

Sequential Habitat Use by Two Resident Killer Whale (*Orcinus orca*) Clans in Resurrection Bay, Alaska, as Determined by Remote Acoustic Monitoring

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Abstract

Killer whales (*Orcinus orca*) are sighted regularly in coastal Alaska during the summer, but little is known about their movements through the area during the winter when weather and light limit the use of boat-based surveys. Acoustic monitoring provides a practical alternative because each extended resident killer whale family group or pod has a unique dialect that can be discerned by differences in their repertoires of stereotyped calls. The repertoires of resident killer whale pods in the northern Gulf of Alaska were updated from earlier studies, and the results used to determine the identity of pods that were recorded on remote hydrophones in Resurrection Bay, Alaska, in the fall, winter, and spring of 1999 to 2004. In total, seven pods of resident killer whales were identified acoustically, comprising four related pods from AB clan and three from AD clan. The frequencies of occurrence of the clans differed between the November to March recording period when AB clan occupied the area, and the April-May period when AD clan was predominant. The sequential use of this habitat during periods of relative prey scarcity has the effect of limiting intergroup resource competition and is consistent with earlier findings that demonstrated divergent resource specialization by sympatric killer whale populations.

Key Words: Killer whales, *Orcinus orca*, acoustic monitoring, behavior, habitat use, distribution, competition

Introduction

Cetaceans are highly mobile animals, and their movements can be difficult to predict. Many species are encountered only rarely and/or in

places or conditions that are not favorable for boat-based surveys. In most areas, more is known about cetacean distributions in summer than during winter (Ford et al., 2000; Scheel et al., 2001). Acoustic monitoring using stationary hydrophones can provide a practical alternative to boat-based surveys for vocally active species. Species studied with fixed hydrophones have included humpback whales (*Megaptera novaeangliae*) (Norris et al., 1999), bowhead whales (*Balaena mysticetus*) (Cummings & Holliday, 1985), blue whales (*Balaenoptera musculus*) (Stafford et al., 1998), and killer whales (*Orcinus orca*) (Morton & Symonds, 2002).

Members of an assemblage of North Pacific populations of fish-eating killer whales referred to as *residents* produce distinctive pulsed calls, whistles, and trains of echolocation clicks (Schevill & Watkins, 1966; Steiner et al., 1979; Ford, 1989) and are vocally active much of the time (Barrett-Lennard et al., 1996). The pulsed calls are characterized by abrupt shifts in pulse rates, which produce discrete call structures that are recognizable over great distances (Schevill & Watkins, 1966; Hoelzel & Osborne, 1986; Ford, 1989; Miller, 2006). Discrete call structures are group specific, making killer whales amenable to group identification through remote acoustic monitoring. Residents are characterized by a nested social structure comprising matriline containing a matriarch and all her descendents, pods containing a set of matriline that associate frequently and use a common repertoire of stereotyped calls or group-specific dialect, clans containing related pods whose dialects include some similar calls, and populations or communities containing one or more associating clan (Ford, 1991, 2002a, 2002b). Despite overlaps in geographic range, all of these groups appear to be closed to immigration.

Dialects can therefore be used to unambiguously identify resident killer whale pods in passive acoustic monitoring studies in Alaska (Yurk et al., 2002).

Members of a second assemblage of North Pacific killer whale populations referred to as *transients* feed almost entirely on marine mammals (Ford et al., 1998). Transients and residents are genetically distinct (Stevens et al., 1989; Hoelzel & Dover, 1990; Barrett-Lennard, 2000) and differ greatly in behavior (e.g., Morton, 1990) and social organization (Baird & Whitehead, 2000). Transient killer whales can be distinguished from residents by their use of distinctively different call types (Deecke et al., 2005; Saulitis et al., 2005; Matkin et al., 2007). Regional transient communities can be distinguished by call type variants (Deecke, 2003); however, further acoustic subdivisions within populations analogous to clan- and pod-specific dialects in residents have not been identified. Transient killer whales use both calls and echolocation clicks much less often and less consistently than residents, making acoustic detection less reliable (Barrett-Lennard et al., 1996; Deecke et al., 2005; Matkin et al., 2007).

A third assemblage of killer whales referred to as *offshores* travels in larger groups and is also highly vocal and characterized by distinct calls (Ford, 2004). However, identification of call repertoires of this population is still incomplete (J. K. B. Ford, pers. comm., 2009). Although offshores occasionally enter the study area (Matkin et al., 1999), calls identified during this study could be unequivocally identified as either transient or resident calls. While it is possible that quiet offshore killer whales were missed, this is unlikely given the typical vocal behavior of these whales when encountered elsewhere.

Resident pods and two populations of transient killer whales, the AT1 and Gulf of Alaska (GOA) transients, are sighted regularly in Prince William Sound, Kenai Fjords, and in the adjacent Gulf of Alaska during the summer and have been the subjects of focused research since the mid-1980s (Matkin et al., 1999, 2008). Far less is known about the use of the above areas, including our study area, in the winter. Low daylight levels, short days, and difficult weather conditions limit the use of extensive boat-based winter surveys.

The value of acoustic monitoring in detecting killer whales was identified as early as the 1970s when the first systematic surveys of this species began. Several acoustic monitoring stations were established at remote locations, including light-houses along the British Columbia (BC) coast (Bigg et al., 1987), research out-stations such as Orcalab on Hanson Island, BC (Deecke et al., 2000; Weiß et al., 2007), field research sites in the

Crozet Islands (Guinet, 1991) and in the Pribilof Islands (Newman & Springer, 2008), and in wilderness parks such as the Glacier Bay National Park in Southeast Alaska (see list of projects in Yurk et al., 2001).

Herein, findings are presented from a 5-y remote acoustic monitoring study in Resurrection Bay, Alaska, which focused on the identification of specific resident pods based on previously determined dialects (Yurk et al., 2002; Yurk, 2005). These findings shed new light on seasonal habitat use of specific resident and transient killer whales in the study area. The most novel finding, however, was that Resurrection Bay appears to be sequentially dominated by different clans of resident killer whales in the fall, winter, and spring of each year. The study also confirmed the feasibility, efficiency, and efficacy of remote acoustic identification and monitoring of groups of killer whales initially identified in boat-based studies.

Materials and Methods

Study Area and System Design

Resurrection Bay, on the southern end of Alaska's Kenai Peninsula, is a glacial fjord that opens into the Gulf of Alaska. It is divided by a narrowing at Caines Head into a protected inner bay with the town of Seward at its north end and an outer bay that gradually widens and opens to the Gulf of Alaska (Figure 1). Caines Head and the outer islands shelter the inner bay from the storms that regularly occur during a Gulf of Alaska winter.

In summer 1998, a remote hydrophone connected via a rugged steel-shielded cable to a radio transmitter (Cetacean Research Laboratory, Vancouver Aquarium Marine Science Centre, British Columbia, Canada) was installed off the south point of Halibut Cove, Fox Island (in Resurrection Bay; Figure 1, point 1). The transmitted FM signal carrying the whales' vocalizations could be monitored by research and other boats traveling in the area. Ambient and vessel noise were often a problem during the summer months because of heavy traffic by tourist and fishing vessels. In the fall and winter months, vessel noise became a less challenging issue, while noise generated by ocean swells and surf on cobble beaches in the outer bay became a serious impediment to acoustic monitoring (Figure 1). These conditions rendered the hydrophone ineffective for much of the winter season in this location, and it was moved to Thumb Point at the entrance to the inner bay in May 1999 (Figure 1, point 2).

This new location was protected from the noise of waves onto cobble beaches but still allowed a large portion of the outer bay to be monitored. This location provided all the acoustic data used in our

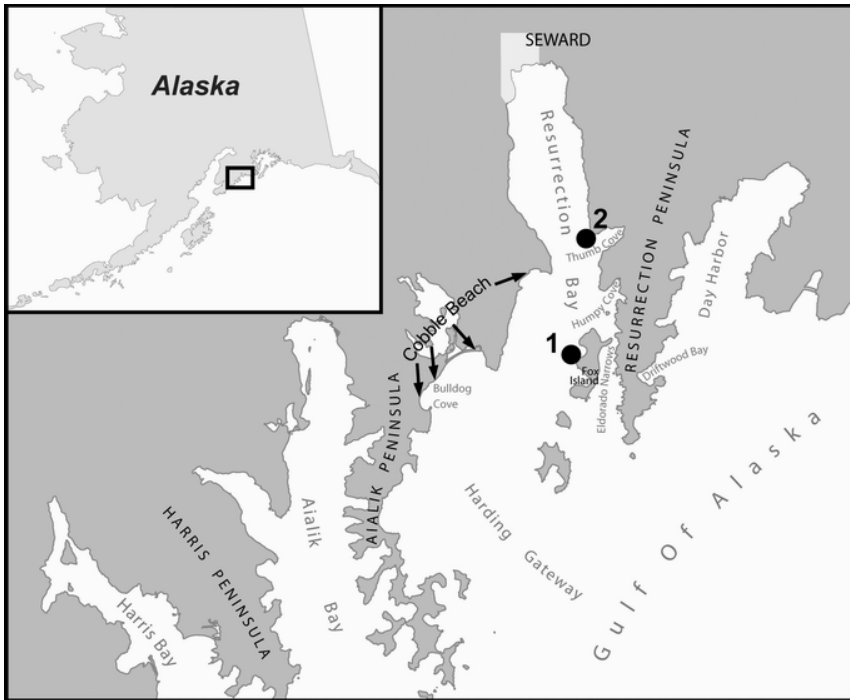


Figure 1. Study area and hydrophone locations (point 1: Fox Island; point 2: Thumb Point)

analysis. Sounds were recorded with an Offshore Acoustics omnidirectional hydrophone connected via cable to a microwave transmitter system (SeeMore Wildlife Systems, Homer, Alaska, USA) that transmitted signals to a receiver/recorder at the Alaska SeaLife Center in Seward.

The sensitivity of the hydrophone was $-154 \text{ dBV}/\mu\text{Pa} \pm 4 \text{ dB}$ at 100 Hz and the frequency response curve showed the following range: 5 Hz to 40 kHz, and was relatively flat up to 14 kHz (Offshore Acoustics). The hydrophone was weighted to the bottom with 80 kg of rocks in mesh netting attached to the cable 1.5 m from the hydrophone. A solid foam fishing-float was attached to the cable directly below the hydrophone to float it off the bottom. The rubberized, 1.9-cm-thick three-conductor cable followed the bottom and came to the surface, exiting the water in a protected area. We added a sheath of high-pressure hydraulic tubing with walls 9.5-mm thick over the wire in the intertidal area to protect the cable from chafing against rocks. The hydrophone was anchored in water 25 m deep.

The transmitter station at Thumb Point was situated on top of a large boulder approximately 5 m above maximum high water. This transmitter station included a microwave transmitter and antenna, three 80-W solar panels, one 100-W wind generator, and four 55 amp/h deep cycle batteries.

It also included a UHF-transceiver that allowed for remote power monitoring and on/off control of the system in the event of low power. Audio from the microphone was fed into an amplifier and then into a 2.4 GHz microwave transmitter. The transmitter had a reported frequency range of 150 Hz to 15 kHz, but the upper-frequency response of the cassette tape recorder used to record calls was limited to 8 kHz ($\pm 3 \text{ dB}$). A microwave signal was transmitted 6 nmi over water to a receiver at the Alaska SeaLife Center in Seward. The audio output of a microwave receiver was monitored opportunistically by an experienced technician (Michael Brittain), and a log was kept of beginning and ending times. During days when the hydrophone was monitored, the technician listened for an average of 6 h (SD 1.2 h). When calls were heard, the cassette tape recorder was manually activated and calls were recorded (mean: 37 min/recording day; SD 19 min). More details on data collection effort are presented in Figure 3.

Call Analysis and Identification of Pods

Experienced observers are used for acoustic identification, which was made aurally and by comparing spectrograms. This method has demonstrated high reliability when distinguishing between calls of transient and resident killer whales, calls from different resident clans and

different resident pods, and for the identification of geographical differences in calls from different transient populations (Ford & Fisher, 1983; Ford, 1991; Deecke et al., 1999; Miller & Bain, 2000; Yurk et al., 2002; Saulitis et al., 2005) and is used in comparisons with other classification methods (Deecke & Janik, 2006). In particular, residents of the same matriline use specific call types as vocal signatures (dialects) to identify their matriline and pod (Ford, 1991; Deecke et al., 2000; Miller & Bain, 2000). Previous studies have provided catalogues of sound samples and spectrograms of group-specific calls and repertoires for each of the resident pods identified in this study, the AT1 transient group, and for some of the Gulf of Alaska transient groups (Yurk et al., 2002; Saulitis et al., 2005). These were updated using previously unpublished data, and sonograms of specific call variants that were essential in our analysis are shown in Figure 2.

Initially, recorded calls made by members of the resident and transient assemblages were separated. Resident calls were further subdivided by clan (AB or AD) following Yurk et al. (2002). Highly distinct dialects (Figure 2) made it possible to identify the clan even when the recording quality (signal-to-noise ratio) was poor.

AD clan calls were further divided by pod; AK, AD5, and AD16 pods are each distinguished by unique variants of AKS01 and AKS09 call types (Figure 2). A fourth AD clan pod, AE, produces distinctive AKS02 call types, but this pod was never identified in our recordings and has never been observed outside Prince William Sound during summer photographic surveys (Matkin et al., 1999).

The seven AB clan pods that were identified use a wider variety of call types but also share a greater number of similar sounding calls. So, for AB clan calls, the type and frequency of call types produced in an encounter was examined, and the pattern of occurrence of specific types was compared with the pattern of occurrence within the established repertoires of calls of AB clan pods. Although many AB clan pods use closely related call variants, it was possible to determine pod identities based on the unique patterns of use of specific call types. Unique call variants or calls occur more frequently in encounters that have more than one pod present (Yurk et al., 2002; Yurk, 2005). This is because some pods share many call types (e.g., AB, AJ, and AN pods). However, AB pod frequently uses the AKS14 call type, while this type is rarely found in AJ and AN pod recordings. Also, spectrographically, AKS14s produced by AJ and AN pods differ from those produced by AB pod. Other typical AB pod calls include a uniquely shaped AKS18 call type with deep

frequency modulations, a clearly distinct AKS11 call variant, and an AKS12 call type that has not been found in the repertoires of the other two pods (Figure 2).

Unique call types that distinguish AJ pod include AKS23 and AKS39. AJ pod also uses a distinct variant of AKS11 (Figure 2), also used for identification in this study. The AKS21 call along with specific variants of the AKS17, AKS18, and AKS22 call types were used to distinguish AN pod. AG pod can be distinguished from other AB clan pods by its use of the distinct AKS27 call type, and AF pod was distinguished by the use of the AKS16 call type, which has a unique upper-frequency component (Figure 2). The AI pod call dialect is very similar to that of AB pod; thus, calls cannot be easily assigned to either pod. However, AI pod does not use the AKS14 call type (Yurk et al., 2002), which is recorded during almost every encounter with AB pod in summer surveys and which occurred regularly in the remote recordings of this study.

If the recording quality was poor (i.e., the recording had a low signal-to-noise ratio, which was decided based on audible ambient noise in the recording and few visible sidebands in spectrograms of pulsed sounds), a particular pod was considered present only if at least two call types were recorded that distinguished the pod, or at least three calls of one distinct type in the same recording day but during different recording sessions. For example, during a 6-h period on the same day, three recordings were made, and in all three, a specific call type/variant was detected. In cases when less evidence was available, the presence of the pod was listed as "probable." If the recording quality was good, the presence of one distinct call or variant was generally sufficient to identify the pod.

Data Analysis

Using the approach described above, the presence of identified pods was confirmed during each recording session. A recording session usually contained one recording but could consist of more if these recordings occurred successively and were not separated by time intervals of more than one hour in the recording logbook. Presence of identified pods was determined during the recording sessions of each 24-h d for which there were recording sessions available. Actual residence time for pods was not estimated as killer whales are often silent when resting or traveling. The number of daily occurrences for each pod was calculated for each month across all years of acoustic monitoring in the context of monthly effort (hours of monitoring time).

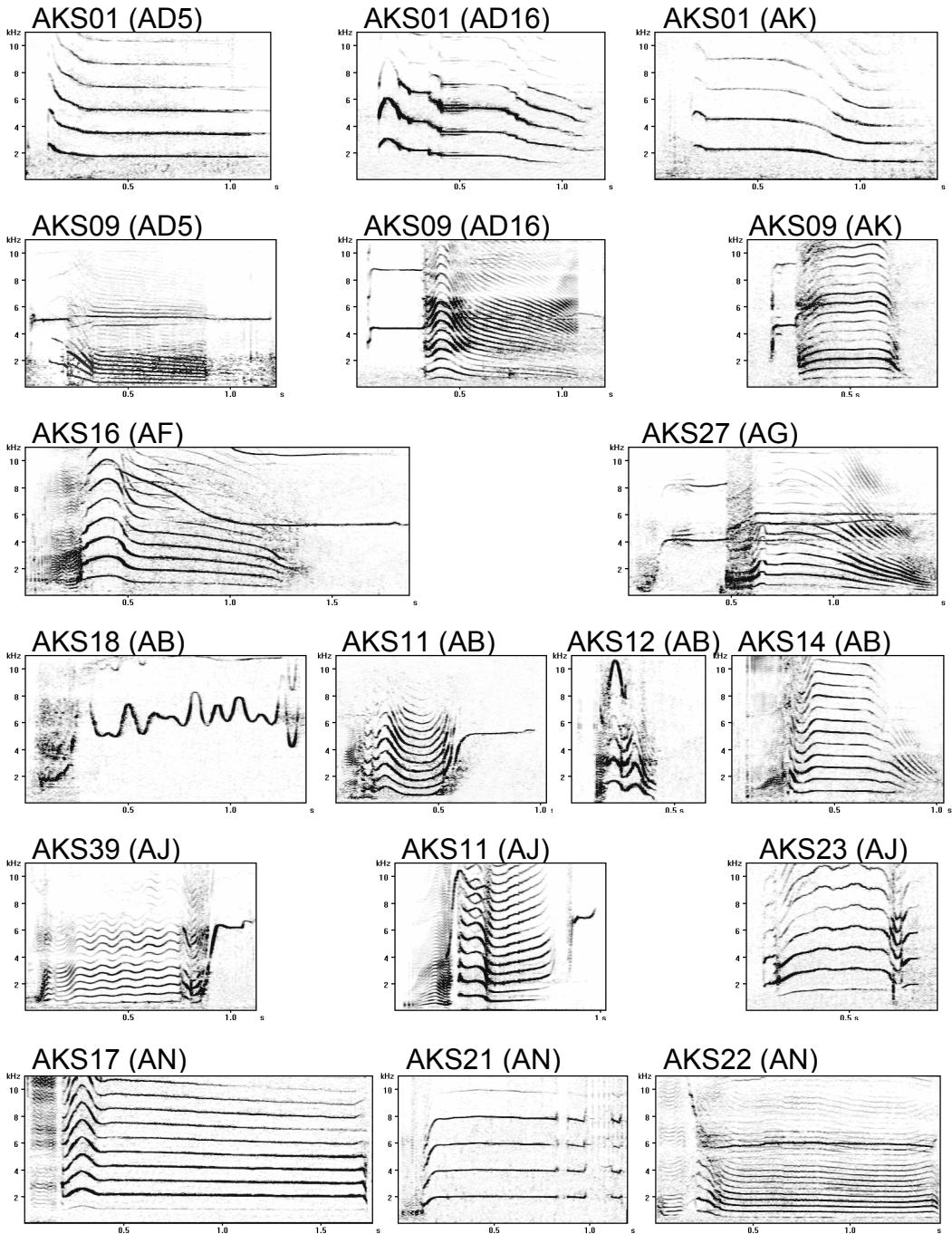


Figure 2. Updated sonograms of unique calls of resident killer whale clans and pods recorded in the study; clans do not share call types which allows distinction between AD5, AD16, and AK pods of AD clan from AB, AF, AG, AJ, and AN pods of AB clan (see Yurk et al., 2002, for details on repertoires).

