Marine Mammal Sightings Report for

Henderson Bay Zone of Influence Project

Prepared for Jeff Drier

The Whale Museum

26 May 2020

Report Authors:

Salma Abdel-Raheem
Jennifer Olson
Jason Wood

The Whale Museum
62 First St. N
Friday Harbor, WA 98250
360-378-4710 ext 28
salma@whalemuseum.org

Table of Contents

1. Introduction: Spatial and temporal extent of analysis

This report on sightings of Southern Resident killer whales (SRKW) and other marine mammals in the inland waters of Washington State and British Columbia (the Salish Sea) was compiled for Jeff Drier for a Washington State Department of Transportation (WSDOT) project to be conducted in the Henderson Bay area. Data reported and presented were from the years of 2009 – 2018 and were in the general Puget Sound area of Washington state (Figure 1).

Based on the geographic data reported, each sighting is assigned to a geographic quadrant. Quadrants are grid cells roughly 4.6 kilometers by 4.6 kilometers that were developed for reporting SRKW, and later used for non-SRKW, sightings before GPS units were readily available (Heimlich-Boran 1988). The primary zone of interest (ZOI) was quadrant 424 (dark orange, Figure 1). SRKW can travel large distances in a day (~100 miles) and other marine mammals are also highly mobile, therefore it is important to analyze this data set across a region, rather than just single quadrants. Furthermore, there is a good chance that whales will be missed within a specific quadrant, thus a proper analysis further necessitates the use of a larger area for comparison to the single ZOI quadrant.

In this case, the larger areas include the land-locked bays to the west of the ZOI quadrant (i.e. Chambers Bay, Carr Inlet, Anderson Island, Butler Cove, Drayton Passage, Dana Passage, Squaxin Passage, Oakland Bay , etc.) as the SRKW and other marine mammals may have traveled into further inland waters en route to or from the ZOI. These areas either shared a border (quadrant 425) or nearby the ZOI and therefore labelled 'adjacent' (Table 1). Cells, moving southward from the entrance to Admiralty Inlet (quadrant 365), to Tacoma Narrows (the last non-bordering quadrant to the ZOI, 422) in Puget Sound were also included in the analysis (blue, Figure 1). This is because if SRKW or other marine mammals were seen in the ZOI or in the adjacent region, it is likely that they traveled through this 'transit' region (Figure 1, Table 1). Table 1 summarizes quadrants' assignment to each region: the text color of the regions corresponds to the map legend in Figure 1 for easier reference. This color scheme is applied throughout the analysis to illustrate sightings patterns in each respective region.

Table 1: Quadrant assignments to geographic regions used for analysis.

Region	Quadrant Number
ZOI	424
Adjacent	425-433
Transit	365-423

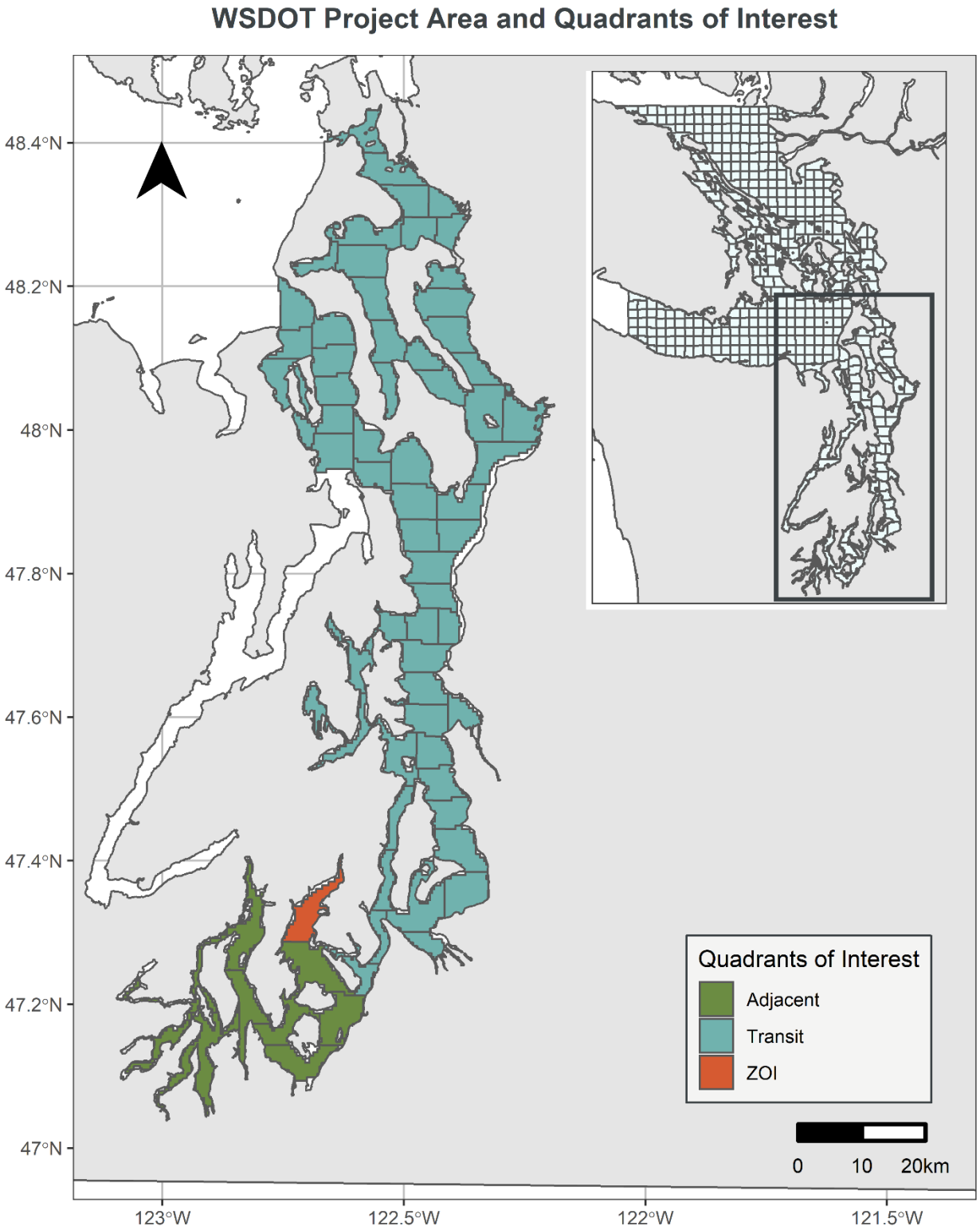

Figure 1: Map depicting the quadrants in the WSDOT project area as well as other quadrants of interest in the Puget Sound area.

2. Data Sources

A. Southern Resident Killer Whales & Orca Master

The Whale Museum's Orca Master data set is the most extensive data set on SRKW sightings in the Salish Sea. The 2018 Orca Master (OM) data set is compiled from 5 different sources (Charapata *et al.* 2012). However, for the ZOI and other named quadrants of this study, only one data source, The Whale Museum's Sightings Archives (TWM-SA) yielded observations during the years of the 2009 to 2018 study period. The source information for this data set are identified in Table 2A including a basic description, periods of coverage, locations, and numbers of records. The remaining 4 sources from the OM data set will be listed for completeness but will not be elaborated upon, as they did not yield data for the present analysis. For more information on any of the listed data sources, please contact the report author.

i) The Whale Museum Sightings Archive (TWM-SA)

The data source is The Whale Museum's Sighting Archives (TWM-SA). The Whale Museum (TWM) has long maintained an archive of marine mammal sightings (Boran 1980, Osborne 1991 and 1999). These sightings are reported to TWM by several channels, including the Whale Hotline (a phone recording for public sightings), Orca Network (an e-mail list service based on Whidbey Island), e-mail through the Museum's website, eyewitness reports from affiliated researchers, logbooks from shipboard naturalists on commercial whale watch boats, Museum staff and visitors, Orca web form data, and Orcasound hydrophone network detections (TWM-HYD). Sightings are recorded on a data sheet and then entered into a Microsoft Access database.

Sighting Archive records are identified as from a public source if the observer is not known to Museum staff (TWM-SA-Pub or TWM-HYD-Pub) and records are identified as reliable if the observer is known to be experienced or professional (TWM-SA-Rel or TWM-HYD-Rel). Reliable opportunistic observations from TWM staff, interns and seasonal independent researchers are also included in the sightings archive.

One data source included in the sightings archive (starting from 2008 to most current) is the direct solicitation of sightings from various whale watch operators and naturalists (in lieu of the pager system) who reliably tracked whale movements and locations throughout the summer and recorded the vital information on a form provided by TWM. Although considered to be reliable, a special source code of "TWM-SA-WW" was assigned to these records in order to better track the number of sightings received by this method. This sighting archive contains records that TWM gathers year-round.

Every effort is made to exclude sighting of transient killer whales from the Orca Master database, however it is possible that a few of the reports in the database were of transient, rather than resident, killer whales.

ii) The Whale Museum in conjunction with Whale Watch Operators' Pager System (TWM-Pager)

iii) The Whale Museum's Soundwatch Boater Education Program (TWM-SW)

iv) The Whale Museum in conjunction with Dr. Otis' Research at Lime Kiln State Park (TWM-Otis)

v) The Whale Museum in conjunction with researchers using SPOT Satellite Data (TWM-SPOT)

Table 2A: Orca Master data sources and number of records for SRKW reported in the ZOI and other named area during the years of 2009-2018.

Data Source	Years	Description	Location Record	Source Code	No. of Records
TWM Sightings Archive	1948-2018 Year-Round	Sighting records reported by public and reliable observers to TWM	Locations given in descriptive terms and matched to TWM Quadrants	TWM-SA-Pub	2,351
				TWM-SA-Rel	2,056
				TWM-SA-WW	45
				TWM-HYD-Pub	34
				TWM-HYD-Rel	159
				Total	**4,645 observations**

B. non-SRKW Marine Mammals

For any non-SRKW marine mammals, TWM's sightings archive was the only source used. As mentioned for the SRKW, these sightings are reported to the Museum by several channels, primarily the Whale Hotline, Orca Network, e-mail through the Museum's website, eyewitness reports from affiliated researchers, Museum staff and visitors, and hydrophone sightings.

As a result, sighting records for other species of marine mammals are not as robust as the Orca Master data set and should be interpreted with care. Rather than calculating averages or summary statistics, these numbers should be thought of as a minimum number of sightings for those species in the area.

Table 2B: TWM Sightings Archive data sources and number of records for non-SRKW marine mammals reported in the ZOI and other named area during the years of 2009-2018.

Data Source	Years	Description	Location Record	Source Code	No. of Records
TWM Sightings Archive	1948-2018 Year-Round	Sighting records reported by public and reliable observers to TWM	Locations given in descriptive terms and matched to TWM Quadrants	TWM-SA-Pub	9,946
				TWM-SA-Rel	8,549
				TWM-SA-WW	284
				TWM-HYD-Pub	25
				TWM-HYD-Rel	47
				TWM	80
				Total	**18,931 observations**

3. Analysis

A. Southern Resident Killer Whales (SRKW)

i) Overall sightings and whale days

As sightings are opportunistic, these observations may include multiple reports of the same pod on the same day. Multiple reports of whales in the same region on the same day are likely to be the same group of animals, therefore an appropriate metric to use is 'whale days' rather than the total number of sightings reported. A 'whale day' is any day SRKW are reported in each quadrant, regardless of the number of times they were reported that day. Table 3 depicts the total number of sightings and 'whale days' reported for each of the three regions in this report.

From January 2009 through December 2018, the OM data set recorded 4,645 sightings of SRKW in the ZOI, adjacent, and transit regions (Figure 1, Table 3.1). None of the reported sightings occurred in the immediate ZOI (Table 3.1). However, 19 observations were reported in adjacent quadrants, and over 4,600 reported observations were in transit quadrants (Table 3.1).

Table 3.1: Number of sightings and whale days of SRKW from 1 Jan 2009 through 31 Dec 2018 by region.

Region	Sightings	Whale Days
ZOI	0	0
Adjacent	19	11
Transit	4626	1911
Total Observations	*4645*	*1922*

ii) Annual SRKW sightings

From 2009 through 2018, the OM data set recorded 1,922 SRKW 'whale days' in the ZOI, adjacent, and transit regions (Figure 2, Table 3.2). None of the reported sightings occurred in the immediate ZOI (Table 3.2). However, SRKW 'whale days' were reported for the years of 2010 (n = 1), 2014 (n=5), and 2015 (n=4) in the region adjacent to the ZOI (Figure 2, Table 3.2). Conversely, SRKW were widely, and consistently reported throughout the years of this study in the transit quadrants (Figure 2, Table 3.2). SRKW 'whale days' in transit quadrants peaked in 2017 (n=248) and were reported in the lowest frequency for that region in 2010 (n=114) [Figure 2, Table 3.2].

An annual mean and the standard error of the mean (SEM) of the number of SRKW 'whale days' was calculated for each region in the study (Table 3.2). SEM was used as the metric to calculate variance because it is a more appropriate estimate of how far a sample mean is likely to be from the true population mean. Because of the spatial and temporal parameters of this report, sightings data were inherently sampled to fulfill those criteria, and therefore can only provide sample statistics of reported 'whale days'. This is especially important to note when attempting to make predictions to future years.

Based on 10-years of sightings, SRKW were not reported in the ZOI on an annual basis, whereas they were reported an average of once per year in adjacent quadrants (n = 1 ± 0.6 whale days/year; Table 3.2). In contrast, SRKW were reported on average, nearly 200 times annually (n = 191 ± 14.7 whale days/year) in transit quadrants, based on the presented temporal data (Figure 2, Table 3.2). Furthermore, SRKW whale days exhibited a slightly oscillating pattern in reported sightings in transit quadrants (Figure 2). Reported SRKW sightings seemed to increase and decrease at semi-regular intervals from year to year (blue bars and line, Figure 2).

Although SRKW were seldom reported in the more secluded ZOI or adjacent quadrants for the years 2009-2018, they have a sustained annual presence in the transit quadrants, which span much of Puget Sound (Figure 1; Table 3.2). The relatively low frequency of 'whale days' in the ZOI or adjacent quadrants may be attributed to lack of reporter presence and/or effort in those more sheltered and inland waters, compared to the more heavily trafficked waters of Puget Sound. It is important to note such external variables when considering annual sighting patterns, as they cannot be accounted for in the dataset.

Table 3.2: SRKW 'whale days' for the three main areas of interest for each year in the study period. The mean and the standard error of the mean are calculated at the bottom for each named region.

Year	ZOI	Adjacent	Transit
2009	0	0	166
2010	0	1	114
2011	0	0	157
2012	0	0	226
2013	0	0	152
2014	0	5	241
2015	0	4	158
2016	0	0	222
2017	0	0	248
2018	0	0	227
Total No. of Whale Days	0	10	1911
Mean No. of Whale Days	0	1	191
Mean ± SEM	0	0.60	14.7

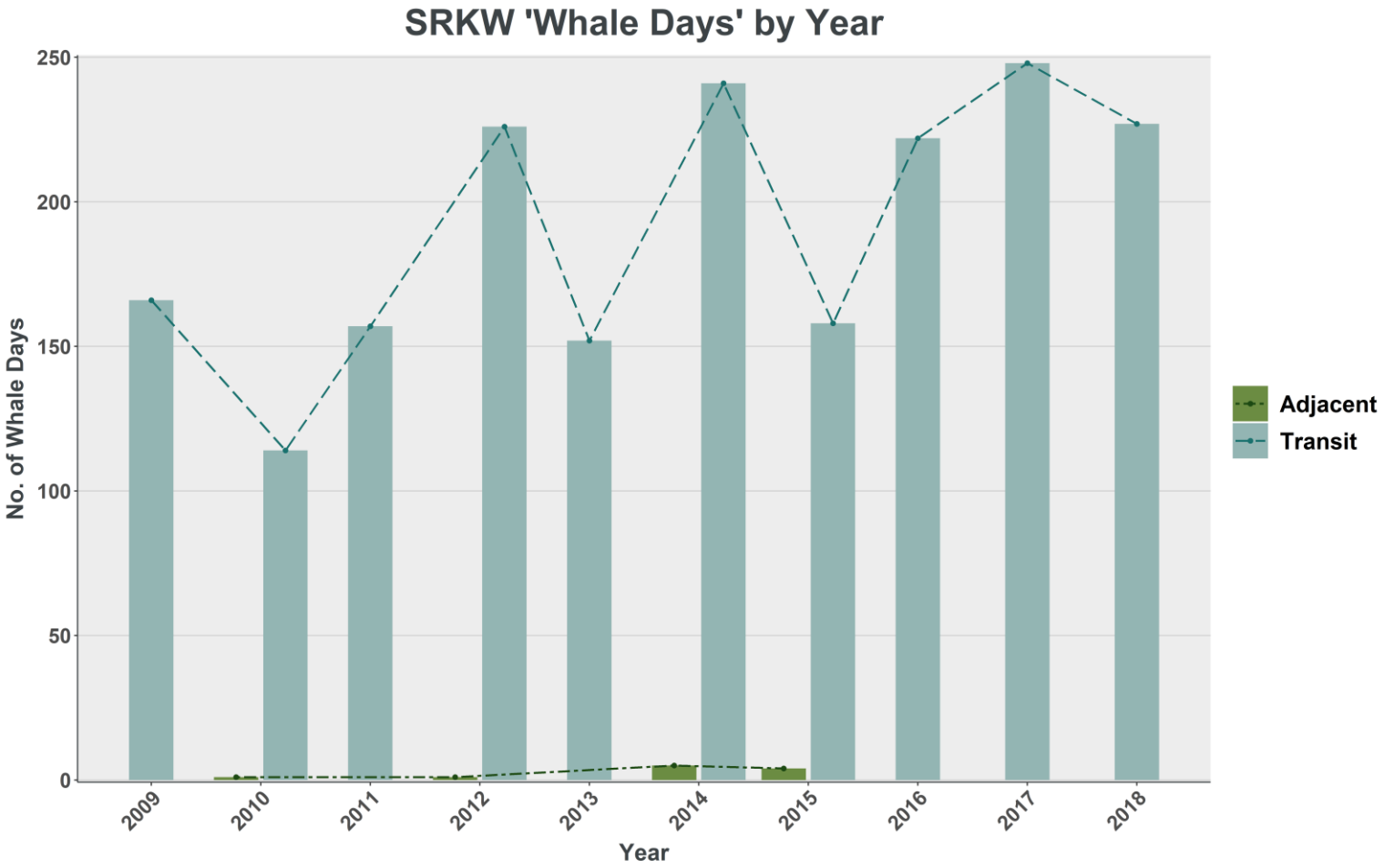

Figure 2: Number of whale days in quadrants adjacent to the ZOI and transit quadrants. SRKW were not reported in the ZOI for the years of 2009-2018.

iii) Monthly SRKW sightings

Like the SRKW reported 'whale days' on an annual cycle, SRKW were not reported in the immediate ZOI for any months of the year throughout 2009 to 2018 (Table 3.3). A few SRKW 'whale days' were reported for the months of April (n = 2), July (n=1), August (n=1), September (n=2), October (n=1), and November (n=4) in the region adjacent to the ZOI (Figure 3, Table 3.3). Conversely, SRKW were reported in a strikingly seasonal, U-shaped pattern throughout the years of the study period (Figure 3, Table 3.3). Reported SRKW 'whale days' in transit quadrants peaked during the month of November (n=571) and were reported in the lowest frequency during the month of August (n=2) throughout the years of 2009 – 2018 (Figure 3, Table 3.3).

Monthly means and standard errors of the mean (SEM) of SRKW 'whale days' were calculated for each region in the study (Table 3.3). Similar to annual trends in sightings, note the use of sample statistics if attempting to make monthly predictions.

Throughout the 10-years of sightings data included in this analysis, SRKW were not reported in the ZOI on a monthly basis, whereas they were reported an average of about once per month in adjacent quadrants (n = 0.9 ± 0.4 whale days/month; Table 3.3). In contrast, SRKW were reported on average, almost 160 times monthly (n = 159 ± 59 whale days/year) in transit quadrants (Figure 3, Table 3.3). Furthermore, SRKW whale days exhibited a sharp increase in reported sightings in transit quadrants between the months of August and September, which continued to sharply increase, before similarly decreasing during the months of January and February (Figure 3).

Interestingly, there are broad similarities in SRKW 'whale day' trends on an annual and monthly basis. For all three regions, ZOI, adjacent, and transit quadrants, reported SRKW 'whale days' were nearly identical or similar (Mean values; Tables 3.2 and 3.3). Although this is most likely due to the relatively great difference in reported 'whale days' in the ZOI/adjacent quadrants and transit quadrants, the pattern is interesting, and at a minimum requires further investigation. What is most striking is the difference in variance in reported 'whale days' on an annual (SEM=± 14.7 'whale days'/year) versus monthly (SEM=± 59 'whale days'/month) scale (Tables 3.2 and 3.3). The relatively low variance, of about 15 'whale days' in a year, exhibited in annual SRKW sighting patterns, suggest that SRKW sightings have somewhat of a regularity, at least on an annual scale. However, the much greater variance of nearly 60 'whale days' in a month, suggests that SRKW sighting patterns are more subject to short-term, rather than long-term changes in sighting behavior. The variation between months seem to take on a pattern of regularity over the years, as SRKW are consistently reported in greater frequencies in the later months of the year, September – December, rather than during the months of March – August (Figure 3). This pattern is consistent with the historical presence of the SRKW in the northern waters of the Salish Sea around the San Juan and Vancouver Islands during the months of May - September (NMFS 2015).

Table 3.3: SRKW 'whale days' for the three main areas of interest for every month of a year. The mean and the standard error of the mean (SEM) are calculated at the bottom for each named region. Although there is variation from month to month, the seasonal cycle with peaks during the months of October through February is clear. Shaded areas correspond with the proposed work period of July 15th through February 15th.

Month	ZOI	Adjacent	Transit
January	0	0	140
February	0	0	109
March	0	0	20
April	0	2	92
May	0	0	18
June	0	0	6
July	0	1	13
August	0	1	2
September	0	2	76
October	0	1	351
November	0	4	571
December	0	0	513
Total No. of Whale Days	0	11	1911
Mean No. of Whale Days	0	0.9	159
Mean ± SEM	0	0.4	59

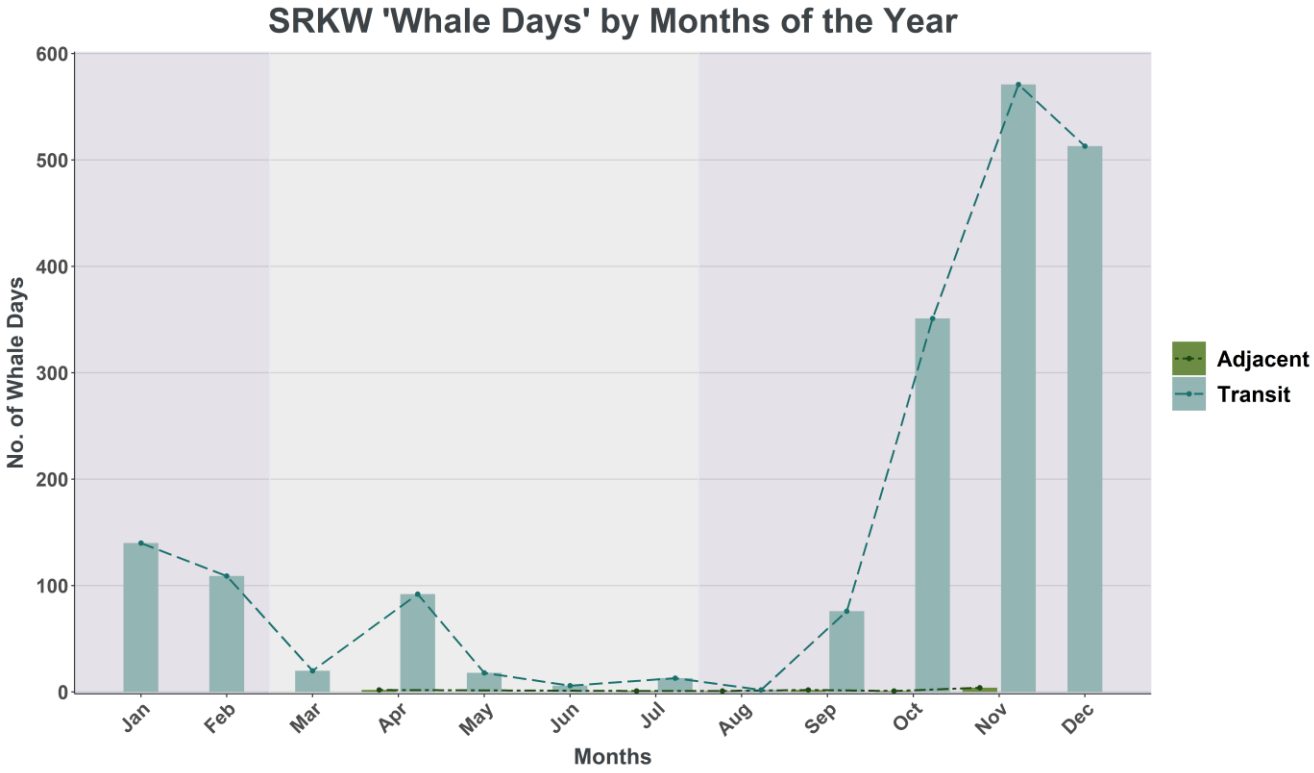

Figure 3: Number of whale days in quadrants adjacent to the ZOI and transit quadrants. SRKW were not reported in the ZOI during any months for the years of 2009-2018. Data in the shaded purple regions denote reported whale days which occurred during the proposed work period of 7/15-2/15 throughout the years included in the analysis.

iv) Seasonal SRKW sightings

Although SRKW are generally sighted in all months of the year, whale sightings in the Salish Sea are highly seasonal. Seasonal trends have been investigated by a number of people (e.g. Hauser *et al.* 2007, McCluskey 2006) and more recently by NMFS who depicted on a map the number of Orca Master sightings per quadrant by month of year, after having removed multiple sightings in the same quadrant on the same day.

SRKW visits to Washington's inland waters tend to peak during the months of May through September. However, those sightings typically coincide with where the SRKW spend much of the summer months: in and around the northern waters of the San Juan Island (NMFS 2015). SRKW residency in the more southern waters of Puget Sound tends to peak in the early fall through winter months (NMFS 2015). The SRKW will begin to leave Puget Sound for their preferred summer habitat in the San Juan Islands in mid-late spring (NMFS 2015).

Consistent with the trends observed on an annual and monthly basis, SRKW were not reported in the immediate ZOI for any season of the year throughout 2009 to 2018 (Table 3.4). A few SRKW 'whale days' were reported for the seasons of Spring (n = 2), Summer (n=4), and Fall (n=5) in the region adjacent to the ZOI (Figure 4, Table 3.4). Reported observations of SRKW were greatest in transit quadrants and were reported in much higher frequencies during the Fall than any other season (n= 1317; Figure 4, Table 3.4). Reported SRKW 'whale days' in transit quadrants were reported in the lowest frequency during the Summer months (n=57) throughout the years of 2009 – 2018 (Figure 4, Table 3.4).

Seasonal means and standard errors of the mean (SEM) of SRKW 'whale days' were also calculated for each region in the study (Table 3.4). Similar to the aforementioned trends in sightings, note the use of sample statistics if attempting to make seasonal predictions.

Throughout the last 10-years of available sightings data, SRKW were not reported in the ZOI on a seasonal basis, whereas they were reported an average of about 3 times per season in adjacent quadrants (n = 2.8 ± 1.1 whale days/season; Table 3.4). In contrast, SRKW were reported on average, almost 500 times in a season (n = 477.8 ± 289.5 whale days/season) in transit quadrants (Figure 3, Table 3.3). These patterns align well with reported monthly trends in SRKW 'whale days' and historical information about their seasonal residency patterns in this region (Figure 3; NMFS 2015).

Table 3.4: SRKW 'whale days' for the three main areas of interest for every season in a year. The mean and the standard error of the mean (SEM) are calculated at the bottom for each named region.

Month	ZOI	Adjacent	Transit
Spring	0	2	133
Summer	0	4	57
Fall	0	5	1317
Winter	0	0	404
Total No. of Whale Days	0	11	1911
Mean No. of Whale Days	0	2.8	477.8
Mean ± SEM	0	1.1	289.5

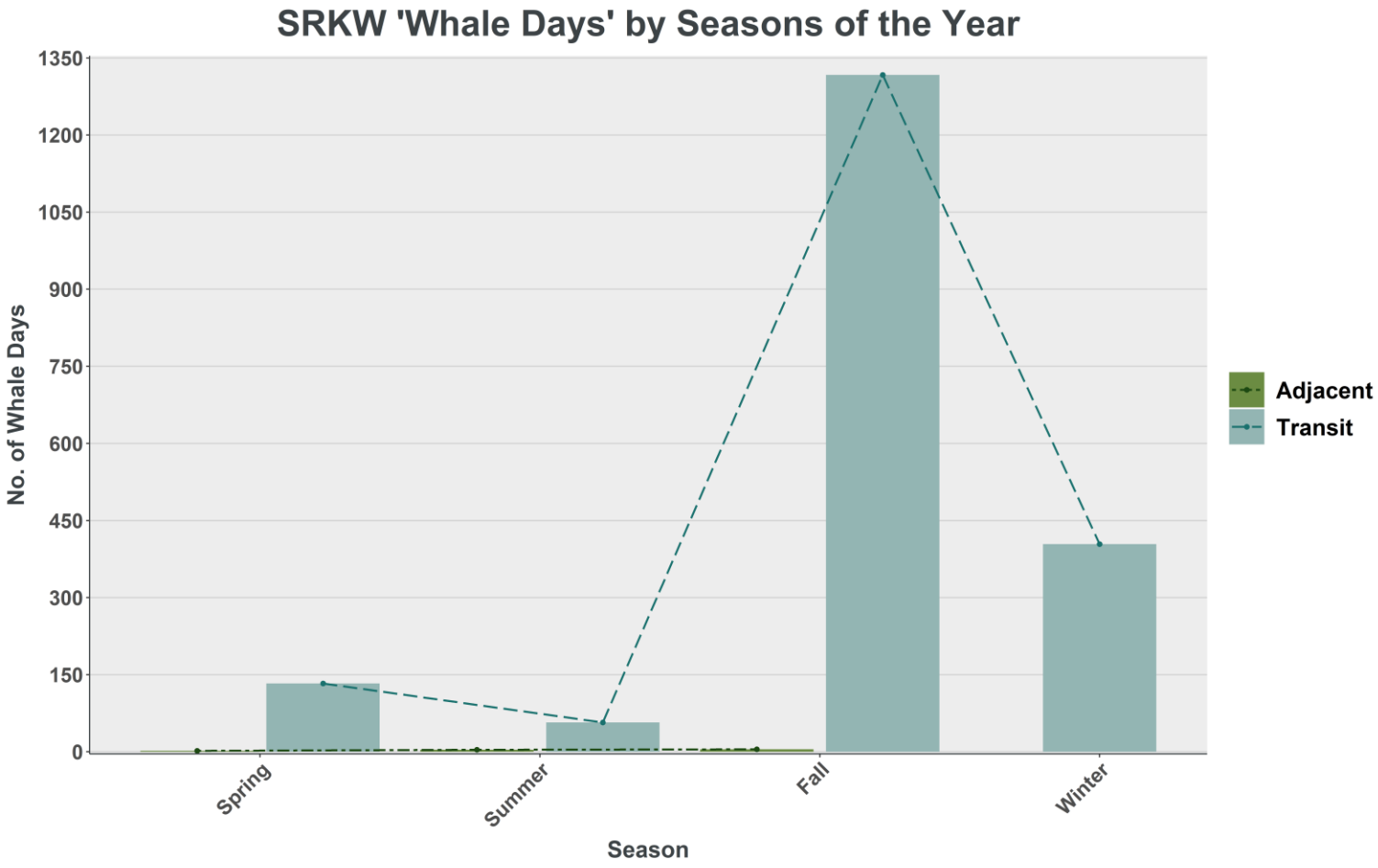

Figure 4: Number of whale days in quadrants adjacent to the ZOI and transit quadrants to the ZOI. SRKW were not reported in the ZOI during any season for the years of 2009-2018.

v) SRKW sightings during the proposed work period (7/15-2/15)

Consistent with previously reported trends, SRKW were not reported in the immediate ZOI either within or outside of the proposed 7/15 – 2/15 work period (Table 3.5). Very few SRKW 'whale days' were reported within (n = 9), or outside of (n=2) the proposed work period in the region adjacent to the ZOI (Figure 5, Table 3.5). Reported observations of SRKW were greatest in transit quadrants and were reported in much higher frequencies within the proposed work period (n= 1724; Figure 5, Table 3.5). Reported SRKW 'whale days' in transit quadrants were reported in much lower frequencies outside of the proposed work period (n=187) throughout the last 10 years of available data (Figure 5, Table 3.5).

Seasonal means and standard errors of the mean (SEM) of SRKW 'whale days' were also calculated for each region in the study (Table 3.5). Similar to the aforementioned trends in sightings, note the use of sample statistics if attempting to make seasonal predictions.

Throughout the last 10-years of available sightings data, SRKW were not reported in the ZOI within or outside of the 7-month period of the proposed work period (Table 3.5). SRKW were reported an average of about 6 times in adjacent quadrants (n = 5.5 ± 3.5 whale days/period; Table 3.5). In contrast, SRKW were reported on average, almost 1000 times (n = 955.5 ± 768.5 whale days/period) in transit quadrants (Figure 5, Table 3.5). These patterns align well with reported monthly (Table 3.3, Figure 3) and seasonal (Table 3.4, Figure 4) trends in SRKW 'whale days' and historical information about their seasonal residency patterns in this region (NMFS 2015).

In fact, SRKW 'whale days' within the proposed work period accounted for over 90% of all reported sightings (Table 3.5, Figure 5). SRKW sightings in adjacent quadrants during the months of interest accounted for 81% of all reported SRKW 'whale days' in that region (Table 3.3; Figure 3). Although SRKW were not reported in the ZOI for any of the trends discussed, the data heavily suggest that they are present within the over all South Puget Sound region. The absence of SRKW sightings in the ZOI should not be attributed to their absence in this area, but may rather be due to lack of reporter presence/effort in the more inland waters of Henderson Bay and the adjacent waters (Figure 1). Data of SRKW sightings in adjacent and transit quadrants hightlight the need for spatial context when analyzing the behaviors of large, highly mobile animals, such as the SRKW.

Table 3.5: SRKW 'whale days' reported during the proposed 7/15 – 2/15 work period ('within') and reported 'outside of' the proposed work period. Data are reported for the three regions of interest, and sample statistics are calculated for each region.

Work Period	ZOI	Adjacent	Transit
Outside of	0	2	187
Within	0	9	1724
Total No. of Whale Days	0	11	1911
Mean No. of Whale Days	0	5.5	955.5
Mean ± SEM	0	3.5	768.5

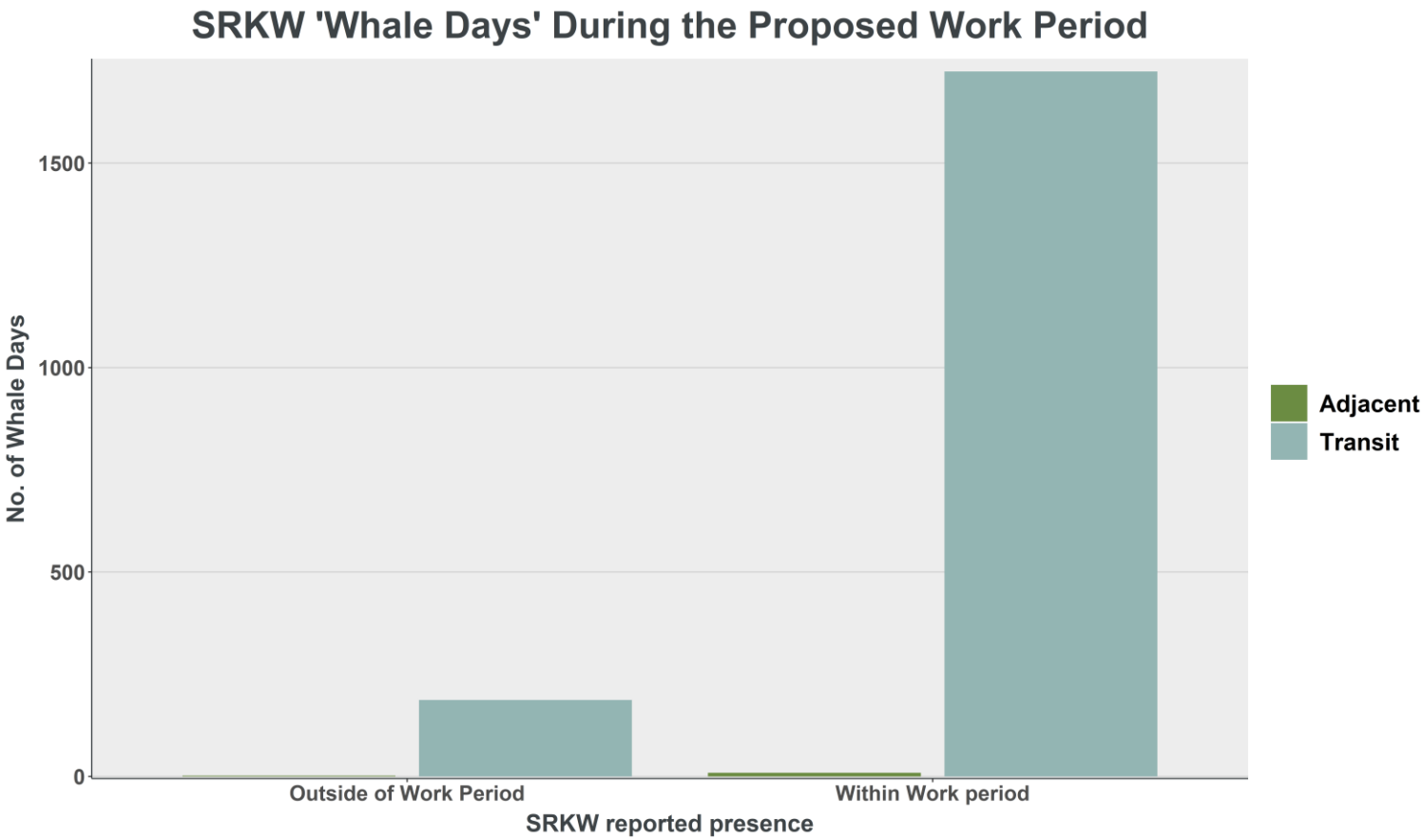

Figure 5: Number of whale days in quadrants adjacent to the ZOI and transit quadrants to the ZOI that were reported during the proposed work period ('within') relative to the number of reported whale days that fell 'outside' of the proposed work period. SRKW were not reported in the ZOI during or outside of the proposed work period (7/15 - 2/15) throughout the years of 2009-2018.

B) non-SRKW Marine Mammals

Approximately 30 different species of marine mammals were reported during the years of 2009 – 2018 in the ZOI, adjacent, and transit quadrants. To better condense these data for clear reporting, these species were aggregated into 6 species groups based on taxonomy. Any uncertain reports were placed into either an "unknown cetacean" or "unknown pinniped" category. These species and their groupings are summarized below in table 4. Transient killer whales (known sightings not included in Orca Master) made up nearly all (99%) large delphinid sightings (Table 4). Throughout the analysis, non-SRKW marine mammal data will be reported in these species' groupings. For more information regarding a species, please reach out to the author.

It should be noted that data presented here for other marine mammals (especially smaller or ubiquitous species such as pinnipeds, porpoises, and minkes) are by no means an exhaustive survey, but rather are collected in an opportunistic fashion. Pinnipeds and porpoises are probably present in the ZOI area close to 365 days per year. The sightings information provided herein should be treated as an absolute minimum level, and, are almost certainly at higher levels. Data regarding SRKW, and to a large degree grey, humpback, and transient killer whales are much more robust in nature.

Table 4: Non-SRKW species reported within the spatiotemporal extent of this analysis. Sightings of animals that could not be confidently identified were grouped with the closest possible taxonomic group, based on information provided by the reporting party.

Species Group	Species (count)	No. of unique species
Balaenopterid	1. Bryde's Whale (n = 2) 2. Fin Whale (n = 21) 3. Gray Whale (n = 3,354) 4. Humpback Whale (n = 2,149) 5. Minke Whale (n = 113) 6. Unidentified mysticete (n = 64)	6
Dolphin/Porpoise	7. Dall's Porpoise (n = 41) 8. Harbor Porpoise (n = 298) 9. Porpoise (n = 10) 10. Bottlenose Dolphin (n = 43) 11. Common Dolphin (n = 20) 12. Pacific White-Sided Dolphin (n = 66) 13. Risso's Dolphin (n = 21) 14. Long-Beaked Common Dolphin (n = 3) 15. Short-Beaked Common Dolphin (n = 1) 16. Unidentified delphinid (n = 60)	10
Large Delphinid	17. Transient Killer Whale (n = 8,541) 18. False Killer Whale (n = 3) 19. Pilot Whale (n = 4)	3
Pinniped	20. Steller Sea Lion (n = 82) 21. Harbor Seal (n = 2,345) 22. Elephant Seal (n = 12) 23. California Sea Lion (n = 1,383) 24. Ribbon Seal (n = 1) 25. Sea Lion (n = 1) 26. Unidentified pinniped (n = 98)	7
Other	27. Sea Otter (n = 4)	1
Unidentified Cetacean	(n = 91)	
Total number of unique species reported		**27**

i) Overall sightings and sighting days

Similar to SRKW sighting data, observations of other marine mammals are opportunistic, and observations may include multiple reports of the same animal in the same day. Multiple reports of animals in the same region on the same day are likely to be the same animal/group of animals. Therefore, an appropriate metric to use is 'sighting days' rather than the total number of sightings reported. Sightings were recorded using a similar quadrant system as described in section 3(i) for SRKW. Like 'whale days', a marine mammal 'sighting day' is any day an animal of a given species is reported in each quadrant, regardless of the number of times it was reported that day. Table 5.1 depicts the total number of non-SRKW sightings and 'sighting days' reported for each of the three regions in this report.

From January 2009 through December 2018, the Whale Museum sightings archive (TWM-SA) recorded 18,931 sightings, and 8,571 'sighting days' of non-SRKW marine mammals in the ZOI, adjacent, and transit regions (Figure 1, Table 5.1A). There were 32 non-SRKW marine mammal sightings reported in the ZOI during the period of analysis and 752 reported whale days in adjacent quadrants (Table 5.1B). Large delphinids and balaenopterid species comprised the majority of reported sighting days, n=41.4% and n=43.9%, respectively (Table 5.1A) Only large delphinids, balaenopterids, and dolphin/porpoise species groups were reported in the immediate ZOI in the last ten years of analysis (Table 5.1A).

Table 5.1A: Number of sightings and 'sighting days' of non-SRKW species groups from 1 Jan 2009 through 31 Dec 2018 by region.

Species Group	Region	Sightings	'Sighting Days'	% 'Sighting Days'
Balaenopterid	ZOI	6	4	43.9
	Adjacent	324	235	
	Transit	5373	3527	
Dolphin/Porpoise	ZOI	4	4	6.1
	Adjacent	130	111	
	Transit	529	407	
Large Delphinid	ZOI	60	24	41.4
	Adjacent	1090	383	
	Transit	7398	3141	
Pinniped	ZOI	0	0	7.5
	Adjacent	6	6	
	Transit	3916	636	
Other	ZOI	0	0	0.05
	Adjacent	4	4	
	Transit	0	0	
Unidentified cetacean	ZOI	0	0	1.05
	Adjacent	13	13	
	Transit	78	76	
Total Observations		18,931	8,571	

Table 5.1B: non-SRKW marine mammal 'sighting days' sample statistics for the three main regions of interest across the ten years, 2009-2018, of analysis.

Region	Total No. of Sighting Days	Mean No. of Sighting Days	Mean ± SEM
ZOI	32	0.5	0.2
Adjacent	745	12.4	2.7
Transit	7489	124.8	22.9

ii) Annual non-SRKW sightings:

From 2009 through 2018, the TWM-SA recorded over 8,500 marine mammal 'sighting days' in the ZOI, adjacent, and transit regions (Table 5.2, Figure 6A and 6B). Only balaenopterids, dolphin/porpoise, and large delphinid species were sighted in the immediate ZOI (Table 5.2, Figure 6B). Conversely, pinnipeds, other, and unidentified cetacean species were rarely, if ever reported in the ZOI and adjacent quadrants (Table 5.2, Figure 6A). Species in the 'other' species group were reported in low frequencies, only once per year for four of the ten years of analysis, and were omitted from analysis (Table 5.2, Figure 6A). Conversely, most species were widely, and consistently reported throughout the years of this study in the transit quadrants (Table 5.2, Figure 6A).

An annual mean and the standard error of the mean (SEM) of the number of marine mammal 'sighting days' was calculated using methods described for SRKW in Section 3A(i) (Table 5.2). This is especially important to note for non-SRKW marine mammals when attempting to make predictions to future years, as data are collected sporadically and are not an exhaustive count of all marine mammals in this region.

Across the 10-years of sightings, 2017 had the greatest number (n=1641) and highest average number (n=91.2) of reported marine mammal sightings (Table 5.2, Figure 6A). Balaenopterids and large delphinids were observed in the highest frequencies in 2018 (n=594) and 2017(n=588), respectively (Table 5.2).

Table 5.2: non-SRKW 'sighting days' for the three main areas of interest for each species group for every year in the study period. The mean and the standard error of the mean are calculated at the bottom for each year.

Species Group	Region	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Balaenopterid	ZOI	0	0	0	0	1	0	0	0	2	1
	Adjacent	7	18	2	8	16	6	17	53	55	48
	Transit	315	413	188	196	187	191	491	441	468	594
Dolphin/Porpoise	ZOI	0	0	1	0	0	0	0	2	1	0
	Adjacent	7	1	10	8	4	0	5	47	21	7
	Transit	27	30	42	16	3	12	39	64	125	36
Large Delphinid	ZOI	0	0	1	0	0	5	6	2	5	5
	Adjacent	37	19	17	4	20	43	101	13	68	61
	Transit	148	197	101	196	230	263	424	421	588	573
Pinniped	ZOI	0	0	0	0	0	0	0	0	0	0
	Adjacent	4	0	0	0	0	0	0	2	0	0
	Transit	19	24	33	2	1	4	7	6	263	35
Other	ZOI	0	0	0	0	0	0	0	0	0	0
	Adjacent	0	0	0	0	0	1	0	0	1	1
	Transit	0	0	0	0	0	0	0	0	0	0
Unidentified cetacean	ZOI	0	0	0	0	0	0	0	0	0	0
	Adjacent	0	0	0	0	0	3	1	3	4	2
	Transit	0	0	0	0	0	1	5	8	40	22
Total No. of Sighting Days		564	702	395	430	462	529	1096	1062	1641	1385
Mean No. of Sighting Days		31.3	39	21.9	23.9	25.7	29.4	60.9	59	91.2	77
Mean ± SEM		18.6	24.5	11.5	14.8	15.8	17.4	34.6	32.3	40.8	43.7

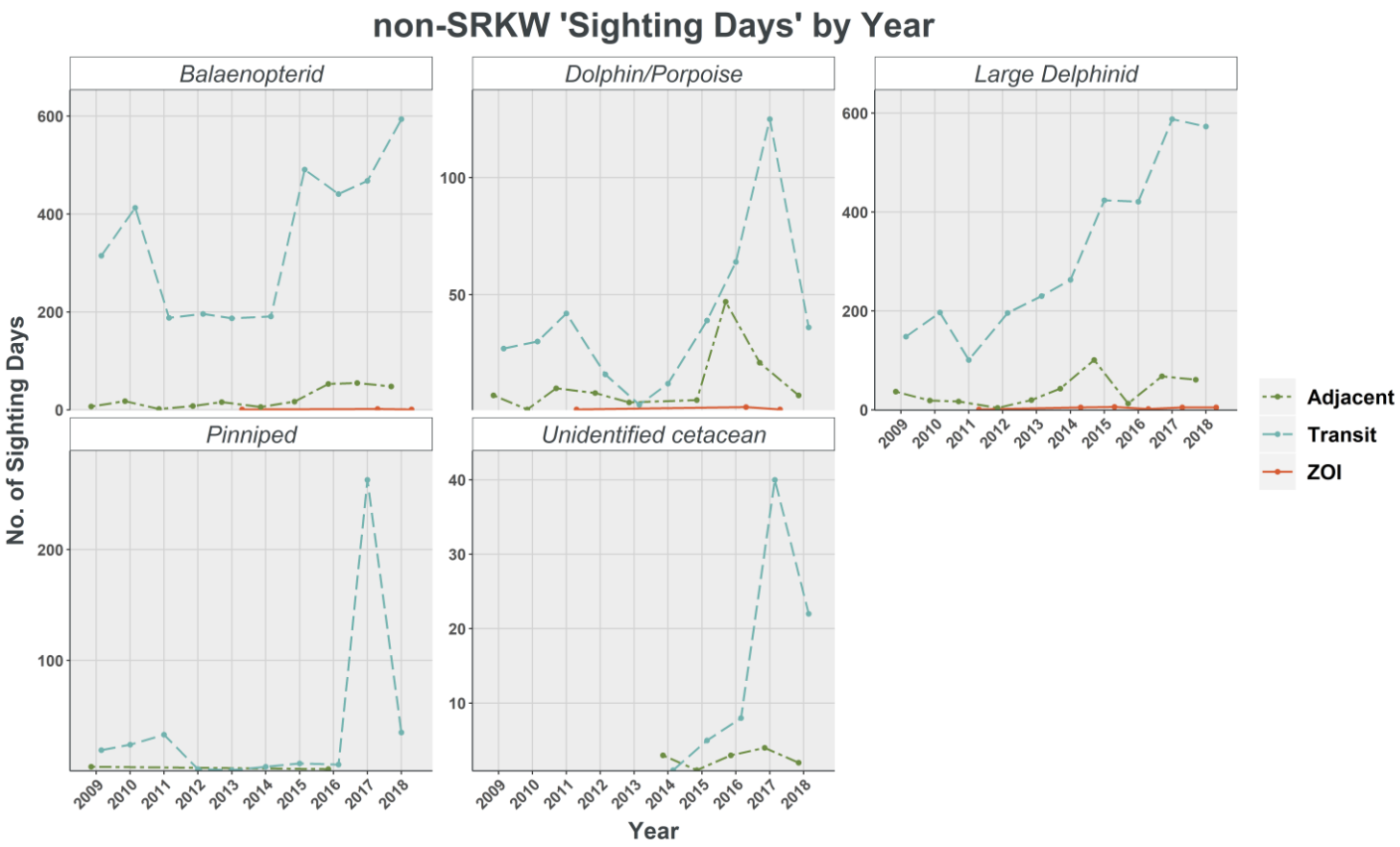

Figure 6A: Number of unique sighting days for all non-SRKW marine mammals species by year. Animals are grouped by 'Species Group' (Table 4). Animals in the 'other' group were omitted as this group was sighted once per year for 4 of the 10 years of data analyzed. Points indicate the total number of unique sighting days of a given species group for the year. Data points are connected by a trend line to illustrate broad patterns in reported sighting days. Note differences in y-axis values across different plots.

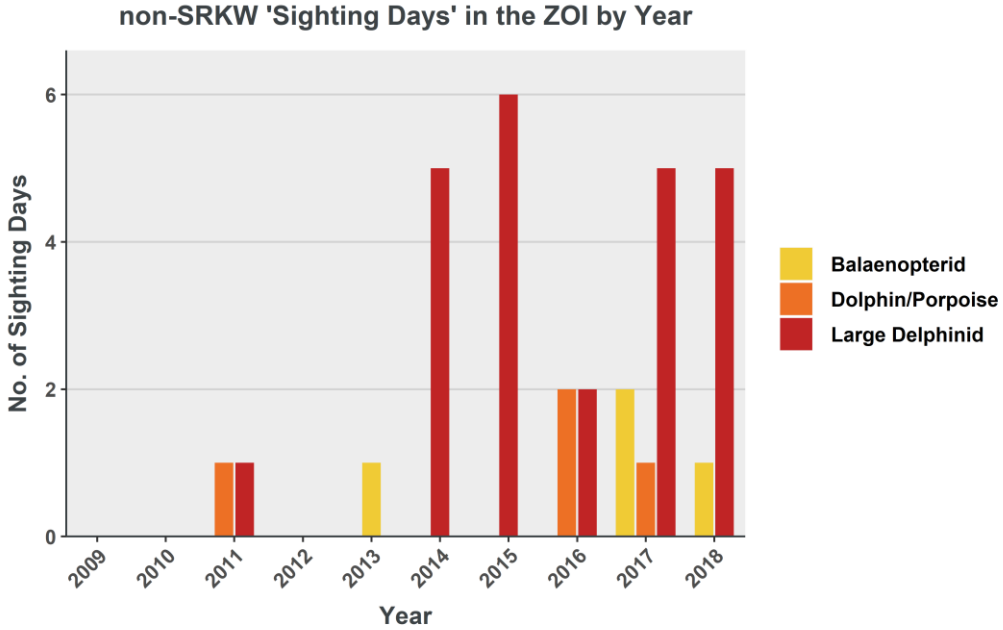

Figure 6B: Number of unique sighting days reported for all non-SRKW marine mammals reported in the ZOI quadrant for the years of 2009-2018. Animal sightings are grouped by 'Species Group' (Table 4).

iii) Monthly non-SRKW sightings:

From 2009 through 2018, the TWM-SA recorded about 32 marine mammal 'sighting days' in the ZOI (Table 5.3, Figure 7A and 7B). Only balaenopterid, dolphin/porpoise, and large delphinid species were sighted in the immediate ZOI (Table 5.2, Figure 6B). Of those four species groups, large delphinids (primarily transient killer whales), appeared most frequently in the ZOI, and were reported at least once for 9 of the 12 months of any given year during the 10-year period of analysis. Additionally, pinniped, other, and unidentified cetacean species were rarely, if ever reported in the ZOI and adjacent quadrants (Table 5.3, Figure 7A). Species in the 'other' group were reported in low frequencies, only once per month for 4 of the 12 months in a year throughout the study period, and were subsequently omitted from analysis (Table 5.3, Figure 6A). Conversely, most species were widely, and consistently reported throughout all months of a given year in the transit quadrants (Table 5.3, Figure 7A).

A monthly mean and the standard error of the mean (SEM) of the number of marine mammal 'sighting days' was calculated using methods described for SRKW in Section 3A(i) (Table 5.3). This is especially important to note for non-SRKW marine mammals when attempting to make predictions to future years, as data are collected sporadically and are not an exhaustive count of all marine mammals in this region.

Across the 10-years of sightings, the month of April had the greatest overall number (n=1414) and highest average number (n=78.6) of reported marine mammal sightings (Table 5.3, Figure 7A). It is also important to point out the relatively large variance for 'sighting days' for all months of a given year. The contrasting monthly variance values for 'sighting days' in comparison to the annual variance reported in Table 5.2 indicate that across years, there was a relatively larger degree of variation in the reported number of 'sighting days' for marine mammals which was then expressed in the overall monthly figures for the study period (Table 5.3). This variation is most likely due to the nature of the TWM-SA, as data for non-SRKW species is collected opportunistically. The greater spread of variation should therefore be attributed as an artifact of the dataset and/or reporter effort, rather than as a biological artifact of species distributions over time.

Balaenopterids and large delphinids were observed in the highest frequencies throughout the month of April, n=833 and n=509, respectively (Table 5.3). Interestingly, pinniped, dolphin/porpoise, and unidentified cetacean species were observed in greater frequencies in later months (December and November) of the year (Table 5.3, Figure 7A). Similarly, the greatest number of 'sighting days' in the ZOI (n=4) for any species group was reported during the months of April, May, and November (Table 5.3, Figure 7B). Lastly, although the number of reported 'sighting days' for marine mammals in the ZOI, adjacent, and transit regions reached maximum frequencies during the months of April, the overall number of 'sighting days' for marine mammals in this area was greater during the shaded months that correspond to the proposed work period (Figure 7A and B).

Table 5.3: non-SRKW 'sighting days' for the three main areas of interest for each species group for every month in a given year during the study period. The mean and the standard error of the mean are calculated at the bottom for each month. Shaded areas correspond with the proposed work period of July 15th through February 15th.

Species Group	Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Balaenopterid	ZOI	0	0	0	0	0	3	1	0	0	0	0	0
	Adjacent	8	9	22	17	37	23	33	16	12	16	29	8
	Transit	94	144	756	816	394	260	135	160	205	247	167	106
Dolphin/Porpoise	ZOI	0	0	0	0	0	1	1	0	0	2	0	0
	Adjacent	7	3	2	1	15	17	26	14	14	8	1	2
	Transit	19	15	32	40	24	34	29	50	29	53	36	33
Large Delphinid	ZOI	2	0	0	4	4	1	2	2	2	0	4	3
	Adjacent	37	5	3	44	83	21	15	39	53	11	36	36
	Transit	160	168	207	461	353	252	266	356	393	179	144	202
Pinniped	ZOI	0	0	0	0	0	0	0	0	0	0	0	0
	Adjacent	4	0	0	0	0	0	1	3	0	0	1	1
	Transit	19	7	14	20	6	1	14	32	9	75	85	90
Other	ZOI	0	0	0	0	0	0	0	0	0	0	0	0
	Adjacent	1	0	0	0	1	0	0	0	0	1	0	0
	Transit	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified cetacean	ZOI	0	0	0	0	0	0	0	0	0	0	0	0
	Adjacent	1	0	1	1	0	0	2	0	0	4	4	0
	Transit	3	10	6	10	0	2	4	10	7	6	12	6
Total No. of Sighting Days		355	361	1043	1414	917	615	529	682	724	602	519	487
Mean No. of Sighting Days		19.7	20.1	57.9	78.6	50.9	34.2	29.4	37.9	40.2	33.4	28.8	27.1
Mean ± SEM		9.8	11.7	42.6	50.2	28.1	19.2	15.8	20.8	23.7	16.4	12.1	12.7

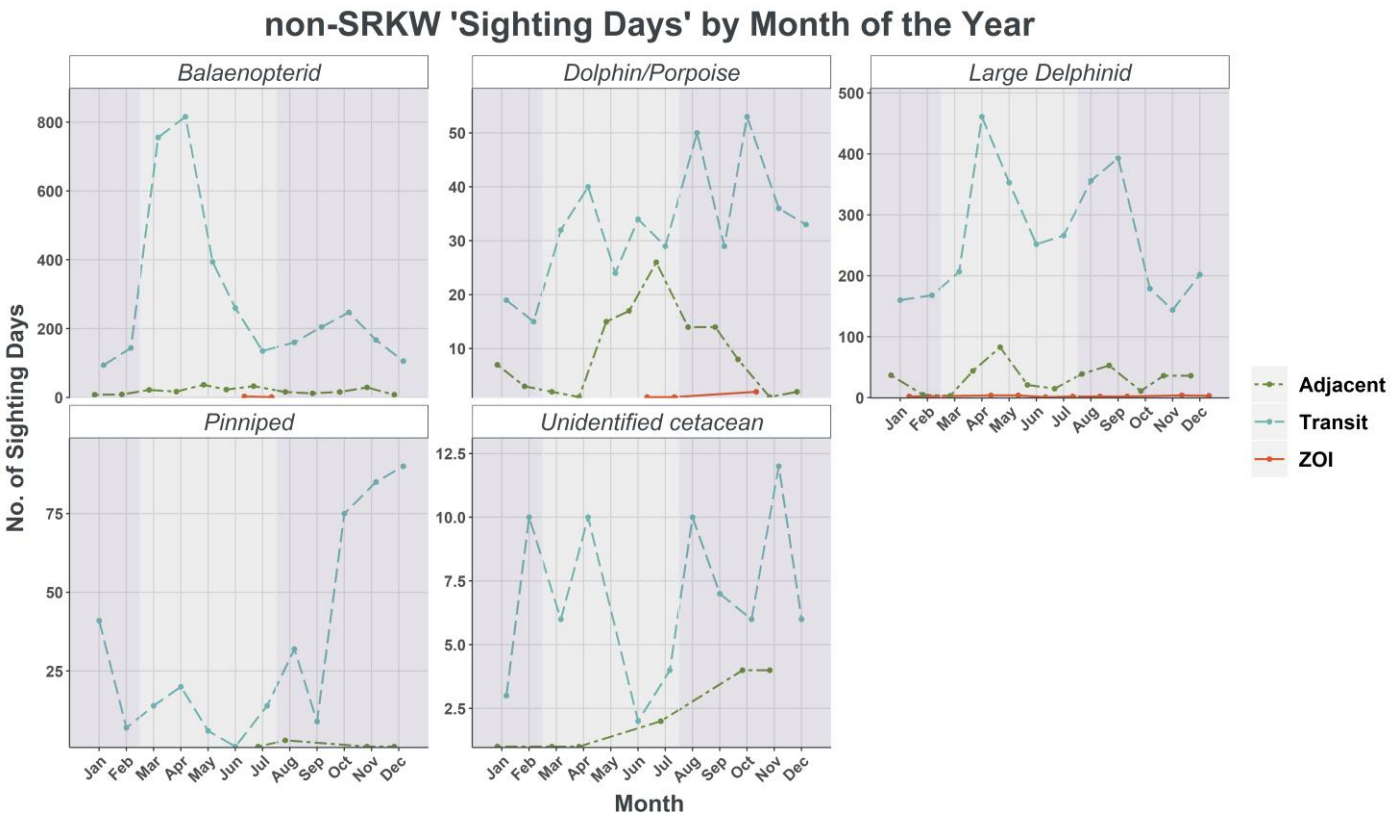

Figure 7A: Number of unique sighting days for all non-SRKW marine mammals species by month. Animals are grouped by their 'Species Group' (Table 4). Animals in the 'other' group were omitted as this group was only reported 1 time for 4 of the 12 months of any year analyzed. Points indicate the total number of unique sighting days of a given species group for the year. Data points are connected by a trend line to illustrate broad patterns in reported sighting days.Data in shaded purple regions denote reported sighting days that occurred during the proposed work period of 7/15-2/15 throughout the years of analysis. Note differences in y-axis values across different plots.

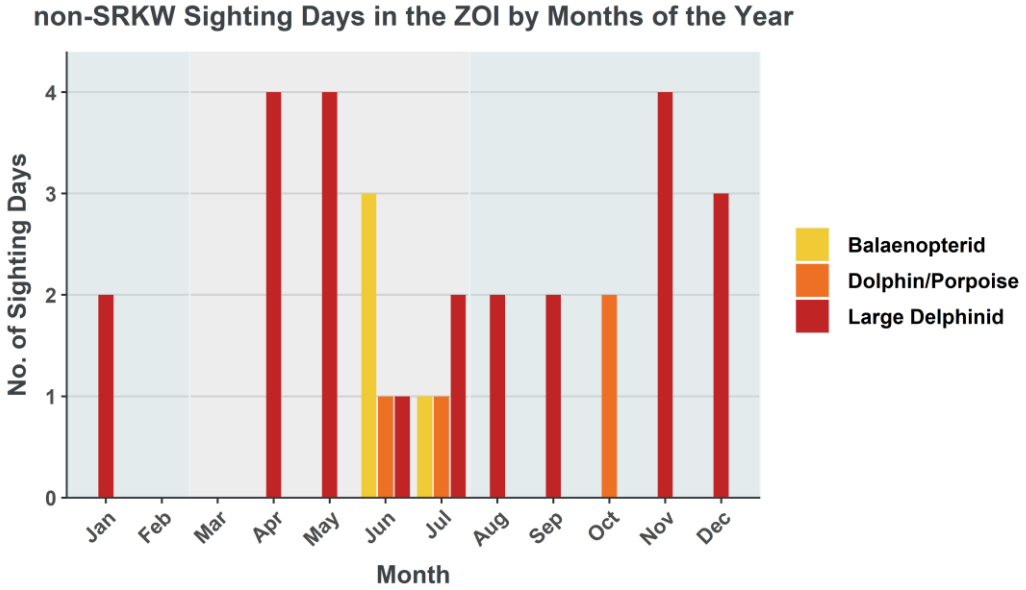

Figure 7B: Number of unique sighting days reported for all non-SRKW marine mammals in the ZOI quadrant during different months between the years of 2009-2018. Animal sightings are grouped by 'Species Group'.Data in shaded blue regions denote reported sighting days that occurred during the proposed work period of 7/15-2/15 throughout the years of analysis.

iv) Seasonal non-SRKW sightings:

Like the SRKW, many other species of marine mammals are seen throughout the year, but there are however, some species that follow seasonal patterns in their migration and distributions. For example, gray and humpback whales are known to travel North through the Salish Sea ecosystem to their preferred Arctic feeding grounds during the summer months (Pike 2011, Rosa *et al.* 2008). Other species, such as harbor porpoises, harbor seals, and stellar sea lions have established residency throughout the Salish Sea (Gaydos and Pearson 2011).

Many of the reported species sightings followed some seasonal pattern in their presence for the areas of interest in this study. Balaenopterids and large delphinids were reported in the greatest frequency during the summer and fall seasons (Table 5.4, Figure 8A). Other species such as dolphin/porpoise and unidentified cetaceans, were reported in greater frequencies between the summer and fall and fall seasons (Table 5.4, Figure 8A).

Overall, there were more reports of animals in the ZOI during the spring than any other season of the year (Table 5.4, Figure 8B). Large delphinids (transient killer whales) were the most frequently reported species group in the ZOI throughout the study period (Table 5.4, Figure 8B).

Seasonal means and standard errors of the mean (SEM) of non-SRKW 'sighting days' were also calculated for each region in the study (Table 5.4). Similar to the aforementioned trends in sightings, note the use of sample statistics, particularly for non-SRKW marine mammal species, if attempting to make seasonal predictions.

On average, non-SRKW were reported in the greatest frequency ($n = 182.3 \pm 111.5$; Table 5.4) during the spring season. This is consistent with trends observed more locally, in the ZOI (Figure 9B). Similar to the monthly sightings patterns, seasonal non-SRKW seasonal patterns also had relatively high degrees of variance, again suggesting a variation in reporter effort and/or the opportunistic nature of the TWM-SA dataset used for this analysis.

Table 5.4: non-SRKW 'sighting days' for the three main areas of interest for each species group for every season of the year during the study period. The mean and the standard error of the mean (SEM) are calculated at the bottom for each season.

Species Group	Region	Spring	Summer	Fall	Winter
Balaenopterid	ZOI	2	2	0	0
	Adjacent	75	65	58	32
	Transit	1785	556	541	602
Dolphin/Porpoise	ZOI	0	2	2	0
	Adjacent	24	58	15	13
	Transit	101	113	124	56
Large Delphinid	ZOI	9	6	7	2
	Adjacent	149	102	79	53
	Transit	1086	1083	447	525
Pinniped	ZOI	0	0	0	0
	Adjacent	0	4	2	0
	Transit	35	50	238	71
Other	ZOI	0	0	0	0
	Adjacent	1	0	1	1
	Transit	0	0	0	0
Unidentified cetacean	ZOI	0	0	0	0
	Adjacent	1	2	8	2
	Transit	13	22	22	19
Total No. of Sighting Days		3281	2065	1544	1376
Mean No. of Sighting Days		182.3	114.7	85.8	76.4
Mean ± SEM		111.5	64.6	38.0	42.2

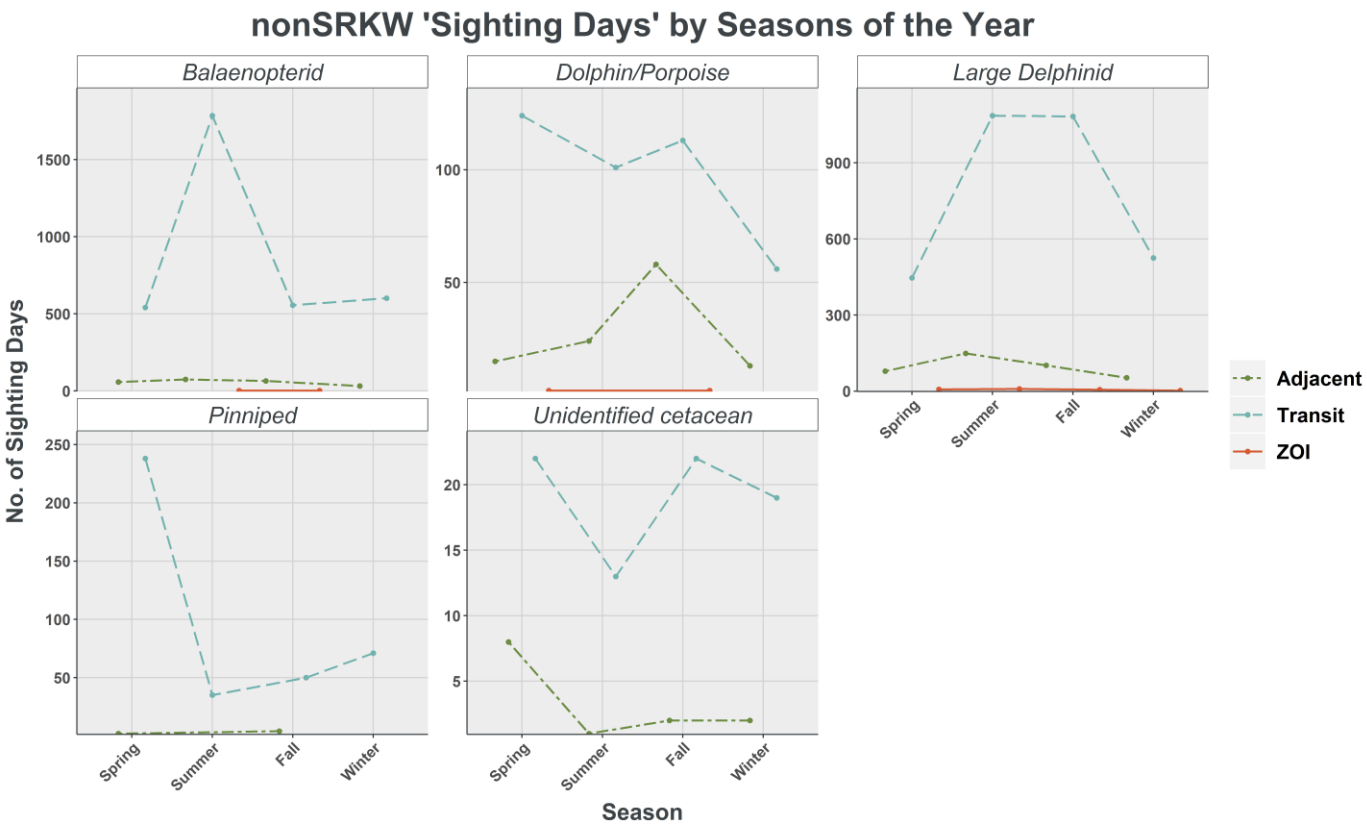

Figure 8A: Number of unique sighting days for all non-SRKW marine mammals species by season. Animals are grouped by their 'Species Group' (Table 4). Animals in the 'other' group were omitted as this group was only reported 1 time for 3 of the 4 seasons of any year analyzed. Points indicate the total number of unique sighting days of a given species group for the year. Data points are connected by a trend line to illustrate broad patterns in reported sighting days.Note differences in y-axis values across different plots.

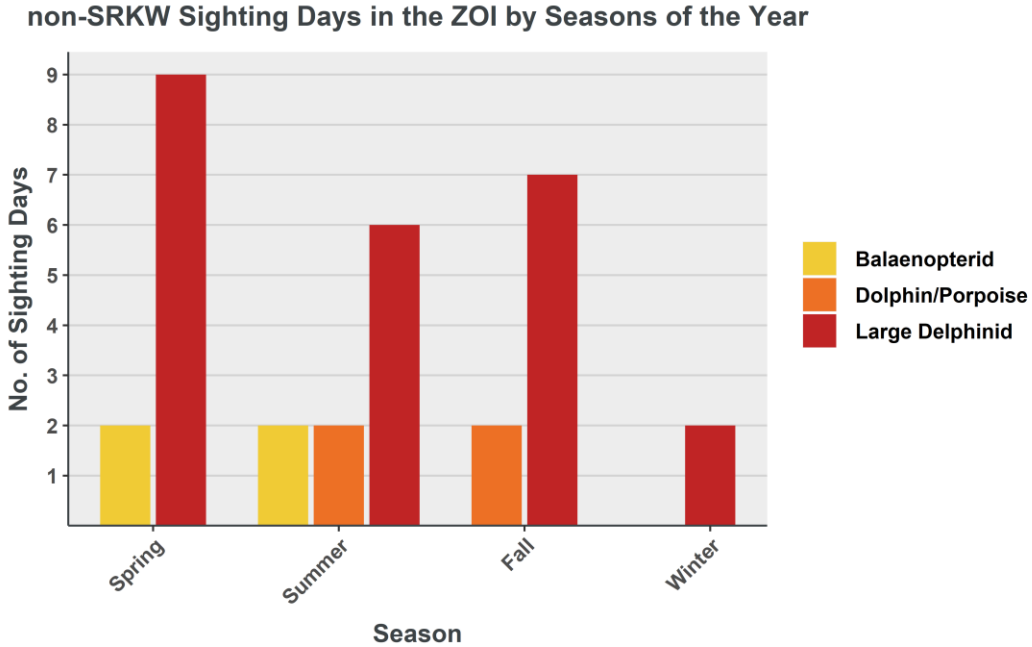

Figure 8B: Number of unique sighting days reported for all non-SRKW marine mammals in the ZOI quadrant during different seasons for the years of 2009-2018. Animal sightings are grouped by 'Species Group' (Table 4).

v) non-SRKW sightings during the proposed work period (7/15-2/15)

Consistent with previously reported trends, most non-SRKW marine mammal species were more commonly reported in the areas of interest outside of (n = 4392) the proposed work period of 7/15 – 2/15 than during (n = 3874) the proposed 7-month period (Table 5.5). Balaenopterids, however, were the only species group which was reported more frequently outside of the proposed work period (n=2392; Table 5.5, Figure 9A), whereas every other species group was reported more frequently during the proposed work period (Figure 9A). Overall however, more animals were reported in the immediate ZOI during the proposed work period (n = 20) than outside of the proposed work period (n = 13; Table 5.5, Figure 9B).

Non-SRKW 'sighting days' within the proposed work period accounted for nearly half (n = ~47%) of all reported sightings (Table 5.5, Figure 9A). Much of these sightings occurred in transit quadrants and fewer in adjacent quadrants, whereas about 33 overall sightings were reported in the ZOI (Table 5.5; Figure 9A and 9B). Although most non-SRKW were not reported in the ZOI for any of the trends discussed, the data heavily suggest that they are present within the over all South Puget Sound region. Much like the SRKW, these other marine mammal species' reported absence, or rather lack of reported sightings, in the ZOI and other areas should not be attributed to their true absence, but may rather be attributed to lack of reporter presence/effort in the more inland waters of Henderson Bay (Figure 1). Data of non-SRKW marine mammals in adjacent and transit quadrants hightlight the need for spatial context when analyzing the behaviors of large, highly mobile animals, and provide clues into these animals' habitat use in the overall area when highly specific data in a particular area is not available or possible to collect.

Table 5.5: non-SRKW 'sighting days' reported during the proposed 7/15 – 2/15 work period ('within') and reported 'outside of' the proposed work period. Data are reported for the three regions of interest, and sample statistics are calculated for each region.

Species Group	Region	Outside of	Within
Balaenopterid	ZOI	3	1
	Adjacent	120	110
	Transit	2377	1107
Dolphin/Porpoise	ZOI	1	3
	Adjacent	48	62
	Transit	149	245
Large Delphinid	ZOI	9	15
	Adjacent	156	227
	Transit	1450	1691
Pinniped	ZOI	0	0
	Adjacent	0	6
	Transit	48	346
Other	ZOI	0	0
	Adjacent	1	2
	Transit	0	0
Unidentified cetacean	ZOI	0	0
	Adjacent	2	11
	Transit	28	48
Total No. of Sighting Days		4392	3874
Mean No. of Sighting Days		244.0	215.2
Mean ± SEM		148.5	107.0

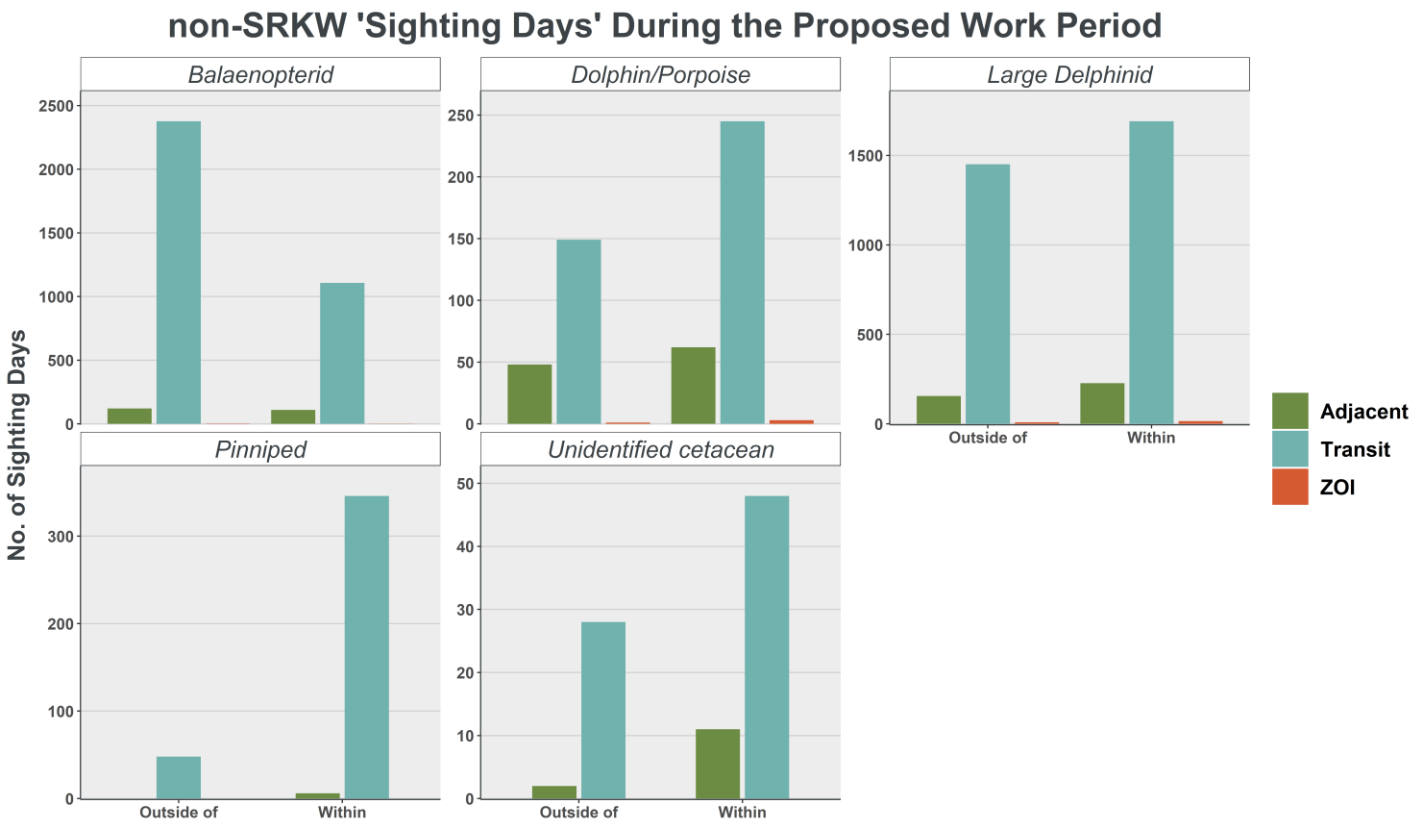

Figure 9A: Number of sighting days for all non-SRKW marine mammals species reported during the proposed work period ('within') relative to the number of reported sighting days that fell 'outside' of the proposed work period of 7/15 - 2/15. Animals are grouped by 'Species Group' (Table 4). Animals in the 'other' group were omitted as this group was reported 4 times throughtout the 10-year study period. Counts of non-SRKW sighting days are displayedpoints as columns. Note differences in y-axis values across different plots.

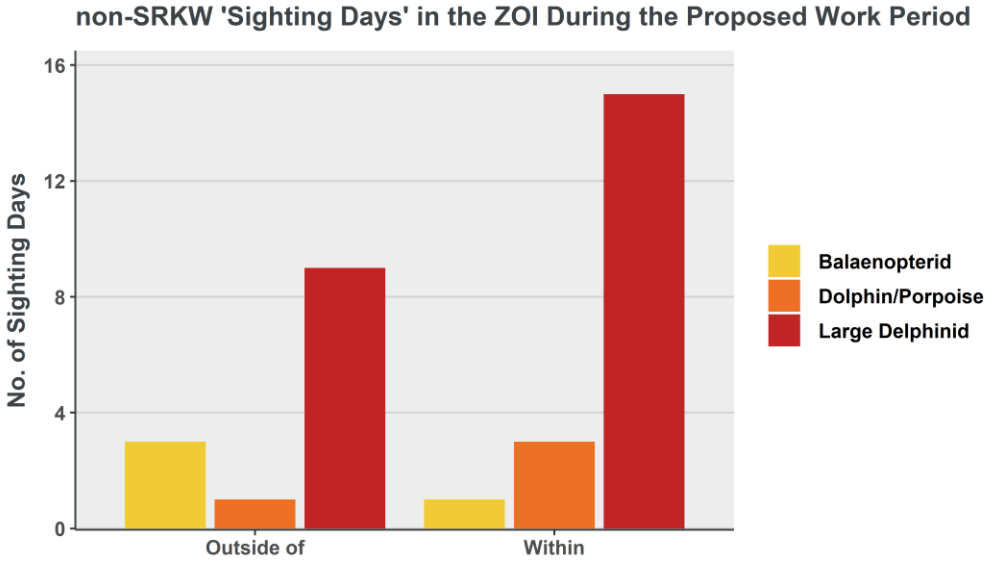

Figure 9B: Number of unique sighting days reported for all non-SRKW marine mammals reported in the ZOI quadrant during the proposed work period of 7/15 - 2/15 for the years of 2009-2018. Animal sightings are grouped by 'Species Group' (Table 4).

4) Synopsis of findings:

The analyses in this report have used TWM's Orca Master data set, the most extensive data set on SRKW sightings in the Salish Sea, as well as TWM's sightings archive. These data sets were not collected in a systematic manner, but are based on voluntary reports from TWM staff, affiliated researchers, professional whale watch operators, and the general public. The Orca Master data set contains data from 2009 - 2018 and a total of 4,645 sightings of SRKW in quadrants adjacent to ZOI quadrant 424, and quadrants used to transit to the ZOI (Figure 1; Table 3.1). SRKW were not reported in the immediate ZOI for the last 10 years of reported data. The average number of days that SRKW present in adjacent quadrants from 2009-2018 was 10 days per year while the average number of days for transit quadrants was 191 (Table 3.2; Figure 2). The number of whale days in the project area shows a consistent periodicity with peak usage occurring during the fall and winter months of September through February (Tables 3.3-5, and Figures 3-5). It is suggested that whale days per month and per seasons for the larger areas of interest also be considered in the WSDOT take estimates since usage by SRKW in single quadrants is likely to be underestimated.

In addition to SRKW, at least 20 additional cetacean species (including transient orcas), 7 pinniped species, and sea otters have been recorded in the reported areas of interest from 2009 – 2018. Since 2008, there have been 32 sighting days for non-SRKW marine mammals in the immediate ZOI quadrant, 745 in adjacent quadrants, and 7489 in transit quadrants (Table 5.1A). For the proposed work period of 7/15 – 2/15, there have been 19 sighting days for non-SRKW marine mammals in the immediate ZOI, whereas there were 418 reported sighting days in adjacent quadrants, and 3397 in transit quadrants (Table 5.5; Figures 9A-B). Because the sightings archive is not as robust as the Orca Master data set, the number of sighting days for other species of marine mammals for the quadrants of interest, and particularly for the ZOI, should be interpreted as a minimum number of sightings for those species rather than as an average or typical value.

5) Acknowledgements:

The Orca Master data set would not be possible without the generous contributions of sightings reports by many people over the years. We thank them for all their contributions. We also acknowledge Dr. Richard Osborne for his management of this data set for many of the years of its existence.

6) References:

Baird, R. W. & Dill, L. M. 1995. Occurrence and behaviour of transient killer whales; seasonal and pod-specific variability, foraging behavior, and prey handling. *Can. J. Zool.* Vol. 73, pp. 1300-1311.

Boran, J.R., 1980. The Whale Hotline, Cetus Vol. 2, No. 2, pp. 4-5.

Charapata, P., Traxler, A., Wood, J.D., & Osborne, R.W. 2012. Southern Resident killer whale sightings compilation 9th Edition (1990-2012). Final contract report # RA133F-12-CQ-0057, NWFSC, NMFS, NOAA, Seattle, WA, 25 p.

Gaydos, Joseph K. and Pearson, Scott F. 2011. Birds and Mammals that Depend on the Salish Sea: A Compilation. *Northwest Naturalist.* Vol. 92(2), pp. 79-94. doi: https://doi.org/10.1898/10-04.1.

Hanson, Brad. 2015. Distribution and Diet of Southern Resident Killer Whales. NOAA Northwest Fisheries Science Center. Program Review. <https://swfsc.noaa.gov/uploadedFiles/Events/Meetings/MMT_2015/Presentations/3.1%20PPT%20ProgramReviewSRKWDistributionDiet071515MBHv2.pdf/>.

Hauser, D.D.W., Logsdon, M.G., Holmes, E.E., VanBlaricom, G.R. & Osborne, R.W. 2007. Summer distribution patterns of southern resident killer whales *Orcinus orca*: core areas and spatial segregation of social groups. *Mar. Ecol. Prog. Ser*. Vol. 351, pp. 301-310.

Heimlich-Boran, J.R., 1988. Behavioral Ecology of Killer Whales (*Orcinus orca*) in the Pacific Northwest. *Canadian Journal of Zoology*. Vol. 66, pp. 565-579.

Koski, K. 2004. NOAA Contract # AB133F-03-SE-1126 Final Program Report: Soundwatch Public Outreach/Boater Education Project 1998-2003. The Whale Museum, Friday Harbor, WA.

Koski, K.L., and R.W. Osborne, 2005. The evolution of adaptive management practices for vessel-based wildlife viewing in the boundary waters of British Columbia and Washington State. Proceedings of the Puget Sound / Georgia Basin Ecosystem Conference 2005, Puget Sound Water Quality Action Team (www.psat.wa.gov/Publications/05_proceedings/index.html.).

Koski, K. 2006. NOAA Contract # AB133F-04-SE-0835 Final Program Report: Soundwatch Public Outreach/Boater Education Project 2004-2005. The Whale Museum, Friday Harbor, WA. NWFSC, NMFS, NOAA, Seattle, WA, 25 p.

Koski, K. 2007. NOAA Contract # AB133F-04-SE-0653 Final Program Report: Soundwatch Public Outreach/Boater Education Project 2006. The Whale Museum, Friday Harbor, WA.

McCluskey, S.M. 2006. Space use patterns and population trends of Southern Resident killer whales (*Orcinus orca*) in relation to distribution and abundance of Pacific salmon (*Onchorynchus* spp.) in

the inland marine waters of Washington State and British Columbia. MSc. thesis. University of Washington.

National Marine Fisheries Service. 2008. Recovery plan for the Southern Resident killer whales (*Orcinus orca*). National Marine Fisheries Service , Northwest Region, Seattle, Washington.

Osborne, R.W., 1991. Trends in killer whale movements, vessel traffic, and whale watching in Haro Strait. Proceedings of Puget Sound Research '91, Seattle, WA., Puget Sound Water Quality Authority, pp.672-688.

Osborne, R.W., 1999.A historical ecology of Salih Sea resident killer whales (*Orcinus orca*) with implications for management. Doctoral thesis, Dept. Geography, University of Victoria, Victoria, B.C., 262 p.

Osborne, R.W., R.E. Tallmon, J. Olson and R.E. Otis, 2004. Southern Resident killer whale sighting compilation 1990-2003. Final contract report # AB133F-03-SE, NWFSC, NMFS, NOAA, Seattle, WA, 14 p.

Pike, Gordon. 2011. Migration and Feeding of the Gray Whale (*Eschrichtius gibbosus*). *Journal of the Fisheries Research Board of Canada*. Vol. 19 (5) pp. 815-838. doi: https://doi.org/10.1139/f62-051.

Rosa, L. Dalla, Secchi, E.R., Maia, Y.G, Zerbini, A.N., and Heide-Jørgensen, M.P. 2008. Movements of satellite-monitored humpback whales on their feeding ground along the Antarctic Peninsula. *Polar Biology*. Vol. 31, pp. 771-781. doi: https://doi.org/10.1007/s00300-008-0415-2.