NOAA Fisheries Service

Southern Resident Killer Whales Research Update

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INSIDE THIS ISSUE

Background

The Southern Resident killer whales (SRKWs) that reside in the Puget Sound region experienced a dramatic decline in the mid-1990s. This decline, along with consideration of other risk factors, resulted in the listing of the population as endangered under the Endangered Species Act (ESA) in 2005. Prior to this ESA listing, Congress initiated funding in 2003 to support NOAA's research and management efforts pertaining to these whales. The Northwest Fisheries Science Center (NWFSC) conducts and supports research, and the Northwest Regional Office (NWR) is responsible for implementing the ESA and Marine Mammal Protection Act (MPA) through various management actions. NOAA-funded research addresses key questions that must be answered to successfully conserve Southern Resident killer whales. Here we summarize some of our latest research results on their taxonomy, behavior, ecology, health, anthropogenic impacts and socioeconomic importance to the citizens of the Pacific Northwest.

Taxonomy and Genetic Relationships

Currently, there is only one recognized global species of killer whales. However, recent data suggest that there are likely several subspecies and potentially more than one species of killer whale worldwide. Furthermore, little is known about the historical range of killer whale ecotypes in the eastern North Pacific (ENP). It is possible that ranges have shifted in the last few decades because of changes in availability of food. To conserve and manage killer whales, we need to identify the number and distribution of distinct populations of killer whale species. Several projects have been funded to determine genetic relationships between Southern Resident killer whales and other killer whales. Results have helped scientists determine how genetically distinct different groups of killer whales are, whether the different groups are interbreeding, and the historical distribution of the SRKW population. For example, Dr. Phil Morin (NOAA Fisheries Service's Southwest Fisheries Science Center) examined killer whale genetics from archeological samples of teeth and bones to investigate historical distributions of SRKWs and the other ENP ecotypes. Results did not show any Southern Resident haplotypes in samples from south of Washington State inland waterways. One whale genetically identified as a Northern Resident extends the known southernmost distribution of the population from Oregon to California.

Peer-reviewed publication: Morin, P.A., LeDuc, R.G., Robertson, K.M., Hedrick, N.M., Perrin, W.F., Etnier, M., Wade, P., and Taylor, B.L. 2006. Genetic Analysis of killer whale *(Orcinus orca)* historical bone and tooth samples to identify western U.S. ecotypes. Marine Mammal Science 22(4): 897–909.

Using only contemporary tissue samples, Dr. Rus Hoelzel (University of Durham) and colleagues estimated average rates of gene flow (genetically effective migration) between the SRKW population and other sampled killer whale populations (offshore, transient, and resident ecotypes) from several geographic regions. These researchers found that the genetic structure was similar between population ecotypes and also found evidence for genetic isolation with geographic distance within ecotypes. Using a model, they predicted that there is ongoing, low-level migration between regional populations (within and between ecotypes) and small effective sizes for extant local populations. Their results indicate a key role for social and foraging behavior in the evolution of genetic structure among conspecific populations of the killer whale.

Peer-reviewed publication: Hoelzel, A.R., Hey, J., Dahlheim, M.E., Nicholson, C., Burkanov, V. and Black, N. 2007. Evolution of population structure in a highly social top predator, the killer whale. Molecular Biology and Evolution 24: 1407-1415.

In 2011, we are collaborating with our colleagues at the SWFSC to sequence the complete mitochondrial genome of one individual from each of the ~25 Southern Resident killer whales matrilines. This work will follow up on an earlier SWFSC study of worldwide mtDNA variation (Morin et al. 2010), which indicated the existence of multiple killer whale species. These new data will allow us to test the hypothesis that the Southern Resident killer whales are a single extended maternal family, and will also be valuable in providing a more accurate estimate of the historical size of the population than is currently possible.

Peer-reviewed publication: Morin, P.A, Archer, F.I., Foote, A.D., Vilstrup, J., Allen, E.E., Wade, P., Durban, J., Parsons, K., Pitman, R., Li, L., Bouffard, P., Abel Nielsen, S.C., Rasmussen, M., Willerslev, E., Gilbert, M.T., and Harkins, T. 2010. Genome Research 20:908-916.

Population Monitoring and Social Structure

The annual census of the Southern Resident killer whale population is an important method by which to assess the status and trends of this endangered population. Photo-identification studies can also provide insight into population dynamics and demography, social structure, and individual life histories. Quantitatively characterizing the social structure of a population provides important insight into the forces shaping key population processes. Moreover, long-term social dynamics provide an avenue for understanding population level responses to changes in socio-ecological conditions.

"Orca Survey" was launched as a census to determine the status of the Southern Resident killer whales. This project is a long-term photo-identification study of killer whales *(Orcinus orca)* in the San Juan Island area of the Pacific Northwest. Principal Investigator Ken Balcomb (Center for Whale Research) initiated the study in 1976 (funded by NOAA Fisheries Service) to ascertain the size of the population of killer whales in the Greater Puget Sound area of Washington State. For over three decades, the Center for Whale Research (CWR) has been conducting annual photo-identification studies of the SRKW population that frequents the inland waters of Washington State and lower British Columbia. This detailed understanding of population status and trends has supported management decisions in both Canada and the United States, including the listing of SRKWs as Endangered in both countries. The data collected during annual surveys provide recent photographs to update photo-identification guides; provide managers with current information on SRKW population status and trends; and provide information on population dynamics, social structure, and individual life histories that can be used for further scientific analysis. The census data are updated annually in catalogs produced by and available from the Center for Whale Research. Up-to-date information is also available at http://www.whaleresearch.com.

One study that used the long-term census data from CWR was conducted by Dr. Kim Parsons (NRC post-doctoral associate, NOAA Fisheries Service's NWFSC and the Center for Whale Research). She, along with her collaborators, quantitatively assessed social structure in the SRKW population from 29 years of photo-identification data and characterized significant temporal changes in sociality. They found that preferential affiliation among killer whales within both genealogical matrilines and pods was supported by two different analytical methods and, despite interannual variability, these social clusters persisted throughout the study. All three pods experienced fluctuations in social cohesion over time, but the overall rate of intra-pod affiliation was consistently lowest within L pod, the largest of the Southern Resident pods. The most recent increase in fluidity within social units, occurring in the mid to late-1990s, was coincident with a significant decline in population size, suggesting a possible common response to external stressors. Quantifying these trends in social structure is the first step towards understanding the causes and consequences of long-term changes in killer whale social structure.

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

In 2011, NWFSC scientists and collaborators at the Center for Whale Research, University of Washington, and the Cascadia Research Collective used the long-term census data in combination with recently collected genetic data to study the patterns of mating within the population. The genetic data were used to determine the paternity of more than 15 Southern Resident calves. The study found that only two of the sampled males (J1 and L41) could be positively identified as breeding members of the population. Several other deceased males were also inferred by indirect methods to be likely fathers of several living individuals. Furthermore, there was statistical support for greater breeding success by older and larger males, and that several individuals were the product of matings by a male and female from the same pod. Despite the within-pod matings, however, there was also evidence that whales have some mechanism of avoiding breeding with close relatives.

Peer-reviewed publication: Ford, M.J., Hanson, M.B., Hempelman, J.A., Ayres, K.L., Emmons, C.K., Schorr, G.S., Baird, R.W., Balcomb, K.C., Wasser, S.K., Parsons, K.M., and Balcomb-Bartok, K. 2011. Inferred paternity and male reproductive success in a killer whale *(Orcinus orca)* population. Journal of Heredity. doi:10.1093/jhered/esr067

Dr. Eric Ward (NOAA Fisheries Service's NWFSC) and his colleagues also used long-term census data to calculate the age structure of female Southern and Northern Resident killer whales and investigate whether attributes of mothers and grandmothers affected the survival of offspring and grand-offspring, respectively. Their results suggest that survival rates for calves born to older mothers were 10% higher than other calves, possibly because older mothers may be better mothers. However, maternal age did not influence juvenile survival, which suggests that the effect of older mothers may only be important during the first year of life. Furthermore, the presence of post-reproductive grandmothers did not appear to impact calf or juvenile survival.

Peer-reviewed publication: Ward, E.J., Holmes, E.E., Parsons, K., Balcomb, K.C. and Ford, J.K.B. 2009. The role of menopause and reproductive senescence in a long-lived social mammal. Frontiers in Zoology, 6(4). http://www.frontiersinzoology.com/content/6/1/4

Seasonal Distribution

A series of workshops that assessed research needs for Southern Resident killer whales identified the population's winter distribution as a primary data gap. In order to determine winter distribution, it is important to fully document sighting and detection locations in inland as well as in coastal waters. The NWFSC has used a variety of technologies, including passive acoustic monitoring, a land-based sighting network, and coastal research cruises to greatly expand our efforts to fill these data gaps.

The NWFSC supports Orca Network (http://www.orcanetwork.org/) as a central reporting point for all killer whales sightings and the SeaSound Remote Sensing Network for acoustic detections. This hydrophone network (http://www.whalemuseum.org/seasound/ref.html) is a partnership of NOAA Fisheries Service, The Whale Museum, OrcaSound, Beam Reach, and many others. The principal investigators of this project are Dr. Jason Wood (The Whale Museum, Beam Reach), Dr. Val Veirs (The Whale Museum, OrcaSound and Beam Reach), and Dr. Scott Veirs (Beam Reach). Currently, there are five hydrophones deployed throughout the Salish Sea Region. These include two on the west side of San Juan Island (Lime Kiln Lighthouse and Smugglers Cove), one at the Port Townsend Marine Science Center, one at the Seattle Aquarium, and one at Neah Bay (near the Makah Cultural Center). These hydrophones allow real-time access for researchers and the general public to monitor acoustic signals from killer whales at these locations. These hydrophones are in operation year-round and are providing information on movement patterns of Southern Resident killer whales, as well as time series of calibrated average sound pressure levels. The Salish Sea hydrophone network website (http://orcasound.net) allows the public to listen to live streams from the hydrophones and access archived sounds. The website also includes links to hydrophones, field cameras, and environmental sensors operated by other groups.

The NWFSC has used several approaches to collect SRKW location information on the Pacific coast. For example, a coastal sighting network was developed and maintained by the Center for Whale Research (principal investigator, Ken Balcomb). The CWR distributes posters and cards that contain sighting network contact information so that the general public can report all sightings of killer whales along the west coast of the U.S., from Washington to central California. A second approach has been to deploy moorings with passive acoustic recorders at key locations along the U.S. West Coast. The principal investigators of this project are: Dr. Brad Hanson (NOAA Fisheries Service's NWFSC), Dr. Jeff Nystuen (University of Washington), and Dr. Marc Lammers (Oceanwide Sciences Institute). Unlike the Salish Sea hydrophone network, the PALs (Passive Acoustic Listening devices) and EARs (Ecological Acoustic Recorders) record acoustic signals over a set time period and then must be recovered to retrieve the acoustic information. These devices have been very successful in detecting and recording Southern Resident killer whales (and other marine mammals) in offshore locations that are very difficult for researchers to access during the winter season when weather and sea-state conditions are often poor. The information gained from these devices provides additional information on the timing and duration of the whale's movements through these areas. A third approach has been to conduct dedicated ocean class shipboard visual and acoustic surveys to locate and track SRKWs. These cruises have been very successful. SRKWs have been located along the Washington and Oregon coasts on 3 of the past 4 cruises conducted by NWFSC scientists.

Habitat Use

Defining Critical Habitat is a requirement for ESA-listed species. The sighting locations in the summer range provided a rich dataset to support Critical Habitat designation in inland waters of Washington in 2006. Understanding habitat use in the summer core region near the San Juan Islands and Canadian Gulf Islands is important for future conservation actions. Several methods have been and are currently being used to better understand pod-specific distribution patterns, movement patterns, and the behavior of Southern Resident killer whales when they are in inland waters, particularly during the summer, but also year-round.

The first step in understanding habitat use and movement patterns of SRKWs was to compile a database of all available SRKW sightings. To accomplish this task, The Whale Museum has archived all inland water killer whale visual sightings/acoustic detections for the past 30 years. The database is composed of all available sighting data from the inland marine waters of Washington State and Southern British Columbia on the Southern Resident population. The primary data sources for this database are: 1) The Whale Museum's sighting archives (which includes all Orca Network sightings posted on the internet, as well as the Museum's Whale Hotline, and sightings from Museum affiliated researchers, naturalists, and whale-watch companies); 2) Commercial whale-watch pager reports; 3) Soundwatch Boater Education program data; 4) a longitudinal data set from Lime Kiln Point State Park; and 5) all acoustic detections. This database is updated annually and has been made freely available to managers and researchers as a common baseline from which to evaluate the movements of the SRKWs in the inland waters of Washington State and British Columbia.

A subset of this database was also used by Donna Hauser (University of Washington) for her master's thesis which aimed to determine the distribution patterns of the three pods of Southern Resident killer whales in their designated summer core critical habitat. Specifically, she used 6 years of sighting information (from whale-watch pager reports) within the inshore waters of Washington and British Columbia to model pod-specific summer distribution and measure relative variation in the density of sightings on a uniform spatial grid. The results indicate that the pods exhibit complex, non-uniform summer space-use patterns. Although some regions are used in common by all pods, some areas are used almost exclusively by individual pods or certain combinations of pods, indicating specialization to particular areas. For example, all pods commonly used Haro Strait (west side of San Juan Island) while L pod alone appeared to frequent the area in the Strait of Juan de Fuca south of Vancouver Island.

M. Sc. Thesis: Hauser, D.D.W. 2006. Summer space use of Southern Resident killer whales *(Orcinus orca)* within Washington and British Columbia inshore waters. University of Washington.

Peer-reviewed publications: Hauser, D.D.W., Logsdon, M.G., Holmes, E.E., VanBlaricom, G.R., and Osborne, R.W. 2007. Summer distribution patterns of Southern Resident killer whales *(Orcinus orca)*: evidence of core areas and spatial segregation of social groups. Marine Ecology Progress Series 351: 301-310.

Hauser, D.D.W., VanBlaricom, G.R., Holmes, E.E., and Osborne, R.W. 2006. Evaluating the use of whalewatch data in determining killer whale *(Orcinus orca)* distribution patterns. Journal of Cetacean Research & Management 8:273-281.

Building on Donna Hauser's work, Dr. Dawn Noren (NOAA Fisheries Service's NWFSC) worked with Donna Hauser to geographically analyze data that were collected in 2006 for Dr. Noren's study on vessel impacts to better understand Southern Resident killer whale habitat use patterns in their core summer critical habitat. Specifically, they used killer whale group activity state data and individual killer whale data on swimming speeds, dive durations, etc to determine habitat use patterns in a uniform spatial grid of one km^2 cells. Differences in diving and swimming patterns as well as directionality and spatial arrangements among the four behaviors (rest, social, travel, forage) suggest that the four behaviors likely serve distinct functions for Southern Resident killer whales. Furthermore, foraging and resting behaviors tended to occur in more localized regions within the core summer habitat. In particular, travel was the predominant behavior that occurred along the west side of San Juan Island while foraging occurred predominantly along the southwest portion of San Juan Island. Resting occurred southwest of Lopez Island as well as south and west of Henry Island. These results have implications for potential future management actions, particularly for the selection of reserve areas where killer whales are protected from vessel traffic and other human activities.

In a related study, Erin Ashe (University of St. Andrews), Dr. Dawn Noren (NOAA Fisheries Service's NWFSC), and Dr. Rob Williams (University of St. Andrews and University of British Columbia) collected behavioral data and used classification trees and spatially explicit generalized additive models to determine feeding "hotspots" in the inshore waters of Washington State (U.S.) and British Columbia (Canada). The researchers focused on feeding behavior because Resident killer whales are most vulnerable to vessel disturbance while feeding, and the aim of this study was to identify a candidate marine protected area in the core summer critical habitat of Southern Resident killer whales. The results showed that Southern Resident killer whales were 2.7 times more likely to be engaged in feeding activity within a small (i.e. a few square miles) site along the southwest side of San Juan Island than they were in adjacent waters. These results are similar to the results from the study conducted by Dr. Dawn Noren and Donna Hauser, who used a very different approach.

Peer-reviewed publication: Ashe, E., Noren, D.P., and Williams, R. 2010. Animal behaviour and marine protected areas: incorporating behavioural data into the selection of marine protected areas for an endangered killer whale population. Animal Conservation 13:196-203.

Foraging Behavior and Prey Relationships

Prey abundance has been suggested to be a significant factor affecting Southern Resident killer whales. Thus, it is important to determine what fish the whales are consuming as well as assess how the killer whale population and its movement patterns are influenced by their prey.

Previous research suggested that the whales showed a strong preference for Chinook salmon, but these studies were limited by a small sample size. Since 2004, Dr. Brad Hanson (NOAA Fisheries Service's NWFSC) and Dr. Robin Baird (Cascadia Research Collective) have followed whales in the San Islands and Puget Sound to collect prey remains following feeding events. Their efforts have expanded the sample size of prey to over 300 prey items analyzed to date. As part of a collaborative effort with Dr. John Ford (Department of Fisheries and Oceans, Canada), they have combined these samples with those collected by Dr. Ford's colleagues in the western Strait of Juan de Fuca. The results of this study confirm the importance of Chinook salmon in the diet of Southern Resident killer whales. Additional analyses using newly developed genetic tools have allowed them to determine that the Fraser River Chinook, and in particular fish from the Upper Middle, and Lower Fraser, and South Thompson are of particular importance to the whales. Using a complementary approach to address the question of prey selection, these researchers and their collaborators initiated another project to genetically analyze prey remains in SRKW feces. The results from this approach also indicate that Chinook salmon is of major importance, although a few other salmon species (excluding pink), as well as some halibut, Dover sole, and lingcod were also found to be part of their diet. The data collected in this study also include behavioral characterization of predation events of Southern Resident killer whales in time and space. Current fecal analyses are focused on determining diet composition using quantitative cloning techniques.

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

In another study that investigated SRKW foraging behavior, Drs. Robin Baird and Brad Hanson used suction cup-attached time-depth recorders to test the hypotheses that dive rates (number of dives per hour greater than or equal to specific depths) varied between males and females, with age, between day and night, and among pods and years. Dive rates to deeper depths during the day decreased over the study, suggesting a long-term change in prey behavior or abundance, though uncertainty regarding the diet of this population precludes determination of the cause of such changes.

Peer-reviewed publication: Baird, R.W., Hanson, M.B., and Dill, L.M. 2005. Factors influencing the diving behaviour of fish-eating killer whales: sex differences and diel and interannual variation in diving rates. Canadian Journal of Zoology 83:257-267.

For her master's thesis, Shannon McCluskey (University of Washington) made a pioneering effort to link the spatially explicit movement behavior of the Southern Resident killer whale population to spatially distributed estimates of salmon abundance. She also assessed how killer whale movement patterns changed prior to and during the population decline as well as how the killer whale population varied with salmon abundance. Generally, whales were not found to distribute themselves preferentially in areas of highest weekly salmon catch, however these insignificant findings may reflect differences in temporal or species scale more than true randomness of distribution on the part of the whales. Movement patterns of all three killer whale pods were significantly different during the early 1990s when the population was increasing and the latter 1990s when the population was decreasing. Specifically, SRKWs traveled over a greater area and movement patterns were more complex in the latter 1990s when prey availability was low. Finally, the population of Southern Resident killer whales tended to fluctuate in response to population fluctuations of salmon.

M. Sc. Thesis: McCluskey, S.M. 2006. Population trends and movement complexity patterns of Southern Resident killer whales *(Orcinus orca)* in relation to Pacific salmon *(Oncorhynchus* spp.) in the inland waters of Washington State and British Columbia. University of Washington.

Previous studies have shown that SRKWs have a strong preference for Chinook salmon. The foraging behavior of killer whales suggests that they depend on echolocation to detect and recognize their prey. In order to determine possible cues in echoes from salmon species, Drs. Whit Au (University of Hawaii), John Horne (University of Washington), and Christopher Jones (University of Washington), examined the backscatter from simulated killer whale echolocation clicks on 3 species of salmon. The results showed that each species had a unique backscatter pattern which was a function of the geometry of the airbladder, which was confirmed by X-ray imagery.

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

Scientists attempt to collect prey and/or fecal samples from J pod in the Puget Sound.

Physiology, Energetics, Stress, Disease, and Contaminants

Some of the risk factors associated with the decline of the SRKWs include nutritional stress due to low prey abundance and/or quality, exposure to toxins (particularly PCBs and PBDEs), and disturbance from boat traffic. Physiological studies and programs that collect samples from free-ranging killer whales can be used to assess the importance of each of the risk factors as well as provide data to determine the health status of the SRKW population. The NWFSC has supported several studies that collect samples to assess the health of SRKWs as well as provide information on the bioenergetics (energetic cost of daily activities and food consumption requirements) of SRKWs.

In 2006, Dr. Brad Hanson (NOAA Fisheries Service's NWFSC) and Dr. Robin Baird (Cascadia Research Collective) initiated a biopsy sampling program to safely obtain small blubber samples from key individual whales. The analysis of samples by Dr. Peggy Krahn and others from the Environmental Assessment Program at the NWFSC confirmed that Polychlorinated Biphenyls (PCBs) burdens are high, although somewhat lower than they were when the last samples were analyzed over a decade ago. Levels of new generation contaminants, such as polybrominated diphenyl ethers (PBDEs, or flame retardants), increased, however, and were particularly high in juvenile animals that were sampled. Additionally contaminant profiles for K and L pods differed from that of J pod, which is related to differences in ranges that the pods occupy in the winter. The results suggest that both K and L pods travel to California to forage, where high levels of DDTs are found in prey. In contrast, J pod generally remains near Puget Sound/Georgia Basin waters where prey has lower ∑DDTs/∑PCBs ratios. These results have been substantiated by multiple sightings of both K and L pods, but not J pod, in waters off the coast of central California. However, the carbon and nitrogen stable isotope signatures indicate that the three pods consume prey from similar trophic levels. This information will be important for determining where to target cleanup efforts. The NWFSC is continuing to collect biopsy samples from all three pods to further assess this factor.

Peer-reviewed publications: Krahn, M.M., Hanson, M.B., Baird, R.W., Boyer, R.H., Burrows, D.G., Emmons, C.K., Ford, J.K., Jones, L.L, Noren, D.P., Ross, P.S., Schorr, G.S., and Collier, T.K. 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., Hanson, M.B., Schorr, G.S., Emmons,C.K., Burrows, D.G., Bolton, J.L., Baird, R.W., and Ylitalo, G.M.. 2009. Effects of age, sex and reproductive status on persistent organic pollutant concentrations in "Southern Resident" killer whales. Marine Pollution Bulletin 58:1522-1529.

For her Master's thesis, Teresa Mongillo (University of Washington) used an individual-based modeling approach to estimate the accumulation of polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) in specific individuals in the Southern Resident killer whale population. The current accumulated levels were also projected into the future under various assumptions and scenarios. Similarities in the predicted PCB and PBDE concentrations in individuals were assessed to identify any natural groupings in the model output. In addition, the respective influences of the life history traits that lead to the pattern of the predicted contaminant levels across demographic categories were also determined. In general, J pod individuals had higher PCB concentrations than K or L pod individuals. The predicted PBDE accumulation doubling time for all three pods ranged from 3 to 4 years. Model projections indicate that PCBs are slowly declining but the killer whales will continue to be exposed for some generations to come. In contrast, PBDEs are projected to increase rapidly, and individuals may experience levels equal to current PCB levels and surpass the health effects threshold in a short period of time. In male SRKWs, no primary factor significantly influenced the PCB concentrations predicted across the individuals. In contrast, the birth year, age, and birth order significantly influenced PBDE concentrations. Age was found to have a generally positive association with PCBs and a significant negative association with PBDEs in male killer whales. In addition, birth order had a generally negative association with PCBs and a significant positive association with PBDE concentrations. Among male killer whales, individuals with the highest PCB concentrations included primarily older individuals with low birth order and individuals with high PBDE concentrations included primarily younger individuals born recently with high birth order. The contaminant levels in female killer whales were primarily influenced by individual reproductive status and were not strongly associated with age or birth order.

M. Sc. Thesis: Mongillo, T.M. 2010. Estimated polychlorinated biphenyl (PCB) and polybrominated diphenyl ether (PBDE) accumulation in Southern Resident killer whales. University of Washington.

For her Ph.D. dissertation, Katherine Ayres (University of Washington), along with her advisor, Dr. Sam Wasser (University of Washington), and other collaborators collected fecal matter to investigate the relative impacts of nutritional and disturbance stress in the SRKW population. Specifically, these researchers used noninvasive hormone measures of stress (glucocorticoids, or GCs) and nutrition (GCs

Fecal samples collected from Southern Resident killer whales will be used for diet and genetics analysis.

and triiodothyronine, or T3) in feces to test food deprivation and disturbance stress associated with Chinook availability, boat traffic, and demographic trends. The hormone data support a reduced prey hypothesis with potential cumulative impacts from boat traffic during years of poor food availability. Average fecal T3 concentrations were lower (indicating relatively poor nutrition) in years when SRKW mortality was higher and birth rates were lower. Also, fecal GC concentrations decreased with increased Chinook salmon returning to the Fraser River, further supporting the importance of this population as a prey base for the SRKW in May-September. Finally, there was a positive correlation between average boat numbers around SRKWs and fecal GCs in 2007, but not in 2008 or 2009. This may be due to added stress from boat traffic around SRKWs during times of relatively poor prey availability, such as 2007. In addition, Ms. Ayres and Dr. Wasser have developed fecal reproductive hormone measures (progestins, estrogens and testosterone). Combined with DNA, these measures can be used to determine sex, maturity and reproductive state of each sampled individual. These measures should prove useful for monitoring reproductive success throughout the SRKW population with respect to possible impacts such as food availability, boat traffic and toxin exposure.

In order to assess if the salmon populations are sufficient to support the population of Southern Resident killer whales, it is important to determine how many fish are available and equally important to know how many fish each whale needs to consume per day to survive. To assess the energetic requirements of killer whales, it is first necessary to understand how much energy killer whales expend per day. As a first step in determining energetic requirements of killer whales, Dr. Rob Williams (University of British Columbia) and Dr. Dawn Noren (NOAA Fisheries Service's NWFSC) used respiration rate and swimming speed data from Northern Resident killer whales in combination with published respirometry values to determine the cost of swimming at various speeds for adult killer whales. They found that energy expenditure increases with increasing swimming speeds, but that the most efficient (lowest energetic expenditure per distance travelled) swim speed for whales travelling long distances is approximately 2.6 – 3.0 m/s.

Peer-reviewed publication: Williams, R. and Noren, D.P. 2009. Swimming speed, respiration rate and estimated cost of transport in adult killer whales. Marine Mammal Science 25: 327-350.

Another study conducted by Dr. Dawn Noren used daily activity budgets to estimate the total energy expenditure and prey energy requirements of all individuals in the Southern Resident killer whale population. The results show that energy expenditure and prey consumption increases with age and body size. Not surprisingly, individual adult male killer whales require more food per day than adult females. However, since the Southern Resident killer whale population is comprised of many more adult females than adult males, this segment of the population, as a whole, consumes the majority of the total prey consumed by Southern Resident killer whales. Furthermore the number of fish consumed per killer whale varies with the size and species of the fish. For example, if Southern Resident killer whales only consume Chinook, which are large and energy-rich, they will consume fewer fish than if they only consumed chum, which are smaller and less energy-rich. These results provide one explanation of why Southern Resident killer whales seem to prefer Chinook over other salmon species.

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

Further research on size and body condition of Southern Resident killer whales was conducted by John Durban (Center for Whale Research and NOAA Fisheries Service's Southwest Fisheries Science Center) and colleagues in 2008. Their study tested the use a novel technique, aerial photogrammetry (a practice of deriving geometric properties from photographic images) as a means to assess the individual growth and nutritional health of whales in the population. The aerial survey was conducted simultaneously with a boat-based effort in order to maximize the number of individuals recorded and to verify individual identifications. Observations were conducted in 2008, with over 2,800 usable images captured. Sixty-nine individual whales were identified (more than ¾ of the entire population), representing all three pods. Analysis of the images identified variation in body length and head width. Researchers were able to link certain states (e.g., neonate, lactating female) to body conditions in some cases. Overall, photogrammetry demonstrated promise for use in assessing body condition, but additional data across seasons and years are needed in order to draw meaningful conclusions about individuals' health over time.

Scales collected after a prey event by a Southern Resident killer whales can be used to identify the species, age, and stock of the fish it came from.

Peer-reviewed publication: Fearnbach, H., Durban, J., Ellifrit, D., and Balcomb, K. 2011. Size and long-term growth trends of endangered fish-eating killer whales. Endangered Species Research 13:173-180.

Vessel Interactions and Ambient Noise

Boat traffic has increased considerably in the whales' summer core range and may have detrimental effects on the whales' foraging success and ultimately survival. In collaboration with university and non-governmental organization partners, the NWFSC and the NWR have conducted and funded several studies to examine the trends in vessel interactions and how the whales react to vessels.

Kayaker with killer whales. Photo credit: Jeff Hogan

Soundwatch (operated by The Whale Museum) provides on-the-water stewardship, public outreach, and boater education, as well as collects data on the number of vessels in the vicinity of killer whales and compliance with whale watch guidelines. Prior to 1976, whale watching in this region was virtually non-existent. This industry exhibited a nearly continuous annual growth from 1984 through 1998. Since 2001, however, the number of U.S. and Canadian whale watch companies has remained relatively level. There has also been a shift in the industry towards more Canadian vessels. In addition to commercial whale watch vessels, this region also attracts great numbers of commercial kayaking companies and private boaters (including kayakers) both for fishing and general recreation. From 1998 to 2010, the average number of vessels (all types) within a half-mile of whales has decreased from 22.5 to 13.5. There is great daily and monthly variability in the numbers of boats with whales. Thus, average numbers of vessels with whales may not be the best way to truly assess vessel number trends. For example, in 2010 the highest vessel count near the whales was 54. In recent years (2005-2010), the most common vessel incidents (events when vessels were observed not following viewing guidelines or laws) include: vessels parked in the path of whales, vessels motoring inshore of whales, vessels motoring within 100 yards of whales, and vessels motoring fast within 400 yards of whales. Vessel incident by vessel type have remained nearly the same since 2003 and occur primarily by private operators (over 50%), followed by Canadian commercial operators, and then U.S. commercial operators. Of the 1,067 incidents in 2010, 41 incidents specific to kayaks (22 commercial and 19 private kayakers) were observed, including parking in the path (20% of kayak incidents in 2010). Kayak incidents are likely underestimated because the Soundwatch observers remain outside of the current voluntary no-go zone where considerable kayak activity takes place. For the summer of 2010, Soundwatch's Kayak Education and Leadership Program (KELP), San Juan County Parks, and the San Juan Island Kayak Association worked together to update and refine a Kayaker Code of Conduct as part of KELP. In addition to providing the guidelines and training for kayakers through the KELP education program, Soundwatch collected new information regarding kayaks from land-based observation points. Top incidents were: kayaks not rafted, parked on headlands or within kelp beds, parked in the path of whales, and stopped within 100 yards of whales.

In another study, Drs. David Bain (University of Washington), Rob Williams (St. Andrews University), David Lusseau (University of Aberdeen), and Jodi Smith (Massey University at Albany) collected data to determine relationships between SRKW behavior and vessels. The researchers measured the behavior of Southern Resident killer whales in the presence and absence of vessels from 2003 to 2005 at 2 different sites along San Juan Island, Washington, U.S. They used a theodolite to track individual killer whales to determine swimming path directness and deviation indices, travel speed, and rates of respiration and surface active display behaviors. They also observed activity states of killer whale groups using scan sampling and collected information on the number of vessels present at various distances from the whales. The major findings of this study were that killer whales reduced their time spent foraging when vessels were present, which is similar to the response observed previously in Northern Resident killer whales. Furthermore, the relationships between number and proximity of vessels and whale behavior are complex. Yet, in general, killer whales swam in more erratic paths when many boats were present.

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

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

For her Ph.D. dissertation, Jennifer Marsh (University of Washington) studied the behavior of Southern Resident killer whales and its relationship with several ecological factors, including vessel presence. Specifically, generalized behaviors (rest, play, forage, travel) and two measures of social behavior (percussive behavior and

synchronous surfacings) were examined because it was hypothesized that each of these might vary with whale-watching pressure. Percussive behaviors (also called surface active behaviors) are considered by some to be communicative and may convey information to conspecifics. Synchronous surfacings may represent a social bond between two animals and has previously been used to define the strength of affiliation among conspecifics. The results showed that some behaviors were correlated with each other and also with ecological factors. For example, some behaviors (e.g., cartwheels and breaches) were more prevalent during the afternoon while other behaviors (e.g., physical contact and spyhop) increased with increasing number of vessels present. Meanwhile, behavior states (rest, play, forage, travel) did not appear to be related to the number of vessels present. The results of this study demonstrate that killer whale behavior is very complex, and that several varying ecological factors may affect killer whale behavior.

Ph.D. Dissertation: Marsh, J.A. 2008. Social behavior and ecology of "Southern Resident" killer whales *(Orcinus orca).* University of Washington.

To assess potential energetic impacts of behavioral responses to vessel disturbance, Dr. Dawn Noren (NOAA Fisheries Service's NWFSC) and her collaborators collected data in the San Juan Islands, U.S. and Gulf Islands, Canada during the summers of 2004 through 2006. Continuous behavioral data, including dive durations, surface durations, swim speeds, and the performance of surface active behaviors (SABs; e.g., spy hops, breaches, tail slaps, pectoral fin slaps) were recorded from individual adult Southern Resident killer whales using a focal follow approach. Vessel counts and distances between the focal whale and the nearest vessels were measured every 10 minutes. In 2006, distances were measured every 5 minutes and during every performance of an SAB by the focal whale. Relationships between vessel presence and dive and surface durations and swimming speeds are very complex, and are still being analyzed. Analysis of the relationships between vessel distance and the occurrence of SABs suggest that close approaches by vessels may elicit a behavioral response. The highest frequency of SABs occurred when the nearest vessel was within 75-99 meters and 125-149 meters of the focal whale in 2005 and 2006, respectively. Furthermore, a significantly greater proportion of SABs occurred when vessels closely approached whales. Finally, there was a significant temporal relationship between close approaches and the occurrence of SABs; most SABs were performed near the time of the closest approach by a vessel. These results suggest that close approaches by vessels (including distances greater than 100 m) elicit behavioral responses in SRKWs.

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

Previous experimental studies documented stereotyped avoidance responses by killer whales to boats. Additional observations collected during these studies also showed an apparent shift in avoidance behavior at high traffic levels. A study conducted by Dr. Rob Williams (University of British Columbia) and collaborators experimentally tested whether Northern Resident killer whales responded differently to approach by few (1–3) versus many (>3) vessels. Data were collected during the summer of 2004 in Johnstone Strait, British Columbia, using a theodolite to track the positions of boats and individually identifiable focal whales during approaches of few versus many boats. Swimming paths became more tortuous when few boats approached whales, but straighter as many boats approached. Pooling treatments would have masked significant responses, falsely suggesting that boat presence had no effect. The division between few and many boats was also supported by 140 opportunistic observations of 26 whales from a population of 216.

Peer-reviewed publication: Williams, R. and Ashe, E. 2007. Killer whale evasive tactics vary with boat number. Journal of Zoology (London) 272: 390-397.

In another recent study Dr. Rob Williams (University of St. Andrews) and colleagues concluded that that kayaks can have a significant impact on killer whale behavior. While previous studies pooled kayaks and motorized vessels together, in the most recent study, the presence of both types of vessels was analyzed separately for data from 1995-2004. In the presence of only kayaks, researchers determined that the probability that the whales would shift to travel behavior from other behavior states (including feeding) significantly increased compared to situations with no vessels present, indicating an avoidance tactic. As a result, the whales spent significantly more time traveling when in the presence of kayaks than they did under no-boat conditions (an 11 percent increase in time spent traveling was observed). Consistent with previous studies, results from the study indicated killer whales significantly reduced overall time spent feeding in the presence of kayaks and powerboats compared to no-boat conditions (30 percent decrease in time spent feeding). With respect to both kayaks and motorized vessels, the duration of feeding decreased and the overall proportion of time spent feeding decreased when vessels were present, regardless of the type of vessel. One model suggested that the effect of kayaks on feeding activity was perhaps less pronounced than the effect of powerboats on feeding activity. The types of effects vessels have on foraging activities seem to be similar whether the boats involved are kayaks or other types of vessels, but the study indicated whales may use different avoidance tactics to deal with the two types of vessels.

Southern Resident Killer Whales - Research Update

For her Ph.D. dissertation, Deborah Giles (University of California Davis, The Whale Museum) collected data during the summer and fall seasons of 2007 and 2008 to characterize spatial and temporal distributions of Southern Resident killer whales with an emphasis on changes in group cohesion and activity state under varying conditions. This biogeography research examines the relationship between whale behavior and variables such as geographic location, bathymetry, tides, currents, and number of vessels. One component of the study assesses whether vessel density, distance, and mode of operation affects whale group cohesion and/or activity state. Ms. Giles' data collection method is unlike any other that has been attempted from a boat-based platform. Specifically, she uses an integrated equipment package which includes a global positioning system (GPS) with built-in data collector to record attribute data (e.g. whale identification, group size, and behaviors), a laser range finder to determine distance, and a compass for bearing. These components are electronically connected and synchronized to generate geo-referenced data for focal whales and vessels. Two integrated equipment packages are used to collect data simultaneously, with the first package dedicated to collecting data on killer whale behavior and location and the second package dedicated to collecting data on vessel behavior and location. Preliminary analyses of the behavioral budget of Southern Resident killer whales indicate that they now engage in resting behavior during daylight hours significantly less when compared to behavioral data taken over the past three decades; however causal factors have not yet been identified. Final results from this study will be made available online in the near future.

Dr. John Hildebrand (University of California San Diego) and collaborators reported source level measurements for a variety of vessels of different sizes, propulsion systems, and operational speeds in Haro Strait. The researchers also opportunistically measured the source spectral levels of a 290 m long Korean container ship, the MV Hanjin Marseilles. The extended frequency range of vessel noise is pertinent to the higher frequency range of killer whale hearing and is particularly relevant to the reception of echolocation signals. Received levels were measured at ranges that varied between 125 and 442 meters for idle, normal cruise speed (17–31 knots), and power acceleration to full speed. Noise spectra were not sufficiently above background levels to make accurate measurements of vessel noise levels under controlled conditions while vessels were idle despite efforts to collect data when there were no other vessels present in the local vicinity. Thus data collected under idle conditions were not considered to be accurate measurements of real vessel noise. Noise source spectra measured from four whale watching vessels varied. For example, above 2 kHz, a 50-foot monohull whale watching vessel with three inboard/outboard (stern) drives produced the highest source spectral levels, while a 38-foot aluminum catamaran with

Scientists collect acoustic recordings and killer whale behavioral data in the San Juan Islands.

jet drives produced the lowest source spectral levels. The catamaran presumably produced the lowest noise levels at higher frequencies because of its jet drive system. The MV Hanjin Marseilles produced significant levels of noise above 2 kHz, and with the exception of the 50-foot monohull vessel, these noise levels were higher than levels from whale watching vessels. These results demonstrate that noise generated by vessels is dependent on a combination of vessel size, engine type, and operating speed.

Because many areas frequented by SRKWs are complex shallow water acoustic environments, it is necessary to consider how transmission loss from source to receiver will affect the sound levels potentially reaching killer whales in the area. In order to begin to address this question, Drs. Chris Jones and Mike Wolfson (Applied Physics Laboratory, University of Washington) modeled propagation of sound emanating from large vessels in the main shipping lanes in Haro Strait, focusing on numerical estimates in the open channel. In all cases, the model results were consistent with the measured results when an estimated ship source level of 175 dB at 3.6 kHz was used. The results for the different cases of sediment and sea surface conditions varied within 3 dB of each other, implying these parameters do not strongly influence model results. Furthermore, variability of the model results did not increase with increased sea surface roughness. Drs. Jones and Wolfson hypothesize that the short distance between ship and receiver results in bathymetric effects that dominate the results while bottom and surface conditions contribute little to propagation effects. Given the complexity of the acoustic environment of the Haro Strait, these researchers also recommend that acoustic modeling is best used as a complement to field measurements.

Dr. Marla Holt (NRC post-doctoral associate, NOAA Fisheries Service's NWFSC) wrote a comprehensive review on what is currently known about killer whale auditory capabilities, the use of sound

by killer whales, the characteristics of sound in their environment, and the effects of sound exposure in killer whales and other dolphins in order to address potential acoustic impacts on the SRKW population. As is the case for all marine mammal groups, it is extremely difficult to address acoustic effects that might have indirect or small but consistent consequences at the population level. In this review, Dr. Holt, using data on spectral levels of vessels and Haro Strait ambient noise from Dr. Hildebrand's 2006 contract report, estimated the horizontal detection range of killer whales echolocating on Chinook salmon. She found that detection ranges varied by vessel type and mode of operation but that in general, boat noise generated by cruise and power up speeds at distances of up to 400 m from whales was predicted to significantly reduce the active space of an echolocation click at 50 kHz. These results demonstrate that vessel noise has the potential to impact echolocation abilities for foraging whales.

Publication: Holt, M.M. 2008. Sound exposure and Southern Resident killer whales *(Orcinus orca)*: A review of current knowledge and data gaps. U.S. Dept. of Comm., NOAA Tech. Memo. NMFS-NWFSC-89, 59 p. Available on-line: http://www.nwfsc.noaa.gov/assets/25/6741_03042008_154832_OrcaSoundExposureTM89Final.pdf

Given their dependence on sound and the many anthropogenic sources of noise in their core habitat, concerns have been raised about acoustic impacts on Southern Resident killer whales. A study by Dr. Marla Holt, and collaborators including NWFSC, Colorado College, and Beamreach researchers have found that SRKWs compensate for the masking effects of vessel noise by calling louder. These researchers found that whales increase their call level of one call type by one decibel for every decibel increase in background noise levels. Since calls are used for communication, it is not surprising that whales call louder as an anti-masking strategy when background noise levels are raised. The researchers also found that underwater noise levels increased as the number of motorized vessels around the whales increased, illustrating that vessel traffic contributes significantly to the background noise levels whales experience in their core habitat. Even though the whales can raise their voices when many vessels are present, there may be costs associated with that, or at some level, vessel noise could completely mask their calls. In this case, the range over which whales could communicate with one another would significantly decrease. Another study took these findings a step further and found that SRKWs increase their call levels across several different call types as background noise levels increased. Even when these variations in sound levels due to noise were controlled for, different call types were produced at different levels. In particular, those call types that had a high frequency component were higher on average. These findings support the idea that toothed whales and dolphins have two different sound generating organs. These findings are also important since researchers need to understand the sound levels of all different types of sounds produced by animals to make informed decisions about anthropogenic noise impacts.

Peer-reviewed publications: Holt, M.M., Noren, D.P., Veirs, V., Emmons, C., and Veirs, S. 2009. Speaking up: Killer whales *(Orcinus orca)* increase their call amplitude in response to vessel noise. Journal of the Acoustical Society of America Express Letters 125: EL27-EL32.

Holt, M.M., Noren, D. P., and Emmons, C. In press. Effects of noise levels and call types on the source levels of killer whale calls. The Journal of the Acoustical Society of America.

In a follow-up study (funded by the Office of Naval Research and NWFSC) initiated in 2010, Drs. Dawn Noren and Marla Holt (NOAA Fisheries Service's NWFSC), in collaboration with Dr. Terrie Williams and colleagues at the University of California, Santa Cruz, are using trained Atlantic bottlenose dolphins to determine the energetic cost of sound production as well as the energetic cost of producing louder sounds. This effort will help determine the biological significance (i.e., whether increased levels of sound production over a long period of time results in increased daily energy expenditure and thus, daily prey requirements) of the results of the field study on killer whales conducted by Dr. Holt and collaborators.

In September 2010, the NWFSC along with collaborators from Cascadia Research Collective and UC Davis initiated a project to study the acoustics and behavior of SRKWs using suction cup attached digital acoustic recorders (DTAGs). The DTAG has a variety of sensors, including two hydrophones, to record received sound levels at the whale, pressure and temperature sensors to determine dive depth, and accelerometers to record their 3D movements under water. It is attached by suctions cups to the skin of the whale for a few hours before release at a preset time and floats for recovery. Its use has become widespread and is commonly used by the cetacean research community to study fine-scale details on the acoustic and movement behavior of numerous cetacean species, including killer whales, in other locations. The study aims to address several of the risk factors of SRKWs. These include the noise levels received by individual SRKWs diving in a three dimensional environment along with the influence that vessels at the surface have on such received sound levels. Other goals of this project are to investigate acoustic behavior and sound use during different activities such as foraging since acoustic signals are the predominant sensory cues used by killer whales for finding prey. These acoustic cues will be validated with field observations including prey sample collection to ultimately determine effects of vessels and associated noise exposure on individual SRKW behavior. Previous studies have indicated that SRKWs decrease foraging activity, increase dive duration, swim speeds, and some surface active behaviors in the presence of vessels (Lusseau et al. 2009; Noren et al. 2009; Williams et al. 2009). However, acoustic data were not collected at the same time that these data were collected so it is unclear whether the physical presence of vessels, the noise associated with vessel activity or

both contribute to the observed behavioral responses. In addition, killer whale behavior was limited to what scientific investigators could observe at the surface, and data from DTAGs will provide a wealth of information about killer whale behavior when researchers cannot observe them visually.

Southern Resident killer whale with attached DTAG.

Cumulative Risk Analysis

Understanding the relative contributions of different risk factors is essential for developing a sound recovery strategy. To start to evaluate the relative importance of different risks, Dr. Eric Ward (NOAA Fisheries Service's NWFSC) in collaboration with Dr. Eli Holmes (NOAA Fisheries Service's NWFSC) have initiated a project to use statistical approaches to examine the relationship between the whales' survival and birth rates and range of risk factors, including salmon abundance, the ocean environment, vessel interactions, and gross exposure to contaminants. Analyses of the fecundity data suggest that the whales' birth rates are more strongly correlated with Chinook salmon abundance than they are with any of the other factors analyzed.

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

Ward, E.J., Semmens, B.X., Holmes, E.E., and Balcomb, K.C. 2011. Effects of multiple levels of social organization on survival and abundance. Conservation Biology 25: 350-355.

Human Dimension Studies

Southern Resident killer whales are subject to a host of pressures potentially complicit in their recent decline. Many of these pressures can be interpreted to be a result of human activity. Various NWFSC marine mammal research projects aim to better understand these pressures. In addition to the biological studies on the whales, the social sciences can inform the human connection to the whales. To better understand one connection between humans and whales, specifically in the whale watching tourism industry, Suzanne Russell (NOAA Fisheries Service's NWFSC) collected sociocultural data on marine mammal tourism linked to the Puget Sound SRKW population. Specifically, this study utilized a survey and interview tools to develop a baseline sociocultural description of the industry. Data collected included demographic information, employment history, and company characteristics. This information provides socioeconomic data that was previously absent, informs a discussion on socioeconomic impacts on the industry, and provides the foundation for future research.

Publication: Russell, S. and Schneidler, M. In press. The U.S. Whale Watching Industry of the Greater Puget Sound: A Description and Baseline Analysis. U.S. Dept. of Comm., NOAA Tech. Memo. NMFS-NWFSC-89, 59 p.

Quantifying the amount and types of marine traffic is critical to understanding the impact of vessels upon killer whale behavior and to determining the best ways to both protect whales and allow for human uses of the marine environment. A recent study by Sysstat, Inc. documented summer vessel traffic in the San Juan Islands, including the western shore of San Juan Island, building upon previous work supported by the San Juan County Marine Resources Committee. This area is currently home to a voluntary "no go" zone as part of the San Juan County Marine Stewardship Area, and has been considered for additional protection. The project catalogued vessels by type and location using aerial photography and GIS. Vessels were counted and categorized into nine types: power, sail, paddle, cargo, commercial fishing, tour, skiff, recreational fishing, and reef netting. Results indicated higher vessel presence on weekends/holidays and a small increase in overall vessel traffic compared to the original 2006 study. The west coast of San Juan Island had the high number of kayaks. Fishing activity was observed along the coast, primarily at the southern end of San Juan Island.

Learn More & Come See Us in Action

Sharing our work with other scientists, with policymakers, and with the public is important to us. To learn more about what we do, please visit the Northwest Fisheries Science Center's website at www.nwfsc.noaa.gov and the Northwest Regional Office's website at www.nwr.noaa.gov. For additional information about the Center, please call 206-860-3200.

Contract reports and additional information about the killer whale research conducted and funded by the NWFSC's Marine Mammal Program for the past several years can be found on our website: http://www.nwfsc.noaa.gov/research/divisions/cbd/marine_mammal/marinemammal.cfm

NOAA Fisheries' five-year review of the ESA status of Southern Resident killer whales was completed in 2011. To learn more about the findings of the review, as well as how NWFSC's research efforts are an integral part of the Recovery Plan and have informed management decisions, visit the NOAA Northwest Regional Office's website: http://www.nwr.noaa.gov/Marine-Mammals.