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ORIGINAL ARTICLE

Temporal and age-related dietary variations in a large population of yellow-legged gulls *Larus michahellis*: implications for management and conservation

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Abstract There was an extraordinary increase in the numbers of European gulls during the twentieth century which has been linked to higher availability of food derived from human activities. At Berlenga island (Portugal), the population of yellow-legged gulls *Larus michahellis* increased from 2600 individuals to a peak of 44,698 gulls (1974–1994), after which control measures have been put in place. Despite the management effort, little is known about the feeding ecology of this population. To investigate temporal and age-related variations in the diet of yellow-legged gulls at Berlenga, 1668 adult pellets and 145 chick regurgitates were collected and analysed between 2009 and 2012. Contradicting the generally accepted idea that these birds depend mainly on human-related food, adult gulls relied substantially on a locally abundant natural prey, the Henslow's swimming crab *Polybius henslowii*. Nevertheless, large amounts of refuse and fish were consumed in periods of apparent lower availability of swimming crabs. Despite the large temporal shifts in diet and feeding areas (change from marine to terrestrial prey), adult gulls consistently provisioned their chicks with a fish-based diet and chick condition remained constant. These results not only highlight the great resilience of this population to changes in food availability but also indicate that food from different human activities remain highly accessible. With the implementation of recent EU legislation regarding the reduction of fishery discards, and the increase of urban populations in the mainland, the monitoring and appropriate management of gull populations will be decisive for the healthy conservation of coastal systems used by these gulls.

Keywords Swimming crabs · Feeding ecology · Biological control · Fishery discards · Landfills · Urban gulls

The authors wish it to be known that, in their opinion, Hany Alonso and Ana Almeida should be regarded as Joint First Authors.

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Introduction

In the last decades, several European populations of large gull species have increased dramatically (Harris 1970; Pons 1992; Duhem et al. 2008), to the point of having considerable impacts on ecosystems (Vidal et al. 1998; Martínez-Abraín et al. 2003; Oro et al. 2005). One of the main causes for these pronounced population growths was the increased availability of food provided by human activities, namely discards from the fisheries industry (Furness et al. 1992; Oro et al. 1995) and waste from dumps and landfills (Sol et al. 1995; Ramos et al. 2009). Another major consequence of the higher human-related food availability was the rapid growth of urban gull populations, which brought potential impacts closer to people (Belant 1997; Rock 2005) and helped to promote a hostile attitude toward these species (Rock 2005; Oro and Martínez-Abraín 2007).

The knowledge of temporal and age-related variations in the use of food resources is a key aspect for understanding the feeding ecology and reproductive performance of opportunistic species, such as large gulls. *Larus* spp. are generalist predators and respond to inter- and intra-annual changes in food availability (e.g. Stenhouse and Montevecchi 1999; Ronconi et al. 2014). For breeding gulls, seasonal variations in diet may also reflect dietary choices related with prey selection to chicks (Annett and Pierotti 1989; Steenweg et al. 2011) or be the consequence of reproductive constrains (Pierotti and Annett 1991). Age-related variations in diet are frequent in gulls (e.g. Nogales et al. 1995; Pedrocchi et al. 1996; Steenweg et al. 2011), as the quality of food provided to chicks affects their growth and survival (Watanuki 1992). Nevertheless, variations in the foraging behaviour of adult gulls can also undermine their reproductive performance, as a change in their foraging grounds can indirectly affect their provisioning behaviour and nest attendance (Bukacińska et al. 1996; Bukaciński et al. 1998).

The yellow-legged gull *Larus michahellis* is a large species whose breeding distribution extends along most Southern Europe and North Africa, including the Atlantic coasts of France, Iberia and Morocco, the Mediterranean and most archipelagos in the Macaronesian region. This abundant seabird in the Iberian coast and Mediterranean basin (Equipa Atlas 2008; Louzao et al. 2011) is a well-known scavenger, which often relies on waste from fisheries and landfills (Duhem et al. 2003, 2005; Arizaga et al. 2011; Louzao et al. 2011). Besides being opportunistic and highly adaptable, the dependence on human-related food sources potentially also makes this species particularly susceptible to changes in the management of human activities (González-Solís et al. 1997a; Arizaga et al. 2014). In the last decades, there has been an increase in the knowledge of the feeding ecology of yellow-legged gulls across their breeding range (e.g. Ramos et al. 2009; Abdennadher et al. 2010; Matias and Catry 2010; Talmat-Chaouchi et al. 2014), including in the Atlantic Iberian coast (Munilla 1997a; Moreno et al. 2010; Arizaga et al. 2013). Nevertheless, very few studies have examined temporal variations in diet (but see Arizaga et al. 2013; Abdennadher et al. 2014), which is an important component to understand and predict the feeding behaviour of opportunistic species.

The Berlenga island archipelago supports one of the largest breeding populations of yellow-legged gulls (25.000 breeding individuals in 2005, Catry et al. 2010) whose number, as in many other colonies, has increased dramatically during the second half of the twentieth century reaching a peak number of 44,698 breeding individuals (Morais et al. 1998). To control population numbers, the Nature Conservation authorities (Institute of Nature Conservation and Forestry) have been applying measures to control the population. During three consecutive years (1994–1996), the culling of adult birds lowered the number of adults by half (Morais et al. 1998), and up to the present day, a large fraction of the clutches are destroyed each breeding season. Despite the importance of this colony for the species, there is a remarkable lack of knowledge regarding the feeding ecology of this population and most of the information is only available as grey literature (Luis 1982; Morais and Vicente 1998; but see Ceia et al. 2014).

The aims of this study were the following: (i) to describe in detail the diet of the large breeding population of yellow-legged gulls on Berlenga island and determine their dependence on natural prey and on human-related activities, (ii) to investigate temporal and age-related variations in diet, (iii) to assess the consequences of those variations on the provisioning of food to chicks (chick condition), and (iv) to discuss the management and conservation implications of the dietary choices and provisioning for the breeding populations of gulls at Berlenga and nearby coastal colonies, related with forthcoming changes in fisheries management.

Methods

Sampling area

Fieldwork was carried out at Berlenga island (39° 24′ 49″ N, 9° 30′ 29″ W), located in the continental shelf, 5.7 miles off the Portuguese coast. This ca. 78 ha island holds the largest breeding colony of yellow-legged gulls of the Portuguese coast (Catry et al. 2010). At Berlenga, the yellow-legged gull incubation period is of approximately 28 days and most chicks hatch during June (from mid-May to mid-July) (Catry et al. 2010), while the chick-rearing stage lasts approximately 35–40 days (Cramp and Simmons 1983).

Data collection

Adult pellets were collected each year from 2009 to 2012 during early chick-rearing, 10th to 27th of June, and late chick-rearing periods, 2nd to 17th of July (N_{2009}=733, N_{2010}=216, N_{2011}=458, N_{2012}=261). A total of 145 chicks spontaneous regurgitates were also collected during the two sampling periods of 2009 and 2011 (N_{2009}=76, N_{2011}=69). This sampling procedure was implemented in order to assess not only the inter-annual and age-related variations in the diet of gulls but also smaller-scale temporal variations along the chick-rearing period. The collection of pellets was held along a transect across the whole island (see Fig. 1) which was walked on average 3 (range 2–5) times per day. Only fresh pellets were collected (old pellets were removed from the transect in the first day of each sampling period) to avoid biases related with the resilience of pellets containing different

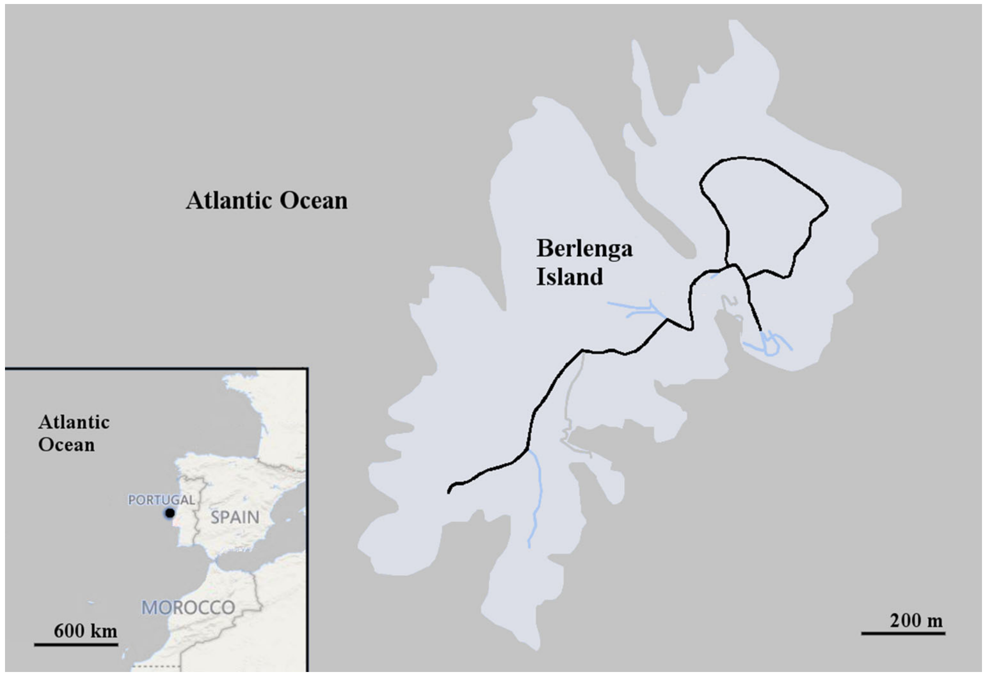

Fig. 1 Map and location of the Berlenga island, showing the transect walked across the island (*dark line*), for the collection of yellow-legged gull adult pellets

types of prey. Chick diet samples were obtained during handling, conducted to take biometric measurements (tarsus length and body mass) during three consecutive years (from 2009 to 2011). This procedure took less than 5 min and was scattered along the island to minimize the disturbance of the birds and avoid sampling the same bird/nest twice. Only one chick was sampled per clutch, being released close to cover (such as vegetation patches), to avoid the attack of neighbouring adult gulls. All diet samples were stored in labelled plastic bags and kept frozen until subsequent analysis.

Analysis of diet composition

The diet samples were analysed in the laboratory under a magnifying glass. The content of each sample was then identified to the lowest possible taxon using our own reference collection of fish hard parts (otoliths, vertebrae and other diagnosing structures) and published guides (Rotheray 1993; Tuset et al. 2008). Fish identification and quantification was mainly based on vertebrae, but otoliths and other hard remains (e.g. scales) were also used.

Statistical analyses

The diet of the yellow-legged gull is described as frequency of occurrence (FO, %) of each taxon in relation to the total number of diet samples, calculated from a binary matrix of presence/absence. In the formula used to calculate FO, i represent a specific prey or prey group, ni is the number of samples in which i is present, while $ntotal$ corresponds to the total number of samples analysed:

$$\mathrm{FO}i = \frac{ni}{ntotal} \times 100\%$$

For most analyses, food items were grouped in six different prey categories: swimming crabs, fish, refuse (which included all organic and inorganic material from human origin, either domestic or commercial, including all meat and bones), insects, molluscs and other prey (including other crustaceans, vegetal material, other mammals, yellow-legged gull eggs or chicks, and algae). Prey items were also grouped according to their origin: terrestrial or marine. Fish was considered to be a marine prey, despite the fact that some could have been captured by gulls in harbours or beaches. To enable a better interpretation of temporal variations in the graphic plots, any prey group that always occurred in less than 5 % of the total number of samples (i.e. not considered a main prey) was included in the category *Other prey.*

Temporal (yearly and intra-annual) and age-related differences in diet composition of adults and chicks were tested using a permutational ANOVA, through the “adonis” function of the “vegan” package running in R software (R Development Core Team 2010). A permutational ANOVA is a distance-based nonparametric multivariate ANOVA that provides a pseudo F value and an associated p value. Two different models were used, for adults and chicks, to test for temporal variations in the diet, both using year and month as factors, and the occurrence of prey as dependent variable. Differences between the diet of adults and chicks were assessed through models that incorporated age (chick vs.

adult) and also year and month as factors. To investigate differences between the diet of smaller and larger chicks, chicks were further classified in two age groups, according to their weight (smaller chicks, <450 g; larger chicks >450 g).

To compare the body condition of chicks among the years 2009, 2010 and 2011, we carried out a linear regression analysis between chick mass (measured to the nearest g) and tarsus length (to the nearest 0.01 mm) and used the residuals as an index of condition.

Results

Temporal variations in the diet of adult gulls

The diet of adult gulls varied considerably among years (ADONIS, pseudo-$F_{3,1660}$=224.46, p<0.001). The Henslow's swimming crab *Polybius henslowii* was the most frequent prey of yellow-legged gulls during most years (Table 1, Fig. 2); however, it was almost absent in June 2011, decreasing from more than 95 % (in the same period of 2009 and 2010) to only 5.2 % (Fig. 2). Intra-annual fluctuations were also highly significant (ADONIS, after removing the effect of year, pseudo-$F_{1,1660}$=13.42, p<0.001). The consumption of crabs was particularly low in July 2010 compared to the precedent month, but the opposite pattern occurred in 2011 (Fig. 2).

Refuse and fish occurred less frequently in the diet of gulls (Table 1), also with substantial temporal variations (Fig. 2). At least 13 different fish species were found to occur in the diet of adult gulls, the most frequent of which were the European pilchard *Sardina pilchardus*, the chub mackerel *Scomber colias* and the horse/blue jack mackerel *Trachurus* spp. (Table 1). Refuse was mainly composed of meat and/or bones of chicken *Gallus gallus* and pork/cow *Sus domesticus*/*Bos taurus*, but inorganic material (e.g. plastic, metal, paper, glass) was also frequent (Table 1).

Diet of chicks and age-related differences

Fish was the main prey group consumed by chicks (Table 2) and the most frequent fish species present in their diet were the European pilchard and the chub mackerel. Demersal species, such as the blue whiting *Micromesistius poutassou* or the European hake *Merluccius merluccius* were also frequent. The diet of yellow-legged gulls offspring varied between years (ADONIS, pseudo-$F_{1,141}$=4.86, p=0.012) and months (ADONIS, pseudo-$F_{1,141}$=5.32, p<0.01). Particularly noticeable was the higher consumption of refuse in 2011, compared to 2009 (Fig. 3).

There were important dietary differences between the diet of chicks and adult gulls in 2009 and 2011 (ADONIS after accounting for the effects of year and month, pseudo-$F_{1,1330}$=221.65, p<0.001) (Fig. 3). While the swimming crab constituted the basis of the adult diet (see Table 1), it was only found in 8 % of the chicks diet samples (Table 2), as adults provisioned their chicks mostly with fish. There were also differences between small and large chicks (ADONIS after accounting for the effects of year and month, pseudo-$F_{1,142}$=5.62, p<0.01; 2009: N_{small}=51, N_{large}=25; 2011: N_{small}=48, N_{large}=21), with larger chicks consuming more refuse (28 %) and crabs (15 %) and less fish (63 %), compared to smaller chicks (10, 5, and 79 %, respectively).

Chick condition

Chicks tarsus length was similar among years (ANOVA, $F_{1,346}$=0.63, p=0.53), suggesting that the chicks were of a similar age. We found no differences in the index of body condition between years of the study (ANOVA, $F_{1,344}$=0.002, p=0.96; see Table S1 and Fig. S1 of Supplementary Material).

Discussion

During our study, adult gulls relied mostly on natural prey, namely swimming crabs, but large dietary fluctuations were found across years and different periods of the chick rearing. Despite the remarkable shifts in the diet of adults, indicating fluctuations in food availability, the body condition of chicks remained constant along the first 3 years of this study, highlighting the resilience of this population and the flexibility of gulls to successfully exploit different food resources.

The use of pellets to assess the diet of marine birds is a common practice but is known to underestimate prey with softer body parts, such as smaller fish or invertebrates (González-Solís et al. 1997b; Votier et al. 2003). In this study, both fish vertebrae and otoliths were used to identify and quantify fish, minimizing biases related with the low occurrence of small or fragile otoliths (Votier et al. 2003; Alonso et al. 2013). While some soft prey could have still been underestimated in comparison with swimming crabs, variations found in diet were very large and potential biases are likely to be smaller by comparison. A recent isotopic study, focused on the individual specialization of yellow-legged gulls, corroborates this idea, since it confirms a dietary shift (from crustaceans to fish/refuse) of yellow-legged gulls during the incubation period (May) of 2011, when crabs were scarcer (Ceia et al. 2014).

The importance of swimming crabs

The Henslow's swimming crab is a well-known prey of yellow-legged gulls breeding along the Atlantic coast (Álvarez and Méndez 1995; Munilla 1997a; Moreno et al.

Table 1 Diet of adult yellow-legged gulls at Berlenga, during the chick rearing, from 2009 to 2012

	2009 (733)	2010 (216)	2011 (458)	2012 (261)
Crustacean	91.8	80.1	29.0	90.0
Henslow's swimming crab *Polybius henslowii*	91.7	80.1	27.1	90.0
Goose barnacle *Pollicipes pollicipes*	0.4		2.0	
Unidentified			0.2	
Fish	6.4	9.7	30.1	2.7
Sand smelt *Atherina* sp.			0.4	
Garfish *Belone belone*	0.1		1.5	
Bogue *Boops boops*	0.5		3.3	
Boarfish *Capros aper*	0.1		1.7	
European conger *Conger conger*	0.1		0.2	
Longspine snipefish *Macrorhamphosus* sp.	0.3		0.2	
European hake *Merluccius merluccius*	0.1		0.7	0.4
Blue whiting *Micromesistius poutassou*	0.1		1.1	
European pilchard *Sardina pilchardus*	2.0	3.2	7.9	0.8
Atlantic chub mackerel *Scomber colias*/sp.	3.4	0.9	2.0	
Atlantic saury *Scomberesox* sp.		0.5		
Horse/Blue jack mackerel *Trachurus* spp.	0.7	0.5	6.3	
Pouting *Trisopterus luscus*			0.9	
Unidentified	1.4	5.1	12.2	1.5
Refuse	2.6	16.2	50.9	6.1
Cow/Pig *Bos taurus*/*Sus domesticus*	0.5	1.9	10.0	1.5
Chicken *Gallus gallus*	0.4	8.3	18.6	1.1
Helmeted guineafowl *Numida meleagris*			0.2	
Sausages	0.4	3.2	7.0	0.8
Unidentified meat	0.5	2.3	6.8	0.8
Fruit seeds or peel		0.5	3.5	
Chicken egg			1.1	
Metal		0.9	2.2	1.1
Paper			2.6	
Plastic	0.4	0.9	9.0	
Glass	0.1	0.5	3.7	
Other refuse	0.1	0.9	1.7	0.8
Insects	0.8	2.8	4.8	1.9
Beetles (Coleoptera)	0.7	2.8	2.8	1.9
Grasshoopers (Orthoptera)	0.3			
Unidentified			2.0	
Molluscs	0.4	1.4	4.1	0.4
Land snails (Stylommatophora)	0.1	0.5	1.3	0.4
Marine snails (Basommatophora)			0.2	
Mediterranean mussel *Mytilus galloprovincialis*	0.1		0.2	
Limpet *Patella* sp.			0.7	
Common cuttlefish *Sepia officinalis*	0.1			
Unidentified Bivalve		0.5	1.1	
Unidentified Gastropoda		0.9	0.7	
Other items	1.4	3.7	7.6	0.8
Algae	0.3	0.5	0.2	
Vegetal material		2.8	4.8	0.4
European rabbit *Oryctolagus cuniculus*	0.1		0.4	

Table 1 (continued)

	2009 (733)	2010 (216)	2011 (458)	2012 (261)
Black Rat *Rattus rattus*	0.1		0.2	
Yellow-legged gull chicks	0.6	0.5	1.3	
Yellow-legged gull eggs			0.4	
Fisheries related items	0.4		0.9	0.4
Unidentified	0.1			

The values presented correspond to the frequency of occurrence (%) of each prey item in relation to the total number of diet samples (number of pellets, in brackets)

2010). This benthonic Portunidae crab has a pelagic stage during its life cycle during which large numbers of individuals emerge in coastal waters, usually in dense patches near the sea surface (González-Gurriarán 1987). These phenomena occur mainly (but by no means exclusively) during the summer months, when a strong upwelling occurs in the Portuguese continental shelf (Sousa et al. 2005). During most of this study, the diet of adult gulls was completely dominated by this swimming crab (occurring in more than 95 % of pellets; see also Table S2 of Supplementary Material) and frequently large rafts of yellow-legged gulls could be observed close to Berlenga feeding on extensive swimming crab shoals (identified *in loco* after collection with a small hand net). The strong reliance of gulls on swimming crabs is not exclusive of yellow-legged gulls (e.g. lesser black-backed gull *Larus fuscus* predation on *Liocarcinus sp*. in the North sea; Schwemmer and Garthe 2005), and it has been suggested that crabs may be an important source of calcium for egg formation and bone development of chicks (Schwemmer and Garthe 2005), despite their low caloric value when compared to fish. It is likely that not only this aspect but also their high abundance close to the colony, their slow swimming performance and the avoidance by gulls of intra and interspecific competition around fishing vessels or inland (Schwemmer et al. 2013) can make this a very attractive prey for breeding gulls, both during the incubation and chick-rearing stages.

Despite the frequent predation of swimming crabs by the yellow-legged gulls breeding at Berlenga, there were large intra- and inter-annual variations in the consumption of this prey, presumably as a response to decreased availability in the vicinity of the colony. This was particularly obvious in June 2011 when this prey was present in less than 5 % of the samples, while the amount of refuse increased markedly. Yellow-legged gulls are well known to use refuse dumps and landfills to feed, taking advantage of an abundant and predictable food source (Sol et al. 1995; Duhem et al. 2003, 2005; Ramos et al. 2009). However, the dependence of breeding populations on this anthropogenic resource is often closely related with the distance to the breeding colony (Ramos et al. 2009). At Berlenga, located about 10 km off the mainland (17 and 39 km from the nearest transfer station and landfill sites, respectively), adult breeding gulls appear to target

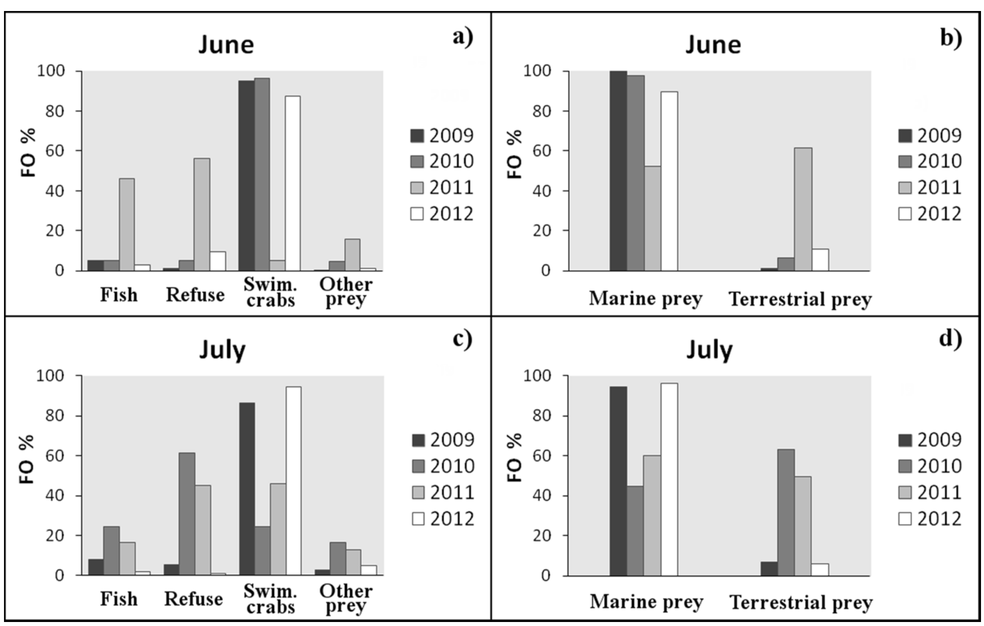

Fig. 2 Temporal variations in the diet of adult yellow-legged gulls during the chick rearing, from 2009 to 2012 (N_{2009}=733, N_{2010}=216, N_{2011}=458, N_{2012}=261). Prey is categorized into the main prey groups (fish, refuse, swimming crabs, other prey) consumed by adult gulls (**a** and **c**) and also according to their origin (marine or terrestrial, **b** and **d**)

Table 2 Diet of yellow-legged gull chicks at Berlenga, during the chick-rearing of 2009 and 2011

	2009 (76)	2011 (69)
Crustacean	7.9	11.6
Henslow's swimming crab *Polybius henslowii*	7.9	8.7
Unidentified Decapoda		2.9
Fish	80.3	65.2
Garfish *Belone belone*	1.3	
Bogue *Boops boops*	1.3	1.4
Boarfish *Capros aper*		1.4
European conger *Conger conger*	1.3	
Longspine snipefish *Macrorhamphosus* sp.	1.3	
European hake *Merluccius merluccius*	9.2	2.9
Blue whiting *Micromesistius poutassou*	6.6	2.9
European pilchard *Sardina pilchardus*	11.8	23.2
Comber *Serranus* sp.	1.3	
Atlantic chub mackerel *Scomber colias*/sp.	15.8	5.8
Horse/Blue jack mackerel *Trachurus* spp.	6.6	1.4
Unidentified	34.2	33.3
Refuse	6.6	26.1
Cow/Pig *Bos taurus*/*Sus domesticus*		2.9
Chicken *Gallus gallus*	3.9	15.9
Sausages		1.4
Unidentified meat	2.6	4.3
Chicken egg		1.4
Seeds		1.4
Paper		1.4
Plastic		2.9
Glass		1.4
Insects	11.8	11.6
Grasshoopers (Orthoptera)		2.9
Rat-tailed maggot (larvae) *Eristalis tenax*	11.8	7.2
Other larvae/pupae		4.3
Molluscs	2.6	2.9
Land snails (Stylommatophora)	1.3	1.4
Mediterranean mussel *Mytilus galloprovincialis*	1.3	
Unidentified Gastropoda		1.4
Other items	0.0	4.3
Algae		2.9
Yellow-legged gull egg		1.4

Values correspond to the frequency of occurrence (%) of each prey item in relation to the total number of diet samples (spontaneous regurgitates, in brackets)

mainly marine prey. Our results support the idea that in periods of presumed lower food availability around the colony, using a distant predicable source of food may be advantageous, despite the increase in the foraging effort, and allow gulls to maintain their provisioning of food to chicks without jeopardizing their condition.

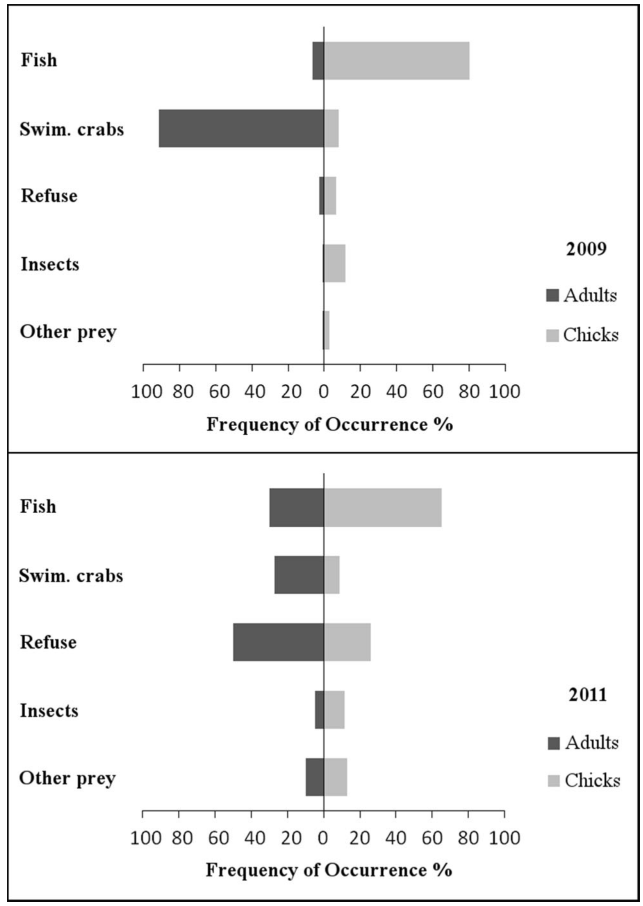

Fig. 3 Diet of adult (N_{2009}=733, N_{2011}=458) and chicks (N_{2009}=76, N_{2011}=69) yellow-legged gulls during the chick rearing of 2009 and 2011. Prey is categorized into the main prey groups (fish, swimming crabs, refuse, insects, other prey) consumed by adults and/or chicks

All is fish that comes to the net

Fish was an important food resource for this population of gulls, particularly for growing chicks. Adults do provide swimming crabs to their chicks, but this prey type is much more difficult to ingest than fish (particularly by smaller chicks, who often reject it; Hany Alonso, pers. obs.) and has much lower caloric content than fish (e.g. crabs 3.59 kJ g^{-1}, clupeids 6.70 kJ g^{-1}; Munilla 1997b) and a higher proportion of hard indigestible structures (Moreno et al. 2010). Despite the clear inter-annual changes in adult's diet and foraging behaviour (see Fig. 2), there was no apparent impact in the provisioning of growing chicks, which maintained a fish-based diet as well as their condition. The body condition of growing chicks reflects the provisioning behaviour of adults and is a good predictor of chick survival (e.g. Hamer et al. 1991; Bukaciński et al. 1998), suggesting that yellow-legged gulls were able to maintain their overall reproductive performance. Nevertheless, very small chicks (e.g. less than 10 days of age) may be more exposed to predation (particularly of conspecifics) if adults have to travel to (more distant) feeding areas (Hamer et al. 1991; Bukaciński et al. 1998); therefore, it is necessary to investigate the consequences of these foraging changes to the survival of younger chicks.

The most frequently consumed fish were the European pilchard, the chub mackerel and the horse mackerel/blue jack mackerel, which are also the most captured by the fishing fleet operating in the area around Berlenga (see Table S3 of Supplementary Material). Overall, these species are also among the main discarded species (by weight) in the Portuguese fisheries, across a wide range of gears (Leitão et al. 2014). Namely, sardine and chub mackerel are frequently discarded by beach seiners, depending on the size and content of the catch (Cabral et al. 2003), while blue jack mackerel *Trachurus picturatus* and chub mackerel are heavily discarded by trawlers (Fernandes et al. 2015). Even in pelagic purse seiners, where discards are generally considered low and occur mainly as slipping (escape of fish over the headline of the net), sardine and chub mackerel can be discarded in substantial quantities (20–30 % of the catch; Borges et al. 2001). Despite the possibility that yellow-legged gulls could have been capturing some fish by themselves, it is likely that the majority of those would have been obtained from human fisheries, whether in interactions at sea with operating vessels (e.g. net hauling in purse seiners) or when the fish is discarded (at sea, harbours or beaches). Indeed, large gull species (*Larus michahelis and L. fuscus*) represent the great majority of the marine birds present in interactions with fishing vessels in Iberian waters (Valeiras 2003; Louzao et al. 2011). Additionally, during the incubation period, gulls from Berlenga do use foraging areas such as the Peniche harbour and the beaches of Costa da Caparica (Ceia et al. 2014), where a large number of beach seiners operate (Cabral et al. 2003), discarding most of the unwanted fish at the site (H. Alonso, pers obs).

Further supporting the idea of a fisheries subsidy (and particularly discards) to diet was the occurrence of bentho or bathypelagic species, such as the European hake *Merluccius merluccius* or the blue whiting *Micromesistius poutassou* (up to 21.4 % of the chicks' diet in June 2009), also heavily discarded by Portuguese trawlers (Borges et al. 2001; Fernandes et al. 2015) and which are unlikely to be captured by gulls in natural conditions or even during hauling. Noteworthy also is the almost complete absence of small epipelagic species from the diet (such as the European anchovy *Engraulis encrasicolus*, sandeels *Ammodytes* spp. and sand smelt *Atherina presbyter*), which were important prey of Berlenga gulls in the past and more likely captured by gulls when foraging without the assistance of human fisheries (Luis 1982; Morais and Vicente 1998).

Management and conservation implications

The demographic evolution of gull populations has been a matter of great concern for conservationists and managers around the globe, as the impacts on sympatric species and human populations became noticeable (Thomas 1972; Belant 1997; Vidal et al. 1998; Oro et al. 2005). Despite that, in many cases, there is a generalized negative opinion over gulls that may not always be evidence based (Oro and Martínez-Abraín 2007). At Berlenga, the yellow-legged gull population has known a rapid growth, particularly in the 1980s and 1990s, reaching 44,698 breeding individuals in 1994 (Morais et al. 1998). The medium-term success of the ongoing clutch destruction is obvious, with the population currently at ca. 13,600 breeding individuals (Morais et al. 2014).

This study shows that yellow-legged gulls in Berlenga depend substantially on a natural and very abundant prey. But if natural prey is abundant, why were gulls scarcer in the first half of the twentieth century? One important factor was, most likely, the large-scale and systematic harvesting of gull eggs, which only ended in the early 1980s (Morais et al. 1998; Catry et al. 2010). While there is no doubt that recent conditions are more favourable in terms of the diversity of abundance of food supplies (namely from fisheries discards and landfills), which allowed a large population growth, it seems nevertheless likely that yellow-legged gulls could have been, in a more remote past without persecution, a relatively abundant seabird in this region, in contrast, for example, with what happens in pelagic and undisturbed offshore islands, where natural prey may be scarcer (e.g. Matias and Catry 2010).

The European Union, under the framework of the new EU Common Fisheries Policy (effective from 1 January 2014), has established the objective of ban fishery discards until 2019, through a total landing obligation (http://ec.europa.eu/fisheries/reform/index_en.htm). A significant change in the availability of discards will likely have a direct effect on scavenging species (Bicknell et al. 2013; Heath et al. 2014), including the yellow-legged gull (Bicknell et al. 2013). This may seriously impact the provisioning and, hence, the breeding success of the gulls from Berlenga, since chicks are currently mostly fed with fish prey. Other scavengers, such as the herring gull *Larus argentatus*, have been declining in the North Sea, presumably due to changes in discards management and diseases such as botulism (Mitchell et al. 2004). Nevertheless, we must also be aware of the difficulties of efficiently implementing a discard ban in some fisheries, particularly in coastal fisheries in Portugal, considering the costs of control measures and low compliance levels with fishery legislation (Sardà et al. 2013). Furthermore, scavengers will most likely respond to a decline in discards by switching to alternative food resources (Bicknell et al. 2013). On Berlenga, we recorded large temporal shifts in the diet of adult gulls, with no apparent consequences for their provisioning performance. These results highlight the flexibility of the foraging behaviour of this population and show that currently alternative food supplies are available, mostly related with other human activities (e.g. landfills). This implies that these birds may be able to maintain their breeding success, even if one of their main food sources is cut off.

The recent colonization of urban areas by yellow-legged gulls along the Portuguese coast (Equipa Atlas 2008; Morais and Casanova 2008) may also become a reason for concern, considering both the recent demographic tendencies in urban areas and the availability of potential breeding sites (Catry et al. 2010). While it is not certain that breeding gulls migrated from Berlenga to coastal areas due to controlling measures taken at colonies, it is well known that a negative pressure (e.g. culling) on the breeding sites may induce the emigration of gulls to nearby alternative colonies (Bosch et al. 2000; Morais and Casanova 2008). Even though the root causes of this colonization are not clear, the results from the present study show that terrestrial food resources are currently available for breeding gulls from Berlenga, and we may foresee that urban gulls may be benefiting both from being closer to those predictable food resources and from considerable less disturbance at their "new" breeding sites.

While keeping the control measures at Berlenga may be essential to control population levels, some issues demand further and urgent research, namely the growth of urban populations, their dependence on human-related food resources and the response of gulls (both insular and urban) to forthcoming changes in discards management. During the implementation of relevant management changes in the fisheries and waste sectors, it is strongly recommended that an effective monitoring of insular and urban gull populations takes place. This should include the monitoring of the numbers, breeding success and foraging activity of gull populations, as well as the impacts on endangered species and on human well-being.

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