Avocetta N° 25 (2): 283-287 (2001)

Purple Heron diet in northern Spain. Differences between feeding areas and between sampling methods

FRANCISCO CAMPOS[1], JESUS M. LEKUONA[2], MARIA RIOS[1] and RAFAEL MIRANDA[1]

[1]*Department of Zoology and Ecology, Faculty of Sciences, University of Navarra, E-31080 Pamplona, Spain. E-mail: fcampos@unav.es*
[2]*Virgen del Puy, 5, E-31011 Pamplona, Spain*

Abstract - Purple Heron (*Ardea purpurea*) diet was analysed by observing foraging adults in rivers and ricefields in northern Spain and by taking food samples from nests (pellets, food remains and spontaneous regurgitates). Diet composition varied between feeding areas (fish were the most abundant prey in rivers and crayfish *Procambarus clarkii* in ricefields) and sampling methods (direct observations underestimated the importance of insects and overestimated crustaceans and amphibians). The Purple Herons in the study area seemed to have adapted their diet to a new trophic resource (the crayfish) recently introduced in the study area.

Introduction

The diet of the Purple Heron *Ardea purpurea* has been thoroughly analysed in several European countries (Vasvari 1930, 1938, Owen and Phillips 1956, Amat and Aguilera 1978, Moser 1984, Rodríguez and Cañavate 1985, Fasola *et al.* 1993, Campos and Lekuona 1997). These studies underline the geographical variation in diet although fish are almost always the main prey. Nonetheless, there are few recent studies on the diet of the Purple Heron. These are important since aquatic ecosystems have undergone important changes in recent decades (Pearce and Crivelli 1994, Peirce *et al.* 1998) and change prey availability. A plentiful trophic resource may tend to be consumed in greater quantities, thereby varying the composition of the diet.

On the other hand, prey profitability in the Purple Heron influences prey selection (Campos and Lekuona 2000) and, therefore, diet composition. During the breeding season this behaviour probably affects the time that herons use to forage to capture prey for nestlings.

All these aspects point out the need to precisely determine the composition of the Purple Heron diet. The most common methods to study ardeid diet are i) direct observations of foraging birds, ii) pellets analysis, iii) analysis of nestling regurgitates, and iv) analysis of stomach contents. Each method presents advantages and disadvantages (Carss 1997). Depending on the experience of the observer, direct observation of the birds can bring about a bias in the size of the captured prey (Bayer 1985, Cezilly and Wallace 1988). Pellets analysis makes it difficult to evaluate the importance of some types of prey or their size (Draulans *et al.* 1987) due to different prey digestion. Nestling regurgitate analysis has undoubtedly been the most common method although differential digestion of prey can notably reduce its precision (Guillén *et al.* 1994). Stomach content analysis normally requires the death of the animal and is not common in ardeids (Ruiz 1985).

In this study we aimed to clarify the composition of the Purple Heron diet in a little studied area (northern Spain). In addition, we analysed whether the results varied with the type of feeding area or methodology used to take the data.

Methods

The study took place in the Ebro river valley in northern Spain, whit eight colonies of Purple Heron in 1994, and a total of 242 breeding pairs (Bergerandi *et al.* 1995). For this study we only used those at Valdelafuente (42°05'N, 1°40'W) with 94 pairs and

Accepted 11 January 2001

Escudera (42°16'N, 1°42'W) with 38 pairs, since their main feeding areas were rivers (Ebro, Aragón and Arga rivers) and ricefields (Campos and Lekuona pers. obs.). The ricefields were flooded at the end of April with water from the Ebro river, using motors that did not allow fish to pass. For this reason, no fish was available in the ricefields.

The feeding data were obtained using two methods: a) direct observations on foraging adult birds in rivers (n = 125) and ricefields (n = 43). All observations were during the breeding season (May-July) in 1994 (rivers) and 1995 (ricefields), at a distance of < 100 m, with a x 20-60 telescope, between 0700 h and 1900 h GMT. For each bird we noted the number, type and size of captured prey. The prey were grouped into seven types: mammals, birds, reptiles (only the snake *Natrix* spp.), amphibians, fish, crustaceans (only crayfish *Procambarus clarkii*) and insects. Prey size was calculated for crayfish and fish in relation to the length of the heron's beak (12.5 cm, Cramp and Simmons 1977), to establish three size classes: small (1-12.5 cm), medium (12.5-25 cm) and large (25-37.5 cm).

b) Collection of food samples from the 33 nests. In June we collected pellets, spontaneous regurgitates from nestlings and other food remains in the Valdelafuente colony. The prey were included in the same broad taxonomic groups as the direct observations. Fish were classified using the pharyngeal bones and scales, and their size was calculated from the regressions of total length and bone length (or scale) from C. de la Riva and R. Miranda (1994, unpublished data).

Prey biomass (g wet weight) was obtained a) for mammals, reptiles, amphibians and insects according to the average weight of similar-sized specimens captured in the study area (see also Campos and Lekuona 1997), b) for fish, according to length-weight regressions of other samples captured in the same area (Lekuona and Campos 1997), c) for crayfish we used the equation $W = 3.28 \cdot 10^{-5} \cdot L^{2.9039}$ (n = 70, $r^2 = 0.827$, $P < 0.001$) where W was the weight (g) and L the length (mm) measured from the rostrum tip to the telson, obtained from specimens collected in the feeding areas of herons.

To assess the species and size of fish in the foraging areas we performed electric fishing in June 1994 at two points along the Ebro River and two more along the Aragón River. All four sites were in areas where we had previously observed Purple Herons forage.

The trophic selection of the fish species was determined using the Wi Savage index (Savage 1931): $W_i = U_i/D_i$, where $U_i = u_i/u_+$, with ui being the observed number of units used from resource i and u_+ the total number of resources used, and $D_i = d_i/d_+$, where di is the number of units available in the environment of the resource i and d_+ the total availability of resources. Values greater or less than 1 indicate positive or negative selection, respectively. This index can be compared using a chi-square test with one degree of freedom (for more details see Manly *et al.* 1993).

The trophic diversity H' was calculated using the Shannon index, $H' = -\Sigma p_i \ln p_i$, where p_i is the relative frequency of each taxonomic group i in the diet. The equitability was calculated using the formula $E = H'/H'_{max}$ (Pielou 1975), where H' is the trophic diversity and H'_{max} is lnS, where S is the number of species or taxonomic groups. E varies between 0 (maximum stenophagia) and 1 (maximum euriphagia). We arbitrarily considered that when E > 0.60, the diet tended to be euriphagia, and when E < 0.40, the diet tended towards stenophagia.

The frequencies of the different prey groups were compared between different areas and between analysis methods using the G test (Sokal and Rolhf 1969), as commonly done in this type of study.

Results

Diet composition

Numerically, the main prey of Purple Herons in rivers were fish and insects, while in ricefields fish were absent from the diet and crustaceans and amphibians dominated (Table 1). In nests, insects were the most abundant prey followed by fish and it was the only place where we found birds (n = 7, all passerines) in the diet. The variations in diets in rivers vs ricefields vs nests were statistically significant (G = 1578.8, 14 df, P > 0.001), all pairwise comparisons being highly significant.

With regards to biomass, fish were 94.1% of the total in rivers (Table 1), which caused a sharp stenophagia (E = 0.17). On the contrary, in ricefields the diet tended towards euriphagia (E = 0.69) due to the elevated percentage of crustaceans and amphibians as well as mammals (10%). In nests, fish were the most important prey with an equitability of E = 0.42.

When all the sample types were considered together (rivers, ricefields and nests) the numerical percentages of fish, insects and crustaceans were almost identical (Table 1), but fish dominated in biomass (59.4%) as opposed to crustaceans and amphibians (17.4% and 12.4%, respectively). Thus, Purple Herons in the study area tended towards euriphagia diet, both in number (E = 0.79) and biomass (E = 0.63). The trophic diversity also increased gradually from rivers to ricefields and nests.

Since fish were the main prey in rivers and nests, we compared their frequencies in nests (the only place where we were able to classify to the species level) and in electric fishing (Table 2). The herons positive-

Table 1. Percentage of the number (n) and biomass (B, g wet weight) of Purple Heron prey from rivers, ricefields and nests in the Ebro river valley, northern Spain. H': trophic diversity (Shannon's index). E: equitability.

	Rivers[a]		Ricefields		Nests		Total	
	n	B	n	B	n	B	n	B
Mammals	–	–	4.1	10.1	8.1	8.5	3.3	5.4
Birds	–	–	–	–	2.7	1.8	0.4	0.4
Reptiles	0.5	0.2	0.6	0.5	3.8	1.4	1.1	0.6
Amphibians	2.1	1.4	28.6	35.6	0.4	0.2	15.1	12.4
Fish	67.5	94.1	–	–	23.1	79.0	26.8	59.4
Insects	29.0	3.8	16.9	4.2	53.8	5.7	26.8	4.4
Crustaceans	0.9	0.5	49.8	49.6	8.1	3.4	26.5	17.4
Total prey items	573	13,113	835	10,067	260	7,367	1,668	30,547
H'	0.77		1.17		1.32		1.52	
E	0.48	0.17	0.73	0.69	0.68	0.42	0.78	0.63

[a] According to Campos & Lekuona (1997)

Table 2. Percentages of fish species found in the Ebro river (electrofishing) and in nests of Purple Heron. H': diversity (Shannon's index), E: equitability. W_i: Savage's index of trophic selection.

Fish species	Electrofishing	Nests	W_i
Chondrostoma toxostoma	53.9	30.0	0.56
Barbus graellsii	30.7	33.3	1.08
Gobio gobio	5.7	8.3	1.46
Phoxinus phoxinus	4.6	–	–
Cyprinus carpio	2.1	11.7	5.57*
Micropterus salmoides	1.1	3.4	3.09
Carassius auratus	1.0	8.3	8.30*
Barbatula barbatula	0.7	–	–
Tinca tinca	0.1	–	–
Cobitis paludicola	0.1	–	–
Rutilus arcasii	–	5.0	–
Total fishes	911	60	
H'	1.23	1.66	
E	0.53	0.85	

* $P < 0.01$

ly selected for Carps, *Cyprinus carpio,* and Crucian Carps, *Carassius auratus*, of which 91.6% (n = 12) were between 12.5-25 cm long. Another four species were consumed according to their abundance in the river (French Nase, *Chondrostoma toxostoma*, and Graell's Barbel, *Barbus graellsii,* were the most abundant), and another four were absent from the diet, possibly due to their scarcity in the river (Tench, *Tinca tinca* and Red Roach, *Rutilus arcasii*), or to their benthic habits (Stone Loach, *Barbatula barbatula* and Spined Loach, *Cobitis paludicola*). Fish diversity and equitability were higher in the nest sample than in electric fishing.

Diet variation according to sampling method

The numerical composition of the diet varied significantly ($G = 269.7$, 7 df, $P < 0.001$) with the sampling method (direct observations vs food samples). With respect to the nest data, direct observations (rivers plus ricefields) underestimated the importance of insects (21.8% vs 53.8%), and overestimated crustaceans (29.9% vs 8.1%) and amphibians (17.8% vs 0.4%).

In biomass, on the contrary, direct observations overestimated the importance of amphibians (16.3% vs 0.2%) and crustaceans (21.8% vs 3.4%), and underestimated fish (53.2% vs 79.0%).

Discussion

The diet of the Purple Heron in our study area was based on fish, as observed elsewhere (Owen and Philips 1956, Moser 1984, Fasola *et al.* 1993, etc.). Nonetheless, our herons consumed a lot of crayfish (26.5%), which is unusual in other European countries, including Spain. Crayfish were introduced in Spain in 1974 (Admetlla and Carrasco 1997), but were absent from the Purple Heron diet until 1983 (Amat and Aguilera 1978, González-Martín *et al.* 1992), and made up 4% of its prey in 1984 in a study in the Guadalquivir marshes (Rodríguez and Cañavate 1985). This suggests that the Purple Heron has adapted its feeding regime to a new and abundant trophic resource. Similar adaptations have been observed in other ardeids (Fasola *et al.* 1993, Peris *et al.* 1995), which confirms that they are opportunistic predators, using trophic resources according to availability.

The percentage of the most abundant fish species (French Nase and Graell's Barbel) in the nest samples were similar to those in rivers, which supports the opportunistic character of the Purple Heron. Nonetheless, herons positively selected for middle sized carps and crucian carps, the most profitable for other ardeids of similar size (Moser 1986), and the most captured in other regions (Rodríguez and Cañavate 1985). In June, when the nest samples were collected, the Purple Heron nestlings were > 20 days old (Campos and Lekuona 1997), already capable of swallowing prey of this size (Moser 1986). This could be an advantage for adult herons since they can feed nestlings with more profitable prey.

In our study area, diet equitability was high. Euriphagia is proper of generalist species, and not for specialists (Sherry 1990). Heron diet can vary among colonies (Campos 1990, Fasola *et al.* 1993) and they can behave as opportunists to obtain food. This suggests that, in the areas where the diet equitability is greater, they have a greater variety of available prey. This can favour the best body condition for herons and a greater reproductive success (Newton 1998). Indeed, during our study period the breeding population of Purple Herons was increasing (Bergerandi *et al.* 1995). With regards to the sampling methods, they provoked a bias in the diet composition analysis (González-Solís *et al.* 1997). In the following years (1994 and 1998), diet composition obtained using the same method (nestling regurgitate analysis) was similar in our study area and in Camargue, France (Thomas *et al.* 1999). However, in the same places and years, different methods provided different results. Thus, it is necessary to unify the sampling criteria before trying to establish a model for the geographic variation of diet (Carss 1997).

Our data demonstrate that there were differences between the percentage of types of prey consumed per foraging adult (rivers and ricefields) and in nest remains. This suggests that adults feed nestlings with the same prey they consume but in different proportions. Before this study we knew that prey brought to the nest varied in size depending on nestling age (among others, Moser 1986), but did not know about the variation in the percentage of the types of prey. The differences found in the diet of amphibians and insects may be explained by two observations: a) amphibians are digested more quickly than insects in the digestive tract of adult herons (Vinokurov 1960, Voisin 1991), and b) probably some adult herons in our sample only foraged in rivers and not ricefields, so that the proportion of the prey types in the nests were different from those noted by direct observation. Indeed, adult herons were more abundant in rivers than in ricefields in our study area (pers. obs.).

Acknowledgements - Our gratitude goes out to all those who helped with the electric fishing, especially Carmen Escala and Carmen de la Riva. Some data on the length-weight relationship in fish were provided by Carmen de la Riva. This study was partially funded by the Government of Navarre.

References

Admetlla E. and Carrasco M. 1997. Potenciales acuícolas de las Marismas del Guadalquivir: cultivo asociado cangrejo-arroz. In: Junta de Andalucía, Edit. Cultivo del arroz en clima mediterráneo. Sevilla pp. 137-145.

Amat J. A. and Aguilera E. 1978. Alimentación de la Garza Imperial (*Ardea purpurea*) en las Marismas del Guadalquivir durante el período de nidificación. Ardeola 24: 95-104.

Bayer R. D. 1985. Bill lenght of herons and egrets as an estimator of prey size. Colonial Waterbirds 8: 104-109.

Bergerandi A., Arzoz M. J., Campos F. and Lekuona J. M. 1995. Aumento de la población reproductora de Garza Imperial (*Ardea purpurea*) en Navarra, Norte de España. Ardeola 41: 173-175.

Campos F. 1990. Alimentación de la Garza Real (*Ardea cinerea*) en la cuenca del Duero (España) durante el período reproductor. Doñana, Acta Vertebrata 17: 141-151.

Campos F. and Lekuona J. M. 1997. Temporal variations in the feeding habits of the Purple Heron *Ardea purpurea* during the breeding season. Ibis 139: 447-451.

Campos F. and Lekuona J. M. 2000. Fish profitability for breeding Purple Herons. Ardeola 47: 105-107.

Carss D. 1997. Techniques for assessing Cormorant diet and food intake: towards a consensus view. Suppl. Ric. Biol. Selvaggina 26: 197-230.

Cezilly F. and Wallace J. 1988. The determination of prey capturated by birds through direct field observations: a test of the method. Colonial Waterbirds 11: 110-112.

Cramp S. and Simmons K. E. L. 1977. The Birds of the Western Palearctic, Vol. 1. Oxford University Press, Oxford.

Draulans D., Perremans K. and van Vessen J. 1987. Analysis of pellets of the Grey heron, *Ardea cinerea*, from colonies in Belgium. J. Zool. Lond. 211: 695-708.

Fasola M., Rosa P. and Canova L. 1993. The diets of squacco herons, little egrets, night, purple and grey herons in their Italian breeding ranges. Rev. Ecol. (Terre Vie) 48: 35-45.

González-Martín M., Ruiz X. and Llorente G. A. 1992. Breeding parameters, feeding habits and nestling growth in a recovering population of Purple Herons from the Ebro delta, Spain. Misc. Zool. 16: 147-160.

González-Solís J., Oro D., Pedrocchi V., Jover L. and Ruiz X. 1997. Bias associated with diet samples in Audouin's Gulls. Condor 99: 773-779.

Guillén A., Prósper J. and Echevarrías J. L. 1994. Estimación de la dieta de la Garcilla Bueyera a partir del análisis de regurgitaciones de pollos: Problemas debidos a la digestión diferencial de las presas. Doñana, Acta Vertebrata 21: 204-212.

Lekuona J. M. and Campos F. 1997. Estrategias de alimentación del Cormorán Grande (*Phalacrocorax carbo sinensis*) en el río Ebro (N España). Misc. Zool. 20: 1-8.

Manly B. F., McDonald L. L. and Thomas D. L. 1993. Resource selection by animals. Statistical desing and analysis for field studies. Chapman & Hall, London.

Moser M. 1984. Resource partitioning in colonial Herons with particular reference to the Grey Heron *Ardea cinerea* L. and the Purple Heron *Ardea purpurea* L. in the Camargue, S. France. Ph. D. Thesis. University of Durham. Durham.

Moser M. 1986. Prey profitability for adult Grey Herons *Ardea cinerea* and the constraints on prey size when feeding young nestlings. Ibis 128: 392-405.

Newton I. 1998. Population limitation in birds. Academic Press, San Diego.

Owen D. F. and Philips G. C. 1956. The food of nesting Purple Heron in Holland. British Birds 49: 494-499.

Pearce F. and Crivelli A. J. 1994. Characteristics of Mediterranean wetlands. Med Wet Publication No. 1, Arles.

Peirce J. J., Weiner R. F. and Vesilind P. A. 1998. Environmental pollution and control. Butterwort-Heinemann, Boston.

Peris S. J., Briz F. J. and Campos F. 1995. Shifts in the diet of the Grey Heron (*Ardea cinerea*) in the Duero river basin, central-west Spain, following the introduction of exotic fish species. Folia Zoologica 44: 97-102.

Pielou E. C. 1975. Ecological diversity. Wiley & Sons, New York.

Rodríguez M. and Cañavate J. P. 1985. Sélection des proies par le Heron Pourpré *Ardea purpurea* pendant la période de reproduction dans les marais du Guadalquivir (Espagne). Oiseau 55: 195-203.

Ruiz X. 1985. An analysis of the diet of cattle egrets in the Ebro delta, Spain. Ardea 73: 49-60.

Savage R. E. 1931. The relation between the feeding of the herring off the cast coast of England and the plankton of the surrounding waters. Fishery Investigation, Ministry of Agriculture, Food and Fisheries, Series 2, 12: 1-88.

Sherry T. W. 1990. When are birds dietarily specialized? Distinguishing ecological from evolutionary approaches. Studies in Avian Biology 13: 337-352.

Sokal R. R. and Rohlf F. J. 1969. Biometría. Blume Ediciones, Madrid.

Thomas F., Deerenberg C., Lepley M. and Hafner H. 1999. Do breeding site characteristics influence breeding performance of the Purple Heron *Ardea purpurea* in the Camargue? Rev. Ecol. (Terre Vie) 54: 269-281.

Vasvari N. 1930. Studien über die Ernährung des Purpurreihers (*Ardea purpurea* L.). Aquila 36-37: 267-293.

Vasvari N. 1938. Die wichtigsten ergebnisse meiner untersuchungen über die ernährungsoekologie der reihervögel (*Ardeidae*). Actas du XIX Congrès Ornithologique International (J. Delacour, Rouen, France) 1938: 415-422.

Vinokurov A. A. 1960. On the food digestion rate in herons. Moskovske Obshchestvo Ispryatelei Pirody Bjulletin. Otdel Biologii Moscow 65: 10 (in Russian).

Voisin C. 1991. The Herons of Europe. T & AD Poyser, London.