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SHORT NOTE

Over-representation of bird prey in pellets of South Polar Skuas

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Abstract We report the first study to compare the contents of pellets and regurgitates of South Polar Skuas, *Stercorarius maccormicki*, at two breeding colonies on the Antarctic Peninsula. Samples were taken across years from identified breeding pairs at Potter Peninsula in sympatry with 30–40 breeding pairs of Brown Skuas, *Stercorarius antarcticus lonnbergi*, and from Cierva Point with 2 pairs of Brown Skuas. In contrast to the general consensus that penguins feature in the diet most prominently in the absence of Brown Skuas, we found a much more frequent occurrence of penguin remains in samples at Potter than Cierva, but only in pellets. At Cierva, penguin feathers were largely replaced in the pellets by a high frequency of non-food moss. The rare occurrence of penguins in regurgitates from both sites is consistent with scavenging rather than active predation. The high frequency of feathers in pellets at Potter is consistent with a gut-cleansing function similar to that performed by moss, which is abundant only at Cierva. We conclude that pellets over-represent penguins in the diet. For any species that consumes feathers, the evidence must consider the alternative possibility of a non-food function of ingesting feathers.

Keywords Antarctica · Dietary analysis · Pellet analysis · Regurgitate analysis · Sympatric

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Zusammenfassung

Überrepräsentation von Vögeln als Beute in den Speiballen von Antarktikskuas

Hier stellen wir die erste vergleichende Studie über die Zusammensetzung von Speiballen und Regurgitaten von Antarktikskuas *Stercorarius maccormicki* in zwei Brutkolonien auf der Antarktischen Halbinsel vor. Die Probennahme erfolgte über Jahre hinweg bei individuell bekannten Brutpaaren; zum einen auf der Potter-Halbinsel, wo sie zusammen mit 30-40 Brutpaaren Subantarktikskuas *Stercorarius antarcticus lonnbergi* vorkommen, sowie auf Cierva Point, wo sie gemeinsam mit zwei Paaren Subantarktikskuas brüten. Abweichend von der verbreiteten Annahme, dass Pinguine dort, wo Subantarktikskuas fehlen, einen Großteil der Nahrung bilden, fanden wir viel mehr Pinguinreste in den Proben von der Potter-Halbinsel als in denen von Cierva Point, allerdings nur in den Speiballen. In Cierva fand sich in den Speiballen anstelle der Pinguinfedern ein hoher Anteil an unverdaulichem Moos. Das seltene Auftreten von Pinguinen in Speiballen von beiden Orten deutet eher auf Aasfressen als auf aktive Beutejagd hin. Der hohe Federanteil in den Speiballen von der Potter-Halbinsel lässt auf eine Rolle bei der Reinigung des Verdauungstraktes schließen, vergleichbar mit der von Moos, welches nur in Cierva häufig vorkommt.

Wir gelangen zu dem Schluss, dass der Anteil von Pinguinen an der Nahrung in den Speiballen überrepräsentiert ist. Daher muss bei jeder Art, die Federn aufnimmt, in Erwägung gezogen werden, dass diese auch aus anderen Gründen als denen der Nahrungsaufnahme verzehrt werden können.

Introduction

Many pelagic birds demonstrate opportunistic foraging strategies in response to spatio-temporally variable environments, resulting in substantial dietary plasticity. The broad and flexible diet of the skua family presents a well-studied extreme of plasticity, and potentially useful indicator of the abundance of fish species such as *Pleuragramma antarcticum* and *Electrona antarctica* (Hemmings 1984). South Polar Skuas (*Stercorarius maccormicki*), which are amongst the most southerly distributed of all seabirds, feed by predation, scavenging and kleptoparasitism (Young 1994), making them efficient opportunists in the harsh Antarctic environment. In areas of sympatry with Brown Skuas (*Stercorarius antarcticus lonnbergi*), South Polar Skuas are reportedly almost wholly piscivorous (amongst many: Pietz 1987; Reinhardt 1997, 1998; Reinhardt et al. 2000; Hahn et al. 2008; Montalti et al. 2009). In allopatry, they reportedly feed largely on penguins and fish (Young 1963, 1994; Müller-Schwarze and Müller-Schwarze 1973, 1977; de Brooke et al. 1999; Baker and Barbraud 2001; Pezzo et al. 2001).

Methods for analysing diet of skuas in Antarctica are often constrained by logistical considerations that generally preclude observations of foraging individuals. Complementary techniques such as isotopic analysis remain unaffordable for many studies, and require ground-truthing against other methods. The two principal sources of data reported in the literature are pellets found on the ground, and regurgitate taken from chicks. Regurgitates of adult skuas reportedly differ little from those of chicks, which are regurgitating food delivered to them by adults (Bearhop et al. 2001).

Between these two methodologies, all the evidence for penguins as a substantial prey of South Polar Skuas comes from analysis of pellets (Peter et al. 1990; Norman and Ward 1990; Mund and Miller 1995; Graña Grilli and Montalti 2011). No study has directly compared the contents of pellets and regurgitates of South Polar Skuas produced by identified breeding pairs. Here, we compare contents of 109 pellets and 143 chick regurgitates, collected over two breeding seasons from two populations of South Polar Skuas with high and low numbers of breeding pairs of Brown Skuas. Our objective is to quantify method-induced biases in diet estimation.

Methods

The site in sympatry with a large number of breeding pairs of Brown Skuas was Potter Peninsula (hereafter Potter), Stranger Point, Isla 25 de Mayo/King George Island (62°16′S, 58°37′W), part of Antarctic Specially Protected Area (ASPA) no. 132. South Polar and Brown Skuas bred together, with abundances estimated at 68–70 and 30–34 pairs, respectively, over an area of 6.5 km^2. They bred in the vicinity of breeding colonies of Adélie (*Pygoscelis adeliae*) and Gentoo (*Pygoscelis papua*) Penguins, with abundances estimated at 3,412 and 3,764 pairs, respectively (Carlini et al. 2009). Between 12 and 14 pairs of Brown Skuas actively defended feeding territories within the penguin colonies.

The site with few breeding pairs of Brown Skuas was Cierva Point (hereafter Cierva), Costa Danco (64°09′S, 60°57′W) in the northwest of the Antarctic Peninsula, part of ASPA no. 134. About 166 pairs of South Polar Skuas bred in the vicinity of about 2,600 pairs of Gentoo Penguins covering an area of 1.5 km^2 (González-Zevallos et al., submitted). Two pairs of Brown Skuas had nests ~15 m from the edge of the penguin colony, and fed principally on penguins (M.M. Santos, personal observation). The extent of their territories was insufficient to exclude South Polar Skuas, which had ~10 % of nests located further within the penguin colony.

Data were collected from individually identified nests of South Polar Skuas during the 2005/6 and 2007/8 reproductive seasons, henceforth referred to as 2006 and 2008, respectively. Adult pellets and chick regurgitates were collected only during the chick-rearing phase of the breeding season, in order to avoid confounding influences of dietary changes in response to stage-dependent energetic requirements.

Pellets may remain intact for years in the Antarctic climate. For this reason, study areas were cleared of pellets at the start of each study period, by scouring the vicinity of every study nest. Thereafter, pellets were collected every 5 days from the vicinity of nests. All chicks aged 3 days and older were stimulated to regurgitate by inversion and gentle massaging of the stomach and then throat (following Barrett et al. 2007).

Collections at Potter in 2006 and 2008 totalled 27 and 10 pellets, and 41 and 19 regurgitates, respectively. Collections at Cierva in 2006 and 2008 totalled 49 and 23 pellets, and 40 and 43 regurgitates, respectively. Laboratory analysis identified the contents of pellets and regurgitates to the lowest taxonomic level possible with a binocular microscope, using reference material. Penguins were identified from eggshell or feather remains, fish from otoliths (with reference to Hetch 1987), mammals from hair, and invertebrates from exoskeleton.

Results

Penguins and fish were the principal items in samples across years at Potter. Penguins were present in 63–90 % of pellets and 0–12 % of regurgitates, and fish were present in 30–44 % of pellets and 84–85 % of regurgitates. Non-food moss was present in 0–4 % of pellets and 5–11 % of regurgitates. At Cierva, with the lower population of Brown Skuas, fish were the principal food item in samples, present in 91–98 % of pellets and 88–95 % of regurgitates. Penguins occurred in 0–13 % of pellets and 0–7 % of regurgitates. Non-food moss was present in 87–88 % of pellets and 0–11 % of regurgitates. Other food types showed no consistent differences by site, year, or collection type, with krill present in 0–36 % of samples, flighted birds in 0–19 %, other crustaceans in 0–16 %, and other prey in 0–10 %.

At the total of 23 nests from which both pellets and regurgitates were collected, food categories could be either absent from both (AA), or present only in pellets (PA), only in regurgitate (AP), or present in both (PP). Penguins were entirely absent from regurgitate, being PA in 12 nests and AA in 11 nests. Binary logistic regression of these responses on site and year showed a difference by site ($z = 2.26$, $P = 0.024$), and no difference by year ($z = 0.73$, $P = 0.46$); penguins were 2.5 times more likely to appear at Potter than Cierva (always only in pellets). Fish were never absent from a nest, being PA in 1 nest, AP in 10 nests, and PP in 12 nests. Binary logistic regression on the 22 AP and PP nests showed a difference by year ($z = 2.18$, $P = 0.029$), and no difference by site ($z = 1.31$, $P = 0.19$); fish were 3.3 times more likely to be present in pellets (as well as regurgitate) in 2006 than in 2008 (when they were present in the pellets of only one nest).

Skuas that feed on fish may not feed on penguins during the same period, and therefore may not produce pellets as frequently. To accommodate this possibility, we additionally analysed a total of 80 nests in a balanced design of 10 nests randomly sub-sampled from each combination of method × site × year. This n was determined by the lowest sample size of 10 nests for the pellets × Potter × 2008 combination. Penguins were present in 17 of the 40 nests with pellets, and entirely absent from nests with regurgitate. Fish were present in 20 of the 40 nests with pellets, and present in 36 of the 40 with regurgitate. Binary logistic regression of fish presence/absence on methodology, site and year showed a difference by method ($z = 3.75$, $P < 0.001$), site ($z = 2.71$, $P = 0.007$) and year ($z = 2.71$, $P = 0.007$). Fish were 2.8 times less likely to be found in pellets than in regurgitate, 1.9 times less likely to be found at Potter than at Cierva, and 1.9 times more likely to be found in 2006 than 2008. The site effect was strongly influenced by fish being present in all 20 regurgitates from Cierva.

The possibility of chicks being preferentially fed a fish-based diet was tested by comparing chick and adult regurgitates. Frequencies of foods from terrestrial sources (penguins, flighted birds, mammals) and marine sources (fish, krill, other crustaceans, molluscs) varied independently of adult- and chick-sourced regurgitate (Fisher exact tests, year 2004 on 61 chick regurgitates, 4 adults stomach samples: $P = 1.00$; 2005 on 78 and 23: $P = 0.22$; 2005 on 41 and 6: $P = 0.26$; 2007 on 43 and 13: $P = 1.00$). Differences in sample sizes are due to the difficulty of doing stomach sampling.

Discussion

Our analyses found similar categories and proportions of items to those of other regurgitate studies and other pellet studies. All studies using regurgitates and direct observations from areas in sympatry with Brown Skuas report a predominance of fish in the diet (Trivelpiece et al. 1980; Pietz 1987; Reinhardt 1998; Montalti et al. 2009; this study). Pellet studies in contrast also report a substantial (20–89 %) contribution from penguins, both in sympatry (Peter et al. 1990; Graña Grilli and Montalti 2011; this study) and in allopatry (e.g. Green 1986; Norman and Ward 1990), even without penguin colonies in the vicinity (Zipan and Norman 1993; Mund and Miller 1995). Pellet studies have underpinned the consensus view that penguins are a principal complement to fish in the diet of breeding South Polar Skuas, raising the possibility of food competition with more dominant Brown Skuas (Pietz 1987; Reinhardt et al. 2000; Malzof and Quintana 2008).

Our combined analysis of pellets and regurgitates revealed strong dietary similarities between sites, despite the predominance of Brown Skuas only at Potter. The regurgitates showed that fish predominated in South Polar Skua diets at both sites across years. The pellets on their own would have suggested an almost exclusively fish-based diet at Cierva, contrasting with a predominance of penguin over fish at Potter. The combined analysis revealed the major switch between sites, from a high representation of moss and low presence of penguin feathers at Cierva to a high representation of penguin and little moss at Potter.

The rare occurrence of penguin in regurgitates at both sites is consistent with occasional and opportunistic predation or scavenging from carcasses or scats of leopard seals, rather than active and constant predation (Green 1986; Young 1990). Without further site replication, however, we cannot rule out the possibility of competitive exclusion by Brown Skuas from Adélie Penguins at Potter, and distaste for the larger Gentoo Penguins at Cierva. Depredations on Gentoos by South Polar Skuas are not recorded in the literature. Santos et al. (2007) reported

Brown Skuas preferentially attacking Adélie nests contiguous with more vigorously defended Gentoo nests on Isla 25 de Mayo/King George Island.

The marked switch in the pellets from a predominance of penguin feathers at Potter to moss at Cierva suggests an alternative function of feather ingestion. The elimination of undigested material in pellets impedes the growth of populations of gastric parasites, and the presence of feathers is associated with diets that otherwise contain little indigestible material (Piersma and Van Eerden 1989). The climatic conditions particular to Cierva support thick carpets of moss over the boulder terrain of the skua colony. During each change of shift on a nest, the bird that is about to be relieved typically picks at moss around the nest. Moss may also be ingested when birds bathe in local moss-lined pools. In contrast, the habitat of the skua colony at Potter is characterized by barren shingle with moss restricted to wet areas. Feather ingestion at this site could therefore substitute for moss in a gut-cleansing function.

Our study warns against overestimating the role of bird in the diets of species that potentially prey on birds and fishes. We suspect that this source of bias may be present in the many previous analyses of South Polar Skua pellets. We recommend that evidence takes account of other non-food functions of ingesting penguin feathers. The distinction between alternative interpretations of feathers in the pellets is important, because a habit of bird predation poses potential risks to the viability of other seabirds, as seen with northern hemisphere skuas (Furness 2007).

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