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Science Response 2023/031

POPULATION STATUS UPDATE FOR THE NORTHERN RESIDENT KILLER WHALE (*ORCINUS ORCA*) IN 2022

Context

Northern Resident Killer Whales (NRKW) are currently designated as 'Threatened' in Canada under the *Species at Risk Act*, due to their small population size, low reproductive rate, and the existence of several anthropogenic threats that are likely to impede their on-going population recovery or cause future population declines (Fisheries and Oceans Canada 2018). Population censusing by photo-identification is a key research activity outlined in the *Species at Risk Act* Action Plan for Resident Killer Whales (Fisheries and Oceans Canada 2017) and has been conducted on the NRKW population each year since 1973, making it one of the longest-running, continuous time series of data for a cetacean population.

This report presents updated population information for NRKW in 2022 and supplements existing publications, including the NRKW photo-identification catalogue (Towers et al. 2020) and the NRKW photo-identification mobile app (Alert Bay Cetological Society 2022). Please cite this document according to the citation provided at the end of this report. The demographic data presented here are not intended to be analyzed for further studies without permission of DFO's Cetacean Research Program. Please contact the corresponding author (Thomas Doniol-Valcroze) for data use requests relating to this report.

This Science Response Report results from the Regional Peer Review of May 15, 2023 on the Report on the 2022 Northern Resident Killer Whale annual census.

Background

The Northern Resident Killer Whale population ranges throughout the coastal waters of British Columbia, Canada and the western United States, from southern Washington State to southeastern Alaska (Ford et al. 2000). The population consists of three acoustical clans (called A, G and R clan), each with a distinct set of dialects (Ford 1991). Photographs of natural markings on the dorsal fins and saddle patches of whales are used as unique identifiers (Bigg 1982) that allow individuals to be recognized each time they are encountered, which makes it possible to track changes in their life history statuses (e.g., events such as birth, sexual maturation, reproduction, and death) with a high degree of accuracy. Each year, extensive field effort is undertaken to find and photograph as many individuals from this population as possible and note their reproductive status and health condition.

Analysis and Response

The methodologies for estimating population parameters that are presented in this report are a brief description of methods that have been previously published in more detail. For more information, see Bigg et al. (1990), Olesiuk et al. (2005), Stredulinsky (2016), Towers et al. (2015) and Towers et al. (2020). Methods for collecting and analyzing census data are not discussed but are provided in Bigg et al. (1986), Ellis et al. (2011) and Towers et al. (2012).

Spatial and temporal range of the census

Historically, NRKW census efforts tended to be geographically restricted to the waters off northeastern Vancouver Island and temporally restricted to the summer months (July-August). In more recent years, however, the geographic range of the census effort has expanded to include all coastal waters of BC and the temporal range of photo-identification data has broadened as well. To keep census data comparable across the entire time series of the study, the ‘census window’ is defined as July 1st - August 31st (Olesiuk et al. 2005). The status of an animal is assessed and documented during that window. For example, if a calf was born in October 1976, its existence would not have been known to researchers until the 1977 census field work began, and thus it could have been born anytime from September 1976 to July 1977; therefore the calf would simply be designated as a 1977 birth. If the same situation were to occur in a more recent year, when the birthdate of an early autumn calf is often precisely known, to remain consistent with the study’s historical data, the calf would be assigned to the following birth year. In some cases, an animal is only encountered outside of the census window during a given year; in these instances, its status information tends to be assigned to the census window immediately following the encounter. For example, an animal seen in June but missing from its matriline in October of the same year would be considered “alive” during that year’s census window, but “missing” for the following year’s census.

Determining ages

For animals born since this study began, young-of-the-year were assigned a year of birth (YOB) equivalent to the census year in which they were first discovered. For newly discovered animals whose body size when first seen suggested that they were born in a previous census year (i.e., they were not young-of-the-year when first seen), YOB was defined as the year of discovery minus the estimated age when first seen (based on expert knowledge of size-at-age). If there was uncertainty in the animal’s age when first seen, an animal’s ‘best’ estimated YOB was calculated using the median of the possible age range, rounded up to the nearest whole year. In many cases, this uncertainty is limited to plus or minus half a year, and thus rounding up results in the best YOB often being equivalent to the maximum YOB.

For animals born prior to the study whose ages when first seen could not be confidently estimated, YOB required estimation based on life history parameters of known-age animals. The initial age estimates for these animals were calculated by Bigg et al. (1990). Over time, more animals have been tracked since birth, which has allowed NRKW life history parameters (and thus ages of animals born prior to the beginning of the study) to be periodically refined. Re-assessments of life history parameters and ages were conducted by Olesiuk et al. (2005) and are currently being undertaken again.

Determining sexes

Animals in this study were sexed through various means:

- Opportunistic observations: Animals may be sexed through visual observation of their undersides. The black and white pigmentation of the posterior-ventral area, as well as the genital slits, are different for males and females.
- Physical manifestation of sexual maturity (see Bigg et al. (1990) for details): for females, this is indicated by the birth of their first calf, and for males, by the onset of accelerated dorsal fin growth or ‘sprouting’.

- Genetic analysis of tissue samples: DNA analysis allows sexing of animals whose tissue was collected via biopsy sampling or post-mortem tissue sampling.
- If an animal of unknown sex reaches 15 y of age without sprouting[1] or producing a calf, it is assumed to be female. If it is later confirmed to be male through any of the means noted above, its sex and sex-specific census statuses are corrected retroactively.

Defining demographic classes

- Calves are animals that are 0 or 1 y old in the given year (animals are considered 0 y old in the year of their birth).
- Female juveniles are animals sexed as female that are 2-11 y old and have not yet given birth.
- Male juveniles are animals sexed as male, older than 1 y old, that have not yet shown physical signs of sexual maturation (i.e., ‘sprouting’; see *Determining sexes*).
- Juveniles of unknown sex are animals between 2-11 y old that have not yet been sexed.
- Adults of unknown sex are animals between 12-14 y of age that have not yet been sexed. Retrospectively, these animals are sexed (through means described in *Determining sexes*); because of this, animals of unknown sex only tend to appear in the population demographics for the most recent years of the study.
- Reproductive-age females are animals known to have given birth in the past or that are assumed female (see *Determining sexes*) and are no older than 42 y, as well as females more than 42 y old that gave birth in the current census year[2].
- Post-reproductive females are females older than 42 y of age who have not given birth in the current year, as well as all females 48 y or older[3].
- Sexually mature males are those who have shown signs of accelerated dorsal fin growth (sprouting), where the growth is not yet asymptotic/complete (Bigg et al. (1990), see *Determining sexes* above).
- Physically mature males are those with fully developed dorsal fins, i.e., fins displaying asymptotic growth; the onset of physical maturity typically occurs at about 18.4 y (Bigg et al. 1990; Olesiuk et al. 2005).

Declaring animals dead

NRKW matrilines most commonly travel as a cohesive group; therefore when a group is encountered, any missing individuals can be presumed dead. As some matrilines are encountered infrequently, or in cases where logistical, behavioural, and environmental constraints prevent a thorough censusing of all animals present, we are cautious in declaring an animal dead until we have had a sufficient number of high-quality encounters with its group to be certain that the animal is indeed dead (until this point, absent animals are considered “missing”). Note that a sufficient number of high-quality encounters to establish an animal’s death may take multiple census

[1]Based on 95% probability of sprouting (Stredulinsky, unpubl. analysis). All males in this population have sprouted by 18 y of age.

[2]Based on 95% probability of reproductive senescence (42 y) (Stredulinsky 2016).

[3]No female older than 48 y has given birth to a calf in this population.

years to reach, as some NRKW groups are infrequently encountered. Year of death (YOD) for such animals was assigned a minimum-maximum range, where the minimum YOD was the first census year in which the animal was noted to be missing (and therefore possibly dead) and the maximum YOD was the census year wherein the animal was confidently designated as dead. An animal's 'best' estimated YOD was considered to be the median of this range, rounded down to the nearest whole year. Since animals are frequently confirmed dead in the census year directly following the year in which they were first noted as missing, the best YOD is therefore often equivalent to the minimum YOD.

Estimating population size

'Best' population size estimates were calculated using the animals' best YOB and YOD estimates (see *Determining ages* and *Declaring animals dead* for details). Because best YOB estimates are often equivalent to maximum YOB and best YOD estimates are often equivalent to minimum YOD (as previously described), the best annual population size estimates tend to be equivalent to the minimum population size estimates in many cases (see Table 1). Annual changes in total population size reported here are based on changes in the best population size estimates between consecutive census years, and therefore simple accounting using the prior year's population size and the current year's number of births, deaths and missing animals may not always be equivalent to the best population size in the current census year. Note that previous NRKW catalogues and annual updates containing population size estimates (e.g., Ellis et al. 2011; Towers et al. 2015, 2020) typically reported minimum number, maximum number or the mean of these two values, and so the 'best' numbers we present here may not align with previous estimates.

Although efforts are made to photograph the majority of NRKW each year, it is not always possible to locate every matrilineal group during each field season due to the large geographic range of this population and its growing abundance since the study began. Matrilines also undergo permanent group splitting over time (Stredulinsky et al. 2021), meaning that the number of distinct matrilineal groups that must be found each year is increasing. Moreover, environmental conditions in the exposed and remote areas in which this population is found can make it difficult to locate and photograph every individual. Here, we report the number of uncensused individuals by year (Figure 1), as well as the proportion of the population that was uncensused in each of the last ten census years (Table 1). Note that counts of uncensused animals do not include missing animals from well-censused matrilines that may have died. The proportion of uncensused animals in the population in every year has been variable over the course of this study, but was generally higher before the year 2000 and has recently increased again over the last three years (Figure 1). If an animal is not seen (i.e., is missing or is uncensused) in a given year, there can be uncertainty about its life history status in that year. This uncertainty is often resolved using information from following census years (e.g., an animal that is seen alive after not being censused for several years will have its status for the intervening years assigned retroactively) but exact years of birth or death will sometimes remain undetermined. For these reasons, some of the recent annual counts presented in this report may change retroactively in future census updates for this population.

Difficulties in locating all matrilineal groups in a given census year also create uncertainty in the number of living animals each year. Minimum population sizes were obtained by assuming that all animals that could have been born in the census year had not yet been born, and that all animals that could have been dead (i.e., were missing) had died. Conversely, maximum population sizes were calculated by assuming that all animals that could have been born in the census year had been born, and that all animals that could have died were still alive (see Table

1). Note that if entire matrilines were not censused (or were poorly censused) in a particular year, the whales belonging to them were considered to be alive for that year's population estimate until future census data indicate otherwise. However, in years with higher proportions of uncensused individuals, this approach underestimates the uncertainty around the estimated population size (i.e., several individuals may have been born and/or may have died among the groups not censused). Once previously undocumented births and deaths are accounted for in subsequent years, population estimates for years with higher proportions of uncensused individuals will become more accurate.

To help account for the additional uncertainty that arises when a proportion of the population is not censused, we estimated a second set of minimum and maximum population sizes that incorporate the possible population trajectories of the uncensused matrilineal groups, given recent observed trends. First, for each census year, we calculated the mean and standard deviation of percent population growth (based on annual changes in best population size estimates) over the previous 10 census years, including the given census year (i.e., [t,t-10) where t is the given census year). We then computed the normal distribution of plausible values of percent population growth based on this mean and standard deviation. We multiplied the number of uncensused individuals in the given census year by the 95% confidence interval limits of this normal distribution to determine the potential range of growth in the uncensused groups (i.e., the number of animals likely to have died and been born given recent trends in growth across the whole population). These upper and lower bounds (rounded to the nearest whole animal) were added to the minimum and maximum population size estimates that were previously generated assuming no births or deaths occurred in uncensused groups (these new uncertainty estimates accounting for plausible growth in uncensused groups begin in 1983, given the need for ten prior years of survey data, and are displayed in Figure 1 and Table 1). Estimated minimum and maximum population sizes that attempt to account for growth in uncensused groups were generally slightly wider than those calculated using the original method we described (Figure 1).

Population update for 2022

The photo-identification census in 2022 accounted for 83% of the NRKW population. In 2022, the following matrilines were either not encountered at all, or were only partially encountered (i.e., some individuals or submatrilines within a larger matriline were not seen, or field conditions did not allow us to locate or thoroughly photo-identify the entire matriline when it was encountered): B07, H05, I17, I18, I19, and R17 matrilines. In total, 54 NRKW were uncensused in 2022 (this does not include missing animals from well-censused matrilines that are possibly dead): 24% of A clan (42 individuals), 0% of G clan (0 individuals) and 20% of R clan (12 individuals). Assuming no births or deaths occurred in the uncensused matrilines in 2022, total best population size was estimated at 341 individuals, for an increase of 4 animals (or 1.2%) compared to the previous survey year. The minimum and maximum estimated population sizes for 2022 were 340 and 348 whales, when accounting for plausible growth in uncensused groups (this range was reduced to 341 to 345 whales if no births or deaths were assumed to have occurred in uncensused groups). Clan sizes in 2022 were 177, 103, and 61 individuals for A, G, and R clan, respectively (Figure 2). Note that the 2022 clan sizes, total population size estimate (including uncertainty) and percent growth reported here are likely to change when the matrilines that were not encountered during the 2022 census window are sighted again in future census years. Until these matrilines are re-encountered, it is impossible for us to know if any individuals that belong to them have died or given birth in 2022. Gaps in the sighting histories of individuals will also lead to increased uncertainty around the assignment of events such as deaths, births and the timing of reproductive maturation to a particular year. Annual NRKW population estimates throughout the history of the photo-identification study are presented in Figure 1, estimates for the ten most-recent census years are provided in Table 1, and annual clan sizes are presented in Figure 2.

Over the entire time series, the NRKW population has shown periods of growth and decline, but overall, it has grown at a mean annual rate of 2.2% (sd = 2.2%). G clan has grown the most since the study began in 1973, at a mean rate of 2.8% per year (sd = 4.1%), followed by R clan at 2.5% per year (sd = 4.1%) and A clan at 1.9% per year (sd = 2.7%). A proportional breakdown of the population by demographic category throughout the time series is presented in Figure 3.

A total of 9 calves were born in 2022, 4 animals were considered missing (possibly dead), 1 animal was declared dead, and 3 new animals were discovered (all of which were calves born during 2020-2021 to mothers that were uncensused during those years). Note that the list of animals discovered in 2022 does not include young-of-the-year (i.e., calves born in 2022) or possible young-of-the-year (i.e., calves born in either 2022 or 2021, with an estimated age of 0.5 y when first encountered); these individuals are included in the list of births for 2022.

- Identities of 2022 calves: A130 (mother: A62), G123 (mother: G50), G124 (mother: G51), G125 (mother: G83), G122 (mother: G62), I173 (mother: I125), I172 (mother: I102), I171 (mother: I104), R82 (mother: R54)
- New animals discovered this year: I170 (mother: I50, YOB ~ 2020-2021), R80 (mother: R40, YOB ~ 2020-2021), R81 (mother: R24, YOB ~ 2020-2021)
- Animals missing (possibly dead) this year: I53 (sex: M, age: 36), I141 (sex: U, age: 9), I33 (sex: F, age: ~51), R05 (sex: F, age: ~73)
- Animals declared dead this year: G88 (sex: M, age: 14)
- Updates to information provided in previous census years: C32 was declared missing in 2021 and is now confirmed to have died in 2021; I166 was declared missing in 2021 but was seen again in 2022 (i.e., confirmed alive)

Conclusions

The 2023 Science Response provides an update of total population size, numbers in each acoustic clan, births, newly discovered animals, and deaths for the NRKW population in 2022. The population showed an increase of 1.2% from 2021 to 2022, a decrease from the 4.3% annual growth rate reported in the previous year. G clan increased by 4% (net gain of 4 animals), and both A and R clans remained the same size (net gain of 0 animals) this year (Figure 2).

Tables

Table 1. Northern Resident Killer Whale population size for the ten most recent census years. Size change (i.e., the net number of animals gained or lost from the population since the previous year's census) and percent growth are based on the best population estimates. For minimum and maximum population size estimates, the numbers not in parentheses assume that no births or deaths have taken place in the uncensused groups. The values for minimum and maximum population sizes that are enclosed in parentheses denote the estimates for which plausible values of population growth have been applied to the number of uncensused individuals to account for this additional source of uncertainty. For uncensused individuals, we display both the total number uncensused and the percentage of uncensused whales (shown in parentheses) relative to the best population size estimate for each year. Note that the 2022 population size estimate and percent growth are likely to change when the matrilines that were not encountered during the 2022 census window are sighted again in future census years.

Year	Minimum	Maximum	Best estimate	Uncensused (%)	Size change	Percent growth
2012	272 (271)	279 (287)	272	114 (41.9)	6	2.3
2013	275 (275)	279 (279)	275	3 (1.1)	3	1.1
2014	289 (289)	290 (292)	289	29 (10)	14	5.1
2015	297 (297)	298 (299)	297	22 (7.4)	8	2.8
2016	301 (301)	303 (306)	301	61 (20.3)	4	1.3
2017	303 (303)	307 (307)	303	5 (1.7)	2	0.7
2018	303 (303)	311 (312)	303	19 (6.3)	0	0.0
2019	313 (313)	316 (317)	313	17 (5.4)	10	3.3
2020	323 (323)	327 (329)	323	43 (13.3)	10	3.2
2021	335 (334)	337 (341)	337	74 (22)	14	4.3
2022	341 (340)	345 (348)	341	54 (15.8)	4	1.2

Figures

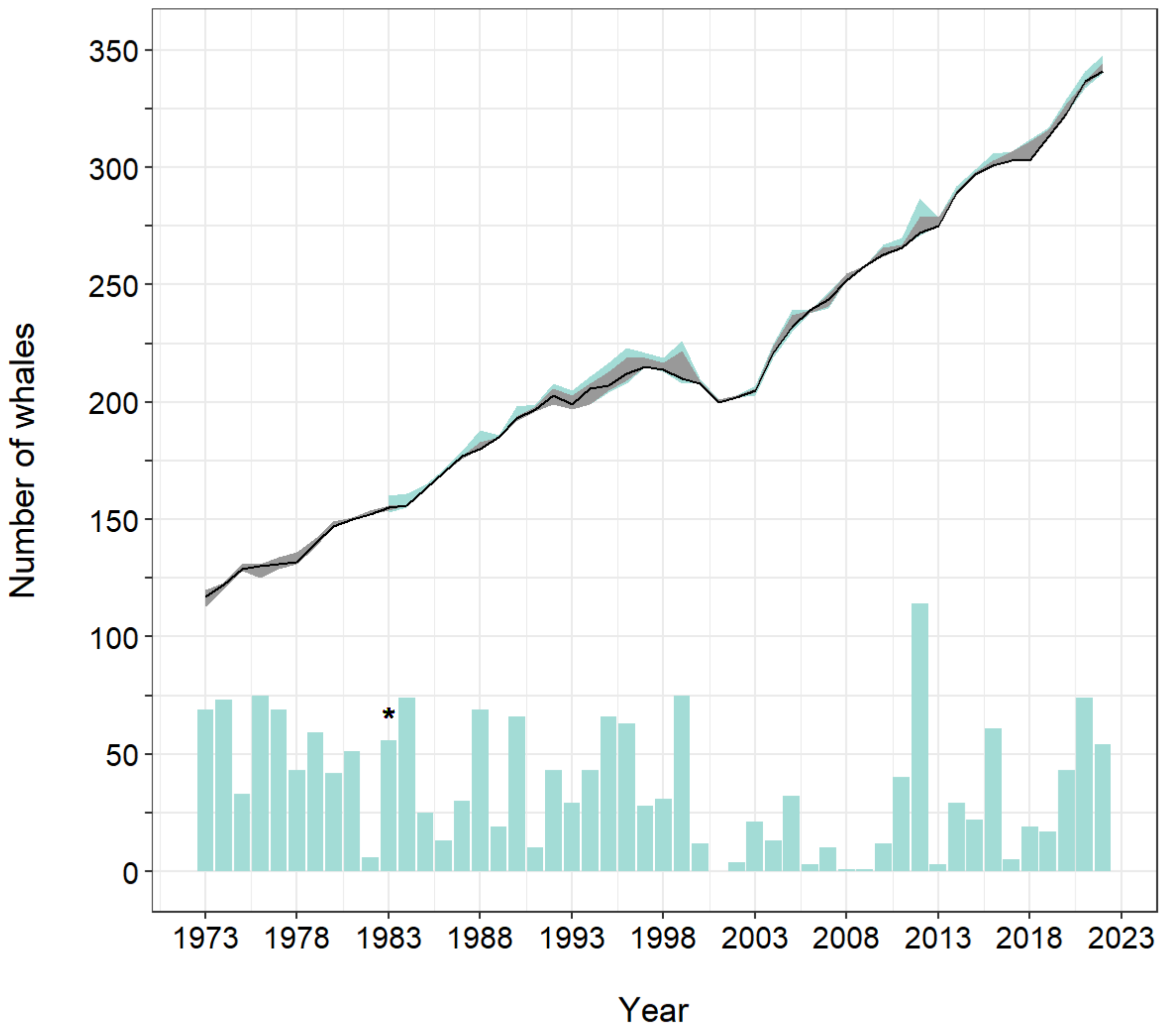

Figure 1. Northern Resident Killer Whale population size (black line; best population size estimate) and number of uncensused animals (blue bars) by census year. Grey band represents the minimum and maximum population size estimates assuming that none of the uncensused animals died or gave birth in the given census year (unless retroactively corrected based on later census information, once uncensused groups were seen again). Blue shaded band represents the minimum and maximum population size estimates generated by applying a plausible range of growth rates to the count of uncensused individuals (this uncertainty estimate begins in 1983 - noted by asterisk - due to the need for ten prior years of census data).

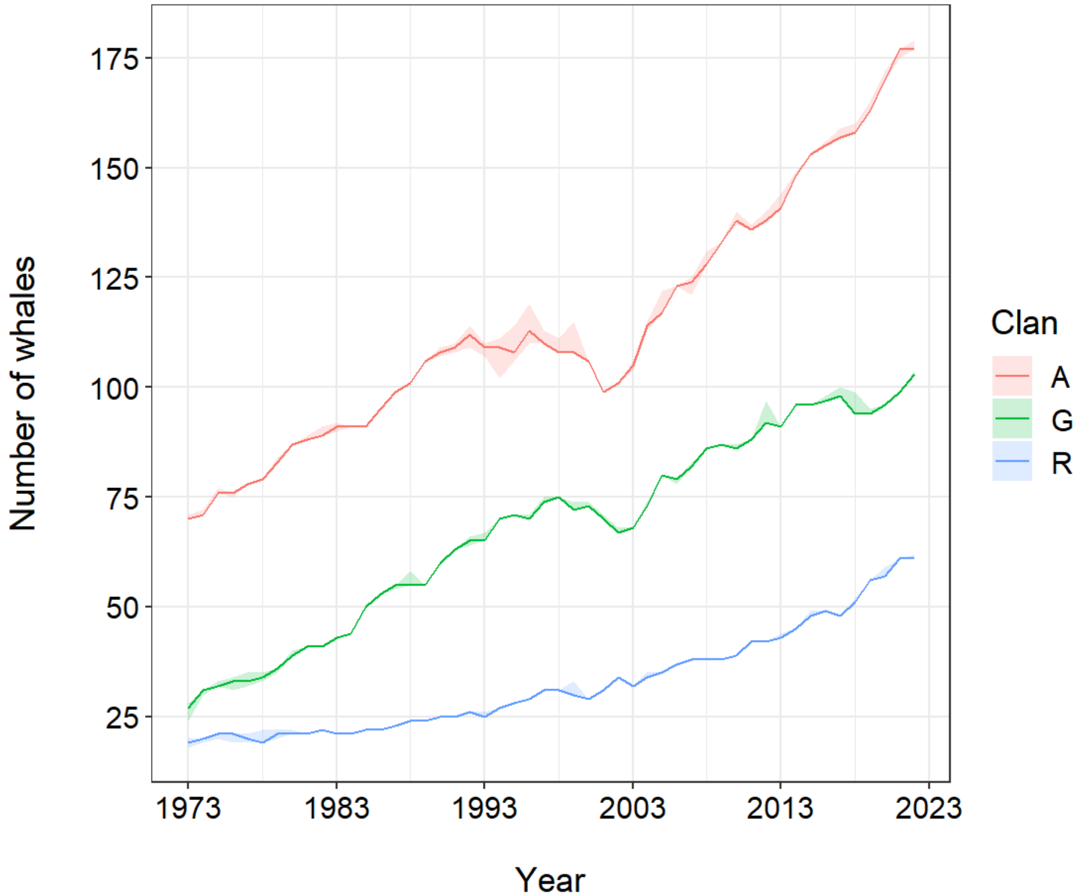

Figure 2. Northern Resident Killer Whale clan sizes by census year. Shaded bands represent minimum and maximum clan size estimates (assuming no births or deaths in uncensused groups, unless retroactively corrected with confirmed demographic data). Coloured lines indicate the best clan size estimates.

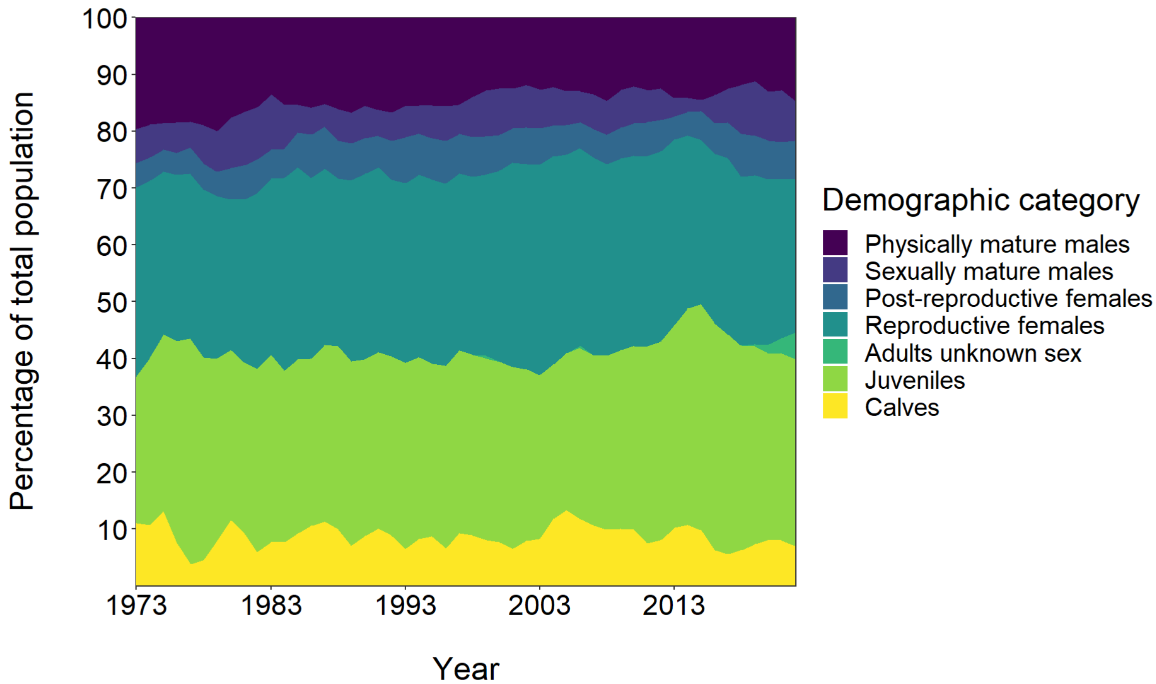

Figure 3. Proportion of individuals in each demographic category of Northern Resident Killer Whales by census year (assuming no births or deaths in uncensused groups, unless retroactively corrected with confirmed demographic data). Calf counts do not include non-viable calves (calves that survive less than 1 y).

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