The Acoustic Signature of Aggression in the Killer Whale (*Orcinus orca*): A Shift in Acoustic Features and Call Type

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Introduction

Agonistic interactions are among the most consequential of all social behaviors, and understanding them should be a high priority in any research program investigating the social dynamics of a species. In the underwater ecology inhabited by cetaceans, acoustics play essential roles, and may be expected to convey information about significant mood/motivational states such as aggression. Attempts to decode the functional significance of animal sounds often depend upon establishing correlations of those sounds with other ongoing behaviors seen by observers (Crockford & Boesch, 2003; Janik, V. & Slater, P., 1998). However, in cetaceans this approach is particularly difficult because so much of their behavior occurs at depths where direct visual observation is not possible. Consequently, wildlife researchers studying these gregarious animals are often left with enigmatic sound recordings with little ability to link the vocalizations produced to ongoing social behavior. Captivity provides unique opportunities to observe cetaceans under clear, well lit conditions, and thus affords opportunities to address questions which would be impossible in the wild.

Methods

The subjects of this investigation were two adult wild-caught Killer Whales (*Orcinus orca*) of Icelandic origin held in captivity at Marineland of Canada (Niagara Falls, Ontario). Twenty-four hour video/audio recordings were collected via underwater viewing windows and in-pool hydrophones. From these recordings, eight aggressive episodes between the two whales were identified. These episodes were characterized by multiple periods of high speed chase, apparent bite attempts, and evasive maneuvers, and lasted an average of 420.6 seconds. All vocalizations during each period of aggressive chase were characterized according to 13 acoustic dimensions and 12 vocal categories. The vocalizations during one hour time-matched control periods (during which no aggressive behavior was observed) from the days prior to the aggressive episodes were similarly analyzed.

Results

In total, 986 vocalizations were recorded during periods of aggression and 2,839 vocalizations during the non-aggressive periods. The differences between these two samples are summarized below.

Vocalization Rate

During times of aggression, the whales vocalized an average of 0.37 calls per second, compared to 0.10 calls per second during the time-matched control periods. See Figure 1.

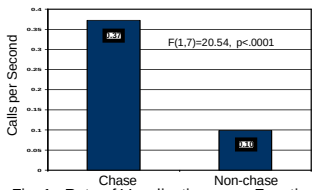


Fig. 1. Rate of Vocalizations as a Function of Chase vs Non-chase Periods

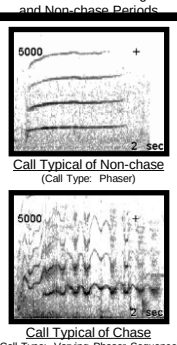
Acoustic Features

Compared to non-aggressive periods, calls produced during periods of chase showed significantly greater amplitude variation (pulsedness), frequency modulation over time (waviness), and variation in tonal components (screechiness), as well as greater variation on those same dimensions within calls (see Table 1). Figure 2 provides illustrative examples.

Table 1: Call Features as a Function of Social State

	Feature	Chase	Non-chase	Comparison
Time-dependent	Length (msec)	0.81	0.93	F(1,1)= 10.9, p=.001
	Number of Segments	2.17	2.72	F(1,1)= 21.2, p<.0001
	Variation in Loudness (1-3)	1.06	0.44	F(1,1)= 293.6, p<.0001
	Pulsedness (1-5)	1.97	0.08	F(1,1)= 1260.4, p<.0001
	Slope	0.73	0.39	F(1,1)= 52.6, p<.0001
	Variation in Waviness (1-5)	3.03	0.48	F(1,1)= 1110.1, p<.0001
	Variation in Wave Size (1-5)	0.65	0.04	F(1,1)= 434.8, p<.0001
Frequency-dependent	Number of Bands	5.70	8.77	F(1,1)= 123.7, p<.0001
	Distance btw Bands (Hz)	911	786	F(1,1)= 22.5, p<.0001
	Waviness (1-5)	2.38	0.33	F(1,1)= 1156.9, p<.0001
	Differences in Slope (1-5)	1.46	1.41	F(1,1)= 1.4, ns
	Differences in Waviness (1-5)	1.35	0.33	F(1,1)= 532.0, p<.0001
	Screechiness (1-5)	2.04	1.41	F(1,1)= 82.7, p<.0001

Fig. 2. Call Spectrograms of Vocalizations Made During Chase and Non-chase Periods



Call Typical of Non-chase
(Call Type: Phaser)

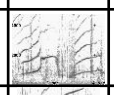
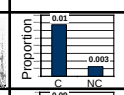
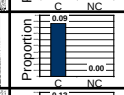
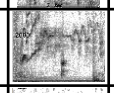
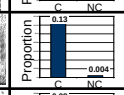
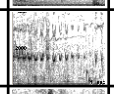
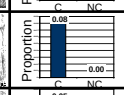
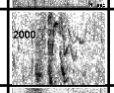
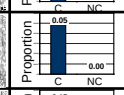
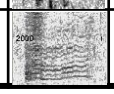
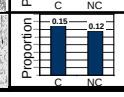
Call Typical of Chase
(Call Type: Varying Phaser Sequence)

Call Type

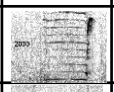
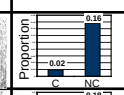
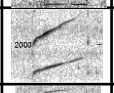
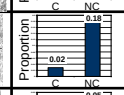
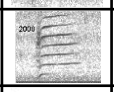
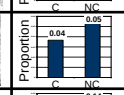
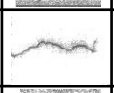
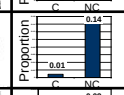
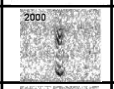
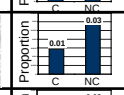
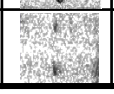
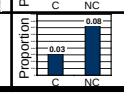
In all, the vocalizations could be categorized into 12 call types characteristic of Killer Whales (cf. Ford, 1987), and the rate of occurrence of each call type differed dramatically between the aggressive and control epochs. Table 2 presents each vocal category, illustrative sound spectrograms, and depictions of the chase vs non-chase differences.

Table 2: Call Types as a Function of Social State (Chase vs Non-chase)

Vocalizations Typical of Chase Periods

Call Type	Sound Spectrogram	Proportion of Call Type (Chase vs Non-Chase)	p
Screech Sequence			p<.0001
Varying Phaser			p<.0001
Varying Phaser Sequence			p<.0001
Hyena			p<.0001
Weewoo			p<.0001
Raspberry			p<.01

Vocalizations Typical of Non-chase Periods

Call Type	Sound Spectrogram	Proportion of Call Type (Chase vs Non-Chase)	p
Huit			p<.0001
Phaser			p<.0001
Catcalf			p<.05
Whistle			p<.0001
Seal			p<.01
Short Balloon Squeak			p<.0001

Conclusions

These striking results seem to define a unique acoustic signature of aggression in the Killer Whale, and this work extends our understanding of the ways in which Killer Whales alter the features of their vocalizations with changes in mood. During such consequential events, it would seem highly adaptive for such powerful animals to have unambiguous communicative signals, as was first theorized in Darwin's Principle of Antithesis (1872), and the extremely distinct aggression/non-aggression vocalizations documented in this study seem to match that expectation. It is hoped that these findings will aide wildlife researchers in interpreting hydrophone recordings of killer whale vocalizations, so that they can better determine the frequency and duration of aggression in wild populations. It is also hoped that captive animal managers will be able to use these acoustic features (pulsedness, wave variation, etc.) to detect, or even anticipate, episodes of aggression so that managed interventions can be employed where warranted (cf. Renner, M. & Kelly, A., 2006) .

References

Crockford, C. & Boesch, C. (2003) Context-specific calls in wild chimpanzees, *Pan troglodytes verus*: Analysis of barks. Animal Behaviour, 66, 115–125.

Darwin, C. (1872) The Expression of Emotions in Man and Animals. London.

Ford, J. (1987) A catalogue of underwater calls produced by Killer Whales (*Orcinus orca*) in British Columbia. Can. Data Rep. Fish. Aquat. Sci. (No.633), 165pp.

Janik, V. & Slater, P. (1998) Context-specific use suggests that bottlenose dolphin signature whistles are cohesion calls. Animal Behaviour, 56, 829–838.

Renner, M. & Kelly, A. (2006) Behavioral Decisions for Managing Social Distance and Aggression in Captive Polar Bears (*Ursus maritimus*). J. Appl. Animal Welf. Sci. 9, 233 - 239.

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