

THE ECHOLOCATION OF FREE-RANGING KAMCHATKAN KILLER WHALES IN DIFFERENT CONTEXTS

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1 INTRODUCTION

Odontocete echolocation has been actively studied in captivity, but there are few studies in the wild. Before 1980, dolphin echolocation was studied in captivity where the conditions are easier to make a controlled experiment and to interpret the results. But studies in the wild are important to observe how dolphins use echolocation under natural conditions. Among the few studies of killer whale echolocation in the wild, it has been shown that killer whales can detect a school of fish at a distance of about 100m (Au[1]). Barrett-Lennard[2] showed that two killer whale ecotypes – fish-eating (resident) and mammal-eating (transient) – differed in certain characteristics of their echolocation trains. Barrett-Lennard[2] also studied some parameters of the echolocation trains of resident killer whales, but they did not separate them into different types of activity. The purpose of our study was to document, measure, and analyze the echolocation parameters of free-ranging resident killer whales, *Orcinus orca*, from Kamchatka, Far East Russia, during different types of activity.

2 METHODS

For this study, we used data collected during the 2005 field season in Avacha Gulf, Kamchatka as part of our overall research into killer whale biology and behaviour. Sounds were recorded from an inflatable boat with a Sony DAT TCD-D100 recorder. Recordings were made with a sampling frequency of 48 kHz. For omnidirectional recording, we used an Offshore Acoustics hydrophone with a bandwidth of 10 Hz to 40 kHz and a sensitivity of $-154 \text{ dB} \pm 4 \text{ dB re } 1 \text{ V}/\mu\text{Pa}$ at 100 Hz. The hydrophone was lowered to a depth of 5-10 m depending on the wave height. For localizing the source of underwater sounds we used a mobile hydrophone stereo system (Filatova[3]). Spectrographic analysis was conducted using Avisoft-SAS Lab Pro and Cool Edit Pro 1.2.

During the recording periods, we noted the number of animals, their distance between each other, and the type of activity, which was defined by observing their surface behaviour. We grouped the activities of killer whales into the following categories: foraging, traveling, resting, and socializing. For foraging, we noted the prey type (Atka mackerel *Pleurogrammus monopterygius* or salmon *Oncorhynchus* sp.) when possible. The distance between animals included the following categories: tight (less than 3 body lengths), compact (3-10 body lengths), and dispersed (more than 10 body lengths). In the cases when whales were divided into several clusters, the distance within and between clusters was described separately. For example, if the distance between whales within a cluster was less than 3 body lengths and between clusters more than 10 body lengths, then the degree of dispersion was described as tight/dispersed.

We divided the recording into 10-second intervals and estimated the number of echolocation clicks in each interval on a scale from 0 to 3 (0 = no clicks, 1 = few clicks, 2 = moderate number of clicks, 3 = many clicks). We pooled multiple recordings from a particular matriline or a particular matriline association from the same situation. In all, 113 situations were included in the analysis. We compared the number of echolocation clicks per animal per minute across types of activity and different distances between animals using a Kruskal-Wallis H-test. We calculated the Spearman rank correlation coefficient between the number of echolocation clicks per animal per minute and the number of animals.

For foraging, traveling, and socializing, we measured the following parameters of the echolocation trains: the length of the train, number of clicks in the train, interclick intervals, and repetition rate (clicks per second). We compared these click train parameters across foraging on Atka mackerel and salmon, traveling, and socializing using a Kruskal-Wallis H-test. We also measured the regularity of the trains using a coefficient of variation (SD/mean interclick interval). The train was “regular” if the coefficient of variation was less than 0.1.

3 RESULTS AND DISCUSSION

Significant differences in the amount of echolocation clicks across activity types ($P < 0.001$, Kruskal-Wallis H-test) and across the different distances between animals ($P < 0.05$, Kruskal-Wallis H-test) were found. The amount of echolocation clicks increased during foraging and when the animals were more dispersed (Figure 1, Figure 2). The amount of echolocation clicks had a negative hyperbolic dependence on the number of animals ($rS = -0.288$, $P < 0.005$), which was especially pronounced during foraging ($rS = -0.904997$, $P < 0.001$) (Figure 3).

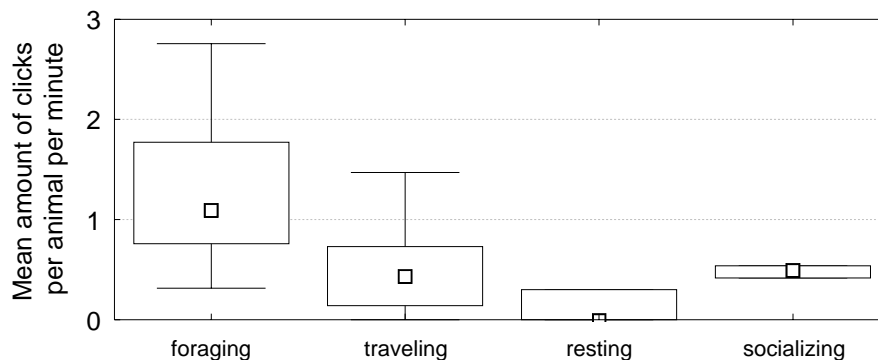


Figure 1. Differences in the amount of echolocation per animal per minute across activity types. Rectangles give the median number of calls, boxes show the percentiles (25%-75%), and whiskers give the non-outlier range.

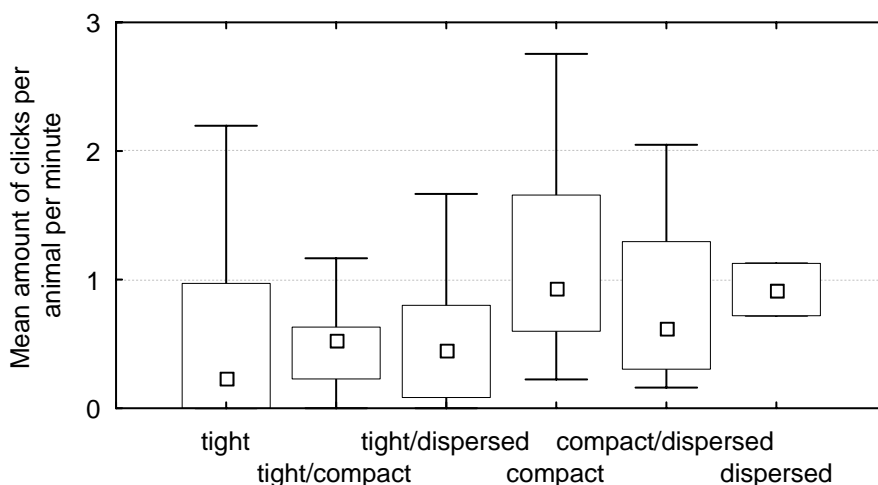


Figure 2. Differences in the amount of echolocation per animal per minute across degrees of dispersion. Rectangles give median number of calls, boxes show the percentiles (25%-75%), and whiskers give the non-outlier range.

A negative correlation between sonar use and group size in killer whales was also shown by Barrett-Lennard[2]. These authors suggested that sonar information was shared and they outlined

three possible hypotheses for how this sharing could occur. First, information obtained by echolocation may be communicated directly between animals. Second, by monitoring the echolocation of group members, individuals may be able to infer the location of foraging hotspots. Third, killer whales may be able to interpret the echoes of the clicks produced by other group members. The increase in echolocation activity when the distance between animals is increased (Figure 2) is evidence in support of the third hypothesis proposed by Barrett-Lennard[2]. To interpret the echoes from the clicks produced by other group members, animals would probably need to be close to each other. As the distance increases, interpretation becomes less plausible, forcing the whales to start using their own sonar. Of course, the close proximity of other animals would not be necessary for direct communication or for localization of foraging hotspots by echolocation of others.

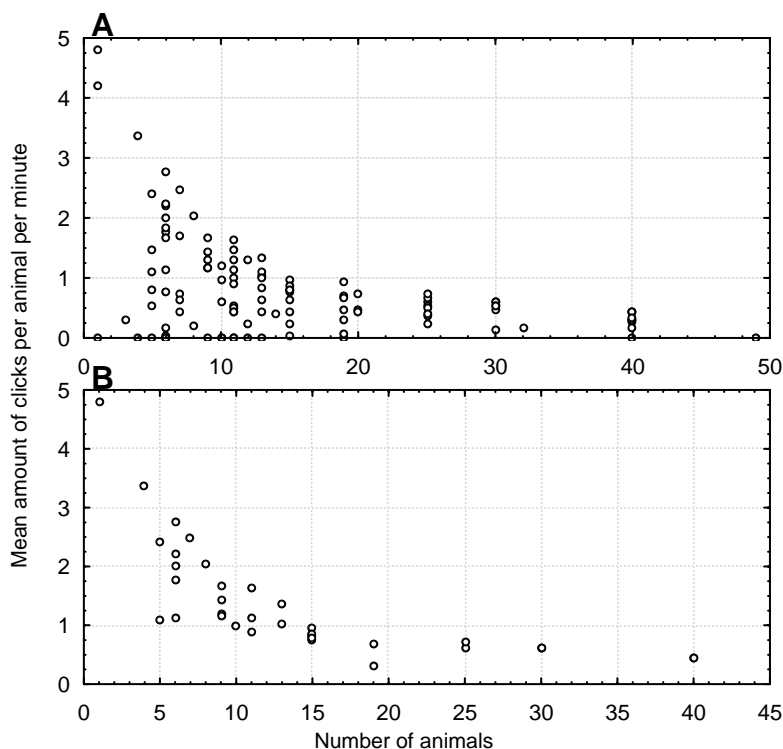


Figure 3. Number of echolocation clicks as a function of the number of animals: **A** – during all types of activity; **B** – during foraging.

Significant differences in all parameters of echolocation trains across activity types (for all, $P < 0.001$, Kruskal-Wallis H-test) were found (Figure 4). The longest trains were emitted during traveling. Trains during foraging on salmon had the highest pulse repetition rate. Some studies of dolphin echolocation in captivity have shown that dolphins increase the pulse repetition rate when the task becomes more difficult (Norris[4]; Giro[5]). Thus, it is likely that foraging on salmon is a more difficult task for a killer whale than foraging on Atka mackerel. This might explain why killer whales often feed on Atka mackerel, although salmon is also present in the area. Salmon is larger than Atka mackerel, so it is a more valuable prey, but it is also more agile. Atka mackerel is easier to catch, but less valuable. As a result, feeding on Atka mackerel could be considered roughly equal to feeding on salmon in terms of energy costs.

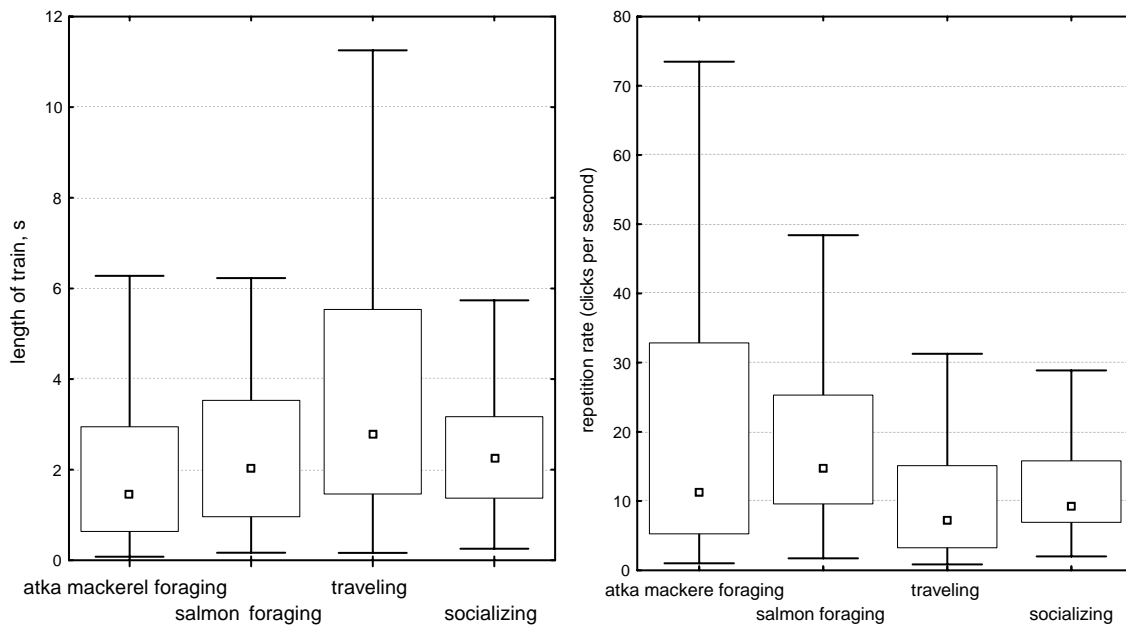


Figure 4. Length of echolocation trains and repetition rate during different types of activity.

The regularity in click trains increased in the row “Atka mackerel foraging”, “salmon foraging”, “traveling”, and “socializing” (Figure 5), which probably reflects the predictability of the movements of the objects upon which the whale echolocates. During socializing, the percentage of the regular series was twice that of foraging on Atka mackerel.

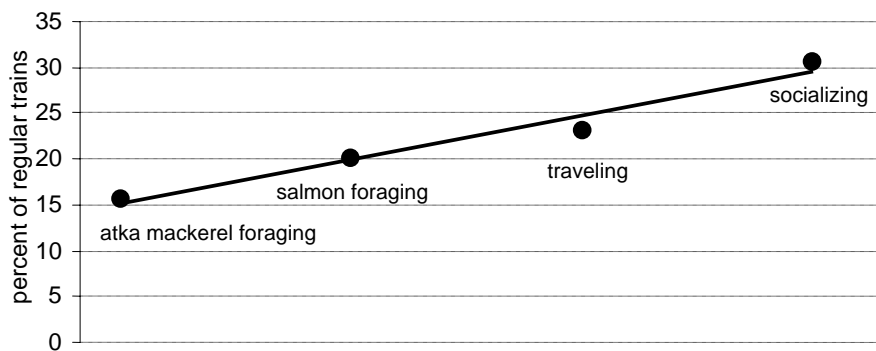


Figure 5. Regularity in click trains during different types of activity.

In summary, our results show that the echolocation parameters of killer whales in the wild are highly variable depending on the object and the conditions.

ACKNOWLEDGEMENTS

This research was supported by WDCS (Whale and Dolphin Conservation Society) and the Rufford Maurice Laing Foundation. Thanks are also due to many individuals but we are especially grateful to our colleagues who have worked tirelessly to get to know more about killer whales in the Russian Far East.

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