2018-2022 southern resident killer whale presence in the Salish Sea (#82537)

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2018-2022 southern resident killer whale presence in the Salish Sea

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The fish-eating Southern Resident killer whales (*Orcinus orca*) of the northeastern Pacific are listed as endangered in both the USA and Canada. The inland waters of Washington State and British Columbia, a region known as the Salish Sea, are designated as Southern Resident critical habitat by both countries. The whales have historically had regular monthly presence in the Salish Sea, with peak abundance occurring from May through September. In recent years, at least partially in response to shifting prey abundance, habitat usage by the Southern Residents has changed. As conservation measures aim to provide the best possible protection for the whales in their hopeful recovery, it is key that policies are based both on historic trends and current data. To this aim, our study shares 2018-2022 daily occurrence data to build upon and compare to previously published whale presence numbers from 1976-2014 and to demonstrate more recent habitat shifts. Based on reports from an extensive network of community scientists as well as online streaming hydrophones, every occurrence was confirmed either visually or acoustically. We document the first ever total absence of the Southern Residents in the Salish Sea in the months of May, June, and August, as well as their continued overall declining presence in the spring and summer, while fall and winter presence remains relatively high.

2018-2022 Southern Resident Killer Whale Presence in the Salish Sea

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Abstract

The fish-eating Southern Resident killer whales (*Orcinus orca*) of the northeastern Pacific are listed as endangered in both the USA and Canada. The inland waters of Washington State and British Columbia, a region known as the Salish Sea, are designated as Southern Resident critical habitat by both countries. The whales have historically had regular monthly presence in the Salish Sea, with peak abundance occurring from May through September. In recent years, at least partially in response to shifting prey abundance, habitat usage by the Southern Residents has changed. As conservation measures aim to provide the best possible protection for the whales in their hopeful recovery, it is key that policies are based both on historic trends and current data. To this aim, our study shares 2018-2022 daily occurrence data to build upon and compare to previously published whale presence numbers from 1976-2014 and to demonstrate more recent habitat shifts. Based on reports from an extensive network of community scientists as well as online streaming hydrophones, every occurrence was confirmed either visually or acoustically. We document the first ever total absence of the Southern Residents in the Salish Sea in the months of May, June, and August, as well as their continued overall declining presence in the spring and summer, while fall and winter presence remains relatively high.

Introduction

The salmonid-eating Southern Resident killer whales (*Orcinus orca*) of the northeast Pacific are considered one of the most well-known wild cetacean populations in the world. They have been the focus of ongoing population monitoring since the early 1970s, with their small population size and coastal habits making them amenable to close observation impossible with many other marine species. Made up of J-, K-, and L-Pods and totaling 73 individuals as of the end of 2022 (Center for Whale Research, unpublished data), each individual's personal and familial life history is known in detail (Bigg et al. 1987, Ford et al. 1994).

After an approximately 20% population decline in the late 1990s and early 2000s, the Southern Resident killer whales (SRKW) were listed as endangered in both Canada in 2001 (Fisheries and Oceans Canada 2018) and the USA in 2005 (National Marine Fisheries Service 2008), with identified risk factors inhibiting their recovery including reduced prey availability, toxic contamination, and vessel effects. Their endangered status has prompted a wide array of additional studies focused on topics such as their diet (e.g. Hanson et al. 2010, Hanson et al. 2021), hormone levels (Ayres et al. 2012), body condition (Stewart et al. 2021), and responses to vessel disturbance (Houghton et al. 2015, Holt et al. 2021). One area that has received comparably less attention is their shifting habitat usage in contrast to before their endangered listing.

Following an endangered listing in either Canada or the US, a critical habitat for the listed species is designated. Critical habitat is defined as the geographic area occupied by the species that contains the physical and/or biological features essential to the conservation of that species. The initial critical habitat designation in the United States occurred in 2008 and was

defined as the inland waters of Washington State, a region just over 2500 square miles, split into three areas: 1) the US waters around the San Juan Islands including Haro Strait (a region defined as the "Core Summer Area"), 2) all of Puget Sound, and 3) the US waters of the Strait of Juan de Fuca (National Marine Fisheries Service 2008). In 2021, the designated critical habitat was revised to include an additional 15,910 square miles along the outer coastal regions of Washington, Oregon, and California (National Marine Fisheries Service 2021).

The initial critical habitat designation in Canada, which also occurred in 2008, was identified as the transboundary waters of southern British Columbia, including the southern Strait of Georgia, Haro Strait, and the Strait of Juan de Fuca. This region was recognized as being of specific importance as a foraging area to all three pods from June through October. In 2018, the Canadian critical habitat expanded to include waters on the continental shelf off southwestern Vancouver Island (Fisheries and Oceans Canada 2018).

The transboundary inland waters of Washington and British Columbia are known as the Salish Sea, and the designation of these waters as critical habitat reflected the historic summer usage of this area by SRKW (Ford et al. 2000). Commonly referred to as the SRKW core summer habitat, all three pods regularly utilized the central Salish Sea from May through September, shifting further south to visit Puget Sound in the fall. K- and L-Pods would spend most of their time on the outer coast in the late fall through early spring, while J-Pod remained in the Salish Sea for much of the year. Nearly 40 years of tracking from 1976-2014 reported that SRKW presence was confirmed in the Salish Sea an average of 193 days per year (Olson et al. 2018). A study spanning 1996-2001 found the SRKW were present in the central Salish Sea an average of 79.3% of the days in May through September (Hauser et al 2007).

Diet studies have demonstrated that the seasonal movements of SRKW correspond to prey abundance (Ford and Ellis 2006). While Chinook salmon make up the majority of the year-round diet of the Southern Residents, there is some seasonal variation, with other salmonid species making up a greater proportion of the diet outside the summer season. The specific Chinook stocks the whales rely on also vary throughout the year. Fraser River Chinook salmon have traditionally dominated the summer diet (Hanson et al. 2010), explaining their extended presence in the central Salish during the months of May through September. In the fall, there is a shift to a much greater proportion of chum salmon in the SRKW diet (Hanson et al. 2021), particularly while whales are in inland waters and corresponding to their visits to Puget Sound. With Chinook and chum salmon stocks varying widely in their numbers from year to year (Losee et al. 2019) and Chinook declining coast-wide overall (Dorner et al. 2017), the SRKW have to adapt to changing prey availability, and may have corresponding shifts in habitat usage as a result.

A few changes in habitat usage over the last few decades have been noted in the literature. Beginning in 1999, Ks and Ls became more frequent fall visitors to Puget Sound (Olson et al. 2018), and beginning in 2005 all three pods' presence in the Salish Sea declined during the spring months of April through June in correlation to declining returns of spring-run Chinook to the Fraser River (Shields et al. 2018).

The aim of this study is to provide an update on the seasonal and annual usage of the Salish Sea by each of the Southern Resident pods and the SRKW population as a whole by assessing confirmed presence over the five year period from 2018-2022.

Materials & Methods

From January 1, 2018 to December 31, 2022, orca sighting reports throughout the Salish Sea were tracked daily from a variety of sources. These sources included research encounters by the Orca Behavior Institute; reports from the Pacific Whale Watch Association shared via their private social media sightings page and proprietary sightings app; public reports shared via Orca Network; encounter summaries from the Center for Whale Research; public sightings reported via social media, often through regional community sightings pages; the Salish Sea Orcasound hydrophone network; and community member reports submitted directly to the Orca Behavior Institute. All Southern Resident killer whale reports were verified visually and/or acoustically by the author, utilizing photos, videos, and/or audio from the observers and referencing established Southern Resident killer whale photo ID catalogues from the Center for Whale Research and acoustic call catalogues (Ford 1987).

Initial and final sighting locations were noted for each day along with travel routes, and geographic region within the Salish Sea was also noted. For the purpose of this study, the Salish Sea was defined as all the inland waters east of Otter Point, BC including Puget Sound and the Strait of Georgia. Geographic regions were defined as: Northern Salish Sea (NSS), north of a line connecting Nanaimo and Vancouver, BC; Puget Sound (PS), south of the Port Townsend-Coupeville ferry lanes and east of the Deception Pass Bridge; and Central Salish Sea (CSS) for all the waters in between (Figure 1). Seasonal presence was noted as winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep), and fall (Oct-Dec).

In addition to confirming the Southern Resident ecotype (as opposed to the sympatric population of Bigg's killer whales), pod(s) present (J, K, or L) were also confirmed based on the media provided. While it was impossible to identify all individuals present through this method, the presence of a single individual from a given pod was deemed sufficient to confirm presence of members of that pod on a given day. The only exception was L87, an L-Pod adult male who routinely traveled with J-Pod from prior to 2018 until early 2020. Since L87 has been documented traveling long-term with each of the three pods, his presence was not considered sufficient to identify the presence of a specific pod.

Any data set making use of a variety of sightings sources is subject to observer bias that cannot be tested or controlled for. In this data set, observer effort was greater east of Sooke and south of Nanaimo. Western Strait of Juan de Fuca reports were sporadic enough that for this report the waters east of Otter Point, BC were excluded; the whales are also likely under-reported in the north-central Strait of Georgia. Observer effort was also higher during spring, summer, and fall months when daylight hours and weather conditions allow for more hours of optimal

whale viewing or searching. The increasingly popularity of social media platforms to track and share whale reports has also led to more observer effort over time.

To account for multiple reports of the same whales on the same day and following previously established methodology (Olson et al. 2018), the metric of "whale day" was used. A whale day is defined as a day of confirmed presence of SRKW (and, similarly, of a specific pod), regardless of the number of reports received on the given day. Despite these acknowledged biases, the cumulative tracking of SRKW in inland waters across these various sightings sources is considered robust, with the whales' presence unlikely to be missed throughout most of the region during most of the year (Olson et al. 2018, Hauser 2006).

In an additional effort to check for under-reporting of SRKW, for 2022 only "speculated whale days" were also tracked. A speculated whale day was defined as a day where, given SRKW average travel speeds and known travel routes, they were in all probability likely to be present in the Salish Sea even though they were not reported. For example, on the morning of January 9, 2022, J-Pod was reported in Swanson Channel near Pender Island, BC. This is approximately 100 miles from the entrance to the Salish Sea, so while there were no reports of them on January 8, January 8 was tallied as a speculated whale day since J-Pod must have been entering the Salish Sea via the Strait of Juan de Fuca on that day. Another example of a speculated whale day is January 21. J-Pod was reporting going north in Haro Strait off San Juan Island, WA on January 20 and coming south down Boundary Pass near Saturna Island, BC on January 22. While there were no reports of them on January 21, January 21 was counted as a speculated whale day as J-Pod was presumably undetected in the Strait of Georgia.

2018-2022 trends of SRKW presence were compared to historic records published in Olson et el. 2018.

Results

After removing duplicate reports of the same group of whales on the same day, there were 732 unique SRKW sightings over the five-year study period, representing 647 whale days and confirmed SRKW presence in the Salish Sea for 35.5% of the five year study period. Note that some days there were multiple groups of SRKW present in different locations (defined as >20 miles apart), which is why the number of sightings is greater than the number of whale days. Presence ranged from a low of 103 days in 2021 to a high of 167 days in 2022, with an average of 129.4 days across the five years. J-Pod was present 592 days, K-Pod 190 days, and L-Pod 170 days. As in historic trends, J-Pod was present nearly every month of the year, while K- and L-Pods were generally absent from late winter through early summer (Table 1).

Combining sightings from all pods (n = 732), the most sightings occurred in the fall (260, 35.5%) and the summer (258, 35.2%) followed by the winter (131, 17.9%) and the spring (83, 11.3%) (Figure 2). Looking at seasonal presence by region, the greatest number of sightings occurred in the Central Salish Sea for the winter (77.1% of total winter sightings), spring (86.8%), and summer (90.3%), while in the fall most sightings were in Puget Sound (51.2% of fall sightings). No Puget Sound sightings were recorded in the months of February or March or

in May through August. The Northern Salish Sea sightings ranged from 3.6% to 12.2% of seasonal totals, with higher percentages of sightings occurring in winter and spring. No Northern Salish Sea sightings were documented in the months of May, June, or August. Figure 3 shows a Salish Sea map of all 2018-2022 SRKW sightings by season.

Looking at the 151 days in the May through September time period (what was formerly considered the core summer season), SRKW presence varied from 29 days in 2021 to 71 days in 2018, with an average seasonal presence of 32.6% of the days.

Two-tailed t-tests were utilized to compare number of SRKW days present each month for 2018-2022 to an identical time span from 20 years prior, 1998-2002, per data in Olson et al. 2018 (Figure 4). Compared to 1998-2002, in the 2018-2022 time period SRKW were present significantly less in the months of April ($t(8) = 2.31$, $p = 0.0497$), May ($t(8) = 10.57$, $p < 0.001$), June ($t(8) = 9.13$, $p < 0.001$), July ($t(8) = 3.53$, $p = 0.008$), and August ($t(8) = 3.18$, $p = 0.013$) and SRKW were present significantly more in November ($t(8) = -3.30$, $p = 0.011$).

In 2022 there were 167 days with confirmed SRKW presence in the Salish Sea, and an additional 63 of days of speculated SRKW presence. Speculated days primarily occurred in Jan-Mar and Oct-Dec, representing both the overall more robust whale tracking that occurs from Apr-Sept and the increased usage of the northern Salish Sea (with lower regional observer effort) in the winter months. Figure 5 shows 2022 confirmed and speculated days by month compared to presence 20 years prior in 2002.

Discussion

These results show a continued decline in annual average SRKW presence (129.4 days or 35.3% of the year) and a new record low for annual days present (103 days). Previously published data from 1976-2014 reported an annual average SRKW presence of 193.1 days (or 52.9% of the year) across the 39 year time period with a low of 139 whale days in 1977 (Olson et al. 2018).

Olson et al. 2018 also reported what they noted as “anomalies” in their data set, with no SRKW reports in April of 2009 or 2013, the only months on record with no SRKW presence in the Salish Sea from 1976-2014. We have documented the continuation of that trend now expanding to additional months, with no SRKW presence in May of 2018, 2020, or 2021, June of 2019 or 2021, or August of 2020, indicating that the total lack of SRKW is becoming less anomalous and more of a regular occurrence.

Data from 1976-2014 showed that 71.7% of Central Salish Sea days occurred between May and September, the months formerly considered the core summer season for SRKW in the Salish Sea (Olson et al. 2018). Similarly, Hauser et al. 2007 reported SRKW presence an average of 79.3% of the time between May and September from 1996-2001. In this data set, looking at 2018-2022, only 49.2% of CSS whale days occured during the months of May-September, with the SRKW present an average of just 32.6% of the days during these months in this study. From 2018-2022, the most CSS days occurred in the months of September (94, 20.66%), July (60, 13.2%), November (48, 10.6%), and March (45, 9.9%). This indicates that the previously

reported declining spring presence of SRKW (Shields et al. 2018) is continuing, and indeed appears to be expanding into the months of July and August, with only September SRKW presence remaining similar to historic numbers. The lack of SRKWs in the Salish Sea during what used to be the core summer months is becoming less anomalous and now more expected in the modern era.

A recent assessment of April-October Chinook salmon availability for the SRKW in the Salish Sea and off the west coast of Vancouver Island over the last 40 years found that overall salmon abundance available to the whales has declined, with the models predicting an energetic deficit for the whales in six years across the study period, including 2018, 2019, and 2020, the final year for which analysis occurred (Couture et al. 2022). The relative contribution of different Chinook salmon stocks and their availability to SRKW has been changing, with Columbia River stocks specifically increasing in their importance to SRKWs compared to Puget Sound stocks. This may help explain the continued decline in presence of SRKW in what was historically their core summer habitat in the Salish Sea.

Olson et al. 2018 had noted that after the 1999-2000 winter, Ks and Ls have increased the number of months they are detected in the Salish Sea by staying in the Salish Sea later into the fall and early winter, a trend that has also continued in the current data. Ks and/or Ls were not present in any January or February from 1978-1999, while they were present for 62.5% of the Januarys and Februarys from 2000-2014 and 2018-2022. Just as the declining spring and summer presence of SRKW correlations to reduced returns of Fraser River Chinook, this increased SRKW presence in Puget Sound in the fall months corresponds to an increased abundance of both wild and hatchery-raised fall and winter chum salmon in Puget Sound over the 1970-2015 time period (Losee et al. 2019).

Looking at Figure 5, the seasonal trend of SRKW presence has essentially reversed from 20 years ago. They used to be present the most from May to September, and this is now when they are here the least. Not only has summer presence declined, but winter presence has increased from October to February. Only the transition months of April and September remain similar to historic numbers. The historic context of SRKW habitat usage is important to keep in mind, especially when identifying critical habitat and aiming for population recovery, but given these new data, it is equally important to consider how the SRKW are currently utilizing their habitat, especially when implementing interim management measures to aid in their recovery.

While considering speculated SRKW days present in 2022 raises the annual total SRKW days present from 167 to 230, which is above the historic average annual presence of 193 days per year, we believe the current data still represents an overall decrease in SRKW presence in the Salish Sea rather than a decrease of confirmed SRKW detections. Figure 5 illustrates that confirmed and speculated days in 2022 are nearly the same during the months of April-September when sightings effort is highest. Most of the speculated days occur in October-March and are primarily due to J-Pod being undetected in the northern Strait of Georgia or inbound/outbound in the Strait of Juan de Fuca. Undetected days of SRKW presence undoubtedly occurred in the historic data set as well, likely also more so in the winter months

due to the same decrease in sightings effort and the habit of the whales to spend more time in less inhabited areas during that time of year. The fact that confirmed and speculated sightings are near-identical during the summer months combined with the fact that confirmed winter sightings are higher overall in 2022 compared to 2002 gives confidence that the rate of confirmed SRKW detections remains the same, and thus that reported declines in abundance are an accurate representation of overall trends. Speculated days are included here to give a sense of how important the Salish Sea has become during what used to be considered the "off-season" months of October to March.

Conclusions

This study demonstrates that SRKW seasonal and annual habitat usage is continuing to shift from historic trends. SRKW presence has declined considerably during most of what used to be the core summer season of May through September, and has increased during the late fall and winter months. These changes correspond to identified shifts in prey availability, with the continued decline of spring and summer Fraser River Chinook, the increasing importance of Columbia River Chinook in the diet of the SRKW (which would take them outside the Salish Sea), and the overall increased abundance of fall and winter chum in Puget Sound. When managing critical habitat and implementing other area-based policy measures to aid in the recovery of the endangered SRKW, it is important to consider both the historic and current habitat usage, which reflect differences in prey availability. Historic trends must be taken into consideration for long-term habitat protections, while current presence/absence is key to consider for short-term/immediate protection measures such as vessel exclusion zones or area-based fisheries closures. With changes in habitat usage occurring both year to year and from decade to decade, it is reasonable to expect that SRKW presence in the Salish Sea will continue to vary as prey stocks recover or decline and important to continue such annual monitoring to document these changing patterns. For now, the SRKW have greatly reduced their Salish Sea presence in the spring and summer, with fall and winter now being the seasons they are more likely to occur.

Acknowledgements

Long-term monitoring studies of highly mobile species such as the SRKW over large geographic areas such as the Salish Sea are only possible with significant community effort. The Pacific Whale Watch Association and Orca Network were key partners in this effort. We thank the hundreds of individual whale spotters that contributed reports, photographs, videos, and audio clips that contributed to the ability to complete this study. Extra gratitude is given to the following individuals for their long-term support of this project, help in tracking down media to confirm reports, and/or identification assistance: Alisa Lemire Brooks, Erin Gless, Rachelle Hayden, Johannes Kreiger, and Sara Hysong-Shimazu.

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Table 1(on next page)

Monthly presence of SRKW in the Salish Sea from 2018-2022

The letters in each cell refer to the pod(s) who were present at least once that month and the number indicates the number of confirmed days of SRKW presence of any pod. Lighter blue cells indicate a single pod's presence while darker cells indicate the presence of two or three pods. The far right column indicates the total number of days present for each year, while the bottom row indicates the average number of days present in a given month across all five years.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2018	JK 4	J 1	JK 7	J 5	NONE	JKL 12	JKL 20	JL 10	JKL 29	JK 7	JK 18	JKL 13	126
2019	JKL 11	JL 4	J 8	J 11	J 4	NONE	JK 2	JKL 17	JKL 20	JL 17	JKL 21	JKL 10	125
2020	JKL 8	JK 6	JL 12	J 6	NONE	L 2	JKL 21	NONE	JKL 22	J 13	JKL 22	JK 14	126
2021	JKL 4	JKL 6	J 13	J 7	NONE	NONE	JKL 5	JL 4	JKL 20	JKL 12	JKL 21	JKL 11	103
2022	JL 10	J 11	J 15	J 11	J 8	JL 11	JKL 14	JKL 9	JKL 15	J 20	JKL 21	JKL 22	167
Average	7.4	5.6	11	8	2.4	5	12.4	8	21.2	13.8	20.6	14	

1

Figure 1

Map of the Salish Sea study area

Salish Sea SRKW sightings were tracked for all the waters east of Otter Point, British Columbia. The region was further divided into the Northern Salish Sea (NSS, north of Vancouver and Nanaimo), Puget Sound (PS, Admiralty inlet and south and east of Deception Pass), and the Central Salish Sea (CSS, all the waters around the San Juan Islands, WA extending to the previously mentioned borders).


British Columbia
Northern Salish Sea
Vancouver Island, BC
Central Salish Sea
Study Area Border
Puget Sound
Washington State

Figure 2

Salish Sea sightings of SRKW from 2018-2022 by season and sub-region

A) Proportion of all sightings from 2018-2022 broken out by season, with winter (blue) representing Jan-Mar, spring (green) Apr-Jun, summer (yellow) Jul-Sep, and fall (purple) Oct-Dec. Subsequent pie charts show sub-region breakdown of SRKW sightings by season for B) Winter, C) Spring, D) Summer, and E) Fall, with CSS = Central Salish Sea, PS = Puget Sound, and NSS = Northern Salish Sea. Refer to Figure 1 for a map of the geographic sub-regions.

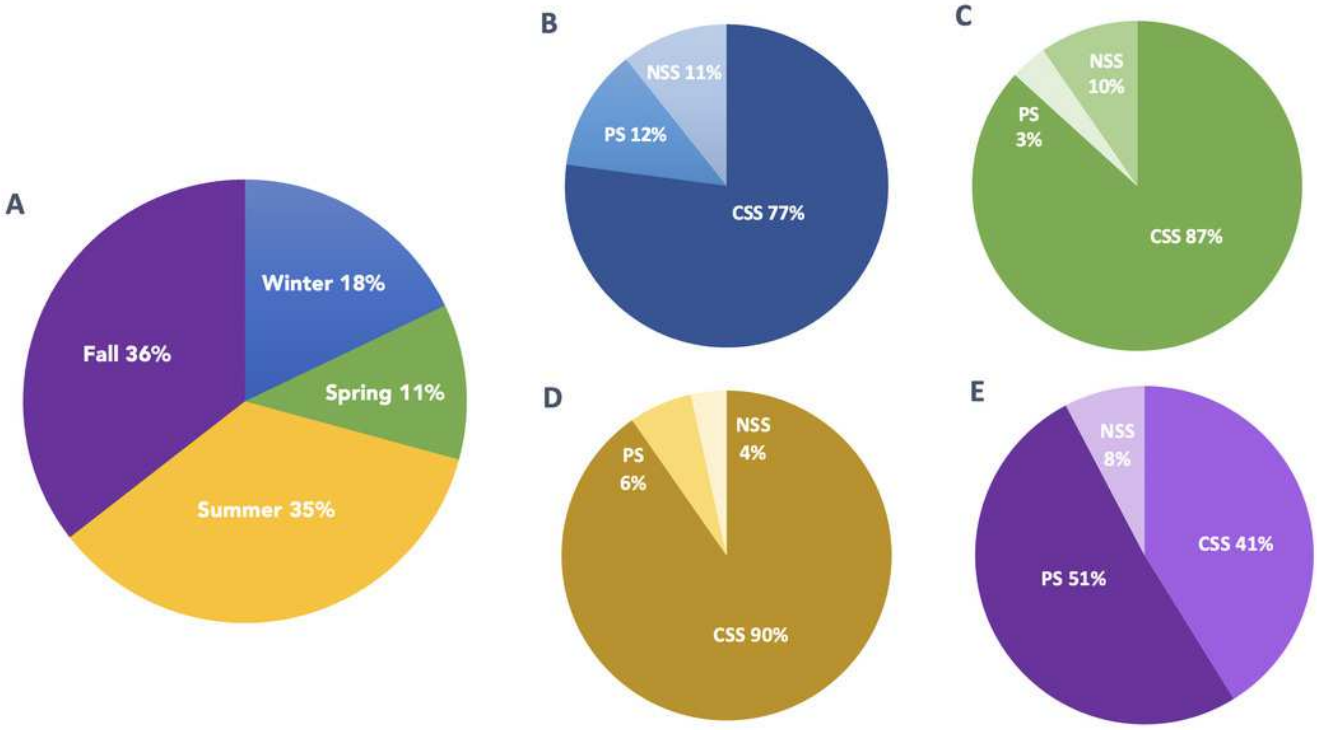
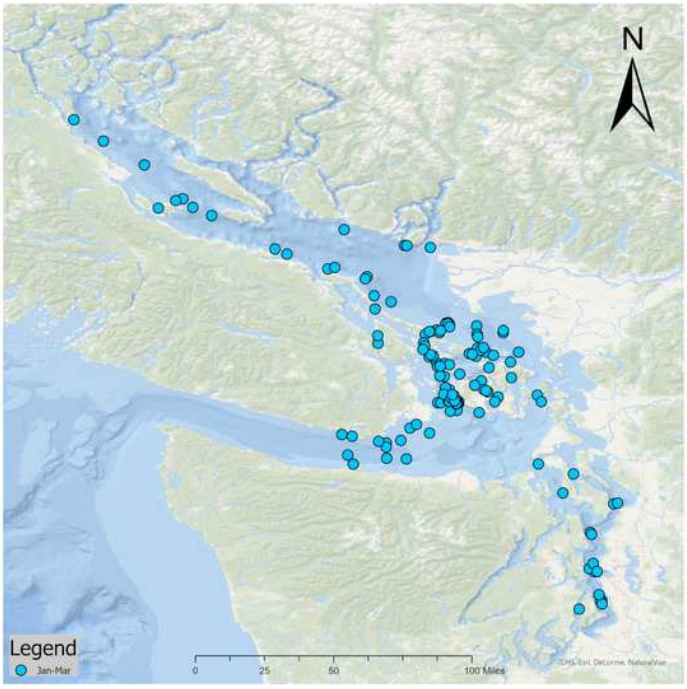
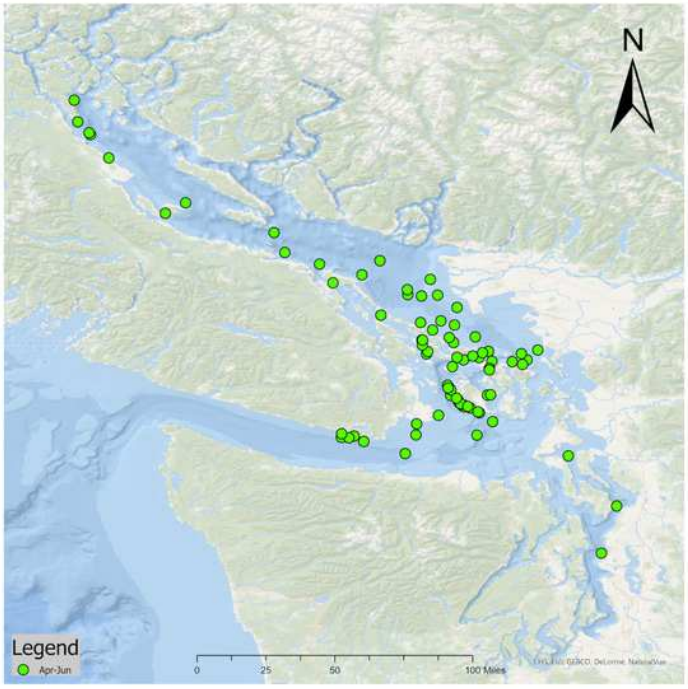


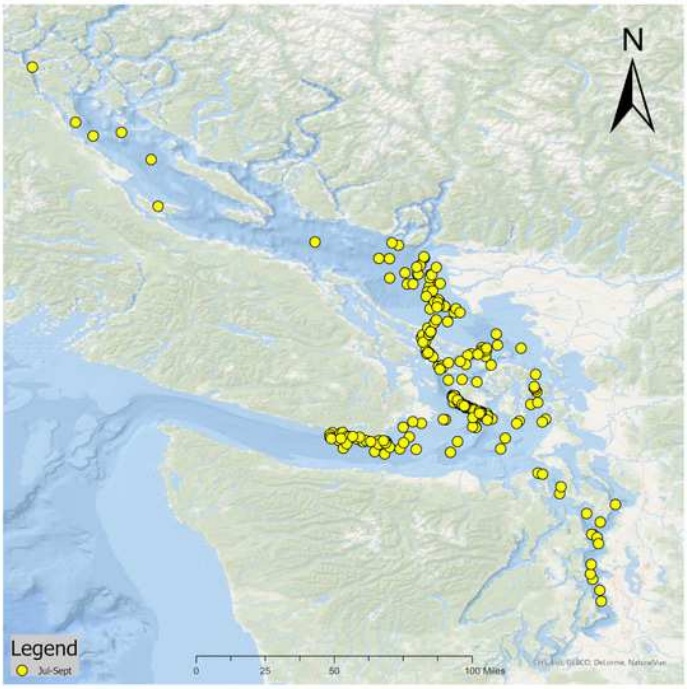
Figure 3

Confirmed seasonal SRKW sightings in the Salish from 2018-2022

Each map shows the initial location of an SRKW sighting, defined as a unique group seen on a unique day. Blue dots indicate winter sightings (Jan-Mar), green spring (Apr-Jun), yellow summer (Jul-Sep), and purple fall (Oct-Dec). Sightings were tracked in all the Salish Sea waters east of Otter Point near Sooke, BC in the Strait of Juan de Fuca on a daily basis from January 1, 2018 to December 31, 2022.


N
Legend
Jan-Mar
0
25
50
100 Miles


N
Legend
Apr-Jun
0
25
50
100 Miles


N
Legend
Jul-Sept
0
25
50
100 Miles

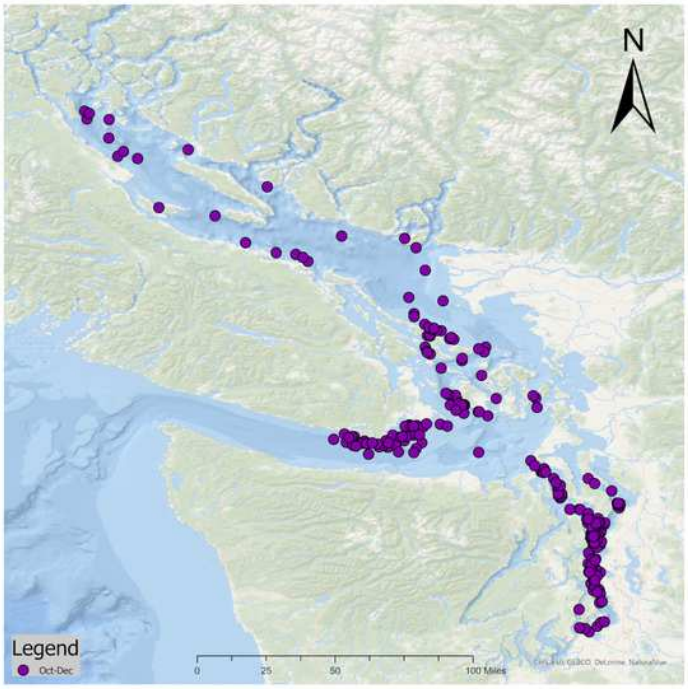

N
Legend
Oct-Dec
0
25
50
100 Miles

Figure 4

Average monthly SRKW presence by month for two 5-year time periods 20 years apart

Average number of days Southern Residents were present in the Salish Sea each month for two time periods 20 years apart. 1998-2002 data, in yellow, is from Olson et al. 2018 Figures S3 and S4. 2018-2022 data, in blue, is from the Orca Behavior Institute. Bars show standard error. Asterisks indicate statistically significant results from two-tailed t-tests, with * indicating p <0.05, ** indicating p <0.01, and **** indicating p <0.0001.

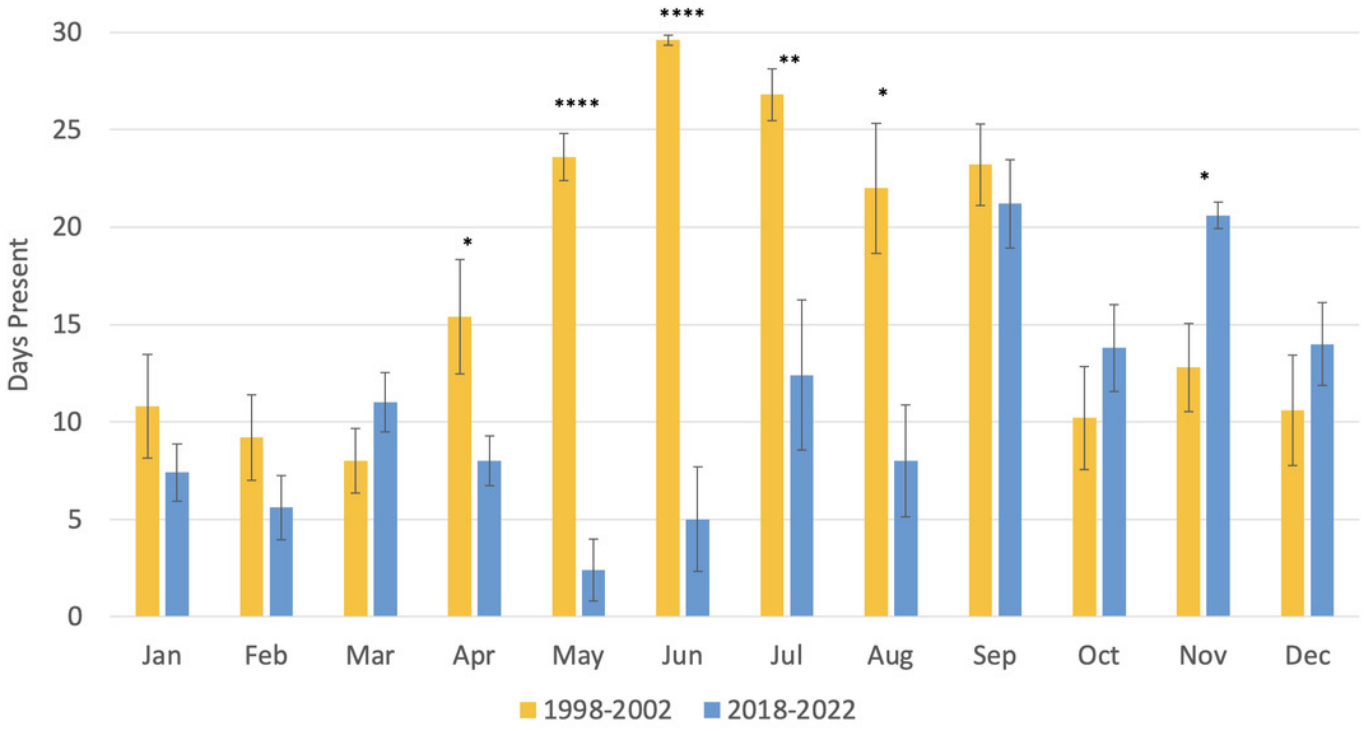


Figure 5

Monthly confirmed and speculated SRKW presence in 2022 compared to the five-year average from 20 years ago

The dark blue line indicates how many days each month SRKWs were confirmed to be present in the Salish Sea in 2022. The light blue line adds speculated SRKW days for 2022, defined as days where SRKW presence was presumed due to typical travel routes and speeds regardless of visual or acoustic confirmation. The yellow line indicates average monthly presence from 2002 per Figures S3 and S4 in Olson et al. 2018.