemetry evidence of re-nesting in the same season by the marbled murrelet. Waterbirds 26(3):261-65.

Hebert, P.N. and R.T. Golightly. 2003. Breeding biology and human-caused disturbance to the nesting of marbled murrelets (*Brachyramphus marmoratus*) in Northern California, Progress Report 2002. Unpublished Draft Report. Department of Wildlife, Arcata, CA, November 12, 2003.

Henkel, L.A., E.E. Burkett, and J.Y. Takekawa. 2003. At-sea activity and diving behavior of a radio-tagged marbled murrelet in Central California. Waterbirds 26(4).

Hirzel, A.H., J. Hauser, D. Chessel, and N. Perrin. 2002. Ecological-niche factor analysis: How to compute habitat-suitability maps without absence data? Ecology 83(7):2027-36.

Hobson, K.A. 1990. Stable isotope analysis of marbled murrelets: evidence for freshwater feeding and determination of trophic level. The Condor 92:897-903.

Huff, M.H., P. Jodice, J. Baldwin, S. Miller, R. Young, K. Ostrom, C.J. Ralph, M. Raphael, C. Strong, C. Thompson, and G. Falxa. 2003. Marbled murrelet effectiveness monitoring - Northwest Forest Plan 2002 annual summary report. 27 pp.

Huff, M.H., M.G. Raphael, S.L. Miller, S.K. Nelson, and J. Baldwin. 2006. Northwest Forest Plan - The first 10 years (1994-2003): Status and trends of populations and nesting habitat for the marbled murrelet. General Technical Report: PNW-GTR-650. U.S. Department of Agriculture, Forest Service, Portland, Oregon, 149 pp.

Hull, C.L., G.W. Kaiser, C. Lougheed, L. Lougheed, S. Boyd, and F. Cooke. 2001. Intraspecific variation in commuting distance of marbled murrelets (*Brachyramphus marmoratus*): Ecological and energetic consequences of nesting further inland. The Auk 118(4):1036-46.

Jodice, P.G.R. and M.W. Collopy. 1999. Diving and foraging patterns of marbled murrelets (*Brachyramphus marmoratus*): Testing predictions from optimal-breathing models. Canadian Journal of Zoology 77(9):1409-18.

Kitaysky, A.S., J.C. Wingfield, and J.F. Piatt. 2001. Corticosterone facilitates begging and affects resource allocation in the black-legged kittiwake. Behavioral Ecology 12(5):619-25.

Kuletz, K.J. 1996. Marbled murrelet abundance and breeding activity at Naked Island, Prince William Sound, and Kachemak Bay, Alaska, before and after the Exxon Valdez oil spill. American Fisheries Society Symposium 18:770-84.

Kuletz, K.J. 2005. Foraging behavior and productivity of a non-colonial seabird, the marbled murrelet (Brachyramphus marmoratus), relative to prey and habit. Doctor of Philosphy in the Department of Biology. University of Victoria,

Kuletz, K.J. and J.F. Piatt. 1999. Juvenile marbled murrelet nurseries and the productivity index. The Wilson Bulletin 111(2):257-61.

Long, L.L. and J.C. Ralph. 1998. Regulation and observations of human disturbance near nesting marbled murrelets. Pacific Southwest Research Station, Arcata, California, 35 pp.

Luginbuhl, J.M., J.M. Marzluff, J.E. Bradley, M.G. Raphael, and D.E. Varland. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. Journal of Field Ornithology 72(4):556-72.

Manley, I.A. 1999. Behavior and habitat selection of marbled murrelets nesting on the sunshine coast. Master of Science in Biological Sciences. Department of Biological Sciences, Simon Fraser University, Burnaby, BC. 1-163.

Manley, I.A. 2000. Radar surveys of marbled murrelets on the northwest coast of Vancouver Island, British Columbia. Ministry of the Environment, Lands, and Parks, Nanaimo, British Columbia, Canada, 44 pp.

Marzluff, J.M., M.G. Raphael, and R. Sallabanks. 2000. Understanding the effects of forest management on avian species. Wildlife Society Bulletin 28(4):1132-43.

Mason, A., A.E. Burger, and B. Hansen. 2002. At-sea surveys of marbled murrelets in Clayoquot Sound, 1996-2000. Pages 15-33. *In*: Burger, A. and T.A. Chatwin (eds). Multi-scale studies of populations, distribution, and habitat associations of marbled murrelets in Clayoquot Sound, British Columbia. Ministry of Water, Land, and Air Protection, Victoria, British Columbia.

Mathews, N.J.C. and A.E. Burger. 1998. Diving depth of a marbled murrelet. Northwestern Naturalist 79(2):70-71.

McBride, P. 2005. Information presented at the Pacific Seabird Group Marbled Murrelet Technical Committee meeting.

McFarlane-Tranquilla, L., B.R. Parker, N. Parker, D. Lank, and F. Cooke. 2003. Replacement laying in marbled murrelets *Brachyramphus marmoratus*. Marine Ornithology 31:75-81.

McShane, C., T.E. Hamer, H.R. Carter, R.C. Swartzman, V.L. Friesen, D.G. Ainley, K. Nelson, A.E. Burger, L.B. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation reports for the 5-year status review of the marbled murrelet in Washington, Oregon, and California. EDAW, Inc., Seattle, Washington, 370 pp.

Melvin, E.F., J.K. Parrish, and L.L. Conquest. 1999. Novel tools to reduce seabird by-catch in coastal gillnet fisheries. Conservation Biology 13(6):1386-97.

Meyer, C.B., S.L. Miller, and C.J. Ralph. 2002. Multi-scale landscape and seascape patterns associated with marbled murrelet nesting areas on the U.S. west coast. Landscape Ecology 17(2):95-115.

Miller, S.L. and C.J. Ralph. 1995. Relationship of marbled murrelets with habitat characteristics at inland sites in California. Pages 205-15. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report: PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Murray Pacific Corporation. 1993. Habitat Conservation Plan for the northern spotted owl on timberlands owned by the Murray Pacific Corporation, Lewis County, Washington. Beak Consultants Incorporated, Tacoma, WA, 154 pp.

Murray Pacific Corporation. 1995. Amendment to the Habitat Conservation Plan and incidental take permit PRT-777837 for the northern spotted owl on timberlands owned by the Murray Pacific Corporation, Lewis County, Washington. Beak Consultants, Inc., Tacoma, WA, 205 pp.

Naslund, N.L. 1993. Why do marbled murrelet attend old-growth forest nesting areas year-round? Auk 110(3):594-602.

Nelson, K. 2005. Note to file on 06/22/05 with Deanna Lynch, U.S. Fish and Wildlife Service, re: marbled murrelet nest densities.

Nelson, S.K. 1997. The birds of North America, No. 276 - marbled murrelet (*Brachyramphus marmoratus*). Pages 1-32. *In*: Poole, A. and F. Gill (eds). The birds of North America: Life histories for the 21st century. The Academy of Natural Sciences & The American Ornithologists' Union, Philadelphia, PA; Washington, D.C.

Nelson, S.K. 2005. Surveys for marbled murrelets in potential habitat in the Oregon coast range: draft final report prepared for the trustees council of the New Carissa oil spill and the U.S. Fish and Wildlife Service. Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, Department of Fisheries and Wildlife, Corvallis, OR, 26 pp.

Nelson, S.K. and T.E. Hamer. 1995a. Nest success and the effects of predation on marbled murrelets. Pages 89-97. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Nelson, S.K. and T.E. Hamer. 1995b. Nesting biology and behavior of the marbled murrelet. Pages 57-67. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Nelson, S.K. and R.W. Peck. 1995. Behavior of marbled murrelets at nine nest sites in Oregon. Northwestern Naturalist 76(1):43-53.

NOAA (National Oceanic and Atmospheric Administration). 1993. Olympic coast national marine sanctuary, final environmental impact statement/management plan. Washington D.C., Volumes I & II pp.

Norse, E.A. 1990. Ancient forests of the Pacific Northwest. Island Press, Washington, D.C. 327 pp.

Northwest Straits Foundation. 2007. Derelict fishing gear priority ranking project. Unpublished report prepared for the Russell Family Foundation.

NRC (Natural Resources Consultants, Inc.). 2007. Final report: Olympic coast national marine sanctuary derelict fishing gear removal project. Seattle, Washington, December 28, 2007, 20 pp.

Peery, M.Z., S.R. Beissinger, B.H. Becker, and S.H. Newman. 2002. Marbled murrelet (*Brachyramphus marmoratus*) demography in central California: 2001 Progress Report. U.S. Fish and Wildlife Service, California State Parks, 21 pp.

Peery, M.Z., L.A. Hall, J.T. Harvey, and L.A. Henkel. 2008. Abundance and productivity of marbled murrelets off central California during the 2008 breeding season. Final Report Submitted to California State Parks, Half Moon Bay, CA, September, 2008, 10 pp.

Perry, D.A. 1995. Status of forest habitat of the marbled murrelet. Pages 381-83. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Piatt, F.F., B.D. Roberts, W.W. Lidster, J.L. Wells, and S.A. Hatch. 1990. Effects of human disturbance on breeding least and crested auklets at St. Lawrence Island, Alaska. Auk 107:342-50.

Piatt, J.F., K.J. Kuletz, A.E. Burger, S.A. Hatch, V.L. Friesen, T.P. Birt, M.L. Arimitsu, G.S. Drew, A.M.A. Harding, and K.S. Bixler. 2007. Status review of the marbled murrelet *(Brachyramphus marmoratus)* in Alaska and British Columbia. U.S. Geological Survey Open-File Report 2006-1387. 258 pp.

Pierce, D.J. and T.R. Simons. 1986. The influence of human disturbance on tufted puffin breeding success. Auk 103:214-16.

Plum Creek Timber Company, L.P. 1996. Multi-species Habitat Conservation Plan on Forestlands owned by Plum Creek Timber Company, L.P., in the I-90 Corridor of the Central Cascades Mountain Range, Washington. Plum Creek Timber Company, L.P., Seattle, WA. 478 pp.

Plum Creek Timber Company, L.P. 1999. Final description and analysis of modifications to Plum Creek Timber Company's Cascade Habitat Conservation Plan. Plum Creek Timber Company, Seattle, Washington. 100 pp.

Popper, A.N. 2003. Effects of anthropogenic sounds of fishes. Fisheries 28(10):24-31.

Port Blakely Tree Farms, L.P. 1996. Habitat Conservation Plan for the Robert B. Eddy Tree Farm. Port Blakely Tree Farms, L.P., Seattle, Washington. 136 pp.

Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt. 1995. Ecology and conservation of the marbled murrelet in North America: An overview. Pages 3-22. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, United States Department of Agriculture, Forest Service, Albany, California. 420 pp.

Raphael, M.G., D. Evans-Mack, J.M. Marzluff, and J.M. Luginbuhl. 2002. Effects of forest fragmentation on populations of the marbled murrelet. Studies in Avian Biology 25:221-35.

Raphael, M.G., G.M. Gelleher, M.H. Huff, S.L. Miller, S.K. Nelson, and R. Young. 2006. Spatially-explicit estimates of potential nesting habitat for the marbled murrelet. Pages 97-146. *In*: Huff, M. (ed). Northwest forest plan - the first 10 years (1994-2003): status and trend of populations and nesting habitat for the marbled murrelet - general technical report. USDA Forest Service, Portland, Oregon. 50 pp.

Raphael, M.G., J.A. Young, and B.M. Galleher. 1995. A landscape-level analysis of marbled murrelet habitat in Western Washington. Pages 177-89. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Raphael, M. 2005. Email on 06/01/05 to Richard Bigley, Deanna Lynch, and Zach Peery, re: 5/27 Progress Report.

Raphael, M.G., J. Baldwin, G. Falxa, M.H. Huff, M.M. Lance, S. Miller, S.F. Pearson, C.J. Ralph, C. Strong, and C. Thompson. 2007. Regional population monitoring of the marbled murrelet: Field and analytical methods. PNW-GTR-716. U.S. Department of Agriculture Forest Service, Portland, Oregon, May 2007, 70 pp.

Renwald, D. 1993. Letter to the Marbled Murrelet Recovery Team on Bureau of Indian affairs' murrelet strategy. Portland, Oregon, December 1993, 89-92 pp.

Ripple, W.J. 1994. Historic spatial patterns of old forests in western Oregon. Journal of Forestry 92(11):45-49.

Ross, B.P., J. Lien, and R.W. Furness. 2001. Use of underwater payback to reduce the impact of eiders on mussel farms. Journal of Marine Science 58:517-24.

Sanborn, S. 2005. Email on 04/07/05 to Deanna Lynch, re: Mamu calls. U.S. Fish and Wildlife.

Simpson Timber Company. 2000. Habitat Conservation Plan: Shelton, Washington Timberlands. Simpson Timber Company, Shelton, WA, 379 pp.

Singer, S.W., D.L. Suddjian, and S.A. Singer. 1995. Fledging, behavior, flight patterns, and forest characteristics at marbled murrelet tree nests in California. Northwestern Naturalist 76:54-62.

Speckman, S.G., J.F. Piatt, and A.M. Springer. 2003. Deciphering the social structure of marbled murrelets from behavioral observations at sea. Waterbirds 26(3):256-74.

Speckman, S.G. 1996. Marbled murrelet distribution and abundance in relation to the marine environment. Master of Science. University of Alaska Fairbanks, Fairbanks, AK. 1-89.

Steevens, C.C., K.L. Russell, M.E. Knafeic, P.F. Smith, E.W. Hopkins, and J.B. Clark. 1999. Noise-induced neurological disturbances in divers exposed to intense water-borne sound: Two case reports. Undersea and Hyperbaric Medicine 26(4):261-65.

Strachan, G., M. McAllister, and C.J. Ralph. 1995. Marbled murrelet at-sea and foraging behavior. Pages 247-53. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. PSW-GTR-152. U.S. Department of Agriculture, Albany, CA. 420 pp.

Strong, C.S., B.K. Keitt, W.R. McIver, C.J. Palmer, and I. Gaffney. 1995. Distribution and population estimates of marbled murrelets at sea in Oregon during the summers of 1992 and 1993. Pages 339-52. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds). Ecology and conservation of the marbled murrelet. General Technical Report: PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Tacoma Public Utilities. 2001. Final Environmental Impact Statement and Final Habitat Conservation Plan for a multiple species incidental take permit issued to the Tacoma Water Department, for their Green River water supply and operations and watershed protection activities, King County, Washington. Tacoma, Washington, July 2001.

Teensma, P.D.A., J.T. Rienstra, and M.A. Yeiter. 1991. Preliminary reconstruction and analysis of change in forest stand age classes of the Oregon coast range from 1850 to 1940. Technical Note OR-9. Bureau of Land Management, Salem, OR, 9 pp.

Thompson, C. 2003. Telephone conversation with Emily Teachout, USFWS, regarding marbled murrelet molt period in regard to hazing.

Thorensen, A.C. 1989. Diving times and behavior of pigeon guillemots and marbled murrelets off Rosario Head, Washington. Western Birds 20:33-37.

Turnpenny, A. and J. Nedwell. 1994. The effects on marine fish, diving mammals and birds of underwater sound generated by seismic surveys. Fawley Aquatic Research Laboratories Limited, Marine and Freshwater Biology Unit, Southampton, Hampshire, UK, 40 pp.

Turnpenny, A., K.P. Thatcher, R. Wood, and J. Nedwell. 1994. The effects on fish and other marine animals of high-level underwater sound. Report FRR 127/94. Fawley Aquatic Research Laboratory, Ltd., Marine and Freshwater Biology Unit, Southampton, United Kingdom, 35 pp.

U.S. Department of Defense. 2002. Record of Decision for surveillance towed array sensor system low frequency active. Federal Register 67(141):48145-54.

USFS (U.S. Forest Service) and USBLM (U.S. Bureau of Land Management). 1994a. Final Supplemental Environmental Impact Statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Portland, Oregon, 557.

USFS (U.S. Forest Service) and USBLM (U.S. Bureau of Land Management). 1994b. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl; standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1995. Biological/Conference opinion regarding a proposed amendment to and approval of an implementation agreement for an incidental take permit (PRT-777837) held by the Murray Pacific Corporation for Mineral Tree Farm, Lewis County, Washington (FWS Reference: 1-3-95-FW-0919). June 23, 1995.

USFWS (U.S. Fish and Wildlife Service). 1996a. Intra-Service Biological Opinion on the Proposed Issuance of an Incidental Take Permit (PRT-808398) for Northern Spotted Owls, Marbled Murrelets, Grizzly Bear, Gray Wolf to Plum Creek Timber Company (FWS Reference: 1-3-96-FW-0190) and the Approval of an Unlisted Species Agreement for All Vertebrate Species. June 24, 1996, 125 pp.

USFWS (U.S. Fish and Wildlife Service). 1996b. Intra-Service Biological/Conference Opinion regarding issuance of a section 10(a)(1)(B) Incidental Take Permit (PRT-813744), and approval of Unlisted Species agreements proposed by Port Blakely Tree Farms, L.P. for the Robert B. Eddy Tree Farm, Pacific and Grays Harbor Counties, Washington (FWS Reference: 1-3-96-FW-593). July 16, 1996, 25 pp.

USFWS (U.S. Fish and Wildlife Service). 1997a. Intra-FWS concurrence memorandum and biological opinion on the proposed issuance of an incidental take permit (PRT- 812521) for northern spotted owls, marbled murrelets, gray wolves, grizzly bears, bald eagles, peregrine falcons, Aleutian Canada geese, Columbian white-tailed deer, and Oregon silverspot butterflies, and the approval of the implementation agreement for the Washington State Department of Natural Resources Habitat Conservation Plan (FWS Reference: 1-3-96-FW-594).

USFWS (U.S. Fish and Wildlife Service). 1997b. Recovery Plan for the threatened marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. U.S. Department of the Interior, Portland, Oregon, 1997, 203 pp.

USFWS (U.S. Fish and Wildlife Service). 1999. Biological Opinion, reinitiation of Intra-Service consultation on the modification of Plum Creek's Cascades Habitat Conservation Plan to accommodate the Interstate-90 Land Exchange. Incidental Take Permit (PRT-808398) (FWS Reference: 1-3-00-FR-0245). Western Washington Fish and Wildlife Office, Lacey, WA, 84 pp.

USFWS (U.S. Fish and Wildlife Service). 2000a. Biological and conference opinion for the proposed issuance of a section 10(a)(1)(B) incidental take permit (PRT-TE020907-0) to the City of Seattle (Seattle Public Utility) for the Cedar River Watershed Habitat Conservation Plan. April 19, 2000.

USFWS (U.S. Fish and Wildlife Service). 2000b. Biological and conference opinions for the issuance of an incidental take permit to Simpson Timber Company, Northwest Operations, for Simpson Washington Timberlands Habitat Conservation Plan, in Mason, Grays Harbor and Thurston Counties, Washington (FWS Ref.: 1-3-00-FWF-2098). Western Washington Fish and Wildlife Office, Lacey, WA, October 12, 2000, 162 pp.

USFWS (U.S. Fish and Wildlife Service). 2001. Biological and conference opinions for the issuance of an incidental take permit to the City of Tacoma's Public Utilities Department, Tacoma Water, under the Tacoma Water Green River Watershed Habitat Conservation Plan (FWS Reference: 1-3-01-FWS-0101). PRT-TE-0447757-0. June 29, 2001.

USFWS (U.S. Fish and Wildlife Service). 2003a. Biological opinion and letter of concurrence for effects to bald eagles, marbled murrelets, northern spotted owls, bull trout, and designated critical habitat for marbled murrelets and northern spotted owls from Olympic National Forest program of activities for August 5, 2003, to December 31, 2008. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Lacey, Washington.

USFWS (U.S. Fish and Wildlife Service). 2003b. Biomonitoring of environmental status and trends program, contaminant assessment process, final contaminant assessment process report for Dungeness NWR. 3 pp.

USFWS (U.S. Fish and Wildlife Service). 2004. Marbled murrelet 5-year review process: overview. Portland, Oregon, 28 pp.

USFWS (U.S. Fish and Wildlife Service). 2006. Director's memorandum on recovery units and jeopardy determinations under the Endangered Species Act. U.S. Fish and Wildlife Service, March 6, 2006.

USFWS (U.S. Fish and Wildlife Service) and NMFS (National Marine Fisheries Service). 1998. Endangered species consultation handbook: Procedures for conducting consultation and conference activities under Section 7 of the Endangered Species Act. U.S. GPO:2004-690-278. March 1998.

Washington Forest Practices Board (WFPB). 2005. Washington Forest Practices Rules - WAC 222-12-041. Washington Department of Natural Resources Forest Practices Division, Olympia, Washington.

Wasser, S.K., K. Bevis, G. King, and E. Hanson. 1997. Noninvasive physiological measures of disturbance in the northern spotted owl. Conservation Biology 11(4):1019-22.

Watanuki, Y. and A.E. Burger. 1999. Body mass and dive durations in alcids and penguins. Canadian Journal of Zoology 77:1838-42.

WDFW (Washington Department of Fish and Wildlife). 2005a. 2004 Washington state herring stock status report. Washington Department of Fish and Wildlife, Fish Program, Fish Management Division, May 2005.

WDFW (Washington Department of Fish and Wildlife). 2005b. 2004 Washington state herring stock status report. Washington Department of Fish and Wildlife, Fish Program, Fish Management Division, May 2005.

WDFW (Washington Department of Fish and Wildlife). 2005c. 2004 Washington state herring stock status report. Washington Department of Fish and Wildlife, Fish Program, Fish Management Division, May 2005.

WDFW (Washington Department of Fish and Wildlife). 2005d. 2004 Washington state herring stock status report. Washington Department of Fish and Wildlife, Fish Program, Fish Management Division, May 2005.

WDNR (Washington Department of Natural Resources). 1997. Final habitat conservation plan. WDNR, Olympia, Washington, September 1997, 546 pp.

WDOE. 2004. Oil spill prevention works, but needs to be broader. Oil Spill Scene 8(2):1-4. WDOE Publication 04-08-004.

WDOE. 2005. Study of tug escorts in Puget Sound. Oil Spill Scene 9(1):1-12. WDOE Publications 05-08-002.

Whitworth, D.L., S.K. Nelson, S.H. Newman, G.B. Van Vliet, and W.P. Smith. 2000. Foraging distances of radio-marked marbled murrelets from inland areas in southeast Alaska. The Condor 102(2):452-56.

Yelverton, J.T. and D.R. Richmond. 1981. Underwater explosion damage risk criteria for fish, birds, and mammals. *In*: 102nd Meeting of the Acoustical Society of America, 36,November 30 - December 04, Miami Beach, Florida. Department of Biodynamics, Lovelace Biomedical and Environmental Research Institute, Albuquerque, New Mexico. 36 pp.

Yelverton, J.T., D.R. Richmond, R.E. Fletcher, and R.K. Jones. 1973. Safe distances from underwater explosions for mammals and birds. Lovelace Foundation for Medical Education and Research, Albuquerque, NM, September 26, 1973, 64 pp.

# Appendix B: USFWS Murrelet Monitoring Protocol
# for
# Manette Bridge Replacement Project

# Appendix B: USFWS Murrelet Monitoring Protocol for Manette Bridge Replacement Project

## Objective

The intent of the monitoring protocol is to:

1. Comply with the requirements of the Endangered Species Act (ESA) Section 7 consultation for the Washington State Department of Transportation (WSDOT) Manette Bridge replacement project.
2. Identify marbled murrelet presence in the vicinity of pile driving activities and communicate with the construction contractor to eliminate chances of injury from elevated underwater sound pressure waves associated with impact pile driving.
3. Track incidental take exempted through the Incidental Take Statement found in the final Biological Opinion (Opinion) for marbled murrelets.
4. A secondary aspect of this monitoring includes attempting to locate marbled murrelets that may be injured or killed as a result of impact pile driving activities.

## Adaptive Approach

All methods identified herein have been developed through coordination between the Washington Fish and Wildlife Office (WFWO) of the U.S. Fish and Wildlife Service (USFWS) and WSDOT. The methods are based on these parties' professional judgment supported by their collective knowledge of marbled murrelets, site conditions, and proposed project activities. Because marbled murrelet monitoring has not previously been conducted at this site, aspects of these methods may warrant modification or discontinuation. The individuals that implement this protocol will assess its effectiveness during implementation. They will use their best professional judgment throughout this process and will seek improvements to these methods when deemed appropriate. Any modifications to this protocol will be coordinated with WSDOT and the WFWO.

## Monitoring

### Activities to be Monitored

Monitoring will only occur in the vicinity of in-water impact pile driving. No monitoring is necessary during vibratory pile driving, pile removal, or any out-of-water pile driving.

## Equipment

- Binoculars - quality 8 or 10 power (4);
- Spotting scopes (2)
- Two-way radios (4);
- Back up signal flag (4)
- Log books (4); and,
- Seabird identification guides.
- Life vest or other personal flotation device for observers in boats.
- Cellular phone to contact WSDOT or WFWO if necessary.

## Locations

Monitoring will occur in the vicinity of in-water impact pile driving. Proposed monitoring locations have been identified in Figure 1 at the end of this document. Because of limitations that could result from the construction activities, the specific monitoring locations will be finalized in the field, noted on an aerial photo or plan sheet, and documented in the final monitoring report. The monitoring location(s) may change depending on site conditions as long as a clear view of the area of potential injury is possible.

## Monitoring Techniques

A minimum of four qualified biologists will conduct the monitoring. Two biologists will be positioned at on-shore vantage points near the pile driving activities. The on-shore vantage points will allow for the best possible view of the monitoring zone at all times. This will also reduce the potential for visual obstruction from the crane, crane platform, and crane operation.

The monitoring area is defined as the area in which diving murrelets could be injured by pile driving noise. For this project, this equates to within 398 m of impact pile driving activity. On site reconnaissance and correspondence with local seabird survey experts determined that for this site due to its calm waters and narrow restricted channel there is a reasonable probability of detecting murrelets within 100 m when the sea state is at a Beaufort scale of 2 or better. The Beaufort scale is presented in Table 1 below. If the sea state exceeds a Beaufort level 2 or visibility is reduced to between 50 and 100 m two additional biologists will be required to effectively cover the monitoring zone. If conditions are such that visibility is less than 50 m, pile driving operations will stop.

Using spotting scopes and binoculars, the two biologists on shore will search for marbled murrelets within the monitoring zone. The other two biologists will be in one boat and will conduct a constant rectangular circuit sweep of the monitoring zone prior to each pile driving attempt to confirm any murrelets sightings made from shore and to further ensure no marbled murrelets are in the monitoring zone. The boat operator can act as a secondary biologist but must meet the

qualifications and training requirements mentioned below. One complete sweep of the monitoring circuit must be completed prior to the start of pile driving. If no marbled murrelets are within the zone, the monitors will notify the WSDOT field inspector to begin pile driving.

During pile driving the biologists on shore will continue scanning the area for marbled murrelets. The biologists in the boat will patrol the area using a constant rectangular circuit sweep centered on the work activities and 600 m in length and 150 m across in width scanning the area using unaided eyesight and binoculars. The total monitoring circuit distance will be 1.5 km. Boat speed will not exceed ten knots during monitoring activities. All biologists will have two-way radios to allow for effective communication during pile driving. If marbled murrelets are seen within the monitoring zone during pile driving, the biologists will immediately notify the WSDOT inspector and he/she will stop pile driving. Pile driving will not resume until the marbled murrelets have left the 398 m zone.

Marbled murrelets are especially vulnerable to disturbance when they are molting and flightless. Molting occurs after nesting in late summer, typically July through September in Puget Sound populations.

**Table 1 – Beaufort Wind Scale develop in 1805 by Sir Francis Beaufort of England (0=calm to 12=hurricane)**

| Force | Wind (knots) | Classification | Appearance of wind effects on the water | Appearance of wind effects on land | Notes specific to on-water seabird observations |
|---|---|---|---|---|---|
| 0 | <1 | Calm | Sea surface smooth and mirror like | Calm, smoke rises vertically | Excellent conditions, no wind, small or very smooth swell. You have the impression you could see anything. |
| 1 | 1-3 | Light air | Scaly ripples, no foam crests | Smoke drift indicates wind direction, still wind vanes | Very good conditions, surface could be glassy (Beaufort 0), but with some lumpy swell or reflection from forests, glare, etc. |
| 2 | 4-6 | Light breeze | Small wavelets, crests glassy, no breaking | Wind felt on face, leaves rustle, vanes begin to move | Good conditions, no whitecaps, texture/lighting contrast of water make murrelets hard to see. Surface could also be glassy or have small ripples, but with a short, lumpy swell, thick fog, etc. |
| 3 | 7-10 | Gentle breeze | Large wavelets, crests beginning to break, scattered whitecaps | Leaves and small twigs constantly moving, light flags extended | Fair conditions, scattered whitecaps present, detection of murrelets definitely compromised, a hit-or-miss chance of seeing them owing to water choppiness and high contrast. This could also occur at lesser wind with a very short wavelength, choppy swell. |
| 4 | 11-16 | Moderate breeze | Small waves 0.3 to 1.1m becoming longer, numerous whitecaps | Dust, leaves, and loose paper lifted, small tree branches move | Poor conditions, end surveys, whitecaps abundant, sea chop bouncing the boat around, etc. If you were nearly done with a survey and running with the wind, you could survey somewhat effectively in these conditions (but shouldn't) |
| 5 | 17-21 | Fresh breeze | Moderate waves 1.1 to 2.0 m taking longer form, many whitecaps, some spray | Small trees begin to sway | |

## Limitations

When conditions are such that visibility is reduced to a distance of greater than 50 m but less than 100 m, two additional land based biologists will be added to the monitoring crew.

No monitoring will be conducted during inclement weather that creates potentially hazardous conditions as determined by the biologist. No monitoring will be conducted when visibility is significantly limited (under 50 m) such as during very heavy rain or fog. Monitoring will not start until one hour after sunrise and will cease one hour before sunset.

## Documentation

The biologist will document all seabirds in the monitoring area with the focus on indentifying marbled murrelets. Marbled murrelet presence/absence in each survey unit during each survey sweep will be documented along with the number and general location of marbled murrelets. A survey unit is defined as either the north or south side of the existing Manette Bridge. Seabird behavior during pile driving will be noted, especially apparent responses to pile driving and other project-related activities.

To the best extent possible, the biologist will also record each marbled murrelet "take" incident that is observed, as defined in the final Opinion. This may include obvious disturbance responses from pile driving or other construction activities, and injury or mortality that can be attributed to project-related activities.

## Timing and Duration

Monitoring will commence approximately one-half hour before the initiation of pile driving (but not before daylight) and will continue until pile driving is completed each day (but not after nightfall).

## Contingency

In the unlikely event that a marbled murrelet is perceived to be injured by pile driving, all pile driving will cease and USFWS will be contacted immediately.

WSDOT will work with USFWS to make necessary changes to the monitoring protocol as described in the section above. Pile driving cannot resume until the protocol has been amended.

## Beach Surveys

Searches for diving seabird carcasses along nearby beaches will be conducted following pile driving activities. The biologist will walk accessible beaches within

0.5 mi of the pile driving location. Beach surveys will be conducted during low or receding tides, if possible, to maximize the chances of finding beached carcasses. Beach surveys will be conducted each day following in-water, impact pile driving as is practical based on the timing of tide events and pile driving activities. Beach surveys are of secondary priority and will not be conducted if such activities would interfere with the implementation of murrelet monitoring or if the timing of low/receding tides imposes unreasonable schedule demands on the biologist.

Any dead murrelets or other diving seabirds found during the beach surveys (or during monitoring and hazing activities) will be collected by monitoring staff and delivered, as soon as possible, to the WFWO in Lacey, Washington for examination. Collected carcasses will be put in plastic bags, and kept cool (but not frozen) until delivery to the WFWO.

## Interagency Communication

Prior to the initiation of monitoring, WSDOT and representatives from the WFWO will meet to review the proposed monitoring location and logistics concerns that may have developed during monitoring preparation. WSDOT will keep the WFWO informed of the progress and effectiveness of the monitoring activities and of the number and disposition of marbled murrelet take that is documented throughout the duration of the project.

WSDOT will notify the WFWO of any problems and/or necessary modification to the monitoring protocol. WSDOT will coordinate with the WFWO in the development of a modified approach and will seek WFWO approval for such modifications.

Primary points of contact at the WFWO are:

1. Emily Teachout – phone: (360) 753-9583
2. Brooke Hamilton – phone: (360) 753-9073
3. Deanna Lynch – phone: (360) 753-9545

Primary points of contact at the WSDOT are:

1. Carl Ward – phone: (360) 570-6706
2. Marion Carey – phone: (360) 705-7404
3. Tom Barton – phone: (360) 570-6729

## Personnel Qualifications and Training

All monitoring personnel must have appropriate qualifications, including education and experience identifying marbled murrelets and other marine birds in Puget Sound; and understanding and documenting animal behavior.

All monitoring personnel will meet at least once for a training session with representatives of the WFWO and the WSDOT project biologist. Topics will include: implementation of the protocol, identifying and tracking take, and reporting requirements.

All monitoring personnel will be provided a copy of the final Opinion. Monitoring personnel must read and understand the contents of the Opinion related to identifying, minimizing, and reporting “incidental take” of marbled murrelets.

## Reporting

At the completion of each in-water work window for which there has been impact pile driving, WSDOT will forward a monitoring report to the WFWO within 30 days. Reports shall be sent to the attention of Emily Teachout, or acting Transportation Team Lead (WFWO). The report shall include:

- Observation dates, times, and conditions
- Description of the any “take” (as described in the final Biological Opinion) identified by the biologist
- Copies of field data sheets or logs

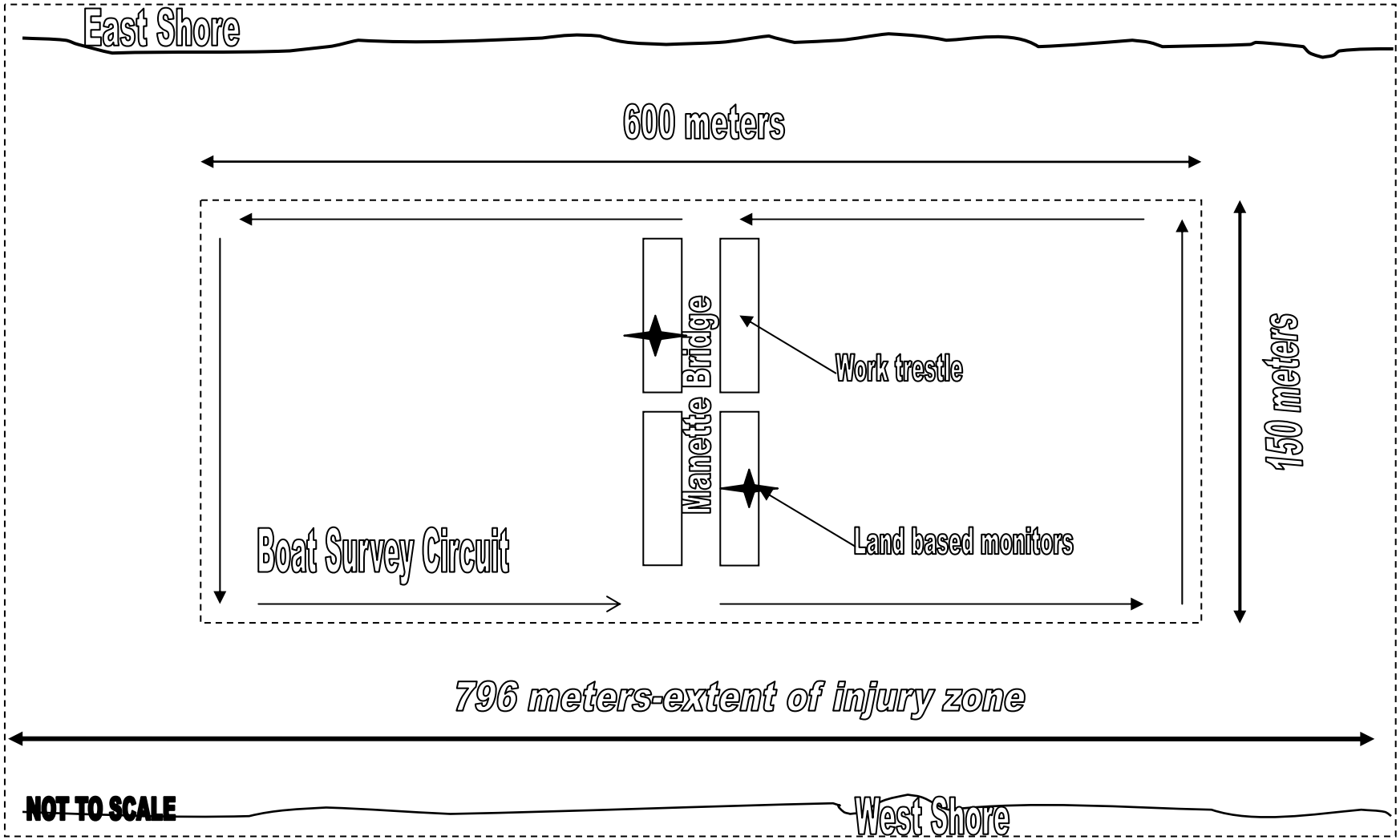


Figure 1. Schematic representation of proposed murrelet survey protocol. Protocol may be altered during times of inclement weather.

# Appendix C: Impact Pile Driving Sound Attenuation Specification

**National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (FWS), Western Washington Fish and Wildlife Office**
**Impact Pile Driving Sound Attenuation Specification**
**Revised: October 31, 2006**

## INTRODUCTION

Air bubbles can reduce sound pressure levels (SPLs) at some frequencies by as much as 30 dB (Gisiner et al. 1998). Bubble curtains are essentially perforated pipes or hoses, surrounding the pile being driven, that produce bubbles when air is pumped through the perforations. Bubble curtains can also reduce particle velocity levels (MacGillivray and Racca 2005).

Bubble curtain designs are highly variable, but can generally be grouped in two categories: unconfined and confined. Unconfined systems are simply a frame which allows for transmission of air bubbles around a pile being driven. Confined systems add a sleeve around the pile to contain the bubbles. The sleeve can consist of fabric, hard plastic, or a larger pile (casing). Spacing of the bubble manifolds, air pressure, tidal currents, and water depth are all factors influencing effectiveness. Improper installation or operation can decrease bubble curtain effectiveness (Pommerenck 2006; Visconty 2004).

Reyff et al. (2002) evaluated the effectiveness of a confined system which used a foam-filled casing and bubble curtain. The casing was 3.8 m in diameter with the interior coated with 2.54 centimeter closed cell foam. The casing surrounded the pile being driven, and contained the bubble flow. This system dramatically reduced both peak pressure and rms levels. Peak pressure was reduced by 23 to 24 dB and rms levels were reduced by 22 to 28 dB.

A confined bubble curtain used in driving 24 in octagonal concrete piles at the Port of Benicia in San Francisco Bay, California, attenuated SPLs between 20 and 30 dB (Rodkin, 2003). At the Benicia Martinez Bridge project in California, the project proponents used a casing that was either dewatered, or included an air bubble system. Both techniques yielded substantial reductions in SPLs. The sleeve with an air bubble curtain reduced peak SPLs by up to 34 dB, which the authors note, equates to a 99 percent reduction in the overall energy of the impulse (Reyff et al, 2002). A confined bubble curtain used in driving 30 in steel piles at a Washington State Ferries facility in Eagle Harbor, Washington, attenuated SPLs by an average of 9.1 dB (MacGillivary and Racca, 2005).

During impact installation of steel piles in an embayment on the Columbia River an unconfined bubble curtain built using a design by Longmuir and Lively (2001) achieved a maximum reduction of 17 dB, although the results were variable (Laughlin 2006). Unconfined bubble curtains used in driving very large steel piles for bridges in San Francisco Bay, California, have attenuated SPLs by as much as 20 dB (Abbott and Reyff 2004). An unconfined bubble curtain used during installation of 24 in steel piles in the City of Vancouver, British Columbia, reduced SPLs by 17 dB (Longmuir and Lively, 2001). At Friday Harbor, Washington, the Washington State Ferries monitored steel pile driving with and without a bubble curtain (Visconty 2004).

Initially, the bubble curtain was improperly installed and no sound attenuation was observed. The bubble curtain was not placed firmly on the bottom; therefore, unattenuated sound escaped under the bubble curtain. After the bubble curtain was modified by adding weight and a canvas skirt to conform to the bottom contour of Puget Sound, the sound was reduced by up to 12 dB, with an average of 9 dB reduction. Vagle (2003) reported reductions of between 18 dB and 30 dB when using a properly designed bubble curtain.

In Washington, the effectiveness of both unconfined and confined systems has been variable and below that of other locations. This may be attributable to an incomplete understanding of design, deployment, and performance, and/or to site specific parameters such as substrate and driving depth. With a common set of design and performance specifications, variability should be minimized and limited to site specificity.

Unconfined Bubble Curtain Specifications:

1. General - An unconfined bubble curtain is composed of an air compressor(s), supply lines to deliver the air, distribution manifolds or headers, perforated aeration pipe, and a frame. The frame facilitates transport and placement of the system, keeps the aeration pipes stable, and provides ballast to counteract the buoyancy of the aeration pipes in operation.

2. The aeration pipe system shall consist of multiple layers of perforated pipe rings, stacked vertically in accordance with the following:

| Water Depth (m) | No. of Layers |
|---|---|
| 0 to less than 5 | 2 |
| 5 to less than 10 | 4 |
| 10 to less than 15 | 7 |
| 15 to less than 20 | 10 |
| 20 to less than 25 | 13 |

3. The pipes in all layers shall be arranged in a geometric pattern which shall allow for the pile being driven to be completely enclosed by bubbles for the full depth of the water column and with a radial dimension such that the rings are no more than 0.5 m from the outside surface of the pile.

4. The lowest layer of perforated aeration pipe shall be designed to ensure contact with the substrate without burial and shall accommodate sloped conditions.

5. Air holes shall be 1.6 mm (1/16-in) in diameter and shall be spaced approximately 20 mm (3/4 in) apart. Air holes with this size and spacing shall be placed in four adjacent rows along the pipe to provide uniform bubble flux.

6. The system shall provide a bubble flux of 3.0 cubic meters per minute per linear meter of pipe in each layer (32.91 cubic ft per minute per linear foot of pipe in each layer). The

total volume of air per layer is the product of the bubble flux and the circumference of the ring:

$V_t = 3.0\ m^3/min/m$ * Circum of the aeration ring in m

or

$V_t = 32.91\ ft^3/min/ft$ * Circum of the aeration ring in ft

7. Meters shall be provided as follows:

   a. Pressure meters shall be installed at all inlets to aeration pipelines and at points of lowest pressure in each branch of the aeration pipeline.

   b. Flow meters shall be installed in the main line at each compressor and at each branch of the aeration pipelines at each inlet. In applications where the feed line from the compressor is continuous from the compressor to the aeration pipe inlet the flow meter at the compressor can be eliminated.

   c. Flow meters shall be installed according to the manufactures recommendation based on either laminar flow or non-laminar flow.

Performance: In Washington, unconfined bubble curtains have achieved a maximum of 17 dB attenuation and more typically range between 9 to 12 dB. Should hydroacoustic monitoring reveal that an unconfined bubble curtain is not achieving (to be determined based on site and project specific considerations), the NMFS and/or USFWS staff person on the project should be contacted immediately regarding modifications to the proposed action. Should attenuation rates continue at less than (to be determined based on site and project specific considerations), re-initiation of consultation may be necessary.

Confined Bubble Curtain Specifications:

1. General - A confined bubble curtain is composed of an air compressor(s), supply lines to deliver the air, distribution manifolds or headers, perforated aeration pipe(s), and a means of confining the bubbles.

   a. The confinement (e.g. fabric, plastic or metal sleeve, or equivalent) shall extend from the substrate to a sufficient elevation above the maximum water level expected during pile installation such that when the air delivery system is adjusted properly, the bubble curtain does not act as a water pump (i.e., little or no water should be pumped out of the top of the confinement system).

b. The confinement shall contain resilient pile guides that prevent the pile and the confinement from coming into contact with each other and do not transmit vibrations to the confinement sleeve and into the water column (e.g. rubber spacers, air filled cushions).

2. In water less than 15 m deep, the system shall have a single aeration ring at the substrate level. In waters greater than 15 m deep, the system shall have at least two rings, one at the substrate level and the other at mid-depth.

3. The lowest layer of perforated aeration pipe shall be designed to ensure contact with the substrate without sinking into the substrate and shall accommodate for sloped conditions.

4. Air holes shall be 1.6 mm (1/16-in) in diameter and shall be spaced approximately 20 mm (3/4 in) apart. Air holes with this size and spacing shall be placed in four adjacent rows along the pipe to provide uniform bubble flux.

5. The system shall provide a bubble flux of 3.0 cubic meters per minute per linear meter of pipe in each layer (32.91 $ft^3$ per minute per linear ft of pipe in each layer). The total volume of air per layer is the product of the bubble flux and the circumference of the ring:

   $V_t = 3.0\ m^3/min/m$ * Circ of the aeration ring in m

   or

   $V_t = 32.91\ ft^3/min/ft$ * Circ of the aeration ring in ft

6. Meters shall be provided as follows:

   a. Pressure meters shall be installed at all inlets to aeration pipelines and at points of lowest pressure in each branch of the aeration pipeline.

   b. Flow meters shall be installed in the main line at each compressor and at each branch of the aeration pipelines at each inlet. In applications where the feed line from the compressor is continuous from the compressor to the aeration pipe inlet the flow meter at the compressor can be eliminated.

   c. Flow meters shall be installed according to the manufactures recommendation based on either laminar flow or non-laminar flow.

Performance: In Washington, few projects have used confined bubble curtains so there is a lack of data. Based on performance in other locations, the effectiveness of a confined system could range from 9 dB to 30 dB. Should hydroacoustic monitoring reveal that a confined bubble curtain is not achieving (to be determined based on site and project specific considerations), the NMFS and/or USFWS staff person on the project should be contacted immediately regarding

modifications to the proposed action. Should attenuation rates continue at less than (to be determined based on site and project specific considerations), re-initiation of consultation may be necessary.

Terms and Conditions:

1. A bubble curtain meeting the above design specifications and performance requirements shall be used for all impact pile driving.

2. The bubble curtain design specifications shall be submitted to NMFS and/or the USFWS a minimum of 60 days prior to impact pile driving. The specification shall include, but not be limited to, details regarding hole size, hole spacing, hammer type and energy level, and air supply configuration and level. For confined systems the specification shall include details of the sleeve size, length, and guide system.

3. A hydroacoustic monitoring plan shall be submitted to NMFS and/or the USFWS for approval a minimum of 60 days prior to impact pile driving. The hydroacoustic monitoring plan must be prepared and implemented by someone with proven expertise in the field of underwater acoustics and data collection and shall include the name and qualifications of the biologist to be present during impact pile driving.

4. The contractor shall perform a performance test of the bubble curtain, prior to any impact pile driving, in order to confirm the calculated pressures and flow rates at each manifold ring. The contractor shall submit an inspection/performance report to NMFS and/or USFWS within 72 hrs following the performance test.

5. Impact pile driving shall not take place between one hour after sunset and one hour before sunrise. (Note: Implementation of this condition will depend on site specific considerations)

6. A qualified biologist shall be present during all impact pile driving operations to observe and report any indications of dead, injured or distressed fishes, including direct observations of these fishes or increases in bird foraging activity.

7. If a barge is used to house the pile-driver, it shall be isolated from the noise-producing operations. This isolation shall be such that noise from the pile driving operation is not transmitted through the barge to the water column.

8. FHWA shall document the effectiveness of the bubble curtain through hydroacoustic monitoring of a minimum of five piles, as early in the project as possible. Factors to consider in identifying the piles to be monitored include, but are not limited to: bathymetry of project site, total number of piles to be driven, sizes of piles, and distance from shore. Peak and rms SPLs, and sound exposure levels (SEL), with and without a bubble curtain, shall be monitored at a distance of 10 m from each pile at mid-water depth.

9. If the hydroacoustic monitoring indicates that the SPLs will exceed the extent of take exempted in the Biological Opinion(s), the FHWA shall contact NMFS and/or the USFWS within 24 hr. The FHWA shall consult with the Service(s) regarding modifications to the proposed action in an effort to reduce the SPLs below the limits of take and continue hydroacoustic monitoring.

10. FHWA shall submit a monitoring report to the consulting biologist(s) at NMFS and/or the USFWS within 60 days of completing hydroacoustic monitoring. The report shall include the following information:

    a. size and type of piles;
    b. a detailed description of the bubble curtain, including the design specifications identified above;
    c. the impact hammer force used to drive the piles;
    d. a description of the monitoring equipment;
    e. the distance between hydrophone and pile;
    f. the depth of the hydrophone;
    g. the distance from the pile to the wetted perimeter;
    h. the depth of water the pile was driven;
    i. the depth into the substrate the pile was driven;
    j. the physical characteristics of the bottom substrate into which the piles were driven; and
    k. the results of the hydroacoustic monitoring, including the frequency spectrum, peak and rms SPLs, and single-strike and cumulative SEL with and without the bubble curtain. The report must also include the ranges and means for peak, rms and SELs for each pile.

## LITERATURE CITED

Abbott, R. R., and J. A. Reyff. 2004. San Francisco - Oakland Bay Bridge, East Span Seismic Safety Project: Fisheries and Hydroacoustic Monitoring Compliance Report. Caltrans.

Gisiner, R. C., and coauthors. 1998. Workshop on the Effects of Anthropogenic Noise in the Marine Environment. R. C. Gisiner, editor Effects of Anthropogenic Noise in the Marine Environment. Marine Mammal Science Program, Office of Naval Research.

Laughlin, J. 2006. Underwater Sound Levels Associated with Pile Driving at the Cape Disappointment Boat Launch Facility, Wave Barrier Project (Revised). Washington State Parks.

Longmuir, C., and T. Lively. 2001. Bubble Curtain Systems for use During Marine Pile Driving. Fraser River Pile and Dredge Ltd., Vancouver, BC.

MacGillivray, A., and R. Racca. 2005. Sound pressure and particle velocity measurements from marine pile driving at Eagle Harbor maintenance facility, Bainbridge Island, WA. Washington State Department of Transportation, Victoria, British Columbia.

Pommerenck, K. 2006. Results of Underwater Sound Measurements for the Construction of Utility Crossing at Stockton Regional Wastewater Control Facility. Ilingworth and Rodkin, Inc., 05-187, Petaluma, CA.

Reyff, J. A., P. R. Donavan, and C. R. Greene. 2002. Underwater Sound Levels Associated with Construction of the Benecia-Martinez Bridge - Preliminary Results Based on Measurements Made During the Driving of 2.4 m Steel-Shell Piles.

Rodkin, R.B. 2003. Reconstruction of Pier 95 (Amports), Port of Benicia, Benicia, California, Report of Underwater Sound Level Measurements Resulting from Pile Driving. Illingworth & Rodkin, Inc., 03-021, Petaluma, CA.

Vagle, S. 2003. On the Impact of Underwater Pile-Driving Noise on Marine Life. Ocean Science and Productivity Division, Institute of Ocean Studies, DFO/Pacific.

Visconty, S. 2004. Friday Harbor Bubble Curtain preliminary results and update. Pages Email from Sasha Visconty of Anchor Environmental representing Washington State Ferries *in* N. M. F. Service, editor. WSDOT, Seattle, WA.

# Appendix D: Hydroacoustic Monitoring Plan

**SR 303**

# *Manette Bridge Replacement Project*
# UNDERWATER NOISE MONITORING PLAN

*Prepared by:*
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***June 16, 2009***

## INTRODUCTION

The Washington State Department of Transportation (WSDOT) proposes to replace the structurally deficient and functionally obsolete Manette Bridge with a new concrete bridge. The new Manette Bridge will be built parallel to and immediately south of the existing bridge, with roadway connections to existing city street intersections on each end of the bridge. Construction of the project is proposed to begin in 2010 and continue for approximately 3 years. The project will occur in three main phases. First, the new bridge piers and central portion of the new bridge will be constructed. Second, the outermost spans of the existing bridge will be removed and the new bridge's outermost spans and abutments will be built. This work includes the completion of stormwater facilities for the new bridge. Finally, the remaining portions of the existing bridge will be demolished and removed.

Temporary work trestles will be built in Port Washington Narrows as part of this project to support both the construction of the new bridge and demolition of the existing bridge. Work trestle construction will include pile driving and falsework bents. Two trestles are required, one on the south side of the bridge for new bridge construction and one on the north side of the bridge for removal of the existing bridge. Up to 542 steel piles, ranging in diameter from 24 to 36 inches will be installed.

## PROJECT AREA

The Manette Bridge is located in Bremerton, Kitsap County, Washington (Figure 1). The legal description of the location is Township 24N, Range 2E, Section 13. The bridge spans the Port Washington Narrows, a 3.5 mi long and 0.25 mi wide fjord that connects Dyes Inlet with Sinclair Inlet (Figure 2). The bridge links the eastern and western portions of Bremerton, which are located on Point Herron and Point Turner, respectively

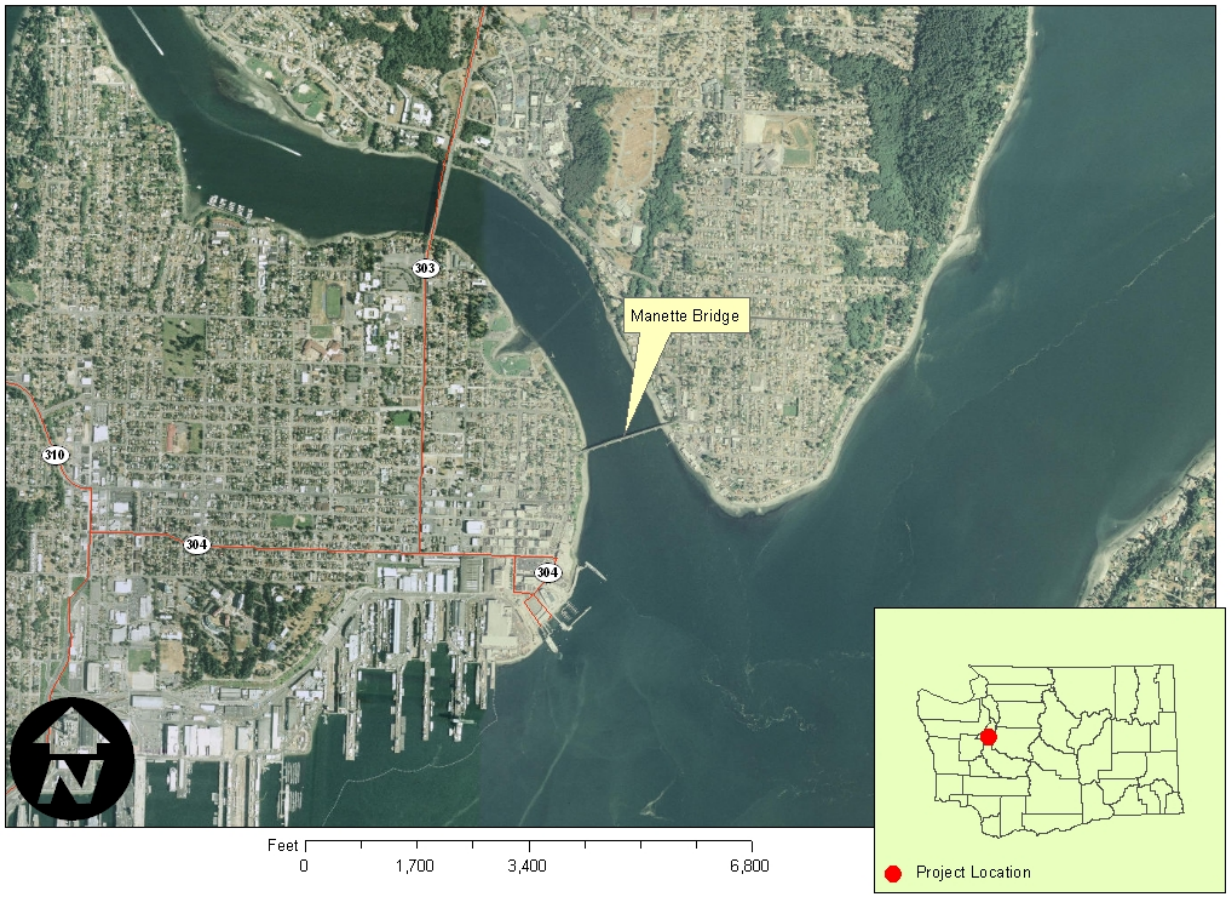


**Figure 1. Vicinity map of Manette Bridge Replacement Project.**

## PILE INSTALLATION LOCATION

Figure 2 indicates the location of the temporary work trestles. The structure colored yellow indicates the general location of pile driving activity. There will be a total of 542 piles driven as part of the temporary work trestles.

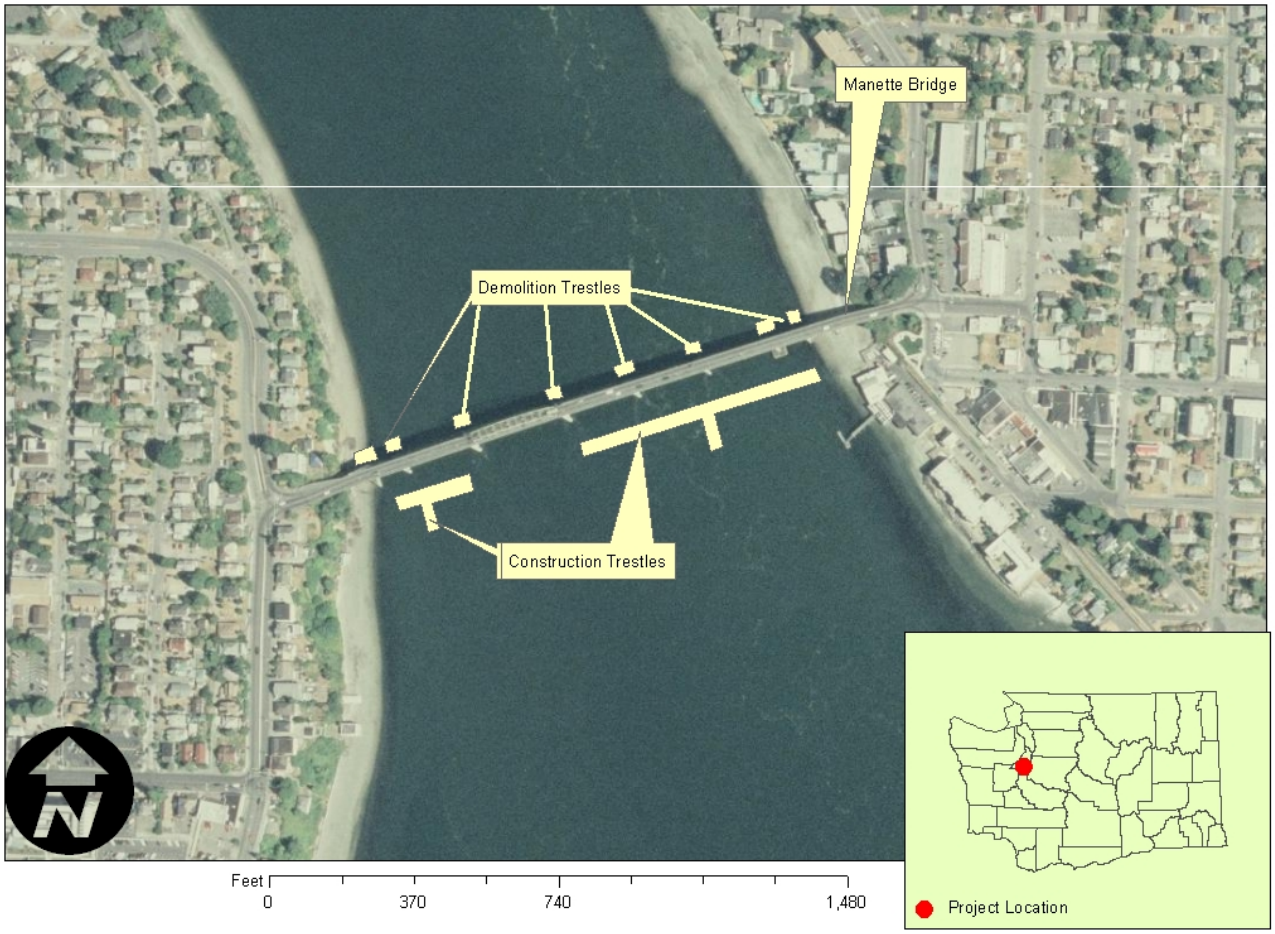


**Figure 2. Location of temporary work trestles where pile driving activity will take place.**

## PILE INSTALLATION

Hydroacoustic monitoring will be conducted during the first five piles struck with an impact hammer in water depths greater than two ft. It is not known where on the construction work trestles the Contractor will start. The water depths range between -1 and -40 ft. An additional fifteen piles (three groups of five) will be monitored that are representative of the variability across the Port Washington Narrows cross-section and the pile size(s) used. Bathymetry, total number of piles to be driven, depth of water, and distance from shore will be taken into consideration when choosing representative piles. Hydroacoustic monitoring of steel pile driving will include:

- Measuring underwater ambient levels,
- Monitoring of 20 steel piles (24-36 inch piles anticipated),

Figure 3 indicates the general location of the piles to be monitored. The hydrophones will be located 10 m from each pile with a clear line-of-sight between the pile and the hydrophone.

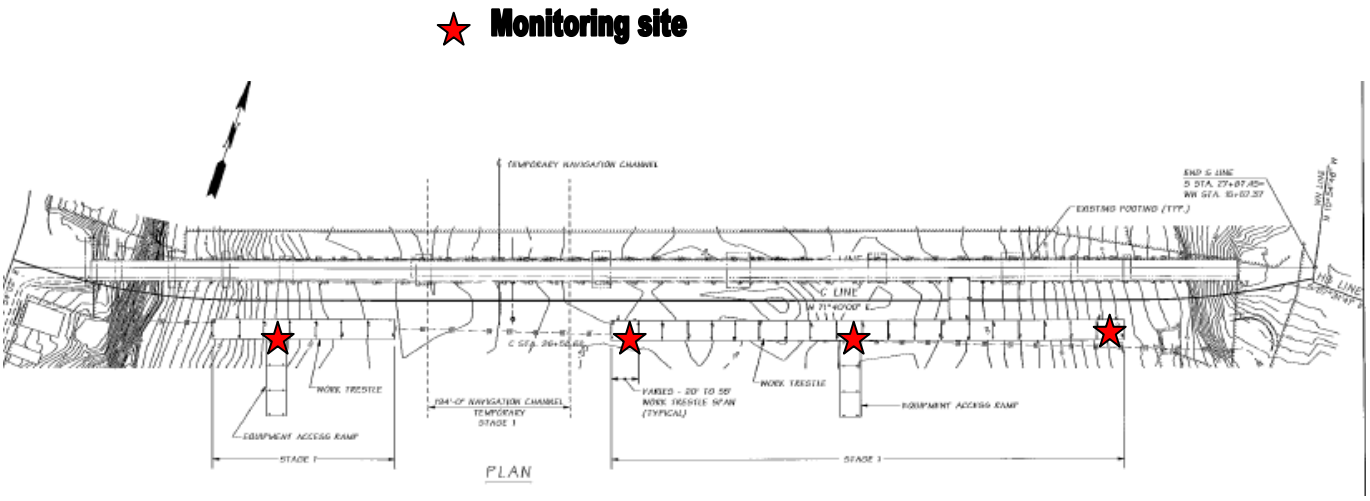


**Figure 3. Approximate location of the 20 piles (4 groups of 5 piles) that will be monitored on the Manette Bridge Replacement Project construction trestle**

## METHODOLOGY

Ambient underwater noise levels will be measured for a minimum of one minute in the absence of construction activities to determine background sound levels. Ambient sound levels will be reported as Root Mean Square (RMS) and include a spectral analysis of the frequencies.

A total of twenty 24 to 36-inch diameter steel piles will be selected for hydroacoustic monitoring. If more than one size of piling is used in trestle construction, monitored piles will represent the various sized used. Monitoring will only occur with the sound attenuation system operating. Table 2 details the equipment that will be used to monitor underwater sound pressure levels.

**Table 2. Equipment for underwater sound monitoring (hydrophone, signal amplifier, and calibrator). All have current National Institute of Standards and Technology (NIST) traceable calibration.2**

| Item | Specifications | Quantity | Usage |
|---|---|---|---|
| Hydrophone with 200 ft of cable | Receiving Sensitivity-<br>211dB ±3dB re 1V/µPa | 1 | Capture underwater sound pressures and convert to voltages that can be recorded/analyzed by other equipment. |
| Signal Conditioning Amplifier (4-channel) | Amplifier Gain-<br>0.1 mV/pC to 10 V/pC<br>Transducer Sensitivity Range-<br>$10^{-12}$ to $10^{3}$ C/MU | 1 | Adjust signals from hydrophone to levels compatible with recording equipment. |
| Calibrator (pistonphone-type) | Accuracy-<br>IEC 942 (1988) Class 1 | 1 | Calibration check of hydrophone in the field. |
| Portable Dynamic Signal Analyzer (4-channel) | Sampling Rate-<br>24K Hz or greater | 1 | Analyzes and transfers digital data to laptop hard drive. |
| Microphone (free field type) | Range- 30 – 120 dBA<br>Sensitivity-<br>-29 dB ± 3 dB (0 dB = 1 V/Pa) | 1 | Monitoring airborne sounds from pile driving activities (if not raining). |
| Laptop computer | Compatible with digital analyzer | 1 | Record digital data on hard drive and signal analysis. |
| Real Time and Post-analysis software | - | 1 | Monitor real-time signal and post-analysis of sound signals. |
| Weighted nylon line marked in 5-foot increments to attach hydrophone. | - | 1 | Takes the strain off of the hydrophone cables preventing damage. |
| Various surface floats. | - | - | To keep the hydrophone at the appropriate depth in relation to the surface. |

Monitoring equipment will be set to a minimum frequency range of DC to 10 KHz and a sampling rate of 24,000 Hz. To facilitate further analysis of data the underwater signal will be recorded as a text file (*.txt).

One hydrophone will be placed at mid water depth at distance of 10 m from each pile being monitored. A weighted tape measure will be used to determine the depth of the water. The hydrophone will be attached to a nylon cord or a steel chain if the current is swift enough to cause strumming of the line. The nylon cord or chain will be attached to an anchor that will keep the line 10 m from the pile. The nylon cord or chain will be attached to a float or tied to a static line at the surface 10 m from the pile. The distance will be measured by a tape measure, where

2 If acoustic monitoring is conducted by a contractor specialized in hydroacoustic monitoring and not conducted directly by WSDOT, the contractor will submit a detailed equipment list for underwater sound pressure level monitoring for approval by a WSDOT acoustic specialist.

possible, or a range-finder. There should be a direct line of sight between the pile and the hydrophone in all cases.

The hydrophone calibration will be checked at the beginning of each day of monitoring activity. Prior to the initiation of pile driving, the hydrophone will be placed at the appropriate distance and depth as described above.

Ambient underwater sound levels will be measured for 1 to 2 min prior to initiation of pile driving as well as in the absence of construction activities. It will be necessary to have the inspector/contractor inform the acoustics specialist when pile driving is about to start because the monitoring equipment will need to be shut down between recordings to change batteries or conserve battery power.

Underwater sound levels will be continuously monitored during the entire duration of each pile being driven. Peak levels of each strike will be monitored in real time. Sound levels will be measured in Pascals which are easily converted to decibel (dB) units (e.g. 1000 Pascals = 180 dB).

Prior to and during the pile driving activity environmental data will be gathered such as wind speed and direction, air temperature, humidity, surface water temperature, water depth, wave height, weather conditions, and other factors that could contribute to influencing the underwater sound levels (e.g. aircraft, boats, etc.). Start and stop time of each pile driving event and the time at which the bubble curtain or functional equivalent is turned on and off will be recorded.

The chief inspector will supply the acoustics specialist with the substrate composition, hammer model and size, hammer energy settings and any changes to those settings during the piles being monitored, depth pile driven, total number of pile strikes, and blows per foot for the piles monitored.

## SIGNAL PROCESSING

Post-analysis of the sound level signals will include determination of absolute peak overpressure and underpressure levels recorded for each pile, Root Mean Square (RMS) value for each absolute peak pile strike, rise time, average duration of each pile strike, number of strikes per pile, percent of strikes exceeding 206 $dB_{peak}$, percent of strikes exceeding 150 $dB_{rms}$, Sound Exposure Level (SEL) of the absolute peak pile strike, mean SEL, and cumulative SEL (Accumulated SEL = single strike SEL + 10*log (# hammer strikes) and a frequency spectrum both with and without mitigation, between 0 and 10,000 Hz for up to eight successive strikes with similar sound levels.

## ANALYSIS

Analysis of the data from the San Francisco-Oakland Bay Bridge Pile Driving Demonstration project (PIDP) indicated that 90 percent of the acoustic energy for most pile driving impulses occurred over a 50 to 100 milliseconds period with most of the energy concentrated in the first 30 to 50 milliseconds. The RMS values computed for this project will be computed over the duration between where 5% and 95% of the energy of the pulse occurs. Cumulative energy levels and Sound Exposure Levels (SEL) will be calculated from data between 5% and 95% of the energy of the pulse. The cumulative SEL energy plot will assist in interpretation of the single strike waveform.

In addition, a waveform analysis of the individual absolute peak pile strikes will be performed to determine any changes to the waveform with the bubble curtain or functional equivalent operating. Units of underwater sound levels will be dB re: 1 micropascal.

## REPORTING

A draft report including data collected and summarized from all phases will be submitted to the Services within 120 days of the completion of hydroacoustic monitoring. The results will be summarized in graphical form and include summary statistics and time histories of impact sound values for each pile. A final report will be prepared and submitted to the Services within 30 days following receipt of comments on the draft report from the Services. The report shall include:

1. Size and type of piles;
2. A detailed description of the bubble curtain or functional equivalent, including design specifications;
3. The impact hammer force used to drive the piles;
4. A description of the monitoring equipment;
5. The distance between hydrophone and pile;
6. The depth of the hydrophone;
7. The distance from the pile to the wetted perimeter;
8. The depth of water in which the pile was driven;
9. The depth into the substrate that the pile was driven;
10. The physical characteristics of the bottom substrate into which the piles were driven;
11. The total number of pile strikes;
12. The ranges and means for peak, RMS, and SEL's for each pile;
13. The results of the hydroacoustic monitoring, including the frequency spectrum, peak and RMS SPL's, and single-strike and cumulative SEL with the attenuation system; and
14. A description of any observable fish or bird behavior in the immediate area will and, if possible, correlation to underwater sound levels occurring at that time.