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ORIGINAL ARTICLE

Diet of Yellow-legged Gull (*Larus michahellis*) chicks along the Spanish Western Mediterranean coast: the relevance of refuse dumps

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Abstract In recent decades, the Yellow-legged Gull (*Larus michahellis*) has become a problematic species in many Mediterranean countries, mainly because it interferes with human interests. However, this gull also has a negative impact on several other bird species, many of which are classified as endangered. Two different European Union Action Plans are currently under development with the aim of decreasing the availability of food derived from human activities, such as garbage and fishery discards, which are considered to be the main causes of the superpopulations of this gull. Here, we describe the diet of Yellow-legged Gull chicks, with particular emphasis on establishing the dependence of each population on refuse dumps, in order to forecast changes in gull population dynamics in response to the management decisions being implemented. We sampled four colonies along the Western Mediterranean in Spain: the Medes Islands, the Ebro Delta, the Columbretes Islands, and Mazarrón Island. To elucidate their feeding ecology and to avoid obtaining a discrete estimation from a single sampling, we collected regurgitates from each colony three times throughout the chick-rearing period. Slightly differential feeding habits were observed between chick age classes. Younger chicks in all four colonies tended to be consistently provisioned with smaller prey such as invertebrates. Distinct uses of several foraging habitats among localities were observed. In particular, the use of refuse dumps was common and abundant in two of the colonies: the Medes and Mazarrón Islands. As a consequence of current management strategies, generalized reductions in Yellow-legged Gull populations and increases in the consumption of alternative food resources to those of fishery discards and refuse scraps are expected. Finally, we predict that decreased food availability will force some gulleries to increase predation on endangered species, thereby raising a conservation concern.

Keywords Dietary analysis · Feeding ecology · Fishery discards · Landfill management · Regurgitate

X. Ruiz: deceased on 27 April 2008.

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Introduction

Over the last several decades, many vertebrate species have increased in abundance as a result of habitat changes resulting from human activity (Garrott et al. 1993). Most of the communities of these species are overpopulated. This overpopulation is attributed to their flexible, opportunistic, and gregarious nature, which makes them highly adapted to living in habitats modified by man. In particular, gulls have been extensively studied as a potential superabundant species in numerous localities around the world (Belant et al. 1993; Bertellotti et al. 2001; Steele and Hockey 1990; Vidal et al. 1998).

In the Mediterranean basin, populations of the Yellow-legged Gull (*Larus michahellis*) have greatly increased over the last four decades and have become problematic in this region (Vidal et al. 1998). Like other gull species, the Yellow-legged Gull is considered a pest because of its negative impact on airports, cities, reservoirs, arable land, and fisheries (Dolbeer et al. 1997; Monaghan et al. 1985; Mudge and Ferns 1982). In other cases, this gull species disturbs, displaces, or even predates on other, often protected, species (Furness and Monaghan 1987; Oro et al. 2005; Swennen and Van de Meer 1992; Thomas 1972). Most of these effects can be attributed to overpopulated gulleries that have arisen from the scavenging capacity of this bird on increasing food resources derived from human activities (Furness et al. 1992), particularly garbage but also fishery discards (Bosch et al. 1994; Mudge and Ferns 1982; Pons 1992).

In general, food availability is a determinant factor of population dynamics and also the breeding success of most species (Oro et al. 2006). In this respect, food sources derived from human activities, such as refuse dumps, are usually abundant and relatively predictable, thereby increasing the carrying capacity of an ecosystem and allowing gulls to improve breeding success and probably survival (Pons 1992). Although the removal of these food resources produces a decrease in the number of breeding pairs, the production per pair is not affected and birds breed successfully without having access to nearby refuse dumps (Kilpi and Öst 1998). In this regard, the European Union Landfill Directive (1999/31/EC) aims to reduce the amount of biodegradable municipal waste sent to landfills by up to 40% of the 1995 level by 2020 (http://ec.europa.eu/environment/waste/landfill_index.htm). Moreover, in October 2002, the European Union also adopted an Action Plan to ensure the sustainability of fisheries in the Mediterranean (http://ec.europa.eu/fisheries/cfp/2002_reform_en.htm). Most of these measures focus on preventing catches of unwanted fish to achieve biologically, environmentally, and economically sustainable fisheries.

Thus, establishing the dietary preferences of several gull populations will facilitate the prediction of changes in and consequences for gull population dynamics. Moreover, any other management measure to effectively control populations of gulls should focus on limiting resource availability during a sensitive season (i.e., the breeding period), thereby reducing the production of a population (Kilpi and Öst 1998). Overall, management decisions are usually costly (Thomas 1972) and should be based on an accurate knowledge of the feeding habits and resources exploited by each gull population.

Dietary analyses to assess feeding habits in birds have several limitations that hamper the accuracy of results (Duffy and Jackson 1986; González-Solís et al. 1997), such as biases of distinct magnitude depending on the type of food sample analyzed. Diet studies based on direct observations are usually biased towards the most conspicuous prey, and prey from gut contents or pellets can be difficult to identify as items are often considerably or completely digested. Among the food sampling methods available, regurgitates are the least biased and most reliable for describing diet composition (González-Solís et al. 1997; Seefelt and Gillingham 2006). However, regurgitate analysis provides only episodic information on feeding habits, i.e., each sample represents only a short collection of specific feeding events in the diet of an individual and does not provide information on resources used in the past.

In this study, we analyzed more than 350 chick regurgitates from four Yellow-legged Gull colonies along the Western Mediterranean coast of Spain. We sampled three age classes of chicks throughout the chick-rearing period to: (1) study the differential use of resources by each chick class; (2) explore the spatial heterogeneity in exploited resources on the basis of potential nearby feeding habitats; and (3) predict population dynamic changes in these colonies as well as in other populations with similar feeding patterns in response to the implementation of future management strategies (see above).

Methods

Study area

The study was carried out in four colonies along the Iberian Mediterranean coast during the chick-rearing period in 2004. From north to south, the colonies sampled were: the Medes Islands, the Ebro Delta, the Columbretes Islands, and Mazarrón Island (Fig. 1). Relevant information about the location of the colonies and the activity of fishing vessels near each area is given in Table 1.

Gull sampling and regurgitate analysis

We visited each colony three times during the chick-rearing period. In each visit, we sampled preferentially chicks of a similar age class. Following this sampling strategy, we sought to check for possible age-differential feeding but also tried to obtain a whole and robust estimation of feeding habits throughout the chick-rearing period. We sampled a single chick from each brood to avoid pseudoreplication of parents feeding the same prey to their offspring. We measured bill, head, and tarsus length to the nearest mm using digital calipers. Previous studies have shown that bill and tarsus length of gulls grow linearly with age (Coulson et al. 1981; Greig et al. 1983; Werschkul 1979). Because we sampled chicks that differed slightly in age, we used a principal components analysis (PCA) with bill, head, and tarsus length as variables to classify them

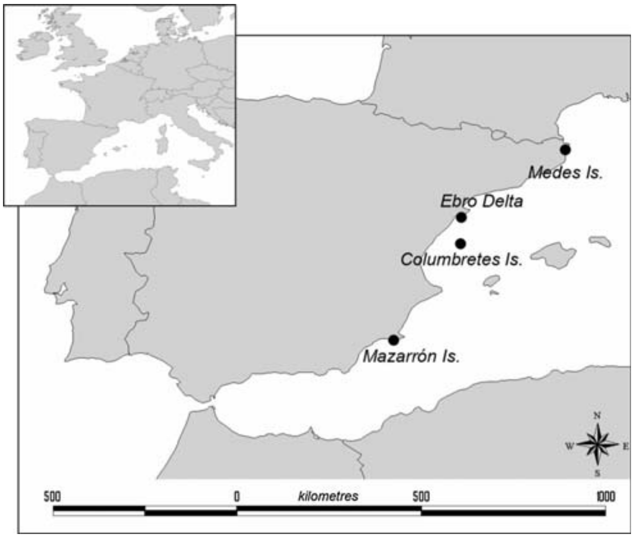

Fig. 1 Map of the Iberian Peninsula. Colony sites (*filled circles*) of the Yellow-legged Gull (*Larus michahellis*) included in the study along the Spanish Western Mediterranean coast are indicated

into three age groups. The PCA generated a continuous variable of global size component, which we artificially trichotomized into discrete categories (Bennett and Owens 2002). Chicks belonging to the first category (first age) were up to 1 week old, the second category (second age) included 2- and 3-week-old chicks and the third category (third age) included chicks just before fledging (between 4 and 5 weeks old).

Food samples were collected as spontaneous regurgitations ($n = 356$) from chicks when they were handled for measuring. Each regurgitate was placed in a sealed plastic bag and kept frozen until the laboratory analysis. Regurgitates were weighed and their contents identified to the order level using standard reference guides. Prey was assigned to six categories on the basis of the foraging habitats where they were captured (Bosch et al. 1994): marine prey (distinguishing between pelagic and benthonic fish); brackish and freshwater; crops and terrestrial environments; refuse tips; and others. The presence of each category in each locality is represented by its relative biomass (the total biomass of the category/mass of all samples). Diet analyses were based on foraging habitats as these could be intuitively compared with the gull's trophic ecology whereas little could be inferred from the taxonomic point of view (Cooper et al. 1990).

Statistical analysis

To compare the use of foraging habitats among localities and age classes, we evaluated the heterogeneity of the exploited habitats inferred from the regurgitate analysis using indexes of diversity (Duffy and Jackson 1986). Habitat heterogeneity was estimated using the Shannon–Weaver index (Keylock 2005; Pielou 1967; Shannon and Weaver 1949):

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where p_i is the proportion of biomass belonging to individuals in the ith species or category (in our case, each foraging habitat). Indexes of diversity (H') were calculated using the biomass of each foraging habitat and were pair-compared following Hutcheson's procedure (Zar 1996) among colonies and among ages. A Bonferroni correction using the sequential Holm's procedure (Holm 1979) was applied to maintain an overall error type I of 0.05 in the 18 simultaneous multiple comparisons.

Table 1 Main informative parameters of the breeding sites of the Yellow-legged Gull (*Larus michahellis*)

	Locality site	Distance from human settlements (km)	Number of breeding pairs	Fishing vessel activity around each area: Relative estimation	Number of vessels	Gross tonnage	References
Columbretes Is. (39°54′N, 0°41′E)	Isolated archipelago in a Marine Reserve	55.0	450	High	329	9,844	Oro et al. (2006)
Ebro Delta (40°40′N, 0°45′E)	Isolated peninsula in a Natural Park	7.5	6,000	High	520	11,440	Oro et al. (2006)
Medes Is. (42°0′N, 3°13′E)	Islands off the coast of a tourist site	0.9	6,500	Moderate–high	579	9,517	Bosch et al. (2000)
Mazarrón Is. (37°33′N, 1°16′W)	Island off the coast of a tourist site	0.5	900	Low	277	4,156	García-Morell and Escribano (2005)

Fishing vessel information for each area was taken from http://ec.europa.eu/fisheries/index_en.htm

Results

In the Columbretes Islands, the feeding pattern of the second and third age classes did not differ. However, a small proportion of freshwater invertebrates was found in the diet of the first age class (Tables 2, 3) but not in the older ones. Chicks from the Ebro Delta showed changes in the feeding pattern throughout the chick-rearing period, although in Mazarrón Island the diet differed only between the youngest and oldest chicks (Table 3). In both localities, a higher proportion of small invertebrates (both from terrestrial and freshwater habitats) was found in the smaller chicks, while the presence of resources from refuse dumps increased in the third age class (Table 2). In the Medes Islands, the second age class differed from the others while no differences were found between the first and third groups (Table 3). Although no consistent feeding patterns were observed throughout the chick-rearing period in the four colonies, a greater proportion of smaller prey, both from brackish and freshwater (Mazarrón Is. and Columbretes Is.) and from crops and terrestrial environments (Ebro Delta and Medes Is.), was detected in the diets of younger chicks (Table 2).

In spite of the significant differences among age classes in most localities, we grouped all regurgitate samples to compare the chicks' diet among colonies to obtain a global assessment of foraging preferences throughout the breeding season in each locality (Fig. 2; Table 2). Dietary heterogeneity showed a gradient among the colonies, with the birds on Mazarrón Island exhibiting the highest value. The index for the Medes Islands was slightly lower, followed by the Ebro Delta, whereas birds from the Columbretes Islands showed the lowest degree of dietary heterogeneity (Table 2). When pair-compared, all the indexes differed (Table 3).

Overall, gulls used three main foraging habitats to feed their chicks: pelagic prey, refuse dumps, and brackish and freshwater ecosystems (Fig. 2). These categories represented 97.6, 87.4, 85.5, and 89.6% of total biomass in the Columbretes Islands, the Ebro Delta, the Medes Islands and Mazarrón Island, respectively. Pelagic fish samples occurred in all four localities, whereas those from refuse dumps were present in the diets of three. However, waste had a considerable relevance only in the Medes Islands (45.4%) and Mazarrón Islands (43.8%), being less important in the Ebro Delta (8.5%). As expected, the regurgitates

Table 2 Diet of Yellow-legged Gull chicks of different age categories

	n	Foraging habitat						$H' \pm$ SE
		Pelagic prey	Benthonic prey	Brackish and freshwater	Crops and terrestrial	Refuse tips	Others	
Columbretes Is.								
1st age	28	88.9	0.0	7.2	0.0	0.0	3.9	0.42 ± 0.015
2nd age	38	96.3	0.9	2.6	0.0	0.0	0.2	0.19 ± 0.009
3rd age	42	96.7	0.4	0.0	0.0	0.0	2.8	0.16 ± 0.007
Total	108	95.7	0.6	1.9	0.0	0.0	1.7	0.22 ± 0.019
Ebro Delta								
1st age	36	56.4	2.5	4.2	29.0	3.9	4.1	1.16 ± 0.018
2nd age	29	82.8	4.4	6.2	0.4	0.0	6.3	0.66 ± 0.018
3rd age	24	75.9	1.0	2.2	0.2	18.7	2.0	0.74 ± 0.022
Total	89	74.7	2.6	4.2	6.0	8.5	4.1	0.95 ± 0.007
Medes Is.								
1st age	36	21.0	0.0	0.0	7.5	56.9	14.5	1.12 ± 0.016
2nd age	35	27.8	0.0	0.0	0.6	62.3	9.3	0.90 ± 0.014
3rd age	27	51.3	14.0	1.8	0.1	31.0	1.9	1.13 ± 0.022
Total	98	39.2	7.2	0.9	1.2	45.4	6.1	1.18 ± 0.006
Mazarrón Is.								
1st age	14	15.5	0.0	48.5	0.0	28.7	7.3	1.19 ± 0.040
2nd age	30	23.4	0.0	25.8	2.2	43.5	5.2	1.29 ± 0.021
3rd age	17	15.5	0.0	19.4	4.0	48.1	13.0	1.35 ± 0.038
Total	61	20.3	0.0	25.5	2.6	43.8	7.8	1.33 ± 0.010

The first age category included 1-week-old chicks, the second 2- to 3-week-old chicks and the third 4- to 5-week-old chicks. Values are given in % of fresh weight (biomass) in relation to age classes and on the basis of foraging habitats. Diversity indexes and their standard errors are also shown

Table 3 Diversity pair-comparisons among age categories and colonies

Age-comparisons	*t* statistic	*df*	*P* value
Columbretes Is.			
1st–2nd	13.57	48	<0.001*
1st–3rd	15.76	42	<0.001*
2nd–3rd	2.21	75	0.030
Ebro Delta			
1st–2nd	19.58	64	<0.001*
1st–3rd	29.05	58	<0.001*
2nd–3rd	8.95	53	<0.001*
Medes Is.			
1st–2nd	10.50	70	<0.001*
1st–3rd	−0.43	52	0.672
2nd–3rd	−9.05	48	<0.001*
Mazarrón Is.			
1st–2nd	−2.17	21	0.041
1st–3rd	−2.96	30	0.006*
2nd–3rd	−1.53	27	0.139
Colony comparisons			
Columbretes–Ebro Delta	−36.37	139	<0.001*
Columbretes–Medes	−48.39	132	<0.001*
Columbretes–Mazarrón	−51.56	158	<0.001*
Ebro Delta–Medes	−23.48	180	<0.001*
Ebro Delta–Mazarrón	−29.48	116	<0.001*
Medes–Mazarrón	−12.16	105	<0.001*

* Significant differences at an overall error type I of 0.05

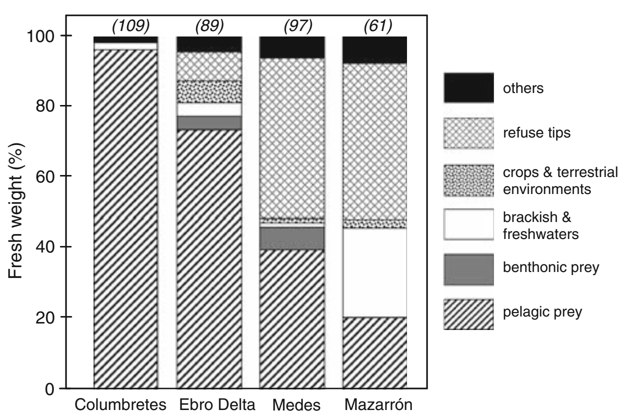

Fig. 2 Fresh weight percentages of prey on the basis of the main foraging habitats in regurgitates of Yellow-legged Gull chicks

collected from the Columbretes Islands did not include food from refuse dumps and most of the food items came from the marine environment (96.3%). Prey from brackish and freshwater habitats were relevant only in regurgitates from chicks inhabiting Mazarrón Island (25.5%).

Discussion

Regurgitation analyses showed that food sources related to human activities, such as refuse or fishery discards, were the main dietary components of our sample of chicks, as reported in the study by Duhem et al. (2003). These sources comprised more than 85% of the total prey biomass in three localities, whereas in the fourth (Mazarrón Island), this value reached 65% (Fig. 2). These values are similar to those reported in a previous study by Bosch et al. (1994) for the colonies on the Medes Islands and in the Ebro Delta. Moreover, our findings are consistent with data from other colonies in the Western Mediterranean (Vidal et al. 1998) indicating that the exploitation of these food resources is maintained over time and space. Therefore, owing to the generalist and opportunistic feeding habits of the Yellow-legged Gull, it is reasonable to assume that the availability of these resources makes a considerable contribution to the expansive dynamics of its populations in the Mediterranean. This opportunistic behavior and high feeding adaptability are relevant factors to take into account when assessing population dynamics or the management of pest species (Thomas 1972).

The information from chick regurgitates showed substantial differences between localities, particularly in the use of the marine habitat. These differences can be explained by the availability per capita (i.e., related to the colony size) of this food resource in each colony as well as by the presence of alternative food sources that are easier to obtain than fish, such as garbage from refuse dumps (Bertellotti et al. 2001). According to the optimal foraging theory, one can expect birds to feed in a way that maximizes their energy intake (Schoener 1971) as well as that of their chicks during the breeding period. Garbage consisting mainly of chicken, pork, and beef scraps has a high energetic value per meal and high fat and protein content per gram (Pierotti and Annet 1991). This observation together with the ease of obtaining this food could explain the high proportion of this food resource in diets when refuse dumps are abundant and close to breeding colonies (in both the Medes Is. and Mazarrón Is.). The lower proportion of garbage in the diet of the chicks sampled in the Ebro Delta, compared to those from the Medes Is., might be related to lower availability of this resource to the colony in the Ebro Delta, as there are five times as many refuse dumps in area around the Medes Islands than in the Ebro Delta (Bosch et al. 1994). According to the optimal foraging theory, for the gulls on the Columbretes Islands, the mainland is too far away from their breeding area to be used for chick provisioning. Consequently, these gulls feed their offspring mainly with fish (see Duhem et al. 2005), which can be obtained from the fisheries operating in the area (Arcos et al. 2001) or even from sub-surface predators (Oro 1995).

Thus, on the Columbretes Islands the Yellow-legged Gull competes not only for space but also for food (Oro et al. 2006), thereby limiting the size of the colony.

Prey from crops and terrestrial environments (mostly small invertebrates) were common in the diet of the chicks sampled in the Ebro Delta, although their relevance decreased with age (Table 2). Similarly, brackish and freshwater prey (also mostly represented by small invertebrate larvae of Syrphidae) was of considerable importance in Mazarrón Island and especially abundant in smaller chicks. The presence of these two prey types in the chicks' diet indicates the opportunistic behavior of Yellow-legged Gulls, as well as the proximity of this food resource to the breeding site. However, the observation that these small prey were specially abundant in younger chicks might be attributed to the need to provide small food items that chicks can easily swallow and digest or to requirements to increase the feeding rates of these chicks during this period (Pedrocchi et al. 1996). Supporting this idea, the diet of these younger chicks was found to show greater heterogeneity than that of older nestlings, and it was also constant in the sampled colonies (Table 2).

Two European Union Action Plans are currently under development and seek to decrease the availability of food derived from human activities to gulleries, such as garbage and fishery discards (see "Introduction"). These management decisions should be taken into account when forecasting changes in gull population dynamics. In this regard, presumed drastic reductions are expected in most Yellow-legged Gull colonies. Reduced availability of fishery discards or decreased access to refuse dumps will broaden the trophic niche of these birds, thereby leading to an increased consumption of alternative food sources, such as those from terrestrial habitats (Duhem et al. 2005), when available and relatively close to the colony. The trophic niche width, measured as the heterogeneity of the foraging habitats exploited, provides a suitable approach to measure the feeding plasticity and opportunism of a species (La Mesa et al. 2000) and could be used as an estimator of the number of distinct foraging opportunities the species has in each locality. Our study suggested that the gull populations on the Medes and Mazarrón Islands will be the most affected by a decrease in refuse dump availability, while birds from the Ebro Delta and the Columbretes Islands will be influenced mainly by the optimization of fishery techniques, which will reduce the amount of discards. However, the colonies on Mazarrón Island and in the Ebro Delta have alternative food resources nearby, such as freshwater or terrestrial invertebrates, which could be more intensely exploited in the future. Drastic reductions in the gull population are expected on the Medes Islands, as their population holds one of the greatest densities of breeding pairs (Bosch et al. 2000) which depends mainly on these two foraging habitats during the whole chick-rearing period. In addition, as a consequence of the reduction of the carrying capacity of the ecosystem, we can predict increasing conflicts in the relatively short-term within Yellow-legged Gull colonies but also with endangered species breeding nearby, e.g., European Storm Petrels (*Hydrobates pelagicus*), Audouin's Gulls (*Larus audouini*), Greater Flamingos (*Phoenicopterus ruber*) and several species of herons (García-Morell and Escribano 2005; Vidal et al. 1998). Interactions with protected species may range from increasing disturbance to active persecution and predation on eggs, chicks, and even adults (Martínez-Abraín et al. 2003; Oro and Martínez-Abraín 2007).

Here, we addressed the spatiotemporal component in the use of distinct foraging habitats by Yellow-legged Gulls during the breeding season. Consistent with the opportunistic behavior of the species, several foraging habitats were identified depending on their availability and proximity to the colony. Using chick diet heterogeneity as an estimator of variability of the feeding habitats exploited, we can evaluate the presence and relevance of alternative food resources to refuse dumps and fishery discards. These results may help us to predict the effects of recent management decisions on gull population dynamics. Generalized reductions in Yellow-legged Gull populations are expected over its whole distribution range. Furthermore, the consumption of alternative food sources to fishing discards and refuse scraps, when available, will gain importance. In addition, a reduction in feeding resources will force some gulleries to increase predation on other species, some of which are endangered, with consequent conservation concern. The results and predictions presented here elucidate future scenarios which should be considered by management authorities in the relatively short term.

Zusammenfassung

Nahrungsangebot für die Küken der Mittelmeermöwe *Larus michahellis* entlang der spanischen westlichen Mittelmeerküste: die Bedeutung von Mülldeponien

Die Mittelmeermöwe *Larus michahellis* ist in den letzten Jahrzehnten zu einer Problemart in den Mittelmeerländern geworden, hauptsächlich wegen ihrer Interaktion mit den Interessen der Menschen, aber auch mit anderen Arten, die normalerweise geschützt sind. Momentan werden zwei verschiedene Aktionspläne der Europäischen Union entwickelt, die versuchen, die Verfügbarkeit von Futter zu reduzieren, das durch menschliche Aktivität anfällt (z.B. Müll und Fischereiabfälle) und als Hauptursache für die übergroßen Möwenpopulationen angesehen wird. Das Ziel

dieser Arbeit war, die Nahrung von Küken der Mittelmeermöwe zu beschreiben und insbesondere die Abhängigkeit der Populationen von Abfall zu ermitteln, um Änderungen in der Populationsdynamik der Möwen absehen zu können, die durch diese Management-Entscheidungen zustande kommen. Vier Kolonien entlang des westlichen Mittelmeers wurden beprobt: Medes-Inseln, Ebrodelta, Columbretes-Inseln und Mazarrón-Insel. Um die Nahrungsökologie der Möwen aufzuklären und es zu vermeiden, eine diskrete Schätzung von nur einer einzigen Beprobung zu erhalten, haben wir in jeder Kolonie hervorgewürgtes Futter dreimal während der Kükenaufzuchtsperiode gesammelt. Wir fanden unterschiedliche Nutzungen verschiedener Nahrungssuchhabitate an den vier Standorten. Die Nutzung von Mülldeponien war üblich und häufig in zwei der untersuchten Kolonien, auf den Medes-Inseln und der Mazarrón-Insel. Es konnte eine leichte Tendenz beobachtet werden, unterschiedlich alte Küken unterschiedlich zu füttern. In allen vier untersuchten Kolonien gab es die Tendenz, dass jüngere Küken durchweg mit kleinerer Beute, z.B. Invertebraten, versorgt wurden. Diese Ergebnisse könnten helfen zu verstehen, welche Auswirkungen die gegenwärtigen Management-Entscheidungen auf zukünftige Ereignisse und Veränderungen in der Populationsdynamik der Möwen haben werden.

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