The summer distribution and occurrence of cetaceans in the coastal waters of the outer southern Moray Firth in northeast Scotland (UK)

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Abstract: Information on the distribution and occurrence of whales, dolphins and porpoises in the coastal waters of Scotland's Moray Firth, in the north-west North Sea, remains fairly sparse to date, with few detailed studies being conducted on species other than the bottlenose dolphin (*Tursiops truncatus*). Consequently, familiar coastal species such as the minke whale (*Balaenoptera acutorostrata*) and harbour porpoise (*Phocoena phocoena*) have received far less attention in these waters, and yet these and other species may be of considerable conservation priority. In the present study, an examination of the animals using the southern coastal waters of the outer Moray Firth was carried out between May and October 2001 to 2005 inclusive. During 9,663 km of dedicated boat survey effort, 751 encounters were recorded with eight different species (six species of toothed whale, and two species of baleen whale) in an 880 km square coastal study area between Fraserburgh and Lossiemouth. The most commonly sighted cetaceans were harbour porpoises (comprising 60% of all encounters) and minke whales (at 25%), but the two most abundant species were porpoises and bottlenose dolphins, jointly accounting for 89% of the total animals encountered. Considerable inter-annual and seasonal variation was observed in both the number of encounters and the diversity of species recorded, and a seasonal increase in harbour porpoises was noted, with inshore movements of females and their calves across the summer months. For each of the other species recorded, all were considered "pelagic", deeper water animals which only sporadically utilised the study site. The temporal and spatial occurrences of the principal coastal species are discussed with respect to the complex ecological, biological and anthropogenic determinants in this location. Recommendations for the subsequent monitoring of this cetacean community are considered to be particularly important for current and future conservation strategies. Further work integrating broader scale survey coverage is proposed, with more detailed studies in particular areas of focal interest or concern with respect to local management and/or conservation directives.

Keywords: Cetaceans, distribution, occurrence, species diversity, boat-based surveys, Moray Firth, Scotland, northern North Sea, conservation, local management.

Introduction

The distribution and occurrence of whales, dolphins and porpoises in the north western North Sea has primarily been described from opportunistic data collected during seabird surveys in the 1980s and 1990s (Mudge et al. 1984, Northridge et al. 1995) and by dedicated volunteer networks (Evans 1992). With the addition of the large-scale SCANS (Small Cetacean Abundance in the North Sea) surveys conducted in 1994 (Hammond et al. 2002), these datasets have been combined to produce a general atlas of distribution for northwest Europe by Reid et al. (2003), featuring 28 cetacean species over a 25 year period. The end result provides a useful illustration of regional trends in cetaceans in these northern, temperate waters. But, due to the patchy nature of the observational coverage compiled, these low-resolution datasets are found to be largely unsuitable for "local" management, where finer scale determinations are typically required (Weir et al. 2007).

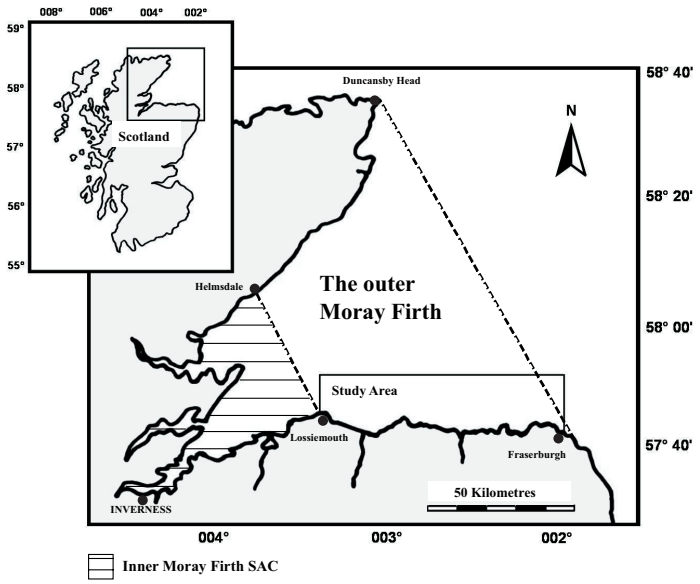

Figure 1. Map of the Moray Firth showing the position of the 880 km^2 study area along the southern coastline of the outer firth between Lossiemouth and Fraserburgh.

In the outer Moray Firth on the east coast of Scotland (57º41'N, 2º00'W), a number of fine and meso-scale studies have intimated the importance of this North Sea coastal embayment for a number of cetacean species (e.g. Hastie et al. 2003, Thompson et al. 2004, Weir et al. 2007). To date, however, the only detailed, year-round studies in the firth have been carried out on bottlenose dolphins (*Tursiops truncatus*) (Wilson et al. 1997, Wilson et al. 1999, Wilson et al. 2000, Grellier et al. 2003, Eisfeld & Robinson 2004, Hastie et al. 2004, Wilson et al. 2004, Durban et al. 2005, Bailey & Thompson 2006, Lusseau et al. 2006, Culloch & Robinson, in press), with few long-term investigations of other species known to occur here. Consequently, several familiar coastal species in this location, such as the minke whale (*Balaenoptera acutorostrata*) (Tetley 2004, Robinson & Tetley 2007) and harbour porpoise (*Phocoena phocoena*) (Whaley & Robinson 2004, Clark 2005), have received far less attention in these waters. Yet these and other inshore species arguably form a significant component of this marine ecosystem, and may be of considerable conservation priority in this respect (Clark et al. 2006).

The aim of this paper is to highlight the abundant cetacean community frequenting the southern outer Moray Firth and the respective importance of this area as a prime coastal habitat for these mammals during the summer and autumnal months. This objective is considered particularly relevant for the evaluation and improvement of existing management policies for the Moray Firth area as a whole – the recent shift in the distribution and range of the "resident" bottlenose dolphin population (see Wilson et al. 2004 and Stockin et al. 2006), for example, having raised questions as to the effectiveness of the current Special Area of Conservation (SAC) within the inner region of the firth. This presentation forms part of a larger, on-going project investigating changes in the spatio-temporal habitat use and site fidelity of the key cetacean species inhabiting this coastal North Sea location.

Materials and methods

The study area

Sharing large-scale environmental determinants, such as water circulation and climate patterns,

the Moray Firth in northeast Scotland is an integral part of the northwest North Sea and Atlantic Ocean beyond (Wright et al. 1998). Bound on two sides by land, it is generally defined as the area of sea from Duncansby Head in the north, to Inverness in the south-west, to Fraserburgh in the east (Harding-Hill 1993) (figure 1). The area to the west of a line drawn from Helmsdale to Lossiemouth is defined to as the "inner" Moray Firth, whilst the remaining sea to the east of this limit is the "outer" Moray Firth.

The characteristics of this large embayment (measuring some 5,230 km^2) vary greatly within its extent. In the inner firth, the seabed slopes gently from the shore to a depth of around 50 m approximately 15 km from the coast, whilst the outer firth more closely resembles the open North Sea (Holmes et al. 2004). The waters are a combination of mixed and coastal waters. Of the twelve major rivers which discharge freshwater into the firth, ten flow into the inner area substantially reducing the salinity here (Holmes et al. 2004). The main marine input is produced by the Dooley current which brings mixed cold waters down from the north that circulate in a clockwise direction (Wilson 1995). The resulting frontal zones are subsequently characterised by strong horizontal gradients in surface or bottom temperatures (Reid et al. 2003). The Moray Firth is internationally recognised as a site of outstanding biological importance and the inner firth was officially appointed a Special Area of Conservation in March 2005 (Scottish Natural Heritage 2006).

Data collection

Data used in the present study were collected from May to October 2001 to 2005 inclusive. Systematic boat surveys were conducted along an 83 km length of the southern Moray Firth coastline (lying between the ports of Lossiemouth and Fraserburgh) using four standardised routes positioned parallel to the shore – three outer routes, approximately 1.5 km apart in latitude, and an inner coastal route (where the probability of sighting bottlenose dolphins was highest) – covering a total survey area of approximately 880 km^2 (figure 2). The dedicated surveys were carried out using 5.4 m outboard boats with an observation frame giving an eye height of approximately 3.5 m above water. Surveys were conducted at mean vessel speeds of seven knots in visibility ≥1 km and Beaufort Sea States ≤3 with a crew of two experienced and up to four additional trained observers. The observers searched the area using a continuous scanning method (Mann 1999), from directly in front

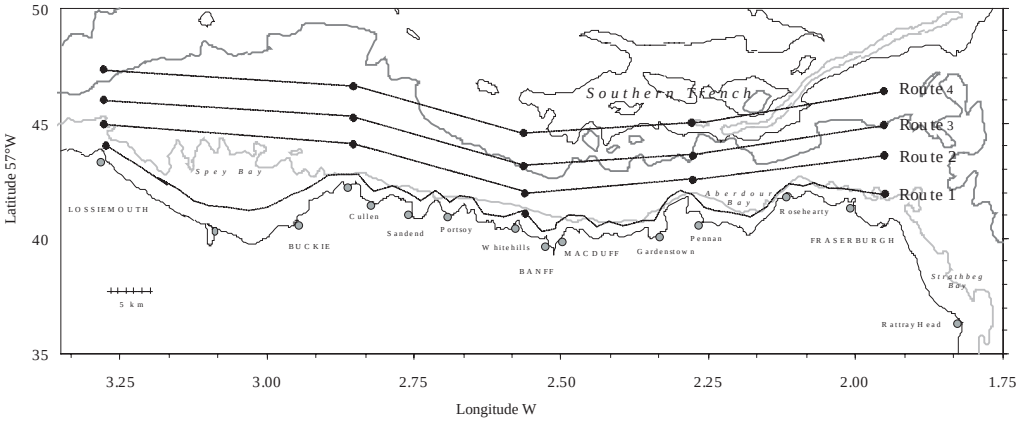

Figure 2. Showing the southern coastline of the outer Moray Firth and the survey routes used during systematic boat surveys. The routes were divided into three longitudinal outer transects (routes 2 to 4 respectively), each approximately one minute apart in latitude, plus an inner coastal transect (route 1) where bottlenose dolphin sightings were concentrated.

of the boat to 90 degrees left and right of the track line. To ensure animals were sighted before they reacted to the presence of the survey vessel, binoculars were used from the observation frame to scan far from the boat, while the remaining crew searched closer to the vessel with the naked eye. This scanning method and configuration of observers was found to minimise heterogeneity in detection probabilities between the different species and/or group sizes (after Palka 2005), as well as facilitating standardisation and comparability between the survey trips.

During survey trips, both the vessel position (using Global Positioning System) and respective environmental data were recorded. When cetaceans were spotted, the boat was gradually slowed (and circled back where necessary) to allow absolute identification of the species encountered. In addition, the number and position of animals were recorded and distances were corrected with respect to the survey vessel accordingly. With the exception of harbour porpoises, photography was used to validate identifications of all the cetacean species encountered.

Results

Across the 5-year survey period, 393 trips were made on 250 days, covering a total survey distance of 9,663 km (table 1). During this time, 751 encounters were recorded with eight different

Table 1. The survey effort for dedicated cetacean surveys conducted between May and October 2001 to 2005 inclusive.

Year	Number survey days	Total survey trips	Survey effort (km)	Total number encounters
2001	45	53	1514.2	63
2002	67	98	2518.6	226
2003	60	80	1946.0	211
2004	35	74	1886.8	62
2005	43	88	1797.6	189
Total	250	393	9663.1	751

Table 2. Showing the cetacean species encountered in the study area respective to the cumulative effort for each of the survey routes 1 to 4. The total number of animals encountered is given in parentheses.

Survey route	Route 1	Route 2	Route 3	Route 4	Total
Total effort (km)	5788.8	1872.9	1485.9	515.6	9663.1
Odontocete whales	248 (1756)	157 (452)	118 (339)	39 (147)	562 (2694)
1) *Phocoena phocoena*	142 (448)	156 (441)	117 (333)	37 (118)	452 (1340)
2) *Tursiops truncatus*	95 (1258)	0 (0)	0 (0)	0 (0)	95 (1258)
3) *Orcinus orca*	5 (13)	0 (0)	1 (6)	0 (0)	6 (19)
4) *Grampus griseus*	4 (19)	1 (11)	0 (0)	0 (0)	5 (30)
5) *Globicephala melas*	1 (6)	0 (0)	0 (0)	2 (29)	3 (35)
6) *Lagenorhynchus acutus*	1 (12)	0 (0)	0 (0)	0 (0)	1 (12)
Mysticete whales	42 (63)	73 (82)	53 (54)	21 (23)	189 (222)
7) *Balaenoptera acutorostrata*	41 (62)	73 (82)	53 (54)	20 (22)	187 (220)
8) *Megaptera novaengliae*	1 (1)	0 (0)	0 (0)	1 (1)	2 (2)
All cetaceans	290 (1819)	230 (534)	171 (393)	60 (170)	751 (2916)

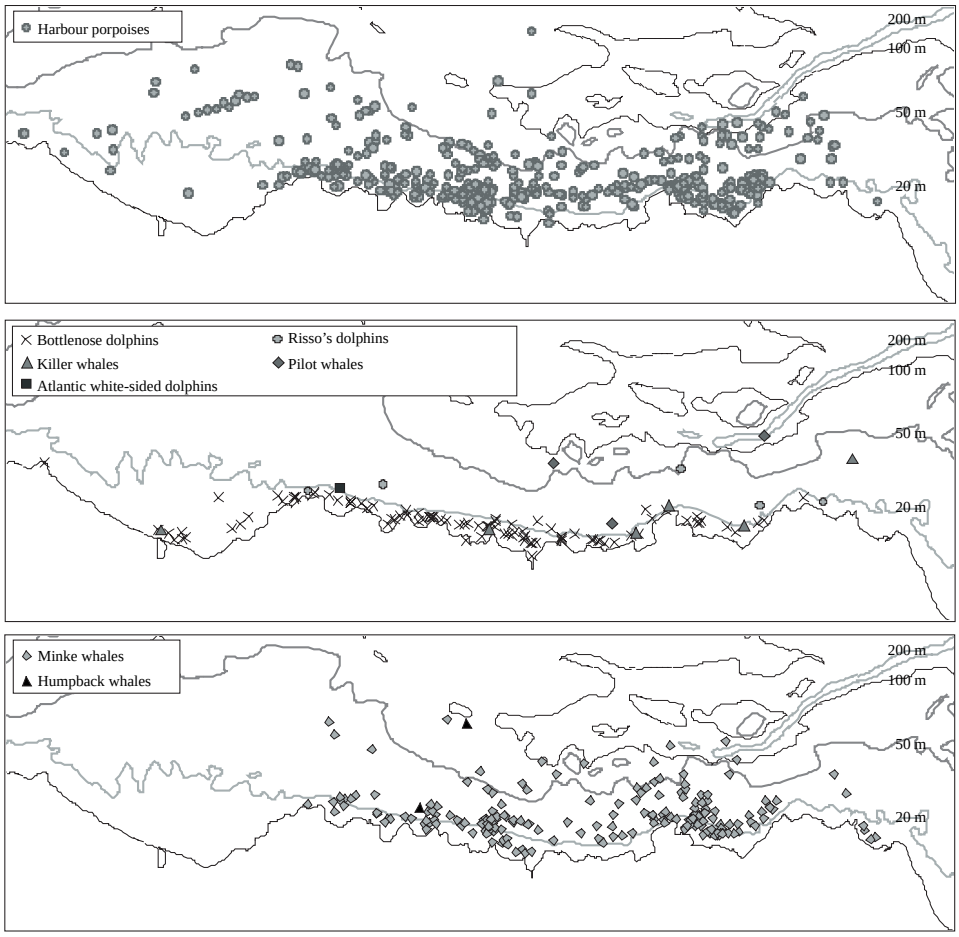

Figure 3. Sightings maps of the southern outer Moray Firth, showing the spatial distribution of cetacean species encountered across the 5-year survey period from May to October 2001 to 2005 inclusive.

species: six species of toothed (odontocete) whale [five delphinids and one phocoenid] and two species of baleen (mysticete) whale, both of which were rorqual whales (table 2). The respective distribution of these encounters is shown in figure 3.

The most commonly sighted species, comprising 60% of all encounters, was the harbour porpoise, followed thereafter by the minke whale at 25%, but the two most abundant species were the harbour porpoise and bottlenose dolphin, jointly accounting for 89% of the cumulative number of animals encountered (table 2). All three of these "coastal" species were recorded within the study area between May and October, with the exception of minke whales during May (figure 4a). Both harbour porpoises and minke whales were encountered throughout the study area on survey routes 1 to 4 respectively, but bottlenose dolphins were only recorded on the innermost survey route (route 1) in shallow waters rarely exceeding 25 m depth (median depth 16.3 m, n=95). Whilst minke whales and harbour porpoises were also recorded on this innermost route, corrections for survey effort revealed a considerably higher abundance of both species on each of the outer survey routes 2 to 4 respectively (table 3).

Throughout the study, considerable variation was observed in both the number of encounters and the diversity of species recorded from one survey year to the next (table 1 and figure 4b). In

Table 3. The encounter rates for harbour porpoises, minke whales and bottlenose dolphins in the outer southern Moray Firth (expressed as the number of encounters per km for each species on survey routes 1 to 4 respectively). The determination in parentheses denotes the total number of animals per km effort.

Species	Route 1	Route 2	Route 3	Route 4
Phocoena phocoena	0.025 (0.077)	0.083 (0.235)	0.079 (0.224)	0.072 (0.229)
Balaenoptera acutorostrata	0.007 (0.011)	0.039 (0.044)	0.036 (0.036)	0.039 (0.043)
Tursiops truncatus	0.016 (0.217)	-	-	-

2004, for example, only harbour porpoise (*n*=54) and a lesser number of bottlenose dolphin (*n*=9) encounters were recorded. In 2001, however, a total of seven different species were identified, although the total number of encounters per km was found to be very much lower than for 2002, 2003 and 2005, and only slightly higher than for 2004 (figure 4b).

A seasonal increase in the number of monthly cetacean encounters was also apparent in the pooled dataset (figure 4a), but this was directly attributed to a progressive increase in harbour porpoise encounters from May through to October. Whilst bottlenose dolphin encounters were highly variable across all months, minke whales were typically recorded in the study area from mid June onwards; with the number of minke whale encounters remaining fairly constant from July to October thereafter. For each of the additional cetacean species encountered, all were considered to be pelagic, deeper water animals that only sporadically utilised the coastal study site, as no obvious patterns of occurrence were determined. That saying, killer whales (*Orcinus orca*) were only sighted between the months of June and August (*n*=6), whilst Risso's dolphins (*Grampus griseus*) were exclusively recorded in September (*n*=5). Regardless of the number of encounters of each of the species recorded in this study, however, all of the species identified (both coastal and pelagic) showed spatial and temporal overlaps in their respective distributions.

Discussion and conclusions

The productive, coastal waters of the outer southern Moray Firth support an interesting diversity of cetaceans. In addition to the wide-scale occurrence of "coastal" bottlenose dolphins, minke whales and harbour porpoises, inshore movements of several other "pelagic" animals can be seen during the summer and autumnal months. Killer whales, pilot whales (*Globicephala melas*) and humpback whales (*Megaptera novaengliae*), for example, were all intermittently encountered in the study area between the months of July and August; Risso's dolphins were seen in increasing abundance during the latter years of the study; and a single sighting of twelve Atlantic white-sided dolphins (*Lagenorhynchus acutus*) was recorded in August 2005. However, at least eight additional species have been documented in the study area, from historical accounts (Smiles 1876, Harvie-Brown & Buckley 1895, Taylor 1899), opportunistic sightings (Mudge et al. 1984, Camphuysen & Winter 1995, Reid et al. 2003, Cave 2006, K.P. Robinson, personal observation) and from incidental strandings records (Baumgartner et al. 2006, R.J. Reid, unpublished data). In no particular order, these include: the white-beaked dolphin (*Lagenorhynchus albirostris*), striped dolphin (*Stenella coeruleoalba*), sperm whale (*Physeter macrocephalus*), northern bottlenose whale (*Hyperoodon ampullatus*), common dolphin (*Delphinus delphis*), Sowerby's beaked whale (*Mesoplodon bidens*), fin whale (*Balaenoptera physalus*) and the sei whale (*Balaenoptera borealis*).

The majority of species encountered during the surveys varied widely in their distribution, but bottlenose dolphins showed a clear preference for shallow, coastal waters less than 25 m in depth. Long-term studies of *Tursiops truncatus* suggest their occurrence in inshore waters is directly related to the distribution of near-shore prey (Defran & Weller 1999), and along the southern coastline of the Moray Firth, migratory salmonids

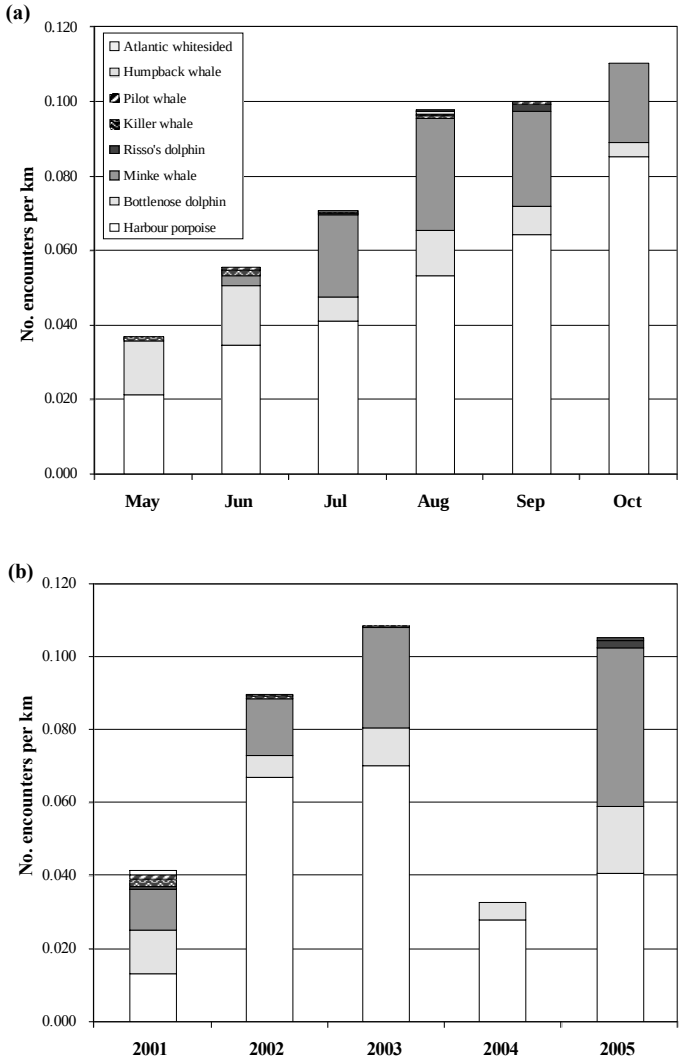

Figure 4. Stack histograms showing (a) the cumulative number of cetacean species per km of survey effort area recorded between May and Oct, and (b) the interannual variability in the number and diversity of cetacean encounters from 2001 to 2005 with respect to the annual survey effort undertaken.

– thought to be highly significant in the diet and the seasonal movements of this dolphin community (Santos et al. 2001, Stockin et al. 2006) – were commonly targeted by the species during the summer and autumnal months (K.P. Robinson, personal observation). Minke whales and harbour porpoises, on the other hand, were more usually abundant in deeper waters further from shore, with mixed species sightings typically occurring along the 20-50 m isobaths. In Scottish waters, sandeels (*Ammodytes* spp.) comprise the principal quarry for both minkes and porpoises (Pierce et al. 2004, Santos et al. 2004), and their comparable distribution in the present study was almost certainly linked to the availability of sandeel prey and the profitability of selected areas for mutual foraging. The relationships between predators and their prey, however, remain inherently complex and dynamic. For example, many species of pelagic fish also targeted by cetaceans

in these waters, including whiting (*Merlangius merlangus*), haddock (*Gadus morhua*) and pelagic mackerel (*Scomber scombrus*) (Santos et al. 1994), are ultimately dependent on sandeel prey themselves (Greenstreet et al. 1998, Robinson & Tetley 2007). Consequently, respective variations in the presence or absence of these key mid-trophic species in the study area, both as predators and as prey, would be further significant to the distributions of the cetacean species observed.

In addition to ecological parameters such as water depth and prey distribution, however, the seasonal and inter-annual variations recorded for cetaceans in the present study area might also be explained by a combination of other factors, including: reactions to anthropogenic impacts (Thompson 1992, Evans 1996), requirements for suitable calving conditions (Yasui & Gaskin 1986, Weir et al. 2007) and even inter-specific competition with other cetacean species (Ross & Wilson 1996), notably the avoidance by porpoises of areas used by bottlenose dolphins. In 2004, for example, the low number of cetacean sightings and the complete absence of minke whales in the study area were believed to be the direct result of regional sandeel depletions due to over-fishing, as corroborated by North Sea fisheries data (FRS 2004, Greenstreet et al. 2006) and the reported breeding failures of many seabirds around the Scottish coastline at this time (Proffitt 2004). In addition, record numbers of large, demersal squid trawlers were recorded in the study area between June and September 2004 (K.P. Robinson, personal observation) – in response to exceptionally high landings of *Loligo forbesi* in the firth the previous summer by the usually small, local fishery (Young et al. 2006) – which may have further resulted in the disturbance or direct displacement of the animals occupying the targeted fishing areas. This conjecture was supported by the low numbers of porpoise and bottlenose dolphin sightings recorded on inshore survey routes between Cullen Bay and Pennan where and when the larger trawlers were most concentrated. Furthermore, post-trawling observations by divers in Cullen Bay and Banff (B. Jamieson & C. Hollingdale, personal communication) revealed deep scarring of the sea floor and extensive damage to the shallow and shelf sedimentary habitats predictably populated by sandeels in this location (Tetley 2004, Clark et al. 2006). Since intensive demersal trawling is known to cause widespread physical and biological changes to marine habitats and their fauna (Lindegarth et al. 2000, Rosenberg et al. 2003), the loss of local sandeel communities and other prey species in affected areas (through associated bycatch and the degradation of critical habitat) would be assumed to impact upon those predatory cetacean species as well.

The absence of white-beaked dolphin encounters in this investigation was also particularly interesting given the high abundance of animals described for the region from earlier datasets (e.g. Northridge et al. 1995, Hammond et al. 2002, C.J. Camphuysen, unpublished data). However, an examination of strandings data for the area (Baumgartner et al. 2006, R.J. Reid, personal communication) suggests that the species may in fact be present here during the colder winter months – incidentally at a time when inter-specific competition from bottlenose dolphins is less prevalent. In harbour porpoises, for example, the avoidance of areas occupied by the larger bottlenose dolphins evidently results in spatial and/or temporal habitat segregation between the species (Thompson et al. 2004). And whilst there are no published cases of directed aggression towards white-beaks by bottlenoses in Scottish waters (the two species being ecologically very different, i.e. near-shore versus pelagic), where sympatric populations exist along the coast of Aberdeen, an inverse relationship has been observed between the temporal occurrences of the two species (C.D. MacLeod, unpublished data), with white-beaks occupying a higher ranking in the community only when the temporal occurrence of bottlenoses is lowest. In the present study area, however, since bottlenoses are seen to be ubiquitous along the coastline for the full duration of the study period (May to October), no such temporal switch over would be possible.

The seasonal differences in the occurrence of the principal cetacean species recorded may further be explained in terms of their reproductive and/or calving requirements. In contrast to minke whales, for example, it appears that harbour porpoises and bottlenose dolphins utilise the sheltered inshore waters of the firth across the warmer summer months to give birth (Grellier et al. 2003, Clark 2005, Culloch & Robinson, in press). Indeed, calves were recorded in 84% of all bottlenose encounters in the present study, with newborn animals being produced from July to October inclusive. For harbour porpoises, however, neonatal calves were typically observed between May and July, consistent with known calving periods for the species throughout the North Sea (Lockyer 1995), and the seasonal increase in porpoises was believed to result from the inshore movements of lactating females with their calves (followed thereafter by the males). Since the consumption rates of female porpoises are known to increase to 80% of their body weight during lactation (Yasui & Gaskin 1986), the energetic demands of calving and nursing may subsequently be a driving factor in the seasonal migrations of the principal species observed.

In conclusion, the distribution data presented here suggest that the spatial and temporal occurrence of cetaceans in the study area is variable and complex. The spatial data indicate that some species restrict their movements and activities to particular areas and depths, whilst others are more widespread and responsive in their distribution. Continued warming of the local waters, however, is predicted to result in further changes to this cetacean community (MacLeod et al. 2005, Learmonth et al. 2006), with probable additions and expected increases in existing warmer-water cetaceans, such as Risso's and common dolphins, and the disappearance or change in the relative and absolute abundances of others, such as pilot whales and killer whales, for example. In this respect, further monitoring of this cetacean community is considered to be particularly important for present and future conservation strategies. On going spatio-temporal analyses of the "priority" coastal species identified in this study will allow us to focus conservation measures in relation to human activities in this area (e.g. bycatch reduction, disturbance by shipping, tourism etc); to identify times and areas of special significance in the life cycle, such as breeding periods and nursery areas; and to measure the effectiveness of current management and action plans, assisting in their future development. Further work should aim to achieve additional coverage of the outer Moray Firth region, integrating broader scale survey data and directing more detailed work in focal areas of particular interest or concern. Such a 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 coastal North Sea area, and these objectives are believed to be fundamental to local management directives for the protection of this and other coastal cetacean communities in UK and European waters.

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Samenvatting

De verdeling en het voorkomen van walvisachtigen gedurende de zomer langs de zuidkust van het buitenste deel van de Moray Firth in noordoostelijk Schotland

Gegevens over het voorkomen en de ruimtelijke verdeling van walvissen, dolfijnen en bruinvissen in de kustwateren van de Moray Firth (Schotland), in het noordwestelijke deel van de Noordzee, zijn tot op heden schaars. Zo zijn er slechts enkele gedetailleerde onderzoekingen aan andere soorten dan de tuimelaar verricht (*Tursiops truncatus*). Daardoor hebben regelmatig aan de kust voorkomende soorten als de dwergvinvis (*Balaenoptera acutorostrata*) en de bruinvis (*Phocoena phocoena*) veel minder aandacht gekregen, ondanks het feit dat maatregelen tot bescherming van deze en andere soorten van groot belang kan zijn. Het hier gepresenteerde onderzoek geeft een beeld van de dieren die in de zomers van 2001 tot en met 2005 gebruik maakten van de kustwateren in het buitenste deel van de Moray Firth. In een kustgebied van 880 km^2 tussen Fraserburgh en Lossiemouth werd een traject van in totaal 9.663 km op systematische wijze geteld, waarbij 751 waarnemingen werden verricht. Er werden acht soorten walvisachtigen waargenomen: zes soorten tandwalvissen en twee soorten baleinwalvissen. De bruinvis en de dwergvinvis werden het vaakst waargenomen (respectievelijk 60% en 25% van alle waarnemingen); de twee in aantal meest voorkomende soorten waren de bruinvis en de tuimelaar, tesamen goed voor 89% van het totaal aantal waargenomen dieren. Van jaar tot jaar en in de loop van de zomer treden er aanzienlijke verschuivingen op in de waargenomen aantallen en de aantallen soorten. Daarnaast treedt er in de loop van het seizoen een toename op van de aantallen bruinvissen, waarbij de verplaatsingen van vrouwtjes met jongen richting kust toenamen. Alle andere waargenomen soorten, die als 'pelagisch', in dieper water levend worden beschouwd, werden slechts incidenteel in de kustwateren waargenomen Het voorkomen in tijd en ruimte van de belangrijkste soorten wordt besproken in relatie tot de complexe ecologische, biologische en antropogene factoren die een rol spelen in het onderzoeksgebied. Aanbevelingen voor het voortzetten van de tellingen van de walvisachtigen in dit gebied zijn van groot belang voor de huidige en toekomstige beschermingsmaatregelen. Verdergaand, grootschaliger monitoringsonderzoek wordt voorgesteld, waarbij meer gedetailleerd gekeken wordt in juist die gebieden die van cruciaal belang zijn voor lokaal beheer en/of beschermingsmaatregelen.

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