The long-term distribution, habitat use and site fidelity of bottlenose dolphins frequenting the outer southern Moray Firth coastline: a spatio-temporal analysis with implications for existing population management.

Word count: 5,090

Abstract

1. With anthropogenic activities heavily impacting on the marine environment, and habitat degradation a serious threat to coastal marine organisms, research to inform and increase the effectiveness of conservation based management initiatives is becoming an ever greater priority. Management directed towards organisms whose distributions are subject to a great deal of spatial and temporal variation is fraught with complexity as often protecting a species throughout its entire natural range is not practical or possible.

2. The present study examines the distribution of the bottlenose dolphin (*Tursiops truncatus*) in an area known as the Outer Moray Firth in the northeast of Scotland. Statistical analyses and the construction of Geographic Information Systems were utilised on a 14 year dataset. Data was extracted on group size, the number of groups with calves and the general distribution of sightings. Abundances, encounter rates and kernel analyses were conducted to observe spatial and temporal patterns of site fidelity and movement, the overall aim to establish the Outer Moray Firth as an area of crucial importance to the bottlenose and not simply a corridor area into the Inner Firth.

3. The results reveal that the Outer Moray Firth consistently has larger group sizes (mean 14.77 $\pm$ 11.7) and proportion of groups with calves (81%) than other areas with populations of bottlenose including the Inner Firth SAC (mean group size 6.45)(Wilson, 1995). Using the most recent population estimate for the Moray Firth together with population estimates for the Outer Moray Firth presented here, it is estimated that 90% of the entire population of the northeast of Scotland utilise the waters of the Outer Moray Firth. Some individuals show particularly high levels of site fidelity, (68% of marked adults resident in 2005), and extreme close proximity to the coastline (mean sightings depth 13.49m $\pm$ 4.4 and distance from shore 617m $\pm$ 418) rendering the population vulnerable and sensitive to anthropogenic influences.

4. Initial conclusions suggest that the Outer Moray Firth is an environment with an important role in supporting the resident bottlenose population, with initiatives aimed at the protection of the species likely to be more effective if evidence such as that presented here for high density and site fidelity in the Outer Firth, is incorporated into management plans.

Methods

Measuring approximately 5,240km^2 the Moray Firth is the largest embayment in the northeast of Scotland. Geographically, the "inner" Moray Firth is defined as the area to the west of a line drawn between Helmsdale in the North and Lossiemouth in the south (Fig. 1). The area to the east of this line, extending to the coastal boundary in the north to Fraserburgh in the south is known as the Outer Moray Firth. Composed of a mixture of coastal and oceanic waters, conditions in the Outer Moray Firth more closely resemble those of the open North Sea (Holmes *et al.* 2004), in comparison to the relatively estuarine conditions of the Inner Firth SAC.

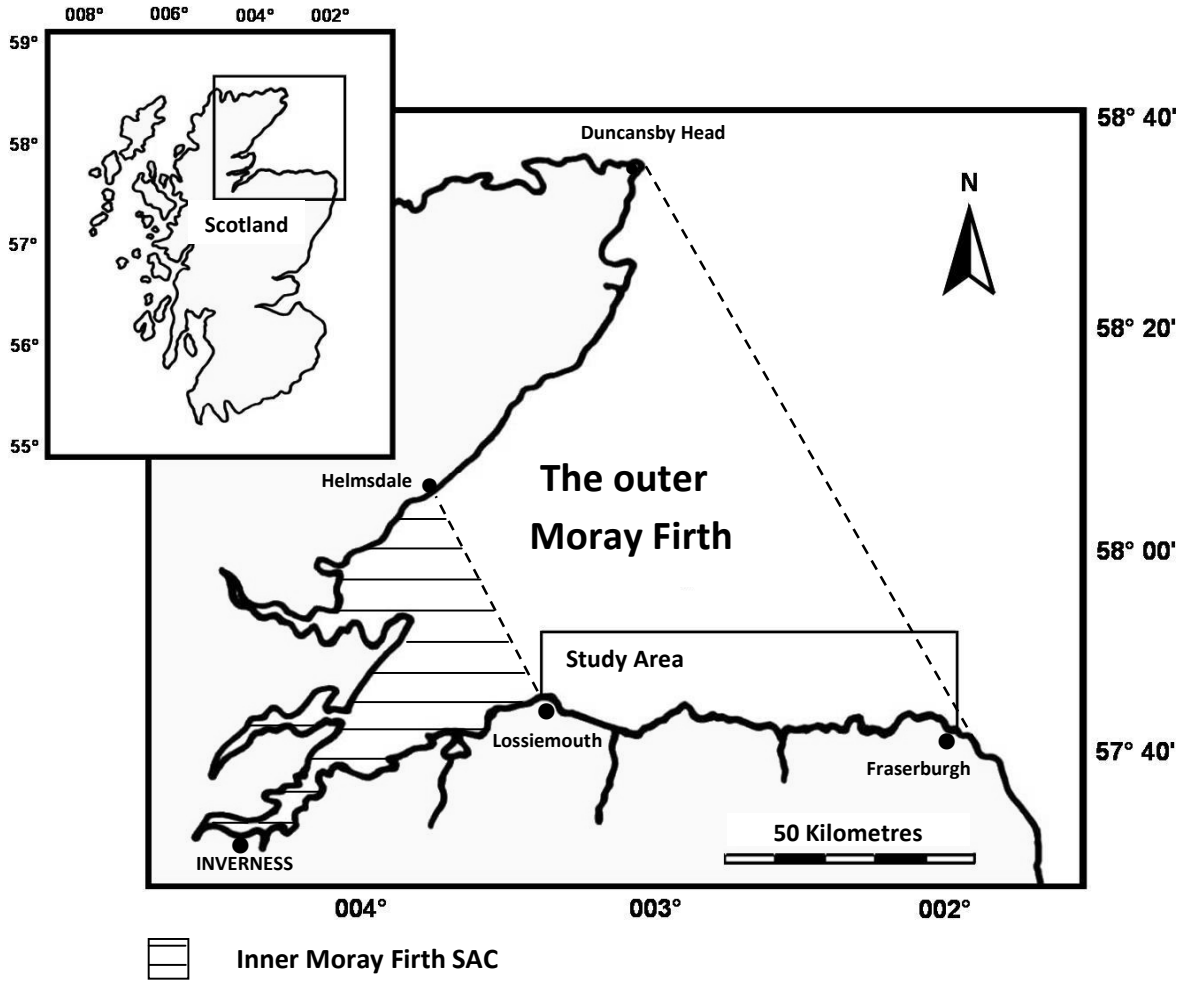

Figure 1. Map of the location of the Moray Firth in Scotland, showing the position of the inner Firth SAC and the 80km stretch of coastline between Lossiemouth and Fraserburgh that represents the area within which all surveys are conducted (taken from Robinson *et al.* 2007).

The present study analyses data collated by the Cetacean Research & Rescue Unit (CRRU) by means of dedicated boat surveys between the months of May and October, over a fourteen year period from 1997 to 2010 inclusive. Surveys were conducted along an 82km stretch of coastline between the ports of Lossiemouth and Fraserburgh (Fig.2) as detailed by Robinson *et al*. (2007) and Culloch & Robinson (2008). The available dataset representing a total of 290 encounters with the study species over 240 survey days was filtered according to the specific analysis being conducted.

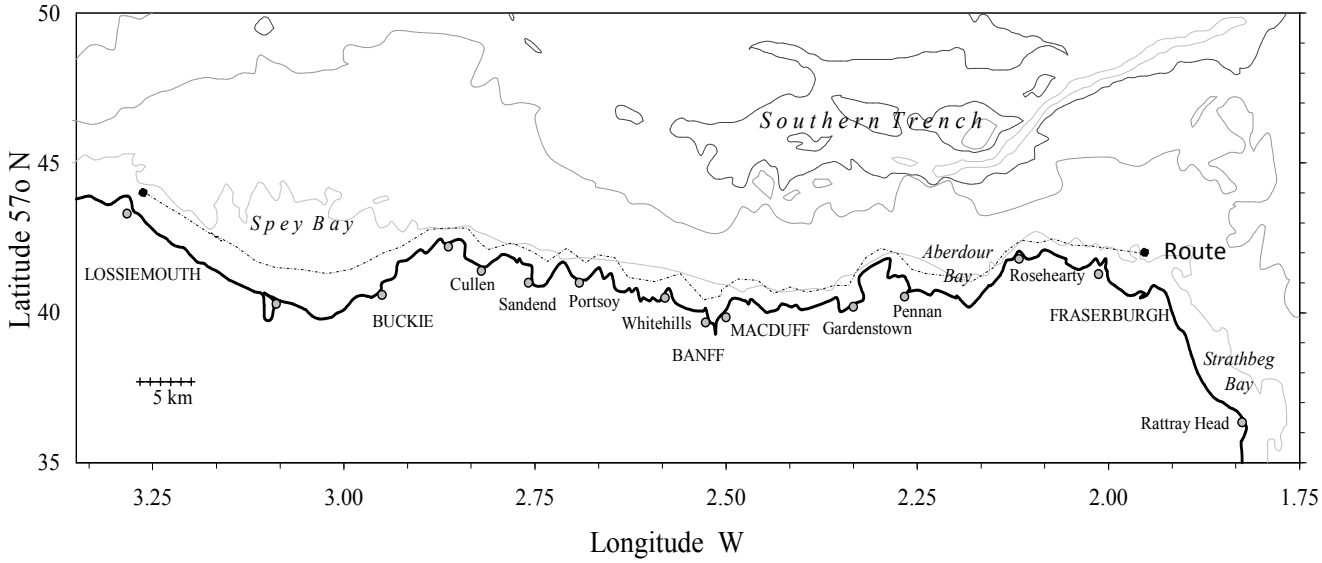

Figure 2. Map of the area of the outer Moray Firth coastline surveyed, showing the study area from which all data used in the analysis was collected (from Robinson *et al.* 2007). The dashed line represents the coastal survey route taken by the CRRU research team when gathering data on bottlenose dolphins.

Spatial Analysis

To observe the distribution of dolphin encounters within the study area, the respective location of each sighting was plotted using a Geographic Information System (ArcView version 9.3). The data frame was set up using a projected coordinate system (WGS 1984 UTM_Zone_1N) which was adapted to centre on the study area. All layers subsequently added were projected using the same coordinate system.

Abundance and encounter rate, calculated manually for every year using distance travelled and group size data, were also determined using ArcView for 2009 and 2010, the only two years for which complete GIS track survey data exists. A rectangular raster grid with a resolution of 1.5km (2.25km^2) was constructed for the entire Moray Firth region. The ArcView Spatial Analyst extensions Intersect and

Spatial Join were used to identify the amount of survey effort (sum length of survey track in meters) and number of sightings in each grid cell, from which abundance (number of animals / effort) and sightings rates (number of encounters / effort), were determined.

In order to further analyse the distribution of bottlenose along the Outer Firth coastline, DigiBath 250m resolution data set (version 2.0, British Geological Survey) was used to assign distance from shore to each of the sightings points. Depth was derived from an onboard digital depth plotter (Raymarine GPS/depth sounder model), as depth extracted using ArcView uses chart datum values and does not take into account tide height thus making the depth plotter more accurate.

Kernel analysis was used to determine the site fidelity of resident adult individuals and to identify areas of particularly high bottlenose density, in order to visualise spatial and temporal patterns in bottlenose occurrence in the Outer Moray Firth. Kernel analysis was conducted using Hawth's Tools (Beyer, 2004) and a raster grid with a resolution of 1km. Analysis was conducted by year and month (by extracting and pooling the GIS coordinates of individuals present each month of the years they were resident). Animals were then further categorised into males, females and females with calves for separate kernel analysis.

Statistical Analysis

All mean results are given as the mean $\pm$ the standard deviation. Differences in abundance, encounter rate, group size and number of groups encountered with calves between years and months were tested using parametric one-way ANOVA (group size data was square-root transformed before analysis to conform to parametric distribution). All analyses were conducted in SPSS (version 17.0).

Results

Between 2001 and 2010 a total of 203 encounters with bottlenose dolphins were recorded by the CRRU team, representing 439 trips and 12,846km of survey effort. Sightings were distributed along the length of the study area (Fig. 3).

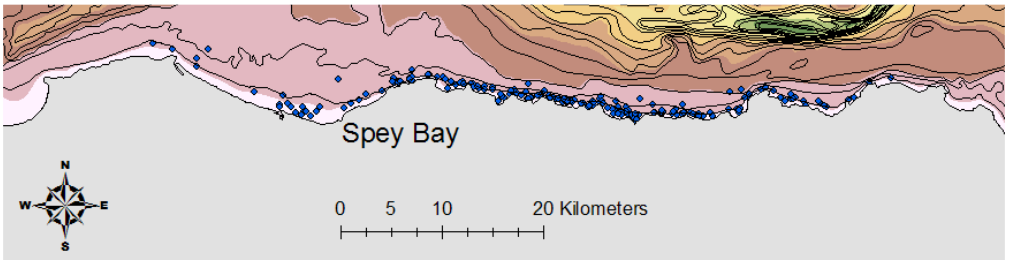

Figure 3. Map of the Moray Firth coastline showing the distribution of bottlenose sightings within the study area from 2001 to 2010 inclusive.

(Appendix A), with a peak of abundance in 2005 (Fig. 4). Overall differences in encounter rate and abundance between years (encounter rate: $F_{9,47}$ = 2.051, P = 0.054; abundance: $F_{9,47}$ = 1.31, P = 0.256) and months (encounter rate: $F_{5,51}$ = 0.661, P = 0.655; abundance: $F_{5,51}$= 0.104, P = 0.991) were found not to be statistically significant.

Table 1. Showing the survey effort, number of encounters, cumulative number of animals, encounter rate and abundance of bottlenose dolphins recorded by the CRRU from 2001 to 2010 inclusive.

Year	Survey effort (km)	Total bottlenose encounters	Total dolphins	Encounter rate per km	Animals per km
2001	1108.25	18	262	0.016	0.236
2002	1417.55	15	153	0.011	0.108
2003	1128.65	20	241	0.018	0.213
2004	1299.3	9	181	0.007	0.139
2005	868.9	33	442	0.038	0.509
2006	1555.55	29	421	0.019	0.271
2007	1172.25	26	355	0.022	0.303
2008	1142.2	20	366	0.017	0.320
2009	2291.86	20	303	0.009	0.132
2010	861.23	13	274	0.015	0.318
Total	12845.74	203	2998	0.016	0.233

The highest encounter rate and abundance was recorded in 2005 with 0.04 sightings and 0.5 animals per km. The lowest annual encounter rate was in 2004 (0.069 per km), but the lowest abundance was observed in 2002 (0.108 animals per km). Abundance and encounter rate were highest in September (0.019 encounters / km; 0.33 animals/km) and June (0.02 encounters/km; 0.26 animals/km) with the lowest in May (0.013 encounters/km; 0.18 animals/km).

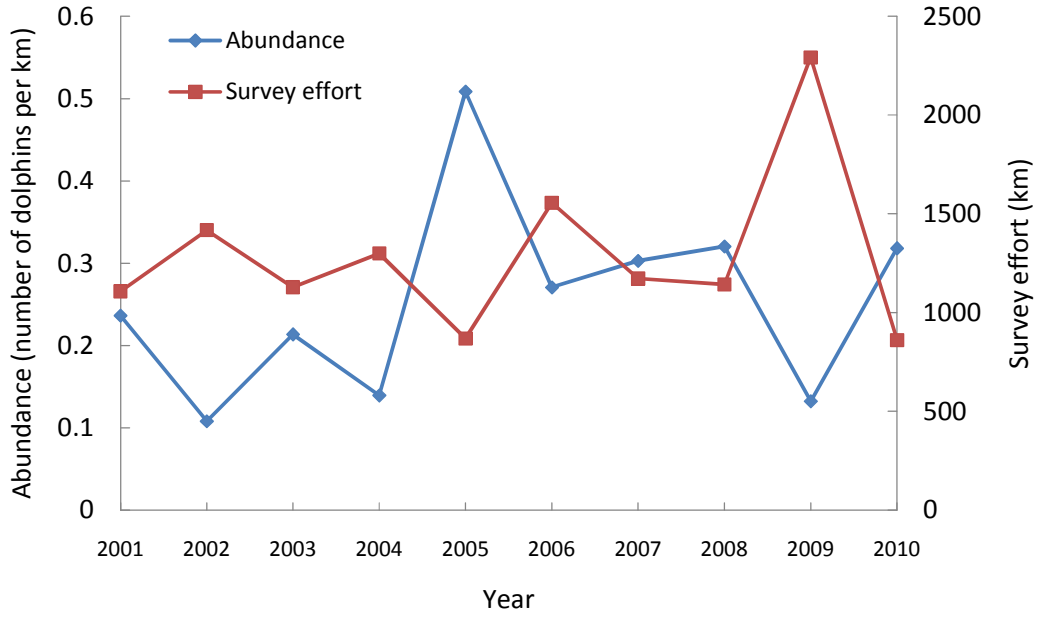

Figure 4. Line graph showing the abundance of bottlenose dolphins per km in the Outer Moray Firth study area between 2001 and 2010 with respect total annual survey effort.

Calculated in ArcView for the combined years 2009 and 2010, abundance ranged from 0.09 to 24 animals per km effort (Fig. 5a). The grid cells with the highest values for abundance and sight rate were mapped at the most westerly point of the transect, the end of Spey Bay, with all other points distributed along the entire length of the coastline between Fraserburgh and Lossiemouth (Fig. 5).

Depth was derived for 117 sightings using data obtained from the onboard GPS. Dolphin encounters were recorded between 4.5 and 35m, with a mean of 13.49m $\pm$ 4.4 and a median of 13.2m, the majority of encounters (89%) occurring at depths of 18m or less. Using ArcView and DigiBath bathymetry data, an approximation of distance from shore was obtained for 202 sightings between 2001 and 2010. One encounter occurred 3.4km from shore but sightings this far north of land appear to be the exception; only three times were sightings >1.8km from the coast. In general dolphins were predominantly encountered close inshore with 85% of all sightings occurring at distances 800m or less from the coastline (mean = 617m $\pm$ 418).

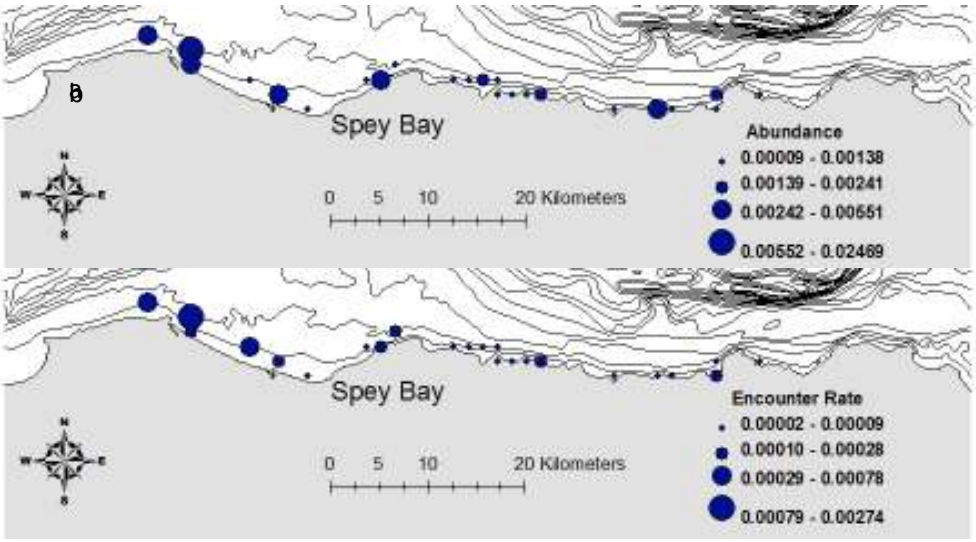

Figure 5. GIS maps showing the abundance (a) and encounter rate (b) of bottlenose dolphins using combined survey data for 2009 and 2010. The size of the symbols reflects abundance and sight rate per meter effort.

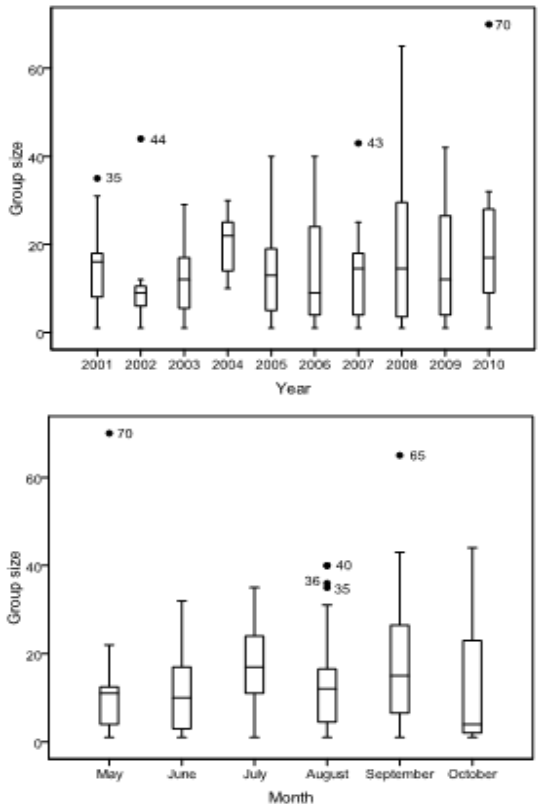

Figure 6. Box plots of the variance in group size between years (a) and cumulative months (b) across the study period, showing the mean and error bars. Outliers are shown along with their respective group size.

Group size was also found to vary between years and months (Fig. 6), with the smallest groups composed of two individuals (n=13) and the largest composed of 65 and 70 respectively. Overall mean group size was 14.77 ± 11.7 individuals. Whilst group size was found not to be significantly different between years (d.f = 9, F = 1.076, P = 0.382) a significant was observed between months (d.f = 5, F = 2.366, P = 0.041), with smaller groups typically observed in cumulative data for June compared to July and September (mean difference of -0.875 and -0.81 respectively). Differences in group sizes between months were drawn from monthly cumulative figures across all years.

Calves were found to be present in 80.79% of all encounters (n=203) recorded between 2001 and 2010 (Appendix B). There was no significant difference in the number of groups containing calves between years ($F_{9,47}$ = 0.959, P = 0.485), but a highly significant difference between cumulative months ($F_{5, 51}$ = 6.30, P

= <0.001). For instance, there were significantly more groups with calves in during the period June through to September, than recorded in May or October, with the highest mean number per group in September (4.4 $\pm$ 2.5), and the lowest in October (0.55 $\pm$ 0.88). New born calves were produced between June and October, with a peak in the number of births in the month of August (Table 2).

Table 2. Cumulative number of neonates born in survey months, as well as the percentage of groups encountered with calves between 2001 and 2010.

	May	**June**	**July**	**August**	**September**	**October**
Number of encounters	15	43	48	44	44	9
Number neonates	0	3	9	17	9	7
% Groups with calves	86.67	67.44	89.58	77.27	90.91	55.56

In order to determine a crude estimation of population size a discovery curve was constructed from individual sightings histories data provided by the CRRU spanning the period from 1997 to 2010 (Fig. 7). Using photo identification records and recorded calving histories from an extensive photo archive database (as described by Culloch *et al.* 2004) the best estimate for the population between 1997 and 2010 was a total of 176 animals. Two further estimates of 111 marked animals and 94 calves were also derived from the dataset. The sum of animals in the latter two categories does not equal the total; where it was thought a calf may have been subsequently recaptured as an adult and catalogued as two separate animals, it was excluded from the 'all recapturable' category to prevent an overestimate of the number of individuals.

In 2001 seventeen previously unrecognised individuals, encountered on 3 occasions (boxed in blue on the chart) were added to the catalogue. Photos of the animals were subsequently matched with photos taken in the Inner Hebrides on the northwest coast of Scotland, the first evidence of translocational movement of animals between these two areas (Robinson *et al*. 2009). The animals were then traced to Ireland, with one individual subsequently travelling to the south of England. The rate at which new marked animals are discovered appears to be steadily increasing, with between two to nine new additions per year (except in 2001), with no more than 4 animals having been added per year since 2007.

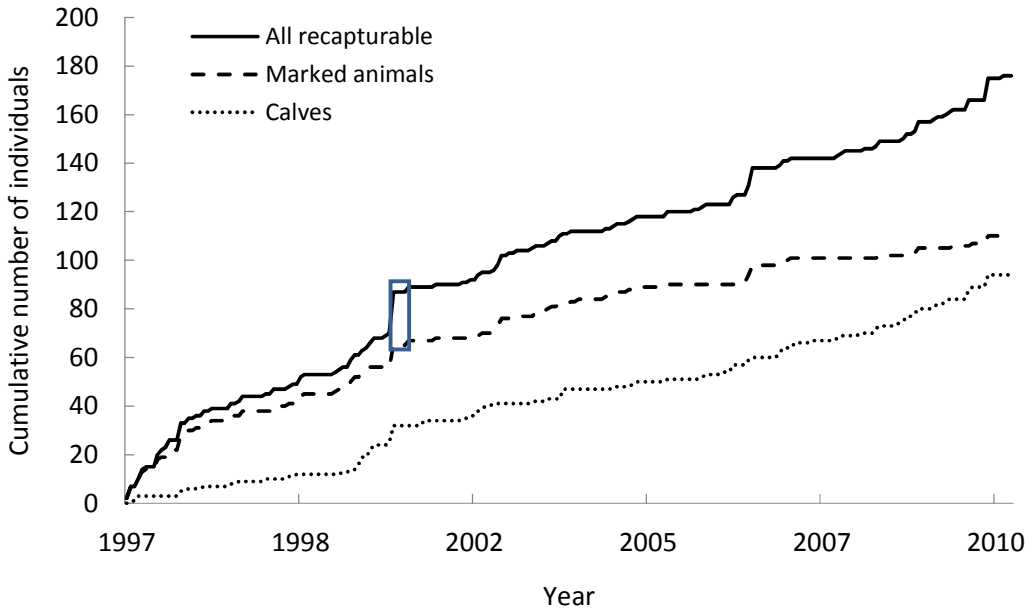

Figure 7. Discovery curves for all recapturable dolphins, marked adult dolphins and calves for the period between 1997 and 2010 inclusive. 'Cumulative individuals' represents the progressive addition of individuals of each category as they are encountered for the first time. The blue box highlights the addition of seventeen previously unrecognised dolphins later traced to the Inner Hebrides.

Recapture data for the 111 marked / recapturable animals encountered between 1997 and 2010 revealed that 32% of the animals have been encountered between 1 and 4 times, with a number of other individuals showing a marked degree of site fidelity, Figure 8 shows the number of individuals subject to the number of recaptures. 17% of marked animals have been encountered more than 40 times in the study area, with one individual (a distinctive adult female 225) having been seen 70 times since first recorded in July 1998.

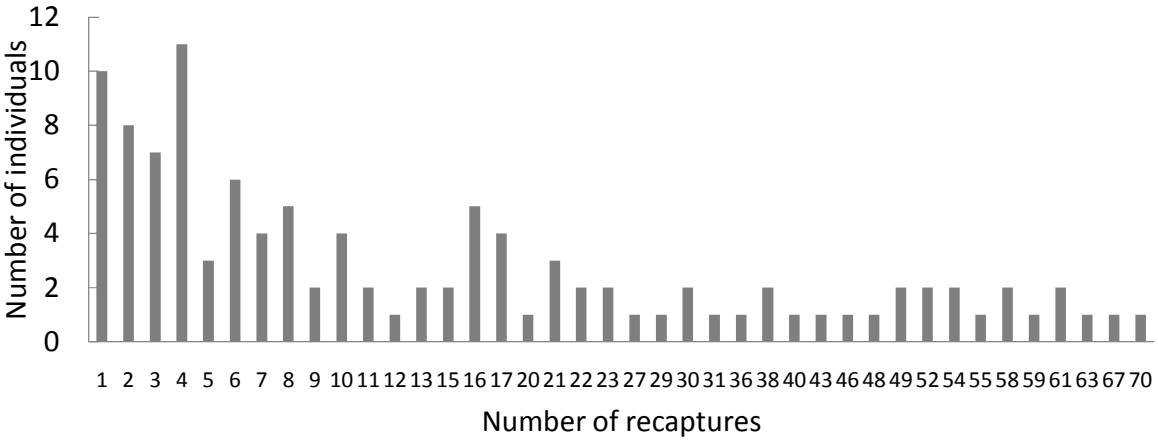

Figure 8. Bar chart showing the range of recaptures with 10 individuals encountered only once, and 1 individual encountered 70 times between 1997 and 2010.

From the 111 marked animals identified in the study area, 85 marked / recapturable adults were selected in order to construct a table of residency. For the purposes of this study and after the criteria applied by Zoolman (2002) and Culloch (2004), residency was defined as the presence of an individual in three or more months of the study season in any particular year. Fifty three animals were found to have been resident between 2001 and 2010. Residency was variable between years (Table 3), particularly high in the period between 2005 and 2008 with 44 individuals resident at some point during this period.

Table 3. Annual residency for bottlenose dolphins between 2001 and 2010. Total animals seen represents the number of animals (sub-adults and calves included) observed that year. Total marked adults represents the number of recapturable adult animals observed that year.

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total animals seen	80	53	66	53	59	96	60	89	67	68
Total marked adults	42	32	42	37	41	58	38	46	36	34
Number of resident adults	8	12	14	6	28	29	21	23	12	14
% resident marked animals	19	37.5	33.3	16.2	68.3	50	55.3	50	33.3	41.2

The percentage of resident animals present annually, while variable, was higher than 30% for eight out of the ten years indicating a large proportion of animals consistently remain in the area for long periods of time. A kernel analysis of resident animals illustrated an even distribution of activity throughout much of the study area (Fig. 9), with a consistent pattern of usage of the entire coastline between years and months (Appendices C and D). Areas subject to a high density of bottlenose sightings are also closely associated with sandy bays such as Sandend (Fig. 9) which may be preferred feeding and nursing areas. Kernel density patterns for males, females and females with calves were indistinguishable from each other, suggesting that all animals (as represented by the 53 resident adults) utilise the entire coastline in an almost identical way (Appendix E).

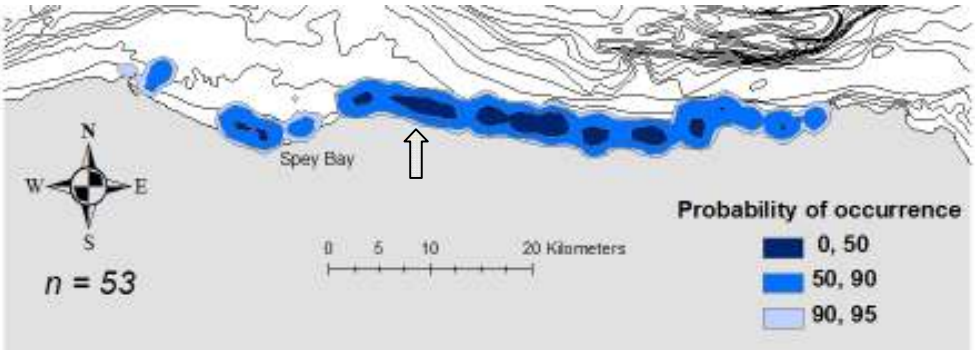

Figure 9. Map of the Moray Firth coastline showing a kernel density pattern, derived from the sightings of 53 adult recapturable dolphins resident at some point between 2001 and 2010. Arrow indicates the location of Sandend bay.

Discussion

Findings in the current study provide evidence for a high abundance of bottlenose dolphins in the Outer Moray Firth, with high densities along the length of the study area suggesting the animals utilise the entire coastline. With higher abundances and group sizes for each cumulative month during the period between June and September, the results are consistent with previous observations of a seasonal variation in abundance corresponding to increased foraging activity and the availability of prey (Wilson *et al*. 1997). With a mean group size of 14.76 $\pm$ 11 the Outer Firth has the largest mean group size of any UK population, exceeding means of 8 for the population off the Aberdeenshire coast (Weir & Stockin 2001), 6.45 for the Inner Firth (Wilson, 1995), between 3 and 5 in Cardigan Bay (Bristow & Rees 2001) and 6.54 in Shannon Estuary, Ireland (Duguid 2003).

The number of groups with calves also exceeded figures for other UK populations with calves seen in over 80% of all encounters in the Outer Moray Firth, compared with 40% of groups sighted with calves in Cardigan Bay (Bristow & Rees 2001) and 44% in encounters off the Aberdeenshire coast (Stockin *et al.* 2006). The best population estimate that could be derived from the photo ID dataset kept by the CRRU was 176 individuals, in comparison to the most recent population estimate for the entire east coast bottlenose population, which was estimated at 193 individuals (Thompson *et al*. 2009). Assuming both figures to be relatively accurate, this suggests that over 90% of the bottlenose population of the east coast of Scotland are known to utilise this area.

Furthermore, interpretation of the data presented here has implications for better understanding the behaviour and habitat use of bottlenose dolphins. Of the two largest groups to be encountered, one was seen in May, the other in September (in separate years). Values for abundance and encounter rate were also highest in June and September, lower in intervening months. It is thought that bottlenose travel into the Moray Firth at the beginning of the summer in large groups; on entering the Firth the group fragments into smaller social groups which then disperse throughout the area and to all accounts remain small. At the end of summer the groups consolidate and leave the area as a larger unit (Robinson, personal communication). Group structure of dolphins is known as an important mechanism for maximising foraging effectiveness (Pryor & Norris 1991) and thus observed variation in group size could be driven by adaptation of hunting strategies to the immediate distribution and availability of prey. Observed variation in group sizes could also potentially be driven by individual variation in movement with some animals known to show keen site fidelity and remain resident in an area for a number of years (Smolker *et al.* 1992), whereas in other cases individuals may undertake long annual migrations (Kenney, 1990), or in a deviation from normally consistent patterns, extend their usual range by hundreds of kilometres (Würsig & Harris, 1990; Robinson *et al.* 2009).

Another explanation for the large 'outlying' group sizes at the beginning and end of the summer could be related to reproduction. Having established that the proportion of groups seen with calves is particularly high, with a peak in the number of births in August, there is evidence to suggest that the Outer Moray Firth is an important calving and nursing area. It is also an environment therefore where the animals feel relatively secure. Given that for many animal species, numbers is the best defence against predation, perhaps the formation of large groups to move into and out of the Firth represents a defensive herding manoeuvre, with animals dispersing into smaller groups once in the relative security of the Moray Firth embayment. None of the shark species likely to prey on dolphins have been documented in these waters, and the only other natural predator, the Killer whale (*Orcinus orca*), is rare (Weir & Stockin 2001). Nevertheless, a defensive behavioural instinct might be responsible for large groups of dolphins entering and exiting the Firth.

Abundance and sight rate for 2009 and 2010 mapped using ArcView show a pattern of occurrence distributed generally along the coastline. Variability in the occurrence and behaviour of bottlenose dolphins is thought to be associated with habitat structure and prey distribution (Defran & Weller, 1999). Whilst the occurrence of bottlenose has been found to be strongly related to the bathymetry of areas in the Moray Firth as they follow routes potentially associated with migrating salmon (Robinson *et*

al. 2009), our understanding of the spatial and temporal distribution of prey makes interpreting movement of bottlenose dolphins difficult (Hastie *et al*. 2004).

The particularly high abundance of 24 animals per km determined using ArcView is markedly higher than the highest abundance estimate calculated manually (0.34). This is likely a consequence of the GIS methodology; abundance represents the number of animals in relation to the amount of survey effort per cell. A cell with a low amount of survey effort but a number of sightings will thus give an unrepresentative estimate of abundance. In this case the cell (correlating to an area at the end of Spey Bay) had the lowest associated effort of any cell (364m), with sightings in other cells in different parts of the study area associated with >1km of effort. This is likely due to its being at the end of the study area and less frequently traversed than the route to the east along the coastline. The value is not a gross overestimate however, and we would still draw the conclusion that the area around Spey Bay seems to have been / is currently highly frequented by dolphins, potentially fishing around the river mouth.

Using the same method of mark recapture Wilson *et al.* (1999) studying the Moray Firth bottlenose population in the inner and to some extent outer Firth found the discovery of new marked individuals to be increasing at a rate of ~4 animals per year and concluded the population to be closed to permanent immigration. The occurrence of the seventeen dolphins recorded in 2001 in the Outer Firth and later traced to the Inner Hebrides shows that the Moray Firth population is open to some extent to transient animals. The current rate of addition of new marked adults was also found to be ~4 animals per year, and a number of individuals show high site fidelity with a maximum of 70 recaptures for one individual. As an open population is generally defined as one known to experience permanent immigrations and emigrations (Lusseau *et al*. 2005), and while the amount of exchange of individuals and genes between populations in UK and Irish waters remains unclear (Thompson *et al*. 2004) the data presented here provides evidence for a closed population, though more in-depth analysis of rates of immigration/emigration would be required to draw a firmer conclusion.

Virtually identical kernel density patterns for resident males, females and females with calves suggest allows initial conclusions to be drawn about habitat use by animals of different sex, assuming the behaviour of the 53 individuals to be generally representative of the entire population. The majority the groups encountered were of mixed composition with animals of varying ages and different sexes travelling together. While the females may use this area primarily as an environment in which to rear their young, they are accompanied by sub-adults, potentially seemingly many former calves (Robinson, personal communication) and males whose sexual interest in adult females leads them to closely accompany female groups even when there are calves in echelon. The high sociality of dolphins may go

some way to explaining kernel density patterns; bottlenose are known to form subunits which frequently change in distribution, termed fission-fusion societies (Struhsaker & Laland 1979). According to research on the social aspects of the bottlenose dolphins of the Outer Moray Firth, all individuals are indirectly linked to all other members of the population forming a large social network (Eisfeld 2003). Kernel density patterns could thereby be interpreted as being similar for males, females and females with calves because sub groups are continually changing and resident individuals are as likely to be encountered with individuals of the opposite sex, or different age classes as they are with their own.

The 53 animals classed as resident in this study likely represent an underestimate of the potential number of residents present in the outer Moray Firth, as surveys are only conducted six months of the year and survey effort is variable within years due to circumstances such as bad weather conditions. The selective criteria for determining residency are also likely too narrow. Selecting individuals present in three or more months of the field season each year does not account for the number of times overall that animal was seen. Male 354 for example, seen 9 times in the course of the present field season does not yet meet our applied criteria for residency; in comparison female 302, seen in only three years and 'resident' for one was only seen once in three months of the 2006 field season. The usefulness of mark-recapture methods for estimating abundance and residency will always be restricted; animals may be more likely to be encountered at certain times and locations than others, there be individual variation in the extent of movement within areas and the possibility that the study area does not encompass the animals full range. All these factors introduce heterogeneity into recapture probabilities that may be lead to inaccurate population estimates (Durban *et al.* 2005). Using the residency method however, it was determined that there are periods such as 2005 (when 68% of the 53 animals were resident) of particular high residency. Between 1998 and 2000 54 marked animals were identified in the Inner SAC (Wilson *et al*. 2004). Using the CRRU dataset, a recapture estimate of 111 marked animals was obtained, 85 of which were marked recapturable adults. Resident animals showed a high level of site fidelity, remaining in the area for periods of at least three months, in the case of some individuals consistently over different years; all evidence to refute the suggestion that the Moray Firth might just be a corridor area to the Inner SAC.

Surveys conducted of the area by the CRRU, which receives no government or university funding, are restricted to six months of the year with no data available on the bottlenose of the Outer Moray Firth out-with the summer field season. Yet the data gathered to date has enabled important conclusions to be drawn about the significance of the Outer Moray Firth for the bottlenose dolphin. The implication for management is the need for acknowledgement of the Outer Moray Firth as an area of potential

importance for bottlenose as a feeding, nursing and calving area. This environment supports around 90% of the northeast Scotland bottlenose population with evidence that animals utilise the entire area with some showing a marked degree of site fidelity. Existing conservation initiatives should therefore take into consideration that management of the Outer Firth is essential for the survival and welfare of the Moray Firth bottlenose population.

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Appendices

Appendix A

Table to show survey effort, the number of encounters, number of dolphins, encounter rate and abundance per km for each cumulative month for the period 2001-2010 inclusive.

Month	Survey effort (km)	Total bottlenose encounters	Total number dolphins	Encounter rate	Animals per km
May	1075.90	15	194	0.0139418	0.180314
June	1876.01	43	482	0.0229210	0.256929
July	4082.53	48	826	0.0117574	0.202326
August	2952.60	44	582	0.0149021	0.197114
September	2293.79	44	776	0.0191822	0.338305
October	564.91	9	138	0.0159317	0.244286
Total	12845.74	203	2998	0.0158029	0.233385

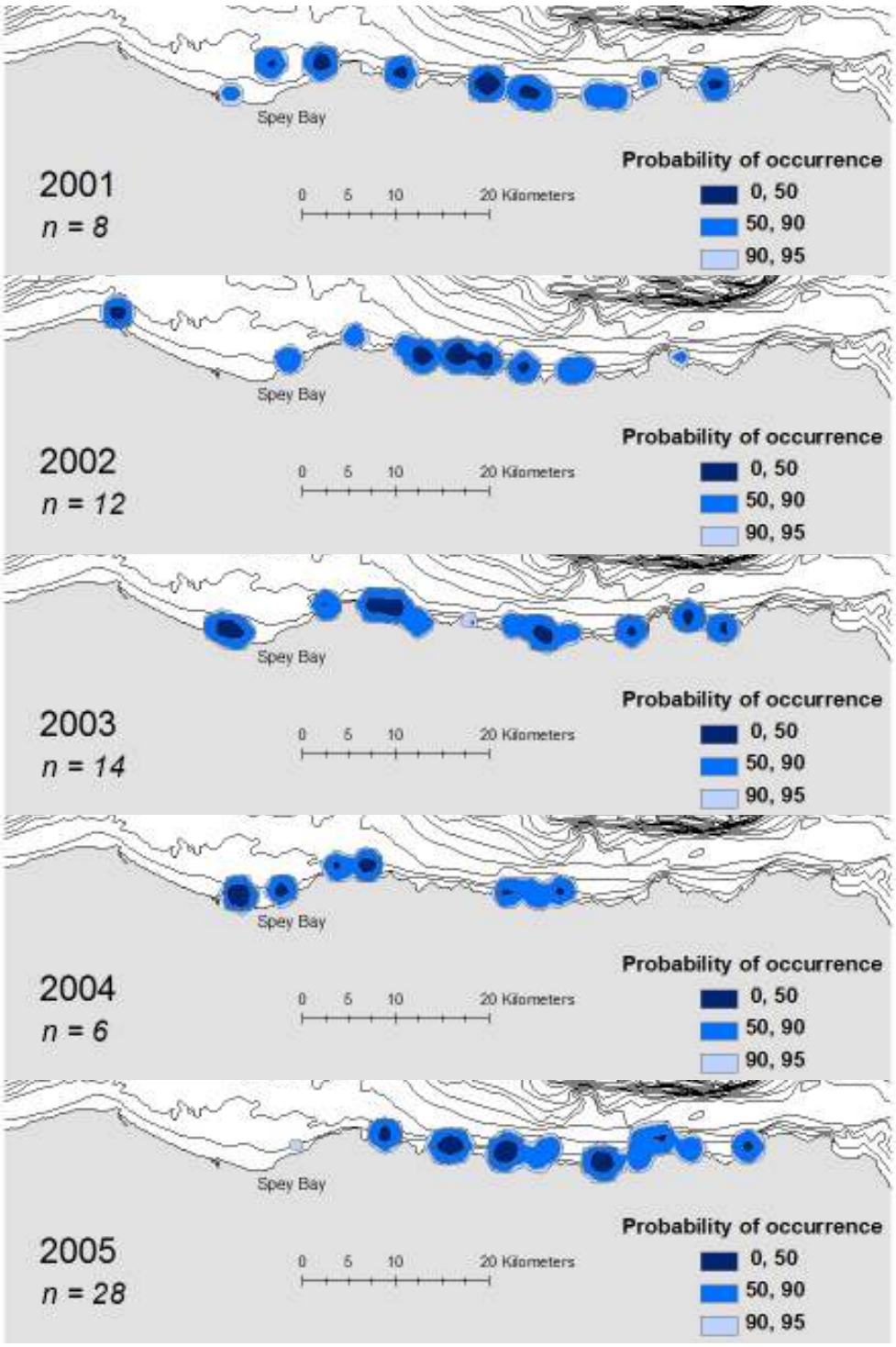
Appendix B

Table to show the annual number of encounters and encounters to include calves, with the overall proportion of groups seen to contain calves for the period between 2001 and 2010 inclusive.

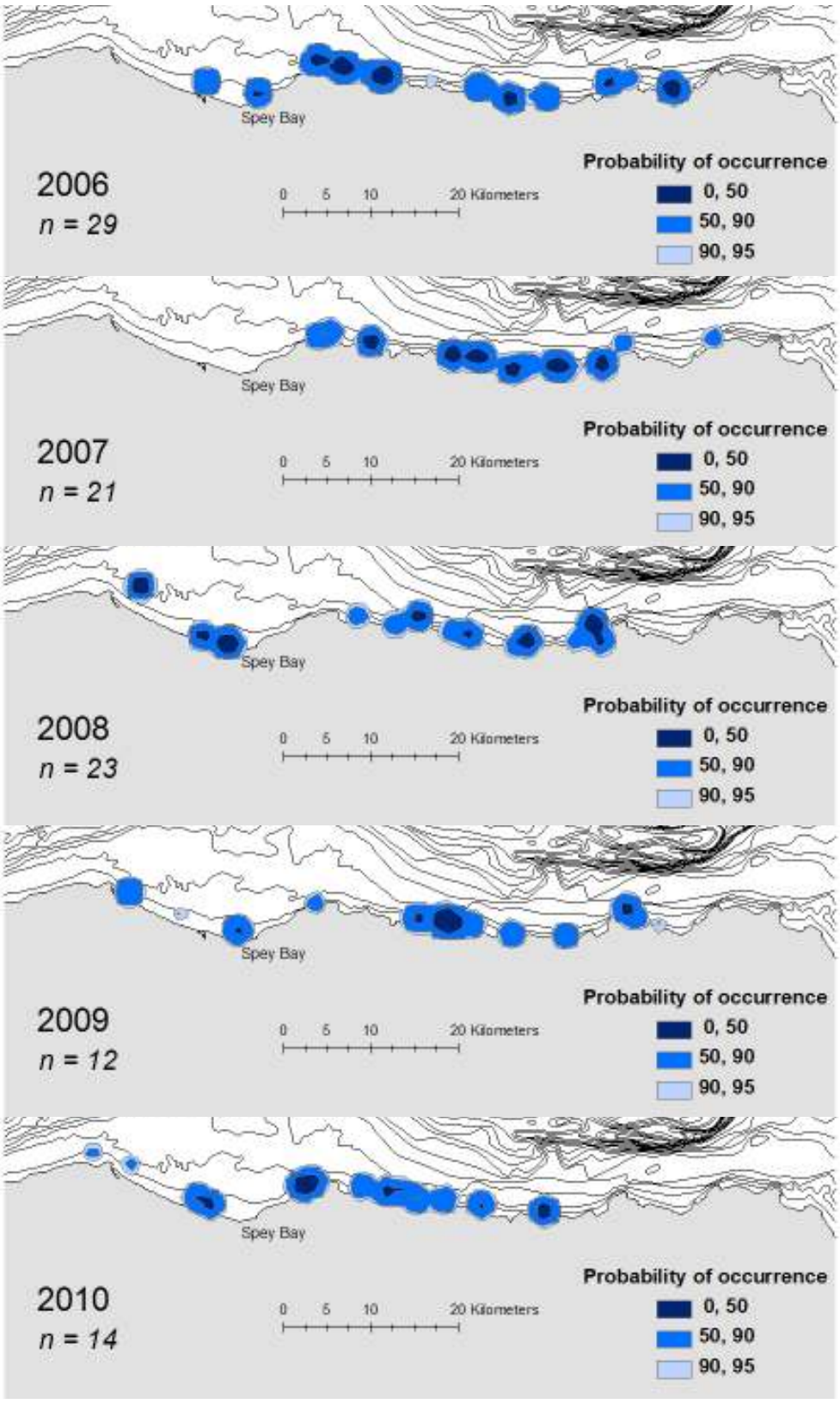
Year	Encounters	Encounters + calves
2010	13	11
2009	20	14
2008	20	14
2007	26	21
2006	29	22
2005	33	29
2004	9	9
2003	20	16
2002	15	13
2001	18	15
Total	203	164
	% groups with calves 2001-2010	80.79

Appendix C

Kernel density plots constructed in ArcView of the movements of resident animals within the study area in successive years between 2001 and 2010 (with the number of resident adults represented shown).

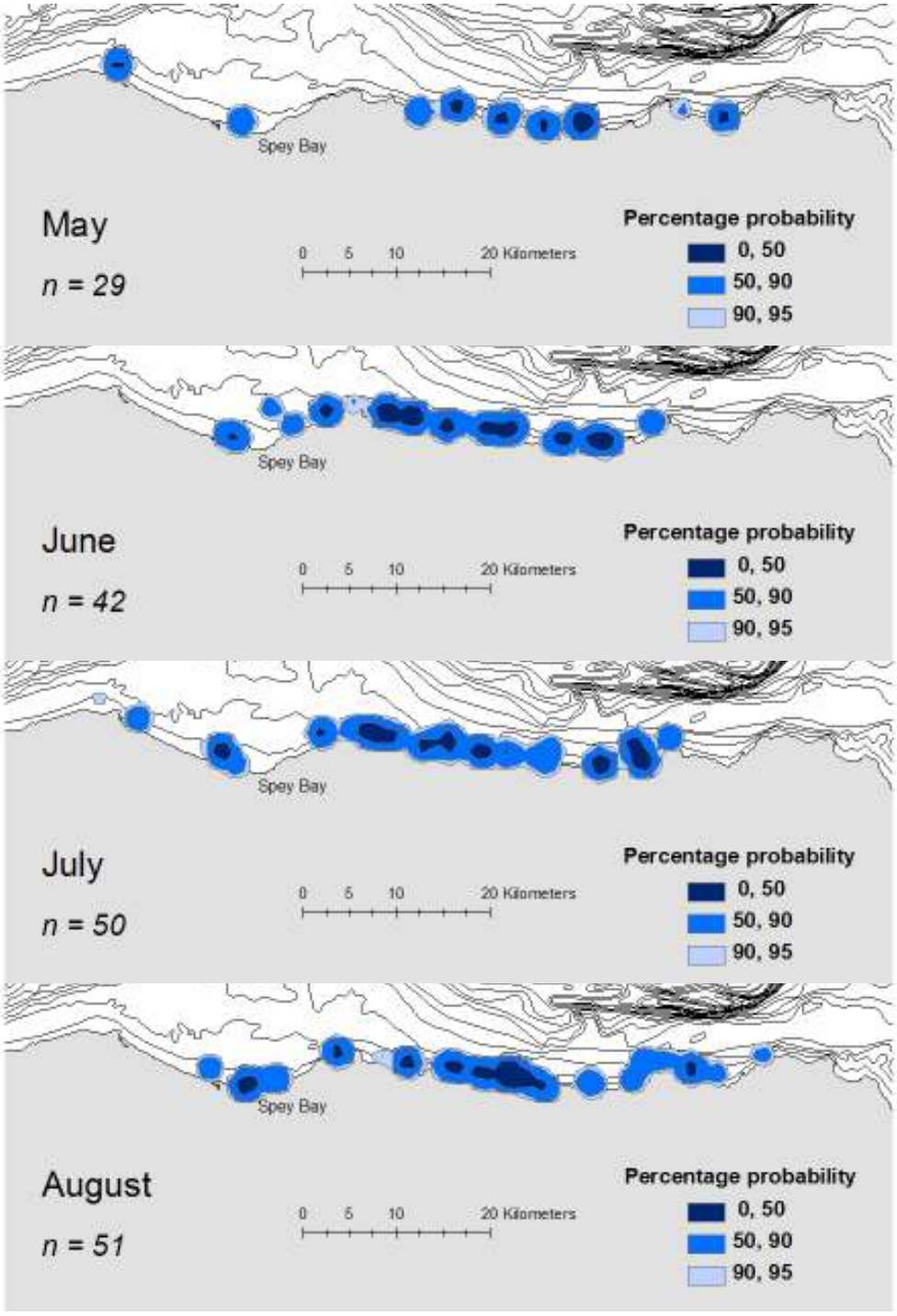


Appendix C (continued)

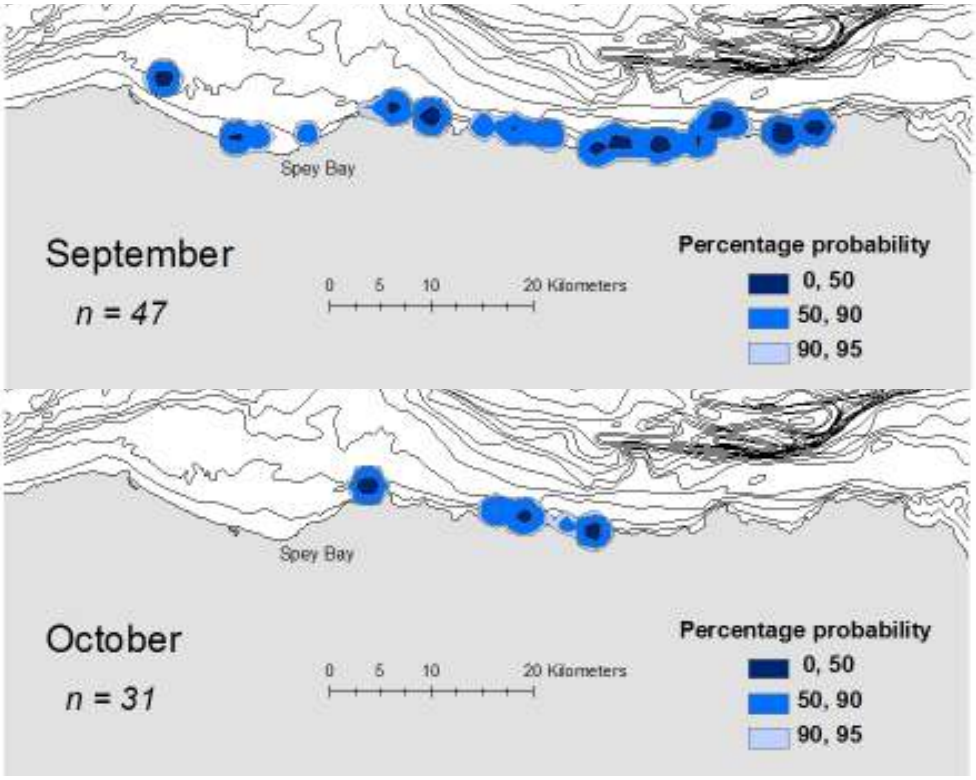


Appendix D

Kernel density plots constructed in ArcView of the movements of resident animals within the study area for the six months of the field season (with the number of resident adults represented shown). Monthly data represents the cumulative addition of sightings of animals resident in the period 2001 to 2010 inclusive.



Appendix D (continued)



Appendix E

Kernel density plots constructed in ArcView of the movements of resident males, females and females with calves within the area of the Moray Firth coastline surveyed, with the number of animals represented in each class shown. Sightings data for all individuals is taken from the period 2001 to 2010 inclusive.