The east coast of Scotland bottlenose dolphin population: Improving understanding of ecology outside the Moray Firth SAC

Authors: Nicola Quick[1], Monica Arso[1], Barbara Cheney[2], Valentina Islas[1], Vincent Janik[1], Paul M. Thompson[2] and Philip S. Hammond[1]

(1) Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, Fife KY16 8LB, UK.

(2) University of Aberdeen, Institute of Biological and Environmental Science, Lighthouse Field Station, Cromarty IV11 8YJ, UK.

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Contents

Summary

The bottlenose dolphins found in the Moray Firth Special Area of Conservation (Moray Firth SAC) are part of a Scottish east coast population of approximately 200 animals that ranges south past Aberdeen to the Firths of Tay and Forth. In the United Kingdom, bottlenose dolphins are protected nationally and internationally, which may need to be considered during impact assessments for marine development and exploration. Before robust impact assessments can be completed, information on species distribution, abundance and population parameters are needed to understand the potential type and magnitude of effects.

Analysis of the photo-identification data collected since 1989 within and outside the Moray Firth SAC estimate an annual probability of apparent survival (0.947 SE=0.005) similar to estimates previously reported for this population, as well as a low probability of dolphins temporarily emigrating outside the study area, consistent with this being a highly resident population. Analysis of detailed information on the calving histories of reproductive females in the study population estimate a mean inter-birth interval of 4.49 years (95% CI 3.94 to 4.93 years) equivalent to an annual fecundity rate of 0.22 (95% CI = 0.22 to 0.25).

More consistent data have been collected outside the Moray Firth since 1997, primarily in the Tayside and Fife area. Sighting histories of individual animals have been constructed using photo-identification of long-lasting natural marks. Individuals are known to range up and down the coast, but there is much spatial and temporal variability in individual movements. Across all years of data, females show a significantly (p=0.0497) higher probability of presence within the Moray Firth SAC than males, and males appear to move between areas more frequently than females. In the Tayside and Fife area dolphins were encountered more often in and around the Tay estuary in waters less than 20 m deep and within 2 km of the coast. The Tay estuary has consistently high encounter rates of bottlenose dolphins over the years. Between 71 (95% CI 63-81) and 91 (95% CI 82-100) bottlenose dolphins from the east coast population were estimated to be using the Tay area during 2009-2013, representing approximately 35-46% of the total Scottish east coast population. In the Tayside and Fife area, a minimum of seven dedicated photo-identification trips, spread over three months, are required to obtain an estimate of abundance with acceptable consistency and precision.

Bottlenose dolphins were also frequently encountered along the coast between Montrose and Aberdeen in waters less than 20 m deep and within 2 km of the coast. Dolphins were frequently found at the entrance to Aberdeen Harbour and adjacent waters. Data collected in 2012-13 indicate that around 25% of the total Scottish east coast population uses the area between Stonehaven and Aberdeen. Based on these recent data, 118 (95% CI: 98-143) and 119 (95% CI: 101-140) individuals were estimated to be using the area between Aberdeen and the Firth of Forth in 2012 and 2013, respectively, representing greater than 60% of the total Scottish east coast bottlenose dolphin population.

Introduction

Studies of bottlenose dolphins off eastern Scotland have primarily focussed on the Special Area of Conservation (SAC) in the Moray Firth. However, the bottlenose dolphins found in the Moray Firth SAC are part of a Scottish east coast population of approximately 200 animals that ranges south past Aberdeen to the Firths of Tay and Forth (Cheney et al. 2013; Thompson et al. 2011). In the Aberdeen area, bottlenose dolphins are seen throughout the year, but especially between October and May, mostly around Aberdeen harbour and between Stonehaven and Muchalls (Evans et al. 2008; Weir et al. 2008). Dolphins in the Moray Firth and Firth of Tay are also seen year round but mainly from May to December in the Moray Firth and May to October in the Firth of Tay (Thompson et al. 2011).

Research effort outside the Moray Firth increased following expansion of the range of the east coast population in the mid-1990s (Wilson et al. 2004). However, to date, these data have been little explored to improve knowledge and understanding of the ecology of the population. In particular, little is known about the movements of dolphins between the Moray Firth SAC and other areas, or about the numbers and habitat use of animals in these other areas. This information is important not only to improve ecological understanding but also to underpin conservation policy and any necessary management action.

Oil and gas exploration and development has potential impacts on bottlenose dolphins outside the Moray Firth SAC (Thompson et al. 2013), and these need to be considered as part of consenting decisions for activities such as conducting seismic surveys and drilling wells, as well as associated supply and support vessel traffic in and out of east coast ports, including Aberdeen, Montrose, Dundee and Leith. Our limited knowledge of bottlenose dolphin ecology along the east coast south of the Moray Firth may constrain the consenting process.

In addition to oil and gas activities, sites off Aberdeen and the Firths of Tay and Forth are being considered for development of large scale wind farms. Three of these are within Scottish Territorial waters and one is a Round 3 Zone lying just outside Scottish Territorial waters ~25 km east of Fife Ness in the outer Firth of Forth and covering ~2,852 km^2 (SeaGreen Wind Energy 2011). There is also a proposed tidal array site located at the entrance to the Montrose Basin. All these sites are currently in the process of obtaining consent and are potential additional pressures on the Scottish east coast bottlenose dolphin population.

Until understanding is improved, it will not be possible to say to what extent oil and gas activities and renewable energy developments affect the population as a whole. This is important because, under the Habitats Directive, EU Member States are required to consider conservation status for species in UK waters as a whole, not just within SACs.

The aim of this report is to analyse existing data on bottlenose dolphins from the east coast of Scotland from areas outside the Moray Firth SAC. There is a focus on the Firth of Tay where most additional photo-identification data have been collected but also new information for the area around Aberdeen. The report aims to bring together knowledge of bottlenose dolphins to help feed into marine energy assessments and consenting decisions and to facilitate industry access to scientific information.

Relevant legislation for bottlenose dolphins

United Kingdom Legislation

In the United Kingdom, bottlenose dolphins are protected by a number of major conservation and biodiversity conventions that may need consideration during impact assessments for marine developments. Protection in UK waters was first conferred on cetacean species by the Wildlife and Countryside Act (1981), which made it an offence to "deliberately disturb" cetaceans. The Countryside and Rights of Way (CRoW) Act (2000) then extended the disturbance offence to include disturbance resulting from "reckless" actions.

The UK Biodiversity Action Plan (UK BAP) was active from 1992-2012 and was the UK Government's response to the Convention on Biological Diversity. The UK BAP described the biological resources of the UK and provided detailed plans for conservation of these resources. Bottlenose dolphins were listed as a priority species in the UK BAP[1]. In 2007, Conserving Biodiversity – the UK Approach was developed to provide a shared vision for UK biodiversity conservation by the devolved administrations and the UK government. This evolved to meet shared challenges and achieve common goals within the UK. From July 2012, The UK Post-2010 Biodiversity Framework[2] now succeeds the UK BAP and Conserving Biodiversity – the UK Approach, and is the result of a change in strategic thinking following the publication of the Convention on Biological Diversity's Strategic Plan for Biodiversity 2011–2020 (JNCC and Defra 2012). Bottlenose dolphins are still listed as a priority species.

European Legislation

All cetaceans are European Protected Species (EPS), and are listed in Annex IV (species of community interest in need of strict protection) of the EU Habitats Directive. The Habitats Directive was translated into UK law by the Conservation (Natural Habitats, &c) Regulations (1994) and strengthened by The Conservation (Natural Habitats, &c) Amendment Regulations (2007). Under regulation 39 of the latter legislation, it is an offence to deliberately or recklessly capture, injure, kill or disturb individuals of a European Protected Species. In addition to species level protection, the EU Habitats Directive also protects important habitats, and requires the establishment of a network of sites, Special Areas of Conservation (SACs), to protect habitats and species listed under Annexes I and II of the Directive. Bottlenose dolphins are listed in Annex II. SACs and Special Protection Areas (SPAs) designated under the Birds Directive, form a network of European protected sites, known as Natura 2000. SACs are chosen to make a significant contribution to species or habitat conservation, and care must be taken not to compromise the integrity of such sites, or their qualifying features. The Moray Firth SAC on the east coast of Scotland is designated for bottlenose dolphins. The Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2007 to December 2012 (JNCC, 2013) assesses activities that may affect the integrity of bottlenose dolphins. Any such activity or project requires an assessment of potential effects.

The European Community is a contracting party to the Convention on European Wildlife and Natural Habitats (the Bern Convention), which was adopted at Bern in 1979, and came into force in 1982.

[1] http://tna.europarchive.org/20110303145238/http:/www.ukbap.org.uk/default.aspx
[2] http://jncc.defra.gov.uk/page-6189

The Convention promotes co-operation between the signatory States in order to conserve wild flora and fauna and their natural habitats, and to protect endangered migratory species. Bottlenose dolphins are listed under Appendix II of the Bern Convention; appropriate legislative and administrative measures must be adopted to conserve listed species. This prohibits all forms of deliberate capture, keeping or killing, deliberate damage or destruction to important breeding and resting sites and any form of deliberate disturbance or trade in these species[3].

International Legislation

The Convention on the Conservation of Migratory Species of Wild Animals (CMS, also known as the Bonn Convention) aims to conserve migratory species throughout their range. Appendix 1 of the Convention lists migratory species threatened with extinction. Appendix 2 of the Convention lists migratory species that need or would significantly benefit from international co-operation[4]. Bottlenose dolphins are listed under Appendix 2.

The Convention on International Trade in Endangered Species (CITES) aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. The species covered by CITES are listed in three Appendices according to the degree of protection they have been awarded. Appendix I list species threatened with extinction. Appendix II lists species in which trade must be controlled. Appendix III lists species that are protected in at least one country, which has asked other CITES parties for assistance in controlling the trade[5]. In the UK, populations of bottlenose dolphins are listed under Appendix II of CITES.

These legal designations are summarised in Table 1.

Table 1: Summary of designations for bottlenose dolphins.

		Bottlenose dolphin
IUCN Conservation status		Least Concern
EU Habitats directive	Annex 2	X
	Annex 4	X
CMS	Appendix II	X
Bern Convention	Appendix II	X
CITES	Appendix II	X
UK Biodiversity Framework	Priority Species	X

[3] http://europa.eu/legislation_summaries/environment/nature_and_biodiversity/l28050_en.htm
[4] http://www.cms.int/documents/appendix/appendices_e.pdf
[5] http://www.cites.org/eng/app/index.php

Spatial and temporal extents of the bottlenose dolphin data available for this report

This report uses data collected by or contributed to the long running east coast Scottish bottlenose dolphin project, coordinated by the University of Aberdeen Lighthouse Field Station and the University of St Andrews Sea Mammal Research Unit. 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 by the University of St Andrews and/or the University of Aberdeen.

Firth of Forth

The historical distribution of bottlenose dolphins around Scotland has been recently reviewed (Cheney et al. 2013). 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 (Reid et al. 2003), the Sea Watch Foundation (http://www.seawatchfoundation.org.uk/) and the Small Cetaceans in the European Atlantic and North Sea (SCANS II) survey (Hammond et al. 2013).

Until 2012, very limited photo-identification effort had taken place in the Firth of Forth. In 2012, four photo-identification trips took place in the Firth of Forth (Arso et al. 2012), and another eight photo-identification trips took place in 2013. Currently, there is no abundance estimate for this area nor is there 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 with existing data.

Montrose to Aberdeen

Twenty surveys conducted during February to April 2008 covered the Grampian coastline area between Montrose and Aberdeen (Thompson et al. 2011). Animals were seen on 11 trips, during which dolphins were encountered on 19 different occasions and 56 different individuals were identified from natural markings (Thompson et al. 2011). In 2012, three photo-identification trips took place between Montrose and Aberdeen (Arso et al. 2012), and another five photo-identification trips took place in the same area in 2013. These data have allowed the first abundance estimate to be calculated for this area (see Section 5).

Firth of Tay

The Tayside and Fife area covers the coastline south from Montrose to south of the Firth of Forth (Figure 1). The east coast of Scotland bottlenose dolphin project database holds information on the trips undertaken in Tayside and Fife by the University of Aberdeen and the University of St Andrews since 1997. A trip, by definition, is generally a boat-based data collection exercise, where animals are approached and data collected. However, three of the trips within the dolphin project database, for the Tayside and Fife area, do not follow this protocol. One trip was a verified boat-based observation from a public source and one trip was a verified land-based observation from a public source.

Neither of these trips collected any high quality images for analysis. The third trip was a land-based observation by the SMRU that did collect images.

The dolphin project database contains information on trip lengths, sighting locations of dolphin groups and individual sighting information for most years. All data collected by the University of Aberdeen Lighthouse Field Station and the SMRU at the University of St Andrews as part of the long running photo-identification project are held within the dolphin project database. Data collected as part of additional projects overseen by Vincent Janik, University of St Andrews are held in a separate Janik lab database. Summary data from these additional projects have been used in this report. High levels of quality control ensure that all sightings have been verified and all photographs used for the purposes of this report have been quality graded to a consistent standard. Only images of individual animals graded as quality 3 (Thompson et al. 2011) have been used for this report.

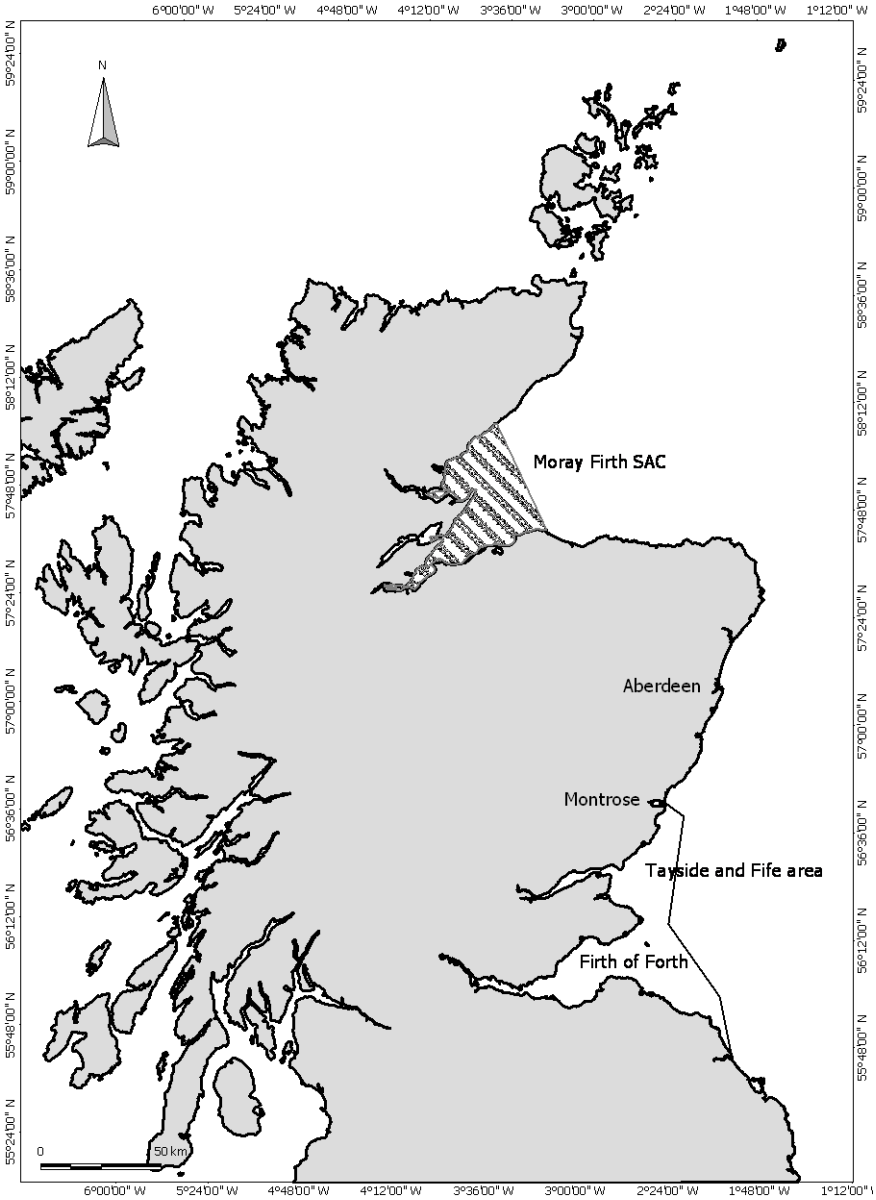


Figure 1: Location of the Moray Firth SAC (shaded area) and the outer boundary of the Tayside and Fife data collection area as defined in the dolphin project database

SECTION 1

Tayside and Fife data

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). The presence of bottlenose dolphins, at least over the summer months, is sufficient for dedicated photo-identification studies to be conducted in the Tayside and Fife area and for the data from these surveys to be incorporated into mark-recapture analyses to estimate the total size of the east coast population (Durban et al. 2005; Corkrey et al. 2008; Cheney et al. 2013).

For some sections of this report, data collected in the Tayside and Fife area from 1997 to 2011 were the primary source for analysis. Where sections draw on data collected in other areas or earlier or later years, this is stated at the start of the section. Individuals are referred to as "well-marked" when they have nicks (tissue missing or cuts in the tissue) on their dorsal fins. These nicks are known to be permanent marks that enable animals to be recognised as a unique individual over the course of the long term dataset. Individuals referred to as "identifiable" can be matched between years based on non-permanent marks, such as scratches, tooth rakes and skin lesions. Both types of individuals (well-marked and identifiable) are assigned an identification number in the catalogue.

Data on bottlenose dolphins have been collected in the Tayside and Fife area since 1997 (Table 2). The total number of trips that were undertaken each year is variable (Table 2 and Figure 2). Peaks in trips occurred in 2003-2004 and 2006-2007 when two PhD projects were conducted. Only in one year, 2005, was there no research effort at all in the Tayside and Fife area. The proportion of trips in which dolphins were seen was also variable (Figure 2). In all but two years dolphins were seen on 50% or more of trips. In 1997 and 2008 dolphins were seen only during one of five and one of six trips, respectively. However, in 1997, all five trips took place in the Firth of Forth and did not cover the Tay estuary area. In 2008, five of the six trips took place between January and April, with the final trip being a land-based observation during October.

In all other years, effort primarily spanned the summer months from May to September, with a peak in trips during July and August (Table 3). This peak is primarily due to better weather conditions that increase sighting probabilities and when light and day length is more suitable for photographs. In greater than 50% of the years (eight of the fifteen), dolphins were sighted in at least 80% of all trips that took place, confirming that bottlenose dolphins are commonly found in the Tayside and Fife area, particularly in the summer months. The amount of photographic effort has also been variable among trips. Photographic information on individuals exists for all years except 1997, 2005 and 2008 when either no trips took place, or animals were not sighted, or animals were sighted but no photographs were collected. As part of this project, further photo-identification surveys took place during May to September in 2012 and 2013.

The number of dolphin encounters each year was also variable (Table 2), ranging from one in 2008 to 51 in 2003. Encounters are defined each time a new group of dolphins is found at sea and data are collected. An encounter ends when the dolphin group is either lost by the observers or data collection is terminated. In any one trip there can be multiple encounters.

In addition to the photo-identification data, dedicated focal follows of individuals took place in the Tay area during 2003 and 2004 as part of a PhD study (Quick and Janik 2012; Quick and Janik 2008). These focal follows collected data on acoustic behaviour, group composition and surface behaviour. During 2006 and 2007, in addition to photo-identification, data on group composition, associations, relatedness and genetics via biopsy sampling, were also collected as part of another PhD study (Islas-Villanueva, V. 2010). These data are all held within the Janik lab database.

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. Information on dolphin detections from these deployments can be found in Thompson et al. (2011).

Table 2: Summary data from Tayside and Fife for 1997-2011. Number of individuals identified each year refers to the number of animals that could be identified from quality 3 photographs from the Tayside and Fife area. (Information combined from the dolphin project database and the Janik lab database).

Year	Total Number of Trips	Trips on which dolphins were seen	Total number of encounters	Photographs taken during the year	Number of individuals identified each year[6]
1997	5	1	2	N	0
1998	2	1	2	Y	10
1999	6	4	4	Y	6
2000	8	5	5	Y	16
2001	3	3	3	Y	43
2002	10	7	10	Y	40
2003	29	22	51	Y	52
2004	14	14	18	Y	43
2005	0	0	0	N	0
2006	18	15	49	Y	66
2007	20	19	47	Y	62
2008	6[7]	1[8]	1	N	0
2009	10[9]	8	32	Y	85
2010	8	8	39	Y	84
2011	10	9	38	Y	91

[6] In some years not all animals may be given an ID number, due to insufficient markings for between year matching. Furthermore, duplicate IDs will exist where animals have been given an ID number but then changed substantially to be non-identifiable and hence given a new ID number.

[7] In all other years trips took place primarily in the summer months. In 2008 five boat-based trips took place between January and April.

[8] This record is a verified public sighting from land, no photographs were taken

[9] Two of these records are from verified land-based observations. Photographs were taken from one of these trips

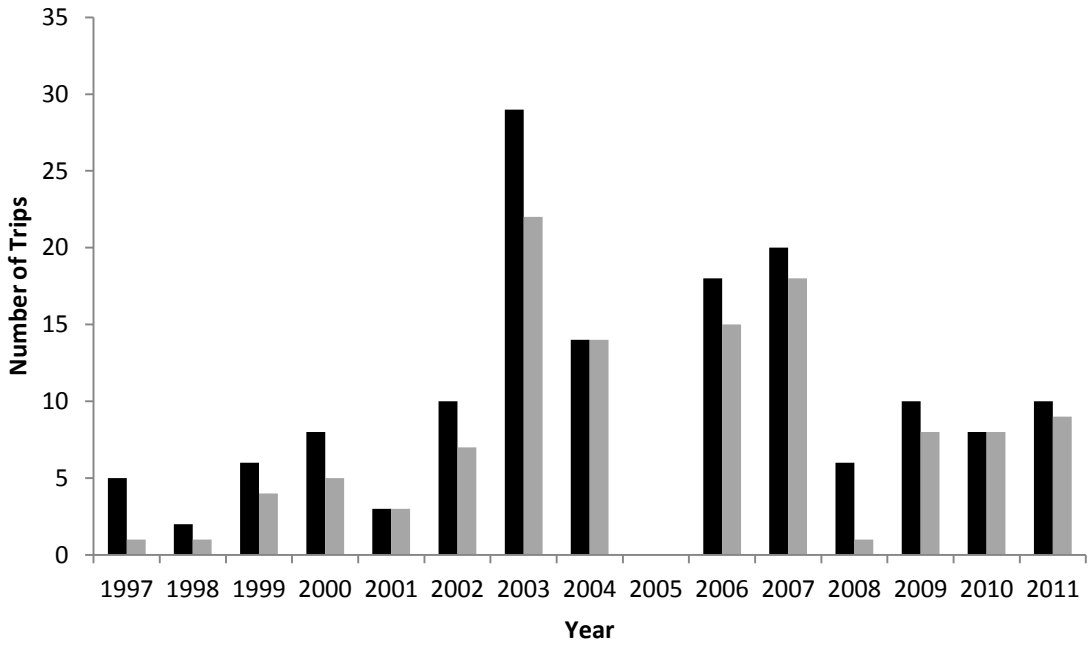


Figure 2: Total number of trips undertaken in Tayside and Fife each year up to 2011 (black bars) and the number of trips on which dolphins were seen (grey bars)

Table 3: Distribution of trips per month per year in the Tayside and Fife area for 1997-2011. (Month 1 = January through to Month 12 = December). For 2012 and 2013 some trips covered Tayside and Fife and Aberdeen within the same day.

Month	1	2	3	4	5	6	7	8	9	10	11	12
1997	0	0	0	0	0	0	0	5	0	0	0	0
1998	0	0	0	0	0	0	0	2	0	0	0	0
1999	0	0	0	0	0	0	2	0	4	0	0	0
2000	0	0	0	0	0	3	3	2	0	0	0	0
2001	0	0	0	0	0	1	2	0	0	0	0	0
2002	0	0	0	0	0	0	2	8	0	0	0	0
2003	0	0	0	0	0	1	13	9	6	0	0	0
2004	0	0	0	0	0	0	7	4	3	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	7	10	1	0	0	0
2007	0	0	0	0	2	2	10	6	0	0	0	0
2008	1	2	1	1	0	0	0	0	0	1	0	0
2009	0	0	0	0	1	2	3	4	0	0	0	0
2010	0	0	0	0	0	1	3	3	1	0	0	0
2011	0	0	0	0	0	4	3	3	0	0	0	0
2012	0	0	0	0	3	3	7	2	3	0	0	0
2013	0	0	0	0	4	6	4	3	3	0	0	0
Total	**1**	**2**	**1**	**1**	**10**	**23**	**66**	**61**	**21**	**1**	**0**	**0**

SECTION 2

Spatial and temporal movement patterns of individual bottlenose dolphins throughout their range along the east coast of Scotland

Movement patterns of all individuals

The number of individuals identified each year between 1997 and 2011 was variable, ranging from 0 to 91 (Figure 3). In the years 1997, 2005 and 2008, no high quality photographs were obtained, even though dolphins were encountered in two of these years. The total number of trips varied annually (Table 2) but there has been a steady rise in the number of individuals identified per year in the Tayside and Fife area over the period of data collection (Figure 3). However, the number of well-marked individuals has remained fairly constant (Figure 3). During 2009-2011, dedicated photo-identification efforts took place in the Tayside and Fife area using standardized techniques that attempted to survey all groups in the area and photograph all group members. This dedicated effort is in contrast to the years 2003-2004 and 2006-2007, when more trips took place but when the main focus of data collection was not photo-identification. These results show there may be an advantage in conducting dedicated photo-identification data collection in terms of the number of animals identified. However, it may also be that more animals were using the Tayside and Fife area in these later years.

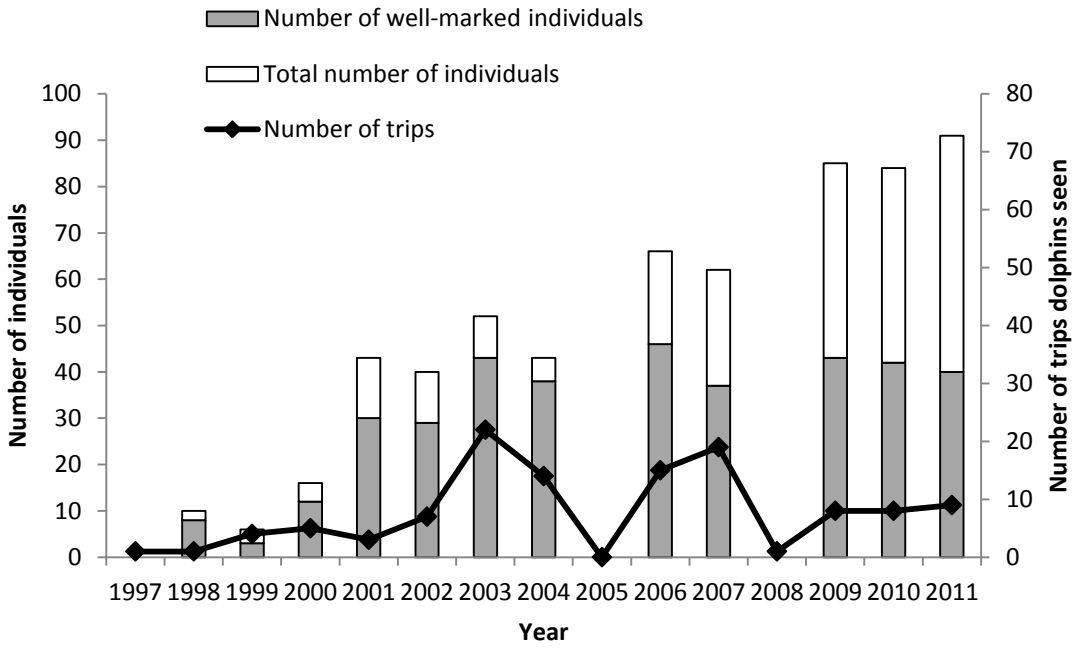


Figure 3: The number of well-marked individuals (grey bars) and the total identifiable individuals (including well-marked) (white bars) from Tayside and Fife, and the number of trips on which dolphins were encountered each year (black line).

Over all years (1997-2011) of data collected from the Tayside and Fife area, 200 individuals (99 well-marked and 101 identifiable) have been given an ID number from high quality photographs by the University of Aberdeen and the University of St Andrews (Table 4, Figure 4). Individuals were included if they had been recorded in the Tayside and Fife area at least once from a high quality photograph in any year and have been given a catalogue number in the long running dolphin project catalogue. This number includes well-marked and identifiable individuals. This number is not the number of individual dolphins seen, rather a cumulative number of IDs given. With most wild dolphin populations, individuals gain different types of marks over time. If individuals are sighted and given an identification number, but then not sighted for a number of years, post first identification, their natural marks may have changed substantially, leading to an inability to match them to their original identification number. This would be probable across a 15 year time series, and it is certain that some individuals are represented by more than one unique identification number.

The number of years that each of the 200 individuals were seen ranged from 1 to 9 years (Table 4 and Figure 4). Seventy-seven individuals were only sighted in the Tayside and Fife area in one year and three individuals were sighted in the area in nine separate years. Over the period 1997-2011, 102 of the 200 individuals were also, at some point, seen in the Moray Firth SAC. Of these 102 individuals, 68 were seen in both Tayside and Fife and the Moray Firth SAC in a single year (Figure 4). In comparison, 98 of the 200 individuals identified in Tayside and Fife were never recorded in the Moray Firth SAC during 1997-2011 (Figure 4); however, eight of these individuals were seen in the SAC prior to 1997.

Table 4: Number of individuals given an identification number, number of well-marked individuals and number of years seen in Tayside and Fife

Number of years sighted in Tayside and Fife	Number of individuals given an ID number	Number of well-marked individuals
1	77	25
2	26	7
3	30	13
4	18	12
5	18	13
6	14	13
7	6	6
8	8	7
9	3	3

The number of individuals in Tayside and Fife and the Moray Firth SAC in any given year shows great variation (Figure 4). This variability may be a consequence of variable field effort over the years studied or may be driven by factors such as social affiliation, variation in foraging opportunities or environmental factors. It is clear that different patterns exist both within individuals and across years, giving rise to different temporal and spatial movement patterns along the east coast. Some individuals were seen in Tayside and Fife one year and then in the Moray Firth SAC the next and vice versa (Figure 4). Other individuals were seen for multiple consecutive years in one area and then switched to the other. For example, individual 30 was consistently found in the Moray Firth SAC until

2001, was then only sighted in Tayside and Fife until 2009, and then only seen back in the SAC in 2010 and 2011. Individuals 23, 31 and 573 were sighted in the Moray Firth SAC in all fifteen years, but all were sighted in Tayside and Fife in 2003. Individual 571 was consistently sighted in the Moray Firth SAC until 2001, but was sighted primarily in Tayside and Fife since 2002, only being seen in the SAC in one further year, 2005. Individual 809 was first sighted in Tayside and Fife in 2000 and 2001, then switched to the Moray Firth SAC, but was seen in both areas in 2011.

Animals with ID numbers 1053 and higher (n = 58) were not sighted before 2006, indicating that most of these individuals are either young animals or could not be matched to a dolphin with an ID number because they were not well-marked (i.e. nicked). Of these 58 individuals, only 14 were recorded in the Moray Firth SAC, with the majority of the remaining 44 being consistently seen in the Tay, during two or more years. The main exceptions are ID numbers 1121-1133 which were only seen once in any area, but were first recorded as neonates or calves in 2011. Of the 98 individuals not recorded in the Moray Firth SAC at any point over the 15 years of data, 35% (34 individuals) were first sighted in 2009 or later (Figure 4). This could mean a number of younger individuals are currently resident in the Tayside and Fife area or that these animals were not given an ID number in previous years, due to not being well-marked.

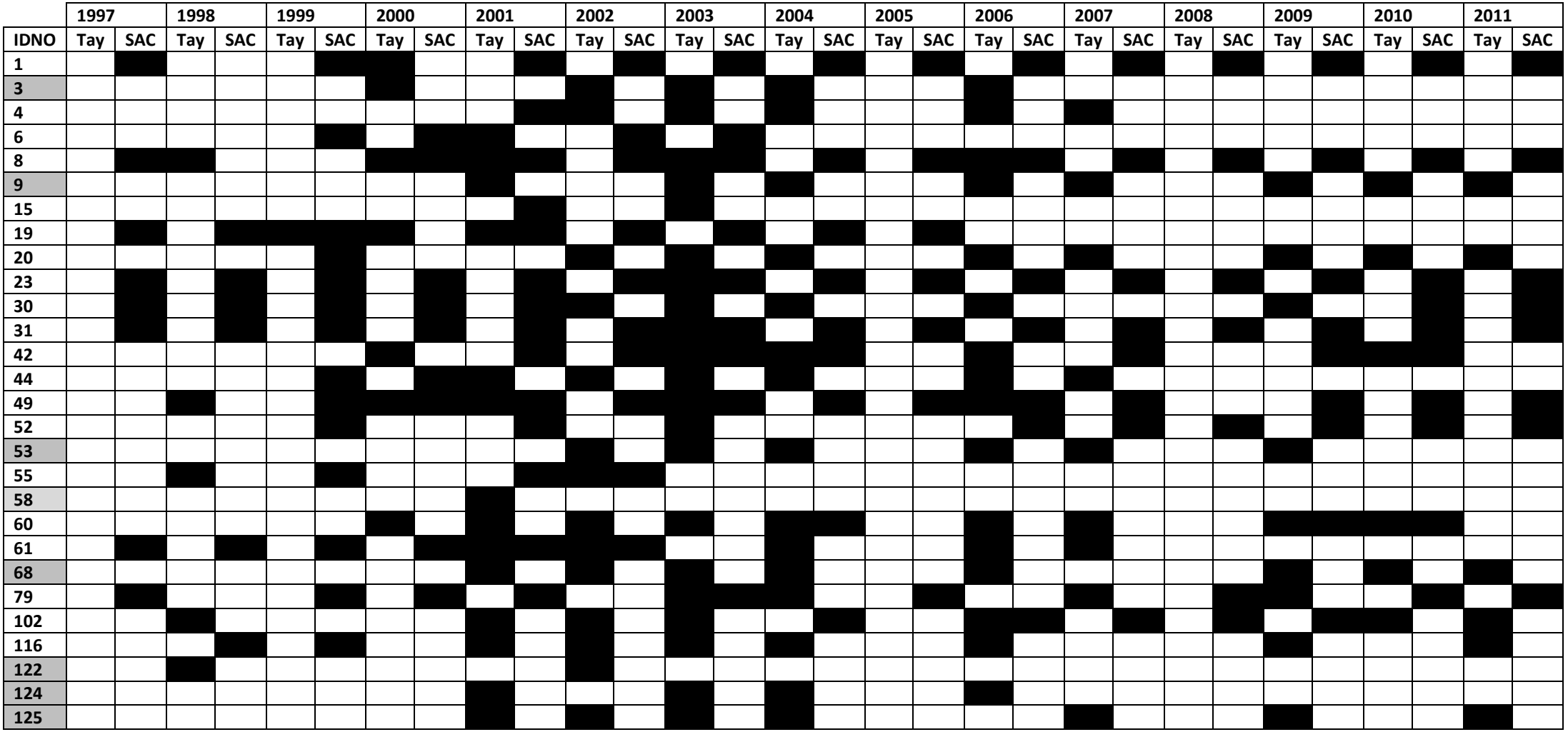
Over the 15 years of data, twelve individuals were sighted in five or more years in both Tayside and Fife and the Moray Firth SAC (Table 5). Of these individuals, all but three were first sighted as adults. There is much variability in the spatial and temporal movement patterns exhibited by these twelve individuals (Figure 4) with some individuals being present in both areas within the same year whilst others showed exclusivity to one area in any one year.

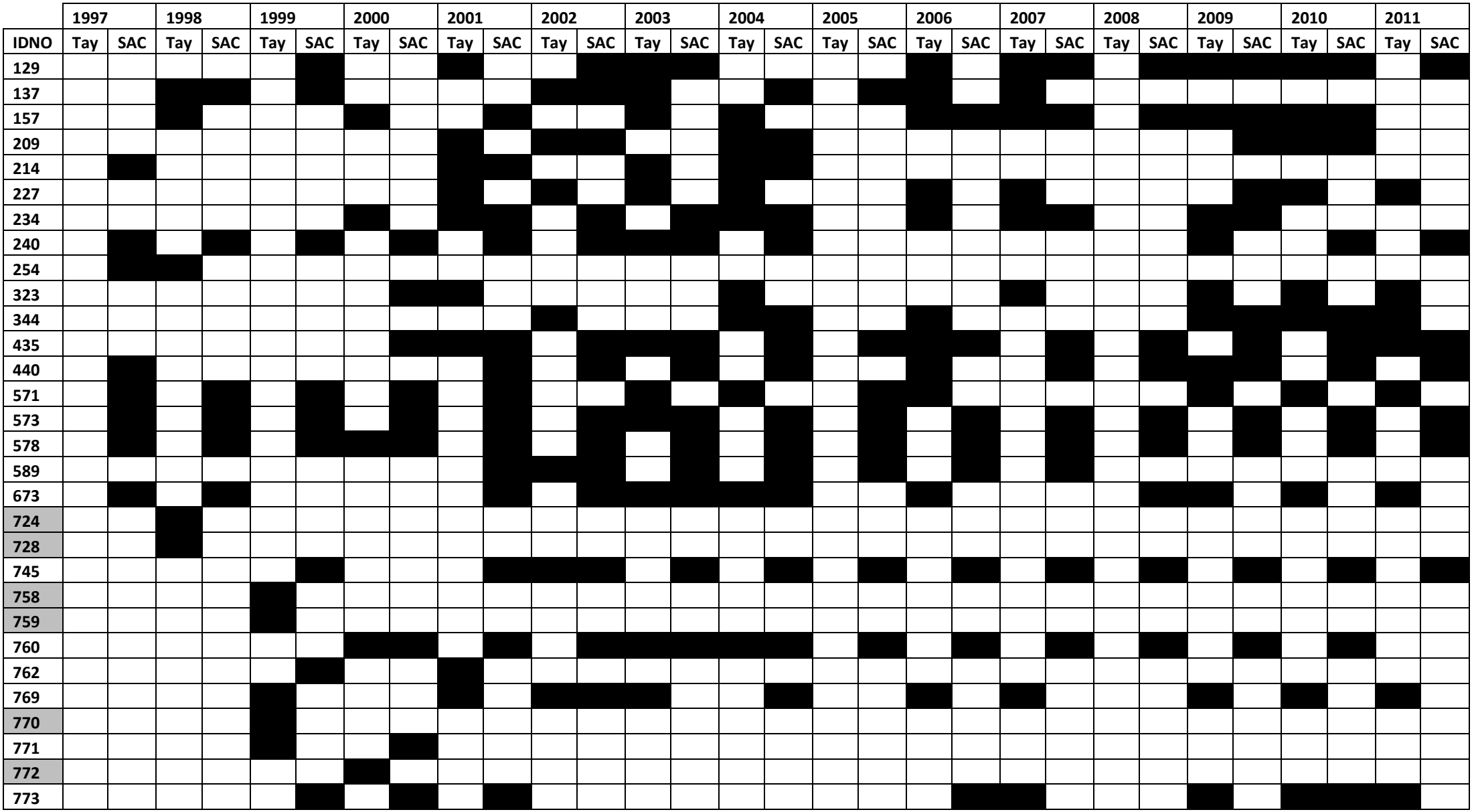
It is clear from the data presented that there is high individual variability in patterns of movement between the Tayside and Fife and Moray Firth SAC areas. This may be expected from a population that lives in a fission-fusion society, characterised by groups that frequently join up and split apart (Quick and Janik 2012). However, whether these differences in movement pattern are driven by social factors, such as age, sex or social affiliates, or by environmental factors, such as differences in foraging strategy, is unknown. What is evident is that a high proportion of bottlenose dolphins from the east coast of Scotland population use both the Tayside and Fife area and the Moray Firth SAC over a range of temporal scales and that any marine development along the east coast should consider this variability during any impact assessments.

Table 5: Twelve individuals sighted five or more times in both Tayside and Fife and the Moray Firth SAC.

IDNO	Years sighted in Tayside and Fife	Years sighted in the MF SAC	Year First Seen	Age First Seen	Sex	Last year sighted
8	5	13	1989	Adult	Male	2012
30	5	7	1989	Adult	Female	2012
42	5	7	1989	Adult	Male	2012
61	5	6	1989	Adult	Female	2007
102	7	5	1989	Sub-Adult	Male	2012
129	6	8	1990	Adult	Male	2012
137	5	5	1990	Adult	Male	2007
157	8	6	1990	Adult	Male	2010
234	6	6	1989	Sub-Adult	Male	2009
571	6	6	1996	Adult	Female	2011
673	6	7	1997	Adult	Female	2012
805	6	6	2000	Juvenile	Female	2012

Figure 4: Summary of whether an individual (well-marked & identifiable) was seen in the Tayside and Fife region ('Tay') and within the Moray Firth SAC ('SAC') in any one year. Black boxes indicate a positive sighting. Grey background to IDNO (identification number) shows animals never sighted in the Moray Firth SAC over the 15 years of data. (Figure continued on next 6 pages).

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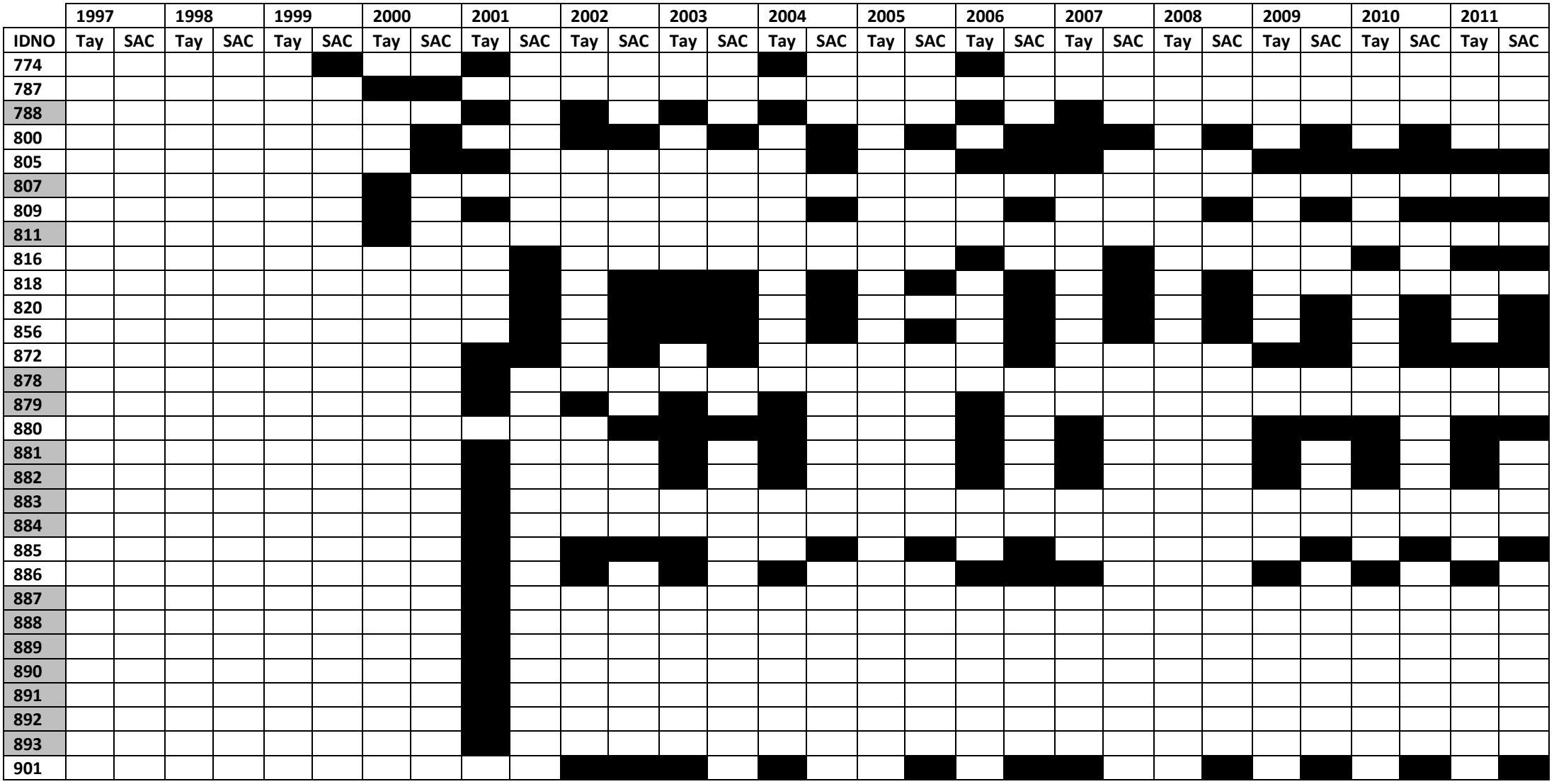
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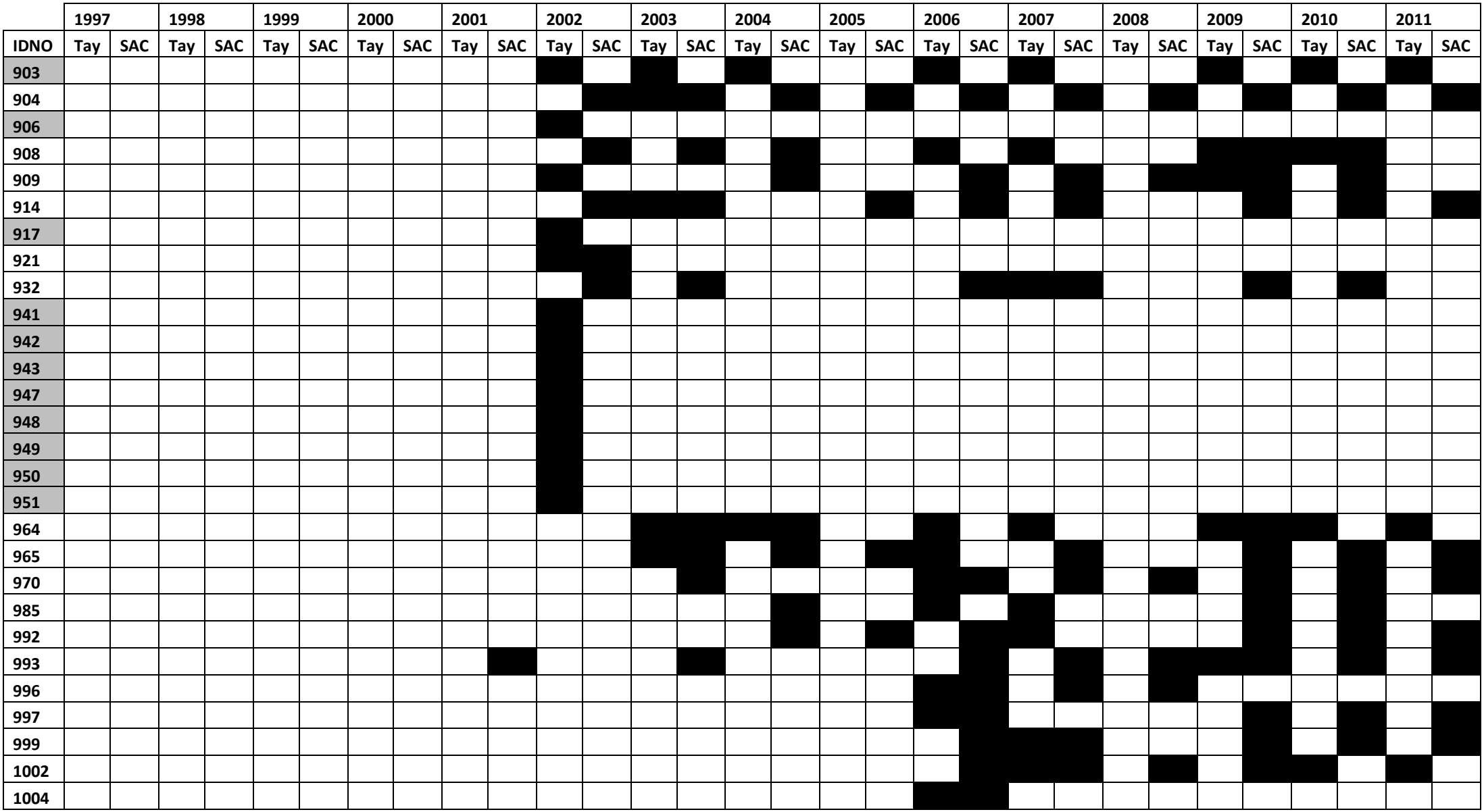
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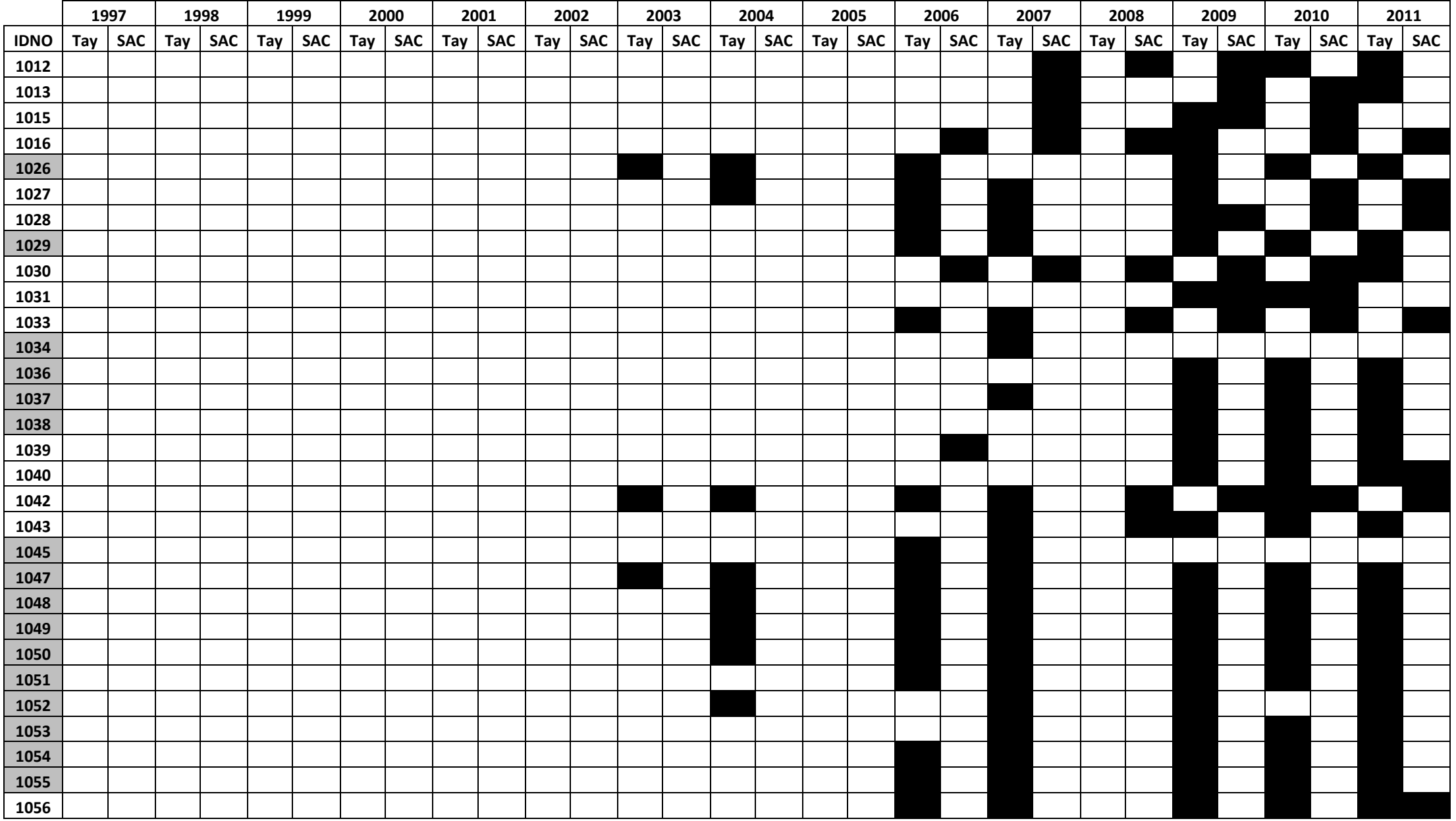
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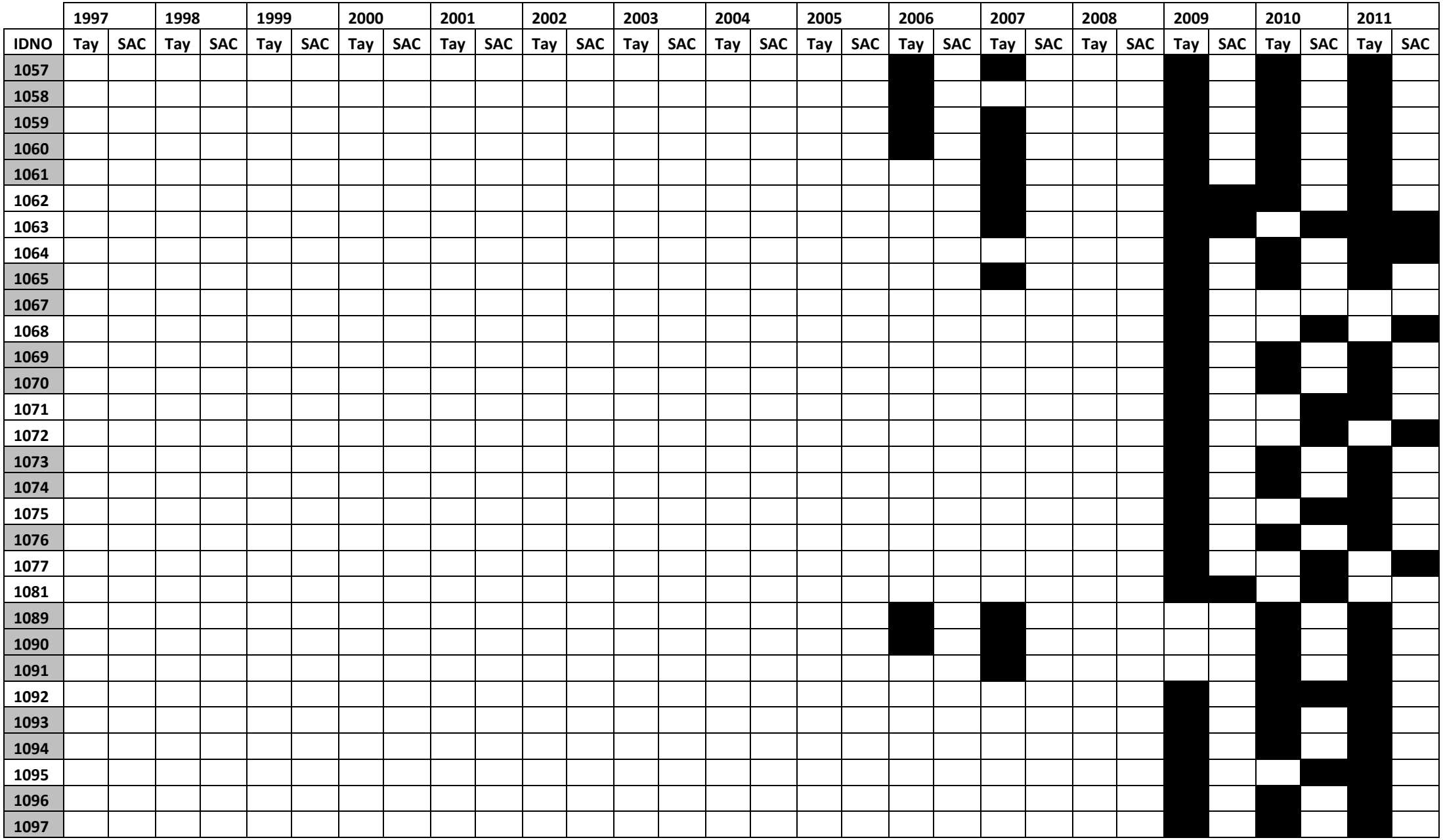
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Movement patterns of calves outside the Moray Firth SAC

For this part of the study we used photo-identification data collected between 1997 and 2012, starting in the year when sampling effort began to occur outside the Moray Firth SAC. We define the following areas: Moray Firth SAC, Outer Moray Firth, Grampian, Tayside and Firth of Forth (Figure 5).

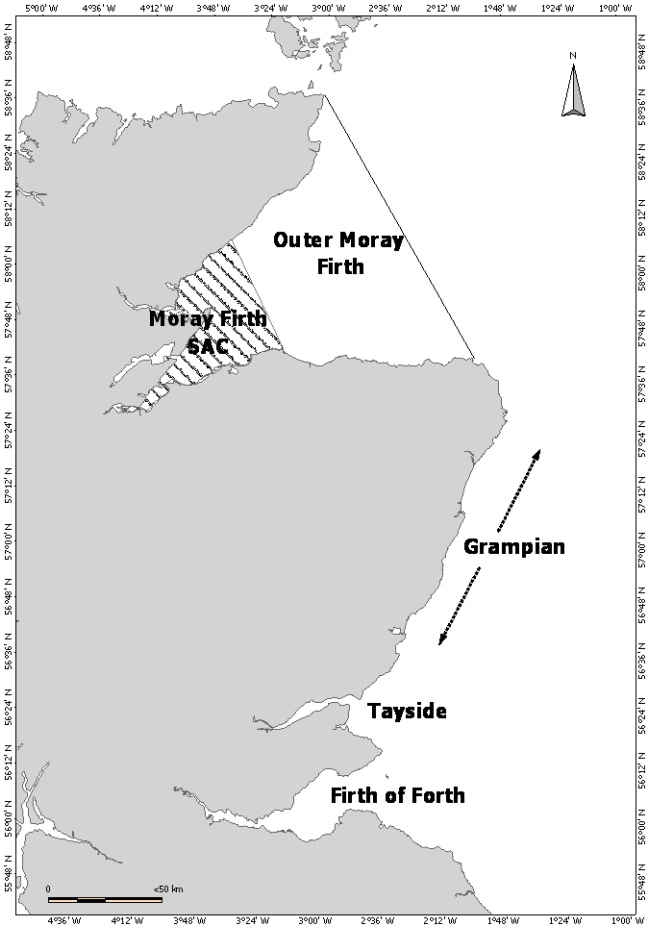


Figure 5: The five defined study areas between the Moray Firth SAC and the Firth of Forth, used to investigate the movements of calves.

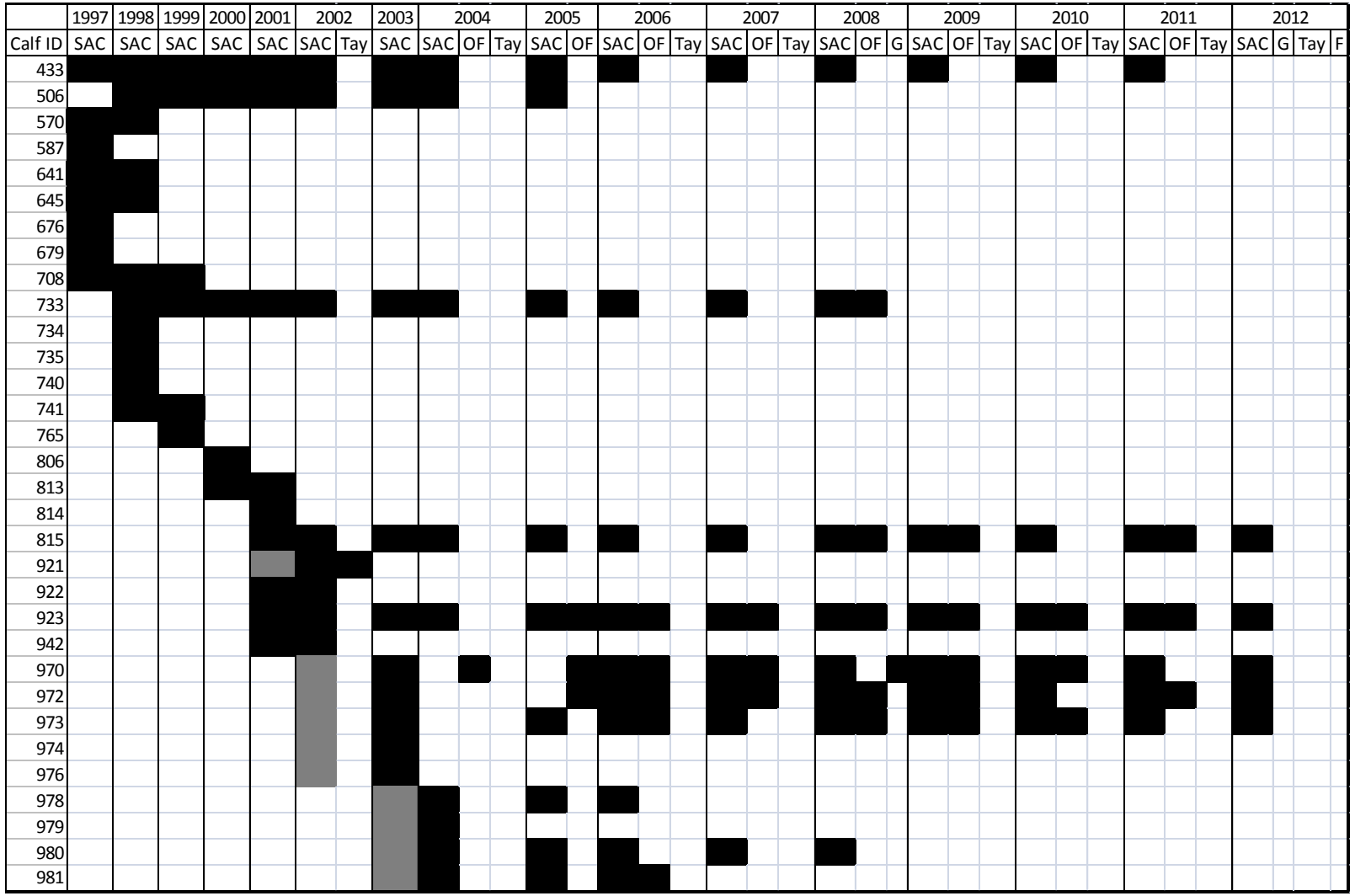
We used sighting data based on high quality photographs from all calves with a known year of birth and information on the areas where they were encountered (Figure 6). When a calf was first sighted as a young of the year, the year of birth (YOB) equalled the year that the calf was first seen. Young of the year were distinguished from older calves by their small size, pale skin, the presence of foetal folds and foetal lines, a characteristic head-out surfacing and nearly constant contact with the mother. In many cases though, a calf was not seen on its year of birth but as an older calf. When a female was not seen in a given year, but sighted repeatedly in subsequent years with an older calf, the YOB of the calf was determined by its relative size and prominence of foetal lines. In this population foetal folds remain visible at least during the first two years of life, and the level of association with the mother is consistently high during the first 2 to 3 years, allowing further confirmation of the identity of calves through their repeated association with a reproductive female (Grellier et al. 2003). Calves' YOB were only extrapolated as far as two years as studies suggest that a calf is likely to become independent of its mother around its third year (Mann et al. 2000).

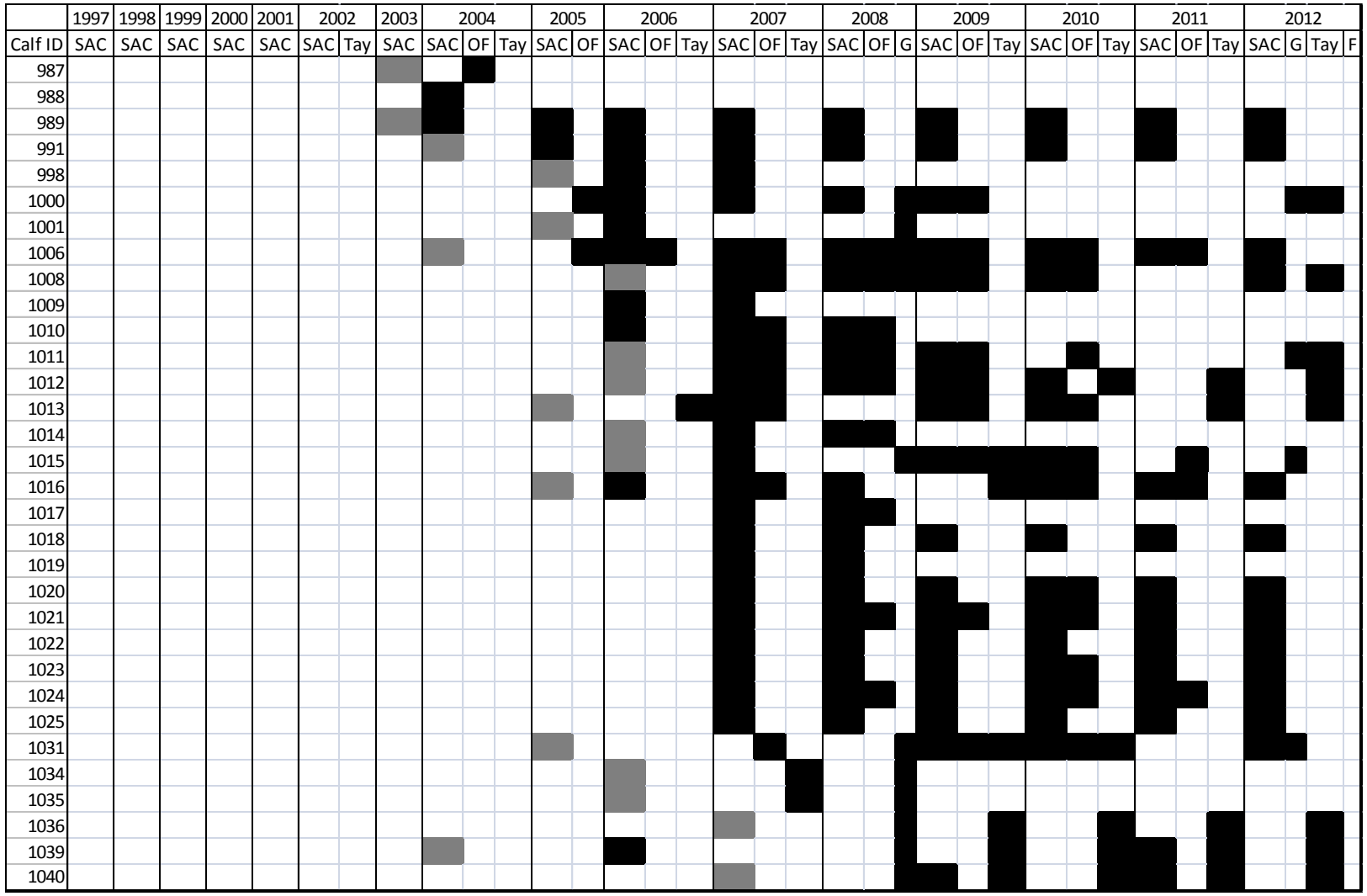
Between 1997 and 2012, a total of 134 dolphins were born and sighted in the entire study area. Additionally, four other dolphins born in 1994 and 1995 were already 2 or 3 years of age in 1997 and were thus included in this part of the analysis. Young of the year were defined as animals born in any given year. Forty-four out of the 134 young of the year were not seen in their year of birth and thus the area used during that year was not known (Figure 6). We classified all individuals between 0 and 3 years of age as calves. This decision was taken on the basis that bottlenose dolphin calves tend to be weaned around their third year of life (Mann et al. 2000), which is in accordance with previous studies in this population that have showed that after 3 years the level of association between mother and calf decreases substantially (Grellier et al. 2003).

Young of the year were sighted exclusively in the Moray Firth SAC between 1997 and 2001, after which they were gradually sighted in other areas (Figure 7, left panel). Similarly, until 2001 all encounters of known calves occurred within the Moray Firth SAC, and then sightings increased in the other areas (Figure 7, right panel). Changes in sampling effort over the years and the introduction of digital photography in 2001 are likely to have had a strong influence on the capability of sighting young of the year and calves in the entire study area (Figure 8 and Table 6). However, while effort in areas outside the Moray Firth SAC varied over the years, effort within the SAC was maintained at high levels between 1997 and 2012, increasing the opportunity to keep track of young of the year dolphins compared to areas in which effort has been more variable. This may partially explain why higher numbers of young of the year and calves were generally seen in the Moray Firth SAC than elsewhere. Results from later years, when effort increased outside the SAC (especially since 2009 in St Andrews Bay and the Firth of Tay), show a considerable increase in the numbers of young of the year and calves regularly seen outside the Moray Firth SAC (Figure 7).

The location of calves during the first 3 years of life will typically be determined by the movements of their mothers. The data show that calves, including young of the year, were sighted in different areas within and among years (Figure 6). For example, in their year of birth, young of the year #921, #1081 and #1145 were seen both in the Moray Firth SAC and in Tayside; #1138 was seen in the Moray Firth SAC and Grampian; and #1150 was seen in Tayside and the Firth of Forth. Similar patterns are evident from calf movement data. Calves sighted in Tayside were also sighted in the Moray Firth SAC, Grampian, and Firth of Forth at some point during the first 3 years of life (e.g. #1013, #1070, #1111, #1113, #1117, #1124, and #1131). Calf #1124, born in 2010, was also seen in the Moray Firth SAC in 2011 and in Tayside and the Firth of Forth in 2012.

Figure 6: Summary of annual locations of all known age calves seen between 1997 and 2012 in the Moray Firth SAC ('SAC'), Outer Firth ('OF'), Tayside and St Andrews Bay ('Tay'), Grampian coast ('G') and Firth of Forth ('F'). Cells shaded grey means that the area used by the calf during the first year is not known as it was not observed until it was >1yr old (Figure continued on next 4 pages).

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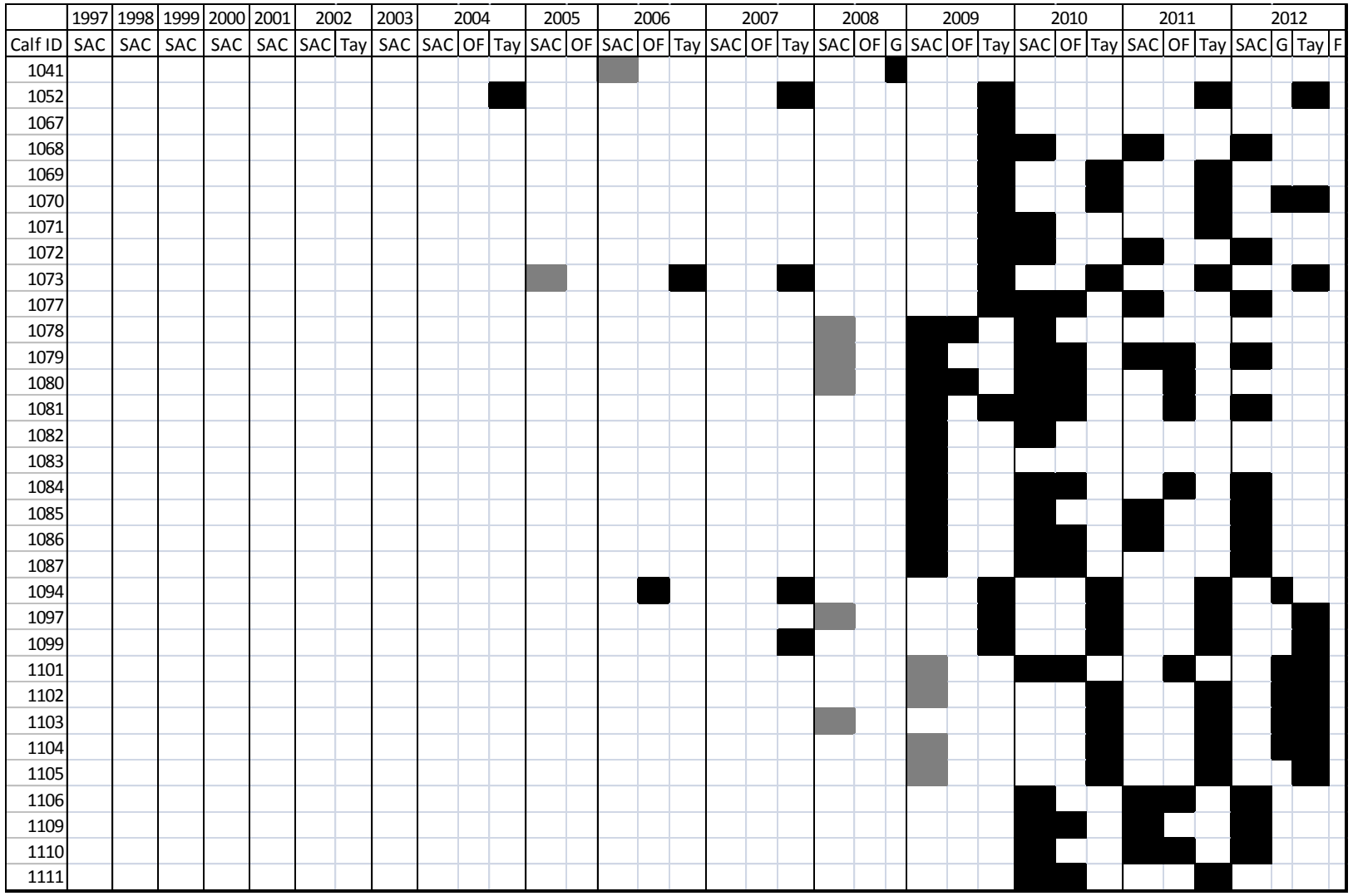
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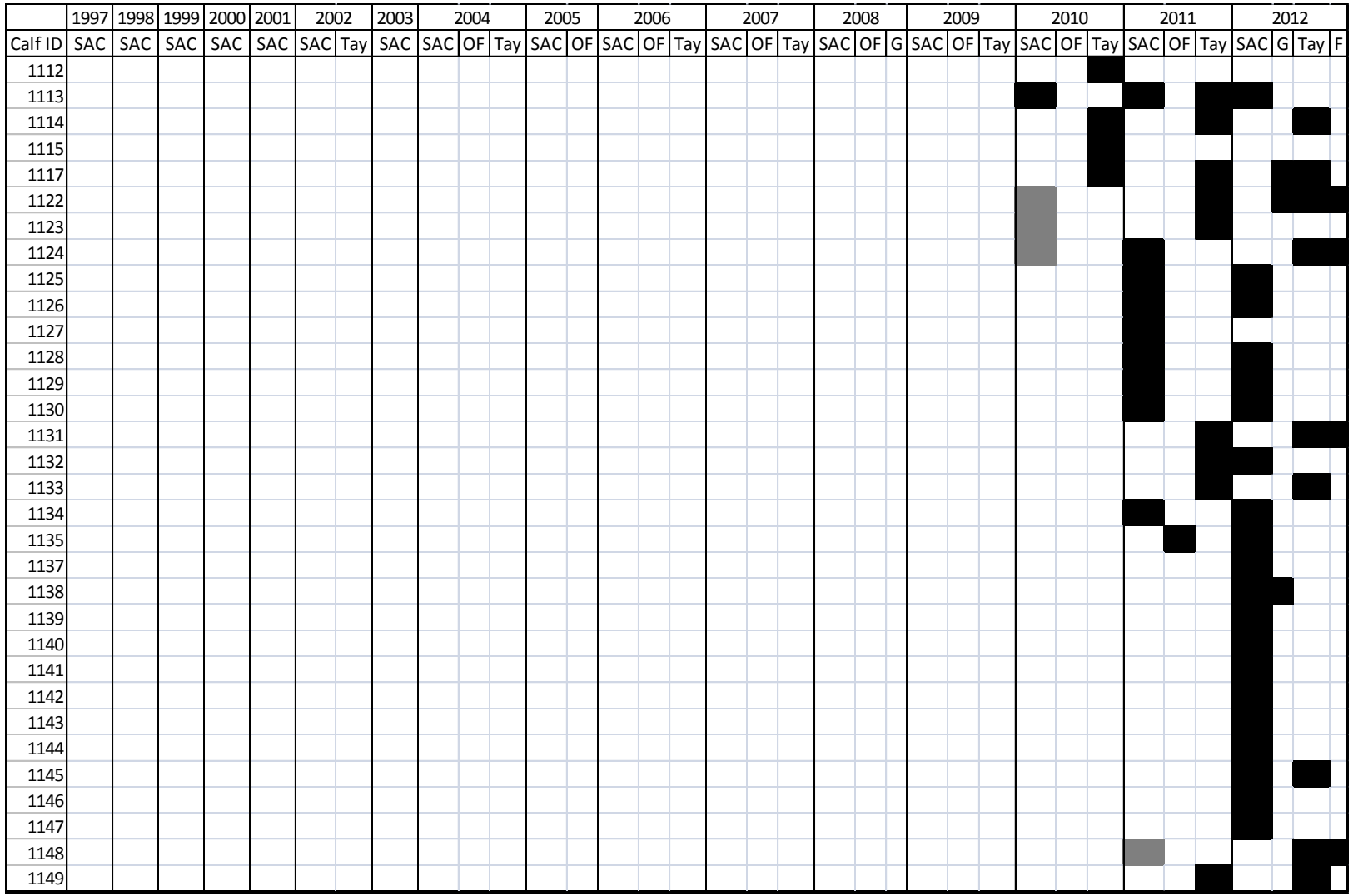
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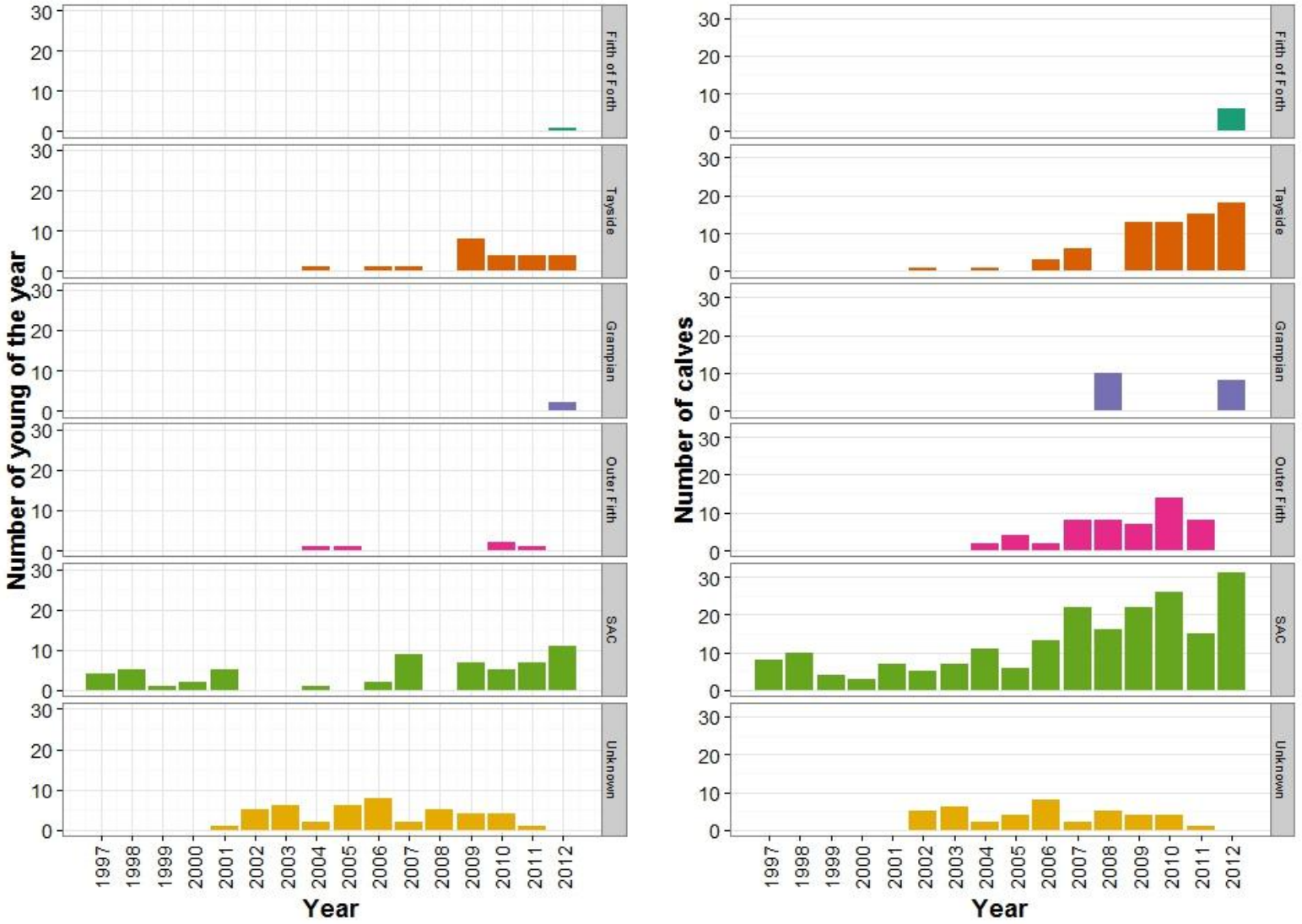


Figure 7: Summary data of the number of young of the year animals (left panel) and calves (right panel) sighted annually in the different areas. Areas include the Moray Firth SAC, Outer Moray Firth, Grampian coast, Tayside, Firth of Forth, and an unknown area if a young of the year was not sighted in its year of birth. The number of individuals sighted in each area are not mutually exclusive, i.e. one individual can be seen in multiple areas in any one year (refer to Figure 6).

Table 6: Total number of young of the year (YOY) and calves seen each year in all areas combined (areas include the Moray Firth SAC, Outer Moray Firth, Grampian coast, Tayside, Firth of Forth).

Year	YOY	Calves
1997	4	8
1998	5	10
1999	1	4
2000	2	3
2001	6	7
2002	5	10
2003	6	13
2004	5	12
2005	7	13
2006	11	20
2007	12	28
2008	5	25
2009	18	33
2010	13	34
2011	13	37
2012	16	38

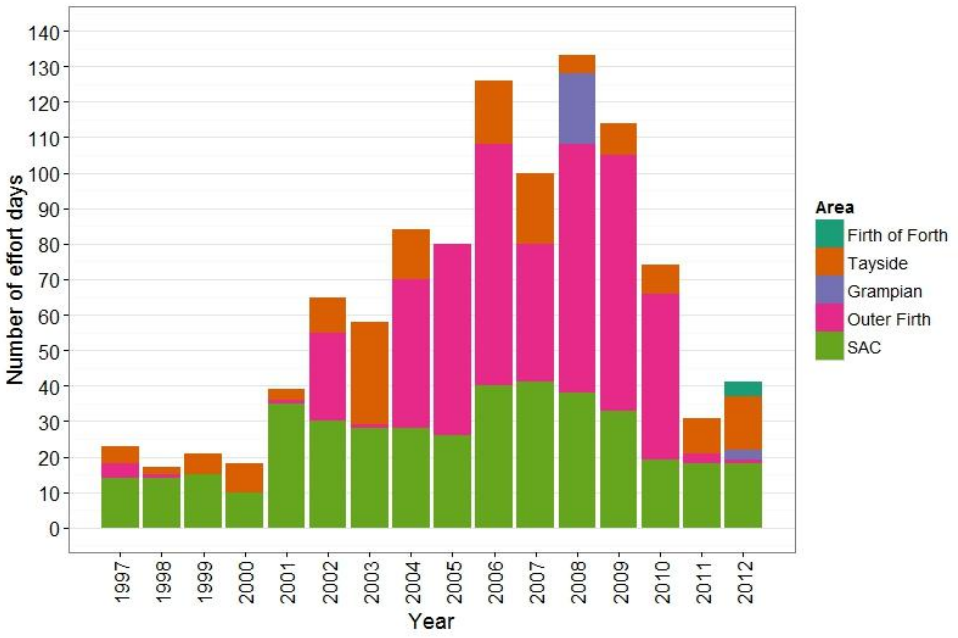


Figure 8: Total number of boat based effort days by area between 1997 and 2012. Areas include Moray Firth SAC, the Outer Moray Firth, the Grampian coast, Tayside, and the Firth of Forth.

SECTION 3

Spatial and temporal movements of bottlenose dolphins along the east coast of Scotland

The data presented in Section 2 show that there is high spatial and temporal variability in individual movement patterns between the Tayside and Fife and Moray Firth SAC areas. In order to inform consenting decisions for marine development, it would be useful to understand the drivers behind these movement patterns, in order to minimise any potential effects. Potential drivers such as differences in foraging strategies or social affiliates are either difficult to obtain data on or have not been extensively studied in this population. However, one potential driver for which information does exist is the sex of individuals. If different sexes use the Tayside and Fife and Moray Firth SAC areas in different ways, then one sex may have a greater chance of exposure from marine developments than the other.

Individual movement data for all 200 individuals seen at least once in Tayside and Fife (Figure 4) were considered for analysis. Individuals were removed from the analysis if they had not been seen since 2007 or had only ever been seen once. This ensured that the analysis used information from animals most likely to be utilising the two areas presently and to ensure that animals had been alive for at least 2 years and hence had an opportunity to travel between the two sites between years. In addition, by only using animals seen at least twice and thus matched between years, the chance of including individuals that had been assigned more than one identification number was reduced. There is still the possibility that slight bias may exist in the data, as the probability of being seen in both areas may be partly dependent upon mark type and both well-marked and identifiable individuals are used in these analyses.

Data collection effort has been variable over the 15 years of data used for this analysis. Consistent dedicated photo-identification effort has occurred in the Moray Firth SAC as part of site monitoring. However, effort has been much less consistent in the Tayside and Fife area (Table 2). In three of the 15 years (1997, 2005 and 2008), no individual animals were identified and these three years (for both areas and all individuals) were removed from the analysis. This ensures that false zero values (i.e. no individuals identified because no data were collected) were not included in analysis.

The remaining data included 143 individuals with sighting histories over 12 years. All 143 individuals were coded as male, female or unknown depending on the data held within the database. Animals have only been assigned known sex if evidence exists from photographs of the genital region, sex has been confirmed by genetic analysis of biopsy samples (Islas-Villanueva, 2010) or animals have routinely been seen with a calf or calves. Of the 143 individuals, 52 were known females, 30 were known males and 61 were of unknown gender. Each year that the 143 individual animals had been sighted was then coded as either the Moray Firth SAC ('SAC'), Tayside ('SAC') or both. Animals could be sighted once or multiple times to be assigned to an area. Only one data point for location was allowed for each individual in any one year to ensure the data were mutually exclusive; that is, in any one year, an animal could not be coded as SAC, Tay and both, only both. This produced a data matrix of individual sightings per area (SAC, Tayside, both) per year, with each individual coded for sex.

All data used for the analysis were nominal and had repeated measures for each individual. As such, an analysis using generalized estimating equations (GEEs) for correlated nominal multinomial responses was used. All analysis was carried out in R software (R Core Team 2013), using the multgee package and the function nomLORgee (Touloumis 2013).

A model was specified to determine the probability of females, males or animals of unknown sex being in either of the three areas (SAC, Tay or both) by pooling sighting histories for each area across years for all individuals of a specified sex (male, female, unknown).

The model used area as the response variable, with sex as a predictor, ID as an identifier of observations from each individual and year as a vector to identify the order of observations and account for potential autocorrelation of repeated measures through time per individual.

The fitted model (Table 7) showed that for individuals that range up and down the coast, across all years the probability of presence within the Moray Firth SAC is significantly higher for females compared to males (p =0.0497; Table 7, Figure 9). However there is no difference in predicted probability of presence between males and females in the Tay or both areas (Table 8, Figure 9).

Table 7: Coefficients from the fitted model referenced against female as the baseline. Estimate = estimates for the parameters in the model; se = standard error; san.z = test statistic; Pr(>|san.z|) = the probability that the test statistic is significant; * = significant at the 0.05 level

	Estimate	SE	san.z	Pr(>|san.z|)
Females SAC	1.15152	0.22239	5.1778	< 2e-16 ***
Males SAC	-0.68307	0.34804	-1.9626	0.04969 *
Unknown SAC	0.20431	0.35343	0.5781	0.56322
Females Tay	1.56142	0.24089	6.4818	< 2e-16 ***
Males Tay	-0.32078	0.36363	-0.8822	0.37768
Unknown Tay	0.53735	0.40969	1.3116	0.18965

Table 8: Fitted values for each sex for each area showing the probability of each sex being found in each area, (95% confidence intervals in parentheses).

Sex	Moray Firth SAC	Tay	Both Areas
Female	**0.354** (0.272-0.450)	**0.534** (0.431-0.627)	**0.112** (0.077-0.158)
Male	**0.264** (0.169-0.381)	**0.571** (0.437-0.691)	**0.165** (0.111-0.236)
Unknown	**0.298** (0.212-0.395)	**0.626** (0.509-0.727)	**0.075** (0.044-0.128)

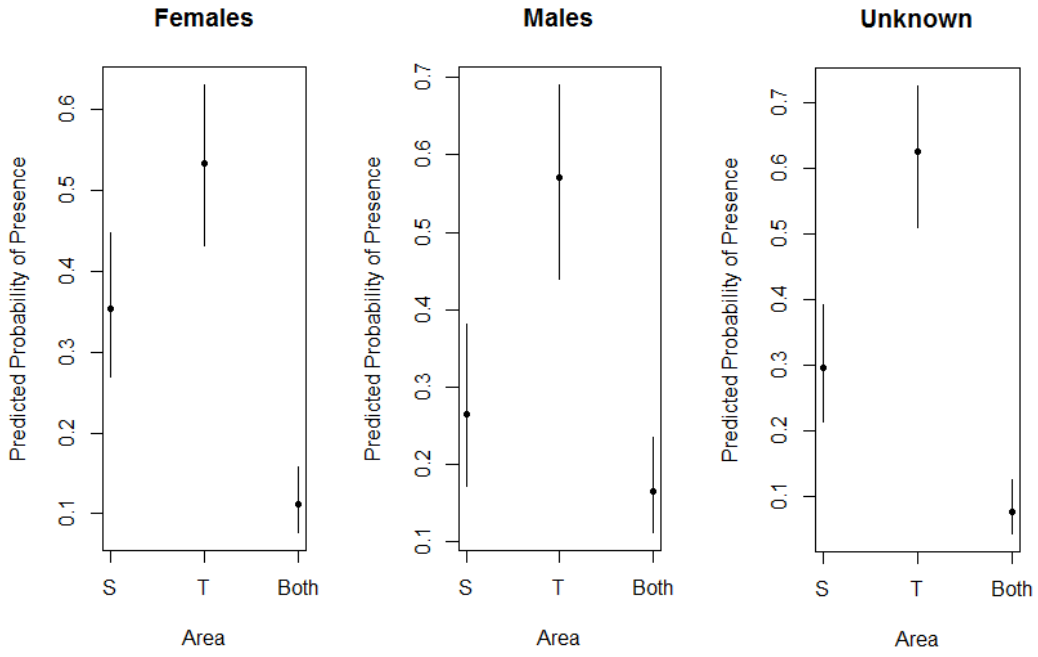


Figure 9: Fitted values and 95% confidence intervals giving the predicted probability of presence for each of the three sex classes across area. For Area, S = Moray Firth SAC, T = Tay. There is a significant difference between males and females in the Moray Firth SAC

This analysis shows that of the animals that have been seen in the Tayside and Fife area, males appear to spend more time outside the Moray Firth SAC than females. The reasons for this are unknown. One possibility is that the Tay is used differently to the Moray Firth SAC in terms of how males and females utilise resources. Females in the Moray Firth SAC may primarily remain in the SAC for a number of years making only infrequent trips to the Tay. This would make females more site faithful in the Moray Firth SAC than males. In contrast males may be less site faithful than females exhibiting wider ranging movement, a pattern which is common in many mammals (Greenwood 1980) and has been documented in inshore bottlenose dolphins *Tursiops aduncus* (Möller and Beheregary 2004).

Increased access to resources, including mates, and the avoidance of inbreeding are important in promoting sex differences in dispersal (Greenwood 1980). Males may not range more widely than females because all individuals, male and female, used in the analysis had been seen in the Tay at least once, but may move more frequently. This would be in line with other well studied populations of bottlenose dolphins in Sarasota Bay, Florida and Shark Bay, Western Australia, in which both sexes are philopatric (Smolker et al. 1992, Connor et al. 2000) but demonstrate high fission-fusion dynamics in an open community (Smolker et al. 1992, Wells 1991), where group composition changes frequently and animals show variation in ranging patterns within a wider resident area.

However, how the sex based movement patterns of dolphins off the east coast of Scotland differ temporally within years is not clear. As a first step to investigate this, the monthly movements within the last three years (2009, 2010 & 2011) were examined using the data included in the individual movement model. These data show that of the 30 known males, ten (33%) were seen in both areas in any one year (Figure 10). Of these ten animals, five (50%) exhibited this level of movement over

two years, but no males moved between both areas in all three years (Figure 12). In contrast, of the 52 known females, ten (19%) were seen in both areas in any one year (Figure 11). Of these ten, nine (90%) exhibited this pattern in only one of the three years (Figure 12). The remaining female was seen in both areas in all three years of data (Figure 12). These patterns suggest a tendency for males to move between the two areas more frequently than females. Why this pattern exists is not clear but it does suggest that the two areas may be important in different ways for the different sexes.

The implication of these differences between males and females are that if males do range more frequently up and down the east coast they are likely to encounter marine developments more often than females. Depending on the nature of the marine developments males and females may be exposed to disturbance in different ways.

Figure 10: Monthly movement of all known males used in the individual movement analysis. Black boxes indicate seen in the Moray Firth SAC, grey boxes indicate seen in the Tay, grey and black combination boxes indicate seen in both areas within the same month. Yellow ID numbers show animals seen in both areas in any one year.

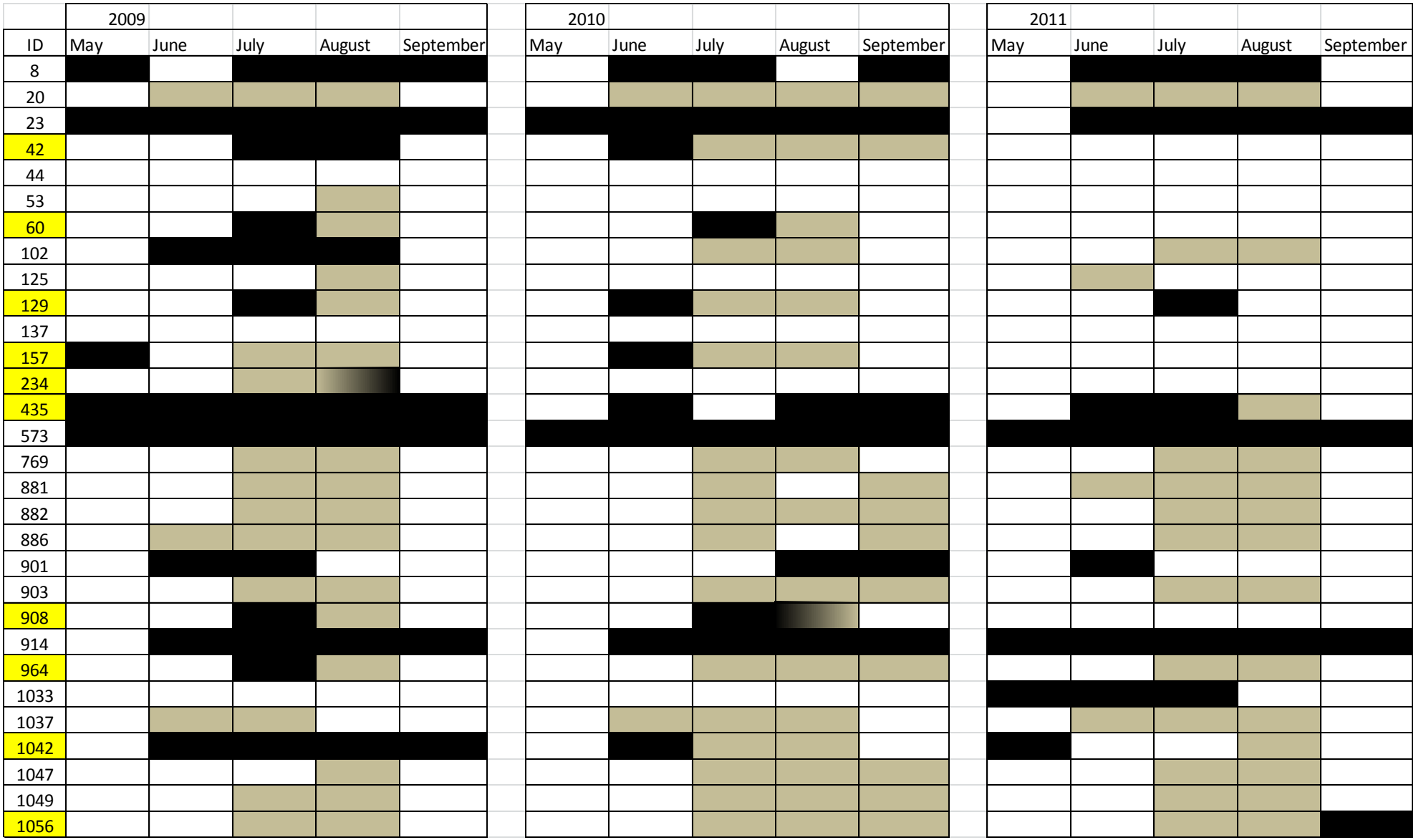
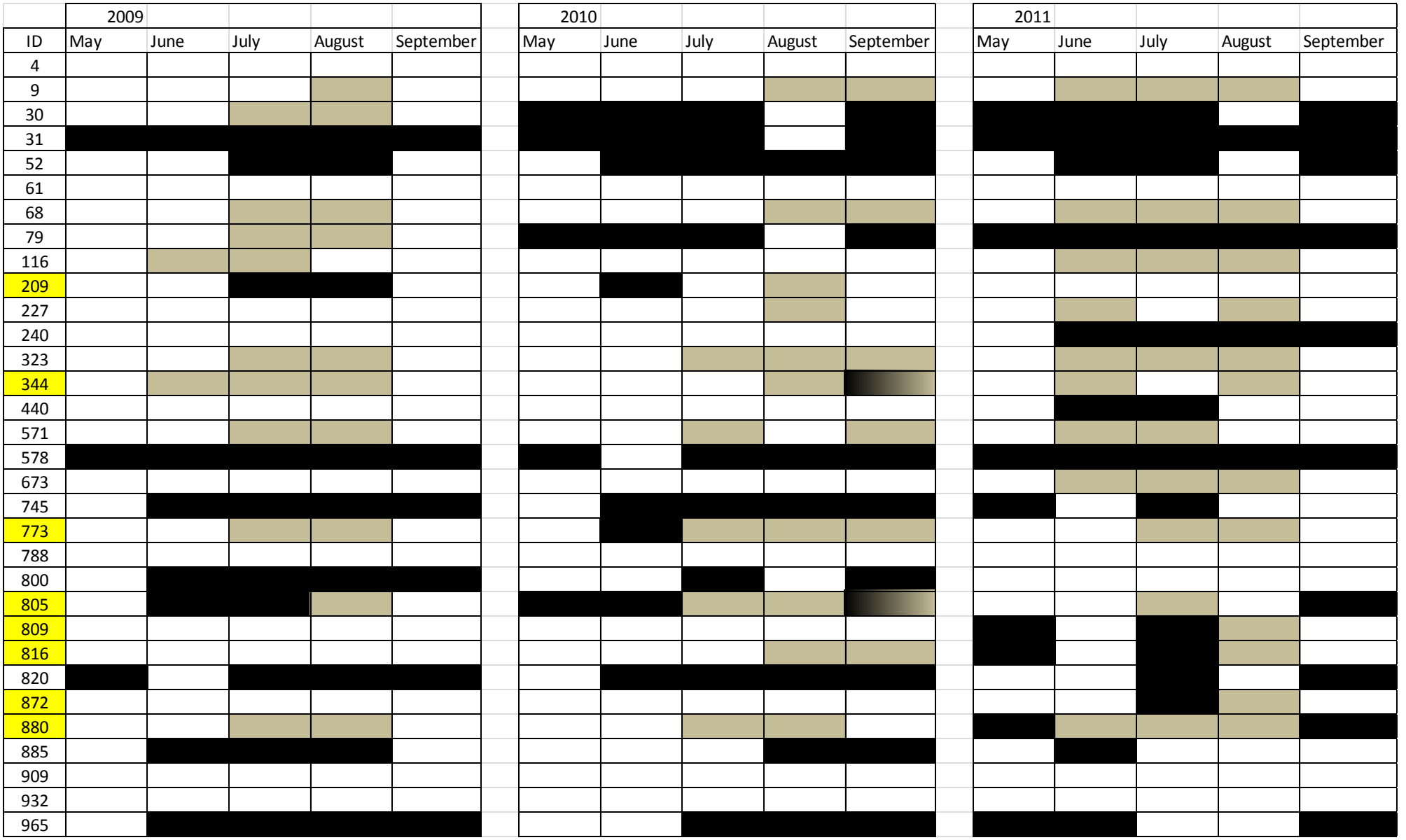


Figure 11: Monthly movement of known females used in the individual movement analysis. Black boxes indicate seen in the Moray Firth SAC, grey boxes indicate seen in the Tay, grey and black combination boxes indicate seen in both areas within the same month. Yellow ID numbers show animals seen in both areas in any one year.



	2009					2010					2011				
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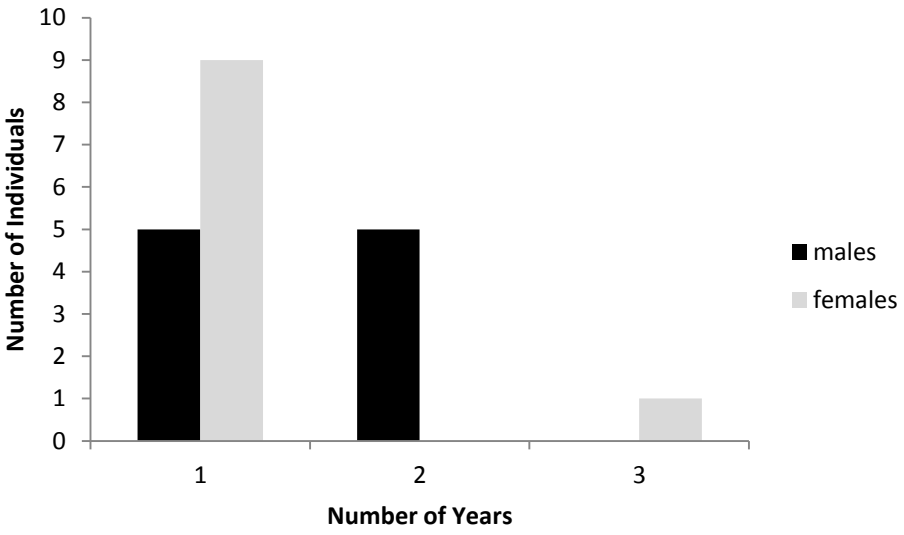

Figure 12: The number of males and females that are seen in both areas across the last three years (2009, 2010, and 2011) of data.

SECTION 4

Distribution of bottlenose dolphins along the east coast of Scotland and identification of high use areas

The analyses in this section used historical data from 1997 to 2011 and also data collected as part of this contract from 2012-2013.

Distribution of bottlenose dolphin encounters

Encounter locations, i.e. the position at which dolphin groups were first sighted, between Aberdeen and the Firth of Forth from all 17 years (1997-2013) of data are shown in Figure 13. Although survey effort and encounters varied by year, the majority of dolphin encounters were recorded within the Tay estuary (Figure 13). Encounters were also common in St Andrews Bay, the coastal waters between Arbroath and Montrose, and around Aberdeen. Only a few encounters occurred in the Firth of Forth, all of them located on the north side of the Forth between Fife Ness and Elie. Systematic photo-identification surveys of the entire Tayside and Fife area did not start until 2009. The distribution of encounters between 1997 and 2008 are therefore influenced by the distribution of survey effort, and do not necessarily represent the true distribution of dolphins within the area for that time period. Between 2009 and 2013, systematic boat surveys to carry out photo-identification were undertaken primarily within the Tay Estuary. Between 2009 and 2011 surveys took place within the Firth of Tay and St Andrews Bay, but during 2012 and 2013 effort was extended south to the Firth of Forth and north to Aberdeen.

Most of the encounters with bottlenose dolphins occurred in waters less than 30 m deep, generally in waters between 2 and 20 m. The dolphins were encountered close to the coast, generally within 2 km from the coast line, except in St Andrews Bay and the entrance to the Tay Estuary, where encounters also occurred further out (Figure 13). The systematic photo-identification surveys completed between 2009 and 2013 provide a more representative picture of the distribution of dolphins in the study area. The survey lines and encounters with groups of bottlenose dolphins are shown in Figures 14 and 15 for those five years. Following the pattern of the previous years, most encounters occurred in the Tay Estuary, from its outer entrance, in waters approximately 15 meters deep, following the sand bar that is exposed at low tide off the north east end of Tentsmuir forest, all the way to Tayport. Between 2009 and 2011 dolphins were also encountered along the coast between Arbroath and Montrose, but only a few groups were encountered in St Andrews Bay, next to the entrance to the Tay (Figure 14). Survey effort was increased in 2012 and 2013 with a larger number of data collection trips, and also extended to include the Firth of Forth. However, most encounters still occurred at the entrance of the Tay and along the sand bar (Figure 15). Bottlenose dolphins were also encountered in St Andrews Bay, although the number of groups encountered was not as large as in the Tay. Dolphins were often encountered along the coast between Arbroath and Lunan Bay, (the large bay south of Montrose), as well as around Montrose. In the Firth of Forth, dolphins were only seen on the north side of the Forth, mostly between Anstruther and Fife Ness. All the groups were encountered within one kilometre of the coast (Figure 15).

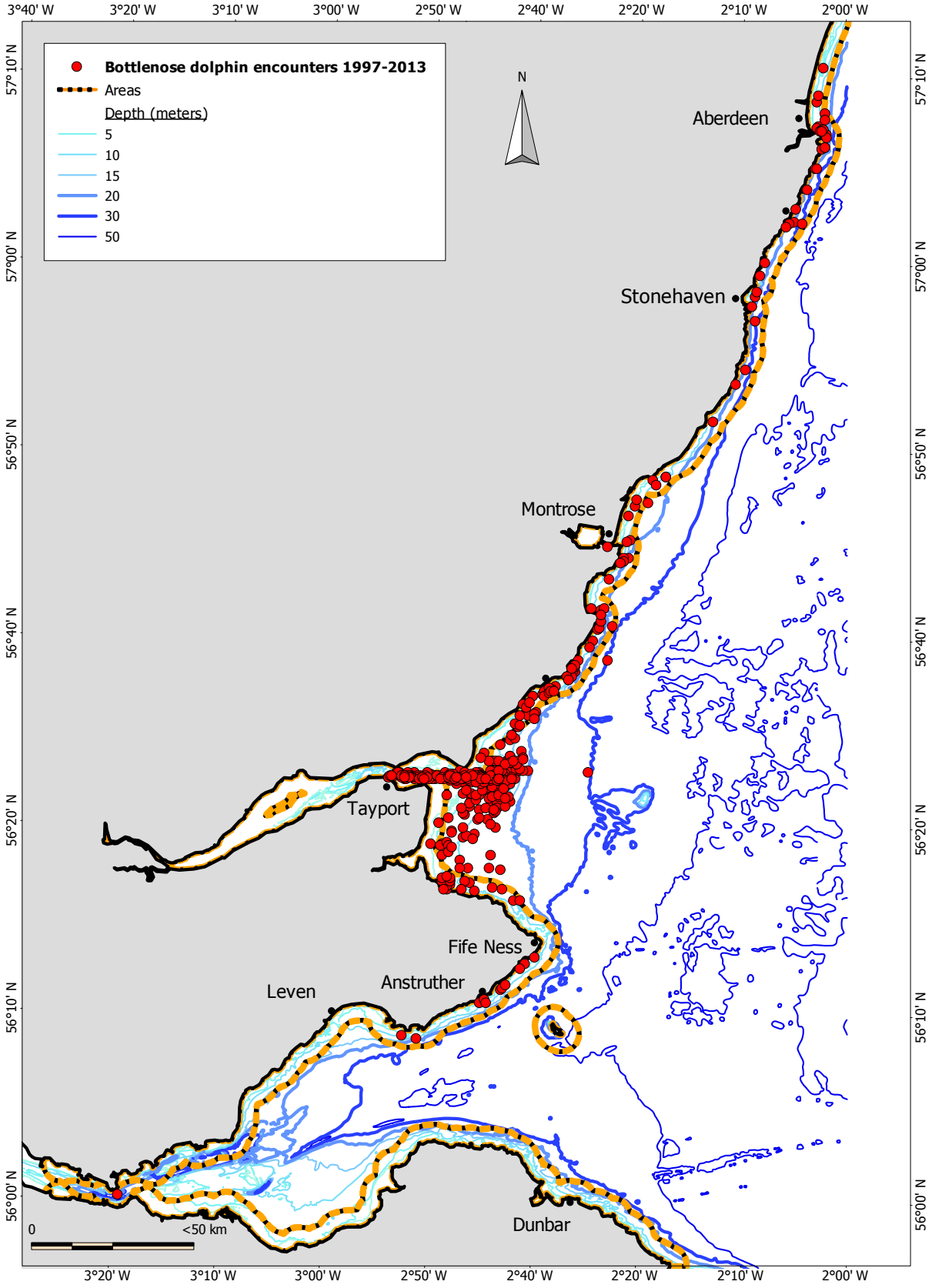

Figure 13: Encounter locations from all years 1997-2013 between Aberdeen and the Firth of Forth.

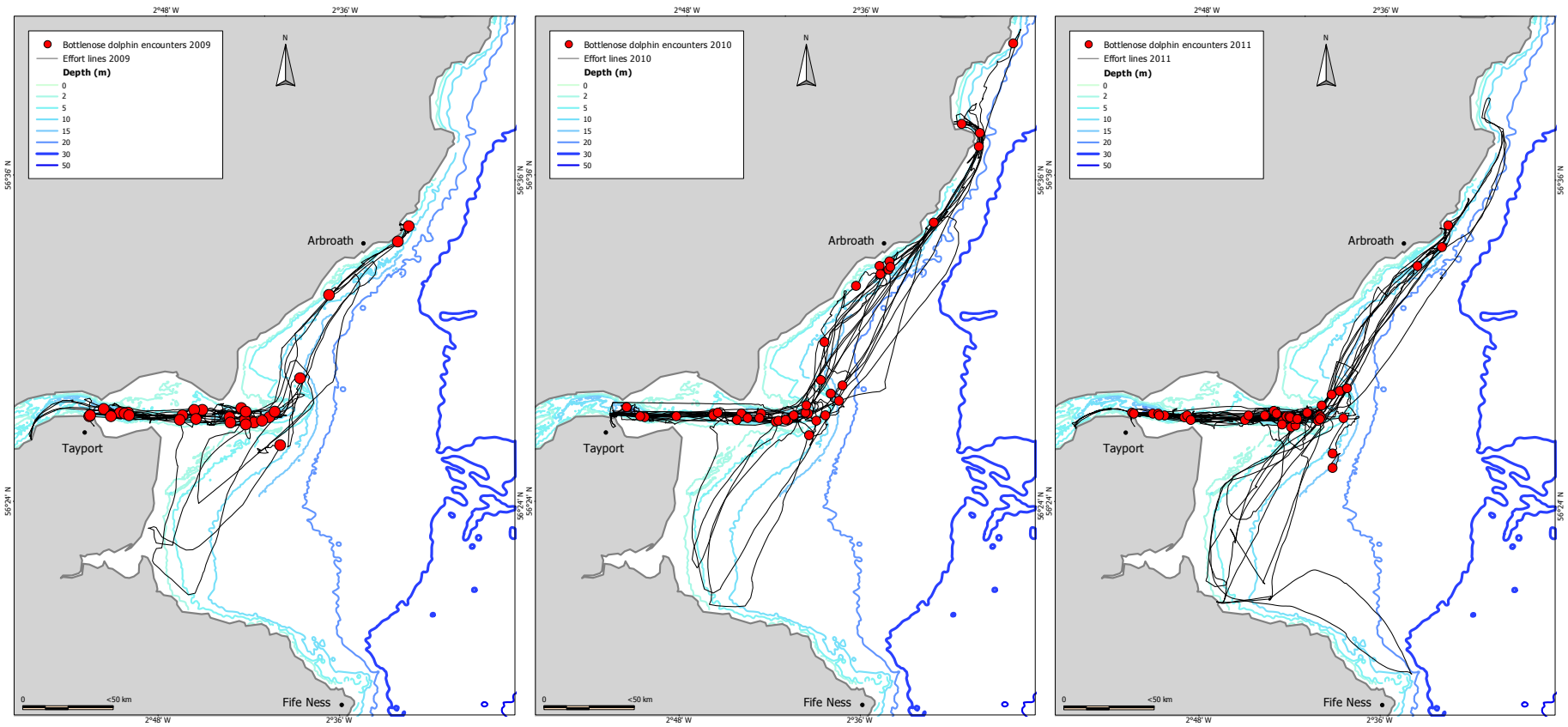

Figure 14: Encounter locations and survey effort in the Firth of Tay and St Andrews Bay in 2009, 2010 and 2011.

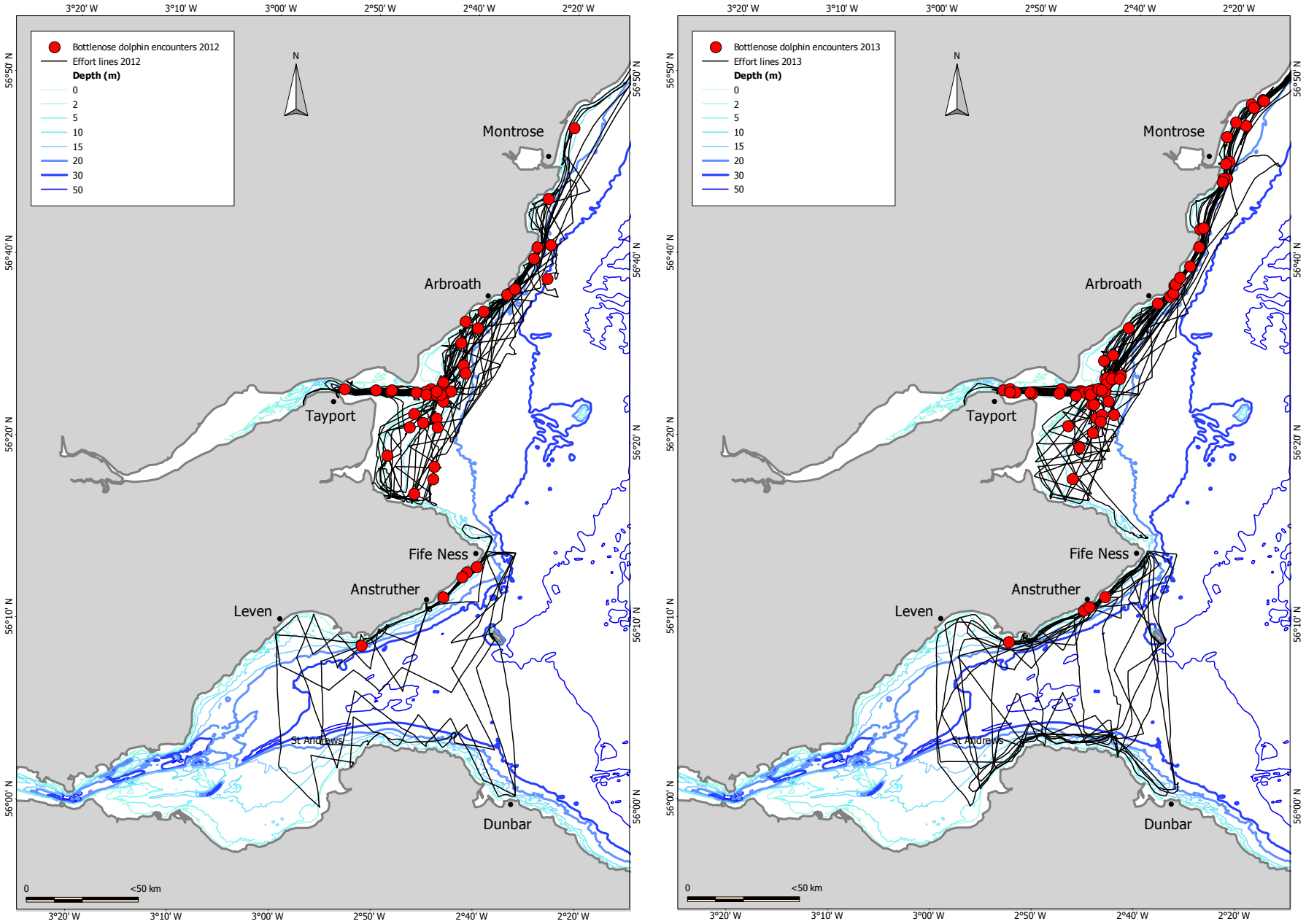

Figure 15: Encounter locations and survey effort between Montrose and the Firth of Forth in 2012 and 2013.

Relative encounter rate

A more informative but still simplistic analysis of these data is to calculate a surface of the index of encounter rates per km^2; that is, a relative abundance surface. The index can be calculated by dividing the number of encounters by the number of effort lines (i.e. the number of times the boat was present whilst on effort) in every 1 km^2 cell in a grid. This provides a surface with more spatial resolution over the area studied. We used systematic boat survey data in the Tayside area collected in 2003 and 2004 (Figures 16 and 17) and data collected between Aberdeen and the Firth of Forth for the time period 2009 to 2013 (Figures 14 and 15). For each of these datasets we generated the encounter rate per km^2 (Figures 18 and 19)

Based on data from 2003 and 2004, it is clear that survey effort did not take place over the entire area within the red polygon (Figure 16) and hence each cell of the km^2 grid was not surveyed by the same length of track each time. However, the density surface of relative encounter rates (Figure 18) does show a pattern consistent with more recent data shown in Figure 19, where higher encounter rates of bottlenose dolphins occur within and at the entrance of the Tay estuary.

Based on data from 2009 to 2013, and in accordance with the results from 2003-2004, high encounter rates occurred at the entrance of the Tay Estuary (Figure 19). The coastal waters between Arbroath and north of Montrose, around Aberdeen and off the north side of the Forth also showed relatively high encounter rates of bottlenose dolphin groups.

Comparison of these two datasets suggests that the entrance to the Tay estuary has consistently high encounter rates of bottlenose dolphins over the years.

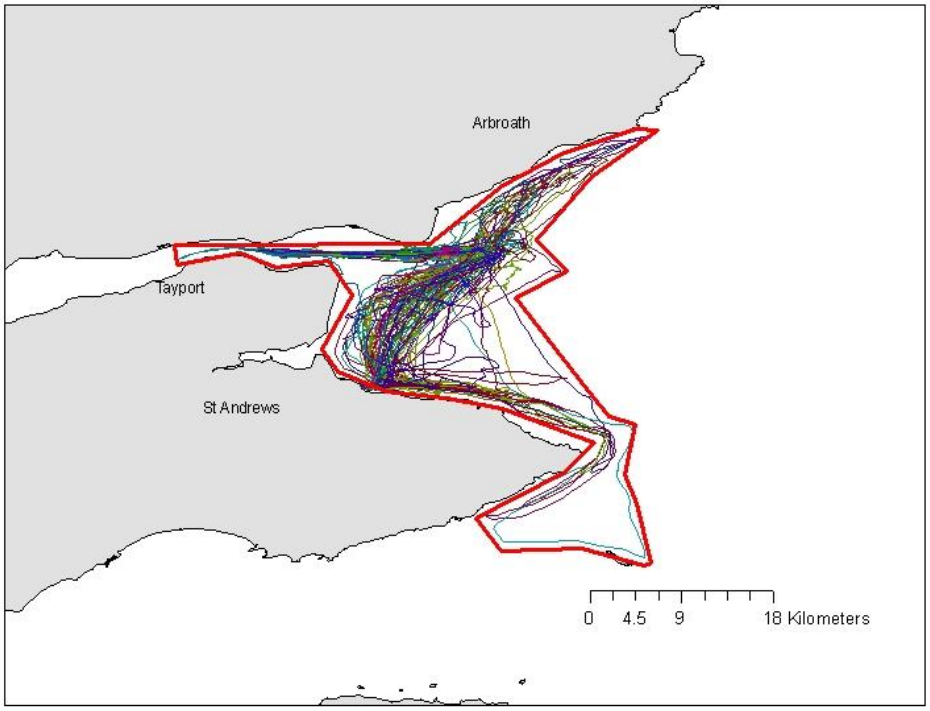

Figure 16: Effort from all 42 trips from 2003 and 2004. Red outline shows the area of the defined polygon used to generate the area for the density estimate.

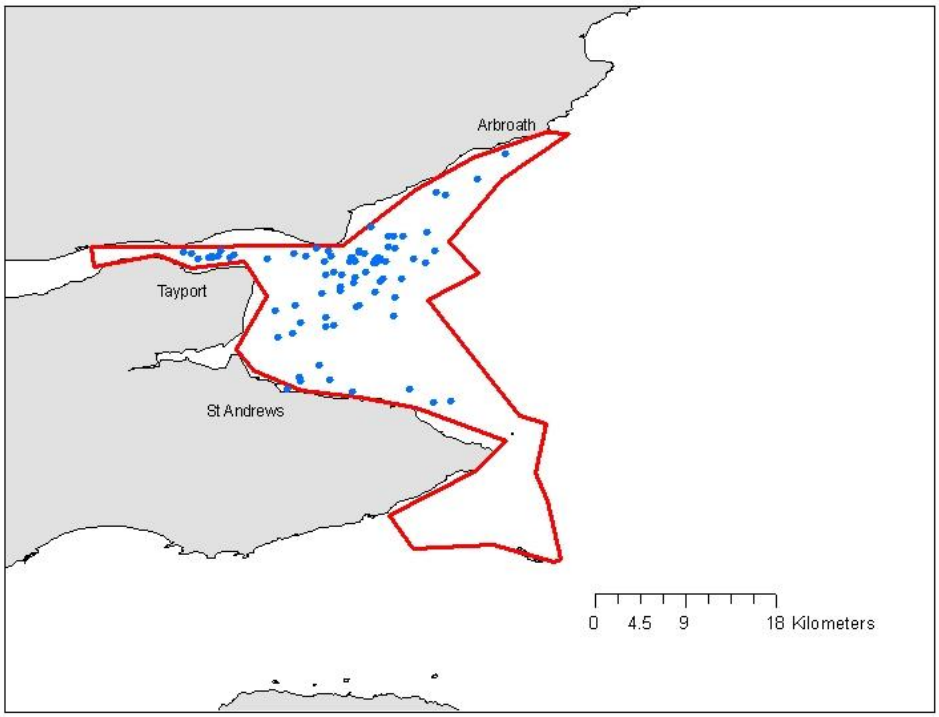

Figure 17: All encounter locations from 2003 and 2004 shown in blue. Red outline shows the area of the defined polygon used to generate the area for the density estimate.

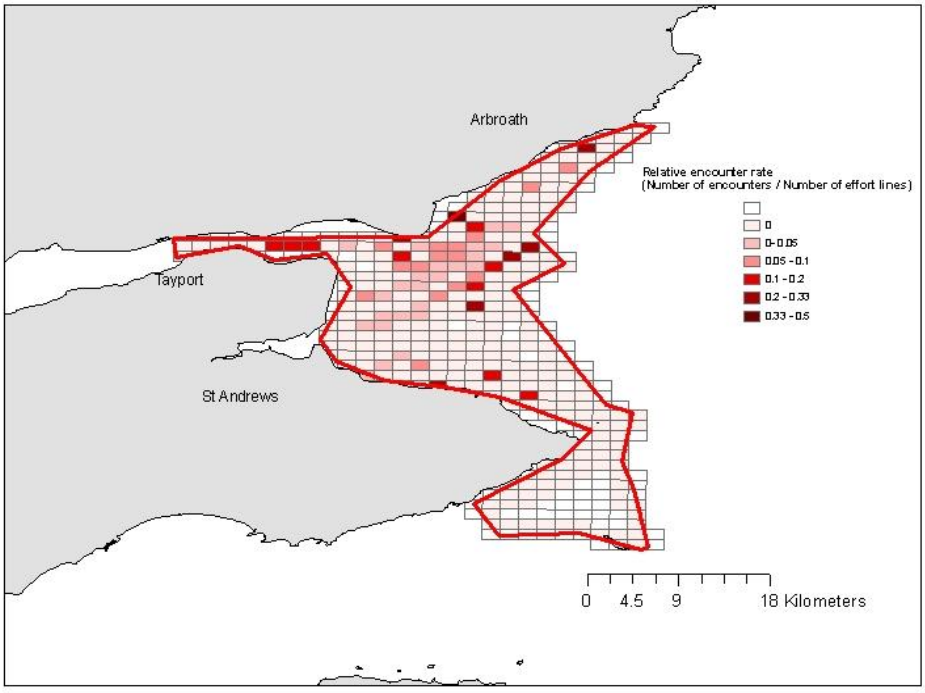

Figure 18: Surface of relative encounter rates, showing areas of higher density of encounters of bottlenose dolphins.

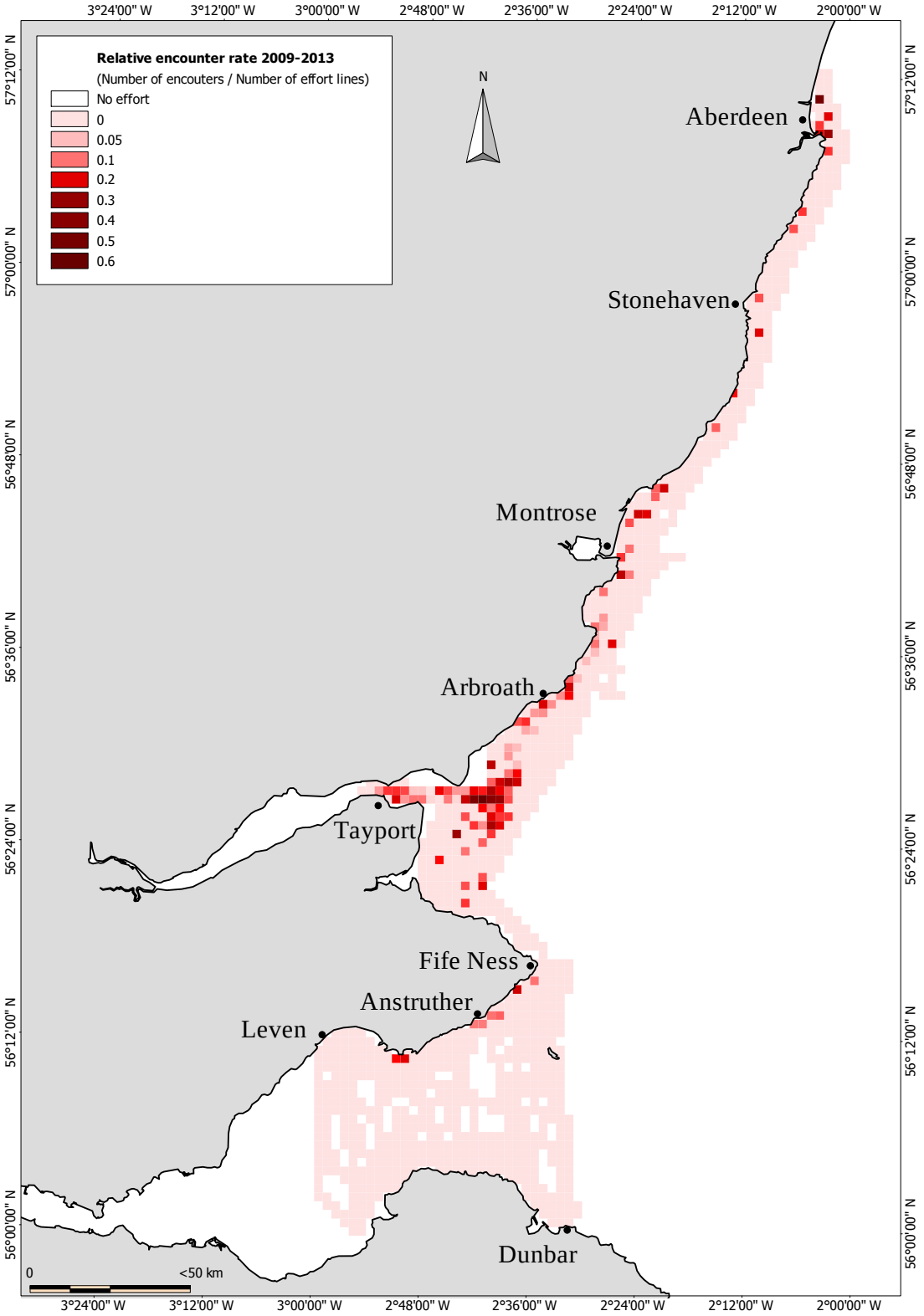

Figure 19: Relative encounter rates from dedicated photo-identification surveys (2009-2013).

SECTION 5

Distribution and abundance of animals off Aberdeen Harbour and adjacent waters

Data on the distribution of bottlenose dolphins at Aberdeen and surrounding waters are available from dedicated surveys conducted in 2008 by the University of Aberdeen Lighthouse Field Station and the University of St Andrews as part of a Scottish Government project (Thompson et al. 2011). Additionally, and as part of the current project, dedicated surveys were conducted in 2012 and 2013 in the same area.

Survey effort and distribution of encounters in 2008, 2012 and 2013

Twenty surveys were conducted between February and April 2008 covering the Grampian coast between Peterhead and Montrose (Thompson et al. 2011) (Table 9 and Figure 20). Animals were seen on 11 trips, during which dolphins were encountered on 19 different occasions. Encounters were spread along the coast from Aberdeen to south of Stonehaven, generally within 2 km from the coast line, and group sizes ranged between 1 and 17 individuals (mean of 8 individuals).

Between May and September 2012 and 2013 a total of 10 trips were conducted between St Andrews Bay and Aberdeen. In two trips, bad weather conditions prevented the boat from reaching Stonehaven and Aberdeen. Bottlenose dolphins were encountered on seven out of the other eight trips that covered the area between Stonehaven and Aberdeen. As in the surveys in 2008, the animals were encountered close to the coast, with group sizes ranging between 2 and 18 animals (mean of 10 individuals) (Table 9 and Figure 21).

In all three years bottlenose dolphins were often encountered at the entrance of Aberdeen harbour and adjacent waters. In 2008, eight groups of bottlenose dolphins were encountered around the harbour representing 42% of the total number of groups encountered between Stonehaven and Aberdeen in that year (Figure 20). In 2012, one group was encountered off the beach north from the north pier in Aberdeen Bay, and another group was encountered just south of Aberdeen harbour, past Nigg Bay (Figure 21). Together, these encounters represented 50% of the total number of groups encountered in 2012 between Stonehaven and Aberdeen. In 2013, seven groups of dolphins were found around Aberdeen, four groups at the entrance of the harbour and another three groups in Aberdeen Bay off the beach, together representing 77% of all encounters between Stonehaven and Aberdeen in 2013 (Figure 21). To give a more detailed description of the use of the area by the bottlenose dolphins encountered in 2012 and 2013, the track lines while following the groups of animals encountered have been also plotted (Figure 21).

Group sizes varied between encounters over the three years, ranging between 4 and 18 individuals on average per trip, with an overall mean group size of 10 individuals (Table 9).

Table 9: Summary of the photo-ID surveys carried out during 2008, 2012 and 2013 between Stonehaven and Aberdeen. Survey time, number and time of bottlenose dolphin encounters and mean group size are given.

Trip #	Year	Date	Survey time (hrs)	No. Enc	Time on Enc (hrs)	Mean group size
1023	2008	10-Feb-08	3.47	0	-	-
1024	2008	12-Feb-08	5.83	0	-	-
1026	2008	13-Feb-08	3.25	0	-	-
1027	2008	14-Feb-08	6.40	0	-	-
1030	2008	19-Feb-08	4.67	0	-	-
1031	2008	28-Feb-08	4.38	4	1.62	5.5
1032	2008	02-Mar-08	5.33	0	-	-
1033	2008	03-Mar-08	5.28	0	-	-
1062	2008	11-Mar-08	1.63	1	1.17	12
1063	2008	15-Mar-08	5.50	0	-	-
1064	2008	17-Mar-08	4.08	2	1.05	5.5
1065	2008	19-Mar-08	3.82	1	0.67	8
1066	2008	26-Mar-08	4.58	2	1.10	13.5
1068	2008	30-Mar-08	4.48	1	1.72	15
1069	2008	31-Mar-08	5.52	3	1.00	4.6
1070	2008	03-Apr-08	5.50	1	1.00	9
1071	2008	04-Apr-08	8.17	2	2.48	7
1072	2008	08-Apr-08	2.85	0	-	-
1073	2008	09-Apr-08	5.00	1	1.15	15
1077	2008	14-Apr-08	3.53	1	0.67	10
All	**2008**		**93.27**	**19**	**13.63**	**9.5**
1467	2012	14-Jul-12	9.77	1	0.77	8
1476	2012	08-Aug-12	8.72	1	1.10	18
1484	2012	20-Sep-12	9.17	2	0.37	11
All	**2012**		**27.66**	**4**	**2.24**	**12.3**
1502	2013	09-Jun-13	9.2	2	0.98	9
1509	2013	25-Jun-13	9.08	3	0.87	4.3
1513	2013	09-Jul-13	10.8	2	1.12	8.5
1516	2013	18-Jul-13	11.18	2	1.08	16
1525	2013	13-Aug-13	7.53	0	0	-
All	**2013**		**47.79**	**9**	**4.05**	**9.45**
Overall (2008 and 2012-13)			**168.72**	**32**	**19.92**	**9.99**

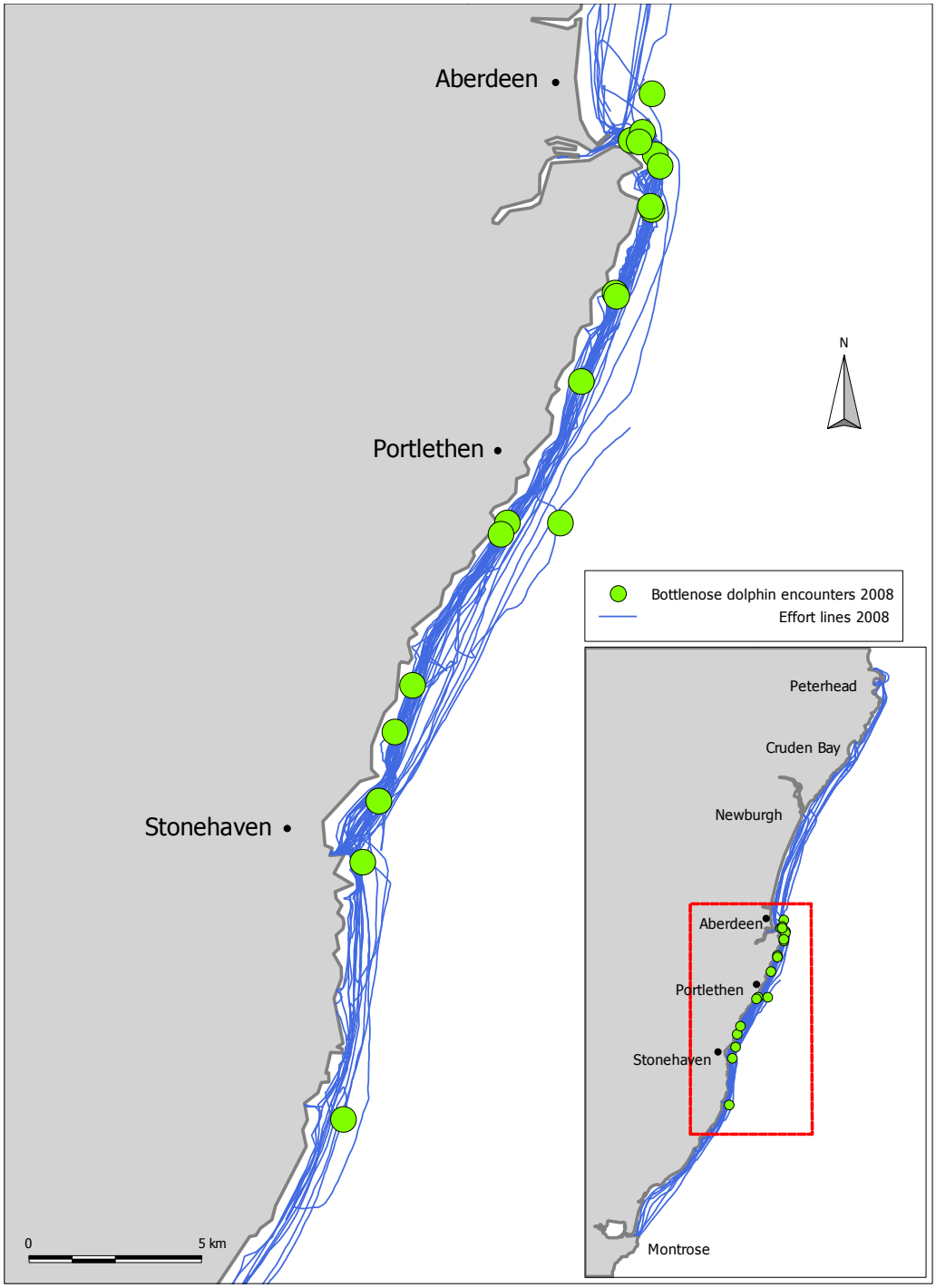

Figure 20: Survey effort along the Grampian coast in 2008 and starting locations for all bottlenose dolphin encounters.

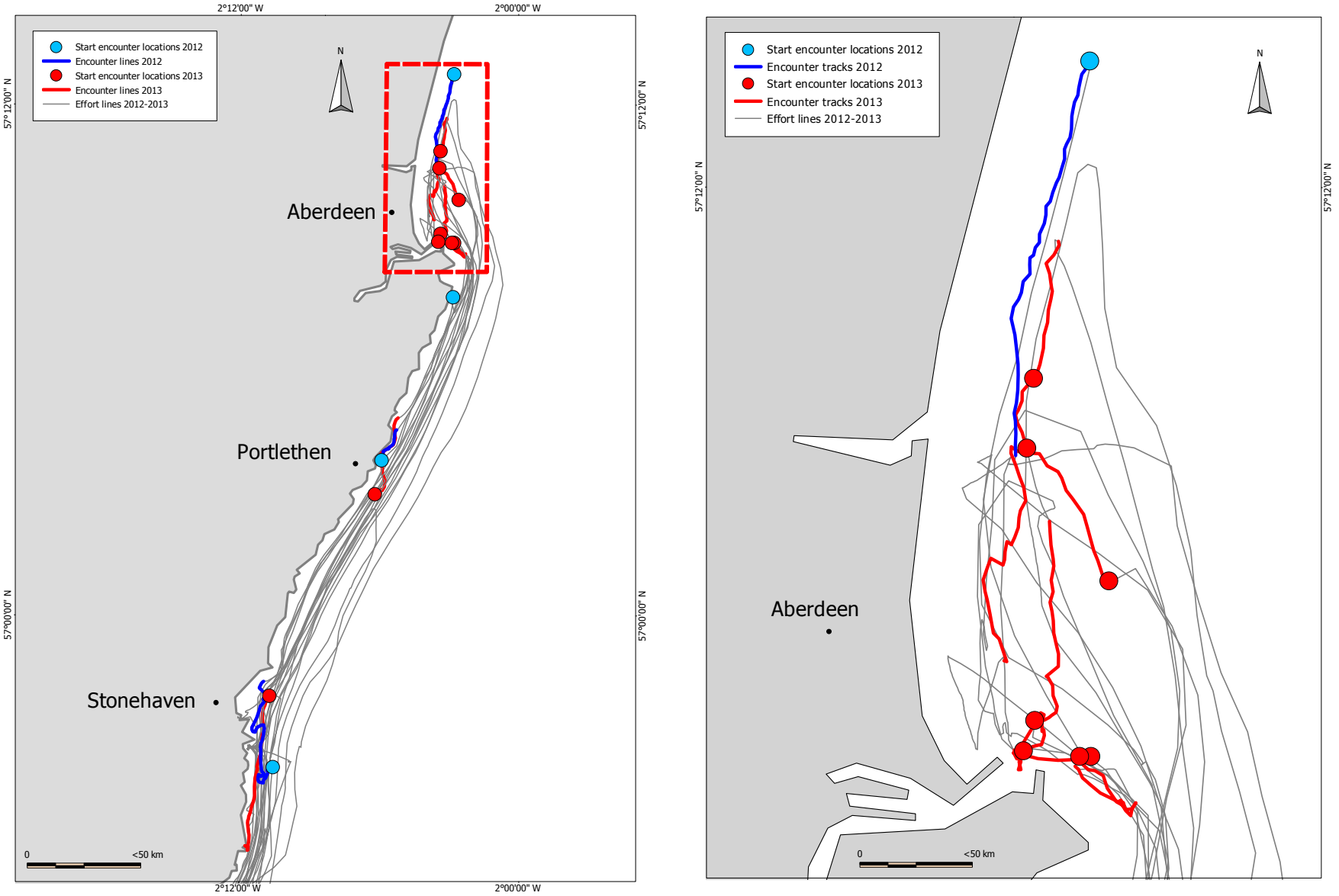

Figure 21: Survey effort and bottlenose dolphin encounters off the Grampian coast in 2012 and 2013. Starting locations of each encounter and boat tracks conducted whilst following the animals are shown (2012=blue; 2013=red) (left panel). The right panel shows the area of Aberdeen Harbour in detail.

Photo-identification of individuals

All photographs taken during the encounters with bottlenose dolphins between Stonehaven and Aberdeen in 2008, 2012 and 2013 were graded for photographic quality and individuals were identified and matched to the catalogue of individually photo-identified individuals maintained by the University of Aberdeen Lighthouse Field Station.

In 2008, 2,518 photographs were taken from which 56 individuals could be identified from high quality photographs. In 2012, 661 photographs were taken, allowing the identification of 17 different individuals. In 2013, a total of 656 photographs were taken from which 27 different individuals were identified. Over the three years, 79 identifiable individual dolphins (i.e. animals with enough natural marks to be matched to the existing catalogue of bottlenose dolphins for this population) were encountered in the waters between Stonehaven and Aberdeen (Figure 22). Thirteen of the individuals seen in 2008 were encountered again in the same area in 2012 or 2013, representing greater than 16% of the total number of dolphins encountered across the three years. Three individuals were seen in all three years and eight individuals were seen in both 2012 and 2013.

Based on observations in the field and on the photographs taken during the trips in 2012 and 2013, reproductive females with calves under the age of 3 years were often encountered in the groups. In 2012 they were present in 50% of the encountered groups, and in 2013 in greater than 75% of the encountered groups. Various types of behaviour were observed including travelling, characterized by a tight group formation with synchronised surfacing, swimming close to the coast in a north-south or south-north direction; feeding behaviour was inferred from observation of individuals performing deep dives spread over an area, including between both piers at the entrance to Aberdeen harbour. On occasion dolphins were seen chasing fish out of the water or with fish in the mouth. Socialising behaviour was also observed along the coast, with aerial displays and a high level of physical contact between individuals.

ID #	2008	2012	2013
1	■		■
4	■		
8	■		
42	■		
49	■		■
52	■		
60	■	■	■
61	■		
102	■		
129	■	■	
157	■		
209	■	■	
210	■		
227		■	
234	■		
435			■
745	■		
769	■		
773	■		■
788	■		
805	■		
809	■		
832			■
872	■		
880	■		
881	■		
882	■		
885	■		
886	■		
901	■		
903	■		
908	■	■	■
932	■		
964	■		
970	■		
985			■
985 calf			■
990	■		
993	■		
999	■		■

ID #	2008	2012	2013
1000	■	■	■
1001	■		
1002	■		
1006	■		
1007	■		
1008	■		■
1011		■	■
1012			■
1013			■
1015	■	■	
1026			■
1027	■		
1029	■		
1031	■	■	
1033	■		
1034	■		
1035	■		
1036	■		
1037	■		
1038	■		
1039	■		■
1040	■		
1041	■		
1045	■		
1055			■
1061		■	
1062	■		
1076			■
1095			■
1100		■	■
1101		■	■
1102		■	
1104		■	
1105			■
1117		■	■
1138		■	
1145			■
1147			■
1153		■	■
Total	**56**	**17**	**27**

Figure 22: Bottlenose dolphin individuals photo-identified in 2008, 2012 and 2013 between Stonehaven and Aberdeen.

Based on high quality photographs from the 2012 and 2013 trips, we investigated whether the individuals identified between Stonehaven and Aberdeen had also been sighted in other areas of the distributional range of the population (Moray Firth SAC or in the Tay and St Andrews Bay) in those two years (Table 10). In 2012, two individuals were sighted between Stonehaven and Aberdeen and nowhere else, five were also sighted in the Moray Firth SAC and ten in the Tay and St Andrews Bay. In 2013, only three individuals were sighted only between Stonehaven and Aberdeen, while another eight were also sighted further south in Montrose. Eleven individuals were also sighted in the Tay and St Andrews Bay and another four in the Moray Firth SAC. Only one individual was sighted in all three areas in either year. The individuals identified between Stonehaven and Aberdeen in 2012 and 2013 had been seen in other parts of the distributional range in previous years.

Despite the limited amount of data and number of years, these observations reflect the variability in the individual ranges of the dolphins in the population. They also suggest the importance of the area between Aberdeen and Stonehaven both as a transiting area between the most distant extremes of the population's range as well as a commonly used area within the year and across years by part of the population.

Table 10: Re-sighting history of identified dolphins between the different areas in 2012 and 2013. Areas include Stonehaven to Aberdeen, Tay and St Andrews Bay, and Moray Firth SAC.
* Another 8 individuals seen between Stonehaven and Aberdeen were also seen at Montrose.

Areas sighted	Number of individuals	
	2012	2013
Stonehaven to Aberdeen only	2	3
Stonehaven to Aberdeen & Tay and St A Bay	10	11
Stonehaven to Aberdeen & Moray Firth SAC	5	4
All three areas	0	1
Total	17	19 *

Abundance of dolphins using the area between Stonehaven and Aberdeen

To estimate the abundance of bottlenose dolphins using the area between Stonehaven and Aberdeen in the years of 2012 and 2013, mark-recapture analyses were applied to the photo-identification data collected over the two year period. The high number of recaptures between and within years allowed the use of mark-recapture analysis methods despite the limited number of trips available for those years.

To avoid biasing mark-recapture estimates of abundance, only high quality photographs from well-marked individuals were used, i.e. those with nicks in their dorsal fin. A capture matrix was constructed to represent whether or not each individual was sighted in each of the trips over the two years. The individual capture histories were then used to estimate the number of well-marked individuals using the area over the two year period. We used program CAPTURE (Rexstad and Burnham 1991), implemented within program MARK (White and Burnham 1999), to determine the

most appropriate closed population model to estimate abundance. Then, the proportion of well-marked animals (θ) in each group encountered between Stonehaven and Aberdeen in 2012 and 2013 was used to obtain a mean θ to inflate the abundance estimate from CAPTURE to obtain a single estimate of total abundance of bottlenose dolphins using the area between Stonehaven and Aberdeen in 2012 and 2013.

After selecting the data, the capture histories of 19 well-marked individuals seen over seven capture occasions (three trips in 2012 and four trips in 2013) were analysed in CAPTURE. The model *Mh* (*Jacknife*) was selected as the most appropriate one for these data based on the model selection within program CAPTURE, and estimated an abundance of 31 well-marked individuals (CV=0.21, 95% CI 24 to 51 individuals) (Table 11). The presence of heterogeneity in capture probabilities (i.e. not all individuals have the same probability of being encountered and photographed in each occasion) was further investigated by fitting a closed population model with two mixtures (Pledger 2000) in program MARK (White and Burnham 1999). The results indicated that approximately 25% (mixture proportion = 0.256; SE=0.11) of the individuals using the area between Stonehaven and Aberdeen in 2012 and 2013 had a higher probability of being seen compared to the other 75% of the individuals. These results suggest that a relatively high proportion of individuals use this area more regularly than others, which is in accordance with the re-sighting rates of individuals between 2008 and the period 2012-13 as well as between and within 2012 and 2013.

The total abundance of animals using the area between Stonehaven and Aberdeen in the years 2012 and 2013 was estimated as 53 individuals (CV=0.23; 95% CI = 34 to 83 individuals), after inflating the estimate of well-marked individuals by the estimated proportion of well-marked animals of 0.58 (CV=0.09) (Table 11).

The most recent estimate of abundance of the Scottish east coast bottlenose dolphins is 195 individuals (95% HPDI: 162-253) (Cheney et al. 2013). Based on this information, our results from the 2012 and 2013 data suggest that greater than 25% of the estimated population used the area between Stonehaven and Aberdeen in 2012 and 2013.

Table 11: Results of the mark-recapture analysis including Occasions = number of sampling occasions; Marked inds = number of well-marked individuals; $\widehat{\boldsymbol{\theta}}$ = proportion of well-marked individuals (with associated coefficient of variance (CV)); $\widehat{\mathbf{N}}$ = abundance estimate for the well-marked population (with associated standard error (SE), coefficient of variation (CV) and 95% Confidence interval (95% CI)); and $\widehat{\mathbf{N}}_{\mathbf{t}}$ = abundance estimate for the total number of individuals using the study area (with associated standard error (SE), coefficient of variation (CV) and 95% Confidence interval (95% CI)).

			Model *Mh* estimates						Total abundance estimates			
Period	**Occasions**	**Marked inds**	$\widehat{\boldsymbol{\theta}}$	**CV($\widehat{\boldsymbol{\theta}}$)**	$\widehat{\mathbf{N}}$	**SE($\widehat{\mathbf{N}}$)**	**CV($\widehat{\mathbf{N}}$)**	**95% CI ($\widehat{\mathbf{N}}$)**	$\widehat{\mathbf{N}}_{\mathbf{t}}$	**SE($\widehat{\mathbf{N}}_{\mathbf{t}}$)**	**CV($\widehat{\mathbf{N}}_{\mathbf{t}}$)**	**95% CI ($\widehat{\mathbf{N}}_{\mathbf{t}}$)**
2012/13	7	19	0.58	0.09	31	6.64	0.21	24-51	53	12	0.23	34-83

SECTION 6

Survival and calving rates of the east coast of Scotland bottlenose dolphin population

Data to estimate survival and calving rates

This analysis used data collected off the east coast of Scotland from 1989 to 2012 by the University of Aberdeen and the University of St Andrews as part of numerous projects. Full details of survey methodologies can be found in Wilson et al. 1997, 2004; Quick 2006; Islas-Villanueva 2010. Photo-identification effort varied across years in terms of areas surveyed and number of survey days. From 1989 to 1995 effort was mainly concentrated in the Moray Firth SAC. Since 1996, effort was gradually extended south along the coast. In 2012, some effort also occurred in the Firth of Forth (Figure 23). Most surveys occurred during the summer months of May to September with the number of trips varying among years and areas (Table 12). Collection of photo-identification data during the winter months only took place intermittently and these data were not included in this analysis.

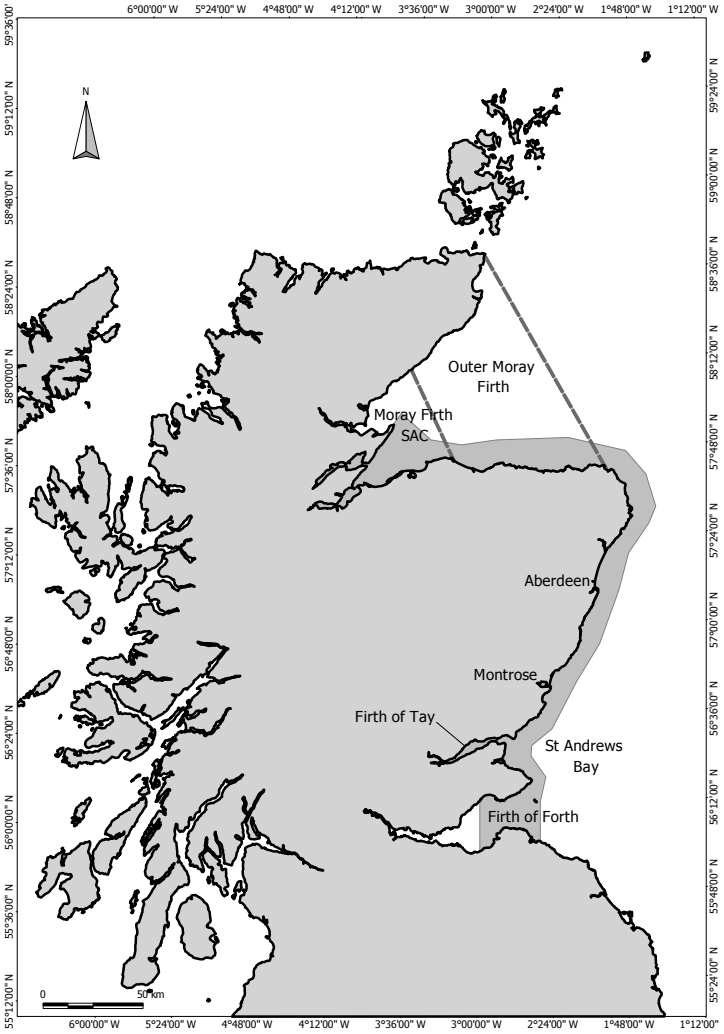

Figure 23: Map showing the areas of survey effort (shading) off the east coast of Scotland.

Table 12: Summary of annual survey effort from 1989 to 2012. Details are given for the method used to photograph the animals (S= 35 mm slides, D=digital photography), the total number of effort days, the number of effort days per area (SAC=Moray Firth SAC, OF=Outer Firth, G=Grampian, T=Tayside & Fife), and the number of newly and total well-marked animals captured.

Year	Sampling period	Method	Total effort days	Effort days by area				Total captured	Newly captured
				SAC	OF	G	T		
1989	02 Jul - 02 Sep	S	8	8	0	0	0	42	42
1990	03 May - 14 Aug	S	21	21	0	0	0	47	13
1991	17 May - 12 Sep	S	48	45	3	0	0	37	6
1992	14 May - 24 Sep	S	51	40	9	2	0	51	6
1993	02 May - 23 Sep	S	30	26	3	0	0	36	5
1994	02 Jun - 24 Sep	S	52	31	19	2	0	36	2
1995	12 May - 20 Sep	S	53	42	7	1	0	47	6
1996	07 May - 05 Sep	S	33	19	8	6	0	39	5
1997	24 May - 24 Sep	S	23	14	4	0	5	26	2
1998	18 May - 22 Sep	S	17	14	1	0	2	28	2
1999	01 May - 22 Sep	S	21	15	0	0	6	34	6
2000	01 May - 19 Sep	S	18	10	0	0	8	34	5
2001	01 May - 17 Sep	D	39	35	1	0	3	72	20
2002	01 May - 09 Sep	D	65	30	25	0	10	65	8
2003	01 May - 28 Sep	D	29	28	1	0	29	74	10
2004	02 May - 11 Sep	D	100	58	42	0	13	87	7
2005	03 May - 17 Sep	D	128	74	54	0	0	54	1
2006	04 May - 25 Sep	D	155	87	68	0	18	84	8
2007	02 May - 28 Sep	D	142	102	39	0	20	82	5
2008	06 May - 26 Sep	D	180	84	70	20	6	41	1
2009	02 May - 30 Sep	D	116	33	72	0	10	89	13
2010	05 May - 21 Sep	D	74	19	47	0	8	95	6
2011	03 May - 29 Sep	D	31	18	3	0	10	88	2
2012	02 May - 27 Sep	D	41	18	1	3	19	101	10

Population survival rate

Data from individuals identified from both 35-mm slides (from 1989 to 2000) and digital photographs (from 2001 to 2012) were used in this analysis. High quality photographs were used for the identification of individual dolphins and each individual was matched to the existing catalogue of identifiable individuals. Only individuals with long-lasting nicks on the trailing edge of the dorsal fin were considered well-marked and thus included in the analysis. The sighting histories of 190 well-marked individuals were included, based on high quality pictures taken during 959 field days from 7,189 individual sightings. The number of individuals identified per year varied, ranging between 26 and 101 individuals (Table 12 and Figure 24). Capture frequencies varied among individuals, with one individual sighted every single year, and 38 (20%) individuals only sighted in 1 year (Figure 25).

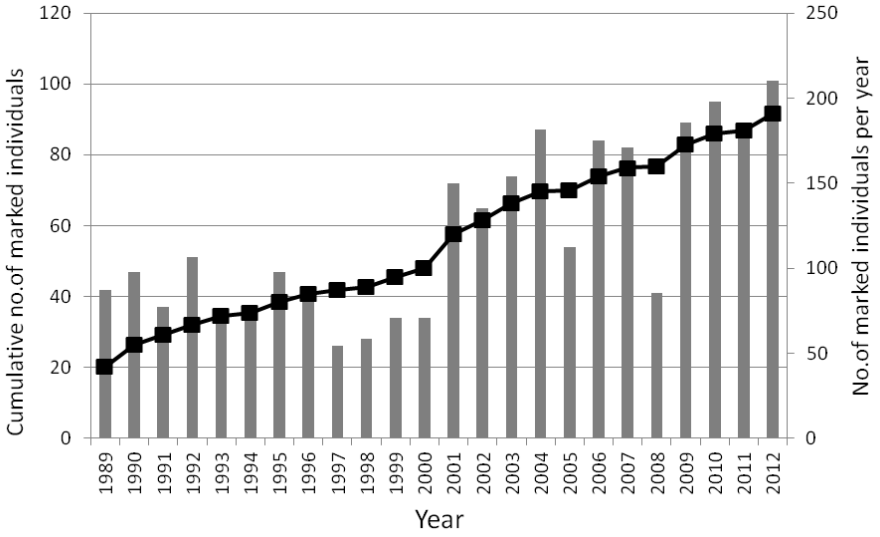

Figure 24: Number of well-marked individuals identified by year and cumulative number of well-marked individuals (black line).

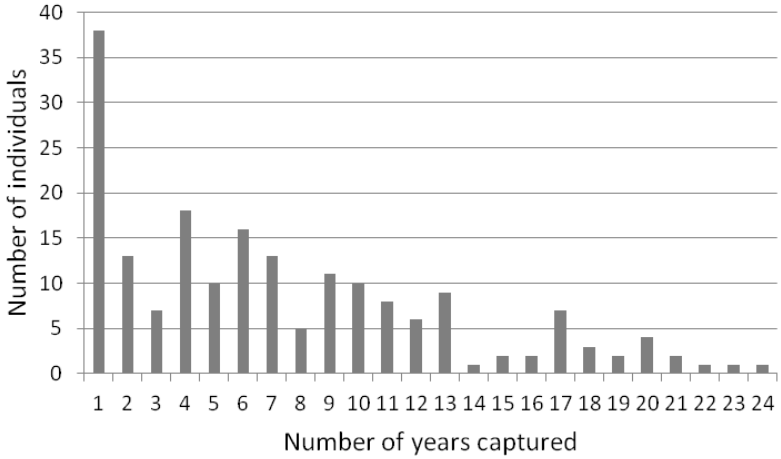

Figure 25: Distribution of capture frequencies of well-marked individuals.

Previous studies have shown that the east coast of Scotland bottlenose dolphin population expanded its distributional range in the mid-1990s (Wilson et al. 2004). To estimate survival rate we

used photo-identification data collected between 1989 and 2012 (Table 12) that encompassed changes in the population's range and in sampling effort throughout the study period. We selected robust design (RD) (Pollock 1982, Kendall et al. 1995, 1997) models to estimate annual survival rates. These models account for heterogeneity or differences in capture probabilities (i.e. the probability of capturing an animal in a photograph) that occur when individuals have different ranging patterns and may not always be present in the area where data collection is taking place. The models were fitted to high quality photo identification data for all individuals regardless of their sex or age to estimate annual apparent survival, annual temporary emigration, and capture/recapture probabilities.

The models were implemented in software MARK (White & Burnham 1999), specifying a range of different parameters to account for different types of heterogeneity in capture probabilities. Each model received a score based on the Akaike Information Criterion (Akaike 1973) adjusted for small samples (AICc) (Burnham & Anderson 2002), and the model with the lowest score was selected as having the most support from the data.

The probability of apparent survival for the study period was estimated to be 0.947 (SE=0.005) based on the best fitting model. This means that an individual had, on average, a 94.7% chance of surviving between consecutive years during the period 1989-2012. Thus, conversely, an individual had, on average, a 5.3% chance of dying or permanently emigrating between years during this period. Capture probabilities varied among and within years; averaged annual capture probabilities ranged between 0.170 (SE=0.120) and 0.762 (SE=0.151). The probability of emigrating temporarily between years from the study area was generally low, especially from the late 1990s onwards when effort was extended outside the Moray Firth and so covered more of the population's range. Exceptions to this low level of temporary emigration were 2005 and 2008 when no sampling effort occurred outside the Moray Firth and animals spending time in this area were unavailable for sampling (Figure 26). The results on temporary emigration since sampling extended outside the Moray Firth are thus consistent with a population showing a high degree of residency and indicate little evidence of transient or temporary emigrants.

Our estimate of apparent survival is similar to the survival estimates previously reported for this population (0.942, SE=0.015; Sanders-Reed et al. 1999, and 0.93, SE=0.029; Corkrey et al. 2008), and at the lower end of the range reported for other populations of bottlenose dolphins (e.g. Currey et al. 2009, Silva et al. 2009, Nicholson et al. 2012). However, this may be because our study included sub-adults which are characterized by a lower survival rate, whereas the other studies reported adult survival rate.

The bottlenose dolphin population off the east coast of Scotland is estimated to be a relatively small (195, 95% HPDI: 162-253; Cheney et al. 2013) and isolated from other conspecifics. Survival rates have a high impact on the population dynamics of marine mammals. Adult survival rate in long-lived mammals, including this population, is the demographic parameter with the greatest effect on population growth rate (Sanders-Reed et al. 1999). Any decrease in survival rate in this population in the future could therefore lead to and be an indicator of a decline in the population's growth rate, compromising its conservation. The survival rate estimated here provides robust baseline information for the future long-term monitoring of the population, which could be used in consenting decisions regarding potential threats to this population of bottlenose dolphins.

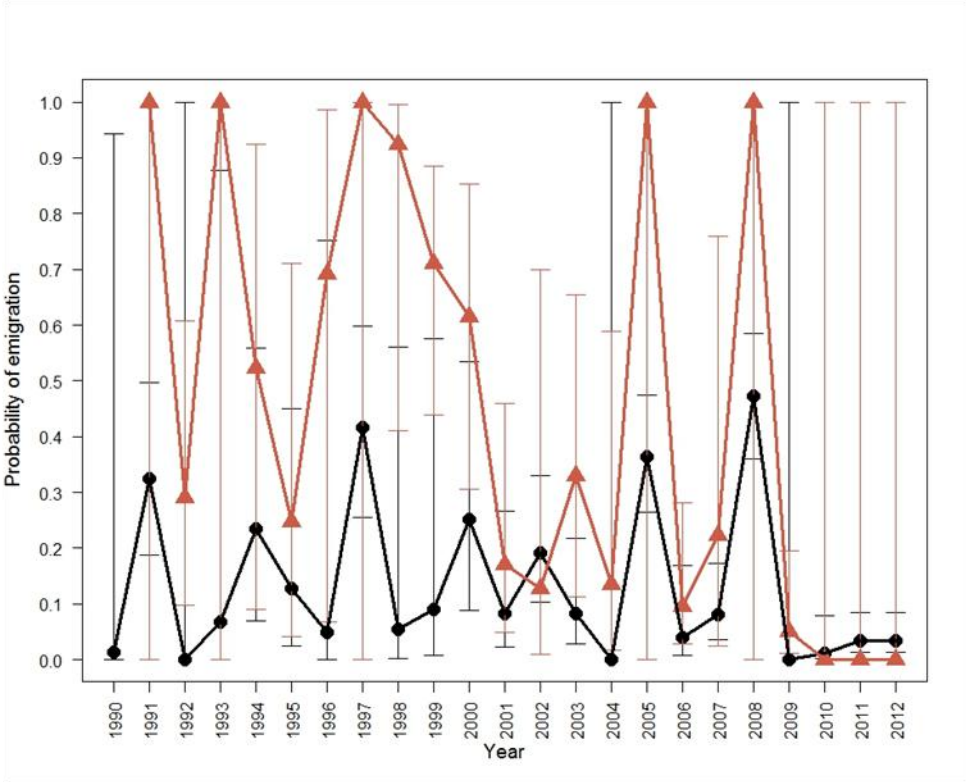

Figure 26: Temporary emigration probabilities estimated from the best-fitting robust design model. The model uses the sighting histories between years to estimate the probability of temporarily emigrating for animals that were in the study area in the previous year (black) and for animals that were outside the study area in the previous year (red). Bars are 95% confidence intervals.

Inter-birth intervals and fecundity rate

To estimate reproductive parameters we used photo-identification data collected from 1989 to 2012. Calves were identified in the field based on their appearance and close association with an adult dolphin. Calves are small and have substantially paler skin than sub adults or adults. The level of association with the mother can vary from 3 to at least 8 years in this population and is consistently high for the first 3 years of life (Grellier et al. 2003). Young of the year (i.e. calves in their first year after being born) have a characteristic head out surfacing behaviour when newly born and show foetal folds in the skin. In this population the foetal folds remain visible during the first year of life and are normally still noticeable well into the second year.

When a female was not seen in a given year, but sighted repeatedly in subsequent years with an older calf, the birth year was determined by its relative size, prominence of foetal folds and association with the mother to a maximum of two years as calves tend to become independent around three years of age (Connor et al. 2000, Grellier et al. 2003).

Between 1989 and 2012, 213 births of identified calves occurred in the study area, 159 of which (75%) could be assigned to a reproductive female (Table 13). For the other 54 calves (26%) there was insufficient confidence to assign a mother to the calf because the calf was seen only rarely and in close proximity to different adults.

Table 13: Annual numbers of young of the year born to known females and total young of the year observed between 1989 and 2012.

Year	Young of the year from known females	Total young of the year
1989	7	9
1990	5	6
1991	5	12
1992	6	10
1993	4	9
1994	8	20
1995	4	6
1996	0	1
1997	2	7
1998	1	6
1999	0	3
2000	1	2
2001	3	6
2002	3	5
2003	5	6
2004	5	5
2005	7	7
2006	11	11
2007	12	12
2008	5	5
2009	18	18
2010	13	13
2011	14	14
2012	20	20
Total	159	213
Mean		8.9
S.E.		1.1

The spacing between births is thought to be one of the primary determinants of female reproductive success in many mammal species, especially in species with slow life histories (long reproduction cycles), and can be used to estimate fecundity rate, a key parameter in any population assessment. Complete inter-birth intervals (IBIs) of females seen every year between births (to avoid analytical issues associated with missing births if a female was not seen in a certain year) were initially investigated. The observed complete IBIs from 33 females ranged between 2 and 9 years (n=61 intervals) with three-year intervals were most typical (41% of intervals) (Figure 27). Only eight IBIs were 2 years long. Of these, three calves are known to have died in their first year of life and two more were suspected to have died as they were not sighted with their mother after the first year. The other three calves were successfully weaned at two-years of age, although that does not seem to be the common pattern for this population, as calves generally have a strong association with their mothers during the first 3 years of life (Grellier et al. 2003).

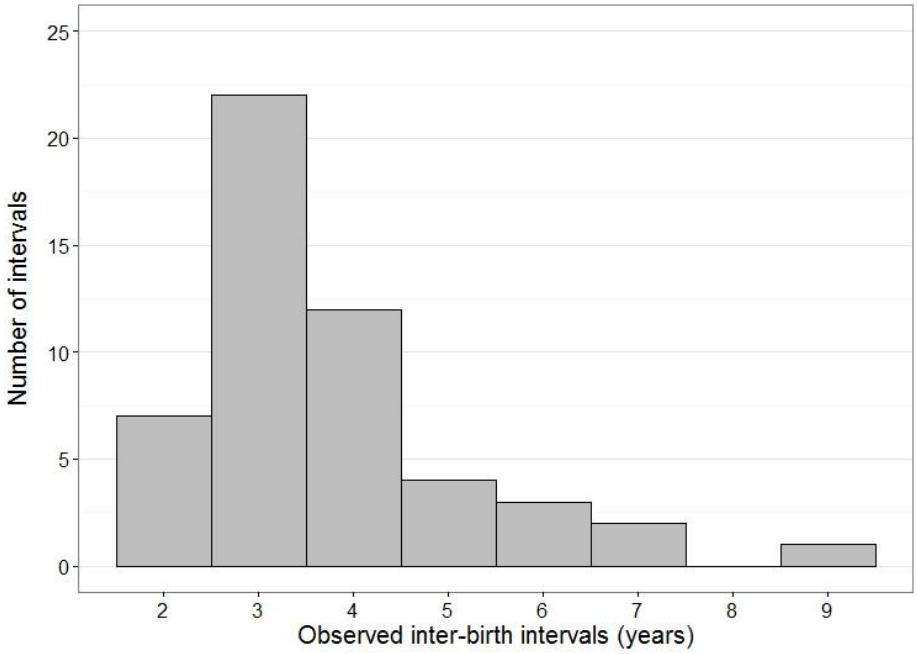

Figure 27: Observed inter-birth intervals for females seen every year between births.

Information on inter-birth intervals requires long-term individual datasets which are difficult to obtain for most cetacean species. Observational data tend to have gaps for a number of reasons including not seeing a female in a particular year, not obtaining a high quality picture of a female, or simply missing a new born calf because it may have died before the female was encountered again following the birth. Consequently, information on inter-birth intervals drawn from observational data is likely to be biased. To overcome such biases and be able to produce an unbiased estimate of inter-birth interval for the study population we developed an approach to estimate IBI by modelling the probability of a female giving birth to a calf based on the number of years since the birth of her previous calf.

The sighting and calving histories of females were initially selected to minimise gaps in the data by only using intervals between births in which a reproductive female had been seen and recorded every year. Missing sightings of reproductive females were only allowed in the year immediately before a known birth under the assumption that a female is not able to give birth in that year because the gestation period is 12 months. We also assumed that a female could not have a calf in the year immediately after a known birth because for the study population there is no record since the start of the research in 1989 of a female giving birth in two consecutive years. The selected data contained the calving histories of 78 females that had 156 calves between 1987 and 2012, with observed intervals ranging between 2 and 9 years.

The analysis was done in the framework of a generalized linear mixed model (GLMM), which combines a generalized linear model (GLM) that estimates fixed effects and deals with non-normal data by using a link function of the exponential family and a linear mixed model (LMM) that allows for random effects. The probability of birth was modelled using a binomial response variable with two possible outcomes: zero if a female did not give birth in a year; one if a female gave birth in a year. The fixed effect explanatory variables in the initial model included the number of years since a previous birth (YSPB), its quadratic form (to account for possible non-linearity in the relationship)

and the cumulative number of calves born to each female. Individual and temporal effects were considered by including the female identity and year as random factors. The GLMMs were fitted with a binomial error distribution and the logit link function (Bolker et al. 2009). All models were fitted using the Lme4 package in R (R Core Team 2013).

Model selection was based on the Akaike Information Criterion (AIC) (Akaike 1973) adjusted for small samples (AICc) (Burnham & Anderson 2002), and the model with the lowest AICc was selected as being the most parsimonious. Model coefficients from the best model were then used to back-transform the probabilities of giving birth based on each YSPB included in the data (i.e. the probability of having a calf after 1,2,…,n years since a female had her previous calf).

The mean inter-birth interval (IBI) was estimated based on the conditional probabilities of having a calf after each observed YSPB from the best model, as follows;

$$\begin{aligned}\text{Mean IBI} = {} & 1 * P_1 + \\ & 2 * (1-P_1) * P_2 + \\ & 3 * (1-P_1) * (1-P_2) * P_3 + \\ & \vdots \\ & n * (1-P_1) * (1-P_2) * \ldots * P_n\end{aligned}$$

where IBI is the inter-birth interval; and P_1, P_2, …, P_n are the conditional probabilities of having a calf after 1,2,…, *n* years since the previous birth occurred (YSPB). A confidence interval around the estimated mean IBI was calculated using a parametric bootstrap based on the fitted model by selecting the 2.5% and 97.5% percentiles of 10,000 mean IBIs estimated in the bootstrap. Each bootstrap replicate randomly selected a new set of model coefficient values from the variance-covariance matrix from the best model. Those coefficient values were then used to estimate a new mean IBI based on the formula described above. The best model produced an estimated inter-birth interval of 4.49 years (95% CI = 3.94 to 4.93 years).

Additionally, we tested the analytical method to ensure it was producing unbiased results. To do so we generated one hundred simulated populations of reproductive females and new born calves. Each simulated population was created by projecting for fifty years an initial sample of 1,000 females, using the demographic parameters estimated for the study population (i.e. recruitment rate, adult survival rate and the probabilities of having a new calf from the best fitted model). Each simulated population was then sampled, during which process we incorporated temporal and individual differences in the probability of capturing an animal to mimic the photo-identification effort. A mean IBI was then estimated for each simulated population as previously done with the real population data. The mean IBI averaged across the one hundred simulated populations was 4.36 years, only 2.8% lower than that estimated for the population study (4.49 years). The small difference supports the analytical method developed as being able to produce unbiased estimates of IBI for the capture probabilities typical of the study.

The fecundity rate is defined as the probability of a mature female having a calf each year and can be estimated as the reciprocal of the mean inter-birth interval. We derived a confidence interval around the estimated fecundity rate by selecting the 2.5% and 97.5% percentiles of 10,000 fecundity rates estimated as the reciprocal of each mean inter-birth interval from the parametric bootstrap previously done. Thus, the fecundity rate for the study population was estimated at 0.22 (95% CI = 0.22 to 0.25) based on the estimated mean IBI of 4.49 years. This means that on average 22% of the mature females produce new born calves (both male and female) annually.

SECTION 7

Abundance of bottlenose dolphins in the Tayside and Fife area and assessment of the number of data collection trips needed per year for a future monitoring programme

Abundance estimation in the Tayside and Fife area

In recent years, the abundance of bottlenose dolphins along the east coast of Scotland has been estimated for the whole population using this area (Durban et al. 2005; Thompson et al. 2011; Cheney et al. 2013) or for those animals using the Moray Firth SAC as part of site condition monitoring for that SAC (Thompson et al. 2006; Thompson et al. 2009; Cheney et al. 2012). These latter estimates have been calculated primarily to inform management questions specifically related to animals from the designated SAC in the Moray Firth (Thompson et al. 2006; Cheney et al. 2012).

Currently only one unpublished abundance estimate exists for the Tay area (Quick 2006; Quick and Janik 2008). The estimate used photo-identification data collected during 35 separate days between July and September of 2003 and 2004. Between 2009 and 2013, 42 systematic boat trips were conducted in the Tayside and Fife area to collect photo-identification data on bottlenose dolphins (Table 14 and Figure 28).

We estimated the total number of animals using the area of Tayside and Fife. Only high quality photographs from well-marked animals were used, i.e. those with nicks in their dorsal fin to avoid biasing mark-recapture estimates of abundance. A capture matrix was constructed to represent whether each individual was sighted in each of the trips in the area. We used closed population models allowing for variation in capture probability by capture occasion, being the most appropriate model for the data. We implemented the model to the annual data in program MARK (White and Burnham 1999). The individual capture histories were then used to estimate the number of well-marked individuals using the area annually. Then, the proportion of well-marked animals (θ) in each group encountered was estimated and used to inflate the abundance estimate from MARK to obtain the total abundance of bottlenose dolphins using the Tayside and Fife area annually based on each data subsets.

Table 14: Population data from mark-recapture analysis in MARK. Number of trips, number of well-marked individuals, total abundance estimates for the Tayside and Fife area with CV and 95% Confidence Intervals.

Year	# Trips	# Well-marked individuals	Total abundance	CV	95% CI
2009	7	43	84	0.06	75 - 94
2010	8	42	91	0.05	82 - 100
2011	9	41	81	0.05	74 - 89
2012	9	37	71	0.06	63 - 81
2013	9	35	89	0.11	72 - 110

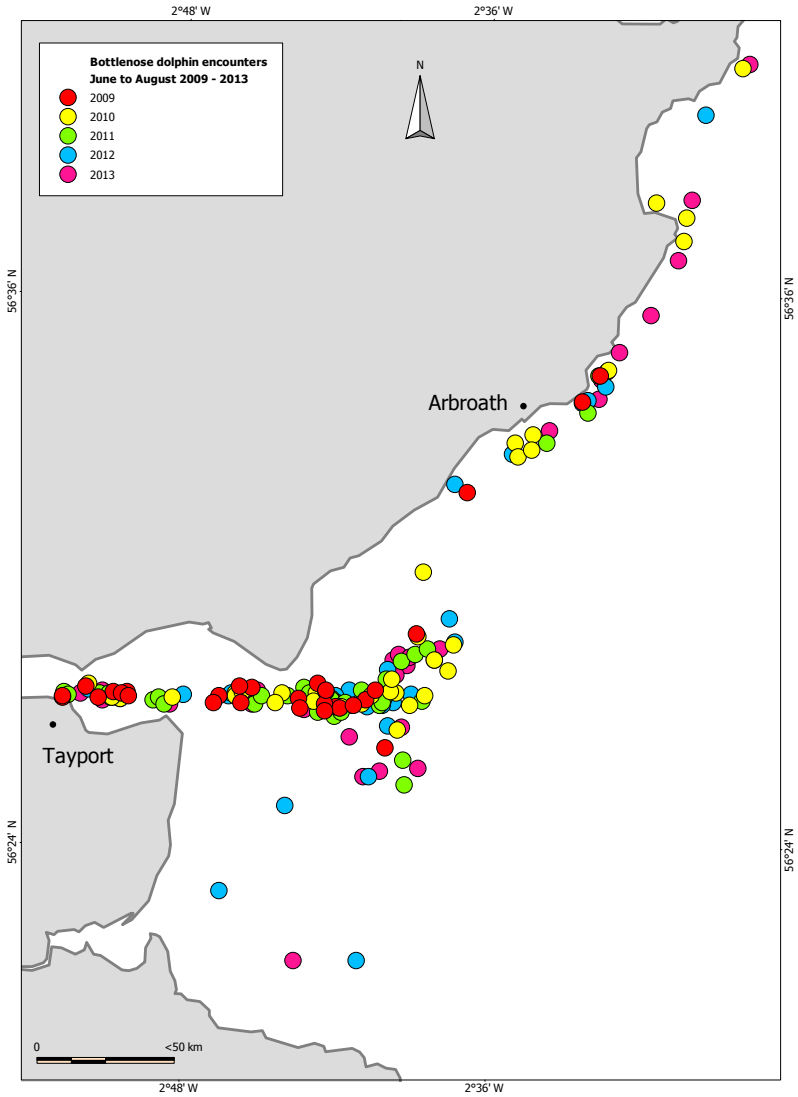

Figure 28: Bottlenose dolphin encounter locations in Tayside and Fife from 2009 to 2013 used to estimate the number of animals using the Tayside and Fife area and to assess the number of data collection trips needed each year for a future monitoring programme.

The abundance estimates obtained annually for 2009 to 2013 show a total number of animals using the Tayside and Fife area ranging between 71 (95%CI: 63 – 81) and 91 (95% CI: 82 – 100) individuals.

Comparison of the Tayside and Fife estimate with estimates from the Moray Firth SAC

Cheney et al. (2012) provide estimates of the number of dolphins using the Moray Firth SAC in the summer from 1990-2010. For the years in which an estimate also exists for the Tay (2009 and 2010), the numbers of dolphins using the Moray Firth SAC are 102 (95% confidence interval: 98-118) for 2009 and 114 (95% confidence interval: 109-131) for 2010. These estimates are slightly higher to those for the Tayside area during the summers of 2009 and 2010. However the estimates of abundance for the Tayside and Fife area might be slightly underestimated as the model selected for does not account for heterogeneity in capture probabilities.

Comparison of the Tayside and Fife estimate with estimates from the east coast of Scotland

The first and, until recently, most commonly used abundance estimate for the population of dolphins on the east coast of Scotland is 129 (95% confidence interval: 110-174) (Wilson et al. 1999). This estimate used data from surveys in the Moray Firth in 1992 and the M_{th} model, implemented in program CAPTURE (Rexstad and Burnham 1991). At that time the majority of the population was believed to use this area on a regular basis. However, the geographical range of this population has expanded over the last 2 decades (Wilson et al. 2004), and now extends from the Moray Firth down the east coast of Scotland to at least as far south as the Firth of Forth.

Durban et al. (2005) developed a Bayesian multi-site mark-recapture framework to account for the geographical dependencies between study sites, and allow for data collected opportunistically and concurrently by different groups at study sites that were defined by practical considerations rather than survey design. This method was applied to data collected in 2006 from three areas that covered the extended known range of this population to generate a population estimate for the east coast of Scotland of 195 (95% highest posterior density interval (HPDI): 162-253) (Cheney et al. 2013). 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 range of the population (see Cheney et al. 2012 for details). For 2009 and 2010, the estimated total population abundance for the east coast was 168 (95% HPDI 143-192) in 2009 and 178 (95% HPDI 151-204) in 2010 and results indicated that there is a >99% probability that the bottlenose dolphin population on the east coast of Scotland is either stable or increasing (Cheney et al. 2012).

Between 71 and 91 bottlenose dolphins from the east coast population were estimated to be using the Tay area during 2009-2013 (Table 14). These numbers represent approximately 35-46% of the 195 individuals (95% HPDI: 162-253) estimated for the east coast of Scotland (Cheney et al. 2013), indicating that Tayside and Fife are important areas for this population, in accordance with the results in other sections of this report.

Assessment of the number of data collection trips needed per year for a future monitoring programme

The encounter rates (Figures 18 and 19) and estimated abundance of animals using the Tayside and Fife area (Table 14) suggests this area is important for the east coast of Scotland bottlenose dolphin population. In order to assess how many data collection trips are needed each year to monitor the abundance of animals using the Tayside and Fife area, we used the photo-identification data available from the systematic surveys conducted from 2009 to 2013 (Figure 28) and looked at the variability in the estimates based on the different amounts of data used.

We selected data collected in the months of June, July and August and excluded May and September for two main reasons: to keep consistency among years because no trips were conducted in those months in 2009 and 2011, and because the period between June and August tends to have the best light and day length conditions for conducting photo-identification surveys. Because photo-

identification was extended to a wider area in the years 2012 and 2013 (north to Aberdeen and south to the Firth of Forth), we selected the encounters located in the area commonly surveyed in all five years (Figure 29). A series of data subsets based on different number of trips ranging between three and nine trips were selected for each of the years.

Only high quality photographs from well-marked animals were used, i.e. those with nicks in their dorsal fin to avoid biasing mark-recapture estimates of abundance. A capture matrix was constructed to represent whether each individual was sighted in each of the trips within each data subsets and year. The individual capture histories were then used to estimate the number of well-marked individuals using the area annually. To do so, we used a closed population model allowing for variation in capture probability by capture occasion, being the most appropriate model for the data. We implemented the model to each data subsets in program MARK (White and Burnham 1999). Then, the proportion of well-marked animals (θ) in each group encountered was estimated and used to inflate the abundance estimate from MARK to obtain the total abundance of bottlenose dolphins using the Tayside and Fife area annually based on each data subsets.

The estimated abundances of dolphins using the area of Tayside and Fife based on the different sub-datasets are shown in Table 15 and Figure 29. For all five years, the increase in the number of trips used resulted in increased consistency of the annual abundance estimates and also an increase in the precision, shown by the decrease in the coefficient of variation (CV) and smaller 95% confidence intervals (Table 15 and Figure 29). Estimates based on only three to five trips were less consistent and generally highly imprecise with very wide 95% confidence intervals. Precision improved as the number of trips increased to about six or seven trips but did not improve further for eight or nine trips in most years (Table 15 and Figure 29).

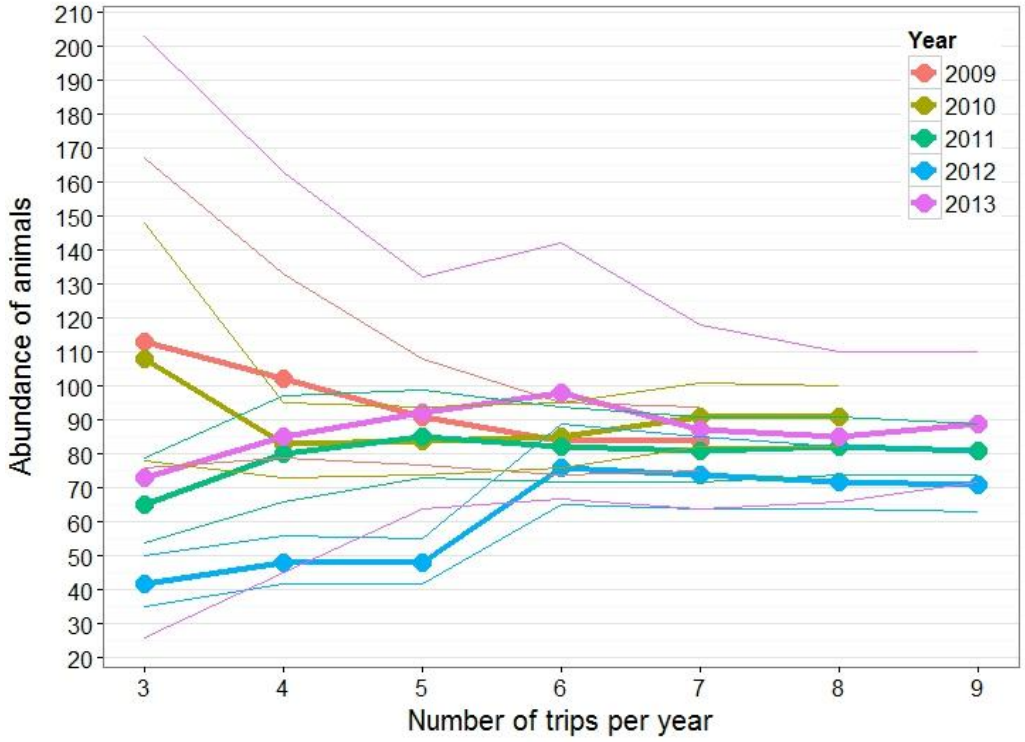

Figure 29: Annual estimates of abundance with 95% confidence intervals for each number of trips selected between June and August (2009 to 2013) in the Tayside and Fife.

Table 15: Population data from mark-recapture analysis in MARK. Number of trips, number of marked individuals, total abundance estimates with CV and 95% Confidence Intervals.

Year	# Trips	# Marked individuals	Total abundance	CV	95% CI
2009	3	36	113	0.20	76 - 167
	4	40	102	0.13	79 - 133
	5	42	91	0.09	77 - 108
	6	42	84	0.06	74 - 95
	7	43	84	0.06	75 - 94
2010	3	36	108	0.16	78 - 148
	4	37	83	0.07	73 - 95
	5	38	84	0.06	74 - 94
	6	39	85	0.06	76 - 95
	7	42	91	0.05	82 - 101
	8	42	91	0.05	82 - 100
2011	3	30	65	0.10	54 - 79
	4	35	80	0.10	66 - 97
	5	39	85	0.08	73 - 99
	6	39	82	0.07	72 - 94
	7	40	81	0.06	72 - 91
	8	41	82	0.05	74 - 91
	9	41	81	0.05	74 - 89
2012	3	22	42	0.09	35 - 50
	4	25	48	0.07	42 - 56
	5	25	48	0.07	42 - 55
	6	37	76	0.08	65 - 89
	7	37	74	0.07	64 - 85
	8	37	72	0.06	64 - 82
	9	37	71	0.06	63 - 81
2013	3	14	73	0.56	26 - 203
	4	20	85	0.34	45 - 163
	5	29	92	0.19	64 - 132
	6	29	98	0.19	67 - 142
	7	29	87	0.16	64 - 118
	8	31	85	0.13	66 - 110
	9	35	89	0.11	72 - 110

The results show that confidence intervals show only little change beyond seven trips per year. We therefore recommend a minimum of seven trips in which bottlenose dolphins are encountered and photo-identification data are collected according to the methodology developed for the long-term monitoring of this population (Cheney et al. 2013) to obtain a robust estimate of abundance with good precision. Less than seven trips per year can produce inconsistent and imprecise abundance estimates, which may lead to difficulties in interpreting changes in the abundance of animals using the area from year to year.

Weather conditions are essential determinants in obtaining good quality photo-identification data and should be considered when planning for a monitoring programme. Dry and sunny weather with no wind or swell are optimal for conducting photo-identification trips. However, these conditions are not often encountered off the east coast of Scotland and so flexibility to plan for extra field trips is recommended to account for times when weather conditions are particularly bad or bottlenose

dolphins are not encountered. Winter trips have been conducted in the past off the east coast of Scotland as part of the long running photo-identification project conducted by the University of Aberdeen Lighthouse Field Station and the University of St Andrews. Even though dolphins have been encountered and photographed during the winter surveys, weather conditions tend to be worst and light and day length are often not sufficient for photographing animals. The summer months between May and September constitute the time period with the most suitable weather and day length to increase sighting probabilities and the collection of good quality photographs.

One of the assumptions of closed population capture-recapture models often used to estimate abundance is that the time period between consecutive capture occasions needs to be long enough for animals in the population to be able to mix before the following capture occasion. Thus, the temporal distribution of the trips needs to be taken into account when planning. For example, field trips on consecutive days or with only two or three days in between would probably be too close to ensure a mixture of the animals between encounter occasions. Planning for a trip every one or two weeks should ensure enough time between occasions to comply with the assumption.

Abundance estimates for the area between Aberdeen and the Firth of Forth (2012 and 2013)

As described above, the dedicated photo-identification surveys were extended south to the Firth of Forth and north to Aberdeen for the years 2012 and 2013, with trips occurring from the start of May until the end of September. All the encounters with bottlenose dolphins between Aberdeen and the Firth of Forth for the time period 2012 to 2013 are shown in Figure 30.

Based on all the photo-identification data collected in 2012 and 2013 between Aberdeen and the Firth of Forth we estimated the abundance of animals using the study area each year. All encounters of each individually marked dolphin in each month from May to September were pulled together when preparing the individual capture histories. As a result, the capture histories of forty-nine and fifty-two well-marked individuals captured in 2012 and 2013 respectively over five capture occasions were analysed in CAPTURE. The model *Mth* (*Chao*) was used to estimate the abundance in both years accounting for heterogeneity of capture probabilities between months.

The abundance estimates of distinctively marked individuals were inflated by an estimated annual proportion of well-marked individuals to obtain a total number of dolphins using the defined study area each year. The results for 2012 and 2013 were very consistent over the two years (Table 16), with 118 (95% CI: 98 – 143) and 119 (95% CI: 101 – 140) individuals estimated for 2012 and 2013 respectively. These estimates represent greater than 60% of the total population estimated by Cheney et al. (2013) for the year 2006.

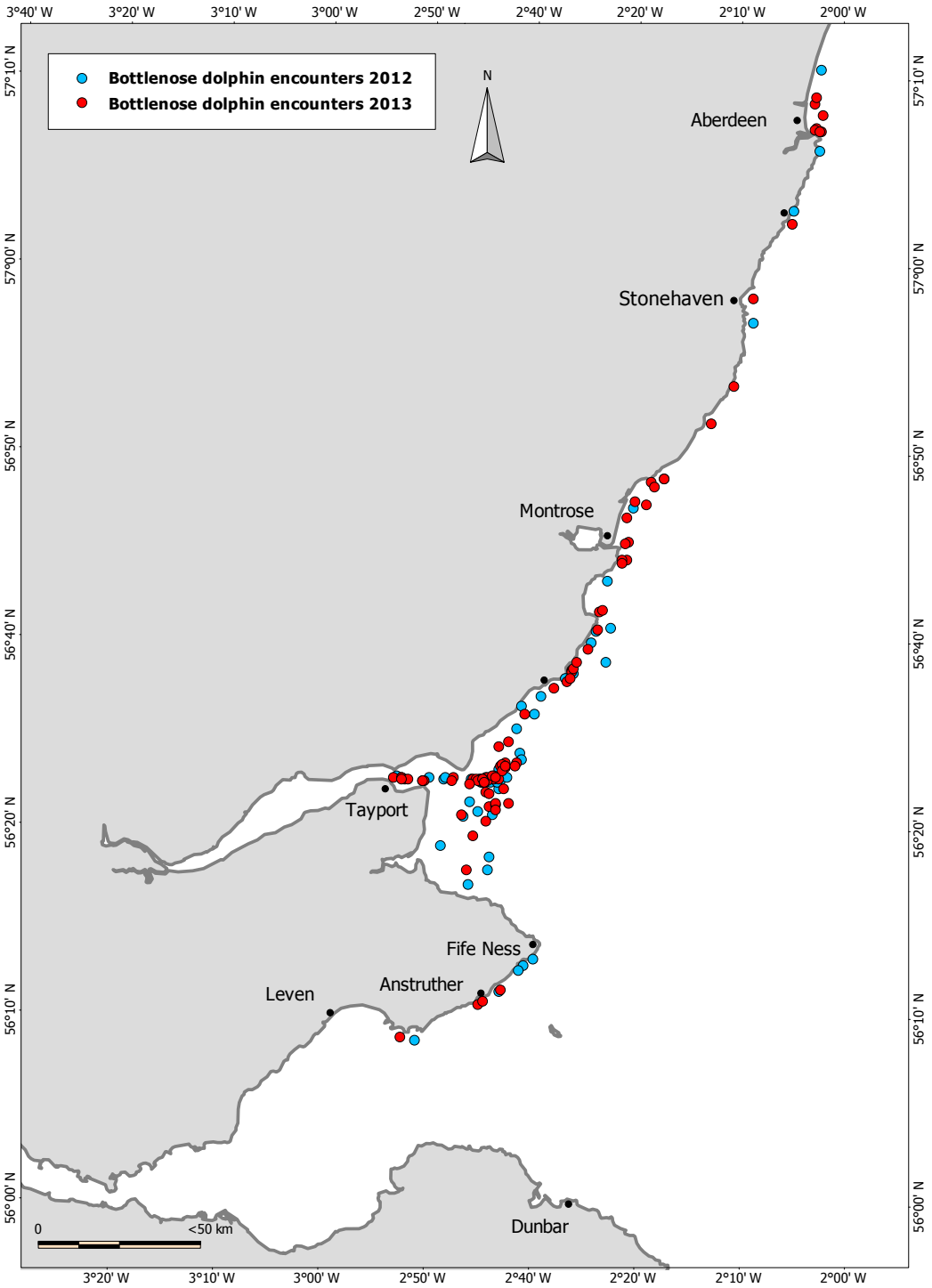

Figure 30: Locations of all bottlenose dolphin groups encountered between Aberdeen and the Firth of Forth from 2012 to 2013 used to estimate annual abundance over the two year period.

Table 16: Population data from mark-recapture model *Mth* (Chao) implemented in CAPTURE. Number of trips, number of well-marked individuals, proportion of well-marked individuals ($\widehat{\theta}$), total abundance estimates with coefficient of variation (CV) and 95% Confidence Intervals are shown.

Year	# Trips	# Well-marked individuals	$\widehat{\theta}$	Total abundance	CV	95% CI
2012	18	49	0.49	118	0.10	98 - 143
2013	25	52	0.49	119	0.08	101 - 140

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APPENDIX A

Introduction

This Appendix provides a summary of the data collection for project "The eastern Scotland bottlenose dolphin population: Improving understanding of ecology outside the Moray Firth SAC". Data were collected between May and September 2012 and 2013 during fieldwork trips conducted from a small boat and photo-identification methods were used to collect data from individual bottlenose dolphins.

Summary of data collection trips

A total of fifty trips were conducted from the start of May until the end of September in 2012 and 2013, twenty-two and twenty-eight respectively, covering three core areas: the Firth of Tay and St Andrews Bay (15 and 13 trips); the Firth of Forth (4 and 8 trips); and Montrose to Aberdeen (3 and 7 trips) (Table 17, Figures 30 and 31).

Surveys were conducted from a small boat (7.4 m aluminium planing hull cruiser with 225 hp outboard engine) when weather conditions were favourable (Beaufort 0 to 3) and preferably when weather was dry. If weather conditions changed during a trip, data collection was aborted until weather improved or the trip was abandoned. For the duration of the trip, the boat position, sea surface temperature and depth were recorded every minute using a Garmin GPS Map 551s GPS/Plotter/Sounder and a temperature sensor. Three crew members conducted the surveys. The basic crew included two marine mammal observers, at least one of which was experienced with photo-identification methods, and the same skipper, with experience of the local area and driving small craft for photo-identification surveys. On six occasions there was an extra marine mammal observer. On four occasions only one marine mammal observer was used.

Survey tracks are shown in Figures 1 and 2. Surveys started from Tayport harbour for the Firth of Tay and St Andrews Bay trips and for the Montrose to Aberdeen trips. For the Firth of Forth trips, surveys started from Anstruther harbour. Survey effort for the Firth of Tay and St Andrews Bay trips ran from Tayport out to the entrance of the Firth of Tay, extending south to St Andrews and north to Montrose. Survey effort for the Aberdeen trips ran from Montrose north up to Aberdeen. On those trips, bottlenose dolphin groups encountered between Tayport and Montrose were recorded but no photo-identification effort was taken due to time constraints. On occasion, when weather and time allowed, survey and photo-identification effort were extended south of Montrose to cover the area from Montrose back to Tayport harbour. Survey effort in the Firth of Forth covered an area between Leven and Fife Ness on the north side of the Forth and between Seton and Dunbar on the south side of the Forth, and included the associated water between.

Table 17: Summary of the photo-ID surveys carried out during 2012 and 2013 in the three core areas. Survey time, number of bottlenose dolphin encounters and time on encounter are given. Species seen: BND = bottlenose dolphin; HP = harbour porpoise; MW = minke whale.

Trip	Date	Month	Area	Survey time (hours)	No. encounters	Time on encounters (minutes)	BND	HP	MW
1449	09-May-12	May	St A Bay	6.75	2	54	yes	yes	-
1451	22-May-12	May	St A Bay	7.30	2	90	yes	yes	-
1453	25-May-12	May	St A Bay	6.87	2	138	yes	-	-
1456	05-Jun-12	June	St A Bay	6.25	0	0	-	-	-
1457	12-Jun-12	June	Forth	7.98	0	0	-	-	-
1458	13-Jun-12	June	St A Bay	4.72	1	11	yes	-	-
1461	25-Jun-12	June	St A Bay	7.55	4	193	yes	-	-
1463	02-Jul-12	July	St A Bay	5.12	3	108	yes	-	-
1464	10-Jul-12	July	St A Bay	7.03	2	230	yes	-	-
1466	12-Jul-12	July	St A Bay	5.40	2	146	yes	-	-
1467	14-Jul-12	July	Aberdeen*	9.77	5	119	yes	yes	-
1468	17-Jul-12	July	St A Bay	5.68	4	108	yes	-	-
1470	20-Jul-12	July	Forth	6.83	0	0	-	-	-
1472	25-Jul-12	July	St A Bay	7.05	4	135	yes	-	-
1475	31-Jul-12	July	St A Bay	5.07	2	156	yes	-	-
1476	08-Aug-12	August	Aberdeen*	8.72	2	102	yes	yes	-
1478	09-Aug-12	August	Forth	7.18	4	65	yes	-	-
1479	19-Aug-12	August	St A Bay	6.75	4	93	yes	yes	yes
1483	07-Sep-12	September	St A Bay	4.37	3	170	yes	-	-
1484	20-Sep-12	September	Aberdeen*	9.17	4	71	yes	yes	-
1486	22-Sep-12	September	Forth	5.70	1	56	yes	yes	-
1487	27-Sep-12	September	St A Bay	3.25	2	45	yes	-	-
1490	07-May-2013	May	St A Bay	5.30	1	36	yes	yes	-
1492	16-May-2013	May	St A Bay	4.17	2	71	yes	-	-
1494	20-May-2013	May	St A Bay	5.80	4	119	yes	-	-
1496	21-May-2013	May	Forth	4.43	0	0	-	-	-
1498	31-May-2013	May	Aberdeen*	7.87	3	92	yes	-	-
1499	03-Jun-2013	June	St A Bay	4.37	3	61	yes	-	-
1501	08-Jun-2013	June	Forth	5.27	0	0	-	-	-
1502	09-Jun-2013	June	Aberdeen*	9.20	7	134	yes	yes	-
1504	10-Jun-2013	June	St A Bay	3.78	1	113	yes	-	-
1506	18-Jun-2013	June	Forth	5.78	1	34	yes	yes	-

Trip	Date	Month	Area	Survey time (hours)	No. encounters	Time on encounters (minutes)	BND	HP	MW
1507	19-Jun-2013	June	St A Bay	4.53	2	44	yes	-	-
1509	25-Jun-2013	June	Aberdeen*	9.08	7	154	yes	-	-
1510	26-Jun-2013	June	St A Bay	7.15	4	132	yes	yes	-
1512	08-Jul-2013	July	St A Bay	6.87	3	69	yes	yes	-
1513	09-Jul-2013	July	Aberdeen*	10.80	5	192	yes	yes	-
1514	10-Jul-2013	July	Forth	6.53	1	52	yes	yes	-
1516	18-Jul-2013	July	Aberdeen*	11.18	7	141	yes	yes	-
1517	19-Jul-2013	July	Forth	5.82	1	19	yes	yes	-
1519	26-Jul-2013	July	St A Bay	6.33	3	67	yes	-	-
1520	27-Jul-2013	July	Forth	7.85	1	41	yes	-	-
1523	05-Aug-2013	August	St A Bay	4.50	5	84	yes	yes	yes
1524	10-Aug-2013	August	St A Bay	6.67	9	114	yes	-	yes
1525	13-Aug-2013	August	Aberdeen*	7.53	5	54	yes	yes	-
1528	22-Aug-2013	August	Forth	3.45	0	0	-	-	-
1533	13-Sep-2013	September	St A Bay	4.60	6	95	yes	-	-
1535	24 Sep-2013	September	St A Bay	6.17	3	85	yes	yes	-
1536	26 Sep-2013	September	Forth	5.28	0	0	-	-	-
1538	27 Sep-2013	September	Aberdeen*	8.12	4	86	yes	yes	-

** The number of encounters for the Aberdeen trips include all encounters between Tayport and Aberdeen*

Photo-identification data were collected using a Canon EOS 50D with a 70-200 mm f2.8 USM Canon lens. Standardised protocols taken from the long running east coast of Scotland bottlenose dolphin project (Cheney et al. 2012) coordinated by the Lighthouse Field Station, University of Aberdeen and the Sea Mammal Research Unit, University of St Andrews, were used at all times. This ensured all data were standardised with and incorporated into the long running data set for Scottish bottlenose dolphins. On all but two encounters the same photographer was used; during the other encounters an equally experienced photographer was used. During all encounters, data on group size, behaviour, and the presence of calves and new born individuals were recorded. In addition, environmental data on sea state, swell, water depth, and sea surface temperature were also recorded. All data were collected under licence from Scottish Natural Heritage (SNH licence no.13292 and no.13855).

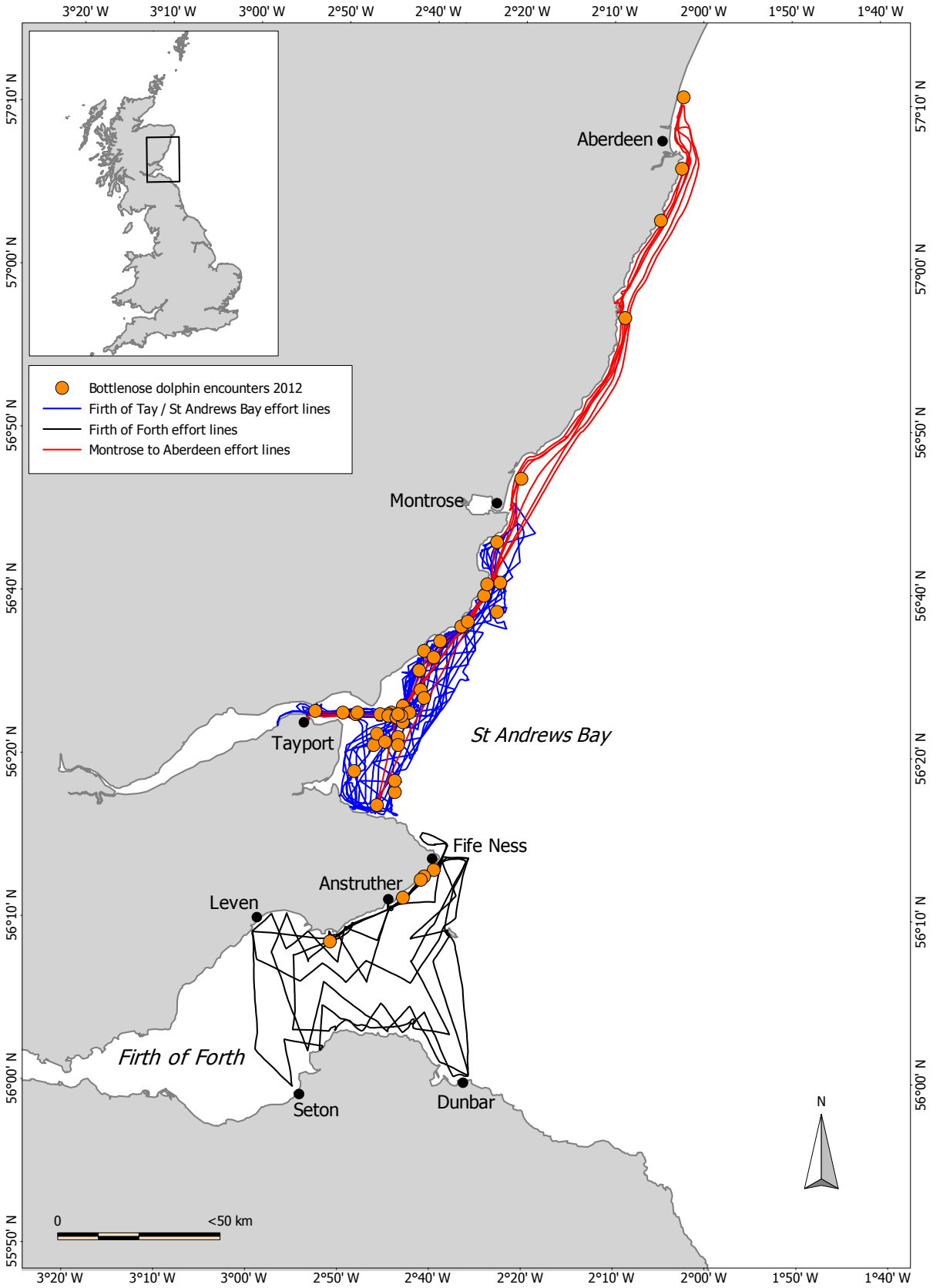

Figure 30: Survey effort in 2012 and bottlenose dolphin encounters. Areas covered include the Firth of Tay / St Andrews Bay (blue), the Firth of Forth (black), and Montrose to Aberdeen (red).

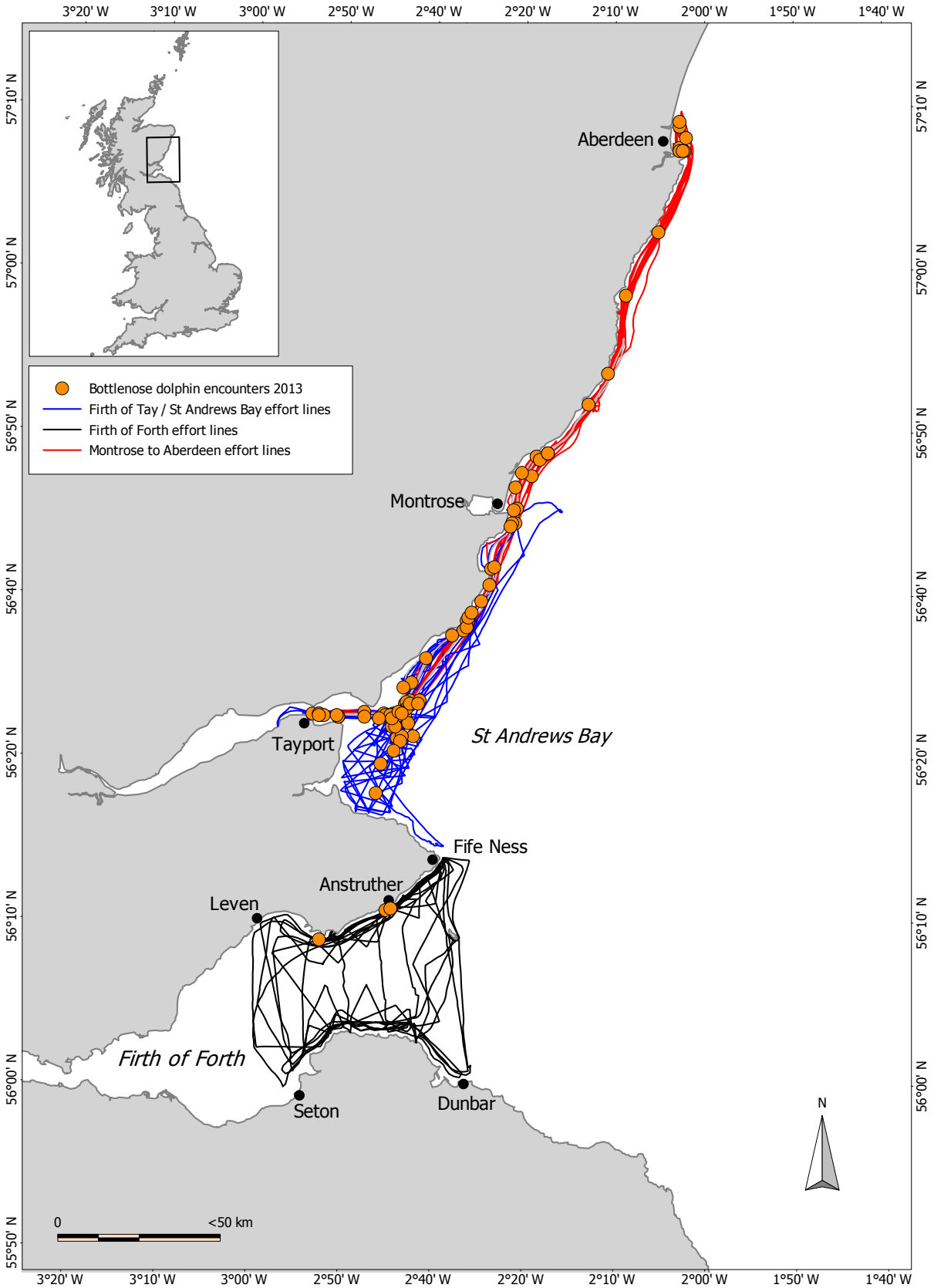

Figure 31: Survey effort in 2013 and bottlenose dolphin encounters. Areas covered include the Firth of Tay / St Andrews Bay (blue), the Firth of Forth (black), and Montrose to Aberdeen (red).

Bottlenose dolphins

Bottlenose dolphins were sighted on 43 of the total 50 trips (86%). Of the 28 trips in the Firth of Tay and St Andrews Bay, dolphins were sighted on 27 trips (96%). Of the 12 trips in the Firth of Forth, dolphins were sighted on 6 trips (50%) and of the 10 trips to Aberdeen dolphins were sighted on all trips (100%), (Table 17). Bottlenose dolphins were seen in all months in which a survey took place, for the Firth of Tay and St Andrews Bay trips and the Aberdeen trips (May, June, July, August, September) (Table 18). For the Firth of Forth trips, dolphins were seen in all months except May (Table 18). The number of trips conducted each month was mainly driven by weather conditions. In 2012, the month of July had the best weather conditions and allowed a total of 8 trips, (all three core areas combined) while the rest of the months allowed for 3 or 4 trips (Table 18). In 2013 the weather was generally better and the month of June had the best weather conditions allowing a total of 8 trips (all three core areas combined). The rest of the months allowed for 4 to 7 trips (Table 18). In total, 322 hours were spent on survey, and bottlenose dolphins were encountered on 141 separate occasions, during 43 of the 50 trips (Tables 17 and 18).

Table 18: 2012 and 2013 summary of survey details by month for all three core areas combined.

Year	Month	No. surveys	Survey Time (mins)	Survey Time (hrs)	Total # of Encounters	Time on Enc (mins)	Time on Enc (hrs)	% Survey Time with Dolphins
2012	May	3	1255	20.92	6	282	4.70	22%
	June	4	1590	26.50	5	204	3.40	13%
	July	8	3117	51.95	22	1002	16.70	32%
	August	3	1359	22.65	10	260	4.33	19%
	September	4	1349	22.48	10	342	5.70	25%
	All 2012	**22**	**8,670**	**144.50**	**53**	**2,090**	**34.83**	**24%**
2013	May	5	1654	13:36	10	318	5.30	19%
	June	8	2950	49.17	25	672	11	23%
	July	7	3323	55.38	21	581	10	17%
	August	4	1329	22.15	19	252	4	19%
	September	4	1450	24.17	13	266	4	18%
	All 2013	**28**	**10,706**	**178.43**	**88**	**2,089**	**34.82**	**20%**
2012/13	**All**	**50**	**19,376**	**322.93**	**141**	**4179**	**69.65**	**22%**

On each trip in which dolphins were seen, between 1 and 9 separate encounters of groups occurred (Table 17). Each encounter lasted on average 29 minutes, giving a total of 68 hours spent with bottlenose dolphins, and represented 21% of the total survey time. Most of the groups were encountered in St Andrews Bay (89 groups), especially around the entrance to the Tay (Figure 30 and 31). In the Tay/St Andrews Bay core area, 47 of the 169 survey hours were spent with bottlenose

dolphins. Encounters lasted on average 32 minutes, and represented 28 % of the survey time in that area (Table 19). Although less effort was undertaken in the Firth of Forth and between Montrose and Aberdeen, there were 9 and 13 encounters with bottlenose dolphins in each of these two areas respectively between 2012 and 2013. In the trips to Aberdeen a total of 17 hours were spent with bottlenose dolphins out of the 81 hours of survey. Encounters lasted on average 24 minutes and represented 21% of the survey time in that area. In the trips to the Firth of Forth, 4 of the 72 hours of survey effort were spent with dolphins. Encounters lasted on average 29 minutes and represented 6% of the total survey time in that area. Estimates of group sizes on all encounters varied between 1 and 35 individuals (Figures 32 and 33 and Table 19), with an estimated mean group size of 11 individuals for all core areas. In the Firth of Tay and St Andrews Bay, estimates of group size ranged between 1 and 35 individuals (mean group size = 11 individuals); between Montrose and Aberdeen estimated group size ranged between 2 and 28 individuals (mean group size = 11 individuals); and in the Firth of Forth estimates of group size ranged between 2 and 29 individuals (mean group size = 12 individuals). In all three core areas, newborn and older calves were sighted during the encounters and many types of behaviour, including fast travel, foraging, socialising and aerial activity were observed.

Table 19: Summary of survey details by core area for 2012 and 2013.

Year	Core area	No. surveys	Survey Time (hrs)	Total # of Encounters	Time on Enc (hrs)	% Survey Time with Dolphins	Group size	Average group size
2012	Tay and St A Bay	15	99.13	43	29.73	30%	2 to 35	15
	Montrose to Aberdeen*	3	17.66	5	3.13	18%	8 to 20	13
	Firth of Forth	4	27.69	5	2.01	7%	2 to 24	10
2013	Tay and St A Bay	13	70.23	46	18.15	26%	1 to 28	9
	Montrose to Aberdeen*	7	63.78	38	14.21	22%	2 to 28	11
	Firth of Forth	8	44.44	4	2.42	5%	5 to 29	14
2012 2013	**Tay and St A Bay**	**28**	**169.36**	**89**	**47.88**	**28%**	**1 to 35**	**11**
	Montrose to Aberdeen*	**10**	**81.44**	**43**	**17.34**	**21%**	**2 to 28**	**11**
	Firth of Forth	**12**	**72.13**	**9**	**4.43**	**6%**	**2 to 29**	**12**

** The number of encounters for the core area Montrose to Aberdeen includes all encounters between Tayport and Aberdeen*

Across all encounters with bottlenose dolphins for both years, 15,379 photographs of dorsal fins were taken for the identification of individual dolphins. In 2012 and 2013, 101 and 109 individuals respectively were identified based on natural markings from the best quality pictures, and matched to the existing catalogue of identifiable dolphins for this population.

Other cetacean species

Four other cetacean species were encountered during the survey trips. Harbour porpoises were seen on 14 encounters during eight separate surveys and minke whales were seen on two encounters during one survey. Risso's dolphins and white beaked dolphins were seen on one encounter together during one survey (Table 17 and Figure 34).

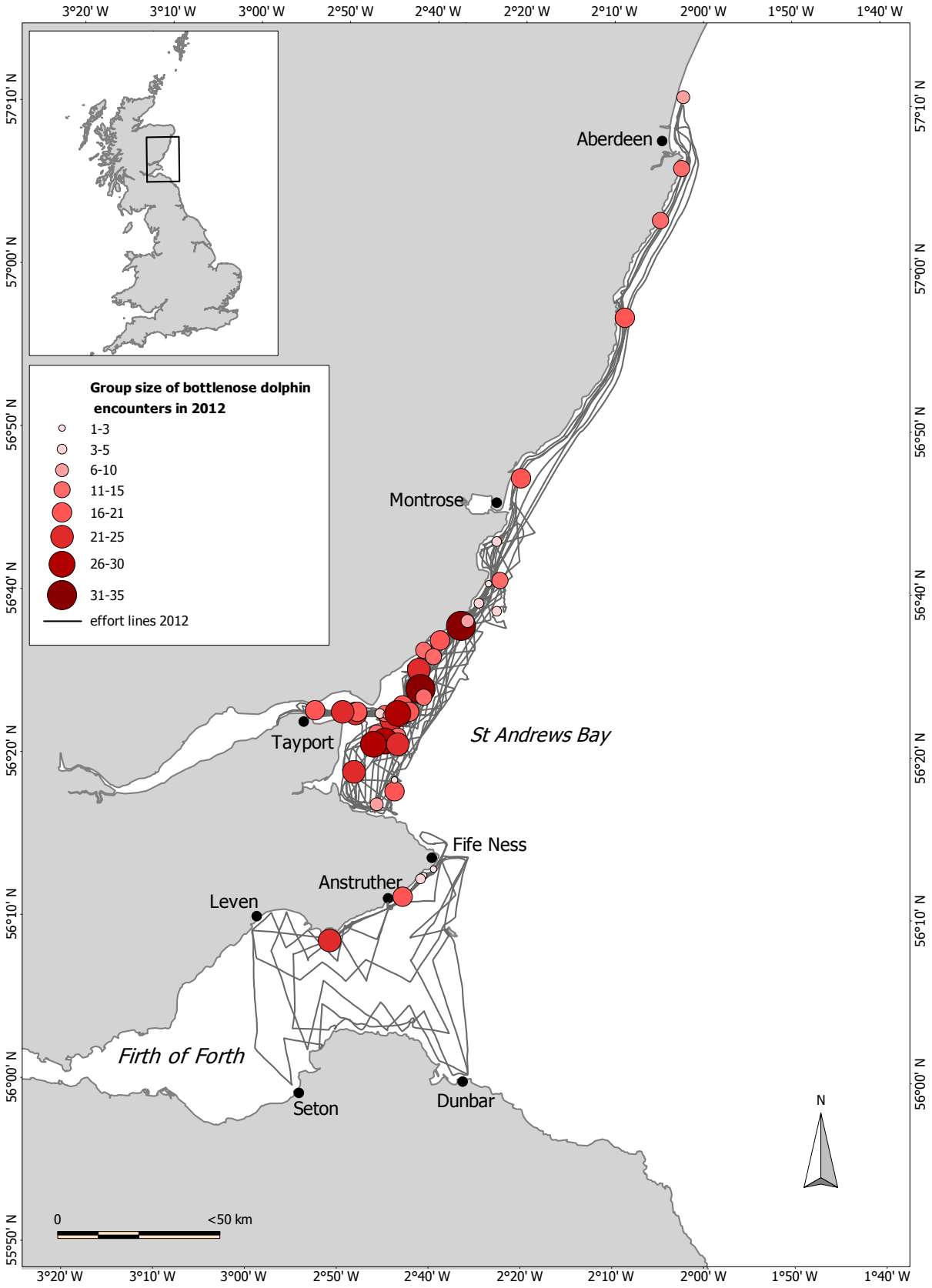

Figure 32: Location of bottlenose dolphin encounters during all surveys in 2012, including best estimates of group size.

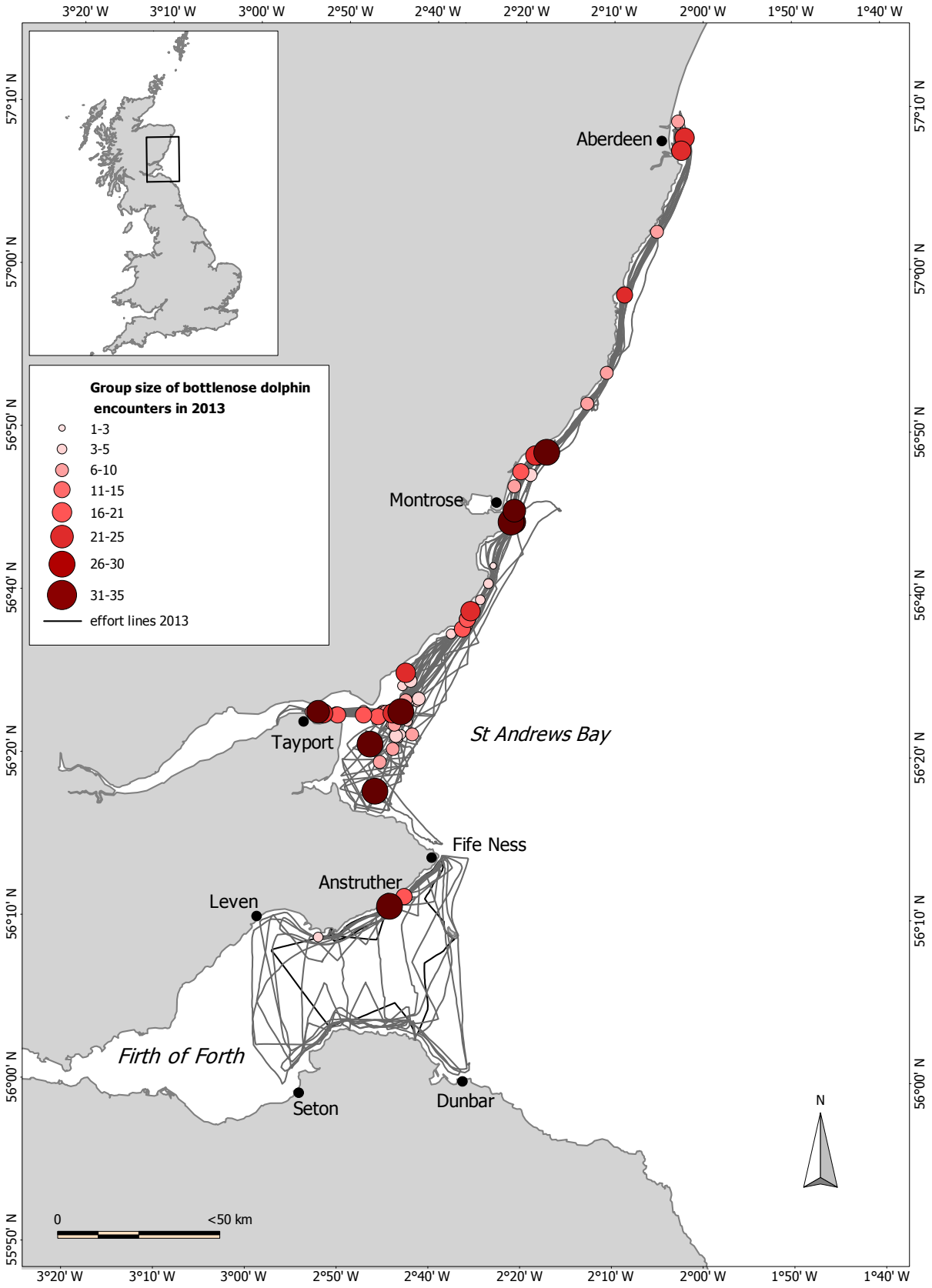

Figure 33: Location of bottlenose dolphin encounters during all surveys in 2013, including best estimates of group size.

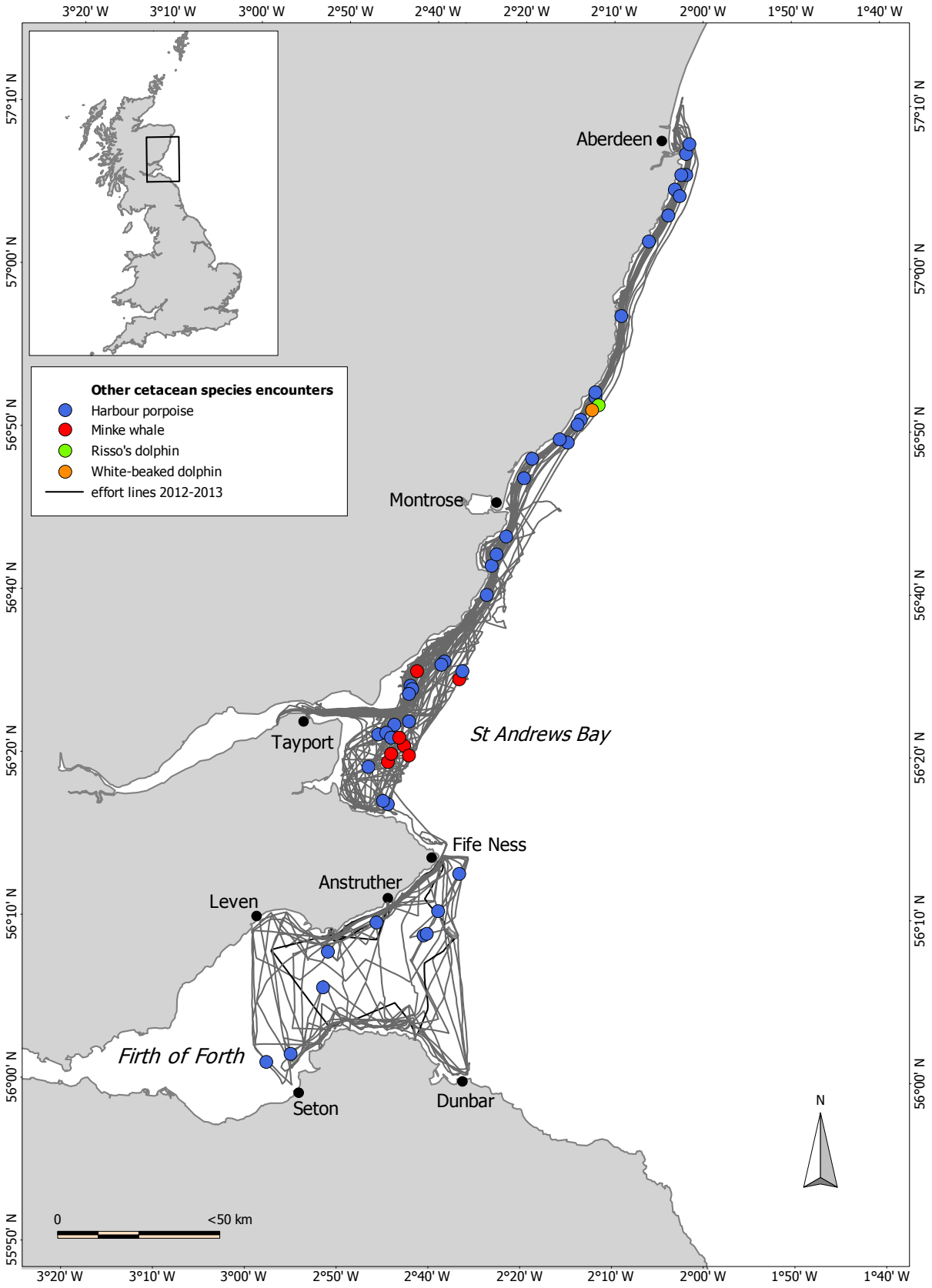

Figure 34: Location of other cetacean species encounters during all surveys in 2012 and 2013.