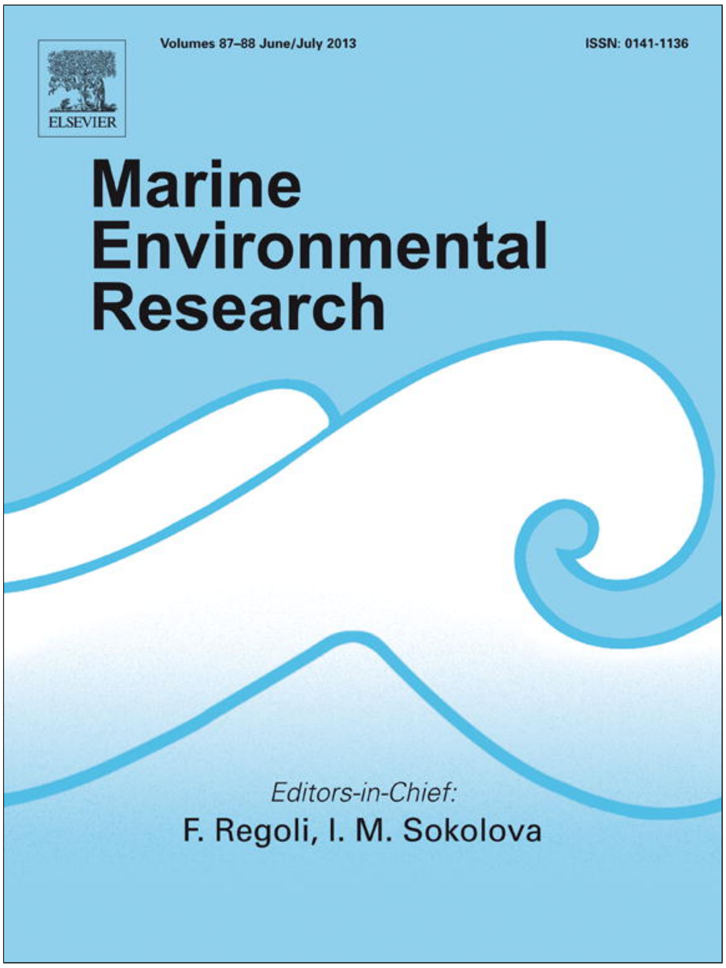

Volumes 87–88 June/July 2013
ISSN: 0141-1136

Marine Environmental Research

Editors-in-Chief:
F. Regoli, I. M. Sokolova

Marine Environmental Research 87-88 (2013) 19–25

Contents lists available at SciVerse ScienceDirect

Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

Trophic ecology of a resident Yellow-legged Gull (*Larus michahellis*) population in the Bay of Biscay

Juan Arizaga[a,*], Lluís Jover[b], Asier Aldalur[a], Juan F. Cuadrado[a], Alfredo Herrero[a], Carola Sanpera[b]

[a] *Department of Ornithology, Aranzadi Sciences Society, Zorroagagaina 11, E-20014 Donostia-S. Sebastián, Spain*
[b] *Department of Animal Biology, Faculty of Biology, University of Barcelona, Avda. Diagonal 643, E-08028 Barcelona, Spain*

ARTICLE INFO

Article history:
Received 12 December 2012
Received in revised form
22 February 2013
Accepted 26 February 2013

Keywords:
Diet
Generalist predator
Gulls
Marine fish prey
Northern Iberia
Refuse tips
Seabirds
Stable isotopes

ABSTRACT

Stable isotopes analyses (SIAs) are an efficient tool to obtain a general insight into the diet of generalist consumers, such as the Yellow-legged Gull (*Larus michahellis*). Here we analysed $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values in feathers of chicks and adults, and used Bayesian triple-isotope mixing models to reconstruct the diet of a Yellow-legged Gull population breeding in the southeastern Bay of Biscay. Questions to test were (1) whether adults and chicks rely on different feeding resources during breeding period; (2) whether there is a seasonal foraging effect involving a higher proportion of refuse food in winter compared to summer, and (3) the magnitude of the annual variation in diet. Prey consumption differed between colonies, among years, and also varied slightly between seasons, and this was mainly due to a differential use of prey of marine origin. However, diet did not differ between age classes. These results suggest a relatively monotonous diet with only slight variations from year to year, seasonally and at a local geographic scale.

1. Introduction

Many large gulls (*Larus* spp.) have experienced a noticeable population increase during recent decades (Olsen and Larson, 2004). With the goal of reducing that population increase or minimizing its consequences (e.g. predation on sympatric seabirds during the breeding period), some gull colonies have been the target of management policies (Smith and Carlile, 1993; Harris and Wanless, 1997; Olijnyk and Brown, 1999; Bosch et al., 2000). However, the management actions undertaken have commonly been revealed to be of doubtful efficacy, in part because such actions address the consequence and not over the causes of the population increase (Bosch et al., 2000). A superabundance of some feeding sources such as refuse tips and fish discards, is among the chief causes explaining this population increase (Bosch et al., 1994; Belant et al., 1998; Bertellotti and Yorio, 1999; Ramos et al., 2006). Thus, identifying the main foraging habitats of a population is critical to understand large gulls' population dynamics (e.g., Oro et al., 1995; Annett and Pierotti, 1999), as well as to design adequate management policies.

The Atlantic coast of Iberia (including the Bay of Biscay) hosts a population of more than 80,000 Yellow-legged Gull (*Larus michahellis*) breeding pairs, as well as a wintering population comprising several gull species, most of which are Yellow-legged Gulls that travel from the Mediterranean (Martínez-Abrain et al., 2002). The Basque Yellow-legged Gull colonies from the southeastern Bay of Biscay have undergone a population increase of 146% between 1980 and 2000 (Arizaga et al., 2009). Refuse tips offer gulls a food source of great energetic value: in some cases such sites have played a very decisive role in driving the population increase observed in a number of gull colonies (Rock, 2005; Duhem et al., 2008). However, the diet of some Yellow-legged Gull colonies from the southeastern Bay of Biscay is reported to depend highly on fish (Arizaga et al., 2011), although this conclusion is derived from studies of regurgitates, that were only collected from chicks. Because this type of sampling reflects food preferences over a short period, it is insufficient for a proper assessment of foraging habits for the entire breeding (in chicks, nestling) season, so additional analyses are required. Furthermore, within a larger geographic scale-level (e.g. the Atlantic coasts of Iberia), studies carried out until now chiefly focused on how chicks' diet varies geographically. By contrast, it is still poorly known how gull diet varies in relation to time (i.e., from year to year or between seasons in a year) and age (e.g., chicks versus adults).

---

* Corresponding author.
E-mail address: jarizaga@aranzadi-zientziak.org (J. Arizaga).

0141-1136/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marenvres.2013.02.016

Stable isotopes have been reported to be useful to identify target prey groups in seabird species (Hobson, 1994), including large gulls (Sanpera et al., 2007; Moreno et al., 2009; Ramos et al., 2009b). Although a stable-isotopes approach (SIA) cannot be used to identify specific prey, it is useful to identify target trophic groups of prey (Hobson, 1994). In opportunistic seabirds that exploit relatively complex food webs, the use of additional isotopic signatures beyond δ^{13}C and δ^{15}N is recommended (Hobson and Welch, 1992). In particular, δ^{34}S has been used to distinguish between terrestrial food and prey of marine origin, and even between prey of marine origin when prey are very diverse (Hobson et al., 1997; Knoff et al., 2002; Moreno et al., 2009). Mixing models constitute and additional step for diet reconstruction, allowing us to link particular isotopic signatures to specific prey groups (for instance see Moreno et al., 2009). Thus, mixing models are useful to obtain the relative contribution of each prey group in a diet.

Using stable isotope values of nitrogen, carbon and sulphur, the main goal of this work was to examine, for the resident Yellow-legged Gull population in the southeastern bay of Biscay, (1) differences in isotopic values and resource consumption among three colonies, (2) temporal variations in foraging behaviour at both the seasonal and annual scales, and (3) differences in isotopic values between adults and chicks to ascertain whether age groups rely on the same or different feeding resources.

(1) Chicks' diet can show geographic variation associated with prey availability (Moreno et al., 2009; Ramos et al., 2009a), this being the reason why Yellow-legged Gull's diet is considered to reliably indicate food abundance at the local scale. There is a lack of knowledge about the cause, or causes of the increase in the Yellow-legged Gull population in the southeastern Bay of Biscay. A priori, the fact that all of the colonies from Gipuzkoa (in the southeastern Bay of Biscay) are situated near harbours with high fishing activity (and, probably, a high amount of fish discards) should be associated with a high intake of marine prey by these colonies compared to other alternative foods such as refuse tips. Nevertheless, waste disposal sites in the area can also constitute a valuable resource.

(2) Another question that has been poorly explored is the temporal changes in foraging behaviour, either from year to year or between seasons (e.g., breeding/winter). Previous analyses in the same area were unable to detect significant differences in the main prey groups consumed by chicks from year to year. However, such results were obtained from a limited number of regurgitates (Arizaga et al., 2011). Assuming that gulls' diet indicate food abundance at a local scale (Moreno et al., 2009; Ramos et al., 2009a), we should expect no change or only slight annual variations in the main type of prey consumed if food availability is rather stable among years. On a seasonal basis, a food shortage during some months should also promote seasonal foraging changes. In northern Iberia, particularly the southeastern Bay of Biscay, fishing activity tends to be lower during late-summer, autumn and even part of the winter, due to bad weather (Fig. 1). Therefore, a higher consumption of refuse tips or other prey types (e.g., terrestrial) is expected if fish availability is limited during this period or when weather conditions prevent foraging on some marine prey. In this case, seasonal variations in the diet may be expected, with lower intake rates of marine prey during winter compared to breeding season.

(3) Adults have been reported to feed chicks with a higher proportion of high quality marine prey, such as fish (Pedrocchi et al., 1996). Therefore, we expect a higher intake of marine prey in chicks compared to adults, who can switch to foraging on refuse tips or other alternative types of prey.

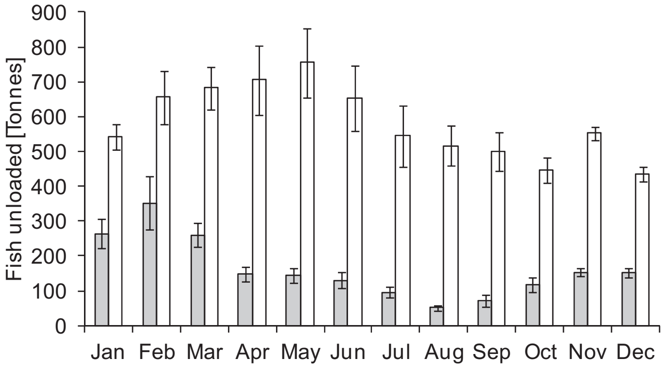

Fig. 1. Mean (±SE) amount of fish unloaded at the Pasaia harbour (Gipuzkoa, Northern Iberia). Years: 2001–2010. Pasaia is one of the main harbours in Gipuzkoa (22% of inshore fishing in 2010) and, therefore, its activity can be considered as representative for the entire region. Bar colours: inshore fishing, open bars; deep-sea fishing, grey bars. Fish discards come primarily from inshore fishing.

No previous studies have simultaneously addressed the spatio-temporal variability in resource consumption, on both a seasonal and yearly scales as well as age-related changes in diet.

2. Materials and methods

2.1. Sampling area and data collection

The study was carried out in three breeding colonies of Yellow-legged Gull in Gipuzkoa (Northern Iberia): Ulia (43°20′N 01°57′W), Santa Clara (43°19′N 01°59′W) and Guetaria (43°18′N 02°12′W) (Fig. 2). All colonies were situated within a distance of 25 km along the coast. Colony sizes were approximately 520, 85 and 92 adult breeding pairs, respectively (Arizaga et al., 2009), accounting for the 92% of the Yellow-legged Gull breeding population from Gipuzkoa, and ca. 15% from the southeastern Bay of Biscay (Arizaga et al., 2009).

During the breeding period of 2007–2010, we collected feather samples from both chicks and adults, in the latter case only from the Ulia colony (Table 1). Mantle feathers from chicks were taken from the back zone (ca. 4 feathers/individual) when they were ca. 20 days of age. Simultaneously, the chicks were ringed (for details see Arizaga et al., 2010) and we recorded body mass (±10 g) and tarsus length (±0.1 mm). When available, freshly regurgitated pellets from chicks (hereafter, regurgitates) were also collected ($n = 18$). Fresh individual prey items from regurgitates were used to obtain prey isotopic signatures (Moreno et al., 2009; Ramos et al., 2009b).

Adults were captured with a spring trap placed in the nest during incubating (breeding period of 2008–2010). Two feathers were taken from each adult bird: P1 (the innermost primary feather, grown at the end of the breeding period so that it contains isotopic signatures of breeding diet), and S6 (the sixth secondary, numbered from outermost to innermost, formed during the winter so that it contains isotopic signatures of winter diet) (Cramp and Simmons, 1983; Olsen and Larson, 2004). The P1 feathers sampled in this study were old feathers from a previous year, so they provided values on diet from the previous breeding period. The Yellow-legged Gull within the Bay of Biscay, and in our sampling area in particular, is resident (Munilla, 1997), so both P1 and S6 are expected to grow within the same geographic area.

To obtain clues about the seasonal and annual fluctuations in fish availability, data on fish discards were obtained at one of the main fishing harbours in the area (Pasaia) (Fig. 2). We differentiated between inshore and deep-sea fishing, as most discards come from inshore fishing.

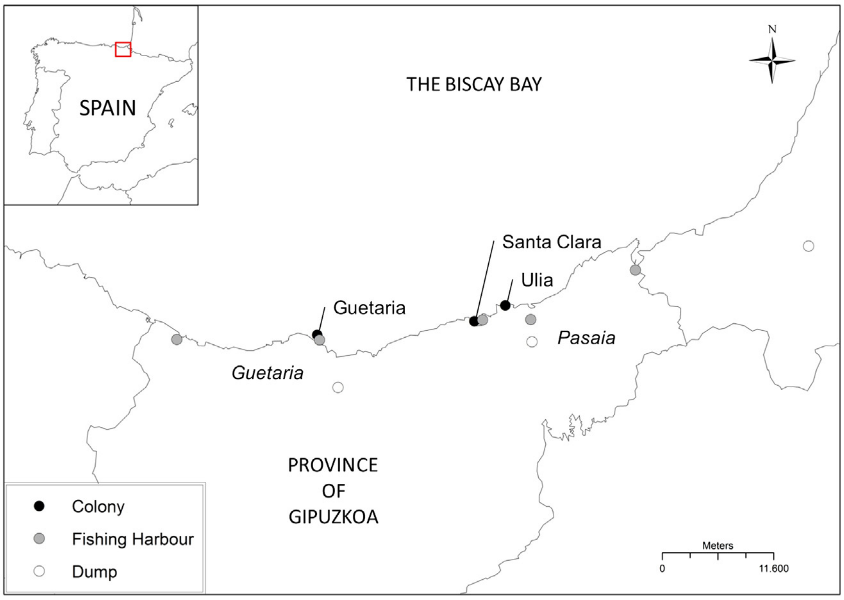

Fig. 2. Location of the Yellow-legged Gull colonies where the study was carried out, in Gipuzkoa, northern Iberia. We also indicate the location of the harbours and dumps known to be used by local gulls. Two main fishing harbours have been indicated (letters in italics).

2.2. Stable isotope analyses and mixing models

Stable isotopes of three elements were analysed: $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$. $\delta^{15}N$ values relate to trophic level because predator tissues are enriched in the heavier $\delta^{15}N$ isotope compared to prey. $\delta^{13}C$ and $\delta^{34}S$ allowed discrimination between prey of terrestrial and marine origin, higher values corresponding to marine prey (Hobson, 1993, 1994). The inclusion of $\delta^{34}S$ also improves the discrimination power of mixing models, as it allows a better estimation of resource contribution, especially when marine prey are very diverse (Moreno et al., 2009).

Feathers were washed once by rinsing in a solution of Na(OH) (1 M), dried (60 °C) and stored in polyethylene bags until they were analysed. Thereafter, both feathers and prey items were homogenised into a fine powder with an impactor mill (Freezer/mill 6750-Spex Certiprep) that operates at ca. −200 °C. Only in order to analyse $\delta^{13}C$, an aliquot of each prey sample was lipid extracted following Folch et al.'s (1957) protocol in order to minimise $\delta^{13}C$ variability due to the differences in lipid content among individual items.

Table 1
Isotopic signatures (mean ± 95% CI) of chicks and adults of a Yellow-legged Gull population from the Bay of Biscay. Year refers to the year when the bird was captured and the feather samples collected.

	Sampling year	Sample size	$\delta^{13}C$	$\delta^{15}N$	$\delta^{34}S$
Chicks[a]					
Ulia	2007	33	−18.4 ± 0.3	13.0 ± 0.2	14.0 ± 0.6
	2008	26	−18.6 ± 0.3	12.4 ± 0.3	13.3 ± 0.6
	2009	27	−19.1 ± 0.3	12.1 ± 0.3	13.6 ± 0.6
Santa Clara	2007	20	−18.5 ± 0.4	12.8 ± 0.3	14.5 ± 0.8
	2008	16	−19.2 ± 0.4	11.5 ± 0.4	12.6 ± 1.0
	2009	14	−19.6 ± 0.4	11.6 ± 0.3	13.1 ± 0.9
Guetaria	2007	6	−17.9 ± 0.4	13.2 ± 0.4	16.4 ± 0.9
	2008	20	−18.6 ± 0.3	12.0 ± 0.3	14.2 ± 0.7
	2009	10	−18.6 ± 0.5	12.4 ± 0.4	15.9 ± 0.7
Adults[b]					
P1 (breeding diet)	2008	6	−19.0 ± 0.6	12.0 ± 0.4	13.7 ± 2.3
	2009	20	−18.7 ± 0.4	12.4 ± 0.4	14.4 ± 1.1
	2010	10	−18.7 ± 0.5	12.6 ± 0.5	14.2 ± 1.6
S6 (winter diet)	2008	6	−18.8 ± 0.3	12.1 ± 0.3	15.5 ± 1.1
	2009	20	−19.0 ± 0.5	12.4 ± 0.6	14.7 ± 1.6
	2010	10	−18.0 ± 0.6	11.9 ± 0.5	17.3 ± 1.8

[a] Feathers (ca. 4/bird) obtained from the back zone. In case of ≥2 chicks in a nest, feathers were taken from only one individual in order to avoid pseudo-replication.
[b] Feathers obtained from a single colony (Ulia).

Weighed sub-samples of powdered feathers and prey (ca. 0.36 mg for $\delta^{13}C$ and $\delta^{15}N$; 3.60 mg for $\delta^{34}S$) were placed into tin capsules for combustion. Isotopic analyses were conducted by elemental analysis-isotope ratio mass spectrometry (EA-IRMS) with a ThermoFinnigan Flash 1112 (for N and C)/1108 (for S) analyser coupled to a Delta isotope ratio mass spectrometer via a ConFlo III interface.

The stable isotopes values were calculated as $\delta X = [(R_{\mathrm{sample}}/R_{\mathrm{standard}})-1] \times 1000$, where X is ^{15}N, ^{13}C or ^{34}S and R the ratio $^{15}N/^{14}N$, $^{13}C/^{12}C$ or $^{34}S/^{32}S$. The standard values for the isotopic ratios of N, C and S are the atmospheric Nitrogen (AIR), Vienna PeeDee Belemnite (VPDB) and the Vienna Canyon Diablo Troilite (VCDT), respectively. International standards (IAEA) were inserted every 12 samples to calibrate the system and compensate for any drift over time. The accuracy was within $\leq 0.1‰$ for the $\delta^{13}C$ measurements, $\leq -0.3‰$ for $\delta^{15}N$ and $\leq 0.3‰$ for $\delta^{34}S$. In reference to elemental concentration, the mean coefficient of variation of repeated samples were 1.4% for nitrogen, 1.1% for carbon and 0.4% for sulphur.

Analyses were carried out at the Serveis Científico-Tècnics, University of Barcelona. The accuracy of stable isotopes ratios measures was 0.1% for carbon and 0.3% for nitrogen and sulphur.

2.3. Statistical analyses

Isotopic values were visualised using quantile–quantile plots to assess if they were normally distributed. As normality was confirmed, parametric statistics were used for data analysis. To test for the effect of the locality and year on stable isotopes values we used the data from chicks, as adults were captured in only one of the colonies (Ulia). Thus, we used two-way ANOVA analysis on each variable ($\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$) with the locality and year as factors.

To test whether prey consumption varied between chicks and adults, we compared the isotopic values of chick and adult feathers grown during a same breeding season (2007, 2008 and 2009): back feathers for chicks and P1 for adults. However, since P1 grows at the end of the breeding season, we collected it during the following breeding season (2008, 2009 and 2010). We used two-way ANOVA analyses with age and season (year) as factors. SNK procedures were used to test for an *a posteriori* pairwise comparison when needed. To detect differences in isotopic values between winter and breeding seasons paired *t*-test on S8 and P1 were conducted.

Diet of chicks can change with age, so chicks' age is thus a factor to be considered (Ramos et al., 2009a). In our samples, however, none of the isotopes analysed were correlated to tarsus length, which could be used as a proxy of chicks' age (δ^{13}C: $r = 0.03$, $p = 0.66$; δ^{15}N: $r = -0.05$, $p = 0.50$; δ^{34}S: $r = -0.06$, $p = 0.44$). Therefore, we did not consider chicks' age in the stable-isotopes analyses.

To interpret isotopic differences, we performed a diet reconstruction using the three isotopes. To estimate the relative contribution of different food resources (marine, terrestrial, refuse), we used a Bayesian stable-isotopes mixing model (SIAR; Parnell et al., 2008) including a non informative Dirichlet prior distribution ($\alpha_i = 1/3$). SIAR was run using its default values for MCMC estimation (chain length = 2×10^5, burning = 5×10^4, thinning = 15), consequently, the distributions of source contributions are based on 10^5 estimations and are presented as Bayesian 95% credibility intervals. The mean isotopic values for the three types of food categories (sources) considered are shown in Table 2. We used the following isotopic discrimination values from the literature: +5.0, +2.2 and +1.3‰ for δ^{15}N, δ^{13}C and δ^{34}S, respectively, for refuse, +4.0, +2.7 and +1.3‰ for terrestrial (Peterson et al., 1985; Bearhop et al., 2002; Hobson and Bairlein, 2003), and +3.0, +0.9 and +1.9‰ (Hobson and Clark, 1992; Ramos et al., 2009a) for fish. A constant value of 0.1 was used as standard deviation to include uncertainty in all mean isotopic discrimination values.

Statistical analyses were performed using PASW Statistics 18.0 and R 2.14 (R Development Core Team, 2011).

3. Results

Focussing on chicks' feathers, univariate models (ANOVAs) revealed variations for all the isotopes analysed in relation to the locality and year without interaction between the two factors. Carbon signatures (for details see Table 1) were found to be lower in Santa Clara than in the other two colonies and differed among years (δ^{13}C: colony, $F_{2,163} = 8.7$, $p < 0.001$; year, $F_{2,163} = 11.1$, $p < 0.001$; colony × year, $F_{4,163} = 1.1$, $p = 0.36$; Fig. 3). Nitrogen signatures (Table 1) increased from Santa Clara to Ulia (Guetaria was intermediate and did not differ in relation to the other two colonies), and were higher in 2007 (δ^{15}N: colony, $F_{2,163} = 9.8$, $p < 0.001$; year, $F_{2,163} = 28.1$, $p < 0.001$; colony × year, $F_{4,163} = 2.2$, $p = 0.07$; Fig. 3). Sulphur signatures (Table 1) were higher in Guetaria and differed among years (with intermediate values in 2009) (δ^{34}S: colony, $F_{2,163} = 17.2$, $p < 0.001$; year, $F_{2,163} = 11.2$, $p < 0.001$; colony × year, $F_{4,163} = 1.8$, $p = 0.13$; Fig. 3).

Table 2
Isotopic signatures (mean ± 95% CI) of different food resources obtained from regurgitates of chicks.

Prey category	*n*	δ^{13}C	δ^{15}N	δ^{34}S
Terrestrial[a]	5	−23.84 ± 2.90	8.86 ± 2.82	7.98 ± 4.41
Refuse tips[b]	3	−21.12 ± 1.17	4.35 ± 1.88	8.09 ± 2.48
Marine fish[c]	8	−18.04 ± 0.65	11.14 ± 1.87	17.99 ± 2.07

[a] Includes annelids (earthworms), mollusks (family *Arionidae*).

[b] Pork, beef or chicken.

[c] Includes fish prey from families *Carangidae*, *Clupeidae* (pelagic), *Sparidae*, *Trachinidae*, and *Gadidae* (benthic).

Stable isotopes analyses showed higher δ^{15}N and δ^{34}S signatures as well as lower δ^{13}C values for marine prey (fish) compared to other prey items (Table 2). Globally, mixing models (Fig. 4) revealed a higher intake of marine prey in 2007 (>40%) and in the colony of Guetaria (always >40%).

When comparing chicks and adults within the Ulia colony, we did not find differences between age classes nor among years (all *F* values associated with a $p > 0.05$) except for the δ^{15}N (age: $F_{1,138} = 0.7$, $p = 0.39$; year: $F_{2,138} = 0.2$, $p = 0.83$; interaction: $F_{2,138} = 5.6$, $p = 0.01$). A more detailed analysis revealed that nitrogen signatures differed among years for chicks but not for adults (for details see Table 1).

The isotopic signatures of adults did not differ between seasons except for the δ^{34}S (δ^{15}N: $t = 1.14$, $p = 0.26$; δ^{13}C: $t = 0.15$, $p = 0.88$; δ^{34}S: $t = 2.06$, $p = 0.04$; $n = 36$; for values see Table 1). δ^{34}S values were marginally higher in winter (15.38 ± 1.11) than during the breeding period (14.23 ± 0.82) suggesting a change in diet. Using SIAR model we found that the proportions of terrestrial, marine and refuse resources were 7.2%, 43.5% and 49.3% during the winter, whereas during the summer they shift to 15.0%, 42.7% and 42.3%, respectively. Additionally, we detected that the isotopic signatures of feathers formed during the breeding and winter were positively correlated (δ^{15}N: $r = 0.54$, $p = 0.001$; δ^{13}C: $r = 0.38$, $p = 0.02$; δ^{34}S: $r = 0.38$, $p = 0.02$; $n = 36$).

4. Discussion

Three stable isotopes (δ^{13}C, δ^{15}N and δ^{34}S) were used to assess the diet of a Yellow-legged Gull population from the Bay of Biscay and its variation according to locality, year, season within a year and gull age. Overall, significant differences were obtained in relation to the locality and year in chicks (for details see Fig. 3), but not between age classes (chicks/adults). Differences between seasons (breeding/winter), tested in adults, were significant for only one of the isotopes (δ^{34}S), with a slightly higher intake of marine prey in winter compared to the summer period.

The isotopic signatures of Yellow-legged Gull chicks differed among colonies, although the difference was slight. In particular, we only detected clear-cut differences among colonies for δ^{34}S (Guetaria having higher values), this indicating that chicks from Guetaria were fed with a higher proportion of marine prey compared to the other two colonies. This result highlights that the diet can differ even at a local level, since distance from the Guetaria to the Santa Clara colony (the nearest sampled one) is only 15 km, underlining a decisive role of certain feeding sources at a small geographic scale. Moreover, these results agree with what has been reported in other areas in Iberia (Ramos et al., 2006; Moreno et al., 2009), i.e., that chicks are fed primarily with fish. The higher proportion of marine prey in Guetaria may be due to its location. Guetaria is the main harbour in the region of Gipuzkoa (46% of inshore fishing in 2010; source: Basque Government, www.euskadi.net). This activity may have had a beneficial effect for this new colony (Arizaga et al., 2009), which is still experiencing a noticeable annual increase (A. Aldalur, obs. pers.). Its dependence on marine prey, most likely consisting mainly of demersal fish from discards (Arizaga et al., 2011), suggests that fish management offshore and/or at harbours is crucial for the population dynamics of opportunistic seabird species, such as the Yellow-legged Gull.

In chicks, result from SIAR showed that in 2007 the diet was richer in marine prey than in subsequent years, particularly in the Guetaria colony. Causes underlying this result are, however, unknown to us. In 2007, the higher intake of marine prey by chicks may have been related to the also higher availability of this resource during that year. Effectively, more fish were landed in the Pasaia

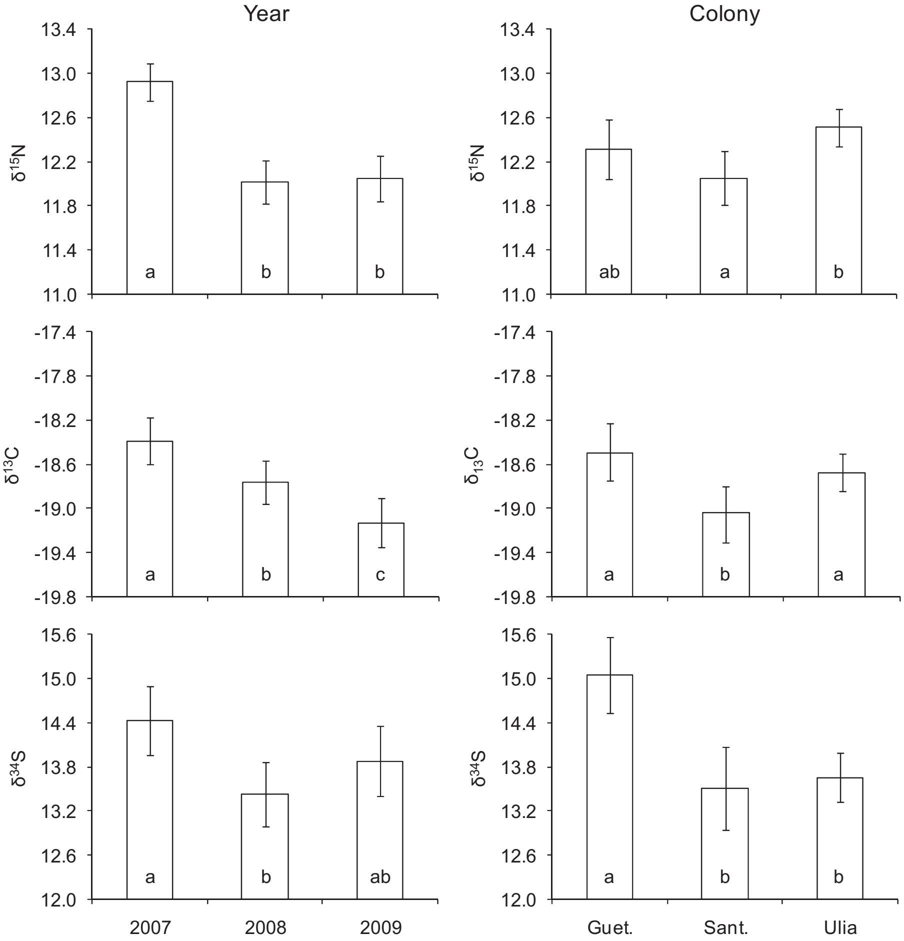

Fig. 3. Mean (95% CI) stable isotopes signatures of feathers obtained from Yellow-legged Gull chicks during the breeding period of 2007–2009, in three study colonies situated in the southeastern Bay of Biscay (from west to east: Guetaria, Santa Clara, Ulia). Groups with the same letters indicate no significant differences. For sample sizes see Table 1.

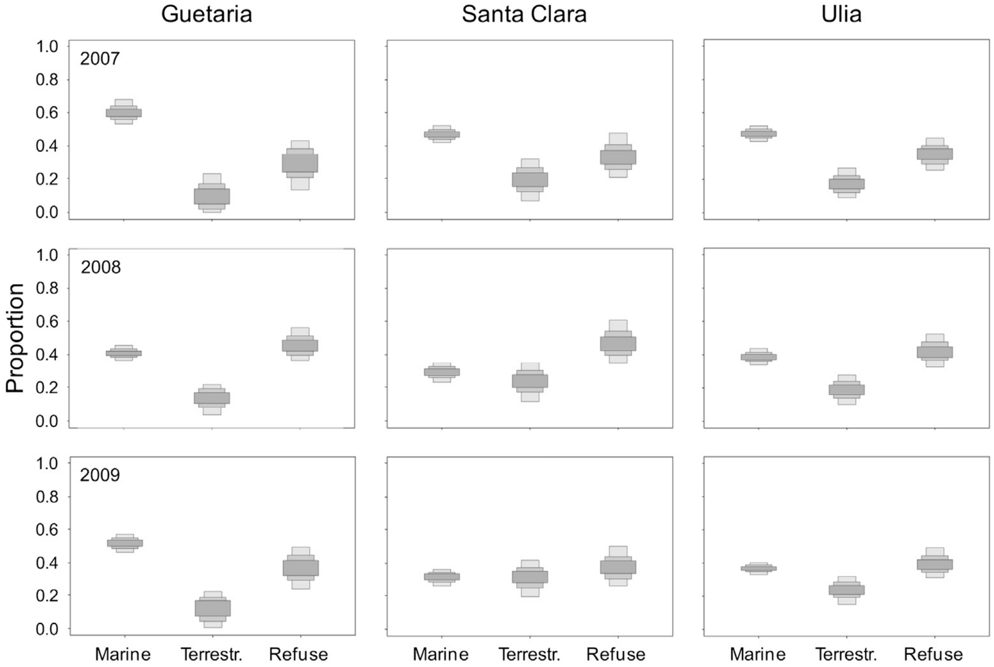

Fig. 4. SIAR (±95, 75 and 50% credibility intervals) results showing prey type contribution to chicks' diet in each year and colony. In marine prey, pelagic and benthic fish have been merged due to the lack of differences in their isotopic means.

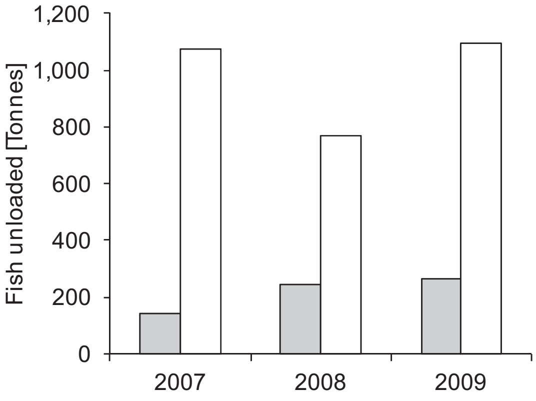

Fig. 5. Amount of fish unloaded at the Pasaia harbour (Gipuzkoa, Northern Iberia) during the months when chicks were reared by adults in the colonies (May and June). Bar colours: inshore fishing, open bars; deep-sea fishing, grey bars. Fish discards come primarily from inshore fishing.

harbour in 2007 than in 2008, but not more than in 2009 (Fig. 5). The lack of a direct relationship between fish consumption by gulls and the amount of fish landed at the harbour denotes some gaps in the use of offloaded fish as a reliable indicator of available quantity of discarded fish.

Interestingly, the fact that the primary dump in the area was closed by the end of 2008 did not seem to have any detectable effect on chicks' diet. Gulls were reported to appear at other nearby dumps (less than 50 km from each colony) as soon as the main dump was closed (A. Aldalur and A. Herrero, pers. obs.). This result highlights that regional management policies are required to prevent gulls from accessing to refuse tips or, overall, certain key sources of food.

Representing a proportion of 20–40% of assimilated biomass, refuse appeared to be more important than was observed for the Atlantic colonies of Northwestern Iberia (Moreno et al., 2009). Accordingly, refuse tips could play a significant role for the survival and productivity of the Yellow-legged Gull population within the southeastern Bay of Biscay. This is an aspect to be tested in future studies.

The isotopic values of chicks and adults during the breeding period were similar. This contrasts with other studies where chicks have been reported to be fed by a higher proportion of high-quality marine prey (Moreno et al., 2009). Since refuse tips availability does not vary seasonally, a sufficiently high amount of fish during breeding period might allow adult birds to maintain a diet as rich in marine prey as that provided to chicks.

In adults, isotopic values were observed to differ slightly between seasons, with higher values of δ^{34}S during winter. The resource percentage estimation from SIAR indicated a noticeable decrease in the use of terrestrial food during the winter, which was compensated for by proportional increase in usage of marine and refuse resources.

The isotopic signatures of feathers moulted during the breeding and winter periods were positively correlated. This suggests either individual foraging specialisation in resource exploitation or a marked individual effect on isotopic fingerprinting mediated by the individual's physiological status, a result that has also been reported for other gull populations (Moreno et al., 2009).

In conclusion, the diet of Yellow-legged Gull chicks from the southeastern Bay of Biscay differed slightly among colonies and years, primarily due to the differential use of marine prey. However, chicks' diet was rather homogeneous across colonies, relying chiefly on marine fish as well as refuse tips; the use of terrestrial prey was observed to be complementary. Isotopic signatures did not differ between age classes (chicks/adults), and in adults we found a small difference between seasons (breeding/winter).

Acknowledgements

To the people who collaborated to collect feather samples, especially to members of the Txingudi Ringing Station (Aranzadi), and those who assisted with the isotopic analyses (R. Moreno, R. Ramos). This research was funded by the Basque Government and the Gipuzkoa Administration. The Gipuzkoa Administration authorised sample collection. I. Munilla provided valuable comments that helped to improve an earlier version of this work.

References

Annett, C.A., Pierotti, R., 1999. Long-term reproductive output in Western Gulls: consequences of alternate tactics in diet choice. Ecology 80, 288–297.

Arizaga, J., Aldalur, A., Herrero, A., Cuadrado, J.F., Mendiburu, A., Sanpera, C., 2011. High importance of fish prey in diet of Yellow-legged Gull *Larus michahellis* chicks from the southeast Bay of Biscay. Seabird 23, 1–6.

Arizaga, J., Galarza, A., Herrero, A., Hidalgo, J., Aldalur, A., 2009. Distribución y tamaño de la población de la Gaviota Patiamarilla *Larus michahellis lusitanius* en el País Vasco: tres décadas de estudio. Revista Catalana d'Ornitologia 25, 32–42.

Arizaga, J., Herrero, A., Galarza, A., Hidalgo, J., Aldalur, A., Cuadrado, J.F., Ocio, G., 2010. First-year movements of Yellow-legged Gull (*Larus michahellis lusitanius*) from the southeastern Bay of Biscay. Waterbirds 33, 444–450.

Bearhop, S., Waldron, S., Votier, S.C., Furness, R.W., 2002. Factors that influence assimilation rates and fractionation of nitrogen and carbon stable isotopes in avian blood and feathers. Physiological and Biochemical Zoology 75, 451–458.

Belant, J.L., Ickes, S.K., Seamans, T.W., 1998. Importance of landfills to urban-nesting herring and ring-billed gulls. Landscape and Urban Planning 43, 11–19.

Bertellotti, M., Yorio, P., 1999. Spatial and temporal patterns in the diet of the Kelp Gull in Patagonia. Condor 101, 790–798.

Bosch, M., Oro, D., Cantos, F.J., Zabala, M., 2000. Short-term effects of culling on the ecology and population dynamics of the yellow-legged gull. Journal of Applied Ecology 37, 369–385.

Bosch, M., Oro, D., Ruiz, X., 1994. Dependence of yellow-legged gulls (*Larus cachinnans*) on food from human activity in two Western Mediterranean colonies. Avocetta 18, 135–139.

Cramp, S., Simmons, K.E.L., 1983. Handbook of the Birds of Europe, the Middle East and North Africa, vol. 3. Oxford University Press, Oxford.

Duhem, C., Roche, P., Vidal, E., Tatoni, T., 2008. Effects of anthropogenic food resources on yellow-legged gull colony size on Mediterranean islands. Population Ecology 50, 91–100.

Folch, J., Less, M., Stanley, G.H.S., 1957. A simple method for the isolation and purification of total lipids from animal tissues. Journal of Biological Chemistry 226, 497–509.

Harris, M.P., Wanless, S., 1997. The effect of removing large numbers of gulls *Larus* spp. on an island population of oystercatchers *Haematopus ostralegus*: implications for management. Biological Conservation 82, 167–171.

Hobson, K.A., 1993. Trophic relationships among high arctic seabirds: insights from tissue-dependent stable-isotope models. Marine Ecology-Progress Series 95, 7–18.

Hobson, K.A., 1994. Using stable isotopes to determine seabird trophic relationships. Journal of Animal Ecology 63, 786–798.

Hobson, K.A., Bairlein, F., 2003. Isotopic fractionation and turnover in captive Garden Warblers (*Sylvia borin*): implications for delineating dietary and migratory associations in wild passerines. Canadian Journal of Zoology-Revue Canadienne De Zoologie 81, 1630–1635.

Hobson, K.A., Clark, R.G., 1992. Assessing avian diets using stable isotopes. II: factors influencing diet-tissue fractionation. Condor 94, 189–197.

Hobson, K.A., Hughes, K.D., Ewins, P.J., 1997. Using stable-isotope analysis to identify endogenous and exogenous sources of nutrients in eggs of migratory birds: applications to Great Lakes contaminants research. Auk 114, 467–478.

Hobson, K.A., Welch, H.E., 1992. Determination of trophic relationships within a high Arctic marine food web using delta-13C and delta-15N analysis. Marine Ecology-Progress Series 84, 9–18.

Knoff, A.J., Macko, S.A., Erwin, R.M., Brown, K.M., 2002. Stable isotope analysis of temporal variation in the diets of pre-fledged Laughing Gulls. Waterbirds 25, 142–148.

Martínez-Abrain, A., Oro, D., Carda, J., Del Señor, X., 2002. Movements of Yellow-Ledged Gulls *Larus [cachinnans] michahellis* from two small western Mediterranean colonies. Atlantic Seabirds 4, 101–108.

Moreno, R., Jover, L., Munilla, I., Velando, A., Sanpera, C., 2009. A three-isotope approach to disentangling the diet of a generalist consumer: the yellow-legged gull in northwest Spain. Marine Biology 157, 545–553.

Munilla, I., 1997. Desplazamientos de la Gaviota Patiamarilla (*Larus cachinnans*) en poblaciones del norte de la Península Ibérica. Ardeola 44, 19–26.

Olijnyk, C.G., Brown, K.M., 1999. Results of a seven year effort to reduce nesting by Herring and Great Black-backed Gulls. Waterbirds 22, 285–289.

Olsen, K.M., Larson, H., 2004. Gulls of Europe, Asia and North America. Christopher Helm, London.

Oro, D., Bosch, M., Ruiz, X., 1995. Effects of a trawling moratorium on the breeding success of the Yellow-legged Gull *Larus cachinnans*. Ibis 137, 547–549.

Parnell, A., Inger, R., Bearhop, S., Jackson, A.L., 2008. SIAR: Stable Isotope Analysis in R. http://cran.r-project.org/web/packages/siar/index.html.

Pedrocchi, V., Oro, D., González-Solis, J., 1996. Differences between diet of adult and chick Audouin's gulls *Larus audouinii* at the Chafarinas Islands, SW Mediterranean. Ornis Fennica 73, 124–130.

Peterson, B.J., Howarth, R.W., Garritt, R.H., 1985. Multiple stable isotopes used to trace the flow of organic matter in estuarine foodwebs. Science 227, 1361–1363.

R Development Core Team, 2011. R: a Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0. URL: http://www.R-project.org/.

Ramos, R., Ramirez, F., Sanpera, C., Jover, L., Ruiz, X., 2009a. Diet of Yellow-legged Gull (*Larus michahellis*) chicks along the Spanish Western Mediterranean coast: the relevance of refuse dumps. Journal of Ornithology 150, 265–272.

Ramos, R., Ramirez, F., Sanpera, C., Jover, L., Ruiz, X., 2009b. Feeding ecology of yellow-legged gulls *Larus michahellis* in the western Mediterranean: a comparative assessment using conventional and isotopic methods. Marine Ecology-Progress Series 377, 289–297.

Ramos, R., Ramirez, F.J., Sanpera, C., de Jover, L., Ruiz, X., 2006. Feeding ecology of Yellow-legged Gulls in four colonies along the western Mediterranean: an isotopic approach. Journal of Ornithology 147, 235–236.

Rock, P., 2005. Urban gulls: problems and solutions. British Birds 98, 338–355.

Sanpera, C., Ruiz, X., Moreno, R., Jover, L., Waldron, S., 2007. Mercury and stable isotopes in feathers of Audouin's Gulls as indicators of feeding habits and migratory connectivity. Condor 109, 268–275.

Smith, G.C., Carlile, N., 1993. Methods for population-control within a Silver Gull colony. Wildlife Research 20, 219–226.