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MOVEMENTS, ABUNDANCE, AGE COMPOSITION AND GROWTH OF BASS, *DICENTRARCHUS LABRAX*, IN THE SEVERN ESTUARY AND INNER BRISTOL CHANNEL

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(Figs. 1–3)

The movements, abundance, age composition and growth of bass, *Dicentrarchus labrax* (L.), in the Severn Estuary and inner Bristol Channel have been described from regular samples of fish taken from power-station intake screens between 1972 and 1977. Bass began to move into the estuary during late August or September and reached peak abundance between September and early November. The tendency for fish to move seawards in the late autumn and winter may be related to declining water temperatures in the estuary. Likewise, differences in abundance between years appear to be related to annual differences in temperature. Although the populations were dominated by the 0+ age class, successively decreasing numbers of the next four age classes and occasional 5+ fish were also present. Respective mean standard lengths of bass in the estuary at the end of their first to fifth years of life were approximately 65 mm (≡ 4·5 g), 130 mm (≡ 37·9 g), 190 mm (≡ 121·1 g), 250 mm (≡ 280·4 g) and 290 mm (≡ 441.5 g). Growth occurred predominantly between May and September, with the mean standard length of 1+ fish increasing from approximately 65 mm (≡ 4·5 g) to 130 mm (≡ 37·9 g).

INTRODUCTION

Bass, *Dicentrarchus labrax* (L.), have long been a highly valued sport fish in British coastal waters, and during recent years have also increased in commercial importance (Anon., 1970; Kelley, 1979). It is thus surprising that comparatively few detailed studies have been made of the biology of this species. However, tagging experiments in marine waters have elucidated movement patterns, spawning areas, and the size and age at maturity (Kennedy & Fitzmaurice, 1972; Holden & Williams, 1974; Kelley, 1979). There is also evidence that estuaries are frequently colonized by juvenile bass (Hartley, 1940) and that their numbers in this type of environment often show marked seasonal and annual fluctuations (Matthews, 1933; Lloyd, 1941; Hardisty & Huggins, 1975; Wheeler, 1979).

An extensive study of the material taken at regular intervals from the cooling-water intake screens of power stations in the Severn Estuary and inner Bristol Channel over a 5-year period has yielded data on a number of fish species

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(Hardisty & Huggins, 1975; Moore & Moore, 1976*a*, *b*; Claridge & Gardner, 1977, 1978; Badsha & Sainsbury, 1978*a*, *b*; Titmus, Claridge & Potter, 1978; Palmer, Culley & Claridge, 1979; Abou-Seedo & Potter, 1979; Claridge, unpublished data). During this period, many bass were obtained, providing an excellent opportunity to examine seasonal movements, annual variations in abundance, age composition and the growth of this species in an estuarine environment. The results of this investigation are of relevance in view of the suggestions by Clark (1971) and Kelley (1979) that bass stocks in U.K. coastal waters have declined in recent decades, and of the proposals to build a tidal barrage across the Severn Estuary for electricity generation (Department of Energy, U.K., 1981).

MATERIALS AND METHODS

Bass were obtained from the cooling-water intake screens of four power stations on the Severn Estuary and inner Bristol Channel between July 1972 and April 1977. All the fish collected by the screens over the previous 24 h were obtained once weekly (48 collections per year) from the station at Oldbury-upon-Severn, Gloucestershire (approximately 55 km downstream from Maisemore Weir). The numbers of bass in each sample were recorded and corrected to correspond to an intake of $2{\cdot}20 \times 10^9$ l, the daily volume of water passing through the screens during the autumn and winter periods when the station was under full load and bass were most abundant. These data enabled seasonal and annual variations in the relative abundance of bass to be determined. Weekly collections were also taken from Berkeley Power Station (7 km upstream of Oldbury), while samples were obtained monthly from the station at Uskmouth, Gwent (1 km upriver from the confluence of the River Usk with the Severn Estuary), and at Hinkley Point, Somerset (approximately 60 km downstream of Oldbury in Bridgwater Bay). Since the samples of fish from these three power stations had accumulated over variable periods of time, they could not be used for direct quantitative comparisons with the Oldbury data. Further information on the sampling procedure and locations can be found in Hardisty & Huggins (1975) and Claridge & Gardner (1977, 1978).

Standard length and wet weight were recorded to the nearest 1 mm and 0·1 g for all bass, except when smaller bass (< 100 mm) were very numerous, in which case measurements on this size category were restricted to a large randomly selected subsample. Otoliths were removed, placed in glycerol and examined under reflected light against a black background. An examination of the opaque and hyaline zones, together with an analysis of length-frequency data, enabled the age of the fish and the growth rate of year classes to be determined.

RESULTS

The collections of fish made at the four power stations over the period between July 1972 and April 1977 show that *Dicentrarchus labrax* utilizes habitats in the Severn Estuary and Bristol Channel throughout the year. However, the quantitative data obtained from Oldbury demonstrate that, at least in the middle region of the estuary, there is considerable seasonal variation in the abundance of this species (Fig. 1). Thus, in all years of the study, the numbers of bass started to increase late in August or early in September, and rapidly reached peak values in September, October or November. Subsequently, the numbers declined sharply to reach a low monthly level between January and April.

The Oldbury data also provide strong indications that the annual abundance of bass in the estuary varies considerably (Fig. 1). For example, the monthly catches ranged from a maximum daily mean of 10 bass in 1974 to 746 in 1976.

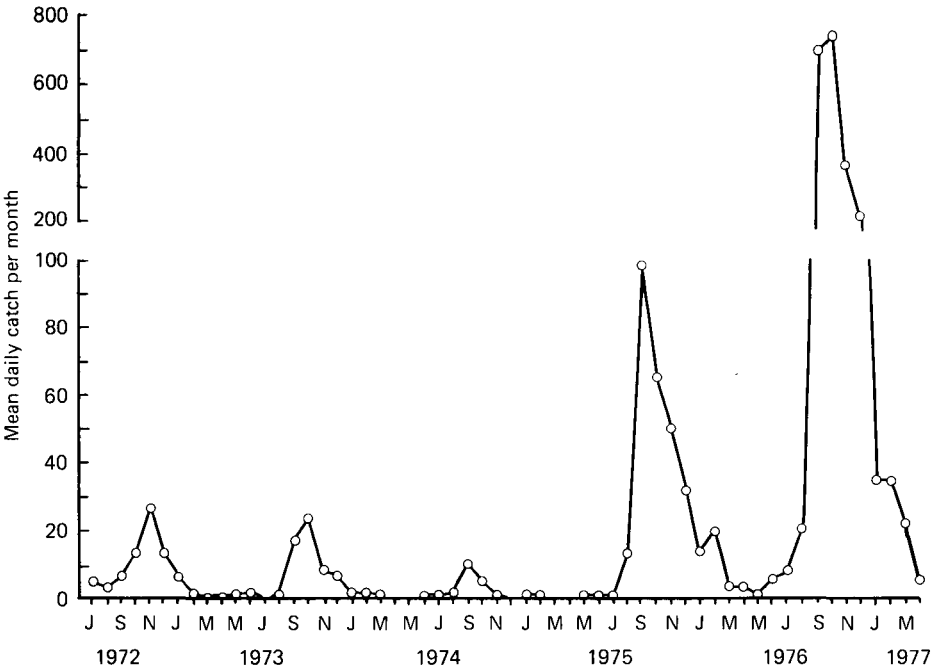

Fig. 1. The mean number of bass collected from the Oldbury Power Station over a 24 h period each month between July 1972 and April 1977. The numbers have been adjusted to correspond to an intake volume of $2{\cdot}2 \times 10^9$ l day^{-1}, the intake recorded during the autumn/winter period of each year.

These annual differences can also be illustrated by comparing the total numbers of 326, 245 and 82 bass collected during once weekly 24 h samples in the years 1972/3, 1973/4 and 1974/5 respectively, with corresponding numbers of 1230 in 1975/6 and 8896 in 1976/7.

Qualitative data from the other three power stations, which were sampled at varying frequencies and times, are consistent with the seasonal and annual variations in number of bass collected at Oldbury. Thus, numbers peaked in the autumn of each year and were far higher in 1976 than in any other year.

Since catches of larger bass (> 100 mm), even in the year of greatest abundance (1976/7), were always relatively small, the age composition of bass found in the Severn Estuary and inner Bristol Channel has had to be based on data collected from all years and for all sites (Fig. 2). The vast majority of fish belonged to the 0+ age-class. However, while bass in their second year of life were also caught in the middle estuary during the autumn, especially in 1975 and 1976, almost all of the fish representing the 2+ to 5+ age-classes were taken at Hinkley Point in the Bristol Channel. The predominance of 0+ bass in samples from Oldbury and Berkeley is illustrated by the fact that the numbers of older age-classes contributed less than 1 % to the total catch in the autumn of the years of greatest abundance (1975 and 1976).

The pattern of growth of 0+ bass can be seen from weekly mean length

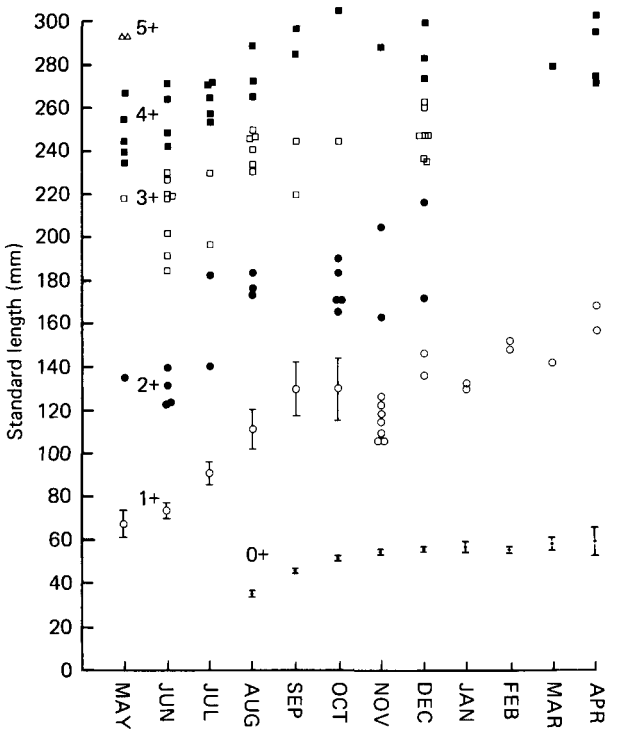

Fig. 2. Standard length measurements for the age classes of bass (0+ to 5+) caught in different months between July 1972 and April 1977. Mean values (±95% confidence limits) are given for 0+ and early 1+ fish, but individual values are given for the small numbers of older fish.

measurements of fish taken at Oldbury in 1975 and 1976 (Fig. 3). The mean standard length of young-of-the-year at the time when they were first caught in reasonable numbers (August) was approximately 35 mm in both years. The length had increased to approximately 55 mm by October/November. The initial rapid increase in length during August, September and the early part of October occurred when water temperatures were still relatively high (14–21 °C), while the cessation of growth over the following 3 months corresponded to a period when temperatures had fallen below 13 °C. The decline in the mean standard length in some samples during this latter period may reflect a tendency for the larger representatives to move seawards first. Certainly, it occurred at a time when the numbers were falling.

The pattern of change exhibited by the mean values for 0+ bass during their first 3 months in the estuary (Figs. 2, 3) suggests that spawning takes place predominantly during May and June. Such a view is consistent with the presence of post-larval bass only in the mid-June and mid-July plankton hauls taken in the Bristol Channel between April and September of 1974 (Russell, 1980). Moreover, our proposed breeding time is also in agreement with the estimates provided by Kennedy & Fitzmaurice (1972) for bass populations in Irish waters.

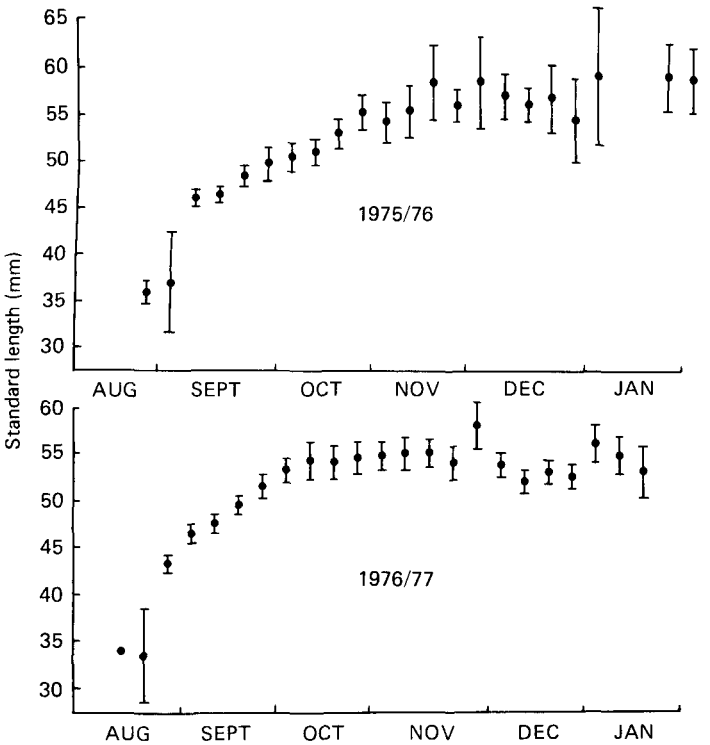

Fig. 3. The mean standard lengths (±95% confidence limits) for 0+ bass caught at Oldbury between August and January of 1975/6 and 1976/7.

Assuming that spawning takes place in May, bass attain a mean length of approximately 65 mm (≡ 4·5 g) in the Severn Estuary at the end of their first year of life (Fig. 2). Corresponding values for 2-, 3-, 4- and 5-year-old bass were approximately 130 mm (≡ 37·9 g), 190 mm (≡ 121·1 g), 250 mm (≡ 280·4 g) and 290 mm (≡ 441·5 g) respectively. Pooled data for 1+ bass showed that growth was most rapid between May and September (Fig. 2). During this period, the mean standard length increased from approximately 65 mm (≡ 4·5 g) to 130 mm (≡ 37·9 g).

The slope of the logarithmic relationship between wet weight and standard length in samples of 0+ bass taken in the Severn Estuary and inner Bristol Channel at different times during the study period ranged from 2·87 to 3·25. The comparable slope for pooled data for fish of age classes 1+ to 5+ was 3·06.

DISCUSSION

This study has demonstrated that the Severn Estuary and inner Bristol Channel is an important nursery area for juvenile bass, *Dicentrarchus labrax*. It is also evident from our length-frequency and otolith data that the populations in the middle reaches of the estuary are dominated by 0+ fish, although

appreciable numbers of 1+ fish are also sometimes present. These findings closely parallel those recorded for other similar environments such as North and South Devon estuaries (Hartley, 1940; Holden & Williams, 1974), the Thames Estuary (Wheeler, 1979) and inshore Irish coastal waters (Kennedy & Fitzmaurice, 1972).

The Severn Estuary also offers valuable nursery grounds to other young teleosts, such as whiting, bib, poor cod, northern rockling, sand goby, sea snail, twaite shad, herring and flounder (Hardisty & Huggins, 1975; Claridge & Gardner, 1977, 1978; Titmus *et al.* 1978; Badsha & Sainsbury, 1978*b*). This nursery function is presumably related to the presence of large areas of relatively shallow and sheltered water containing an abundant food supply (Moore, Moore & Claridge, 1979). Moreover, as in most estuaries, the numbers of most predatory fish species in the Severn are lower than in marine environments (Hardisty & Huggins, 1975).

Although juvenile bass were always found in the Severn Estuary in the autumn, it is obvious from the data presented earlier that their abundance was great in some years. This point is well illustrated by the fact that in 1976/7 almost 9000 *D. labrax* were obtained from the once-weekly 24 h samples taken at Oldbury Power Station; the majority of these coming from the 4-month period between September and December. When taken in the context of the restricted timing and location of our sampling regime, these numbers clearly imply that very large schools of bass must have entered the estuary in the autumn of that year.

It is well known that there are 'weak' and 'strong' year classes of bass and that these can be related to lower or higher than usual temperatures at the time of spawning and during the first summer growth period (Kelley, 1979). Our data suggest that spawning success and larval survival in 1975, and more especially 1976, were significantly greater than in the preceding 3 years. It is thus almost certainly significant that summer water temperatures in the Severn Estuary reached a mean monthly maximum of 21 °C in 1975 and 1976, compared with values of 18–19 °C for the preceding years. Wheeler (1979) has also drawn attention to the presence of large numbers and an extreme penetration of bass in the Thames Estuary in the autumn following the very warm summer of 1976. In the context of the strong 0+ year class in 1976, it is noteworthy that particularly good catches of bass were obtained in 1982 (Kelley, personal communication), at which time this year class would have been of a size suitable for commercial and recreational exploitation (Kelley, 1979).

In an historical context, Hartley (1940) found 0+ bass in the Tamar Estuary in the autumn of 1935 but not in the same period in 1936. Similarly, whereas Matthews (1933) considered small *D. labrax* to be common around stream mouths in the Severn Estuary and Bristol Channel, Lloyd (1941) recorded them as present in this area only rarely between 1937 and 1940.

In addition to its possible effect upon spawning success and subsequent survival, it seems likely that temperature also influences the seasonal movements of bass in British waters. For example, three independent studies have shown

that adult bass move southwards (and apparently sometimes offshore) during the late autumn and winter (Kennedy & Fitzmaurice, 1972; Holden & Williams, 1974; Kelley, 1979). Since in Irish waters this movement occurs at a time when water temperatures decline below 13–14 °C (Kennedy & Fitzmaurice, 1972), it is probably significant that the pronounced movement of juvenile bass out of the Severn Estuary occurred at a very similar temperature. The view that temperatures help regulate seasonal movements is also consistent with the observation that such movements are less pronounced in those areas in which the winter temperatures are higher (Holden & Williams, 1974). The apparent importance of temperature to aspects of the biology of this species may partly be explained by considering its distribution. The bass is a southern species which is widely distributed in the Mediterranean and even in the summer does not extend much above a latitude corresponding to the most northern of British coastal waters (Wheeler, 1969).

The growth of 0+ and 1+ bass in the Severn Estuary is similar to that reported for fish in Irish waters (Kennedy & Fitzmaurice, 1972), but less than that in more southerly areas (Hartley, 1940; Ottaway & Simkiss, 1979). Thus in the Tamar Estuary, Hartley (1940) caught 0+ and 1+ *D. labrax* in the autumn and winter of 1935/6 with mean total lengths of 105 mm (approximately 85 mm standard length) and 188 mm (approximately 152 mm standard length). These values can be compared with respective means of 55 and 130 mm standard length for fish from the Severn Estuary at the same time of the year. Slightly less marked regional differences in standard length are apparent for bass caught in the Tamar by Ottaway & Simkiss (1979), who give mean back-calculated values of 78 and 147 mm for 1- and 2-year-old fish respectively. However, it may be relevant that bass apparently spawned earlier (March/April) in the waters off Plymouth in the 1930s (Russell, 1935) than the May/June period estimated in the current study for the Bristol Channel area during the 1970s. The earlier spawning can be related to the presence of higher temperatures in south-western English waters at that time (Maddock & Swann, 1977), a feature that would have led to an extended initial growing period in the first year of life and probably also to an overall increase in growth rate.

In the context of the relationship between temperature and growth, it is worth noting that the mean standard lengths of approximately 55 mm attained by bass in the Severn Estuary in October of 1975 and 1976 were greater than the mean values of approximately 36, 43 and 41 mm recorded for the much smaller numbers of individuals taken in the same month in 1972, 1973 and 1974 respectively. As mentioned earlier, mean monthly water temperatures in the summer of 1975 and 1976 peaked at 2–3 °C higher than in the other years. Similar correlations between temperature and growth have been made by Kennedy & Fitzmaurice (1972) for bass in Irish waters.

Although a few bass of the 4+ and 5+ age classes were taken in the Severn Estuary and, more particularly, the Bristol Channel during this study, all had relatively small gonads. Thus mean gonadosomic ratios for eight males and eight females taken in the spring were 0·06 and 0·46 respectively. These low values,

together with the absence in samples of what can be considered to be adult *D. labrax*, suggest that this species does not mature in the area and that spawning takes place in marine rather than estuarine environments; a view consistent with the observations of previous authors (Hartley, 1940; Kennedy & Fitzmaurice, 1972).

It is apparent from the preceding discussion that the Severn Estuary and inner Bristol Channel play an important role in the early life-history of bass and other marine fish species. The Severn Barrage Committee (Department of Energy, U.K., 1981) considered the region to be relatively unimportant as a fish spawning area and, by implication, therefore to have relatively little value as nursery grounds. It was concluded that the development of a tidal-power generation scheme across the estuary would probably have no short or long-term deleterious effects on marine fisheries. The results of the present investigation are clearly relevant to this question and are not wholly in accordance with the views of the Committee.

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