Rice crops occupy an area larger than any other crop in the world (1500000 km²; Fasola & Ruiz, 1996). European rice fields account for 0.3% of the world’s rice crop cover only. The amount of rice cultivation in Europe has increased slightly during the last decade (Fasola & Ruiz, 1996), and is mainly concentrated in the Axios Delta in northern Greece, the Po Plains and Po Delta areas in Italy, the Rhone Delta in southern France, the Ebro Delta, Albufera de Valencia and Marismas del Guadalquivir in Spain, and the Tejo and Sado plains and coastal areas in Portugal (Tinarelli, 1989; Hafner & Fasola, 1992).

European rice fields are intensively used by foraging waterbirds during some periods of their annual cycle (Fasola & Barbieri, 1978; Fasola, 1986; Fasola et al., 1996; Kazantzidis & Goutner, 1996) and thus they may replace the lost natural wetlands (Fasola & Ruiz, 1996). For instance, the sizes of the breeding populations of herons are positively correlated with the area of rice fields around the colonies both in Italy and in Spain (Fasola & Barbieri, 1978; Hafner & Fasola, 1992). Rice fields are recognised as a very important agricultural system for the conservation of waterbirds in the Mediterranean region (Dixon, 1994; Erwin, 1996). Fasola et al. (1996) estimate that the number of waterbirds in the Mediterranean could drop drastically if changes in the methods of rice cultivation were to take place, mainly if cultivation in dry soil increases.

Although no exact figures are available, rice fields extend over most of the arable land in the Sado Estuary, while the remains of the natural freshwater wetlands are much scarcer. For this reason, the availability of freshwater wetlands for waterbirds in this area is mainly related to the cycle of rice cultivation. Rice fields ecosystems are highly dynamic, because their physical and chemical parameters and water level change very quickly due to their human use. The associated biological communities tend to develop rapidly in response to these changes (Forrés & Comín, 1992). In this study we characterise the monthly variation in the abundance of prey for waterbirds within the rice fields during a whole rice cycle in the Sado estuary, in an attempt to evaluate the importance of this habitat for foraging waterbirds.

This study was conducted in the southern part of the Sado Estuary Natural Reserve (Setúbal, Portugal) within an area of 130 ha (38° 25’ N, 8° 42’ W), from December 1995 to September 1996. The rice paddies suffered a limited human intervention. Only some fields were ploughed and dried up during the winter 1995-1996, depending solely on the atmosferical conditions. Most fields were flooded during the whole winter, until the beginning of March. The labour of the fields began during March and April, with land ploughing and planishing. During April, the rice paddies were prepared and by the end of April-beginning of May they were flooded. The water came directly from a small dam and it wasn’t pumped or filtered in the way to the rice fields (the water level was maintained between 15 and 20 cm until August). The fields were flooded by means of a network of extended canals, none of which was covered with concrete. From the end of April to the beginning of May the rice was sown (by aeroplane), and germination occurred approximately 10 days after sowing. The rice plants emerged from the water approximately one
month later (June). During July the rice plants grew very fast, achieving ear formation in August and ear ripening in September. Rice plants reached its maximum height in August. During September and before harvesting, the fields were dried up.

Rice fields were sampled monthly from December 1995 to September 1996 (from the beginning of the preparation of the fields for sowing until harvesting) during the first 10 days of each month. Sampling was conducted early in the morning, since the abundance of most aquatic animals varies during the day (Kersten et al., 1991). The fields sampled in a given sampling period were chosen randomly. Each selected field was sampled once. The number of samples varied from 6 in September to 19 in May (averaging 13.8 per month). The reduced number of samples in September was due to the fact that the number of flooded rice fields, which were not harvested, was small. Samples were taken using a long-handled net (20 × 40 cm) that sampled all the water column. The mesh size was of approximately 1 mm. The long handle-net was drag more than 5 metres at the maximum velocity. Sampling was always done near the edge of the rice fields, where plant density is lower than in the middle. Although this could have biased the results for the last months before harvesting, as plant density affects the distribution of aquatic vertebrates in the freshwater habitats (Kersten et al., 1991), it was not practical to sample within fields. The net sampled efficiently all the prey except adult frogs and large fish (Fasola, 1986), so that these two groups could have been underestimated. Fasola (1986), Hafner & Fasola (1992) and Fasola et al. (1996) used this method. Specimens were grouped taxonomically and then oven-dried at 60°C until constant weight and weighted to calculate biomass. Groups of prey were defined on the basis of the works of Fasola (1986) and González-Solís et al. (1996). The dry mass of the prey collected, divided by the surface swept, gave a quantitative estimate of prey abundance.

The biomass of prey available in the rice fields increased slightly from December to March, reaching a peak in the latter month of approximately 2 kg/ha (Fig. 1). From March until May, when human intervention in the rice fields begun, there was a decrease in the medians of the monthly biomass values. From the date of such intervention (flooding and sowing of fields in May) and until August there was a slight rise in median biomass values, that accelerated suddenly in September due to the removal of the water of the rice fields and the concentration of potential prey in the flooded remains. In fact, median values of biomass were significantly different between August and September (Mann-Whitney U = 0; P =

Fig. 1.—Monthly variation of biomass (kg dry mass/ha) of potential prey for waterbirds in the Sado estuary rice fields. Circles are median values, and vertical lines show the range between the upper and the lower quartiles.

[Variación mensual de la biomasa (kg peso seco/ha) de presas potenciales para las aves acuáticas en los arrozales del estuario del Sado. Los círculos representan las medianas y las líneas verticales los rangos entre cuartiles.]
0.0082), and median biomass reached its absolute peak in the latter month (73 kg/ha). Amphibians, crustaceans and fish were the three more abundant types of prey in terms of biomass (Fig. 2). Amphibians were present from May until August, reaching the highest value of biomass in June (0.52 kg/ha). However, this pattern could have been partly due to the fact that only tadpoles were well sampled with our method (Fasola, 1986; pers. obs.), and most tadpoles metamorphosed into adults by June. The most abundant prey species was the marsh frog (*Rana perezi*) with over 95% of the total amphibian biomass. Other amphibians found were western spadefoots (*Pelobates cultripes*), shap-ribbed salamanders (*Pleurodeles waltii*) and Bosca’s newts (*Triturus boscai*).

The fish and crustaceans showed parallel variations in median biomass (Fig. 2). The two groups were present during all the sampling period and had two major peaks, a lower one in March (median biomass of 3.6 and 6.1 kg/ha, respectively) and a much larger one in September (median biomass of 52.6 and 32.8 kg/ha, respectively). This fact could have been due to the concentrations of these animals in the flooded remains after the removal of water from rice fields. The introduced mosquito fish (*Gambusia affinis*) was by far the most abundant fish in number and in biomass, followed by carps (*Cyprinus carpio*) with less than 5% of the total fish biomass. The introduced red swamp crayfish (*Procambarus clarkii*) was the only species of crustacean found in the study area.

The results obtain by González-Solís et al. (1996) in the Ebro Delta (Spain) for the seasonal variation of prey availability in the period between May and September were similar to ours, and yield an identical profile of variation, the highest value being achieved also in September (yet the maximum value being much lower -approximately 6 kg/ha). The strong variation detected in the estimates of biomass was also observed by other authors (Fasola & Ghidini, 1983; Fasola et al., 1996; González-Solis et al., 1996). This could indicate that the spatial distribution of prey has a clumped pattern (considering that the variance is higher than the mean; Fasola & Ghidini, 1983), which may result from the dispersal and recolonisation of rice fields by the organisms, with fields near the main canals having greater densities (it is in the main canals that, during the drying of the fields, the organisms survive, and then recolonise the rice fields).

The values of biomass are within the interval of variation of the most important rice fields areas for birds in Europe (Hafner & Fasola, 1992; Fasola et al., 1996). During the breeding and wintering periods the area support a large number of waterbird species, namely an important population of *Egretta garzetta* and *Bu*

![Fig. 2.—Seasonal variation of the median biomass (kg dry mass/ha) of the three most abundant types of prey for waterbirds (crustaceans, fish and amphibians) in rice fields of the Sado estuary.](image.png)

[Variación estacional de la biomasa de los tres tipos de presas de las aves acuáticas (crustáceos, peces y anfibios) más abundantes en los arrozales del estuario del Sado.]
bulcus ibis (Dias, 1991; Farinha & Trindade, 1994). The major peaks of biomass coincide with the pre-nuptial and post-nuptial migrations, increasing its value for waterbirds that used rice fields as stopover foraging habitat, such as waders, ducks or storks (Fasola & Ruiz, 1996). This dependence can be hazardous, because the rice cultivation is susceptible to sudden changes in agricultural practices, which may result in a serious impact to the local and migratory populations.

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