Distribution of small cetaceans within a candidate Special Area of Conservation; implications for management

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ABSTRACT

Information on cetacean distribution plays an important role in the identification of suitable boundaries for marine protected areas, but is also crucial for developing management and monitoring programmes. In response to the European 'Habitats Directive', a candidate Special Area of Conservation (cSAC) has been established in the Moray Firth, northeast Scotland to protect a small and isolated population of common bottlenose dolphins (*Tursiops truncatus*). Limited data on the distribution of bottlenose dolphins and on temporal changes in distribution have recently constrained attempts to mitigate against the impacts of new developments upon this population. In response to the need for current information on the distribution of dolphins throughout the cSAC, this study aims to provide data on the distribution of dolphins and other small cetaceans throughout the Moray Firth. Changes in the distribution patterns of dolphins in the inner Moray Firth were examined using data collected between 1990 and 2000. In addition, combined passive acoustic and visual survey techniques were used to determine the distribution of dolphins and harbour porpoises (*Phocoena phocoena*) on a broader scale across the whole Moray Firth. Dolphin schools were distributed throughout the inner Moray Firth, but there were concentrations of sightings around three deep, narrow channels that were consistent over the ten year study period. Results from surveys across the whole of the Moray Firth showed that all sightings and acoustic detections of dolphins were made within the area of the cSAC. In contrast, porpoise sightings were widely distributed throughout the Moray Firth. The median encounter rate of porpoises across the whole Moray Firth was 1.69 per 100km. Encounter rates of porpoises were similar in the outer Moray Firth and the cSAC. This combination of distribution studies at differing spatial scales provides a valuable tool for monitoring the distribution of animals and identifying important habitats, and the results of this study have directly supported efforts to manage the cSAC.

KEYWORDS: AREA-SCOTLAND; INDEX OF ABUNDANCE; SURVEY-ACOUSTIC; MANAGEMENT PROCEDURE; CONSERVATION; SANCTUARIES; DISTRIBUTION

INTRODUCTION

In recent years, many studies of distribution have aimed to identify critical habitats for cetaceans (Gregr and Trites, 2001; Harwood, 2001) and, in several cases, such data have been used to support the establishment of marine protected areas (Dawson and Slooten, 1993; Hooker *et al.*, 1999). In European waters, the European Union's (EU) Habitats Directive requires member states to identify Special Areas of Conservation (SAC) for certain species such as common bottlenose dolphins (*Tursiops truncatus*). In several countries, information from previous (Evans, 1992; Berrow *et al.*, 1996; Wilson *et al.*, 1997) or ongoing (Ingram and Rogan, 2002) studies of dolphin distribution have allowed the identification of boundaries for candidate SAC (cSAC), and management plans for these new marine protected areas are currently being implemented (Baxter, 2001).

Whilst most attention has previously focused on identifying suitable boundaries for marine protected areas, it is clear that information on cetacean distribution may subsequently be required to support management actions. This could simply form part of ongoing site monitoring to confirm that distribution patterns remain similar through time. Alternatively, additional data may be required to assess the potential impact of proposals for new human activities within the area, and to advise on mitigation against the impact of such developments. Although the details will vary depending upon the species and area in question, it is likely that data to support these designation and management phases will need to be collected at different temporal and spatial scales. This paper illustrates these issues by outlining recent studies of the distribution of bottlenose dolphins carried out in response to concern over the potential impact of industrial developments within the Moray Firth cSAC in northeast Scotland.

The inner Moray Firth was one of the first areas in Europe to be identified as a marine cSAC for bottlenose dolphins (Thompson *et al.*, 2000). In recent decades, the area has been used predictably and intensively by the only known 'resident' population of bottlenose dolphins remaining in the North Sea (Wilson *et al.*, 1999). No dedicated surveys have been carried out to permit the identification of critical habitats for this species in UK waters but regional data from seabird sighting cruises (Mudge *et al.*, 1984), a network of volunteer observers (Evans, 1992) and ongoing photo-identification surveys (Wilson *et al.*, 1997) were used to identify boundaries of the Moray Firth cSAC. Proposals to include this Moray Firth cSAC in a suite of UK marine sites were submitted to the European Union in 1994, and responsibility for managing the site was taken on by the Moray Firth Partnership (MFP) —a voluntary organisation representing a wide range of statutory and non-statutory organisations. A management scheme was subsequently developed, involving widespread public consultation, and the management plan was launched in January 2002 (MFP, 2001).

In 2001, prior to the launch of the management scheme, plans were put forward to replace a sub-sea oil pipeline that was routed through the Moray Firth cSAC from the Beatrice oilfield to an onshore terminal in the inner Moray Firth (Fig 1). Although the EU had not yet ratified this (or any other) cSAC, it was assumed that the Habitats Directive should

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immediately be applied to all cSACs (Baxter, 2001). Consequently, the developers were required to conduct an environmental assessment to determine whether the pipeline replacement could have a significant impact on the bottlenose dolphin population, and to develop mitigation measures to minimise any potential impacts (Talisman Energy (UK) Ltd, 2001b). Furthermore, it was decided that, whilst the cSAC was primarily to protect bottlenose dolphins, mitigation procedures should minimise potential impacts on all cetaceans using the area, particularly harbour porpoises (*Phocoena phocoena*) known to occur regularly in the Moray Firth (Mudge *et al.*, 1984; Sheldrick *et al.*, 1994). This case represented the first occasion on which statutory organisations were required to consider impacts upon a cetacean population within a cSAC. Despite this population being the most intensively studied coastal cetacean population in Europe, this process immediately identified uncertainties about cetacean distribution that constrained management decisions. In particular, information on the distribution of bottlenose dolphins in the offshore and northern parts of the cSAC was limited to data collected in 1982 and 1983 (Mudge *et al.*, 1984), and data from inshore areas was collected prior to 1993 (Wilson *et al.*, 1997). Although these sources suggested that there were almost no bottlenose dolphin sightings in the part of the cSAC affected by the pipeline, there was emerging evidence that the population has extended its geographical range during the last ten years (Stone, 2001; Wilson *et al.*, In review). Consequently, the distribution patterns previously underpinning the designation of this cSAC may have changed, making it difficult to assess the probability that bottlenose dolphins would interact with the pipe-laying activities.

This study was designed to provide current information on the distribution of bottlenose dolphins and harbour porpoises throughout the Moray Firth, with emphasis on the waters within the Moray Firth cSAC. In particular, the study aimed to determine whether there have been temporal changes in the relative distribution of dolphins within the Moray Firth cSAC during a period in which they are known to have extended the southern boundary of their geographical range (Wilson *et al.*, In review). To achieve this, the distribution of bottlenose dolphins within the Moray Firth is described at two spatial scales. First, data from regular photo-identification surveys were used to extend analyses carried out by Wilson *et al.* (1997) and examine whether there have been changes in distribution patterns within the inner Moray Firth. Secondly, the broader-scale distribution of dolphins was examined using ship-based surveys across the outer Moray Firth, focusing particularly on the areas affected by the recent pipeline replacement.

METHODS

Inner Moray Firth

Regular boat-based surveys were made within the inner Moray Firth between 1990 and 2000 along a standard survey route (Fig. 1). Two surveys were made each month between May and September using an established field protocol and data collection described in detail by Wilson *et al.* (1997). A total of 103 surveys were carried out between 1990 and 2000. Data on the distribution of dolphin schools for each year between 1990 and 2000 were compared.

To map the distribution of dolphins within the inner Moray Firth, locations of all schools of dolphins were plotted using a GIS software package (Arcview version 3.2, ESRI Inc.). The inner Moray Firth was divided into eight sub-regions as used in analyses by Wilson *et al* (1997), and the number of schools sighted in each sub-region was calculated. Each year, the sub-regions were ranked from lowest to highest based on the number of schools sighted in each of them divided by the area of each sub-region. A Friedman test was then used to test for consistency in the pattern of distribution in each year between 1990 and 2000.

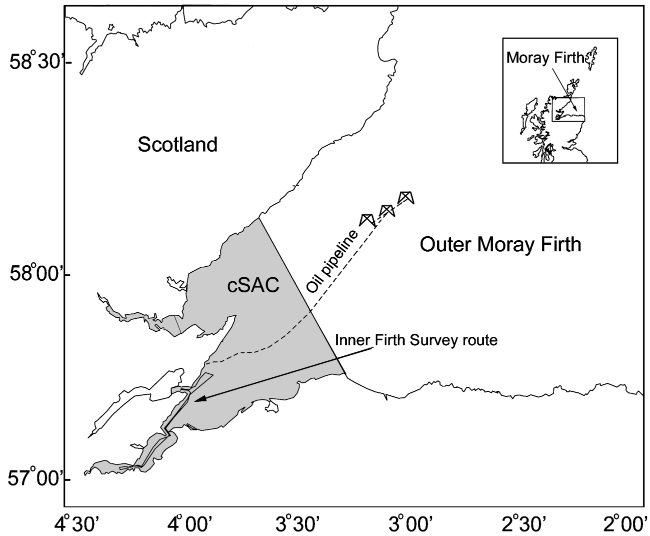

Fig. 1 Map of Scotland (inset) showing the Moray Firth, the area of the cSAC (shaded area) in the west of the Moray Firth and the outer Moray Firth. The dashed line and symbols represent the Beatrice oil pipeline and platforms and the solid line shows the inner Moray Firth survey route.

cSAC and outer Moray Firth

Combined boat-based passive acoustic and visual surveys were conducted in the cSAC and outer Moray Firth between January 2001 and October 2001. Ten surveys were made, collecting a total of 2,128km of acoustic data and 785km of visual data. The majority of surveys were made from *Seaspring*, a 56m pollution control vessel. In addition, three surveys were made in the outer Moray Firth from *Scotia* a 60m oceanographic research vessel. Survey speeds of *Seaspring* and *Scotia* were 9 knots and 12 knots respectively.

Although surveys covered most of the cSAC and the Moray Firth, effort was not distributed evenly across the region. Due to concerns about the impact of the sub-sea oil pipeline replacement on cetaceans (Talisman Energy (UK) Ltd, 2001b), much of the survey effort focused on the route of this pipeline, in the northern Moray Firth (Fig. 1).

A three-person team worked in shifts 24 hours a day to search for cetaceans from *Seaspring.* During daylight hours, two people searched visually and one person continually monitored signals from a towed hydrophone array. Each hour, observers alternated between visual searching and acoustic monitoring to ensure that concentration was maintained. At night, the three-person team worked in shifts to monitor the hydrophone array. Visual searches were made by eye and using 7×50 binoculars from either side of the bridge of the ship, approximately 11m above sea level. When a school was sighted, information on the geographic location, species and number of individuals, estimated distance, bearing from the bow and school heading were noted and recorded in a database using the *Logger2000* software (Gillespie, 1997). In addition, environmental details including an estimate of sea state, cloud cover, wind direction, precipitation and visibility distance were recorded each hour. No visual searches were made from *Scotia*; a two-person team worked in shifts to continually monitor the hydrophone array. Weather conditions encountered during the visual observation periods were good; no precipitation occurred and sea states were generally less than force 3. Furthermore, the proportion of survey hours in each sea state within the cSAC and outer Moray Firth were not significantly different (Chi-squared test, $\chi^2 = 0.225$, $p = 0.894$)

The acoustic equipment consisted of a towed stereo hydrophone streamer, an amplification and filtering unit and a computer for making recordings (Gillespie, 1997; Leaper *et al.*, 2000). The system was flat to frequencies to 15kHz and had good sensitivity up to 22kHz. The streamer was towed on a 400m strengthened cable behind the vessel. At speeds of 10 knots, this design of array generally tows at around 5-6m below the surface (Gillespie, 1997). The array was towed from the stern of the vessel and attached by means of a rope and rubber bungee, designed to minimise the shock loads during towing.

Signals from the hydrophones were filtered using high pass filters set at 400Hz or 1600Hz depending on background noise conditions, and amplified by 20dB or 30dB using a custom-built differential amplifier/filter unit. This recording system is capable of detecting bottlenose dolphin vocalisations but not those from harbour porpoises. Signals from the hydrophones were monitored continuously and the occurrence of dolphin vocalisations was noted using *Logger2000* (Gillespie, 1997). In addition, the software made recordings to hard disk for 30 seconds every 2 minutes. This program also maintained a database of monitoring effort and aural detections.

Sample sizes for both porpoise and dolphin sightings were insufficient to make reliable estimates of density or abundance. Therefore, the median encounter rates of each species, expressed as the number of schools encountered per 100km of survey effort, were calculated for waters within the cSAC and in the outer Moray Firth. Independent encounters were defined as those sightings or acoustic detections of schools greater than 2km apart. On occasions when acoustic detections of dolphins were made together with a visual sighting, a single encounter was recorded. Survey tracks and the positions of sightings and acoustic detections were plotted in a GIS software package (Arcview version 3.2, ESRI Inc.).

RESULTS

Inner Moray Firth

A total of 243 schools of dolphins were sighted during photo-id surveys within the inner Moray Firth between 1990 and 2000. These ranged in size from 1 to 35 dolphins, with a mean of 5.1. Although dolphin schools were distributed along the whole of the inner Moray Firth survey route, the distribution of schools showed a distinctive pattern that was consistent in each of the years between 1990 and 2000 (Friedman test, $\chi^2 = 53.37$, $p < 0.001$); being concentrated in and around three narrow channels at the entrances to the Cromarty, Inverness and Beauly Firths (Table 1). Sightings of schools of porpoises along the survey route were infrequent; only twelve schools were sighted on ten of the surveys. The majority of the sightings were along the north-eastern sections of the survey route.

cSAC and outer Moray Firth

A total of 30 sightings were made during the combined acoustic and visual surveys; 23 schools of porpoises were sighted and 7 schools of bottlenose dolphins. The mean school size of porpoises and bottlenose dolphins was 1.83 and 6.7 respectively.

The hydrophone array was deployed successfully across the majority of the survey route. It proved practical to deploy the array and collect useful data from both survey vessels. Noise levels were reasonable at both vessel's regular cruising speeds. The combination of visual and acoustic detection methods produced ten encounters with dolphins (three schools of dolphins were detected acoustically but were not sighted). All sightings and acoustic detections of dolphins were made within the area of the cSAC (Fig. 2 and Table 2). Encounter rates of dolphins in the cSAC and outer Moray Firth were significantly different (Kruskall Wallis test, $\chi^2 = 6.88$, $p = 0.009$).

Porpoise sightings were distributed throughout the Moray Firth (Fig. 3). The median encounter rate of porpoises across the whole Moray Firth was 1.69 schools per 100km (Table 3). Encounter rates of porpoises in the cSAC and outer Moray Firth were not significantly different (Kruskall Wallis test, $\chi^2 = 0.054$, $p = 0.816$).

DISCUSSION

This study has provided a current evaluation of the distribution of small cetaceans throughout the Moray Firth cSAC and outer Moray Firth. Although based on a few

Table 1

The number of dolphin schools sighted during boat-based surveys in sub-areas of the inner Moray Firth between 1990 and 2000 (the region names used by Wilson *et al.* (1997) are shown in parentheses if different from the current study). Each year, the sub-regions were ranked from lowest to highest based on the number of dolphin schools sighted per km^2 and a test for consistency in the pattern of distribution was carried out. Mean rank of each area is shown in the right hand column. There was no significant variation in the pattern of distribution over the years (Friedman test, χ^2=53.37, p<0.001).

Region	Number of dolphin schools sighted per km^2											
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Mean rank
Cromarty Firth entrance (Sutors)	1.89	1.14	0.97	0.16	0.38	0.65	0.92	0.54	0.65	0.86	1.08	7.27
Cromarty Firth	0.00	0.13	0.13	0.13	0.00	0.00	0.00	0.50	0.13	0.00	0.00	3.14
Three Kings	0.00	0.00	0.26	0.00	0.05	0.11	0.05	0.05	0.11	0.16	0.05	3.23
Eathie	0.10	0.17	0.17	0.02	0.14	0.12	0.22	0.12	0.14	0.12	0.14	4.73
Inverness Firth entrance (Chanonry)	0.40	0.56	0.81	0.08	0.65	0.40	0.56	0.56	0.40	0.48	0.56	6.55
Inverness Firth	0.00	0.09	0.09	0.04	0.00	0.04	0.13	0.09	0.06	0.00	0.02	2.95
Beauly Firth entrance (Kessock)	1.25	2.50	1.00	0.00	0.50	1.25	1.50	1.25	0.25	0.25	0.00	6.32
Beauly Firth	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.05	0.01	0.00	0.00	1.82

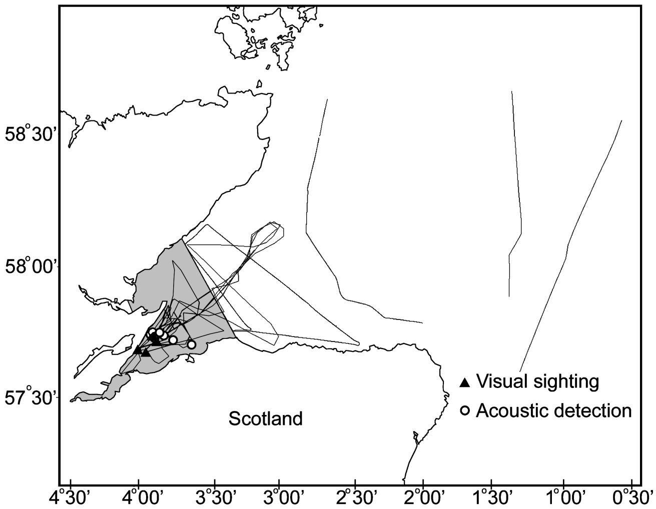

Fig. 2 The distribution of dolphins across the Moray Firth from ten combined visual and acoustic surveys carried out during 2001. The black line represents the survey track; visual sightings of dolphins are shown by the triangles and acoustic detections by the circles.

Table 2

Encounter rates of bottlenose dolphins in the Moray Firth. Results from the combined visual and passive acoustic surveys are expressed as the number of dolphin schools sighted per 100km of survey track, for the Moray Firth, within the candidate Special Area of Conservation (cSAC) and in the outer Moray Firth. Standard deviation is shown in parentheses. Encounter rates of dolphins in the cSAC and outer Moray Firth were significantly different (Kruskall Wallis, $\chi^2 = 6.88$, $p = 0.009$).

	Effort (km)	*n*	Median encounter rate (schools per 100 km)
Moray Firth	2,204	10	0 (1.24)
cSAC	1,293	10	0.45 (1.25)
Outer MF	911	0	0 (0)

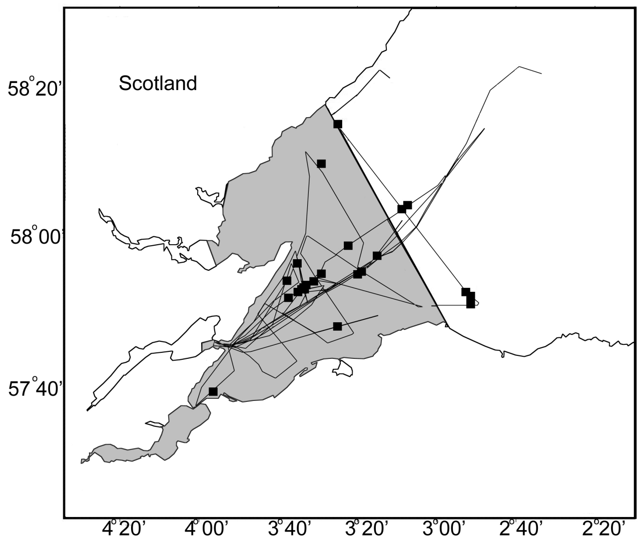

Fig. 3 The distribution of porpoises across the Moray Firth from visual surveys carried out during 2001. The black line represents the survey track and visual sightings of porpoises are shown by the squares.

wide-scale surveys, these results provide a basic framework for monitoring the distribution of dolphins within the Moray Firth cSAC and hence provide a valuable tool in the management of this population. More specifically, the results of the study provide a focus for the establishment of

Table 3

Encounter rates of harbour porpoises in the Moray Firth. Results from the visual surveys are expressed as the number of porpoise schools sighted per 100km of survey track, for the Moray Firth, within the candidate Special Area of Conservation (cSAC) and in the outer Moray Firth. Standard deviation is shown in parentheses. Encounter rates of porpoises in the cSAC and outer Moray Firth were not significantly different (Kruskall Wallis, $\chi^2 = 0.054$, $p = 0.816$).

	Effort (km)	*n*	Mean school size	Median encounter rate (schools per 100km)
Moray Firth	685	22	1.83	1.69 (3.96)
cSAC	610	17	2	0.78 (5.42)
Outer MF	175	5	1.33	0 (2.22)

monitoring strategies and can be used to target regions of the cSAC for the implementation of specific levels of monitoring effort or particular survey methods (e.g. Talisman Energy (UK) Ltd, 2001a).

Although dolphins were sighted along the whole of the inner Moray Firth survey route, there was a distinctive distribution pattern of sightings that was consistent throughout the study period. This pattern is the same as that identified by Wilson *et al.* (1997) from data collected between 1990 and 1993, with sightings being centred around three main areas, the deep narrow entrances to the Cromarty, Inverness and Beauly Firths. Although there were distinctive inter-annual changes in the relative number of schools sighted within the inner Moray Firth (Table 1), the stability of the distribution pattern over the decade highlights the importance of these small deep areas for dolphins during the summer months and emphasises the importance of detailed management plans for key areas such as these (MFP, 2001).

The broader-scale distribution of dolphins throughout the cSAC and outer Moray Firth also showed a distinctive pattern, with all sightings and acoustic detections of dolphins made within the cSAC, around the coastal margins of the inner Moray Firth. This is similar to the results from earlier surveys previously undertaken over the whole Moray Firth. During these surveys, Mudge *et al.* (1984) noted that all sightings of bottlenose dolphins were made within narrow firth entrances in the inner Moray Firth and this led, in part, to the setting of the current geographical boundaries of the cSAC. The median encounter rate of dolphin schools in this study was estimated to be 0.45 schools per 100km within the cSAC. This is similar to sighting rates of bottlenose dolphins in several other areas: 0.98 in the northern Gulf of Mexico (Baumgartner *et al.*, 2001); 0.07-0.29 in the north-central Gulf of Mexico (Mullin *et al.*, 1994); 0.81 off South Africa (Ross *et al.*, 1987). However, it appears markedly lower than in others: 7.6 in the Gulf of California (Silber *et al.*, 1994) and 7.36 off Texas (Barham *et al.*, 1980).

Recent evidence suggests that, over the last decade, the distribution of dolphins has extended southwards down the Scottish coast leading to concerns about the management of the population (Wilson *et al.*, In review). Nevertheless, the data presented in this current study suggest that the importance of different areas within the Moray Firth has remained relatively stable. However, there remain few data from the winter months, when dolphin abundance in the inner firth is lower (Wilson *et al.*, 1997). Further work in offshore areas is required to determine which areas are used at these times of year, and combined visual and acoustic surveys provide a promising method for collecting such data in poor sea conditions.

The lack of porpoise sightings around the inner Moray Firth suggests that this region, although important for dolphins (Wilson *et al.*, 1997), does not represent a particularly suitable habitat for porpoises. As the two species appear to occupy different niches (Santos *et al.*, 1994), it is likely that they are exploiting different habitat types. However, recent discoveries that bottlenose dolphins attack and kill harbour porpoises in this area (Ross and Wilson, 1996) cannot exclude the possibility that porpoises actively avoid areas with higher dolphin density.

The median encounter rate of porpoise schools in this study was estimated to be 1.69 schools per 100km within the Moray Firth. Although estimates in other studies are highly variable, this current result is generally in the lower margins of porpoise encounter rates: 0.85-2.4 schools per 100km in the Bering Sea (Moore *et al.*, 2002); 3.4-7.8 in the Gulf of California (Carretta *et al.*, 2000); 43.5 off the San Juan Islands (Raum-Suryan and Harvey, 1998) and 9-70 around the coast of the UK (Northridge *et al.*, 1995). However, no attempt was made to stratify the data for variables likely to affect sighting rates (such as environmental conditions or observer configuration) therefore direct comparisons of the encounter rates of dolphins and porpoises between this study and other studies are difficult. Furthermore, it is unclear whether data collected from combined passive acoustic and sighting surveys are directly comparable to data collected during visual surveys.

Despite these caveats, the distribution of porpoises throughout the Moray Firth was clearly different to the distribution of dolphins, with porpoises sighted throughout the survey route within the cSAC and the outer Moray Firth. This concurs with sightings made from previous seabird surveys, showing that porpoises were present all year round throughout most of the Moray Firth (Mudge *et al.*, 1984). In addition, this result also emphasises the fact that the visually more obvious dolphins were not present on the offshore legs of the surveys.

Combined acoustic and visual methods proved to be practical and cost effective for monitoring the distribution of dolphins throughout the Moray Firth. Acoustic monitoring worked well aboard the survey vessels and data collection was achieved around the clock using a small, two to three-person team. Indeed, no dolphin schools were sighted without being detected first using the hydrophone. This study assumed that all whistles were produced by bottlenose dolphins. This assumption is reasonable within the inner Moray Firth, where sightings of other dolphin species are rare (University of Aberdeen, unpublished data). However, this may not be the case in waters further offshore where species such as white-beaked dolphins (*Lagenorhynchus albirostris*) and white-sided dolphins (*Lagenorhynchus acutus*) may be more common (Mudge *et al.*, 1984; Hammond *et al.*, 2002). Although no dolphins were heard in these offshore waters in this study, future work may need to differentiate between species using analyses to discriminate between the acoustic characteristics of the vocalisations (e.g. Rendell *et al.*, 1999). Furthermore, although the current system allows the detection of bottlenose dolphin whistles, this could be extended to include an automated detection system to record porpoises (Chappell *et al.*, 1996; Gordon *et al.*, 1998). When used alongside visual methods, these acoustic monitoring techniques can provide markedly enhanced estimates of density and distribution (Fristrup and Clark, 1997). This is especially important where year-round coverage is required in areas such as the outer Moray Firth, where rough seas are common and winter days are short.

Implications for management

This combination of distribution studies at differing spatial scales is an extremely valuable tool in monitoring the distribution of animals and identifying important habitats (Pribil and Picman, 1997). Data from this study have provided a basis for the management of this coastal population of dolphins; data have already supported the development of management plans for the cSAC and been used in environmental assessments for industrial developments (e.g. Talisman Energy (UK) Ltd, 2001a).

The results support evidence from studies in the inner Moray Firth which show that the narrow entrances to coastal inlets provide the most intensively used areas by bottlenose dolphins within the cSAC. This emphasises the importance of these coastal channels and when building management plans for the cSAC, particular care is needed to mitigate against potential impacts from activities in these core regions. Although fewer dolphins were sighted in outer firth areas, there are known to be distinctive seasonal variations in the use of more coastal areas and therefore, it would be pertinent to conduct dedicated surveys when major new activities are planned in the less intensively used regions of the cSAC.

Further work should aim to achieve year-round, representative coverage of the cSAC and surrounding areas, integrating broader scale survey data, such as those used in this study, with more detailed work in areas of particular interest or concern (e.g. Hastie *et al.*, 2003). This multi-scale approach should ultimately lead to the identification of oceanographic, biological and anthropogenic determinants that underlie the distinctive patterns of distribution seen in this population of bottlenose dolphins.

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