SCIENTIA MARINA

Age and growth of leaping grey mullet (*Liza saliens* (Risso, 1810)) in Minorca (Balearic Islands)*

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SUMMARY: A population of leaping grey mullet (*Liza saliens* (Risso, 1810) was studied in order to measure seasonal and annual growth rates. The annual growth rates were similar to those reported for other populations from the central Western Mediterranean and intermediate between those living in northern and southern areas. As usual, the growth rate of adult males was slower than that of females. Males reached adulthood in their third summer. Females of the same age showed a moderate gonadal development, but did not ripen until the next summer. Mullets of all ages gained weight only when the water temperature was higher than 20°C. However adults and immature fish showed reduced growth in mid-summer, when that of the juveniles peaked. This difference is not a consequence of the reproductive cost, because the growth rate of immatures was greatly reduced although they did not spawn.

Key words: Balearic Islands, coastal lagoons, *Liza saliens*, growth, age.

INTRODUCTION

Leaping grey mullet (*Liza saliens* (Risso, 1810)) are found in Mediterranean estuaries (Ben Tuvia, 1986). Age and growth have been studied by several authors (Heldt, 1948 ; Farrugio, 1975 ; Quignard and Farrugio, 1981; Sostoa, 1983; Drake *et al*., 1984; Patón *et al*., 1994), but information is still too scarce to provide us with a detailed life story of the species in its whole distribution range. Very little information exists about the biology of this species in the Balearic Islands (Riera, 1980; Cardona, 1994a), and nothing is known about age and growth in the archipelago, although they represent the bulk of the fish community in many coastal lagoons (Cardona, 1994b).

The aim of this work was to study age and growth of leaping grey mullet in the Balearic Islands, with special emphasis on seasonal growth, one of the least studied aspects of their biology.

MATERIAL AND METHODS

The study was carried out in 1989 in Albufera des Grau, a 72 hectares coastal lagoon located in the Balearic Islands (Pretus, 1989).

Sampling

Samples were collected monthly from January to December 1989 using trammel nets of 25 mm stretched mesh size. Specimens smaller than 11 cm (total length) were caught with a beach seine

of 5 mm stretched mesh size. After collection, fish were stored on ice and frozen at -20 °C in less than 3 hours.

Age and growth

Fish were defrosted, measured to the nearest millimetre (total length and standard length) and weighed to the nearest milligram. Standard length-frequency distribution using the Bhattacharya method (1967) was used for age-class identification. Average length and weight were calculated monthly for every age-class.

The growth curves of the population (standard length and total weight) were constructed by considering that the birth date of all specimens was August 15th, because the population was thought to spawn in mid summer (see below). The von Bertalanffy growth equation (von Bertalanfy, 1975 quoted by Sparre and Venema, 1996) was calculated for both sexes. All the parameters were determined using the Ford-Walford linear method (Walford, 1946 quoted by Sparre and Venema, 1996)

Sexual stage and maturity

Gonads were weighed to the nearest milligram and sex was determined by gonad color: orange for females and white for males. Gonad development was measured using the gonadosomatic index (Greeley *et al.*, 1988):

$$GSI = 100 \times GW/W$$

where GSI is the gonadosomatic index, GW is the gonad weight, and W is the body weight. The average GSI was calculated monthly for every age-class.

Seasonal growth

The condition factor was calculated monthly using the Foulton equation (Busacker *et al.*, 1990):

$$CF = 100 \times W/SL^3$$

where W is the body weight and SL is the standard length.

Also following Busacker *et al.* (1990), the specific growth rate was calculated for each month and age class using the equation:

$$G_w = 100 \times (\ln(W_{t+1}) - \ln(W_t))/T$$

where G_w is the specific growth rate as percentage increase per day, ln is the natural logarithm, W_{t+1} is the average weight of the age class in period $t+1$, W_t is the average weight of the age class in period t and T is the time interval in days between t and $t+1$.

G_w was calculated only when the Student-t test (Cuadras, 1984) revealed significant differences ($P<0.05$) between the average weight of the population in two consecutive months. If there was no difference between them, the specific growth rate was zero. The specific growth rate of the standard length (G_l) was also calculated for each month in the same way.

A linear regression (Cuadras, 1984) was calculated between specific growth rates and water temperature.

RESULTS

A total of 900 specimens were studied. No fish were collected in January, probably due to the very low water temperature. Only three age classes (2+, 3+ and 4+) were abundant enough in the samples to allow the seasonal study of growth rate.
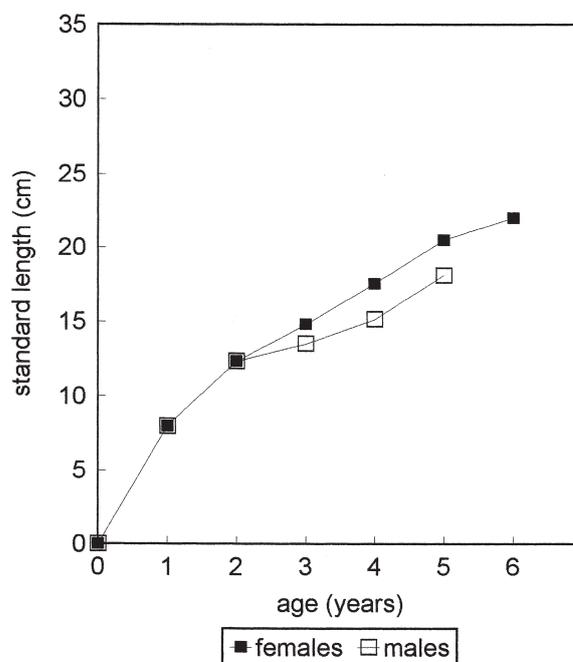

FIG. 1. – Age-length curves of *Liza saliens* from the Albufera des Grau lagoon

Age and growth

Six age classes were identified in August, which allowed the age-length curves of the population to be calculated (Fig. 1). The von Bertalanffy equations for the two sexes were:

males: $TL_t = 34.25 \ (1-e^{-0,26(t+0.44)})$
          $SL_t = 27.73 \ (1-e^{-0.24 \ (t+0.34)})$

females: $TL_t = 38.69 \ (1-e^{-0.2 \ (t+0.31)})$
          $SL_t = 30.23 \ (1-e^{-0.2 \ (t+0.39)})$

Total length and standard length were significantly correlated ($TL = -4.65 + 1.31 \ SL$; $P<0.001$; $r = 0.9908$; both sexes pooled together).
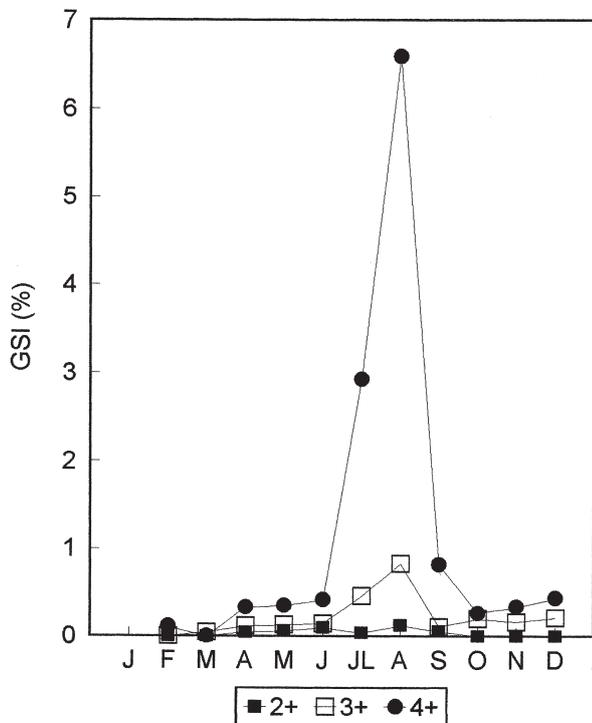

FIG. 2. – Monthly profile of the average gonadosomatic index of three age-classes of *Liza saliens* from the Albufera des Grau lagoon

Sexual stage and maturity

The GSI of the specimens of the 4+ class peaked in August (Fig. 2), when 95.4% had ripe gonads (Fig. 3). For this reason, they were considered to be adults and spawning was believed to happen in that month, although some specimens might already have spawned in July. The GSI of the specimens of the 2+ class was very small in August and did not
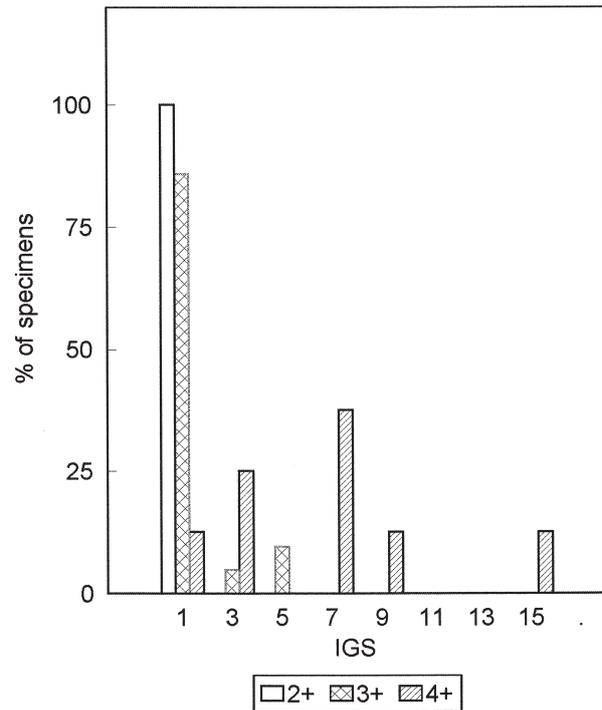

FIG. 3. – Distribution frequencies of gonadosomatic index measured in August in three age-classes of *Liza saliens* from the Albufera des Grau lagoon

change throughout the year (Fig. 2). Hence, they were considered to be juveniles. The GSI of the specimens of the 3+ class peaked in July and August (Fig. 2), but only 19.3% had ripe gonads in August (Fig. 3). Hence, most of the specimens of this age class were classified as immature. A total of 80% of the specimens of this age class with ripe gonads were males.

Seasonal growth

Specimens of the three age classes lost weight from February to March (Fig. 4), when water temperature was below 20 °C. They gained weight again in April and growth rates increased throughout late spring and early summer. Sharp differences among classes were observed in mid summer, when the growth rate of the juveniles peaked and that of the older specimens dropped dramatically. The growth rate of immatures and adults recovered in late summer and early autumn. The growth rate of all specimens became negative in late autumn .

Length growth started later, in early summer (Fig. 4), when the condition factor had recovered
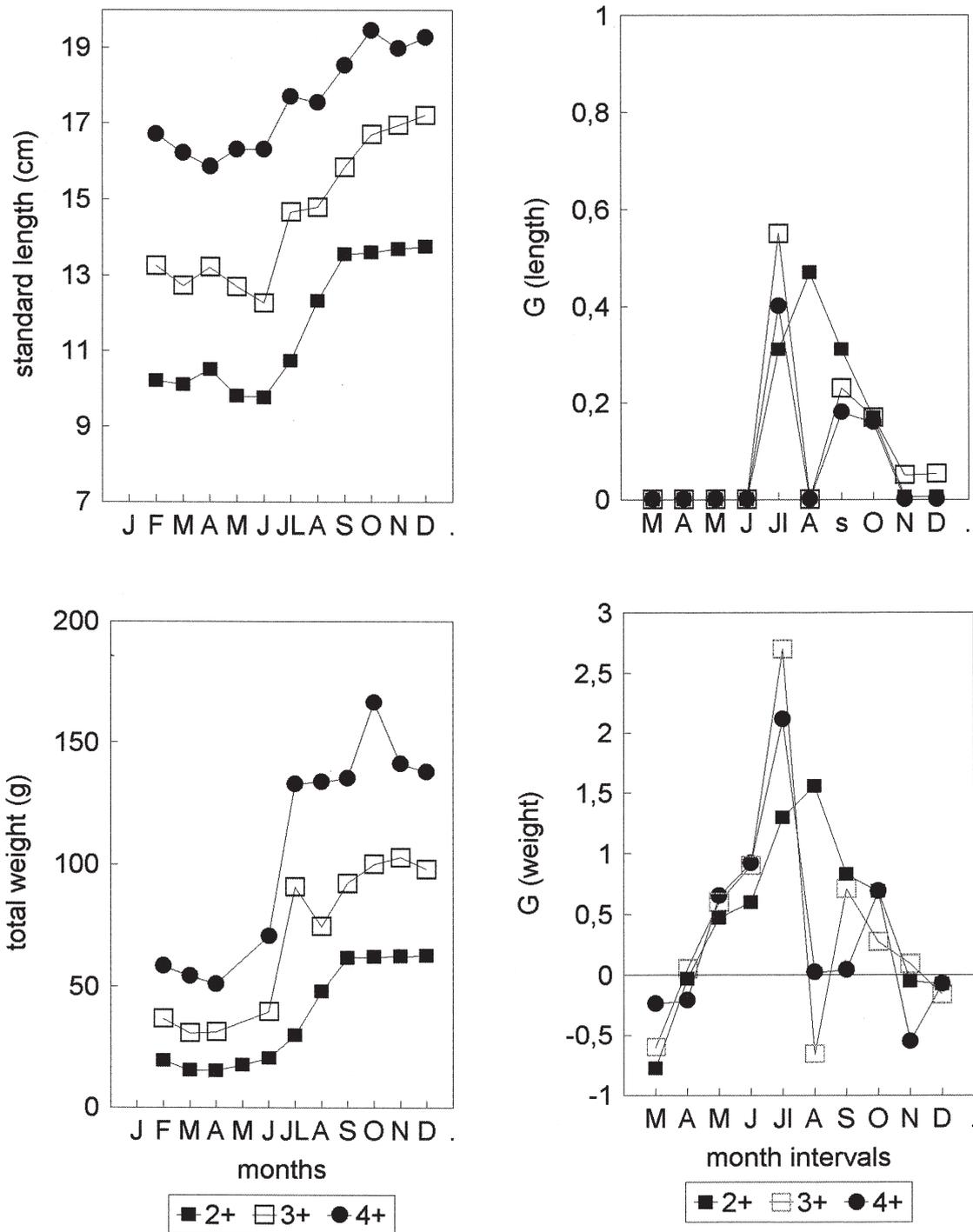
FIG. 4. – Monthly profile of the average standard length, weight and growth rates of three age-classes of *Liza saliens* from the Albufera des Grau lagoon

after winter weight loss (Fig. 5). Again, the growth of juveniles peaked in mid summer, when that of immatures and adults was greatly reduced. Growth ceased in mid autumn.

The monthly profile of water temperature is shown in Figure 6. The weight growth rate of the juveniles and the water temperature were signifi-cantly correlated ($G_w = 2.009 + 0.112$ T; P<0.001; r = 0.902). The same was true for the length growth rate and the water temperature ($G_l = -0.435 + 0.026$ T; P<0.002; r = 0.842). However, the water temperature was not correlated with the weight growth rate or the length growth rate of any other age class (P>0.05 in all cases).
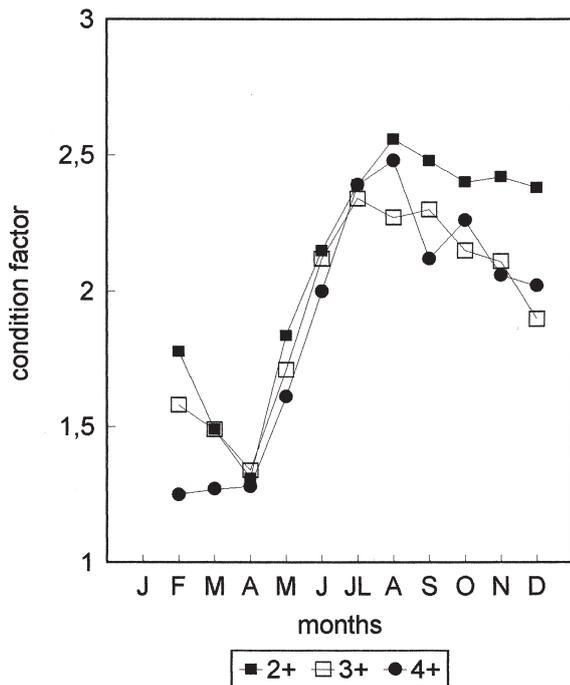
FIG. 5. – Monthly profile of average condition factor of three age-classes of *Liza saliens* from the Albufera des Grau lagoon
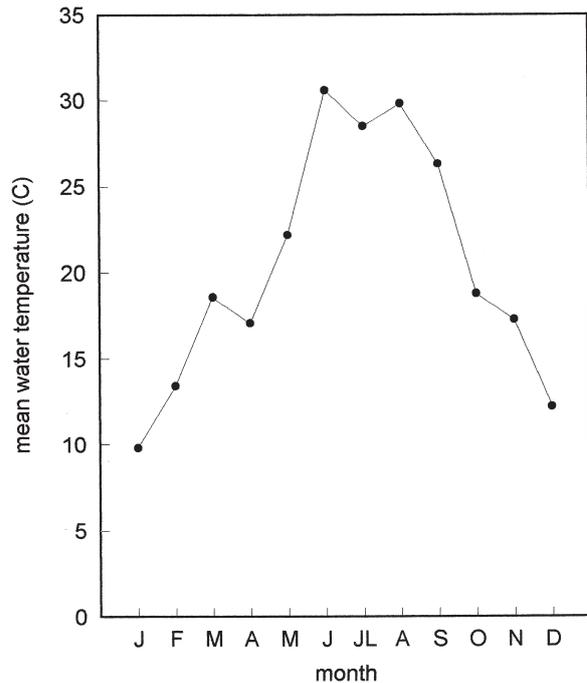

FIG. 6. – Monthly profile of water temperature in the Albufera des Grau lagoon

DISCUSSION

Determining the age and growth rate of grey mullet from the growing marks recorded in hard tissues is not a simple task. Although widely used, scale reading is difficult to apply because two *annuli* may appear yearly and sometimes the early *annuli* disappear as the fish grow (Quignard and Farrugio, 1981; Almeida *et al.*, 1995, Ibañez-Aguirre *et al.*, 1996). Otolith reading is difficult because the *sagitta* of older specimens often become too opaque (Erman, 1959; Kennedy and Fitzmaurice, 1969 ; Ibáñez-Aguirre *et al.*, 1996). Bone reading is also not easy (Hickling, 1970).

An alternative are those methods based on Petersen's procedure of cohort identification using a length-frequency plot. Quignard and Farrugio (1981) claimed that these methods are generally useless for grey mullet because large samples of all size classes are needed and well defined size classes do not exist as a consequence of a long spawning season.

This may be true for some species, but none of these problems affected the present study, because leaping grey mullet were abundant in all months, except in January, and the spawning season was limited to August. Hence, well defined cohorts were observed and each specimen could be unambiguously assigned to a specific cohort. Indeed, this method has been successfully used in several grey mullet species, leaping grey mullet included (Thomson, 1951; Thomson, 1957; El Zarka, 1964; Zaky-Rafail, 1968; Kennedy and Fitzmaurice, 1969; El Zarka *et al.*, 1970; Drake *et al.*, 1984; Claridge and Potter, 1985 ; Ibáñez-Aguirre *et al.*, 1995).

Another problem of using Petersen's method in grey mullet is that the growth of males and females cannot be studied separately until adulthood, because there is no sexual dimorphism. This shortcoming seems to be of little importance, because other authors, using scale reading for age determination, have not observed significant differences in the growth rate of males and females until their third (El Zarka, 1964; El Zarka, *et al.* 1970) or fourth year of life (Ezzat, 1965), although Sostoa (1983) reported a lower growth rate for males in their first year. Males of the studied population reached adulthood one year earlier than females and grew more slowly after sexual maturation, as is usual in this species (Ezzat, 1965; El Zarka, 1964; El Zarka, *et al.* 1970; Sostoa, 1983).

The seasonal growth pattern of the three studied age classes was very different. Fish in the 2+ age-class were juveniles and their growth rate was

greatly increased by high water temperatures. On the other hand, the growth of fish in the 3+ and 4+ age classes was greatly reduced in mid-summer. As most of the fish in the 4+ age class were adults and were ripe in mid-summer, it seems reasonable to believe that such a growth reduction was caused by gonad development. However, less than 20% of the specimens in the 3+ age class became ripe in mid-summer and the growth of the whole class was also reduced. This suggests that growth reduction in mid-summer is not directly caused by gonad development. Further research is needed on this subject.

Among the European grey mullet, only stripped mullet (*Mugil cephalus* L. 1758) has a pattern of seasonal growth similar to that shown by the leaping grey mullet (Sostoa, 1983). Both are very scarce in the Atlantic north of the Tagus estuary (Arné, 1938; Costa, 1986; Docampo and Rallo, 1987; Arruda *et al.*, 1991), where water temperature seldom rises above 20° C (Fincham, 1987 ; Arruda *et al.*, 1991). Golden grey mullet (*Liz aurata* (Risso, 1810)), thin-lip grey mullet (*Liza ramada* (Risso, 1826)) and the thick-lip grey mullet (*Chelon labrosus* (Risso, 1826)) are less cold sensitive, grow at water temperatures far below 20 °C and have longer growing seasons even in cooler areas (Sostoa, 1983; Caldridge and Potter, 1985; Arruda *et al.*, 1991; Almeida *et al*. 1995).

Direct comparison between the growth curves of the studied population and those reported by other authors for other populations of leaping grey mullet is not possible. Growth curves calculated with data from hard tissue reading techniques give information about fish length in those periods when resting lines are formed. On the other hand, those calculated with data from length-frequency plots in the spawning season provide information about fish length on the birth date anniversary. As the spawning season and slow growth season do not always overlap, differences between these two sources of information might be important in leaping grey mullet, which spawn in summer and stop growing in winter.

Patón e*t al*. (1994) reported the formation of a resting line the first winter of life of this species, when the fish are four months old. However, data from other authors suggest that resting lines do not appear until the second year of life (Quignard and Farrugio, 1981; Sostoa, 1983), when fish are sixteen months old. If this is true, lengths calculated from scale reading growth curves would be longer than those calculated from the length-frequency distribution in mid summer.

Regardless of these problems, winter lengths of the studied population show that its growth rate was similar to that of the populations living on the Mediterranean coast of the Iberian Peninsula (Sostoa, 1983 ; Patón *et al.*, 1994) and France (Ezzat, 1965) and intermediate between those of northern (Aleev, 1956, quoted by Thomson, 1966) and southern populations (Drake *et al.*, 1984; Zaky-Rafail, 1968; El Zarka, 1964; El Zarka *et al.*, 1970). This negative relationship between growth rate and latitude observed in the Mediterranean is probably due to a reduced growing season on the northern shore, because this species does not grow at water temperatures lower than 20 °C.

However, water temperature is not the only factor affecting grey mullet growth. Neighbouring populations of this species are known to grow at different rates (El Zarka, 1964; El Zarka *et al.*, 1970; Drake *et al.*, 1984). Quignard and Farrugio (1981) suggested that this may be due to variations in the population density and the quantity of available food. This hypothesis is supported by the negative correlation between leaping grey mullet density and growth rate observed by Drake *et al*. (1984) in non-fertilized fish ponds.

Another interesting point is the wide variability in the spawning season of this species in the Mediterranean sea. Many of the papers reviewed by Brusle (1981) reported spawning periods of more than three months, often with bimodal profiles. Similar patterns have been reported by some recent works (Vidy and Franc, 1992 ; Brusle and Cambrony 1992), but some other populations are known to show very limited spawning seasons, usually June and July or July and August (Brusle, 1981 ; Sostoa, 1983 ; Gisbert *et al.*, 1995 ; Cardona, present paper). In a long term study on the recruitment of estuarine fish from Cadiz Bay, Arias and Drake (1990) observed that *L. saliens* did not have a constant recruiting pattern, *i.e.*, fry some years occurred almost exclusively in July and other years showed a bimodal recruiting pattern. The reasons for such a variability are unknown and deserve more research.

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