Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat
Pacific Region **Science Response 2022/027**

POPULATION STATUS UPDATE FOR THE NORTHERN RESIDENT KILLER WHALE (*ORCINUS ORCA*) IN 2021

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 2021 and supplements existing publications, particularly between releases of NRKW photo-identification catalogues. 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 Science Response Process of May 6, 2022 on the Report on the 2021 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

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 range of this population, its growing size since the study began, and the tendency for matrilines to split apart over time (Stredulinsky et al. 2021), meaning an increasing number of matrilineal groups must be found each year. Conditions in the exposed and remote areas in which this population is found can also make it difficult to locate and photograph every individual. Therefore, there can be uncertainty about an animal's life history status in a given 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. 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 – in years with low census completion, 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 low census completion years will become more accurate. An exception to this would be a calf that was born and also died during the year(s) when its matriline was not seen, as the existence of such individuals cannot be known and they are therefore never captured in population size estimates.

'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. 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.

Population update for 2021

The photo-identification census in 2021 accounted for 78% of the NRKW population. Due to the constraints of the COVID-19 pandemic in the summer of 2021 and other logistical limitations, we were not able to census as much of the NRKW population as we would have in a typical year (usually >90% of the population is successfully censused). In 2021, 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): A24, B07, H05, I17, I18, I11, I33, R05 and R17 matrilines. In total, of all NRKW that could be presumed alive, 22% of A clan (39 individuals), 7% of G clan (7 individuals) and 47% of R clan (28 individuals) were not encountered in 2021. Assuming no births or deaths occurred in the uncensused matrilines in 2021, total best population size was estimated at 332 individuals (range = 332-336), for an increase of 8 animals (or 2.5%) compared to the previous survey year. Clan sizes in 2021 were 175, 98, and 59 individuals for A, G, and R clan, respectively. Note that the 2021 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 2021 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 2021. 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 2% per year (sd = 2.7%). A proportional break-down of the population by demographic category throughout the time series is presented in Figure 3.

A total of 12 calves were born in 2021, 4 animals were considered missing (possibly dead), no animals were declared dead, and no new animals were discovered (aside from young-of-the-year, i.e., calves born in 2021).

- Identities of 2021 calves: A127 (mother: A75), A130 (mother: A62), A128 (mother: A70), A129 (mother: A90), A126 (mother: A69), D33 (mother: D12), D34 (mother: D17), G119 (mother: G69), G120 (mother: G37), G121 (mother: G82), R78 (mother: R22), R79 (mother: R41)
- Animals missing (possibly dead) this year: C32 (sex: U, age: 8), I53 (sex: M, age: 35), I141 (sex: U, age: 8), I166 (sex: U, age: 1)
- Updates to information provided in previous census years: the mother of I168 (born in 2020) is I83, not I132 as previously reported; G03 was declared missing in 2020 but is now confirmed to have died in 2020; I117 is retroactively being declared dead in 2020 after not being seen in 2019 or 2020.

Conclusions

The 2022 Science Response provides an update of total population size, numbers in each acoustic clan, births and deaths for the NRKW population in 2021. The population showed an increase of 2.5% from 2020 to 2021, a slight decrease from the 3.5% annual growth rate reported in the previous year. A clan increased by 2.3% (net gain of 4 animals) this year and G clan increased by 2.1% (net gain of 2 animals). We cannot provide an accurate annual growth rate for R clan this year, as only just over 50% of the animals belonging to this clan were encountered in 2021.

Tables

Table 1. Northern resident killer whale population size for the ten most recent census years. Size change and percent growth are based on the best population estimate. Note that the 2021 population size estimate and percent growth are likely to change when the matrilines that were not encountered during the 2021 census window are sighted again in future census years.

Year	Minimum	Maximum	Best estimate	Size change	Percent growth (%)
2011	266	267	266	3	1.1
2012	272	279	272	6	2.3
2013	275	279	275	3	1.1
2014	289	290	289	14	5.1
2015	297	298	297	8	2.8
2016	302	303	302	5	1.7
2017	303	307	303	1	0.3
2018	303	311	303	0	0.0
2019	313	316	313	10	3.3
2020	324	324	324	11	3.5
2021	332	336	332	8	2.5

Figures

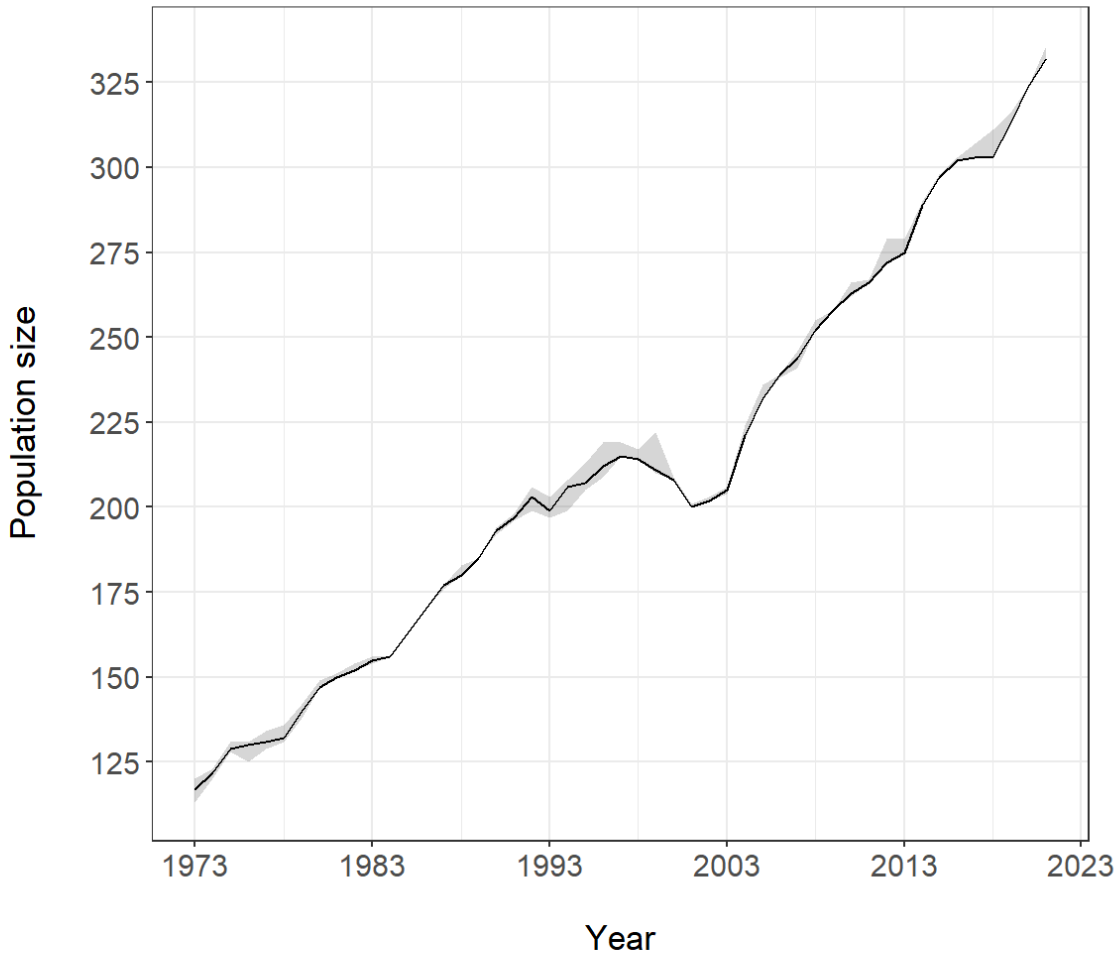

Figure 1. Northern resident killer whale population size by census year. Grey shaded band represents minimum and maximum population size estimates. Black line indicates the best population size estimate.

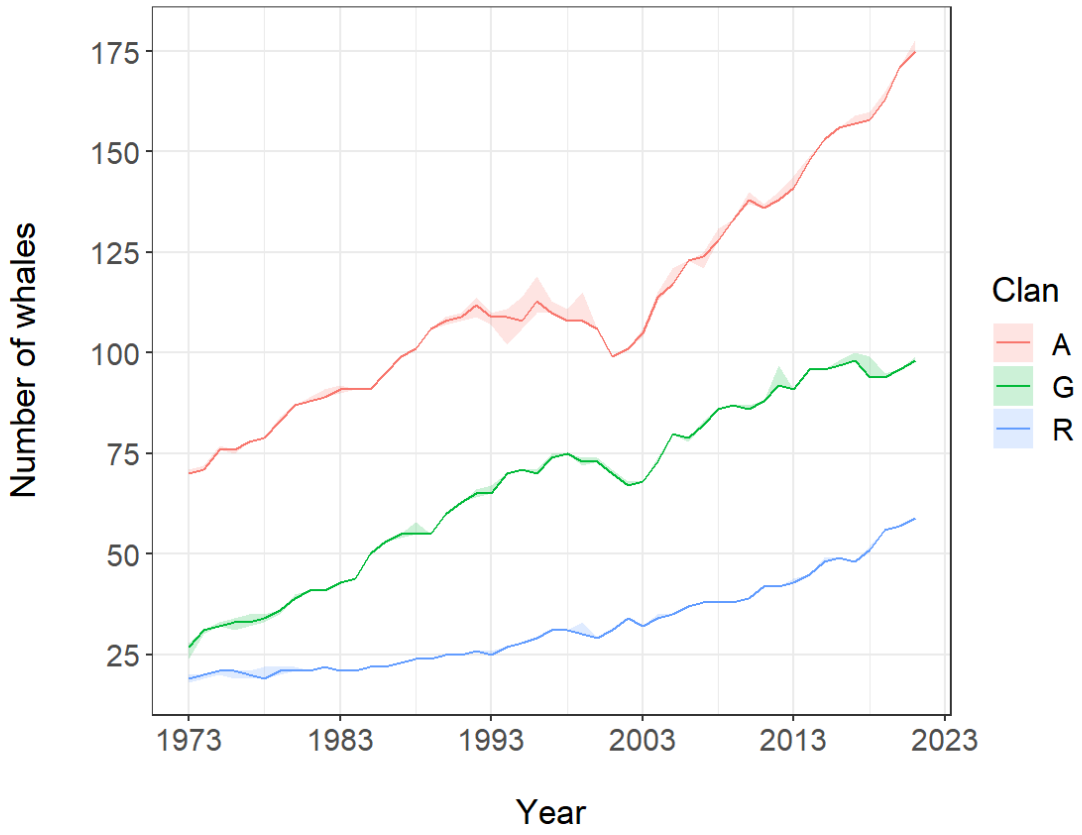

Figure 2. Northern resident killer whale clan sizes by census year. Shaded bands represent minimum and maximum clan size estimates. Coloured lines indicate the best clan size estimates.

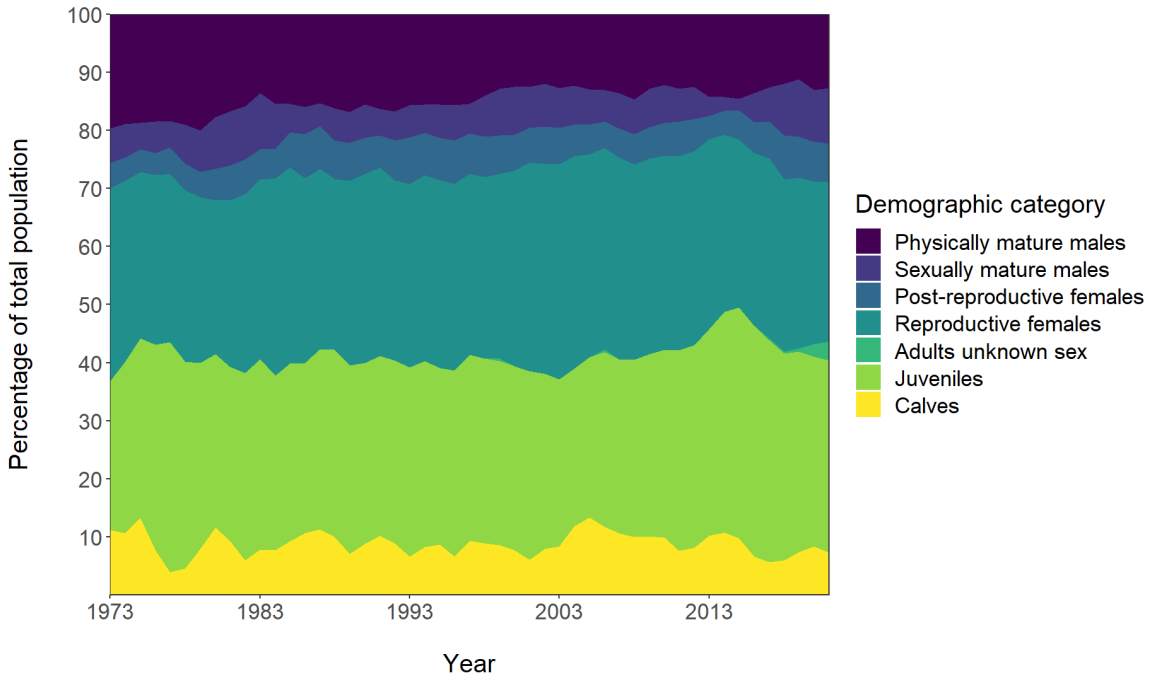

Figure 3. Proportion of individuals in each demographic category by census year. Calf counts do not include non-viable calves (calves that survive less than 1 y).

Contributors

Name	Affiliation
Thomas Doniol-Valcroze	DFO Science, Pacific Region
Graeme Ellis	DFO Science, Pacific Region
John Ford	DFO Science, Pacific Region
James Pilkington	DFO Science, Pacific Region
Eva Stredulinsky	DFO Science, Pacific Region
Jared Towers	DFO Science, Pacific Region
Brianna Wright	DFO Science, Pacific Region

Approved by

Andrew Thomson
Science Branch, Pacific Region
Fisheries and Oceans Canada
June 8, 2022

Acknowledgements

This report was written by Brianna Wright, Eva Stredulinsky and Thomas Doniol-Valcroze. Census data entry and analysis were conducted by Jared Towers. NRKW photo-identification census data for 2021 were collected in the field by Graeme Ellis, John Ford, Brian Gisborne, James Pilkington, Jared Towers, and Brianna Wright, with additional contributions also made by Lance Barrett-Lennard, Elysanne Durand, Stan Hutchings, Andrew Jones, Hermann Meuter, Alexandra Morton, Tasli Shaw, Dylan Smyth, Gary Sutton, Sheila Thornton, Scott Toews, Scott Turton, and Adam U. We thank Sean Anderson for his assistance in using the csasdown R package to produce this report.

This census update builds upon a foundation of long-term photo-identification work conducted on killer whales in British Columbia since 1973 by Michael Bigg, Graeme Ellis, John Ford and others. We are grateful for the ongoing logistical support and collaboration provided by the following organizations: Bay Cetology, BC Cetacean Sightings Network, BC Marine Mammal Response Network, Canadian Coast Guard, Cascadia Research Collective, Center for Whale Research, Cetacealab, Cetus Research and Conservation Society, Coastal Ocean Research Institute, Gitga'at First Nation, Heiltsuk First Nation, Kitasoo/Xai'xais First Nation, Langara Fishing Lodge, Marine Education and Research Society, North Coast Cetacean Society, North Island Marine Mammal Stewardship Association, Ocean Wise Conservation Association, Orcalab, Pacific Whale Society, Raincoast Conservation Society, Salmon Coast Field Station, Strawberry Isle Marine Research Society, and UBC's Marine Mammal Research Unit. Major funding for the NRKW photo-identification study has been provided by the *Species At Risk* program of Fisheries and Oceans Canada since 2001 and most field work was conducted under DFO Marine Mammal Research License MML-001.

Sources of Information

Bigg, M.A. 1982. An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. Rep. Int. Whal. Commn. 32: 655–666.

Bigg, M.A., Ellis, G.M., and Balcomb, K.C. 1986. The photographic identification of individual cetaceans. Whalewatcher J. Amer. Cetacean Soc. 20(2): 10–12.

Bigg, M.A., Olesiuk, P.F., Ellis, G.M., Ford, J.K.B., and Balcomb, K.C. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Rep. Int. Whal. Commn. Special Issue 12: 383–405.

Ellis, G.M., Towers, J.R., and Ford, J.K.B. 2011. Northern resident killer whales of British Columbia: Photo-identification catalogue and population status to 2010. Can. Tech. Rep. Fish. Aquat. Sci. 2942: v + 71 p.

Fisheries and Oceans Canada. 2017. Action Plan for the Northern and Southern Resident Killer Whale (*Orcinus orca*) in Canada. *Species at Risk Act* Action Plan Series. Fisheries and Oceans Canada, Ottawa. v + 33 pp.

Fisheries and Oceans Canada. 2018. Recovery Strategy for the Northern and Southern Resident Killer Whales (*Orcinus orca*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. x + 84 p.

Ford, J.K.B. 1991. Vocal traditions among resident killer whales (*Orcinus orca*) in coastal waters of British Columbia. Can. J. Zool. 69(6): 1454–1483.

Ford, J.K.B., Ellis, G.M., and Balcomb, K.C. 2000. Killer Whales: The Natural History and Genealogy of *Orcinus orca* in British Columbia and Washington State. UBC Press; University of Washington Press, Vancouver, BC; Seattle, WA.

Olesiuk, P.F., Ellis, G.M., and Ford, J.K.B. 2005. Life history and population dynamics of northern resident killer whales (*Orcinus orca*) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/045. iv + 75 p.

Stredulinsky, E.H. 2016. Determinants of group splitting: An examination of environmental, demographic, genealogical and state-dependent factors of matrilineal fission in a threatened population of fish-eating killer whales (*Orcinus orca*). Master's thesis, University of Victoria, Victoria, BC. xii + 104 p.

Stredulinsky, E.H., Darimont, C.T., Barrett-Lennard, L., Ellis, G.M., and Ford, J.K.B. 2021. Family feud: Permanent group splitting in a highly philopatric mammal, the killer whale (*Orcinus orca*). Behav. Ecol. Sociobiol. 75: 56.

Towers, J.R., Ellis, G.M., and Ford, J.K.B. 2015. Photo-identification catalogue and status of the northern resident killer whale population in 2014. Can. Tech. Rep. Fish. Aquat. Sci. 3139: iv + 75 p.

Towers, J.R., Ford, J.K.B., and Ellis, G.M. 2012. Digital photo-identification dataset management and analysis: Testing protocols using a commercially available application. Can. Tech. Rep. Fish. Aquat. Sci. 2978: iv + 16 p.

Towers, J.R., Pilkington, J.F., Gisborne, B., Wright, B.M., Ellis, G.M., Ford, J.K.B., and Doniol-Valcroze, T. 2020. Photo-identification catalogue and status of the northern resident killer whale population in 2019. Can. Tech. Rep. Fish. Aquat. Sci. 3371: iv + 69 p.

This Report is Available from the:

Centre for Science Advice (CSA)
Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Rd.
Nanaimo, BC, V9T 6N7

E-mail: csap@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-3769
ISBN 978-0-660-44235-8 Cat No. Fs70-7/2022-027E-PDF

Correct Citation for this Publication:

DFO. 2022. Population status update for the Northern Resident Killer Whale (*Orcinus orca*) in 2021. DFO Can. Sci. Advis. Sec. Sci. Resp. 2022/027.

Aussi disponible en français :

*MPO. 2022. Mise à jour de l'état de la population d'épaulards résidents du nord (*Orcinus orca*) en 2021. Secr. can. des avis sci. du MPO. Rép. des Sci. 2022/027.*