Fledging weights of Atlantic Puffins *Fratercula arctica* on Sule Skerry, Scotland, with reference to a relatively poor season in 2005

Archer, M. G.[1*] & Taylor, R. C.[2]

** Correspondence author. Email: mikearcher@care4free.net*
[1] *14 The Elms, Chesterwood Drive, Sheffield S10 5DU, UK.*
[2] *21 Dallin Road, Plumstead, London SE18 3NY, UK.*

Abstract
The weights and wing lengths of fledgling Atlantic Puffins *Fratercula arctica* on the island of Sule Skerry, Scotland were recorded in eight seasons between 1982 and 2005. Chicks in 2005 were notably underweight compared to previous years. Measurements of 38 chicks over a period of 21 days showed that chicks grew very slowly and that fledging success was low. These findings and the records of pipefish (Sygnathidae) in the diet, suggest that conditions were unusually poor for Atlantic Puffins at Sule Skerry in 2005.

Figure 1. Atlantic Puffins *Fratercula arctica*, Sule Skerry, summer 2007. © *Roger Taylor*

Introduction

The offshore island of Sule Skerry, at 59°05'N 04°24'W, lies 72 km west of Mainland Orkney and a similar distance north of Tongue, Sutherland, Scotland. Half of its 14 ha comprises a peaty plateau at about 13 m above sea level on which grows extensive Sea Mayweed *Tripleurospermum maritimum*. Rocky areas and cliffs surround the plateau. It is a large seabird colony, and the Seabird 2000 census estimated the population of Atlantic Puffins *Fratercula arctica* there at 59,500 apparently occupied burrows, making it the second largest colony in Britain and Ireland at the time (Harris & Wanless 2004). The Sule Skerry Ringing Group has made 21 visits to the island since 1975, primarily to ring a sample of adult Atlantic Puffins (hereafter 'Puffins') and chicks, to monitor breeding numbers and adult survival and to monitor the condition of fledglings. Whilst visits in most years were for one or two weeks, in 2005 we were present for four weeks. Here we report on measurements of fledging Puffins over a 23-year period and chick development and fledging success in 2005.

Methods

Puffin fledglings leave their burrows during the hours of darkness and make their way alone to the sea (Lockley 1934). Sule Skerry has an unmanned lighthouse in the centre of the Puffin colony and many fledglings are attracted to the base of the lighthouse, both by the light and by the noise of the lighthouse generator when it is running. In eight years between 1982 and 2005 samples of fledglings were caught, weighed to the nearest 10 g (but to the nearest 1 g in 2005), and had their wings measured to the nearest 1.0 mm using the maximum flattened chord method with a stopped ruler, before being ringed and released. Mean values are given ± 1 SE.

In 2005, to study chick growth four areas were selected, at least 80 m apart and located along an approximately straight line across the island running southeast to northwest. Each was approximately 5–7 m in diameter and 10 m from permanent concrete tracks, or from burrow-free paths established on our arrival in early July and well away from where other activities were concentrated. Within each area, 10 burrows with an egg or a chick were selected on a first-found-first-used basis and were at least 2 m apart to minimise disturbance and damage to vegetation. Each burrow was marked with a cane standing higher than the surrounding vegetation and coloured red at the top. A small area next to each burrow entrance was marked with non-toxic orange spray to further assist in re-finding them on later visits.

Chicks were ringed when large enough, and wing and weight measurements were taken then, and on each subsequent visit. Wing measurements were taken, as before, using the maximum flattened chord method. Weighing was to the nearest 1.0 g using a Pesola balance sheltered in a container to eliminate the distorting effect of air movement. Visits to the selected burrows were made commencing in mid-afternoon on 14, 21 and 28 July and 3 August 2005 (Visits 1, 2, 3 and 4 respectively). Fifty-one pipefish were collected from one nest (burrow 38) and their body lengths were measured with a stopped ruler to the nearest 1 mm.

Results

The mean body mass of fledglings varied significantly between years (ANOVA, $F_{7,2869}$ = 112.99, P < 0.001), but the corresponding variation in wing length was much less pronounced (ANOVA, $F_{7,2869}$ = 4.57, P < 0.001). A greater and significant variation between years occurred in the mean ratio between body mass and wing lengths of fledglings (ANOVA, $F_{7,2869}$ = 119.58, P < 0.001). Chicks in 2005 fledged at a lower weight than in most previous years (Table 1), their mean body mass being 87.6% of the mean for earlier years (265.2 g, each year given equal weight). There seemed to be a tendency for a decline in fledging mass over the years, but the trend was not significant (linear regression, n = 8, R^2 = 0.36, P = 0.118).

Of the 40 burrows monitored in 2005, 38 contained chicks and two contained eggs on Visit 1 (Table 2, Appendix). Two burrows could not be located on Visit 2, one of these was re-discovered on Visit 3, but another was lost on this visit. Both eggs disappeared from the burrows during the period of the study.

Table 1. Mean body mass (g), wing length (mm), and mass/wing ratio of Atlantic Puffin *Fratercula arctica* fledglings on Sule Skerry in different years.

Year	Date range	Modal date	n	Mass	SE	Wing	SE	Mass/wing	SE
1982	20–27 Jul	25 Jul	156	268.4	1.90	140.2	0.33	1.916	0.015
1983	28 Jul–3 Aug	28 Jul	30	286.2	4.58	138.4	0.79	2.070	0.036
1984	28 Jul–1 Aug	31 Jul	412	244.6	1.14	139.9	0.23	1.749	0.008
1985	16 Jul–1 Aug	25 Jul	965	263.9	0.86	138.7	0.32	1.906	0.006
1990	24 Jul–27 Jul	26 Jul	34	272.6	5.30	138.0	0.85	1.973	0.033
1993	20–25 Jul	24 Jul	536	264.0	1.02	138.4	0.17	1.908	0.007
2003	20–25 Jul	23 Jul	216	256.4	1.76	137.8	0.26	1.860	0.012
2005	22 Jul–5 Aug	27 Jul	528	232.4	1.11	138.1	0.42	1.684	0.008

Table 2. Summary data from four visits to 40 Atlantic Puffin *Fratercula arctica* study burrows in 2005.

Description	14 July	21 July	28 July	3 Aug.
Number of burrows located	40	38	38	38
Burrows with eggs	2	1	0	0
Burrows formerly with eggs, now empty	0	1	2	2
Burrows with chicks, all ringed	38	36	33	15
Burrows empty, chick presumed fledged			1	15
Burrows empty, chick may not have fledged			2	6

Table 3. Mean increase in wing length (mm) and body mass (g) of Atlantic Puffin *Fratercula arctica* chicks between visits to 38 study burrows.

Period	Days between visits	Wing length (mm)		Body mass (g)	
		n	Mean daily increase ± SE	n	Mean daily increase ± SE
Visit 1–2	7	34	2.55 ± 0.11	36	1.47 ± 0.45
Visit 2–3	7	31	1.96 ± 0.10	32	0.50 ± 0.47
Visit 3–4	6	14	1.29 ± 0.21	15	1.27 ± 0.80

It was difficult to determine fledging success since no chicks were found dead in the burrows and 15 chicks remained in burrows when we left the island. The average gain in wing length between Visits 1 and 2 was 2.55 ± 0.11 mm per day. Therefore, if this growth had continued between Visits 3 and 4, a chick's wing length should have increased by approximately 15 mm. The lower 95% confidence limit of the mean wing length of the 2005 fledglings was 137 mm so we consider that any chicks with a wing length equal to, or greater than 122 mm when last present would have fledged. Using this assumption, the overall fledging success in 2005 was at least 63% (24 of 38 chicks). Many more predated, partly grown chicks were seen in 2005 than in previous years (pers. obs.). These were mainly in gull middens or close to Great Skua *Stercorarius skua* nests, and were presumably starving chicks caught at burrow entrances, or chicks caught away from their burrows while attempting to fledge.

As could be expected, chick wing lengths increased consistently over the four visits, while changes in mass were highly variable between individual chicks (Figure 2). A small number of chicks put on weight steadily, others remained close to the weight recorded on the first visit and some lost weight (see Appendix). Notwithstanding these variations, there was an increase in mean weights of individuals between visits (Table 3). Whilst wing lengths increased steadily throughout the period, this was less marked between Visits 3 and 4, perhaps due to the reduced sample size on the last visit or possibly because the remaining chicks were starving.

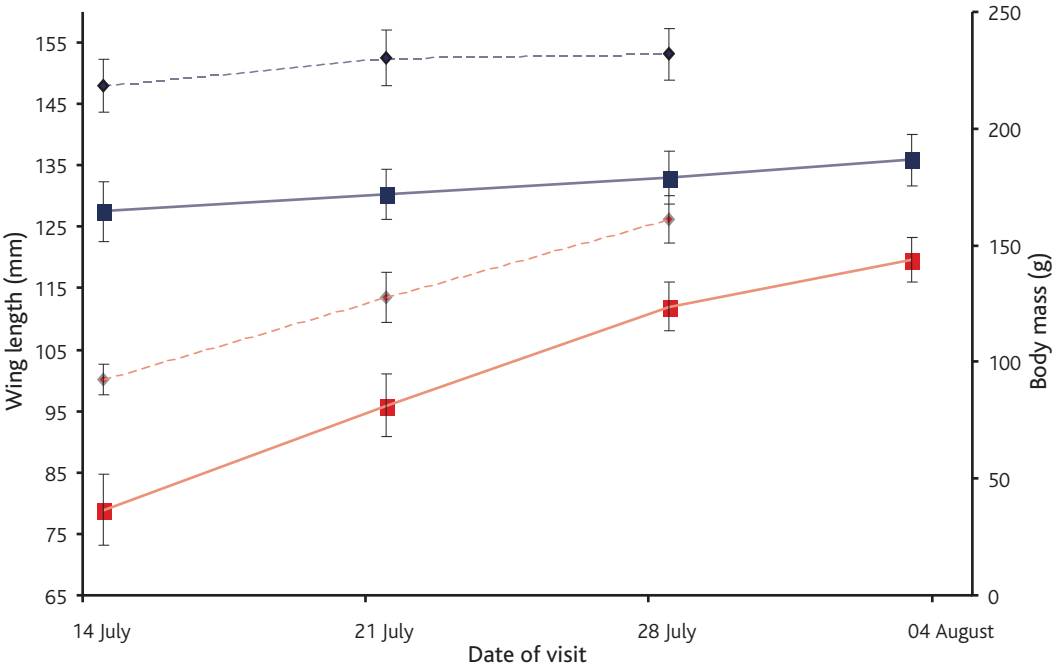

Figure 2. Changes in mean wing length ± SE (red lines) and body mass ± SE (blue lines) of Atlantic Puffin *Fratercula arctica* chicks between four visits at 38 study burrows in 2005. Chicks that were not found at their study burrow after Visit 3 are represented by the dashed line, and chicks present on all four visits are represented by the solid line.

Body lengths of pipefish collected from burrow 38 ranged from 21–33 cm (mean = 27.4 ± 0.36 cm, n = 51).

Discussion

The major determinant of Puffin breeding success is the availability and quality of prey at the appropriate stages of the annual breeding cycle, which in turn can be determined by environmental factors such as sea temperature affecting lower trophic levels and/or the growth and development of prey species (Harris *et al*. 1998; Durant *et al*. 2003). When high quality prey is abundant, Puffin chicks grow rapidly until reaching a peak of 70-80% of adult body mass aged 4–5 weeks, before fledging at a slightly lower mass aged 6–7 weeks (Harris 1984). If food is scarcer or of lower quality, mass gain can be more gradual with chicks fledging at a later age at or near their peak mass, but lighter than in more productive seasons (Barrett *et al*. 1987; Barrett & Rikardsen 1992). In more extreme cases, such as on Røst, north Norway, there can be mass mortality of chicks through starvation, either close to possible fledging or within a week of hatching, and complete breeding failure (Lid 1980; Anker-Nilssen 1987). This last situation persisted for successive breeding seasons in the 1970s and 1980s due to stock collapse of the Puffin's main prey, Norwegian spring-spawned Herring *Clupea harengus*, and the lack of reliable energy-rich alternate species within foraging range of the colony (Durant *et al*. 2003).

Fledging mass of chicks attracted to lights and generator noise at an army camp on Hirta, St Kilda was significantly correlated with breeding success in 10 years between 1973–1996 when both sets of data were available (Harris *et al*. 1998). In one year of abnormally low success (1985: c. 0.44), fledging mass (175.8 ± 5.8 g, n = 7) was 35% lower than the maximum recorded (1977: 269.7 ± 1.8 g, n = 281), although the 1985 sample size was small. In the other nine years, breeding success ranged from c. 0.65–0.85 and fledging mass from c. 220–270 g. Fledging mass on Sule Skerry in 2005 was towards the lower end of this range, and both mass and the mass/wing ratio were 19% lower than the maximum recorded (in 1983) which, even allowing for the possibility of a slight size difference in birds breeding at the two colonies (Harris 1985), suggests a moderately poor breeding season in 2005.

No marked peak in weight is discernible in Figure 2; rather, the pattern of growth in 2005, and the low mass/wing ratio of fledglings compared to earlier years suggests food shortage. Some chicks remained above the 2005 mean fledging weight (232.4 g) throughout the study period but most remained below and some of these probably left their burrows very underweight. Whether or not this will have an adverse effect on their post-fledging survival is unclear since the only study made to date failed to detect any effect of peak or fledging weight, or pattern of growth, on subsequent survival (Harris 1983).

Following widespread seabird breeding failures in 2004 in northern and eastern Britain, the breeding season there was generally late in 2005 for many seabird species. Puffin breeding success was monitored at three other major Scottish colonies in 2005 (Mavor *et al*. 2006). On Dùn, St Kilda (360 km southwest of Sule

Figure 3. Atlantic Puffins *Fratercula arctica*, Sule Skerry, summer 2007. © *Roger Taylor*

Skerry), low success of 0.26 chicks fledged per egg laid was considered a maximum value; large numbers of both downy and fully-feathered chicks were found dead at burrow entrances, which contained tangles of dead pipefish. On Fair Isle, 160 km northeast of Sule Skerry, breeding success was higher (0.67) and chick diet in July comprised 54% sandeels (Ammodytidae) (by number), 36% Sprat *Sprattus sprattus* and 3% pipefish, although many discarded pipefish were noticed around burrows. On the Isle of May, where chicks were largely fed sandeels (92% by number), despite a late season breeding success (0.70) was higher than in 2004 (0.60) but below the long-term average (0.75), while success in 2005 was even higher (0.84) on the Farne Islands, northeast England. Given unknown hatching success and fledging success of c. 63%, breeding success on Sule Skerry in 2005 appears to have been intermediate between St Kilda and Fair Isle.

In 2005, Puffins were seen carrying pipefish for the first time on Sule Skerry, probably Snake Pipefish *Entelurus aequoreus*, and up to 20–30 were found in many burrows. No details were recorded apart from those collected from burrow 38. The chick in this burrow grew very slowly and was missing on Visit 4, long before it had reached proper

condition for fledging. Pipefish are structurally and nutritionally unsuitable food for chicks of Puffins and other seabirds (Harris *et al*. 2008), as was demonstrated by this (and other) individual's failure to eat those found in its burrow, despite being seriously underweight. The appearance of pipefish on Sule Skerry in 2005 was part of a widespread phenomenon that started in 2003 (Harris *et al*. 2008), and it will be interesting to follow their occurrence in Puffin diet in future, especially if this reflects climatic changes affecting marine ecosystems in the northeast Atlantic.

Acknowledgements

Many individuals contributed to ringing activity on Sule Skerry over the years. Adrian Blackburn and Dave Budworth led most expeditions, and without their enthusiasm and drive much of these data would not of have been collected. Kevan Brett, Alex Lewis, Tim Naylor, Dave Parsons and Jackie Savery helped with the fieldwork in 2005. Jez Blackburn encouraged writing this paper from its inception, and Mike Harris and Stuart Newson gave invaluable assistance and advice on its preparation. Finally, we thank Tycho Anker-Nilssen and Matt Parsons for their comments as referees.

References

Anker-Nilssen, T. 1987. The breeding performance of Puffins *Fratercula arctica* on Røst, northern Norway in 1979–1985. *Fauna norvegica, Series C, Cinclus* 10: 21–38.

Barrett, R.T., Anker Nilssen, T., Rikardsen, F., Valde, K., Røv, N. & Vader, W. 1987. The food, growth and fledging success of Norwegian Puffin chicks *Fratercula arctica* in 1980–1983. *Ornis Scandinavica* 18: 73–83.

Barrett, R. T. & Rikardsen, F. 1992. Chick growth, fledgling periods and adult mass loss of Atlantic Puffins *Fratercula arctica* during years of prolonged food stress. *Colonial Waterbirds* 15: 24–32.

Durant, J. M., Anker-Nilssen, T. & Stenseth, N. C. 2003. Trophic interactions under climate fluctuations: the Atlantic puffin as an example. *Proceedings of the Royal Society of London B* 270: 1461–1466.

Harris, M. P. 1984. *The Puffin*. Poyser, London.

Harris, M. P. 1985. Morphology and breeding of Puffins at Isle of May and St Kilda, Scotland. *Biological Conservation* 32: 81–97.

Harris, M. P., Murray, S. & Wanless, S. 1998. Long-term changes in breeding performance of Puffins *Fratercula arctica* on St Kilda. *Bird Study* 45: 371–374.

Harris, M. P., Newell, M., Daunt, F., Speakman, J. R. & Wanless, S. 2008. Snake Pipefish *Entelurus aequoreus* are poor food for seabirds. *Ibis* 150: 413–415.

Harris, M. P. & Wanless, S. 2004. Atlantic Puffin *Fratercula arctica*. In: Mitchell, P. I., Newton, S. F., Ratcliffe, N., & Dunn, T. E. (eds.) *Seabird populations of Britain and Ireland*: 392–406. Poyser, London.

Lid, G. 1980. Reproduction of the Puffin on Røst in the Lofoten Islands in 1964–1980. *Fauna norvegica, Series C, Cinclus* 4: 30–39.

Lockley, R. M. 1934. On the breeding habits of the Puffin: with special reference to the incubation- and fledging-period. *British Birds* 27: 214–223.

Mavor, R. A., Parsons, M., Heubeck, M. & Schmitt, S. 2006. *Seabird numbers and breeding success in Britain and Ireland, 2005*. Joint Nature Conservation Committee, Peterborough. (UK Conservation, No.30)

Appendix. Wing length (mm) and body mass (g) of Atlantic Puffin *Fratercula arctica* chicks on four visits to 38 study burrows on Sule Skerry in 2005, sorted by (a) whether found on one, two, three or four visits, and (b) body mass on Visit 1.

	Visit 1		Visit 2		Visit 3		Visit 4		
Burrow	**Wing (mm)**	**Mass (g)**	**Wing (mm)**	**Mass (g)**	**Wing (mm)**	**Mass (g)**	**Wing (mm)**	**Mass (g)**	**Fledged?**
26	84	226	marker lost						?
24	58	124	77	118	marker lost				?
14	79	178	103	192					?
17	97	237	115	229					?
34	119	247	130	240					F
38		86	50	97	69	101			?
32	85	160	101	179	113	188			?
2	99	174	114	183	121	178			?
21	75	180	98	205	115	188			?
20	102	195	118	218	129	226			F
6	99	201	117	205	130	252			F
4	93	210	112	209	125	224			F
37	112	223	123	203	131	197			F
16	89	226	110	219	125	242			F
1	102	231	122	292	137	255			F
36	111	232	122	258	131	237			F
28	96	243	117	295	132	266			F
3	97	250	118	229	130	255			F
8	110	251	124	264	137	295			F
27	104	254	122	270	137	285			F
10	113	261	126	258	136	241			F
19	110	263	126	269	140	254			F
25	104	292	123	290	135	290			F
13		56		65		65		74	?
18	44	111	71	160	92	154	101	177	?
22	60	118	82	147	100	148	100	148	?
11	40	126	60	152	83	145	96	167	?
7	63	128	85	153	100	178	110	157	?
15	62	155	86	180	101	162	109	152	?
31	87	171	99	181	115	182	126	210	F
30	87	175	105	173	112	170	126	197	F
33	93	176	100	167	117	197	126	214	F
9	73	178	98	194	116	208	125	221	F
23	93	195	110	181	122	190	125	184	F
29	96	197	114	195	125	208	135	204	F
5	101	224	119	233	131	242	128	219	F
12	99	229	not found		125	200	134	239	F
35	106	229	118	225	129	237	135	237	F