Correlating Southern Resident Orca Sightings with Pacific Salmon Densities: A Three Part Analysis

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Introduction

In the Salish Sea region of northern Washington and southern British Columbia, lives an ecotype of killer whale (*Orincus orca*) called residents. These southern resident killer whales (SRKW) live in matrilineal groups and have a "home range" in which they live. During the early summer to fall months, they reside mainly in the Salish Sea region, while in the winter months they are known to travel south to the California coast (Ford et al. 2000). It has been found that resident killer whales in the Salish Seas have a very strong preference to feeding on salmon species with only rare examples, derived from prey samples or fecal samples, of them eating other marine species (Hanson et al. 2010). In recent years it has been shown that they particularly, and almost exclusively, hunt Chinook salmon (*Oncorhynchus tshawytscha*). Ford et al. (1998) determined from observational data over many years, and through examining stomach contents of stranded whales, that over two-thirds of the fish the southern resident orcas consumed could be identified as Chinook salmon. Chinook tend to be much larger than other salmon and have the highest fat content, which may play a large role in the whales' preference (Ford et al. 1998). The main exception to this is when they (much less often) will prey on available Chum salmon (*Oncorhynchus keta)* (Ford and Ellis, 2006).

Since the southern resident killer whales very specifically hunt the Chinook, it has been the focus

of many studies for over 30 years. Spring, Summer, and Fall salmon runs occur in the Salish Seas, most notably for the Columbia and Fraser rivers (Trudel et al. 2009), which corresponds with when the SRKWs are most often sighted in the area. Chinook abundance has been shown to directly correspond with killer whale mortality, depicting the dependent bottom-up relationship the SRKWs have with the salmon (Ford et al. 2009). It has also been shown that PCB toxin bioaccumulation is occurring from the whales eating Chinook with high PCB concentrations (more noticeably Chinook from the south) (Cullon et al. 2009). This unique predator-prey relationship is even more interesting due to the fact that Chinook salmon in the study area are declining and have been listed as threatened and endangered (Myers et al. 1998), as have the SRKWs themselves. The National Oceanic and Atmospheric Association (NOAA) listed different evolutionary significant units (ESUs) of Chinook in the Salish Seas as either endangered or threatened in 1999, including Columbia River and Puget Sound runs. The SRKWs were later listed as endangered as well, in 2005 (NOAA, 2011).

Previous studies have been conducted on the Northern resident killer whales, looking at the correlation between the killer whale sightings and salmon numbers to infer about seasonal movement of the killer whale pods (Nichol and Shackleton, 1996). Other studies have focused on where feeding behaviour is most likely to occur. Ashe et al. (2009) found that during the summer months, SRKWs were most likely to display foraging behaviour on the south-west coast of San Juan Island. This suggests that fish density may be highest in this area, and this region will be of particular interest in the current study. Chinook salmon are often found at depths of 50m or more, and have been known to dive down to depths of up to 300m (Candy and Thomas, 1999). These depths correspond well with the bathymetry of Haro Strait (on the west side of San Juan Island), since it has varying depths up to over 200m in many places.

Echosounder and fish finder data has previously been used to conduct fish analyses during killer whale encounters in the San Juan Islands. Horne and Gauthier (2004) used an echosounder to view images of biomass in the water. They were able to characterize fish in the water during SRKW foraging events by size of the targets in the images and by depth at which the targets were found. They also trawled for salmon from the boat in order to positively identify salmon species presence.

In this study, similar methods to those used by Nichol and Shackleton (1996) and Horne and Gauthier (2004) are used to look at correlations between SRKWs and their salmon prey while they are residing in the Salish Seas in the summer and fall months. Since the killer whales' survival is so much linked to their salmon prey, it is hypothesized that number of whale sightings in the Haro Strait and Fraser River areas will positively correlate with salmon densities at the time of sightings. Furthermore, it is also hypothesized that the time the whales spend exhibiting foraging behaviour while the whales are observed in the field will correspond positively with estimated salmon numbers (determined by size and depths analysis of the images) obtained by taking fish finder readings while observing the whales from a boat. This study will look at three different examples of this correlation: the large scale example using the archive whale sighting data and salmon numbers for the Salish Seas region, a localized example using archive whale sightings data and echosounder data specifically localized at Lime Kiln State Park, WA, and a finer scale example using data collected out in the field over a 20 day period.

Methods

All data collected and analyzed was for the southern resident killer whales and salmon species in the Salish Seas off of Northern Washington, USA and Southern British Columbia, Canada. The methods used in this paper are an adaptation of the methods used by Nichol and Shackleton (1996) in their study of the Northern resident killer whales, and Horne and Gauthier (2004) in their study of killer whale prey presence.

Archive Data Analysis

Archive data of salmon densities was obtained from the Department of Fisheries and Oceans and the Pacific Salmon Commission for the Haro Strait and Lower Fraser River areas. This data is recorded as weekly estimates of fish density, and a total of twenty weeks in June- October from 2007-2011 were used for the first part of the analysis. Whale sightings data was obtained from the Orca Master database through the Whale Museum in Friday Harbor, WA, and was queried using SQLShare (Fourdeuce, inc. 2005-2009). The number of "whale days" (days in which the orcas were sighted) were summed for each of the study weeks. The number of whale days per week was then regressed against the weekly salmon counts to see the relationship between the two. ANOVA statistical analysis was then performed using Systat statistical software (Systat version 13 © Systat inc. 2008) ($\alpha = 0.05$) to determine whether the relationship in the regression was significant.

A second archive data analysis was performed with echosounder data from the Lime Kiln State Park lighthouse WA, from the Spring of 2011. Echosounder image data from the lighthouse was analysed to determine the presence, count, and depth of large target fish (considered to be salmon). Size analysis of the targets was performed using ImageJ software (Rasband, 1997-2011) to further determine if the large targets could be counted as salmon species. The salmon counts

determined from the images were then correlated with whale sightings data from the Orca Master database specifically at the Lime Kiln lighthouse, and an ANOVA statistical test was performed.

Field Study Analysis

Observational data collection was carried out on board the sailing biodiesel/electric catamaran, Gato Verde, over a twenty day period. Total time spent observing the whales each day was recorded, as well as amount of time foraging behaviour was observed. Foraging behaviour is difficult to define, but whales were considered to be foraging when they were alternating between milling and travelling, and lunging or chasing events could be inferred when prey was present, as per the NOAA behavioural definitions determined in a conference in 2004. Using a GP-1650 WF fish finder, salmon counts were estimated at sites where whales were observed foraging, using the backscatter images. Images from the fish finder were analyzed to determine presence, count, and depth of large target fish (considered to be salmon). Size estimates of the fish finder images of large fish were determined by using ImageJ software (Rasband, 1997-2011) to further determine if the targets were in fact salmon. Trolling with salmon fishing gear was also performed on the boat at depths where large fish finder targets were being detected to determine presence of salmon species. The percent of time the whales spent foraging was calculated and was regressed against the estimated salmon counts from the fish finder backscatter images. An ANOVA statistical test was then performed (as with the archive data) to determine the significance of the regression.

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