BUREAU OF RECLAMATION

Long-Term Operation – Biological Assessment

# Chapter 11 – Southern Resident Killer Whale

October 2024

This page intentionally left blank.

# Contents

# Tables

# Figures

This page intentionally left blank.

# Chapter 11 Southern Resident Killer Whale

The federally endangered Southern Resident killer whale (*Orcinus orca*) distinct population segment (DPS) and designated critical habitat do not occur in the action area but Chinook salmon that originate from the Central Valley can be consumed as prey by the southern resident killer whales. Killer whales are the largest member of the Delphinidae family and are widely distributed across all the world's oceans. However, the endangered DPS of Southern Resident killer whales spends most of its life in the nearshore marine environment, coastal bays, and estuaries along the Pacific northwest coast of North America and the southwest coast of Canada. The southern resident killer whale population consists of three pods designated J, K and L, each containing 25, 16 and 32 members, respectively as of the 2022 census (Center for Whale Research 2022).

## 11.1 Status of Species and Designated Critical Habitat

National Marine Fisheries Service (NMFS) first listed the southern resident killer whale DPS as endangered on November 18, 2005 (70 *Federal Register* [FR] 69903) and reaffirmed as endangered on August 5, 2013 (78 FR 47277; National Marine Fisheries Service 2021a). NMFS designated critical habitat for the southern resident killer whale DPS in inland waters of Washington State on November 29, 2006 (71 FR 69054). USFWS listed the southern resident killer whale DPS to the List of Endangered and Threatened Wildlife on April 4, 2007 (72 FR 16284). NMFS revised the critical habitat area to include six additional coastal critical habitat areas along the U.S. West Coast on August 2, 2021 (86 FR 41668) and completed a review of scientific information to date relevant to critical habitat (National Marine Fisheries Service 2021b).

The 2006 designated critical habitat consisted of three areas: (1) The Summer Core Area in Haro Strait and water\s around the San Juan Islands; (2) Puget Sound Area; and (3) the Strait of Juan de Fuca Area (71 FR 69054). The 2021 critical habitat revision added coastal waters between the 6.1 meter (m) and 200-m depth contours off the coast of Washington, Oregon, and California from the U.S. international border with Canada south to Point Sur, California (86 FR 41668) (Figure 11-1).

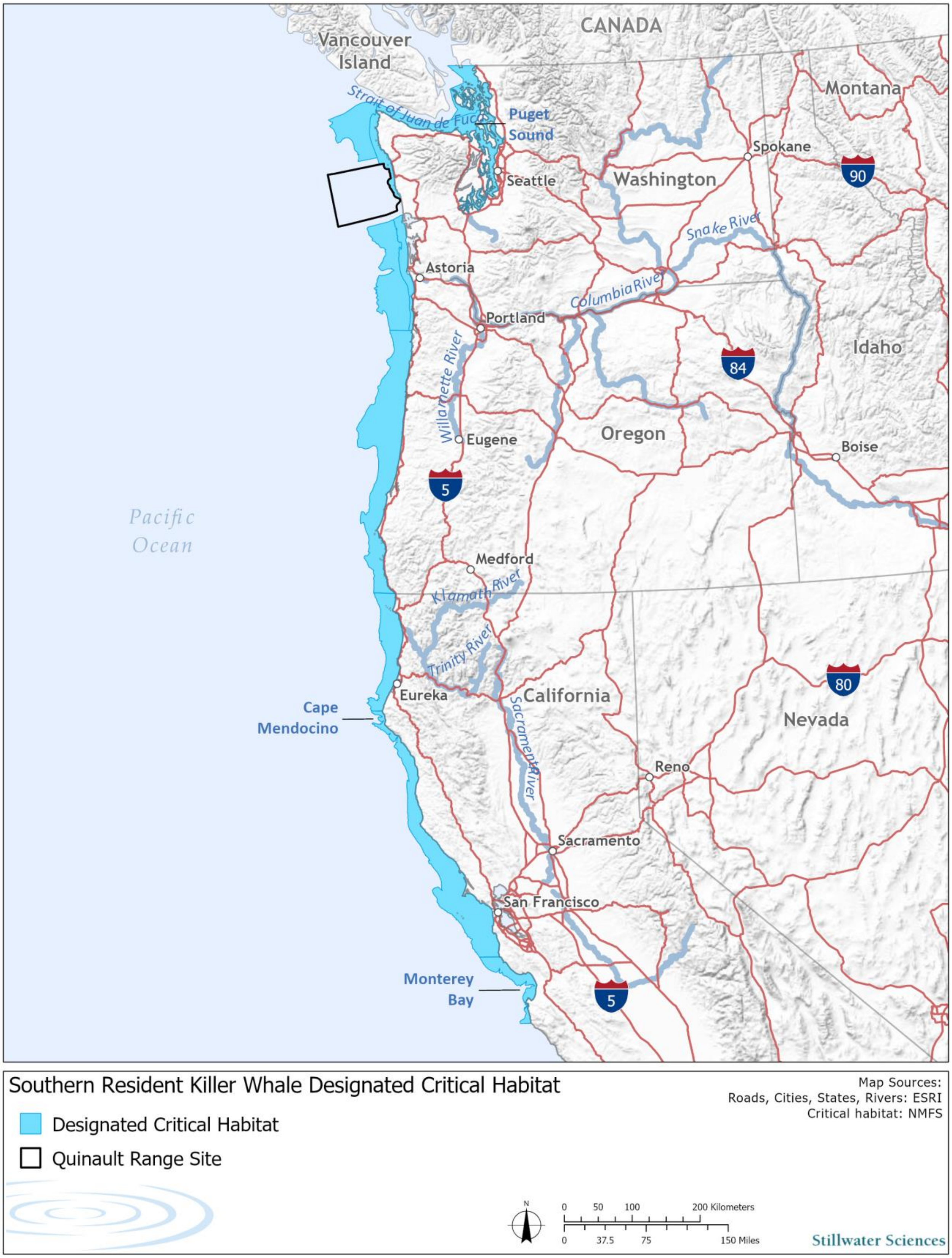



Figure 11-1. 2021 Map – Southern Resident Killer Whale Critical Habitat (86 FR 41668)

NMFS released a *Recovery Plan for Southern Resident Killer Whales* in 2008 (National Marine Fisheries Service 2008) and the most recent 5-year review was issued in 2021 stating, *"Overall, while this new information increases our knowledge of [southern resident killer whale] conditions and threats, it does not indicate a change to the species' status or the magnitude or imminence of the threats since the listing."*

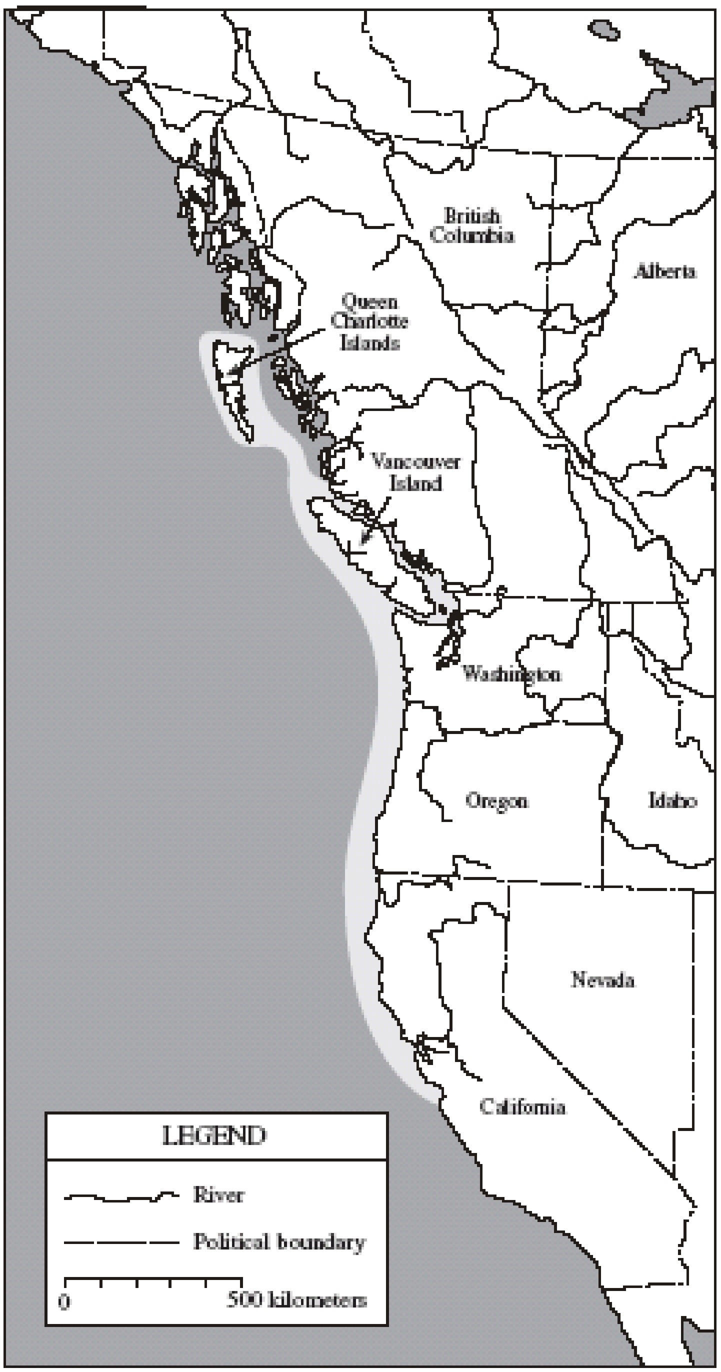
### 11.1.1 Distribution and Abundance

There are three forms of killer whales; termed as residents, transients, and offshores. Resident killer whales in the northeast Pacific are distributed from Alaska to California, with four distinct communities recognized: southern, northern, southern Alaska, and western Alaska. The southern resident killer whales are known to occur frequently in the inland waters of Washington, USA, and British Columbia, Canada also known as the Salish Sea (Strait of Georgia, Strait of Juan de Fuca, and Puget Sound), the outer coastal waters (within ~50 kilometers of shore) from Haida Gwaii, Canada down the West coast of Vancouver Island, Washington, Oregon, and California as far south as Monterey Bay (Figure 11-2).

The southern resident killer whale population comprises three pods (J, K, and L) which each contain several matrilines (a group of whales related through their maternal lines of descent). J pod matrilines are not documented in the coastal waters off California and Oregon and occur mostly in the Salish Sea and off the west coast of Vancouver Island. Photo identification studies (Center for Whale Research 2022), satellite tagging studies (NOAA Fisheries and Cascadia Research unpublished data), prey studies (Hanson et al. 2021), contaminant studies (Krahn et al. 2007; Krahn et al. 2009), passive acoustic monitoring (Hanson et al. 2013), as well as land-based and boat-based sighting networks indicate that J pod individuals rarely, if ever, travel beyond the coastal waters off Washington and British Columbia and rarely forage on salmon originating from the Central Valley (National Marine Fisheries Service 2008, 2021b). K and L pods also occur frequently in the Salish Sea and off the west coast of Vancouver Island but also make frequent excursions to the coastal waters off Oregon and occasional excursions to the coastal waters off California (National Marine Fisheries Service 2021b). K and L pods members have been observed as far south as the coastal waters off Monterey Bay (National Marine Fisheries Service 2008, 2021b). Excursions to coastal California happen more often in February but have been documented, albeit rarely, in December, January, March, and April. The same group of studies listed above indicate that the K and L pods forage more often on salmon originating from California than the J pod.

Historically, the abundance of southern resident killer whales is estimated from a low population level of 140 individuals to an unknown upper bound (National Marine Fisheries Service 2008). From 1964-1974, the southern resident killer whale population was the target of live capture harvests for the aquarium trade that ultimately removed at least 34 animals from the population (Bigg and Wolman 1975; Asper and Cornell 1977; Olesiuk et al. 1990; Ward et al. 2009). Since then, the desire to capture for display has become unfavorable in North America and prohibitions for capture to display have been put in place by states, provinces, and countries. The Marine Mammal Act of 1972 is the prominent regulation for killer whales in the United States The southern resident killer whale population has fluctuated from as low as 71 in 1976 to as high as 98 in 1995. A 20 percent decline occurred between 1996 and 2001 that could not be explained by residual demographics from the historical live captures and prompted consideration of the southern resident killer whale for listing under the Endangered Species Act.

The Center for Whale Research completed their 2022 annual census for NMFS on July 1, 2022, and reported the southern resident killer whale population at 73 individuals: with J pod at 25 individuals, K pod at 16, and L pod at 32 (Center for Whale Research 2022). This is a decrease from 74 individuals since the last census completed July 1, 2021. The southern resident killer whale population has not been this low since 1984.




Source: Wiles 2004.

Figure 11-2. Range of the Southern Resident Killer Whale

### 11.1.2 Life History and Habitat Requirements

#### *11.1.2.1 Social Structure and Communication*

Killer whales are highly social animals that occur primarily in pods of up to 40 – 50 individuals (Heyning and Dahlheim 1988; Baird 2000). The killer whale social structure is usually branched out via maternal descent (Baird 2000; Ford et al. 2000; Center for Whale Research 2022) with resident killer whales exhibiting particularly strong, life-long social bonds through matrilineal relationships with few exceptions. A southern resident killer whale matriline descends from a female, her offspring, and the offspring of her daughters and granddaughters (Center for Whale Research 2022). Members seldom separate from the group. Matriarchal females in long-lived mammals likely hold important social knowledge that guides the behavior of individual matrilines (Boran and Heimlich 1999; McComb et al. 2001).

Killer whales have complex vocalizations that are essential for foraging, navigation, and communication (Dahlheim and Awbrey 1982; Ford et al. 2000; Miller 2002; Miller et al. 2004; Saulitis et al. 2005). Sounds are made by forced air in nasal passages and are amplified by a fatty enlargement near the top of the head, known as the melon.

Adult southern resident killer whale females travel and forage with their matrilineal groups, usually with their mother and/or other close female relatives (i.e., grandmother and/or maternal aunts), and their offspring. At any given time, adult reproductive-age females could be pregnant, lactating, or "resting" (i.e., not pregnant), while older individuals (usually ~40 years or older) are reproductively senescent (Ward et al. 2009) but continue to travel with their matriline and offspring, sometimes for many decades. The presence of a senescent female improves the likelihood of grand offspring survival (Nattrass et al. 2019) potentially through assisting with calf care; increasing foraging success through shared historical knowledge of prime foraging locations and timing of salmon migrations and honed hunting skills; and/or participation in and leadership of cooperative hunting and prey sharing. Female southern resident killer whales give birth to their first surviving calf between the ages of 12 and 16 years (mean = about 14.9 years) (Olesiuk et al. 1990; Matkin et al. 2003). Females produce an average of 5.4 surviving calves during a reproductive life span lasting about 25 years (Olesiuk et al. 1990).

Adult southern resident killer whale males almost always travel and forage with their matrilineal groups including their living mother, grandmother, maternal aunts, and/or sisters. Adult males occasionally travel and forage individually or with another pod for short amounts of time but usually stay in the general area of their matriline with a few, rare exceptions.

Juvenile southern resident killer whales travel and forage with their matrilineal groups including their mother, grandmother, maternal aunts, and/or sisters. Nursing calves travel in very close proximity to their mothers, often touching. Given these tight social structures and cooperative hunting and prey sharing, effects on one individual likely affects the whole matriline or pod in a similar manner; however, there is some evidence that the winter and early spring months can be more challenging for juvenile southern resident killer whales than adult males (Fearnbach et al. 2020).

#### *11.1.2.2 Diet and Foraging*

Killer whale social structure is strongly influenced by their feeding behavior and hunting methods. Resident, transient, and offshore pods often favor different feeding methods. Mammal-eating killer whales are the only cetacean to routinely prey on marine mammals, with attacks documented on more than 35 mammal species, including baleen whales (Heyning and Dahlheim 1988; Jefferson et al. 1991; Baird 2000; Pitman et al. 2001). Other killer whales hunt and consume fish (including tuna, rays, and sharks) and squid, with penguins, seabirds, and sea turtles also taken (Nishiwaki and Handa 1958; Caldwell and Caldwell 1969; Condy et al. 1978; Ivashin 1982; Fertl et al. 1996; Similä et al. 1996; Ford et al. 1998; Heyning and Dahlheim 1988; Baird 2000; Aguiar dos Santos and Haimovici 2001; Ainley 2002; Visser and Bonoccorso 2003; Pitman and Dutton 2004; Reyes and García-Borboroglu 2004). There are no verified records of wild killer whales killing humans.

Resident populations in the northeastern Pacific Ocean eat fish almost exclusively. Southern Resident killer whales have a strong preference for Chinook salmon (Ford et al. 2005; Ford and Ellis 2006; Hanson et al. 2010; Ford et al. 2016). Spatial data on the salmon biomass available to the southern resident killer whale on a daily or weekly basis is limited, but researchers have found suggestive correlations of demographic data with salmon data. Ford et al. (2000) found that Pacific Salmon Commission (PSC) regional indices of Chinook salmon correlated with both killer whale survival and fecundity and these regional indices are thought to have the strongest correlation with ocean abundance of Chinook salmon (Pacific Salmon Commission 2013).

Ward et al. (2009) detected a correlation between southern resident killer whale fecundity and a proxy for the total annual salmon biomass available to southern resident killer whale using historical regional indices of abundance calculated by the PSC and Pacific Fishery Management Council (PFMC). They used three PSC regional indices – Chinook indices in southeast Alaska, northern British Columbia, and western Vancouver Island and found that the West Coast Vancouver Island index (WCVI) with a one-year lag explained the variance in the fecundity data the best of the three indices examined. Following highly productive salmon years as measured by the WCVI, the probability of calving is 50% higher at the population level compared to years following low salmon production years (Ward et al. 2009). The WCVI Chinook abundance is dominated by salmon from Puget Sound, and the Columbia and Fraser rivers with Chinook salmon from other river systems (including the Central Valley) making up smaller proportions of the total abundance.

Ward et al. (2009) took this study further by conducting a finer-scale examination of the multiple Chinook salmon stocks that make up the WCVI to see if they could further tease out which ones are most important to southern resident killer whales' diet. This examination found that late-run Fraser River Chinook salmon was most correlated with southern resident killer whale demographics (Ward et al. 2009). These results are consistent with Ayres et al. (2012) that found fecal stress hormones correlate with Fraser River Chinook salmon abundance suggesting that the whales experience higher physiological stress when Fraser River Chinook salmon abundance is lower. While the Ward et al. (2009) and Ayres et al. (2012) suggest that Fraser River Chinook are important during the summer and early fall, there is still a lot of uncertainty around southern resident killer whale-Chinook salmon relationships during winter and early spring seasons and southern resident killer whale sightings off the coast of Oregon and California happen more often in the winter. Also, Ward et al. (2009) combined data from all three pods and there are pod differences in habitat use, where K and L pods have been observed south of Washington as far as Monterey, California and J pod has not been documented south of Washington state.

Bellinger et al. (2015) estimated that Central Valley (CV) Chinook salmon made up about 22 percent of the Chinook salmon sampled off the Oregon coast and about 50 percent of those sampled off the California coast (south to Big Sur). While this apex predator certainly eats a variety of other species as well, CV Chinook salmon (all runs) can be estimated to make up approximately 40 percent of the southern resident killer whale diet when these mammals are off the California coast, and 18 percent of the southern resident killer whale diet when they are off the Oregon coast.

The southern resident killer whale pods move with the seasonal abundance of adult salmonids concentrating into greater densities as they stage for and initiate their spawning migrations into fresh water. Southern resident killer whales optimize their foraging tactics by taking advantage of these relatively dense concentrations of adult salmon and working cooperatively to spread out and locate them. Members of the pod can then communicate prey locations to the rest of the group (Heimlich-Boran 1988; Bigg et al. 1990; Hoelzel 1993). Herd tactics of prey species are expected to occur, but in general, once a fish is located, individual pursuit takes place. Once foraging is successful, southern resident killer whales often share prey with other individuals, usually matriline members (Ford and Ellis 2005).

Based on coded wired tag surveys from the Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement, Inland Harvest, and ocean Harvest in 2020, 29% of the fall-run Chinook salmon that return to natural spawning areas are natural-origin salmon. While 13% of fall-run Chinook salmon that return to hatcheries are natural-origin salmon. Combining these two results to represent the total population of salmon that returned comes to 21% natural-origin fall-run Chinook salmon. This percentage can then be used to represent the percentage of natural-origin salmon in the ocean and a part of the southern resident killer whale diet.

#### *11.1.2.3 Reproduction and Growth*

Killer whales are polygamous (Heyning and Dahlheim 1988). Male reproductive success correlates with age and size (Ford et al. 2011) with the oldest and largest males being the most successful. Mating may occur more often from April to October (Nishiwaki 1972; Olesiuk et al. 1990, 2005; Matkin et al. 1997) but birthed calves have occurred in all months showing that conception can happen year-round. Calving intervals is estimated to average between 4.9 to 7.7 years for resident killer whales (Olesiuk et al. 1990, 2005; Krahn et al. 2002, 2004; Matkin et al. 2003). Gestation periods in captive killer whales average about 17 months (Walker et al. 1988; Duffield et al. 1995; Robeck et al. 2004). Calves remain close to their mothers during their first year of life. Exact weaning age is hard to define, but nursing probably ends at 1-2 years of age (Haenel 1986; Kastelein et al. 2003).

Females achieve sexual maturity at body lengths of 4.6-5.4 m (Perrin and Reilly 1984). Fecundity data show a rapid increase in fecundity starting around age 10, reaching a maximum between ages 20-22, followed by a slow decline to age 40, and then a rapid decline to full cessation (Ward et al. 2009). Males become sexually mature at body lengths ranging from 5.2-6.4 m (Christensen 1984; Perrin and Reilly 1984; Duffield and Miller 1988; Olesiuk et al. 1990). This happens around ages of 11-15, and a sign of maturity is an enlargement of the dorsal fin known as "sprouting." Males remain sexually active throughout their adult lives (Olesiuk et al. 1990; Ford et al. 2011).

At birth, the average life expectancy of southern resident killer whales is about 29 years for females and 17 years for males (Olesiuk et al. 1990). Once a killer whale has reached 6 months, mean life expectancy increases to 30-46 years for females and 19-31 years for males (Olesiuk et al. 2005). Maximum life expectancy is estimated to be over 100 years in females and 60-70 years for males (Olesiuk et al. 1990, 2005; Center for Whale Research 2022). Natural mortality in killer whales remains largely unknown due to animals sinking after death or dying too far offshore to be recovered making it hard for researchers to gather carcasses. Killer whales have no natural predators in the wild (Baird 2000). Shark interactions occur but are not expected to significantly impact mortality even with young animals (Baird 2000).

### 11.1.3 Limiting Factors, Threats, and Stressors

NMFS's 2008 *Recovery Plan for Southern Resident Killer Whales* defines potential threats. The major threats are prey availability, pollution and contamination, vessel effects, oil spills, and acoustic effects. The most recent five-year review came out in 2021 and determined that new information increases the knowledge of southern resident killer whale conditions and threats, but it does not indicate a change to the species' status or the magnitude or imminence of the threats since the listing. More recent studies (Lacy et al 2017; Murray et al. 2021) are focusing on finding correlations between threat and population. Lacy et al. (2017), found prey availability had the largest impact and suggested prey increase in combination with reduced acoustic disturbance could help reach the targeted growth rate. Murray et al. (2021) did not suggest one threat to be more impactful than the other.

#### *11.1.3.1 Prey Availability*

Southern resident killer whales forage on fish. Chinook salmon are their preferred prey (Ford and Ellis 2005); however, they will eat other salmonids, some groundfish, and, rarely, other types of fish and cephalopods (Hanson et al. 2021). They tend to diversify their diet more in the wintertime to include steelhead, chum, lingcod, and halibut but Chinook salmon remain their preferred prey when available (Hanson et al. 2021). Fall-run and spring-run Chinook salmon that originate from the Central Valley of California make up some of the prey consumed by southern resident killer whales (Hanson et al. 2021) with a higher proportion of CV Chinook (19%) identified in prey samples collected in outer coastal waters and a smaller proportion of CV Chinook (<5%) identified in prey samples collected in Puget Sound. This is consistent with studies that show Chinook salmon of Central Valley origin can occur as far north as the coastal waters off British Columbia during their ocean-going life-history phase; however, the majority of them do not travel further north than the border of California and Oregon (Weitkamp 2009; Shelton et al. 2019).

There are multiple lines of evidence of poor body condition in southern resident killer whale (Durban et al. 2009; Fearnbach et al. 2011; Matkin et al. 2017; Fearnbach et al. 2018, Fearnbach et al. 2020) and how these whales may be affected by limitations of their primary prey, Chinook salmon (Ward et al. 2009; Ayres et al. 2012; National Marine Fisheries Service 2016; Wasser et al. 2017) NMFS recently reviewed this evidence in their biological opinions on fisheries conducted under the PFMC Salmon Fishery Management Plan for Southern Resident Killer Whales (National Marine Fisheries Service 2020, 2021). Several studies in the past have identified correlations or connections between Chinook salmon abundance indices and southern resident killer whale health, survival, social cohesion, growth rate, and fecundity (Ward et al. 2009; Ayres et al. 2012; Ford et al. 2010; Fearnbach et al. 2011; Ward et al. 2013; Wasser et al. 2017).

Researchers have also applied temporal measures of fecal hormone metabolites to test competing hypotheses of nutritional limitation and vessel disturbance. With these methods, researchers also tested potential interactions on indices of long-term nutritional state (triiodothyronine, or T3) as well as more short-term physiological stress (glucocorticoids, or GCs) (Ayres et al. 2012; Wasser et al. 2017). Ayres et al. (2012) showed that GCs correlate closely with Fraser River Chinook salmon on short time scales with GCs decreasing with increasing Fraser River salmon abundance and that vessel disturbance may interact with this correlation, but Fraser River Chinook salmon explained the most variance in the data. They also showed that the southern resident killer whales tend to come into the Salish Sea in the spring and early summer with higher thyroid hormone that decreases over time into the late fall months. This pattern was suggestive that the southern resident killer whales are less food limited at the start of the summer coincident with the time following the coastal early spring Columbia River Chinook salmon run which is consistent with telemetry data showing K and L pods occurring and likely foraging off the Columbia River (Hanson et al 2013) that time of year.

Wasser et al. (2017) built on the work of Ayres et al. (2012) and used reproductive hormone metabolites of progesterone and testosterone to test the hypothesis that low nutritional state results in reproductive failure at various levels. Models from this study suggest that nutritional stress is associated with reproductive failure.

In addition to the physiological effects of reduced prey abundance that have been observed in southern resident killer whale, there is also evidence of a negative impact on social cohesion when salmon abundance is low (Parsons et al. 2009; Foster et al. 2012). Social cohesion likely plays an important role in southern resident killer whales' survival, growth, and reproduction. When prey abundance is low, whales must spread out to find food and dedicate more of their time to foraging rather than on social interactions such as reproduction and information transmission (Foster et al. 2012). Researchers have observed a correlation between reduced reproduction in southern resident killer whales and low salmon abundance (Ford et al. 2010), although this correlation is weaker in recent years than it was in the past. Thus, it is unclear to what extent the interruption of social cohesion as a result of reduced salmon abundance may impact the population or limit recovery.

In recent years, the relationship between Chinook salmon abundance and southern resident killer whale demographic rates have weakened (e.g., southern resident killer whale status continues to decline with varying levels of Chinook abundance) and uncertainty remains due to several challenges in quantitatively characterizing the relationship between southern resident killer whale abundance and Chinook salmon abundance (National Marine Fisheries Service 2020, 2021; Pacific Fishery Management Council 2020). Also, documented relationships to date between southern resident killer whale and Chinook salmon are biased toward the summer and early fall months because southern resident killer whales are more accessible to boat-based researchers at that time of year. Spatial-temporal data suggest that K and L pods make excursions to the coast of Oregon and California in the winter and early spring.

Between 2010 and 2021, harvest of Chinook salmon within the range of the southern resident killer whale, including Haida Gwaii, Canada to Monterey Bay, USA, has averaged 611,297 fish annually (Pacific Fishery Management Council 2023; Pacific Salmon Commission 2022). Regulations on ocean harvest have been modified due to its impact on southern resident killer whale prey availability (National Marine Fisheries Service 2021c).

#### *11.1.3.2 Pollutants and Contaminants*

Persistent organic pollutants (POPs) or “legacy contaminants” occur at high concentrations in southern resident killer whale blubber and have been linked to endocrine, metabolic, mRNA, and immune disruption, cancer, decreased reproduction, and increased calf mortality in marine mammals (Reijnders 1986; de Swart et al. 1996; Ross et al. 2000; Schwacke et al. 2002; Ylitalo et al. 2001; Herman et al. 2005; Ylitalo et al. 2005; Buckman et al. 2011; Gockel and Mongillo 2013; Lundin et al. 2016; Mongillo et al. 2016; Hall et al. 2018).

The main POPs of concern are polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDE), and dichlorodiphenyltrichloroethane (DDT) as well as its primary metabolite dichlorodiphenyldichloroethane (DDE). Southern resident killer whales have blubber PCBs at concentrations that far exceed the threshold known to have detrimental health effects on harbor seals in Puget Sound. Recent biopsies indicate that the concentration of PCBs in male killer whales has decreased since the 1990s, likely as a result of decreased exposure due to regulations banning their production in the United States beginning in 1979 (Ross et al. 2000; Krahn et al. 2007). However, PCBs continue to be a concern for killer whales worldwide (Desforges et al. 2018). PBDEs have been used in many common household items as flame retardants since the 1970s and have also been detected at relatively high levels in the whales’ blubber. Their use peaked in the late 1990s. Flame retardant manufacturers in the United States voluntarily stopped producing the PentaBDE (used in furniture foam) and OctaBDE (used in electronic products) varieties of the PBDEs in 2004 and have begun producing alternative flame retardants; however, DecaBDE continues to be produced and used in the United States primarily in television casings. However, based on declining concentrations found in other species and decreased production in the U.S. and Canada, the accumulation of PBDEs in Southern resident killer whale is expected to slow in similar fashion to PCBs (Law et al. 2010; West et al. 2011; Ross et al. 2013; Mongillo et al. 2016). High levels of DDT/DDE have also been found in the whales, especially in K and L pods, which spend more time foraging in the coastal waters of California in the winter where DDTs still persist at relatively high levels in the marine ecosystem (Sericano et al. 2014).

Whales become exposed to POPs through consuming prey. Adult females also offload large amounts of POPs stored in their blubber when it is metabolized to produce milk and the contaminated milk transfers the POPs to their offspring. High contaminant levels may exacerbate the effects of reduced prey abundance as the contaminants become mobilized in the blood stream when stored fat is metabolized in the absence of food.

#### *11.1.3.3 Vessel Effects*

Commercial shipping, whale watching, ferry operations, and recreational boat traffic have increased in recent decades. Studies have shown or suggested that impacts from vessels, their behavior, the sounds they generate, and/or the exhaust created may affect foraging efficiency, communication, social cohesion, stress physiology, energy expenditure, and/or health (Williams et al. 2002; Foote et al. 2004; Williams et al. 2006; Noren et al. 2009; Williams et al. 2009; Williams et al. 2010; Ayres et al. 2012; Williams et al. 2014; Lundin et al. 2018; Joy et al. 2019; Holt et al. 2021) but this is most relevant to vessel traffic in the inland waters of Washington, United States, and British Columbia, Canada where the whales are more accessible and vessel traffic is more concentrated. Collisions with vessels are another potential source of serious injury and mortality and have been recorded, although rarely, for both Southern and Northern resident killer whales.

#### *11.1.3.4 Oil Spills*

Exposure to petroleum hydrocarbons released into the marine environment via oil spills and other discharge sources represents another potentially serious health threat for killer whales in the northeastern Pacific. Marine mammals are generally able to metabolize and excrete limited amounts of hydrocarbons, but acute or chronic exposure poses greater toxicological risks (Grant and Ross 2002). Unlike humans, cetaceans have a thickened epidermis that greatly reduces the likelihood of petroleum toxicity from skin contact with oiled waters (Geraci 1990; O'Shea and Aguilar 2001). Inhalation of vapors at the water's surface and ingestion of hydrocarbons during feeding are more likely pathways of exposure. Transient killer whales may be especially vulnerable after consuming prey debilitated by oil (Matkin and Saulitis 1997). Matkin et al. (1994) reported that killer whales did not attempt to avoid oil-sheened waters following the Exxon Valdez oil spill in Alaska. In marine mammals, acute exposure to petroleum products can cause changes in behavior and reduced activity, inflammation of the mucous membranes, lung congestion, pneumonia, liver disorders, and neurological damage (Geraci and St. Aubin 1990). Oil spills are also potentially destructive to prey populations and therefore may adversely affect killer whales by reducing food availability.

### 11.1.4 Management Activities

The NMFS's 2008 *Recovery Plan for Southern Resident Killer Whale* describes a Recovery Program that outlines recovery measures needed to achieve the plan's goals and objectives.

#### 11.1.4.1 Recovery Plan Activities Related to the Long-Term Operation of the Central Valley Project and State Water Project

The following recovery and research focused management activities, identified in the 2008 Recovery Plan for southern resident killer whale, are associated with the CVP and SWP or related facilities.

- **Hatchery Management:** The U.S. Department of the Interior Bureau of Reclamation (Reclamation) has multiple hatchery operations that are considered independent related activities under the environmental baseline. These hatcheries are not part of the consultation on the operation of the CVP and SWP.
- **Use NMFS authorities under the ESA and the MSFCMA to protect prey habitat, regulate harvest, and operate hatcheries:** As part of this effort, Reclamation will be providing an assessment of Essential Fish Habitat.

#### 11.1.4.2 Other Recovery Plan Activities

Additional recovery and research focused management activities identified in the 2008 Recovery Plan do not involve the operations of the CVP, SWP, nor related facilities. Some of these activities may fall within additional Reclamation and DWR authorities to contribute to the recovery of listed species as projects and programs with their own administration and consultation processes.

- **Support Salmon Restoration Efforts in the Region.**
    - *Habitat Management:* Reclamation has ongoing efforts related to this management activity pursuant to the Central Valley Project Improvement Act (CVPIA) 3406(b)(13) and other programs, but those efforts are not addressed in this consultation.
    - *Hatchery Management:* Reclamation has multiple hatchery operations that are considered independent related activities under the environmental baseline. These activities have their independent Section 7 consultation. In addition, these activities have Hatchery and Genetic Management Plans covered under Section 10 consultation.
- **Support Regional Restoration Efforts for Other Prey Species:** Reclamation has ongoing efforts related to this management activity pursuant to the CVPIA 3406(b)(13), but those efforts are not addressed in this consultation.

#### 11.1.4.3 Monitoring

NMFS's 2008 *Recovery Plan for Southern Resident Killer Whales* describes a Recovery Program that outlines research and monitoring needed to achieve the plan's goals and objectives. For the purposes of CVP and SWP action area, the CVP and SWP do not have roles in the monitoring and research objectives as described within the plan. However, the CVP and SWP do perform salmonid monitoring (Appendix U).

### 11.1.5 Current Incidental Take Statement

The NMFS 2019 Biological Opinion concluded that the Proposed Action in that consultation would result in incidental take in the form of harm to southern resident killer whale individuals in the K and L pods by reducing prey availability and impairing feeding behavior when southern resident killer whales forage for longer periods without success, migrate to alternate locations to seek prey, and experience nutritional stress and related health effects. Because impacts to foraging behavior of individual killer whales from general prey reduction could not be observed or quantified, NMFS did not have the data or metrics needed to monitor and establish relationships between the effects of the Proposed Action in that consultation and individual southern resident killer whale health; therefore, NMFS relied on surrogates in the form of effects on Chinook salmon populations as well as the measures of surrogates used for the Delta Cross Channel Gates and CVP and SWP Pumping Facilities.

## 11.2 Effects Analysis

The following sections summarize potential effects of the Proposed Action to the southern resident killer whale population by stressors identified in the recovery plan (National Marine Fisheries Service 2008). Appendix D, *Seasonal Operations Deconstruction*, analyzes potential stressors for the operation of the CVP and SWP. Deconstruction of the operation systematically evaluated how each stressor identified may or may not change from the proposed operation of CVP and SWP facilities to store, release, divert, route, or blend water. Stressors not linked to the Proposed Action were identified as "not anticipated to change". Stressors that the Proposed Action may change to an extent that is insignificant or discountable were documented. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Based on best judgment, a person would not be able to meaningfully measure, detect, or evaluate insignificant effects. Discountable effects are those extremely unlikely to occur. Based on best judgment, a person would not be able to expect discountable effects to occur.

The impacts to stressors are the same for all life stages with potentially varying degrees of impact for a given life stage, but not notably different. Impacts below are not broken up into life stages as they have been for previous species.

The Proposed Action is not anticipated to change the stressors: *Pollutants and Contaminants, Vessel Effects, Oil Spill, or Acoustic.* Conclusions are explained in Appendix D.

The stressor that may change at a level that is discountable or insignificant is:

- The Proposed Action may increase the *prey availability* stressor. The proposed storage, diversion, blending, and releasing of water may increase the prey availability stressor by decreasing the number of natural-origin Chinook salmon that make it to the ocean and grow into adults. The analysis for this is in Chapter 5, *Winter-Run Chinook Salmon*, Chapter 6, *Spring-Run Chinook Salmon*, and Chapter 7, *Steelhead,* for winter-run, spring-run, and steelhead, where impacts to these fisheries are expected. Additionally, Appendix D, Appendix I, *Old and Middle River Flow Management,* Appendix J, *Winter and Spring Pulses and Delta Outflow—Smelt, Chinook Salmon, and Steelhead Migration and*

*Survival*, Appendix L, *Shasta Coldwater Pool Management*, Appendix M, *Folsom Reservoir Flow and Temperature Management,* and Appendix Q, *Georgiana Slough Barrier*, address impacts to prey. The Proposed Action is expected to impact out-migrating natural-origin juvenile salmon and have minimal impacts to out-migrating hatchery produced juvenile salmon. The out-migrating salmon are a small proportion of the southern resident killer whale diet. More specifically K and L pod's diet, since they have been documented traveling as far south as Monterey Bay (National Marine Fisheries Service 2008, 2021), while J pod has not been observed south of Washington State.

Based on the Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement, Inland Harvest, and ocean Harvest in 2020, it is estimated that 21% of the fall-run Chinook salmon that return to natural spawning areas and hatcheries are natural-origin salmon. While this an estimate for fall-run Chinook salmon, this percentage can represent the percentage of natural-origin salmon along the California coast and subsequently the percentage of southern resident killer whale diet. Belinger et al. estimates 50% of K and L pod's diet consisted of CV salmon along the California coast, and with 21% of CV salmon being natural-origin salmon, the percentage of natural-origin CV salmon in K and L pod's diet is 10.5%, while along the California coast. That leaves 39.5% being hatchery produced CV Chinook salmon. The Proposed Action is not impacting hatchery operations and the impacts to the out migration of hatchery produced salmon is considered insignificant due to release strategies. Therefore, the Proposed Action could potentially impact up to 10.5% of K and L pod's diet for potentially up to 5 months of the year, on the years the whales do travel far south. As the southern resident killer whale travels north, this percentage reduces. Actual changes in the production of natural spawning fall-run Chinook salmon as a result of the Proposed Action are anticipated to be much smaller.

Additionally, impacts are expected on Chinook salmon in the Trinity River watershed in a similar fashion to the Central Valley watershed. Trinity River Chinook salmon are an even smaller proportion of the southern resident killer whale diet and considered discountable.

Attachment F.7 provides a quantitative comparison of modeled Central Valley Chinook salmon available to Southern Resident Killer Whales under each alternative. The analysis concludes with Table 12-1 that shows relative differences in modeled Central Valley Chinook salmon abundance available to Southern Resident Killer Whales under each alternative. Alternative 3 shows the highest estimate of Chinook salmon available for prey, Alternative 2v3 without TUCP has the second highest estimate, followed by Alternative 1, then the No Action Alternative, then Alternative 2 with TUCP, then Alternative 2v1 without TUCP, then Alternative 4, then Alternative 2v2 without TUCP. However, the total number of Chinook salmon available to Southern Resident killer whales as prey across all of the alternatives is within 700 estimated adult fish so the differences are likely negligible given the likely cumulative error in estimates across all models and the relative abundance of Central Valley Chinook to total Chinook salmon available in the ocean as prey as well as the likelihood that hatchery fish drive the amount of Chinook salmon from the Central Valley available as prey to killer whales and the operational alternatives have little effect on survival of hatchery fish in the ocean and total numbers of adult hatchery fish derived from the Central Valley.

Table 11-1. Abundance of Central Valley Chinook salmon available as prey for Southern Resident Killer Whales under the LTO scenarios.

| | NAA | ALT1 | Alt2v1 woTUCP | Alt2v1 wTUCP | Alt2v2 woTUCP | Alt2v3 woTUCP | ALT3 | ALT4 |
|---|---|---|---|---|---|---|---|---|
| Natural Chinook (all runs combined) in Bay by Scenario | 5,381,791 | 5,390,916 | 5,380,299 | 5,380,659 | 5,378,778 | 5,397,836 | 5,440,697 | 5,380,185 |
| Hatchery Chinook in Bay = same in all scenarios | 15,657,749 | 15,657,749 | 15,657,749 | 15,657,749 | 15,657,749 | 15,657,749 | 15,657,749 | 15,657,749 |
| Total Juvenile Chinook in Bay | 21,039,541 | 21,048,666 | 21,038,048 | 21,038,408 | 21,036,528 | 21,055,585 | 21,098,447 | 21,037,934 |
| Bay to Ocean Adult Survival | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 | 0.0112 |
| Ocean Adult Chinook Abundance | 235,165 | 235,267 | 235,149 | 235,153 | 235,132 | 235,345 | 235,824 | 235,147 |
| Ocean Adult Chinook Biomass** | 3,531,009 | 3,532,541 | 3,530,759 | 3,530,819 | 3,530,503 | 3,533,702 | 3,540,895 | 3,530,740 |

**Median adult weight of 15.015 pounds

## 11.3 Critical Habitat

On September 1st, 2021, NMFS revised the critical habitat designation for southern resident killer whales. The final rule maintains the previously designated, but not in the action area, critical habitat in inland waters of Washington and expands it to include certain coastal waters off Washington, Oregon, and California. The revision adds to critical habitat approximately 15,910 square miles of marine waters between the 6.1-meter and 200-meter depth contours from the U.S.-Canada border to Point Sur, California (86 FR 41668). The three essential physical or biological features (PBF) did not change in the most recent critical habitat revision.

Each of the critical habitat PBFs for southern resident killer whale are described in the sections below. Although there is no Critical Habitat designated for southern resident killer whale, we provided an analysis of the PBF Prey Species.

### 11.3.1 Water Quality to Support Growth and Development

There are no impacts to the water quality PBF because the Proposed Action does not influence water quality in the ocean.

### 11.3.2 Prey Species of Sufficient Quantity, Quality, and Availability to Support Individual Growth, Reproduction, and Development, as well as Overall Population Growth

As identified in Section 11.2, *Effects Analysis*, the Proposed Action has an indirect effect on prey availability stressor and may impact critical habitat PBF 2 (prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth). The critical habitat analysis for PBF 2 is the same as the effects analysis for the *Prey Availability* stressor in Section 11.2. The Proposed Action is expected to have an impact on a small proportion of the southern resident killer whale diet.

### 11.3.3 Passage Conditions to Allow for Migration, Resting, and Foraging

There are no impacts to passage conditions because the Proposed Action does not influence passage conditions in the ocean.

## 11.4 References


Aguiar dos Santos, R., and M. Haimovici. 2001. Cephalopods in the Diet of Marine Mammals Stranded or Incidentally Caught along Southeastern and Southern Brazil (21-34°S). *Fisheries Research* 52(1):99–112.

Ainley, D. G. 2002. The Ross Sea, Antarctica, Where All Ecosystem Processes Still Remain for Study, but Maybe Not for Long. *Marine Ornithology* 30:55–62.

Asper, E. D., and L. H. Cornell. 1977. Live Capture Statistics for the Killer Whale (*Orcinus orca*) 1961–1976 in California, Washington and British Columbia. *Aquatic Mammals* 5:21–26.

Ayres, K. L., R. K. Booth, J. A. Hempelmann, K. L. Koski, C. K. Emmons, R. W. Baird, K. Balcomb-Bartok, M. B. Hanson, M. J. Ford, and S. K. Wasser. 2012. Distinguishing the Impacts of Inadequate Prey and Vessel Traffic on an Endangered Killer Whale (*Orcinus orca*) Population. PLoS One 7:e36842.

Baird, R. W. 2000. The Killer Whale: Foraging Specializations and Group Hunting. *In* J. Mann, R. C. Connor, P. L. Tyack, and H. Whitehead (eds.), *Cetacean societies: Field Studies of Dolphins and Whales,* pp. 127–153. University of Chicago Press, Chicago, IL.

Bellinger, M. R., M. A. Banks, S. J. Bates, E. D. Crandall, J. C. Garza, G. Sylvia, and P. W. Lawson. 2015. Geo-Referenced, Abundance Calibrated Ocean Distribution of Chinook Salmon (*Oncorhynchus tshawytscha*) Stocks across the West Coast of North America. *PLoS ONE* 10(7):e0131276. doi: 10.1371/journal.pone.0131276.

Bigg, M. A., P. F. Olesiuk, G. M. Ellis, J. K. B. Ford, and K.C. Balcomb, III. 1990. *Social Organization and Genealogy of Resident Killer Whales* (Orcinus orca) *in the Coastal Waters of British Columbia and Washington State*. Report of the International Whaling Commission Special Issue 12:383–405.

Bigg, M. A., and A. A. Wolman. 1975. Live-capture killer whale (*Orcinus orca*) fishery, British Columbia and Washington, 1962-73. *Journal of the Fisheries Research Board of Canada* 32:1213–1221.

Boran, J. R., and S. L. Heimlich. 1999. Social learning in cetaceans: hunting, hearing and Hierarchies. *In* H. O. Box and K. R. Gibson (eds.), *Mammalian social learning: comparative and ecological perspectives*, pp. 282–307. Cambridge University Press, Cambridge, UK.

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 and Technology* 45:10194–10202.

Caldwell, D. K., and M. C. Caldwell. 1969. The addition of the leatherback sea turtle to the known prey of the killer whale, *Orcinus orca*. *Journal of Mammalogy* 50:636.

Center for Whale Research. 2022. *Southern Resident Killer Whales ID Guide*. Friday Harbor, WA, USA.

Christensen, I. 1984. Growth and Reproduction of Killer Whales, *Orcinus orca*, in Norwegian Coastal Waters. *Report of the International Whaling Commission* (Special Issue 6):253–258.

Condy, P. R., R. J. van Aarde, and M. N. Bester. 1978. The seasonal occurrence of killer whales Orcinus orca, at Marion Island. Journal of Zoology (London) 184:449–464.

Dahlheim, M.E. and F. Awbrey. 1982. A classification and comparison of vocalizations of captive killer whales. Journal of the Acoustical Society of America 72:661–670.

de Swart, R. L., P. S. Ross, J. G. Vos, and A. Osterhaus. 1996. Impaired immunity in harbour seals (*Phoca vitulina*) exposed to bioaccumulated environmental contaminants: Review of long-term feeding study. *Environmental Health Perspectives* 104:823–828.

Desforges, J.-P., A. Hall, B. McConnell, A. Rosing-Asvid, J. L. Barber, A. Brownlow, S. D. Guise, I. Eulaers, P. D. Jepson, R. J. Letcher, M. Levin, P. S. Ross, F. Samarra, G. Víkingson, C. Sonne, and R. Dietz. 2018. Predicting global killer whale population collapse from PCB pollution. *Science* 361:1373–1376.

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.

Duffield, D. A., D. K. Odell, J. F. McBain, and B. Andrews. 1995. Killer whale (*Orcinus orca*) reproduction at Sea World. *Zoo Biology* 14:417–430.

Durban, J., H. Fearnbach, D. Ellifrit and K. Balcomb. 2009. Size and body condition of southern resident killer whales. Contract AB133F08SE4742 report to the Northwest Regional Office, National Marine Fisheries Service 22 pp. Available: https://www.researchgate.net/publication/265982452_SIZE_AND_BODY_CONDITION_OF_SOUTHERN_RESIDENT_KILLER_WHALES.

Fearnbach, H., J. W. Durban, D. K. Ellifrit, and K. C. Balcomb, III. 2011. Size and long-term growth trends of Endangered fish-eating killer whales. *Endangered Species Research* 13:173–180.

Fearnbach, H., J. W. Durban, D. K. Ellifrit, and K. C. Balcomb III. 2018. Using aerial photogrammetry to detect changes in body condition of endangered southern resident killer whales. *Endangered Species Research* 35:175–180.

Fearnbach, H., J. W. Durban, L. G. Barrett-Lennard, D. K. Ellifrit, and K. C. Balcomb III. 2020. Evaluating the power of photogrammetry for monitoring killer whale body condition. *Marine Mammal Science* 36:359–364.

Fertl, D., A. Acevedo-Gutiérrez, and F. L. Darby. 1996. A report of killer whales (*Orcinus orca*) feeding on a carcharhinid shark in Costa Rica. *Marine Mammal Science* 12:606–611.

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., and G. M. Ellis. 2005. Prey selection and food sharing by fish-eating 'resident' killer whales (*Orcinus orca*) in British Columbia. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Research Document 2005/041. 30 pp. Available: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2005/2005_041-eng.htm.

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., 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*. University of Washington Press, Seattle, WA.

Ford, J. K. B., G. M. Ellis, and P. F. Olesiuk. 2005. Linking prey and population dynamics: did food limitation cause recent declines of 'resident' killer whales (*Orcinus orca*) in British Columbia? Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Research Document 2005/042. 27 pp. Available: http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2005/2005_042-eng.htm.

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. September 15, 2009. doi: 10.1098/rsbl.2009.0468.

Ford, M. J., M. B. Hanson, J. Hempelmann, K. L. Ayres, C. K. Emmons, G. S. Schorr, R. W. Baird, K. C. Balcomb, S. K. Wasser, K. M. Parsons, and K. Balcomb-Bartok. 2011. Inferred Paternity and Male Reproductive Success in a Killer Whale (*Orcinus orca*) Population. *Journal of Heredity* 102:537–553.

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.

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.

Geraci, J. R. 1990. Physiologic and toxic effects on cetaceans. *In* J. R. Geraci and D. J. S. Aubin (eds.), *Sea Mammals and Oil: Confronting the Risks*, pp. 167–197. Academic Press, San Diego, CA.

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

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. Available: https://www.eopugetsound.org/sites/default/files/features/resources/PBDEs_Puget_Sound_Report.pdf.

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. xii + 111 p. pp. Available: https://www.researchgate.net/publication/237636125_Southern_Resident_Killer_Whales_at_Risk_Toxic_Chemicals_in_the_British_Columbia_and_Washington_Environment.

Haenel, N. J. 1986. General notes on the behavioral ontogeny of Puget Sound killer whales and the occurrence of allomaternal behavior. *In* B. C. Kirkevold and J. S. Lockard (eds.), *Behavioral biology of killer whales*, pp. 285–300. Alan R. Liss, New York, NY.

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., C. K. Emmons, M. J. Ford, M. Everett, K. Parsons, L. K. Park, J. Hempelmann, D. M. V. Doornik, G. S. Schorr, J. 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.

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

Herman, D. P., D. G. Burrows, P. R. Wade, J. W. Durban, C. O. Matkin, R. G. LeDuc, L. G. Barrett-Lennard, and M. M. Krahn. 2005. Feeding ecology of eastern North Pacific killer whales *Orcinus orca* from fatty acid, stable isotope, and organochlorine analyses of blubber biopsies. *Marine Ecology Progress* Series 302: 275–291.

Heyning J. E., and M. E. Dahlheim. 1988. Killer Whale-Orcinus orca. *Handbook of Marine Mammals* 6(11):281–322.

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

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*. doi: 10.3389/fmars.2020.582182.

Ivashin, M. V. 1982. USSR progress report on cetacean research June 1979-May 1980. *Report of the International Whaling Commission* 32:221–226.

Jefferson, T. A., P. J. Stacey, and R. W. Baird. 1991. A review of killer whale interactions with other marine mammals: predation to co-existence. *Mammal Review* 21: 151–180.

Joy, R., D. Tollit, J. Wood, A. MacGillivray, Z. Li, K. Trounce, and O. Robinson. 2019. Potential Benefits of Vessel Slowdowns on Endangered Southern Resident Killer Whales. *Frontiers in Marine Science* 6:344.

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. U.S. Department of Commerce, NOAA Technical Memorandum No. NMFS-NWFSC-54. 133 pp. Available: https://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/killer_whales/esa_status/krahn2002tm.pdf.

Krahn, M. M., M. J. Ford, W. F. Perrin, P. R. Wade, R. P. Angliss, M. B. Hanson, G. L. Taylor, G. M. Ylitalo, M. E. Dahlheim, J. E. Stein, and R. S. Waples. 2004. 2004 Status review of Southern Resident killer whales (*Orcinus orca*) under the Endangered Species Act. U.S. Department of Commerce, NOAA Technical Memorandum No. NMFS-NWFSC-62. 73 pp.

Krahn, M. M., M. B. Hanson, R. W. Baird, R. H. Boyer, D. G. Burrows, C. K. 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* 54:1903–1911.

Krahn, M. M., M. B. Hanson, G. S. Schorr, C. K. Emmons, D. G. Burrows, J. L. Bolton, R. W. Baird, and G. M. Ylitalo. 2009. Effects of age, sex and reproductive status on persistent organic pollutant concentrations in "Southern Resident" killer whales. *Marine Pollution Bulletin* 58:1522–1529.

Lacy, R.C., R. Williams, E. Ashe, K.C. Balcomb III, L.J.N. Brent, C.W. Clark, D.P. Croft, D.A. Giles, M. MacDuffee, P.C. Paquet (2017). Evaluating anthropogenic threats to endangered killer whales to inform effective recovery plans. *Scientific Repeports* 7:14119. doi: https://doi.org/10.1038/s41598-017-14471-0.

Law, R. J., J. Barry, P. Bersuder, J. L. Barber, R. Deaville, R. J. Reid, and P. D. Jepson. 2010. Levels and trends of brominated diphenyl ethers in blubber of harbor porpoises (*Phocoena phocoena*) from the U.K., 1992-2008. *Environmental Science and Technology* 44:4447–4451.

Lundin, J. I., R. L. Dills, G. M. Ylitalo, M. B. Hanson, C. K. Emmons, G. S. Schorr, J. Ahmad, J. A. Hempelmann, K. M. Parsons, and S. K. Wasser. 2016. Persistent Organic Pollutant Determination in Killer Whale Scat Samples: Optimization of a Gas Chromatography/Mass Spectrometry Method and Application to Field Samples. *Archives of Environmental Contamination and Toxicology* 70:9–19.

Lundin, J. I., G. M. Ylitalo, D. A. Giles, E. A. Seely, B. F. Anulacion, D. T. Boyd, J. A. Hempelmann, K. M. Parsons, R. K. Booth, and S. K. Wasser. 2018. Pre-oil spill baseline profiling for contaminants in Southern Resident killer whale fecal samples indicates possible exposure to vessel exhaust. *Marine Pollution Bulletin* 136:448–453. doi: https://doi.org/10.1016/j.marpolbul.2018.09.015.

Matkin, C. O., and E. Saulitis. 1997. Restoration notebook: killer whale (Orcinus orca). Exxon Valdez Oil Spill Trustee Council, Anchorage, AK.

Matkin, C. O., G. E. Ellis, M. E. Dahlheim, and J. Zeh. 1994. Status of killer whales in Prince William Sound, 1984–1992. *In* T. R. Loughlin (ed.), *Marine mammals and the Exxon Valdez*, pp. 141–162. Academic Press, San Diego, CA.

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. Exxon Valdez Oil Spill Restoration Project Final Report, Restoration Project 030012.

Matkin, C. O., M. J. Moore, and F. M. D. Gulland. 2017. Review of Recent Research on Southern Resident Killer Whales (SRKW) to Detect Evidence of Poor Body Condition in the Population. Independent Science Panel Report to the SeaDoc Society10.1575/1912/8803. 3 pp. + Appendices pp.

McComb, K., C. Moss, S. M. Durant, L. Baker, and S. Sayialel. 2001. Matriarchs as repositories of social knowledge in African elephants. *Science* 292:491–494.

Miller, P. J. O. 2002. Mixed-directionality of killer whale stereotyped calls: a direction of movement cue? *Behavioral Ecology and Sociobiology* 52:262–270.

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.

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 No. NMFS-NWFSC-135. 107 pp. Available: https://repository.library.noaa.gov/view/noaa/12818.

Murray, C. C., L. C. Hannah, T. Doniol-Valcroze, B. M. Wright, E. H. Stredulinsky, J. C. Nelson, A. Locke, and R. C. Lacy. 2021. A Cumulative Effects Model for Population Trajectories of Resident Killer Whales in the Northeast Pacific. *Biological Conservation* 257:109124.

National Marine Fisheries Service. 2008. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region. 251 pp. Available: https://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/killer_whales/esa_status/srkw-recov-plan.pdf.

National Marine Fisheries Service. 2016. Southern Resident Killer Whales (Orcinus orca) 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, West Coast Region. 72 pp. Available: https://www.westcoast.fisheries.noaa.gov/publications/status_reviews/marine_mammals/kw-review-2016.pdf.

National Marine Fisheries Service. 2020. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Conference Opinion Consultation on Implementation of the Pacific Fishery Management Council Salmon Fishery Management Plan in 2020 for Southern Resident Killer Whales and their Current and Proposed Critical Habitat. National Marine Fisheries Service, West Coast Region. NMFS Consultation No. WCRO-2019-04040. 149 pp.

National Marine Fisheries Service. 2021a. Southern Resident Killer Whales (Orcinus orca) 5-Year Review: Summary and Evaluation. 102 pp.

National Marine Fisheries Service. 2021b. Revision of the Critical Habitat Designation for Southern Resident Killer Whales: Final ESA Section 4(b)(2) Report (to accompany the Final Rule). 37 + Appendices pp.

National Marine Fisheries Service. 2021c. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Conference Opinion Biological Opinion 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. NMFS Consultation No.WCRO-2019-04074. April 21, 2021. 190p.

Nattrass, S., D. P. Croft, S. Ellis, M. A. Cant, M. N. Weis, B. M. Wright, E. Stredulinsky, T. Doniol-Valcroze, J. K. B. Ford, K. C. Balcomb, and D. W. Franks. 2019. Postreproductive killer whale grandmothers improve the survival of their grand offspring. *PNAS* 116(52):26669–26673. Available: www.pnas.org/cgi/doi/10.1073/pnas.1903844116.

Nishiwaki, M. 1972. General biology. *In* S. H. Ridgway (ed.), *Mammals of the sea: biology and medicine*, pp. 3–204. Thomas, Springfield, IL.

Nishiwaki, M., and C. Handa. 1958. Killer whales caught in the coastal waters off Japan for recent 10 years. *Scientific Reports of the Whales Research Institute* 13:85–96.

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

O'Shea, T. J., and A. Aguilar. 2001. Cetacea and Sirenia. *In* R. F. Shore and B. A. Rattner (eds.), *Ecotoxicology of wild mammals*, pp. 427–496. John Wiley and Sons, Chichester, UK.

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. B. Ford. 2005. Life History and Population Dynamics of Northern Resident Killer Whales (*Orcinus orca*) in British Columbia. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Research Document 2005/045. 75 pp. Available: http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2005/2005_045-eng.htm.

Pacific Fishery Management Council. 2020. Pacific Fishery Management Council Salmon Fishery Management Plan Impacts to Southern Resident Killer Whales. Risk Assessment. May 2020. Agenda Item E.2.a. SRKW Workgroup Report 1. June 2020. Available: 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/.

Pacific Fishery Management Council. 2023. Review of 2022 Ocean Salmon Fisheries: Stock Assessment and Fishery Evaluation Document for the Pacific Coast Salmon Fishery Management Plan. (Document prepared for the Council and its advisory entities.).

Pacific Salmon Commission. 2013. 2008/2009 Twenty Fourth Annual Report. Vancouver, Canada. 186 pp.

Pacific Salmon Commission. 2022. Joint Chinook Technical Committee Report. Annual Report of Catch and Escapement for 2021. Report TCCHINOOK(22)-04. June 30, 2022.

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.

Perrin, W. F., and S. B. Reilly. 1984. Reproductive Parameters of Dolphins and Small Whales of the Family Delphinidae. *Report of the International Whaling Commission* (Special Issue 6):97–133.

Pitman, R. L., and P. H. Dutton. 2004. Killer whale predation on a leatherback turtle in the northeast Pacific. *Pacific Science* 58:497–498.

Pitman, R. L., L. T. Balance, S. I. Mesnick, and S. J. Chivers. 2001. Killer whale predation on sperm whales: observations and implications. *Marine Mammal Science* 17:494–507.

Reijnders, P. J. 1986. Reproductive failure in common seals feeding on fish from polluted coastal waters. *Nature* 324:456-457.

Reyes, L. M., and P. García-Borboroglu. 2004. Killer whale (*Orcinus orca*) predation on sharks in Patagonia, Argentina: a first report. *Aquatic Mammals* 30:376–379.

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.

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.

Ross, P. S., M. Noël, D. Lambourn, N. Dangerfield, J. Calambokidis, and S. Jeffries. 2013. Declining concentrations of persistent PCBs, PBDEs, PCDEs, and PCNs in harbor seals (*Phoca vitulina*) from the Salish Sea. *Progress in Oceanography* 115:160–170. doi: https://doi.org/10.1016/j.pocean.2013.05.027.

Saulitis, E. L., C. O. Matkin, and F. H. Fay. 2005. Vocal repertoire and acoustic behavior of the isolated AT1 killer whale subpopulation in southern Alaska. *Canadian Journal of Fisheries and Aquatic Science* 83:1015–1029.

Schwacke, L. H., E. O. Voit, L. J. Hansen, R. S. Wells, G. B. Mitchum, A. A. Hohn, and P. A. Fair. 2002. Probabilistic risk assessment of reproductive effects of polychlorinated biphenyls on bottlenose dolphins (*Tursiops truncatus*) from the southeast United States coast. *Environmental Toxicology and Chemistry* 21:2752–2764.

Sericano, J. L., T. L. Wade, S. T. Sweet, J. Ramirez, and G. G. Lauenstein. 2014. Temporal trends and spatial distribution of DDT in bivalves from the coastal marine environments of the continental United States, 1986–2009. *Marine Pollution Bulletin* 81:303–316.

Shelton, A. O., W. H. Satterthwaite, E. J. Ward, B. E. Feist, and B. Burke. 2019. Using hierarchical models to estimate stock-specific and seasonal variation in ocean distribution, survivorship, and aggregate abundance of fall run Chinook salmon. *Canadian Journal of Fisheries and Aquatic Science* 76(1):95–108. PubMed PMID: WOS:000454939000009.

Similä, T., J. C. Holst, and I. Christensen. 1996. Occurrence and diet of killer whales in northern Norway: seasonal patterns relative to the distribution and abundance of Norwegian spring-spawning herring. *Canadian Journal of Fisheries and Aquatic Sciences* 53:769–779.

Visser, I. N., and F. J. Bonoccorso. 2003. New observations and a review of killer whale (*Orcinus orca*) sightings in Papua New Guinea. *Aquatic Mammals* 29:150–172.

Walker, L. A., L. Cornell, K. D. Dahl, N. M. Czekala, C. M. Dargen, B. Joseph, A. J. W. Hsueh, and B. L. Lasley. 1988. Urinary concentrations of ovarian steroid hormone metabolites and bioactive follicle-stimulating hormone in killer whales (*Orcinus orca*) during ovarian cycles and pregnancy. *Biology of Reproduction* 39:1013–1020.

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.

Ward, E. J., M. J. Ford, R. G. Kope, J. K. B. Ford, L. A. Velez-Espino, C. K. Parken, L. W. LaVoy, M. B. Hanson, and K. C. Balcomb. 2013. Estimating the Impacts of Chinook Salmon Abundance and Prey Removal by Ocean Fishing on Southern Resident Killer Whale Population Dynamics. U.S. Department of Commerce, NOAA Technical Memorandum No. NMFS-NWFSC-123. 71 pp. Available: https://repository.library.noaa.gov/view/noaa/4527.

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.

Weitkamp, L. A. 2009. Marine Distributions of Chinook Salmon from the West Coast of North America Determined by Coded Wire Tag Recoveries. *Transactions of the American Fisheries Society* 139:147–170. doi: http://dx.doi.org/10.1577/T08-225.1.

West, J. E., S. M. O'Neill, J. Lanksbury, G. M. Ylitalo, and S. Redman. 2011. Current conditions, time trends and recovery targets for toxic contaminants in Puget Sound fish: the Toxics in Fish Dashboard Indicator. Vital signs website.

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.

Williams, R., C. W. Clark, D. Ponirakis, and E. Ashe. 2014. Acoustic quality of critical habitats for three threatened whale populations. *Animal Conservation* 17(2):174–185.

Ylitalo, G. M., C. O. Matkin, J. Buzitis, M. M. Krahn, L. L. Jones, T. Rowles, and J. E. Stein. 2001. Influence of life-history parameters on organochlorine concentrations in free- ranging killer whales (Orcinus orca) from Prince William Sound, AK. *The Science of the Total Environment* 281:183–203.

Ylitalo, G. M., J. E. Stein, T. Hom, L. L. Johnson, K. L. Tilbury, A. J. Hall, T. Rowles, D. Greig, L. J. Lowenstine and F. M. D. Gulland. 2005. The role of organochlorines in cancer-associated mortality in California sea lions (*Zalophus californianus*). *Marine Pollution Bulletin* 50:30–39.