Behaviour of a social unit of sperm whales (*Physeter macrocephalus*) entangled in a driftnet off Capo Palinuro (Southern Tyrrhenian Sea, Italy)

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ABSTRACT

Driftnet fishing is notorious for being the major source of fatal entanglement of cetaceans and for its devastating impact on some pelagic species of the Mediterranean fauna. Of all the large cetaceans, the sperm whale (*Physeter macrocephalus*) is most affected by this fishing technique. On 9 August 2004, a group of five sperm whales, two adult females and three juvenile individuals, was found trapped in a driftnet 40 miles southwest off Capo Palinuro (Italy). Their tails were totally immobilised by the net and one animal was completely entangled. All the animals showed numerous lesions on their bodies. The group was freed by the Italian Coast Guard scuba-diving team during a two-day rescue operation.

This exceptional case of sperm whale disentanglement was a unique opportunity to study the group's acoustic and general behaviour during a particularly stressful event. Out of a total video/acoustic recording of 110 minutes, 91 were examined. During the rescue procedures, the whales' behaviour was described as open mouthed, sideways roll, agitation of fluke and pectoral fins, head rubbing, fluke contact (with head, flippers and back by the liberated animals) and defecation. As expected, the entangled individuals produced different patterns of clicks, identified as 'usual clicks', 'codas' and 'creaks'. Each pattern was associated with specific behaviour.

Despite international and national regulation banning fishing with driftnets in the Mediterranean Sea, driftnets continue to be used illegally in this sperm whale habitat, posing a constant threat to the species' survival in the region.

KEYWORDS: INCIDENTAL CATCHES; SPERM WHALE; DRIFTNET; MEDITERRANEAN SEA; BEHAVIOUR; NORTHERN HEMISPHERE

INTRODUCTION

On 9 August at 14.00, a social unit (sensu Whitehead, 2003) of five sperm whales (*Physeter macrocephalus*), two adult females and three juvenile individuals, was found entangled in a driftnet 40 miles southwest off Capo Palinuro (Southern Tyrrhenian Sea, Italy). Driftnets are large, floating nets made of a mesh of monofilament or multifilament line, generally deployed in open marine waters. They can be up to 50km long and hang vertically 20-30m from the surface. They are designed primarily to trap and entangle large fish such as tuna (*Thunnus* sp.) and swordfish (*Xiphias gladius*), however, left to drift freely, they indiscriminately trap and kill non-target large pelagic species such as whales, dolphins, sharks, turtles, rays and seabirds.

Large-scale pelagic driftnet fishing is of considerable international concern; the United Nations banned the use of large-scale driftnet operations on the open seas from 31 December 1992 and the European Union prohibited the use of driftnets of all sizes from the 1 January, 2002.

Driftnets were the main cause of fatal entanglements for cetaceans in the Mediterranean Sea, with serious consequences for some populations (Di Natale and Notarbartolo di Sciara, 1994; IWC, 1994). Between 1986 and 1990, 83% of all recorded cetacean strandings were attributed to fisheries by-catch, nearly all in driftnets (Cagnolaro and Notarbartolo di Sciara, 1992). At the peak of driftnet deployment, an annual by-catch of over 7,000 cetaceans was estimated for the Italian seas alone (Notarbartolo di Sciara, 1990).

Despite their illegal status, these nets are still in use in Italy (where both nets and vessels are usually called 'spadare') and continue to cause harm and/or the death of unknown numbers of protected species each year. Of the large cetaceans, the sperm whale is the most affected by this method of fishing (Lazaro and Martin, 1999; Notarbartolo di Sciara *et al*., 2004). Between 1986 and 2000, 64 sperm whales were killed in Italy alone as a result of entanglement in fishing gear (they showed injury or were stranded as a result entanglement); most, if not all, of these were attributable to driftnet bycatch (Reeves and Notarbartolo di Sciara, 2006).

The aim of this work is to describe the behaviour and acoustic vocalisations (clicks) of an entangled social unit of sperm whales during the rescue operation conducted by the Italian Coast Guard scuba-diving team.

Sperm whale clicks are sharp-onset, broadband, impulsive vocalisations with a frequency of between 5 and 25kHz (Madsen *et al*., 2002), arranged in various patterns (usual clicks, slow clicks, codas, creaks, etc.) and used in a variety of circumstances (Whitehead, 2003). Within sperm whale social groups, clicks are possibly representative of intimate interactions among its members and the exchange of codas is probably the most evident form of communication (Watkins and Schevill, 1977) aimed at social interaction. Hence, a detailed analysis of these sounds, emitted during the rescue procedures, was performed.

METHODS

A professional underwater camera was used to record the sperm whales' behaviour during the disentanglement process. Out of a total video/acoustic recording of 110 minutes, 91 were visually examined with the aim of

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analysing the animals' behaviour during the rescue actions. For the study, a short behavioural catalogue of seven activities – open mouthed, sideways roll, agitation of fluke and pectoral fins, head rubbing, fluke contact (with head, flippers and back by the liberated animals) and defecation – was established.

For the acoustical analysis, three categories were identified: 'usual clicks'; 'codas'; and 'creaks'.

'*Usual clicks*': a series composed of regularly spaced clicks lasting for several minutes. These have been interpreted as echolocation clicks, used for locating prey and orientation (Whitehead and Weilgart, 1990), but may also serve to keep widely dispersed foraging groups in contact (Andrè and Kamminga, 2000).

'*Codas*': distinctive stereotyped patterns of clicks (Watkins and Schevill, 1977) with different rhythms. Each rhythm defines a distinct coda type (Weilgart and Whitehead, 1997), these characterise diverse vocal clans within sperm whale populations. Coda repertoires are reported to be transmitted culturally within the sperm whale social unit (Rendell and Whitehead, 2003).

'*Creaks*': patterns of closely spaced clicks with inter click intervals (ICIs) ranging from 5 to 100ms and lasting from 0.1 to 45s. Creaks are thought to be produced by sperm whales investigating objects at close range (Mullins *et al*., 1988). In social context they have been called codacreaks (Weilgart, 1990), rapid clicks or chirrups (Goold, 1999). They have been described as social sounds (Gordon, 1987) but their exact function is still unknown.

Forty-five minutes of acoustic recordings were examined using the *Rainbow Click* software package (see Gillespie and Leaper, 1997; Jaquet *et al*., 2001; Leaper *et al*., 2000). Codas were then marked and outputs of the digitised sound data for each click in each coda were used for IPI (interpulse interval) analysis. A *MATLAB* routine written by Rendell and Whitehead (2003) was used to automatically analyse clicks by extracting the maximum value from the cepstrum, following Goold's (1996) method. Only codas for which IPI estimates were identical in 50% or more of the clicks were included.

RESULTS

The sperm whales were found with their tails totally immobilised by the net and one animal was completely entangled (Fig. 1). All the whales showed numerous lesions on their bodies; their flukes in particular appeared to have been seriously injured. The estimated lengths of the two adult females were 10-12m, while the younger animals (gender unknown) was 5-7m long.

On the first day the divers managed to free two of the trapped whales; an adult and a younger individual by severing the nylon netting with cutters. It took 65 minutes to free the entangled adult whale, which remained calm throughout the rescue procedures and subsequently stayed close by, frequently touching the other entangled members of the group on their heads, flanks and flukes and observing the divers whilst they released a juvenile animal. The younger whale, freed 45min later, was relatively agitated compared to the adult during the net cutting operations, vigorously moving its fluke and frequently opening its mouth. Both the freed whales remained nearby surveying the divers at work and repeatedly rubbing on their trapped schoolmates' flanks with their heads and stroking their entangled flukes. This physical interaction hindered the liberation of the other animals by effectively stopping the divers' work. At 18:50hr, the young whale gradually abandoned the rescue site and disappeared from the divers' view. At 20:00hr, the rescue operations were suspended, scheduled to recommence the next day at daybreak.

During the night, the whales were constantly monitored from the Coast Guard vessel by radar and night-vision equipment. The freed adult whale remained near the group almost all night, moving away just before sunrise. On 10 August, at 06:30hr, the divers resumed cutting through the netting, managing to liberate a second young whale at 08:15hr and at 08:30hr the remaining juvenile was cut free. Finally, the largest animal was disentangled at 08:50hr. Following release, this female lingered close to the divers for over an hour, moving slowly and accepting hand contact on her side.

The behaviour of the sperm whales during the rescue operations included several specific actions: open mouthed (29%); sideways roll (17%); agitation of fluke (21%) and pectoral fins (12%); head rubbing (9%; Fig. 2), fluke contact with head, flippers and back by the released animals (9%; Fig. 3); and defecation (3%). No threatening or other aggressive behaviour toward the divers was recorded.

As expected, the entangled individuals produced different patterns of clicks, identified as 'usual clicks', 'codas' and 'creaks'. Almost all of the sounds provided an estimated length of between 9.30 and 9.35m (Fig. 4), suggesting that they were produced by the same whale or by the two adults that were similar in size.

A coda frequency rate of 1.13 codas per minute was recorded, with a total number of 51 codas detected. About 88% lasted between 200 and 600ms. Only 10% exceeded 600ms in total duration and just 2% were shorter than 200ms (Fig. 5). The overall mean duration of the codas was 398ms (N=51, SD=133.4, range 195-813, mode 284, median 377).

Fig. 1. The entangled whales.

Fig. 2. Head rub.

Fig. 3. Fluke touch.

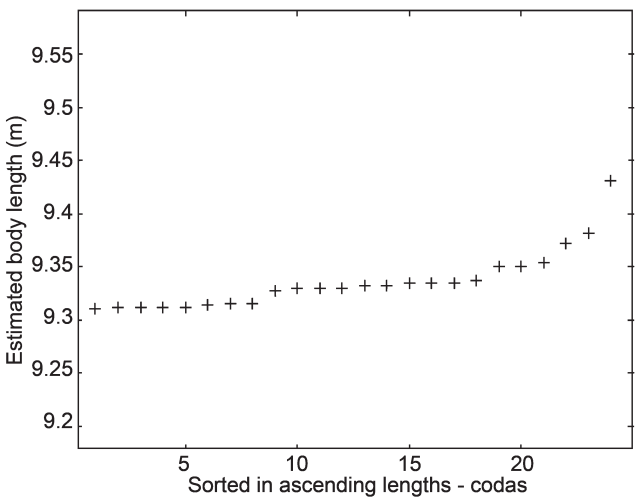

Fig. 4. Body length estimates from IPI.

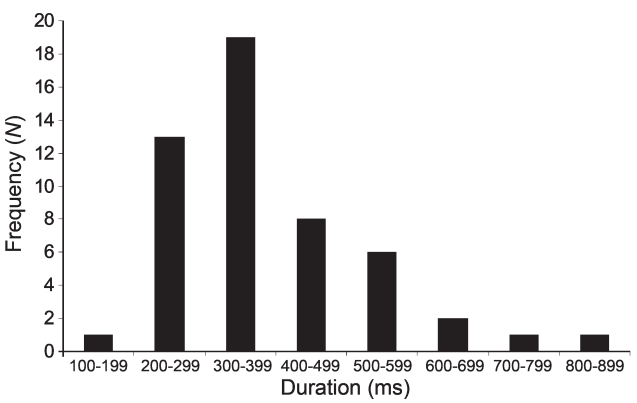

Fig. 5. Frequency distribution of codas duration.

Six coda types, containing 3-6 clicks, were catalogued and classified in accordance with Weilgart and Whitehead (1993). Two patterns of 3-click and 3+1-click codas were found to be the most common, constituting 80% of all codas recorded (Table 1). Codas were principally heard when the animals swished their flukes and during contact with other entangled tails.

Codacreaks analysis indicated that the frequency rate was 10.51min^{-1}, with a total number of 473 codacreaks detected. The number of clicks in codacreaks ranged from 3 to 45, with the modal value within the 20-30 clicks class (Fig. 6). This type constituted about 36% of the total, followed by the 10-20 type (30%). The overall mean duration of the

Table 1

Coda types.

Type	*N*
2+1	2 (4%)
3R	23 (45%)
3+1	17 (33%)
4R	6 (12%)
4+1	1 (2%)
5+1	2 (4%)

codacreaks was 614ms (N=473, SD=302.8, range 43-1,706, median 663, mode 765), with 61% lasting between 400 and 900ms. Only 14% of the codacreaks had an overall duration of more than 900ms and 26% were shorter than 400ms (Fig. 7). From the behavioural point of view, codacreaks were associated with 'open mouthed' and 'sideways roll' displays, even if, like codas, they were heard when the animals swished their flukes.

DISCUSSION

'Head rubbing' and 'fluke contact' were the most obvious demonstrations of social behaviour showed by these animals. Female sperm whales are reported to cooperatively assist their offspring and other whales in dangerous situations, (Caldwell *et al*., 1966) and the members of a school seem to safeguard injured calves. This tendency was evident during this event, where the first freed adult female whale showed a higher number of 'fluke contact' displays than the younger individuals (even when liberated), clearly trying to comfort the animals still entangled in the net. Females and immature sperm whales socialising near the

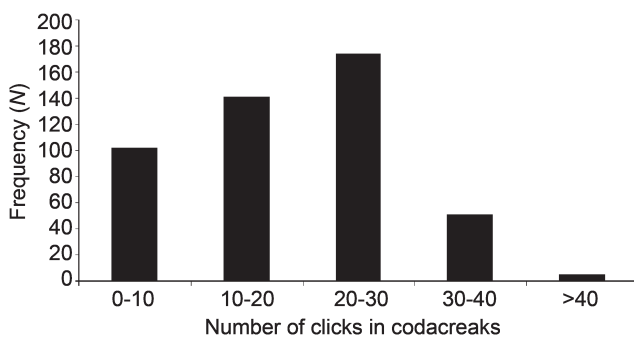

Fig. 6. Frequency distribution of clicks in codacreaks.

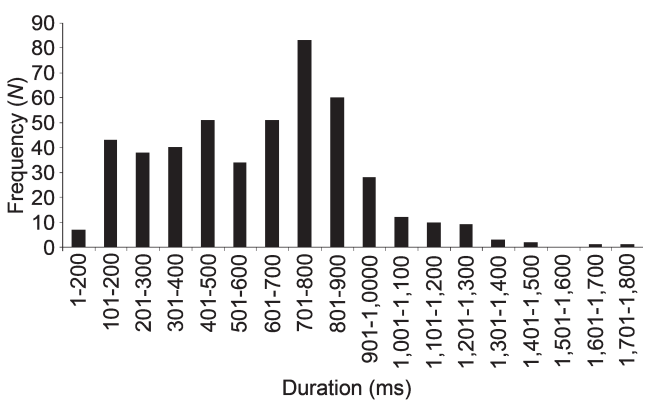

Fig. 7. Frequency distribution of codacreaks duration.

surface often touch and stroke one another with the jaw or flippers, actively maintaining physical contact with each other (Whitehead and Weilgart, 2000). In this case, physical contact appeared to be central to reassuring the entangled animals. An intense 'head rubbing' movement, performed primarily on the whales' sides without emitting any form of vocalisation, was also observed mutually between adults and juveniles. The lack of acoustic patterns associated with such contact seems to indicate the importance of touch to reinforce bonds between group members and demonstrates the significance of tactile signals as a direct form of support. As reported, the first disentangled female remained with the group for many hours after liberation, demonstrating this supportive behaviour towards individuals who may or may not have been related. Female sperm whales live in a social, ecological and physical environment where supportive behaviour may develop and be commonly practiced (Mesnick *et al*., 2003). Reinforcing social bonds through cooperation and association is adaptive behaviour and calf protection would seem to be the most likely primary functions of sociality among females (Whitehead and Weilgart, 1991).

The other notable behaviour observed, both in adult and immature individuals, was 'open mouthed'. This action was performed exclusively when the animals were trapped and was repeatedly associated with vocalisations. 'Open mouthed' displays are frequently reported in other odontocetes species during aggressive/agonistic bouts (Samuels and Gifford, 1997) or in stressful situations. It seems likely that this type of behaviour was accentuated during this traumatic experience; it may occur more frequently in stressful circumstances than under normal conditions.

'Sideways roll' and 'agitation of flukes and pectoral fins', correlated with vocalisations, were principally observed in, but not limited to, immature individuals. As sperm whales often roll along each others' bodies during interactive social sessions or roll onto a flank, with one of its fluke lobes out of the water, during prolonged periods of surface swimming (Whitehead, 2003). It is possible they behaved in this way, not only to try to free themselves from the net but also to facilitate visual observation (in this case, the divers cutting the net). Furthermore, the movements of flukes and flippers were often associated with the cutting procedures near the peduncle; this was possibly a reaction to pain caused by the net cutting into the numerous wounds and vocalisations were often heard. In female sperm whales there is a strong correlation between categories of visually observable behaviour and vocalisation types (Whitehead and Weilgart, 2000).

The recorded coda repertoire, i.e. the set of codas emitted by a set of whales in a particular circumstance (Whitehead, 2003), dominated by 3R and 3+1, is analogous to that recorded off the Balearic Islands (Nutthila, 2004) and in the Tyrrhenian Sea (Drouot, 2003), suggesting that these whales may belong to the same clan (sensu Whitehead, 2003). However, the complete recorded repertoire of the entangled whales, consisting of six different coda types, slightly differs from data reported by Drouot (2003) for the Tyrrhenian Sea and is in contrast with previous studies (Borsani and Pavan, 1994; Pavan *et al*., 2000).

Codas were principally heard when the animals swished their tails and during contact with entangled tails. This last finding is consistent with other observations, which report that an extensive coda repertoire is generally associated with cohesive groups near the surface and during exchanges with other whales (Whitehead and Weilgart, 1991). The acoustic results strongly suggest an interactive function of codas and codacreaks within the social group, underlining the link between their production, communication and sociality (Whitehead, 2003). It has been hypothesised that vocalisations may not only reflect the general 'disposition' of an animal but may also be indicative of moods and emotions. It cannot be ruled out that in such traumatic conditions, vocalisations serve to communicate emotions, since it has been suggested they may play a role in social interaction (Aureli, 1997) and could be adaptive, evolving in species where social bonding, group cohesion and mutual interactions favour the species' survival. Codas and codacreaks production may be related to levels of anxiety and possibly apparent dangers (they were higher during the initial phases of the rescue procedures) and seem to be emulative between animals. However, the echolocation function for close objects cannot be excluded.

In the Mediterranean Sea, driftnets are still a major threat to certain vulnerable pelagic species and, despite international and national regulation banning them from the region, numerous sperm whales have been found dead following entanglement in driftnets illegally set for swordfish. In the last three decades (from 1971 to 2004) the documented number of sperm whales found dead or entangled for Spain, France and Italy was collectively 229 and the true number is probably much higher (Reeves and Notarbartolo di Sciara, 2006).

The majority of whale strandings (recognisable from the characteristic wounds on the whales' bodies or the presence of net fragments) in Italy and Mediterranean Spain were caused by entanglement in high seas driftnets (Lazaro and Martin, 1999; Podestà and Magnaghi, 1989); deaths from this illegal activity persist today (ACCOBAMS, 2003; Tudela *et al*., 2003). While the true abundance of sperm whales in the Mediterranean Sea is unknown, most estimates suggest stock sizes in the hundreds rather than in the thousands (Reeves and Notarbartolo di Sciara, 2006). Given such low population numbers, there are major concerns over the impact of this type illegal fishing on this isolated population. Urgent management measures are clearly needed to monitor illegal fisheries and to protect cetaceans and other marine species, from the devastating effects of driftnet bycatch.

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