Bol. Inst. Esp. Oceanogr. 19 (1-4). 2003: 505-508

BOLETÍN. INSTITUTO ESPAÑOL DE OCEANOGRAFÍA
ISSN: 0074-0195

Diets of the sole *Solea vulgaris* Quensel, 1806 and *Solea senegalensis* Kaup, 1858 in the lower estuary of the Guadiana River (Algarve, southern Portugal): Preliminary results

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Received January 2003. Accepted December 2003.

ABSTRACT

The feeding habits of two major species of sole, the common sole *Solea vulgaris* Quensel, 1806 and the Senegalese sole *Solea senegalensis* Kaup, 1858 were studied in the lower estuary of the Guadiana River (Algarve, southern Portugal). An evaluation of the number, weight, and feeding coefficient of prey types showed that *S. vulgaris* feed on a limited variety of prey (only Polychaeta and Tanaidacea) and present low-intensity feeding activity, with small differences in diet between seasons. *S. senegalensis* also have a low-diversity diet (with only one more taxa, Amphipoda), but exhibit more intense feeding activity which varies seasonally, although with little seasonal variation in the relative importance of the main preys. The diet composition of these two species suggests feeding specialization.

Keywords: Stomach contents, *Solea*, flatfish, Guadiana River, estuary, Portugal.

RESUMEN

Hábitos alimentarios de los lenguados* Solea vulgaris *Quensel, 1806 y* Solea senegalensis *Kaup, 1858 en el bajo estuario del río Guadiana (el Algarve) (sur de Portugal): Primeros resultados

Se han examinado los hábitos alimentarios de dos especies importantes de lenguado, Solea vulgaris *Quensel, 1806 y* Solea senegalensis *Kaup, 1858, en el bajo estuario del río Guadiana (en el Algarve, sur de Portugal). La actividad depredadora de* S. vulgaris *es escasa y la variedad de sus presas limitada (únicamente poliquetos y tanaidaceos), con una ligera variación estacional de la dieta.* S. senegalensis *también se alimenta de una variedad reducida de presas, aunque con un taxón más (anfípodos), y tiene una actividad depredadora mayor, que varía estacionalmente, aunque no hay variaciones en la importancia relativa de la presa con la estación del año. La composición de la dieta de estas dos especies sugiere la especialización de su alimentación.*

Palabras clave: Contenido estomacal, *Solea*, lenguados, Guadiana, estuario, Portugal.

INTRODUCTION

The present study was carried out within the framework of a project that aims to characterise the icthyofauna and trophic interactions in the estuary of the Guadiana River. The stomach contents of the principal species of fish of this estuary, and the Castro Marim salt marsh, were examined. The common sole *Solea vulgaris* Quensel, 1806, and the Senegalese sole *Solea senegalensis* Kaup, 1858, repre-

sent a major benthic resource in this estuary for the local fisheries. Estuarine and coastal areas have been recognised as important habitats for many flatfish species (e.g. Koutsikopoulos *et al.*, 1989; Andrade, 1992; Henderson and Seaby, 1994; Cabral and Costa, 1999).

To date, there have been no studies on the diets of the principal species of fish in the Guadiana River estuary and Castro Marim salt marsh.

These common, commercially valuable species were studied in order to evaluate their feeding habits and possible seasonal changes.

MATERIALS AND METHODS

We analysed the stomach contents of individuals of these two species of sole, caught by otter trawl in the lower estuary of the Guadiana River (Algarve, southern Portugal) on a monthly basis from September 2000 to August 2001. The monthly data were grouped by season. All sampling was carried out during the night. For each specimen, length to the nearest millimetre, and total and gutted weight to the nearest gram were recorded.

The stomachs were removed and individually stored, first in 4 % formalin and then, after one week, in 70 % alcohol. The stomachs were opened, the contents removed, and the prey separated into major taxonomic groups and preserved. The number of empty stomachs was recorded. Prey items were identified, counted and weighed. Diet characterization was based on stomach contents alone, to avoid overestimation of prey with exoskeletons or other hard structures (Cabral, 2000). There may be disadvantages in this method due to rapid gastric evacuation, but most previous studies on the diet of *Solea* spp. have been based on stomach contents only: Ramos (1981), Lagardère (1987) and Molinero and Flos (1991, 1992).

The methods used to quantitatively and qualitatively describe the diet were: 1) numeric percentage (Cn) of individuals of a prey category to the total number of prey individuals in the stomachs; and 2) percentage weight (Cw) of a prey category to the weight of the total stomach contents. The most important food items were determined using the Feeding Coefficient $Q = Cn \cdot Cw$ (Hureau, 1970), which characterises the relative importance of the different preys in a diet. Using this coefficient, prey were separated into three categories (table I).

Table I. Relative importance of differnt preys in the diet, according to the feeding coefficient (Q)

Q	Relative importance
$Q > 200$	Principal prey
$20 < Q < 200$	Secondary prey
$Q < 20$	Occasional prey

Feeding activity was evaluated by the Emptiness Index (EI), defined as the percent of empty stomachs (Hyslop, 1980; Casadevall, Matallanas and Bartolí, 1994; Gonçalves and Erzini, 1998).

Diversity of food resources used by each species was measured using the most commonly used diversity measure, the Shannon-Wiener index (H') (Shannon and Weaver, 1963 in Terrats, Petrakis and Papaconstantinou, 2000):

$$H' = -S\ p_i\ (\log\ p_i)$$

where p_i is the proportion of the i-th prey item in the stomach content.

RESULTS

The *S. vulgaris* analysed in the study ranged from 8.1 cm - 28.6 cm in total length, with a mean value of 19.6 cm. The *S. senegalensis* ranged from 11.3 cm - 31.1 cm in total length, with a mean value of 20.6 cm.

We analysed 107 stomachs, of which 53.3 % were of *S. vulgaris* and 46.7 % of *S. senegalensis*. Both species were only caught in spring and winter.

The EI was high at all times for *S. vulgaris* and in spring for *S. senegalensis* (mean values by season of 57.9 % and 40.4 %, respectively), with the lowest values found in winter (table II).

Only three types of prey were found for both species: Polychaeta (worms) and Crustacea, represented by the taxa Tanaidacea and Amphipoda. The Q coefficient showed that the diet of these species consists primarily of Polychaeta and secondarily of the Tanaidacea group (table III). All preys were taken by both species, but in different quantities.

The comparison of the winter 2000 and the spring 2001 diets of *S. vulgaris* showed that the only difference was in the relative importance of Tanaidacea, which became a principal prey in spring. For *S. senegalensis,* Polychaeeta were the principal prey in the winter, whereas amphipods were also occasional prey in the spring.

Table II. Type of stomach content, in percentages, for each species overall and by season. The type named *Others* comprises detritus and sediment

S. vulgaris			
Stomach content	Season		
	Total	Winter	Spring
Emptiness Index	56.1	55.8	60.0
With prey	29.8	28.8	40.0
Others	14.0	15.4	

S. senegalensis			
Stomach content	Season		
	Total	Winter	Spring
Emptiness Index	34.0	27.0	53.8
With prey	64.0	70.3	46.2
Others	2.0	2.7	

DISCUSSION

The high EI values found in the present study were probably due to a high rate of gastric evacuation. De Groot (1971) reported that due to the characteristics of its digestive tract and a rapid digestive process, *S. vulgaris* feeds on small quantities of prey very often. This suggests a high evacuation rate between the stomach and the intestine, and lack of digestion in the stomach (Lagardère, 1987).

Cabral (2000) points out that previous studies have reported that the most important prey items of *S. vulgaris* are Polychaeta, Crustacea and Mollusca (Ramos, 1981; Lagardère, 1987; Henderson, James and Holmes, 1992), with regional differences (English Channel, northern France and the western Mediterranean). The range of fish lengths analysed, along with other factors, probably partly accounts for these differences in diet (Cabral, 2000). The results obtained in the present study for the Guadiana estuary are in agreement with those reported by these authors.

Molinero, García and Flos (1991), in the western Mediterranean, reported that the diets of *S. senegalensis* and *S. vulgaris* were very similar. In the Tagus estuary, for both species, the importance of larger prey items in the diet, namely a worm (*H. diversicolor*) and a shrimp (*Crangon crangon*), increased with fish size, and dietary differences mainly reflected prey availability (Cabral, 2000).

Table III. Analysis of the stomach contents of *S. vulgaris* and *S. senegalensis* overall and by season. The contribution of each food item in the diet is expressed as percentage numeric composition (Cn) and percentage weight (Cw); the feeding coefficient (Q) was used to evaluate the relative importance of the different prey items in the diet, where PP is principal prey, SP is secondary prey, and OP is occasional prey; the Shannon-Weaver index (H') was used to characterise the diversity of the food resources used by each species

S. vulgaris					
Season	Prey	Cn	Cw	Q	H'
Total	Amphipoda	2.2	0.01	0.02 OP	0.90
	Polychaeta	65.2	98.0	6 394.2 PP	
	Tanaidacea	32.6	1.9	63.4 SP	
Winter	Amphipoda	2.3	0.01	0.02 OP	0.74
	Polychaeta	65.1	98.2	6 393.0 PP	
	Tanaidacea	32.6	1.8	59.0 SP	
Spring	Polychaeta	66.7	54.3	3 617.2 PP	0.16
	Tanaidacea	33.3	45.7	1 524.7 PP	

S. senegalensis					
Season	Prey	Cn	Cw	Q	H'
Total	Amphipoda	5.0	0.1	0.3 OP	0.94
	Polychaeta	90.0	99.8	8 983.5 PP	
	Tanaidacea	5.0	0.1	0.6 OP	
Winter	Polychaeta	96.4	99.9	9 629.5 PP	0.15
	Tanaidacea	3.6	0.1	0.5 OP	
Spring	Amphipoda	16.7	0.5	8.5 OP	0.72
	Polychaeta	75.0	99.4	7 457.4 PP	
	Tanaidacea	8.3	0.1	0.5 OP	

Molinero and Flos (1992) observed significant differences in feeding habits between seasons and between sexes in each season for *S. vulgaris*. For *S. senegalensis*, García-Franquesa *et al.* (1996) suggested that feeding habits in the Ebro estuary (Spain) were significantly influenced by sex, age and season.

In our analysis, the Q coefficient showed that the diet of these species consists primary of the Polychaeta group, and the other two groups present in the stomachs seemed to indicate a relatively low level of adaptation of the species to the food available.

Common sole and Senegalense sole within the Guadiana estuary seem to show low dietary variation, which suggests that the trophic spectrum of these two species is extremely narrow.

In conclusion, *S. vulgaris* feeds on a low variety of prey (only Polychaeta and Tanaidacea) and present a low-intensity feeding activity, with only a slight seasonal variation in the diet (e.g., relative importance of Tanaidacea). *S. senegalensis* also feeds on a limited number of prey species (but with one more taxa, Amphipoda), and has a higher feeding activity that varies seasonally, but with no seasonal variation in the relative importance of preys. The dietary composition of these two species in the Guadiana estuary suggests feeding specialization.

Further studies on feeding competition between these two species, as well as differences according to sex, age and trophic profile for each species, would provide better understanding of their trophic importance.

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