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The reproductive histories and inter-birth, calving intervals of female coastal bottlenose dolphins (*Tursiops truncatus*) in northeast Scotland


Photo credit: Kevin Robinson/CRRU

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In association with the
Cetacean Research & Rescue Unit

I hereby declare that this thesis is my own work. Where I have used the work of other persons or quoted the work of other persons the sources of the other work or information have been detailed explicitly in the presentation.

Signed:_____________________________

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Writing this project has been a major learning curve from the very start. I would like to thank both my supervisors, Dr Graham Pierce and Dr Kevin Robinson, for their help throughout.

Thanks to Graham, who has been exceptionally patient and obliging in aiding me with the statistical methods needed for the project. His input has greatly improved my understanding of the techniques I employed in this work.

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With their guidance I have been able to better understand what makes for a good piece of biological writing, and I hope this is reflected in my finished work.

ABSTRACT

Inter-birth intervals (IBIs), reproductive rates, and calf survival of bottlenose dolphins (*Tursiops truncatus*) using the southern coastline of the outer Moray Firth, in north east Scotland, were investigated using data compiled by the Cetacean Research & Rescue Unit from 1997 to 2013 inclusive. A total of 61 females and 135 calves were identified from this region during the study period.

Inter-birth intervals could only be examined for females which had produced at least two calves; amounting to 33 females and 107 calves. Individual IBIs (n=74) ranged from 2 to 8 years, with an average of 3.72 ± 1.29 years. Further investigation revealed that females with continuous sighting histories had a shorter IBI on average (3.5 ± 1.27 years), suggesting 3.72 years as an average IBI for individuals in the study population may be an overestimate. Observed differences between the IBIs recorded after a calf loss and those not occurring after a loss were not statistically significant. However, differences between the first IBI and later intervals were significant, suggesting females take longer to raise a first-born calf than subsequent offspring. The results also indicated that a longer IBI influenced calf mortality, suggesting that a longer period of maternal recovery is beneficial to calf survival. Likelihood of calf production was reduced as the time since a previous calf birth increased, suggesting females with an interval of six years or more since their last birth are reaching the end of their natural reproductive cycle, or are unhealthy. Individual and annual calving rates showed no significant variation. An average calf mortality of 10.37% was calculated for this population, while a breeding season between May and October was identified.

The present study allows further insight into a population of bottlenose dolphins whose reproductive parameters have been little studied. Environmental conditions within the Moray Firth may support a high level of calf survival and as a result, females may display greater reproductive success compared to bottlenose in other regions. In the long term this may be beneficial to a population which is considered vulnerable, and internationally significant.

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1 INTRODUCTION

The bottlenose dolphin (*Tursiops truncatus*) is a slow reproducing mammal which lives in a fission-fusion society governed by long and short term interactions (Smolker et al., 1992). Long term studies on interacting individuals of this species have been essential in ascertaining population dynamics within and between groups, as well as patterns of distribution, habitat use and mating strategies (Connor, 2002; Pesante et al., 2008). However, few studies have focused on reproductive histories and inter-birth, calving intervals in this species, and especially within temperate waters. The current study represents the first of its kind on one particular group of coastal bottlenose dolphins within the Moray Firth in north-east Scotland.

The longest term studies of bottlenose dolphins have largely focused on two coastal populations in Sarasota Bay, Florida and in Shark Bay, Australia. Our current understanding of relationship networks, mother-calf interactions, and reproductive tendencies in this species has thus been largely accrued from these sub-tropical and tropical populations. Observations from these communities have shown permutation in associations between individuals, with some animals showing more social connections within the population than others (Wiszniewski et al., 2010). Long term associations may be formed from as early as two weeks of age (Mann & Smuts, 1998). Females tend to maintain more fluid, shorter-term bonds within their communities while males have been documented forming long-term coalitions with other male affiliates (Wells, 1998).

The difference in sociality reflects the contrasting mating strategies of each sex. Male coalitions are typically composed of dyads or triads, but in some cases small groups of individuals will band into ‘superalliances’ (Connor et al., 2001). These male-male associations may travel singly or together to aggressively herd cycling females, in a strategy known as ‘male roving’ (Whitehead, 1990). Such alliances are a response to the unpredictable distribution of reproductively available females across a population’s range, and aggressive interactions between competing male coalitions have been reported (Connor et al., 2001).

In response to this, females associate closely with other females, often forming mother-calf groups (Wells, 1998; Scott et al., 2012). Such groups are governed by the reproductive status of the females within them and may be composed of related individuals (Mann et al., 2000;

Connor, 2002). Members within female social units may actively interact and assist in the care of calves (Mann & Smuts, 1998). Female bottlenose also mate promiscuously with consorting males (Connor, 2002). This mating strategy is thought to protect calves from intraspecific attacks by non-paternal males (Robinson, 2014) but allows females to take advantage of widely dispersed foraging opportunities (Mann et al., 2000).

Bottlenose dolphins have a life expectancy of up to 50 years (Reeves et al., 2002). Females may reach sexual maturity between eight and ten years of age, and typically produce their first calf within this age range (Boness et al., 2002). Gestation lasts 12 months (Wells, 1998; Boness et al., 2002; Scott et al., 2012), and weaning occurs within 20 months of birth (Reeves et al., 2002), yet non-nutritional nursing can occur up to eight years of age (Grellier et al., 2003; Gibson & Mann, 2008). The average inter-birth interval is three years (Wells, 1998; Haase & Schneider, 2001; Boness et al., 2002; Reeves et al., 2002). Male bottlenose dolphins offer no parental investment (Wells, 1998), whilst females incur large energy costs associated with gestation, parturition, lactation, and post-weaning calf care (Gittleman & Thompson, 1988). Accordingly, reproductive life histories and strategies are best studied by examining the female of the species, and her interactions with the environment.

As the sole provider of care to her offspring, calf production and survival is subsequently dependent on the condition of the mother, whose well-being is directly affected by her immediate environment, including the availability of resources and habitat quality (Whitehead & Mann, 2000; Wade & Schneider, 1992). These environmental indicators can therefore be used to make inferences about the fitness of individual females within a population and how these animals interact with their environment (e.g. Pomeroy et al., 1999) thereby helping to develop a greater understanding of reproductive success in this species.

In Europe, three categories of bottlenose communities have been defined according to their habitat use and range as coastal, resident or oceanic populations (ICES, 2013), and each category is respectfully managed according to defined Management Units (MUs) which show limited dispersal and genetic exchange with other identified populations (ICES, 2012). In Scotland the east and west coasts are habitat to sub-populations of bottlenose dolphins. On the west coast, individuals make up two small, segregated populations numbering approximately 15 individuals in each, while approximately 200 individuals contribute to the east coast population. The range and extent of interactions varies between individuals in this region

(ICES, 2012). The east coast North Sea population has further been designated a single MU which includes individuals encountered between Caithness and the English-Scottish border (Evans & Teilmann, 2009; Thompson et al., 2011).

The southern coastline of the Moray Firth is thought to offer important calving and nursing regions for the east coast bottlenose population (Robinson et al., 2007; Culloch & Robinson, 2008). Dedicated surveys in this area, conducted by the Cetacean Research and Rescue Unit (CRRU) from 1997 to the present, have allowed identification of 135 calves produced by 61 known mothers to date (Robinson, unpublished data).

This east coast population is considered vulnerable due to the small number of individuals, although recent evidence suggests that long-term distance movements between east and west coast communities do in fact occur (Robinson et al., 2012). Nonetheless, current concerns over the status of this and other UK bottlenose communities confer the importance of ascertaining breeding success and reproductive histories of such coastally occurring populations. The availability of long-term sightings data for known females in this North Sea population facilitates the potential for an in-depth investigation into the reproductive life history of these animals. In this respect, the current study aims to investigate the reproductive rate and between-female variation in inter-birth periods from known, resident females identified from the long-term dataset gathered by the CRRU, focusing on known females which have produced at least two calves between 1996 and 2013. The calving success of these females will also be examined in the present study, along with the survivability of calves by age and maternal experience. Finally, the study will consider female reproductive strategies and implications for calf care in this population with respect to observed inter-birth intervals and individual calving success.

2 METHODS AND MATERIALS

2.1 *The Study area*

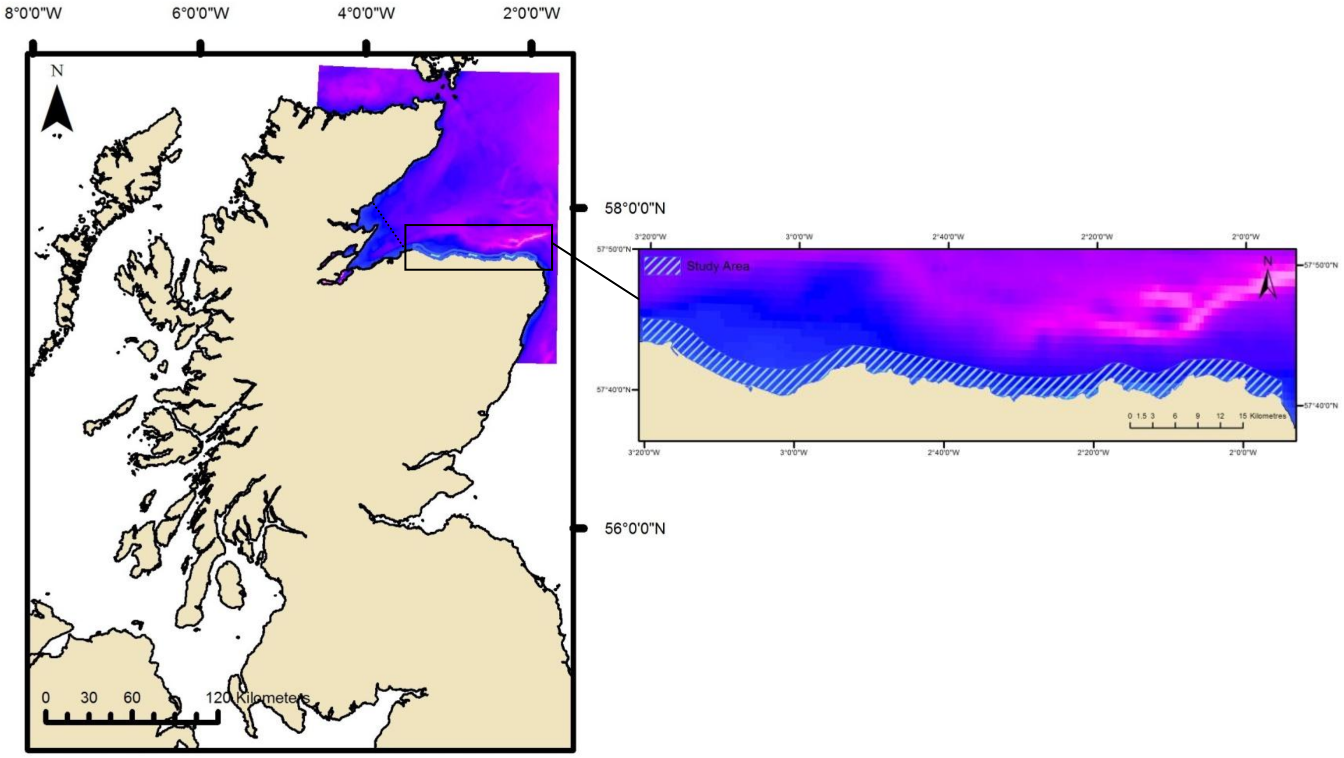

Figure 2.1 Map of Scotland indicating the position of the study area along the coastline of the outer Moray Firth

Measuring approximately 5,230km^2 the Moray Firth in north-east Scotland is the largest firth or embayment in the country, extending from Duncansby Head in the northeast, to Inverness in the southwest to Fraserburgh in the east (Harding-Hill, 1993). It is divided into two geographical areas, namely; the ‘outer’ and ‘inner’ firths respectively. The outer firth represents the area of sea to the west of a diagonal line drawn from Helmsdale in the north to Lossiemouth in the south. The data utilised in the present study was collected from dedicated boat surveys along an 83km area of southern coastline of the outer firth (illustrated in figure 2.1), lying between Lossiemouth and Fraserburgh.

The Moray Firth is a geologically diverse area, displaying variation in sediment type and seabed topography attributed to previous ice ages (Holmes et al., 2004). The retreat and advance of ice has resulted in coastline uplift and variation in sediments across the firth, culminating in a combination of hard cliff coastline, beach terrace and estuarine environments

(Holmes, et al., 2004). With a rocky, convoluted coastline, the outer firth is considered to closely mirror conditions found in the open North Sea (Harding-Hill, 1993).

Evidence suggesting the inner firth was utilised for calving and nursing by bottlenose dolphins led to this region being categorised as a Special Area of Conservation under the EU Habitat Directive in 2005 (Culloch & Robinson, 2008; Weir et al., 2008). The Moray Firth as a whole provides habitats for a diverse range of seabirds, fish and invertebrates, and two other commonly sighted coastal cetacean species, namely, the minke whale (*Balaenoptera acutorostrata*) (Robinson et al., 2009) and harbour porpoise (*Phocoena phocoena*) (Robinson et al., 2007; 2009).There is also evidence that the outer Moray Firth may also be an important resource for a number of other cetaceans, species including killer whales (*Orcinus orca),* long-finned pilot whales (*Globicephala melas*), Risso's dolphins (*Grampus griseus*) and common dolphins (*Delphinus delphis*) were also sporadically sighted within the present study area (Robinson et al., 2007; 2010).

2.2 *Dataset Provided*

The data set used in the current study was collated by the Cetacean Research & Rescue Unit (CRRU) during dedictaed summer boat surveys in the outer southern Moray Firth between May and October 1997 to 2013 inclusive. Calf births from 1996 were identified by the age of those calves encountered with study females in subsequent years. Dedicated inshore coastal surveys were conducted using rigid-hulled-inflatable boats (RHIBs) at mean vessel speeds of 7 knots in visibility of >1km and Beaufort Sea States of <3. Crews consisted of two experienced and up to five additional trained observers (as detailed in Robinson, et al., 2007 and Culloch & Robinson, 2008). A dataset totalling 413 encounters with the study species over 361 survey days was provided for the present analysis from the 17 year study period. From this dataset, all known females with extensive recapture histories that had produced at least two calves were selected for the following examination of inter-birthing periods.

2.3 *Subjects*

Calves were distinguished by their small size, presence of foetal folds, and light colouration (after Eisfeld, 2003). Newborn, first-year calves were the smallest (approx. 1 metre or less in size), displaying prominent foetal folds, and were closely associated with their mothers.

Second year calves were seen to be substantially bigger than first year, but were also lightly coloured and foetal folds were still present. Finally, third year calves were that much larger than first and second year animals, were still lightly coloured, but foetal folds were no longer present.

The association of mothers and calves were determined by the CRRU research team from repeated recaptures during boat surveys and from a long-term knowledge of individuals within the study population by the lead researcher (Robinson, pers. comm.). Calves were seen to associate closely with their mothers up to four years of age (Robinson, unpublished data.). However after separation, the juvenile animals often remained philopatric, allowing their continued identification within the study through to maturity, when many known, former calves were seen to produce offspring of their own during the 17 year research period (Robinson, pers. comm.).

Only known females with extensive recapture histories were included in the following qualitative analysis. These were often individuals that displayed distinctive marks upon the fin and back, such as dorsal edge markings (DEMs), wounds, scars, scratches and lesions, aiding in their repeated recapture. In total, 61 known females with 135 calves were identified from the CRRU dataset for the present analysis.

2.3 *Data analyses: Inter-birth intervals*

33 females that had produced at least two calves were selected for the following examination of inter-birth intervals (IBIs), or the period of time between two consecutive births. IBIs for females which had experienced a calf loss were also explored, as well as the interval between a female’s first and second known births. In addition, the IBI was investigated for all females which had been consistently sighted during their reproductive period. First-born deceased calves were identified, and the average IBI after the birth of the subsequent calf determined. Unpaired t-tests were utilised to perceive any significant differences between IBIs after a calf loss and those which did not occur after a loss, and between IBIs after a first born calf and those IBIs not recorded as a female’s first interval. An identical test was also utilised to ascertain any significant differences between the IBI of deceased first born calves and those that were deceased and not first born.

2.4 *Variation in calving rate between individuals, and between years*

Individual calving rates were determined by using the number of known calves produced by each selected female as a proportion of the years within which that female had been encountered since she was reproductively mature (taken as a year before the production of the first known calf). Annual calving rates were determined by using the number of known calves as a proportion of the number of reproductively mature females sighted that year. For this analysis, annual birth rates were calculated for the study years 2001 to 2013 inclusive. A chi-squared goodness of fit test was used to determine whether differences in birth rates between individual females and annual birth rates were evident. Years sighted and calf number for females with ID #s 178, 387, 445, 463 and 482 were combined as they were only sighted for one or two years within the entire study, ensuring no expected values were below one. Significance in all statistical analyses was taken as p=<0.05.

2.5 *Calf survival and female reproductive success*

Overall numbers of known living and deceased calves, and the number of births per year were further examined. The outcome for many calves could not be established due to the low recapturability of both females and calves as they matured. Chi-square tests were used to detect if any significant variation in annual calf production existed. If expected values were too low, categories were combined to ensure the analysis was valid. Chi-square tests were also used to identify if any variation in calf deaths and the survivability of calves existed. Female reproductive success was established by examining the number of calves which were noted as definite survivors as a proportion of the total calves said female(s) had produced. From this, the percentage of surviving calves from each female was calculated.

2.6 *Birth seasonality*

Known birth months and years for all known calves were examined to determine the intra and inter-annual range in births for the population. Chi-squared goodness of fit tests were used to detect if any significant variation in birth months existed.

2.7 *Generalised Additive Models (GAMs)*

The ‘Minimalist Generalised Cross Validation’ (mgcv) function of the statistical software package ‘Brodgar’ was finally used to perform Generalised Additive Models (GAMs) on the dataset. GAMs were chosen due to their ability to deal with data that is not normally distributed. They were utilised in a number of ways; using various variables from the filtered data as fixed effects, such as IBIs, number of previous calves and calf birth months and birth years. The effect of study year was removed from GAM analyses due to its confounding effect upon the model as a result of a relatively small data series (18 years, 1996-2013). The partial effects of the explanatory variables on the response variable was visualised in the plots obtained. The models were subsequently examined for influential data points, and patterns within the residuals. Continuous explanatory variables could be used as ‘smooth’ terms. The significance of the effect of the explanatory variables upon the response was represented by p-values, and the percentage deviance indicated how well the models fitted the chosen data.

Specific questions addressed and investigated using GAMs were:

- Did the status of an individual females previous calves and the time since the birth of those offspring affect that individual’s probability of producing future calves?
- Does the length of an inter-birth interval and status of previous calves affect the survivability of the next calf produced?
- Did the birth month and outcome of a female’s first recorded calf affect the inter-birth interval between that individuals second calf?
- Does the birth month of a female’s first known calf affect its survival?

3 RESULTS

3.1 *Inter-birth intervals observed over the study period*

A total of 61 female dolphins with 135 assigned calves were identified from the CRRU dataset provided. However, since inter-birth intervals could only be examined from females known to have produced a minimum of two or more calves, 33 females with 107 assigned calves (comprising 74 inter-birth intervals) were selected for IBI analysis.

Inter-birth intervals for the outer firth community in the Moray Firth ranged from two to eight years, with a mean of 3.72 ± 1.29 years (median= 3 years, n=74). Selected females with continuous sighting histories (n=7) had IBIs ranging from two to six years, with a mean of 3.5 ± 1.27 years (n= 16 intervals, median= 3 years).

The shortest IBI between successive surviving calves was just two years, and six females had an inter-birth interval of two years after the loss of a calf. The inter-birth interval after the birth of the first known calf ranged from two to eight years, with an average of 4.09 ± 1.42 years (n= 33 intervals, median= 4 years) (presented in table 3.1). An average IBI of 3.3 ± 2.05 years (n=10 intervals, range= 2-8 years, median= 2 years) was observed for the ten mothers that calved again after the loss of a calf (table 3.1).

The interval between the birth of the first known calf produced by a female, which was later lost, and that female's second calf averaged 4.40 ± 2.51 years (n=5 intervals, range= 2-8 years, median= 5 years).

There was a significant difference between the first IBI (interval between the first and second calves) and later IBIs; t=2.55, p=<0.05 (table 7.1, appendix). However, no significant difference was recorded between IBIs after a calf loss, and those not occurring after a calf death; t=-0.72, p=>0.05 (table 7.1, appendix). Similarly, no significant difference was established between IBIs after the loss of a first born calf, and IBIs after a deceased calf that was not first born; t=1.93, p=>0.05 (table 7.1, appendix).

The majority of females displayed only one or two intervals, as illustrated by fig. 3.1. The most frequently observed IBI values were three and four years (figure 3.2). Longer intervals of seven and eight (n=3) years were also recorded but were not as common (table 3.1, figure

3.2). Of the ten IBIs which were recorded as two years in the full dataset, six of these occurred after a calf loss (table 3.1).

Table 3.1. Length of inter-birth interval across all inter-birth intervals (n=74). 'Complete intervals' are the intervals displayed by seven females which showed continuous sighting histories across the study period. The inter-birth interval after the production of the first known calf, and the intervals recorded after a calf loss are also illustrated.

Inter-birth interval (years)	Frequency across all intervals	Frequency of complete intervals	Frequency of intervals after 1st calf	Frequency of intervals after calf loss
2	10	3	3	6
3	28	7	10	1
4	20	3	9	0
5	9	1	6	2
6	4	2	3	0
7	2	0	1	0
8	1	0	1	1
Total	74	16	33	10
Mean	**3.72**	**3.50**	**4.09**	**3.3**
Standard deviation	**1.29**	**1.27**	**1.42**	**2.05**
Median	**3**	**3**	**4**	**2**

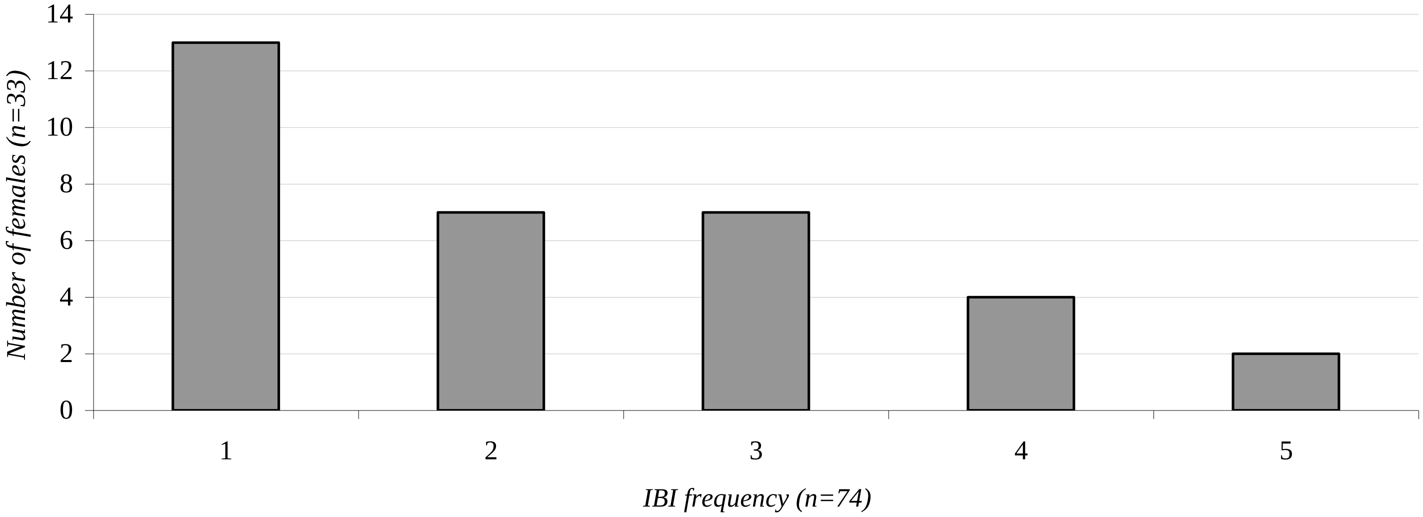

Figure 3.1 The frequency of inter-birth intervals shown by the 33 known females in the study.

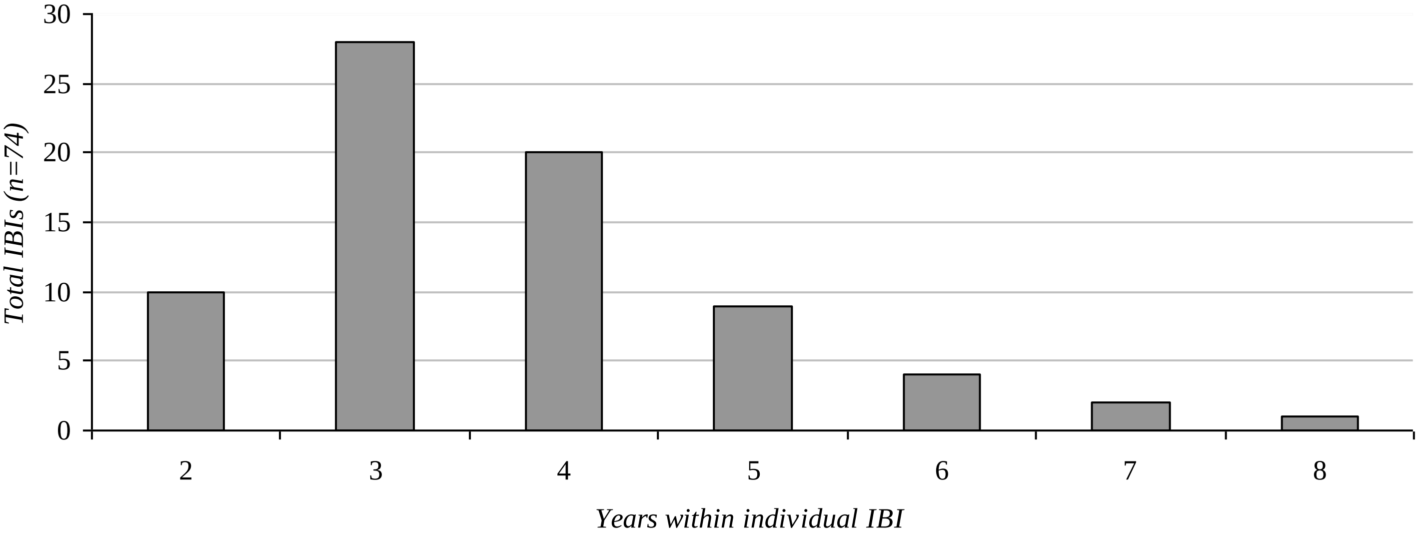

Figure 3.2 Number of years within each inter-birth interval displayed by bottlenose females examined from the available Moray Firth dataset.

3.2 *Variation in individual calving rate*

Individual calving rates were found to be variable within this population (figure 3.3 and table 7.1, appendix), although chi-squared tests revealed no significant difference between the calving rates of different females (χ^2_{27}= 32.42, p =>0.05) (table 7.2, appendix). Two females (ID#s 003 and 187) represented the most productive females recorded from the 17 year dataset, with each producing six calves between 1996 and 2013 respectively (table 3.2).

Table 3.2 Individual female calving rates, showing female ID number (CRRU), total known calves, the number of years where that female was encountered when she was reproductively mature, and the calving rate as a proportion of the total calves and the number of years sighted. Females were sometimes only encountered once or twice across the study period, and accompanying calves were aged by researchers on appearance, resulting in the high number of calves per year for females with ID#s 87, 178 and 468.

Mother ID	Total calves	Years sighted	Calves per year
3	6	15	0.40
15	3	10	0.30
35	2	13	0.15
65	5	15	0.33
67	5	15	0.33
80	3	5	0.60

81	2	6	0.33
85	2	4	0.50
87	4	4	1.00
89	4	10	0.40
102	4	6	0.67
112	5	7	0.71
118	5	13	0.38
119	4	13	0.31
162	3	9	0.33
178	2	1	2.00
187	6	17	0.35
216	3	9	0.33
225	4	14	0.29
327	3	9	0.33
362	3	7	0.43
378	3	8	0.38
379	2	3	0.67
387	2	2	1.00
389	2	9	0.22
396	2	5	0.40
410	2	0	0.00
432	2	9	0.22
445	4	3	1.33
455	2	2	1.00
463	2	3	0.67
468	4	2	2.00
482	2	7	0.29

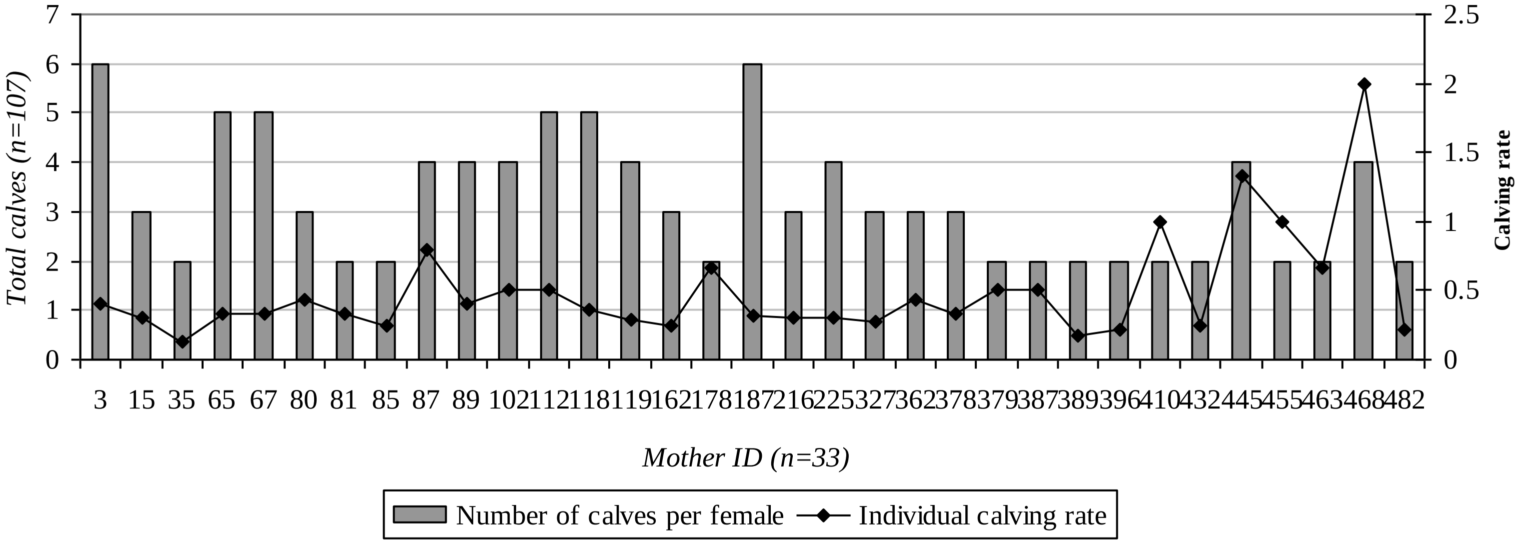

Figure 3.3 Showing the productivity of each of the female bottlenose dolphins examined in the present study from the Moray Firth dataset.

3.3 *Annual variation in calving rate*

Average annual calving rates between 2001 and 2013 (across all females observed in a given year) were found to be highly variable, with total numbers ranging from 4 newborns in 2008 to 12 in 2012 (table 3.3 and fig. 3.4), and a mean annual calving rate of 0.43± 0.12 calves per year. 2008 showed the greatest decline in calving rate over the 13 years examined. However, the inter-annual variation in calving rates was not significant (χ^2_{12}= 10.23, p =>0.05) (table 7.3, appendix). Peaks in calving rate may be observed in 2007 and 2012, with subsequent drops in production in the following years of 2008 and 2013, respectively.

Table 3.3 Annual calving rates across each study year, with total calves produced in that year, number of reproductively mature study females encountered in that year and calving rate as a proportion of total calves and females seen.

Year	Total calves	Females sighted	Calving rate
2001	6	15	0.40
2002	5	12	0.42
2003	5	14	0.36
2004	6	17	0.35
2005	6	19	0.32
2006	9	23	0.39
2007	11	15	0.73
2008	4	24	0.17
2009	8	17	0.47
2010	8	19	0.42
2011	10	19	0.53
2012	12	20	0.60
2013	6	15	0.40

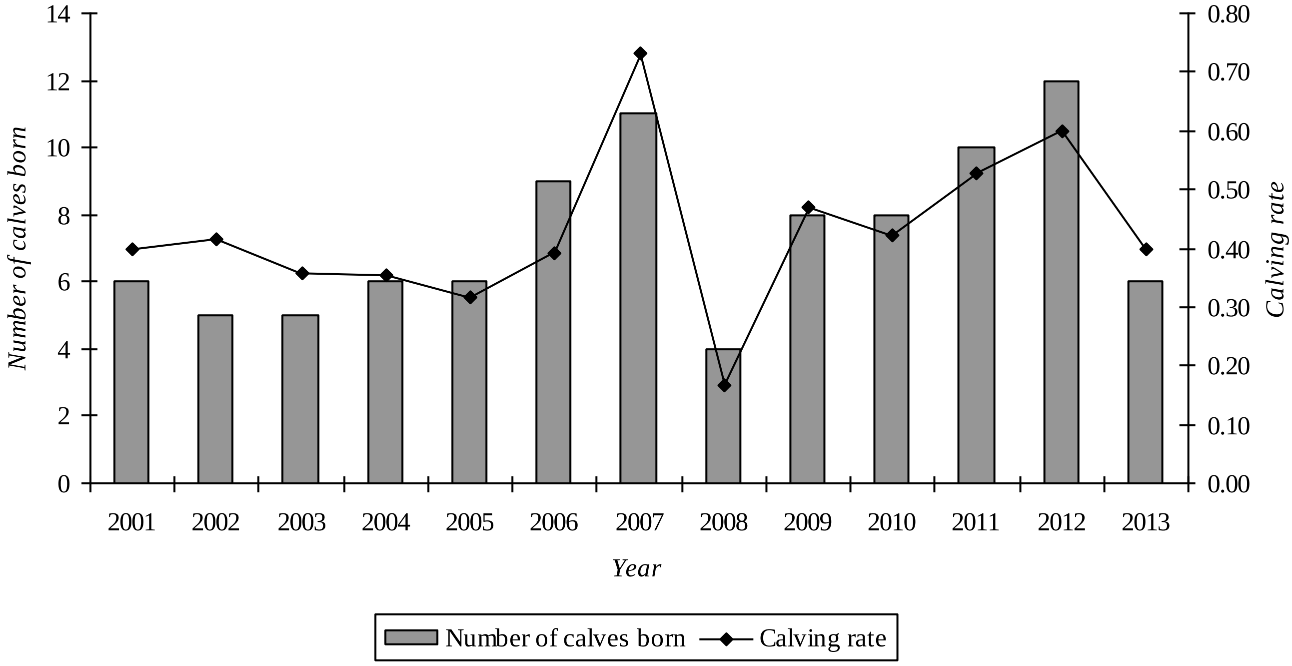

Figure 3.4 Illustrating the annual bottlenose dolphin calving rates and number of known calves produced each year by sample females between 2001 and 2013.

3.4 *Calf survival and female reproductive success*

Of 135 confirmed calves recorded by the CRRU research team between 1996 and 2013 inclusive, 14 were known to have died and 36 were of an unknown status. Nevertheless, 85 (63%) of the 135 known calves were successfully tracked by the CRRU team up until and including 2013 (table 7.4, appendix). Neither the number of known surviving calves, nor the number of deceased calves showed significant variation between study years (χ^2_{13}=1.91, p=>0.05 and χ^2_4= 2.08, p=>0.05) (table 7.5 & 7.6, appendix).

Annual calf production versus the number of calves known to have died in each study year may be observed in fig. 3.5. All known calf deaths (n=14) were attributed to different females (table 3.4). However, the number of calf losses was highest in 2012, where four deceased calves were documented, out of the 16 born. Birth numbers per year increased over time, and the total number of births significantly varied from year to year, (χ^2_{17}= 42.92, p=<0.05) (table 7.7, appendix). Out of the 14 confirmed calf deaths, five occurred in calves recorded as the first known offspring of their respective mothers.

Focusing on individuals from the IBI analysis, eight females had the maximum calving success rate (100% survival of known calves produced) over the 17 years of the study period.

Individual female reproductive success is illustrated in fig. 3.6. Two females, ID #81 and #178, both produced two calves, neither of which could be positively identified as surviving, representing 6.06% of selected females (table 7.8, appendix). A single surviving calf was recorded for 33.33% of bottlenose females which had produced more than one offspring. 27.27% of females had two surviving calves, 18.18% had three surviving calves and 15.15% had four calves which were positively identified as alive up until 2013.

The average age of the ten first time mothers identified from the whole data set was 8.8 years, and of all the first calves born only one did not survive. The first calf of female ID# 65 is recorded as deceased yet this individual went on to successfully raise her four subsequent calves (Table 7.9, appendix).

Table 3.4 Females which suffered a definite calf loss over the study period. Showing ID of individual female (CRRU), birth year and month of deceased calf with birth year and month of subsequent calf and the IBI between the deceased calf and subsequent calf. Also illustrating the sighting record of each mother in the IBI between lost calf and subsequent calf.

[1] Female not included in IBI analysis
*** Female has not calved since calf loss.**

Mother ID	Birth year	Birth Month	Subsequent calf birth year	Subsequent calf birth month	IBI	Mother sighted in IBI?
3	2000	October	2002	Unknown	2	Yes
15	2007	October	2010	October	3	Yes
65	1997	August	2002	September	5	No
87	2012	October	*	*	*	N/A
118	2011	August	2013	August	2	Yes
119	2010	August	2012	July	2	Yes
187	2004	August	2006	August	2	Yes
216	2002	Unknown	2007	Unknown	5	No
387	2009	September	2011	Unknown	2	No
389	2004	August	2012	September	8	No
410	2011	August	2013	August	2	No
445	2012	October	*	*	*	Yes
482	2012	July	*	*	*	Yes
530[1]	2012	September	*	*	*	N/A
				Total	10	
				Mean	3.3	
				Standard deviation	2.05	
				Median	2	

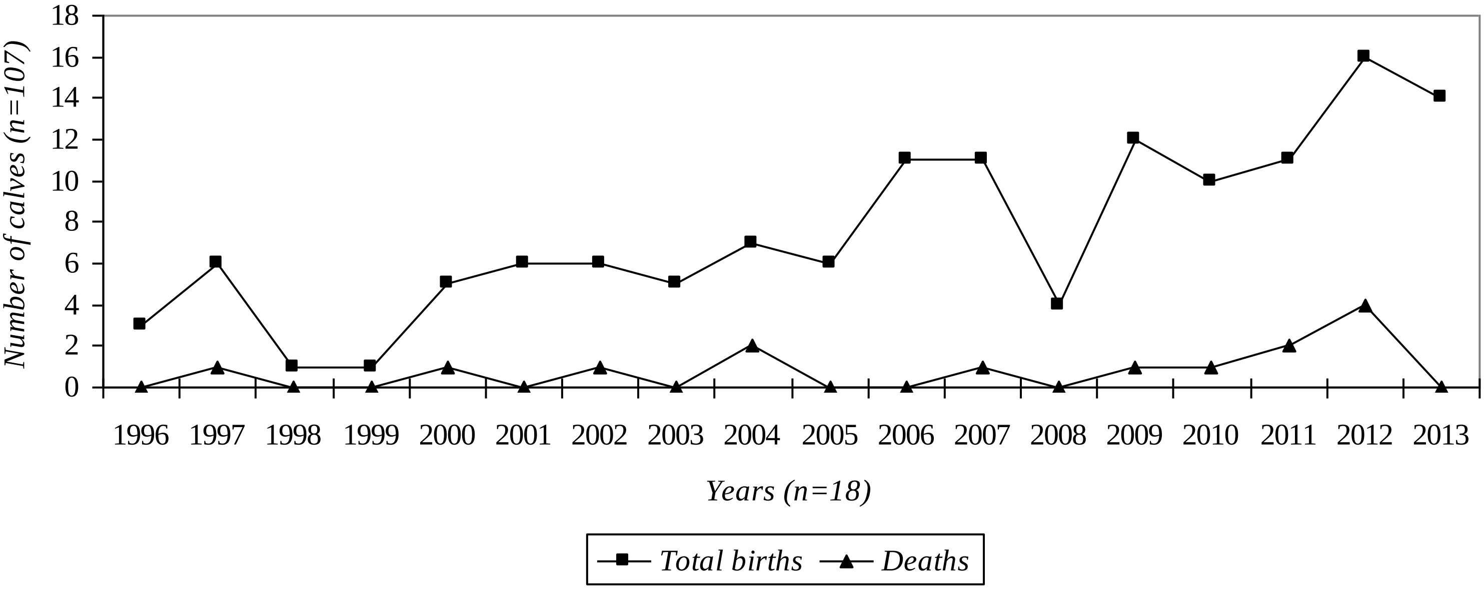

Figure 3.5 The number of calf births and deaths observed during the current study from 1996 to 2013.

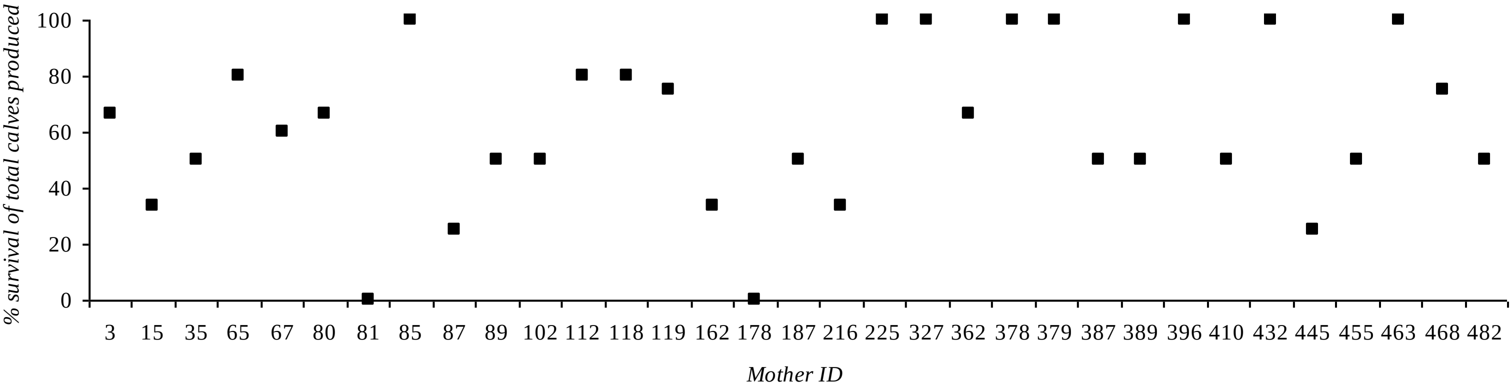

Figure 3.6 Percentage of all calves born to individual females from the IBI analysis which were positively identified as alive in the outer Moray Firth.

3.5 *Birth seasonality*

Calves in the Moray Firth population were born between the months of May and October, with a peak in birth numbers during August. The birth months of all calves for which this detail was available are identified in fig. 3.7. Of the calves with a known birth month (n=86), 46.51% were born during August. Fewer calves were born between May and July inclusive (n=15), while larger numbers of calves were recorded between August and October inclusive (n=71).

There were four years within the study period that presented no calves which could be accurately assigned birth months (1996, 1998, 1999 and 2004) (table 3.5). August was generally the most common month of birth for calves in this population, but the available data revealed that in some years this was not the case, such as in 2000, 2002, 2005 and 2007-2009. Fewer calves on average were born across the years where August did not represent a peak in birth numbers (n=4 calves per year). By comparison, an average of 7.6 calves were produced across the years where calf births were most commonly recorded in August.

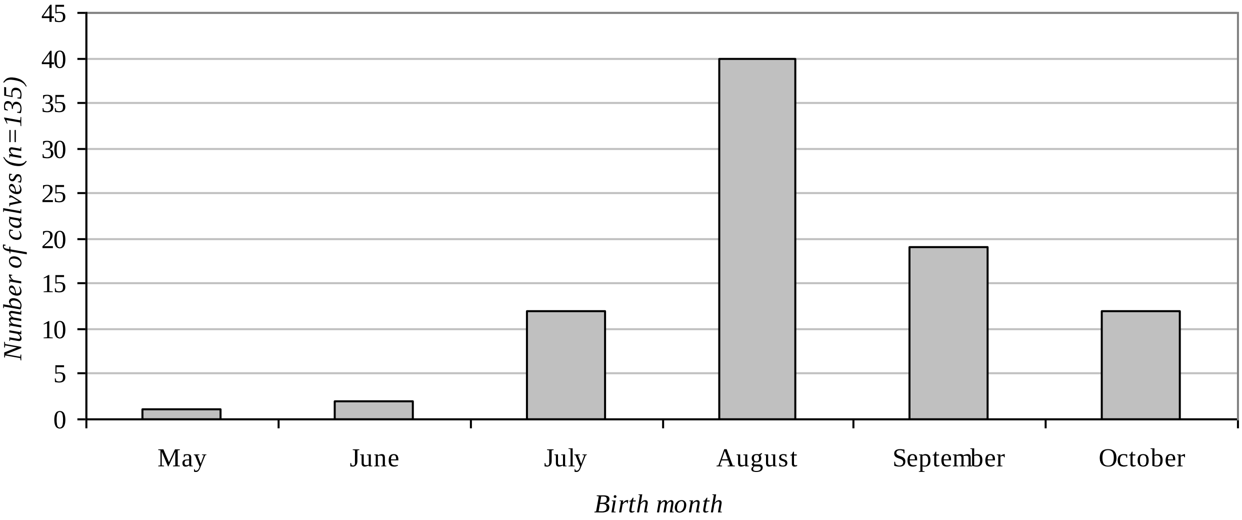

Figure 3.7 Illustrating the known birth months for all calves produced during the current study in the Moray Firth.

Table 3.5 Number of calf births in each month by year of study. 'Unknown' refers to the number of calves born in that year with undetermined birth months. Total calves born in each year, and each month are also shown.

Year	Month May	June	July	August	September	October	Unknown	Total
1996	0	0	0	0	0	0	3	3
1997	0	0	1	2	0	0	3	6
1998	0	0	0	0	0	0	1	1
1999	0	0	0	0	1	0	0	1
2000	0	0	0	0	0	2	3	5
2001	0	1	0	3	0	0	2	6
2002	0	0	1	0	2	1	2	6
2003	0	0	0	0	0	0	5	5
2004	0	0	0	3	0	0	4	7
2005	0	0	1	1	0	0	4	6
2006	0	1	0	3	2	1	4	11
2007	0	0	2	0	2	1	6	11
2008	0	0	0	1	1	2	0	4
2009	1	0	2	2	2	0	5	12
2010	0	0	0	4	1	1	4	10
2011	0	0	1	6	0	2	2	11
2012	0	0	3	6	4	2	1	16
2013	0	0	1	9	4	0	0	14
Month total	1	2	12	40	19	12	49	135

3.6 *GAM analyses*

3.6.1 *Is calf production affected by the time since previous calf birth and previous calf survival?*

Analyses were undertaken to ascertain if the probability of a female producing a calf was affected by the time interval since a previous calf was born. Similarly, further analyses were undertaken to establish if the number of surviving previous calves produced by a female affected that individual's probability of calving again. A GAM was fitted with calf birth event, or occurrence of calf birth (1 or 0) as the response, with number of surviving calves and the time since previous birth utilised as continuous explanatory variables (fitted as smoothing terms). A non-linear relationship was indicated between the time since previous calf and the number of previous calves recorded as alive. 17.7% of residual deviance was explained by the fitted model.

The effects of the time since a previous birth upon the probability of calving may be observed in fig. 3.8A. The positive effect of increasing the time since a previous birth increased the probability of a calving event until after approximately six years had passed, where the probability begins to decrease (the relationship is significant, p= 0.02). Larger numbers of calves were likely to be produced if the time since a previous calf was longer but after six years without producing a calf, the likelihood of reproduction decreases.

The positive significant effect of the number of surviving calves on the probability of calving in a given year is demonstrated in fig. 3.8B. A larger number of surviving calves is associated with a higher probability of a calf birth.

3.6.2 *Does the IBI and the status of a previous calf and affect calf survival?*

Investigations were also undertaken to understand the factors affecting the survival of calves in the study area. A GAM was constructed, with the number of deceased calves as a response, and IBI and number of surviving calves as the explanatory variables. The resulting model explained 18% of residual deviance.

The number of surviving calves for a female showed no clear relationship between the number of deceased calves observed (fig. 3.9A). Despite this, the model output suggested that the number of surviving calves had a significant effect on the number of deceased calves (p=<000.1). This implies a coincidental relationship, where the numbers of surviving and deceased calves is a function of the number of calves produced. In this case, as more calves successfully survive, the number of deceased calves can also be expected to increase.

The effect of IBI on the survival of calves was also investigated by the previously mentioned GAM (fig. 3.9B). There was an unclear relationship between IBI and number of deceased calves yet the model output indicated that it was a significant interaction (p=0.03). The model suggested that numbers of dead calves decreased as length of inter-birth interval increased for individual females.

3.6.3 *Does birth month and status of the first calf affect female's first IBI?*

A similar investigation was attempted to determine if the birth month and status of a female's first calf had an effect upon the subsequent IBI (between first and second calves). The explanatory variables showed no significant effect upon the first IBI of selected females ($p>0.05$). The small sample sizes of these variables may have affected this result; as birth months and status of some calves remained undetermined.

3.6.4 *Does calf birth month affect the survival of the first calf?*

The possible effect of birth month upon the survival of the first calf was also examined. A generalised additive model was applied with status of first calf as the response, and birth month of first calf as the smooth term. The fitted model explained 33% of residual deviance, but no significant relationship was observed between calf survival and birth month ($p=0.69$). The lack of relationship between these variables is illustrated in fig. 3.10. The large confidence limits may be attributed to the low number of calf births in June and October.

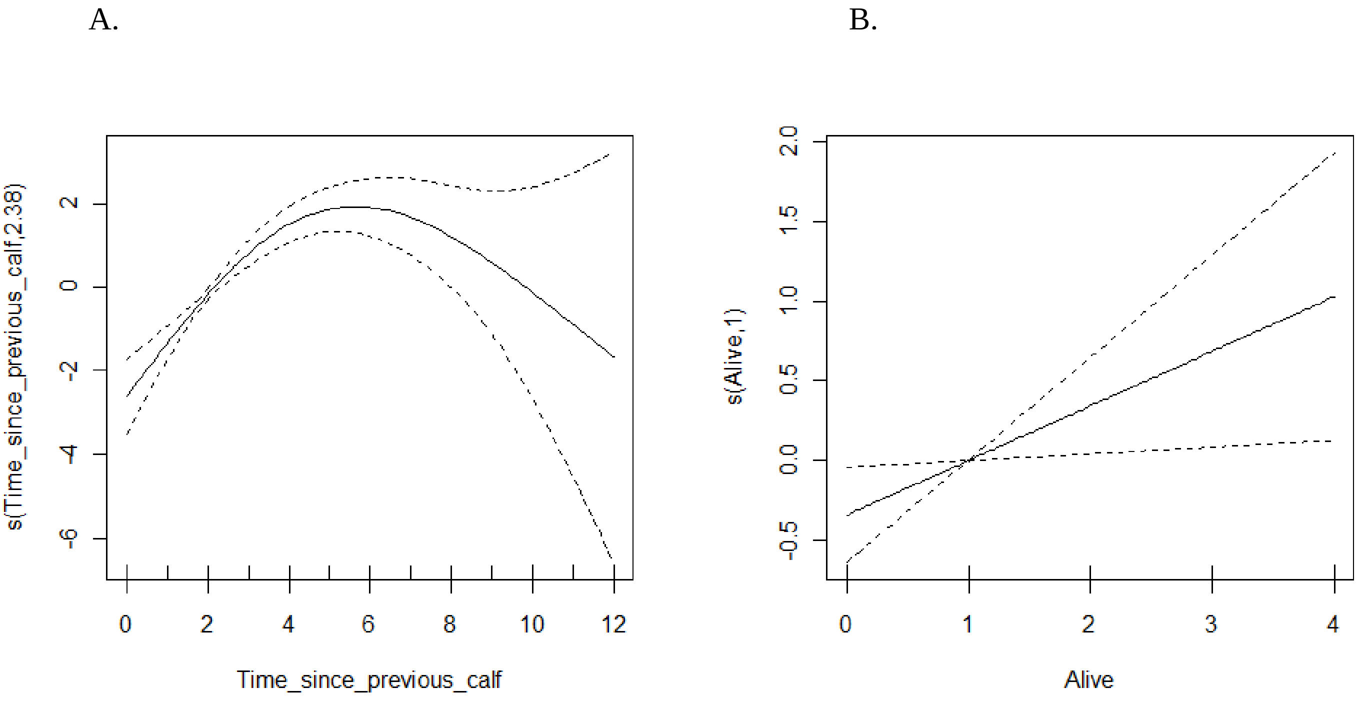

Figure 3.9 Plots illustrating the partial effects of IBI and surviving calves on the probability of a calving event for female bottlenose dolphins in the Moray Firth. Left to right: effect of IBI on the calving probability; and effect of previous surviving calves on the calving probability.

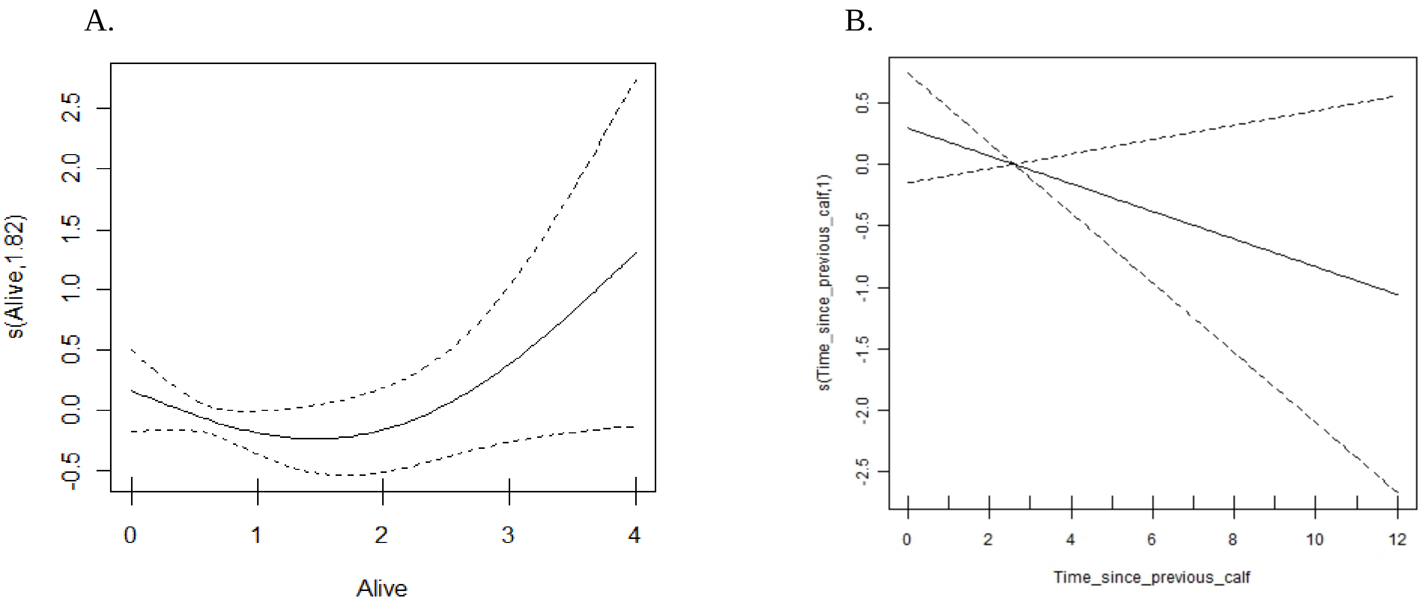

Figure 3.10 Plots demonstrating the effect of the number of surviving calves and IBI on calf survival (as number of deceased calves) in the Moray Firth. Left to right: effect of the number of surviving calves on deceased calves; and effect of IBI on numbers of deceased calves.

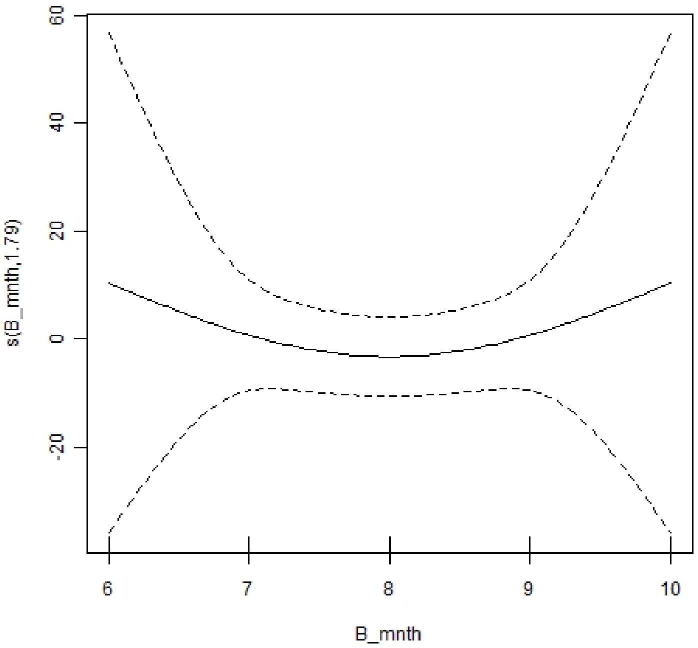

Figure 3.11 Plot illustrating the lack of relationship between the first known calf's birth month on its survival status.

4 DISCUSSION

Long-term studies are vital for our understanding of reproductive parameters in long-lived, slow reproducing marine mammals. In the present study, the number of calves identified in the 17 year dataset (n=135), represented a large proportion of the total population, estimated at 193 animals (Cheney et al., 2013).

4.1 *Observed inter-birth intervals*

The study population showed an average inter-birth interval of 3.72 years, although individuals with continuous sighting histories displayed an average IBI of 3.5 years. This suggests 3.72 years as an average IBI may be an overestimate for this population, as some calves may have been missed. By comparison, in Doubtful Sound, New Zealand, average IBI was three years, ranging between two and five years (Haase & Schneider, 2001). In Sarasota Bay, the IBI was identified as three years, while in Shark Bay females produce a calf around every four years with a range between three and six years (Mann et al., 2000; Boness et al., 2002). Both calculated average IBIs for the study population are longer than those observed in other populations.

Why would female dolphins in the Moray Firth display longer IBIs than those observed in other populations? Firstly, the dolphins inhabit temperate waters at the northernmost extreme of their global range, where temperatures are below those observed in other regions. Low temperatures increase the metabolic demands of small, young calves that have yet to develop adequate insulation through layers of blubber. In response to this, females may increase the period of calf care, minimising the detrimental effects of low temperature by allowing their offspring to nurse for longer. Secondly, longer IBIs may allow females to build the energy reserves required to raise large calves, as animals within the Moray Firth are the largest of their species. Growth rates of calves from the Moray Firth have yet to be investigated, and it is unknown if they mature at a slower pace than calves from other populations. Finally, male dolphins may have less control over the distribution of females throughout the firth, allowing them to avoid harassment and pregnancy by escaping from herding attempts. By comparison, males in Sarasota Bay can easily monopolise females as the water depth is often below 10m, presenting females little opportunity for escape from male coalitions (Scott et al., 2012). The water depth in the Moray Firth is far greater and may facilitate female avoidance of males.

The estimate of 3.5 years as an average IBI is based on a reasonably high number of females with full sighting and calving histories, and may therefore be considered reliable. As shown by fig.3A, a longer recovery time between birth events improves the survivability of a female's future offspring in this population, suggesting that longer lactation and calf care is being selected for. The slightly longer average IBI for females in the Moray Firth compared to some other populations would support this hypothesis.

The weaning age of bottlenose dolphins is known to be between 18 to 20 months of age in captivity (McBride & Kritzler, 1951), yet the average inter-birth interval of 3.5 years is far longer than this. It is understood that calves can associate with their mothers for up to eight years in the Moray Firth (Grellier et al., 2003), well past the age of nutritional gain as a post-weaned infant (Gibson & Mann, 2008). Indeed, one female (ID #389) in the outer firth community had an IBI of eight years, and was encountered in all but two of those years since the birth of her first known calf. In Sarasota, an undersized and anaemic male calf associated with his mother for ten years (Leatherwood & Reeves, 2012), suggesting that periods of female care may be extended if a calf is in poor condition. In the present study, two calves from females #67 and 118 were recorded as suffering from spinal deformities (Haskins & Robinson, 2007). However, calf production was less likely more than six years after the previous calf was born for females in this population. This may suggest that females with unusually long inter-birth intervals are reaching the end of their natural reproductive output, as many female mammals experience a decline in reproductive rate as they age (Parker et al., 1998), or are otherwise unhealthy.

Despite an average IBI of almost four years, and a number of IBIs which were considerably more than this, there were ten intervals which were recorded at just two years in the study population. Of these, six occurred after a calf loss. A total of 14 calves were known to have died from the present data set, and the subsequent average IBI until the next calf was shorter than when the previous calf survived. This may indicate that pregnancy can occur shortly after a calf death. Mann et al. (2000) suggest that if a female loses an infant calf, or suffers a loss when the time remaining may allow reproduction within the next breeding season, she may begin to cycle rapidly after the death of that calf. The same study indicated that females were unlikely to breed the next season if they lost a calf of an older age. Six study females calved within two years of a calf death, suggesting the energy loss associated with the death of infant calves is minimal enough to allow a rapid consecutive pregnancy, and that those calves may have been very young when they died. Therefore, young calves may be exposed to an increased intraspecific infanticide risk from adult males if females can become pregnant rapidly with the offspring of the attacking animal, while maternal calf protection may be enhanced during the vulnerable newborn stage to prevent this (Stanton et al., 2011). Indeed, there have been a number of confirmed cases of intraspecific infanticide in the Moray Firth (Patterson et al., 1998). One such case involved female ID #187, whose calf was lost at six months of age possibly as a result of complications caused by an attempted infanticidal attack occurring shortly after its birth (see Robinson, 2014).

Four females (ID #s 65, 85, 112 and 327) displayed a two year interval which did not occur after a calf loss, suggesting other factors may contribute to this observation. Females may shorten the period of care for their current calf in order for that offspring to be independent upon the birth of its sibling. This is vital as females would be unable to cope with the associated energy costs of caring for both an infant and juvenile calf (Evans & Stirling, 2001). Bottlenose dolphins have been shown to continue nursing current calves after the onset of an ensuing pregnancy, potentially increasing their reproductive output (Connor et al., 2000; Mann et al., 2000). Indeed, only female ID #85 produced less than three calves, yet she may be a relatively young mother as her first calf was born in 2007. If inter-gender competition in the outer firth is similar to that in other populations, females may be monopolised while their current calf is nursing. While this may be disadvantageous to individual offspring by shortening their period of care, females will subsequently display an inferred increased reproductive output, potentially shown by female ID #s 65, 112 and 327, producing five, five and three calves respectively over the study period.

In addition, shorter IBIs may be the result of increased maternal experience and fitness, where females which have previously produced calves take less time to successfully raise new offspring. For each of the four study females previously mentioned, it was the most recent calf produced which occurred after a two year interval suggesting these females were experienced mothers. Experienced females may be able to better understand prey movements across their range, with that information being accrued from previous pregnancies. This would potentially increase their energy intake, and therefore fitness, during gestation and lactation and subsequently reduce the period needed to raise a calf to independence, directly linking a shorter IBI to resource availability. Indeed, the cognitive abilities of bottlenose dolphins suggest they can maintain long-term memory of fluctuations in prey availability within their environments (Connor, 2007).

Investigation into the average IBI between a female’s first and second calf revealed that it was significantly longer than the average IBI between calves which were not first born (4.09 and 3.41 years, respectively). In contrast, Mann et al. (2000) reported a shorter average IBI between first and second calves in Shark Bay. However, Shark Bay ecotypes rarely reach over 230cm (Smolker et al., 1992), while animals in the Moray Firth are among the largest of their species (Wilson, 1995). First-time mothers in the study population may require a longer period to recover after their first birth as they invest more heavily in the production of large offspring able to survive in colder northern waters. This would potentially lengthen the inter-birth interval before the production of the next calf. Interestingly, some primate species such as mandrills and Japanese macaques also display longer IBIs between their first and second offspring (Itoigawa et al., 1992; Setchell et al., 2002). Researchers suggested that primiparous females lacked the experience necessary to raise an infant to independence in a shorter time period, and that young mothers made a significant trade-off between growth and first lactation, incurring large energy costs. Such a trade-off can also be observed in marine mammals, where energy is allocated to reproduction only if an individual is above a certain critical mass (Boyd, 2002), and which may in part explain the longer first IBI of female bottlenose dolphins in the Moray Firth.

4.2 *Variation in annual and individual calving rates*

Individuals will naturally display a variation in reproductive rate depending on their age, size, health, and access to resources and mates. In the present study individual variation in calving rate between bottlenose mothers was not found to be statistically significant. The majority of individuals produced two calves, yet some females produced up to six generations of calves and consequently, had high calving rates. These individuals may be older, and at optimal reproductive output. Studies have shown that female reproductive success in bottlenose dolphins is greatly influenced by maternal body condition, which in turn is determined by habitat quality and access to resources (Mann & Watson-Capps, 2005).

Annual calving rates may be of more interest in light of recent conservation efforts to protect the bottlenose dolphin in the Moray Firth. Since the designation of the inner Moray Firth as an SAC in 2005, there have been few published conclusions investigating its effect on annual reproductive rates. One such investigation published shortly after the designation of the inner firth as an SAC found no statistically significant variation in annual calving rate (Mitcheson, 2008), mirroring the results from an identical analysis on annual rates in the present study.

4.3 *Calf survival and female reproductive success*

Calves in the Moray Firth had a high survival probability compared to the survival of calves seen in tropical and sub-tropical populations. In Sarasota and Shark Bay, 46% and 44% of calves died before weaning respectively (Connor et al., 2000). Indeed, both Sarasota and Shark Bay bottlenoses are predated upon by sharks, and animals visiting Monkey Mia in Shark Bay are also artificially provisioned (Connor et al., 2000; Mann et al., 2000). Provisioned females have been shown to reduce calf care, subsequently increasing calf mortality (Mann et al., 2000). However, the majority of offspring encountered by the CRRU researchers over the study period are still documented as alive. Why does the Moray Firth bottlenose population display such reduced calf mortality in comparison to other populations?

At first, the lack of predation upon bottlenose dolphins within the Moray Firth would seem to enhance calf survival. Sharks present a significant predation risk to calves in Shark Bay and Sarasota (Mann & Barnett, 1999; Scott et al., 2012), but sightings of predators in the Moray Firth, such as killer whales, are rare (Wilson et al., 1997). However, studies suggest that calf mortality is affected to a greater extent by maternal care and resulting calf condition rather than predation (Mann & Watson-Capps, 2005). With this in consideration, it could be suggested that overall calf condition is higher in the Moray Firth compared to areas such as Shark Bay and Sarasota, contributing to the greater survival of offspring.

Secondly, one may consider Moray Firth dolphins at a disadvantage with the influx of the dolphin-watching tourism industry. The region has been subject to the fastest growing cetacean tourism in the UK (Hughes, 2004), yet this has mainly developed within the inner firth. Disturbance from boats has been shown to cause disruption in normal behavioural patterns (Janik & Thompson, 1996; Sini et al., 2005). Notably, it has been suggested females will travel more in response to boat traffic, allowing shorter and fewer periods of time where calves may nurse (Stensland & Berggren, 2007). As a result, reproductive success may be decreased in areas of boat-based tourism (Constantine & Bejder, 2008). Nevertheless, mortality and reproductive success may be less affected by this industry in the Moray Firth. Females may be able to range further along the coast to avoid disturbance to boats, or perhaps breeding site fidelity is not restricted to the inner firth alone meaning populations of females and calves remain unaffected. Indeed the current SAC in the Moray Firth was established to protect a proposed calving site for female bottlenose in the region, but other regions within the firth may be equally important for calf rearing (Grellier, 2000; Culloch & Robinson, 2008). It may also be considered that a number of calves may have actually died, and with the inherent difficulty in recovering a carcass or tracking poorly marked juveniles after separation it is likely that the mortality of calves in the outer firth was underestimated.

Five of the 14 deaths documented occurred in the first born of young, inexperienced females. Mortality of first calves compared to subsequent offspring has been unexplored in bottlenose dolphins, yet studies of primates suggest that mortality is twice as high in offspring of primiparous females (Bercovitch et al., 1998). Inexperienced first-time mothers have been shown to restrict the independence of their offspring (Bercovitch et al., 1998), which would directly reduce the survival probability of bottlenose dolphin calves, where more dependent calves have a higher mortality rate (Mann & Watson-Capps, 2005). However, as previously mentioned, primiparous females were found to have longer inter-birth intervals and potentially longer periods of care for their calves in the study population, potentially increasing offspring fitness and reducing calf mortality.

5 CONCLUSIONS

Findings from the present study offer new estimations for the inter-birth intervals, reproductive rates and calf survivability of female bottlenose dolphins in the Moray Firth. Inter-birth intervals have been shown as longer than previously estimated, with obvious effects upon this reproductive parameter when a calf is lost or first born. Further investigation is needed to understand the long-term effects of such changes on the reproductive rate of this population, and if mating strategies are altered as a consequence.

The environmental conditions within the Moray Firth may be of a high quality, allowing for increased survivability among calves. However, if this is the case, it is of utmost importance to ascertain whether high reproductive rates and low calf mortality can be sustained in a region affected continuously by human activities. Indeed, such proximity to humans does seem to affect the health of these animals (Wilson, 1995) and in a geographically isolated area, this may serve to increase the vulnerability of this population.

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7 APPENDICES

Table 7.1 Unpaired t-test results for the comparison of IBI type. 'Later'= the average of 41 IBIs not recorded as a female's first interval. '1st/2nd'= the average of the 33 IBIs between the first and second calf. 'No loss'=the average IBI recorded not occurring after a calf loss, while 'Loss'= the average of 10 IBIs which occurred after the loss of a calf. 'Loss of later' = the average IBI recorded for deceased calves which were not first born, while 'Loss of first'=the average IBI calculated for deceased first born calves.

IBI	Later	1st/2nd	No Loss	Loss	Loss of later	Loss of first
Mean	3.41	4.15	3.78	3.3	2.2	4.4
SD	1.09	1.35	1.13	2.06	0.45	2.51
t		2.54		-0.72		1.93
p		0.014		0.49		0.13
DF		61		9		4

Table 7.2 Chi^2 calculations for individual study female calving rates. Identifying female ID# (including ID# 187, 387, 445, 463, 482 under 'combined females'), the known number of calves produced by that female, the total years within the study that female was sighted, the observed calving rate and resulting chi-squared calculations.

ID	Calf no.	Years sighted	Observed calving rate	Expected calving rate	Expected calf no.	O-E	O-E2	O-E2/E
3	6	15	0.40	0.42	6.25	-0.25	0.06	0.01
15	3	10	0.30	0.42	4.16	-1.16	1.35	0.33
35	2	13	0.15	0.42	5.41	-3.41	11.64	2.15
65	5	15	0.33	0.42	6.25	-1.25	1.55	0.25
67	5	15	0.33	0.42	6.25	-1.25	1.55	0.25
80	3	5	0.60	0.42	2.08	0.92	0.84	0.41
81	2	6	0.33	0.42	2.50	-0.50	0.25	0.10
85	2	4	0.50	0.42	1.67	0.33	0.11	0.07
87	4	4	1.00	0.42	1.67	2.33	5.45	3.27
89	4	10	0.40	0.42	4.16	-0.16	0.03	0.01
102	4	6	0.67	0.42	2.50	1.50	2.26	0.90
112	5	7	0.71	0.42	2.91	2.09	4.35	1.49
118	5	13	0.38	0.42	5.41	-0.41	0.17	0.03
119	4	13	0.31	0.42	5.41	-1.41	2.00	0.37
162	3	9	0.33	0.42	3.75	-0.75	0.56	0.15
187	6	17	0.35	0.42	7.08	-1.08	1.16	0.16
216	3	9	0.33	0.42	3.75	-0.75	0.56	0.15
225	4	14	0.29	0.42	5.83	-1.83	3.34	0.57
327	3	9	0.33	0.42	3.75	-0.75	0.56	0.15
362	3	7	0.43	0.42	2.91	0.09	0.01	0.00
378	3	8	0.38	0.42	3.33	-0.33	0.11	0.03
379	2	3	0.67	0.42	1.25	0.75	0.56	0.45
389	2	9	0.22	0.42	3.75	-1.75	3.05	0.81
396	2	5	0.40	0.42	2.08	-0.08	0.01	0.00
410	2	9	0.22	0.42	3.75	-1.75	3.05	0.81
432	2	3	0.67	0.42	1.25	0.75	0.56	0.45
455	2	3	0.67	0.42	1.25	0.75	0.56	0.45
468	4	7	0.57	0.42	2.91	1.09	1.18	0.40
Combined females	12	9	1.33	0.42	3.75	8.25	68.11	18.18
Total	107	257			107.2			32.42

DF	χ^2	p
27	32.42	<0.05

Table 7.3 Chi-squared goodness of fit test results for determining significance between annual calving rates. Identifying year of study, number of known calves produced in that year, observed annual calving rate and resulting chi-squared calculations.

Year	Calf no.	Known reproductively mature females sighted	Observed calving rate	Expected calving rate	Expected calf no.	O-E	O-E2	O-E2/E
2001	6	15	0.40	0.42	6.29	-0.29	0.08	0.01
2002	5	12	0.42	0.42	5.03	-0.03	0.00	0.00
2003	5	14	0.36	0.42	5.87	-0.87	0.76	0.13
2004	6	17	0.35	0.42	7.13	-1.13	1.27	0.18
2005	6	19	0.32	0.42	7.97	-1.97	3.86	0.48
2006	9	23	0.39	0.42	9.64	-0.64	0.41	0.04
2007	11	15	0.73	0.42	6.29	4.71	22.20	3.53
2008	4	24	0.17	0.42	10.06	-6.06	36.74	3.65
2009	8	17	0.47	0.42	7.13	0.87	0.76	0.11
2010	8	19	0.42	0.42	7.97	0.03	0.00	0.00
2011	10	19	0.53	0.42	7.97	2.03	4.14	0.52
2012	12	20	0.60	0.42	8.38	3.62	13.07	1.56
2013	6	15	0.40	0.42	6.29	-0.29	0.08	0.01
Total	96	229			96.02			10.23

DF	χ^2	p
12	10.23	<0.05

Table 7.4 Showing all 60 females recorded with calves between 1996 and 2013 in the outer Moray Firth: female ID number (CRRU), total calves produced by that female, and numbers of calves recorded as 'alive', 'dead', and 'unknown'. Total percentage of each status is included.

		Status		
Mother ID	Total calves	Alive	Dead	Unknown
3	6	4	1	1
5	1	0	0	1
15	3	1	1	1
22	1	1	0	0
26	1	0	0	1
35	2	1	0	1
46	1	0	0	1
55	1	1	0	0
65	5	4	1	0
67	5	3	0	2
72	1	0	0	1
78	1	0	0	1
80	3	2	0	1
81	2	0	0	2
85	2	2	0	0
87	4	1	1	2
89	4	2	0	2
102	4	2	0	2
112	5	4	0	1
118	5	4	1	0
119	4	3	1	0
162	3	1	0	2
178	2	0	0	2
187	6	2	1	3
216	3	1	1	1
225	4	4	0	0
252	1	1	0	0
253	1	1	0	0
302	1	0	0	1
316	1	1	0	0
327	3	3	0	0
359	1	1	0	0
362	3	2	0	1
374	1	0	0	1
378	3	3	0	0
379	2	2	0	0
385	1	1	0	0
387	2	1	1	0
389	2	1	1	0
396	2	2	0	0
404	1	1	0	0
410	2	1	1	0
432	2	2	0	0
445	4	1	1	2
455	2	1	0	1
463	2	2	0	0
465	1	1	0	0

468	4	3	0	1
482	2	1	1	0
486	1	1	0	0
498	1	1	0	0
502	1	0	0	1
504	1	1	0	0
506	1	1	0	0
517	1	1	0	0
521	1	1	0	0
526	1	1	0	0
529	1	1	0	0
530	1	0	1	0
567	2	2	0	0
Total	135			
Percentage of total (%)		62.96	10.37	26.67

Table 7.5 Chi-squared goodness of fit test results for surviving calves over the study period. No. alive/no. dead refers to the number of alive and dead calves in that year.

Year	No. alive	No. dead	Expected alive	O-E	O-E2	O-E2/E
1996-2000	2	2	3.43	-1.43	2.06	0.60
2001	2	0	1.72	0.28	0.08	0.05
2002	4	1	4.29	-0.29	0.09	0.02
2003	3	0	2.58	0.43	0.18	0.07
2004	4	2	5.15	-1.15	1.33	0.26
2005	4	0	3.43	0.57	0.32	0.09
2006	4	0	3.43	0.57	0.32	0.09
2007	8	1	7.73	0.27	0.07	0.01
2008	3	0	2.58	0.42	0.18	0.07
2009	9	1	8.59	0.41	0.17	0.02
2010	8	1	7.73	0.27	0.07	0.01
2011	9	2	9.44	-0.44	0.2	0.02
2012	11	4	12.88	-1.88	3.53	0.27
2013	14	0	12.02	1.98	3.92	0.33
Total	83	14	85			1.91

DF	χ^2	p
13	1.91	>0.05

Table 7.6 Chi-squared goodness of fit test results for deceased calves over the study period. No. alive/no. dead refers to the number of alive and dead calves in that year.

Year	No alive	No. dead	Expected dead	O-E	O-E2	O-E2/E
1996-2000	8	3	1.56	1.44	2.09	1.34
2003-2005	11	2	1.84	0.16	0.03	0.01
2006-2008	15	1	2.26	-1.26	1.59	0.70
2009-2011	26	4	4.24	-0.24	0.06	0.01
2012-2013	25	4	4.10	-0.10	0.01	0.00
Total	85	14	14			2.08

DF	χ^2	p
4	2.08	>0.05

Table 7.7 Chi-squared goodness of fit test results for significance in calf birth number in each year of the study. Total born highlights the total number of calves born in that year.

Year	Total born	Expected born	O-E	O-E2	O-E2/E
1996	3	7.38	-4.38	19.18	2.60
1997	6	7.38	-1.38	1.90	0.26
1998	1	7.38	-6.38	40.70	5.52
1999	1	7.38	-6.38	40.70	5.52
2000	5	7.38	-2.38	5.66	0.77
2001	6	7.38	-1.38	1.90	0.26
2002	6	7.38	-1.38	1.90	0.26
2003	5	7.38	-2.38	5.66	0.77
2004	7	7.38	-0.38	0.14	0.02
2005	6	7.38	-1.38	1.90	0.26
2006	11	7.38	3.62	13.10	1.78
2007	11	7.38	3.62	13.10	1.78
2008	4	7.38	-3.38	11.42	1.55
2009	12	7.38	4.62	21.34	2.89
2010	10	7.38	2.62	6.86	0.93
2011	11	7.38	3.62	13.10	1.78
2012	16	7.38	8.62	74.30	10.07
2013	14	7.38	6.62	43.82	5.94
Total	135	132.84			42.92

DF	χ^2	p
17	42.92	<0.05

Table 7.8 Individual female success, focusing on the 33 females identified for the IBI analysis. Showing ID number (CRRU), total calf number and the number of those calves which can be confidently identified as alive in the final year of the study.

ID	Total calves	Alive	Reproductive success rate
3	6	4	0.67
15	3	1	0.33
35	2	1	0.50
65	5	4	0.80

67	5	3	0.60
80	3	2	0.67
81	2	0	0.00
85	2	2	1.00
87	4	1	0.25
89	4	2	0.50
102	4	2	0.50
112	5	4	0.80
118	5	4	0.80
119	4	3	0.75
162	3	1	0.33
178	2	0	0.00
187	6	3	0.50
216	3	1	0.33
225	4	4	1.00
327	3	3	1.00
362	3	2	0.67
378	3	3	1.00
379	2	2	1.00
387	2	1	0.50
389	2	1	0.50
396	2	2	1.00
410	2	1	0.50
432	2	2	1.00
445	4	1	0.25
455	2	1	0.50
463	2	2	1.00
468	4	3	0.75
482	2	1	0.50

Table 7.9 Age of first time mothers. ID number (CRRU), mother birth year (CRRU/AULFS), age of mother upon birth of first calf, current status of calf.

ID	Mother birth year	Age at first calf	First calf status	Total calves
65	1988	9	Dead	5
253	2000	13	Alive	1
359	2004	9	Alive	1
385	2006	7	Alive	1
396	2001	9	Alive	2
455	1998	6	Alive	2
465	2004	9	Alive	1
498	2005	8	Alive	1
506	2003	10	Alive	1
597	2001	8	Alive	2
	Mean age	8.80		

8 RISK ASSESSMENT

Fieldwork

ID:		***Start Date:***	Ongoing	***Finish Date:***	October 2013

Location of Fieldwork (attach map if appropriate:	Outer southern Moray Firth coast
Identity of fieldworker(s) + status (e.g. student):	Part-time research undergraduate student
Staff member responsible for safety + contact no.:	Cetacean Research & Rescue Unit (CRRU), Banff: Dr Kevin Robinson (01261) 851696
Fieldwork description and techniques to be used:	Photo-identification studies of coastal bottlenose dolphins from small boats

Specific Hazards:							
Use of boats:	☒	***Working in water:***	☒	***Transport to and from site:***	☒		
Lone working:	☐	***Working on trees/cliffs:***	☐	***Electro fishing:***	☐	***Tropical working:***	☐
Dangerous Equipment:	☐	***Dangerous Chemicals:***	☐	***Biological Hazards:***	☒		

Details of training provided:	No boat to be used without the skipper being qualified in accordance with the CRRU Charity and Marine Safety Agency. The skipper must also be approved by Dr Kevin Robinson before using any boat at the CRRU's Rigid Inflatable Boats. In addition, the boat must comply with MCA workboat regulations. Regular crew members should be able to swim and non-swimming persons should be identified.
Safety procedures adopted:	HAZARDS 1. Collision. Risks: collision with other boats, rocks, and flotsam. 2. Sinking. Risks: collision; consequent injury, hypothermia and drowning. 3. Fire. Risks: ignition of fuel; electrical/mechanical fault; misuse of distress flares. 4. Capsize. Risks: adverse weather / sea conditions; incorrect stowage / over loading; flooding of deck space. 5. Man overboard. Risks: hypothermia, exhaustion and drowning; entanglement with propeller and consequent injury or fatality. 6. Mechanical breakdown. Risks: loss of propulsion and steerage way resulting in collision, capsize, sinking or inability to make landfall. 7. Weather. Risks: effect on boat stability; effect on ability to maintain course; disorientation due to reduced visibility; entrapment on isolated sand banks; injury at launch sites; hypothermia; dehydration. 8. Disorientation. Risks: inability to make landfall; collision. 9. Cargo. Risks: movement of cargo causing instability. 10. Launch and retrieval. Risks: physical strain; personnel being carried away by currents; accidental injury. 11. Tidal waters. Risks: boat swept away by tidal currents after mechanical failure; personnel swept away by tidal currents; isolation by rising tide; consequent hypothermia, exhaustion and drowning. 12. Slips and falls. Risks: uneven and slippery surfaces. 13. Vehicles. Risks: road traffic accident; breakdown or other malfunction of the vehicle or trailer; fire; driver incompetence; weather; entrapment of vehicle below

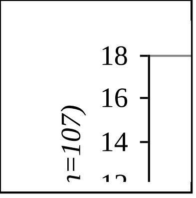
	the high tide mark. 14. Infection. Risks: contamination with human effluent. 15. Light. Risks: sunburn; skin cancer; eye damage (e.g. due to use of optical equipment in bright sunlight). 16. Manual handling. Risks: injury while lifting equipment; struck by hand winch on trailer. CONTROL MEASURES (statutory regulations to be followed in all cases). In most cases the skipper is to ensure control measures are followed and appropriate equipment is carried on board the vessel. 1. At least one person on board to be appropriately qualified for skippering the type of boat in the water in which it is to be used. Skipper to: know, understand and follow the International Regulations for the Prevention of Collisions at Sea; ensure marine VHF radio, flares and radar reflector are carried; ensure navigation lights and equipment work, and know how to use them; use sounder where fitted; ensure a good look out is maintained; avoid periods of poor visibility. 2. Follow precautions outlined in point 1 (above). All personnel to wear lifejackets while afloat and while launching, retrieving or boarding a boat. All crew to wear immersion suits. Skipper to: ensure bailing equipment is carried; ensure the vessel is seaworthy before launching/departure; report any faults to Kevin Robinson. 3. Smoking is not allowed on any of the CRRU vessels. If removable fuel tanks are used re-fuelling/transfer of petrol to be undertaken outside the boat. Flares to be stored in appropriate container. Where appropriate regular crew to be instructed on safe flare use. Flares to be launched away from fuel tanks. VHF radios to be kept away from petrol tanks. 4. Skipper to: ensure cargo securely stowed and evenly distributed; ensure vessel is not over-loaded with cargo or people; avoid windy conditions, or periods of rough seas; ensure ports for draining deck spaces are open and unobstructed during inclement weather. 5. Skipper to ensure that: all crew positioned inboard; standard procedures for recovering over-board persons are followed; all personnel are wearing DOT approved lifejackets; dry suits are worn if appropriate; lifejacket lights and torches are carried if night sailing is a possibility. 6. Skipper to ensure that: engines and transmission equipment is maintained in good order; tools and spares are carried; an anchor with a suitable length of chain and warp as well as a drift anchor are on board; spare fuel and spare fuel hoses for outboard engines are on board; marine VHF radio and distress flares are on board. 7. Skipper to ensure that: periods of bad weather are avoided; if caught in worsening weather alternative courses for safe land fall are plotted as necessary; an up-to-date marine weather forecast is obtained before departure; Coastguard weather broadcasts are obtained as appropriate; speed and course is modified to suit the current and expected conditions; crew are wearing clothing as described earlier; launch is not undertaken in rough conditions; sea conditions are continuously monitored. 8. Skipper to: monitor weather conditions and ensure appropriate navigation equipment is carried and used. 9. Skipper to ensure that: cargo is appropriately and securely stowed; flammable cargo is stowed away from sources of heat/ignition and is not likely to spill; hazardous substances are properly packaged. 10. Skipper to ensure that: there are sufficient people to complete the launch/retrieval; so far as is possible, periods of high winds/tidal currents are avoided; the boat is not launched with people standing behind it.

	11. Vehicle driver to: consult tidal tables and (if necessary) tidal stream data; ensure equipment is well maintained; check ground softness before launching; avoid driving on soft surfaces. 12. Exercise care on slipways. All personnel to wear lifejacket when launching, retrieving or boarding boats. 13. Check the vehicle before use each day. Ensure the vehicle is safely parked off the road. Segregate any passengers from moving traffic. 14. Dress all existing cuts. Wash hands after being in contact with seawater (especially that around launch sites). 15. Use a high factor UV sun block and UV opaque sunglasses. Avoid pointing optical equipment directly at the sun, bright lights or glare on the surface of the water. 16. Ensure there are sufficient people present before manhandling large or heavy items. When winching boats onto trailers, do not let go of the winch handle until the boat is securely tied on and all persons are at a safe distance.
Detail safety equipment used:	Boat safety equipment in accordance with MCA regulations. Lifejackets plus spares, immersion suits for all regular crew. Full marine emergency kit, including VHF radio, distress flares, spares, tools, first aid kit, fire extinguisher, appropriate navigation equipment.
Procedures for reporting in each day:	The Coastguard (01224 592334) should be informed of every boat trip at the time of departure <u>and when returned.</u>
Planned action in case of accident:	Contact Coastguard as necessary. Issue distress message using recognised marine distress procedures as necessary (give identity, location, nature of distress, description of boat and persons on board, and assistance required). Inform the responsible person via private radio channel / mobile phone if possible. If the vessel is late arriving the responsible person is to check to see if vessel is approaching or has left a message indicating delay, they should also attempt to contact the vessel via mobile phone. If no sign of the overdue vessel then the responsible person should contact HM Coastguard (999 for emergency, otherwise 01224 592334) giving name & details of the vessel, number of people on board, intended routes and ETA.

Lone working - details:	Lone working in boats is not permitted.
Working on trees/cliffs - details:	None.
Working in water - details:	Slipways and beaches during launch and retrieval of boats.
Use of boats - details:	As earlier.
Dangerous Equipment - details:	None.
Dangerous Chemicals - details:	None.
Biological Hazards - details:	Untreated sewage discharge outfalls close to launch sites.
Tropical Working - details:	None.

Signed: KPRobinson

Date: **5/12/13**



9 COMMENTS

BI4106 Honours Research Project
Student assessment of conditions experienced during honours project and thesis writing
- TO BE COMPLETED AND SUBMITTED WITH THESIS -

NAME OF STUDENT: ______Texa Mhairi Crawford Sim_______

NAME OF SUPERVISOR: _Graham Pierce and Kevin Robinson_ DEGREE STUDIED__Marine Biology___

Please comment on any aspect of the project and thesis writing that you wish to be considered by the examiners:

1. Were any special difficulties or opportunities experienced?

No particular difficulties were experienced, but I feel that this project has allowed me to further investigate a subject I am interested in and has offered a good insight into what opportunities might be available to me in a possible future career.

2. How much help was available from either or both University staff or external staff?

Guidance and help was available whenever it was needed as the thesis project progressed. When meeting face to face was not possible, contact could be maintained whenever I needed it via email.

3. General comments that might apply:

4. If you wish to make any comments that should remain confidential, please submit this form separately to Wendy Wilson or Hayley Murison in room G32 Zoology instead of enclosing it with the thesis. This should be done at the same time as submission of the thesis.

Signed: ____ Date: