Polar Biol (1998) 19: 32–36

ORIGINAL PAPER

M. Favero · M.P. Silva

How important are pelagic preys for the kelp gull during chick-rearing at the South Shetland Islands?

Received: 7 October 1996 / Accepted: 14 July 1997

Abstract An analysis of pellets regurgitated indicated adult kelp gulls (*Larus dominicanus*) on the South Shetland Islands consumed predominantly intertidal prey, whereas previous studies at Antarctic Peninsula sites have reported kelp gulls consuming predominantly pelagic species. The pellets collected at Nelson Island during the chick-rearing period indicated that the limpet *Nacella concinna* was their most frequent prey, followed by carrion, gammariids, snails and krill. Fish were scarcely represented. Also, regurgitated stomach contents of chicks showed that limpets and carrion were the most frequent food items, accounting for 70% of the mass. However, gammariids were particularly important by number. Significant differences were observed in the overall comparison of the diet as reflected by the two sampling methods. In general, the importance of pelagic prey was negligible when compared to intertidal or scavenged prey. Our results differ greatly from those reported for the Antarctic Peninsula, where chicks were almost exclusively fed with the pelagic fish *Pleuragramma antarcticum*. These differences could be related to the abundance of pelagic resources in southernmost latitudes, and/or to the presence of more extensive intertidal foraging areas at the South Shetland Islands.

Introduction

The kelp gull *Larus dominicanus* is widely distributed in the southern hemisphere, sub-Antarctic islands and Antarctica (Watson 1975). The distribution and population size of this species have increased (e.g. Fordham 1970; Boekel 1976), presumably because the presence of waste of anthropic origin represents a highly predictable food supply (Crawford et al. 1982). Distribution data suggest that, before the current levels of agriculture and industrial production, kelp gulls were much more dependent on intertidal prey than they are now (Fraser 1989). Their diet remains unmodified in the sub-Antarctic and Antarctic (Branch 1985; Fraser 1989), as well as in other undisturbed intertidal places of South America (Bahamondes and Castilla 1986). Information on their food and foraging behaviour in the Antarctic Peninsula has indicated a shift from an abundance of limpets (*Nacella concinna*) in the diet to offshore fish and crustaceans during the chick-rearing period (Maxson and Bernstein 1984; Fraser 1989). Similar results were reported for the northern hemisphere, where gulls feed nestlings with seasonally superabundant oceanic prey (Ingolfsoon 1976; Trapp 1979; Irons et al. 1986; Annet 1987).

The goal of this study was to determine the relative importance of limpets versus oceanic prey in the diet of kelp gulls during the chick-rearing period at Harmony Point (Nelson Island, South Shetland Islands, Antarctica), by the analysis of pellets from adults and chicks' regurgitations.

Materials and methods

The study was conducted from 26 December 1995 to 25 January 1996 at Harmony Point, Nelson I., South Shetland Is., Antarctica (62°18′S, 59°10′W), during the kelp gull chick-rearing period. The diet of the adult specimens was assessed by the analysis of 167 pellets collected in breeding territories, which were cleaned previous to the samplings. The samples were dissected and the hard remains identified using a stereo microscope (× 20) and then sorted into alimentary items to the lowest taxonomic level possible. Additional prey remains were collected in the shoreline in order to estimate the size of those preys that were not swallowed in the intertidal but carried ashore for handling. The shell lengths of limpets and snails were measured.

M. Favero (✉)
Universidad Nacional de Mar del Plata,
Facultad de Ciencias Exactas y Naturales,
Departamento de Biología,
Funes 3250 (7600) Mar del Plata, Argentina
e-mail: mafavero@mdp.edu.ar
M.P. Silva
CIC-Universidad Nacional de Mar del Plata,
Facultad de Ciencias Exactas y Naturales,
Departamento de Ciencias Marinas,
Funes 3350 (7600) Mar del Plata, Argentina

The diet of the chicks was studied by the analysis of 52 regurgitations induced by handling. Since the foraging behaviour and time budget of gulls are influenced by tides (Irons et al. 1986; Fraser 1989; Silva 1996), samplings were homogeneously distributed at different tidal heights. Fresh samples were sorted and weighed (accuracy 0.1 g) in the laboratory. Data were grouped according to the chick age and weight: small chicks (less than 2 weeks old and/or smaller than 300 g); medium (from 2 to 4 weeks old and/or 300–750 g); and large chicks (older than 4 weeks and/or larger than 750 g).

When present, fish otoliths were recovered and identified to species by comparison with reference material and descriptions and illustrations in Hecht (1987). Fish total length (TL) was estimated from otolith length using equations from Casaux and Barrera-Oro (1993) and Hecht (1987).

Breeding success was estimated by monitoring 38 nests that were located during the incubation period and checked in mid-January with the help of binoculars (× 10). At this time, nearly all chicks were fledged, and therefore subsequent mortality was assumed to be negligible. Hereafter, "carrion" refers to remains of penguin eggs or chicks/adult carcasses, which were obtained by the gulls mainly through scavenging at penguin rookeries.

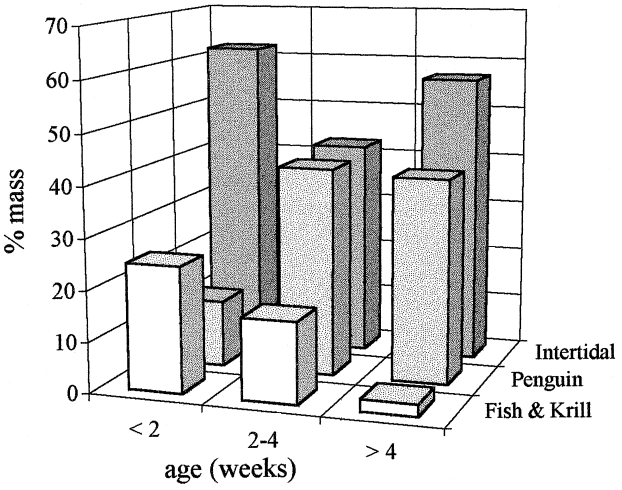

Fig. 1 Importance in mass of prey items found in chicks' regurgitations, pooled in relation to potential areas where captured. Intertidal prey includes limpets, snails, Polyplacophora, polychaetes, Coelenterata, amphipods and isopods. Carrion includes penguin eggs or carcasses obtained mainly by scavenging at penguin colonies

Results

Limpets were the most common prey item in regurgitated pellets from adults (Table 1), and also predominated by number. Limpets found in pellets (mean shell length = 30.8 mm, SD = 8.6, n = 911) were significantly smaller (t = 24.74, df = 1074, P < 0.0001) than limpets carried ashore for handling and found stranded in the shoreline (mean length = 47.6 mm, SD = 4.0, n = 165). The most important prey items found in chicks' regurgitations, both in occurrence and weight, were limpets and carrion, accounting for 70% by mass (Table 1, Fig. 1).

In adult pellets, limpets were followed in importance by carrion, gammariids and fish. Algae were frequently found in the samples, but could be in part accidentally obtained together with other benthic prey; however, field observations revealed gulls obtaining algae from intertidally exposed rocks. In importance by number, limpets were followed by gammariids, trochiid snails and krill. Fish constituted a low proportion of total prey in adults (Table 1). Among trochiids, the smaller specimens (1.0–4.0 mm in length) were the most important in number (70%), followed by medium-sized (4.0–9.0 mm; 17%) and large-sized individuals (>9.0 mm; 13%). From a total of 33 pellets containing fish remains, only 9 individuals were identified, belonging to 5 species: *Electrona antarctica* (TL = 6.2 cm, n = 4), *Notothenia coriiceps* (TL = 23.9 cm, n = 2), *Gymnoscopelus nicholsii* (TL = 13.7 cm, n = 1), *Gobionotothen gibberifrons* (TL = 18.6 cm, n = 1) and *Parachaenichtys georgianus* (TL = 36.6 cm, n = 1).

Table 1 Frequency of occurrence and importance in number and mass of prey items found in pellets and chicks' regurgitations

Food item	Pellets from adults		Chick regurgitations		
	Frequency	% Number	Frequency	% Number	% Mass
Limpets	88.6	44.7	44.2	3.3	34.4
Trochiid snails	19.2	9.5	25.0	5.2	0.6
Polyplacophora	3.6	0.5	9.6	0.3	0.1
Octopus	2.4	0.3	–	–	–
Errant polychaetes	–	–	1.9	0.1	0.0
Sedentary polychaetes	–	–	1.9	0.1	0.0
Coelenterata	–	–	9.6	2.9	3.2
Gammariids	27.5	27.5	38.5	83.1	10.0
Hyperiids	0.6	0.1	3.9	0.2	0.0
Isopods	0.6	0.1	1.9	0.1	0.3
Euphausiids	4.2	5.8	13.5	2.2	2.9
Fish	19.8	2.1	11.5	0.4	8.1
Carrion[a]	70.1	6.1	40.4	1.3	34.9
Flying birds	2.4	0.2	–	–	–
Seals	1.8	0.2	1.9	0.1	0.3
Algae	39.5	3.2	26.9	0.8	5.0
Stones	45.5	–	15.4	–	–
Unidentified	–	–	1.9	0.1	0.1

[a] Including penguin eggs or chicks and adult penguins obtained mainly by scavenging at penguin colonies

In chick regurgitations, gammariids were particularly important in number, with a maximum of 550 and 408 individuals per regurgitation in medium and large chicks respectively. Despite algae being considered in some cases as accidentally ingested by adults, in two regurgitations from small and medium chicks algae were the only contents. Fish were found in 20% of the samples, but only accounted for 2% of the mass. The only identified specimens were juvenile *Notothenia coriiceps,* ranging in size from 11.1 to 25.0 cm length ($n = 3$). Although the frequency of occurrence of the preys found in regurgitations did not vary significantly with chick age ($\chi^2 = 33.5$, $df = 30$, $P > 0.05$), there were significant differences in their importance in number and mass ($\chi^2 = 200.9$, $df = 28$, $P < 0.01$; $\chi^2 = 299.0$, $df = 28$, $P < 0.01$, respectively). As chicks grew older, carrion became more important in mass whereas the importance of fish and krill decreased. Intertidal food remained the most important resource in the three age ranges considered, ranging from 43 to 62% in mass (Fig. 1).

The diet composition as reflected by the analysis of adult pellets and chick regurgitations showed significant differences in frequencies of occurrence and number of the items ($\chi^2 = 73.5$, $df = 16$, $P < 0.001$; $\chi^2 = 1365.6$, $df = 16$, $P < 0.0001$, respectively). The occurrence of limpets and scavenged-prey food from penguin rockeries was much higher in pellets; however, soft-bodied prey such as Coelenterata and polychaetes were only observed in chick regurgitations. Considering importance in number, the strongest differences were observed in limpets and gammariids; the former were highly represented in adult pellets, and the latter in chick regurgitations.

The breeding success observed in the 38 controlled nests was 1.45 chicks/pair, which was distributed as follows: 5 empty nests, 16 nests with 1 chick, 12 with 2, and 5 with 3 chicks fledged.

Discussion

Intertidal prey, together with food obtained by scavenging and predation in penguin colonies, constituted the bulk of the diet of kelp gulls during the chick-rearing period, both in terms of frequency of occurrence and number. Fish present in pellets and chicks' regurgitations were both demersal-benthic (most of them nototheniids) and pelagic (myctophiids) species. Their presence in the diet of gulls could not be attributed only to predation: the smaller sizes of the species belonging to the former group were particularly abundant in intertidal pools during low tides (P. Silva, unpublished work). During the study period, we observed three successful attempts of adult gulls foraging on juvenile *Notothenia coriiceps* specimens of *ca.* 10–15-cm length. Larger notothenid specimens, which are rare in the intertidal and inaccessible for gulls in waters deeper than 1 m, could be obtained by kleptoparasitism on Antarctic shag *Phalacrocorax bransfieldensis* (R. Casaux, unpublished work) or by scavenging parts of prey from Weddell seals, which occasionally were seen consuming large notothenids near the surface (M. Favero, personal observation). Although pelagic fish *E. antarctica* and *Gymnoscopelus nicholsii* may have been taken in surface waters, there is a possibility that the otoliths found in pellets arise in part from Weddell seals' faeces and/or regurgitations, which constituted a food resource frequently used by giant petrels (*Macronectes giganteus*) and pale-faced sheathbills (*Chionis alba*), and occasionally by brown skuas (*Catharacta antarctica*) and kelp gulls (M. Favero, unpublished work). Supporting this hypothesis, one regurgitation from a small chick was found to be entirely composed of a seal's regurgitation. Moreover, all the fish species represented by otoliths, and octopus beaks found in pellets, occurred in seals' faeces or regurgitations (R. Casaux, unpublished work).

As a result of strong winds and storms, krill are occasionally abundant nearshore and stranded onshore, where they are often scavenged by kelp gulls and other birds (Favero 1996). Furthermore, as reported by Emslie et al. (1995) for King George Island, observations on gentoo penguin colonies at Harmony Point revealed intense gull scavenging, particularly during the penguins' guard and crèche periods, coinciding with the end of gulls' chick-rearing. Thus krill, which are primarily considered as an offshore resource, could also be obtained by gulls near the shore or in penguin rookeries.

Although both in adult pellets and chicks' regurgitations limpets and carrion from penguin colonies were the most important prey, an overall comparison showed significant differences between both sets of data. The advantages and biases of different sampling methods for the analysis of the diet in seabirds were extensively discussed (e.g. Duffy and Laurenson 1983; Duffy and Jackson 1986; Irons 1987). Pellet analysis allows us to infer the sizes of some prey and large sample sizes but is biased against soft-bodied prey (Irons 1987). However, chick regurgitations could be biased, depending on stomach fullness or the stomach content due to the willingness of chicks to regurgitate (Duffy and Jackson 1986). The two sampling methods are not fully comparable, but taking into account that adult gulls transfer almost whole preys (e.g. intertidal preys, krill and small fish) to their chicks, it is possible that some strong differences observed in the comparison (as the importance in number of amphipods in chick regurgitations) could be due to the origin of the samples (from adults or chicks) and not merely to the sampling procedure.

The low importance of pelagic prey in the chicks' diet (Fig. 1) and the high number of fledglings per pair (1.45), show positively that these prey are not a key factor for breeding success of kelp gulls at the South Shetland Islands. The breeding success at Harmony Point was much higher than that reported by Jablonski (1986) at King George Island (0.68 per nest), and not far from the 1.91 and 1.80 chicks/pair reported for Anvers Island in 1974–1975 and 1975–1976, respectively, during

exceptionally good summers with a superabundance of pelagic fish (Maxson and Bernstein 1984). The chicks' diet was very different compared to that reported for the Antarctic Peninsula (Fraser 1989), where nestlings were almost exclusively fed with the pelagic fish *Pleuragramma antarcticum* (98% of 396 feedings observed). In fact, it has been suggested for this area that *Pleuragramma antarcticum* represents a substantial resource because most kelp gull feeding territories cannot supply enough intertidal or scavenged food to support both adults and chicks (Maxson and Bernstein 1984). This hypothesis was based on the fact that in the same area, but during severe summers, when offshore resources were not abundant and gulls were forced to forage primarily in their territories, reproductive success dropped to 0.4 and 0.6 fledged chicks/pair (1978–1979 and 1979–1980 seasons, respectively) (Maxson and Bernstein 1984). These authors concluded that, while possession of feeding territories had several benefits such as time and energy saving and predation-reducing advantages, these territories themselves did not produce sufficient food for the gulls to achieve high reproductive success. In agreement, Irons et al. (1986) reported that glaucous-winged gulls (*L. glausescens*), while feeding nestlings in the Arctic, infrequently forage in the intertidal zones; during that time, the preys regurgitated to the nestlings were 96% fish and 4% zooplankton. However, after the young had begun to fledge, the gulls returned to forage more frequently in the intertidal. A similar correlation in the timing of the switch in the diet with hatching was reported for western gulls (*L. occidentalis*) in North America (Annett 1987).

The increase of carrion prey in the diet as chicks become larger allow us to hypothesise that carrion, and not merely the abundance of limpets, is an important factor in providing adequate food to fledge gull chicks in the study area. In the Antarctic Peninsula, Maxson and Bernstein (1984) found that, as chicks grew, foraging time on territory increased little but the time spent foraging off-territory increased considerably. This situation resembles that observed in chicks' diet during our study, since off-territory prey could be represented by carrion obtained mainly at penguin colonies.

The data reported here are in close agreement with those from a 3-year database on gulls' diet carried out during breeding seasons in several areas of King George and Nelson Islands. Although significant differences were found in the diet within the reproductive periods in previous seasons, the importance of fish as prey was always negligible (Silva and Favero 1994; Silva 1996; Favero et al. 1997). In all of these summers intertidal prey and carrion constituted the bulk of the diet for breeding gulls, revealing that there exist strong differences in the diet, at least during the chick-rearing period, between gulls from the South Shetland Islands and those from more southern parts of the Antarctic Peninsula. Such differences could be explained by a differential abundance of prey resources; *Pleuragramma antarcticum* inhabits waters of both the Antarctic Peninsula and South Shetland Islands, but seems to be more abundant close to the peninsula, particularly further south in Palmer archipelago (Slosarczyk and Cielniaszek 1985; Kellermann 1986). In contrast, extensive intertidal areas and penguin colonies in the South Shetland Islands offer a wide set of prey, which may have lower energy contents than fish (see Reinhardt and Van Vleet 1986) but which can still be profitable because of the proximity of foraging areas from the breeding areas and their high predictability.

Acknowledgements The fieldwork was carried out during the Antarctic Summer Expeditions 1995/1996 of the Instituto Antártico Argentino. We thank R. Casaux for the identification of otoliths and the unpublished information supplied. O. Iribarne made helpful comments on an earlier draft. We thank also J. A. van Franeker and two anonymous referees whose criticisms and suggestions improved the manuscript.

References

Annett C (1987) Proximate mechanisms affecting dietary switches in breeding gulls. Stud Avian Biol 10:102

Bahamondes I, Castilla JC (1986) Predation of marine invertebrates by the kelp gull *Larus dominicanus* in an undisturbed intertidal rocky shore of central Chile. Rev Chil Hist Nat 59:65–72

Boekel C (1976) Extension of range in the Dominican gull. Aust. Bird Watcher 6:162–167

Branch GM (1985) The impact of predation by kelp gulls *Larus dominicanus* on the Subantarctic limpet *Nacella delesserti*. Polar Biol 4:171–177

Casaux R, Barrera-Oro E (1993) The diet of the blue-eyed shag, *Phalacrocorax atriceps bransfieldensis* feeding in the Bransfield Strait. Antarct Sci 5:335–338

Crawford RJM, Cooper J, Shuldon PA (1982) Distribution, population size, breeding and conservation of the kelp gull in Southern Africa. Ostrich 53:164–177

Duffy DC, Jackson S (1986) Diet studies of seabirds: a review of methods. Colon Waterbirds 9:1–17

Duffy DC, Laurenson LJB (1983) Pellets of Cape cormorants as indicators of diet. Condor 85:305–307

Emslie SD, Karnovski N, Trivelpiece W (1995) Avian predation at penguin colonies on King George Island, Antarctica. Wilson Bull 107:317–327

Favero M (1996) Antarctic tern *Sterna vittata* feeding on the stranded krill at King George Islands, South Shetland Island, Antarctica. Mar Ornithol 23: (in press)

Favero M, Silva MP, Ferreyra G (1997) Trophic relationships between the kelp gull and the Antarctic limpet at King George Island, South Shetland Islands, Antarctica. Polar Biol 17:431–436

Fordham RA (1970) Mortality and population change of Dominican gull in Wellington, New Zealand. J Anim Ecol 39:13–27

Fraser WR (1989) Aspects of the ecology of kelp gull (*Larus dominicanus*) on Anvers Island, Antarctic Peninsula. PhD Thesis, University of Minneapolis

Hecht T (1987) A guide to the otoliths of Southern Ocean fishes. S Afr J Antarct Res 17:1–87

Ingolfsoon A (1976) Feeding habits of great black-backed gull *Larus marinus* and glaucous gull *L. hyperboreous* in Iceland. Acta Nat. Isl 24:2–19

Irons DB (1987) Diets of glaucous-winged gulls: a comparison of methods for collecting and analysing data. Stud Avian Biol 10:103

Irons DB, Anthony RG, Estes JA (1986) Foraging strategies of glaucous-winged gulls in a rocky intertidal community. Ecology 67:1460–1474

Jablonski B (1986) Distribution, abundance and biomass of a summer community of birds in the region of the Admiralty Bay (King George Island, South Shetland Islands, Antarctica) in 1978/79. Pol Polar Res 7:217–260

Kellermann A (1986) Geographical distribution and abundance of postlarval and juvenile *Pleuragramma antarcticum* (Pisces, Notothenioidei) off the Antarctic Peninsula. Polar Biol 6:111–119

Maxson SJ, Bernstein NP (1984) Breeding season time budgets of the southern black-backed gull in Antarctica. Condor 86:401–409

Reinhardt SB, Van Vleet ES (1986) Lipid composition of twenty-two species of Antarctic midwater zooplankton and fish. Mar Biol 91:149–159

Silva MP (1996) La dieta de la Gaviota Cocinera *Larus dominicanus* en Islas Shetland del Sur, Antártida. Thesis, Universidad Nacional de Mar del Plata

Silva MP, Favero M (1994) *Nacella concinna* como recurso trófico de *Larus dominicanus* en Isla 25 de Mayo (King George Island), Shetland del Sur, Antártida. Acta III Jornadas Comunicaciones cientificas Antárticas. IAA-CONICET, Buenos Aires

Slosarczyk W, Cielniaszek Z (1985) Postlarval and juvenile fish (Pisces, Perciformes and Myctophiformes) in the Antarctic Peninsula during BIOMASS-SIBEX, 1983/1984. Pol Polar Res 6:159–165

Trapp JL (1979) Variations in summer diet of glaucous-winged gulls in the western Aleutian Islands: an ecological interpretation. Wilson Bull 91:412–419

Watson GE (1975) Birds of the Antarctic and Sub-Antarctic. American Geophysical Union, Washington, DC