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Short communication

# Snake Pipefish *Entelurus aequoreus* are poor food for seabirds

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There is now a general consensus that widespread changes are occurring in the world's oceans, leading to concerns about the effect that changes in fish stocks are likely to have on the more obvious and charismatic wildlife, including seabirds. As regards seabirds, two questions are often posed: (1) if environmental change results in the decline of the preferred prey species, will numbers of other fish increase?; and (2), if so, then are these possible alternative prey likely to be as useful to seabirds as the species that are lost?

Starting in about 2003, the abundance and range of the Snake Pipefish *Entelurus aequoreus* in the northeast Atlantic and the North Sea increased dramatically, although the causes for this increase are currently unclear (Kirby *et al.* 2006, Harris *et al.* 2007, Kloppmann & Ulleweit 2007). Since then, the species has started to be recorded in the diet of both adult and young seabirds, and in some instances in the UK there has appeared to be a parallel shortage of the seabirds' normal prey, Lesser Sandeel *Ammodytes marinus* (Mavor *et al.* 2005, 2006). Concurrent opportunistic observations suggested that birds were having difficulty in swallowing these long thin fish, leading to speculation that Snake Pipefish, with their strong and inflexible vertebral column and rigid body armour, might be low-quality food and were perhaps only eaten when other prey were in short supply (Harris 2006, Harris *et al.* 2007, Kloppmann *et al.* 2007). However, few data on the energy content of Snake Pipefish are available and the present communication reports on the energy content and nutrient composition of the Snake Pipefish from near a Scottish seabird colony and compares the results with values of other prey of seabirds collected at the same time and place.

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## MATERIAL AND METHODS

Between May and July 2006, ten and 91 Snake Pipefish (hereafter 'Pipefish') were caught at sea inshore of the Isle of May, Firth of Forth, Scotland (56°11′N, 2°34′W) and at Montrose (50 km north), respectively. There was no significant difference in the lengths of these two samples of fish ($t_{99} = 0.20$, $P = 0.84$), so the data were pooled. Each fish was measured (± 1 mm), bagged immediately after capture, frozen and later weighed (± 0.1 g). Samples of the main prey species of Atlantic Puffins *Fratercula arctica* and Common Guillemots *Uria aalge* were also collected and measured.

Eight Pipefish (chosen to span the range of available lengths), and 53 Lesser Sandeel (50 '0'-group (young of the year), three older, aged by the examination of otoliths), 15 Sprat *Sprattus sprattus*, and four Gadidae (two rockling *Gairdropsarus/Ciliata* sp., one Saithe *Pollarchius virens* and one Whiting *Merlangius merlangus*) collected from seabirds were dried to constant weight at 60 °C (dry mass) and the fat extracted using diethyl ether in a soxhlet apparatus (Reynolds & Kunz 2001). The remaining material was dried, reweighed (fat-free mass) and put in a muffle furnace at 600 °C for 10 h to incinerate the protein. The remaining ash was then weighed to determine the mineral content (mineral mass). All measurements were made on a four-figure balance and the total fat and protein content of each fish was determined as follows: fat content (g) = dry mass – fat-free mass; protein content (g) = fat-free mass – mineral mass. The energy value of each fish was then obtained from the body composition using the energy equivalents of 39.6 kJ/g for fat and 23.7 kJ/g for protein (Crisp 1971). Guillemots and puffins carry food to the chicks held in the bill and such fish lose weight due to dehydration (Montevecchi & Piatt 1987), so all energy values are presented on a dry weight basis.

## RESULTS

The mean (± se) lengths and masses of Pipefish were 33.6 ± 0.4 cm and 4.75 ± 0.2 g, respectively, and there was a highly significant relationship between mass and length (mass (g) = $0.0004 \times \text{length (cm)}^{2.6843}$, $r^2 = 85\%$, $P < 0.001$). Pipefish were not sexed but five were breeding males given that they were carrying developing eggs; all were small individuals with a mean length of 27.1 ± 0.1 cm (range 25.3–29.2). These individuals were not included among the fish analysed.

The mean energy content of the eight Pipefish was 19.8 kJ and there was a highly significant positive relationship between the energy content and the length of the fish ($R^2 = 87\%$, $P < 0.001$) that was due to an increase in the

**Table 1.** Composition and energy content of fish from or near the Isle of May in 2006. Means are given ± se.

| Species | *n* | Length (cm) | Dry mass (g) | Fat (%) | Protein (%) | Ash (%) | Total fish (kJ) | Energy density (kJ/g dry wt) |
|---|---|---|---|---|---|---|---|---|
| Snake Pipefish | 1 | 22.5 | 0.399 | 6.84 | 67.49 | 25.66 | 7.46 | 18.71 |
| Snake Pipefish | 1 | 24.6 | 0.642 | 7.82 | 68.4 | 23.78 | 12.4 | 19.31 |
| Snake Pipefish | 1 | 25.3 | 0.695 | 4.32 | 66.75 | 28.93 | 12.18 | 17.53 |
| Snake Pipefish | 1 | 31.6 | 0.736 | 5.21 | 69.35 | 25.44 | 13.61 | 18.5 |
| Snake Pipefish | 1 | 33.6 | 1.401 | 8.68 | 67.25 | 24.06 | 27.14 | 19.38 |
| Snake Pipefish | 1 | 34.5 | 1.244 | 5.96 | 69.37 | 24.67 | 23.38 | 18.8 |
| Snake Pipefish | 1 | 36.5 | 1.366 | 9.61 | 66.65 | 23.74 | 26.77 | 19.6 |
| Snake Pipefish | 1 | 38.9 | 1.689 | 13.59 | 65.19 | 21.22 | 35.18 | 20.83 |
| Snake Pipefish | Mean (8) | 30.9 ± 2.1 | 1.021 ± 0.162 | 7.75 ± 1.04 | 67.56 ± 0.51 | 24.69 ± 0.77 | 19.78 ± 3.42 | 19.08 ± 0.34 |
| Sandeel 0-group | 50 | 6.1 ± 0.1 | 0.110 ± 0.01 | 5.04 ± 0.30 | 82.42 ± 0.30 | 12.54 ± 0.28 | 2.40 ± 0.19 | 21.53 ± 0.10 |
| Sandeel older | 3 | 11.6 ± 2.2 | 1.75 ± 1.14 | 25.4 ± 2.44 | 66.1 ± 2.16 | 8.48 ± 0.30 | 46.1 ± 30.4 | 25.73 ± 0.46 |
| Sprat | 15 | 10.5 ± 0.2 | 2.132 ± 0.11 | 16.32 ± 2.29 | 73.17 ± 1.94 | 10.51 ± 0.41 | 50.95 ± 3.24 | 23.80 ± 0.45 |
| Gadidae | 4 | 5.3 ± 1.4 | 0.39 ± 0.22 | 8.75 ± 1.59 | 78.9 ± 0.67 | 11.97 ± 1.08 | 8.35 ± 4.80 | 22.26 ± 0.509 |

amount of fat (Table 1). The mean energy density (19.1 kJ/g dry weight) was significantly lower than that of the other fish species eaten by Puffins and Guillemots (21.5–22.3 kJ/g dry weight; GLM with the five groups shown in Table 1; ($F_{1,75} = 40.65$, $P < 0.001$)). This was due mainly to the very high mineral content of Pipefish (25%, compared with 8–13% for the other species).

## DISCUSSION

Snake Pipefish had, on average, a lower energy density than the other fish examined, the main difference being between Pipefish and medium and large Sandeels and Sprat, lipid-rich species that form the bulk of the diet of most seabirds nesting on the Isle of May (our unpubl. data). The only published data on the energy values of Snake Pipefish are three samples (totalling 121 individuals) from well offshore of northeast England in August 2006 that had a mean of 15.65 kJ/g dry (3.96 kJ/g wet weight for fish with a water content of 74.7%; Kloppmann *et al.* 2007), even lower than our determinations. Snake Pipefish have the lowest energy value of all but one of 49 species of fish eaten by seabirds for which values have been determined by the same method (van Pelt *et al.* 1997, Anthony *et al.* 2000 after allowing for differences in energy equivalents, this paper). The ash content of the Pipefish (24.7%) was also higher than that of 17 other species of fish eaten by seabirds for which data are available (mean 13.7 ± 1.1%, maximum 22.1%) (van Pelt *et al.* 1997, this study).

Previous work at several colonies has shown that seabirds breed most successfully when they can feed their chicks on high-lipid content fish such as Sprat, Herring *Clupea harengus* and Capelin *Mallotus villosus* and are generally less successful when they have to rely either on species of lower lipid (and hence energy) value or when for some reason these normal prey have lower than average energy value (Harris & Hislop 1978, Litzow *et al.* 2002, Wanless *et al.* 2005). Atlantic Puffins, Tufted Puffins *Fratercula cirrhata* and Black-legged Kittiwakes *Rissa tridactyla* appear to have reduced chick growth and productivity when provisioning young with a species, like Whiting and Walleye Pollock *Theragra chalcograma*, with a relatively low lipid content (Harris & Hislop 1978, Rosen & Trites 2000, Romano *et al.* 2006).

In recent years, several large breeding failures of seabirds in the UK have been documented, and these have been attributed to food shortage (Mavor *et al.* 2005, 2006). During some, but not all, of these failures Pipefish were recorded in the diet, suggesting that the birds may have been eating Pipefish because the normal food was unavailable (Harris *et al.* 2007). Time series data indicate that Pipefish are becoming much more frequent in the diet. For instance, on the Isle of May in 2006 Pipefish were recorded in 42 (46%) of 92 regurgitations by Black-legged Kittiwakes and four (9%) of 45 regurgitations by European Shags *Phalacrocorax aristotelis*; corresponding figures for 1986–2005 were six (0.3%) of 2174 regurgitations and zero of 575 regurgitations, respectively. Although in terms of energy density, Pipefish are poor food, they might still be useful to seabirds and other marine top predators when better prey are not available. However, their length and rigidity means that they are very difficult to swallow. We have many records of adult European Shags, Great Black-backed Gulls *Larus marinus*, Northern Gannets *Morus bassanus* and Common Eiders *Somateria mollissima*, species with adult masses of 1.5–3.5 kg, struggling to swallow small Pipefish weighing only 5–7 g, apparently because of both the bony nature of the fish and the extreme difficulty (perhaps impossibility) of breaking Pipefish into swallowable lengths. Not surprisingly, smaller species of seabird have more severe problems with young apparently starving to death even when sitting on piles of uneaten Pipefish (Money 2005, Newell 2006). In extreme cases, young of the smallest species, such as terns, choke to death on Pipefish stuck in their gullets (Harris 2006).

The initial stage of the digestion of food by seabirds occurs in the proventriculus and ventriculus by muscular contractions and acid proteolysis (Stevens & Hume 1995). We did not carry out any *in vitro* digestion trials but while digesting seabird regurgitations using a saturated solution of biological (enzyme) washing powder heated in an oven at 40 °C with occasional agitation, we noted that Pipefish remained intact after 48 h, a duration which allowed for almost complete digestion of Sandeels and Sprats. Support for the suggestion that Pipefish are hard to digest comes from observations that Black-legged Kittiwakes that do not normally regurgitate pellets of undigested prey remains do so when they are eating Pipefish (Kloppmann *et al*. 2007, our pers. obs.). The high ash content in the diet might also interfere with the absorption of other food eaten at the same time (Speakman 1987). Thus, both from nutritional and structural perspectives, Snake Pipefish appear to be unsuitable prey for seabird chicks and the continuing increase in abundance would seem unlikely to compensate seabirds for any reduction in the availability of Sandeels, Sprat or Herring.

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## REFERENCES

**Anthony, J.A., Roby, D.D. & Turco, K.R.** 2000. Lipid content and energy density of forage fishes from the northern Gulf of Alaska. *J. Experim. Mar. Biol. Ecol.* **248**: 53–78.

**Crisp, D.J.** 1971. Energy flow measurements. In Holme, N.A. & McIntyre, A.D. (eds) *IBP Handbook*: 197–279. Oxford: Blackwell Scientific Publications.

**Harris, M.P.** 2006. Seabirds and pipefish: a request for records. *Br. Birds* **99**: 148.

**Harris, M.P. & Hislop, J.R.G.** 1978. The food of young Puffins (*Fratercula arctica*). *J. Zool., Lond.* **185**: 213–239.

**Harris, M.P., Beare, D., Toresen, R., Nøttestad, L., Kloppmann, M., Dörner, H., Peach, K., Rushton, D.R.A., Foster-Smith, J. & Wanless, S.** 2007. A major increase in snake pipefish (*Entelurus aequoreus*) in northern European seas since 2003: potential implications for seabird breeding success. *Mar. Biol.* **151**: 973–983.

**Kirby, R.K., Johns, D.G. & Lindley, J.A.** 2006. Fathers in hot water: rising sea temperatures and a Northeastern Atlantic pipefish baby boom. *Biol. Lett.* **2**: 597–600.

**Kloppmann, M.H.F. & Ulleweit, J.** 2007. Off-shore distribution of snake pipefish, *Entelurus aequoreus* (Linnaeus, 1758), west of the British Isles. *Mar. Biol.* **151**: 271–275.

**Kloppmann, M., Ehrich, S. & Karl, H.** 2007. Die Grosse Schlangennadel als Nahrung für Seevögel. *Seevögel* **28**: 18–24.

**Litzow, M.A., Piatt, J.F., Prichard, A.K. & Roby, D.D.** 2002. Responses of pigeon guillemots to variable abundance of high-lipid and low-lipid prey. *Oecologia* **132**: 286–295.

**Mavor, R.A., Parsons, M., Heubeck, M. & Schmitt, S.** 2005. *Seabird Numbers and Breeding Success in Britain and Ireland, 2004*. Peterborough: Joint Nature Conservation Committee (UK Nature Conservation No. 28).

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

**Money, S.** 2005. *St Kilda Seabird and Marine Ranger Annual Report 2005*. Edinburgh: National Trust for Scotland.

**Montevecchi, W.A. & Piatt, J.F.** 1987. Dehydration of seabird prey during transport to the colony: effects on wet weight energy densities. *Can. J. Zool.* **65**: 2822–2824.

**Newell, M.** 2006. A moribund young Kittiwake surrounded by snake pipefish. *Br. Birds* **99**: 500–501.

**van Pelt, T.I., Piatt, J.F., Lance, B.K. & Roby, D.D.** 1997. Proximate composition and energy density of some North Pacific forage fishes. *Comp. Biochem. Physiol.* **118A**: 1393–1398.

**Reynolds, D.S. & Kunz, T.H.** 2001. Standard methods for destructive body composition analysis. In Speakman, J.R. (ed.) *Body Composition Analysis of Animals. A Handbook of Non-Destructive Methods*: 39–55. Cambridge: Cambridge University Press.

**Romano, M.D., Piatt, J.F. & Roby, D.D.** 2006. Testing the junk-food hypothesis on marine birds: effects of prey type on growth and development. *Waterbirds* **29**: 407–414.

**Rosen, D.A.S. & Trites, A.W.** 2000. Pollock and the decline of Steller sea lions: testing the junk-food hypothesis. *Can. J. Zool.* **78**: 1243–1250.

**Speakman, J.R.** 1987. Apparent absorption efficiencies for redshank (*Tringa totanus* L.) and oystercatcher (*Haematopus ostralegus* L.) – implications for the predictions of optimal foraging models. *Am. Nat.* **130**: 677–691.

**Stevens, C.E. & Hume, I.D.** 1995. *Comparative Physiology of the Vertebrate Digestive System*. Cambridge: Cambridge University Press.

**Wanless, S., Harris, M.P., Redman, P. & Speakman, J.** 2005. Low fish quality as a probable cause of a major seabird breeding failure in the North Sea. *Mar. Ecol. Prog. Ser.* **294**: 1–8.

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