The structure of fish communities in the Tagus Estuary, Portugal, and its role as a nursery for commercial fish species

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SUMMARY: The Tagus is the largest estuary in Portugal (320 km^2). Its fish community is composed of 44 species, with species diversity values varying between 0.85 and 2.237. Seven fish species use the estuary as a nursery area: *Trisopterus luscus* (Linnaeus, 1758), *Ciliata mustela* (Linnaeus, 1758), *Dicentrarchus labrax* (Linnaeus, 1758), *Trigla lucerna* Linnaeus, 1758, *Platichthys flesus flesus* (Linnaeus, 1758), *Solea vulgaris vulgaris* Quensel, 1806, and *Solea senegalensis* Kaup, 1858. While in the estuary, their growth rate is very high. This may be related to the availability of suitable food items. The brown shrimp *Crangon crangon* (Linnaeus, 1758) also uses the estuary as a nursery, and is a prefered prey of *T. lucerna*, *D. labrax* and *C. mustela*, and a secondary prey for *S. vulgaris* and *P. flesus*. The main food of these last two species are two polychaete species, *Nereis diversicolor* Müller, 1852 and *Lanice conchilega* Pallas, 1778. Three shallow water stations near highly productive salt-marshes are the principal nursery areas for fishes. Young of the year *D. labrax* were caught first in nursery areas in May with a minimum standard length of 25 mm. The first catches of *Solea vulgaris* occurred in April, when juveniles had a standard length of 30 mm. The highest density was observed in May with 142.3 ind. 1000 m^{-1}. Density values of *Solea senegalensis* were lower.

Key words: estuaries, fishes, nursery areas, coastal fisheries.

INTRODUCTION

Knowledge of estuarine nurseries may provide an answer to the important role they play in preserving offshore stocks of commercial fishes. Several studies have been made on estuarine fish communities, such as those of BODDEKE *et al.* (1969); CREUTZBERG & FONDS (1971) ALLEN & HORN (1975); POXTON & NASIR (1975); HOFF & YBARRA (1977); VAN DEN BROEK (1978); RAUCK & ZIJLSTRA (1978); WARBBURTON (1978); DANKERS & DE VEEN (1979); CHESNEY & IGLESIAS (1979); MARCHAND (1980); DAY *et al.* (1981); HAEDRICH (1983); CLARIDGE & POTTER (1984). Only a few of these investigate the role of the estuaries as nurseries.

Large estuaries, such as that of Tagus, play an important ecological and economic role as fishery areas. However, in addition to the mortality of young fish caused by fishing activites, mainly fishing of brown shrimp *Crangon crangon* (Linnaeus, 1758), the Tagus estuary is subjected to intense human disturbance. The domestic sewage from Lisbon (over 1 million inhabitants), as well as the un-treated effluents of several industrial plants, are released into the estuary. It is necessary to study the structure and function of its fish communities, in order to preserve them.

The structure and diversity of fish communities in the estuary was described by COSTA (1986). These data were re-examined and the main diets of six fish species that use the estuary as a nursery were reanalyzed. Because of their high commercial value, we chose sea bass, *Dicentrarchus labrax*, and sole, *Solea vulgaris vulgaris* and *Solea senegalensis*, to study the population growth, density and distribution of fish in the nursery areas.

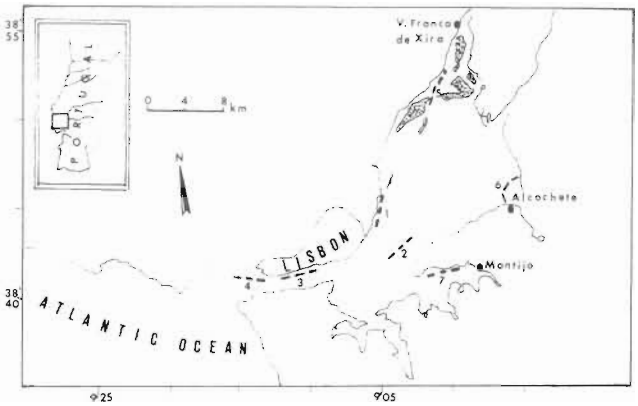

FIG. 1. — Map of sampling stations in the Tagus estuary.

MATERIAL AND METHODS

To study the structure, abundance and diversity of the fish community (COSTA, 1986), monthly catches were made between 1978 and 1981 at 7 stations (Fig. 1), using a 4 m beam-trawl with a stretched mesh of 20 mm.

The feeding habits of all demersal fishes caught have been studied (COSTA, 1988). The data obtained were re-examined and stomach contents were analysed using only the occurrence of the main food items, expressed as percentages of non-empty stomach number. This was done for all species that use the estuary as a nursery.

After being detected, the main nursery sites (Stations 5 and 6), were surveyed intensely in 1986 for *D. labrax*, *S. vulgaris* and *S. senegalensis*. Several 15 min. catches for 0-group sole and sea bass were taken two days a month using a 6 m beamtrawl with a stretched mesh of 20 mm pulled at a speed of about 1.5 knots. Samples were taken near Vila Franca de Xira and Alcochete, from April to October, 1986, using a fisherman's boat usually set to fish shrimp. No catches were made in August.

Specimens were separated in age groups, using PAULY'S (1980) method, and by reading some burned otoliths (CHRISTENSEN, 1964).

RESULTS

Fish community structure and diversity

Based on data obtained from 1979 to 1981, we learned that the fish community of the Tagus Estuary was composed of 42 species (3 selachians and 39 teleosts). During the subsequent intensive survey near Vila Franca de Xira and Alcochete in 1986, two new species were caught: the sea-lamprey *Petromyzon marinus* Linnaeus, 1758 and the sole *Solea senegalensis* (Table I). Seven fish species are known to use the estuary as a nursery area: *Trisopterus luscus, Ciliata mustela, Dicentrarchus labrax, Trigla lucerna, Platichthys flesus flesus, Solea vulgaris vulgaris* and *Solea senegalensis*.

In an estuary, the pattern of water circulation along with human activities, leads to the creation of different habitats related to different kinds of substrate, salinity, temperature, pollutants, crowding, etc. To understand the resulting fish community structure, we submitted the data obtained in 1980-1981 to some ordinative and agglomerative methods, and calculated the Shannon-Wiener div-

TABLE I. — Species list of fish recorded in Tagus Estuary. Classification after CLOFNAM (HUREAU & MONOD, 1973). The species with * use the estuary as a nursery.

Petromyzon marinus Linnaeus, 1758
Scyliorhinus canicula (Linnaeus, 1758)
Mustelus asterias Cloquet, 1821
Raja undulata Lacepède, 1802
Sardina pilchardus (Walbaum, 1792)
Sprattus sprattus (Linnaeus, 1758)
Alosa fallax (Lacepède, 1803)
Engraulis encrasicolus (Linnaeus, 1758)
Cyprinus carpio (Linnaeus, 1758)
Barbus barbus bocagei (Steindachner, 1864)
Anguilla anguilla (Linnaeus, 1758)
Conger conger (Artedi, 1738; Linnaeus, 1758)
Syngnathus abaster Risso, 1826
Syngnathus typhle Linnaeus, 1758
Hippocampus ramulosus Leach, 1814
Pollachius pollachius (Linnaeus, 1758)
* *Trisopterus luscus* (Linnaeus, 1758)
* *Ciliata mustela* (Linnaeus, 1758)
* *Dicentrarchus labrax* (Linnaeus, 1758)
Trachurus trachurus (Linnaeus, 1758)
Argyrosomus regius (Asso, 1801)
Diplodus sargus (Linnaeus, 1758)
Diplodus vulgaris (E. Geoffroy Saint-Hillaire, 1817)
Pagellus bogaraveo (Brünnich, 1768)
Spondyliosoma eantharus (Linnaeus, 1758)
Symphodus bailloni (Valenciennes, in Cuv. & Val., 1839)
Gobius niger Linnaeus, 1758
Gobius paganellus Linnaeus, 1758
Pomatoschistus minutus (Pallas, 1770)
Aphia minuta (Risso, 1810)
Callyonymus lyra Linnaeus, 1758
Blennius gattorugine Brünnich, 1768
Mugil cephalus Linnaeus, 1758
Chelon labrosus (Risso, 1826)
Liza ramada (Risso, 1826)
Liza aurata (Risso, 1810)
Atherina presbyter (Cuvier, 1829)
* *Trigla lucerna* Linnaeus, 1758
Scophthalmus rhombus (Linnaeus, 1758)
Arnoglossus laterna (Walbaum, 1792)
* *Platichthys flesus flesus* (Linnaeus, 1758)
* *Solea vulgaris vulgaris* Quensel, 1806
* *Solea senegalensis* Kaup, 1858
Dicologoglossa cuneata (de la Pylaie Moreau, 1881)

TABLE II. Number of species and diversity indices per station.

Stations	Number of species		Diversity index (H)	
	1979	*1980-81*	*1979*	*1980-81*
1	12	18	1.462	1.747
2	11	22	1.605	2.580
3	15	21	2.136	1.472
4	21	25	2.254	2.106
5	14	24	1.776	1.092
6	21	24	1.499	1.511
7	11	24	1.320	2.042

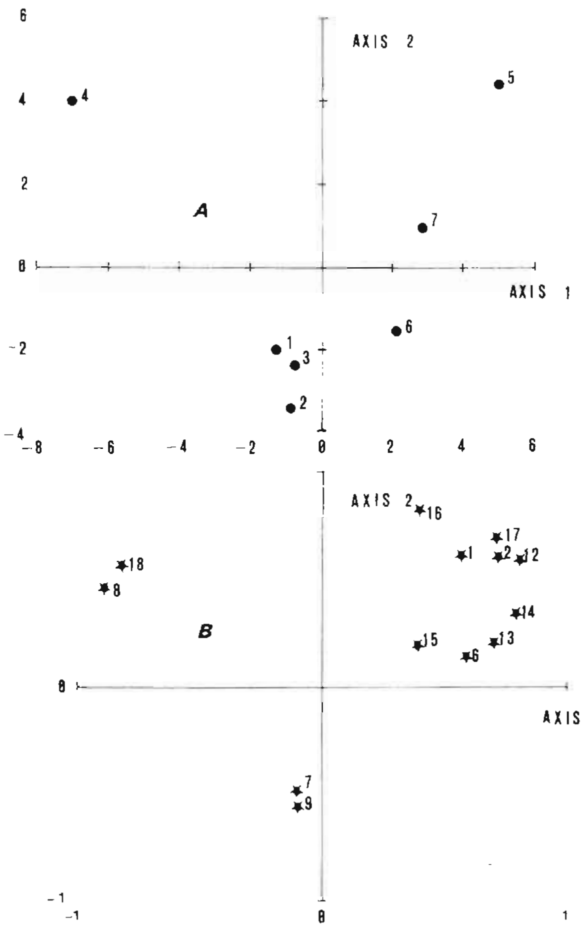

FIG. 2 — Principal Component Analysis. Plotting of the stations (A) and of the species (B) on axis 1 and 2. Points plotted together in (B): 1, 3, 4; 2, 5; 8, 10 and 7, 11. The species are: 1, *Alosa fallax;* 2, *Engraulis encrasicolus;* 3, *Cyprinus carpio;* 4, *Barbus barbus;* 5, *Anguilla anguilla;* 6, *Conger conger;* 7, *Hippocampus guttulatus;* 8, *Trisopterus luscus;* 9, *Ciliata mustela;* 10, *Chelon labrosus;* 11, *Blennius gattorugine;* 12, *Mugil cephalus;* 13, *Liza ramada;* 14, *Liza aurata;* 15, *Atherina presbyter;* 16, *Platichthys flesus;* 17, *Solea vulgaris;* 18, *Dicologoglossa cuneata.*

ersity index (SHANNON & WEAVER, 1963), both for each station and for the estuary as a whole. Diversity values are shown in Table II, and the first two axes of a principal component analysis is shown in figure 2.

Station 4, near the mouth, had a larger number of species and a higher diversity index. This is due to its normal seawater salinity, that allows some marine species to feed there. This is the case for *Arnoglossus laterna, Dicologoglossa cuneata* and *Pagellus bogaraveo*, which occurred only there.

Stations 1, 2 and 3 are pulled together with the PCA but they can nevertheless be considered different with regard to their number of species and diversity values. Station 1 has a very low number of species, due to the stress caused by intense chemical pollution from a plant nearby; its diversity value is 1.747.

Stations 5, 6 and 7, corresponding to shallower waters near highly productive salt-marshes, are very important nurseries, especially the first two. Station 5, however, is separated from the others in the PCA because fresh-water fish species such as *Barbus barbus bocagei* and *Cyprinus carpio* occur there during floods. Diversity values at stations 5, 6 and 7 were comparatively low: 1,092, 1,511 and 2,042. The low diversity value is due to the existence of a high number of soles, which dominate the community. However, the number of species is high.

Food

Crangon crangon is the main food item for *Trigla lucerna* (79 % day and 100 % night), *Trisopterus luscus* (89 % day and 87 % night), *Ciliata mustela* (78 % day and 65 % night) and *Dicentrarchus labrax* (58 % day). The percentage of empty stomachs is very low in all these species: (0.62 % day and 0 % night in *T. luscus;* 1.69 % day and 7.14 % night in *C. mustela;* 4.64 % in *D. labrax;* 8.7 % day and 11.7 % night in *T. lucerna*).

Solea vulgaris vulgaris and *Platichthys flesus flesus* are infaunal eaters, feeding mainly on polychaetes whose frequency of occurrence varies from 46 % during the day to 64 % at night for *S. vulgaris*, and from 77 % during the day to 52 % at night for *P. flesus*.

The most abundant worm prey is *Nereis diversicolor* Müller, 1852. This species is very abundant in the estuary, and extremely tolerant to temperature and salinity changes, as well as to organic pollutants. It is a major prey for both *S. vulgaris* and *P. flesus*. *Lanice conchilega* Pallas, 1778, a species that inhabits fine-grain sands, is the main prey for *P. flesus*, a fish that undergoes intertidal feeding migrations (WOLFF, 1980; WIRJOATMODJO & PITCHER, 1984). *C. crangon* is also a prey for these flat fish species, but with very low frequencies of occurrence. The percentage of empty stomachs was also very low (*P. flesus*, 15.9 % day and 13.0 % night; *S. vulgaris,* 5.3 % day and 17 % night).

Population density and distribution

Dicentrarchus labrax

The distribution of 0-group sea-bass is shown in figure 3. This size class prefered Alcochete, although it was also caught in Vila Franca de Xira. This preference may be due to the greater abundance of *C. crangon* in that area. The highest density of sea bass was found in July (36 ind. 1000 m^{-2}) and the highest biomass in October (140.8 g fresh weight 1000 m^{-2}; Table III).

Young fish of 20 mm standard length were caught in the estuary in May. Even though they prefered Alcochete, their growth rate was faster in Vila Franca de Xira, where they reached a standard length of 11.16 cm in October, while only 8.97 cm in Alcochete (Table IV). The sex-ratio was close to 1, with males slightly more abundant than females.

Solea vulgaris

The sole population of the estuary consisted of both young and adults. However, adults migrated to the sea during the winter for spawning. DINIS (1986) considers February as the maximum spawning month. The microscopic study of gonad slides taken from these migrating fish show that they were in a pre-spawning condition. The sex-ratio was close to 1 until June, when the number of females slightly ex-

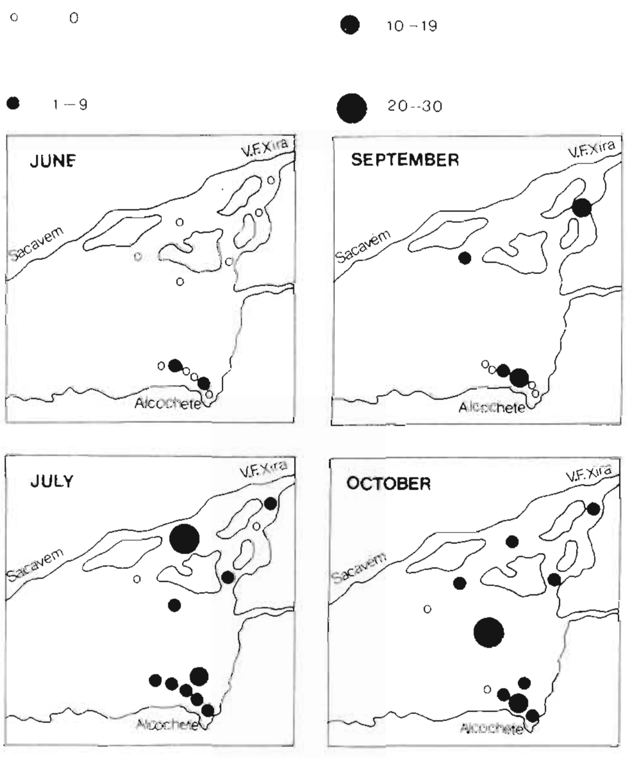

FIG. 3. — Distribution of 0-group *D. labrax*. Individuals per 1000 m^2 fished.

TABLE III. — 0-group sea-bass catch densities (numbers and biomass per 1000 m^2 in the nursery area

Months	*Numbers*	*Biomass (g)*
May	9.6	2.9
June	29.3	35.9
July	36.0	137.8
September	9.6	128.1
October	6.3	140.8

TABLE IV. — Monthly mean length (cm) of 0-group sea-bass *Dicentrarchus labrax* in two zones of the estuary

Area	*May*	*June*	*July*	*Sept.*	*October*
Alcochete	2.8	3.98	6.33	7.86	8.97
V. F. de Xira		4.48	6.76	9.76	11.16

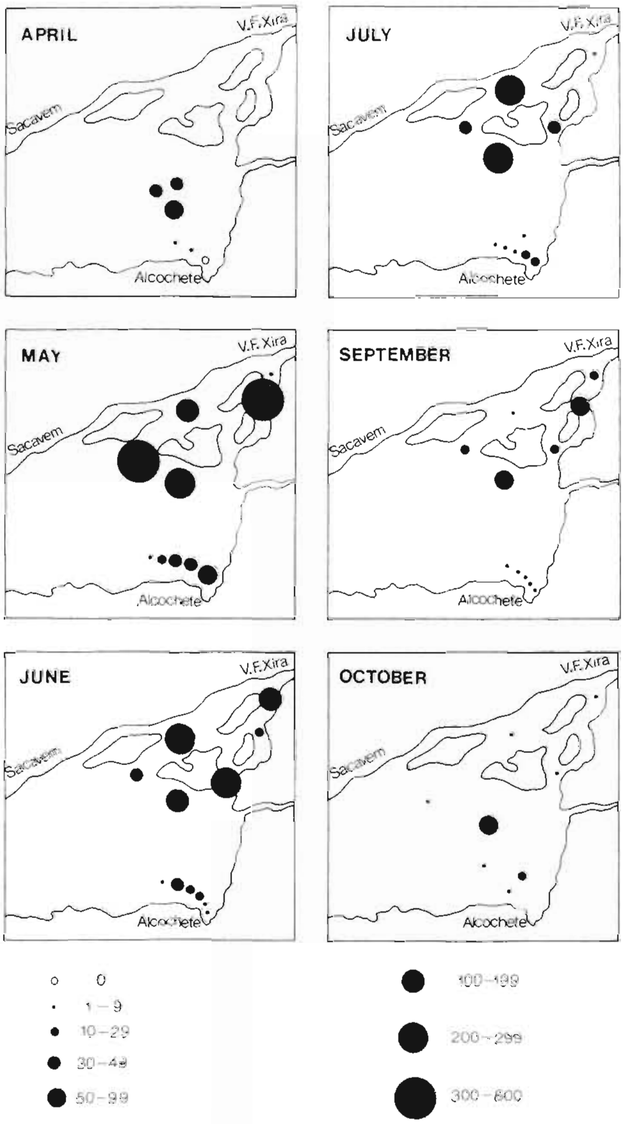

FIG. 4. — Distribution of 0-group *S. vulgaris* Individuals per 1000 m^2 fished.

ceeded the number of males. Young-of-the-year (modal class of standard lenght 30 mm) were captured in Alcochete while migrating to their favorite nursery area (Fig. 4) located upstream, near Vila Franca de Xira. Several conditions made this area suitable for 0-group sole: shallow waters providing shelter from predators, good feeding resources and suitable substrate composed of black thick mud and muddy sand with invertebrate populations dominated by *N. diversicolor*.

Growth was very fast in both zones (Table V), being slightly faster in Alcochete (13.87 cm in October) than in Vila Franca de Xira (10.86 cm). The highest density values (mean numbers 1000 m^{-2}) in the nursery area were observed in May with 142.3 ind. 1000 m^{-2}, then decreased steadily with values of 61.2 in June, 46.6 in July, 18.2 in September and 6.5 in October. Corresponding biomasses are 221.3, 171.4, 326.8, 229.2 and 116.3 g 1000 m^{-2} respectively (Table VI).

TABLE V. — Monthly mean length (cm) of 0-group sole *Solea vulgaris vulgaris* in two zones of the estuary

Area	*April*	*May*	*June*	*July*	*Sept.*	*Oct.*
Alcochete	3.67	5.37	6.24	7.96	12.7	13.87
V. F. de Xira		5.19	6.29	8.06	10.59	10.86

TABLE VI. — 0-group sole *Solea vulgaris vulgaris* catch densities (numbers and biomass per 1000 m^2) in the nursery area

Months	*Numbers*	*Biomass (g)*
May	143.2	221.3
June	61.2	171.4
July	46.6	326.8
September	18.2	229.2
October	6.5	116.3

TABLE VII. — 0-group sole *Solea senegalensis* catch densities (number and biomass per 1000 m^2) in the nursery area

Months	*Numbers*	*Biomass (g)*
May	—	—
June	0.8	0.8
July	4.6	25.5
September	3.3	46.7
October	4.1	63.7

TABLE VIII. — Monthly mean length (cm) of 0-group sole *Solea senegalensis* in two parts of the estuary

Area	*June*	*July*	*September*	*October*
Alcochete	6.31	7.31	10.31	8.19
V. F. de Xira		7.45	9.84	10.19

Solea senegalensis

This species did not have a large population in the estuary (Fig. 5). *S. senegalensis* recruited to the estuary after *S. vulgaris*; this corresponded with a later spawning season beginning in May (DINIS, 1986). Juveniles were first caught in June with a standard length of 40 mm. Although their arrival began in June, larger numbers of individuals per 1000 m^2 were found in July (Table VII). Their growth was faster in Vila Franca de Xira than in Alcochete (Table VIII).

DISCUSSION

Of all the species that use the Tagus estuary as a nursery ground, *S. vulgaris* and *D. labrax* have the highest densities. Although they live in the same

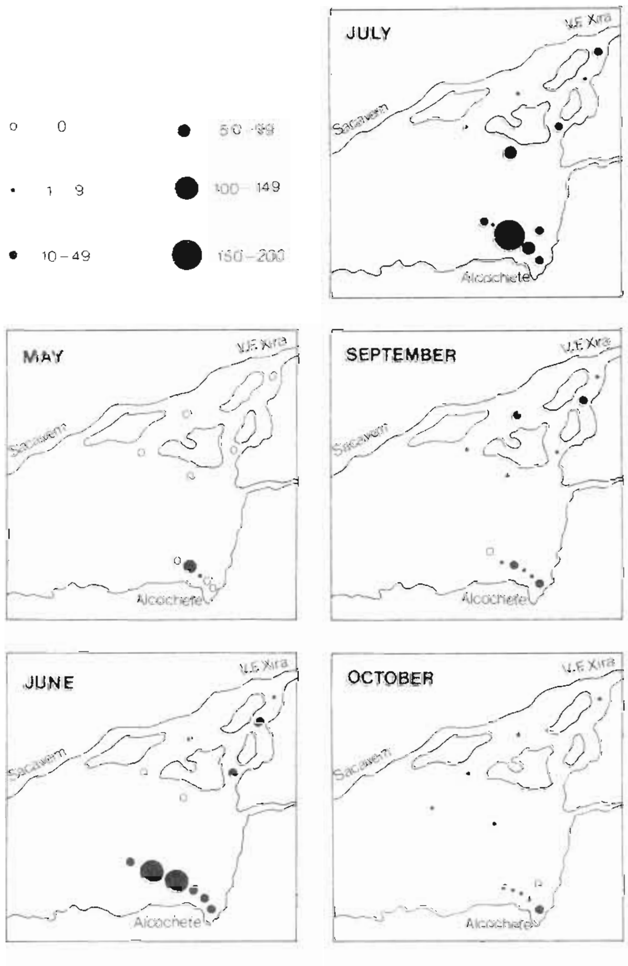

FIG. 5 — Distribution of 0-group *S. senegalensis*. Individuals per 1000 m^2 fished.

area, they occupy different habitats. Alcochete is a nursery site mainly for *D. labrax*. Its abundance is probably related to the large quantities of *C. crangon*, the main prey of 0-group individuals, a fact already noticed by KELLEY (1987).

The 0-group *S. vulgaris* and *S. senegalensis* are very euryhaline. They are most abundant in the zones near Vila Franca de Xira with highly productive salt-marshes where muddy substrate and invertebrate feeding conditions are better for them (Tables IV, V, and VIII). The growth of soles in the estuary is very fast. In the case of 0-group *S. vulgaris*, their montly growth constant K is 0.0392, which is almost at the maximum of 0.04 recorded by FONDS (1975) for North Sea soles.

We think that one of the main reasons the Tagus acts as a nursery is its high production of suitable food. Both *S. vulgaris* and *D. labrax* have a very low percent of empty stomachs (5.2 %). By contrast, LABOURG & STEQUERT (1973), investigating young *D. labrax* at Arcachon Bay, found that 20 % of fish had no food in them. Their high growth in the Tagus is also due to good temperature conditions. FONDS & SASKENA (1977) showed that 0-group soles grow faster at high temperatures. However, in all species considered, growth rates are lower in populations with higher densities.

Finally, this is a first attempt to quantify the role of the Tagus as a nursery for *D. labrax, S. vulgaris* and *S. senegalensis*. Further studies are being made to determine production rates. The Tagus estuary is very rich in terms of diversity and densities of young fish, especially flat fish. It is critical to reduce pollution in this important estuary and to preserve it as a nursery area.

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