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The diet of an endemic subspecies of the Eurasian Spoonbill *Platalea leucorodia balsaci*, breeding at the Banc d'Arguin, Mauritania

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In the period 1998–2010 the endemic subspecies of the Eurasian Spoonbill *Platalea leucorodia balsaci* breeding in Mauritania has decreased in numbers considerably. The causes for this decline are unknown. This study aimed to investigate the diet of the species. We analysed faecal material collected in the breeding colonies in 8 different years. The results show that Mauritanian Spoonbills almost exclusively eat shrimp (59.7%) and small fish (35.4%), the latter being dominated by Gobiidae (20.8%), Soleidae (4.8%) and Mugilidae (2.8%). Another 10 fish families were represented in small proportions. Shrimp were quantified on the basis of (parts of) mandibles present in the samples. All prey items eaten by the Spoonbills were extremely small. Diet composition of adult birds and chicks appeared to be similar. There was great variation in diet composition of adults between years, but there was no trend in any of the major diet components over the study period. This indicates that the decline of the Spoonbill population is not correlated with changes in food composition. Our diet study has been of a qualitative nature. Considering the dramatic population decline we plea for a more detailed ecological study of the species, including a quantitative approach of food intake and foraging conditions.

Key words: *Platalea leucorodia balsaci*, Eurasian Spoonbill, diet, otoliths, monitoring, Banc d'Arguin, Mauritania

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Population sizes depend on many different factors such as food, predation and weather (e.g. Begon *et al.* 1990, Gese & Knowlton 2001). These factors may interact, making it even more challenging to obtain a thorough understanding of population dynamics. Understanding population dynamics is of importance for conservation purposes, especially of threatened species as their small population size makes them vulnerable to extinction (Gilpin & Soule 1986, Shaffer 1981, Saether *et al.* 1998). The factors driving population fluctuations of threatened species are typically not known, however, and only studied once a sharp decline in numbers is observed. The African subspecies of the Eurasian Spoonbill, *Platalea leucorodia balsaci*, is such an example. The population size of this endemic breeding bird of the Parc National du Banc d' Arguin (Mauritania) is in sharp decline: population estimates, carried out between 1998 and 2010 have shown a decrease in numbers from roughly 6000 (1998–2002) to about 2500 individuals in recent years (Overdijk *et al.* 2001). In all years of observation the breeding colonies were irregularly and infrequently visited. Since breeding is spread over a prolonged period (March–September) no reliable data are available on the number of young fledged. The data available suggest that breeding success was very low in all years of observation except in 2010 when more than 2200 chicks (fledged or close to fledging) were found.

Several factors may be responsible for the decline of the Spoonbill population. In a number of cases the wardens of the park observed breeding failure due to raids by Common Jackals *Canis aureus* or flooding during high tides. They also found deserted colonies with dead chicks and adults, suggesting that disease plays a role. In 2009 and 2010, data obtained from birds equipped with satellite transmitters showed that colonies were deserted in the incubation or chick-rearing phase. This also occurred in colonies on Jackal-free islands and in situations in which flooding during high tides was unlikely (O. Overdijk, unpubl. data).

In colonial waterbirds and seabirds food shortages may lead to reduced breeding success and to nest desertion (Monaghan *et al.* 1992, Chaurand & Weimerskirch 1994, Chastel *et al.* 1995, Lorenz *et al.* 2002, Quillfeldt *et al.* 2003). This leads to the question whether food availability may have played a role in breeding failure and the subsequent decrease of the Mauritanian Spoonbill population.

In this paper we describe the results of a study investigating whether the population decline is correlated with a change in the composition of the diet. Previous studies have shown that Eurasian Spoonbills *P. l. leucorodia* feed predominantly on shrimp and small fish (Kemper 1995, van Wetten & Wintermans 1986, Aguilera *et al.* 1996) and we hypothesize that fluctuations in these food resources may cause a reduction in reproductive output and recruitment into the population. Spoonbills feed on nekton, which is caught by sieving small prey while making sideward movements with head and bill in shallow water. As a consequence, quantifying the diet of spoonbills is not a trivial task, as observing prey intake in the field is almost impossible. We therefore chose to use an indirect method to obtain information on diet composition by looking at prey remains in faeces, which are deposited around the nests. This is a potentially useful method provided that all important prey species are represented in the faeces with recognizable and quantifiable undigested remains. Faecal analysis has the additional advantage that it is easy to collect samples with little or no disturbance to the birds.

In this study we aimed to analyse the composition of the diet of the Spoonbills in retrospect, which was possible through an analysis of faeces collected between 1998 and 2010. We dealt with the following questions: (1) What was the diet of the Spoonbills during the study period, and (2) Were there any changes in diet composition over the years? Finally, we consider the possible relationship between diet and population changes.

METHODS

Study site and species

The Atlantic coast from Morocco to Guinea is characterized by the Sahelian Upwelling Marine Ecoregion, which results in an area of high biological productivity. Within the region the Parc National du Banc d'Arguin is of special importance. About half of the 12,000 km^2 of the park consists of shallow coastal waters with tidal flats which are partly covered by highly productive seagrass beds (Wolff & Smit 1990). The park is an important spawning and nursery area for fish (Campredon & Schrieken 1989, Jager 1993) and shrimp (Schaffmeister *et al.* 2006), which are preyed upon by large numbers of waterbirds, both migratory and resident. Spoonbills are one of the many species, and of special interest as they occur in large numbers (thousands) originating from two distinct populations. Adult European breeding Spoonbills of the subspecies *P. l. leucorodia* use the park as a wintering area. Juvenile birds of this population usually stay in the park, until they migrate to their European breeding areas when 3 to 5 years old. The park is also the home of the locally breeding and endemic subspecies *P. l. balsaci*, which is the subject of this study.

During the study period breeding colonies of *P. l. balsaci* were recorded on 10 islands spread over the Banc d'Arguin Park. The number of breeding birds per colony is highly variable as the birds easily move from one island to another between years. The Spoonbills of the Banc d'Arguin are almost completely resident, with small numbers wandering to neighbouring wetlands in southern Mauritania (Diawling) and northern Senegal (Delta of Senegal River) (Overdijk *et al.* 2001).

Eurasian Spoonbills forage singly or in small groups. Prey is caught standing or walking, in shallow water (depth till *c.* 40 cm), by sideward sweeping of the bill. Spoonbills breeding on the Banc d' Arguin find their food within 5 km from the breeding colony (O. Overdijk, unpubl. data). The birds seem to prefer feeding in pools on seagrass covered tidal flats in which small prey is trapped at low tide (van der Laan & Wolff 2006).

Diet analysis

The breeding season of the Spoonbills at the Banc d'Arguin lasts from March to September. Breeding Spoonbills defecate while standing or sitting on the nest and faeces are usually deposited on the nest rim or just beside the nest. Faeces of chicks, which are smaller, usually end up within the nest cup. Under the tropical conditions at the Banc d'Arguin faeces quickly dry out,

Figure 1. Droppings of chicks (left) and adult (right) Spoonbills collected on 1 June 2002 in a colony on the Island of Nair, Banc d'Arguin, Mauritania.

after which they may remain more or less intact for several years. This makes it possible to also collect droppings outside the breeding season. We collected the material analysed in this study during the breeding season (April–June 2002, 2005, 2008, 2009 and 2010) as well as after the breeding season had ended (collection in January–February following the breeding seasons of 1998, 1999, 2000, 2002). In the latter case we assumed that the material collected originated from the previous years' breeding attempts. During a typical visit, a representative part of the breeding colony was visited and droppings were collected. This method is easy to execute but introduces some methodological constraints as addressed in the Discussion. The droppings collected usually had a cylindrical shape and followed a bimodal size distribution resulting in two dominant size classes with a diameter of 3–5 and 6–10 mm. Based on experience with European-breeding spoonbills (*P. l. leucorodia*), it is assumed that these types of droppings belong to chicks and adult birds, respectively. In all samples droppings of adult birds were found in much higher frequencies than droppings of chicks. In order to investigate the potential effect that a mixture of dropping types may have on the diet composition, we separately analysed the droppings of adults and chicks collected in one colony in 2002 (Figure 1).

After collection, the droppings were kept in plastic bags and stored under dry conditions. They were then put in 15 × 25 cm bags made out of plankton netting with a mesh size of 0.3 mm (Scrynel PA 300/47) and soaked for 24 hours in hot water with washing powder. If necessary, droppings were then gently rubbed by hand until they fell apart, after which the droppings (still in the plankton netting bags) were put in a standard washing machine to be washed at 70°C (pre-wash and main washing program with washing powder, no use of centrifuge). Washed samples were dried and spread out on black cardboard for inspection under a binocular microscope (Novex zoom, 6–45×). Samples were first searched for fish otoliths and then another 4 times for other recognizable and quantifiable parts of prey (including otoliths overlooked during the first search). Only two types of prey appeared to be abundantly present: fish otoliths and shrimp mandibles. For both prey types, the numbers found during successive searching rounds strongly decreased until few new items were found. We present estimates for the detection probability for both diet types (see below for statistical procedure).

Otoliths were extremely small (length typically ranged from 0.3–2.5 mm, but more than 95% were less than 2.0 mm in length) and often failed to show species-specific characteristics. Most otoliths could be identified at the family level. Shrimp mandibles were also small. Shrimp mandibles were generally damaged and in most cases we collected separate molar and incisor processes. Shrimp mandibles (or their parts) all looked morphologically similar and we were not able to identify any shrimp or prawn species. Other prey remains were found in small numbers and could only be partly identified at the species level.

Otoliths (only sagittae) were identified, using reference collections of VEDA consultancy and the Royal Natural History Museum, Brussels, together with literature sources (Nolf *et al.* 2009, Veen & Hoedemakers 2005).

Prey remains were categorized as follows: (a) fish otoliths (only sagittae), (b) shrimp mandibles (molar or incisor processes, whichever were most abundant), (c) claws of crabs, (d) shells of gastropods, (e) jaws of worms and (f) unknown. All categories refer to remains that are present in pairs in the intact individual, except for the gastropod shells. The latter were extremely rare and we therefore present the prey remains found in numbers without compensating for the slight overrepresentation of the gastropods.

Statistical procedure

The detection probability p of a prey item follows a geometric distribution which requires the assumptions that each round of searching is independent and p is the same across rounds. The probability to detect an item in round k is given by $(1–p)^{k–1}\times p$. This distribution was truncated to only include the number of rounds searched by normalising p in each round by the sum of the probabilities over all rounds. We numerically obtained the maximum likelihood estimate of the detection probability for otoliths and shrimp mandibles and their 95% confidence interval (approximated by the range of values falling within 1.92 units of the maximum likelihood estimate).

As most of the faeces collected probably contained a small proportion of chick droppings we first tested whether the diet of chicks differed from that of adults, using Pearson's Chi-squared test. In the next step we investigated whether diet composition changed over the years. The diet data consisted of proportions, which are 'sum constrained', i.e. add up to 1. This is accounted for with an *ln*-ratio transformation (Aitchison 1986, Kucera & Malmgren 1998). The dependent variables (diet items, n in total) are

$$y'_i = \ln\left(\frac{y_i}{(\prod_{i=1}^{n} y_i)^{\frac{1}{n}}}\right),$$

where y_i is the proportion of the diet represented by the i^{th} diet item and $(\prod_{i=1}^{n} y_i)^{\frac{1}{n}}$ is the geometric mean of a diet item. After this transformation we analysed the relationship between years and different diet types using linear regressions. We had no *a priori* predictions regarding the relationship between food abundance and population size and therefore included a quadratic term to test for non-linear relationships. Model fit was assessed using an analysis of variance (Crawley 2007). Potential correlations between shrimp, fish and 'other prey' were evaluated using Pearson's correlation coefficient (qualitatively the same results were found using the Spearman test which allows for non-normally distributed data). All statistical analyses were performed in R 2.15 (R Development Core Team 2012).

RESULTS

The diet

An overview of all prey remains found in the samples is given in Table 1. We recorded mainly shrimp (59.7%) and fish (35.4%) in the faeces of the Mauritanian Spoonbills. Furthermore, small numbers of crabs, gastropods, worms and unknown prey remains (all less than 2%) were identified. Among the fish there was a clear dominance of Gobiidae (20.8%), followed by Soleidae (4.8%) and Mugilidae (2.8%). Another 10 fish families were represented in small proportions (all less than 2%; combined 7.1%). Many otoliths could not be

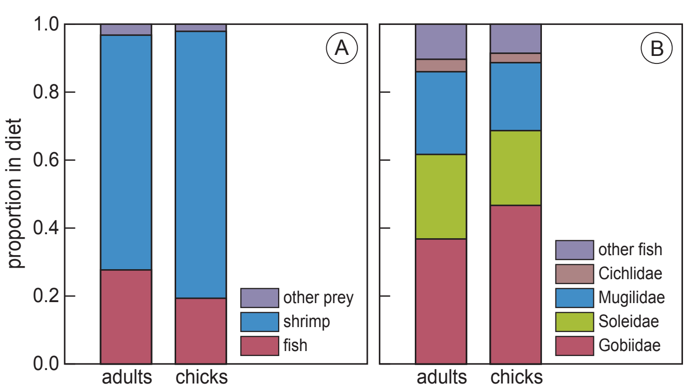

Figure 2. Diet composition of adult Spoonbills and Spoonbill chicks (nestlings) based on an analysis of faeces collected on 1 June 2002 in a colony on the island of Nair, Banc d' Arguin, Mauritania. The three major diet groups are presented in A (based on 1401 and 1303 prey remains extracted from adult and chicks faeces, respectively) and diet composition of fish families in B (based on 382 and 251 otoliths extracted from adult and chicks faeces, respectively).

identified at the species level because of their small size. Based on differences in shape and structure we estimated the presence of at least 25 fish species in the material analysed. The detection probability for a given otolith was 0.95 (confidence interval: 0.95 – 0.95) and for a shrimp mandible 0.59 (0.56 – 0.61).

Differences between adults and chicks

The diet composition of adults and chicks collected from the same colony in 2002 were similar (Figure 2). Although the differences were small, the proportions of shrimp, fish and others did differ significantly (Pearson's Chi-squared test, $\chi^2 = 26.65$, $df = 2$, $P < 0.001$), but the proportions of the most frequently recorded fish families did not (Pearson's Chi-squared test, $\chi^2 = 6.63$, $df = 4$, $P = 0.157$, Figure 2B). As the difference in diets of adults and chicks was small, and the proportion of presumed droppings from juveniles (0–15%) was also small, we assumed that lumping all faecal samples provided an unbiased estimate of the Spoonbill diet.

Diet differences between years

Large fluctuations in diet composition were observed between years (1998–2010) with shrimps varying from 31.6–85.7%, fish from 8.4–56.8% and 'other prey' from 1.2–19.5% (Figure 3). In 2005 the proportion of fish was extremely low. There were no trends over the study period in any of the prey items. The term *year*^{2} was excluded from the fish model ($F = 0.433$, $P = 0.540$) and rest-group ($F = 1.036$, $P = 0.355$) and year was insignificant in both final models (Table 2). The quadratic year term was retained in the shrimp model ($F = 20.104$, $P = 0.006$) (Table 2). Correlations between the three diet categories were all negative and non-significant.

The occurrence of the dominant fish families fluctuated among years, but no significant trend was found (Figure 4). The Gobiidae occurred with the highest frequency, with the exception of 2005. The data from 2005 have to be assessed with care as sample sizes were low ($n = 20$ summed over the four categories)

Table 1. Overview of all prey remains found in faeces of Mauritanian breeding Spoonbills *Platalea leucorodia balsaci* collected between 1998 and 2010 in breeding colonies on the Banc d'Arguin, Mauritania. Number and % of diet refer to all prey items found (summed for all years); mean of yearly % refers to the average of yearly percentages.

	Family	Species	Number of items	(%)	Mean of yearly %
Fishes	Atherinidae	*Atherina* spec.	170	(1.19)	1.12
	Batrachoididae	*Halobatrachus didactylus*	11	(0.08)	0.13
	Bothidae	Unknown	1	(0.01)	0.01
	Cichlidae	Unknown (1–3 species)	286	(1.99)	4.16
		Saratherodon melanotheron	8	(0.06)	
	Gerreidae	*Eucinostomus melanopterus*	5	(0.04)	0.04
	Gobiidae	Unknown (>5 species)	2,935	(20.50)	19.10
		Gobius paganellus	47	(0.33)	
	Labridae	Unknown	16	(0.11)	0.17
	Moronidae	*Dicentrarchus punctatus*	7	(0.05)	0.06
	Mugilidae	Unknown (1–3 species)	395	(2.76)	1.84
	Polynemidae	*Galeoides decadactylus*	1	(0.01)	0.03
	Sciaenidae	*Umbrina* spec.	1	(0.01)	0.02
	Soleidae	*Microchirus* spec.	1	(0.01)	3.60
		Solea senegalensis	689	(4.81)	
	Sparidae	Unknown (>5 species)	145	(1.01)	1.02
		Diplodus sargus	7	(0.05)	
	Indeterminata		337	(2.35)	3.05
Shrimps	Palaemonidae	Unknown	8,543	(59.67)	58.45
Crabs	unknown		34	(0.24)	0.25
Gastropods	Hydrobiidae	*Hydrobia ulvae*	257	(1.80)	1.64
Worms	Nereidae	*Nereis* spec.	148	(1.03)	1.12
Unknown			270	(1.89)	4.19
Total			14,317	(100.00)	100.00

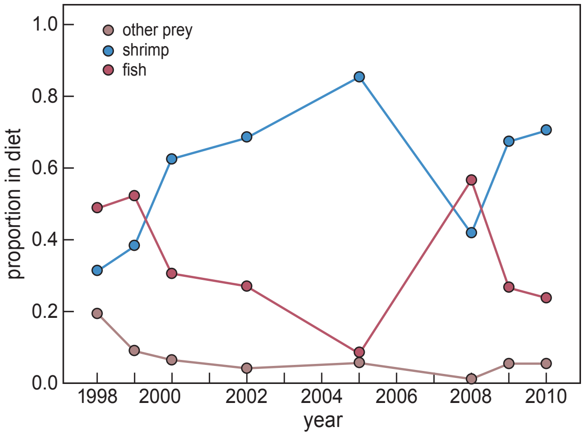

Figure 3. Diet composition (all prey items) of adult Spoonbills in successive years on the Banc d'Arguin, Mauritania.

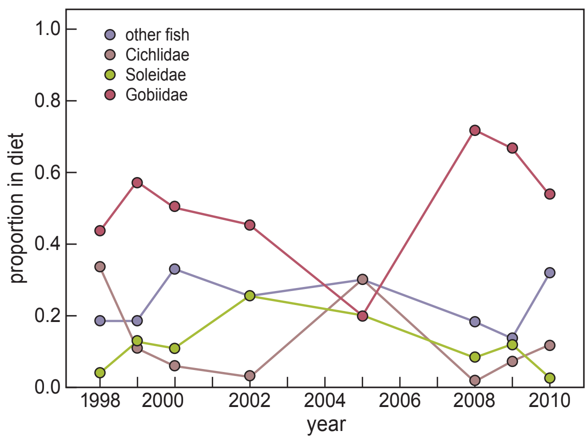

Figure 4. Composition of the proportion of fish in the diet of Spoonbills in successive years on the Banc d'Arguin, Mauritania. Regression analyses detected no trends over the years (Gobiidae, $F_{1,6}$ = 0.64; Soleidae, $F_{1,6}$ = 0.04; Cichlidae, $F_{1,6}$ = 0.34; other fish, $F_{1,6}$ = 0.42; all non-significant).

DISCUSSION

The diet of the Spoonbills consisted mainly of fish and shrimp, irrespective of age (adult or chick). Diet composition fluctuated considerably between years, but there were no significant trends over the years which could be linked with the population decline.

Our results show great similarity with diet composition found in other studies on spoonbills feeding in salt water habitat, as those also indicate spoonbills to be almost exclusively shrimp and fish eaters. Ueng *et al.* (2007) report finding 94% fish (predominance of Gobiidae and Mugilidae) and 4% shrimp in an analysis of the stomach contents of 43 Black-faced Spoonbills *Platalea minor* from Taiwan. In The Netherlands, fish (Gobiidae) and shrimp (*Crangon crangon*) are reported to be the main food source for the Eurasian Spoonbill by several authors (Tinbergen 1934, van Wetten & Wintermans 1986, Kemper 1995, Wintermans 2002). In our diet analysis several other prey species or species groups were found in small proportions such as worms and gastropods. Swennen & Yu (2005) mention that the Black-faced Spoonbill does not feed on benthic prey. While bivalves and gastropods were abundant in their study area, the birds rarely ate them and stopped feeding when no shrimp and fish were caught. They state that the gizzard of spoonbills is not a strong chewing organ, so strong-shelled species cannot be digested. At the Banc d' Arguin bivalves and gastropods are common as well and we suggest that the small proportion of 'other prey' in our samples refers to prey items accidentally swallowed.

The great overlap in diet composition in marine environments may result from similarities of feeding behaviour (combined with the co-occurrence of similar food resources). The spoonbills breeding at the Banc d'Arguin seem to be very similar in this respect to what has been described for other *Platalea* species: they feed

Table 2. Results of a regression analysis of the three main transformed diet components: fish, shrimp and all other prey types grouped together (see Table 1), against year and year^2.

Diet component		Estimate	SE	*t*	*P*
Fish	Intercept	11.388	97.449	0.117	0.911
	Year	–0.006	0.049	–0.113	0.914
Shrimp	Intercept	-1.084×10^5	2.414×10^4	–4.490	0.006
	Year	1.081×10^2	2.410×10	4.487	0.006
	Year^2	–0.027	0.006	–4.484	0.007
Other prey types	Intercept	132.069	80.490	1.641	0.152
	Year	–0.067	0.040	–1.657	0.149

on small nekton by sweeping their bills horizontally in shallow water. They probably do not hunt for a specific prey species but take all that can be caught and swallowed as has been suggested for the Black-faced Spoonbill (Swennen & Yu 2005), Roseate Spoonbill *Platalea ajaja* (Allen 1942), Royal Spoonbill *Platalea regia* (Lowe 1982) and Yellow-billed Spoonbill *Platalea flavipes* (Vestjens 1975).

The Spoonbills of the Banc d'Arguin almost exclusively took very small prey (an estimated 95% of fish were smaller than 5 cm). This is in agreement with findings for other *Platalea* species feeding in salt water habitat. For the Black-faced Spoonbill, Swennen and Yu (2005) report 97% of prey being smaller than 5 cm and only 3% larger. For the Eurasian Spoonbill, fish of 3–8 cm is a typical food item (Wintermans 2002).

Our results show that one can detect considerable diet variation, including in small prey types, by extracting and analysing hard bony structures from faeces. For hard-to-monitor locations like West Africa, this method may provide a cost and time effective monitoring tool. Our sampling and analysing method did not allow us to look at the diet composition of an individual, the preferred level of statistical analyses, as all the samples were pooled and thus may contain droppings from the same individual or parents and their nestling. This approach resulted in the (unavoidable) treatment of each bony structure as an independent data point, increasing our sample sizes, which may lead to inflated significance levels. This does not affect the interpretation of our non-significant results (with the exception of the differences between adults and chicks which we interpreted of being of little biological significance). We recommend future sampling programs to sample, if possible, one individual dropping per nest and select nests not adjacent to one another to reduce the sampling of the same individual multiple times. Subsequently, the droppings can be individually analysed and used as the sampling unit, but this will cost considerably more time than the approach taken here.

There was considerable variation between years in the proportion of shrimp and fish as well as in the composition of the fish portion of the diet. With the exception of 2005, the Gobiidae were clearly the most numerous fish family in the diet of the Spoonbills (Figure 3). The strong correlation between Gobiidae and proportion of all fish in the diet suggests that the availability of this family may be of particular importance for the Spoonbills. If a monitoring scheme for avian food resources were started at the Banc d'Arquin in the future, we would recommend the inclusion of Gobiidae as a proxy for fish availability for Spoonbills.

The aim of this study was to determine whether changes in diet composition from year to year could provide new insights into the population decline of the Mauritanian subspecies of the Eurasian Spoonbill. We did not find a trend in any of the major diet components over the study period. We therefore have no evidence that diet composition, which likely reflects food availability, caused the population decline of the Spoonbills during the past decade. Unfortunately, we have no data on food availability, which could improve a mechanistic insight into diet fluctuation. We also lack information on the amount of food eaten and its consequences for body condition. We therefore plea for a more detailed ecological study of this critically endangered endemic subspecies, including food availability and food intake. This should be done concurrently with observations on other factors supposed to affect breeding success, such as predation by Jackals and flooding by high tides.

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SAMENVATTING

De in Mauritanië broedende endemische ondersoort van de Lepelaar *Platalea leucorodia balsaci* is in de periode 1998–2010 sterk in aantal achteruitgegaan. Het is onbekend wat hiervan de oorzaak is. In deze studie wordt het voedsel van de Lepelaars onderzocht op basis van een analyse van uitwerpselen die in acht verschillende jaren in de broedkolonies zijn verzameld. De resultaten tonen aan dat de Lepelaars vrijwel uitsluitend garnalen (59,7%) en kleine vissen (35,4%) aten. Wat de vissen betreft, vonden we vooral vertegenwoordigers van de familie der Gobiidae (20,8%). Vissen en garnalen werden vastgesteld op basis van respectievelijk otolieten (gehoorsteentjes) en (delen van) kaakjes. De garnalen konden niet op soortniveau gedetermineerd worden. Hetzelfde gold voor veel otolieten. Alle gegeten prooien bleken erg klein te zijn. Het voedsel van volwassen dieren en hun kuikens was grotendeels hetzelfde. De samenstelling van het voedsel van de volwassen dieren vertoonde grote verschillen tussen de jaren. Voor geen enkele prooisoort werd echter een duidelijke trend binnen de onderzoeksperiode gevonden. Hieruit blijkt dat de achteruitgang van de onderzochte populatie Lepelaars niet gecorreleerd is met veranderingen in de voedselsamenstelling. Daarbij moet echter benadrukt worden dat ons onderzoek kwalitatief van aard was. Gezien de dramatische achteruitgang van de populatie wordt gepleit voor een meer gedetailleerde ecologische studie, waarbij tevens aandacht wordt besteed aan voedselopname en voedselaanbod.

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