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A Long-Term Opportunistic Photo-Identification Study of Bottlenose Dolphins (*Tursiops truncatus*) off Aberdeen, United Kingdom: Conservation Value and Limitations

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Abstract

The waters of the Inner Moray Firth were designated a Special Area of Conservation (SAC) in 2005 for the conservation of the bottlenose dolphin (*Tursiops truncatus*) in northeast Scotland. However, the long-term conservation of this population requires monitoring throughout its entire known range. Opportunistic photo-identification of bottlenose dolphins occurred during 65 cetacean surveys conducted between 1999 and 2008 in the coastal waters of Aberdeenshire. A total of 88 bottlenose dolphin photo-identification encounters resulted in one to 45 animals identified per survey. The minimum annual total population size based on marked animals alone was 62 individuals, and the discovery curve indicated that the population has not yet been adequately sampled. Of 40 highly distinctive adult animals, the annual sighting rate ranged from 0.167 (seen in one year only) to 1.000 (seen every year). The cumulative monthly sighting rate varied from 0.091 (photographed in one month only) to 0.636 (photographed during seven of the 11 combined survey months in the 2001 to 2008 study period). The overall seasonal occurrence of dolphins off Aberdeenshire peaked during May and June, when 65% of distinctively marked animals were recorded per month (combined data for 2001 to 2008). Eighty-four percent of distinctively marked dolphins were matched with those photographed in the Inner Moray Firth, while 93% were matched with those photographed in the southern Outer Moray Firth. Despite its opportunistic nature, the photo-identification study provided valuable information on a population of bottlenose dolphins in a poorly studied part of their range. The high percentage of matches with dolphins from the Moray Firth SAC indicates that over half of the known northeast Scotland population uses the Aberdeenshire region, and some individuals do so regularly. The frequent occurrence off Aberdeen of bottlenose dolphins from a protected SAC has repercussions for the conservation and management of the population and for the effectiveness of the SAC for their long-term protection.

Key Words: photo-identification, population size, distribution, marine protected area (MPA), Aberdeen, bottlenose dolphin, *Tursiops truncatus*

Introduction

The development of effective population conservation/management plans and the mitigation of potential anthropogenic impacts upon a population depend on knowledge of several factors: (1) the size of the population, (2) population status, and (3) the spatio-temporal distribution of the population (Evans & Hammond, 2004). Most animal monitoring programmes are carried out primarily to detect trends in population size (Marsh & Trenham, 2008). However, establishing a long-term monitoring programme for cetaceans is scientifically challenging and often costly, requiring considerable field and analytical resources. Cetacean population size can be estimated using distance sampling or mark-recapture techniques (Evans & Hammond, 2004). The latter method is the most economical and is widely used for long-term monitoring of suitable cetacean species, relying on the presence of unique natural features (e.g., the size and location of notches and cuts on dolphin dorsal fins; Würsig & Jefferson, 1990) to identify individual animals. The data required to estimate population size using mark-recapture analysis are representative sets of good-quality images of individual animals from two or

more sampling occasions (Evans & Hammond, 2004). Mark-recapture analyses make a number of assumptions, including (1) that marks are recognisable with certainty during recaptures, (2) that marks do not change to the extent that they affect subsequent recognition, (3) that marked animals do not demonstrate behavioural responses that affect the probability of their recapture, and (4) that all individuals have the same probability of capture within a sampling session (Hammond, 1986).

Off the northeast coast of Scotland, an ongoing long-term photo-identification study of the bottlenose dolphin (*Tursiops truncatus*, Montagu, 1821) has been conducted by the University of Aberdeen (UoA) in the Inner Moray Firth since the late 1980s (Wilson, 1995; Wilson et al., 1999). Bottlenose dolphins are listed on Annex II of the EC Habitats and Species Directive (92/43/EEC), which includes "species of community interest whose conservation requires the designation of Special Areas of Conservation (SAC)." In March 2005, an area of the Inner Moray Firth (Figure 1) was designated as a marine SAC for the conservation of the bottlenose dolphin population, which is estimated to contain approximately 130 individuals (Wilson et al., 1999). However, members of this population are known to regularly inhabit coastal waters throughout the southern Moray Firth (Lewis & Evans, 1993; Robinson et al., 2007; Culloch & Robinson, 2008) and south along the east coast of Scotland to at least the Firth of Forth (Wilson et al., 2004; Stockin et al., 2006). A southerly range expansion has been proposed in recent years (Wilson et al., 2004). Understanding the long-term status of this dolphin population and implementing appropriate conservation measures therefore requires monitoring throughout their known range.

The waters around Aberdeen are regularly inhabited by bottlenose dolphins, and boat surveys have been completed along the Aberdeenshire coast since 1999 with the aim of monitoring the distribution and seasonal occurrence of bottlenose dolphins and other cetaceans in the region (Weir & Stockin, 2001; Canning, 2007). Photo-identification was conducted on an opportunistic basis during these surveys, and images of bottlenose dolphins were compiled into a central

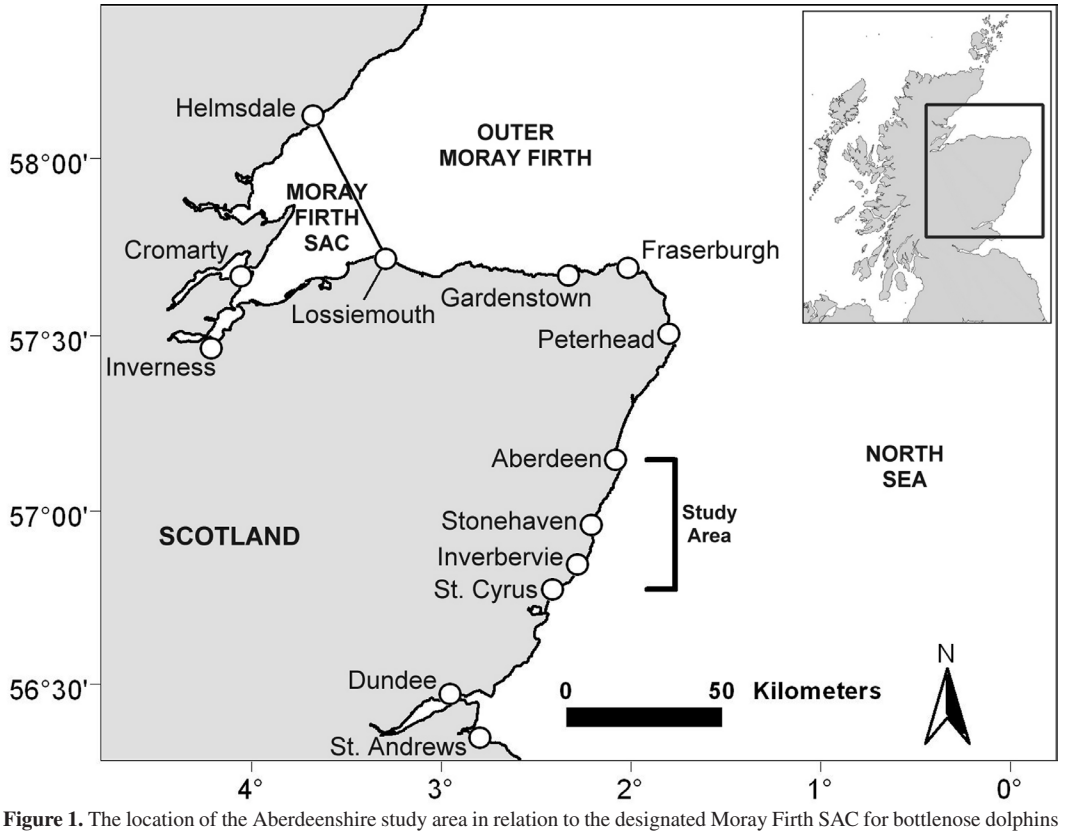

Figure 1. The location of the Aberdeenshire study area in relation to the designated Moray Firth SAC for bottlenose dolphins (*T. truncatus*)

resource—the *Aberdeenshire Cetacean Catalogue* (*ACC*) (2008).

Here, we consider the value of the opportunistic photo-identification surveys conducted off Aberdeenshire between 1999 and 2008, evaluating their potential contribution to the conservation and management of the northeast Scotland bottlenose dolphin population. The three main objectives of this study were (1) to calculate the minimum population size in Aberdeenshire waters, (2) to examine annual and seasonal site fidelity, and (3) to establish the extent of the link with the Moray Firth dolphin population. The value and limitations of this long-term opportunistic photo-identification dataset are discussed.

Materials and Methods

Data Collection

Boat-based cetacean surveys were conducted in shallow (< 20 m bottom depth), coastal (< 1.5 km offshore) waters off Aberdeenshire in northeast Scotland (Figure 1) between May 1999 and May 2008. Surveys were opportunistic rather than systematic and depended on various factors, including availability of the boat and personnel, funding, and prevailing weather conditions. A 10-m motor boat was used to survey the waters between Stonehaven and Aberdeen (return trip of 48 km taking approximately 4 h). Three surveys ran southwards from Stonehaven to St. Cyrus (return trip of 50 km taking approximately 4 h). Between two and eight observers (at 3 m eye height) scanned continually for cetaceans with the naked eye and through the use of 8-10× binoculars. Standardised data forms were used to record the vessel position (GPS), course, speed, and environmental data (Beaufort sea state, swell, and visibility) at 15-min intervals. When cetaceans were sighted, data were recorded detailing the species, time, position, environmental conditions, behaviour, and group size/composition (see Stockin et al., 2006). Opportunistic photo-identification surveys carried out from other vessels and from shore (at Aberdeen Harbour, Girdleness, and Cove) were also included in the analysis of minimum population size.

Not all surveys during the 1999 to 2008 study period focused on photo-identification. However, only those surveys in which bottlenose dolphin images were taken are considered here, and the photographed sightings are termed *bottlenose dolphin encounters* for the remainder of this paper.

Images were taken using 35-mm transparency film (1999 to 2005) or digital SLR equipment (2006 to 2008). Prior to 2006, the research emphasis was on the collection of baseline distribution data, and photographs were taken opportunistically during dolphin encounters without concerted effort to ensure that every individual in the group was photographically *captured*. Since June 2006, the research emphasis focused more on photo-identification work; thus, more rigorous attempts were made to photograph as many animals as possible within each group.

Photo-Identification Analysis

All nondigital images were scanned at high resolution (4,000 dpi) and converted to an electronic format. Each image was linked to a database containing the survey date, photographer, time and position of the sighting, and group size. Images were graded with a quality rating based on the focus, angle, and size of the fin within the image (1 = poor to 3 = excellent, following Parsons, 2003). Photographs of grades 2 and 3 were primarily used to identify and catalogue individuals using standard methods (Würsig & Jefferson, 1990). However, some grade 1 images were used when highly distinctive animals could be recognised. Recognisable individuals were coded in separate, mutually exclusive categories according to whether they exhibited permanent (e.g., nicks, notches, damaged fins, or diagnostic fin shape) or temporary (e.g., depigmentation, skin lesions, scars, scratches, tooth rakes) features on their dorsal fin, with the former category having priority (i.e., individuals bearing both permanent and temporary markings would be coded as permanently marked). The recognition of individuals and their visibility within images of different grades depended on the distinctiveness of each animal. Individual animals with permanent fin markings (or other obvious features such as fin shape or spinal deformities) were therefore assigned a distinctiveness value (DV), varying from 1 (subtle or small notches) to 3 (deep nicks and cuts, which were evident even in poor-quality images) (Heinrich, 2006). All identified animals were catalogued in the *ACC* (2008).

Data Analysis

Three independent analyses were carried out on the data: (1) calculation of minimum population size in Aberdeenshire waters, (2) analysis of annual and seasonal site fidelity, and (3) matching of individual dolphins between the *ACC* and two dolphin catalogues for the Moray Firth region.

The term *population* is defined here as those bottlenose dolphins frequenting the Aberdeenshire study area rather than having genetic or absolute abundance implications. The minimum population size was calculated on an annual basis since temporary features (scratches and scars) used to identify individuals might heal and even permanent features may change over relatively short

temporal periods. The total minimum population size was calculated as the number of recognisable individuals recorded. Within each year, this calculation included (1) all animals bearing permanent dorsal fin features, (2) animals with temporary features where both left and right side images were acquired, and (3) animals with temporary features wherein only one side was photographed. In the latter category, either the left- or the right-side images were analysed each year, depending on which side had been photographed for the most individuals. Since the minimum population size was being calculated separately per survey year and did not involve mark-recapture or calculation of absolute abundance (where it is important to know the number of unmarked animals within the population), images of all quality and distinctiveness were used, together with data collected from all platforms. This was because the aim was simply to calculate the minimum number of individuals identified in Aberdeenshire waters each year, and both poor-quality images showing highly distinctive animals and high-quality images showing relatively poorly marked animals were relevant for this analysis.

The analyses of site fidelity were restricted to animals with DVs of 2 or 3 to reduce the likelihood of false negatives/positives. Only data from dedicated cetacean boat surveys were used in these analyses to improve the probability of identifying animals. Since the number of photo-identification surveys in 1999 and 2000 was low (Figure 2), only data from 2001 to 2008 (total = 8 y) were used to examine site fidelity. Three parameters were investigated: (1) annual sighting rate (ASR), (2) monthly sighting rate (MSR), and (3) cumulative monthly sighting rate (CMSR).

The ASR was calculated as the number of years in which a dolphin was photographed as a proportion of the total number of years surveyed (Parra et al., 2006). An individual observed in only one survey year would have an ASR of 0.125, while an animal photographed in all 8 y (i.e., at least once annually in each of eight survey years) would have an ASR of 1.000. Since many of the individual dolphins were not encountered off Aberdeenshire until 2006, a corrected version of the ASR was also calculated using only those years since (and including) the year of first photographic capture. Animals first photographed in 2008 (n = 2) were eliminated from the analysis because of the zero potential for their recapture in subsequent years.

The MSR was calculated as the total number of individual months in which a dolphin was photographed as a proportion of the total number of individual survey months over the 2001 to 2008 study period in which at least one photo-identification survey was conducted (n = 36 mo) (Parra et al., 2006). A dolphin recorded in only one of the 36 survey months would have an MSR of 0.028, while an animal occurring in all 36 mo would produce a MSR of 1.000.

Since surveys were not conducted in each month of every year, a CMSR was also calculated using the annually combined monthly data over the 2001 to 2008 study period to indicate whether individual dolphins utilised Aberdeenshire waters at particular times of the year or year-round. At least one (and up to 12) photo-identification surveys were carried out in every annually combined month except for January. The CMSR was calculated as the number of annually combined months a dolphin was photographed in as a proportion of the annually combined number of months in which at least one photo-identification survey was conducted (n = 11 mo). A dolphin recorded in only one of the 11 possible annually combined survey months would have a CMSR of 0.091, while an animal occurring in all 11 mo would produce a CMSR of 1.000.

Overlap with the Moray Firth Dolphin Population

Individual dolphins with DVs of 2 or 3 (n = 44) in the *ACC* were matched with dolphin catalogues from two other areas: (1) the Inner Moray Firth via a catalogue maintained by the UoA Lighthouse Field Station at Cromarty and (2) the southern Outer Moray Firth between Lossiemouth and Fraserburgh via a catalogue maintained by the Cetacean Research and Rescue Unit (CRRU).

Results

Photo-Identification Effort and Bottlenose Dolphin Encounters

Eighty-eight bottlenose dolphin photo-identification encounters were recorded during a total of 65 surveys between May 1999 and May 2008, comprising 49 dedicated cetacean boat surveys, an additional three encounters from other vessels, and 13 encounters from shore-based sites (Aberdeen Harbour, Girdleness, and Cove). The 65 photographic surveys were not distributed evenly over the 1999 to 2008 study period, with the number of surveys increasing over consecutive years (Figure 2A) and showing a strong seasonal peak between April and June (Figure 2B).

Dolphin encounters were distributed throughout the surveyed coastline (Figure 3), with particular clusters of sightings between Stonehaven and Muchalls and in the region of Aberdeen Harbour. The number of photographic encounters per cetacean boat survey ranged from one to three, and the number of individual animals photographed during each survey varied from one to 45 animals. Mean group size during bottlenose dolphin encounters was

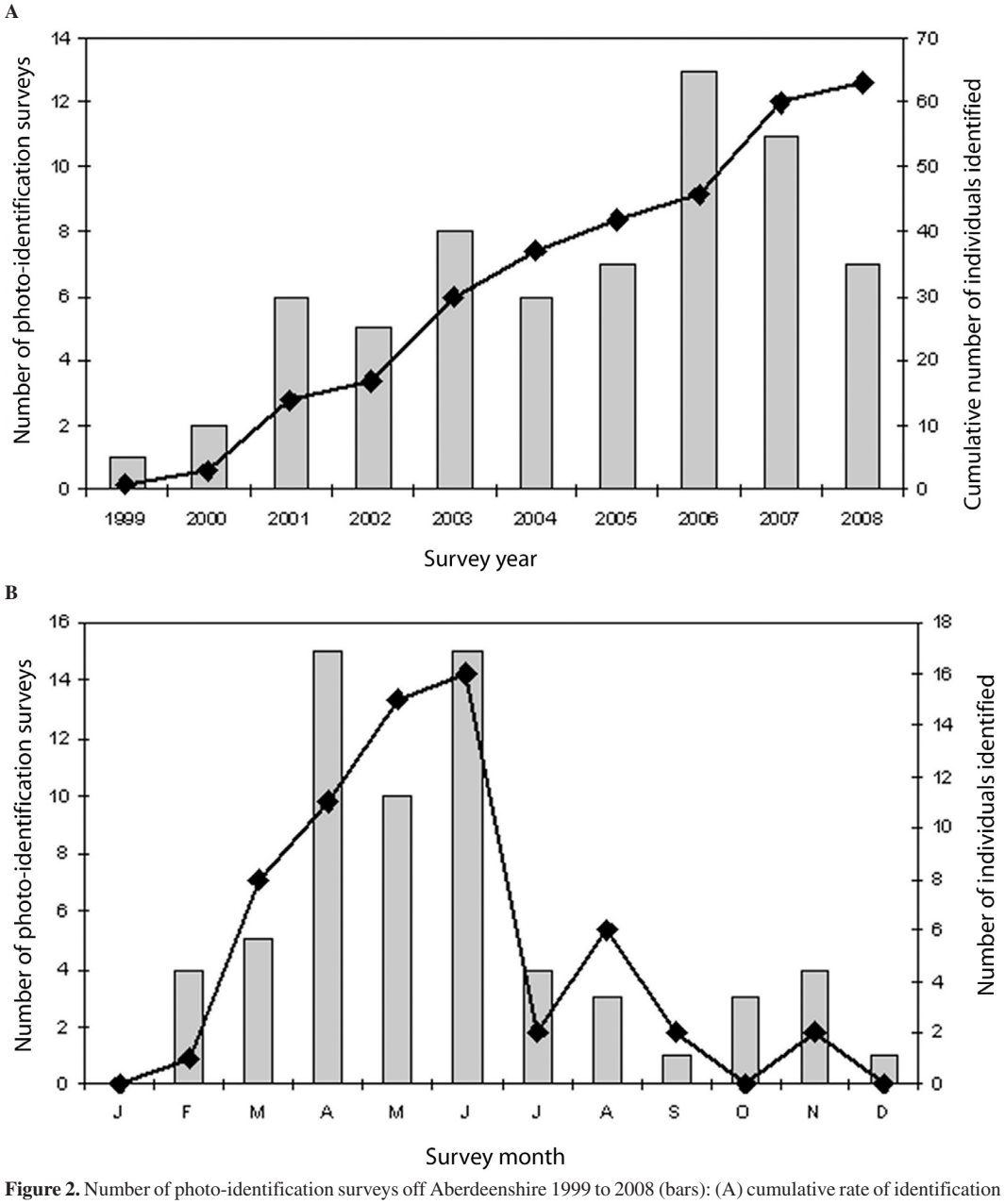

Figure 2. Number of photo-identification surveys off Aberdeenshire 1999 to 2008 (bars): (A) cumulative rate of identification of new bottlenose dolphins (*T. truncatus*) (line) over time ("rate of discovery"), and (B) number of new animals identified per month

higher during the spring than during other months (Table 1), although this difference was not significant (Kruskal-Wallis test, H = 1.81, df = 3, $p = 0.61$).

Minimum Population Size

A total of 63 permanently marked and 61 temporarily marked animals were identified and entered into the *ACC*. Duplication may have occurred within the latter category, however, because of the long time period over which images were collected (during which some animals may have changed in appearance) and because both sides were photographed for only ten individuals (left-side only, $n = 19$; right-side only, $n = 32$).

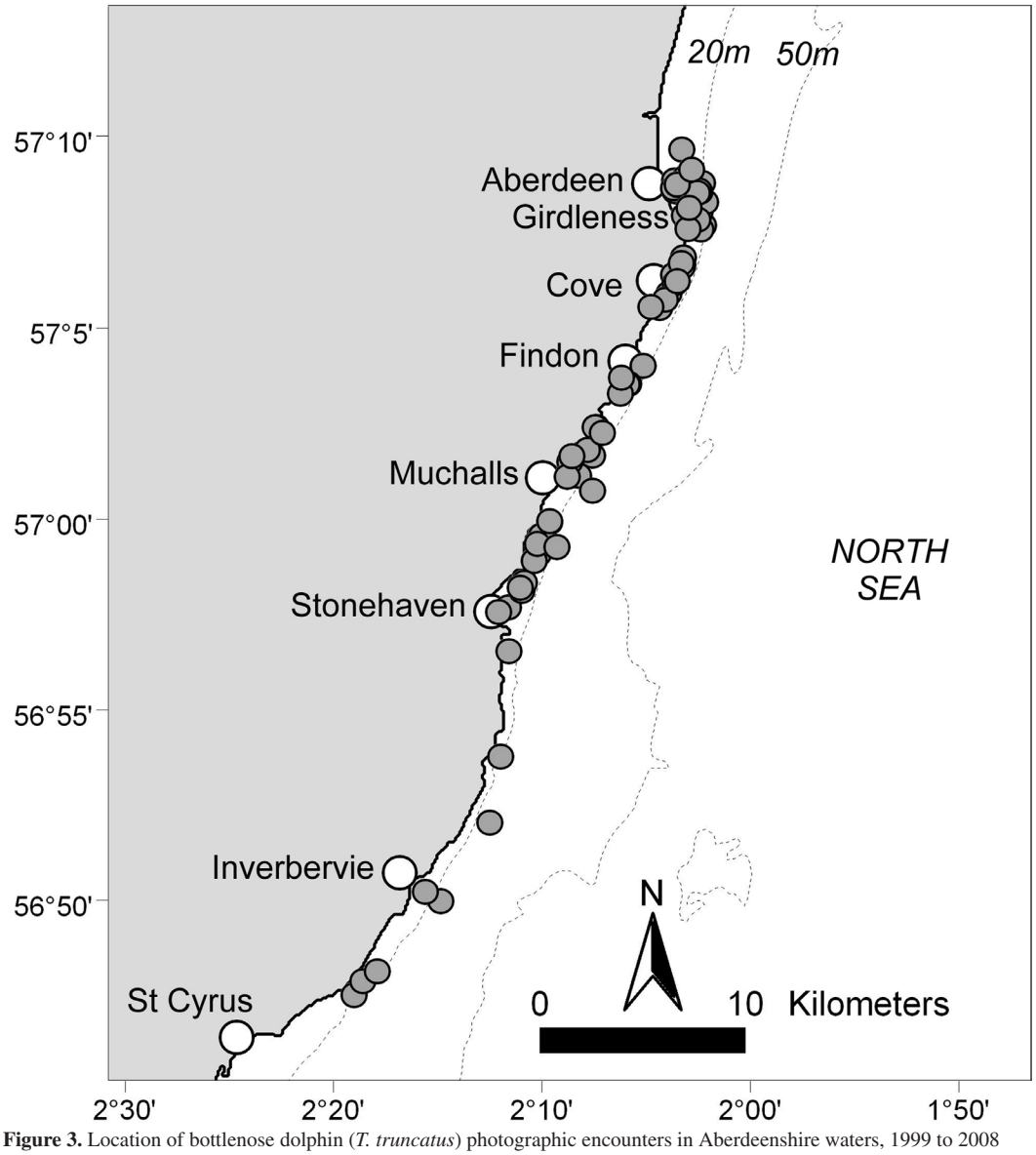

Figure 3. Location of bottlenose dolphin (*T. truncatus*) photographic encounters in Aberdeenshire waters, 1999 to 2008

The minimum annual total population size for Aberdeenshire waters based on photo-identification estimates alone ranged from one to 62 animals (Table 2). However, there was a strong positive correlation between the number of photo-identification surveys carried out and the minimum number of animals identified in each year (Spearman's rank order correlation: $rs = 0.874$, $n = 10$, $p = 0.001$). In 2006 and 2007, when the highest annual number of surveys were conducted, the population estimates were highest at 29 and 62 animals, respectively (Table 2).

A discovery curve of photographic captures of new permanently marked individuals ($n = 63$) showed a steady increase over time (Figure 2A). Both the period of greatest survey effort and the number of new permanently marked animals identified showed an overall peak between April and June (Figure 2B).

Site Fidelity

Of the 59 permanently marked adult animals (four permanently marked calves were omitted from the analysis since their site fidelity was

Table 1. Seasonal group size during bottlenose dolphin (*T. truncatus*) encounters in the Aberdeenshire study area between 1999 and 2008

Season	*n*	Range	Median	Mean	SD
Overall	78	1-60	10.0	10.91	8.30
Spring (March-April)	39	2-60	9.0	12.18	10.87
Summer (June-August)	28	1-20	10.0	10.11	4.25
Autumn (September-November)	8	4-15	8.5	9.13	4.12
Winter (December-February)	3	4-12	4.0	6.67	4.62

Table 2. Total number of distinctively marked bottlenose dolphins (*T. truncatus*) photographed in the Aberdeenshire study area between 1999 and 2008

Measure	1999 (from May)	2000	2001	2002	2003	2004	2005	2006	2007	2008 (to May)
Number of photo-identification encounters	1	2	6	5	8	6	7	13	11	6
Number of animals with permanent features	1	2	13	13	22	22	14	16	41	22
Number of animals with temporary features (both sides)	0	0	0	0	0	0	0	1	10	0
Number of animals with temporary features (one side)	0	0	3	2	1	1	4	12	11	4
Side used (left/right)	N/A	N/A	L/R	L	L	L	R	R	R	R
Total minimum population size	1	2	16	15	23	23	18	29	62	26

assumed to reflect that of their mothers), 40 (68%) had DVs of 2 or 3 (Table 3). Individual dolphins were photographed during between one and seven of the eight survey years (Figure 4A). The ASR was significantly higher (Mann-Whitney U test, $U = 119.5$, $p = 0.032$) for bottlenose dolphins with a DV of 3 than for dolphins with a DV of 2 (Table 3). Twenty-one of the 40 animals (53%) were only photographed for the first time during or after 2006, allowing relatively little potential for annual recaptures. When the analysis was corrected to account for only those years since (and including) the first year of sighting, the corrected ASRs indicated that, on average, individual dolphins were recorded in over half of the possible years available for recapture (Figure 4B; Table 3).

Individual dolphins were photographed on an average during four out of the 36 survey months (Table 3). The MSR was significantly higher (Mann-Whitney U test, $U = 118.5$, $p = 0.030$) for bottlenose dolphins with a DV of 3 than for dolphins with a DV of 2. When calendar months were pooled over the 2001 to 2008 study period, individual dolphins were photographed on an average during three out of the 11 annually combined months (Figure 4C). The CMSR was significantly higher (Mann-Whitney U test, $U = 119.5$, $p = 0.032$) for bottlenose dolphins with a DV of 3 than for dolphins with a DV of 2 (Table 3). The overall seasonal occurrence of 40 distinctively marked bottlenose dolphins photographed during boat surveys between 2001 and 2008 peaked during May and June, when 65% of the 40 individuals were recorded each month (Figure 5).

Overlap with the Moray Firth Dolphin Population

Of the 44 permanently marked individuals rated at DV2 or DV3, 37 (84%) were matched with the UoA's bottlenose dolphin catalogue for the Inner Moray Firth. A total of 41 animals (93%) photographed off Aberdeenshire were matched with the CRRU dolphin catalogue for the southern Outer Moray Firth.

Discussion

Value and Limitations of the Opportunistic Photo-Identification Dataset

Despite its opportunistic nature, the photo-identification study presented here provides valuable

Table 3. Annual (2001 to 2008) and monthly (February to December) sighting rates for individual bottlenose dolphins (*T. truncatus*) of DVs 2 and 3 in the Aberdeenshire study area

Measure	*n*	Range	Mean	SD
Annual sighting rate				
Overall	40	0.125-0.875	0.366	0.225
DV2	18	0.125-0.750	0.285	0.200
DV3	22	0.125-0.875	0.432	0.227
Corrected[1]	38	0.167-1.000	0.553	0.227
Monthly sighting rate				
Overall	40	0.028-0.389	0.114	0.092
DV2	18	0.028-0.250	0.082	0.065
DV3	22	0.028-0.389	0.140	0.104
Cumulative monthly sighting rate				
Overall	40	0.091-0.636	0.277	0.155
DV2	18	0.091-0.455	0.217	0.129
DV3	22	0.091-0.636	0.326	0.160

[1]Corrected to account only for those years since (and including) the first year of sighting

long-term information on a population of bottlenose dolphins using Aberdeenshire coastal waters, a part of their distribution range that was largely unstudied. The analyses add information on population size and site fidelity to the seasonal distributional information presented by Stockin et al. (2006). The data also further highlight the extent of overlap between bottlenose dolphins off Aberdeenshire and the Moray Firth dolphin population, with 84% and 93% of individuals off Aberdeenshire matched with dolphin catalogues for the Inner and Outer Moray Firth, respectively. These data are particularly important given the Annex II (EC Habitats and Species Directive, 92/43/EEC) conservation status of the dolphin population being considered and the recent documented range extension of this population to include novel areas where few existing data are available (Wilson et al., 2004).

Opportunistic photo-identification datasets, such as the one presented here, need to be reviewed with caution and carefully quality controlled to produce data appropriate for robust population assessment (Evans & Hammond, 2004). The main limitations identified in the dataset were that (1) the population was not sampled evenly (i.e., data were not collected during every month of each year) over the time period covered, (2) most images were not of grade 3 quality, and (3) several assumptions of mark-recapture methodology were violated (as described below) such that an analysis of total population size could not be calculated.

For reasons including boat availability, inclement weather conditions, and limited funding, boat surveys were not conducted on a regular basis over the timeframe considered, affecting the likelihood of dolphin (re)capture. This was clearly demonstrated by (1) the significant correlation between the number of surveys conducted and the number of individuals identified annually, (2) the corresponding seasonal peaks in the number of dolphins photographically captured and survey effort, and (3) undersampling of the population indicated by the discovery curve. The sampling interval is particularly likely to impact estimation of overall population size within the study area, which clearly limits the potential to measure long-term population status or trends. However, variation in sampling effort could be accounted for in some analyses, for example, by using ASR and MSR to broadly incorporate survey effort into site fidelity analyses. Consequently, this opportunistic dataset provided information on the use of Aberdeenshire coastal waters by the study population, with some individuals showing long-term use of the area (occurring in over half of the possible years available for recapture) and some being sighted in most calendar months of the year. These data confirm that some dolphins are very regularly observed off Aberdeen despite the relatively low level of survey effort. Wilson et al. (1997) reported that the distribution of bottlenose dolphins within the Moray Firth SAC was stratified such that certain individuals occurred regularly in particular areas while others did not. Furthermore, Wilson et al. (2004) were able to identify three dolphin subsets based on their occupation of northeast Scottish coastal waters, varying from those occurring only in the Inner Moray Firth to those seen from the Inner Firth to the coast south of Fraserburgh. Since some dolphins from the Moray Firth SAC were seen less often within the SAC during the 1990s (Wilson et al., 2004), the combined data suggest that,

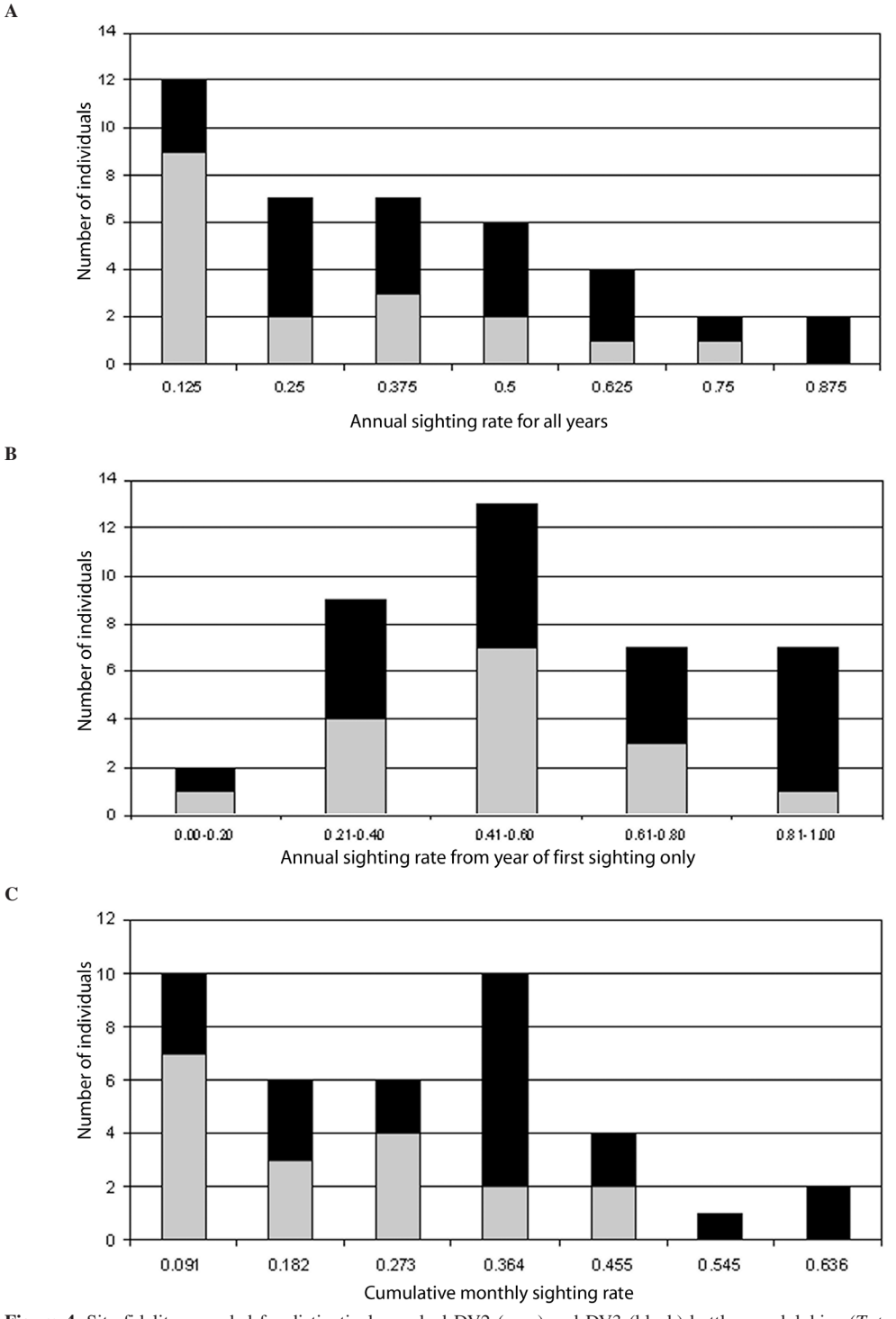

Figure 4. Site fidelity recorded for distinctively marked DV2 (grey) and DV3 (black) bottlenose dolphins (*T. truncatus*) recorded during dedicated boat surveys off Aberdeen: (A) Annual Sighting Rate (ASR) for all years; (B) ASR from year of first sighting only; and (C) Cumulative Monthly Sighting Rate (CMSR)

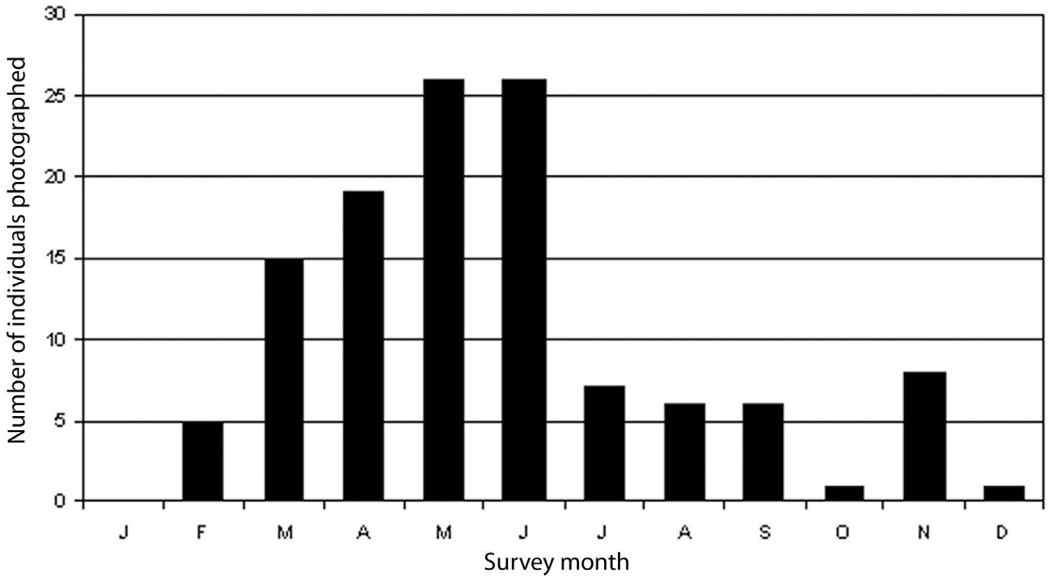

Figure 5. Monthly occurrence of 40 adult distinctively marked (DVs 2 and 3) bottlenose dolphins (*T. truncatus*) recorded during dedicated boat surveys, 2001 to 2008

although a proportion of the bottlenose dolphin population is wide-ranging, in recent years some animals occupy Aberdeenshire waters on a regular basis.

Both the lengthy duration over which the data were collected and the low level of sampling effort could also potentially violate one of the assumptions of mark-recapture analysis since several of the dolphins are known to have significantly changed appearance over the duration of this study. These changes could be identified in the present study via comparisons with the UoA and CRRU dolphin catalogues from the Moray Firth where sampling has been systematic over the same temporal period. However, without such comparisons, opportunistic photo-identification is highly dependent on sampling frequency to avoid increasing the number of false positives and negatives. Comparisons between the *ACC* and other photo-identification catalogues from adjacent geographic areas might also add valuable information to those studies, for example, by providing information on individuals that have disappeared from other study sites, on animals that have changed appearance, or on new calves. This is particularly important since the Aberdeen dataset (although unsystematic) spans many years and most months, whereas some other studies (although systematic) within the population range are limited to particular temporal periods (e.g., May to October; Culloch & Robinson, 2008). Such data are essential for determining population dynamics (e.g., deaths, recruitment, and mark changes) and for assessing population size.

Perhaps the greatest limitation arising from opportunistic photo-identification was the inability to use the data for mark-recapture analysis to estimate total population size in Aberdeenshire waters. This was related to the scarcity of Quality 3 images within the database which prevented animals from being recognised with certainty and also because of the lack of emphasis on photo-identification during the early years of the Aberdeen study which meant that heterogeneity of capture probability almost certainly occurred.

Conservation Implications

Despite the limitations discussed above, the data expand on current knowledge of the extent of the overlap between bottlenose dolphins recorded off Aberdeenshire and the Moray Firth population. Wilson et al. (2004) reported that of 54 dolphins identified in the Inner Moray Firth between 1990 and 2000, 33 (61%) were also recorded along the coast between Fraserburgh and the Firth of Forth. Eight animals photographed off Aberdeen during 2001 were sighted in the Inner Moray Firth in or prior to 2001 (Stockin et al., 2006). The data presented here revealed that 84% of bottlenose dolphins photographed off Aberdeenshire had previously been recorded in the Inner Moray Firth, and a 93% match was also recorded between Aberdeenshire and the southern coastline of the Outer Moray Firth. Most, if not all, of the bottlenose dolphins sighted off Aberdeenshire, therefore, originate from the population for which the Moray Firth SAC was designated. The minimum

estimate of 62 individuals using Aberdeenshire coastal waters during 2007 represents approximately half of the estimated Moray Firth dolphin population (~130 animals; Wilson et al., 1999). Since the ~130 animal population estimate for the Inner Moray Firth was based on both marked and unmarked animals (using mark-recapture analysis) (Wilson et al., 1999), the true number of animals using Aberdeenshire waters is likely to be far greater than indicated by the presence of 62 well-marked animals alone. These results indicate a much higher usage of Aberdeenshire waters by the Moray Firth bottlenose dolphin population than indicated by Wilson et al. (2004) or by Stockin et al. (2006).

The opportunistic photo-identification dataset has implications for the conservation of the northeast Scotland bottlenose dolphin population, particularly regarding the effectiveness of the designated Moray Firth SAC for their long-term protection. In recent years, marine protected areas (MPAs) of varying spatial extent have been established for cetaceans, ranging from small geographic locations such as the Banks Peninsula in New Zealand for Hector's dolphin (*Cephalorhynchus hectori*) to large-scale geographic areas such as the internationally designated Southern Ocean whale sanctuary (Hooker & Gerber, 2004). Optimal protection of a cetacean population requires the protection of the entire area inhabited year-round by that population (Reeves, 2000). This is problematic for highly mobile species such as baleen whales and pelagic dolphins which might range widely across entire ocean basins on a year-round basis. To date, MPAs for such species have typically encompassed only limited spatial protection in well-defined parts of their range, for example, the seasonal breeding grounds of humpback whales (*Megaptera novaeangliae*) in the Hawaiian Islands and southern right whales (*Eubalaena australis*) at Peninsula Valdes (Hooker & Gerber, 2004), and offer no protection for the same populations on their foraging grounds and migration routes.

More effective protection is achieved when a defined MPA incorporates the breeding and feeding ranges and all life stages of a population (Hyrenbach et al., 2000; Reeves, 2000) as was initially identified for the Moray Firth SAC. However, the recent range expansion of the Moray Firth bottlenose dolphin population to areas outside of the protected SAC demonstrates the limitations of designating a defined spatial area for the protection of a mobile species (Wilson et al., 2004). This change in distribution of a well-studied dolphin population was not predicted when the Moray Firth SAC was proposed in 1996 (Wilson, 2008) and suggests that the long-term viability of MPAs might require ongoing assessment and a dynamic approach to defining boundaries (Hyrenbach et al., 2000).

Under European Union legislation, the bottlenose dolphins from the protected Moray Firth SAC must be maintained at favourable conservation status, requiring long-term monitoring programmes. While intensive year-round mark-recapture studies of the northeast Scotland bottlenose dolphin population have been ongoing for many years within the SAC (Wilson et al., 1999, 2004), the long-term effective conservation of this population depends on monitoring and protecting the population across its entire range and not just within a single designated area. This is particularly important when anthropogenic activities such as geophysical seismic surveys and offshore wind farm developments might potentially impact upon the Moray Firth dolphin population in areas of its range outside of the protected SAC.

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