Journal of the Marine Biological Association of the United Kingdom, 2008, 88(6), 1237–1243.
doi:10.1017/S0025315408000210 Printed in the United Kingdom

Bottlenose dolphins using coastal regions adjacent to a Special Area of Conservation in north-east Scotland

ROSS M. CULLOCH[1,2] AND KEVIN P. ROBINSON[1]

[1]Cetacean Research and Rescue Unit (CRRU), PO Box 11307, Banff, AB45 3WB, Scotland, UK, [2]School of Biological Sciences, The University of Wales, Bangor, LL57 2UW, Wales, UK

In a four year study of bottlenose dolphins along the southern shore of the outer Moray Firth we show that whilst dolphins were encountered along the majority of the survey area, there was a significant preference to the western section, which is the area directly adjacent to the current Special Area of Conservation (SAC). We also show that 80% of all groups encountered (N = 62) included calves, and that neonates were seen throughout the months of July, August, September and October. The mark–recapture abundance estimates for the southern outer Moray Firth were variable, with a highest annual estimate of 108 (95% CI = 79–129), which is similar to previous estimates for the number of animals using the entire Moray Firth. In contrast, the lowest annual estimate of 61 (95% CI = 48–74) suggests that not all individuals regularly use the entire geographical range of the population and that individual ranging patterns may vary across years. The findings of this study indicate that the southern outer Moray Firth is an important area for this population and that it should not simply be considered as a corridor to other areas of more importance. For this reason, we believe that further consideration of the current management of this population in areas outside the existing SAC is necessary.

Keywords: conservation; management; mark–recapture; abundance; photo-identification; cetacean; *Tursiops truncatus*.

Submitted 6 February 2007; accepted 14 November 2007; first published online 17 March 2008

INTRODUCTION

The bottlenose dolphin (*Tursiops truncatus*, Montagu, 1821) is regularly sighted throughout the coastal waters of the British Isles (see Lockyer & Morris, 1986; Wilson *et al.*, 1997; Wood, 1998; Bristow *et al.*, 2001; Bristow & Rees, 2001; Ingram & Rogan, 2002; Grellier & Wilson, 2003; Robinson *et al.*, 2007) and it is arguably the best known and most studied of all the cetacean species found in Scotland's east coast waters. Furthermore, the population that inhabits the Moray Firth in north-east Scotland (57°40′N 3°30′W) is known to be one of only two well studied resident populations of this species in UK waters (Wilson *et al.*, 1997), the other being in Cardigan Bay, Wales (Bristow *et al.*, 2001; Bristow & Rees, 2001).

Currently, bottlenose dolphins are listed under Annex II of the European Union's Habitats Directive which requires the designation of a Special Area of Conservation (SAC) for their protection. In 1994 an area of the Moray Firth, commonly referred to as the 'inner Moray Firth' (Figure 1), was put forward as a candidate SAC (cSAC) (Hastie *et al.*, 2003a). It was not until 2005 that the cSAC was officially designated as a SAC. However, additional research conducted before this time had clearly shown that the home range of the population extends much further than originally thought (Wilson *et al.*, 1999; Thompson *et al.*, 2004; Wilson *et al.*, 2004).

At present, the majority of the research carried out on this population has been within the inner Moray Firth with fewer dedicated studies occurring in the southern outer Moray Firth by comparison. Nevertheless, bottlenose dolphins have been recorded in the southern outer Moray Firth previously (e.g. Wilson *et al.*, 1999; Hastie *et al.*, 2003a; Thompson *et al.*, 2004; Wilson *et al.*, 2004; Durban *et al.*, 2005), although fewer dolphins are thought to use this region than the inner Moray Firth (Hastie *et al.*, 2003a). However, given the lack of dedicated surveys in the southern outer Moray Firth we cannot determine whether dolphins use this area for prolonged periods or simply as a corridor between the inner Moray Firth and areas further south.

The primary aim of this study was to assess the abundance of bottlenose dolphins within our study area and their potential uses for the southern outer Moray Firth. We did this by assessing the distribution of dolphins, assessing the group composition of dolphins with a particular interest in calves and neonates, and finally by calculating the abundance of animals utilizing this area by applying mark–recapture abundance estimate techniques.

MATERIALS AND METHODS

Data collection

Regular surveys were conducted in the southern outer Moray Firth using two Avon 5.4 m Searider Rigid Inflatable Boats (RIBs). Surveys took place between May and September in 2001 and 2003, and between May and October in 2002 and 2004. The survey route was approximately 80 km, and closely followed the coastline of the southern outer Moray

Corresponding author:
R.M. Culloch
Email: ross.culloch@durham.ac.uk

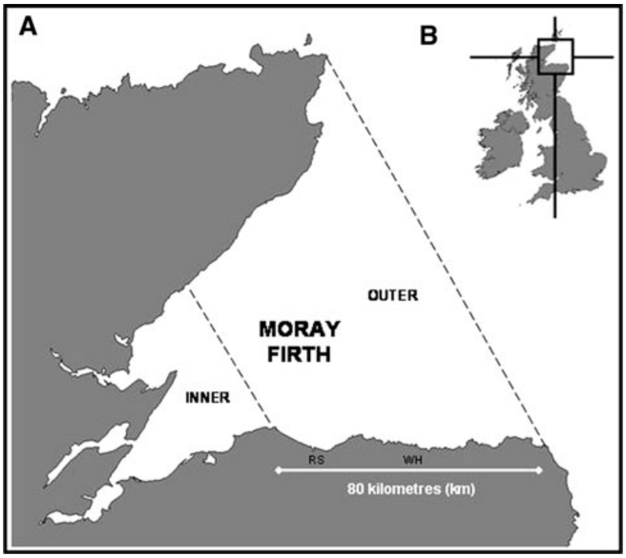

Fig. 1. Map showing: (A) the layout of the Moray Firth, north-eastern Scotland, defining the inner and outer sections of the Moray Firth; RS, River Spey; WH, Whitehills; and (B) the location of the Moray Firth within the British Isles.

Firth (Figure 1). The majority of surveys began at Whitehills where both survey vessels were berthed.

All surveys were conducted at 12–15 km/h, in Beaufort Sea State 3 or less, and in good light conditions. Aboard were two experienced observers and up to four additional observers. The crew scanned from the front of the survey vessel to 90° left and right of the track line. If bottlenose dolphins were encountered during a survey, the boat was slowed and the position was recorded using a Global Positioning System (GPS). The dolphins were approached and photographs were taken of dorsal fins and other identifying marks. It was not considered necessary to photograph both sides of the dorsal fin. The camera used during this study was a 35 mm Nikon F5 auto focus camera with a F2.8 100–300 mm zoom lens, using Fuji 400 or 800 ASA colour print film. During an encounter the animals were counted and the group composition and the age-classes (adults, calves and neonates) of school members were estimated. Adults were defined by their large size and dark coloration, a calf was defined by its smaller size, lighter coloration, often discernible foetal folds, and usually swimming in close association with an adult, and a neonate was defined as a very small animal, very light in coloration, with very bold foetal folds, and a strong, close association with an adult (Shane, 1990). At the end of the encounter the time and GPS position were recorded and the survey was ended.

Temporal and spatial distribution

The survey route was divided into 1 km longitudinal sections. The GPS position at the start of each encounter was then plotted within these 1 km sections. Subsequent time spent working with the dolphins during encounters was recorded as off-effort. The number of times each 1 km section was visited whilst on-effort was calculated, and the encounter rate (ER) within each section of the survey route was derived as follows:

$$ER_i = \frac{n_i}{E_i}$$

Where n is the total number of encounters in section i and E is the number of times section i was visited on-effort.

By calculating ER we eliminated effort-related bias from derived distribution patterns arising from uneven survey effort caused by time and weather restrictions. The distribution was analysed both temporally and spatially. For the temporal analysis we examined the total ER for the entire survey routes for each survey month for the compiled years of 2001 to 2004, and for each survey year. This was done using a Kruskal–Wallis test. For the spatial analysis we used the ER within each 1 km section and statistically compared the ER between the east and the west of the survey area using a Mann–Whitney *U*-test. All statistical analysis was carried out using Minitab® *14*.

Photo-identification

Dolphin identifications were made using natural markings considered long-term or permanent (see Wilson *et al.*, 1999, 2000). We graded photographs according to their quality in order to minimize the number of errors associated with incorrect identifications (Wilson *et al.*, 1999; Read *et al.*, 2003). Only photographs that were in focus, well lit, and relatively close and parallel to the subject were included in the analysis and all photographs not satisfying these requirements were discarded. To further reduce potential false positive and false negative errors (Gunnlaugsson & Sigurjonsson, 1990; Stevick *et al.*, 2001) a dedicated computer program developed by Leiden University for the EuroPhlukes Initiative was used to assist in the photo-identification process.

Mark–recapture models

We assumed that the population would fit a closed model for our mark–recapture abundance estimates, as a discovery curve of newly sighted individuals appeared to reach an asymptote during 2004 (Figure 2). However, it is important to note that because birth and death do occur in the natural environment the discovery curve will never become truly asymptotic. In addition long-term studies of this population indicate that there is no evidence of immigration or emigration (Parsons *et al.*, 2002) or predation (Wilson, 1995), and abundance estimates have remained similar for more than a decade (Wilson, 1995; Wilson *et al.*, 1999; Durban *et al.*, 2005).

We used the program CAPTURE, which was run using the FORTRAN program MARK, version 4.1 (developed by the Department of Fisheries and Wildlife, Colorado State University (2004)) to calculate mark–recapture abundance estimates. We used the Chao *Mth* model, which is tolerant of heterogeneity in capture probabilities between sampling events and between individuals (Chao *et al.*, 1992; Williams *et al.*, 1993; Wilson *et al.*, 1999). Population closure in a natural environment can only be considered a reasonable assumption if the analyses are conducted over relatively short durations. Given that the weather conditions restricted surveys in the autumn and winter months the data sets were easily divided by year as follows: between May to September, inclusive, for 2001 and 2003; and between May and October, inclusive for 2002 and 2004.

Williams *et al.* (1993) used the proportion of photographs that were good enough to show a mark if one was present.

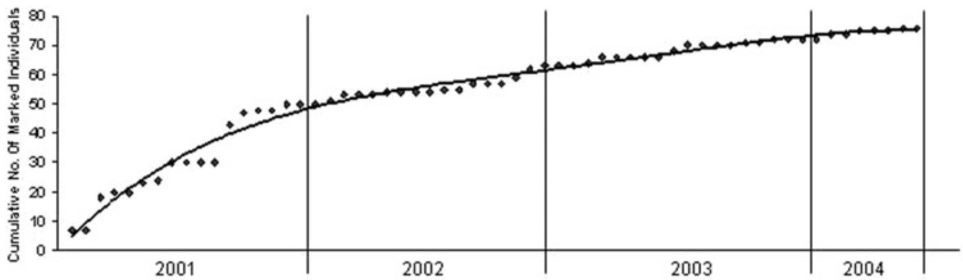

Fig. 2. Discovery curve showing that fewer and fewer newly identified marked individuals were captured over time. The Y-axis shows the cumulative number of marked individuals identified and the X-axis shows the cumulative number of dolphins seen (N = 823); the X-axis has been displayed as encounters across the four survey years.

However, in the present study, after Wilson *et al.* (1999), the actual ratio of marked individuals was used to give an even more accurate estimate of the size of the population by further reducing the probability of heterogeneity between recaptures. In this study, the numbers of calves and neonates identified during each year were included in the estimates made for unmarked animals.

RESULTS

Survey effort

A total of 193 survey trips were made between 2001 and 2004, which amounted to a total of 432 hours 45 minutes of survey time. During this time there were 62 encounters with bottlenose dolphins, resulting in a cumulative encounter time of 78 hours and 30 minutes.

Temporal and spatial distribution

Bottlenose dolphins were encountered during every year surveyed and in all months of the year. A significant difference in ER was found between years (Kruskal–Wallis-H = 9.71, df = 3, $P = 0.021$), which is likely to have been caused by the higher annual encounter rates in 2001 (Figure 3B). The monthly analysis showed a varied ER over the survey months (Figure 3A); however, these variations were not significant (Kruskal–Wallis-H = 8.53, df = 5, $P = 0.130$).

Bottlenose dolphins were only encountered within the coastal region of the study area, and were never encountered in waters deeper than 25 m chart datum (Figure 4B). Encounters with bottlenose dolphins occurred along the majority of the southern outer Moray Firth coastline; however, there was a significant preference to the western section of the survey area (median ER east 0.007; median ER west 0.01) (Mann–Whitney *U*-test-W = 1029.5, $P = 0.001$), which is visually apparent when ER is plotted against

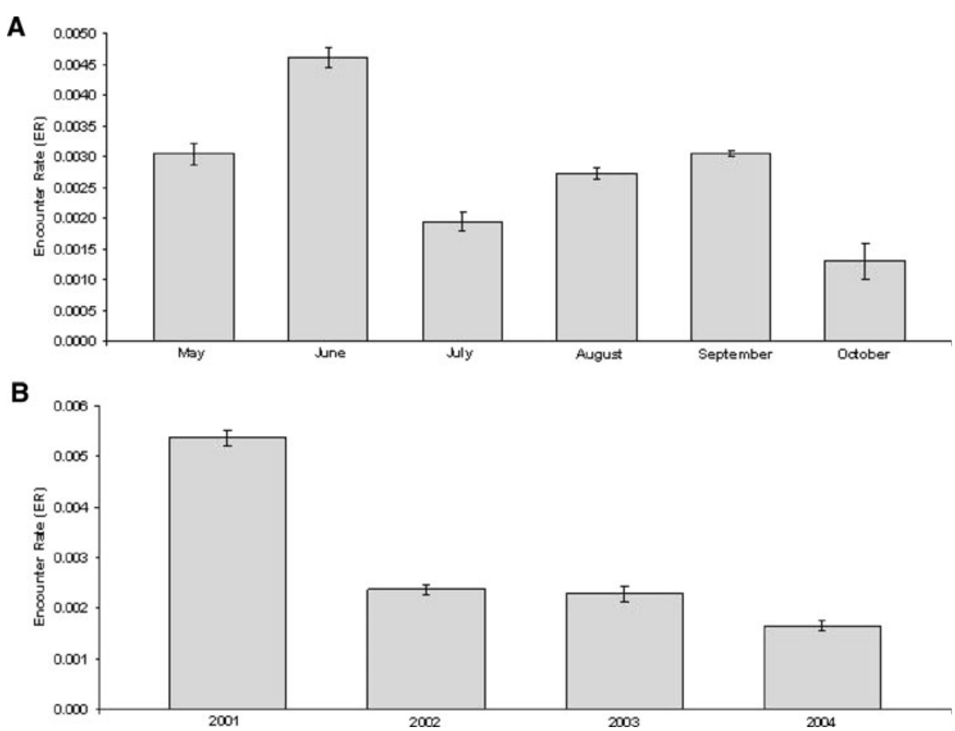

Fig. 3. Frequency histograms of encounter rates for bottlenose dolphins across: (A) each survey month; and (B) across each survey year; both graphs show a 95% confidence interval.

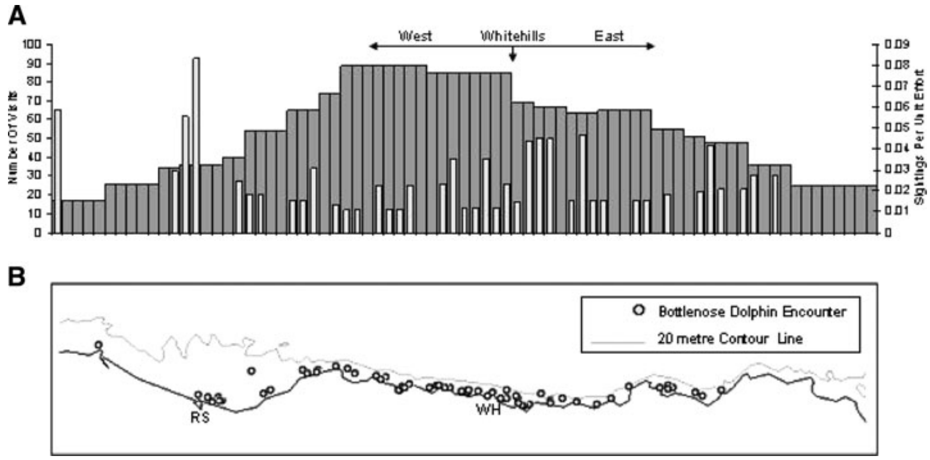

Fig. 4. Analysis of the distribution of bottlenose dolphin encounters across the survey area by: (A) bar chart where each bar is a 1 km section (N = 82) of the survey area displaying the number of visits to each of these 1 km sections against the encounter rate; the legend shows the position of Whitehills; and by (B) a map showing the Global Positioning System positions at the beginning of each encounter (N = 62) in relation to the 20 m contour line; RS, River Spey; WH, Whitehills.

on-effort data (Figure 4A). In addition, Figure 4A illustrates that there is no apparent relationship between ER and on-effort data, which highlights that the results are unlikely to be a product of any bias in the survey effort.

Group sizes and group composition

Group sizes ranged between 2 and 44, with only two solitary animals being encountered throughout the entire study. Eighty per cent of all groups included calves. Calves were recorded throughout all the survey months; however, neonates were only recorded in July, August, September and October (Table 1).

Abundance estimates

The results from the abundance estimates are shown in Table 2A, and the corrections applied to the respective annual estimates are shown in Table 2B and Figure 5. The abundance estimates varied between years, with the lowest estimate of 61 ± 13 animals (coefficient of variation (CV) = 0.21) in 2004 and the highest estimate of 108 ± 21 animals (CV = 0.19) in 2003 (Table 2B).

DISCUSSION

Temporal and spatial distribution

Although bottlenose dolphins were encountered along the majority of the southern outer Moray Firth coastline, there was a significant preference for the west of the survey area, which is the area directly adjacent to the current SAC. In addition, it appears that Spey Bay, and in particular, the mouth of the River Spey may be an import area to these animals as these sections have a comparably higher ER than the majority of the other 1 km sections within the survey area (Figure 4A). There are two factors that make Spey Bay a unique habitat within the survey area. The first is that it is exceptionally shallower than the other areas (Figure 4B), which is a factor that has been related to reproductive success in *Tursiops* sp. in Shark Bay, Australia (Mann *et al.*, 2000). The reason for this is unknown; however, Mann *et al.* (2000) consider that their findings could be related to easier detection of predators which is not an issue for this population (Wilson, 1995), but they also consider that shallower areas

Table 1. The survey effort, the number of encounters, the number of neonates encountered, and the percentage (%) of groups with calves for all survey years across the five survey months.

	May	June	July	August	September	October
Total no. of survey trips	29	39	74	50	38	9
Total no. of encounters	9	16	14	12	9	1
% of groups with calves	78	75	93	67	89	100
Number of neonates	0	0	4	4	6	1

Table 2A. Abundance estimates for marked animals using the Chao *Mth* model.

Year	N	*P*	N-hat	SE (N-hat)	CV (N-hat)	95% CI
2001	50	0.13	58	4.76	0.08	53–73
2002	37	0.11	46	5.79	0.13	51–65
2003	48	0.1	73	11.26	0.15	59–101
2004	36	0.27	43	4.42	0.1	39–57

N, number of marked individuals; *P*, mean probability of recapture; Ň-hat, abundance estimate; SE, standard error; CV, coefficient of variation; CI, confidence interval.

Table 2B. The corrected abundance estimates and 95% confidence intervals for all animals.

Year	X	Y	Proportion X	Proportion Y	N-hat	CV (N-hat)	95% CI
2001	50	27	0.649	0.351	89	0.21	70–118
2002	37	16	0.698	0.302	66	0.23	51–81
2003	48	23	0.676	0.324	108	0.19	87–129
2004	36	15	0.706	0.294	61	0.21	48–74

X, number of marked individuals; Y, number of unmarked individuals; Ň-hat, abundance estimate; CV, coefficient of variation; CI, confidence interval.

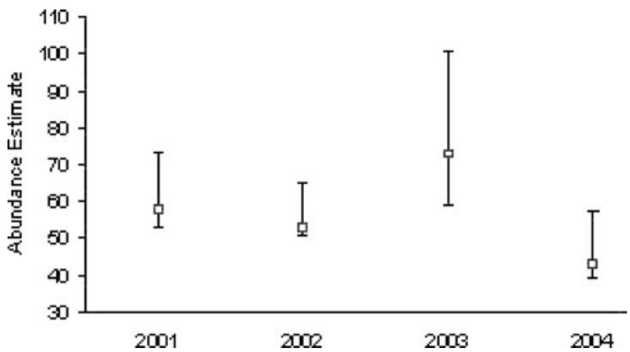

Fig. 5. The abundance estimates with 95% confidence intervals for the southern outer Moray Firth for each survey year.

could have a higher prey density than deeper areas. The latter hypothesis could relate to this habitat, as the River Spey supports a major spawning population of Atlantic salmon (*Salmo salar*) (Harding-Hill, 1993) which is known to be a prey species of bottlenose dolphins in this area (Santos *et al.*, 2001). However, without a more fine-scale study in Spey Bay it is not possible to determine why this area appears to be important to this population.

All encounters with bottlenose dolphins were at depths no greater than 25 m chart datum. The maximum depth showed an interesting contrast with the findings from studies in the inner Moray Firth, where bottlenose dolphins were found in their highest abundance at depths in excess of 50 m with a steep gradient (Hastie *et al.*, 2003b, 2004). This is likely to be a result of significant differences between the two environments: in the inner Moray Firth strong currents and tidal fronts have been documented to occur within deep constricted channels and it is thought that the dolphins use these to aid foraging (Mendes *et al.*, 2002). However, in other areas where these features do not occur or are not as prominent, as in the southern outer Moray Firth, bottlenose dolphins may use the coastline to aid foraging (e.g. Shane *et al.*, 1986).

Although the distribution of dolphins across survey months indicated no significant monthly variation in encounter rate the results do appear to complement previous findings in the inner Moray Firth (Wilson *et al.*, 1997), and in a 10 km section of the southern outer Moray Firth (Thompson *et al.*, 2004) where sightings were higher in the summer months. Furthermore, along the eastern Aberdeenshire coastline, just south of the southern outer Moray Firth, encounters were highest between the months of February and May and then again in October (Stockin *et al.*, 2006). These combined patterns of movement between the neighbouring areas of the home range of this population further suggest that the majority of the population travel south during the winter period. However, given that sea conditions in the North Sea during these months are not suitable for surveys, the true year-round range of the population during these months remains unknown.

Group sizes and group composition

The percentage of groups encountered with calves in the southern outer Moray Firth between 2001 and 2004 was 80%, with neonate sightings occurring in July, August, September and October, which is a common finding in populations living in temperate waters (e.g. Wilson, 1995; Bristow *et al.*, 2001; Bristow & Rees, 2001). The use of the Moray Firth by mothers and calves has been attributed to the warmer temperatures of the area during the summer months which are thought to play a key role during the summer calving season (Wilson, 1995; Wilson *et al.*, 1997). Therefore, the use of the southern outer Moray Firth by mothers and nursing calves should also be considered when planning conservation and management strategies. This is particularly important since the European Union's Habitats Directive is in place to protect against the 'deliberate disturbance' of cetaceans, 'particularly during the period of breeding, rearing, hibernation and migration'; and 'the deterioration and destruction of breeding sites or resting places' (Article 12, Paragraph 1 of the Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora of 21 May 1992, 2004).

Abundance estimates

The mark–recapture estimates presented here have shown the highest abundance of bottlenose dolphins using the southern outer Moray Firth to be 108 (95% CI = 87–129) (Table 2B). This estimate is lower than Wilson *et al*'s (1999) calculation (N = 129, 95% CI = 110–174) which included the inner Moray Firth as well as the southern outer Moray Firth. In recent studies individuals have been shown to be solely resident within defined sections of the Moray Firth and areas further south (Wilson *et al.*, 2004; Durban *et al.*, 2005). Given the results of these studies, it is evident that some individuals from this population are showing a high level of site fidelity to specific areas, including sections of the southern outer Moray Firth (Durban *et al.*, 2005). Therefore, there are individuals that are unlikely to be within our survey area for any great length of time, if at all, which further explains the lower abundance estimate. Nevertheless, this study has shown that the southern outer Moray Firth is an important area for a large percentage of this population, with a substantial number of individuals using the southern outer Moray Firth during each of the survey years. However, the abundance estimates were seen to vary considerably from year to year, with the lowest estimate of 61 (95% CI = 48–74) in 2004. This annual change in abundance illustrates a variation in use of the home range by the population as a whole on a relatively short time scale.

Conservation and management implications

Knowing the distribution and ranging patterns of cetaceans is important for implementing effective boundaries for marine protected areas. This study demonstrates that bottlenose dolphins are found along the majority of the coastline of the southern outer Moray Firth and that this area is likely to represent an important part of their habitat rather than simply a corridor between other key areas. This raises the issue that the SAC is only protecting a small proportion of the individuals within the population at any one time, and it is therefore only protecting a small section of the habitat that is likely to be important to the population as a whole.

Given the previous lack of research in the southern outer Moray Firth and the relatively recent increase in the public interest in bottlenose dolphins in this area, it is hard to say whether the southern outer Moray Firth has increased in importance as a result of a recent range expansion from the inner Moray Firth (Wilson *et al.*, 2004). Nevertheless, as research on this population continues it becomes increasingly clear that the current boundaries of the newly appointed SAC are likely to be ineffective in protecting this population at more than a local scale. At present, more research needs to be carried out on identifying the seasonal changes in the geographical range of this population before effective boundaries can be reconsidered. It is also important that current research stretching from the inner Moray Firth to St Andrews Bay and beyond is continued in order to give us a detailed understanding as to how the members of this vulnerable population are using the waters of eastern Scotland year-round.

ACKNOWLEDGEMENTS

A special thanks to the many volunteers and people that helped to collect the data that was used in this study. Particular thanks go to Mike Tetley, Nicola Clark, Cameron McPherson, Caroline Passingham, Elaine Galston, Tracy Guild, Carmel O'Kane, Christine O'Sullivan and Pine Eisfeld for their help and support. Many thanks also go to Simon Ingram, Ben Wilson and Paul Thompson for their comments on earlier drafts of this manuscript. The authors would also like to thank Graham Pierce and one anonymous referee for their comments which greatly improved this manuscript. This work has been supported by Care for the Wild International, the British Ecological Society, The Miller Foundation and Ecocorps Scotland.

REFERENCES

Bristow T., Glanville N. and Hopkins J. (2001) Shore-based monitoring of bottlenose dolphins (*Tursiops truncatus*) by trained volunteers in Cardigan Bay, Wales. *Aquatic Mammals* 27, 115–120.

Bristow T. and Rees E.I.S. (2001) Site fidelity and behaviour of bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay, Wales. *Aquatic Mammals* 27, 1–10.

Chao A., Lee S.M. and Jeng S.L. (1992) Estimating population size for capture–recapture data when capture probabilities vary by time and individual animal. *Biometrics* 48, 201–216.

Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora of 21 May (2004) Consolidated text produced by the CONSLEG system of the Office for Official Publications of the European Communities, CONSLEG 1992L0043–01/05/2004, 57 pp.

Durban J.W., Elston D.A., Ellifrit D.K., Dickson E., Hammond P.S. and Thompson P.M. (2005) Multi-state mark–recapture for cetaceans: population estimates with Bayesian model averaging. *Marine Mammal Science* 21, 80–92.

Grellier K. and Wilson B. (2003) Bottlenose dolphins using the Sound of Barra, Scotland. *Aquatic Mammals* 29, 378–382.

Gunnlaugsson T. and Sigurjónsson J. (1990) A note on the problem of false positives in the use of natural marking data and abundance estimation. In Hammond P.S. *et al.* (eds) *Individual recognition of cetaceans: use of photo-identification and other techniques to estimate population parameters. Report of the International Whaling Commission* (Special Issue) 12, pp. 143–145.

Harding-Hill R. (1993) *The Moray Firth review*. Scottish Natural Heritage, north-west region, Scotland. 257 pp.

Hastie G.D., Barton T.R., Grellier K., Hammond P.S., Swift R.J., Thompson P.M. and Wilson B. (2003a) Distribution of small cetaceans within a candidate Special Area of Conservation; implications for management. *Journal of Cetacean Research and Management* 5, 261–266.

Hastie G.D., Wilson B. and Thompson P.M. (2003b) Fine-scale selection by coastal bottlenose dolphins: application of a new land-based video-montage technique. *Canadian Journal of Zoology* 81, 469–478.

Hastie G.D., Wilson B., Wilson L.J., Parsons K.M. and Thompson P.M. (2004) Functional mechanisms underlying cetacean distribution patterns: hotspots for bottlenose dolphins are linked to foraging. *Marine Biology* 144, 397–403.

Ingram S.N. and Rogan E. (2002) Identifying critical areas and habitat preferences of bottlenose dolphins (*Tursiops truncatus*). *Marine Ecology Progress Series* 244, 247–255.

Lockyer C.H. and Morris R.J. (1986) The history and behaviour of a wild, sociable dolphin (*Tursiops truncatus*) off the north coast of Cornwall. *Aquatic Mammals* 12, 3–12.

Mann J., Connor R.C., Barre L.M. and Heithaus M.R. (2000) Female reproductive success in bottlenose dolphins (*Tursiops* sp.): life history, habitat, provisioning, and group size effects. *Behavioural Ecology* 11, 210–219.

Mendes S., Turrell W., Lütkebohle T. and Thompson P.M. (2002) Influence of the tidal cycle and a tidal intrusion front on the spatio-temporal distribution of coastal bottlenose dolphins. *Marine Ecology Progress Series* 239, 221–229.

Parsons K.M., Noble L.R., Reid R.J. and Thompson P.M. (2002) Mitochondrial genetic diversity and population structuring of UK bottlenose dolphins (*Tursiops truncatus*): is the NE Scotland population demographically and geographically isolated? *Biological Conservation* 108, 175–182

Read A.J., Urian K.W., Wilson B. and Waples D.M. (2003) Abundance of bottlenose dolphins in the bays, sounds, and estuaries of North Carolina. *Marine Mammal Science* 19, 59–73.

Robinson K.P., Baumgartner N., Eisfeld S.M., Clark N.M., Culloch R.M., Haskins G.N., Zapponi L., Whaley A.R., Weare J.S. and Tetley M.J. (2007) The summer distribution and occurrence of cetaceans in the coastal waters of the outer southern Moray Firth in north-east Scotland (UK). *Lutra* 50, 19–30.

Santos M.B., Pierce G.J., Reid R.J., Patterson I.A.P., Ross H.M. and Mente E. (2001) Stomach contents of bottlenose dolphins (*Tursiops truncatus*) in Scottish waters. *Journal of the Marine Biological Association of the United Kingdom* 81, 873–878.

Shane H.S., Wells R.S. and Würsig B. (1986) Ecology, behaviour and social organisation of the bottlenose dolphin: a review. *Marine Mammal Science* 2, 34–63.

Shane S.H. (1990) Behaviour and ecology of the bottlenose dolphin at Sanibel Island, Florida. In Leatherwood S. and Reeves R.R. (eds) *The bottlenose dolphin*. San Diego, CA: Academic Press, pp. 245–265.

Stevick P.T., Palsbøll P.J., Smith T.D., Bravington M.V. and Hammond P.S. (2001) Errors in identification using natural markings: rates, sources, and effects on capture–recapture estimates of abundance. *Canadian Journal of Fisheries and Aquaculture Science* 58, 1861–1870.

Stockin K.A., Weir C.R. and Pierce G.J. (2006) Examining the importance of Aberdeenshire (UK) coastal waters for North Sea bottlenose dolphins (*Tursiops truncatus*). *Journal of the Marine Biological Association of the United Kingdom* 86, 201–207.

Thompson P.M., White S. and Dickson E. (2004) Presence of bottlenose dolphins reduces the probability of sighting harbour porpoises. *Marine Mammal Science* 20, 322–328.

Williams J.A., Dawson S.M. and Slooten E. (1993) The abundance and distribution of bottlenose dolphins (*Tursiops truncatus*) in Doubtful Sound, New Zealand. *Canadian Journal of Zoology* 71, 2080–2088.

Wilson B. (1995) *The ecology of the bottlenose dolphins in the Moray Firth, Scotland: a population at the northern extreme of the species' range*. PhD thesis, University of Aberdeen, Scotland, UK.

Wilson B., Grellier K., Hammond P.S., Brown G. and Thompson P.M. (2000) Changing occurrence of epidermal lesions in wild bottlenose dolphins. *Marine Ecology Progress Series* 205, 283–290.

Wilson B., Hammond P.S. and Thompson P.M. (1999) Estimating size and assessing trends in a coastal bottlenose dolphin population. *Ecological Applications* 9, 288–300.

Wilson B., Reid R.J., Grellier K., Thompson PM. and Hammond P.S. (2004) Considering the temporal when managing the spatial: a population range expansion impacts protected areas-based management for bottlenose dolphins. *Animal Conservation* 7, 1–8.

Wilson B., Thompson P.M. and Hammond P.S. (1997) Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. *Journal of Applied Ecology* 34, 1365–1374.

and

Wood C.J. (1998) Movements of bottlenose dolphins around the south-west coast of Britain. *Journal of Zoology* 246, 155–164.

Correspondence should be addressed to:
Ross M. Culloch
School of Biological and Biomedical Sciences
University of Durham
South Road
Durham
DHI 3LE
UK
email: ross.culloch@durham.ac.uk