DIET STUDIES OF "SOUTHERN RESIDENT" KILLER WHALES:

PREY SAMPLING AND BEHAVIORAL CUES OF PREDATION

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Summary

In an effort to better understand the diet of so-called "southern resident" killer whales, we collected prey remains from feeding whales and recorded information on behavioral cues of predation around the San Juan Islands in August and September 2004. During the seven days of effort, killer whales were encountered on eight occasions over four days, and attempts to collect prey remains were made during five encounters. Whales were followed for the purposes of prey sample collection for a total of 12.7 hours, and events suggesting predation were observed 27 times. Prey remains were collected from 10 of these events (37%). Only three of the 10 cases involved a series of fast non-directional surfacings or active prey chases, characteristics that have been used to indicate feeding in one previous study. Behavioral observations from four of the 10 sampling events indicated that the prey chase and capture occurred out of sight of surface-based observers, and in one further case the prey capture occurred beneath the surface, with only initial signs of the chase visible at the surface. Prey captures were observed simultaneous with social interactions that were not related to foraging, suggesting that foraging behavior and social behavior can occur simultaneously. Further, this suggests that studies observing behavior from distances that are too far to observe prey in the water column may not always accurately characterize the behavior of fish-eating killer whales.

Introduction

The so-called "southern resident" killer whales are found primarily in the inshore waters around southern Vancouver Island and in northwestern Washington in the summer and fall months. The diet of individuals in this population is poorly known. Unlike the sympatric population of so-called "transient" killer whales (see Baird and Dill 1995), documented observations of predatory interactions with other species of marine mammals have been extremely rare. Based on the lack of such observations, combined with occasional anecdotal observations of predation on fish (e.g., Felleman 1986; Heimlich-Boran 1988) and the spatial and temporal co-occurrence of whales and pre-spawning runs of salmon (Heimlich-Boran 1986; Osborne 1999), it is widely accepted that this population feeds primarily, if not entirely, on fish, at least in summer and fall. However, relatively little is known about which species of fish are taken and how this varies seasonally or

between pods. The only published study of diet, involving analyses of available stomach contents and collection of fish scales from behind foraging whales, concluded that salmon, and primarily chinook salmon, form the vast majority of the diet (Ford et al. 1998). Sample sizes for that study are small (samples from 27 predation events and 5 stomach contents from "southern residents", collected over an extended period of time), and information on the details of predation on fish are limited. Hoelzel (1993) noted that "a series of fast turns and rolls at the surface [were] always seen when an interaction with fish prey was apparent". In their scale sampling study, Ford et al. (1998) used cues "such as rapid acceleration, sudden direction changes, or circling" as indicators of potential predation.

The primary purpose of this study is to gain additional information on the diet and foraging behavior of this population through the observation and collection of prey remains from foraging whales, as well as examine the behavioral cues associated with predation to assess potential biases associated with the prey sampling methodology. In addition, information collected can be used to help estimate the effort required to obtain a sufficient sample size to rigorously characterize the diet of this population, at least during the summer and fall when the whales are in inshore waters. The purpose of this report is to summarize field efforts in August and September 2004 and comment on behavioral cues of predation and some of the implications for prey sampling and behavioral research with this population. Analyses for species identification of prey samples is currently underway, and these results will be reported separately.

Methods

Field activities were based out of Friday Harbor, WA, and were undertaken each day between August 27 and September 2, 2004 using a 6-m rigid-hulled inflatable boat. Three to five crew were onboard the vessel each day, with one designated to drive, one to record data, and one (positioned at the bow) to collect prey parts. All crew were involved in observing behavior and identifying whales. Killer whales were found primarily based on sightings reported by other researchers, commercial whale watching operators, or The Whale Museum Soundwatch Program. Information recorded for each encounter included location, "pods" (groups of individuals which spend >50% of their time together over a period of years; Bigg et al. 1990)

present, the number of boats with whales, and the approximate area covered by the group of whales (an indicator of how spread out the group was). If whales were not approached closely (see below), information on pod identity was provided by other vessels on site (e.g., from the Soundwatch Program or other researchers); for groups that were approached closely we used the catalog of van Ginneken et al. (2004) to identify individuals. No effort was made to determine whether all whales in each pod identified were present in each encounter. Although some recognize only three pods (J, K, L) in the "southern resident" community, we follow Hoelzel (1993) in splitting L-pod into multiple pods, as sub-pods within L-pod have generally spent less than 50% of their time together in recent years. We recognize four pods (J, K, L8, L10); the L35 pod (Hoelzel 1993) no longer travels as a discrete unit.

Whales were not approached closely if they were nearshore (< 500 m) in areas of high human habitation, or if more than a couple whale watching boats were with a whale subgroup and the whales were all in a tight group (e.g., if the whales were in an area of 0.25 km^2 or less). If whales were not close to shore or in a tight group in close proximity to whale watching vessels, collection of samples was undertaken in two different circumstances, during "follows" of one or more focal whales, or opportunistically, if the number of whales present within several hundred meters of the vessel was too great to keep track of individual whales. Given the short duration of this field project, we did not attempt to distribute effort randomly or evenly between different pods or individuals, but chose whales to follow based primarily on distance from commercial or recreational whale watching vessels. During focal follows, information on the whales' speed (slow, medium, fast), directionality (directional/non-directional), spacing between individuals (tight, loose, spread), and orientation (linear, flank, non-linear) were recorded every ten minutes. Identity of individual whales in the focal group were recorded when possible, using the catalog of van Ginneken et al. (2004). The size of the focal group was recorded as it changed, with an operational definition of the "group" being those whales within an approximately 300 m radius around the research boat that could be continuously observed and potentially approached if cues of predation were observed. Laser range finders (Bushnell Yardage Pro 1000) were used to help in determining/estimating distances to whales. The radial distance for including individuals in the "group" decreased with increasing glare or deteriorating sea conditions. Distance between the

boat and whales during observations varied depending on the number of whales being observed and their configuration relative to each other, and ranged from approximately 10 to 300 m.

Several cues were used to trigger close approaches to look for fish parts in the "fluke prints" (glassy areas of water caused by upwelling from the whales' tail as it dives). Cues included fast directional surfacings (FDS) that were out of context (i.e., not part of a series of fast directional surfacings characteristic of fast travel), fast and moderate non-directional surfacings, and (for pairs of whales) a sudden decrease in one whale's speed associated with a long-dive by a second whale in a pair. Non-directional surfacings were defined as surfacings where the whale's trajectory changed part-way through the surfacing. Fast non-directional surfacings (FNDS) involved generation of white water when the whale surfaced, while moderate non-directional surfacings (MNDS) did not, yet were at higher swim speeds than a typical surfacing. Chases involved a prolonged series of FNDSs and prolonged high-speed surface swimming (with part of the body visible). The time of each FDS, FNDS, and MNDS from animals within approximately 300 m of the observation vessel was recorded to the second.

Upon observing one or more FDS, FNDS or MNDS we would note the time, approach the fluke print of the target whale, and record the time of our arrival to the fluke print (to the second). We would also note the presence of other whales nearby and record information on the context (e.g., social interactions with the target whale). Approaches were made in a way to avoid or minimize disturbance to the whale(s) present, by slowing the vessel speed either to a stop in the fluke print (if the whale(s) was still actively milling), or matching the speed of the whale(s) upon arrival at the fluke print. Reactions of whales to follows and close approaches were recorded, and if whales reacted, we increased the distance between the boat and the whale(s) or the close approach was discontinued. Once at the fluke print, we recorded whether fish, fish scales, or fish parts were observed, and if seen, estimated the number of prey parts visible in the water column. When no prey parts were observed in the first fluke print we would proceed to subsequent fluke prints to search for prey parts. During all surfacings when in close proximity to whales (i.e., less than 20 m) one observer on the boat would attempt to watch the mouth-line of the whales as they surfaced to try to assess whether the whales were carrying prey. A long-handled fine-mesh net was used for collecting parts observed in the water, which were stored in ziplock bags in a cooler

while in the field. Prey samples (comprised of one or more prey parts) were later frozen for analyses. To confirm the identity of difficult to identify individuals, we attempted to obtain photographs of the dorsal fin of whales from which prey remains were collected. Photographs were taken with a 35 mm digital camera with a 100-300 mm lens.

Results and Discussion

During the nine days of potential field activities we spent time on the water on seven days. Boat problems on one day prevented field work and all whale pods were reported out of the study area on another day, thus no effort was expended. In the seven days we covered a total of 905 km on the water for a total of approximately 53 hours of effort. Location of search effort is shown in Figure 1. Killer whales were encountered on eight different occasions on four different days. During the remaining three days on the water no whales were seen, and no whales were reported within our operational area. All four "southern resident" pods were involved in one or more of the eight encounters. During three of the eight encounters we did not approach closely, due to the large numbers of boats with whales (between 3 and 26 boats), as well as the tight spatial arrangement of the whales and their proximity to shore (see Table 1). Follows and approaches were typically undertaken in the late afternoon and evening hours, as locating whales early in the morning prior to the arrival of whale watching boats was unproductive, and large numbers of boats were usually with the whales from mid-morning through mid-day.

Whales were followed for the purpose of collecting prey remains during five encounters, for a total of 12.7 hours. Twenty focal follows were undertaken during this period, for a total of 8.04 hours (mean follow duration = 0.40 hours, SD = 0.34 hours). Group size in focal follows ranged from 1 to 5 (mean = 2.35; SD = 1.14). While information on general behavior was recorded during these follows (see Methods), because of the small sample size, we have not included that information here. Events prompting close approaches occurred on 27 different occasions, including 13 FNDSs, 8 MNDSs, 2 FDSs, 2 chases, and 2 cases where a whale decreased speed associated with another whale's long dive. Time intervals between the event occurrence (or start of event if there was a series of FNDSs or a prolonged chase) and our collecting prey remains ranged from 0.45 to 5.12 minutes (mean = 2.23 min, SD = 1.79 min). Prey or prey parts were

observed in 10 of these cases (Table 2), with the number of prey parts (scales or other bits) observed ranging from 1 to over 100 (mean = 27, SD = 37). Prey remains were often seen as deep as 1 m into the water column, though varying water visibility and glare conditions influenced the depth at which prey parts could be observed. Prey samples were collected on all 10 occasions when prey parts were observed (37% of approaches), with the number of prey parts per collection ranging from 1 to 10 (mean = 4.8, SD = 3.8). Prey samples were collected from three of the four "southern resident" pods (K, L10, L8); while J pod was present during one of the encounters during which prey samples were collected, there were no opportunities to collect samples from J pod whales (i.e., no prey parts were observed in association with J pod whales). Four of the prey samples were collected during the 8.04 hours of focal follows, the remaining six samples were collected during the 4.66 hours of opportunistic sampling. Prey samples were collected from three of the FNDSs (23%), 2 of the MNDSs (25%), one of the FDSs (50%), and from both of the chases and both cases where a whale decreased speed associated with another whale's long dive (100% in each case). During nine of the 10 cases when prey parts were observed/collected, one or more whales were in close proximity (within 50 m) of the target whale. During two of these cases the target whale was the object of social interactions by another whale, i.e., another whale was socializing with the whale while it was actively chasing and capturing a fish. In these two cases we observed the second whale swimming inverted beneath and slightly behind the target whale, with frequently body contact, apparently in an attempt to mate with the target whale.

Reactions of whales to follows or close approaches were only observed on two occasions (one during a follow and one during a close approach), and in both cases involved apparent avoidance of the research vessel (i.e., the whale consistently changing direction away from the vessel).

The cues used to suggest an ongoing predation event varied widely in terms of how obvious they were. Of the 10 cases where prey remains were observed (and collected), only two were obvious as fish chases, with repeated high-speed non-directional surfacings and high-speed surface swimming (with the dorsal fin showing), though a third case did involve a series of FNDSs (but with no high-speed surface swimming). This latter case involved three whales, and from a distance such behavior could easily have been misinterpreted as non-foraging social interactions,

rather than social foraging. As noted above, two of the remaining seven cases involved two whales that were obviously engaged in social activities, yet only one whale in the pair was actively foraging, based on observations and collection of prey remains. This suggests that attributing a single behavioral state (e.g., foraging or socializing) to multiple whales, particularly if the observation distance is too great to observe prey in the water, may be inaccurate. As noted above, two of the cases involved a pair of whales where the primary cue suggesting predation was a reduction in swimming speed and slow milling by one of the whales while the second whale was on a long dive. Only after the second whale surfaced several minutes later did we observe and collect fish remains from the fluke prints of this whale. In two other cases the only surface signs of a prey capture event was a single FNDS or MNDS; the prey chase and capture both occurred well beneath the water's surface.

Such observations suggest that indicators of foraging activity may be both subtle and confounded with other behaviors (e.g., socializing). Only three of our 10 confirmed predation events were likely to fit the definition used by Hoelzel (1993) as indicators of feeding. It is likely that a change in sampling methodology to primarily following in the fluke prints of whales would result in an even greater proportion of prey sampling coming from more subtle (sub-surface) predation events. We recommend that such methodology be adopted in future studies, to reduce the potential bias associated with sampling only predation events with an obvious surface component, which may be biased towards surface-oriented prey.

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Table 1. Encounters and effort to sample prey.

Date	Pods present	Start time	Time spent attempting to sample (h)	# prey samples[1]	Comments[2]
29/08/04	J, K, L8	13:31	2.85	0	whales spread
30/08/04	L10	11:55	0	0	11 boats, whales tight
30/08/04	J, K	15:26	2.97	3	whales spread
31/08/04	L8, L10, J	9:25	0	0	3-8 boat, whales tight
31/08/04	J, K, L8	15:19	0	0	26 boats, whales tight, close to shore
31/08/04	L10	16:02	3.00	3	few boats, whales spread
01/09/04	L8	13:24	2.07	1	too rough, close to shore
01/09/04	L10	16:11	1.82	3	
Total			**12.70**	**10**	

[1]A "prey sample" was defined as one or more prey parts (e.g., fish scales or other tissue) collected from a single behavioral event (see Table 2). [2]Whales "spread" if approximate area covered by group was usually > 1 km^2; whales "tight" if approximate area covered by group was usually < 0.25 km^2.

Table 2. Prey sample collections (each line represents one sample).

Date	Cue[1]	Surface or sub-surface capture	# parts collected	Target whale ID, age/sex[2]	Time between cue and collection (minutes)	Comments
30/08/04	FNDS	Surface?	2	K28	0.67	during social behavior
30/08/04	FNDS	Surface	1	K14?	5.12	5-6 FNDSs, fish seen in mouth
30/08/04	MNDS	Surface	5	K28	0.75	during social behavior
31/08/04	FNDS	Sub-surface	2	L41	1.83	samples in foot print after dive
31/08/04	FDS	Sub-surface	10	adult female size	4.40	samples seen after long dive
31/08/04	MNDS	Sub-surface	4	2 adult females	0.45	
01/09/04	Long Dive	Sub-surface	1	L53	n/a	
01/09/04	Chase	Surface	3	L79	3.18	
01/09/04	Chase	Surface	10	adult female size	1.43	fish seen in mouth
01/09/04	Long Dive	Sub-surface	10	L79	n/a	fish seen in mouth
Mean			**4.8**		**2.23**	
SD			**3.79**		**1.79**	

[1]FNDS = fast, non-directional surfacing; MNDS = moderate, non-directional surfacing; FDS = fast, directional surfacing. [3]IDs listed with ? if identification not positive.

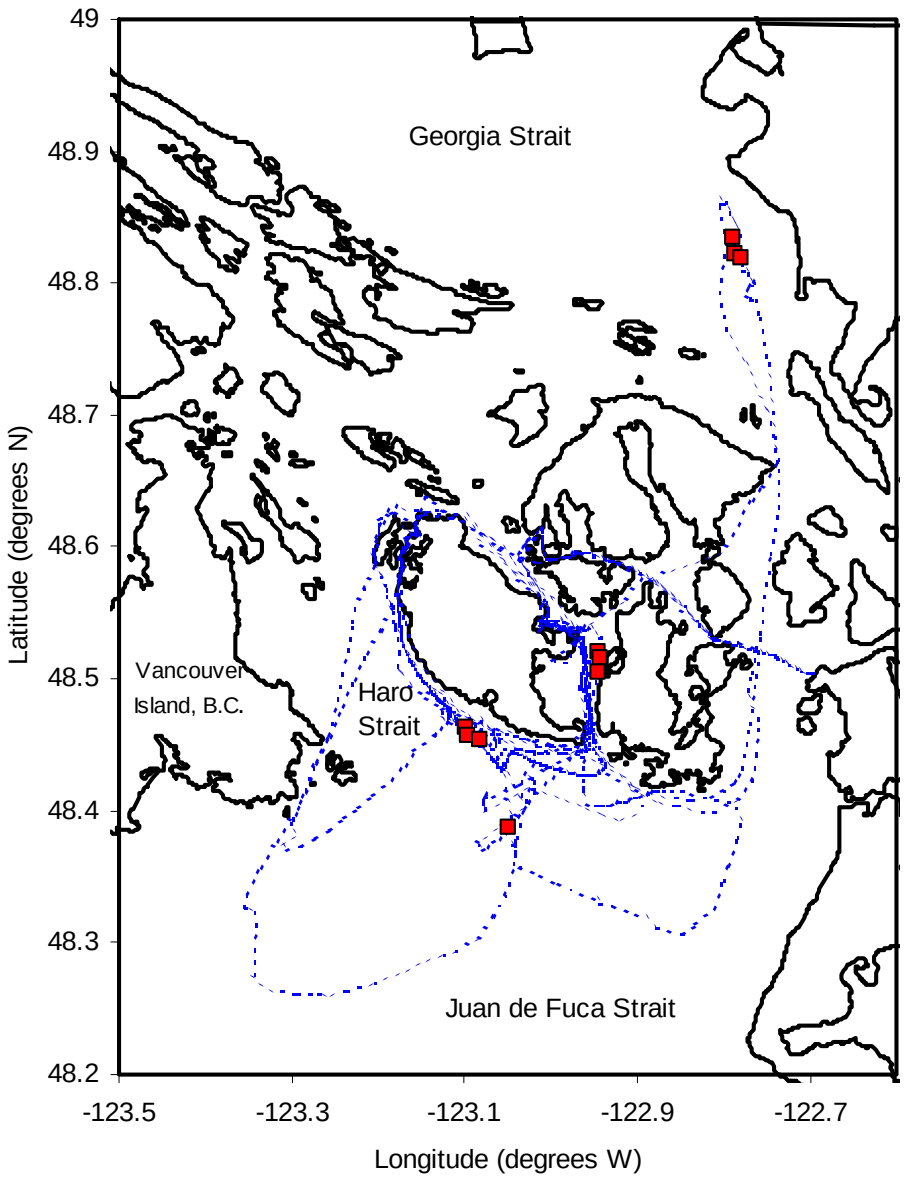

Figure 1. Map showing search effort (------) and prey sampling locations (■). All encounters were in U.S. waters.