Biological Assessment of the Southern Resident Orcas (*Orcinus orca*) in Oregon and Evaluation of Criteria to Classify the Species as Endangered under the Oregon Endangered Species Act

Photo: NMFS

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Contents

EXECUTIVE SUMMARY

The Southern Resident orcas (*Orcinus orca*) are a distinct population of orcas (killer whales) native to the eastern North Pacific Ocean with a range that extends from southeastern Alaska to central California. Orcas are the largest member of the dolphin family and a top marine predator. Their striking black and white coloration is easily recognizable, and differences in the appearance of their dorsal fins and saddle patches are unique to individual orcas, allowing them to be identified visually. Of the three orca ecotypes in the northeastern Pacific region—resident, transient, and offshore—resident orcas are distinct in living in large stable pods and relying almost entirely on fish for their diet, particularly Pacific salmon (*Oncorhynchus spp*.). The Southern Residents, like other orcas, are highly social animals with a well-developed social structure consisting of several female-led matrilines in three pods (designated J, K, and L), one clan (J), and a community (population). The most recent population size for the Southern Residents (as of the 2022 census) is 73 individuals (25 in J pod, 16 in K pod, and 32 in L pod). Two new calves (one female and one male) were born in L pod after the 2022 census but as of this writing, the 2023 census has not yet been completed. Vocalizations are critical for communication between individuals, maintaining social bonds, navigation, and foraging. Each orca pod has a unique vocal repertoire, or dialect, which can be used to identify pods acoustically. Orcas, in general, are polygamous and males usually mate with females outside of their own pods, which helps to reduce the risk of inbreeding. Female orcas typically produce their first calf at between 12 and 17 years of age and can be reproductively active for 20 to 24 years before entering a post-reproductive phase. Male orcas reach sexual maturity at 11–15 years of age and remain reproductively active throughout their lives. The average life expectancy of Southern Resident orcas is 29 years for females and 17 years for males, with maximum life spans of 80–90 years and 60–70 years, respectively.

The National Marine Fisheries Service (NMFS) designated the Southern Resident orcas as depleted under the Marine Mammal Protection Act (MMPA) in 2003, and subsequently listed them as endangered under the U.S. Endangered Species Act (ESA) in 2005. In their latest status review in 2021, NMFS determined that the population should remain listed as endangered. The Southern Residents are also featured in NMFS's "Species in the Spotlight" program, which is intended to focus attention and resources on the species most at risk of extinction. In Washington State, the Southern Residents, along with other orcas occurring in the state's waters, have been listed as endangered since 2004. The Washington Department of Fish and Wildlife (WDFW) concluded in its 2016 status review that the Southern Residents should remain listed as endangered. Since 2001, the Southern Resident orcas have been listed as endangered in Canada under the Species at Risk Act (SARA).

On February 16, 2023, the Oregon Fish and Wildlife Commission (Commission) was petitioned by the Center for Biological Diversity, Defenders of Wildlife, and Whale and Dolphin Conservation to list Southern Resident orcas as endangered under the Oregon Endangered Species Act (OESA). At its April 21, 2023 meeting, the Commission found that the petition to list Southern Resident orcas as endangered presented "substantial scientific information" to begin a rulemaking process, leading to a listing determination by the Commission in February of 2024.

In determining whether to list a species as state-threatened or endangered, the Commission must base its decision on documented and verifiable scientific information about the species' biological status and find that the natural reproductive potential of the species is in danger of failure due to limited population numbers, disease, predation, or other actions affecting its continued existence. To be listed, the population must also be undergoing deterioration of its range or habitat, be overutilized commercially, recreationally, or for scientific/educational purposes, or existing state or federal programs must be found to be inadequate to protect the species or its habitat (ORS 496.176; OAR 635-100-0105). Additional listing criteria outlined in OAR 635-100-0105 include requirements for the species to be native to Oregon and in danger of extinction throughout any significant portion of its range within the state. With respect to the species range within Oregon, the Commission shall consider the total geographic area in the state used by the species, the nature of the habitat (e.g., any unique or distinctive characteristics of the habitat used for breeding, resting, or foraging), and the extent to which the species habitually uses the geographic area within the state.

In developing this biological assessment, the Oregon Department of Fish and Wildlife (ODFW) reviewed and considered documented and verifiable scientific information and other best available data on the Southern Resident orcas' natural history, population status and trends, habitat use and condition, threats to the population's continued existence, and management actions taken to recover the population. The biological assessment of the Southern Resident orcas resulted in the following conclusions:

Chinook salmon are important in the diet of the Southern Residents. Most of their diet is comprised of salmonids (about 96% during the summer season), with Chinook salmon accounting for 65–72% of the prey consumed in the summer and fall in the Salish Sea and around 67% during the winter and early spring in outer coastal waters. Chinook appear to be selected over other salmon species such as Sockeye and Pink salmon, even when the other species are much more abundant. Chinook may be preferred by Southern Residents due to their relatively large size and high fat content, resulting in a greater energy return per unit of foraging effort. Recent genetic analyses of prey samples indicate that the Southern Residents, overall, consume Chinook salmon from a wide variety of stocks from many river systems ranging from northern British Columbia to central California. Having access to a diverse mix of Chinook stocks throughout the year may provide the Southern Residents with greater resiliency in their diet, especially as Chinook stock abundances fluctuate. During the winter, the Southern Residents' diet appeared to be broader and included more steelhead and non-salmonids, presumably because of the low abundance of their preferred prey, Chinook salmon, at that time of year. In the outer coastal waters of Washington, Oregon, and California, Columbia River Chinook salmon comprised nearly 54% of the prey samples collected during the winter and spring, with most of the samples coming from the Washington coast. Genetic analyses suggest that spring and fall Chinook originating from the lower Columbia River account for 27% of the Southern Residents' diet during the winter and early spring. These are the stocks most likely to have origins in Oregon tributaries and hatchery salmon release areas. Of the ten highest priority Chinook salmon stocks identified by NMFS and WDFW as important in guiding recovery efforts for the Southern Residents, five originate in the Columbia River basin. Of note, no Chinook salmon from Oregon coastal rivers were collected in prey samples in coastal waters so Oregon coastal Chinook stocks are not listed as a high priority for Southern Resident orca recovery.

The Oregon Coast provides important habitat for the Southern Residents. In 2021, NMFS expanded the critical habitat for Southern Resident orcas to include six areas along the outer coasts of Washington, Oregon, and northern/central California. This expansion of critical habitat was based on recent research using visual sightings, acoustic recordings, and satellite tagging. The combined data indicated that K and L pods spent considerable time in the outer coastal waters during the winter and early spring, especially along the southern Washington coast and around the mouth of the Columbia River. The presence of the Southern Residents in these areas coincided with the timing of the return of spring Chinook salmon to the Columbia. Satellite tagging data indicated that Oregon coastal waters between Cape Meares and the California border served as an important travel corridor for the Southern Residents as they moved between foraging areas to the north and south. The Southern Residents traveling along the Oregon Coast stayed within a relatively narrow corridor ranging from 1.2 mi to 7.5 mi from shore, with an average distance from shore of 3.7 mi. The median depth of water used by the Southern Residents was 187 ft. Recent observations indicate that the Southern Residents may be spending less time in their core habitat areas in the Salish Sea and more time in outer coastal waters, possibly due to lower abundances of salmon in the inland marine waters during the late spring and early summer.

The Southern Resident population size was greatly reduced by the removal of individual animals to support the large aquaria trade in the late 1960s and early 1970s and has since varied over time with periods of growth and decline over the last 60 years. Since peaking at 98 individuals in 1995, the Southern Resident population has exhibited an overall declining trend. Although this population decline initially corresponded with lower Chinook salmon abundance in the late 1990s, the association between Chinook salmon abundance and Southern Resident population status has weakened in recent years as the population continues to decrease even during periods of improved Chinook salmon abundance. Since other factors such as contaminant exposure and noise/vessel disturbance can negatively affect the Southern Residents, it is very difficult to assign a single primary contributing factor to the population's long-term decline. The current Southern Resident population size (73) remains below what it was when the population was federally listed in 2005 (88), and the small population size makes the community vulnerable to inbreeding and catastrophic events and means that its age and sex compositions are heavily influenced by the births and deaths of individual animals.

There are signs of reproductive issues within the Southern Resident population. Researchers found that 52% of the calves born between 1990 and 2015 were sired by only two males and that there were four highly inbred offspring in the population. Also, unlike most orca populations, mating within pods appeared to be more common for the Southern Residents. These findings indicated that the Southern Resident population is more inbred than other North Pacific orca populations. The average calving interval of 6.1 years for Southern Resident females is longer than for Northern Resident females, resulting in a lower fecundity rate (births per year) for the Southern Resident population. The sex ratio of the Southern Resident population was recently estimated to be 55% male and 45% female, placing the population at a reproductive disadvantage due to the lower proportion of females. Recent research also indicates that several late-term miscarriages have occurred among Southern Resident females and the proportion of reproductive-age females that have not given birth to a calf is relatively high. Potential inbreeding depression, along with the other reproductive issues, likely make the recovery of the Southern Resident population more difficult.

Population viability modeling by NMFS's Northwest Fishery Science Center (NWFSC) indicates that the Southern Resident's population size is projected to decrease over the next 25 years. By 2045, the population may number between about 39 and 64 individuals, depending on the survival and fecundity rates used in the modeling. Even though survival rates for the Southern Resident population have been slowly increasing since the 1990s, the downward projections largely reflect the population's relatively low fecundity rates and recent shifts in the age and sex compositions of population, particularly for its younger members.

NMFS's Biological Review Team (BRT) identified the following factors as the main threats to the continued existence of Southern Resident orcas: 1) prey availability, 2) environmental contaminants, 3) sound and vessel disturbance, and 4) oil spills. These threats form the basis of the federal recovery plan for the Southern Residents and help guide recovery efforts.

- **Prey availability**—Reductions in the abundance of Chinook salmon in the Pacific Northwest over the last 150 years due to overfishing, habitat loss and degradation, poor hatchery practices, and hydropower operations on the Columbia River and other rivers have affected a critical part of the prey base for Southern Resident orcas. Most of the Chinook salmon stocks that experienced reductions in abundance over this timeframe are in Washington, Oregon, Idaho, California, and southern British Columbia, and many of the stocks contribute to the diet of the Southern Residents. In addition to reductions in the quantity of prey available to the Southern Residents, there are indications that the quality of the prey has also decreased. Many populations of Pacific salmon, including Chinook salmon, have decreased in physical size over the past several decades. Potential reasons for this reduction in size include harvest and fish culture practices, as well as ocean conditions. Smaller prey may result in fewer calories being consumed per unit of foraging effort for the orcas, leading to reduced foraging efficiency and more energy expended to meet dietary needs. Researchers have documented poor body condition in some Southern Residents, and poor body condition may be linked to nutritional stress, although other factors such as long-term exposure to contaminants and disease, may also contribute. Nutritional stress can lead to increased mortality and poor reproductive success and may negatively impact the social cohesion of the Southern Resident population.

- **Environmental contaminants**—The class of contaminants known as persistent organic pollutants (POPs), consisting of organochlorines such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), and polybrominated diphenyl ethers (PBDEs), are considered to present the greatest contaminant risk to the Southern Residents due to their persistent qualities and the fact that they are fat-soluble and stored in the blubber of orcas. Even though many types of POPs have been banned in the United States and Canada, they continue to be manufactured in other countries and can be transported to the eastern North Pacific by ocean currents and prevailing winds. High concentrations of POPs can bioaccumulate in top marine predators such as orcas through their consumption of contaminated prey. Chinook salmon in Puget Sound were found to have higher levels of contaminants than other salmon species there, particularly among Chinook stocks with longer residence times in the Sound. Female orcas transfer much of their contaminant burden to their offspring during nursing. The Southern Residents have been exposed to PCBs and DDT in Puget Sound for several decades and

modeling suggests that it may take up to 60 years for PCB concentrations in the Southern Residents to fall below levels considered to be harmful to marine mammals. Although concentrations of some contaminants in the Southern Residents have been slowly decreasing, there are some indications that they may have stabilized at levels that are still relatively high. High POP concentrations in marine mammals have been linked to endocrine, metabolic, and immune system disruption, cancer, decreased reproduction, and increased calf mortality. Some researchers have suggested that orca calves may be especially vulnerable to POP-induced endocrine disruption because of their exposure to contaminants at a very young age and during an important time in their growth and development. Calves may also become more susceptible to disease if their still-developing immune systems are compromised due to high levels of POPs in their bodies. The health impacts of high POP concentrations on the Southern Residents can be influenced by other stressors such as a lack of prey because a shortage of food can cause an orca's body to draw on its fat reserves, mobilizing POPs into the circulatory system where they can potentially have toxic effects.

- **Sound and vessel disturbance**—Noise from vessel traffic, dredging/drilling, seismic testing, construction activities, and possibly ocean energy developments can potentially interfere with the Southern Residents' ability to communicate with each other and forage efficiently. Commercial shipping, ferry operations, whale watching, and recreational boating traffic have expanded within the northeastern Pacific region in recent decades. Orcas respond to close-range vessel encounters with short-term behavioral changes that include increased swimming speed, less directed swimming paths, and decreased foraging activities. Vessels in the paths of orcas can also impede important social behaviors such as prey sharing and nursing. Noise from vessels may mask or prevent the perception of vocalizations made by orcas, interfering with communications important for maintaining social structure and cohesion. Researchers have reported that call duration increased by 10–15 percent in Southern Resident pods when whale-watching boats were present, suggesting that they were attempting to compensate for the noisier environment. Additionally, interference with echolocation may reduce foraging efficiency by decreasing the range at which orcas can detect salmon in the water column. Research indicates that behavioral changes in orcas can occur at varying distances from vessels, ranging from 100 m (109 yd) to 400 m (437 yd) or greater. Whale watching is an important tourist industry in several coastal communities, serving a dual purpose of boosting the local economy and increasing the public's awareness of and appreciation for marine mammals and the environmental issues they face. In Washington and British Columbia, orcas are the primary species of interest for the commercial whale-watching industry due to their historically reliable presence in the Salish Sea. Whale watching off the Oregon Coast focuses on gray whales (*Eschrichtius robustus*) because of their regular spring and fall migrations, as well as a subset of gray whales that feed off the Oregon Coast during the summer months. Orcas are seldom observed in Oregon, with sightings usually occurring during April–June, and the orcas observed are usually the transient ecotype. The development of marine renewable energy projects (wave energy and offshore wind energy) off the Oregon Coast is currently being investigated. Planning is underway for testing wave energy devices at one of two facilities either 2 or 6 nautical miles off the coast near Newport, Oregon, and for potential commercial development of offshore wind facilities located more than 18 miles off the southern Oregon coast. Installation or operation of ocean energy infrastructure may

produce sound at levels exceeding ambient conditions that could have a range of effects on marine mammals.

- **Oil spills**—The possibility of a major oil spill is considered one of the greatest short-term threats to orcas and other coastal organisms in the northeastern Pacific region. The *Exxon Valdez* oil spill in Prince William Sound, Alaska in 1989 resulted in unprecedented mortalities for resident and transient orca pods in southern Alaska. Inhalation of vapors at the water's surface and ingestion of polycyclic aromatic hydrocarbons (PAHs) during feeding are the most likely pathways of exposure for orcas. Marine mammals acutely exposed to PAHs can experience inflammation of mucous membranes, pneumonia, liver disorders, and neurological damage. Oil spills can also significantly affect prey populations that the Southern Residents rely on, reducing the amount of food available to them. A study evaluating the impacts of a potential oil spill on marine mammals in British Columbia coastal waters identified Northern and Southern Resident orcas as being among the most vulnerable populations due to their relatively small population sizes, strong site fidelity to areas with high risk of oil spills, large group (pod) size, late reproductive maturity, low reproductive rate, and specialized diet.

It is unclear, and may be impossible to determine, which threat, or threats pose the highest risk for the survival and future existence of the Southern Resident orcas. This uncertainty makes it more difficult to prioritize the threats for actions that expedite the population's recovery. It is highly likely that the Southern Residents experience cumulative, and probably synergistic, effects from multiple threats, and that these effects are exacerbated by the population's small size. For example, a lack of prey over several years could have cumulative effects as an orca's body condition worsens and potentially makes the animal more susceptible to disease. A lack of food also causes more fat to be metabolized for energy, releasing toxicants into the bloodstream where they can potentially have deleterious effects, such as reduced immune system function and reproduction. Vessel noise can disrupt foraging, potentially leading to poor nutrition, increased body toxicity, and increased susceptibility to disease.

Many management actions have been taken to address the threats facing the Southern Residents. Some actions, such as salmon recovery and pollution control efforts, have been ongoing for several decades. In 2018, Washington's governor established the Southern Resident Killer Whale Task Force, comprised of members from state agencies, the Washington legislature, tribal and local governments, businesses, and nonprofits, to develop a long-term plan to recover Southern Resident orcas. A total of 49 actions were recommended by the Task Force, with a comprehensive approach taken to address the main threats to the Southern Residents. Several of the Task Force's recommendations, such as increased production of hatchery Chinook salmon and further restrictions on the whale watching industry in Washington's inland marine waters, have begun to be implemented.

Funding from the Pacific Salmon Treaty (PST) and the Washington legislature seeks to increase the amount of Chinook salmon available to the Southern Residents by 4–5%, which roughly corresponds to an additional 35–50 million smolts released annually. The funding goes to state, federal, and tribal hatcheries in Washington and Oregon, with the enhanced hatchery production targeted on stocks contributing to the Southern Resident's diet during the summer in the Salish Sea and over the winter and spring in the outer coastal waters off Washington and the Columbia River mouth. While increasing

production of hatchery Chinook is thought to be beneficial to the Southern Residents, and is supported by NMFS, there is a recognition that increasing releases of hatchery salmon needs to be done carefully to avoid adverse impacts to wild salmon. The 2019–2028 PST includes harvest reductions in U.S. and Canadian Chinook salmon fisheries which reduces fishery impacts on Chinook salmon stocks important to the Southern Residents, and Amendment 21 of the Pacific Fishery Management Council's (PFMC) Pacific Coast Salmon Fishery Management Plan outlines reductions in PMFC salmon fisheries that would occur if Chinook salmon abundance in the North of Falcon area is below an established threshold level (currently set at 623,000 Chinook). Additionally, Puget Sound salmon fisheries co-managers (Treaty Indian tribes and WDFW) annually take actions to reduce the fisheries' impacts to Southern Resident orcas, including fishery closures or Chinook salmon non-retention requirements in certain months and areas. NMFS's Section 7 consultations for a variety of salmon fisheries have concluded that fishery harvest has caused small reductions in prey availability for the Southern Residents; however, these reductions were not likely to jeopardize the continued existence of ESA-listed Chinook salmon or Southern Resident orcas, nor adversely modify their critical habitats. Although reductions in fishery harvest of Chinook salmon and programs designed to increase Chinook salmon production in hatcheries could increase the amount of prey available to the Southern Residents, there is still uncertainty regarding how much an increase in prey availability translates to measurable improvements in Southern Resident population parameters. Some portion of an increase in Chinook salmon abundance will likely be offset due to predation by species other than orcas, and there is a lack of information on the foraging efficiency of the Southern Residents. Therefore, it is difficult to determine how much Chinook salmon or what density of salmon needs to be available to the Southern Residents for survival and successful reproduction.

Several federal, state, and local regulations, agencies, and programs address environmental contaminants. Under the 1972 Clean Water Act (CWA), the Environmental Protection Agency (EPA) implements pollution control programs, sets wastewater standards, and develops national water quality criteria recommendations for pollutants in surface waters. The agency also has the authority to enforce water quality regulations. The National Pollutant Discharge Elimination System (NPDES), which regulates point-source pollution and is typically administered by state agencies, has been responsible for significant improvements in water quality. In 2007, Washington State established the Puget Sound Partnership, a new agency intended to oversee the restoration of Puget Sound's environmental health, with particular emphasis on improving habitat conditions for Southern Resident orcas. In Oregon, the Department of Environmental Quality (DEQ) is the state agency responsible for protecting and improving the state's water quality for multiple beneficial uses, including aquatic habitat for fish and wildlife. It develops and implements water quality standards and clean water plans, regulates sewage treatment systems and industrial dischargers, and evaluates water quality. Additionally, the City of Portland's Bureau of Environmental Services (BES) manages the city's wastewater and stormwater systems, enforces local, state, and federal environmental regulations, and is the lead agency in the Portland Harbor Superfund Program. The city's Water Pollution Control Laboratory investigates reports of pollution in rivers and streams and conducts water quality testing. During the past several decades, regulatory actions, improved waste handling, and ongoing cleanup efforts, particularly of Superfund sites in Puget Sound, have led to substantial improvements in the regions' water quality. However, despite these advancements, and the banning of POPs such as PCBs, DDT, and PBDEs, these legacy contaminants

continue to be a concern for the Southern Residents. Currently, there is no strong evidence for a marked reduction in contaminant load in Southern Resident orcas, including their calves.

A variety of measures have been taken to reduce sound and vessel disturbance of the Southern Residents. In 2011, NMFS implemented regulations that prohibit vessels from approaching within 200 yd of orcas, and from parking in the path of orcas within 400 yd in the inland waters of Washington State. Although these federal regulations are still in place, NMFS recently completed a public scoping process to examine the need for updating the regulations and is working with the State of Washington and the Province of British Columbia on the potential for alignment of regulations. Current Washington State regulations, which apply specifically to Southern Resident orcas within the state's inland waters, require vessels to stay 300 yd from the orcas on either side and 400 yd from them when in front of or behind the orcas. Additional guidelines suggest that boat speed should be <7 knots within ½ mile of the Southern Residents and vessel operators are advised to disengage their engines if orcas appear within 300 yd. In addition to these regulations, there is also a voluntary "no boat" zone along the west coast of San Juan Island. In 2025, a new Washington State law will go into effect that expands the vessel buffer on all sides of a Southern Resident orca to 1,000 yd, and will require that vessel operators maintain a speed of <7 kts within 1,000 yd and disengage the engine within 400 yd. The federal regulations apply to orcas in inland waters that are not Southern Residents (e.g., Bigg's transients). Canadian regulations require buffers between vessels and all orcas that range from 200 m (219 yd) to 400 m (437 yd), depending on the location. Interim orca sanctuary zones, which prohibit all vessel traffic, have also been established around Saturna and Pender islands near the southern end of Vancouver Island. In the outer coastal waters off Washington, Oregon, and California, current federal viewing guidelines require that vessels stay at least 100 yd from "whales", including orcas. In 2021, working with the commercial whale-watching industry, Washington State implemented a Commercial Whale Watch Licensing Program (CWWLP) requiring commercial operators to have a commercial whale-watching license to view Southern Resident orcas. The program places additional restrictions on the number of commercial whale-watching vessels that can be within a half nautical mile of the Southern Residents, the time of day and year that commercial viewing of Southern Residents is allowed, and the number of trips a commercial operator can make to view Southern Residents in a day. NMFS works with the State of Washington and non-profit partners to collect data on vessel interactions, enforce regulations, and increase boater awareness of the regulations through public education. The Soundwatch Boater Education Program has boat crews that monitor the waters around the San Juan Islands during the summer months, recording data on vessels near the orcas and incidents of non-compliance with the regulations. Crews also educate boaters on state and federal regulations and the Be Whale Wise guidelines. Additionally, NMFS promotes awareness of the Southern Residents and the Be Whale Wise guidelines through public education efforts in partnership with WDFW, the Seattle Aquarium, Orca Network, and other partners.

Since noise generated by non-whale-watching vessels, such as large cargo ships, can also affect the orcas, voluntary slow-down trials for commercial vessels, known as the Enhancing Cetacean Habitat and Observation (ECHO) program, were recently implemented in Canadian waters. These trials showed reductions in the level of ambient noise in the frequency range used by the Southern Residents, and the success of ECHO led to the development of an equivalent program in the U.S. called Quiet Sound. Programs and procedures are also in place to minimize or eliminate potential negative effects from in-

water activities such as dredging, drilling, and construction. Construction activities are permitted by the Army Corps of Engineers (ACOE) under section 404 of the Clean Water Act and section 10 of the Rivers and Harbors Act of 1899 and by the State of Washington under its Hydraulic Project Approval (HPA) program. NMFS conducts consultations on these permits and helps project applicants to incorporate conservation measures into their plans. A wide variety of management actions have been implemented to reduce disturbance to the Southern Residents from sound and vessel activity, with adjustments made as new information becomes available. While much progress has been made, there remains room for improvement in educating the public about regulations and guidelines, increasing compliance, and achieving better alignment of regulations at the state, federal, and international levels.

Several statutes, policies, and programs address oil spill prevention and response in the northeastern Pacific region. These include the International Maritime Organization (IMO), the U.S. Oil Pollution Act (OPA), the Canada Shipping Act, and the Northwest Area Committee (NWAC). The OPA serves as the leading federal regulatory mechanism to prevent, respond to, and address damage caused by oil spills. It also created the Oil Spill Liability Trust Fund. In 2001, the U.S. Coast Guard (USCG), EPA, Department of Interior (Fish and Wildlife Service) and NOAA (NMFS and NOS) entered into an agreement intended to ensure inter-agency cooperation and facilitate compliance with the ESA to protect listed species and critical habitat, without compromising the response to an oil spill. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) outlines oil spill planning and response procedures to achieve those objectives. In addition, an orca-specific oil spill response plan has been adopted as part of the Northwest Area Contingency Plan. In Oregon, the USCG and DEQ have primary responsibility for preventing, planning for, and responding to spills of oil and other hazardous materials.

The documented and verifiable scientific information presented in this biological assessment indicate that the criteria for an endangered listing under the OESA for the Southern Resident orcas have been satisfied. The natural reproductive potential of the Southern Residents is in danger of failure due to multiple factors, including small population size, reduced availability of prey, and exposure to contaminants and noise. Population viability modeling indicates that recent poor reproduction in the Southern Resident population is likely to lead to a steeper decline in the population over the next 25 years. The available information also indicates that the habitat of the Southern Residents has been altered and degraded due to reductions in the abundance and size of their primary prey, Chinook salmon, a long history of pollution, particularly in Puget Sound, and an increase in vessel traffic in the Salish Sea, which has increased ambient noise levels for the Southern Residents. It is difficult to determine if the Southern Residents are being “overutilized” by the commercial whale-watching industry in Washington’s inland waters; however, Washington State’s recent implementation of a commercial whale-watching licensing program suggests that additional regulation of the industry was necessary. Although existing federal and state programs have helped address some of the threats facing the Southern Residents, there is need for improvement as many Chinook salmon populations have not recovered, legacy contaminants such as POPs continue to linger in the environment and in the bodies of the Southern Residents, and better public awareness of and compliance with vessel regulations is necessary. The Southern Resident orcas are native to the State of Oregon as their known range extends from southeastern Alaska to central California, including the waters off the Oregon Coast to within 1.2 mi of shore (Oregon state waters extend to 3 mi off the coastline). Population viability modeling indicates that the Southern Residents are in danger of extinction across their range, including from Oregon state

waters. The entire length of the Oregon Coast is included in the critical habitat for the Southern Residents, though various areas are important for different life history needs. The designated critical habitat within Oregon state waters is estimated to be 720 mi^2, with approximately 20% of the area considered to be an important foraging area for the Southern Residents and the remaining 80% used primarily as a travel corridor. The Southern Resident orcas have been documented on a regular basis in the outer coastal waters as far south as Monterey Bay, California for decades. Regular sightings and acoustic detections off the California coast indicate that the Southern Residents have been traveling the full length of the Oregon Coast for many years. Although Southern Resident orcas have been documented off the Oregon Coast in every month of the year, they are primarily present during the winter and spring months. To date, two of the three Southern Resident pods (K and L) appear to utilize the habitat along the Oregon Coast, while the third (J pod) has not been documented in Oregon waters.

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INTRODUCTION

On February 16, 2023, the Oregon Fish and Wildlife Commission (Commission) was petitioned by the Center for Biological Diversity, Defenders of Wildlife, and Whale and Dolphin Conservation to list Southern Resident orcas (*Orcinus orca*) as endangered under the Oregon Endangered Species Act (OESA). Under state statute (ORS 496.172 and 496.176), the Commission has management authority for threatened and endangered species in Oregon and is authorized to determine whether any wildlife species native to the state is a threatened or endangered species. Further, ORS 496.176 and OAR 635-100-0110 outline the process which the Commission follows upon receiving a state listing petition. On April 21, 2023, the Commission found that the petition to list Southern Resident orcas as endangered presented "substantial scientific information" to begin a rulemaking process, leading to a listing determination by the Commission in February of 2024.

Criteria for OESA Listing

In determining whether to list a species as state-threatened or endangered, the Commission must base its decision on documented and verifiable scientific information about the species' biological status and find that the natural reproductive potential of the species is in danger of failure due to limited population numbers, disease, predation, or other actions affecting its continued existence. To be listed, the population must also be undergoing deterioration of its range or habitat, be overutilized commercially, recreationally, or for scientific/educational purposes, or existing state or federal programs are inadequate to protect the species or its habitat (ORS 496.176; OAR 635-100-0105). Additional listing criteria outlined in OAR 635-100-0105 include requirements for the species to be native to Oregon and in danger of extinction throughout any significant portion of its range within the state. With respect to the species range within Oregon, the Commission shall consider the total geographic area in the state used by the species, the nature of the habitat (e.g., any unique or distinctive characteristics of the habitat used for breeding, resting, or foraging), and the extent to which the species habitually uses the geographic area within the state.

Federal, State, and International Status

The National Marine Fisheries Service (NMFS) designated the Southern Resident stock of killer whales (orcas) as depleted under the Marine Mammal Protection Act (MMPA) in 2003 (68 FR 31980). In 2005, NMFS listed the Southern Resident killer whale distinct population segment (DPS) as endangered under the U.S. Endangered Species Act (ESA) (70 FR 69903) and produced a Southern Resident killer whale recovery plan in 2008 (NMFS 2008). NMFS reviews the status of the Southern Resident killer whale DPS every five years, and in their most recent review in 2021, they concluded that the DPS should remain listed as endangered (NMFS 2021b). Southern Resident killer whales are also featured in NMFS's "Species in the Spotlight" program, which is intended to focus attention and resources on the species most at risk of extinction (NMFS 2023a).

The State of Washington added killer whales, including but not limited to the Southern Resident population, to its endangered species list in 2004 (WSR 04-05-110). The Washington Department of Fish

and Wildlife's (WDFW) latest status review in 2016 concluded that killer whales should remain listed as endangered in the state, primarily due to serious concerns with the Southern Resident population (Wiles 2016).

The Government of Canada, through the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), designated Southern Resident killer whales as endangered in 2001 and they are listed in Schedule 1 of the Species at Risk Act (SARA) (S.C. 2002, c. 29).

Purpose of Biological Assessment

The purpose of this biological assessment for Southern Resident orcas is to provide the Commission with documented and verifiable scientific information on the species' background and natural history, the current biological status of the population, the use and condition of its habitat, and threats affecting the population's continued existence. Our summary of current knowledge on Southern Resident orcas is based on the work of numerous agencies, organizations, and individuals over many years, and was compiled from agency reports, peer-reviewed articles, and the websites of various regional, federal, state, and local agencies and organizations. Where applicable, we have highlighted the population's connection to Oregon and the relevance of the available information to state listing criteria.

SPECIES BACKGROUND

Description

Killer whales, or orcas, are the largest member of the family Delphinidae (marine dolphins) and have a striking and easily recognizable black-and-white appearance. Males can attain lengths of 9.0 m (29.5 ft) and weights up to 5,568 kg (12,275 lb), while females may reach a length of 7.7 m (25.3 ft) and a weight of 3,810 kg (8,400 lb) (Dahlheim and Heyning 1999). The dorsal fin in males is taller and more pointed, but shorter and more curved in females. The prominent dorsal fins of orcas vary in size and shape and may have distinctive indentations or scars. The area of whitish-gray pigmentation just behind the dorsal fin, called a "saddle patch", also varies in size, shape, color, and presence of scratches or scars. These differences in dorsal fins and saddle patches are unique to individual orcas and allow members of populations such as the Southern Residents to be individually counted and monitored during annual censuses (Bigg et al. 1987; Center for Whale Research 2023a). It also enables detailed photographs of orcas taken by observers to be used for identification by matching them to cataloged photos compiled for the northeastern Pacific region (NMFS 2008).

Distribution

Orcas have the largest distribution of any cetacean and can be found in all the world's oceans. Globally, there are an estimated 50,000 orcas (NMFS 2023b). They are more common in coastal areas and northern latitudes, and the roughly 2,500 orcas inhabiting the eastern North Pacific Ocean are

distributed from the Aleutian Islands down along the west coast of North American (Dahlheim and Heyning 1999).

Taxonomy, Ecotypes, and Populations

Orcas are the only living species within the genus *Orcinus* (iNaturalist 2023), but their taxonomy at the subspecies level has been unclear (NMFS 2008). Two un-named subspecies of *O. orca* (eastern North Pacific resident killer whale and eastern North Pacific transient killer whale, or Bigg's killer whale; Krahn et al. 2004) have been proposed for official subspecies status; however, they are not currently listed as subspecies due to insufficient peer-reviewed evidence (The Society for Marine Mammalogy 2023).

Despite uncertainty regarding the classification of subspecies, orcas are clearly recognized as comprising a set of ecotypes that are genetically distinct and finely tuned to their ecological niches. These ecotypes in the eastern North Pacific include resident, transient, and offshore orcas. Differences in traits between the ecotypes, such as genetic makeup, body size and pigmentation, dorsal fin shape, vocalization patterns, social structure, and diet are maintained through a lack of interbreeding among ecotypes even when their distributions overlap (Riesch et al. 2012).

Resident Orcas

Resident orcas range from Alaska to California and are comprised of four distinct populations or communities: Southern, Northern, Southern Alaska, and Western Alaska (Krahn et al. 2004). Resident orcas in the northeastern Pacific region are distinguished by having dorsal fins that are more curved and rounded than transient and offshore orcas, and by relying almost entirely on fish for their diet, particularly Pacific salmon (*Oncorhynchus spp*.). Resident orcas also have different vocalization patterns than transient and offshore orcas and live in relatively large and stable pods (Ford et al. 2000).

Southern Residents—This population consists of three pods designated J, K, and L pods. Although their known range extends from southeastern Alaska to central California, they primarily spend the late spring, summer, and fall in the inland marine waters of Washington State and southern British Columbia—Puget Sound, the Strait of Juan de Fuca, and the Strait of Georgia—collectively referred to as the Salish Sea (Ford et al. 2000). During the winter and early spring, two of the Southern Resident pods (K and L) spend a considerable amount of time off the coasts of Washington, Oregon, and northern California. Recent research has highlighted the importance of these coastal areas for the Southern Residents during winter and spring (NMFS 2021a; NMFS 2021b) and will be discussed in greater detail later in this report.

Northern Residents—This population is comprised of 16 pods (A1, A4, A5, B1, C1, D1, H1, I1, I2, I18, G1, G12, I11, I31, R1, and W1) and ranges from southeastern Alaska to the outer Washington coast. The Northern Residents spend much of the year along the northern part of Vancouver Island in Johnstone Strait and Queen Charlotte Strait (Ford et al. 2000, 2017). Even though the ranges of the Northern Resident and Southern Resident populations overlap, the two communities do not appear to intermix, and genetic analyses indicate that they are likely reproductively isolated from each other (Ford et al. 2000; Barrett-Lennard and Ellis 2001).

Southern Alaska Residents—At least 25 pods make up this resident population, although information on some of them is limited (Matkin et al. 2003). Southern Alaska Residents occur in the waters of southeastern Alaska and the Gulf of Alaska, including Prince William Sound, Kenai Fjords, and the area around Kodiak Island (Dahlheim et al. 1997; Matkin et al. 1997). Genetic analyses indicate that this population is closely related to both the Northern Residents (Barrett-Lennard and Ellis 2001) and Western Alaska Residents (Hoelzel 2004), suggesting that occasional interbreeding may occur between these populations.

Western Alaska Residents—This population is thought to be the largest resident orca community; however, the exact number of pods is unknown. Their distribution extends from Kodiak Island west to the Aleutian Islands and Bering Sea (Krahn et al. 2004). This relatively remote population has not been studied as extensively as the other resident communities.

Transient Orcas

Transient orcas live in smaller pods (often <10 individuals) compared to resident orcas and their social structure is more fluid (Ford and Ellis 1999; Baird 2000). Their diet consists primarily of marine mammals such as harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and various porpoise species (Ford et al. 1998). Transient orca dorsal fins have a more pointed tip than resident or offshore orcas (Ford and Ellis 1999; Ford et al. 2000). Transients in the eastern North Pacific have been identified as belonging to one of three genetically distinct groups: 1) West Coast transients (southern California to southeastern Alaska), 2) Gulf of Alaska transients (Gulf of Alaska, Aleutian Islands, and Bering Sea), and 3) the AT1 pod (Prince William Sound and Kenai Fjords) (Ford and Ellis 1999; Barrett-Lennard and Ellis 2001). Little or no intermixing occurs among the transient groups. Transient orcas also do not associate with resident or offshore orcas even where their ranges overlap. Interestingly, there is some evidence which suggests that transient and resident orcas may deliberately avoid each other when traveling on intersecting routes (Baird 2000).

Offshore Orcas

Less is known about offshore orcas due to their tendency to occur in waters 15 km (9 mi) or more offshore and the scarcity of their sightings. Offshore orcas have been sighted as far as 500 km (311 mi) off the Washington coast but may sometimes enter coastal and inland marine waters (Krahn et al. 2002). Offshore orcas have the largest geographic range of the eastern North Pacific ecotypes, extending from southern California to the Aleutian Islands and Bering Sea (Ford and Ellis 1999; Krahn et al. 2002). They travel in groups of 2–70 individuals, with group membership being very fluid. Offshore orcas are thought to primarily feed on sharks, with teleost fishes such as salmon and halibut comprising a much smaller portion of the diet. Groups of offshore orcas have been known to make extensive movements (≥4,400 km [2,734 mi]) within their range, particularly to northern areas during the spring, summer, and fall (Ford et al. 2014). Offshore orcas do not mix with resident or transient orcas and genetic analyses indicate that they appear to be reproductively isolated from the other ecotypes (Barrett-Lennard and Ellis 2001).

SOUTHERN RESIDENT ORCA NATURAL HISTORY

Social Organization

Like other orcas, the Southern Resident orcas are highly social animals. The basic and most important social unit is the matriline, a stable and hierarchical family group based on maternal descent. It typically consists of a female and her sons and daughters, along with her daughters' offspring, and may include one to five generations (Ford et al. 2000; Ford et al. 2014). Members of a matriline maintain very strong bonds and usually do not separate from the group for more than a few hours or by more than a few kilometers. Matriarchal females appear to hold important knowledge critical for social functioning and survival that is passed on to the members of the matriline (Boran and Heimlich 1999).

Groups of related matrilines are known as pods. A pod is typically comprised of one to four matrilines (although some pods have had as many as 12 matrilines) which share a common maternal ancestor and associate more closely with each other than with matrilines from other pods (Baird 2000; Ford et al. 2000). Pods are less cohesive than matrilines and member matrilines may spend up to several weeks or even months apart from the rest of the pod. Resident orcas in general tend to live in larger pods than transient and offshore orcas, possibly conferring an advantage when attempting to detect and pursue schools of fish (Ford et al. 2000). As of the 2022 census for the Southern Residents, J pod had 25 members, K pod had 16 members, and L pod had 32 members—a total population size of 73 orcas (Center for Whale Research 2023b). In July of 2023, researchers confirmed the presence of two new calves (one female and one male) in L pod (Center for Whale Research 2023c). These are the first calves born in L pod since 2021, and the first calf for one of the mothers. As of this writing, results from the 2023 census were not yet available as surveys are generally completed at the end of October. Changes in pod structure and cohesion occur with the births and deaths of individual members. Deaths of matriarchal females have sometimes led to the fragmentation of matrilines, having a profound effect on their structure and functioning (Ford et al. 2000).

Clans are composed of pods which share similar vocal dialects and whose members are related, but in the more distant past. Clans often overlap in their geographic ranges and pods from different clans have frequently been observed intermingling. The three Southern Resident pods all belong to one clan designated as "J" (Ford et al. 2000).

The highest level of social organization for resident orcas is the community (population). Communities are based on association rather than relation or vocal similarities. The Southern Resident orcas are a community consisting of three pods and one clan. Because there is only one clan in the Southern Resident community, all members of the community happen to be related. This is not the case in larger communities such as the Northern Resident community which is comprised of 16 pods in three clans (A, G, and R; OrcaLab 2023). NMFS's decision to list the Southern Resident orcas was partially based on the conclusion that the Southern Resident community was discrete from other North Pacific resident orcas and that it was significant with respect to North Pacific resident taxon (NMFS 2008).

Vocalizations and Hearing

Vocal communication is highly advanced in orcas and is critical to social functioning and survival. Like other dolphins, orca vocalizations consist of several different types that are used for communication between individuals, navigation, and foraging (Ford 1989; Miller et al. 2004). The three main categories of sounds produced by orcas include echolocation clicks, tonal whistles, and pulsed calls (Ford 1989). Clicks can be emitted singly or in click trains and are primarily used for navigation and detecting prey and other objects in the environment. Whistles may be used for different purposes among communities. For example, Southern Residents use whistles for both long-range communication (e.g., during foraging or travel) and close-range social interactions while Northern Residents use whistles almost exclusively for social interaction (Riesch et al. 2006). Pulsed calls are the most common type of vocalization in orcas and sound like squeaks, screams, or squawks to humans. Discrete calls are primarily used for maintaining contact with other members of the group during foraging or travel, especially at distances beyond visual range (Ford 1989; Ford et al. 2000).

The vocal repertoires of orcas consist of several specific types of calls which together form a dialect. Dialects are complex, stable, and unique to individual pods. Orcas likely learn their dialect from their mothers and other members of the pod early in life, and these dialects are an important way for pods to maintain group identity and cohesiveness (Ford 1989; Miller and Bain 2000).

Orcas detect sounds through the lower jaw and other portions of the head, where they are transmitted to the middle and inner ears (Møhl et al. 1999). Orcas have been found to have the most sensitive hearing of all the toothed whales (which includes dolphins), and their hearing appears to be most sensitive around 20 kHz, which corresponds closely with the peak energy of orca echolocation clicks (Szymanski et al. 1999).

Diet and Foraging

Orcas are a top marine predator, and while orcas in some parts of the world are known to be generalists, populations inhabiting the eastern North Pacific likely evolved to specialize in certain prey resources that were historically abundant year-round within their range (Ford 2002). Furthermore, they appear to have developed specific foraging strategies that reflect the nature and behavior of their prey. For example, transient orcas, which feed on marine mammals, forage in small groups and minimize vocalizations to avoid detection by their wary prey (Ford and Ellis 1999). On the other hand, resident orcas mostly consume fish such as salmon, and forage in larger groups, which may aid in detecting and capturing smaller and more dispersed prey (Ford et al. 2000). Noteworthy aspects of orca foraging behavior include cooperative hunting, food sharing, and innovative learning (Felleman et al. 1991; Hoelzel 1993; Ford and Ellis 2006). All these characteristics have been observed in Southern Resident orcas and these behavioral traditions are likely passed from generation to generation through social learning (Ford et al. 1998). Knowledge of productive foraging areas may also be passed along in a similar manner.

Behavioral traditions likely play a role in determining acceptable prey types for orca populations. For example, Southern Resident orcas have been observed killing harbor porpoises, but the porpoises were not consumed (R. W. Baird, unpublished data *in* NMFS 2008). Also, sea lions and porpoises have been

frequently observed swimming near resident orcas without any signs of alarm or attempts to avoid the orcas, suggesting that the resident orcas do not present a threat to them (Ford et al. 1998). Within acceptable prey types, such as fish for resident orcas, other factors such as prey availability (abundance and catchability) and prey profitability (energy return from prey vs. energy expended in capture) may largely determine which specific prey species are sought (Bowen et al. 2002).

Earlier studies on the diet of resident orcas, including the Southern Residents, focused on the waters around Vancouver Island and parts of the Salish Sea, and most of the data were from the summer and early fall (June–November) when both Northern Residents and Southern Residents congregate in the area. These studies found that during this time of the year resident orcas fed almost exclusively on salmonids (~96% by prey type) with Chinook salmon accounting for 65–72% of the salmonids taken (Ford et al. 1998; Ford and Ellis 2006). Because Chinook salmon were not the most abundant salmonid present during the sampling timeframe (Sockeye and Pink salmon were much more abundant), but comprised most of the prey consumed, researchers suggested that Chinook salmon may be selected over other salmon species by resident orcas. However, there was some concern that because prey samples only included fish scales and tissue fragments collected from the water surface after feeding events, the samples were potentially biased against prey species not brought to the surface. Subsequent studies that included collection of fecal samples (which are presumably less biased toward surface feeding), and were focused more on the Southern Resident population, confirmed the importance of salmonids, and especially Chinook salmon, in the diet of Southern Resident orcas (Hanson et al. 2010; Ford et al. 2016; Hanson et al. 2021). It may be that Chinook salmon are preferred by Southern Residents because of their relatively large size and high fat content, which would provide a high energy return for orcas (Ford and Ellis 2006). Chinook salmon have a higher total energy content than other salmon species, and O'Neill et al. (2014) estimated that it would take approximately three Coho, Chum, or Sockeye or six Pink salmon to equal the energy content of one Chinook salmon. Researchers have found that orcas can detect and distinguish Chinook salmon from other salmon species due to their differing echo signature (Au et al. 2010). Coho salmon were the second most common salmonid consumed during the summer (Ford et al. 2016), but in the fall, Chum salmon became an important part of the Southern Resident diet in Puget Sound (Hanson et al. 2021).

More recent studies have started to fill in information gaps and provide greater detail on the diet of Southern Resident orcas. To address the lack of information on the Southern Residents' diet during the winter and spring, and in little-studied areas such as the outer coastal waters, Hanson et al. (2021) collected and analyzed prey remain samples (fish scales and tissue, n = 54) and fecal samples (n = 28) from Southern Resident orcas between January and May off the coasts of Washington, Oregon, and California. They utilized data from satellite tagged Southern Residents to track the orcas in outer coastal waters and obtain samples (Hanson et al. 2017). Like previous studies in the summer and fall, Chinook salmon were found to be an important component of the winter-spring diet, comprising about 67% of the prey consumed in outer coastal waters (based on analysis of fecal samples) (Figure 1). The prey species composition from fecal samples tended to be more varied than species compositions obtained from scale and tissue samples, particularly during the winter. The broader Southern Resident diet during winter, which included more steelhead and non-salmonids such as ling cod, halibut, and other flatfishes, may reflect the lack of their preferred prey, Chinook salmon, during that time (Hanson et al. 2021). The researchers found that by April and May, Chinook salmon were once again dominant in the diet.

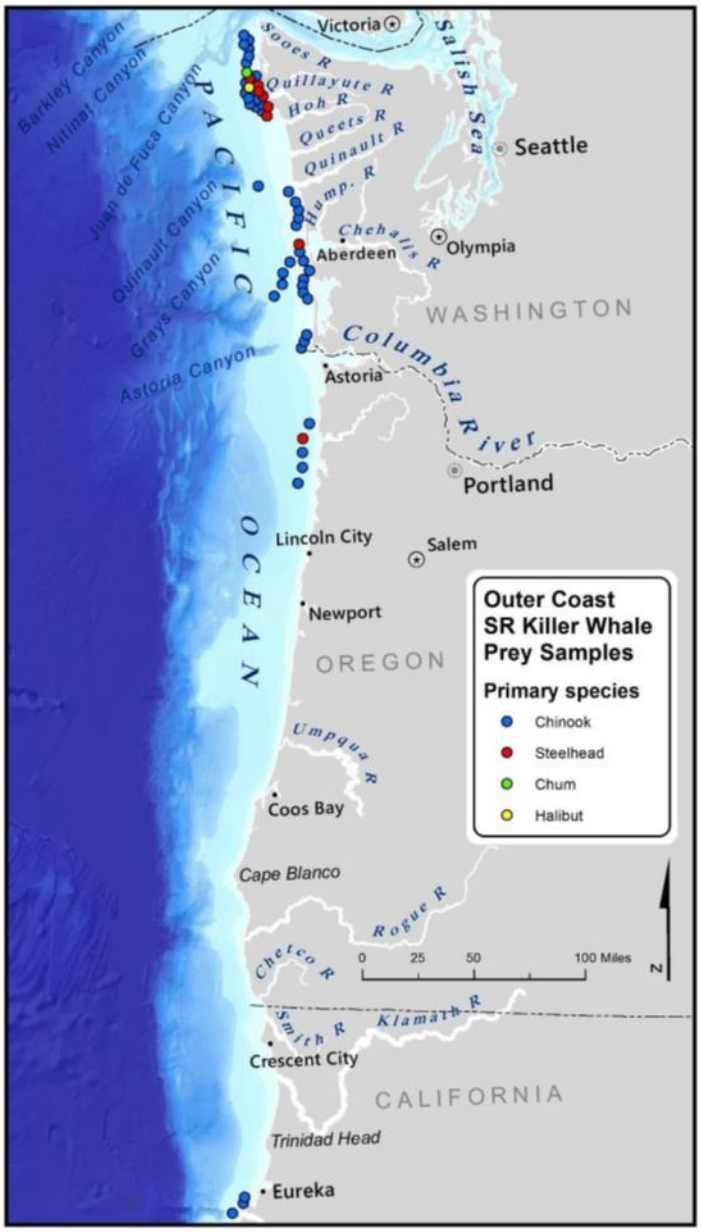

Figure 1. Location and species associated with scale and tissue samples taken from prey remains of Southern Resident orcas in outer coastal waters during winter and spring (NMFS 2021a, see Hanson et al. 2021).

Genetic stock identification methods have been useful in identifying the Chinook salmon stocks that contribute to the Southern Residents' diet. Generally, the Southern Residents consumed Chinook salmon stocks close to their natal rivers—e.g., Puget Sound stocks in Puget Sound, Fraser River stocks near the San Juan Islands, and Columbia River stocks along the Washington coast and near the mouth of the Columbia. However, non-local stocks were also important at certain times. For example, almost half of the Chinook salmon remains collected in Puget Sound during the fall were from stocks outside of Puget Sound, including Columbia River fall Chinook (Hanson et al. 2021). Therefore, migrating Chinook salmon that are still far from their natal river can also contribute to the Southern Residents' diet. Overall, Southern Resident orcas were found to consume a wide variety of Chinook salmon stocks from a large

swath of the North American west coast, ranging from the Sacramento River in California to the Taku River in northern British Columbia. Having access to a diverse mix of Chinook salmon stocks throughout the year may provide the Southern Residents with greater resiliency in their diet, especially as Chinook salmon stock abundances fluctuate (Hanson et al. 2021).

Columbia River Chinook

In the outer coastal waters of Washington, Oregon, and California, Columbia River Chinook salmon comprised nearly 54% of the prey samples collected during the winter and spring, with most of the samples collected off the Washington coast. Hanson et al. (2021) reasoned that the high proportion of samples from Columbia River stocks was due to: 1) the relatively large amount of time that Southern Residents (K and L pods) spend near the Columbia River mouth (NMFS 2021a), 2) the high density of Columbia River Chinook salmon moving through the area during seasonal spawning migrations, and 3) the relatively large number of Chinook salmon returning to the Columbia River compared to other West Coast rivers. Columbia River Chinook salmon stocks contributing to the Southern Residents' winter-spring diet in outer coastal waters are listed in Table 1. The results of the genetic analysis suggest that spring and fall Chinook salmon originating from the lower Columbia River account for 27% of the Southern Residents' diet during the winter and early spring. These are the stocks most likely to have origins in Oregon tributaries and hatchery salmon release areas. Of note, no Chinook salmon from Oregon coastal rivers were collected in prey samples in coastal waters; however, Rogue River Chinook salmon (unknown race) were found in prey samples from Puget Sound (Hanson et al. 2021).

Table 1. Columbia River Chinook salmon stocks contributing to the Southern Resident orcas' diet in outer coastal waters during winter and early spring. [1]

Stock	Percent of Total Prey Samples
Lower Columbia Spring	17.5%
Lower Columbia Fall	9.9%
Mid/Upper Columbia Spring	4.6%
Mid-Columbia Fall (Tule)	10.0%
Upper Columbia Summer-Fall	9.4%
Snake Spring-Summer	2.2%
Columbia River Total	**53.6%**

[1] From Hanson et al. 2021.

Prey Requirements

Estimating the prey requirements of Southern Resident orcas is challenging because data on body mass, and field metabolic rates, two variables that largely determine the amount of prey needed to meet daily energy requirements, are difficult to obtain from wild orcas. Moreover, metabolic rates are influenced by several factors such as age, body size, growth, reproductive status, activity level, and environmental conditions (Noren 2011). Therefore, researchers have had to adjust data collected from captive and live-captured orcas to model these parameters in a wild population such as the Southern Residents. Noren (2011) estimated daily prey energy requirements for Southern Resident orcas ranging from 41,376–

130,246 kcal per day for whales between 1 and 6 years of age, to 149,972–217,775 kcal per day for females > 12 years of age, and 155,885–269,458 kcal per day for males > 12 years of age. Assuming a hypothetical diet consisting solely of Chinook salmon with an energy density of 16,386 kcal/fish, the 2008 Southern Resident population would have required an estimated 289,131–347,000 Chinook salmon per year. Based on their own modeling of energy requirements for the 2009 Southern Resident population, and research indicating that Chinook salmon comprised 83% of the Southern Residents' diet during the summer months (90% Fraser River stock), Williams et al. (2010) estimated that the population could consume between 42,000 and 97,600 Fraser River Chinook salmon during their May–September residence in the waters around the San Juan Islands. They also estimated a total annual requirement of 211,600–364,100 Chinook salmon for the Southern Resident population, although this was also based on an exclusively Chinook salmon diet. Estimating the number of Chinook salmon needed annually in the Southern Residents' diet is complicated by the fact that the Southern Residents do not exclusively prey on Chinook salmon, sometimes consuming a more diverse diet—e.g., during winter months in outer coastal waters (Hanson et al. 2021). Chinook salmon stocks also vary in their caloric content (Noren 2011), and since Southern Resident orcas consume Chinook salmon from a variety of stocks throughout the year (Hanson et al. 2021), precisely estimating the number of Chinook salmon that they require to meet their annual energy needs is difficult.

Reproduction and Growth

Orcas, in general, are polygamous and males usually mate with females outside of their own pods (Dahlheim and Heyning 1999), which helps to reduce the risk of inbreeding (Barrett-Lennard and Ellis 2001). Differences in dialect may assist males in distinguishing females from other pods (Ford 1989; Ford et al. 2000). Orcas in the eastern North Pacific typically mate from April to October (Olesiuk et al. 1990), although the birth of calves in all months indicates that mating can occur at any time of the year. Estimates of average calving intervals (the time between births of surviving calves for a reproductive female) in resident orcas vary from 4.9 to 7.7 years (Olesiuk et al. 1990; Krahn et al. 2004). The average calving interval reported for Southern Resident females is 6.1 years (NMFS 2021b). Gestation periods in orcas are prolonged and average 17 months for captive orcas (Robeck et al. 2004). Births of calves usually occur between September and December, but as previously noted, can take place at any time of the year (Olesiuk et al. 2005). Only single calves are born and sex ratios at birth likely average 1:1 (Dahlheim and Heyning 1999). Newborns average 2.2–2.7 m (7.2–8.9 ft) in length and weigh about 200 kg (440 lb) (Olesiuk et al. 1990; Ford 2002).

Calves remain close to their mothers during the first year, and although the exact time of weaning is unknown, it likely occurs between 1 and 2 years of age. Calves may begin taking solid food from their mothers as early as about 3 months of age (Haenel 1986; Kastelein et al. 2003). Young orcas are very active and curious, and typically spend more time with siblings and other members of the pod as they get older (Haenel 1986). Growth rates in orcas have been reported to be linear during the first 9–12 years for females and first 12–16 years in males, after which growth slows in both sexes (Bigg 1982; Duffield and Miller 1988). Orcas continue to grow until they reach physical maturity at 16 to 25 years of age (Olesiuk et al. 2005). Most wild orca females in the eastern North Pacific give birth to their first calf at between 12 and 17 years of age. Resident females can be reproductively active for 20 to 24 years and produce an average of 2.2 to 4.1 surviving calves during that time. Females continue to breed until about

38–45 years of age, after which they enter a post-reproductive phase that lasts for 10–30 years until their death (Olesiuk et al. 1990, 2005). The dorsal fins in male resident orcas begin to enlarge or "sprout" at 11–15 years of age, signaling the onset of sexual maturity. Male orcas remain sexually active throughout their lives (Olesiuk et al. 1990).

Longevity and Mortality

At birth, the average life expectancy of Southern and Northern Resident orcas is 29 years for females and 17 years for males. However, if a calf survives the first six months, life expectancy increases to 30–46 years for females and 19–31 years for males. Maximum life span is estimated to be 80–90 years for female resident orcas and 60–70 years for males (Olesiuk et al. 1990, 2005).

Mortality curves are U-shaped for resident orcas of both sexes, with high mortality rates for calves in the first six months of life (upwards of 37–50%) and post-reproductive females >50 years of age (4.7–6.8%). Mortality is relatively low for juveniles and females of reproductive age. Overall, an estimated 61–82% of calves may reach maturity (Olesiuk et al. 1990, 2005). After reaching sexual maturity, mortality rates for male resident orcas generally continue to increase throughout their lives (Olesiuk et al. 2005). Seasonal mortality rates for resident orcas have not been assessed; however, there is some reason to believe that mortality rates are higher during winter and spring as individual orcas more often "go missing" after the summer census and prior to the next year's census (J. K. B. Ford, personal communication; K. C. Balcomb, personal communication *in* NMFS 2008).

Sources of Mortality

Natural Mortality—As orcas have no natural predators (other than humans), natural causes of mortality are often difficult to identify. Animals usually sink after dying, so the only opportunity to examine carcasses comes from the relatively infrequent strandings of individual orcas. Therefore, identifying the source of high mortality in calves has been challenging (Baird 2000; Ford 2002). Nevertheless, a couple of potential sources of natural mortality for orcas include lack of food (nutritional stress) and disease. Recent developments in aerial photogrammetry and fecal sample analysis have allowed researchers to assess body condition and hormone levels, respectively, in Southern Resident orcas. Studies have documented poor body condition in some Southern Resident orcas (some of which disappeared from the population), and Stewart et al. (2021) found that orcas in poor body condition had a mortality probability 2–3 times higher than orcas that were in a more robust condition. Researchers also found that the Southern Residents were under nutritional stress at certain times of the year, such as during their summer residence in the Salish Sea. Interestingly, nutritional stress was lower in the early spring when the Southern Residents first arrive in the Salish Sea, suggesting that they had been feeding on prey of high nutritional value during their time in outer coastal waters. This may further highlight the importance of Columbia River spring Chinook salmon in the early spring diet of Southern Resident orcas (Wasser et al. 2017; NMFS 2021a).

Although orcas are susceptible to a variety of diseases that commonly affect them and other marine mammals, identifying mortalities due to specific diseases is extremely difficult because of the lack of opportunity to examine carcasses (NMFS 2008). No pathogens have been known to cause epidemics in

orca populations (Gaydos et al. 2004) and NMFS does not currently consider infectious disease to be a limiting factor for the Southern Residents (NMFS 2021b). However, emerging diseases such as mucormycosis, which is caused by a fungal pathogen first observed in the Pacific Northwest in 2012, have caused the death of at least one Southern Resident orca and could become a threat in the future (NMFS 2021b). Recent research has also identified skin lesions on almost all the Southern Residents. Although the lesions were not correlated with mortality, they could be related to decreased immune system function (Gaydos et al. 2023). Overall, there is concern that because of the Southern Residents' small population size, tendency to congregate during the summer, and highly social nature, a disease outbreak within the community could lead to high mortality (NMFS 2008).

Human-Related Mortality—Direct mortality due to humans has occurred in the past from harvest by indigenous peoples, commercial exploitation, attempts at predator control, and during capture for the aquaria trade. The extent to which indigenous peoples in the northeastern Pacific region hunted and utilized orcas is uncertain due to limited documentation. However, it is known that many coastal North American tribes revered orcas and considered it taboo to kill them (NMFS 2008). Commercial hunting of orcas dates to the 1700s in Japan, but never became prominent globally due to the limited amounts of oil that could be extracted from orcas, their small populations, and the relative difficulty in capturing them. While it is probable that commercial exploitation reduced populations of orcas in some parts of the world where harvest was larger, limited commercial harvest of orcas in the eastern North Pacific likely had little impact on populations in the region (NMFS 2008).

Even when not directly exploited for commercial purposes, orcas have been killed or wounded by whalers, seal hunters, and fishers (commercial and sport) when perceived to be a competitor for desired resources (NMFS 2008). In some cases, governments supported lethal control measures on orcas. Deaths from deliberate shootings of orcas were likely common in some areas, as approximately 25 percent of orcas captured in Puget Sound for aquaria prior to 1970 had scars from bullets. Although hostility towards orcas has generally abated, it continues to persist where orcas are believed to interfere with human economic activities (e.g., stealing fish from longline fishing gear).

Mortalities also occurred during capture operations for aquaria in the 1960s and 1970s. Puget Sound was a preferred capture location due to its numerous small bays and shallow waters, which made it more difficult for orcas to escape the capture gear. Focusing capture operations on Puget Sound had a disproportionately large effect on the Southern Residents, with 48 of the 68 orcas (70%) retained for aquaria (36) or dying during capture (12) coming from the Southern Resident population (NMFS 2008). Although technically alive, the captive Southern Residents were permanently removed from the population, so from a population standpoint, they would be considered as mortalities, which had a profound and long-lasting impact on the population. The last surviving Southern Resident orca in captivity died in August of 2023.

Sources of incidental mortality include drowning from entanglement in fishing gear and vessel strikes. The available data suggest that gear entanglement is a relatively minor source of fishing-related mortality for orcas. They have been observed avoiding nets by swimming around or underneath them, and not all entanglements resulted in death (Jacobsen 1986; Matkin 1994). Resident orcas have been

injured or killed after being struck by vessels ranging from tugboats to speed boats (usually by the propeller), but these collisions are thought to be relatively rare events (NMFS 2008).

Currently, human-related sources of orca mortality of an indirect nature are more common than direct, targeted mortalities. Potential sources of indirect mortality include systemic pollution and oil spills. Because orcas are at the top of the food chain, they encounter pollutants primarily through the consumption of contaminated prey (with mothers passing on contaminants to calves through nursing). Major oil spills, though relatively infrequent, can have devastating consequences for orca populations. The *Exxon Valdez* oil spill in Prince William Sound, Alaska in 1989 resulted in unprecedented mortalities for resident and transient orca pods in Southern Alaska (Matkin et al. 1994). Pods that were in the most heavily oiled waters sustained the highest mortalities with AB pod losing 14 of its 36 members within two years, and AT1 pod losing 10 of its 22 members within the same timeframe.

Habitat Use

As a species, orcas can be found in a variety of marine habitats around the world that provide adequate prey resources, and they do not appear to be constrained by water depth, temperature, or salinity (Baird 2000). Knowledge of productive feeding areas or sites used for other purposes such as “beach rubbing” (by Northern Residents) likely determine specific habitats used by orcas, and this important information is passed from one generation to the next (Ford et al. 1998). However, habitat use by orcas is also considered dynamic, and to date, specific resting, breeding, and calving areas have not been documented (NMFS 2021a). Resident orcas in inland marine waters tend to spend more time in deeper water and rarely enter water <5 m (~16 ft) in depth (Heimlich-Boran 1988; Baird 2000). Foraging may take place in the upper 30 m (~100 ft) of the water column over deep open water and along sloped areas, or near bottom topography characterized by subsurface canyons and ridges (Heimlich-Boran 1988; Felleman et al. 1991; Hoelzel 1993). Resting and socializing usually take place in open water.

The distribution of resident orcas is strongly associated with areas of greater salmon abundance (Heimlich-Boran 1988; Felleman et al. 1991). All three Southern Resident pods spend part of the year (primarily late spring, summer, and fall) in the Salish Sea (Figure 2; Ford et al. 2000; Krahn et al. 2002). The waters around the San Juan Islands (e.g., Haro and Rosario straits) are an important foraging area during the summer as Fraser River salmon pass through the area during their migration to their natal river (Hanson et al. 2021). The Southern Residents’ use of these inland marine waters has been extensively studied since the 1970s (NMFS 2008).

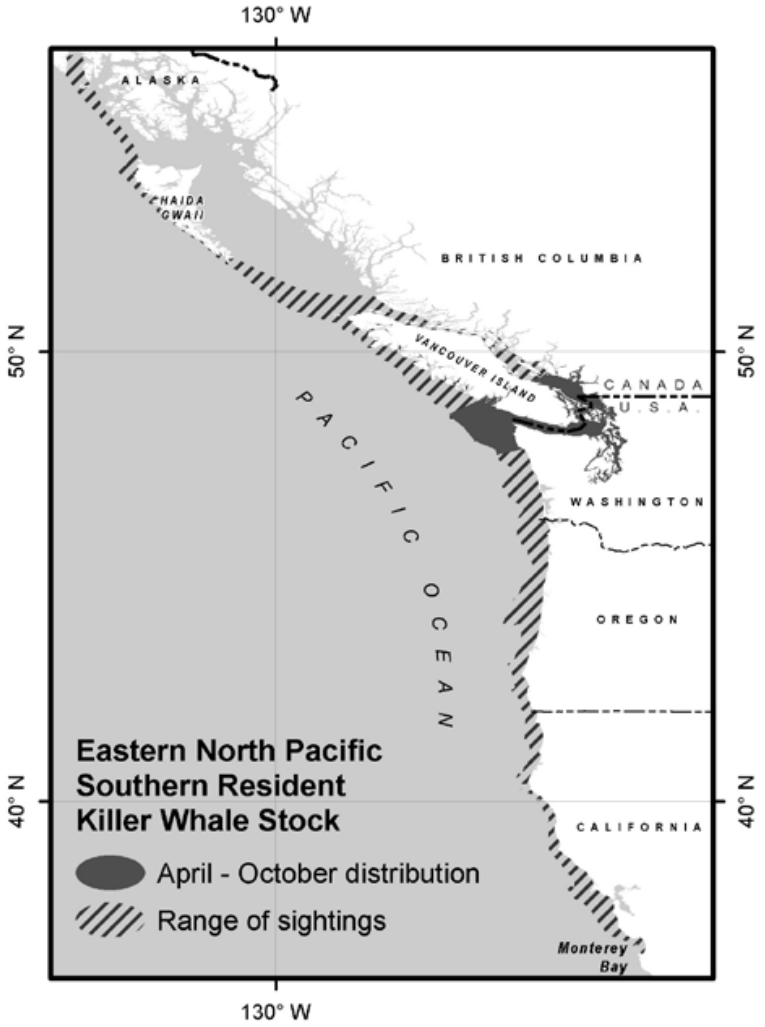

Figure 2. Approximate distribution of Southern Resident orcas during late spring, summer, and fall (shaded area) and range of sightings (diagonal lines) (Carretta et al. 2019).

Southern Resident orcas have been documented as far north as southeastern Alaska and as far south as central California (Figure 2); however, until recently, there has been very little information on the Southern Residents' use of the outer coastal waters off Washington, Oregon, and California (NMFS 2021a). Consequently, when NMFS designated critical habitat for the Southern Resident killer whale DPS in 2006, they only included three areas: 1) the Summer Core Area (Haro Strait and waters around the San Juan Islands), 2) Puget Sound, and 3) the Strait of Juan de Fuca (Figure 3; 71 FR 69054). NMFS recognized that other areas within their jurisdiction such as the outer coastal waters were used by Southern Residents; however, because of the lack of data for these areas, they did not include them in the critical habitat at the time (NMFS 2008). Since then, research has focused on learning more about the Southern Residents' winter-spring distribution, as well as collecting more detailed information on their use of the outer coastal waters (NMFS 2021a).

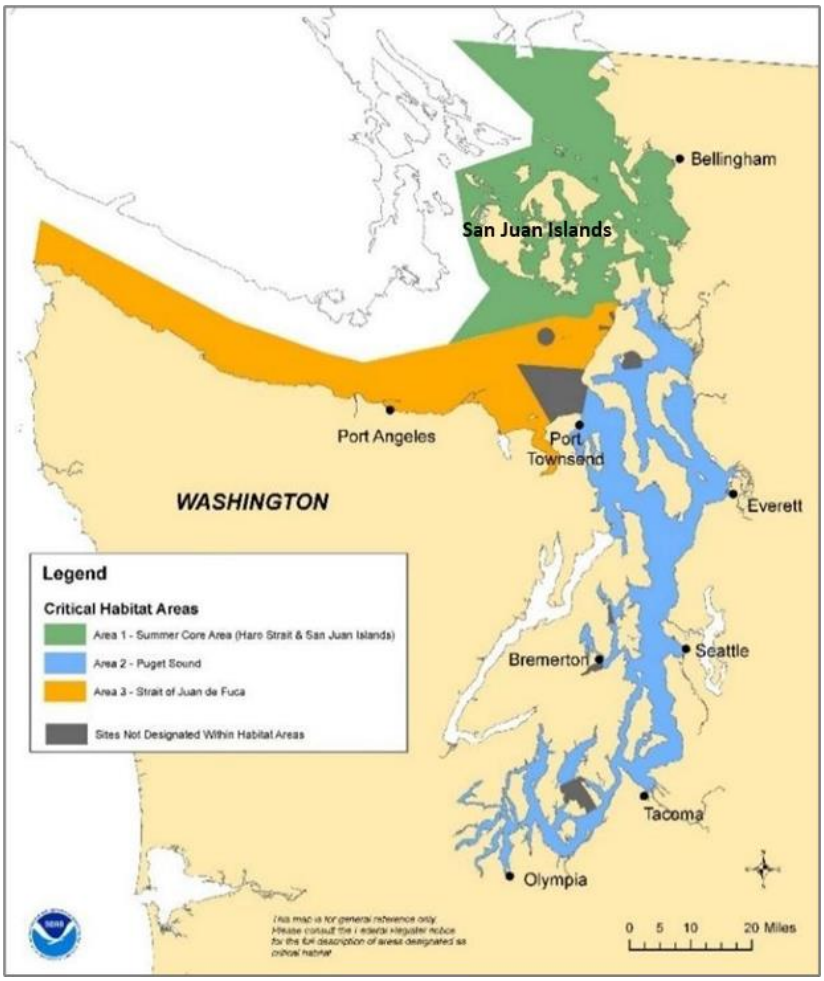

Figure 3. Areas included in 2006 designation of Southern Resident killer whale DPS critical habitat (NMFS 2021a).

Efforts to learn more about the Southern Residents' winter range have included use of land- and vessel-based visual sightings (both opportunistic and survey-based), acoustic research, and satellite tracking of tagged orcas (NMFS 2021a). Sightings since 2005 from both public observers and ship-based researchers have provided updated information on the location and timing of Southern Resident orcas present off the coasts of Washington, Oregon, and California (Figure 4). The new sightings data confirmed the southern extent of the Southern Residents' range (near Monterey Bay, California) and highlighted some potentially important areas for Southern Residents such as the Westport, Washington area (Grays Harbor), mouth of the Columbia River, and San Francisco and Monterey bays. Currently, an orca sightings network in Oregon, comprised of approximately 10,000 members of the public, is collecting additional sightings data on orcas, including Southern Residents, off the Oregon Coast (J. McInnes, University of British Columbia, personal communication).

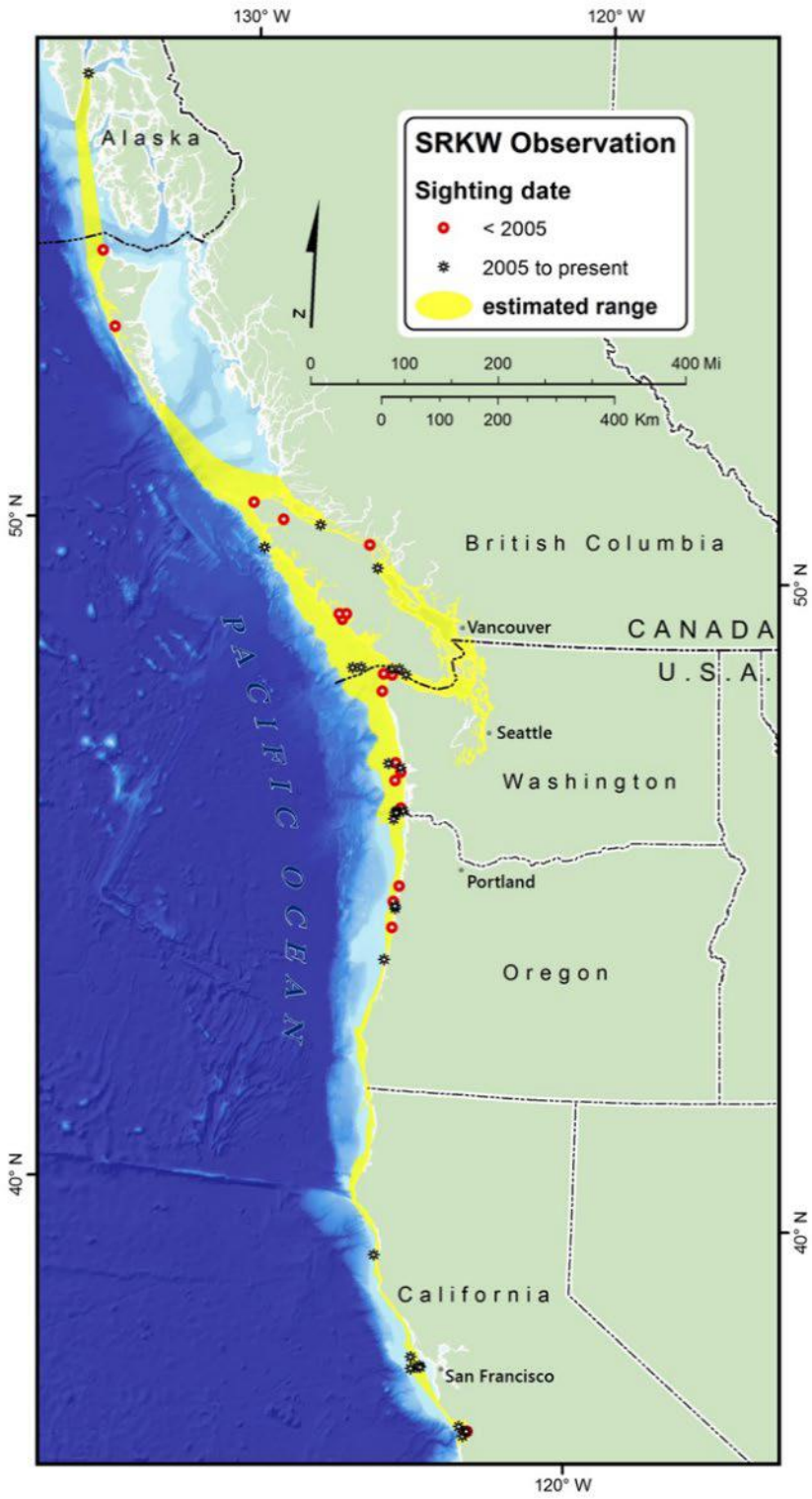

Figure 4. Visual sightings of Southern Resident orcas in outer coastal waters, 1975-2016 (NMFS 2021a, see Hanson et al. 2017).

Since resident orcas have pod-specific dialects, each of the Southern Resident pods can be identified acoustically by their signature calls (Hanson et al. 2013). This provides an opportunity to passively detect

Southern Resident orcas using acoustic recorders. Beginning in 2006, acoustic recorders were deployed along the coasts of Washington, Oregon, and northern California (Figure 5; NMFS 2021a).

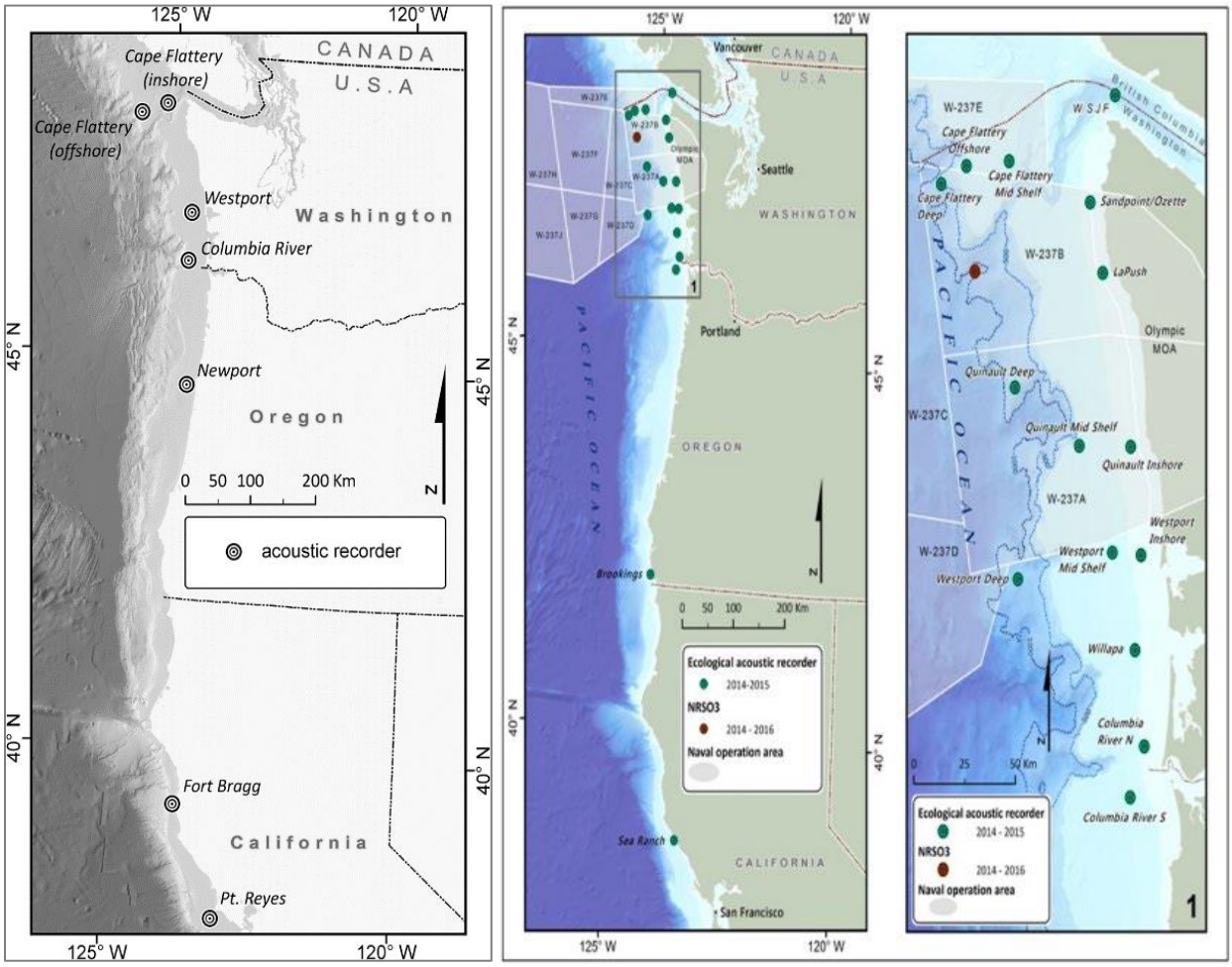

Figure 5. Acoustic recorders deployed in outer coastal waters during 2006-2011 (left; Hanson et al. 2013) and 2014-2015 (middle; Hanson et al. 2017). The right panel shows the recorders between Cape Flattery, Washington and the Columbia River in greater detail.

Data collected from the recorders indicated that Southern Residents (K and L pods) spent a relatively large amount of time off the outer coast of Washington, with detections occurring in every month of the year (Hanson et al. 2013; NWFSC unpublished data *in* NMFS 2021a). The third Southern Resident pod, J pod, was only detected infrequently on the northernmost recorders. K and L pods were also detected off the Oregon and northern California coasts during the winter months. Of note, K and L pods appeared to spend more time near the mouth of the Columbia River during the late winter and early spring than might be expected based on the amount of recording effort in the area (Hanson et al. 2013). Their presence near the Columbia River coincided with the return timing of spring Chinook salmon to the river, highlighting the importance of this stock to the Southern Residents' winter-spring diet. Passive acoustic data alone may underestimate the presence of the Southern Residents in outer coastal waters because recorders cannot detect animals that are not vocalizing, and vocalizations can be missed due to noise from storms or vessel traffic (NMFS 2021a).

A relatively recent development is the use of satellite tags to track the movements of Southern Resident orcas. Between 2012 and 2016, eight satellite tags were deployed on Southern Residents (2 from J pod, 2 from K pod, and 4 from L pod; NMFS 2021a). All tagged orcas were adult males. The tracking data generally confirmed the location and timing information derived from acoustic recorders and opportunistic sightings, although the tagged orcas did not travel to the southernmost extent of the sightings. Members of J pod spent very little time in outer coastal waters, but members of K and L pods regularly used the coastal waters off Washington and Oregon during the winter months (Hanson et al. 2017). The tracking data also provided details on the Southern Residents' preferred depths and distances from shore during their coastal migrations. The tagged orcas spent almost all (97%) of their time in waters ≤200 m (656 ft) in depth and were rarely in waters <18 m (59 ft) deep. They appeared to exhibit a preference for waters in the 18 m (59 ft) to 54 m (177 ft) range. In addition, almost all locations from the tagging data (95%) were within 34 km (21 mi) of shore and the tagged orcas rarely moved within 2 km (1.3 mi) of shore (Hanson et al. 2017). The tagged orcas moved in a broader area along the Washington coast than they did along the Oregon and California coasts. The highest use area occurred off the Washington coast, particularly between Grays Harbor and the mouth of the Columbia River (Figure 6; Hanson et al. 2017). This was consistent with findings from the acoustic research.

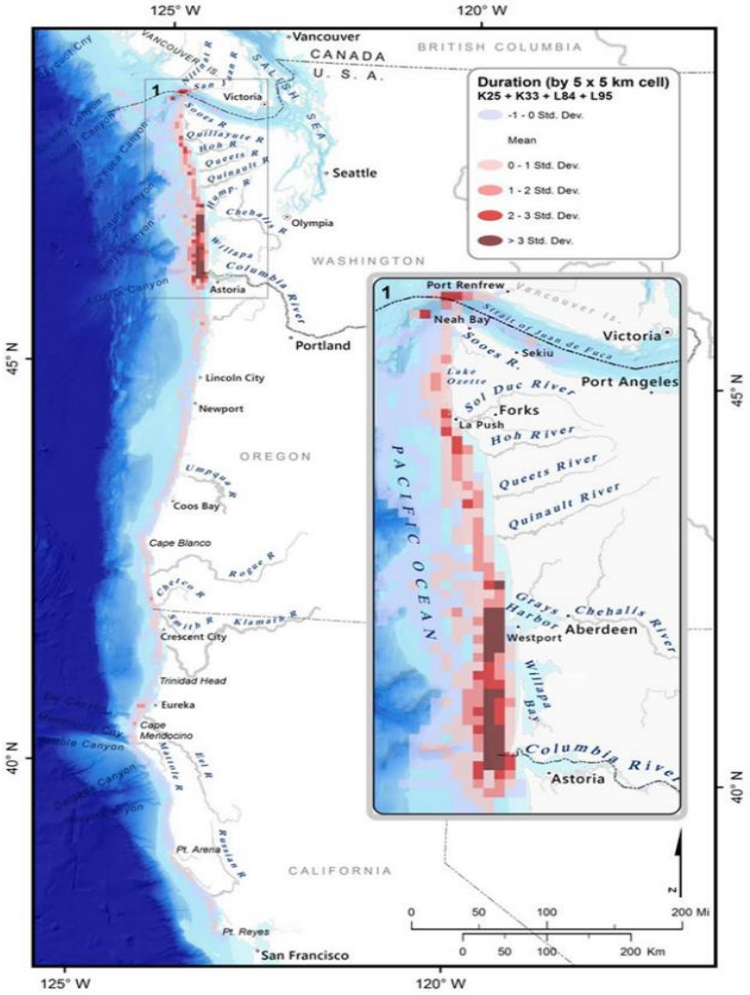

Figure 6. Location information derived from satellite tagged Southern Resident orcas (NMFS 2021a, see Hanson et al. 2017). Darker shades indicate areas of higher use.

NMFS evaluated the combined data from visual sightings, acoustic recordings, and satellite tagging and determined that the updated information on the use of outer coastal waters by Southern Resident orcas warranted a revision of the critical habitat for the Southern Resident killer whale DPS (NMFS 2021a). In 2021, NMFS expanded the critical habitat to include six additional areas along the outer coasts of Washington, Oregon, and California, extending from Cape Flattery, Washington to Point Sur, California, just south of Monterey Bay (Figure 7; 86 FR 41668; NMFS 2021a). The critical habitat areas in waters off the Oregon Coast include Areas 1, 2, and 3. Boundaries between areas were selected to roughly coincide with existing boundaries for fishery management areas under the jurisdiction of the Pacific Fishery Management Council (e.g., North of Falcon, Klamath Management Zone) but also considered changes in the orca's migratory behavior according to the satellite tagging data (e.g., transitions between foraging and traveling areas). Based on the tagging data, the inshore (eastern) boundary of the areas was set at the 6.1-m (20-ft) isobath relative to mean high water, including where it crosses river mouths and entrances to bays and estuaries. Currently, no data from sightings or satellite tagging indicate that Southern Residents enter river mouths or semi-enclosed bays (NMFS 2021a). However, NMFS stated that activities by federal agencies in areas shallower than 20 ft or upstream of critical habitat areas which have the potential to adversely affect critical habitat may still warrant consultation under Section 7 of the ESA (NMFS 2021a). The offshore (western) boundary of the areas was set at the 200-m (656-ft) isobath.

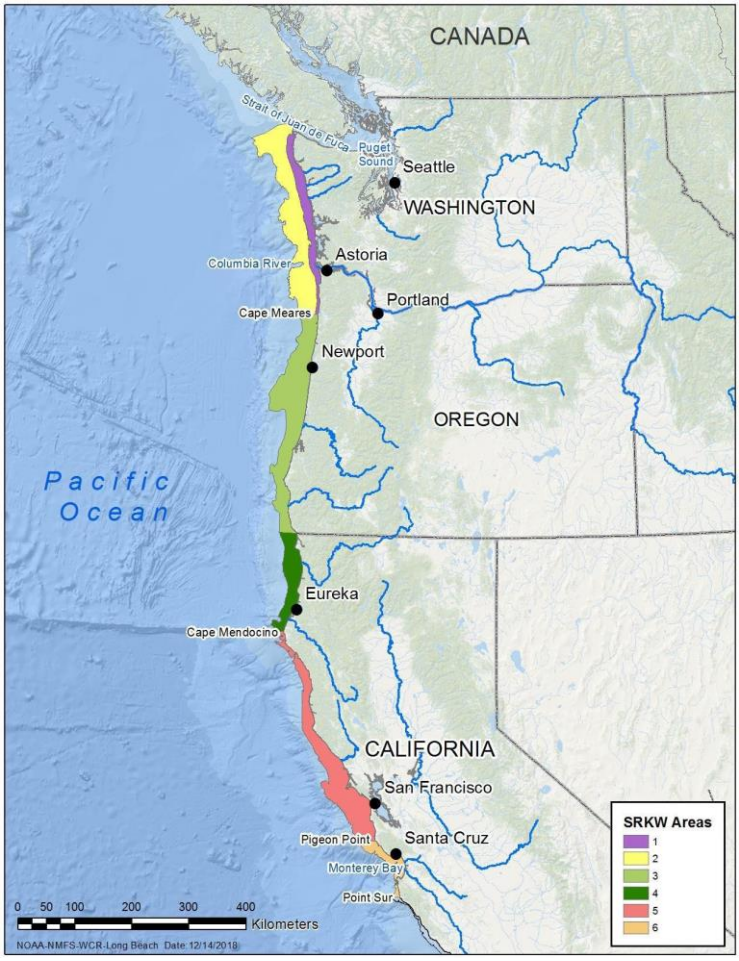

Figure 7. Areas added to critical habitat for Southern Resident orcas in 2021 (NMFS 2021a).

The essential habitat features found in each area are listed in Table 2. For Areas 1 and 2 along the northern Oregon coast, NMFS identified prey as the most important habitat feature. This is largely based on the importance of Columbia River Chinook salmon to the winter-spring diet of Southern Resident orcas. Although Southern Residents do forage in Area 3 along the central and southern Oregon coasts, few prey samples were found in this area, and tagged orcas moved more quickly through this area, suggesting that they were mostly traveling (NMFS 2021a). Therefore, Area 3 has been identified as primarily serving as a travel corridor between Areas 1/2 and Area 4 where more intensive foraging takes place. Most tagged orcas traveling along the Oregon Coast stayed within a relatively narrow corridor ranging from 2 km (1.2 mi) to 12 km (7.5 mi) from shore, with an average distance from shore of 6 km (3.7 mi) (NMFS 2021a). The median depth of water used by the Southern Residents was 57 m (187 ft).

Table 2. Areas added to Southern Resident killer whale DPS critical habitat along the outer coasts of Washington, Oregon, and California, and the essential habitat features identified for each area (NMFS 2021a). The primary habitat feature is underlined.

Area	Essential Habitat Feature
1 - Coastal Washington/Northern Oregon *Inshore*	Prey, passage, water quality
2 - Coastal Washington/Northern Oregon *Offshore*	Prey, passage, water quality
3 - Central/Southern Oregon Coast	Passage, prey, water quality
4 - Northern California Coast	Prey, passage, water quality
5 - North Central California Coast	Passage, prey, water quality
6 - Monterey Bay	Prey, passage, water quality

There are some indications that the seasonal distribution of Southern Residents may have shifted in recent years, as they were noted in 2013, 2016, 2017 and 2018 as spending significantly less time in inland marine waters than they typically do (Shields et al. 2018; Marine Mammal Commission 2023). This change could be due to a lower abundance of Chinook salmon in the Salish Sea in late spring and early summer.

POPULATION STATUS, TRENDS, AND DEMOGRAPHICS

The Southern Resident orca community may have numbered more than 200 individuals until the mid- or late 1800s (Krahn et al. 2002), when Euro-American settlement began to impact the region's natural resources. Genetic analyses indicate that the level of genetic diversity in the Southern and Northern Resident populations is similar, suggesting that their population sizes may have been comparable at one time (Barrett-Lennard and Ellis 2001). Prior to 1974, when regular photo-identification surveys began, assessing the population size of the Southern Residents was difficult due to a lack of empirical data (NMFS 2008). Olesiuk et al. (1990) modeled the population size of the Southern Residents between 1960 and 1973 and these are the best available estimates for that period. Beginning in 1974, photo-identification surveys of the Southern Residents have been conducted annually, first by Canadian researcher Michael Bigg (Bigg et al. 1976), and since 1976, by the Center for Whale Research (Center for Whale Research 2023a, 2023b). The surveys are usually conducted between May and October when all three pods reside near the San Juan Islands, and they are considered complete censuses of the entire population (NMFS 2008).

The Southern Resident population size has varied over time with periods of growth and decline (Figure 8). Between 1960 and 1967, the estimated number of orcas in the Southern Resident population increased from 78 to 96. This increase likely reflects the recovery of the population as occurrences of opportunistic shootings declined but may also be due to some unidentified improvement in the habitat's capacity to support the Southern Residents (Olesiuk et al. 1990). During the late 1960s and early 1970s, the capture of Southern Resident orcas for aquaria had an immediate negative impact on the population as the community lost 30% of its members between 1967 and 1971 (NMFS 2008). Collections for aquaria decreased dramatically after 1971 due to public opposition and ended in the mid-1970s. Although this allowed the Southern Resident population to gradually rebuild until peaking at 98 orcas in 1995, the selective removal of younger orcas and males during the aquaria collection era skewed the age and sex composition of the population, likely resulting in a slower and more prolonged recovery (Olesiuk et al. 1990).

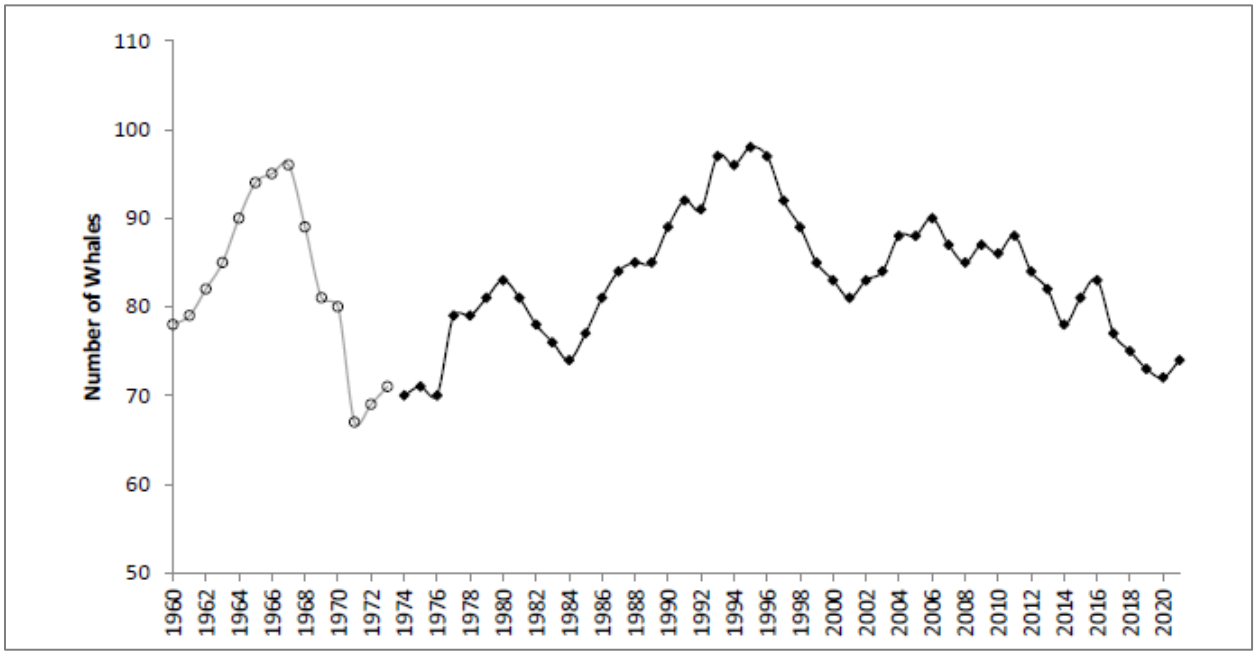

Figure 8. Population size and trend of Southern Resident orcas, 1960–2021. Data points for 1960–1973 (open circles) are modeled projections from Olesiuk et al. (1990). Data for 1974–2021 (solid diamonds) were obtained from photo-identification surveys of the three Southern Resident pods and were provided by Center for Whale Research (unpublished data) and NMFS (2008). Data for these years represent the number of orcas present at the end of the calendar year (1974–2011) or at the end of the summer (May–October) census (2012–2021) (NMFS 2021b).

Since 1995, the Southern Resident population size has generally exhibited a declining trend, although there have been brief periods of improvement. The primary factor contributing to the long-term decline is unclear. The decrease in population numbers during the latter half of the 1990s coincided with a period of poor Chinook salmon abundance in the Pacific Northwest (Ward et al. 2009; Ford et al. 2010). However, in recent years, the associations between Chinook abundance and Southern Resident population parameters have weakened as the population continues to decline while Chinook abundance has been more variable (NMFS 2021a). Much of the overall decrease in population size since 1995 has been driven by poor survival in L pod, the largest of the Southern Resident pods. In contrast, J and K

pods have changed little during the same timeframe (Wiles 2016; NMFS 2021b). The current population size for the Southern Residents (as of the 2022 census) is 73 individuals (25 in J pod, 16 in K pod, and 32 in L pod) (Center for Whale Research 2023b). Two new calves (one female and one male) were born in L pod after the 2022 census (Center for Whale Research 2023c), but as of this writing, the 2023 census has not yet been completed. While the birth of the calves is encouraging, the Southern Resident population size nevertheless remains below what it was when it was listed under the ESA in 2005 (88 orcas). This small population size makes the community vulnerable to inbreeding and means that its age and sex compositions are more heavily influenced by the births and deaths of individual animals (NMFS 2021b).

Using data from the 2021 census, when the population size was also 73, approximately 38% of the population was comprised of reproductive-age females, 36% were reproductive-age males, 16% were juveniles (<10 years of age), and 10% were post-reproductive females (NMFS 2021b). However, not all reproductive orca males are equally successful in breeding, with the largest and oldest males tending to be the most successful breeders (NMFS 2008). Based on genetic paternity analyses, Ford et al. (2018) reported that 52% of the calves born into the Southern Resident population between 1990 and 2015 were sired by two males. They also found that there were four highly inbred offspring in the population, and that unlike most orca populations, mating within pods was relatively common for the Southern Residents. This indicated that the Southern Resident population was more inbred than other North Pacific orca populations. Potential inbreeding depression in the Southern Resident population, along with environmental factors, may contribute to the lack of recovery of the population (Northwest Fishery Science Center, unpublished data *in* NMFS 2021b).

The average interval between successful calf births for reproductively active Southern Resident females has been reported as 6.1 years, which is longer than the 4.9 years estimated for Northern Resident females (Olesiuk et al. 2005). The calving interval for Southern Resident females does allow for population growth, but at a slower rate due to a lower population fecundity rate (births per year). In addition, recent research analyzing pregnancy hormones in the feces of Southern Resident females has detected evidence of several miscarriages, particularly late in the pregnancy (Wasser et al. 2017). These reproductive issues also contribute to the difficulty of population recovery.

NMFS's Northwest Fishery Science Center (NWFSC) recently used a population viability model to project the Southern Residents' population size through 2045 (Figure 9; NMFS 2021b). Projections were made using survival and fecundity estimates for all years in the data set (1985–2021), the years with the highest survival and fecundity estimates (1985–1989), and the five most recent years (2017–2021), which reflect relatively low survival and fecundity. The population viability analysis does not link projections to a specific threat but instead reflects the combined impact of all past threats. All three projections indicate an overall decline in the population over the next 25 years, although the projection using the highest survival and fecundity estimates showed more stability and even slight growth in the next 10 years. Even though survival rates for the Southern Resident population have been slowly increasing since the 1990s, the downward projections largely reflect the population's relatively low fecundity rates and recent shifts in the age and sex compositions of the population, particularly for its younger members. For example, past modeling has assumed a 50:50 ratio of males to females at birth; however, recent estimates put it closer to 55% male and 45% female (NMFS 2021b), placing the population at a reproductive disadvantage due to the lower proportion of females. In its latest status

review for the Southern Residents, NMFS assessed that all the modeled population trajectories reflect the endangered status of the Southern Residents, but that using the projection based on 2017–2021 survival and fecundity likely provides a more reliable forecast for the population if current levels of survival and poor reproduction continue (NMFS 2021b). Moreover, as many females of reproductive age in the Southern Resident community have not produced a calf in the past decade, the population would be expected to decline more rapidly if the number of females not reproducing continues to increase.

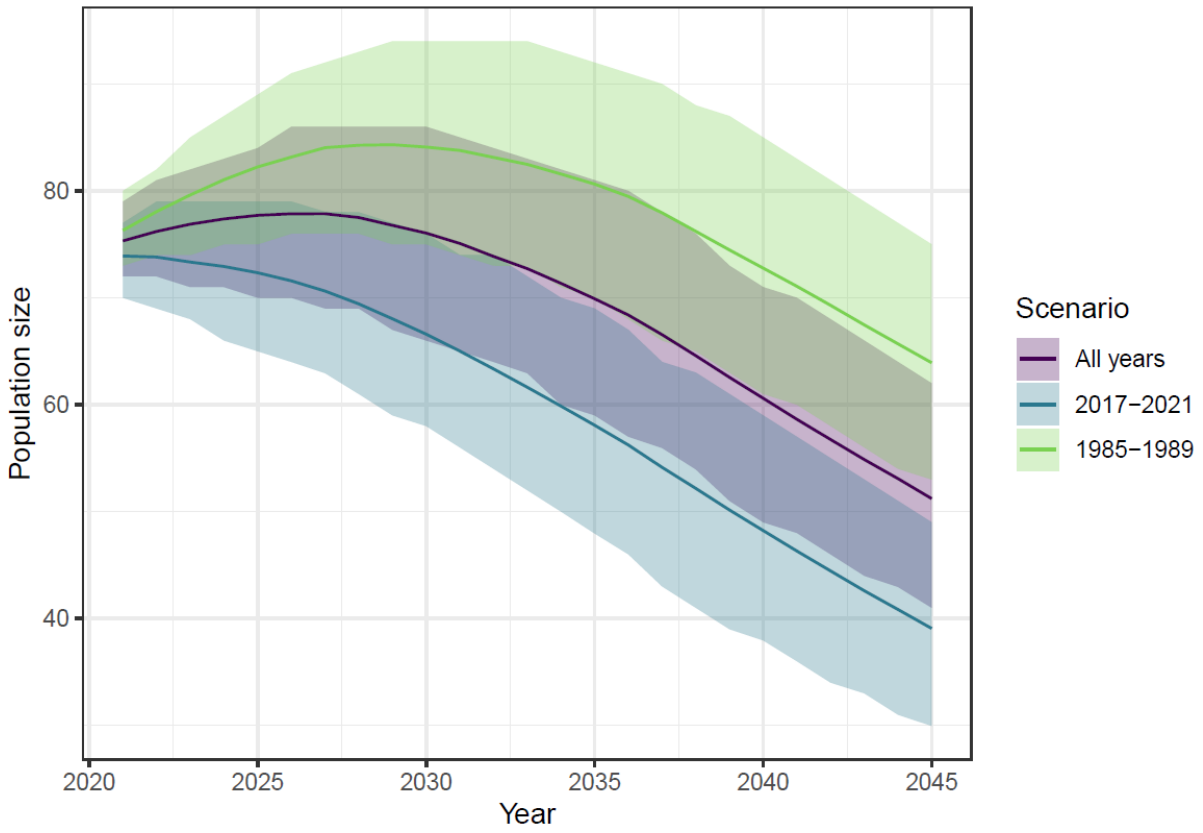

Figure 9. Southern Resident orca population size projections from 2020 to 2045 under three scenarios: (1) use of fecundity and survival rates estimated over the entire time series (1985–2021, purple), (2) use of rates estimated over the last five years (2017–2021, blue), and (3) use of the highest estimated survival and fecundity rates (1985–1989, green) (NMFS 2021b).

POPULATION THREATS

In its 2004 review of the status and viability of the Southern Resident orca population, NMFS's Biological Review Team (BRT) identified several potential threats to the population's survival and continued existence. The main threats included: 1) reduction in the quantity and quality of prey, 2) environmental contaminants, 3) sound and vessel disturbance, and 4) oil spills. Addressing these threats formed the basis of NMFS's recovery plan for the Southern Residents; however, NMFS acknowledged the difficulty in determining which threat or threats presented the highest risk to the population or were limiting factors

in its recovery (NMFS 2008). Nevertheless, the threats listed here have contributed to the modification and degradation of the Southern Resident's habitat through much of the community's range.

Prey Availability

Healthy orca populations depend on adequate levels of quality prey, and reductions in the quantity and/or quality of prey may lead to poor nutrition, lower reproductive rates, and lower survival (NMFS 2008). Several studies have reported the importance of salmon, especially Chinook salmon, in the diet of Southern Resident orcas (Ford et al. 1998; Ford and Ellis 2006; Hanson et al. 2010; Ford et al. 2016; Hanson et al. 2021). Past associations between Chinook salmon abundance and Southern Resident population parameters such as growth rates, survival rates, and fecundity were statistically strong (Ward et al. 2009; Ford et al. 2010). However, these associations have weakened in recent years (NMFS 2021a), suggesting that other factors also play an important role in the health of the Southern Resident population. Nonetheless, reductions in the abundance of Chinook salmon in the Pacific Northwest over the last 150 years due to overfishing, habitat loss and degradation, poor hatchery practices, and hydropower operations on the Columbia River and other rivers (Chapman 1986; Nehlsen et al. 1991; Northcote and Atagi 1997; Lichatowich 1999) have affected a critical part of the prey base for Southern Resident orcas (NMFS 2008). Most of the Chinook salmon stocks that experienced reductions in abundance over this timeframe are in Washington, Oregon, Idaho, California, and southern British Columbia, and many of these stocks contribute to the Southern Resident's diet (Hanson et al. 2010; Hanson et al. 2021). Nine Chinook salmon evolutionarily significant units (ESUs) on the U.S. West Coast are listed as either threatened or endangered (five from the Columbia River basin, one from Puget Sound, and three from northern and central California) (NMFS 2023c). In addition, three populations of Fraser River Chinook salmon were assessed as endangered in 2020 and are eligible for listing under Canada's Species at Risk Act (Government of Canada 2023).

In the past, if salmon were deficient in one area, the Southern Residents may have simply moved to another area where salmon were more abundant or switched to alternative stocks. However, as more salmon stocks declined in abundance, particularly those of their favored prey, Chinook, these other options may have become less viable (Ford et al. 2000). McCluskey (2006) reported that the Southern Residents showed reduced movements when overall salmon abundance was higher, such as in the early 1990s. However, when salmon abundance declined in the late 1990s, all three pods showed increased movements between late spring and early fall, presumably spending more time foraging and searching larger areas for prey. The importance of the waters around the San Juan Islands as a summer foraging area for the Southern Residents has been well documented (Ford et al. 1998; Ford and Ellis 2006; Hanson et al. 2010; Wasser et al. 2017). Fraser River Chinook salmon passing through the area on their way to their natal river have been identified as a key component of their summer diet (Hanson et al. 2010; Wasser et al. 2017). Recent research has also shown that Chum salmon, which become abundant in Puget Sound during the fall, are an important part of the Southern Resident's diet during that time, and that just over half of the prey consumed by Southern Residents in outer coastal waters during the winter and early spring consists of Columbia River Chinook salmon (Hanson et al. 2021). Shields et al. (2018) reported that in recent years the Southern Residents appeared to be spending less time in their core habitat area within the Salish Sea. It is possible that they are staying longer in outer coastal waters to take advantage of greater numbers of Chinook salmon in those waters relative to the Salish Sea. Many

of the salmon populations that contribute to the Southern Resident's diet are supplemented with hatchery fish, and although Southern Residents do consume hatchery salmon (J. K. B. Ford, unpublished data *in* NMFS 2008), the extent to which they do so in comparison to wild salmon is unknown. Even with this uncertainty, NMFS assessed that hatchery salmon likely benefited the Southern Residents to some undetermined extent (NMFS 2008).

In addition to reductions in the quantity of prey available to the Southern Residents, there are indications that the quality of the prey has also decreased. Many populations of Pacific salmon, including Chinook salmon, have decreased in physical size over the past several decades (Bigler et al. 1996; NMFS 2008). Potential reasons for this reduction in size include harvest and fish culture practices, as well as ocean conditions (Weitkamp et al. 1995; Bigler et al. 1996). Smaller prey may result in fewer calories being consumed per unit of foraging effort for the orcas, leading to reduced foraging efficiency (NMFS 2008). Therefore, with smaller prey, the Southern Residents must expend more time and energy to meet their daily energy requirements.

Researchers have documented poor body condition in some Southern Residents, which may be linked to nutritional stress, although other factors such as long-term exposure to contaminants and disease, may also contribute (NMFS 2021a). Nutritional stress can lead to increased mortality and poor reproductive success (NMFS 2008; Wasser et al. 2017). There is also evidence that social cohesion in Southern Residents is negatively impacted when salmon abundance is low (Parsons et al. 2009; Foster et al. 2012). When prey abundance is low, the orcas must spread out to find food and spend more time on foraging and less time on social interactions (Foster et al. 2012). Social cohesion likely plays an import role in the growth, survival, and reproduction of the Southern Residents (NMFS 2021a). Although some of the effects of nutritional stress on the Southern Residents are becoming clearer, establishing strong relationships between the population's nutritional stress levels and Chinook salmon availability continues to be challenging (Hilborn et al. 2012; PFMC 2020), likely due to the presence of other confounding factors.

Environmental Contaminants

Many environmental contaminants have the potential to harm marine mammals, but the class of contaminants known as persistent organic pollutants (POPs), consisting of organochlorines such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), and polybrominated diphenyl ethers (PBDEs), are considered to present the greatest contaminant risk to orcas (Ross et al. 2000; Krahn et al. 2002; Mongillo et al. 2016). POPs have been manufactured for industrial and agricultural purposes in vast amounts since the 1920s and 1930s, and although use of DDT pesticides for agriculture ended in the United States in 1972 and production of PCBs ceased in 1977, these chemicals continue to be used in other parts of the world such as Latin America and Asia (NMFS 2008). PBDEs are one of many "emerging" contaminants of concern due to their expanding presence in the environment, wildlife, and humans. They have been used extensively in flame retardants and many common household products since the 1970s, and although banned in both the U.S. and Canada since 2004, they can still be found in many products manufactured before 2004 (NMFS 2021a). The persistent qualities of POPs enable them to linger in the environment, long after their use or manufacture has ended, and they can enter the marine environment via several pathways, including terrestrial runoff, ocean currents, and atmospheric

transport (Iwata et al. 1993; Grant and Ross 2002; Hartwell 2004). Much of the POP load in the northern Pacific Ocean is carried there through atmospheric transport from Asia due to prevailing westerly winds (Iwata et al. 1993). High concentrations of POPs can bioaccumulate in top marine predators such as marine mammals through trophic transfer (O'Shea 1999). As such, orcas are susceptible to accumulating high POP concentrations because of their position at the top of the food web, as well as their long-life expectancy (Grant and Ross 2002). Orcas encounter these compounds through their consumption of contaminated prey (Hickie et al. 2007; Mongillo et al. 2016), and because POPs are fat-soluble, they accumulate and are stored in the orcas' blubber (O'Shea 1999). The Southern Residents have been exposed to PCBs and DDT in Puget Sound for several decades. The presence of the chemicals in the Sound's sediments peaked in the 1960s and have decreased since then (Grant and Ross 2002). Hickie et al. (2007) modeled estimated PCB concentrations in both Northern and Southern Residents from 1930 to 2030 and the results indicated that PCB concentrations in the orcas peaked in about 1969 and have gradually decreased since. Modeling projections suggest that it may take up to 60 years for PCB concentrations in the Southern Residents to fall below levels considered to be harmful to marine mammals. Mongillo et al. (2016) assessed that average PCB, PBDE, and DDT concentrations in the Southern Residents during 2004–2013 continued to be elevated. Differences in contaminants among the pods have also been noted. J pod had relatively higher PCB levels while K and L pods had higher DDT ratios, suggesting that J pod spent more time in Puget Sound where PCBs are the dominant contaminant, whereas K and L pods had more of a "California signature" (due to high historical use of DDT for agriculture in California's Central Valley), reflecting the time they spend off the California coast (Krahn et al. 2007; NMFS 2021a).

Male orcas continue to accumulate POPs throughout their lives, but reproductive females "off load" much of their contaminant burden by transferring it to their offspring during gestation and nursing. During nursing, the POPs are mobilized from the female's blubber to her fat-rich milk, where they are passed on to the calf (Reijnders and Aguilar 2002). After females enter the post-reproductive phase of their lives, contaminant levels once again rise in their bodies (Ross et al. 2000). Based on testing samples, it is likely that all male and most female Southern Residents have POP concentrations that exceed the level considered to cause health issues in marine mammals (Ross et al. 2000). High POP concentrations in marine mammals have been linked to endocrine, metabolic, and immune system disruption, cancer, decreased reproduction, and increased calf mortality (Béland et al. 1993; Ross et al. 1996; Ross 2002; De Guise et al. 2003; Gregory and Cyr 2003; Reijnders 2003; Buckman et al. 2011; Gockel and Mongillo 2013; Hall et al. 2018). Mongillo et al. (2016) suggested that orca calves may be especially vulnerable to POP-induced endocrine disruption due to their exposure to contaminants at a very young age and during an important time in their growth and development. Calves may also become more susceptible to disease if their still-developing immune systems are compromised due to high levels of POPs in their bodies. The health impacts of high POP concentrations on the Southern Residents can be influenced by other stressors such as a lack of prey. A shortage of food can cause an orca's body to draw on its fat reserves, mobilizing POPs into the circulatory system where they can potentially have toxic effects (Krahn et al. 2002; Mongillo et al. 2016). Mongillo et al. (2016) cautioned against focusing too much on individual contaminants due to the potential for contaminants to interact in an orca's body, possibly resulting in increased toxicity. Therefore, even relatively low doses of contaminants, when combined, could have a greater effect on orcas than individual contaminants at the same dosage.

Toxic elements such as mercury, lead, and cadmium are another area of concern for cetaceans (O'Shea 1999). These metals tend to accumulate in the liver, kidney, or bones, and although concentrations generally increase throughout an animal's life, many marine mammal species can tolerate high amounts of metals or detoxify them (Reijnders and Aguilar 2002). Although there are very few published accounts of metal-caused pathology in cetaceans (O'Shea 1999), the effect of metals on orcas in Washington or British Columbia has not been investigated (NMFS 2008).

Relatively few studies have examined concentrations of POPs in the prey of orcas. However, there is evidence that Chinook salmon from Puget Sound have higher levels of PCBs and PBDEs than Chinook from other locations sampled along the North America west coast (O'Neill et al. 2005, 2006). Of the five salmon species occurring in Puget Sound, Chinook salmon were found to have the highest concentrations of these chemicals. The studies also found that Puget Sound Chinook stocks with longer residency times in the Sound had much higher PCB and PBDE loads than Chinook stocks that spent most of their lives in the open ocean. Research on PCB levels in Coho salmon revealed that Coho from the more industrialized southern part of the Sound had higher PCB concentrations than those from the northern part of the Sound (West et al. 2001). Furthermore, many contaminant hot spots are located near important nursery areas for salmon. DDT loads in Chinook salmon were similar in populations from Puget Sound, the Columbia River, and central California, but higher than those in British Columbia populations (O'Neill et al. 2006). Because contaminants enter the marine ecosystem from a variety of local, regional, and international sources, it is difficult to determine the relative contribution of these sources to the contamination of the Southern Resident's prey (NMFS 2008). Ross et al. (2000) suggested that the high POP concentrations in the Southern Residents might be the result of consuming relatively small amounts of highly contaminated prey from waters near heavily industrialized areas. However, even salmon that spend much of their lives in the open ocean are likely contaminated by chemicals deposited there via atmospheric pathways and ocean currents. Regardless, Chinook salmon are likely a significant source of contaminants for the Southern Residents because of their importance in the Southern Resident's diet and their relatively high contaminant loads (Mongillo et al. 2016).

Although much has been learned about the exposure of Southern Resident orcas to contaminants and the potential effects that high contaminant loads might have on their health, there is still not enough data to establish effects thresholds that could help guide recovery efforts (NMFS 2021a). Furthermore, better information is needed on contaminant levels in the Southern Residents and their prey, as well as specific health effects of contaminants on orcas, particularly their calves (Mongillo et al. 2016).

Sound and Vessel Disturbance

Communication is vital for a social species such as orcas, and echolocation allows them to accurately navigate and detect and locate their prey. Anthropogenic sources of sound from vessel traffic, naval operations, construction activities, and possibly ocean energy developments can potentially interfere with the Southern Residents' ability to communicate with each other and forage efficiently (NMFS 2008). Commercial shipping, ferry operations, whale watching, and recreational boating traffic have expanded within the northeastern Pacific region in recent decades. Vessels primarily affect orcas through underwater sound generated by their engines, but their presence and activities can also impact them (NMFS 2021a). Williams et al. (2010) reported that Northern Residents significantly altered their

movements and spent less time foraging when motorized vessels were nearby, but also spent more time traveling in the presence of kayaks, indicating that the physical presence of vessels, in addition to vessel sound, can affect the orcas.

Orcas respond to close-range vessel encounters with short-term behavioral changes that have been well documented over many years (Kruse 1991; Williams et al. 2002; Foote et al. 2004; Bain et al. 2006; Williams et al. 2006; Lusseau et al. 2009; Noren et al. 2009; Williams et al. 2009; Senigaglia et al. 2016). Observed behavioral changes include increased swimming speed, less directed swimming paths, and decreased foraging activities. Vessels in the paths of orcas can also impede important social behaviors such as prey sharing and nursing. Noise from vessels may mask or prevent the perception of vocalizations made by orcas, interfering with communications important for maintaining social structure and cohesion (Giles and Cendak 2010). Foote et al. (2004) reported that call duration increased by 10–15 percent in the Southern Resident pods when whale-watching boats were present, suggesting that they were attempting to compensate for the noisier environment. Additionally, interference with echolocation may reduce foraging efficiency by decreasing the range at which orcas can detect salmon in the water column (Holt 2008). It has been estimated that reduced foraging efficiency due to vessel noise could result in an 18% decrease in the energy intake of Southern Resident orcas (Williams et al. 2006; Lusseau et al. 2009).

Research indicates that behavioral changes in orcas can occur at varying distances from vessels, ranging from 100 m (109 yd) to 400 m (437 yd) or greater (Williams et al. 2002; Bain et al. 2006; Lusseau et al. 2009; Noren et al. 2009; Williams et al. 2009; Giles and Cendak 2010). A recent study using digital acoustic tags (DTAGs) confirmed that orcas spent less time foraging and more time traveling when vessels were nearby, with the orcas making fewer deep foraging dives involving prey capture when the average distance to nearby vessels was less than 400 yd (Holt et al. 2021). Moreover, female orcas switched from foraging to traveling more often than males, suggesting that vessel disturbance may have a disproportionate effect on females, with potential repercussions for the population's reproductive capacity. The study also found that, at a given distance, vessel speed was an important indicator of the level of noise received by the orcas. A variety of vessel types have the potential of operating near orcas, including whale-watching boats, recreational boats, commercial fishing vessels, ferries, and cargo ships. Of these vessel types, commercial whale-watching operators and recreational boaters have the highest likelihood of encountering orcas (NMFS 2008). Whale watching is an important tourist industry in several coastal communities, serving a dual purpose of boosting the local economy and increasing the public's awareness of and appreciation for marine mammals and the environmental issues they face. In Washington and British Columbia, orcas are the primary species of interest for the commercial whale-watching industry due to their historically reliable presence in the Salish Sea, particularly in the waters around the San Juan Islands. The Southern Residents have historically been observed regularly by whale-watching operators during their summer residence in Haro and Rosario straits (NMFS 2008). Whale watching off the Oregon Coast typically focuses on gray whales (*Eschrichtius robustus*) due to their regular spring and fall migrations, as well as a subset of gray whales that feed off the Oregon Coast during the summer months (Oregon Whale Watch 2023). Orcas are seldom observed, with sightings usually occurring during April–June (P. McBride; L. Parsons, Oregon Parks and Recreation Department, personal communication). Also, orcas observed in the waters off Oregon are usually the transient ecotype (J. McInnes, University of British Columbia, personal communication). Recent studies have found

that noise from large ships can extend into the frequency range used by the Southern Residents for echolocation (Veirs et al. 2016). This could have implications for the orcas' foraging success when they are in the vicinity of large ships.

Human activities in the marine environment other than vessel operation also create sounds that could potentially affect orcas (NMFS 2021a). Some of these activities include dredging, drilling, seismic testing, construction, and the use of sonar (Richardson et al. 1995; Gordon and Moscrop. 1996). There is also interest in developing alternative energy projects in the Pacific Northwest that utilize waves, tides, or currents as an energy source, but the possible effects of these projects on marine mammals are largely unknown (NMFS 2008). The development of marine renewable energy projects (wave energy and offshore wind energy) off the Oregon coast is currently being investigated. Planning is underway for testing wave energy devices at one of two facilities either 2 or 6 nautical miles off the coast near Newport, Oregon (https://pacwaveenergy.org/), and for potential commercial development of offshore wind facilities located more than 18 miles off the southern Oregon coast (https://www.boem.gov/renewable-energy/state-activities/Oregon). Installation or operation of ocean energy infrastructure may produce sound at levels exceeding ambient conditions that could have a range of effects on marine mammals (ODFW 2023).

Oil Spills

The possibility of a major oil spill is considered one of the greatest short-term threats to orcas and other coastal organisms in the northeastern Pacific region (Krahn et al. 2002). A large oil spill could have devastating effects on the Southern Resident population. The *Exxon Valdez* oil spill in Prince William Sound, Alaska in 1989 resulted in unprecedented mortalities for resident and transient orca pods in southern Alaska (Matkin et al. 1994). In addition, the *Deepwater Horizon* oil spill in the Gulf of Mexico in 2010, the largest oil spill in history, resulted in high mortalities and significant health effects for a wide range of species, including cetaceans (NMFS 2023d).

Exposure to polycyclic aromatic hydrocarbons (PAHs), a component of both crude and refined oil, can occur through five pathways: dermal contact, adhesion, inhalation, direct ingestion, and ingestion of contaminated prey (Rosenberger et al. 2017). Since cetaceans have a thickened epidermis that reduces the likelihood of exposure to petroleum toxicity through the skin (Geraci 1990; O'Shea and Aguilar 2001), inhalation of vapors at the water's surface and ingestion of PAHs during feeding are more likely pathways of exposure (NMFS 2021a). Marine mammals acutely exposed to petroleum products can experience changes in behavior, inflammation of mucous membranes, lung congestion, pneumonia, liver disorders, and neurological damage (Geraci and St. Aubin 1990). Oil spills can also significantly affect prey populations that the Southern Residents rely on, reducing the amount of food available to them (NMFS 2021a). A study evaluating the impacts of a potential oil spill on marine mammals in British Columbia coastal waters identified Northern and Southern Resident orcas as being among the most vulnerable populations due to their relatively small population sizes, strong site fidelity to areas with high risk of oil spills, large group (pod) size, late reproductive maturity, low reproductive rate, and specialized diet (Jarvela-Rosenberger et al. 2017).

Combined Threats

It is unclear, and may be impossible to determine, which threat, or threats pose the highest risk for the survival and future existence of the Southern Resident orcas. This uncertainty makes it more difficult to prioritize the threats for actions that expedite the population's recovery. It is highly likely that the Southern Residents experience cumulative, and probably synergistic, effects from multiple threats, and that these effects are exacerbated by the population's small size (NMFS 2008; NMFS 2021b). For example, a lack of prey over several years could have cumulative effects as an orca's body condition worsens, potentially making the animal more susceptible to disease. A lack of food also causes more fat to be metabolized for energy, releasing toxicants into the bloodstream where they can potentially have deleterious effects, such as reduced immune system function and reproduction. Vessel noise can disrupt foraging, leading to poor nutrition, increased body toxicity, and increased susceptibility to disease. Some researchers have also warned of the possible synergistic effects of different chemicals (Mongillo et al. 2016). The many ways in which the threats' effects can potentially accumulate and interact with each other greatly complicate recovery efforts.

MANAGEMENT ACTIONS

Many of the issues currently identified as threats to the Southern Resident orcas have been the focus of management actions and remediation efforts for a long time. For instance, salmon recovery efforts on the West Coast have been ongoing for many years to improve freshwater and estuarine habitat, hydropower system passage, and hatchery practices, as well as to reduce exploitation of ESA listed salmon and steelhead in fisheries. Programs and regulations to improve water quality and prevent oil spills have likewise been implemented for several decades (NMFS 2008; NMFS 2021b). After the federal listing of the Southern Residents, additional attention was placed on reducing pollution and the likelihood of oil spills in areas important to the Southern Residents such as Puget Sound. Similarly, in recent years, the needs of the Southern Residents have started to be considered when planning hatchery salmon production and managing salmon fisheries (NMFS 2008; NMFS 2021b). The following is a summary of management actions currently being taken to address the four main threats to the Southern Residents.

Prey Availability

Since many Pacific salmon and steelhead populations in the U.S. and Canada are considered threatened or endangered, efforts to recover these populations are ongoing and likely to continue for years. These are among the most important actions being taken with respect to prey availability for the Southern Residents as recovery of wild salmon and steelhead populations is the key to ensuring the Southern Residents an abundant source of prey in the long-term (NMFS 2008).

In 2018, NMFS and WDFW prioritized Chinook salmon stocks between California and southeastern Alaska in terms of their importance as prey for Southern Resident orcas. The priority modeling was based on three factors that were weighted for stocks that were: 1) an observed part of the Southern Residents' diet, 2) consumed during periods of lower body condition and/or times of dietary flexibility

(i.e., winter-early spring timeframe), and 3) overlapped spatially and temporally with the Southern Residents' distribution (NMFS and WDFW 2018). The prioritized Chinook salmon stocks are listed in Table 3, and the list is intended to help guide efforts to protect and enhance the primary prey of the Southern Residents. Of the ten highest priority Chinook stocks, two are from the Fraser River and Strait of Georgia, three originate in Puget Sound tributaries, and five are from the Columbia River basin. The top five stocks are all fall Chinook stocks, but Lower Columbia and Fraser spring Chinook are also important.

Table 3. Priority of Chinook salmon stocks potentially serving as prey for Southern Resident orcas. [1]

Stock	Run	Total Score [2]
Northern Puget Sound	Fall	5.00
Southern Puget Sound	Fall	5.00
Lower Columbia	Fall	4.63
Strait of Georgia	Fall	4.63
Upper Columbia and Snake	Fall	4.25
Fraser	Spring	4.25
Lower Columbia	Spring	4.25
Middle Columbia	Fall	4.06
Snake River	Spring-Summer	3.88
Northern Puget Sound	Spring	3.88
Washington Coast	Spring	3.69
Washington Coast	Fall	3.69
Central Valley	Spring	3.50
Middle and Upper Columbia	Spring	3.31
Upper Columbia	Summer	3.31
Fraser	Summer	2.88
Central Valley	Fall and Late Fall	2.75
Klamath River	Fall	2.75
Klamath River	Spring	2.75
Upper Willamette	Spring	2.25
Southern Puget Sound	Spring	1.88
Central Valley	Winter	1.50
North and Central Oregon Coast	Fall	1.41
West Coast Vancouver Island	Fall	1.38
Southern Oregon and Northern California Coast	Fall	0.75
Southern Oregon and Northern California Coast	Spring	0.75
California Coastal	Fall	0.75
California Coastal	Spring	0.75
Southeastern Alaska	Spring	0.00
Northern BC	Spring	0.00
Central BC	Mostly Summer	0.00

[1] From NMFS and WDFW 2018.

[2] Total score for three factors used in analysis.

Also in 2018, Washington's governor established the Southern Resident Killer Whale Task Force (Task Force, Executive Order 18-02), comprised of members from state agencies, the Washington legislature, tribal and local governments, businesses, and nonprofits, to develop a long-term plan to recover Southern Resident orcas. The Task Force produced a total of 49 recommendations in 2018 and 2019 that focused on addressing the main threats to the Southern Resident population (WSRCO 2023a, 2023b). The Task Force's recommendations regarding prey availability covered the full range of actions necessary to recover and enhance Chinook salmon populations, including habitat restoration, predator management, better passage at hydropower projects, reduced bycatch in fisheries, and increased hatchery production. In recent years, state, federal, and tribal hatcheries in Washington and Oregon have received federal funding (in association with the Pacific Salmon Treaty), and Washington hatcheries have also received funding through the Washington legislature, to increase hatchery Chinook production in Puget Sound, along the Washington coast, and in the Columbia River basin. The aim is to increase the amount of Chinook salmon available as prey to the Southern Residents by approximately 4–5 percent (roughly equivalent to an additional 35–50 million smolts released annually), with the enhanced hatchery production targeted on stocks contributing to the Southern Resident's diet during the summer in the Salish Sea and over the winter and spring in the outer coastal waters off Washington and the Columbia River mouth (WSRCO 2023b; NMFS 2021b; NMFS 2023e; PST 2023). However, there is a recognition that increasing releases of hatchery salmon needs to be done carefully to avoid adverse impacts to wild salmon (WSRCO 2023b).

Another management action that can be taken to potentially increase the amount of Chinook salmon available as prey to the Southern Residents is to reduce Chinook catch and bycatch in ocean fisheries. The Pacific Salmon Treaty (PST) is an agreement between the U.S. and Canada that facilitates cooperation between the countries regarding the management, research, and enhancement of salmon stocks of mutual concern (PSC 2023). Salmon fisheries off Southeast Alaska, British Columbia, Washington, and Oregon that have the potential to intercept the other country's stocks are managed under the PST. In 2018, the U.S. and Canada reached a new 10-year agreement that included harvest reductions for Chinook salmon fisheries in both countries that would help protect a variety of stocks that are important to the Southern Residents (NMFS 2021b). The Pacific Fishery Management Council (PFMC) manages salmon fisheries off the coasts of Washington, Oregon, and California. In 2019, the PFMC formed the Ad Hoc Southern Resident Killer Whale Workgroup (Workgroup) to reassess the effects of PFMC-area ocean salmon fisheries on the Southern Residents. The Workgroup's Risk Assessment concluded that fishery effects on the Southern Residents were likely small, although it did acknowledge the particular importance of Chinook abundance in the North of Falcon fishery management area (Cape Falcon, Oregon to the Canadian border) to the Southern Residents (NMFS 2021b; PMFC 2023a). Consequently, Amendment 21 of the Pacific Coast Salmon Fishery Management Plan outlines reductions in PMFC salmon fisheries that would occur if Chinook salmon pre-fishery abundance in the North of Falcon area is below a threshold level (currently 623,000 Chinook) (NMFS 2023f; PFMC 2023b; PFMC 2023c). Additionally, Puget Sound salmon fisheries co-managers (Treaty Indian tribes and WDFW) annually take actions to reduce the fisheries' impacts to Southern Resident orcas, including fishery closures or Chinook salmon non-retention requirements in certain months and areas (NMFS 2021b). NMFS ensures that fisheries comply with ESA requirements for the Southern Residents through Section 7 consultations. Their Section 7 consultations for a variety of salmon fisheries in recent years have concluded that fishery harvest has caused small reductions in prey availability for the Southern

Residents; however, these reductions were not likely to jeopardize the continued existence of ESA-listed Chinook salmon or Southern Resident orcas, nor adversely modify their critical habitats (NMFS 2021b). NMFS also assessed that fishery impacts on Chinook have been reduced coastwide over the past decades, including in areas where Southern Resident orcas are more likely to occur.

Although reductions in ocean fishery mortality of Chinook salmon and programs designed to increase Chinook salmon production in hatcheries could increase the amount of prey available to the Southern Residents, there is still uncertainty regarding how much an increase in prey availability translates to measurable improvements in Southern Resident population parameters. Some portion of an increase in Chinook salmon abundance will likely be offset due to predation by species other than orcas, and there is a lack of information on the foraging efficiency of the Southern Residents. Therefore, it is difficult to determine how much Chinook salmon or what density of salmon needs to be available to the Southern Residents for survival and successful reproduction (NMFS 2021b).

Environmental Contaminants

Under the 1972 Clean Water Act (CWA), the Environmental Protection Agency (EPA) implements pollution control programs, sets wastewater standards, and develops national water quality criteria recommendations for pollutants in surface waters (EPA 2023). The agency also has the authority to enforce water quality regulations. The CWA made it unlawful to discharge any pollutant from a point source into navigable waters unless a permit is obtained through the National Pollutant Discharge Elimination System (NPDES). Since its inception in 1972, the NPDES permit program, which is administered through applicable state agencies, has been responsible for significant improvements in water quality (NMFS 2008). In 2001, the EPA, Fish and Wildlife Service, and NMFS concluded an agreement to enhance coordination under the CWA and the ESA (66 FR 11201), recognizing the importance of protecting both the aquatic environment and the listed species that depend on it (NMFS 2008). In 2007, Washington State established the Puget Sound Partnership, a new agency intended to oversee the restoration of Puget Sound's environmental health, with particular emphasis on improving habitat conditions for Southern Resident orcas (NMFS 2008). In Oregon, the Department of Environmental Quality (DEQ) is the state agency responsible for protecting and improving the state's water quality for multiple beneficial uses, including aquatic habitat for fish and wildlife (DEQ 2023a). The agency develops and implements water quality standards and clean water plans, regulates sewage treatment systems and industrial dischargers, and evaluates water quality. Additionally, the City of Portland's Bureau of Environmental Services (BES) manages the city's wastewater and stormwater systems, enforces local, state, and federal environmental regulations, and is the lead agency in the Portland Harbor Superfund Program. The city's Water Pollution Control Laboratory investigates reports of pollution in rivers and streams and conducts water quality testing (BES 2023). Recommendations made by the Task Force regarding pollutants largely centered on accelerating implementation of Washington state government's ban on the purchase of products containing PCBs, identifying emerging contaminants for discontinuation of production and use in Washington, and improving monitoring and compliance with existing regulations (WSRCO 2023c).

During the past several decades, regulatory actions, improved waste handling, and ongoing cleanup efforts, particularly of Superfund sites in Puget Sound, have led to substantial improvements in the

regions' water quality. However, despite these advancements, and the banning of some types of POPs such as PCBs, DDT, and PBDEs, these legacy contaminants continue to be a concern for the Southern Residents. Currently, there is no strong evidence for a marked reduction in contaminant load in Southern Resident orcas, including their calves (NMFS 2021b).

Sound and Vessel Disturbance

A variety of measures have been taken to reduce sound and vessel disturbance of the Southern Residents. In 2011, NMFS implemented regulations that prohibit vessels from approaching within 200 yd of orcas, and from parking in the path of orcas within 400 yd in the inland waters of Washington State (76 FR 20870; NMFS 2021a). Although these federal regulations are still in place, NMFS recently completed a public scoping process to examine the need for updating the regulations and is working with the State of Washington and Province of British Columbia on the potential for alignment of regulations (NMFS 2021b). Current Washington State regulations, which apply specifically to Southern Resident orcas within the state's inland waters, require vessels to stay 300 yd from the orcas on either side and 400 yd from them when in front of or behind the orcas. Additional guidelines suggest that boat speed should be <7 knots within ½ mile of the Southern Residents and vessel operators are advised to disengage their engines if orcas appear within 300 yd. In addition to these regulations, there is also a voluntary "no boat" zone along the west coast of San Juan Island. In 2025, a new Washington State law will go into effect that expands the vessel buffer on all sides of a Southern Resident orca to 1,000 yd, and will require that vessel operators maintain a speed of <7 kts within 1,000 yd and disengage the engine within 400 yd. The federal regulations apply to orcas in inland waters that are not Southern Residents (e.g., Bigg's transients) (Be Whale Wise 2023; WDFW 2023). Canadian regulations require buffers between vessels and *all* orcas that range from 200 m (219 yd) to 400 m (437 yd), depending on the location (Be Whale Wise 2023). Interim orca sanctuary zones, which prohibit all vessel traffic, have also been established around Saturna and Pender islands near the southern end of Vancouver Island. In the outer coastal waters off Washington, Oregon, and California, current federal viewing guidelines require that vessels stay at least 100 yd from "whales", including orcas (NMFS 2023g).

In 2021, working with the commercial whale-watching industry, Washington State implemented a Commercial Whale Watch Licensing Program (CWWLP)—one of the recommendations made by the Task Force (WSRCO 2023c). The CWWLP requires commercial operators to have a commercial whale-watching license to view Southern Resident orcas and places additional restrictions on the number of commercial whale-watching vessels within a half nautical mile of the Southern Residents, the time of day and year that commercial viewing of Southern Residents is allowed, and the number of trips a commercial operator can make to view Southern Residents in a day (NMFS 2021b).

NMFS works with the State of Washington and non-profit partners to collect data on vessel interactions, enforce regulations, and increase boater awareness of the regulations through public education. The Soundwatch Boater Education Program (Soundwatch), created by and administered through The Whale Museum in Friday Harbor, Washington, has boat crews that monitor the waters around the San Juan Islands during the summer months, recording data on vessels near the orcas and incidents of non-compliance with the regulations. Crews also educate boaters on state and federal regulations and the Be Whale Wise guidelines (NMFS 2021b; Be Whale Wise 2023; The Whale Museum 2023). Additionally,

NMFS promotes awareness of the Southern Residents and the Be Whale Wise guidelines through public education efforts in partnership with WDFW, the Seattle Aquarium, Orca Network, and other partners (NMFS 2021b).

Since noise generated by vessels not targeting the orcas, such as large cargo ships, can also affect them, voluntary slow-down trials for commercial vessels were recently implemented in Canadian waters. These trials showed reductions in the level of ambient noise in the frequency range used by the Southern Residents (Burnham et al. 2021). The success of these trials, known as the Enhancing Cetacean Habitat and Observation (ECHO) Program, have led to the development of an equivalent program in the U.S. called Quiet Sound, another one of the Task Force's recommendations (NMFS 2021b). The NWFSC continues to conduct research on the potential impacts of large vessel noise on the Southern Residents.

Programs and procedures are also in place to minimize or eliminate potential negative effects from in-water activities such as dredging, drilling, and construction. Construction activities are permitted by the Army Corps of Engineers (ACOE) under Section 404 of the CWA and Section 10 of the Rivers and Harbors Act of 1899 and by the State of Washington under its Hydraulic Project Approval (HPA) program (NMFS 2021a). NMFS conducts consultations on these permits and helps project applicants to incorporate conservation measures into their plans.

A wide variety of management actions have been implemented to reduce disturbance to the Southern Residents from sound and vessel activity, with adjustments made as new information becomes available. Although much progress has been made, there remains room for improvement in educating the public about regulations and guidelines, increasing compliance, and achieving better alignment of regulations at the state, federal, and international levels (NMFS 2021b).

Oil Spills

Several statutes, policies, and programs address oil spill prevention and response in the northeastern Pacific region. These include the International Maritime Organization (IMO), the U.S. Oil Pollution Act (OPA), the Canada Shipping Act, and the Northwest Area Committee (NWAC) (NMFS 2008). The OPA serves as the leading federal regulatory mechanism to prevent, respond to, and address damage caused by oil spills. It also created the Oil Spill Liability Trust Fund. In 2001, the U.S. Coast Guard (USCG), EPA, Department of Interior (Fish and Wildlife Service) and NOAA (NMFS and NOS) entered into an agreement intended to ensure inter-agency cooperation and facilitate compliance with the ESA to protect listed species and critical habitat, without compromising the response to an oil spill. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) outlines oil spill planning and response procedures to achieve those objectives (NMFS 2021a). In addition, an orca-specific oil spill response plan has been adopted as part of the Northwest Area Contingency Plan (USCG et al. 2018). In Oregon, USCG and DEQ have primary responsibility for preventing, planning for, and responding to spills of oil and other hazardous materials (DEQ 2023b).

EVALUATION OF OESA LISTING CRITERIA

For a species to be listed as threatened or endangered under the OESA, state statutes and rules require that certain criteria be met. In this section we will evaluate whether, given the information presented in this report, the Southern Resident orcas meet these listing criteria.

A listing determination is based on documented and verifiable information about the species' biological status ORS 493.176(3); OAR 635-100-0105(1)—The information in this Biological Assessment was compiled from agency reports (primarily NMFS), peer-reviewed articles, and the best available information on the websites of several regional, federal, state, and local agencies and organizations. The Southern Residents have been studied for many years and research results are well documented (see this report's References section). NMFS completed its latest status review for the Southern Residents in 2021 and determined that they should remain listed as endangered (NMFS 2021b).

The natural reproductive potential of the species is in danger of failure due to limited population numbers, disease, predation, or other actions affecting its continued existence ORS 493.176(3); OAR 635-100-0105(6)—Small population size has made the Southern Residents vulnerable to inbreeding. Researchers found that 52% of the calves born into the population between 1990 and 2015 were sired by only two males, that mating within pods was common, and that the level of inbreeding in the Southern Resident population was higher than in other North Pacific orca populations (Ford et al. 2018). Inbreeding depression may be one of the factors contributing to the population's lack of recovery (NMFS 2021b). Nutritional stress from a lack of prey can lead to poor reproductive success (NMFS 2008; Wasser et al. 2017). Additionally, high concentrations of POPs, which have been documented in the Southern Residents, have been linked to decreased reproduction in marine mammals (Béland et al. 1993; Reijnders 2003; Gockel and Mongillo 2013). It is also highly likely that the Southern Residents experience cumulative and synergistic effects from multiple stressors (e.g., lack of prey, noise disturbance, contaminants, disease), which can contribute to decreased reproductive capacity. Population viability modeling indicates that recent poor reproduction in the Southern Resident population is likely to lead to a steeper decline in the population over the next 25 years (NMFS 2021b).

In addition, <u>one or more</u> of the following factors must exist:

> ***Most populations are undergoing imminent or active deterioration of their range or primary habitat ORS 493.176(3)(a); OAR 635-100-0105(6)(a)***—The Southern Residents are comprised of a single population. The habitat of the Southern Residents has been negatively affected by reductions in prey abundance and quality, pollution, and increased ambient noise levels from vessel traffic and other in-water activities such as dredging, drilling, and construction. Numerous Chinook salmon stocks important as prey to the Southern Residents, such as Fraser River Chinook (Hanson et al. 2010) and Columbia River Chinook (Hanson et al. 2021), have declined over the last 150 years due to various factors such as habitat degradation and loss, overfishing, hydropower system losses, and poor hatchery practices (Nehlsen et al. 1991; Northcote and Atagi 1997). A long history of pollution, particularly in Puget Sound where the Southern Residents spend much of the year, has led to the orcas having very high concentrations of contaminants in their bodies (NMFS 2008; NMFS 2021b). Contamination of Chinook salmon in

Puget Sound is thought to be one of the primary contributors to the high level of POPs in Southern Residents (O'Neill et al. 2005, 2006; Mongillo et al. 2016). Vessel traffic, especially in the Salish Sea, has increased over the last several decades. Whale watching has also become more popular. These developments have led to an increase in ambient noise levels in the waters frequented by the Southern Residents (NMFS 2008). Disturbance from sound and vessel activity has been identified as one of the main threats to the Southern Resident population, and can affect communications between individuals, as well as foraging efficiency (Foote et al. 2004; Holt 2008; Giles and Cendak 2010).

Overutilization for commercial, recreational, scientific, or educational purposes is occurring or is likely to occur ORS 493.176(3)(b); OAR 635-100-0105(6)(b)—The Southern Resident population was clearly overutilized commercially (and perhaps for scientific and educational purposes as well) in the late 1960s and early 1970s when approximately 30% of the population was permanently removed for aquaria. These removals had a profound negative impact on the population's status and its ability to recover (NMFS 2008). Current utilization of the Southern Residents by humans is related to commercial whale watching and research activities. Whale watching has become more popular in recent decades, particularly in the core habitat area of the Southern Residents near the San Juan Islands (NMFS 2008). Although it is difficult to determine if the Southern Resident population is being overutilized by the whale watching industry, to reduce pressure on the population, Washington State implemented the CWWLP in 2021 to regulate the industry more formally. The licensing program placed restrictions on the number of commercial whale watching vessels within a half nautical mile of the Southern Residents, the time of day and year that commercial viewing of Southern Residents is allowed, and the number of trips taken to view the Southern Residents in a day (NMFS 2021b).

Existing state or federal programs or regulations are inadequate to protect the species or its habitat ORS 493.176(3)(c); OAR 635-100-0105(6)(c)—While progress has been made addressing some of the threats faced by the Southern Residents, many problems remain unresolved. Several Chinook salmon populations important to the Southern Residents continue to be listed as threatened or endangered and recovery has been slow. The manufacture of several types of POPs such DDT, PCBs, and PBDEs was banned in the U.S. and Canada, but because of their persistent qualities and production in other countries, these legacy contaminants continue to threaten the Southern Residents (NMFS 2008; NMFS 2021b). Several measures have been implemented to reduce noise and vessel disturbance to the Southern Residents; however, there is still room for improvement in educating boaters, improving compliance with regulations, and aligning regulations between different jurisdictions (NMFS 2021b).

The species is native and is in danger of extinction throughout any significant portion of its range within this state OAR 635-100-0105(3)(a) and (3)(b)—The Southern Resident orcas are native to the northeastern Pacific region and their range extends from southeastern Alaska to central California and includes the waters off the Oregon Coast to within 1.2 mi of shore (NMFS 2021a). Population viability modeling by NMFS's Northwest Fishery Science Center indicates that, given recent survival and fecundity rates for the population, the Southern Resident population could decline to less than 40 individuals by 2045, and possibly as few as 30 (NMFS 2021b). In their 2021 status review, NMFS's decision to continue

to list the Southern Residents as endangered reflects their conclusion that the population remains in danger of extinction (NMFS 2021b).

Under OAR 635-100-0105(3)(b), regarding the species' range, the commission shall consider:

The total geographic area in this state used by the species for breeding, resting, or foraging and the portion thereof in which the species is or is likely within the foreseeable future to become in danger of extinction OAR 635-100-0105(5)(a)—It is difficult to estimate the total geographic area in the state that is used by the Southern Resident orcas for breeding, resting, or foraging. The approximately 70 miles of the Oregon coastline between the mouth of the Columbia River and Cape Mears has been identified as an important foraging area for the Southern Residents during the winter and early spring (Critical Habitat Area 1, NMFS 2021a). Given that the Southern Residents have been found to occupy waters within approximately 1 mi of the Oregon shore, and state waters extend to 3 mi from shore, a very rough estimate of the area within state waters inside Area 1 that is used for foraging by the Southern Residents would be about 140 mi^2, which is about 20% of the total critical habitat area (720 mi^2) contained in Oregon marine state waters (see below). Although the waters off the Oregon Coast between Cape Mears and the California border (Critical Habitat Area 3, NMFS 2021a) are primarily used by the Southern Residents as a travel corridor, the orcas do occasionally forage within the area. Based on the available data, it is impossible to accurately estimate the areas of all potential foraging and resting locations within state waters in Area 3, which comprises most of the Oregon Coast. A conservative approach, assuming that any part of the Oregon Coast could potentially be used for foraging, resting, or even breeding by the Southern Residents, uses the entire length of the Oregon coastline (approximately 360 mi) and a 2 mi width (the difference between the 3 mi state waters boundary and the observed occurrence of Southern Residents within 1 mi of shore) to yield a total geographic area estimate of 720 mi^2. Since two of the Southern Resident pods (K and L) currently use the area off the Oregon Coast, and given the population's endangered status, the Southern Residents would be in danger of becoming extinct from the entire area.

The nature of the species' habitat, including any unique or distinctive characteristics of the habitat the species uses for breeding, resting, or foraging OAR 635-100-0105(5)(b)—ODFW estimates that about 20% of the Oregon Coast marine state waters has been identified as an important foraging area for the Southern Residents. In particular, the area near the mouth of the Columbia River is considered a foraging "hotspot" as the orcas appear to spend a considerable amount of time there during the winter and early spring. Presumably, this is to feed on spring Chinook salmon returning to the Columbia during that timeframe (Hanson et al. 2021). This foraging area is critical to the Southern Residents at a time of year when many stocks of their preferred prey, Chinook salmon, are absent or in relatively low abundance (Hanson et al. 2021; NMFS 2021a). While the majority of the Oregon Coast is used by the Southern Residents as a travel corridor between foraging areas to the north and south, some foraging does take place in Area 3, and undoubtedly, the orcas must occasionally rest during their travels (NMFS 2021a). Breeding by the Southern Residents off the Oregon Coast has never been documented, but since calves are born in every month of the year (NMFS 2008), there is the potential for breeding to occur off Oregon.

The extent to which the species habitually uses the geographic area (OAR 635-100-0105 (5)(c))—Southern Resident orcas have been observed on a regular basis in the outer coastal waters as far south as Monterey Bay, California for decades. More recent acoustic research has also detected the Southern Residents in coastal waters (NMFS 2021a). Regular sightings and detections off the California coast indicate that the Southern Residents have been traveling the full length of the Oregon Coast for many years. Although Southern Resident orcas have been documented off the Oregon Coast in every month of the year, they are primarily present during the winter and early spring months (NMFS 2021a). The available data are not sufficient to quantify how much time Southern Residents spend in Oregon waters. To date, two of the three Southern Resident pods (K and L) appear to utilize the habitat along the Oregon Coast while the third (J pod) has not been documented in Oregon waters.

REFERENCES

Au, W. W. L., J. K. Horne, and C. Jones. 2010. Basis of acoustic discrimination of Chinook salmon from other salmons by echolocating, *Orcinus orca*. Journal of the Acoustical Society of America 128: 2225-2232.

Bain, D. E., J. C. Smith, R. Williams, and D. Lusseau. 2006. Effects of vessels on behavior of Southern Resident killer whales (*Orcinus* spp.). National Marine Fisheries Service Contract Report No. AB133F03SE0959 and AB133F04CN0040. 61 pp.

Baird, R. W. 2000. The killer whale: foraging specializations and group hunting. Pages 127-153 in J. Mann, R. C. Connor, P. L. Tyack, and H. Whitehead, editors. Cetacean societies: field studies of dolphins and whales. University of Chicago Press, Chicago, Illinois.

Barrett-Lennard, L. G. and G. M. Ellis. 2001. Population structure and genetic variability in northeastern Pacific killer whales: towards an assessment of population viability. Research Document 2001/065, Canadian Science Advisory Secretariat, Fisheries and Oceans Canada, Ottawa, Ontario.

Be Whale Wise. 2023. The Laws—Washington State. Be Whale Wise, NOAA, Department of Fisheries and Oceans Canada, Transport Canada, Washington Department of Fish and Wildlife, The Whale Museum. https://www.bewhalewise.org/, accessed August 25, 2023.

Béland, P., S. De Guise, C. Girard, A. Lagacé, D. Martineau, R. Michaud, D. C. G. Muir, R. J. Norstrom, E. Pelletier, S. Ray, and L. R. Shugart. 1993. Toxic compounds and health and reproductive effects in St. Lawrence beluga whales. Journal of Great Lakes Research 19:766-775.

BES (Bureau of Environmental Services). 2023. What we do. Bureau of Environmental Services, Portland, Oregon. https://www.portlandoregon.gov/bes/31000, accessed August 25, 2023.

Bigg, M. 1982. An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. Report of the International Whaling Commission 32:655-666.

Bigg, M. A., I. B. MacAskie, and G. Ellis. 1976. Abundance and movements of killer whales off eastern and southern Vancouver Island with comments on management. Arctic Biological Station, Ste. Anne de Bellevue, Quebec.

Bigg, M. A., G. M. Ellis, J. K. B. Ford, and K. C. Balcomb. 1987. Killer whales—a study of their identification, genealogy, and natural history in British Columbia and Washington State. Phantom Press, Nanaimo, British Columbia.

Bigler, B. S., D. W. Welch, and J. H. Helle. 1996. A review of size trends among North Pacific salmon (*Oncorhynchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences 53:455-465.

Boran, J. R. and S. L. Heimlich. 1999. Social learning in cetaceans: hunting, hearing, and hierarchies. Pages 282-307 *in* H. O. Box and K. R. Gibson, editors. Mammalian social learning: comparative and ecological perspectives. Cambridge University Press, Cambridge, United Kingdom.

Bowen W. D., D. Tully, D. J. Boness, B. M. Bulheier, and G. J. Marshall. 2002. Prey-dependent foraging tactics and prey profitability in a marine mammal. Mar Ecol Prog Ser 244:235–245.

Buckman, A. H., N. Veldhoen, G. Ellis, J. K. B. Ford, C. C. Helbing, and P. S. Ross. 2011. PCB-associated changes in mRNA expression in killer whales (*Orcinus orca*) from the NE Pacific Ocean. Environmental Science & Technology 45: 10194-10202.

Burnham, R. E., S. Vagle, C. O'Neill, and K. Trounce. 2021. The efficacy of management measures to reduce vessel noise in critical habitat of Southern Resident killer whales in the Salish Sea. Frontiers in Marine Science, 8, 664691.

Carretta, J. V., K. A. Forney, E. M. Oleson, D. W. Weller, A. R. Lang, J. Baker, M. M. Muto, B. Hanson, A. J. Orr, H. Huber, M. S. Lowry, J. Barlow, J. E. Moore, D. Lynch, L. Carswell, and R. L. Brownell Jr. 2020. U.S. Pacific marine mammal stock assessments: 2019. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-629. 377 pp. + Appendix. Retrieved from: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-region

Center for Whale Research. 2023a. Orca identification. Center for Whale Research, Friday Harbor, Washington. https://www.whaleresearch.com/orca-id, accessed August 1, 2023.

Center for Whale Research. 2023b. Southern Resident killer whale census 2022. Center for Whale Research, Friday Harbor, Washington. https://www.whaleresearch.com/orca-population, accessed August 10, 2023.

Center for Whale Research. 2023c. Not one, but two new babies in L Pod! Center for Whale Research, Friday Harbor, Washington. https://www.whaleresearch.com, accessed August 10, 2023.

Chapman, D. W. 1986. Salmon and steelhead abundance in the Columbia River in the nineteenth century. Transactions of the American Fisheries Society 115(5):662–670.

Dahlheim, M. E., D. K. Ellifrit, and J. D. Swenson. 1997. Killer whales of southeast Alaska: a catalogue of photo-identified individuals. National Marine Mammal Laboratory, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, Washington.

Dahlheim, M. E. and J. E. Heyning. 1999. Killer whale *Orcinus orca* (Linnaeus, 1758). Pages 281-322 *in* S. Ridgway and R. Harrison, editors. Handbook of marine mammals. Academic Press, San Diego, California.

De Guise, S., K. B. Beckmen, and S. D. Holladay. 2003. Contaminants and marine mammal

immunotoxicology and pathology. Pages 38-54 *in* J. G. Vos, G. D. Bossart, M. Fournier, and T. J. O'Shea, editors. Toxicology of marine mammals. Taylor & Francis, London.

DEQ (Department of Environmental Quality). 2023a. Water quality. Oregon Department of Environmental Quality, Salem, Oregon. https://www.oregon.gov/deq/wq/Pages/default.aspx, accessed August 29, 2023.

DEQ (Department of Environmental Quality). 2023b. Emergency response program. Oregon Department of Environmental Quality, Salem, Oregon. https://www.oregon.gov/deq/hazards-and-cleanup/er/pages/default.aspx, accessed August 25, 2023.

Duffield, D. A. and K. W. Miller. 1988. Demographic features of killer whales in oceanaria in the United States and Canada, 1965-1987. Rit Fiskideildar 11:297-306.

EPA (Environmental Protection Agency). 2023. Summary of the Clean Water Act. Environmental Protection Agency, Washington, D.C. https://www.epa.gov/laws-regulations/summary-clean-water-act, accessed August 29, 2023.

Felleman, F. L., J. R. Heimlich-Boran, and R. W. Osborne. 1991. The feeding ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. Pages 113-147 *in* K. Pryor and K. S. Norris, editors. Dolphin societies: discoveries and puzzles. University of California Press, Berkeley, California.

Foote, A. D., R. W. Osborne, and A. R. Hoelzel. 2004. Whale-call response to masking boat noise. Nature 428:910.

Ford, J. K. B. 1989. Acoustic behavior of resident killer whales (*Orcinus orca*) off Vancouver Island, British Columbia. Canadian Journal of Zoology 67:727-745.

Ford, J. K. B. 2002. Killer whale *Orcinus orca*. Pages 669-676 *in* W. F. Perrin, B. Würsig, and J. G. M. Thewissen, editors. Encyclopedia of marine mammals. Academic Press, San Diego, California.

Ford, J. K. B. and G. M. Ellis. 1999. Transients: mammal-hunting killer whales of British Columbia, Washington, and southeastern Alaska. UBC Press, Vancouver, British Columbia.

Ford, J. K. B. and G. M. Ellis. 2006. Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. Marine Ecology Progress Series 316:185-199.

Ford, J. K. B. and G. M. Ellis. 2014. You are what you eat: foraging specializations and their influence on the social organization and behavior of killer whales. Pages 75-98 *in* J. Yamagiwa and L. Karczmarski, editors. Primates and cetaceans: field research and conservation of complex mammalian societies. Springer, Tokyo, Japan.

Ford, J. K. B., G. M. Ellis, L. G. Barrett-Lennard, A. B. Morton, R. S. Palm, and K. C. Balcomb III. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British

Columbia and adjacent waters. Canadian Journal of Zoology 76:1456-1471.

Ford, J. K. B., G. M. Ellis, and K. C. Balcomb. 2000. Killer whales: the natural history and genealogy of *Orcinus orca* in British Columbia and Washington State. 2nd edition. UBC Press, Vancouver, British Columbia.

Ford, J. K. B., G. M. Ellis, P. F. Olesiuk, and K. C. Balcomb. 2010. Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? Biology Letters 6: 139-142. 15 September 2009. 10.1098/rsbl.2009.0468.

Ford, J. K. B., E. H. Stredulinsky, G. M. Ellis, J. W. Durban, and J. F. Pilkington. 2014. Offshore killer whales in Canadian Pacific waters: distribution, seasonality, foraging ecology, population status and potential for recovery. DFO Canadian Science Advisory Secretariat Research Document.

Ford, J. K. B., J. F. Pilkington, A. Riera, M. Otsuki, B. Gisborne, R. M. Abernethy, E. H. Stredulinsky, J. R. Towers, and G. M. Ellis. 2017. Habitats of special importance to resident killer whales (*Orcinus orca*) off the west coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/035. viii + 57 p.

Ford, M. J., J. Hempelmann, M. B. Hanson, K. L. Ayres, R. W. Baird, C. K. Emmons, J. I. Lundin, G. S. Schorr, S. K. Wasser, and L. K. Park. 2016. Estimation of a killer whale (*Orcinus orca*) population's diet using sequencing analysis of DNA from feces. PLoS One 11: e0144956.

Ford, M. J., K. M. Parsons, E. J. Ward, J. A. Hempelmann, C. K. Emmons, M. B. Hanson, K. C. Balcomb, and L. K. Park. 2018. Inbreeding in an endangered killer whale population. Animal Conservation 21: 423-432. https://doi.org/10.1111/acv.12413.

Foster, E. A., D. W. Franks, L. J. Morrell, K. C. Balcomb, K. M. Parsons, A. V. Ginneken, and D. P. Croft. 2012. Social network correlates of food availability in an endangered population of killer whales, *Orcinus orca*. Animal Behaviour 83: 731-736.

Gaydos, J. K., K. C. Balcomb, III, R. W. Osborne, and L. Dierauf. 2004. Evaluating potential infectious disease threats for Southern Resident killer whales, *Orcinus orca*: a model for endangered species. Biological Conservation 117:253-262.

Gaydos, J. K., J. St. Leger, S. Raverty, H. Nollens, M. Haulena, E. J. Ward, C. K. Emmons, M. B. Hanson, K. Balcomb, D. Ellifrit, M. N. Weiss, and D. Giles. 2023. Epidemiology of skin changes in endangered Southern Resident killer whales (*Orcinus orca*). PLoS ONE 18(6): e0286551. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0286551, accessed September 19, 2023.

Geraci, J. R. 1990. Physiologic and toxic effects on cetaceans. Pages 167-197 i*n* J. R. Geraci and D. J. S. Aubin eds. Sea Mammals and Oil: Confronting the Risks. Academic Press, San Diego, California.

Geraci, J. R. and D. J. St. Aubin. 1990. Sea mammals and oil: confronting the risks. Academic Press, New York, New York.

Giles, D. A. and R. Cendak. 2010. An assessment of vessel effects on the cohesion state of Southern Resident killer whale groups and measuring vessel compliance with boating guidelines. Contract AB133F-07-SE-3026 report to the National Marine Fisheries Service. 56 pp.

Gockel, C. and T. Mongillo. 2013. Potential effects of PBDEs on Puget Sound and Southern Resident killer whales: A report on the Technical Workgroups and Policy Forum. EPA and NOAA. 20 pp. Retrieved from https://www.eopugetsound.org/articles/report-potential-effects-pbdes-puget-sound-and-southern-resident-killer-whales.

Gordon, J. and A. Moscrop. 1996. Underwater noise pollution and its significance for whales and dolphins. Pages 281-319 *in* M. P. Simmonds and J. D. Hutchinson, editors. The conservation of whales and dolphins: science and practice. John Wiley & Sons, Chichester, United Kingdom.

Government of Canada. 2023. Chinook salmon (*Oncorhynchus tshawytscha*): COSEWIC assessment and status report 2020. Government of Canada, Ottowa, Ontario. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/chinook-salmon-2020.html, accessed August 30, 2023.

Grant, S. C. H. and P. S. Ross. 2002. Southern Resident killer whales at risk: toxic chemicals in the British Columbia and Washington environment. Canadian Technical Report of Fisheries and Aquatic Sciences 2412:1-111.

Gregory, M. and D. G. Cyr. 2003. Effects of environmental contaminants on the endocrine system of marine mammals. Pages 67-81 *in* J. G. Vos, G. D. Bossart, M. Fournier, and T. J. O'Shea, editors. Toxicology of marine mammals. Taylor & Francis, London, United Kingdom.

Haenel, N. J. 1986. General notes on the behavioral ontogeny of Puget Sound killer whales and the occurrence of allomaternal behavior. Pages 285-300 *in* B. C. Kirkevold and J. S. Lockard, editors. Behavioral biology of killer whales. Alan R. Liss, New York, New York.

Hall, A. J., B. J. McConnell, L. H. Schwacke, G. M. Ylitalo, R. Williams, and T. K. Rowles. 2018. Predicting the effects of polychlorinated biphenyls on cetacean populations through impacts on immunity and calf survival. Environmental Pollution 233: 407-418.

Hanson, M. B., R. W. Baird, J. K. B. Ford, J. Hempelmann-Halos, D. M. Van Doornik, C. R. Candy, C. K. Emmons, G. S. Schorr, B. Gisborne, K. L. Ayres, S. K. Wasser, K. C. Balcomb, K. Balcomb-Bartok, J. G. Sneva, and M. J. Ford. 2010. Species and stock identification of prey consumed by endangered Southern Resident killer whales in their summer range. Endangered Species Research 11: 69-82.

Hanson, M. B., C. K. Emmons, E. J. Ward, J. A. Nystuen, and M. O. Lammers. 2013. Assessing the coastal occurrence of endangered killer whales using autonomous passive acoustic recorders. Journal of the Acoustical Society of America 134: 3486-3495.

Hanson, M. B., E. J. Ward, C. K. Emmons, M. M. Holt, and D. M. Holzer. 2017. Assessing the movements and occurrence of Southern Resident killer whales relative to the U.S. Navy's Northwest Training Range Complex in the Pacific Northwest. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center under MIPR N00070-15-MP-4C363. 30 June 2017. 23 pp.

Hanson, M. B., C. K. Emmons, M. J. Ford, M. Everett, K. Parsons, L. K. Park, J. Hempelmann, D. M. Van Doornik, G. S. Schorr, J. K. Jacobsen, M. F. Sears, M. S. Sears, J. G. Sneva, R. W. Baird, and L. Barre. 2021. Endangered predators and endangered prey: Seasonal diet of Southern Resident killer whales. PLoS ONE 16(3): e0247031. https://doi.org/10.1371/journal.pone.0247031

Hartwell, S. I. 2004. Distribution of DDT in sediments off the central California coast. Marine Pollution Bulletin 49:299-305.

Heimlich-Boran, J. R. 1988. Behavioral ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. Canadian Journal of Zoology 66:565-578.

Hickie, B. E., P. S. Ross, R. W. Macdonald, and J. K. B Ford. 2007. Killer whales (*Orcinus orca*) face protracted health risks associated with lifetime exposures to PCBs. Environmental Science & Technology 41: 6613-6619.

Hilborn, R., S. P. Cox, F. M. D. Gulland, D. G. Hankin, N. T. Hobbs, D. E. Schindler, and A. W. Trites. 2012. The effects of salmon fisheries on Southern Resident killer whales: final report of the Independent Science Panel.

Hoelzel, A. R. 1993. Foraging behaviour and social group dynamics in Puget Sound killer whales. Animal Behaviour 45:581-591.

Hoelzel, A. R. 2004. Report on killer whale population genetics for the BRT review on the status of the Southern Resident population. Unpublished report to the BRT.

Holt, M. M. 2008. Sound exposure and Southern Resident killer whales (*Orcinus orca*): a review of current knowledge and data gaps. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-NWFSC-89. 59 pp. Retrieved from https://www.nwfsc.noaa.gov/assets/25/666_03042008_154832_OrcaSoundExposureTM89Final.pdf.

Holt, M. M., J. B. Tennessen, E. J. Ward, M. B. Hanson, C. K. Emmons, D. A. Giles, and J. T. Hogan. 2021. Effects of vessel distance and sex on the behavior of endangered killer whales. Frontiers in Marine Science, 7, 1211.

iNaturalist. 2023. Genus *Orcinus*. iNaturalist. https://www.inaturalist.org/taxa/41520-Orcinus, accessed August 2, 2023.

Iwata, H., S. Tanabe, N. Sakai, and R. Tatsukawa. 1993. Distribution of persistent organochlorines in the oceanic air and surface seawater and the role of the ocean on their global transport and fate. Environmental Science and Technology 27:1080-1098.

Jacobsen, J. K. 1986. The behavior of *Orcinus orca* in the Johnstone Strait, British Columbia. Pages 135-185 *in* B. C. Kirkevold and J. S. Lockard, editors. Behavioral biology of killer whales. Alan R. Liss, New York, New York.

Jarvela-Rosenberger, A. L., M. MacDuffee, A. G. J. Rosenberger, and P. S. Ross. 2017. Oil spills and marine mammals in British Columbia, Canada: development and application of a risk-based conceptual framework. Archives of Environmental Contamination and Toxicology 73: 131-153.

Kastelein, R. A., J. Kershaw, E. Berghout, and P. R. Wiepkema. 2003. Food consumption and suckling in killer whales *Orcinus orca* at Marineland Antibes. International Zoo Yearbook 38:204-218.

Krahn, M. M., P. R. Wade, S. T. Kalinowski, M. E. Dahlheim, B. L. Taylor, M. B. Hanson, G. M. Ylitalo, R. P. Angliss, J. E. Stein, and R. S. Waples. 2002. Status review of Southern Resident killer whales (*Orcinus orca*) under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWFSC-54, U.S. Department of Commerce, Seattle, Washington.

Krahn, M., M. J. Ford, W. F. Perrin, P. R. Wade, R. P. Angliss, M. B. Hanson, B. L. Taylor, G. M. Ylitalo, M. E. Dahlheim, J. E. Stein, and R. S. Waples. 2004. Status review of Southern Resident killer whales (*Orcinus orca*) under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWFSC-62. 73pp.

Krahn, M. M., M. B. Hanson, R. W. Baird, R. H. Boyer, D. G. Burrows, C. E. Emmons, J. K. B. Ford, L. L. Jones, D. P. Noren, P. S. Ross, G. S. Schorr, and T. K. Collier. 2007. Persistent organic pollutants and stable isotopes in biopsy samples (2004/2006) from Southern Resident killer whales. Marine Pollution Bulletin.

Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B.C. . Pages 149-159 *in* K. Pryor and K. S. Norris eds. Dolphin societies: discoveries and puzzles. University of California Press, Berkeley, California.

Lichatowich, J. 1999. Salmon without rivers: a history of the Pacific salmon crisis. Island Press, Washington, D.C.

Lusseau, D., D. E. Bain, R. Williams, and J. C. Smith. 2009. Vessel traffic disrupts the foraging behavior of Southern Resident killer whales *Orcinus orca*. Endangered Species Research 6: 211-221.

Marine Mammal Commission. 2023. Southern Resident killer whale—distribution. Marine Mammal Commission, Bethesda, Maryland.

https://www.mmc.gov/priority-topics/species-of-concern/southern-resident-killer-whale/, accessed August 18, 2023.

Matkin, C. 1994. An observer's guide to the killer whales of Prince William Sound. Prince William Sound Books, Valdez, Alaska.

Matkin, C. O., G. E. Ellis, M. E. Dahlheim, and J. Zeh. 1994. Status of killer whales in Prince William Sound, 1984-1992. Pages 141-162 *in* T. R. Loughlin, editor. Marine mammals and the Exxon Valdez. Academic Press, San Diego, California.

Matkin, C. O., D. R. Matkin, G. M. Ellis, E. Saulitis, and D. McSweeney. 1997. Movements of resident killer whales in southeastern Alaska and Prince William Sound, Alaska. Marine Mammal Science 13:469-475.

Matkin, C. O., G. Ellis, L. Barrett-Lennard, H. Yurk, E. Saulitis, D. Scheel, P. Olesiuk, and G. Ylitalo. 2003. Photographic and acoustic monitoring of killer whales in Prince William Sound and Kenai Fjords. Restoration Project 030012 Final Report, Exxon Valdez Oil Spill Restoration Project, North Gulf Oceanic Society, Homer, Alaska.

McCluskey, S. M. 2006. Space use patterns and population trends of Southern Resident killer whales (*Orcinus orca*) in relation to distribution and abundance of Pacific salmon (*Oncorhynchus* spp.) in the inland marine waters of Washington State and British Columbia. M.S. Thesis, University of Washington, Seattle, Washington.

Miller, P. J. O. and D. E. Bain. 2000. Within-pod variation in the sound production of a pod of killer whales, *Orcinus orca*. Animal Behaviour 60:617-628.

Miller, P. J. O., A. D. Shapiro, P. L. Tyack, and A. R. Solow. 2004. Call-type matching in vocal exchanges of free-ranging resident killer whales, *Orcinus orca*. Animal Behaviour 67:1099-1107.

Møhl B., W. W. L. Au, J. Pawloski, and P. E. Nachtigall. 1999. Dolphin hearing: relative sensitivity as a function of point of application of a contact sound source in the jaw and head region. Journal of the Acoustical Society of America 105:3421-3424.

Mongillo, T. M., G. M. Ylitalo, L. D. Rhodes, S. M. O'Neill, D. P. Noren, and M. B. Hanson. 2016. Exposure to a mixture of toxic chemicals: implications for the health of endangered Southern Resident killer whales. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-NWFSC-135. 107 pp. Retrieved from: https://repository.library.noaa.gov/view/noaa/12818.

Nehlsen, W., J. Williams, and J. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4–21.

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

NMFS (National Marine Fisheries Service). 2021a. Revision of the critical habitat designation for Southern Resident killer whales, final biological report (to accompany the final rule). West Coast Region, National Marine Fisheries Service, Seattle, Washington.

NMFS (National Marine Fisheries Service). 2021b. Southern Resident killer whales (*Orcinus orca*) 5-year review: summary and evaluation. West Coast Region, National Marine Fisheries Service, Seattle, Washington.

NMFS (National Marine Fisheries Service). 2023a. Endangered species conservation: species in the spotlight. National Marine Fisheries Service, Silver Spring, Maryland. https://www.fisheries.noaa.gov/topic/endangered-species-conservation/species-in-the-spotlight, accessed August 8, 2023.

NMFS (National Marine Fisheries Service). 2023b. Species directory: killer whale. National Marine Fisheries Service, Silver Spring, Maryland. https://www.fisheries.noaa.gov/species/killer-whale, accessed August 8, 2023.

NMFS (National Marine Fisheries Service). 2023c. ESA protected species—Pacific salmon and steelhead. National Marine Fisheries Service, Silver Spring, Maryland. https://www.fisheries.noaa.gov/species/pacific-salmon-and-steelhead#esa-protected-species, accessed August 21, 2023.

NMFS (National Marine Fisheries Service). 2023d. Sea turtles, dolphins, and whales - 10 years after the *Deepwater Horizon* oil spill. National Marine Fisheries Service, Silver Spring, Maryland. https://www.fisheries.noaa.gov/national/marine-life-distress/sea-turtles-dolphins-and-whales-10-years-after-deepwater-horizon-oil#:~:text=An%20estimated%204%2C900%E2%80%937%2C600%20large,on%20sea%20turtle%20nesting%20beaches, accessed August 24, 2023.

NMFS (National Marine Fisheries Service). 2023e. Increased hatchery production aims to boost Chinook salmon for endangered killer whales. National Marine Fisheries Service, Silver Spring, Maryland. https://www.fisheries.noaa.gov/feature-story/increased-hatchery-production-aims-boost-chinook-salmon-endangered-killer-whales, accessed August 28, 2023.

NMFS (National Marine Fisheries Service). 2023f. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and conference on the authorization of the West Coast ocean salmon fisheries through approval of the Pacific Salmon Fishery Management Plan including Amendment 21 and promulgation of regulations implementing the plan for Southern Resident killer whales and their current and proposed critical habitat. National Marine Fisheries Service, Silver Spring, Maryland. https://repository.library.noaa.gov/view/noaa/29545, accessed August 29, 2023.

NMFS (National Marine Fisheries Service). 2023g. Marine life viewing guidelines: guidelines & distances. National Marine Fisheries Service, Silver Spring, Maryland.

https://www.fisheries.noaa.gov/topic/marine-life-viewing-guidelines/guidelines-&-distances, accessed August 24, 2023.

NMFS (National Marine Fisheries Service) and WDFW (Washington Department of Fish and Wildlife). 2018. Southern Resident killer whale priority Chinook stocks report. West Coast Region, National Marine Fisheries Service, Seattle, Washington. Retrieved from: https://media.fisheries.noaa.gov/dam-migration/srkw_priority_chinook_stocks_conceptual_model_report___list_22june2018.pdf.

Noren, D. P., A. H. Johnson, D. Rehder, and A. Larson. 2009. Close approaches by vessels elicit surface active behaviors by Southern Resident killer whales. Endangered Species Research 8: 179-192.

Noren, D. P. 2011. Estimated field metabolic rates and prey requirements of resident killer whales. Marine Mammal Science 27: 60-77.

Northcote T. G. and D. Y. Atagi. 1997. Pacific salmon abundance trends in the Fraser River watershed compared with other British Columbia systems. Pages 199–219 *in* D.J. Stouder, P.A. Bisson, and R.J. Naiman, editors. Pacific salmon & their ecosystems. Springer, Boston, Massachusetts.

O'Neill, S. M., G. M. Ylitalo, M. Krahn, J. E. West, J. Bolton, and D. Brown. 2005. Elevated levels of persistent organic pollutants in Puget Sound versus other free-ranging populations of Pacific salmon: the importance of residency in Puget Sound. Abstract of presentation at 2005 Puget Sound Georgia Basin Research Conference. Seattle, Washington.

O'Neill, S. M., G. M. Ylitalo, J. E. West, J. Bolton, C. A. Sloan, and M. M. Krahn. 2006. Regional patterns of persistent organic pollutants in five Pacific salmon species (*Oncorhynchus* spp) and their contributions to contaminant levels in Northern and Southern Resident killer whales (*Orcinus orca*). Abstract from 2006 Southern Resident Killer Whale Symposium, Seattle, Washington.

O'Neill, S. M., G. M. Ylitalo, and J. E. West. 2014. Energy content of Pacific salmon as prey of Northern and Southern Resident killer whales. Endangered Species Research 25: 265-281.

O'Shea, T. J. 1999. Environmental contaminants and marine mammals. Pages 485-563 *in* J. E. Reynolds III and S. A. Rommel, editors. Biology of marine mammals. Smithsonian Institution Press, Washington, D.C.

O'Shea, T. J. and A. Aguilar. 2001. Cetacea and Sirenia. Pages 427-496 *in* R. F. Shore and B. A. Rattner, editors. Ecotoxicology of wild mammals. John Wiley & Sons, Chichester, United Kingdom.

ODFW (Oregon Department of Fish and Wildlife). 2023. Ocean energy—key concerns. Oregon Department of Fish and Wildlife, Salem, Oregon. https://www.dfw.state.or.us/mrp/ocean_energy/key_concerns.asp, accessed August 25, 2023.

Olesiuk, P. F., M. A. Bigg, and G. M. Ellis. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the

International Whaling Commission, Special Issue 12:209-243.

Olesiuk, P. F., G. M. Ellis, and J. K. Ford. 2005. Life history and population dynamics of Northern Resident killer whales (*Orcinus orca*) in British Columbia. DFO Canadian Science Advisory Secretariat Research Document 2005/045.

OrcaLab. 2023. Learn about orcas. OrcaLab, Alert Bay, British Columbia. https://orcalab.org/orcas/#:~:text=For%20Resident%20orcas%2C%20a%20pod,Southern%20Residents%20have%20just%20three, accessed August 10, 2023.

Oregon Whale Watch. 2023. Oregon Whale Watch Info. Oregon State Parks, Salem, Oregon. https://orwhalewatch.org/, accessed August 25, 2023.

Parsons, K. M., K. C. Balcomb III, J. K. B. Ford, and J. W. Durban. 2009. The social dynamics of Southern Resident killer whales and conservation implications for this endangered population. Animal Behaviour 77(4): 963-971.

PFMC (Pacific Fishery Management Council). 2020. Pacific Fishery Management Council salmon fishery management plan impacts to Southern Resident killer whales. Risk assessment. May 2020. Ad-Hoc SRKW Workgroup. 165p.

PFMC (Pacific Fishery Management Council). 2023a. Pacific Fishery Management Council salmon fishery management plan impacts to Southern Resident killer whales—risk assessment. Pacific Fishery Management Council, Portland, Oregon. Retrieved from: https://www.pcouncil.org/documents/2020/05/e-2-srkw-workgroup-report-1-pacific-fishery-management-council-salmon-fishery-management-plan-impacts-to-southern-resident-killer-whales-risk-assessment-electronic-only.pdf/.

PFMC (Pacific Fishery Management Council). 2023b. Salmon FMP Amendment 21: Fishery management measures included to limit impacts on Southern Resident killer whales. Pacific Fishery Management Council, Portland, Oregon. https://www.pcouncil.org/actions/salmon-fmp-amendment-21-fishery-management-measures-included-to-limit-impacts-on-southern-resident-killer-whales/, accessed August 29, 2023.

PFMC (Pacific Fishery Management Council). 2023c. Salmon technical team report on potential Southern Resident killer whale Chinook salmon abundance threshold updates. Pacific Fishery Management Council, Portland, Oregon. Retrieved from: https://www.pcouncil.org/documents/2022/11/d-2-a-supplemental-stt-report-2.pdf/

PSC (Pacific Salmon Commission). 2023. The Pacific Salmon Treaty. Pacific Salmon Commission, Vancouver, British Columbia. https://www.psc.org/about-us/history-purpose/pacific-salmon-treaty/, accessed August 29, 2023.

PST (Pacific Salmon Treaty). 2023. Hatchery production initiative for Southern Resident killer whales

—December 20, 2021. Technical document. Retrieved from: http://centralpt.com/upload/560/Advocacy/2021/21743_2021HatcheryIncreases.pdf.

Reijnders, P. J. H. 2003. Reproductive and developmental effects of environmental organochlorines on marine mammals. Pages 55-66 *in* J. G. Vos, G. D. Bossart, M. Fournier, and T. J. O'Shea, editors. Toxicology of marine mammals. Taylor & Francis, London, United Kingdom.

Reijnders, P. J. H. and A. Aguilar. 2002. Pollution and marine mammals. Pages 948-957 *in* W. F. Perrin, B. Würsig, and J. G. M. Thewissen, editors. Encyclopedia of marine mammals. Academic Press, San Diego, California.

Richardson, W. J., C. R. Greene, Jr., C. I. Malme, and D. H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego, California.

Riesch, R., J. K. B. Ford, and F. Thomsen. 2006. Stability and group specificity of stereotyped whistles in resident killer whales, *Orcinus orca*, off British Columbia. Animal Behaviour 71:79-91.

Riesch, R., L. G. Barrett-Lennard, G. M. Ellis, J. K. B. Ford, and V. B. Deeke. 2012. Cultural traditions and the evolution of reproductive isolation: ecological speciation in killer whales? Biological Journal of the Linnean Society 106:1–17.

Robeck, T. R., K. J. Steinman, S. Gearhart, T. R. Reidarson, J. F. McBain, and S. L. Monfort. 2004. Reproductive physiology and development of artificial insemination technology in killer whales (*Orcinus orca*). Biology of Reproduction 71:650-660.

Rosenberger, A. L. J., M. MacDuffee, A. G. J. Rosenberger and P. S. Ross. 2017. Oil spills and marine mammals in British Columbia, Canada: Development and application of a risk-based conceptual framework. Archives of Environmental Contamination and Toxicology 73: 131-153.

Ross, P. S. 2002. The role of immunotoxic environmental contaminants in facilitating the emergence of infectious diseases in marine mammals. Human and Ecological Risk Assessment 8:277-292.

Ross, P. S., R. L. de Swart, H. van Loveren, A. D. M. E. Osterhaus, and J. G. Vos. 1996. The immuntoxicity of environmental contaminants to marine wildlife: a review. Annual Review of Fish Diseases 6:151-165.

Ross, P. S., G. M. Ellis, M. G. Ikonomou, L. G. Barrett-Lennard, and R. F. Addison. 2000. High PCB concentrations in free-ranging Pacific killer whales, *Orcinus orca*: effects of age, sex, and dietary preference. Marine Pollution Bulletin 40:504-515.

Senigaglia, V., F. Christiansen, L. Bejder, D. Gendron, D. Lundquist, D. P. Noren, A. Schaffar, J. C. Smith, R. Williams, E. Martinez, K. Stockin, and D. Lusseau. 2016. Meta-analyses of whale-watching impact studies: comparisons of cetacean responses to disturbance. Marine Ecology Progress Series 542: 251-263.

Shields, M. W., J. Lindell, and J. Woodruff. 2018. Declining spring usage of core habitat by endangered fish-eating killer whales reflects decreased availability of their primary prey. Pacific Conservation Biology 24, 189-193. https://doi.org/10.1071/PC17041

Stewart, J. D., J. W. Durban, H. Fearnbach, L. G. Barrett-Lennard, P. K. Casler, E. J. Ward, and D. R. Dapp. 2021. Survival of the fattest: linking body condition to prey availability and survivorship of killer whales. Ecosphere, 12(8), e03660.

Szymanski, M. D., D. E. Bain, K. Kiehl, S. Pennington, S. Wong, and K. R. Henry. 1999. Killer whale (*Orcinus orca*) hearing: auditory brainstem response and behavioral audiograms. Journal of the Acoustical Society of America 106:1134-1141.

The Society for Marine Mammalogy. 2023. List of proposed, un-named marine mammal species and subspecies. The Society for Marine Mammalogy, Yarmouth Port, Massachusetts. https://marinemammalscience.org/science-and-publications/list-marine-mammal-species-subspecies/list-of-proposed-un-named-marine-mammal-species-and-subspecies/, accessed August 2, 2023.

The Whale Museum. 2023. What is Soundwatch? The Whale Museum, Friday Harbor, Washington. https://whalemuseum.org/pages/soundwatch-boater-education-program, accessed August 30, 2023.

USCG (U. S. Coast Guard), EPA (Environmental Protection Agency), Oregon Department of Environmental Quality, Idaho Office of Emergency Management, and Washington Department of Ecology. 2018. Northwest Area Contingency Plan. Retrieved from: https://www.rrt10nwac.com/Files/NWACP/2018/Northwest%20Area%20Contingency%20Plan%202018.pdf.

Veirs, S., V. Veirs, and J. D. Wood. 2016. Ship noise extends to frequencies used for echolocation by endangered killer whales. PeerJ, 4, e1657.

Ward, E. J., E. E. Holmes, and K. C. Balcomb. 2009. Quantifying the effects of prey abundance on killer whale reproduction. Journal of Applied Ecology 46: 632-640.

Wasser, S. K., J. I. Lundin, K. Ayres, E. Seely, D. Giles, K. Balcomb, J. Hempelmann, K. Parsons, and R. Booth. 2017. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales (*Orcinus orca*). PLoS One 12: e0179824.

WDFW (Washington Department of Fish and Wildlife). 2023. New legislation creates 1,000-yard mandatory vessel buffer around endangered Southern Resident killer whales effective January 2025. Washington Department of Fish and Wildlife, Olympia, Washington. https://wdfw.wa.gov/newsroom/news-release/new-legislation-creates-1000-yard-mandatory-vessel-buffer-around-endangered-southern-resident-killer, accessed August 25, 2023.

Weitkamp, L. A., T. C. Wainwright, G. J. Bryant, G. B. Milner, D. J. Teel, R. G. Kope, and R. S. Waples.

1995. Status review of coho salmon from Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-24, Department of Commerce, Seattle, Washington.

West, J., S. O'Neill, G. Lippert, and S. Quinnell. 2001. Toxic contaminants in marine and anadromous fishes from Puget Sound, Washington. Washington Department of Fish and Wildlife, Olympia, Washington.

Wiles, G. J. 2016. Periodic status review for the killer whale in Washington. Washington Department of Fish and Wildlife, Olympia, Washington.

Williams, R., D. E. Bain, J. K. B. Ford, and A. W. Trites. 2002. Behavioural responses of male killer whales to a 'leapfrogging' vessel. Journal of Cetacean Research and Management 4: 305-310.

Williams, R., D. Lusseau, and P. S. Hammond. 2006. Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). Biological Conservation 133: 301-311.

Williams, R., D. E. Bain, J. C. Smith, and D. Lusseau. 2009. Effects of vessels on behaviour patterns of individual Southern Resident killer whales *Orcinus orca*. Endangered Species Research 6: 199-209.

Williams, R., E. Ashe, and D. Lusseau. 2010. Killer whale activity budgets under no-boat, kayak-only, and power-boat conditions. Contract via Herrera Consulting. 29 pp.

WSRCO (Washington State Recreation and Conservation Office). 2023a. Southern Resident Killer Whale Task Force. Washington State Recreation and Conservation Office, Olympia, Washington. https://orca.wa.gov/about/, accessed August 28, 2023.

WSRCO (Washington State Recreation and Conservation Office). 2023b. Recommendation 6. Washington State Recreation and Conservation Office, Olympia, Washington. https://orca.wa.gov/recommendation/6/, accessed August 28, 2023.

WSRCO (Washington State Recreation and Conservation Office). 2023c. All recommendations. Washington State Recreation and Conservation Office, Olympia, Washington. https://orca.wa.gov/progress/all-recommendations/, accessed August 29, 2023.