Deep-Sea Research II 88–89 (2013) 97–105

Contents lists available at SciVerse ScienceDirect

Deep-Sea Research II

journal homepage: www.elsevier.com/locate/dsr2

Biosonar, diving and movements of two tagged white-beaked dolphin in Icelandic waters

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ARTICLE INFO

Available online 16 July 2012

Keywords:
Bioacoustics
Echolocation
Marine mammals
White-beaked dolphins
Lagenorhynchus albirostris

ABSTRACT

For the first time bio-logging tags were attached to free-ranging white-beaked dolphins, *Lagenorhynchus albirostris*. A satellite tag was attached to one animal while an acoustic A-tag, a time-depth recorder and a VHF transmitter complex was attached to a second dolphin with a suction cup. The satellite tag transmitted for 201 day, during which time the dolphin stayed in the coastal waters of western Iceland. The acoustic tag complex was on the second animal for 13 h and 40 min and provided the first insight into the echolocation behaviour of a free-ranging white-beaked dolphin. The tag registered 162 dives. The dolphin dove to a maximum depth of 45 m, which is about the depth of the bay in which the dolphin was swimming. Two basic types of dives were identified; U-shaped and V-shaped dives. The dolphin used more time in U-shaped dives, more clicks and sonar signals with shorter click intervals compared to those it used in V-shaped dives. The dolphin was in acoustic contact with other dolphins about five hours after it was released and stayed with these for the rest of the tagging time. Possible foraging attempts were found based on the reduction of click intervals from about 100 ms to 2–3 ms, which suggests a prey capture attempt. We found 19 punitive prey capture attempts and of these 53% occurred at the maximum dive depth. This suggests that more than half of the possible prey capture events occurred at or near the sea bed.

1. Introduction

White-beaked dolphins (*Lagenorhynchus albirostris*) are only found in the North Atlantic (Reeves et al., 1999). They are the most common delphinid species in Icelandic waters (Gunnlaugsson et al., 1988; Gunnlaugsson and Sigurjónsson, 1990; Pike et al., 2009; Rasmussen and Miller, 2002; Víkingsson and Ólafsdóttir 2004). The acoustic repertoire of white-beaked dolphins consists of whistles (Rasmussen and Miller, 2002; Rasmussen et al., 2006) and clicks (Rasmussen and Miller, 2002; Rasmussen et al., 2002). North Atlantic Sightings' Surveys have been conducted in Icelandic waters since 1986, usually in July. The distribution of dolphins seemed consistent from aerial surveys conducted in 1986, 1987, 1995 and 2001 with dolphin sightings concentrated in the south-western, north-eastern and south-eastern parts of Iceland, in relatively coastal waters (Pike et al., 2009). Magnúsdóttir (2007) studied the annual distribution of white-beaked dolphins around Reykjanes Peninsula and she found white-beaked dolphins in Faxaflói Bay also during the winter. The corrected abundance estimate was 31,653 (95% CI 17,679–56,672) from the 2001 survey (Pike et al., 2009). Whale watching started in Iceland in 1991 (O'Connor et al., 2009) and white-beaked dolphins are among the most commonly sighted species on whale watching tours in Iceland (Rasmussen, 1999; Salo, 2004; Magnúsdóttir, 2007; Bertulli, 2010).

Rather little is known about the movements of white-beaked dolphins in Icelandic waters. Photo-identification studies have been conducted in Faxaflói Bay from 1997–2010 (Rasmussen, 1999, 2004; Magnúsdóttir, 2007; Bertulli, 2010). Rasmussen and Jacobsen (2003) showed that 12%–20% of the dolphins had markings that could be used for individual identification and the same individual was re-sighted up to nine times during a season. Bertulli (2010) found a total of 28 re-sightings of the same individual in Faxaflói Bay between 2007 and 2009. So far only a few re-matches of the same individual between areas have been found. One dolphin was photographed in Breiðafjörður and re-photographed in Skjálfandi Bay, Northeast Iceland. The dolphins

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http://dx.doi.org/10.1016/j.dsr2.2012.07.011

moved about 300 km in just a few days (Tetley et al., 2006). Three other individuals were photographed in Faxaflói Bay and re-sighted in Skjálfandi Bay in 2009 (Bertulli, 2010).

Satellite tags and radio tags have been deployed on many species of small cetaceans. Perrin et al. (1979) deployed various types of radio tags on spotted dolphins (*Stenella attenuata*) and spinner dolphins (*Stenella longirostris*). Scott et al. (1990) reviewed various methods for the tagging of small cetaceans and described the tagging of bottlenose dolphins (*Tursiops truncates*), Hawaiian spinner dolphins, common dolphins (*Delphinus delphis*), and white-sided dolphins (*Lagenorhynchus acutus*). Later Mate et al. (1994, 1995) deployed satellite tags on a white-sided dolphin and a bottlenose dolphin. The total estimated straight-line distance travelled by the white-sided dolphin was 308.9 km (Mate et al., 1994) and the overall distance travelled by bottlenose dolphins was at least 581 km (Mate et al., 1995). Satellite tags have been deployed on other species of odontocetes like on harbour porpoises (*Phocoena phocoena*) (Read and Westgate, 1997), belugas (*Delphinapterus leucas*) (Suydam et al., 2001; Hobbs et al., 2005) and narwhals (*Monodon monoceros*), (Dietz and Heide-Jørgensen, 1995; Dietz et al., 2001).

The diving behaviour of white-beaked dolphins is unknown. However, various time depth recorders (TDRs) have been used to study diving in other odontocetes (Baird et al., 2002, 2006, 2008; Otani et al., 1998; Westgate et al., 1995; Teilmann et al., 2007; Johnson et al., 2009). Hooker and Baird (2001) published a review on the subject describing the diving behaviour of 13 species of odontocetes. Of these, four were dolphin species: Common dolphins (*Delphinus delphis*), Heaviside's Dolphin, (*Cephalorhynchus heavisidii*), Pantropical spotted dolphins (*Stenella attenuate*) and Atlantic spotted dolphins (*Stenella frontalis*). Otani et al. (1998) and Westgate et al. (1995) described different types of dives for harbour porpoises. Otani et al. (1998) report V-shaped dives without a defined bottom time, which they classified as transit and travelling dives. Westgate et al. (1995) described U-shaped dives with a flat bottom phase lasting seconds to several minutes, which are believed to be foraging dives. Scott and Chivers (2009) recorded night-time U-shaped dives for spotted dolphins with rapid changes in depth ("wiggles") while at the bottom of the dive and suggested these occurred during the pursuit of prey.

Sigurjónsson and Vikingsson (1997) estimated that white-beaked dolphins in Icelandic waters feed mainly on fish (95%) and squid (5%). From indirect data Sæmundsson (1939) concluded that capelin and herring were the most common prey species in Icelandic waters. While confirming these two species as a part of the diet of white beaked dolphins, more recent studies identified larger fish such as haddock (*Melanogrammus aeglefinus*), cod (*Gadus morhua*), and saithe (*Pollachius virens*) as the most important constituents in the white-beaked dolphins' diet (Víkingsson and Ólafsdóttir, 2004). Inside Faxaflói Bay they also feed on sandeels (*Ammodytidae* sp.) (Rasmussen, 1999, 2004; Rasmussen and Miller, 2002; Bertulli, 2010).

Presumably they use their echolocation clicks to find prey and to navigate. Some properties of these signals have been investigated with a hydrophone or hydrophone arrays operated from small boats (Rasmussen and Miller, 2002; Rasmussen et al., 2002, 2004). Attaching acoustic tags on free-ranging dolphins is an effective method for studying how they use echolocation during prey capture. The most commonly used acoustic tags on small cetaceans, like porpoises, are A-tags, developed in cooperation with the National Research Institute of Fisheries Engineering in Japan (Akamatsu et al., 2005c). D-tags, developed at Wood Hole Oceanographic Institution in USA (Johnson and Tyack, 2003), have been deployed on larger odontocetes among other cetaceans. The A-tag has two hydrophones and necessary electronics to function as a 2-channel, high frequency, event-recorder to capture the ultrasonic clicks of odontocetes. A-tags have been used to describe echolocation behaviour of wild harbour porpoises (Akamatsu et al., 2007; Linnenschmidt et al., in press) and finless porpoises (*Neophocaena phocaenoides*) (Akamatsu et al., 2000, 2005a, 2005b, 2010). The D-tag samples the signal waveform at a high rate on two channels, among other behavioural parameters depending on the aim of the project. D-tags have been used to record both communication sound for example in narwhals (Shapiro, 2006), and to study foraging and echolocation behaviour for example in sperm whales (*Physeter macrocephalus*) (Miller et al., 2004), beaked whales (Zimmer et al., 2005; Johnson et al., 2004, 2006), short-finned pilot whales (*Globicephala macrorhynchus*) (Aguilar Sotoa et al., 2008), and captive harbour porpoises (Deruiter et al., 2009).

Often when interpreting the results from A-tags and D-tags it has been assumed that the echolocation behaviour of foraging toothed whales can be divided into search (long click intervals), approach (decreasing click intervals) and terminal or catch phases (very short intervals) often called 'buzzes'. These three phases were first described for echolocating bats when capturing insect prey (Griffin, 1958), but can also be applied to foraging odontocetes like captive harbour porpoises when capturing fish (Deruiter et al., 2009; Miller, 2010; Verfuss et al., 2009). Recordings of uninstrumented free-ranging narwhals also reveal click sequences that suggest foraging (Miller et al., 1995). Most of the odontocetes equipped with acoustic tags show click phases indicative of prey capture (Johnson et al. 2004, 2007; Linnenschmidt et al., in press; Miller et al., 2004; Madsen et al., 2005).

Many studies on echolocation behaviour of captive odontocetes especially the bottlenose dolphins are summarised in Au (1993) and Au et al. (2000). There are also studies describing the echolocation of wild dolphins using hydrophone-arrays (Au and Herzing, 2003; Rasmussen et al., 2002; Wahlberg et al., 2011). But, no studies exist describing the echolocation behaviour of free-ranging dolphins using acoustic tags.

Consequently, one aim of this study was to describe the acoustic and dive behaviour of a free-ranging dolphin using an attached A-tag and dive recorder. A second aim was to record the movements of a second white-beaked dolphin. This animal wore a satellite tag to record seasonal movements in Icelandic waters. The dolphins were captured in a hoop net with permission from Icelandic authorities (Nachtigall et al. 2008).

2. Materials and methods

The project was conducted in July and August 2006 in Faxaflói Bay, Southwest Iceland (see Fig. 3) for the purpose of capturing wild white-beaked dolphins to study hearing, movements and acoustic behaviour (Nachtigall et al., 2008; Mooney et al., 2009). We modified a fishing vessel with a platform on the bow for catching dolphins and a holding tank for maintaining dolphins during hearing studies and tagging. We spent around 340 h on the water and captured two dolphins using a hoop net. The dolphins were placed in a stretcher and lifted on-board into a tank with dimensions of $1 \times 1 \times 3.7$ m for the hearing experiment. Sounds were projected in front of the dolphin and suction cup electrodes were places on the head of the animal as well as a reference electrode on the dorsal fin. Before release the dolphins were equipped with tags (Nachtigall et al., 2008).

2.1. The acoustic tag package

The acoustic tag we used (A-tag, W20-AS, 2-channel, drift: 1 s per day, Little Leonardo, Tokyo, Japan) functions as an ultrasonic event recorder that registers the sound pressure (peak to peak (p–p) re 1 μPa) and the exact time of detection at each of two hydrophones, that are spaced about 120 mm apart. Signals are band pass filtered (55–235 kHz) and a hardware detection