Impacts of acoustic identity pinger tags on bottlenose dolphins (Tursiops truncatus)

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The use of active acoustic tags to study the movements and behavior of marine animals (mostly teleosts and elasmobranchs) has increased exponentially in the last two decades with over 40 000 tags deployed worldwide. Tags typically produce narrow band time-coded pulses in the 69 or 180 kHz frequency range. There is a growing concern of the impact of these tags on non-target animals which may be able to hear them. The response of wild bottlenose dolphins (*Tursiops truncatus*) to the sounds of a pinger tag was investigated. Two CPODS (automated cetacean click loggers) were placed on moorings 2 km apart and a single Vemco V16 69 kHz tag and dummy tag were alternated between moorings over a period of 5 months. Overall dolphin presence (detection positive hours per day) was significantly lower during impact periods, regardless of mooring location while encounter duration was significantly longer. Masking of dolphin detections on the C-POD is unlikely as the duration of the ping is very short (seconds) compared to the unit of measure of presence dolphins (hourly). Results show that the sound alone from acoustic tags may cause significant changes in dolphin distribution or acoustic behavior and further research is recommended.

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1. INTRODUCTION

Studying the movements of animals in the oceans is logistically challenging due to the large spaces, depths and harsh environments at sea. Biologging or telemetry is the use of animal-borne electronic devices ("tags") to gather data on the behavior and physiology of animals and the environment in which they move (McIntyre 2014). Telemetry is one of the most powerful techniques available to investigate animal movements and behavior at sea. Advances in computing power and battery life have lead to rapid developments in the capabilities of electronic tags used in this field, and scientific study using some form of telemetry has increased at exponential rates in the last two decades (McIntyre 2014, Hussey et al. 2015). Electronic tags can now be equipped with sensors to measure a wide range of parameters including animal movement at various degrees of precision (e.g. geolocation, ARGOS, GPS, accelerometers), temperature, conductivity, depth, sound and fluorescence and are even beginning to communicate amongst themselves (McIntyre 2014, Hussey et al. 2015).

Although the insight offered by telemetry into the lives of wild animals is unparalleled, there have been longstanding concerns over the impacts of the tags themselves on the animals and there is an acknowledged lack of research in the area, at least on marine mammals (McIntyre 2014). Such impacts include capture and attachment/insertion related injuries and stress (Guiler et al. 1987, Esch et al. 2009, Jewell et al. 2011, Sakai et al. 2011, Balmer et al. 2014), changes in behavior subsequent to capture or tagging (Elwen et al. 2006, Balmer et al. 2014) reduction or changes in swimming ability and subsequent survival (Todd et al. 1996, Gauther-Clerc et al. 2004, Balmer et al. 2014, van der Hoop et al. 2014) and the potential risk to predators from consumption of the tagged prey, amongst others.

Acoustic tags (also called ultrasonic coded transmitters UCTs; Cunningham et al. 2014) are a subset of the telemetry tools available to study marine animals. Acoustic tags produce a series of short duration, high frequency 'pings' typically around 69 kHz or 180 kHz, with a source level of 140 – 165 dB re 1 μPa at 1 m (Bowles et al. 2010, Cunningham et al. 2014). Tags may either produce pings continuously, for use in focal follow type studies (e.g. Jewell et al. 2012, Towner et al. 2015), or periodically, typically every 2 to 3 mins, for detection from a network of moored receivers (Cowley et al. 2014, Iverson & Whoriskey 2014). In addition to the general ethical concerns mentioned above, the sounds produced by acoustic tags have the potential to affect both the tagged animal and those around it.

The pings generated by acoustic tags are routinely assumed to be above the hearing capabilities of fish (Popper et al. 2004, Popper & Hastings 2009), although they are well within the audible range of many cetacean (Richardson et al., 1995) and pinniped species (Bowles et al. 2010, Cunningham et al. 2014). For example, common bottlenose dolphins (*Tursiops truncatus*), the focal species in this study, are most sensitive at 45 kHz, with good hearing between 15 kHz and 100 kHz (Au 1993, Popov et al. 2007, Au et al. 2009). This coincides with the frequency at which they produce both communication signals (such as whistles, Janik 2009) and echolocation clicks (Au 1993). Although information on hearing in mysticete cetaceans is extremely limited, they are low frequency vocal specialists and unlikely to be particularly sensitive at the frequency range used by acoustic tags (Southall et al. 2007).

Studies of captive pinnipeds have shown that these animals are capable of both hearing the sound of 69 kHz pinger tags (Cunningham et al. 2014) as well as learning to associate that sound with food (Stansbury et al. 2015). Although captive studies are extremely valuable to understanding the behavior and responses of individual animals in controlled environments, the results do not always transfer well to natural settings where responses and acoustic behavior may be additionally affected by a range of intrinsic or extrinsic factors such as behavior, group size, calf presence (Badenas Krakauer 2016, Gridley et al. 2016, Heiler et al. 2016), motivation state (e.g. hungry or well fed) or the presence of additional background noises or predators. No single study approach allows for all these factors to be accounted for simultaneously. Studies of the response of marine mammals to human impacts or around acoustic receivers have typically used either a shored based approach, often using a theodolite to accurately measure distances and locations of animals (e.g. Nuuttila, Thomas, et al. 2013, Götz & Janik 2015) or passive acoustic monitoring (e.g. Leeney et al. 2007, Carlström et al. 2009, Todd et al. 2009, Williamson et al. 2016) to infer presence and behavior from the sounds produced by the animals themselves. The low aspect of the coastline in Walvis Bay largely ruled out a shore based approach for this study. Although PAM is subject to several of the limitations mentioned above, it has the benefit of collecting data continuously over long periods allowing for large sample sizes, and importantly collects data on the underwater behavior of animals where they spend the majority of their time, rather than just the brief surfacing events seen from shore-based studies. The use of a control-impact study design overcomes many of complicating variables, notably those related to the environment such as variation in transmission loss or received level with environment or weather conditions as these conditions are equivalent between sites.

The goal of this study was to investigate the responses of free-swimming, wild bottlenose dolphins in the vicinity of an acoustic pinger. We investigate the potential effect of the intermittent pings generated by a single Vemco V16 69kHz tag on wild common bottlenose dolphins over a period of several months. Dolphins in the study area were presumed to be naïve to the sound of acoustic pinger tags, as to the best of our knowledge no acoustic tags have been deployed on any fish in Namibian waters. The nearest study site using acoustic telemetry is in southern Angola, approximately 800 km to the north (Iverson & Whoriskey 2014). Thus, dolphins in the study population had no reason to associate the sound of the tag with either prey or predator and we could investigate their response to the sound only. Three types of response were possible: no response, attraction to investigate a novel stimulus as has been observed for seals near acoustic deterrent devices (Bordino et al. 2002) or avoidance of a disturbing stimulus.

2. METHODS

The study took place in Walvis Bay, Namibia, which is a north-facing, shallow bay (mostly < 15 m deep), approximately 10 km x 10 km in area with a muddy/sandy bottom. Walvis Bay is the only embayment of significant size along the Namibian coastline providing shelter from strong southwesterly swells and winds. Human activities in the bay include a commercial and fishing harbor which is currently undergoing seaward expansion, oyster and mussel aquaculture and a large boat-based marine tourism industry focused on dolphin watching (27 boats operating in 2010, Leeney 2014, and no major changes since then).

The Namibian population of coastal bottlenose dolphins is apparently isolated from other bottlenose dolphin populations along the west coast of Africa (Best 2007) and numbers fewer than 100 individuals. Walvis Bay is thought to be the center of their range along the Namibian coast and represents an important habitat for this population, providing both shelter from the prevailing weather and good foraging opportunities, especially in the shallow lagoons on the southern end of the bay. Boat surveys were conducted to collect distribution and photo-identification data from cetaceans in the bay at the same time as the current study.

To investigate the effect of acoustic pinger tags on bottlenose dolphin behavior, we used a simple control-impact study design, broadly following the design used by Leeney et al. (2007) to investigate the effect of acoustic deterrent devices (ADDs) on common bottlenose dolphins in the Shannon River estuary, Ireland. We set up two moorings 2 km apart in 10 m of water depth, on the north-eastern side of the bay, in an area known to be frequented regularly by bottlenose dolphins. All instruments were set up to be mid-water depth approximately 5m from the sea floor. A single Vemco V16-6x-L, 69 kHz tag (152 dB source level, 180 sec ping rate) and an inactive dummy tag with an expired battery, were alternated between the moorings approximately biweekly for a period of 5 months. A Vemco VR2W receiver was moored on a single mooring to ensure 1) that no other tags were detected, 2) to confirm ad hoc that that the tag was not detectable when on the alternate mooring and 3) that the tag was operating when on the same mooring. The V16 tags tested in this study are regarded as having effective detection radius in the order of 500 m, although they can be regularly detected to over 1000 m in some conditions (Kessel et al. 2015). An initial deployment period where the moorings were only 1500 m apart resulted in regular detections of the tag from the control mooring during the calm mornings typical in the area. Data from this period were excluded from this study.

A C-POD (cetacean and porpoise detector, www.chelonia.co.uk), was attached to each mooring, just above the active or inactive tag. C-PODs (and their predecessors T-PODs) record summaries of tonal ultrasonic clicks as the input to a process that identifies click trains and classifies the likely source. This is carried out on a PC following each deployment using custom designed software CPOD.exe. They are well proven click detectors capable of long-term deployments to detect broad band clicking dolphins including bottlenose dolphins (Bailey et al. 2009, Elliott et al. 2011, Leeney et al. 2011, Nuuttila et al. 2013), narrow-band high frequency clicking species such as porpoises (Koschinski et al. 2008, Kyhn et al. 2012) and Heaviside's (*Cephalorhynchis heavisidii*) dolphins (Leeney et al. 2011), as well as differentiating boat sonars. C-POD detections can be used to infer dolphin behavior relative to the moorings and tag presence (Leeney et al. 2007). C-PODs can detect common bottlenose dolphins up to 1200 - 1300 m away (Philpott et al. 2007, Elliott, Dawson, & Rayment 2011) and possibly even further (Nuuttila, Thomas, et al. 2013), but the effective detection radius (the distance at which there is a 50% probability of detection) is much smaller, in the 200 – 500m range, varying slightly with behavior, local sound conditions and ambient noise levels (Nuuttila, Thomas, et al. 2013). Dolphin click detections can be exported from the custom C-POD.exe software at a range of scales from individual click and click-train parameters to detection positive minutes per hour (DPM/H) and detection positive hours per day (DPH/D).

Detection data from the C-PODs were downloaded approximately monthly and all data were subjected to careful visual validation of detections (author NT) to check on data quality and to remove likely false positives. Click presence data measured at the scale of minutes is likely to be auto-correlated and influenced by dolphin group size and behaviour (Badenas Krakauer 2016). Encounter duration, defined as continuous periods of dolphin detections (dolphin positive minutes) separated by at least 10 min of no detections was measured. As no encounter was longer than 1 hr and the majority were less than 30 minutes, detection positive hours (DPH) were used as an independent measure of dolphin presence.

As the study used only acoustic methods, it was not possible to account for factors such as group size, calf presence or group membership, all of which are factors which may affect general as well as acoustic behavior of dolphins (Badenas Krakauer 2016, Gridley et al. 2016, Heiler et al. 2016). The goal of this study was to investigate overall levels of dolphin presence in the vicinity of an acoustic pinger and is similar in design and assumptions to a number of other studies using passive acoustic monitoring to investigate potential impacts (Leeney et al. 2007, Carlström et al. 2009, Todd et al. 2009, Williamson et al. 2016). Thus, the response of dolphins was tested in three ways: 1) within moorings, between control and impact periods, 2) between moorings (using only data from periods when both moorings were simultaneously operational) and 3) the duration of acoustic encounters around the moorings during control and impact periods using non-parametric Kruskal-Wallis tests.

3. RESULTS

Between 08 July and 21 Nov 2015, 5284 full hours of CPOD data were recording from the two moorings sites combined, resulting in 2784 hrs of control period and 2500 hrs of impact period on both moorings combined. After removal of partial hours and days of recording resulting from deployment or recovery days, 88 full days (24 full hours of recording) were available for analysis in which both moorings were fully operational.

Looking at only days when a full 24 hours was recorded on both instruments, dolphins were detected at both moorings on a regular basis with detections occurring in up to 8 hrs in any one day (Fig. 2), although detections were not necessarily continuous within those periods. Although dolphins were regularly recorded at both moorings within a day, the general pattern observed was that of avoidance of the mooring on which the acoustic pinger tag was deployed (Fig. 2, 3). Of the 34 days during which the impact tag was on the southern mooring, detections (DPH/day) were higher on the control mooring on all 18 days on which dolphins were detected. Of the 54 days during which the impact tag was on the northern mooring, detections were higher on the control mooring on 17 days versus 5 days when detections were higher on the impact mooring.

Dolphin detections, measured as detection positive hours per day differed significantly between control and impact periods both within moorings (north mooring, KW chi-squared = 15.4586, df = 1, P = <0.001 and south mooring, KW chi-squared = 5.3091, df = 1, P = 0.021) (Fig. 2,3) and between moorings (paired Wilcoxon test for pinger on south mooring: V = 190, P = < 0.001, and pinger on north mooring: V = 108, P = 0.0276). Conversely, the duration of acoustic encounters (periods of detections separated by longer than 10 mins of no detections), were on average longer during impact than control periods (Fig. 4, 5, KW chi-squared = 17.4044, df = 1, p-value = < 0.001) with mean encounter duration equal to 7.56 and 11.41 mins for control and impact situations respectively. This pattern was driven by a higher proportion of short encounters during control periods with maximum encounter durations similar between control and impact periods (Fig. 5)

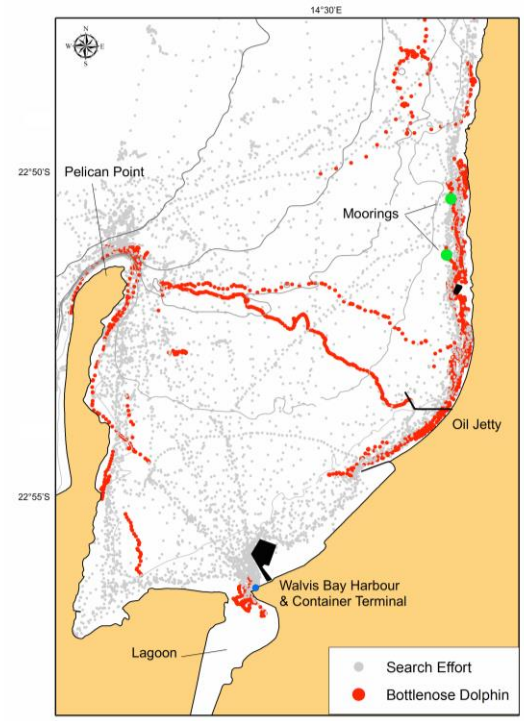

Fig 1. Map of the study area, showing location of the harbor, moorings sites (green dots) and search tracks followed by the research boat (grey dots, one per minute) during the study period and locations of bottlenose dolphins during focal follows (red dots, one per minute).

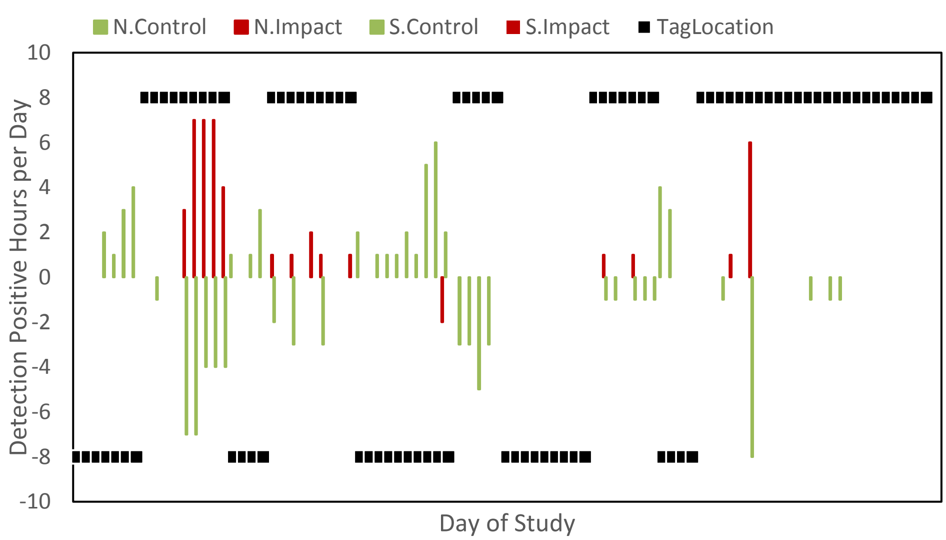

Fig 2. Detections of common bottlenose dolphins on two C-POD hydrophones moored 2000 m apart in Walvis Bay, Namibia. Detections shown as Detection Positive Hours per Day (DPH) with values inverted for south mooring for display purposes. Location of Vemco V16 acoustic pinger tag at north or south mooring shown as a single point for each day at y-axis value of 8 or -8. Data only shown for 88 days between 08 July and 21 Nov 2015, where a full 24 hours was recorded on both moorings.

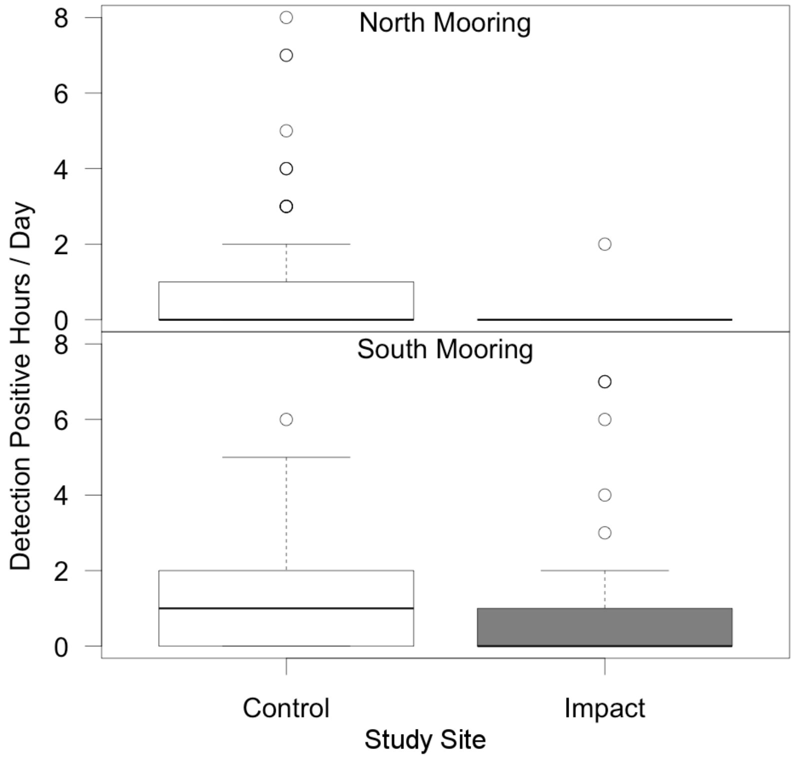

Fig 3. Boxplots showing detection positive hours per day around each C-POD hydrophone mooring site for impact (active Vemco V16 69kHz tag on mooring) and control periods (inactive tag on mooring). Boxplot shows median, interquartile limits IQR (box), 1.5xIQR (whiskers) and outliers (dots).

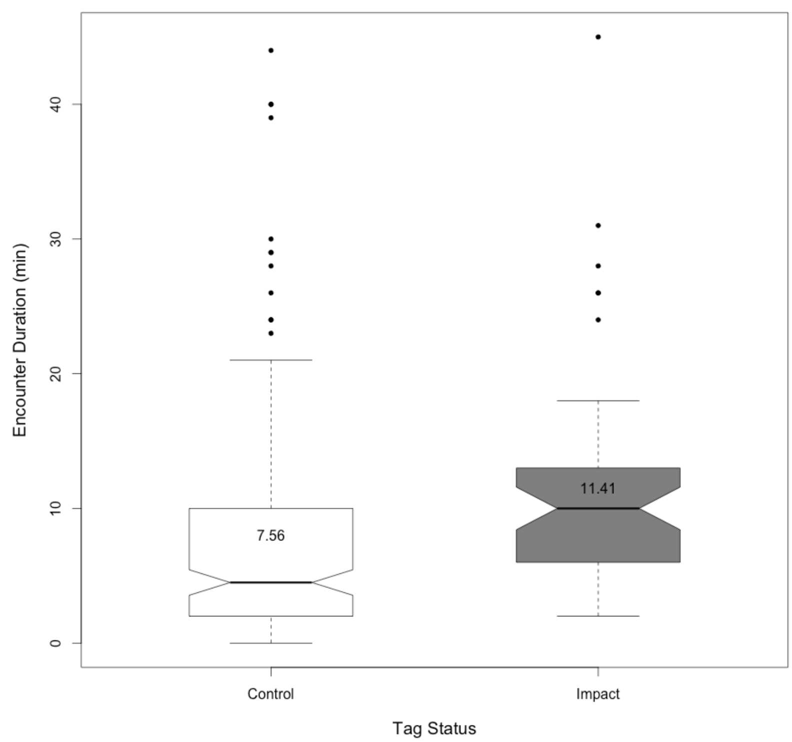

Fig 4. Boxplot showing the duration of acoustic encounters (i.e. periods of dolphin presence separated by more than 10 mins of no detections), during impact (active Vemco V16 69kHz tag on mooring) and control periods (dud tag on mooring). Boxplot shows median, interquartile limits quartiles IQR (box), 1.5xIQR (whiskers) and outliers. Mean values shown as text on boxes.

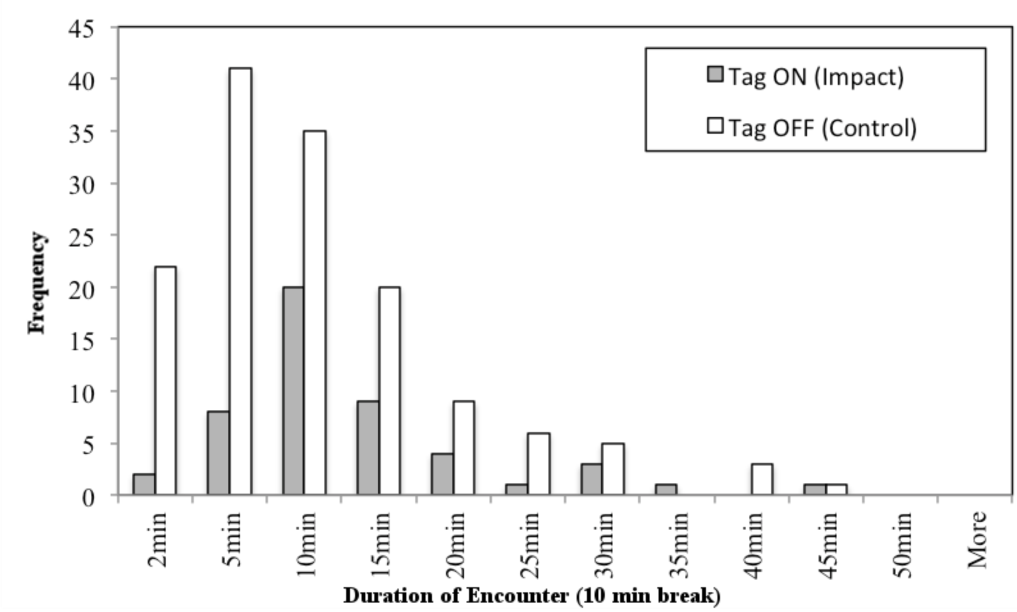

Fig 5. Histogram of encounter duration of bottlenose dolphins around C-POD hydrophones during impact (active Vemco V16 69kHz tag on mooring) and control periods (inactive tag on mooring), excluding single minute detections.

4. DISCUSSION

In this study, we used two passive acoustic listening devices placed on moorings 2 km apart to investigate the potential impacts of a 69 kHz acoustic pinger tag on the presence of bottlenose dolphins. Dolphin detections (hours with dolphins present) were lower when the active tag was present on the mooring than during periods when it was not, both within and between moorings. Dolphin behavior was not confirmed visually during this study and the observed pattern could theoretically also be explained by two alternate mechanisms; 1) dolphins echolocate less in the presence of the tag or 2) the presence of the tag decreased dolphin detections. Although we cannot entirely discount reduced echolocation near the impact mooring, and echolocation rate has been shown to vary with behavior, dolphins do echolocate regularly in all behavioral states observed in this population (Badenas Krakauer 2016). Any reduction in echolocation rate would have been masked by the use of the hourly time scale for description of presence or absence and the regular detection of dolphins on the impact mooring support this. Reduced detection of dolphin echolocation due to masking by the tag ping is also unlikely as the duration of the tag ping is very short and only occurred every 2 min and thus, the patterns observed are thus likely to reflect dolphin presence in the vicinity of the two moorings.

The control and impact moorings were placed only 2km apart, in an area known to be used regularly by dolphins. The rocky reef in this area results in very fine scale patterns of habitat preference by the dolphins, and moving the moorings further apart would likely have resulted in much larger differences in attendance patterns between the two moorings. Significant decreases in detections of bottlenose dolphins occurred both within and between mooring locations suggesting that the observed pattern was independent of location. Dolphins were regularly detected on both moorings within a day, although the general pattern of attendance showed avoidance of the mooring with the active tag, regardless of mooring. Since there are no studies in the areas using pinger tags, it is assumed that dolphins in this population were naïve to sounds of the tag and any association of the sound with either potential predators or prey, and were thus reacting solely to the acoustic component of the stimulus. The response detected is similar to that observed for bottlenose dolphins (Leeney et al. 2007) and harbor porpoises (Culik et al. 2001) around acoustic deterrent devices, which are explicitly designed to deter marine mammals from an area.

The observation of increased encounter durations during impact periods appears to contradict the general pattern of avoidance described above. This pattern may be explained as 1) a social effect, for example a subset of curious animals investigating the impact pinger extensively, 2) prey related effects whereby fish number, species or behaviour and thus the dolphin's hunting techniques may differ between impact and control conditions. Figure 5 suggests that the difference is not driven by a few occurrences of long encounters, but rather by a higher proportion of short encounters in control situations, at least partially ruling our social effects. Play-back experiments to captive fish have shown several species to change to either a faster or slower swimming speed or deeper depth in response to acoustic deterrent devices (Kastelein et al. 2007). No similar data are available for local fish species, but an effect of the pinger on fish behavior cannot be ruled out and would benefit from further study.

Acoustic pinger tags are one of the most widely used forms of animal tracking in the oceans. The Ocean Tracking Network (OTN) is a research and technology platform that has coordinated and conducted research using acoustic pinger tags, receivers and associated equipment globally since 2008. More than 90 species of marine animal have been tracked by over 400 researchers in 18 countries with over 40 000 tags released resulting in nearly 100 million received data records in the OTN databases at the end of 2014 (Iverson & Whoriskey 2014 and OTN Data Warehouse). The total number of pings produced by these tags is not available or easily calculable due to the differences in longevity and ping rate, but presumably the number received by the (predominantly) statically moored receivers is only a fraction of the total number produced. This represents a significant and growing amount of potential acoustic pollution produced by the scientific community in the pursuit of knowledge.

Acoustic pinger tags are sometimes referred to as 'ultrasonic coded transmitters' (Cunningham et al. 2014), but this is clearly a misnomer as they are only ultrasonic to some animals, notably humans and most, but not all fish species (Popper et al. 2004), although hearing in fish is generally not well studied. There is good evidence that several phocid and otariid seal species can hear the signals produced by acoustic tags in the 69-83 kHz range (Bowles et al. 2010, Cunningham et al. 2014) and grey seals have been shown to be able to hear (and avoid) the pulses made by 200 and 375 kHz commercial sonar systems, as elements of the sound produced extend in the frequencies audible to the seals (Hastie et al. 2014). Although narrow-band in nature, acoustic pinger tags also produce brief broadband pulses at the onset and end of the coded pulses (Bowles et al. 2010), and it is thus likely that tags which use the 180 kHz range may also be audible to many species of marine mammal.

Grey seals have learned to associate the sound of pinger tags with fish presence in a captive study (Stansbury et al. 2015). We only investigated the impact of the sound on the behavior of dolphins, but it is likely that dolphins could also learn to associate the sounds of tags with food if sufficient prey animals in their environment were fitted with pinger tags. This so-called 'dinner bell' effect, was first reported for Chinook salmon where high loss rates of tagged fish were linked to at least some level of marine mammal predation (Wargo Rub et al. 2012). Whether the potential increase in food availability to dolphins would counteract the effects of habitat potentially lost by avoidance is unknown and would be extremely challenging to study effectively in the wild. Given the patterns observed in this study as well as the evidence discussed above for the hearing of and response to supposedly ultrasonic tags and sonar by both cetaceans and pinnipeds

(Cunningham et al. 2014, Hastie et al. 2014, Stansbury et al. 2015) it is advisable that the scientific community making use of acoustic telemetry use a cautionary approach.

5. CONCLUSION

Several potentially important covariates such as individual differences in responses and variation with habitat or behavior were not addressed by the relatively simple study design used here. Thus, we are careful in drawing wide ranging conclusions based on the results of this study. However, the apparent avoidance of the area ensonified by the active pinger may cause concern if the results are validated elsewhere. Our study could have important implications for the use of active acoustic tags in the study of wild fish populations. High use in localized areas such as reefs, could theoretically result in avoidance of these areas by acoustically sensitive marine mammals, with likely negative implications for both the animals as well as biased results for any research. Further study into both the short and long-term behavior of dolphins and seals around acoustic pinger tags is clearly needed to address some of these issues and investigate responses in a wider range of species.

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