Report name: **Cetacean Baseline Characterisation for the Firth of Tay based on existing data: Bottlenose dolphins**

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1 Summary

The only current abundance estimate of bottlenose dolphins for the Tay area uses data from the summer months of 2003-2004 and gives a range of 81-142 dolphins. More recent photo-identification data from the summers of 2009 and 2010 identified 107 animals in the Tay area. The most recent abundance estimate for the whole east coast population of bottlenose dolphins is 195 (95% highest posterior density interval (HPDI): 162-253) from data from 2006. This suggests that a substantial proportion of the bottlenose dolphins on the east coast of Scotland use the Tay area.

During the summer months of 2009 and 2010 bottlenose dolphins were distributed throughout the Tay area with the majority of encounters within the Tay estuary. There was no pattern in the distribution of group sizes in either year, with both large and small groups being sighted across the study area. Groups comprised all age groups and both sexes. In addition, all behaviour types, including foraging, socialising and travelling, have been sighted in the Tay area. This suggests that the Tay area is an important habitat for this east coast bottlenose dolphin population.

Seasonal data on dolphin presence comes from T-PODs, moored at Arbroath and Fife Ness during 2006 to 2009. Despite inter-annual and seasonal differences between sites, T-PODs showed that dolphins were detected in every year and every month of deployment. This suggests that bottlenose dolphins are not just occasional visitors to the Tay area but are site faithful as they are detected year round and in multiple years.

Photo-identification data from 2009 and 2010 showed that 35 individuals were sighted within the Tay area and also within the Moray Firth SAC within these two years. This shows a high degree of connectivity between the two sites over the course of these two years. However, there was variability in movement patterns of individuals between and within years.

2 Introduction

The Forth and Tay Offshore Wind Developers Group (FTOWDG) consist of the developers of the proposed Scottish Territorial waters offshore wind farm sites off the Firths of Forth and Tay and the Round 3 Zone off the Firth of Forth. In total three sites are considered within FTOWDG. Two of these are within Scottish Territorial waters. The first is the proposed site for the Inch Cape offshore wind farm in the outer Firth of Tay region located approximately 15-22km to the east of the Angus coastline and covering approximately 150km^2. (SeaEnergy Renewables 2010). The second is the proposed site for the Neart na Gaoithe offshore wind farm, which is 15.5km east of Fife Ness in the Firth of Forth and covers an area of approximately 105 km^2 (Neart na Gaoithe undated). The Round 3 Zone lies just outside of Scottish Territorial waters, approximately 25km east of Fife Ness in the outer Firth of Forth, and covers an area of approximately 2,852km^2 (Seagreen Wind Energy 2011).

The FTOWDG are currently in the process of obtaining consent for the wind farms sites and as part of this process are collating available ecological data on marine mammals to help characterise the sites. This report details information on the bottlenose dolphins that are known to reside off the east coast of Scotland. Bottlenose dolphins are listed as European protected species and in Annex II of the EC Habitats Directive and as such require the designation of a Special Areas of Conservation (SAC) for their protection. There is one SAC with bottlenose dolphins as a qualifying interest, relevant to the FTOWDG wind farm developments; this is the Moray Firth SAC (Moray Firth Partnership 2009). The bottlenose dolphins found in the Tay area are individuals from the same population using the Moray Firth SAC (Thompson *et al*., 2011). In any one year a proportion of individuals are sighted both within the SAC and also within the Tay area.

The aim of this report is to provide background information to inform the FTOWDG site assessments. The first section of this report deals with the spatial and temporal extent of the data; the second the relative abundance and distribution of bottlenose dolphins in the Tay area; the third reviews current information on east coast of Scotland bottlenose dolphin total population size; the fourth assesses the connectivity of individual animals between the Tay and the Moray Firth SAC; and the fifth outlines the main conclusions.

Section 1

3 The spatial and temporal extent of the data.

1.1 Firth of Forth

The historical distribution of bottlenose dolphins around Scotland has been recently reviewed (see Thompson *et al*., 2011 for details). Records of bottlenose dolphins within the Firth of Forth come from stranding information and also from numerous sightings including the Joint Nature Conservation Committee (JNCC) Cetacean Atlas, the Sea Watch Foundation and the Small Cetaceans in the European Atlantic and North Sea II (SCANS II) survey (see Thompson *et al*., 2011 for details). Currently no dedicated photo-identification effort has taken place in the Firth of Forth, so there is no abundance estimate for this area or information on the fine scale distribution of animals either temporally or spatially. As such no firm conclusions on how animals may be distributed or the relative importance of the Firth of Forth in terms of habitat can be made. The Firth of Forth area will not be considered further in this report.

1.2 Firth of Tay

Data collection on bottlenose dolphins has taken place in the Firth of Tay since 1997. The data collection has taken place with support from a variety of different organisations and as part of numerous projects, including PhD studentships and government funding, but on the understanding that the data and resulting outputs of subsequent analysis are freely available to support additional research and management questions. All data used in this report are owned, either in part or full by the Sea Mammal Research Unit, University of St Andrews or the University of Aberdeen.

Varying levels of photo-identification effort, in terms of number of days of survey, have been undertaken in the Tay area in the last 14 years. Effort generally spans the summer months from May to September, when better weather conditions increase sighting probabilities and light is more suitable for photographs. However, some effort has taken place during the winter. Specifically in 2007/2008, 5 winter surveys were conducted (Thompson *et al.,* 2011). Current photographic records exist for 1997, 1998, 1999, 2000, 2003, 2004, 2006, 2007, 2009 and 2010. In addition a further 10 photo-identification surveys have taken place during June to August 2011.

In addition, dedicated behavioural focal follows took place in the Tay during 2003 and 2004 as part of a PhD study. These follows consisted of data collection on acoustic behaviour, group composition and surface behaviour in addition to photo-identification. During 2006, 2007 and 2010 data collection on group composition, associations and relatedness, acoustic behaviour and surface behaviour in addition to photo-identification also took place to varying degrees as part of two further PhD studies.

Passive acoustic monitoring took place from the middle of December 2006 to the middle of March 2009 using Timing Porpoise Detectors (T-PODs). T-PODs were moored near Arbroath and Fife Ness as part of a Scottish Government and Scottish Natural Heritage (SNH) project.

1.3 Data available for this study

For the purposes of this report, information is drawn from publically available sources to provide background information and review. The only unpublished data that will be included is from dedicated photo-identification data from the Tay from 2009 and 2010.

Section 2

4 Relative abundance and distribution of bottlenose dolphins in the Tay

2.1 Abundance estimation in the Tay

Individual bottlenose dolphins on the east coast of Scotland are known to range over large distances (Wilson *et al*., 2004), but also exhibit some level of residency with many individuals being re-sighted within the same areas both within and between years (Wilson *et al.,* 1997, Quick 2006, Thompson *et al.,* 2011). Although this population is often considered resident in the Moray Firth, it is known that animals from this population regularly use other areas (Wilson *et al.,* 2004, Quick and Janik 2008, Thompson *et al*., 2011). One such area is the Firth of Tay. Since 1997, data have been collected in the Firth of Tay and St Andrews Bay area. There are enough sightings of bottlenose dolphins, at least over the summer months, for dedicated photo-identification studies to be conducted, and for the data from these surveys to be incorporated into mark recapture analysis of total population size (Durban *et al.,* 2005; Corkrey *et al*., 2008; Cheney *et al*., In review).

Traditionally, abundance estimation of bottlenose dolphins on the east coast of Scotland has been for the whole population using the entire east coast (Durban *et al*., 2005; Thompson *et al.,* 2011; Cheney *et al.,* In review) or for the parts of the population using the Moray Firth SAC as part of site condition monitoring for the SAC (Thompson *et al.,* 2006; Thompson *et al.,* 2009; Cheney *et al.,* In prep). On the whole, these estimations have been carried out with respect to management questions specifically related to animals from the designated SAC in the Moray Firth (Thompson *et al.*, 2006; Cheney *et al*., In prep).

Currently only one abundance estimate exists for the Tay area, using photo-identification data taken during 35 separate days between July and September of 2003 and 2004 (Quick 2006; Quick and Janik 2008). A further 7 trips were undertaken in this time period with no sightings of bottlenose dolphins. These data were collected between Arbroath to the North and Fife Ness to the South in sea states of Beaufort 3 or less. This work formed part of a behavioural focal follow study, with the photo-identification data collected primarily to determine the associations of the focal animal. The data collected were therefore biased towards marked animals and effort was constrained by the movements of the focal animal group. As such, the data are not typical of data that are collected for abundance estimation. However, methodologies exist to account for bias in mark-recapture photo-identification data because, even using standard protocols, it is likely that the probability of sighting each individual is not the same. This is termed heterogeneity in capture, and results from factors such as variation in individual movement patterns (i.e. an animal that stays nearer the coast may be more available to photograph), animals being boat shy or boat happy (i.e. animals that like to bow-ride may be easier to photograph) or researchers concentrating on taking photographs of more nicked or distinct animals (i.e. it is easier to know if you have photographs of animals with very obvious marks or colours on their fins).

Due to the high level of heterogeneity, the study by Quick (2006) used both conventional and Bayesian methods of analysis to provide an estimation of abundance for 2003 and 2004 combined. The conventional method used Chao *et al*.'s (1992) M_{th} model, implemented in the programme CAPTURE (Rexstad and Burnham 1991). The Bayesian method involved mark-recapture with occasion and individual effects, where abundance estimation is achieved through Bayesian model selection in a fixed dimensional parameter space (Durban and Elston 2005). This method involves fitting a continuous logistic-normal model to the data to yield a full probability distribution for the number of dolphins, which demonstrates both the extent and the shape of the uncertainty of the estimate. This estimate is achieved using Markov Chain Monte Carlo (MCMC) simulation methods that involve sampling, rather than maximising the likelihood and are run within the program WinBUGS. The sighting histories of 65 animals with permanent marks were used in the analysis (Table 1). Thirty marked animals were sighted in both 2003 and 2004. Individuals were sighted between 1 and 9 times during the study with 13 (20%) marked animals sighted only once (Figure 1). The re-sight rate of 58% suggests that some individuals may use this area regularly or be partly resident during the summer months. To inflate the estimates to the total population, the proportion of clean or unmarked animals was also calculated for each trip.

Table 1: Total number of animals identified with permanent marks (i.e. nicks, deformities, unusual fin shapes and white fringes) during each study year and both years combined.

Year	Number of fieldwork trips	Total number of animals identified with permanent marks	Number of permanently marked animals re-sighted
2003	29	52	
2004	13	43	30
Both years	42	65	

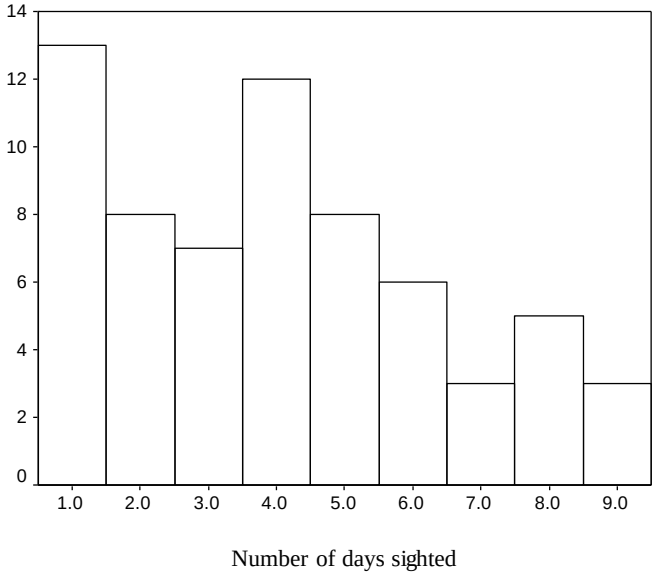


Figure 1: Frequency of sightings for the 65 marked individuals throughout the 35 sampling days in 2003 and 2004 (mean = 4, standard deviation ± 2.4, N= 65).

The best abundance estimates from the two methods, conventional and Bayesian were 89 (95% confidence interval (CI) 81-98) and 112 (95% credible interval (CI) 89-142) animals, respectively. Whilst the precision of the conventional estimate was higher than that of the Bayesian estimate as shown by the lower coefficient of variation values (CV = 0.107-0.111), the mean abundance estimate of 112 for the Bayesian method was larger than for the conventional method. It is difficult, with only 2 years of data, to know if the conventional method is underestimating the abundance or if the Bayesian model is overestimating. However even if one combines both estimates and take the lowest and highest confidence limits of the estimates from both methods, between 81-142 dolphins were using the Tay area during the summer months of 2003 and 2004.

2.2 Distribution of animals in the Tay

In June to August 2009 and June to September 2010 dedicated photo-identification surveys took place in the Tay and St Andrews Bay area. All trips departed from Tayport harbour and employed opportunistic search patterns until bottlenose dolphin groups were encountered. On detection of a dolphin group, standard photo-identification techniques, following the survey protocol for this population (for detailed survey protocols see Thompson *et al*., 2011), were used. In total 8 trips were carried out each year and dolphins were encountered on all trips, giving a rate of 100% of dolphin positive days (Table 2).

Table 2: Summary of trips, encounters and group sizes for 2009 and 2010 data.

Year	No. of trips	Total survey time (hours)	No. of encounters	Min group size (based on best estimate)	Max group size (based on best estimate)	Percentage of dolphin positive days
2009	8	43	30	1	35	100
2010	8	56	39	1	31	100

More survey effort and more encounters were evident in 2010, but the general pattern of encounter locations is very similar between years (Figures 2 and 3). In both years the majority of encounters took place within the Tay estuary, on the northern side of the large sand bar that marks the south of the shipping channel (Figures 2 and 3). There is no pattern in the distribution of group sizes in either year, with both large and small groups being sighted across the study area (Figures 2 and 3).

In 2010, survey effort was increased to north of Arbroath to just south of Montrose. Dolphins were also encountered on these trips (Figure 3). In both years, some effort took place south of the Tay sand bar off the Eden estuary and into St Andrews Bay. No dolphin encounters were seen on these parts of the trips. However, dolphins have been sighted in St Andrews Bay in recent years (Quick 2006) and detections from a moored acoustic device in St Andrews Bay has detected delphinid whistles, (species level confirmation was not possible), during the summer of 2011 (SMRU Ltd, Unpublished data). The only other species of cetacean seen during the 2009 and 2010 trips were on two separate days in 2010 when harbour porpoise were sighted.

All the bottlenose dolphin encounters from both years are located within the coastal waters of the Tay area. As such they are within 20km of the Inch Cape and Neart na Gaoithe Scottish territorial waters sites and within 30km of the Round 3 Firth of Forth site (Figure 4). It should be noted that systematic surveys of the entire area have not be undertaken. The distribution of encounters are therefore influenced by the distribution of survey effort, and do not necessarily represent the overall distribution of dolphins within the area.

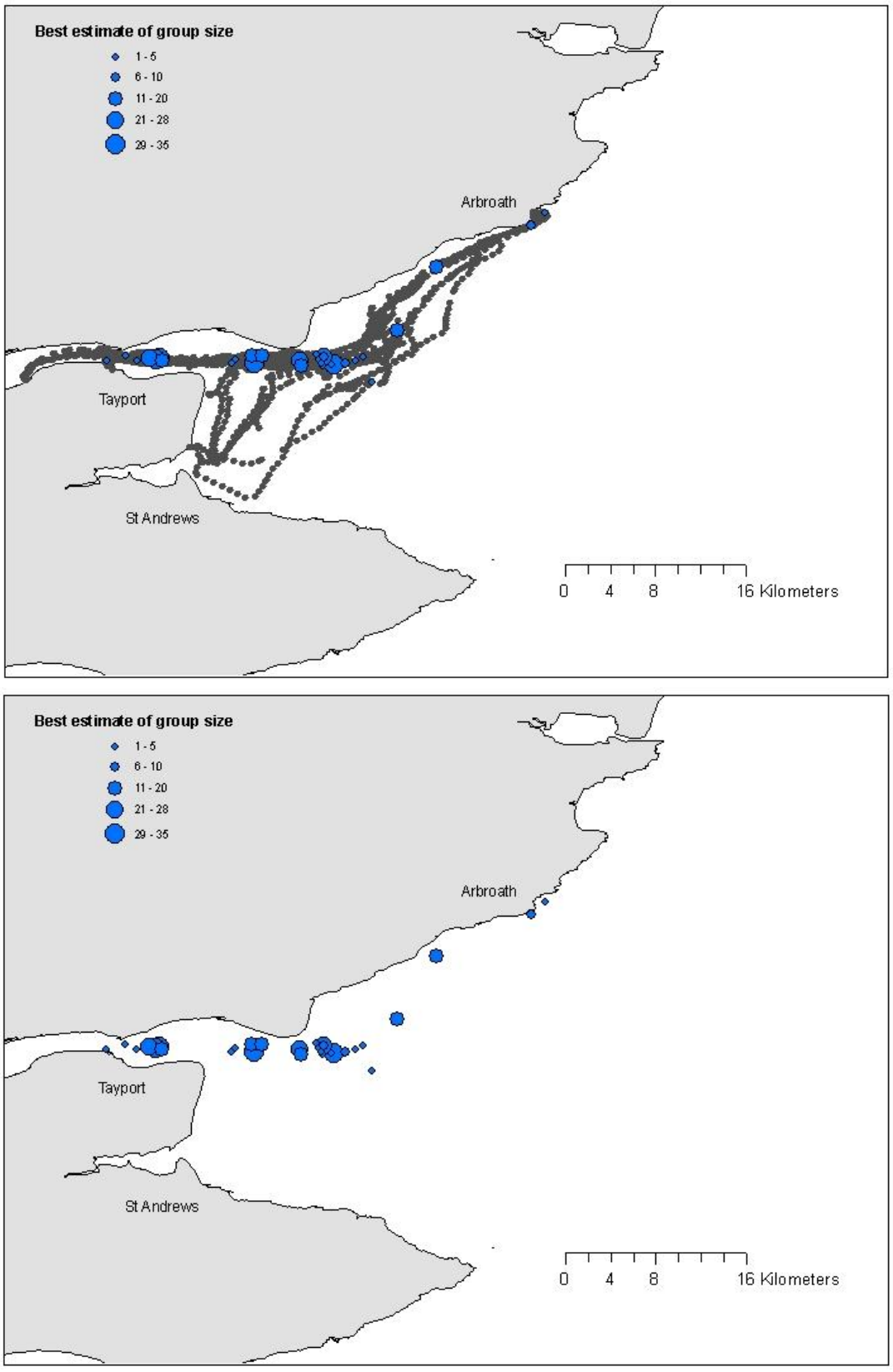


Figure 2: Top panel: effort from all 8 photo-identification surveys from 2009, including location of all encounters. Bottom panel: encounter locations from 2009, with size of circles indicating group sizes.

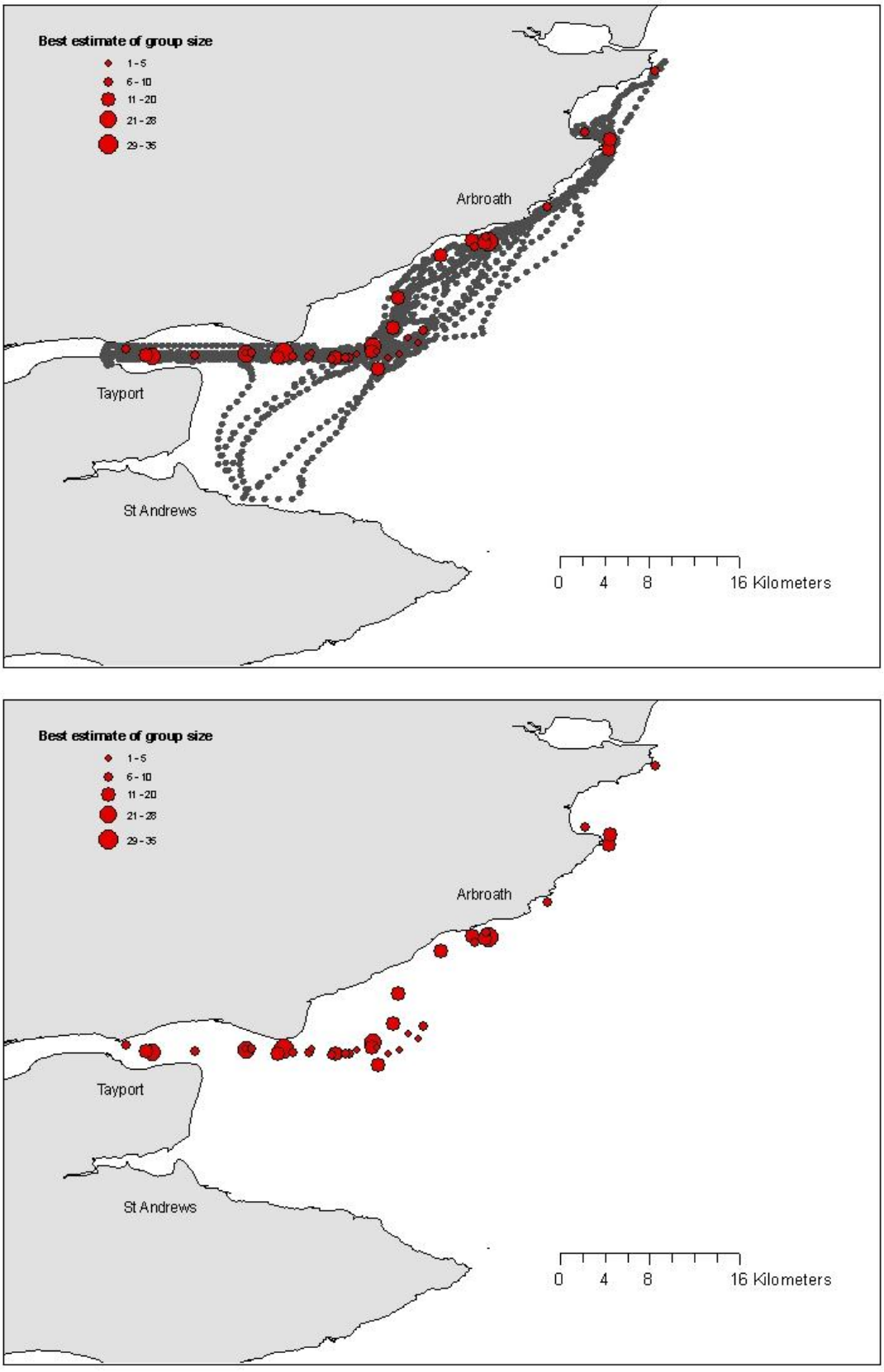


Figure 3: Top panel: effort from all 8 photo-identification surveys from 2010, including location of all encounters. Bottom panel: encounter locations from 2010, with size of circles indicating group sizes.

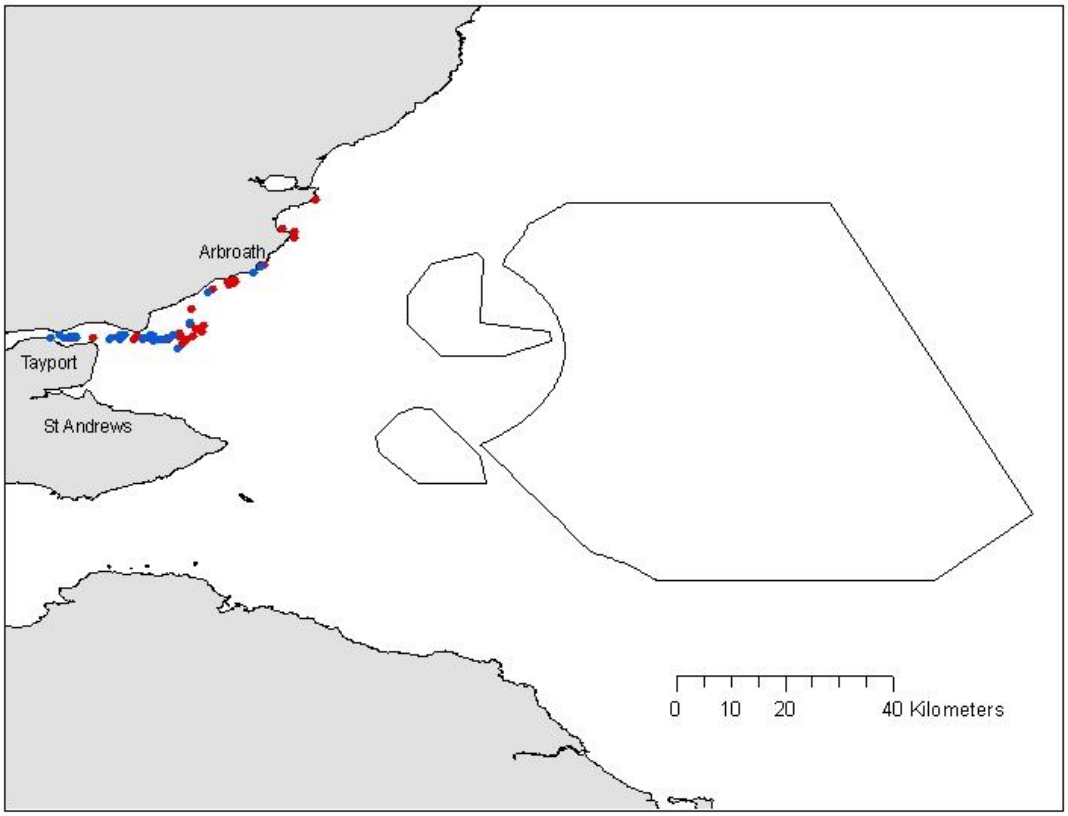


Figure 4: Location of all encounters (blue=2009 and red=2010) with respect to the location of the Inch Cape, Neart na Gaoithe and Round 3 Firth of Forth proposed wind farm zones (black shape outlines represent wind farm sites).

2.3 T-POD data from Arbroath and Fife Ness

Between 2006 and 2009 Timing Porpoise Detectors (T-PODs) (Figure 5), were deployed on moorings at Arbroath and Fife Ness by the University of Aberdeen, as part of a series of deployments at 18 sites around the east coast of Scotland (Thompson *et al.,* 2011). Data from this project are available from January 2007 to March 2009 at Arbroath and from December 2006 to March 2009 at Fife Ness.

T-PODs can be used to provide data on patterns of occurrence of dolphins. T-PODs incorporate a hydrophone, analogue processor and digital timing systems that automatically log the start and end of each echolocation click to 10 μs resolution. In every minute, the T-POD runs 6 successive scans within different user-defined frequencies, logging detections for periods of up to 5 months. An accompanying software program is used to post-process the recovered data, detect characteristic click trains, and remove noises from other sources such as boat sonar (see www.chelonia.co.uk for details). Resulting data on the number of click trains recorded in each minute can be used to determine the presence or absence of target species in different time periods, or to identify the timing and duration of encounters with target species.

We used Version 4 and 5 T-PODs to detect echolocation click trains, and processed all data using version 8.24 of the manufacturer's software (version 4.1 train filter). Following the manufacturer's guidelines for use in areas where both harbour porpoises and bottlenose dolphins might be detected, T-PODs were configured to detect clicks from dolphins and porpoises on alternate channels. For dolphins, we set a target frequency of 50 kHz and a reference frequency of 70 kHz.

Previous studies both in the Moray Firth (Bailey *et al*., 2009) and Ireland (Philpot *et al*., 2007) have confirmed that T-PODs can successfully detect bottlenose dolphins at distances of 900-1250m. Combined visual and acoustic studies in the mouth of the Cromarty Firth further showed that T-PODs detected all groups of dolphins that spent at least 30 minutes in the area (Bailey *et al*., 2009), suggesting that the technique can be used for determining presence or absence of dolphins at hourly sampling scales. It should be noted that whilst dolphin detections in these areas are likely to represent bottlenose dolphin occurrence, these devices cannot be used to discriminate between bottlenose dolphins and other species such as white-beaked dolphins.

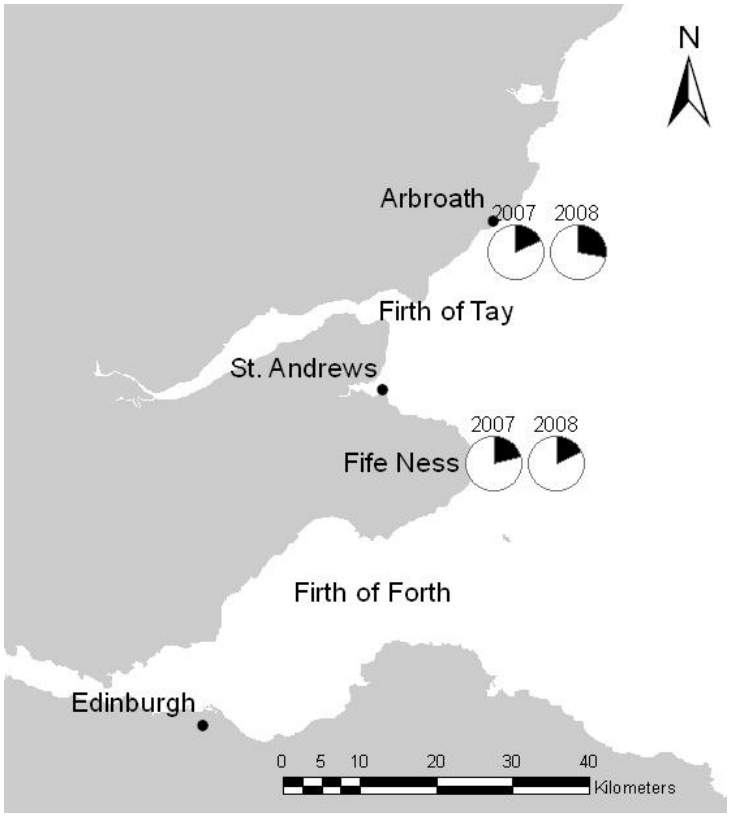
Figure 5. A Timing Porpoise Detector (T-POD).

Dolphins were detected on T-PODs at both sites throughout the deployments (Figure 6). Over the deployment period, dolphins were detected on 24% of days in Arbroath and 18% of days in Fife Ness. However, both these sites show lower detection rates in comparison with a core site in the SAC (the mouth of the Cromarty Firth) where dolphins were detected on over 70% of days over the same time period (Thompson *et al.,* 2011). Although, in Fife Ness there was no inter-annual differences in the number of days of detections between 2007 and 2008 (the years with most data), in Arbroath there were significantly more days with dolphin detections in 2008 (Table 3 and Figure 6a).

Table 3. Summary of Chi-Square test comparing the proportion of dolphin positive days in 2007 and 2008 from T-PODs around the Firth of Tay, where N = the total number of days sampled and p = proportion of days in which dolphins were detected.

AREA	2007		2008		Chi-Sq	DF	P-Value
	N	p	N	P			
Arbroath	365	0.18	366	0.28	9.3041	1	0.002
Fife Ness	365	0.21	363	0.18	0.9791	1	0.322

a.



b.

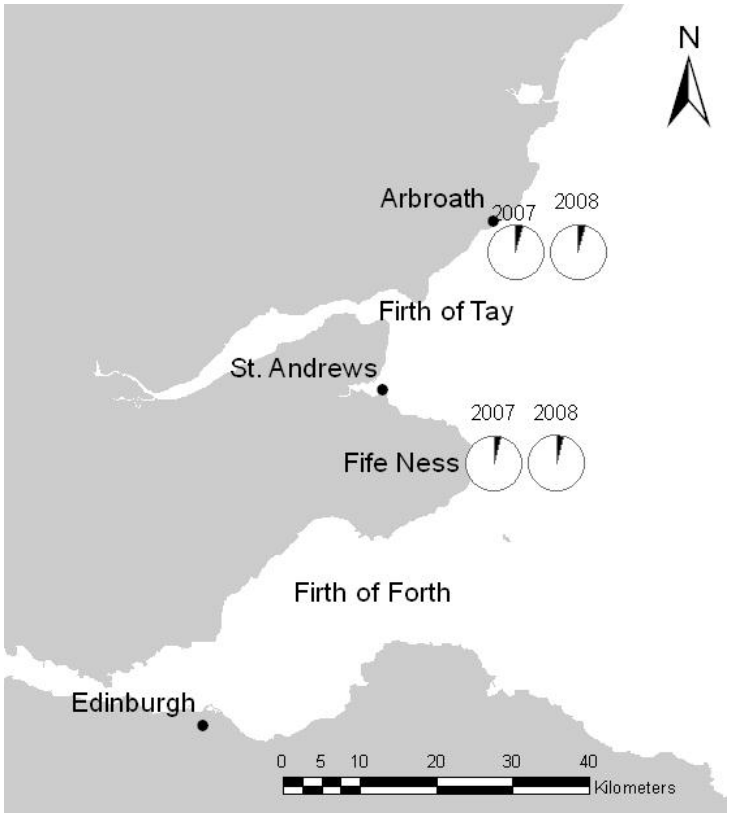


Figure 6. Occurrence of bottlenose dolphins around the Firth of Tay in 2007 and 2008. Pie charts represent a. the proportion of dolphin positive days and b. the median number of hours with dolphin detections on dolphin positive days.

Although dolphins were detected in Arbroath and Fife Ness on a high proportion of days each year, the time spent in these areas was relatively low, with no difference between the two sites. On the days that dolphins were detected, they were recorded for a median of one hour (range 1-4 hours in 2007 and 1-5 hours in 2008 in Arbroath, and 1-5 hours in 2007 and 2008 in Fife Ness) (Figure 6b). In comparison, within the core of the Moray Firth SAC (at the mouth of the Cromarty Firth), dolphins were recorded for a median of 4 hours per day, on the days they were detected (range 1 to 16 hours) over the same time period (University of Aberdeen unpublished data). This suggests that although dolphins regularly visit Arbroath and Fife Ness they do not spend long periods in these areas and may simply be travelling through each area.

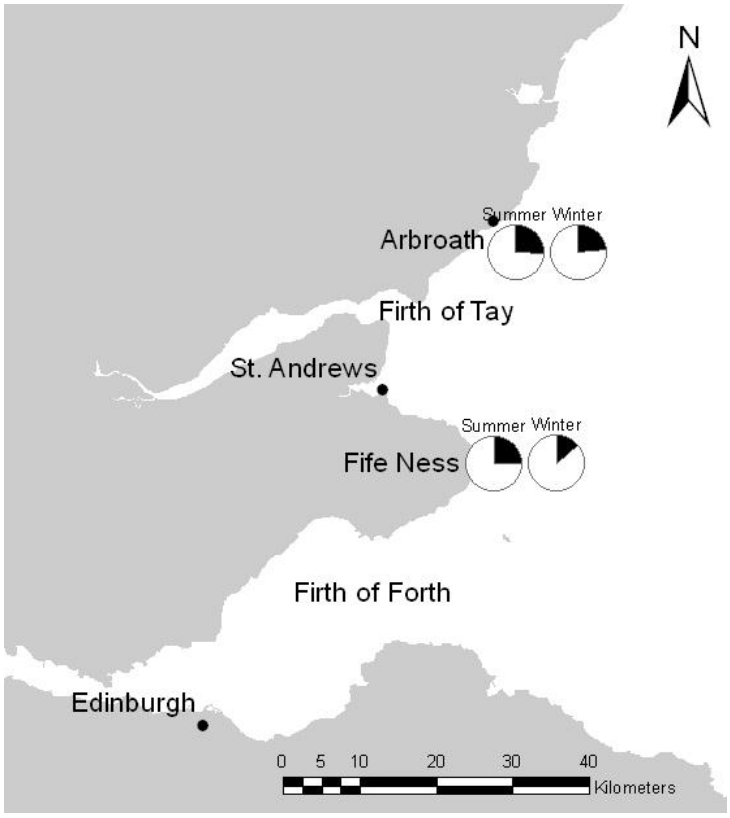
These data were also used to investigate seasonal differences in occurrence. In Arbroath dolphin detections in winter and summer remained similar, but there were seasonal differences at Fife Ness, where there was a decrease in detections during the winter (Table 4 and Figure 7a). Despite dolphins being detected on over 25% of days in the summers at both Fife Ness and Arbroath (Table 4), these sites again showed lower detection rates in comparison with the mouth of the Cromarty Firth, where dolphins were detected on 94% of days in the same time period (Thompson *et al.,* 2011). Winter detections were also higher at the Cromarty Firth with 56% of days (Thompson *et al.,* 2011) compared to 14% and 24% at Fife Ness and Arbroath respectively (Table 4). In Fife Ness dolphins were recorded between 1 and 5 hours per day in both summer and winter (Figure 7b). In Arbroath, dolphins were recorded between 1 and 3 hours in the summer, but this increased to between 1 and 6 hours in the winter.

Finally, monthly patterns of occurrence were also explored (Figure 8 and 9). Dolphins were detected in every month at both Arbroath and Fife Ness. Daily dolphin detections at Fife Ness increased from May to October but with decreases in July and September, compared to Arbroath where detections appeared relatively consistent in every month (Figure 8).

Table 4. Summary of Chi-Square test comparing the proportion of dolphin positive days in combined summers (May-Sept) and winters (Jan-Apr, Oct-Dec) from T-PODs around the Firth of Tay from 2006-2009, where N = the total number of days sampled and p = proportion of days in which dolphins were detected.

AREA	Summer		Winter		Chi-Sq	DF	P-Value
	N	p	N	p			
Arbroath	306	0.26	514	0.24	0.320	1	0.571
Fife Ness	306	0.25	511	0.14	17.049	1	<0.0001

a.



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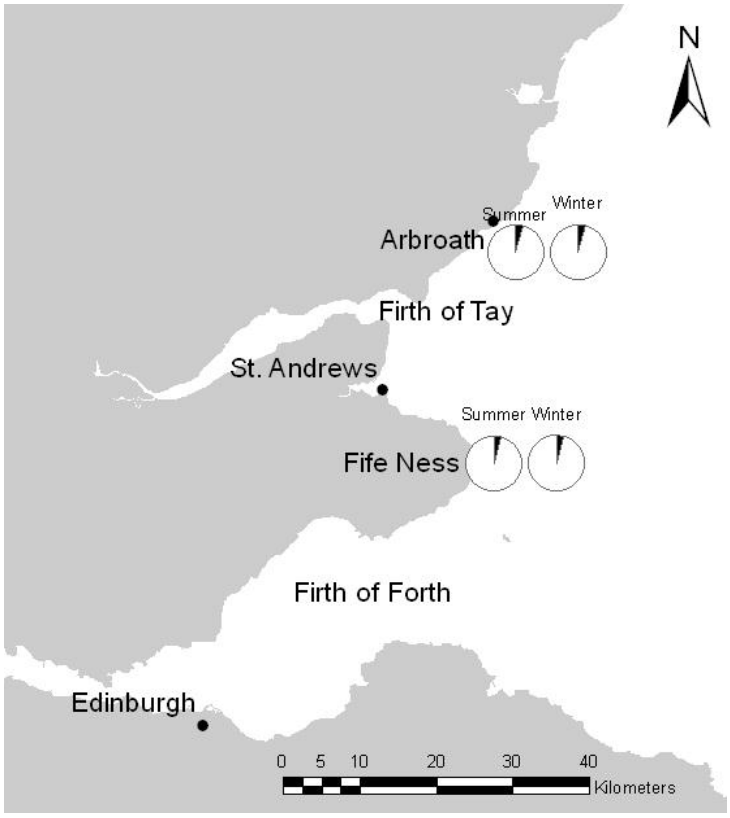
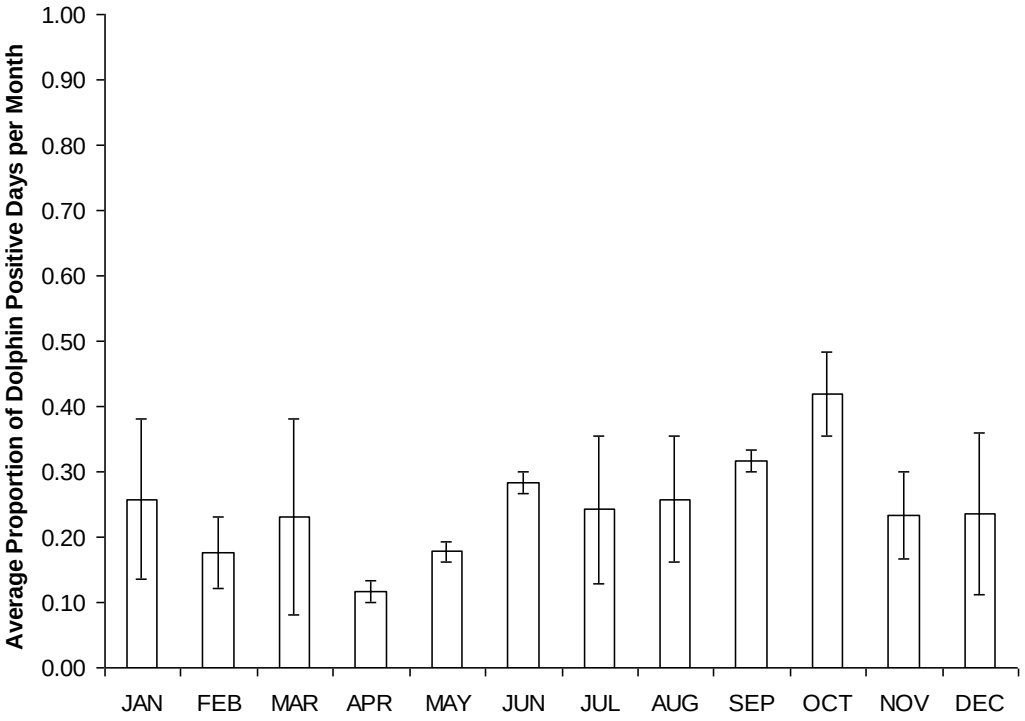
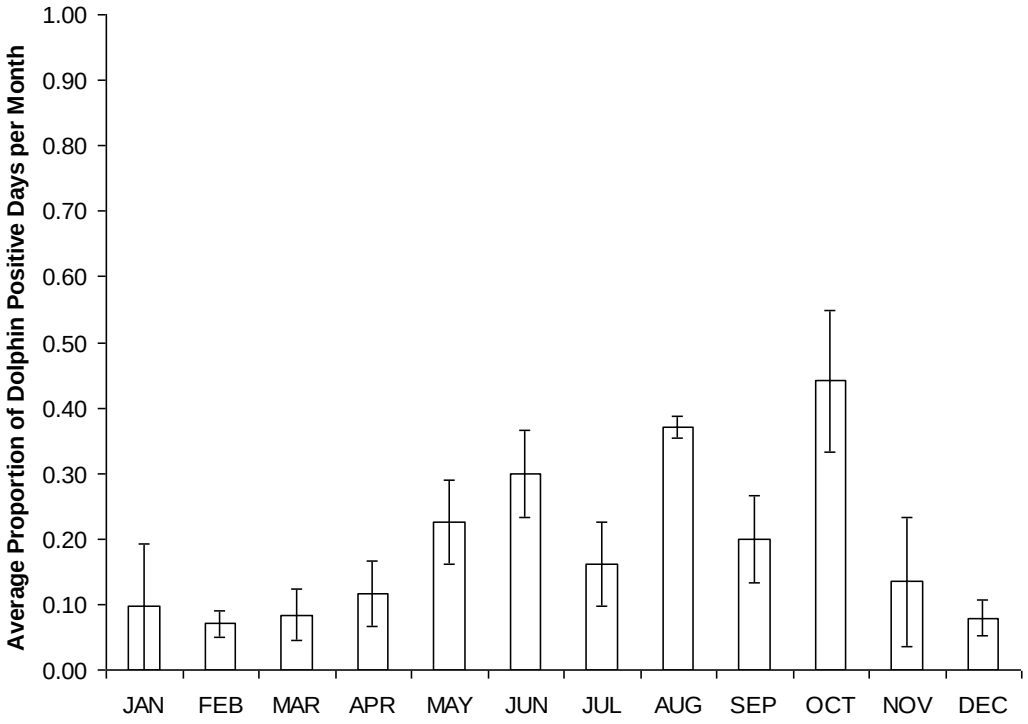


Figure 7. Occurrence of bottlenose dolphins around the Firth of Tay in winter and summer between 2006 and 2009. Pie charts represent a. the proportion of dolphin positive days and b. the median number of hours with dolphin detections on dolphin positive days.



a.



b.

Figure 8. The average proportion of dolphin positive days in each month (+/- SE) for T-POD sites a. Arbroath, b. Fife Ness for the entire T-POD deployment period.

2.4 Behaviour, group size and group composition of animals in the Tay

Behaviour

Bottlenose dolphins engage in all types of behaviour in the Tay area. Groups have been observed travelling through the area, socialising, foraging, engaged in aerial behaviour, bowriding vessels and logging at the surface (Quick 2006, Quick and Janik 2008). There has been no dedicated effort to quantify the time budgets that each group may spend engaged in different behavioural activities. However, Quick and Janik (2008) carried out visual focal follows whilst simultaneously recording vocalisation rates of groups, to assess the vocal rates associated with different behavioural types. Although many different behavioural types were observed, including foraging events, there were four main behavioural types recorded in their analysis (Table 5).

All behavioural types were observed throughout the study site and frequently groups would switch between behaviour types during the course of a focal follow (Quick and Janik 2008). However, it is not possible to make firm conclusions about habitat use or frequency of different behaviours in the Tay area without targeted analysis of behavioural data.

Table 5: Definitions of behavioural activities assigned to focal and other groups during behavioural sampling

Behaviour Type	Definition
Surface Travel	Animals all moving in the same direction, not creating white water in their wake
Non polarised movement	Animals exhibiting non directional movements with all surfacings facing different directions
Socialising	Animals interacting with each other in close proximity; including rubbing together, rolling over, showing bellies, fins and heads out.
Jumping/body slaps	Animals leave water to exhibit aerial behaviour, often causing splashing

Group composition and size.

Group sizes of bottlenose dolphins in the Tay range from one individual up to groups of over 30 (Table 2, Quick and Janik 2008). However, multiple subgroups are often present and these sub-groups frequently join and split. Observations of young of the year (i.e. animals <6 months old), calves, juveniles, sub adults and adults are common throughout the study site during each year (University of St Andrews Unpublished data, University of Aberdeen Unpublished data). Groups may be made up of all age classes or may primarily contain only one age class. Although, published data

on the sex ratio of groups within this area are lacking, data from the 107 identified individuals in 2009 and 2010 comprise 19 known males, 29 known females and 59 of unknown sex (University of Aberdeen Unpublished data).

2.5 Density Surface

Currently no fine scale density estimate of bottlenose dolphins exists for the Tay area. Estimating density for mobile marine mammals is challenging due to methodological differences and genuine variability in population estimates caused by temporal and spatial factors. For the Tay area, there is only an abundance estimates for 2003 and 2004 (Quick 2006), and efforts to generate a density surface are therefore limited to these years. The limitations of this are that the estimate will only be applicable over the spatial area and temporal period for which the data were collected, and cannot be extrapolated to areas or times/seasons where no survey effort has taken place. In addition these data were collected as part of a focal follow protocol and effort across the area was not uniform. The most simplistic application of these data into a density estimate is to take the total area over which the data were collected, to provide a simple density value for the whole region. During 2003 and 2004, 42 trips took place in the Tay and St Andrews Bay area (Figure 9). Trips departed from St Andrews harbour and generally travelled north up to the Tay. Areas south of St Andrews Bay were usually visited if no animals were sighted in the Tay area, or if prevailing weather made this area more accessible. Trips ranged in duration, dictated mainly by level of data collection and weather conditions.

A crude estimate of density for the area has been made by drawing a polygon around the area surveyed and using the values for abundance and area. This method carries the assumption that animals are distributed equally over the area constrained by the polygon, which is not the case (Figures 2 and 3) Furthermore, levels of uncertainty are not available for these estimates, so these density values should not be considered as robust estimates for the density of bottlenose dolphins in the defined area for the summer months of 2003 and 2004.

The size of this defined polygon was calculated as approximately 319km^2. Taking the abundance estimates generated by Quick (2006), this gives a density of between 0.28 and 0.35 bottlenose dolphins/km^2 (Table 6)

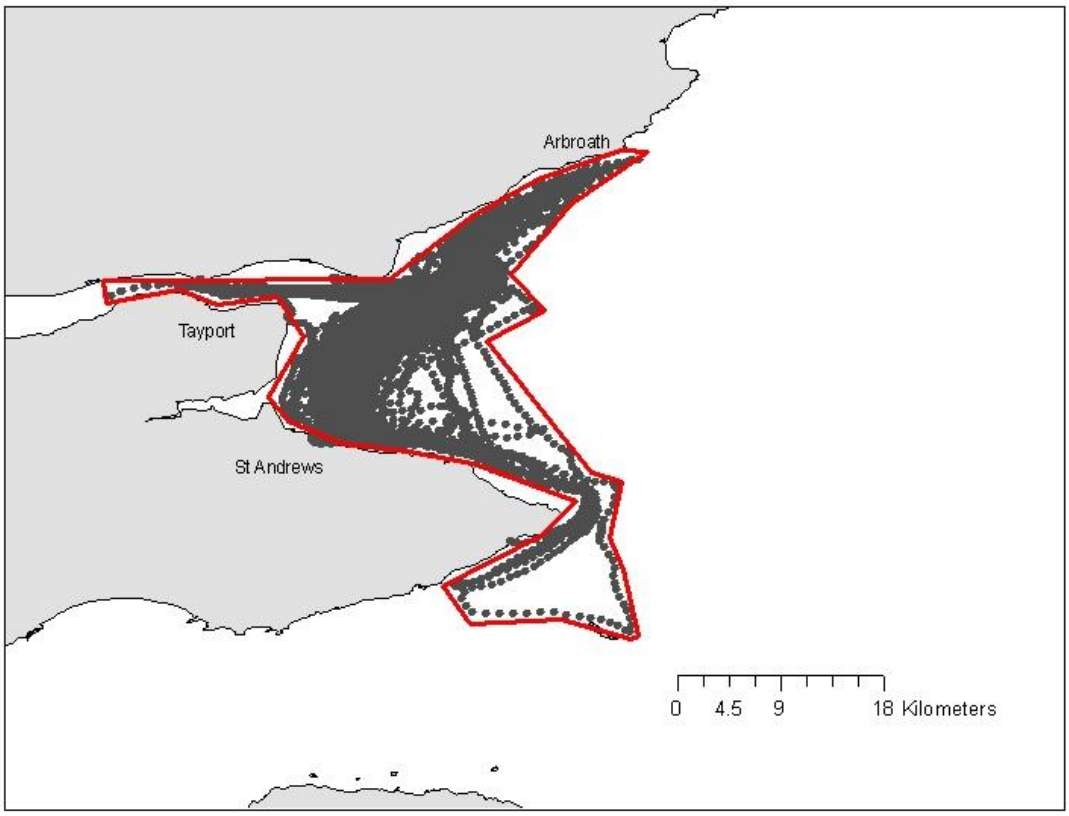


Figure 9: Effort from all 42 trips from 2003 and 2004 shown in grey. Red outline shows the area of the defined polygon used to generate the area for the density estimate.

Table 6: Density estimates derived from both conventional and Bayesian abundance estimates for the 2003-2004 data from the Tay.

Abundance estimate	Area (km^2)	Density (animals/km^2)
89 (Conventional)	319	0.28
112 (Bayesian)	319	0.35

Both these density estimates are considerably higher than the density estimate for bottlenose dolphins from the SCANS II survey for block V (i.e. the block containing the Tay area) of 0.0008 individual/km^2 (SCANS II 2008). However, the SCANS II survey was conducted over a much larger area, using line transect methodology, so is not directly comparable to the fine scale data presented here.

Section 3

5 Review of current information on total bottlenose dolphin population size

3.1 Current estimates

The most commonly used estimate for the population of dolphins on the east coast of Scotland is 129 (95% confidence interval (CI): 110-174) (Wilson *et al.,* 1999). Wilson *et al.,* 1999 used data from surveys in the Moray Firth in 1992 and Chao *et al*.'s (1992) M_{th} model, implemented in the programme CAPTURE (Rexstad and Burnham 1991). At that time the majority of the population were believed to use this area on a regular basis. However, further work has shown that the geographical range of this population has expanded over the last 2 decades (Wilson *et al.,* 2004), extending from the Moray Firth down the east coast of Scotland. This range expansion makes it logistically difficult for any one research group to cover the entire range of the population and therefore collaboration between research groups and new methods to accurately estimate population size were required.

Durban *et al.,* (2005) developed a Bayesian multi-site mark-recapture framework to account for the geographical dependencies between study sites, and allow for the fact that data were collected opportunistically and concurrently by different groups at study sites that were defined by practical considerations rather than random design. This method was applied to data collected in 2006 from 3 areas that covered the extended known home range of this population (the inner Moray Firth, including data from the University of Aberdeen boat-based surveys and Whale and Dolphin Conservation Society (WDCS) land-based observations; the southern Moray Firth coast, including data from the WDCS boat-based surveys and the Cetacean Research and Rescue Unit; and the Grampian and Fife coast, including data from the South Grampian Regional Group of the Sea Watch Foundation and the University of St Andrews). This provided a current population estimate for the east coast of Scotland of 195 (95% highest posterior density interval (HPDI): 162-253) (Cheney *et al*., In review). To investigate trends in overall population size, Corkrey *et al.,* (2008) developed a Bayesian capture-recapture model using a state-space approach to incorporate data from different survey areas. This model was updated using 1990-2010 data from surveys across the known home range of the population (see Cheney *et al*., In prep for details). This state-space approach uses different statistical techniques and the population estimates are lower than the previous estimates. However, the confidence limits of each year's comparison are overlapping, providing support for this Bayesian capture-recapture method. Results suggested that there is a >80% probability that the bottlenose dolphin population on the east coast of Scotland is either stable or increasing (Cheney *et al.*, In prep).

3.2 Implications of the Tay estimate

Between 81-142 bottlenose dolphins from the east coast population were estimated to be using the Tay area during 2003-2004. For a population currently estimated at 195 individuals (Cheney et al., In review), this is a considerable proportion of the population. Although the abundance estimate from the Tay comes only from data from 2003-2004, and the current total population estimate from 2006,

the values give a relative measure for comparison and indicate that the Tay area is important habitat for this population.

Section 4

6 Connectivity of animals between the Tay and the Moray Firth SAC

In the summers (May to September) of 2009 and 2010, a total of 192 individuals (including 95 well-marked dolphins, i.e. animals with dorsal fin nicks that could be identified from either the left or right side) were identified by the University of Aberdeen and SMRU in high quality photographs on the east coast of Scotland. Of these 107 (52 well-marked) were identified in the Tayside region, 120 (61 well-marked) were seen within the Moray Firth SAC and 67 (34 well-marked) were seen in the outer Moray Firth. Of the total number of individuals seen in 2009 and 2010, 85 (43 well-marked) were seen within the SAC but not in the Tay.

Of the 107 individual bottlenose dolphins seen in the Tayside region in 2009 and 2010, 35 (18 well-marked dolphins) were seen in these same years within the SAC (Figure 10). An additional 17 individuals have been seen in the SAC in previous years. However, 55 (21 well-marked) dolphins seen in the Tay in 2009 and 2010 have never been seen in the SAC. Over 50% (29% of well-marked) of these were first identified in 2009 or 2010.

In a previous study of social structure, Lusseau *et al.* (2006) concluded that bottlenose dolphins on the east coast of Scotland belonged to two social units with different yet overlapping ranging patterns. Community 1 contained individuals that ranged outside the inner Moray Firth and community 2 contained animals never seen outside the inner Moray Firth (Lusseau *et al*. 2006). This analysis was carried out on data collected between 1990 and 2002, and only 31 of the 107 individuals seen in the Tayside region in 2009 and 2010 were included in that study. However, it is interesting to note that eight of these individuals that were previously assigned as community 2 members (i.e. only seen in the inner Moray Firth) were seen in the Tay and of these three were not seen within the SAC in 2009 or 2010.

Patterns of movement between Tayside and the SAC therefore appear variable between individuals and years (Figure 11). Some individuals were seen in Tayside one year and then in the SAC the next year, or vice versa. For example, 18 individuals only seen in the Tay in 2009 were only seen in the SAC in 2010. Similarly, of six individuals only seen in the SAC in 2009, three that were seen again in the SAC at the beginning of summer 2010 were seen in the Tay by July or August. Other dolphins moved between the SAC and the Tay within a year and, in some cases, even within a month. For example, in 2009 and 2010 seven and ten individuals respectively were either seen in the Tay at the start of the summer and in the SAC by the end of the summer, or vice versa. Also, eight individuals were seen in both the Tay and the SAC within a month. Yet other individuals seem to make multiple trips between the Tay and SAC within the year. In 2009 four individuals, and in 2010 two individuals, seen in the SAC at the start of the summer, were subsequently seen in the Tay and were finally seen back in the SAC by the end of the summer (Figure 11). For example, ID#1031 was seen in the SAC on the 18th August 2010, subsequently seen in the Tay on the 26th August and 1st September, but was seen again in the SAC by the 21st September. The shortest trip observed between the Tay and SAC was in 2009, where 3 individuals were seen in the Tay on the 8th August 2009 and then in the SAC on

the 13th August. It is likely that this movement is representative of other individuals which were either not encountered during surveys in either the Tay or SAC or were only seen in poorer quality pictures.

It is apparent from these two years of data, that there is high variability in the movement of individuals between the Tay area and the Moray Firth SAC. From these data there are no clear patterns of individual or group movement and different individuals appear to employ different temporal and spatial scales of movement. What drives these different movement patterns is unknown, but a high proportion of bottlenose dolphins on the east coast of Scotland use both the Tay area and the Moray Firth SAC over a range of temporal scales, from monthly through to annually.

		2009		2010	
IDNO	WELL-MARKED	TAY	SAC	TAY	SAC
9	N	■		■	
20	Y	■		■	
30	Y	■			■
42	Y		■	■	■
53	Y	■			
60	Y	■	■	■	■
68	Y	■		■	
79	Y	■			■
102	Y		■	■	
116	Y	■			
125	Y	■			
129	Y	■	■	■	■
209	Y		■	■	■
227	Y			■	
234	Y	■	■		
240	N	■			■
323	Y	■		■	
344	Y	■		■	■
440	N	■	■		■
571	Y	■		■	
673	N	■		■	
769	Y	■		■	
773	Y	■		■	■
805	Y	■	■	■	■
816	Y			■	
872	N	■	■		■
880	Y	■		■	
881	Y	■		■	
882	Y	■		■	
886	Y	■		■	
903	Y	■		■	
908	Y	■	■	■	■
909	N	■	■		■
964	Y	■	■	■	
993	N	■	■		■
1002	N		■	■	
1012	N		■	■	
1015	N	■	■		■
1016	Y	■			■
1026	Y	■		■	
1027	Y	■			■
1028	Y	■	■		■
1029	Y	■		■	
1031	N	■	■	■	■
1036	N	■		■	
1037	Y	■		■	
1038	Y	■		■	
1039	Y	■		■	
1040	N	■		■	
1042	Y		■	■	■
1043	N	■		■	
1047	Y	■		■	
1048	Y	■		■	
1049	Y	■		■	

		2009		2010	
IDNO	WELL-MARKED	TAY	SAC	TAY	SAC
1050	Y	■		■	
1051	Y	■		■	
1052	Y	■			
1053	N	■		■	
1054	N	■		■	
1055	N	■		■	
1056	Y	■		■	
1057	N	■		■	
1058	Y	■		■	
1059	N	■		■	
1060	N	■		■	
1061	N	■		■	
1062	N	■		■	
1063	Y	■			■
1064	N	■		■	
1065	Y	■		■	
1066	N	■		■	
1067	N	■			
1068	N	■			■
1069	N	■		■	
1070	N	■		■	
1071	N	■			■
1072	N	■			■
1073	Y	■		■	
1074	Y	■		■	
1075	N	■			■
1076	N	■		■	
1077	N	■			■
1081	N	■			■
1089	N			■	
1090	N			■	
1091	N			■	
1092	N	■		■	■
1093	Y	■		■	
1094	N	■		■	
1095	N	■			■
1096	N	■		■	
1097	N	■		■	
1098	N	■		■	
1099	N	■		■	
1100	Y	■		■	
1102	N			■	
1103	N			■	
1104	N			■	
1105	N			■	
1107	N			■	
1108	Y			■	
1112	N			■	
1114	N			■	
1115	N			■	
1116	N			■	
1117	N			■	
1118	N			■	

Figure 10. Summary of whether an individual identified in the Tayside region in either 2009 or 2010 were also seen within the Moray Firth SAC in those same years.

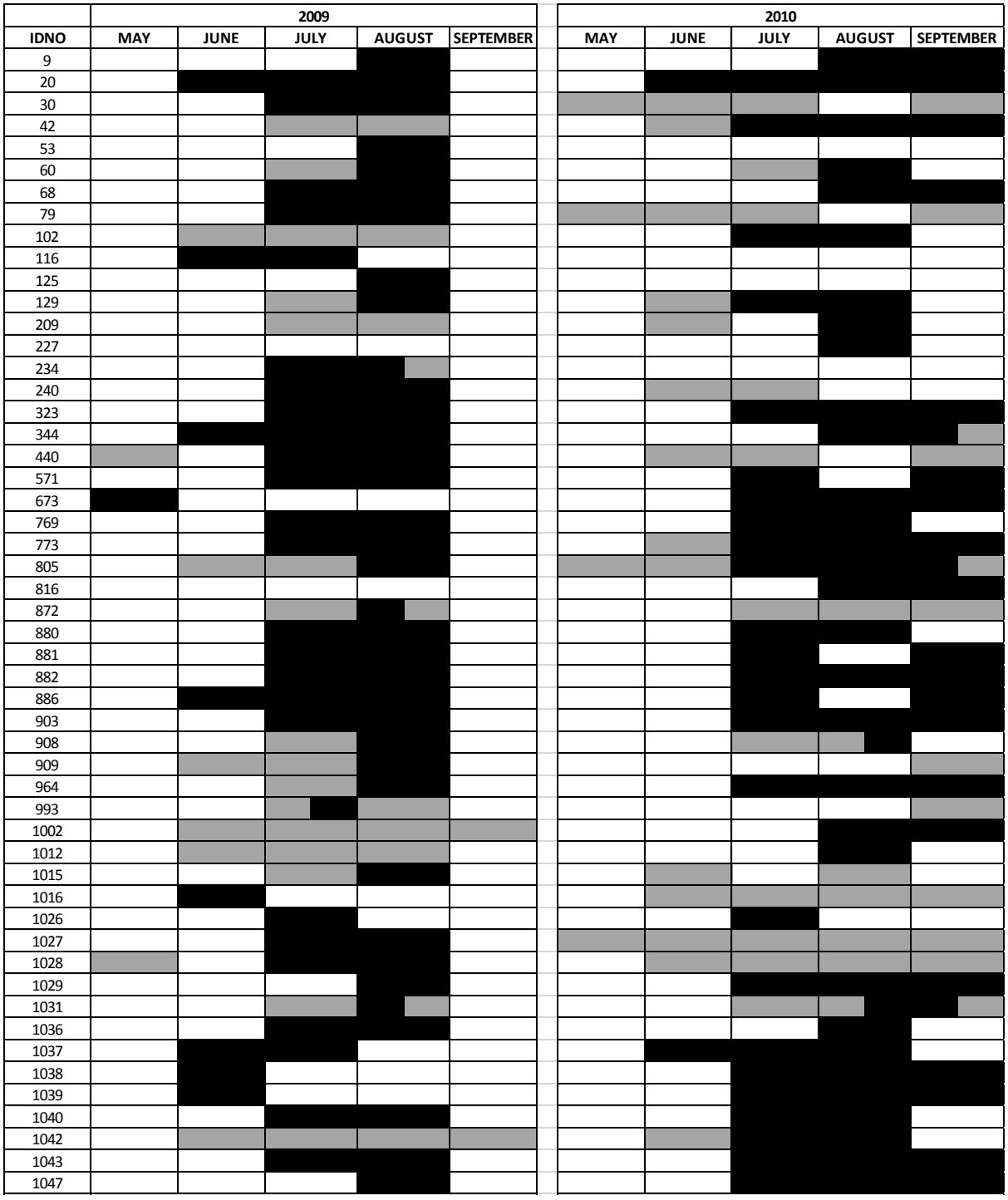


Figure 11. Monthly locations of all individuals seen in the Tayside region in 2009 and 2010. Black boxes = seen in Tayside and grey = seen in the SAC (continued on next page).

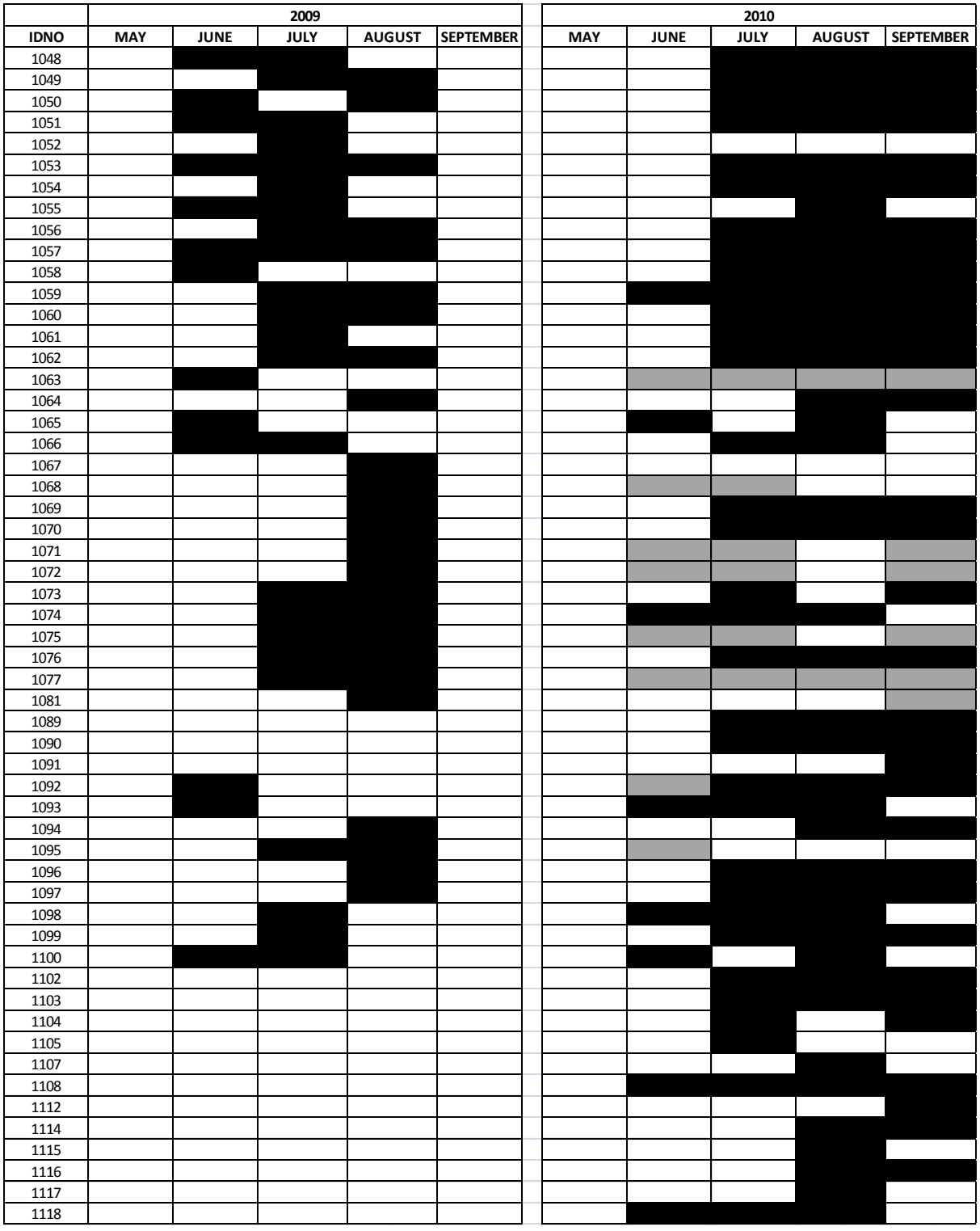


Figure 11. Monthly locations of all individuals seen in the Tayside region in 2009 and 2010. Black boxes = seen in Tayside and grey = seen in the SAC.

Section 5

7 General conclusions

The only current abundance estimate of bottlenose dolphins for the Tay area uses data from the summer months of 2003 and 2004 and gives a range of 81-142 dolphins (Quick 2006). Photo-identification surveys from the summers of 2009 and 2010 identified 107 animals in the Tay area. The two published abundance estimate for the entire east coast bottlenose dolphin population were 129 animals (CI 110-174) in 1992 (Wilson *et al*., 1999) and the most recent estimate of 195 animals (95% HPDI 162-253) from 2006 (Cheney *et al*., In review). These population estimates show an apparent increase in the number of bottlenose dolphins on the east coast of Scotland between 1992 and 2006, which is also supported by a trend analysis using data from 1990 to 2010 (Cheney *et al.,* In prep). These sources of data show that a substantial proportion of the Scottish east coast population of bottlenose dolphins uses the St Andrews Bay and Tay area, at least in the summer.

During the summer months the animals are distributed throughout the Tay area with the majority of encounters within the Tay estuary (Figures 2 and 3). There is no pattern in the distribution of group sizes in either year, with both large and small groups being sighted across the study area (Figures 2 and 3). It is clear from these data that the Tay is an important habitat for the east coast population of bottlenose dolphins, as a substantial number of individuals are not only seen in the area in any one year but are also re-sighted between years.

It is difficult to make firm conclusions about seasonal use of the Tay estuary area by the bottlenose dolphins, as limited data exists outside of the summer months of June-August. During the winter months of 2007-2008, 23 hours of photo-identification effort over 5 trips took place in the area but no bottlenose dolphins were recorded (Thompson *et al.,* 2011). T-POD data from Arbroath and Fife Ness shows that dolphins were detected in all years of deployment and in every month of the year, although one cannot be certain that some of these detections were of other species (Figure 7 and 8). Seasonal patterns showed dolphin detections in winter and summer remained similar in Arbroath, but there was a decrease in detections during the winter at Fife Ness (Figure 7a). Detection rates, both daily and monthly, at both Arbroath and Fife Ness were generally less than those from the core SAC area and may be suggestive of animals travelling through each area.

Bottlenose dolphins engage in all types of behaviour in the Tay area, with groups observed travelling through the area, socialising, foraging, engaged in aerial behaviour, bowriding vessels and logging at the surface (Quick 2006, Quick and Janik 2008). In addition, all age classes, both sexes and a variety of group sizes have been observed throughout the study area. This is suggestive of the area being important habitat for the animals.

The data from 2009 and 2010 show that 35 individuals were sighted within the Tay area and also within the Moray Firth SAC within these two years. This shows a high degree of connectivity between the two sites over the course of these two years. However, there was high variability in

movement patterns of individuals both between and within years and it is impossible to know what is driving these differences in movements.

Further work

This study concentrated on published literature and dedicated photo-identification data collected in the Tay area over 2009 and 2010. It is clear from these two years of data that there is inter-annual and within individual variability in ranging patterns and site fidelity. A detailed examination of the entire photo-identification dataset over a longer time period may allow a better assessment of intra and inter-annual variation in movement patterns on varying temporal scales, however this is a reasonably large undertaking and outputs from this work would not be available within the timescale of the FTOWDG developers' applications.

The only currently available abundance estimate from the Tay area is from 2003-2004. Producing a new abundance estimate of animals using the Tay and the east coast population as a whole was beyond the scope of this study but the there is a more comprehensive dataset covering a longer period of time that could be used to provide such estimates, if required. Similarly, the density surface estimate presented here using currently available data provides an estimate of the density of bottlenose dolphins in the Tay area. However, it may be possible to incorporate more recent data using advanced statistical methods to provide a more robust estimate of density in this area, but similarly, this is unlikely to be possible within the developers' timescales.

The re-deployment of passive acoustic monitoring in key coastal locations such as Arbroath and Fife Ness could provide further information on inter-annual and seasonal variability in bottlenose dolphin presence in the area. With additional information from photo-identification surveys, deployments in other areas of the Tay where dolphins have been seen more regularly will provide more detailed information on the amount of time bottlenose dolphins actually spend in this area.

8 Literature Cited

Bailey, H., Clay, G., Coates, E.A., Lusseau, D., Senior, B. and Thompson, P.M. (2009) Using T-PODS to assess variations in the occurrence of coastal bottlenose dolphins and harbour porpoises. *Aquatic Conservation: Marine and Freshwater Ecosystems* 20(2): 150-158.

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

Cheney, B., Thompson, P.,M., Ingram, S.N., Hammond, P.S., Stevick, P.T., Durban, J.W., Culloch, R.M., Elwen, S.H., Mandleberg, L., Janik, V.M., Quick, N.J., Islas-Villanueva, V., Robinson, K.P., Costa, M., Eisfel, S.M., Walters, A., Phillips, C., Weir, C.R., Evans, P.G.H., Anderwald, P., Reid, R.J., Reid, J.B. and Wilson, B. (*In review*) Integrating multiple data sources to assess the distribution and abundance of bottlenose dolphins (*Tursiops truncatus*) in Scottish waters. *Mammal Review*.

Cheney, B., Corkrey, R., Quick, N.J., Janik, V.M., Islas-Villanueva, V., Hammond, P.S. and Thompson, P.M. (*In prep*) *Site Condition Monitoring of bottlenose dolphins within the Moray Firth Special Area of Conservation: Final report.* Scottish Natural Heritage Commissioned Report.

Corkrey, R., Brooks, S., Lusseau, D., Parsons, K., Durban, J.W., Hammond, P.S. and Thompson, P.M. (2008) A Bayesian capture-recapture population model with simultaneous estimation of heterogeneity. *Journal of the American Statistical Association*, 103, 948-960

Durban, J. W. and Elston, D. A. (2005). Mark-recapture with occasion and individual effects: Abundance estimation through Bayesian model selection in a fixed dimensional parameter space. *Journal of Agricultural, Biological and Environmental Statistics* 10: 291-305.

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

Lusseau, D., Wilson, B., Hammond, P.S., Grellier, K., Durban, J.W., Parsons, K.M., Barton, T.R. and Thompson PM (2006). Quantifying the influence of sociality on population structure in bottlenose dolphins. *Journal of Animal Ecology* 75: 14-24.

Moray Firth Partnership (2009). *The Moray Firth Special Area of Conservation Management Scheme (Revision 2)* The Moray Firth Partnership (http://www.morayfirth-partnership.org/work-2-sac-publications.html).

Neart na Gaoithe (undated). Project Update Information brochure. Available from http://www.neartnagaoithe.com/downloads/ProjectUpdateInformationBrochure.pdf

Philpott, E., Englund, A., Ingram, S. and Rogan, E. (2007) Using T-PODs to investigate detection range and echolocation behaviour of coastal bottlenose dolphins. *Journal of the Marine Biological Association (UK)* 87: 11-17.

Quick N.J. (2006) *Vocal behaviour and abundance of bottlenose dolphins in St Andrews Bay*. PhD Thesis, University of St. Andrews, St. Andrews, UK.

Quick, N. J. and Janik, V.M. (2008) Whistle rates of wild bottlenose dolphins: influences of group size and behavior. *Journal of Comparative Psychology* 122: 305-311.

Rexstad, E. and Burnham, K.P. (1991) *User's Guide for Interactive Program CAPTURE*. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, CO, USA.

SCANS II (2008). Small cetaceans in the European Atlantic and North Sea. Final Report, Life project LIFE04NAT/GB/000245.

SeaEnergy Renewables (2010). Inch cape Offshore Wind Farm, Non Technical Summary of the Environmental Impact assessment Scoping Report August 2010. Available from http://www.inchcapewind.com/assets/docs/inch_cape_scoping_nts_web.pdf

SeaGreen Wind Energy (2011) Firth of Forth Offshore Wind Farm Zone, Phase 1, Project Information January 2011. Available from http://www.seagreenwindenergy.com/assets/seagreen_exhibition_brochure.pdf

Thompson, P.M., Corkrey, R., Lusseau, D., Lusseau, S.M., Quick, N., Durban, J.W., Parsons, K.M. & Hammond, P.S. (2006) *An assessment of the current condition of the Moray Firth bottlenose dolphin population.* Scottish Natural Heritage Commissioned Report No. 175 (ROAME No. F02AC409

Thompson, P.M, Cheney, B., Cândido, A.T. & Hammond, P.S. (2009) *Site Condition Monitoring of bottlenose dolphins within the Moray Firth Special Area of Conservation: Interim report 2005-2007*. Scottish Natural Heritage Commissioned Report.

Thompson, P.M., Cheney, B., Ingram, S., Stevick, P., Wilson, B. and Hammond, P.S. (Eds) (2011) *Distribution, abundance and population structure of bottlenose dolphins in Scottish waters.* Scottish Government and Scottish Natural Heritage funded report. Scottish Natural Heritage Commissioned Report No. 354.

Wilson, B., Reid, R.J., Grellier, K., Thompson, P.M. and Hammond, P.S. (2004). Considering the temporal when managing the spatial: a population range expansion impacts protected areas-based management for bottlenose dolphins. *Animal Conservation* 7: 331-338.

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