Chapter 14 Basic Biology and Life History of Southern Resident Killer Whales, Distribution and Abundance, and Effects of the Proposed Action

Introduction

Three distinct forms of killer whales, termed residents, transients, and off shores, are recognized in the northeastern Pacific Ocean. Resident killer whales in U.S. waters are distributed from Alaska to California, with four distinct communities recognized: Southern, Northern, Southern Alaska, and Western Alaska (Krahn et al., 2002; 2004). Resident killer whales are fish eaters and live in stable matrilineal pods. Of these, only the Southern Resident Distinct Population Segment (DPS) is listed as endangered under the ESA.

Legal Status

The Southern Resident DPS of killer whales was listed as endangered under the Endangered Species Act on November 18, 2005 (NMFS 2005). Killer whales are the world's largest dolphins and the listed Southern Resident DPS overlaps in range in the Northeastern Pacific Ocean with other whale populations classified as transient, resident, and offshore populations. The Southern Resident population consists of three pods designated J, K and L, each containing 24, 22 and 44 members respectively (Ford et al. 2000; Center for Whale Research 2006, unpublished data). These pods generally spend late spring, summer and fall in inland waterways of Washington State and British Columbia. They are also known to travel as far south as central California and as far north as the Queen Charlotte Islands. Winter and early spring movements are largely unknown for this DPS.

Critical habitat for the Southern Resident DPS was designated under the Endangered Species Act on November 29, 2006 (NMFS 2006a). The critical habitat designation encompasses parts of Haro Strait and the waters around the San Juan Islands, the Strait of Juan de Fuca and all of Puget Sound.

General Biology

Wild 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). Males become sexually mature at body lengths ranging from 5.2-6.4 meters, which corresponds to between the ages of 10 to 17.5 years (mean = about 15 years) (Christensen 1984, Perrin and Reilly 1984, Duffield and Miller 1988, Olesiuk et al. 1990), and are presumed to remain sexually active throughout their adult lives (Olesiuk et al. 1990).

Most mating of Southern Resident killer whales in the North Pacific is believed to occur from May to October (Nishiwaki 1972, Olesiuk et al. 1990, Matkin et al. 1997); however, conceptions apparently happen year-round because births of calves are reported in all months. Mean interval between viable calves is four years (Bain 1990). Newborns measure 2.2-2.7 m long and weigh about 200 kg (Nishiwaki and Handa 1958, Olesiuk et al. 1990, Clark et al. 2000, Ford 2002). Mothers and offspring maintain highly stable social bonds throughout their lives and this natal relationship is the basis for the matrilineal social structure in the Southern Resident population (Bigg et al. 1990, Baird 2000, Ford et al. 2000).

Most published information on resident killer whale prey originates from a single study (Ford et al. 1998, Ford and Ellis 2005) in British Columbia, including southeastern Vancouver Island. This study focused primarily on Northern Residents and included a relatively small number of observations for Southern Residents. Of the 487 records of apparent fish predation events from 1974-2004, only 68 (14 percent) observations came from Southern Residents. The study recorded surface observations from predation events and also analyzed the stomach contents from stranded killer whales. Southern Resident killer whales are known to consume 22 species of fish and one species of squid (Scheffer and Slipp 1948, Ford et al. 1998, 2000, Ford and Ellis 2005, Saulitis et al. 2000). In recent years additional data has been collected on Southern Residents in parts of Puget Sound (Hanson, et al. 2005, NWFSC unpubl. data). In addition to collections of scales from observed predation events, fecal samples have also been collected for analysis.

Ford and Ellis (2005) found that salmon represent over 96 percent of the prey consumed during the spring, summer, and fall. Chinook salmon were selected over other species, comprising over 70 percent of the identified salmonids taken. This preference occurred despite the much lower abundance of Chinook in the study area in comparison to other salmonids and is probably related to the species' large size, high fat and energy content and year-round occurrence in the area. Other salmonids eaten in smaller amounts include chum (22 percent of the diet), pink (3 percent), coho (2 percent), sockeye (less than 1 percent), and steelhead (less than 1 percent) (Ford and Ellis 2005). This work suggested an overall preference of these whales for Chinook during the summer and fall, but also revealed extensive feeding on chum salmon in the fall.

Rockfish (*Sebastes* spp.), Pacific halibut (*Hippoglossus stenolepis*), and Pacific herring (*Clupea pallasi*) were also observed during predation events (Ford and Ellis 2005). Although it is unclear how important salmon, and southern U.S. salmon in particular, may be as prey while the Southern Resident DPS is offshore, the observed preference for salmon in other areas makes it likely that when available, salmon are taken as prey in ocean waters. A number of smaller flatfish, lingcod (*Ophiodon elongates*), greenling (*Hexagrammos* spp.) and squid have been identified in stomach content analyses of resident killer whales (Ford et al. 1998). Other information raises questions about the preference of Chinook over other prey species, including the abundance of other salmon (particularly sockeye and pink) when Southern Residents are present, the consistency in migratory patterns between Southern Residents and other salmon species, and the greater amount of time whales spend at depths commonly used by species other than Chinook (i.e., less than 30 m) (Baird et al. 2003, 2005; Hoelzel 1993; Ishida et al. 2001; Quinn and terHart 1987; Quinn et al. 1989; Ruggerone et al. 1990), which are usually found at greater depths (25-80 m) (Candy and Quinn 1999). Baird et al. (2005) recently reported a shift to shallower daytime depths among Southern Residents between 1993 and 2002, which possibly reflects a long-term change in prey behavior or selection of prey. Little is known about the winter and early spring diet of Southern Residents or whether individual pods have specific dietary preferences.

NMFS (2008) estimated biological requirements of Southern Resident killer whales including the diet composition and number of salmon the population requires in their coastal range. NMFS estimated the current population of Southern Residents (87) would be required to consume between 392,555 and 470,288 salmon based on diet compositions and bioenergentic needs in their coastal range. These estimated were based on Chinook comprising 70 to 88 percent of their diet.

Based on observations of captive killer whales, studies have extrapolated the energy requirements of wild killer whales and estimate an average size value for the five salmon species combined. Osborne (1999) estimated that adult killer whales would consume 28-34 adult salmon per day, and that younger killer whales (less than 13 years of age) would consume about 15-17 salmon per day to meet their daily energy requirements. By extrapolating these results, we estimate that the Southern Resident population (approximately 90 individuals) would consume about 750,000 to 850,000 adult salmon per year. These estimates are based on two assumptions that could affect the applicability of the results to Southern Resident killer whales in the wild. First, the wild killer whales probably have greater energy requirements than those held in captivity. Second, since salmon differ significantly in size across species and runs, any prey preference among salmon would affect the annual consumption rates, so fewer salmon per day would be required from a larger preferred prey species, such as Chinook salmon while larger numbers of salmon per day would be required for smaller fish, such as chum.

Population Status and Trends

In general, there is little information available regarding the historical abundance of Southern Resident killer whales. Some evidence suggests that, until the mid- to late-1800s, the Southern Resident killer whale population may have numbered more that 200 animals (Krahn et al. 2002). This estimate was based, in part, on a recent genetic analysis of microsatellite DNA, which found that the genetic diversity of the Southern Resident population resembles that of the Northern Residents (Barrett-Lennard 2000, Barrett- Lennard and Ellis 2001), and concluded that the two populations were possibly once similar in size. Recent efforts to assess the killer whale population during the past century have been hindered by an absence of empirical information prior to 1974 (NMFS 2006b). For example, a report by Scheffer and Slipp (1948) is the only pre-1974 account of Southern Resident abundance in the area, and it merely noted that the species was “frequently seen” during the 1940s in the Strait of Juan de Fuca, northern Puget Sound, and off the coast of the Olympic Peninsula, with smaller numbers along Washington’s outer coast. Olesiuk et al. (1990) estimated the Southern Resident population size in 1967 to be 96 animals. At about this time, marine mammals became popular attractions in zoos and marine parks, which increased the demand for interesting and exotic display animals. Between 1967 and 1973, it is estimated that 47 killer whales, mostly immature, were taken from the Southern Resident population for public display. The rapid removal of individual whales caused an immediate decline in numbers (Ford et al. 2000). By 1971, the level of removal decreased the population by about 30 percent, to approximately 67 whales (Olesiuk et al. 1990). In 1993, two decades after the live capture of killer whales ended, the three Southern Resident pods – J, K, and L – totaled 96 animals (Ford et al. 2000).

Over the past decade, the Southern Resident population has fluctuated in numbers. For example, the population appeared to experience a period of recovery by increasing to 99 whales in 1995, but then declined by 20 percent to 79 whales in 2001 (- 3.3 percent per year) before another slight increase to 83 whales in 2003 (Ford et al. 2000; Carretta et al. 2004). NMFS (2008) estimated the 2007 population to be 87 whales. The population estimate in 2006 was approximately 90 animals (+ 3.5 percent per year since 2001) (Center for Whale Research 2006), the decline in the 1990's, unstable population status, and population structure (e.g., few reproductive age males and non-calving adult females) continue to be causes for concern. Moreover, it is unclear whether the recent increasing trend will continue because these observations may represent an anomaly in the general pattern of survival or a longer-term shift in the survival pattern. Several individuals disappeared in the fall of 2006 and one new calf has been identified since the 2006 population estimate.

Range and Distribution

Southern Resident killer whales spend a significant portion of the year in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound, particularly during the spring, summer, and fall, when all three pods are regularly present in the Georgia Basin (defined as the Georgia Strait, San Juan Islands, and Strait of Juan de Fuca) (Heimlich-Boran 1988, Felleman et al. 1991, Olson 1998, Osborne 1999). The Southern Resident population consists of three pods, identified as J, K, and L pods. Typically, K and L pods arrive in May or June and spend most of their time in this core area until departing in October or November. During this time, both pods also make frequent trips lasting a few days to the outer coasts of Washington and southern Vancouver Island (Ford et al. 2000). J pod continues to spend intermittent periods of time in the Georgia Basin and Puget Sound during late fall, winter and early spring.

While the Southern Residents are in inland waters during the warmer months, all of the pods concentrate their activities in Haro Strait, Boundary Passage, the southern Gulf Islands, the eastern end of the Strait of Juan de Fuca, and several localities in the southern Georgia Strait (Heimlich-Boran 1988, Felleman et al. 1991, Olson 1998, Ford et al. 2000). In general, they spend less time elsewhere, including other sections of the Georgia Strait, Strait of Juan de Fuca, and San Juan Islands, Admiralty Inlet west of Whidbey Island, and Puget Sound. Individual pods are similar in their preferred areas of use (Olson 1998), although there are some seasonal and temporal differences in certain areas visited by each pod (Hauser 2006). For example, J pod visits Rosario Strait more frequently than K or L pods (Hauser 2006).

The movements of Southern Resident killer whales relate to those of their preferred prey – salmon. Pods commonly seek out and forage in areas where salmon occur, especially those associated with migrating salmon (Heimlich-Boran 1986, 1988; Nichol and Shackleton 1996). Notable locations of particularly high use include Haro Strait and Boundary Passage, the southern tip of Vancouver Island, Swanson Channel off North Pender Island, and the mouth of the Fraser River delta, which is visited by all three pods in September and October (Felleman et al. 1991, Ford et al. 2000, K.C. Balcomb, unpubl. data). These sites are major corridors for migrating salmon.

Late spring and early fall movements of Southern Residents in the Georgia Basin have remained fairly consistent since the early 1970s, with strong site fidelity shown to the region as a whole (NMFS 2006b). However, some areas of use have changed over time. Visits to Puget Sound have diminished since the mid-1980s, while Swanson Channel has become an area of higher use (K.C. Balcomb, unpubl. data). One possible explanation for these alterations in habitat use may be the long-term differences in the availability of salmon at particular sites (NMFS 2006b). Another possible cause may be the loss of information regarding alternative sites due to the mortality of older, more experienced whales that knew of other good feeding sites, but who can no longer guide their pods to these sites or along favored travel routes (NMFS 2006b).

During late fall, winter, and early spring, the ranges and movements of the Southern Residents are less well known. Throughout this time period, J pod continues to occur intermittently in the Georgia Basin and Puget Sound, but its location during apparent absences is uncertain (Osborne 1999). One sighting of this pod was made off Cape Flattery, Washington, in March 2004 (Krahn et al. 2004). Prior to 1999, K and L pods followed a general pattern in which they spent progressively less time in inland waters during October and November and departed the area entirely by December of most years (Osborne 1999). Sightings of both groups passing through the Strait of Juan de Fuca in late fall suggested that activity shifted to the outer coasts of Vancouver Island and Washington, although it was unclear if the whales spent a substantial portion of their time in this area or were simply in transit to other locations (Krahn et al. 2002). Since the winter of 1999-2000, K and L pods have extended their use of inland waters until January or February each year. Since 1999, both pods are completely absent from the Georgia Basin and Puget Sound only from about early or mid-February to May or June. In recent years between January and March K and L pods have been sighted as far south as Monterey, California. Table 14-1 summarizes the known and potential sightings of Southern Resident killer whales along the California coast.

Table 14-1. Summary of known and potential sightings of Southern Resident killer whales along the California coast.

Date	Location	Pods	Source
Jan. 29, 2000	Monterey Bay	K and L pods	Nancy Black Seen and photographed feeding on fish
Mar. 13, 2002	Monterey Bay	L pod	Nancy Black
Feb. 16, 2005	Farallon Islands	L and K pods	Balcomb, CWR
Jan. 26, 2006	Point Reyes	L pod	S. Allen
Jan. 24, 2007	San Francisco Bay	K pod	Nancy Black
Mar. 18, 2007	Fort Bragg	L pod	Reported on CWR web page
Mar. 24-25, 2007	Monterey	K and L pods	Reported on CWR web page
Jan. 24, 2008	Monterey	L pod	Reported on CWR web page

Effects of the Proposed Action

Project operations have the potential to affect the prey base of Southern Resident killer whales. Chapters 11, 13, and 16 discuss the effects of project operations upon Central Valley steelhead, Sacramento River winter-run Chinook salmon, Central Valley sprint-run Chinook salmon, Southern Oregon/Northern California Coast coho salmon, Central California Coast steelhead, Central Valley fall-run Chinook salmon, and Central Valley late-fall run Chinook salmon. Project operations would only affect Southern Resident killer whales to the extent that the effects of the project operations alter salmonids populations which could indirectly lead to a reduction in prey availability to the Southern Resident killer whales. Reductions in prey availability may force the whales to spend more time foraging, and could lead to reduced reproductive rates and higher mortality.

It is important to note that salmon from streams affected by project operations constitute only a portion of the Southern Resident killer whale prey base; other prey (even assuming all prey are salmon, which is not the case) originate from Puget Sound streams, coastal streams in Washington, Oregon, and California. It is not known what portion of the prey base is composed of salmonids from streams affected by project operations. The spring, summer and fall range of the Southern Resident killer whales includes the inland waterways of Puget Sound, the Strait of Juan de Fuca, and the Southern Georgia Strait, (NMFS 2005). Their wide-ranging migratory patterns put them in the proximity of numerous other stocks of salmon.

The portion of the killer whale prey base that comes from the streams affected by project operations includes both wild and hatchery produced salmon, both ESA-listed and non ESA-listed groups. Salmon distribution and population are also affected by many factors in addition to the proposed actions which include ocean conditions and pollution.

As discussed earlier, little is known about the winter and early spring prey preference of Southern Residents when they are in offshore waters. Studies of resident killer whales indicate that fish, and particularly salmon, are the major prey of resident whales with a reported preference for Chinook salmon (Ford et al. 1998; Ford et al. 2000, Ford et al. 2005). While these studies are predominantly based on observations of Northern Resident whales from May to October in coastal regions of British Columbia, more recent data on Southern Residents in Haro Strait and Puget Sound from May to September also support preference for Chinook (Hanson et al. 2005, NWFSC unpubl. data). Ford et al. (2005) looked at correlations between survival of Northern and Southern Resident killer whales and Chinook stocks from Alaska to Oregon, and reported a strong correlation between changes in overall coast wide Chinook abundance and combined mortalities of both resident communities. There are, however, limitations to applying the analysis and questions regarding the interpretation of the results.

On a local scale, Ford et al. (2005) found a weak correlation between Southern Resident survival and Chinook abundance in Washington and Oregon ($R^2 = .115$). According to the study, the strongest correlations with Southern Resident killer whale survival were with Chinook in North Coast B.C. ($R^2 = .54$) and SE Alaska ($R^2 = .698$). In addition, this study did not analyze the importance of additional Chinook stocks that do appear to be in the range of the Southern Residents, such as those in California. Moreover, the limited information on offshore distribution of Southern Resident killer whales limits our ability to interpret the extent of overlap of the whales and specific Chinook stocks, particularly during winter months. There may also be a correlation with environmental factors common to both Southern Resident killer whales and Chinook salmon, but not necessarily an actual connection between the two species.

Although the importance of salmon to the offshore diet of Southern Residents is not clearly defined, particularly for southern U.S. salmon, the observed preference for salmon in other areas makes it likely that, when available, killer whales take salmon as prey in ocean waters. Chemical analyses of killer whale fatty acids and contaminant ratios are also consistent with a salmon diet (NWFSC unpubl. data).

According to National Marine Fisheries Service (NMFS), "… it appears that the abundance of Washington, Oregon, and California Chinook and coho salmon increased significantly during the period of decline for Southern Resident killer whales between 1996 and 2001. Some studies have evaluated a potential time lag of one or two years between changes in salmon abundance and changes in Southern Resident survival (McClusky 2006). Even accounting for this potential lag time, the available information does not support a strong link between the trends in abundance of these particular salmon stocks and the abundance of Southern Resident killer whales." (NMFS 2007). Generally, there is only a weak correlation between Southern Resident killer whale survival and Chinook salmon abundance in Washington and Oregon (Ford et al. 2005, NMFS 2007).

Salmon originating in California streams are estimated to contribute 3 percent of salmon population off the Washington coast based on Genetic Stock Identification (GSI) of Washington troll catch in May of 1981 and 1982 (Utter et al. 1983). Research in the mid-1970s estimated California's contribution at 5 percent (Wright 1976). More recent data from the Collaborative Research on Oregon Ocean Salmon using GSI estimate 59 percent of salmon analyzed from the Oregon commercial harvest (June – October 2006) were Central Valley fall-run or spring-run Chinook salmon (Project CROOS 2006). It is important to note that these percentages could vary during different years or seasons.

Reclamation funds the operation and maintenance of the Coleman, Livingstone, and Nimbus hatcheries. These hatcheries have a combined yearly production goal of 17,200,000 Chinook salmon smolts. DWR funds the operation of the Feather River Hatcheries for production of approximately 8 million Chinook salmon smolts annually (yearly production goal).

Analysis of Chinook salmon otoliths in 1999 and 2002 found that the contribution of hatchery produced fish (from the Sacramento and San Joaquin River System) made up approximately 90 percent of the ocean fishery off the central California coast from Bodega Bay to Monterey Bay (Barnett-Johnson et al. 2007). Similar studies have not been completed to assess the percentage Central Valley hatcheries contribute to the salmon originating from California off the Oregon and Washington coasts but it suggests that hatchery fish would likely be the majority.

Effects of project operations on juvenile salmon are removed both in time and in place from when and where these salmon potentially become prey for Southern Resident killer whales. Based on data showing that hatchery produced fish make up 90 percent of the ocean fishery off the central California coast it is expected that this trend would carry throughout the range of salmon originating from the Central Valley. Project operations affect juvenile salmon in California Central Valley streams and the Trinity River. Thus any potential effects of the project operations on listed killer whale prey are indirect; are removed in both time and place from the action; represent an unknown portion of the killer whale prey base; are masked by the contribution of hatchery fish; and are intermingled with a host of other factors. Based on this information we have determined that project operations may affect but are not likely to adversely Southern Resident killer whales since the effects are discountable due to the high percentages of hatchery produced fish overshadowing the potential effects of project operations.

Critical Habitat

Critical habitat was designed for Southern Resident Killer Whales on November 29, 2006 (NMFS 2006a). Approximately 2,560 square miles of marine habitat in Washington were designated as critical habitat including portions of Puget Sound, the Strait of Juan de Fuca, Haro Strait, and the waters surrounding the San Juan Islands. Based on the natural history of the Southern Residents and their habitat needs, NMFS determined the following are the physical or biological features essential to conservation (Primary Constituent Elements): (1) Water quality to support growth and development; (2) Prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) Passage conditions to allow for migration, resting, and foraging.

The designated critical habitat does not overlap with the Action Area for this consultation, nor are there any discernible changes to the physical environment that occur within designated critical that could be correlated to project operations. The only potential affect of project operations on the identified physical or biological features essential to conservation would to prey quantity, quality, and availability. Project operations have the potential to affect only a portion of juvenile salmon originating in California Central Valley streams. As discussed earlier, Salmon originating in California streams are estimated to contribute between 3 and 5 percent of salmon population off the Washington coast based on analysis of troll catches. These estimates were made based on data collected during the time of year when the Southern Residents are present. As discussed above, the majority of the fish attributed to California streams that are affected by project operations are expected to be hatchery fish. The effects of the project operations on salmon populations are not likely to adversely affect designated critical habitat since the effects are discountable due to the small percentage of California salmon potentially present in Washington waters identified as critical habitat.

Cumulative Effects

As discussed in the Federal Register listing notice (NMFS 2005), three main human-caused factors that may continue to impede the recovery of this species and have affected the Southern Resident killer whale population, including contaminants, vessel traffic, and reductions in prey availability.

Exposure to contaminants may result in harm to the species. The presence of high levels of persistent organic pollutants (POPs), such as PCBs and DDT, have been documented in Southern Resident killer whales (Ross et al. 2000, Ylitalo et al. 2001, and Herman et al. 2005). These and other chemical compounds have the ability to induce immune suppression, impair reproduction, and produce other adverse physiological effects, as observed in studies of other marine mammals. High levels of “newly emerging” contaminants that may have similar negative effects, such as flame retardants, have been documented in killer whales, and are also becoming more prevalent in the marine environment (Rayne et al. 2004). Although contaminants enter marine waters and sediments from numerous sources, these chemical compounds enter killer whales through their prey. Because of their long life span, position at the top of the food chain, and their blubber stores, killer whales are capable of accumulating high concentrations of contaminants. In addition to reductions in prey abundance, the amount of contaminants in prey may exceed levels that cause mortality or reproductive failure.

Commercial shipping, whale watching, ferry operations, and recreational boat traffic have increased in recent decades. Several studies have linked vessels with short-term behavioral changes in Northern and Southern Resident killer whales (Kruse 1991; Williams et al. 2002a; 2002b; Foote et al. 2004). Although the potential impacts from vessels and the sounds they generate are poorly understood, these activities may affect foraging efficiency, communication, and/or energy expenditure through their physical presence, increased underwater sound level, or both. Collisions with vessels are another potential source of serious injury and mortality and have been recorded for both Southern and Northern Resident whales.

Potential effects of project operations on salmon prey species, in particular, Chinook, could be compounded by ongoing and future effects of other activities including declines due to habitat degradation from development (e.g., agriculture, timber harvest, dam construction, and urban construction), harvest practices, and past hatchery operations. Some historically productive salmon populations are no longer large, whereas other runs may have increased in abundance through hatchery production. Limited evidence indicates that hatcheries do not greatly change the ocean distribution of coho salmon (Weikamp et al.1995), but they can strongly influence the nearshore presence of salmon and thus the overall availability of salmon for predators (Krahn et al. 2002). Historical sources of the Pacific salmon prey base include Alaskan, Canadian, Puget Sound, Columbia Basin and Central California water systems. Specifically, declines in food availability from the Columbia and the California Central Valley are identified by NMFS as major sources for the decline in the Pacific salmon prey base of Southern Resident killer whales. Reductions in prey availability may force the whales to spend more time foraging, and could lead to reduced reproductive rates and higher mortality.

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