

# Numbers of Atlantic Puffins *Fratercula arctica* found on beached bird surveys in Orkney and Shetland over a 30-year period

Heubeck, M.<sup>1\*</sup>, Meek, E. R.<sup>2</sup>, Mellor, R. M.<sup>1</sup> & Wilson, M.<sup>2</sup>

\*Correspondence author. Email: martinheubeck@btinternet.com

<sup>1</sup> Aberdeen Institute of Coastal Science and Management, University of Aberdeen, c/o Sumburgh Head Lighthouse, Virkie, Shetland ZE3 9JN, Scotland, UK.

<sup>2</sup> RSPB, 14 North End Road, Stromness, Orkney KW16 3AG, Scotland, UK.

## Abstract

Long-term beached bird survey data from Orkney and Shetland were examined for abnormal mortality patterns of Atlantic Puffins *Fratercula arctica* that coincided with decreased breeding numbers at colonies in eastern Britain. Unusually high numbers of dead Atlantic Puffins were found in the late winters of 2002/03 and 2003/04, autumn and early winter 2006, and autumn 2007, although not necessarily in both island groups at the same time. The 2007 mortality was unusual in that some adult birds were replacing their primaries.

## Introduction

After breeding, Atlantic Puffins *Fratercula arctica* disperse widely at sea and are rarely seen from land until the following spring. Ringing data suggest that birds from colonies in the north and west of Britain mainly move into Atlantic waters, whereas those breeding in eastern Scotland and northeast England mainly remain in the North Sea and the Skagerrak (Harris 2002). Oil pollution, environmental factors such as severe weather and/or food shortage, drowning in fishing nets, and hunting, in descending order of frequency, are the reported causes of death for ringed birds found dead outside the breeding season, although given the species' pelagic habits there will be biases in the relative importance of these mortality factors, and in the geographic distribution of recoveries (Harris 2002).

Little is known of the winter ecology of the Atlantic Puffin (hereafter 'Puffin'), but studies of individually marked birds show that winter survival of adults is generally high (90% or greater), although it can vary markedly between years, and less dramatically but significantly over longer periods (Harris *et al.* 1997; Breton *et al.* 2005; Harris *et al.* 2005). Counts of burrows at the two largest colonies in the North Sea, the Isle of May, Firth of Forth and the Farne Islands in 2008, indicated a drop of c. 30% since 2003, and further counts in 2009 confirmed the decline on the Isle of May and found similar declines at two nearby colonies (Harris *et al.* 2009; Steel 2009). Return rates of colour-ringed adult Puffins to the Isle of May were also low in 2007 and 2008, suggesting an increase in adult mortality in the

previous winters (Harris *et al.* 2009), while spring counts on Fair Isle, Shetland were 46% lower in 2009 than in 2001 (Shaw *et al.* 2009). Here we examine beached bird survey (BBS) data from Orkney and Shetland, the only long-term monthly BBS schemes in the UK, for any recent changes in the number of Puffins found dead, particularly outside the breeding season.

### Methods

Systematic BBS began in Orkney in March 1976 and in Shetland in June 1978 in response to the construction of oil-exporting terminals on the island of Flotta in Scapa Flow, Orkney, and at Sullom Voe, Shetland, and details of methods and selected results have been published periodically (Heubeck *et al.* 1992; Heubeck 2006). This analysis examines data for the 30 years from March 1979 to February 2009.

The Orkney BBS, co-ordinated from the local RSPB office, is carried out by staff and volunteers on the day of the full moon, or in the week following this. The 29 stretches of coast currently surveyed total 48.1 km in length (range = 0.6–4.7 km, mean = 1.7, SE =  $\pm$  0.21), of which 24.6 km are on the western approach to, and the north and east shores of Scapa Flow, a 230 km<sup>2</sup> sheltered body of water between the islands of Hoy, Mainland and South Ronaldsay; two beaches face the Pentland Firth to the south (1.6 km), six face the Atlantic Ocean to the west (9.6 km) and eight face the North Sea to the east (12.3 km). The Shetland BBS, co-ordinated by University of Aberdeen under contract from the Shetland Oil Terminal Environmental Advisory Group (SOTEAG), is also carried out by staff and volunteers, but on or around the last Sunday in each calendar month. The 76



**Figure 1.** Atlantic Puffins *Fratercula arctica* collected on Scapa beach, Orkney, October 2007: (left) a first-winter bird without bill grooves, (right) an adult with three bill grooves. © Eric Meek

beaches currently surveyed total 48.4 km in length (range 0.1–5.3 km, mean = 0.6, SE =  $\pm$  0.10), of which 34 (totalling 15.6 km) face the Atlantic Ocean, 28 (12.1 km) face the North Sea, and 14 (20.8 km) are on the sheltered coasts of Sullom Voe and the adjacent Yell Sound. Differences in the relative coverage of sheltered coasts and those exposed to the open sea, the lengths of beaches surveyed, and the nature of the coastlines make direct comparison of the number of corpses found in the two island groups difficult. Instead, we examine changes in numbers over time within each island group.

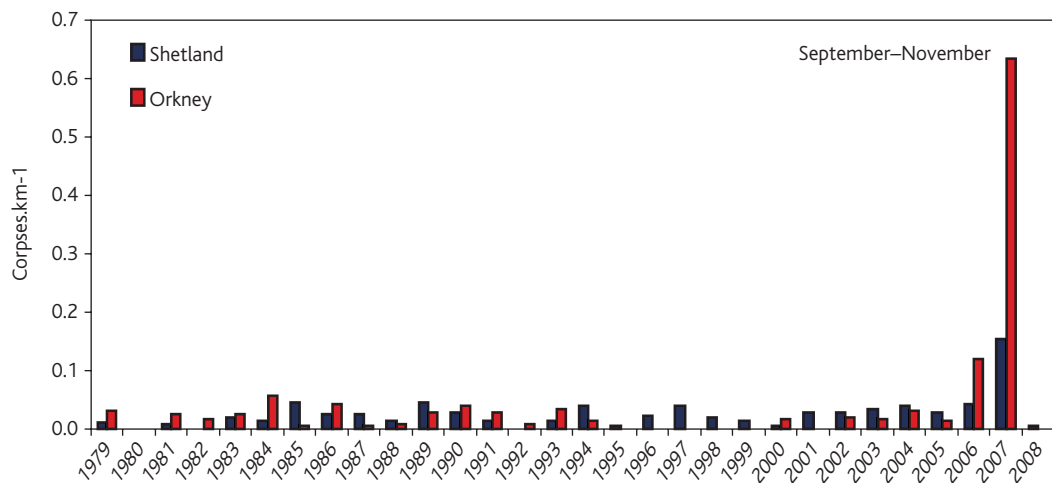
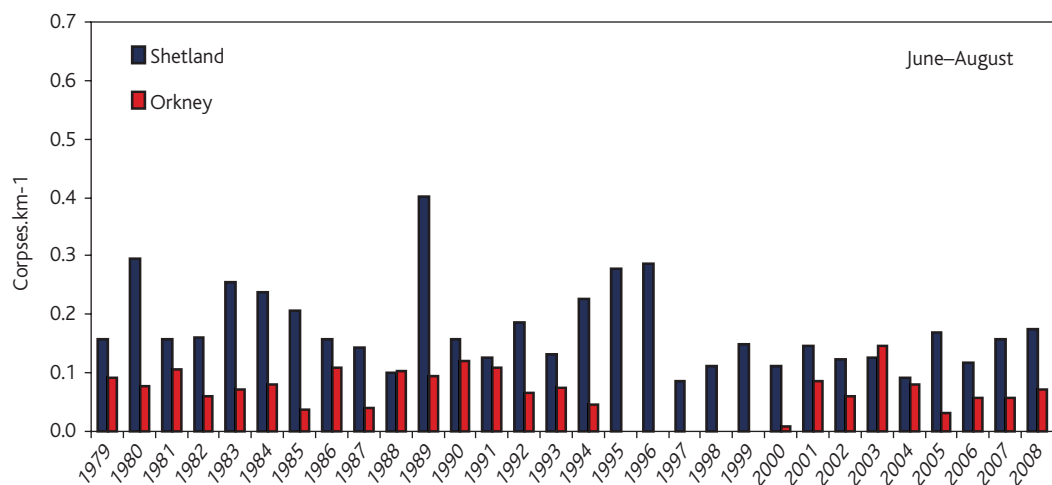
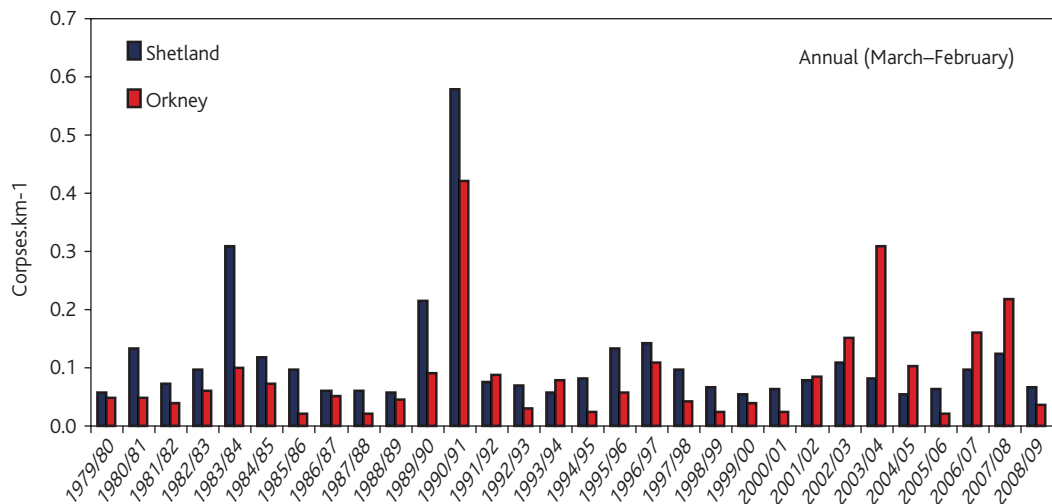
The Orkney BBS reports annually for the period March to February. Monthly records from March 1995 to February 2000 were lost but annual totals were available. The period March to February was therefore used for both Orkney and Shetland to examine 'annual' changes. To examine seasonal occurrence we used the periods June to August ('summer'), September to November ('autumn'), December to February ('winter'), and March to May ('spring'), expressing as 'densities' the total number of corpses found in those months divided by the total number of km surveyed. Since the Orkney BBS is based on the lunar month, approximately every three years there were 13 surveys within a calendar year. When this occurred, data from the two surveys most out of synchrony with calendar months were combined to best match the timing of the Shetland surveys, e.g. in autumn/winter 2003/04 surveys in Orkney between 3–16 October became the 'October' survey (46.1 km), those between 3 November and 20 December became the 'November' survey (95.3 km), and those between 4–12 January 2004 became the 'December' survey (46.7 km). 'Unusually high' numbers were arbitrarily defined as those exceeding the 30-year annual or seasonal mean by more than three times the standard error of that mean.

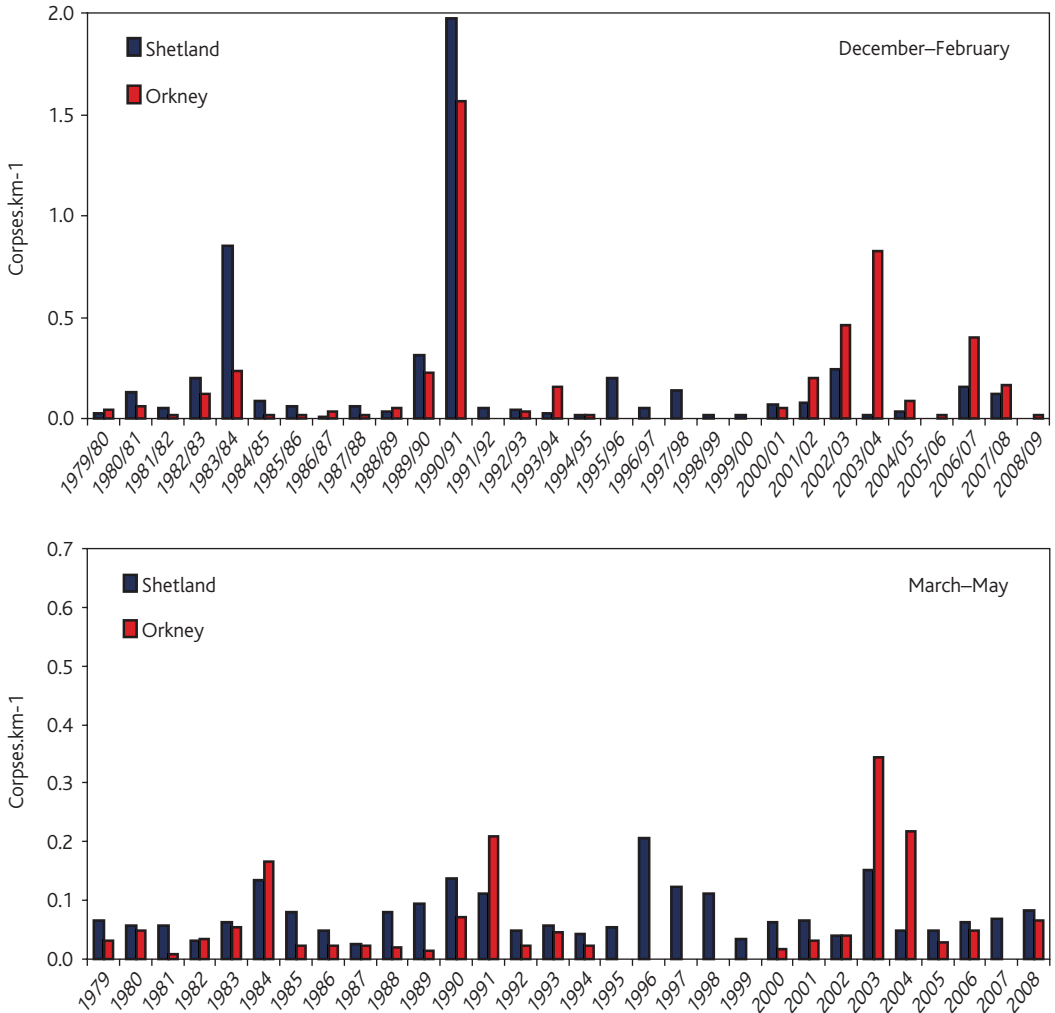
All bird remains were included in the analysis, from intact corpses to a single wing. Some comparisons are made with the number of Puffins found on specific surveys and the number of other pelagic auks, i.e. Common Guillemot *Uria aalge*, Razorbill *Alca torda*, and Little Auk *Alle alle*. In Orkney, no systematic attempt was made to assign corpses to age categories, but in Shetland where possible Puffins were aged by the number of bill grooves (Harris 1981). Corpses were examined for contamination by oil, which may have occurred before death, or may have occurred post-mortem.

## Results

**Annual:** Totals for the distance surveyed and the number of Puffins found were, in Orkney 15,457 km and 1,400 Puffins of which 43 (3.1%) were oiled, and in Shetland 17,404 km, 1,990 Puffins, 130 (7.5%) oiled (Appendix 1 & 2). In Orkney, the mean annual density of Puffins (both unoiled and oiled) was  $0.087.\text{km}^{-1}$  (SE =  $\pm$  0.016), and unusually high numbers ( $> 0.136.\text{km}^{-1}$ ) were recorded in five of the 30 years (Figure 2), four of which were in the last decade. In Shetland, the mean annual density was almost 30% higher ( $0.112.\text{km}^{-1}$ , SE =  $\pm$  0.019), and unusually high numbers ( $> 0.169.\text{km}^{-1}$ ) were recorded in only three years, none of which were in the last decade, and in only one of which (1990/91) were unusually large numbers also recorded in Orkney.

Numbers of Atlantic Puffins found on beached bird surveys in Orkney and Shetland





**Figure 2.** Annual (March–February) and seasonal densities of Atlantic Puffins *Fratercula arctica* on beached bird surveys in Orkney and Shetland, March 1979 to February 2009. Seasonal data for Orkney are missing for the period March 1995 to February 2000.

In both island groups, the number of oiled Puffins found per year was considerably lower in the past decade than during the previous 20 years: Orkney: 1979/90–1998/99, mean = 0.0038.km<sup>-1</sup>, SE = ± 0.0010; 1999/00–2008/09, mean = 0.0007.km<sup>-1</sup>, SE = ± 0.0004,  $t = 2.06$ ,  $P < 0.05$ ; Shetland: 1979/90–1998/99, mean = 0.0116.km<sup>-1</sup>, SE = ± 0.0021; 1999/00–2008/09, mean = 0.0007.km<sup>-1</sup>, SE = ± 0.0003,  $t = 3.55$ ,  $P < 0.01$ .

**Summer:** Relatively fewer Puffins were found dead in Orkney during summer (19% of the total) than in Shetland (39% of the total), which is unsurprising considering the respective sizes of the breeding populations and the greater proximity of large colonies to BBS beaches in Shetland (Harris & Wanless 2004). In both island groups, the maximum number found in any summer was only about twice the



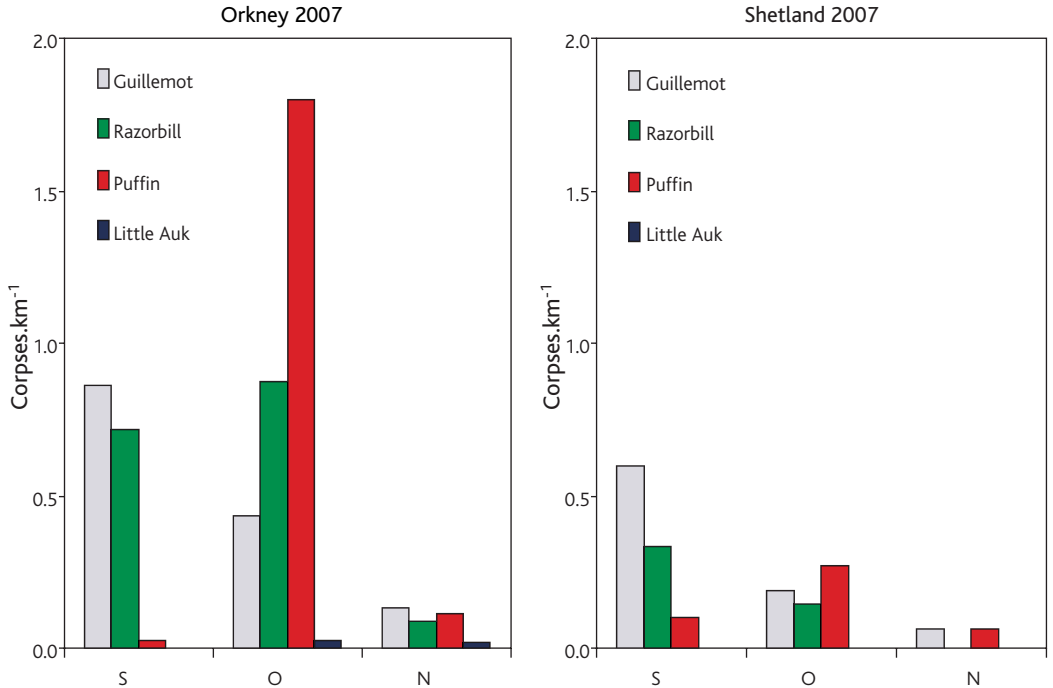
**Figure 3.** Beached bird survey at Grutness, Shetland, December 2009. © Roger Riddington

seasonal average (1.9 times in Orkney in 2003, 2.3 times in Shetland in 1989). In Shetland, summer densities during the past decade were either equal to (2008) or below the seasonal average, which was also the case in Orkney, apart from in 2003 when 21 birds were found (ten in June, two in July, nine in August), following unusually high numbers in spring that year.

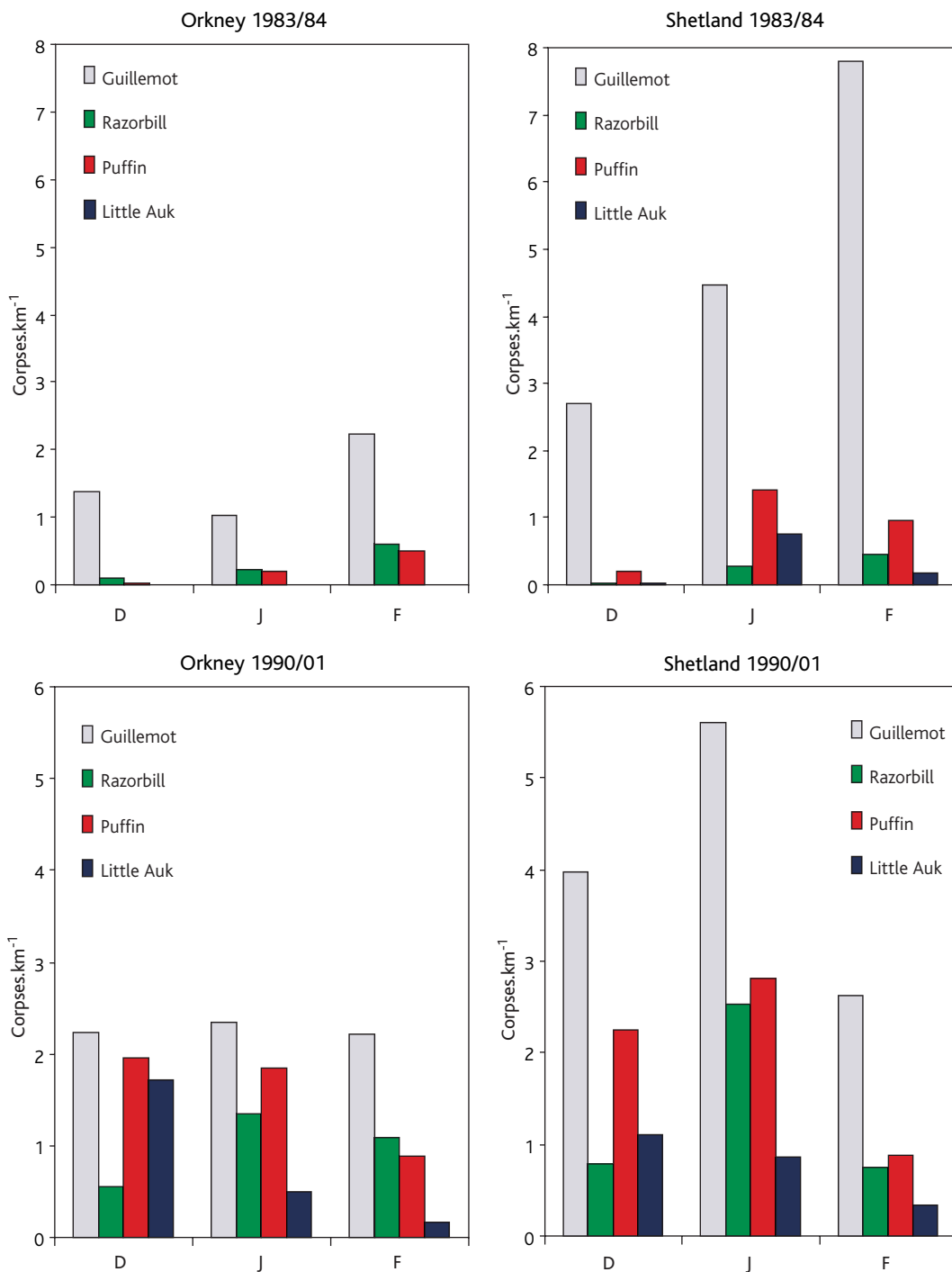
**Autumn:** Prior to 2006, Puffins were equally scarce in autumn in Orkney (mean =  $0.021.km^{-1}$ , SE =  $\pm 0.003$ , n = 22 years) and Shetland (mean =  $0.021.km^{-1}$ , SE =  $\pm 0.003$ , n = 27 years). In 2006, the 20 birds found in Orkney (one in September, eight in October, 11 in November) were six times this previous seasonal average, but did not exceed the threshold of 'unusually high' numbers. All but one was recorded as intact, nine were on beaches in Scapa Flow, one on 10 October was reported as in wing moult, and three had been ringed as adults, on the Farne Islands in 1982, Craigleith, Firth of Forth in 1986, and Isle of May in 1998. The six birds found in Shetland in autumn 2006 were only twice the previous seasonal average: an adult and two unaged in September; an adult, a first-winter ringed on the Isle of May, and one unaged in November.

The 80 birds found in Orkney in autumn 2007 (one in September, 74 in October, five in November) were 30 times the 1979–2005 seasonal average; on the October BBS (25 October–3 November), 58 of the 74 were on just two beaches in Scapa Flow. No ringed birds were reported, nor were any details on age or state of moult recorded. In Shetland, the 20 birds found in autumn 2007 were seven times the 1979–2005 seasonal average: an adult and four immatures in September; seven

adults and four indeterminate adult/immatures (including eight in various stages of wing moult and one ringed as an adult on Isle of May in 2000), one immature and one juvenile in October; two unaged in November. Larger numbers had been noticed washing ashore freshly dead on four beaches during strong southwest winds in the third week of October, but no author was in Shetland at the time and the extent of the mortality was not investigated. By the time of the BBS (27 October–7 November) rising and very high tides and a northwest gale meant that most of these corpses had refloated and disappeared. The four examples above were: 'lots' on a 1.6 km beach in the 3rd week of October (H. Moncrieff pers. comm.) (one adult found on 30 October BBS); 18 removed from a 1.5 km beach during the 3rd week of October (one adult found on 30 October BBS); five adults and five immatures on a 0.5 km beach from 15 October onwards (E. Gillard pers. comm.) (one adult found on 28 October BBS); up to 20 on a 0.5 km beach in the third week of October (five adults and one unaged found on 1 November BBS). Given these examples, the number of dead Puffins on BBS beaches in Shetland around 21 October 2007 was probably well in excess of 100, i.e. more than 30 times the pre-2006 autumn average. Three unusual aspects of this mortality were that Puffins outnumbered the other pelagic auks (Figure 4), it appeared to involve a high proportion of adult birds soon after the end of the breeding season, and that many of these were in wing moult 5–6 months earlier than was thought to be normal for the species (Harris & Yule 1984). In striking contrast to 2006 and 2007, no Puffins were found in Orkney and only a long-dead adult in Shetland in autumn 2008.



**Figure 4.** Monthly densities of Common Guillemots *Uria aalge*, Razorbills *Alca torda*, Atlantic Puffins *Fratercula arctica* and Little Auks *Alle alle* on beached bird surveys in Orkney and Shetland during autumn 2007.



**Figure 5.** Monthly densities of Common Guillemots *Uria aalge*, Razorbills *Alca torda*, Atlantic Puffins *Fratercula arctica* and Little Auks *Alle alle* on beached bird surveys in Orkney and Shetland during the winters 1983/84 and 1990/91. Note the different y-axis scales.



**Winter:** Unusual numbers of Puffins were recorded in Shetland in winter 1983/84 (11 in December, 76 in January, 56 in February; no age data collected; 15% oiled); in the same period numbers in Orkney were only 23% higher than the seasonal average (Figure 2). In both island groups, but particularly in Shetland, auk mortality in winter 1983/84 was dominated by Common Guillemots (Figure 5). The winter 1990/91 wreck occurred in both Orkney and Shetland, and was unusual in that it persisted over three months and that all four pelagic auk species occurred in relatively high numbers, the number of Little Auks found being the highest in both island groups during the 30-year period (Figure 5). No age bias was found in a sample of 98 Puffins from Shetland on the December 1990 BBS, compared to the calculated age structure of the Isle of May population at the end of the 1990 breeding season (Harris *et al.* 1991).

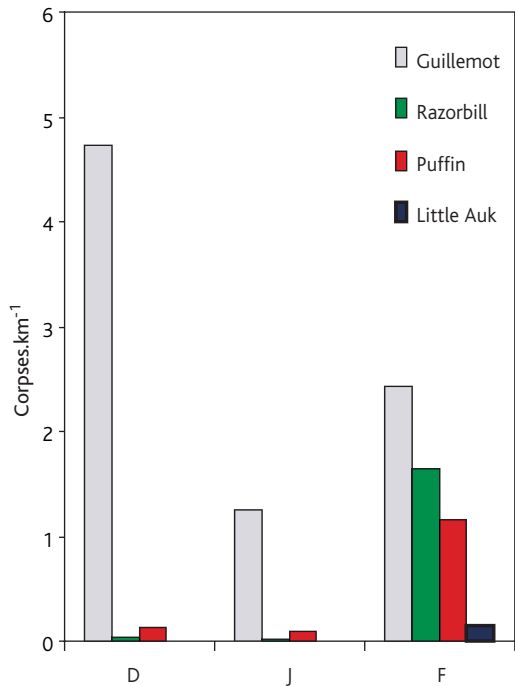
The next instance of unusual winter numbers of Puffins was in 2002/03 in Orkney (six in December, four in January, 55 in February); smaller numbers were recorded in Shetland at the same time (two in December, seven in January, 27 in February), of which 14 were adult, eight were immature, and 14 were unaged. Larger numbers of Common Guillemots and Razorbills were found dead in both island groups at the time (Figure 6), particularly in Shetland in February when 20% of Guillemots were first-winter and 80% older ( $n = 247$ ), and 13% of Razorbills were first-winter, 11% were immature, and 76% were adults ( $n = 96$ ).

Numbers of Common Guillemots and Razorbills were unexceptional in both Orkney and Shetland in winter 2003/04, but Puffin density in Orkney in February 2004 (103 birds,  $2.141.\text{km}^{-1}$ ) was the highest monthly figure on record there (the winter 1990/91 wreck was more spread over three months), and again mostly involved birds on beaches around Scapa Flow. February 2004 was also the first winter month in either island group that Puffin was the predominant pelagic auk on a BBS. In complete contrast, two unaged Puffins in February 2004 were the only ones found in Shetland that winter.

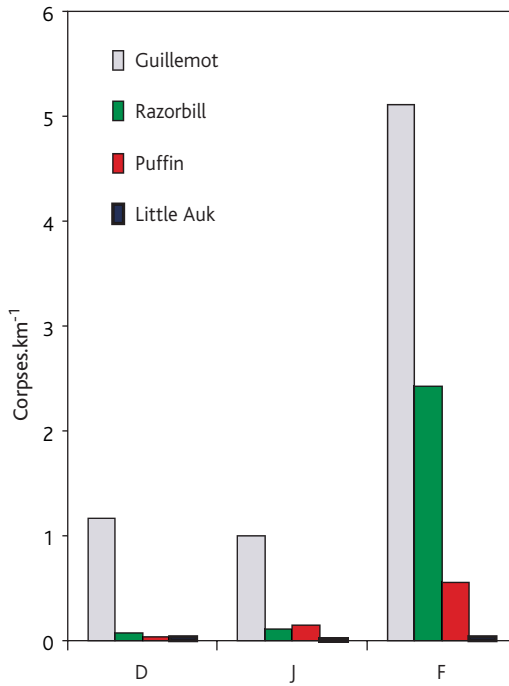
Puffin was again the predominant auk on Orkney BBS in December 2006 (43 birds,  $0.923.\text{km}^{-1}$ ), following slightly elevated numbers there in late autumn. The smaller numbers found in Shetland in winter 2006/07 comprised 16 adults, four immatures, and three unaged.

**Spring:** Annual variation in numbers in spring has been much less than in winter, the maximum density being only five times the seasonal average in Orkney (2003) and three times the average in Shetland (1996). In both island groups, unusually high numbers of Puffins in spring have tended to occur after higher numbers in the preceding winter. In the past decade, this was the case in Orkney in spring 2003 and 2004 (27 in March, 12 in April, seven in May 2003; 17 in March, eight in April, three in March 2004), although numbers in Shetland in spring 2003 (six, six, ten, respectively) may have reflected an early increase to normally higher summer levels rather than a decline from a February peak.

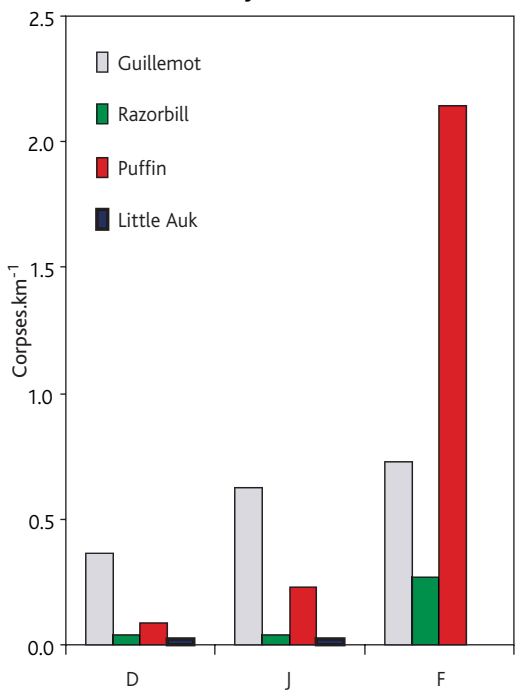
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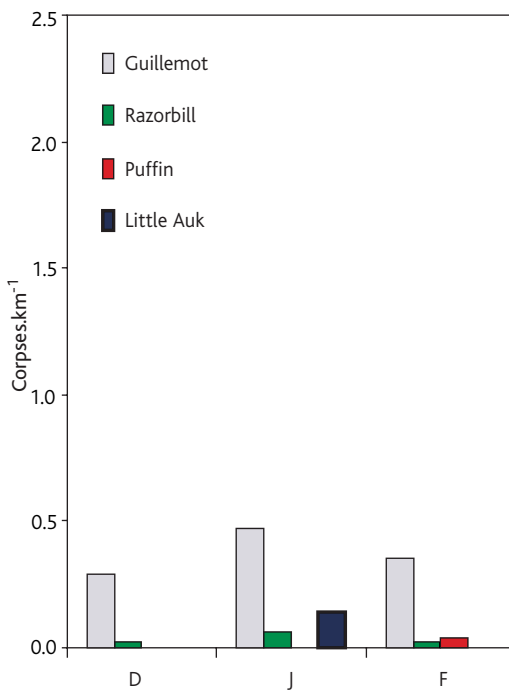
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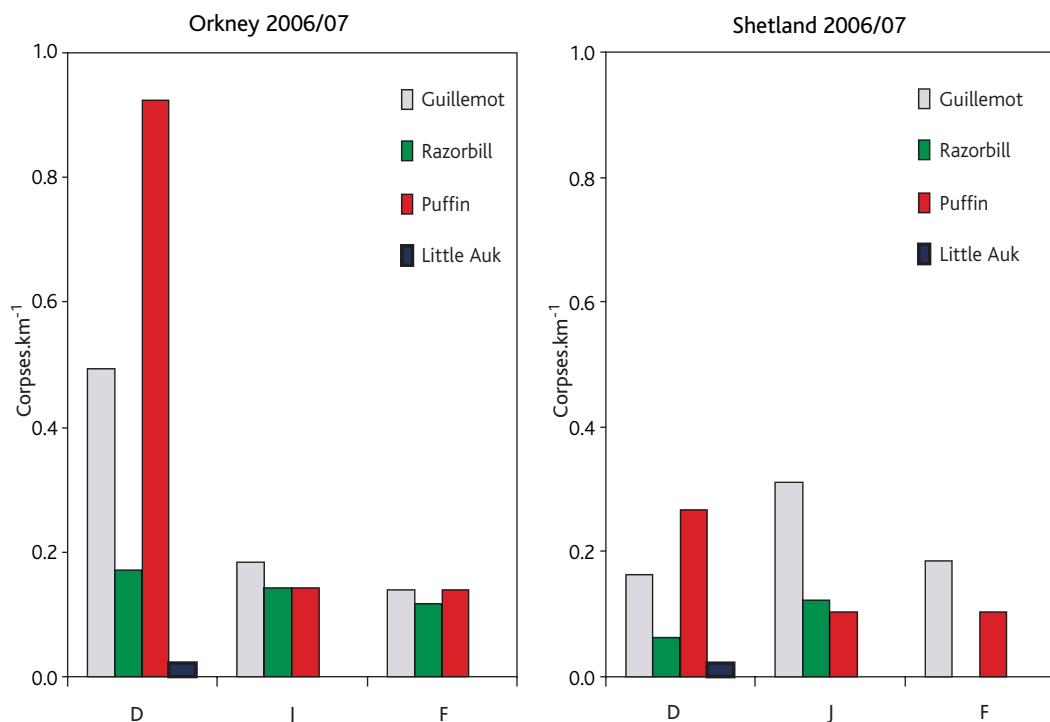


Orkney 2003/04



Shetland 2003/04





**Figure 6.** Monthly densities of Common Guillemots *Uria aalge*, Razorbills *Alca torda*, Atlantic Puffins *Fratercula arctica* and Little Auks *Alle alle* on beached bird surveys in Orkney and Shetland during the winters of 2002/03, 2003/04 and 2006/07. Note the different y-axis scales.

**Summary:** Within the past decade, unusual numbers of dead Puffins were found on BBS in Orkney and Shetland in: **(1)** February and spring of 2003, mainly in Orkney, and associated with larger numbers of Common Guillemots and Razorbills; **(2)** February and spring of 2004, exclusively in Orkney, and with Puffins outnumbering the larger auks for the first time in winter; **(3)** December 2006, mainly in Orkney, again with Puffins predominating; **(4)** October 2007 (and probably also October 2006) in both island groups, again with Puffins predominating. The proportion of birds found that were oiled during 1999/00–2008/09 was significantly lower than in the previous two decades in both island groups.

## Discussion

Despite an Atlantic breeding population of c. 6 million pairs, wrecks of Puffins have been recorded less often than, for example, for Common Guillemots and have involved many fewer individuals found dead on beaches (Harris 1984; Harris *et al.* 1991; Harris & Wanless 2004). In a large wreck of auks in eastern Britain in February 1983, Puffins comprised only 5.3% (c. 1,640) of 31,000 auks identified to species (Underwood & Stowe 1984), and despite 53 recoveries of birds ringed at colonies in the Firth of Forth (Hudson & Mead 1984), no decrease in adult survival was detected on the Isle of May in 1983, although colony attendance patterns were apparently disrupted that summer (Harris *et al.* 1997). Twelve birds ringed at Firth of Forth colonies were among only c. 500 Puffins found dead in Orkney and

**Table 1.** The number of Atlantic Puffins *Fratercula arctica* found per km surveyed ( $n$  = total birds) on the February beached bird survey in different regions of the UK, 2002–07. Northwest Britain: the Lancashire/Cumbria border to Cape Wrath, Sutherland; northeast Britain: Cape Wrath to the North Yorkshire/Humberside border; southeast England: the North Yorkshire/Humberside border to the Kent/East Sussex border; southern England: the Kent/East Sussex border to Land’s End, Cornwall; southwest Britain: Land’s End to the Lancashire/Cumbria border, including Wales. Data: RSPB, unpublished.

	2002	2003	2004	2005	2006	2007
Northwest Britain	0.019 (14)	0.015 (9)	0.038 (25)	0.021 (14)	0.002 (1)	0.019 (12)
Shetland	0.062 (3)	0.535 (26)	0.041 (2)	0.021 (1)	0.000 (0)	0.083 (4)
Orkney	0.065 (3)	1.160 (55)	2.141 (103)	0.066 (3)	0.000 (0)	0.115 (5)
Northeast Britain	0.013 (8)	0.056 (36)	0.040 (24)	0.246 (152)	0.008 (5)	0.010 (6)
Southeast England	0.005 (2)	0.043 (16)	0.007 (2)	0.118 (38)	0.003 (1)	0.009 (3)
Southern England	0.004 (1)	0.003 (1)	0.008 (2)	0.000 (0)	0.000 (0)	0.006 (1)
Southwest Britain	0.030 (11)	0.015 (5)	0.003 (1)	0.000 (0)	0.000 (0)	0.007 (2)
Northern Ireland	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)	0.013 (2)

Shetland in winter 1990/91 (Harris *et al.* 1991), yet mortality of adults at the Isle of May colony increased by 140% that winter (Harris *et al.* 1997). Presumably, the birds found in Orkney and Shetland in 1990/91 represented a much smaller fraction of the actual mortality at the time than was the case in 1983, and most dead birds went undetected, either having disintegrated far at sea, or being overlooked on coasts with no BBS.

A national BBS resumed in 1991, organised annually by the RSPB in late February, surveying c. 2,000–2,500 km of the UK coast (Schmitt 2008). In addition, a monthly BBS was established in northeast England in 2003 (Turner 2008). Slightly elevated numbers of Puffins were found in northeast Britain in February 2003 and in northern Britain in 2004, while a wreck of Puffins and other auks on the east coast of mainland UK in February 2005 did not extend as far north as Orkney or Shetland (Table 1). The mortality in Orkney and Shetland in December 2006 was not detected in northeast England (D. Turner pers. comm.), or by the national February 2007 BBS, while only five Puffins were found on 144 km surveyed in northeast England in autumn 2007. The October 2007 Puffin mortality occurred two to three weeks after a major wreck of Razorbills (predominantly adults) on the Skagerrak and Kattegat coasts of Norway and Sweden, which also involved smaller numbers of Puffins (Isaksen & Bredesen 2007).

Storms can be frequent in autumn and winter around the North Isles of Scotland, but there was no obvious connection between unusually severe local weather conditions and these recent incidents of unusual Puffin mortality. The Meteorological Observatory at Lerwick, Shetland recorded gales on two days in February 2003 and on five days in February 2004 (1971–2000 February average 6.1 days), seven days in December 2006 (1971–2000 December average 7.4), and on four days in October 2007 (1971–2000 October average 4.0) (monthly weather summaries in *The Shetland Times* newspaper). Only 15 Puffins (all oiled) were found on intensive BBS following the *Braer* oil spill in Shetland on 5 January

1993 (Heubeck 1997), a month when gales were recorded at Lerwick on 25 days (1951–80 average 8.4) and Atlantic weather systems contributed to a wreck of normally pelagic Iceland Gulls *Larus glaucoides* (Weir *et al.* 1995) and Black-legged Kittiwakes *Rissa tridactyla* (Weir *et al.* 1996). This suggests that food availability and starvation may be a more significant trigger for abnormal Puffin mortality during autumn and winter than severe weather *per se*. What is also clear, in the context in which these BBS were initially established, is that oiling had nothing to do with these recent mortalities.

Moderate densities of Puffins (1–5 birds.km<sup>-2</sup>) occur in the waters between Orkney and Shetland during August and September, but numbers decrease considerably during October and November and by winter (December to February) they are present only in very low densities in these waters (Pollock *et al.* 2000; Forrester *et al.* 2007). Surveys of Scapa Flow during 1988/89 and 1998/99 found maxima of 10 and 13, respectively, wintering there (Williams 2000), possibly healthy individuals as very few were found on BBS in those winters. Similarly, Puffins have usually been either absent or present in only very low numbers on more than 30 years of inshore surveys of wintering seabirds around Shetland (Pennington *et al.* 2004). For example, only ten live birds were seen during a survey by boat of Sullom Voe and Yell Sound on 8 January 1991, at the height of the 1990/91 wreck (SOTEAG unpublished data).



**Figure 7.** Counting Atlantic Puffin *Fratercula arctica* burrows on the Isle of May, Firth of Forth, spring 2008. © Mike Harris

Scapa Flow appears to act as a refuge for pelagic auks when individuals become weakened by environmental conditions in the open sea, and the concentration of BBS beaches around the relatively sheltered shorelines there makes it more probable that corpses will be found and recorded than on exposed beaches facing the open ocean. This has also been the case, although to a lesser extent, during most auk wrecks in Shetland when concentrations of dead and dying auks have been found at the heads of sheltered inlets. Only a few such beaches are included in the Shetland BBS since very few seabird corpses normally occur there, but checking these beaches during wrecks does provide a valuable source of relatively fresh, intact corpses to increase sample sizes for post-mortem examination, and to check for rings.

Regular, systematic BBS conducted throughout the year can be a useful tool in identifying abnormal mortality events of seabirds that might otherwise go unrecorded, although attempting to quantify the scale of such mortality will always be problematic. Despite the relatively small numbers of birds found dead, a link seems likely between decreased numbers at colonies in the Firth of Forth and the Farne Islands in 2008 and 2009 and abnormal autumn mortality around in Orkney and Shetland in Octobers 2006 and 2007. It is perhaps no coincidence that the lack of dead Puffins on BBS in Orkney and Shetland between September 2008 and February 2009 was followed by no further decrease in numbers on the Isle of May between 2008 and 2009 (Harris *et al.* 2009).

### Acknowledgements

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**Appendix 1.** Summary details of Atlantic Puffins *Fratercula arctica* found on the Orkney beached bird survey, March 1979 to February 2009. Unusually high numbers (bold) are those in excess of the seasonal or annual mean, plus three times the standard error.

ORKNEY Year	March–May		June–August		Sept.–November		Dec.–February		Annual (March–Feb.)	
	n	n.km <sup>-1</sup> % Oil	n	n.km <sup>-1</sup> % Oil	n	n.km <sup>-1</sup> % Oil	n	n.km <sup>-1</sup> % Oil	n	n.km <sup>-1</sup> % Oil
1979/80	3	0.032 66.7	9	0.092 11.1	3	0.031 0.0	5	0.040 40.0	20	0.048 25.0
1980/81	4	0.049 25.0	6	0.078 0	0	0.000 0.0	6	0.065 0.0	16	0.047 6.3
1981/82	1	0.009 0.0	<b>12</b>	<b>0.106</b> 0	3	0.026 0.0	3	0.020 0.0	19	0.039 0.0
1982/83	4	0.035 0.0	7	0.061 0	2	0.017 0.0	14	0.124 0.0	27	0.059 0.0
1983/84	6	0.056 16.7	8	0.072 0	3	0.026 0.0	27	0.239 0.0	44	0.099 2.3
1984/85	<b>19</b>	<b>0.166</b> 5.3	10	0.080 0	7	0.056 0.0	3	0.018 33.3	39	0.073 5.1
1985/86	3	0.022 33.3	5	0.037 0	1	0.007 0.0	2	0.015 50.0	11	0.020 18.2
1986/87	3	0.022 33.3	<b>14</b>	<b>0.108</b> 14.3	6	0.042 66.7	5	0.035 60.0	28	0.051 35.7
1987/88	3	0.022 0.0	5	0.041 0	1	0.007 0.0	3	0.016 33.3	12	0.020 8.3
1988/89	3	0.021 33.3	<b>14</b>	<b>0.105</b> 0	1	0.007 0.0	7	0.051 0.0	25	0.046 4.0
1989/90	2	0.015 0.0	12	0.093 8.3	4	0.029 0.0	31	0.222 3.2	49	0.091 4.1
1990/91	10	0.071 0.0	<b>15</b>	<b>0.120</b> 13.3	7	0.039 14.3	<b>212</b>	<b>1.565</b> 0.0	<b>244</b>	<b>0.421</b> 1.2
1991/92	<b>28</b>	<b>0.210</b> 3.6	<b>13</b>	<b>0.109</b> 15.4	4	0.029 0.0	0	0.000 0.0	45	0.087 6.7
1992/93	3	0.022 0.0	9	0.067 11.1	1	0.007 0.0	4	0.032 0.0	17	0.032 5.9
1993/94	6	0.046 0.0	9	0.076 0.0	4	0.033 0.0	21	0.159 0.0	40	0.080 0.0
1994/95	3	0.022 33.3	6	0.047 0.0	2	0.014 0.0	2	0.015 0.0	13	0.024 7.7
1995/96									32	0.059 15.6
1996/97									62	0.109 1.6
1997/98									19	0.042 0.0
1998/99									12	0.024 0.0
1999/00									21	0.039 4.8
2000/01	2	0.016 0.0	1	0.008 0.0	2	0.017 0.0	7	0.054 0.0	12	0.024 0.0
2001/02	2	0.032 0.0	12	0.087 0.0	0	0.000 0.0	26	0.203 0.0	40	0.085 0.0
2002/03	5	0.040 0.0	8	0.061 0.0	3	0.021 0.0	<b>65</b>	<b>0.461</b> 0.0	<b>81</b>	<b>0.150</b> 0.0
2003/04	<b>46</b>	<b>0.345</b> 2.2	<b>21</b>	<b>0.146</b> 8.7	3	0.016 0.0	<b>118</b>	<b>0.826</b> 0.8	<b>188</b>	<b>0.305</b> 1.1
2004/05	<b>28</b>	<b>0.219</b> 3.6	11	0.080 0.0	4	0.031 0.0	11	0.085 0.0	54	0.103 1.9
2005/06	4	0.029 0.0	4	0.030 0.0	2	0.014 0.0	2	0.015 0.0	12	0.022 0.0
2006/07	6	0.048 0.0	7	0.056 0.0	20	0.119 0.0	<b>56</b>	<b>0.412</b> 0.0	<b>89</b>	<b>0.160</b> 0.0
2007/08	0	0.000 0.0	7	0.058 0.0	<b>80</b>	<b>0.633</b> 0.0	24	0.166 0.0	<b>111</b>	<b>0.218</b> 0.0
2008/09	8	0.067 0.0	8	0.070 0.0	0	0.000 0.0	2	0.017 0.0	18	0.038 0.0
Sum/Mean	202	0.065 10.3	233	0.076 3.3	163	0.049 3.2	656	0.194 8.8	1400	0.087 5.2
± 1 SE		0.016 3.5		0.006 1.1		0.025 2.7		0.068 3.6		0.016 1.5



**Appendix 2.** Summary details of Atlantic Puffins *Fratercula arctica* found on the Shetland beached bird survey, March 1979 to February 2009. Unusually high numbers (bold) are those in excess of the seasonal or annual mean, plus three times the standard error.

SHETLAND Year	March-May		June-August		Sept.-November		Dec.-February		Annual (March-Feb.)	
	n	n.km <sup>-1</sup> % Oil	n	n.km <sup>-1</sup> % Oil	n	n.km <sup>-1</sup> % Oil	n	n.km <sup>-1</sup> % Oil	n	n.km <sup>-1</sup> % Oil
1979/80	8	0.065	21	0.157	2	0.012	5	0.025	36	0.058
1980/81	11	0.059	<b>52</b>	<b>0.296</b>	0	0.000	20	0.134	83	0.134
1981/82	9	0.058	21	0.158	1	0.010	6	0.049	37	0.072
1982/83	5	0.031	24	0.160	0	0.000	28	0.197	57	0.096
1983/84	11	0.064	<b>42</b>	<b>0.254</b>	3	0.021	<b>143</b>	<b>0.849</b>	<b>199</b>	<b>0.309</b>
1984/85	<b>21</b>	<b>0.135</b>	<b>36</b>	<b>0.237</b>	2	0.014	15	0.088	74	0.119
1985/86	13	0.080	32	0.207	<b>8</b>	<b>0.047</b>	10	0.059	63	0.096
1986/87	8	0.048	27	0.158	4	0.024	2	0.012	41	0.061
1987/88	4	0.025	22	0.143	4	0.025	9	0.058	39	0.062
1988/89	13	0.080	16	0.101	2	0.013	5	0.031	36	0.057
1989/90	15	0.095	<b>63</b>	<b>0.403</b>	<b>7</b>	<b>0.046</b>	48	0.311	<b>133</b>	<b>0.214</b>
1990/91	<b>20</b>	<b>0.138</b>	22	0.159	4	0.028	<b>283</b>	<b>1.976</b>	<b>329</b>	<b>0.577</b>
1991/92	<b>16</b>	<b>0.111</b>	18	0.125	2	0.014	7	0.049	43	0.075
1992/93	7	0.048	27	0.187	0	0.000	6	0.042	40	0.070
1993/94	8	0.056	18	0.133	0	0.014	4	0.028	32	0.057
1994/95	6	0.042	<b>32</b>	<b>0.226</b>	6	0.041	2	0.014	46	0.080
1995/96	8	0.055	<b>40</b>	<b>0.279</b>	1	0.007	29	0.200	78	0.135
1996/97	<b>30</b>	<b>0.207</b>	<b>41</b>	<b>0.287</b>	3	0.022	7	0.048	81	0.141
1997/98	<b>18</b>	<b>0.125</b>	12	0.086	6	0.041	20	0.142	56	0.098
1998/99	<b>16</b>	<b>0.110</b>	16	0.112	3	0.021	3	0.021	38	0.066
1999/00	5	0.035	21	0.148	2	0.014	3	0.021	31	0.054
2000/01	9	0.062	16	0.112	1	0.007	10	0.069	36	0.062
2001/02	7	0.065	21	0.147	4	0.027	11	0.075	43	0.079
2002/03	6	0.041	18	0.125	4	0.027	36	0.247	64	0.110
2003/04	<b>22</b>	<b>0.152</b>	18	0.126	5	0.034	2	0.014	47	0.081
2004/05	7	0.048	13	0.090	6	0.041	4	0.031	30	0.053
2005/06	7	0.049	24	0.168	4	0.028	0	0.000	35	0.064
2006/07	9	0.063	17	0.119	<b>6</b>	<b>0.042</b>	23	0.158	55	0.095
2007/08	10	0.069	22	0.156	<b>20</b>	<b>0.155</b>	18	0.124	70	0.125
2008/09	12	0.083	25	0.175	1	0.007	0	0.000	38	0.066
Sum/Mean	341	0.077	777	0.174	113	0.026	759	0.169	1990	0.112
± 1 SE		0.008	2.2	0.013	3.9	0.005	0.069	4.3	0.019	1.4