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Distribution, Growth, and Reproduction of the Lightfish *Maurolicus muelleri* (Sternoptychidae) off South-East Australia

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DISTRIBUTION, GROWTH AND REPRODUCTION OF THE LIGHTFISH *MAUROLICUS MUELLERI* (STERNOPTYCHIDAE) OFF SOUTH-EAST AUSTRALIA

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Abstract

Off south-east Australia, *Maurolicus muelleri* (Gmelin) is most frequently found close to the bottom during the day over bottom depths of 150-400m. At night, it moves upwards and inshore; small fish appear to migrate further upwards than large ones. Seasonal differences in size composition indicate that fish are 35-40mm long at the age of one year, and that a small fraction live at least two years and reach 45-50mm. The principal spawning season appears to be late winter and spring; individual females may spawn more than once per season. Batch fecundities are very low; even the largest females spawn only about 500 eggs. A parasitic fungus occurs in fish over 30mm long; incidence is highest in the largest fish.

INTRODUCTION

The lightfish *Maurolicus muelleri* is a small sternoptychid fish associated with the continental shelf in subtropical to temperate areas of all oceans except the north-east Pacific (Grey 1964). It occurs mostly between 25° and 45° latitude in both hemispheres, but extends up to 70°N in the east Atlantic and apparently closer to the equator in the north-east Atlantic and south-east Pacific (Grey 1964, Robertson 1976). Although *M. muelleri* - especially its eggs and larvae - has been recorded from oceanic areas, it appears to be most abundant and regularly found over bottom depths of 200-400m (e.g. Robertson 1976). Within this depth range, *M. muelleri* appears to be an important part of the food web off Japan (Okiyama 1971), and in several situations, e.g., off Australia (Anon. 1977) and off Norway (Gjøsaeter 1981), has been found in such dense concentrations that it may prove to be commercially harvestable. Along the edge of the continental shelf off south-east Australia, acoustic surveys have indicated dense schools over bottom depths of *ca.* 150-300m during the day, and catches of up to 500 kg in 50 minutes with a modified Engel trawl have been reported (Gorman and Graham 1977). It is an important item in the diets of jack mackerel *Trachurus declivis*

(Maxwell 1979) and mirror dory *Zenopsis nebulosus* (S. Brandt pers. comm.) captured near the shelf edge. This study examined data and specimens of *M. muelleri* collected off south-east Australia by the CSIRO Division of Fisheries Research and the New South Wales State Fisheries. The results provided the bases for estimates - in many cases, very tentative - of certain life history and ecological parameters and allow some comparison with studies on the same species in other parts of the world.

MATERIALS AND METHODS

All data and specimens were collected by pelagic trawls over or near the edge of the continental shelf off New South Wales and Tasmania (33^{o}-43^{o}S and 148-152^{o}E). Trawl depth, bottom depth, time of day, date and presence or absence of *M. muelleri* in the catch were recorded from logs of all pelagic trawl stations taken on Cruises 6-30 (February 1976 - January 1978) of the CSIRO FRV *Courageous*. Data on occurrences of *M. muelleri* were also taken from Cruise Reports of the New South Wales State Fisheries FRV *Kapala* (Gorman and Graham 1977, 1978, 1980) or from records of *Kapala* specimens deposited in the Australian Museum. Towing depth and bottom depth for each station were taken as the averages of the minimum and maximum recorded during the horizontal portion of the tow. For consideration of vertical distribution, stations were eliminated if towing depth changed by more than 40m during the tow or if bottom depth changed by more than 40m for depths less than 200m or by more than 80m for depths over 200m. Stations which caught *M. muelleri* will be termed 'positive', those which did not, 'negative'.

Specimens of *M. muelleri* were available from 14 of the 18 tows from *Courageous* Cruise 19 (April 1977), eleven other *Courageous* stations, and seven *Kapala* stations. For these, standard length (SL) was measured to the nearest millimetre of all or a subsample of *ca.* 100 specimens. Size composition data for ten other *Kapala* samples were given by Gorman and Graham (1977, 1978, 1980). The *Courageous* samples were collected with a 308 x 800mm Engel trawl with 10mm mesh cod end lining, and the *Kapala* samples with a 434 x 400mm Engel trawl with 12mm mesh in the cod end. The size composition of the catches of both nets was probably biased toward larger fish because of size-related escapement through the cod end meshes. Size-frequency data from different catches with the same net could be validly compared, and for present purposes it was assumed that the difference in bias between nets was negligible.

Conclusions drawn from the data on presence and absence or size composition of *M. muelleri* must be regarded as very tentative since the samples were neither systematic nor unbiased with respect to variables such as time of day, depth, season, etc. For example, there were some day and night tows within most 20m depth intervals over bottom depths from 20 to 400m, but many tows were aimed at acoustic targets - frequently not *M. muelleri* - resulting in bias toward tows near the bottom by day and near the surface at night. Likewise, specimens or length-frequency data were available from all but three months of the year, but the samples were taken in different years, at different locations, and different depths and times of day.

If possible, at least twenty fish from each available sample were dissected, sexed, and examined for parasites. (Fish less than 30mm SL could not be reliably sexed.) For females, a portion of the ovary was examined at 100X and size (to the nearest 0.01mm) and development of the largest ova recorded. Ova size-frequencies were determined for twelve females with ripening ova by counting and measuring all ova over 0.10mm in a subsample of the ovary. The ova were not spherical and were measured at whatever orientation (presumably random) they held in the microscope field. For 23 females with a size mode of ripening ova distinct from the smaller ova, all ova in the mode in both ovaries were counted and the wet weight of the ovaries and the remainder of the fish ('somatic weight') were measured to the nearest 0.5mg. Since all such fish had been held in alcohol for several years, the weights were probably underestimates due to solution of lipids, but the gonad/somatic weight ratio was probably not seriously affected.

RESULTS AND DISCUSSION

Vertical Distribution

The average bottom depths of positive daytime stations were all over 165m, and for most, the average towing depth was within 50m of the bottom (Figure 1). Bottom depth of positive night time stations was as shallow as 110m, and towing depths ranged from near the bottom at depths of up to almost 400m to within 10m of the surface (Figure 1). Except for occasional catches over bottom depths greater than 400m, none of the eliminated stations indicated extensions of the depth ranges beyond those shown in Figure 1. The diel differences in distribution of positive stations are consistent with an upward and inshore migration at night and generally agree with observations on the vertical distribution and migration of *M. muelleri* in Japan and New Zealand (Okiyama 1971, Robertson 1976).

The deep night catches of *M. muelleri* may have been artefacts resulting from capture at shallower depths during descent and ascent of the open

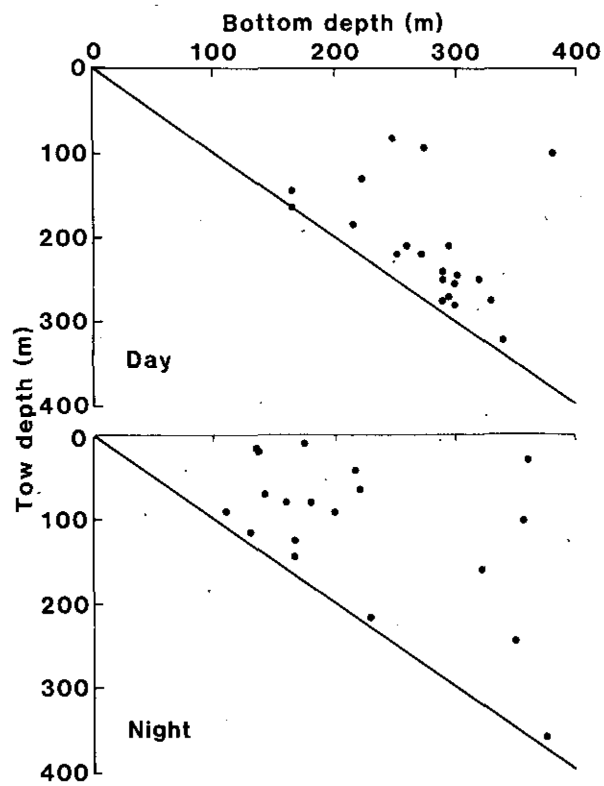

Figure 1.

Bottom depth and tow depth for trawl collections which captured *Maurolicus muelleri* off south-east Australia.

trawls, but it is also possible that some fraction of the population does not always migrate upwards at night. Differences in size composition with depth (see below) indicate that the latter is true at least some of the time. For both day and night there were many negative tows within the ranges of the positive tows - particularly above 150m by day and above 100m at night. These indicate that the vertical distribution and probably also the occurrence of *M. muelleri* are quite variable along the shelf edge.

On *Courageous* Cruise 19 (April 1977), *M. muelleri* were taken in day tows which fished between 180 and 325m and night tows between 50 and 370m in the same area (*ca.* 38°S, 150°E). With two exceptions, bottom depths were 200-400m for the positive stations. For the seven night stations for

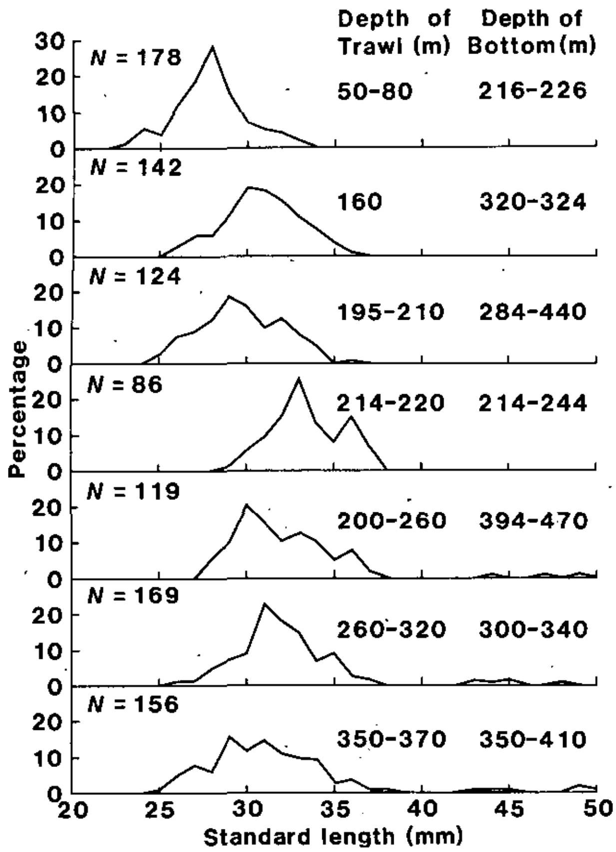

Figure 2.

Size composition of subsamples of *Maurolicus muelleri* from seven night trawl collections at different depths taken off New South Wales April 1977 (*F.R.V. Courageous* Cruise 19).

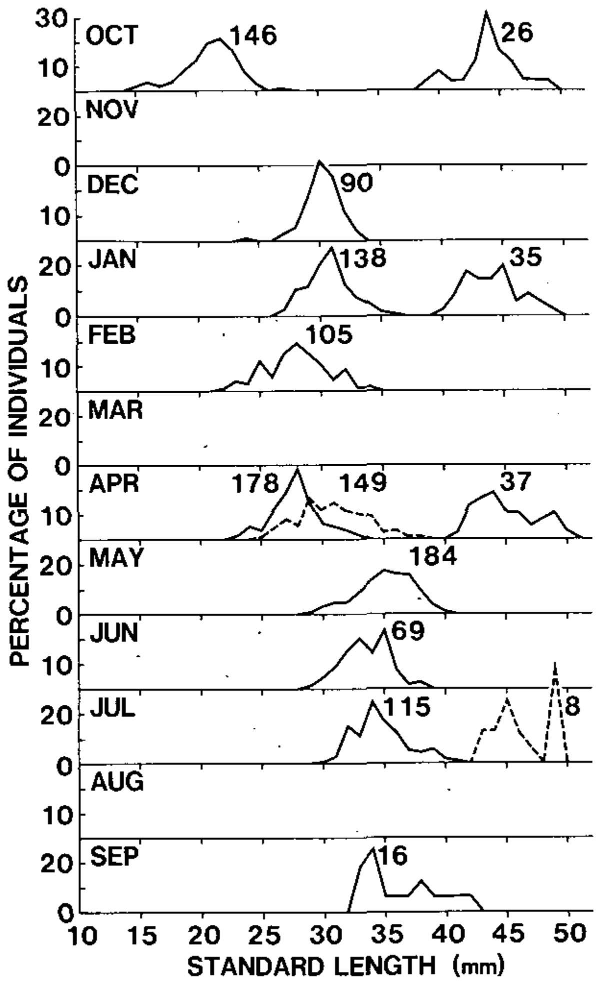

Figure 3.

Size composition of subsamples of *Maurolicus muelleri* from trawl collections taken in nine months off south-east Australia. Probable young of the year are considered separately from older fish even if both occurred in the same subsample; numbers measured for each group are adjacent to each plot. For small fish from April, data from the two most different samples (see Fig.2) are given (dashed lines for one) to illustrate possible variability due to different time, depth, etc., among the samples. For July the probable older size group is distinguished by dashed lines.

which specimens were available, there were significant differences in size-frequency (Kolmogorov-Smirnov test, $P<0.05$) between all adjacent (in depth) pairs of samples. The differences indicated that larger fish tended to occur deeper (Figure 2). There were two size groups of fish taken, 23-39mm SL and 43-50mm SL. Only the smaller groups were taken in the four shallowest tows (average depths 65-217m), and the modal size tended to increase with depth in this range. In the three deepest tows (230-360m) the size-frequency of the smaller fishes showed no trend with depth, perhaps because most of these were caught during transit to and from towing depth. The larger size-group of fish, although never a major fraction of the catch, occurred only in these samples. Similar changes in size-frequency with depth have been reported for many other stomiatoid fishes (e.g. Clarke 1974). There were also significant differences in size-frequency among the five day tows (average depths 210-325m), but no clear trend with depth. Fish from the larger size group were found only in the deepest tow and made up only 2% of the sample.

Age and Growth

The available data provided only a rough picture of seasonal changes in size-frequency (Figure 3). There were several samples from three or four different years only for the months of May and April. The modal size and size ranges of all tows from May were similar to that of the sample selected for Figure 3. With the exception of data from a sample taken 30 April 1980 (which was similar to that from other May samples), the two most dissimilar samples from April were both from the *Courageous* Cruise 19 depth series. This indicates that year-to-year differences in growth were less important sources of variability in the size-frequency data than were differences in sampling depth among the available tows.

The smallest fish captured were from October and were distinctly separated from a larger size group in the same sample. These small fish were just over the size at completion of transformation (Okiyama 1971) and were probably from spawning that began no earlier than July of the same year (see below). Size groups which likely represent the same age group, hereafter called '0' group, were present in data from other months. Although the fish from the December and January samples were larger than those from February and the difference between the two most dissimilar April samples was almost as great as that between February and May, the modal size of this group generally increased throughout the year to about that of the larger size group in the October sample. Thus *M. muelleri* appears to reach a length of 35-40mm at the end of the first year. The large size group, present only in the data from October, January, April and July, would thus probably represent '1+' fish; those from July would be about two years old. There was no obvious trend with time in size of this group.

Gjøsaeter (1981) estimated ages of Norwegian *M. muelleri* from both annular and minimal, presumably daily, rings on otliths. As might be expected from the differences in temperature and latitude, his data from annual rings indicated that overall growth is somewhat slower than indicated above for Australian *M. muelleri*. His counts of minimal rings on '0' group fish, however, indicate that growth between the spring spawning and late summer is comparable to that of the Australian fish.

For most samples of fish over 30-35mm, the average size of females was greater than that of males and the largest fish in any size group were all females (Fig. 4). Among all the specimens examined, the largest male was only 46mm, but there were several females 47-50mm. Because fish less than 30mm could not be reliably sexed, the size at which such differences become apparent could not be determined. These differences indicate that any future studies of growth should consider the two sexes separately.

Reproduction

Ovarian ova less than 0.10mm in diameter were transparent and contained no yolk. Ova 0.10-0.15mm ranged from clear to nearly opaque with at least some yolk granules visible; between 0.15-0.20mm the ova were semi-transparent to opaque with the nucleus rarely or barely visible. Ova 0.20-0.35mm were opaque but colourless, and the outer membrane was smooth and simple as in smaller ova. Ova greater than 0.35mm had dense, yellow yolk, and the membrane

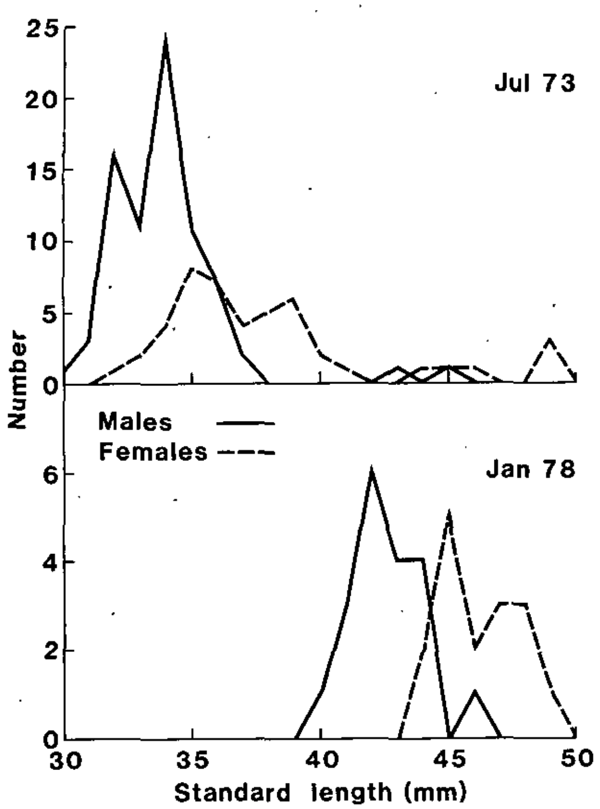

Figure 4.

Size-frequencies of male and female *Maurolicus muelleri* in samples from July 1973 (N = 123) and January 1978 (N = 35).

was rougher and thicker. These ova occurred as a distinct size mode separated from smaller ova. In ova greater than 0.50mm, the yolk was sometimes separated into globules, and the outer membrane appeared to be developing the hexagonally arranged points which distinguish the planktonic egg (Okiyama 1971). The largest ova were *ca.* 0.80mm, slightly less than the yolk diameter reported for spawned eggs (Okiyama 1971). No oil droplets or anything like hydrated ova were found.

Seasonal differences in ova size indicated that spawning occurred between July and October and that females reached first maturity at the end of the first year. The '0' group females from January were clearly immature; the gonads of both sexes were barely developed. The '1+' females from January had relatively larger ovaries than did the '0' females, but all ova were less than 0.10mm. The ovaries of '0' females from April were somewhat more developed than those from January, but the ova were less than 0.10mm. Some of the '1+' females from April had ova up to 0.20mm. In the July sample, some females of all sizes had nearly mature ova (greater than 0.50mm), but the '1+' fish (43-49mm) and the largest of the '0' fish were generally more mature than the small '0' fish (Table 1). None of the four females (37-40mm) available from September contained ova greater than 0.20mm and were perhaps spent. All eleven females from October (39-43mm) contained ova greater than 0.35mm; in most individuals, the largest ova were greater than 0.50mm. A single mature-sized female (45mm) from December contained ova up to 0.15mm that were opaque centrally with what appeared to be regressing yolk rather than nuclear material, and the ovaries were somewhat less regressed than in the '1+' females from January.

The apparent spawning season of *M. muelleri* off Australia coincides with the period of increased plankton production reported by Humphrey (1963) and Grant and Kerr (1970) and thus appears timed for maximum survival of larvae. Spawning off New Zealand occurs from late winter to early autumn with most in spring and summer (Robertson 1976). Gjøsaeter (1981) found ripe females from March to May off Norway, and Okiyama's (1971) data suggest a late winter to early spring season off Japan.

Size of females at first maturity off Australia appears to be considerably less than that reported from other areas. The data indicate that all females from the previous year's spawning - including some only about nine months old (spawned in October

Table 1. Numbers of fish *vs.* maximum size of ova for four size groups of female *Maurolicus muelleri* from a sample taken off New South Wales in July 1973 (Australian Museum No. 17882-001).

Diameter of largest ova (mm)	Standard length (mm)	Number of Fish			
		32-35	36-38	39-41	43-46
<0.20		3	-	-	-
0.20-0.35		5	1	-	-
0.35-0.50		2	7	3	2
>0.50		5	8	6	4

of the previous year) and 32mm long - begin to ripen ova by July. The smallest ripe female reported from Japan by Okiyama (1971) was 42mm, and Gjøsaeter (1981) found that fish less than 39mm were always immature off Norway.

Ova size-frequency distributions were determined for 12 females (five from July and seven from October) with ova larger than 0.35mm. In all specimens, the largest ova formed a size mode distinct from the smaller, less developed ova. In one specimen (Figure 5a), the mode was centered at 0.35-0.40mm and incompletely separated from the smaller ova; in other cases (e.g. Figure 5b,c,d) the mode was completely separated. In some specimens from both months with modes at 0.50-0.75mm (e.g. Figure 5c and d), there appeared to be a second mode at 0.25-0.30mm barely distinguished from the smaller ova. Such second, smaller modes, which indicate that *M. muelleri* may spawn more than once per season, were also found by Okiyama (1971) and Gjøsaeter (1981).

Batch fecundity, the total number of ova in the largest size class, was in the range 30-456 for 23 fish of 33.5-48.5mm SL and 0.382-1.260g wet somatic weight (Figure 6). Eliminating the data for a 46mm fish with much lower fecundity than others of similar length or weight, the least squares relationships between fecundity (F, number of ova/individual) and SL in millimetres and between F and wet weight (W) in grams were:

$$F = -788 + 25.7SL, \quad r^2 = 0.84, \text{ and}$$
$$F = -85 + 437.2W, \quad r^2 = 0.81$$

Though the coefficients of determination (r^2) were fairly high, there was much scatter about the regression lines. Relative fecundity ranged from 75-468 ova/g wet somatic weight (median = 336), and there was no obvious relationship between relative fecundity and either length or weight. The gonad/somatic weight ratio of these fish ranged from 1.6 to 9.6%; there was no overall correlation with relative fecundity. Other reported values of batch fecundity of *M. muelleri* appear lower than those for similar-sized Australian fish. Okiyama (1971) gave fecundities of 109-333 for seven fish 42-48mm from Japan, and Gjøsaeter (1981) found 200-500 ova in 15 Norwegian fish 47-55mm.

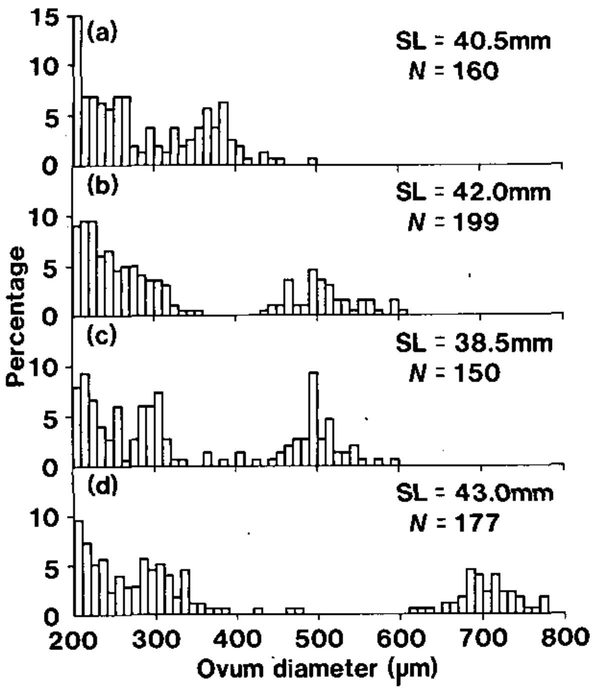

Figure 5.

Ova size frequencies from four specimens of *Maurolicus muelleri* collected October 1977.

Parasites

External copepods, internal nematodes, and a single trematode were found on *M. muelleri*, but the most frequent parasite was a fungus growing as a spheroid mass in the body cavity. Up to three 2-3mm diameter growths were found in a single fish, and in one specimen the wet weight of the fungi was about 1.5% of the fish's weight. The incidence of fungi seemed to increase with size. None were found in any fish under 30mm SL, and only seven out of 175 fish (30-41mm) from June and July were infected. Among the '1+' fish (all over 42mm SL) the fungus occurred in six out of 35 from January and 13 out of 25 from April and July. In two specimens from September, what appeared to be hyphae from the same or similar fungus were erupting through the body wall to the outside. In no other cases did the infected fish appear seriously debilitated by the

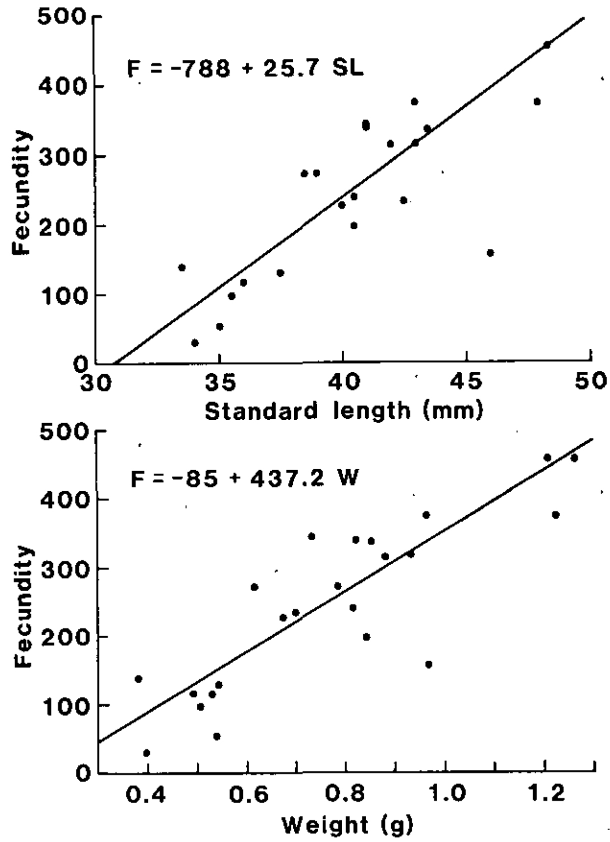

Figure 6.

Batch fecundity vs. standard length and somatic wet weight for 23 *Maurolicus muelleri* from July 1973 and October 1977. Two points on length plot each represent two specimens with the same values. Lines and equations are from least squares linear regression of data from all but a 46mm, 0.97g fish that appeared inordinately low on both plots.

fungus, and, although one infected female had very low relative fecundity, several others with fungi that caused hemispherical identations in the ovaries had relative fecundities similar to those of the uninfected females.

Dr R. Lester of the Department of Parasitology of the University of Queensland has tentatively identified the fungus as *Ichthyophonus* sp. It resembles *I. hoferi*, a widespread parasite which has been reported from

Tasmania and which may be a serious cause of mortality in certain North Sea haddock and plaice stocks. Judged from its high incidence in order (=larger) *M. muelleri*, the fungus may seriously affect survival of '1+' fish. Also, it may be transmittable to predators which feed on *M. muelleri*.

CONCLUSION

Given the apparent age composition of the population and the fecundity data, it appears that survival of *M. muelleri* from egg to first spawning must be both high and consistent for the population to remain relatively stable from year to year. Batch fecundity is very low, and even if females ripen and spawn more than one batch of ova per season, at best only a few thousand eggs per female would result. The '1+' fish were a very small fraction of the catches, and, if anything, are probably overrepresented since mesh escapement is likely higher for the smaller '0' group fish. Thus it appears that the number of fish surviving to spawn during a second season is too low to provide a buffer against poor recruitment in a given year. Consequently, poor larval survival during an entire spawning season or heavy exploitation of '0' group fish before spawning could cause sharp population declines from which recovery might be rather slow.

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