Age, growth, and reproductive biology of greater amberjack and cobia from Louisiana waters

Thompson, Wilson, Render, Beasley, and Cauthron

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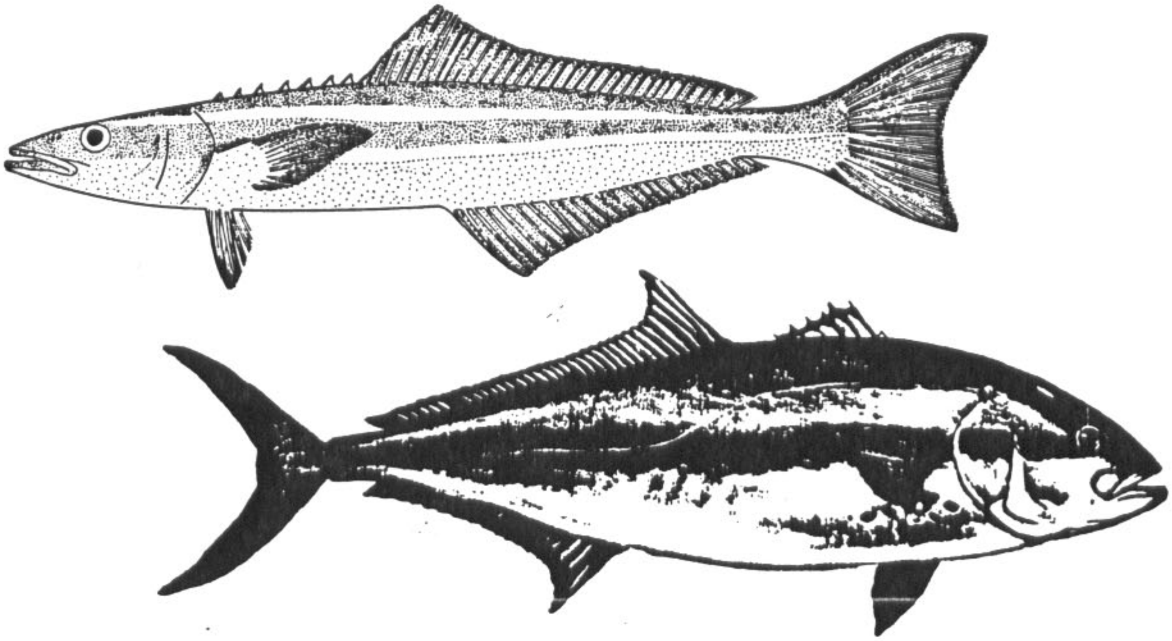
FINAL REPORT



COASTAL FISHERIES INSTITUTE

LSU Center for Coastal, Energy,
and Environmental Resources

LOUISIANA STATE UNIVERSITY

AGE, GROWTH, AND REPRODUCTIVE BIOLOGY OF GREATER AMBERJACK AND COBIA FROM LOUISIANA WATERS

The Final Report to

United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Cooperative Agreement
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Marine Fisheries Initiative (MARFIN) Program

by

Bruce A. Thompson
Charles A. Wilson
Jeffrey H. Render
Marty Beasley
Cerise Cauthron

Coastal Fisheries Institute
Center for Coastal, Energy, and Environmental Resources
Louisiana State University
Baton Rouge, LA 70803-7503

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PREFACE

This document presents the final results of our research on cobia and greater amberjack in Louisiana. This information builds on, and has been added to, our first year's work. Thus, this document supersedes the work presented in:

> Thompson, B. A., C. A. Wilson, J. H. Render, and M. Beasley. 1991. Age, Growth, and Reproductive Biology of Greater Amberjack and Cobia from Louisiana Waters. Year One. Coastal Fisheries Institute. 55 pp.

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INTRODUCTION

Cobia and greater amberjack are popular targets of recreational fishermen in Louisiana. Interest in cobia by recreational fishermen is evidenced by the many popular articles discussing life history, habitat and fisheries for this species (Arrington 1989, Dugger 1989, Fontova 1989). Similarly, greater amberjack is highly prized by sports divers and fishermen for the excitement of the fight after capture.

Although the commercial fishery for cobia remains small in Louisiana, commercial landings of greater amberjack have increased as traditional southern Louisiana seafood restaurants have added the species to its menus. This increase can be attributed to its reasonable price (compared to snapper and grouper), the appreciation of its culinary qualities, and increased restrictions on more traditional commercial species such as red drum, spotted seatrout, and red snapper (Seafood Leader Buyer's Guide 1988).

There have been several restrictions placed on the commercial and recreational harvest of these species by both federal and Louisiana laws. State and federal recreational regulations on cobia are the same:

1) Minimum size 33 inch FL, 37 inch TL
2) Creel limit of 2 per person per day
3) Cobia must be landed with head and fins whole.

The recreational regulations on greater amberjack, both Louisiana and federal, are:

1) Minimum size 28 inch FL
2) Creel limit of 3 per person per day.

Commercial restrictions on cobia include the same minimum size limits as the recreational harvest. Commercial limits on greater amberjack are 36 inch FL minimum size limit and a total quota of harvest for the Gulf of Mexico.

Although restrictions were placed on the commercial and recreational harvest of both of these species, presumably to insure resource protection, basic life history data (i.e., age and growth, age at maturity, reproductive season, fecundity) was lacking. We undertook this project to provide information on these under-studied species from Louisiana waters.

STUDY GOALS

The goal of this study was to collect biological data from cobia and greater amberjack harvested in coastal Louisiana waters to determine selected aspects of their life history and population dynamics. Specific objectives to meet these goals were:

1) To validate aging periodicity using sagittal otoliths via marginal increment analysis,
2) To determine age and growth patterns,
3) To determine sex ratios, fecundity (if possible), and timing and location (if possible) of reproductive development and gonad maturation,
4) To compare (where possible) data from different fishery sources (commercial, hook and line, diver, etc.), and

5) To compare our Louisiana data with other published data (e.g., Richards 1967, 1977; Burch 1979; Shaffer and Nakamura, 1989).

METHODS AND MATERIALS

Cobia and greater amberjack were obtained from the following sources:

1) Cajun Bayou Distributors, Baton Rouge, LA,
2) recreational fishermen aboard the charter boats of Mr. Charlie Hardison, Fourchon, LA,
3) recreational fishermen and divers at various saltwater fishing rodeos across coastal Louisiana, and
4) rod and reel samples from Mobil Rig West Cameron 352 during research trips.

Samples were processed as shown in Figure 1. During this project, 760 cobia and 865 greater amberjack were analyzed. Specimens of Almaco jack, lesser amberjack, and banded rudderfish were processed for comparison with greater amberjack. In addition, specimens of several species of Caranx were also used for otolith growth pattern comparisons.

A. Age and Growth

Age estimates for cobia and greater amberjack were obtained from otolith readings. Terminology to describe otolith morphology follows Rojo (1991). The largest otoliths (sagittae) were removed from all fish sampled during our laboratory processing. Each otolith was washed to remove any extraneous tissue and stored in 100% ETOH. Otoliths were then dried and weighed. When otolith weight was used as a variable in analyses, heaviest otolith weight was used (right vs. left) to avoid underestimation of sagitta weight which might have resulted from chipped or broken otoliths. Otoliths were embedded in Spurr medium (Spurr 1969), and sectioned through the core in the transverse plane using a Buehler Isomet low-speed saw. Sections approximately 0.7 mm thick were mounted on glass slides with clear thermoplastic cement, sanded, and polished with alumina micropolish to obtain a smooth, more readable surface. Examinations were made with a compound microscope using transmitted light with a blue filter at 40 to 100 x magnification.

Von Bertalanffy growth equations were fit by nonlinear regression (SAS 1985) for fork length (L) and total weight (W) in the forms:

$$L_t = L\infty\ [1-e^{-k(t-to)}]$$

$$W_t = W\infty\ [1-e^{-k(t-to)}]^b$$

where L_t and W_t are estimated fork length and total weight, $L\infty$ and $W\infty$ are the fork length and total weight asymptotes, k is a growth coefficient, t is age in years, t_o is a hypothetical age when fork length or total weight is zero, and b is the exponent from our length-weight regression. Plots of residuals from regression models were used to check the assumption of normality; all residuals appeared normally distributed about the regression lines. An F-test was used to test for differences in the various models.

1. Cobia

Observations of cobia sections showed a pattern of alternating opaque (dark) and translucent (more clear) zones. Examination of each section was done without knowledge of date of capture, biological data, or other reader's age estimates. Age information involved counting opaque marks from the core to the edge of the medial side of the otolith usually adjacent to the sulcus (Figure 2). The otolith margin was recorded as either opaque (annulus forming) or translucent (during active growing season) and each coded for degree of completion as follows:

Code	Interpretation
	Opaque Zone
1	Opaque zone 0 to 1/3 formed at otolith edge
2	Opaque zone 1/3 to 2/3 formed at edge
3	Opaque zone 2/3 to complete at edge
	Translucent Zone
4	Translucent zone 0 to 1/3 formed at otolith edge
5	Translucent zone 1/3 to 2/3 formed at edge
6	Translucent zone 2/3 to complete at edge

Frequency of increment formation was determined by marginal increment analysis, documenting the progression of opaque and translucent zones throughout the year. With a frequency of one opaque and one translucent zone formed each year, these increments can then be correctly called annuli and be used to estimate the true age of cobia.

Age estimates of cobia were based on otolith annulus (see section on validation) counts and adjusted, if necessary, by edge ranking. One year was assigned for each complete or partially formed annulus. Using knowledge of the spawning season based on our studies of cobia reproduction, a uniform birth rate of June 1 was given to all specimens in this study. The degree of marginal annulus completion (otoliths coded 1-3) was used to adjust ages of certain individuals captured at the same time of year. A cobia nearing completion of a translucent growth zone (Code 6) could be approximately the same age as a fish beginning its next opaque zone (Code 1), although there would be one additional annuli (e.g., a cobia coded 3-6, meaning 3 annuli and a nearly complete growth zone would be nearly the same age as one coded 4-1, meaning 4 annuli with the fourth one just starting) and each fish would belong to the same year-class.

Cross-sections of otoliths for selected age groups of cobia are shown in Figure 3 (a-h).

2. Greater Amberjack

Greater amberjack otoliths have proved difficult to section in a manner which provides consistent information (Figure 4a). To date only 30-40% of the sagittae sectioned are readable (Figure 4b and c). Growth rings are assumed to be annuli, although validation is not as complete as found in cobia.

Attempts have been made to enhance growth features of greater amberjack sagittae. These include staining as outlined by Richter and McDermott (1990), use of different light sources as outlined by Fowler (1990), etching otoliths as outlined by Haake et al. (1982) and coating the exterior surface with a gold-palladium mixture. Of the techniques tested, two show promise for enhancing readability. Acid etching appears to enhance readability of general otolith microstructure as well as what we suspect are daily growth increments (unvalidated). Exterior coating with gold-palladium appears to enhance readability of exterior features (large grooves, Figure 4d) which we suspect are associated with annuli, but possibly not on a one-to-one relationship.

B. Reproduction

Examination of the reproductive biology of cobia and greater amberjack included determination of gonadosomatic indices, and stage and rate of maturation. Selected ovaries were examined prior to preservation to obtain fresh oocyte diameters and to locate hydrated oocytes before preservation distortion, similar to the technique reported by Kjesbu (1991).

Documentation of reproductive development was accomplished by expression of gonad weight as a function of body size using the gonadosomatic index (GSI) (Htun-Han 1978). This index is:

$$\text{GSI} = 100 \times \frac{\text{gonad weight (wet wt blotted dry)}}{\text{body weight (total wt-viscera and gonads)}}$$

Gonads were preserved in 10-15% formalin after weighing. Following fixation of the ovary or testis, one tissue sample was randomly selected from one of six regions of the gonad (Figure 5), placed in a OmniSette tissue cassette, embedded in paraffin, sectioned, stained with Gill's hematoxylin and counterstained with eosin (H&E). Prior to implementing random sampling schemes for stage of maturity counts, ANOVA (SAS 1985) was used to determine if the distribution of oocyte stages was homogeneous between and within lobes. Six regions of 3 ovaries were tested for homogeneity of oocyte counts (anterior, medial and posterior regions of each lobe). Differences were not significant at $P < 0.05$ (Table 1). Embedding, sectioning, and staining were completed by the LSU School of Veterinary Medicine, Department of Pathology. Assessment of oocyte stages were made following Wallace and Selman (1981), deVlaming (1983), Erickson et al. (1985), and Selman and Wallace (1986). Follicle terminology is patterned after Nagahama (1983), Hunter and Macewicz (1985), and Fitzhugh et al. (1987).

1. Primary Growth Phase (PG) Cytoplasm is very basophilic and has large nucleus to cytoplasm area ratio. One to several large nucleoli may be evident near the periphery of the unstained nucleus. Cytoplasm is less basophilic upon growth and cell size range overlaps the following stage. Late follicle consists of primary oocyte surrounded by a layer of squamous cells (Figure 6a and b).

2. Cortical Alveolar (CA) Cytoplasm is less basophilic during this gonadotropin-dependent stage and follicle is identified by the appearance of "yolk vesicles" which increase in size and proliferate throughout the cytoplasm (Figure 6c and d). Nucleus now stains.

3. Vitellogenesis (V) This stage is denoted by the appearance of dark acidophilic yolk globules signalling the uptake of vitellogenin (yolk protein) exogenously and accounts for the great size range within this stage. Early vitellogenesis is characterized by a moderately basophilic cytoplasm as seen in the previous stage and membrane-bound peripheral yolk spheres. As cell growth continues, yolk spheres proliferate, increase in size, and cytoplasm takes on an acidophilic appearance. Zona radiata and follicular layer become more apparent and may separate from the oocyte as an artifact of preparation in paraffin embedded tissues. Progression of this stage is shown in Figure 7a and b.

4. Hydration (H) Nuclear membrane becomes less evident as migration of nucleus towards animal pole begins and coalescence of yolk is observed in early phase hydration. Coalescence continues and cytoplasm takes on a smooth appearance as oocyte enlarges. Maximum size before ovulation is reached and an irregular shape or collapse due to sectioning is

prominent in late hydration. Examples of collapsed cobia hydrated oocytes are shown in Figure 7c.

5. Postovulatory Follicle (POF) Following ovulation/spawning, the follicle collapses into the opening left behind by the shed hydrated oocyte. Cytological proof that spawning has taken place. They are characterized by a highly vascularized thecal layer and distinctive granulosa cells. They are reabsorbed by the fish but probably remain for one to three days. POFs from greater amberjack are shown in Figure 7d.

A systematic sampling scheme was employed to identify oocyte stages. A starting point was randomly selected and all identifiable oocyte stages within a field were counted before moving on to a new field using a graduated mechanical stage. Movement along the transect was generally inward along the ovigerous lamellae (when possible) from outer tunica albuginea toward the center of the ovary with realignment along a vertical axis (Weibel 1979). Oocytes were counted within the field if 50% of the cell was visible within a field, and was identifiable to developmental stage. A minimum of 200 oocytes were counted from each slide and numbers were expressed as percentages of total (Htun-Han 1978, Holdway and Beamish 1985). In addition to stage, other unique histological features were noted when they occurred.

Egg diameters were measured using a micrometer mounted in a diopter lens. At least ten leading stage oocytes were measured from each female that was examined histologically. Measurements were taken on the long and short axes of each oocyte and diameter was calculated as the mean of these two measurements (Foucher and Beamish 1980, Mayer et al. 1988).

The problems of batch spawning with regards to both frequency and fecundity estimates are being examined following procedures similar to Hunter and Goldberg (1980) and Hunter et al. (1992).

Specialized staining techniques were done on additional ovarian slides to further investigate the problems of certain greater amberjack with arrested gonad maturation. These were:

1) McManus' Method for Glycogen (PAS),
2) modified Brown-Brenn Method for Gram (+) or Gram (-) Bacteria (GRAM),
3) Ziehl-Neelsen Method for Acid-Fast Bacteria (AFB).

Similar to the H&E preparations, these were prepared by the LSU Vet School, Department of Veterinary Pathology.

RESULTS AND DISCUSSION

A. Cobia

1. Age and Growth

a. Otolith structure

The sagittae of cobia are elongated, and slightly flattened. The anterior rostrum is pointed, with a small pointed anti-rostrum. The posterior end is roundly truncated and blunt. The outer surface is irregular with fine bony protuberances on the dorsal and ventral edges. The sulcus acusticus is relatively wide and deep with a distinct "J" near the posterior end. Age estimates from whole sagittae were not possible due to the general opaqueness of the structure. Sectioned otoliths revealed alternating opaque and translucent zones (Figure 3) that we interpret as annuli. These growth increments are not formed uniformly on all axes, resulting in the otolith core being near the ventral surface. The most uniform otolith growth occurs dorsal to the core, particularly to the medial side of the sulcus acusticus. There appears to be little otolith growth to the ventral side of the core. The core is often dark, with no interpretations possible. Opaque and translucent margins used to validate growth patterns were those adjacent to the sulcus. Figure 2 shows a section with 5 annuli and an opaque margin interpreted to be completing an annulus (coded 3). Annulus counts for cobia in this study ranged from 1 to 10.

b. Validation

Cobia otoliths were analyzed from every month of the year during this study, and marginal increment data are consistent with an interpretation of a single annulus formed each year. No difference in opaque/translucent edge pattern was seen in cobia of different age classes or between sexes, so all data were combined in the marginal increment analysis for validation. Additional specimens of age seven or older cobia could be examined in future studies to verify that increments form annularly in older fish since these cobia were rare in our samples. Figure 8 shows the percent of sagittal otoliths with translucent growth margins by month of capture. Nearly all otoliths examined between August and January possessed a translucent margin. Some cobia caught between March and August had partially to completely formed opaque marks at the margins. The opaque growth zone in cobia is very wide and somewhat diffuse, making the coding for the completeness of the increment somewhat subjective. In most cases where disagreement on increment formation occurred between readers, it was with otoliths where some portion of the increment had started, but was not completely formed (code 1 vs. 2). We feel this does not significantly influence our conclusion on otolith growth of only a single increment being formed each year, generally in the spring.

c. Size and age structure

We have size information (length and weight) for 756 cobia caught between 1987 and 1991. Figure 9 shows our cobia sample frequency by month during the five-year period. Over this time period, females averaged slightly longer (Figure 10) and heavier (Figure 11) than males, but the contrast in size is not as large as reported by Richards (1967) from Virginia. Richards (1967) found few males over 35 lbs (16 kg) and noted that all cobia over 42 lbs (19 kg) were female. In comparison, we found 40 males over 16 kg with the heaviest being 30.8 kg. Variation in length and weight for each of the five years was:

	FL Range (mm)	$\bar{x}$ FL (mm)	TotWt Range (kg)	$\bar{x}$ TW (kg)	N
1987					
M	574-1225	914.8	1.8-23.7	9.0	103
F	358-1355	979.8	4.0-30.1	12.9	65
1988					
M	680-1175	942.1	3.0-20.3	9.9	68
F	681-1270	1049.8	3.2-29.3	15.3	25
1989					
M	675-1432	956.8	4.7-30.8	12.1	121
F	633-1352	1042.3	2.6-33.6	14.0	60
1990					
M	528-1250	1002.6	1.5-22.6	12.2	96
F	830-1445	1114.4	7.1-45.6	17.6	36
1991					
M	562-1184	926.4	2.0-22.1	9.8	76
F	478-1430	1053.1	1.0-36.9	15.2	32

Although our data show a slight average increase in size from 1987 to 1990, we feel this may be due to a growing public awareness of the minimum size (838 mm FL, 940 mm TL) restriction placed in effect in 1987. In 1991, mean sizes returned to that found for 1987-8.

We found an unbalanced sex ratio for each year, 1987-1991, always skewed towards males. Male:female ratios were:

1987 1.59:1
1988 2.72:1
1989 2.02:1
1990 2.67:1
1991 2.38:1

Interestingly, this seems in contradiction to the possibility that our data set is biased towards larger fish because of the strong desire by fishermen to enter their largest cobia in rodeos. This, perhaps, should have biased our sex ratio in favor of females.

Our data set includes cobia between one and ten years old caught by hook and line and recreational diving. We do not feel our data are biased towards older fish because of the nature of fish entered at fishing rodeos (we have examined many specimens that were too small to place on the weight boards). The minimum size restrictions result in all young-of-the-year, most one-year old and many two-year cobia from being adequately represented in our study, although an occasional small fish was obtained from a fisherman not sure of its identity.

During the five-year period, year class composition of recreational catch was dominated by two to four-year olds that comprised about 75% of our specimens. Year-of-birth (YOB) for our cobia catch is presented in Figure 12.

It has been the underlying assumption in growth models that the structure used for aging "grows" with the fish (Casselman 1983, 1987). Studies have shown that this may not be true for scales, particularly in older fishes (see Casselman 1987 for review), resulting in underestimation of ages. We tested the sagitta of cobia to see if this structure "grew" as the fish aged. Regression equations (log transformed, base 10) were fit to predict body size (fork length, FL and total weight, TW) from sagitta weight (Sagwt) as shown in Figures 13 and 14. These equations are:

$$\text{male } FL_{(cm)} = 31.62(\text{Sagwt})^{0.31} \quad (r^2 = 0.81)$$

$$\text{female } FL_{(cm)} = 28.84(\text{Sagwt})^{0.36} \quad (r^2 = 0.84)$$

$$\text{male } TW_{(kg)} = 0.26(\text{Sagwt})^{1.02} \quad (r^2 = 0.81)$$

$$\text{female } TW_{(kg)} = 0.20(\text{Sagwt})^{1.02} \quad (r^2 = 0.84)$$

In addition, we examined the relationship between sagitta weight and age to see if this structure "grew" during the entire life of the fish (Figure 15). These equations are:

$$\text{male Age (yrs)} = 0.09\ (\text{Sagwt}) + 0.34\ (r^2 = 0.82)$$

$$\text{female Age (yrs)} = 0.08\ (\text{Sagwt}) + 0.54\ (r^2 = 0.81)$$

Von Bertalanffy growth models for fork length at age and total weight at age for Louisiana cobia are shown in Figures 16 and 17. Models that differentiate sex account for greater variability than models that do not, indicating significant differences ($P < 0.001$) in growth between sexes. Our length (FL) models are:

Female $L_{t(cm)} = (1294\ (1-e^{0.56(t-0.11)}))/10)$

Male $L_{t(cm)} = (1132\ (1-e^{0.49(t+0.49)}))/10)$

Our weight model also showed a significant difference ($P < 0.001$) between sexes for total weight at age. The weight models are:

Female $W_{t(kg)} = ((37493\ (1-e^{-0.31(t+0.79)})^{3.23})/1000)$

Male $W_{t(kg)} = ((21538\ (1-e^{-0.31(t+1.35)})^{3.23})/1000)$

Richards (1967, 1977) found more extreme sexual dimorphism in cobia growth from Virginia waters, with both $L\infty$ and $W\infty$ being much larger for females (female$L\infty$ 164cm vs. male$L\infty$ 121; female$W\infty$ 54.5kg vs. male$W\infty$ 21.3).

Figure 18 presents fork length frequencies for cobia taken as commercial by-catch between October 1990 and March 1991. Modal length (approx. 900 mm FL) is similar to the recreational catch (Figure 10), but few larger (1000 mm + FL) are included. At present, cobia is not an important species in Louisiana's saltwater commercial fishery.

d. Body shape relationships

1) Length-weight - A regression equation, log-transformed (base 10) was calculated to predict total weight (kg) from fork length (mm) for males and females. The equations were compared between sexes to determine whether they were statistically different. The equation slopes did not differ significantly ($P < 0.05$), but are given for each sex because they are used in our growth models. Resultant equations to predict total weight (TW) from fork length (FL) was:

$$\text{male } TW_{(kg)} = 4.01 \times 10^{-6} (FL_{(cm)})^{3.23} \quad (r^2 = 0.98)$$

$$\text{female } TW_{(kg)} = 3.89 \times 10^{-6} (FL_{(cm)})^{3.23} \quad (r^2 = 0.98)$$

$$\text{both sexes } TW_{(kg)} = 3.80 \times 10^{-6} (FL_{(cm)})^{3.24} \quad (r^2 = 0.97)$$

2) Fork length-Total length - A regression was fit to predict total length (TLmm) from fork length (FLmm), and vice versa, for males and females. The slopes of the regressions did not differ significantly for males or females ($P < 0.05$) generally indicating the sexes are shaped similarly in the tail region. The resultant equations were fit linearly as:

$$TL_{(cm)} = 1.13 (FL_{(cm)}) + 0.57 \; (r^2 = 0.98)$$

$$FL_{(cm)} = 0.87 (TL_{(cm)}) + 0.94 \; (r^2 = 0.98).$$

3) Gutted weight-Total weight - A regression equation was developed to predict total weight from gutted weight. The initial model was fit to

linearly predict total weight from gutted weight by sex. Resultant equations were:

Model 1 -

Male: $\text{Total weight}_{(kg)} = 1.11\ (\text{Gutted weight}_{(kg)}) - 0.04\ (r^2 = 0.99)$

Female: $\text{Total weight}_{(kg)} = 1.16\ (\text{Gutted weight}_{(kg)}) - 0.28\ (r^2 = 0.99)$

Since total body weight can be significantly influenced by gonadal development, we refit the model to predict total weight from gutted weight in relation to time (month). Our data set is dominated by fish collected between May and October, so caution should be noted if cobia from other months are used. The resultant equations were:

Model 2 -

Male: $\text{Total weight}_{(kg)} = 1.11\ (\text{Gutted weight}_{(kg)}) - 0.02\ (\text{month}) + 0.12\ (r^2 = 0.99)$

Female: $\text{Total weight}_{(kg)} = 1.15\ (\text{Gutted weight}_{(kg)}) - 0.13\ (\text{month}) + 0.71\ (r^2 = 0.99)$

To test how well the models predicted total weight from gutted weight, data were randomly selected by month and sex and predicted values for total weight from each model were compared to actual total weight (Table 2). The models in which time was fit in addition to gutted weight more closely predicted total weight in 7 of 10 tests.

2. Reproductive Information

a. Size/age at Maturity

Richards (1967) reported that male cobia matured at a smaller size to females, with his smallest mature male weighing 2.5 lbs. (1.1 kg) and 20.4

inches (518 mm) FL. The smallest female was 7.2 lbs. (3.3 kg) and 27.4 inches (696 mm) FL. These cobia were reported to be 2 and 3 years old, respectively.

All of our one year old cobia examined to date appear to be immature (Figure 6b). These fish are underrepresented in our samples because of minimum size restrictions imposed on recreational and commercial fishermen. Between 1987 and 1990, 31 cobia have been examined containing a single annulus. These were caught between May and December, so they had all started their second year of growth. The smallest female examined was 358 mm FL, the smallest male 528 mm FL. It appears that some cobia females mature at least some oocytes at age two. Most males appear ripe (loose sperm in gonads) at age two. There is a wide range of size at maturity for both sexes, being between 700 mm to about 950 mm FL.

All cobia of both sexes three years old and older were mature and possessed vitellogenic oocytes during the spawning season (Figure 7a, b, c).

b. Maturation and Development

There is little information on reproductive development and maturation in cobia other than Richards (1967). He presented the following stages of development, based on two females:

1. Immature: oocytes 0.10-0.30 mm diam, clear
2. Maturing: oocytes 0.36-0.66 mm diam, cloudy
3. Mature: oocytes 1.09-1.31 mm diam, clear with oil globule

He noted that these mature oocyte diameters (of unfertilized eggs) averaged slightly smaller than the fertilized eggs reported by Ryder (1885).

Richards' (1967) information on oocyte diameters agrees with our findings in that cobia is clearly a "batch spawner". To determine whether all regions of the ovary were uniform in their maturation rates, we tested two females for developmental heterogeneity (Table 1). Examination of the six regions of the ovary for the relative percentage of primary growth, cortical alveoli, and vitellogenic oocytes found no significant differences for either female. We have proceeded with our work with the understanding that female cobia have uniform oocyte development among all regions of the ovary.

Although Richards (1967) presented fecundity estimates for six cobia, he presented no information on ovarian heterogeneity or spawning frequency. Without this information, his fecundity data is incomplete. Unfortunately, to date, we have not found enough hydrated oocytes or post-ovulatory follicles to adequately estimate fecundity or spawning frequency. Without this information, we will only be able to estimate fecundity of a single batch of oocytes similar to that presented by Richards (1967). Apparently the precise spawning time and location is often not coincident with our sample locations.

Previous reports on spawning (Joseph et al. 1964), location of fertilized eggs (Hassler and Rainville 1975), and presence of small juveniles (Dawson 1971) suggest we are obtaining cobia from the Louisiana coastal region where they should be spawning.

We have weighed cobia gonads from most months of the year, particularly between May and September, to help estimate the spawning season for cobia. Figure 19 shows average monthly GSI from 1987 through 1991. Figure 20 presents a composite for all years. Maximum values for both sexes (7.7 for females, 4.1 for males) occurred during June.

Fishermen along the Louisiana coast talk about a second, late-summer spawn for cobia. Although no hydrated oocytes or post-ovulatory follicles have been found, there is a slight rise in average GSI values for female cobia during September in 1989 and 1990. We found no evidence to suggest a "second spawn" as reported, particularly since no elevated GSI values were found during this time in 1987, 1988, and 1991.

Based on histological analyses, peak spawning of cobia occurred May through July for 1987 through 1991 evidenced by late stage vitellogenic oocyte classes (Figure 21). Oocyte frequency by maturity class for 1987 is shown in Figure 22. As mentioned previously, hydrated oocytes and post-ovulatory follicles were rare in ovaries analyzed histologically indicating that spawning location or timing is not completely coincident with our sample collection. Atresia of mature oocytes was observed during July through August during the 1987 spawning season (Figure 21). Ovaries from specimens examined during fall, winter and early spring were comprised of primary "resting" stage oocyted.

B. Greater Amberjack

1. Age and Growth

a. Otolith structure

The sagittae of greater amberjack are narrow, very elongate, and slightly curved. The anterior rostrum is thin and pointed, with a small sharply-pointed anti-rostrum. The posterior end is roundly truncated and often bifurcate at the posterior end of the sulcus acousticus. The surface of the otolith is strongly scalloped with the outer margins fairly straight.

The sulcus acousticus is a deep groove along the center of the otolith, nearly dividing it in half. The distinctive "J" found in cobia sagittae is lacking. Age estimates from whole otoliths were not possible due to the general opaqueness of the structure, although we are continuing our search for substances that will remove some (or all) of the opaqueness.

b. Validation

Complete validation and age and growth of greater amberjack will be presented in a Master's thesis in the L.S.U. Dept. Oceanography and Coastal Studies by Mr. Marty Beasley, entitled "Age and Growth of Greater Amberjack, Seriola dumerili (Risso), from the northern Gulf of Mexico".

c. Size and age structure

We have not completed age validation for greater amberjack, so age structure information should be considered preliminary.

We have size information for 865 greater amberjack caught between 1989 and 1991. Figure 23 shows our greater amberjack sample frequency by month during this period. Females averaged slightly larger than males (mean 879mm FL vs. 854mm FL), ranging from 374 to 1441mm FL. Males did not reach as large a size, ranging from 387 to 1203mm FL (Figure 24). The smaller size of males can be seen in that 72% of greater amberjack over 1000mm FL and 78% over 25kg were female.

Although our information is still incomplete, preliminary aging data are presented. Greater amberjack were aged between 0 and 15 years (Figure 25). One and two year olds made up 57% of our sample. There was strong sexual dimorphism in maximum longevity, with males living until 7 years old and females to 15 years.

d. Body shape relationships

1) Length-weight - A regression equation, log-transformed (base 10) was calculated to predict total weight from fork length for males and females (Figure 26). The equations were compared between sexes and the slopes did not differ significantly ($P < 0.05$). The resultant equation to predict weight (TW) from fork length (FL) was:

$$TW_{(kg)} = 3.02 \times 10^{-5} (FL_{(cm)})^{2.84} \quad (r^2 = 0.99).$$

2) Fork length-Total length - A regression was fit to predict total length (TL) from fork length (FL), and vice versa, for males and females. The slopes of the regressions did not differ significantly for males or females ($P < 0.05$). The resultant equations were fit linearly as:

$$TL_{(cm)} = 1.13 (FL_{(cm)}) + 1.68 \quad (r^2 = 0.99)$$

$$FL_{(cm)} = 0.88 (TL_{(cm)}) - 1.17 \quad (r^2 = 0.99).$$

3) Body size-Otolith weight - Regression equations (log transformed - base 10) were fit to predict body size (fork length (FL) and total weight (TW) from sagitta weight. These relationships are presented in Figure 27 and 28. The equations were compared by sex to determine whether the slopes of the equations differed significantly ($P < 0.05$). Slopes did not differ significantly for either relationship but separate equations are presented:

$$\text{male } FL_{(cm)} = 12.49 (\text{Sagitta weight}_{(mg)})^{0.60} \quad (r^2 = 0.96)$$

$$\text{female } FL_{(cm)} = 12.27 (\text{Sagitta weight}_{(mg)})^{0.61} \quad (r^2 = 0.96)$$

$$\text{male } TW_{(kg)} = 0.04 (\text{Sagitta weight}_{(mg)})^{1.71} \quad (r^2 = 0.96)$$

$$\text{female } TW_{(kg)} = 0.04 (\text{Sagitta weight}_{(mg)})^{1.74} \quad (r^2 = 0.96)$$

2. Reproductive Information

a. Size/age at maturity

Maturity estimations for greater amberjack are being hampered by problems of readability of the otoliths and suspected disease conditions interfering with oocyte maturation. They should be considered preliminary since they may be overestimations.

GSI values from 1988 and 1989 coupled with verification from histological analysis suggest that both sexes of greater amberjack can reach maturity between 800 and 950 mm FL and 11 to 13 kg. This is based on fish caught during May and June, presumably at the peak of the spawning season. Preliminary age estimates place these amberjack at 2 to 3 years old. Contrary to this information, there are some greater amberjack 13 to 15 kg that possess only resting (primary growth) oocytes. These are either late maturing fish or the possibility exists that a portion of the population does not spawn each year.

b. Maturation and Development

Based on GSI, peak spawning occurred in May and June during 1989 (Figure 29). This assessment was confirmed histologically as ovaries examined during this period were comprised of various oocyte developmental stages (i.e., primary, cortical alveolar, vitellogenic). This pattern indicates that greater amberjack are batch or serial spawners. Post-ovulatory follicles, indicating that spawning had occurred were observed in June 1989 samples (Figure 7d). By July of 1989, ovaries had returned to a "resting" post spawning condition.

The same trend was not evident during 1990 (Figures 29 and 30). Ovaries collected during April, May, and June 1990 showed no progression of oocyte development beyond primary growth stage with the exception of four ovaries collected in early May which contained large vitellogenic oocytes in normal spawning condition. The ovaries that did not show oocyte progression (47 of 51 examined histologically) appeared to be infected with an unknown pathogen that was observed in the interstitial areas around the oocytes within the ovaries (Figure 31).

c. Gonad Pathology

Examination of ovary slides of Seriola dumerili, Greater Amberjack, led to the discovery of bacterial infections and developmental abnormalities of the oocytes. Bacterial infections were produced primarily by rod-shaped bacillus (Figure 32), although a coccus form was also noted in addition to the bacillus in a limited number of specimens. Oocyte development was arrested (without the influence of bacteria) in a number of other fish - the oocytes did not progress beyond the cortical alveoli stage of development and were in the process of atresia. It should be noted that neither bacterial infections or developmental abnormalities were noted from examination of any of the male testicular slides.

Certain ovaries possessed oocytes which never reached the fully yolked or hydrated stage. These amounted to 5-6% of the total number of ovaries examined and were concentrated in fish collected in the summer of 1990. The oocytes appeared normal in all morphological aspects (other than the normal morphological changes due to the process of atresia), and had successfully developed a limited number of cortical alveoli. Aside from the oocytes themselves, no ovarian support tissue (connective, muscular, nervous, etc.) displayed any gross abnormality which might indicate a diseased condition.

One possible explanation for this condition is a deficiency in the production or secretion of gonadotropic hormone(s) (GTH). That cortical alveoli have been formed in these oocytes indicates that ovarian estrogens are being produced; estrogens have been implicated in the hepatic synthesis of vitellogenin and formation of oocyte cortical alveoli in other teleost fishes (Campbell and Idler 1976, Crim and Idler 1978, Kagawa et al. 1981, Wallace and Selman 1981). The initial production of estrogens is stimulated by pituitary GTH (Idler and Campbell 1980, Kagawa et al. 1981, Zohar and Billard 1984). Vitellogenin uptake by the oocytes from the circulating plasma is also under the control of GTH, and it is before this point that oocyte development ceases in these abnormal ovaries. Production and secretion of GTH synthesis and secretion has been demonstrated in fishes subjected to thermal, saline, handling, pollution and disease-mediated stress (Ball 1960, DeMontalembert et al. 1978, Lam 1983, Spies and Rice 1988, Wallace and Selman 1981). Testing of this hypothesis would require obtaining plasma samples from live fish for assessment of circulating and ovarian GTH levels, as well as levels of steroid sex hormones; there are no tests which can be performed with the formalin-preserved tissues used in this study aside from tests which indicate the presence or absence of cholesterol (Lillie 1954). In addition, other mechanisms must be considered such as direct environmental influences on the oocytes and inactivation or desensitization of GTH receptors in the ovary.

Another 8-10% of the S. dumerili ovaries examined were infected by a spore-forming rod-shaped and coccus bacteria. Gram and AFB staining identified the bacteria as Gram positive and non-acid fast (Lillie 1954, Luna 1968). A species identification of the bacteria has not been made at this time, and probably cannot be accomplished with preserved material. With standard H&E staining the infected area of the slides could be easily seen with the unaided eye as highly eosinophilic (for slides with yolked and hydrated oocytes) or weakly basophilic (slides with unyolked oocytes) areas. Regardless of ovarian staging, the infections were limited to the interior portion of the ovary and produced a variety of characteristic symptoms. The oocytes in the infected area of the ovary were in varying degrees of atresia with the dissolution of integrity of the cytoplasm and nucleus. Oocytes not yet sufficiently developed to possess a zona radiata or those with an early-stage zona radiata often displayed an accumulation of pale-staining fluid at the periphery of the cytoplasm. The zona radiata remained thin and assumed a wavy or foliate appearance. The cytoplasm stained weakly basophilic in comparison with the oocytes in the non-infected area of the ovary. Very early stage oocytes did not appear to react to the presence of the bacteria and, generally, were highly disrupted. Lymphocytes and leucocytes of unknown identity were found in high numbers in both the infected and non-infected areas of the ovary and the connective tissue (both the fibrous and matrix portions) was somewhat thickened and proliferative.

Ovaries in near-spawning condition possessed certain features in addition to those listed above for the less highly developed ovaries. The yolk mass was a homogeneous eosinophilic mass which became less eosinophilic with increasing infection intensity and the zona radiata was highly thickened for oocytes in the infected zones. The thickening of the zona radiata was not accompanied by proliferation in either the follicular or thecal cells. The connective tissue matrix was heavily fibrous and highly edemic with both the fibrous elements and the fluid matrix were highly eosinophilic. As

S. dumerili is a batch spawner, unyolked and partially yolked oocytes are found in conjunction with the near-spawn follicles. These oocytes possessed the features of the infected areas of the early-stage ovaries discussed above; however, the staining of the nucleus, nucleoli and cytoplasm was eosinophilic. Lymphocytes and leucocytes were proliferative in the infected and non-infected zones; although less so than in the most heavily infected areas. No gross changes were seen in the muscular, vascular or nervous tissue investing the ovary. At the infected/non-infected area interface a pronounced thickening of the connective tissue was found in some slides along with a "lake" of fluid which stained eosinophilically.

Aside from a high number of leucocytes in the connective tissue, non-infected areas of the ovaries appeared normal; there were no oocyte abnormalities and atresia and oocyte resorption was only marginally increased. The symptoms produced by the bacteria were confined to the area physically infected by the bacteria.

Staining with the Gram and AFB stained paralleled the H&E preparations. In the bacterially infected areas, Gram-stained slides were uniformly yellow; whereas in the non-infected areas, the zona radiata, unyolked oocytes and certain leucocytes stained varying degrees of red (the zona radiata stained intensely red). In the AFB preparations, the infected areas were intensely cyan; non-infected areas of the slides were more violet in color. The PAS stain was not performed with a digestion control; therefore, the staining was not specific for glycogen. Most polysaccharides, mucopolysaccharides and glycoproteins (also, potentially, proteins containing serine, threonine and hydroxylysine) will react positively with the PAS reaction resulting in varying colors from faint pink to vivid magenta or red; therefore, collagen, elastin, mucins, myelin, etc. stained positively in the *S. dumerili* preparations. In the oocytes, the zona radiata stained intensely red with PAS; although the yolk vesicles or cortical alveoli were only weakly PAS positive. In the goldfish, *Carassius auratus* yolk vesicles were found to be strongly PAS positive (Khoo 1979). Yolk globules in *S. dumerili* were PAS negative and the homogeneous yolk mass of oocytes in infected areas of the ovary stained with varying blue-purple. The zona radiata retained its brilliant staining with these oocytes, even for the most thickened structures. The staining of the elements of the connective tissue was not different in the infected areas than in the non-infected areas, although due to the thickening of the connective tissue matrix, the overall staining of the infected regions was more intense. The fluid "lake" seen at the infected/non-infected area interface was weakly to moderately PAS positive.

There is controversy among researchers who have examined these slide preparations as to whether the infections witnessed were pre- or post-mortem. Pre-mortem infection could produce the symptoms seen in the examined ovaries include: excess fluid in the connective tissue matrix, high numbers of leucocytes and lymphocytes in the tissue, thickening of the zona radiata, increased eosiniphilicity of the infected areas. However, the infected regions tended to be restricted to the interior portion of the ovaries. This would be expected if the infections were post-mortem, caused by insufficient penetration of fixative. In addition, some of the ovaries lacked various characteristics such as thickening of the zona radiata and connective tissue matrix, which could be attributable to pre-mortem infection. Due to the limited number of specimens displaying bacterial infection (or disrupted oocyte maturation) and the narrow time frame in which the fish were taken, no long term patterns can be analyzed. With no long-term profile, relatively low numbers of affected fish and limitations on the types of further testing which can be undertaken, no definitive statement on the impact to fisheries can reliably be given. Further research is suggested for Greater Amberjack which would include additional studies designed to gain information on the previously discussed gonadal anomalies. Hopefully, the timing of the gonadal infections (pre- or post-mortem) and the mechanism for the developmental abnormalities can be clarified.

3. Identification Problems

A major concern addressed for amberjack has been correct species identification. There are four species of Seriola in the Gulf of Mexico, all apparently occurring in Louisiana waters. These are:

1)	Seriola dumerili	Greater Amberjack
2)	Seriola rivoliana	Almaco Jack
3)	Seriola fasciata	Lesser Amberjack
4)	Seriola zonata	Banded Rudderfish

Our experience has been that most Louisiana fishermen don't (perhaps cannot or don't bother to) distinguish among these forms, leading to a misleading concept of which species occur here. Ginsburg (1952) and Mather (1958) reviewed the genus Seriola and provided valuable historical information on nomenclatorial stability and generic limits. Berry and Burch (1979) provided some diagnostic characters for the four species of Seriola as part of their description of the southern Florida amberjack fishery.

Table 3 is a comparative outline of certain characteristics that have been developed to aid in our species identification between greater and lesser amberjacks from Louisiana.

Lesser amberjack appears to be nearly a dwarf species compared to greater amberjack. Our largest lesser amberjack examined to date is only 428 mm FL, compared to 1441 mm FL for greater amberjack. There is some color differentiation between the two species, with lesser amberjack having more yellow in the second dorsal fin, and bronze in the caudal fin as compared to similar-sized greater amberjack. Lesser amberjack possess many more gill rakers than greater amberjack, but caution should be used, since, as noted by Mather (1958) and Berry and Burch (1979), these counts change with age. As shown in Table 3, lesser amberjack possess a larger eye than greater amberjack, resulting in very different snout/eye and head/eye proportions. We would predict that once familiar to the commercial fishermen in Louisiana, lesser amberjack will become a target species resulting in increased harvest since it will fill the same market demand of smaller greater amberjack (now illegal).

Although Almaco jacks are often not distinguished from greater amberjack by Louisiana fishermen, they are readily differentiated. They are much darker in color (often almost black), are much deeper in body depth, have a smaller eye, have a high gill raker count (similar to the count of lesser amberjack), and have much longer lobes on both the second dorsal and anal fins.

We examined four specimens of the banded rudderfish. One noticeable oddity is that our specimens do not have the distinctive body bands these species normally possess. This species appears to be very similar to greater amberjack in many characteristics such as eye size, finlobe length and gill raker count. We suspect that this species is presently being confused with greater amberjack with its true abundance being masked by this confusion.

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Table 1. Scheffe's Test for percentage heterogeneity among six regions (A-F) of cobia ovary.

Cobia 1					Cobia 2			
AP	66.2	DP	68.3	NS (α = .05)	AP	73.0	DP	77.7
BP	69.4	EP	61.7		BP	75.7	EP	72.4
CP	70.2	FP	68.6		CP	71.6	FP	66.8
AC	11.5	DC	8.7	NS (α = .05)	AC	12.6	DC	5.5
BC	9.4	EC	8.0		BC	7.9	EC	10.9
CC	8.1	FC	10.1		CC	8.9	FC	12.7
AV	22.4	DV	23.0	NS (α = .05)	AV	14.5	DV	16.9
BV	21.2	EV	30.3		BV	16.5	EV	16.8
CV	21.8	FV	21.4		CV	19.5	FV	20.5

P = primary growth, C = cortical alveoli, V = vitellogenic

Table 2. Comparison of models to predict total weight of cobia from gutted weight and percent deviation from measured weight.

Month	Sex	Measured Total Weight	Measured Gutted Weight	Model 1 Predicted Total Weight	Model 2 Predicted Total Weight
5	M	11,453	10,092	11,183(-2.4%)	11,257(-1.7%)
5	F	14,118	11,794	13,364(-5.6%)	13,735(-2.8%)
6	M	19,278	17,123	18,988(-1.5%)	19,040(-1.2%)
6	F	29,257	24,438	28,034(-4.5%)	28,270(-3.5%)
7	M	4,253	3,856	4,261(+0.2%)	4,293(+1.0%)
7	F	6,917	6,237	6,917(0.0%)	7,024(+1.5%)
8	M	9,497	8,533	9,453(-0.4%)	9,463(-0.3%)
8	F	12,644	11,283	12,771(+1.0%)	12,745(+0.8%)
9	M	2,722	2,523	2,782(+2.0%)	2,771(+1.8%)
9	F	2,155	1,985	1,985(-8.5%)	1,827(-17.9%)

All weights given in grams.

Table 3. Comparison of selected characters between greater and lesser amberjack from Louisiana.

Character	Gr. Amberjack[1]	Ls. Amberjack
Maximum FL	~ 1450 mm	~ 430 mm
Maximum Tot Wt.	~ 60 kg	~ 2 kg
Est. Maturity Wt.	12-14 kg	1-2 kg
Yellow Body Stripe	present	present
Eye Bar	present	present
Second Dorsal Fin Color	tan-white	yellow
Second Dorsal Ray Count	32-37	30-32
Total Gill Raker Count	Low, 14-16	High, 22-26
Body Depth	~ 27% SL	~ 29-30% SL
Body Width/Body Depth	~ 59%	~ 55%
Snout L/eye Diam.	~ 2.3	~ 1.6
Head L/eye Diam.	~ 6	~ 4.3
Upper Jaw Length/Width	~ 2.6	~ 2.8
Lower Caudal Lobe Color	gray-white	bronze

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[1] Only greater amberjack approximately the same size as lesser amberjack have been used for shape comparisons.

FIGURES

Figure 1.	General sampling protocol for obtaining and processing cobia and amberjacks for this study.
Figure 2.	Photomicrograph of a transverse section of a cobia otolith (sagitta), taken 7-7-90 showing sulcus acousticus (SA) and core (C). Each arrow shows mark we interpret to be an annulus.
Figure 3.	Cross-section of cobia otoliths: a) 7-7-90, coded 2-4; b) 8-12-90, coded 3-4; c) 7-6-90, coded 4-3; d) 7-28-90, coded 5-4; e) 7-28-90, coded 6-4; f) 7-28-90, coded 7-4; g) 7-27-90, coded 8-4; h) 6-2-90, coded 10-3.
Figure 4.	Cross-section of greater amberjack otoliths: a) 8-18-89, reading uncertain; b) 11-12-89, possibly still in first year of growth (no annulus); c) 5-10-89, coded 4-3; d) exterior of greater amberjack showing large grooves on surface (suspected annuli).
Figure 5.	Ovary shown whole (A) and in cross-section (B), showing regions that were randomly sampled for histological analysis.

Figure 6.	Early ovarian maturation stages: a) greater amberjack primary growth oocytes, (4-15-89); b) cobia primary growth oocytes, (9-3-89); c) cobia cortical alveolaroocyte (7-12-87); d) greater amberjack cortical alveolar oocytes, showing appearance of yolk vesicles (7-8-90).
Figure 7.	Late ovarian maturation stages: a) cobia vitellogenic oocytes with complete yolk vesicles (5-29-88); b) cobia oocytes showing onset of yolk coalescence (5-29-88); c) cobia hydrated oocytes (5-27-90); d) greater amberjack postovulatory follicles (6-4-89).
Figure 8.	Percent of cobia otoliths with translucent margin through an annual cycle; arrow denotes period of annulus formation (all sizes, all years combined).
Figure 9.	Sample frequency, by month, of Louisiana cobia, 1987-1991.
Figure 10.	Length frequency (FL, mm) of Louisiana cobia, 1987-1991.
Figure 11.	Weight frequency (Total weight, kg) of Louisiana cobia, 1987-1991.
Figure 12.	Year of birth (YOB) for cobia taken during 1987 through 1991, with dominant age groups.

Figure 13. Relationship of sagitta weight (mg) to fork length (mm) for Louisiana cobia (male: solid line, female: dashline).

Figure 14. Relationship of sagitta weight (mg) to total weight (kg) for Louisiana cobia (male: solid line, female: dash line).

Figure 15. Relationship of sagitta weight (mg) to age of Louisiana cobia (male: solid line, female: dash line).

Figure 16. Von Bertalanffy growth models by fork length for male (solid line) and female (dash line) cobia.

Figure 17. Von Bertalanffy growth models by total weight for male (solid line) and female (dash line) cobia.

Figure 18. Length frequency (Fl mm) for Louisiana cobia taken in commercial by-catch between October 1990 and March 1991.

Figure 19. Average monthly gonadosomatic index values (GSI) for Louisiana cobia, 1987-1990.

Figure 20. Composite average monthly gonadosomatic index values (GSI) for Louisiana cobia for entire study (1987-1991).

Figure 21. Oocyte maturation stages for Louisiana cobia, May-October, for 1987-1990.

Figure 22. Relationship between histological staging (presence of vitellogenic oocytes) and average GSI values.

Figure 23. Sample frequency, by month, of Louisiana greater amberjack, 1989-1990.

Figure 24. Length frequency (FL, mm) of Louisiana greater amberjack, 1989-1990.

Figure 25. Age frequency of greater amberjack from Louisiana, all sources combined.

Figure 26. Relationship of fork length to total weight for Louisiana greater amberjack.

Figure 27. Relationship of sagitta weight (mg) to fork length (mm) for Louisiana greater amberjack.

Figure 28. Relationship of sagitta weight (mg) to total weight (kg) for Louisiana greater amberjack.

Figure 29. Average monthly gonadosomatic index values (GSI) for Louisiana greater amberjack, 1989 through 1991.

Figure 30. Comparison of 1989 and 1990 GSI values, related to Fork Length of greater amberjack showing the lack of gonad development in 1990.

Figure 31. Photomicrographs of greater amberjack ovaries from 1990, showing lack of oocyte maturation associated with unknown pathogen.

Figure 32. Photomicrographs of greater amberjack ovaries from 1990, a) bacterial pathogen; b) abnormal mature oocytes.

Sampling Protocol

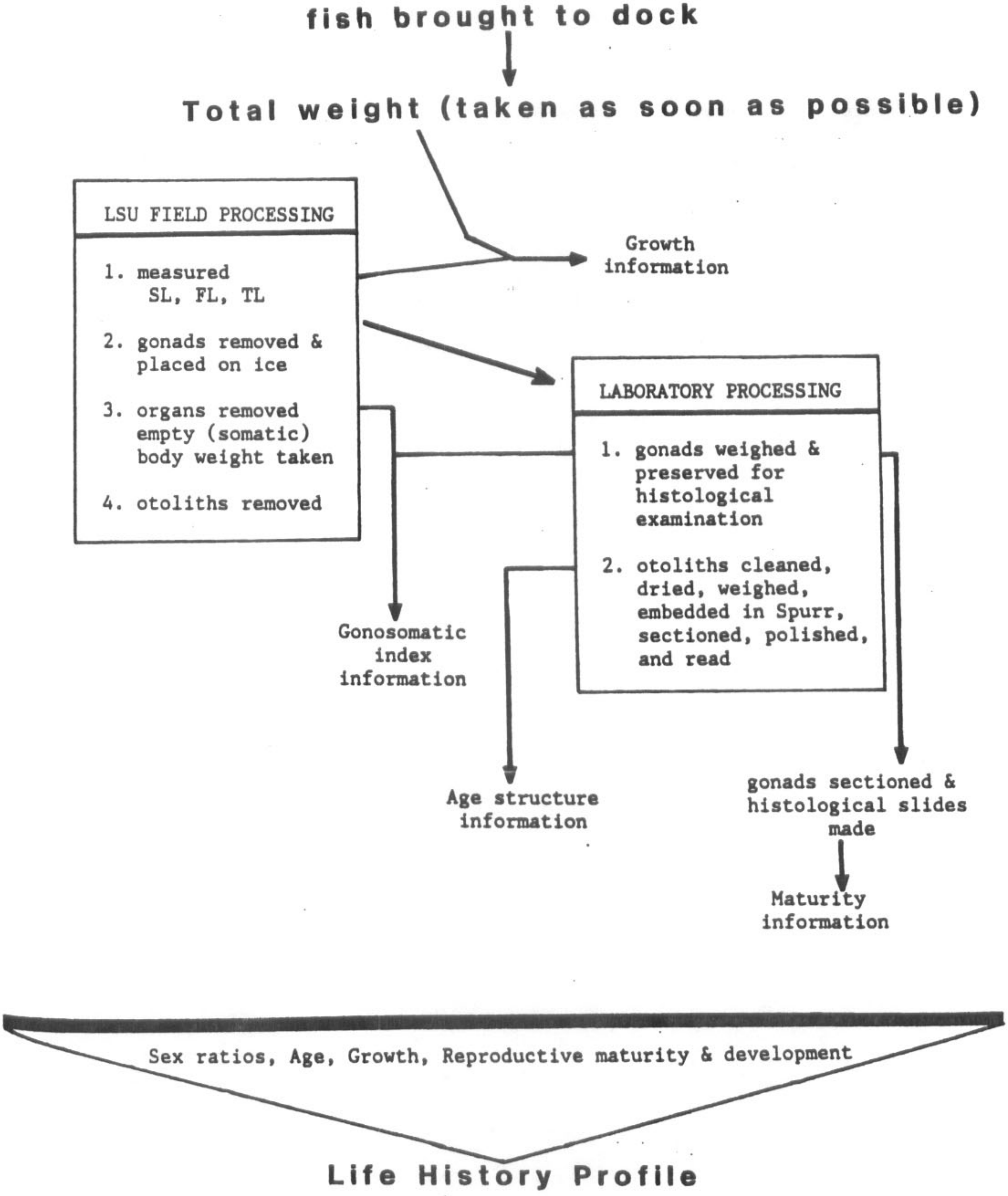


Figure 1.

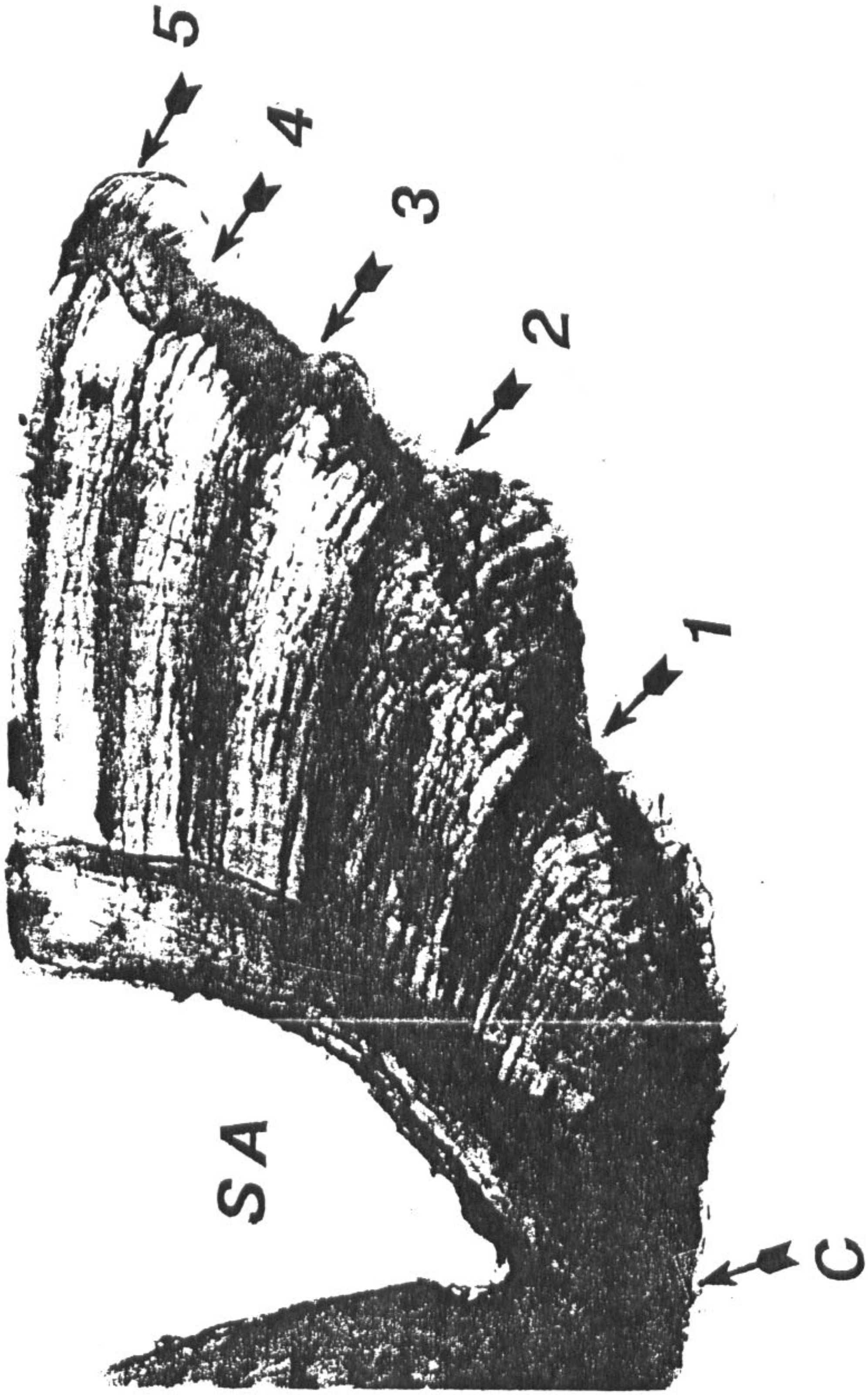


Figure 2.

Figure 3.

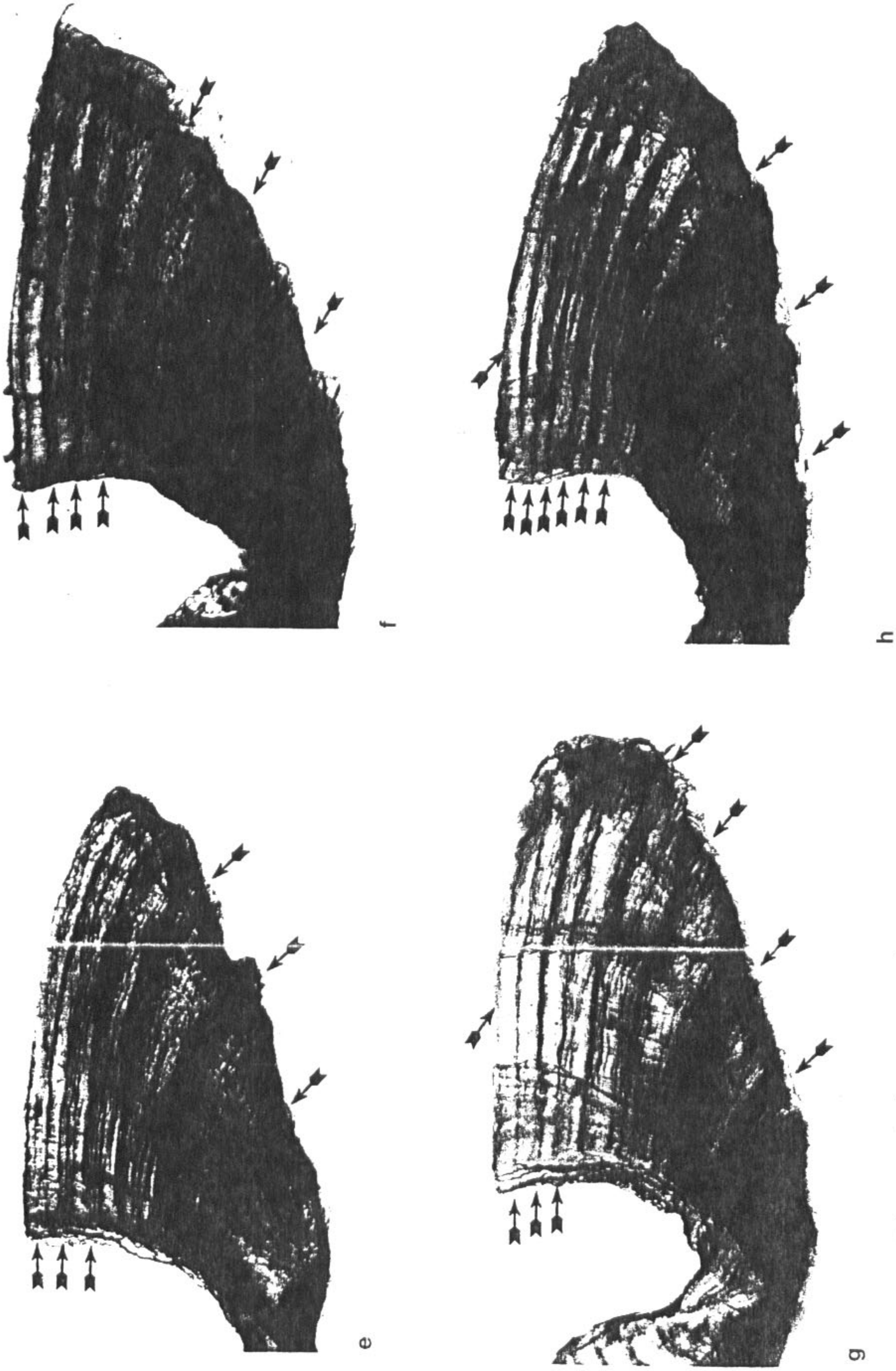


Figure 3 (continued).

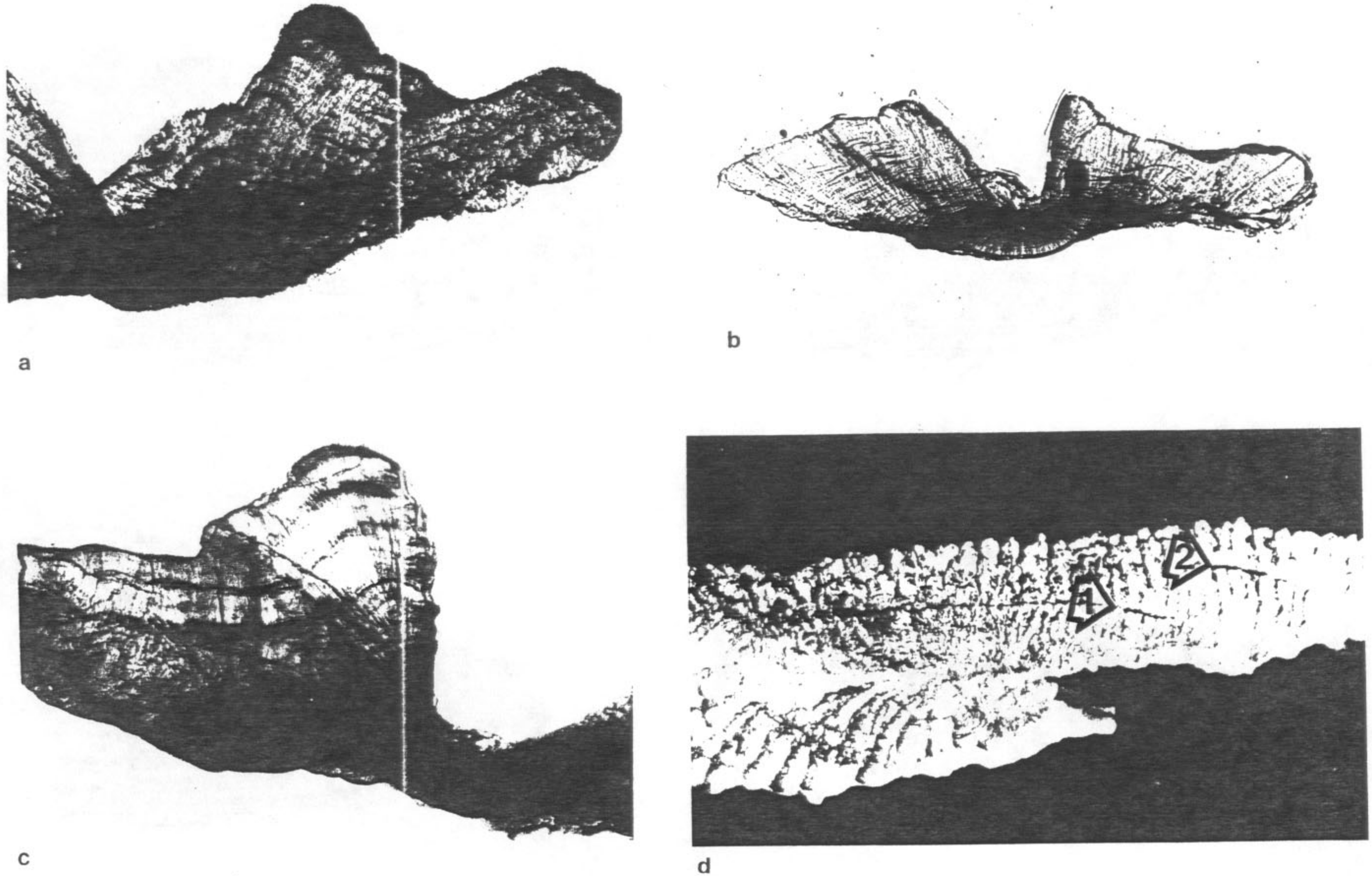


Figure 4.

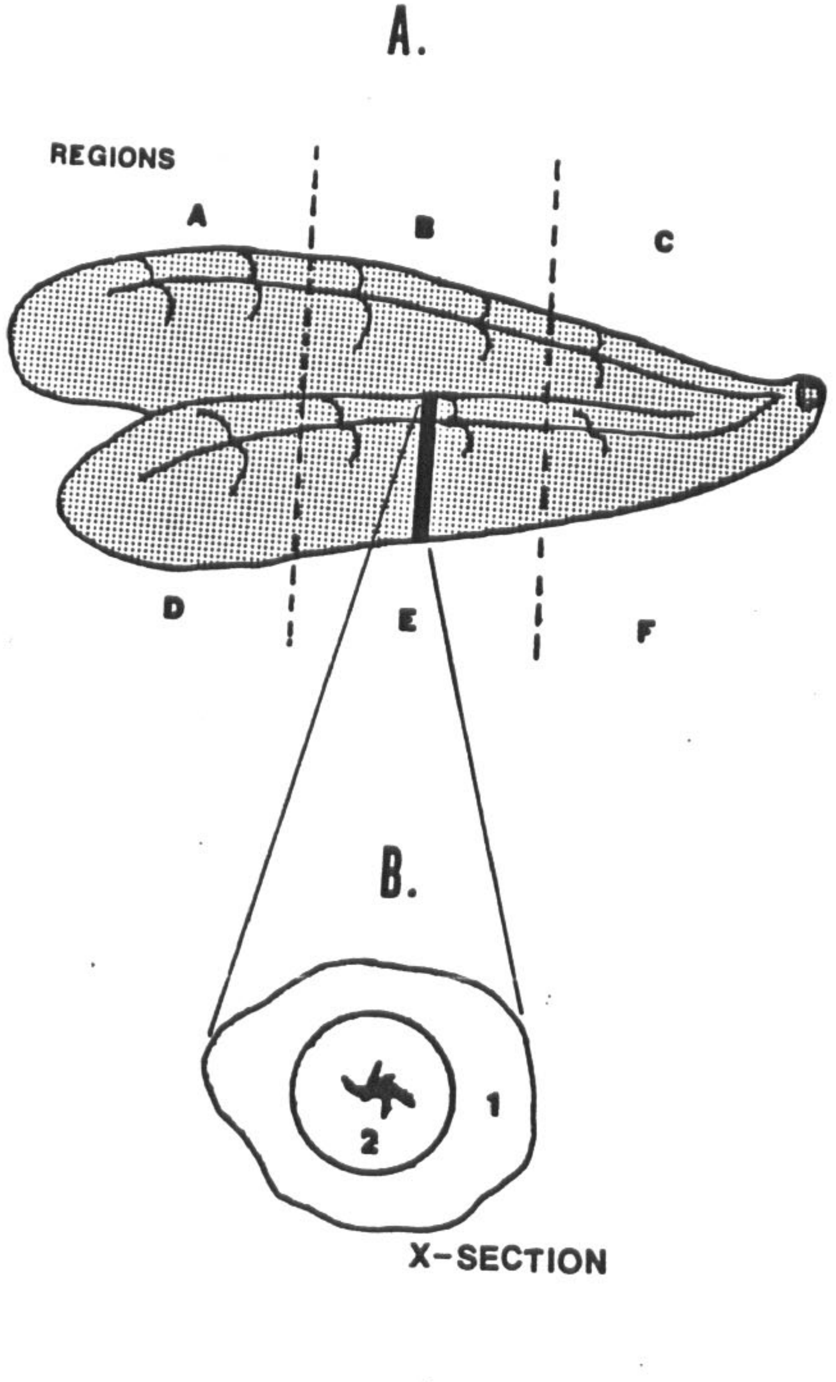


Figure 5.

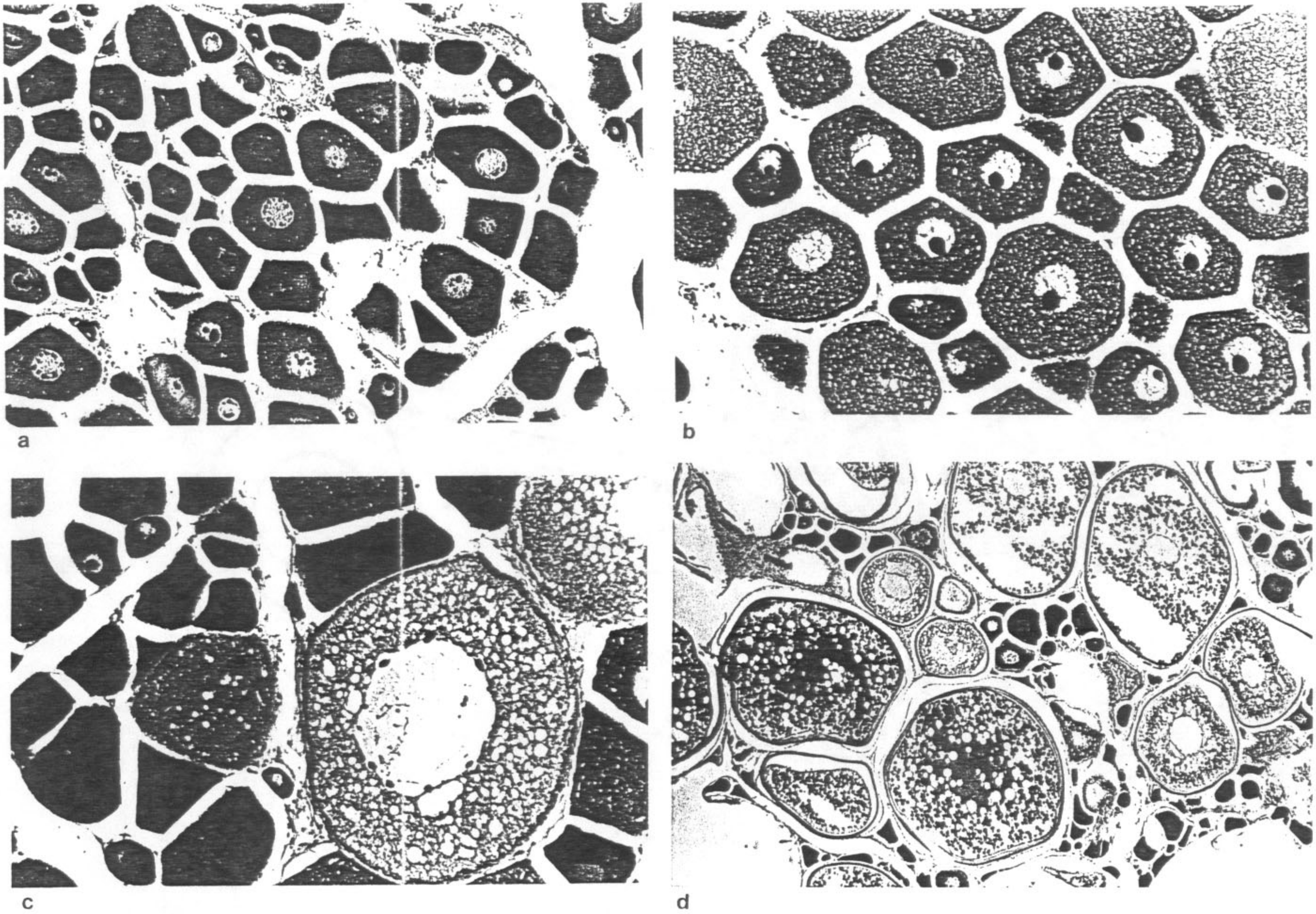


Figure 6.

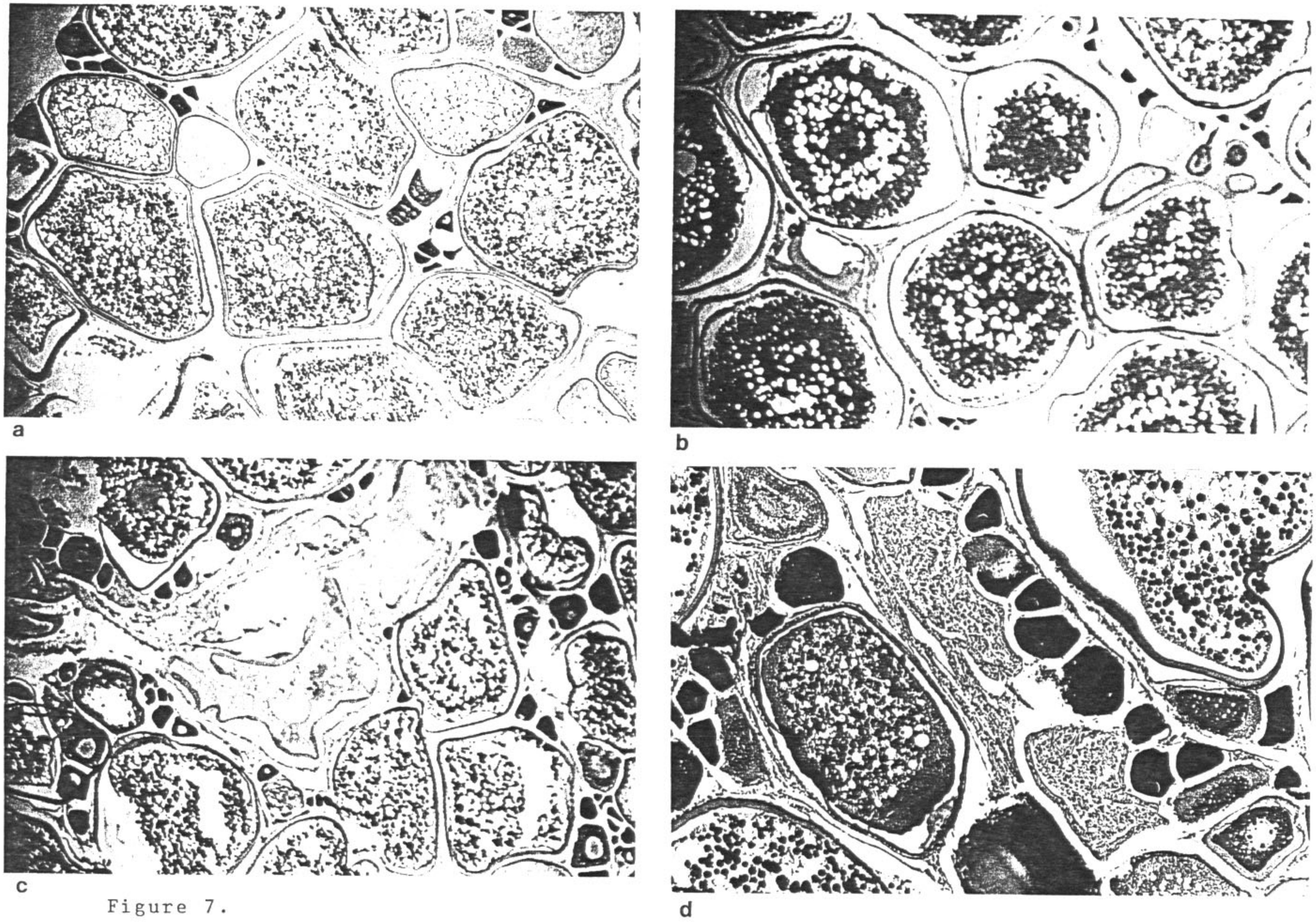


Figure 7.

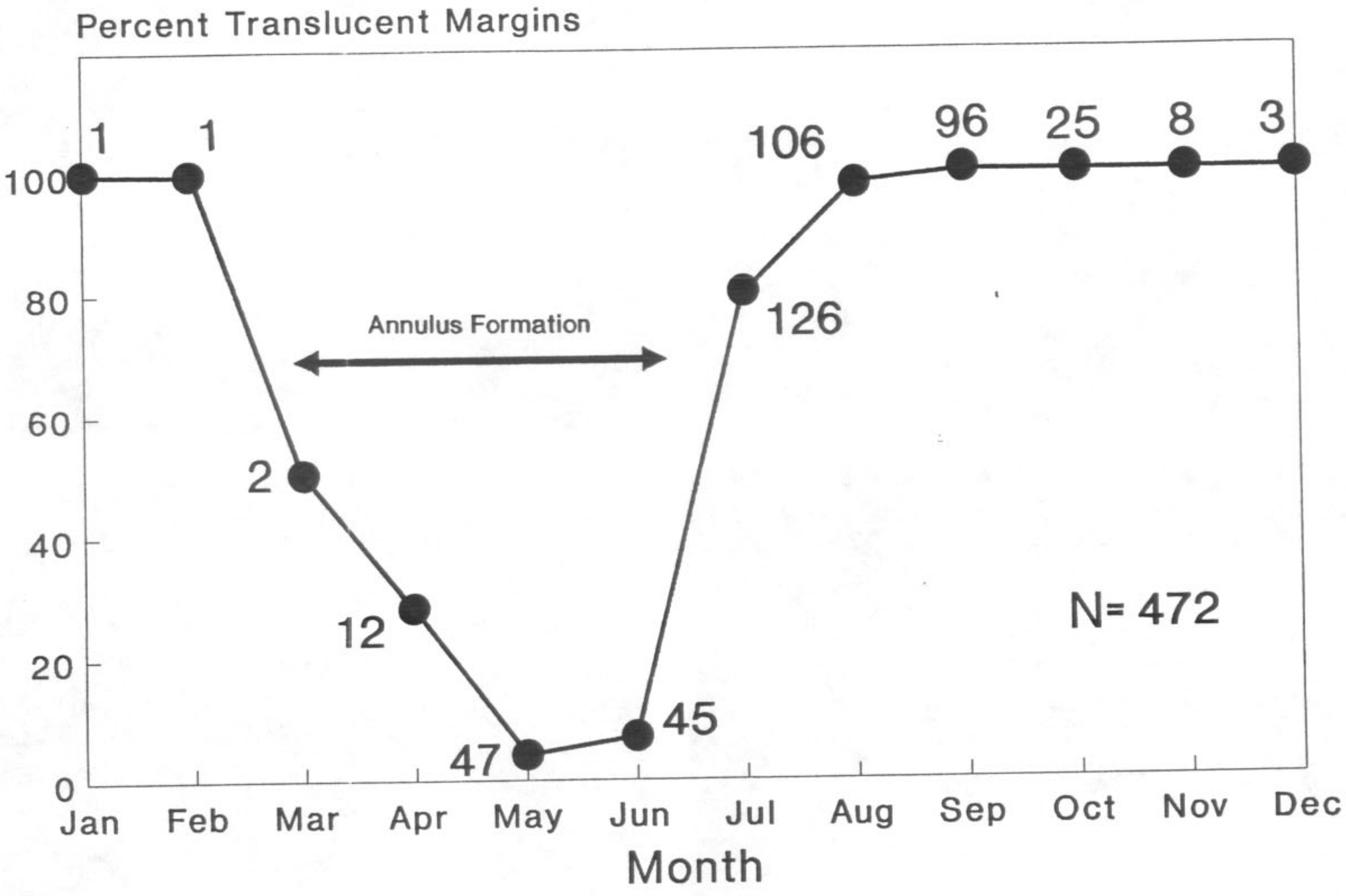
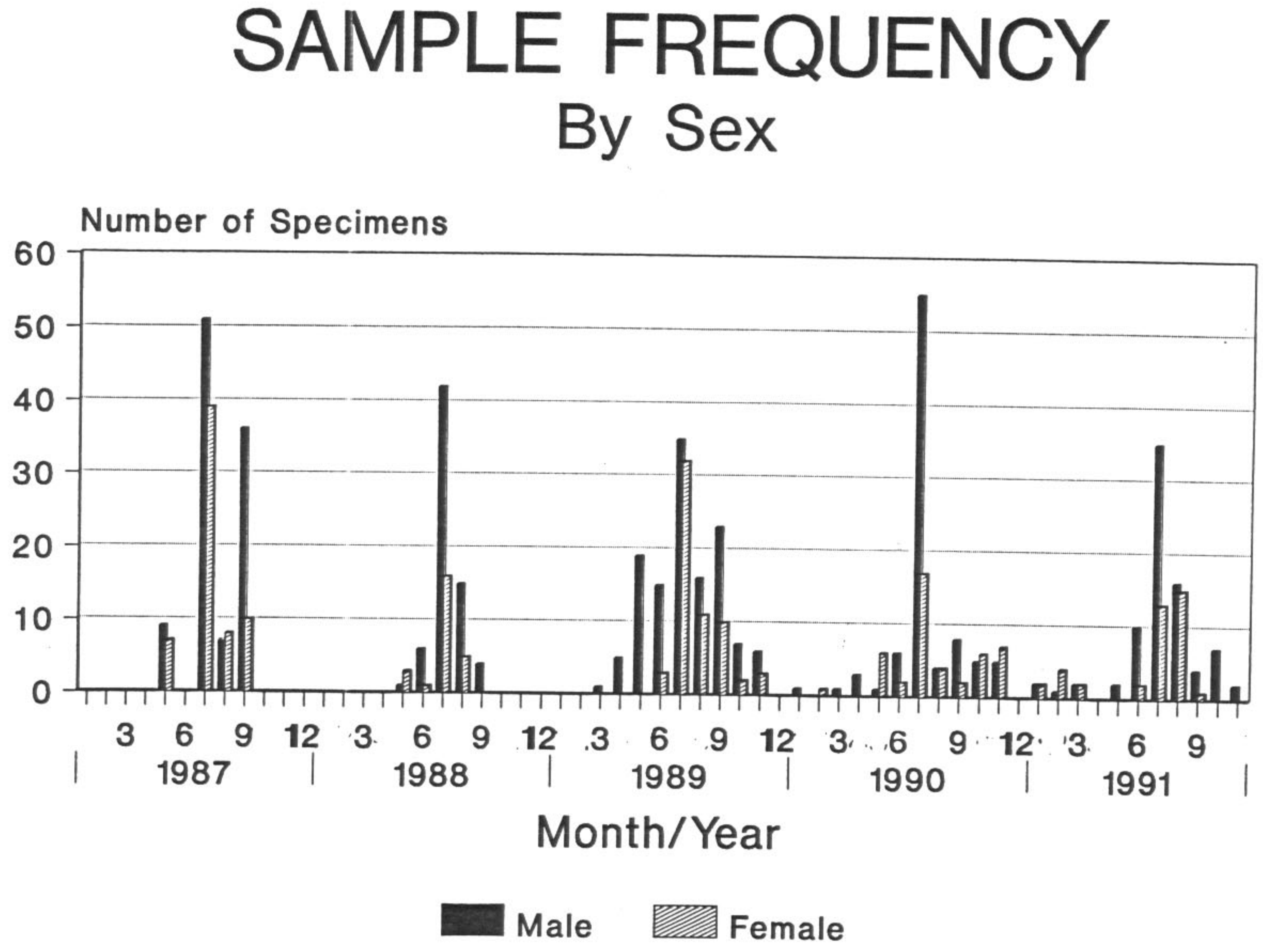
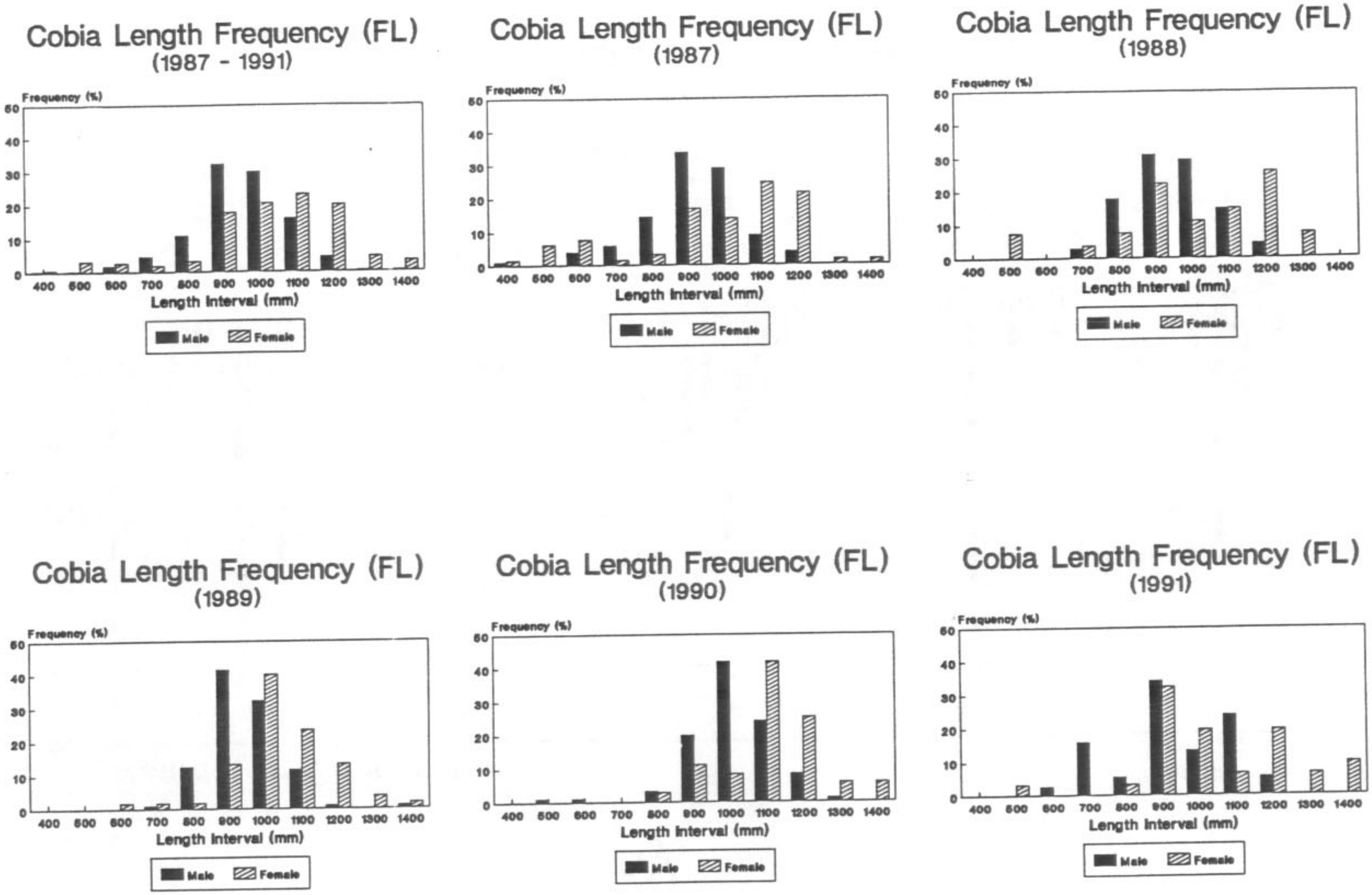

Percent Translucent Margins
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
1
1
2
12
47
45
126
106
96
25
8
3
Annulus Formation
N= 472

Figure 8.



Cobia

Figure 9.



Cobia Length Frequency (FL) (1987 - 1991)

Cobia Length Frequency (FL) (1987)

Cobia Length Frequency (FL) (1988)

Cobia Length Frequency (FL) (1989)

Cobia Length Frequency (FL) (1990)

Cobia Length Frequency (FL) (1991)

Figure 10.

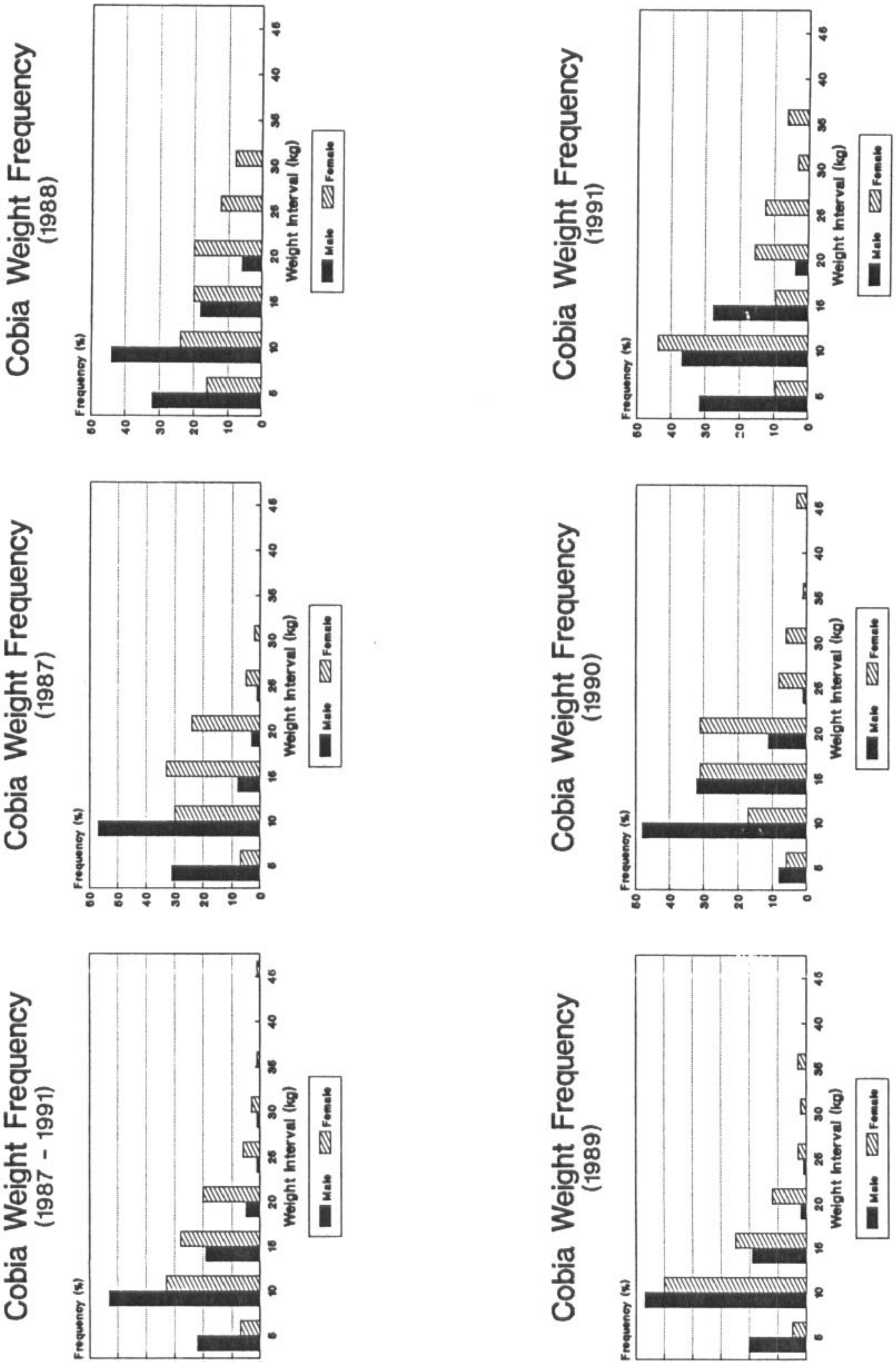

Cobia Weight Frequency
(1988)
Cobia Weight Frequency
(1987)
Cobia Weight Frequency
(1987 - 1991)
Cobia Weight Frequency
(1991)
Cobia Weight Frequency
(1990)
Cobia Weight Frequency
(1989)
Frequency (%)
Weight Interval (kg)
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
Male
Female

Figure 11.

YOB		'90	'89	'88	'87	'86	'85	'84	'83	'82	'81	'80	'79	'78	N	DOM. AGE
'87	M				0	10	21	30	11	7	1	2	1	1	84	2-3
	F				0	8	13	13	8	5	3	0	0	0	50	
'88	M			0	1	15	16	19	10	4	1	0	0	1	67	2-4
	F			0	3	8	4	6	3	2	0	1	0	0	27	
'89	M		0	3	30	58	9	9	5	5	0	0	1		120	2-3
	F		0	3	14	32	6	0	1	0	3	0	0		59	
'90	M	0	2	3	33	42	10	4	1	1	0	0			96	3-4
	F	0	0	6	13	11	4	1	0	0	0	1			36	
'91	M	14	19	5	18	13	3	2	0	0	1				75	2-5
	F	1	15	3	4	7	1	1	0	0	0				32	

Figure 12.

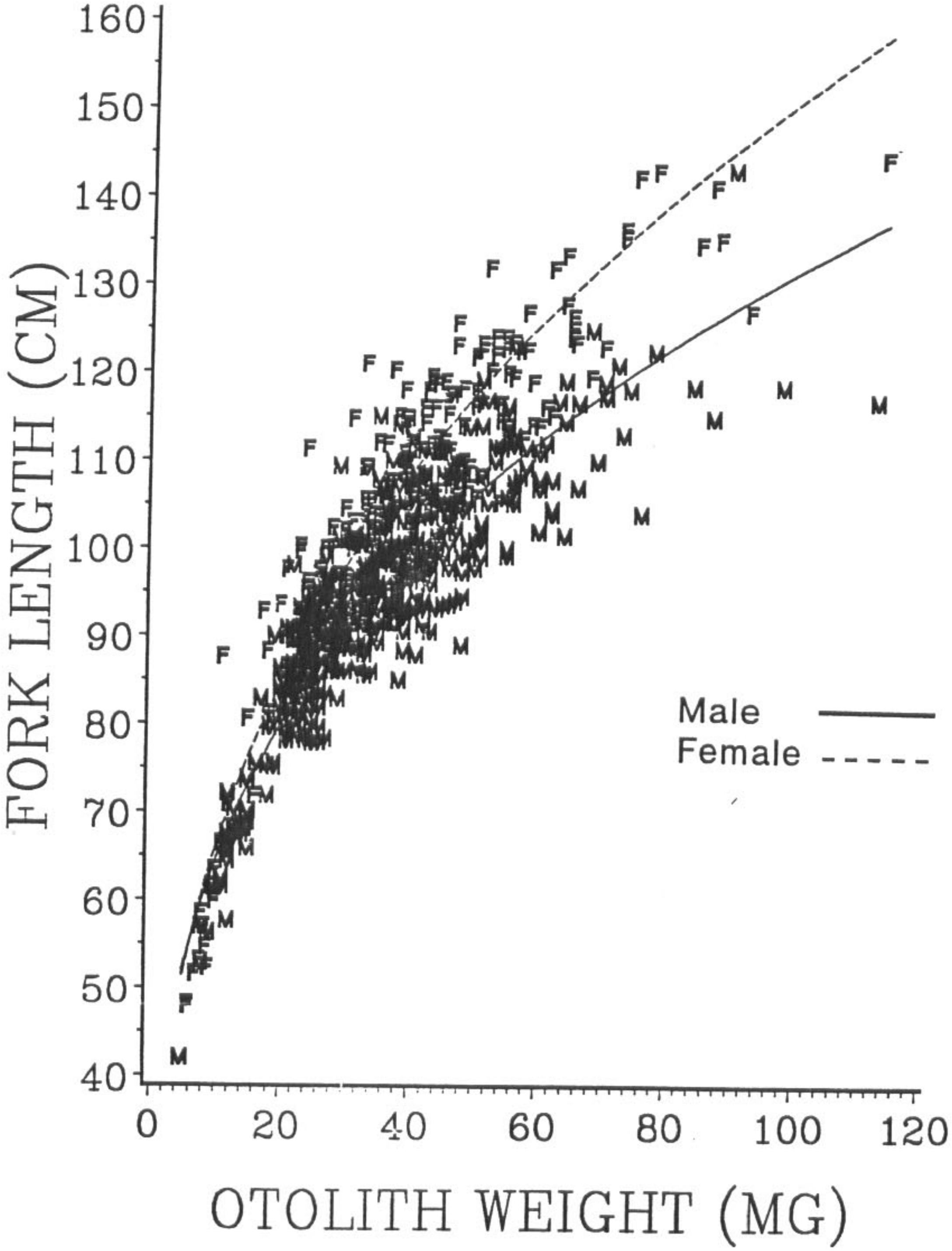

FORK LENGTH (CM)
160
150
140
130
120
110
100
90
80
70
60
50
40
OTOLITH WEIGHT (MG)
0
20
40
60
80
100
120
Male
Female
F
M

Figure 13.

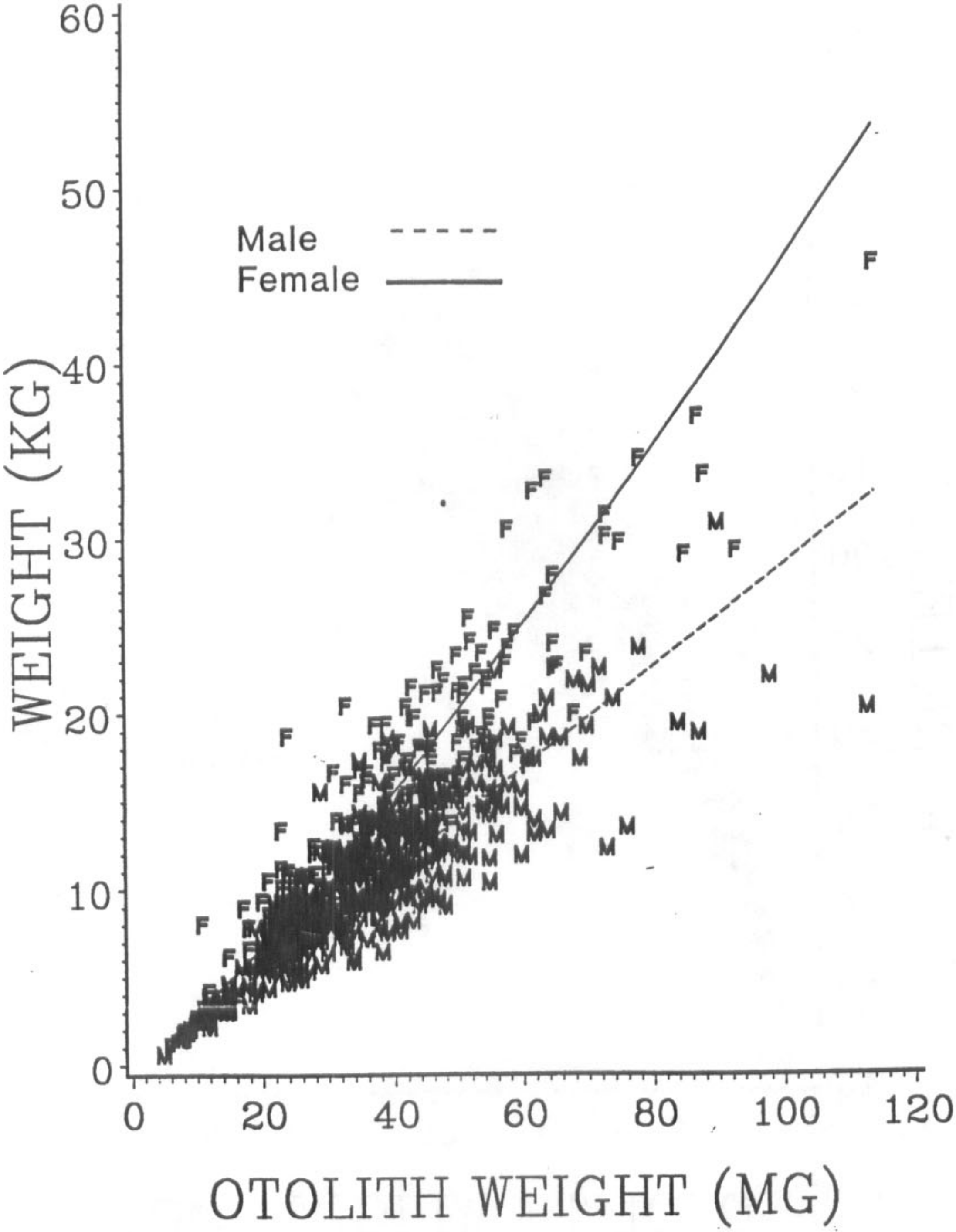

60
50
40
30
20
10
0
WEIGHT (KG)
Male
Female
0
20
40
60
80
100
120
OTOLITH WEIGHT (MG)

Figure 14.

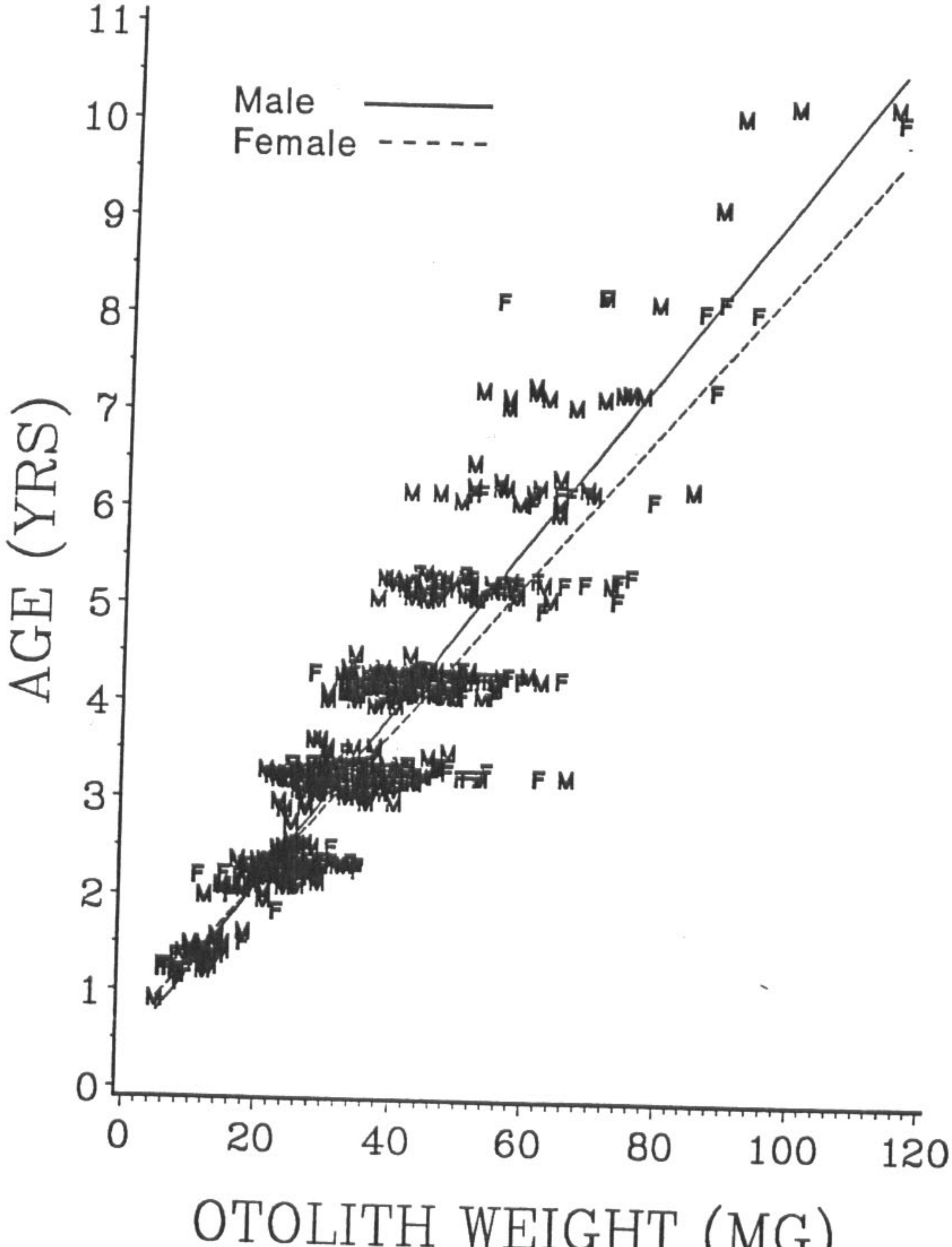

Male
Female
AGE (YRS)
OTOLITH WEIGHT (MG)
0
1
2
3
4
5
6
7
8
9
10
11
0
20
40
60
80
100
120
M
F

Figure 15.

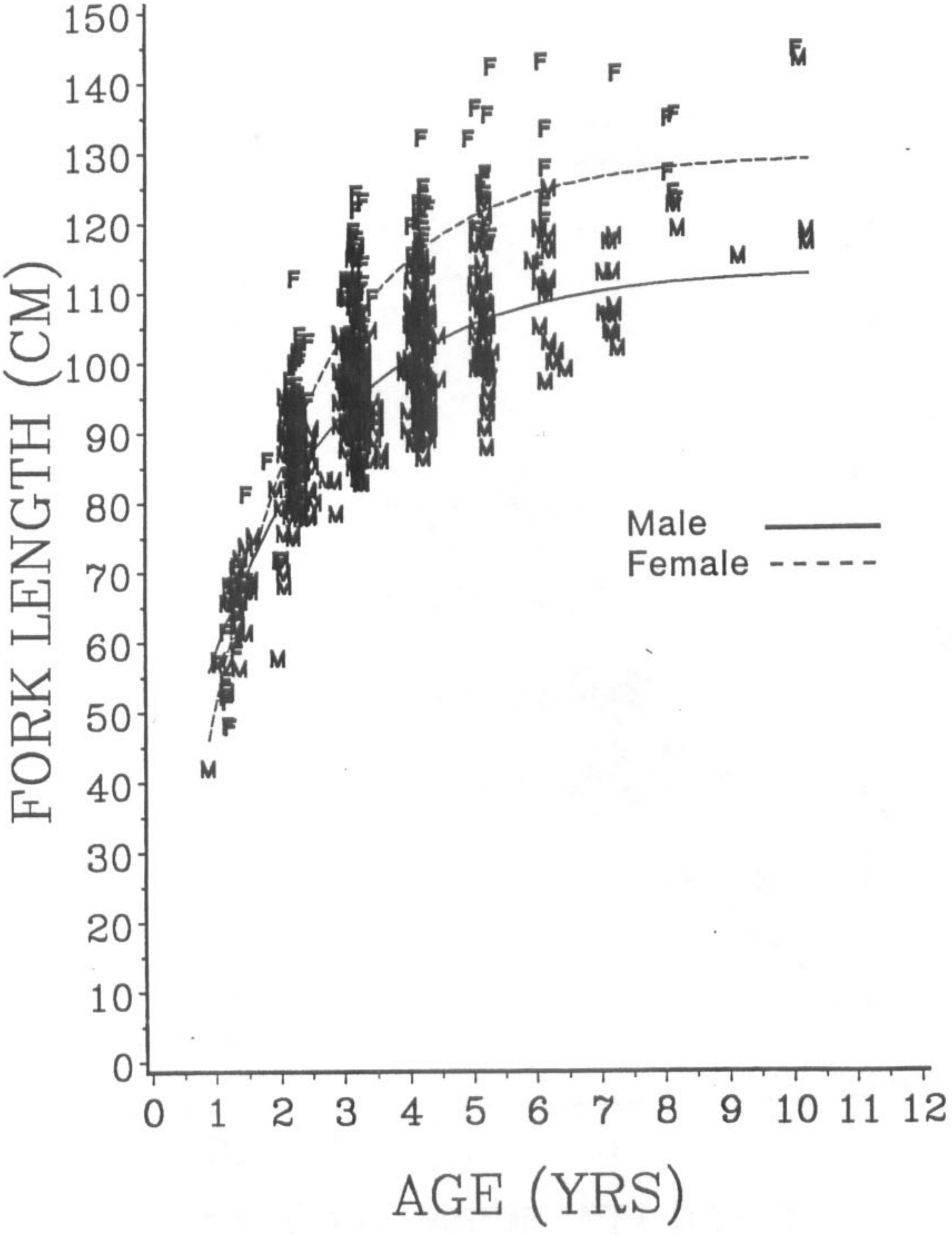
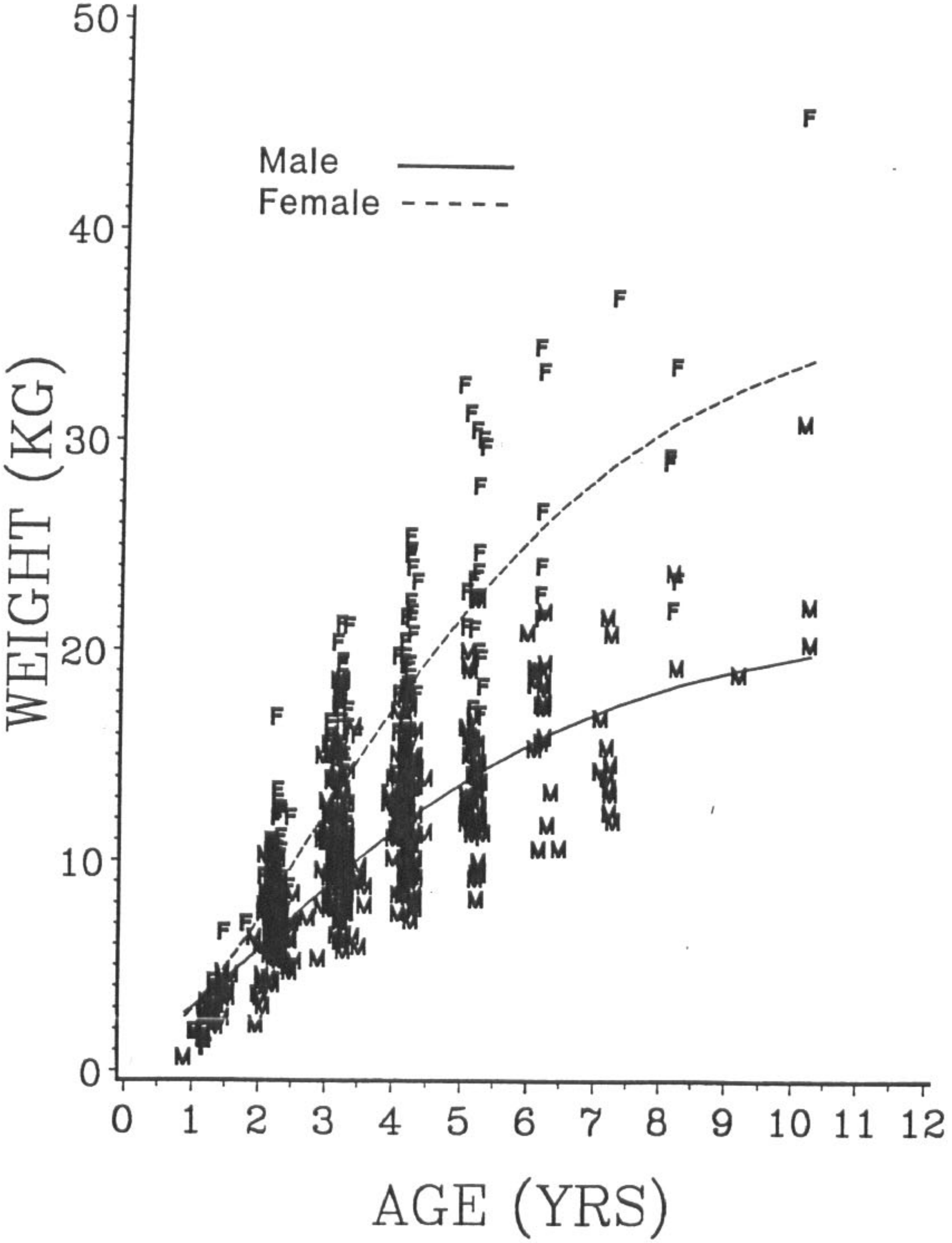
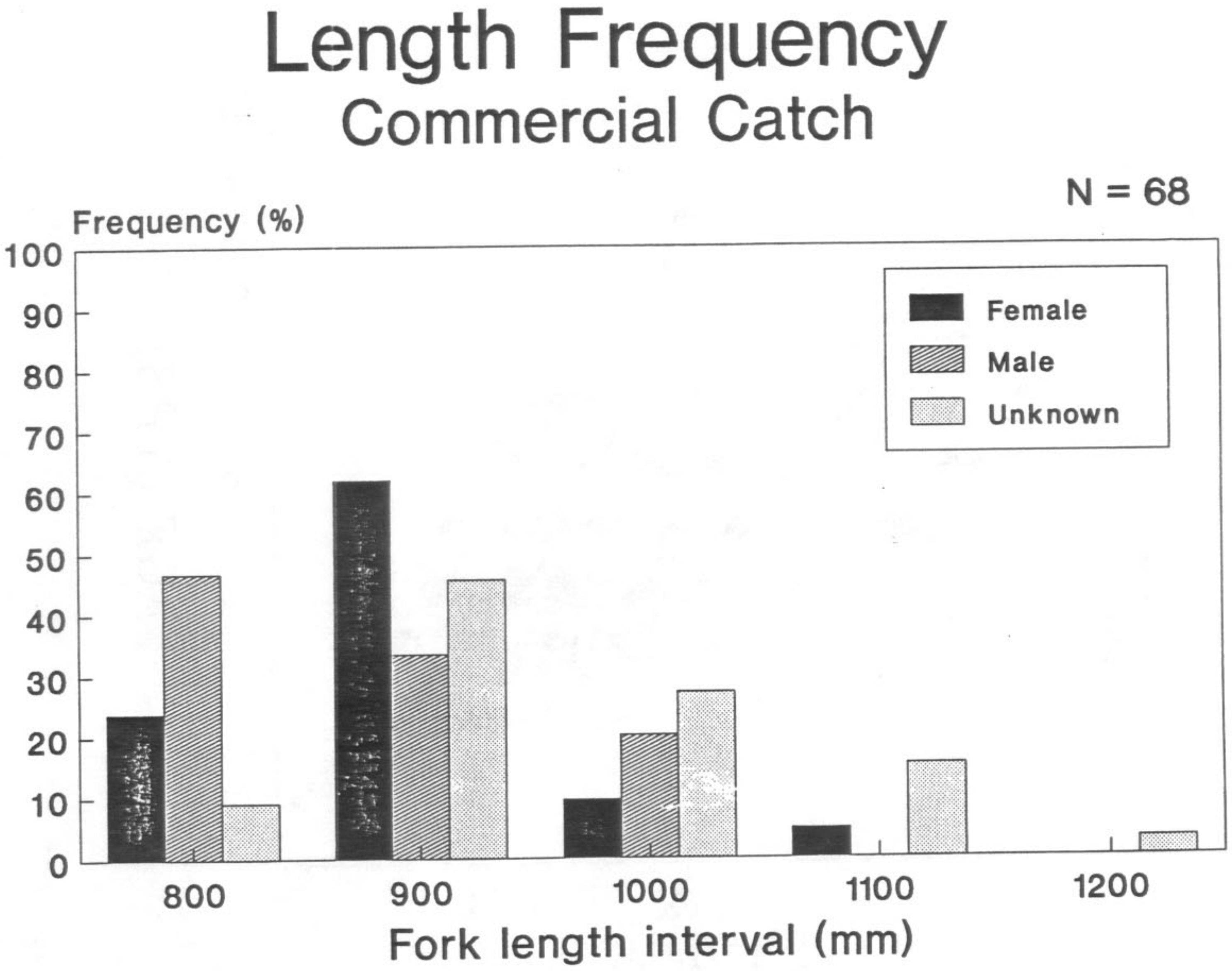

FORK LENGTH (CM)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
AGE (YRS)
0
1
2
3
4
5
6
7
8
9
10
11
12
Male
Female
M
F

Figure 16.



WEIGHT (KG)
50
40
30
20
10
0
AGE (YRS)
0
1
2
3
4
5
6
7
8
9
10
11
12
Male
Female
F
M

Figure 17.



Length Frequency
Commercial Catch

Figure 18.

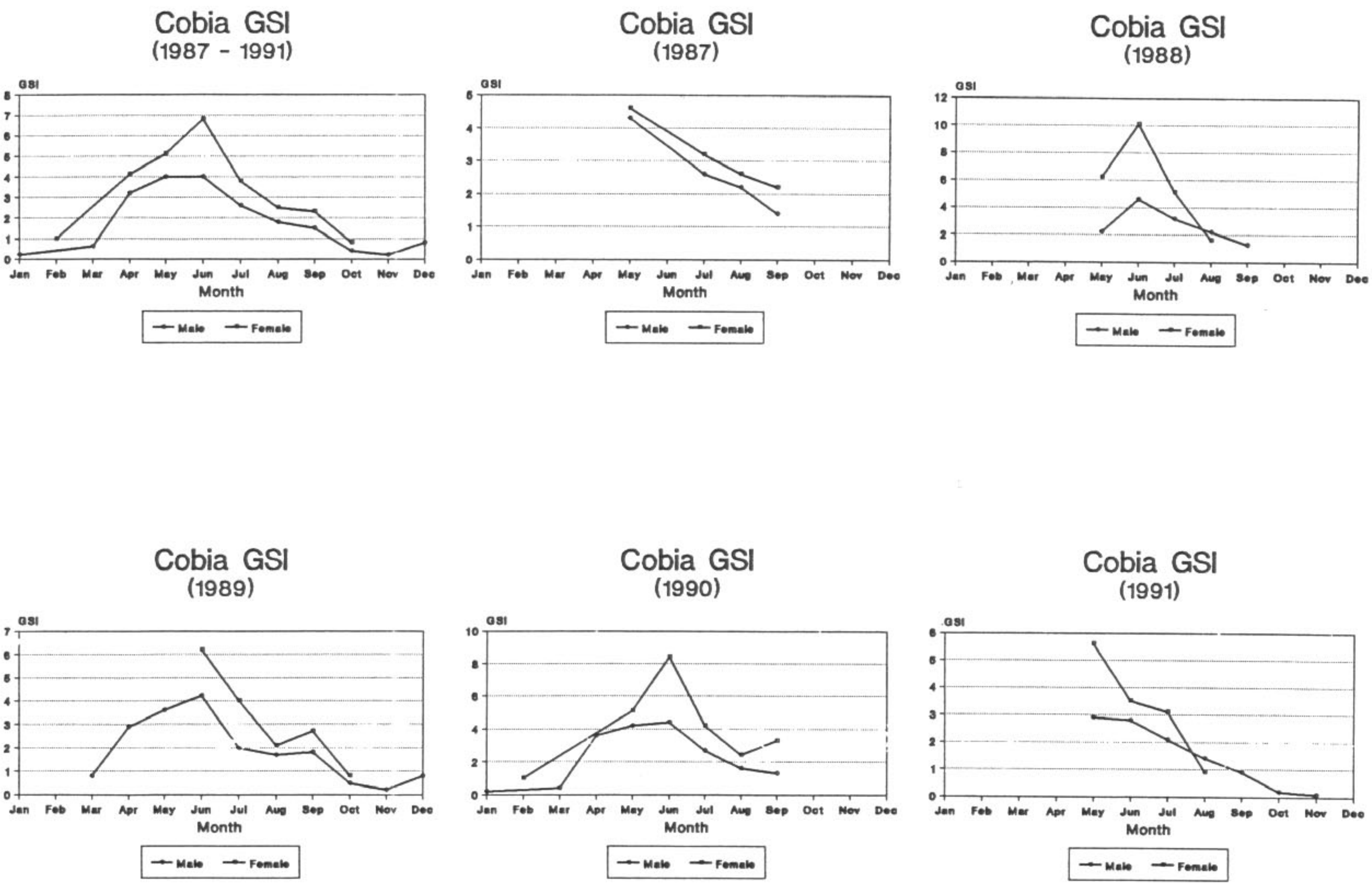

Cobia GSI
(1987 - 1991)
GSI
0
1
2
3
4
5
6
7
8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Male
Female
Cobia GSI
(1987)
GSI
0
1
2
3
4
5
Month
Male
Female
Cobia GSI
(1988)
GSI
0
2
4
6
8
10
12
Month
Male
Female
Cobia GSI
(1989)
GSI
0
1
2
3
4
5
6
7
Month
Male
Female
Cobia GSI
(1990)
GSI
0
2
4
6
8
10
Month
Male
Female
Cobia GSI
(1991)
GSI
0
1
2
3
4
5
6
Month
Male
Female

Figure 19.

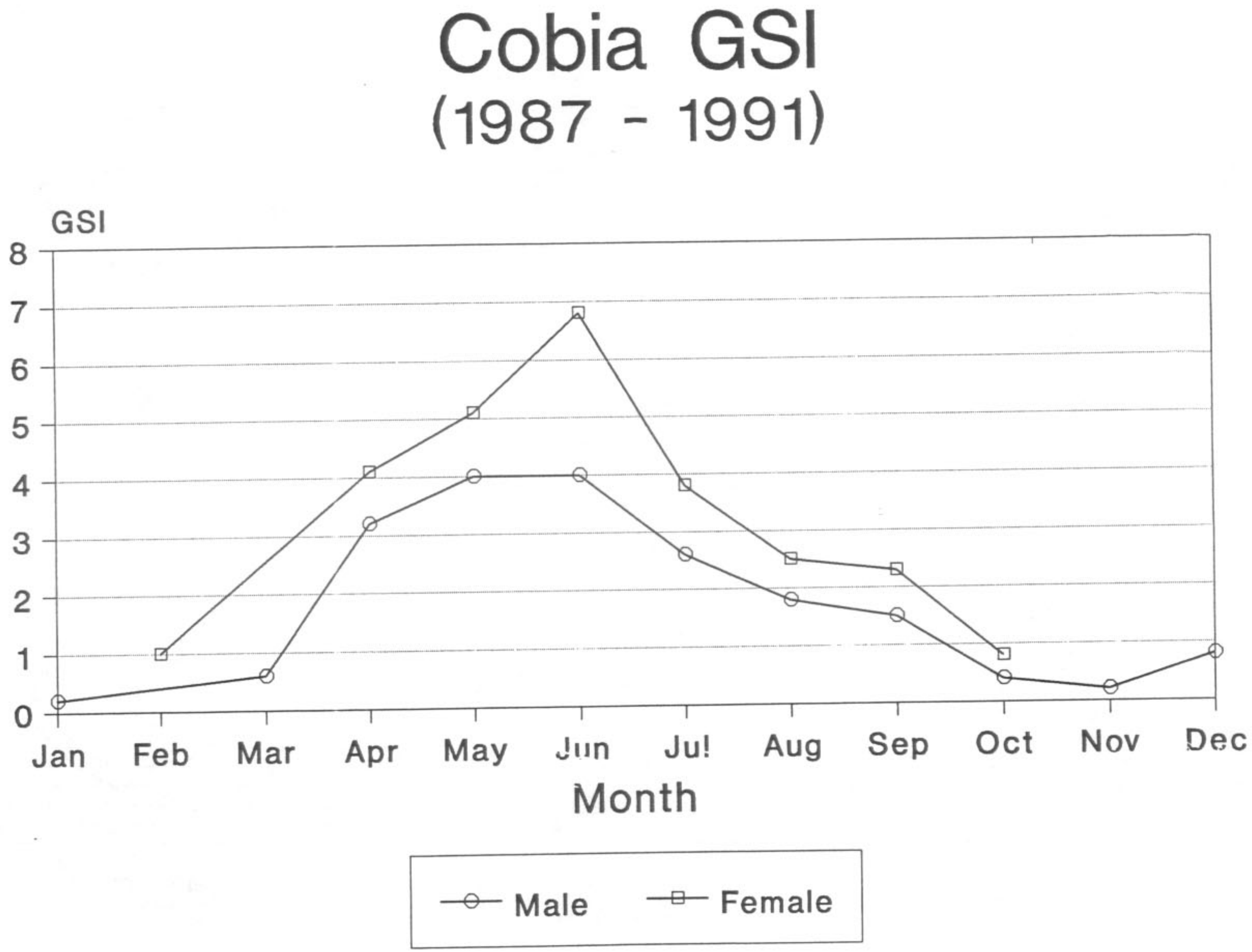

Cobia GSI
(1987 - 1991)
GSI
8
7
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Male
Female

Figure 20.

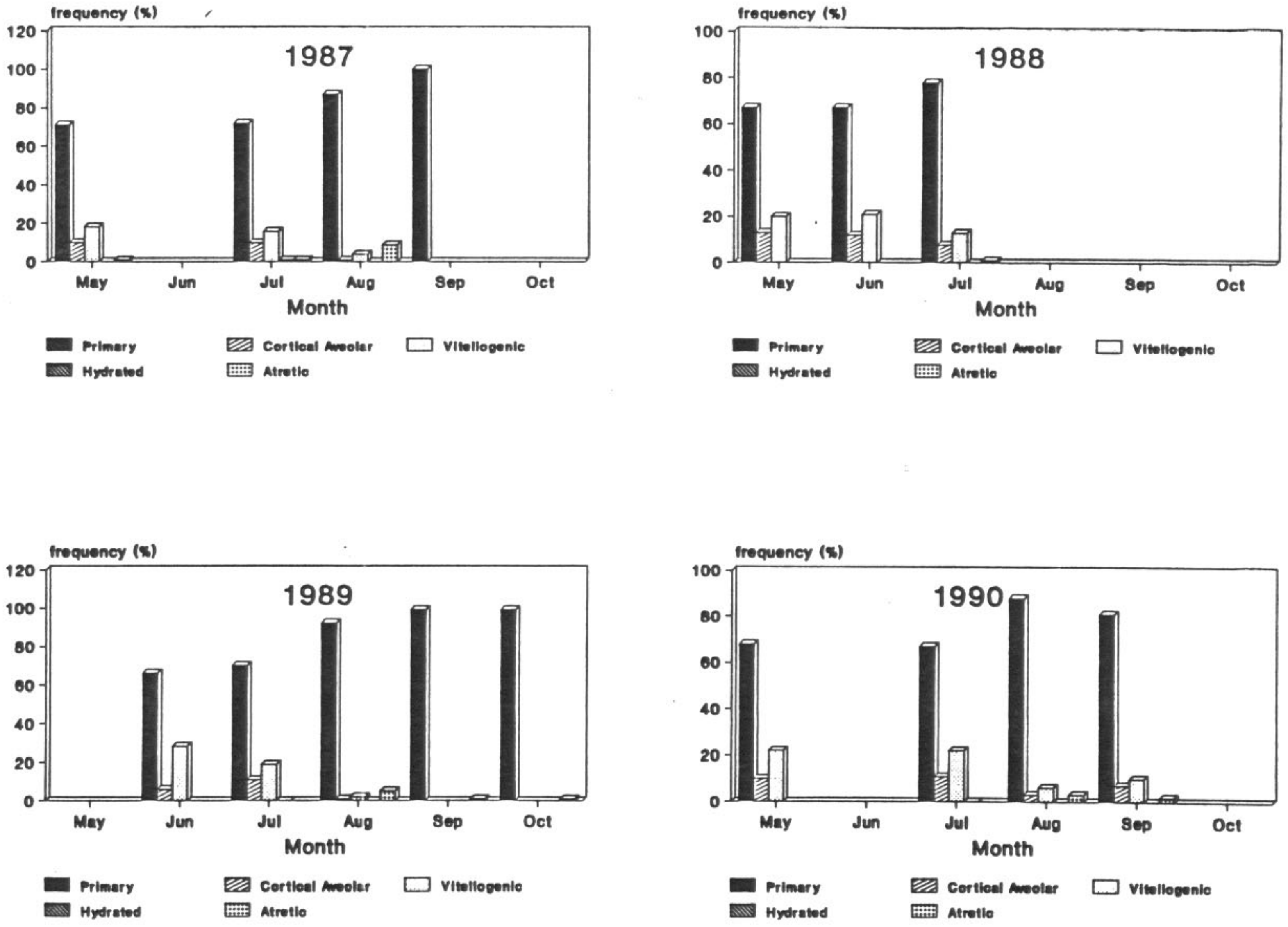

frequency (%)
1987
120
100
80
60
40
20
0
May
Jun
Jul
Aug
Sep
Oct
Month
Primary
Hydrated
Cortical Aveolar
Atretic
Vitellogenic
frequency (%)
1988
100
80
60
40
20
0
May
Jun
Jul
Aug
Sep
Oct
Month
Primary
Hydrated
Cortical Aveolar
Atretic
Vitellogenic
frequency (%)
1989
120
100
80
60
40
20
0
May
Jun
Jul
Aug
Sep
Oct
Month
Primary
Hydrated
Cortical Aveolar
Atretic
Vitellogenic
frequency (%)
1990
100
80
60
40
20
0
May
Jun
Jul
Aug
Sep
Oct
Month
Primary
Hydrated
Cortical Aveolar
Atretic
Vitellogenic

Figure 21.

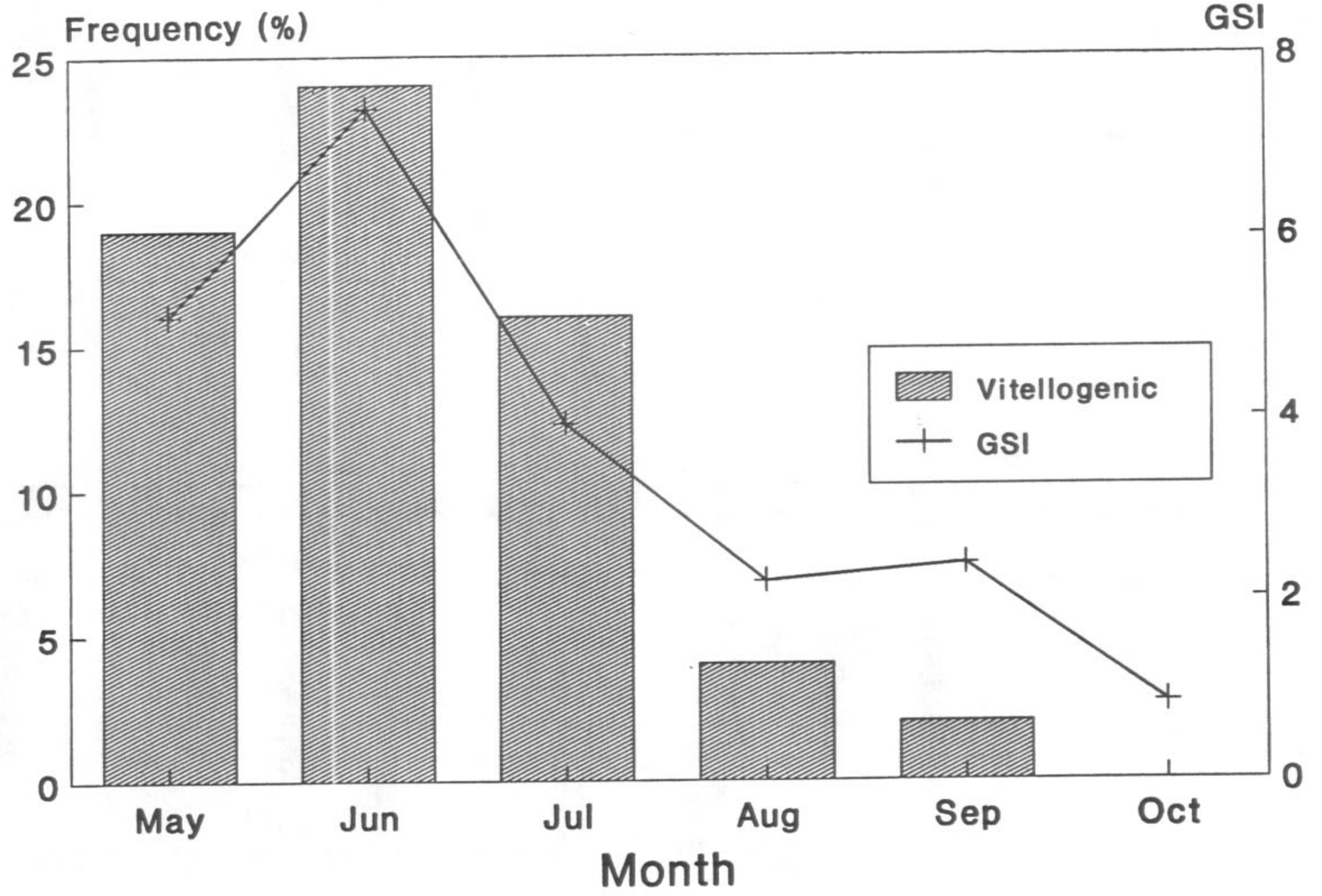

Frequency (%)
GSI
25
20
15
10
5
0
8
6
4
2
0
May
Jun
Jul
Aug
Sep
Oct
Month
▨ Vitellogenic
GSI

Figure 22.

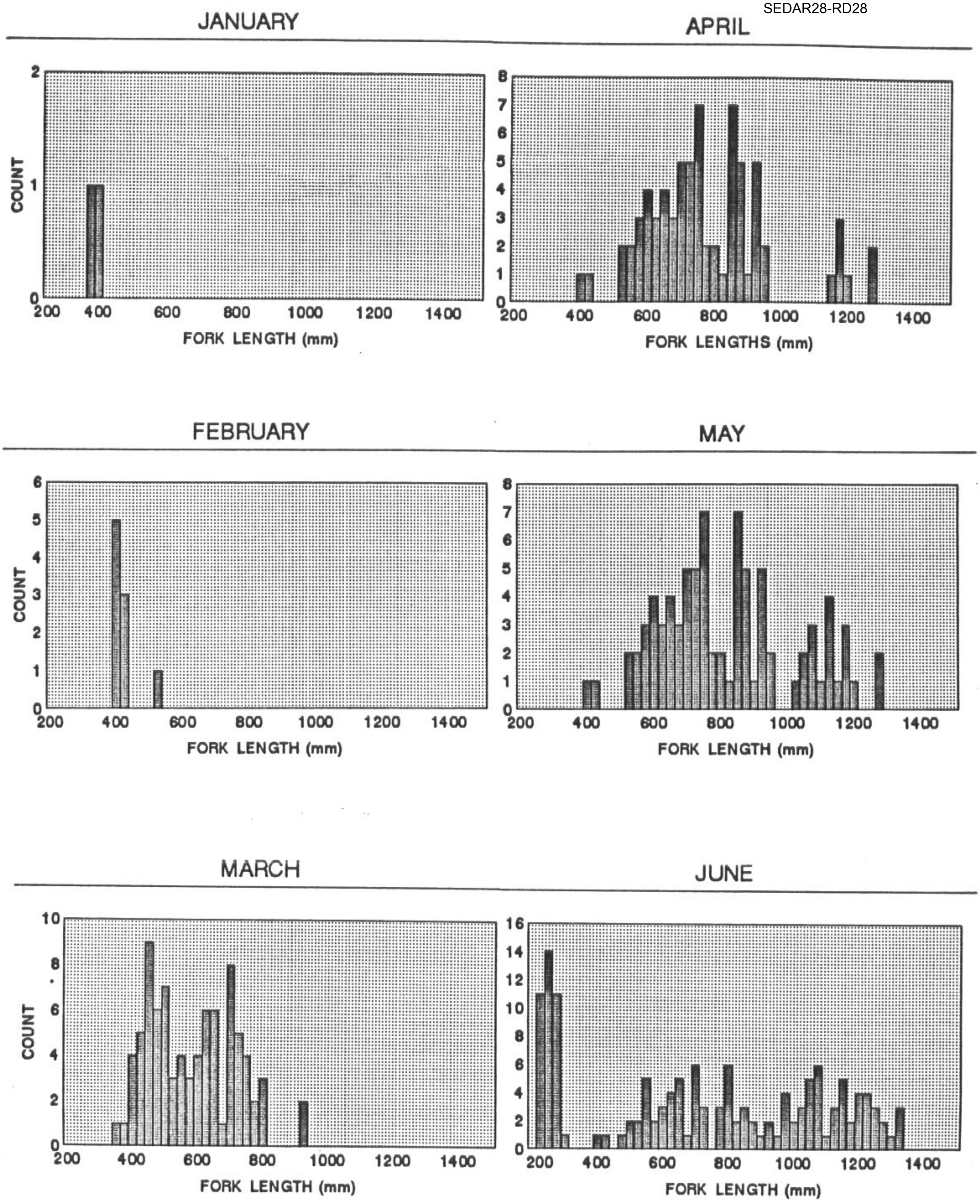

JANUARY
COUNT
0
1
2
200
400
600
800
1000
1200
1400
FORK LENGTH (mm)
APRIL
0
1
2
3
4
5
6
7
8
FORK LENGTHS (mm)
FEBRUARY
COUNT
6
FORK LENGTH (mm)
MAY
FORK LENGTH (mm)
MARCH
COUNT
10
FORK LENGTH (mm)
JUNE
12
14
16
FORK LENGTH (mm)

Figure 23.

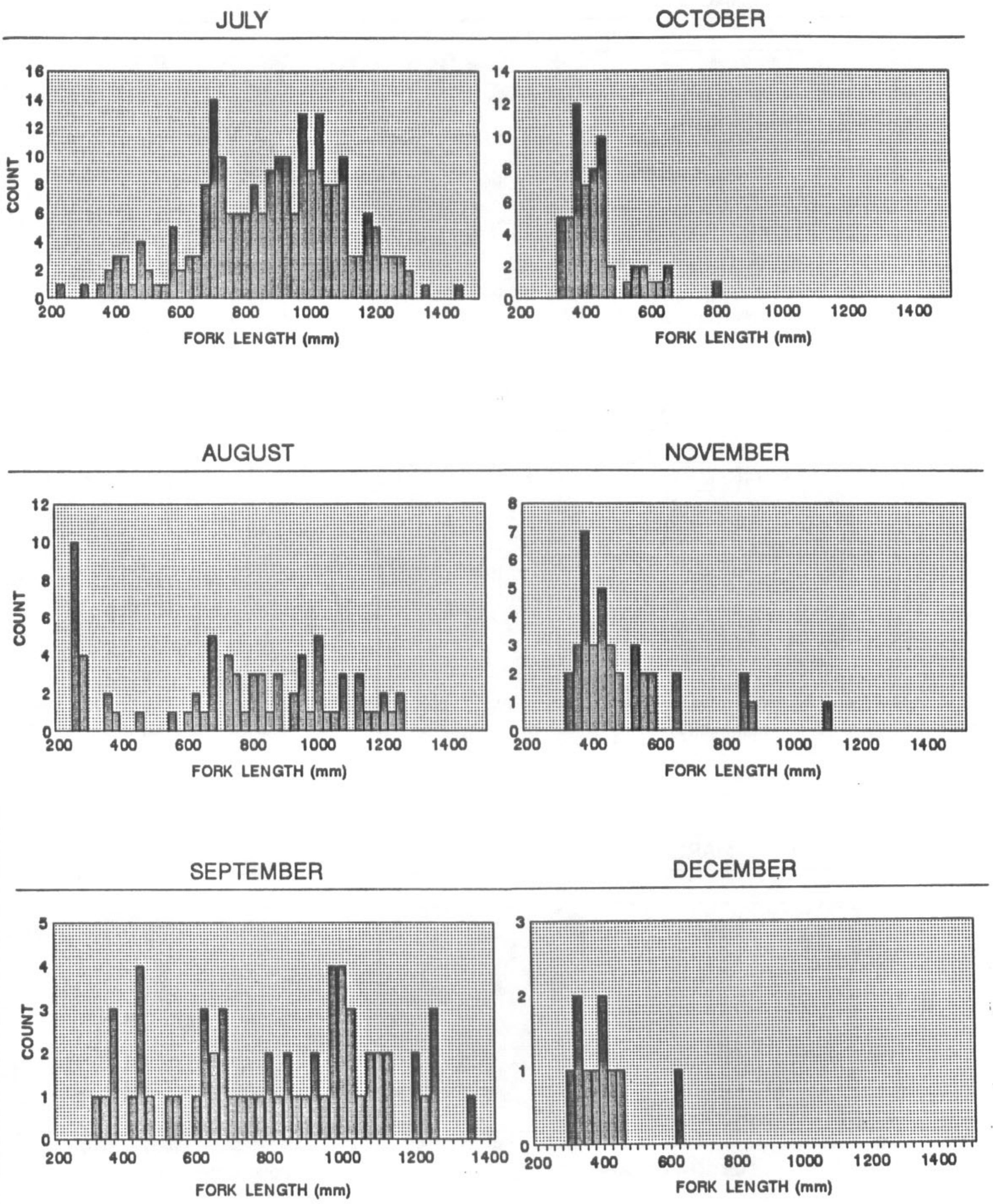
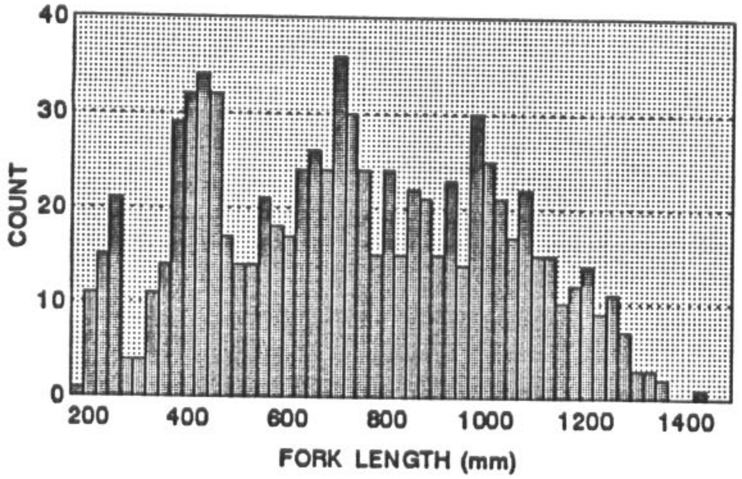
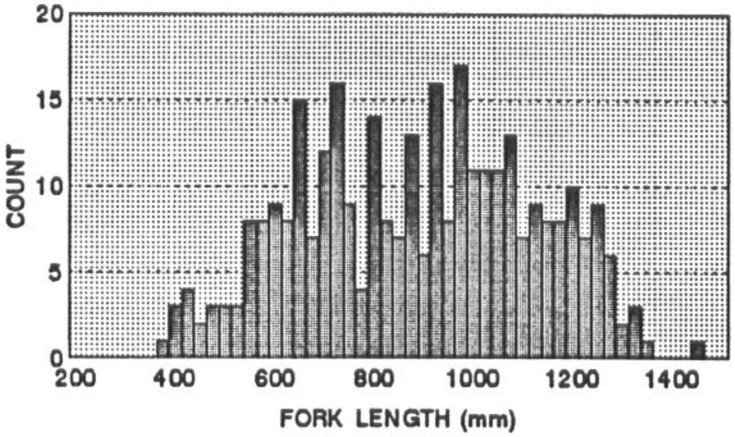


Figure 23 (continued).


FORK LENGTH


FEMALES

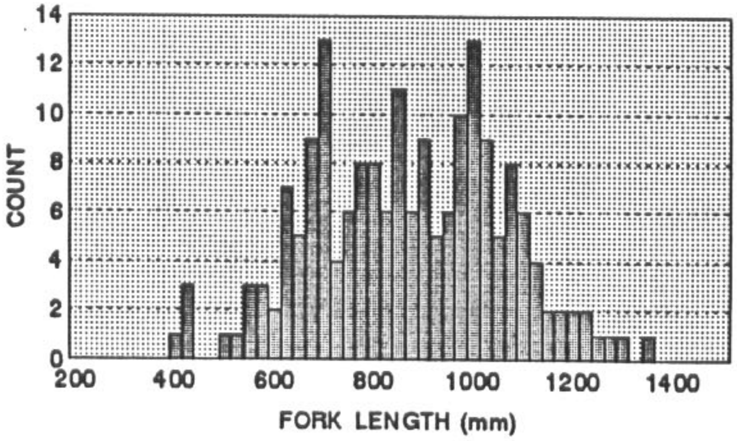

MALES

Figure 24.

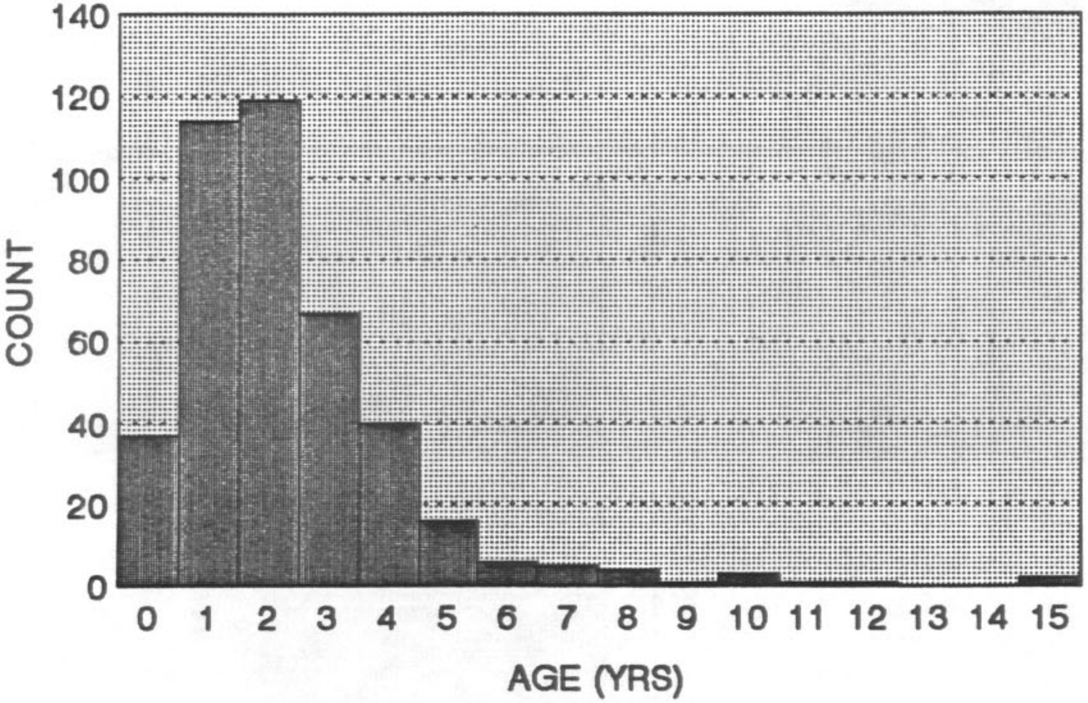

140
120
100
80
60
40
20
0
COUNT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
AGE (YRS)

Figure 25.

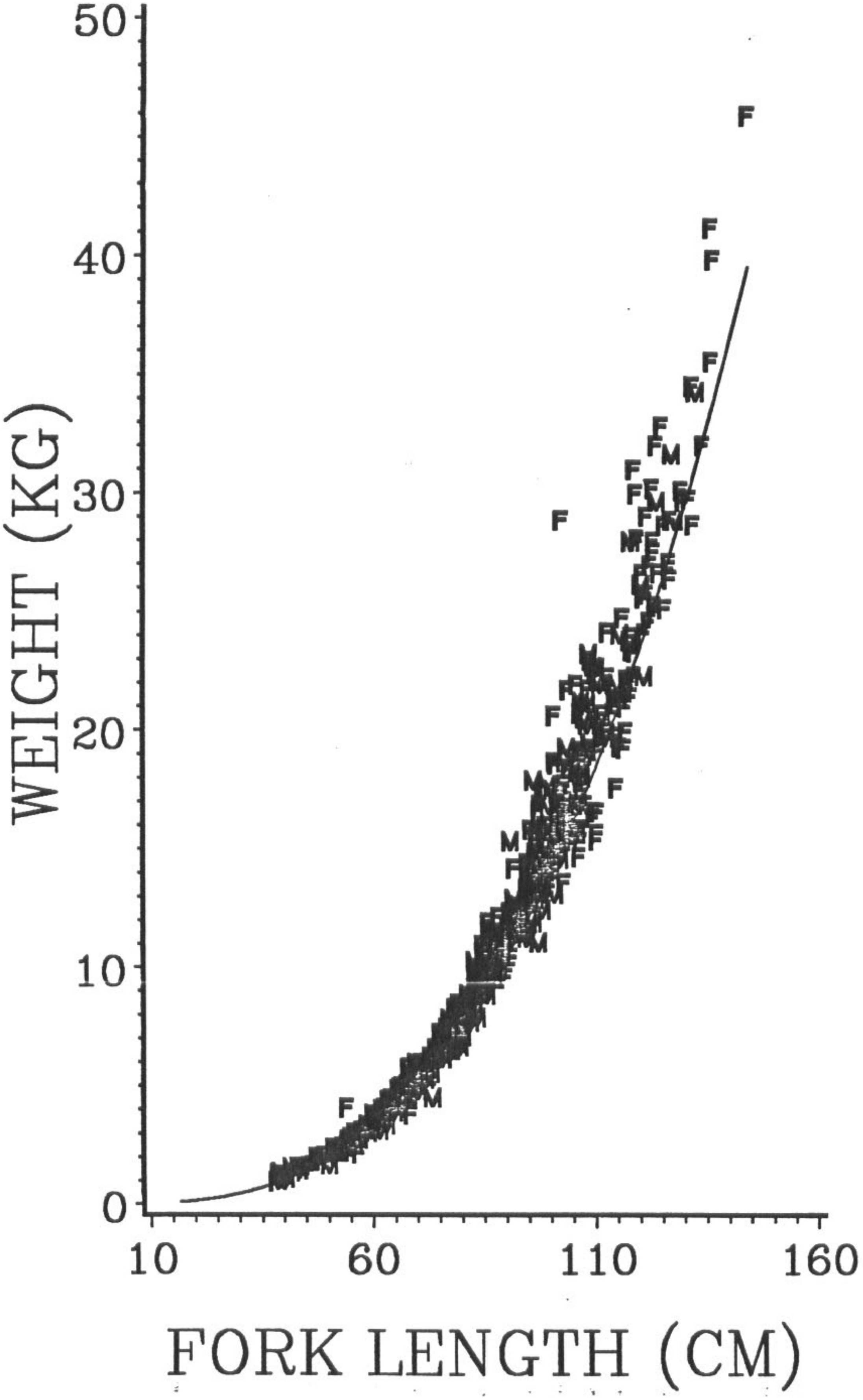


Figure 26.

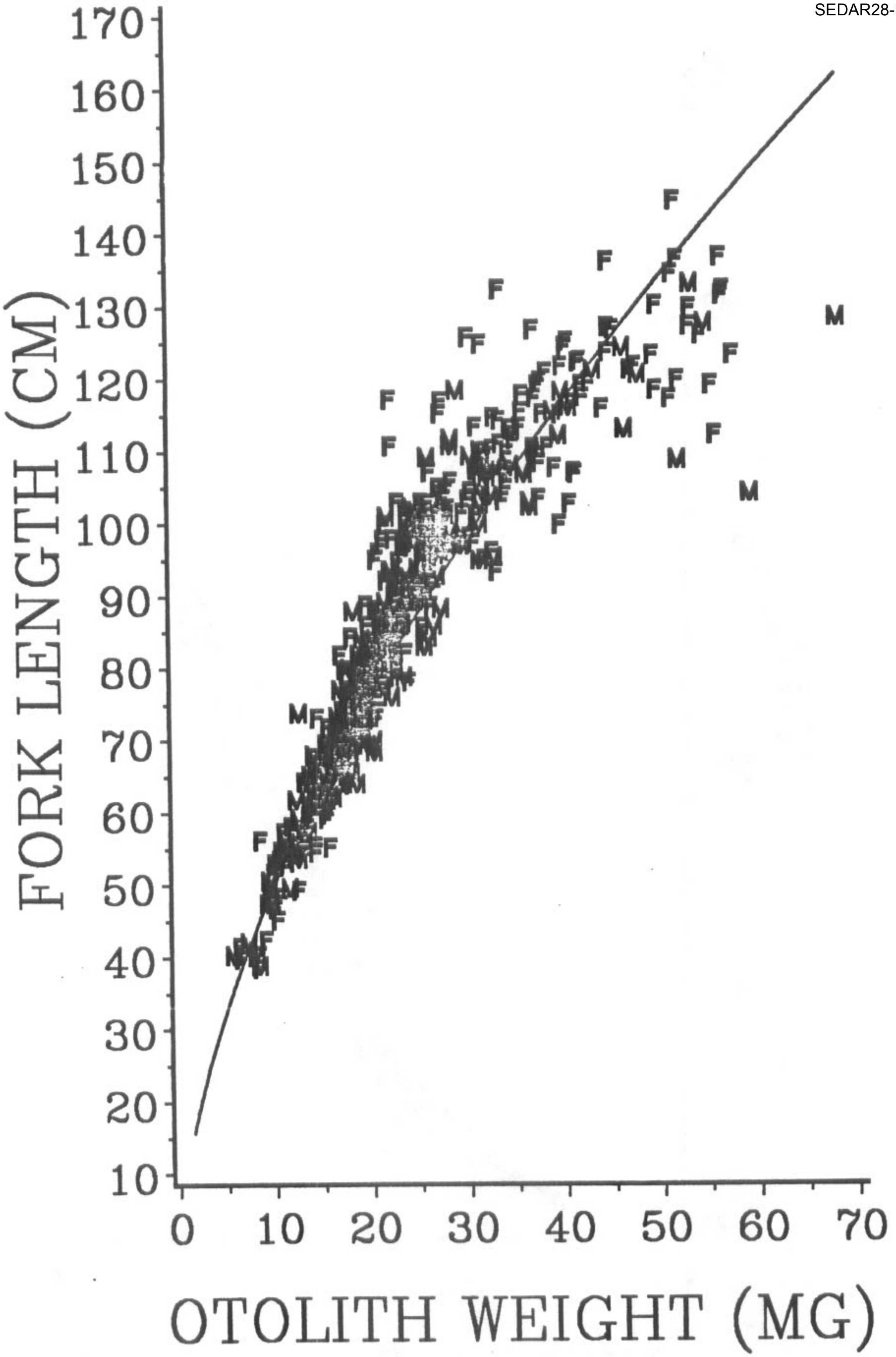

FORK LENGTH (CM)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
OTOLITH WEIGHT (MG)
0
10
20
30
40
50
60
70
F
M

Figure 27.

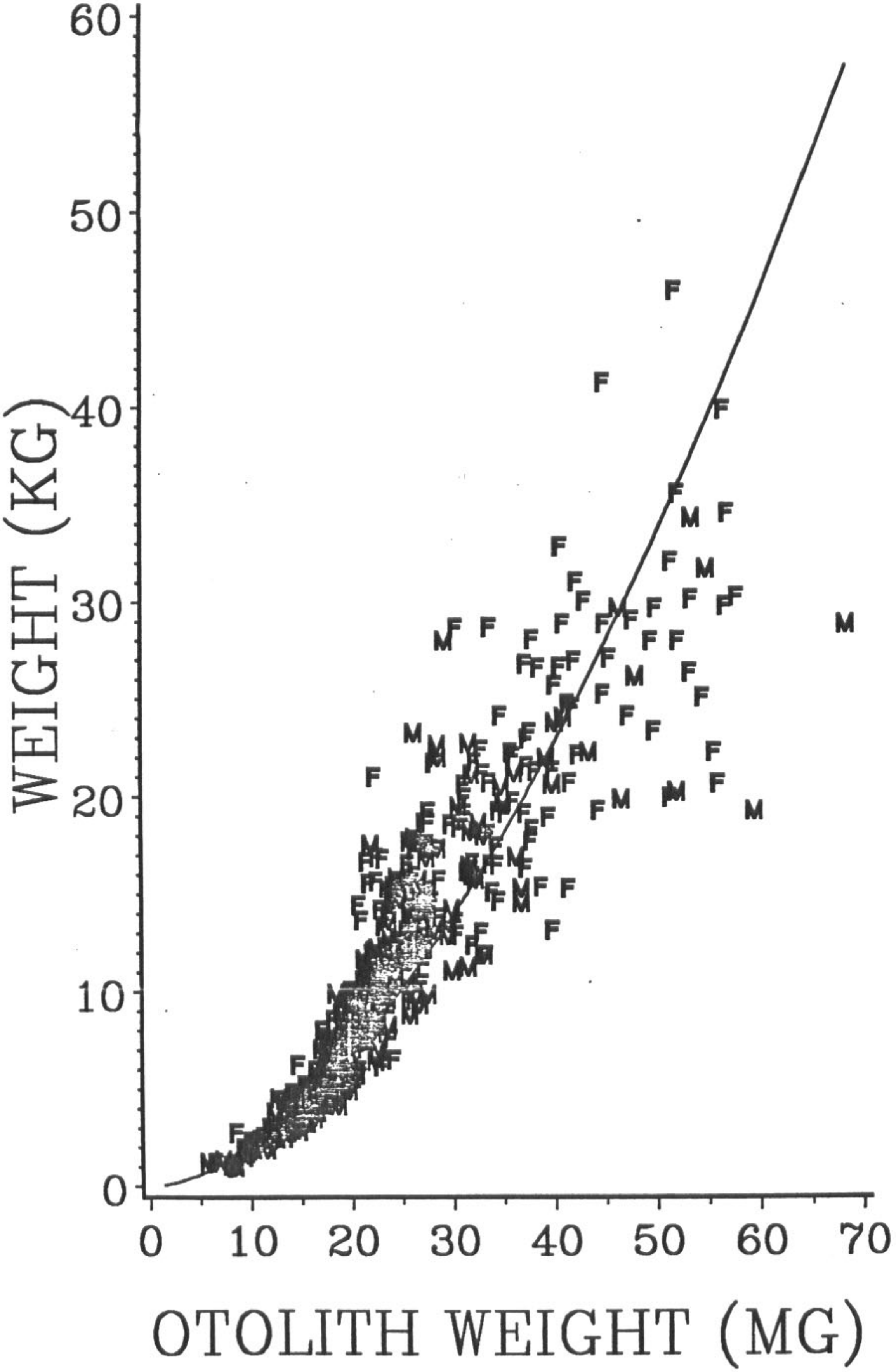

WEIGHT (KG)
60
50
40
30
20
10
0
OTOLITH WEIGHT (MG)
0
10
20
30
40
50
60
70
F
M

Figure 28.

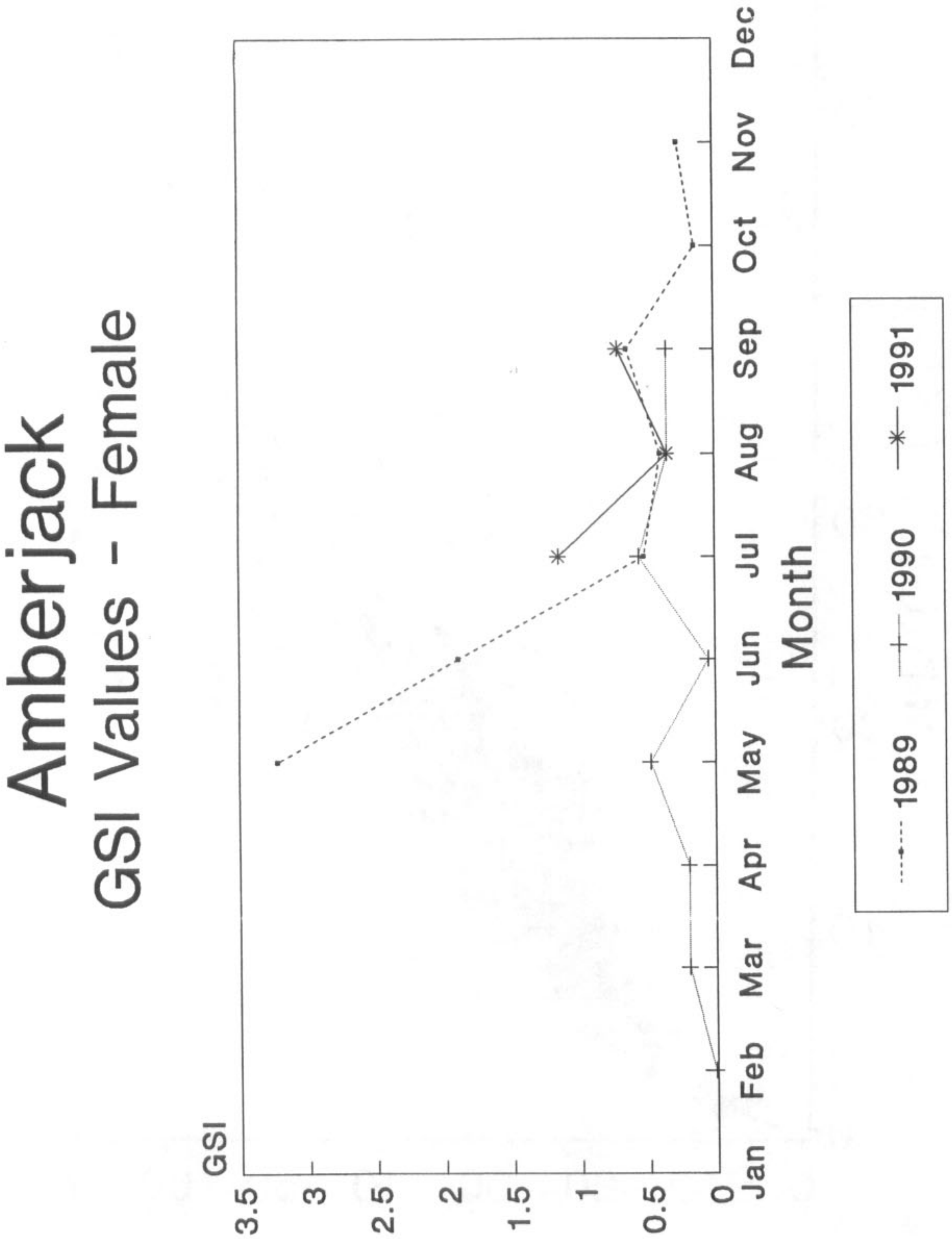

Amberjack
GSI Values - Female
GSI
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
1989
1990
1991

Figure 29.

AMBERJACK 1989 & 1990

Comparison of GSI & FL, June 1989 & 1990

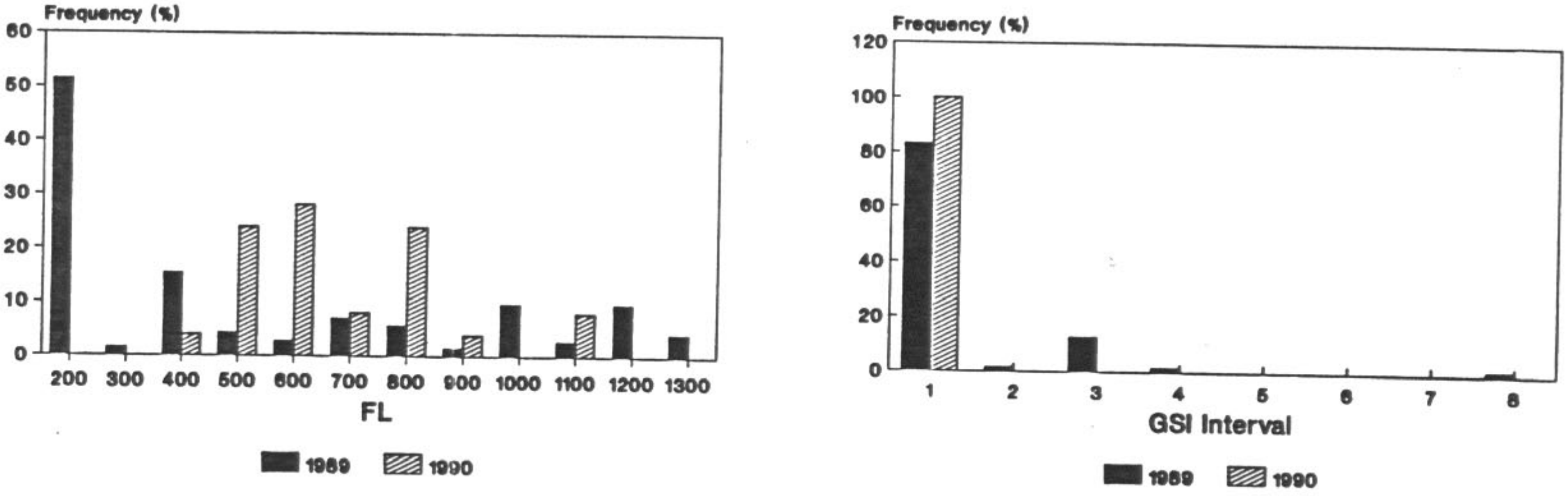


Figure 30.

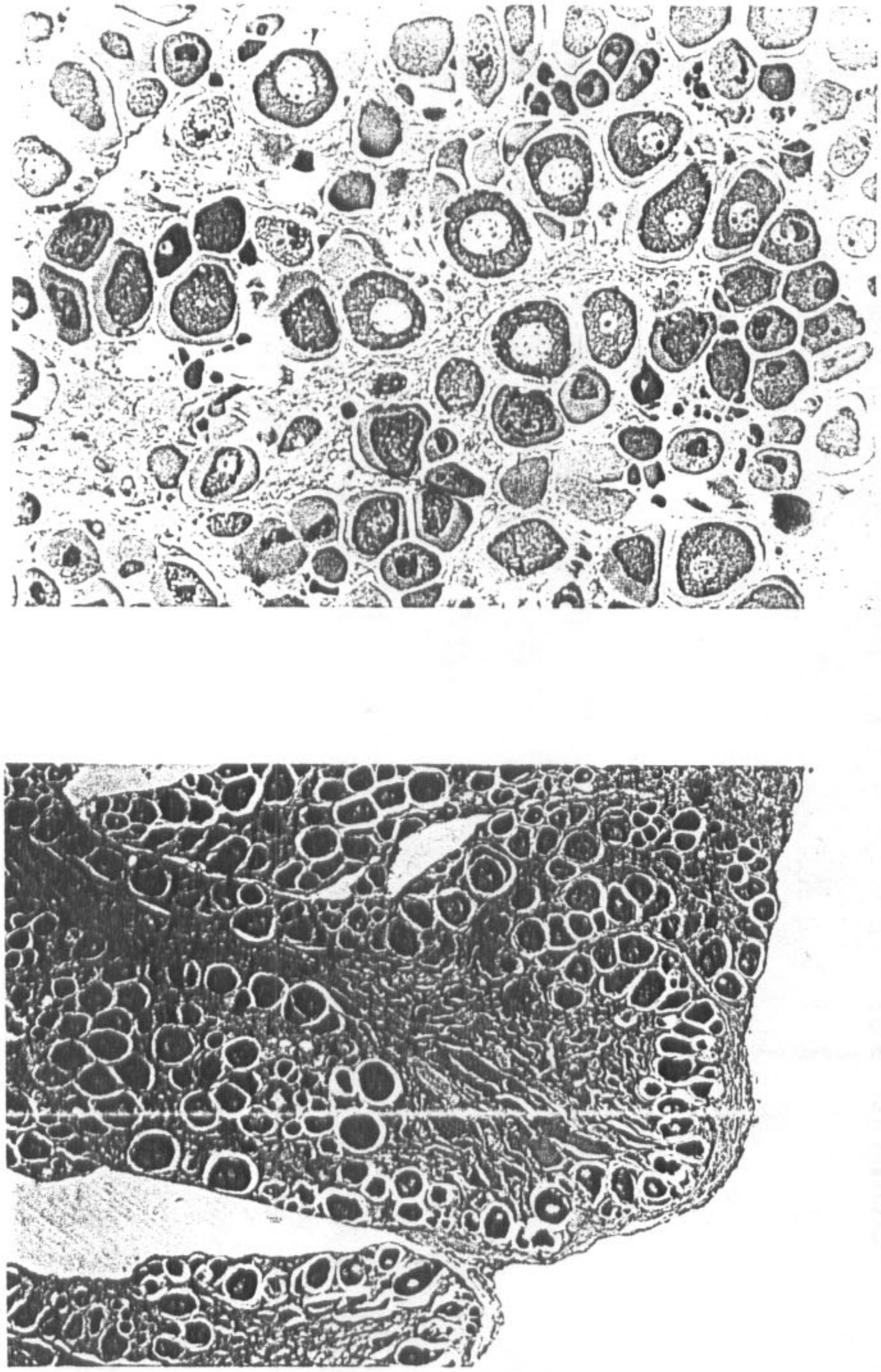


Figure 31.

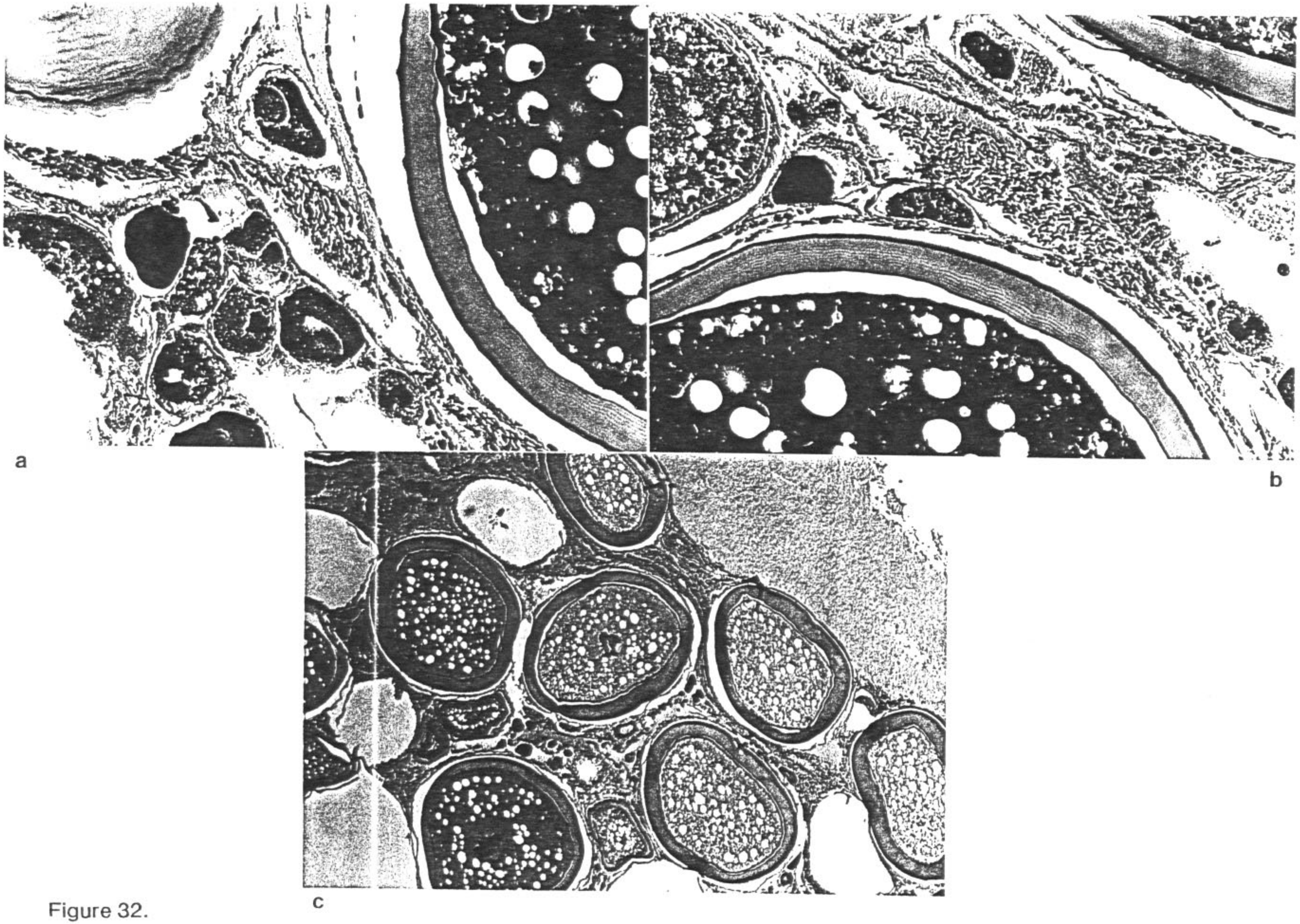


Figure 32.