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DISTRIBUTION, ABUNDANCE AND SIZE COMPOSITION OF MULLET POPULATIONS IN THE SEVERN ESTUARY AND BRISTOL CHANNEL

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(Figs. 1–5)

Mullet were collected over several years in regular samples from Berkeley, Oldbury and Uskmouth in the Severn Estuary and from Hinkley Point and Minehead in the inner Bristol Channel, and also during five trips to Pembroke, Milford Haven, on the south-western tip of Wales. The numbers of thin-lipped mullet, *Liza ramada*, were far greater in samples from the Severn Estuary and Bristol Channel than in Milford Haven, whereas the reverse was true for thick-lipped mullet, *Chelon labrosus*. Golden mullet, *Liza aurata*, was only found in Milford Haven. The estimated spawning time of the *L. ramada* population that gave rise to the individuals found in the estuary was between April and June. While there was great variation in the numbers of *L. ramada* entering the estuary in different years, peak abundance was always reached in October or November. Growth of *L. ramada* was slow, with mean standard lengths of only 55–58 mm being attained after approximately 10–12 months. In general, the 0+ age class was the most abundant but considerable numbers of 1+ and occasionally 2+ individuals were also collected. The data indicate that *Liza ramada* tends to move out into deeper water as it increases in size.

INTRODUCTION

The following three species of grey mullet (Mugilidae) are recorded by Wheeler (1978) for the waters of north-western Europe: thick-lipped mullet, *Chelon labrosus* (Risso, 1826); thin-lipped mullet, *Liza ramada* (Risso, 1826) and golden mullet, *Liza aurata* (Risso, 1810). *Liza ramada* was obtained in relatively large numbers during the course of extensive sampling of the material collected on the intake screens of power stations in the Bristol Channel and Severn Estuary (for details of other studies see e.g. Claridge & Gardner, 1977, 1978; Titmus, Claridge & Potter, 1978; Abou-Seedo & Potter, 1979; Claridge & Potter, 1983, 1984). Since there is apparently no detailed information on the biology of the thin-lipped mullet in the estuaries of north-western Europe based on regular frequent collections, the power station material was used to provide data on seasonal and annual abundance, size composition, growth and lip depth of this species in the Severn Estuary and Bristol Channel. Comparisons have been made between these data and those obtained for *C. labrosus* from the same environments and more particularly from outside the area at Pembroke where much larger collections of this latter species were taken.

MATERIALS AND METHODS

Samples from the inner Severn Estuary were obtained weekly from Oldbury Power Station between July 1972 and June 1977 and from 7 km upstream at Berkeley Power Station between September 1974 and June 1977. Collections at Uskmouth in the River Usk, 1 km from its confluence with the outer Severn Estuary, and from Hinkley Point in the inner Bristol Channel were made monthly between October 1975 and June 1977. Occasional samples of small fish were also obtained from a commercial fisherman at Minehead in the inner Bristol Channel between October 1975 and October 1976. Between September 1976 and February 1977, five samples were obtained from Pembroke Power Station in Milford Haven which lies on the south-western tip of Wales and opens into the southern Irish Sea.

Each of the collections from Oldbury represented the total amount of fish entrained over a period of 24 h. The numbers of mullet in these samples have been adjusted to correspond to an intake volume of $2{\cdot}2 \times 10^9$ l, the typical daily volume of water passing through the screens during the autumn, winter and spring when the station was under full load and mullet were most numerous. Variability in the time over which the entrained material had accumulated at the other power stations prevented the quantification of the catches from Berkeley, Uskmouth, Hinkley Point and Pembroke in the same manner as those from Oldbury. Moreover, subsamples were occasionally taken from Berkeley, Uskmouth and Hinkley Point when large amounts of material collected at these three stations, a feature that in some cases may have resulted in a slight preferential collection of larger fish. The standard length, maximum depth of upper lip and weight of all mullet were recorded to the nearest 1 mm, 0·1 mm and 0·1 g respectively.

RESULTS

Morphological distinction and distribution of mullet species

The characters given by Wheeler (1978) to distinguish between mugilids enabled the majority of older and larger mullet to be assigned to either *Liza ramada* or *Chelon labrosus*. However, differences in the degree of ventral apposition of the opercular flaps of the small representatives of these two species could be used to separate more rapidly and conclusively the juveniles of these two species. Thus, whereas in both species the ventral part of these flaps abut posteriorly, the gap anteriorly is much wider in *L. ramada* than in *C. labrosus*. In addition to this character, the body of juvenile *L. ramada* is appreciably more flattened dorso-ventrally than *C. labrosus*. After subsequently examining a wide size range of *L. ramada* and *C. labrosus*, it became clear that it was dangerous to rely only on a visual examination of the size of the lip of mullet below 200 mm to separate with certainty those *L. ramada* which had relatively thick lips from those *C. labrosus* with comparatively thin lips. This point is illustrated by the fact that, whereas the intercepts of the lines relating maximum lip diameter and standard length in the two species were significantly different ($P < 0{\cdot}001$), and the lip diameters for similar-sized representatives of the two species did not overlap, the values were sometimes very close (Fig. 1).

While the sampling effort at the different sites varied greatly, it is clear from the total numbers of the three mullet species collected during this study that *L. ramada* is relatively much more abundant than *C. labrosus* in the Severn Estuary and Bristol Channel, whereas the reverse situation applies at Pembroke outside the Bristol Channel (Table 1). While no *L. aurata* were taken in either the Severn Estuary or inner Bristol Channel, three representatives of this species were collected from Pembroke (Table 1). *L. aurata* could be distinguished from the

other two mullet species by golden marks on the cheek and gill covers, the relatively long pectoral fins and the larger and more widely spaced teeth on the upper lip.

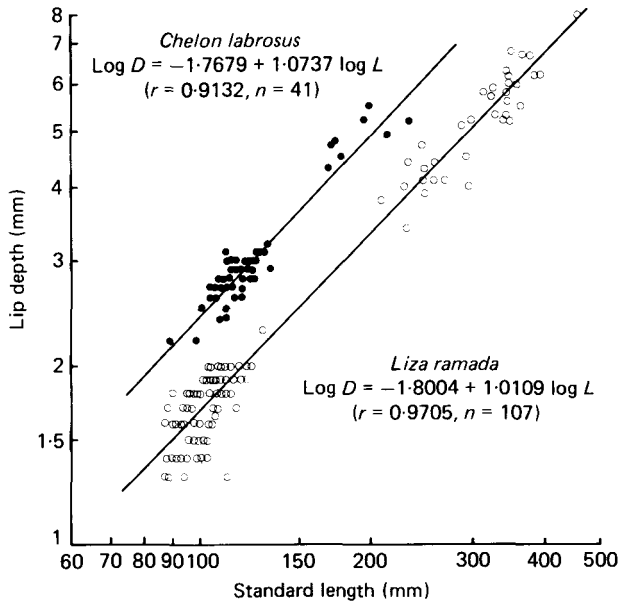

Fig. 1. The relationship between lip depth (D) and standard length (L) for thick-lipped mullet (*Chelon labrosus*) and thin-lipped mullet (*Liza ramada*).

Table 1. *Total numbers of mullet collected from each sampling site between September 1974 and June 1977*

	Severn Estuary			Bristol Channel		South-west Wales:
	Berkeley	Oldbury	Uskmouth	Hinkley	Minehead	Pembroke
Liza ramada	348	3501	148	416	487	5
Chelon labrosus	0	9	0	4	0	80
Liza aurata	0	0	0	0	0	3
No. of samples	119	140	16	21	13	5

Seasonal and annual abundance of Liza ramada

Peak abundance of *L. ramada* at Oldbury was attained in November of all years between 1972 and 1976, except for 1974 when it occurred in October (Fig. 2). The peak values for the mean daily catch per month varied greatly however between years, ranging from 3·3 in October 1974 to 263·5 in November 1976. Since these values are about one-thirtieth of the numbers that would be expected to be taken in a month, the total number of *L. ramada* that would have been entrained in the above two months was approximately 99 and 7905 respectively.

Size and growth of Liza ramada

The standard length of *L. ramada* caught in the Severn Estuary during the whole study ranged from 20 mm (≡ 0·11 g) to 455 mm (≡ 1264 g). The modal classes in the length-frequency histograms were sufficiently consistent and discrete to be able to assign with confidence the major size groups to a particular

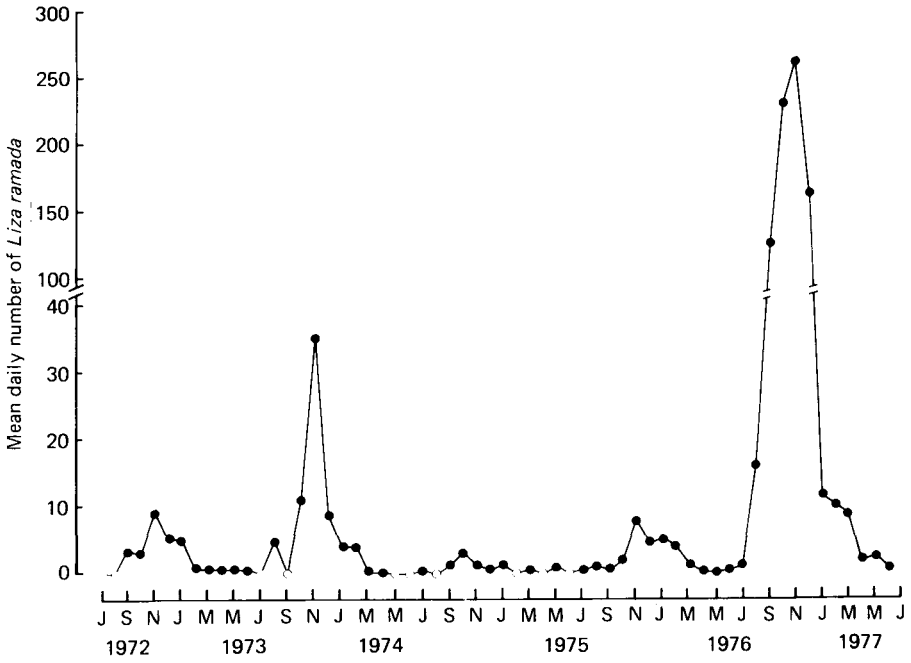

Fig. 2. The mean daily number of thin-lipped mullet (*Liza ramada*) collected from Oldbury Power Station each month between July 1972 and June 1977. Values correspond to an intake volume of $2{\cdot}2 \times 10^9$ l day^{-1}, the typical intake during autumn and winter.

age class (Fig. 3). The histograms for the months between August 1976 and April 1977 show in most cases two clearly defined modes. The modal length class corresponding to the group of smaller individuals increased from 40–49 mm (≡ 1·1–2·0 g) in August 1976 to 50–59 mm (≡ 2·1–3·5 g) in October 1976. The modal length class did not change in the subsequent months up to May 1977, after which numbers in the estuary declined (Fig. 2). The second mode, which generally occurred at 100–110 mm (≡ 17·5–23·4 g), undoubtedly represents the second age class (Fig. 3). Few animals longer than 140 mm were found during this period. However, length-frequency histograms based on pooled data for the months between October 1974 and May 1975 yielded a third modal length class at 160–170 mm (≡ 74·0–89·1 g) which presumably represents the third age class. Although a few 2+ and possibly older fish were collected between the autumn of 1975 and the spring of 1976, the structure of the histograms bore a much greater similarity to those taken over the same period in 1976/77, i.e. the 0+ was the

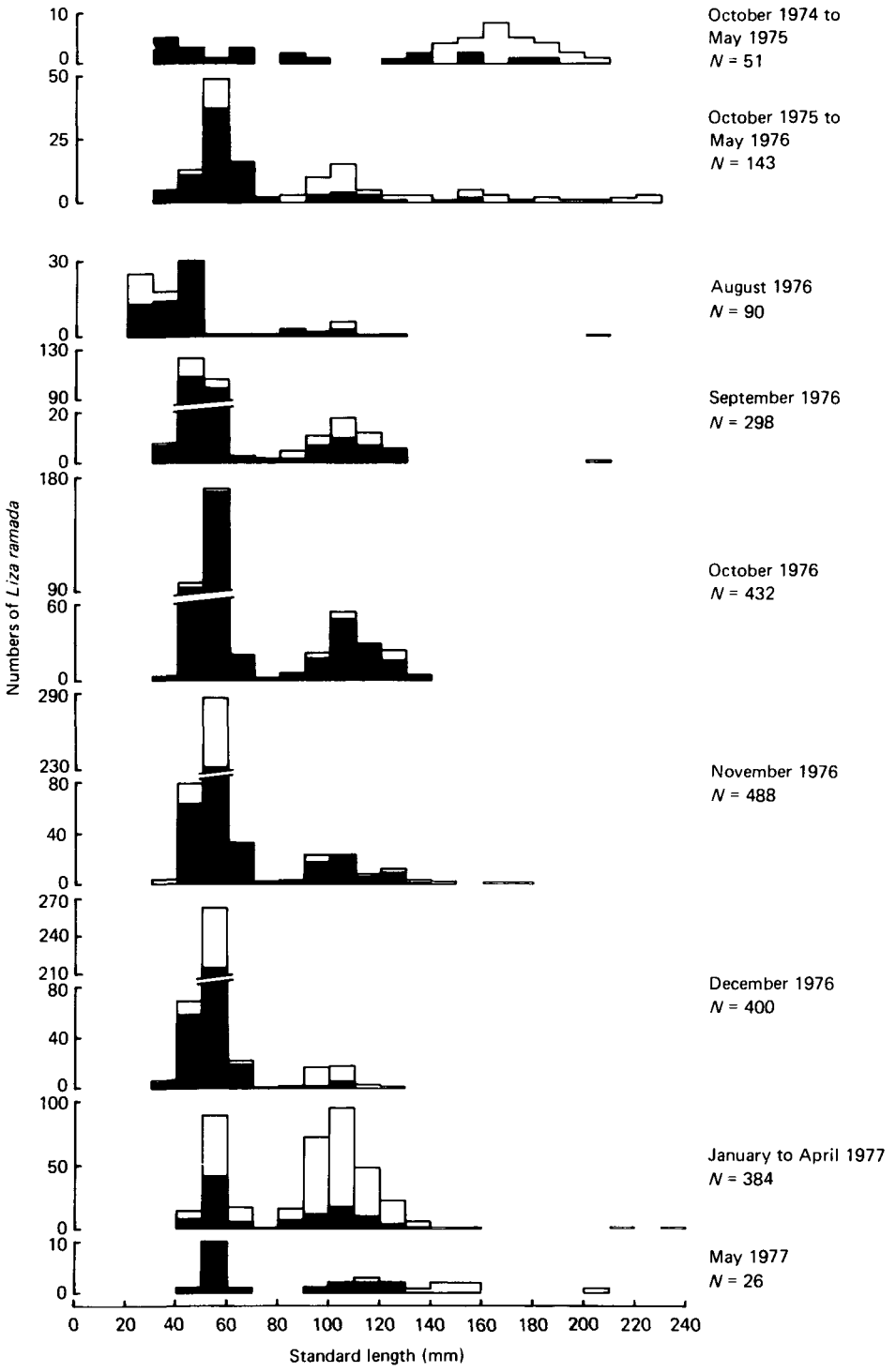

Fig. 3. Length–frequency histograms for thin-lipped mullet (*Liza ramada*) collected from Berkeley, Oldbury, Uskmouth and Hinkley Point Power Stations. The data for Oldbury, which was based on all fish collected once weekly over a 24 h period, are shown in black. The 75 individuals occurring irregularly at standard lengths between 240 and 455 mm are not shown in this Figure.

dominant age class (Fig. 3). While only five *L. ramada* with lengths greater than 200 mm were collected from Oldbury, the samples from Berkeley yielded 89 in this size range (N.B. The 75 fish scattered through the length range from 240–455 mm are not shown on Fig. 3). The samples of *L. ramada* caught at Uskmouth between the late summer and early winter of 1976 contained few animals exceeding 80 mm, reflecting a high predominance of the 0+ age class, a feature also found at this time in fishermen's catches at Minehead. By contrast, the length-frequency histograms for Hinkley Point contained a considerable number of larger individuals belonging to the 1+ age class.

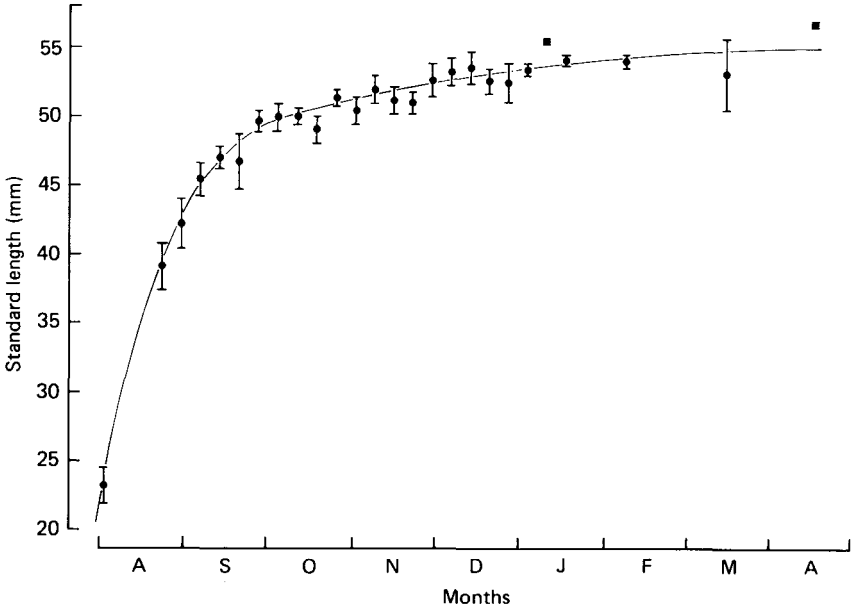

Fig. 4. Mean values (±95% confidence limits) for the standard length of thin-lipped mullet (*Liza ramada*) collected weekly between August 1976 and April 1977.

The mean length of 0+ *L. ramada* when they were first caught at Oldbury Power Station in early August 1976 was 23·2 mm (≡ 0·19 g), with individual values ranging from 20 to 26 mm (Fig. 4). While the mean length had risen to 53·2 mm (≡ 2·5 g) by December, a curve drawn by eye through the means for the individual weekly samples emphasizes that growth over this period is markedly asymptotic with only a small amount of increase in length occurring between October and December (Fig. 4), at a time when temperatures were declining (see Claridge & Potter, 1984, for details of temperature regime at Oldbury). The mean length in April 1977, just before mullet disappeared from the samples, was 56·6 mm (≡ 3·1 g), a value very similar to that recorded at Minehead in April 1976.

Size data for Chelon labrosus

The standard length of the thirteen thick-lipped mullet from within the estuary ranged from 61 to 197 mm (≡ 2·8–139·8 g), whereas the 80 from Pembroke lay mainly within the range 80–140 mm (≡ 8·1–45·2 g). The latter animals, which

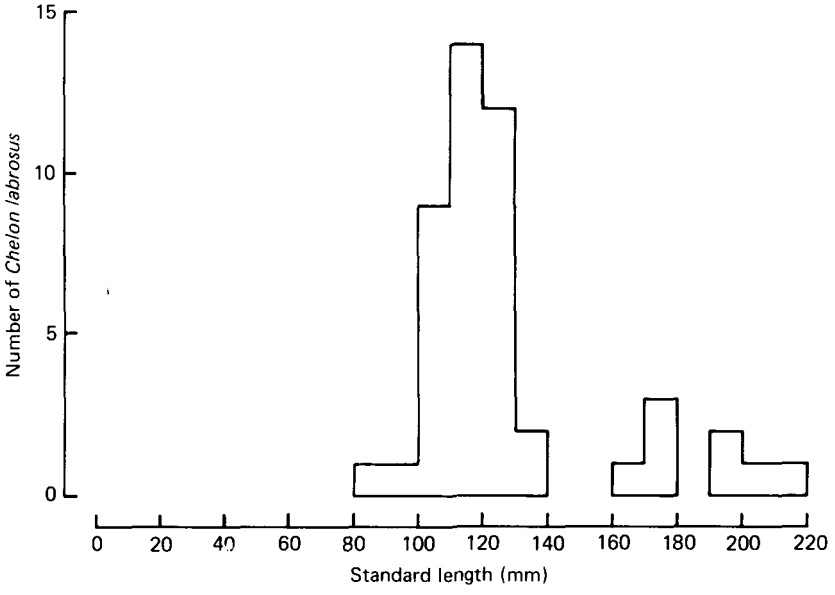

Fig. 5. Length–frequency histogram for thick-lipped mullet (*Chelon labrosus*) collected from Pembroke in the late autumn and winter.

like those from the estuary were collected predominantly in the late autumn and winter, produced a well-defined modal length at 110–119 mm (Fig. 5), corresponding to weights of 21·5–28·1 g. The standard length of the remaining animals ranged from 162 to 218 mm (≡ 70·8–176·7 g).

DISCUSSION

The results of this study provide strong indications that the juveniles of *Liza ramada* exhibit a much greater tendency to enter estuaries than those of *Chelon labrosus*. This view is based on the capture of large numbers of *L. ramada* at Berkeley, Oldbury and Uskmouth in the Severn Estuary and the almost total absence of this species from Pembroke, whereas the converse was observed with *C. labrosus*. This conclusion parallels that drawn by Hickling (1970) and is entirely consistent with the physiological studies of Lasserre & Gallis (1975) which showed that, in contrast to *L. ramada*, *C. labrosus* did not have 'long term capabilities for hypoosmotic regulation'. Although Lasserre & Gallis (1975) also found that *C. labrosus* was incapable of surviving for long periods in fresh water,

Hickling (1970) reports that he occasionally found this species in 'wholly freshwater habitats' and that it would 'acclimatise well to fresh water'.

The large numbers of *L. ramada* and virtual absence of *C. labrosus* in collections from the Severn Estuary and inner British Channel during this study contrasts with the report in an earlier detailed study by Lloyd (1941) that the thick-lipped mullet was the more abundant species in these regions. In view of our evidence that the thin-lipped mullet penetrates estuaries to a greater extent than the thick-lipped mullet, and that characters have now been developed to distinguish more readily between the 0+ representatives of these two species, it seems likely that the findings of Lloyd were based on an incorrect identification.

Although only three *L. aurata* were collected during this study, it may be significant that these all came from the limited number of samples taken from Pembroke. In other words, *L. aurata* may not tend to enter estuaries to the same extent as *L. ramada*, a view previously expressed by Hickling (1970). However, while *L. ramada* may have a greater preference for reduced salinities than either *C. labrosus* or *L. aurata*, the studies of Zismann & Ben-Tuvia (1975) on a hypersaline lagoon in Israel showed that on occasions all three species could be found in the same environment when salinities were high and tributary rivers were not present.

Since the length of the 2+ *L. ramada* in the Severn Estuary is comparable with that of 2+ *C. labrosus* in Irish waters (Kennedy & Fitzmaurice, 1969; Hickling, 1970), these two species apparently grow at a similar rate. The size of *L. ramada* when it was first captured in the estuary and a visual backwards extrapolation of the growth curve, together with the assumption that the pattern of early growth is similar to that of *C. labrosus*, suggests that the spawning of the population of this species in the Bristol Channel region takes place between April and June. This is considerably earlier than the autumnal spawning period proposed for thin-lipped mullet in southern English waters by Hickling (1970) on the basis of two ripening and one spent female. It is also worth noting that very different spawning times have been found in another mullet species, *Aldrichetta forsteri* (Valenciennes), in different geographical regions (Thomson, 1957), and that even in the same region, the breeding season lasts for many months (Chubb *et al.* 1981). It is possible, however, that the spawning period of mullet in British waters may be protracted or vary markedly between areas or years. Indeed, on the basis of the times when very young *C. labrosus* were collected by Kennedy & Fitzmaurice (1969) off Ireland and by Demir (1971) off Plymouth, the last of these workers concluded that spawning of thick-lipped mullet could occur in British waters between the end of May and the end of September. While spawning periods of between October and January were recorded for *L. ramada* by Faouzi (1938), Heldt (1948), Bograd (1961) and Le Dantec (1955) these applied to populations in far more southerly areas than the Severn.

Since the new 0+ age class of *L. ramada* in the first sample in which they were taken from both Uskmouth and Oldbury in 1976 was mainly between 20 and 26 mm, this is presumably slightly larger than the length at which the thin-lipped

mullet enters the Severn Estuary. Such a length, which would be rather less than that given by Zismann & Ben-Tuvia (1975) for comparable stages in a Mediterranean population of this species, would be close to the values recorded for many populations of different species of mullet caught early in this estuarine phase in various parts of the world (Wallace & van der Elst, 1975; De Silva, 1980; Chubb *et al.* 1981). The movement of mullets into estuaries is believed to constitute an active migration (De Silva, 1980).

Although there are apparently no data on the early growth of *L. ramada* in the more northern part of its distribution, Hickling (1970) does give a length of 118 mm for this species at the end of its second year of life in British waters. Since this value is only 10–15 mm greater than the modal standard length class obtained for thin-lipped mullet in the late winter when they were approximately 22–24 months old and just about to leave the Severn Estuary, the growth of the population of *L. ramada* found in this estuary is apparently similar to that recorded by Hickling. The lengths given by Hickling and ourselves for thin-lipped mullet at the end of their second year of life and the fact that this species only reached a mean length of 55–58 mm in the Severn after approximately 10–12 months, imply that *L. ramada* grows slowly in British waters. Such a view is supported by the reports that during the same period in more southern waters this species attains mean lengths of 181–191 mm (Wimpenny, 1932; Arné, 1938). Moreover the sea mullet, *Mugil cephalus* L., can reach mean total lengths of 178–220 mm in just under a year (Chubb *et al.* 1981), which correspond to those attained by *L. ramada* in British waters after three years of life (Hickling, 1970).

While there may occasionally have been some selection for the larger mullet in collections from all power stations except Oldbury, there can be no doubt that the considerable differences between the numbers of bigger fish in different regions do reflect a real and consistent difference between sites. The much greater numbers of larger thin-lipped mullet (> 200 mm) in samples from Berkeley than the nearby Oldbury Power Station is probably related to differences in the position from which cooling water is drawn. Thus, while the water at Oldbury is taken from a shallow region of the river which has to be dredged constantly to maintain water depth, it is pumped from the main deep water channel at Berkeley. Since the Uskmouth samples contained comparatively few fish greater than 80 mm in length, it is probably significant that water at this station is drawn from a tributary river of the Severn where the water depth is also less than at Berkeley. Likewise, the presence of large numbers of 1+ within the Channel at Hinkley Point and the virtual absence of this age class at Minehead probably reflects the fact that sampling took place through an offshore intake pipe at the former locality and by inshore netting in the latter region. Thus, the relatively much greater numbers of larger *L. ramada* at Berkeley and Hinkley Point than at Oldbury, Uskmouth and Minehead, implies that thin-lipped mullet move away from the shores and into deeper water as they increase in age and size, a finding which parallels that recorded for species of mullet in South Africa and Australia (Whitfield & Blaber, 1978; Chubb *et al.* 1981). While other fish, such as some

gadoids, show a similar pattern of movement in the Severn Estuary (Claridge & Potter, 1984), it does not appear to be as pronounced as in thin-lipped mullet.

Much more work has been carried out in north-western Europe on the growth of *C. labrosus* than *L. ramada*. The extensive studies of both Kennedy & Fitzmaurice (1969) and Hickling (1970) yielded similar results with respective mean total lengths of between 125 and 90 mm being recorded for two year old fish. Since the former value, based on studies in Irish waters, corresponds closely to the modal length class of those obtained from Pembroke during the winter, these latter animals were presumably in their second year of growth.

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