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SIZE COMPOSITION AND SEASONAL CHANGES IN ABUNDANCE OF JUVENILE SOLE, *SOLEA SOLEA*, IN THE SEVERN ESTUARY AND INNER BRISTOL CHANNEL

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(Figs. 1–3)

Samples collected at regular intervals from the intake screens of power stations in the Severn Estuary (Berkeley, Oldbury-upon-Severn and Uskmouth) and Inner Bristol Channel (Hinkley Point), together with the catches of a fisherman near Hinkley Point, have provided data on seasonal variations in the size composition, age and abundance of sole in nursery areas in this south-western region of the United Kingdom. 0+ sole first appeared at Oldbury in the Inner Severn Estuary in July at total lengths as small as 23 mm (≡ 0·1 g). On the basis of pooled data for three years in the mid-1970s, this group had reached a mean length of 84·1 mm (≡ 4·4 g) by September and approximately 92·7 mm (≡ 5·9 g) by the following April when it was entering its second year of life. By the following August, the modal length class of the I+ fish was 140–159 mm (≡ 21·6–32·3 g). While most of the sole in the Inner Estuary were below 240 mm (≡ 117 g) a few fish up to 289 mm (≡ 224 g), and individuals of 345 mm (≡ 367 g), 349 mm (≡ 370 g) and 400 mm (= 546 g) were also caught. The numbers of sole in the Inner Estuary reached high values in September, declined markedly in the winter and started to rise again in March or April.

INTRODUCTION

During a period of five years in the mid-1970s, fish were collected at weekly intervals from the Severn Estuary and Bristol Channel. The resultant data on the abundance and lengths of these fish have provided valuable information on the times when the juveniles of several marine species are recruited into the estuary and on their pattern of growth during the first years of life (Claridge & Gardner, 1977; Titmus, Claridge & Potter, 1978; Claridge & Potter, 1983, 1984, 1985; Potter & Claridge, 1985). One of the marine species found in the Severn Estuary for which no seasonal data on density or body size have been presented is the sole, *Solea solea* (L.), whose relative abundance ranked it amongst the top ten species in two of the five years of our study (Claridge, Potter & Hardisty, 1986).

The sole is one of the most valuable European flatfish in northern European waters (Møller Christensen, 1960; Bromley, 1977; Muus & Dahlstrom, 1977). While the spawning of this species typically occurs during April, May and June

in these regions (Anon, 1965; De Veen, 1970; Fonds, 1975), it is concentrated in March and April on the coasts of Ireland and southern England (Muus & Dahlstrom, 1977), with young fish appearing in plankton trawls in the Bristol Channel in April and May (Russell, 1980). Spawning takes place in coastal waters and the resultant pelagic eggs and larvae are carried by residual currents towards those inshore and estuarine areas with soft bottoms which act as nursery grounds for the young demersal fish (Fluchter, 1970; Riley, 1974; Van de Valde, 1975; Rauck & Zijlstra, 1978; Riley, Symonds & Woolner, 1981).

Although the sole is an important commercial species and is known to occur in numbers in estuarine waters in northern Europe (see e.g. Zijlstra, 1972; Muus & Dahlstrom, 1977; Wheeler, 1978), detailed information on monthly changes in the abundance and length of the juveniles of this species in estuarine environments is rather limited (e.g. Van den Broek, 1979, 1980; Fonds, 1983). The current study has analysed weekly catches from Oldbury to provide data on seasonal changes in the abundance, total length and age composition of sole in the Inner Severn Estuary. These data, together with those obtained from elsewhere in the estuary and the Bristol Channel into which it flows, have then been compared with results for the Medway Estuary (Van den Broek, 1979, 1980) and Wadden Sea (Møller Christensen, 1960; Creutzberg & Fonds, 1971; Zijlstra, 1972; Fonds, 1983).

MATERIALS AND METHODS

Sole were collected from the cooling water intake screens of power stations at Berkeley and Oldbury-upon-Severn in the Inner Severn Estuary, Uskmouth on the River Usk near its confluence with the Outer Severn Estuary and at Hinkley Point in the Inner Bristol Channel. (N.B. The precise location of sampling stations, and the regions of the estuary and channel designated by Radford, Uncles & Morris (1981), are shown in Claridge *et al.* (1986).) Samples were taken weekly at Oldbury between July 1972 and June 1977 and at Berkeley between September 1974 and June 1977, and monthly from Uskmouth and Hinkley Point between October 1975 and June 1977. In contrast to the situation at the other stations, each Oldbury sample represented the total number of fish entrained on the screens over 24 h. Where necessary, these numbers have been adjusted to correspond to a daily intake volume of $2{\cdot}2 \times 10^9$ l, the typical intake during the period when the numbers of fish on the screens were greatest (Claridge *et al.* 1986). Fish were also collected in September, October and early November of 1984 from the Oldbury and Hinkley Point power stations and from Mr B. Sellick, a commercial fisherman who fishes near Hinkley Point.

The larger sole and a random subsample of smaller sole ($<$ *ca.* 100 mm) obtained from power station samples between August 1974 and June 1977 were measured and weighed. No adjustment has been made to the length-frequency histograms to compensate for those sole excluded from measurement (Fig. 2). All the sole collected between September and early November of 1984 were measured and weighed (Fig. 1). Measurements of the total length and weight of fish were recorded to the nearest 1 mm and 100 mg respectively. Regression equations relating these two parameters were calculated and used to derive the weight equivalents given in this paper. Otoliths were removed from representatives of the fish caught in 1984 and the presence of any annuli recorded. The resultant data on the relationship between length and age were used to help ascertain whether size classes in samples from the mid-1970s represented age classes.

RESULTS AND DISCUSSION

The pooled length data obtained in September 1984 for sole collected from Oldbury and Hinkley Point power stations and from a fisherman (B. Sellick) near the latter site, produced a pronounced modal length class at 80–89 mm (≡ 3·7–5·2 g) (Fig. 1). A second modal length class was evident at 160–169 mm

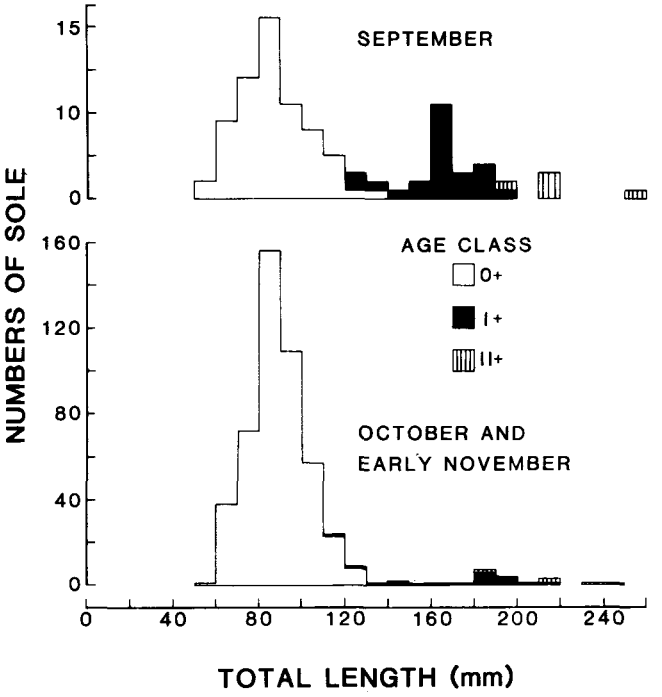

Fig. 1. Length-frequency histograms for sole collected in 1984 from the Oldbury-upon-Severn and Hinkley Point power stations and from a fisherman's nets at a site near Hinkley Point. N.B. A fish of 299 mm caught in September is not shown.

(≡ 32·9–39·0 g) and one fish of 299 mm (= 242·0 g) was caught with a length above 250 mm. In the pooled samples for October and early November 1984, the predominant modal length class was also 80–89 mm (≡ 3·7–5·2 g) and a second but far less abundant group produced a modal length class at 180–189 mm (≡ 47·6–55·4 g) (Fig. 1). Only two fish, whose lengths were 233 mm (= 119 g) and 240 mm (= 142 g), exceeded 220 mm.

The absence of annuli on the otoliths of the predominant size group in both September and October/early November showed that the sole from which they were taken belonged to the 0+ age class (Fig. 1). Likewise, the presence of one annulus on the otoliths of the majority of fish between 120 and 190 mm demonstrated that these came from I+ sole. Examination of otolith annuli also showed that the II+ sole in the samples ranged in length from 181 to 299 mm.

The above data on the age of sole in the Inner Severn Estuary and Inner Bristol

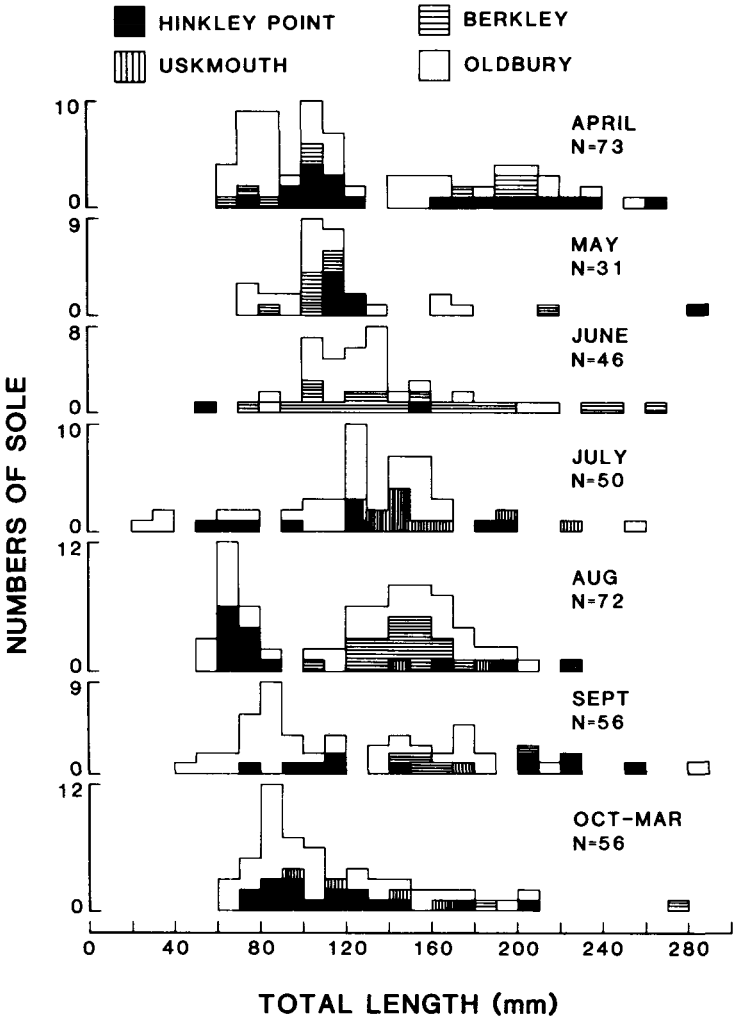

Fig. 2. Length-frequency histograms for sole collected in different months between August 1974 and June 1977 on power station screens at Berkeley. Oldbury-upon-Severn, Uskmouth and Hinkley Point. N.B. The smaller fish (< *ca.* 100 mm) are represented by a random subsample (see Materials and Methods). Sole with lengths of 400 and 349 mm from Oldbury in April and May respectively and of 345 mm from Berkeley in October–March are not shown.

Channel can now be used to elucidate the significance of the different size groups of this species obtained from power stations in the mid-1970s (Fig. 2). The smallest sole (23–36 mm) (≡ 0·1–0·3 g) collected between August 1974 and June 1977 were found in July samples and these are assumed to represent young 0+ fish. Such a conclusion is entirely consistent with the observation that the modal size class of 80–89 mm found for the group of smallest fish caught in September and October in the 1970s was identical to that of the 0+ age class in the same months in 1984 (cf. Figs. 1, 2). Moreover, a modal length class of 80–89 mm is

very similar to that of 0+ sole in the Wadden Sea at the same time (Creutzberg & Fonds, 1971), and lies within the length range of 60–110 mm recorded for 0+ sole in the autumn in the same region (Zijlstra, 1972). It should be noted that since only a subsample of the smaller fish was measured (see Materials and Methods), the peak for the 0+ fish in the 1970s data is not nearly as tall as it would have been if all the fish had been measured, as they were in the samples for September to early November 1984 (cf. Figs. 1, 2). The mean length of 84·1 mm (≡ 4·4 g) in pooled samples from September had increased to approximately 93 mm (≡ 5·9 g) by April, when sole started reappearing in reasonable numbers. Since April is one of the months in which spawning occurs in Irish and south-western English waters (Muus & Dahlstrom, 1977), this length corresponds to that achieved after about a year's growth. This value is very similar to those recorded for the same age class in the same month by Tesch (1913) and Fonds (1983) and approaches the means of 103 to 118 mm given by Zijlstra (1972) for the I+ age class in May. It is far lower, however, than the 132 mm obtained in April by Hermanns (unpublished but reported in Anon, 1965) and by Ghirardelli (1959) and Ramos (1982*a*) for more southern populations.

The view that the group of smallest fish caught in the Severn Estuary and Bristol Channel in April, which ranged in length from 65 to 120 mm (≡ 1·9–13·3 g), was approximately 12 months old agrees with the observation that by August the modal size class of this group had increased to 140 to 159 mm (≡ 21·6–32·2 g), which is only just below that recorded for the I+ age class in September of 1984 (cf. Figs. 1, 2). Moreover, the comparable group in September ranged in length from 131 to 188 mm (≡ 17·5–54·5 g), which is very similar to that of the I+ fish in the same month in September 1984. The modal length class for this group was not clearly distinguishable in the length-frequency histograms for October–March, or for April when fish would have been entering their third year of life (Fig. 2). However, the mid-point of the range (*ca.* 169 mm) in September (Fig. 2) and the mean length of 173 mm for the I+ age class in October/early November 1984 (Fig. 1) would be expected, after allowing for some growth, to yield values in the following April which approach those given by several authors for two year old fish at a comparable time of the year (Tesch, 1913; Bückmann, 1935; Boerema & Stam, 1952; Hermanns 1955 in Anon 1965; Møller Christensen, 1960).

The observation that the majority of sole caught within the Severn Estuary were less than 240 mm in length parallels closely the situation found by Van den Broek (1980) in the Medway Estuary. The three sole caught above 300 mm (345, 349, 400 mm) were almost certainly more than two years old. Since sole do not generally reach sexual maturity until they are at least 240 mm (Møller Christensen, 1960; Ramos, 1982*b*), and only a very few fish could have belonged to this category in our samples, it seems unlikely that this species typically spawns in the Inner Severn Estuary. The studies on the distribution of the eggs by Riley (1974) have shown, however, that sole sometimes breeds in the lower reaches of the Blackwater and Thames estuaries on the south-eastern coast of England.

Annual and seasonal abundance

Estimates of the total number of sole that would have been taken on the screens at Oldbury if the pumps had been running continuously at $2{\cdot}2 \times 10^9$ l day^{-1} ranged from 305 in 1972/3 to 933 in 1975/6 (Fig. 3). Since sole is a southern

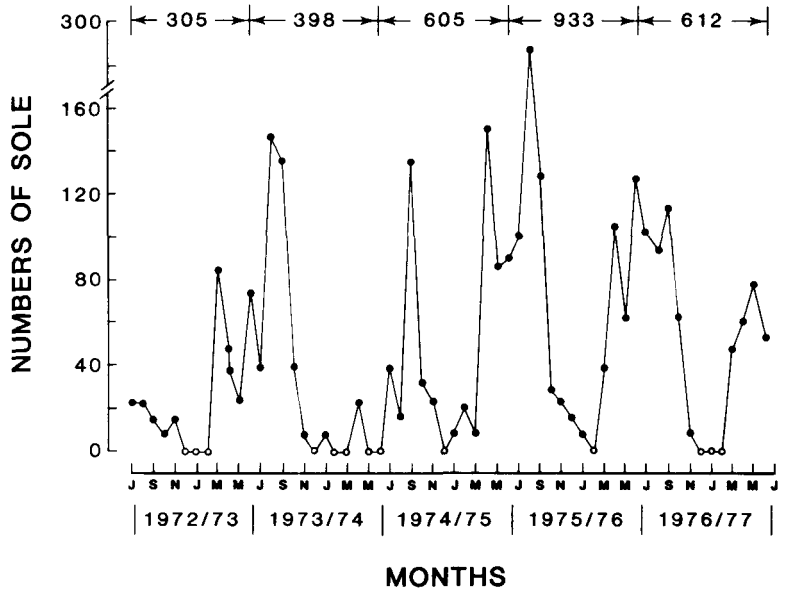

Fig. 3. Monthly and annual estimates (between arrows) for the number of sole that would have been entrained on the intake screens at the Oldbury Power Station between July 1972 and June 1977 if the daily intake volume had been constant at 2.2×10^9 l.

species which thrives best at temperatures between 16 and 22 °C (Fonds, 1975; Fonds & Saksena, 1977), it might be significant that greater numbers of sole were taken at Oldbury in 1975/6 and 1976/7 than in 1972/3 and 1973/4. This view is based on the observation that in 1975/6 and 1976/7 the maximum mean monthly temperatures in the summer approached 22 °C, whereas in the other two earlier years they were appreciably lower (for temperature data see Claridge & Potter, 1984).

The abundance of sole at Oldbury in the Inner Severn Estuary underwent pronounced seasonal changes (Fig. 3). Relatively high numbers were found in September of each of the last four years of the study, a result of the immigration of 0+ fish (cf. Figs. 1, 2, 3), and low numbers or no fish were recorded between November and February. Numbers started to rise in March or April with the entry of fish which were approximately twelve months old (cf. Figs. 2, 3). Although each of the separate samples from Berkeley could not be related to a specific duration of sampling, it was evident that the collections from this site 7 km farther upstream in the Inner Severn Estuary followed a similar trend.

The first appearance of the new 0+ sole in nursery areas in the Severn Estuary and Bristol Channel in July, which is one month later than at Hinkley Point in the Bristol Channel, parallels precisely the situation in the Wadden Sea (Møller Christensen, 1960; Creutzberg & Fonds, 1971) and is similar to that found in the Medway Estuary (Van den Broek, 1979, 1980). There was also close correspondence in the modal sizes of both the 0+ and I+ fish in these areas in August. The marked decline in numbers of sole in the Inner Severn Estuary between late autumn and early spring parallels the situation in the Wadden Sea where the 0+ representatives move out into deeper water at this time (Creutzberg & Fonds, 1971; Zijlstra, 1972). It has been suggested that this migration into deeper waters enables young sole to avoid the low temperatures to which they are particularly susceptible (Woodhead, 1964; Zijlstra, 1972). The marked seasonality of the occurrence of sole at Oldbury, allied with the variety of different patterns of seasonal movements exhibited by other species, contribute at this site towards a gradual change in the fish assemblage which is only moderately affected by environmental conditions (Potter, Claridge & Warwick, 1986). It is also worth remembering that, during their first summer and autumn, 0+ sole of similar size use not only shallow areas such as Oldbury in the Inner Estuary at times when salinities are sometimes considerably below those of full strength sea water, but also those at Hinkley Point in the Inner Bristol Channel where salinities rarely fall below 30 ‰ (Claridge *et al.* 1986). The presence of 0+ sole over a wide range of salinities is consistent with the results reported for young sole by Riley *et al.* (1981).

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