United States Department of the Interior

FISH AND WILDLIFE SERVICE

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

JAN 15 2020

In Reply Refer To:
01EWFW00-2017-F-0826-R001

Captain M.L. Arny
U.S. Navy
Commanding Officer
Naval Air Station Whidbey Island
3730 North Charles Porter Avenue
Oak Harbor, Washington 98270-5000

Dear Captain Arny:

This letter transmits the U. S. Fish and Wildlife Service's Biological Opinion on the Naval Air Station Whidbey Island Complex EA-18G "Growler" Airfield Operations Project (Project) implemented by the March 2019 Record of Decision. Formal consultation on the action was conducted in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*) (ESA). Your August 20, 2019, request for re-initiation of formal consultation was received on August 21, 2019. The enclosed Biological Opinion assesses impacts of the action, as described in the Record of Decision for the Project.

The enclosed Biological Opinion is based on information provided in the April 2017, Biological Assessment, draft and final Environmental Impact Statements, Record of Decision, emails, telephone conversations, and other information cited in the Biological Opinion. The Incidental Take Statement accompanying the Biological Opinion provides an exemption for incidental take of the marbled murrelet (*Brachyramphus marmoratus*) caused by the action. A complete record of this consultation is on file at the Washington Fish and Wildlife Office in Lacey, Washington. An electronic copy of this Biological Opinion will be available to the public approximately 14 days after it is finalized. A list of Biological Opinions completed by the USFWS since October 1, 2017 can be found on the USFWS Environmental Conservation Online System (ECOS) website at https://ecos.fws.gov/ecp/report/biological-opinion.html.

Additionally, we received your confirmation on December 20, 2019 that the action, as implemented by the Record of Decision, would have "no effect" on marbled murrelet critical habitat. There is no requirement for the Service to concur with "no effect" determinations and those determinations rest with the action agency.

If you have any questions regarding the enclosed Biological Opinion, our response to your concurrence request, or our shared responsibilities under the ESA, please contact Katherine Fitzgerald at 360-753-9593, or Emily Teachout at 360-753-9583.

Sincerely,

for Brad Thompson, State Supervisor
Washington Fish and Wildlife Office

Enclosure

cc:
NAVFAC NW, Oak Harbor, WA (M. Bianchi)
US Fleet Forces, Norfolk, VA (R. J. Nissen)
US Fleet Forces, Norfolk, VA (A. Farak)

Endangered Species Act - Section 7 Consultation

BIOLOGICAL OPINION

U.S. Fish and Wildlife Service Reference:
01EWFW00-2017-F-0826-R001

Naval Air Station Whidbey Island Complex EA-18G "Growler" Airfield Operations Project

Island County, Washington

Federal Action Agency:

United States Department of the Navy

Consultation Conducted By:

U.S. Fish and Wildlife Service
Washington Fish and Wildlife Office
Lacey, Washington

for Brad Thompson, State Supervisor
Washington Fish and Wildlife Office

15 JANUARY 2020
Date

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ACRONYMS AND ABBREVIATIONS

AGL	Above Ground Level
CFR	Code of Federal Regulations
CI	confidence interval
dB	decibel
dBA	A-weighted decibel level
DEIS	Draft Environmental Impact Statement
DPS	Distinct Population Segment
ENSO	El Niño-Southern Oscillation
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act of 1973, as amended (16 U.S.C. l531 *et seq.*)
FCLP	field carrier landing practice
FEIS	Final Environmental Impact Statement
FMO	Foraging, Migration and Overwintering
fps	feet per second
FR	Federal Register
ft^2	square feet
HPA	hypothalamic–pituitary–adrenal axis
INRMP	Integrated Natural Resources Management Plans
km^2	square kilometers
MSL	mean sea level
NAS	Naval Air Station
Navy	U.S. Navy
NPDES	National Pollutant Discharge Elimination System
NWFP	Northwest Forest Plan
NWFPEM	Northwest Forest Plan's Effectiveness Monitoring Program
NWTT	Northwest Training and Testing
OEIS	Overseas Environmental Impact Statement
OLF	Outlying Field
Opinion	Biological Opinion
PBDE	polybrominated diphenyl ethers
PCBs	Polychlorinated Biphenyls
PDO	Pacific Decadal Oscillation
ROD	Record of Decision
RPM	Reasonable and Prudent Measures
SEL	Sound Exposure Level
Service	U.S. Fish and Wildlife Service
SL	sound level
T&G	touch-and-go
VTS	Vessel Traffic Service
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources

1 INTRODUCTION

This document represents the U. S. Fish and Wildlife Service's (Service) Biological Opinion (Opinion) based on our review of the alternative implemented by the U.S. Navy (Navy) in its Record of Decision (ROD) for the Navy's Final Environmental Impact Statement (FEIS) of March 12, 2019, for the Naval Air Station (NAS) Whidbey Island complex EA-18G "Growler" Airfield Operations located in Island County, Washington, and its effects on bull trout (*Salvelinus confluentus)* and 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.*) (ESA). Your August 20, 2019, request for re-initiation of formal consultation was received on August 21, 2019.

This Opinion is based on information provided in the April 2017, "Consultation Package," the November 2016 draft Environmental Impact Statement, the September 2018 final Environmental Impact Statement, the March 2019 ROD, emails, telephone conversations, field investigations, and other sources of information as detailed below. A complete record of this consultation is on file at the Washington Fish and Wildlife Office in Lacey, Washington.

2 CONSULTATION HISTORY

The following is a summary of important events associated with this consultation:

- A previous formal consultation was concluded on June 14, 2018, and the Service issued the Navy a biological opinion with an accompanying incidental take statement based on a surrogate co-extensive with the proposed action.
- The Navy issued its final Environmental Impact Statement regarding Growler operations in September 2018.
- On March 12, 2019, the Navy issued its ROD for the Growler operations. The selected alternative differed from the proposed action analyzed in the 2018 biological opinion. In particular, the selected alternative included a larger number of interfacility flights.
- On August 20, 2019, the Navy requested reinitiation of formal consultation, for the purposes of clarifying the surrogate used for the Incidental Take Statement and refining the analysis pertaining to the alternative implemented by the Navy's ROD.

3 CONCURRENCE

3.1 Bull Trout

In its 2018 biological opinion, the Service concurred with the Navy's determination that the proposed action may affect, but is not likely to adversely affect bull trout. The Service has reviewed that concurrence in light of the alternative implemented under the ROD, and reaches the same conclusion. The nearshore marine areas around Whidbey Island provide foraging, migrating, and overwintering (FMO) habitat for bull trout, which is essential to maintaining connectivity between core areas and local populations, as well as providing foraging and

overwintering opportunities. Adult and subadult bull trout may be present in the FMO habitat throughout the year. Therefore, bull trout may be present in the action area (refer to Section 5.4 of this Opinion) during the implementation of the action.

The additional impervious surfaces that will be created by expanding parking areas and constructing new storage facilities will increase stormwater runoff at Ault Field (refer to Figure 1). These actions will require a National Pollutant Discharge Elimination System (NPDES) stormwater permit from the U.S. Environmental Protection Agency (EPA). An NPDES stormwater permit requires implementation of site-specific best management practices to eliminate erosion, sedimentation, and discharge of pollutants in runoff and we therefore expect the impacts of increased stormwater runoff to bull trout and their habitat to be insignificant.

The Navy's Growlers will produce elevated sound levels (SLs) as they are flown through their training operations. Loud noise can disrupt the normal sheltering, feeding, and breeding behavior of bull trout and excessively loud noises can injure bull trout.

Transmission of sound from aircraft flying over an underwater receiver is affected by the differing acoustic properties of air and water. Most of the acoustic energy is reflected away from the water column, which results in alteration of the characteristics of in-air sounds as they travel through the air-water interface (Richardson et al. 1995, pp. 80-83). A sound wave propagating from an aircraft must enter the water at an angle of incidence of 13 degrees or less from the vertical for the wave to continue to propagating under the water's surface (Richardson et al. 1995, pp. 80-83). This means that in-air sound transfers into the water mainly in a narrow cone under the aircraft, and is strongest just below the water's surface. At greater angles of incidence, the water acts as a reflector of the sound wave and allows very little penetration below the water (Urick 1983, pp. 128-129).

Sounds generated by flights at low altitudes remain at relatively high sound levels at the water surface, but the area of the water's surface where the sound may be transmitted underwater is relatively small. As an aircraft gains altitude, sound reaching the water surface diminishes, but there is a larger area of the water's surface where sound can be transmitted underwater (Eller and Cavanagh 2000, p. 7).

Bull trout that are present in the action area are currently exposed to high levels of ambient underwater noise. At Admiralty Inlet, within the action area, the most significant contributors to ambient noise levels are commercial shipping and ferry traffic, with secondary contributions from rain, wind, and marine mammal vocalizations (Bassett et al. 2012, pp. 3711-3714).

Because the sounds of aircraft overflight are expected to be altered by the interface between the air and water, and the background levels of underwater sound within the action area are already high, we do not expect that the proposed action will result in underwater sound exposures that substantially alter the acoustic environment experienced by bull trout in the action area. Therefore, we expect the impacts of increased SLs from Growler operations to be insignificant to bull trout.

Based on the conclusions stated above, the Service concurs with the Navy's conclusion that the action, as implemented according to the ROD, may affect, but is not likely to adversely affect bull trout.

4 BIOLOGICAL OPINION

5 DESCRIPTION OF THE ACTION

A federal action means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies in the United States or upon the high seas (50 CFR 402.02).

The Navy proposes to conduct the following actions:

1. Construct and renovate facilities at Ault Field to accommodate additional Growler aircraft.

2. Station additional personnel and their family members at the NAS Whidbey Island complex and in the surrounding community.

3. Add additional Growler aircraft to the squadrons currently stationed at the NAS Whidbey Island complex.

4. Continue and expand existing EA-18G ("Growler") operations at the NAS Whidbey Island complex (Figure 1), to include field carrier landing practice (FCLP) at Ault Field and Outlying Field (OLF) Coupeville.

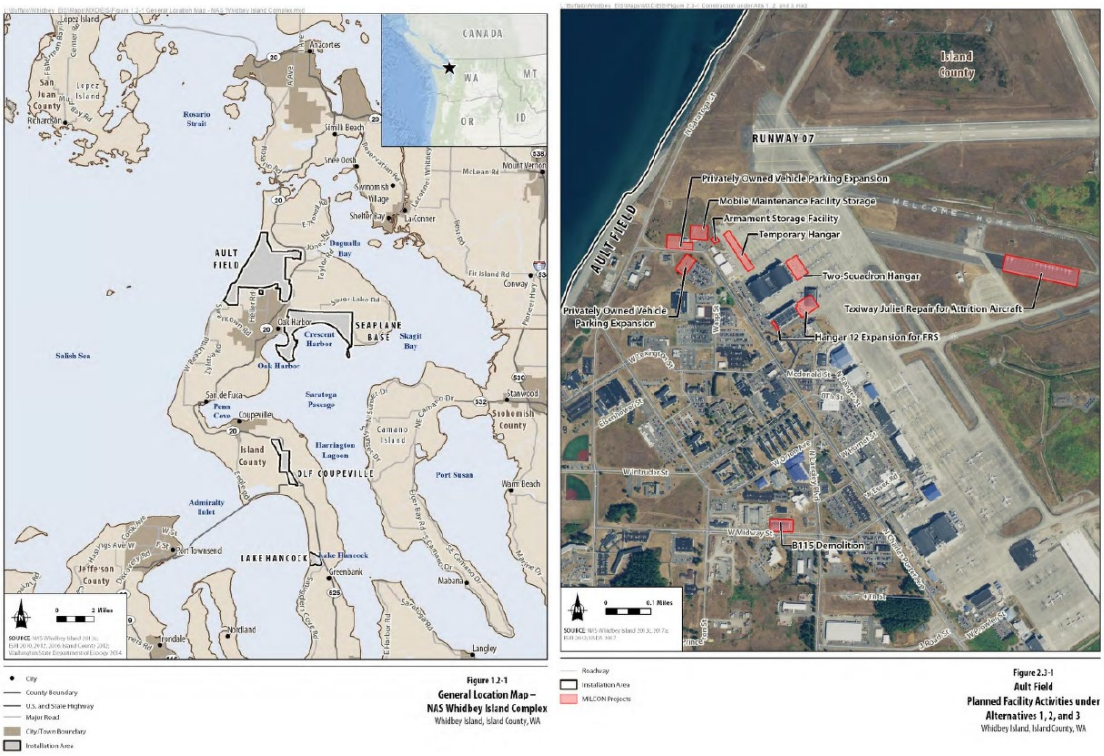

Figure 1. General location of NAS Whidbey Island complex, and construction and renovations included in the proposed action.
Excerpted from Navy 2018, pp. 1-2, 2-14

5.1 Facility Construction and Renovation

The action implemented by the Navy includes modifying existing buildings and constructing new facilities and infrastructure. These efforts include construction and/or repair of aircraft pavement, aircraft parking apron, flight training and briefing building, maintenance hangars, armament storage, a mobile maintenance facility, repair to inactive taxiways, and expanded personnel parking (Figure 1). All of the construction and repair work will occur at Ault Field. In total, the new facilities and parking will add approximately 2 acres of impervious surfaces to the complex.

5.1.1 Facility Construction and Renovation Conservation Measures

1. Activities such as vehicle maintenance, chemical or waste oil storage, or transferring potential contaminants will be conducted in covered areas so contaminants will not wash into storm drains or surface waters.

2. Stormwater from uncovered areas will be retained and diverted to the sanitary sewer system.

3. Storm drains will not be used to dump or discharge any materials or chemicals. All storm drains will be labeled with "no dumping" signs.

4. As required for a NPDES stormwater permit from the EPA, the Navy will develop a site-specific plan for managing stormwater runoff and describe the best management practices to be implemented to eliminate erosion, sedimentation, and stormwater pollution.

5.2 Continued and Expanded Growler Operations

The action implemented by the Navy includes Growler operations within the airspace control of the NAS Whidbey Island complex. Growlers leaving the NAS Whidbey Island complex to train in a Military Operations Area further away (such as the Olympic Peninsula, Okanogan, or Boardman) will not be within the airspace controlled by the NAS Whidbey Island complex after they climb above 4,000 ft in altitude or leave the area around the north Puget Sound. Growlers performing training operations in the north Puget Sound and beginning and ending their flights at the NAS Whidbey Island complex are included in the action. The Growler operations quantified here and in the FEIS are airfield operations, that is, takeoffs and landings (or other approaches) at Ault Field or OLF Coupeville.

Growler operations will occur year round, any day of the week, and at any time of day or night. Approximately 15 percent of all Growler operations will occur between the hours of 10:00 pm and 7:00 am. The action includes Growler operations for the next 30 years (through 2049), as that is the amount of time the Navy expects to continue flying Growlers (Bianchi, M., in litt. 2018a). The typical pace and frequency of operations will be punctuated by periods of relatively high activity when pilots are preparing for deployment, which can occur at any time of the year. Growler operations will include departures (aircraft taking off), pattern operations, arrivals (aircraft landing), and interfacility flights. Many different typical flight paths will be used for each departure, pattern operation, and arrival. Each airstrip at the NAS Whidbey Island complex

will be used from either direction. For example, aircraft can depart and arrive on the 07/25 airstrip by travelling east (runway 07) or by travelling west (runway 25). There are four runways at Ault Field (07, 25, 14, and 32) and two runways at OLF Coupeville (14 and 32). Each flight operation (departure, pattern operation, arrival, or interfacility flight) has one to six different typical flight paths for every runway used for the flight operation. Due to prevailing winds, Ault Field runway 25 is used more often during April through September and Ault Field runway 14 is used more often during October through March.

Each type of Growler operation is described below. These descriptions include a number describing how often, on average, the Navy expects to conduct each type of operation in a given year. The descriptions also include a number describing how often the Navy expects to conduct each type of operation in year with particularly high activity (especially with respect to field carrier landing practice and associated interfacility flights), referred to as a "high tempo" year. The average year described below is not simply a typical year, but reflects the long-term mean level of Growler training activity that the Navy anticipates, averaging together years of high, low, and moderate activity levels. The descriptions of high tempo years below are not apart from the average, but are at the high end of the range of activity that would be included in the average. The description of a high tempo year is included here to give a reasonable depiction of the maximum level of Growler activity expected at Whidbey Island during a given year, especially with respect to flight tracks, such as interfacility flights, that travel longer distances over water. Note that some operations will be conducted less often than average in a high tempo year, though the total number of operations will increase.

5.2.1 Departures

Departures are simply aircraft taking off to a local or non-local training area. Although any take-off could be described as a departure, the departures quantified here include only those that leave the NAS Whidbey Island complex airspace. As noted above, we consider the portion of the flight within NAS Whidbey Island complex airspace, below 4,000 ft. In an average year of the action implemented by the Navy, there will be around 17,415 Growler departures from Ault Field. In a high tempo year, there will be around 17,454 Growler departures from Ault Field.

5.2.2 Pattern Operations

A pattern consists of an approach followed by a take-off. Therefore, pattern operations occur in pairs, and each circuit of the flight track is associated with two pattern operations. The types of pattern operations included in the action are: touch-and-go (T&G), field carrier landing practice (FCLP), ground-controlled approach, and depart and re-enter patterns. Touch-and-go and FCLP operations both involve aircraft making an approach to the runway, going to full power, and taking off again without coming to a full stop. In an average year, about 11,855 T&G airfield operations will be conducted at Ault Field. In a high tempo year, about 12,157 T&G airfield operations will be conducted at Ault Field.

Typical FCLP training periods (also called FCLP evolutions in the FEIS, e.g., Navy 2018, p. 4-320) will each accomplish multiple operations and will entail three to five aircraft conducting a total of eight to ten approaches and take offs and last for approximately forty-five minutes. Eight

approaches and eight take offs during an FCLP training period adds up to 16 airfield operations, but only eight circuits of the pattern, or in other words, eight times around the flight track. Aircraft participating in FCLP periods are usually paced about one minute apart. In an average year, about 5,936 FCLP airfield operations will be conducted at Ault Field and 23,729 at OLF Coupeville. In a high tempo year, about 6,413 FCLP airfield operations will be conducted at Ault Field and 26,128 at OLF Coupeville. Growlers following typical FCLP flight paths will not travel more than three nautical miles laterally (about 3.5 miles) from the runway (Navy 2018, pp. A4-15-A4-16, A4-30).

Ground-controlled approaches are patterns in which the pilot lands the aircraft with additional guidance from ground-based air traffic controllers to practice or conduct arrivals under adverse weather conditions. Ground-controlled approach operations will only be conducted at Ault Field. On average, each year, about 14,391 ground-controlled approach operations will be conducted at Ault Field. In a high tempo year, about 14,911 ground-controlled approach operations will be conducted at Ault Field. Compared with FCLP operations, typical flight paths for ground-controlled approaches have much larger flight paths. Growlers following typical flight paths for ground-controlled approaches will stay within 14.5 nautical miles laterally (about 16.7 miles) of Ault Field (Navy 2018, p. A4-23).

In depart and re-enter patterns, Growlers make a wide lateral arc around one side of the runway before performing an overhead break arrival. In an average year, about 3,859 depart and re-enter patterns will be conducted at Ault Field. In a high tempo year, about 3,849 depart and re-enter patterns will be conducted at Ault Field. Flight paths for depart and re-enter patterns do not typically extend more than 3.75 nautical miles (about 4.3 miles) from the runway.

5.2.3 Arrivals

There are several types of arrivals included in the action. Straight-in/full-stop arrivals, overhead break arrivals, and instrument approaches all conclude with the aircraft landing but each type of arrival has a different typical flight path. Although any approach or landing could be described as an arrival, the arrivals quantified here include only those that are returning from outside the NAS Whidbey Island complex airspace, rather than arrivals that make up part of a pattern or an interfacility flight. As noted above, we consider the portion of the flight within NAS Whidbey Island complex airspace, below 4,000 ft. In an average year of the action implemented by the Navy, about 6,530 straight-in/full-stop arrivals, 9,963 overhead break arrivals, and 922 instrument approaches will be conducted at Ault Field. In a high tempo year, about 6,532 straight-in/full-stop arrivals, 10,007 overhead break arrivals, and 914 instrument approaches will be conducted at Ault Field.

5.2.4 Interfacility Flights

Growlers begin and end their training at Ault Field, so to conduct FCLP operations at OLF Coupeville Growlers must fly from Ault Field to OLF Coupeville and back. For interfacility flights, only the take-off or landing at Ault Field is counted as an interfacility flight operation. The corresponding approach or take-off at OLF Coupeville is counted as an FCLP operation. In an average year, Growlers will depart Ault Field for OLF Coupeville 1,481 times, then return to

Ault Field and perform an overhead break arrival about 1,483 times. In a high tempo year, Growlers will depart Ault Field for OLF Coupeville 1,631 times, then return to Ault Field and perform an overhead break arrival about 1,632 times. Note that Ault Field departures and arrivals are different as a result of the modeled averages for flight operations (Farak, in litt. 2019a).

5.2.5 Summary

The exact number of airfield operations in a year will depend on the Navy's training needs. The expected total number of airfield operations over the term of the action is the average number of airfield operations for a single year multiplied by 30, the number of years in the term of action. The annual averages, high tempo year estimates, and expected total number of airfield operations over 30 years are summarized below in Table 1. Growler flights normally follow routes called flight tracks. In maps, single lines depict the predominant path that aircraft follow, but the actual paths of flight may be several miles from the mapped track depending on aircraft performance, pilot technique, air traffic, and weather conditions (Navy 2018, p. 3-7). Refer to Appendix A for maps of typical flight tracks for the airfield operations included in the action.

Table 1. Summary of Growler airfield operations included in the action

Type of Operation		Annual Average Number of Airfield Operations	Number of Airfield Operations - High Tempo Year	Expected Total Number of Airfield Operations over 30 years*
AULT FIELD				
Departures		**17,415**	**17,454**	**522,450**
Arrivals	Straight-in/Full-stop	**6,530**	**6,532**	**195,900**
	Overhead Break	**9,963**	**10,007**	**298,890**
	Instrument Approach	**922**	**914**	**27,660**
Pattern Operations	FCLP	**5,936**	**6,413**	**178,080**
	T&G	**11,855**	**12,157**	**355,650**
	Ground-controlled Approach	**14,391**	**14,911**	**431,730**
	Depart and Re-enter	**3,859**	**3,849**	**115,770**
OLF COUPEVILLE				
Pattern Operations	FCLP	**23,729**	**26,128**	**711,870**
Interfacility Flights	Ault Field to OLF Coupeville	**1,481**	**1,631**	**44,430**
	OLF Coupeville to Ault Field	**1,483**	**1,632**	**44,490**
TOTAL		***97,564***	***101,628***	***2,926,920***

* Expected 30-year totals are calculated by multiplying the annual average number of airfield operations by 30.

5.3 Conservation Measures

The Navy has implemented Precision Landing Mode technology known as Maritime Augmented Guidance with Integrated Controls for Carrier Approach and Recovery Precision Enabling Technologies (or MAGIC CARPET). The technology makes aircraft carrier approaches and landings more automated and reduces the training required of pilots. The use of this technology is estimated to reduce the overall requirement for FCLP training by 20 percent, and this reduction is already accounted for in the number of operations analyzed here (Navy 2018, p. 1-33). Compared with the version of the action described in the Draft Environmental Impact Statement (DEIS), the version of the action selected in the ROD and analyzed here has 30 percent fewer FCLPs and 13 percent fewer total airfield operations, partly as a result of this technology (Navy 2018, p. 1-62).

5.4 Action Area

The action area is defined as all areas to be 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 for this federal action is based on the geographic extent of increased in-air sound levels above ambient conditions resulting from Growler operations. Growlers fly miles away from airfields during some activities, and Growler flights along flight tracks will extend the physical, chemical, and biotic effects of the action to their greatest extent. Growlers will commonly operate near the 85% power setting along the flight tracks included in the action, and at this power setting, the sound level produced by Growlers will be 111 dBA_{Lmax} re: 20µPa measured at 400 ft from the jet (Navy 2015, p. 3.6-60; Navy 2018, pp. A5-7 – A5-24). The farthest extent of the action area will be where the loudest noise from Growlers (dBA_{Lmax}) will not be noticeable above ambient sound levels.

To determine the furthest extent of the loudest noise from Growlers, we estimated the ambient sound level, and then use the practical spreading loss model to determine the distance needed for the source sound level (in this case the Growler jets) to reach the background (or ambient) sound level. The practical spreading loss model predicts that in-air sound will attenuate at a rate of 6 dB for every doubling of distance for hard sites, including open water. Sounds have a higher attenuation rate, 7.5 dB per doubling of distance, in areas with vegetation. Since much of the Growler flight will occur over water we used the lower attenuation rate to determine the action area. The best available estimate of ambient sounds for industrialized marine shorelines is from data collected by NAVFAC (2012, p. 24) at Naval Base Kitsap at Bangor, Washington. They documented in-air ambient sound levels at 65 $dBAL_{max}$. With application of the practical spreading loss model, we expect that noise from Growlers will attenuate to 65 $dBAL_{max}$ approximately 15 miles from the aircraft.

Flight tracks with the farthest geographical extent (ground-controlled arrivals and interfacility flights) define the farthest extent of where noise will originate, though we note that flights may sometimes vary several miles from the mapped flight tracks. We assume that this variability will not send the Growlers more than 5 miles farther from the airfields than depicted in the mapped

flight tracks. Therefore, the action area (Figure 2) for the Navy's action is defined as 20 miles, including 5 miles for variability in flight tracks and 15 miles for sound attenuation, from the farthest flight tracks followed for Growler operations.

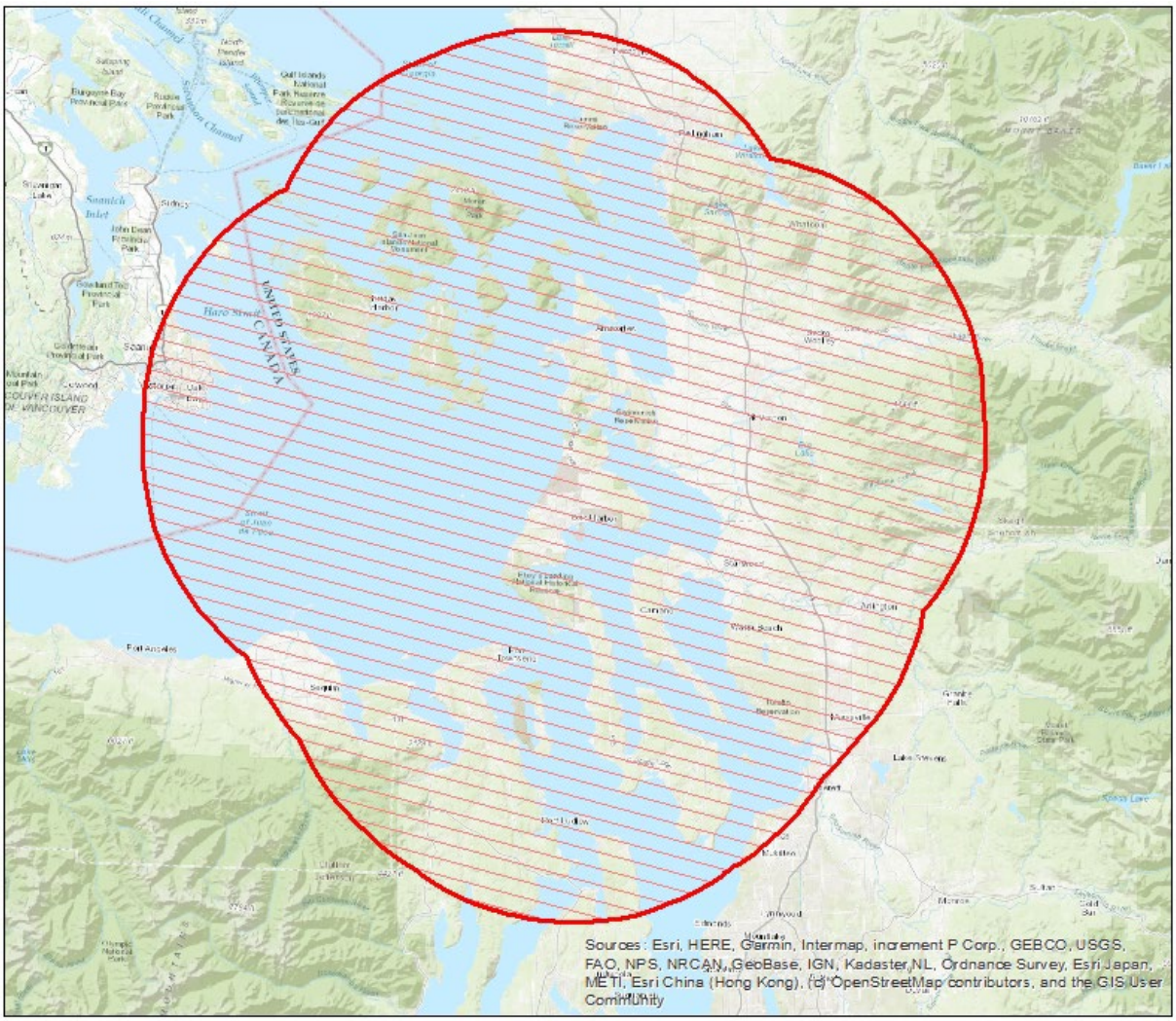

Figure 2. Action area of the action implemented by the Navy

At the outer edges of the action area, we expect that sounds associated with this action will be audible only infrequently, and even then, only at levels slightly above ambient sound levels. Where the outer edges of the action area are in forested areas, sounds associated with this action may attenuate to background levels faster, due to the higher attenuation rate, so forested areas at the outer edges of the action area may not be affected at all by sounds associated with this action. However, for simplicity, we have not attempted to map different attenuation rates in different parts of the action area, but have used only the lower attenuation rate, a conservative approach that avoids underestimating the area that will be affected by the action.

6 ANALYTICAL FRAMEWORK FOR THE JEOPARDY DETERMINATION

In accordance with policy and regulation, the jeopardy determination in this Opinion relies on the following components:

The Status of the Species, which evaluates the species' range-wide condition relative to its reproduction, numbers, and distribution, the factors responsible for that condition, and its survival and recovery needs.

The Environmental Baseline, which evaluates the condition of the species in the action area relative to its reproduction, numbers, and distribution without the consequences caused by the proposed action, the factors responsible for that condition, and the relationship of the action area to the survival and recovery of the species.

The Effects of the Action, which evaluates all future consequences to the species that are reasonably certain to be caused by the proposed action, including the consequences of other activities that are caused by the proposed action, and how those impacts are likely to influence the conservation role of the action area for the species; and

Cumulative Effects, which evaluates the consequences of future, non-Federal activities reasonably certain to occur in the action area on the species, and how those impacts are likely to influence the conservation role of the action area for the species.

In accordance with policy and regulation, the jeopardy determination is made by evaluating the consequences of the proposed Federal action in the context of the species' current range-wide 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 species in the wild. The key to making this finding is clearly establishing the role of the action area in the conservation of the species as a whole, and how the effects of the proposed action, taken together with cumulative effects, are likely to alter that role.

Conservation zones for the marbled murrelet were defined in the final recovery plan. In the section 7 process, these zones are recognized as recovery units. Pursuant to Service policy, when an action impairs or precludes the capacity of a recovery unit from providing both the survival and recovery function assigned to it, that action may represent jeopardy to the species. When using this type of analysis, the biological opinion describes how the action affects not only the recovery unit's capability, but the relationship of the recovery unit to both the survival and recovery of the listed species as a whole.

The analysis in the following sections applies the above approach and considers the relationship of the action area to the recovery unit and the relationship of the recovery unit to both the survival and recovery of the marbled murrelet as a whole as the context for evaluating the significance of the effects of the Federal action, taken together with cumulative effects, for purposes of making the jeopardy determination.

7 STATUS OF THE SPECIES: Marbled Murrelet

The marbled murrelet was listed as a threatened species in Washington, Oregon, and California in 1992 under the federal Endangered Species Act. The primary reasons for listing included extensive loss and fragmentation of old-growth forests which serve as nesting habitat for marbled murrelets and human-induced mortality in the marine environment from gillnets and oil spills (57 FR 45328 [Oct. 1, 1992]). Although some threats such as gillnet mortality and loss of nesting habitat on Federal lands have been reduced since the 1992 listing, the primary threats to species persistence continue (USFWS 2019a, p. 65).

The most recent population estimate for the entire Northwest Forest Plan (NWFP) area in 2017 was 23,000 marbled murrelets (95 percent confidence interval [CI]: 18,500 to 27,600 birds) (McIver et. al 2019, p. 3). The long-term trend derived from marine surveys for the period from 2001 to 2017 indicate that the marbled murrelet population across the NWFP area has increased at a rate of 0.34 percent per year (McIver et. al 2019, p. 3). While the overall trend estimate across this time period is slightly positive, the evidence of a detectable trend is not conclusive because the confidence intervals for the estimated trend overlap zero (95% -0.9 to 1.6 percent) (McIver et. al 2019, p. 3).

Marbled murrelet population size and marine distribution during the summer breeding season is strongly correlated with the amount and pattern (large contiguous patches) of suitable nesting habitat in adjacent terrestrial landscapes (Falxa and Raphael 2016, p. 109). The loss of nesting habitat was a major cause of marbled murrelet decline over the past century and may still be contributing as nesting habitat continues to be lost to fires, logging, and wind storms (Miller et al. 2012, p. 778). Monitoring of marbled murrelet nesting habitat within the NWFP area indicates nesting habitat has declined from an estimated 2.53 million acres in 1993 to an estimated 2.23 million acres in 2012, a total decline of about 12.1 percent (Falxa and Raphael 2016, p. 72). The largest and most stable marbled murrelet subpopulations now occur off the Oregon and northern California coasts, while subpopulations in Washington declined at a rate of approximately -3.9 percent per year for the period from 2001 to 2017 (McIver et al. 2019, p. 3). Rates of nesting habitat loss have also been highest in Washington, primarily due to timber harvest on non-Federal lands (Falxa and Raphael 2016, p. 37), which suggests that the loss of nesting habitat continues to be an important limiting factor for the recovery of marbled murrelets.

Factors affecting marbled murrelet fitness and survival in the marine environment include: reductions in the quality and abundance of marbled murrelet forage fish species, harmful algal blooms, toxic contaminants; marbled murrelet by-catch in gillnet fisheries; marbled murrelet entanglement in derelict fishing gear; oil spills, and human disturbance in marine foraging areas (USFWS 2019a, pp. 29-61). While these factors are recognized as stressors to marbled murrelets in the marine environment, the extent that these stressors affect marbled murrelet populations is unknown. As with nesting habitat loss, marine habitat degradation is most prevalent in the Puget Sound area where anthropogenic activities (e.g., shipping lanes, boat traffic, shoreline development) are an important factor influencing the distribution and abundance of marbled murrelets in in nearshore marine waters (Falxa and Raphael 2016, p. 106).

For a detailed account of marbled murrelet biology, life history, threats, demography, and conservation needs, refer to Appendix B: Status of the Species: Marbled Murrelet.

8 ENVIRONMENTAL BASELINE: Marbled Murrelet

The environmental baseline refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the action. The environmental baseline includes the past and present impacts of all federal, state, or private actions and other human activities in the action areas, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline. (50 CFR 402.02).

8.1 Current Condition of the Marbled Murrelet in the Action Area

8.1.1 Marbled Murrelet Population and Distribution in the Action Area

The action area includes the marine waters of northern Puget Sound, the eastern end of the Strait of Juan de Fuca, and the southern end of the Strait of Georgia (refer to Figure 2), and falls within Conservation Zone 1 as defined in the Marbled Murrelet Recovery Plan (see Appendix B, Figure 1). Zone 1 extends south from the U.S.-Canadian border along the east shore of Puget Sound to the southern end of Puget Sound, then turning westward along the north shore of the Olympic Peninsula to Koitlah Point, just northeast of Cape Flattery. Zone 1 includes all of Puget Sound and most waters of the Strait of Juan de Fuca. Zone 1 extends inland a distance of 50 miles from eastern Puget Sound and includes the northern and eastern section of the Olympic Peninsula.

The Service considers the Northwest Forest Plan's Effectiveness Monitoring Program (NWFPEM) to be the best available information on the population status and trends of marbled murrelets in Puget Sound during the breeding season (Table 2). Surveys conducted as part of the NWFPEM for marbled murrelets resulted in a population estimate of 3,837 marbled murrelets (95 % CI of 1,911 – 6,956) in Conservation Zone 1 in 2018, the last year for which an estimate is available (McIver et al. 2019, p. 15). Since 2001, the NWFPEM-estimated population size for Conservation Zone 1 has ranged from a low of 2,801 marbled murrelets in 2014 to a high of 9,758 in 2002 (McIver et al. 2019, pp. 10-15). Between 2001 and 2018, the estimated average marbled murrelet density in Conservation Zone 1 has ranged from 0.80 to 2.79 marbled murrelets per km^2 (McIver et al. 2019, pp. 10-15). The estimated marbled murrelet population in Conservation Zone 1 has fluctuated from year to year; for example, it increased between 2014 and 2016 (**Error! Reference source not found.**3). Overall, however, the population in Conservation Zone 1 has been generally declining over the history of NWFPEM surveys, decreasing at around 4.9 percent per year (McIver et al. 2019, p. 9).

Table 2. Marbled murrelet breeding season population estimates and densities for Zone 1.

Year	Population Estimate	Confidence Intervals		Density (birds/km^2)
		Lower 95%	Upper 95%	
2001	8,936	5,740	11,896	2.55
2002	9,758	5,954	14,149	2.79
2003	8,495	5,795	11,211	2.43
2004	5,465	2,921	7,527	1.56
2005	7,956	4,900	11,288	2.28
2006	5,899	4,211	8,242	1.69
2007	6,985	4,148	10,639	2.00
2008	4,699	3,000	6,314	1.34
2009	5,623	3,786	8,497	1.61
2010	4,393	2,719	6,207	1.26
2011	7,187	4,807	9,595	2.06
2012	8,442	5,090	12,006	2.41
2013	4,395	2,298	6,954	1.26
2014	2,801	1,598	3,876	0.80
2015	4,290	2,783	6,492	1.23
2016	4,614	2,298	7,571	1.32
2017	not surveyed			
2018	3,837	1,911	6,956	1.097

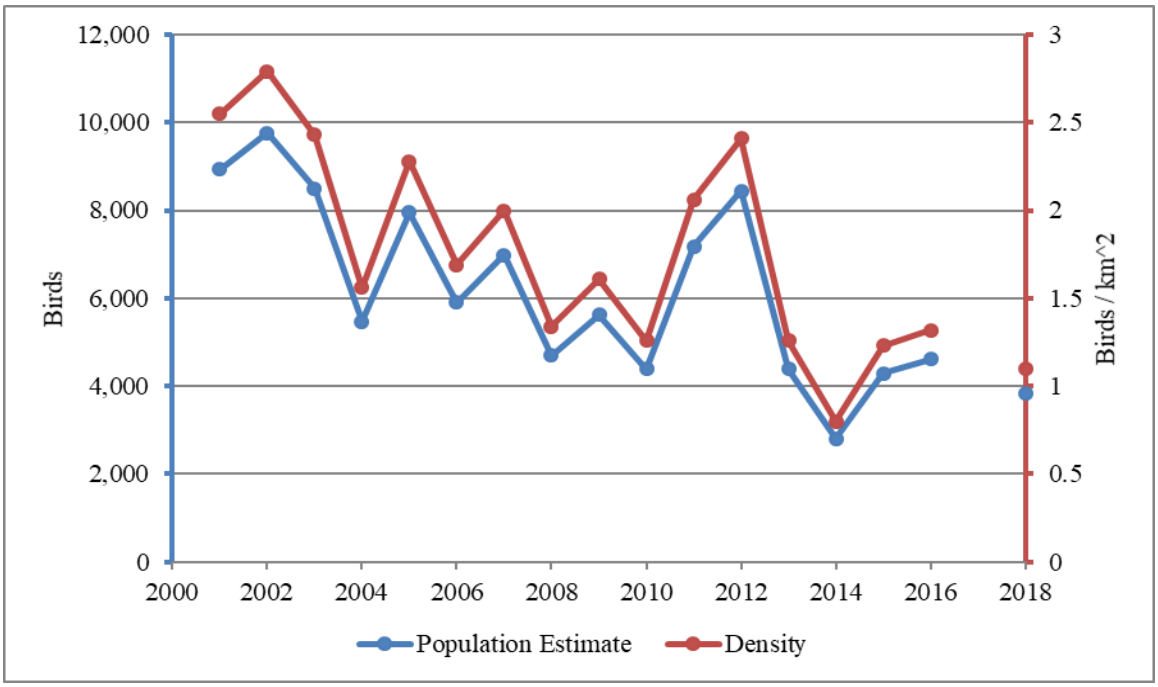

Figure 3. NWFPEM marbled murrelet population estimates and densities in Conservation Zone 1
(McIver et al. 2019, pp. 10-15)

Marbled murrelet population density is not uniform throughout Conservation Zone 1. During the breeding season, NWFPEM surveys are conducted in three monitoring areas, or strata (Figure 4, Figure 5). NWFPEM Stratum 1 is located along the Strait of Juan de Fuca, and almost always has the highest marbled murrelet densities, ranging from 1.24 birds/km^2 in 2014 to 7.21 birds/km^2 in 2002 (McIver et al. 2019, pp. 10-15). Since 2012, marbled murrelet density in NWFPEM Stratum 1 has averaged 2.84 birds/km^2. NWFPEM Stratum 2, encompassing the San Juan Islands, most of Rosario Strait, the western shore of Admiralty Inlet, northern Hood Canal, and Whidbey Basin, usually has the next highest density, ranging from 0.66 birds/km^2 in 2013 to 2.43 birds/km^2 in 2005 (McIver et al. 2019, pp. 10-15). Since 2012, marbled murrelet density in NWFPEM Stratum 2 has averaged 1.35 birds/km^2. NWFPEM Stratum 3 includes central and southern Puget Sound, southern Hood Canal, the western shore of Whidbey Island, and all other areas along the mainland coast, and generally has lower marbled murrelet densities, ranging from 0.064 birds/km^2 in 2015 to 2.07 birds/km^2 in 2001 (McIver et al. 2019, pp. 10-15). Since 2012, marbled murrelet density in NWFPEM Stratum 3 has averaged 0.49 birds/km^2. The action area includes a small portion of NWFPEM Stratum 1, and more substantial portions of NWFPEM Strata 2 and 3.

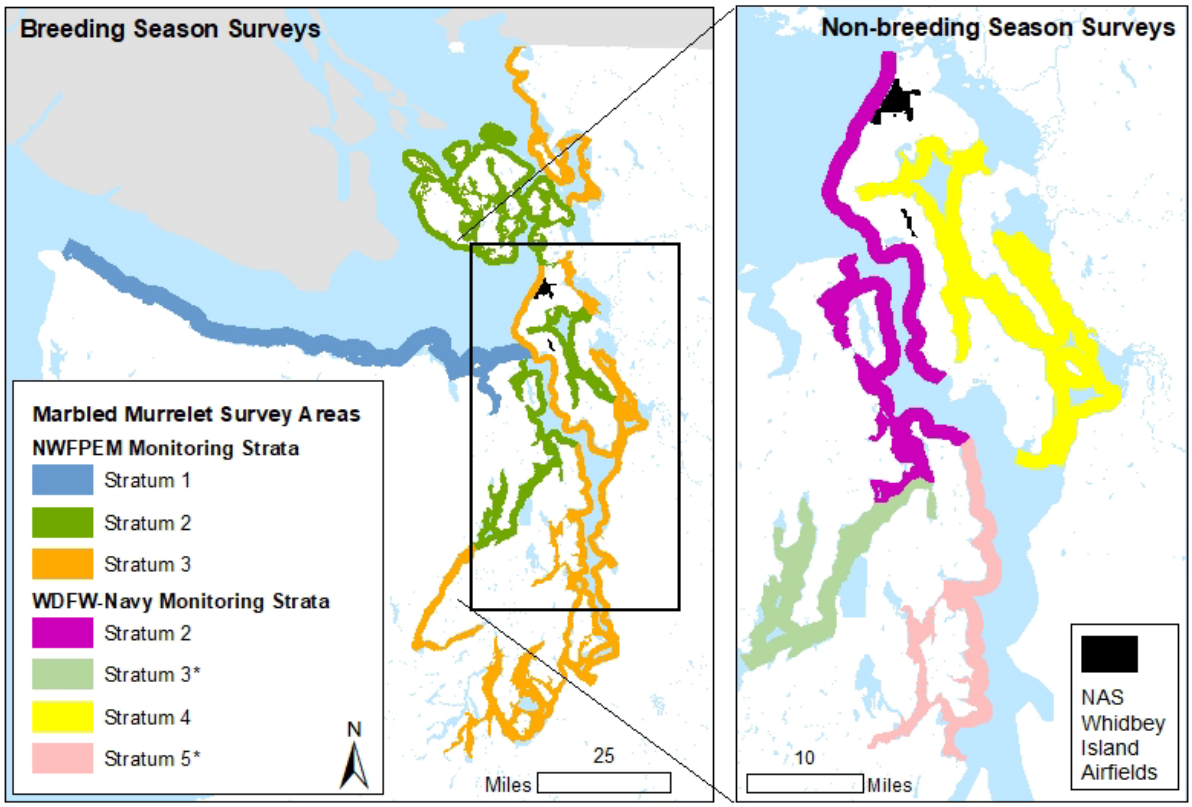

Figure 4. Marbled murrelet at-sea survey strata within Conservation Zone 1.

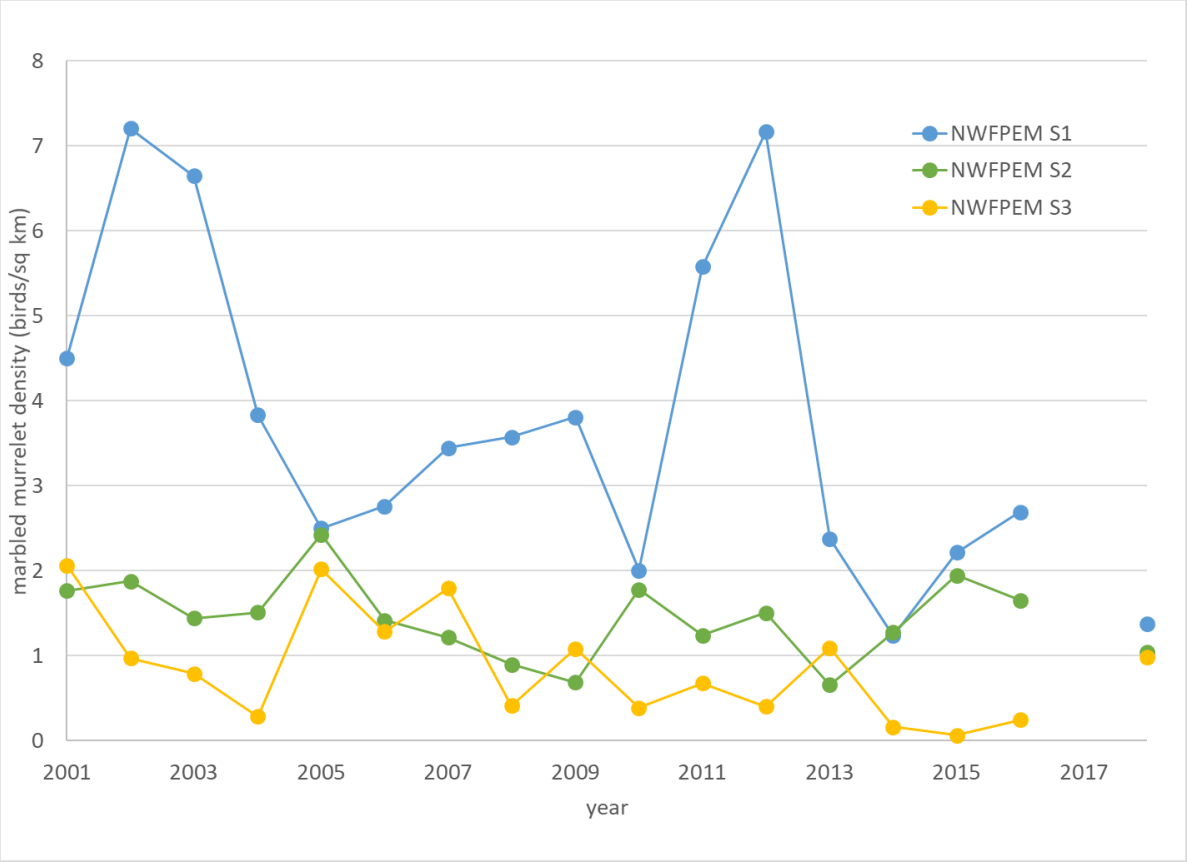

Figure 5. Breeding season marbled murrelet densities in NWFPEM strata within 2 or 5 km of shore
(McIver et al. 2019, pp. 10-15)

In addition, the action area includes areas offshore of the sampled strata, which extend 5 km (NWFPEM Stratum 1) or 2 km (NWFPEM Strata 2 and 3) from shore. Marbled murrelets are expected to be present in these offshore areas during the breeding season (for example, see Lorenz et al. 2016, p. 3), but at a lower density than closer to shore. Based on the preliminary data used to design the NWFPEM surveys, we assume that within the Strait of Juan de Fuca, five percent of marbled murrelets will be located farther than 5 km from shore during daylight hours of the breeding season, and in Strata 2 and 3, densities will be ten times higher within 2 km for shore than they are farther than 2 km from shore (Bentivoglio et al. 2002, p. 22).

Outside of the breeding season, marbled murrelets from British Columbia and from Conservation Zone 2 move into more sheltered waters in Puget Sound and the Strait of Georgia, which contributes to increased numbers of marbled murrelets in Puget Sound during those seasons (Burger 1995; Ralph et al. 1995, p. 9; Speich and Wahl 1995, p. 325; Beauchamp et al. 1999, entire). Since 2012, the Navy has funded Washington Department of Fish and Wildlife (WDFW) to survey areas near Navy installations throughout the non-breeding season (Pearson and Lance 2013, entire; Pearson and Lance 2014, entire; Pearson and Lance 2015, entire; Pearson and Lance 2016, entire; Pearson and Lance 2017, entire; Pearson and Lance 2018, entire). These surveys use the same methods as the NWFPEM surveys, and similarly include

areas within 2 km of shore, but the areas are divided into strata differently (Figure 4). WDFW-Navy Stratum 2 includes the northernmost end of Hood Canal, Admiralty Inlet, and the western side of Whidbey Island, and WDFW-Navy Stratum 4 encompasses most waters to the east of Whidbey Island (Pearson and Lance 2018, p. 10). The other strata sampled as a part of this effort, WDFW-Navy Strata 3 and 5, are located farther south and have minimal, if any, overlap with the action area.

Over the entire non-breeding season, marbled murrelet densities in WDFW-Navy Stratum 2 have ranged from 1.75 birds/km^2 in fall 2016 through spring 2017 to 5.5 birds/km^2 in fall 2012 through spring 2013; densities in Stratum 4 have ranged from 0.44 birds/km^2 in fall 2016 through spring 2017 to 1.22 birds/km^2 in fall 2013 through spring 2014 and again in fall 2015 through spring 2016 (Pearson and Lance 2013, p. 10; Pearson and Lance 2014, p. 11; Pearson and Lance 2015, p. 13; Pearson and Lance 2016, p. 12; Pearson and Lance 2017, p. 12; Pearson and Lance 2018, p. 13). Since 2012, marbled murrelet densities have averaged 3.08 birds/km^2 in Stratum 2 and 0.91 birds/km^2 in Stratum 4 (Figure 6). Midwinter aerial survey data indicate that marbled murrelets use offshore areas more heavily during the non-breeding season than during the breeding season, with 28 percent of midwinter marbled murrelet observations recorded farther than 2 km from shore (WDFW 2019a). Note that we do not use aerial survey data to estimate marbled murrelet density directly, because the survey methods are not designed to have good marbled murrelet detectability, but the information is suitable for comparing the number of observations in different parts of the area surveyed.

Even within a survey stratum in a particular season, marbled murrelet densities are consistently concentrated more in some areas than in others. We refer to areas as marbled murrelet hotspots when we have information indicating that marbled murrelets can be found there regularly during the breeding season, the non-breeding season, or throughout the year, at densities higher than other areas in the region. Although marbled murrelet population densities are elevated at these hotspots, we expect that marbled murrelets will at least occasionally be present in all other marine waters of the action area. When particular marine areas are surveyed repeatedly, marbled murrelets are usually observed at least once in each area, though in some areas they are present only sporadically and at low densities (Merizon et al. 1997, p. 19; Speich and Wahl 1995, pp. 315-316).

In the action area, marbled murrelet hotspots are present in both the breeding and non-breeding seasons at the southern end of Lopez Island (MMEMM 2015, USFWS 2017a, p. 27; Wahl et al. 1981, p. 784; WDFW 2019a), Admiralty Inlet (Pearson and Lance 2013, Table 3; Pearson and Lance 2014, Table 3; Pearson and Lance 2015, Table 3; Pearson and Lance 2016, Table 3; Pearson and Lance 2017, Table 3; Pearson and Lance 2018, Table 3; MMEMM 2015; WDFW 2019a), Burrows Bay, Deception Pass, and nearby areas (Courtney et al. 1996, pp. 20-21; Merizon et al. 1997, p. 19; MMEMM 2015; USFWS 2017a, p. 28; Wahl et al. 1981, p. 784; WDFW 2019a), along the western shoreline of Orcas Island (Lorenz and Raphael 2018, p. 207; MMEMM 2015; USFWS 2017a, p. 27; WDFW 2019a), the area around Decatur Island (Courtney et al. 1996, p. 20; WDFW 2019a), and northern Hood Canal (Merizon et al. 1997, p. 15; MMEMM 2015; Speich et al. 1992, p. 53; WDFW 2019a). High densities of marbled murrelets are present during the latter part of the breeding season and into the non-breeding

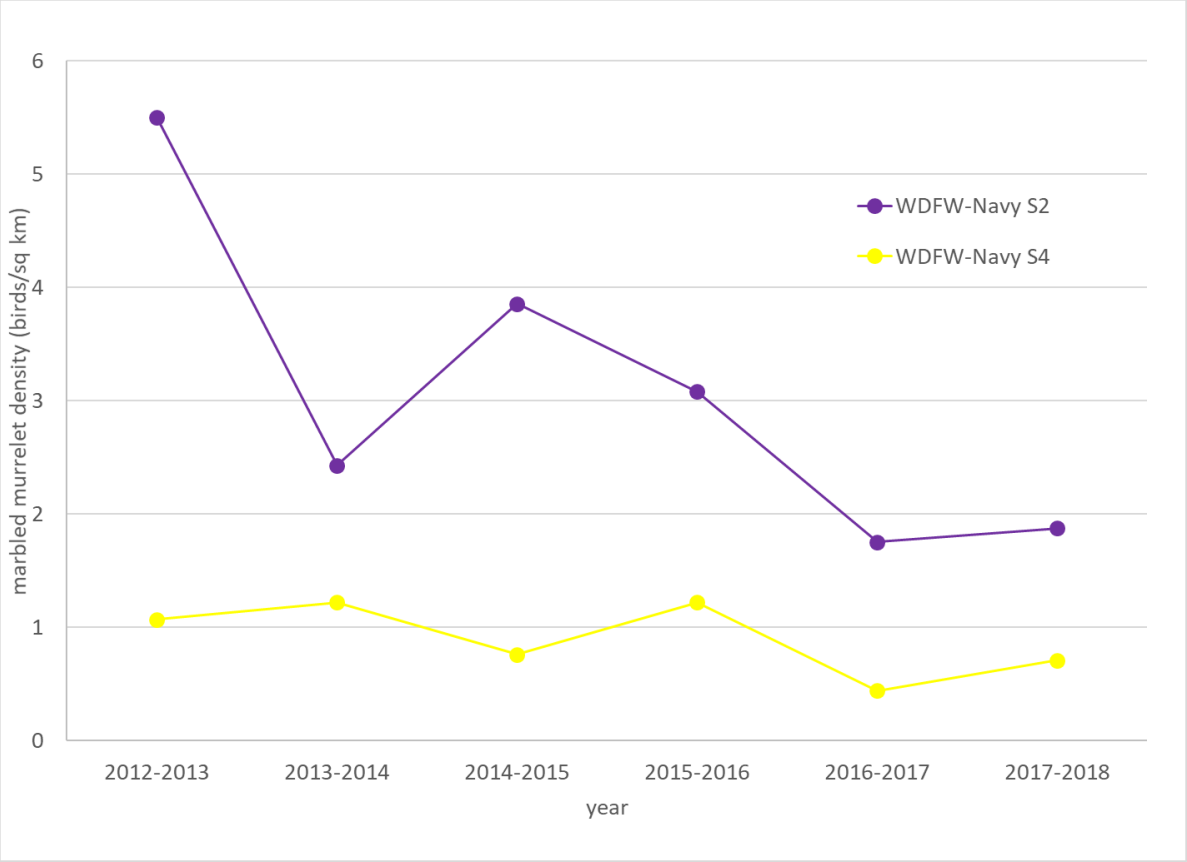

Figure 6. Non-breeding season marbled murrelet densities in WDFW-Navy strata 2 and 4 within 2 km of shore
(Pearson and Lance 2013, 2014, 2015, 2016, 2017, 2018)

season in northern San Juan Channel and around Waldron Island (Lorenz and Raphael 2018, p. 207; USFWS 2017a, p. 27; Wahl et al. 1981, p. 784; WDFW 2019a). During the breeding season, aggregations of marbled murrelets have been observed along the northwestern shoreline of Camano Island (Courtney et al. 1996, p. 20; Merizon et al. 1997, p. 19), and in northern Possession Sound and southern Port Susan (MMEMM 2015). During the non-breeding season, other areas become marbled murrelet hotspots, including Penn Cove (Courtney et al. 1996, p. 20; USFWS 2017a, p. 31; WDFW 2019a), western Skagit Bay (USFWS 2017a, p. 31; WDFW 2019a), Sequim and Discovery Bays (Speich and Wahl 1995, pp. 314-315; WDFW 2019a), Bellingham Bay (Wahl et al. 1981, p. 784; WDFW 2019a), Guemes Channel (USFWS 2017a, p. 27; Wahl et al. 1981, p. 784; WDFW 2019a), East Sound and Obstruction Pass (USFWS 2017a, p. 28; Wahl et al. 1981, p. 784; WDFW 2019a), Sucia Island (USFWS 2017a, pp. 27-28; WDFW 2019a); and Point Roberts (Wahl et al. 1981, p. 784; WDFW 2019a).

8.1.2 Marbled Murrelet Suitable Nesting Habitat in the Action Area

Although the action area is largely over marine waters, it does include terrestrial areas as well. Some suitable nesting habitat is present in the action area. This includes suitable habitat on the islands within the action area, as well as suitable habitat on the Olympic Peninsula and the mainland, at the margins of the action area. Some of the suitable habitat areas within the action area have been surveyed for occupancy, but many have not.

There are a few areas of nesting habitat within the action area where audio-visual surveys have detected marbled murrelets engaged in behaviors associated with nesting habitat occupancy. These include an area managed by the Washington State Department of Natural Resources (WDNR) along the shore of Padilla Bay, where occupancy behaviors were observed in 2004; several areas of WDNR- and U.S. Forest Service-managed lands south of Sequim Bay, where occupancy behaviors were observed in 1990 through 2002; an area of WDNR-managed land north of Dabob Bay, where occupancy behaviors were observed in 2001; and several areas of WDNR- and U.S. Forest Service-managed lands in the eastern portion of the action area, where occupancy behaviors were observed in 1992 through 2009 (WDFW 2019b).

Other areas with substantial patches of potentially suitable nesting habitat within the action area, as depicted by a widely-used habitat model developed for NWFP analyses (Raphael et al. 2016b, p. 72), include Cypress Island, Blakely Island, Lummi Island, Waldron Island, and parts of Orcas and San Juan Islands. Small areas of San Juan Island and Cypress Island have been surveyed, and were not found to be occupied (NPS 2008, p. 148; WDFW 2019b); however, most of these areas have not been surveyed. Where large, unsurveyed patches of suitable habitat are present, we assume that occupancy is likely.

Although small patches of older forest may be found on other islands, and indeed the NWFP habitat model depicts small patches of suitable habitat scattered throughout the rest of the action area, we do not expect these small patches to be occupied, as marbled murrelets are most likely to nest within 5 km of other marbled murrelet nests (Meyer et al. 2002, p. 103), which would be difficult in such fragmented habitat. Furthermore, some forested areas on the islands within the action area have microclimates that may be too windy or dry for the development of the large, moss-covered limbs that are typical of marbled murrelet nest platforms (Milner 2016, p. 1). For these reasons, we do not expect marbled murrelets to nest on Whidbey Island, Fidalgo Island, Camano Island, Lopez Island, Shaw Island, Guemes Island, or any of the smaller islands within the action area.

8.1.3 Marbled Murrelet Behavior in the Action Area

Marbled murrelets spend most of their time at sea, and their activities within the marine portion of the action area include foraging, resting, preening, molting, flying, and social interaction. Like density and distribution, marbled murrelet activity within the action area changes seasonally. Notably, molting and breeding activities are both energetically costly, and these energetic costs are not distributed evenly throughout the year (Becker and Beissinger 2006, p. 477; Carter and Stein 1995, p. 102).

The marbled murrelet breeding cycle begins with the female's production of the egg, which takes approximately 14 days (McFarlane Tranquilla et al. 2003, p. 110). Marbled murrelets produce only one egg per season, barring possible re-nesting attempts following nesting failure (Hébert et al. 2003, p. 263). The eggs are relatively large, approximately 16 to 19 percent of the female's body weight (De Santo and Nelson 1995, pp. 38-39; Hirsch et al. 1981, p. 264; Nelson and Hamer 1995, p. 58; Sealy 1975a, p. 500; Simons 1980, p. 6). After the female lays the egg, the two parents take turns incubating the egg in shifts of 24 hours, exchanging duties at dawn (Nelson and Hamer 1995, pp. 58-59). The non-incubating parent forages at sea during the time away from the nest. Occasionally, the nest may be unattended for several hours, presumably due to the incubating parent leaving the nest early, before the dawn exchange, for additional foraging time (Nelson and Hamer 1995, p. 59). The egg hatches after approximately 30 days of incubation, and parents brood the chick in 24 hour shifts for around two days, until the chick is able to thermoregulate (Nelson and Hamer 1995, pp. 59-60). Subsequently, the parents leave the nestling unattended except when they bring fish to the nest to feed the chick. The chick typically receives between one and eight meals per day, most often around dawn (Nelson and Hamer 1995, pp. 61-62). After approximately 30 days of the nestling stage, the parents cease their visits to the nest, and the chick departs the nest alone, around dusk (Nelson and Hamer 1995, pp. 60-61). The timing of marbled murrelet nesting varies widely among individuals. In Washington and neighboring areas of Oregon and British Columbia, egg-laying generally occurs in late April through July, incubation occurs in late May through August, and nestlings fledge between mid-June and late September (USFWS 2012a, p. 2). In recent years, juvenile marbled murrelets have been observed at sea earlier, even as early as May 21 (Havron 2012, p. 4; Pearson 2018, in litt.; Strong 2019, p. 6), indicating that at least occasionally, egg laying begins in March.

During the breeding season, breeding marbled murrelets' presence at sea and foraging behaviors vary depending on the nesting phase. Prior to egg-laying, we assume that breeding pairs visit nesting habitat to select and establish nest sites (Nelson and Hamer 1995, p. 58; USFWS 2012a, p. 2). After egg-laying, each breeding adult spends about half of its time inland, incubating the egg, and half at sea, where it must meet two days' worth of its own energy needs in one day's foraging time. During the nestling phase, the parents return to spending most of their time at sea, but must forage for themselves and their chick, and make one or more inland flights each day to carry fish to the nestling. During these phases of nest attendance, breeding adults increase their foraging effort while they are at sea, whereas foraging rates of breeders and non-breeders are similar to one another both before and after nesting (Peery et al. 2009, p. 128; Ronconi and Burger 2008, p. 253).

Marbled murrelets undergo the "pre-alternate molt" approximately four to six weeks before the beginning of breeding, and the "pre-basic molt" follows the breeding season (Naslund 1993, p. 598). Timing of each molting period varies among individual birds and across the range of the marbled murrelet (Carter and Stein 1995, pp. 104-107; Nelson 1997, p. 23; Peery et al. 2008, p. 118; Stein and Nysewander 1999, pp. 6-7 and Figure 10; Strong 1998, entire). We assume that in Washington, the pre-alternate molt takes one month and largely occurs during March, with subadults molting later in the spring (Carter and Stein 1995, p. 105). We also assume that pre-basic molt takes between 37 and 75 days, and that following the peak of the breeding season, but before December, there is a period of one or two months when many of the marbled murrelets in the action area are in pre-basic molt. Both molts involve the replacement of feathers, but only

the pre-basic molt includes the shedding and re-growth of flight feathers, which renders the bird flightless (Carter and Stein 1995, pp. 102-103). Thus, during the pre-basic molt, an individual marbled murrelet must remain in the marine environment, and cannot travel far to reach distant foraging areas. Even during the pre-alternate molt, when birds are still able to fly, marbled murrelet inland presence is reduced, perhaps due to the energetic demands of molting and egg production, which occur simultaneously (Hamer Environmental 2009, pp. 26-28; Naslund 1993, p. 598; Sanzenbacher et al. 2014, p. 171). During pre-basic molt, in spite of the energetic costs, marbled murrelets are able to gain mass when food resources are adequate, though when food resources are inadequate they prioritize rapid molt over mass gain (Peery et al. 2008, p. 120).

Marbled murrelet foraging behavior within the action area is not thoroughly understood. Some information is available regarding prey species and preferred foraging areas in and near the action area. Other information, including the likely full range of prey species, prey sizes, patterns of foraging effort, and linkages between prey availability and marine conditions, is available from other parts of the range, and its applicability to the action area is variable.

In Washington, marbled murrelets are known to consume Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea pallasii*), and northern anchovy (*Engraulis mordax*) (Burkett 1995, pp. 225-227; Grettenberger et al. 2005; Lance and Pearson 2012, p. 11). All of these species are present in the action area. In addition, marbled murrelets in other parts of the range are known to consume smelt species (Osmeridae), rockfish and their relatives (*Sebastes* species and other Scorpaenidae), salmonids (Salmonidae), pricklebacks (Stichaeidae), walleye pollock (*Gadus chalcogrammus*), shiner perch (*Cymatogaster aggregata*), Pacific sandfish (*Trichodon trichodon*), red Irish lord (*Hemilepidotuz hemilepidotus*), rock greenling (*Hexagrammos lagocephalus*), and Pacific sardine (*Sardinops sagax*), as well as invertebrates including krill (Euphausiids), amphipods (Amphipoda), decapods (Decapoda), mysid shrimp (Mysidae), market squid (*Loligo opalescens*), and snails (Gastropoda) (Burkett 1995, pp. 225-227; Nelson et al. 1997, pp.7-9; Peery et al. 2016, p. 2; Sealy 1975b, pp. 421-428; Speckman et al. 2003, p. 270). These groups are also present in the action area, though some are infrequent visitors, while others are abundant and widespread (Kemp and Keister 2015, pp. 18-19; Pietsch and Orr 2015, pp. 19-26, 29-36, 40, 56, 65).

Adult, subadult, and fledged hatch-year marbled murrelets typically consume larval and juvenile fish 60 mm in size or smaller, as well as invertebrates (Burkett 1995, pp. 240-241). In parts of the range where marbled murrelet diet and foraging have been more thoroughly observed, euphausiids appear to be important prey during winter and spring, whereas fish predominate in the summer diet (Becker and Beissinger 2007, pp. 274-277; Barrett 2008, p. 47; Nelson 1997, p. 9). For nestlings, adults catch larger, less abundant fish, perhaps second-year fish, 60 to 120 mm in size (Burkett 1995, pp. 241-242; Carter 1984, p. 23; Carter and Sealy 1987, p. 289; Carter and Sealy 1990, p. 100; Nelson 1997, p. 8). The delivery of large, highly-nutritious prey items to nestlings appears to minimize the need for adult energy expenditures in flights to and from the nest while still providing for the nutritional needs of developing chicks (Burkett 1995, pp. 242-243; Carter and Sealy 1987, p. 290). Most chick meals consist of a single fish, though adults have occasionally been observed in the action area and elsewhere flying inland with multiple fish

(Carter and Sealy 1987, p. 289; Nelson and Hamer 1995, p. 62; Thoresen 1989, p. 36). Although studies of seasonal and age-specific diets have not been conducted in or near the action area, we assume that foraging patterns in the action area are similar to those described above.

When marbled murrelet foraging behavior has been carefully tracked, focal birds averaged between 11 and 19 percent of at-sea daylight time underwater, presumably in pursuit of prey (Henkel et al. 2003, p. 10; Jodice and Collopy 1999, p. 1412; Peery et al. 2009, p. 128). Though none of this information was collected in or near the action area, we assume that marbled murrelet foraging activity in the action area generally falls into this range. Marbled murrelets also forage during the night (Carter and Sealy 1982, pp. 217-218); in particular, breeding adults forage during the pre-dawn hours for fish that they deliver to nestlings around dawn (Carter and Sealy 1990, p. 100; Nelson and Hamer 1995, pp. 63-64). However, some studies have tracked marbled murrelets that rarely or never dove at night (Henkel et al. 2003, p. 11; Jodice and Collopy 1999, p. 1411). The prevalence of night-time foraging may vary individually, geographically, seasonally, or depending on the daily movement patterns of prey species at a given place and time. In the absence of information about night-time foraging specific to the action area, we assume that at least the breeding adults in the action area do forage during the pre-dawn hours.

During the nestling phase, breeding marbled murrelets must divide their foraging activity between efforts to feed themselves and efforts to catch fish for delivery to the nestling. Fish suitable for delivery to nestlings may be harder to find, and breeding adults may need to fly to specific foraging areas that differ from the areas where they can most easily catch food suitable for feeding themselves, though they may also find both types of prey in one area (Barrett 2008, p. 47; Carter 1984, p. 85; Carter and Sealy 1990, p. 100). After catching a fish for delivery to the nestling, the adult holds the fish in its bill until it is ready to fly inland, and therefore the adult is not able to forage for itself until after it delivers the fish to the nestling (Carter 1984, p. 83; Thoresen 1989, p. 36). Fish-holding behavior is most commonly observed before dusk, though it may also occur at other times of day (Carter 1984, p. 77; Carter and Sealy 1990, p. 100; Mahon et al. 1992, p. 740; Thoresen 1989, p. 36). In other parts of the range, fish-holding marbled murrelets gather consistently in known locations to stage for their inland flights (Strachan et al. 1995, pp. 251-252). Similar information is not available for the action area, but fish-holding adults have been observed flying inland from the vicinity of Deception Pass (Thoresen 1989, p. 36). This area, as well as Burrows Bay, appear to be likely locations for birds nesting north and south of the Skagit River to stage for their inland flights, given that marbled murrelets often fly inland along consistent flight paths that follow river courses (Becker and Beissinger 2003, p. 245; Peery et al. 2004a, p. 348). We expect that other portions of the action area are used as staging areas by marbled murrelets nesting in other inland locations.

Foraging effort varies depending on ocean conditions and prey availability, as well as the breeding status of the adult and phase of the nesting cycle. As discussed above, breeding adults during the incubation phase must spend more of their at-sea time foraging, and adults feeding nestlings must spend time, perhaps in alternative foraging areas, finding fish suitable for nestling meals. In the California Current system, when prey are abundant, marbled murrelets forage closer to nesting habitat, and dive less frequently overall, but may concentrate diving activity in places and times where prey are likely to be most abundant (Becker and Beissinger 2003, p. 252;

Peery et al. 2004b, p. 1094; Peery et al. 2009, pp. 131-132). When prey are sparse, the birds must travel farther to reach foraging areas, spend more time diving, and may engage in energetically costly anaerobic dives (Becker and Beissinger 2003, p. 252; Jodice and Collopy 1999, p. 1416; Peery et al. 2004b, p. 1094). In and near the action area, marbled murrelets fly longer distances at sea when waters are warmer, likely because prey are less abundant in warm-water years (Lorenz et al. 2017, p. 318).

The variability in marbled murrelet foraging effort, depending on breeding phase and prey availability, demonstrates some flexibility in the marbled murrelet activity budget (Ronconi and Burger 2008, p. 253). However, this flexibility is likely limited. In several seabird species, including the closely-related thick-billed murre (*Uria lomvia*), there generally appears to be an upper limit to daily energy expenditure, and breeding adults typically operate near this limit (Elliott et al. 2014, pp. 137, 142). For example, if a bird must increase energy spent in flying to reach distant foraging areas, it will have less energy to spend diving or flying around once it gets there. In thick-billed murres, individuals cannot overcome this constraint simply by eating more, even if food is abundant, because the energy ceiling appears to be determined by the birds' ability to digest food (Elliott et al. 2014, p. 143). Some thick-billed murres can overcome the constraint on a short-term basis, but only by dipping into their fat reserves, leading to reduced body condition (Elliott et al. 2014, p. 141). This type of study has not been conducted on marbled murrelets, but we assume that they also have a limited energy budget, and that breeding birds are likely to be operating near that limit. When marbled murrelets spend time loafing at the water's surface, we cannot assume that their apparent inactivity indicates that they could forage more or engage in other activities if they wanted to. They may need to spend time resting in order to digest food, recover from dives, or simply to avoid activities that would use more energy (Elliott et al. 2014, p. 143; Jodice and Collopy 1999, p. 1415; Peery et al. 2009, p. 121). Furthermore, when food is less available, the ability to find food is likely to impose an additional, lower ceiling on energy expenditure (Elliott et al. 2014, p. 142).

In summary, marbled murrelets spending time in the action area are likely to be engaged in a variety of important behaviors, including foraging, molting, and loafing. These behaviors vary seasonally, with molting occurring before and after the breeding season, and intensive foraging effort by nesting adults during the incubation and nestling phases. Only a few species of forage fish are confirmed as marbled murrelet prey in Washington, but it is likely that diets in the action area include an array of fish and invertebrate species. Foraging effort is variable depending on the abundance and concentration of prey at any given time, but there is likely a cap on how much energy marbled murrelets can spend on foraging or any other task. In poor forage years, the limit on energy expenditure will likely depend on prey availability, but even when food is abundant and available, we expect there will be a ceiling on energy expenditure, imposed by marbled murrelet physiology.

8.1.4 Factors Responsible for the Condition of Marbled Murrelets in the Action Area

Marbled murrelets were listed as threatened in 1992 due, in large part, to habitat loss and predation in the terrestrial environment, and oil spills and net fisheries entanglement in the marine environment (57 FR 45333-45336 [October 1, 1992]). In 2012, the Service convened the marbled murrelet Recovery Implementation Team which concluded that the primary cause of the

continued population decline is sustained low recruitment (USFWS 2012b). That conclusion was supported in the recent Periodic Status Review for the Marbled Murrelet from the WDFW, which recommended changing the State's designation of the species from threatened to endangered (Desimone 2016, pp. iii-iv, 9, 14). Sustained low recruitment can be caused by nest failure, low numbers of nesting attempts, and/or low juvenile survival rates due to 1) terrestrial habitat loss, 2) nest predation, 3) changes in marine forage base which reduce prey resources, and 4) cumulative effects of multiple smaller impacts. The Service's 5-year reviews (USFWS 2009, pp. 27-67; USFWS 2019a, pp. 19-65) identified the following additional threats in marine waters:

- elevated levels of toxic contaminants, including polychlorinated biphenyls (PCBs), polybrominated diphenyl ether, polycyclic aromatic hydrocarbons, and organochlorine pesticides, in marbled murrelet prey species;
- the presence of microplastics in marbled murrelet prey species;
- changes in prey abundance, availability and quality;
- harmful algal blooms, biotoxins, and dead zones;
- derelict fishing gear that causes entanglement;
- energy development projects (wave, tidal, and on-shore wind energy projects) leading to mortality;
- disturbance, injury, and mortality in the marine environment from exposures to elevated sound levels (caused by pile-driving, underwater detonations, and potentially by vessel traffic); and
- climate change in the Pacific Northwest that may exacerbate many of the marine-related threats described above.

Within Washington, marine threats have generally been considered "lower priority" mechanisms of continued marbled murrelet population decline, as compared with terrestrial threats, in part due to a lack of clear information about the marine environment (USFWS 1997, p. 3; USFWS 2012b, pp. 12-15). Recent evidence affirms the importance of both terrestrial nesting habitat and marine foraging habitat, as well as the spatial juxtaposition of the two habitat types. For example, in the action area (but not in the rest of the listed range), the marine human footprint is second only to the quantity of nearby nesting habitat in determining the abundance of marbled murrelets in a given marine location (Falxa and Raphael 2016, pp. 106-110). Since 1993, Washington has lost more nesting habitat than have Oregon or California, but a smaller proportion of the remaining habitat is used in Washington than in other portions of the range, suggesting that other factors are also limiting the marbled murrelet population in Washington (Falxa and Raphael 2016, p. 71; Lorenz et al. 2017, p. 318).

Sustained low recruitment appears to be the primary cause of continuing population declines (USFWS 2012b, p. 3). In Washington, the proportion of adult marbled murrelets attempting to breed was only 20 percent in a 5-year radio telemetry study (Lorenz et al. 2017, p. 316). The low breeding propensity of marbled murrelets in Washington is likely due in part to high energetic costs associated with breeding. Nesting adult marbled murrelets in the action area have

the longest commuting distances between nest and sea, compared with marbled murrelets that have been studied elsewhere in the species range (Lorenz et al. 2017, p. 317). Elsewhere in the range, breeding marbled murrelets forage in marine areas close to their nesting habitat, which minimizes energetic costs associated with the commute between nest and sea (Peery et al. 2009, pp. 127, 130). Within the action area, long commuting distances were associated both with the distance of nesting habitat from the coast, and the distance of foraging habitat from the shore (Lorenz et al. 2017, pp. 314, 317-318). This pattern suggests that marbled murrelet breeding attempts are stymied not only by a lack of high-quality coastal nesting habitat, but also by poor or poorly-distributed foraging habitat.

In, and adjacent to, the action area, marbled murrelet diet quality has decreased over the last 150 years, with shifts in the pre-breeding diet to include a smaller proportion of fish and a greater proportion of invertebrates (Norris et al. 2007, p. 879), and a shift in the nestling diet to include a higher proportion of sand lance and lower proportions of more nutritious herring, anchovy, sardine, and smelt (Gutowsky et al. 2009, p. 251). Over a 40-year period, marbled murrelet abundance in any given year was closely correlated with pre-breeding diet quality four years earlier, and it appears that diet quality is currently a limiting factor for marbled murrelet populations in the vicinity of the action area (Norris et al. 2007, p. 880). Near the action area and in other parts of the range, where marbled murrelets are also eating lower on the food chain than they did 100 years ago, the phenomenon is thought to result from past and ongoing overfishing and possibly from effects of climate change (Becker and Beissinger 2007, pp. 476-477; Norris et al. 2007, p. 880).

Post-fledging mortality also contributes to sustained low recruitment in the action area, but less information is available about the relative contribution of the causes of this mortality to the population declines. Sources of post-fledging mortality in the marine environment include entanglement in gillnets, purse seines, and derelict gear; oil spills; and impulsive underwater sound from impact pile driving and underwater detonations (USFWS 2012b, p. 13).

Some efforts are being made to ameliorate these threats. Numerous state, tribal, and federal agencies participate in nearshore restoration efforts, which are intended in part to improve and protect habitat for forage fish (WDFW 2015). Between 2002 and 2016, the Northwest Straits Initiative's Derelict Fishing Gear Program removed 5,667 old derelict fishing nets from Puget Sound (NWSF 2016; Wilson, A. in litt. 2016). However, it is unknown whether these efforts will be effective in restoring high-quality marine habitat, much less slow or reverse the decline of the marbled murrelet population in the action area. For example, the prevalence of unpermitted shoreline armoring calls into question reported progress on shoreline restoration (Kinney et al. 2015, pp. 8-13; Dunagan 2016). Other trends may magnify these threats. For example, we expect climate change may further exacerbate the decline in foraging habitat quality (refer to section 8.4).

The Navy implements Integrated Natural Resources Management Plans (INRMPs) within the action area. These INRMPs may benefit the marbled murrelet. At NAS Whidbey Island, two restoration projects have increased habitat for forage fish. The Crescent Harbor Salt Marsh Restoration Project restored approximately 300 acres and the Maylor Beach Restoration Project restored approximately 2,000 feet of beach area. In August 2009, the restoration of Crescent

Harbor Marsh to full tidal flow was completed by the cutting of a new free flowing tidal channel to Crescent Harbor. Channel morphology is still evolving and vegetation is converting to more salt tolerant types (Farak, in litt. 2019b). In 2018, NAS Whidbey Island cooperated with the Northwest Straits Foundation, Island County, Puget Sound Partnership, the EPA, and the Service to remove hard shoreline armor from the base of the feeder bluff between Maylor Point and Forbes Point. Since the removal, finer sediments have accumulated on the beach and forage fish have been documented spawning in the newly available habitat (Farak, in litt. 2019b).

8.1.4.1 Boat and Small Aircraft Traffic In the Action Area

Although it is not generally considered to be a major threat to the species (see the bulleted list above), information regarding marine vessel traffic within the action area provides important context for the evaluation of the Navy's action. Small aircraft, such as seaplanes, are also used frequently within the action area, and information about small aircraft traffic also provides important context.

The U.S. Coast Guard's Vessel Traffic Service (VTS), which provides monitoring and navigation advice for large boats in confined, busy waterways, handles approximately 230,000 transits per year in Conservation Zone 1, including 170,000 Washington State Ferries transits per year (Van Dorp and Merrick 2017, p. 4). Large boats, such as the ferries, cruise ships, tankers, and cargo ships tracked by VTS, are more likely than smaller boats to cause energetically-costly flight responses. Smaller boats, such as those commonly used for fishing and recreation, are not generally handled by VTS (WDOE 2019, p. 115), and they are estimated to account for around one-third of all boat-days on the water in Zone 1 and adjacent Canadian waters (Van Dorp and Merrick 2017, p. 7). In particular, movements of these small boats in the northern portion of the action area account for around 24 percent of all boat traffic in Zone 1 and adjacent Canadian waters, and some areas of particularly intense small vessel activity coincide with marbled murrelet hotspots such as the southern end of Lopez Island, other parts of the San Juan Islands, Burrows Bay, and the area near Deception Pass (Van Dorp and Merrick 2017, p. 7). If we assume that recreational and fishing boats spend about as much time on average per trip as the boats handled by VTS, we can use algebra to estimate that these smaller boats make around 115,000 trips per year, for a total of 345,000 boat transits (230,000 + 115,000 = 345,000 and 115,000 = 345,000/3).

We do not have an estimate of annual small airplane traffic over the action area, but we note that multiple commercial seaplane flights are offered daily, and more often during the breeding season, between Seattle and the San Juan Islands, as well as along other routes within the action area (Friday Harbor Seaplanes 2019; Kenmore Air 2019). Thus, we estimate that there are at minimum around 5,000 small airplane flights in the action area each year. In total, we estimate that there are annually at least 350,000 (345,000 boat transits + 5,000 small airplane flights) opportunities for marbled murrelets to be exposed to boats and small airplanes in the action area and Zone 1.

8.2 Conservation Role of the Action Area

The final Recovery Plan for the marbled murrelet (USFWS 1997, entire) outlines the conservation strategy for the species. Of the primary recovery plan recommendations, the most pertinent to the needs of marbled murrelets within the action area are 1) protect the quality of the marine environment essential for marbled murrelet recovery, and 2) reduce adult and juvenile mortality in the marine environment. Marbled murrelets are declining due to habitat loss and degraded marine conditions which lead to low reproductive success. The loss of individuals through death or injury in the marine environment is also a major threat.

The Recovery Plan describes six Conservation Zones: Zone 1, Puget Sound; Zone 2, Western Washington Coast Range; Zone 3, Oregon Coast Range; Zone 4, Siskiyou Coast Range; Zone 5, Mendocino; and Zone 6, Santa Cruz Mountains. These Zones, which are functionally equivalent to recovery units, were delineated to enable the maintenance of a well-dispersed population, which is necessary for the long-term survival and recovery of the marbled murrelet (USFWS 1997, p. 115). The division of the range in to Zones was also intended to assist in the evaluation of stressors and the design of management actions at appropriate scales. Marbled murrelet recovery may be achieved when: (1) trends in estimated population size, densities, and productivity have been stable or increasing in four of the six zones over a 10-year period, which should encompass at least one to two El Niño events, and (2) management commitments, including protection and monitoring in marine and terrestrial habitats, have been implemented to provide adequate protection of marbled murrelets in the six Marbled Murrelet Conservation Zones for at least 50 years (USFWS 1997, pp. vi, 113).

The status of marbled murrelet populations varies among Conservation Zones. In particular, the Recovery Plan noted that Zone 5 could not be relied upon to contribute to recovery during the near term, and the population in this Zone remains small (McIver et al. 2019, pp. 10-15; Pearson et al. 2018, p. 4; USFWS 1997, pp. 115-116). In addition the Recovery Plan noted that Zone 6, while expected to contribute to recovery, is vulnerable to extirpation and may not be able to maintain a viable population over the long term, and here, too, the population remains smaller than in the four northern Zones (Felis et al. 2019, p. 8; USFWS 1997, p. 116). The circumstances in the two southern Zones magnify the importance of the four northern Zones, including Zones 1 and 2, for achieving recovery and long-term survival of the species.

The action area provides foraging habitat that is essential to marbled murrelet survival and recovery. All waters of Puget Sound and the Strait of Juan de Fuca, including the waters of the San Juan Islands and river mouths, are considered to be concentration areas of breeding marbled murrelets essential for foraging and loafing (USFWS 1997, p. 135). During the nesting season adult marbled murrelets depend on the action area as foraging habitat for themselves and their nestlings. In particular, the San Juan Islands and Admiralty Inlet, both within the action area, draw marbled murrelets from various locations in Washington and British Columbia, sometimes after long flights to travel to these foraging areas (Lorenz et al. 2017, p. 314). In some summers, the majority of marbled murrelets in Washington make foraging trips to the San Juan Islands (Lorenz et al. 2017, p. 312). Outside of the nesting season the action area provides foraging habitat for a mixed population of marbled murrelets that originate from both British Columbia and Conservation Zones 1 and 2 in Washington. Marbled murrelet presence in marine waters is

linked with tidal activity (Speich and Wahl 1995, p. 323) and prey availability, which can vary depending on regional and local upwelling conditions created by seawater temperature changes and seafloor topography (Becker and Beissinger 2003, pp. 251-252). The action area includes several areas, such as Admiralty Inlet and the waters off of southern Lopez Island, where marbled murrelets tend to congregate throughout the year, likely due to the presence of prey. As outlined by the Recovery Plan (USFWS 1997, pp. 112), increasing habitat quantity and quality in the marine environment is essential to the conservation and recovery of the marbled murrelet. The Recovery Plan recommends protection of nearshore waters extending two kilometers (1.2 miles) from shore, to include estuaries, river mouths, and the ocean floor (USFWS 1997, p. 136).

Decreasing adult mortality in the marine environment is also a key element of the strategy to conserve and recover the marbled murrelet (USFWS 1997, pp. 112, 122, 125, 140-141, 154). Net fisheries and oil spills are the primary threats known to lead to marbled murrelet mortality in the marine environment, especially in Conservation Zone 1 (USFWS 1997, pp. 125, 140-141, 154). Impulsive underwater sound and harmful algal blooms are additional threats that may lead to mortality in the action area (USFWS 2012b, pp. 13-14; USFWS 2019, pp. 58-63). Other factors, such as marine pollution, low food availability, and disturbance from boat traffic, may lead to lower survivorship, injury, or increased energy expenditure by marbled murrelets, but these effects are less clear (USFWS 1997, pp. 155-156; USFWS 2012b, p. 13).

A well-distributed, viable population must be maintained in Conservation Zone 1 to allow for the long-term survival and recovery of the species throughout the listed range (USFWS 1997, pp. 115-122). Marbled murrelets spend the majority of their time in the marine environment, so most feeding and mortality events also happen in the marine environment (USFWS 1997, p. 120).

8.3 Previously Consulted-upon Effects

Within the action area, the Service has consulted on the effects of many projects including:

- harbor expansions
- shoreline armoring
- ferry terminal upgrades
- aquaculture activities
- discharges from wastewater treatment plants
- construction of piers, ramps, and floats
- bridge, road, pier, and wharf maintenance and upgrades

The effects to marbled murrelets associated with these projects are similar to one another, and are related to a combination of exposure to increased sound pressure levels from pile driving, decreased water quality due to increased turbidity and the introduction and circulation of contaminants, and adverse impacts to forage fish populations.

The Service has recently consulted on the continued Treaty and non-Treaty salmon fisheries throughout Puget Sound, which affect marbled murrelets directly through net entanglements (USFWS 2017b). The Service also issued a Habitat Conservation Plan for the Skookumchuck Wind Energy Project, which was subject to consultation (USFWS 2019b), and included removal of lost or derelict fishing gear in Puget Sound, as a measure to mitigate for marbled murrelet mortality at inland wind turbines.

The Service has also consulted on military training activities. This includes Growler airfield operations at NAS Whidbey Island Complex that have been ongoing since 2012, when the Service completed an informal consultation regarding the introduction of the Growler fleet (USFWS 2012c). Information developed for the "no action" alternative in the 2018 FEIS lists 73,895 Growler operations per year (Bianchi, M., in litt. 2018b), and this represents the best available information regarding the level of Growler activity in recent years. The Service consulted on the Navy's Northwest Training and Testing (NWTT) activities in 2016 (USFWS 2016) and 2018 (USFWS 2018). Within the present action area, NWTT activities are expected to affect marbled murrelets directly through the use of helicopters and explosives. At Crescent Harbor, explosive ordnance disposal training is expected to injure or kill approximately three groups of marbled murrelets, equivalent to around six individuals, over the next 20 years, on occasions when Navy personnel do not detect the birds prior to triggering the explosion. Explosive ordnance disposal training is also expected to affect marbled murrelet prey species that spawn near Crescent Harbor; namely, surf smelt (*Hypomesus pretiosus*), Pacific herring, and Pacific sand lance individuals will be killed by explosions, but the number of deaths is not expected to lead to reductions in the populations of any of the species. In addition, significant behavioral disruptions, resulting from helicopter rotor wash, are expected to affect approximately seven groups of marbled murrelets, equivalent to around 14 individuals. The use of helicopters is associated with a variety of training activities, some of which occur within the present action area.

With respect to terrestrial nesting habitat in the action area, the Service recently consulted upon its proposed issuance of a permit amendment to WDNR. This permit amendment updates the 1997 Habitat Conservation Plan, which covers forest management activities on WDNR-managed lands, to incorporate a Marbled Murrelet Long-Term Conservation Strategy. This strategy conserves certain areas of current and future marbled murrelet habitat, including all areas where surveys have detected occupancy behaviors. Other areas of current and future habitat, including areas that have not been surveyed and may be occupied, would be released for harvest under this strategy. The present action area includes marbled murrelet habitat that will be conserved under the conservation atrategy, as well as marbled murrelet habitat that will be harvested.

8.4 Climate Change

8.4.1 Global Climate Change

Consistent with Service policy, our analyses under the ESA include consideration of ongoing and projected changes in climate. The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2014a, pp. 119-120).

The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2014a, p. 119). Various types of changes in climate can have direct or indirect effects on species and their habitats. These effects may be positive, neutral, or negative, and they may change over time. The nature of the effect depends on the species' life history, the magnitude and speed of climate change on abiotic and biotic components of the species habitat, and other relevant considerations, such as the effects of interactions of climate with other variables (e.g., habitat fragmentation) (IPCC 2014b, pp. 64, 67-69, 94, 299). In our analyses, we use our expert judgment to weigh relevant information, including uncertainty, in considering various aspects of climate change and its effects on marbled murrelets and their habitat. We focus in particular on how climate change affects marbled murrelets' capability to successfully complete their life cycle, and the ability of their habitat to support that outcome.

The Status of the Species (Appendix B) contains a detailed look at the ongoing and anticipated effects of climate change on the marine habitats that are important to marbled murrelets, including some information particular to Conservation Zone 1. The information relevant to the action area is summarized below. The effects of climate change in Conservation Zone 1, including the action area, are particularly complex because they stem not only from changes in the California Current ecosystem, but also from changes in the freshwater ecosystems that flow into the Salish Sea, and from interactions between the oceanic and freshwater influences. There are some ongoing and future climate effects that can be predicted with confidence, but others are uncertain, with substantial scientific information supporting a range of possible effects.

8.4.1.1 Summary of Climate Change Effects to Marine Habitat in the Action Area

Trends toward warmer air and water temperatures, drier summers, and wetter winters are ongoing and are expected to continue. These trends are superimposed over naturally-occurring climate cycles such as the El Niño-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation, and others. Because some of the longer-term climate cycles have recently entered a warm phase, or are predicted to enter a warm phase within the next few years, it is possible that the warming trend will be exaggerated during the next two decades, although the warming trend would then be diminished when the long-term climate cycles enter their cool phases.

Changes in temperature and the seasonality of precipitation over land affect the freshwater inflows to the action area, with warmer, smaller spring and summer inflows and increased winter inflows. These changes will, in turn, affect water circulation and stratification within the action area. The exchange of waters between Puget Sound and the northeastern Pacific Ocean, flowing through the Strait of Juan de Fuca, is expected to increase during the winter months and decrease during the summer, but because of the vigorous mixing of waters that occurs in Admiralty Inlet and other parts of the action area, the effects of altered water exchange are likely to be less pronounced in the action area than in other parts of Conservation Zone 1. The quality of the Pacific Ocean water flowing in to the action area through the Strait of Juan de Fuca is also changing. The California Current, which runs along Washington's outer coast, is heavily influenced by upwelling, in which a combination of winds and currents causes water to rise from

the deep ocean to the surface. These upwelled waters are generally, cold, nutrient-rich, relatively acidic, and low in dissolved oxygen. Trends and projected changes in upwelling are somewhat uncertain, but many studies show that the winds that lead to upwelling have intensified in recent decades, and some studies project a later, shorter, more intense upwelling season off of Washington. Regardless of changes in upwelling, the waters of the action area, as well as the waters entering the action area via the Strait of Juan de Fuca, are becoming more acidic. The timing and intensity of nutrient inputs, both from freshwater and upwelled sources, is likely changing. Although hypoxia is a problem in some parts of Conservation Zone 1, it is less likely to be an issue in the action area, now or in the future, because of the vigorous mixing of waters in many parts of the action area. Sea level rise is another factor affecting the action area, especially in places where subsidence is causing the land to sink even as the sea level rises.

These physical changes are expected to affect primary productivity. At a large scale, primary productivity may increase in or near the action area, as a result of warmer temperatures, increased carbon dioxide, and potentially increased nutrients. However, these effects vary by species and other environmental conditions, such as sunlight levels or the ratios of different nutrients. For example, phytoplankton with shells are expected to decrease in abundance due to acidification interfering with shell formation. On the other hand, eelgrass (*Zostera marina*) in Padilla Bay, within the action area, may benefit from the combination of sea level rise and increased dissolved carbon dioxide, with projected increases in productivity and area covered. Changes in primary productivity are likely to vary by season and by location, even at fine scales. For example, in Possession Sound, within the action area, primary productivity is more sensitive to nutrient inputs than other parts of Conservation Zone 1. Phytoplankton blooms within and near the action area have become earlier and more variable. Harmful algal blooms, which produce a variety of toxins and other harmful substances, are likely to benefit from warmer, more acidic waters. However, at least one species of harmful alga, *Alexandrium catanella*, is expected to increase the length of its blooming season in some parts of Conservation Zone 1, but not in the Whidbey Basin.

Changes in primary productivity are expected to affect higher trophic levels within the food web, and some consumer species will also be affected directly by physical changes associated with climate change. For example, ocean acidification has direct negative effects on a wide variety of zooplankton and marine animals, including marbled murrelet prey such as krill, sea snails, rockfish, and herring. These effects include interference with shell formation, reduced growth rates, altered sensory perception, and behavior changes, among others. Effects operating via the food web include changes in the timing of prey availability, potentially leading to mismatches with consumers' need for food; alterations in the abundance of prey leading to alterations in the abundance of consumers; and changes in competitive interactions. For example, when jellyfish and forage fish compete for food resources, the conditions that are becoming more frequent due to climate change are likely to favor jellyfish. In Rosario Strait, within the action area, the abundances of jellyfish and forage fish are negatively correlated, which may indicate that the two groups compete.

A food web model of Puget Sound shows that moderate or strong acidification effects to calcifying species are expected to result in reductions in fisheries yield for several species, including salmon and Pacific herring, and increased yield for others (Busch et al. 2013, pp. 827-

829). Additionally, the same model shows that these acidification effects are expected to cause reductions in forage fish biomass, which are in turn expected to lead to reductions in diving bird biomass (Busch et al. 2013, p. 829). While Busch and coauthors (2013, p. 831) express confidence that this model is accurate in terms of the nature of ocean acidification effects to the Puget Sound food web of the future, they are careful to note that there is a great deal of uncertainty when it comes to the magnitude of the changes. The model also illustrates that some of the effects to the food web will dampen or make up for other effects to the food web, so that changes in abundance of a given prey species will not always correspond directly to changes in the abundance of their consumers (Busch et al. 2013, pp. 827, 830).

Many species of forage fish are expected to fare poorly in the changing climate. For many species of forage fish, abundance is negatively correlated with seasonal sea surface temperatures. Within the action area, abundance of surf smelt and Pacific herring in the Skagit River estuary are positively associated with coastal upwelling during the spring and early summer, likely because nutrient-rich upwelled water increases the availability of their food sources (Reum et al. 2011, pp. 210-212). If projections of later, shorter upwelling seasons are correct (see above), the delays may lead to declines in these stocks of herring and surf smelt, as happened in 2005 (Reum et al. 2011, p. 212). In contrast, anchovy abundance in the action area and elsewhere in Zone 1 was unusually high in 2005, as it was in 2015 and 2016 following the marine heatwave widely known as "the Blob," and is positively associated with sea surface temperature (Duguid et al. 2019, p. 38).

Appropriate prey availability is not guaranteed, even if prey species maintain or increase their abundance. For example, if the peak of prey availability shifts to an earlier time of year, consumers may need to shift the timing of their breeding season, or suffer breeding failures. Furthermore, regardless of whether prey availability remains good or even increases during some years, increased variability in prey availability can lead to increased variability in the demography of consumers. All of these responses – breeding failures resulting from shifts in timing of prey availability, adjustments in breeding dates, and increased population variability – have been documented for alcid species breeding elsewhere in the range of the marbled murrelet, but specific examples are not available from the action area.

In addition, some aspects of prey quality may change, even if prey species remain abundant, available, and stable. For example, prey nutritional value may be altered by changes in the flow of energy through marine food webs. In Alaska, sand lance of the age fed to marbled murrelet nestlings became smaller and had declining lipid content over the period from 2012 through 2016, coinciding with "the Blob" (von Biela et al. 2019, pp. 175-177). Additionally, prey can be contaminated by the toxins generated by harmful algal blooms. In Alaska, sand lance contaminated with an algal toxin were implicated in the deaths of a number of Kittlitz's murrelet (*Brachyramphus brevirostris*) nestlings, and contaminated fish could be an explanation for one or more of the documented marbled murrelet nest failures in Washington and Vancouver Island that could not be attributed to any specific cause (Lorenz et al. 2019, p. 162). In California, marbled murrelet mortality rates increased during a harmful algal bloom in 1998 (Peery et al. 2006, p. 83). Note that even if harmful algal blooms do not increase in frequency, duration, intensity, size, or toxicity within the action area, they are projected to do so near the action area, and fish that become contaminated outside of the action area may move into the action area, or

may be consumed by marbled murrelets that then move into the action area. Prey can also be contaminated by heavy metals or other anthropogenic pollutants. Due to changes in the Salish Sea food web, climate change is projected to increase levels of mercury and, to a lesser extent, PCBs in forage fish and top marine predators (Alava et al. 2018, pp. 4). Marbled murrelets have generally been considered to be at lower risk for elevated exposures to these types of contaminants, because most of their marine distribution is along coastlines with low levels of human development (Fry 1995, p. 258; Jackson et al. 2016, p. 23). However, concentrations of these toxins is higher in piscivorous birds and forage fish within the action area than in areas farther from human population centers (Ackerman et al. 2016, p. 11; Good et al. 2014, pp. 371-372; Jackson et al. 2016, p. 11; West et al. 2017, p. 222). Over the long term, a diet of fish with anthropogenic contaminant levels similar to those currently found in the action area could affect behavior, reproduction, and immune system function (Good et al. 2014, p. 377), and increases in the concentration of these toxins will bring about these effects more quickly.

8.4.1.2 Summary of Climate Change Effects to Marbled Murrelets in the Action Area

Marbled murrelets that spend time within the action area are likely to experience changes in foraging and breeding ecology as the climate continues to change. Most studies relating marbled murrelet demography to ocean conditions suggest that the effects of climate change will be to reduce marbled murrelet reproductive success via climate change effects to prey. All of these studies have been conducted outside of the action area, and there may be differences in climate change effects to prey and marbled murrelets within the action area versus other parts of the range.

Sea surface temperatures are correlated with reproductive success, as well as foraging effort and marine habitat selection. Throughout the range, including within the action area, cool waters are generally associated with better conditions for marbled murrelets. On the west side of Vancouver Island, there is a strong negative correlation between sea surface temperature and the number of marbled murrelets observed at inland sites displaying behaviors associated with nesting (Burger 2000, p. 728). In central California, marbled murrelet diets vary depending on ocean conditions, and there is a trend toward greater reproductive success during cool water years, likely due to the abundant availability of prey items such as euphausiids and juvenile rockfish (Becker et al. 2007, pp. 273-274). Marbled murrelets in California also tend to select marine habitats with cooler water temperatures, especially when prey are scarce (Becker and Beissinger 2003, pp. 249-250). In and around the action area, warm water temperatures are associated with longer at-sea flights, suggesting that marbled murrelets must spend more time and energy traveling to foraging areas during warmer conditions (Lorenz et al. 2017, p. 318). Perhaps surprisingly, marbled murrelet adult survival in California is higher during warm-water years and lower during cold-water years, likely because fewer marbled murrelets attempted nesting during warm years, reducing exposure to the physiological stresses of breeding and additional predator risk associated with inland flights (Peery et al. 2006, pp. 83-85).

Along the California Current, regional upwelling conditions are also related to marbled murrelet foraging effort, habitat selection, and nesting success. In California, marbled murrelets make shorter movements at sea, forage closer to nesting habitat, and spend more time diving during short-term upwelling events (Becker and Beissinger 2003, p. 251; Peery et al. 2009, pp. 125-132). It is not clear whether short-term upwelling events make prey easier to find, as might be inferred from the shorter flight distances, or more difficult, as might be inferred from the increased diving), but on an annual timescale, upwelling is beneficial to marbled murrelets. Years with strong upwelling are also years with cooler water, higher prey abundance, and higher nesting success (Peery et al. 2009, p. 131). The timing of upwelling is also important. In 2005, upwelling was delayed along the northern portion of the California Current, and marbled murrelets on the west side of Vancouver Island experienced reduced prey availability, increased foraging effort in response, and still produced very few chicks (Ronconi and Burger 2008, pp. 250-252).

In the action area, the effects of upwelling may differ from those along the outer coast. On one hand, recruitment of Pacific herring and surf smelt in the action area is positively related to upwelling along the outer coast, and the delayed upwelling in 2005 led to reduced abundance of the young of these species, especially Pacific herring (Reum et al. 2011, pp. 210-211). On the other hand, while anchovy populations along the outer coast suffered recruitment failure in 2005, anchovy abundance in the action area was higher than usual (Duguid et al. 2019, p. 37; Takahashi et al. 2012, pp. 397-403). Similarly, marbled murrelet reproductive success in 2005 showed contrasting patterns along the outer coast and within the action area, as measured by the ratio of fledged juveniles to older birds on the water. Along the west side of Vancouver Island, this ratio showed near complete reproductive failure, whereas in the San Juan Islands, which lie to the east of Vancouver Island and are largely within the action area, the ratio was very high, indicating a year of relatively successful reproduction (Lorenz and Raphael 2018, p. 209; Ronconi and Burger 2008, p. 255). Within Conservation Zone 1, the breeding season distribution of marbled murrelets was unusual in 2005, with lower-than-usual marbled murrelet densities in Stratum 1 along the Strait of Juan de Fuca, and higher-than-usual marbled murrelet densities in Strata 2 and 3 (see Figure 5). It appears that marbled murrelets redistributed themselves across Conservation Zone 1, moving away from the Strait of Juan de Fuca, which is more directly influenced by coastal upwelling, and into the more sheltered, estuarine areas of Zone 1. Radio-tagged marbled murrelets spent more time in the San Juan Islands in 2005 than in other years (Lorenz et al. 2017, p. 312). In the inland waters of Strata 2 and 3, including the action area, prey availability is likely to be heavily influenced by tidal processes, including localized upwellings at sills, as well as freshwater inputs and turbidity from river inflows (Hunt 1995, p. 222). If projections of later, more intense future upwelling seasons are accurate, changes in upwelling are likely to affect the action area differently from the rest of the listed range, with redistribution of foraging effort into the action area from Stratum 1 or even from Conservation Zone 2, and potentially without the same negative effects to reproductive success.

In summary, alterations in the physical properties of the marine waters within the action area are likely to lead to changes in primary productivity and to the food web. Marbled murrelet prey species, including Pacific herring and rockfish species, are expected to be vulnerable to aspects of climate change, including ocean acidification, alterations in regional upwelling, and increased

competition with jellyfish. However, other prey species, potentially including anchovy, may benefit from the altered conditions. Even if prey availability is stable or increases, prey in and near the action area are likely to be increasingly contaminated by algal and anthropogenic toxins.

9 EFFECTS OF THE ACTION: Marbled Murrelet

The effects of the action are all consequences to listed species or critical habitat that are caused by the action, including the consequence of other activities that are caused by the action. A consequence is caused by the action if it would not occur but for the action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (50 CFR 402.02).

The aircraft operations of the action implemented by the Navy will create stressors to marbled murrelets. The stressors created by aircraft operations are collisions between aircraft and birds (aircraft strike), and increased sound pressure levels. Adverse effects to marbled murrelets may occur when the action creates stressors in the same time and place as marbled murrelets.

9.1 Aircraft Strike

To determine the effects of aircraft strikes to marbled murrelets resulting from the action, we examined the potential for marbled murrelets to be exposed to aircraft strikes and the expected response of marbled murrelets to an aircraft strike.

9.1.1 Marbled Murrelet Exposure to Aircraft Strike

Growler flights and marbled murrelets overlap. Growlers will perform operations within the action area year-round and marbled murrelets will be present in the marine waters of the action area year-round.

There are areas and times where and when marbled murrelets are extremely unlikely to be exposed to aircraft strikes. Marbled murrelets typically fly close to the surface when flying over water. Growlers typically fly at least 800 ft above mean sea level (MSL) when they are more than two miles from a runway and often, Growler flight takes place around 2,500 ft MSL when over water away from shore (Navy 2018, pp. A5-7 – A5-24). Therefore, for much of the area where Growlers are operating, the aircraft will be far above the typical over-water flight altitude for marbled murrelets. Adult marbled murrelets also go through two molting periods. Marbled murrelets go through a molt before the breeding season (typically from mid-March through April) and a second molt which lasts for around sixty-five days (typically occurring between early August and late November) after they conclude chick-rearing (Carter and Stein 1995, p. 104). During the pre-basic molt after the breeding season, marbled murrelets replace their primary flight feathers and are flightless for a time (Carter and Stein 1995, pp. 104, 106). When marbled murrelets are either flying low and close to the water surface or flightless due to molting, aircraft strikes are extremely unlikely, or in other words, discountable.

Aircraft strikes are possible over land, close to shore, and during the breeding season. Near shorelines and over land, Growlers will fly at low altitudes (down to the ground) when they are arriving to or departing from Ault Field or OLF Coupeville. Marbled murrelets fly from foraging areas and the forests where they rear their hatchlings, and may fly over land when moving between marine foraging areas separated by land. We do not have information about marbled murrelet flights between marine areas, so we assume that marbled murrelet flights between marine areas are similar to inland flights to nesting sites. Inland flights are higher than flights solely over water. Numerous studies conducted in Washington have included measurements of inland flight altitudes (Cooper 2010, p. 2; Cooper et al. 2001, pp. 225-226; Cooper and Mabee 2010, p. 19; Hamer Environmental 2009, p. 37; Plissner and Cooper 2007, p. 4; Sanzenbacher et al. 2015, p. 15; Stumpf et al. 2011, p. 126). Mean flight altitudes above ground level ranged from 142 m (466 ft; Cooper 2010, p. 2) to 308 m (1,010 ft; Hamer Environmental 2009, p. 37), with individual flights heights ranging from 12 m (38 ft; Hamer Environmental 2009, p. 37) to 819 m (2,687 ft; Hamer Environmental 2009, p. 37). The flight altitudes of Growlers and marbled murrelets will therefore overlap as Growlers descend toward or climb away from runways and marbled murrelets climb away from the water toward their inland flight altitudes. However, even with the overlap in altitudes not all marbled murrelets will be exposed to potential aircraft strikes.

There is no known nesting habitat on Whidbey Island, and only a small percentage of marbled murrelets flying from the marine water of the action area to inland nesting sites are likely to fly through the Growler approach or departure flight tracks. A study conducted from 2004 to 2008 found that only small proportion (no more than twenty percent) of adult marbled murrelets foraging in Washington waters attempted to breed (Lorenz et al. 2017, p. 312). The use of radio transmitters in this study may have decreased the proportion of marbled murrelets attempting to breed, but studies using similar radio transmitters in other locations have documented much higher breeding rates, so it is likely that breeding rates are lower in Washington than in some other areas (Peery et al. 2004b, p. 1094). Other researchers have used information regarding the population estimates, rates of population change, and availability of breeding habitat, to arrive at the assumption that only approximately 60 percent of breeding-age adults in Washington (around 40 percent of the total population) breed in any given year, due to lack of breeding habitat (Peery and Jones 2019, pp. 14, 25-26). We therefore assume that fewer than half of the marbled murrelets in the action area are likely to be making daily inland flights during the breeding season, though non-breeding individuals are also expected to fly inland regularly (Peery et al. 2004a, p. 349).

Only a portion of marbled murrelets flying inland will be flying in the general direction to expose themselves to aircraft strikes. Marbled murrelets foraging west of Whidbey Island that nest on the Olympic Peninsula or Vancouver Island will fly away from the NAS Whidbey Island complex, as will marbled murrelets foraging east of Whidbey Island that nest near the Cascades. However, we do not know how many breeding adults will fly over the NAS Whidbey Island complex to travel between marine foraging and nesting areas. Some marbled murrelets may fly over Whidbey Island to travel from one marine foraging area to another. It is unclear how many marbled murrelets are likely to fly close enough to the NAS Whidbey Island complex runways to be struck by a Growler. The Navy monitors bird strikes at NAS Whidbey Island and, if possible, identifies the species of bird that was struck. In the last ten years the Navy has not identified any struck birds to be marbled murrelets (Bianchi, M., in litt. 2018c). Based on the locations of

suitable nesting habitat in relation to the marine action area, it is extremely unlikely that marbled murrelets will cross the path of a Growler during the small and intermittent windows of time when Growlers are flying at low altitudes taking off or landing.

9.1.2 Aircraft Strike Conclusion

While it is possible that marbled murrelets will be affected by aircraft strikes, best available information indicates that exposure is extremely unlikely. Based on the lack of suitable nesting habitat in the immediate vicinity of airfields, combined with the relatively small and intermittent windows of time when Growlers are flying at low altitude we expect that the potential for aircraft strike of marbled murrelets is discountable.

9.2 Aircraft Overflights

The acoustic and visual components of aircraft overflights have the potential to elicit responses from marbled murrelets. In general, we expect that the sound from aircraft overflights will lead to responses by marbled murrelets within the areas where those sounds can be heard. Whether or not the responses of marbled murrelets to sounds from aircraft have negative impacts depends on a variety of factors that are described below. To determine the maximum potential exposure area, we identified the area subject to increased SL.

Increased SL can have a range of effects on marbled murrelets. Aspects of sound that are important to determining the effects of the increased SL on marbled murrelets include the:

- frequency of the sound (in units of hertz [Hz] or kilohertz [kHz])
- intensity of the sound
- frequency of exposures (in units of occurrences over time)
- duration of the sound

The frequency of the sound is important for two reasons. First, marbled murrelets regularly communicate with each other while foraging in the marine environment and sounds at a similar frequency can interfere with, or "mask," marbled murrelet calls. The sound energy of most common type of marbled murrelet call ("keer") is centered around 3 kHz (Sanborn et al. 2005). Second, many of the potential responses to sounds, such as hearing injury and changes in behavior (see below), are most likely to occur following exposure to sounds at frequencies individuals can hear. We assume that marbled murrelets can hear sounds ranging from 480 Hz to 12.5 kHz, based on the frequencies of their calls (Nelson 1997, p. 10; Sanborn et al. 2005). Based on site visits and observations of Growler operations, the sounds produced by Growlers are not a pure tone, but rather made up of a range of frequencies. We assume that there is overlap in the frequencies of Growler sounds and marbled murrelet calls and that marbled murrelets are capable of hearing Growlers.

The intensity of the sound, or loudness, is a measure of the pressure difference exerted by a sound wave. Sound intensity is important because it provides a gauge for the amount of force an animal, organ, or tissue will be subjected to when exposed to a sound. The Service uses several

sound intensity thresholds for determining potential effects to marbled murrelets. We use best available science to inform our expectation that exposure to sounds exceeding 140 dBA_{Peak} re:20µPa causes auditory injury in marbled murrelets. This level of sound injures the sensory hair cells within a bird's inner ear (Dooling and Popper 2007, p. 24). These are the cells responsible for translating sound energy into a signal in the bird's nervous system, so damage to hair cells equates to hearing loss (Dooling and Popper 2007, pp. 19-20). In birds, unlike mammals, hair cells can regenerate, so hearing damage resulting from exposure to sounds exceeding 140 dBA_{Peak} re:20µPa will not necessarily be permanent (Dooling and Popper, pp. 24-27). However, based on the same analysis used to address the likelihood of aircraft strikes, it is extremely unlikely that marbled murrelets will be close enough to Growlers to be exposed to SLs that would cause this type of injury.

Exposure to SLs from aircraft that are greater than 92 dBA_{SEL} re:20µPa^2s may disrupt the normal behavior of marbled murrelets (Teachout 2015, pp. 1-5, 13-14; responses to noise exposure are discussed further in section 9.2.3). For the remainder of this Opinion, unless stated otherwise, sound measurements will have the same reference pressure as the Service thresholds (re:20µPa for dBA_{Peak} and re:20µPa^2s for dBA_{SEL}). There is evidence that even species that appear to be relatively tolerant of aircraft disturbance have a stronger reaction to multiple overflights (Smit and Visser 1993, pp. 12-13). The Service's disturbance threshold is in terms of Sound Exposure Level, which measures the total sound energy of an event, and longer-duration sounds can result in higher Sound Exposure Level (SELs). We refer to SL at 92 dBA_{SEL} or louder as "disturbance-level" sounds.

Marbled murrelets may be exposed to elevated SL resulting from Growler overflights either in terrestrial nesting habitat, or in the marine environment. Because the life history function of nesting habitat and marine habitat are drastically different, and marbled murrelet behavior differs between the two types of habitat, we analyze marine and terrestrial exposures separately.

9.2.1 Opportunities for Exposure to Growler Overflight Sounds

As described in section 5.2, pattern operations involve two airfield operations per pattern, an approach followed by a take-off. The sound-related stressors to marbled murrelets will occur as the aircraft travels along its flight path, not specifically during takeoff and landing at the airfields. For each time the aircraft travels along the flight path (one pattern circuit, also referred to in this document as a flight or an opportunity for exposure), two airfield operations are counted. For FCLPs, T&Gs, ground-controlled approaches, and depart and re-enter patterns, the number of times an aircraft travels along the flight path is half the number of airfield operations shown in Table 1. We therefore considered each pattern circuit, rather than each airfield operation, as an opportunity for exposure. Since pattern circuits involve two airfield operations, the total number of pattern circuits for FCLPs, T&Gs, ground-controlled approaches, and depart and re-enter patterns are the number of airfield operations for these activities divided by two (refer Table 3). For other types of operations (arrivals, departures, and interfacility flights), since only one airfield operation is counted per Growler flight along the flight track, the number of opportunities of exposure is the same as the number of operations.

Table 3. Growler airfield operations and opportunities for marbled murrelet exposure

Type of Operation		Number of Airfield Operations		Number of Flights With Potential Marbled Murrelet Exposure to Stressors	
		Average Year	High-Tempo Year	Average Year	High-Tempo Year
AULT FIELD					
Departures		**17,415**	**17,454**	**17,415**	**17,454**
Arrivals	Straight-in/Full-stop	**6,530**	**6,532**	**6,530**	**6,532**
	Overhead Break	**9,963**	**10,007**	**9,963**	**10,007**
	Instrument Approach	**922**	**914**	**922**	**914**
Pattern Operations	FCLP	**5,936**	**6,413**	**2,968**	**3,207**
	T&G	**11,855**	**12,157**	**5,928**	**6,079**
	Ground-controlled Approach	**14,391**	**14,911**	**7,196**	**7,456**
	Depart and Re-enter	**3,859**	**3,849**	**1,930**	**1,925**
OLF COUPEVILLE					
Pattern Operations	FCLP	**23,729**	**26,128**	**11,865**	**13,064**
Interfacility Flights	Ault Field to OLF Coupeville	**1,481**	**1,631**	**1,481**	**1,631**
	OLF Coupeville to Ault Field	**1,483**	**1,632**	**1,483**	**1,632**
	TOTALS	***97,564***	***101,628***	***67,681***	***69,901***

9.2.2 Marbled Murrelet Exposure to Elevated Sound Levels in the Marine Environment

9.2.2.1 Exposure to Elevated Sound Levels in the Marine Environment

The number of marbled murrelets exposed to elevated SL by Growler flights will depend on the area of marine habitat exposed, the density of marbled murrelets within those areas, and the duration and frequency (occurrences over time) of exposures. We analyze two scenarios: an "average" scenario, which combines the recent annual average density of marbled murrelets in each area of marine habitat with the projected average number of flights per year; and a "high exposure" scenario, which combines realistically high estimates of marbled murrelet densities with the number of flights in a "high tempo" year. The average scenario depicts the expected average level of exposure over the long term. The high exposure scenario depicts the greatest level of exposure that is reasonably likely to occur over the course of any given year.

9.2.2.1.1 Marine Area Exposed to Elevated Sound Levels by Each Flight

The area exposed to elevated SLs by any given Growler flight will be the same, regardless of the average or high exposure scenario. The area exposed to elevated SLs by each Growler flight will depend primarily on the Growler's power setting, altitude, and flight path. Environmental

conditions can add a suite of variables that can influence the SLs to which marbled murrelets will be exposed. Wind can raise ambient noise levels and may mask some of the noise from Growlers, as well as disturbing the surface of the water and thereby changing how sound will reflect off the water. However, wind can create complex sonic situations – such as upward sound refraction and shadow zones that can reduce transmission of aircraft noise at low altitudes (Ward et al. 199, p. 370). Landforms can also cause sound to behave differently in different locations. Tall trees can absorb sound waves and increase the sound attenuation rate, while large cliffs may reflect and focus sound waves. We do not have sufficient information to accurately incorporate the variability of environmental conditions into our exposure analysis. Because environmental factors can both increase and decrease exposure, it is reasonable to assume that the aggregate influence of environmental conditions will be neutral.

Power settings are a measure of the thrust generated by the jet's engines; higher power settings are louder than lower power settings (Navy 2015, p. 3.6-60). Based on the flight profiles presented in the FEIS, Growlers will spend very short periods of time at 65 percent power, the large majority of flight time Growlers will operate at above 80 percent power. When Growlers are not directly over the runway, power settings are between 80 and 85 percent power (Navy 2018, pp. A5-7 – A5-24). The Final Environmental Impact Statement/Overseas Environmental Impact Statement for the Navy's Northwest Training and Testing Activities (NWTT FEIS/OEIS) stated that birds at the ocean surface would be exposed to noise from Growlers, that the noise levels would decrease with increasing distance from the flight track centerline, and provided single-event SLs (with accompanying SELs) for Growlers at three different power settings. The sound information provided in the NWTT FEIS/OEIS is described as pertaining to a single event (Navy 2015, pp. 3.6-59 – 3.6-60). Based on the information provided in the NWTT FEIS/OEIS, we treat the SEL data provided as relating to a single overflight which takes the duration of the exposure into account. For the analysis of this action, we will therefore use the SEL information from the NWTT FEIS/OEIS for analyzing the sound exposure from overflights.

A Growler operating at 85 percent power will produce SLs of 114 dBA_{SEL} when measured 400 ft away from the jet (Navy 2015, p. 3.6-60). We do not have SL measurements for the lowest power setting that Growlers will operate at for short periods during some activities (65 percent; Navy 2018, pp. A5-7 – A5-24). We will therefore conservatively use the sound data associated with the lowest available power setting (78 percent; Navy 2015, p. 3.6-60) as a substitute for when Growlers are at their lowest power setting. We also do not have SL measurements for the highest power setting that Growlers will operate at primarily over runways (97 percent; Navy 2018, pp. A5-7 – A5-24). It is unclear how accurate it would be to extrapolate a 97-percent sound level from the highest available power setting (93 percent; Navy 2015, p. 3.6-60), so we considered sound data associated with the 93 percent power setting as the best available information for the highest extent of sound generated by Growlers.

Noise energy dissipates as it travels away from its source, thus a nearby receiver will experience a higher-intensity SL than a receiver that is farther away. Depending on the power setting of the Growler, marbled murrelets within about 1,250 to 8,000 ft of the aircraft overflight will be exposed to an SL that exceeds the 92 dBA_{SEL} disturbance threshold. At the common 85 percent

power setting, marbled murrelets within about 4,000 ft of a Growler will be exposed to SLs exceeding the 92 dBA_{SEL} disturbance threshold. Refer to Table 4 for a summary of SLs and attenuation distances for Growlers.

Table 4. Sound levels and distances required for attenuation below the disturbance threshold for Growler power settings

Power Setting (%)	SL at 400 ft (dBA_{SEL})*	Distance for sound to attenuate below 92 dBA_{SEL} threshold (ft)
93	120	8,000**
85	114	4,000
78	101	1,250

* Navy 2015, p. 3.6-60
**At the 93 percent power setting, SL is expected to be 96 dBA_{SEL} at 5,000 ft and 90 dBA_{SEL} at 8,000 ft, so the distance at which the SL attenuates below the 92 dBA_{SEL} disturbance threshold would be somewhat shorter than 8,000 ft.

The amount of marbled murrelet habitat exposed to a SL exceeding the disturbance threshold by each flight will depend not only on the power setting of the Growler, but also the altitude and flight path of the Growler. In the action implemented by the Navy, Growlers will fly below 4,000 ft above ground level (AGL, refer to Section 5.2) down to ground level (since all flights include take-offs, approaches, or both). Since we assume that sound will travel away from the Growler in all directions, Growlers that are closer to the surface of the water will expose a larger area of the water to noise, as compared with Growlers flying higher. For example, a Growler at 85 percent power 1,200 feet above the water will expose about 1.6 square miles of the water surface around the jet to an SL exceeding the disturbance threshold (refer to Figure 7). The same Growler at the same power setting, but 2,000 feet above the water will expose about 1.4 square miles of the water surface to an SL exceeding the disturbance threshold. Note that these areas of exposure are measures of instantaneous exposure and do not account for the movement of Growlers.

Flight paths will partially determine the amount of marbled murrelet habitat exposed to disturbing SLs because Growlers have the potential to expose areas along entire flight paths and flight paths vary in their shape and length (refer to Appendix A: Predominant Growler Flight Tracks). Some flight tracks keep Growlers largely over land and would limit exposure to the marine environment, while other flight tracks take Growlers more than ten miles away from land and have the potential to expose more of the marine environment to noise. The majority of the flight tracks for FCLP and T&G activities are over land, and together, these make up nearly a third of the average total annual opportunities to expose marbled murrelets to stressors, in both average and high-tempo years (refer to Table 3). At the power setting used for the majority of FCLP and T&G operations (≈ 85 percent, Navy 2018, pp. A5-19-A5-23), noise from Growlers exceeding the disturbance threshold will extend less than one mile from the Growlers (Figure 7 illustrates this scenario with the maximum altitude flown for FCLP/T&Gs from the DEIS). Therefore, Growlers performing FCLPs and T&Gs will only expose marbled murrelet marine

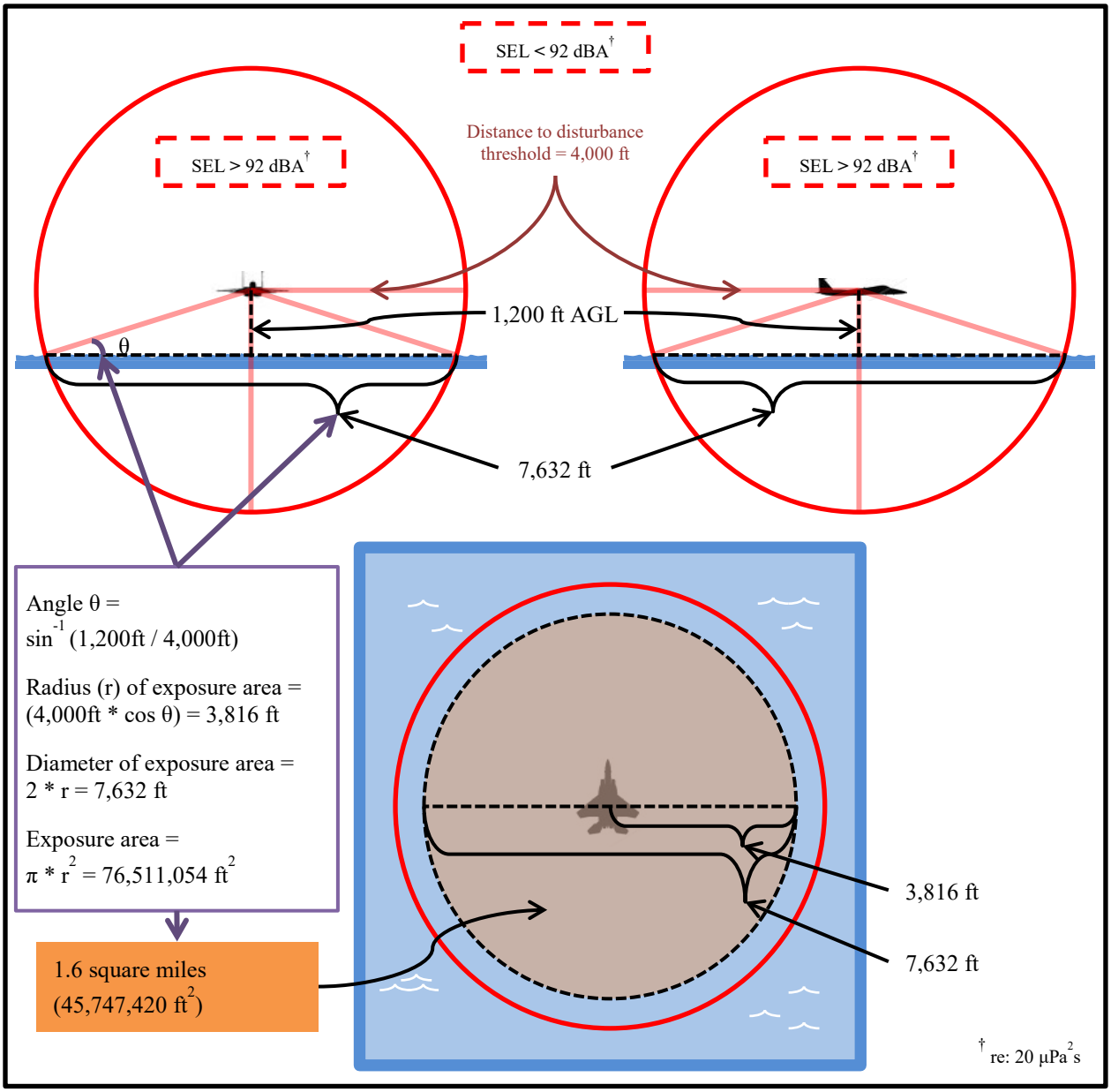

Figure 7. Example of area of exposure to noise exceeding disturbance threshold around a Growler operating at 85% power setting at a point in time, the Growler will carry the area of exposure with it along the flight path.

Note: the bars across the top two circles are intended to depict the surface of the water, and the height of the blue line is not intended to indicate depth beneath the surface or imply an analysis of subsurface effects of noise.

habitat to disturbing sound when they are above the water, within one mile of the water, or landing and taking off (when power settings are higher). Other types of flights, especially ground-controlled approaches, interfacility flights, and depart and re-enter patterns, will expose much more marbled murrelet habitat to noise from Growlers. Those flights take Growlers over the water for long distances and over areas known for having high densities of marbled murrelets (see next section). Compared with FCLPs and T&Gs, Growlers will fly at higher altitudes for

portions of the flight tracks for ground-controlled approaches, interfacility flights, and depart and re-enter patterns, but not high enough to allow noise from the jets to attenuate to an SL below the disturbance threshold at sea level.

There are 115 different modeled flight tracks associated with 11 types of operations in the action. Within each flight track, Growlers will use several power settings and fly at different altitudes. To estimate the amount of marbled murrelet marine habitat that will be exposed to disturbance level sound we simplified the flight tracks by using the predominant power setting used and an altitude that was representative of the average altitude along the flight track (see Appendix C for power settings and altitudes used to represent each flight type). The flight tracks provided in the FEIS are the predominant paths of aircraft, but Growlers may fly as much as several miles to the left or right of the predominant path based on aircraft performance, pilot technique, other air traffic, and weather conditions (Navy 2018, p. 3-7). Due to this variability and the uncertainty it creates, we were conservative in our estimation of exposure areas, meaning that we erred on the side of estimating more exposure. That conservative approach guards against the exposure from action having greater effects than those that we analyzed. A more detailed description of the methods we used to estimate the area of marbled murrelet marine habitat disturbance is included in Appendix C: Estimating Marbled Murrelet Marine Habitat Exposure to Growler Disturbance. The estimated minimum, average, and maximum areas that Growlers on different flight tracks could expose marbled murrelets to noise exceeding the disturbance threshold is summarized in Table 5. Note that the average area exposed for each type of operation is a weighted average, based on the annual frequency of use described for each flight track (Navy 2018, pp. A3-5-A3-9, A4-5-A5-30; also see Appendix D).

As shown in Table 5, each Interfacility Flight, Ground-controlled Approach, and Departure will expose substantially more marbled murrelet marine habitat than FCLPs and T&Gs. However, the exposure of marbled murrelets to each type of operation will also depend on how many marbled murrelets are present in the vicinity of each flight track, and the frequency, timing, and duration of the aircraft's presence in any given location.

9.2.2.1.2 Marbled Murrelets Exposed to Elevated Sound Levels by Each Flight

The density of marbled murrelets in the action area varies naturally, geographically, annually, and seasonally. Therefore, we estimated marbled murrelet exposure separately for the breeding season, April through September, and the non-breeding season, October through March. Note that the breeding season in Washington is usually considered to extend from April 1 through September 23 (USFWS 2012a, entire). However, for the purposes of this opinion, we include the last week of September as part of the breeding season, because for purposes of analysis, it is more straightforward to have two seasons of six months each, rather than one season of 25 weeks and another of 27 weeks. Also, the Navy describes runway use as differing between April through September and October through March (Navy 2018, p. 3-7). For each season, we assigned each flight track to a survey stratum (see Figure 4). Where flight tracks crossed multiple strata in a given season, we assigned the entire flight track to the stratum with higher marbled murrelet densities in that season. For each flight track, we also estimated how much of the ensonified marine area would be within 2 km of shore, and how much would be farther from shore.

Table 5. Estimated area of marbled murrelet marine habitat exposed to disturbance-level noise from Growler activities

Type of Operation		Estimated Marbled Murrelet Marine Habitat Exposure Area per Incident (miles^2 [km^2])		
		Minimum	**Average***	**Maximum**
AULT FIELD				
Departures		**33.3 (86.1)****		
Arrivals	Straight-in/Full-stop	**14.6 (37.7)**	**21.4 (55.4)**	**22.7 (58.7)**
	Overhead Break	**14.6 (37.7)**	**21.5 (55.7)**	**28.4 (73.5)**
	Instrument Approach	**7.9 (20.5)**	**11.4 (29.4)**	**15.9 (41.1)**
Pattern Operations	FCLP and T&G***	**0.0 (0.0)**	**4.4 (11.4)**	**8.8 (22.9)**
	Ground-controlled Approach	**30.7 (79.6)**	**39.7 (102.8)**	**64.3 (166.5)**
	Depart and Re-enter	**21.3 (55.2)**	**28.2 (73.0)**	**38.1 (98.8)**
OLF COUPEVILLE				
Pattern Operations	FCLP	**3.8 (9.9)**	**5.2 (13.6)**	**8.8 (22.8)**
Interfacility Flights	Ault Field to OLF Coupeville	**15.5 (40.2)**	**42.1 (109.1)**	**53.7 (139.2)**
	OLF Coupeville to Ault Field	**16.5 (42.8)**	**32.6 (84.4)**	**44.5 (115.2)**

* Average area of exposure is weighted by the annual use of different flight tracks (Navy 2018, pp. A3-5-A3-9, A4-5-A5-30, and see Appendix D)

** Flight paths for departures were estimated to have equal exposure areas due to Growlers climbing to high altitudes in a relatively short distance

*** FCLPs and T&Gs follow the same flight tracks

For each season, the nearshore and offshore area of each stratum were associated with separate density estimates for the "average exposure" and "high-exposure" scenarios. For the "average exposure" scenario, we used the average marbled murrelet density for the period from 2012 through 2018. This is the period for which we have non-breeding season data collected by WDFW along both the east and west sides of Whidbey Island, and for the breeding season, this period includes years of relatively high marbled murrelet density and years of very low marbled murrelet density. For the "high-exposure" scenario, we used breeding season data from 2005, a year in which marbled murrelet densities in the action area were particularly high, possibly related to delayed upwelling along the outer coast (see section 8.4). For the non-breeding season, we do not have data for 2005, so we used data from the 2012-2013 non-breeding season. The breeding season Conservation Zone 1 density estimate for 2012 was similar to the density estimate for 2005, even though the distribution among strata was different, so it is reasonable to use the 2012-2013 non-breeding season population density estimates in conjunction with the 2005 breeding season estimates. The 2012-2013 non-breeding season is also the highest-density year in the non-breeding season dataset, making it appropriate for a "high exposure" scenario.

We combined these density estimates with the estimates of area ensonified at levels louder than 92 dBA_{SEL} by each flight track. The setup and results of these calculations are given in full in Appendix E: Marbled Murrelet Exposure to Each Flight Track. Summaries of the results are

shown in Tables 6, 7, 8, and 9. In a year with average marbled murrelet densities, we estimate that each individual flight will expose between a minimum of 0 and a maximum of 497 marbled murrelets to these sound levels. In a year with high marbled murrelet densities, we estimate that each flight will expose a minimum of 0 and a maximum of 886 marbled murrelets. On average, FCLPs and T&G patterns at Ault Field are generally expected to expose the smallest numbers of marbled murrelets to elevated sound levels, and interfacility flights and ground-controlled arrivals are generally expected to expose the largest numbers. The flight tracks that are not expected to expose any marbled murrelets to sounds louder than 92 dBA_{SEL} are expected to occur entirely over land. The flight tracks that expose the largest numbers of marbled murrelets to loud sounds include the longest ground-controlled approach tracks, which travel along Rosario Strait and into the San Juan Islands. The exposure estimates comport with recent (2014 and 2015) winter observations of hundreds or even more than 1,000 marbled murrelets in hotspots in Burrows Bay and along southern Lopez Island (USFWS 2017a, p. 28). Some interfacility flight tracks are nearly as extensive and travel through other marbled murrelet hotspots, such as Admiralty Inlet.

We calculated two different weighted averages for each type of operation in each season. One average is weighted based on the annual usage of each flight track (Navy 2018, pp. A-126-A-127, A3-5-A3-9, A4-5-A4-30). The other is based on the assumption that flight tracks using Ault Field runway 25 would be used primarily in the breeding season, flight tracks using Ault Field runway 14 would be used primarily in the non-breeding season, and other flight tracks would be split between the two seasons to distribute the number of flights evenly between the seasons (Navy 2018, p. 3-7; see also Description of the Action, section 5). We expect that the actual distribution of flight tracks between the seasons is likely to fall in between the two distributions that we modeled, as it was for Ault Field runway 14 during 2018 (Bianchi, in litt. 2019a). More details regarding the calculation of these two weighted averages is included in Appendix D and Appendix E. Incorporating the assumption about the seasonal use of runways alters our expectations of how many marbled murrelets will be exposed to the sounds of overflights from each type of operation, but it is not clear from the per-flight calculations whether the total exposure would be greater with seasonal use of runways than it would be if runway use remained constant throughout the year. Therefore, we carry both weightings through the exposure analysis.

Table 6. Estimated number of marbled murrelets exposed to disturbance-level noise from each type of Growler flight during breeding season, "average exposure" scenario

Type of Operation		Estimated Number of Marbled Murrelets Exposed Per Flight (Breeding Season)			
		Minimum	**Average* (Annual Weighting)**	**Average* (Seasonal Weighting)**	**Maximum**
AULT FIELD					
Departures		**8**	**52.8**	**8.6**	**116**
Arrivals	Straight-in/Full-stop	**5**	**53.9**	**69.9**	**71**
	Overhead Break	**10**	**40.3**	**30.5**	**71**
	Instrument Approach	**4**	**20.6**	**10.1**	**47**
Pattern Operations	FCLP and T&G**	**0**	**4.5**	**2.6**	**7**
	Ground-controlled Approach	**74**	**102.6**	**77.7**	**216**
	Depart and Re-enter	**23**	**78.0**	**79.2**	**118**
OLF COUPEVILLE					
Pattern Operations	FCLP	**5**	**12.2**	**12.2**	**31**
Interfacility Flights	Ault Field to OLF Coupeville	**44**	**231.0**	**296.6**	**323**
	OLF Coupeville to Ault Field	**37**	**128.7**	**110.1**	**272**

* Average marbled murrelet exposure is weighted by the use of different flight tracks annually and in different seasons; see Appendix D.

** FCLPs and T&Gs follow the same flight tracks

Table 7. Estimated number of marbled murrelets exposed to disturbance-level noise from each type of Growler flight during non-breeding season, "average exposure" scenario

Type of Operation		Estimated Number of Marbled Murrelets Exposed Per Flight (Non-breeding Season)			
		Minimum	**Average (Annual Weighting)**	**Average (Seasonal Weighting)**	**Maximum**
AULT FIELD					
Departures		**68**	**78.4**	**88.7**	**266**
Arrivals	Straight-in/Full-stop	**23**	**73.4**	**97.8**	**146**
	Overhead Break	**23**	**52.6**	**57.4**	**125**
	Instrument Approach	**15**	**45.1**	**71.6**	**109**
Pattern Operations	FCLP and T&G**	**0**	**9.0**	**13.3**	**14**
	Ground-controlled Approach	**176**	**240.7**	**295.7**	**497**
	Depart and Re-enter	**137**	**183.5**	**182.4**	**272**
OLF COUPEVILLE					
Pattern Operations	FCLP	**9**	**26.4**	**26.4**	**70**
Interfacility Flights	Ault Field to OLF Coupeville	**31**	**296.0**	**255.0**	**355**
	OLF Coupeville to Ault Field	**87**	**232.5**	**258.2**	**302**

* Average marbled murrelet exposure is weighted by the use of different flight tracks annually and in different seasons; see Appendix D.

** FCLPs and T&Gs follow the same flight tracks

Table 8. Estimated number of marbled murrelets exposed to disturbance-level noise from each type of Growler flight during breeding season, "high exposure" scenario

Type of Operation		Estimated Number of Marbled Murrelets Exposed Per Flight (Breeding Season)			
		Minimum	**Average (Annual Weighting)**	**Average (Seasonal Weighting)**	**Maximum**
AULT FIELD					
Departures		**34**	**116.4**	**35.0**	**209**
Arrivals	Straight-in/Full-stop	**20**	**99.1**	**126.0**	**127**
	Overhead Break	**40**	**99.9**	**108.9**	**128**
	Instrument Approach	**20**	**49.3**	**41.4**	**85**
Pattern Operations	FCLP and T&G**	**0**	**18.5**	**10.5**	**29**
	Ground-controlled Approach	**133**	**184.8**	**140.0**	**390**
	Depart and Re-enter	**96**	**141.5**	**142.7**	**212**
OLF COUPEVILLE					
Pattern Operations	FCLP	**20**	**30.0**	**30.0**	**55**
Interfacility Flights	Ault Field to OLF Coupeville	**79**	**242.6**	**272.2**	**285**
	OLF Coupeville to Ault Field	**66**	**182.7**	**162.5**	**241**

* Average marbled murrelet exposure is weighted by the use of different flight tracks annually and in different seasons; see Appendix D.

** FCLPs and T&Gs follow the same flight tracks

Table 9. Estimated number of marbled murrelets exposed to disturbance-level noise from each type of Growler flight during non-breeding season, "high exposure" scenario

Type of Operation		Estimated Number of Marbled Murrelets Exposed Per Flight (Non-breeding Season)			
		Minimum	**Average (Annual Weighting)**	**Average (Seasonal Weighting)**	**Maximum**
AULT FIELD					
Departures		**83**	**118.1**	**114.7**	**474**
Arrivals	Straight-in/Full-stop	**28**	**116.1**	**174.2**	**260**
	Overhead Break	**28**	**71.4**	**86.2**	**128**
	Instrument Approach	**18**	**74.2**	**126.5**	**195**
Pattern Operations	FCLP and T&G**	**0**	**10.7**	**15.7**	**16**
	Ground-controlled Approach	**314**	**429.4**	**527.5**	**886**
	Depart and Re-enter	**244**	**327.4**	**325.4**	**486**
OLF COUPEVILLE					
Pattern Operations	FCLP	**11**	**43.3**	**43.3**	**125**
Interfacility Flights	Ault Field to OLF Coupeville	**38**	**525.5**	**450.6**	**633**
	OLF Coupeville to Ault Field	**155**	**414.8**	**460.6**	**538**

* Average marbled murrelet exposure is weighted by the use of different flight tracks annually and in different seasons; see Appendix D.

** FCLPs and T&Gs follow the same flight tracks

In summary, we expect the per-flight number of marbled murrelet exposures, to SL louder than 92 dBA_{SEL}, to vary substantially depending on flight track, season, and the distribution of flight tracks between seasons. We also expect year-to-year variation, but over the long run we expect that the number of exposures per flight will be similar to those in the "average exposure" scenario described in Tables 6 and 7, or perhaps less, given the declining population. Note that we do not simply project the current population decline forward in time over the next 30 years, which would result in reduced estimates of exposure. The rate of population decline has slowed over the last ten years in Zone 1 and throughout the range, and in parts of the range where the population was previously declining, population trends now appear to be increasing (see Falxa et al. 2015, p. 8; McIver et al. 2019, p. 9; Miller et al. 2012, p. 775). If the Zone 1 population decline continues slowing or reverses during the next 30 years, then projecting the current decline forward would result in an underestimate of exposure. Even if the population does continue to decline overall, we expect substantial year-to-year variation. Over the next 30 years, it is reasonable to expect that some years will be similar to the "high exposure" scenario described in Tables 8 and 9. The breeding season estimates in the "high exposure" scenario came from the year 2005, a year in which coastal upwelling was delayed and the distribution of marbled murrelets in Conservation Zone 1 shifted toward higher density in the action area and lower density elsewhere. Some projections of future conditions indicate that coastal upwelling

will be delayed more often in the future (see section 8.4, Climate Change), which could in turn result in a higher frequency of years with marbled murrelet breeding season distributions similar to those seen in 2005.

9.2.2.1.3 Duration of Exposures

Each instance of marbled murrelet exposure to the sounds of Growler aircraft, as counted in Tables 6 through 9, consists of one overflight of a given patch of marine habitat. Each individual exposure is expected to be relatively short in duration. For this action, Growler aircraft flight speeds are generally expected to vary from 130 to 350 knots (219 to 519 feet per second [fps]). This range of speeds, combined with the range of flight heights and attenuation distances to 92 dBA_{SEL}, can be used to estimate the duration of exposure to sounds louder than 92 dBA_{SEL}, though we note that marbled murrelets will be able to hear the aircraft over the ambient sound level for a longer period of time.

The longest duration of an individual exposure will result from aircraft traveling at the slowest speed and highest power setting, while also flying low over the water. At 93 percent power, the highest power setting for which we have sound information, a radius within 8,000 ft of the aircraft will be exposed to disturbance-level sounds (See section 9.2.2.1.1, Table 4, and Figure 7). If the aircraft is 500 ft above sea level, and a marbled murrelet is directly beneath the flight track, the bird will be exposed to SL higher than 92 dBA_{SEL} as the aircraft travels along a 15,969-ft length of the flight track (see section 9.2.2.1.1). If the aircraft is flying at 130 knots (219 fps), the exposure to disturbance-level sounds will last approximately 73 seconds, though the bird will also be able to hear the aircraft for a longer period of time.

The shortest duration of an individual exposure will result from aircraft traveling at the quickest speed and lowest power setting, while also flying high over the water. At 78 percent power, the lowest power setting for which we have sound information, a radius within 1,250 ft of the aircraft will be exposed to disturbance-level sounds (See section 9.2.2.1.1, Table 4, and Figure 7). In general, power levels this low or lower are only used when the aircraft are flying at higher altitudes, and do not result in any exposure of birds to disturbance-level sounds. If the aircraft is flying at 1,200 ft above sea level at this power, and a marbled murrelet is directly beneath the flight track, the bird will be exposed to SL higher than 92 dBA_{SEL} as the aircraft travels along a 350-ft length of the flight track (see section 9.2.2.1.1). If the aircraft is flying at 350 knots (519 fps), the exposure to disturbance-level sounds will last less than one second.

Most individual instances of exposure will fall between these extremes of duration. For example, we calculate the duration of a flight at a speed, power setting, and altitude similar to one used in the FCLP flight pattern at OLF (Navy 2018, p. A5-23). At 85 percent power, the lowest power setting for which we have sound information a radius within 4,000 ft of the aircraft will be exposed to disturbance-level sounds (see section 9.2.2.1.1, Table 4, and Figure 7). If the aircraft is flying at 800 ft above sea level at this power, and a marbled murrelet is directly beneath the flight track, the bird will be exposed to SL higher than 92 dBA_{SEL} as the aircraft travels along a 7,838-ft length of the flight track (see section 9.2.2.1.1). If the aircraft is flying at 150 knots (253 fps), the exposure to disturbance-level sounds will last approximately 31 seconds. Many of the Growler flight patterns used in the action will predominantly use this power setting

at higher altitudes and faster speeds (Navy 2018, Appendix 5), and each individual exposure will therefore be shorter than 31 seconds in duration. Furthermore, most marine area, and therefore most marbled murrelets, will not be directly under a given flight path, but will be farther from the aircraft and will receive disturbance-level sounds for a shorter period of time than birds that are directly below.

Some individual exposures may occur in rapid succession. In this case, while each individual exposure may be relatively short in duration, a bird may perceive the multiple exposures as being all part of the same, longer-duration event. This is because we do not expect sound to attenuate to background levels between periods of disturbance-level sounds. A bird will still be able to hear the aircraft in between exposures to disturbance-level sounds, but the sound level will be below 92 dBA_{SEL} for some period of time. Below, we distinguish between "double exposures," which occur when a flight track passes over the same patch of water more than once; "triple exposures," which are associated with three aircraft traveling one behind the other during interfacility flights, and FCLP periods, which involve multiple aircraft flying repeatedly over the same area for a 45-minute duration.

Primarily, multiple short-duration exposures will combine in a longer-duration event when FCLP training is carried out. The FCLP periods consist of between three and five aircraft, each performing eight to ten approaches and eight to ten takeoffs, for eight to ten circuits around the flight track. Additionally, when FCLP periods occur at OLF, each participating aircraft makes an interfacility flight from Ault Field to OLF at the beginning of the period, and another interfacility flight from OLF to Ault Field at the end of the period. In total, these periods involve between 48 and 100 airfield operations and last approximately 45 minutes. Although the marine areas exposed to these periods may not be ensonified at SL louder than 92 dBA_{SEL} for the entire 45-minute duration of the period, we expect that birds that happen to be in the area will perceive the entire period as a single, long-duration instance of loud sound, because we do not expect that the aircraft sounds will ever attenuate to background levels during the 45-minute period within the areas beneath the flight tracks.

Interfacility flights will typically occur in groups of three to five aircraft, taking off approximately one minute apart, all traveling from Ault Field to OLF at the beginning of a FCLP period or from OLF to Ault Field at the end of an FCLP period. Where these flight tracks approach or depart OLF, birds are likely to perceive the sounds of these flights as part of the longer FCLP period. Along the flight track between the two airfields, we expect that birds will perceive the three flights as part of a single event, approximately three minutes in duration. We refer to this type of exposure event as a "triple exposure," and "triple exposures" are made up of three individual exposures. In reality, interfacility flights could involve up to five aircraft, which would result in an exposure event approximately five minutes long, and would be more accurately termed a "quintuple exposure." We analyze triple exposures, rather than quintuple exposures, because assuming that aircraft travel together in smaller groups leads us to estimate a greater number of exposure events, and therefore avoid underestimating the frequency at which marbled murrelets are exposed.

Multiple exposures in quick succession will not always be related to multiple aircraft operating in close proximity. Some individual flight patterns will involve exposures of the same marine area twice in succession, which may be perceived by the birds as a single longer-duration exposure, depending on the amount of time between the repeated overflights. This occurs when flight tracks include loops. In the methods we used to calculate exposure, the second overflight of each patch of marine habitat is counted as an additional exposure of marine habitat and of marbled murrelets, but the birds may perceive a single sound with two louder periods as the aircraft passes overhead, rather than two separate loud sounds. We term this type of exposure a "double exposure." We expect that double exposures could occur during interfacility flights from OLF to Ault Field, overhead break arrivals, and depart and re-enter patterns, along the portions of the flight tracks that are close to shore near Ault Field. Interfacility flights landing at Ault Field will always be associated with the triple exposures described above, so the repeated flight over the same area is likely to be perceived as part of this longer, 3-minute event. Interfacility flights making approach to OLF will also include a loop that will lead to this type of double exposure, but these flight patterns will occur at the beginning of FCLP training periods and we expect that the double exposure will be perceived by birds in the area as a part of the longer, 45-minute period. Therefore, overhead break arrivals and depart and re-enter patterns are the types of operations that will lead to "double exposures" (see maps in Appendix A, or Navy 2018, pp. A4-11 – A4-12, A4-19). Most areas of marine habitat, and therefore most individual marbled murrelets, that are exposed to these types of flights will only experience a single overflight. However, individual marbled murrelets using marine habitat immediately west or northwest of Ault Field will be exposed to two overflights in quick succession from some flight tracks associated with these activities. Our exposure modeling methods do not provide an estimate of how many of the exposures estimated for these flight types will be single exposures and how many will make up half of a double exposure. Therefore, we combine single and double exposures in our analysis of the frequency of exposure below, counting each exposure as an independent exposure event (Section 9.2.2.1.5).

9.2.2.1.4 Timing of Exposures

Growler aircraft may operate at any time of the day and on any day of the year. Flights will occur more frequently between the hours of 0700 and 2200, which the Navy terms "day," than between the hours of 2200 and 0700, which the Navy terms "night." For some flight types, the Navy has also identified how many flights will occur during the hours of darkness that fall during the "day" between 0700 and 2200 (Navy 2018, pp. A-126-A-127). The number of flights for each time of day is shown in Table 10 for an average year, and the same proportions are applied to each type of flight in a high-tempo year in Table 11. Note that the total proportion of night flights increases in a high-tempo year, because activities with higher proportions of night flights increase in high tempo years, but activities with lower proportions of night flights increase to a smaller degree or even decrease. In addition, to the information shown in the tables, it is notable that the OLF airfield is usually closed between the hours of midnight and 0700, so interfacility flights and FCLPs at OLF will rarely, if ever, occur during the early morning hours. Ault Field is open 24 hours a day, but in practice, training flights, and especially FCLP periods, are not generally scheduled during the early morning hours (Bianchi, in litt. 2019b).

Table 10. Number and percentage of Growler flights at each time of day for an average year.

Type of Operation		Number (Percentage) of Flights		
		During the Day (0700-2200)		At Night (2200-0700)
		Daylight	Darkness	Darkness
AULT FIELD				
Departures		**16,390 (94 %)**		**1,025 (6 %)**
Arrivals	Straight-in/Full-stop	**6,077 (93 %)**		**453 (7 %)**
	Overhead Break	**8,768 (88 %)**	**317 (3 %)**	**878 (9 %)**
	Instrument Approach	**873 (95 %)**		**49 (5 %)**
Pattern Operations	FCLP	**3,110 (52 %)**	**1,617 (27 %)**	**1,209 (20 %)**
	T&G	**8,416 (71 %)**	**1,433 (12 %)**	**2,006 (17 %)**
	Ground-controlled Approach	**10,515 (73 %)**		**3,876 (27 %)**
	Depart and Re-enter	**3,736 (97 %)**		**123 (3 %)**
OLF COUPEVILLE				
Pattern Operations	FCLP	**11,467 (48 %)**	**7,470 (31 %)**	**4,792 (20 %)**
Interfacility Flights	Ault Field to OLF Coupeville*	**749 (51 %)**	**367 (25 %)**	**365 (25 %)**
	OLF Coupeville to Ault Field	**1,239 (83 %)**	**--**	**244 (16 %)**
TOTAL		***82,544 (85 %)***		***15,020 (15 %)***

* Percentages do not sum to 100% due to rounding.

Table 11. Number of Growler flights at each time of day for a high tempo year.

Type of Operation		Number of Flights		
		During the Day (0700-2200)		At Night (2200-0700)
		Daylight	Darkness	Darkness
AULT FIELD				
Departures		**16,427 (94 %)**		**1,027 (6 %)**
Arrivals	Straight-in/Full-stop	**6,079 (93 %)**		**453 (7 %)**
	Overhead Break	**8,807 (88 %)**	**318 (3 %)**	**882 (9 %)**
	Instrument Approach	**865 (95 %)**		**49 (5 %)**
Pattern Operations	FCLP	**3,360 (52 %)**	**1,747 (27 %)**	**1,306 (20 %)**
	T&G	**8,630 (71 %)**	**1,470 (12 %)**	**2,057 (17 %)**
	Ground-controlled Approach	**10,895 (73 %)**		**4,016 (27 %)**
	Depart and Re-enter	**3,726 (97 %)**		**123 (3 %)**
OLF COUPEVILLE				
Pattern Operations	FCLP	**12,627 (48 %)**	**8,225 (31 %)**	**5,276 (20 %)**
Interfacility Flights	Ault Field to OLF Coupeville*	**825 (51 %)**	**404 (25 %)**	**402 (25 %)**
	OLF Coupeville to Ault Field	**1,363 (83 %)**	**--**	**269 (16 %)**
TOTAL		***85,768 (85 %)***		***15,860 (15%)***

We can interpret this information in terms that are applicable to marbled murrelets' daily activities. Certain marbled murrelet behaviors, such as foraging and staging for inland flights, are more likely to occur during the pre-dawn, daylight, or pre-dusk period during the breeding season. During the marbled murrelet breeding season, sunrise in the action area occurs between 0500 and 0710, depending on the date. We expect that only a small proportion of the breeding season Growler flights will occur during the pre-dawn period. Sunset during the breeding season occurs between 1930 and 2115, depending on the date. Thus, the pre-dusk period falls within the daytime hours, 0700 through 2200, when most Growler flights will occur. Similarly, much of the period of daylight falls within this period of more intensive Growler activity. During the non-breeding season, it is not clear whether there are particular times of day that are more or less significant for particular marbled murrelet behaviors, so we do not analyze the daily timing of flights within this season.

Similar information is not available regarding the seasonality of Growler flights, and we assume that on average over the long term, the temporal distribution of Growler flights will be spread evenly throughout the year. Therefore, we assume that on average, half of the Growler flights will occur during the breeding season and half will occur during the non-breeding season. The maximum number of Growler flights in a given season (breeding season or non-breeding season)

is not anticipated to greatly exceed half of the flights listed for a high-tempo year (Farak, in litt. 2019a), so we similarly assume that during a high-tempo year, half of the Growler flights will occur during the breeding season and half during the non-breeding season.

Individual flight tracks will be used more or less frequently during different seasons, depending on prevailing wind patterns. For example, flight tracks that use Ault Field runway 14 are more likely to be used during the non-breeding season, when prevailing winds are most often from the southeast, and those that use Ault Field runway 25 are used more often during the breeding season, when prevailing winds are generally from the southwest (Navy 2018, p. 3-7).

9.2.2.1.5 Frequency of Exposures Over Time

There are several possible approaches to describing the frequency of marbled murrelet exposures to disturbance-level sound from Growler aircraft. The most straightforward is to simply count the number of exposures per year, which is a product of the number of exposures per flight track and the number of times each flight track will be flown per year. In terms of the effects to the species, it is also informative to consider how often specific areas of marine habitat are ensonified at 92 dBA_{SEL} or louder. Finally, in an effort to understand how individual birds are likely to respond to the action, we would like to understand how often individual birds will be exposed to disturbance-level sound.

The estimated annual number of individual marbled murrelet exposures to loud sounds from Growler overflights is given for the "average exposure" scenario, which combines an average year of Growler operations with average marbled murrelet densities, in Table 12, which uses a weighted average based on the annual distribution of flight tracks, and Table 13, which uses a weighted average based on a seasonal distribution of flight tracks. The estimate for a "high exposure" scenario, which combines a high-tempo year of Growler operations with higher-than-average marbled murrelet densities, is given in Table 14, which uses a weighted average based on the annual distribution of flight tracks, and Table 15, which uses a weighted average based on a seasonal distribution of flight tracks. Each table also lists the expected number of exposures to 45-minute FCLP periods and to groups of three aircraft participating in an interfacility flight. The boldfaced values in Tables 12, 13, 14, and 15 show which weighting scheme, annual or seasonal, resulted in a higher exposure estimate for a given type of operation, time period, and exposure scenario.

In general, higher total estimates of exposure annually and during the breeding season result from the assumption that flight track use would be the same in both seasons (annual weighting), and higher total estimates of exposure during the non-breeding season result from the assumption that flight track would be heavily skewed by season (seasonal weighing). However, this varies by type of operation. We analyze exposures to FCLP periods, groups of three interfacility flights, and single exposures separately, because each of these types of exposure differ in duration. In each case, we carry forward the weighting scheme that leads to the greater level of exposure (bolded in Tables 12 through 15 below). In some cases, we use different estimates for the breeding and non-breeding season, because we do not want to underestimate exposure in any given season. We expect that the actual seasonal distributions of the various flight tracks will fall in between the two distributions modeled here, but may be closer to one distribution than the

other. Therefore the actual exposure will also fall between the two estimates, but may be closer to one estimate than the other. We use the higher estimate for each type of exposure (single exposure, triple exposure, and FCLP period) to avoid underestimating marbled murrelet exposures of each duration.

Table 12. Estimated annual number of individual marbled murrelet exposures to disturbance-level noise from Growler activities, "average exposure" scenario, with annual weighting of flight tracks

Type of Operation		Estimated Number of Individual Marbled Murrelet Exposures Per Year		
		Breeding Season	**Non-Breeding Season**	**Annual Total**
AULT FIELD				
Departures		**459,673**	682,804	**1,142,477**
Arrivals	Straight-in/Full-stop	176,142	239,681	415,824
	Overhead Break	**200,700**	262,108	**462,808**
	Instrument Approach	**9,489**	20,783	30,272
Pattern Operations	T&G	**13,346**	26,584	39,931
	Ground-controlled Approach	**369,252**	865,888	1,235,140
	Depart and Re-enter	75,245	**177,033**	**252,278**
	FCLP (FCLP periods)*	**6,696** **(279)**	13,529 (564)	20,224 (843)
OLF COUPEVILLE				
Pattern Operations	FCLP (FCLP periods)*	**72,602** **(3,025)**	**156,867** **(6,536)**	**229,469** **(9,561)**
Interfacility Flights	Ault Field to OLF Coupeville (Triple exposures)**	171,083 (57,028)	**219,172** **(73,057)**	390,255 (130,085)
	OLF Coupeville to Ault Field (Triple exposures)**	**95,406** **(31,802)**	172,382 (57,461)	267,789 (89,263)
TOTAL INDIVIDUAL EXPOSURES		***1,649,634***	*2,836,832*	*4,486,467*
TOTAL SINGLE (NON-FCLP, NON-INTERFACILITY) EXPOSURES*		***1,303,848***	*2,274,883*	***3,578,730***
TOTAL FCLP PERIOD EXPOSURES		***3,304***	*7,100*	*10,404*
TOTAL INTERFACILITY EXPOSURES		*88,830*	***130,518***	*219,348*

* The number in parenthesis is the number of exposures to FCLP periods, which is the number of individual exposures associated with FCLP flights, divided by 24, because each FCLP period is associated with 48 operations, equivalent to 24 circuits of the flight track.

** The number in parenthesis is the number of triple exposures from interfacility flights, which is the number of individual exposures associated with interfacility flights, divided by 3.

***This total is the total number of individual non-FCLP, non-interfacility exposures, and includes individual exposures that are part of a double exposure.

Table 13. Estimated annual number of individual marbled murrelet exposures to disturbance-level noise from Growler activities, "average exposure" scenario, with seasonal weighting of flight tracks

Type of Operation		Estimated Number of Individual Marbled Murrelet Exposures Per Year		
		Breeding Season	**Non-Breeding Season**	**Annual Total**
AULT FIELD				
Departures		75,025	**772,464**	847,489
Arrivals	Straight-in/Full-stop	**228,337**	**319,186**	**547,523**
	Overhead Break	152,086	**286,093**	438,179
	Instrument Approach	4,646	**33,029**	**37,675**
Pattern Operations	T&G	7,484	**39,417**	**46,901**
	Ground-controlled Approach	279,607	**1,063,784**	**1,343,391**
	Depart and Re-enter	**76,441**	175,961	252,402
	FCLP (FCLP periods)*	3,882 (162)	**19,788** **(825)**	**23,670** **(986)**
OLF COUPEVILLE				
Pattern Operations	FCLP (FCLP periods)*	**72,602** **(3,025)**	**156,867** **(6,536)**	**229,469** **(9,561)**
Interfacility Flights	Ault Field to OLF Coupeville (Triple exposures)**	**219,651** **(73,217)**	188,823 (62,941)	**408,474** **(136,158)**
	OLF Coupeville to Ault Field (Triple exposures)**	81,641 (27,214)	**191,434** **(63,811)**	**273,076** **(91,025)**
TOTAL INDIVIDUAL EXPOSURES		*1,201,403*	***3,246,847***	***4,448,250***
TOTAL SINGLE (NON-FCLP, NON-INTERFACILITY) EXPOSURES*		*823,626*	***2,689,935***	*3,513,561*
TOTAL FCLP PERIOD EXPOSURES		*3,187*	***7,361***	***10,547***
TOTAL INTERFACILITY EXPOSURES		***100,431***	*126,752*	***227,183***

* The number in parenthesis is the number of exposures to FCLP periods, which is the number of individual exposures associated with FCLP flights, divided by 24, because each FCLP period is associated with 48 operations, equivalent to 24 circuits of the flight track.

** The number in parenthesis is the number of triple exposures from interfacility flights, which is the number of individual exposures associated with interfacility flights, divided by 3.

***This total is the total number of individual non-FCLP, non-interfacility exposures, and includes individual exposures that are part of a double exposure.

Table 14. Estimated annual number of individual marbled murrelet exposures to disturbance-level noise from Growler activities, "high exposure" scenario, with annual weighting of flight tracks

Type of Operation		Estimated Number of Individual Marbled Murrelet Exposures Per Year		
		Breeding Season	**Non-Breeding Season**	**Annual Total**
AULT FIELD				
Departures		**1,016,068**	**1,030,511**	**2,046,578**
Arrivals	Straight-in/Full-stop	323,573	379,269	702,842
	Overhead Break	499,701	357,170	856,871
	Instrument Approach	**22,532**	33,912	56,444
Pattern Operations	T&G	**56,181**	**32,244**	**88,425**
	Ground-controlled Approach	**689,067**	1,600,628	2,289,695
	Depart and Re-enter	136,206	**315,022**	**451,228**
	FCLP (FCLP periods)*	**29,694** **(1,237)**	17,287 (720)	**46,981** **(1,958)**
OLF COUPEVILLE				
Pattern Operations	FCLP (FCLP periods)*	**196,239** **(8,177)**	**283,093** **(11,796)**	**479,332** **(19,972)**
Interfacility Flights	OLF Coupeville to Ault Field (Triple exposures)**	197,841 (65,947)	**428,550** **(142,850)**	**626,391** **(208,797)**
	OLF Coupeville to Ault Field (Triple exposures)**	**149,078** **(49,693)**	338,442 (112,814)	487,520 (162,507)
TOTAL INDIVIDUAL EXPOSURES		***3,316,179***	*4,816,128*	***8,132,307***
TOTAL SINGLE (NON-FCLP, NON-INTERFACILITY) EXPOSURES*		***2,743,328***	*3,748,756*	***6,492,084***
TOTAL FCLP PERIOD EXPOSURES		***9,414***	*12,516*	***21,930***
TOTAL INTERFACILITY EXPOSURES		*115,639*	***255,664***	***371,304***

* The number in parenthesis is the number of exposures to FCLP periods, which is the number of individual exposures associated with FCLP flights, divided by 24, because each FCLP period is associated with 48 operations, equivalent to 24 circuits of the flight track.

** The number in parenthesis is the number of triple exposures from interfacility flights, which is the number of individual exposures associated with interfacility flights, divided by 3.

***This total is the total number of individual non-FCLP, non-interfacility exposures, and includes individual exposures that are part of a double exposure.

Table 15. Estimated annual number of individual marbled murrelet exposures to disturbance-level noise from Growler activities, "high exposure" scenario, with seasonal weighting of flight tracks

Type of Operation		Estimated Number of Individual Marbled Murrelet Exposures Per Year		
		Breeding Season	**Non-Breeding Season**	**Annual Total**
AULT FIELD				
Departures		305,735	1,000,981	1,306,716
Arrivals	Straight-in/Full-stop	**411,386**	**569,022**	**980,408**
	Overhead Break	**545,017**	**431,455**	**976,471**
	Instrument Approach	18,907	**57,814**	**76,721**
Pattern Operations	T&G	31,507	47,806	79,313
	Ground-controlled Approach	521,816	**1,966,362**	**2,488,178**
	Depart and Re-enter	**137,316**	313,115	450,431
	FCLP (FCLP periods)*	17,218 (717)	**25,283** **(1,053)**	42,501 (1,771)
OLF COUPEVILLE				
Pattern Operations	FCLP (FCLP periods)*	**196,239** **(8,177)**	**283,093** **(11,796)**	**479,332** **(19,972)**
Interfacility Flights	Ault Field to OLF Coupeville (Triple exposures)**	**221,950** **(73,983)**	367,425 (122,475)	589,375 (196,458)
	OLF Coupeville to Ault Field (Triple exposures)**	132,608 (44,203)	**375,820** **(125,273)**	**508,428** **(169,476)**
TOTAL INDIVIDUAL EXPOSURES		*2,539,698*	***5,438,176***	*7,977,873*
TOTAL SINGLE (NON-FCLP, NON-INTERFACILITY) EXPOSURES***		*1,971,683*	***4,386,555***	*6,358,238*
TOTAL FCLP PERIOD EXPOSURES		*8,894*	***12,849***	*21,743*
TOTAL INTERFACILITY EXPOSURES		***118,186***	*247,748*	*365,934*

* The number in parenthesis is the number of exposures to FCLP periods, which is the number of individual exposures associated with FCLP flights, divided by 24, because each FCLP period is associated with 48 operations, equivalent to 24 circuits of the flight track.

** The number in parenthesis is the number of triple exposures from interfacility flights, which is the number of individual exposures associated with interfacility flights, divided by 3.

***This total is the total number of individual non-FCLP, non-interfacility exposures, and includes individual exposures that are part of a double exposure.

Over 30 years, we expect the total number of exposures to be thirty times the average annual exposures (30 times the bolded numbers in the right-most columns in the lower three rows of Tables 12 and 13). This amounts to 107,362,950 exposures of individual marbled murrelets to single or double exposures, 6,762,630 triple exposures caused by interfacility flights, and 158,220 exposures to 45-minute FCLP training periods. We expect that no more than 39,115,650 of the single or double exposures, 3,159,120 of the triple exposures, and 49,560 of the FCLP period exposures will occur during the breeding season, and no more than 68,247,300 of the single or double exposures, 3,915,540 of the triple exposures, and 110,400 of the FCLP period exposures will occur during the non-breeding season. In some cases, the breeding season

and non-breeding season numbers add up to a number larger than the year-round total. This is because we are uncertain as to how exposures will be distributed between the two seasons, but in these cases we do not expect that exposure will be at the maximum level in both seasons.

We analyzed the frequency of exposure of several specific areas of marine habitat. These areas include locations near the airfields, which will receive the most frequent exposure to disturbance-level sounds, and several marbled murrelet hotspots within the action area that are beneath one or more flight tracks. The locations include the nearshore area west and northwest of Ault Field, Admiralty Bay, Saratoga Passage, the main basin of Skagit Bay, Dugualla Bay, the area around Deception Pass, Rosario Strait, Crescent Harbor, Penn Cove, Admiralty Inlet, Burrows Bay, and the area off of southern Lopez Island. To conduct this analysis, we looked at the flight track maps (Appendix A, and see also Navy 2018, Appendices A4 and A5) to determine which flight tracks crossed each of the specific areas. We combined this information with the information regarding how often each flight track is used each year (see Appendix D) to determine how many flights are expected to cross each area in an average or a high tempo year. We then divided the annual numbers of overflights by 365 to determine how many times per day overflights are expected to occur in each area, and when appropriate, we divided the daily numbers by 24 to determine the number of overflights per hour.

The nearshore area to the west and northwest of Ault Field will be the area most often exposed to sounds 92 dBA_{SEL} or louder from Growler aircraft. In addition to FCLP periods at Ault Field, most or all of which will affect this area, a large proportion of pattern operations, arrivals at, and departures from Ault Field will ensonify this area. In an average year, 5,936 FCLP airfield operations will be performed at Ault. If each FCLP period involves three aircraft performing 16 airfield operations apiece, then each period involves 48 airfield operations and there will be approximately 124 FCLP periods at Ault. In a high tempo year, 6,413 FCLP airfield operations will be performed at Ault Field, which equates to approximately 134 FCLP periods. We assume that each FCLP period will ensonify the area to the west and northwest of Ault Field for approximately 45 minutes, with some portions of the area subjected to sounds louder than 92 dBA_{SEL} for much of that time. The number of FCLP periods ensonifying the area west and northwest of Ault Field will be reduced if some periods involve 4 or 5 aircraft, if aircraft perform 18 or 20 airfield operations apiece during some periods, or if some periods use only flight track 25FM1, which travels entirely over land. Aside from FCLP periods, Growler aircraft will fly over this area approximately 36,020 times in an average year, and 36,667 times in a high tempo year. In either type of year, this amounts to approximately 100 exposures per day, or one exposure every 15 minutes. However, since few flights are expected in the early morning hours, overflights during the day are likely to occur at intervals of less than 15 minutes. Most of the time, these overflights will take place immediately after takeoff or immediately before landing, when aircraft are flying low and often using high power, but exposure of any given area to 92 dBA_{SEL} or louder sounds is still expected to last no longer than 75 seconds.

Admiralty Bay will be ensonified by FCLP periods at OLF, and occasionally by other flights. Each FCLP period at OLF will use either runway 14 or runway 32, but not both. Periods that use runway 32 will ensonify Admiralty Bay. In an average year, about 16,941 FCLP airfield operations will be performed at OLF runway 32, which equates to approximately 353 FCLP periods. In a high-tempo year, about 18,654 FCLP airfield operations will be performed at OLF

runway 32, which equates to approximately 389 FCLP periods. Since FCLP periods are typically not scheduled on weekends, we assume that there will be many days with no FCLP periods scheduled and many days with multiple FCLP periods scheduled. Some interfacility flights will ensonify Admiralty Bay. Many of these will be flights arriving at or departing from OLF runway 32, and we assume that each of these will be immediately followed or preceded by an FCLP period that uses runway 32, so will not really lead to an independent exposure of the marine environment to sound. However, around 241 interfacility flights in an average year, and 265 interfacility flights in a high-tempo year, will depart from runway 14 before flying over Admiralty Bay. We assume that these occur in groups of three aircraft that have just completed an FCLP period, and therefore constitute 80 or 88 groups of exposures. We expect these overflights will be spaced one minute apart and may not be perceived by marbled murrelets as separate events. If four or five aircraft are involved, this will reduce the number of incidents, but increase the duration of each incident. Additionally, around 23 times per year, Growler aircraft conducting a non-break arrival at Ault will first fly over Admiralty Bay. We expect that these will be single exposures. In all, most of the loud ensonification of Admiralty Bay is expected to result from frequent FCLP periods, with less than one additional triple or single overflight, on average, per day.

Saratoga Passage will also be ensonified by FCLP periods at OLF and by other flights. Periods that use OLF runway 14 will ensonify Saratoga Passage. In an average year, about 6,788 FCLP airfield operations will be performed at OLF runway 14, which equates to approximately 141 FCLP periods. In a high-tempo year, about 7,474 FCLP airfield operations will be performed at OLF runway 14, which equates to approximately 156 FCLP periods. Some interfacility flights will ensonify Saratoga Passage. Many of these will be flights arriving at or departing from OLF runway 14, and we assume that each of these will be immediately followed or preceded by an FCLP period that uses runway 14, so will not really lead to an independent exposure of the marine environment to sound. However, around 74 flights in an average year, and 82 flights in a high-tempo year, will depart from runway 32 before flying over Saratoga Passage. We assume that these occur in groups of three aircraft that have just completed an FCLP period, and therefore constitute 25 or 27 triple exposures. Additionally, many arrivals to runway 32 at Ault Field involve overflights of Saratoga Passage. These overflights are expected to occur around 760 times in an average year and 769 times in a high-tempo year. In all, Saratoga Passage is expected to be ensonified at 92 dBA_{SEL} several times per week by FCLP periods, and a little more than two times per day by single or triple overflights.

Skagit Bay and Dugualla Bay will be ensonified regularly by interfacility flights and single overflights. Interfacility flights will pass over these areas 800 times during an average year or 880 times during a high-tempo year. We assume that these occur in groups of three aircraft traveling to or from an FCLP period, and therefore constitute 267 or 293 groups of exposures, likely perceived by marbled murrelets as a single 3-minute event. Additionally, other, single Growler aircraft are expected to ensonify Skagit Bay 16,938 times in an average year, or 17,151 times in a high-tempo year. Single overflights are expected to ensonify Dugualla Bay 15,447 times in an average year, or 15,706 times in a high-tempo year. For both Skagit Bay and Dugualla Bay, this averages to between 42 and 47 exposures per day, or almost 2 per hour. Exposures may be more frequent during the breeding season, since many of the flight tracks

associated with these exposures involve arrivals at Ault Field runway 25, which is used most often between April and October. Exposures will also be more frequent during the day, and less frequent during the early morning hours.

Rosario Strait and the area around Deception Pass will also be ensonified regularly by single overflights, and some interfacility flights will ensonify the southern portion of Rosario Strait. Interfacility flights are expected to travel into Rosario Strait approximately 653 times in an average year or 718 times in a high-tempo year, equivalent to 218 or 239 events each consisting of three exposures in quick succession. In addition, single overflights are expected to ensonify Rosario Strait around 8,724 times in an average year, or 8,848 times in a high-tempo year. Single overflights are expected to ensonify Deception Pass and nearby areas around 8,533 times in an average year, or 8,791 times in a high-tempo year. This amounts to 23 or 24 single overflights per day, on average, or one exposure per hour. In Rosario Strait, both the single and triple exposures are likely to be more frequent in the non-breeding season, and less frequent in the breeding season, since many of the flight tracks involve Ault Field runway 14, which is used most often between October and April. In both of these locations, exposures are likely to be more frequent during the day, and less frequent during the early morning hours.

Crescent Harbor will be ensonified by interfacility flights and single flights. Interfacility flights are expected to pass over Crescent Harbor approximately 552 times in an average year or 608 times in a high-tempo year, equivalent to 184 or 203 events each consisting of three exposures in quick succession. In addition, single overflights are expected to ensonify Crescent Harbor around 3,973 times in an average year, or 4,058 times in a high-tempo year. This amounts to around 11 single overflights per day, on average, or a little less than one exposure every two hours, and an additional, triple exposure approximately every two days. Crescent Harbor will likely be exposed to loud sounds more frequently during the non-breeding season, and less frequently during the breeding season, since many of the flight tracks involve Ault Field runway 14, which is used most often between October and April. As in other areas, exposures are likely to be more frequent during the day, and less frequent during the early morning hours.

Penn Cove and Admiralty Inlet will be ensonified mainly by interfacility flights, but also by single flights. Interfacility flights are expected to pass over Penn Cove approximately 1,398 times in an average year or 1,539 times in a high-tempo year, equivalent to 466 or 513 events each consisting of three exposures in quick succession. Admiralty Inlet is expected to be exposed to interfacility flights approximately 1,648 times in an average year or 1,815 times in a high-tempo year, equivalent to 549 or 605 triple exposures. Because FCLP periods are typically not scheduled on weekends, we assume that there will usually be two days each week without interfacility flights. Therefore, Penn Cove and Admiralty Inlet are each likely to receive around two triple exposures per day on weekdays. In addition, single overflights are expected to ensonify Penn Cove around 785 times in an average year, or 787 times in a high-tempo year. This amounts to around two single overflights per day, on average. In Admiralty Inlet, single overflights are expected only 154 times in either an average year or a high-tempo year. This amounts to less than one flight every two days.

Burrows Bay and the waters off of southern Lopez Island will be ensonified only by single overflights. Burrows Bay is expected to be exposed to loud overflights around 5,611 times in an

average year or 5,689 times in a high-tempo year. This averages out to 15 or 16 exposures per day, or around 2 exposures every 3 hours. Overflights are expected to ensonify the waters off southern Lopez Island approximately 2,388 times in an average year or 2,432 times in a high-tempo year. This averages out to around 7 exposures per day, or one exposure approximately every 4 hours. In Burrows Bay, overflights are likely to be more frequent in the non-breeding season, and less frequent in the breeding season, since most of the flight tracks involve Ault Field runway 14, which is used most often between October and April. In both of these locations, exposures are likely to be more frequent during the day, and less frequent during the early morning hours.

Marbled murrelets are very mobile during most of the year, and can move in and out of marine foraging areas often as part of their natural behavior responding to ocean conditions (Becker and Beissinger 2003, p. 251; Lorenz et al. 2017, pp. 312-318). However, at least in some locations, many marbled murrelets do exhibit fidelity to core foraging areas during the day (Bradley 2002, p. 53). In addition, marbled murrelets are flightless for a time, and therefore less mobile, while undergoing the pre-basic molt in the fall. Therefore, we expect variation in marbled murrelet movement patterns, depending on the season, ocean conditions, prey conditions, and variability between individual birds.

A foraging marbled murrelet dives repeatedly, with short pauses in between dives. Typically, a diving bout lasts around half an hour, with considerable variation among birds and depending on the sea state (Henkel et al. 2003, p. 10; Jodice and Collopy 1999, pp. 1412-1413). During the day, successive foraging bouts are separated by a period of around an hour, during which time the bird may rest or move to a different location (Henkel et al. 2003, p. 10; Jodice and Collopy 1999, pp. 1411-1412). Thus, we expect foraging marbled murrelets to spend at least 30 minutes in a given location, and more likely several hours, unless low prey availability or disturbing events prompt it to move sooner. Less is known about the timing of marbled murrelet movements and activities that do not involve foraging activity. During the breeding season, aggregations of marbled murrelets, including fish-holding birds, have been observed to gather at nearshore locations for around an hour before flying inland at dusk (Strachan et al. 1995, pp. 251-252). It is not clear whether similar behavior may occur prior to dawn, the time of day when most nestlings are fed (Nelson and Hamer 1995, pp. 61-62), but if so, these gatherings may be less easily observed by humans in the pre-dawn darkness. In short, whether marbled murrelets are actively foraging or not, we expect that they will generally stay in one place for an extended period of time, unless prompted by external factors to move to another location.

Therefore, especially in areas of high marbled murrelet concentration, many of which likely have consistent prey availability or other important features, we expect that individual marbled murrelets using these areas will be subject to overflights at approximately the frequencies described above. Such areas include Admiralty Inlet, Burrows Bay, Penn Cove, the vicinity of Deception Pass, and the waters south of Lopez Island (see Courtney et al. 1996, pp. 23-24; MMEMM 2015; USFWS 2017a, p. 28). In areas with less consistent marbled murrelet presence, we expect that individual marbled murrelet visits to these areas may be shorter. Therefore, in areas where marbled murrelets are less often concentrated, birds may visit the areas in between overflights, or may only stay for a portion of the day's overflights, as described above.

The entire Zone 1 breeding season population has included around 4,730 individuals, on average, during 2012 through 2018 (McIver et al. 2019, pp. 13-15). Assuming that this is the population using the action area during the breeding season, each individual will be subjected to an average of 349 overflights during the breeding season (1,649,634 divided by 4,730), or two per day during the breeding season, given the average breeding season total of 1,649,634 individual exposures (Table 12). We expect that these exposures will consist of 1,303,848 single or double exposures, 100,431 triple exposures to interfacility flights, and 3,304 45-minute exposures to FCLP periods (Tables 12 and 13). Therefore, in a year with average exposure, Zone 1 marbled murrelets will each be exposed to an average of 276 single or double exposures and 21 triple exposures during the breeding season, and a little more than two-thirds of individuals will be exposed to a breeding season FCLP period. Given that at least some individuals are likely to vary in their use of the action area and specific areas near flight tracks, we expect a large degree of variation in the exposure of individual marbled murrelets, with some rarely or never being exposed to Growler overflights and others exposed to many more than two loud overflights per day. However, we do not have enough information to construct a histogram predicting how many marbled murrelets will be exposed at different frequencies.

During the non-breeding season, the population of marbled murrelets within Zone 1 and the action area usually increases. In the immediate area of Whidbey Island, the non-breeding season population doubles or triples, on average, from the breeding season population (see Section 8.1.1). In Conservation Zone 1 as a whole, the population has historically increased by around three- to five-fold (Fitzgerald, in litt. 2016). If we assume a three-fold increase in the number of marbled murrelets at least occasionally present in the area beneath Growler flight tracks, the average winter population of marbled murrelets that could be exposed to Growler overflights would include 14,190 individuals. With 3,246,847 individual exposures on average in the non-breeding season (Table 13), we would expect an average of 229 exposures per individual (3,246,847 divided by 14,190), or a little more than one per day. We expect that these exposures will consist of 2,689,935 single or double exposures, 130,518 triple exposures from interfacility flights, and 7,361 45-minute exposures to FCLP periods (Tables 12 and 13). Therefore, in an "average exposure" year, Zone 1 marbled murrelets will each be exposed to an average of 190 single or double exposures and 9 triple exposures during the non-breeding season, and around half of individuals will be exposed to a non-breeding season FCLP period. (Note that if we assumed a four- or five-fold increase in the population, the number of individuals would increase, but the number of exposures per individual would decrease.) Similar to the breeding season, we expect that some marbled murrelets using the action area during the non-breeding season will avoid exposure altogether, while others will be exposed substantially more than once per day.

In a "high exposure" year, in which high-tempo Growler operations coincide with higher-than-average marbled murrelet densities, we refer to the 2005 breeding season marbled murrelet population as our reference point. That year, the Conservation Zone 1 population included an estimated 7,956 individuals (McIver et al. 2019, p. 11). Given a "high exposure" estimate of 3,316,179 individual exposures during the breeding season (Table 14), we would expect an average of 417 exposures per individual (3,316,179 divided by 7,956), or a little more than two per day. We expect that these exposures will consist of 2,743,328 single or double exposures, 118,186 triple exposures from interfacility flights, and 9,414 45-minute exposures to FCLP

periods (Tables 14 and 15). Therefore, in a "high exposure" year, Zone 1 marbled murrelets will each be exposed to an average of 345 single or double exposures and 15 triple exposures during the breeding season, and one breeding season FCLP period. As during an average year, these estimates should be regarded as population averages, and some individuals are likely to have greater exposure while others may be exposed to few, if any, loud Growler overflights.

If we again assume a tripling of the population between the breeding and non-breeding seasons, in a "high exposure" year we would expect that 23,868 marbled murrelets might be present in the action area and have a possibility of exposure to loud Growler overflights. Given a "high exposure" estimate of 5,438,176 individual exposures during the non-breeding season (Table 15), we would expect an average of 228 exposures per individual (5,438,176 divided by 23,868), or a little more than one per day. We expect that these exposures will consist of 4,386,555 single or double exposures, 255,664 triple exposures from interfacility flights, and 12,849 45-minute exposures to FCLP periods (Tables 14 and 15). Therefore, in a "high exposure" year, Zone 1 marbled murrelets will each be exposed to an average of 184 single or double exposures and 11 triple exposures during the non-breeding season, and around half of individuals will be exposed to an FCLP period. Again, some individuals will receive greater exposure and others may not receive any exposure.

In summary, we expect that the action, as implemented by the Navy, will result in 4,486,467 exposures of individual marbled murrelets to individual overflights in an "average exposure" year, though some of these will be grouped together in events lasting 3 or 45 minutes. In a "high exposure" year, we expect 8,132,307 individual exposure events. Although these numbers of exposures are high, they amount to Conservation Zone 1 population averages of around two exposures per marbled murrelet per day during the breeding season, and around one exposure per marbled murrelet per day during the non-breeding season, regardless of the "average exposure" or "high exposure" scenario. In any given season, marbled murrelets on average will be exposed to one or fewer 45-minute FCLP period per season, and fewer than two FCLP periods per year. We expect that exposure levels will vary across the population. If there are individuals that regularly use the area to the west and northwest of Ault Field, Admiralty Bay, or Saratoga Passage, these individuals are likely to receive more intense and, in the case of the area near Ault Field, more frequent exposures; however, these areas are not known to have high marbled murrelet densities. In areas where larger numbers of marbled murrelets are likely to spend longer periods of time, exposure frequencies range from multiple exposures per hour during the day (for example, the area around Deception Pass) to a few exposures per day (for example, Admiralty Inlet and Penn Cove), with Burrows Bay and the important foraging area to the south of Lopez Island falling in between.

9.2.3 Marbled Murrelet Response to Increased Sound Pressure Levels in the Marine Environment

The Navy has been conducting flight operations from Whidbey Island since the 1940s (Navy 2017, p. 30), and flying Growlers from the Island since 2012 (Navy 2017, p. 9). Throughout this period marbled murrelets have continued to be observed in the marine environment around Whidbey Island. However, the continued presence of a species in an area subject to loud sounds does not necessarily mean that individuals of that species are unaffected by exposure to those

sounds (Francis and Barber 2013, p. 305). Even in cases where disturbances have large negative effects on an individual's fitness, individuals may remain present in the disturbed area if there are no better alternative habitat areas (Gill et al. 2001, p. 266). When a species does not have an obvious response to a stressor (e.g., completely avoiding an area where stressors occur) it can be challenging to assess the consequences of exposure.

There are no known research efforts on the response of birds to Growler overflights, or of marbled murrelets to military aircraft overflights. Therefore, we relied on more general information on the response of other birds to military aircraft overflights, other aircraft overflights, and other noise, as well as information on the responses of marbled murrelets to other types of aircraft and to other stressors, mainly boats, in the marine environment. Researchers have studied the responses of birds to noise generally, and some have investigated response to aircraft overflights, and even military aircraft overflights, specifically. Of these, some are more applicable to analyzing the expected response of marbled murrelets to noise from Growler overflights. Since marbled murrelets will be exposed to noise from Growler overflights in their marine habitat rather than their nesting habitat, we focused primarily on studies of non-nesting birds, and especially of birds in aquatic habitats. However, we refer also to studies of closely-related species (other alcids), even when these studies took place at breeding colonies. Also, studies that examine the effects of continuous, relatively low-level noise (Kleist et al. 2018 for example) are not as useful for analyzing this action, which will present intermittent, higher-level noise of shorter duration.

If and when marbled murrelets respond to Growler overflights, their responses may be behavioral, physiological, or both. Behavioral responses may or may not be easily detectable by an observer. Physiological responses are invisible to an observer, and detection of these responses often necessitates collecting biological samples or placing monitoring equipment inside or at least in direct contact with the subject. Both visible and invisible responses may have fitness consequences for the individual, in terms of reproductive success or survival.

9.2.3.1 Behavioral Responses to Overflights

Although no information is available regarding marbled murrelets' responses to Growlers or other military aircraft, some information is available regarding their responses to small airplanes. Several studies have been conducted in which researchers attempted aerial surveys of marbled murrelets at sea, and in most cases, compared aerial and boat-based survey results. In two cases, substantially fewer marbled murrelets were counted from the air than from a boat (Nysewander et al. 2005, p. 125; Strong et al. 1995, p. 347). Although much of the discrepancy was likely due to the difficulty of observing a small bird from a relatively fast-moving platform, the "wary" behavior of the birds probably played a role (Nysewander et al. 2005, p. 105). In one survey, at least eight percent of marbled murrelets visibly dove in front of the airplane (Strong et al. 1995, p. 347). In another case, marbled murrelet population density estimates generated from aerial and boat-based surveys were similar, and statistical evaluation of the boat-based data, via distance sampling, indicated that marbled murrelets were not avoiding the survey boat (Henkel et al. 2007, pp. 148-149). This implies that they also did not dive to avoid the airplane. In a fourth case, no comparison was made with boat-based methods, but the researchers were confident that marbled murrelets were not diving ahead of the airplane, because the visibility conditions were

so clear that birds could be identified even when they were underwater immediately after diving (Varoujean and Williams 1995, p. 328). Several researchers hypothesized that discrepancies in the effectiveness of aerial surveys were due to differences in the sound levels generated by the various aircraft used for these surveys (Henkel et al. 2007, p. 146; Nysewander et al. 2005, p. 105). All of the aforementioned studies used aircraft flying near 60 m (200 ft) above sea level, so in these cases, differences in marbled murrelet response were not due to differences in flight altitude (Henkel et al. 2007, p. 146; Nysewander et al. 2005, p. 3; Strong et al. 1995, p. 340; Varoujean and Williams 1995, p. 327). Another study documented a negative correlation between marbled murrelet counts and the number of boats and low-flying aircraft present, but this study did not include observations of behavioral responses, nor did it examine the effect of aircraft separately from the effect of boats (Kuletz 1996, pp. 776-778).

Marbled murrelets' responses to the approach of boats have been more thoroughly documented than their responses to airplanes. Most studies involve small (4 to 9 m [13 to 30 ft]), motorized boats (Bellefleur et al. 2009, p. 532; Entranco Inc. and Hamer Environmental L.P. 2005, p. 7; Hentze 2006, p. 10; Speckman et al. 2003, p. 32; Strong et al. 1995, p. 339), although one study involved cruise ships (Marcella 2014, entire). These responses generally fall into three categories: avoidance diving, flying, and no apparent reaction. Avoidance dives are distinguished from foraging dives by the bird's behavior immediately before the dive. Avoidance dives are preceded by the bird looking in the direction of the boat, paddling away from the boat, or surfacing very near the boat, followed by an immediate dive (Entranco Inc. and Hamer Environmental L.P. 2005, p. 14). When marbled murrelets respond to small boats, avoidance dives are the most common response. Between 8 and 31 percent of marbled murrelets dive when approached by a small boat, whereas between 1 and 15 percent fly, and between 58 and 90 percent had no apparent response (Bellefleur et al. 2009, p. 4; Entranco Inc. and Hamer Environmental L.P. 2005, p. 14; Hentze 2006, p. 3; Strong et al. 1995, p. 347). Notably, in the case with the lowest response rate, marbled murrelets were actively foraging on herring, even though the birds were less than 300 m from active marine pile driving (Entranco Inc. and Hamer Environmental L.P. 2005, pp. 9, 20). A species that feeds on mobile or aggregated prey, like herring, may be especially committed to high-value foraging sites, regardless of the presence of potentially disturbing stimuli (Gill et al. 2001, p. 267). In another case, however, nearly all of the birds that flew in response to the boat also left the area where they had been foraging previously, relocating at least 200 m away (Bellefleur et al. 2009, p. 5). The likelihood of marbled murrelets reacting at all, or leaving the area in particular, increases in windy conditions, when the sea state is choppy, and decreases when they are in a group (Hentze 2006, p. 20). Marbled murrelet response to large cruise ships is more likely to involve flight, and nearly all individuals respond to approach by cruise ships (Marcella 2014, p. 56).

Fish-holding marbled murrelets also sometimes swallow the fish when approached by boats. This response has been observed at least eight times, all in cases when the bird was holding fish crosswise in the bill (Speckman et al. 2004, p. 33). The researchers did not report the total number of fish-holding birds they approached, so the rate at which fish-holding marbled murrelets swallow the fish as a startle response remains unknown. Marbled murrelets also hold fish lengthwise in the bill (Carter and Sealy 1987, p. 289), which may make fish-holding and fish-swallowing behavior more difficult to detect.

Birds exhibit a range of responses to military and other aircraft overflights, including no change in behavior at all, looking in the direction of the sound, alert posture, increased vigilance, agitated movements, paddling or walking away, changes in resting, cessation of foraging, increase in preening and other "comfort" behaviors, avoidance diving, flight, increase in agonistic behaviors, and leaving the area (Bélanger and Bédard 1989, pp. 716-718; Conomy et al. 1998, pp. 1139-1140; Dunnet 1997, pp. 60-63; Fleming et al. 1996, pp. D-8-D-13; Fuller et al. 2018, p. 263; Goudie 2006, pp. 29-31; Goudie and Jones 2004, pp. 290, 293-295; Komenda-Zehnder et al. 2003, pp. 6-7; Olsson and Gabrielsen 1990, pp. 13-17; Rojek et al. 2007, p. 64; Smit and Visser 1993, pp. 8, 11-13; Strong et al. 1995, p. 347; Ward et al. 1999, pp. 375-377; Williams 2007, p. 430). Depending on a variety of circumstances, the proportion of individuals reacting to an overflight ranges from 1.3 percent for American wigeons (*Mareca americana*) (Fleming et al. 1996, p. D-10-D-11) to 100 percent for greater snow geese (*Chen caerulescens atlantica*) (Bélanger and Bédard 1989, p. 718). When an overflight does elicit a response, the duration of the response may range from a few seconds, for example, when green-winged teals (*Anas crecca carolinensis*) return to resting 15 seconds after flushing in response to a military overflight (Fleming et al. 1996, pp. D-10-D-13), to at least two hours, for example, when harlequin ducks (*Histrionicus histrionicus*) exhibit increased agonistic behaviors during the two hours following military overflights (Goudie and Jones 2004, p. 294).

The likelihood of responding, the type of response, and the duration of response all vary by species, even within the same genus (Smit and Visser 1993, p. 13; Ward et al. 1999, pp. 375-377). For example, when subjected to overflights, flocks of Canada geese (*Branta canadensis taverneri*) are less likely to flush than flocks of Pacific brant geese (*Branta bernicla nigricans*), though many Canada geese do exhibit alert posture without flushing (Ward et al. 1999, pp. 376-377). Among shorebirds, depending on species, between 15 and 100 percent of individuals have been observed to react to aircraft overflights, and between 5 and 87 percent of flocks have been observed to flush in response to overflights, meaning that at least half of the individuals in the flock took flight (Smit and Visser 1993, pp. 12-13). Eurasian curlews (*Numenisu arquata*) resumed foraging 7 minutes after flushing in response to aircraft overflight, whereas oystercatchers (*Mermatopus ostralegus*) at the same site did not resume foraging until 30 minutes after flushing (Smit and Visser 1993, p. 13). Diving birds, such as white-breasted cormorants (*Phalacrocorax carbo lucidus*) and little grebes (*Tachybaptus ruficollis*), have been observed to dive in response to aircraft overflights (Williams 2007, p. 430).

When aircraft overflights are observed at seabird breeding colonies, as they have been for a variety of alcid and other seabird species, birds' responses depend in part on their breeding status (Dunnet 1977, pp. 60-62; Fuller et al. 2018, pp. 264-265; Olsson and Gabrielsen 1990, pp. 20-21; Rojek et al. 2007, p. 66). In particular, common murres (*Uria aalge*) and thick-billed murres lay eggs directly on the rock, and flushing by a brooding bird risks dislodging the egg (Fuller et al. 2018, p. 265; Olsson and Gabrielsen 1990, p. 24; Rojek et al. 2007, p. 63). Other bird species may also be more likely to remain on the nest and guard eggs or nestlings, rather than flushing in response to perceived threats (Fuller et al. 2018, pp. 264-265; Palestis 2005, p. 89; Vos et al. 1985, p. 17). In some cases when flushing has been observed at breeding colonies as a response to aircraft overflights, observers have noted that the flushed birds were not guarding nests; these flushing birds may have had a mate on brooding duty at the time or may have been non-breeders simply roosting at the colony (Dunnet 1977, pp. 60, 62; Olsson and Gabrielsen 1990, pp. 13-17;

Rojek et al. 2007, p. 66). Brooding birds have been observed to flush, but appears that they do so at lower rates (Olsson and Gabrielsen 1990, p. 16). This factor must be considered when applying information collected at breeding colonies to birds on the water.

A number of aircraft-related factors also appear to affect the likelihood and type of response to overflights, including the type of aircraft, sound level, flight altitude, and lateral distance. Helicopters generally cause more disturbed behavior than do fixed-wing aircraft (Fuller et al. 2018, p. 263; Komenda-Zehnder et al. 2005, p. 8; Rojek et al. 2007, p. 64; Ward et al. 1999, p. 376). Observations from different studies vary as to whether military jets provoke more (Fuller et al. 2018, p. 262; Goudie 2006, p. 31) or less (Fleming et al. 1996, p. A-8; Smit and Visser 1993, p. 11) of a reaction than other aircraft. Lower altitude overflights are generally more likely to induce a response from nearby birds (Fuller et al. 2018, p. 265; Komenda-Zehnder et al. 2005, pp. 6-7), with several studies showing effects tapering off to zero between 300 and 450 m (around 1,000 to 1,500 ft) AGL (Fuller et al. 2018, p. 265; Komenda-Zehnder et al. 2005, p. 7; Rojek et al. 2007, p. 64). However, this pattern is inconsistent, at least for helicopters (Rojek et al. 2007, p. 64), and birds have been observed to react to helicopter overflights as high as 1,219 m (4,000 ft) (Ward et al. 1999, pp. 375-376). Lateral distance is also important, with the closest passes leading to the strongest responses (Fuller et al. 2018, p. 264; Ward et al. 1999, p. 376), but responses have been observed when aircraft are as far away as 2.5 km (1.6 miles) or even 4.8 km (3 miles) (Olsson and Gabrielsen 1990, p. 19; Ward et al. 1999, p. 375). Louder overflights are associated with greater changes in behavior (Fleming et al. 1996, pp. D-10-D-11; Goudie 2006, p. 33; Goudie and Jones 2004, p. 294; Ward et al. 1999, p. 376).

Habituation is often invoked as an explanation for low response rates or as a moderating factor when noise-related stressors will occur regularly (e.g., Fleming et al. 1996, p. A-9; Smit and Visser 1993, pp. 16-17; Williams 2007, p. 431). Habituation is a process in which an individual animal learns over time that a particular stimulus is not associated with detrimental or beneficial consequences, and reduces its response (Bejder et al. 2009, p. 180). Some studies have found some degree of evidence for habituation of birds to aircraft noise (Ward et al. 1999, p. 378), but others have not (Komenda-Zehnder et al. 2003, p. 10; Olsson and Gabrielsen 1990, p. 22). Different species, even closely related species, can have differing capacities for habituation to the same stimulus; for example, black ducks (*Anas rubripes*) habituated to recorded military aircraft sounds played 48 times per day, but wood ducks (*Aix sponsa*) did not (Conomy et al. 1998, pp. 1139-1140). In some cases, researchers have observed increasing reactions to overflights over time, possibly due to sensitization, or to associations with other stimuli (Fuller et al. 2018, p. 264; Smit and Visser 1993, p. 16). For example, breeding common murres were likely to flush in response to drone overflight in a year when bald eagles (*Haliaeetus leucocephalus*) were present near the colony than in a year when eagles were not present (Brisson-Curadeau et al. 2017, p. 6). Even when habituation does occur, exposure to overflights may continue to have physiological or fitness effects, in spite of reduced or absent behavioral responses (Frances and Barber 2013, p. 311; and see Section 9.2.3.2 and 9.2.4).

Putting all of this information together, we are reasonably certain that some, but not all, marbled murrelets will exhibit behavioral responses to Growler overflights. The proportion of marbled murrelets reacting visibly to aircraft or boats ranges from 8 to 42 percent, well within the range of individual rates of response reported for various bird species to various aircraft overflight

types. We found only two studies reporting responses to both boats and aircraft for the same species and location; both reported greater responses to aircraft than to boats. Greater snow geese spent more time flying, and paused for a longer time before resuming foraging, after flushing in response to aircraft than when flushing was caused by boats (Bélanger and Bédard 1989, pp. 716-718). When breeding colonies were approached by aircraft, common murres were more likely to respond at all, and more likely to respond by flushing, than when colonies were approached by boat (Rojek et al. 2007, p. 64). In addition, marbled and Kittlitz's murrelets have a higher response rate when disturbances are moving faster (Agness et al. 2008, pp. 351-352; Bellefleur et al. 2009, pp. 534-535), and the slowest Growler (130 knots or about 240 km/hr, Navy 2018, pp. A5-7 – A5-24) will be travelling much faster than the fastest boat from these studies (48 km/hr, Agness et al. 2008, p. 348). Furthermore, louder disturbances generally elicit stronger behavioral reactions in birds (Ward et al. 1999, pp. 375-377; Goudie and Jones 2004, pp. 293-294; Goudie 2006, p. 33), and Growlers will be louder than the small boats used in the boat disturbance studies. On the other hand, marbled murrelet response rates to boats increase as the boats approach close to the birds (Bellefleur et al. 2009, p. 354; Hentze 2006, p. 12; Strong et al. 1995, p. 345). While Growlers close to the runways will fly low enough to be at distances comparable to disturbance distances observed for most boats (100 m, Hentze 2006, p. 12), the aircraft will be at higher altitudes along the majority of their flight tracks. Marbled murrelets have been observed to flush or dive at distances up to 800 m (around 2,600 ft), a common flight altitude for Growler overflights in this action, in response to large cruise ships (Marcella 2014, p. 56). Taken together, we interpret this information to indicate that marbled murrelets are generally more likely to respond to aircraft overflights than to boats.

There is likely to be a range of response rates to overflights, as there is to boats. For example, we assume that when marbled murrelets are intently foraging on a school of readily-available fish, they will be less likely to exhibit behavioral responses to overflights than when they are resting between foraging bouts. We acknowledge that individual marbled murrelets may habituate to overflights, and some may already be highly tolerant of overflights; on the other hand, sensitization is also possible, and may depend on context, such as the presence of predators. Without specific information, we do not assume that most marbled murrelets will habituate or become sensitized to Growler overflights. We assume that marbled murrelets' behavioral responses to Growler overflights will include the same behaviors they exhibit in response to boats: avoidance diving, taking flight, leaving the area, and, for fish-holding birds, swallowing the fish. Some of the behavioral responses recorded for other bird species, such as decreases in resting time, decreases in foraging time, or increases in preening, are also possible. We do not assume that marbled murrelets will increase agonistic interactions in response to overflights, since we are not aware of any observations of this type of behavior for marbled murrelets at sea, with or without overflights.

9.2.3.2 Physiological Responses to Overflights

Marbled murrelets exposed to Growler overflights may also experience physiological responses, which may or may not be accompanied by behavioral responses. Physiological responses are considerably more difficult to observe than behavioral responses, and no attempts have been made to measure marbled murrelet physiological responses to Growlers or other aircraft. Most investigations of physiological response to disturbance involve responses to human handling or

presence, especially given that humans must be near the animal, and usually handle it, in order to collect this type of data. One such study has been performed on marbled murrelets. A few studies have documented physiological responses of other bird species to real or simulated aircraft overflights, and have observed changes in body temperature, heart rate, growth rates, or stress hormones.

Much of the research on physiological responses to stressors has involved penguins. Numerous studies have recorded varying degrees of response to handling or human presence, in terms of increased heart rate, increased body temperatures, or stress hormone responses (e.g., Ellenberg et al. 2007, p. 57; Ellenberg et al, 2013, p. 6; Regel and Putz 1997, p. 249). In one case, Emperor penguin (*Aptenodytes forsteri*) body temperature increases of at least 0.9 °C (1.62 °F) were also recorded in response to helicopter overflights, and this response did not differ from the same individuals' responses to various research procedures (Regel and Putz 1997, p. 249). In adults, body temperature remained elevated for an average of 75 minutes (Regel and Putz 1997, p. 249). The penguins in this study had been captured and were kept in a pen, where they were handled regularly for research. Their physiological responses to stressors may be different from those of birds in more natural settings, without handling (Regel and Putz 1997, p. 252), but this result does demonstrate that temperature increases in response to aircraft overflight can be similar to those that occur in response to handling.

Some investigations have been carried out regarding ducks' physiological responses to recordings of military jet sounds (Fleming et al. 1996, pp. F-1-F-11; I-6). Heart rates were measured in captive black ducks for several days, including four days in a row when recorded overflights were played back 48 times per day, with a peak SL of 110 dBA (Fleming et al. 1996, p. F-1). Note that 110 dBA_{Peak} is not directly comparable to the 92 dBA_{SEL} standard used in our analysis. On the first day of sound playbacks, the ducks' heart rates spiked 37 percent of the time during the first six playbacks of the day, whereas over the same timeframe on previous days, heart rates only spiked 18 percent of the time. On subsequent days with sound playbacks, heart rates spiked at rates similar to the days prior to the playbacks (Fleming et al. 1996, p. F-11). Note that this species also demonstrated behavioral habituation in a related experiment (Conomy et al. 1998, p. 1139; see above in Section 9.2.3.1). In another related experiment, newly hatched, captive-bred mallard (*Anas platyrhynchos*) ducklings were also exposed to recorded FB111 military jet sounds 48 times a day, with SL varying from 100 to 120 dBA_{Peak}, and average duration of 31 sec, over a four-week period (Fleming et al. 1996, pp. I-4-I-6). At four weeks of age, ducklings subjected to aircraft sounds had 4.6 percent less biomass than control ducklings raised without aircraft sounds and also had altered skeletal growth (Fleming et al. 1996, p. I-6). The researchers hypothesized that stress hormones played a role in the reduced growth rates (Fleming et al. 1996, p. I-10).

Stress hormones, or glucocorticoids, are steroid hormones produced through a hormonal cascade that starts in the hypothalamus and pituitary and ends in the adrenal glands (hypothalamic–pituitary–adrenal axis, HPA axis) (Sapolsky et al. 2000, p. 64). This hormonal cascade is a negative-feedback loop that can be turned off once a stressor disappears. Although glucocorticoids, which generally take the form of corticosterone in birds, are commonly referred to as stress hormones, their full range of physiological functions is not entirely understood. They are involved not only in stress responses, but also in mediating a variety of physiological

processes and behaviors, including feather growth, migration, and reproduction (DesRochers et al. 2009, pp. 48-50; Eikenaar et al. 2017, pp. 3-4; Wingfield and Sapolsky 2003, p. 714). However, the basic role of glucocorticoids in an individual's stress response is well-understood. In the short term, an individual's stress response and associated hormonal production are critical for its capacity to adapt to environmental conditions and maintain homeostasis, redirecting the individual's behavior and physiological activity toward essential functions for immediate survival. When an animal no longer perceives a stressor, the stress response should decline to baseline levels, after negative feedback is provided to the HPA axis via glucocorticoid receptors in the brain. If a stressor persists, leading to chronic stress, baseline glucocorticoid levels can be altered, sometimes to the point of causing dysfunction of the HPA axis. This dysfunction is often termed "allostatic overload", and can cause a variety of negative effects to the individual. Essentially, corticosterone in birds can be both beneficial and detrimental to individuals, depending on the time frame in which elevated levels persist (Martin 2009, p. 72; McEwen and Wingfield 2003, entire; Wingfield 2005, entire).

Investigations of avian stress responses often attempt to measure both baseline corticosterone levels, as well as increases induced by stressors, as these provide different types of information. When a bird is exposed to a stressor, corticosterone levels take several minutes to rise, so blood corticosterone levels measured immediately after an animal is captured are usually interpreted as reflecting baseline levels, in spite of the fact that the handling required for blood collection is typically quite stressful for the bird (Wingfield et al. 1995, p. 287). Stress-induced corticosterone responses are typically measured 15 or 30 minutes following capture (e.g. Ellenberg et al. 2007, p. 56; Malueg 2007, p. 63).

In the single available study of corticosterone in marbled murrelets, the capture process typically took longer than five minutes, and baseline corticosterone levels could not often be measured, so the main measurement variable was the peak corticosterone level at 30 minutes post-capture (McFarlane Tranquilla 2001, pp. 71-72, 75). This study compared peak corticosterone levels of birds to which radio transmitters were attached during handling and birds who were captured and handled with no radio transmitter attachment, and found no difference between the two groups (McFarlane Tranquilla 2001, pp. 76, 82).

In a few cases, studies have investigated the corticosterone responses of birds to stressors involving aircraft noise, or simulated aircraft noise. Blue tit (*Cyanistes caeruleus*) chicks exposed to one hour of sound simulating an airport runway did not differ from unexposed chicks in their corticosterone levels (Wolfenden 2017, pp. 83-84, 89-90). Northern cardinals (*Cardinalis cardinalis*) living in high-activity areas of a military base, and therefore exposed to frequent, intense helicopter sounds and other activities, showed no difference in baseline or stress-induced corticosterone levels as compared with cardinals living in low-activity areas (Barron et al. 2012, p. 915). However, male red-cockaded woodpeckers (*Picoides borealis*) exposed to military training activities, which included helicopter use among other activities, had reduced baseline levels of corticosterone, as compared with those living in habitat buffered by 200 to 600 ft from the military activities (Malueg 2007, pp. 61, 67). Other studies have also observed that when exposures to stressors are unpredictably repeated over the long term, baseline corticosterone levels, as well as stress-induced corticosterone levels, may be reduced (Barron et al. 2012, p. 912).

None of these studies closely approximates the conditions that marbled murrelets will experience as a result of this action. Studies involving captive birds obviously take place in a very different environment, and physiological responses of captive birds to stressors may be altered by their regular and close contact with humans (Regel and Putz 1997, p. 252). Several studies of free-living birds did investigate physiological responses to stressors related to aircraft noise, but other factors make it unclear how applicable the results might be to marbled murrelets exposed to Growler overflights. For example, one study did not distinguish between helicopter overflights and infantry training (Malueg 2007, p. 61), and another exposed very young nestling birds to a single one-hour recording of intermittent aircraft noise (Wolfenden 2017, pp. 83-84). Nonetheless, this collection of studies represents the best available information regarding avian physiological responses to aircraft overflight. Therefore, uncertainty remains as to whether marbled murrelets will respond to Growler overflights with increased body temperatures, increased heart rates, reduced growth rates, or changes in baseline or stress-induced corticosterone levels. However, this uncertainty does not greatly affect our evaluation of the resulting effects of the action to individuals, as outlined in the next section.

9.2.4 Resulting Effects to Individuals of Behavioral and Physiological Responses

The behavioral and physiological responses discussed above are relevant when they result in negative consequences for individual marbled murrelets. Most consequences of the potential reactions, including both the behavioral and physiological responses, involve a change in energy intake, or output, or both. These consequences may be negative or neutral, depending on the context. The behavioral and physiological responses of adults, subadults, and fledged juveniles exposed to Growler overflights will at times disrupt foraging, reducing energy intake, and may involve movement or increases in metabolic rate, both of which increase energy output. In addition, when a fish-holding breeding adult swallows the fish, this may result in the loss of a feeding and reduced energy intake for the nestling. We discuss the effects to exposed individuals and effects to nestlings separately below.

9.2.4.1 Effects to Adults, Subadults, and Fledged Juveniles

One consequence of marbled murrelet responses to Growler overflight is the interruption of foraging activity. The different behavioral responses vary in the degree to which they are likely to interrupt foraging. First, Growler overflights that occur during a foraging bout are more likely to disrupt foraging than are flights that occur while marbled murrelets are engaged in other activities. Growler overflights that do not occur during a foraging bout could still potentially alter foraging behavior, given that altered behavior patterns in other species have been observed within the two hours after exposure to military jet overflights (Goudie and Jones 2004, p. 294). However, a flush response to Growler overflight during the middle of a foraging bout is more clearly a disruption of foraging, especially when the bird leaves the foraging area (Bellefleur et al. 2009, p. 5). When interruptions to marbled murrelet foraging have been measured in response to boats, they have averaged 105.4 seconds, including flight time and time until foraging resumed following the flight (Hentze 2006, p. 25). We note that even when marbled murrelets leave a foraging area in response to Growler overflight, we expect that they will return later the same day or the next day, rather than avoiding the area altogether, based on the responses of closely-related Kittlitz's murrelets to boat traffic (Agness et al. 2008, p. 352). We

assume that marbled murrelets are more likely to fly away from an area when the Growler exposure is protracted or repeated multiple times in a short period, as it will be along the northwest side of Whidbey Island, in Admiralty Bay, and in Saratoga Passage. When birds dive in response to Growler overflight, it is not clear whether avoidance diving might sometimes lead to incidental foraging opportunities, but it seems likely that avoidance dives are less likely to result in the consumption of prey than foraging dives targeted at catching prey.

Marbled murrelet energy intake may be limited in one of two ways: when prey are abundant and readily available, energy intake is likely to be limited by the bird's capacity for digestion, as it is in thick-billed murres (Elliott et al. 2014, p. 143, and see section 8.1.3). When prey are scarce, energy intake is likely to be limited by the ability to find and catch prey (Elliott et al. 2014, p. 142). When marbled murrelet responses to Growler overflights interrupt foraging activities, the consequences may be different in each of these situations. When prey are abundant and readily available, we assume that brief disruptions in foraging are inconsequential, in terms of energy intake, because it will not be difficult to catch additional prey. When prey are scarce, disruptions in foraging are more likely to lead to opportunity costs, since it may be difficult or impossible for marbled murrelets to replace the prey they could have caught, if they had not spent time reacting to Growler overflight. We also recall the example of marbled murrelets foraging intently on herring, in spite of nearby active pile driving and the presence of boats, which were being used in an attempt to haze marbled murrelets away from the construction area (Entranco Inc. and Hamer Environmental L.P. 2005, pp. 9, 20). In a season when prey are generally scarce, if marbled murrelets find an area where prey are available, they may exhibit lower rates of behavioral responses to Growler overflights, and continue foraging instead. This type of response would be in keeping with the behavior of ruddy turnstones (*Arenaria interpres*), which flush more readily when approached by humans after receiving supplemental mealworms (Beale and Monaghan 2004, pp. 1067-1069).

Other behavioral and potential physiological responses, including flushing, avoidance diving, increases in body temperature, and increases in heart rate, are all likely to increase energy output. Among behavioral responses, flushing is likely to require the greatest energy expenditure, but avoidance diving may also be costly, especially if some avoidance dives are anaerobic. Increases in body temperature and heart rate also increase energy expenditure.

Flight is costly for marbled murrelets, as it is for other alcids (Elliott et al. 2004, p. 645; Hull et al. 2001, p. 1036; Pennycuick 1987, pp. 343-345). There is some uncertainty as to exactly how costly, as characteristics of marbled murrelets' flight appear to contradict the assumptions of existing flight energetics models (Elliott et al. 2004, pp. 646-651). Nonetheless, existing flight energetics models provide the best available information regarding alcid flight energetics, and have been used to estimate how flight responses to boats increase energy output for Kittlitz's murrelets.

Kittlitz's murrelets are very similar to marbled murrelets in size, life history, and foraging behavior. Marbled and Kittlitz's murrelets share a similar suite of behaviors in response to the presence of boats, including diving, flying, and leaving the area, though non-breeding Kittlitz's murrelets appear to favor a flight response (Agness et al. 2008, pp. 249-352). Non-breeding Kittlitz's murrelet flight responses to peak levels of boat traffic for Glacier Bay, Alaska, are

estimated to result in increased energy expenditure of at least 10 percent, and sometimes even more than 50 percent, as compared with no vessel traffic (Agness et al. 2013, p. 16). Each additional boat increased a non-breeding Kittlitz's murrelet's energy expenditures by 3.99 kJ, approximately 0.6 percent of daily energy expenditure (Agness et al. 2013, p. 18). Breeding Kittlitz's murrelets are less likely to fly, so their flight responses to peak boat traffic are estimated to cause energy expenditure increases of up to 30 percent (Agness et al. 2013, p. 16). At average rates of vessel traffic, Kittlitz's murrelets are likely to have smaller increases in energy expenditure, usually less than 10 percent, and breeding birds will only be affected on 25 percent of days (Agness et al. 2013, p. 16). Boat traffic in these models ranged from 0 to 1.5 boats per hour (Agness et al. 2008, p. 348). We expect that marbled murrelets will dive more often than fly, in response to Growler overflights, so flight-related increases in marbled murrelet energy expenditure due to the Navy's action may more closely resemble those of breeding Kittlitz's murrelets. However, parts of the action area, such as the northwest shoreline of Whidbey Island, Deception Pass, and Burrows Bay, are likely to receive higher rates of Growler exposure than the boat passage rates modeled for Glacier Bay, so flight-related increases in energy expenditure may be greater in these locations.

Diving is likely to be less costly than flying, but diving does still have an energetic cost. The energetic costs of diving are measured in terms of the diving metabolic rate, and its ratio to resting, basal, or standard metabolic rates, which are all slightly different ways to represent the metabolic rate of an animal at rest. Increases in metabolic rate indicate that an animal is using energy more quickly. Estimates of diving metabolic rates of various diving bird species range from being similar to resting metabolic rates, up to nine times the basal metabolic rates for the same species (Croll et al. 1992, p. 351; Ponganis 2016, p. 170). For thick-billed murres, diving metabolic rate is estimated to be around three times the resting metabolic rate (Croll et al. 1992, p. 351). A model of marbled murrelet diving energetics assumed ratios of diving to standard metabolic rates between 1.5 and 6 (Peery et al. 2009, p. 125). Most marbled murrelet dives use aerobic respiration, but longer dives, or dives that follow especially short rest periods on the surface, use anaerobic respiration, which is more energetically costly, results in lactic acid build-up in muscle tissue, and requires a longer recovery time at the surface (Butler and Jones 1997, pp. 840, 879; Jodice and Collopy 1999, pp. 1413, 1416; Peery et al. 2009, pp. 128-130). Marbled murrelets sometimes avoidance dive immediately after surfacing from a foraging dive, or avoidance dive repeatedly when the perceived threat is still present at the end of the first avoidance dive (Entranco Inc., and Hamer Environmental L.P. 2005, p. 14; Fitzgerald, in litt. 2018). In these cases, anaerobic respiration may be necessary, increasing the energetic cost of the diving. We assume that a single avoidance dive without rest is likely when a marbled murrelet surfaces during a Growler overflight, and that repeated avoidance diving is most likely in longer-duration exposures, either from low, slow, high-powered Growler overflights or from clusters of overflights, as will occur during interfacility flights.

If marbled murrelets respond to Growler overflights with increased body temperature or heart rate, these physiological responses will also be associated with increased metabolic rate, and will involve increased energy use. When molting penguins exhibited increased body temperatures in response to helicopter overflights, the estimated increase in daily energy expenditure from the reaction to each overflight was 1.7 percent for adults, and 9.9 percent for chicks (Regel and Putz 1997, p. 251). When black ducks were exposed to recorded aircraft noise, their short-lived heart

rate increases were not enough to increase daily energy expenditures (Fleming et al. 1996, p. F-14), but heart rate and energy expenditure are so closely related that heart rate monitors have been used to measure black duck daily energy expenditures (Wooley and Owen 1978, p. 739). We are not certain whether, or to what degree, marbled murrelets will exhibit these physiological responses to Growler overflights, but if they do, the immediate consequence to the individual will be the same as the consequences of diving or flight: an increase in energy expenditure.

Although we are reasonably certain that marbled murrelet exposure to Growler overflight will sometimes result in flying, diving, or physiological responses that use energy, we are uncertain how often, and so we cannot quantify an average expected increase in energy expenditure per exposure or per bird. The average number of exposures per bird per day is expected to be around two during the breeding season, and fewer during the non-breeding season, for both an average year and a high-exposure year; some birds will be exposed more often and some more rarely. Most exposures to SL louder than 92 dBA_{SEL} are expected to be less than 30 seconds, especially for marbled murrelets that are not immediately beneath the flight path. In fact, some individuals that are present in the ensonified marine area may miss the exposure altogether, if it occurs while they are underwater during a foraging dive. The average foraging dive lasts around 25 seconds, and many dives are longer than average (Henkel et al. 2003, p. 10; Jodice and Collopy 1999, p. 1412; Peery et al. 2009, 128). Thus, many birds will have brief, intermittent exposures, and will probably not spend large amounts of energy in response. Individuals that spend much of their time in areas receiving more frequent low-altitude Growler traffic, including marbled murrelet hotspots like Deception Pass and Burrows Bay, are likely to be exposed far more often, in some cases multiple times per hour, and we expect that birds that spend time in these areas will respond in ways that increase their energy expenditure to some degree, perhaps up to a 30 percent increase, as was estimated for breeding Kittlitz's murrelets responding to boat traffic at a maximum to 1.5 boats per hour (Agness et al. 2013, p. 16), or even more, given that overflights are likely to be more disruptive than boat approaches.

Increases in energy expenditure will have consequences for individual marbled murrelets, especially when energy intake is decreased at the same time. Non-breeding adult Kittlitz's murrelets must consume more than a third of their body weight in Pacific sand lance to maintain their typical metabolic rate (Hatch 2011, pp. 75, 81). During chick rearing, the amount of Pacific sand lance required increases to two-thirds of the breeding adult's body weight (Hatch 2011, pp. 75, 81). We expect adult marbled murrelets to have similar nutritional requirements, although we also expect them to consume a wider variety of prey. When nutritionally-adequate prey resources are abundant and available, non-breeding marbled murrelets are likely to be able to forage more to make up for increased energy expenditures. When marbled murrelets are breeding, even when high-quality prey resources are readily available, we expect that their energy intake and expenditure is already near the physiological maximum, and that any energy spent on reactions to Growler overflights will either be taken from body reserves, as has been observed in breeding thick-billed murres (Elliott et al. 2014, p. 141), or result in reductions in energy spent on foraging for self-maintenance, foraging for chicks, or flying inland. In addition, if marbled murrelets use anaerobic metabolism to fuel their avoidance dives, they will have to compensate for the energy lost to extra activity while also spending more time at the surface to recover from those anaerobic dives. In this situation marbled murrelets will still have the energy deficit, but compensating for the lost energy by catching additional prey will be more difficult

due to the required recovery time at the surface. When prey are scarce, or when the nutritional quality of available prey is poor, we expect that marbled murrelets will not be able to readily offset increases in energy expenditure with additional foraging, and will need to draw on body reserves.

When a marbled murrelet must use body reserves to meet its energy needs, there may or may not be fitness consequences, most likely in terms of reproductive success. Marbled murrelets in good physical condition with adequate fat reserves may not experience fitness consequences from short-term use of body reserves, but we expect that often, many marbled murrelets will not be in good physical condition with adequate fat reserves, and will experience these fitness consequences. For seabirds in general, when forage conditions are moderate to poor, many individuals forgo breeding (Cairns 1987, p. 264; Cury et al. 2011, p. 1704; Field et al. 2010, pp. 2228-2231; Furness 2007, p. 249). This phenomenon has been observed for marbled murrelets, as well (Becker et al. 2007, p. 276; Peery et al. 2004b, pp. 1094-1095; Ronconi and Burger 2008, p. 252). When adult marbled murrelets must increase their energy expenditures, and this expenditure cannot be offset by increased foraging, we expect individual marbled murrelets to be less likely to attempt breeding, and breeding marbled murrelets may be more likely to abandon nesting attempts.

Increased energy expenditure without increased energy intake can also affect survival. In general, long-lived seabirds like marbled murrelets are expected to prioritize their own survival over their breeding success in any given year (Davis et al. 2005, p. 1047; Kitaysky et al. 2007, p. 246). Indeed, marbled murrelets in California had better survival rates in a year with poor prey availability than in a year with better forage conditions, probably because fewer attempted breeding in the year when food was scarce (Peery et al. 2006, pp. 83-85). However, at least for some seabird species, there is evidence that adults may sometimes continue a nesting attempt, even when increased effort is required, and this can decrease adult survival rates (Davis et al. 2005, p. 1054). It is not clear whether there are conditions in which breeding marbled murrelets would prioritize the success of a current nesting attempt over their future survival, but especially during moderate or poor forage conditions, increased energy demands during the breeding season are likely to require them to prioritize either current reproductive success or survival. When forage conditions are very poor, marbled murrelets are likely to have lower-than-usual survival rates even when they are not attempting to breed, and additional energy expenditures are likely to reduce survival rates further. For seabirds in general, forage conditions poor enough to cause adult starvation are thought to be rare, and typically associated with anomalous ocean conditions (Cairns 1987, p. 262). However, these conditions do occur, and may be increasing in frequency; several mass recent mortality events involving emaciated adult alcids have occurred along the Pacific Coast, from California to Alaska (Jones et al. 2018, pp. 3193, 3197; Jones et al. 2019, pp. 8-9, 11, 16). Within the action area, mass mortality of adult rhinoceros auklets (*Cerorhinca monocerata*) in 2016 was linked with poor forage fish availability (Hodum et al. 2018, pp. 5, 10-12). The diets of rhinoceros auklets and marbled murrelets substantially overlap, and although widespread adult starvation of marbled murrelets has not been observed, three individual adult marbled murrelet carcasses have been found in the action area in emaciated condition (NWHC 2011, p. 1; NWHC 2012, p. 1; NWHC 2015, p. 1).

There are a variety of factors that can affect the physical condition of marbled murrelets, including prey availability, breeding (or attempting to), disease, toxic pollutants, travelling long distances, and disturbances. These stressors can interact. For example, when birds become malnourished, they become more susceptible to infection (Beer 1968, p. 122; Smith 1975, p. 243). Similarly, toxic exposures can interact with malnourishment, with nutritional deficiencies leading to more severe effects from some kinds of toxic exposures (Eeva et al. 2003, pp. 1246-1248; Fox 1979, pp. 96-100). Therefore, we expect that in situations when marbled murrelets become malnourished due to energy expended on responses to Growler overflights, they will not only be at increased risk of mortality due directly to starvation, but will also be at increased risk of illness or mortality due to infection or exposure to toxic pollutants.

Food abundance and body condition influence baseline and peak corticosterone levels in common murres and other seabirds (Kitaysky et al. 1999, pp. 579-581; Kitaysky et al. 2007, pp. 249-252). If and when marbled murrelets become malnourished due to increased energy expenditure that is not offset by increased intake, baseline corticosterone levels and peak stress-induced levels may both rise. Increased baseline and stress-induced corticosterone levels may be beneficial for adult survival, as they facilitate foraging behavior and mobilize stored energy reserves for movement, but can lead to reduced effort spent on breeding (Kitaysky et al. 1999, p. 583; Kitaysky et al. 2001, pp. 620, 622-624; Kitaysky et al. 2007, p. 251). However, common murres with elevated baseline corticosterone levels may also have reduced survival rates (Kitaysky et al. 2007, p. 252). These physiological responses to food stress are markedly different from the stress hormone responses, or in some cases lack of response, that have been measured in the context of aircraft overflights. We do not know whether there will be a direct influence of Growler overflights on the marbled murrelet HPA, but if so, this influence is likely to take place in the context of the corticosterone response to prey availability and body condition, which will in turn be influenced by marbled murrelet energetic expenditure in response to Growler overflight. Unless the direct influence of Growler overflights somehow counteracts the body condition effects on the HPA, we expect that the influence of Growler flights on the marbled murrelet HPA are likely to be in keeping with the rest of the effects discussed here: decreased probability of breeding and decreased effort toward breeding, with the effects on survival being less clear.

We expect that responses to the action could lead to energy deficits for breeding adults, non-breeding adults, subadults, and juveniles throughout the year. These energy deficits will affect birds differently depending on age, breeding status, and time of year. If breeding adults are faced with energy deficits that deplete their energy stores and reduce their body condition, they may reduce the amount of effort they spend foraging for the nestling (see next section) or abandon the nest altogether, prioritizing their own survival at the expense of a season of breeding success. Alternatively, they may continue the breeding attempt, potentially with the cost of decreasing their own survival probability. During the pre-basic molting phase, adult and subadult marbled murrelets typically gain weight, even though molting is energetically costly (Peery 2008, pp. 119-120). When faced with reduced food availability, they prioritize rapid molting over weight gain (Peery 2008, p. 120). Recently fledged juveniles do not undergo the pre-basic molt, so they are not affected by this trade-off. However, marbled murrelets fledge at only 58 to 71 percent of their adult weight (Nelson 1997, p. 19), so juveniles must continue growing once they reach the marine environment. Additionally, juvenile marbled murrelets may

be less likely to respond to stressors, but more likely to respond with energetically-costly flight when they do respond (Bellefleur et al. 2009, p. 536). If marbled murrelets are affected by the sounds of military overflights in a manner similar to mallard ducklings, their growth may be reduced. Marbled murrelets that fail to gain weight during the fall may become malnourished during the winter, when storms can preclude foraging for several days. Marbled murrelet nutritional status at the end of winter likely influences whether or not the bird initiates a breeding attempt.

In summary, we expect that for adult, subadult, and fledged juveniles, the consequences of behavioral and physiological responses to Growler overflights will be reduced energy intake when foraging is interrupted, and increased energy output from fight, diving, or physiological responses to overflights. In many cases, the consequences of the reduced energy intake or increased energy output will be insignificant. Insignificant consequences are expected for non-breeding birds when forage conditions are moderate or good, because we expect that they will be able to forage more at a different time to compensate. Similarly, breeding birds in good body condition will sometimes experience insignificant consequences, especially when they are not exposed frequently, even if they must occasionally use body reserves to maintain the energetic demands of breeding. Breeding birds that are exposed more frequently, that are not in good body condition, or that are experiencing low food availability are likely to experience reduced breeding success, and we expect that some will forgo or abandon nesting attempts due to increased energy expenditures. In very poor forage conditions, we expect that breeding and non-breeding birds will experience malnutrition, increasing the likelihood of starvation, or mortality or illness due to infections or toxic exposures.

9.2.4.2 Effects to Nestlings

When breeding adult marbled murrelets drop a fish that they were holding to take inland to their offspring, there are two potential outcomes (Speckman et al. 2004, p. 33). If prey suitable for delivery to the nestling are readily available, and it is early enough in the day, the adult may be able to catch another fish to replace the swallowed fish. This outcome will result in additional energy costs to the adult. Although this outcome involves the adult swallowing a fish it was not intending to eat, it is not clear that this unexpected meal for the adult actually results in additional energy intake for the adult, because when food is readily available, breeding adults are likely already operating at maximum capacity for food intake, in which case additional ingestion would lead to a digestive bottleneck (Elliott et al. 2014, pp. 138, 143). If it is not feasible for the adult to obtain a replacement fish, the nestling will miss a meal, with energy costs to the chick.

Fish-holding behavior could take place anywhere in the action area, at any time of day, from late April through late September. However, we expect that fish-holding will occur substantially more often during the pre-dawn and pre-dusk hours, and exposure of fish-holding birds may be concentrated near Deception pass and in Burrows Bay (see section 8.3.1). Growler flights during the pre-dawn hours of the breeding season are expected to be rare, but the pre-dusk hours coincide with the time of day when Growler activity will be highest. Therefore, we expect that fish-swallowing in response to Growler overflights will be most common at dusk. Throughout the year, we expect Growler overflights to occur once every 60 to 90 minutes in the vicinity of Deception Pass and Burrows Bay, respectively (see section 9.2.2.1.5). In Burrows Bay, Growler

overflight frequency may be lower than once every 90 minutes during the breeding season, since many of the flight tracks involved are used more frequently during the winter; however, it is not clear how much the frequency will be reduced. Given the frequency of Growler overflights in these areas, we expect that overflights will occur regularly during the hour or two preceding dusk. Furthermore, we expect that individual birds nesting north and south of the Skagit River are likely to use these areas regularly to stage for their inland flights, and will have multiple opportunities to be exposed to Growler overflights while holding fish. Although we do not know the frequency with which fish-holding marbled murrelets will swallow fish in response to overflight, we expect that some marbled murrelets staging in Burrows Bay and near Deception Pass will respond in this way during each breeding season, and possibly multiple times within the same breeding season.

During chick rearing, feedings take place at all times of the day and evening, but are most common at dawn and dusk (Nelson 1997, p. 18). Both males and females feed chicks at sunrise more frequently than at sunset, with morning flights accounting for up to 80 percent of daily provisioning events (Barbaree 2011, p. 128). In a review of evening versus morning marbled murrelet activity, Nelson and others (2013, p. 11) noted that dusk flights to nest sites were highly variable, and ranged from 11 to 43 percent of frequency of morning flights (mean = 28.5 percent). Chicks receive 1 to 8 meals per day (average = 3.2 +1.3) and typically fledge within 30 days after hatching, but both feeding frequency and chick development varies depending on food availability and quality (Nelson 1997, p. 18, De Santo and Nelson 1995, p. 46). These descriptive statistics regarding chick feedings are summarized in Table 16.

Table 16. Summary of average daily feeding times and rates for marbled murrelet nestlings.

	Morning feedings - 1 hour before sunrise to 2 hours after sunrise	**Mid-day feedings - 2 hours after sunrise to 2 hours before sunset**	**Evening feedings - 2 hours before sunset to 1 hour after sunset**	**Average total feedings**
Daily feedings	2	0.2	1	3.2
30-day total feedings	60	6	30	96
Percent of total feedings	62.5%	6.3%	31.3%	100%

Source: Based on average feeding rates reported by Nelson (1997, p. 18).

Fish-eating alcids, including marbled murrelets, exhibit wide variations in nestling growth rates. They grow rapidly compared to other alcids (Simons 1980, p. 7), but variation in chick development is largely influenced by access to high quality foods. On average, marbled murrelets require daily fish meals of two herring or nine male capelin per day for the nestling period, for a total of 38 herring to 255 capelin in total to raise a marbled murrelet chick (Kuletz 2005, p. 44). The nestling stage of marbled murrelet development can vary from 27 to 40 days between hatching and fledging (De Santo and Nelson 1995, p. 45). During this time, chicks invest all of their energy into growth, maintenance, and fat deposition. For a variety of seabird species (including least auklets [*Aethia pusilla*], another alcid), fat reserves are deposited only after maintenance and lipid-free dry mass maintenance energetics are met (Roby 1991, p. 137),

and we assume that this is the case for marbled murrelets as well. The variations in alcid development are attributed to constraints on feeding ecology, such as specialized foraging behaviors, unpredictable and patchy food distributions, and great distances between feeding and nesting sites (Oyan and Anker-Nilssen 1996, p. 830). Food limitation often results in poor growth, delayed fledging, increased mortality of chicks, and nest abandonment by adults (Oyan and Anker-Nilssen 1996, p. 836).

Daily feedings directly affect the rate of nestling development. If we assume that on average, each nestling receives 3.2 feedings per day, a single missed feeding would represent a loss of 33 percent of a nestling's daily food and water intake. In the short term, a missed feeding represents the loss of a portion of the day's caloric intake, but if repeated over several days, the loss of a daily feeding can quickly begin to influence the growth and development trajectory for the chick. This caloric deficit can result in developmental delays and growth stunting, which results in a longer duration at the nest for chicks, as observed for a wide variety of bird species (Richner et al. 1989, pp. 617, 621; Schew 1995, pp. 2-4; Brzęk and Konarzewski 2004, p. 1193). Missing a cumulative total of 3.2 feedings would prolong nestling development for a minimum of one day. Each successive day of missed feedings increases the risk of nest failure because adult marbled murrelets may not be able to compensate for missed feedings, and the rate of daily provisioning becomes inconsistent towards the end of nestling development (Barbaree 2011, p. 130).

One missed meal for a developing chick can have serious developmental ramifications. For the growing chick, developmental plasticity may be the only available response to such fluctuations in food resources. When decreases in food intake occur, growth is compromised so that maintenance, thermoregulation, and activity remain unaffected Schew and Ricklefs 1998, p. 294). Seabird chicks provisioned on reduced amounts of food exhibit slower growth and have a longer nesting period (Visser 2002, p. 458). Although growing more slowly in body mass, seabird chicks may allocate energy to certain aspects of growth, such as wing length, that will help ensure that they fledge successfully (Reid et al. 2000, p. 193; Dahdul and Horn 2003, p. 1073). Reproductive success and alcid chick survival are higher when diets consist of high-lipid content prey Litzow et al. 2002, p. 290). Alcid nestlings reared on high-lipid prey ingest more energy and metabolize it more efficiently (Romano et al. 2006, p. 50), resulting in large differences in body mass growth as compared to nestlings fed lower-lipid diets. Overall, chick growth rates and fledging weight are positively correlated with diets that are lipid-rich and energy-dense (Golet et al. 2000, p. 86; Kuletz 2005, p. 43).

Marbled murrelet chicks grow notably fast, even compared to other alcids, gaining 5-15 g/day during the first nine days (Nelson and Hamer 1995, p. 60). This rate of growth is due to very high assimilation efficiencies; in other words, nutrients from the food source can easily be utilized to synthesize new tissue. For example, rhinoceros auklet chicks can take in around 80 percent of the energy content of Japanese sand lance (*Ammodytes personatus*) and Japanese anchovy (*Engraulis japonicus*), similar assimilation efficiencies to those observed in other fish-eating seabird chicks (Niizuma and Yamamura 2004, pp. 99-100). The caloric deficit from missed feedings is further exacerbated by the natural drop in food deliveries from marbled murrelet parents prior to fledging (Bradley et al. 2002, p. 180). Calories delivered to the chick decrease in the last 15 days of the 30-day chick rearing period, resulting in significantly reduced food intake by marbled murrelet chicks before fledging (Bradley et al. 2002, p. 181). Alcid

chicks remain in the nest and fledge only when they are fully developed, at approximately 60 percent of adult body size (Kitaysky 1999, p. 471). Chicks must be both the correct size and have the appropriate amount of energy reserves to support their first flight. If they are not of adequate size after 30 days due to inadequate nutrition, they stay in the nest longer, further increasing the risk of predation and death (Roby 1991, p. 459).

Food restriction can significantly affect developmental stages and how the body allocates energy to the growth of different body resources in times of scarcity. Food scarcity and the consumption of inadequate calories has long term effects on the development of young chicks. Growth only occurs within a certain time window and terminates at a specific age, therefore poor feeding conditions can result in either permanent stunting or a failure to reach maturity (Golet et al. 2000, p. 80; Janssen et al. 201, p. 865). The patterns of growth and prioritization seen in marbled murrelets during times of food scarcity are consistent with the tenets of the adaptive growth hypothesis, which predicts that individual nestlings preferentially allocate resources to growth of high-priority body components (Janssen et al. 2011, p. 864), such as those for flight and feeding. For example, both wing length, bill length, and wing growth were prioritized because they are crucial for prey capture during the first week of independence in the absence of post-fledging parental care. Wing growth is essential to reach independence because failure to reach the ocean on the first flight is usually fatal (Janssen et al. 2011, p. 866). Grounded fledglings that were not able to complete their first independent flight to sea, were exhausted, and had a very low survival rate due to high predation on the ground (DeSanto and Nelson 1995, p. 46). In addition, nestlings have minimum daily energetic demands to sustain life and development, and mortality from starvation occurs when nestlings do not receive sufficient food (Kitaysky 2009, p. 471).

The consumption of insufficient calories can have both short and long term effects to developing chicks. Although there are some compensatory mechanisms that can be activated in the chick body in response to short term reductions in food availability, chicks are most often unable to demonstrate compensatory whole-body growth following calorie deficits (Schew and Ricklefs 1998, p. 296, Brzek and Konarzewski 2004, p. 3072), even following three days of high food availability. There can be significant differences in post-hatching growth rates as a result of the available food supply (Visser 2001, p. 443). Stunting and changes to the chick developmental sequence began when chicks were given 74 percent of an ad libitum diet (Brzek and Konarzewski 2004, p. 3068), demonstrating that even at ¾ of their normal caloric intake there were significant effects. At 60 percent of normal intake, chicks showed reductions in body mass, tarsus length, and length of the third primary, and wing growth was reduced by 70 percent after only one day, as compared to a control population (Schew 1995, p. 24). Studies in other animals have found that a 50 percent reduction in dietary intake resulted in permanent growth stunting of progeny (Hsueh et al. 1967, p. 197) and impairment in protein absorption (Lee and Chow 1965, p. 442). Food restriction results in effects throughout the body, including a notable reduction in body mass, intestinal mass, pectoral muscle mass, fat reserves, body temperature, and resting metabolic rate (Brzek and Konarzewski 2001, p. 3069). Chicks that were maintained on a diet that only supported maintenance for 10 days slowed wing growth to about 20 percent, and tarsus growth to 15 percent of the control group, oxygen consumption decreased, and body temperature dropped. Growth of all tissues except the brain ceased, and the rate of maturation decreased (Schew 1995, pp. 25, 138). When faced with a food restriction, birds depend on fat reserves, but

their reserves can be depleted rapidly. Structural growth is maintained at the expense of other body tissues such as the intestine, which can be catabolized as a source of protein in the absence of any fat reserves (Schew 1995, p. 24). When growth is slowed but maturation is not similarly delayed, the chick's developmental trajectory deviates from its normal course, and the chick could fail to attain normal adult size before maturity closes off the growth phase. The result would be permanent stunting and reduced fitness (Richner et al. 1989, p. 620). In addition, growth retardation is also linked to impaired immune function, reduced cognitive function, and metabolic disturbances (Braca and Ferrari 2002, p. 14, Criscuolo et al. 2008, p. 1568). As a collective, all of these effects influence the adult morphology of the bird (Searcy et al. 2004, p. 274) and its lifetime fitness.

Contemporary studies of marbled murrelet diets in the Puget Sound–Georgia Basin region indicate that Pacific sand lance now comprise the majority of the marbled murrelet diet (Gutowsky et al. 2009, p. 251). Historically, energy-rich fishes such as herring and northern anchovy made up the majority of the marbled murrelet diet (Becker and Beissinger 2006, p. 470; Gutowsky et al. 2009, p. 247). This is significant because sand lance have the lowest energetic value of the fishes that marbled murrelets commonly feed on. For example, a single northern anchovy has nearly six times the energetic value of a sand lance of the same size (Gutowsky et al. 2009, p. 251), so a chick would have to eat six sand lance to get the equivalent energy of a single anchovy. Lower caloric value food resources increases the significance of missed feeding events. Assuming nestlings receive an average of three single-fish feedings per day (Nelson and Hamer 1995, p. 61), a nestling being fed a low-quality diet composed primarily of sand lance may be on the edge of its energetic needs for successful development.

When highly nutritious prey of suitable size for delivery to nestlings is readily available, chicks are likely well-fed, and a few, intermittent missed feedings may have little effect on chick growth, developmental trajectory, and eventual adult fitness. Even in this situation, if the chick misses most of its evening meals, it will be near the 74 percent threshold at which chicks began to suffer from stunting and altered development (Brzek and Konarzewski 2004, p. 1194). When only lower-quality prey are available, or prey availability is unreliable over the course of the nestling's developmental period, nestlings may already be suffering the effects of stunting and altered development, and missed feedings will make these effects more severe.

In summary, we are reasonably certain that Growler overflights will cause some adult marbled murrelets to swallow fish intended for delivery to nestlings. We expect this to occur mainly in the evening and mainly while birds are staging for inland flights to nests located along the Skagit River corridor. Depending on forage conditions in any given breeding season, as well as how often a particular adult swallows fish intended for a nestling, the effects to the chick may be negligible or severe, but can result in the death of the nestling, if its development is not sufficient for successful fledging.

9.2.4.3 Quantification of the Number of Individuals Affected

We are reasonably certain that a subset of marbled murrelets exposed to Growler overflights will experience the significant consequences of Growler overflights discussed above. However, we are not able to quantify the number of individuals that will be affected in this way. In short, this

is because the effects of Growler overflights to individual birds are likely to be highly variable depending on context. We can describe the contexts in which birds are more likely to experience significant consequences, and in some cases we can roughly estimate how many individuals might be affected by a specific context. However, none of these estimates are satisfactory, because all exclude some individuals that will experience significant consequences and include some individuals that will not.

Important elements of the context include the abundance, availability, and quality of prey in and near the action area at a given time; the body condition of the affected individual; life stage of the affected individual; the time of day and year of exposures; the frequency of exposures; and the location of exposures. Some of these factors are fairly straightforward to quantify, but others are not.

Past abundance and quality of prey can be estimated to some degree, based on forage fish survey data (e.g. Duguid et al. 2019, pp. 26-29; Reum et al. 2011, pp. 205-206). Interpretation of this information is hampered by an incomplete understanding of the full array of marbled murrelet prey species in the action area and its surroundings (see Environmental Baseline Section). This information also is not informative regarding prey availability within marbled murrelet foraging areas. Prey is likely to be highly available when prey species are concentrated in small areas at appropriate depths and distances from shore for marbled murrelet foraging, but at other times, prey will be more widely dispersed, or located too deep in the water or too far from shore to be readily available to marbled murrelets. Timing is also important with respect to the availability of prey of appropriate size and nutritional quality for nestling feedings: an abundant supply of this prey category is of little use to marbled murrelets if it is not available during the nestling period. The dynamics of prey availability are poorly understood in the action area and its surroundings. Furthermore, past prey abundance and quality are not necessarily predictive of prey abundance and quality over the next 30 years.

Numerous factors related to the changing climate, combined with other anthropogenic influences, are likely to alter the species composition within the zooplankton and forage fish communities in and near the action area, with many projections indicating an overall downward trend in forage fish abundance (see Section 8.4 and Appendix B). There is a possibility that a particularly high-quality prey resource, northern anchovy, may increase in and near the action area, though even if so, it is not clear whether it will be readily available for marbled murrelets. There is also a possibility that the nutritional quality of particular prey species will be altered in the future. Even if we could be reasonably certain about future trends in prey abundance, availability, and nutritional quality, interannual variability will remain. We are reasonably certain that, over the next 30 years, there will be times of high, moderate, and low prey abundance and availability; however, we do not know how many years of each type are likely to occur. In other parts of the marbled murrelet range, poor forage years are related to El Niño or delayed upwelling, but these factors are not influential in the same way in and near the action area (see Environmental Baseline section).

We expect that forage conditions will be a major factor determining how many individuals experience significant consequences of the action in any given year. Forage conditions will alter the opportunity costs when individuals pause or abandon a foraging bout due to Growler

overflights: when prey are readily available, these costs will be low, because prey will be available later or in a different location, but when prey are scarce, the costs will be high, because it will take time and effort to find prey elsewhere or at another time. Forage conditions will also influence the body condition of individual marbled murrelets, which in turn will influence the consequences of the action for individuals. Marbled murrelets in good condition, with adequate energy reserves, can dip into these energy reserves to meet short-term energy needs beyond their daily energy budget, without significant consequences to survival or breeding success. When adults with lower body reserves make frequent energy expenditures related to Growler overflights, the additional energy expenditure will sometimes influence the whether the bird attempts breeding or continues a breeding attempt. In very poor forage conditions, Growler-related energy expenditures will contribute to malnourishment of adults, subadults, and fledged juveniles. Similarly, when there is abundant, available, highly nutritious prey appropriate for nestlings, breeding adults will be able to provide adequate nutrition for their nestlings with fewer inland flights than when only less nutritious prey are available, and foraging costs for nestling meals will be lower. Also, nestlings that are regularly fed more than enough to support their growth and development can use the excess nutrients to build energy reserves, and will be able to miss an occasional meal without significant consequences. With decreasing availability of appropriate, highly-nutritious prey for nestlings, a missed meal will have increasing consequences for chick growth, development, and fledging success.

As indicated in the previous paragraph, the life stage of the individual affected is likely to be highly influential in determining the types of consequences the individual experiences from Growler overflights. Breeding birds and their dependent nestlings are the most likely to experience significant consequences. Therefore, we considered making an estimate of the number of birds experiencing significant consequences based on the number of breeding marbled murrelets. In a recent population viability analysis, current population trends in Washington could be reproduced fairly well with an assumption that approximately 40 percent of the population consists of breeding adults (Peery and Jones 2019, pp. 18, 26). Considering the recent average Zone 1 population size of 4,730 individuals, we expect that 1,892 (40 percent) of these would be breeding adults. However, not all breeding birds will experience significant consequences of Growler overflights; in fact, some will rarely or never even be exposed to Growler overflights, while others will be exposed numerous times each day.

If breeding and non-breeding marbled murrelets have similar spatial distributions within the marine waters of Zone 1, then breeding birds will experience an average of around two overflights per day. If marbled murrelet energy expenditure in response to Growler overflight is similar to breeding Kittlitz's murrelet energy expenditure in response to boat traffic, as discussed above, then this rate of exposure is considered "low" (Agness et al. 2008, p. 348), whereas somewhat higher levels of exposure would lead to increased energy expenditures only 25 percent of the time, and always less than a 10 percent increase (Agness et al. 2013, p. 16). The consequences of this energy expenditure will vary with forage conditions and the body condition of the individual, as described above, but we expect that they will often be insignificant. However, some breeding birds are likely to be exposed more frequently, with maximum individual exposure rates around once per hour in frequently-used areas. We do not have enough information to construct a histogram of how many birds will be exposed at each frequency, but we expect that a small fraction of breeding birds will be exposed at the maximum frequency,

given that the average is two exposures per day. As an illustration of this concept, for each individual exposed 24 times per day, to maintain an average of 2 exposures per day, 11 individuals would need to be exposed 0 times per day ([24 + 0 * 11]/12 = 2), or 22 individuals would need to be exposed 1 time per day ([24 + 1 * 22]/23 = 2). Thus, the number of breeding birds exposed 24 times per day could be at most 8.3 percent of the breeding population, because if all individuals have either no exposure or are exposed 24 times per day, there would be 11 unexposed birds for every exposed bird, so 1/12 birds would be exposed 24 times per day. This amounts to 157 individuals (1,892 estimated breeding adults * 8.3 percent). Even this 157 individuals estimate is unrealistically high, because mathematically this number can only be reached if all other breeding birds avoid exposure altogether.

As illustrated above, an estimate of the number of breeding adults includes many individuals that will not be significantly affected by the action, regardless of the forage conditions, because some breeding birds will not even be exposed to Growler overflights. In addition, this estimate of breeding adult numbers includes individuals that will be exposed to varying frequencies of Growler overflights. The significance of a given level of energy level prior to the breeding season is likely to depend on prey availability and the bird's body condition, because as these decline, increased energy expenditures will influence the likelihood of a nesting attempt in the following season. The significance of a given level of energy expenditure during the breeding season is likely to depend in part on the availability of high-quality prey for nestlings, since this will influence the energy costs of breeding, as noted above. At the highest frequencies of exposure, energy expenditures will be likely to affect nesting success in a given breeding season, and to result in adults swallowing prey intended for delivery to nestlings and missed nestling meals. However, we cannot quantify the number of breeding birds exposed to overflights this frequently except to say that it is less than 157 individuals. On the other hand, a focus on breeding adults leaves out non-breeding adults, subadults, and fledged juveniles, which are likely to experience significant consequences of increased energy expenditures, at least during poor prey conditions.

The frequency with which an individual of any life stage is exposed to Growler overflights will depend greatly on how much time that individual spends in areas that are beneath Growler flight tracks, and especially in areas that are beneath multiple flight tracks. The areas with the greatest exposure to Growler overflights include the northwest coastline of Whidbey Island near Ault Field, Skagit Bay, Dugualla Bay, Rosario Strait, the area near Deception Pass, Burrows Bay, and Crescent Harbor, which are listed from most to least exposed, will each be exposed to Growler overflights between 10 and 100 times per day, on average (i.e., the northwest coastline of Whidbey Island near Ault field is expected to be exposed to Growler overflights on average 100 times per day, and Crescent Harbor, 10 times per day on average). The northwest coastline of Whidbey Island near Ault Field, Admiralty Bay, and Saratoga Passage will also be regularly exposed to 45-minute FCLP periods. Many of the most frequently-affected areas are used inconsistently or at very low densities by marbled murrelets, which implies that few, if any, individuals regularly spend time in those locations.

Some areas with frequent overflights (on the order of 12-24 overflights per day or one every hour or two), however, are marbled murrelet hotspots, including the Deception Pass area and Burrows Bay. Since marbled murrelets are consistently found in these areas, and at least some marbled

murrelets show a degree of fidelity to foraging areas, it is likely that some individual marbled murrelets are regularly present in these locations, and therefore are subjected to overflights once every hour or two. If marbled murrelet energy expenditure in response to Growler overflight is similar to breeding Kittlitz's murrelet energy expenditure in response to boat traffic, as discussed above, then this rate of exposure is considered "high" (Agness et al. 2008, p. 348), and will almost always result in elevated energy expenditures, sometimes up to a 30 percent increase (Agness et al. 2013, p. 16). Individuals using these areas regularly are therefore more likely than others to experience significant consequences of Growler exposure. Furthermore, these areas are known or likely to be staging areas for fish-holding marbled murrelets before their inland flights. Therefore, flights over these areas at dusk are likely to at least sometimes lead fish-holding individuals to swallow fish, which will lead to consequences, ranging from insignificant to severe depending on forage conditions, for the nestlings that miss a meal. We assume that many or most marbled murrelets flying inland from these locations are heading to nests to the north and south of the Skagit River.

We do not have marbled murrelet population density data specific to Deception Pass and Burrows Bay (rather than the full NWFPEM Stratum 2) for the 2012-2018 period used as a reference for population averages in our analysis. We do have some information about average densities from shore: between 2009 and 2014, the area within 500 m of shore had densities between 1 and 3 marbled murrelets per km^2, and the densities between 500 m and 2000 m from shore were less than 1 bird per km^2 (MMEMM 2015). The entire survey area was around 56 km^2, with about 20 km^2 within 500 m of shore. Therefore, if the average densities hold true in this area, we estimate that no more than 96 (20 * 3 + [56 - 20] * 1) individual marbled murrelets are typically present in Burrows Bay and near Deception Pass during the breeding season. We do not have similar data for average densities during the non-breeding season, but nearly 400 individuals were observed in Burrows Bay during one winter survey (USFWS 2017a, p. 28), and older surveys conducted in August through November led to similar estimates on occasion (Courtney et al. 1996, p. 6; Merizon et al. 1997, p. 17). Although any birds present in Burrows Bay and near Deception Pass will receive frequent exposure to Growler overflights, it is not clear how many are likely to receive this level of exposure for a full day or on a daily basis, since marbled murrelets are mobile and even those that have fidelity to foraging areas may need to use different foraging areas to forage for themselves and for nestlings. The most significant consequences are likely to accrue to individuals that consistently forage in these areas, and to nestlings of individuals that stage for inland flights in these areas. In spite of occasional large numbers of marbled murrelets observed in Burrows Bay, we assume that the number of birds regularly using these areas is substantially less than 96, since the numbers fluctuate and are often less than the average. We assume that the average number of nestlings affected by a parent swallowing fish in these areas is less than 48 (96/2), and probably not more than 19 (40% * 96/2), since we estimate that around 40 percent of the population consists of breeding adults, and each nestling has two parents.

As with estimates based on the numbers of breeding adults, estimates based on the number of birds using specific areas are likely to include birds that will often not be significantly affected, depending on forage conditions and life stage. In this case, only a subset of the 96 individuals present at any given time in Burrows Bay and near Deception Pass will be birds that use the area regularly. On the other hand, far more than 96 individuals are likely to use the area occasionally,

and some of these could also experience significant consequences of frequent overflights, especially if forage conditions are not good or if they are already operating at their maximum energy expenditure due to breeding costs. Furthermore, similar consequences, including swallowed fish leading to missed deliveries to nestlings, could occur in many other areas, including marbled murrelet hotspots such as Admiralty Inlet and Lopez Island, and frequently-exposed areas such as the northwest coastline of Whidbey Island. Although marbled murrelet presence and Growler overflight may coincide less frequently in these other areas, this does not preclude effects to individual marbled murrelets using these other areas, especially given that the same individual birds could easily be exposed in multiple locations over the course of a day or a season. Like estimates based on breeding status, estimates based on usage of particular areas of marine habitat are not satisfactory to quantify the number of individual marbled murrelets that will experience significant consequences as a result of the action.

We were able to quantify the area of suitable habitat in the terrestrial environment that will be exposed to daily overflights, and to estimate the number of nests that will be affected. Approximately 3,871 acres of suitable habitat on Cypress and Blakely Islands, likely containing approximately four nests, will be exposed to these flights. Nestlings at these nests will occasionally miss meals when overflights coincide with feeding attempts, which is most likely to occur at dusk. Although we are reasonably certain that these missed feedings will sometimes result in significant changes to the growth and development of nestlings, we are not able to estimate how often or quantify the total number of affected chicks, because these depend on future forage conditions, which we are not able to project.

In summary, because of the intersection of a variety of confounding factors that we cannot determine or project, we are not able to quantify with any precision the subset of marbled murrelet individuals that will experience significant consequences from the Growler overflights, in terms of reductions in breeding success, the likelihood of breeding or survival, malnutrition, or disruptions to growth and development. At most, we can attempt to estimate the number of birds most heavily affected by frequent overflights—a figure of less than 157 individuals. We are not inclined to define the subset as always less than 157 individuals, however, because a larger proportion of the population is likely to experience less frequent overflights, leading to consequences that are smaller in magnitude, except when forage conditions are moderately poor or very poor, which we are not able to project. As a result, our analysis refers to “some” and “a subset” of marbled murrelets, rather than setting a specific number which would suggest a precision not reasonably attainable.

9.2.5 Marbled Murrelet Exposure to Elevated Sound Levels in Suitable Nesting Habitat

Occupied or unsurveyed suitable nesting habitat will be exposed to elevated SL from Growler flights if the flight tracks pass over or near the habitat. Most flights within airspace control of the NAS Whidbey Island complex do not fly over or near suitable nesting habitat, but there are a few exceptions.

Two Instrument Approach Arrival flight tracks, arriving at Ault Field runways 7 and 14, pass over an area of suitable nesting habitat where occupancy behavior has been observed. As depicted in the mapped flight tracks (Navy 2018, pp. A4-13, A5-10), Growler aircraft are

expected to be flying at approximately 4,000 ft above sea level when they cross the area of nesting habitat, and will be operating at 70 percent power. We do not have sound measurements for Growler aircraft operating at 70 percent power, but at 78 percent power, we expect SL to be 92 dBA_{SEL} or less at a distance of 1,250 ft from the aircraft. We expect that aircraft operating at 70 percent power would be quieter, and that the SL would attenuate to 92 dBA_{SEL} or less at distances closer than 1,250 ft. Therefore, we expect that the volume of air exposed to SL 92 dBA_{SEL} or louder will not extend to altitudes lower than 2,750 ft above sea level in the vicinity of the nesting habitat. The terrain in the vicinity of the occupancy detections reaches heights around 2,126 ft above sea level, but the marbled murrelet detections were at much lower elevation, and since the trees are certainly not 600 ft tall, we do not expect that the occupied nesting habitat will be exposed to SL 92 dBA_{SEL} or louder.

In addition, two ground-controlled approach flight tracks, both associated with Ault Field runway 14, pass over large patches of unsurveyed suitable nesting habitat on Cypress Island, and one of these also passes over unsurveyed suitable nesting habitat on Blakely Island. As depicted in the mapped flight tracks (Navy 2018, pp. A4-23, A5-25), Growler aircraft are expected to be flying between 1,800 and 2,700 ft above sea level when they cross Cypress and Blakely Islands, and will be operating at 82 or 84 percent power. At 85 percent power, we expect the SL to be 92 dBA_{SEL} or less at a distance of around 4,000 ft from the aircraft. Since Growlers operating at 82 or 84 percent power are likely to make sounds nearly as loud as Growlers operating at 85 percent power, we expect the nesting habitat on Cypress and Blakely Islands to be exposed to sounds louder than 92 dBA_{SEL} when Growlers fly along these flight tracks. At sea level, we expect that the area ensonified at these levels to be between 2,951 and 3,572 ft wide (see Figure 7). Cypress Island reaches elevations approximately 1,500 ft above sea level, and at this elevation, the distance between the aircraft altitude and the ground will range 300 ft to 1,200 ft. We would expect the area of the island ensonified to 92 dBA_{SEL} to be between 3,816 and 3,989 ft wide. Most of Cypress Island and the relevant portion of Blakely Island are less than 1,500 ft above sea level, so the area ensonified will vary with elevation, but will generally be between 2,951 and 3,989 ft wide. The area of forest of the age and species composition that can make up suitable nesting habitat is approximately 3,871 acres (WDNR 2019). Any of this area could be ensonified by a given flight, given that flight tracks are not exact.

According to the runway and flight track utilization information presented in the FEIS, the flight track that flies over Cypress and Blakely Islands will be used for 4.5 percent of annual ground-controlled approaches, and the flight track that flies only over Cypress Island will be used for 3 percent of annual ground-controlled approaches (see Appendix D). There will be 14,391 airfield operations (takeoffs and landings) associated with ground-controlled approaches in an average year, and 14,911 in a high-tempo year; since each flight includes both a takeoff and an approach, this equates to 7,196 flights in an average year and 7,456 flights in a high-tempo year. The flight track passing over both Cypress and Blakely Islands will be used 324 times in an average year and 335 times in a high-tempo year, and the flight track passing only over Cypress Island will be used 216 times in an average year and 224 times in a high-tempo year. If these flights were divided equally between the breeding and non-breeding seasons, the flight track passing over both Cypress and Blakely Islands will be used 162 times in an average breeding season and 168 times during the breeding season of a high-tempo year, and the flight track passing only over Cypress Island will be used 108 times in an average breeding season and 112 times during the

breeding season of a high-tempo year. This amounts to an average of around 1.5 overflights per day affecting some part of the suitable nesting habitat, though not necessarily the same area of suitable nesting habitat in every flight.

Ault Field runway 14 is used more frequently during the non-breeding season than during the breeding season, though the seasonal usage may vary depending on weather conditions and other operations occurring at the airfield. In 2018, a little less than one-third of all operations at runway 14 occurred during April through September (Bianchi, in litt. 2019a). If we assume that one-third, rather than one-half, of the annual flights occur during the breeding season, the flight track passing over both Cypress and Blakely Islands will be used 108 times in an average breeding season and 112 times during the breeding season of a high-tempo year, and the flight track passing only over Cypress Island will be used 72 times in an average breeding season and 75 times during the breeding season of a high-tempo year. This amounts to an average of around one overflight per day affecting some part of the suitable nesting habitat, though the overflight will not affect the same swath of suitable nesting habitat every time.

We expect that flights will not be evenly distributed in time, but that there could be periods with more frequent flights interspersed with periods of no flights and periods of average flight frequencies. However, over the course of 30 years of flights, we expect that any marbled murrelets nesting on Cypress or Blakely will be exposed to overflights of their nest site numerous times.

We do not expect large numbers of marbled murrelets to nest on these islands. The average terrestrial marbled murrelet density estimated for Washington is 189 acres per marbled murrelet (Raphael et al. 2018, pp. 315, 317). By this measure, we would expect approximately 20 individual marbled murrelets to be associated with the 3,871 acres of nesting habitat on the islands, though this estimate is based on an average population density, and the true number may be more or less. This estimate represents all age classes, including breeding and non-breeding birds. In a recent population viability model developed to explore the relationship between marbled murrelet populations and nesting habitat in Washington, the model best matched current population dynamics when it was assumed that breeding adults make up only about 40 percent of the total marbled murrelet population in Washington, while the remainder of the population are juveniles and non-breeding adults (Peery and Jones 2019, pp. 25-26). By this calculation, we would expect eight breeding adults, or four nests, to be associated with this area of habitat. In reality, the number of nests may be lower, given that parts of northern Cypress Island have been surveyed with no inland marbled murrelet detections, that the age of the forest is relatively young, and that winds and rain shadow effects may affect the formation of suitable nest platforms. However, we do assume that one or more nests are present and will be exposed to the sounds of Growler overflights at 92 dBA_{SEL} or louder.

9.2.6 Marbled Murrelet Response to Elevated Sound Levels in Suitable Nesting Habitat

Expected responses to aircraft overflight at nest sites differ from responses in the marine environment. There are no experimental studies that have evaluated marbled murrelet responses to aircraft overflights at the nest. However, there are a handful of incidental observations that have been described. Long and Ralph (1998, p. 19) noted that marbled murrelets did not have an

observable response to either airplanes or helicopters flying overhead, except perhaps when they passed at low altitude. One chick did not respond to an airplane passing twice within 0.25 mile at a height of about 1,000 ft, but another chick lay flat on the branch "when an aircraft passed at low altitudes" ("low altitudes" was not defined) (Long and Ralph 1998, p. 19). During a study of radio-tagged marbled murrelets in British Columbia, helicopters were used to locate the incubating adults by circling and hovering over nest sites. The hovering and circling came within distances of 100 to 300 m of the nest and lasted approximately three minutes. None of the radio-tagged adults incubating any of the 125 nests flushed (R. Bradley, Univ. BC, 2002, pers. comm. in USFWS 2003, p. 278).

Observations of marbled murrelet responses to other sources of noise disturbance at nest sites have primarily been modifications of posture and on-nest behaviors indicating alerting, without flushing or abandoning the nest (Hébert and Golightly 2006, pp. 35-39; Long and Ralph 1998, p. 22). Hébert and Golightly (2006) monitored nesting marbled murrelets exposed to experimental bouts of chainsaw noise and the presence of people hiking on trails in Redwood National and State Parks in northern California. Adult and chick responses to chainsaw noise, vehicle traffic, and people walking on forest trails resulted in no flush responses. However, adults exposed to chainsaw noise spent more time with their head raised, and their bill raised up in a posture of alert, vigilant behavior. When undisturbed, adult marbled murrelets spent 95 percent of the time resting or motionless (Hébert and Golightly 2006, pp. 35-39).

Marbled murrelet chicks exposed to chainsaw noise also spent more time with their head raised, and their bill up during the disturbance trials, although compared to pre- and post-disturbance trials, the relationship was not statistically significant (Hébert and Golightly 2006, p. 36). The relevance of the behavioral responses seen in adults tending nests is unknown, but the behavior is similar to an adult marbled murrelet reaction to the presence of a nest predator (Hébert and Golightly 2006, p. 35). The authors suggest that marbled murrelets responding to a noise by moving or shifting position would increase the chance that it will be detected by a predator. Additionally, the energetic cost of increased vigilance to protracted disturbance could have negative consequences for nesting success (Hébert and Golightly 2006, p. 37).

Adult marbled murrelets typically feed their chicks in the early morning and in the evening. Exposure to loud noise while an adult approaches a nest to provision a chick may cause sufficient disturbance to result in abortion or delay of the feeding. Hamer and Nelson (1998, p. 9) noted that adult marbled murrelets would abort feeding attempts or flush off the nest branch during attempted food deliveries when people on the ground were visible to the birds and within a distance of 15 to 40 m, or occasionally when vehicles passed directly under a nest tree. Marbled murrelet chicks appear to be much more unlikely than adults to respond in a way that is visible to observers, and there are no documented instances of a nestling marbled murrelet falling due to sound or visual disturbance, including disturbances due to researchers climbing nest trees, handling young, and placing cameras close to young (USFWS 2003, p. 269).

Marbled murrelets have evolved several mechanisms to avoid predation; they have cryptic coloration, are silent around the nest, minimize movement at the nest, and limit incubation exchanges and chick feeding to occur mainly during twilight hours (Nelson 1997, p. 14). Hébert and Golightly (2006) suggest that flushing as a result of a noise disturbance might not provide a

benefit compared to the potential risk of exposure to predators. When confronted with the presence of potential predators, marbled murrelets remain on the nest in alert or defensive postures (Hébert and Golightly 2006) and are reluctant to flush unless confronted directly by a large predator such as a raven (Singer et al. 1991).

Based on the best available information concerning marbled murrelet responses to disturbance asscoated with noise, activity, and human presence, we draw the following conclusions:

- Adult marbled murrelets are most likely to exhibit a flush response while attempting to deliver food to the chick at dawn or dusk. Therefore, disturbances that occur in close proximity to occupied nests during dawn or dusk periods can cause adult marbled murrelets to flush and abort a feeding attempt.
- Adult marbled murrelets that are incubating an egg are not likely to flush from noise disturbance alone. The only observations of flushes during incubation involved a direct approach to the nest by a researcher or a predator such as a raven.
- The normal behavior of incubating adults is to rest and remain motionless during the day. Noise disturbance can disrupt this normal behavior by causing the adults to remain vigilant and alert during a time when they are normally resting.
- Marbled murrelet chicks appear to be mostly unaffected by visual or noise disturbance. The greatest risk to marbled murrelet chicks from disturbance is the potential for missed feedings, which occur primarily during dawn and dusk periods, but do occasionally occur during mid-day hours.

Exposure to loud aircraft noise while an adult approaches a nest to feed a chick may cause disturbance sufficient to result in abortion or delay of the feeding. Aircraft noise disturbance has the potential to affect marbled murrelet fitness in several ways. The effects to the chick of aborted feeding attempts are the same as those discussed above that occur when an adult swallows a fish meant for delivery to the chick. In addition, exposure to Growler overflights at the nest could potentially increase the risk of predation to adults, eggs, or nestlings, or increase energetic expenditure in adults who delay nest establishment activities or have to increase the number foraging trips or time in flight.

Losses of eggs and chicks to avian predators have been determined to be an important cause of nest failure in marbled murrelets (McShane et al. 2004, p. 4-109). Marbled murrelets appear to be most sensitive to noise or visual disturbances when they are approaching a nest site for an incubation exchange or delivering fish to a nestling. There are several documented instances where ground-based activities caused adult marbled murrelets to abort or delay feedings of nestlings, caused adults to divert their flight paths into nesting habitat or caused marbled murrelets to vacate suitable habitat (Hamer and Nelson 1998, pp. 8-17). Disturbances that cause a marbled murrelet to flush can advertise the nest's location, thereby creating a likelihood of predation of the eggs or nestlings (USFWS 2006, p. 27). When an adult is flushed, it can alert a predator to its location and the location of its egg or chick, thereby facilitating predation. While this has never been observed directly in marbled murrelets, it is a potential outcome of exposure to anthropogenic noise and/or visual disturbance.

Noise and visual disturbance that causes an adult marbled murrelet to abandon or delay nest establishment or abort a prey delivery to a nestling creates a likelihood of injury for the adult through an increased energy cost, and by exposing the adult to an increased risk of predation. Hull and others (2001, p. 1036) report that marbled murrelets spend 0.3 to 3.5 hours per day (mean 1.2 ± 0.7 hours per day) commuting to nests during the breeding season. The distance traveled between the nest site and foraging areas ranged from 12 to 102 km, which creates a substantial energy demand for the adults. Each flight to the nest is energetically costly, increases the risk of predation from avian predators, and detracts from time spent in other activities such as foraging (Hull et al. 2001, p. 1036). Given the proximity of Cypress and Blakely Islands to high-quality foraging areas in the San Juan Islands, we expect that in this case energetic costs of additional trips to the nest could be less than energetic costs of additional foraging. However, as discussed above (section 9.2.4), increases in prey capture and delivery efforts by the adults are likely to result in reduced adult body condition by the end of the breeding season (Kuletz 2005, pp. 43-45).

Marbled murrelets that do not visibly react, or only exhibit minor behavioral responses, to sound or visual disturbance may have physiological response similar to those discussed above (section 9.2.3.2). In addition to the effects discussed above of aircraft noise and associated stressors on avian corticosterone responses, we note that northern spotted owls (*Strix occidentalis caurina*) nesting in close proximity to roads and timber harvest activities can have elevated levels of fecal corticosterone, though this response varies by sex and nutritional status (Hayward et al. 2011, pp. 6-8; Wasser et al. 1997 pp. 1020-1021). Although increased stress hormone levels can indicate stress, and can be associated with fitness consequences, elevated stress hormones do not necessarily lead to reduced survival or reproductive success (Busch and Hayward 2009, pp. 2846-2847). Birds subjected to regular noise exposures can also have reduced baseline stress hormones (Malueg 2007, pp. 61, 67), and depressed baseline or stress-induced corticosterone responses also have an inconsistent relationship with survival and reproductive rates (Busch and Hayward 2009, p. 2847). At this time we are unable to determine with certainty how aircraft overflights of the nest affect marbled murrelet stress hormones, and what the fitness consequences of that physiological response might be. Therefore, we continue to rely on behavioral responses as indicators of the severity of potential disturbance effects at the nest.

In most cases, we expect exposure to loud aircraft noise will result in either no response from adults or chicks, or minor behavioral responses such as head-turning, increased vigilance, or brief startle responses resulting in flattening on a branch. The effect of increased vigilance and alerting may increase energetic demands to adults, but this is likely to be most significant for individuals that are exposed to prolonged disturbances over a period of days, which we do not expect to occur frequently, if ever, over Cypress and Blakely Islands during the 30-year timeframe of the action. Aircraft overflights represent brief disturbance events that are most likely to result in increased vigilance for a short period (minutes).

When marbled murrelets do respond to a greater degree, they may exhibit a range of responses to aircraft overflights. Hillman and others (2015, p. 1196) observed that only 1 of 8 least terns (12.5 percent), flushed during incubation when exposed to military jet aircraft noise that exceeded a maximum 1-second equivalent average sound level of 90 dBA (MaxLEQ). Contrary to their expectations, the authors noted "even if the loudest overflights affected incubation

behavior, the effect size was minimal and the effect was not likely to influence demographic rates, particularly as the effect was not towards reduced time incubating during an overflight, but towards more time incubating after an overflight" (Hillman et al. 2015, p. 1196).

Similarly, Derose-Wilson and others (2015, p. 1256) evaluated the effects of military aircraft overflights to incubating Wilson's plovers (*Charadrius wilsonia*). This study evaluated vigilance behavior, incubation rate, and heart rates before, during, and after overflights (Derose-Wilson et al. 2015, p. 1249). Wilson's plovers were alert and scanned more during overflights, but heart rates and incubation rates did not change in response to overflights (Derose-Wilson et al. 2015, p. 1250). The authors noted that because Wilson's plovers rely primarily on secrecy and cryptic coloration to protect their nests from predators, they may not incubate less because of overflights, even if they perceive them as threatening (Derose-Wilson et al. 2015, p. 1252). The authors concluded that although the transient increase in vigilance observed during these flights was not likely to directly influence fitness, it did indicate that incubating Wilson's plovers perceive and react to overflights under some conditions (Derose-Wilson et al. 2015, p. 1252).

Rojek and others (2007, p. 61) noted that from 4 to 31 percent of low-elevation aircraft flyovers caused some common murres to flush during nesting. Aircraft flights in this study were both non-military fixed-wing and helicopters, and low-elevation flights were defined as an altitude of less than 1,000 ft (305 m). Flush rates varied widely by colony, with individuals in some colonies flushing more frequently than in others. No sound information was reported for the aircraft overflights. In another study, between 0 and 36 percent of aircraft flyovers caused some common murres to flush during nesting, depending on the type of aircraft, with fixed-wing aircraft (flushing on 1 percent of overflights) less likely to cause flushing than helicopters (19 percent), and military aircraft (flushing on 36 percent of overflights) more likely to cause flushing than other aircraft types (ranging from 0 to 30 percent) (Fuller et al. 2018, p. 263). Brown (1990, p. 591) subjected crested terns (*Sterna bergii*) to high-amplitude simulated aircraft noise and noted that about 8 percent of terns flushed in response to the noise.

We cite these examples to illustrate that the responses to aircraft noise can vary widely between different species, and response can also vary between individuals within a species exposed to the same stressor. The studies cited above are from bird species that nest in open habitats with little or no vegetation to absorb sound energy or provide a visual screen between the birds and distant aircraft. Because marbled murrelets nest in a forested environment, they may be shielded to some degree by forest cover over their nests. The most comparable studies of aircraft disturbance to forest-nesting birds are for Mexican spotted owls (*Strix occidentalis lucida*). Mexican spotted owls typically respond to aircraft overflights by orienting or alerting towards the aircraft. More severe responses such as movements or flushing are rare, and only occurred when aircraft approached at close range (Delaney et al. 1999, p. 68; U.S. Air Force 2012, p.3-99).

The weight of evidence indicates that marbled murrelet responses to the type and duration of Growler overflights at the nest will most often be brief periods (minutes) of increased vigilance and alerting behaviors. All incidental observations of flush responses in marbled murrelets have been associated with ground-based disturbances that occurred within direct visual range of the

birds. The species relies on cryptic behavior to avoid detection of predators, so a flush response is likely to be a rare event. We do not expect significant energetic costs to be associated with brief periods of vigilance.

We expect that marbled murrelets will not flush in response to aircraft noise unless the disturbance event coincides directly with a prey delivery to a chick. At any one location, exposure to high-amplitude aircraft noise is a brief event lasting less than a minute, so the risk of any given overflight coinciding directly with a marbled murrelet prey delivery is low. However, over the course of 30 years, we expect that aborted feedings due to Growler overflights will occur from time to time. The result of the aborted feeding is expected to be as discussed above (section 9.2.4.2).

9.2.7 Aircraft Overflights Conclusion

Based on the above analysis, we conclude that adult, sub-adult, and fledged juvenile marbled murrelets will be exposed to noise from Growler operations in their marine habitat. When adult marbled murrelets are exposed during the nesting season they may swallow fish intended for delivery to nestlings. In addition, adults and nestlings will be exposed to noise from Growler operations in areas of suitable nesting habitat on Cypress and Blakely Islands. As a result of the exposure of fish-holding adults during the nesting season, both at sea and at the nest, some nestlings will experience missed feedings.

Growlers will be operating at power settings and altitudes that will expose adult, sub-adult, and fledged juvenile marbled murrelets to SLs exceeding 92 dBA_{SEL} in their marine habitat. The amount of marine habitat exposed to SLs above 92 dBA_{SEL} will depend on the Growlers' flight tracks, altitudes, power settings, and the environmental conditions during the operations. The number of marbled murrelets within the exposed habitat will depend on the area, the season, and natural variation in marbled murrelet movements. Though there are many variables that influence how many marbled murrelets will be exposed, due to the relatively high densities of marbled murrelets in the action area and the large number of overflights per year, over thirty years, we conclude that sub-adult and adult marbled murrelets will be exposed to noise from Growler overflights year-round, during both the day and the night, over the 30-year term of the action. We estimate that the total number of exposures of individual marbled murrelets to individual Growler overflights, over 30 years, will be approximately 134,595,180.

We expect that any marbled murrelet foraging in Conservation Zone 1 during the breeding and non-breeding seasons could be exposed to Growler overflights, although some may avoid exposure if their movement patterns do not happen to coincide with Growler use. This group of birds includes many of those that breed in Conservation Zone 2 and parts of British Columbia, which enter the action area during the non-breeding season. We expect that, on average, birds that are present in Conservation Zone 1 will be exposed to approximately two overflights per day during the breeding season, and one overflight per day during the non-breeding season. Although the average expected number of exposures per bird is slightly higher during a "high exposure" year than during an "average" year, it is still likely to be close to two exposures during the breeding season and one during the non-breeding season. We expect that approximately one-third of the population will be exposed to an FCLP period in any given season, unless a high-

tempo year of Growler operations coincides with a year of high marbled murrelet density, in which case approximately two-thirds will be exposed to FCLP periods during the breeding season and one-third during the non-breeding season. Marbled murrelets using some of the hotspots within the action area, including Burrows Bay, the area off of southern Lopez Island, and Deception Pass, will be exposed to a higher-than-average frequency of Growler overflights, up to an average of one per hour near Deception Pass.

A portion of the marbled murrelets that are exposed to aircraft overflights in their marine habitat will respond by altering their normal foraging and resting behaviors. Physiological responses are also expected. Marbled murrelets that respond behaviorally to the aircraft overflights in the marine environment are most likely to dive, but we expect some to fly and leave the foraging area. Individual sub-adult and adult marbled murrelets that leave the foraging area are expected to have their foraging efficiency reduced, possibly for the remainder of the day. Both diving and flying are energetically costly behaviors, and some of the potential physiological responses are also energetically costly. When an overflight during the nesting season corresponds with exposure of an adult, fish-holding, breeding marbled murrelet, we expect that some of those individuals will swallow their prey items. Some will expend additional energy finding and capturing a new prey item for the chick. When marbled murrelets spend energy as a result of their responses to overflights, this expended energy can only be replaced by capturing additional prey for self-maintenance.

Given the number of overflights included in the action, and the long duration of the action (30 years), we expect that some adult, sub-adult, and fledged juvenile marbled murrelets will not be able to replace energy spent to respond to disturbance, especially those that regularly use the more frequently-disturbed portions of the action area. When adult, sub-adult, and fledged juvenile marbled murrelets are unable to compensate for these energetic expenditures we expect they will become malnourished, and we expect that malnourishment will degrade the physical condition of adult, sub-adult, and juvenile marbled murrelets. A degraded physical condition will make these sub-adult and adult marbled murrelets more susceptible to the other factors that negatively affect their fitness. We expect the most frequent effect to fitness to be a reduction in the likelihood that individuals will breed, which already varies depending on marine conditions. We also expect that malnourishment resulting from exposure to overflights will make sub-adult and adult marbled murrelets more likely to starve, suffer ill effects of toxic exposures, or contract infections. Ultimately, the inability of sub-adult and adult marbled murrelets to replace energy lost to responses to overflights creates a likelihood of injury or death from starvation or disease, and a reduction in the likelihood of attempting to nest or nesting successfully.

We expect that during the nesting season, exposure of adult marbled murrelets in the marine habitat, especially, but not exclusively, near Deception Pass and in Burrows Bay, will impair their ability to deliver prey items to chicks on some occasions. When overflights correspond with exposure of adult, fish-holding, breeding marbled murrelets, we expect that some of those individuals will swallow their prey items. If the fish cannot be replaced, this will result in missed feedings to chicks. Similarly, Growler overflights of Cypress and Blakely Islands will occasionally coincide with evening chick feeding attempts, and when they do, we expect that

adults will flush and abort or delay the feeding attempt. Missed feedings will hinder the growth and development of nestlings, and if one chick misses multiple feedings, or if the prey conditions are poor, missed feedings will contribute to reduced fitness or lead to mortality.

9.3 Air Pollutants

Air pollutants are emitted during the Navy's use of aircraft. Criteria pollutants are the six major air pollutants of concern: carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, suspended particulate matter, and lead. The EPA regulates 187 substances as hazardous air pollutants known to cause or suspected of causing cancer or other serious health effects. Criteria and hazardous air pollutants are generated by the combustion of fuel by aircraft. Pollutant levels are based on location, altitude, number of aircraft, and length of activity.

9.3.1 Exposure to Air Pollutants

Emission of pollutants occurs throughout the action area. Air pollutants emitted above 3,000 ft elevation are above the atmospheric mixing height and do not affect ground-level air quality (USEPA 1992 as cited by Navy 2015, p. 3.2-7). We expect that atmospheric dispersion will quickly reduce potential impacts of the Navy emissions of air pollutants. Emissions of increased air pollutants will be intermittent and limited in physical extent and duration.

Greenhouse gasses are another class of air pollutants generated by the action and linked to climate change. While climate change is a significant threat to listed species, we do not anticipate measurable effects from contributions of the action in the context of existing and predicted global climate conditions.

9.3.2 Air Pollutants Conclusion

The release of these criteria and hazardous air pollutants is not expected to result in measureable effects to marbled murrelets. As such, we consider the effects of increased air pollutants on these listed species to be insignificant.

9.4 Conclusion

The stressors associated with the action include aircraft strikes, air pollution, and Growler overflights causing marbled murrelet exposure, in both marine and terrestrial habitats, to sounds louder than 92 dBA_{SEL}. We conclude that aircraft strikes are discountable, and the effects of air pollution resulting from the action are insignificant. Marbled murrelets will be exposed numerous times to Growler overflights, and the effects of this exposure are expected to be significant for a subset of exposed individuals.

The numbers of exposures in each season are described in Tables 17, 18, and 19. Table 17 lists the estimate of average annual exposure, and is drawn from Tables 12 and 13; Table 18 lists the estimate of exposure in a high-tempo year with particularly high marbled murrelet densities, and is drawn from Tables 14 and 15; and Table 19 lists the total number of exposures expected over 30 years, which are 30 times the numbers in Table 17. We expect that the average number of

exposures per year will be similar to the numbers listed in Table 17, but that some years will have exposures more similar to those listed in Table 18, balanced by other years with lower exposure than what is listed in Table 17.

Table 17. Estimated average annual exposures of marbled murrelets to disturbance-level noise from Growler overflights

Type of Exposure	Total Annual Exposures*	Including no more than Breeding Season Exposures	Including no more than Non-breeding Season Exposures
Single or double overflights	3,578,730	1,303,848	2,689,935
Triple overflights (interfacility flights)	227,183	100,431	130,518
45-minute FCLP periods	10,547	3,304	7,361
Overflights over suitable nesting habitat	270	270	n/a

*Note that breeding season exposures plus non-breeding season exposures may sum to a number higher than the total annual exposures, due to uncertainty regarding how exposures will be distributed between the seasons. The average annual total is not anticipated to be higher than that listed in the total annual exposures.

Table 18. Estimates of marbled murrelets to disturbance-level noise from Growler overflights in a high-tempo year with elevated marbled murrelet densities

Type of Exposure	Total Annual Exposures*	Including no more than Breeding Season Exposures	Including no more than Non-breeding Season Exposures
Single or double overflights	6,492,084	2,743,328	4,386,555
Triple overflights (interfacility flights)	371,304	118,186	255,664
45-minute FCLP periods	21,930	9,414	12,849
Overflights over suitable nesting habitat	280	280	n/a

*Note that breeding season exposures plus non-breeding season exposures may sum to a number higher than the total annual exposures, due to uncertainty regarding how exposures will be distributed between the seasons. The average annual total is not anticipated to be higher than that listed in the total annual exposures.

Table 19. Estimates of marbled murrelets to disturbance-level noise from Growler overflights over a 30-year period

Type of Exposure	Total Annual Exposures*	Including no more than Breeding Season Exposures	Non-breeding Season Exposures
Single or double overflights	107,361,910	39,115,427	80,698,042
Triple overflights (interfacility flights)	6,815,498	3,012,929	3,915,539
45-minute FCLP periods	316,423	99,122	220,819
Overflights over suitable nesting habitat	8,100	8,100	n/a

*Note that breeding season exposures plus non-breeding season exposures may sum to a number higher than the total annual exposures, due to uncertainty regarding how exposures will be distributed between the seasons. The average annual total is not anticipated to be higher than that listed in the total annual exposures.

The action will affect marbled murrelets by causing some marbled murrelets to respond behaviorally or physiologically to the overflights, and this will have an energetic cost to those birds. Marbled murrelets will respond to some proportion of overflights by diving or flying away, which result in reduced energy intake when feeding is interrupted, as well as energy expenditures involved in taking action. As a result of the energetic costs of these responses, breeding adults exposed to frequent overflights are likely to experience reductions in breeding success, and in some cases will forgo or abandon nesting attempts. Some adult, subadult, and fledged juvenile marbled murrelets will be unable to compensate for the extra energetic cost of their response and will become malnourished. Malnourished marbled murrelets will be more likely to be injured or killed by starvation, illness, or toxic exposures.

Breeding marbled murrelets will sometimes swallow prey held for chicks during their response to overflights, and in suitable nesting habitat, overflights that coincide with feeding attempts will sometimes cause an aborted feeding attempt. In many cases, swallowed fish or aborted feeding attempts will cause the chick to experience a missed feeding, because we do not expect that adults will often, if ever, be able to obtain replacement meals for chicks. In some cases, we expect that the energetic expense to the adult of additional foraging may be too great, given that breeding adults are expected to operate near their energetic ceiling. Even if the energetic cost is manageable for a given breeder, we expect that these disruptions are most likely to happen near dusk, at which point adults may not have time left in the day to catch another chick-appropriate meal and fly inland. Unless a nestling is very well-nourished, a missed feeding will alter the growth and development of the chick, lengthening the nestling phase, in some cases leading to stunting, and reducing the likelihood for the chick to fledge successfully.

10 CUMULATIVE EFFECTS: Marbled Murrelet

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 would not occur but for the proposed action are not considered in this section because they are addressed in separate consultations pursuant to section 7 of the ESA.

Within the action area, all State, Tribal, local, and private construction or excavation actions are required to obtain a U.S. Army Corps of Engineers permit for work conducted in, over, or under navigable waters under the authority of Section 10 of the Rivers and Harbors Act and/or for the discharge of dredged or fill material under Section 404 of the Clean Water Act. Therefore, new actions involving construction or excavation within the action area will require section 7 consultation with the Service. Similarly, fisheries within the action area are managed under the authority of the Pacific Fishery Management Council, as specified by the Magnuson-Stevens Fishery Conservation Management Act, or other authorities with a federal nexus (e.g., Bureau of Indian Affairs funding for Treaty Tribal fisheries); any fisheries that are not managed under these authorities are likely to be interrelated or interdependent with the fisheries that do have a federal nexus. Therefore, fisheries activities that may affect marbled murrelets will require section 7 consultation with the Service. In addition, many actions affecting marbled murrelets within the terrestrial portion of the action area have a federal nexus, and are therefore included in the baseline, rather than as cumulative effects.

However, marbled murrelets will continue to be affected by other ongoing non-federal activities within the action area and along rivers and streams draining into the action area. Threats to marine habitat quality that do not involve a federal nexus include shoreline development and armoring above Mean Higher High Water (Carman et al. 2010, p. 49), human population growth, urbanization that increases the amount of impervious surfaces, pressures on water supplies, and water and air pollution. The population of the Puget Sound region is growing quickly, with an estimated increase of 700,000 people between 2008 and 2020 (WDOE 2016).

Human population increases result in higher levels of toxic chemicals entering the action area from surface runoff, groundwater discharges, and municipal and wastewater outfalls. These contaminants include oil, grease, PCBs, and heavy metals. Many areas surrounding Puget Sound are highly urbanized, and development is spreading to the surrounding areas, causing conversion of agriculture and forested lands to impervious surfaces. The increase in impervious surfaces increases storm water runoff, which carries contaminants into the action area (WDOE 2006; WDOE and King County 2011, p. 30). Air pollution increases due to increased urbanization also lead to the increased deposition of contaminants such as polybrominated diphenyl ethers (PBDEs, used as flame retardants) into the marine environment (WDOE and King County 2011, p. 32). Contaminants have been found in marbled murrelet prey species within the action area at levels that may affect prey health and reproductive success (USFWS 2009, p. 39-40; Liedtke et al. 2013, p. 5). These contaminants increase in concentration as they move up the food chain (Borgå et al. 2001, pp. 191-196). Such contaminants have been shown to cause developmental abnormalities, wasting, disruption of thyroid function, immunosuppression, and decreased reproductive success in fish-eating birds (reviewed in Luebke et al. 1997, pp. 7-10; Rolland 2000, pp. 615, 620-626).

Oil tanker and barge traffic in and near the action area is increasing (Felleman 2016, p. 27; Etkin et al. 2015, p. 271). In particular, the Canadian Trans Mountain pipeline expansion project, now owned by the Canadian government as a federal Crown corporation, was halted in accordance with a ruling by the Canadian Federal Court of Appeal in August 2018 (Trans Mountain 2019). However, after reconsidering environmental and cultural effects, the Canadian National Energy Board has recently recommended again that the expansion move forward, including the expansion of a terminal in Burnaby, British Columbia, Canada, a port on the Canadian portion of the Salish Sea (NEB 2019, p. 1). If ultimately completed, it will lead to approximately one additional oil tanker per day departing Burnaby and traveling through the action area (Felleman 2016, pp. 37-38; Kinder Morgan 2016; Van Dorp et al. 2014, pp. 38, 52), and tanker and tug traffic related to the expansion are projected to increase vessel traffic through the Georgia, Haro, and Juan de Fuca Straits by approximately 7 to 14 percent over 2012 traffic rates (NEB 2019, p. 363). Other types of vessel traffic within the action area may increase or decrease, depending on economic conditions (WDOE 2019, pp. 43-49).

Increases in oil transportation within the action area raise the likelihood of an oil spill affecting the action area. A major oil spill into the action area would likely kill marbled murrelets, as has been documented as a result of previous oil spills in other areas (reviewed by Carter and Kuletz 1995, entire). Oil spills may also cause sublethal injury to marbled murrelets and may affect forage fish populations (Carter and Kuletz 1995, p. 264). Oil spill remediation may also be damaging to forage fish populations (Penttila 2007, p. 19).

Ongoing non-federal actions also include State, tribal, local, private, and Canadian habitat restoration programs. These programs are directed at protecting, enhancing, and restoring marine and estuarine habitats and the native fish and wildlife populations they support. Habitat restoration programs also provide for the advancement of marine and estuarine science, refinement of applied techniques, and public participation and education.

These cumulative effects, acting in concert with other stressors on marbled murrelet individuals, are on the whole likely to increase marbled murrelet mortality rates and depress reproductive rates over time.

11 INTEGRATION AND SYNTHESIS OF EFFECTS: Marbled Murrelet

The Integration and Synthesis section is the final step in assessing the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action and cumulative effects to the environmental baseline and, in light of the status of the species and critical habitat, formulate the Service's opinion as to whether the action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat.

11.1 Summary of the Action

The Navy is expanding existing EA-18G "Growler" operations at NAS Whidbey Island complex, including the addition of personnel and aircraft and continuing and expanding flight operations. The Navy will also construct and renovate facilities at Ault Field to accommodate

the expansion of Growler squadrons. Growler operations at NAS Whidbey Island complex include departures, several types of arrivals, interfacility flights, and pattern operations. The majority of airfield operations will occur at Ault Field, but OLF Coupeville will be used for FCLPs. The action, as implemented by the 2019 ROD, includes an annual average of 97,564 airfield operations (which equate to 67,681 flights, see Table 3) annually for the remainder of years the Navy expects to fly EA-18G "Growlers" (30 years).

11.2 Range-wide Status Summary

The most recent population estimate for the entire NWFP area in 2017 was 23,000 marbled murrelets (95 percent CI: 18,500 to 27,600 birds) (McIver et. al 2019, p. 3). The long-term trend derived from marine surveys for the period from 2001 to 2017 indicate that the marbled murrelet population across the NWFP area has increased at a rate of 0.34 percent per year, with confidence intervals overlapping 0 (95% CI: -0.9 to 1.6 percent) (McIver et. al 2019, p. 3). This indicates an inconclusive trend, and the population may be increasing, decreasing, or stable.

The loss of nesting habitat was a major cause of marbled murrelet decline over the past century and may still be contributing as nesting habitat continues to be lost to fires, logging, and wind storms. Rates of suitable nesting habitat loss are highest in Washington, and Washington is the portion of the range with the most definitive ongoing population declines, at a rate of 3.9 percent per year. This suggests that the loss of nesting habitat continues to be an important limiting factor for the recovery of marbled murrelets.

In the marine environment, marbled murrelet fitness and survival are affected by reductions in the quality and abundance of marbled murrelet forage fish species, harmful algal blooms, toxic contaminants; marbled murrelet by-catch in gillnet fisheries; marbled murrelet entanglement in derelict fishing gear; oil spills, and human disturbance in marine foraging areas (USFWS 2019a, pp. 29-61). The extent that these stressors affect marbled murrelet populations throughout the range is unknown. As with nesting habitat loss, marine habitat degradation is most prevalent in the Puget Sound area where anthropogenic activities (e.g., shipping lanes, boat traffic, shoreline development) are an important factor influencing the distribution and abundance of marbled murrelets in in nearshore marine waters (Falxa and Raphael 2016, p. 106).

11.3 Threats to Marbled Murrelet Survival and Recovery

Since it was listed under the ESA, the marbled murrelet population has continued to decline in portions of its range as a result of poor reproduction and recruitment. The Recovery Implementation Team for the marbled murrelet identified the following major factors that appear to be contributing to this decline (USFWS 2012b, pp. 10-11):

- Ongoing and historic loss of nesting habitat;
- Predation on marbled murrelet eggs and chicks in their nests;
- Changes in marine conditions that affect the abundance, distribution, and quality of marbled murrelet prey species;

- Post-fledging mortality (e.g., due to predation, entanglement in gillnets, and exposure to oil-spills); and
- Cumulative and synergistic effects of various factors affecting individuals and populations.

Climate change is also considered to be a threat to marbled murrelet survival and recovery. Although seabirds, such as the marbled murrelet, have life-history strategies adapted to variable marine environments, ongoing and future climate change could present changes at a frequency and scope that exceeds their capacity to adapt in a timely and effective manner (USFWS 2009, p. 46).

11.4 Marbled Murrelet Conservation Needs

General criteria for marbled murrelet recovery and delisting are established under the marbled murrelet recovery plan (USFWS 1997, p. 114-115). These general criteria include:

- Documenting stable or increasing trends in population size, density, and productivity in four of the six Conservation Zones for a 10-year period; and
- Implementing management and monitoring strategies in the marine and terrestrial environments to ensure protection of marbled murrelets for at least 50 years.

Conservation Zones 5 and 6, at the southern end of the range, may be limited in their short- and long-term viability, respectively, which increases the importance of Conservation Zones 1 through 4 in meeting these criteria.

Thus, increasing marbled murrelet reproductive success and reducing the frequency, magnitude, or duration of any anthropogenic stressor that directly or indirectly affects marbled murrelet fitness or survival in the marine and terrestrial environments are the priority conservation needs of the species. The Service estimates recovery of the marbled murrelet will require at least 50 years (USFWS 1997).

Reestablishing an abundant supply of high quality marbled murrelet nesting habitat is a vital conservation need given the extensive removal of that habitat during the 20th century. Much of the federal lands managed under the NWFP that currently do not support marbled murrelet nesting habitat are expected to transition into mature and older-forest habitat over the next few decades (Raphael et al. 2011, p. 44). In addition to increasing nesting habitat, there are other conservation imperatives. Foremost among those is increasing marbled murrelet reproductive success and productivity (i.e., fecundity) by increasing the number of breeding adults, improving marbled murrelet nest success (due to low nestling survival and low fledging rates), and reducing anthropogenic stressors in marine and terrestrial habitat that reduce individual marbled murrelet fitness or lead to mortality. Marbled murrelets would also likely benefit from improvements in the health of the marine food web in the Salish Sea and along the Pacific Coast in Washington (Lorenz et al. 2017, p. 319).

11.5 Summary of the Environmental Baseline in the Action Area

The action area includes northern Puget Sound, the San Juan Islands, and portions of the Strait of Juan de Fuca and the Strait of Georgia. The action area is in marbled murrelet Conservation Zone 1 (USFWS 1997, pp. 113-114). The marbled murrelet population in Conservation Zone 1 has declined over the past two decades due to multiple environmental and anthropogenic stressors that reduce marbled murrelet productivity and survival. The population estimate for Zone 1 in 2018 was 3,837 marbled murrelets (95 percent CI: 1,911 – 6,956), with a -4.9 percent (95 percent CI: -7.3 to -2.4) average annual rate of decline for the 2001 – 2018 period (McIver et al. 2019, pp. 9, 15). Although the average change is negative, the population fluctuates from year to year, and sometimes the population increases from one year to the next. For example, the Zone 1 population was larger in 2015 than in 2014 (Lynch et al. 2016, p. 13).

Within the action area during the summer months, marbled murrelets forage at the highest densities in the nearshore waters along the Strait of Juan de Fuca, San Juan Islands, Rosario Strait, and Admiralty Inlet. They are found during the breeding season at lower densities in Possession Sound, Skagit Bay, Bellingham Bay, and along the eastern shores of the Strait of Georgia. Beginning in August, marbled murrelet distributions within the action area shift and an influx of marbled murrelets enters the action area from British Columbia and the outer coast of Washington. Marbled murrelet densities in the fall and winter do not show substantial changes along the eastern Strait of Georgia, apparently exhibit a dip followed by a larger late fall increase in Admiralty Inlet, and increase late in the breeding season in all other portions of the action area.

The decline of marbled murrelets within the action area is attributed to low reproductive rates stemming from the loss of terrestrial habitat, nest predation, degraded marine conditions affecting prey resources, and cumulative effects of multiple smaller impacts. The conditions specifically affecting the marine environment within the action area include prey contamination with polychlorinated biphenyls; changes in the prey base; harmful algal blooms and other biotoxins; dead zones; entanglement in derelict fishing gear; elevated sound level in the marine environment leading to disturbance, injury, or death; and climate change, which is expected to exacerbate some of the preceding conditions. The Marbled Murrelet Recovery Plan (USFWS 1997) identified the need to protect the quality of marine habitat for marbled murrelets and to reduce adult and juvenile mortality in the marine environment. Although not generally considered to constitute threats to the species, Zone 1 and the action area have a large volume of boat and small aircraft traffic, with 230,000 large boat transits, including 170,000 Washington State Ferries transits, an estimated 115,000 small boat trips, and at least 5,000 small aircraft trips per year.

Within the action area, the Service has previously consulted on numerous federal agency actions that include a variety of construction projects along shorelines and within harbors, aquaculture, wastewater treatment plant discharges, and military activities. Many of these actions expose marbled murrelets to increased underwater sound pressure levels in a way that can injure or kill individual birds. Many projects also negatively affect the marbled murrelets prey. Some actions also increase the level of contaminants entering the action area. Among the military activities included in the baseline area the Navy's NWTT activities, and a previous informal consultation

with the Navy regarding Growler operations. Existing Growler operations, prior to the adoption of the 2019 ROD, included 73,895 annual airfield operations.

The effects of previous and ongoing greenhouse gas emissions have resulted in changes to the physical and biological characteristics of the action area, and these changes are expected to continue and in some cases accelerate. Physical changes include increases in water and air temperatures, changes in precipitation seasonality, possible disruptions in naturally-occurring climate cycles such as ENSO and PDO, alterations in the timing and amount of fresh water inputs, patterns of nutrient upwelling, acidification, deoxygenation, and sea level rise. These changes are likely to affect primary productivity, with potentially beneficial effects to eelgrass, kelp, and toxic algae species. The changes in physical conditions and primary producers are likely to have both positive and negative effects on higher trophic levels, and may lead to reorganization of marine food webs. Although some species are likely to benefit from climate change, the effects to marbled murrelets and their preferred forage fish prey are generally expected to be detrimental.

11.6 Summary of the Effects of the Action on Marbled Murrelets

The Service expects Growler flights to expose marbled murrelet marine habitat, 3,871 acres of terrestrial nesting habitat, and marbled murrelets within those marine and terrestrial habitats to noise from aircraft overflights that exceeds the disturbance threshold (92 dBA_{SEL} re:20μPa^2s).

In response to exposure to noise from aircraft overflights, the Service expects some of the exposed marbled murrelets to significantly alter their normal behavior by interrupting their foraging, and increasing their diving or flying rates in response. Physiological responses, including increased body temperature and heart rate, are also expected. As a consequence of the additional diving, flying, and physiological responses, marbled murrelets will expend energy that they otherwise would have retained. Marbled murrelets require energy to maintain their baseline metabolism and continue their essential behaviors. Marbled murrelet behavior is especially energy intensive while the birds are breeding and flying inland to feed nestlings. When food conditions are good, and marbled murrelets are not already consuming the maximum amount of food they can digest, we expect that marbled murrelets to be able to compensate for some of the energy lost to behavioral responses to noise by catching additional prey. However, compensating for lost energy will not be possible for all breeding marbled murrelets, which often function at their maximum energy expenditure. Compensating by increasing foraging effort is expected to be difficult during periods of lower prey availability or if marbled murrelets are already in poor condition (i.e. low body weight or low energy reserves). Given the large number of exposures per year, and the concentration of exposures in some known marbled murrelet hotspots, we expect that some marbled murrelets will be exposed repeatedly, multiple times each day, and will be unable to compensate for the additional energy expenditure. We expect the resulting energy deficit to result in lower probability of attempting nesting, lower nesting success, and in some cases, lower survival rates due to a combination of malnutrition, increased susceptibility to toxic exposures, and increased susceptibility to disease.

Exposure to noise from aircraft overflights will also indirectly affect nestling marbled murrelets. Behavioral responses to aircraft overflights can cause marbled murrelets to swallow prey intended for delivery to nestlings, or to abort or delay the prey delivery at the nest site. Unless a

nestling is very well-nourished, a single missed feeding will negatively impact its growth and development. Only a fraction of adult marbled murrelets breed each year and we expect many exposed breeders to either retain their prey or be able to catch replacement prey. However, due to the large number of expected aircraft overflights associated with the action, especially in areas where marbled murrelets are known or suspected to hold fish before flying inland, we expect that a portion of breeding adults will be exposed, and will drop or swallow prey being held for a nestling, and those that stage near Deception Pass and in Burrows Bay are likely to do so more than once per breeding season. It is unlikely that all of those adult marbled murrelets will be able to replace lost prey items, especially when fish are dropped near dusk in a year of low prey availability, and as a result, some nestlings will miss feedings. Missed feedings delay the growth and development of chicks, and can reduce the fitness of the chick, decrease the chance of a successful first flight to the marine environment, and in some cases, lead to death.

Ultimately, we expect the consequence of exposure to aircraft overflights will be impacts to growth, development, and survival of some chicks and decreased reproduction in some adults. Some nestlings will have a prolonged period of growth and development before fledging. Delayed growth and development increases the risk of predation, accidental death from falling, or abandonment by the parents. Some juvenile and adult marbled murrelets will be more likely to die or become ill due to starvation, toxic exposures, and infections during periods of low prey availability, and adult marbled murrelets will have reduced breeding success.

11.7 Effects of the Action on Marbled Murrelet Distribution, Reproduction, and Population

In this section, we add the effects of the action and cumulative effects to the environmental baseline and in light of the status of the species, provide our opinion as to whether the action is likely to jeopardize the continued existence of the marbled murrelet, that is, whether the action is reasonably to be expected, directly, or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the marbled murrelet Distinct Population Segment (DPS) by reducing its reproduction, numbers, or distribution.

11.7.1 Distribution

The marbled murrelets of the DPS that utilize the action area include those that nest in terrestrial habitats in Conservation Zones 1 and 2. (There are also marbled murrelets that utilize the action area that nest in British Columbia, but any impacts from the action to these marbled murrelets will not affect the survival and recovery of the U.S.-designated DPS). The marbled murrelets from Conservation Zone 2 occur in the action area primarily during the non-breeding season. We do not expect the action to interfere with marbled murrelet movements between wintering habitats in the action area and their breeding habitats elsewhere, because it does to create any barriers to movement. To the extent that the action affects the distribution of marbled murrelets, this effect will be limited to changes in distribution of marbled murrelets within the waters of Zone 1. As summarized in section 9.2.3.1, we expect that marbled murrelets will sometimes leave foraging areas in the action area in response to Growler overflights, especially the areas that will be continuously affected by loud aircraft noise for 45 minutes at a time. However, as discussed in section 9.2.3.1, we expect them to return to these areas at a later time, rather than

ceasing to use them altogether. Because there will be no permanent disruption of foraging areas for marbled murrelets in the action area, and no disruption in movements between wintering and breeding habitats, the action will not result in a reduction in the distribution of marbled murrelets at the scale of the action area, Conservation Zones, or rangewide.

11.7.2 Reproduction

We expect that a small, but variable, number of the adult marbled murrelets exposed to Growler overflights will become malnourished because of the energetic costs of their response to the disturbance. This will reduce the likelihood of success of the breeding attempts of those affected birds, and reduce the likelihood that they attempt to breed at all. We also expect that some well-nourished adults exposed to Growler overflights will sometimes experience reductions in nesting success, because we expect that breeding adults are often already operating at maximum energy intake and output. These reductions in breeding attempts and nesting success are most likely to affect marbled murrelets that are frequently exposed to Growler overflights, multiple times per day. We also expect that the indirect effects of Growler overflights to chicks, resulting from both marine and terrestrial overflights, will decrease nest success. Collectively then, we conclude the action is likely to result in a small reduction in marbled murrelet reproduction in Conservation Zone 1. The action is not expected to result in reductions in breeding success in Conservation Zone 2, because we expect that marbled murrelets breeding in Zone 2 will not often forage during the breeding season within the areas most frequently exposed to overflights. However, some marbled murrelets that nest in Zone 2 and winter in Zone 1 will have a reduced likelihood of attempting breeding during some years, when the energetic expense of responses to Growler overflights contributes to malnourishment. We conclude that the action is likely to result in a small reduction in marbled murrelet reproduction in Zone 2, and that reduction will be even smaller than the reduction affecting Zone 1. Because low recruitment is thought to be the major limiting factor for marbled murrelet populations (USFWS 2012b, p. 10), decreases in the already low reproductive rates in Conservation Zones 1 and 2 may contribute to some degree to further decline of the populations.

11.7.3 Numbers

The action is not expected to result in direct mortality of adult, subadult, or fledged juvenile marbled murrelets, because the sound levels associated with Growler overflights are not at levels that cause injury to ears or internal organs, and the energetic costs of responses to overflights are not expected to be lethal by themselves. The action is expected to indirectly result in a slight increase in the mortality of some adult, subadult, or fledged juvenile marbled murrelets, particularly in years with very low prey availability, due to the energetic costs of responses to the overflight disturbance. In these conditions, the effects of the action will contribute to malnourished body condition, increased susceptibility to toxic exposures, and disease. As a result, we expect that the number of marbled murrelets that die in a given poor prey year will be slightly higher as a result of the action, as compared with the number that would die if the action did not occur. This small increase in mortality will affect marbled murrelets associated with both Zone 1 and Zone 2, because malnutrition can occur at any time of the year, including the non-breeding season when birds from Zone 2 are present in the action area. However, we expect greater effects to survival of Zone 1 birds than of Zone 2 birds, because Zone 1 birds are present

in the action area year-round. We expect that the increase in mortality will be small, because we expect that only the small number of birds exposed to very frequent overflights, multiple times per day, will experience major energetic costs as a result of the action. Most individuals will move in and out of the frequently-exposed areas and will experience smaller energetic costs that will be unlikely to affect their survival chances. Marbled murrelet adult survival rates are typically very high, and we expect that in most circumstances, non-breeding birds will be able to absorb the increased energetic costs by foraging more, and breeding birds are more likely to abandon breeding than to die.

11.7.4 Effects to the Survival and Recovery of the Species

The marbled murrelet population in Zone 1 has declined at an estimated rate of 4.9 percent (95 percent confidence interval, 2.4 to 7.3 percent) per year over the period from 2001 through 2018 (McIver et al. 2019, p. 9). The rate of decline shows signs of slowing in recent years: for 2001 through 2010, the rate of decline was estimated at 7.4 percent (95 percent confidence interval, 3.5 to 11.2 percent) per year (Miller et al. 2012, p. 775), and for 2001 through 2014, it was 5.4 percent (95 percent CI, 1.6 to 9.1 percent; Falxa et al. 2015, p. 8). The Navy has been flying military jets from Ault Field during the entire period of marbled murrelet population monitoring, and began flying Growlers, with an average of 73,895 airfield operations per year, in 2012. Therefore, the effect of military jets in general, and 73,895 airfield operations involving Growlers in particular, is already reflected in the environmental baseline and in the current measures of population decline in Zone 1. (We note that the introduction of Growlers in 2012 did not lead to a steeper population decline, but rather coincided with a slowing of the decline). The current action includes an average of 97,564 airfield operations per year involving Growlers, an increase of 32 percent over the level of Growler use that is already reflected in baseline population trends.

We based our expectations of marbled murrelet responses to Growler overflights largely on their observed responses to the approach of small boats, as well as their observed responses to small airplanes. The environmental baseline reflects marbled murrelet population-level responses to a very large amount of boat traffic and to a not insignificant amount of small plane traffic in the action area and in Zone 1. As summarized in Section 8.1.4.1, we estimate that there are at least 350,000 opportunities annually for marbled murrelets to be exposed to boats and small airplanes in the action area and Zone 1 (345,000 boat transits and 5,000 small airplane flights). As discussed in section 8.3, there are 73,895 annual Growler airfield operations already accounted for in the baseline. Based on the types of flights operations in this estimate of existing Growler operations (Bianchi, in litt. 2018b), and counting two operations per closed pattern and one operation per other flight (see Section 9.2.1 and Table 3), these airfield operations represent 52,780 flights already accounted for in the baseline. The action would add 14,901 additional flights annually to the existing baseline.

Boat transits and Growler overflights differ in a variety of ways; for example, some boats travel all the way through Puget Sound and the Strait of Juan de Fuca, which is far longer than any of the flight tracks included in the action, and boats travel more slowly, giving more opportunity for different marbled murrelets to move into the area exposed to a given boat or for the same marbled murrelet to be exposed repeatedly to the same boat. Therefore, if we assume that an

average boat transit exposes the same number of marbled murrelets as an average Growler overflight, we are likely to underestimate the exposure to boat transits or overestimate the exposure to Growler overflights. However, equating the two modes of exposure allows us to estimate that the baseline includes the effects of at least 402,780 (350,000 boats and small aircraft plus 52,780 Growler flights) opportunities for exposure of marbled murrelets, and the current action will add the effects of 14,901 opportunities for exposure, which results in an increase of less than four percent over baseline levels.

Put another way, if Zone 1 marbled murrelets are exposed to an average of two Growler overflights per day during the breeding season, as we estimated in Section 9.2.2.1.5, then 1.5 of these overflights are already accounted for in the baseline. In addition, this means that the birds are also exposed to an average of more than ten boats and small aircraft each day (67,681/2 = 350,000/10.3). As noted above, these estimates likely underestimate exposure to boats, and therefore overestimate the proportional increase attributable to Growler overflights.

Because we expect similar individual-level responses to boats, small airplanes, and Growlers, we also expect that the population-level effects of each type of exposure will be the same: small reductions in individual survival and reproduction, with some population-level effects resulting from reduced breeding success. Some types of boat transit are likely to increase in the action area, due to non-federal actions described in the Cumulative Effects (section 10). We expect that these additional boat transits will also have similar effects.

Marbled murrelet population trends are tracked via at-sea surveys. These surveys produce highly variable results, due to both natural variability and sampling error. Thus, although it is clear that the Zone 1 population is currently declining, the 95 percent confidence interval for the rate of decline is wide, ranging between 2.4 and 7.3 percent per year (McIver et al. 2019, p. 9). Small changes in demographic parameters, such as breeding success, will alter rates of population decline, but these changes are not likely to be detectable unless they are large and consistent over time. We do not expect that the action will reduce breeding success consistently over time, but instead will have variable effects depending on foraging conditions, with the greatest, but still small, effects when prey availability and quality are moderate. Because we expect the action to have a small and intermittent, rather than large and consistent, effect on breeding success, we expect that any alteration of the rate of population decline will not be detectable against the backdrop of natural variability and statistical uncertainty.

The addition of 16,408 additional Growler flights (associated with the 23,669 additional airfield operations) when added to the existing baseline and considering cumulative effects is unlikely to change the rate of population decline enough to have a detectable effect on the population trend in Conservation Zone 1. The addition of 16,408 Growler flights represents at most a four percent increase in the number of times marbled murrelets in the action area will encounter boats or airplanes leading to a potential startle response. As discussed elsewhere in this analysis, not all encounters will lead to a behavioral response such as flight or avoidance diving, not all behavioral or physiological responses will lead to a detrimental effect to the individual, and not

all detrimental effects to individuals will lead to mortality or lost opportunities for reproduction. Because the action will not cause the Zone 1 population trend to be detectably altered from the baseline Zone 1 population trend, the action is not likely to reduce appreciably the likelihood of survival of marbled murrelets in Zone 1.

As discussed above, the Zone 2 marbled murrelet population will experience similar effects to individual survival and reproduction, but to a smaller degree since most of the effects to individuals will be confined to the non-breeding season. The Zone 2 population appears to be declining at 3 percent per year, but with some uncertainty about the direction of the trend, because the 95 percent confidence interval ranges from a 6.8 percent annual decline to a 0.9 percent annual increase (McIver et al. 2019, p. 9). During the non-breeding season, marbled murrelets that nest in Zone 2 and winter in Zone 1 experience the same boat and airplane traffic as marbled murrelets that reside in Zone 1 year-round, so the effects of these non-breeding season exposures are already included in the Zone 2 baseline. For the same reasons outlined above for Zone 1, we do not expect that mainly non-breeding exposures to the additional overflights will lead to a detectable change in the Zone 2 population trend. Because the action will not cause the Zone 2 population trend to be detectably altered from the baseline Zone 2 population trend, the action is not likely to reduce appreciably the likelihood of survival of marbled murrelets in Zone 2.

We also consider whether the likelihood of marbled murrelet recovery will be appreciably reduced by the action. Recovery may be achieved once four of the six Conservation Zones show stable or increasing population trends over a ten-year period, and monitoring and habitat protection commitments in all Conservation Zones are adequate to protect marbled murrelets for at least the near future (50 years). The action does not affect monitoring or habitat protection commitments, but because it does have some effects on individual survival and reproduction, we consider whether the action affects the likelihood of achieving stable or increasing population trends in Zones 1 and 2.

Currently, it appears that marbled murrelet populations, including in Conservation Zone 1, are limited by sustained low recruitment due to low reproductive rates, and perhaps juvenile and subadult survival rates, rather than adult survival (USFWS 2012b, pp. 10-13). Low nesting success in Zones 1 and 2 is likely to due to a shortage of suitable nesting habitat in close proximity to high-quality foraging areas (Lorenz et al. 2017 pp. 317-318). Evidence from long-term counts of recently-fledged juveniles suggests that the number of breeding adults has remained stable, while the number of non-breeding marbled murrelets has declined (Lorenz and Raphael 2018, p. 211). To the extent that the Zone 1 and Zone 2 populations are limited by the availability of suitable nesting habitat in close proximity to high-quality foraging areas, this means that they are larger than the current carrying capacity of the available habitat, and are likely to continue to decrease until they match the carrying capacity. After that, adult survival rates may become more important in determining whether the population stabilizes or continues to decline. If survival rates are too low, the population will continue to decline, even if the carrying capacity of nesting habitat increases. In a recent population viability analysis, a 90 percent adult survival rate was high enough to allow for population stabilization and increase, whereas an 87 percent survival rate was too low and led to declines even as nesting habitat capacity increased (Peery and Jones 2019, pp. 8, 50, 53-54, 56-57).

This action is not related to the availability of nesting habitat or high-quality foraging habitat, and does not affect the carrying capacity of the habitat. Instead, these habitat limitations are a legacy effect of past harvest of old forest in the terrestrial environment and loss of high-quality foraging areas due to development of shorelines and, potentially, past fisheries. If these habitat limitations cannot be lifted, recovery may still be achieved in Zone 1 and Zone 2, with population stability at smaller sizes than the current populations. Increases in Zone 1 and Zone 2 marbled murrelet populations will depend on the ingrowth of nesting habitat closer to high-quality foraging areas, or the improvement of prey quality and distribution, or both. The action does not affect the likelihood of these habitat improvements.

Once the populations have declined to the current carrying capacity, or the carrying capacity has increased to accommodate current populations, population stability is not guaranteed. If survival rates are too low, the populations will not be able to stabilize or increase, but instead will continue to decline. We expect the action to lead to increases in mortality rates, but these increases are expected to be small and mainly confined to years with poor prey availability. The occasional small increases in mortality rates attributable to the action are not likely to make the difference between population stability and continued decline. The apparent slowing of population declines in Zone 1 following the introduction of Growlers illustrates this lack of influence. We conclude that the action is not likely to appreciably reduce the likelihood of recovery in Zone 1, since other factors are currently limiting populations. If these limitations are lifted, the action is not likely to play the deciding role in determining whether populations stabilize or continue declining.

We conclude that the action is not expected to reduce appreciably the likelihood of survival and recovery of marbled murrelets in Zone 1or Zone 2. Therefore, the action is not expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of marbled murrelets rangewide, because we do not expect appreciable reductions in the likelihood of survival and recovery at the scale of any Conservation Zone.

12 CONCLUSION: Marbled Murrelet

After reviewing the current status of marbled murrelet, the environmental baseline for the action area, the effects of the NAS Whidbey Island Complex EA-18G “Growler” Airfield Operations, and the cumulative effects, it is the Service's Opinion that the NAS Whidbey Island Complex EA-18G “Growler” Airfield Operations, as implemented according to the ROD, is not likely to jeopardize the continued existence of the marbled murrelet.

13 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA 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 Service 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 Service 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 ESA 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 Navy for the exemption in section 7(o)(2) to apply. The Navy has a continuing duty to regulate the activity covered by this Incidental Take Statement. If the Navy fails to assume and implement the terms and conditions, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Navy must report the progress of the action and its impact on the species to the Service as specified in this Incidental Take Statement [50 CFR 402.14(i)(3)].

14 AMOUNT OR EXTENT OF TAKE

The Service anticipates incidental take, resulting from this proposed action, of a subset of the adult, subadult, and fledged juvenile marbled murrelets exposed to Growler overflights, and nestlings of exposed adults. The subset cannot be quantified because the size of the subset will vary over time, according to foraging conditions and the movements of individual marbled murrelets in and out of the action area, and both of these factors are inherently unpredictable. Most instances of incidental take are expected to be in the form of harass, because exposure to aircraft overflights will create a likelihood of injury to a subset of marbled murrelets by significantly disrupting normal behaviors such as foraging and resting. Altered behavior will result in some adult and subadult marbled murrelets being more susceptible to injury or mortality from starvation or illness; reductions in body condition resulting from behavioral or physiological responses to Growler overflights will sometimes lead marbled murrelets to forgo breeding; and missed feedings of nestlings will increase the likelihood that some chicks will suffer from stunted growth and altered development, which in turn increase the chances that chicks will die from starvation or failure to complete the first flight to the marine waters. Some instances of incidental take are expected to be in the form of harm, because in some cases when chicks miss meals as a result of the action, stunting and altered development will be direct consequences.

The Service anticipates incidental take of marbled murrelets will be difficult to detect for the following reasons: the action will introduce stressors to large areas over short periods; marbled murrelets are widely distributed throughout the marine environment and their distribution is likely to change frequently; locating marbled murrelet nests is difficult even when the general location of the nest is known, and in addition to the nesting habitat that will be subjected to overflights directly, nesting habitat for adult birds exposed to stressors in the marine environment is likely to encompass the entire terrestrial range of the marbled murrelet in Washington.

Furthermore, detection of the reductions in body condition or changes in chick development associated with the expected take would require capture and handling of marbled murrelets, which would involve additional take of individuals, and would be very stressful for the individuals monitored in this way, leading to some of the same consequences associated with the action. Dead or injured individuals that were affected by the action are unlikely to be found in either the marine or terrestrial environments, and if they are, it will be difficult to determine whether exposure to Growler overflights contributed to the injury or death.

However, pursuant to 50 CFR 402.14(i)(1)(i), the Service can use a surrogate to express the anticipated level of take in an incidental take statement, provided: (1) we explain why measuring take impacts to a listed species is not practical; (2) we describe the causal link between the surrogate and take of the listed species is described; and (3) we set a clear standard for determining when the level of anticipated take based on the surrogate has been exceeded.

The Service's regulations state that significant habitat modification or degradation caused by an action that results in death or injury to a listed species by significantly impairing its essential behavior patterns constitutes take in the form of harm. Those regulations further state that an intentional or negligent act or omission that creates the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt its normal behavioral patterns constitutes take in the form of harass. Such annoyance can be caused by actions that modify or degrade habitat conditions (e.g., excessive noise or smoke). In cases where this causal link between effects of a federal action to habitat and take of listed species is established, and the biological opinion or incidental take statement explains why it is not practical to express and monitor the level of take in terms of individuals of the listed species, the Service's regulations authorize the use of habitat as a surrogate for expressing and monitoring the anticipated level of take, provided a clear standard is established for determining when the level of anticipated take has been exceeded.

The following narrative presents the Service's analysis and findings with respect to the three regulatory criteria for use of a surrogate in this Incidental Take Statement to express the anticipated level of take likely to be caused by the action.

In this case, a surrogate is necessary to express the extent of take because it is not practical to monitor take impacts to individual marbled murrelets due to difficulty of monitoring marbled murrelet behavior and physiology throughout the action area, as well as the extremely low likelihood of finding dead or injured individuals in the aquatic or terrestrial environments. The Service is using a coextensive surrogate based on an estimate of the number of times individual marbled murrelets are exposed to the stressors causing the taking. The number of times each flight track is used is combined with information about marbled murrelet presence in different marine areas at different times of the year. Thus, the surrogate links the cause (noise disturbance from overflights) to the exposure (which is a necessary component of the effects) of the marbled murrelets present in the area. Not all individuals exposed to noise disturbance from overflights will be taken, but all individuals that are taken will have been exposed to noise disturbance from overflights, or will be the dependent nestlings of adults that are exposed.

The Service anticipates incidental take of a subset of adult, subadult, and juvenile marbled murrelets that will collectively receive an annual average of 3,578,730 exposures of individual marbled murrelets to single or double overflights, 227,183 triple exposures caused by interfacility flights, and 10,547 exposures to 45-minute FCLP training periods (see Section 9.2.2.1.5, Tables 12 and 13). We anticipate that on average, in a given year, no more than 1,303,848 exposures to single or double overflights, 100,431 triple exposures caused by interfacility flights, and 3,304 exposures to 45-minute FCLP training periods will occur during April through September (see Section 9.2.2.1.5, Tables 12 and 13).

We expect that the amount of exposure will vary from year to year, and that some years will have higher- or lower-than-average numbers of exposures. We anticipate that the action will not result in more than 6,492,084 exposures of individual marbled murrelets to single or double overflights, 371,304 triple exposures caused by interfacility flights, and 21,930 exposures to 45-minute FCLP training periods in any given single year (see Section 9.2.2.1.5, Tables 14 and 15). We anticipate that the action will not result in more than 2,743,730 exposures of individual marbled murrelets to single or double overflights, 118,186 triple exposures caused by interfacility flights, and 9,414 exposures to 45-minute FCLP training periods in any given single breeding season, April through September (see Section 9.2.2.1.5, Tables 14 and 15).

Furthermore, we expect that years with higher-than-average exposure will be distributed throughout the 30-year term of the action, interspersed with years with lower-than-average exposure. Therefore, we anticipate that the annual average numbers of exposures described above will apply at the timescale of a 5-year rolling average; that is, in any given period of 5 consecutive years, the annual exposure, averaged over the 5-year period, will not exceed the annual average exposure described above, even though some years may individually have levels of exposure up to the maximum level described above for a single year. Also, in any given period of 5 consecutive years, the breeding season exposure, averaged over all breeding seasons within the 5-year period, will not exceed the levels described for an average year above.

In total, over 30 years, we anticipate 107,361,910 exposures of individual marbled murrelets to single or double overflights, 6,815,498 triple exposures caused by interfacility flights, and 316,423 exposures to 45-minute FCLP training periods (see Section 9.2.2.1.5). We anticipate that over 30 years, no more than 39,115,427 exposures to single or double overflights, 3,012,929 triple exposures caused by interfacility flights, and 99,122 exposures to 45-minute FCLP training periods will occur during the April through September breeding season (see Section 9.2.2.1.5).

In addition, marbled murrelets associated with 3,871 acres of suitable nesting habitat will be exposed to aircraft overflights during the breeding season created by an average of 270 and a maximum of 280 Growler flights per year for 30 years, with no more than 8,100 over the entire 30-year period, over Cypress and Blakely Islands during the period from April 1 through September 30.

Thus, the level of anticipated take utilizing the coextensive surrogate, as evaluated on a rolling average basis, as well as a maximum yearly and seasonal level, is described in the following three tables (Tables 20, 21, and 22). Note that we would expect the maximum level of exposure to occur only if marbled murrelet densities are at their maximum at the same time as Growler activity is at its maximum.

Table 20. Annual average exposures (rolling average over a 5-year period) and total 30-year exposures

Type of Exposure (Year-round)	**Annual Average Exposures (5-year Rolling Average)**	**Total 30-year Exposures**
Single or double overflights	3,578,730	107,361,910
Triple overflights (interfacility flights)	227,183	6,815,498
45-minute FCLP periods	10,547	316,423

Table 21. Breeding season average exposures (rolling average over a 5-year period) and total breeding season exposures over 30 years

Type of Exposure (Breeding Season, April – September)	**Average Seasonal Exposures (5-year Rolling Average)**	**Total Seasonal Exposures Over 30 Years**
Single or double overflights	1,303,848	39,115,427
Triple overflights (interfacility flights)	100,431	3,012,929
45-minute FCLP periods	3,304	99,122
Overflights over suitable nesting habitat	270	8,100

Table 22. Maximum number of exposures in any one breeding season or year

Type of Exposure	Maximum Breeding Season (April–September) Exposures	Maximum Annual Exposures
Single or double overflights	2,743,328	6,492,084
Triple overflights (interfacility flights)	118,186	371,304
45-minute FCLP periods	9,414	21,930
Overflights over suitable nesting habitat	280	280

15 EFFECT OF THE TAKE

In the accompanying Opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the marbled murrelet.

16 REASONABLE AND PRUDENT MEASURES

The Service believes the following reasonable and prudent measure(s) (RPM) are necessary and appropriate to minimize the impacts (i.e., the amount or extent) of incidental take of marbled murrelet:

RPM 1: Monitor implementation of the action and report the annual number of Growler airfield operations and their associated flight tracks to ensure that the level of take exempted by this Incidental Take Statement is not exceeded.

RPM 2: Ensure that, in the aggregate, the areas ensonified to sound levels of 92dBASEL or greater are not larger than those estimated in Appendix C of this document (see Table 5 for summary). If larger areas are exposed to 92dBASEL or greater, the level of take exempted in this Incidental Take Statement may be exceeded.

17 TERMS AND CONDITIONS

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

To implement RPM 1:

1a. The Navy shall submit a monitoring report to the Service (Washington Fish and Wildlife Office, attn.: Federal Activities Branch) by February 1 of each year. The report shall describe the Growler airfield operations of the previous calendar year. At a minimum, this report shall include the number of Growler airfield operations by type (e.g. departures, ground-controlled arrivals, etc.), flight track, and season (April through September or October through March). For FCLP operations, the report shall include the number of FCLP periods at each location, and which runways and flight tracks were used, by season. For interfacility flights, the report shall list include the number of times groups of Growler aircraft departed Ault Field for OLF Coupville, and vice versa, as well as which runways and flight tracks were used, by season. If any of these numbers cannot be recorded and reported directly, the report shall contain an estimate of the numbers and explain the method used to derive the estimate. Methods used to derive estimates must be based on the best available information that is current at the time of the monitoring report. In addition to the information regarding Growler flights, the Navy shall provide its estimates for the previous year and previous 5-year rolling averages of the numbers of marbled murrelets exposed to Growler overflights in the breeding and non-breeding seasons, to be estimated by the spreadsheet described in 1b.

1b. While implementing the action, the Navy shall use a spreadsheet, to be provided by the Service, to track throughout the reporting period the estimated number of marbled murrelet exposures to overflights in the marine environment, and to track how often suitable nesting habitat is exposed on Cypress and Blakely Islands. The spreadsheet will contain the exposure model that relates each Growler overflight to the number of marbled murrelets exposed (see Appendix E). The use of this spreadsheet will provide the Navy with early warning if it is on track to exceed the exempted levels of take, allowing the Navy to adjust operations to reduce the number of marbled murrelet exposures, or, if that is not possible, re-initiate consultation prior to exceeding the exempted levels of take. The Service may periodically update the spreadsheet with new information regarding the expected number of marbled murrelets in each part of the action area.

1c. The Navy shall contact the Service if the monitoring described in 1a or 1b shows that the five-year rolling annual or breeding season average of marbled murrelet exposures exceeds the annual or breeding season average, respectively, exempted by this Incidental Take Statement, or a single year's or breeding season's exposure exceeds the maximum annual or breeding season exposure levels, respectively, exempted by this Incidental Take Statement. If updated information is available regarding marbled murrelet population densities at sea during the Growler operations, the Service will update the exposure model to reflect the new information. If the updated exposure model still indicates that the five-year rolling average or the maximum exceeds the level exempted by this Incidental Take Statement, this will trigger re-initiation.

To implement RPM 2:

2a. The Navy shall prepare, and submit to the Service for approval, a Plan that details the monitoring necessary to characterize the in-air sound levels of Growler flight operations, to demonstrate that the area ensonified by sound levels greater than 92 dBA_{SEL} does not, in the aggregate, exceed that which is summarized in Table 5. The Plan shall include:

- The Navy's proposed method for calculating an estimate of the ensonified area for the flight tracks identified in Appendix C, based on sound measurements taken during Growler overflights associated with the action;
- Identification of a sampling scheme to represent flight types and the conditions under which they will be operated;
- A description of proposed data collection methods and equipment necessary to measure the sound of Growler overflights within 2 m of the water's surface in the local marine environment in the vicinity of NAS Whidbey Island; and
- A description of the proposed method to associate the sound data described above with information about the corresponding flight type and conditions for the purpose of calculating the estimate of the ensonified area.

2b. The Navy shall provide a draft of the Plan to the Service on or before October 1, 2020. The monitoring required in 2a shall not commence prior to the approval of the Plan by the Service.

2c. Following execution of the Plan described in 2b, the Navy shall submit a report describing the results to the Service (Washington Fish and Wildlife Office, attn.: Federal Activities Branch) no later than February 1, 2026. This report shall include, for each overflight for which sound was measured, the date and location of the measurement, an estimate of the distance from the aircraft, the type of flight operation, weather conditions, sound measurements, sound levels in dBA_{SEL} at the location of the measurement, and a calculation of the area ensonified to 92dBA_{SEL}.

2d. If the aggregate results of monitoring indicate that the area ensonified to 92 dBA_{SEL} is greater than expected, take may be exceeded. Aggregate is intended to mean that the monitoring results indicate that collectively all flight types, rather than individual flights, exceed the area ensonified (i.e., the Service assumes that an individual flight may exceed the estimated area ensonified, on occasion). In order to determine whether take is exceeded, the area ensonified must be combined with information regarding the other elements of exposure, such as the density of marbled murrelets in the areas exposed, and the duration, frequency, and timing of flight operations.

The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the 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 Federal agency must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the action or the reasonable and prudent measures.

The Service 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 Service's Washington Fish and Wildlife Office at (360) 753-9440.

18 CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA 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 an action on listed species or critical habitat, to help implement recovery plans, or to develop information.

1. Restore and enhance forage fish habitat in Conservation Zone 1, to increase productivity and prey available to marbled murrelets, utilizing the Navy's INRMP or other opportunities that become available.

2. Improve water quality in the marine waters of Conservation Zone 1, utilizing the Navy's INRMP, or other opportunities that become available.

3. Continue to monitor incidents of aircraft/bird strikes, identify the species of bird struck, and report findings to the Service.

4. Limit the number of FCLPs performed at OLF Coupeville. Interfacility flights (which are only needed to perform FCLPs at OLF Coupeville) expose large areas of marine habitat along their flight tracks and limiting the number of FCLPs at OLF Coupeville will limit the number of interfacility flights.

5. Limit the use of flight tracks that expose a greater number of marbled murrelets to Growler overflights. Within each type of operation there are flight tracks that expose larger or smaller numbers of marbled murrelets. Limiting use of flight tracks that expose larger numbers of marbled murrelets will decrease the negative effects of the action to marbled murrelets.

6. Limit the use of flight tracks that expose areas of high marbled murrelet density during the breeding season. Also, minimize the number of flights at dusk during the breeding season. Limiting use of these flight tracks, and minimizing flights at dusk, will decrease the negative effects of the action to breeding adults and to chicks at the nest.

7. Avoid the use of flight tracks that fly over Cypress and Blakely Island during the breeding season, especially at dusk. Limiting these flight tracks to the non-breeding season will eliminate the exposure of nesting marbled murrelets to aircraft overflights in their nesting habitat. Avoiding the use of these flight tracks at dusk will reduce the likelihood that an overflight will result in a missed nestling feeding.

8. Fund breeding season at-sea marbled murrelet surveys during years when NWFPEM surveys are not conducted. Ideally, provide off-year funding so that NWFPEM surveys can be conducted every year in both Washington conservation zones (Zone 1 and Zone 2). Alternatively, fund breeding season at-sea surveys corresponding with the annual non-breeding season at-sea surveys funded by the Navy and conducted by WDFW, to be conducted during years when NWFPEM surveys are not conducted in Zone 1.

9. Fund or conduct surveys, in cooperation with WDNR, for marbled murrelets nesting on Cypress and Blakely Islands. Surveys should be conducted using the Marbled Murrelet Inland Survey Protocol that is current at the time of the survey.

10. Work with the Service to design and conduct a study that measures the physiological responses and/or the physiological and fitness consequences of behavioral responses to military aircraft overflights by alcid species, or other proxies for marbled murrelets. Conducting such studies on marbled murrelets themselves is likely to be extremely difficult and to have significant negative effects to the individuals studied, so we do not suggest direct studies of marbled murrelet behavioral and physiological responses, except to the extent that marbled murrelet behavioral responses can be observed from shore.

11. Facilitate surveys for streaked horned larks (*Eremophila alpestris strigata*) by trained biologists at Ault Field and OLF Coupeville. Streaked horned larks nest at other airfields in western Washington and Oregon, and although their presence is not documented at NAS Whidbey Island, recovery actions may lead to range expansions.

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

19 REINITIATION NOTICE

This concludes formal consultation on the action outlined in the request for reinitiation of formal consultation. 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.

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APPENDIX A
PREDOMINANT GROWLER FLIGHT TRACKS

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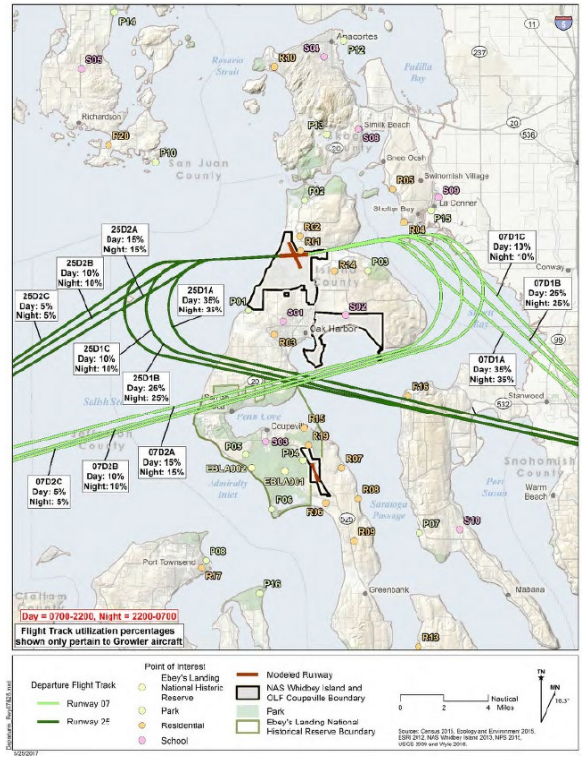
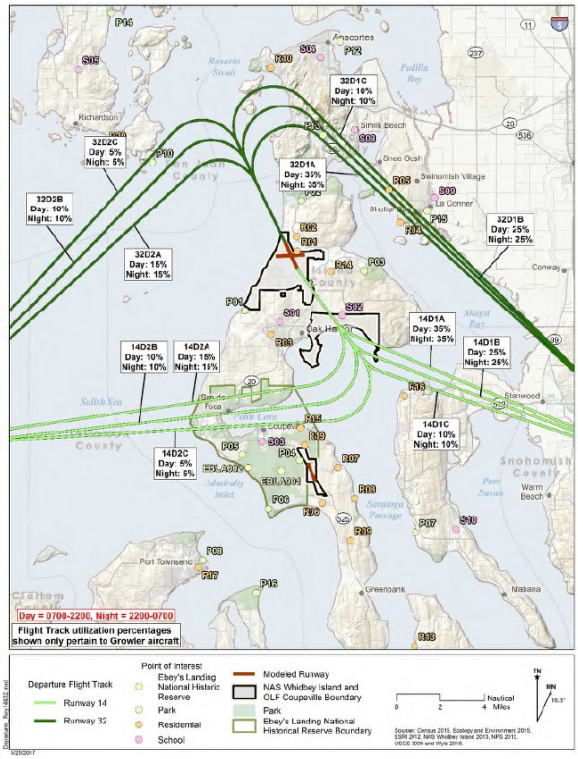
APPENDIX A
Predominant Growler Flight Tracks

Departures:

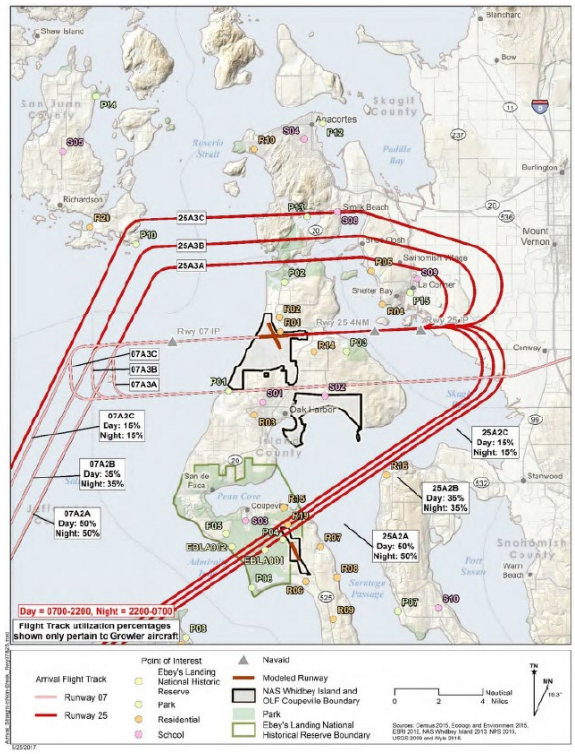


(Navy 2018, p. A4-5)

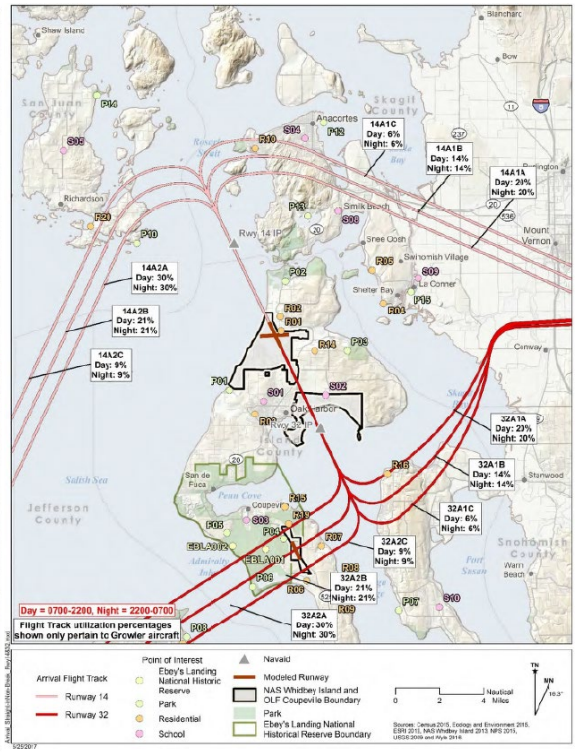


(Navy 2018, p. A4-6)

Straight-in/Full-stop Arrivals:

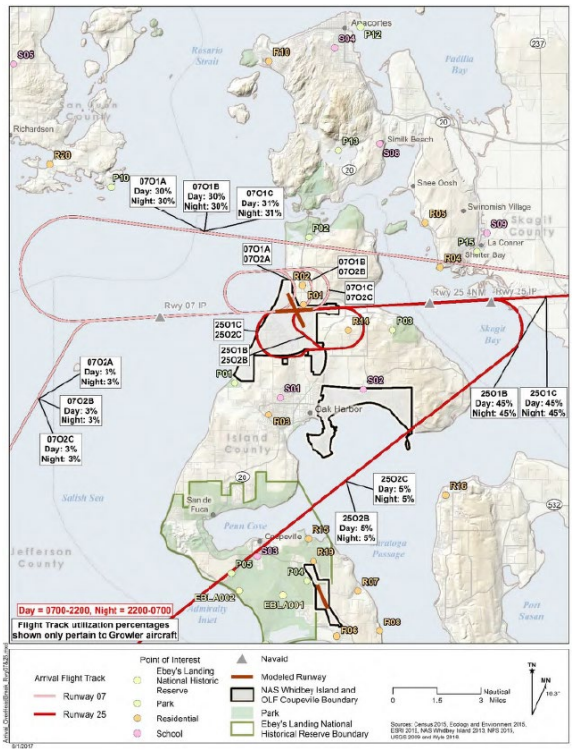


(Navy 2018, p. A4-7)

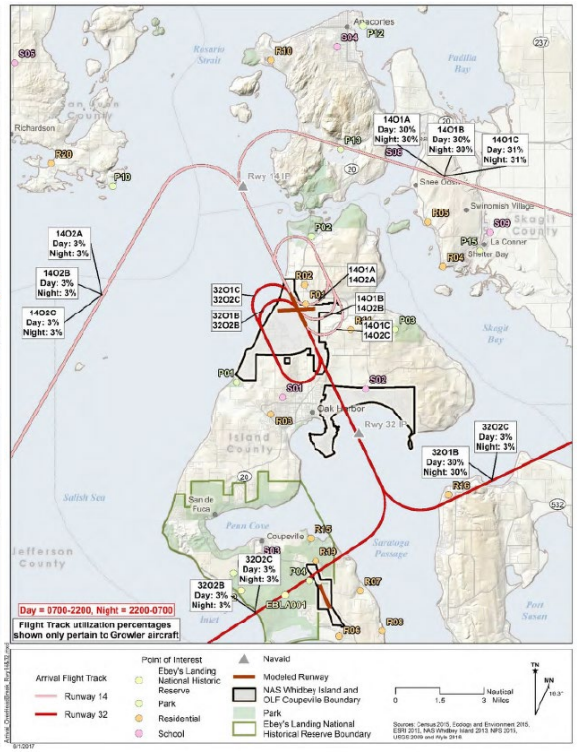


(Navy 2018, p. A4-8)

Overhead Break Arrivals:



(Navy 2018, p. A4-11)



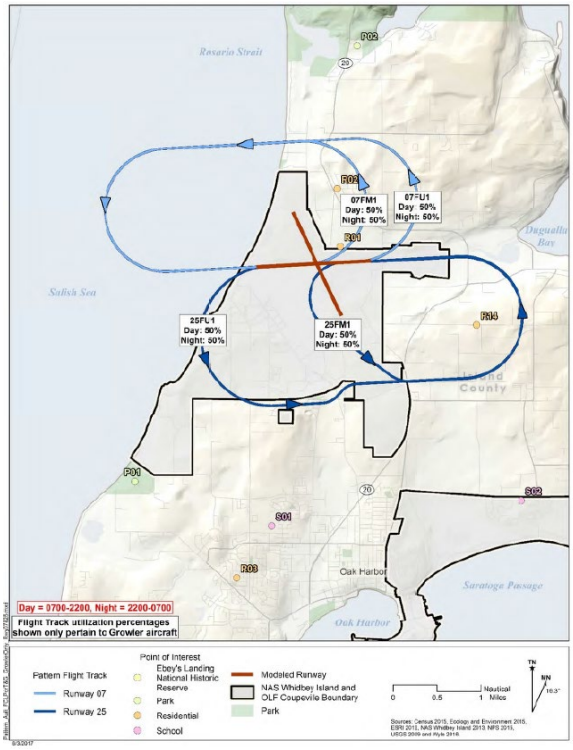
(Navy 2018, p. A4-12)

Instrument Approaches:

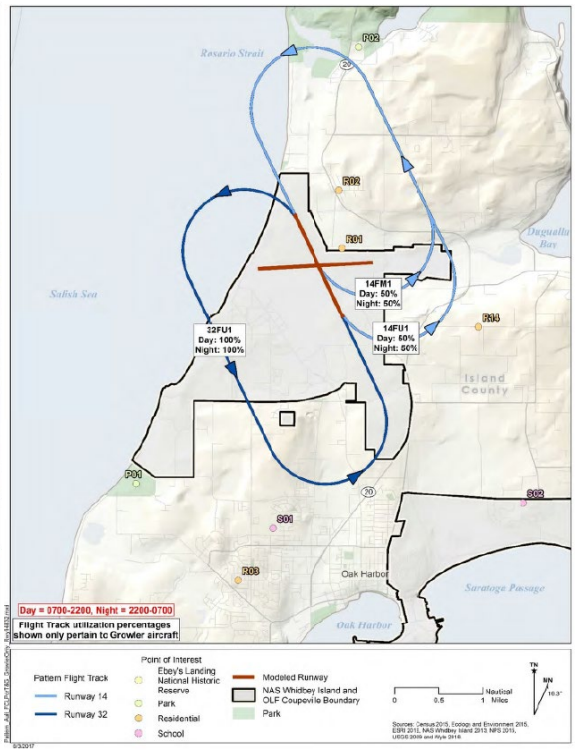
(Navy 2018, p. A4-13)

Field Carrier Landing Practice/Touch-and-go:

Ault Field

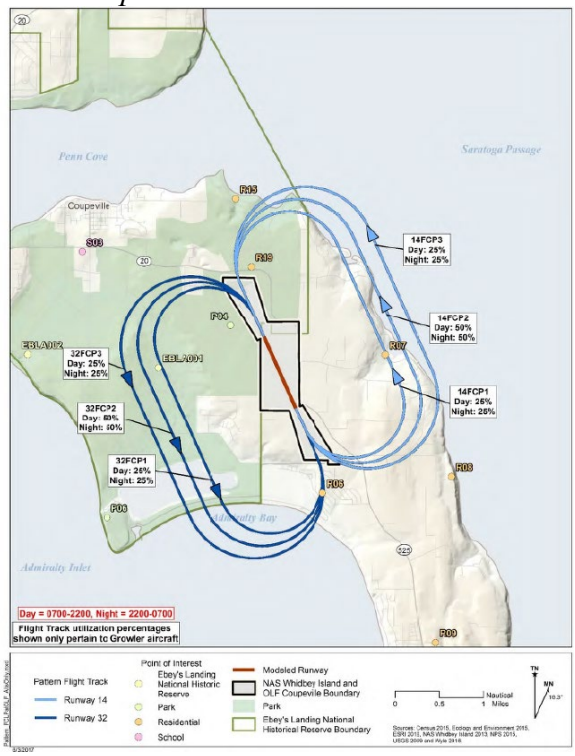


(Navy 2018, p. A4-15)



(Navy 2018, p. A4-16)

OLF Coupeville

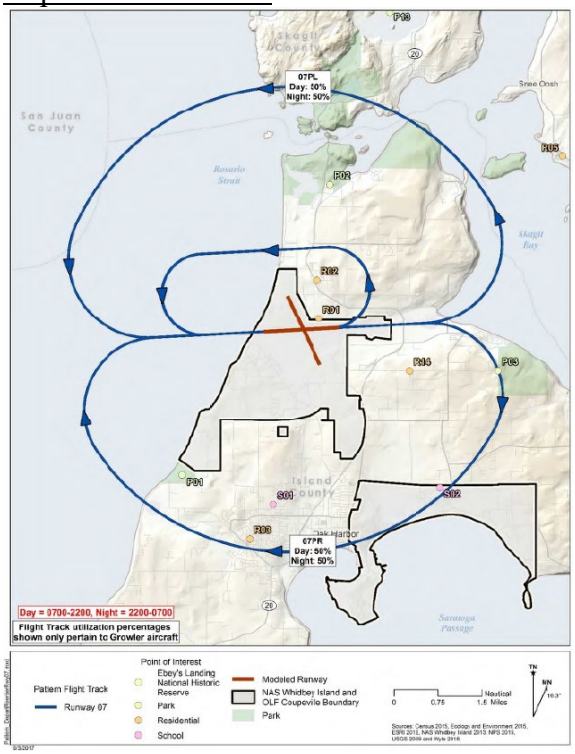


(Navy 2018, p. A4-30)

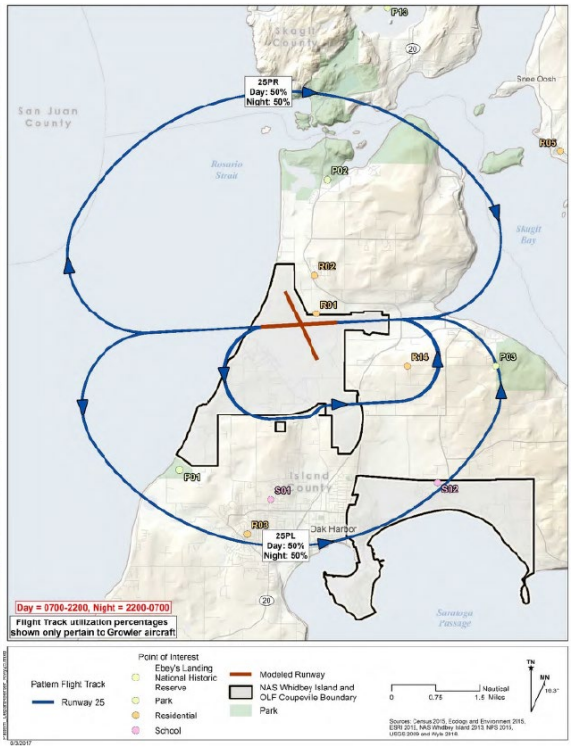
Ground/Carrier Controlled Approaches:

(Navy 2018, p. A4-23)

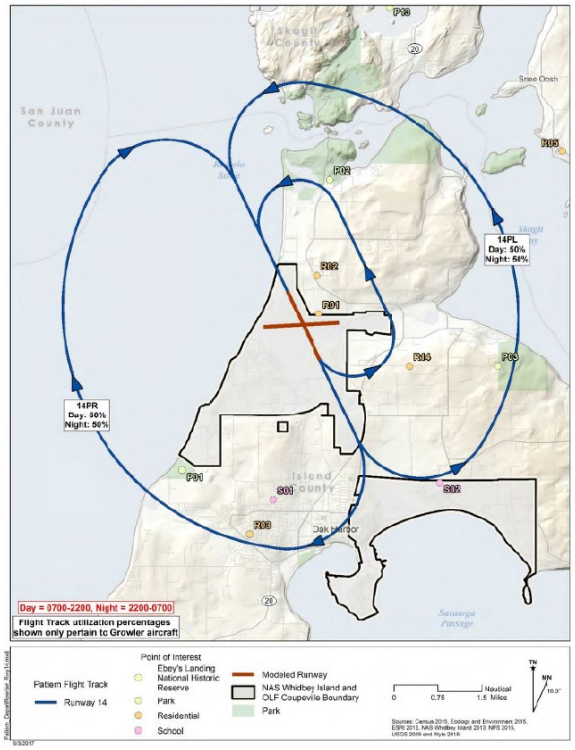
Depart and Re-enter:



(Navy 2018, p. A4-19)



(Navy 2018, p. A4-20)



(Navy 2018, p. A4-21)

(Navy 2018, p. A4-22)

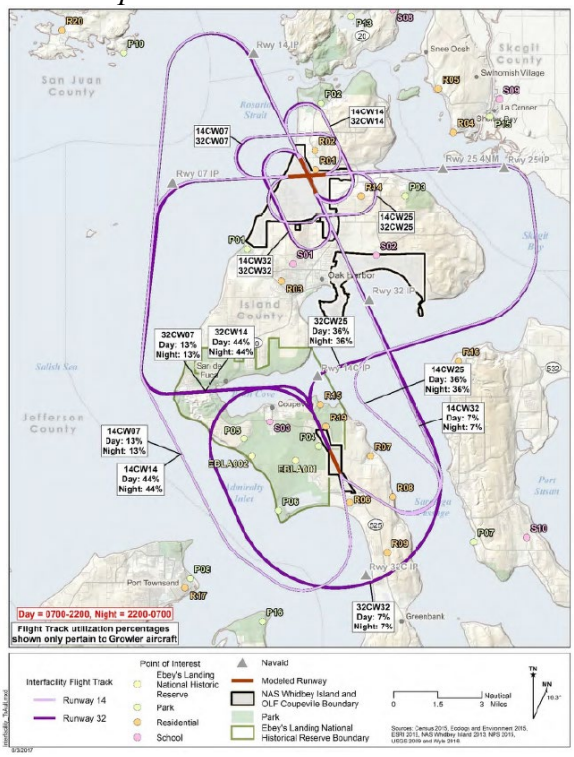
Interfacility Flights:

Ault Field to OLF Coupeville

(Navy 2018, p. A4-28)

(Navy 2018, p. A4-29)

OLF Coupeville to Ault Field



(Navy 2018, p. A4-27)

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APPENDIX B
STATUS OF THE SPECIES: MARBLED MURRELET

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Appendix B
Status of the Species: Marbled Murrelet

The marbled murrelet (*Brachyramphus marmoratus*) (murrelet) was listed by the U.S. Fish and Wildlife Service (Service) as a threatened species in Washington, Oregon, and California in 1992. The primary reasons for listing included extensive loss and fragmentation of the older-age forests that serve as nesting habitat for murrelets, and human-induced mortality in the marine environment from gillnets and oil spills (57 FR 45328 [Oct. 1, 1992]). Although some threats such as gillnet mortality and loss of nesting habitat on Federal lands have been reduced since the 1992 listing, the primary threats to species persistence continue (75 FR 3424 [Jan. 21, 2010]).

Life History

The murrelet is a small, fast-flying seabird in the Alcidae family that occurs along the Pacific coast of North America. Murrelets forage for small schooling fish or invertebrates in shallow, nearshore, marine waters and primarily nest in coastal older-aged coniferous forests. The murrelet lifespan is unknown, but is expected to be in the range of 10 to 20 years based on information from similar alcid species (De Santo and Nelson 1995, pp. 36-37). Murrelet nesting is asynchronous and spread over a prolonged season. In Washington, the murrelet breeding season extends from April 1 to September 23. Egg laying and incubation occur from April to early August and chick rearing occurs between late May and September, with all chicks fledging by late September (Hamer et al. 2003; USFWS 2012a).

Murrelets lay a single-egg which may be replaced if egg failure occurs early in the nesting cycle, but this is rare (Nelson 1997, p. 17). During incubation, one adult sits on the nest while the other forages at sea. Adults typically incubate for a 24-hour period, then exchange duties with their mate at dawn. Chicks hatch between May and August after 30 days of incubation. Hatchlings appear to be brooded by an adult for several days (Nelson 1997, p. 18). Once the chick attains thermoregulatory independence, both adults leave the chick 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, p. 18). 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 1995, p. 62).

Murrelets and other fish-eating alcids exhibit wide variations in nestling growth rates. The nestling stage of murrelet development can vary from 27 to 40 days before fledging (De Santo and Nelson 1995, p. 45). The variations in alcid chick development are attributed to constraints on feeding ecology, such as unpredictable and patchy food distributions, and great distances between feeding and nesting sites (Øyan and Anker-Nilssen 1996, p. 830). Food limitation during nesting often results in poor growth, delayed fledging, increased mortality of chicks, and nest abandonment by adults (Øyan and Anker-Nilssen 1996, p. 836).

Murrelets are believed to be sexually mature at 2 to 4 years of age (Nelson 1997, p. 19). Adult birds may not nest every year, especially when food resources are limited. For example, in central California, the proportion of murrelets attempting to breed was more than four times higher (50 percent versus 11 percent) in a year when prey availability was apparently good than

in a year when more foraging effort was required (Peery et al. 2004, p. 1095). In Oregon, none of the 61 murrelets radio-tagged in 2017 attempted nesting, likely because anomalous ocean conditions reduced prey availability (Horton et al. 2018, p. 77). At other times and places, radio-telemetry and demographic modeling indicate that the proportion of adults breeding in a given year may vary from 5 to 95 percent (Lorenz et al. 2017, p. 312; McShane et al. 2004, p. 3-5). In other words, in some years, very few marbled murrelets attempt nesting, but in other years, almost all breeding-age adults initiate nesting.

Murrelets in the Marine Environment

Marbled murrelets spend most (>90 percent) of their time at sea. They generally forage in pairs on the water, but they also forage solitarily or in small groups. In addition to foraging, their activities in the marine environment include preening, social behaviors, and loafing. Following the breeding season, murrelets undergo the pre-basic molt, in which they exchange their breeding plumage for their winter plumage. They replace their flight feathers during this molt, and for a few weeks they are flightless. Therefore, they spend this entire period at sea. Their preferred marine habitat includes sheltered, nearshore waters, although they occur farther offshore in some locations and during the nonbreeding season (Huff et al. 2006, p. 19).

Breeding Season

The murrelet is widely distributed in nearshore waters along the west coast of North America. It occurs primarily within 5 km of shore (Alaska, within 50 km), and primarily in protected waters, although its distribution varies with coastline topography, river plumes, riptides, and other physical features (Nelson 1997, p. 3). Murrelet marine habitat use is strongly associated with the amount and configuration of nearby terrestrial nesting habitat (Raphael et al. 2015, p. 17). In other words, they tend to be present in marine waters adjacent to areas of suitable breeding habitat. Non-breeding adults and subadults are thought to occur in similar areas as breeding adults. This species does occur farther offshore during the breeding season, but in much reduced numbers (Strachan et al. 1995, p. 247). Their offshore occurrence is probably related to current upwelling and plumes during certain times of the year that tend to concentrate their prey species. Even within the breeding season, individual murrelets may make large movements, and large average marine home ranges (505 km^2 and 708 km^2, respectively) have been reported for northern California and Washington (Hébert and Golightly 2008, p. 99; Lorenz et al. 2017, p. 318).

Non-breeding Season

Marbled murrelet marine habitat use during the non-breeding season is poorly documented, but they are present near breeding sites year-round in most areas (Nelson 1997, p. 3). Murrelets exhibit seasonal redistributions following the pre-basic molt (Peery et al. 2008a, p. 119), and can move up to 750 km from their breeding season locations (Hébert and Golightly 2008, p. 101; Adrean et al. 2018). Generally they are more dispersed and may be found farther offshore than during the breeding season, although the highest concentrations still occur close to shore and in

protected waters (Nelson 1997, p. 3). For example, murrelets move from the outer exposed coasts of Vancouver Island and the Straits of Juan de Fuca into the sheltered and productive waters of northern and eastern Puget Sound.

Foraging and Diet

Murrelets dive and swim through the water by using their wings in pursuit of their prey; their foraging and diving behavior is restricted by physiology. They usually feed in shallow, nearshore water less than 30 m (98 ft) deep, which seems to provide them with optimal foraging conditions for their generalized diet of small schooling fish and large, pelagic invertebrates: Pacific sand lance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea harengus*), surf smelt (*Hypomesus* sp.), euphausiids, mysids, amphipods, and other species (Nelson 1997, p. 7). However, they are assumed to be capable of diving to a depth of 47 m (157 ft) based on their body size and diving depths observed for other Alcid species (Mathews and Burger 1998, p. 71).

Contemporary studies of murrelet diets in the Puget Sound–Georgia Basin region indicate that Pacific sand lance now make up the majority of the murrelet diet (Gutowsky et al. 2009, p. 251). Historically, energy-rich fishes such as herring and northern anchovy comprised the majority of the murrelet diet (Becker and Beissinger 2006, p. 470; Gutowsky et al. 2009, p. 247). This is significant because sand lance have the lowest energetic value of the fishes that murrelets commonly consume. For example, a single northern anchovy has nearly six times the energetic value of a sand lance of the same size (Gutowsky et al. 2009, p. 251), so a murrelet would have to eat six sand lance to get the equivalent energy of a single anchovy. Reductions in the abundance of energy-rich forage fish species is likely a contributing factor in the poor reproduction in murrelets (Becker and Beissinger 2006, p. 470).

The duration of dives appears to depend upon age (adults vs. juveniles), water depth, visibility, and depth and availability of prey. Dive duration has been observed ranging from 8 seconds to 115 seconds, although most dives are between 25 to 45 seconds (Day and Nigro 2000; Jodice and Collopy 1999; Thoresen 1989; Watanuki and Burger 1999). Diving bouts last over a period of 27 to 33 minutes (Nelson 1997, p. 9). They forage in deeper waters when upwelling, tidal rips, and daily activity of prey concentrate prey near the surface (Strachan et al. 1995). Murrelets are highly mobile and some make substantial changes in their foraging sites within the breeding season. For example, Becker and Beissinger (2003, p. 243) found that murrelets in California responded rapidly (within days or weeks) to small-scale variability in upwelling intensity and prey availability by shifting their foraging behavior and habitat selection within a 100-km (62-mile) area. In Washington, changes in water temperature, likely also related to prey availability, influence foraging habitat use, but the influence of upwelling is less clear (Lorenz et al. 2017, pp. 315, 318).

For more information on murrelet use of marine habitats, see literature reviews in McShane et al. 2004, USFWS 2009, and USFWS 2019.

Murrelets in the Terrestrial Environment

Murrelets are dependent upon older-age forests, or forests with an older tree component, for nesting habitat (Hamer and Nelson 1995, p. 69). Specifically, murrelets prefer high and broad platforms for landing and take-off, and surfaces which will support a nest cup (Hamer and Nelson 1995, pp. 78-79). In Washington, murrelet nests have been found in live 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). Most murrelets appear to nest within 37 miles of the coast, although occupied behaviors have been recorded up to 52 miles inland, and murrelet presence has been detected up to 70 miles inland in Washington (Huff et al. 2006, p. 10). Nests occur primarily in large, older-aged trees. Overall, nests have been found in trees greater than 19 inches in diameter-at-breast and greater than 98 ft tall. Nesting platforms include limbs or other branch deformities that are greater than 4 inches in diameter, and are at greater than 33 ft above the ground. Substrate such as moss or needles on the nest platform is important for protecting the egg and preventing it from falling off (Huff et al. 2006, p. 13).

Murrelets do not form the dense colonies that are typical of most other seabird species. Limited evidence suggests they may form loose colonies 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). Individual murrelets are suspected to have fidelity to nest sites or nesting areas, although this is has only been confirmed with marked birds in a few cases (Huff et al. 2006, p. 11). There are at least 15 records of murrelets using nest sites in the same or adjacent trees in successive years, but it is not clear if they were used by the same birds (McShane et al. 2004, p. 2-14). At the landscape scale, murrelets are probably faithful to specific watersheds for nesting (McShane et al. 2004, p. 2-14). Murrelets have been observed visiting nesting habitat during non-breeding periods in Washington, Oregon, and California which may indicate adults are maintaining fidelity and familiarity with nesting sites and/or stands (Naslund 1993; O'Donnell et al. 1995, p. 125).

Loss of nesting habitat reduces nest site availability and displaces any murrelets that may have had nesting fidelity to the logged area (Raphael et al. 2002, p. 232). Murrelets have demonstrated fidelity to nesting stands and in some areas, fidelity to individual nest trees (Burger et al. 2009, p. 217). Murrelets returning to recently logged areas may not breed for several years or until they have found suitable nesting habitat elsewhere (Raphael et al. 2002, p. 232). The potential effects of displacement due to habitat loss include nest site abandonment, delayed breeding, failure to initiate breeding in subsequent years, and failed breeding due to increased predation risk at a marginal nesting location (Divoky and Horton 1995, p. 83; Raphael et al. 2002, p. 232). Each of these outcomes has the potential to reduce the nesting success for individual breeding pairs, and could ultimately result in the reduced recruitment of juvenile birds into the local population (Raphael et al. 2002, pp. 231-233).

Detailed information regarding the life history and conservation needs of the murrelet are presented in the *Ecology and Conservation of the Marbled Murrelet* (Ralph et al. 1995), the Service's 1997 *Recovery Plan for the Marbled Murrelet* (USFWS 1997), and in subsequent 5-year status reviews (McShane et al. 2004; USFWS 2009; USFWS 2019).

Distribution

Murrelets are distributed along the Pacific coast of North America, with birds breeding from central California through Oregon, Washington, British Columbia, southern Alaska, westward through the Aleutian Island chain, with presumed breeding as far north as Bristol Bay (Nelson 1997, p. 2), and non-breeding distribution extending as far south as the Southern California Bight (Hall et al. 2009, p. 5081). The federally-listed murrelet population in Washington, Oregon, and California is classified by the Service as a distinct population segment (75 FR 3424). The coterminous United States population of murrelets is considered significant as the loss of this distinct population segment would result in a significant gap in the range of the taxon and the loss of unique genetic characteristics that are significant to the taxon (75 FR 3430).

The inland nesting distribution of murrelets is strongly associated with the presence of mature and old-growth conifer forests. Murrelets have been detected farther than100 km inland in Washington (70 miles).The inland distribution in the southern portion of the species range is associated with the extent of the hemlock/tanoak vegetation zone which occurs up to 16-51 km inland (10-32 miles) (Evans Mack et al. 2003, p. 4). Although murrelets are distributed throughout their historical range, the area of occupancy within their historic range appears to be reduced from historic levels. The distribution of the species also exhibits five areas of discontinuity: a segment of the border region between British Columbia, Canada and Washington; southern Puget Sound, WA; Destruction Island, WA to Tillamook Head, OR; Humboldt County, CA to Half Moon Bay, CA; and the entire southern end of the breeding range in the vicinity of Santa Cruz and Monterey Counties, CA (McShane et al. 2004, p. 3-70).

Murrelets use inland habitats primarily for nesting, including egg laying, incubation, and feeding of nestlings. In addition, murrelets have been observed in nesting habitat demonstrating social behaviors, such as circling and vocalizing, in groups of up to ten birds (Nelson and Peck 1995, p. 51). Nest sites tend to be clustered spatially, indicating that although murrelets are not colonial seabirds, they also are not strictly solitary in their nesting behavior (Conroy et al. 2002, p. 131; Naslund et al. 1995, p. 12). In California and southern Oregon, marbled murrelets occupy habitat more frequently when there is other occupied habitat within 5 km (Meyer et al. 2002, p. 103), and we assume that the same is true in Washington. Usually, multiple nests can be found in a contiguous forested area, even in places where they are not strongly clustered (Evans Mack et al. 2003, p. 6).

Murrelets spend most of their lives in the marine environment, primarily in nearshore marine waters within 5 km of the coast (Nelson 1997, p. 3). The distribution of murrelets in marine waters during the summer breeding season is highly variable along the Pacific coast, with areas of high density occurring along the Strait of Juan de Fuca in Washington, the central Oregon coast, and northern California (Raphael et al. 2015, p. 20). Low-density areas or gaps in murrelet distribution occur in central California, and along the southern Washington coast (Raphael et al. 2015, p. 21). Analysis of various marine and terrestrial habitat factors indicate that the amount and configuration of inland nesting habitat is the strongest factor that influences the marine distribution of murrelets during the nesting season (Raphael et al. 2015, p. 17). Local aggregations or "hot spots" of murrelets in nearshore marine waters are strongly associated with landscapes that support large, contiguous areas of mature and old-growth forest. In Puget Sound

and along the Strait of Juan de Fuca, these "hot spots" are also strongly associated with a low human footprint in the marine environment, for example, areas natural shorelines and relatively little vessel traffic (Raphael et al. 2016a, p. 106).

During the non-breeding season, marbled murrelet distribution varies slightly from the breeding season distribution. The southern end of the range extends as far south as the Southern California Bight; but some individuals also move northward at the end of the breeding season (Hall et al. 2009, p. 5081; Peery et al. 2008a, p. 121). Although marbled murrelet densities remain highest near shore during the non-breeding season, they apparently use offshore areas more frequently than during the breeding season. The farthest offshore records of murrelet distribution are 60 km off the coast of northern California in October and 46 km off the coast of Oregon in February (Adams et al. 2014) and at least 300 km off the coast in Alaska (Piatt and Naslund 1995, p. 287). Known areas of winter concentration include and southern and eastern end of Strait of Juan de Fuca (primarily Sequim, Discovery, and Chuckanut Bays), San Juan Islands and Puget Sound, Washington (Speich and Wahl 1995, p. 314).

Distribution of Nesting Habitat

The loss of nesting habitat was a major cause of the murrelet's decline over the past century and may still be contributing as nesting habitat continues to be lost to fires, logging, insects, tree diseases, and wind storms (Miller et al. 2012, p. 778; Raphael et al. 2016b, pp. 80-81). Due mostly to historical timber harvest, only a small percentage (~11 percent) of the habitat-capable lands within the listed range of the murrelet currently contain potential nesting habitat (Raphael et al. 2016b, p. 69). Monitoring of murrelet nesting habitat within the Northwest Forest Plan (NWFP, equivalent to Conservation Zones 1 through 5) area indicates nesting habitat declined from an estimated 2.53 million acres in 1993 to an estimated 2.23 million acres in 2012, a decline of about 12.1 percent (Raphael et al. 2016b, p. 72). Fire has been the major cause of nesting habitat loss on Federal lands, while timber harvest is the primary cause of loss on non-Federal lands (Raphael et al. 2016b, p. 79). While most (60 percent) of the potential habitat is located on Federal reserved-land allocations, a substantial amount of nesting habitat occurs on non-federal lands (34 percent) (Table 1).

Table 1. Estimates of higher-quality murrelet nesting habitat by State and major land ownership within the area of the NWFP – derived from 2012 data.

State	Habitat capable lands (1,000s of acres)	Habitat on Federal reserved lands (1,000s of acres)	Habitat on Federal non-reserved lands (1,000s of acres)	Habitat on non-federal lands (1,000s of acres)	Total potential nesting habitat (all lands) (1,000s of acres)	Percent of habitat capable land that is currently in habitat
WA	10,851.1	822.4	64.7	456	1,343.1	12 %
OR	6,610.4	484.5	69.2	221.1	774.8	12 %
CA	3,250.1	24.5	1.5	82.9	108.9	3 %
Totals	20,711.6	1,331.4	135.4	760	2,226.8	11 %
Percent		60 %	6 %	34 %	100 %	-

Source: (Raphael et al. 2016b, pp. 78-81).

Population Status

The 1997 *Recovery Plan for the Marbled Murrelet* (USFWS 1997) 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) (Figure 1). Recovery zones are the functional equivalent of recovery units as defined by Service policy (USFWS 1997, p. 115). The subpopulations in each Zone are not discrete. There is some movement of murrelets between Zones as indicated by radio-telemetry studies (e.g., Bloxton and Raphael 2006, p. 162), but the degree to which murrelets migrate between Zones is unknown. Genetic studies also indicate that there is movement of murrelets between Zones, although Zone 6 is more isolated genetically than the other Zones (Friesen et al. 2005, pp. 611-612; Hall et al. 2009, p. 5080; Peery et al. 2008b, pp. 2757-2758; Peery et al. 2010, p. 703; Vásquez-Carrillo et al. 2014, pp. 251-252). For the purposes of consultation, the Service treats each of the Conservation Zones as separate sub-populations of the listed murrelet population.

Population Status and Trends

Population estimates for the murrelet are derived from marine surveys conducted during the nesting season as part of the NWFP effectiveness monitoring program. Surveys from 2001 to 2017 indicated that the murrelet population in Conservation Zones 1 through 5 (NWFP area) increased at a rate of 0.34 percent per year (McIver et al. 2019, p. 3). While the trend estimate across this period is slightly positive, the evidence of a detectable trend is not conclusive because the confidence intervals for the estimated trend overlap zero (95% confidence interval [CI]: -0.9 to 1.6 percent), indicating that at the scale of the NWFP area, the population could be decreasing slightly, stable, or increasing slightly (McIver et al. 2019, p. 3) (Table 2).At the state scale,

Washington exhibited a significant declining trend between 2001 and 2017 (3.9% decrease per year, while Oregon and California showed significant positive trends (OR = 2.0% increase per year; CA = 4.5% increase per year (McIver et al. 2019, p. 3) (Table 2).

While the direct causes for population declines in Washington are unknown, potential factors include the loss of nesting habitat, including cumulative and time-lag effects of habitat losses over the past 20 years (an individual murrelets potential lifespan), changes in the marine environment reducing the availability or quality of prey, increased densities of nest predators, and emigration (Miller et al. 2012, p. 778). As with nesting habitat loss, marine habitat degradation is most prevalent in the Puget Sound area where anthropogenic activities (e.g., shipping lanes, boat traffic, shoreline development) are an important factor influencing the marine distribution and abundance of murrelets in Conservation Zone 1 (Falxa and Raphael 2016, p. 110).

The most recent population estimate for the entire NWFP area in 2017 was approximately 23,000 murrelets (95 percent CI: 18,500 to 27,600 birds) (McIver et al. 2019, p. 3). The largest and most stable murrelet subpopulations now occur off the Oregon and northern California coasts, while subpopulations in Washington have experienced the greatest rates of decline. Murrelet zones are now surveyed on an every other-year basis, so the last year that an extrapolated range-wide estimate for all zones combined is 2017 (Table 2).

The murrelet subpopulation in Conservation Zone 6 (central California- Santa Cruz Mountains) is outside of the NWFP area and is monitored separately by California State Parks and the U.S. Geological Survey using similar at-sea survey methods (Felis et al. 2019, p. 1). Surveys in Zone 6 indicate a small population of murrelets with no clear trends. Population estimates from 2001 to 2018 have fluctuated from a high of 699 murrelets in 2003, to a low of 174 murrelets in 2008 (Felis et al. 2019, p. 7). In 2018, surveys indicated an estimated population of 370 murrelets in Zone 6 (95% CI: 250-546) (Felis et al. 2019, p. 7) (Table 2).

Table 2. Summary of murrelet population estimates and trends (2001-2017/2018) at the scale of Conservation Zones and states.

Zone	Year	Estimated number of murrelets	95% CI Lower	95% CI Upper	Average density (at sea) (murrelets /km^2)	Average annual rate of change (%)	95% CI Lower	95% CI Upper
1	2018	3,837	1,911	6,956	1.097	-4.9	-7.3	-2.4
2	2017	1,758	1,041	2,623	1.065	-3.0	-6.8	+0.9
3	2018	8,414	5,866	12,183	5.274	+1.4	-0.4	+3.3
4	2017	8,574	6,358	11,155	7.397	+3.7	+1.4	+6.1
5	2017	868	457	1,768	0.983	+7.3	-4.4	+20.3

Zone	Year	Estimated number of murrelets	95% CI Lower	95% CI Upper	Average density (at sea) (murrelets /km^2)	Average annual rate of change (%)	95% CI Lower	95% CI Upper
Zones 1-5	2017	23,040	18,527	27,552	2.623	+0.34	-0.9	+1.6
Zone 6	2018	370	250	546	na	na	na	na
WA	2017	5,984	3,204	8,764	1.16	-3.9	-5.1	-2.0
OR	2017	10,945	8,018	13,872	5.28	2.0	0.5	3.6
CA Zones 4 & 5	2017	6,111	4,473	7,749	3.90	4.5	2.2	6.9

Sources: (McIver et al. 2019, pp. 8-17, Felis et al. 2019, p. 7).

Factors Influencing Population Trends

Murrelet populations are declining in Washington, but increasing in Oregon and northern California (McIver et al. 2019, p. 3). Murrelet population size and distribution is strongly and positively correlated with the amount and pattern (large contiguous patches) of suitable nesting habitat and population trend is most strongly correlated with trend in nesting habitat, although marine factors also contribute to this trend (Raphael et al. 2016, p. 115). From 1993 to 2012, there was a net loss of about 2 percent of potential nesting habitat from on federal lands, compared to a net loss of about 27 percent on nonfederal lands, for a total cumulative net loss of about 12.1 percent across the NWFP area (Raphael et al. 2016, p. 72). Cumulative habitat losses since 1993 have been greatest in Washington, with most habitat loss in Washington occurring on non-Federal lands due to timber harvest (Raphael et al. 2016, pp. 80-81) (Table 3).

Table 3. Distribution of higher-suitability murrelet nesting habitat by Conservation Zone, and summary of net habitat changes from 1993 to 2012 within the NWFP area.

Conservation Zone	1993	2012	Change (acres)	Change (percent)
Zone 1 - Puget Sound/Strait of Juan de Fuca	829,525	739,407	-90,118	-10.9 %
Zone 2 - Washington Coast	719,414	603,777	-115,638	-16.1 %
Zone 3 - Northern to central Oregon	662,767	610,583	-52,184	-7.9 %
Zone 4 - Southern Oregon - northern California	309,072	256,636	-52,436	-17 %
Zone 5 - north-central California	14,060	16,479	+2,419	+17.2 %

Source: (Raphael et al. 2016b, pp. 80-81).

The decline in murrelet populations from 2001 to 2013 is weakly correlated with the decline in nesting habitat, with the greatest declines in Washington, and the smallest declines in California, indicating that when nesting habitat decreases, murrelet abundance in adjacent marine waters may also decrease. At the scale of Conservation Zones, the strongest correlation between habitat loss and murrelet decline is in Zone 2, where murrelet habitat has declined most steeply and marbled murrelet populations have also continued to decline. However, these relationships are not linear, and there is much unexplained variation (Raphael et al. 2016a, p. 110). While terrestrial habitat amount and configuration (i.e., fragmentation) and the terrestrial human footprint (i.e., cities, roads, development) appear to be strong factors influencing murrelet distribution in Zones 2-5; terrestrial habitat and the marine human footprint (i.e., shipping lanes, boat traffic, shoreline development) appear to be the most important factors that influence the marine distribution and abundance of murrelets in Zone 1 (Raphael et al. 2016a, p. 106).

Like other marine birds, murrelets depend for their survival on their ability to successfully forage in the marine environment. Despite this, it is apparent that the location, amount, and landscape pattern of terrestrial nesting habitat are strongest predictors of the spatial and temporal distributions of murrelets at sea during the nesting season (Raphael et al. 2015, p. 20). Outside of Zone 1, various marine habitat features (e.g., shoreline type, depth, temperature, human footprint, etc.) apparently have only a minor influence on murrelet distribution at sea. Despite this relatively weak spatial relationship, marine factors, and especially any decrease in forage species, likely play an important role in explaining the apparent population declines, but the ability to detect or model these relationships is currently limited (Raphael et al. 2015, p. 20). Over both the long and short term, there is evidence that diet quality is related to marbled murrelet abundance and reproductive success (Becker et al. 2007, p. 276; Norris et al. 2007, p. 881).

Population Models

Prior to the use of survey data to estimate trend, demographic models were more heavily relied upon to generate predictions of trends and extinction probabilities for the murrelet population (Beissinger 1995; Cam et al. 2003; McShane et al. 2004; USFWS 1997). However, murrelet population models remain useful because they provide insights into the demographic parameters and environmental factors that govern population stability and future extinction risk, including stochastic factors that may alter survival, reproductive, and immigration/emigration rates.

In a report developed for the *5-year Status Review of the Marbled Murrelet in Washington, Oregon, and California* (McShane et al. 2004, pp. 3-27 to 3-60), models were used to forecast 40-year murrelet population trends. A series of female-only, multi-aged, discrete-time stochastic Leslie Matrix population models were developed for each conservation zone to forecast decadal population trends over a 40-year period with extinction probabilities beyond 40 years (to 2100). The authors incorporated available demographic parameters (Table 4) for each conservation zone to describe population trends and evaluate extinction probabilities (McShane et al. 2004, p. 3-49).

McShane et al. (2004) used mark-recapture studies conducted in British Columbia by Cam et al. (2003) and Bradley et al. (2004) to estimate annual adult survival and telemetry studies or at-sea

survey data to estimate fecundity. Model outputs predicted -3.1 to -4.6 percent mean annual rates of population change (decline) per decade the first 20 years of model simulations in murrelet Conservation Zones 1 through 5 (McShane et al. 2004, p. 3-52). Simulations for all zone populations predicted declines during the 20 to 40-year forecast, with mean annual rates of -2.1 to -6.2 percent per decade (McShane et al. 2004, p. 3-52). While these modeled rates of decline are similar to those observed in Washington (McIver et al. 2019, p. 3), the simulated projections at the scale of Zones 1-5 do not match the apparently stable or increasing populations observed in Oregon and California during the 2001-2018 monitoring period.

Table 4. 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 (2007)	McShane et al. 2004
Juvenile Ratio (Ŕ)	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	-
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 U.S. Fish and Wildlife (1997).

Reproduction

Overall fecundity is a product of the proportion of marbled murrelets that attempt nesting and the proportion of nest attempts that succeed. Telemetry studies can be used to estimate both the proportion of murrelets attempting nesting, and the proportion of nest attempts that succeed. When telemetry estimates are not available, at-sea surveys that separately count the number of hatch-year and after-hatch-year birds can be used to estimate productivity. Telemetry estimates are typically preferred over marine counts for estimating breeding success due to fewer biases (McShane et al. 2004, p. 3-2). However, because of the challenges of conducting telemetry studies, estimating murrelet reproductive rates with an index of reproduction, referred to as the juvenile ratio (**Ŕ**),[1] continues to be important, despite some debate over use of this index (see discussion in Beissinger and Peery 2007, p. 296).

Marbled murrelet fecundity is likely limited in part by low rates of nesting attempts in some parts of the range. Radio-telemetry monitoring Washington between 2004 and 2008 indicated only a small portion of 158 tagged adult birds actually attempted to nest (13 to 20 percent) (Lorenz et al. 2017, p. 316; Raphael and Bloxton 2009, p. 165). Studies from California and Oregon also report low rates. Two studies from central and northern California reported that an average of

[1] The juvenile ratio (**Ŕ**) for murrelets is derived from the relative abundance of hatch-year (HY; 0-1 yr-old) to after-hatch-year (AHY; 1+ yr-old) birds (Beissinger and Peery 2007, p. 297) and is calculated from marine survey data. All ratios presented here are date-corrected using the methods of Peery et al. (2007, p. 234) to account adults incubating and chicks not yet fledged at the time of the survey.

around 30 percent of radio-tagged murrelets attempted to nest (Hébert and Golightly 2006, p. 130; Peery et al. 2004, p. 1093). In preliminary results from a study in Oregon, 137 individuals were tagged over two years, but only 12 individuals, all tagged during the second year, made inland movements indicative of nesting attempts (Adrean et al. 2018, p. 2; Adrean et al. 2019, p. 2; Horton et al. 2018, p. 77). Averaged across years, this indicates that eight percent of tagged birds attempted to breed, the lowest rate yet reported for the species; however, the study is not yet complete and is therefore not comparable to the others cited above. These low rates of nesting are not intrinsic to the species; other studies outside of the listed range reported that between 46 and 80 percent of marbled murrelets attempted to breed each year (Barbaree et al. 2014, p. 177; Bradley et al. 2004, p. 323), and most population modeling studies suggest a range of 80 to 95 percent of adults breed each year (McShane et al. 2004, p. 3-5). The process of radio-tagging or the additional weight and drag of the radio tag itself may reduce the probability that a tagged individual will attempt to breed, but studies reporting higher rates of attempted nesting used similar radio tags, so radio-telemetry methods do not account for differences between the studies conducted in the listed range and those conducted elsewhere (Peery et al. 2004, p. 1094).

Although difficult to obtain, nest success rates[2] are available from telemetry studies conducted in California (Hébert and Golightly 2006; Peery et al. 2004, p. 1094), Washington (Lorenz et al. 2017, p. 312; Lorenz et al. 2019, p. 160),and, preliminarily, in Oregon (Adrean et al. 2019, p. 2). In northwestern Washington, Lorenz and others (2017, p. 312; 2019, pp. 159-160) documented a nest success rate of 0.20 (3 chicks fledging from 15 nest starts). In central California, murrelet nest success is 0.16 (Peery et al. 2004, p. 1098) and in northern California it ranges from 0.069 to 0.243 (Hébert and Golightly 2006, p. 129). In Oregon, preliminary results from a telemetry study indicate that 3 of 7 active nests successfully fledged young, a rate of 0.43, but this success rate may not be comparable to the others reported above; for example, it is not clear whether it includes all nesting attempts (Adrean et al. 2019, p. 2).

At least one telemetry study reported overall fecundity rates, combining both the rates of nesting attempts with the rates of fledging success. In central California, the fecundity rate was estimated to be 0.027, or 2.7 female chicks produced per year for every 100 females of breeding age (Peery et al. 2004, p. 1094). In other studies, the overall fecundity rate is not known, because it is not clear how many of the radio-tagged birds were of breeding age. However, in northern California, of 102 radio-tagged birds, at least two and at most six successfully produced fledglings (Hébert and Golightly 2006, pp. 130-131), and in Washington and southern Vancouver Island, of 157 radio-tagged birds, four produced fledglings (Lorenz et al. 2017, p. 312). If we assume (as in Peery et al. 2004, p. 1094) that 93 percent of captured birds in each sample were of breeding age, and that half of all captured birds and half of all fledged chicks were female, fecundity rates from these samples would be 0.027 in Washington, and between 0.021 and 0.063 in northern California.

Unadjusted and adjusted values for estimates of murrelet juvenile ratios also suggest low reproductive rates. In northern California and Oregon, annual estimates for **Ŕ** range from 0 to 0.140, depending on the area surveyed (Strong 2014, p. 20; Strong 2015, p. 6; Strong 2016, p. 7;

[2] Nest success here is defined by the annual number of known hatchlings departing from the nest (fledging) divided by the number of nest starts.

Strong 2017, p. 6; Strong 2018, p. 7; Strong 2019, p. 6; Strong and Falxa 2012, p. 4). In Conservation Zone 4, the annual average between 2000 and 2011 was 0.046 (Strong and Falxa 2012, p. 11). In central California, estimates of **Ŕ** range from 0.01 to 0.11, with an annual average of 0.049, over 19 years of survey between 1996 and 2017 (Felis et al. 2018, p. 9). An independent calculation of **Ŕ** among murrelets captured in central California between 1999 and 2003 resulted in estimates ranging from 0 to 0.111, with an average of 0.037 (Peery et al. 2007, p. 235). Estimates for **Ŕ** in the San Juan Islands in Washington tend to be higher, ranging from 0.02 to 0.12, with an average of 0.067, over 18 years of survey between 1995 and 2012 (Lorenz and Raphael 2018, pp. 206, 211). Notably, **Ŕ** in the San Juan Islands did not show any temporal trend over the 18-year period, even while the abundance of adult and subadult murrelets declined (Lorenz and Raphael 2018, pp. 210-211).

Although these estimates of **Ŕ** are higher than one would expect based on fecundity rates derived from radio-telemetry studies, they are below the level thought to be necessary to maintain or increase the murrelet population. Demographic modeling, historical records, and comparisons with similar species all suggest that murrelet population stability requires juvenile ratios between 0.176 and 0.3 (Beissinger and Peery 2007, p. 302; USFWS 1997, p. B-13). Even the lower end of this range is higher than any current estimate for **Ŕ** for any of the Conservation Zones. This indicates that the murrelet reproductive rate is likely insufficient to maintain stable population numbers throughout all or portions of the species' listed range. These sustained low reproductive rates appear to be at odds with the potentially stable population size measured for Zones 1 through 5, and are especially confusing in light of apparent population increases in Oregon and California.

Integration and Summary: Murrelet Abundance, Distribution, Trend, and Reproduction

A statistically significant decline was detected in Conservation Zones 1 and 2 for the 2001-2017 period (Table 2). The overall population trend from the combined 2001-2017 population estimates (Conservation Zones 1 - 5) indicates a potentially stable population with a 0.34 percent increase per year (McIver et al. 2019, p. 3). Because the confidence intervals for this estimate overlap 0, there is not clear evidence of either or a positive or negative trend. At the state-scale, significant declines have occurred in Washington, while subpopulations in Oregon and California show a statistically meaningful increase (McIver et al. 2019, p. 3).

The current ranges of estimates for fecundity and for **Ŕ**, the juvenile to adult ratio, are below the level assumed to be necessary to maintain or increase the murrelet population. Whether derived from radio-telemetry, marine surveys or from population modeling (**Ŕ** = 0.02 to 0.13, Table 4), the available information is in general agreement that the current ratio of hatch-year birds to after-hatch year birds is insufficient to maintain stable numbers of murrelets throughout the listed range. The current estimates for **Ŕ** also appear to be well below what may have occurred prior to the murrelet population decline (Beissinger and Peery 2007, p. 298).

The reported stability of the population at the larger scale (Zones 1 through 5) and growth of subpopulations in Oregon and California appear to be at odds with the sustained low reproductive rates reported throughout the listed range. A number of factors could contribute to this discrepancy. For example, population increases could be caused by an influx of murrelets

moving from the Canadian population into Oregon and California, or into Washington and displacing Washington birds to Oregon and California. The possibility of a population shift from Washington to Canada has previously been dismissed, based on nest-site fidelity and the fact that both Washington and British Columbia populations are declining simultaneously (Falxa et al. 2016, p. 30), but these arguments do not rule out the possibility that non-breeding murrelets originating in Canada may be spending time foraging in Oregon or California waters.

Another possibility is the proportion of birds present on the water during surveys, rather than inland at nest sites, may be increasing. If so, this would artificially inflate population estimates. If so, this could be driven by low nesting rates, as were observed in Oregon in 2017 (Adrean et al. 2018, p. 2; Horton et al. 2017, p. 77); or by shifts toward earlier breeding, for which there is anecdotal evidence (for example, Havron 2012, p. 4; Pearson 2018, in litt.; Strong 2019, p. 6); or a combination of both factors. In either case, individuals that would in earlier years have been incubating an egg or flying inland to feed young, and therefore unavailable to be counted, would now be present at sea and would be observed during surveys. For the same number of birds in the population, the population estimate would increase as adults spend more of the survey period at sea.

Finally, the shift that occurred in 2015 to sampling only half of the Conservation Zones in each survey year (McIver et al. 2019, p. 5) is increasing the uncertainty in how to interpret the survey results, especially in light of large-scale movements that can occur during the breeding season, sometimes involving numerous individuals (Horton et al. 2018, p. 77; Peery et al. 2008a, p. 116). Murrelets that move into or out of the zone being sampled during the breeding season could artificially inflate or deflate the population estimates.

Some of these factors would also affect measures of fecundity and juvenile ratios. For example, if murrelets are breeding earlier on average, then the date adjustments applied to juvenile ratios may be incorrect, possibly resulting in inflated estimates of **Ŕ**. If current estimates of **Ŕ** are biased high, this would mean that the true estimates of **Ŕ** are even lower, exacerbating, rather than explaining, the discrepancy between the apparently sustained low reproductive rates and the apparently stable or increasing subpopulations south of Washington.

Considering the best available data on abundance, distribution, population trend, and the low reproductive success of the species, the Service concludes the murrelet population within the Washington portion of its listed range currently has little or no capability to self-regulate, as indicated by the significant, annual decline in abundance the species is currently undergoing in Conservation Zones 1 and 2. Populations in Oregon and California are apparently more stable, but reproductive rates remain low in those areas, and threats associated with habitat loss and habitat fragmentation continue to occur. The Service expects the species to continue to exhibit further reductions in distribution and abundance into the foreseeable future, due largely to the expectation that the variety of environmental stressors present in the marine and terrestrial environments (discussed in the *Threats to Murrelet Survival and Recovery* section) will continue into the foreseeable future.

Threats to Murrelet Survival and Recovery

When the murrelet was listed under the Endangered Species Act in 1992, several anthropogenic threats were identified as having caused the dramatic decline in the species:

- habitat destruction and modification in the terrestrial environment from timber harvest and human development caused a severe reduction in the amount of nesting habitat
- unnaturally high levels of predation resulting from forest "edge effects" ;
- the existing regulatory mechanisms, such as land management plans (in 1992), were considered inadequate to ensure protection of the remaining nesting habitat and reestablishment of future nesting habitat; and
- manmade factors such as mortality from oil spills and entanglement in fishing nets used in gill-net fisheries.

The regulatory mechanisms implemented since 1992 that affect land management in Washington, Oregon, and California (for example, the NWFP) and new gill-netting regulations in northern California and Washington have reduced the threats to murrelets (USFWS 2004, pp. 11-12). However, additional threats were identified, and more information was compiled regarding existing threats, in the Service's 5-year reviews for the murrelet compiled in 2009 and 2019 (USFWS 2009, pp. 27-67; USFWS 2019, pp. 19-65). These stressors are related to environmental factors affecting murrelets in the marine and terrestrial environments. These stressors include:

- Habitat destruction, modification, or curtailment of the marine environmental conditions necessary to support murrelets due to:
    - elevated levels of toxic contaminants, including polychlorinated biphenyls, polybrominated diphenyl ether, polycyclic aromatic hydrocarbons, and organochlorine pesticides, in murrelet prey species;
    - the presence of microplastics in murrelet prey species;
    - changes in prey abundance and availability;
    - changes in prey quality;
    - harmful algal blooms that produce biotoxins leading to domoic acid and paralytic shellfish poisoning that have caused murrelet mortality;
    - harmful algal blooms that produce a proteinaceous foam that has fouled the feathers of other alcid species, and affected areas of murrelet marine habitat;
    - hypoxic or anoxic events in murrelet marine habitat; and
    - climate change in the Pacific Northwest.
- Manmade factors that affect the continued existence of the species include:
    - derelict fishing gear leading to mortality from entanglement;

- disturbance in the marine environment (from exposures to lethal and sub-lethal levels of high underwater sound pressures caused by pile-driving, underwater detonations, and potential disturbance from high vessel traffic); and
- wind energy generation, currently limited to onshore projects, leading to mortality from collisions.

Since the time of listing, some murrelet subpopulations have continued to decline due to lack of successful reproduction and recruitment, and while other subpopulations appear to be stable or increasing, productivity in these populations remains lower than the levels likely to support sustained population stability. The murrelet Recovery Implementation Team identified five major mechanisms that appear to be contributing to poor demographic performance (USFWS 2012b, pp. 10-11):

- Ongoing and historic loss of nesting habitat.
- Predation on murrelet eggs and chicks in their nests.
- Changes in marine conditions, affecting the abundance, distribution, and quality of murrelet prey species.
- Post-fledging mortality (predation, gill-nets, oil-spills).
- Cumulative and interactive effects of factors on individuals and populations.

Climate Change

In the Pacific Northwest, climate change affects both the marine and forested environments on which marbled murrelets depend. Changes in the terrestrial environment may have a direct effect on marbled murrelet reproduction, and also affect the structure and availability of nesting habitat. Changes in the marine environment affect marbled murrelet food resources. Changes in either location may affect the likelihood, success, and timing of marbled murrelet breeding in any given year.

Changes in the Physical Environment

Projected changes to the climate within the range of the marbled murrelet include air and sea surface temperature increases, changes in precipitation seasonality, and increases in the frequency and intensity of extreme rainfall events (Mauger et al. 2015, pp. 2-1 – 2-18; Mote and Salathé 2010, p. 29; Salathé et al. 2010, pp. 72-73). Air temperature warming is already underway, and is expected to continue, with the mid-21st century projected to be approximately four to six degrees Fahrenheit (°F) (2.2 to 3.3 degrees Celsius [°C]) warmer than the late 20th century (Mauger et al. 2015, p. 2-5; USGCRP 2017, pp. 196-197). Similarly, sea surface temperatures are already rising and the warming is expected to continue, with increases between 2.2 °F (1.2 °C) and 5.4 °F (3 °C) projected for Puget Sound, the Strait of Georgia, and the Pacific Coast between the late 20th century and mid-or late-21st century (Mote and Salathé 2010, p. 16; Riche et al. 2014, p. 41; USGCRP 2017, p. 368). Summer precipitation is expected to decrease, while winter precipitation is expected to increase (Mauger et al. 2015, p. 2-7; USGCRP 2017,

p. 217). In particular, heavy rainfall events are projected to occur between two and three times as frequently and to be between 19 and 40 percent more intense, on average, in the late 21st century than they were during the late 20th century (Warner et al. 2015, pp. 123-124).

The warming trend and trends in rainfall may be masked by naturally-occurring climate cycles, such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) (Reeder et al. 2013, p. 76). These oscillations have similar effects in the Pacific Northwest, with relatively warm coastal water and warm, dry winter conditions during a "positive" warm phase, followed by cooler coastal water and cooler, wetter winter conditions during the cool "negative" phase (Moore et al. 2008, p. 1747). They differ in that one phase of the ENSO cycle typically lasts between 6 and 18 months (one to three years for a full cycle), whereas, during the 20th century, each phase of the PDO cycle lasted approximately 20 to 30 years (approximately 40 to 60 years for a full cycle) (Mantua and Hare 2002, p. 36). Some studies break the PDO into two components, one with a full cycle length between 16 and 20 years and the other with a 50 to 70 year period, with the longer component referred to as the Pacific Multidecadal Oscillation (PMO) (Steinman et al. 2015, p. 988). Another recent study has identified a 60-year cycle separate from the longer-term component of the PDO, also referring to this as the PMO (Chen et al. 2016, p. 319). An additional pattern, the North Pacific Gyre Oscillation, is associated with changes in the alongshore winds that drive upwelling, and appears to complete approximately one cycle per decade (Di Lorenzo et al. 2008, pp. 2-3).

The overall warming projections described above for the listed range of the murrelet will be superimposed over the natural climate oscillations. The climate models used to project future trends account for naturally occurring cycles (IPCC 2014, p. 56). Therefore, the projected trend combined with the existing cycles mean that temperatures during a cool phase will be less cool than they would be without climate change, and warm phases will be warmer. During the winter of 2014-2015, the climate shifted from a negative cool phase of the PDO to a positive warm phase (Peterson et al. 2016, p. 46). Additionally, one study predicts that the PMO will enter a positive warm phase around the year 2025 (Chen et al. 2016, p. 322). The phases of these long-term climate cycles in addition to the projected warming trend imply that we should expect sea surface temperatures during the period over the next couple of decades to be especially warm. However, climate change may also alter the patterns of these oscillations, for example, by shortening the cycle length of the PDO (Zhang and Delworth 2016, pp. 6007-6008). Many studies of climate effects to marine species and ecosystems use indices of these climate oscillations, rather than individual climate variables such as sea surface temperature, as their measures of the climatic state (e.g. Becker and Beissenger 2006, p. 473). Therefore, if climate factors that covary with a given oscillation become decoupled, the relationships inferred from these studies may no longer be valid in the future.

Changes in the Forest Environment

Forested habitats in the Pacific Northwest are affected by climate change mainly via changes in disturbances, including wildfire, insects, tree diseases, and drought mortality. These types of disturbances can all cause the loss of marbled murrelet nesting habitat, though it is hoped that this loss will be offset by ingrowth as existing mid-successional forest matures. Following stand-replacing disturbances, climate conditions may not allow recruitment of the tree species

that are currently present, leading to ecotype change; however, the effect of this kind of ecotype change may not directly affect marbled murrelet habitat availability until many decades in the future.

Historical fire regimes have varied throughout the range of the marbled murrelet. In many of the moist forests of western Washington and Oregon, the fire regime has historically been typified by large, stand-replacing fires occurring at intervals of 200 years or more (Halofsky et al. 2018a, pp. 3-4; Haugo et al. 2019, pp. 2-3; Long et al. 1998, p. 784). Parts of the murrelet range in southern Oregon and California have historically had low- and mixed-severity fires occurring every 35 years or less (Haugo et al. 2019, pp. 2-3; Perry et al. 2011, p. 707). Still other areas throughout the range historically had mixed severity fires occurring between 35 and 200 years apart (Haugo et al. 2019, pp. 2-3; Perry et al. 2011, p. 707). Within each type of historical fire regime, fire has occurred less frequently during the recent decades usually used for statistical analyses of fire behavior or projections of future fire than it did historically (Huago et al. 2019, pp. 8-9; Littell et al. 2010, p. 150).

Between 1993 and 2012, monitoring based on a database of large (1,000 acres or greater) fire perimeters detected losses associated with wildfires of 22,063 acres of Maxent-modeled high-quality marbled murrelet nesting habitat on federal and non-federal lands in the NWFP area (Raphael et al. 2016b, pp. 80-81). Fire was the leading natural cause of habitat loss within the NWFP area, but this ranking was driven by the 20,235-acre loss to fire on federal lands in the Klamath Mountains, and fire was far less important elsewhere in the range. Within subregions overlapping the listed range of the murrelet, the proportion of area currently "highly suitable" for large fires varies from less than 1 percent in the Coast Range of Oregon and Washington to 18 percent in the Klamath Mountains (Davis et al. 2017, p. 179). The fire regime in the listed range of the murrelet has historically been sensitive to climate conditions, though less so during recent decades (Henderson et al. 1989, pp. 13-19; Littell et al. 2010, p. 140; Littell and Gwozdz 2011, pp. 130-131; Weisberg and Swanson 2003, pp. 23-25).

The area burned in the range of the murrelet is expected to increase in the coming decades, but there is great uncertainty about the magnitude of the increase, and it is likely to affect some areas more than others (Davis et al. 2017, pp. 179-182; Rogers et al. 2011, p. 6; Sheehan et al. 2015, p. 25). On forested lands in the Cascades, Coast Ranges, and Klamath Mountains of Washington and Oregon, the percentage of forested area highly suitable for large fires is projected to increase from the current (less than 1 percent to 18 percent, varying by ecoregion) up to between 2 and 51 percent by the late 21st century, with much of this increase projected to occur after 2050 (Davis et al. 2017, pp. 179-181). At the same time, the percentage of forested lands with low suitability for large fire is expected to decrease from the current range of 21 to 97 percent to a lower range of 4 to 85 percent, depending on ecoregion. The increase in large fire suitability is expected to have the greatest effect on the Klamath ecoregion and the smallest effect on the Coast Ranges, with Cascades ecoregions falling in between (Davis et al. 2017, pp. 181). One study has classified most of the marbled murrelet range as having low vulnerability to fire for the 2020-2050 period, relative to all western forests, but parts of the range in southern Oregon and northern California are classified as having medium or high vulnerability (Buotte et al. 2018, pp. 5, 8). A different study found that forests west of the Cascade Crest are likely to be more vulnerable other western forests, because they will be sensitive to hotter, drier summers, but will

not benefit from increased winter precipitation since soils are already saturated during winter months (Rogers et al. 2011, p. 6). Throughout the range, the annual number of days with high wildfire potential is expected to nearly double by mid-century (Martinuzzi et al. 2019, pp. 3, 6). Fire severity is also projected to increase over the 21st century (Rogers et al. 2011, p. 6).

Two recent studies have modeled future fires based on projected climate and vegetation characteristics, rather than simply using statistical projections based on past rates of wildfire. One study projected a 1.5- to 5-fold increase in forest fire in western Washington between the historical period and the 21st century (Halofsky et al. 2018b, p. 10). The baseline annual percentage of area burned was based on information about pre-European settlement fire rotation in western Washington, 0.2 to 0.3 percent of the forest land base burned per year, which is a much greater annual area burned than we have observed in the recent past. The late 21st-century annual area burned was projected to reach 0.3 to 1.5 percent of the forest land base per year, with extreme fire years burning 5 to 30 percent of the forest land base (Halofsky et al. 2018b, p. 10). The other study projected a 2- to 4-fold increase in western Washington and Oregon between the late 20th century and mid-century (Sheehan et al. 2019, p. 14). This study started with even larger baseline annual percentage of area burned, starting at 0.47 to 0.56 percent per year in the late 20th century and increasing to 1.14 to 1.99 percent per year by the mid-21st century (Sheehan et al. 2019, p. 14). In both studies, smaller increases in annual area burned were associated with a model assumption that firefighting would continue to be effective.

Insects and disease were the leading natural cause of marbled murrelet habitat loss within most ecoregions within the NWFP area between 1993 and 2012 (Raphael et al. 2016b, p. 81). Across the NWFP area, 8,765 acres of Maxent-modeled high-quality marbled murrelet habitat were lost to insects and disease, with the majority of these on federal lands in Washington. The USFS and WDNR have worked together since 1981 to collect and distribute aerial survey data regarding the presence of insects, disease, and other damage agents in Washington's forests (WDNR and USFS 2018). This dataset dataset indicates the identity of various insect and disease problems that have been recorded in the current marbled murrelet habitat: Douglas-fir beetle (*Dendroctonus pseudotsugae*), "dying hemlock," fir engraver (*Scolytus ventralis*), spruce aphid (*Elatobium abietinum*), Swiss needle cast (*Phaeocryptopus gaeumannii*), and western (*Lambdina fiscellaria lugubrosa*) and phantom (*Nepytia phantasmaria*) hemlock loopers. It is likely that various root diseases have also attacked marbled murrelet habitat, but these are generally classified as bear damage during the aerial surveys (Clark et al. 2018, p. 31). Root diseases that may be present include annosus (*Heterobasidium annosum*), armillaria (*Armillaria ostoyae*), and black stain (*Leptographium wageneri*) root diseases, as well as laminated (*Phellinus weirii*), tomentosus (*Inonotus tomentosus*), and yellow (*Parenniporia subacida*) root rots (Goheen and Willhite 2006, pp. 72-87).

Some of these pests, such as Swiss needle cast, are most typically found in younger stands, and are more likely to affect the development of marbled murrelet habitat over the long term; whereas others, such as Douglas-fir beetle, are more likely to attack older trees (Goheen and Willhite 2006, pp. 30, 224). Swiss needle cast typically does not result in tree mortality (Maguire et al. 2011, pp. 2069-2070), but can affect mixed-species forest stands by allowing increased western hemlock growth in stands where severe Swiss needle cast affects Douglas-fir growth (Zhao et al. 2014, entire). Higher average temperatures, in particular warmer winters,

and increased spring precipitation in the Oregon Coast Range have contributed to an increase in the severity and distribution of Swiss needle cast in Douglas-fir (Stone et al. 2008, pp. 171-174; Sturrock et al. 2011, p. 138; Zhao et al. 2011, p. 1,876; Lee et al. 2013, pp. 683-685; Ritóková et al. 2016, p. 2). The distribution of Swiss needle cast increased from about 131,087 ac (53,050 ha) in 1996 to about 589,840 ac (238,705 ha) of affected trees in 2015 within 31 mi (50 km) of the coast in the Oregon Coast Range (Hansen et al. 2000, p. 775; Ritóková et al. 2016, p. 5).

Drought has not historically been a major factor in most of the listed range of the murrelet, because these forests are not typically water limited, especially in Washington and northern Oregon (Littell et al. 2010, p. 139; McKenzie et al. 2001, p. 531; Nemani et al. 2003, p. 1560). Nonetheless, every part of the listed range has been affected by multi-year drought at some point during the 1918-2014 period, varying geographically from areas with occasional mild two- to five-year droughts, to areas with moderate-severity two- or three-year droughts, to a few small areas, all in Washington, that have had at least one extreme three-year drought (Crockett and Westerling 2018, p. 345). Over the last few decades, the number of rainy summer days has decreased and the rain-free period has lengthened in much of the murrelet's listed range, especially in Oregon and Washington (Holden et al. 2018, p. 4). In the Pacific Northwest generally, drought is associated with Douglas-fir canopy declines that can be observed via satellite imagery (Bell et al. 2018a, pp. 7-10). In Western Washington, Oregon, and Southwestern British Columbia, tree mortality more than doubled (from around 0.5 percent per year to more than 1 percent per year) over the 30-year period between 1975 and 2005, likely due to increasing water stress (van Mantgem et al. 2009, pp. 522-523). Tree mortality may be caused by warm dry conditions in and of themselves (via xylem failure) or when hot, dry conditions compound the effects of insects, disease, and fire.

Some of the insects and pathogens already present in murrelet habitat, such as Douglas-fir beetles, are likely to become more prevalent and cause greater mortality in the future. Douglas-fir trees stressed by heat and drought emit ethanol, which attracts Douglas-fir beetles, and have lowered chemical defenses, which is likely to increase the endemic levels of Douglas-fir infestation and could result in higher probability of epidemic infestation (Agne et al. 2018, p. 326-327; Bentz et al. 2010, p. 605). Similarly, higher temperatures as the 21st century progresses will also increase the potential of spruce beetle (*Dendroctonus rufipennis*) outbreaks, which require mature spruce forests such as those found within the range of the murrelet (Bentz et al. 2010, p. 607). There is more uncertainty with respect to future levels of infection by Swiss needle cast, a disease that that has increased in severity over the past decade (Agne et al. 2018, p. 326). Warm, wet spring weather is thought to provide ideal conditions for Swiss needle cast infection, whereas warm, dry spring weather may inhibit the pathogen. Future spring weather will be warmer, but it is not clear whether it will be wetter, drier, or both (i.e., more variable), or perhaps current precipitation patterns will continue. Swiss needle cast effects to trees appear to be more severe during drought conditions, however. Therefore, the worst-case scenario for Swiss needle cast would be warm, wet springs followed by hot, dry summers. Swiss needle cast is also expected to spread inland and north to sites where fungal growth is currently limited by cold winter temperatures (Stone et al. 2008, p. 174; Zhao et al. 2011, p. 1,884; Lee et al. 2013, p. 688). Future climate conditions are also hypothesized to promote other diseases, such as Armillaria root disease, that could affect murrelet habitat (Agne et al. 2018, p. 326).

All climate models project increased summer warming for the Pacific Northwest, and most project decreased spring snowpack and summer precipitation, resulting in increasing demand on smaller amounts of soil water in the forest during the growing season. Forests within the murrelet range are expected to experience increasing water deficits over the 21st century (McKenzie and Littell 2017, pp. 33-34). These deficits will not be uniform, with the California and southern Oregon Coast Ranges, Klamath region, eastern Olympic Peninsula, and parts of the Cascades and northern Oregon Coast Range projected to experience much greater hydrological drought, starting sooner than in other places, while there are even projected reductions in water deficit for some other portions of the Washington Cascades and Olympic Mountains (McKenzie and Littell 2017, p. 31). Spring droughts, specifically, are projected to decrease in frequency in Washington and most of Oregon, but to increase in frequency in most of California, with some uncertainty as to the future likelihood of spring drought near the Oregon-California border (Martinuzzi et al. 2019, p. 6). The projected future warm, dry conditions, sometimes called "hotter drought" or "climate change-type drought" in the scientific literature, are expected to lead to continued increases in tree mortality. Though projections of future drought-related tree mortality in throughout the listed range of the murrelet are not available, the effects of the recent multi-year drought in the Sierra Nevada may provide some context about what to expect. Drought conditions in California during 2012 through 2015 led to an order of magnitude increase in tree mortality in Sierra Nevada forests (Young et al. 2017, p. 83). More mesic regions, including most areas of marbled murrelet habitat, are unlikely to have near-future impacts as severe as those already seen in the Sierra Nevada. For example, redwood forests in northwestern and central California, which include areas of murrelet nesting habitat, are more resistant to drought effects than other California forests (Brodrick et al. 2019, pp. 2757-2758). However, extreme climate conditions are eventually likely to further increase drought stress and tree mortality, especially since trees in moist forests are unlikely to be well-adapted to drought stress (Allen et al. 2010, p. 669; Allen et al. 2015, pp. 19-21; Anderegg et al. 2013, p. 705; Crockett and Westerling 2018, p. 342; Prestemon and Kruger 2016, p. 262; Vose et al. 2016, p. 10).

Blowdown is another forest disturbance that has historically caused extensive stand-replacing disturbances in the Pacific Northwest. The effect of climate change on blowdown frequency, extent, and severity is unknown, and there are reasons to believe that blowdowns may become either more or less frequent or extensive. Blowdown events are often associated with extra-tropical cyclones, which are often associated with atmospheric rivers. Blowdown is influenced by wind speeds and by soil saturation. Hurricane-force winds hit the Washington coast approximately every 20 years during the 20th century (Henderson et al. 1989, p. 20). Destructive windstorms have occurred in the Pacific Northwest in 1780-1788, 1880, 1895, 1921, 1923, 1955, 1961, 1962, 1979, 1981, 1993, 1995, and 2006 (Henderson et al. 1989, p. 20; Mass and Dotson 2010, pp. 2500-2504). During the 20th century, the events in 1921, 1962, and 2006 were particularly extreme. Although there are some estimates of timber losses from these events, there are no readily available estimates of total marbled murrelet habitat loss from particular events. In addition to habitat loss from these extreme blowdown events, a smaller amount of habitat is lost each year in "endemic" blowdown events. Wind damage may be difficult to detect via methods that rely on remotely sensed data (e.g., Raphael et al. 2016b, pp. 80-81) because much of the wind-damaged timber may be salvaged, and therefore appears to have been disturbed by harvest rather than wind. Nonetheless, between 1993 and 2012, 3,654 acres of

Maxent-modeled higher suitability nesting habitat loss was detected via remote sensing and attributed to blowdown or other natural, non-fire, non-insect disturbances (Raphael et al. 2016b, pp. 80-81). Nearly all of the habitat loss in this category affected federal lands in Washington.

Because we did not locate any studies attempting to project murrelet habitat loss to blowdown into the future, we looked to studies regarding the conditions associated with blowdown: wind, rain, and landscape configuration. There are indications that average wind speeds over the Pacific Northwest have declined since 1950, and average wind speeds are projected in most climate models to decline further by the 2080s (Luce et al. 2013, pp. 1361-1362). However, it is not clear how average wind speeds might be related to blowdown, since blowdown events usually happen during extreme wind events. Extreme extra-tropical cyclones are expected to become less frequent in the Northern Hemisphere in general, and perhaps along the Pacific Northwest coastline in particular, but these predictions involve many uncertainties. Different models show local increases in storm frequency in different places (Catto et al. 2011, pp. 5344-5345). Also, how "extreme" events are categorized differs between studies, and the results vary depending on what definition of "extreme" is used (Catto et al. 2001, p. 5348; Ulbrich et al. 2009, p. 127). One recent model projects no change in the extreme ground-level winds most likely to damage nesting habitat, and an increase in the frequency of extreme high-altitude winds (Chang 2018, pp. 6531, 6539). Atmospheric rivers are expected to become wetter and probably more frequent. The frequency of atmospheric river days is expected to increase by 50 to around 500 percent over the 21st century, depending on latitude and season (Gao et al. 2015, p. 7182; Warner and Mass 2017, p. 2135), though some models project up to an 18 percent decrease in frequency for either the northern or the southern end of the listed range (Payne and Magnusdottir 2015, p. 11,184). The most extreme precipitation events are expected to be between 19 and 40 percent wetter, with the largest increases along the northern California coast (Warner et al. 2015, p. 123). If increased rain causes greater soil saturation, it is easily conceivable that blowdown would become likely at lower wind speeds than would be needed to cause blowdown in less saturated conditions, but we did not find studies addressing this relationship. Since blowdown is more likely at forest edges, increased fragmentation may lead to more blowdown for the same wind speed and amount of soil saturation. The proportion of Maxent-modeled higher suitability nesting habitat located along forest edges increased between 1993 and 2012, and now makes up the majority of habitat in the NWFP area (Raphael et al. 2016b, p. 77). Some forested areas within the range may become less fragmented over the next 30 years, as conservation plans such as the NWFP continue to allow for forest growth; other areas may become more fragmented due to harvest, development, or the forest disturbances discussed above. Thus, the amount of marbled murrelet habitat likely to be lost to blowdown over the next 30 years is highly uncertain.

Synergistic effects between drought, disease, fire, and/or blowdown are likely to occur to some extent, and could become widespread. If large increases in mortality do occur, interactions between these agents are likely to be involved (Halofsky et al. 2018a, pp. 4-5). The large recent increase in tree mortality in the Sierra Nevada has been caused in large part due to these kinds of synergistic interactions. As noted above, range of the murrelet is unlikely to be as severely affected and severe effects are likely to happen later in time here than drier forests (where such effects are already occurring). In fact, one study rates much of the range as having low vulnerability, relative to other western forests, to drought or fire effects by 2049 (Buotte et al.

2018, p. 8). However, that study and many other studies do indicate that there is a risk of one or more of these factors acting to cause the loss of some amount of murrelet habitat over the next 30 years.

In addition to habitat loss resulting from forest disturbances at the scale of a stand or patch, habitat features may be altered as a result of climate change. For example, epiphyte cover on tree branches may change as a result of the warmer, drier summers projected for the future (Aubrey et al. 2013, p. 743). Climate-related changes in epiphyte cover will be additive or synergistic to changes in epiphyte cover resulting from the creation of forest edges through timber harvest (Van Rooyen et al. 2011, pp. 555-556). Epiphyte cover is assumed to have decreased throughout the listed range as the proportion of suitable habitat in edge condition has increased (USFWS 2019, p. 34), and as epiphyte cover decreases further, nest sites will become less available even in otherwise apparently suitable habitat.

In summary, forest disturbances, including wildfire, insect damage, disease, drought mortality, and windthrow, are likely to continue to remove murrelet nesting habitat, and many of these disturbances are likely to remove increasing amounts of habitat in the future. The effects of each type of disturbance are likely to be variable in different parts of the range, with wildfire affecting the Klamath Mountains far more than other parts of the range, and insect and disease damage largely focused in Washington. The magnitude of future increases is highly uncertain, and it is unclear whether windthrow will increase, decrease, or remain constant. Habitat not lost to disturbance may nonetheless be affected by climate change, as particular habitat features may be lost. The effects of habitat loss and the loss of habitat features will reduce the availability of nesting habitat, which will reduce the potential for marbled murrelet reproduction.

Changes in the Marine Environment

Changes in the climate, including temperature changes, precipitation changes, and the release of carbon dioxide into the atmosphere, affect the physical properties of the marine environment, including water circulation, oxygen content, acidity, and nutrient availability. These changes, in turn, affect organisms throughout the marine food web. For top predators like the marbled murrelet, Prey abundance, quality, and availability are all likely to be affected by climate change. Climate change is also likely to change the murrelet's level of exposure to toxic chemicals and potentially to disease agents. All of these changes are likely to alter the reproduction and survival of individual murrelets.

Marine waters within the range of the murrelet have warmed, as noted above. This warming involves not only a gradual increase in average temperatures, but also extreme marine heatwaves, which have dramatic effects on marine ecosystems. Preceding the development of El Niño conditions in 2015, a rise in sea surface temperatures in the Gulf of Alaska occurred in late 2013, likely due to a shift in wind patterns, lack of winter storms, and an increase in sea-level pressure (Bond et al. 2015, p. 3414; Leising et al. 2015, pp. 36, 38, 61). This warm water anomaly expanded southward in 2014, with further warming along the California Current in 2015, and then merged with another anomaly that developed off Baja California, becoming the highest sea surface temperature anomaly observed since 1982 when measurements began (NMFS 2016, p. 5). These anomalies became known as "the Blob" (Bond et al. 2015, p. 3414)

and helped to compress the zone of cold upwelled waters to the nearshore (NMFS 2016, p. 7). During the late summer of 2019, a new marine heatwave began developing, and is currently on a trajectory to be as extreme as the 2014-2015 "Blob" (NMFS 2019).

The marine portion of the listed range of the murrelet is located along the California Current and estuary systems (including the Salish Sea) adjacent to it. The California Current is strongly influenced by upwelling, in which water rises from the deep ocean to the surface. Upwelling along the west coast leads to an influx of cold waters rich in nutrients such as nitrates, phosphates, and silicates, but that are also acidic (due to high dissolved carbon dioxide content) and low in dissolved oxygen (Johannessen et al. 2014, p. 220; Krembs 2012, p. 109; Riche et al. 2014, pp. 45-46, 48; Sutton et al. 2013, p. 7191). Changes in upwelling are likely to occur, and to influence the ecosystem components most important to murrelets. If changes in upwelling occur along the outer coast of Washington, these changes will also affect the interchange of waters through the Strait of Juan de Fuca (Babson et al. 2006, p. 30; Newton et al. 2003, p. 718). It has been hypothesized that as climate change accentuates greater warming of air over land areas than of air over the ocean, alongshore winds will intensify, which will lead to an increase in upwelling (Bakun 1990, entire). Historical records show that these winds have intensified over the past several decades (Bylhower et al. 2013, p. 2572; García-Reyes and Largier 2010, p. 6; Sydeman et al. 2014, p. 78-79; Taboada et al. 2019, p. 95; Wang et al. 2015, pp. 390-391). Projections for future changes in upwelling offer some support for this hypothesis, but are more equivocal (Foreman et al. 2011, p. 10; Moore et al. 2015, p. 5; Mote and Mantua 2002, p. 53-3; Rykaczewski et al. 2015, pp. 6426-6427; Wang et al. 2010, pp. 263, 265). Some studies indicate a trend toward a later, shorter (but in some cases, more intense) upwelling season, though at the southern end of the range the season may be lengthening (Bograd et al. 2009, pp. 2-3; Bylhower et al. 2013, p. 2572; Diffenbaugh et al. 2004, p. 30; Foreman et al. 2011, p. 8; García-Reyes and Largier 2010, p. 6). Trends and projections for the future of upwelling in the California Current may be so variable because upwelling is inherently difficult to model, or because upwelling in this region is heavily influenced by climate cycles such as the NPGO, PDO, and ENSO (Macias et al. 2012, pp. 4-5; Taboada et al. 2019, p. 95; Wang et al. 2015, p. 391).

Regardless of potential changes in the timing or intensity of upwelling, the dissolved oxygen content of the waters in the listed range is expected to decrease. The solubility of oxygen in water decreases with increasing temperature, so as the climate becomes warmer, the dissolved oxygen content of the marine environment is expected to decrease (IPCC 2014, p. 62; Mauger et al. 2015, pp. 7-3, 7-8). The oxygen content in the North Pacific Ocean has declined significantly since measurements began in 1987 (Whitney et al. 2007, p. 184), and this decline is projected to continue (Whitney et al. 2013, p. 2204). Hypoxic and anoxic events, in which the lack of dissolved oxygen creates a dead zone, have occurred in Puget Sound and along the outer coasts of Washington and Oregon (PSEMP Marine Waters Workgroup 2017, p. 22; PSEMP Marine Waters Workgroup 2016, p. 15; Oregon State University 2017, entire). These dead zones have expanded into shallower depths and areas closer to shore, and impacts are expected to increase rapidly (Chan et al. 2016, p. 4; Somero et al. 2016, p. 15). If upwelling does increase in intensity, the effect would likely be to further reduce the oxygen content of nearshore waters, but these changes are not likely to be consistent throughout the region or throughout the year. Changes in oxygen content, or in the timing of low-oxygen periods, may have important biological consequences (see below). Oxygen content also responds to biological activity. In

addition to climate change-induced effects, some locations will likely experience reductions in oxygen content stemming from biological responses to eutrophication in areas that receive (and do not quickly flush) nutrient inputs from human activities (Cope and Roberts 2013, pp. 20-23; Mackas and Harrison 1997, p. 14; Roberts et al. 2014, pp. 103-104, 108; Sutton et al. 2013, p. 7191).

Similarly, acidification of waters in the listed range is expected to increase, regardless of any changes in upwelling. Acidification results when carbon dioxide in the air dissolves in surface water, and is the direct consequence of increasing carbon dioxide emissions (IPCC 2014, pp. 41, 49). Marine waters are projected to continue becoming more acidic, and ocean acidification is now expected to be irreversible at human-relevant timescales (IPCC 2014, pp. 8-9, 49; IPCC 2019, pp. 1-4, 1-7, 1-14). Both the surface and upwelled waters of North Pacific Ocean have become more acidic due to carbon dioxide emissions (Feely et al. 2008, pp. 1491-1492, Murray et al. 2015, pp. 962-963), and this trend is expected to continue (Byrne et al. 2010, p. L02601; Feely et al. 2009, pp. 40-46). These waters also contribute to acidification Conservation Zone 1 as they flow in through the Strait of Juan de Fuca (Feely et al. 2010, p. 446, Murray et al. 2015, p. 961). Any increase in upwelling intensity or changes in seasonality would respectively increase acidification or change the timing of pH changes in the murrelet range. It is unknown whether regional carbon dioxide emissions cause additional localized acidification within particular parts of the range (Newton et al. 2012, p. 36), but it is likely that other products of fossil fuel combustion, such as sulfuric acid, do contribute (Doney et al. 2007, pp. 14582-14583). Linked to reductions in dissolved oxygen (Riche et al. 2014, p. 49), acidification has important biological consequences (see below), and also responds to biological activity. For example, local areas of eutrophication are likely to experience additional acidification beyond that caused directly or indirectly by carbon dioxide emissions (Newton et al. 2012, pp. 32-33).

Sea level rise is also expected to affect the listed range of the murrelet. Sea level rise is a consequence of the melting of glaciers and ice sheets combined with the expansion of water as it warms (IPCC 2014, p. 42). At regional and local scales, numerous factors affect sea level rise, including ocean currents, wind patterns, and plate tectonics (Mauger et al. 2015, p. 4-1; Dalrymple 2012, p. 81; Petersen et al. 2015, p. 21). Sea level is rising at most coastal locations in the action area (Mauger et al. 2015, p. 4-2; Dalrymple 2012, pp. 79-81; Shaw et al. 1998, p. 37). These increases in sea level are likely to continue and may accelerate in the near future (Bromirski et al. 2011, pp. 9-10; Dalrymple 2012, pp. 71, 102; Mauger et al. 2015, pp. 4-3 – 4-5; Mote et al. 2008, p. 10; Petersen et al. 2015, pp. 21, 29, and Appendix D). However, in some places, such as Neah Bay,Washington, plate tectonics are causing upward land movement that is currently outpacing sea level rise (Dalrymple 2012, p. 80; Montillet et al. 2018, p. 1204; Mote et al. 2008, pp. 7-8; Petersen et al. 2015, pp 24-26). In other places, sea-level rise is expected to have consequences for near-shore ecosystems (see below).

Physical Changes Specific to Conservation Zone 1

Conservation Zone 1 will be affected by changes in upwelling, dissolved oxygen content, and acidification discussed above, but these effects are expected to vary, both between Conservation Zone 1 and the other Zones, and within Zone 1, based on the exchange of waters through the Strait of Juan de Fuca and water circulation patterns within Zone 1. These water circulation

patterns, in and of themselves, are expected to be affected by climate change. The complexity of the physical environment within Zone 1 can make some climate change effects difficult to predict.

Changes in temperature and the seasonality of precipitation over land affect the freshwater inflows to Conservation Zone 1. Spring and summer freshwater inflows are expected to be warmer and reduced in volume, whereas winter freshwater inflows are expected to increase (Lee and Hamlet 2011, p. 110; Mauger et al. 2015, p. 3-8; Moore et al. 2015, p. 6; Mote et al. 2003, p. 56). Many watersheds draining to the Salish Sea have historically been fed by a mix of rain and snowmelt, but are expected to be increasingly dominated by rainfall, which will cause the timing of peak flows to shift from spring to winter (Elsner et al. 2010, pp. 248-249; Hamlet et al. 2001, pp. 9-11; Hamlet et al. 2013, pp. 401-404; Mauger et al. 2015, pp. 3-4 – 3-5). With winter warming and increases in heavy rainfall events, flooding has increased, and this increase is expected to continue (Hamlet and Lettenmaier 2007, pp. 25-16; Lee and Hamlet 2011, p. 113; Mauger et al. 2015, pp. 3-6 – 3-7). Increased winter freshwater inflows, in combination with melting glaciers, are expected to bring increased sediments to the mouths of rivers; however, it is uncertain whether these sediments are more likely to enter the marine waters or to be deposited in estuaries (Czuba et al. 2011, p. 2; Lee and Hamlet 2011, pp. 129-134; Mauger et al. 2015, pp. 5-7 – 5-10).

These changes in seasonal freshwater inflows are expected to alter water circulation and stratification within Conservation Zone 1, and to affect the rate and timing of exchange of waters through the Strait of Juan de Fuca between the Puget Sound and the North Pacific Ocean (Babson et al. 2006, pp. 29-30; MacCready and Banas 2016, p. 13; Mauger et al. 2015, p. 6-2, Riche et al. 2014, pp. 37-39, 44-45, 49-50). This exchange occurs in two layers, with fresh water at the surface flowing toward the ocean, and denser, saltier ocean waters flowing from the ocean at greater depths (Babson et al. 2006, p. 30). With the projected changes in timing of freshwater inflows, the rate of exchange is expected to increase during winter and decrease during summer (Mauger et al. 2015, pp. 6-2 – 6-3). The effect of changes in freshwater inflow on stratification is likely to vary by location within the action area, with greater potential for effect in, for example, southern Puget Sound than in well-mixed channels like Admiralty Inlet and Dana Passage (Newton et al. 2003, p. 721).

When hypoxic (low dissolved oxygen) events occur in the waters of Zone 2, these waters also flow into the inland waters of Conservation Zone 1, driving down the oxygen content there as well, although there is considerable variation over time, space, and depth, due to patterns of circulation and mixing within the Salish Sea (Bassin et al. 2011, Section 3.2; Johannessen et al. 2014, pp. 214-220). For example, Hood Canal is particularly susceptible to hypoxic conditions, partly because circulation of water through Hood Canal is slow (Babson et al. 2006, p. 30), whereas the vigorous tidal currents in Haro Strait allow for the mixing of oxygen-rich surface water throughout the water column (Johannessen et al. 2014, p. 216). Increased stratification, as is expected during winter with the larger freshwater inflows, can lead to hypoxic conditions in deeper waters (Mauger et al. 2015, p. 6-3; Whitney et al. 2007, p. 189). On the other hand, weaker stratification, as expected in the summer, may decrease the probability of low oxygen due to greater mixing, or increase the probability of low oxygen due to slower circulation (Newton et al. 2003, p. 725).

Primary Productivity

Changes in temperature, carbon dioxide, and nutrient levels are likely to affect primary productivity by phytoplankton, macroalgae, kelp, eelgrass, and other marine photosynthesizers (IPCC 2019, p. 5-72; Mauger et al. 2015, p. 11-5). In general, warmer temperatures, higher carbon dioxide concentrations, and higher nutrient levels lead to greater productivity (Gao and Campbell 2014, pp. 451, 454; Nagelkerken and Connell 2015, p. 13273; Newton and Van Voorhis 2002, p. 10; Roberts et al. 2014, pp. 11, 22, 108; Thom 1996, pp. 386-387), but these effects vary by species and other environmental conditions, such as sunlight levels or the ratios of different nutrients (Gao and Campbell 2014, pp. 451, 454; Krembs 2012, p. 109; Kroeker et al. 2013, p. 1889; Low-Decarie et al. 2011, p. 2530). In particular, phytoplankton species that form calcium carbonate shells, such as coccolithophores, show weaker shell formation and alter their physiology in response to acidification, and are expected to decline in abundance with continued acidification (Feely et al. 2004, pp. 365-366; IPCC 2019, p. 5-62; Kendall 2015, pp. 26-46). Due to changes in the seasonality of nutrient flows associated with upwelling and freshwater inputs, there may also be alterations in the timing, location, and species composition of bursts of primary productivity, for example, earlier phytoplankton blooms (Allen and Wolfe 2013, pp. 6, 8-9; MacCready and Banas 2016, p. 17; Mauger et al. 2015, p. 6-3). Changes in primary productivity may not occur in every season; for example, during winter, sunlight is the major limiting factor through most of Conservation Zone 1 (Newton and Van Voorhis 2002, pp. 9, 12), and it is not clear whether winter sunlight is likely to change with climate change. Models project reductions in overall annual marine net primary productivity in the world's oceans during the 21st century, trends will vary across the listed murrelet range, with decreases at the southern end of the range and increases at the northern end (IPCC 2019, pp. 5-31, 5-38). Changes in primary productivity are also likely to vary at smaller scales, even within a Conservation Zone; for example, primary productivity in Possession Sound is more sensitive to nutrient inputs than other areas within Puget Sound (Newton and Van Voorhis 2002, pp. 10-11). In sum, in addition to localized increases and decreases in productivity, we expect changes in the timing, location, and species dominance of primary producers.

Eelgrass (*Zostera marina*) is a particularly important primary producer in some parts of the range. In some areas, such as Padilla Bay in Zone 1, sea level rise is expected to lead to larger areas of suitable depth for eelgrass meadows. In such areas, eelgrass cover, biomass, and net primary production are projected to increase during the next 20 years (Kairis 2008, pp. 92-102), but these effects will depend on the current and future topography of the tidal flats in a given area. In addition, increasing dissolved carbon dioxide concentrations are associated with increased eelgrass photosynthetic rates and resistance to disease (Groner et al. 2018, p. 1807; Short and Neckles 1999, pp. 184-186; Thom 1996, pp. 385-386). However, increasing temperatures are not likely to be beneficial for eelgrass, and in combination with increased nutrients, could favor algal competitors (Short and Neckles 1999, pp. 172, 174; Thom et al. 2014, p. 4). Changes in upwelling are likely to influence eelgrass productivity and competitive interactions in small estuaries along the California Current (Hayduk et al. 2019, pp. 1128-1131). Between 1999 and 2013, eelgrass growth rates in Sequim Bay and Willapa Bay increased, but at a site in central Puget Sound, shoot density over a similar time period was too variable to detect trends (Thom et al. 2014, pp. 5-6). Taken together, these studies indicate that climate change

may benefit eelgrass over the coming decades, but these benefits may be limited to specific areas, and negative effects may dominate in other areas (Thom et al. 2014, pp. 7-9).

Kelp forests also make important contributions to primary productivity in some parts of the range. Like eelgrass, bull kelp (*Nereocystis luetkeana*) responds to higher carbon dioxide concentrations with greater productivity (Thom 1996, pp. 385-386). On the other hand, kelp forests are sensitive to high temperatures (IPCC 2019, p. 5-72), and warming waters (among other factors) have reduced the range of giant kelp (*Macrocystis pyrifera* [Agardh]) (Edwards and Estes 2006, pp. 79, 85; Ling 2008, p. 892). In central and northern California, kelp forests have declined, but not along Oregon, Washington, and Vancouver Island (Krumhansl et al. 2016, p. 13787; Wernberg et al. 2019, p. 69). Along Washington's outer coast and the Strait of Juan de Fuca, bull kelp and giant kelp canopy area did not change substantially over the 20th century, though a few kelp beds have been lost (Pfister et al. 2018, pp. 1527-1528). In southern Puget Sound, bull kelp declines were observed between 2013 and 2017-2018, likely resulting from increasing temperature along with decreasing nutrient concentrations, suspended sediment, and the presence of parasites and herbivores (Berry et al. 2019, p. 43). In northern California, a severe decline in bull kelp occurred in conjunction with the marine heatwave of 2014 and 2015, though a number of other ecological factors were involved (Catton et al. 2019, entire). In central California, trends in giant kelp biomass are related to climate cycles such as the NPGO, making the effect of climate change difficult to detect (Bell et al. 2018b, p. 11). It is unclear what the future effects of climate change will be on kelp in the listed range of the murrelet.

In contrast, increases in harmful algal blooms (also known as red tides or toxic algae) have been documented over the past several decades, and these changes are at least partly due to climate change (IPCC 2019, pp. 5-85 – 5-86; Trainer et al. 2003, pp. 216, 222). Future conditions are projected to favor higher growth rates and longer bloom seasons for these species. In the case of one species, *Alexandrium catanella,* increases in the length of bloom season are projected primarily due to increases in sea surface temperature (Moore et al. 2015, pp. 7-9). As with other climate change effects discussed above, increases in the length of the toxic algae bloom season is likely to vary across the listed range. Even within Zone 1, in the eastern end of the Strait of Juan de Fuca and the inlets of southern Puget Sound, the *A. catanella* bloom season is projected to increase by 30 days per year by 2069, in contrast with Whidbey basin, where little or no change in season length is projected (Moore et al. 2015, p. 8). In another genus toxic algae, *Pseudo-nitzschia*, toxin concentrations increase with increasing acidification of the water, especially in conditions in which silicic acid (used to construct the algal cell walls) or phosphate is limiting (Brunson et al. 2018, p. 1; Tatters et al. 2012, pp. 2-3). These and many other harmful alga species also exhibit higher growth rates with higher carbon dioxide concentrations (Brandenburg et al. 2019, p. 4; Tatters et al. 2012, pp. 3-4). During and following the marine heatwave in 2015, an especially large and long-lasting outbreak of *Pseudo-nitzschia* species stretched from southern California to the Aleutian Islands and persisted from May to October, rather than the typical span of a few weeks (Du et al. 2016, pp. 2-3; National Ocean Service 2016; NOAA Climate 2015, p. 1). This harmful algal bloom produced extremely high concentrations of toxic domoic acid, including the highest ever recorded in Monterey Bay, California (NOAA Climate 2015, p. 2; Ryan et al. 2017, p. 5575). With future climate change, toxic algae blooms are likely to be more frequent than in the past, and the larger, more toxic event of 2015 may become more typical (McCabe et al. 2016, p. 10374).

Higher Trophic Levels

There are several pathways by which climate change may affect species at higher trophic levels (i.e, consumers, including marbled murrelets and their prey). Changing physical conditions, such as increasing temperatures, hypoxia, or acidification will have direct effects on some species. Other consumers will be affected via changes in the abundance, distribution, or other characteristics of their competitors or prey species. Changes in the timing of seasonal events may lead to mismatches in the timing of consumers' life history requirements with their habitat conditions (including prey availability as well as physical conditions) (Mackas et al. 2007, p. 249). The combination of these effects is likely to cause changes in community dynamics (e.g. competitive interactions, predator-prey relationships, etc.), but the magnitude of these effects cannot be predicted with confidence (Busch et al. 2013, pp. 827- 831).

A wide variety of marine species are directly affected by ocean acidification. Like their phytoplankton counterparts, foraminiferans and other planktonic consumers that form calcium carbonate shells are less able to form and maintain their shells in acidified waters (Feely et al. 2004, pp. 356-366). Similarly, chemical changes associated with acidification interfere with shell development or maintenance in pteropods (sea snails) and marine bivalves (Busch et al. 2014, pp. 5, 8; Waldbusser et al. 2015, pp. 273-278). These effects on bivalves can be exacerbated by hypoxic conditions (Gobler et al. 2014, p. 5), or ameliorated by very high or low temperatures (Kroeker et al. 2014, pp. 4-5), so it is not clear what the effect is likely to be in a future that includes acidification, hypoxia, and elevated temperatures. Acidification affects crustaceans, for example, slowing growth and development in Pacific krill (*Euphausia pacifica*) and Dungeness crabs (*Cancer magister*) (Cooper et al. 2016, p. 4; Miller et al. 2016, pp. 118-119). Fish, including murrelet prey rockfish species (*Sebastes* spp.) and Pacific herring (*Clupea pallasii*), are also negatively affected by acidification. Depending on species, life stage, and other factors such as warming and hypoxia, these effects include embryo mortality, delayed hatching, reduced growth rates, reduced metabolic rates, altered sensory perception, and changes in behavior, among other effects (Baumann 2019, entire; Hamilton et al. 2014, entire; Nagelkerken and Munday 2016, entire; Ou et al. 2015, pp. 951, 954; Villalobos 2018, p. 18).

Climate effects are expected to alter interactions within the marine food web. When prey items decrease in abundance, their consumers are also expected to decrease, and this can also create opportunities for other species to increase. In California's Farallon Islands, the recently increasing variance of climate drivers is leading to increased variability in abundance of prey species such as euphausiids and juvenile rockfish, associated with corresponding variability in the demography of predators such as seabirds and salmon (Sydeman et al. 2013, pp. 1662, 1667-1672). In future scenarios with strong acidification effects to benthic prey in the California Current, euphausiids and several fish species are expected to decline, while other species are expected to increase (Kaplan et al. 2010, pp. 1973-1976). An investigation of the planktonic food web off of Oregon shows that sea surface temperature has contrasting effects on different types of zooplankton, and competitive interactions are much more prevalent during warm phases of ENSO or PDO than during cool phases (Francis et al. 2012, pp. 2502, 2505-2506). A food web model of Puget Sound shows that moderate or strong acidification effects to calcifying species are expected to result in reductions in fisheries yield for several species, including salmon and Pacific herring, and increased yield for others (Busch et al. 2013, pp. 827-829).

Additionally, the same model shows that these ocean acidification effects are expected to cause reductions in forage fish biomass, which are in turn expected to lead to reductions in diving bird biomass (Busch et al. 2013, p. 829). While Busch and coauthors (2013, p. 831) express confidence that this model is accurate in terms of the nature of ocean acidification effects to the Puget Sound food web of the future, they are careful to note that there is a great deal of uncertainty when it comes to the magnitude of the changes. The model also illustrates that some of the effects to the food web will dampen or make up for other effects to the food web, so that changes in abundance of a given prey species will not always correspond directly to changes in the abundance of their consumers (Busch et al. 2013, pp. 827, 830).

Changes in seasonality at lower trophic levels may lead to changes in population dynamics or in interactions between species at higher trophic levels. In central and northern California, reproductive timing and success of common murres (*Uria aalge*) and Cassin's auklets (*Ptychoramphus aleuticus*) are related to not only the strength but also the seasonal timing of upwelling, as are growth rates of *Sebastes* species (Black et al. 2011, p. 2540; Holt and Mantua 2009, pp. 296-297; Schroeder et al. 2009, p. 271). At the northern end of the California Current, Triangle Island in British Columbia, Cassin's auklet breeding success is reduced during years when the peak in copepod prey availability comes earlier than the birds' hatch date, and this mismatch is associated with warm sea surface temperatures (Bertram et al. 2009, pp. 206-207; Hipfner 2008, pp. 298-302). However, piscivorous seabirds (tufted puffins [*Fratercula cirrhata*], rhinoceros auklets [*Cerorhinca monocerata*], and common murres) breeding at the same Triangle Island site have, at least to some extent, been able to adjust their breeding dates according to ocean conditions (Bertram et al. 2001, pp. 292-293; Gjerdrum et al. 2003, p. 9379), as have Cassin's auklets breeding in the Farallon Islands of California (Abraham and Sydeman 2004, p. 240). Because of the changes in tufted puffin, rhinoceros auklet, and common murre hatch dates at Triangle Island, the breeding periods of these species have converged to substantially overlap with one another and with that of Cassin's auklet (Bertram et al. 2001, pp. 293-294), but studies have not addressed whether this overlap has consequences for competitive interactions among the four species. Note that all four of these bird species are in the family Alcidae, which also contains marbled murrelets. All these species also breed and forage within the listed range of the murrelet.

Several studies have suggested that climate change is one of several factors allowing jellyfish to increase their ecological dominance, at the expense of forage fish (Parsons and Lalli 2002, pp. 117-118; Purcell et al. 2007, pp. 154, 163, 167-168; Richardson et al. 2009, pp. 314-216). Many (though not all) species of jellyfish increase in abundance and reproductive rate in response to ocean warming, and jellyfish are also more tolerant of hypoxic conditions than fish are (Purcell 2005, p. 472; Purcell et al. 2007, pp. 160, 163; see Suchman et al. 2012, pp. 119-120 for a Northeastern Pacific counterexample). Jellyfish may also be more tolerant of acidification than fish are (Atrill et al. 2007, p. 483; Lesniowski et al. 2015, p. 1380). In the California Current, jellyfish populations appear to be increasing, but nearshore areas are likely to be susceptible to being dominated by jellyfish, rather than forage fish (Schnedler-Meyer et al. 2016, p. 4). Jellyfish abundance in southern and central Puget Sound has increased since the 1970s (Greene et al. 2015, p. 164). Over the same time period, herring abundance has decreased in south and central Puget Sound, and surf smelt (*Hypomesus pretiosus*) abundance has also decreased in south Puget Sound, although other Puget Sound forage fish populations have been stable or

increasing (Greene et al. 2015, pp. 160-162). Forage fish abundance and jellyfish abundance were negatively correlated within Puget Sound and Rosario Strait (Greene et al. 2015, p. 164). In the northern California Current, large jellyfish and forage fish have similar diet composition and likely compete for prey, in addition to the two groups' contrasting responses to climate and other anthropogenic factors (Brodeur et al. 2008, p. 654; Brodeur et al. 2014, pp. 177-179).

Many species of forage fish are expected to fare poorly in the changing climate, regardless of any competitive effects of jellyfish. North of the listed range, in the Gulf of Alaska, Anderson and Piatt (1999, pp. 119-120) documented the crash of capelin (*Mallotus villosus*), Pacific herring, and species of Irish lord (*Hemilepidotus* spp.), prickleback (Stichaeidae family), greenlings and mackerel (*Hexagrammos* and *Pleurogrammus* spp.), as well as several shrimp species, as part of a major community reorganization following a climate regime shift from a cool phase to a warm phase in the 1970s. In the northeastern Pacific Ocean, capelin, sand lance (Ammodytidae family), and rockfish abundance are all negatively correlated with seasonal sea surface temperatures (Thayer et al. 2008, p. 1616). A model of multiple climate change effects (e.g., acidification and deoxygenation) to marine food webs in the Northeast Pacific consistently projects future declines in small pelagic fish abundance (Ainsworth et al. 2011, pp. 1219, 1224). Within Zone 1, abundance of surf smelt and Pacific herring in the Skagit River estuary are positively associated with coastal upwelling during the spring and early summer, likely because nutrient-rich upwelled water increases food availability (Reum et al. 2011, pp. 210-212). If projections of later, shorter upwelling seasons are correct (see above), the delays may lead to declines in these stocks of herring and surf smelt, as happened in 2005 (Reum et al. 2011, p. 212). Similarly, delayed upwelling in 2005 led to reduced growth rates, increased mortality, and recruitment failure of juvenile northern anchovies (*Engraulis mordax*) off of the Oregon and Washington coasts (Takahashi et al. 2012, pp. 397-403). In contrast, anchovy abundance in Zone 1 was unusually high in 2005, as it was in 2015 and 2016 following the marine heatwave, and is positively associated with sea surface temperature (Duguid et al. 2019, p. 38). In the northeastern Pacific, Chavez and coauthors (2003, pp. 217-220) have described a shift between an "anchovy regime" during the cool negative phase of the PDO and a "sardine regime" during the warm positive phase, where the two regimes are associated with contrasting physical and biological states. However, global warming may disrupt the ecological response to the naturally-occurring oscillation, or alter the pattern of the oscillation itself (Chavez et al. 2003, p. 221; Zhang and Delworth 2016, entire).

Marbled Murrelets

Marbled murrelets are likely to experience changes in foraging and breeding ecology as the climate continues to change. Although studies are not available that directly project the effects of marine climate change on marbled murrelets, several studies have been conducted within and outside the listed range regarding ocean conditions and marbled murrelet behavior and fitness. Additionally, numerous studies of other alcids from Mexico to British Columbia indicate that alcids as a group are vulnerable to climate change in the northeastern Pacific.

These studies suggest that the effects of climate change will be to reduce marbled murrelet reproductive success, likely mediated through climate change effects to prey. In British Columbia, there is a strong negative correlation between sea surface temperature and the number

of marbled murrelets observed at inland sites displaying behaviors associated with nesting (Burger 2000, p. 728). In central California, marbled murrelet diets vary depending on ocean conditions, and there is a trend toward greater reproductive success during cool water years, likely due to the abundant availability of prey items such as euphausiids and juvenile rockfish (Becker et al. 2007, pp. 273-274). Across the northern border of the listed range, in the Georgia Basin, much of the yearly variation in marbled murrelet abundance from 1958 through 2000 can be explained by the proportion of fish (as opposed to euphausiids or amphipods) in the birds' diet (Norris et al. 2007, p. 879). If climate change leads to further declines in forage fish populations (see above), those declines are likely to be reflected in marbled murrelet populations.

The conclusion that climate change is likely to reduce marbled murrelet breeding success via changes in prey availability is further supported by several studies of other alcid species in British Columbia and California. Common murres, Cassin's auklets, rhinoceros auklets, and tufted puffins in British Columbia; pigeon guillemots (*Cepphus columba*), common murres, and Cassin's auklets in California; and even Cassin's auklets in Mexico all show altered reproductive rates, altered chick growth rates, or changes in the timing of the breeding season, depending on sea surface temperature or other climatic variables, prey abundance, prey type, or the timing of peaks in prey availability (Abraham and Sydeman 2004, pp. 239-243; Ainley et al. 1995, pp. 73-77; Albores-Barajas 2007, pp. 85-96; Bertram et al. 2001, pp. 292-301; Borstad et al. 2011, pp. 291-299; Gjerdrum et al. 2003, pp. 9378-9380; Hedd et al. 2006, pp. 266-275; Sydeman et al. 2006, pp. 2-4). The abundance of Cassin's auklets and rhinoceros auklets off southern California declined by 75 and 94 percent, respectively, over a period of ocean warming between 1987 and 1998 (Hyrenbach and Veit 2003, pp. 2546, 2551). Although the details of the relationships between climate variables, prey, and demography vary between bird species and locations, the consistent demonstration of such relationships indicates that alcids as a group are sensitive to climate-related changes in prey availability, prompting some researchers to consider them indicator species for climate change (Hedd et al. 2006, p. 275; Hyrenbach and Veit 2003, p. 2551).

In addition to effects on foraging ecology and breeding success, climate change may expose adult and juvenile marbled murrelets to health risks. For example, it is likely that they will experience more frequent domoic acid poisoning, as this toxin originates from harmful algae blooms in the genus *Pseudo-nitzchia*, which are expected to become more prevalent in the listed range (see above). In central California, domoic acid poisoning was determined to be the cause of death for at least two marbled murrelets recovered during a harmful algae bloom in 1998 (Peery et al. 2006, p. 84). During this study, which took place between 1997 and 2003, the mortality rate of radio-tagged marbled murrelets was highest during the algae bloom (Peery et al. 2006, p. 83). Domoic acid poisoning has previously been shown to travel through the food chain to seabirds via forage fish that feed on the toxic algae (Work et al. 1993, p. 59). Other types of harmful algae, including the *Alexandrium* genus, which is also likely to become more prevalent in the listed range (see above), produce saxitoxin, a neurotoxin that causes paralytic shellfish poisoning. Consumption of sand lance contaminated with saxitoxin was implicated in the deaths of seven out of eight (87.5 percent) of Kittlitz's murrelet (*Brachyramphus brevirostrus*) chicks that were tested following nest failure at a study site in Alaska in 2011 and 2012 (Lawonn et al. 2018, pp. 11-12; Shearn-Bochsker et al. 2014). Yet another species of harmful algae produces a foam that led to plumage fouling and subsequent mortality of common murres and other seabird

species off of Oregon and Washington during October of 2009, and similar events may become more frequent with climate change (Phillips et al. 2011, pp. 120, 122-124). Due to changes in the Salish Sea food web, climate change is projected to increase mercury and, to a lesser extent, polychlorinated biphenyls (PCB) levels in forage fish and top marine predators (Alava et al. 2018, pp. 4); presumably marbled murrelets will experience a similar increase. Climate change may also promote conditions in which alcids become exposed to novel pathogens, as occurred in Alaska during 2013, when crested auklets (*Aethia cristatella*) and thick-billed murres (*Uria lomvia*) washed ashore after dying of avian cholera (Bodenstein et al. 2015, p. 935). Murrelets in Oregon may be especially susceptible to novel diseases, because these populations have lack diversity in genes related to immunity (Vásquez-Carrillo et al. 2014, p. 252). Counterintuitively, in the 1997-2003 study of radio tagged marbled murrelets in California, marbled murrelet adult survival was higher during warm-water years and lower during cold-water years, likely because they did not breed and therefore avoided the associated physiological stresses and additional predator risk (Peery et al. 2006, pp. 83-85).

Overall, the effects of climate change in marine ecosystems are likely to be complex, and will vary across the range. Alterations in the physical properties of the marine environment will affect the productivity and composition of food webs, which are likely to affect the abundance, quality, and availability of food resources for murrelets. These changes, in turn, will affect marbled murrelet reproductive performance. In addition, toxic algae and potentially disease organisms are expected to present increasing risks to murrelet health and survival. Different types of effects can be predicted with varying levels of certainty. For example, large increases in the prevalence of harmful algal blooms have already been observed, whereas the likely future magnitude and direction of overall changes in net primary productivity remain highly uncertain. Some changes may be positive (for example, the potential for a northward shift in anchovy abundance), but on the whole climate change is expected to have a detrimental effect to marbled murrelet foraging and health.

Summary of Climate Change Effects

In summary, marbled murrelets are expected to experience effects of climate change in both their nesting habitat and marine foraging habitat. Natural disturbances of nesting habitat are expected to become more frequent, leading to accelerated habitat losses that may outpace ingrowth even in protected landscapes. Marine food chains are likely to be altered, and the result may be a reduction in food resources for marbled murrelets. Even if food resources remain available, the timing and location of their availability may shift, which may alter marbled murrelet nesting seasons or locations. In addition, health risks from harmful algal blooms, anthropogenic toxins, and perhaps pathogens are likely to increase with climate change.

Within the marine environment, effects on the murrelet food supply (amount, distribution, quality) provide the most likely mechanism for climate change impacts to murrelets. Studies in British Columbia (Norris et al. 2007) and California (Becker and Beissinger 2006) have documented long-term declines in the quality of murrelet prey, and one of these studies (Becker and Beissinger 2006, p. 475) linked variation in coastal water temperatures, murrelet prey quality during pre-breeding, and murrelet reproductive success. These studies indicate that murrelet recovery may be affected as long-term trends in ocean climate conditions affect prey resources

and murrelet reproductive rates. While seabirds such as the murrelet have life-history strategies adapted to variable marine environments, ongoing and future climate change could present changes of a rapidity and scope outside the adaptive range of murrelets (USFWS 2009, p. 46).

Conservation Needs of the Species

Reestablishing an abundant supply of high quality murrelet nesting habitat is a vital conservation need given the extensive removal during the 20th century. Even following the establishment of the NWFP, habitat continued to be lost between 1993 and 2012, and the rate of loss on non-federal lands has been 10 times greater than on federal lands (Raphael et al. 2016b, pp. 80-81). If this rate of loss continues, the conservation of the murrelet may not be possible because almost half of the higher-suitability nesting habitat is on non-federal lands (Raphael et al. 2016b, p. 86). Therefore, recovery of the murrelet will be aided if areas of currently suitable nesting habitat on non-federal lands are retained until ingrowth of habitat on federal lands provides replacement nesting opportunities (USFWS 2019, p. 21).

There are also other conservation imperatives. Foremost among the conservation needs are those in the marine and terrestrial environments to increase murrelet fecundity by increasing the number of breeding adults, improving murrelet nest success (due to low nestling survival and low fledging rates), and reducing anthropogenic stressors that reduce individual fitness or lead to mortality. The overall reproductive success (fecundity) of murrelets is directly influenced by nest predation rates (reducing nestling survival rates) in the terrestrial environment and an abundant supply of high quality prey in the marine environment before and during the breeding season (improving breeding rates, potential nestling survival, and fledging rates). Anthropogenic stressors affecting murrelet fitness and survival in the marine environment are associated with commercial and tribal gillnets, derelict fishing gear, oil spills, and high underwater sound pressure (energy) levels generated by pile-driving and underwater detonations (which can be lethal or reduce individual fitness). Anthropogenic activities, such as coastline modification and nutrient inputs in runoff, also affect prey availability and harmful algal blooms, which in turn affect murrelet fitness.

Further research regarding marine threats, general life history, and marbled murrelet population trends in the coastal redwood zone may illuminate additional conservation needs that are currently unknown (USFWS 2019, p. 66).

Recovery Plan

The Marbled Murrelet Recovery Plan outlines the conservation strategy with both short- and long-term objectives. The Plan places special emphasis on the terrestrial environment for habitat-based recovery actions due to nesting occurring in inland forests.

In the short-term, specific actions identified as necessary to stabilize the populations include protecting occupied habitat and minimizing the loss of unoccupied but suitable habitat (USFWS 1997, p. 119). Specific actions include 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. The designation of critical habitat also

contributes towards the initial objective of stabilizing the population size through the maintenance and protection of occupied habitat and minimizing the loss of unoccupied but suitable habitat.

Long-term conservation needs identified in the Plan 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.

General criteria for murrelet recovery (delisting) were established at the inception of the Plan and they have not been met (USFWS 2019, p. 65). More specific delisting criteria are expected in the future to address population, demographic, and habitat based recovery criteria (USFWS 1997, p. 114-115). The general criteria include:

- documenting stable or increasing population trends in population size, density, and productivity in four of the six Conservation Zones for a 10-year period and
- implementing management and monitoring strategies in the marine and terrestrial environments to ensure protection of murrelets for at least 50 years.

Thus, increasing murrelet reproductive success and reducing the frequency, magnitude, or duration of any anthropogenic stressor that directly or indirectly affects murrelet fitness or survival in the marine and terrestrial environments are the priority conservation needs of the species. The Service estimates recovery of the murrelet will require at least 50 years (USFWS 1997).

Recovery Zones in Washington

Conservation Zones 1 and 2 extend inland 50 miles from marine waters. 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 the Puget Sound, including the north Cascade Mountains and the northern and eastern sections of the Olympic Peninsula. Conservation Zone 2 includes marine waters within 1.2 miles (2 km) off the Pacific Ocean shoreline, with the northern terminus immediately south of the U.S.-Canadian border near Cape Flattery along the midpoint of the Olympic Peninsula and extending to the southern border of Washington (the Columbia River) (USFWS 1997, pg. 126).

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 miles off the coast, and 5) habitat within occupied murrelet sites on private lands (USFWS 1997).

Summary

At the range-wide scale, annual estimates of murrelet populations have fluctuated, with no conclusive evidence of a positive or negative trend since 2001(+0.34 percent per year, 95% CI: -0.9 to 1.6%) (McIver et al. 2018, p. 3). The most recent extrapolated population estimate for the entire NWFP area was 23,000 murrelets (95 percent CI: 18,500 to 27,600 birds) in 2017 (McIver et al. 2019, p. 3). The largest and most stable murrelet subpopulations now occur off the Oregon and northern California coasts, while subpopulations in Washington have steadily declined since 2001 (-3.9 percent per year; 95% CI: -5.8 to -2.0%) (McIver et al. 2019, p. 3).

Monitoring of murrelet nesting habitat within the NWFP area indicates nesting habitat declined from an estimated 2.53 million acres in 1993 to an estimated 2.23 million acres in 2012, a decline of about 12.1 percent (Raphael et al. 2016, p. 72). Murrelet population size is strongly and positively correlated with amount of nesting habitat, suggesting that conservation of remaining nesting habitat and restoration of currently unsuitable habitat is key to murrelet recovery (Raphael et al. 2011, p. iii). Given likely future increases in forest disturbances that can cause habitat loss, conservation of remaining nesting habitat is especially important.

The species decline has been largely caused by extensive removal of late-successional and old growth coastal forest which serves as nesting habitat for murrelets. Additional factors in its decline include high nest-site predation rates and human-induced mortality in the marine environment from disturbance, gillnets, and oil spills. In addition, murrelet reproductive success is strongly correlated with the abundance of marine prey species. Overfishing and oceanographic variation from climate events and long-term climate change have likely altered both the quality and quantity of murrelet prey species (USFWS 2009, p. 67).

Although some threats have been reduced (e.g., habitat loss on Federal lands), some threats continue and new threats now strain the ability of the murrelet to successfully reproduce. 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 low resilience to deleterious population-level effects and are at high risk of continuing or renewed declines. Activities that degrade the existing conditions of occupied nest habitat or reduce adult survivorship or nest success of murrelets will be of greatest consequence to the species. Actions resulting in the loss of occupied nesting habitat, mortality to breeding adults, eggs, or nestlings will reduce productivity, contribute to continued population declines, and prolong population recovery within the listed range of the species in the coterminous United States.

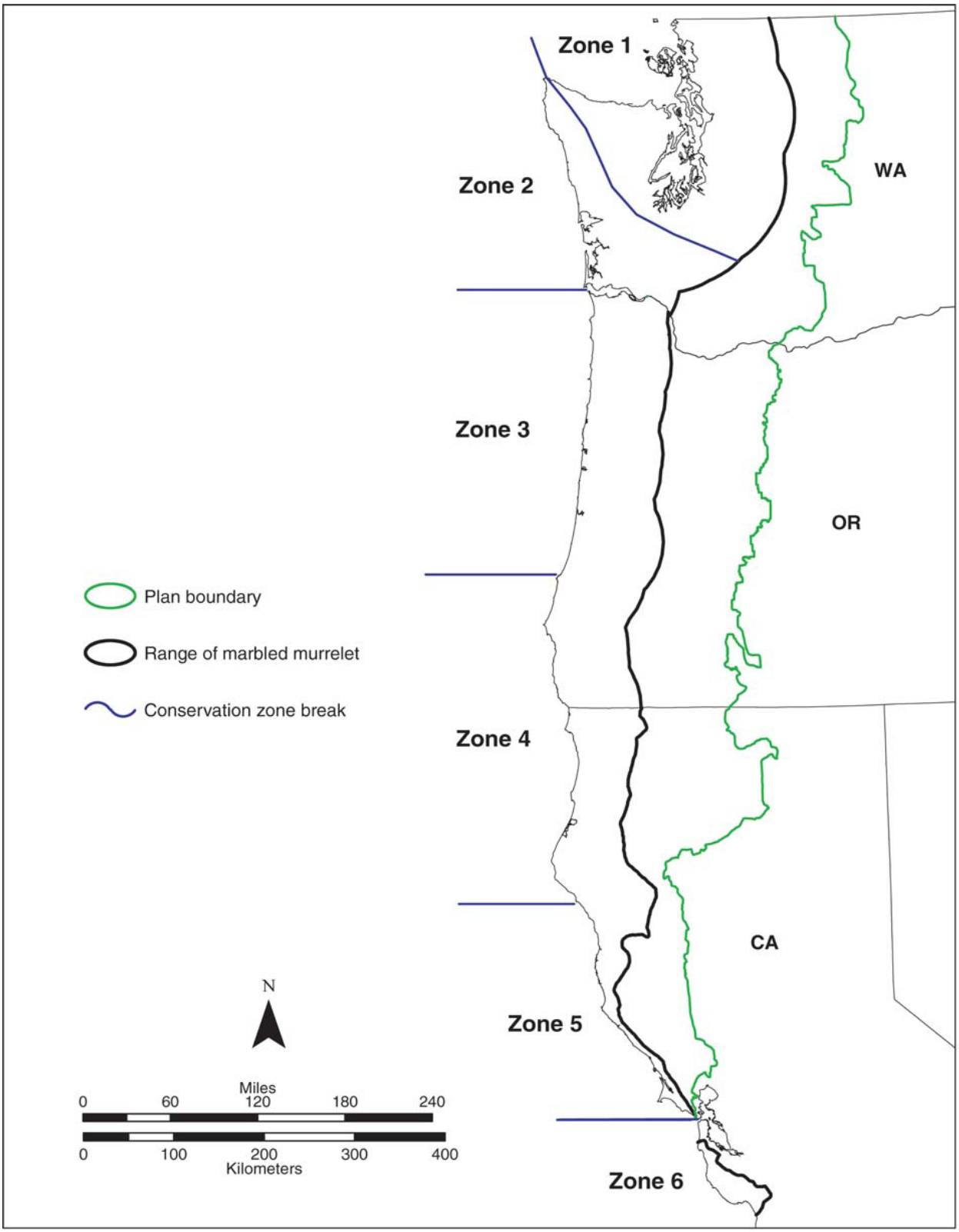

Figure 1. The six geographic areas identified as Conservation Zones in the recovery plan for the marbled murrelet (USFWS 1997). Note: "Plan boundary" refers to the NWFP. Figure adapted from Huff et al. (2006, p. 6).

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APPENDIX C
ESTIMATING MARBLED MURRELET MARINE HABITAT EXPOSURE TO GROWLER OVERFLIGHTS

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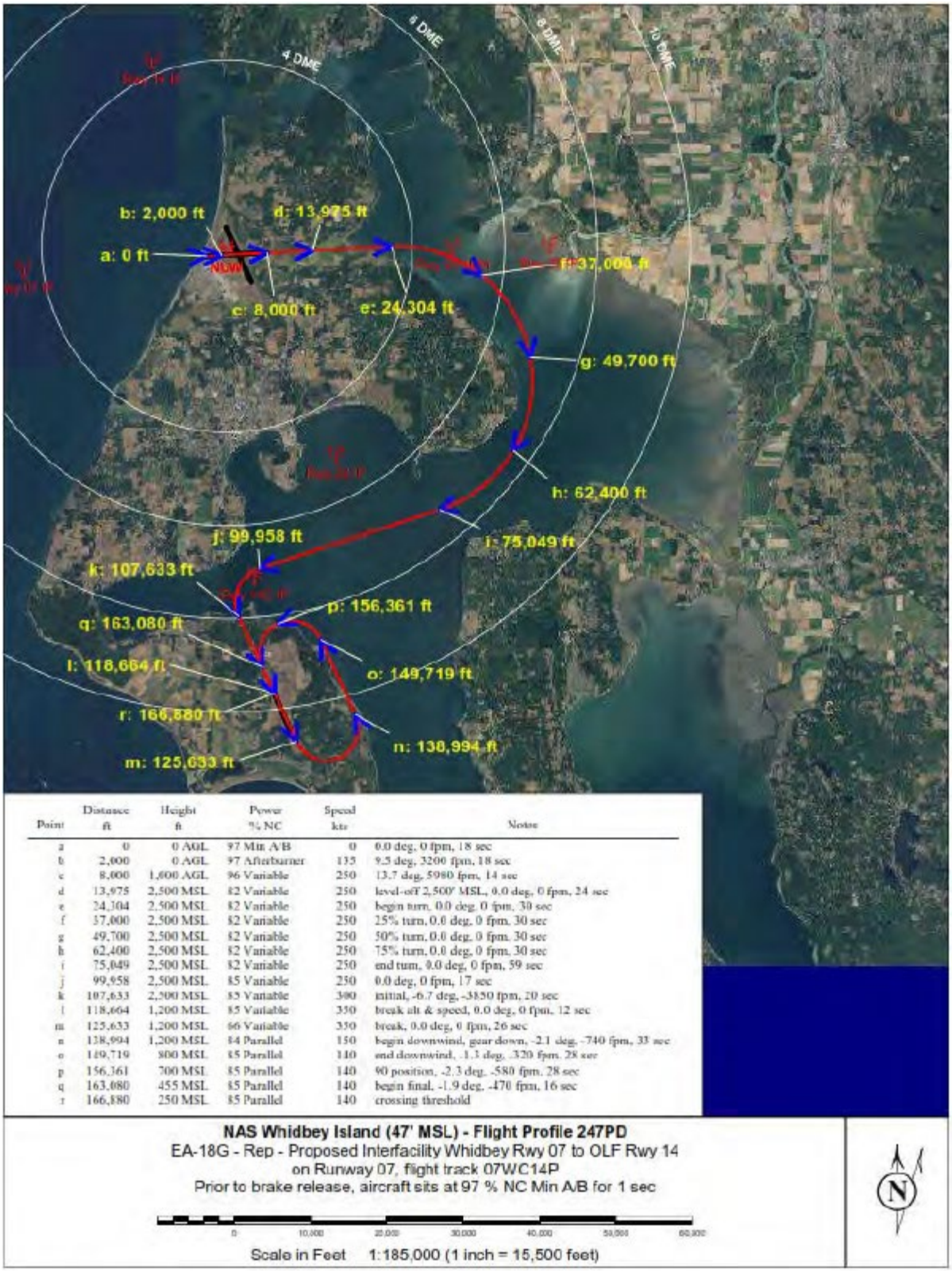
Appendix C
Estimating Marbled Murrelet Marine Habitat Exposure to Growler Overflights

In previous analyses, the U.S. Fish and Wildlife Service (Service) concluded that exposure to aircraft noise above 92 dBA_{SEL} re: $20\mu Pa^2s$ may result in changes to breeding, feeding, and resting behaviors in marbled murrelets (USFWS 2013, pp. 101-102; Teachout 2015, entire). Depending on the duration, intensity, timing and frequency of those exposures, could cause significant behavioral responses that would create a likelihood of injury. To expose marbled murrelet marine habitat to noise levels with the potential to cause significant behavioral responses, Growler overflights must have a power level and altitude to cause noise above 92 dBA_{SEL} re: $20\mu Pa^2s$ at the water surface.

The first step in estimating the amount of marbled murrelet marine habitat that will be exposed to noise at this level is to determine where Growlers will fly. The Final Environmental Impact Statement for EA-18G "Growler" Airfield Operations at Naval Air Station Whidbey Island Complex (the FEIS) provides maps of the 115 different modeled flight tracks associated with 11 types of Growler flight operations in the proposed action (Navy 2018, pp. A4-5 – A4-30, A5-7 – A5-24). The maps in the FEIS illustrate the predominant flight tracks, but Growlers may fly several miles to either side of the mapped flight tracks depending on aircraft performance, pilot technique, air traffic and whether conditions. For the purposes of our analysis, we took the mapped, predominant flight tracks as the best available information on where Growlers would fly for the proposed action.

To determine the amount of marbled murrelet marine habitat that will be exposed along those flight tracks, we examined the more detailed information provided for a representative subset of flight tracks (Navy 2018, pp. A5-7 – A5-24). The detailed information shows that, along the majority of flight tracks, Growlers are operating at power levels between 80 and 85 percent (see Figure 1 for an example). For our estimation of an area of exposure we assumed that, in most cases, Growlers would be operating at 85 percent power along the entirety of their flight tracks. We used 85 percent power as the predominant power setting because it was the power setting with available Sound Exposure Level (SEL) data for Growlers that would not underestimate effects.

At 85 percent power, a Growler overflight will produce sound that exceeds the Service's disturbance threshold within 4,000 ft of the aircraft. Therefore, Growler overflights less than 4,000 ft above ground level (AGL) will expose the water surface to disturbance-level noise. Departure flight tracks were the exception to using 85 percent power along the flight tracks. Departing Growlers drop from 96 percent power to 84 percent power somewhere between two of the points provided in the FEIS (Navy 2018, p. A5-7). Since it is uncertain where the Growler would drop to the lower power level, we used higher available power setting that we had SEL data for (93 percent power) for departure flight tracks. We also simplified our calculations by selecting a representative altitude that we estimated to be an average altitude flown along the flight track (for the portion of the flight track that was below 4,000 ft AGL; see Figure 1). The predominant power settings and representative altitudes for each type of flight operation are shown in the tables at the end of this appendix.



Point	Distance ft	Height ft	Power % NC	Speed kts	Notes
a	0	0 AGL	97 Min A/B	0	0.0 deg, 0 fpm, 18 sec
b	2,000	0 AGL	97 Afterburner	135	9.5 deg, 3200 fpm, 18 sec
c	8,000	1,600 AGL	96 Variable	250	13.7 deg, 5980 fpm, 14 sec
d	13,975	2,500 MSL	82 Variable	250	level-off 2,500' MSL, 0.0 deg, 0 fpm, 24 sec
e	24,304	2,500 MSL	82 Variable	250	begin turn, 0.0 deg, 0 fpm, 30 sec
f	37,000	2,500 MSL	82 Variable	250	25% turn, 0.0 deg, 0 fpm, 30 sec
g	49,700	2,500 MSL	82 Variable	250	50% turn, 0.0 deg, 0 fpm, 30 sec
h	62,400	2,500 MSL	82 Variable	250	75% turn, 0.0 deg, 0 fpm, 30 sec
i	75,049	2,500 MSL	82 Variable	250	end turn, 0.0 deg, 0 fpm, 59 sec
j	99,958	2,500 MSL	85 Variable	250	0.0 deg, 0 fpm, 17 sec
k	107,633	2,500 MSL	85 Variable	300	initial, -6.7 deg, -3850 fpm, 20 sec
l	118,664	1,200 MSL	85 Variable	350	break alt & speed, 0.0 deg, 0 fpm, 12 sec
m	125,633	1,200 MSL	66 Variable	350	break, 0.0 deg, 0 fpm, 26 sec
n	138,994	1,200 MSL	84 Parallel	150	begin downwind, gear down, -2.1 deg, -740 fpm, 33 sec
o	149,719	800 MSL	85 Parallel	140	end downwind, -1.3 deg, -320 fpm, 28 sec
p	156,361	700 MSL	85 Parallel	140	90 position, -2.3 deg, -580 fpm, 28 sec
q	163,080	455 MSL	85 Parallel	140	begin final, -1.9 deg, -470 fpm, 16 sec
r	166,880	250 MSL	85 Parallel	140	crossing threshold

Figure 1. Example of detailed information provided in the FEIS (Navy 2018, p. A5-13)

The predominant power settings gave us the distance to 92 dBA_{SEL} re: $20\mu Pa^2s$. For 93 percent power, we expect the sound from Growler overflights to attenuate to below 92 dBA_{SEL} re: $20\mu Pa^2s$ at 8,000 ft from the Growler (Navy 2015, p. 3.6-60). For 85 percent power, we expect the sound from Growler overflights to attenuate to below 92 dBA_{SEL} re: $20\mu Pa^2s$ at 4,000 ft from the Growler (Navy 2015, p. 3.6-60). Using these distances and representative altitudes, we calculated the width of marbled murrelet marine habitat that will be exposed to noise above 92 dBA_{SEL} re: $20\mu Pa^2s$ using the Pythagorean Theorem and doubling the result to account for noise on both sides of Growlers:

$$\textit{Width of Exposure Area} = 2 * \sqrt{(Distance\ to\ the\ disturbance\ threshold^2 - Altitude^2)}$$

Using the detailed information on representative flight tracks from the FEIS (Navy 2018, pp. A5-7 – A5-24), we estimated the linear distance along each flight track where Growlers would fly over water or near enough to water to cause sound levels to exceed 92 dBA_{SEL} re: $20\mu Pa^2s$. For some flight tracks, we were able to calculate distances using detailed information provided in the FEIS (in most instances this involved comparing less detailed flight track maps to the detailed flight track maps). For flight tracks without applicable detailed information, we measured flight tracks and estimated the distance using the scale of the map. The linear distances of marbled murrelet marine habitat exposure for each flight track are shown in the tables at the end of this appendix.

To estimate the total area of marbled murrelet marine habitat expected to be exposed to noise by each Growler flight along a flight track, we multiplied the width of the exposure area along the path by the linear distance we estimated Growlers will fly over marbled murrelet marine habitat. Flight tracks vary in the paths they take and consequently vary in the amount of marbled murrelet marine habitat they expose to noise. The maximum and minimum areas of marbled murrelet marine habitat that we expect to be exposed by flights of each type of flight operation are shown in the tables at the end of this appendix.

We also calculated a weighted average area of marbled murrelet marine habitat exposure by flight operation type. We weighted the average because flight tracks vary in the amount of marbled murrelet marine habitat they will expose and some flight tracks are used more than others. To determine the proportionate use of flight tracks within each type of flight operation we combined the runway utilization percentages and the flight track utilization percentages from the FEIS (see Figure 2 for an example of flight track utilization; Navy 2018, pp. A3-5-A3-9, A4-5-A5-30; also see Appendix D of this document). The annual percentages of flights expected to follow each predominant flight track are shown in the tables at the end of this appendix.

Figure 2. Example of predominant flight track map from FEIS (Navy 2018, p. A4-28)

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Departures

Predominant Power Setting:	93%	Distance to92 dBA_{SEL} :	8,000 ft
Representative Altitude:	2,000 ft AGL	Width of Exposure along Path:	15,716 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
07D1A	5.93	59,000	33.3	Flight paths for departures estimated to have equal exposure area due to quick climb of Growlers. Refer to Navy 2018, pp. A4-5 – A4-6, A5-7.
07D1B	4.24	59,000	33.3	
07D1C	1.69	59,000	33.3	
07D2A	2.54	59,000	33.3	
07D2B	1.69	59,000	33.3	
07D2C	0.85	59,000	33.3	
14D1A	10.52	59,000	33.3	
14D1B	7.51	59,000	33.3	
14D1C	3.01	59,000	33.3	
14D2A	4.51	59,000	33.3	
14D2B	3.01	59,000	33.3	
14D2C	1.50	59,000	33.3	
25D1A	17.48	59,000	33.3	
25D1B	12.49	59,000	33.3	
25D1C	4.99	59,000	33.3	
25D2A	7.49	59,000	33.3	
25D2B	4.99	59,000	33.3	
25D2C	2.50	59,000	33.3	
32D1A	1.07	59,000	33.3	
32D1B	0.76	59,000	33.3	
32D1C	0.31	59,000	33.3	
32D2A	0.46	59,000	33.3	
32D2B	0.31	59,000	33.3	
32D2C	0.15	59,000	33.3	

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
33.3	33.3	33.3

Straight-in/Full-stop Arrivals

Predominant Power Setting:	85%	Distance to92 dBA$_{SEL}$:	4,000 ft
Representative Altitude:	1,500 ft AGL	Width of Exposure along Path:	7,416 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
07A2A	8.47	85,270	22.7	(c-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-7.
07A2B	5.93	85,270	22.7	(c-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-7.
07A2C	2.54	85,270	22.7	(c-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-7.
14A1A	6.01	54,787	14.6	(((c-d)/2)-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
14A1B	4.21	54,787	14.6	(((c-d)/2)-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
14A1C	1.80	54,787	14.6	(((c-d)/2)-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
14A2A	9.02	85,270	22.7	(c-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
14A2B	6.31	85,270	22.7	(c-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
14A2C	2.71	85,270	22.7	(c-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
25A2A	24.53	85,270	22.7	(c-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-7.
25A2B	17.17	85,270	22.7	(c-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-7.
25A2C	7.36	85,270	22.7	(c-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-7.
32A1A	0.79	54,787	14.6	(((c-d)/2)-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
32A1B	0.55	54,787	14.6	(((c-d)/2)-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
32A1C	0.24	54,787	14.6	(((c-d)/2)-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
32A2A	1.18	54,787	14.6	(((c-d)/2)-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
32A2B	0.83	54,787	14.6	(((c-d)/2)-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.
32A2C	0.35	54,787	14.6	(((c-d)/2)-f) from Navy 2018, p. A5-8; see also Navy 2018, p. A4-8.

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
14.6	21.4	22.7

Overhead Break Arrivals

Predominant Power Setting:	85%	Distance to 92 dBA_{SEL} :	4,000 ft
Representative Altitude:	1,500 ft AGL	Width of Exposure along Path:	7,416 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
07O1A	5.07	106,700	28.4	(k-c) from Navy 2018, p. A5-9; see also Navy 2018, p. A4-11
07O1B	5.07	106,700	28.4	
07O1C	5.24	106,700	28.4	
07O2A	0.51	106,700	28.4	
07O2B	0.51	106,700	28.4	
07O3C	0.51	106,700	28.4	
14O1A	8.73	74,703	19.9	(((c-d)/2)-k-13,000) from Navy 2018, p. A5-9; see also Navy 2018, p. A4-12 [subtracted 13k ft (portion of break) for path over land]
14O1B	8.73	74,703	19.9	
14O1C	9.02	74,703	19.9	
14O2A	0.87	93,700	24.9	(k-c-13,000) from Navy 2018, p. A5-9; see also Navy 2018, p. A4-12 [subtracted 13k ft (portion of break) for path over land
14O2B	0.87	93,700	24.9	
14O2C	0.87	93,700	24.9	
25O1B	22.50	76,700	20.4	(k-c-30,000) from Navy 2018, p. A5-9; see also Navy 2018, p. A4-11 [subtracted 30k ft (majority of break) for path over land
25O1C	22.50	76,700	20.4	
25O2B	2.50	76,700	20.4	
25O2C	2.50	76,700	20.4	
32O1B	1.80	54,703	14.6	(((c-d)/2)-k-33,000) from Navy 2018, p. A5-9; see also Navy 2018, p. A4-12 [subtracted 33k ft (southern approach and portion of break) for path over land]
32O1C	1.80	54,703	14.6	
32O2B	0.20	54,703	14.6	
32O2C	0.20	54,703	14.6	

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
14.6	21.5	28.4

Instrument Approach Arrivals

Predominant Power Setting:	85%	Distance to 92 dBA_{SEL}:	4,000 ft
Representative Altitude:	1,500 ft AGL	Width of Exposure along Path:	7,416 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
07AHT	16.32	59,715	15.9	(g-d) from Navy 2018, p. A5-10; see also Navy 2018, p. A4-13
14AHT	27.00	59,715	15.9	
25AHT	52.68	29,715	7.9	(g-d-30,000) from Navy 2018, p. A5-10; see also Navy 2018, p. A4-13 [subtracted 30k ft for path over land]
32AHT	4.00	29,715	7.9	

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
7.9	11.4	15.9

Field Carrier Landing Practice and Touch-and-Go at Ault Field

Predominant Power Setting:	85%	Distance to 92 dBA_{SEL} :	4,000 ft
Representative Altitude:	400 ft AGL	Width of Exposure along Path:	7,960 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
07FM1	9.57	30,988	8.8	Originally estimated by measuring flight track from Navy 2016, p. A-279; see also Navy 2018, p. A4-15.
07FU1	9.57	30,988	8.8	
14FM1	14.97	19,431	5.5	(h-e) from Navy 2018, p. A5-19; see also Navy 2018, p. A4-16.
14FU1	14.97	19,431	5.5	
25FM1	24.27	0	0.0	Flight track is over land only; see Navy 2018, p. A4-15.
25FU1	24.27	13,361	3.8	(g-e) from Navy 2018, p. A5-19; see also Navy 2018, p. A4-15.
32FU1	2.40	19,431	5.5	(h-e) from Navy 2018, p. A5-19; see also Navy 2018, p. A4-16.

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
0.0	4.4	8.8

Ground-controlled Approach

Predominant Power Setting:	85%	Distance to 92 dBA_{SEL}:	4,000 ft
Representative Altitude:	2,000 ft AGL	Width of Exposure along Path:	6,928 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
07G1	13.50	173,197	43.0	(e-c)+(l-f) from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
07G2	1.80	173,375	43.1	r2*[(d-((d-c)/2)+c)+(l-f)] from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
07G3	2.70	209,206	52.0	r3*[(d-((d-c)/2)+c)+(l-f)] from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
14G1	22.50	152,500	37.9	(d-c)+(f-e)+(l-g) from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
14G2	3.00	214,349	53.3	r2*[(((g-f)/2)+f)-c)+(l-(((h-g)/2)+g)] from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
14G3	4.50	258,649	64.3	r3*[(((g-f)/2)+f)-c)+(l-(((h-g)/2)+g)] from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
25G1	36.95	136,132	33.8	(g-b)+(l-k) from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
25G2	4.93	172,203	42.8	r2*[(g-b)+(l-k)] from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
25G3	7.39	171,908	42.7	r3*[(f-b)+(l-k)] from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
32G1	2.05	123,600	30.7	(d-b)+(k-g) from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
32G2	0.27	152,428	37.9	r2*[(((d-c)/2)+c)-b)+(h-e)+(l-j)] from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.
32G3	0.41	183,931	45.7	r3*[(((d-c)/2)+c)-b)+(h-e)+(l-j)] from Navy 2018, p. A5-24; see also Navy 2018, p. A4-23.

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
30.7	39.7	64.3

NOTE: Ratios (r2 [1.26] and r3 [1.53]) were applied to estimate larger flight tracks. The ratios were calculated by comparing the sizes of flight tracks on Navy 2016, pp. A-287 and A-318, and estimating the difference in circumference of the flight tracks.

Depart and Re-enter

Predominant Power Setting:	85%	Distance to 92 dBA_{SEL}:	4,000 ft
Representative Altitude:	1,000 ft AGL	Width of Exposure along Path:	7,746 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
07PL	8.50	137,274	38.1	(i-c)+(p-l) from Navy 2018, p. A5-18; see also p. A4-19
07PR	8.50	113,184	31.4	(e-d)+(h-g)+(f-c)+(p-l) from Navy 2018, p. A5-18; see also p. A4-19
14PL	14.48	76,733	21.3	(j-f)+(p-n) from Navy 2018, p. A5-18; see also p. A4-21
14PR	14.48	95,866	26.6	(e-d)+(j-f)+(p-n) from Navy 2018, p. A5-18; see also p. A4-21
25PL	25.02	87,382	24.3	(e-d)+(h-g)+(f-c)+(n-m) from Navy 2018, p. A5-18; see also p. A4-20
25PR	25.02	117,965	32.8	(i-c)+(l-k) from Navy 2018, p. A5-18; see also p. A4-20
32PL	2.00	102,734	28.5	(e-d)+(j-f)+(p-m) from Navy 2018, p. A5-18; see also p. A4-22
32PR	2.00	83,601	23.2	(j-f)+(p-m) from Navy 2018, p. A5-18; see also p. A4-22

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
21.3	28.2	38.1

Field Carrier Landing Practice at OLF Coupeville

Predominant Power Setting:	85%	Distance to 92 dBA_{SEL}ce :	4,000 ft
Representative Altitude:	400 ft AGL	Width of Exposure along Path:	7,960 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
14FCP1	7.15	30,766	8.8	(k-g) from Navy 2018, p. A5-23; see also Navy 2018, p. A4-30
14FCP2	14.30	30,766	8.8	
14FCP3	7.15	30,766	8.8	
32FCP1	17.85	13,361	3.8	(k-i) from Navy 2018, p. A5-23; see also Navy 2018, p. A4-30
32FCP2	35.70	13,361	3.8	
32FCP3	17.85	13,361	3.8	

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
3.8	5.2	8.8

Interfacility Flights – Ault Field to OLF Coupeville

Predominant Power Setting:	85%	Distance to92 dBA_{SEL} :	4,000 ft
Representative Altitude:	2,500 ft AGL	Width of Exposure along Path:	6,244 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
07WC14P	1.80	107,419	24.1	(k-e)+(q-n) from Navy 2018, p. A5-13; see also Navy 2017, p. A4-28
07WC32P	16.20	195,358	43.8	(o-e)+(t-r) from Navy 2018, p. A5-16; see also Navy 2017, p. A4-28
14WC14P	3.02	69,319	15.5	(k-h)+(q-n) from Navy 2018, p. A5-13; see also Navy 2017, p. A4-29 (estimating first overwater section = (k-h)
14WC32P	27.22	157,262	35.2	(o-h)+(t-r) from Navy 2018, p. A5-16; see also Navy 2017, p. A4-28 (estimating first overwater section = (j-h)
25WC14P	4.95	131,719	29.5	(k)+(q-n) from Navy 2018, p. A5-13; see also Navy 2017, p. A4-28 (assuming western route is same as (k-a))
25WC32P	44.56	219,662	49.2	(o)+(t-r) from Navy 2018, p. A5-16; see also Navy 2017, p. A4-28 (assuming western route is same as (o-a))
32WC14P	0.22	152,019	34.0	(k)+(q-n) from Navy 2018, p. A5-13; see also Navy 2017, p. A4-29 + 20,300 ft (assuming western route is same as (k-a) + an estimated additional 20,300 ft)
32WC32P	2.02	239,962	53.7	(o)+(t-r) Navy 2018, p. A5-16; see also Navy 2017, p. A4-29 + 20,300 ft (assuming western route is same as (o-a) + an estimated additional 20,300 ft)

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
15.5	42.1	53.7

Interfacility Flights – OLF Coupeville to Ault Field

Predominant Power Setting:	85%	Distance to 92 dBA_{SEL}:	4,000 ft
Representative Altitude:	2,500 ft AGL	Width of Exposure along Path:	6,244 ft

Flight Track	Flight Track Use (% flights)	Linear Distance Water Exposure (ft)	Total Area Exposed per Flight (square miles)	Notes on Estimating Linear Distance Over Water
14CW07	3.70	171,078	38.3	(s-p) + (n-e) from Navy 2018, p. A5-17; see also Navy 2018, p. A4-27.
14CW14	12.54	198,507	44.5	Originally estimated by measuring flight track from Navy 2016, p. A-291; see also Navy 2018, p. A4-27.
14CW25	10.26	142,191	31.8	Originally estimated by measuring flight track from Navy 2016, p. A-291; see also Navy 2018, p. A4-27.
14CW32	1.99	73,825	16.5	Originally estimated by measuring flight track from Navy 2016, p. A-291; see also Navy 2018, p. A4-27.
32CW07	9.30	127,598	28.6	Originally estimated by measuring flight track from Navy 2016, p. A-291; see also Navy 2018, pp. A4-27, A5-17.
32CW14	31.46	156,581	35.1	Originally estimated by measuring flight track from Navy 2016, p. A-291; see also Navy 2018, pp. A4-27, A5-17.
32CW25	25.74	114,474	25.6	Originally estimated by measuring flight track from Navy 2016, p. A-291; see also Navy 2018, p. A4-27.
32CW32	5.01	152,024	34.0	Originally estimated by measuring flight track from Navy 2016, p. A-291; see also Navy 2018, p. A4-27.

Minimum Area Exposed (square miles)	Average Area Exposed Weighted by Flight Track Use (square miles)	Maximum Area Exposed (square miles)
16.5	32.6	44.5

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APPENDIX D
ANNUAL AND SEASONAL WEIGHTED AVERAGES OF FLIGHT TRACK USAGE FOR USE IN EXPOSURE ESTIMATES

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Appendix D
Annual and Seasonal Weighted Averages
Of Flight Track Usage for use in Exposure Estimates

Our analysis of marbled murrelet exposure to Growler overflights relies upon estimates of the size and location of marine habitat that will be exposed to aircraft sounds 92 dBA_{SEL} re: $20\mu Pa^2s$ or louder. In Appendix C, we outline our methods for estimating the area of marine habitat exposed to these sound levels by each mapped flight track. To estimate the total amount of exposure, we must also know how often each flight track is used. As noted in Appendix C, actual flight paths may deviate from the mapped flight tracks, but the flight track maps provide the best available information regarding expected Growler flight paths.

The Final Environmental Impact Statement for EA-18G "Growler" Airfield Operations at Naval Air Station Whidbey Island Complex (the FEIS) provides information that can be used to calculate how often each mapped flight track is likely to be used on an average annual basis. The flight track maps (Navy 2018, pp. A4-5 – A4-30) provide an estimate of how often each flight track is used, as a percentage of daytime (0700 to 2200) and nighttime (2200 to 0700) operations of a particular type on each runway. In addition, for each category of Growler operations (e.g., departures, FCLPs, etc.), the FEIS provides information regarding how often each runway is used, as a percentage of daytime (0700 to 2200) and nighttime (2200 to 0700) operations (Navy 2018, pp. A3-7 – A3-8). Finally, the FEIS provides estimates of the number of airfield operations of each type that will occur during the daytime and during the nighttime (Navy 2018, pp. A-126 – A-127).

We combine this information to generate overall estimates of how often each flight track will be used in an average year. For a given category of Growler operation, the overall usage of each flight track during the daytime is the percentage of daytime operations at the runway associated with the flight track (from Navy 2018, pp. A3-7 – A3-8), multiplied by the daytime percentage shown on the flight track map (see Figure 1). Similarly, the overall usage of each flight track during the nighttime is the percentage of nighttime operations at the runway associated with the flight track (from Navy 2018, pp. A3-7 – A3-8), multiplied by the nighttime percentage shown on the flight track map (see Figure 1). These two percentages are combined in an overall estimate weighted by the percentages of operations occurring during the daytime and nighttime (derived from Navy 2018, pp. A-126 – A-127). We assume that the proportional usage of flight tracks will be the same in a high-tempo year as in an average year, though the total number of flights for each type of operation will vary.

Because there is seasonal variation in the density and distribution of marbled murrelets, as well as in the potential for certain types of effects, our estimate of exposure also incorporates information regarding how often flights over marine habitat will occur during the breeding (April through September) and non-breeding (October through March) seasons. The FEIS does not provide a seasonal breakdown of flight track usage, except to note that due to prevailing winds, Ault Field runway 25 is used more often during April through September and Ault Field runway 14 is used more often during October through March (Navy 2018, p. 3-7). Therefore, we generated two possible scenarios of seasonal flight track usage, one in which flight track usage is the same in each season, and another in which flight track usage differs starkly by season.

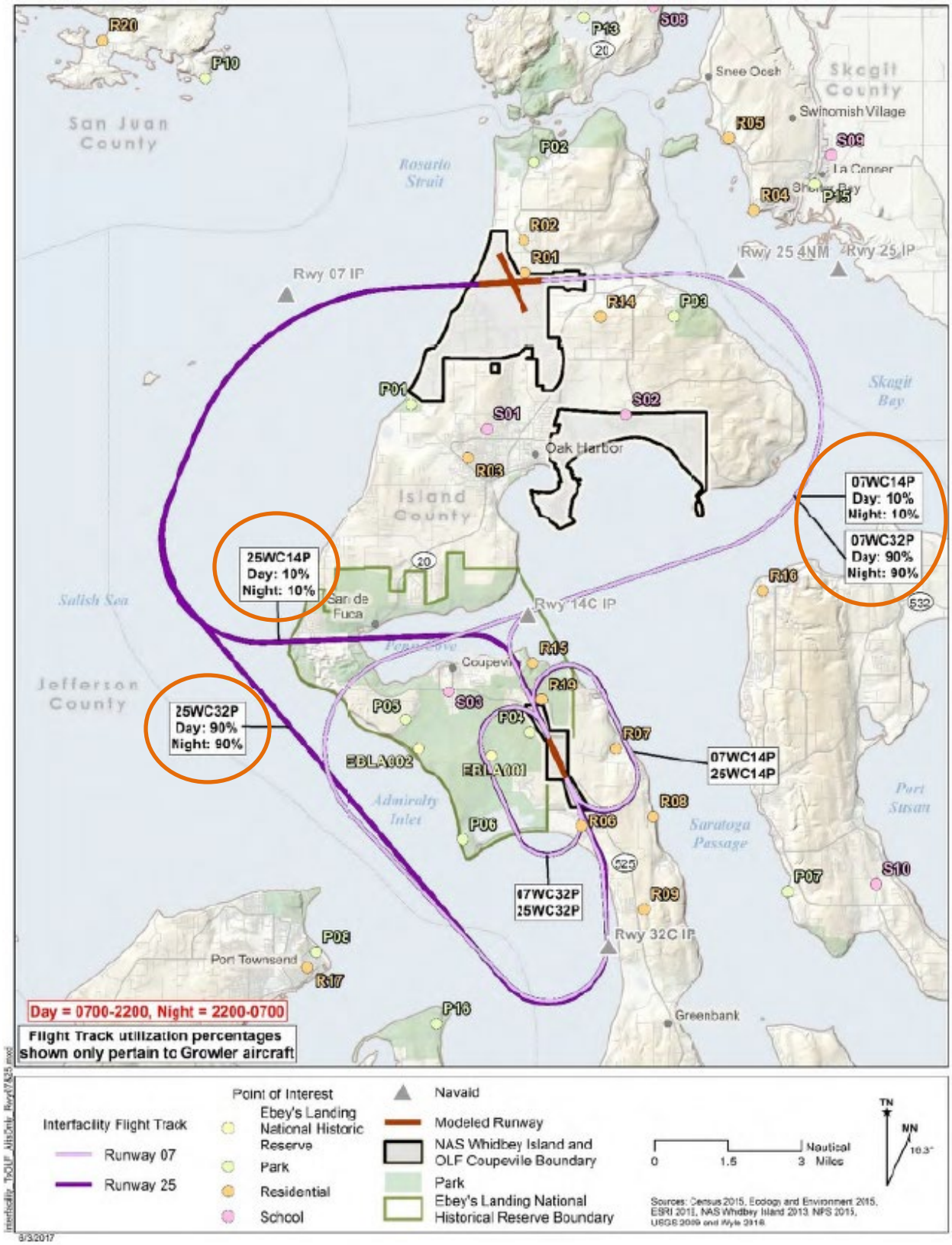

Figure 1. Flight track map from FEIS (Navy 2018, p. A4-28), with highlighted information regarding the frequency of use of each flight track (circled in orange).

In the first scenario, which we refer to as "annual weighting," we simply used the same annual flight track usage percentages described above. We assumed that the usage of each flight track would be distributed evenly between the two seasons. In the second scenario, which we refer to as "seasonal weighting," we assumed that flight tracks using Ault runway 25 would be used primarily in the breeding season, flight tracks using Ault runway 14 would be used primarily in the non-breeding season, and other flight tracks would be split between the two seasons to distribute the number of flights evenly between the seasons. These two scenarios bracket the likely seasonal patterns of flight track usage.

We expect that actual seasonal patterns of flight track usage will fall in between the two scenarios. For example, in 2018, approximately 30 percent of all operations at runway 14 occurred during the breeding season, and 70 percent occurred during the non-breeding season (Bianchi 2019, in litt.). In the "annual weighting" scheme outlined above, 50 percent of all operations at runway 14 would have occurred during each season. In "seasonal weighting" scheme outlined above, there would have been no or almost no usage of runway 14 during the breeding season, and 100 percent, or close to 100 percent, of runway 14 usage would have occurred during the non-breeding season. The reality was between the two scenarios.

On the following pages, we provide the annual and seasonal flight track weighting schemes for each type of Growler operation. The information given on the following pages was used to calculate weighted averages for the area of marine habitat exposed to Growler overflights (annual weighting only) and for the number of marbled murrelets exposed to Growler overflights during the breeding and non-breeding season (annual and seasonal weighing).

LITERATURE CITED

Bianchi, M. 2019. Natural Resources Manager, U.S. Navy, NAS Whidbey Island complex, Oak Harbor, Washington. Email to: Katherine Fitzgerald, Endangered Species Biologist, Washington Fish and Wildlife Office, U.S. Fish and Wildlife Service, Lacey. Topic: November 21, 2019, email and attachment of Ault Field runway 14 data showing usage of the runway tabulated by month for 2018.

Navy (U.S. Department of the Navy). 2018. Final environmental impact statement for EA-18G "Growler" airfield operations at Naval Air Station Whidbey Island complex. Naval Facilities Engineering Command Atlantic, Norfolk, Virginia. 1080 pp. and 13 appendices.

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Key to the Tables on the Following Pages

Type of Operation

Total Annual Operations (Average Year): A		Total Annual Operations (High Tempo Year): B
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: C	Nighttime (2200 – 0700) Operations: D	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
	E	F	G	H	I	J	K	L	M
	100 * C / A	100 * D / A	Navy 2018, pp. A3-7 – A3-8		Navy 2018, Appendix A4 maps for each flight track (see Figure 1 in the present appendix)		G * I	H * J	E * K + F * L

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
	N	O	P	Q	R	S	T	U	V	W	X	Y
	A * M	B * M	N / 2	N / 2	O / 2	O / 2	Distributed N operations so that Ault runway 25 operations occur during the breeding season, Ault runway 14 operations occur during the non-breeding season, and other flights are distributed so that the total number of operations (for all flight tracks) in each season add up to A / 2.		Distributed O operations so that Ault runway 25 operations occur during the breeding season, Ault runway 14 operations occur during the non-breeding season, and other flights are distributed so that the total number of operations (for all flight tracks) in each season add up to B / 2.		100 * T / A or 100 * V / B (These expressions are intended to be equal.)	100 * U / A or 100 * W / B (These expressions are intended to be equal.)

Note: On the following pages, whole numbers of subsets of the total operations (e.g., seasonal operations or operations using particular flight tracks) may not sum to the total numbers of operations, due to rounding. All calculations were made prior to rounding.

Departures

Total Annual Operations (Average Year): 17,415		Total Annual Operations (High Tempo Year): 17,454
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 16,390	Nighttime (2200 – 0700) Operations: 1,025	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
07D1A	94.11 %	5.89 %	17 %	16 %	35 %	35 %	5.95 %	5.60 %	5.93 %
07D1B	94.11 %	5.89 %	17 %	16 %	25 %	25 %	4.25 %	4.00 %	4.24 %
07D1C	94.11 %	5.89 %	17 %	16 %	10 %	10 %	1.70 %	1.60 %	1.69 %
07D2A	94.11 %	5.89 %	17 %	16 %	15 %	15 %	2.55 %	2.40 %	2.54 %
07D2B	94.11 %	5.89 %	17 %	16 %	10 %	10 %	1.70 %	1.60 %	1.69 %
07D2C	94.11 %	5.89 %	17 %	16 %	5 %	5 %	0.85 %	0.80 %	0.85 %
14D1A	94.11 %	5.89 %	30 %	31 %	35 %	35 %	10.50 %	10.85 %	10.52 %
14D1B	94.11 %	5.89 %	30 %	31 %	25 %	25 %	7.50 %	7.75 %	7.51 %
14D1C	94.11 %	5.89 %	30 %	31 %	10 %	10 %	3.00 %	3.10 %	3.01 %
14D2A	94.11 %	5.89 %	30 %	31 %	15 %	15 %	4.50 %	4.65 %	4.51 %
14D2B	94.11 %	5.89 %	30 %	31 %	10 %	10 %	3.00 %	3.10 %	3.01 %
14D2C	94.11 %	5.89 %	30 %	31 %	5 %	5 %	1.50 %	1.55 %	1.50 %
25D1A	94.11 %	5.89 %	50 %	49 %	35 %	35 %	17.50 %	17.15 %	17.48 %
25D1B	94.11 %	5.89 %	50 %	49 %	25 %	25 %	12.50 %	12.25 %	12.49 %
25D1C	94.11 %	5.89 %	50 %	49 %	10 %	10 %	5.00 %	4.90 %	4.99 %
25D2A	94.11 %	5.89 %	50 %	49 %	15 %	15 %	7.50 %	7.35 %	7.49 %
25D2B	94.11 %	5.89 %	50 %	49 %	10 %	10 %	5.00 %	4.90 %	4.99 %
25D2C	94.11 %	5.89 %	50 %	49 %	5 %	5 %	2.50 %	2.45 %	2.50 %
32D1A	94.11 %	5.89 %	3 %	4 %	35 %	35 %	1.05 %	1.40 %	1.07 %
32D1B	94.11 %	5.89 %	3 %	4 %	25 %	25 %	0.75 %	1.00 %	0.76 %
32D1C	94.11 %	5.89 %	3 %	4 %	10 %	10 %	0.30 %	0.40 %	0.31 %
32D2A	94.11 %	5.89 %	3 %	4 %	15 %	15 %	0.45 %	0.60 %	0.46 %
32D2B	94.11 %	5.89 %	3 %	4 %	10 %	10 %	0.30 %	0.40 %	0.31 %
32D2C	94.11 %	5.89 %	3 %	4 %	5 %	5 %	0.15 %	0.20 %	0.15 %

Departures, continued

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
07D1A	1,033	1,035	516	516	517	517	0	1,033	0	1,035	0.00 %	5.93 %
07D1B	738	739	369	369	370	370	0	738	0	739	0.00 %	4.24 %
07D1C	295	296	148	148	148	148	0	295	0	296	0.00 %	1.69 %
07D2A	443	444	221	221	222	222	0	443	0	444	0.00 %	2.54 %
07D2B	295	296	148	148	148	148	0	295	0	296	0.00 %	1.69 %
07D2C	148	148	74	74	74	74	11	137	10	138	0.06 %	0.79 %
14D1A	1,836	1,836	918	918	918	918	0	1,832	0	1,836	0.00 %	10.52 %
14D1B	1,312	1,312	656	656	656	656	0	1,309	0	1,312	0.00 %	7.51 %
14D1C	525	525	262	262	262	262	0	523	0	525	0.00 %	3.01 %
14D2A	787	787	393	393	393	393	0	785	0	787	0.00 %	4.51 %
14D2B	525	525	262	262	262	262	0	523	0	525	0.00 %	3.01 %
14D2C	262	262	131	131	131	131	0	262	0	262	0.00 %	1.50 %
25D1A	3,044	3,051	1,522	1,522	1,525	1,525	3,044	0	3,051	0	17.48 %	0.00 %
25D1B	2,174	2,179	1,087	1,087	1,090	1,090	2,174	0	2,179	0	12.49 %	0.00 %
25D1C	870	872	435	435	436	436	870	0	872	0	4.99 %	0.00 %
25D2A	1,305	1,308	652	652	654	654	1,305	0	1,308	0	7.49 %	0.00 %
25D2B	870	872	435	435	436	436	870	0	872	0	4.99 %	0.00 %
25D2C	435	436	217	217	218	218	435	0	436	0	2.50 %	0.00 %
32D1A	187	187	93	93	93	93	0	186	0	187	0.00 %	1.07 %
32D1B	133	133	67	67	67	67	0	133	0	133	0.00 %	0.76 %
32D1C	53	53	27	27	27	27	0	53	0	53	0.00 %	0.31 %
32D2A	80	80	40	40	40	40	0	80	0	80	0.00 %	0.46 %
32D2B	53	53	27	27	27	27	0	53	0	53	0.00 %	0.31 %
32D2C	27	27	13	13	13	13	0	27	0	27	0.00 %	0.15 %

Straight-in/Full-stop Arrivals

Total Annual Operations (Average Year): 6,530		Total Annual Operations (High Tempo Year): 6,532
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 6,077	Nighttime (2200 – 0700) Operations: 453	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
07A2A	93.06 %	6.94 %	17 %	16 %	50 %	50 %	8.50 %	8.00 %	8.47 %
07A2B	93.06 %	6.94 %	17 %	16 %	35 %	35 %	5.95 %	5.60 %	5.93 %
07A2C	93.06 %	6.94 %	17 %	16 %	15 %	15 %	2.55 %	2.40 %	2.54 %
14A1A	93.06 %	6.94 %	30 %	31 %	20 %	20 %	6.00 %	6.20 %	6.01 %
14A1B	93.06 %	6.94 %	30 %	31 %	14 %	14 %	4.20 %	4.34 %	4.21 %
14A1C	93.06 %	6.94 %	30 %	31 %	6 %	6 %	1.80 %	1.86 %	1.80 %
14A2A	93.06 %	6.94 %	30 %	31 %	30 %	30 %	9.00 %	9.30 %	9.02 %
14A2B	93.06 %	6.94 %	30 %	31 %	21 %	21 %	6.30 %	6.51 %	6.31 %
14A2C	93.06 %	6.94 %	30 %	31 %	9 %	9 %	2.70 %	2.79 %	2.71 %
25A2A	93.06 %	6.94 %	49 %	50 %	50 %	50 %	24.50 %	25.00 %	24.53 %
25A2B	93.06 %	6.94 %	49 %	50 %	35 %	35 %	17.15 %	17.50 %	17.17 %
25A2C	93.06 %	6.94 %	49 %	50 %	15 %	15 %	7.35 %	7.50 %	7.36 %
32A1A	93.06 %	6.94 %	4 %	3 %	20 %	20 %	0.80 %	0.60 %	0.79 %
32A1B	93.06 %	6.94 %	4 %	3 %	14 %	14 %	0.56 %	0.42 %	0.55 %
32A1C	93.06 %	6.94 %	4 %	3 %	6 %	6 %	0.24 %	0.18 %	0.24 %
32A2A	93.06 %	6.94 %	4 %	3 %	30 %	30 %	1.20 %	0.90 %	1.18 %
32A2B	93.06 %	6.94 %	4 %	3 %	21 %	21 %	0.84 %	0.63 %	0.83 %
32A2C	93.06 %	6.94 %	4 %	3 %	9 %	9 %	0.36 %	0.27 %	0.35 %

Straight-in/Full-stop Arrivals, continued

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
07A2A	553	553	276	276	276	276	0	553	0	553	0.00 %	8.47 %
07A2B	387	387	193	193	194	194	0	387	0	387	0.00 %	5.93 %
07A2C	166	166	83	83	83	83	0	166	0	166	0.00 %	2.54 %
14A1A	393	393	196	196	196	196	0	393	0	393	0.00 %	6.01 %
14A1B	275	275	137	137	137	137	0	275	0	275	0.00 %	4.21 %
14A1C	118	118	59	59	59	59	0	118	0	118	0.00 %	1.80 %
14A2A	589	589	295	295	295	295	0	589	0	589	0.00 %	9.02 %
14A2B	412	412	206	206	206	206	0	412	0	412	0.00 %	6.31 %
14A2C	177	177	88	88	88	88	0	177	0	177	0.00 %	2.71 %
25A2A	1,602	1,603	801	801	801	801	1,602	0	1,603	0	24.53 %	0.00 %
25A2B	1,121	1,122	561	561	561	561	1,121	0	1,122	0	17.17 %	0.00 %
25A2C	481	481	240	240	240	240	481	0	481	0	7.36 %	0.00 %
32A1A	51	51	26	26	26	26	9	42	9	42	0.14 %	0.64 %
32A1B	36	36	18	18	18	18	36	0	36	0	0.55 %	0.00 %
32A1C	15	15	8	8	8	8	15	0	15	0	0.24 %	0.00 %
32A2A	77	77	39	39	39	39	0	77	0	77	0.00 %	1.18 %
32A2B	54	54	27	27	27	27	0	54	0	54	0.00 %	0.83 %
32A2C	23	23	12	12	12	12	0	23	0	23	0.00 %	0.35 %

Overhead Break Arrivals

Total Annual Operations (Average Year): 9,963		Total Annual Operations (High Tempo Year): 10,007
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 9,085	Nighttime (2200 – 0700) Operations: 878	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
07O1A	91.19 %	8.81 %	17 %	16 %	30 %	30 %	5.10 %	4.80 %	5.07 %
07O1B	91.19 %	8.81 %	17 %	16 %	30 %	30 %	5.10 %	4.80 %	5.07 %
07O1C	91.19 %	8.81 %	17 %	16 %	31 %	31 %	5.27 %	4.96 %	5.24 %
07O2A	91.19 %	8.81 %	17 %	16 %	3 %	3 %	0.51 %	0.48 %	0.51 %
07O2B	91.19 %	8.81 %	17 %	16 %	3 %	3 %	0.51 %	0.48 %	0.51 %
07O3C	91.19 %	8.81 %	17 %	16 %	3 %	3 %	0.51 %	0.48 %	0.51 %
14O1A	91.19 %	8.81 %	29 %	30 %	30 %	30 %	8.70 %	9.00 %	8.73 %
14O1B	91.19 %	8.81 %	29 %	30 %	30 %	30 %	8.70 %	9.00 %	8.73 %
14O1C	91.19 %	8.81 %	29 %	30 %	31 %	31 %	8.99 %	9.30 %	9.02 %
14O2A	91.19 %	8.81 %	29 %	30 %	3 %	3 %	0.87 %	0.90 %	0.87 %
14O2B	91.19 %	8.81 %	29 %	30 %	3 %	3 %	0.87 %	0.90 %	0.87 %
14O2C	91.19 %	8.81 %	29 %	30 %	3 %	3 %	0.87 %	0.90 %	0.87 %
25O1B	91.19 %	8.81 %	50 %	50 %	45 %	45 %	22.50 %	22.50 %	22.50 %
25O1C	91.19 %	8.81 %	50 %	50 %	45 %	45 %	22.50 %	22.50 %	22.50 %
25O2B	91.19 %	8.81 %	50 %	50 %	5 %	5 %	2.50 %	2.50 %	2.50 %
25O2C	91.19 %	8.81 %	50 %	50 %	5 %	5 %	2.50 %	2.50 %	2.50 %
32O1B*	91.19 %	8.81 %	4 %	4 %	45 %	45 %	1.80 %	1.80 %	1.80 %
32O1C*	91.19 %	8.81 %	4 %	4 %	45 %	45 %	1.80 %	1.80 %	1.80 %
32O2B*	91.19 %	8.81 %	4 %	4 %	5 %	5 %	0.20 %	0.20 %	0.20 %
32O2C*	91.19 %	8.81 %	4 %	4 %	5 %	5 %	0.20 %	0.20 %	0.20 %

*Flight track utilization percentages for overhead break arrivals on runway 32, as listed in the FEIS (Navy 2018, p. A4-12), do not sum to 100 %. Therefore, we assumed that flight track utilization for runway 32 would follow a pattern similar to that for runway 25 (Navy 2018, p. A4-11).

Overhead Break Arrivals, continued

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
07O1A	505	508	253	253	254	254	0	505	0	508	0.00 %	5.07 %
07O1B	505	508	253	253	254	254	0	505	0	508	0.00 %	5.07 %
07O1C	522	525	261	261	262	262	0	522	0	525	0.00 %	5.24 %
07O2A	51	51	25	25	25	25	0	51	0	51	0.00 %	0.51 %
07O2B	51	51	25	25	25	25	0	51	0	51	0.00 %	0.51 %
07O3C	51	51	25	25	25	25	0	51	0	51	0.00 %	0.51 %
14O1A	869	873	435	435	437	437	0	869	0	873	0.00 %	8.73 %
14O1B	869	873	435	435	437	437	0	869	0	873	0.00 %	8.73 %
14O1C	898	902	449	449	451	451	0	898	0	902	0.00 %	9.02 %
14O2A	87	87	43	43	44	44	0	87	0	87	0.00 %	0.87 %
14O2B	87	87	43	43	44	44	0	87	0	87	0.00 %	0.87 %
14O2C	87	87	43	43	44	44	0	87	0	87	0.00 %	0.87 %
25O1B	2,242	2,252	1,121	1,121	1,126	1,126	2,242	0	2,252	0	22.50 %	0.00 %
25O1C	2,242	2,252	1,121	1,121	1,126	1,126	2,242	0	2,252	0	22.50 %	0.00 %
25O2B	249	250	125	125	125	125	249	0	250	0	2.50 %	0.00 %
25O2C	249	250	125	125	125	125	249	0	250	0	2.50 %	0.00 %
32O1B	179	180	90	90	90	90	0	179	0	180	0.00 %	1.80 %
32O1C	179	180	90	90	90	90	0	179	0	180	0.00 %	1.80 %
32O2B	20	20	10	10	10	10	0	20	0	20	0.00 %	0.20 %
32O2C	20	20	10	10	10	10	0	20	0	20	0.00 %	0.20 %

Instrument Approach Arrivals

Total Annual Operations (Average Year): 922		Total Annual Operations (High Tempo Year): 914
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 873	Nighttime (2200 – 0700) Operations: 49	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
07AHT	94.69 %	5.31 %	16 %	22 %	100 %	100 %	16 %	22 %	16.32 %
14AHT	94.69 %	5.31 %	27 %	27 %	100 %	100 %	27 %	27 %	27.00 %
25AHT	94.69 %	5.31 %	53 %	47 %	100 %	100 %	53 %	47 %	52.68 %
32AHT	94.69 %	5.31 %	4 %	4 %	100 %	100 %	4 %	4 %	4.00 %

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
07AHT	150	149	75	75	75	75	0	150	0	149	0.00 %	16.32 %
14AHT	249	247	124	124	123	123	0	249	0	247	0.00 %	27.00 %
25AHT	486	482	243	243	241	241	461	25*	457	25	50.00 %	2.68 %
32AHT	37	37	18	18	18	18	0	37	0	37	0.00 %	4.00 %

*Since more than half of annual operations use runway 25, some runway 25 operations were allocated to the non-breeding season in the seasonal weighting scenario, to maintain equal numbers of operations in each season.

Touch-and-Go

Total Annual Operations (Average Year): 11,855		Total Annual Operations (High Tempo Year): 12,157
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 9,849	Nighttime (2200 – 0700) Operations: 2,006	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
07FM1	83.08 %	16.92 %	18 %	18 %	50 %	50 %	9.00 %	9.00 %	9.00 %
07FU1	83.08 %	16.92 %	18 %	18 %	50 %	50 %	9.00 %	9.00 %	9.00 %
14FM1	83.08 %	16.92 %	30 %	30 %	50 %	50 %	15.00 %	15.00 %	15.00 %
14FU1	83.08 %	16.92 %	30 %	30 %	50 %	50 %	15.00 %	15.00 %	15.00 %
25FM1	83.08 %	16.92 %	49 %	49 %	50 %	50 %	24.50 %	24.50 %	24.50 %
25FU1	83.08 %	16.92 %	49 %	49 %	50 %	50 %	24.50 %	24.50 %	24.50 %
32FU1	83.08 %	16.92 %	3 %	3 %	100 %	100 %	3.00 %	3.00 %	3.00 %

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
07FM1	1,067	1,094	533	533	547	547	0	1,067	0	1,094	0.00 %	9.00 %
07FU1	1,067	1,094	533	533	547	547	0	1,067	0	1,094	0.00 %	9.00 %
14FM1	1,778	1,824	889	889	912	912	0	1,778	0	1,824	0.00 %	15.00 %
14FU1	1,778	1,824	889	889	912	912	0	1,778	0	1,824	0.00 %	15.00 %
25FM1	2,904	2,978	1,452	1,452	1,489	1,489	2,904	0	2,978	0	24.50 %	0.00 %
25FU1	2,904	2,978	1,452	1,452	1,489	1,489	2,904	0	2,978	0	24.50 %	0.00 %
32FU1	356	365	178	178	182	182	119	237	122	243	1.00 %	2.00 %

Field Carrier Landing Practice at Ault Field

Total Annual Operations (Average Year): 5,936		Total Annual Operations (High Tempo Year): 6,413
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 4,727	Nighttime (2200 – 0700) Operations: 1,209	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
07FM1	79.63 %	20.37 %	22 %	19 %	50 %	50 %	11.00 %	9.50 %	10.69 %
07FU1	79.63 %	20.37 %	22 %	19 %	50 %	50 %	11.00 %	9.50 %	10.69 %
14FM1	79.63 %	20.37 %	30 %	29 %	50 %	50 %	15.00 %	14.50 %	14.90 %
14FU1	79.63 %	20.37 %	30 %	29 %	50 %	50 %	15.00 %	14.50 %	14.90 %
25FM1	79.63 %	20.37 %	47 %	50 %	50 %	50 %	23.50 %	25.00 %	23.81 %
25FU1	79.63 %	20.37 %	47 %	50 %	50 %	50 %	23.50 %	25.00 %	23.81 %
32FU1	79.63 %	20.37 %	1 %	2 %	100 %	100 %	1.00 %	2.00 %	1.20 %

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
07FM1	635	686	317	317	343	343	71	564	77	609	1.20 %	9.50 %
07FU1	635	686	317	317	343	343	0	635	0	686	0.00 %	10.69 %
14FM1	884	955	442	442	478	478	0	884	0	955	0.00 %	14.90 %
14FU1	884	955	442	442	478	478	0	884	0	955	0.00 %	14.90 %
25FM1	1,413	1,527	707	707	763	763	1,413	0	1,527	0	23.81 %	0.00 %
25FU1	1,413	1,527	707	707	763	763	1,413	0	1,527	0	23.81 %	0.00 %
32FU1	71	77	36	36	39	39	71	0	77	0	1.20 %	0.00 %

Ground-controlled Approach

Total Annual Operations (Average Year): 14,391		Total Annual Operations (High Tempo Year): 14,911
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 10,515	Nighttime (2200 – 0700) Operations: 3,876	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
07G1	73.07 %	26.93 %	18 %	18 %	75 %	75 %	13.50 %	13.50 %	13.50 %
07G2	73.07 %	26.93 %	18 %	18 %	10 %	10 %	1.80 %	1.80 %	1.80 %
07G3	73.07 %	26.93 %	18 %	18 %	15 %	15 %	2.70 %	2.70 %	2.70 %
14G1	73.07 %	26.93 %	30 %	30 %	75 %	75 %	22.50 %	22.50 %	22.50 %
14G2	73.07 %	26.93 %	30 %	30 %	10 %	10 %	3.00 %	3.00 %	3.00 %
14G3	73.07 %	26.93 %	30 %	30 %	15 %	15 %	4.50 %	4.50 %	4.50 %
25G1	73.07 %	26.93 %	49 %	50 %	75 %	75 %	36.75 %	37. 50 %	36.95 %
25G2	73.07 %	26.93 %	49 %	50 %	10 %	10 %	4.90 %	5.00 %	4.93 %
25G3	73.07 %	26.93 %	49 %	50 %	15 %	15 %	7.35 %	7.50 %	7.39 %
32G1	73.07 %	26.93 %	3 %	2 %	75 %	75 %	2.25 %	1.50 %	2.05 %
32G2	73.07 %	26.93 %	3 %	2 %	10 %	10 %	0.30 %	0.20 %	0.27 %
32G3	73.07 %	26.93 %	3 %	2 %	15 %	15 %	0.45 %	0.30 %	0.41 %

Ground-controlled Approach, continued

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
07G1	1,943	2,013	971	971	1,006	1,006	0	1,943	0	2,013	0.00 %	13.50 %
07G2	259	268	130	130	134	134	0	259	0	268	0.00 %	1.80 %
07G3	389	403	194	194	201	201	0	389	0	403	0.00 %	2.70 %
14G1	3,238	3,355	1,619	1,619	1,677	1,677	0	3,238	0	3,355	0.00 %	22.50 %
14G2	432	447	216	216	224	224	0	432	0	447	0.00 %	3.00 %
14G3	648	671	324	324	335	335	0	648	0	671	0.00 %	4.50 %
25G1	5,318	5,510	2,659	2,659	2,755	2,755	5,318	0	5,510	0	36.95 %	0.00 %
25G2	709	735	355	355	367	367	709	0	735	0	4.93 %	0.00 %
25G3	1,064	1,102	532	532	551	551	1,064	0	1,102	0	7.39 %	0.00 %
32G1	295	305	147	147	153	153	7	288	7	298	0.05 %	2.00 %
32G2	39	41	20	20	20	20	39	0	41	0	0.27 %	0.00 %
32G3	59	61	29	29	31	31	59	0	61	0	0.41 %	0.00 %

Depart and Re-enter

Total Annual Operations (Average Year): 3,859		Total Annual Operations (High Tempo Year): 3,849
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 3,736	Nighttime (2200 – 0700) Operations: 123	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
07PL	96.81 %	3.19 %	17 %	17 %	50 %	50 %	8.50 %	8.50 %	8.50 %
07PR	96.81 %	3.19 %	17 %	17 %	50 %	50 %	8.50 %	8.50 %	8.50 %
14PL	96.81 %	3.19 %	29 %	28 %	50 %	50 %	14.50 %	14.00 %	14.48 %
14PR	96.81 %	3.19 %	29 %	28 %	50 %	50 %	14.50 %	14.00 %	14.48 %
25PL	96.81 %	3.19 %	50 %	51 %	50 %	50 %	25.00 %	25.50 %	25.02 %
25PR	96.81 %	3.19 %	50 %	51 %	50 %	50 %	25.00 %	25.50 %	25.02 %
32PL	96.81 %	3.19 %	4 %	4 %	50 %	50 %	2.00 %	2.00 %	2.00 %
32PR	96.81 %	3.19 %	4 %	4 %	50 %	50 %	2.00 %	2.00 %	2.00 %

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
07PL	328	327	164	164	164	164	0	328	0	327	0.00 %	8.50 %
07PR	328	327	164	164	164	164	0	328	0	327	0.00 %	8.50 %
14PL	559	557	279	279	279	279	0	559	0	557	0.00 %	14.48 %
14PR	559	557	279	279	279	279	0	559	0	557	0.00 %	14.48 %
25PL	965	963	483	483	481	481	965	0	963	0	25.02 %	0.00 %
25PR	965	963	483	483	481	481	964	1	962	1	24.99 %	0.03 %
32PL	77	77	39	39	38	38	0	77	0	77	0.00 %	2.00 %
32PR	77	77	39	39	38	38	0	77	0	77	0.00 %	2.00 %

Field Carrier Landing Practice at OLF Coupeville

Total Annual Operations (Average Year): 23,729		Total Annual Operations (High Tempo Year): 26,128
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)*		
Daytime (0700 – 2200) Operations: 18,937	Nighttime (2200 – 0700) Operations: 5,276	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
14FCP1	79.81 %	20.19 %	28 %	31 %	25 %	25 %	7.00 %	7.75 %	7.15 %
14FCP2	79.81 %	20.19 %	28 %	31 %	50 %	50 %	14.00 %	15.50 %	14.30 %
14FCP3	79.81 %	20.19 %	28 %	31 %	25 %	25 %	7.00 %	7.75 %	7.15 %
32FCP1	79.81 %	20.19 %	72 %	69 %	25 %	25 %	18.00 %	17.25 %	17.85 %
32FCP2	79.81 %	20.19 %	72 %	69 %	50 %	50 %	36.00 %	34.50 %	35.70 %
32FCP3	79.81 %	20.19 %	72 %	69 %	25 %	25 %	18.00 %	17.25 %	17.85 %

			Annual Weighting				Seasonal Weighting**					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
14FCP1	1,697	1,869	848	848	934	934	848	848	934	934	3.58 %	3.58 %
14FCP2	3,394	3,737	1,697	1,697	1,869	1,869	1,697	1,697	1,869	1,869	7.15 %	7.15 %
14FCP3	1,697	1,869	848	848	934	934	848	848	934	934	3.58 %	3.58 %
32FCP1	4,235	4,663	2,118	2,118	2,332	2,332	2,118	2,118	2,332	2,332	8.92 %	8.92 %
32FCP2	8,471	9,327	4,235	4,235	4,663	4,663	4,235	4,235	4,663	4,663	17.85 %	17.85 %
32FCP3	4,235	4,663	2,118	2,118	2,332	2,332	2,118	2,118	2,332	2,332	8.92 %	8.92 %

* The number of daytime and nighttime operations listed in the FEIS (Navy 2018, p. A-127) are 16,582 and 4,193, respectively, totaling 20,765. Given the increase to 23,729 annual operations for this activity in the alternative implemented by the ROD, we assumed that the proportion of daytime and nighttime flights would stay the same (79.81 and 20.19 percent, respectively), and multiplied these percentages by the annual total to generate the numbers of operations by time of day.

**The FEIS does not provide information regarding seasonal use of runways 14 and 32 at OLF. Therefore, the seasonal weighting and annual weighting are identical for this activity.

Interfacility Flights – Ault Field to OLF Coupeville

Total Annual Operations (Average Year): 1,481		Total Annual Operations (High Tempo Year): 1,631
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 1,116	Nighttime (2200 – 0700) Operations: 365	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
07WC14P	75.35 %	24.65 %	18 %	18 %	10 %	10 %	1.80 %	1.80 %	1.80 %
07WC32P	75.35 %	24.65 %	18 %	18 %	90 %	90 %	16.20 %	16.20 %	16.20 %
14WC14P	75.35 %	24.65 %	30 %	31 %	10 %	10 %	3.00 %	3.10 %	3.02 %
14WC32P	75.35 %	24.65 %	30 %	31 %	90 %	90 %	27.00 %	27.90 %	27.22 %
25WC14P	75.35 %	24.65 %	50 %	48 %	10 %	10 %	5.00 %	4.80 %	4.95 %
25WC32P	75.35 %	24.65 %	50 %	48 %	90 %	90 %	45.00 %	43.20 %	44.56 %
32WC14P	75.35 %	24.65 %	2 %	3 %	10 %	10 %	0.20 %	0.30 %	0.22 %
32WC32P	75.35 %	24.65 %	2 %	3 %	90 %	90 %	1.80 %	2.70 %	2.02 %

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
07WC14P	27	29	13	13	15	15	0	27	0	29	0.00 %	1.80 %
07WC32P	240	264	120	120	132	132	0	240	0	264	0.00 %	16.20 %
14WC14P	45	49	22	22	25	25	0	45	0	49	0.00 %	3.02 %
14WC32P	403	444	202	202	222	222	0	403	0	444	0.00 %	27.22 %
25WC14P	73	81	37	37	40	40	73	0	81	0	4.95 %	0.00 %
25WC32P	660	727	330	330	363	363	660	0	727	0	44.56 %	0.00 %
32WC14P	3	4	2	2	2	2	0	3	0	4	0.00 %	0.22 %
32WC32P	30	33	15	15	16	16	8	22	9	24	0.55 %	1.48 %

Interfacility Flights – OLF Coupeville to Ault Field

Total Annual Operations (Average Year): 1,483		Total Annual Operations (High Tempo Year): 1,632
Average Year – Operations By Time of Day (Navy 2018, pp. A-126 – A-127)		
Daytime (0700 – 2200) Operations: 1,239	Nighttime (2200 – 0700) Operations: 244	

Flight Track	Operations during daytime (%)	Operations during nighttime (%)	Daytime operations on runway (%)	Nighttime operations on runway (%)	Daytime runway operations using flight track (%)	Nighttime runway operations using flight track (%)	Overall daytime operations using flight track (%)	Overall nighttime operations using flight track (%)	Overall annual operations using flight track (%)
14CW07	83.55 %	16.45 %	28 %	31 %	13 %	13 %	3.64 %	4.03 %	3.70 %
14CW14	83.55 %	16.45 %	28 %	31 %	44 %	44 %	12.32 %	13.64 %	12.54 %
14CW25	83.55 %	16.45 %	28 %	31 %	36 %	36 %	10.08 %	11.16 %	10.26 %
14CW32	83.55 %	16.45 %	28 %	31 %	7 %	7 %	1.96 %	2.17 %	1.99 %
32CW07	83.55 %	16.45 %	72 %	69 %	13 %	13 %	9.36 %	8.97 %	9.30 %
32CW14	83.55 %	16.45 %	72 %	69 %	44 %	44 %	31.68 %	30.36 %	31.46 %
32CW25	83.55 %	16.45 %	72 %	69 %	36 %	36 %	25.92 %	24.84 %	25.74 %
32CW32	83.55 %	16.45 %	72 %	69 %	7 %	7 %	5.04 %	4.83 %	5.01 %

			Annual Weighting				Seasonal Weighting					
Flight Track	Annual operations – Average Year	Annual operations – High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: Average Year	Non-breeding season operations: Average Year	Breeding season operations: High Tempo Year	Non-breeding season operations: High Tempo Year	Breeding season operations: (as % of total annual operations)	Non-breeding season operations: (as % of total annual operations)
14CW07	55	60	27	27	30	30	55	0	60	0	3.70 %	0.00 %
14CW14	186	205	93	93	102	102	0	186	0	205	0.00 %	12.54 %
14CW25	152	167	76	76	84	84	152	0	167	0	10.26 %	0.00 %
14CW32	30	33	15	15	16	16	30	0	33	0	1.99 %	0.00 %
32CW07	138	152	69	69	76	76	49	89	54	98	3.31 %	5.99 %
32CW14	467	513	233	233	257	257	0	467	0	513	0.00 %	31.46 %
32CW25	382	420	191	191	210	210	382	0	420	0	25.74 %	0.00 %
32CW32	74	82	37	37	41	41	74	0	82	0	5.01 %	0.00 %

APPENDIX E
MARBLED MURRELET EXPOSURE TO GROWLER OVERFLIGHTS

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Appendix E
Marbled Murrelet Exposure to Growler Overflights

Our analysis of marbled murrelet exposure to Growler overflights relies upon estimates of the size and location of marine habitat that will be exposed to aircraft sounds 92 dBA_{SEL} re: $20\mu Pa^2s$ or louder ("disturbance-level sounds"), how often those areas are exposed during the breeding and non-breeding season, and how many marbled murrelets are present in the area exposed to disturbance-level sounds. In Appendix C, we outline our methods for estimating the area of marine habitat exposed to these sound levels by each mapped flight track. To estimate the total level of exposure, we must also know how often each flight track is used. In Appendix D, we present two different scenarios regarding the frequency of each flight track's use during the breeding (April through September) and non-breeding (October through March) seasons. We refer to the two scenarios, respectively, as "annual weighting," in which flight track use does not vary seasonally, and "seasonal weighting," in which flight tracks involving Ault runway 25 are used almost exclusively during the breeding season and flight tracks involving Ault runway 14 are used exclusively during the non-breeding season. In this appendix, we combine the information from Appendices C and D with information about marbled murrelet presence in different portions of the action area during the breeding and non-breeding seasons.

Marbled Murrelet At-sea Density Data

Marbled murrelet density within the action area is discussed and displayed graphically in the Environmental Baseline section of the body of the biological opinion (see section 8.1.1). In this appendix, we provide additional details and display marbled murrelet density information in tabular form. Breeding season at-sea surveys conducted for the Northwest Forest Plan's Effectiveness Monitoring Program (NWFPEM), as well as non-breeding season surveys funded by the Navy and conducted by the Washington Department of Fish and Wildlife (WDFW), provide the best available information regarding population densities of marbled murrelets within the marine waters of the action area. These survey programs each divide the surveyed area into strata, as shown in Figure 1. These surveys are conducted within 2 km of shore, except in NWFPEM Stratum 1, where they are conducted area within 5 km of shore. In this analysis, we refer to the area within 2 km of shore (5 km of shore for NWFPEM Stratum 1) as the "nearshore." Nearshore marbled murrelet densities for the breeding and non-breeding seasons are displayed in Tables 1 and 2.

Marbled murrelets are also present in areas farther from shore, though typically at lower density than in nearshore areas. In this analysis, we refer to areas farther than 2 km from shore (5 km from shore for NWFPEM Stratum 1) as "offshore" areas. During the breeding season, we assume that within the Strait of Juan de Fuca, five percent of marbled murrelets will be located farther than 5 km from shore during daylight hours of the breeding season; we also assume that in Strata 2 and 3, densities will be ten times higher within 2 km of shore than they are farther than 2 km from shore (Bentivoglio et al. 2002, p. 22). These estimates are based on the preliminary data used to design the NWFPEM surveys. We combined these estimates of the proportions of marbled murrelets in the offshore area with measured nearshore marbled murrelet densities to generate offshore marbled murrelet density estimates. The resulting density estimates, along with the calculations used to generate them, are displayed in Table 3.

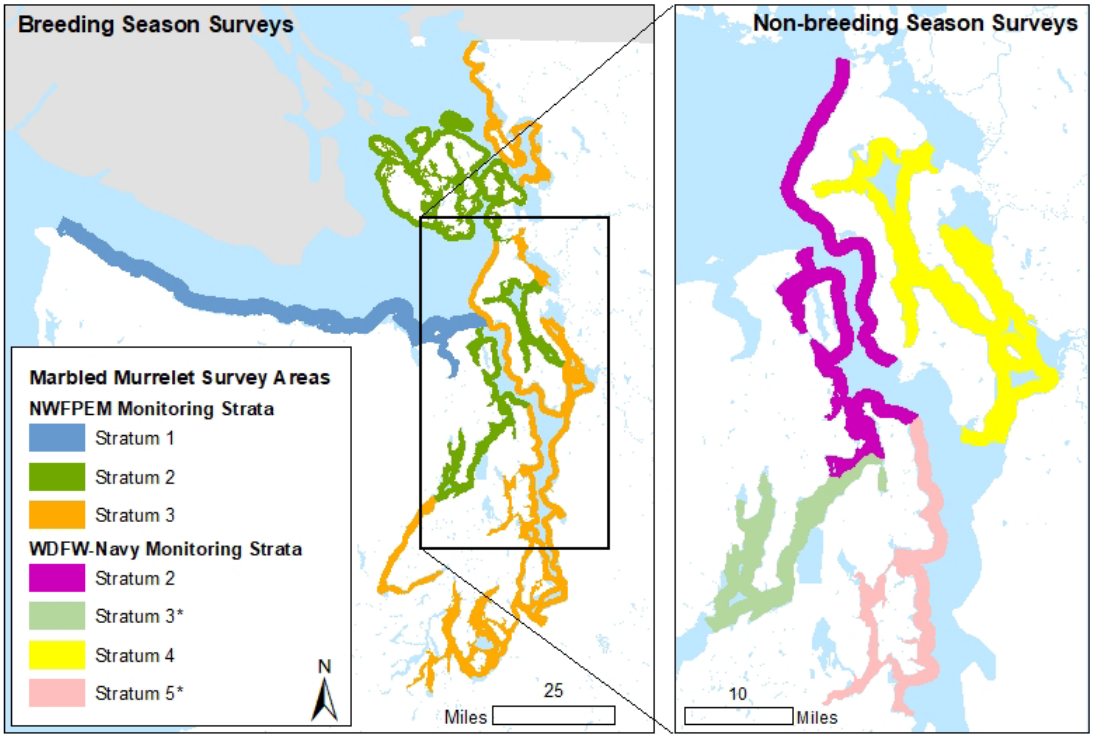

Figure 1. Marbled murrelet at-sea survey strata intersecting, or adjacent to, the action area. WDFW-Navy strata 3 and 5 have little overlap with the action area and are not analyzed further.

Table 1. Nearshore breeding season marbled murrelet at-sea densities (birds/km^2) (McIver et al. 2019, pp. 10-15).

Year	NWFPEM Stratum 1	NWFPEM Stratum 2	NWFPEM Stratum 3
2001	4.506	1.764	2.067
2002	7.207	1.879	0.972
2003	6.644	1.441	0.793
2004	3.833	1.513	0.286
2005	2.501	2.426	2.021
2006	2.76	1.418	1.284
2007	3.445	1.218	1.796
2008	3.572	0.899	0.416
2009	3.811	0.689	1.083
2010	2.004	1.783	0.391
2011	5.58	1.243	0.676
2012	7.166	1.507	0.402
2013	2.379	0.657	1.097
2014	1.235	1.274	0.162
2015	2.218	1.945	0.064
2016	2.693	1.655	0.249
2017	not surveyed		
2018	1.375	1.044	0.98

Table 2. Nearshore non-breeding season marbled murrelet at-sea densities (birds/km^2) (Pearson and Lance 2013, p. 10; Pearson and Lance 2014, p. 11; Pearson and Lance 2015, p. 13; Pearson and Lance 2016, p. 12; Pearson and Lance 2017, p. 12; Pearson and Lance 2018, p. 13).

Year	WDFW-Navy Stratum 2	WDFW-Navy Stratum 4
2012-2013	5.5	1.07
2013-2014	2.43	1.22
2014-2015	3.856	0.763
2015-2016	3.08	1.222
2016-2017	1.754	0.443
2017-2018	1.877	0.71

Table 3. Offshore breeding season marbled murrelet at-sea densities (birds/km^2).

Year	NWFPEM Stratum 1*	NWFPEM Stratum 2	NWFPEM Stratum 3
Information from Bentivoglio et al. 2002, p. 22.	5 % of marbled murrelets farther than 5 km from shore	nearshore density 10 times offshore density	nearshore density 10 times offshore density
Calculation method	0.05 * nearshore density / 0.95	nearshore density / 10	nearshore density / 10
2001	0.237	0.176	0.207
2002	0.379	0.188	0.097
2003	0.350	0.144	0.079
2004	0.202	0.151	0.029
2005	0.132	0.243	0.202
2006	0.145	0.142	0.128
2007	0.181	0.122	0.180
2008	0.188	0.090	0.042
2009	0.201	0.069	0.108
2010	0.105	0.178	0.039
2011	0.294	0.124	0.068
2012	0.377	0.151	0.040
2013	0.125	0.066	0.110
2014	0.065	0.127	0.016
2015	0.117	0.195	0.006
2016	0.142	0.166	0.025
2017	no data – nearshore not surveyed		
2018	0.072	0.104	0.098

*Notes on calculation method for Stratum 1: assumed nearshore and offshore areas approximately the same size, 845 km^2 (McIver et al. 2019, p. 10), given ~20-km total width of Strait of Juan de Fuca including 5 km nearshore on either side. Total number of birds (for southern half of SJF) is nearshore number of birds divided by 0.95, because the surveys only account for nearshore birds, which are 95 percent of the total. Offshore number of birds is 0.05 times the total number of birds. The number of birds in the nearshore area is the nearshore density times 845, and the density of birds in the offshore area is the offshore number of birds divided by 845. The full equation is 0.05*845*(nearshore density/0.95)/845, and the 845 in the numerator and denominator cancel.

For the non-breeding season, similar estimates of the relative nearshore and offshore densities are not available. Instead, we used midwinter aerial survey data collected by WDFW (WDFW 2019) to estimate ratios of the numbers of marbled murrelets nearshore and offshore. We estimated separate ratios for WDFW-Navy Strata 2 and 4. Although these midwinter aerial seabird surveys have been conducted since 1994, we used data only from 1999 and later, because data collection methods were less consistent in earlier years (Pearson 2019, pers. comm.). We do not use aerial survey data to estimate marbled murrelet density directly, because the survey method has a relatively low detection rate for marbled murrelets (Nysewander et al. 2005, pp. 105, 125). However, the information is suitable for comparing the number of observations in different parts of the area surveyed, because there is no known bias toward detecting more or fewer marbled murrelets nearshore versus offshore. This dataset provides the best available information regarding the relative densities of marbled murrelets in nearshore and offshore areas during the non-breeding season.

Midwinter aerial survey data are available in a geodatabase for use in a geographic information system (GIS). We used GIS to delineate an offshore area adjacent to WDFW-Navy Strata 2 and 4. The delineated offshore area adjacent to WDFW-Navy Stratum 2 included offshore areas of the eastern Strait of Juan de Fuca, southern Rosario Strait, and Admiralty Inlet, and covered approximately 990 km^2. The delineated offshore area associated with WDFW-Navy Stratum 4 covered approximately 98 km^2, and consisted of areas farther than 2 km from shore within the Whidbey Basin, plus the area offshore of the southern end of Whidbey Island in the northern main basin of Puget Sound. We then mapped these areas along with the surveyed nearshore areas (Figure 1) and the midwinter aerial survey data. We extracted the marbled murrelet observations within the WDFW-Navy Strata 2 and 4 and the adjacent offshore areas, and tabulated the number of marbled murrelets observed each year in each of those four areas (Table 4). For each year from 1999 to 2017 (the last year in the data set), we calculated the ratio of marbled murrelets observed in an offshore area to the number observed in the corresponding nearshore stratum (Table 4). Averaged across years, the offshore: nearshore ratio of marbled murrelet counts for Stratum 2 was 0.63, and the ratio for Stratum 4 was 0.12.

We then combined these average ratios with the non-breeding season nearshore data from 2012 through 2018 to estimate offshore marbled murrelet densities over the same time period. We multiplied the number of birds estimated for each survey stratum, which is reported along with marbled murrelet density (Pearson and Lance 2013, p. 10; Pearson and Lance 2014, p. 11; Pearson and Lance 2015, p. 13; Pearson and Lance 2016, p. 12; Pearson and Lance 2017, p. 12; Pearson and Lance 2018, p. 13), by the applicable ratio to estimate the number of birds in the corresponding offshore area, then divided by the number of square km in the offshore area to produce an offshore area density. The results of these calculations are listed in Table 5.

Table 4. Counts and ratios of marbled murrelets observed during midwinter aerial surveys (WDFW 2019) within the nearshore and offshore areas of WDFW-Navy Strata 2 and 4.

Year	WDFW-Navy Stratum 2			WDFW-Navy Stratum 2		
	Nearshore marbled murrelet count	Offshore marbled murrelet count	Offshore: Nearshore ratio	Nearshore marbled murrelet count	Offshore marbled murrelet count	Offshore: Nearshore ratio
1999	13	8	0.62	3	0	0
2000	29	14	0.48	8	0	0
2001	37	6	0.16	26	4	0.15
2002	no data					
2003	25	22	0.88	3	2	0.67
2004	20	6	0.30	16	0	0
2005	56	9	0.16	33	0	0
2006	64	5	0.08	5	1	0.20
2007	8	2	0.25	0	0	n/a
2008	11	31	2.82	0	0	n/a
2009	52	48	0.92	9	1	0.11
2010	89	13	0.15	11	2	0.18
2011	60	43	0.72	2	0	0
2012	112	11	0.10	27	2	0.07
2013	60	42	0.70	20	0	0
2014	28	37	1.32	17	2	0.12
2015	66	32	0.48	7	1	0.14
2016	38	20	0.53	8	3	0.38
2017	35	29	0.83	8	0	0

Table 5. Offshore non-breeding season marbled murrelet at-sea densities (birds/km^2).

Year	WDFW-Navy Stratum 2	WDFW-Navy Stratum 4
Calculation method (see text for details)	nearshore # of marbled murrelets * 0.63 / 990	nearshore # of marbled murrelets * 0.12 / 98
2012-2013	0.09	0.45
2013-2014	0.40	0.52
2014-2015	0.63	0.32
2015-2016	0.50	0.52
2016-2017	0.29	0.19
2017-2018	0.31	0.30

We used two different strategies to select data from these datasets for use in the exposure analysis. For use in the analysis of the average expected level of exposure, we used the average marbled murrelet densities from 2012 through 2018 for both the breeding and non-breeding seasons. These averages are shown in Table 6. To calculate the maximum exposure level expected in any given breeding season or non-breeding season over the next 30 years, we selected seasons with particularly high densities. For the breeding season, we used data from 2005, a year in which upwelling failed along the outer coast of Washington, and marbled murrelet distribution shifted eastward into the action area, resulting in high densities in NWFPEM Strata 2 and 3. For the non-breeding season, we used data from 2012-2013, which was the year with the highest marbled murrelet density in WDFW-Navy Stratum 2, and a higher-than-average density in WDFW-Navy Stratum 4. The data used for analysis of the maximum exposure level is shown in Table 7.

Table 6. 2012-2018 average marbled murrelet densities (birds/km^2).

Stratum	Nearshore	Offshore
Breeding season: NWFPEM strata		
Stratum 1	2.84	0.15
Stratum 2	1.35	0.14
Stratum 3	0.49	0.05
Non-breeding season: WDFW-Navy strata		
Stratum 2	3.08	0.50
Stratum 4	0.91	0.38

Table 7. 2005 breeding season and 2012-2013 non-breeding season marbled murrelet densities (birds/km^2).

Stratum	Nearshore	Offshore
Breeding season: NWFPEM strata		
Stratum 1	2.50	0.13
Stratum 2	2.43	0.24
Stratum 3	2.02	0.20
Non-breeding season: WDFW-Navy strata		
Stratum 2	5.50	0.90
Stratum 4	1.07	0.45

Combining Marbled Murrelet Data and Growler Flight Information

We combined marbled murrelet data with information about Growler activities, using the information presented in Appendices A, C, and D. We built upon the procedures outlined in Appendix C to estimate how much nearshore and offshore area would be exposed to disturbance-level noise from each flight track. For example, if a flight track crossed the nearshore area (within 2 km of shore) twice, approximately perpendicularly, we estimated that the length of the nearshore area exposed would be 4 km, with the width of the exposed nearshore area as

calculated in Appendix C. The remainder of the exposed area, as calculated in Appendix C, would be in the offshore area. We assigned each flight track to a single stratum for each season, in each case selecting the stratum that had the highest density. This strategy for assigning flight tracks to a single stratum allows us to avoid underestimating exposure, without doing an excessively-detailed breakdown of each flight track into segments crossing the nearshore and offshore areas of multiple strata.

For each mapped flight track, we estimated the number of marbled murrelets exposed to disturbance-level sounds in an average year (using the marbled murrelet densities in Table 6) and in a year with high marbled murrelet densities (Table 7). We multiplied the exposed nearshore area by the assigned nearshore density to estimate the number of marbled murrelets exposed in the nearshore, and similarly multiplied the exposed offshore area by the exposed offshore density to estimate the number of marbled murrelets exposed in the offshore area. We then summed these to estimate the total number of marbled murrelets exposed to disturbance level sounds by a Growler flying along the flight track. We performed these calculations separately for the breeding and non-breeding seasons, and for average and high-density years.

For each type of Growler activity, we then calculated the total exposure by multiplying the estimated number of exposures to each flight track by the number of times each flight track is expected to be used in each season. To estimate the average level of exposure, we combined average marbled murrelet densities (Table 6) with average-year operations. To estimate the maximum level of exposure expected in a given season or year over the next 30 years, we combined high marbled murrelet densities (Table 7) with high-tempo operations. Because we did not have a breakdown of the expected use of flight tracks by season, we used the "annual weighting" and "seasonal weighting" scenarios outlined in Appendix D to estimate the seasonal distribution of flight track use.

For two types of activities, FCLPs and interfacility flights, flights are expected to occur in groups. In the case of FCLPs, a group of three to five Growlers will collectively perform approximately 48 operations over a period of 45 minutes, traveling repeatedly along the same flight track. This 45-minute event is referred to as an FCLP period. Interfacility flights are only performed before or after FCLP periods at OLF Coupeville, and involve the same three to five Growlers that will conduct the FCLP activities flying approximately one minute apart. Because these flights will occur in groups, we assume that exposures to individual overflights associated with these activities will not be perceived as independent events by marbled murrelets. Therefore, we consider exposure to FCLP periods (operations divided by 48), rather than to single circuits of the flight track (operations divided by 2); and we consider exposure to groups of interfacility flights (interfacility flight operations divided by 3) rather than to single interfacility flights (count of interfacility flight operations). For all other activities, we consider exposure to a single pass of a Growler along a flight track. For pattern operations, this is the number of operations divided by 2, and for arrivals and departures, it is simply the number of operations.

The tables on the following pages show the methods and results of the combination of marbled murrelet density information with expected Growler activity.

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Key to the Tables on the Following Pages

Type of Operation

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	Information from Appendix C, visual inspection of flight track maps, and Figure 1 (this appendix)		Visual inspection of flight track maps and Figure 1 (this appendix)	Maximum nearshore and offshore densities from Table 6 (this appendix) among strata listed in C		A * D	B * E	F + G	Same method used in C	Maximum nearshore and offshore densities from Table 6 (this appendix) among strata listed in I		A * J	B * K	L + M

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
	A	B	C	O	P	Q	R	S	I	T	U	V	W	X
	Same as above		Same as above	Maximum nearshore and offshore densities from Table 7 (this appendix) among strata listed in C		A * O	B * P	Q + R	Same method used in C	Maximum nearshore and offshore densities from Table 7 (this appendix) among strata listed in I		A * T	B * U	V + W

All Operations - Synthesis

Type of Operation	Average Year, Average Marbled Murrelet Density						High Tempo Year, High Marbled Murrelet Density					
	Annual Weighting			Seasonal Weighting			Annual Weighting			Seasonal Weighting		
	Breeding season exposure	Non-breeding season exposure	Total exposure	Breeding season exposure	Non-breeding season exposure	Total exposure	Breeding season exposure	Non-breeding season exposure	Total exposure	Breeding season exposure	Non-breeding season exposure	Total exposure
	aa	bb	cc	dd	ee	ff	gg	hh	ii	jj	kk	ll
Arrivals and departures	Sum, over all flight tracks, of H * Appendix D, column P	Sum, over all flight tracks, of N * Appendix D, column Q	aa + bb	Sum, over all flight tracks, of H * Appendix D, column T	Sum, over all flight tracks, of N * Appendix D, column U	dd + ee	Sum, over all flight tracks, of S * Appendix D, column R	Sum, over all flight tracks, of X * Appendix D, column S	gg + hh	Sum, over all flight tracks, of S * Appendix D, column V	Sum, over all flight tracks, of X * Appendix D, column W	jj + kk
Pattern operations (except FCLP)	(Sum, over all flight tracks, of H * Appendix D, column P) / 2	(Sum, over all flight tracks, of N * Appendix D, column Q) / 2	aa + bb	(Sum, over all flight tracks, of H * Appendix D, column T) / 2	(Sum, over all flight tracks, of N * Appendix D, column U) / 2	dd + ee	(Sum, over all flight tracks, of S * Appendix D, column R) / 2	(Sum, over all flight tracks, of X * Appendix D, column S) / 2	gg + hh	(Sum, over all flight tracks, of S * Appendix D, column V) / 2	(Sum, over all flight tracks, of X * Appendix D, column W) / 2	jj + kk
FCLP	(Sum, over all flight tracks, of H * Appendix D, column P) / 48	(Sum, over all flight tracks, of N * Appendix D, column Q) / 48	aa + bb	(Sum, over all flight tracks, of H * Appendix D, column T) / 48	(Sum, over all flight tracks, of N * Appendix D, column U) / 48	dd + ee	(Sum, over all flight tracks, of S * Appendix D, column R) / 48	(Sum, over all flight tracks, of X * Appendix D, column S) / 48	gg + hh	(Sum, over all flight tracks, of S * Appendix D, column V) / 48	(Sum, over all flight tracks, of X * Appendix D, column W) / 48	jj + kk
Interfacility flights	(Sum, over all flight tracks, of H * Appendix D, column P) / 3	(Sum, over all flight tracks, of N * Appendix D, column Q) / 3	aa + bb	(Sum, over all flight tracks, of H * Appendix D, column T) / 3	(Sum, over all flight tracks, of N * Appendix D, column U) / 3	dd + ee	(Sum, over all flight tracks, of S * Appendix D, column R) / 3	(Sum, over all flight tracks, of X * Appendix D, column S) / 3	gg + hh	(Sum, over all flight tracks, of S * Appendix D, column V) / 3	(Sum, over all flight tracks, of X * Appendix D, column W) / 3	jj + kk

Note: On the following pages, whole numbers of subsets of the total operations (e.g., seasonal operations or operations using particular flight tracks) may not sum to the total numbers of operations, due to rounding. All calculations were made prior to rounding.

Departures

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07D1A	86.1	0.0	S3	0.49	0.05	42.41	0.00	42.41	S4	0.91	0.38	77.92	0.00	77.92
07D1B	86.1	0.0	S3	0.49	0.05	42.41	0.00	42.41	S4	0.91	0.38	77.92	0.00	77.92
07D1C	86.1	0.0	S3	0.49	0.05	42.41	0.00	42.41	S4	0.91	0.38	77.92	0.00	77.92
07D2A	86.1	0.0	S2, S3	1.35	0.14	116.02	0.00	116.02	S4	0.91	0.38	77.92	0.00	77.92
07D2B	86.1	0.0	S2, S3	1.35	0.14	116.02	0.00	116.02	S4	0.91	0.38	77.92	0.00	77.92
07D2C	86.1	0.0	S2, S3	1.35	0.14	116.02	0.00	116.02	S4	0.91	0.38	77.92	0.00	77.92
14D1A	86.1	0.0	S2	1.35	0.14	116.02	0.00	116.02	S4	0.91	0.38	77.92	0.00	77.92
14D1B	86.1	0.0	S2	1.35	0.14	116.02	0.00	116.02	S4	0.91	0.38	77.92	0.00	77.92
14D1C	86.1	0.0	S2	1.35	0.14	116.02	0.00	116.02	S4	0.91	0.38	77.92	0.00	77.92
14D2A	86.1	0.0	S2	1.35	0.14	116.02	0.00	116.02	S4	0.91	0.38	77.92	0.00	77.92
14D2B	71.5	14.6	S2	1.35	0.14	96.36	1.97	98.33	S4	0.91	0.38	64.72	5.59	70.31
14D2C	71.5	14.6	S2	1.35	0.14	96.36	1.97	98.33	S4	0.91	0.38	64.72	5.59	70.31
25D1A	9.6	76.6	S3	0.49	0.05	4.72	3.77	8.49	S2	3.08	0.50	29.53	38.57	68.10
25D1B	9.6	76.6	S3	0.49	0.05	4.72	3.77	8.49	S2	3.08	0.50	29.53	38.57	68.10
25D1C	9.6	76.6	S3	0.49	0.05	4.72	3.77	8.49	S2	3.08	0.50	29.53	38.57	68.10
25D2A	9.6	76.6	S3	0.49	0.05	4.72	3.77	8.49	S2	3.08	0.50	29.53	38.57	68.10
25D2B	9.6	76.6	S3	0.49	0.05	4.72	3.77	8.49	S2	3.08	0.50	29.53	38.57	68.10
25D2C	9.6	76.6	S3	0.49	0.05	4.72	3.77	8.49	S2	3.08	0.50	29.53	38.57	68.10
32D1A	86.1	0.0	S2, S3	1.35	0.14	116.02	0.00	116.03	S2	3.08	0.50	265.54	0.00	265.54
32D1B	86.1	0.0	S2, S3	1.35	0.14	116.02	0.00	116.03	S2	3.08	0.50	265.54	0.00	265.54
32D1C	86.1	0.0	S2, S3	1.35	0.14	116.02	0.00	116.03	S2	3.08	0.50	265.54	0.00	265.54
32D2A	86.1	0.0	S2, S3	1.35	0.14	116.02	0.00	116.03	S2	3.08	0.50	265.54	0.00	265.54
32D2B	86.1	0.0	S2, S3	1.35	0.14	116.02	0.00	116.03	S2	3.08	0.50	265.54	0.00	265.54
32D2C	86.1	0.0	S2, S3	1.35	0.14	116.02	0.00	116.03	S2	3.08	0.50	265.54	0.00	265.54

Departures, continued

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07D1A	86.1	0.0	S3	2.02	0.20	174.08	0.00	174.08	S4	1.07	0.45	92.16	0.00	92.16
07D1B	86.1	0.0	S3	2.02	0.20	174.08	0.00	174.08	S4	1.07	0.45	92.16	0.00	92.16
07D1C	86.1	0.0	S3	2.02	0.20	174.08	0.00	174.08	S4	1.07	0.45	92.16	0.00	92.16
07D2A	86.1	0.0	S2, S3	2.43	0.24	208.96	0.00	208.96	S4	1.07	0.45	92.16	0.00	92.16
07D2B	86.1	0.0	S2, S3	2.43	0.24	208.96	0.00	208.96	S4	1.07	0.45	92.16	0.00	92.16
07D2C	86.1	0.0	S2, S3	2.43	0.24	208.96	0.00	208.96	S4	1.07	0.45	92.16	0.00	92.16
14D1A	86.1	0.0	S2	2.43	0.24	208.96	0.00	208.96	S4	1.07	0.45	92.16	0.00	92.16
14D1B	86.1	0.0	S2	2.43	0.24	208.96	0.00	208.96	S4	1.07	0.45	92.16	0.00	92.16
14D1C	86.1	0.0	S2	2.43	0.24	208.96	0.00	208.96	S4	1.07	0.45	92.16	0.00	92.16
14D2A	86.1	0.0	S2	2.43	0.24	208.96	0.00	208.96	S4	1.07	0.45	92.16	0.00	92.16
14D2B	71.5	14.6	S2	2.43	0.24	173.55	3.54	177.09	S4	1.07	0.45	76.54	6.61	83.16
14D2C	71.5	14.6	S2	2.43	0.24	173.55	3.54	177.09	S4	1.07	0.45	76.54	6.61	83.16
25D1A	9.6	76.6	S3	2.02	0.20	19.36	15.47	34.83	S2	5.50	0.90	52.69	68.81	121.50
25D1B	9.6	76.6	S3	2.02	0.20	19.36	15.47	34.83	S2	5.50	0.90	52.69	68.81	121.50
25D1C	9.6	76.6	S3	2.02	0.20	19.36	15.47	34.83	S2	5.50	0.90	52.69	68.81	121.50
25D2A	9.6	76.6	S3	2.02	0.20	19.36	15.47	34.83	S2	5.50	0.90	52.69	68.81	121.50
25D2B	9.6	76.6	S3	2.02	0.20	19.36	15.47	34.83	S2	5.50	0.90	52.69	68.81	121.50
25D2C	9.6	76.6	S3	2.02	0.20	19.36	15.47	34.83	S2	5.50	0.90	52.69	68.81	121.50
32D1A	86.1	0.0	S2, S3	2.43	0.24	208.96	0.00	208.96	S2	5.50	0.90	473.74	0.00	473.74
32D1B	86.1	0.0	S2, S3	2.43	0.24	208.96	0.00	208.96	S2	5.50	0.90	473.74	0.00	473.74
32D1C	86.1	0.0	S2, S3	2.43	0.24	208.96	0.00	208.96	S2	5.50	0.90	473.74	0.00	473.74
32D2A	86.1	0.0	S2, S3	2.43	0.24	208.96	0.00	208.96	S2	5.50	0.90	473.74	0.00	473.74
32D2B	86.1	0.0	S2, S3	2.43	0.24	208.96	0.00	208.96	S2	5.50	0.90	473.74	0.00	473.74
32D2C	86.1	0.0	S2, S3	2.43	0.24	208.96	0.00	208.96	S2	5.50	0.90	473.74	0.00	473.74

Straight-in/Full-stop Arrivals

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07A2A	4.52	54.23	S3	0.49	0.05	2.23	2.67	4.90	S2	3.08	0.50	13.94	27.32	41.26
07A2B	4.52	54.23	S3	0.49	0.05	2.23	2.67	4.90	S2	3.08	0.50	13.94	27.32	41.26
07A2C	4.52	54.23	S3	0.49	0.05	2.23	2.67	4.90	S2	3.08	0.50	13.94	27.32	41.26
14A1A	37.74	0.00	S2, S3	1.35	0.13	50.84	0.00	50.84	S2	3.08	0.50	116.35	0.00	116.35
14A1B	37.74	0.00	S2, S3	1.35	0.13	50.84	0.00	50.84	S2	3.08	0.50	116.35	0.00	116.35
14A1C	37.74	0.00	S2, S3	1.35	0.13	50.84	0.00	50.84	S2	3.08	0.50	116.35	0.00	116.35
14A2A	44.96	13.78	S2, S3	1.35	0.13	60.57	1.86	62.42	S2	3.08	0.50	138.62	6.94	145.56
14A2B	44.96	13.78	S2, S3	1.35	0.13	60.57	1.86	62.42	S2	3.08	0.50	138.62	6.94	145.56
14A2C	44.96	13.78	S2, S3	1.35	0.13	60.57	1.86	62.42	S2	3.08	0.50	138.62	6.94	145.56
25A2A	51.85	6.90	S2, S3	1.35	0.13	69.85	0.93	70.78	S4	0.90	0.38	46.91	2.64	49.55
25A2B	51.85	6.90	S2, S3	1.35	0.13	69.85	0.93	70.78	S4	0.90	0.38	46.91	2.64	49.55
25A2C	51.85	6.90	S2, S3	1.35	0.13	69.85	0.93	70.78	S4	0.90	0.38	46.91	2.64	49.55
32A1A	17.08	20.67	S2, S3	1.35	0.13	23.00	2.78	25.79	S4	0.90	0.38	15.45	7.91	23.36
32A1B	17.08	20.67	S2, S3	1.35	0.13	23.00	2.78	25.79	S4	0.90	0.38	15.45	7.91	23.36
32A1C	17.08	20.67	S2, S3	1.35	0.13	23.00	2.78	25.79	S4	0.90	0.38	15.45	7.91	23.36
32A2A	17.08	20.67	S2, S3	1.35	0.13	23.00	2.78	25.79	S2, S4	3.08	0.50	52.64	10.41	63.06
32A2B	17.08	20.67	S2, S3	1.35	0.13	23.00	2.78	25.79	S2, S4	3.08	0.50	52.64	10.41	63.06
32A2C	17.08	20.67	S2, S3	1.35	0.13	23.00	2.78	25.79	S2, S4	3.08	0.50	52.64	10.41	63.06

Straight-in/Full-stop Arrivals, continued

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07A2A	4.52	54.23	S3	2.02	0.20	9.14	10.96	20.10	S2	5.50	0.90	24.86	48.74	73.60
07A2B	4.52	54.23	S3	2.02	0.20	9.14	10.96	20.10	S2	5.50	0.90	24.86	48.74	73.60
07A2C	4.52	54.23	S3	2.02	0.20	9.14	10.96	20.10	S2	5.50	0.90	24.86	48.74	73.60
14A1A	37.74	0.00	S2, S3	2.43	0.24	91.56	0.00	91.56	S2	5.50	0.90	207.59	0.00	207.59
14A1B	37.74	0.00	S2, S3	2.43	0.24	91.56	0.00	91.56	S2	5.50	0.90	207.59	0.00	207.59
14A1C	37.74	0.00	S2, S3	2.43	0.24	91.56	0.00	91.56	S2	5.50	0.90	207.59	0.00	207.59
14A2A	44.96	13.78	S2, S3	2.43	0.24	109.08	3.34	112.43	S2	5.50	0.90	247.31	12.39	259.69
14A2B	44.96	13.78	S2, S3	2.43	0.24	109.08	3.34	112.43	S2	5.50	0.90	247.31	12.39	259.69
14A2C	44.96	13.78	S2, S3	2.43	0.24	109.08	3.34	112.43	S2	5.50	0.90	247.31	12.39	259.69
25A2A	51.85	6.90	S2, S3	2.43	0.24	125.80	1.67	127.47	S4	1.07	0.45	55.48	3.12	58.60
25A2B	51.85	6.90	S2, S3	2.43	0.24	125.80	1.67	127.47	S4	1.07	0.45	55.48	3.12	58.60
25A2C	51.85	6.90	S2, S3	2.43	0.24	125.80	1.67	127.47	S4	1.07	0.45	55.48	3.12	58.60
32A1A	17.08	20.67	S2, S3	2.43	0.24	41.43	5.01	46.44	S4	1.07	0.45	18.27	9.36	27.63
32A1B	17.08	20.67	S2, S3	2.43	0.24	41.43	5.01	46.44	S4	1.07	0.45	18.27	9.36	27.63
32A1C	17.08	20.67	S2, S3	2.43	0.24	41.43	5.01	46.44	S4	1.07	0.45	18.27	9.36	27.63
32A2A	17.08	20.67	S2, S3	2.43	0.24	41.43	5.01	46.44	S2, S4	5.50	0.90	93.92	18.58	112.50
32A2B	17.08	20.67	S2, S3	2.43	0.24	41.43	5.01	46.44	S2, S4	5.50	0.90	93.92	18.58	112.50
32A2C	17.08	20.67	S2, S3	2.43	0.24	41.43	5.01	46.44	S2, S4	5.50	0.90	93.92	18.58	112.50

Overhead Break Arrivals

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07O1A	13.6	60.0	S2, S3	1.35	0.13	18.27	8.08	26.34	S2	3.08	0.50	41.81	30.20	72.01
07O1B	13.6	60.0	S2, S3	1.35	0.13	18.27	8.08	26.34	S2	3.08	0.50	41.81	30.20	72.01
07O1C	13.6	60.0	S2, S3	1.35	0.13	18.27	8.08	26.34	S2	3.08	0.50	41.81	30.20	72.01
07O2A	13.6	60.0	S3	0.49	0.05	6.68	2.95	9.63	S2	3.08	0.50	41.81	30.20	72.01
07O2B	13.6	60.0	S3	0.49	0.05	6.68	2.95	9.63	S2	3.08	0.50	41.81	30.20	72.01
07O3C	13.6	60.0	S3	0.49	0.05	6.68	2.95	9.63	S2	3.08	0.50	41.81	30.20	72.01
14O1A	51.5	0.0	S2, S3	1.35	0.13	69.32	0.00	69.32	S2, S4	0.90	0.38	46.56	0.00	46.56
14O1B	51.5	0.0	S2, S3	1.35	0.13	69.32	0.00	69.32	S2, S4	0.90	0.38	46.56	0.00	46.56
14O1C	51.5	0.0	S2, S3	1.35	0.13	69.32	0.00	69.32	S2, S4	0.90	0.38	46.56	0.00	46.56
14O2A	38.4	26.2	S2, S3	1.35	0.13	51.69	3.53	55.22	S2	3.08	0.27	118.31	7.03	125.33
14O2B	38.4	26.2	S2, S3	1.35	0.13	51.69	3.53	55.22	S2	3.08	0.27	118.31	7.03	125.33
14O2C	38.4	26.2	S2, S3	1.35	0.13	51.69	3.53	55.22	S2	3.08	0.27	118.31	7.03	125.33
25O1B	52.8	0.0	S3	0.49	0.05	26.01	0.00	26.01	S4	0.90	0.38	47.80	0.00	47.80
25O1C	52.8	0.0	S3	0.49	0.05	26.01	0.00	26.01	S4	0.90	0.38	47.80	0.00	47.80
25O2B	52.8	0.0	S2, S3	1.35	0.13	71.17	0.00	71.17	S4	0.90	0.38	47.80	0.00	47.80
25O2C	52.8	0.0	S2, S3	1.35	0.13	71.17	0.00	71.17	S4	0.90	0.38	47.80	0.00	47.80
32O1B	17.0	20.7	S2, S3	1.35	0.13	22.92	2.78	25.71	S2, S4	0.90	0.38	15.40	7.91	23.31
32O1C	17.0	20.7	S2, S3	1.35	0.13	22.92	2.78	25.71	S2, S4	0.90	0.38	15.40	7.91	23.31
32O2B	17.0	20.7	S2, S3	1.35	0.13	22.92	2.78	25.71	S2, S4	0.90	0.38	15.40	7.91	23.31
32O2C	17.0	20.7	S2, S3	1.35	0.13	22.92	2.78	25.71	S2, S4	0.90	0.38	15.40	7.91	23.31

Overhead Break Arrivals, continued

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07O1A	13.6	60.0	S2, S3	2.43	0.24	32.90	14.54	47.44	S2	5.50	0.90	74.59	53.88	128.47
07O1B	13.6	60.0	S2, S3	2.43	0.24	32.90	14.54	47.44	S2	5.50	0.90	74.59	53.88	128.47
07O1C	13.6	60.0	S2, S3	2.43	0.24	32.90	14.54	47.44	S2	5.50	0.90	74.59	53.88	128.47
07O2A	13.6	60.0	S3	2.02	0.20	27.41	12.12	39.52	S2	5.50	0.90	74.59	53.88	128.47
07O2B	13.6	60.0	S3	2.02	0.20	27.41	12.12	39.52	S2	5.50	0.90	74.59	53.88	128.47
07O3C	13.6	60.0	S3	2.02	0.20	27.41	12.12	39.52	S2	5.50	0.90	74.59	53.88	128.47
14O1A	51.5	0.0	S2, S3	2.43	0.24	124.85	0.00	124.85	S2, S4	1.07	0.45	55.07	0.00	55.07
14O1B	51.5	0.0	S2, S3	2.43	0.24	124.85	0.00	124.85	S2, S4	1.07	0.45	55.07	0.00	55.07
14O1C	51.5	0.0	S2, S3	2.43	0.24	124.85	0.00	124.85	S2, S4	1.07	0.45	55.07	0.00	55.07
14O2A	38.4	26.2	S2, S3	2.43	0.24	93.10	6.35	99.45	S2	5.50	0.27	211.07	7.03	218.10
14O2B	38.4	26.2	S2, S3	2.43	0.24	93.10	6.35	99.45	S2	5.50	0.27	211.07	7.03	218.10
14O2C	38.4	26.2	S2, S3	2.43	0.24	93.10	6.35	99.45	S2	5.50	0.27	211.07	7.03	218.10
25O1B	52.8	0.0	S3	2.02	0.20	106.79	0.00	106.79	S4	1.07	0.45	56.54	0.00	56.54
25O1C	52.8	0.0	S3	2.02	0.20	106.79	0.00	106.79	S4	1.07	0.45	56.54	0.00	56.54
25O2B	52.8	0.0	S2, S3	2.43	0.24	128.19	0.00	128.19	S4	1.07	0.45	56.54	0.00	56.54
25O2C	52.8	0.0	S2, S3	2.43	0.24	128.19	0.00	128.19	S4	1.07	0.45	56.54	0.00	56.54
32O1B	17.0	20.7	S2, S3	2.43	0.24	41.29	5.01	46.30	S2, S4	1.07	0.45	18.21	9.36	27.57
32O1C	17.0	20.7	S2, S3	2.43	0.24	41.29	5.01	46.30	S2, S4	1.07	0.45	18.21	9.36	27.57
32O2B	17.0	20.7	S2, S3	2.43	0.24	41.29	5.01	46.30	S2, S4	1.07	0.45	18.21	9.36	27.57
32O2C	17.0	20.7	S2, S3	2.43	0.24	41.29	5.01	46.30	S2, S4	1.07	0.45	18.21	9.36	27.57

Instrument Approach Arrivals

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07AHT	4.52	36.62	S2, S3	1.35	0.13	6.09	4.93	11.02	S2	3.08	0.50	13.94	18.45	32.39
14AHT	34.25	6.89	S2, S3	1.35	0.13	46.13	0.93	47.06	S2	3.08	0.50	105.58	3.47	109.06
25AHT	20.47	0.00	S3	0.49	0.05	10.08	0.00	10.08	S4	0.90	0.38	18.52	0.00	18.52
32AHT	13.58	6.89	S2, S3	1.35	0.13	18.29	0.93	19.22	S4	0.90	0.38	12.29	2.64	14.92

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07AHT	4.52	36.62	S2, S3	2.43	0.24	10.97	8.88	19.85	S2	5.50	0.90	24.86	32.91	57.78
14AHT	34.25	6.89	S2, S3	2.43	0.24	83.09	1.67	84.76	S2	5.50	0.90	188.37	6.20	194.56
25AHT	20.47	0.00	S3	2.02	0.20	41.37	0.00	41.37	S4	1.07	0.45	21.90	0.00	21.90
32AHT	13.58	6.89	S2, S3	2.43	0.24	32.95	1.67	34.62	S4	1.07	0.45	14.53	3.12	17.65

Touch-and-Go and Field Carrier Landing Practice at Ault Field*

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07FM1	9.70	13.21	S3	0.49	0.05	4.78	0.65	5.43	S4	0.90	0.38	8.78	5.06	13.84
07FU1	9.70	13.21	S3	0.49	0.05	4.78	0.65	5.43	S4	0.90	0.38	8.78	5.06	13.84
14FM1	14.37	0.00	S3	0.49	0.05	7.07	0.00	7.07	S4	0.90	0.38	13.00	0.00	13.00
14FU1	14.37	0.00	S3	0.49	0.05	7.07	0.00	7.07	S4	0.90	0.38	13.00	0.00	13.00
25FM1	0.00	0.00	n/a	n/a	n/a	0.00	0.00	0.00	n/a	n/a	n/a	0.00	0.00	0.00
25FU1	9.88	0.00	S3	0.49	0.05	4.86	0.00	4.86	S4	0.90	0.38	8.94	0.00	8.94
32FU1	14.37	0.00	S3	0.49	0.05	7.07	0.00	7.07	S4	0.90	0.38	13.00	0.00	13.00

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07FM1	9.70	13.21	S3	2.02	0.20	19.61	2.67	22.28	S4	1.07	0.45	10.38	5.98	16.36
07FU1	9.70	13.21	S3	2.02	0.20	19.61	2.67	22.28	S4	1.07	0.45	10.38	5.98	16.36
14FM1	14.37	0.00	S3	2.02	0.20	29.04	0.00	29.04	S4	1.07	0.45	15.37	0.00	15.37
14FU1	14.37	0.00	S3	2.02	0.20	29.04	0.00	29.04	S4	1.07	0.45	15.37	0.00	15.37
25FM1	0.00	0.00	n/a	n/a	n/a	0.00	0.00	0.00	n/a	n/a	n/a	0.00	0.00	0.00
25FU1	9.88	0.00	S3	2.02	0.20	19.97	0.00	19.97	S4	1.07	0.45	10.57	0.00	10.57
32FU1	14.37	0.00	S3	2.02	0.20	29.04	0.00	29.04	S4	1.07	0.45	15.37	0.00	15.37

*Touch-and-go and FCLP at Ault Field use the same flight tracks, and therefore expose the same number of marbled murrelets for each circuit along a given flight track.

Ground-controlled Approach

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07G1	59.45	52.02	S2, S3	1.35	0.13	80.08	7.01	87.09	S2, S4	3.08	0.50	183.28	26.21	209.49
07G2	71.53	40.06	S2, S3	1.35	0.13	96.35	5.40	101.74	S2, S4	3.08	0.50	220.50	20.18	240.69
07G3	80.99	53.66	S2, S3	1.35	0.13	109.09	7.23	116.32	S2, S4	3.08	0.50	249.67	27.04	276.71
14G1	98.14	0.00	S2, S3	1.35	0.13	132.20	0.00	132.20	S2, S4	3.08	0.50	302.56	0.00	302.56
14G2	137.95	0.00	S2, S3	1.35	0.13	185.82	0.00	185.82	S2, S4	3.08	0.50	425.27	0.00	425.27
14G3	160.02	6.45	S2, S3	1.35	0.13	215.55	0.87	216.42	S2, S4	3.08	0.50	493.32	3.25	496.58
25G1	51.20	36.42	S2, S3	1.35	0.13	68.97	4.91	73.87	S2, S4	3.08	0.50	157.85	18.35	176.19
25G2	64.77	46.07	S2, S3	1.35	0.13	87.24	6.21	93.45	S2, S4	3.08	0.50	199.67	23.21	222.88
25G3	55.06	55.59	S2, S3	1.35	0.13	74.17	7.49	81.65	S2, S4	3.08	0.50	169.74	28.00	197.74
32G1	73.11	6.44	S2, S3	1.35	0.13	98.48	0.87	99.35	S2, S4	3.08	0.50	225.38	3.25	228.63
32G2	85.23	12.88	S2, S3	1.35	0.13	114.80	1.74	116.54	S2, S4	3.08	0.50	262.74	6.49	269.23
32G3	99.07	19.32	S2, S3	1.35	0.13	133.44	2.60	136.04	S2, S4	3.08	0.50	305.40	9.73	315.13

Ground-controlled Approach, continued

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07G1	59.45	52.02	S2, S3	2.43	0.24	144.23	12.62	156.85	S2, S4	5.50	0.90	326.98	46.76	373.74
07G2	71.53	40.06	S2, S3	2.43	0.24	173.52	9.72	183.24	S2, S4	5.50	0.90	393.39	36.01	429.40
07G3	80.99	53.66	S2, S3	2.43	0.24	196.48	13.02	209.50	S2, S4	5.50	0.90	445.43	48.23	493.67
14G1	98.14	0.00	S2, S3	2.43	0.24	238.10	0.00	238.10	S2, S4	5.50	0.90	539.79	0.00	539.79
14G2	137.95	0.00	S2, S3	2.43	0.24	334.66	0.00	334.66	S2, S4	5.50	0.90	758.72	0.00	758.72
14G3	160.02	6.45	S2, S3	2.43	0.24	388.22	1.57	389.78	S2, S4	5.50	0.90	880.13	5.80	885.93
25G1	51.20	36.42	S2, S3	2.43	0.24	124.22	8.83	133.05	S2, S4	5.50	0.90	281.61	32.73	314.34
25G2	64.77	46.07	S2, S3	2.43	0.24	157.13	11.18	168.30	S2, S4	5.50	0.90	356.23	41.40	397.63
25G3	55.06	55.59	S2, S3	2.43	0.24	133.58	13.49	147.06	S2, S4	5.50	0.90	302.83	49.96	352.79
32G1	73.11	6.44	S2, S3	2.43	0.24	177.36	1.56	178.93	S2, S4	5.50	0.90	402.10	5.79	407.89
32G2	85.23	12.88	S2, S3	2.43	0.24	206.76	3.13	209.88	S2, S4	5.50	0.90	468.75	11.58	480.32
32G3	99.07	19.32	S2, S3	2.43	0.24	240.33	4.69	245.02	S2, S4	5.50	0.90	544.86	17.36	562.22

Depart and Re-enter

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07PL	86.24	12.55	S2, S3	1.35	0.13	116.17	1.69	117.86	S2, S4	3.08	0.50	265.87	6.32	272.19
07PR	60.51	20.94	S2, S3	1.35	0.13	81.51	2.82	84.33	S2, S4	3.08	0.50	186.54	10.55	197.09
14PL	55.21	0.00	S2, S3	1.35	0.13	74.37	0.00	74.37	S2, S4	3.08	0.50	170.21	0.00	170.21
14PR	39.65	29.34	S2, S3	1.35	0.13	53.41	3.95	57.36	S2, S4	3.08	0.50	122.23	14.78	137.01
25PL	50.34	12.54	S2, S3	1.35	0.13	67.81	1.69	69.50	S2, S4	3.08	0.50	155.19	6.32	161.51
25PR	63.95	20.94	S2, S3	1.35	0.13	86.14	2.82	88.96	S2, S4	3.08	0.50	197.14	10.55	207.69
32PL	44.59	29.34	S3	0.49	0.05	21.95	1.44	23.40	S2	3.08	0.50	137.47	14.78	152.25
32PR	60.16	0.00	S2, S3	1.35	0.13	81.03	0.00	81.03	S2, S4	3.08	0.50	185.45	0.00	185.45

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07PL	86.24	12.55	S2, S3	2.43	0.24	209.22	3.04	212.26	S2, S4	5.50	0.90	474.33	11.28	485.60
07PR	60.51	20.94	S2, S3	2.43	0.24	146.79	5.08	151.88	S2, S4	5.50	0.90	332.80	18.82	351.62
14PL	55.21	0.00	S2, S3	2.43	0.24	133.95	0.00	133.95	S2, S4	5.50	0.90	303.68	0.00	303.68
14PR	39.65	29.34	S2, S3	2.43	0.24	96.19	7.12	103.31	S2, S4	5.50	0.90	218.07	26.37	244.44
25PL	50.34	12.54	S2, S3	2.43	0.24	122.13	3.04	125.17	S2, S4	5.50	0.90	276.87	11.27	288.15
25PR	63.95	20.94	S2, S3	2.43	0.24	155.14	5.08	160.22	S2, S4	5.50	0.90	351.72	18.82	370.54
32PL	44.59	29.34	S3	2.02	0.20	90.12	5.93	96.05	S2	5.50	0.90	245.25	26.37	271.62
32PR	60.16	0.00	S2, S3	2.43	0.24	145.94	0.00	145.94	S2, S4	5.50	0.90	330.86	0.00	330.86

Field Carrier Landing Practice at OLF Coupeville

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
14FCP1	22.75	0.00	S2	1.35	0.13	30.64	0.00	30.64	S2	3.08	0.50	70.13	0.00	70.13
14FCP2	22.75	0.00	S2	1.35	0.13	30.64	0.00	30.64	S2	3.08	0.50	70.13	0.00	70.13
14FCP3	22.75	0.00	S2	1.35	0.13	30.64	0.00	30.64	S2	3.08	0.50	70.13	0.00	70.13
32FCP1	9.88	0.00	S3	0.49	0.05	4.86	0.00	4.86	S4	0.90	0.38	8.94	0.00	8.94
32FCP2	9.88	0.00	S3	0.49	0.05	4.86	0.00	4.86	S4	0.90	0.38	8.94	0.00	8.94
32FCP3	9.88	0.00	S3	0.49	0.05	4.86	0.00	4.86	S4	0.90	0.38	8.94	0.00	8.94

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
14FCP1	22.75	0.00	S2	2.43	0.24	55.19	0.00	55.19	S2	5.50	0.90	125.12	0.00	125.12
14FCP2	22.75	0.00	S2	2.43	0.24	55.19	0.00	55.19	S2	5.50	0.90	125.12	0.00	125.12
14FCP3	22.75	0.00	S2	2.43	0.24	55.19	0.00	55.19	S2	5.50	0.90	125.12	0.00	125.12
32FCP1	9.88	0.00	S3	2.02	0.20	19.97	0.00	19.97	S4	1.07	0.45	10.57	0.00	10.57
32FCP2	9.88	0.00	S3	2.02	0.20	19.97	0.00	19.97	S4	1.07	0.45	10.57	0.00	10.57
32FCP3	9.88	0.00	S3	2.02	0.20	19.97	0.00	19.97	S4	1.07	0.45	10.57	0.00	10.57

Interfacility Flights – Ault Field to OLF Coupeville

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07WC14P	53.61	8.71	S2, S3	1.35	0.13	72.21	1.17	73.38	S4	0.90	0.38	48.50	3.33	51.83
07WC32P	104.61	8.71	S1, S2, S3	2.84	0.15	297.55	1.30	298.86	S2, S4	3.08	0.50	322.50	4.39	326.89
14WC14P	31.51	8.70	S2	1.35	0.13	42.44	1.17	43.61	S4	0.90	0.38	28.50	3.33	31.83
14WC32P	82.52	8.71	S2, S3	1.35	0.13	111.15	1.17	112.32	S2, S4	3.08	0.50	254.38	4.39	258.77
25WC14P	61.67	14.74	S2, S3	1.35	0.13	83.07	1.99	85.05	S2, S4	3.08	0.50	190.11	7.43	197.54
25WC32P	112.68	14.75	S1, S2, S3	2.84	0.15	320.49	2.21	322.70	S2	3.08	0.50	347.37	7.43	354.80
32WC14P	67.56	20.63	S2, S3	1.35	0.13	91.00	2.78	93.78	S2, S4	3.08	0.50	208.26	10.39	218.65
32WC32P	118.57	20.63	S3	0.49	0.05	58.37	1.02	59.39	S4	0.90	0.38	107.26	7.90	115.16

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
07WC14P	53.61	8.71	S2, S3	2.43	0.24	130.05	2.11	73.38	S4	1.07	0.45	48.50	3.33	51.83
07WC32P	104.61	8.71	S1, S2, S3	2.50	0.24	261.64	2.11	298.86	S2, S4	5.50	0.90	322.50	4.39	326.89
14WC14P	31.51	8.70	S2	2.43	0.24	76.44	2.11	43.61	S4	1.07	0.45	28.50	3.33	31.83
14WC32P	82.52	8.71	S2, S3	2.43	0.24	200.18	2.11	112.32	S2, S4	5.50	0.90	254.38	4.39	258.77
25WC14P	61.67	14.74	S2, S3	2.43	0.24	149.61	3.58	85.05	S2, S4	5.50	0.90	190.11	7.43	197.54
25WC32P	112.68	14.75	S1, S2, S3	2.50	0.24	281.81	3.58	322.70	S2	5.50	0.90	347.37	7.43	354.80
32WC14P	67.56	20.63	S2, S3	2.43	0.24	163.89	5.00	93.78	S2, S4	5.50	0.90	208.26	10.39	218.65
32WC32P	118.57	20.63	S3	2.02	0.20	239.62	4.17	59.39	S4	1.07	0.45	107.26	7.90	115.16

Interfacility Flights – OLF Coupeville to Ault Field

Exposure per flight track at average marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
14CW07	88.35	10.89	S1, S2, S3	2.84	0.15	251.29	1.63	252.92	S2	3.08	0.50	272.36	5.49	277.84
14CW14	94.52	20.63	S1, S2, S3	2.84	0.15	268.85	3.09	271.93	S2	3.08	0.50	291.39	10.39	301.78
14CW25	76.67	5.81	S2, S3	1.35	0.13	103.28	0.78	104.06	S2, S4	3.08	0.50	236.38	2.93	239.30
14CW32	25.42	17.41	S2, S3	1.35	0.13	34.24	2.34	36.58	S2, S4	3.08	0.50	78.37	8.77	87.13
32CW07	63.13	10.89	S2, S3	1.35	0.13	85.03	1.47	86.50	S2, S4	3.08	0.50	194.61	5.49	200.10
32CW14	79.94	10.89	S2, S3	1.35	0.13	107.68	1.47	109.14	S2, S4	3.08	0.50	246.43	5.49	251.92
32CW25	60.60	5.81	S2, S3	1.35	0.13	81.63	0.78	82.41	S2, S4	3.08	0.50	186.81	2.93	189.74
32CW32	70.78	17.41	S1, S2, S3	2.84	0.15	201.32	2.61	203.92	S2, S4	3.08	0.50	218.20	8.77	226.97

Exposure per flight track at high marbled murrelet densities

Flight Track	Nearshore exposure area (km^2)	Offshore exposure area (km^2)	Breeding season strata (NWFPEM)	Breeding season nearshore density (birds/ km^2)	Breeding season offshore density (birds/ km^2)	Breeding season # birds exposed nearshore	Breeding season # birds exposed offshore	Breeding season total # birds exposed	Non-breeding season strata (WDFW-Navy)	Non-breeding season nearshore density (birds/ km^2)	Non-breeding season offshore density (birds/ km^2)	Non-breeding season # birds exposed nearshore	Non-breeding season # birds exposed offshore	Non-breeding season total # birds exposed
14CW07	88.35	10.89	S1, S2, S3	2.43	0.24	130.05	2.11	132.16	S2	1.07	0.45	57.36	3.94	61.30
14CW14	94.52	20.63	S1, S2, S3	2.50	0.24	261.64	2.11	263.75	S2	5.50	0.90	575.37	7.83	583.20
14CW25	76.67	5.81	S2, S3	2.43	0.24	76.44	2.11	78.55	S2, S4	1.07	0.45	33.71	3.94	37.65
14CW32	25.42	17.41	S2, S3	2.43	0.24	200.18	2.11	202.30	S2, S4	5.50	0.90	453.84	7.83	461.67
32CW07	63.13	10.89	S2, S3	2.43	0.24	149.61	3.58	153.18	S2, S4	5.50	0.90	339.18	13.25	352.42
32CW14	79.94	10.89	S2, S3	2.50	0.24	281.81	3.58	285.38	S2, S4	5.50	0.90	619.73	13.25	632.98
32CW25	60.60	5.81	S2, S3	2.43	0.24	163.89	5.00	168.89	S2, S4	5.50	0.90	371.56	18.54	390.10
32CW32	70.78	17.41	S1, S2, S3	2.02	0.20	239.62	4.17	243.79	S2, S4	1.07	0.45	126.86	9.34	136.21

All Operations - Synthesis

Type of Operation	Average Year, Average Marbled Murrelet Density						High Tempo Year, High Marbled Murrelet Density					
	Annual Weighting			Seasonal Weighting			Annual Weighting			Seasonal Weighting		
	Breeding season exposure	Non-breeding season exposure	Total exposure	Breeding season exposure	Non-breeding season exposure	Total exposure	Breeding season exposure	Non-breeding season exposure	Total exposure	Breeding season exposure	Non-breeding season exposure	Total exposure
Arrivals and departures												
Departures	459,673	682,804	1,142,477	75,025	772,464	847,489	1,016,068	1,030,511	2,046,578	305,735	1,000,981	1,306,716
Straight-in/ full-stop arrivals	176,142	239,681	415,824	228,337	319,186	547,523	323,573	379,269	702,842	411,386	569,022	980,408
Overhead break arrivals	200,700	262,108	462,808	152,086	286,093	438,179	499,701	357,170	856,871	545,017	431,455	976,471
Instrument approach arrivals	9,489	20,783	30,272	4,646	33,029	37,675	22,532	33,912	56,444	18,907	57,814	76,721
Pattern operations (except FCLP)												
Touch-and-go	13,346	26,584	39,931	7,484	39,417	46,901	56,181	32,244	88,425	31,507	47,806	79,313
Ground-controlled approach	369,252	865,888	1,235,140	279,607	1,063,784	1,343,391	689,067	1,600,628	2,289,695	521,816	1,966,362	2,488,178
Depart and re-enter	75,245	177,033	252,278	76,441	175,961	252,402	136,206	315,022	451,228	137,316	313,115	450,431
Total exposures to arrivals, departures, and non-FCLP patterns	*1,303,848*	*2,274,883*	*3,578,730*	*823,626*	*2,689,935*	*3,513,561*	*2,743,328*	*3,748,756*	*6,492,084*	*1,971,683*	*4,386,555*	*6,358,238*
FCLP evolutions												
Ault Field	279	564	843	162	825	986	1,237	720	1,958	717	1,053	1,771
OLF Coupeville	3,025	6,536	9,561	3,025	6,536	9,561	8,177	11,796	19,972	8,177	11,796	19,972
Total exposures to FCLP evolutions	*3,304*	*7,100*	*10,404*	*3,187*	*7,361*	*10,547*	*9,414*	*12,516*	*21,930*	*8,894*	*12,849*	*21,743*
Interfacility flights (groups of three)												
Ault to Coupeville	57,028	73,057	130,085	73,217	62,941	136,158	65,947	142,850	208,797	73,983	122,475	196,458
Coupeville to Ault	31,802	57,461	89,263	27,214	63,811	91,025	49,693	112,814	162,507	44,203	125,273	169,476
Total exposures to interfacility flights	*88,830*	*130,518*	*219,348*	*100,431*	*126,752*	*227,183*	*115,639*	*255,664*	*371,304*	*118,186*	*247,748*	*365,934*

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