The distribution and relative abundance of the harbour porpoise (*Phocoena phocoena* L.) in the southern outer Moray Firth, NE Scotland

Thesis submitted for the degree of
Bachelor of Science

By

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April 2004

Photo credit: Kevin Robinson / CRRU

"There is about as much educational benefit to be gained in studying dolphins in captivity as there would be studying mankind by only observing prisoners held in solitary confinement".

- Jacques Cousteau

Abstract

Throughout its range, the distribution of the harbour porpoise (*Phocoena phocoena* L.) has contracted significantly in the last century, particularly in the North Sea. Reasons for this decline have been primarily attributed to detrimental anthropogenic activities, but the current lack of data on the species has been noted as the foremost reason for the apparent complacency with which the UK and EC governments have regarded it to date.

In areas where shore sightings of the species are prevalent, quantitative data on the distribution and abundance of this small cetacean will be fundamental to population estimates and ultimately essential to management proposals for their protection. Along the southern coastline of the outer Moray Firth in NE Scotland, the species is found in significant numbers during the summer months. In this respect, the aim of the present study was to determine the coastal distribution and habitat use of the animals in this location; to provide estimates of relative abundance; and to record the general group structure and behaviour of the porpoises encountered.

Line transect surveys were conducted between the months of May and September 2003 using a 5.4 m rigid inflatable boat at speeds of between 8 and 12 km h^{-1}, and in sea states of Beaufort four or less. The transects were undertaken perpendicular to the shore line between the ports of Findochty and Fraserburgh using 4 different survey routes, each approximately 1.5 km apart. The total survey area covered was estimated as 550 km^2. When animals were sighted, details such as the GPS position, number of adults and calves, the direction of travel and the activity of the animals present were recorded.

From 123 dedicated survey hours conducted on 38 survey days, a cumulative total of 415 animals were recorded from 134 encounters. Areas adjacent to Whitehills and within Aberdour Bay were identified as potential “hotspots” for the species. The overall abundance was calculated as 0.752 animals per square kilometre, which was significantly higher than in other small-scale investigations of the species. Group sizes of harbour porpoise ranged 1 to 17 animals with a mean of 2.64 ± 1.18; single porpoise and pairs of animals were most frequently recorded. Higher levels of feeding were recorded in May and June, which coincided with known calving periods for the species. 12.68% of all groups encountered contained calves.

In conclusion, the results showed a high level of abundance of harbour porpoises in the study area throughout the summer months. Two main sites of high usage are identified, although further study would be desirable to establish whether the area is also important as a nursery ground for the animals. The evidence so far suggests that the coastline of the outer southern Moray Firth may constitute a potential “safe area” candidate for the species in this NE Scottish location.

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1. Introduction

Whales, dolphins and porpoises belong to the Order Cetacea, comprising 85 members to date arranged in two suborders (Rice, 1998; Hoezel, 2001; IWC, 2001), of which the common or harbour porpoise (*Phocoena phocoena* Linnaeus 1758) is the smallest and most abundant member in British waters (Evans, 1992). The presence of teeth in this species places it within the suborder Odontoceta – amongst the dolphins and larger toothed whales, rather than the baleen whales or Mysticeta – alongside 5 additional members of the family Phocoenidae.

The phocoenids are all quite different in appearance from the other odontocete families (fig. 1.1). Typically, the harbour porpoise is short and stocky (giving it a distinctly rotund shape), with a small, triangular dorsal fin, no obvious beak, and characteristic spade-shaped teeth. Unusual for cetaceans, the female grows larger in size than the male; up to 160 cm in length and 60 kgs in weight, compared to 145 cm and 50 kgs (Read, 1990). The average life span of the species is between 8 to10 years, with sexual maturity reached at 3 to 4 years (Read & Hohn, 1995). Females become pregnant again shortly after giving birth to a single calf. With an 11-month gestation period, the calves are born from May onwards, with most births occurring in June and copulations in July (Lockyer, 1995). At birth, the calves are usually about 70 to 75 cm in length and 5 kgs in weight, with a higher percentage of blubber then the adults. They are weaned for just one year.

The most northerly-located member of the porpoise family, the harbour porpoise is found throughout the North Sea, North Atlantic, North Pacific and Black Sea (fig. 1.2). Based on the reproductive isolation of the species, it has been split into 3 sub-species: *Phocoena phocoena vomeria* for the Pacific Ocean, *Phocoena phocoena relicta* for the Black Sea and *Phocoena phocoena phocoena* for the Atlantic and North Sea areas (Kroger, 1986). The Atlantic and North Sea variety inhabits virtually all coastal waters around the UK, but is now rare or absent in the English Channel (Read, 1999). So far, only one calving ground has been identified for the species in the North Sea, at the Slyt/Amrum area of the Wadden Sea in Denmark (Sonntag *et al.*, 1997).

Harbour porpoises are usually found in small groups or as individual animals (Hoek, 1992; Reeves *et al.*, 2002), although there have been sightings of groups of more than 100 reported. Baines (1997) reported approximately 700 porpoises off of Strumble Head, southwest Wales, in a single August day. The animals are usually observed at near shore sites or at upwellings, where they can be observed foraging (Pierpoint, 1993). During the winter, however, the coastal population is considerably reduced when the species is thought to move offshore towards the continental shelf (DETR *et al.*, 2000).

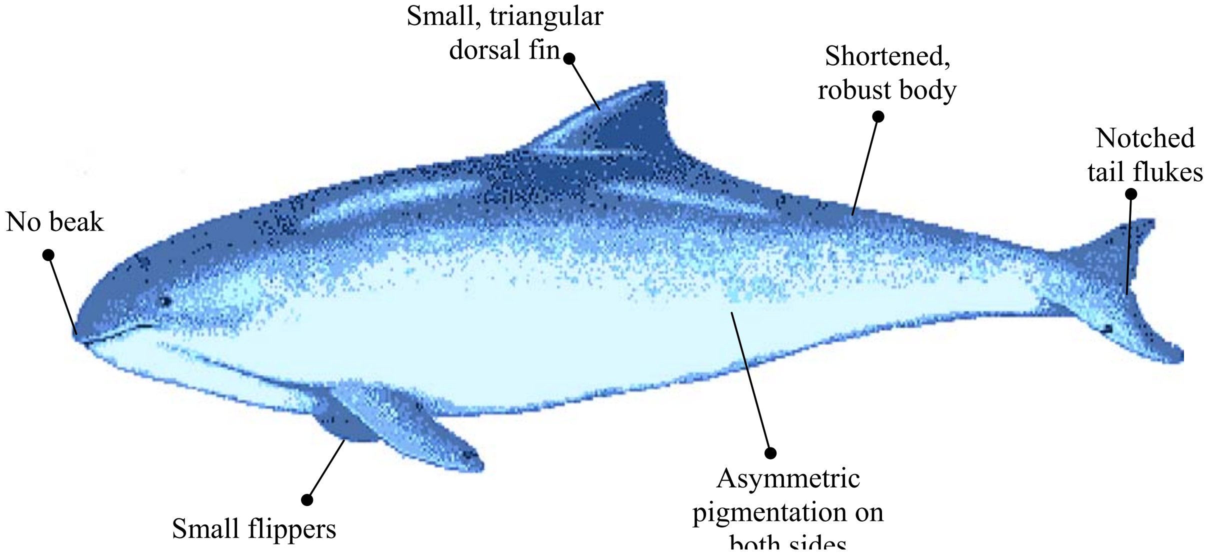


Figure 1.1. Drawing of the common or harbour porpoise, *Phocoena phocoena*. The species shows a number of external physical features common to most porpoises, but it is often difficult to see many of these under field conditions (Carwardine, 1995).

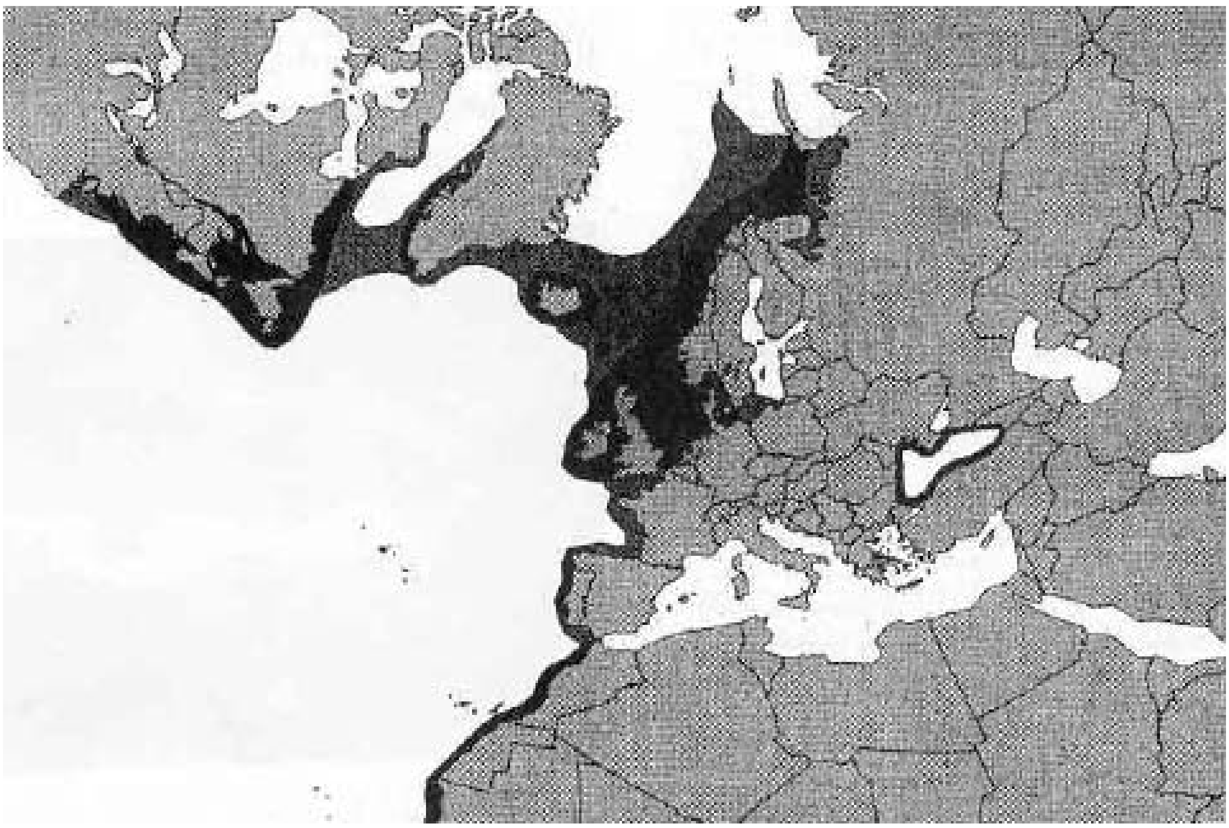


Figure 1.2. Map showing the distribution of harbour porpoises in European waters and the Northeast Atlantic.

So why do harbour porpoises choose particular areas? Smith and Gaskin (1983) suggest that reproduction, foraging and feeding are key factors affecting observed distribution patterns in the species. Seasonal variation occurs with a peak of near shore sightings in the summer with fewer in the winter months (Gaskin & Watson, 1985; Barlow, 1988; Sekiguchi, 1995). It is likely that these seasonal movements are a response to changing oceanographic conditions, such as sea surface temperature (Lockyer, 1995; Bräger *et al*., 2003) and changes in the availability and distribution of prey (DETR *et al*., 2000). Other physical factors that may also contribute include depth, current velocity, sub-surface topography and gradient, all of which result in features such as high degrees of water mixing, upwellings and strong tidal streams associated with high biological productivity (Hui, 1979; Shanks, 1983; Barlow, 1988; Shanks, 1988; Raum-Suryam & Harvey, 1998; Carretta *et al*., 2001; Hastie *et al.*, 2003). Genetic studies also indicate that female porpoises may demonstrate site fidelity and preferences, forming local populations (Walton, 1997).

Current estimates for the population in the North Sea and surrounding areas are relatively high at 350,000 (Hammond *et al*., 1994), but a decline in the number of the species throughout its range has been observed even as far back as the 1940's. What was once the most common of the cetaceans in European waters has now seen a serious decline of between 53,000 and 89,000 animals in the last century (Reijinders, 1992). In the North Sea, the distribution of this small cetacean has contracted significantly, virtually disappearing altogether in the Baltic Sea. An estimated population of 279,367 ± 115,633 (95% confidence interval) was given for European waters after the SCANS survey was conducted in 1984 (Hammond *et al.*, 1995), but no specific records exist for smaller areas. Whilst the reasons for decline in the species are not entirely clear-cut, anthropogenic activities, incidental bycatch, chemical / acoustic pollution and habitat change from over-fishing, for example, are believed to be largely responsible for this reduction in numbers.

By-catch, where non-targeted animals are accidentally caught in fishing nets, is currently the main focus of many conservation groups. Whilst this seems to be an acceptable hazard of the fishing industry, current figures for by-catch remain disturbingly high, especially for the harbour porpoise. In the North Sea, Hammond *et al.* (1994) report that 4.6% of the harbour porpoise population is lost to by-catch each year. A further 4% (amounting to 6785 individuals) are caught in Danish nets (Vinther, 1999), and 0.6% (approximately 1000 individuals) in UK nets (Northridge & Hammond, 1999). Indeed, post mortem examinations carried out by the Institute of Zoology on stranded harbour porpoises between 1990 and 1995 established that 66 (38%) of 176 individuals had died as a result of entanglement in fishing nets (Kirkwood *et al.*, 1997). The International Whaling Committee (IWC) has agreed that an annual loss as high as 1% was cause for concern (IWC, 1995), yet annual estimated figures are clearly way above this threshold. Even the figure of 1.7% set for European Union members under ASCOBANS is being breached. According to the IWC, levels of by-catch this high are not sustainable, as they exceed more then 50% of the annual population growth rate (Bjorge & Donovan, 1995; IWC, 1996).

Acoustic deterrents, or pingers, have been widely demonstrated to reduce by-catch in gillnet fisheries (Gearin *et al.*, 2000). In 2000, Read extensively reviewed the use of pingers in US fisheries and reported that by-catch rates for certain fisheries were reduced significantly; 10-fold for harbour porpoise. Indeed, subsequent work carried out by the University of St. Andrew's Sea Mammal Research Unit (SMRU) on the set net fishery in the Celtic Sea, yielded a 92% reduction in by-catch of harbour porpoises in nets with pingers compared to those without (SMRU, 2001). Moreover, since August 2000 the mandatory use of pingers between the months of August and October in the Danish cod wreck fishery is reported to be as close to 100% reduction in by-catch (Larsen *et al*., 2002; Vinther & Larsen, 2002).

Introspectively, Johnston & Woodley (1998) state that the use of acoustic deterrents may actually keep harbour porpoise away from parts of their habitat. In this respect, more recent research has been directed towards interactive pingers with a deterrent device that only emits sound when triggered by the sonar clicks of an approaching porpoise (Amundin *et al.*, 2002). This approach addresses the concerns of noise pollution and habituation, with the pingers transmitting sounds only when needed. Although sea trials had been scheduled for 2002, results thus far have only been reported from work with captive harbour porpoises (CEC, 2002). As such, further trials with interactive pinger use in bottom-set gillnet fisheries remain crucial to current management and recovery plans for the North Sea porpoise population.

In the Moray Firth, the study area for the following investigation, interspecific aggression from bottlenose dolphins (*Tursiops truncatus* Montagu) is also well documented for the harbour porpoise. Ross & Wilson (1996) state that over 60% (90 out of 140) of the harbour porpoises found dead on the Northeast Scottish coastline between 1992 and 1996 showed signs of systematic battery by bottlenose dolphins. The targeted porpoise are apparently isolated from their groups by juvenile bottlenoses, entered into chase, and then repeatedly attacked, even tossed clear of the water, until the animal is dead. Patterson *et al.* (1998) reasoned in explanation of these attacks that such behaviour by the dolphins might be related to infanticide observed in the species. Figures provided by the Scottish Agricultural College from 1992 show that 137 (33.4%) of the 410 porpoise necropsied had died as the result of attacks from bottlenose dolphins (Bob Reid, pers. comm.).

A further effect threatening the status of cetacean species in coastal locations is pollution, particularly noise pollution, as whales and dolphins rely heavily on sound for hunting, communication and navigation (Hughes, 1998). Extraneous noise pollution is thought to be very significant in the North Sea in view of the large amounts of fishing and commercial shipping traffic, seismic testing for oil and gas supplies, and naval activities / sonar testing in this area. Harbour porpoises are known to avoid close contact with ships (Polacheck & Thorpe, 1990), and Goold (1996) has demonstrated that cetaceans can be displaced from critical habitats by seismic activity. Although in 1986 tributyltins (TBT's) were banned on boats of less than 25 metres, they are still used on tankers and military vessels to date (Ambrose, 1994). The effects of TBT's have been studied for many species of marine animal, but as yet there have been no studies on their effects on coastal cetaceans (Parsons *et al*., 2000).

Oil pollution from spills or leaks at oil sites is also known to have detrimental effects on marine mammal populations and the environment in which they live (Hughes, 1998). Over short periods of time, however, cetaceans are known to be able to detoxify hydrocarbon compounds (Geraci & St.Aubin, 1982), but the effects of prolonged exposure on species such as the harbour porpoise inhabiting estuarine areas and bays are as yet unknown. Mercury and other heavy metals are certainly known to accumulate in the body tissues of cetaceans with increasing age (Law *et al.*, 1991). In one harbour porpoise found in the river Dee, Aberdeenshire, levels as high as 150 milligrams of mercury per gram of body weight were recorded (Santos, 2004); against a tolerance limit proposed by Wagemann & Muir (1984) of 100 - 400 $\mu g\ g^{-1}$. Moreover, in Greenland, Joiris *et al.* (1991) recorded individuals with even higher levels of heavy metal contamination in an area with far less industry.

The harbour porpoise is protected locally under the North East Biodiversity & Moray Firth Action Plans, nationally by the UK Biodiversity Action Plan and Wildlife and Countryside Act (1981), and internationally under the European Community's (EC) Habitats Directive, Berne Convention (Appendix II), Bonn Convention, Agreement on Small Cetaceans of the Baltic and North Seas (ASCOBANS) and the Convention on the International Trade in Endangered Species (CITES). Under CITES, the species is listed under level II which states that the harbour porpoise is "strictly protected, endangered and vulnerable"; Appendix II of the Berne Convention (1979) includes all cetacean species in the North and Baltic Seas; whilst the EC Habitats Directive (1992) lists the porpoise under Annex II as eligible for Special Area of Conservation (SAC) status. However, article 4, paragraph 1 of the Habitat's Directive states that: "for aquatic species which range over wide areas, such sites will be proposed only where there is a clearly identifiable area representing the physical and biological factors essential to their life and reproduction". As such, the criteria laid down by Directive 92/43/EEC are clearly inapplicable for the harbour porpoise.

It is, in fact, the current lack of data on the species that has been noted as perhaps the foremost reasons for the apparent complacency with which the species has been regarded in the UK to date. Although a general estimate of abundance was given in the SCANS study (Hammond *et al.*, 1994), there have been few small-scale surveys undertaken for the species in "critical" areas of abundance. In view of the present inadequacies in our own restricted knowledge of these animals in UK coastal waters, specific studies of the harbour porpoise in areas thought to form important ecological sites will be instrumental to the future development of potential "safe areas" for the species.

At present, the "inner" Moray Firth – defined as the area west of Helmsdale in the North to Lossiemouth in the South (see map in chapter 2, fig. 2.1) – is a candidate Special Area of Conservation (cSAC); hosting one of just two known populations of bottlenose dolphins in UK waters and featuring sub-tidal sandbanks as an additional qualifying interest (MFP, 2001). This cSAC status circumstantially affords protection to harbour porpoises in the inner firth, but recent data collected by the Cetacean Research & Rescue Unit (CRRU) suggests that the southern coastline of the "outer" Moray Firth, the larger area to the east of the cSAC boundary, may be used intensively by the species throughout the summer months (Robinson, 2003).

The conservation of ecologically important sites for coastal species such as the harbour porpoise, that exclusively use particular habitats, makes the monitoring of small inshore populations a necessity; particularly in view of current inadequacies for their management and protection. In this respect, the present study was undertaken to provide a clearer picture of the distribution and status of the animals using the coastal waters of the southern outer Moray Firth. Using established methods and original data collection from dedicated boat surveys, the principle objectives of this study aimed:

- to map the general distribution and activity of harbour porpoises along the southern coastline of the outer Moray Firth;
- to provide estimates of relative abundance for the animals frequenting this coastal location;
- to identify sites of high fidelity and/or potential "hotspots" for the animals with a view to future "safe areas" for the species; and
- to record the number and association of calves in the study area, to relate habitat use to the presence of prospective nursery areas.

2. Study Area

Measuring approximately 5230 km^2, the Moray Firth in NE Scotland (57º40′N, 3º30′W) is the largest embayment or firth in the country (Tilbrook, 1986). Bounded on two sides by land - from Duncansby Head in the north, to Inverness in the southwest, and to Fraserburgh in the east - it contains within it three smaller firths and a number of smaller bays and inlets. Following Harding-Hill (1993), the area west of Helmsdale in the North to Lossiemouth in the South is generally referred to as the "inner" Moray Firth, whilst the area to the North and East of these landmarks is known as the "outer" Moray Firth (fig. 2.1).

The bathymetry of the Moray Firth is relatively simply on a large scale. From the inner firth, the seabed slopes gently from the coast to a depth of about 50 m, approximately 15 km offshore (Admiralty Chart C22, 1997). The coastline of this area consists of dune systems, cliffs and tidally exposed mudflats. Of 12 major rivers flowing into the Moray Firth, 10 discharge freshwater into the inner Firth creating an estuarine-like environment that changes to the North and East (Adams & Martin, 1986). In contrast, the outer Moray Firth – where the present study is focused – resembles more the open sea. Here, the seabed slopes more rapidly to depths of up to 200 m within 26 km of the shoreline (Admiralty Chart C22, 1997), and the typically rugged coastline forms a composite of headlands and small bays consistent with the more irregular topography of the seabed in this area.

On a fine scale, the transition between the inner Moray Firth and the outer Firth is less distinct. A number of prominent submarine banks in the outer Firth create shallow areas that reduce the depth to just 33 m in places. Conversely, the narrow mouths of the Cromarty, Inverness and Beauly Firths, within the inner Moray Firth, are composed of steeply sided basins creating depths of over 50 m only 1 km offshore. Whilst sediments in the Moray Firth are predominantly sandy, grain size is inversely correlated to depth (Reid & McManus, 1987). The shallower areas of the Firth are made up of coarse sands, whilst the deepest areas off the southern shoreline are typically composed of mud.

A combination of coastal and mixed waters (coastal and oceanic) is found in the Moray Firth. The main part of the mixed waters is brought down from the North by the Dooley current, which then circulates in a clockwise direction within the firth (Adams, 1987). Because of the major freshwater input into the inner Moray Firth, the water salinity is substantially reduced. Since "permanent" estuarine conditions decrease gradually with increasing distance from the inner Moray Firth, the salinity in the outer Moray Firth typically exceeds 34.8 psu (or practical salinity units).

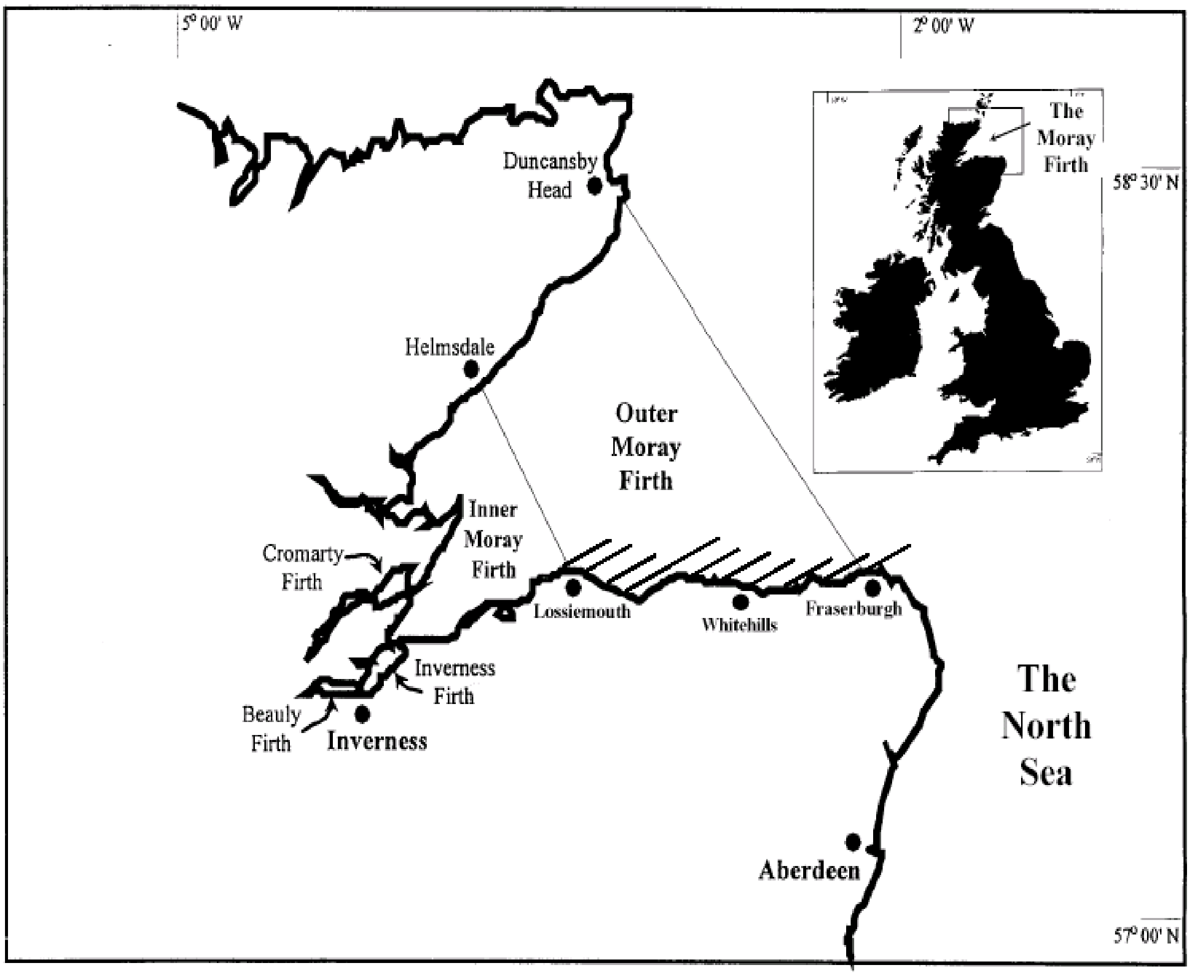


Figure 2.1. Map of Northeast Scotland showing the location of the Moray Firth and the area in which the CRRU's boat survey work is undertaken (shaded area). Redrawn and adapted from Wilson (1995).

3. Materials & Methods

3.1. Data collection

Data were collected between May and October 2003 using boat-based surveys along an 82 km stretch of coastline in the outer southern Moray Firth. The surveys were conducted using a 5.4 m Avon Searider Rigid Inflatable Boat (RIB) fitted with a 90 hp Johnston Evinrude outboard engine at speeds of 8 to 12 km per hour whilst searching for animals. Trips were made on as many days as possible throughout the season at sea states of Beaufort 3 or less and during good lighting conditions. If the sea state increased to Beaufort 4 or above, or if heavy or continuous rain occurred during the course of a survey, the trip was either stopped or aborted.

During the present study, a total survey area of 550 km^2 was systematically covered between the ports of Portknockie and Fraserburgh using 4 different transect routes; each running parallel to one another and the adjacent shoreline and divided further into 3 sub routes (see fig. 3.1).

3.2. Observations recorded

For each boat survey, a *Trip Log* was used to record the trip details. Using a laminated sheet and chinagraph pen, information such as the route covered, survey start and finish times, GPS start and finish positions, the sea state / environmental conditions, and the number of observers on board were detailed. When animals were sighted, the boat was slowed to minimise disturbance and an encounter start time and GPS start position were recorded on additional *Encounter Log* sheets, as well as further details on the number of adults and calves sighted, their direction of travel and the behavioural activity of the individuals present. Recorded behaviour was simplistically characterised according to the following descriptions (Kevin Robinson, pers. comm.):

Behaviour	**Description**
Travelling	Heading in a particular direction, normal speed, often purposefully.
Foraging	Animals spread out, changing directions, circling.
Feeding	Rapid movements, quick dives, fast pursuit of prey. Can involve jumping (Gaskin, 1997).

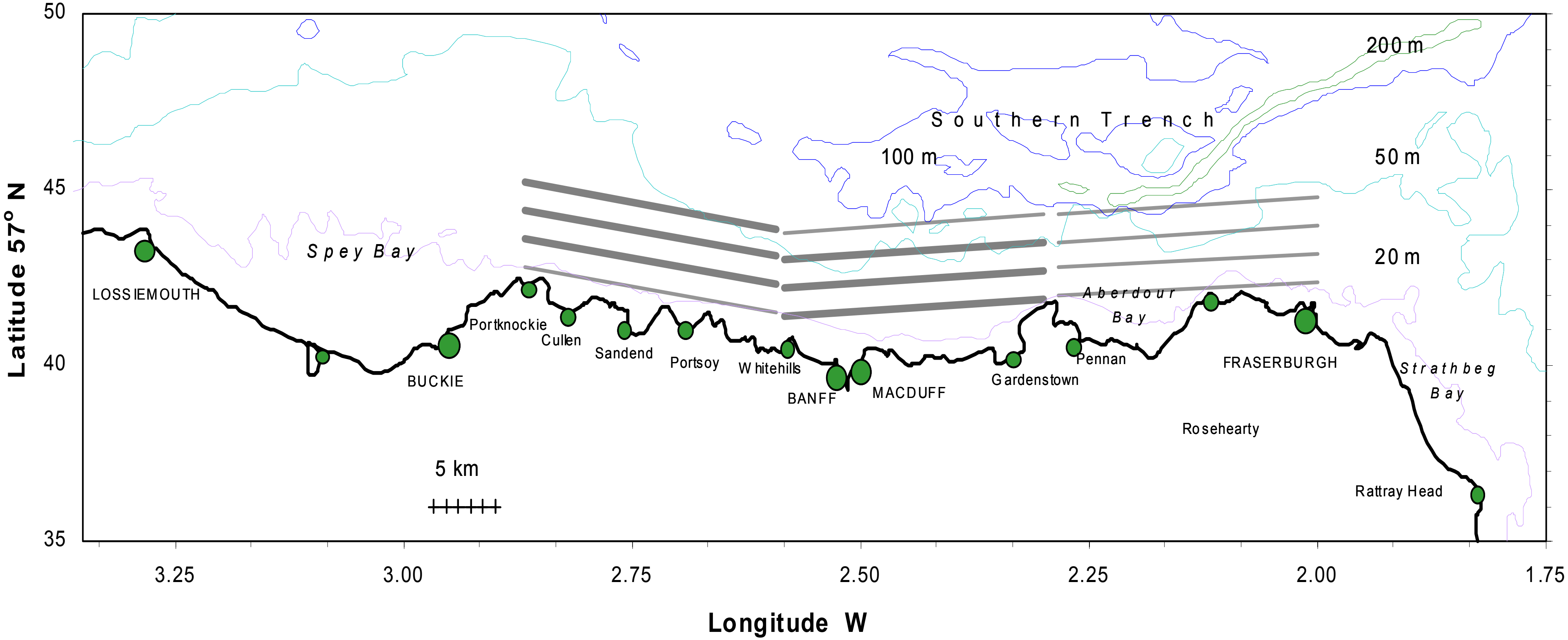


Figure 3.1. Map showing the coastline of the outer southern Moray Firth and the line transect survey routes undertaken in the present study between the ports of Portknockie and Fraserburgh. The transects were divided into 4 longitudinal routes, each approximately 45 minutes apart in latitude (depicted by parallel silver lines running adjacent to the shoreline, above).

Since multiple encounters could be made during a single survey trip, the recording procedure was repeated for each individual encounter made. Once the required data had been collected, the encounter was terminated and the end time and end GPS positions recorded accordingly.

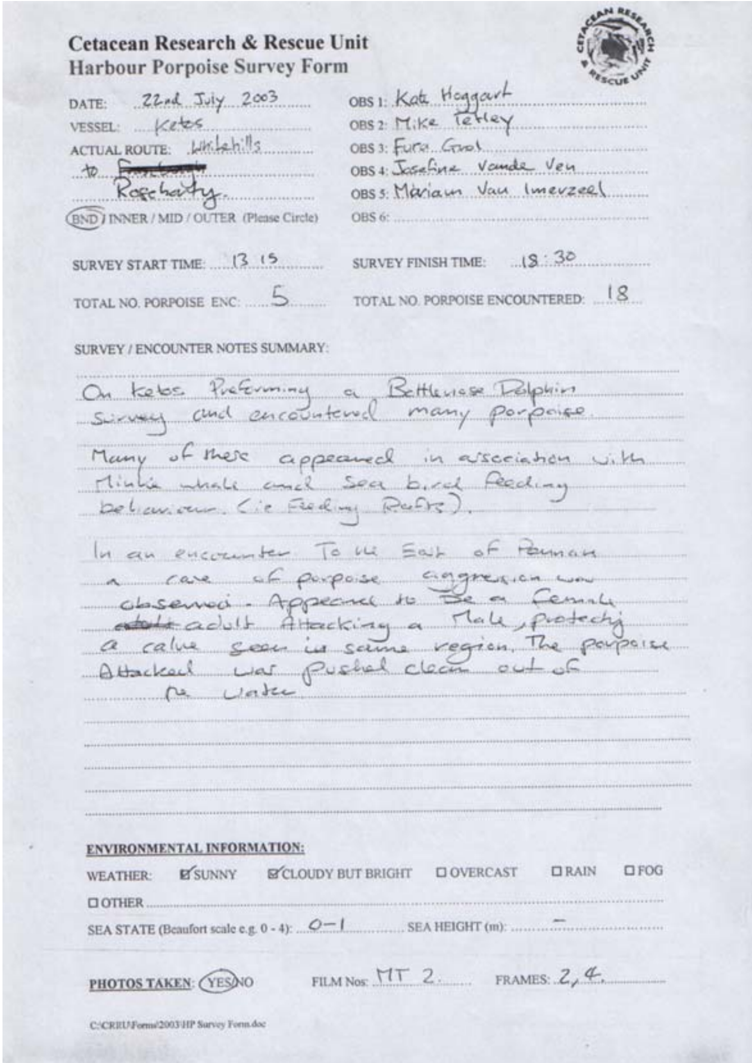
Photos were occasionally taken of the porpoise during encounters, although photo-identification of individual animals from natural markings was not possible for the species; primarily due to its very small size and brief surface appearance, as noted by Koopman & Gaskin (1994).

3.3. Data analysis

Back on the shore, the collected data were transferred from the laminated boat recording sheets to a *Summary Trip / Encounter Form* (fig. 3.2). The details from each encounter were subsequently entered into an MS Excel spreadsheet from which the GPS coordinates could be plotted on a map using the graph function.

Indices for abundance of animals were determined by sightings rates and expressed as animals per square kilometre. Plots could then accordingly be made by sightings and effort variables over required time scales.

All mean values provided herein are expressed as the mean ± one standard deviation (± SD). MINITAB version 13 was used to perform Mann Whitney U tests and all GIS mapping was carried out using ArcGis version 8.



Cetacean Research & Rescue Unit
Harbour Porpoise Survey Form

DATE: 22nd July 2003
VESSEL: Ketos
ACTUAL ROUTE: Whitehills to ~~[illegible]~~ Rosehearty.
BND / INNER / MID / OUTER (Please Circle)

OBS 1: Kate Hoggart
OBS 2: Mike Tetley
OBS 3: Fura Grol
OBS 4: Josefine Vande Ven
OBS 5: Mariam Van Imerzeel
OBS 6:

SURVEY START TIME: 13 15
SURVEY FINISH TIME: 18:30
TOTAL NO. PORPOISE ENC: 5
TOTAL NO. PORPOISE ENCOUNTERED: 18

SURVEY / ENCOUNTER NOTES SUMMARY:

On Ketos Preforming a Bottlenose Dolphin survey and encountered many porpoise.

Many of these appeared in association with Minke whale and sea bird feeding behaviour. (ie Feeding Rafts).

In an encounter To the East of Pennan a case of porpoise aggression was observed. Appeared to Be a female ~~adult~~ adult Attacking a Male, protecting a calve seen in same region. The porpoise Attacked was pushed clean out of the water.

ENVIRONMENTAL INFORMATION:

WEATHER: ☑ SUNNY ☑ CLOUDY BUT BRIGHT ☐ OVERCAST ☐ RAIN ☐ FOG
☐ OTHER
SEA STATE (Beaufort scale e.g. 0 - 4): 0-1 SEA HEIGHT (m): –

PHOTOS TAKEN: YES/NO FILM Nos: MT 2. FRAMES: 2, 4.

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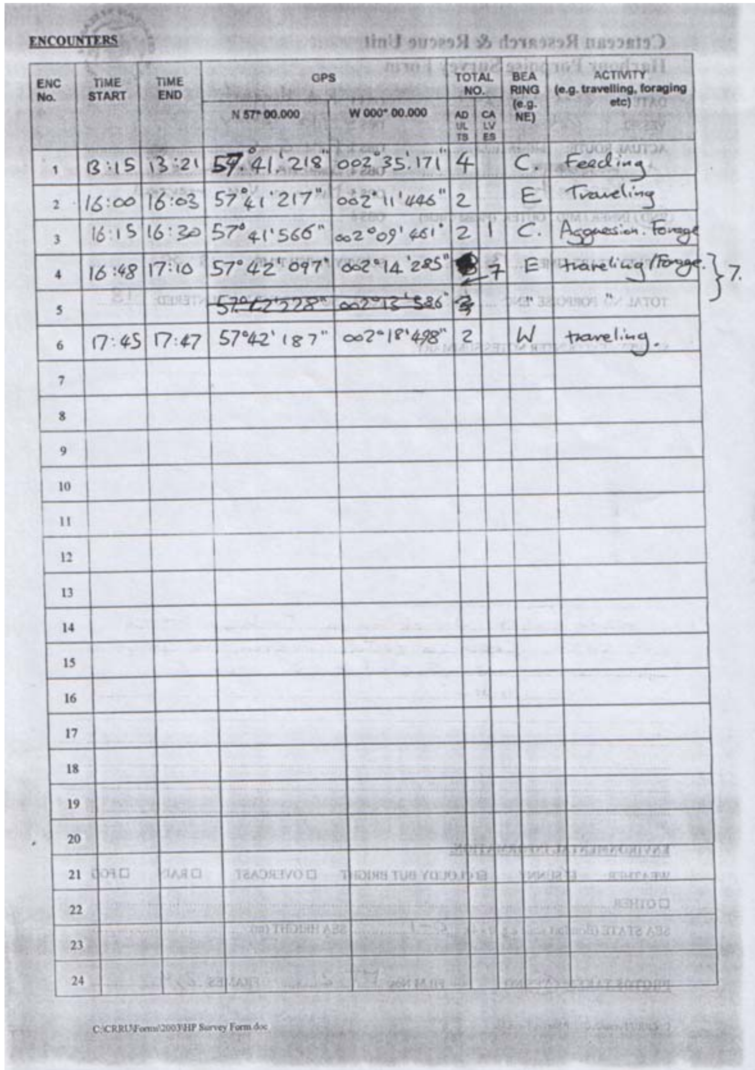

ENCOUNTERS

ENC No.	TIME START	TIME END	GPS N 57° 00.000	GPS W 000° 00.000	TOTAL NO. ADULTS	TOTAL NO. CALVES	BEARING (e.g. NE)	ACTIVITY (e.g. travelling, foraging etc)
1	13:15	13:21	57° 41.218"	002° 35.171	4		C.	Feeding
2	16:00	16:03	57° 41'217"	002° 11'446"	2		E	Traveling
3	16:15	16:30	57° 41'566"	002° 09' 461'	2	1	C.	Aggression. Forage
4	16:48	17:10	57° 42' 097'	002° 14' 285"	[illegible]	7	E	traveling/Forage. } 7.
5			~~57° 42'228"~~	~~002° 13' 586"~~	3		"	
6	17:45	17:47	57°42' 187"	002° 18' 498"	2		W	traveling.
7								
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Figure 3.2. Showing an example of a completed summary boat trip / encounter form (front and back of form) used in the present study. The forms provide a hard copy of the raw data, subsequently entered into a spreadsheet format, for each individual survey trip made.

4. Results

4.1. Survey effort

Between the dates of 23 May and 30 September 2003, a total of 44 surveys were carried out, producing a total survey effort of 122.87 survey hours (table 4.1) and covering a distance of approximately 1,200 km. The shortest survey duration recorded during this period was 45 minutes, and the longest 7 hours. During the survey period, May to September, the number of surveys, and therefore the total survey effort recorded, showed much variability between months (table 4.1). The lowest survey effort took place in June (just 7 hrs 11 mins), the number of surveys conducted being restricted by poor weather conditions. Similar restrictions of intermittent bad weather also impeded the survey effort in August. Whilst only 6 surveys were undertaken during May, the surveys did not, however, commence until the 23rd day of the month. The highest survey effort was recorded during the month of July (49 hrs 52 mins), over a total of 18 surveys.

77.78% of the surveys were carried out at sea state 2 or less (table 4.2), with a further 20% being undertaken in sea state 3. Only 2.22% of the survey trips were conducted during sea state 4, with no surveys taking place in sea state 5 or above.

4.2. Distribution and abundance of encounters

From May to September 2003, a total of 131 encounters were recorded on 42 survey days, producing a cumulative total of 415 animals (table 4.3). Group sizes of harbour porpoise ranged from 1 to 17 animals with a mean of 2.64 ± 1.18. The largest group of 17 animals was recorded in September. Single animals and pairs of animals were most frequently recorded, with single animals accounting for 29.85% of the total encounters recorded; although the size of groups showed a significant increase ($P<0.05$) with progression throughout the season. The distribution of group sizes is shown in figure 4.1.

The highest number of porpoise encounters were logged during July (table 4.3) – consistent with the highest number of surveys undertaken throughout the period in this very same month – which resulted in a cumulative total of 146 animals recorded for July, with group sizes ranging from 1 to 13 individuals. The lowest number of encounters was recorded in June, with just 4 encounters from 3 survey trips, each encounter of a single harbour porpoise.

Table 4.1. Showing the total survey effort and encounter information recorded by month.

Month	No. of survey's	Survey hours	Total no. encounters	No. of adults encountered	No. of calves encountered
May	6	14 hrs 51 mins	14	25	0
June	3	7 hrs 11 mins	4	4	0
July	18	49 hrs 52 mins	45	138	8
Aug	7	17 hrs 07 mins	36	119	6
Sep	10	34 hrs 01 mins	32	110	5
Total	44	122 hrs 52 mins	131	396	19

Table 4.2. Showing the sea state conditions recorded during harbour porpoise survey trips from May to Sep 2003.

Sea state (Beaufort scale)	Percentage of surveys
0	17.77
1	31.11
2	28.89
3	20
4	2.22

Table 4.3. Showing the mean and range of harbour porpoise group sizes encountered by month, from May to Sep 2003.

Survey month	Total no. of encounters	Mean group size encountered	Range		No. single animal encountered
			Min	Max	
May	14	1.79±0.89	1	4	6
Jun	4	1.00±0.00	1	1	4
Jul	45	3.29±2.92	1	13	15
Aug	36	3.47±1.89	1	9	6
Sep	32	3.66±3.17	1	17	7
Overall	131	2.64±1.18	1	17	38

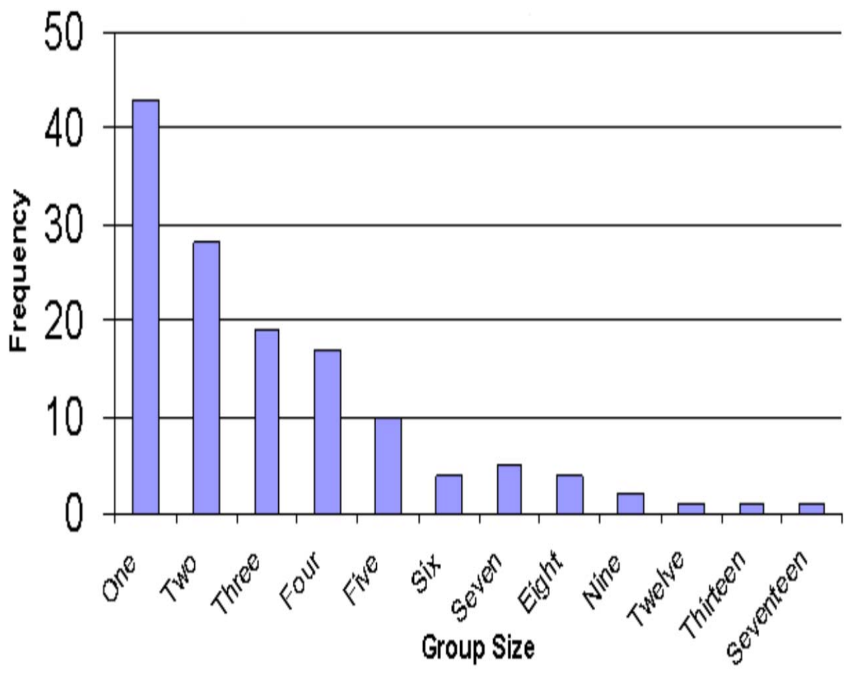

Figure 4.1. Histogram showing the range and frequency of harbour porpoise group sizes recorded between May and September 2003 (n=134).

12.68% of the groups encountered contained calves, accounting for 4.79% of the total cumulative number of porpoises encountered. No encounters of calves were recorded during the months of May and June, but encounter were made from July to September with a peak in July (table 4.1).

The distribution of harbour porpoise encounters from May to September is shown in figures 4.2 a–e . Throughout this study period, a noticeable shift in the distribution of the species was observed. During the month of May, the animals were only recorded adjacent to the ports of Whitehills and Macduff (fig. 4.2a), but were distributed from right in against the shoreline to out beyond the 50-metre depth line. In June, the few animals recorded were encountered to the west of Macduff towards Cullen and Findochty (fig. 4.2b). From July, however, the animals were recorded throughout most of the study area (fig. 4.2c), although areas of highest fidelity included locations adjacent to Whitehills and within Aberdour Bay. During August, a large majority of the sightings recorded were made in Aberdour Bay (fig. 4.2d) and almost exclusively adjacent to the 20-metre depth line. In September, however, the encounters showed a more patchy distribution of animals with greater dispersal of groups from the coastline to beyond the 100-metre depth contour (fig. 4.2.e).

The relative abundance for animals throughout the entire study area (measuring approximately 550 km^2) was calculated as 0.75 animals per square kilometre.

a) May

b) June

c) July

d) August

e) September

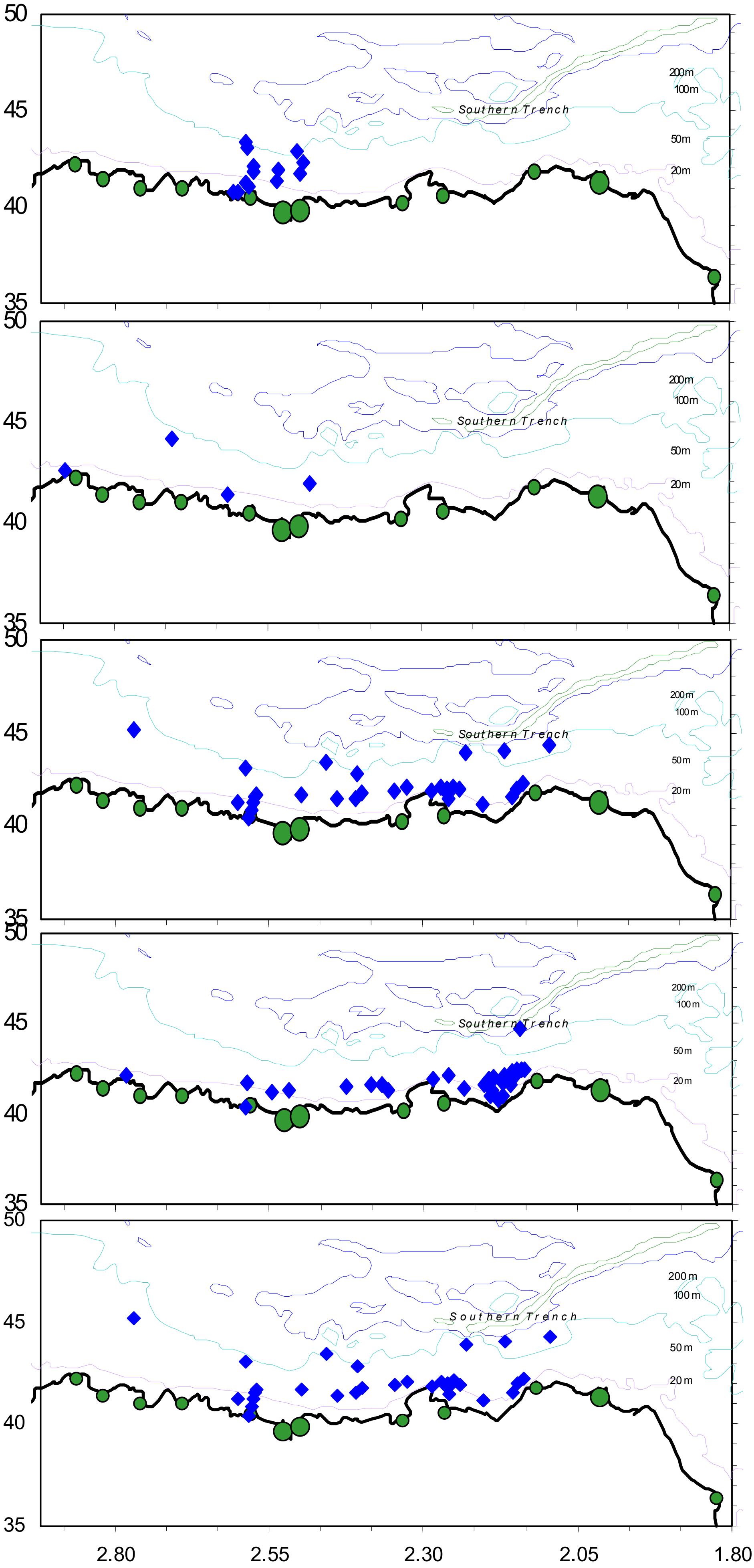

Figure 4.2. Maps a) to e), showing the monthly distribution of harbour porpoise encounters recorded from line transect surveys between the months of May and September 2003.

4.3. Activity

During the months of May and June 2003, over 70% of the animals encountered were engaged in feeding or foraging activities (figure 4.3). However, this activity dropped to nearly half during the following 3 months, when the animals encountered were more often recorded travelling in typically larger group sizes (table 4.3).

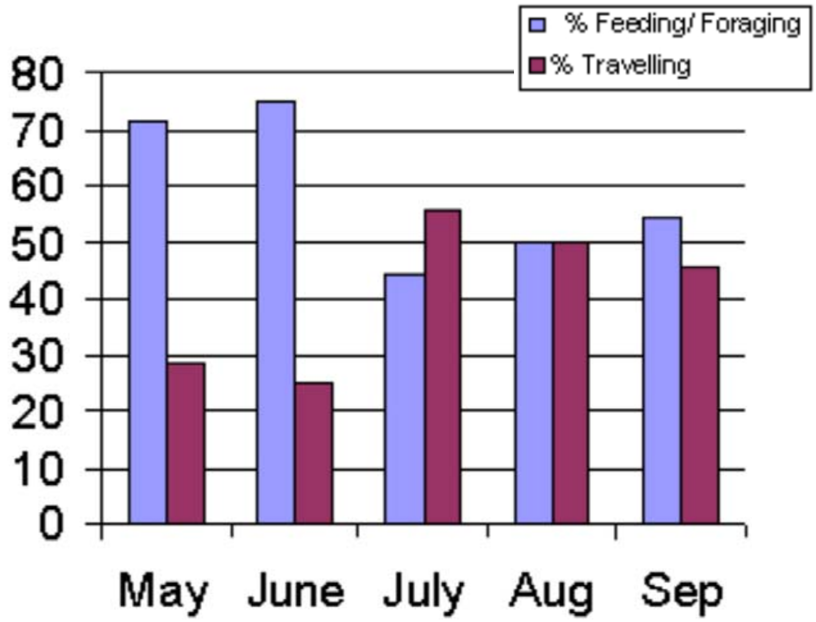

Figure 4.3. Histogram showing the activity of harbour porpoise groups recorded during encounters from May to September 2003.

4.4. Overall distribution and density

The distribution of all porpoise encounters for the entire period, May to September 2003, is shown in figure 4.4. Two areas of high fecundity are identified for the species: that of Aberdour Bay to the east of the survey area, and Whitehills in the middle of the survey area. A total of 71.85% of the total sightings recorded occurred within these two areas, 41.48% in Aberdour Bay and 30.37% in Whitehills. Only 3 encounters were made at depths of 100-metres, the majority of animals being recorded close to the 20-metre depth line.

The encounter data for all sightings plotted in figure 4.4 was subsequently transferred to ArcGis version 8 for an analysis of harbour porpoise density, which would take into account the number of animals encountered at each location. The density plot obtained is shown in figure 4.5, the intensity of shading depicting those areas of highest density observed. Potential “hotspots” were identified in 5 locations: 2 within Aberdour Bay and 3 adjacent to and to the west of Whitehills.

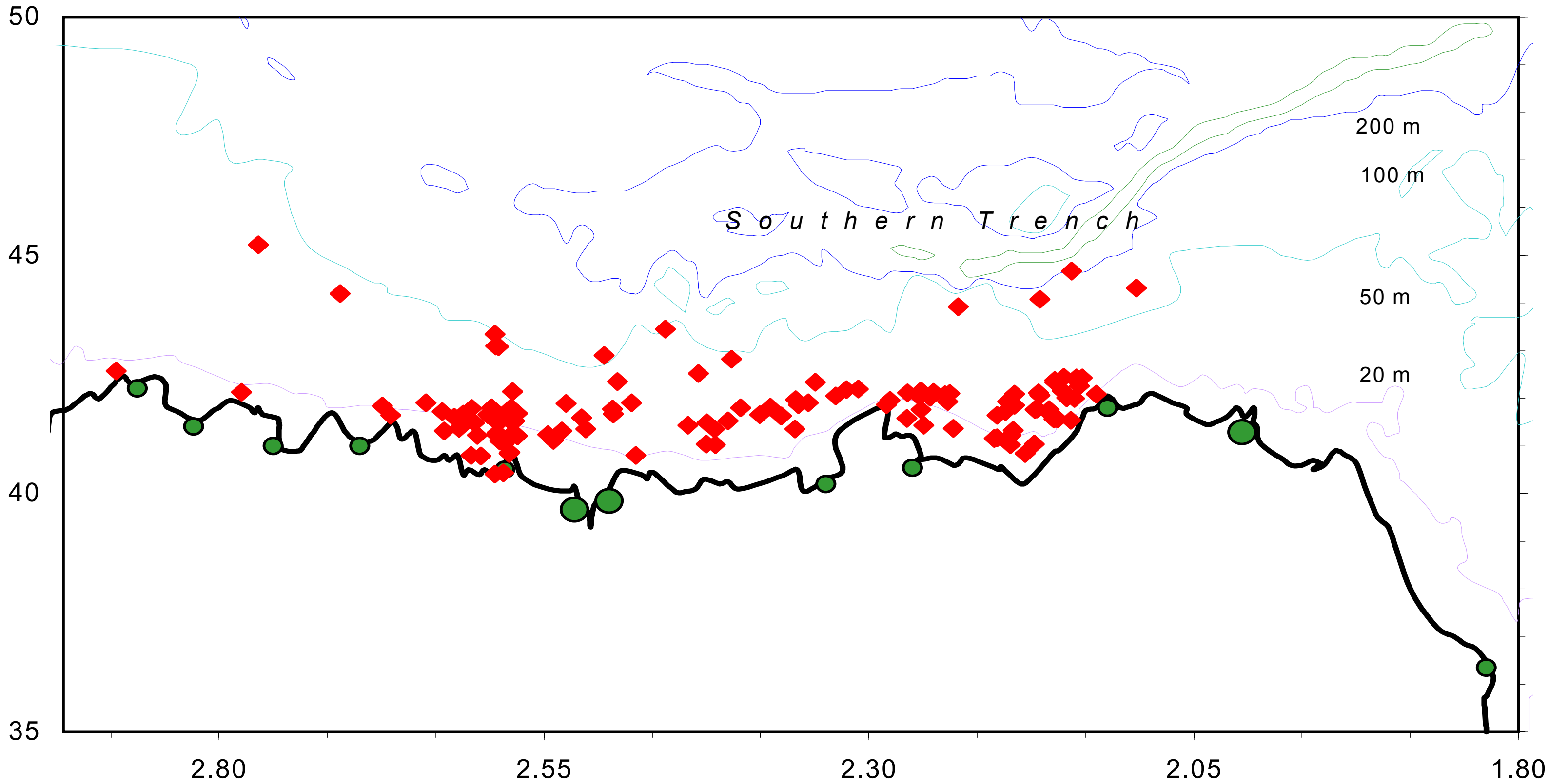

Figure 4.4. Distribution map showing all encounters with harbour porpoises in the study area between the months of May and September 2003.

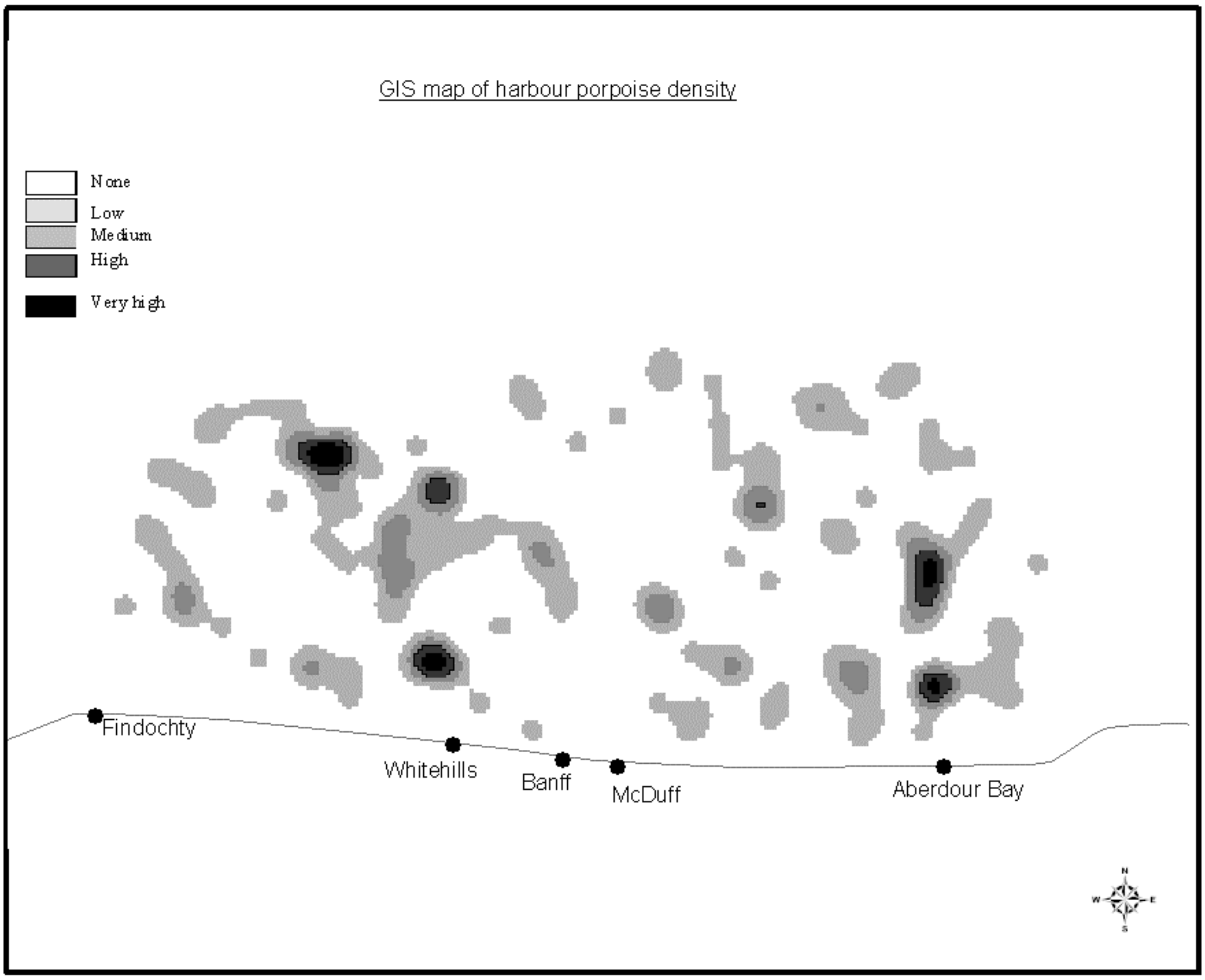

Figure 4.5. ArcGis plot showing the density of encounters and potential "hotspot areas" for harbour porpoise in the present study area.

5. Discussion

To date, there have been few small-scale studies of the harbour porpoise *Phocoena phocoena* in UK coastal waters and no previous work in the Moray Firth. The only survey to take this area of Scotland into account was the SCANS survey of 1984, which included a section of the outer Moray Firth along with other regions of northeast Scotland and adjacent areas of the North Sea classified as Block D (see fig. 5.1). Population estimates for this area are given as 37,144 animals (Hammond *et al.*, 1994).

In the present study area – representing just 1.14% of the SCANS Block D area – a cumulative total of 415 animals were recorded from just 44 surveys carried out from May to September over a survey area of approximately 1,200 km. In comparison, Pierpoint (2001) logged 254 animals during survey work in southwest Wales over a distance of 1,287 km, whilst Leopold *et al.* (1992) recorded 251 animals over 270 km in a small scale study in southwest Ireland. In addition, Weir *et al.* (2001) compiled sightings from the west and north coast of Scotland over 19 years, between 1979 and 1998, and recorded only 1,318 animals from 650 sightings. These initial figures would suggest that the coastline of the outer southern Moray Firth might represent a significant habitat for this species during the summer months at least.

This is further supported by the estimation of abundance made for the present study area. The calculated figure of 0.752 animals per square km compares well with other data from around the country. For example, Hammond *et al.* quote a figure for block D in SCANS of 0.363 animals per km, less then half of the estimate made in the present study. The estimates made by Pierpoint range from 0.14 to 0.72 animals per km in southwest Wales. The SCANS survey for the Celtic sea (Block A) provided estimations of 0.57 animals per km, although Leopold *et al.* (1992) found a density of 0.77 per km for a smaller, coastal area. Block F, the central North Sea, is the area that had the highest density in the SCANS survey of 0.776 animals per km. Interestingly, this figure is only slightly above that determined for the present study area.

Taylor & Dawson (1984) note that the harbour porpoise is typically found singularly or in small groups. Indeed, the present study area was no exception to this finding, with 89% of encounters involving groups of 5 individuals or less. That saying, single groups of 13 and 17 animals were encountered during the present study during July and September respectively. Evans (1976) reports that large groups are common between July and October after calving and groups numbering in excess of 40 animals have been recorded during September and October in the southern outer Moray Firth (Robinson, unpublished data). The most common encounter was with solo animals (43 encounters in all), followed by groups of

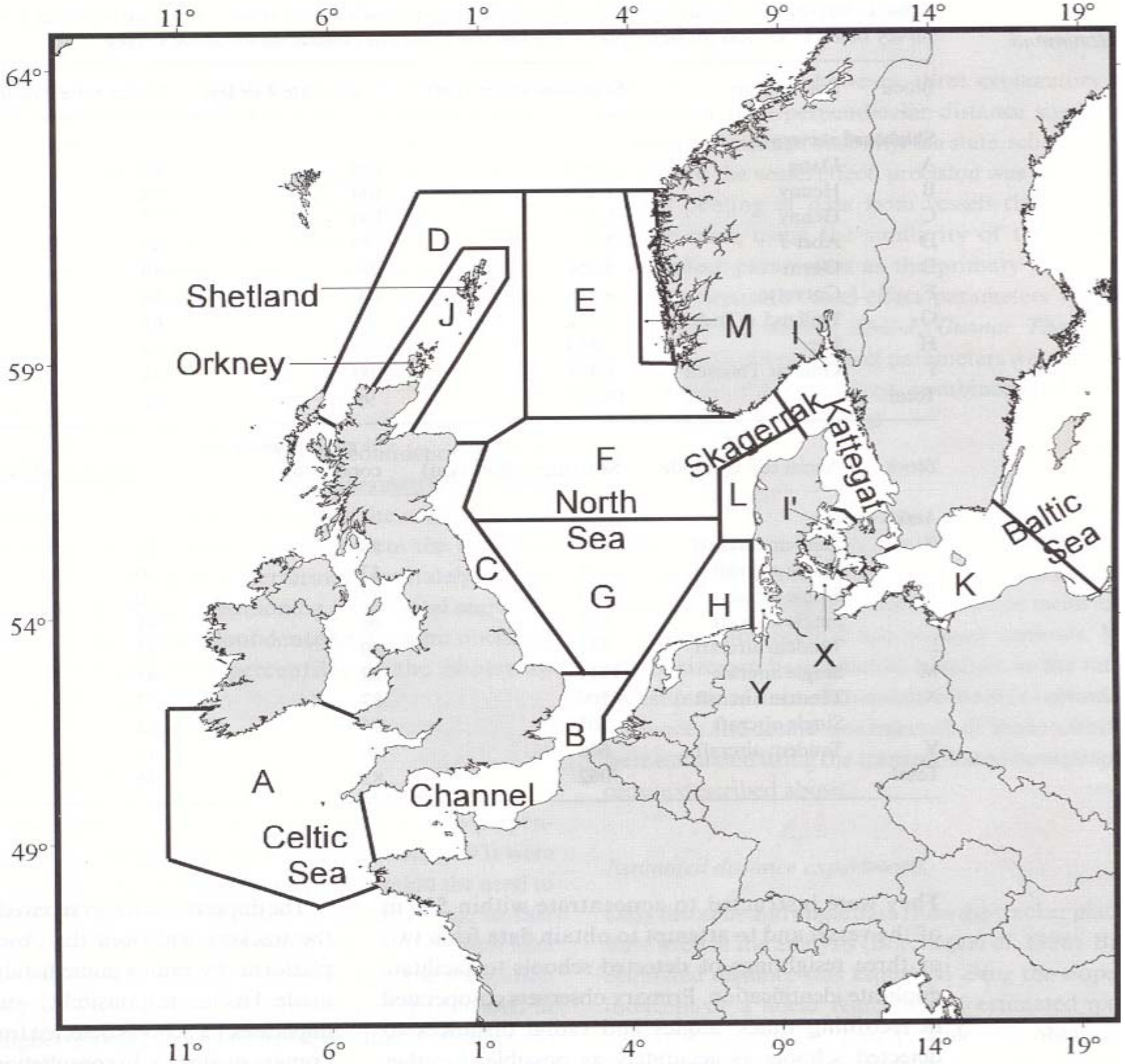

Figure 2Figure 5.1. SCANS map detailing the blocks A toM surveyed. Block D encompasses the whole of the northeast of Scotland and envelopes within it the Shetland and Orkney Islands, assigned as Block J. Reproduced from Hammond *et al.* (1994).

2 (28 encounters), 3 (19 encounters), 4 (17 encounters) and 5 (10 encounters). The mean group size of 2.641±1.18 determined for the present data set, however, was found to be higher than that recorded from other studies. For example, Pierpoint (2001) states a mean school size of 1.74 and the SCANS survey gives a mean of 1.42 for Block D. Results obtained by Bjørge & Øien (1995) provided a mean group size for the species in Norwegian waters of 2.15 animals, although almost half of their recorded sightings were of solitary individuals in this area.

Northridge *et al*. (1995) observed that the sea state may have a significant impact on the detectability of certain cetacean species, and particularly harbour porpoises, during dedicated survey work from boats. The suggested optimum sea states proposed when surveying for porpoises are between Beaufort 0 to 2 (Baines *et al*., 1997). In the present study, 77.78% of the surveys made were carried out under these criteria. This is in line with other studies, such as that by Pierpoint (2001) for example who recorded 77% of his results at sea state 2 or less. It should be noted, however, that the criteria for sea state selection might be subjective to individual interpretation by the observer. In the present study, a Mann Whitney U test preformed using MINITAB showed a significant correlation between the sea state and the number of sightings observed (P=0.037).

Indeed, factors affecting sighting probability, all central to the observer, are his or her own experience, personal awareness, and perception (when an animal is seen and recognised), all of which may be influenced by the sea state, weather conditions, visibility, swell height, species grouping, height of the observer above the water, and the vessel type used (Laake *et al*., 1997; Raum-Suryam & Harvey, 1998; Carretta *et al*., 2001). Also, harbour porpoises spend a large proportion of their time below the surface of the water; 89% according to Reed *et al.* (2000), whereas Barlow *et al.* (1988) document 23.9% time spent at the surface. With such a short surface duration and very little, if any, above surface activity, it is easy for animals to be missed by observers studying this species, resulting in availability bias (Laake *et al.*, 1997).

Virtually all the encounters recorded in the study area occurred either on or near the bathymetric slopes where nutrient upwellings are most likely to occur (Harding-Hill, 1993). Cetaceans tend to forage around up-wells, as this is a good place for locating prey, and porpoise have been noted to use such vicinities previously (Pierpoint *et al*., 1994), where they can often be observed feeding alongside minke whales (*Balaenoptera acutorostrata* Lacépède) (Dick, *in prep*; Kevin Robinson, pers. comm.). The porpoises were rarely recorded close to the shoreline and were never observed in the presence of bottlenose dolphins, which typically use the rocky areas and bays close in to the shore (Kevin Robinson, pers. comm.).

The porpoises are thought to avoid the bottlenose in view of interspecific aggression directed towards them by the larger dolphins (Patterson *et al.*, 1998).

Early on in the present field season, the animals appeared to be spread out over the entire survey area. During the month of August, however, there was a definite shift in the population to the eastern side of the survey area that was thought to be prey-related. Porpoise are thought to primarily feed on high-energy white fish and sand eels (Santos *et al.*, 2004), although their diet may vary depending on location. The geographical differences in fish species consumed by the species suggests that these mammals are catholic feeders (Martin, 1995) and that the prey consumed probably represents the species abundant at that time. Samples from the Shetland Isles have shown that gadoids are a major food source. Where there are sand eels there are also other species of fish, and these fish are prey to other predators and their presence can therefore have an effect on the porpoise. The study area of the Moray Firth is home to a large fishing community, and at the beginning of August 2003 there was an appearance of about a dozen very large fishing vessels that began to trawl intensively throughout the study area, from Cullen Bay to Gardenstown, by day and by night. Such activity had never been seen before in this area (Robinson, pers. comm.) and was the response of a number of recently “decommissioned” boats to a very large influx of squid into the Firth – which had resulted from the atypically hot summer weather. This activity coincided directly with the eastwardly shift of the porpoises (and indeed the emigration of large numbers of minke whales and bottlenose dolphins along this coastline), with very few if any sightings occurring in the vicinity of these trawlers. Koschinski *et al.* (2003) has shown that harbour porpoises will give a large berth to wind generators with an engine frequency of 2 MW. Whilst there is no data for avoidance of ships in the species, the presence of large trawlers in a small area would surely generate far more noise than this, particularly when pair trawling and hauling in nets. The impacts of such anthropogenic disturbance could be catastrophic to the area and the species that frequent it; resulting in bycatch, overfishing and habitat change.

In the present findings, two main areas stand out as potential “hot-spots”, zones of critical habitat supporting aggregations of animals (as defined by Pierpoint, 2001): one adjacent to the port of Whitehills (Zone A), and the other within the confines of the secluded Aberdour Bay (Zone B). These two areas contained between them 71.85% of all sightings. Both hot-spot areas appear to be clustered along the 20-metre shelf line. Apart from this, the two areas appear to have little in common. Whilst Zone A lies adjacent to a busy marina, Zone B is a quiet bay with little boat traffic. However, since both areas are found adjacent to areas where upwellings may occur, which also proved to be hot-spots for minke whales as well (pers. obs.), the clumped distribution of animals at these two sites is likely to be related to the presence of prey. Since upwellings and water mixing produce high levels of primary production near the surface (Tynan, 1997), this cascade of production will inevitably transmit to the higher trophic layers occupied by the porpoises and minkes. It would therefore be very useful in future studies to use newly available techniques such as remote sensing, for example, to attempt to correlate phytoplankton distributions with the site fidelity of these marine mammals.

The overall percentage of calves sighted in the present investigation was 4.58% and the number of groups with calves in tow was 17 out of 134 encounters (12.68%). In comparison, Sonntag *et al.* (1999) found a percentage of calves to adults in the Slyt/Amrum area of 14%, whereas SCANS block D recorded 6.2%. There could be a number of reasons why the percentage of calves recorded in the outer Moray Firth was much lower that these other studies. The initial thought would be that calves do not frequent this coastal area of the firth. Notwithstanding, however, it may simply have been that calves were often difficult to distinguish from adults due to the small differences in size and colouration. It was not possible in the present study to identify foetal folds in the young animals, for example. Also, the months of May and June are identified as the main calving months (Hughes, 1998), but very few (3) surveys were carried out in the present study during the month of June (the peak month for calving) due to the very poor weather conditions experienced. This may have accounted for the lower percentage of calves recorded herein.

Throughout the study period, the recorded activity of porpoises showed a progressive change in area usage. Earlier on in the season, during May and June, more than 70% of the groups encountered were observed feeding and/or foraging for food. Harbour porpoises have limited energy storage capacity and are known to consume approximately 3.5% of their total body weight per day (Yasui & Gaskin, 1986), but this may increase by up to 80% over the summer months for pregnant and lactating females (Read & Westgate, 1997). Notably, the high percentages of feeding activity observed are seen to coincide with this calving period, so it is possible that this activity is related to the necessity of the female porpoises to nourish their weaning calves. Indeed, as the field season continued through the months of July to September, an approximately equal percentage of animals encountered were recorded travelling or transiting. Whilst this might simply be explained by the patchiness of potential prey items (as described for other cetacean species by Norris & Dohl, 1980), or indeed the absence of prey due to the activities of the trawlers in the area, the change in behaviour could simply imply that there is no longer such a high requirement for food intake during this latter quarter. Indeed, Hughes (1998) notes that the harbour porpoise is typically found in larger, travelling herds during the latter summer months, perhaps, as with many delphinid species, necessary for the alloparental care, protection and raising of new offspring, all of which are very much easier within a group.

In conclusion, the findings from the present study intimate a strong case for this area of the southern, outer Moray Firth to be considered as a candidate "safe area" for the harbour porpoise: due to its high presence and usage of the area, the significantly high estimates of abundance recorded, and the potential importance of specific, highlighted sites as central feeding and/or calving areas for the species (Whaley & Robinson, 2004, see appendix A).

With an estimated abundance level of 0.752 animals per square kilometre, the present study area has one of the highest abundance levels yet recorded in UK coastal waters. The figure determined is double that recorded by the SCANS survey for Block D, which encompasses the study site, and is even higher than that recorded for the current candidate Special Area of Conservation site in Wales at 0.72 animals per km and the Celtic Sea at 0.57. In fact only one Block of the SCANS survey contained a higher figure of 0.776 animals per km than that recorded in the present study area

Within the study period, the distribution of harbour porpoise was widespread throughout the entire study area. This shows continuous movement and usage within the study site boundaries. Although high numbers of animals were identified in "hotspot" areas adjacent to Whitehills and Aberdour Bay, the movement of animals would suggest that the entire area of the present study and beyond would require some sort of protection.

With large amounts of feeding and/or foraging activity occurring in May and June in coincidence with the known calving period for the study species, it would appear that specific areas of the study site might provide fundamental habitats for calving and/or nursery areas for new-born calves. Whilst, however, the overall percentage of calves identified in the present investigation was low at 4.58% compared to other study areas, difficulties in identifying the young animals from the low survey platform used may have negatively biased the recorded figures. As such, further research needs to be carried out to clearly identify calf numbers in this area of the Moray Firth, particularly during the peak calving period where poor weather conditions restricted the number of possible surveys in the current study.

Along with the recommendation of further study of calves, other types of surveys might need to be considered for the area of the outer southern Moray Firth. At this time, current knowledge of the acoustic behaviour of wild porpoises is scarce. Thus, acoustic studies could be used, such as the use of static porpoise detectors or POD's, for example, to complement simultaneous sightings data. These acoustic devices can be set to recognise the frequency and bandwidth of porpoise echolocation signals (Calderan, 2003). When deployed at key sites, the recorded data can be used to provide information on fine-scale temporal cycles of presence, absence and activity of the animals. Such methods have the advantage of being able to operate 24 hours a day in poor weather conditions, and can therefore provide long sequences of data which could be used to compliment additional environmental data, such as wind direction and strength of tidal race, which may also be influencing factors that may need to be considered in distribution studies of this small cetacean species. In this respect, the present study provides a useful foundation for further research studies of this potentially important, coastal population of phocoenids. Such fundamental work will remain crucial to the development and subsequent implementation of much sought-after, “safe areas” for the species in NE Scottish waters and indeed throughout the UK as a whole.

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Appendix A

Poster presented at the *18th Conference of the European Cetacean Society, Kolmården, Sweden, 28 - 31 March 2004.*