Final Report

Aerial Surveys of Marine Mammals Conducted in the Inland Puget Sound Waters of Washington, Summer 2013–Winter 2016

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Killer whales (*Orcinus orca*) observed on 18 January 2016 in the Seattle sub-region of Puget Sound. Photograph by Mark Deakos under National Marine Fisheries Service permit 14245-03.

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14. ABSTRACT
From 2013 to 2016, we conducted systematic line-transect aerial surveys in 8 sub-regions of Puget Sound encompassing inland waters of Washington State. U.S.-funded surveys were conducted year-round and focused on estimating seasonal in-water density and abundance of marine mammals, particularly harbor porpoises and harbor seals. A total of 35,102 km of survey effort was conducted during 61 flights on 35 days during the following six survey periods: (1) August–September 2013 (n=10 flights); (2) July 2014 (n=9 flights); (3) September 2014 (n=13 flights); (4) January 2015 (n=1 flight); (5) April 2015 (n=15 flights); and (6) January 2016 (n=13 flights). In 2015, the January survey period was curtailed by inclement weather; however, the January 2016 surveys provide data on winter occurrence of harbor porpoises in the 8 Puget Sound sub-regions of the study area comparable in effort level to the other 3 seasons. Researchers confirmed 11 marine mammal species (including a single river or sea otter) in a total of 5,772 groups for an estimated 10,673 individuals. Sightings identified to species included: harbor seal; harbor porpoise; California sea lion; Steller sea lion; humpback whale; gray whale; common minke whale(only in Strait of Juan de Fuca, not in Puget Sound); Risso's dolphin (seen twice between Seattle and south to Vashon Island [north of Tacoma] during August-September 2013, likely the same two individuals); Dall's porpoise; killer whale resident and transient pods; and odtter (river otter or sea otter).Totals of 1,693 digital photographs and 14.5 min of video were taken (including of feeding gray whales near Everett in the East Whidbey Island sub-region). Totals of 98 harbor porpoise calves, 25 harbor seal pups, and 2 killer whale calves were seen. Pups and calves were defined as individuals less than one-half of the body length of the most closely accompanying apparent adult and do not necessarily represent newborn animals. The highest relative proportion

of harbor porpoise calves was observed during July (2014) and September (2013 and 2014) (6 to 8 percent of all groups versus 1 percent during January and April 2015 and <1 percent in January 2016). Harbor seal pups also were most commonly seen during the July and September survey periods. Mean group size for all pooled marine mammal species was approximately one to two individuals for in-water sightings. However, when considered separately, killer whales (mean group size=6.8, SE=1.4, n=4 groups) and Dall's porpoises (mean group size=4.5, SE=3.5, n=2) had larger mean group sizes than other species observed. Mean group size of hauled-out harbor seals was 1.8 (SE=0.1, n=144). Most (96 percent, n=5,533) pinniped groups were seen in the water (68% of California sea lions, 96% of Steller sea lions, and 97 percent of harbor seals), with the remaining groups hauled out.Density and abundance analyses were limited to in-water sightings of 386 harbor porpoise, 2,170 harbor seal, and 66 sea lion (California and Steller) groups made during 7,649 km of observation effort considered suitable for distance-sampling analysis (systematic, BSS 2, with cloud cover used as a filtering factor only for harbor porpoise). Harbor porpoise and harbor seal density and abundance estimates were corrected for missed trackline animals using g(0) (trackline detection probability) from previous studies of these species in Puget Sound and adjacent waters.Overall, estimated pooled harbor porpoise density was 0.86 individuals/km^2, with an abundance of 2,269 (CI95=1,187-2,729, CV=37.8). Highest seasonal densities occurred in summer (1.05 individuals/km^2) and lowest occurred in winter (0.42 individuals/km^2). Geographically, highest overall densities occurred in the South Whidbey (2.03 individuals/km^2), Admiralty Inlet (1.72 individuals/km^2), and Southern Puget Sound (0.86 individuals/km^2) sub-regions, with notably fewer animals in the Bainbridge (0.53 individuals/km^2) and Vashon Island (0.25 individuals/km^2) sub-regions. Harbor porpoises were also observed in Hood Canal, including shallow tidal areas where they had been absent for decades. For harbor seals seen in water, overall estimated pooled density was 3.57 individuals/km^2, with an abundance of 9,404 (CI95=1,453–60,860, CV=118.6). Because pinniped haul-out areas were avoided during surveys, density estimates represent in-water densities outside of haul-out areas, and abundance does not represent the total abundance in Puget Sound. Additional study by WDFW will consider counts at haul-outs and during times of year and day when most harbor seals would be expected to be visible and counted. Highest seasonal densities of harbor seals occurred in spring and summer (4.73 individuals/km^2 and 4.70 individuals/km^2, respectively) and lowest in winter (2.2 individuals/km^2). Geographically, highest densities occurred in the Southern Puget Sound (6.37 individuals/km^2) and Hood Canal sub-regions (5.74 individuals/km^2), with notably fewer animals in the Seattle (1.17 individuals/km^2) sub-region. For sea lions seen in water, overall estimated pooled density was 0.02 individuals/km^2 with an abundance of 53 (CI95=38-74, CV=16.8). The sub-region with the highest estimated in-water abundance and density of sea lions was Admiralty Inlet, with an estimated 15 sea lions (density=0.06 sea lions/km^2). Seasonal fluctuations were apparent among in-water densities, with highest estimated abundances in spring (66) and lowest in winter (20). However, our survey area did not include areas with the highest known haul-out numbers (located in restricted "no-fly" areas); thus, our in-water abundance estimates are not representative of the entire Puget Sound study area. Behavioral observations indicated that most observed marine mammal species tended to rest or transit (i.e., travel) Puget Sound during the day with intermittent apparent feeding bouts. The predominant first-observed behavioral state of nearly all marine mammal species groups was rest/slow travel, followed by medium/fast travel, with smaller proportions of milling (including possible foraging and/or socializing). Milling behavior was more frequently seen among harbor porpoises (16%) than any other species (≤4%), a behavior that is likely associated with feeding and/or socializing. Actual foraging/feeding was rarely observed (<2%) and was only seen among harbor porpoises, harbor seals, Steller sea lions, gray whales, and a minke whale (outside of Puget Sound). Such behavior included the following specific behavioral events: harbor seals diving repeatedly near foraging birds, gray whales surfacing with mud plumes, and sightings/photographs of presumed gray whale feeding troughs in exposed mudflats near where feeding gray whales had been seen. It is unknown if feeding and socializing increase during the night. Acoustic studies by Jeffries indicate that harbor porpoises vocalize more at night than during the day in Burrows Pass, north of our survey area, suggesting that foraging may occur predominantly at night. Harbor porpoises were historically common in Puget Sound through the 1940s. However, their abundance declined in successive decades, with few to no individuals observed in Puget Sound during aerial and vessel surveys in 1991 and 1994. Our results confirm that harbor porpoises have recolonized all eight sub-regions of Puget Sound and are present year-round in relatively large numbers. Reasons for the harbor porpoise increase are unknown. Contrastingly, there has been a decrease in Dall's porpoise sightings, the reasons for which are also unknown. The highest proportion of harbor porpoise calf sightings during summer and fall support the theory that calving occurs during this period in Puget Sound. With respect to pinnipeds, results also support historical and other studies indicating that the harbor seal continues to be the most common marine mammal species in Puget Sound year-round. In contrast, Steller sea lions and California sea lions inhabit the region primarily during spring and fall, when they occur throughout much of Puget Sound.

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Executive Summary

From 2013 to 2016, we conducted a series of systematic line-transect aerial surveys for marine mammals in eight sub-regions of Puget Sound encompassing inland waters of Washington State. Effort consisted of six separate survey periods spanning four seasons (winter, spring, summer, and fall) and was funded by the U.S. Navy. Surveys focused on estimating seasonal in-water density and abundance of marine mammals, particularly harbor porpoises (*Phocoena phocoena*) and harbor seals *(Phoca vitulina).*

Observations were conducted from a high-winged, twin-engine Partenavia aircraft by three observers: one observer positioned on each side of the aircraft looking through bubble windows and a third observer looking through a belly window. A dedicated recorder in the co-pilot seat recorded the following information on a small laptop running Mysticetus™ observation software: species, group size, number of calves, declination angle and bearing, behavior state, within-group individual spacing (i.e., nearest neighbor maximum dispersal distance) based on number of animal body lengths apart, and reaction/no reaction to the aircraft. Species, calf presence, and group size were confirmed with high-resolution photographs as needed. Density and abundance estimates were calculated with both conventional and multiple-covariate distance-sampling methods using DISTANCE 6.2 software.

A total of 35,102 kilometers (km) of survey effort was conducted during 61 flights on 35 days during the following six survey periods:

1. August–September 2013 (*n*=10 flights)
2. July 2014 (*n*=9 flights)
3. September 2014 (*n*=13 flights)
4. January 2015 (*n*=1 flight)
5. April 2015 (*n*=15 flights)
6. January 2016 (*n*=13 flights).

In 2015, the January survey period was curtailed by inclement weather (see Smultea et al. 2015); however, the January 2016 surveys provide data on winter occurrence of harbor porpoises in the eight Puget Sound sub-regions of the study area comparable in effort level to the other three seasons.

Researchers confirmed 11 marine mammal species (including a single river or sea otter) in a total of 5,772 groups for an estimated 10,673 individuals. A sighting was defined as a group of one or more animals in close proximity to one another. Sightings identified to species included the following:

- Harbor seal
- Harbor porpoise
- California sea lion (*Zalophus californianus*)
- Steller sea lion (*Eumetopias jubatus*)

- Humpback whale (*Megaptera novaeangliae*)
- Gray whale (*Eschrichtius robustus*)
- Common minke whale (*Balaenoptera acutorostrata*) (only in Strait of Juan de Fuca, not in Puget Sound)
- Risso's dolphin (*Grampus griseus*) (seen twice between Seattle and south to Vashon Island [north of Tacoma] during August-September 2013, likely the same two individuals)
- Dall's porpoise (*Phocoenoides dalli*)
- Killer whale (*Orcinus orca*) resident and transient pods
- Otter (river otter [*Lontra canadensis*] or sea otter [*Enhydra lutris*]).

Totals of 1,693 digital photographs and 14.5 minutes of video were taken (including feeding gray whales near Everett in the East Whidbey Island sub-region).

Totals of 98 harbor porpoise calves, 25 harbor seal pups, and 2 killer whale calves were seen. Pups and calves were defined as individuals less than one-half of the body length of the most closely accompanying apparent adult and do not necessarily represent newborn animals. The highest relative proportion of harbor porpoise calves was observed during July (2014) and September (2013 and 2014) (6 to 8 percent of all groups versus 1 percent during January and April 2015 and <1 percent in January 2016). Harbor seal pups were also most commonly seen during the July and September survey periods.

Mean group size for all pooled marine mammal species was approximately one to two individuals for in-water sightings. However, when considered separately, killer whales (mean group size=6.8, standard error [*SE*]=1.4, *n*=4 groups) and Dall's porpoises (mean group size=4.5, *SE*=3.5, *n*=2) had larger mean group sizes than other species observed. Mean group size of hauled-out harbor seals was 1.8 (*SE*=0.1, *n*=144). Most (96 percent, *n*=5,533) pinniped groups were seen in the water (68 percent of California sea lions, 96 percent of Steller sea lions, and 97 percent of harbor seals), with the remaining groups hauled out.

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Overall, estimated pooled harbor porpoise density was 0.86 individuals/square kilometer (km^2), with an abundance of 2,269 (95 percent confidence interval [CI_{95}]=1,187-2,729, coefficient of variation [*CV*]=37.8). Highest seasonal densities occurred in summer (1.05 individuals/km^2) and lowest occurred in winter (0.42 individuals/km^2). Geographically, highest overall densities occurred in the South Whidbey (2.03 individuals/km^2), Admiralty Inlet (1.72 individuals/km^2), and Southern Puget Sound (0.86 individuals/km^2) sub-regions, with notably fewer animals in the

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Behavioral observations indicated that most observed marine mammal species tended to rest or transit (i.e., travel) Puget Sound during the day with intermittent apparent feeding bouts. The predominant first-observed behavioral state of nearly all marine mammal species groups was rest/slow travel, followed by medium/fast travel, with smaller proportions of milling (including possible foraging and/or socializing). Milling behavior was more frequently seen among harbor porpoises (16 percent) than any other species (≤4 percent), a behavior that is likely associated with feeding and/or socializing. Actual foraging/feeding was rarely observed (<2 percent) and was only seen among harbor porpoises, harbor seals, Steller sea lions, gray whales, and a minke whale (outside of Puget Sound). Such behavior included the following specific behavioral events: harbor seals diving repeatedly near foraging birds, gray whales surfacing with mud plumes, and sightings/photographs of presumed gray whale feeding troughs in exposed mudflats near where feeding gray whales had been seen. It is unknown if feeding and socializing increase during the night. Acoustic studies by Jeffries (2012) indicate that harbor porpoises vocalize more at night than during the day in Burrows Pass, north of our survey area, suggesting that foraging may occur predominantly at night.

Harbor porpoises were historically common in Puget Sound through the 1940s. However, their abundance declined in successive decades, with few to no individuals observed in Puget Sound during aerial and vessel surveys in 1991 and 1994. Our results confirm that harbor porpoises have recolonized all eight sub-regions of Puget Sound and are present year-round in relatively large numbers. Reasons for the harbor porpoise increase are unknown. Contrastingly, there has been a decrease in Dall's porpoise sightings, the reasons for which are also unknown. The highest proportion of harbor porpoise calf sightings during summer and fall support the theory that calving occurs during this period in Puget Sound.

With respect to pinnipeds, results also support historical and other studies indicating that the harbor seal continues to be the most common marine mammal species in Puget Sound year-round. In contrast, Steller sea lions and California sea lions inhabit the region primarily during spring and fall, when they occur throughout much of Puget Sound.

Future results of tagging and passive acoustic studies, along with additional surveys, may help elucidate distribution and behavioral patterns of Puget Sound marine mammals. This would help improve information about presence and behavior of the less-common species observed during our study.

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Appendix

Tables

Figures

Acronyms and Abbreviations

BSS	Beaufort Sea State
CI	Confidence Interval
CI_{95}	95% confidence interval
CV	coefficient of variation
ESA	Endangered Species Act
ESW	effective strip width
g(0)	trackline detection probability
GPS	Global Positioning System
Hr	hour(s)
ICMP	Integrated Comprehensive Monitoring Program
km	kilometer(s)
km^2	square kilometer(s)
m	meter(s)
MMPA	Marine Mammal Protection Act
NAVBASE	Naval Base
NMFS	National Marine Fisheries Service
nmi	nautical mile(s)
NWFSC	Northwest Fisheries Science Center
NWTT	Northwest Training and Testing (Study Area)
PSD	perpendicular sighting distance
SAR	Stock Assessment Report
SRKW	Southern resident killer whale
SE	standard error
U.S.	United States
WAAS	Wide Area Augmentation System
WDFW	Washington Department of Fish and Wildlife

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1. Introduction

The United States (U.S.) Navy, in order to meet regulatory requirements under the Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA) as well as program objectives under the Integrated Comprehensive Monitoring Program (ICMP), identified the need for marine mammal surveys to be conducted in the Northwest Training and Testing (NWTT) Study Area. The ICMP is intended for use as a planning tool to focus U.S. Navy monitoring priorities pursuant to ESA and MMPA requirements (NWTT Final Environmental Impact Statement, published online July 2015 at: http://nwtteis.com/DocumentsandReferences/NWTTDocuments/FinalEISOEIS.aspx). The NWTT Study Area (Study Area) is composed of established maritime operating and warning areas in the eastern North Pacific Ocean region, to include the Strait of Juan de Fuca, Puget Sound, and Western Behm Canal in southeastern Alaska. The Study Area includes four existing range complexes and facilities: the Northwest Training Range Complex the Keyport Range Complex, Carr Inlet Operations Area, and the Southeast Alaska Acoustic Measurement Facility. In addition to these range complexes, the Study Area also includes Navy pierside locations where sonar maintenance and testing occurs as part of overhaul, modernization, maintenance, and repair activities at Navy piers at Naval Base (NAVBASE) Kitsap Bremerton, NAVBASE Kitsap Bangor, and Naval Station Everett.

The U.S. Navy hired HDR who contracted with Smultea Environmental Sciences, LLC (Smultea Sciences) to conduct line-transect aerial surveys to estimate densities and abundances of marine mammal species near the U.S. naval installations in the inland Puget Sound study area. These operations were performed under three separate task orders:

1. Contract #N62470-10-D-3011, Task Order JP02 consisting of one aerial survey during the late summer period of 2013
2. Contract #N62470-10-D-3011, Task Order JP04 consisting of at least four aerial survey periods across the four calendar seasons during 2013–2015
3. Contract #N62470-15-D-8006, Task Order KB05 consisting of at least one aerial survey during January 2016.

Results of the first contract for the one 2013 aerial survey were summarized in Smultea et al. (2014); results of the 2013–2015 surveys were summarized in Smultea et al. (2015); and results of the January 2016 survey were summarized in Smultea et al. (2016).

This report summarizes data from all six survey periods conducted under all three of the aforementioned task orders. This was done to increase sample size robustness and thus resulting density and abundance estimates. The primary objectives for these aerial surveys were:

1. Conduct aerial surveys during four seasonal periods within the inland Puget Sound Survey Area to assess potential differences in seasonal distribution, numbers, and behavioral state patterns of marine mammals.
    - o Seasons were initially defined as winter (January–late March), spring (April–June), summer (July–September), and fall (October–December).

- However, it was later decided to use the following seasonal analysis periods to increase data robustness by pooling the following surveys: summer (June–August), fall (September–November), spring (April–May), winter (December–February).

2. Collect data to estimate densities of marine mammals in the inland Puget Sound waters for species with sufficient sightings.
3. Estimate abundance for each marine mammal species seen an adequate number of times, with estimates of $f(0)$ and $g(0)$.
4. Document the distribution and habitat use of each species observed.
5. Document and describe behaviors seen without performing focal follows.

2. Methods

Smultea Sciences conducted aerial surveys during six separate survey periods in 2013–2016, spaced as evenly apart in time as possible, to provide four different "seasonal" perspectives. These survey periods occurred during the following windows:

1. Summer/Fall 2013: 30 August–4 September 2013 (Smultea et al. 2014)
2. Summer 2014: 21–27 July 2014 (Smultea et al. 2015)
3. Fall 2014: 14–21 September 2014 (Smultea et al. 2015)
4. Winter 2015: 5–12 January 2015 (Smultea et al. 2015)
5. Spring 2015: 15–22 April 2015 (Smultea et al. 2015)
6. Winter 2016: 16–26 January 2016.

2.1 Study Area

The survey study area was focused in Puget Sound, Washington, and was divided into eight survey blocks (i.e., sub-regions) identified by the U.S. Navy. References to Puget Sound henceforth in this report include the polygon encompassed by these eight survey sub-regions depicted in **Figure 1**:

1. Admiralty Inlet (255.2 square kilometers [km^2])
2. East Whidbey (646.0 km^2)
3. South Whidbey (267.7 km^2)
4. Hood Canal (391.1 km^2)
5. Bainbridge (93.8 km^2)
6. Seattle (211.3 km^2)
7. Vashon (316.5 km^2)
8. Southern Puget Sound (455.8 km^2).

Opportunistic surveys were also flown over the Strait of Juan de Fuca (3,047 km^2), and north of the study area (i.e., outside Puget Sound) during three survey periods in July and September 2014, and April 2015.

Parallel transect lines were positioned along an east-west orientation, generally perpendicular to the bathymetric contours/coastline to avoid biasing surveys by following depth contours (**Figure 1**). Aerial survey lines were spaced 3.7 km apart excepting a change in survey route during the January 2016 survey in Hood Canal where transect lines were spaced approximately 1.8 km apart. Final survey design was approved by the Navy Technical Representative.

Four restricted air traffic zones located within the Puget Sound study area are indicated on **Figure 1** as smaller red polygons:

1. Naval Base Kitsap at Bangor
2. Naval Station Everett
3. Naval Base Kitsap at Bremerton
4. Naval Magazine Indian Island.

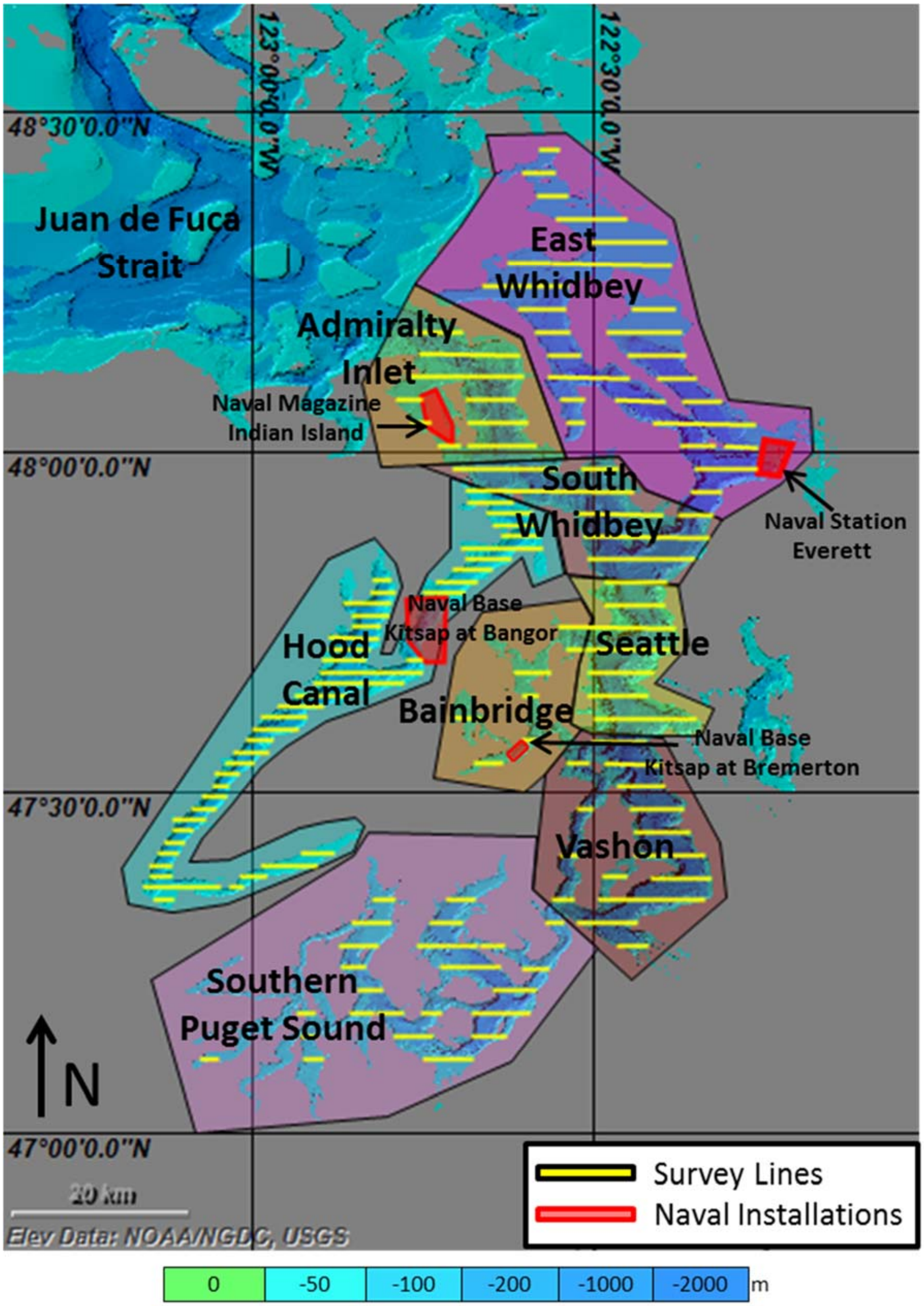

Figure 1. Map of the Puget Sound study area with outlines of the eight pre-defined sub-regions (depicted by colored polygons). Red polygons indicate no-fly and National Security areas; yellow lines represent planned aerial transect lines.

However, only Prohibited Area P-51 over Naval Base Kitsap at Bangor is a true “no-fly” zone where civilian planes are not permitted to enter. As such, three initially identified flight lines in the Bangor no-fly zone could not be flown during any of the aerial surveys; thus, any marine mammals in that area would not have been seen by observers, resulting in a gap in sightings and effort.

The other three restricted air traffic zones are termed National Security Areas and are marked on aviation charts as “…it is requested that pilots avoid flying below 2900 [Everett: 1900] feet.” However, no survey lines were located within these three areas. Because of the small size of these three National Security Areas, observers were able to see marine mammals in these areas from nearby tracklines.

2.2 Aerial Surveys

Aerial surveys were conducted from a Partenavia P68-C, twin-engine high-wing aircraft operated by Aspen Helicopters, Inc. (www.aspenhelicopters.com) based out of Oxnard, California.

One pilot and four professionally trained marine mammal biologists (or three biologists and a recorder) were aboard the aircraft. Two observers were positioned in the center seats of the aircraft to look through the bubble windows on each side of the plane. A third observer looked through the aircraft’s belly window to provide visual coverage of the area beneath the plane to ensure that no sightings directly on the transect line were missed, consistent with line-transect survey protocol (see **Section 2.2.1**). The fourth person served as a data recorder and was positioned in the front right co-pilot seat. Surveys were flown at speeds of approximately 185 km/hour (hr) (100 knots) and at a target altitude of 229 meters (m).

2.2.1 Defining Line Transects

Established line-transect survey protocol was used (see Buckland et al. 2001) following systematic survey lines. To maintain consistency, survey procedures were kept as similar as possible to previous marine mammal aerial survey work conducted in the Puget Sound area. The latter area includes Puget Sound, the Strait of Juan de Fuca, and the San Juan Islands in U.S. waters (e.g., Calambokidis et al. 1992; Osmek et al. 1996; Laake et al. 1997; Nysewander et al. 2005). The aerial survey protocol also matched that used in other U.S. Navy training ranges (e.g., Smultea and Mobley 2009; Smultea and Bacon 2012).

2.2.2 Defining Sightings

A sighting was defined as one or more individual animals within simultaneous view of the observer that could not be considered independent of one another, per line-transect theory assumptions (Buckland et al. 2001). On most occasions, for all marine mammal species, a sighting consisted of individuals in coordinated groups where >50 percent of the individuals were behaving similarly, i.e., engaged in the same behavior state (see ethogram in Smultea and Bacon 2012 and Smultea et al. 2015). A sighting typically consisted of one or more individual animals behaving similarly and/or in a coordinated manner within 10 m of one another (i.e., the 10-m chain rule; Acevedo-Gutierrez 2009). However, for harbor porpoises (*Phocoena phocoena*), on some occasions (mainly in Admiralty Inlet), there were aggregations of individuals/small groups of individuals that were within 500 m of one another where one sighting cued the next and then the next due to all occurring within a 500-m radius; in the latter cases, it was necessary to 'lump' these into one sighting so as not to violate assumptions of distance sampling that each sighting is independent of the next.

Pinniped sightings were considered "in-water" if their belly rested on sand, but a portion of their bodies was still in the water. This definition that determined which harbor seals (*Phoca vitulina*) were considered hauled out or in water differs from that applied by Jeffries et al. (2014) for Puget Sound. Our surveys were focused on cetaceans, primarily harbor porpoises, while Jeffries et al. (2014) aerial surveys were focused on hauled-out pinnipeds. For example, Jeffries et al. (2014) estimated population abundance and density based on counts of hauled-out animals including areas known as large haul-out sites that were not surveyed during our aerial surveys.

2.3 Data Collection

2.3.1 Data Collection Software System

We used customized Mysticetus™ Observation Platform software for data collection (www.Mysticetus.com). Recorded data included basic sighting and environmental data (e.g., Beaufort Sea State [BSS], visibility, glare, precipitation, and cloud cover, see **Tables 1** and **2**). Software was loaded onto a small laptop computer equipped with a touchscreen for use in the field. This set-up followed that used during the U.S. Navy's Southern California Range Complex aerial surveys conducted during 2011–2013 and other U.S. Navy range surveys (e.g., Smultea and Mobley 2009; Smultea and Bacon 2012). Each new entry was automatically assigned a time stamp, a sequential sighting number, and a Wide Area Augmentation System-enabled (WAAS) Global Positioning System (GPS) position. GPS locations of the aircraft were automatically recorded at 1- or 5-second intervals on a WAAS-enabled Bluetooth Global-Sat BT368i mini GPS, and for redundancy/back-up, on a handheld Garmin™ 78S GPS and the aircraft's Garmin 296 GPS. Suunto® handheld clinometers were used by the observers to measure declination angles to sightings. If the sighting was not directly in line with the right or left wing (i.e., perpendicular to the track line) when the angle was taken, a bearing to that sighting was recorded. Declination angle and bearing were used in Mysticetus™ to automatically calculate a sighting position.

Table 1. Definitions of environmental data collected.

Data Point	Definition
Beaufort sea state	See **Table 2**
Glare	The estimated percentage of glare present within the observer viewing area to the nearest approximate 5%. For each bubble-window observer, this consisted of the 90-degree area from dead ahead to directly abeam of the aircraft. For the belly window observer, glare was estimated for the entire area within view.
Cloud Cover	Estimated percent cloud cover over 360 degrees to nearest approximate 5% (Smultea and Bacon 2012).
Visibility	Estimated number of kilometers within which a group of 25 dolphins may be observed; calibrated for each observer based on declination angle converted to distance by Mysticetus (Smultea and Bacon 2012).

Table 2. Beaufort sea state scale.

Force	Speed			Name	Conditions at Sea
	knots	km/hr	mi/hr		
0	< 1	< 2	< 1	Calm	Sea like a mirror.
1	1–3	1–5	1–4	Light air	Ripples only.
2	4–6	6–11	5–7	Light breeze	Small wavelets (0.2 m). Crests have a glassy appearance.
3	7–10	12–19	8–11	Gentle breeze	Large wavelets (0.6 m), crests begin to break.
4	11–16	20–29	12–18	Moderate breeze	Small waves (1 m), some whitecaps.
5	17–21	30–39	19–24	Fresh breeze	Moderate waves (1.8 m), many whitecaps.
6	22–27	40–50	25–31	Strong breeze	Large waves (3 m), probably some spray.
7	28–33	51–61	32–38	Near gale	Mounting sea (4 m) with foam blown in streaks downwind.
8	34–40	62–74	39–46	Gale	Moderately high waves (5.5 m), crests break into spindrift.
9	41–47	76–87	47–54	Strong gale	High waves (7 m), dense foam, visibility affected.
10	48–55	88–102	55–63	Storm	Very high waves (9 m), heavy sea roll, visibility impaired. Surface generally white.
11	56–63	103–118	64–73	Violent storm	Exceptionally high waves (11 m), visibility poor.
12	64+	119+	74+	Hurricane	14 m waves, air filled with foam and spray, visibility bad.

2.3.2 Data Points Collected

Observational and environmental data collected included the following:

1. Location and time of sighting (collected via GPS), and distance of sighting from the trackline as applicable (converted based on bearing and declination angle to the sighting from the aircraft—see above)
2. Species identification of all marine mammals
3. Number of individuals (i.e., group [sighting] size,) and/or composition (i.e., calves, subadults, adults)
4. If present, number of calves/pups (individuals less than one-half adult body size) observed and/or photographed
5. Duration of sighting
6. The best possible detailed description of behavior, disposition, and reaction/no reaction to the aircraft
7. Direction of travel (magnetic)
8. Photographs and/or video, if needed
9. Environmental information associated with each sighting event (see **Tables 1** and **2**).

Observers used image-stabilized Steiner 7 × 25 or Swarovski® 10 × 32 binoculars if helpful to identify species, number of individuals, behaviors, etc.

Environmental data were collected at the start of each systematic survey line and each time there was a change in effort type (systematic, random, transit, or circling leg types [see **Table 3**]) or environmental conditions. Behavioral data were collected when a sighting was first made and included the first-observed behavioral state (slow travel/rest, medium travel, fast travel, mill, hauled out, foraging, other) that at least 50 percent of the group was engaged in (see **Table 4;** Smultea et al. 2016). Other first-observed data that were collected included group heading (in degrees magnetic) and minimum and maximum dispersal distances (estimated in adult body lengths) between nearest neighbors within subgroups. The two closest individuals in a group were used to estimate minimum dispersion and the two individuals farthest from each other without intervening individuals were used to measure maximum dispersion.

Table 3. Definitions of leg types flown during Puget Sound Marine Mammal Aerial Surveys.

Leg Type	Leg Type Definition
Systematic	Flying pre-determined line-transect legs
Transiting	Flying between the airport and the survey grid locations and transiting between transect lines
Overland	Flying over land
Circling	Flying circles around sightings to verify species and group size via photography

Table 4. Ethogram defining behavioral states and individual behaviors (events). Behavioral states were determined based on what >50% of the group was doing.

Behavioral State (>50% of group's activity--noted once per min[1])	Code abbreviation	Definition
Rest/Slow Travel	RE	Exhibiting little or no forward movement (<1 km/hr) remaining at the surface in the same location or drifting/traveling slowly with no wake
Travel	TR	Swimming with an obvious consistent orientation (directional) and speed, no surface activity. Medium travel = 1-3 km/hr wake with no white water; Fast travel = >3 km/hr with white water observed
Mill	MI	Swimming with no obvious consistent orientation (non-directional) characterized by asynchronous headings, circling, changes in speed, and no surface activity. Includes feeding.
Probable Foraging	PF	Apparent searching for prey; the process of finding, catching, and eating food
Unknown	UN	Unable to determine behavior state. (e.g., animals out of sight, too far to determine, on a dive, etc.)
Other	OT	Describe in notes

Sources: Smultea et al. 2015, Heithaus and Dill 2009

A behavioral reaction was recorded when an animal made a sudden change in behavioral state or heading in possible response to the aircraft. When sightings were circled, additional behavioral information was collected opportunistically. No extended (e.g., >15 min) focal follows were conducted, consistent with the scope of work for this Task Order.

2.3.3 Photography/Videography

A Canon EOS digital single-lens reflex camera (e.g., Canon 5DSR or Canon 7D) with a Canon EF 100-400-millimeter image-stabilized zoom lens was used to document and verify species for each sighting as feasible/needed. A Sony™ Handycam® HDR-XR55OV or a Sony Handycam HDR-PJ79OV video camera was used to document unusual behaviors (e.g., a large group of foraging harbor seals).

When conditions allowed, photographs were taken opportunistically to confirm species. Photographs were taken through small, opening porthole windows in the plane's copilot window or left rear window.

2.4 Line-Transect Analysis Methods

We used both conventional line-transect methods (i.e., Conventional Distance Sampling) and multiple-covariate line-transect methods (i.e., Multiple Covariate Distance Sampling) to analyze the aerial survey data for estimating density and abundance of marine mammals (Buckland et al. 2001; Marques and Buckland 2004). Survey data were filtered with the following criteria to extract data for the final line-transect analyses (to ensure meeting assumptions of line-transect theory):

- Only data (e.g., sightings and effort) collected on systematic transect lines (thus, data during transit and connector effort were excluded).[1]
- Only data collected in BSS 0–2 (following the protocols of Calambokidis et al. 1992; Laake et al. 1997).
- Only data without significant glare issues (i.e., "hard" glare within which a marine mammal could not be seen occurring within over 30 percent of any observer's field of view for over 3 minutes).
- For harbor porpoise analyses, only data collected during conditions with cloud cover of 50 percent or less (see Laake et al. 1997).[2]

The filtered data were assembled into Excel™ spreadsheets for preparation of the line-transect input files, which were analyzed using the software DISTANCE 6.2, Release 1 (Thomas et al.

[1] Note that "connector effort" refers to short lines that connect the main transect lines, perpendicular to transect lines. In most cases, connector lines are overland, yet even over water connector lines are excluded because associated data are often parallel to shore or at a depth contour that leads to issues regarding how representative they are of the density that is being estimated.

[2] However, due to mainly cloudy conditions during the January 2016 survey, we relaxed this condition and used cloud cover from 0 to 100 percent for the winter estimates. Otherwise, we would have insufficient data to calculate winter estimates.

2010). Estimates of density and abundance (and their associated coefficients of variation) were calculated using the following standard formulae:

$$\hat{D} = \frac{n\ \hat{f}(0)\ \hat{E}(s)}{2\ L\ \hat{g}(0)}$$

$$\hat{N} = \frac{n\ \hat{f}(0)\ \hat{E}(s)\ A}{2\ L\ \hat{g}(0)}$$

$$C\hat{V} = \sqrt{\frac{\hat{\mathrm{var}}\,(n)}{n^2} + \frac{\hat{\mathrm{var}}\,[\hat{f}(0)]}{[\hat{f}(0)]^2} + \frac{\hat{\mathrm{var}}\,[\hat{E}(s)]}{[\hat{E}(s)]^2} + \frac{\hat{\mathrm{var}}\,[\hat{g}(0)]}{[\hat{g}(0)]^2}}$$

where D = density (of individuals),

n = number of on-effort sightings,

f(0) = detection function evaluated at zero distance,

E(s) = expected average group size (using size-bias correction in DISTANCE),

L = length of transect lines surveyed on effort,

g(0) = trackline detection probability,

N = abundance,

A = size of the survey area,

CV = coefficient of variation

var = variance

Estimates were made only for harbor porpoises, harbor seals, and sea lions (both California [*Zalophus californianus*] and Steller sea lions [*Eumetopias jubatus*] combined). This is because sample sizes of all other marine mammal species identified during the survey were considered insufficient (i.e., detected fewer than 60 times, since 60 to 80 is the minimum number of sightings considered adequate to obtain reliable line-transect estimates for marine mammals, per Buckland et al. 2001).

We did not stratify estimates by BSS or other environmental parameters. We produced estimates of density and abundance using the entire filtered dataset (i.e., all seasons) and stratified by all eight survey sub-regions, and also produced overall pooled estimates. To examine seasonal variation, we also produced estimates stratified by the four seasons (defined in **Section 2.0, Methods**.

Final estimates all used the Multiple Covariate Distance Sampling approach, as this approach resulted in estimates with the highest level of precision (as determined by the lowest *CVs*). Although harbor porpoise analyses used both BSS and cloud cover as covariates, pinniped analyses used only Beaufort, as cloud cover has not been identified as a significant factor for these species that spend more time visible at the surface.

To avoid potential overestimation of group size, we used the size-bias-adjusted estimate of average group size available in DISTANCE. To facilitate modeling, perpendicular sighting distance (PSD) data were truncated to remove outliers. We experimented with several different truncation strategies, and settled on the most appropriate one (in terms of *CVs* and examination of PSD plots) for each species group for final analyses. We modeled data with the Half-Normal (with hermite polynomial and cosine adjustments) and Hazard Rate (with simple polynomial and cosine adjustments) models. The model with the lowest value of Akaike's Information Criterion was selected for the final estimates.

Trackline detection probability could not be estimated from the data collected in this study, as we did not conduct diving experiments nor use independent observers. Therefore, we applied values of *g*(0) from previous surveys (Laake et al. 1997) for harbor porpoises (*g*[0]=0.292, *SE*=0.107). Laake et al. (1997) used nearly identical methods and equipment to ours, and in fact we modeled our survey procedures after Laake et al. (1997). Harbor seal analyses used *g*(0) values from the study by Jefferson et al. (2016)—(*g*[0]=0.204, *SE*=0.242), which used dive and surface time data collected in the nearby San Juan Islands area (see Wilson et al. 2014). For sea lions, we simply assumed that *g*(0)=1.0, due to indications from survey observations that most sea lions were not diving but were often floating or hauled out at or near the surface.

The standard *CVs* for our estimates incorporated the variance factor for the *g*(0) component that we used, even though these are not related to our surveys and are not strictly part of the variance associated with our work. The variance factor of the *g*(0) estimates was generally quite large. Because these *g*(0) values came from previous studies, and not our own analyses, we also presented *CVs* for our estimates as if *g*(0) was known with certainty. Therefore, we did not include a variance factor for *g*(0) in them—these are denoted as *CV'*. Our logic for the latter is as follows. The *CV* of the density and abundance estimates is essentially a measure of the variance of the data used in calculating the density and abundance estimates. Since in this case we used the values of *g*(0) from other studies, and we did not incorporate raw data from those studies into our estimates, the variance of *g*(0) is not part of our actual calculations. We simply used their computed value as a correction factor for our estimates. However, because there is indeed uncertainty associated with the *g*(0) estimates that we used, we have also presented the *CV* that includes the variance component for *g*(0), which we label as *CV*.

Line-transect analysis is seldom used to estimate density and abundance of pinnipeds, and most studies that use this method involve hauled-out seals on ice in high-latitude areas. There are numerous challenges in estimating numbers for amphibious species, such as pinnipeds, which move regularly between in-water and hauled-out locations. This situation is intensified for harbor seals in Puget Sound, which has a large number of sand- and mud-flats in the intertidal zone, and when used by harbor seals can blur the distinction between animals in-water and those out-of-water.

In this study, we assumed that all pinnipeds encountered were in one of three categories:

1. Seals largely submerged in the water (these are clearly 'in-water')
2. Seals 'high and dry' on haul-out areas (islands, rocks, piers, submarines, etc.) (these are 'out-of-water')

3. Seals that are lying on mud or sand flats partially submerged or with ‘wet bellies’.

Since the sand- and mud-flat areas are part of the study area that is generally considered water (i.e., they do not show up as land on most maps, and were included among the water areas for determining size of our various study sub-areas), for the purposes of this analysis, we considered pinnipeds in the third category to be ‘in-water’, and therefore incorporated these sightings into our line-transect estimates. This approach ensured consistency in our estimates for all species of marine mammals that we analyzed (i.e., harbor porpoise, harbor seal, California sea lion, and Steller sea lion).[3]

[3] Note that in a related report using the same aerial survey data (Jefferson et al. 2017), harbor seals with “wet bellies” were excluded from that density analysis because of differing methods and study objectives. The reader is referred to the methods section of that report for further details.

3. Results

3.1 Effort

A total of 61 survey flights was conducted on 35 days during six survey periods within four different seasons (**Tables 5** and **6**). Weather permitting, two flights were conducted each day, given the aircraft's limited flight duration due to fuel (**Table 5**). Morning flights were sometimes impeded by a heavy marine fog layer, which delayed the start of surveys until it had subsided.

A total of 184 hr or 35,102 km (18,954 nautical miles) of flight (i.e., "in air") time from "wheels up" to "wheels down" was flown over the 35 survey days, 90 percent (166 hr) of which consisted of observation effort over water (**Table 5**) (**Figures 2a and 2b**). Both totals include opportunistic observations in the Strait of Juan de Fuca at the end of the July 2014 and September 2014 survey periods, after the primary survey tracklines had been fully completed at least twice. An additional 8 hr 23 min of "engines-on" time on the runway occurred (i.e., waiting in line to take off from the Auburn Municipal Airport) (**Table 5**).

Most in-air flight time consisted of either systematic line-transect effort (34 percent) when all three observers were on watch on systematic transect lines (**Figure 3**), or flight time over land (34 percent) (**Table 7**). This was followed by 23 percent in transit and 9 percent circling. Flight time over land was relatively high due to the large number of islands characterizing the survey area. The total number of flight hours and the flight descriptions for each day by date are listed in **Table 5.** More detailed information on survey- and season-specific maps of trackline effort and sightings can be found in Smultea et al. (2015) and Smultea et al. (2016).

The predominant BSS during the surveys was BSS 1 (35 percent) followed by BSS 2 (27 percent) or BSS 3 (27 percent) (**Table 8**). When BSS 5 or higher was encountered for more than several minutes, the survey route was aborted and another region was surveyed if BSS conditions were better, or the flight was terminated/postponed to avoid poor sighting conditions.

After excluding environmental conditions that did not meet conditions considered suitable to estimate density and abundance (i.e., systematic effort and BSS=0–2), there was a total of 7,649 km of usable effort. Most (38 percent) of the usable effort occurred during fall (2,896 km) followed by spring (1,658 km), summer (1,574 km), and winter (1,522 km, **Table 9**).

Table 5. Flight effort by date during Puget Sound Marine Mammal Aerial Surveys 2013–2016.

Date (Month/Day/ Year)	Flight of Day (No.)	Engine On Time (hr:min)	Engine Off Time (hr:min)	Total Engine On Duration (hr:min)	Wheels Up Time (hr:min)	Wheels Down Time (hr:min)	Total Time Plane in Air (hr:min)	Total Flight Distance (km)	Total Flight Distance (nautical miles)	Start Obs. Time	End Obs. Time	Total Obs. Duration*
8/30/2013	1	8:52	12:42	3:50	8:59	12:41	3:42	716	387	9:12	12:28	3:16
8/30/2013	2	14:05	17:20	3:15	14:12	17:18	3:06	592	320	14:20	17:13	2:52
8/31/2013	1	8:14	12:19	4:05	8:33	12:18	3:45	697	376	8:39	12:12	3:33
8/31/2013	2	13:48	17:11	3:23	13:51	17:08	3:17	618	334	13:56	17:02	3:05
9/1/2013	1	8:11	11:44	3:33	8:18	11:41	3:23	645	348	8:46	11:39	2:53
9/1/2013	2	13:22	16:55	3:33	13:27	16:54	3:27	630	340	13:36	16:48	3:12
9/2/2013	1	7:58	11:09	3:11	8:04	11:07	3:03	556	300	8:12	11:00	2:47
9/2/2013	2	12:37	17:13	4:36	12:41	17:11	4:30	835	451	12:46	17:05	4:18
9/3/2013	1	14:22	18:44	4:22	14:27	18:42	4:15	782	422	14:35	18:34	3:59
9/4/2013	1	8:32	10:13	1:41	8:38	10:11	1:33	289	156	8:45	10:04	1:19
7/21/2014	1	9:40	13:38	3:58	9:46	13:36	3:50	730	394	9:51	13:25	3:34
7/21/2014	2	15:05	18:47	3:42	15:08	18:44	3:36	687	371	15:21	18:29	3:08
7/24/2014	1	13:54	15:45	1:51	13:57	15:43	1:46	351	190	14:04	15:37	1:33
7/25/2014	1	9:47	13:00	3:13	9:56	12:58	3:02	595	321	10:02	12:48	2:46
7/25/2014	2	14:33	18:06	3:33	14:38	18:04	3:26	630	340	14:45	17:58	3:13
7/26/2014	1	8:26	12:25	3:59	8:32	12:23	3:51	718	388	8:37	12:06	3:29
7/26/2014	2	14:07	16:28	2:21	14:13	16:25	2:12	419	226	14:55	16:16	1:21
7/27/2014	1	8:37	11:22	2:45	8:44	11:18	2:34	483	261	8:50	11:15	2:25
7/27/2014	2	12:41	16:12	3:31	12:44	16:10	3:26	649	350	12:45	16:02	3:17
9/14/2014	1	9:23	13:01	3:38	9:29	13:00	3:31	679	367	9:35	12:50	3:15
9/14/2014	2	14:29	16:30	2:01	14:35	16:28	1:53	362	195	14:42	16:21	1:39
9/15/2014	1	9:18	12:44	3:26	9:23	12:43	3:20	637	344	9:30	12:36	3:06
9/15/2014	2	14:14	16:14	2:00	14:19	16:12	1:53	350	189	14:24	16:05	1:41
9/16/2014	1	8:20	12:05	3:45	8:27	12:03	3:36	691	373	8:33	11:53	3:20
9/16/2014	2	13:23	16:26	3:03	13:28	16:23	2:55	566	306	13:32	16:16	2:44
9/17/2014	1	8:54	12:43	3:49	9:00	12:40	3:40	683	369	9:06	12:33	3:27
9/17/2014	2	14:07	16:35	2:28	14:12	16:33	2:21	462	249	14:30	16:26	1:56
9/18/2014	1	13:19	16:29	3:10	13:24	16:26	3:02	583	315	13:29	16:19	2:50

Date (Month/Day/ Year)	Flight of Day (No.)	Engine On Time (hr:min)	Engine Off Time (hr:min)	Total Engine On Duration (hr:min)	Wheels Up Time (hr:min)	Wheels Down Time (hr:min)	Total Time Plane in Air (hr:min)	Total Flight Distance (km)	Total Flight Distance (nautical miles)	Start Obs. Time	End Obs. Time	Total Obs. Duration*
9/19/2014	1	9:04	12:35	3:31	9:07	12:27	3:20	643	347	9:12	12:12	3:00
9/19/2014	2	13:56	17:46	3:50	13:59	17:44	3:45	747	403	14:05	17:36	3:31
9/20/2014	1	13:00	16:06	3:06	13:04	16:03	2:59	615	332	13:10	15:55	2:45
9/21/2014	1	9:04	12:04	3:00	8:53	12:03	3:10	660	356	9:00	11:55	2:55
1/6/2015	1	12:02	15:25	3:23	12:09	15:23	3:14	618	334	12:39	15:07	2:28
4/15/2015	1	10:53	15:20	4:27	10:59	15:17	4:18	813	439	11:03	15:08	4:05
4/16/2015	1	7:58	12:05	4:07	8:05	12:03	3:58	746	403	8:12	11:56	3:44
4/16/2015	2	13:35	16:44	3:09	13:39	16:43	3:04	588	317	13:43	16:37	2:54
4/17/2015	1	7:57	11:44	3:47	8:03	11:43	3:40	688	371	8:07	11:33	3:26
4/17/2015	2	16:18	17:07	0:49	16:26	17:05	0:39	144	78	16:26	16:55	0:29
4/18/2015	1	8:00	11:35	3:35	8:06	11:33	3:27	662	357	8:09	10:31	2:22
4/18/2015	2	13:11	16:17	3:06	13:16	16:15	2:59	573	309	13:22	16:09	2:47
4/19/2015	1	7:51	10:31	2:40	7:58	10:29	2:31	481	260	8:02	10:23	2:21
4/19/2015	2	12:11	16:36	4:25	12:14	16:34	4:20	771	416	12:18	16:26	4:08
4/20/2015	1	8:15	11:49	3:34	8:21	11:47	3:26	658	355	8:27	11:40	3:13
4/20/2015	2	13:16	15:11	1:55	13:20	15:09	1:49	348	188	13:24	15:03	1:39
4/21/2015	1	7:56	11:03	3:07	8:03	11:00	2:57	572	309	8:09	10:53	2:44
4/21/2015	2	12:23	15:16	2:53	12:27	15:15	2:48	532	287	12:56	15:05	2:09
4/22/2015	1	7:52	11:10	3:18	7:58	11:08	3:10	612	330	8:02	11:03	3:01
4/22/2015	2	12:13	14:20	2:07	12:16	14:18	2:02	391	211	12:20	14:12	1:52
1/16/2016	1	12:33	13:35	1:02	12:42	13:31	0:49	181	98	12:55	13:24	0:28
1/16/2016	2	15:03	15:56	0:52	15:10	15:54	0:44	135	73	15:15	15:48	0:33
1/18/2016	1	7:58	8:48	0:49	8:16	8:46	0:30	103	56	8:20	8:40	0:19
1/18/2016	2	9:37	12:57	3:19	9:42	12:55	3:13	617	333	9:45	12:50	3:04
1/18/2016	3	13:45	16:59	3:14	13:52	16:57	3:05	596	322	13:56	16:50	2:53
1/19/2016	1	7:58	11:33	3:34	8:10	11:29	3:19	624	337	8:17	11:25	3:07
1/19/2016	2	11:54	13:48	1:54	12:00	13:46	1:46	356	192	12:01	13:38	1:37
1/20/2016	1	12:55	16:45	3:50	13:05	16:43	3:38	700	378	13:12	16:33	3:21
1/22/2016	1	11:53	14:51	2:57	12:01	14:49	2:48	550	297	12:06	14:42	2:36

Date (Month/Day/ Year)	Flight of Day (No.)	Engine On Time (hr:min)	Engine Off Time (hr:min)	Total Engine On Duration (hr:min)	Wheels Up Time (hr:min)	Wheels Down Time (hr:min)	Total Time Plane in Air (hr:min)	Total Flight Distance (km)	Total Flight Distance (nautical miles)	Start Obs. Time	End Obs. Time	Total Obs. Duration*
1/24/2016	1	8:01	11:48	3:47	8:12	11:45	3:33	701	379	8:21	11:43	3:22
1/24/2016	2	12:52	16:32	3:40	12:57	16:30	3:33	687	371	13:06	16:23	3:16
1/25/2016	1	8:09	11:53	3:44	8:18	11:49	3:31	669	361	8:23	11:48	3:24
1/25/2016	2	13:07	16:43	3:36	13:12	16:41	3:29	686	370	13:14	16:31	3:17
TOTAL	**61 Flights**		**Total Engine Time On**	**191:53**		**Total Flown:**	**183:31**	**35,102**	**18,954**		**Total Obs. Time**	**166:54**

Key: hr:min=hours:minutes; km=kilometers

* Total represents all effort from the initial transit period through the last transit section of the flight. Flight types included here are overland, transit, systematic, circling, etc. Note it is continuous from the start time to the end time.

Table 6. Total aerial observation effort 2013–2016.

Year	Season	Survey Period	No. of Flights	No. of Days Flown of Days Available	Total Observation Hours* (hr:min)
2013	Summer	30 August–4 September	10	6 of 6	20:54
2014	Summer	21–27 July	9	5 of 7	17.36
2014	Fall	14–21 September	13	8 of 8	25.06
2015	Winter	5–12 January	1	1 of 8	2.12
2015	Spring	15–22 April	15	8 of 8	26.48
2016	Winter	16–25 January	13	7 of 10	19:15
Total			**61**	**35 of 47**	**111:51**

*This total includes only effort periods where two observers were actively looking (transit, circling, systematic); no overland or compromised effort periods were included in this calculation.

Key: hr:min=hours:minutes; No.=number.

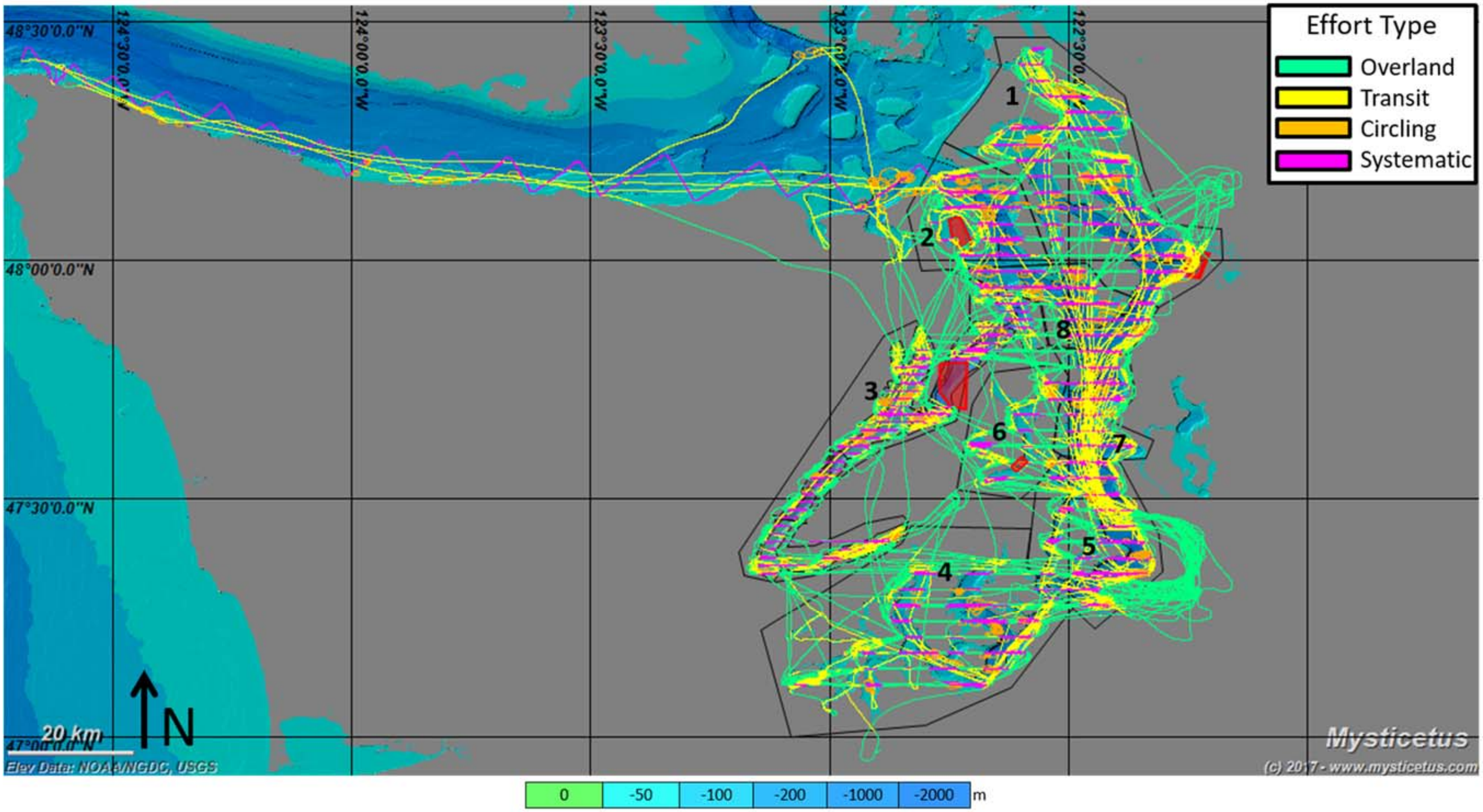

Figure 2a. All tracklines flown during the 2013–2016 Puget Sound Aerial Surveys. Numbers indicate eight pre-defined sub-region polygons (1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey). Red polygons indicate no-fly and National Security areas (see Figure 1).

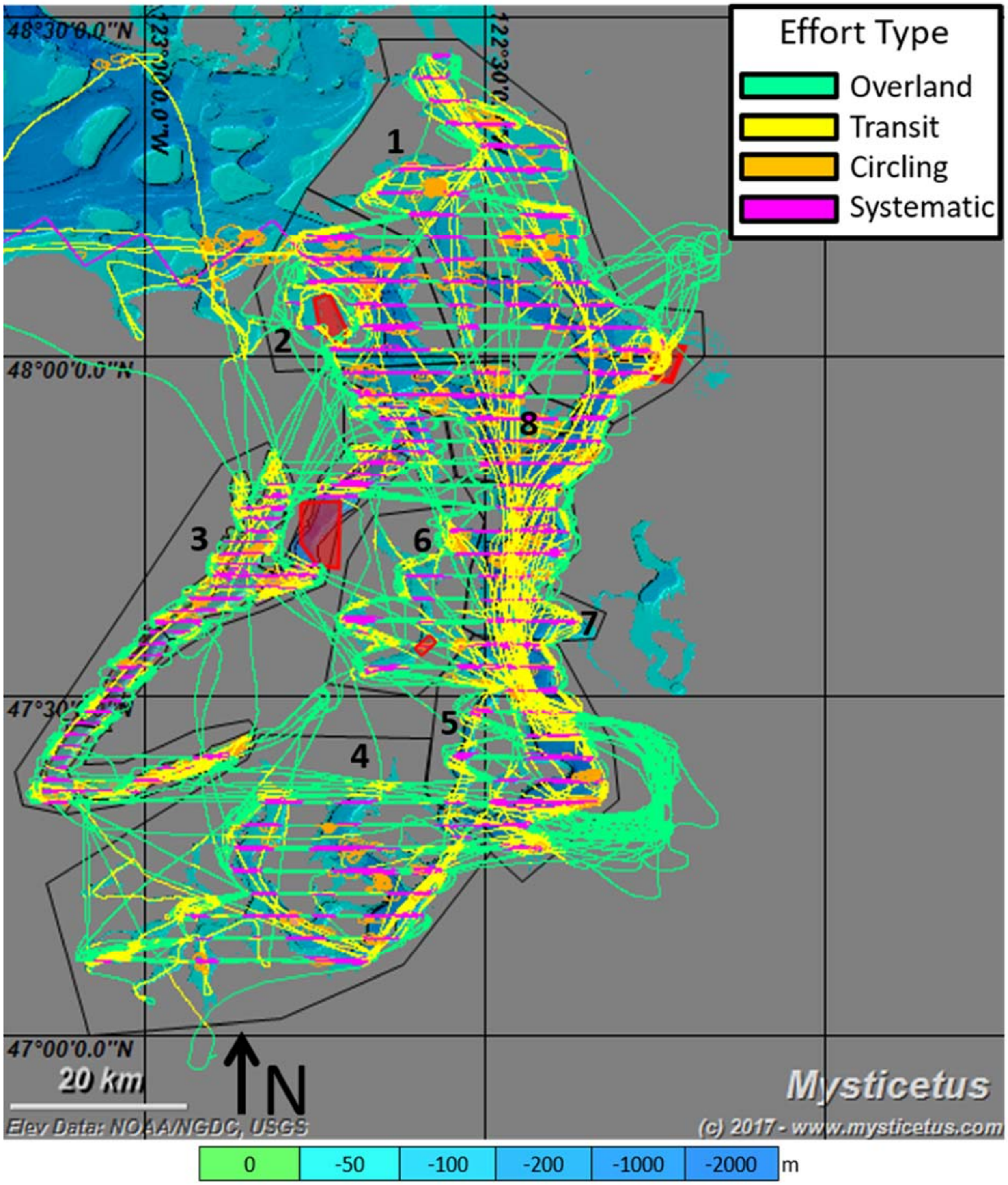

Figure 2b. A zoomed-in view of the same effort focused on the eight sub-regions within the Puget Sound survey area. Numbers indicate eight pre-defined sub-region polygons (1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey). Red polygons indicate no-fly and National Security areas (see Figure 1).

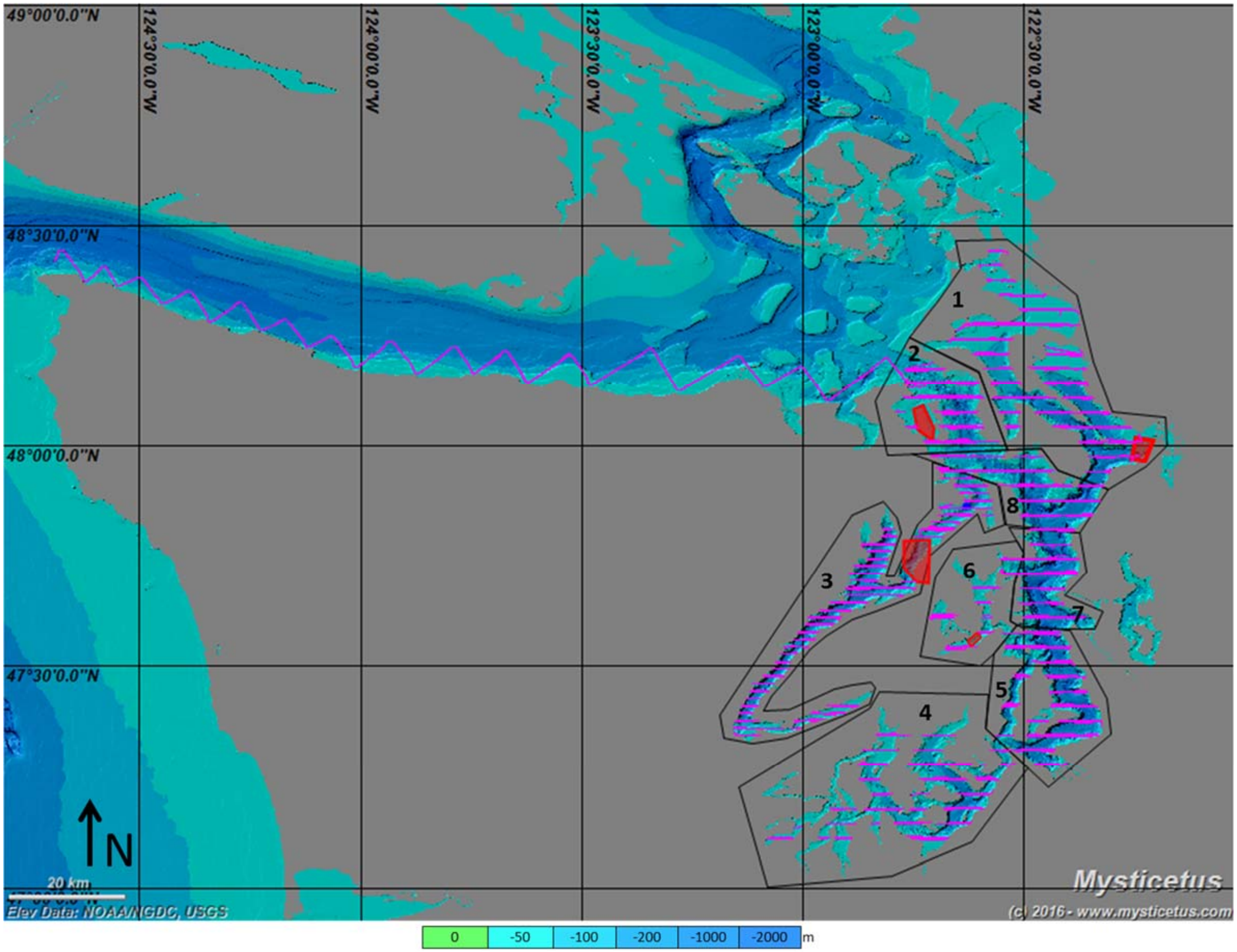

Figure 3. Systematic on-effort tracklines (purple lines) for the 2013–2016 Puget Sound aerial surveys. Numbered polygons identify the eight pre-defined survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

Table 7. Total flight time and distance by survey leg type.

Survey Period	Leg Type								Total	
	Overland		Transit		Systematic		Circling			
	hr:min	km	hr:min	km	hr:min	km	hr:min	km	hr:min	km
Aug–Sep 2013	12:11	2,328	5:57	1,161	11:58	2,205	3:52	666	33:58	6,360
Jul 2014	8:51	1,710	7:47	1,512	9:34	1,752	1:33	288	27:45	5,262
Sep 2014	12:37	2,511	10:06	2,077	13:42	2,543	3:01	547	39:26	7,678
Jan 2015	0:43	155	0:41	149	1:14	219	0:32	95	03:10	618
Apr 2015	16:05	3,088	9:50	1,927	14:22	2,706	4:56	858	45:13	8,579
Jan 2016	13:26	2,630	6:49	1,380	12:11	2,315	1:33	280	33:59	6,605
OVERALL TOTAL	**63:53**	**12,422**	**41:10**	**8,206**	**63:01**	**11,740**	**15:27**	**2,734**	**183:31**	**35,102**

Key: hr:min=hours:minutes; km=kilometer(s)

Table 8. Effort by Beaufort sea state (BSS) when observation effort was "on" during transit and systematic legs of 2013–2016 aerial surveys.

BSS	Observation Effort (km)	% of Flight Effort
0	1,120	7%
1	5,732	35%
2	4,396	27%
3	4,317	27%
4	531	3%
5	99	1%
6	3	<1%
Total	**16,198**	**100**

Table 9. Survey effort completed by sub-region and season, including only portions usable for line-transect density estimation (i.e., systematic, Beaufort sea state 0–2).

	Sub-region	Survey Effort by Season (km)				
		Winter	Spring	Summer	Fall	Total
North Puget Sound	Admiralty Inlet	72.9	95.9	112.2	228.6	509.6
	East Whidbey	286.4	384.8	387.9	712.9	1,772
	South Whidbey	157.4	137.1	162.0	261.1	717.6
Hood Canal	Hood Canal	384.7	236.3	183.8	367.0	1,171.8
South Puget Sound	Seattle	130.8	112.0	101.0	218.8	562.6
	Bainbridge	52.2	68.4	60.2	86.7	267.5
	Southern Puget Sound	261.1	408.9	365.7	516.8	1,552.5
	Vashon	176.1	214.6	201.0	503.8	1,095.5
Total		**1,521.6**	**1,658.0**	**1,573.8**	**2,895.7**	**7,649.1**

3.2 Sightings and Relative Occurrence

During the 2013–2016 surveys, there were 5,772 sightings of an estimated 10,673 individual marine mammals (**Table 10**). Of these sightings, 98 percent (5,671 groups of 10,546 individuals) were identified to species; the remaining 101 sightings (127 individuals) were of unidentified marine mammals. Eleven species were documented over the 35 survey days in Puget Sound and opportunistically in the Strait of Juan de Fuca (in descending order of sighting frequency):

- Harbor seal (*Phoca vitulina*)
- Harbor porpoise (*Phocoena phocoena*)
- California sea lion (*Zalophus californianus*)
- Steller sea lion (*Eumetopias jubatus*)
- Gray whale (*Eschrichtius robustus*)
- Killer whale (*Orcinus orca*) resident and transient population
- Humpback whale (*Megaptera novaeangliae*)
- Minke whale (*Balaenoptera acutorostrata*)
- Risso's dolphin (*Grampus griseus*)
- Dall's porpoise (*Phocoenoides dalli*)
- Otter (river otter [*Lontra canadensis*] or sea otter [*Enhydra lutris*]).

Table 10. Total number of marine mammal sightings and mean group size by species.

Common Name*	No. Groups	% of all Groups Sighted	Total No. Individuals**	No. Calves/ Pups	Mean Group Size	SE
Harbor Seal	4,392	76%	8,012	25	1.8	0.1
Harbor Porpoise	1,026	18%	2,168	98	2.1	0.1
California Sea Lion	166	3%	238	0	1.4	0.1
Steller Sea Lion	70	1%	77	0	1.1	<0.1
Unidentified Small Marine Mammal	46	<1%	53	0	1.2	0.1
Unidentified Pinniped	29	<1%	43	0	1.5	0.2
Unidentified Marine Mammal	20	<1%	22	0	1.1	0.1
Gray Whale	5	<1%	7	0	1.4	0.2
Killer Whale	4	<1%	27	2	6.8	1.4
Unidentified Dolphin	3	<1%	5	0	1.7	0.3
Humpback Whale	2	<1%	2	0	1.0	0.0
Minke Whale	2	<1%	2	0	1.0	0.0
Risso's Dolphin	2	<1%	4	0	2.0	0.0
Unidentified Porpoise	2	<1%	3	0	1.5	0.5
Dall's Porpoise	2	<1%	9	0	4.5	3.5
Unidentified Otter	1	<1%	1	0	1.0	0.0
Total	**5,772**	**100%**	**10,673**	**125**	**1.8**	**0.1**

*Species are listed in descending order of group sighting frequency.
**Total numbers of individuals include calves and pups.
Key: %=percent; No.=number; *SE*=standard error

Although two rare sightings of a pair of Risso's dolphins were made in 2013 (Smultea et al. 2014), none were seen in 2014, 2015, and 2016 surveys (see **Section 3.4**). Based on number of individuals, the harbor seal was the most commonly seen species, comprising 76 percent (*n*=8,012) of all 10,546 observed individuals identified to species, followed by the harbor porpoise (18 percent; *n*=2,168) (**Table 10**). The two sea lions and unidentified animals were the only other marine mammals observed more than ten times.

Overall, observers recorded four killer whale sightings: two sightings of transient pods and two sightings of southern resident killer whale (SRKW) pods. To assess population and pod membership, data from our four killer whale sightings (e.g., date, time, location, group size/composition) were compared to the Orca Network online sightings archives (Orca Network, n.d.(a)), including associated maps, and with researchers at the National Marine Fisheries Service (NMFS) NWFSC. NMFS confirmed one sighting of transients and one SRKW and the remaining transient and SRKW sightings match with Orca Network sightings, so identification is likely correct. Detailed sighting data are often available and are summarized below:

- On 20 September 2014 at approximately 15:00, we observed a group of three killer whales engaged in rest/slow travel amidst numerous small vessels, including whale-watch vessels, off the southwest side of San Juan Island (offshore of False Bay). These whales likely belonged to the Southern Resident J pod, or possibly the Resident K or L pods. Our sighting location best matched the only three reported sightings of killer whales in the Orca Network online database on that day. The latter included a sighting of a J pod whale (J27 "Blackberry") reported off False Bay off the southwest coast of San Juan Island (no time of day indicated; Orca Network n.d.(a)). Also on that day, killer whales were reported at 10:30 near Lime Kiln (central-west coast of San Juan Island, approximately 8 km northwest of False Bay). Finally, the Resident J, K and likely L pod members were reported as present near Turn Point, approximately 25 km north-northwest of False Bay on this date.
- On 15 April 2015 at 13:23, we observed a group of nine killer whales including one small calf traveling at medium speed in the Vashon sub-region at the northeastern tip of Vashon Island. We observed a small research vessel following these whales. We later learned via email communications with NMFS NWFSC researchers that this was their boat (B. Hanson and C. Emmons, NMFS NWFSC, pers. comm. August 2015). They informed us via email that this group belonged to the West Coast Transient (Biggs) population and included members of the pods T65A, T65B, T75B and T75C. Per their post on Orca Network (Orca Network n.d.(a)), this pod included a new calf that still had fetal folds and a bent-over dorsal fin. When these researchers first arrived at the whale group, the whales were working on a kill and one individual was carrying around part of the kill that appeared to have been a large mammal based on the bits and pieces left behind.
- Four days later on 19 April 2015 at approximately 15:30, we observed a group of six killer whales composed of two subgroups, including a possible calf. The whales were traveling fast in the Whidbey sub-region off the central west coast of the island. This sighting closely matched the location and time of numerous reported Orca Network sightings of a similar number of killer whales, reported by one observer as Transients

(Orca Network, n.d.(a)). Orca Network reports indicated that a small calf and at least two males and three females were present in this group.

- We observed a group nine of killer whales including one calf on 18 January 2016 at 11:03. The whales were exhibiting rest/slow travel behavior in the Seattle sub-region. This closely matched the location and time of reported Orca Network sightings of a similar number of killer whales and was later identified by NMFS as part of the J22 group of Southern Resident Killer whales (J. Waite and C. Emmons, NMFS NWFSC, pers. comm. July 2016).

Overall, mean group size of marine mammal species was 1.8 individuals across survey periods. However, mean group sizes for the four killer whale sightings and two Dall's porpoise sightings were higher than the overall mean (6.8 and 4.5, respectively; **Table 10**). In addition, mean group size of hauled-out harbor seals was much larger (mean=14.4, *SE*=1.8) than those in water (mean=1.3, *SE*=0.04) (see **Table 13 in Section 3.4**). Group sizes of marine mammal species ranged from 1 to 150 individuals. The largest groups consisted of hauled-out harbor seals (*n*=150 seals). Calves/pups were observed among three of the total 11 confirmed species, including harbor porpoises, killer whales, and harbor seals (**Table 10**). Across all six survey periods, calves comprised 5 percent (*n*=98) of all individual harbor porpoises seen. The proportion of calves to all harbor porpoises seen by seasonal survey period ranged from 0 percent in January 2016 to 6–8 percent during August–September 2013 and July and September 2014 (**Table 11 and Figures 5a and 5b**). In the 98 cases in which calves were observed among harbor porpoise groups, only one calf was present in 82 percent of those cases. The only other calf sightings consisted of two single killer whale calves, each seen among a group of nine killer whales. Among harbor seals, pups comprised 0.3 percent (*n*=25) of all individuals observed (**Table 10**), and all pups were seen in the water. Harbor seal pups were seen most commonly during the July 2014 survey period (**Table 12** and **Figures 4a and 4b**).

Table 11. Numbers and proportions of harbor porpoise calves seen by seasonal survey period 2013–2016. Individuals less than one-half the body length of nearby adults were considered calves.

Harbor Porpoise	Aug-Sept 2013	July 2014	Sept 2014	Jan 2015	April 2015	Jan 2016	Total
Total calves	11	36	46	1	4	0	**98**
Total all individuals	143	567	771	128	362	117	**2,088**
Percentage of all individuals	8%	6%	6%	1%	1%	0%	**5%**

Table 12. Numbers and proportions of harbor seal pups seen by seasonal survey period 2013–2016. Individuals less than one-half the body length of nearby adults were considered pups.

Harbor Seal	Aug-Sep 2013	Jul 2014	Sep 2014	Jan 2015	Apr 2015	Jan 2016	Total
Total pups	5	16	2	0	1	1	**25**
Total all individuals	1,499	1,866	2,092	71	1,764	719	**8,011**
Percentage of all individuals	<1%	1%	<1%	0	<1%	<1%	**0.3%**

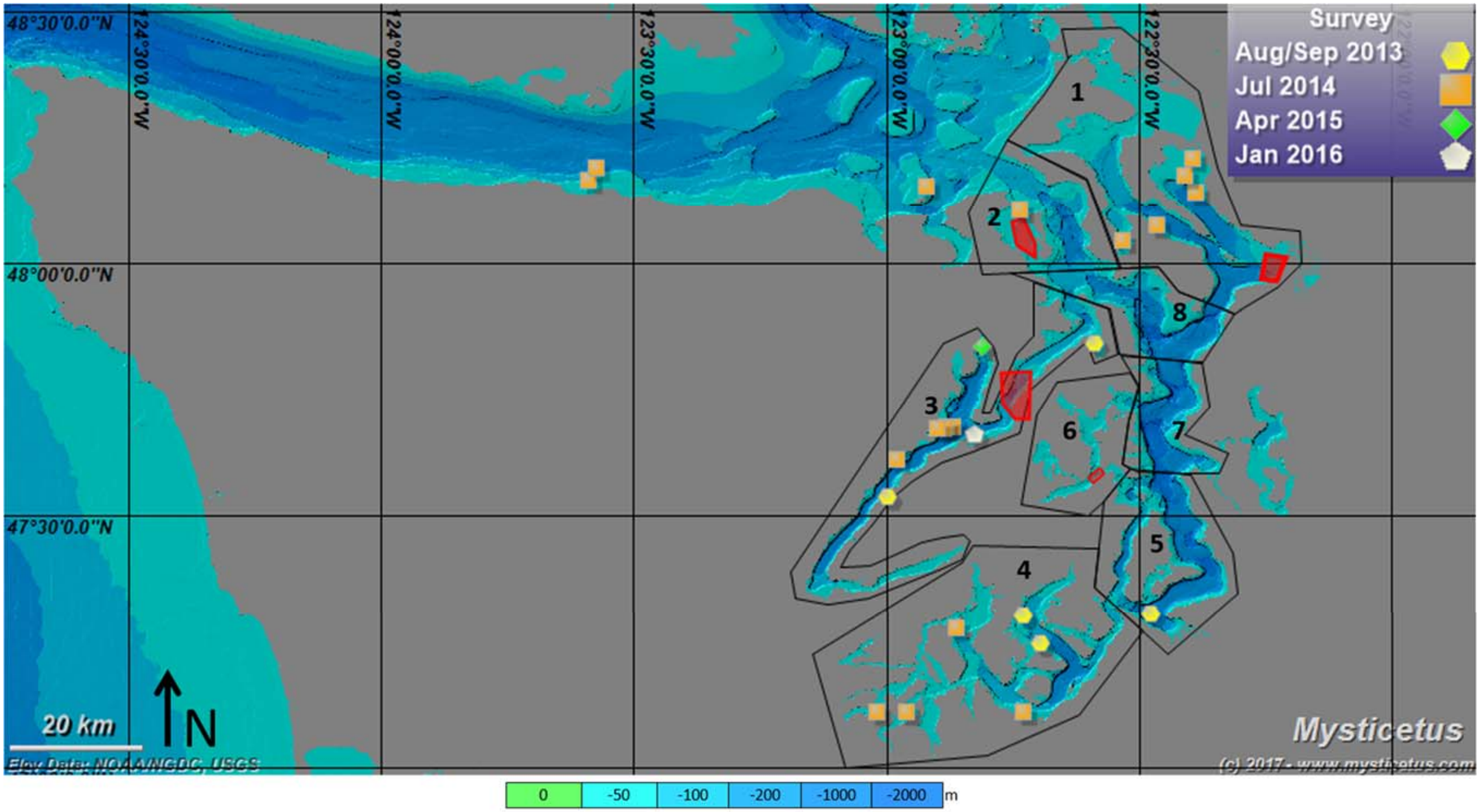

Figure 4a. For 2013–2016 Puget Sound aerial surveys: All harbor seal pup sightings within the aerial survey area. Pup" was defined as an individual less than one-half the body length of nearby adults, so pups are not restricted to newborn animals. Numbers indicate polygons for the eight survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

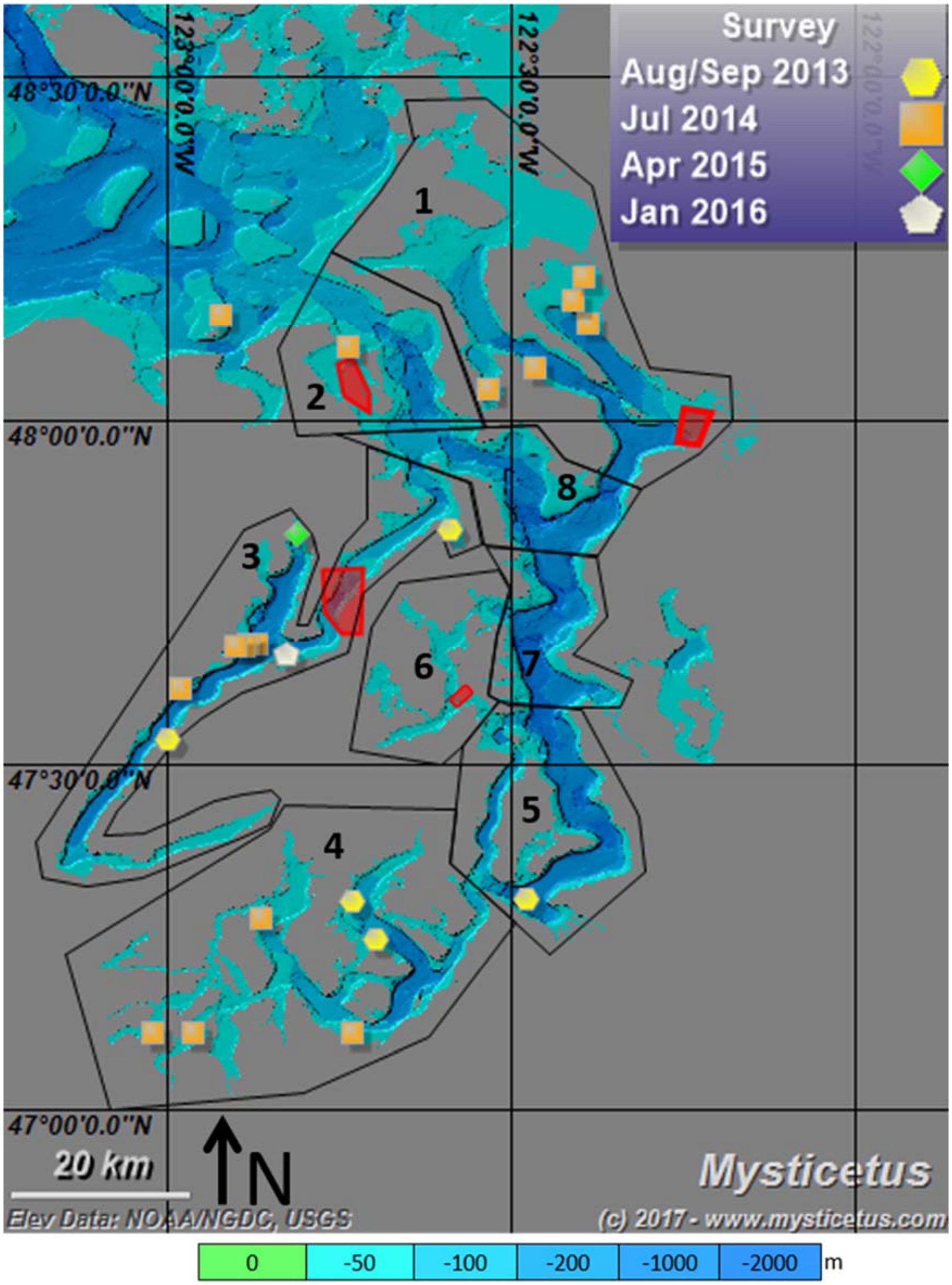

Figure 4b. For 2013–2016 Puget Sound aerial surveys harbor seal pup sightings: a zoomed in view of the same map focused on the main Puget Sound survey area and eight sub-regions. "Pup" was defined as an individual less than one-half the body length of nearby adults, so pups are not restricted to newborn animals. Numbers indicate polygons for the eight survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

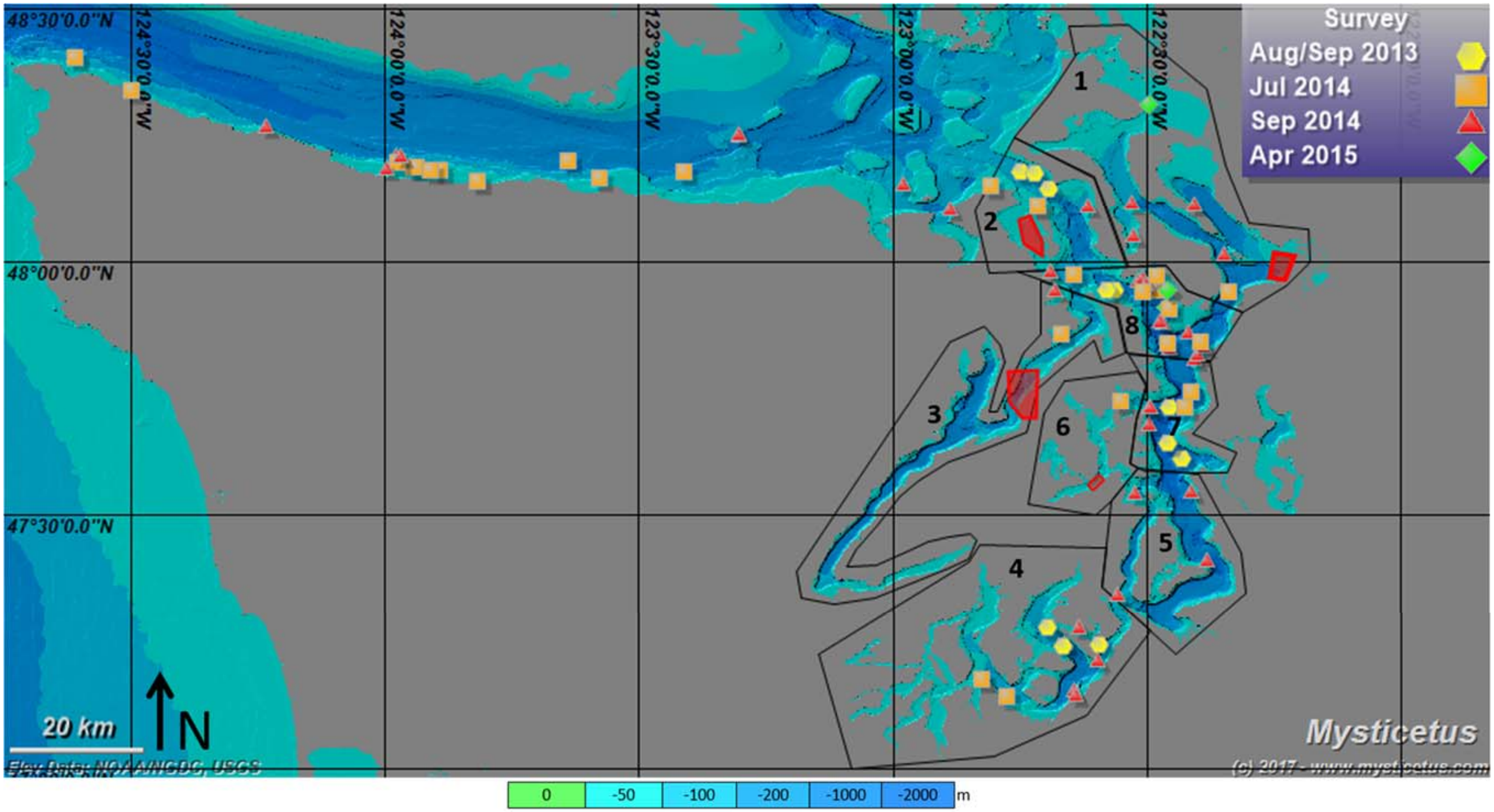

Figure 5a. For 2013–2016 Puget Sound aerial surveys: all harbor porpoise calf sightings within the aerial survey area. "Calf" was defined as an individual less than one-half the body length of nearby adults, so calves are not restricted to newborn animals. Numbers indicate polygons for the eight survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

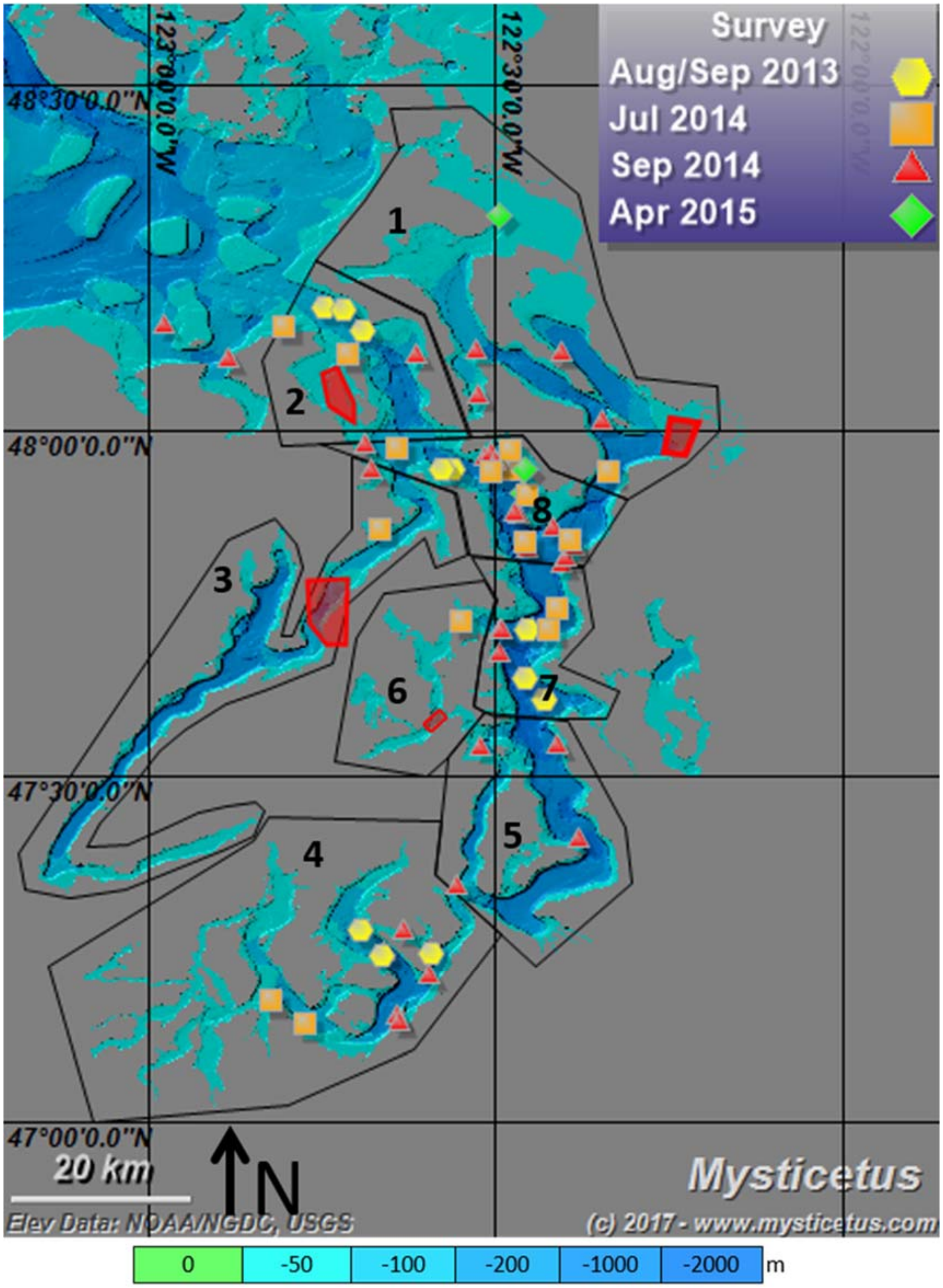

Figure 5b. For 2013–2016 Puget Sound aerial surveys harbor porpoise calf sightings: a zoomed in view of the same map focused on the main Puget Sound survey area and eight sub-regions. "Calf" was defined as an individual less than one-half the body length of nearby adults, so calves are not restricted to newborn animals. Numbers indicate polygons for the eight survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

3.3 Pinnipeds in Water and Hauled Out

Most harbor seal, California sea lion, and Steller sea lion groups were seen in water (96 percent, 68 percent, and 96 percent, respectively) (**Table 13**). However, surveys were designed to detect cetaceans in water and specifically avoided seal and sea lion haul-out areas, and some haul-out areas were in the designated no-fly zone. For completeness of data, numbers of seals and sea lions opportunistically observed hauled out are included in **Table 13**.

3.4 Occurrence and Distribution within Survey Sub-regions

Descriptive summary of relative occurrence and distribution by sub-region and season was limited to the harbor porpoise and harbor seal, since sample sizes of remaining species were relatively small. However, comparisons in this section are relative and are not corrected for effort or size of sub-region, and should thus be interpreted cautiously. Furthermore, stratification by eight sub-regions and four seasons pooled from six survey periods results in relatively small sample sizes, subject to potential over-interpretation, particularly given potential inter-annual variability common to marine ecosystems, including Puget Sound (e.g., see https://sites.google.com/a/psemp.org/psemp/home). **Section 3.6, Density and Abundance,** provides a more appropriate quantitative comparison of relative numbers and use for these two species by sub-region and season, since numbers are corrected for effort. While general relative comparisons are noted in this section for harbor porpoises and harbor seals, larger sample sizes are required for more meaningful and robust interpretation. Note that our discussion excludes the Juan de Fuca straight region, as these surveys focused on Puget Sound proper.

Recognizing the above caveats, overall (for all primary Puget Sound study area sub-regions excluding the opportunistic surveys in the Strait of Juan de Fuca) from 2013 to 2016, relative frequency of individual harbor porpoise sightings was highest in the South Whidbey sub-region (24 percent or 514 individuals), followed by East Whidbey and the Strait of Juan de Fuca (both 15 percent), with 11 to 12 percent in the Admiralty Inlet and Southern Puget Sound sub-regions (**Table 14**). The lowest proportions were observed in the Vashon, Bainbridge and Seattle sub-regions (4 to 6 percent). A notable apparent gap in harbor porpoise distribution occurred during all six survey periods within the Vashon sub-region in waters from Federal Way north to Burien and west to Vashon Island (**Figure 6**).

Across the six survey periods spanning four seasons, highest relative proportions of harbor porpoises by sub-region generally reflected areas with highest relative reported densities, with some exceptions related to corrected versus uncorrected for effort as discussed above (see **Section 3.6**). During the summer-fall July-September surveys, most harbor porpoises were seen in the South Whidbey, East Whidbey and Southern Puget Sound sub-regions (**Table 15**, **Figure 6**). However, during winter in January, highest relative sightings included the Hood Canal as well as the East Whidbey sub-regions. The one April spring survey also showed the relatively highest proportions of harbor porpoises in the Hood Canal and East Whidbey sub-regions, but also the Seattle and Southern Puget Sound sub-regions (**Table 15**, **Figure 6**).

Table 13. Total number of pinniped groups observed in water or hauled out.

Species	No. of Groups	No. of Groups in Water	% of Groups in Water	Mean of Maximum Dispersal for In-water Groups (*SE*)	Mean Group Size in Water (*SE*)	No. of Groups Hauled Out	% of Groups Hauled Out	Mean of Maximum Dispersal* for Hauled-out Groups (*SE*)	Mean Group Size Hauled Out (*SE*)
Harbor Seal	4,392	4,213	96	6.4 (0.5)	1.3 (<0.1)	179	4	4.9 (0.4)	14.4 (1.8)
California Sea Lion	166	113	68	1.6 (0.3)	1.3 (0.1)	53	32	0.9 (0.9)	1.8 (0.3)
Steller Sea Lion	70	67	96	1.4 (0.3)	1.1 (<0.1)	3	4	n/a	n/a

*Dispersal distance values based only on those groups of at least two individuals, estimated in species adult body lengths. Dispersal herein refers to maximum dispersal distance between neighbors within a group with no intervening individuals. Dispersal was not recorded for every group observed.

Key: %=percent; n/a=not available; No.=number; *SE*=standard error.

Table 14. Harbor porpoise and harbor seal sightings by sub-region during 2013–2016 aerial surveys of Puget Sound.

Survey Sub-region	Harbor Porpoise			Harbor Seal*		
	No. Indiv.	No. Groups	% Total Indiv./ Sub-region	No. Indiv.	No. Groups	% Total Indiv./ Sub-region
Admiralty Inlet	251	103	11%	281	209	4%
Bainbridge	100	35	5%	222	134	3%
East Whidbey	318	165	15%	2,013	984	25%
Hood Canal	173	113	8%	1,776	982	22%
Seattle	119	68	6%	188	130	2%
South Whidbey	514	178	24%	292	243	4%
Southern Puget Sound	265	155	12%	2,056	1,154	26%
Vashon	96	57	4%	424	363	5%
Strait of Juan de Fuca (Opportunistic)	319	143	15%	405	213	5%
*Other***	13	9	<1%	355	70	4%
TOTAL	**2,168**	**1,026**	**100**	**8,011**	**4,391**	**100**

* Includes harbor seals in water and hauled out.

Key: %=percent; Indiv.=individuals; No.=number

** 'Other' signifies sightings that occurred outside of the eight pre-defined Puget Sound subregion polygons and the Strait of Juan de Fuca (e.g., other = surveyed waters north and/or east of these regions, including San Juan Islands/Haro Strait) and a handful of sightings that fell on the border between defined polygons

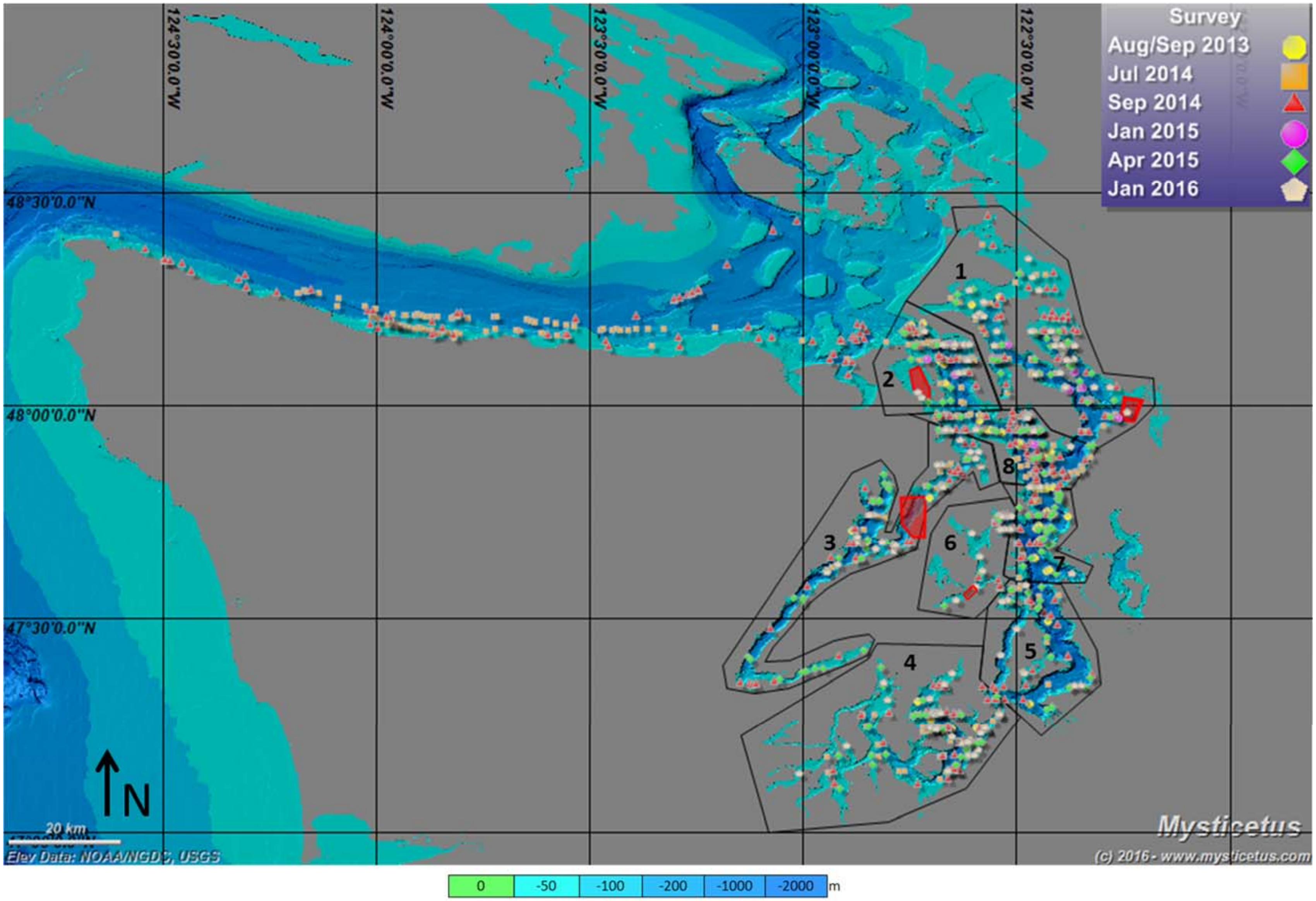

Figure 6. All harbor porpoise groups sighted during the 2013–2016 Puget Sound aerial surveys (see Figure 1). Numbers indicate polygons for the eight survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

Table 15. Number of groups sighted by species in the primary eight sub-regions (AI=Admiralty Inlet, B=Bainbridge, EW=East Whidbey, HC=Hood Canal, S=Seattle, SW=South Whidbey, SPS=Southern Puget Sound, V=Vashon) and the Strait of Juan de Fuca (SJF) during the 2013–2016 Puget Sound aerial surveys*.

Survey Period and Species**	AI	B	EW	HC	S	SW	SPS	V	SJF	Other***	Total
August-September 2013											
Harbor Seal	45	14	99	117	27	29	260	76	0	2	669
Harbor Porpoise	19	0	2	4	12	16	9	2	0	1	65
California Sea Lion	2	0	2	2	4	0	2	2	0	1	15
Risso's Dolphin	0	0	0	0	1	0	0	1	0	0	2
Survey Total	**66**	**14**	**103**	**123**	**44**	**45**	**271**	**81**	**0**	**4**	**751**
July 2014											
Harbor Seal	46	12	203	119	26	43	272	49	60	11	841
Harbor Porpoise	36	1	41	13	9	56	40	10	85	0	291
California Sea Lion	0	0	1	0	0	1	0	0	0	0	2
Survey Total	**82**	**13**	**245**	**132**	**35**	**100**	**312**	**59**	**145**	**11**	**1,134**
September 2014											
Harbor Seal	49	26	201	179	21	83	180	69	152	39	999
Harbor Porpoise	21	15	48	37	17	74	49	18	58	7	344
California Sea Lion	0	2	0	1	2	4	1	11	0	1	22
Killer Whale (SRKW)****	0	0	0	0	0	0	0	0	0	1	1
Minke Whale	0	0	0	0	0	0	0	0	2	0	2
Steller Sea Lion	24	1	3	6	4	11	5	8	6	0	68
Survey Total	**94**	**44**	**252**	**223**	**44**	**172**	**235**	**106**	**218**	**48**	**1,436**
January 2015											
Harbor Seal	13	2	23	2	9	14	0	1	0	0	64
Harbor Porpoise	2	1	10	1	0	1	0	0	0	0	15
Survey Total	**15**	**3**	**33**	**3**	**9**	**15**	**0**	**1**	**0**	**0**	**79**

Survey Period and Species**	AI	B	EW	HC	S	SW	SPS	V	SJF	Other***	Total
April 2015											
Harbor Seal	33	49	254	346	25	49	333	123	1	18	1,231
Harbor Porpoise	12	6	34	31	27	23	38	20	0	1	192
California Sea Lion	10	2	11	13	14	4	2	20	0	0	76
Dall's Porpoise	0	0	0	1	0	0	0	0	0	0	1
Gray Whale	0	0	5	0	0	0	0	0	0	0	5
Killer Whale (Transient)*****	0	0	1	0	0	0	0	1	0	0	2
Steller Sea Lion	0	0	0	0	0	1	0	0	0	0	1
Otter (sea or river)	0	0	0	0	0	0	0	0	0	0	0
Survey Total	**55**	**57**	**305**	**391**	**66**	**77**	**373**	**164**	**1**	**19**	**1,508**
January 2016											
Harbor Seal	23	31	114	219	22	25	109	45	0	0	588
Harbor Porpoise	12	12	30	27	3	7	19	7	0	0	117
California Sea Lion	5	2	5	16	4	12	1	6	0	0	51
Killer Whale (SRKW)*****	0	0	0	0	1	0	0	0	0	0	1
Steller Sea Lion	0	0	0	0	1	0	0	0	0	0	1
Dall’s Porpoise	1	0	0	0	0	0	0	0	0	0	1
Humpback Whale	0	0	0	0	0	0	2	0	0	0	2
Otter (sea or river)	0	0	0	0	0	0	1	0	0	0	1
Survey Total	**41**	**45**	**149**	**262**	**31**	**44**	**132**	**58**	**0**	**0**	**762**
OVERALL TOTAL	**353**	**176**	**1,087**	**1,134**	**229**	**453**	**1,323**	**469**	**364**	**82**	**5,670**

*Sightings are uncorrected for effort.

**These data do not include any unidentified marine mammals.

*** 'Other' signifies sightings that occurred outside of the eight pre-defined Puget Sound subregion polygons and the Strait of Juan de Fuca (e.g., other = surveyed waters north and/or east of these regions, including San Juan Islands/Haro Strait) and a handful of sightings that fell on the border between defined polygons

****20 September 2014 – three killer whales sighted off San Juan Island (Strait of Juan de Fuca), likely SRKW based on Orca Network reports

*****19 April 2015 – six killer whales sighted off East Whidbey, likely transients based on Orca Network reports and 15 April 2015, nine killer whales sighted off Vashon, confirmed transients by NMFS

******18 January 2016 – nine killer whales sighted in Seattle region, confirmed SRKW by NMFS

For individual harbor seals, relative sighting frequency by sub-regions was highest in the Southern Puget Sound (26 percent or 2,055 individuals) and East Whidbey sub-regions (25 percent or 2,013 individuals), followed by Hood Canal (22 percent) (**Table 14**). The lowest relative proportion (2 percent) occurred in the Seattle sub-region (**Figure 7**). During all six survey periods, a notable apparent gap in harbor seal distribution occurred in the upper northeastern portion of Hood Canal; however, approximately the southern one-third of this area was not surveyed or observable due to the presence of a restricted no-fly area associated with the Naval Base Kitsap at Bangor Installation (**Figures 1 and 4a and 4b**). Pooled species presence in the eight sub-regions is shown in **Table 15** and **Figure 7**. Because we were unable to survey the aforementioned high-density haul-out areas, we do not further discuss harbor seal relative occurrence and distribution by season and sub-region herein except in **Section 3.6, Density and Abundance**. See Jeffries et al. (2014) for a more detailed discussion of harbor seal distribution and occurrence in the Puget Sound Region based on aerial surveys of major haul-out areas.

Sightings of cetacean species other than harbor porpoises were relatively uncommon and/or seasonal in nature (**Tables 10 and 15; Figure 8**). All five of the gray whale sightings occurred during April 2015 in the East Whidbey sub-region, three of which were in the eastern portion of Possession Sound northwest of Naval Station Everett. The four killer whale sightings occurred in three different sub-regions: East Whidbey (April 2015), Vashon (April 2015), and Seattle (January 2016), and outside the survey area near San Juan Island (August-September 2013). The only minke whale sightings consisted of two single whales observed during opportunistic surveys in the southeastern Strait of Juan de Fuca in August-September 2013 (outside the eight primary sub-regions). The two humpback whale sightings occurred in the Southern Puget Sound sub-region (January 2016) and were identified as the same animal based on proximity of sightings and photographs. Both sightings of Risso’s dolphins occurred in the Seattle/Vashon sub-regions during August-September 2013. A single Dall’s porpoise was observed in the Hood Canal sub-region, specifically in Dabob Bay (April 2015), and a group of 8 Dall’s porpoises was observed in Admiralty Inlet in January 2016. Steller sea lions and California sea lions inhabited the Puget Sound primarily during spring and fall. Although seen throughout the entire region, the majority of Steller sea lions were sighted in the Admiralty Inlet sub-region, while the majority of California sea lions were sighted in the Vashon sub-region (**Figures 9a and 9b**).

One otter sighting (river or sea otter) of a single unidentified otter occurred in the Southern Puget Sound sub-region during the January 2016 survey period.

3.5 Photography and Video

A total of 1,693 digital photographs was taken during the six survey periods (**Table 16**). As indicated previously, photographs were taken primarily of unusual/rare sightings and initially unidentified or unconfirmed species to confirm or verify species as possible (see **Section 2.3.3**). Photographs included feeding gray whales and what appeared to be feeding pits made by gray whales in mudflats of the Snohomish River Delta during low tide in the eastern half of Possession Sound northwest of Naval Station Everett in April 2015. Video was taken during the January and April 2015 survey period and included feeding gray whales, totaling 14:29 minutes.

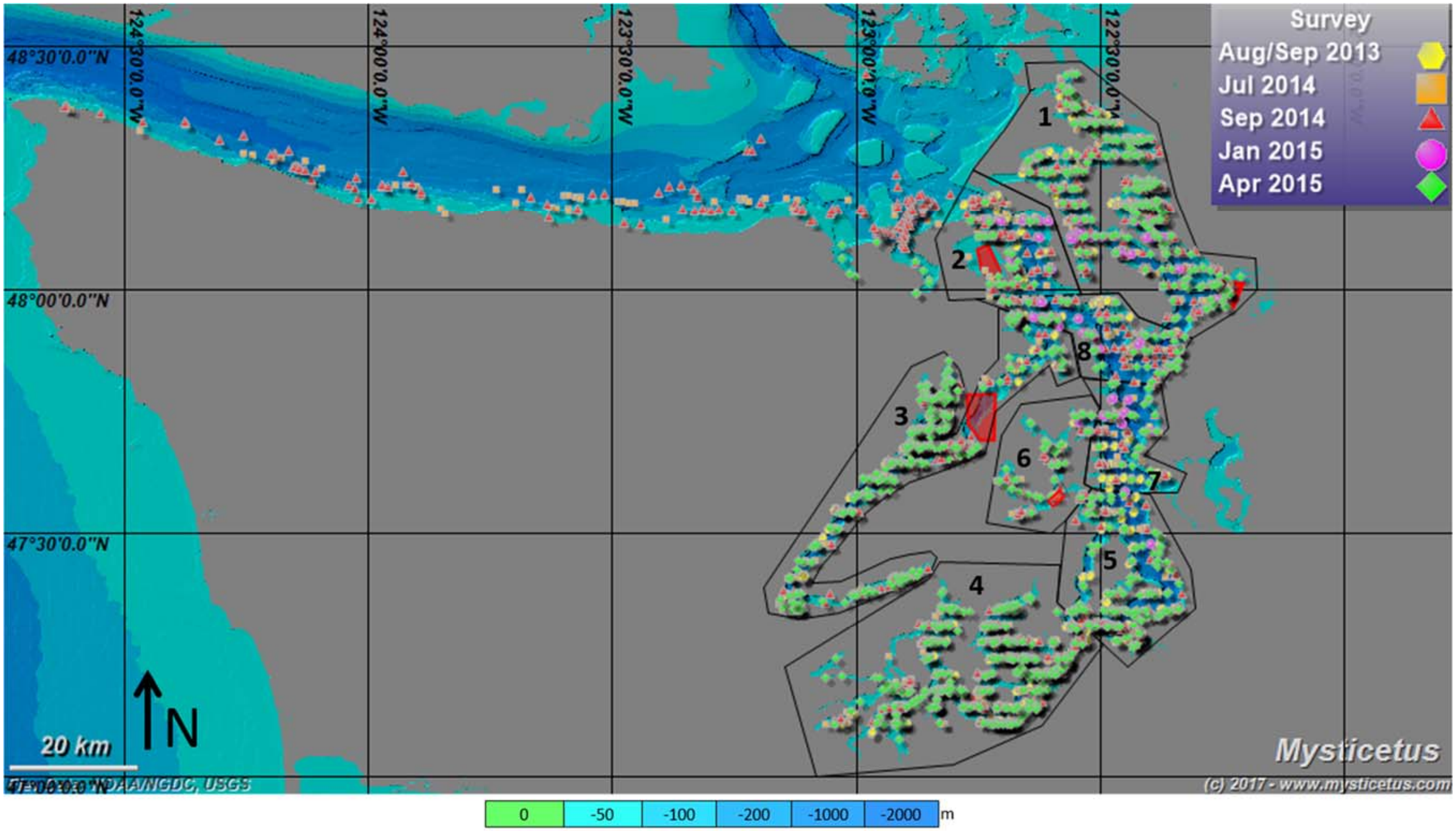

Figure 7. All harbor seal group sightings for Puget Sound aerial surveys 2013–2016. Numbers indicate polygons for the eight survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

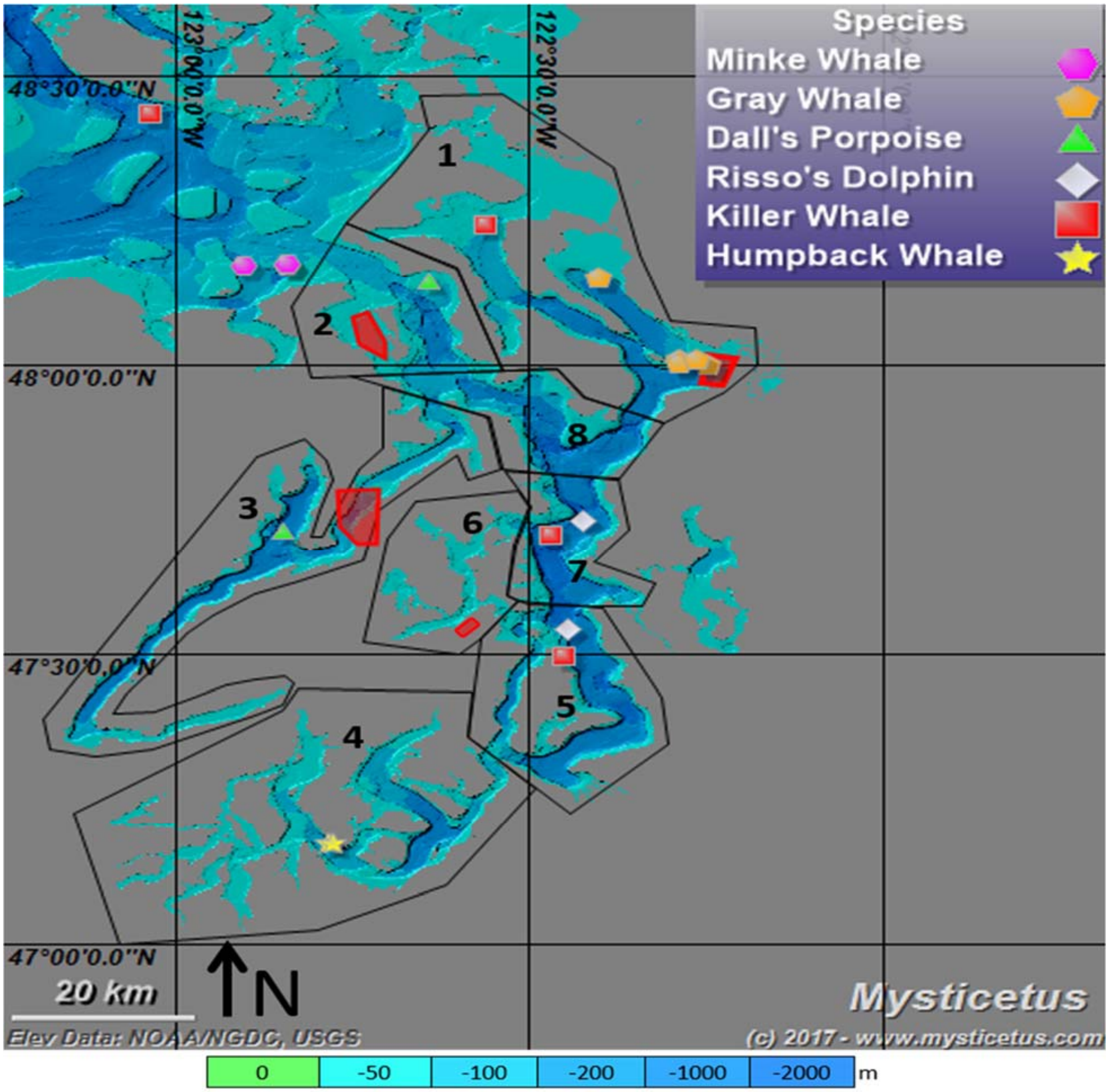

Figure 8. All group sightings of cetacean species (excluding harbor porpoises and unidentified species) for Puget Sound aerial surveys 2013–2016. Numbers indicate the eight survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

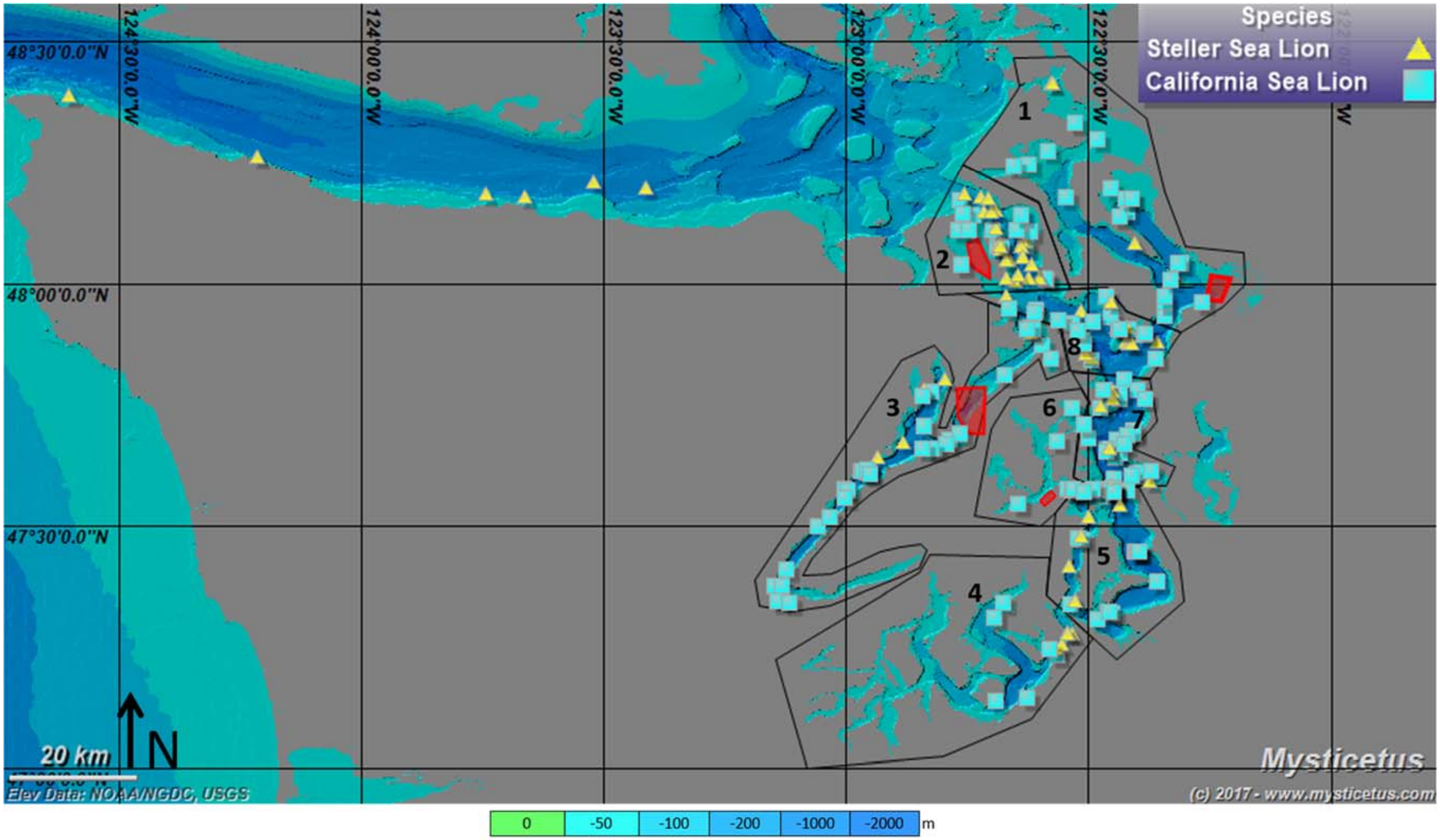

Figure 9a. All group sightings of pinniped species (excluding harbor seal, otter, and unidentified species) for Puget Sound aerial surveys 2013–2016 within and outside the primary eight study area sub-region polygons. Numbers indicate the eight survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

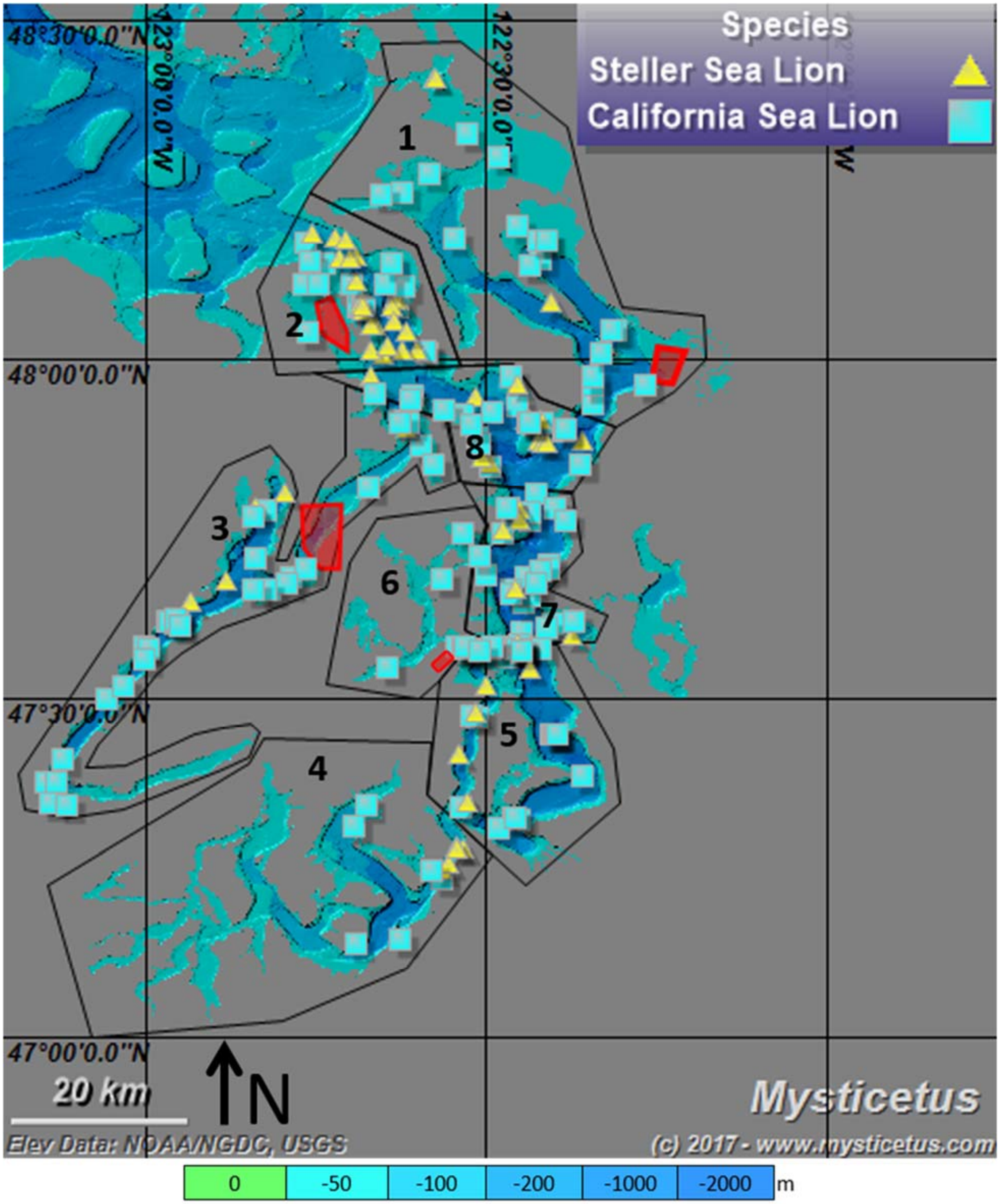

Figure 9b. Blow up of the same figure focused only on pinniped group sightings made within the primary eight study area sub-regions. Numbers indicate the eight survey sub-regions: 1=East Whidbey, 2=Admiralty Inlet, 3=Hood Canal, 4=Southern Puget Sound, 5=Vashon, 6=Bainbridge, 7=Seattle, and 8=South Whidbey. Red polygons indicate no-fly and National Security areas (see Figure 1).

Table 16. Summary of digital photographs and video taken during the 2013–2016 Puget Sound aerial surveys.

Survey Period	# of Photos Taken	Video Taken (min:sec)	Description
Aug-Sep 2013	500	0:00	
Jul 2014	74	0:00	
Sep 2014	188	0:00	
Jan 2015	32	2:13	
Apr 2015	538	12:16	15 April—killer whales traveling, identified by NMFS researchers as west coast Biggs' transients consisting of T65As, T65Bs, T75Bs and T75C, including a new calf (C. Emmons, NMFS Northwest Fisheries Science Center [NWFSC], pers. comm. August 2015; Orca Network n.d.(a)); 20 April—gray whale; 21 April—probable gray whale feeding pits in mud; 22 April—gray whales feeding
Jan 2016	361	0:00	
Total	**1,693**	**14:29**	

3.6 Density and Abundance

After we filtered for survey conditions suitable to estimate density and abundance, sample size was sufficient for 3 of the 10 species sighted during the surveys: the harbor porpoise, harbor seal, and combined sea lions (California and Steller) (see **Section 2.3**). Of 1,026 total harbor porpoise groups seen, 385 (38 percent) were suitable for density and abundance analyses; 2,170 of 4,391 (49 percent) total harbor seal groups and 66 of 236 (28 percent) total sea lion groups were suitable for these analyses based on criteria described in **Section 2.3**. Hauled-out harbor seal and sea lion sightings were not used for in-water density estimation purposes because seals were completely out of the water. However, harbor seals with their bellies resting on sand or mud but still partially in the water were included for in-water density estimates (see **Section 2.0, Methods**).

3.6.1 Harbor Porpoises

Harbor porpoises occurred in all sub-regions surveyed, including the San Juan de Fuca region outside the eight primary sub-regions (**Tables 14** and **15**, **Figures 5a and 5b**). Aerial survey data provided a robust pooled sample size for analysis (n=385 after truncation), with a good fit to the PSD data using a Half-Normal model with a cosine adjustment (**Figure 10**). The overall effective strip width (ESW) was estimated at 0.241 km. Harbor porpoise densities were highest in northern Puget Sound (i.e., Admiralty Inlet and South Whidbey sub-regions) and lowest in the Vashon, Seattle, Bainbridge, and Hood Canal sub-regions. The highest abundances were for Admiralty Inlet, East Whidbey, and South Whidbey, although Southern Puget Sound had a reasonably high abundance as well, indicating that harbor porpoise use of the southern Sound is extensive. The lowest density was in the Vashon sub-region, while the lowest abundance was in the Bainbridge sub-region. The overall average density and number of harbor porpoises in the study area was estimated at 0.86 porpoises/km^2 and 2,269 porpoises (**Table 17**).

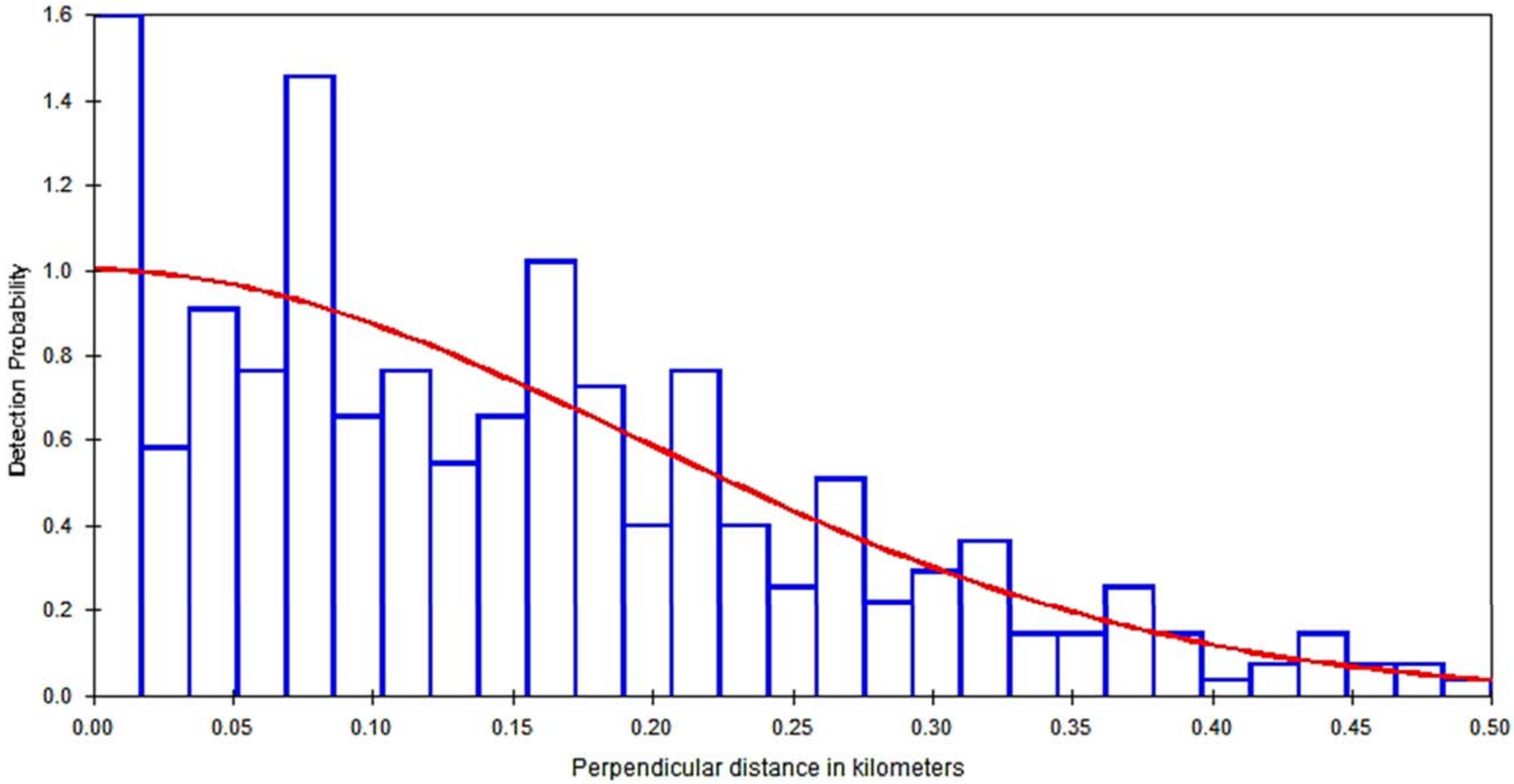

Figure 10. Perpendicular sighting distance plot for harbor porpoise, with chosen model (Half-Normal model with a cosine adjustment) shown based on 2013–2016 sighting data.

Table 17. Harbor porpoise line-transect parameters and estimates of density and abundance for Puget Sound aerial surveys 2013–2016.

Season	Stratum	Number of Sightings *	Effort (km)	Average Group Size	Trackline Detection Probability [*g*(0)] **	Individual Density (#/km²)	*CI₉₅* (Density)	Abundance	*CI₉₅* (Abundance)	%*CV*	%*CV'*
Seasons Pooled	Admiralty Inlet	50	318	1.5	0.292**	1.72	0.80-3.69	438	309-622	40.6	17.4
Seasons Pooled	Bainbridge	13	240	1.4	0.292**	0.53	0.20-1.43	50	23-107	53.3	38.7
Seasons Pooled	East Whidbey	78	1,338	1.8	0.292**	0.75	0.34-1.64	482	319-729	41.8	20.2
Seasons Pooled	Hood Canal	38	1,045	1.7	0.292**	0.44	0.19-0.98	170	108-269	43.1	22.7
Seasons Pooled	Seattle	27	482	1.3	0.292**	0.54	0.19-1.53	113	47-269	55.9	42.3
Seasons Pooled	South Whidbey	61	467	2.2	0.292**	2.03	0.91-4.53	544	353-839	42.5	21.6
Seasons Pooled	Southern Puget Sound	100	1,425	1.7	0.292**	0.86	0.39-1.88	391	262-582	41.5	19.7
Seasons Pooled	Vashon	18	896	1.7	0.292**	0.25	0.11-0.57	81	51-127	43.2	22.9
Winter	*Puget Sound Pooled*	*50*	*1,310*	*1.5*	*0.292***	*0.42*	*0.28-0.62*	*1,095*	*727-1,647*	*42.0*	*20.5*
Spring	*Puget Sound Pooled*	*103*	*1,658*	*2.0*	*0.292***	*0.88*	*0.62-1.25*	*2,320*	*1,639-,3283*	*40.6*	*17.5*
Summer	*Puget Sound Pooled*	*126*	*1,574*	*1.8*	*0.292***	*1.05*	*0.70-1.57*	*2,765*	*1,842-4,152*	*42.0*	*20.4*
Fall	*Puget Sound Pooled*	*106*	*1,670*	*1.5*	*0.292***	*0.68*	*0.45-1.00*	*1,786*	*1,209-2,638*	*41.5*	*19.5*
Seasons Pooled	*Puget Sound Pooled*	***385***	***6,212***	***1.7***	***0.292****	***0.86***	***0.72-1.03***	***2,269***	***1,887-2,729***	***37.8***	***9.4***

*After truncation
**From Laake et al. 1997

Harbor porpoise seasonal use of Puget Sound showed an interesting pattern, with higher numbers in the study area during spring and summer months, and lower numbers in fall and winter. The highest seasonal abundance (summer) was estimated at 2,765 porpoises (**Figure 11** and **Table 17**).

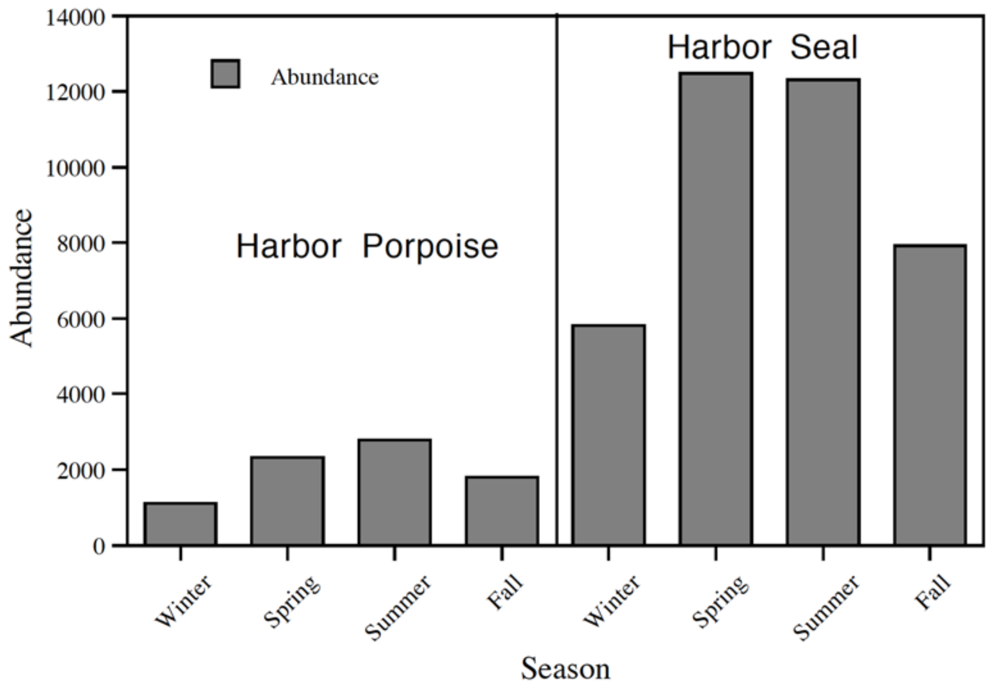

Figure 11. Seasonal estimates of abundance for the two most common species of marine mammals in Puget Sound, harbor seals and harbor porpoises, showing spring/summer peaks for both species.

3.6.2 Harbor Seals

Harbor seals used all of the study area, consistent with studies indicating that they are common throughout Puget Sound (**Tables 14** and **15**, **Figure 6**). Our surveys provided a robust set of data for analysis (n=3,170 harbor seal groups after truncation), with a good fit to the PSD data using a Half-Normal model with a cosine adjustment (**Figure 12**). Resulting estimates had high *CV*s, but this was largely related to the high variability in surface and dive times used to develop the $g(0)$ variance component. Conversely, *CV*s that did not incorporate this factor were quite low, ranging from approximately 6 to 19 percent, indicating high statistical precision. The overall ESW was estimated at 0.227 km. Densities were highest in Southern Puget Sound and Hood Canal, and lowest in the Vashon and Seattle sub-regions. The highest abundances were also in the Southern Puget Sound and Hood Canal sub-regions, with lowest abundance in the Seattle sub-regions. The overall average density and number of harbor seals in the study area was estimated at 3.57/km^2 and 9,404 individuals (**Table 18**).

Seasonal use of Puget Sound by harbor seals showed a strong pattern, with highest numbers during spring and summer months (about 12,000 individuals), and much lower numbers in fall and winter (approximately 6,000 to 8,000). The highest seasonal abundance (spring) was estimated at 12,471 harbor seals (**Table 18**).

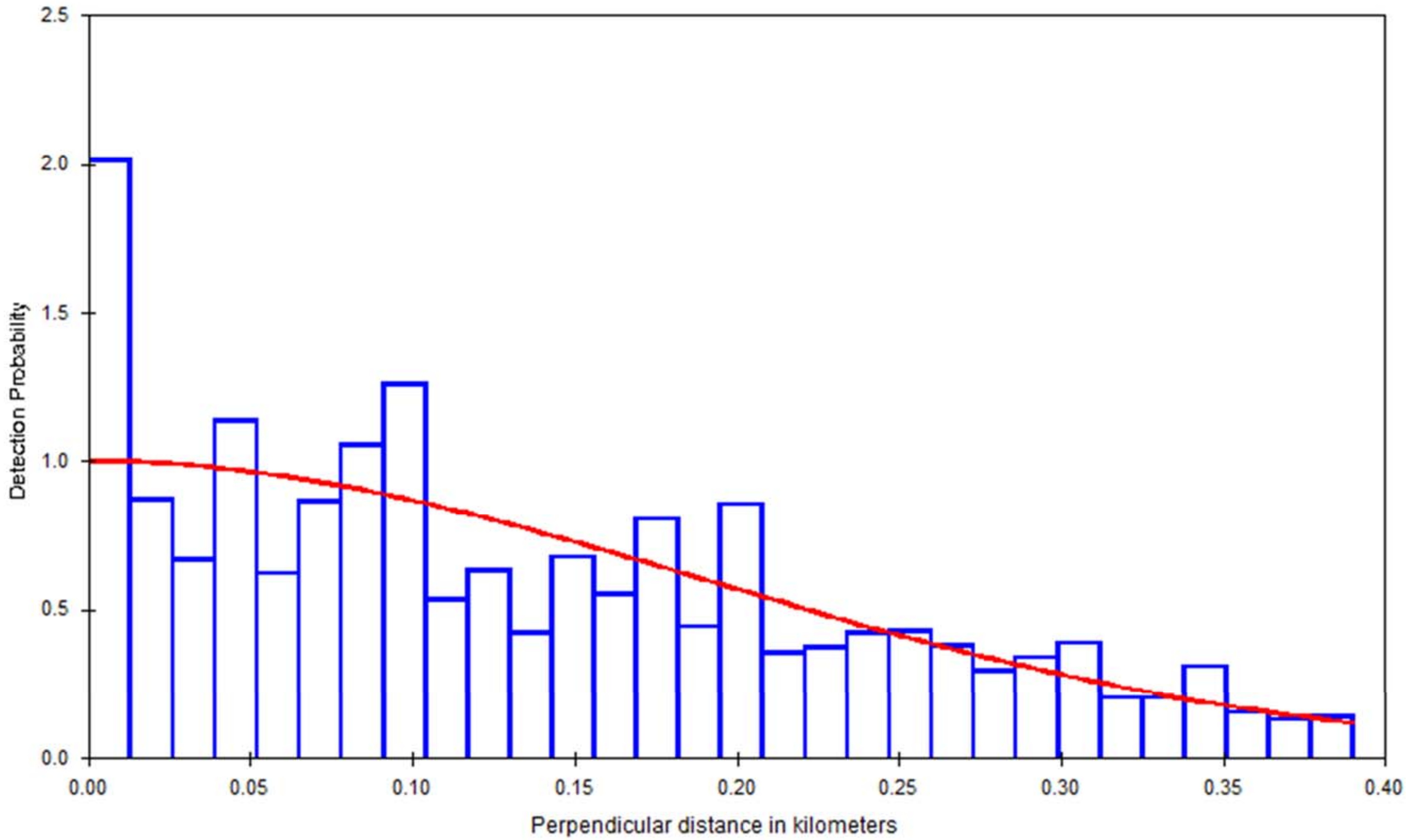

Figure 12. Harbor seal perpendicular sighting distance histogram and fitted detection function based on 2013–2016 sighting data. Model used is Half-Normal, with cosine adjustment.

Table 18. Harbor seal line-transect parameters and estimates of density and abundance for Puget Sound aerial surveys 2013–2016. Note that abundance estimates are based on observations of harbor seals in water and underrepresent actual harbor seal abundance in Puget Sound because no correction was made for seals hauled out during surveys.

Season	Stratum	Number of Sightings*	Effort (km)	Average Group Size	Trackline Detection Prob. - *g*(0) **	Individual Density (#/km²)	CI_{95} (Density)	Abundance	CI_{95} (Abundance)	%CV	%CV'
Seasons Pooled	Admiralty Inlet	73	551	1.3	0.204**	2.02	0.32-12.77	516	82-3258	119.2	13.8
Seasons Pooled	Bainbridge	71	268	1.1	0.204**	3.21	0.51-20.24	301	48-1898	119.1	13.1
Seasons Pooled	East Whidbey	430	1,812	1.1	0.204**	2.98	0.47-18.92	1,926	304-12,221	119.7	17.4
Seasons Pooled	Hood Canal	521	1,172	1.2	0.204**	5.74	0.91-36.13	2,246	357-14,131	118.8	10.5
Seasons Pooled	Seattle	56	563	1.0	0.204**	1.19	0.19-7.54	252	40-1,594	119.5	16.3
Seasons Pooled	South Whidbey	115	718	1.3	0.204**	2.52	0.40-15.98	674	106-4,279	119.7	17.4
Seasons Pooled	Southern Puget Sound	742	1,553	1.2	0.204**	6.37	1.01-40.22	2,905	460-18,330	119.1	19.2
Seasons Pooled	Vashon	162	1,096	1.1	0.204**	1.85	0.29-11.64	584	93-3,685	119.1	12.9
Winter	*Puget Sound Pooled*	307	1,522	1.1	0.204**	2.2	0.35-13.85	5,812	924-36,535	118.8	9.5
Spring	*Puget Sound Pooled*	*639*	*1,658*	*1.1*	0.204**	*4.73*	*0.75-29.78*	*12,471*	*1,980-78,830*	*118.9*	*11.3*
Summer	*Puget Sound Pooled*	*543*	*1,655*	*1.3*	0.204**	*4.7*	*0.73-29.69*	*12,317*	*1,937-78,310*	*119.9*	*18.8*
Fall	*Puget Sound Pooled*	*681*	*2,896*	*1.2*	0.204**	*3.01*	*0.48-18.90*	*7,928*	*1,261-49,833*	*118.7*	*9.2*
Seasons Pooled	***Puget Sound Pooled***	***2,170***	***7,731***	***1.2***	0.204**	***3.57***	***0.55-23.08***	***9,404***	***1,453-60,860***	***118.6***	***6.3***

*After truncation

**From Jefferson et al. 2017.

3.6.3 Sea Lions

The analysis combined both California and Steller sea lions into one group, as the sample sizes for both species were small, and both general patterns of use and detectability were very similar for the two species. We did not have an appropriate value for trackline detection probability (*g*[0]); thus, for reasons discussed above, resulting estimates (**Table 19**) are not corrected for missed trackline animals (note that it is possible that some bias could result, if indeed many animals were diving at the time of the surveys).

Despite the small sample size of useable sightings (*n*=76), we obtained a good fit of the PSD data for sea lions using a Half-Normal model with a cosine adjustment (**Figure 13**). The ESW was estimated at 0.255 km. Estimates of density and abundance were low, and it is clear that only small numbers of sea lions were in-water during the study period. It should be noted that pinnipeds present in substantial numbers at haul-out sites in Puget Sound, which were not consistently captured due to the survey method, which focused on in-water animals. Several haul-out sites were also located underneath the umbrella of a no-fly zone, and animals at these sites were therefore not recorded by the observers.

Although sea lions used the entire study area, very low numbers occurred in the southern sub-regions (e.g., Southern Puget Sound had an estimated abundance of only two sea lions). The Admiralty sub-region had both the highest density (0.06 sea lions/ km^2) and highest estimated abundance (15 individuals). The overall year-round average number of sea lions in-water the study area was estimated at 53 individuals (**Table 19**); however, as discussed above, the survey methods used in this project may vastly underestimate overall sea lions numbers, due to most animals being on land or under a no-fly zone, and thus not sampled during these surveys.

Sea lion seasonal use patterns also showed variation, as expected (**Table 19**). Lowest numbers (*n*=20) were recorded in the summer with highest numbers recorded in spring and fall (approximately 60 in each season) with winter numbers in between (**Table 19**).

Table 19. Sea lion (California and Steller) line-transect parameters and estimates of density and abundance for the Puget Sound study area 2013–2016.

Season	Stratum	Number of Sightings*	Effort (km)	Average Group Size	Trackline Detection Probability *g*(0)	Individual Density (#/km^2)	*CI₉₅* (Density)	Abundance	*CI₉₅* (Abundance)	%*CV*
Seasons Pooled	Admiralty Inlet	11	551	1.3	1.0	0.06	0.03-0.12	15	7-32	38.4
Seasons Pooled	Bainbridge	3	268	1.0	1.0	0.02	0.01-0.06	2	1-6	54.5
Seasons Pooled	East Whidbey	10	1,812	1.0	1.0	0.01	0.01-0.02	7	4-12	25.9
Seasons Pooled	Hood Canal	15	1,172	1.0	1.0	0.03	0.01-0.05	10	5-18	30.3
Seasons Pooled	Seattle	4	563	1.0	1.0	0.01	0.01-0.03	3	1-7	41.4
Seasons Pooled	South Whidbey	11	718	1.0	1.0	0.03	0.02-0.05	8	5-14	27.8
Seasons Pooled	Southern Puget Sound	3	1,553	1.0	1.0	0	0.00-0.01	2	0-6	68.8
Seasons Pooled	Vashon	9	1,096	1.2	1.0	0.02	0.01-0.05	7	3-14	37.6
Winter	*Puget Sound Pooled*	*10*	1,522	*1.1*	1.0	*0.02*	*0.01-0.03*	*40*	*22-72*	*30.5*
Spring	*Puget Sound Pooled*	*21*	*1,658*	*1.0*	1.0	*0.02*	*0.02-0.03*	*66*	*46-93*	*17.5*
Summer	*Puget Sound Pooled*	*4*	*1,655*	*1.3*	1.0	*0.01*	*0.00-0.02*	*20*	*6-62*	*61.3*
Fall	*Puget Sound Pooled*	*31*	*2,896*	*1.1*	1.0	*0.02*	*0.01-0.04*	*63*	*38-102*	*24.7*
Seasons Pooled	***Puget Sound Pooled***	***66***	***7,731***	***1.1***	1.0	***0.02***	***0.01-0.03***	***53***	***38-74***	***16.8***

*After truncation

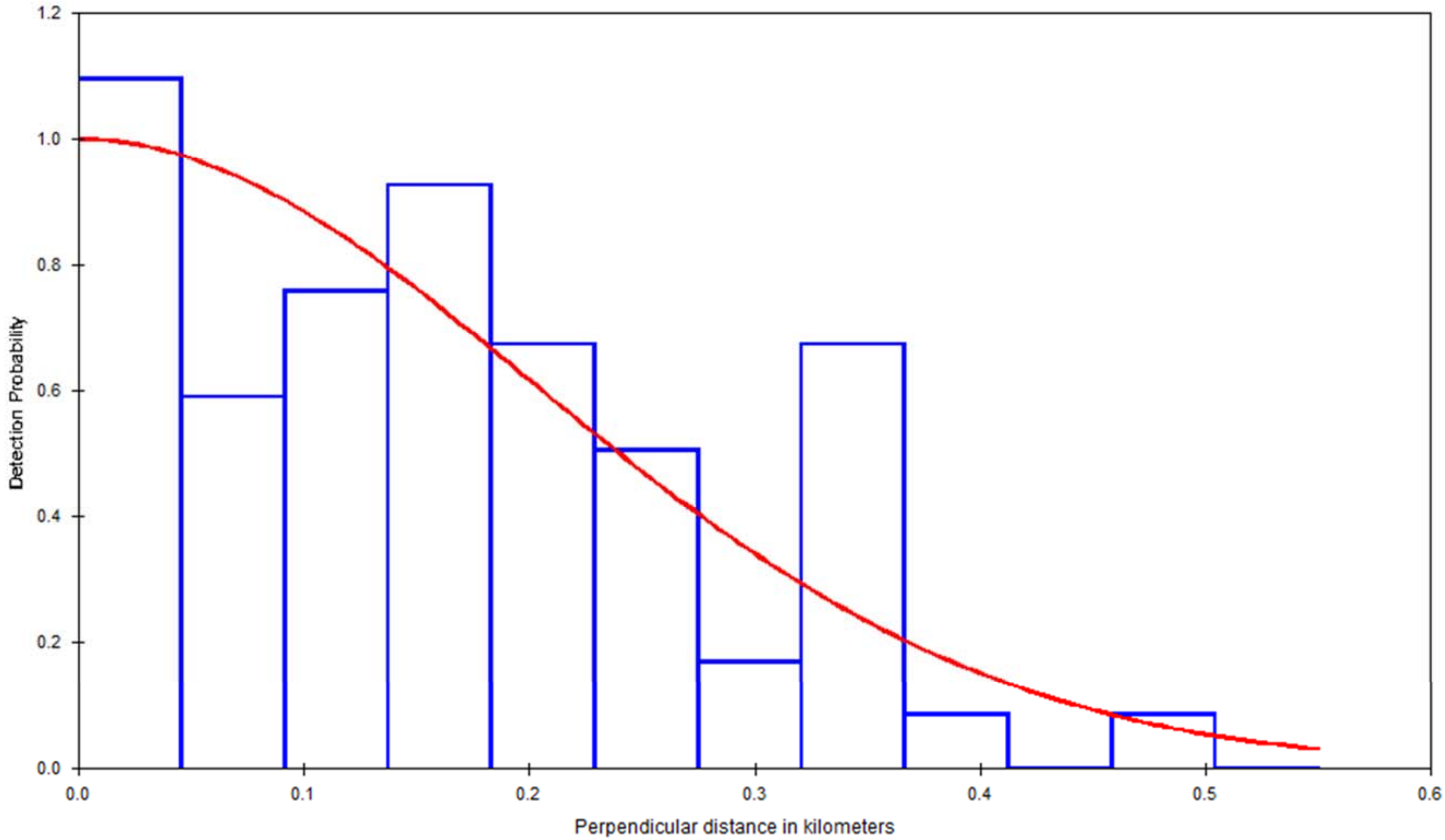

Figure 13. Perpendicular sighting distance plot for California and Steller sea lions, with chosen model (Half-Normal model with a cosine adjustment) shown.

3.6.4 Harbor Porpoise and Harbor Seal Occurrence near Naval Installations

To address harbor porpoise and harbor seal occurrence near specific naval installations in Puget Sound, we report observations of these species and the average estimated number of individuals based on density in the sub-region for areas of 2-nautical mile (nmi) radius around six naval installations (**Tables 20** through **22, Figure 14**). The estimated abundance within the 2-nmi radius was calculated by *Water Area (km²) × Density in Sub-region***.** It should be noted that raw counts are reported for information purposes only and are not corrected for effort or other variables. Abundances within the 2-nmi radii represent average expected abundances within in-water areas based on densities within the larger encompassing sub-regions. Thus, the latter estimated values do consider effort, visibility, sighting bias, etc. However, associated data were not sufficient to include a seasonal component or to consider how density may differ within the smaller 2-nmi areas compared to the larger sub-regions.

Table 20. Names and locations of naval installations for which harbor porpoise and harbor seal abundances were estimated in water for a 2-nmi radius around the installation. Latitudes and longitudes were chosen to be close to the shoreline of each installation to allow inclusion of the largest area of water within the 2-nmi radii.

Naval Installation	Longitude (W)	Latitude (N)	Description
Naval Base Kitsap at Bangor	122.7248	47.7544	Northwest edge of EHW2
Naval Air Station Whidbey Island	122.5873	48.2829	Crescent Harbor approximately 2 miles west of neck of Polnell Point
Dabob Bay	122.8530	47.7116	Center of bay approximately halfway between Seal Rock and Zelatched Point
Naval Station Everett	122.2337	47.9816	Southwest corner of western Everett pier
Manchester Fuel Depot	122.5310	47.5650	Approximate mid-point of the northeast point of the depot
Naval Base Kitsap at Bremerton	122.6421	47.5531	Central location along the shoreline at edge of dock at approximate center of facility along shoreline of Sinclair Inlet

Table 21. Harbor porpoise sightings (upper table) and estimated average abundances (lower table) within a 2-nmi radius of six naval installations based on densities in the appropriate larger, encompassing sub-regions.

Survey:	Aug-Sep 2013		Jul 2014		Sep 2014		Jan 2015		Apr 2015		Jan 2016		Total	
Sub-Region	**# Group**	**# Indiv.**	**# Group**	**# Indiv.**	**# Group**	**# Indiv.**	**# Group**	**# Indiv.**	**# Group**	**# Indiv.**	**# Group**	**# Indiv.**	**# Group**	**# Indiv.**
Naval Base Kitsap at Bangor	1	1	0	0	0	0	0	0	0	0	0	0	1	1
Naval Air Station Whidbey Island	0	0	0	0	0	0	0	0	1	1	1	5	2	6
Dabob Bay	2	4	1	1	2	3	0	0	1	1	2	2	8	11
Naval Station Everett	0	0	4	4	1	1	1	2	0	0	1	2	7	9
Manchester Fuel Depot	0	0	3	4	7	10	0	0	3	4	2	2	15	20
Naval Base Kitsap at Bremerton	0	0	0	0	0	0	0	0	1	1	1	1	2	2

Abundance in each 2-nmi Radius Based on Sub-Regional Density Data					
Sub-Region	**Total Area (km²)**	**Water Percentage**	**Water Area (km²)**	**Density in Sub-region**	**Abundance in 2-nmi Radius**
Naval Base Kitsap at Bangor	43	43.30%	18.6	0.44	8
Naval Air Station Whidbey	43	64.10%	27.6	0.75	21
Dabob Bay	43	78.80%	33.9	0.44	15
Naval Station Everett	43	54.40%	23.4	0.75	18
Manchester Fuel Depot	43	54.70%	23.5	0.25	6
Naval Base Kitsap at Bremerton	43	34.70%	14.9	0.53	8

Table 22. Harbor seal sightings (upper table) and estimated average abundances (lower table) within a 2-nmi radius of six naval installations based on densities in each larger encompassing sub-regions.

Survey:	Aug-Sep 2013		Jul 2014		Sep 2014		Jan 2015		Apr 2015		Jan 2016		Total	
Sub-Region	# Groups	# Indiv.	# Groups	# Indiv.	# Groups	# Indiv.	# Groups	# Indiv.	# Groups	# Indiv.	# Groups	# Indiv.	# Groups	# Indiv.
Naval Base Kitsap at Bangor	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naval Air Station Whidbey Island	9	21	5	17	11	27	0	0	7	14	2	2	34	81
Dabob Bay	19	21	9	11	30	33	0	0	40	43	9	9	107	117
Naval Station Everett	0	0	7	7	3	3	1	1	20	34	7	9	38	54
Manchester Fuel Depot	2	16	3	3	15	104	0	0	13	14	13	33	46	170
Naval Base Kitsap at Bremerton	3	3	4	4	5	5	0	0	4	4	2	2	18	18

Abundance in each 2-nmi radius Based on Sub-Regional Density Data					
Sub-Region	Total Area (km^2)	Water Percentage	Water Area (km^2)	Density in Sub-region	Abundance in 2nmi Radius
Naval Base Kitsap at Bangor	43	43.30%	18.6	5.74	107
Naval Air Station Whidbey	43	64.10%	27.6	2.98	82
Dabob Bay	43	78.80%	33.9	5.74	195
Naval Station Everett	43	54.40%	23.4	2.98	70
Manchester Fuel Depot	43	54.70%	23.5	1.85	43
Naval Base Kitsap at Bremerton	43	34.70%	14.9	3.21	48

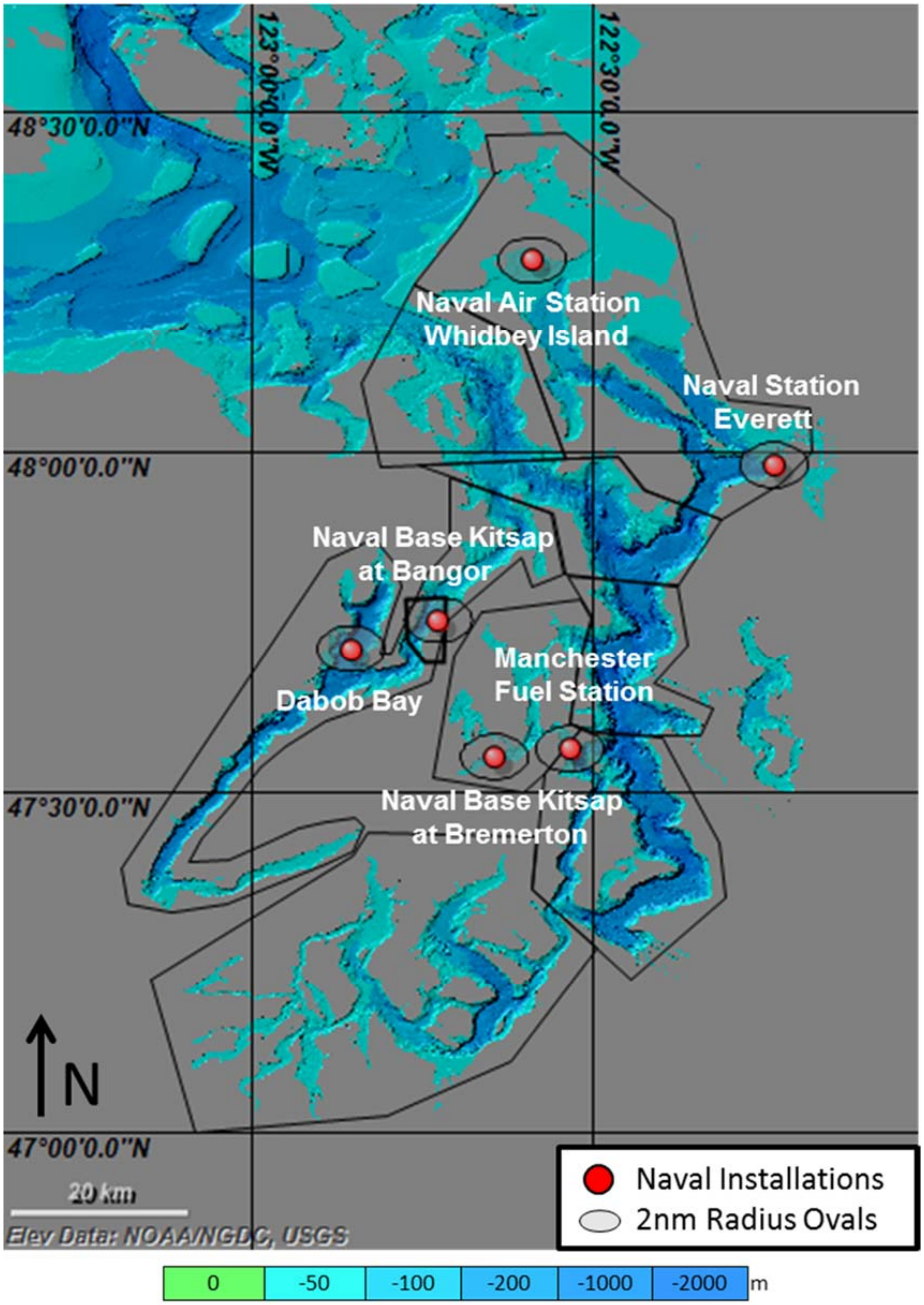

Figure 14. Estimated in-water abundance of harbor porpoises and harbor seals within a 2-nmi radius of designated naval installations derived from densities of sub-regions determined during Puget Sound aerial surveys 2013–2016. Red dots indicate the location within each installation used as the center of the 2-nmi radius. (Note: 2-nmi circles look slightly oval due to projection of a round globe on a flat map (see Figure 1).

3.7 Summary of First-Observed Behavioral Analysis

Behavioral data were summarized for the first-observed maximum dispersal distance (estimated in adult body lengths by species) and behavioral state for the subsample of marine mammal sightings for which such data were available. It was not always possible to record these data because during periods with many sightings, observers prioritized data needed for density and abundance estimation (e.g., species, group size, bearing, and declination angle/lateral distance). Summary statistics for maximum dispersal distance were calculated for the two most commonly sighted species, the harbor seal and harbor porpoise (*n*=252 and 275 groups, respectively) (**Table 23**). Including both in-water and hauled-out harbor seals, mean maximum dispersal distance was slightly larger for harbor seals (4.8 body lengths) compared to harbor porpoises (3.9 body lengths) (**Table 23**).

Table 23. Summary statistics for dispersal distance (in body lengths) within groups of harbor porpoises and harbor seals.

Survey Month/ Year	Species	Number of Groups	Minimum Dispersal Distance	Maximum Dispersal Distance	Mean of Maximum Dispersal	Standard Deviation
Sep-13	Harbor Seal	41	0.5	50	6.4	9.5
	Harbor Porpoise	29	0.5	50	4.1	9.4
Jul-14	Harbor Seal	49	0.2	15	4.5	4.6
	Harbor Porpoise	80	0	10	2.2	2.4
Sep-14	Harbor Seal	80	0.1	70	7.9	13.5
	Harbor Porpoise	106	0.1	275	9.4	33.1
Jan-15	Harbor Seal	2	0.5	1	0.8	0.4
	Harbor Porpoise	9	0.5	35	0.8	11.3
Apr-15	Harbor Seal	80	0	50	7.1	9.2
	Harbor Porpoise	51	0	25	4.8	5.7
Jan-16	Harbor Seal	48	0	17	2.2	0.7
	Harbor Porpoise	37	0	8	2.3	1.2
Total	**Harbor Seal**	**252**	**0**	**70**	**4.8**	**2.8**
	Harbor Porpoise	**275**	**0**	**275**	**3.9**	**3**

Data on behavioral state were obtained for all 11 species we sighted (**Table 24**). For species with at least 10 sightings (harbor seal, California sea lion, Steller sea lion, and harbor porpoise), the most commonly observed behavioral state was slow travel/rest; an exception was the harbor porpoise, where medium-fast travel was more frequently seen than slow travel/rest. Mill was also commonly seen among harbor porpoises. Rest was the only behavioral state noted among hauled-out pinnipeds, as expected. Probable foraging consisting of what appeared to be chasing prey underwater while turning in tight circles or sprinting was occasionally seen among harbor porpoises and harbor seals, and for one Steller sea lion. On one occasion, a group of harbor seals was seen foraging below a large group of diving birds (species unknown) in the Strait of Juan de Fuca during opportunistic survey effort. One gray whale group was observed feeding after they were first observed traveling, and video was taken of this group in the East Whidbey sub-region. Plumes of mud were seen at the surface as these whales surfaced. In addition, photographs of gray whale feeding pits were taken in the general vicinity of the feeding gray whales.

Reaction, no reaction, or unknown was recorded for all marine mammal sightings to indicate whether the observer thought an observed change in behavior may have been related to the presence of the aircraft. A possible reaction was rarely observed (0.3 percent or 31 of the total 10,412 individual marine mammals sighted). A possible reaction was recorded only for harbor porpoises (n=7 single animals), harbor seals (22 individuals in 8 groups), one California sea lion, and a pair of Steller sea lions. All possible observed reactions to the aircraft consisted of an abrupt dive.

Table 24. Overall frequency of occurrence and percentage of behavioral states of marine mammal groups during Puget Sound marine mammal aerial surveys 2013–2016*.

Species	Frequency of Occurrence (Percent of Occurrence)								
	Slow Travel/ Rest	Med. Travel	Fast Travel	Mill	Dive	Probable Forage	Other	Unk.	Total No. of Groups
Harbor Seal, In-Water	3,463 (82%)	455 (11%)	20 (<1%)	151 (4%)	21 (1%)	7 (<1%)	42 (1%)	87 (2%)	**4,246**
Harbor Seal, Hauled Out	122 (84%)	1 (1%)	-	1 (1%)	-	-	8 (6%)	13 (9%)	**145**
California Sea Lion, In-Water	100 (71%)	24 (17%)	3 (2%)	4 (3%)	-	-	8 (6%)	2 (1%)	**141**
California Sea Lion, Hauled Out	22 (88%)	-	-	-	-	-	-	3 (12%)	**25**
Steller Sea Lion, In-Water	43 (64%)	17 (25%)	5 (7%)	1 (2%)	-	1 (2%)	-	-	**67**
Steller Sea Lion, Hauled Out	3 (100%)	-	-	-	-	-	-	-	**3**
Harbor Porpoise	371 (36%)	400 (39%)	36 (4%)	158 (15%)	1 (<1%)	5 (1%)	41 (4%)	14 (1%)	**1,026**
Gray Whale	4 (80%)	1 (20%)	-	-	-	-	-	-	**5**
Killer Whale	2 (50%)	1 (25%)	1 (25%)	-	-	-	-	-	**4**
Minke Whale	2 (100%)	-	-	-	-	-	-	-	**2**
Humpback Whale	2 (100%)	-	-	-	-	-	-	-	**2**
Risso's Dolphin	-	1 (50%)	-	-	-	-	-	1 (50%)	**2**
Dall's Porpoise	-	1 (100%)	-	-	-	-	-	-	**1**
Otter (River or Sea)	1 (100%)	-	-	-	-	-	-	-	**1**

* Limited to groups where behavior state was recorded. Feeding gray whales and a probable feeding (milling) minke whale were observed once, though the first-observed behavior was travel as recorded here. Key: med. = medium; No. = number; Unk. = unknown

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4. Discussion

Our findings on the relative occurrence, distribution and abundance of marine mammals in Puget Sound are in some cases quite different compared to those from earlier studies. For instance, a study by Everitt et al. (1980) was conducted from 1977-1979, and since then there have been some major changes in the region (e.g., the continued recovery of pinniped populations, the re-occupation of Puget Sound by harbor porpoises, and the massive decline of Dall's porpoise). Our six aerial survey periods in 2013–2016 provide updated systematically collected data on the in-water density, abundance, distribution, and behavior of marine mammals in Puget Sound, addressing a critical management need for harbor porpoises. Our results are also important in providing density and abundance across all four solar seasons and by eight sub-regions. In addition, we report the first in-water density and abundance estimates for harbor seals that are useful for management decisions affecting this species.

Harbor seals and harbor porpoises were the most commonly seen species during our surveys, providing robust sample sizes allowing estimation of their density and abundance within Puget Sound. However, because our estimates for harbor seals are limited to in-water observations, they do not include haul-out areas or adjustments for tidal state or variation in pupping season through the region. Rather, our data regarding harbor seals will complement data collected in 2013–2014 by Jeffries et al. (2014) to estimate harbor seal abundance in Puget Sound based on hauled-out animals. Although we documented eight other marine mammal species during our aerial surveys (including one river or sea otter), associated sample sizes were too small to calculate meaningful density and abundance estimates. The one exception was for sea lions in which combining both species (California and Steller sea lions) provided a sufficient sample size to preliminarily estimate density and abundance in water. Our estimates do not include large haul-out areas or areas in no-fly zones, which include known haul-outs. Therefore, our in-water estimates presumably underestimate numbers of pinnipeds in the study area.

Results confirm that harbor porpoises have increased in numbers and recolonized Puget Sound, particularly Southern Puget Sound and Hood Canal, where they had previously substantially declined (Calambokidis et al. 1992; Osmek et al. 1995). For example, trends in stranding, acoustic, and other sightings data indicated that harbor porpoise use of Puget Sound has been generally increasing (e.g., Hanson et al. 2012; Jeffries 2011, 2012, 2014; Anderson 2014; Calambokidis et al. 2015); however, the latter data did not provide density and abundance information throughout Puget Sound. Our results provide an important updated population estimate for harbor porpoise. This information is critically needed to update the NMFS Marine Mammal Stock Assessment Report (SAR) for harbor porpoises in inland Puget Sound waters because of outdated estimates (NMFS et al. 2005; Carretta et al. 2014). Abundance and density estimates of harbor porpoises in our study region in spring, summer, and fall based on our 2013–2015 data have been published in a peer-reviewed journal (Jefferson et al. 2016).

Results of our 2013–2016 aerial surveys also suggest that the general occurrence and relative abundance of marine mammal species in Puget Sound has changed where geographically overlapping historical data are available from earlier studies. For example, during 1977–1979, Everitt et al. (1980) documented 15 species of cetaceans in the Greater Puget Sound Region, including the Strait of Juan de Fuca, San Juan Islands, and northern Puget Sound. They reported that the most common cetacean species at that time (in descending order) were the harbor porpoise, Dall's porpoise, gray whale, minke whale, and killer whale. These cetacean species were most abundant in spring and summer, except for gray whales, which were most common in November–December and February–March (during migrations). Although we observed all five of the latter species during our 2013–2016 aerial surveys, only the harbor porpoise was commonly seen. Other cetacean species we observed relative to historical reports are described below and include sightings made within our primary eight survey sub-regions as well as opportunistic sightings made in the Strait of Juan de Fuca and other areas such as the southern San Juan Islands/Haro Strait (**Figure 8**).

4.1 Harbor Porpoises

Historical information on the occurrence of harbor porpoises in Puget Sound prior to the 1940s is limited to a review of scattered anecdotal sightings (Scheffer and Slipp 1948). However, in the 1940s, this species was considered "common" throughout the year in Puget Sound (Scheffer and Slipp 1948). Flaherty and Stark (1982) cite a personal communication with J. Slipp indicating that the harbor porpoise population subsequently essentially disappeared from southern Puget Sound sometime between the late 1940s and early 1960s. Few harbor porpoises were sighted in the region during aerial and vessel surveys in 1991 (Osmek et al. 1996) or 1994 (Osmek et al. 1995). Osmek et al. (1996) reported that a substantial decline in harbor porpoises had occurred in Puget Sound. Aerial surveys for harbor porpoises in Washington and British Columbia in 1996 did not include Puget Sound because densities were expected to be extremely low in that area (Osmek et al. 1997). Surveys in 2002–2003 suggested some potential recovery (Calambokidis et al. 2015). However, Ű (2009) reported no significant trend in harbor porpoise abundance based on small-vessel surveys in portions of inland Washington waters from 2000 to 2008.

From 2009 to 2014, increased numbers of strandings, acoustic detections, opportunistic sightings, and sightings during dedicated bird surveys conducted by the Washington Department of Fish and Wildlife suggested that harbor porpoise were returning to Puget Sound (Hanson et al. 2012; Carretta et al. 2014; Evenson et al. 2015, 2016; Huggins et al. 2015). From 1995 to 2014, Evenson et al. (2016) reported an overall increase of 10.4 percent per year in the density of harbor porpoise throughout the inland Washington State marine waters (comprised of Puget Sound, the Strait of Juan de Fuca, and Washington Sound including the Strait of Georgia and San Juan Islands). However, no abundance estimates specific to Puget Sound were reported from these surveys.

Our 2013–2016 aerial survey results suggest that the Puget Sound harbor porpoise population is rebounding. We estimated an abundance of 2,269 porpoises (CI_{95}=1,887–2,729; CV=0.378) with an overall density of 0.86/km^2 (95 CI_{95}=0.72–1.03) for our Puget Sound study area (**Table 17**). In addition, our study indicates that harbor porpoises occur throughout Puget Sound waters compared to previous decades, as we saw them in all eight of our study sub-regions. Highest estimated densities occurred in the Admiralty Inlet and South Whidbey sub-regions, with moderate densities in all other sub-regions except Bainbridge and Vashon, where the relatively lowest densities occurred (**Table 17**). Reason(s) for the apparent general gap in distribution within the Vashon sub-region from Federal Way north to Burien and west to Vashon Island are unknown (**Figure 6**), but could be related to a number of potentially inter-related factors including prey availability, vessel traffic, water quality, water depth, or current. These apparent anomalies may merit further investigation. Similarly, Evenson et al. (2016) reported recent expansion of harbor porpoises throughout inland Puget Sound waters based on results from bird-focused aerial surveys.

Our study results also indicate that harbor porpoises now occur throughout the year in relatively large numbers in Puget Sound (**Table 15**). This is further supported by recent acoustic, vessel and aerial survey results documenting harbor porpoise presence year-round in portions of Puget Sound (Jeffries 2011, 2012, 2014; Anderson 2014; Evenson et al. 2016). Highest relative numbers of harbor porpoises have previously been reported during winter based on acoustic detections (Jeffries 2014) and visual sightings during aerial surveys from 1993 to 2014 (Evenson et al. 2015, 2016). In contrast, our 2013–2016 data suggest highest overall harbor porpoise densities in spring and summer (**Figure 6**). Seasonal changes in harbor porpoise numbers in our Puget Sound study area may be related to changes in the abundance of prey. We believe that our highest spring-summer densities likely represent an influx of porpoises into Puget Sound from farther north or offshore, and coincide with spawning of Pacific herring (*Clupea harengus*). This forage fish is a major prey for harbor porpoise, and peak spawning inside Puget Sound occurs during spring months (but lasts from mid-January to early June [Stick et al. 2014]). Substantiation of this apparent correlation requires further investigation.

The WDFW has been recording harbor porpoise observations annually incidental to bird surveys in the Puget Sound and Strait of Juan de Fuca regions since 1993 (Evenson et al. 2015). These observations revealed a shift of harbor porpoise further into Puget Sound with larger overall numbers and densities observed from 1993 to 2014 (Evenson et al. 2015, 2016). Reasons for harbor porpoise declines prior to the 1990s and 2000s are unknown, though some suggestions include entrapment in gillnet fisheries, pollutant effects, habitat degradation, and vessel avoidance (Calambokidis and Baird 1994; Jefferson et al. 2016). Osmek et al. (1995) suggested competition with Dall's porpoises could also have contributed to the decline, as Dall's porpoises increased in abundance during the harbor porpoise decline in Puget Sound and the Strait of Juan de Fuca (Evenson et al. 2015).

Our observed mean group size for harbor porpoises ranged from 1 to 150 individuals, with means for each survey season of approximately 1.8, with the exception of 7.5 (*SE*=10.4) in January 2015. However, mean group size was only 1.7 (*SE*=0.16) in January 2016. Our overall mean group size of 1.8 is similar to the 1.87 (*SE*=0.06) mean group size reported for the San Juan Islands area in 1991–1992 (Raum-Suryan and Harvey 1998).

The last available abundance estimate for the Washington Inland Waters stock of harbor porpoises recognized by the National Marine Fisheries Service (comprised of Puget Sound, U.S. Strait of Juan de Fuca, and San Juan Islands area waters) was 10,682 animals based on aerial survey data collected in 2002 and 2003 (Carretta et al. 2014). However, the latter estimate is now over 14 years old and is not considered recent enough for use in Marine Mammal Stock Assessment Reports (NMFS 2005). Using 2013–2015 data from our study, Jefferson et al. (2016) presented a new and somewhat larger stock size estimate of 11,233 porpoise (*CV*=37%) for the Washington Inland Waters harbor porpoise stock. Increased abundance and densities of harbor porpoises in Puget Sound may represent a redistribution of porpoises from more northern inland waters to Puget Sound (Jefferson et al. 2016), possibly resulting from increased resource competition (Evenson et al. 2016). Whether observed increases in the abundance, density and geographic expansion of harbor porpoises in Puget Sound are related to immigration and/or actual increases in population remain to be determined.

In summary, our estimates will contribute to a new abundance estimate for the Washington Inland Waters stock of harbor porpoises. This abundance estimated is based on integration of our 2016 winter aerial survey data reported herein with our results published in 2016 (Jefferson et al. 2016) that included a spring 2015 survey in waters north of Puget Sound funded by NMFS/National Marine Mammal Laboratory (in the Strait of Juan de Fuca, San Juan Islands area, and southern Strait of Georgia). The harbor porpoise estimates generated from our aerial surveys are of relatively high precision. Since the harbor porpoise was one of the focal species for our surveys, we made special effort to conduct the fieldwork and analyses to maximize the chances of obtaining high-quality data for this species. Furthermore, the overall sample size is adequate for obtaining a reliable estimate of the current number of animals using Puget Sound.

4.2 Harbor Seals

Harbor seals were the most common species of marine mammal we observed in Puget Sound, consistent with other historical studies in the region. This includes a 1977–1979 study that counted 2,000 seals in 1979 (Everitt et al. 1980). Calambokidis and Baird (1994) similarly reported harbor seals as the most abundant marine mammal in the trans-boundary area between the U.S. and Canada, with abundance increasing in the late 1980s and early 1990s. In 1996, Osmek et al. (1997) reported harbor seals as the most commonly sighted species in Washington and British Columbia inside waters. In 1999, Jeffries et al. (2003) reported that harbor seal populations in Washington were near carrying capacity. Data from 1999 surveys (Jeffries et al. 2003) are the most recent data used for abundance estimates in the NMFS Marine Mammal SAR (Carretta et al. 2014).

We estimated in-water density of harbor seals in the Puget Sound area to be 3.57 seals/km^2 (CI_{95}=0.55-23.08) and abundance to be 9,404 (CI_{95}=1,453-60,860; CV=0.118.6) (**Table 18**). Previous estimates from our preliminary Puget Sound surveys showed some modeling issues and did not account for missed trackline animals (Smultea et al. 2015); however, herein we have focused more effort and used more sophisticated analysis methods that provide an improved and reliable set of density and abundance estimates for harbor seals.

It should be noted that there are differences in methodology between the Jeffries et al. (2014) aerial survey for harbor seals and our surveys. Jeffries et al. (2014) followed the methodology of Jeffries et al. (2000) and Huber et al. (2001) by surveying counts at haul-outs during the summer and correcting for animals in the water but missed during the haul-out count. Our survey periods only included animals in the water (and partially submerged on sand/mud banks). Therefore, the estimates are not comparable. Our observations also did not include haul-out areas. Further, we did not consider differences in haul-out behavior in Hood Canal in which harbor seals are apparently more likely to haul-out at high tide (implying more time spent in water at low tide) than in other areas of Puget Sound (London et al. 2012). Pupping and molting periods also differ between Hood Canal and other Puget Sound areas (London et al.

2012). These trends were accounted for in survey design in Jeffries et al. (2014) but not in our surveys, which were focused on cetaceans rather than pinnipeds.

Like the case for harbor porpoise, the increased abundance of harbor seals in spring and summer (**Figure 7**) may be related to the spawning of Pacific herring, which spawn inside Puget Sound primarily in spring months (but lasting from mid-January to early June—Stick et al. 2014). However, this apparent relationship needs to be confirmed through further work.

The estimates of Hood Canal harbor seal density and abundance from this report are not directly comparable to the estimates from the Hood Canal harbor seal report (Jefferson, in prep.). This is due to slightly different approaches and study area boundaries between the two studies, but it is nevertheless instructive to examine the two estimates of total harbor seal in-water abundance. The estimate from this report is 2,246 seals, and the one from Jefferson (in prep.) is 2,020 seals, a difference of approximately 10 percent. This is suggestive that, on average, approximately 10 percent of harbor seals in Hood Canal are lying on sand- or mud-flats, and thus are not clearly in either the ‘in-water’ or ‘out-of-water’ category (the third category, as defined above). This is useful information that should be considered in future survey efforts.

4.3 California and Steller Sea Lions

California and Steller sea lions use the study area, but not as part of their breeding ranges. There are no breeding haul-outs or rookeries in the study area for these species (Jeffries et al. 2000). We observed relatively few “in-water” sea lions in the study area, and it is likely that even if we underestimated their numbers, no more than several dozen to a few hundred would be in the study area at any one time (but see below).

California sea lions breed farther south in Mexico and southern California, and it is almost exclusively males that make their way as far north as Washington State (Steiger and Calambokidis 1986). Steller sea lions breed mostly to the north in British Columbia and Alaska waters, although there is some breeding in Oregon and central California. Steller sea lions in Puget Sound also appear to be mostly males (Steiger and Calambokidis 1986). For both species, the breeding season is from late spring to summer, when nearly the entire population is thought to be on the breeding grounds. Therefore, most records of sea lions in inshore Washington waters are from autumn through spring (Everitt et al. 1980; Steiger and Calambokidis 1986). Our data are consistent with this, with only a handful of California sea lions observed in May–July, and no Steller sea lions observed at that time of year. California sea lions appear to be more abundant than Steller sea lions by a factor of nearly two to one.

We observed Steller sea lions in small numbers in April and September 2015 and one was observed in the Seattle sub-region in January 2016. California sea lions were more abundant than Steller sea lions during our survey periods, and were observed in all survey months (April, July, August, September, and January). In 1977–1979, Everitt et al. (1980) documented California and Steller sea lions from October to June at abundances of less than 300 for each species during peak periods. It should be noted that the three largest documented California sea lion haul out sites in Puget Sound are located at three Navy installations: Naval Base Kitsap at Bangor, Naval Station Everett, and Naval Base Kitsap at Bremerton (Jeffries et al. 2014). However, our survey area did not include the haul-out location at Naval Base Kitsap at Bangor, as this air space is considered a no-fly zone. Although results of our surveys noted California sea lions in the water near Naval Station Everett and Naval Base Kitsap at Bremerton, no sightings were made of hauled-out animals there. Therefore, our sighting data exclude the large haul-out site located at Naval Base Kitsap at Bangor.

Steller sea lions are known to occur regularly in Puget Sound, with as many as 100 individuals observed each winter on a derelict barge at the mouth of the Nisqually River south of Tacoma. Steller sea lions are also observed hauled out in small numbers on port security barriers at Naval Base Kitsap at Bremerton and Naval Station Everett (S. Jeffries, WDFW, pers. comm., September 2015).

4.4 Gray Whales

We observed gray whales on five occasions in the East Whidbey sub-region in April 2015, including feeding gray whales documented with photographs and video. A small number of gray whales were observed in Puget Sound during 1984–1993 (Calambokidis et al. 1994) and observations continue to present (Calambokidis et al. 2002; Orca Network n.d.(b)). Sightings of gray whales increased from 2004 to 2011 in south and central Puget Sound, where gray whales feed on ghost shrimp (Orca Network n.d.(b)). Between 10 and 12 gray whales return most years to feed near northwestern or southeastern Whidbey Island, and Port Susan, Camano Island, arriving as early as January and leaving as late as July (www.orcanetwork.org provides a map of feeding areas at http://www.orcanetwork.org/Main/index.php?categories_file=Gray%20Whales). Before 1980, gray whales were considered common in Puget Sound (Everitt et al. 1980). We sent photographs and video of gray whales from April 2015 to Cascadia Research Collective in response to a request from J. Calambokidis, as they are conducting studies of this species in Puget Sound.

4.5 Minke Whales

We observed and photo-documented solitary common minke whales on two occasions outside of our eight Puget Sound sub-regions during opportunistic survey effort in the Strait of Juan de Fuca in September 2014. On one occasion, the minke whale appeared to be feeding, based on its tight circling behavior. The two sightings may have been the same individual as they were seen on the same day in the same general area. The occurrence of minke whales is uncommon in central and southern Puget Sound (see DoN 2006). However, minke whales are seasonally common during summer in the more northern San Juan Islands (Dorsey et al. 1990; Jefferson et al. 2015). Prior to 1980, minke whales were considered common in Puget Sound (Everitt et al. 1980).

4.6 Killer Whales

Two ecotypes of killer whales (transient and resident) occur in Puget Sound (DoN 2006). Based on confirmed identifications from NMFS for 2 of the 4 sightings, both transient and southern resident killer whales were observed during our surveys. The other 2 sightings were likely transient and SRKW based on Orca Network data. It is unlikely that killer whales observed in Puget Sound are part of the offshore stock given its offshore boundaries (Carretta et al. 2014).

The ecotypes of killer whales often share the same range, but are not believed to intermix (Jefferson et al. 2015). Southern Resident killer whales (listed as Endangered under the ESA), are seen in northern (Admiralty Inlet and East and South Whidbey study area sub-regions) and central Puget Sound (Seattle, Bainbridge and Vashon sub-regions) occasionally during the winter; they are also seen in spring, summer, and fall in the San Juan Islands and Strait of Juan de Fuca, British Columbia (Hanson et al. 2010; Holt et al. 2012). Southern Resident killer whales are rarely seen in southern Puget Sound (Southern Puget Sound sub-region). Transient killer whales are occasional visitors to the inland waters of Puget Sound during all seasons (Wiles 2004; Houghton et al. 2015). Based on data collected by the Orca Network (http://www.orcanetwork.org), DoN (2014) estimated that density of killer whales would be very low (approximately 0.00051 animals/km^2) in Puget Sound, with even lower density in Hood Canal (0.00001 animals/km^2).

4.7 Risso's Dolphins

We saw Risso's dolphins in 2013 and obtained aerial photographs of them (see Smultea et al. 2014), but did not see them again in 2014, 2015, or 2016. Although sightings of Risso's dolphins in Puget Sound are quite rare, a pair of Risso's dolphins was seen there intermittently from 2011 to at least 2013 (C. Emmons, NMFS NWFSC, pers. comm., July 2012). On 30 December 2011, a Risso's dolphin pair was seen at the entrance of Eld Inlet near Olympia (southern Puget Sound) and photographs were sent to Cascadia Research Collective. On 4 July 2012, a pair was observed between Lagoon Point and Marrow Stone Island (southern Puget Sound). On 13 July 2012 a pair was seen near Colvos Pass near Gig Harbor, also in southern Puget Sound. Calambokidis et al. (2015) report 32 sightings of a pair of Risso's dolphins in Southern Puget Sound from 12 November 2011 to 4 April 2013. To the best of our knowledge, it has not been confirmed whether or not these sightings are of the same two Risso's dolphins. We sent our photographs of two Risso's dolphins obtained during our 2013 aerial survey to Cascadia Research Collective in Olympia, Washington; however, photos were not of sufficient quality across sightings to determine if the photographs were from the same two animals (A. Douglas, Cascadia Research Collective, pers. comm., July 2014). Everitt et al. (1980) did not report any records of Risso's dolphins in Puget Sound, even as rare or extralimital occurrences. Calambokidis and Baird (1994) reported that Risso's dolphins were observed once in British Columbia in inshore waters in the late 1970s.

4.8 Dall's Porpoises

Everitt et al. (1980) reported that Dall's porpoises were present year-round in Puget Sound in the late 1970s. Dall's porpoises were commonly observed in Puget Sound in the past, with counts as high as 71 individuals in the late 1980s (Miller 1990). In 1996, Dall's porpoises were the third most commonly observed species in aerial surveys of the inside waters of Washington and British Columbia (Osmek et al. 1997). From 1993 to 2014, the WDFW reported declines in observations of Dall's porpoises (Evenson et al. 2015). Our results support the decline of Dall's porpoises in Puget Sound, with only a single Dall's porpoise sighted in Hood Canal in April 2015 and another single Dall's porpoise sighted in Admiralty Inlet in January 2016. Similarly, Jeffries (2011) reported no Dall's porpoise sightings in Burrows Pass near Anacortes during a year-long study (located 137 km north of Seattle and outside our primary survey area). It is unknown whether this decline is due to emigration or an actual decline in population abundance. Anderson (2014) and Evenson et al. (2015) noted that Dall's porpoise abundance was thought to have increased in conjunction with declines in harbor porpoises in Puget Sound. Thus, it is possible that declines in Dall's porpoises are associated with harbor porpoise recovery in the area. For example, this could be due to behavioral exclusion or niche competition because there is overlap in prey species (Walker et al. 1998). See Jefferson et al. (2016) for more discussion of the potential interaction of these two species in Puget Sound.

4.9 Humpback Whales

Humpback whales have historically been documented in Puget Sound on occasion (Green et al. 1992; Falcone et al. 2005). On 22 and 25 January 2016 we observed a single humpback whale in the Southern Puget Sound sub-region. Based on location and photographs the humpback whale was considered to be the same animal. Calambokidis and Baird (1994) reported that humpback whales were once common in the trans-boundary area between the U.S. and Canada, including Puget Sound, but were uncommon in the early 1990s. There was a series of sightings of a humpback whale in Hood Canal, including Dabob Bay, between 2 and 23 February 2012, and at least one humpback was confirmed, though photos were not suitable quality for photo-identification (J. Calambokidis, Cascadia Research Collective, pers. comm., August 2015).

4.10 River or Sea Otter

We observed one otter, which may have been a sea otter (*Enhydra lutris*) or a North American river otter (*Lontra canadensis*) and was thus included as a marine mammal in our results. Sea otters are rare in Puget Sound (Everitt et al. 1980), although a few individuals have been reported there and in the San Juan Islands (Lance et al. 2004). The current range of sea otters in Washington State extends from near Destruction Island on the outer coast to Pillar Point into the Strait of Juan de Fuca, where 504 to 743 individuals were counted in 2000 to 2004 (Lance et al. 2004). In contrast, river otters are commonly sighted along shorelines of both freshwater and marine water bodies in Washington State, including Puget Sound (Lance et al. 2004). Based on the distribution of the two species, it is likely that our single sighting was a river otter but this could not be confirmed from the aircraft.

4.11 Behavior

Behavioral state of marine mammals observed during our surveys consisted primarily of travel. Flaherty and Stark (1982) similarly found that harbor porpoise behavior in the Strait of Juan de Fuca, Strait of Georgia, and San Juan Islands mostly consisted of traveling and milling. It should be noted that our surveys occurred only during daylight hours, so activities during the night are unknown. Aside from rest and travel, milling was observed for 15 percent of harbor porpoise groups, but represented less than 5 percent of group behavior among other species (**Table 24**). Milling behavior is likely to involve foraging as it consists of animals within a group with asynchronous headings, with individuals often changing their headings. Such behavior has been associated with feeding/foraging in numerous marine mammal species including delphinids, mysticetes, and pinnipeds, while searching for or chasing prey (e.g., Shane et al. 1986; Heithaus and Dill 2009). We also observed foraging behavior by harbor seals, harbor porpoises, Steller sea lions, gray whales, and a minke whale, for which the animals were swimming in tight rapid circles or crisscrossing one another and associated with feeding birds. Note that the two minke whales observed during this study were seen outside of Puget Sound in the Strait of Juan de Fuca. Milling has also been associated with social behavior, characterized by animals touching and/or interacting/facing one another (e.g., Würsig et al. 1985; Shane et al. 1986, 1990; Heithaus and Dill 2009). Harbor seals were additionally observed diving and harbor seals, California sea lions, and harbor porpoises all spent small amounts of time in undefined “other” behavior states (**Table 24**). The lack of observed milling and foraging may indicate that marine mammals do not use Puget Sound much for socializing or feeding during the day, but more information is needed to determine nocturnal behavioral patterns.

Apparent possible reactions to the aircraft were rarely observed (0.3 percent of all sightings) and consisted of abrupt dives, mostly by harbor seals or harbor porpoises. It is possible that this behavior could also have been indicative of normal foraging or other types of dives.

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5. Summary

In summary, the harbor seal and harbor porpoise were the most abundant species observed in Puget Sound during our aerial surveys in 2013–2016. These species were observed in all seasons. California sea lions were the third-most abundant species, seen most commonly during winter and spring. This was followed by Steller sea lions, seen nearly exclusively during the fall. Other rare species were distributed throughout the survey sub-regions and seasons.

Data were sufficient to estimate in-water densities and abundances of harbor seals and harbor porpoises with good precision, though data collected on harbor seals were opportunistic and did not include haul-out areas. Our density and abundance estimates for sea lions, though based on small sample sizes and somewhat imprecise, are the first for Puget Sound. Although information obtained during our surveys is generally consistent with prior information indicating that harbor seals are common in Puget Sound, our density estimates differ notably from those reported by Jeffries et al. (2014). This is due to a number of factors, including different protocol, different density modeling input, and different focal species and thus approaches (we focused on in-water densities of cetaceans while the Jeffries et al. [2014] study focused on counting hauled-out pinnipeds at haul-out concentration areas that we did not observe as they were not within view).

In contrast, in the early 1990s, harbor porpoise abundance had declined to the point at which none were observed during surveys, though they have been reported in small numbers in the last decade during aerial bird surveys in Puget Sound (e.g., Nysewander et al. 2005). Our observations therefore document a marked increase in the abundance and density of this species since that time. This is concurrent with a decline in Dall's porpoise sightings in Puget Sound, the reasons for which are unknown.

Behavioral state of all species observed was mostly rest or travel, with a few observations of milling, as well as a very low percentage of foraging by harbor seals, gray whales, and a minke whale (which was observed in the Strait of Juan de Fuca). This may indicate that marine mammals tend to transit Puget Sound during the day with intermittent feeding bouts, but it is unknown if feeding and socializing may increase during the night. Acoustic studies by Jeffries (2012) indicate that harbor porpoises vocalize more at night than during the day in their Burrows Pass/Anacortes survey area (outside of our study area), suggesting that foraging occurs predominantly at night for that species. Tagging and acoustical studies, along with additional surveys, may help elucidate behavioral patterns of Puget Sound marine mammals and help improve information about presence and behavior of the less common species observed during our study.

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Appendix A. Puget Sound Aerial Survey: Best Photos

Harbor porpoise mother/calf pair, 1 September 2013, 48.175 N 122.721 W – Admiralty Inlet, photographed by M. Smultea under NMFS permit 15569.

Harbor porpoise mother/calf pair, observed 30 August 2013 at 47.243 N 122.594 W – Southern Puget Sound, photographed by D. Steckler under NMFS permit 15569.

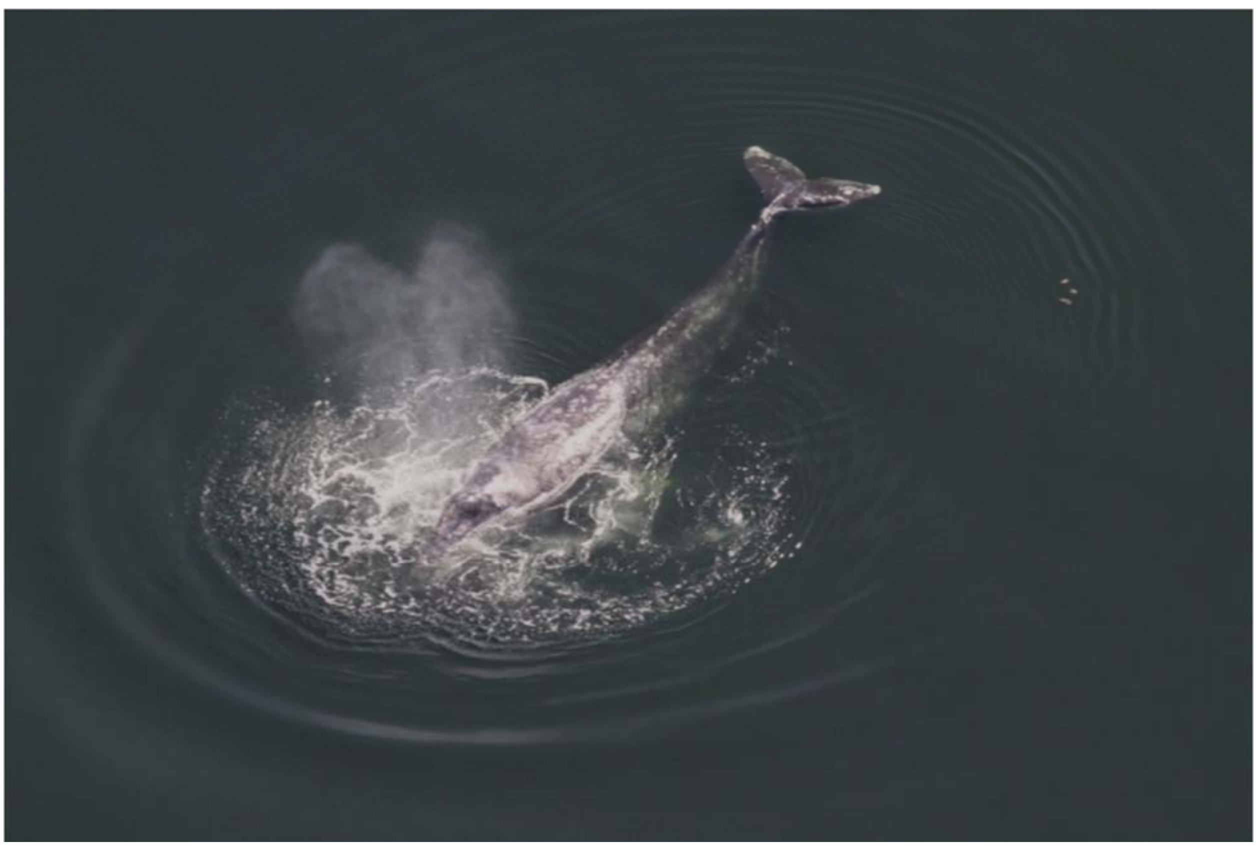
Harbor porpoises, including mother and calf, observed 26 July 2014 at 47.942 N 122.584 W – South Whidbey, photographed by M. Smultea under NMFS permit 15569.

Harbor seal, observed 31 August 2013 at 47.307 N 122.820 W – Southern Puget Sound, photographed by M. Deakos under NMFS permit 15569

Harbor seal mother and pup, observed 1 September 2013, at 47.303 N 122.730 W – Southern Puget Sound, photographed by D. Steckler under NMFS permit 15569.

Harbor seals hauled out on mudflats, observed 25 July 2014 at 48.306 N 122.447 W – East Whidbey, photographed by M. Deakos under NMFS permit 15569.

Gray whale, observed 20 April 2015 at 48.009 N 122.290 W – East Whidbey, photographed by T. Hanks under NMFS permit 14451.



Gray whale, observed 20 April 2015, at 48.009 N 122.290 W – East Whidbey, photographed by T. Hanks under NMFS permit 14451.

Possible gray whale feeding pits, observed 21 April 2015 at 47.992 N 122.231 W – East Whidbey, photographed by T. Hanks under NMFS permit 14451.

Killer whales, adults and possible calf, observed 19 April 2015 at 48.243 N 122.563 W – East Whidbey, photographed by M. Deakos under NMFS permit 14451.

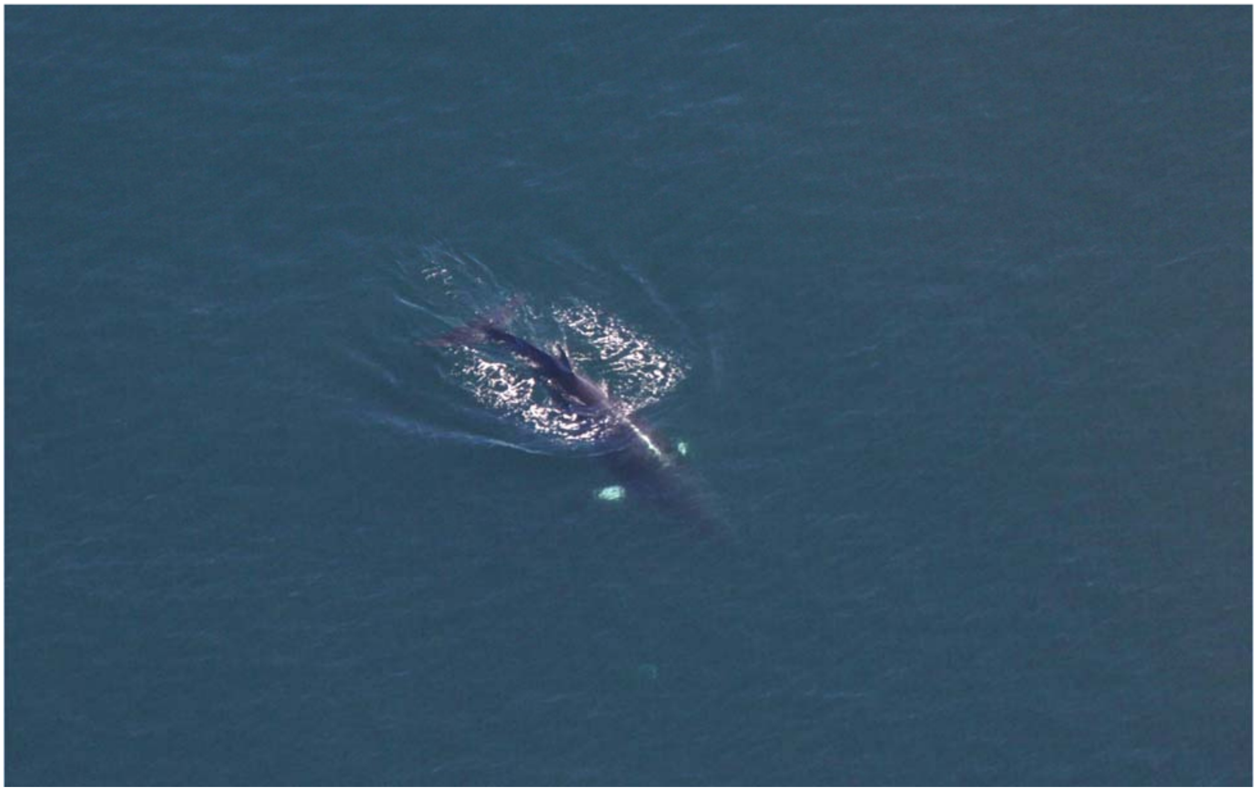
Killer whales, adults and possible calf, observed 19 April 2015 at 48.243 N 122.563 W – East Whidbey, photographed by M. Deakos under NMFS permit 14451.

Risso's dolphin pair, observed 4 September 2013 at 47.733 N 122.423 W - Seattle, photographed by V. James under NMFS permit 14451.

California sea lion, observed 2 September 2013 at 48.073 N 122.679 W – Admiralty Inlet, photographed by D. Steckler under NMFS permit 15569.

Steller sea lion, observed 17 September 2014 at 47.517 N 122.501 W - Vashon, photographed by T. Hanks under NMFS permit 15569.

Minke whale, 20 September 2014, 48.173 N 122.844 W – Juan de Fuca, photographed by M. Deakos under NMFS permit 14451.



Minke whale diving, observed 20 September 2014 at 48.171 N 122.904 W – Juan de Fuca, photographed by M. Deakos under NMFS permit 14451.

Killer whale with calf observed on 18 January 2016 at 47.708 N 122.468 W - Seattle, photographed by M. Deakos under NMFS permit 14245-03.

Killer whale group observed on 18 January 2016 at 47.708 N 122.468 W - Seattle, photographed by M. Deakos under NMFS permit 14245-03.

Humpback whale observed on 22 January at 47.174 N 122.784 W, and 25 January 2016 at 47.173 N 122.77 W – Southern Puget Sound, photographed by M. Deakos under NMFS permit 14245-03.