THE DIET OF THE MARBLED TEAL *MARMARONETTA ANGUSTIROSTRIS* IN SOUTHERN ALICANTE, EASTERN SPAIN

Cristina FUENTES[1,2], Marta I. SÁNCHEZ[1], Nuria SELVA[1,3] & Andy J. GREEN[1,4]

RÉSUMÉ

Le régime alimentaire de la Sarcelle marbrée *Marmaronetta angustirostris* a été étudié dans les marais du sud de l'Alicante, le site le plus important pour la population européenne de cette espèce globalement menacée. Nous avons analysé les contenus stomacaux de 64 individus volants, récoltés entre le 16 juin et le 24 novembre, de 1992 à 2000, ainsi que de 31 canetons (29 de la classe d'âge Ia, récemment éclos), obtenus entre le 18 mai et le 16 juillet, de 1994 à 1998. Les canetons décédèrent après leur récupération dans un conduit d'irrigation bétonné et tous les individus volants, sauf quatre, périrent lors de divers épisodes de mortalité généralisée. Nous avons aussi analysé les échantillons fécaux de 20 oiseaux volants recueillis en juillet-août, en 1999 et 2000, plus ceux correspondant à cinq couvées récupérées dans le conduit d'irrigation. Les graines (72 % en volume) et les invertébrés (21 %) dominaient dans les gésiers des oiseaux volants. Les graines de *Scirpus litoralis* (43 % en volume), principalement consommées quand elles flottent à la surface de l'eau, constituaient l'item alimentaire le plus important. L'importance des invertébrés a probablement été sous-estimée en raison de la mauvaise qualité des contenus stomacaux. Les larves et les pupes de chironomes, les Corixidés et leurs œufs, les fourmis, les ostracodes et les amphipodes étaient, en volume, les invertébrés les plus abondants. Les végétaux verts (probablement *Potamogeton pectinatus*) étaient abondants dans les fèces de juillet. Aucune saisonalité alimentaire n'a été clairement détectée, peut-être en raison de la qualité médiocre de la plupart des échantillons stomacaux et des variations interannuelles des patrons saisonniers d'abondance des divers graines et invertébrés. Les canetons se nourrissent principalement d'invertébrés, en particulier d'adultes et de pupes de chironomes, de Coléoptères, de Corixidés et de fourmis. Ils consomment plus de végétaux verts que de graines.

SUMMARY

We present a study of the diet of the globally threatened Marbled Teal *Marmaronetta angustirostris* in the southern Alicante wetlands, the most important site for the European population. We analysed the gut contents of 64 fully-grown teal collected between 16 June and 24 November from 1992 to 2000, and 31 ducklings (29 of the newly hatched age class I a) collected between 18 May and 16 July from 1994 to 1998. The ducklings died following rescue from a concrete irrigation channel, and all but 4 fully-grown teal died in various mortalities. We also analysed 20 faecal samples collected from fully-grown teal in July-August in

[1] Estación Biológica de Doñana, Avenida de María Luisa s/n, Pabellón del Perú, 41013 Sevilla, Spain.

[2] Universidad de Alicante, Departamento de Ecología, Apdo. 99, 03080 Alicante, Spain

[3] Current address : Mammal Research Instituse, 17-230 Biolowieza, Poland.

[4] Correspondence to: Andy J. Green. Tel +34 95 4232340 ext. 202; Fax +34 95 4621125; E-mail: ajgreen@ebd.csic.es

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1999 and 2000, plus faecal samples collected from five broods after their rescue from the channel. Seeds (72% by aggregate percent of gullet volume), supplemented by invertebrates (21%) dominated gut samples from fully-grown teal. The most important food item was *Scirpus litoralis* seeds (43% by aggregate percent of gullet volume) consumed mainly when floating on the water surface. The importance of invertebrates was probably underestimated owing to the poor quality of gut samples. Chironomid larvae and pupae, Corixidae and their eggs, ants, ostracods and amphipods were the most abundant invertebrates by volume. Green plant material (probably *Potamogeton pectinatus*) was abundant in July faeces. There were no clear seasonal trends in diet, perhaps because of the poor quality of most gut samples and variation between years in the seasonal patterns of abundance of different seeds and invertebrates. Ducklings fed mainly on invertebrates, especially chironomid adults and pupae, Coleoptera, Corixidae and ants. They consumed more green plant matter than seeds.

INTRODUCTION

Although the Anatidae (ducks, geese and swans) have been the subject of much research, it has been greatly concentrated on migratory species breeding in northern Europe or North America (Batt *et al*., 1992; Kear, in press). The findings may not be representative of the biology of little known species found elsewhere, such as those breeding in the Mediterranean region.

The Marbled Teal *Marmaronetta angustirostris* is a globally threatened species (BirdLife International, 2000) considered to be the most primitive member of the pochards Aythyini (Livezey, 1996). Its life history appears well adapted to exploit the marked fluctuations in habitat availability found in natural, shallow Mediterranean wetlands (Green, 2000). Its habitat use and feeding behaviour is similar to that of the dabbling ducks Anatini (Green, 1998a; Green & El Hamzaoui, 2000). However, there is little information available on its diet (Green & Selva, 2000; Green & Sánchez, in press) and none from the southern Alicante wetlands in eastern Spain, which hold the majority of the European population (Green, 1996; Green & Navarro, 1997; Green *et al*., in press).

In this paper we compare Marbled Teal diet in southern Alicante at different times of the annual cycle, and compare the diet of ducklings with that of fully-grown birds, analysing gut contents from 95 teals. We also use faecal analysis, a particularly useful method when the collection of healthy birds for diet studies is not practical (Razafindrahanta, 1999; Green & Selva, 2000).

STUDY AREA

Most birds or faecal samples were collected from El Hondo, a complex of 25 brackish wetlands (total 1,650 ha) in the south of Alicante province (38º11´N, 00º45´W) protected as a Natural Park and Ramsar site (Bernués, 1998), which includes two shallow reservoirs (total 1,100 ha, maximum depth 2.5 m) used to store irrigation water. From February 1999 to August 2000, conductivity in the reservoirs (where most Marbled Teals are found) varied from 6 to 25 mS. Large *Phragmites* reedbeds form the dominant emergent vegetation, with smaller areas of *Scirpus litoralis* and other species (Cirujano *et al*., 1995). Submerged vegetation is dominated by *Potamogeton pectinatus*, with smaller amounts of *Ruppia maritima*, *R. cirrhosa*, *Najas marina*, charophytes and other species. There are large areas of saltmarsh vegetation (especially *Salicornia ramosissima*, *Sarcocornia fruticosa*, *Arthrocnemum macrostachyum* and *Suaeda*) that include temporary pools. A few teal samples came from three neighbouring wetlands providing similar habitat: a)

Salinas de Santa Pola (38°11´N, 00°38´W), a brackish to saline complex of 550 ha (excluding the saltworks, Bernués, 1998), b) Clot de Galvany (38°15´N, 00°33´W), two brackish ponds totalling 3 ha, c) Hondo de Amorós (38°08´N, 00°42´W), a brackish pond of 3 ha. Up to 91 pairs of teal breed at El Hondo, up to 16 pairs at Santa Pola and up to three pairs at the other sites (Green *et al.,* in press).

Marbled Teal are recorded in these wetlands all year round, but are more abundant from April to November since most birds are thought to winter in North Africa (Navarro & Robledano, 1995). Broods hatch from early May to mid July (Green *et al*., 1999).

METHODS

A total of 64 fully-grown birds (spanning from 16 June to 24 November) and 31 ducklings (18 May to 16 July) were collected from 1992 to 2000 from a variety of sources (see Appendix 2 for details). Most birds were frozen shortly after collection and then sent to us, although in some cases we only received the guts or their contents, and the gut contents of one duckling were preserved immediately after death. Juveniles (numerous from July onwards) are difficult to separate from adults (Navarro & Robledano, 1995) and we could not age most fully-grown birds, which we refer to collectively as FGBs from hereon. Teal become sexually mature in their first year of age (Kear, in press). Where possible, we sexed and aged birds based on plumage characteristics, gonad inspection and presence or absence of the bursa of Fabricius (Larson & Taber, 1980). Most FGBs were found during mortalities, being collected many hours or even days after their death. Thus gut contents often reached us partially decomposed and the causes of death may have influenced food selection prior to death. Ducklings (n = 31) were collected from 1994 to 1998 and were casualties following an operation to rescue broods trapped in a concrete irrigation channel (Green *et al.,* 1999), and most had spent hours without feeding before their death and thus had empty gullets. Ducklings included 29 from age class Ia, one from class Ic and one from class IIa (Appendix 2).

We also analysed faecal samples collected from healthy FGBs and ducklings (Appendix 2). Faecal samples from FGBs were collected from islands (from 13 July to 18 August) where monospecific groups were observed resting. Faecal samples for ducklings were collected from whole broods (one sample per brood) after rescue from the irrigation channel by placing filter paper on the bottom of the boxes housing broods and removing the paper several hours later.

Food items found in the gizzard and gullet (oesophagus plus proventriculus) were stored in 70% ethanol. Faecal samples were stored individually in envelopes and air-dried. Prior to analysis they were rehydrated in water for 24 hours and then shaken using a vortex to loosen them. They were then washed in a 0.04 mm sieve before preservation in 70% ethanol. Animal and plant food items were sorted and identified to the lowest possible taxonomic level using a binocular microscope at 10-25X magnification and reference material of potential food items collected at the study site, together with suitable keys (see Green & Selva, 2000; Sánchez *et al.,* 2000).

The percentage of individual samples in which each food item was recorded (i.e. the percentage occurrence) was calculated for faecal and gut samples for each season and sample origin. Our division of FGBs into groups was restricted by the lack of precise dates of the birds we received from the 1997 mortality (collected between 8 September and 24 November), and we separated these from the birds collected between 28 June and 7 September in 1999-2000 (found during mortalities with different causes to that of 1997, Appendix 2). We also separated those birds likely to provide more reliable data about diet (a female that died by colliding with a power line on 16 June 1994, and three birds shot in October 1992). The actual volume of the contents of the gullet were measured by displacement. For organisms or fragments of volume < 0.01 ml, volume was estimated from linear measurements. The contents of three gullets and gizzards were mixed before we received them, and we measured the combined volume. The proportion of the volume of the faecal sample that was made up of each component was estimated using five categories of abundance: absent, < 10%, 10-50%, 51-90% and > 90% of total volume. For faecal samples in which green plant material was relatively abundant (≥10% of total volume), this material was examined with an optical microscope at 40-250X magnification. Epidermal structure was observed in an attempt to identify the vegetation types, using reference samples.

Volumetric measurements of all food items in the gullet were expressed as the mean of volumetric percentages (aggregate percent) and/or percentage of total volume (aggregate volume, Swanson *et al.,* 1974). Although aggregate percent is generally considered the most representative measure of diet composition for samples collected when birds are feeding, in our case where most birds are collected in poor condition, and only a few have their gullets full, aggregate volume may be more representative since it gives higher weight to these larger samples.

For comparisons between seasons, years and ages, food items were combined into major categories. However, more detailed information on diet composition facilitates comparisons and reviews of different diet studies, or of the importance of a given food plant to waterbirds (see Gaevskaya, 1966; Payne, 1992; Sánchez *et al*., 2000). Furthermore, little previous information is available about the invertebrates and plants present in our study sites. Thus, full details of taxonomic identifications of plant and animal matter are provided (Appendix 1).

RESULTS

A broad variety of seeds and invertebrates were recorded in both FGBs and ducklings (Tables I-III). Green plant matter was often present in gut samples but in small quantities (Tables I-II). However, it was abundant in some faeces (Table III).

Diet of fully-grown teal

Gut samples for FGBs from the 28 June-7 September (JnSe) and 8 September-24 November (SeNo) mortalities showed a similar pattern with seeds being dominant, especially *Scirpus litoralis* seeds that made up about half of the volume of gullet contents (Tables I-II). Invertebrates were present in smaller quantities, although they were likely under-represented given the method of collection and small gullet volume (JnSe: range 0.003-0.2 ml. SeNo: range 0.001-8.1 ml). Chironomid larvae and pupae constituted 16% of aggregate gullet volume in Se-No samples, and various other groups (ants, amphipods, ostracods, nematodes) exceeded 5% in some volumetric measure (Table II). The nematodes recorded may have been parasitic or saprophagous organisms colonizing the birds before or after death and were not necessarily ingested.

TABLE I

Percentage occurrence of food items in the gullet (A) and gizzard (B) of Marbled Teal

	JnSe		SeNo		Oct	Dkg	
	A (13)	B (16)	A (29)	B (44)	AB (3)	A (2)	B (31)
Seeds and oospores	76.1	100	89.7	100	100	-	54.8
Atriplex spp.	-	-	6.9	2.3	-	-	3.2
Suaeda spp.	-	-	6.9	6.8	-	-	38.7
Arthrocnemum spp.	-	-	3.5	-	-	-	-
Ranunculus spp.	-	-	3.5	-	66.7	-	-
Scirpus spp.	-	-	24.1	6.8	66.7	-	6.5
Scirpus litoralis	61.5	81.3	65.5	93.2	33.3	-	-
Scirpus maritimus	-	6.3	20.7	22.7	33.3	-	-
Carex spp.	-	-	-	-	-	-	6.5
Phragmites australis	-	6.3	-	-	-	-	-
Sorghum bicolor	-	-	-	-	66.7	-	-
Potamogeton pectinatus	-	12.5	-	6.8	66.7	-	3.2
Ruppia spp.	15.4	43.8	6.9	22.7	66.7	-	3.2
Unid. seeds	7.7	18.8	20.7	9.1	100	-	12.9
Chara spp., oospore	-	-	10.3	6.8	-	-	-
Green plant material	7.7	-	41.4	45.5	33.3	-	87.1
Invertebrates	46.2	68.8	69.0	40.9	-	100	61.3
Bryozoa, floatoblast	-	-	3.5	4.6	-	-	-
Nematoda	-	-	13.8	2.3	-	-	6.5
Oligochaeta	-	-	3.5	-	-	-	-
Polychaeta	-	6.3	-	-	-	-	-
Gastropoda	-	-	6.9	4.6	-	-	-
Cladocera, a.	-	-	-	-	-	-	3.2
Cladocera, ephippia	7.7	6.3	13.8	4.6	-	-	-
Ostracoda	7.7	12.5	17.2	4.6	-	-	-
Copepoda	-	-	-	2.3	-	-	-
Decapoda	-	-	-	-	-	-	3.2
Amphipoda	7.7	12.5	-	-	-	-	-
Isopoda	-	-	3.5	-	-	-	-
Arácnida	-	-	-	-	-	50	-
Odonata, l.	-	-	17.2	4.6	-	-	3.2
Corixidae	7.7	37.5	17.2	2.3	-	-	-
Corixidae, eggs	-	6.3	6.9	-	-	-	-
Aphididae	-	-	-	-	-	50	-
Formicidae	7.7	18.8	6.9	2.3	-	50	19.4
Mallophaga	-	-	6.9	4.6	-	-	-
Coleoptera, a.	-	18.8	13.8	4.6	-	-	25.8
Coleoptera, l.	-	-	3.5	2.3	-	-	-
Trichoptera, l.	-	-	3.5	-	-	-	-
Chironomidae, l.	7.7	6.3	13.8	-	-	-	-
Chironomidae, p.	-	6.3	13.8	4.6	-	-	-
Chironomidae, a.	-	-	-	-	-	50	3.2
Ephydridae, p.	-	-	10.3	9.1	-	-	-
Unid. Insecta	7.7	6.3	34.5	25.0	-	50	35.5
Unid. Invertebrate	7.7	-	-	-	-	50	3.2
Unid. Invertebrate eggs	-	6.3	13.8	11.4	-	-	-

Values in parentheses = n (some teals had empty gullets). JnSe = fully-grown birds (FGBS) from mortality of 28 June to 7 September 1999/2000; SeNo = FGBs from mortality of 8 September to 24 November 1997; Oct = FGBs shot in October 1992. Dkg = ducklings. See Appendix 2 for details. See Table II for occurrence of items in a female from June 1994. Unid. = unidentified. - = 0 ; l., larvae; p., pupae; a., adult.

TABLE II

Mean of volumetric percentages in the gullet (aggregate percent, %ag) and percentage of total volume in the gullet (aggregate volume, Vag) of food items in Marbled Teal

	Jun (1)	JnSe (13)		SeNo (29)		Oct (3)		Dkg (2)	
	Vag	%ag	Vag	%ag	Vag	%ag	Vag	%ag	Vag
Seeds and oospores	4.7	76.6	97.8	68.9	73.2	99.5	99.7	-	-
Atriplex spp.	0.8	-	-	0.02	0.1	-	-	-	-
Suaeda spp.	1.3	-	-	0.1	0.04	-	-	-	-
Arthrocnemum spp.	-	-	-	tr	0.02	-	-	-	-
Ranunculus spp.	-	-	-	tr	0.03	0.8	0.1	-	-
Scirpus spp.	-	-	-	10.9	15.8	9.4	0.5	-	-
Scirpus litoralis	-	52.8	57.0	45.3	55.3	0.04	0.03	-	-
Scirpus maritimus	-	-	-	5.5	1.4	0.2	0.1	-	-
Sorghum bicolor	-	-	-	-	-	43.3	82.8	-	-
Potamogeton pectinatus	-	-	-	-	-	6.6	1.1	-	-
Ruppia spp.	-	15.4	1.6	0.1	0.1	0.3	0.5	-	-
Zannichellia peltata	2.1	-	-	-	-	-	-	-	-
Unid. seeds	0.5	7.7	37.2	6.7	0.4	38.9	14.7	-	-
Chara spp., oospore	-	-	-	0.1	0.01	-	-	-	-
Green plant material	-	0.8	2.1	11.3	4.7	0.6	0.4	-	-
Invertebrates	95.3	23.4	2.2	19.8	22.1	-	-	100	100
Bryozoa, floatoblast	-	-	-	tr	tr	-	-	-	-
Nematoda	tr	-	-	8.6	0.7	-	-	-	-
Oligochaeta	-	-	-	0.8	0.0	-	-	-	-
Gastropoda	0.2	-	-	0.1	0.5	-	-	-	-
Cladocera ephippia	-	0.0	0.0	0.5	0.6	-	-	-	-
Ostracoda	6.3	7.7	0.5	0.6	0.9	-	-	-	-
Amphipoda	1.7	7.7	0.5	-	-	-	-	-	-
Isopoda	0.2	-	-	0.03	0.03	-	-	-	-
Arácnida	-	-	-	-	-	-	-	0.4	0.7
Plecoptera, l.	0.4	-	-	-	-	-	-	-	-
Odonata, l.	0.2	-	-	0.4	0.5	-	-	-	-
Corixidae	-	0.2	0.1	1.2	1.4	-	-	-	-
Corixidae, eggs	-	-	-	0.1	0.1	-	-	-	-
Aphididae	-	-	-	-	-	-	-	0.1	0.1
Formicidae	-	7.7	0.6	0.1	0.02	-	-	0.02	0.04
Mallophaga	-	-	-	0.2	tr	-	-	-	-
Coleoptera, a.	0.03	-	-	0.2	0.2	-	-	-	-
Coleoptera, l.	1.1	-	-	tr	0.01	-	-	-	-
Trichoptera, l.	0.04	-	-	0.1	0.1	-	-	-	-
Chironomidae l.	67.1	0.1	0.02	2.6	13.4	-	-	-	-
Chironomidae p.	14.7	-	-	0.6	2.8	-	-	-	-
Chironomidae a.	-	-	-	-	-	-	-	48.8	97.7
Ceratopogonidae, l.	0.01	-	-	-	-	-	-	-	-
Ephydridae, p.	2.5	-	-	0.2	0.4	-	-	-	-
Unid. Insecta	0.8	0.1	0.4	2.4	0.5	-	-	0.7	1.5
Unid. Invertebrates	-	0.1	0.0	-	-	-	-	50.0	0.02
Unid. Invertebrate eggs	-	-	-	1.2	0.1	-	-	-	-

Values in parentheses = n. Jun = female killed by collision with power line on 16.6.94; JnSe = FGBs from mortality of 28 June to 7 September 1999/2000; SeNo = FGBs from mortality of 8 September to 24 November 1997; Oct = FGBs shot in October 1992 (data for gullet and gizzard combined); Dkg = ducklings. See Appendix 2 for details. Unid., unidentified; l., larvae; p., pupae: a., adults. - = 0. tr: % value < 0.005.

Amongst four gut samples collected in better condition (Tables I-II), a female collected on 16.6.94 had a full gullet (4.8 ml) with 95% invertebrates (82% chironomid larvae and pupae), whilst three teals shot in October 1992 contained almost exclusively seeds, with *Sorghum bicolor* (used by hunters as bait to attract ducks) forming 83% of aggregate volume and 43% of aggregate percent. Other unidentified seeds (possibly including other seeds used as hunters' bait) formed 39% by aggregate percent for these birds (Table II).

TABLE III

Contents of Marbled Teal faeces, showing the percentage occurrence of each food item (PO) and the percentage of samples in which the given item represented at least 10% of sample volume (V ≥ 10)

	CGJl (2)		EHJl (17)		EHAg (1)		Brd (5)	
	PO	V≥10%	PO	V≥10%	PO	V≥10%	PO	V≥10%
Seeds	-	-	5.9	-	100	100	-	-
Scirpus spp.	-	-	5.9	-	100	100	-	-
Ruppia spp.	-	-	-	-	100	-	-	-
Green plant material	50	-	100	100	100	-	80	20
Invertebrates	100	100	100	64.7	-	-	100	80
Oligochaeta	-	-	-	-	-	-	20	-
Cladocera, a.	-	-	11.8	-	-	-	-	-
Cladocera, ephippia	50	-	41.2	5.9	-	-	-	-
Ostracoda	100	-	35.3	-	-	-	20	-
Unid. Crustacea	-	-	5.9	-	-	-	-	-
Odonata	-	-	17.7	-	-	-	-	-
Corixidae	100	100	94.1	-	-	-	60	40
Corixidae, eggs	-	-	100	64.7	-	-	20	-
Aphididae	-	-	5.9	-	-	-	-	-
Formicidae	-	-	-	-	-	-	40	-
Coleoptera, a.	100	50	76.5	-	-	-	100	40
Chironomidae, l.	-	-	29.4	5.9	-	-	40	-
Chironomidae, p.	-	-	5.9	-	-	-	60	40
Chironomidae, a.	-	-	17.7	-	-	-	-	-
Unid. Diptera	-	-	5.9	-	-	-	20	-
Unid. Invertebrate	-	-	29.4	-	-	-	40	20
Unid. Invertebrate eggs	-	-	29.4	-	-	-	20	-

Values in parentheses = n. Samples from fully-grown birds as follows: CGJl = breeding pair at Clot de Galvany 13.7.99, EHJl = El Hondo 19.7.00, EHAg = El Hondo 18.8.00. Brd = from broods rescued from a canal at El Hondo, 1998-2000. See Appendix 2 for details. Unid. = unidentified. - = 0. l., larvae; p., pupae: a., adults.

Invertebrates made up > 90% of the volume of faecal samples from a breeding pair at Clot de Galvany on 13 July that fed mainly on Corixidae and Coleoptera (Table III). Faecal samples collected from El Hondo on 19.7.00 revealed a variety of invertebrates, with a high abundance of Corixidae (eggs as well as adults or nymphs), Chironomidae, Coleoptera and Cladocera. However, green plant material was exceptionally abundant in these samples (Table III), making up > 90% of the volume of 6 of 17 samples. All the material was from either *Potamogeton pectinatus* or *Ruppia*. The epidermal structure was too similar to permit distinction between the two genera. A faecal sample from a separate location in El Hondo a month later on 18.08.00 contained *Scirpus* and *Ruppia* seeds plus green plant material (Table III), with *Scirpus* seeds constituting > 90% of the volume.

Diet of ducklings

Gut and faecal samples suggest that, in volumetric terms, ducklings consumed relatively more invertebrates and fewer seeds than FGBs (Tables II-III). While a higher proportion of FGB gizzards contained seeds than invertebrates, the reverse was true for ducklings (Table I). Ducklings consumed less *Scirpus* and *Ruppia* seeds but more of the smaller *Suaeda* seeds than FGBs (Table I, Appendix 1). Two duckling gullet samples (volume 0.0003-1.4 ml) contained only invertebrates, mainly emergent adult chironomids (Table II). More than 90% of the volume of 4 of 5 faecal samples from broods was constituted by invertebrates, especially Corixidae, Coleoptera and Chironomidae (Table III). Gizzard and faecal samples suggested that ducklings consumed more green plant material than seeds (Table I, III).

DISCUSSION

Ours is the first study of Marbled Teal diet in the area holding most of the European population of this globally threatened species. While our study is heavily dependent on gut samples received in poor condition, we have combined these data with analyses of faeces from healthy birds to improve the study. Despite the biases inherent in faecal analysis owing to differing digestibility, it allows a good approximation of diet composition, especially when making comparisons between different wetlands or seasons (Green & Selva, 2000, 2003). Our use of faecal analysis was limited by the lack of dry land roost sites from which faeces could be collected. Thus, most of our faecal samples from fully-grown teal came from the same location on the same day (Appendix 1), and are not strictly independent samples. This probably explains the unusual abundance of green plant material in July faeces. Our gut samples and faecal samples elsewhere (Green & Selva, 2000; Green & Sánchez, 2003) suggest that seeds are generally more important food items than green plant material.

Our diet samples cover the June-November period during and after the breeding season, and cover a total of eight different years. We expect major annual and spatial variation in diet that confounds the seasonal patterns likely in a given wetland in a given year. We have observed major variation in the abundance of different invertebrates and aquatic plants and their seeds in different wetlands in the study area at a given moment, and in a given wetland in different years (authors unpublished data). High annual variation in seed and invertebrate production and availability is typical of Mediterranean wetlands (Bonis *et al.*, 1995; Grillas & Roché, 1997). We have also observed major changes between months and years in the habitat selection of teal.

A total of 60 birds collected from mortalities in El Hondo between 28 June and 24 November provided no clear evidence of a seasonal diet shift, with *Scirpus litoralis* seeds being abundant throughout. This may largely be a consequence of the confounding effects of years, as birds were collected before and after 8 September in 1997 and 1999-2000 respectively. Differences in the cause of death and quality of the samples (Appendix 2) make it harder to detect seasonal patterns. The small number of samples from healthy birds were more consistent with the possibility that, at the height of the breeding season, adult teal consume more invertebrates. Thus, faeces from adults with a brood, and the gullet of a female recovered on 16 June showed these birds were feeding almost entirely on invertebrates. Similarly, the only faecal sample from August and three birds shot in October were consistent with a greater dependency of post-breeding teal on seeds. However, we have too few samples from healthy birds, and these were collected from too many different locations and years, to be conclusive about any seasonal diet switches.

In Sidi Moussa, Morocco, seeds were equally dominant in teal diet in May (when many birds were paired) and October (Green & Sánchez, 2003). Other Aythyini and Anatini ducks breeding in north-temperate regions typically feed more on invertebrates during the prebreeding and nesting periods than in the non-breeding season (Krapu & Reinecke, 1992; Kear, in press). However, numerous exceptions to this generalization can be found in the literature (Green *et al*., 2002), and studies on ducks breeding outside the temperate zone suggest they can be much less dependent on invertebrates (Kingsford, 1989; Petrie, 1996).

Although we have no samples before 16 June or after 24 November, we suspect teal may consume *S. litoralis* seeds all year round, subject to their availability. Seeds begin to fall onto the water from May onwards after the plants have produced fruits (Valdés *et al*., 1987) and are readily available to the teal since they float for days or weeks and become highly concentrated around the plants or downwind. Marbled teal in El Hondo glean the *S. litoralis* seeds from the water surface, as described in Turkey (Green & Selva, 2000). However, the availability of floating *S. litoralis* seeds is highly variable over time (Fig. 1), especially in relation to fluctuations in water level. Some years (e.g. in 2001) the areas occupied by *S. litoralis* have dried out by the time seeds are produced, so that they concentrate on the sediment surface and then become available in autumn or winter when reflooding occurs. Major differences between years are recorded in the phenology of seed availability (Fig. 1), making it hard to detect a seasonal change in diet from samples collected over several years.

In Doñana and Sidi-Moussa, Marbled Teal were much more dependent on similarly sized *Ruppia* seeds than on *Scirpus* seeds (Green & Sánchez, 2003). In the southern Alicante wetlands, both *Ruppia* and *Scirpus* seeds are abundant in the sediments (authors unpublished data) where they were mainly inaccessible to the teal at the time of sampling because of the depth. Our study, together with those of Green & Selva (2000) and Green & Sánchez (2003), suggest that fully-grown teal are heavily reliant on small seeds (especially *Ruppia* and *Scirpus*) but avoid large seeds such as those of *Potamogeton pectinatus*, and consume less green plant material than many other Aythyini and Anatini (Cramp & Simmons, 1977).

We have observed no consistent seasonal changes in feeding methods used by fully-grown teal in our study area, where they fed mainly in the top 10cm of the water column. Of 336 observations of feeding birds recorded from 15.9.98 to 29.10.00, 53.9% were picking items off the surface, 3.0% were gleaning, 37.8% were head-dipping, 5.1% neck-dipping and only 1 (0.3%) was upending (see Green, 1998a for details of behaviours and corresponding depths).

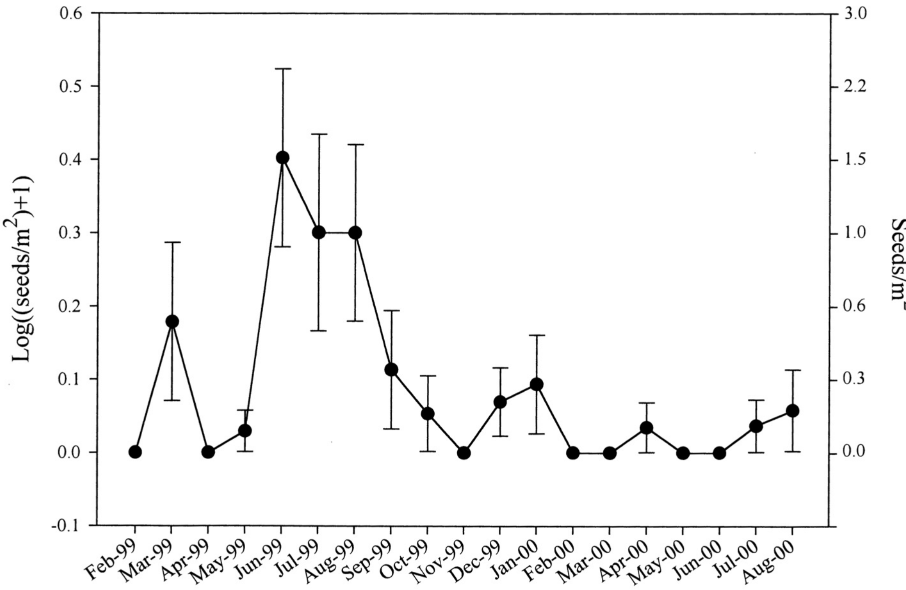

Figure 1.— Seasonal variation in the availability of *Scirpus litoralis* seeds in El Hondo. Data expressed as number of seeds floating (m^{-2}, $\log_{10}$ transformed, mean ± s.e.) at 26 fixed points sampled monthly within three ponds (Poniente, Levante and Reserva). 200 cm^2 of water surface was sampled at each point each month. The scale on the right hand gives untransformed numbers equivalent to geometric means. Owing to the clumped distribution of seeds, these are lower than the arithmetic means of untransformed data, which ranged from 3.5 to 11.8 seeds/m^2 from June to August 1999.

Our study shows that class I ducklings feed mainly on aquatic invertebrates. Similarly, Green & Sánchez (2003) found that class II teal broods in Doñana were feeding mainly on aquatic invertebrates (especially Chironomidae, Ephydridae and Coleoptera). Ducklings of most species have a diet particularly rich in invertebrate protein vital for growth (Krapu & Reinecke, 1992). In contrast to fully-grown teal, we found the gizzards of our class I ducklings to lack the grit required to break down seeds (Mateo *et al.,* 2001). Selection of seed sizes appears to be related to body size, with ducklings consuming more of the tiny (length *c*.1mm) *Suaeda* seeds and less of the other seeds (e.g. *S. litoralis*, length *c*.2.5 mm) than fully-grown birds. Ducklings also consume terrestrial invertebrates, as shown by the presence of ants (in this study) and spiders (this study and Green & Sánchez, 2003) in their diet. Since our samples came from ducklings trapped in an irrigation canal, our results may be biased towards food items accessible in the canal. However, since the canal was modified in 1998 to allow broods to get out easily, they have continued to concentrate there, probably because of the abundance of invertebrates (authors, unpublished data). We also found ants to be relatively abundant in the diet of fully-grown teal, and they were probably consumed mainly from the above water stems of *Phragmites* or *S. litoralis*. We know of no other study of duck diet in which ants were so abundant, although Green & Sánchez (2003) also recorded ants.

It is possible that we overlooked some invertebrates consumed by teal because they left no visible trace in guts or faeces. Cladocera and other zooplankton are readily digested and their importance as food items may have been underestimated. The cladoceran ephippia recorded from guts and faeces may have been ingested while still inside reproductive individuals, or they may have been ingested from sediments or while floating at the surface. We have observed Marbled Teal filtering *Daphnia magna* at El Hondo, and they have sufficiently fine lamellae in their bill (similar to those of Eurasian Teal *Anas crecca*) to enable them to filter larger zooplankton (Nummi, 1993; Green & Selva, 2000).

The green plant material consumed by teal may partly have been consumed when selecting invertebrates or seeds concentrated amongst the leaves of pondweeds occupying the surface layer. Corixidae (*Sigara* spp., including *S. stagnalis*) eggs in our study area are usually attached to the leaves of *P. pectinatus* or other submerged vegetation and their relative abundance in July faeces suggests the plant leaves may have been ingested while teal were feeding on these eggs (or vice versa).

The only previous detailed study of waterbird diet in our study area is that of Sánchez *et al.* (2000) for stifftails (White-headed Duck *Oxyura leucocephala,* North American Ruddy Duck *O. jamaicensis* and their hybrids, all of which have similar feeding ecology). When comparing the diet of stifftails which feed by diving with that of Marbled Teal, several differences are apparent. *Scirpus* seeds are more abundant in teal diet and *P. pectinatus* and *Ruppia* seeds are more abundant in *Oxyura*. *Oxyura* consume more Chironomidae larvae and pupae (although chironomid adults have only been recorded in the teal) and more polychaetes and gastropods. In contrast, Corixidae eggs, Ephydridae pupae and ants are more frequent in Marbled teal diet. These differences are explained by the greater dependency of *Oxyura* on benthic invertebrates and seeds in the sediments in El Hondo, a wetland mostly too deep for teal to feed on the bottom. Marbled Teal are strongly dependent on invertebrates and seeds available at or close to the water surface.

This and other recent studies (Livezey, 1996; Green, 2000; Green & Sánchez, 2003) suggest that the Marbled Teal differs considerably in both evolutionary and ecological terms from the north-temperate ducks that have been the focus of much more research. More research is required to establish how our preliminary study reliant on poor quality samples reflects the diet of this species in Alicante. There is also a need for studies of winter diet, as there are no data for December to April inclusive from any part of the range. A detailed study of seasonal changes in diet in a given annual cycle is also required (e.g. analysis of faeces collected at regular intervals).

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APPENDIX 1

Taxonomic classification of food items recorded in Marbled Teal faeces and guts in southern Alicante, showing the number of samples in which each item was recorded. P., Phyllum; sP., Subphyllum; C., Class; sC., Subclass; O., Order; sO., Suborder; F., Family; sF., Subfamily; Tr., Tribe; Unid., unidentified item; l., larvae; p., pupae; a., adult. Values in parentheses = n (5 broods for duckling faeces)

Food item	Fully-grown		Ducklings	
	Gut (64)	Faeces (20)	Gut (31)	Faeces (5)
Seeds and oospores				
F. Chenopodiaceae				
Atriplex spp.	3		1	
Suaeda spp.	5		13	
Arthrocnemum spp.	1			
F. Ranunculaceae, *Ranunculus spp.*	3		1	
F. Cyperaceae				
Scirpus spp.	12	2	2	
Scirpus litoralis	58			
Scirpus maritimus	15			
Carex spp.			2	
F. Gramineae				
Phragmites australis	1			
Sorghum bicolor	2			
Unid. Gramineae	2			
F. Potamogetonaceae, *P. pectinatus*	7		1	
F. Ruppiaceae, *Ruppia spp.*	19	1	1	
F. Zannichelliaceae, *Z. peltata*	1			
F. Polygonaceae, unid.	1			
F. Compositae, unid.	1			
F. Fabaceae, unid.	3			
F. Umbelliferae, unid.	1			
Unidentified seeds	14		4	
F. Characeae				
Chara spp., oogonia	5			
Green plant material	28	19	26	4
F. Characeae	1			
Invertebrates				
Ph. Bryozoa				
Cl. Phylactolecmata				
Plumatella fungosa, floatoblast	3			
Fredericella sultana, statoblast	1			
Ph. Nematoda	5		2	
Ph. Annelida				
Cl. Oligochaeta	1			1
Cl. Polychaeta	1			
Ph. Mollusca				
Cl. Gastropoda				
sCl. Prosobranchia				
F. Hydrobiidae				
Hydrobia spp.	2			
sCl. Pulmonata				
F. Planorbidae	1			
F. Ancylidae	1			

APPENDIX 1 (ctd)

Food item	Fully-grown		Ducklings	
	Gut (64)	Faeces (20)	Gut (31)	Faeces (5)
Unid. Gastropoda	3			
Ph. Artropoda				
Cl. Branchiopoda				
O. Anomopoda (Cladocera)				
F. Daphnidae				
Daphnia magna		2		
Daphnia spp. ephippia	6	7		
Moina spp. ephippia	2	5		
Cl. Ostracoda	7	9		1
Cl. Copepoda				
F. Cyclopidae				
Cyclops spp.	1			
Cl. Malacostraca				
O. Decapoda				
F. Palaemonidae				
Palaemonetes spp.			1	
O. Amphipoda				
F. Gammaridae	2			
Unid. Amphipoda	1			
O. Isopoda				
F. Sphaeromatidae				
Lekanesphaera hookeri	2			
Unid. Crustacea		1		
sPh. Unirramia				
Cl. Aracnida				
O. Acarina			1	
Cl. Insecta				
O. Plecoptera, l.	1			
O. Odonata				
sO. Zygoptera				
F. Coenagrionidae, l.	3			
Unid. Odonata, l.	3	3	1	
O. Hemiptera				
sO. Heteroptera				
F. Corixidae *Sigara* spp.	11	18		3
Sigara spp., eggs	3	17		1
sO. Homoptera				
F. Aphididae		1	1	
O. Hymenoptera				
F. Formicidae	6		7	2
O. Mallophaga	4			
O. Coleoptera				
F. Hydrophilidae				
Berosus sp., l.	2			
Hydrobius sp., l.	1			
Unid. Coleoptera, a.	7	10	8	5
O. Trichoptera				
Trichoptera, l.	2			
O. Diptera				
F. Chironomidae				

APPENDIX 1 (ctd)

Food item	Fully-grown		Ducklings	
	Gut (64)	Faeces (20)	Gut (31)	Faeces (5)
sF. Chironominae				
Tr. Chironomini, l.	3			
Tr. Tanytarsini, l.	3			
Unid. Chironominae, l.	6	5		2
Unid. Chironomidae, p.	6	1		3
Unid. Chironomidae, a.		3	1	
F. Ceratopogonidae				
Ceratopogoninae, l.	1			
F. Ephydridae				
Ephydridae, p.	6			
Unidentified Insecta	20	2	12	3
Unidentified Invertebrate	1	5	2	
Unidentified Invertebrate, eggs	10	5		1

APPENDIX 2

Details of the date, location and method of collection of gut and faecal samples from Marbled Teal in southern Alicante wetlands. Unless otherwise stated, the samples were collected from El Hondo. Sample sizes are given in parentheses

FULLY GROWN INDIVIDUALS

Jun: (1) adult female found dead under an electric pylon on 16.06.94.

JnSe: (16) found dead during bird mortalities from June to September in 1999 and 2000. Death was caused by gastro-enteritis type diseases (involving *Salmonella* sp., *E. coli, Campylobacter* sp., *Proteus* sp. and others, P. María, pers. comm.) related to the poor quality of water entering the wetland from the heavily polluted River Segura. Six birds (three males, three females) were sexed. 12 were collected between 28.6.99 and 27.7.99, one on 5.8.99, one on 7.9.99, two on 21.8.00.

SeNo: (44) found dead during a bird mortality from 8 September to 24 November in 1997. The mortality was due to a combination of lead-poisoning and botulism (García *et al*., 1998a,b; Mateo *et al*., 2001). Precise dates of collection are unknown. Only 30 birds (15 males, 15 females) could be sexed and 17 (12 juveniles, 5 adults) could be aged.

Oct: (3) Adult male, juvenile male and juvenile female shot illegally and then confiscated in October 1992 (one in Salinas de Santa Pola). Gullet and gizzard contents were mixed together before we received them.

EHJl: (17) Faecal samples collected on 19.07.00, on an islet in the Poniente reservoir of El Hondo used consistently by Marbled Teal (but no other waterbirds) during the preceding 15 days. 73 teals were observed immediately before collection.

EHAg: (1) Faecal sample collected on 18.08.00, from the side of the central canal in El Hondo.

CGJl: (2) Faeces from a breeding pair (with a class Ia brood) on 13.07.99, in the Clot de Galvany.

DUCKLINGS

Dkg: (31) Died within hours of being rescued from the Azarbe del Convenio and Azarbe de Dalt irrigation channels that run through El Hondo and alongside Hondo de Amorós. Most broods became trapped there just after hatching, when moving between nest sites and brood rearing ponds. Collection dates were from 28 May to 16 July in 1994 (1), 1995 (3), 1996 (7), 1997 (9) and 1998 (11). 29 were age class Ia (< 8 days old, see Larson & Taber, 1980; Green, 1998b), one was class Ic (9-18 days old, collected on 16.7.98) and one was class IIa (19-22 days old, collected on 12.7.94). Only two ducklings (class Ia) had food items in the gullet, the best sample coming from an individual that died during rescue on 7.6.95 that was immediately injected with 5% formol to conserve gut contents.

Brd: (5) Faecal samples from five broods rescued from the irrigation channels (12 class IIb ducklings rescued on 30.6.98; three class Ia ducklings on 25.6.99; four class III ducklings rescued on 8.7.99; class Ia brood of unknown size on 22.6.00; brood of unknown size and age in July 2000).