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Differences between diet of adult and chick Audouin's Gulls *Larus audouinii* at the Chafarinas Islands, SW Mediterranean

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Differences in diet between chicks and adults of Audouin's Gull *Larus audouinii* were examined in the Chafarinas Islands (SW Mediterranean) during the breeding seasons of 1993 and 1994. The major food type for chicks on the Chafarinas Islands were fish, both epipelagic (some of them coming from purse-seine activity) and benthonic (coming from trawler discards), forming a minimum 70% by biomass. The amount of fish fed to young increased with chick age, up to 95% by biomass. Adults also consumed mainly fish (75% by number and 90% by biomass), mostly clupeiforms, Sardina *Sardina pilchardus* and Gilt Sardine *Sardinella aurita*. Terrestrial prey were especially given to youngest chicks, probably because of requirements to increase the feeding rates of these chicks. Shorter foraging trips to the near Moroccan coast to feed on terrestrial prey (chiefly arthropods and isopods) may allow adults especially to guard/brood small chicks, and eventually to increase the feeding rates. Feeding rates significantly decreased with brood size, and also decreased with chick age, although this effect was not significant. Weight and size of food items fed to chicks increased with chick age, and fledglings were fed with larger items than those consumed by adults. This was probably related to the increase in gape width with chick age, and the trade-off between food load carried to feed chicks and the distance traveled to catch the fish.

1. Introduction

Audouin's Gull *Larus audouinii* is a rare seabird breeding in the Mediterranean region (Cramp & Simmons 1985). Several studies described its diet in the main breeding colonies (Witt et al. 1981, Català et al. 1990, Ruiz et al. 1996), and they show that the species is a nocturnal specialist fishing on clupeiforms. However, the diet of chicks and adults has never been compared. Many dietary studies on Laridae have been published around the world, but few deal with the differences in diet of chicks and adults as these studies used different types of samples for each age class (Spaans 1971, Nogales et al. 1995), resulting in a bias that is difficult to overcome. Differences often appeared between youngest chicks and the other age classes, but these were not always clear (Nogales et al. 1995).

In this study, data on the diet of chick and adult Audouin's Gulls are compared during two breeding seasons. For the first time, comparisons were carried out using the same type of regurgitates, which are the least biased diet sample in many seabird species (Harris & Wanless 1993). Differ-

ences in diet among the age classes were assessed at both taxonomic and type levels. Size, weight and number of feeds per nest and day were also analyzed in relation to chick age.

2. Study colony and methods

Field work was carried out at the Chafarinas Islands (Melilla, Spain: 35°11′N, 3°46′35″E), during the breeding seasons of 1993 and 1994. The archipelago holds the second largest colony of Audouin's Gull in the world, with ca. 4 000 pairs in 1994.

Regurgitates produced by chicks in the presence of the researcher were collected every three days. Chicks were aged using tarsus length (unpublished data). As it is not possible during the chick rearing period to distinguish if regurgitates from adult gulls were intended to feed chicks or to be consumed by the adults themselves, data from adult gulls were collected from adults caught on eggs at the end of the incubation period. Since Audouin's Gulls have a high synchronous breeding season (Oro et al. 1996), we assume that in this short period of time (from late-incubation to fledglings, max. 5 weeks), food type availability did not greatly vary around the colony, and results were not influenced by prey seasonal variation (see also Ruiz et al. 1996). Five age classes were considered: chicks from 1 to 10 days, 11 to 20, 21 to 30, and more than 30 days, and adult gulls. Regurgitates were frozen and later identified in the laboratory. Fish otoliths and scales were used for identification when prey were partially digested.

Each item was assigned to a taxonomic group and a type (benthic, epipelagic, terrestrial or others). Epipelagic prey are fish (mainly clupeiforms) and sepioida, while benthic are also fish but include other prey such as decapoda. Types were based on prey locomotive characteristics, which might determine different hunting behaviour, predation effort or foraging habitat: "terrestrial" includes arthropods such as ortoptera, himenoptera and isopoda; "others" category includes indeterminate fish, garbage from refuse tips and fruits and seeds (see Table 1); the rest are "epipelagic", which includes fish that can be caught by the gulls on the sea surface by themselves or taking advantage of the purse-seine activity, and "benthic", which includes prey only available from trawler discards. The following diet descriptors were used for every age class: numerical percentage (%N), percentage of occurrence (%P) and percentage of dry biomass (%B), both at the taxonomic and type levels. Diet diversities (Brillouin Index, Pielou 1975) at levels of individuals and population were calculated, and a jacknife procedure was used to obtain the confidence limits of the diversity in-

Table 1. Diet parameters of Audouin's Gull at Chafarinas Islands by different age classes and at the taxonomic level. N = number of food items (number of regurgitates); Type = type categorization (E = Epipelagic, B = Benthic, T = Terrestrial, O = Others); %N = numerical percentage; %P = percentage of occurrence; %B = percentage of dry biomass.

		Chicks 1–10 days n = 89 (48)			Chicks 11–20 days n = 60 (35)			Chicks 21–30 days n = 201 (98)			Chicks > 30 days n = 115 (61)			ADULTS n = 43 (21)		
ORDERS	Type	%N	%P	%B	%N	%P	%B	%N	%P	%B	%N	%P	%B	%N	%P	%B
Clupeiforms	E	20.22	37.50	34.06	28.33	42.86	37.81	28.86	43.88	51.10	23.48	40.98	34.28	41.86	47.62	70.21
Perciforms	B/E	7.87	14.58	7.40	30.00	40.00	37.78	27.86	39.80	24.58	32.17	40.98	43.05	32.56	38.10	15.04
Anguiliforms	B	2.25	4.17	4.16	–	–	–	5.47	11.22	3.30	8.70	9.84	6.96	2.33	4.76	0.19
Gadiforms	B	2.25	4.17	5.04	10.00	5.71	13.15	8.46	10.20	13.29	6.09	9.84	5.61	–	–	–
Ateriniforms	B	7.87	2.08	20.08	1.67	2.86	2.52	1.00	1.02	0.29	–	–	–	2.33	4.76	2.58
Ceiforms	B	–	–	–	1.67	2.86	0.74	2.99	2.04	0.44	1.74	3.28	0.40	–	–	–
Gasterosteiforms	B	–	–	–	–	–	–	0.50	1.02	0.12	–	–	–	–	–	–
Indeterminated Fish	O	10.11	18.75	18.79	6.67	11.43	5.54	2.49	5.10	1.51	6.96	13.11	4.93	4.65	9.52	5.16
Sepioida	E	1.12	2.08	0.55	–	8.57	–	5.47	7.14	3.40	18.26	9.84	4.61	2.33	4.76	0.73
Orthoptera	T	32.58	18.75	5.52	18.33	2.86	2.24	15.42	5.10	0.35	2.61	4.92	0.16	11.63	9.52	0.76
Isopoda	T	15.73	2.08	4.40	1.67	–	0.09	–	–	–	–	–	–	–	–	–
Decapoda	B	–	–	–	–	–	–	0.50	1.02	–	–	–	–	–	–	–
Himenoptera	T	–	–	–	–	–	–	0.50	1.02	–	–	–	–	–	–	–
Organic Garbage	O	–	–	–	–	–	–	0.50	1.02	1.64	–	–	–	2.33	4.76	5.32
Fruits and Seeds	O	–	–	–	1.67	2.86	0.13	–	–	–	–	–	–	–	–	–

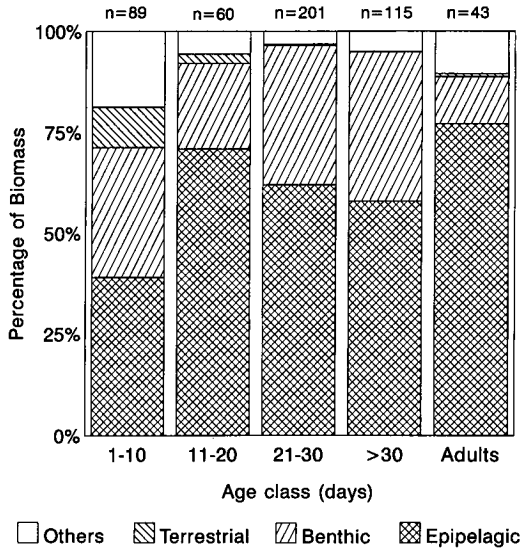

Fig. 1. Percentage of biomass consumed by age class at tipologic level at the Chafarinas Islands. N = number of prey items.

dex (Krebs 1989). The likelihood ratio G-test for contingency tables was used to assess differences among diets of age classes, and differences were analyzed looking at the adjusted standardized residuals (Zar 1984).

Length and dry weight (65°C) were measured for every prey or piece of prey when undigested. Differences in length and dry biomass among age classes were analyzed by the Kruskall-Wallis test.

Feeding rates were recorded by direct observation. Observations were conducted during the 1994 breeding season from a blind in front of 20 marked nests. Two observers made changeovers every 3 h, from 07.00 h to 21.00 h. Total observation time was 221 h. Results are presented as number of feedings/nest/day/number of chicks in the brood.

Daily commercial catch statistics of purse-seine fisheries in the area were used to estimate fish availability, and thus, to assess their relationship with the consumption of terrestrial prey. We assumed that when the purse-seine fleet did not operate (they stopped for holidays, poor fishing conditions or bad weather as shown by daily catches), clupeiforms attracted to the surface by the boat lights were then not available, thus fish availability which may be caught by the gulls themselves decreased. The influence of fish availability on the predation of terrestrial preys was assessed by comparing the number of terrestrial and non-terrestrial items (depending on whether the fisheries were active or not) in a contingency table, and a chi-square test was carried out to detect significant differences.

3. Results

We analyzed a total of 263 regurgitates, with 508 food items identified (Table 1). At the taxonomic level, Audouin's Gull fed mainly on clupeiforms (Table 1), especially Sardine *Sardina pilchardus* and Gilt Sardine *Sardinella aurita*, though fish was consumed less by the youngest chicks. Results confirm that the species is a predator specialist on clupeiforms, and corroborate those obtained previously (Witt et al. 1981), although in the northwestern Mediterranean, Anchovies *Engraulis encrasicholus* seem to replace Gilt Sardines (Ruiz et al. 1996). A taxonomic level may correspond to several type levels, depending on the prey species (Table 1)(e.g. perciforms, which includes benthic fish and the Scad *Trachurus trachurus*, a species that belongs to the epipelagic type). Significant differences among the diet of the different age classes were found at both taxonomic and type levels ($G = 120.3$, $df = 24$, $P < 0.0001$; $G = 94.3$, $df = 12$, $P < 0.0001$ respectively, see Table 1 and Fig. 1). Adjusted residuals showed higher than expected feeding rates of sepioida for the > 30 days age class and of orthoptera for the 1–10 days class. In contrast, the > 30 age class consumed fewer than expected orthoptera and the 1–10 days class consumed fewer perciforms.

The presence of terrestrial prey depending on whether the fisheries were active or not (as indicator of clupeiform availability), was not significantly different ($\chi^2 = 0.0$, $df = 1$, $P = 0.98$).

The same trend was found at the type level, and the youngest chicks were fed especially frequently with terrestrial prey, mainly orthoptera and isopoda (Fig. 1). However, fish biomass consumption was much higher than any other prey in all the age classes considered (a minimum of 70% by biomass in the youngest chicks)(Fig. 1). Benthic fish represented ca. 30% by biomass for all chick age classes, whereas adults consumed

lower amounts of benthic fish (only 10%). Arthropoda biomass consumption was higher for younger chicks, whereas sepioida biomass was higher for older chicks and adults.

Prey size and biomass were significantly different (Fig. 2) among age classes (Kruskall-Wallis, $H = 46.1$, $n = 180$, $P < 0.05$ for length; Kruskall-Wallis, $H = 93.9$, $n = 237$, $P < 0.05$ for weight). Prey size increased with the age of chicks.

Population diet diversity decreased with chick age (Table 2). Although the number of food items per regurgitate was similar for each age class, the number of different prey species per regurgitate increased with chick age. Table 3 shows the number of feedings/nest/day/number of chicks in the brood: although the number of feedings decreased with both the age of the chicks and the number of chicks in the brood, only the effect of the number of siblings was significant (for age classes $F = 0.86$, $df = 2$, n.s. and for different brood sizes $F = 20.1$, $df = 1$, $P < 0.0001$ respectively).

4. Discussion

Audouin's Gull at any age consumed mainly fish (a minimum 70% by biomass). Benthic fish came from trawler discards, since Audouin's Gull is known to exploit this food resource (Ruiz et al. 1996). In contrast, epipelagic fish could be actively caught by gulls or were caught by gulls taking advantage of the fish attracted to the surface by the lights of purse-seine boats; both foraging strategies occurred at night (Oro 1995). However, the youngest chicks were also fed with arthropoda and other terrestrial prey (mainly grasshoppers and isopods), whereas fish were less represented. These terrestrial prey were caught along the neighbouring African coast. Several authors also found in other *Larus* species that the youngest chick were often fed with arthropods (Spaans 1971, Kirham & Morris 1979, Fox et al. 1990, Hario 1990, Nogales et al. 1995). Some authors (Jarvis & Southern 1976, Kirham & Morris 1979, Chudzik et al. 1994, Hillström et al. 1994) have related the arthropod consumption with low fish availability, which forced gulls to feed on terrestrial prey. Nevertheless, we found no relationship between the consumption of terrestrial prey and our estimate of the availability of fish around the colony. Thus, the consumption of terrestrial prey by the youngest chicks probably indicates an intrinsic switch of the foraging behavior of the adult gulls (see also Annett & Pierotti 1989). Rejection of food by the chicks (because of its size or composition) could modify the behavior of the parents (Annett & Pierotti 1989).

Some authors (Nogales et al. 1995) considered that invertebrates may provide small but essential quantities of the minerals and vitamins necessary for growth in gull chicks, whereas others (Spaans 1971, Murphy et al. 1984) pointed out that caloric value is generally higher in fish, and chicks fed on fish grew better than those fed on marine invertebrates. Although invertebrates were abundant in the Audouin's Gull chick diet, their importance by biomass was low (maximum 10% by biomass in the youngest chicks). At the same time, population diet diversity decreased with chick age. Nevertheless, adult foraging range may be "time constrained" by the need to brood or guard very young chicks. In fact, the number of feedings per chick by adults depended on the number of chicks in a brood rather than on the age of the chicks. Therefore, it is difficult to determine if the switch of the diet is related to special nutritional requirements during the earliest period of the chick growth or to time constraints. Since samples from adult and chicks were not necessarily collected at the same time in the breeding season, there was no evidence for either hypothesis.

Table 2. Jack-knife diet population diversity (Brillouin Index, Pielou 1975) in Audouin's Gull diet by age class. Mean ± s.e. are given. N = number of regurgitates.

	Chicks 1–10 n = 48	Chicks 11–20 n = 35	Chicks 21–30 n = 98	Chicks > 30 n = 61	ADULTS n = 21
Brillouin diversity	2.95 ± 0.31	2.61 ± 0.23	2.77 ± 0.14	2.56 ± 0.13	2.19 ± 0.25
No. of species/reg.	1.04 ± 0.03	1.20 ± 0.08	1.30 ± 0.07	1.33 ± 0.08	1.24 ± 0.10
No. of items/reg.	1.85 ± 0.39	1.71 ± 0.23	2.05 ± 0.20	1.89 ± 0.22	2.05 ± 0.25

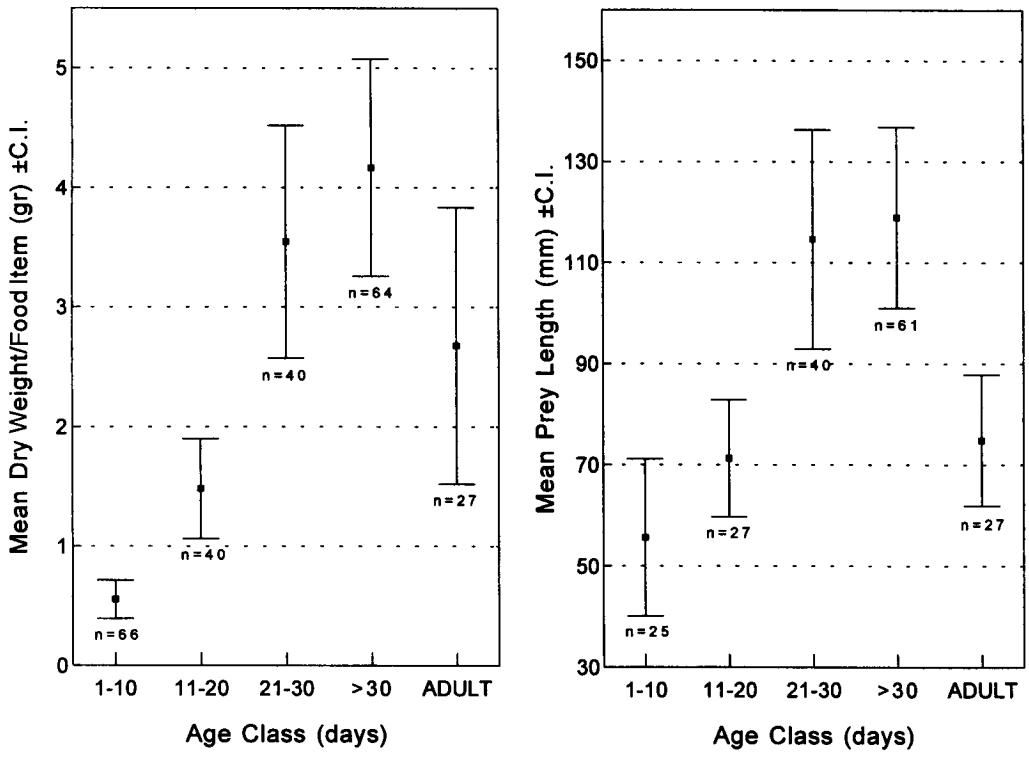

Fig. 2. Mean length and mean dry weight of prey from Audouin's Gull regurgitates by age class at the Chafarinas Islands.

Our results show that while the youngest chicks consumed a similar number of items per regurgitate than the oldest, the size of items increased with chick age (see also Brandl & Nelsen 1988, Nogales et al. 1995). Observations from the blind also showed that adults broke up the prey (especially when chicks were very small), or they regurgitated them when prey were more digested (see also Spaans 1971, Mudge & Ferns 1983). Thus, the small gape width of the smallest chicks may not be the only factor to explain the higher consumption of invertebrates.

Higher feeding rates necessary for youngest chicks may also be involved in their higher consumption of invertebrates (Spaans 1971, Kirham & Morris 1979). These rates may also be related to the higher number of chicks per nest, during the first weeks of the rearing stage (Chudzik et al. 1994). The Audouin's Gull feeding rates were low (Table 2), similar to those recorded in other piscivorous and pelagic seabirds (see revision in Brandl & Nielsen 1988). We found that the youngest chicks were fed at higher rates than older chicks (see similar results in Chudzik et al. 1994), although the significance of the results is only attributed to brood size. Thus, the need to increase

Table 3. Number of feedings (mean ± SD) by adult Audouin's Gulls in different age classes of chicks and in broods of different size.

Number of chicks/brood	Number of feedings	n
Chicks 1–10 days old		
1	3.1 ± 2.4	13
2	4.7 ± 2.0	18
3	5.0 ± 2.0	5
Average	4.2 ± 2.2	36
Chicks 11–20 days old		
1	2.4 ± 1.2	19
2	4.4 ± 2.4	16
Average	3.3 ± 2.1	35
Chicks 21–35 days old		
1	2.1 ± 0.9	15
2	4.0 ± 1.9	5
Average	2.6 ± 1.4	20

the feeding rates of the youngest chicks may be compensated for by shorter foraging trips to the nearer Moroccan coast, instead of searching for fish at longer distances from the colony, as they normally do during the rest of their breeding season. Although this feeding strategy resulted in smaller food items, it probably allows an increase in nest guarding time (Martin 1992), which is necessary because of the higher risk of predation on young chicks (see also Southern & Southern 1984, Velarde 1992).

Although prey size increased with age, fledgling chicks were fed with larger prey than those consumed by adult gulls. This is probably optimal because, when foraging at a distance from the nest site, the adults incur a fixed travel cost in time and energy with each trip back to the nest to feed the young (O'Connor 1984).

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Selostus: Aikuisten ja poikaslintujen ravinnon koostumus Välimerenlokilla

Kirjoittajat tutkivat Välimerenlokin ravintoa lounaisella Välimerellä vuosina 1993 ja 1994. Pääravintona sekä poikasilla että aikuisilla oli kalat (vähintään 70% ravinnon painosta), sekä epipelaagiset, joita lokit hankkivat osittain kalastajien nuottauksen avustamana, että pohjakalalajit, jotka olivat peräisin troolijätteestä. Kalaravinnon osuus kasvoi poikasten ravinnossa aina 95% iän myötä. Aikuisten lintujen tärkeimmät ravintokohteet olivat kaksi sardiinilajia (*Sardina chardus* ja *Sardinella aurita*). Nuoria poikasia ruokittiin tiheästi ja niiden ravinnossa oli enemmän maalta hankkittuja ravintokohteita (niveljalkaisia ja kilkkejä) kuin vanhemmilla poikasilla. Ruokintatiheys laski pesyekoon kasvaessa. Poikasille tarjottujen ravintokohteiden koko suureni ja paino nousi poikasten kasvaessa, ja lentopoikasten ravinto koostui aikuisten ravintoa suuremmista kohteista. Nämä muutokset otaksuttavasti heijastelevat poikasten mahdollisuuksia kasvun myötä niellä yhä suurempia ravintokohteita ja suurempien ravintoerien kantamisen edullisuutta aikuisille ravinnonhankintamatkojen pidentyessä pesinnän edistyessä.

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