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## ICELANDIC KILLER WHALES *ORCINUS ORCA* USE A PULSED CALL SUITABLE FOR MANIPULATING THE SCHOOLING BEHAVIOUR OF HERRING *CLUPEA HARENGUS*

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### ABSTRACT

Icelandic and Norwegian killer whales feed on herring, after debilitating them with underwater tail slaps. We analysed sound recordings of Icelandic and Norwegian killer whales engaged in feeding and other behaviour. We describe a pulsed call made by Icelandic killer whales shortly before underwater tail slaps, which had an atypical low frequency (average peak frequency:  $683 \pm 131$  Hz), long duration ( $3.0 \pm 1.1$  s) and high intensity (source level 169–192 dB pp re  $1 \mu\text{Pa}$  @ 1 m). The low-frequency emphasis of this call was below the most sensitive hearing range of killer whales, suggesting that the call may not be optimal for interspecific communication. However, herring could easily perceive the killer whale call since the frequency content is similar to the resonant frequency of their swim bladder as well as to the most sensitive frequency band of hearing in this species. Previous studies have shown that sound may cause schooling herring to cluster. A high density of herring in a school would increase the effectiveness of the underwater tail slaps. We suggest that some Icelandic killer whales use this low-frequency call to herd herring into dense schools immediately before delivering an underwater tail slap, thereby increasing their foraging success.

Keywords: Killer Whale, *Orcinus orca*, vocalisations, tail slaps, Atlantic Herring, *Clupea harengus*.

### INTRODUCTION

Many animals use signals in specific situations (Bradbury & Vehrenkamp 1998). Context-specific acoustic signals have been

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reported from insects (Hoy *et al.* 1988), birds (Elgar 1986), primates (Seyfarth *et al.* 1980; Clark & Wrangham 1993), deer (Clutton-Brock & Albon 1979) and marine mammals (Renouf 1984; D'Vincent *et al.* 1985; Janik 2000; Miller *et al.* 2004) among others. The majority of these sounds are related to mating, the establishment of territory and hierarchy (Hoy *et al.* 1988; Clutton-Brock & Albon 1979), or to feeding (D'Vincent *et al.* 1985; Elgar 1986; Clark & Wrangham 1993; Janik 2000; Miller *et al.* 2004). Most food-related signals seem to carry information about food availability (Elgar 1986; Clark & Wrangham 1993), but there are a few reports of specific acoustic signals used for herding prey or the coordination of attacks and / or prey handling (MacGinitie & MacGinitie 1949; Norris and Møhl 1983; D'Vincent *et al.* 1985; Janik 2000; Marten *et al.* 2001). In addition, most toothed whales and echolocating bats produce high rates of echolocation signals in the final stages of prey capture (e.g. Schnitzler & Kalko 2001; Verfuss *et al.* 1999; Madsen *et al.* 2005; Miller *et al.* 2004). These signals can be seen as examples of highly context specific phonations.

Acoustic signals travel more efficiently through water than any other form of energy (Urick 1983). Sound is therefore the most efficient communication channel in water, and both fish and marine mammals produce a wide variety of sounds. Our knowledge of the behavioural context of these phonations is limited due to the technical difficulties in studying animal behaviour under water. Correlations between the rates of production of certain sound types and the activity state of the phonating animal have been investigated for several species of cetaceans (Sjare and Smith 1986; Ford 1989; Weilgart & Whitehead 1990; Thomsen *et al.* 2002; Van Opzeeland *et al.* 2005), but there are few examples of specific underwater signals that are correlated to a specific behaviour (D'Vincent *et al.* 1985; Janik 2000; Miller *et al.* 2004).

Killer whales *Orcinus orca* produce three types of underwater vocalisations: echolocation clicks, whistles and pulsed calls (Ford 1989). Studies of the vocal repertoires of northeast Pacific resident populations indicate distinct group dialects consisting of pulsed calls (Ford 1991). Differences in dialect reflect the maternal genetic distance between the groups (Barrett-Lennard 2000). Studies made in Norway and Iceland indicate that killer whales from these areas might have group-specific dialects as well (Moore *et al.* 1988; Strager 1995).

Killer whale populations usually specialise in one or several prey species of marine mammals, penguins or fish, which they often hunt cooperatively (Jefferson *et al.* 1991; Guinet 1992; Boran & Heimlich 1999). When hunting in groups, communication between individuals may be advantageous. The patterns of acoustic behaviour whilst hunting vary with the types of prey, most likely due to differences in the hearing abilities of the prey (Barrett-Lennard *et al.* 1996; Deecke

*et al.* 2005). Killer whales feeding on fish (with comparatively poor hearing abilities) usually phonate extensively, whilst those feeding on marine mammals (with acute hearing) are generally silent when hunting (Barrett-Lennard *et al.* 1996; Deecke *et al.* 2005).

All the killer whale populations studied so far vary the rates of vocalisations according to the behavioural context (Ford 1989; Guinet 1992; Deecke *et al.* 2005; Van Opzeeland *et al.* 2005; Simon *et al. submitted*). Neither the pulsed calls of northeast Pacific piscivorous killer whales studied by Ford (1989) nor the pulsed calls of Norwegian killer whales studied by Van Opzeeland *et al.* (2005) were found to be context-specific. However, the rates of certain calls studied by Ford (1989) were higher for various behavioural contexts. The acoustic behaviour of marine mammal-eating killer whales is characterised by the whales being silent prior to prey capture and producing high rates of calls following a successful capture (Deecke *et al.* 2005). The whales around the Crozet archipelago that specialize in catching penguins and marine mammals likewise do not seem to have context-specific calls. However, the pre-capture calls have specific characteristics and have been described as “excited” calls (Guinet 1992).

Icelandic and Norwegian killer whales feed on Atlantic Herring, *Clupea harengus* (Christensen 1982; Sigurjónsson & Leatherwood 1988). Norwegian killer whales use air bubbles, the white parts of their bodies, and possibly also sound to herd herring into tight schools near the surface (Similä & Ugarte 1993). They hit the school with their tail fluke, producing a broadband multi-pulsed sound (Similä & Ugarte 1993; Simon *et al.* 2005). The sound is a by-product of the tail slap, apparently produced by a combination of cavitation and physical contact with the fish (Domenici *et al.* 2000a; Simon *et al.* 2005). The underwater tail slaps immobilise the fish, which are then consumed one by one (Similä & Ugarte 1993). Icelandic killer whales use a similar hunting technique (Simon *et al.* 2005). Killer whales in Norway and Iceland produce high rates of pulsed calls and clicks while foraging (Similä & Ugarte 1993; Simon *et al. submitted*). Earlier studies suggested that these sounds were used for herding, debilitation of prey and communication (e.g. Similä & Ugarte 1993; Bisther & Vongraven 1995; Similä 1998; Marten *et al.* 2001). However, no studies have yet been made to support these hypotheses.

The aim of this work is to describe the acoustical characteristics of a distinct low-frequency call used by some Icelandic killer whales during foraging and immediately preceding underwater tail slaps. We discuss the possible use of this call as a tool to manipulate the prey in order to enhance the efficiency of the killer whales' hunting strategy.

## METHODS

### Sound recordings and behaviour

We made recordings of 10-min duration in the proximity of killer whales in coastal waters off southern Iceland during 17 days in June and July 2002 (N = 64 recordings). We used a custom-built hydrophone (Woods Hole Oceanographic Institute, frequency response flat within  $\pm 4$  dB up to 20 kHz). In Northern Norway, from October to December 2000 and 2001, we made sound recordings of 5 min duration (N = 40 recordings). In Norway we used a hydrophone produced by Offshore Acoustics (frequency response flat within  $\pm 4$  dB, up to 14 kHz). In all locations we deployed the hydrophones at depths of 2 to 5 m and recorded on a Sony TCD-D8 DAT recorder (flat frequency response 0.1 - 22 kHz). Water depths were 20-150 m in Iceland and 50-700 m in Norway.

When a group of stationary killer whales had been located, the boat was placed approximately 30 meters upwind and the engine switched off so that the boat could drift across the feeding spot while recording. When a group of travelling killer whales had been located the boat was placed approximately 100 m ahead of the whales and the engine was switched off while recording. This procedure resulted in minimal disturbance to the herring and whales.

To avoid pseudoreplication, we did not make two consecutive recordings on the same day of the same group of killer whales showing the same behaviour.

The surface behaviour of the killer whales recorded in Icelandic and Norwegian waters was identified as either "Feeding" or "Other". "Feeding" activity was defined as whales arching their body before diving, whales surfacing in different directions, seabirds taking fish at the diving spot and the presence of herring on the surface (Similä & Ugarte 1993). "Other" activity included all activities not identified as "Feeding".

### Acoustic analysis

All calls and sounds of underwater tail slaps were counted and the time of occurrence was registered (*behaviour sampling*; Martin & Bateson 1993). All calls that occurred within three seconds of an underwater tail slap were registered.

The pulsed calls in the recordings were inspected aurally and visually (Janik 1999; Deecke *et al.* 1999; Jones *et al.* 2001) using the Cool Edit Pro software (Syntrillium, Inc.). The call that is the subject of this paper was compared with a catalogue of sonograms of 35 pulsed calls of Icelandic killer whales published by Moore *et*

*al.* (1988). This call was not observed in the catalogue and, in order to be consistent with the system proposed by Moore *et al.* (1988), it was classified as I36 (Figure 1). Call I36 was quantitatively described using the time and frequency variables. Total call duration ( $\tau_{\text{total}}$ ), was measured by placing the cursors at the ends of the waveform of the sound, which were identified visually (Figure 1). The precision of these measurements depended on the signal to noise ratio of the recording but was probably in the order of 100 ms for the sounds analysed here. The peak frequency ( $f_p$ ) was defined as the frequency containing most energy and the centre frequency ( $f_c$ ) was defined as the frequency dividing the spectrum in two, with equal amount of energy on each side. The frequency bandwidth was given as the -3dB and -10dB bandwidths (*sensu* Au 1993). The analyses were made with

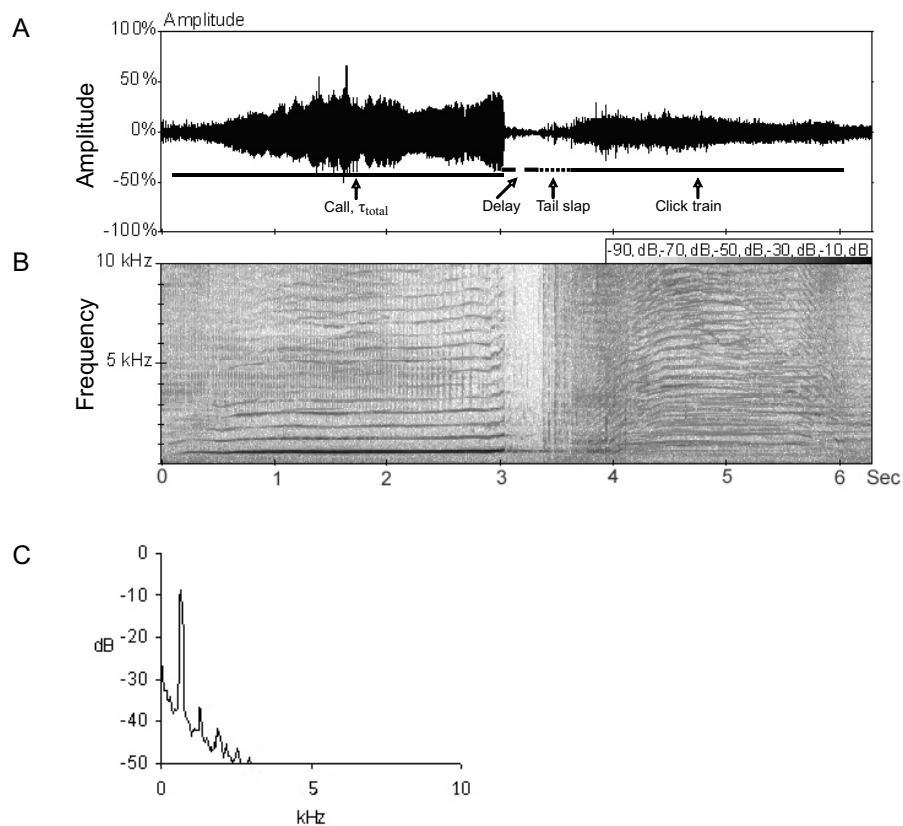


Figure 1. Waveform (A) and spectrogram (B) of call I36, tail slap and click trains. The call is followed by a delay (a short period of silence between the end of the call and the first pulse of the tail slap) after which the tail slap is seen. Click trains follow the tail slap. Average power spectrum of the I36 call (C). Settings: FFT size 1,024 samples, Hann window, frequency resolution: 66 Hz, 90% overlap (sampling rate 48,000 Hz).

BatSound Pro (Petterson Elektronik, Upsala, Sweden), and Avisoft SASLab software.

### Estimation of source level

To calculate the received level of the I36 call, we recorded a calibration signal (600 Hz, 100 mV rms) on the DAT recorder set at the highest recording level used in the field. Using the peak-to-peak levels of the call and the calibration signal, the minimum received level of the call was calculated relative to the hydrophone sensitivity (-167dB re 1 V/ $\mu$ Pa @ 600Hz). The source level was then back calculated to the range of distances the phonating whale was believed to be from the hydrophone.

There are two sources of potential bias on the estimation of the received level. First, due to variations in recording settings of the DAT, the reported received and source levels may be underestimated with up to 16 dB. Secondly, long signals, such as call I36, may be distorted by surface reflected paths interfering with the direct path. This is, however, a problem for all existing studies on dolphin calls and whistles recorded from animals close to the surface, irrespectively of the recording hydrophone depth. This may lead to severe underestimation of the sound level on the direct path as measured from the received level of the signal reaching the hydrophone, or an overestimation of the signal on the direct path by up to 6 dB.

## RESULTS

In Iceland, group sizes closest to the boat ranged from 6-25 individuals during recordings. The number of killer whale groups within sight of the boat (i.e. within a radius of approximately 1500 m) during the recording sessions varied from 1 to more than 5, and the number of individual whales in sight ranged from 6 to more than 50. As a rule, all the groups in sight were engaged in the same behaviour. A total of 34 recordings of "Feeding" Icelandic killer whales were analysed as well as 30 recordings of Icelandic killer whales engaged in "Other" activities. Underwater tail slaps were heard in all 34 recordings of "Feeding" activity (N = 159 tail slaps). Besides underwater tail slaps, high rates of echolocation clicks and pulsed calls were heard in all the recordings of "Feeding" killer whales. Call I36 was heard within 3 seconds before a tail slap in 47% of the recordings of "Feeding" Icelandic killer whales (N = 51 calls associated with tail slaps in 16 recordings of "Feeding"). Neither tail slaps nor I36 calls were heard in recordings of Icelandic killer whales engaged in "Other" activities (Table 1).

The size of the killer whale groups recorded in Norway ranged

TABLE 1

Percentage of recording sessions (10 min duration in Iceland, N = 64, five min duration in Norway, N = 40) of Icelandic and Norwegian killer whales engaged in Feeding and Other activities that contained sound of underwater tail slaps and associated low-frequency calls of type I36

Activity	Feeding		Other	
	Tail slaps	Call I36	Tail slaps	Call I36
Iceland	100%	47%	0%	0%
Norway	80%	0%	0%	0%

from 2-12 individuals. During the majority of the recordings there was only one group of killer whales within sight of the boat. A total of 10 recordings of “Feeding” Norwegian killer whales and 30 recordings of Norwegian killer whales engaged in “Other” activities were analysed. Underwater tail slaps (N = 135) were heard during eight of the 10 recordings of “Feeding” Norwegian killer whales. No underwater tail slaps were recorded during the 150 minutes of Norwegian killer whales in “Other” activities (Table 1). Call I36 was never heard in any of the recordings during “Feeding” or during “Other” activities of Norwegian killer whales. Therefore only the Icelandic recordings were further analysed.

Figure 1 shows call I36 followed by a tail slap and click trains. The average total duration of I36 calls associated with underwater tail slaps was  $X \pm SE = 3.0 \pm 1.1$  seconds, N = 38. The call was slightly amplitude modulated and the average frequency of the first harmonic (the fundamental) was  $X \pm SE = 683 \pm 131$  Hz, N = 38 (Figure 1), which was also the peak frequency in all the calls. The harmonics caused by the repetition rate of the pulsed call were weak (see Figure 1). The centre frequency was  $X \pm SE = 630 \pm 42$  Hz and the -3dB/-10dB bandwidths were  $X \pm SE = 9.6 \pm 10.8$  Hz and  $X \pm SE = 27.7 \pm 17.2$  Hz, respectively (Q-value = 71.4). Figure 2 shows examples of calls classified as type I36. For comparison, Figure 3 shows examples of other call types heard in the recordings. The minimum RL of the call I36 was  $X \pm SE = 149 \pm 8.4$ dB (pp) re.1 $\mu$ Pa at 1m, N = 11 (range 141 – 166 dB). Table 2 shows the back-calculated source levels (SL), given as peak-peak (pp), root-mean-square (rms) and energy flux measurements, of the received levels, assuming different realistic distances between the phonating whale and the hydrophone.

Seventy-three percent of the I36 calls ceased within one second before a tail slap (Figure 1). Due to the relatively large numbers of killer whales present, we do not know which individuals produced the recorded sounds, and therefore there may be an issue of statistical dependence between the samples within the data set. However,

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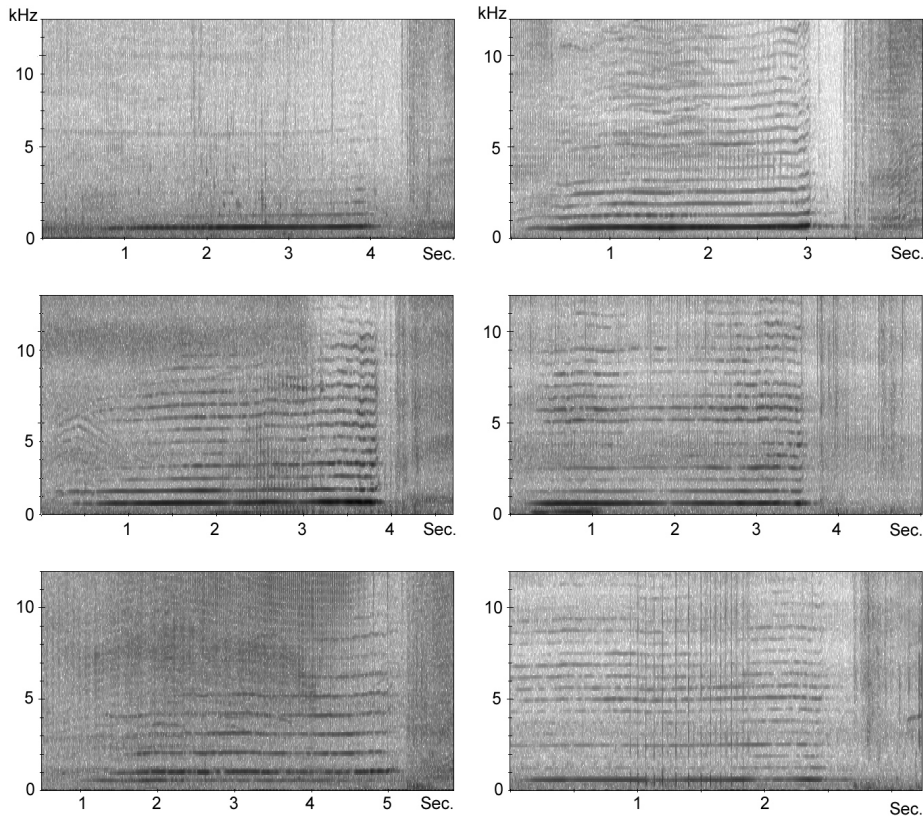


Figure 2. Spectrograms of six examples of call I36 and the following tail slap. Settings: FFT size 1,024 samples, Hann window, frequency resolution: 66 Hz, 90% overlap (sampling rate 48,000 Hz).

assuming that each recording is a statistically independent event, a test of single proportion gives a significant relationship ( $Z = 3.22$ ,  $N = 51$ , 95% CI 0.60 - 0.85,  $P < 0.001$ , Clarke & Cooke 1998), meaning that the call was significantly associated with the tail slap.

The time delays from the end of the I36 call to the start of the tail slaps were measured from the waveform (Figure 1). On average the underwater tail slaps started  $X \pm SE = 0.29 \pm 0.17$  seconds,  $N = 51$  (ranging from 0.02 to 0.70 seconds) after cessation of the call. No tail slaps were heard within one minute before a call, and no calls were heard within one minute after an underwater tail slap. Click trains from one or several whales followed 137 out of the 159 underwater tail slaps recorded in Iceland (see Figure 1).

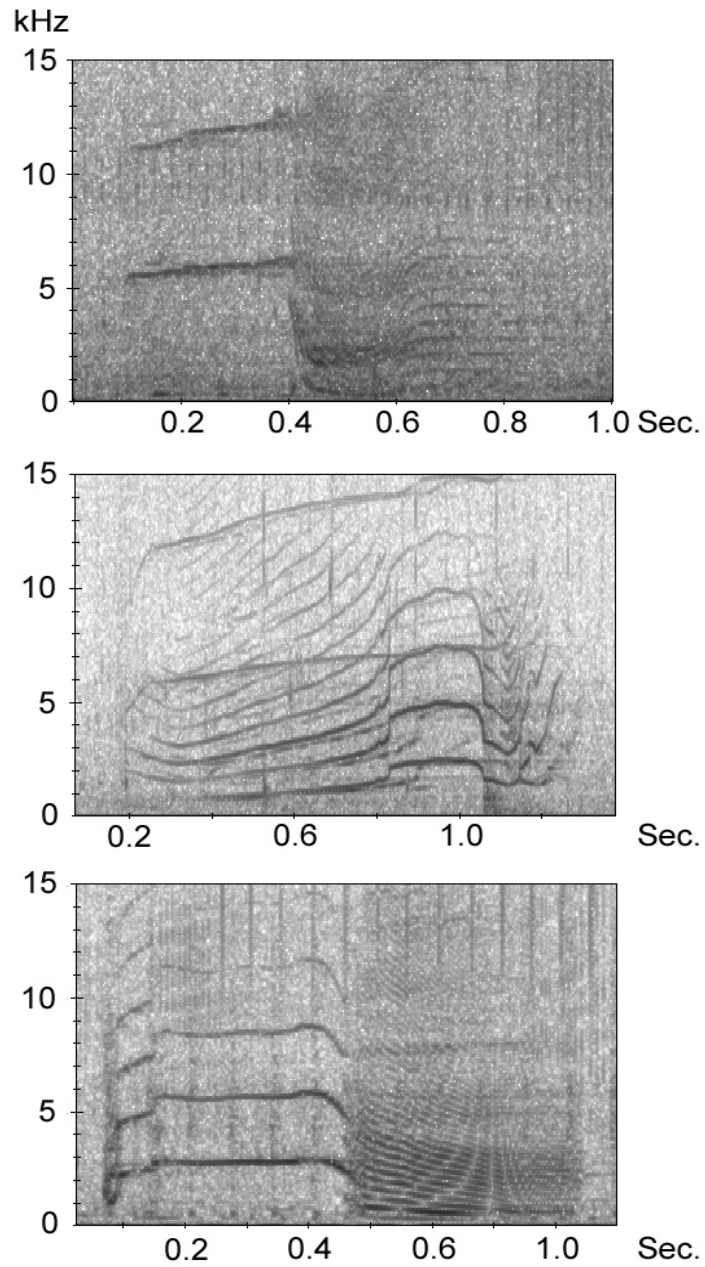


Figure 3. Spectrograms of three examples of pulsed calls other than I36 recorded from Icelandic killer whales showing the large variation of Icelandic killer whale calls. Settings: FFT size 1,024 samples, Hann window, frequency resolution: 66 Hz, 90% overlap (sampling rate 48,000 Hz).

TABLE 2

Source levels (SL) of the calls, assuming that they were produced at distances between 10 – 100 m from the hydrophone (N = 11)

Distance	10 m	20 m	30 m	40 m	50 m	60 m	80 m	100 m
SL, rms (dB re 1 $\mu$ Pa at 1m $\pm$ 8.4 dB)	160	166	169	172	174	176	178	183
SL, pp (dB re 1 $\mu$ Pa at 1m $\pm$ 8.4 dB)	169	175	178	181	183	185	187	192
SL, energy flux (dB re 1 $\mu$ Pa <sup>2</sup> s)	165	171	174	177	179	181	183	188

## DISCUSSION

Call I36 was similar to the Icelandic killer whale call I12 described by Moore *et al.* (1998). However, there is an increase in frequency at the beginning of call I12, which is not observed in call I36. Therefore we do not think that call I36 is a variant of call I12. Call I36 is a unique low frequency call described here for the first time.

A similar call (peak frequency: 622 Hz, duration: 3.2 s) was reported from transient killer whales in Prince William's Sound, Alaska (Saulitis 1993). These whales feed on marine mammals that have a hearing sensitivity over the whole frequency range of killer whale vocalisations (compiled by Richardson *et al.* 1995). For this reason, transient killer whales are almost silent during hunting and prey capture and the call reported by Saulitis (1993) is not used during foraging contexts. In contrast, call type I36 was produced mainly during feeding situations. Therefore, the call reported by Saulitis (1993) is likely to have a different usage than call type I36.

Call I36 was significantly correlated to the underwater tail slaps used by Icelandic killer whales while foraging on herring. The call ceased less than one second before the tail slap and was only recorded from killer whales during feeding. This suggests that Icelandic killer whales have context-specific pulsed calls and that the unique I36 pulsed call might serve a specific purpose in the feeding strategy of Icelandic killer whales.

We never heard or recorded call I36 from Norwegian killer whales and this call has not been depicted in any of the published sonograms of Norwegian killer whales (Strager 1993, 1995; Simon & Ugarte 2002; Van Parijs *et al.* 2004, Van Opzeeland *et al.* 2005). In addition, we have not heard this call in a collection of several hours of recordings from Norwegian killer whales, made between 1990 and

2001 (unpublished data). Therefore we conclude that call I36, which is often produced by killer whales feeding on herring in Iceland, is non-existent or very rarely used by Norwegian killer whales.

The absence of call I36 in the recordings of Norwegian killer whales and the fact that this call was present in only 47% of the recordings from feeding Icelandic killer whales indicate that the call is not universally spread among herring-eating killer whales. This suggests that the call might be culturally transmitted, either as part of a feeding-behaviour independent of kinship or as part of a group-specific dialect (*sensu* Ford 1991). We attempted to photographically identify the killer whales recorded during this study. Several of the approximately 100 killer whales individually identified in the area were present during the recordings, and some individuals were close by during more than one recording session (unpublished data). Unfortunately, we did not manage to photograph all the killer whales in the area during every recording session. This means that we can neither confirm nor reject the hypothesis that call type I36 is used only by one, or a few killer whale groups. We believe that the association between call type I36 and underwater tail slaps used by feeding killer whales, as shown in this study, is in itself interesting, regardless of the number of whales using this call. Further studies combining sound recordings with photo-identification and / or DNA finger-printing are needed to elucidate whether call I36 is shared among social groups.

The use of underwater tail slaps for prey debilitation is common for the killer whales in Icelandic and Norwegian waters, suggesting either a cultural link or evolutionary convergence (Simon *et al.* 2005). The killer whales recorded in Norway follow the migration of the Norwegian spring-spawning stock of herring (Similä *et al.* 1996), while the killer whales that we recorded in Iceland seem to follow the stock of Icelandic summer-spawning herring (Sigurjónsson & Leatherwood 1988). These two herring stocks collapsed in the 1950's and 1960's (Jakobsson & Stefánsson, 1999). In earlier times, these two herring stocks mixed on the feeding areas on the coastal banks of Northern Iceland, and their winter grounds were geographically close (Dragesund *et al.* 1980; Jakobsson & Stefánsson 1999; Jakobsson & Østvedt 1999; Holst *et al.* 2004), making the contact between Norwegian and Icelandic killer whales likely. After the collapses, the migration patterns of the fish changed, and since then these two stocks of herring do not seem to overlap in space and time. Thus contact between Icelandic and Norwegian killer whales has most likely decreased since the 1970s. If the tail slap behaviour has spread as a consequence of a cultural link and call I36 is connected to this behaviour independent of maternal kinship (i.e.: is not part of a dialect, *sensu* Ford 1991), then call I36 might have evolved after the contact between the two populations of killer whales declined.

The acoustic characteristics of call I36 differ from killer whale calls described earlier. Most killer whale calls have a frequency emphasis between 1 and 6 kHz with durations between 0.5 - 2.2 seconds (Ford 1989, Strager 1995). The call described in this study had a peak frequency of 683 Hz and an average duration of 3.0 seconds. Both of these measurements are outside the range of normal killer whale calls. Also the estimated source levels are probably higher than source levels measured for other calls, as calls from northeast Pacific resident killer whales had a maximum SL of 168 dB (pp) re.1 $\mu$ Pa (Miller 2000).

The energy-flux estimated for call I36 is comparable with the energy-flux measured from blue whale calls, some of the signals with the highest energy-flux measured in the animal kingdom (Richardson *et al.* 1995). Is call I36, with its high intensity, long duration and low frequency, suitable for communication among killer whales? Underwater video recordings show that Norwegian killer whales often feed on herring debilitated by their own tail slaps or those of neighbouring killer whales (Similä & Ugarte 1993). Therefore, a whale about to hit the fish school with its tail might signal other whales that herring will soon be debilitated. This seems unlikely, however, as the underwater tail slap itself causes intense sound (Simon *et al.* 2005), which would transmit the same information making the call redundant. The call could also be a warning signal to other whales. Again, this seem unlikely since tail slaps are sometimes used by Icelandic killer whales without the preceding call, and Norwegian killer whales show no signs of warning prior to tail slaps (*pers. obs* from underwater video recordings). Also, there are no video recordings of a killer whale hitting a neighbour with its tail during a tail slap.

The hearing of killer whales is especially sensitive in the frequency range from 2 kHz – 80 kHz (Szymanski *et al.* 1999). Current audiograms of killer whales do not extend below 1 kHz. However, the hearing threshold rapidly increases at frequencies from 2 kHz to 1 kHz indicating that sensitivity to frequencies below 1 kHz must be poor. This is corroborated by an early audiogram on a killer whale by Hall & Johnson (1972) as well as from the generally poor hearing abilities of other Odontocetes at low frequencies (reviewed by Richardson *et al.* 1995). The Icelandic call I36 is outside the optimal hearing range of killer whales and therefore is not optimally adapted for intra-specific communication.

Could call I36 be directed to the herring? The density of herring schools increase when herded by killer whales (Domenici *et al.* 2000b), and a high density of herring within a school is likely to increase the efficiency of underwater tail slaps (Nøttestad 1999). Sound can elicit anti-predator responses from herring, such as schooling or swimming away (Sharpe & Dill 1997; Wilson & Dill 2002; Olsen 1990). However, for the call to be effective in herding herring, the

fish must be able to hear it. The main energy of the low-frequency call is at 683 Hz. Atlantic Herring *Clupea harengus* and Pacific Herring *Clupea pallasii* are most sensitive to frequencies between 100 and 1000 Hz (Enger 1967, Mann *et al.* 2005). Call I36 lies within the best hearing range of herring suggesting that the call could influence fish swimming behaviour. Playback experiments with Pink Snapper *Pagrus auratus* revealed that extensive damage to the sensory epithelia could be caused by intense sound pressures (McCauley *et al.* 2003). Our estimates of the source level suggest that the call is in fact sufficiently intense to cause long-term hearing damage in fish at close range (McCauley *et al.* 2003). Also, the resonance frequency of the herring swim bladder is about 700 Hz for a fish at 5-10 m depth (Løvik & Hoven 1979). If the swim bladder is brought into resonance by calls, it might start vibrating and hamper the fish in its swimming and escape performance.

Herring have a sensitive hearing system with a direct connection between the inner ear, the lateral line system (acoustico lateralis) and the swim bladder (Coombs & Braun, 2003). This is probably the reason for their high sensitivity to sound, both in terms of sound pressure and particle displacement (Enger, 1967). Tail slapping has been reported from a number of large marine vertebrates, such as the Thresher Shark *Alopias vulpinus* (Muus *et al.* 1988), billfish (Van der Elst & Roxburgh 1981; McGowan 1988), Bottlenose Dolphin *Tursiops truncatus* (Smolker & Richards 1988) and Norwegian and Icelandic Killer Whale (Similä & Ugarte 1993; Simon *et al.* 2005). Most of these reports were from animals feeding on herring. Herring swimming abilities and buoyancy are probably easily affected by a rapidly varying sound pressure and particle displacement, due to their high sensitivity to these modalities (Enger 1967, Blaxter & Batty 1985). On this basis Simon *et al.* (2005) suggested that the tail slapping behaviour might be a feeding strategy especially well adapted for predators feeding on herring. If call I36 is used to manipulate the behaviour of the herring, it would be one more example of a special adaptation by Icelandic killer whales to hunt herring.

Humpback Whale *Megaptera novaeangliae* feeding on herring herd the schools by using bubble nets (Jurasz & Jurasz 1979). During bubble-net feeding the whales make a specific cry with duration of 0.4 – 8.2 sec., relatively little frequency modulation and a fundamental frequency of 360 - 980 Hz (Cerchio & Dahlheim 2001). This cry is very similar to call I36, that has a duration of  $3.0 \pm 1.1$  sec., little or no frequency modulation and a fundamental frequency of  $683 \pm 131$  Hz. The similarity between this humpback whale cry and the killer whale call I36 could be an example of an evolutionary convergent acoustic behaviour that would facilitate the capture of herring.

In conclusion, we suggest that some Icelandic killer whales use a specific call to acoustically manipulate the behaviour of schooling herring prior to using underwater tail slaps that debilitate their prey. Our study provides initial evidence that this acoustic signal has a unique design and is used in a specific context to fulfil a precise function. To verify this postulate more behavioural studies of the acoustic behaviour of killer whales and the effect of sound signals on herring schools are needed.

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