Lauren M. Kuehne
School of Aquatic and Fishery Sciences
University of Washington, Seattle WA 98195
Phone: 206-685-9582, E-mail: lkuehne@uw.edu

Following are comments of Lauren Kuehne, an ecologist and research scientist within the University of Washington's College of the Environment. I am an aquatic ecologist by training, but my research experience includes diverse evaluations of human impacts in environmental and socio-ecological systems. I have conducted and been part of professional monitoring and research efforts on the Olympic Peninsula periodically since 2007. Most recently and relevant to the NWTT Draft Supplemental Environmental Impact Statement, one of these efforts was a one-year monitoring project during 2017-2018 which used passive acoustic monitoring to evaluate the impact of military aircraft on the soundscape of the Olympic Peninsula. I am also currently in the process of initiating a new large-scale project on the Peninsula in 2020 using passive acoustic monitoring to evaluate sustainable forest management practices. As such, I have substantial professional knowledge about the wildlife of the Olympic Peninsula region, the Olympic National Park, and the residential communities in the region. My resume is attached in the mailed hard copy of these comments for reference.

Definitions:
For clarity and consistency, I use the following abbreviations that are referenced frequently within these comments:

- DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT/ OVERSEAS ENVIRONMENTAL IMPACT STATEMENT for NORTHWEST TRAINING AND TESTING ("the DSEIS")
- Appendix J: Airspace Noise Analysis for the Olympic Military Operations Areas ("Appendix J" or "Noise Modeling Analysis")
- Olympic Military Operations Area ("MOAs")
- Naval Air Station Whidbey Island ("NASWI")
- Boeing EA-18G Aircraft ("Growler" or "Growler jet")
- Report titled *Impact of military flights on Olympic Peninsula Soundscapes,* Final Report dated 11 June 2019 ("L. Kuehne, Final Report, 11 June 2019")

Background to comments:
Many of my comments on the DSEIS focus on the Noise Modeling Analysis, to which the year-long soundscape monitoring study that I conducted is directly related. I have attached a Final Report (L. Kuehne, Final Report, 11 June 2019) from those data, which are also being prepared for submission to a peer-reviewed journal. This report represents a large portion of the information that is available from the study that I conducted in 2017- 2018, but there are still many analyses that could be done from these data to provide context for the DSEIS. I requested an extension of the public comment period from the Navy on May 28, 2019 for this purpose (request letter attached in the mailed hard copy of these

comments). Although I received a rather cryptic reply about 10 days later requesting my research "methods and results", to which I provided a copy of the Initial Summary of Findings (email exchange attached in the mailed hard copy of these comments), I have to date received no answer with respect to my request for an extension of the public comment period. As a result, my comments on the DSEIS and Noise Modeling Analysis are less complete than would be possible if the extension had been granted to conduct and finalize additional analyses. Nonetheless, the results of my study – along with other research - document substantial inadequacies and deficiencies in the Noise Modeling Analysis that prevent any practical assessment of noise impacts as they are experienced by people and wildlife. This, in turn, makes it impossible to evaluate impacts and potential detriment to valued cultural and socioeconomic resources. I have grouped my comments under two broad categories (I. Evaluating Impacts from Noise Metrics, and II. Modeling Deficiencies) with 6 sub-headings.

I. Inability to Evaluate Impacts from Noise Metrics

a. Inadequacy in providing metrics that allow evaluation of impact on residents and visitors

The Noise Modeling Analysis creates only two acoustic metrics with which impacts on people can be evaluated. The first of these is the L_{dn} or average of the sound exposure over an "average" 24-hour period (the average potentially being obtained over a very long period such as an entire year) with a penalty for nighttime noise. The L_{dn} can provide some very basic assessment of average noise levels over a time period, but is nearly useless as an indicator of noise impacts because it bears no relationship whatsoever to noise as experienced by people. This is particularly true when the flight events bear more resemblance to periodic, implusive events as opposed to more consistent levels of noise (e.g., in areas surrounding a commercial airport). Furthermore, the L_{dn} is highly inappropriate in wilderness areas, because the noise impacts will be **offset by a quiet ambient sound level**; in this way, the very noise impacts that will be perceived as more intrusive (Mace et al. 2004, attached in the mailed hard copy of these comments) will be measured as less intrusive.

The only other metric provided is a duration and probability of experiencing the most extreme events (the L_{max}), which will be limited to if a person happens to be directly under a flight event that is flying at the absolute lowest altitude. This probability is further averaged across the entire geographic space of the MOAs (Table J-13). Based on the metrics in the Noise Modeling Analysis, impact on people is available to be assessed as either a function of a L_{dn} metric that is never actually experienced (nor readily monitored due to perpetually confounding influences on sound pressure levels like weather), or as the likelihood of happening to experience the absolute maximum noise level. No other impacts on people can be assessed with these two metrics, and the inadequacy of using these to evaluate impact of military overflight events on residents and visitors cannot be overstated.

People do not experience noise from aircraft events as a 24-hour average with a 10dB penalty at night. People experience noise exposure as a function of frequency of events (i.e., number of disruptions), duration (length of time of exposure), loudness (i.e., dB or dB(A)), and the cumulative exposure that is a function of these interacting factors. People also experience these factors more acutely depending on the expected levels and frequency of noise, particularly in wilderness areas (Mace et al. 2004). There are numerous acoustic metrics that facilitate assessment of impacts on human health and well-being, many of which are mentioned in the DSEIS (e.g., percent time audible, exceedance or time above certain dB or dB(A) thresholds), and no one metric allows evaluation of all impacts. At a minimum, the Noise Modeling Analysis should produce metrics that related to known levels of noise disturbance resulting in impacts on human health (Smith and Pijanowski 2014, Fox and Morris 2017, attached in the mailed hard copy of these comments). These health impacts include impairments in concentration, memory, cognition, and mental health status when noise levels reach 40 - 55 dB(A) and serious cardiovascular health effects of hypertension, stroke, and risk of ischemic heart disease associated with levels above 55 dB(A) (Smith and Pijanowski 2014, Basner et al. 2017, attached in the mailed hard copy of these comments). Number of overflight events and duration of time above these exceedance thresholds would be much better indicators of the impacts on people, particularly residents that will experience more consistent exposures to overflights.

For assessing impact on visitors to wilderness areas, metrics of percent time audible (L. Kuehne, Final Report, 11 June 2019; also described in Appendix J) and exceedance thresholds (described on p. J-27 in the Noise Modeling Analysis) are good indicators of the extent to which visitors in wilderness areas are likely to be impacted. To these metrics, I would also add the utility of the number of flight events (L. Kuehne, Final Report, 11 June 2019) as an indicator of the number of disruptive events a person in a location is likely to experience. This metric allows for an estimate of the number of potential disturbance or interruptive events a person may experience while doing activities like recreating, working, learning, sleeping, etc.

b. Failure to provide noise metrics that allow evaluation of impacts on wildlife

The inadequacy of the two metrics in the Noise Modeling Analysis described above for people is compounded when trying to assess impacts of noise disturbance from military overflights on wildlife. For one thing, the dB(A) scale used in the Noise Modeling Analysis emphasizes the 1-4 kHz frequencies that human ears interpret most readily, and de-emphasizes acoustic information below 1 kHz. Despite an overall paucity of information related to noise disturbance impacts on wildlife (Shannon et al. 2016, attached in the mailed hard copy of these comments), many species of wildlife are known to detect and respond to sounds below 1 kHz (i.e., "infrasound", Beason 2004, attached in the mailed hard copy of these comments). In fact, some species of birds are highly sensitive to noise in this range and have been shown to exhibit "behavioral and physiological responses to these low frequencies" (Beason 2004). Critical components of acoustic metrics with relevance for wildlife include time interval, duration, frequency components, noise level or sound pressure levels, acuteness or how acutely events are perceived, and contrast with background or ambient sound levels (McKenna et al. 2016, Gill et al. 2014, attached in the mailed hard copy of these comments). These combined acoustic metrics allow for assessment of a diverse range of potential impacts of noise on wildlife, which can include damage to auditory organs and receptors due to excessive or cumulative exposure to noise, masking of critical animal communication systems, and disturbance during crucial activities such as feeding or protecting young (Shannon et al. 2016, McKenna et al. 2016, Beason 2004).

For this reason, the Noise Modeling Analysis at a minimum needs to include metrics that allow assessment of acoustic disturbance relevant to specific species (i.e., species listed under the Endanged Species Act, species with substantial cultural or socio-economic significance) and/or commercially, culturally or socially important species groups (e.g., owls, ungulates, salmon). For the Olympic Peninsula, these include ESA-listed marbled murrelet, northern spotted-owl, orca or killer whales, bull trout, Chinook and sockeye salmon (Figure 8, L. Kuehne, Final Report, 11 June 2019). Other commercially and culturally important species-groups include salmon, grey whales, owls, Olympic marmot, Roosevelt elk, and numerous bird species that live and migrate through the Olympic Peninsula region. Residents and visitors alike highly value the wildlife experiences in the region, making the impacts on wildlife critical to assess adequately not only for the impacts on wildlife populations *per se,* but for their corresponding implications for socio-economic activities related to healthy wildlife populations (e.g., impacts on tourist activities like birding or fishing).

c. Failure to provide noise metrics that allow evaluation of impact on socio-economic resources

Basically, people enjoy living in and visiting quiet places, and this experience is degraded by noise (Mace et al. 2004). The impacts of noise on property values have been well established and measured in multiple settings, and reviewed previously (e.g., Navrud 2004, attached in the mailed hard copy of these comments). In recreational areas, noise intrusion has been shown to affect enjoyment to the extent that the impact can be economically measured (Merchan et al. 2014, attached in the mailed hard copy of these comments). In wilderness areas, the effects of noise disturbance are experienced more profoundly precisely because of the expectation of quiet (Mace et al. 2004). All of these effects are already being experienced and almost certain to increase in the future for residents and visitors of the Olympic Peninsula region and the Olympic National Park under the proposed increases in aircraft activity in the DSEIS. Valued recreational activities that are highly dependent on quiet such as camping, birdwatching, fishing, and backpacking are all compromised by noise. Residents that have reasonable expectations of quiet based on distance from urban areas are already exposed to consistently high percent time audible for military aircraft (L. Kuehne, Final Report, 11 June 2016). Over time, accumulated annoyance of residents and visitors may well lead to losses in economic opportunities associated with reduced tourism and business/property values.

However, as currently presented in the DSEIS, there is no way that these impacts (largely contained in Section 3.12.3.2.1.1) can currently be evaluated using the metrics presented in the Noise Modeling Analysis. As noted in my comment Sections I(a) and I(b), the lack of metrics that are relevant to assess effects on people's health, well-being, and enjoyment allows no path to describe the impacts on resulting socio-economic resources such as lifestyle, tourism, and cultural values. As demonstrated below in comment Section II, Modeling Deficiencies do not capture the geographic and temporal extent of current impacts.

Collectively, these deficiencies preclude adequate evaluation of socio-economic consequences, which are often sweepingly described in DSEIS Section 3.12.3.2.1.1. For example, Section 3.12.3.2.1.1 states "While airborne acoustics from aircraft overflights are likely to be heard and may disturb some visitors to the national park, economic indicators representing tourism and recreational activities in the region, including in the national park, have been trending upwards in recent years and are projected to continue to increase". It does not follow that because tourism has been on an upswing for a while that the trend cannot be interrupted or terminated due to excessive noise or disturbance. Rather, visitors may be drawn to a landscape because it is traditionally or reportedly quiet, and leave irritated. Similarly, Section 3.12.3.2.1.1 states, "Although noise from overflights during transit could be higher than average background noise levels in the national park, national forest, and wilderness areas, on average they would not be substantially above the range of commonly heard natural sounds in the national park or nearby areas". This assessment of "impact" completely ignores that people distinguish qualities and characteristics of natural and human sounds, particularly in wilderness areas (Mace et al. 2004). One further example is the statement "From 2015 through 2017, the average annual number of Navy EA-18G aircraft transits to and from the Olympic MOAs was 2,224. Under Alternative 1, EA-18G transits to and from the Olympic MOAs are proposed to increase by 300 per year. This proposed increase equates to, on average, less than one additional transit per day over a calendar year". The impact of the increased transit flights (which are of negligible duration or "NA" in Appendix J Table J-7) is assessed in this fairly straightforward way that includes frequency of events and duration. However, comparable assessment is missing for the **62% proposed increase** in electronic warfare training (with an average duration of **90 minutes/aircraft**). Rather than pull apart 3.12.3.2.1.1 line by line, I will conclude this section by reiterating that lack of relevant noise metrics for people and wildlife can only result in weak and inconsequential assessments of impact on socioeconomic resources.

II. Modeling Deficiencies

a. Incomplete description of aircraft engine variant used in modeling

The Noise Modeling Analysis specifies that the "loudest available variants" of the F-15 and P-8A aircraft were used for noise modeling, but does not specify which engine variant is used for the EA-18G. Since the proposed increases in Aircraft/Year for the EA-18G comprise 56% of all proposed increases for the combined Olympic A&B and W-237 A&B regions, and **98% of the proposed increases** for the Olympic A&B (where most of the noise impacts are experienced) (Tables J-3 to J-10, Appendix J), this represents a critical omission. The "enhanced" F414-GE-400 engine for the EA-18G is reportedly capable of twice the horsepower and 18% greater thrust (see news articles attached in the mailed hard copy of these comments regarding notification of the contract to General Electric for enhanced F414-GE-400 engines). The Noise Modeling Analysis should be based on this louder variant, unless the Navy can establish that enhanced engines will not be used in the EA-18G fleet at NASWI.

b. Inappropriate spatial and temporal averaging of noise impacts

The Noise Modeling Analysis using the software program NoiseMap did not actually produce any noise maps, which would create noise impact contours that could be evaluated spatially. As a result, the only spatial information that is provided in Appendix J is limited to the model inputs that state "the aircraft events are uniformly distributed throughout the SUA within the 3 NM offset with a diminishing distribution from the offset to the SUA boundary". As documented in (L. Kuehne, Final Report, 11 June 2019), based on year-long monitoring at three locations within or just adjacent to the MOAs, noise impacts may be correlated but are not equally experienced across locations (Table 1, Figure 7), indicating that there are "hotspots" where activity is concentrated. This may be due to operational features and constraints (e.g., Entry/Exit points, positions of electronic warfare transmitters, which are limited to specific locations) that results in common or emphasized flight paths. Given that available evidence indicates unevenness of impacts across the MOAs, the Navy should create actual noise maps that incorporate flight paths and emphasized routes. The Navy should also conduct noise monitoring across a broad geographic range both within and outside of the MOAs to evaluate spatial concentration of noise impacts. Results from this type of monitoring could be used to help mitigate realized impacts and refine the noise modeling to account for emphasized flight paths.

A second key result from (L. Kuehne, Final Report, 11 June 2019) is that impacts of military aircraft are strongly concentrated between the hours of 9 AM and 5 PM. The Noise Modeling Analysis reduces this effect by only considering and reporting on "daytime" as the very large range between 7 AM and 10 PM, during which period 94-99% of the EA-18G Aircraft/Year are reportedly active (Appendix J Table J-3). One reason for delineating daytime in this way is made clear for the purposes of adding a 10dB penalty to nighttime events and calculating a 24-hr DNL. However, this very limited division between daytime and nighttime obscures the fact that nearly ¾ (74%) of military flights were documented between 9AM and 5PM, with the majority of the remainder (19%) documented between 5PM and 10PM (leaving 5% between 10PM-7AM, and 2% between 7AM – 9AM). This results in an intense temporal concentration of all noise impacts, which show strong peaks in the middle of the day (Figure 6, L. Kuehne, Final Report, 11 June 2019), where percent time audible in some location-date-hours exceeded 80%. Given that the Proposed Training Missions for the EA-18G (Appendix J Table J-7) show Aircraft/Year increases on the orders of 13% (Entry/Exit, Air-to-Air) - 62% (Electronic Warfare Close Air Support), but without changes in the Day/Night percentages, it is reasonable to assume that 1) percent time audible will increase by ~13-62% uniformly across current hours, retaining the strong temporal concentration during certain portions of the day and/or 2) more flights will occur in the lesser-utilized hours of 5 PM-10 PM and/or 3) activity will occur on greater numbers of days (i.e., weekends) during the year. The ~13-62% increases in activity will have to be "fit in" somewhere. Regardless of the actual planned scenario, based on patterns from the monitoring data, the current division into only two daily time periods and use of the 24-hr DNL do not reflect strong temporal concentration of aircraft activity. This makes impossible any real evaluation of impacts of noise on people, wildlife, and socio-economic and cultural resources. Some possibilities for expanding the Noise Modeling Analysis to better reflect temporal concentration include: a) modeling the distribution of noise impacts across each hour of the day (e.g., Figure 6, L. Kuehne, Final Report 11 June 2019), b) conducting on-the-ground monitoring that establishes those distributions across the MOAs, c) modeling and reporting on smaller temporal time periods that correspond to peoples' schedules, such as mornings, school or work periods, evenings, sleeping periods. The latter would need to reflect schedules that are relevant for both residents and visitors (e.g., campers and backpackers) to the area.

c. Incomplete modeling that downplays and disregards impacted areas

The modeling and conclusions also imply that noise impacts will not extend beyond the SUA boundary; again, the model inputs "events are uniformly distributed throughout the SUA within the 3 NM offset with a diminishing distribution from the offset to the SUA boundary." is the only information that references the overall acoustic footprint from activities in the MOA. However, as the data in (L. Kuehne, Final Report, 11 June 2019) clearly show, one of the monitored locations in that study that is 1.8 km (1 NM) outside of the MOA boundary experiences ***an average of*** 6-14% time audible for military aircraft between the hours of 9 AM and 5 PM. These averages were obtained over 40 days of sampling (in four 10-day periods), which means that percent time audible was substantially higher within sampling periods and on specific days. For example, out of the 185 date-hours when monitoring detected military aircraft at this location, 114 (or 62%) exceeded 10% time audible for that hour, and 19/185 date-hours exceeded 50% time audible for that hour. To achieve these consistent noise levels outside of the MOAs boundary despite a 3 NM offset (Appendix J, p. J-24 "The highest terrain beneath the Olympic MOAs is found at the eastern most border of the MOAs, where aircraft presence is unlikely due to the 3 NM offset used by aircrew to avoid accidentally spilling out of the airspace") means that *1)* either pilots are consistently in the offset and operating much closer to the boundary than is assumed in the modeling and/or *2)* that the acoustic footprint or detection range of Growler jets is ***at least*** 4 NM**.** Anecdotal evidence from people that live in the area around NASWI suggests that – depending on weather conditions – Growler jets are audible at a range of at least 8-9 NM, which is consistent with the frequency of events and percent time audible recorded at the Hoh River Trail location (L. Kuehne, Final Report, 11 June 2019). Modeling the noise impacts based on the actual audible range and based on likely frequency of events – including transit or Entry/Exit events - will certainly extend the total acoustic footprint from activity within the MOAs. However, this is the only way in which an actual assessment of the geographic extent and impacts on corresponding socio-economic and cultural resources (e.g., Olympic National Park) can be done. Again, conducting noise monitoring vs. only doing modeling will also allow assessment of realized impacts on the landscape, and ability to mitigate or minimize those impacts by adjusting operations.

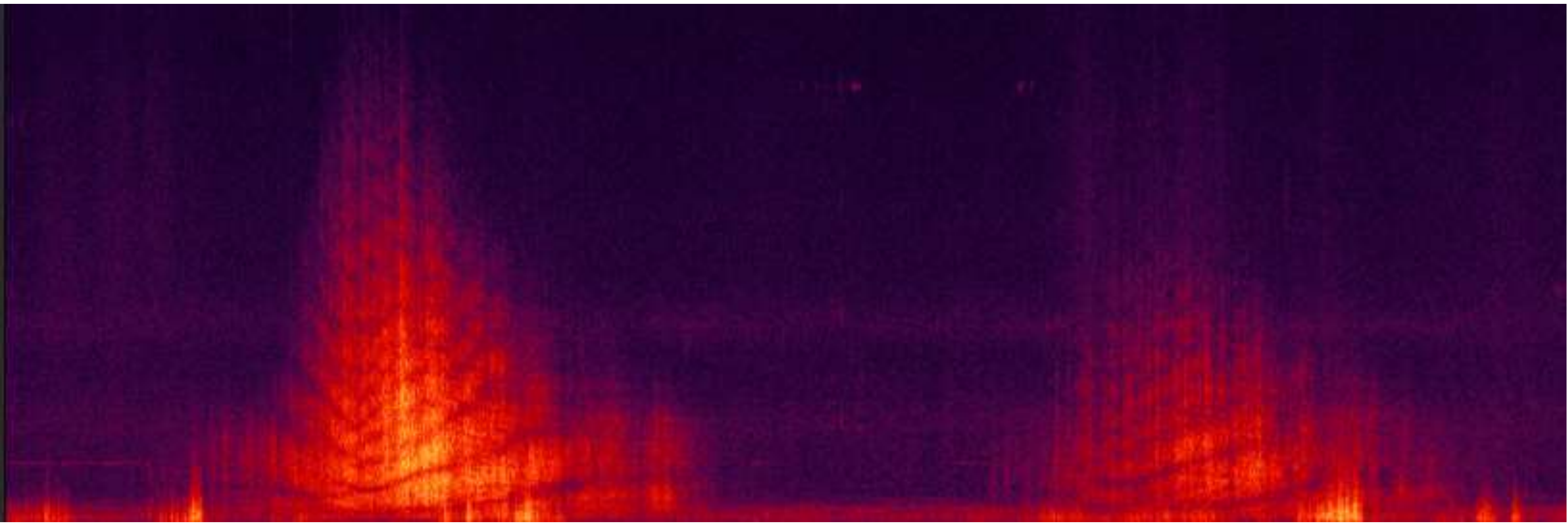
Conclusions/Implications:

The modeling and metrics presented in the Noise Modeling Analysis in the DSEIS are highly inadequate to evaluate the impact of Growler jets on people living in and around the MOAs and/or underneath transit routes to and from the MOAs from NASWI. The metrics bear little to no relevance to how noise is experienced by people and wildlife, offering little basis for the subsequent conclusions of minimal or negligible impact to socio-economic and ecological resources (Section 3.12.3.2.1.1). The modeling downplays or disregards impacted areas, does not model noise in areas where it is clearly occurring, and ignores the existence and implications of spatio-temporal concentrations of noise impacts. This modeling and analysis should be updated to produce noise maps and metrics that are relevant to assessing impact on people and wildlife, as well as incorporating detailed information from existing acoustic monitoring data. Noise monitoring by independent parties should be conducted over a broad geographic area to evaluate realized impacts. The feasibility and utility of conducting this type of monitoring to inform environmental impacts of aircraft is exemplified in (L. Kuehne, Final Report, 11 June 2019) as well as the 2010-2011 Acoustic Monitoring Report by the National Park Service (described on pages J-26 and J-27 of the Appendix J).

These comments were submitted (with all attachments) via certified US Postal Service Mail on June 12th, 2019. The comments were also submitted (with only the file titled L. Kuehne, Final Report, 11 June 2019 to accommodate the 1 MB file upload limit) using the online form. I would like to note that the 1 MB file upload limit is highly restrictive and causes unnecessary burden on those participating in the public comment process.

Lauren Kuehne
Research Scientist
University of Washington

Impact of military flights on Olympic Peninsula soundscapes



Final Report

June 11, 2019

Lauren Kuehne, MSc
Research Scientist

University of Washington's College of the Environment
School of Aquatic and Fishery Sciences
1122 NE Boat Street
Seattle, WA 98105

Executive Summary

Military activity over the Olympic Peninsula has been undergoing transition over the past decade due to changes in aircraft used and operations from nearby facilities, resulting in reported increases in overall duration and levels of noise experienced by residents and tourists. Operations are slated to increase in the future, and are currently being evaluated as part of an Environmental Impact Statement under NEPA. However, given the lack of any on-the-ground monitoring that can establish current levels of noise experience on the Peninsula, evaluation of impacts on people and wildlife are difficult if not impossible to assess. The objectives of this study were to conduct monitoring and collect acoustic data to provide that baseline data, calculate metrics that could begin to establish current contributions of military aircraft on the soundscape, and provide context to evaluate proposed increases. We collected and analyzed 10 days of audio data in four seasons at three locations (120 location-days in total) on the west side of the Olympic Peninsula. Locations were within or just adjacent to the Olympic Military Operations Area (MOA).

We determined that 85% of all audible air traffic was military, suggesting that changes in military operations will play a dominant role in dictating the future soundscape of the region. Percent time audible varied by location, but all sites exhibited strong peaks during daytime hours when military activity was concentrated. Across all recording days, the percent time audible during daytime hours averaged 6-17% depending on the location and hour, but routinely approached or exceeded 20-25% within some sampling periods. Individual locations can experience large numbers of disturbance events associated with flight activity, with 80-100 events recorded in some locations on a single day. The impact of military aircraft on any given day and hour were correlated at the three locations across distances up to 51 km, indicating the broad geographic reach of operations. The location that was outside of the MOA experienced substantial noise (an average of 6-12% audible during daytime hours), indicating that the noise footprint extends well beyond the MOA and has the potential to impact a very large proportion of Olympic National Park as well as other areas outside of the MOA.

Importantly, in this study we also demonstrate the feasibility and utility of on-the-ground monitoring to advance practical soundscape management. By measuring the noise frequency and levels likely to be currently experienced, we establish a basis for inquiry into the specific nature of proposed increases in flight operations and how they will be realized on the landscape. This is the only way that the potential impacts and consequences of noise can be adequately assessed for people and wildlife, as well as providing a necessary basis for appropriate management of the soundscape as a common-pool resource that is integral to and integrated with other land use planning and goals.

Note on this report version: This Final Report, dated June 11, 2019, includes some updates to the Initial Summary of Findings that were prepared on June 4th, 2019 and made available on June 5th, 2019. This Final Report includes minor corrections to the Initial Summary, which were the ranges of percent time audible summarized in the Executive Summary and the Results sections from the data in Table 1. This version also includes the following additions: 1) clarification of how flight events that were partially discontinuous were delineated (Methods), 2) a comparison with the monitoring study conducted by the National Park Service in 2010-2011 (Discussion), 3) page numbers, 4) Acknowledgements section, 5) GIS software and sources of data layers (Figure captions). It should be noted that these data and results are currently being finalized for submission to a peer-reviewed journal.

Introduction

Military activity over the Olympic Peninsula has been undergoing transition over the past decade due to changes in operations and training for personnel out of the Naval Air Station Whidbey Island ("NASWI"). Although naval flights have been operating in the area for decades, the transition from Northrup Grumman EA-6B (aka "Prowler") to Boeing EA-18G ("Growler") aircraft in past years has been identified as a pivot point in the level of noise experienced by residents and visitors to the Olympic Peninsula. National consolidation of training for Growlers to NASWI and the recent addition of 36 Growler jets, increasing the fleet from 82 to 118 jets (Record of Decision for Growler Environmental Impact Statement, March 13, 2019) means that training flights will increase into the future. However, the nature of that increase – in terms of more days, hours, or numbers of jets operating simultaneously – and corresponding impacts on realized frequency and level of noise for the Peninsula is highly unclear.

The Olympic Peninsula is a historically, culturally, and ecologically unique place. Olympic National Park, which encompasses a large range of geologically significant and unique features (e.g., mountains, Lake Ozette, coastal beaches), receives more than 3 million visitors every year and has been designated as a World Heritage Site. Eight Native American Tribes call the Peninsula home, with strong historical and current connections and dependencies with wildlife (e.g., salmon, whales) for subsistence and culture. The geologic history of the region has supported creation of unique biota, with no less than 29 species or sub-species of mammal, birds, amphibians and fish that are found only on the Peninsula (1). Extensive historic swathes of large forests and unimpounded rivers with protected headwaters have also provided important landscapes and habitat for forest-dependent species, including multiple species listed under the US Endangered Species Act (ESA), and some of the healthiest salmon runs in the state.

The impacts of noise disturbance on wildlife are generally very poorly researched, although efforts have been increasing in recent years. The effects of noise on humans are better documented, but outdated (e.g., all EPA research related to noise disturbance ended in the mid-1970's) and geared almost exclusively toward extreme and persistent noise on human health (2, 3). Studies also tend to focus on urban areas (4–7), leaving the impacts of noise on wildlife and people in remote areas minimally investigated; however, as large-scale human use of landscapes (e.g., mining, air traffic, road noise) have become more prevalent and far-reaching, this area of research has become more prominent (8, 9). The science of "soundscapes" has emerged around the recognition that noise can be a critical form of disturbance for wildlife and people, and that the acoustic environment is part of and an indicator of the overall health of ecosystems (10).

A majority of the research related to noise and wildlife has recently been summarized by Shannon et al. 2016, which documents the diverse consequences of noise disturbance from 119 studies on birds, mammals, fish, reptiles and amphibians, and invertebrates. These documented impacts include: avoidance of noisy areas, changes in behavior, increased physiological stress, reduced reproductive success, declines in abundance and occupancy of sites, and changes in species communities and interactions. Research at community and ecosystem scales has demonstrated that noise disturbance can result in shifts in entire bird communities (11, 12) and even alter and disrupt ecosystem functions (13). Although studies that examine impacts on fitness (vs. behavior) of animal are rarer, at least four studies document reductions in breeding success of birds due to different types of noise disturbance (14–16). Notably, one is a recent and comprehensive field study that examined the impacts of simulated off-highway vehicle noise on endangered Northern spotted owls, and documented increased physiological stress levels and reduced fledging as a result of noise disturbance (17). As acoustically specialized predators, owls may be particularly vulnerable to noise interference on their ability to hunt (8). Similarly, ESA-listed marbled murrelet can be sensitive to disturbance by humans and transportation (18), although the impact of aircraft on murrelet has not been explicitly studied. Overall, research studies on military activity are less common than for industrial and transportation-associated noise (19), leaving large knowledge gaps in evaluating the impact of intermittent and periodically intense overflight events on wildlife.

Noise disturbance also has myriad effects on human health and well-being. As with wildlife, however, the majority of research into the effects of aircraft noise on human health has been for commercial vs. military aircraft. In a 2017 review of the health impacts associated with noise, the Washington State Department of Health noted the "paucity of published research on military aircraft noise" (20). The basis on which to estimate health consequences for military overflights, which differ from commercial aircraft in loudness, duration, and frequency, is therefore currently very poor. However, based on reviews of literature it is understood that negative health effects of unwanted noise begin to manifest (typically as annoyance and related stress responses) in humans when levels rise above 40 dB(A) (21). Concentration, memory, cognition, and mental health status can be impaired when noise levels reach 40 **-** 55 dB(A) (20–23). Levels above 55 dB(A) are associated with serious cardiovascular health effects, including hypertension, stroke, and risk of ischemic heart disease (20, 21). When noise is experienced in wilderness areas, perception and psychological effects of disturbance can be exacerbated based on the expectation of quiet (24, 25), as well as intermittence and lack of predictability of events (26). Vulnerability to detrimental impacts of noise is believed to vary across individuals and groups (e.g., higher impacts on children and elderly), but these relationships are only poorly documented at present (20).

As we enter the era of unprecedented human alteration of landscapes, protected and wilderness areas around the world are grappling with the challenge of managing acoustic environments that are integral to landscape uses by wildlife and people (9, 27). However, it is impossible to evaluate and manage the impact of something that is unmeasured. The goals of this study, therefore, were to establish baseline noise levels for the Olympic Peninsula by a dominant user of the soundscape, which is military aircraft. The study sought to answer two questions: *1)* What are the current noise levels and contributions of different aircraft on the Olympic Peninsula soundscape? and *2)* How might these levels change with proposed increases in military training and operations? Answering these questions will facilitate a realistic appraisal of potential impact to residential communities and wildlife, to better inform management and mitigation both now and in the future (28, 29).

Methods

Sites and Data Collection

Three locations on the west side of the Olympic Peninsula were selected for monitoring during 2017 and 2018: Third Beach (elevation 64 m), River Trail (199 m), and Hoh Watershed (28 m) (Figure 1). Third Beach and River Trail are within the Olympic National Park, and were also monitored in 2010 and 2011 as part of a soundscape inventory by the National Park Service (30). The Hoh Watershed site is adjacent to the National Park boundary near the southern region (i.e., Oil City). Third Beach and Hoh Watershed sites are within the Olympic Military Operations Area (the "MOA") (Figure 1); the River Trail site is located outside of the MOA, at a distance of 1.8 km from the nearest edge of the MOA boundary. Distances between the three sites are 22 km (Third Beach-Hoh Watershed), 40 km (Hoh Watershed-River Trail), and 51 km (Third Beach-River Trail).

Acoustic data was collected at each site using SongMeter recording units (Wildlife Acoustics, SM4 or SM2), which are well designed to capture a broad range of frequencies. Three recording units were deployed and scheduled to record simultaneously for a minimum of two-week periods in June 2017, September 2017, January 2018, and April 2018. Single-channel recording (sampling rate = 44.1 kHz) was used to maximize battery life and recording time, and batteries were changed as needed during the recording periods. Recording was continuous at all sites and periods with the exception of Hoh Watershed in the June 2017, September 2017, and January 2018 periods, where the recorder was scheduled to be off from 2 AM and 4 AM to extend battery life. Microphones were tested using a calibrator (Bruel & Kjaer, Model 4230) prior to deployment and on retrieval.

Data Processing and Analysis

From each recording period, 10 days of audio files were processed to identify and classify all aircraft activity that was audible at each location. The 10-day periods were: 6/22/2017-7/1/2017, 9/25/2017-10/4/2017, 1/1/2018-1/10/2018, and 4/22/2018-5/1/2018. Audio files were processed using the software program *Audacity*. The spectrogram of files was visually and auditorily inspected to identify any potential aircraft events. Once events were identified in a file, the start and end times were delineated by listening for the point at which the aircraft became audible and then disappeared relative to background noise. If flight activity was partially discontinuous (e.g., maneuvering that resulted in interspersed quiet and audibility), we considered an interval of 5-seconds of quiet to designate a new event. Events were then classified as "military", "commercial", and "propeller" (or "helicopter") by listening to the event until the listener was confident of the identification (Figure 2). If there was great uncertainty in identification, listeners could classify events using a first and second choice (e.g., "1-commercial" & "2-military"). Less than 1% (n=275) of all flight events were identified using a double classification, and the majority of those were evenly divided between "military-commercial" and "commercial-military". "Helicopters" could also be difficult to distinguish from "propeller", but were rare overall. About half of all audio files were initially processed by trained volunteers, and then validated by the project lead or a trained intern to ensure continuity in identification and delineation. The duration of all flight events was calculated along with the time of day, and assembled into a database for analysis of the number of flight events by sampling period, location, date, or hour of the day. The duration of types of different aircraft events was also calculated as the percent time audible (total duration in seconds/recording time in seconds).

Information from the weekly flight notification schedule (https://www.cnic.navy.mil/regions/cnrnw/installations/nas_whidbey_island/news/news_releases/field-carrier-landing-practice-at-nas-whidbey-island-complex-for.html) was summarized as an indication of flight operations activity from NASWI for comparison with recorded data. The flight notification schedule is of course not an official flight schedule. However, according to the NASWI Complex Growler FEIS, 83% of current operations at Ault Field are Growlers (Table 3-1.3); the flight notifications for Ault Field should be a reasonable indicator of when enhanced or elevated military aircraft activity can be expected in and around the Olympic MOA. The date, location (e.g., Ault Field), and Time Frame of operations was extracted from the weekly notifications for the one year period most closely corresponding to the year when recording was done (May 28, 2017 – May 27, 2018). The number of Time Frames reported were summarized for each day and location (e.g., "Night to Late Night" = 2 time frames), and the dataset was filtered to focus on activity for Ault Field.

Results

2,814 hours of audio files were processed from the three sites and four sampling periods; the difference from the number of continuous hours during that period (24 hrs*10 days*3 sites*4 periods) is due to no recording from 2-4 AM at the Hoh Watershed in three periods, and one equipment failure that led to loss of 6.5 hours of audio. All calculations of percent time audible were correspondingly corrected for actual recorded time.

Across all hours of recorded data, 4,644 flight events were identified. Of these, 85% were classified as military, 8% commercial, 6% propeller, and <1% were helicopters. As noted above, a very small number of events were classified with some uncertainty, but uncertainty was evenly balanced between different combinations. When calculated as the sum of duration (in seconds), percentages were nearly identical, reflecting the close correlation between number of flight events and total daily duration of time audible (R^2=0.93). Mean durations of different types of aircraft events were highly similar (range: 131-142 secs), although the variance was much higher for military flight events (min-max: 4–1400 secs) as compared with other aircraft event types (Figure 3).

For the one-year period from May 28, 2017 – May 27, 2018, flight notifications indicated activity on Ault Field on 118 days (Figure 4). Days where flight activity out of Ault Field was indicated overlapped with recording and processing days by 0.55, or 22 out of 40 recording days. There was a strong and significant correlation between the number of time frames where activity was reported for Ault Field and the average number of flights recorded in that day across all three sites (R^2=0.48, p<0.001; Figure 5A). The strength of the correlation varied somewhat between the three locations individually, being weakest for the River Trail (R^2=0.29, p<0.001) and strongest at Third Beach (R^2=0.54, p<0.001). On the busiest days, we recorded an average of up to 70-85 flight events per location (Figure 5A). However, these did not correspond with the days of highest reported activity at Ault Field, suggesting that substantial on-the-ground impacts can occur even under median numbers of reported timeframes. The distribution of flight events recorded at individual locations was slightly left-skewed, but tended to cluster around 25-50 flights in recorded days (Figure 5B). The maximum number of flight events recorded on a single day at locations were 73 (Hoh Watershed), 104 (River Trail), and 81 (Third Beach).

Military aircraft constituted by far the largest majority of audible aircraft at most hours of the day, representing 85% of the total duration of time aircraft noise was recorded; commercial aircraft and propeller/helicopter craft represented similar percentages (8% and 7% respectively) of the total time audible (Figure 6). Although recordings were conducted on an approximately normal ratio of weekend days and weekdays (1:4), only 7.5% of military flights were documented on weekends. Nearly three-quarters (74%) of all military flights were documented between 9 AM-5 PM, 19% were between 5–10 PM, and 5% were between 10 PM-7 AM (data not shown).

All three locations displayed similar daily patterns in military flight activity (i.e., strong peak during the middle of the day) but varied in the total percent time audible (Table 1). Across all recording days, the two coastal locations experienced audible military aircraft an average of 12% (range: 8-17%) of the time during daytime hours between 9AM-5 PM, while military aircraft were audible an average of 10% (range: 6-14%) of those same hours at River Trail. In contrast, the next largest contributor of aircraft noise was commercial, which were audible on average only 0.5% (range: 0.1-1.2%) of the same hours (Table 1). The duration of time in each day and hour that military aircraft were audible was highly correlated across the three locations, indicating flight activities impacted a large geographic area at any given time (Figure 7). Correlations were stronger between the two coastal sites than for the coastal-interior site pairs.

Discussion and Implications

In this study, we used on-the-ground acoustic monitoring to evaluate the impact of different types of aircraft on the Olympic Peninsula soundscape, with the intention of providing context and guidance with respect to increased military operations in the future. Toward that goal, we tried to calculate metrics that advance the goal of assessing impacts of military overflights on people and wildlife, which are currently understudied and poorly understood (19–21). With the exception being the loss of only one audio file over an entire year, we also demonstrate feasibility of on-the-ground acoustic monitoring to reliably assess changes in military operations now and in the future. It should be mentioned for our results that the 6.5 hr file loss occurred during the day (when most flight activity was recorded), potentially representing a relatively substantial loss of information. Based on flight activity recorded earlier in the day at that location and the correlation relationship with other locations during that timeframe, we estimate that the missing audio data likely included 25-40 additional military and 1-2 commercial flight events (Figure 5A). However, this only increases confidence that our overall results are a fair reflection of fact, and may be conservative.

We found that military aircraft are a dominant contributor to the soundscape of the Olympic Peninsula, representing 85% of the total time aircraft are audible. Percent time audible was substantial during daytime hours, particularly at the coastal sites, which averaged 12% audible during daytime hours across all 40 recording days. However, to achieve this average level meant that on some individual days the percent time audible during these hours was far greater (e.g., 49-52% of the time). Individual locations can experience in the range of up to 80-100 events in a single day. In areas where residents (and tourists) have an expectation of quiet, experiencing noise at these levels is likely to occur as even more intrusive or disruptive than in urbanized settings (24, 25). It also stands, therefore, that increases in military training operations and activities (e.g., Record of Decision for Growler Environmental Impact Statement, March 13, 2019) may result in fundamental changes to the Olympic Peninsula soundscape. For example, given knowledge that daytime percent time audible approaches or exceeds 20% on a consistent basis in some locations, we can ask if additional operations would increase that percentage? Alternatively, increases might result instead in more hours of the day or numbers of days per year impacted. Using the baseline data from this study to establish daily, weekly, and geographic patterns of activity, it is now possible to more specifically consider what those increases would look like, and whether they will represent sustainable or reasonable exposure levels for wilderness areas and residential communities.

Audible events were not evenly experienced across different locations, as we demonstrated differences in the numbers of flight events and percent time audible for the two coastal locations as compared with the interior location just outside of the MOA. Since only three locations were monitored, it is impossible to know how impacts are distributed across the entire MOA. However, impact on a daily and hourly basis was correlated at distances of 22,40, and 51 km apart. Although the range at which aircraft can be detected will depend on speed, altitude, and power of the particular aircraft as well as terrain and atmospheric conditions, local information from residents that live around NASWI suggests that Growlers are audible at a distance of 14-19 km away. This does raise some possibility of spatio-temporal autocorrelation of detection of aircraft events in our data collection and processing, particularly between the two coastal sites that were 22 km distant. However, the fact that even sites that were 40 and 51 km from each other were well correlated indicates the broad geographic scope of activities on any given day and time period. Additional monitoring over larger areas would better describe how localized impacts are at any given time, and if there are “hotspots” where communities, visitors, and wildlife may experience greater exposure to duration, intensity, or number of disturbance events.

Our data showed that areas outside of the MOA are clearly impacted, with the Hoh River location averaging 6-12% audible during daytime hours (with a maximum of 52% recorded on one sampling day-hour). The Airspace Noise Analysis for the Olympic Military Operations Area (Appendix J) in the NWTT EIS/OEIS indicates that pilots typically plan to complete maneuvers within 3 nm of the boundary of the MOA. That the River Trail location, positioned 1.8 km outside the MOA, receives such consistent noise from military aircraft indicates that the noise footprint extends well beyond the MOA. It should be noted that all monitoring locations were either in the Olympic National Park or extremely close to the Park, and therefore reflect the range of exposure that visitors to the region are likely to experience currently. Two of the monitoring locations (Third Beach and Hoh Watershed) are also highly proximate to the Quileute Tribe and Hoh Nation, offering a coarse estimate of potential impact for people of those Tribal Nations.

An important outcome of this study was demonstrating feasibility in identifying different types of aircraft from audio recordings, that were processed using widely available software. In this way, our study differs from the only other acoustic monitoring available for this region, which was a noise inventory study conducted by the National Park Service in 2010-2011 (30). Although we purposefully replicated two of those locations to help begin to establish an acoustic record over time for this region, the study goals and the methods used to process the recorded audio data differed, making the results difficult to compare. The audio processing protocols used by the by the National Park Service are based on evaluation of short (10-

sec) subsamples. These protocols are highly appropriate for the purpose of conducting an inventory of contributions of general categories of sound (i.e., human vs. natural) across the entire park (30), but are neither intended for nor conducive to identification of specific soundscape users. Conversely, our protocols, which involve listening to entire events, were designed to distinguish sources more specifically. It should be noted, however, that a strength of passive acoustic monitoring is the creation of a permanent audio record, and either of these datasets could conceivably be revisited and reanalyzed in a way that allows closer contrast between the audio data collected in the two periods.

We then used these data to calculate metrics relevant for people and wildlife, which do not experience and respond to noise and disturbance as calculated by long-term averages (i.e., the 24 hr day-night average sound level that is the standard applied by the Federal Aviation Administration). This is particularly true when evaluating the impact of noise and disturbance in rural and wilderness areas, which provide important habitat for valued and even endangered species (Figure 8) as well as being areas where people expect to experience quiet (24, 25). Developing and measuring metrics that reflect the impact of noise in wilderness and rural areas is fundamental to assessing impact. In this study, we have mainly relied on the number of flight events (i.e., disturbance events) and percent time audible, but other metrics that would be valuable in evaluating impact include the number of events that exceed certain dB or dB(A) thresholds, noise profiles for different locations around the Peninsula (e.g., the hourly distribution of L_{50}) (30), and numbers of events that are likely to disrupt sleep, classroom-based learning, or recreational activities. Our dataset includes the potential to create and examine these types of metrics, which we hope to do in a future summary.

By demonstrating workability and utility of this approach, we hope to encourage the use of on-the-ground monitoring as a critical evaluation and mitigation strategy. It is clearly impossible to mitigate impacts that are not quantified. By assessing the realized contribution of military aircraft to the soundscape based on factors like geography and time of day, we can begin to consider where possible mitigation strategies might focus. These might include approaches such as working with residents to set upper limits on the total percent time all military aircraft will be audible and monitoring use against that threshold. Alternatively, metrics can be used to communicate and set expectations for a community, such as informing tourists about the noisiest areas and times of day to adjust their activities as needed. Critically, on-the-ground monitoring evaluates the impact of combined users on a space. For example, although NASWI may contribute only partially to the overall noise and traffic in the MOA, residents, tourists, and wildlife experience the totality of disturbance (regardless of the specific source). To evaluate impact based on contribution of a single user (e.g., the NWTT EIS/OEIS) invites the tragedy of the commons, and runs counter to the need to manage soundscapes as other types of common-pool resources are managed (29).

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Figures and Tables

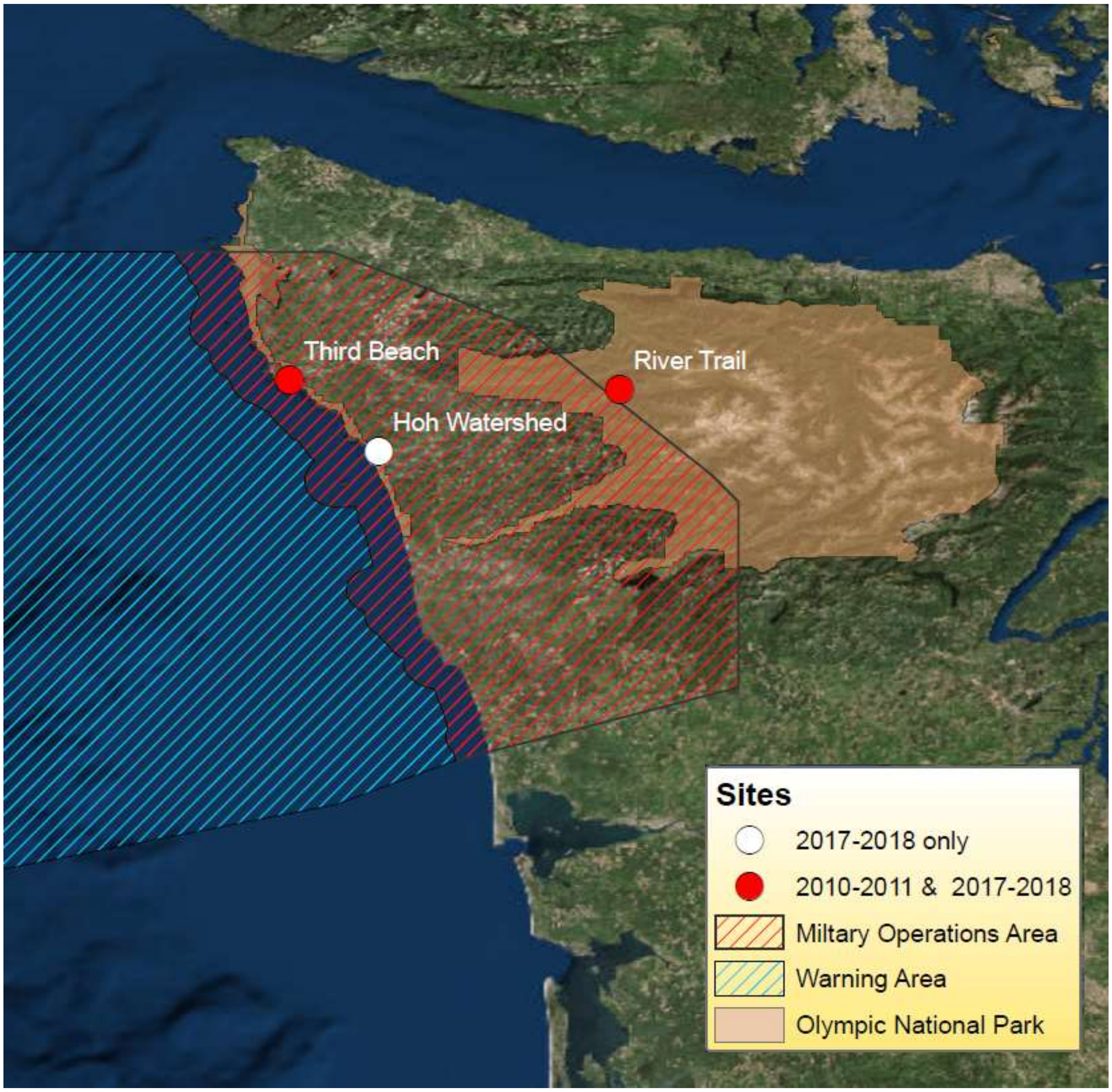

Figure 1. Locations of the three monitoring sites and proximity to the Olympic Military Operations Area. The Third Beach and River Trail sites (red symbols) are within the Olympic National Park, and were monitored by the National Park Service as part of a soundscape inventory in 2010 and 2011. The Hoh Watershed site is adjacent to but not within the National Park boundary (e.g., proximate to Oil City). This map was created in ArcGIS 10.2 using the Basemap imagery (Esri). Layers for the Military Operations area (source: Federal Aviation Administration Special Use Airspace 2019-04-25T09:01:00) and the Administrative Boundaries of National Park Service Units (Geospatial Dataset 2225713) were both downloaded on May 26, 2018.

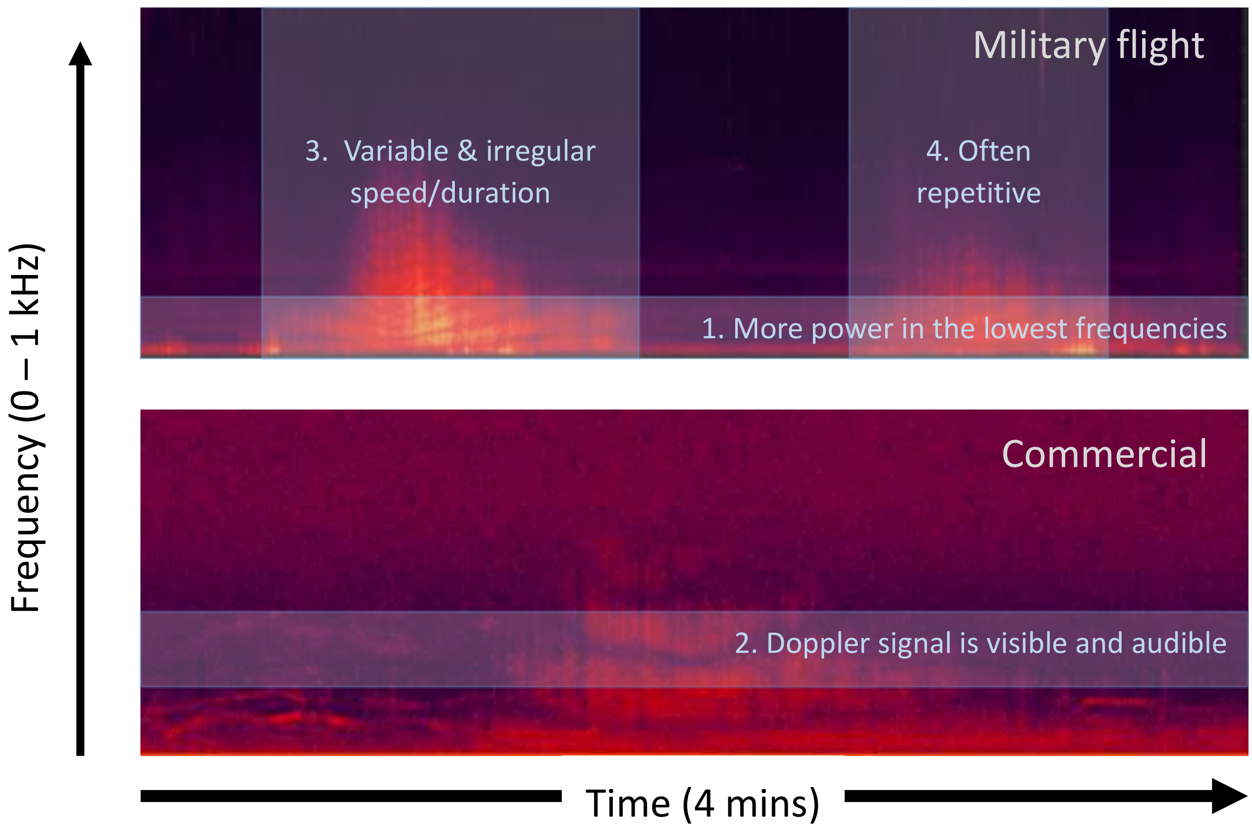

Figure 2. Contrasting spectrograms of typical flights classified as "military" (upper) and "commercial" (lower) demonstrate the ways in which listeners visually and auditorily identified aircraft events. Military aircraft typically had greater power in the lowest frequencies, variable and irregular speed and duration, sudden onsets, and often occurred in clusters. The Doppler signal is also typically compressed compared with commercial aircraft that traveled at more continuous speeds.

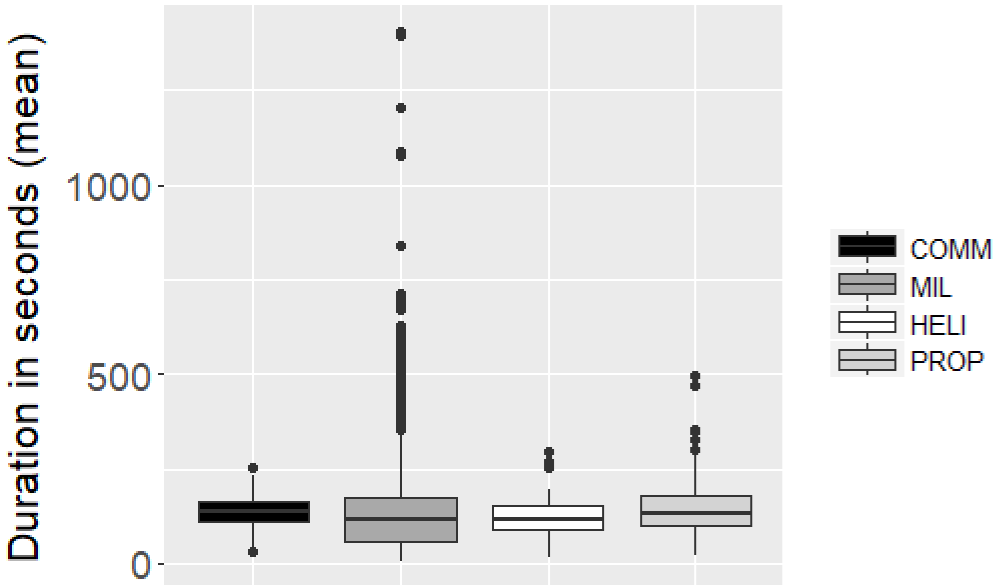

Figure 3. Duration of different flight event types across all hours of processed audio data [boxes represent the first and third quartiles, and whiskers extend to 1.5 times the interquartile range]. Aircraft types are coded as: Commercial (COMM), Military (MIL), Helicopter (HELI), and Propeller (PROP).

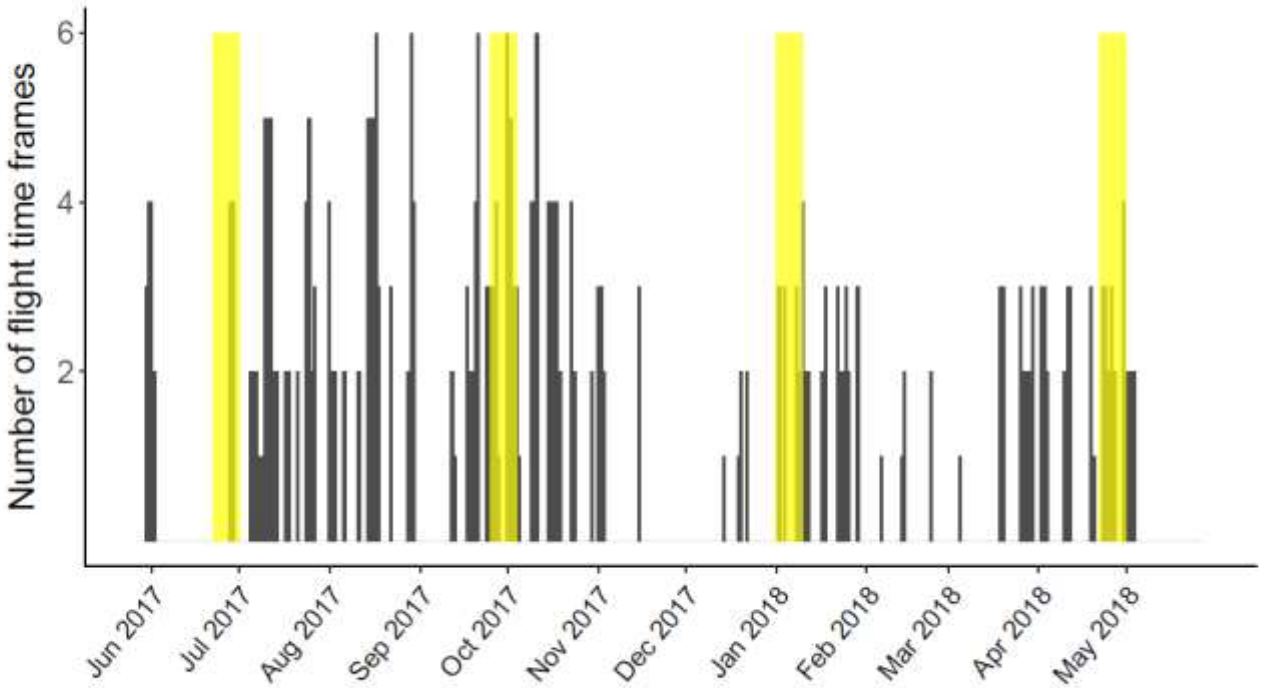

Figure 4. Number of time frames of activity by day (dark grey bars) published in the flight notification schedule for Ault Field for the period of May 28, 2017 – May 27, 2018. Yellow shading indicates days when recorded audio data was collected and processed for the three sites.

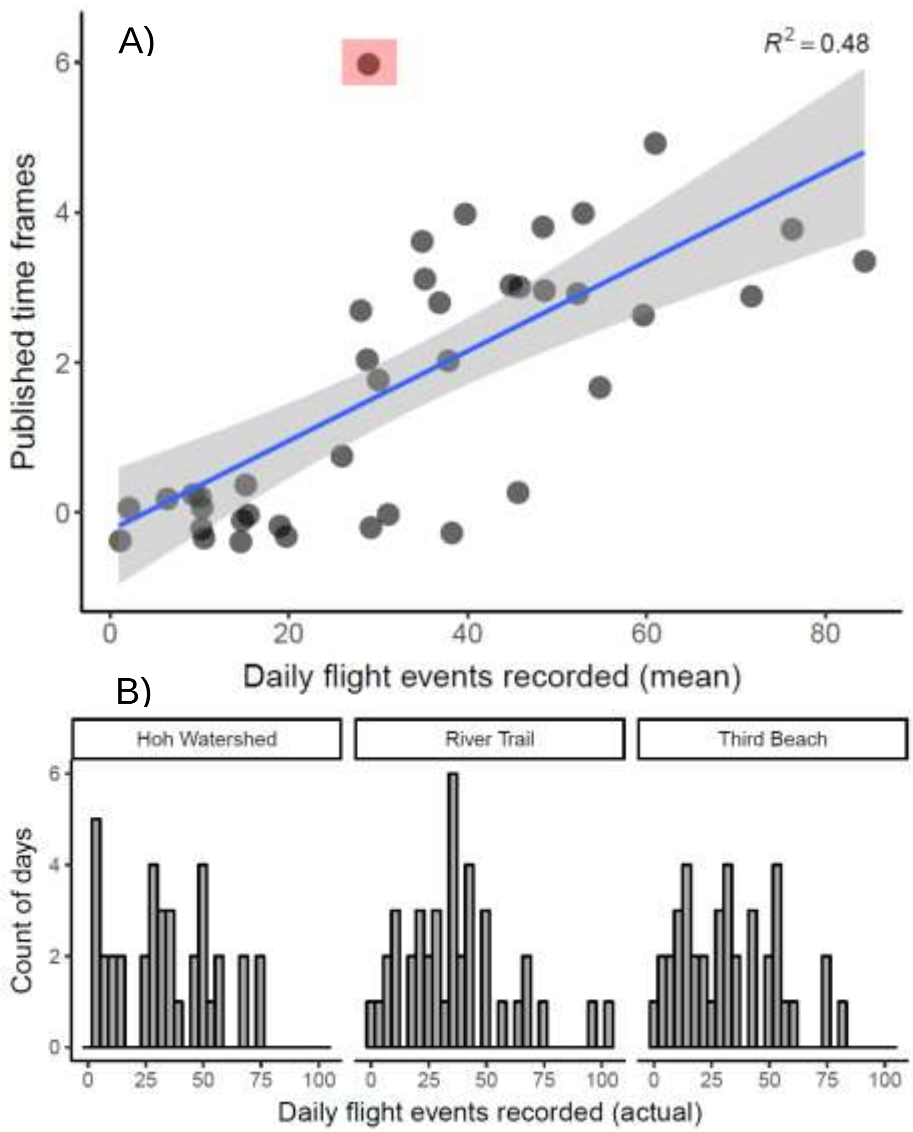

Figure 5. A) Relationship between number of time frames when activity was indicated for Ault Field and the average number of military flights recorded across the three monitoring sites on that day. Blue shading shows the 95% confidence interval for the regression, which was significant ($p<0.001$). Points are jittered slightly to avoid overplotting; the single red shaded point is the day where equipment failure resulted in 6.5 hours of missing daytime audio at one location. B) Distribution of the number of actual daily flight events recorded at the Hoh Watershed, River Trail, and Third Beach locations over the 40 days of recording.

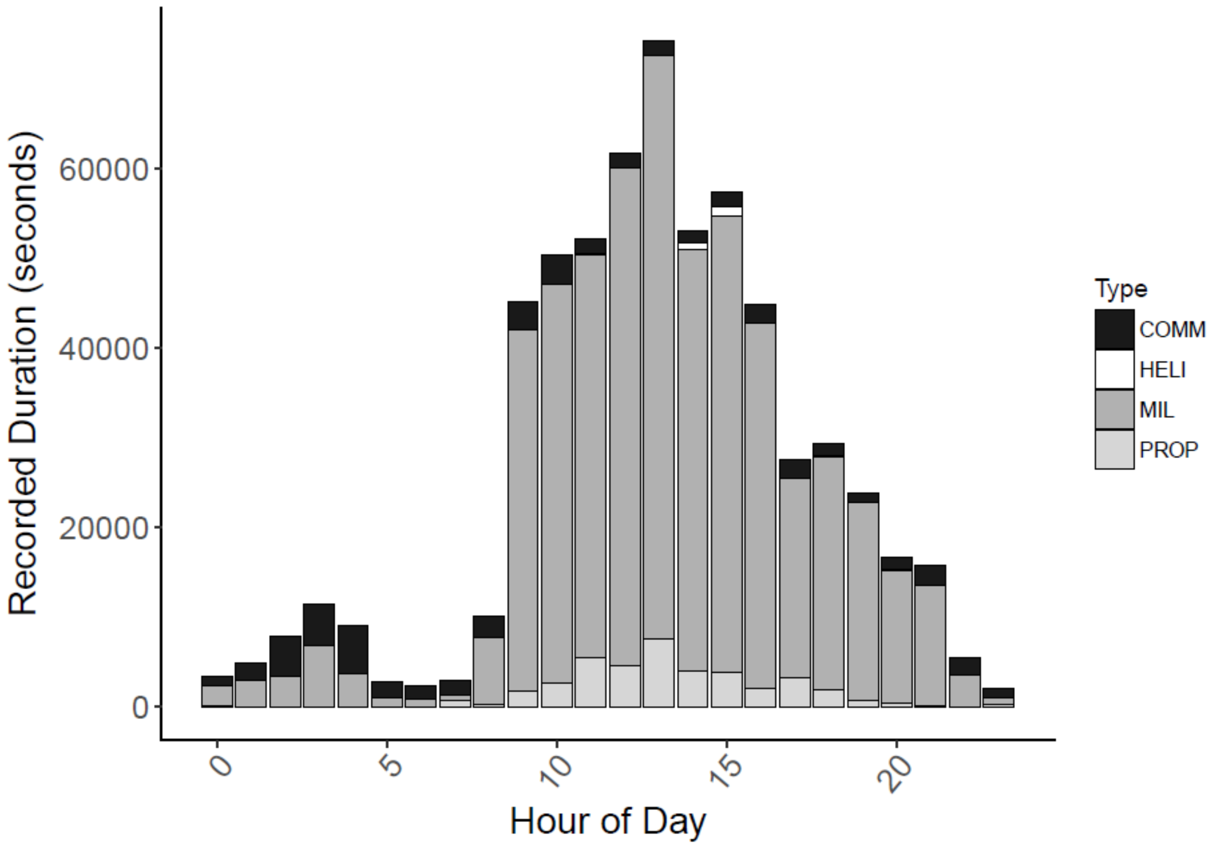

Figure 6. Contribution of different aircraft to the total duration of seconds of recorded audible time by hour of the day (total duration is across all three locations and four sampling periods). Aircraft types are coded as: Commercial (COMM), Military (MIL), Helicopter (HELI), and Propeller (PROP).

Table 1. Percent time audible for military and commercial aircraft by the hour of the day. Calculations are based on all time that aircraft were audible and the actual recording time at that location and hour (i.e., corrected for time(s) recorders were off).

	Hour of day																							
Military aircraft	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Third Beach	0.8	0.5	0.5	1.5	0.8	0.2	0.2	0.1	2.5	10.7	10.4	10.4	13.3	17.3	11.2	14.3	8.5	4.0	6.8	4.6	2.4	2.9	0.7	0.3
Hoh Watershed	0.4	0.4	0.5	0.8	0.4	0.2	0.1	0.1	1.7	10.7	10.6	12.0	15.6	16.3	9.7	14.1	10.4	5.9	7.0	5.4	4.0	3.6	0.6	0.4
River Trail	0.2	1.3	1.6	3.0	1.4	0.2	0.3	0.2	2.6	7.8	9.5	9.1	11.1	14.0	9.7	9.8	6.4	4.0	5.5	4.1	3.0	2.9	1.1	0.0
	Hour of day																							
Commercial aircraft	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Third Beach	0.1	0.5	3.6	4.2	1.9	0.5	0.1	0.2	0.7	0.9	0.6	0.4	0.4	0.8	0.3	0.7	0.5	0.3	0.1	0.3	0.3	0.6	0.8	0.2
Hoh Watershed	0.4	0.7	1.3	1.0	0.8	0.5	0.5	0.7	0.6	0.7	1.2	0.8	0.4	0.2	0.1	0.6	0.5	0.7	0.5	0.1	0.3	0.5	0.1	0.2
River Trail	0.1	0.4	1.3	1.0	0.9	0.3	0.2	0.2	0.5	0.6	0.5	0.1	0.2	0.2	0.2	0.1	0.3	0.3	0.2	0.2	0.3	0.4	0.6	0.2

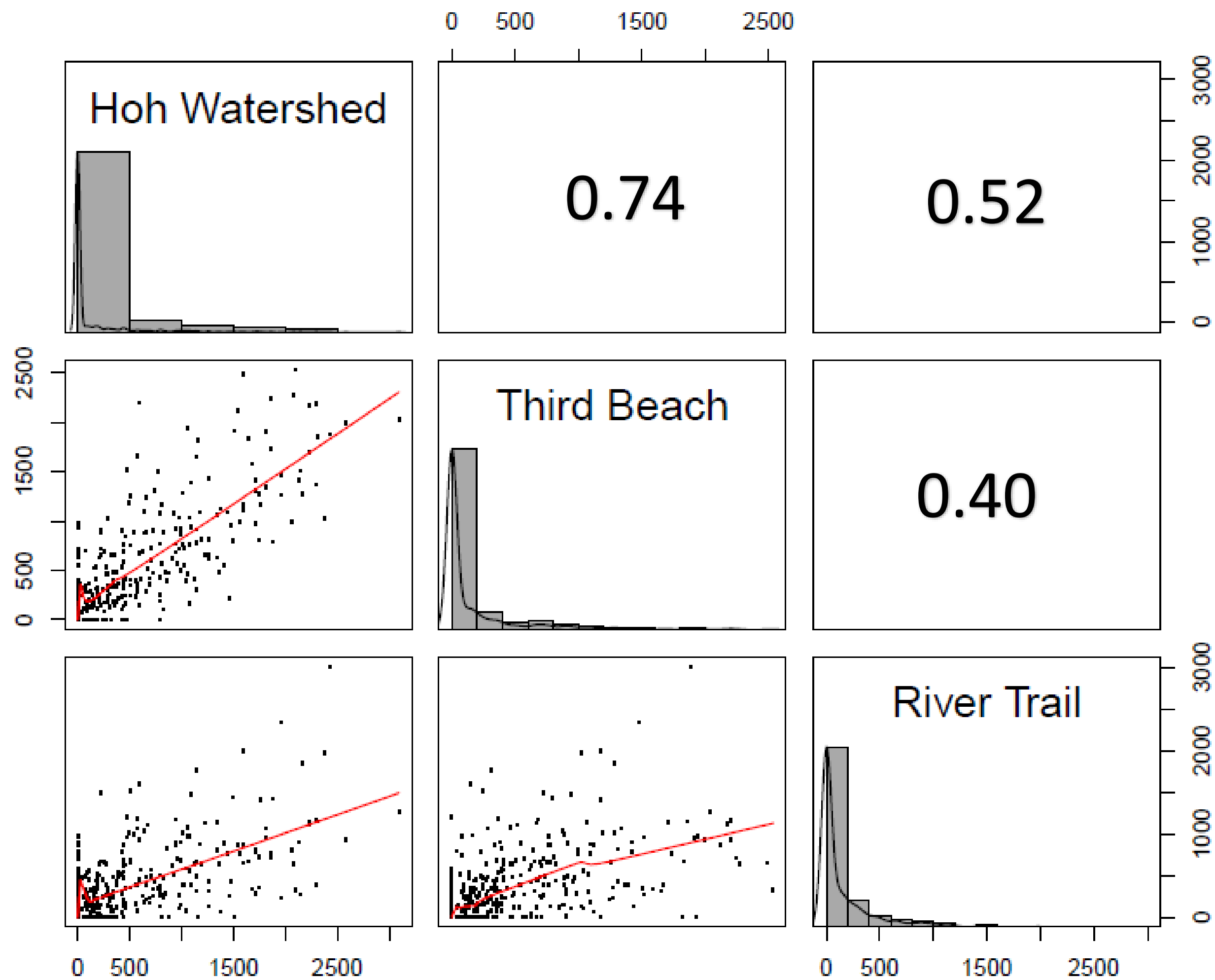

Figure 7. Correlation matrix (with Pearson's R^2 coefficient) based on the duration of military aircraft events recorded at the three different locations by date and hour of each recording day, and distributions of the duration of events for that location. All correlations were significant ($p<0.001$).

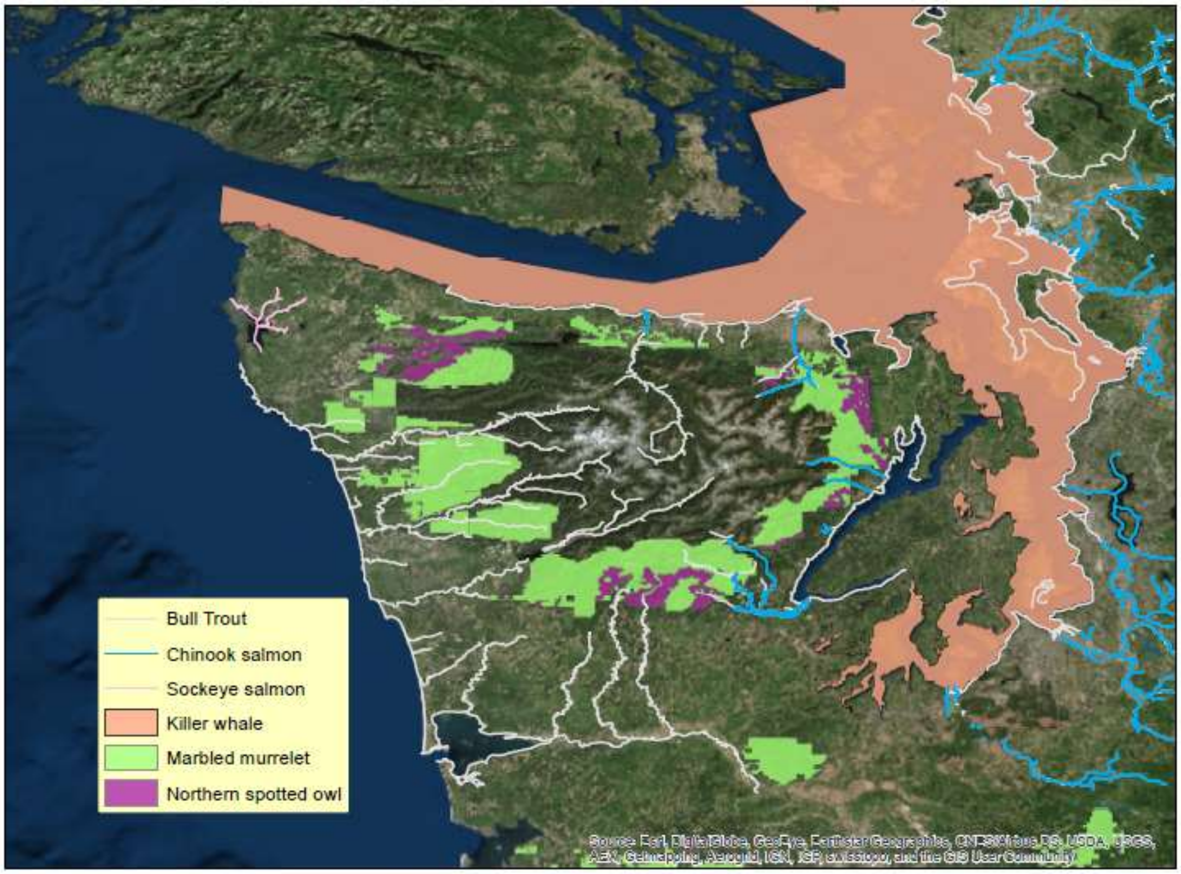

Figure 8. The Olympic Peninsula region with critical habitat for all species currently listed as Threatened or Endangered under the Endangered Species Act. This map was created in ArcGIS 10.2 using the Basemap imagery (Esri). Critical habitat layers for ESA-listed species were downloaded on from U.S. Fish and Wildlife Environmental Conservation Online System on May 25, 2019.