The Diet of the Glossy Ibis During the Breeding Season in Doñana, Southwest Spain

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Abstract.—We present the first detailed study of the diet of Glossy Ibis (*Plegadis falcinellus*) in Europe, from an expanding breeding colony in Doñana, southwest Spain. In 2000, fecal samples, mainly from adults, were collected from 15 nests. In 2001, 36 regurgitates were collected, mainly from large chicks. Fecal contents were dominated by aquatic beetles (Coleoptera) and dragonfly (Odonata) larvae, which were present in 100% and 93% of samples respectively. Regurgitates contained mainly aquatic beetles (41% by aggregate percent, mainly *Cybister* spp.), dragonfly larvae (29%, mainly *Sympetrum fonscolombei*, *Aeshna mixta* and *Anax imperator*), Sharp-ribbed Salamanders (*Pleurodeles waltl*, 12%) and Carp (*Cyprinus carpio*, 7%). The absence of vertebrate and other hard remains from feces was presumably due to their excretion in pellets. Thus fecal analysis is not a suitable method to investigate the food of the Glossy Ibis. The results suggest that there may be no major difference in the diet of breeding adults and their chicks, and that the recent increase in numbers of this ibis in Doñana is not explained by the abundance of introduced Red-swamp Crayfish (*Procambarus clarkii*) in the breeding area. *Received 23 October 2003, accepted 18 February 2004.*

Key words.—Diet, Doñana, fecal analysis, food items, Glossy Ibis, Odonata, *Plegadis falcinellus*.

Waterbirds 27(2): 234-239, 2004

Although the Glossy Ibis (*Plegadis falcinellus*) is the most widely distributed ibis species (del Hoyo *et al.* 1992), it is a species of conservation concern in Europe where it is in decline (Tucker and Heath 1994). The Glossy Ibis is considered IUCN Vulnerable in Spain (Figuerola *et al.* 2003). However since 1996, a new colony has been established in Doñana, Spain which has rapidly increased to become the largest colony in western Europe and held 370-400 pairs in 2002 (Figuerola *et al.* 2003).

The few detailed studies of Glossy Ibis diet that have been conducted to date (Acosta *et al.* 1996; see review by Davis and Kricher 2000) have been carried out outside Europe. Here, we present a study of the diet within the breeding colony in Doñana. We compared results from fecal analysis and from regurgitates, and looked for changes in diet composition within a breeding season. We test the hypothesis that the dramatic increase of ibis in Doñana can be explained by its consumption of the recently introduced Red-swamp Crayfish (*Procambarus clarkia*) which is extremely abundant in the study area (Gutiérrez-Yurrita and Montes 1999). Crayfish and crabs are consumed by ibis elsewhere (Acosta *et al.* 1996; Davis and Kricher 2000). We also consider the implications of our results for the conservation of the species in Spain and elsewhere.

STUDY AREA AND METHODS

The Glossy Ibis studied were breeding together with six heron species in a colony in a *Typha* bed in the Lucio de la FAO (also called the Lucio Cerrado Garrido), an artificial lake of 60 ha just inside the northern edge of Doñana National Park in Andalusia, southwest Spain (37°05'N, 6°23'W). The lake is fed with water extracted from an underlying aquifer and conductivity is below 5 mS cm^{-1}. Ibis feces and regurgitates were collected during the course of banding operations conducted with the aim of marking a high proportion of ibis chicks with metal and PVC bands. Dates of entry into the colony were chosen when there were many large chicks. On 14 June and 6 July 2000, samples of fresh feces were taken from 15 nests. Most nests sampled contained only eggs and/or small chicks, and thus most fecal samples were from adults. In 2001, an increase in the colony size made it easier to collect regurgitate samples, and we obtained 29 on 24 May, three on 15 June, two on 6 July and two on 19 July. Most regurgitates were obtained from chicks during handling, but some found in the nests may have been from adults attending their chicks or eggs.

Fecal samples were stored individually in tubes and air-dried. They were rehydrated in water for 24 h prior to analysis and shaken using a Heidolph vortex to loosen them. Both feces and regurgitates were washed in a sieve

(0.04 mm for feces), and the retained material preserved in 70% ethanol and examined with a 10-25× binocular microscope. Regurgitates were composed mainly of large organisms and most were washed in a 1 mm sieve. Only five were washed in a 0.04 mm sieve. The abundance of small organisms such as ostracods, cladocerans or chironomid larvae may thus have been underestimated in our study. However, such organisms constituted a very small proportion of the ingested biomass.

Animal and plant food items were sorted and identified to the lowest possible taxonomic level, using reference material of potential food items collected at the study sites with sweep nets, together with suitable keys (see Green and Selva 2000; Sánchez *et al.* 2000). Dragonfly larvae from regurgitates were identified to species following Askew (1988). The volume of the fecal sample represented by each food item was estimated using three categories of abundance: absent, <10% and ≥10% of total volume. The volume of the contents of regurgitates were measured by displacement. For organisms or fragments of volume <0.01 ml, volume was estimated from linear measurements. Volumetric measurements of all food items in regurgitates were expressed as the mean of individual volumetric percentages from each sample (aggregate percent) and/or percentage of total volume combined for all samples (aggregate volume; Swanson *et al.* 1974). Aggregate percent is generally considered a more representative measure of diet composition, as it corrects for differences in sample volume (Swanson *et al.* 1974).

RESULTS

Fecal samples from the 2000 breeding season were dominated by Odonata larvae and aquatic beetles (Coleoptera adults and larvae) which made up >10% of the volume of 93% and 100% of samples respectively (Table 1). A variety of other insects (especially Corixidae and Diptera) and other aquatic invertebrates were also recorded, as were small quantities of plant material (Table 1).

A greater variety of food items was recorded in the regurgitates from the 2001 breeding season, and the good condition of the largely undigested items allowed a more complete taxonomic description of the major invertebrate groups (Table 1). Odonata larvae (97%) and Coleoptera (92%) were again the groups with the highest percentage occurrences. At least six species of Odonata were present (Table 3). Some 56% of larvae were Libellulidae (mainly *Sympetrum fonscolombei*) and 34% were Aeshnidae (mainly *Aeshna mixta* and *Anax imperator*, Table 3). The unidentified Coenagrionidae were probably *Ischnura graellsi*, the dominant zygopteran in the study area.

Molluscs, decapod crustaceans (the Red Swamp Crayfish), fish (Carp *Cyprinus carpio*) and amphibians (adult and larval Sharp-ribbed Salamanders *Pleurodeles waltl*) were all absent from feces, yet observed frequently in regurgitates (Table 1). These groups all have hard parts likely to be expelled as pellets following digestion rather than as a component of feces. A variety of aquatic seeds were observed in small quantities in both feces and regurgitates, including *Ranunculus* (N = 4 samples), *Salicornia* (N = 2), *Zannichellia* (N = 3), *Phragmites* (N = 1), *Scirpus* (N = 2) and *Ruppia* (N = 1) seeds. Charophyte oogonia were also recorded (Table 1).

Volumetric measurements showed that Coleoptera, Odonata, fish and amphibians were the most important dietary components in regurgitates (Table 2). By aggregate percent, Coleoptera constituted 41% (36% Dytiscidae, mainly *Cybister* spp. larvae), Odonata 29% (12% Aeschnidae and 15% Libellulidae), amphibians 12% and carp 7% of food items. Because samples containing vertebrates tended to be particularly voluminous, amphibians (24%) and carp (11%) were relatively more important by aggregate volume, although invertebrates (65%) remained dominant (Table 2). Crayfish (6% by aggregate percent, 7% by aggregate volume) were the only other group of food items that exceeded 5% in either of the volumetric measures.

There were no statistically significant seasonal trends in major food items (Tables 1 and 2). Between May and June-July, the proportion of regurgitate volume represented by salamanders decreased while that of carp increased (Table 2), but these differences were not statistically significant (Mann-Whitney U tests, N = 7, 29, U = 92.5 for carp, U = 65.5 for salamanders, both n.s.).

DISCUSSION

This is the most detailed study of Glossy Ibis diet to date from a breeding colony anywhere, and the first detailed study of diet in Europe. We found diet to be dominated by aquatic Coleoptera and Odonata at different times of the breeding season and in different

Table 1. Percentage occurrence of food items in Glossy Ibis regurgitates and feces (PO) and the percentage of fecal samples in which the given item represented at least 10% of volume (V≥10). Samples for May and June-July are analyzed separately. Sample sizes are given in parentheses. L = larvae, A = adults. Odonata and Coleoptera could not be identified to family level in feces.

	Regurgitates PO (36)			Feces (15)	
	May (29)	June/July (7)	Total	PO	V ≥ 10
Plant material	**21**	**43**	**25**	**40**	**7**
Angiosperm seeds	21	29	22	20	—
Charophyte oogonia	3	14	6	7	—
Green plant material	—	—	—	27	7
Invertebrates	**100**	**86**	**97**	**100**	**100**
Bryozoan statoblasts					
Plumatella spp.	14	14	14	33	—
Nematoda	—	14	3	—	—
Mollusca					
Gastropoda	41	57	45	—	—
Bivalvia	7	—	6	—	—
Crustacea					
Ostracoda	7	—	6	7	—
Cladoceran ephippia	17	14	17	13	—
Decapoda: *Procambarus clarkii*	10	—	8	—	—
Insecta					
Odonata	100	86	97	93	93
Zygoptera (L)	10	29	14		
Aeschnidae (L)	72	71	72		
Libellulidae (L)	93	71	89		
Coleoptera	97	71	92	100	100
Dytiscidae (LA)	90	71	86		
Hydrophilidae (LA)	24	—	19		
Calchididae	3	14	6	7	—
Formicidae	—	29	6	—	—
Notonectidae (A)	10	14	11	—	—
Corixidae (A)	38	29	36	80	—
Chironomidae (L)	3	—	3	40	—
Other Diptera (L)	14	57	22	20	—
Unidentified Insects	3	14	6	20	—
Arachnida	7	29	11	-	—
Unidentified invertebrates	10	14	11	13	—
Unidentified invertebrate eggs	3	—	3	13	—
Vertebrates	**66**	**86**	**69**	—	—
Unidentified bone fragments	14	43	19	—	—
Amphibia: *Pleurodeles waltl*	48	14	42	—	—
Fish: *Cyprinus carpio*	28	29	28	—	—

years. Coleoptera and Odonata appear to be dominant in the diet of both breeding adult ibis (as indicated by fecal analysis) and chicks (as indicated by regurgitates). These results contrast with studies from other parts of the range, although one chick studied in Australia had been fed mainly on Odonata and Coleoptera (Lowe 1983). Four chicks in Florida had been fed on Orthoptera, crayfish, moth larvae (Noctuidae) and snakes (Davis and Kricher 2000). In Cuban rice fields, ibis collected in the breeding season had fed mainly on crabs and Coleoptera, with some Odonata and rice grains (Acosta *et al.* 1996).

The analysis of regurgitates is a better method than fecal analysis for the study of ibis diet, especially because vertebrate remains were not represented in the latter. The regurgitates we obtained were largely undigested, and we do not think that our volumetric analysis underestimated the importance of soft bodied prey items (e.g., we

Table 2. Percentage of total volume (aggregate volume) and mean of volumetric percentages (aggregate percent) of food items in Glossy Ibis regurgitates. Samples for May and June-July are analyzed separately. Sample sizes are given in parentheses. L = larvae, A = adults. Tr < 0.001%.

	Aggregate Volume			Aggregate percent		
	May (29)	June/July (7)	Total (36)	May (29)	June/July (7)	Total (36)
Plant material	0.02	0.01	0.01	0.5	0.07	0.5
Angiosperm seeds	0.02	0.006	0.01	0.5	0.05	0.4
Charophyte oogonia	Tr	0.005	Tr	Tr	0.02	0.003
Invertebrates	69	46	65	82	71	80
Bryozoan statoblasts *Plumatella* spp.	Tr	Tr	Tr	0.001	Tr	0.001
Nematoda	—	Tr	Tr	—	Tr	Tr
Mollusca						
Gastropoda	0.9	0.9	0.9	2	10	3
Bivalvia	0.01	—	0.008	0.02	—	0.02
Crustacea						
Ostracoda	Tr	—	Tr	Tr	—	Tr
Cladoceran ephippia	0.01	0.001	0.007	0.01	Tr	0.01
Decapoda: *Procambarus clarkii*	8	—	7	7	—	6
Insecta						
Odonata	24	8	22	32	19	29
Zygoptera (L)	0.03	0.2	0.06	0.08	0.4	0.1
Aeschnidae (L)	18	3	15	14	8	12
Libellulidae (L)	7	4	6	18	11	17
Coleoptera	35	37	35	41	41	41
Dytiscidae (LA)	34	37	34	35	40	36
Hydrophilidae (LA)	0.8	—	0.7	0.9	—	0.8
Notonectidae (A)	0.005	0.001	0.004	0.007	0.005	0.006
Corixidae (A)	0.005	0.001	0.004	0.01	0.001	0.01
Chironomidae (L)	Tr	—	Tr	Tr	—	Tr
Other Diptera (L)	0.02	0.2	0.06	0.09	0.9	0.3
Formicidae	—	0.03	0.006	—	0.2	0.03
Calchididae	Tr	Tr	Tr	Tr	Tr	Tr
Unidentified insects	0.003	0.006	0.004	0.05	0.09	0.06
Arachnida	0.02	0.09	0.03	0.01	0.3	0.06
Unidentified invertebrates	0.008	0.01	0.008	0.04	0.005	0.03
Unid. invertebrate eggs	Tr	—	Tr	Tr	—	Tr
Vertebrates	31	54	35	17	29	19
Unid. bone fragments	0.001	0.007	0.002	0.002	0.09	0.02
Amphibia: *Pleurodeles waltl*	29	0.6	24	16	0.3	3
Fish: *Cyprinus carpio*	2	53	11	2	28	7

observed intact chironomid larvae and salamander larvae). On the other hand, in the absence of information on the digestibility of different prey, we do not know how the volumetric analysis reflects the energy acquired via the ibis. It is possible that vertebrate prey provided more calories per unit volume ingested, although salamanders may be relatively indigestible because of their toxic skin (Duellman and Trueb 1986).

The Doñana marsh ecosystem has been affected by the introduction of the Red Swamp Crayfish to the area in 1974 from Louisiana (Gutiérrez-Yurrita and Montes 1999). Despite the fact that crayfish and crabs were important food items in some other studies (Acosta *et al.* 1996; Davis and Kricher 2000), our results do not suggest that the recent colonization of Doñana by Glossy Ibis is related to the availability of crayfish prey during the breeding season. With the exception of carp (introduced over two centuries ago), ibis feed mainly on autochthonous prey, especially insects. The crayfish may have reduced the biomass of aquatic insects available to birds, as they feed

Table 3. Odonata larvae identified in Glossy Ibis regurgitates in 2001, listing numbers of individuals (N) and percentages of the total recorded (%). Not all larvae were sufficiently intact to enable specific identification.

Taxa	N	%
F. Coenagrionidae	**33**	**10**
Ischnura spp.	2	0.6
Unidentified Coenagrionidae	31	10
F. Aeshnidae	**109**	**34**
Aeshna mixta	64	20
Anax imperator	38	12
Anax sp.	1	0.3
Unidentified Aeshnidae	6	2
F. Libellulidae	**180**	**56**
Sympetrum fonscolombei	159	49
Sympetrum sanguineum	6	2
Sympetrum sp.	2	1
Crocothemis erythraea	8	2
Unidentified Libellulidae	5	2

on and compete with insects (Gutiérrez-Yurrita *et al.* 1998). Outside the breeding season, when ibis concentrate in nearby rice fields during the harvest from October to December, we have often observed Glossy Ibis taking crayfish, but we have been unable to collect pellets or regurgitates from ibis during the non-breeding season.

Previous work (Aguesse 1962; Bigot and Marazanof 1965; Montes *et al.* 1982) on the availability of different aquatic insects in the seasonal marshes in Doñana National Park suggests that ibis may show relative selection of *Sympetrum fonscolombei* amongst the Odonata and of Dytiscidae amongst the Coleoptera, although further work is required to confirm this. We have found ibis to be dependent on prey items available in the relatively freshwater, seasonal, natural marshes. They do not feed in the large areas of permanent, brackish marshes that are too saline to support Odonata and large Coleoptera. In contrast, these brackish marshes provide suitable foraging areas for breeding flamingoes and the Marbled Teal (*Marmaronetta angustirostris*) (Green and Sánchez 2003). The dependency of ibis on the freshwater marshes may have prevented them from breeding, during particularly dry years (e.g., the colony was not active in 1999, Figuerola *et al.* 2003) and makes their conservation in western Europe heavily reliant on the future of these freshwater marshes, which are highly threatened by water extraction and climate change (Manzano 2001).

ACKNOWLEDGMENTS

The Equipo de Seguimiento de los Procesos Naturales de la Estación Biológica de Doñana, Fernando Hiraldo, Jordi Figuerola, Cristina Fuentes and Francisco Vilches helped to collect the samples. Cristina Fuentes helped in the data analysis. Carlos Fernández-Delgado identified the fish. Juan A. Amat and Eduardo Aguilera provided helpful comments on an earlier version of the manuscript.

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