Seasonality of killer whale (*Orcinus orca*) ecotypes in the Northwest Training Range Complex

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14. ABSTRACT
Since 2004, PAM using High-frequency Acoustic Recording Packages (HARPs) has been conducted at two sites in the Navy's Northwest Training Range Complex; one offshore in Quinault Canyon (site QC) and the other closer inshore near Cape Elizabeth (site CE). For this report, killer whale signals were analyzed for periods of deployment from January 2011 – April 2014 in order to determine the seasonal occurrence and distribution of different killer whale ecotypes at these sites. Residents were encountered in spring and early summer at both sites and in October 2011 at site CE. Transients had the highest relative presence of all ecotypes at both sites. Transients were detected most months but mainly from spring until early summer at site QC and from late spring until early fall at site CE. The lack of Transient seasonality has been noted in previous PAM efforts and suggests this area is an important habitat for Transients year-round. Offshores were encountered during most months at site QC but only during August and September at site CE.

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Executive Summary:

Three different killer whale (*Orcinus orca*) ecotypes are known to inhabit the Northeastern Pacific: Residents, Transients and Offshores. These ecotypes are distinguished by morphological, genetic, behavioral and acoustic differences. Killer whales of each ecotype produce distinct, stereotypic pulsed calls that can be used as acoustic indicators of presence, making passive acoustic monitoring (PAM) a useful method for assessing intraspecies differences in spatial and temporal patterns.

Since 2004, PAM using High-frequency Acoustic Recording Packages (HARPs) has been conducted at two sites in the Navy's Northwest Training Range Complex; one offshore in Quinault Canyon (site QC) and the other closer inshore near Cape Elizabeth (site CE). For this report, killer whale signals were analyzed for periods of deployment from January 2011 – April 2014 in order to determine the seasonal occurrence and distribution of different killer whale ecotypes at these sites.

HARPs recorded continuously at a 200 kHz sampling rate and data analysis consisted of scanning long-term spectral averages for encounters of killer whale pulsed calls. Individual calls were then examined to attribute them to specific ecotypes.

Site CE had an overall higher percent of days with presence than site QC. A peak in relative daily presence occurred in July at site CE, with 17.6% of days having killer whale encounters. Site QC had overall lower relative presence of killer whale encounters, with peaks in March (8.9%) and December (9.2%).

Residents were encountered in spring and early summer at both sites and in October 2011 at site CE.

Transients had the highest relative presence of all ecotypes at both sites. Transients were detected most months but mainly from spring until early summer at site QC and from late spring until early fall at site CE. The lack of Transient seasonality has been noted in previous PAM efforts and suggests this area is an important habitat for Transients year-round.

Offshores were encountered during most months at site QC but only during August and September at site CE.

Introduction:

The waters off the coast of Washington are inhabited by killer whales (*Orcinus orca*) year-round. Three distinct killer whale ecotypes have been identified in this region of the Northeastern Pacific: Residents, Transients and Offshores. These ecotypes have been shown to differ morphologically, genetically, behaviorally and acoustically (Ford 1987; Deecke et al. 2005; Bigg et al. 1990; Barrett-Lennard 2000; Dahlheim et al. 2008; Ford et al. 1998; Hoelzel et al. 1998). Resident killer whales travel in stable pods consisting of one or more matrilines, the smallest killer whale social unit consisting of a female and her offspring, from which there is little to no dispersal (Ford 1989; Bigg et al. 1990). There are two communities of Resident killer whales that frequent the waters from Northern British Columbia to California, the Northern Residents and the Southern Residents. The Northern Residents are typically found from Southwest Vancouver Island to Southeast Alaska while the Southern Residents are found in the southern Salish Sea (Ford 1987). Both communities of Residents feed exclusively on fish, mainly salmon (*Oncorhynchus* spp.; Ford et al. 1998; Ford & Ellis 2006). Transient killer whales have less predictable travel patterns and live in smaller groups, with occasional dispersal from maternal groups documented (Ford 1987; Bigg et al. 1990). The population of Transients found in the Northeastern Pacific from Southern Alaska to Northern Mexico has been dubbed West Coast Transients and can be further broken down into Southeast Alaska Transients, British Columbia Transients and California Transients. Transients prey almost exclusively on marine mammals and only occasionally on seabirds (Ford 1987; Ford et al. 1998). Relatively little is known about the third ecotype, the Offshores. Offshores are typically seen in larger groups of 50-100 individuals and have been documented to prey upon a variety of fish species, including sharks (Dahlheim et al. 2008; Ford et al. 2011).

In terms of differences in acoustic behavior, Residents and Offshores have unique call repertoires but share similar call and echolocation rates while Transients vocalize significantly less often (Barrett-Lennard et al. 1996; Deecke et al. 2005). Deecke et al. (2002; 2005) suggest that the decreased vocal rates seen among Transients was likely due to the increased cost of vocal communication when hunting marine mammals, as these prey are able to hear killer whale calls from several kilometers away.

Killer whales produce 3 main types of vocalizations: echolocation clicks, whistles (which can be further subdivided into low frequency and ultrasonic) and pulsed calls (Ford 1989; Samarra et al. 2010; Simonis et al. 2012). Pulsed calls are the most common type of vocalization emitted by killer whales. They are characterized by a high repetition rate of pulsed sounds (typically 250-2000 pulses/s but can be as high as 4000/s) which results in distinctive calls that sound tonal (Ford 1989). Pulsed calls generally have a fundamental frequency between 1-6 kHz and they are usually 0.5-1.5 seconds in duration (Ford 1989). There are three different types of pulsed calls: discrete, variable and aberrant (Ford 1989). Discrete calls are the most common and are highly stereotyped such that distinct call types can be identified. Variable calls do not fit into these call type categories and are not repeated. Aberrant calls appear to be based on discrete call types but have modified structures and are often produced during social interactions (Ford 1991). For this report, pulsed calls were used for killer whale ecotype identification because different ecotypes are known to produce distinct pulsed call types.

The acoustic differences among the three ecotypes allow PAM to be used for ecotype identification. In Resident killer whales, social structure is reflected acoustically, allowing for groups to be easily identified using PAM (Ford 1987). Within a matriline, all whales share the same call types. Matrilines that travel together are known as pods and they will share most call types, although some variation exists. Variation between matrilines and pods, which results in dialects, happens via slight alterations to shared call types. A group of pods that are acoustically related are referred to as a clan. Members of a clan do not all produce the same repertoire of calls but share at least one call type (Ford 1991; Ford 1987). Deecke (2003) found that there are call types unique to different groups of Transients (California Transients and British Columbia Transients) even though both groups are a part of the West Coast Transient population. Offshores may have acoustic differentiation at the group level, but a better understanding of Offshore acoustics and social structure is still necessary to confirm if this may be the case.

Previous studies have used long-term passive acoustic recordings to assist in determining critical habitat for these at-risk groups and to determine their winter distributions, which are still not well understood. The aim of the current study is to provide detailed information on killer whale ecotype seasonal distribution in this region over the last four years and to provide a long-term view of the spatial and temporal patterns of the different ecotypes of this species.

Methods:

Passive Acoustic Monitoring:

Passive acoustic monitoring has been conducted at an inshore and offshore site in the Navy's Northwest Training Range Complex using High-frequency Acoustic Recording Packages (HARPs) since 2004.

The offshore site was Quinault Canyon (QC) at the shelf slope and the inshore site was located on the continental shelf off of Cape Elizabeth (CE). Site CE was monitored from May 2011 – January 2012 and again from July – August 2013. Site QC was monitored almost continuously from January 2011 – April 2014 (Table 1).
Data Quality:

The OCNMS16 recording from site QC was 260 days in duration, but a hydrophone malfunction reduced the quality of the low frequency data by increasing electronic self-noise. The malfunction was not consistent in severity nor over time, allowing for analysis but typically with reduced data quality. Currently, a hydrophone re-design is underway to prevent this type of malfunction in future deployments.

Data Analysis:

HARPs are capable of long-term (up to 300 days) recording and are placed on the seafloor with a calibrated hydrophone suspended 10m above (Wiggins & Hildebrand 2007). During the deployments analyzed for this report, HARPs recorded continuously at a 200 kHz sampling rate. Before analysis, data were decimated by a factor of 20 for more effective scanning up to 5000 Hz. Long-term spectral averages (LTSAs) were created using a 5s time average and a 10Hz resolution and were scanned by an analyst for killer whale whistles and pulsed calls. When a potential killer whale signal was identified in the LTSA, a 30 sec long spectrogram (1000 FFT length, 65% overlap) was examined in order to confirm that the calls belonged to killer whales. Calls were logged as encounters, where each encounter was bounded by at least 15 minutes of recording that did not contain any calls.

Ecotype Identification:

Each encounter was later examined for pulsed calls which, when found, were scrutinized in a 10 sec long spectrogram window in order to visually and aurally identify call types that could be used to distinguish between different ecotypes. Resident and Transient call types were identified using a digitized catalogue of call types made from recordings provided by Deecke (2003) and from the reference catalogue published by Ford (1987). Residents were identified as Southern Resident or Northern Resident and clans and pods were identified when possible. Transients were identified as either BC Transient, CA Transient or, when an encounter could not be attributed with certainty to either group, Unidentified Transient (U Transient). Offshore encounters were confirmed by John Ford and James Pilkington. Encounters that could not be identified to the ecotype level were labeled Unknown. Unknown encounters were typically short in duration and contained short and faint calls that were not suitable for making ecotype identifications.

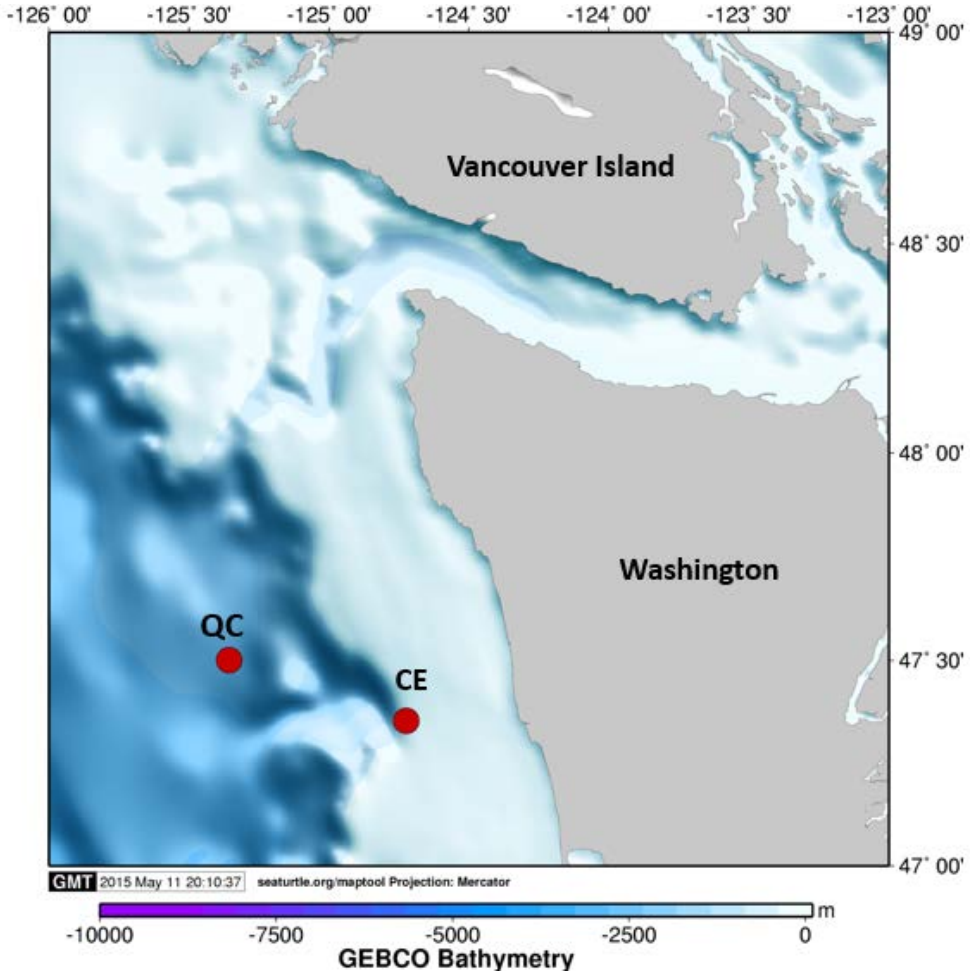

Figure 1. Locations of High-frequency Acoustic Recording Packages at sites QC and CE deployed in the NWTRC intermittently during January 2011 – April 2014. Color shows bathymetric depth.

Table 1. HARP deployment locations and time periods analyzed in this report.

Deployment	Latitude	Longitude	Depth (m)	Deployment Start	Deployment End
OCNMS12-QC	47° 30.00N	125° 21.20W	650	1/27/2011	10/7/2011
OCNMS13-CE	47° 21.12N	124° 43.26W	118	5/21/2011	11/6/2011
OCNMS14-CE	47° 21.14N	124° 43.28W	150	12/7/2011	1/17/2012
OCNMS14-QC	47° 30.03N	125° 21.21W	1394	12/7/2011	7/11/2012
OCNMS15-QC	47° 30.03N	125° 21.22W	1394	9/14/2012	6/30/2013
OCNMS16-CE	47° 21.17N	124° 42.47W	120	7/17/2013	8/04/2013
OCNMS16-QC	47° 30.04N	125° 21.26W	1384	7/17/2013	4/03/2014

Results:

Recording effort varied greatly between sites. Site QC had 1007 days of recording effort while site CE only had 228 days of effort. However, site CE had an overall higher average percent of days with killer whale acoustic presence, with July representing a peak in relative daily presence at 17.6% of days with killer whale acoustic encounters. Site QC showed overall lower relative presence, with peaks in March (8.9%) and December (9.2%). Overall there were 87 days with encounters: 45 days at site QC and 42 days at site CE. At site QC the number of days with recording effort increased each year from 2011-2013 but the number of days with encounters did not (23, 14, and 14 respectively).

Residents were encountered on 10 days: 3 days at site QC and 7 days at site CE. This accounted for an overall relative presence of 10.3% of the days with encounters (5.9% at QC and 14.9% at CE). Residents were encountered in March, May and June at site QC and in May, June and October at site CE. The October encounters occurred only in 2011 and included a detection of Northern Residents. All encounters at QC were Southern Residents while the one encounter of the Northern Residents was at CE. This encounter was identified as G clan. For some Southern Resident encounters it was possible to identify which pods were present. At site QC one of the encounters was attributed to J pod while at site CE 4 of the encounters were attributed to L pod and one encounter showed J, K and L pod presence.

Transients were encountered on 49 days: 16 days at QC and 33 days at CE. Relative presence for Transients was 50.5% of the days with encounters overall, 31.4% at QC and 70.2% at CE. More than half of the Transient encounters could be attributed to BC Transients, and there were more days with BC Transient encounters than CA Transient encounters at both sites. There were 6 days where BC Transients and CA Transients were detected within the same encounter. Transients were detected most months but mainly from March to June at site QC and from May to August at site CE. At site QC there were around 5 days with Transient encounters each year from 2011-2013 whereas at site CE, 28 of the 33 Transient encounters occurred in 2011.

Offshores were encountered on 17 days: 14 days at QC and 3 days at CE. Relative presence for Offshores was 17.5% of the days with encounters overall, 27.5% at QC and 6.4% at CE. Offshores were encountered during most months at site QC throughout all years of the study but only during August and September 2011 at site CE.

There were 22 days with encounters that could not be identified (Unknowns): 18 at QC and 4 at CE. The lack of identification was often due to encounters being short and only containing short, faint, and nondescript calls. There was presence of Unknown killer whales on 22.7% of days with encounters overall, 35.3% at QC and 8.5% at CE.

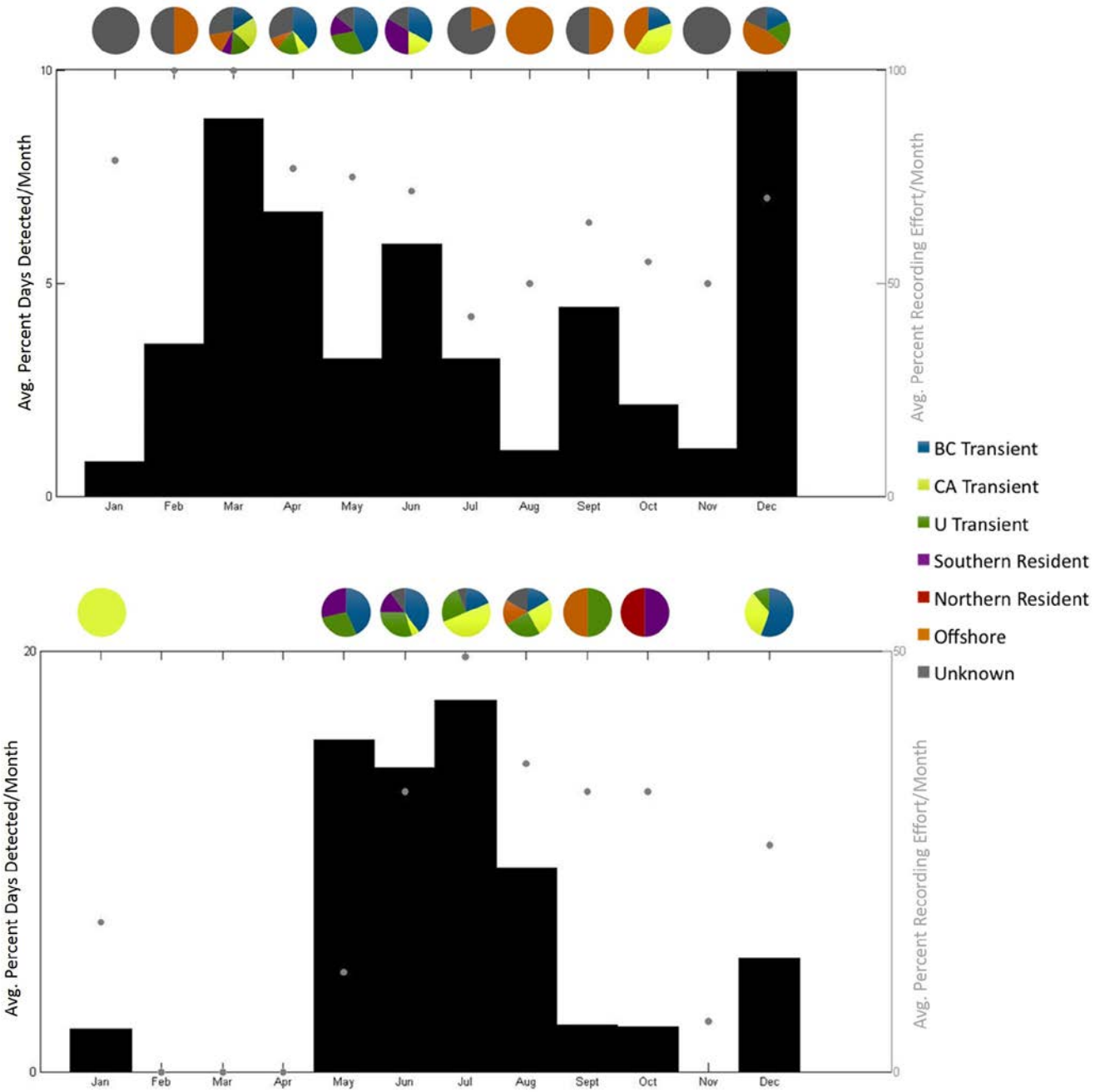

Figure 1. Presence of killer whale ecotypes at site QC from January 2011 – April 2014 (top) and at site CE from May 2011 – August 2013 (bottom). Bars represent the average percent of days with detections each month. Grey dots represent the average percent of recording effort each month. Pie charts show relative presence of each killer whale ecotype during each month.

Discussion:

Killer whales were present year round off the coast of Washington State. Transients were the most frequently encountered ecotype, followed by Offshores and then Residents. There was a higher relative daily presence of killer whales at site CE compared to site QC. However, when examining each ecotype individually, Transients and Residents showed higher relative presence at the on-shelf site, CE, while Offshores, as expected, had a higher relative presence at the shelf edge site, QC. Encounters that were labeled Unknown were also more common at site QC. It is thought that many of the Unknown encounters are Offshores but they could not be identified with certainty due to sample quality and limited knowledge of Offshore acoustics (compared to current knowledge of Resident and Transient acoustics).

Transients showed the highest relative presence of all ecotypes and they were encountered during most months. This lack of seasonality has been noted in previous PAM efforts in this region (Oleson et al. 2009; Širović et al. 2011; Riera 2012). Though not as frequently detected as Transients, Offshores also showed a lack of seasonality as has been reported previously (Oleson et al. 2009). The fact that Offshores were only encountered at site CE in 2011 is possibly due to limited effort during the following years. Southern Residents have been reported at site CE mainly from February to June (Oleson et al. 2009; Riera 2012) while in this study they are reported mainly in May and June at site CE. However, site CE had no effort from February to April during all years of the study.

It is therefore possible that Resident encounters were reported as lower in this report than previously due to lack of recording effort at site CE. Based on the previously reported data from 2008-2009 (Riera 2012; Širović et al. 2011) there appeared to be a seasonal pattern of Northern Residents being detected from July to September and Southern Residents from January to June, although Northern Residents were also heard in February. The current study, however, only found one Northern Resident encounter and it occurred in October 2011, a month when Southern Residents were also encountered, therefore showing no apparent seasonal separation of these two communities in this area. Riera (2012) reported K pod as the most commonly detected Southern Resident pod whereas L pod was the most common in the current study. This may be due to lack of effort at site CE, as Riera (2012) reported all K pod encounters occurred during February to April.

Site QC had recording effort almost continuously from January 2011 to April 2014. There was a slight increase in effort from 2011-2013 (277 days in 2011 to 348 days in 2013) and a decrease in the number of days with encounters, from 23 to 14 days. During 2014, there was effort until the beginning of April but there were no encounters during this period. During the same period in 2011-2013 there were 11, 3 and 10 encounters for each respective year. The lack of encounters during this period in 2014 may be due to the hydrophone malfunction that occurred during this deployment, which caused a reduced and variable detection range. By expanding the comparison to previous PAM efforts in this region it will be possible to see if, however, there is perhaps a downward trend in killer whale encounters at this location.

Seasonality of Prey:

A common explanation for a given species' presence in an area at a certain time is the presence and migration patterns of prey species. Resident killer whales have a very strong preference for salmon, specifically Chinook salmon (*Oncorhynchus tshawytscha*; Ford and Ellis 2006). Chinook salmon are known to return to the Columbia River in late August with smaller runs occurring in spring and summer (Groot & Margolis 1991). Peterson et al. (2010) found that salmon were most abundant off the coast of Washington and by the Columbia River during June and would shift inshore and southward by September, likely because of the stronger upwelling conditions in June that decrease by September. In the current study, Southern Residents were detected mainly in May and June at both sites, which coincides with the period of high upwelling and increased Chinook abundance in June. Transients, on the other hand, prey most commonly on pinnipeds, typically harbor seals (*Phoca vitulina*; Ford et al. 1998). Harbor seals typically remain close to shore (within 20km), are common off the coast of Washington and are not migratory (Zier & Gaydos 2014; Calambokidis 2004). Jefferson (1991) found that Transients preyed upon a large number of young, likely because they are more vulnerable and therefore are easier targets. Harbor seal pupping takes place at different times along the coast of British Columbia and Washington: June to August around the San Juan Islands, May to July for the northern coast of Washington and mid-April to July from around Grays Harbor south towards the Columbia River (Zier & Gaydos 2014). Transient presence at site CE was highest in June and July and it is possible that this is because they are taking advantage of the availability of harbor seal pups closer to shore. In general, however, the fact that Transients were detected in the area year-round, is likely a result of the constant presence of a prey source.

Yurk et al. (2010) found that in SE Alaska there was a seasonal segregation of Resident clans during periods of reduced prey availability, which is likely a reflection of intergroup prey competition. Since killer whale ecotypes in the Northeastern Pacific have distinct prey preferences, it is not expected ecotypes would show seasonal segregation for this reason, although different communities within each ecotype may segregate. However, we found no seasonal segregation between Northern and Southern Residents or BC and CA Transients.

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