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Seasonal distribution and spawning of small tunas (*Auxis rochei* and *Sarda sarda*) in the northwestern Mediterranean*

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SUMMARY: Bullet tuna, *Auxis rochei* and Atlantic bonito, *Sarda sarda* are the most abundant small tuna species in the Mediterranean Sea. Both species are commercially exploited by a small-scale inshore fishery off the Catalan coast. Catches of *A. rochei* are highly seasonal, with maximum values in the warmest months (June to September), which is also the spawning period. Larvae of *A. rochei* were collected between July and September and were particularly abundant in July, when the mean sea surface temperature was 25.4ºC. In summer, adults of this species migrate from the Atlantic to the Western Mediterranean, including the Catalan Sea, to spawn, but they are not found in this last region during the colder months. *S. sarda* is taken all year round in the Catalan Sea, with maximum catches from September to March, and minimum levels during the spawning period (May to July). Larvae of this species were only observed in July and larval abundance was considerably lower than that of larval *A. rochei*. Unlike *A. rochei*, *S. sarda* is resident over the continental shelf in the Western Mediterranean all year long, but at the beginning of summer, coinciding with the arrival of the other species, it moves to other areas in order to spawn.

Key words: small tunas, fish larvae, catch, migration, NW Mediterranean.

INTRODUCTION

Tuna inhabit tropical and temperate seas all around the world and carry out major feeding and spawning migrations (Nakamura, 1969; McKeown, 1984). The migrations of the large tuna species (e.g. bluefin tuna *Thunnus thynnus* and albacore *Thunnus alalunga*) are well known and have been described by different authors (Nakamura, 1969; Baker, 1978). Thus, *Thunnus thynnus* carries out a spawning migration from the Atlantic Ocean through the Strait of Gibraltar and then to its spawning grounds in the Western Mediterranean Sea. In contrast, information concerning migration patterns of small tunas in the Western Mediterranean is scarce and fragmented (De Buen, 1930; Rey and Cort, 1981).

Bullet tuna *Auxis rochei* (Risso, 1810) and Atlantic bonito *Sarda sarda* Cuvier, 1829 are the most abundant small tuna species in the Mediterranean Sea (ICCAT, 1996). The world-wide distribution patterns and biological features of these two species have been thoroughly described (Demir 1963; Yoshida, 1980; Uchida, 1981). *A. rochei* is a cosmopolitan species inhabiting warm waters in oceans all over the world and is also pre-

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sent in the Mediterranean (Collette, 1986). *S. sarda* inhabits a broad distribution range spanning tropical and temperate areas of the Atlantic Ocean, including the Mediterranean. Both species are similar in size and apper along the continental shelf, where they form large schools near the surface (Collete and Nauen, 1983).

A. rochei and *S. sarda*, spawn in the Mediterranean Sea. The spawning period for the first species lasts from June to September (Uchida, 1981; Piccinetti *et al.*, 1996; Alemany, 1997), whereas the spawning for *S. sarda* takes place from May to July (Sanzo, 1932; Rodríguez Roda, 1966). Earlier studies have established the spatio-temporal distribution of tuna eggs and larvae in the Mediterranean. Those studies have shown that *Auxis rochei* larvae are abundant in different regions in both the Western and Eastern Mediterranean basins (e.g. Ehrenbaum, 1924; Duclerc *et al.*, 1974; Dicenta and Piccinetti, 1975; Dicenta *et al.*, 1983; Piccinetti and Piccinetti Manfrin, 1994; Piccinetti *et al.*, 1996). On the contrary, the eggs and larvae of *Sarda sarda* were seldom collected in the Western Mediterranean, with small numbers reported in the Balearic Islands (Duclerc *et al.*, 1974; Piccinetti *et al.*, 1996) and in Algeria (Ehrenbaum, 1924; Piccinetti and Piccinetti Manfrin, 1994). Conversely, a broad distribution and high abundance of *Sarda sarda* eggs were described in the Black Sea and Sea of Marmara (Mayorova and Tkacheva, 1959; Demir, 1963).

Both species are exploited by small-scale inshore fisheries in both the Atlantic Ocean and Mediterranean Sea. Catches of *A. rochei* are much higher in the Atlantic than in the Mediterranean (ICCAT, 1996). In contrast, catches of *S. sarda* are much higher in the Mediterranean and especially in its Eastern basin (FAO, 1995). Both species are captured by the same small-scale fleet operating off the Catalan coast (NW Mediterranean) (Recasens, 1990), and are landed at most regional ports and their commercialization is local.

The aim of the present paper consists in trying to determine the occurrence of possible migrations by both species in relation to spawning in the Catalan coast (NW Mediterranean). For this, the spawning area and spawning period of both species are described on the basis of the spatio-temporal larval distributions. In addition, seasonal variability in the abundance and distribution of the adult population was studied from commercial landings in the region.

MATERIALS AND METHODS

Fish larvae

Ichthyoplankton sampling was performed monthly from April to October 1983, (except for August) off the Catalan coast (NW Mediterranean). This sampling procedure was permitted to encompass the whole spawning period of *Auxis rochei* and *Sarda sarda*. A grid of 44 stations along 17 transects perpendicular to the coast covering the entire continental shelf were visited on each cruise (Figs. 1 and 2). Plankton tows were carried out using a Bongo net with a mouth diameter of 40 cm and a mesh size of 333 μm. The volume of water filtered by the net was measured by a flowmeter deployed in the net mouth. Hauls were oblique from near the bottom to the surface, or from 200 m to the surface at stations where bottom depth was over 200 m. Hydrographic conditions at each station were recorded, on the first three cruises by means of CTD casts, on the remaining cruises by means of 5-L Niskin bottles at 20-m depth intervals. The number of larvae collected at each station was standardized to number of larvae/10 m^2. Additional information on the methods employed are available in Sabatés (1990). Identification of *Auxis rochei* and *Sarda sarda* larvae followed Padoa (1956), Gorbunova (1969), Duclerc *et al.* (1974), and Fahay (1983).

Adults

The adult populations of *Auxis rochei* and *Sarda sarda* are caught along the Catalan coast by the same small-scale fishing fleet using purse seines, longlines, and gill nets, operating daily over the continental shelf. The historical (1987-1997) series of monthly catches of both species were compiled for 6 harbours (Sant Carles, Ametlla de Mar and Tarragona located at the southern part of the Catalan coast and Barcelona, Blanes and Port de la Selva in the northern part; see Fig. 1), based on data provided by Fishermen's associations. The average monthly catches over the study period were estimated in order to assess the seasonality of catches.

RESULTS

Auxis rochei

Larvae of *Auxis rochei* appeared exclusively during the summer (July and September), and were

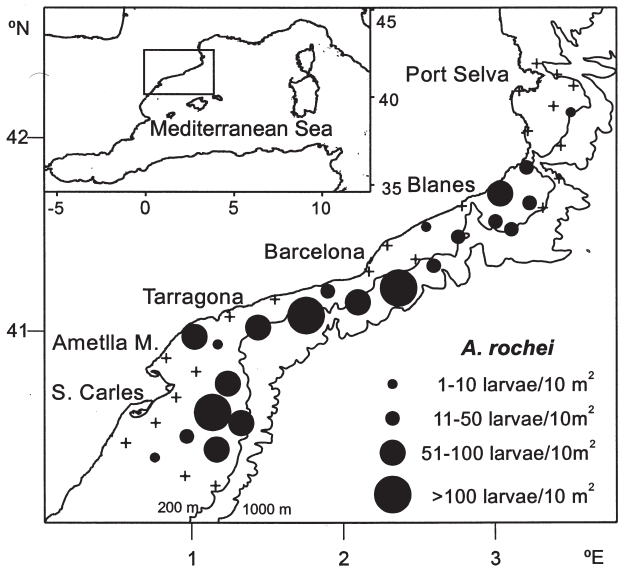

FIG. 1. – Spatial distribution and abundance of *Auxis rochei* larvae in July, along the Catalan coast.

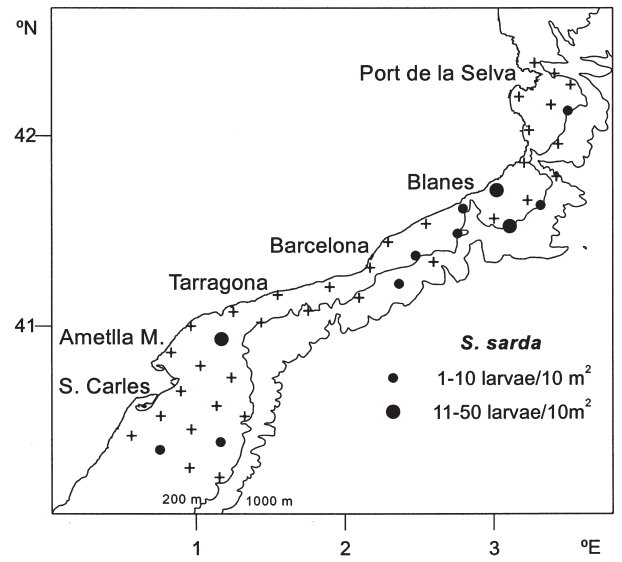

FIG. 2. – Spatial distribution and abundance of *Sarda sarda* larvae in July along the Catalan coast.

absent in spring (April to June) and autumn (October). The peak of abundance (183 larvae/10 m^2) was recorded in July and larvae were distributed all over the entire sampling area, being specially abundant over the shelf break in the southern part of the area (Fig. 1). In September, fish larval abundance was appreciably lower (13 larvae/10 m^2). Mean sea surface temperature was 25.4ºC in July, the period of peak larval abundance, while in June and September it was lower (20.3ºC and 23.7ºC respectively) (Table 1).

The mean annual catch yielded by the adult population off Catalan coast was around 12 tonnes in

TABLE 1. – Surface water temperature (mean ± sd, ºC) during the study period.

April	13.5±0.45
May	16.2±0.59
June	20.3±0.81
July	25.4±0.58
September	23.7±0.83
October	22.7±0.52

TABLE 2. – Annual landings (t) of *Auxis rochei* and *Sarda sarda* along the Catalan coast as reported by Fishermen's Associations. a) Southern zone (ports of Sant Carles, Ametlla de Mar and Tarragona); b) Northern zone (ports of Barcelona, Blanes and Port de la Selva); Mean catch (±sd).

	a) South		b) North	
Year	*A. rochei* Catch	*S. sarda* Catch	*A. rochei* Catch	*S. sarda* Catch
1987	2.4	56.6	1.2	167.3
1988	3.9	103.3	1.0	232.2
1989	5.7	215.5	6.4	236.5
1990	66.3	127.9	31.9	209.2
1991	26.1	46.2	12.6	81.1
1992	6.0	21.9	3.5	27.3
1993	5.2	26.7	11.4	32.2
1994	1.3	34.9	0.7	91.2
1995	4.7	82.8	16.6	268.0
1996	2.2	75.6	3.8	214.6
1997	3.3	29.3	1.0	41.8
Mean Catch	11.6±19.4	74.6±57.8	8.2±9.6	145.6±92.1

the southern part and 8 t in the northern part (Table 2), ranging from 1.3 to 66 t per year in the South and 0.7 to 32 t per year in the North. Total catches were markedly seasonal in nature, with highest values around 20 t during the warmest months (July and August), the species' spawning period (Fig. 3). This peak is specially marked in the Southern part of the Catalan coast. Catches were reduced between November and June (below 5 t), and indeed, between January and March the species was not even caught at all.

Sarda sarda

Despite the long sampling period, *Sarda sarda* larvae were only collected in July. They were located at different stations along the sampling area, chiefly over the 200-m isobath in the northern part of the region. Nevertheless, abundance levels were relatively low, with peak values of only 30 larvae/10m^2 (Fig. 2).

Annual landings of *S. sarda* were relatively high, and ranged from 20 to 220 t in the southern part of the coast and between 30 to 270 t in the North, with an average yearly catch of 75 and 150 t respectively

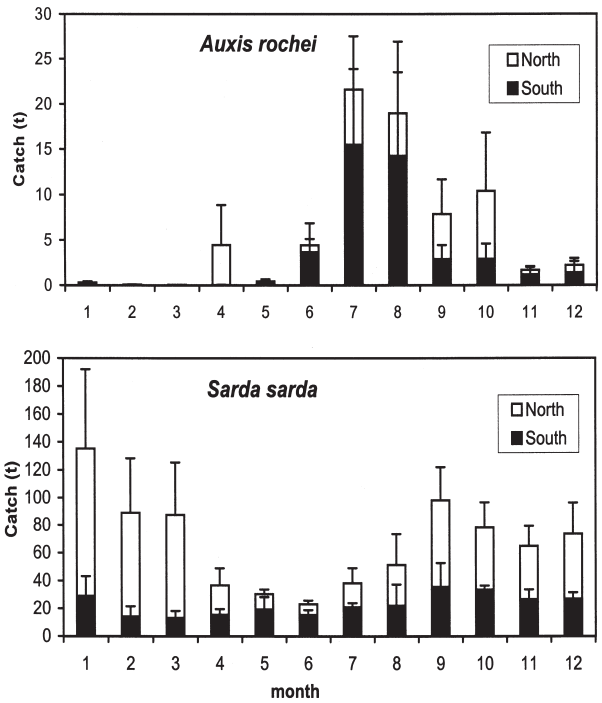

FIG. 3. – Monthly landings (mean±se) of *Auxis rochei* and *Sarda sarda* at the northern and southern zones of the Catalan coast.

(Table 2). Unlike the preceding species, *S. sarda* was captured throughout the year, although catches were still seasonal (Fig. 3). The highest values were recorded in autumn and winter (September to March), ranging from 70 in November to 140 t in January; values fell to minimum levels (around 30 t per month) in spring and summer (April-July) (Fig. 3). This trend is specially marked in the northern part of the coast.

DISCUSSION

Auxis rochei and *Sarda sarda* are the two most abundant small tuna species in the Mediterranean Sea (ICCAT, 1996). According to our results, the occurrence of both species showed a highly seasonal variability in the western Mediterranean. *A. rochei* was caught primarily between June and September. This peak season has been reported for other geographic areas and has been related to the annual temperature cycle. Accordingly, the presence of *Auxis* off South Africa and Australia coincides with the period of maximum water temperatures (Uchida, 1981). Off the Catalan coast, *A. rochei* was chiefly taken during the period of highest water temperatures which also coincides with the species' spawning period.

The presence of *A. rochei* larvae off the Catalan coast is also limited to the warmest months (July-September), when the sea surface temperature range was 23.7-25.4ºC. This is lower than the optimum temperature range for the occurrence of larvae of this species in the Gulf of California (27-27.9ºC, Klawe *et al.* 1970). Nevertheless, *Auxis* larvae exhibit broad tolerance to temperature and have been found from 21.6 to 30.5ºC (Richards and Simmons, 1971; Uchida, 1981). Previous studies carried out in different parts of the Mediterranean have also reported a similar period for the presence of *A. rochei* larvae in the plankton, running from June to September (Duclerc *et al.*, 1974; Piccinetti *et al.*, 1996; Alemany, 1997). The broad spatial distribution of *A. rochei* larvae found in the present study, suggests that spawning takes place over the entire continental shelf. Though the possibility that the distribution range may extend out towards the open sea cannot be ruled out because of the absence of plankton samples beyond the continental shelf. Indeed, earlier studies carried out in the Mediterranean have reported broad distributions for larval *A. rochei* and have noted the abundance of larvae of this species as compared to the larvae of other tuna species (Duclerc *et al.*, 1974; Piccinetti and Piccinetti Manfrin, 1994; Piccinetti *et al.*, 1996; Alemany, 1997).

The pronounced seasonal variability in the occurrence and abundance of adult *Auxis rochei* off the Catalan coast, as inferred from commercial landings, could be attributed to a reproductive migration. Spawning migrations were reported for this species in other geographical regions (Uchida, 1981). In our study area, *A. rochei* may enter the Mediterranean through the Strait of Gibraltar and proceed to various areas in the Mediterranean to spawn, of which the Catalan Sea is such a spawning area. This hypothesis would be supported by the monthly catch data for the Mediterranean coast of Spain reported by Camiñas *et al.* (1986). Their data indicated a seasonal variation along a latitudinal gradient suggestive of a northward inbound migration and a southward outbound migration (Table 3). In addition, our results showed a higher abundance, of both larvae and adults, in the southern part of the Catalan coast which would be in accordance with the proposed south-north migration.

Concerning *Sarda sarda,* their larvae were considerably less abundant than larval *Auxis rochei* and were only collected in July, the month in which the highest sea surface temperatures were recorded (around 25ºC). This is consistent with the spawning

TABLE 3. – Monthly catches of *Auxis rochei* and *Sarda sarda* in 1984 for the Mediterranean coast of Spain, along a latitudinal gradient (in bold maximum values) [modified after Camiñas *et al*. (1986)] (data in tons)

	Auxis rochei			*Sarda sarda*		
	36-37°N	37-39°N	39-42°N	36-37°N	37-39°N	39-42°N
January	0	0	0	**50.7**	**16.7**	**26.3**
February	0	0	0	8.6	1.5	**38.0**
March	29.4	0	0	0.6	2.0	13.4
April	**89.1**	**12.7**	0.3	2.0	2.3	4.2
May	0.8	**14.4**	1.2	1.9	**13.6**	3.7
June	1.1	0.1	**6.7**	0.3	2.1	4.8
July	0	0	**20.4**	0.6	0.1	7.6
August	0	**32.3**	3.4	7.1	0	3.2
September	0.9	**25.8**	1.3	1.8	0	19.3
October	**60.2**	6.2	0.3	**25.1**	6.1	9.4
November	0	0	0.6	7.3	8.8	15.0
December	0	0	0.1	3.2	0.4	7.7
Total Catch	181.6	91.5	34.4	109.1	53.5	152.6

period reported for this species in the Mediterranean, running from May to July with a peak in June (Demir, 1963; Rodríguez Roda, 1966). The presence of larvae in the study area suggests that while the main part of the population probably spawns elsewhere, a small proportion of the population does spawn off the Catalan coast. Similarly low levels of abundance of *S. sarda* larvae were reported in other ichthyoplankton studies in the Western Mediterranean (Duclerc *et al*., 1974; Piccinetti and Manfrin, 1994; Piccinetti *et al*., 1996).

As for the adult population, *Sarda sarda* were found off the Catalan coast all year round, although the lowest catch levels were recorded during the spawning period (May-July). This pattern is similar for the entire Mediterranean coast of Spain (Camiñas *et al*. 1986) suggesting that, although this species is resident in the NW Mediterranean, at the start of the spawning period a sizeable portion of the population may migrate to other areas to spawn, and return at the end of summer. The spawning migrations of this species in the Eastern Mediterranean are well documented. *S. sarda* overwinters in the Adriatic and Aegean seas and migrates through the Sea of Marmara to its spawning areas in the northern part of the Black Sea (Demir, 1963; Ivanov and Beverton, 1985). A high abundance and wide distribution of eggs and juveniles have been reported in this area (Demir, 1963). However, this species' spawning migration in the Western Mediterranean is not currently known.

Considering that the Catalan coast is located in the northern part of the Western Mediterranean, a southward spawning migration would be possible, though it would go against the migrations carried out by all other tuna species in the Mediterranean (Baker, 1978; Ivanov and Beverton, 1985). Our results neither show an increase of the catches to the south during the spawning period. In addition, the data for the Spanish Mediterranean fisheries (Camiñas *et al*. 1986), along a wider latitudinal gradient (Table 3), reflect similar trends over the entire area (minimum catches in spring-summer and maximum values in autumn and winter) and therefore do not support a migration pattern of that type. Another possibility might be that *Sarda sarda* spawning was concentrated in the Eastern Mediterranean, considering the low abundance of larvae collected in ichthyoplankton studies in the Western Mediterranean. Nevertheless, no mixing of individuals between the Western and Eastern Mediterranean basins has been reported in tagging experiments (Rey *et al*., 1984) and so long-distance migrations from the western to eastern Mediterranean are unlikely. Accordingly, the most acceptable explanation appears to be that the adults migrate towards the open sea to spawn. Such areas are less exploited by small-scale fisheries, which are carried out mainly over the continental shelf, and that would account for the decrease in catches in the summer. Nevertheless, if *S. sarda* has a spawning area in the Western Mediterranean, it must be in the general vicinity of the Catalan coast, where we have reported the largest concentrations of larvae for this species in the western Mediterranean.

In summary, *Auxis rochei* migrate from the Atlantic to different parts of the Western Mediterranean during the summer to spawn and the Catalan Sea is one of these areas. *A. rochei* subsequently leave the area during the colder times of the year. On

the contrary, *Sarda sarda* is resident over the shelf in the Western Mediterranean all year round, but at the beginning of summer, coinciding with the arrival of *A. rochei*, it migrates to other areas to spawn. Thus, these two small tuna exhibit different spawning behaviours in the Western Mediterranean, which may be a strategy to avoid competition between two similar species which, moreover, spawn at the same time of the year.

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