Diurnal Acoustic Activity of Southern Resident Killer Whales in the Salish Sea

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Intro

The southern resident killer whales that inhabit the Salish Sea during the summer months are currently being considered for classification as a threatened species under the Endangered Species Act due to a general decline population over the last decade (NMFS 2005). The proximity of their habitat to several major cities on the west coast of the US and Canada makes them vulnerable to a host of hazards. Major risk factors include: the decline of salmon, particularly Chinook salmon, their primary food source during the summer months; toxicity through polluted food sources; and the acoustic and physical constraints of increased boat traffic in the waters where they live (NMFS 2005). Their precarious situation necessitates a better understanding of how they use their environment.

The two populations of resident orcas of the northwest Pacific coast are the most studied groups of the species worldwide, yet there is still much left unknown about them. Their daytime activities and travel during the summer months have received much attention by researchers and the public in recent years but (Osbourne and Otis data, Orcanetwork), however we know very little about where they go and what they eat during their winter months away from the San Juan Islands and also very little about how much activity, both physical and acoustic, takes place at night. Impending management issues warrant a comprehensive study of nocturnal range and activity to provide a complete picture of diurnal habitat usage in their summering waters.

While nocturnal vocal activity has been observed in both Southern and Northern resident killer whale populations (Bain, Balcomb, pers. comm.), no study has thoroughly investigated diurnal patterns in vocal activity for southern residents. A recent study on Pacific bottlenose dolphins off the coast of California showed more feeding (1.7 times) and social behavior (1.8 times), and less travel at night compared to day (Day and Defran 1995). Studies of black bears (*Ursus americanus*) and brown bears (*Ursus arctos*) in British Columbia showed a seasonal shift to nocturnal foraging during peak salmon runs. Increased capture efficiencies during darkness were discovered in both studies (Reimchen 1998, Klinka and Reimchen 2002, respectively). Considering the high level of boat noise surrounding the Southern Residents during the day, I believe they may experience increased foraging success during the quieter night hours due to the decrease of active space caused by boat noise (Bain 2002). My desire to explore diurnal foraging patterns inspired me to first address some basic questions about nighttime orca activity. How often do killer whales vocalize at night? Is there a pattern in how often acoustic behavior is detected throughout a 24-hour period? Can association with acoustic activity reliably describe physical activity? For example, how much quieter are orcas during resting behavior than during other behaviors? I expect to find that the southern residents undergo periods of high and low activity at night that are similar to those observed during the day, but with more time spent at low activity levels.

Gathering observations at night proved difficult in the complex waters around the San Juan Archipelago, but I did manage to observe the orcas at many hours of the day. Over a four-week period (26 September through 22 October, 2005) aboard a 42 foot sailing catamaran in the Salish Sea, I recorded underwater sounds near the orcas as early as 9:30 a.m. and as late as 10:00 p.m., several hours after dark. Recordings were made as early as 8:00 a.m. and as late as 1:00a.m., but without audible vocalizations or strong evidence that the orcas were nearby.

Methods

My research consisted of two distinct parts. First, I observed the amount of daytime surface activity and vocal activity at different times of day throughout the four-week study period and during a twelve hour period on October 21. Second, I studied the above and below water acoustic behavior of several small groups of L and J pods at night on three separate occasions taking place on October 11, 21, and 22, 2005.

Acoustic Recordings

I studied SRKW vocal activity using a single stationary hydrophone, a single towed hydrophone, and a two-hydrophone stationary localizing array deployed periodically throughout the four-week study period. My classmates and I detected underwater sound using ITC hydrophone units with built-in pre-amps and a detection range of 80Hz to 22kHz running into a high impedance instrumentation amplifier with stereo input capability and fixed gain settings of 1x and 10x for each channel. We collected recordings to analyze using a Marantz recorder with a digitizing rate of 44100, yielding a highest detection frequency of 22050, according to the Nygist sampling theorem. We synchronized the Marantz recorder's time to our GPS unit and used a preset function to continuously collect one minute WAV files stamped with the start time of each file and written to a 516MB flash card. We downloaded the flash card to one of three Macintosh computers (Scott's iBook and either Brett or Wilfredo's PowerMac) between observations or when the card became full. All files were backed up on CDs and an external hard drive. We found that PC computers did not always preserve the GPS time stamp from the Marantz recording once the sound files were transferred to CDs and so avoided downloading to them whenever possible. Careful records of start times and observation numbers were also included in many data sheets to allow corroboration of actual start times. Gain settings were adjusted at the start of recording to allow for maximum gain without overloading the recorder and noted. We also adjusted gain settings as needed during recording due to the changing nature of background boat noise. The majority of the recordings I analyzed came from the single stationary hydrophone, which I deployed off the port stern of the boat by dropping the hydrophone and approximately 20 to 40 feet of cable into the water with the boat's engines off. This allowed us to avoid flow noise caused by water moving over the hydrophone and also the length of cable lowered reduced most surface noise. Occasionally we lowered up to 140 feet of cable attached to an eight-pound weight to potentially increase the quality of sound and range of detection of our system. On average, I found that we could clearly hear the orcas calling beyond our visual range of around three nautical miles with loud boat intereference. In one observation may have been able to hear them as much as nine nautical miles away. During intense boat noise our effective range became very small, certainly less than one nautical mile and probably much smaller than that.

The two-hydrophone localizing array nicknamed the "ears" existed in two forms during the study period. The first consisted of two ITC hydrophones attached to either end of a 1.2 meter pole and lowered into the water on the port side of the boat so that the pole lay parallel to the surface of the water and the side of the boat. A variety of rope attachments kept the setup relatively stable in the water and reduced noise created by cables slapping the side of the boat. The second incarnation of the "ears" used the same two ITC hydrophones now separated from each other and suspended by rope with a five pound weight from either the bow or stern of the port side of the boat 10.5 meters apart. The weight held each hydrophone relatively vertical in the water.

Our single towed hydrophone, or "toad," remained largely experimental during much of the study period. I became interested in designing and testing the towed configuration to allow continuous recording during night follows. The setup involved one ITC hydrophone with a 50 meter cable attached to an eight pound weight using about two feet of bungee line tied to the hydrophone cable 20 feet from the hydrophone itself. We secured the weight to the boat using 140 feet of rope, allowing the hydrophone to be trailed 160 feet behind the boat. Tests conducted with the toad deployed off the port stern and the starboard engine running showed that although we could detect orca calls with one engine idling, our engine noise had a masking effect on whale sounds when the engine reach over 1700 RPM, well below that required to maintain a speed similar to the whales. On October 21 we tested the towed system for the first time while sailing near the whales, and with encouraging results. The boat averaged five knots during the observation and I noticed a recognizable increase in background noise compared to the same setup when stationary. Still, the sound recordings made during the "whale sail" event contained very clear calls and the background level that I associate with flow noise maintained at a low enough frequency that it did not appear to have as great a masking affect on calls nearby as the engine noise. During our idling engine tests we were still able to hear whales that were 2.5 to 3 nautical miles away, but the calls quickly became masked as RPMs increased and were again audible when the engines returned to idle.

Attenuation of sound in water and the masking effects of background noise, either ship or flow related, is an important issue to address when describing when the whales were vocal. In a simplified system with very deep water assuming the most conservative model of sound attenuation, I would expect to be able to hear a 164dB orca call above an 80dB background at 15 miles. When the background is raised to 90dB, the range of the call decreases to 7miles. Of course, a number of less simplified conditions prevail in the waters we traveled, including complex bathymetry,

Night Observation

I planned to follow the same group of whales continuously for several days to give the best depiction of day/night patterns. We conducted one practice follow into the late evening on October 11 on the west side of San Juan Island and attempted two night follows on October 21 and 22 in the Strait of Juan de Fuca from Hein Bank to Race Rocks and Hein Bank to Point Wilson, respectively. We were unable to stay with the whales on either night follow attempt, however we did manage to extend our underwater observations by about four hours.

The criteria for beginning a good night follow include good visibility, nearly-full moonlight, mild weather with light to no wind, smooth enough water texture to see dangerous debris, and consistent contact with a group of whales before sunset. Once the night became too dark to visually track the orcas, we positioned spotters on the two bows of the boat to watch for debris in the water while moving and to listen for blows when stopped. Because light winds required us to use our engine, we stopped frequently to listen for blows get a compass bearing to the whales using a hand bearing compass and flashlight. (Under stronger wind conditions, the noise of whitecaps and wind in the rig may also require stopping to listen…) We then proceeded forward along that bearing for ten to twenty minutes before again stopping to listen.

Our position at each stop was determined by a hand-held Garmin GPS unit and plotted on a nautical chart along with the magnetic bearing to the blows. To allow us to keep moving, we lowered the single hydrophone setup approximately twenty (feet?) into the water every second or third stop and made short three to five minute recordings. While recording, the bow spotters relayed their observations of the bearing to blows, the synchronicity of blows, the perceived spread of individuals, and the number of percussive behaviors heard to me in the cockpit. This procedure was followed until blows could no longer be heard and no vocalizations were audible through the hydrophone.

Once contact was lost, we proceeded on the expected path of the whales based on the general direction of travel discerned from our plotting efforts, a process known in marine navigation as dead reckoning, and stopped once more to listen for blows and calls underwater. In previous tests we were able to hear calls up to nine nautical miles away, representing our outer range for acoustic detection, however possible masking due to large ship traffic in some areas likely decreased our effective listening no range.

Surface Observation

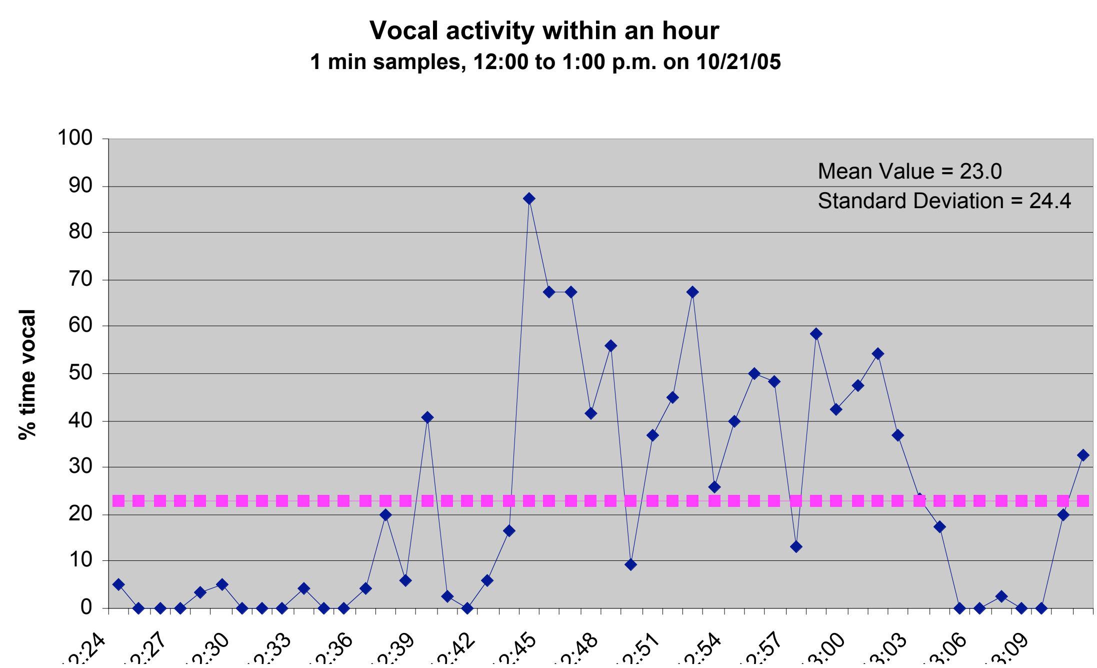
I attempted to use several parameters to describe the overall activity level of each group of animals we observed. I expected these activity categories, laid out in Deecke et al. (2005) for describing transient orcas, to allow for easy quantification while also giving some basic clues to the pod's general activity level (i.e., resting, foraging, socializing, traveling). The parameters I looked for included spread of individuals, number of percussive behaviors (i.e., breaches, tail lobs, and pectoral fin slaps), directionality, and breath synchrony between individuals. However, upon testing I found that the large groups of southern residents we often encountered made these classifications difficult to assess because at most times there were some members doing most of these activities within the same short time period. The best categories that I found descriptive of general activity include traveling, surface active, milling, and resting. Surface active is defined as including periods of tactile behavior, percussive behavior, and little overall direction of movement of the pod. During this behavior pods appeared to be from moderately spread out with sub groups that were closely associated but generally taking non-synchronous breaths. Traveling constituted a high level of directionality, speeds of six knots or greater, whales moderately to highly spread, but with smaller groups of three to eight individuals in close groups and breathing synchronously. Most often many percussive behaviors were also observed at these times. I considered a group to be milling when there was little to no directionality in overall movement; individuals were highly dispersed and non-synchronous. Resting took place when most members of a group were closely associated, breathing in synchrony, and traveling at three to five knots.

Data Analysis

I analyzed sound files using Audacity 1.2.3, a free audio editing program provided by SoundForge.net. I listened to the recordings and measured the amount of time when vocalizations took place rounded to the nearest second. The spectrogram view helped me to accurately mark the start and end of calls and quiet periods (against the time of the recording?). The total time of an observation began at the first call on the recording and lasted through the last call. This method corrected for the likelihood that the whales might have been out of acoustic range at the beginning or end of an observation. The start time, duration when vocal, and total time was then entered into an Excel spreadsheet along with the date and observation number when the recording took place and the recording file number. To handle the large numbers of files complied on October 21, I sampled every fifth sound file in each observation or more to ensure that at least two files were sampled from each hour of the day. I calculated the average for each hour and the mean and standard deviation over the twelve hour period and a several one hour periods using an embedded function in my excel spread sheet.

Results

We successfully observed members of the southern resident community into the evening on three separate occasions. On October 21 we successfully followed members of L pod for 13 hours and made acoustic recordings of their underwater sounds in each of twelve hours. I looked at the percent of time they spent vocally active during each minute of our



recordings for our longest observation, 48 minutes between 12:24 and 13:11 (Fig.1).

Figure 1. Vocal activity within an hour of recording starting 12:24 and ending 13:11 on October 21, 2005Recordings were made using the single towed hydrophone system while sailing at about 5 knots. The blue indicates the percent of time in each minute recording that contained vocal activity. The pink indicates the mean percent vocal (23%) over the hour. Notice the range of values from several minutes without any detectable vocalization to 87.5% vocalization at 12:44. The standard deviation (24.4%) reflects this high variability.

This observation gives a good example of the extremes and variability I observed within a short period of time. This particular hour contains some of the most vocally active minutes observed throughout the day (highest value 87.5 percent vocal) and also contains periods of relative silence that show the short-term variability in vocal activity. The hour-long average, 23 percent vocal, is the second highest hourly average for the day and the standard deviation of 24.4 reflects the wide range of values found. I made recordings during this time period using the single towed hydrophone while sailing with the general movement of the whales at about 5 knots speed. It is interesting to note that most of the quiet minutes occur during the beginning and end of the observation when whales were closest to the boat.

I randomly sampled one in every five sound files made throughout the rest of this day and computed hourly averages to look for the pattern of activity throughout the entire day (Fig. 2). Our observations began around 9 a.m. and continued until 9 p.m. before we lost positive contact with the whales.

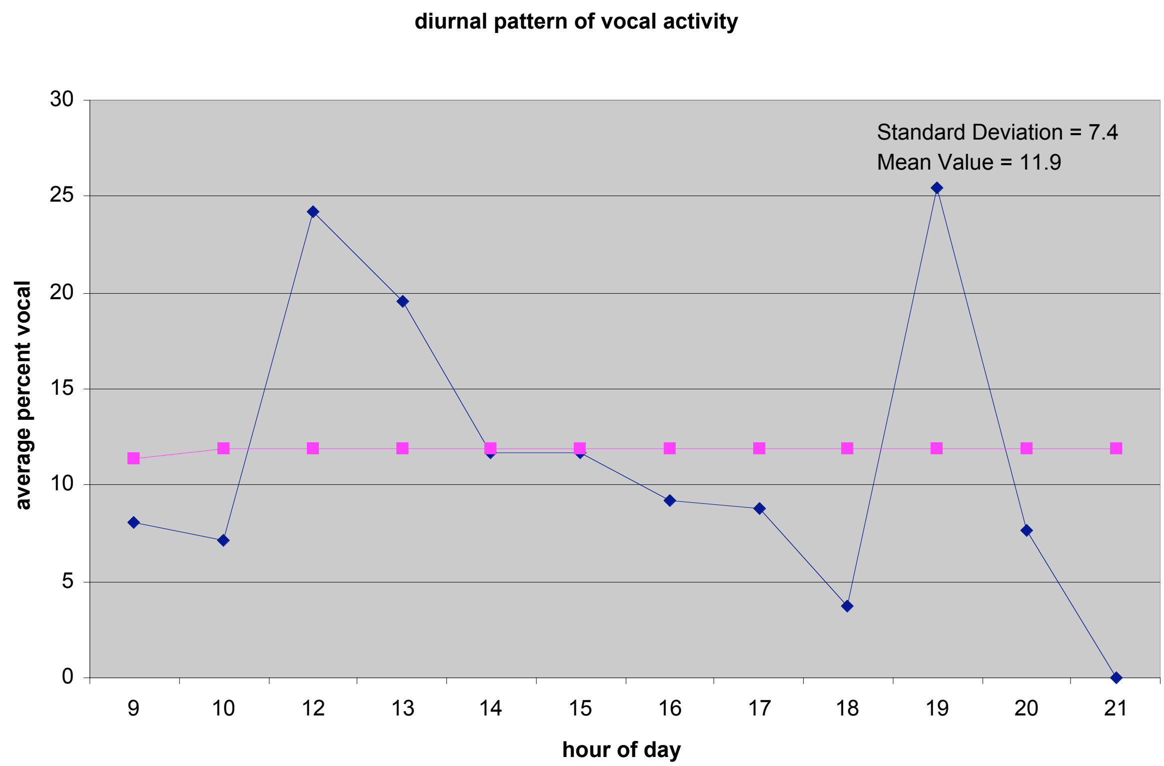


Figure 2. Diurnal pattern in acoustic activity during our day long follow of members of L pod on October 21, 2005. The blue line tracks the trend throughout the day with the dots indicating the average percentage of time spent vocal in each hour. The pink line show the mean value for the entire day. There are two distinct peaks in vocal activity, one around noon and the other just after dark. There are vocalizations recorded in every hour of the day except the last observation. The standard deviation reflects a fairly low level of variability throughout the day.

The latest hour in which we have recordings from each night observation is between 6 p.m. and 7 p.m. .I analyzed each minute sound file recorded during this time period for each night and found the average vocal activity level (Fig.3), to provide comparison of differences in activity patterns that may occur from day to day.

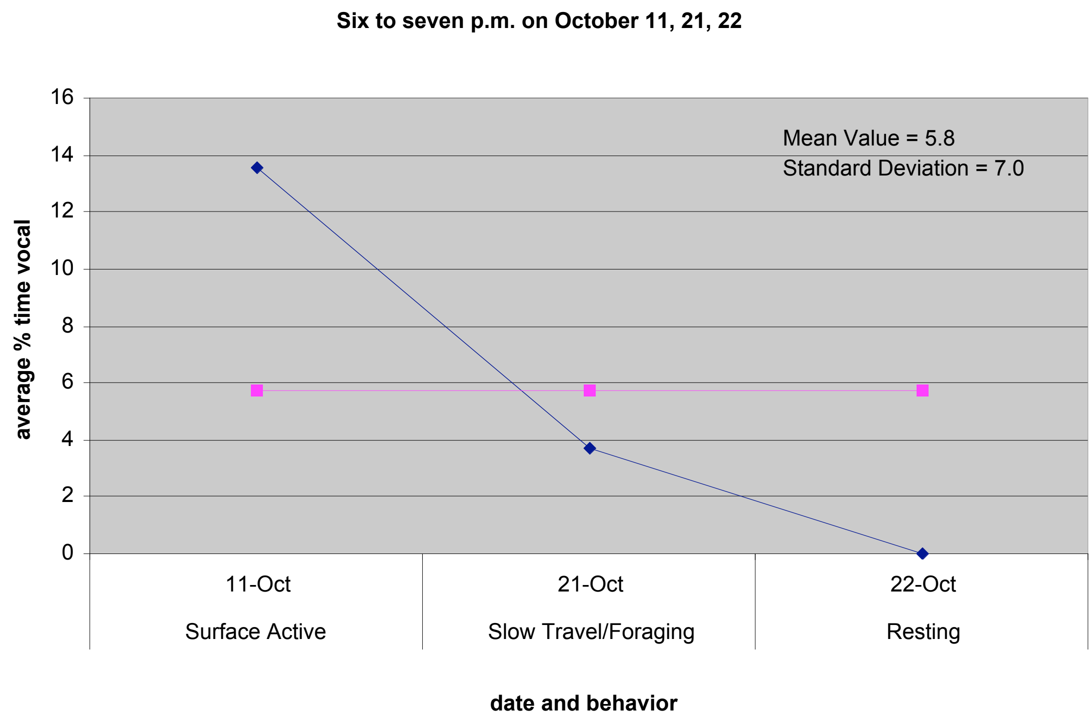


Figure 3. Comparison of the six to seven p.m. hour on three different nights. Each blue dot indicates the average percent of vocal activity that took place during that hour. The pink line shows the mean value for the three nights. Note the extreme differences between the first and last night. I identified a different behavior state during each of the three observations, listed below the date of the observation.

There is a wide range in vocal activity between the three nights with the first night being the most vocally active at 13.5 percent of the time containing vocalizations. There were no vocalizations recorded on the last night, even though the whales were well within range and there was minimal background noise. I observed a different behavior state at each of the three observations, which likely explains the differences in vocal activity.

Discussion

The difficulty of following the whales throughout the night proved to be a formidable challenge during the period of my study. I was unable to describe the Southern Resident's acoustic pattern over a full 24-hour period, however I was able to collect data over twelve consecutive hours on one occasion and briefly examine the great variation in activity that took place. Many more follows at the same time and with the same pod of whales would be necessary before any real pattern could be convincing. I did not make observations of the whales late enough into the evening or often enough to get a fully descriptive interpretation of how active they are at night. The three nights of data that I did collect and analyze suggest to me the orcas' acoustic activity depended much more on what behavior they were doing and less on the hour of the day. This, along with two particularly interesting and distinct observations of L pod traveling and J pod resting, supported my hypothesis that vocal activity levels and physical activity levels are related.

More study is needed to observe the same group of animals during many different activity states to confirm this theory more conclusively.

The large range of variability within the middle section of observation 4 on October 11(Fig. 1) is representative of the short term variability in vocalization that we witnessed during most encounters. The concentration of quiet minutes at the beginning and end of the observation are likely to be due largely to proximity of the whales to the hydrophone. As whales get closer to the hydrophone I would expect to hear more calls, not because they are calling more, but because more of their calls are audible above the background noise level. Most often the whales are passing by us during observations, entering and exiting our detection range as they pass. In situations where there is more background noise, such as flow noise during towed hydrophone use or a nearby tanker passing, we may not hear vocalizations at all until they are very close by, giving the impression of quick "bursts" of vocal activity followed by quiet periods. To address this issue, I counted the total time for an observation starting at the first call and ending after the last call. This decreases the likelihood that quiet periods are due to the whales moving in and out of range.

In the future, a comprehensive study to follow the same group of whales over several days and on several occasions throughout a season and year is the approach that I see getting a good correlation between vocal activity levels and behavior. Including night observations in this study would also allow for characterizing an overall pattern to the activity levels of the Southern Residents, especially at night.

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References

Barrett-Lennard, L.G., J.K.B. Ford, and K.A. Heise. 1996. The mixed blessing of echolocation: differences in sonar use by fish-eating and mammal-eating killer whales. *Animal Behaviour*, 51, 553-565.

Bain, D.E. 1986. Acoustic behavior of Orcinus: Sequences, periodicity, behavior

Deeke, V.B., J.K.B. Ford, and P.J.B. Slater. 2005. The vocal behaviour of mammal-eating killer whales: communicating with costly calls. *Animal Behaviour*, 69, 395-405.