Sexual maturity, spawning and fecundity of king weakfish
Macrodon ancylodon, caught off Rio Grande do Sul State
(southern coast of Brazil)

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● *Abstract::* Investigations on the sexual maturity, spawning and fecundity of king weakfish, *Macrodon ancylodon*, off the southern coast of Brazil (lat. 29° to 32°S) were carried out from September, 1976, to August, 1977. The sex ratio varied monthly, with slight predominance of males (51.14%) over females (48.86%). The mean size at first maturity was estimated as 27.4 cm TL for females and 21.5 cm TL for males. The macroscopic examination of gonads and analysis of the gonadal index indicated that December and February were the most intensive spawning months. Fish weight proved to be the best predictor data of fecundity: $F = 17056.2500 + 425.3712$ Wt ($r^2 = 0.6434$), were F is the total number of eggs in both ovaries. The number of eggs of 199 females varied from 59,850 for 33.4 cm TL fish to over 358,450 for 37.2 cm TL; the mean fecundity verified was 165,273 eggs per female. Frequency distributions of egg diameter in the ovaries were polymodal, suggesting fractional spawning during the reproduction season.

● *Descriptors*: Sex ratio, Sexual maturity, Spawning seasons, Fecundity, *Macrodon ancylodon*, Brazil: Rio Grande do Sul.

● *Descritores*: Proporção do sexo, Maturação sexual, Época de desova, Fecundidade, *Macrodon ancylodon*, Rio Grande do Sul.

Introduction

Investigations on the life history of *Macrodon ancylodon* (Bloch & Schneider, 1801) off the southern coast of Brazil were started by Lara (1951) and afterwards, several researchers have reported on the spawning and fecundity of the king weakfish in the southern coast of Brazil: (Vazzoler, 1963; 1965; Yamaguti, 1967; Vazzoler *et al.*, 1973).

It is expected that the aspects of spawning covered by this study should contribute to the information available, and supply more data on the fecundity of *Macrodon ancylodon* caught off the southern coast of Brazil.

Material and methods

Macrodon ancylodon specimens were obtained monthly from commercial landings, chiefly at the port of

Santos - São Paulo State - from the catches in waters off Rio Grande do Sul State (lat. 29°S to 32°S). Most samples consisted of about 200 fish (Table 1). Stratified subsampling (Gulland, 1971) was used to represent all length classes. About 100 specimens per month were assessed for several other characteristics, of which only the following are relevant to the present work: total length (TL-cm), total weight (g), gonad weight (g), sex, and maturity stage. The paired gonads of female fish were stored in Gilson's fluid (Simpson, 1951) and were used for quantitative estimates of the fecundity and size distribution of eggs. A 2.0 ml capacity Stempel pipette was used to obtain a subsample of the oocytes which had been placed in a known volume of alcohol. For the determination of oocyte diameter distribution, about three hundred oocytes were taken randomly, and measured on square perspex dish at a magnification of x 40 with an ocular micrometer, along a horizontal axis, regardless of their shapes. The accuracy of sampling was tested by taking five replicates of the subsamples. All the oocytes in the subsamples were counted but for fecundity estimates only yolked oocytes greater than 170 μm were considered (yolked ova according to Vazzoler, 1963).

The scale of maturity was based on that described in Laevastu (1971), composed of seven stages,

corresponding to that used by Yamaguti, 1967, in which the size and colour of the gonads, and oocytes were taken into consideration. A short description of the gonadal macroscopic characteristics at the different developmental stages is given in Table 2.

Table 1. Number of fishes examined by range of total length (mm) of *Macrodon ancylodon* September/76 and August/77 period

Months	Number of fish	Range of total length (mm)
September/76	349	130 - 373
October	195	185 - 420
November	216	185 - 375
December	216	145 - 401
January/77	196	170 - 370
February	165	215 - 376
March	213	178 - 340
April	193	153 - 383
May	229	160 - 382
June	225	135 - 422
July	202	123 - 354
August	257	133 - 384
Totals	2656	123 - 422

Sex ratio was calculated from the estimated total number of males and females in the catches. The relative frequency of each sex are presented in Figure 2.

Resting ovaries cannot easily be distinguished from juvenile ones. Therefore, the length at first maturity was estimated based only on data of the peak spawning season, when most adult fish would have mature gonads. Length at first maturity was acertained from males and females collected in December and February. They were separated into two maturity classes: immature (stages I and II) and mature fish (stages III, IV, V and VI). The relative percentages were plotted per 10 mm length class (Fig. 3).

The spawning season was deduced both from monthly occurrence of maturity stages (Fig. 4) and monthly averages of gonadal index of both sexes as presented in Figure 5. The gonadal index (GI) used in this study is given by the following mathematical expression:

$$GI = \frac{WO}{W_t} \times 10^3$$

where: WO is the weight of both ovaries in grams and Wt is the total weight of the fish in grams. The GI was calculated for males and females individually and the mean values analyzed monthly (Fig. 5) and for different developmental stages (Fig. 6).

Fecundity, defined as the potential number of mature eggs (= yolked ova, over 170 μm diameter) - that could be spawned during a reproductive season, was estimated from ovaries containing clearly discernible eggs (stages IV, V and VI). Regressions were used to examine relationships of total fecundity on total weight (grams); on

total length (centimeters); on ovary weight (grams). The results from December and February are shown in Figure 7.

The oocyte size frequencies obtained from stages III, IV, V and VI in December and February are presented in Figure 8.

Table 2. Macroscopic characteristics of testes and ovaries at different developmental stages and average values of gonad index (GI) (numbers of specimens examined in parentheses)

Developmental Stage	Macroscopic characteristics
I Virgin	Testes and ovaries less than a half length of body cavity, thread-like, glassy or pale. GI = 0.08 - 0.52 (184) ♂♂ GI = 0.14 - 0.36 (473) ♀♀
II Developing virgin or recovering	Testes and ovaries translucent, about a half length of the body cavity; oocytes can be seen by magnifying glass. GI = 0.12 - 0.82 (322) ♂♂ GI = 0.31 - 0.76 (433) ♀♀
III Developing	Testes and ovaries opaques; oocytes visible to naked eye. GI = 0.20 - 0.67 (264) ♂♂ GI = 0.66 - 3.51 (419) ♀♀
IV Developed	Testes firm, becoming whiter; ovaries yellow, large oocytes visible. GI = 0.42 - 0.88 (129) ♂♂ GI = 2.09 - 5.49 (262) ♀♀
V Ripe	Testes fills body cavity, pure white; hyaline oocytes present, producing speckled appearance. GI = 0.66 - 0.96 (38) ♂♂ GI = 3.22 - 9.28 (32) ♀♀
VI Running	Milt and oocytes runs from vent on slight pressure; parts becoming soft. GI = 0.50 - 1.11 (31) ♂♂ GI = 5.02 -12.64 (44) ♀♀
VII Spent	Testes flaccid, grey-brown, there may be a little residual milt; ovaries flaccid, dark red, less than half of body cavity; a few large residual oocytes visible.

Results

The size of immature fish varied for females from 13 to 36 cm TL, and for males from 13 to 32 cm TL. Mature fish varied from 25 to 42 cm TL and 19 to 38 cm TL for females and males, respectively (Fig. 1).

Sex composition

Sex ratios fluctuated monthly (Fig. 2): males predominated from September to March (variation from 51.48 to 72.26%), and females from April to July (variation from 53.89 to 60.60%). The mean annual sex ratio (females: males) was 0.96.
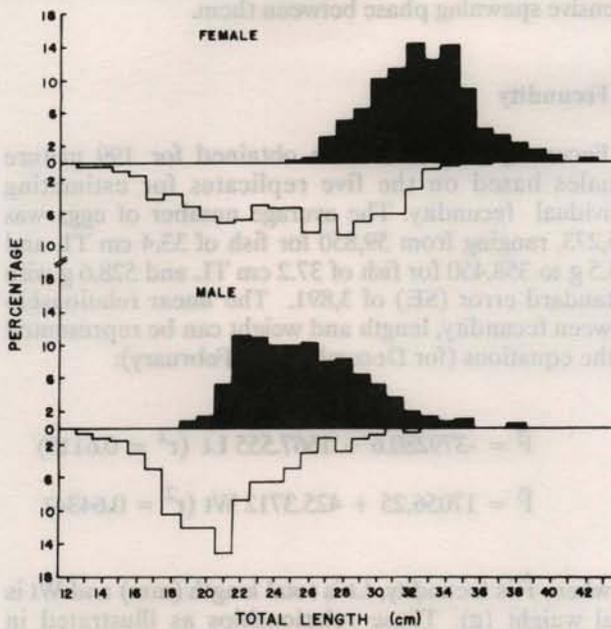
Fig. 1. Length frequencies histograms of immature (show in white) and mature (black) female and male fish of *Macrodon ancylodon* caught during the period from September 1976 to August 1977.
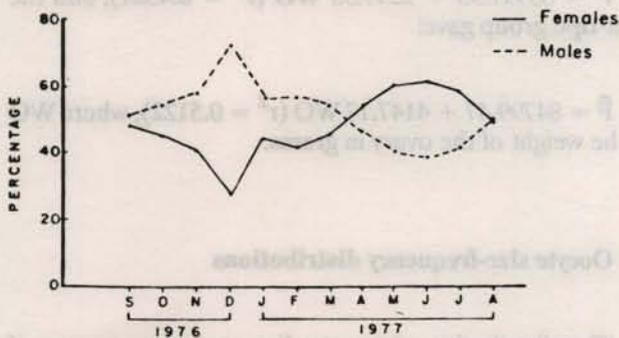

Fig. 2. Relative frequency of females and males of *Macrodon ancylodon*.

Size at sexual maturity

No female less than 25 cm TL and all greater than 31 cm TL, and no male less than 19 cm TL and all greater than 24 cm TL were sexually mature. Estimated mean sizes of sexual maturity (LT 50%) were: for females 27.4 cm TL, and for males 21.5 cm TL.

Time and mode of spawning

The spawning season of king weakfish was deduced from relative monthly occurrence of gonadal stages of

females and males (Fig. 4). Fish in stage I occurred more frequently during winter than summer. High rates of fish in stage II were caught from March to July, decreasing after August. Fish in stage III constituted 51% of the sample in August, which suggests that the fish in stage II in previous months were developing into stage III, these fish matured into stage IV which resulted in high representation in the samples collected in November (50%) and February (52%). The occurrence of fish in stages V and VI in November could indicate the onset of spawning activity which seemed to have continued until April. Two peaks of high spawning activity were observed: one in December and other in February, indicating that king weakfish is a fractional spawner.
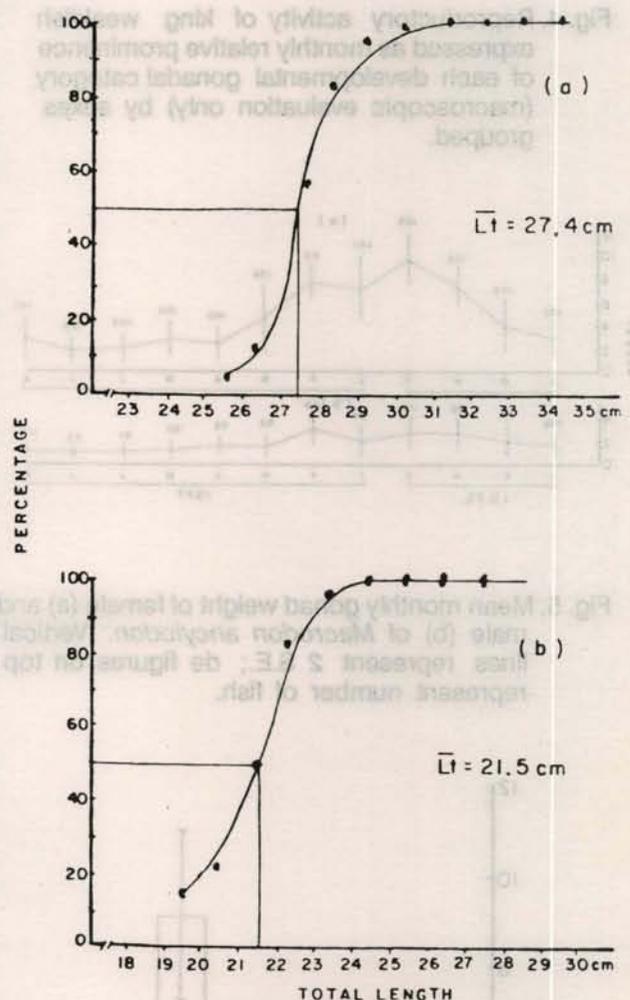

Fig. 3. Length at first maturity of king weakfish collected from November/76 and February/77 (a) females, (b) males.

Variation in gonad weight

Monthly changes in the mean gonadal index (GI) are shown in Figure 5. Variations in the mean weights of the ovary during the maturation cycle are shown in Figure 6. There were two peaks of gonadal index coincident for females and males, one in December and another in February. The high GI values seem to agree with the
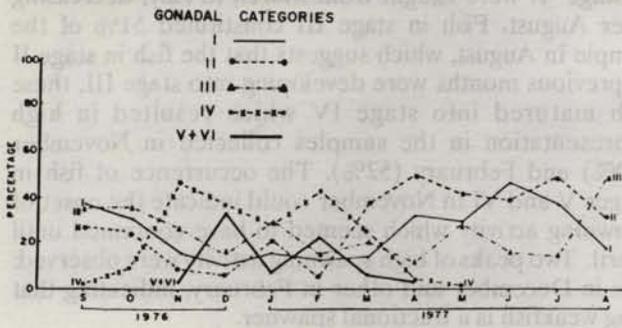
Fig. 4. Reproductory activity of king weakfish expressed as monthly relative prominence of each developmental gonadal category (macroscopic evaluation only) by sexes grouped.
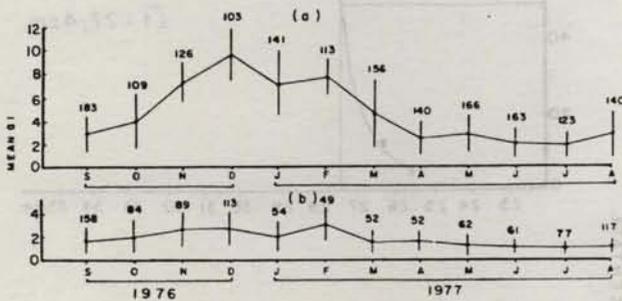

Fig. 5. Mean monthly gonad weight of female (a) and male (b) of *Macrodon ancylodon*. Vertical lines represent 2 S.E.; de figures on top represent number of fish.
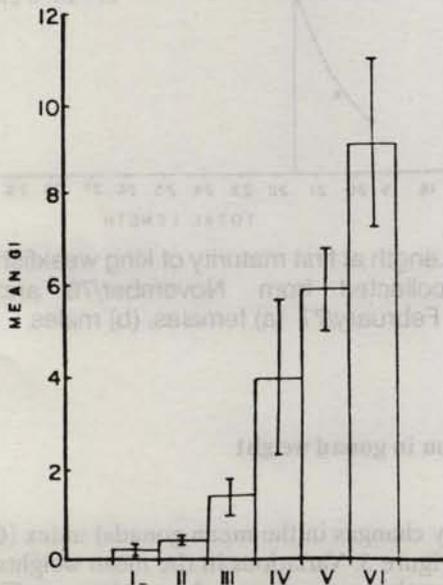

Fig. 6. Mean 2 S.E. GI at different developmental stages of females.

spawning period as inferred from the monthly variations in the maturity stages of the gonads. Between the two GI peaks the gonadal index falls, indicating that there is a less intensive spawning phase between them.

Fecundity

Fecundity estimates were obtained for 199 mature females based on the five replicates for estimating individual fecundity. The average number of eggs was 165,273, ranging from 59,850 for fish of 33.4 cm TL and 355.5 g to 358,450 for fish of 37.2 cm TL and 528.6 g with a standard error (SE) of 3,891. The linear relationship between fecundity, length and weight can be represented by the equations (for December and February):

$$\hat{F} = -379280.6 + 1667.555 \, Lt \ (r^2 = 0.6118)$$

$$\hat{F} = 17056.25 + 425.3712 \, Wt \ (r^2 = 0.6434)$$

where $\hat{F}$ is fecundity, Lt is total length (mm) and Wt is total weight (g). These relationships as illustrated in Figure 7 indicate an increase in egg production with increase in length and weight. Total weight proved to be the best predictor of fecundity. When fecundity is plotted against the weight of the ovary, an interesting relationship becomes apparent between those fish considered to be in a ripe group (stages V and VI) and those in a non-ripe group (stage IV) (Fig. 7). The ripe group gave the relationship (for December and February):

$$\hat{F} = 85991.95 + 2597.35 \, WO \ (r^2 = 0.4321), \text{ and the}$$
non-ripe group gave:

$$\hat{F} = 84799.47 + 4147.17 \, WO \ (r^2 = 0.5122), \text{ where WO}$$
is the weight of the ovary in grams.

Oocyte size-frequency distributions

The distribution of oocyte diameter over a range of maturity stages is shown in Figure 8. The distribution of the oocytes diameter within an ovary was similar to that illustrated for other fractional spawning fishes (Macer, 1974). At all ovarian stages described as developing, a group of ripening oocytes was discernible; this group grows in size and relative proportions (presumably as smaller ones move into the ripening group) as GI increases (see Tab. 2). Thus in the frequency distribution of oocytes for December (Fig. 8) in the developing stage, the last modal group of the oocytes ranged from 540 to 660 μm, in the developed stage the modal group ranged from 780 to 900 μm and in the ripe stage the last mode ranged from 1140 to 1260 μm. Finally, in the running stage the last modal group ranged from 1440 to 1560 μm. In February, we observed the same pattern of the modal groups described in December, but the oocyte diameters in February were larger than those observed in December, as summarized in Figure 8.
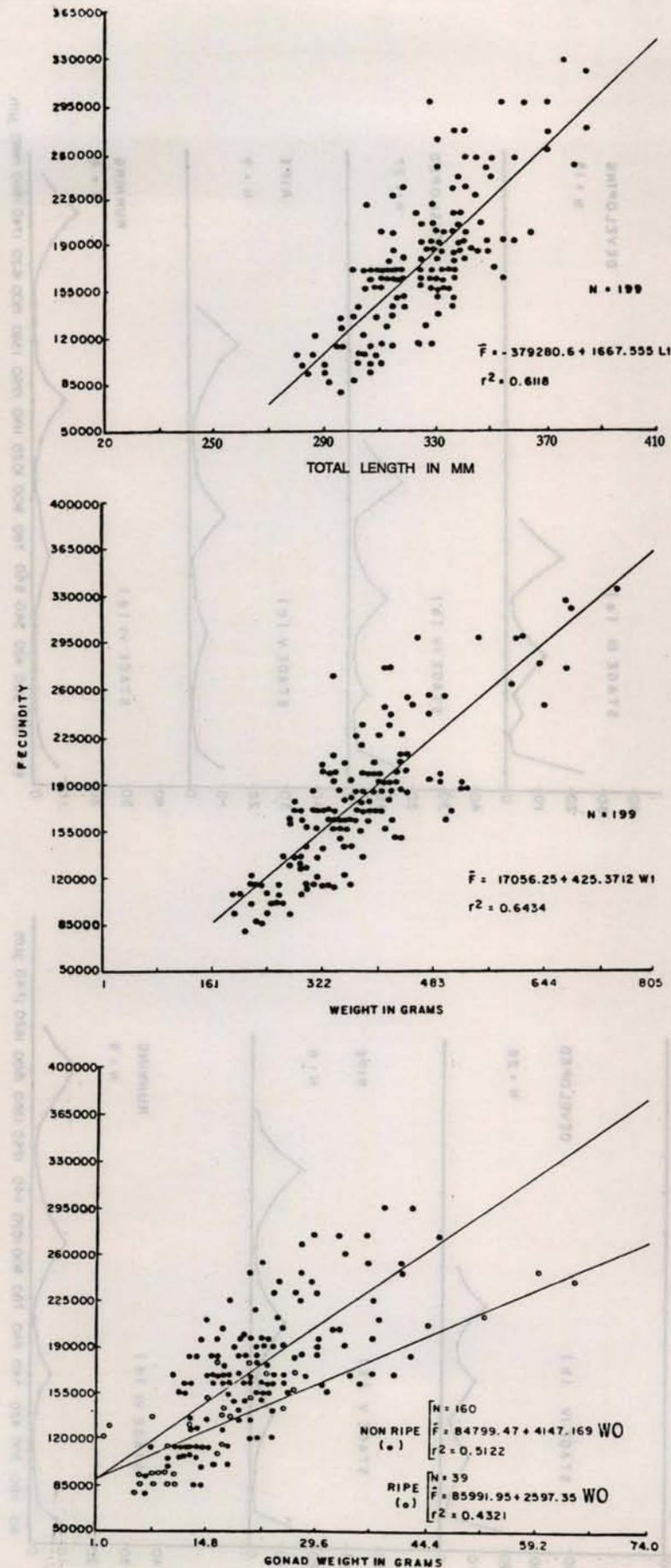
Fig. 7. Relationship between fecundity and three predictors: (top) length; (middle) weight and (bottom) gonad weight of 199 king weakfish for December and February months.
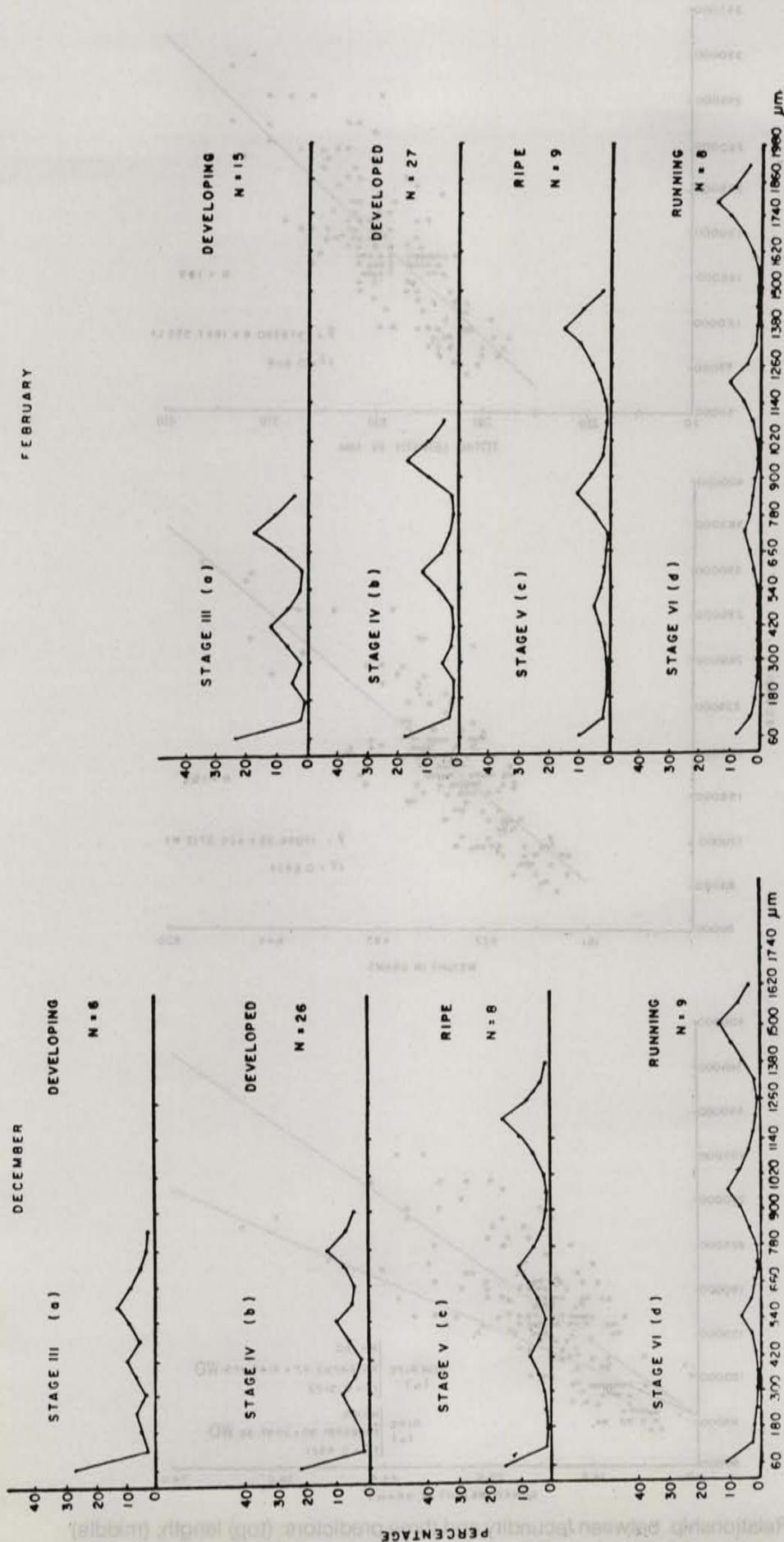
Fig. 8. Composite oocyte size-frequency curves representing the stages of ovarian development in *Macrodon ancylodon*, during December and February (N = number of fish).

Discussion and conclusions

In relation to maximum length of fish, we observed that females attained larger size (42 cm TL) than males (39 cm TL) (see Fig. 1), and this fact is related to the prior attainment of sexual maturity of males, as observed for other species of fish (Templeman *et al.*, 1978).

Sex composition

Nikolsky (1969) stated that there is often a surplus of males in the spawning groups of some species, and cited a number of examples by way of explanation of this phenomenon. He also stated that sex ratio can show a regular change during the spawning migration, males predominating at the start, after which the ratio becomes 1:1, and then females predominate. But in our study there was a predominance of males during the spawning season and of females afterward. Yamaguti (1967) observed very similar sex ratio variations and probably there are more males than females in adult populations at the spawning area during the spawning season.

Higher occurrence of females from April to July can be attributed to feeding migration and to the movement of the fishing fleet accompanying them, as suggested by Yamaguti *(op. cit.)*.

Size at first maturity

Lara (1951) found that 50% of the females in the size of 25.5 cm SL of the king weakfish population off Santos (SP) were mature. Vazzoler (1963) and Yamaguti (1967) found 26 cm TL and 25 cm TL for females caught off Rio Grande do Sul coast, respectively. In this work 21.5 cm TL (males) and 27.4 cm TL (females) were the sizes verified at first maturity. The differences observed with the results obtained by other investigators may reflect different growth rates occuring in different sampling periods and in various areas from those investigated by Lara.

Variations in gonad weight; time and frequency of spawning

A study of the monthly changes in the gonadal index has been used to determine the spawning period for many species (Stequert, 1976). The two peaks of gonadal index values observed in male and female samples in December and February suggest fractional spawning. This view is also supported by the presence of the high frequency of gonads in stages V-VI in December and February. These results agree with the observations of Vazzoler (1963), Yamaguti (1967) and Vazzoler *et al.* (1973) that king weakfish spawn from late spring until summer in Rio Grande do Sul State.

Fecundity

Our estimate of fecundity based on counts of maturing oocytes in ripe or nearly ripe fish, apparently was greater (average fecundity = 165, 273 eggs) than those verified by Vazzoler (1963) (average fecundity = 120,579 eggs). The difference between these values may have been due primarily to the different sampling periods and to the size of the fish examined; it can be also due to variations in the biotic or abiotic environmetal factors affecting fecundity directly or indirectly (Nikolsky, 1969; Bagenal, 1973), and to the fractional spawning behavior of the king weakfish

which would also increase the variability in the number of ova estimated for fish of the same size range (Bagenal & Braum, 1971).

The comparison of correlation coefficients in this work shows that fecundity can be explained in terms of weight ($r^2 = 0.6434$) almost as well as by length ($r^2 = 0.6118$). Vazzoler (1963) obtained correlation between fecundity/total length $r^2 = 0.69$ and fecundity/weight $r^2 = 0.64$, for king weakfish caught in the same area; MacGregor (1968) said that the relationship of length and weight to egg production is masked in many species of fish, because egg production occurs over a relatively short range in size, and because variation in number of eggs produced at each length is great; this fact can explain our results when compared with those of Vazzoler (*op. cit.*).

In this work, the difference verified in the regression of fecundity on gonad weight in ripe and non-ripe maturity groups, can be attributed to an increase in weight of ovary in the ripe group caused by sudden hydratation of eggs, without increase of fecundity.

Hunter & Goldberg (1980) have improved a method for the estimation of annual fecundity for females in partial spawning species, such as *Engraulis mordax* and determined batch fecundity and spawning frequency. For the estimation of batch fecundity they counted hydrated oocytes and for determinating the spawning frequency they used the incidence of postovulatory follicles in ovaries. Later Alheit *et al.* (1984) applied the same methods sucessfully in *Engraulis ringens*.

Hunter & Leong (1981) estimated that *E. mordax* spawns about 20 times per year and a similar figure was obtained for the sciaenid *Seriphus politus* by DeMartini & Fountain (1981). Hunter *et al.* (1984) stressed that species with indeterminate annual fecundity (partial spawners) spawns so repeatedly that the only methods for estimating the annual fecundity were by batch fecundity and spawning frequency.

For *Macrodon ancylodon* the estimates of the standing stock of oocytes over 170 μm are roughly three times the batch fecundity and do not represent the annual fecundity of each female.

Oocyte size-frequency distributions

Eggs in the gonad of pre-spawning fish present a polymodal distribution of diameters, suggesting that they are spent successively within each spawning season; these results are similar to those described by Vazzoler (1963).

Species such as the king weakfish are referred to as fractional spawners and the problem with this reproductive category is how to identify the oocytes which are potencially capable of being released in the current season. The acquisition of yolk is one of the most obvious signs of oocyte development, a common criterion adopted also by other authors in studies of reproduction in fishes (Vazzoler, 1963; Macer, 1974).

Nikolsky (1969) showed that the quality and size of the eggs, and the yolk content, are dependent on the age and the food supply and can vary from year to year; the same author stated that the tendency for the increase of egg size and decrease of fecundity during the course of spawning, can be an adaptation to the poorer food supply in the environment for the larvae, and the eggs with more yolk reserve would provide food for the future larvae for a longer period of poor supply in the sea. This fact would explain the greater oocyte diameters in the more advanced

mode in February with reduction of fecundity (second spawning peak) from that of the first spawning peak (December) observed in *Macrodon ancylodon*. Ware (1975) observed a similar tendency where winter and spring spawners species must produce larger eggs than summer spawning.

Acknowledgments

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