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The Biology and Fishery of Atlantic Sailfish *Istiophorus platypterus*, from Southeast Florida

JOHN W. JOLLEY, JR.

Florida Department of Natural Resources
Marine Research Laboratory

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ABSTRACT

Jolley, John W., Jr. 1977. Biology and fishery of Atlantic sailfish, *Istiophorus platypterus*, from southeast Florida. Fla. Mar. Res. Publ. No. 28. 31 pp. During May 1970 through June 1974, 1300 Atlantic sailfish were examined from sport landings primarily in southeast Florida. Dorsal and anal fin spines were removed from 635 and examined for "annular" marks. Fin spine sections from 149 specimens (24%) were legible. Ages ranged from 0 to VIII, ages III and IV were most numerous. Mean age of males and females was about IV; maximum age may be IX or X. Inspection of the age-weight relationship suggested that mean weight attained at ages I-III was about 50% less than previous estimates using the length-frequency method. Age-weight relationships between males and females were compared by analysis of covariance; regression coefficients (b) differed significantly (P = .05). Growth was not further analyzed because of insufficient sample size.

Regressions of body length, eye-to-fork length and total length on trunk length were highly correlated. Mean size of 499 males and 621 females was 15 kg (120 cm TKL) and 19 kg (127 cm TKL) respectively. Approximately 80% of the sample weighed 8.4 to 27.8 kg (110.0 to 139.5 cm TKL). Females predominated in total landings examined by 1.2 to 1 and were notably more prevalent in sizes $\geqslant$ 18 kg; the largest female weighed 43.2 kg (187.0 cm TKL). The 1970-71 and 1973-74 TKL frequency data compared favorably with those taken in 1953-55, indicating that the biological status of southeast Florida sailfish stocks remains healthy.

Reproduction was evaluated by microscopic examination of histologically prepared subsamples of gonadal tissues. Females reached maturity at between 13 and 18 kg (about 120 cm TKL). Major spawning classes measured 121 to 146 cm TKL. Males appeared to mature by 10 kg and at an earlier age than females. Most spawning took place during late May through early September. Fractional or multiple spawning also occurred. At least three batches of eggs may be shed, and a 33.4 kg sailfish may release as many as 4.8×10^6 ova per season. Observations about spawning behavior were similar to reports in previous studies.

Scombridae, Cephalopoda, Exocoetidae, Carangidae, Belonidae and Clupeidae were most common food items, indicating that diet had not changed in the past 20 years. Acanthuridae, Lobotidae, Scaridae, Serranidae and Syngnathidae were reported in stomach contents of Atlantic sailfish for the first time. *Hemiramphus* spp. and *Mugil curema* were most popular baits trolled for sailfish in southeast Florida. *Caranx crysos* and *Selar crumenophthalmus* were prominent live baits. Available information indicated that sailfish feed primarily during daylight.

Severe damage to sailfish by angling methods was caused by hooks perforating eyes and severing or partially tearing optic nerves and eye muscles. Everting the stomach did not cause any evident damage.

Broken and deformed spears and damaged fins were most common external abnormalities. Absence of one gonad and gonadal atrophy were also observed. Stomach and intestinal ulcers occurred, and both external and internal parasites were commonly observed.

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INTRODUCTION

Sailfish, *Istiophorus platypterus* (Shaw and Nodder) is a migratory pelagic fish found in all warm oceans of the world. In the western North Atlantic it commonly occurs to 35°N latitude with abundance greatest inside the continental shelf and/or near land masses (Ueyanagi et al, 1970). Sailfish belong to the family, Istiophoridae, which includes marlins and spearfishes. These billfishes are of growing worldwide commercial and recreational importance.

Sailfish are plentiful throughout most of Florida's offshore waters and have become one of the State's most highly prized marine recreational fishes (Figure 1). In 1975, its prominence was officially recognized when the Florida Legislature and Governor Reubin O'D. Askew designated sailfish as the State's official marine game fish. Sailfish in Florida are landed mainly by anglers for trophy mounting purposes, and the flesh is often smoked before consumption. Many sailfish are released by anglers. Today, sport catches between Fort Pierce and Miami, Florida probably exceed 10,000 fish annually. By comparison, average catch of sailfish and spearfish combined by Japanese commercial longliners was only 6,000 annually during 1962 through 1971 in roughly 3,000,000 square miles of the western North Atlantic Ocean (Fisheries Agency of Japan, 1965-1973). Apparently, southeast Florida's sport fishery for sailfish is one of the fastest growing and most intensive in the world.

Research on the biology of sailfish in Florida began in 1948 (Voss, 1953). Since that time more has been learned about sailfish biology than any other billfish. However, Beardsley, Merrett and Richards (1975) presented a synopsis on sailfish and pointed out several critical needs. Data on growth rates, age and size composition, maximum longevity, and size and age at first maturity are insufficient. In addition, significant differences exist in length-weight relationships of males and females (Jolley, 1974; and Wares and Sakagawa, 1974). Females are heavier for a given length, and females attain greater maximum size. Partial differential mortality of either sex and/or different growth rates could cause this size disparity between sexes. Also spawning frequency is not known and fecundity estimates have varied greatly among different researchers.

In 1970 the Florida Department of Natural Resources (FDNR) initiated studies to resolve some of the critical needs concerning biology of

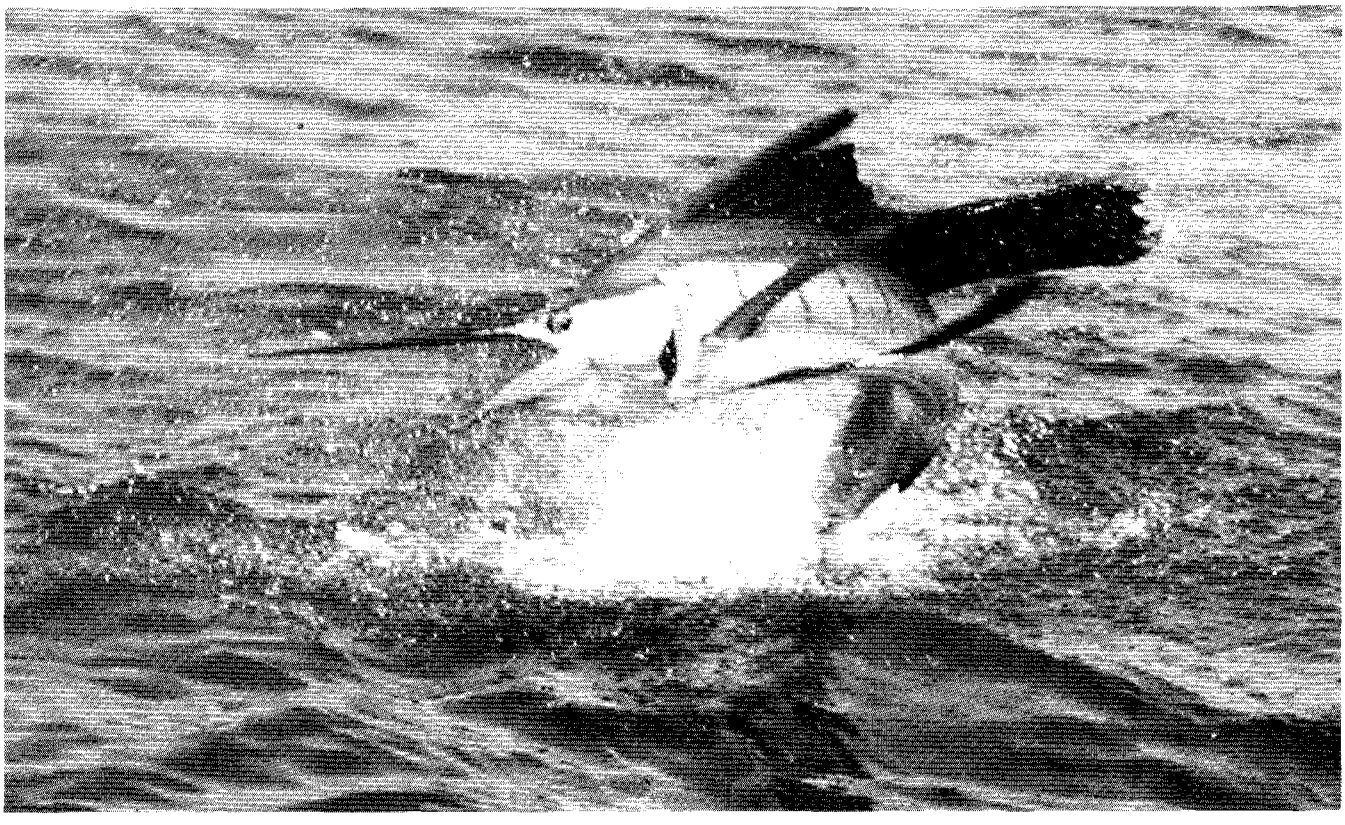

Figure 1. Sailfish are best known to anglers for their high speed runs, tail walking and twisting leaps in the air. Photo by Bounce Anderson, courtesy of the West Palm Beach Fishing Club.

sailfish with emphasis on determining the welfare of southeast Florida's sailfish stocks (Jolley, 1974). This report is the second in a series on the biology and sport fishery for sailfish in Florida waters. It contains additional findings concerning age and growth, size composition, sex ratio and sex-size differential, seasonal gonadal development, size and age at maturity, spawning time and frequency, fecundity, diet, abnormalities and several aspects about the fishery. This information should lead to greater understanding of sailfish population dynamics and ultimately to a better assessment of the biological status of sailfish stocks.

METHODS

During May, 1970 through June, 1974, 1300 sailfish were examined at taxidermy facilities and various other locations throughout southeast Florida. Collection and processing procedures remained as previously described by Jolley (1974). Total length (TL)--tip of the bill to a vertical line between the tips of the caudal lobes; trunk length (TKL)--posterior edge of the orbit to the origin of the caudal keels, after deSylva (1957); and body length (BL)--tip of the mandible to mid point on the posterior margin of middle caudal rays, after Rivas (1956) were taken throughout the study. In May, 1973, standard length (SL) tip of the bill to the middle caudal base was discontinued because of difficulty in determining the end point of the last hypural vertebra (Rivas, 1956). Eye-to-fork length (EF) posterior margin of eye (orbit) to the posterior margin of the middle caudal rays after Merrett (1968) was substituted, thus enabling additional length-length and length-weight comparisons. Age-length and age-weight relationship regressions were computed using logarithmic transformations of variates to assure normality. Stomach contents from 778 sailfish were recorded and identified to family when possible. Food preference analysis was based on frequency of occurrence. Everted stomachs and additional observations about specimens and the fishery were also recorded.

SELECTIVITY OF SAMPLING

Specimens were selected from the entire size range available during each sampling trip. Sailfish weighing less than 5 kg (11 lb) and exceeding 32 to 34 kg (70 to 75 lbs) were not frequently available but were examined at every opportunity. A criticism that a bias may exist at taxidermy houses because large sailfish are more sought after by anglers for trophy mounting purposes did not appear valid. In fact, small sailfish are often more highly prized as trophies (Jesse Webb, Pflueger Taxidermy, personal communication). Also, mean size of specimens landed for trophy mounting was similar to the mean size of specimens landed for other purposes (i.e. consumption).

SELECTION OF FIN SPINES FOR AGING

Fin spines and rays have been used successfully in aging studies by Holtzmayer (1924), Boyko (1946), Pantulu (1961), Holden and Meadows (1962), Bilton and Jenkinson (1969) and Huff (1975). Dorsal and anal fin spines were chosen for this study because they were the only readily accessible bones that exhibited distinct circuli which increased in number with fish size. Problems associated with other structures for aging sailfish have been briefly described (Jolley, 1974:84).

FIN SPINE DESCRIPTION

The first dorsal fin contains 37 to 48 ($\bar{x}$ = 43.66) spines and rays and the first anal fin has 8 to 16 elements ($\bar{x}$ = 12.80) (Morrow and Harbo, 1969).

At least the first dorsal fin spine is rudimentary, and the second is usually too small for aging (also see Rivas, 1956:26). Spines III, IV and V are larger, relatively easy to cut and can be used for age assessment. Remaining elements have thin shafts that are easily broken during removal. In large sailfish and other marlins these latter elements, when carefully processed, often provide legible sections and their usefulness in this regard should be thoroughly evaluated. Anal fin spines II and III were also suitable for aging.

Gross morphology of dorsal and anal fin spines is basically similar. Each is a single unit composed of an expanded base (articulary head) with lateral condyles and a shaft (Figure 2). Muscles attached to the condyles function in deploying fins. Growth of sailfish spines is believed similar to that of cod, in which cones are laid down one upon the other (Goodrich, 1904).

Cross sections of spines are eliptical in shape and bilobed (Figure 3). Internal morphology is characterized by a centrally located soft core, amber in color. This area (Figure 3) appears to be a vascular matrix similar to the marrow common in bones. The core is variable in size. Broad opaque bands and narrow translucent circuli alternate outward from the center. Similar zones were noted in the catfish, *Mystus gulio* (Hamilton) by Pantulu (1961). Bands and circuli appear most distinct laterally because of their wider separation. In large

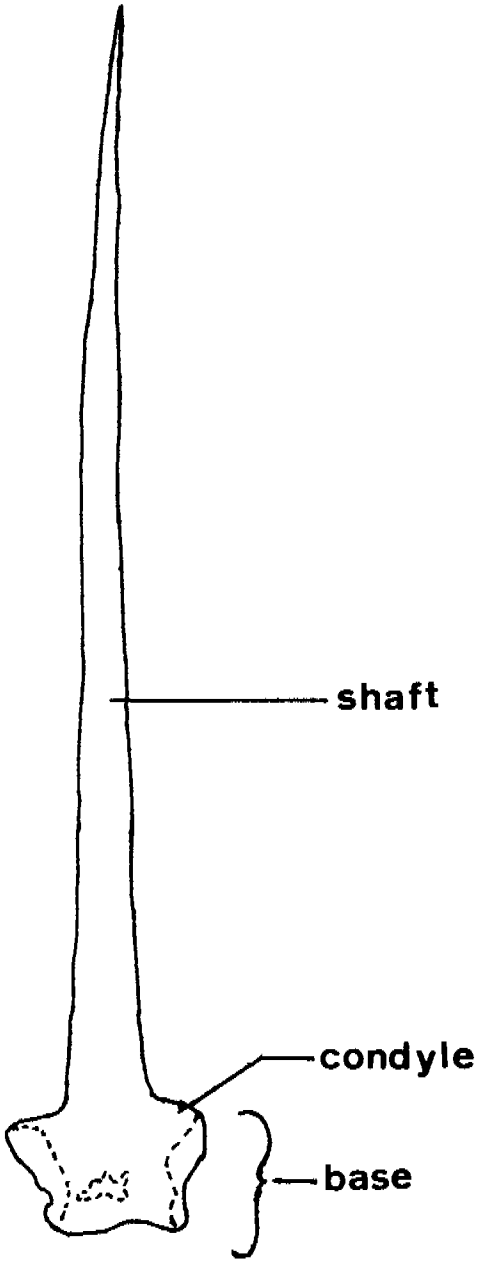

Figure 2. Skinned and dried dorsal fin spine ready for sectioning.

sailfish these areas become crowded near the margin, making age assessment more difficult.

SPINE PROCESSING AND EVALUATION

Spinal cross sections were initially taken with a Dremel Tool as described by Jolley (1974) but were later obtained with a standard jeweler's hand saw and No. 4 blades. The latter technique was described by Evans (1969:36-37) and Wares (Paul G., NOAA — NMFS, personal communication) for cutting Pacific billfish spines and has also been used for cutting sections of sturgeon pectoral fin spines (Huff, 1975). This technique was faster and reduced burning and cracking problems experienced using the Dremel Tool.

Sections were evaluated as follows: each major (translucent) circulus was counted as an "annulus" and the total number of these recorded. Margins were either translucent (ring forming, age N+) or opaque (no ring formation, age N). Age N+ was utilized as age N+1 in all calculations.

Measurements using an ocular micrometer were obtained only from sections cut at 2.5 mm above the condyles of fourth (IV) dorsal fins spines. Most legible (right or left) lobe of each section was measured (Figure 3) and the following measurements recorded: 1) *spine radius* — maximum lateral distance (straight line) from the estimated center of the core to the right or left side of each section (selection of a central starting point was always the most critical factor affecting measurements and calculations); 2) *radius to each successive annulus* — distance from the estimated center of the core to outer edge of each translucent ring; 3) marginal increment — maximum lateral distance between outer edge of the last annulus and the margin of each section. General legibility of sections was labeled as good, fair, poor or difficult.

Results were accepted and recorded for age when three independent readings were in agreement. Sections of good and fair legibility that yielded unacceptable readings were reevaluated. Examination of additional dorsal and anal spine sections from the same fish frequently resolved discrepancies. Occasionally, age could be determined when partially obscured annuli were discovered in the vascular core of one or more additional spine sections.

GONADAL EVALUATIONS

Sex and gonadal development were initially determined by gross examination of both gonads. However, microscopic evaluations were required for verification of gonadal categories. Subsamples

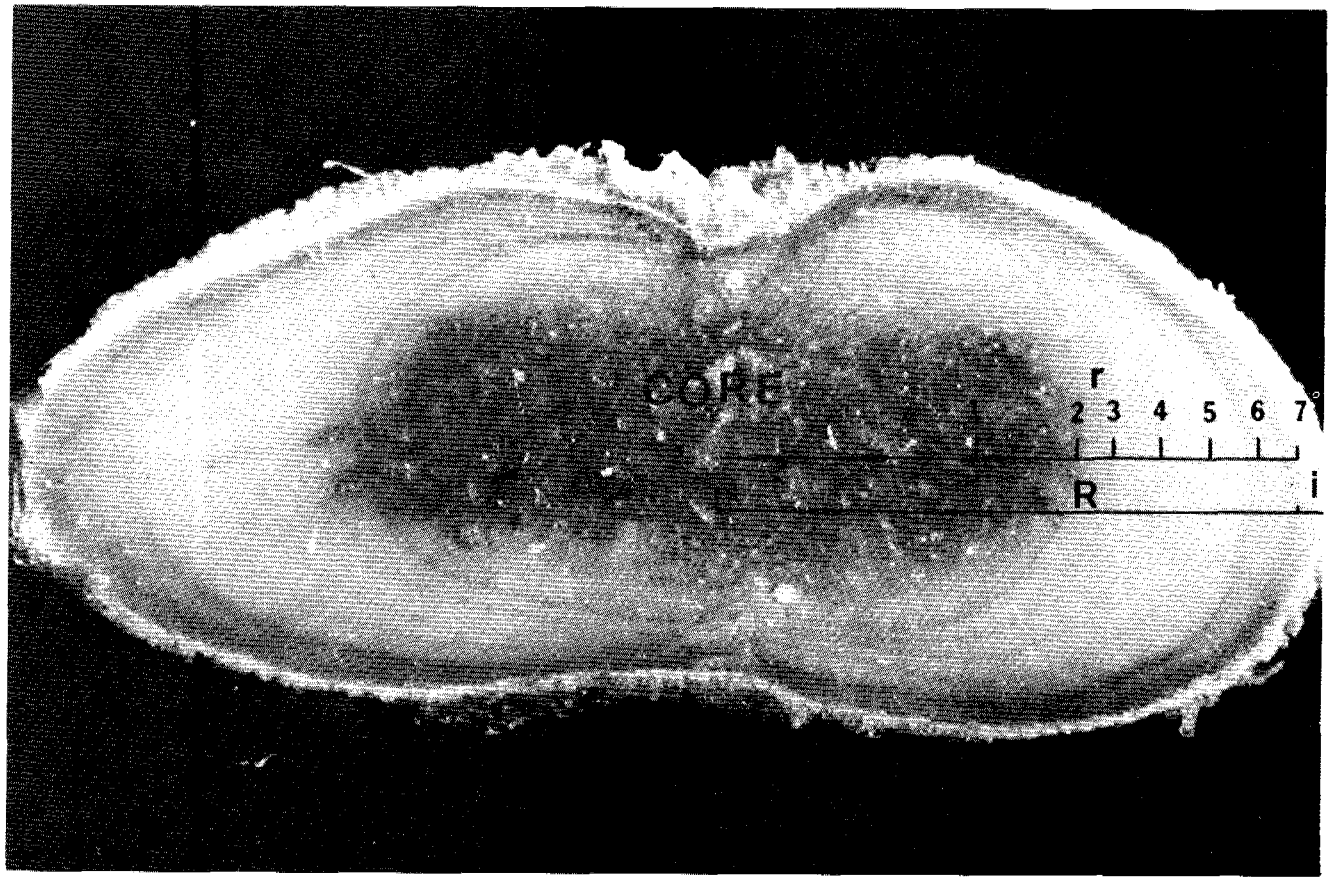

Figure 3. Cross section from a fourth (IV) dorsal fin spine showing internal structure: core, spine radius (R), radii of each successive annulus (r) and marginal increment (i). Note obliteration of first annulus by an extensive vascular core.

of ovarian and testicular tissue were removed from the mid-portion of either the right or left gonad and initially preserved in Zerker's fixative and later rinsed in water and stored in Lugol's solution for histological preparation (Jolley, 1974:83-84). These samples were considered adequate for determination of seasonal gonadal development.

Ovarian tissues were examined in detail and classified into the following five categories: 1) immature, 2) resting, 3) active, 4) ripe and 5) spent (Table 1). Oogenic evaluation was based upon the five progressive cellular stages described for red grouper, *Epinephelus morio* (Valenciennes), by Moe (1969:14-18). Size and relative abundance of each oocytic stage determined ovarian development. Ten to thirty ova of each stage were measured at random using an ocular micrometer. Measurements recorded in ocular micrometer units (omu) were later converted to microns (μ). Only oocytes of reasonably rounded appearance which had been sectioned through the center (nucleus) were measured. Ranges and mean diameters were recorded for each stage (Table 2). The shrinkage factor during histological preparation was estimated to be approximately 10 to 30%.

Removal of whole ripe ovaries for additional fecundity estimates followed earlier descriptions by Jolley (1974:84) and provided a check of previous estimates. Ripe (stage V) oocytes from a total of 10 ovaries were counted and measured. These estimates may be conservative because of the inevitable loss of some stage V oocytes during capture and handling.

Testicular tissues were examined and then categorized according to the extent of tubule formation (Merrett, 1970:361) and proliferation of five spermatocyte stages following Bruger (1974:14-16). Nevertheless, spermatogenesis was not as readily separated into developmental catagories as was oogenesis, and thus seasonal progress in males has not been emphasized.

TABLE 1. A GENERALIZED CLASSIFICATION OF OVARIAN DEVELOPMENT IN ATLANTIC SAILFISH FOR DETERMINING SPAWNING TIME AND MATURITY.[1]

IMMATURE — Ovaries small, compact and weigh < 100 g with no evidence of having spawned; tissue pink. Fibrous connective tissue septa well developed and often connected centrally. No oocyte development in youngest specimens but oogonia and stages I and II oocytes become progressively more numerous with age and seasonal development. Oocytes not visible to naked eye. Lumen, if present, surrounded by connective tissue.

RESTING — Mature resting ovaries remain compact but weigh > 85 g. Muscular ovarian tunic well developed and thick. Color of tissue pinkish-orange to dark red. Stage II oocytes dominate and are arranged into well defined rows called lamellae. Vitellogenesis may have occurred previously but has ceased temporarily. Rejuvenated oocytes (Figure 27) may be numerous. Lumen present in post-spawning adults and *not* surrounded by connective tissue.

ACTIVE — Ovaries enlarging because of vitellogenesis. Weight $\geqslant 200$ g (1-9% of total body weight); color changes from dark red to yellowish-orange. Oocytes first become visible to naked eye. As development proceeds, stages III and IV oocytes become progressively more numerous. Simultaneously, lamellar integrity lessens and diameter of the ovarian tunic decreases.

RIPE — Ovaries turgid, attaining maximum size of 2-4 kg and occupying most of the body cavity. Translucent stage V oocytes visible through a very thin and now transparent ovarian tunic. Developing stages III, IV and ripe stage V oocytes dominant. Lamellar integrity is completely lost. Ripe oocytes are rupturing from the follicles and can be extruded with light pressure.

SPENT — Ovaries become flaccid and greatly reduced in weight from active and ripe phases. Diameter of the ovarian tunic rapidly increases; tissue often pitted in appearance with yellow egg remnants present. Color varies progressively from reddish-orange to dark red; lumen usually enlarged. Any advanced oocytes that are still retained often are degenerating and being absorbed. Stage II oocytes again dominate throughout the recovering ovary, and many advanced stage II's appear to be undergoing rejuvenation.

[1] Males produce sexual products earlier in the season and remain in active-ripe condition longer than females. This is probably a biological advantage which enhances successful spawning by insuring the availability of viable males when females are ready to shed their eggs. Therefore, a more precise estimate of sailfish spawning seasonality is derived from examining ovarian tissues.

TABLE 2. SIZE OF ATLANTIC SAILFISH OOCYTES FROM HISTOLOGICAL PREPARATIONS

Developmental Stages	Number Ovaries Examined	Diameter Range (μ)	Mean Diameter (μ)
Oogonia	10	6-20	11.9
Stage I	121	10-72	30.4
Stage II	124	40-168	73.1
Stage III	92	80-420	174.0
Stage IV	58	230-810	477.0
Stage V	17	550-1255	885.5

RESULTS AND DISCUSSION

AGE AND GROWTH

Fin spines were examined from 635 sailfish; about 24% (N=149) were legible, and illegibility appeared to be an inherent but unpredictable characteristic. Often double, false and vague annuli precluded age assessments. Such complications have been found in bony structures of other fishes; and in sailfish spines this problem was very common. Ages ranged from 0 to VIII; age groups III and IV were most numerous (Table 3). Assuming that the translucent check marks were annular (Figures 4-9), mean age of males and females was about four years. A female sailfish from age group VIII measured 150.5 cm (59.3 in)

TABLE 3. AGE COMPOSITION OF ATLANTIC SAILFISH USING ONLY LEGIBLE DORSAL AND ANAL FIN SPINE SECTIONS
AGE N+ = N + 1

Number of annuli	0	I	II	III	IV	V	VI	VII	VIII	TOTAL
Frequency										
Males	1	5	11	18	23	13	4	—		75
Females	1	5	5	19	29	9	5	—	1	74
Total	2	10	16	37	52	22	9	—	1	149

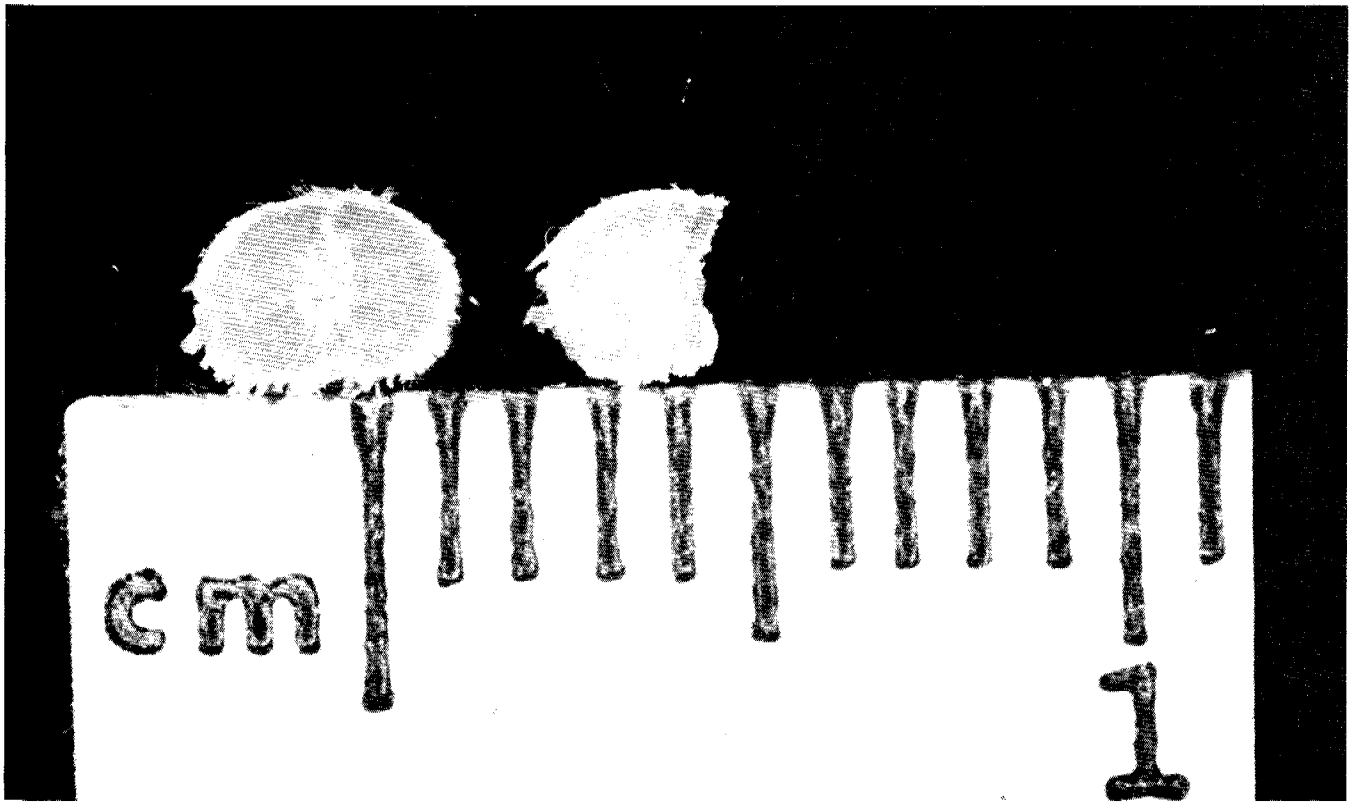

Figure 4. Dorsal fin spine sections from an age class 0, 2.8 kg (75.5 cm TKL), female Atlantic sailfish caught August 1, 1971.

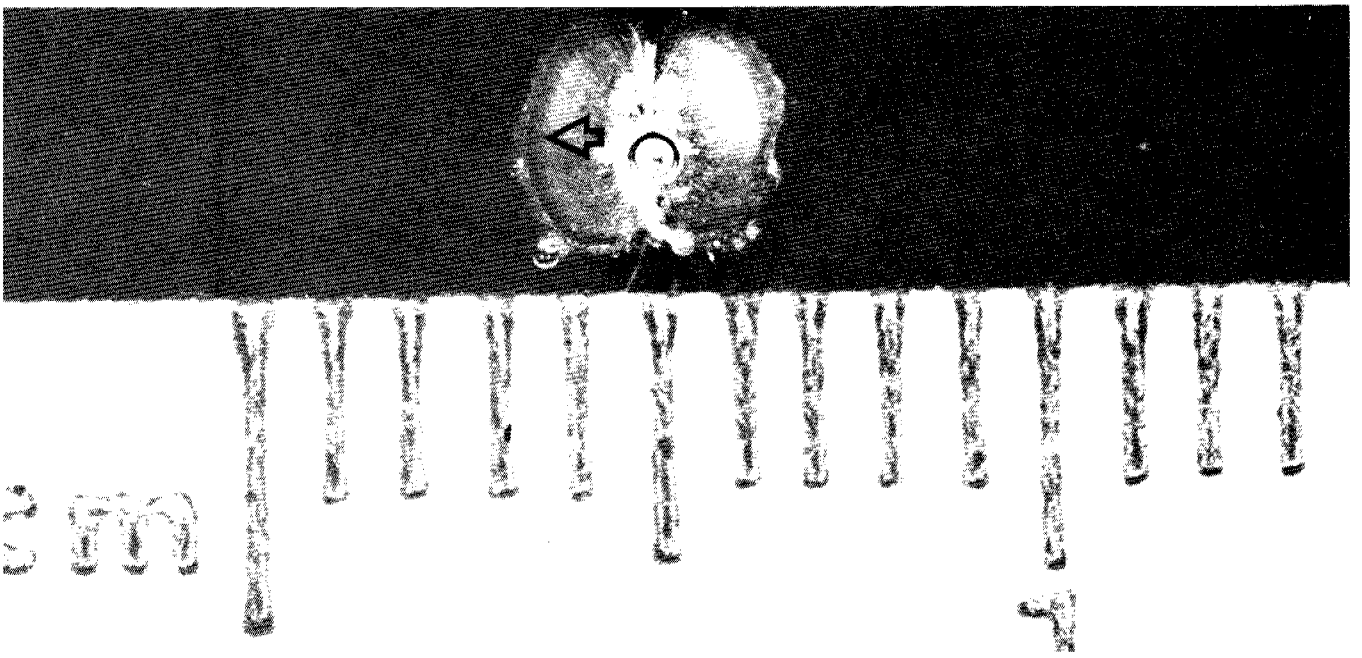

Figure 5. Section from an age class I, 3.6 kg (81.5 cm TKL), female taken off Palm Beach March 28, 1973. Note that formation of the annulus was recently completed on the margin.

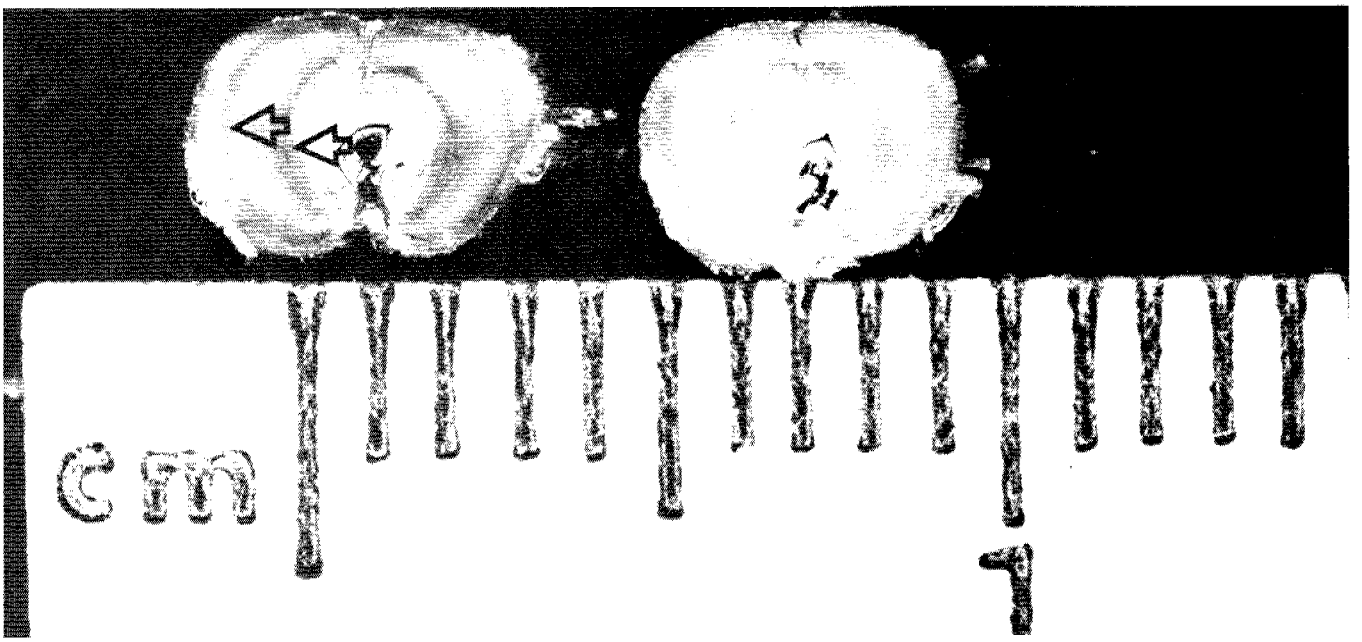

Figure 6. Sections from an age class II, 8.2 kg (100 cm TKL), male taken off Jupiter March 30, 1971.

TKL (about 8 ft TL) and weighed 37.4 kg (82.5 lb) but was not the largest specimen examined, suggesting that maximum age is greater, possible IX or X.

Voss (1972: 8-9) suggested that for sailfish, weight would be a finer criterion for measuring absolute growth. This was true for white marlin, ***Tetrapturus albidus*** Poey (deSylva and Davis, 1963). I found that weight gave consistently higher correlations with age than did length, and thus chose this parameter.

The age-weight relationship indicated that mean weight attained at ages I through III (Figure 10) was about 50% less than that reported by

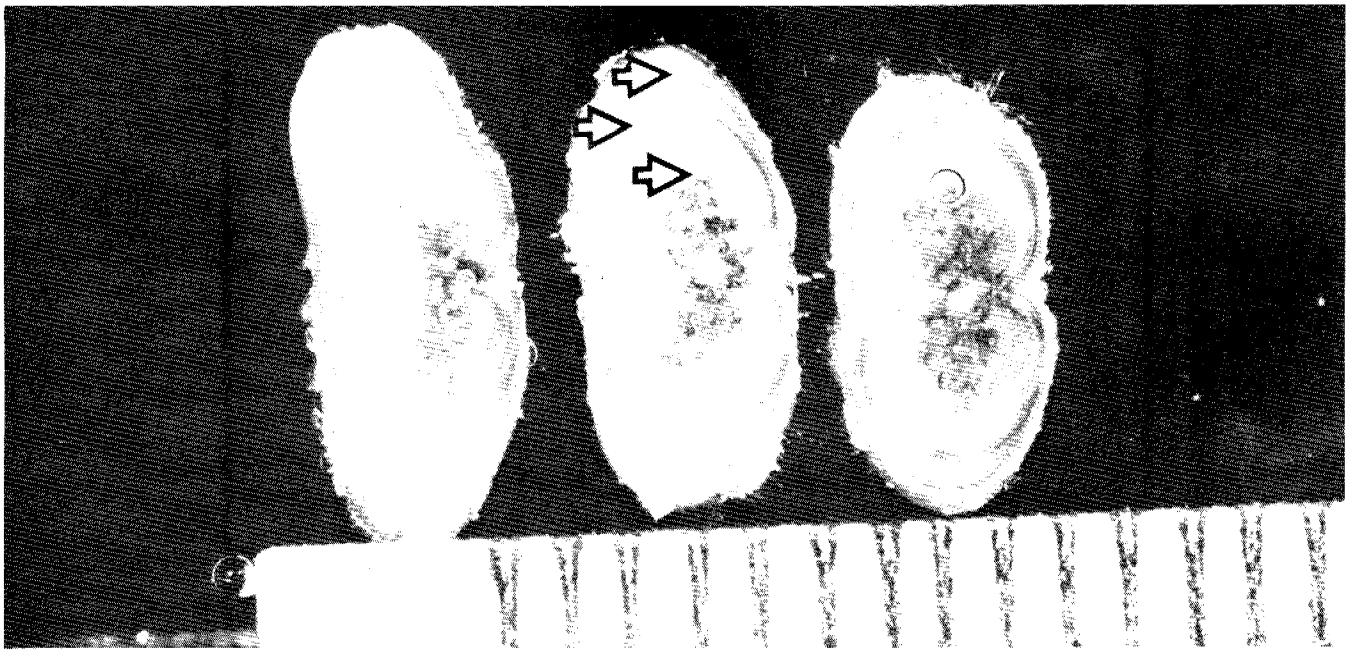

Figure 7. Sections from an age class III 13.2 kg (108.5 cm TKL), male taken off Palm Beach February 5, 1971.

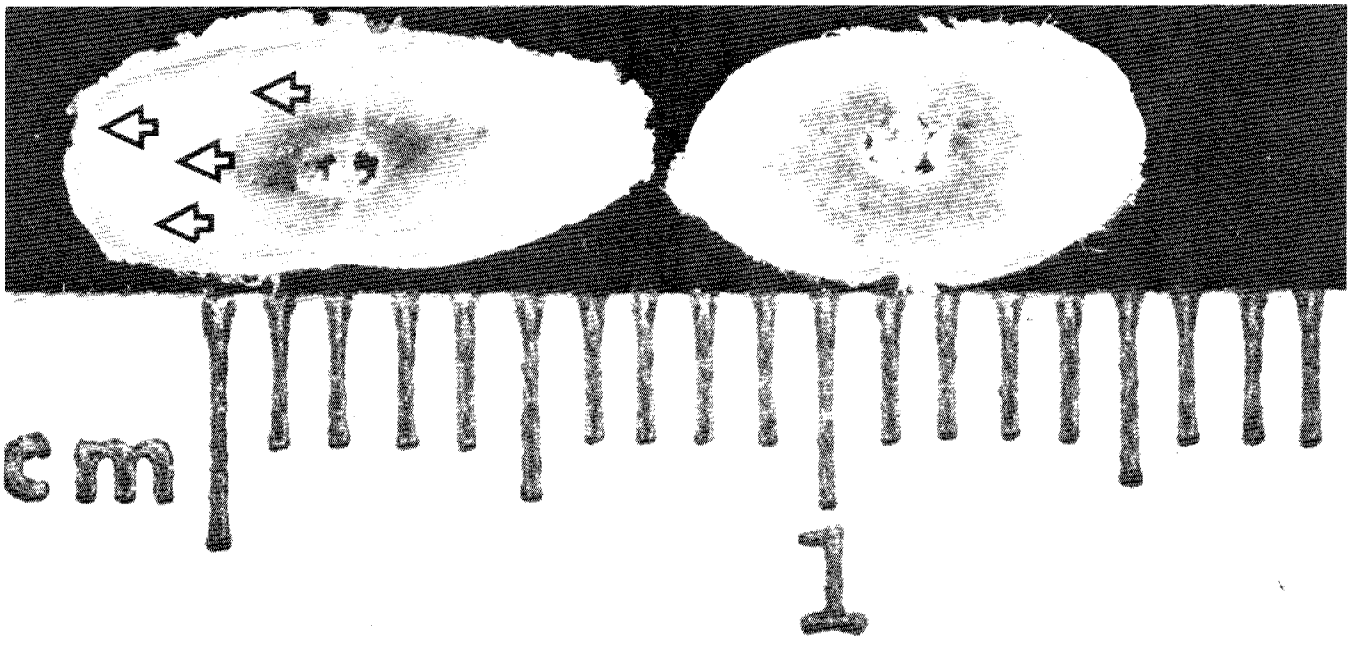

Figure 8. Sections from an age class IV, 16.0 kg (123 cm TKL), male taken off Palm Beach October 6, 1971.

deSylva (1957). This was a consequence of aging techniques used in each study.

Age-weight relationships between male and female sailfish were compared by analysis of covariance as described by Snedecor and Cochran (1967). Regression coefficients (b) differed significantly ($P = .05$). Table 4 contains regression data for possible future comparisons. Growth rate has not yet been fully analyzed using back calculations of theoretical weights (or lengths) for comparison with empirical data because of insufficient sample size. Evaluation of additional sailfish spines (August, 1973 - June, 1974 and those from future collections) will be made when time permits, in order to make such calculations available and further test these findings.

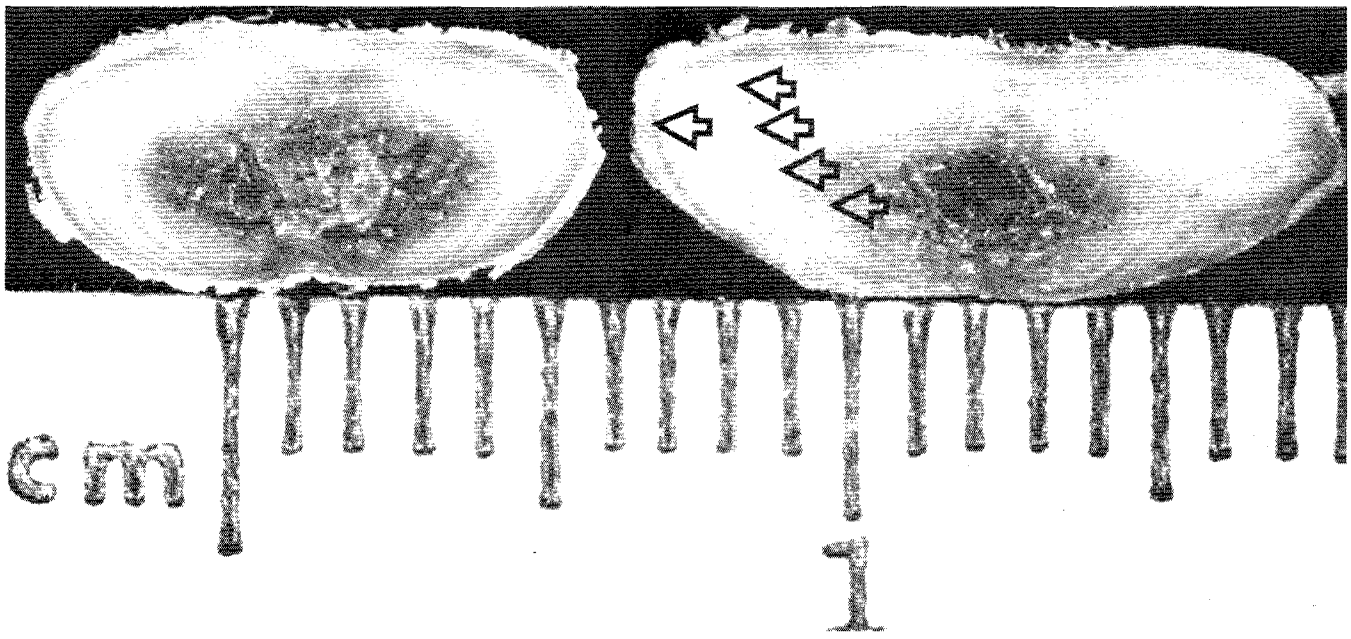

Figure 9. Sections from an age class V or VI, 19.2 kg (128 cm TKL), female taken off Palm Beach October 1, 1970. Note faint but probable annulus at the periphery of the vascular core; one other annulus may be obliterated.

TABLE 4. ATLANTIC SAILFISH REGRESSION DATA, AGE-WEIGHT RELATIONSHIP*

	N	Σx^2	Σy^2	Σxy	$\bar{X}$	$\bar{Y}$	b	a	r
Males	74	14.5618	15.7652	12.9320	1.1807	2.5330	0.8881	1.4844	0.8535
Females	73	13.6360	19.5059	14.2948	1.2337	2.6303	1.0483	1.3369	0.8765

*($\ln Y = \ln a + b \ln X$)

VALIDITY OF THE AGING TECHNIQUE

Annual layering in fin spines and rays of several fishes was first suggested in 1916 by Kler and later confirmed in 1924 by Holtzmayer (in Menon, 1950). Criterion for such work were similar to those established for scales by van Oosten (1929):

1. The aging structures must develop early in life and remain constant in number and identity.
2. Growth of the structure must be proportional to growth of the fish.
3. Check marks (annuli) must form at approximately the same time each year.
4. Theoretical lengths or weights back calculated from various annuli must have positive correlations with empirical data.

Sailfish dorsal fin spines appeared to satisfy the first three of these criteria: 1) spines developed early in larval stages (Voss, 1953), and according to Gehringer (1956:146) spination was completed in a specimen measuring 11.3 mm SL; 2) width of the fourth dorsal fin spine, measured at 0.5 cm above the condyles, was proportional to TKL (Jolley, 1974:84). Also, total number of annuli in different spines from the same sailfish was always equal; and 3) evaluation of margin status (translucent or

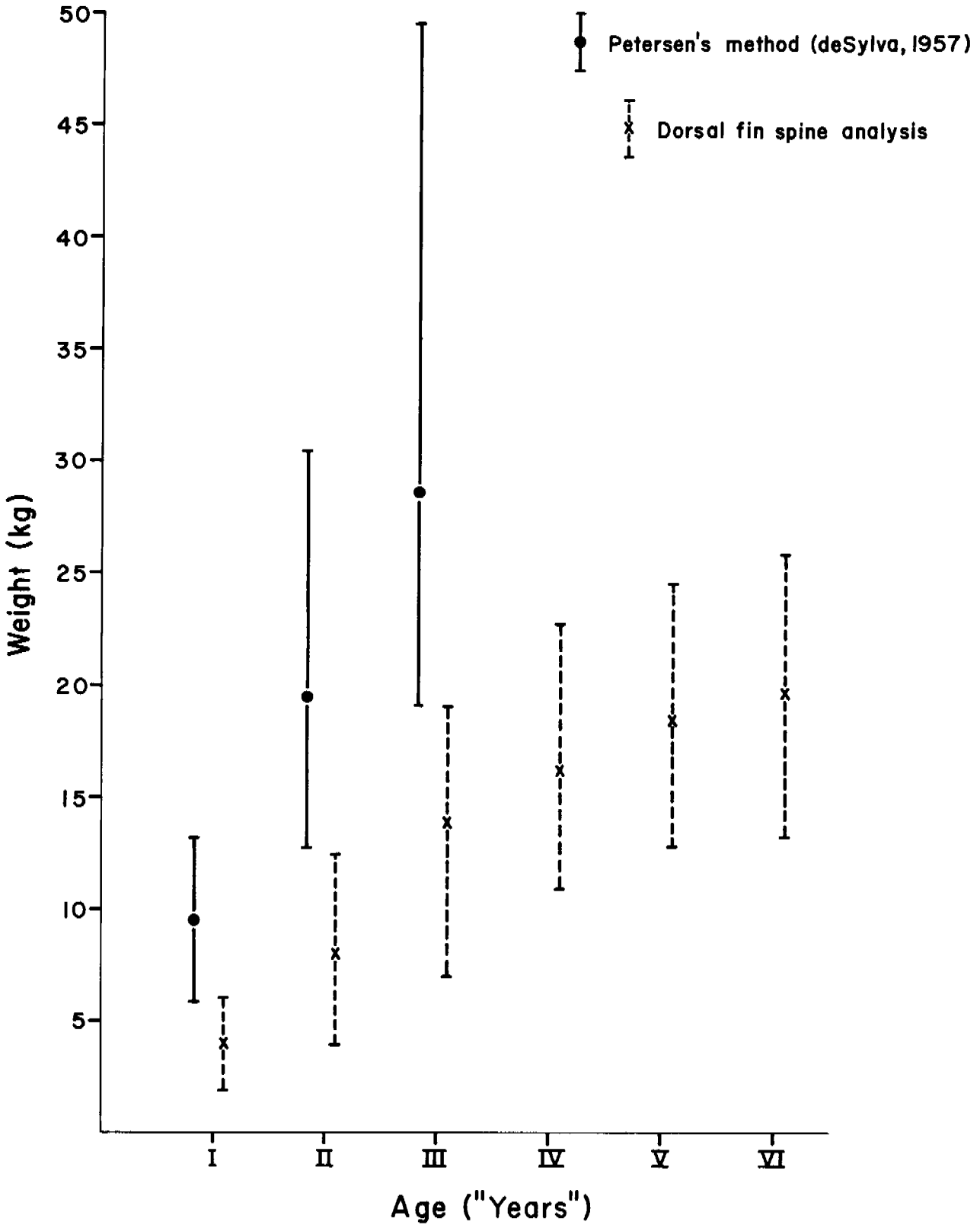

Figure 10. Comparison of the age-weight relationships of Atlantic sailfish (sexes combined) using two different aging techniques. Range and mean weight are plotted for each age group. Many large sailfish $>$ 20 kg could not be accurately aged by the fin spine method, and therefore maximum size of age groups $\geq$IV may not be adequately represented.

opaque) with sexes and all age groups combined showed a lengthy but annual cycle of formation (Figure 11). Opaque bands formed primarily during spring and summer and the translucent annuli during fall through winter. Persistent occurrences of translucent margins during spring and summer were probably due to thinness near margins. A similar problem was noted by Dark (1975) for Pacific hake, *Merluccius productus* (Ayres). Repeated and prolonged immersion of fin spine sections in glycerine also increased translucency of margins.

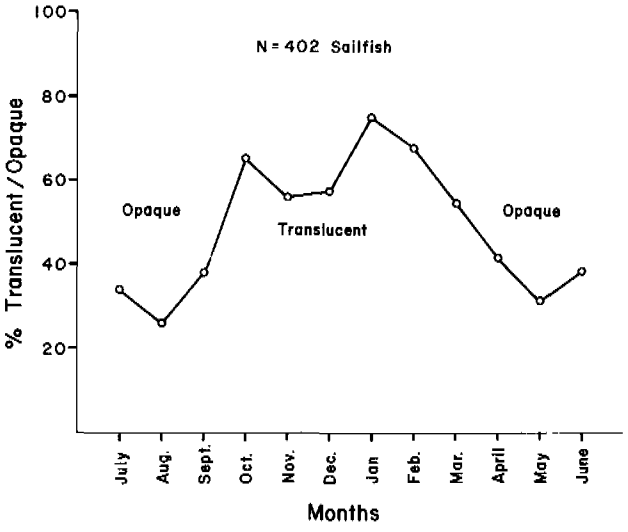

Figure 11. Pooled monthly percent margin translucency and opacity for Atlantic sailfish (sexes and all age groups combined, 1970-73). Evaluation of margin status for about 33% (N=233/635) were unacceptable.

Analysis of marginal increment for time of annulus formation was inconclusive partially because of small sample size. Also inherent structural characteristics of sailfish spines and cutting procedures preempted accurate measurement of marginal increments.

Extended periods of annulus formation are not unusual for tropical and sub-tropical fishes, especially when spawning periods are prolonged and geographical range of the population is great. In Florida waters for example, annuli in otoliths of red grouper (Moe, 1969) form from March through July. In dolphin, *Coryphaena hippurus* Linne, annuli are formed on scales in November through February (Beardsley, 1967). According to Bruger (1974) bonefish, *Albula vulpes* (Linne), form annuli on scales year round because spawning occurs year round. King mackerel, *Scomberomorus cavalla* (Cuvier), and Spanish mackerel, *S. maculatus* (Mitchell), form annuli in otoliths predominately during April through June and May through July, respectively (Beaumariage, 1973; and Powell, 1975).

Separate age groups can form annuli at different times. Moe (1969) described such phenomenon and stated that the lag in annulus formation of older age groups probably reflected lower metabolic rates and shorter annual growth periods. Sample size presently precludes this analysis with sailfish.

Knowledge about time of first annulus formation and accurate measurement of its radius should be stressed in future studies. Since most annuli are formed during the fall and winter, it is possible that the first "annulus" was deposited prior to a full year's growth (see Figures 4, 5 and 6). Such a phenomenon would support deSylva's (1957) contention that many small, immature sailfish during fall and winter are young of the year and may be entering the fishery for the first time. My age-weight relationship (see Figure 10) might more accurately reflect size of ages .5, 1.5, 2.5, etc. This would help to explain notable size differences between my age group I sailfish and those six months old by deSylva (1957). It would also indicate that initial growth is very rapid. As previously stated insufficient sample size precluded development of theoretical growth curves through back calculations.

SIZE COMPOSITION

Mean size of 499 males and 621 females was about 15 and 19 kg (33 and 42 lb) and 120 and 127 cm (47 and 50 in) TKL, respectively. Combined mean size was 17 kg (37 lb) and 124 cm (49 in) TKL (also see Voss, 1953:223; and Jolley, 1974:85).

Sailfish weighing 0.4 kg (1.0 lb) were landed by anglers each year of this study but were very rare (<1%). Specimens ≤ 8.4 kg (18.5 lb) and ≤ 110.0 cm (43.3 in) TKL accounted for about 10% of total landings. Approximately 80% weighed 8.4 to 27.8 kg (18.5 to 61.0 lb) and measured 110.0 to 139.5 cm (43.3 to 54.9 in) TKL. The largest sailfish was a female weighing 43.2 kg (95.0 lb) and measuring 187.0 cm (73.6 in) TKL.

Figure 12 shows sailfish TKL frequency distributions for 1970-71 and 1973-74. These data appeared quite similar to 1953-55 combined adult TKL frequencies described by deSylva (1957). In both instances most abundant size groups measured between about 106 to 145 cm (42 to 57 in) TKL. Such similarity between data collected almost 20 years apart suggests that the biological status of southeast Florida sailfish stocks remains healthy.

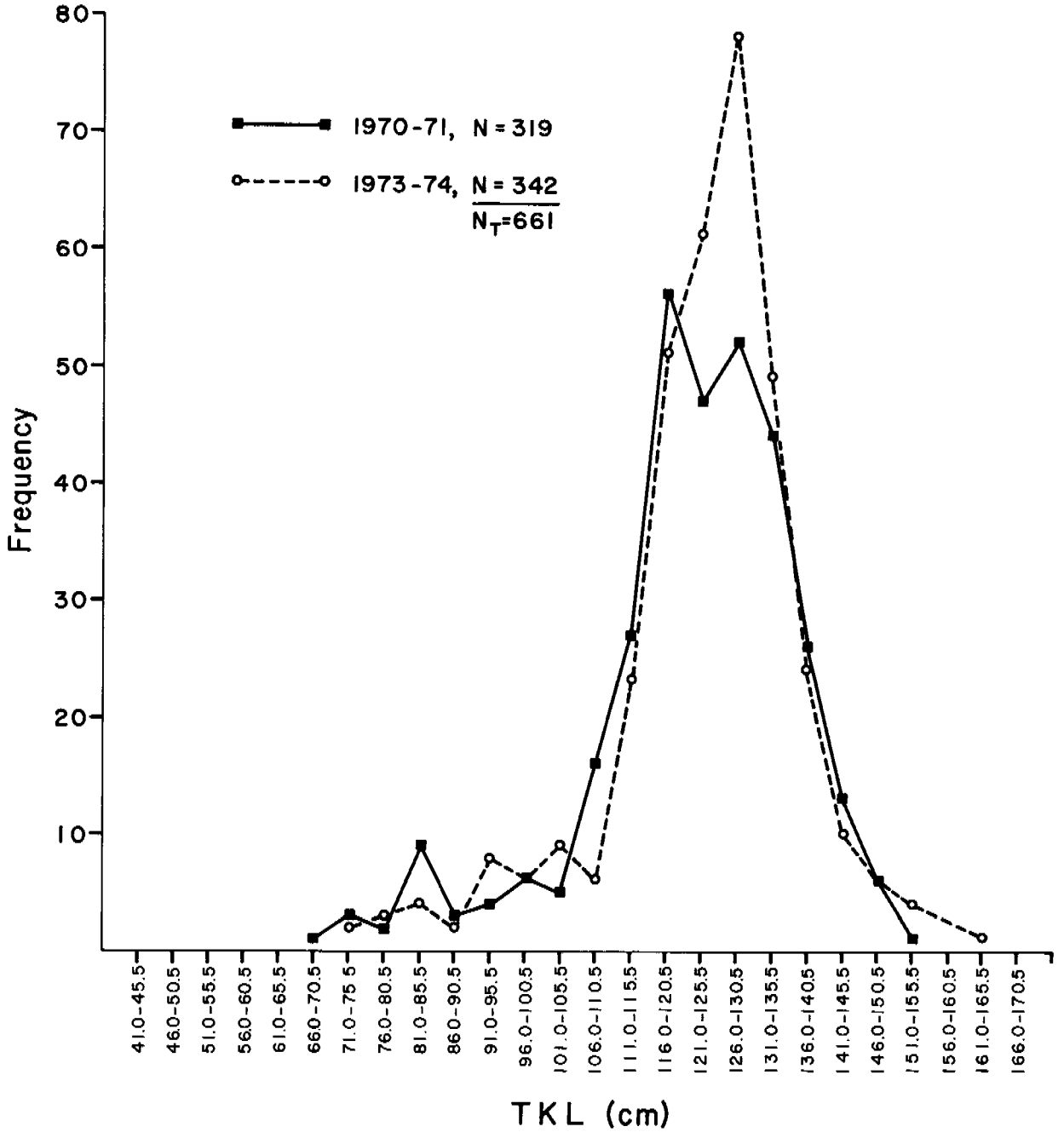

Figure 12. Trunk length frequency distributions of Atlantic sailfish (sexes combined) examined during May-June 1970-71 and 1973-74.

LENGTH-LENGTH RELATIONSHIPS

Body, eye-to-fork, trunk and total length measurements have been used in earlier studies of Atlantic and Pacific sailfish. Regressions of body length, eye-to-fork length and total length on trunk length are provided for easy conversion among Atlantic specimens (Figures 13-15). All are linear and were fitted by least squares regression. The total length - trunk length regression appeared almost identical to that given by deSylva (1957).

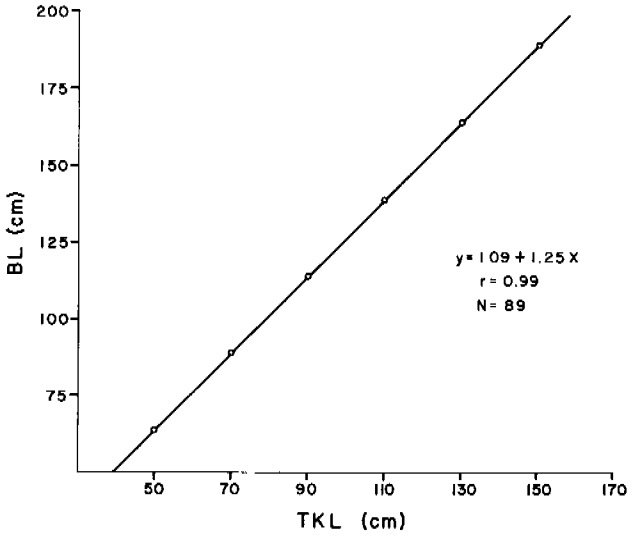

Figure 13. Regression of body length on trunk length in Atlantic sailfish.

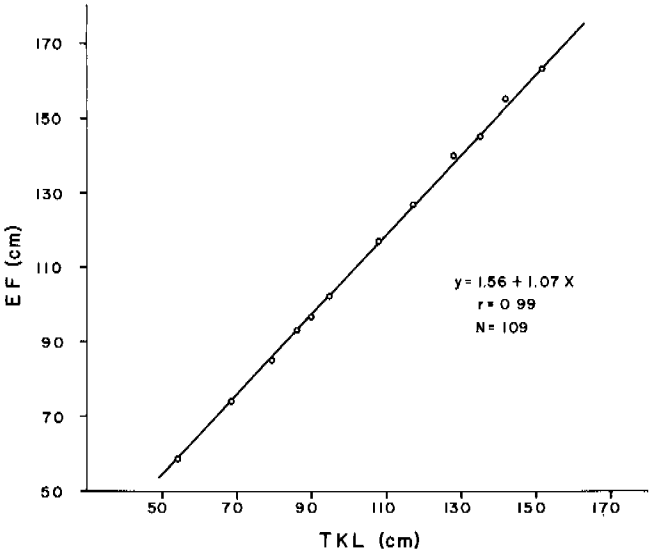

Figure 14. Regression of eye-to-fork length on trunk length in Atlantic sailfish.

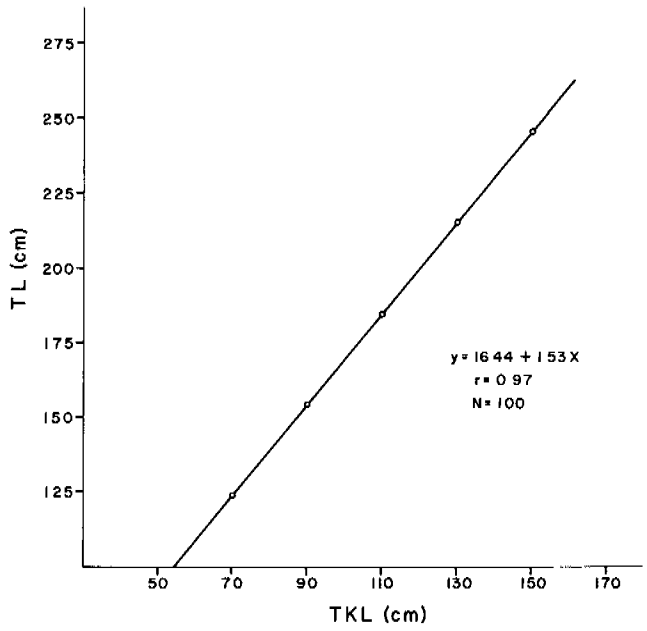

Figure 15. Regression of total length on trunk length in Atlantic sailfish.

SEX RATIO AND SIZE DIFFERENTIAL

Sex ratios fluctuated with seasons (Figure 16) and were not similar for all years. Overall, females outnumbered males by about 1.2 to 1. A predominance of females in the sport catch has also been reported for the northern Gulf of Mexico (Nakamura, 1971; Nakamura and Rivas, 1972; Rivas, 1973, 1974; and Rivas and Pristas, 1975).

Sailfish ⩾ 18 kg (40 lb) were predominately females by a margin of 2.4 to 1. For specimens ⩾ 23 kg (50 lb) the ratio was 7.7 to 1. Large ovaries in ripe females did not affect this size differential

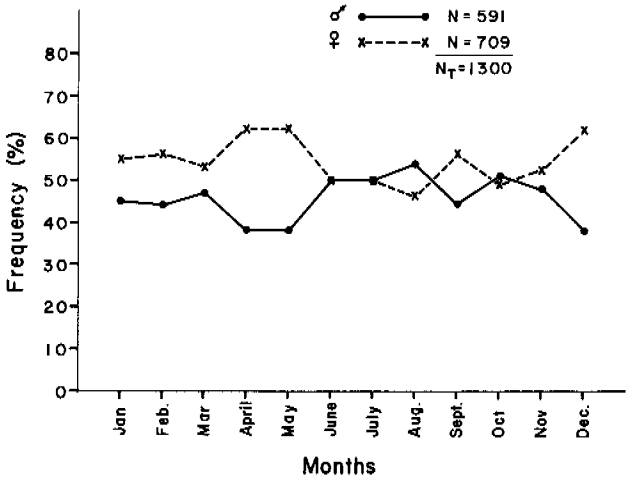

Figure 16. Monthly percent frequency distribution of male and female Atlantic sailfish examined during 1970-74 combined.

since it was noted throughout the year. A similar, but more pronounced, sex-size differential occurs in blue marlin, *Makaira nigricans* Lacépède (Merrett, 1971; Beardsley, 1974; Rivas, 1975), white marlin, (deSylva and Davis, 1963; Beardsley, 1974) and swordfish, *Xiphias gladius* Linne (Beckett, 1974).

The predominance of female sailfish in landings, a notable size differential between the sexes, plus specimens ⩾ 24 kg having more annuli (most were illegible females and were not recorded in Table 3) suggested that females might have longer maximum life spans than males. However, this cannot be confirmed without additional data on growth and longevity. In addtion, differential "schooling" and/or migration of the sexes by season may influence sex-size composition of billfish landings, and this has been suggested by Nakamura (1949), deSylva and Davis (1963), Kume and Joseph (1969), and Rivas (1975).

MORPHOLOGY AND DEVELOPMENTAL DESCRIPTION OF THE GONADS

Morphology of Atlantic sailfish gonads fitted detailed descriptions given by Merrett (1970:357) for species of Indian Ocean billfish. Atlantic sailfish gonads were bilobed and frequently asymmetrical. Sexes were always separate and distinguishable. Similar accounts of gonadal asymmetry and sex were noted in Pacific sailfish by Eldridge and Wares (1974).

Microscopic examinations were made of ovarian tissues from 224 females weighing 0.4 to 39.4 kg (1.0 to 87.0 lb). In smallest females a thin muscular ovarian tunic and fibrous connective tissue septa had already formed (Figure 17).

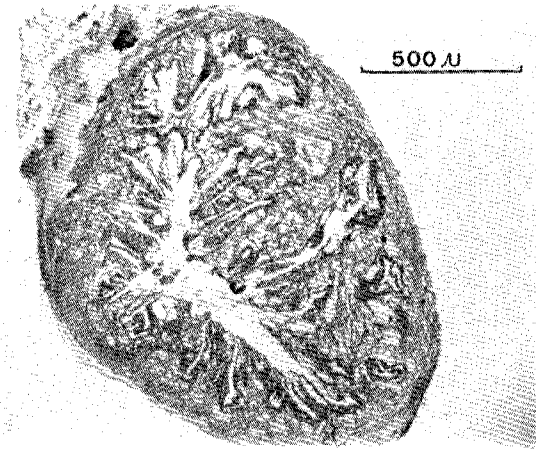

Figure 17. Early stage in development of an immature Atlantic sailfish ovary. Fibrous connective tissue septa compose the entire internal morphology at this stage. False lumen is an artifact of histological processing. From a 0.4 kg specimen taken off Georgia in August, 1971.

Oogonia and primary (stage I) oocytes had not yet developed.

Females 2.5 to 5.0 kg (5.5 to 11.0 lb); 72.0 to 89.0 cm (28.3 to 35.0 in) TKL had developed ovaries with major septa that were distinct and joined centrally (prelumen phase). Diameter of the muscular ovarian tunic measured about 50-100 μ but was wider at the origin of septa. Oogonia 6 to 20 μ in diameter were faintly recognizable throughout non-fibrous connective tissue (see Moe, 1969; and Merrett, 1970). These cells formed stage I oocytes by mitosis (Figure 18). Nucleoli of

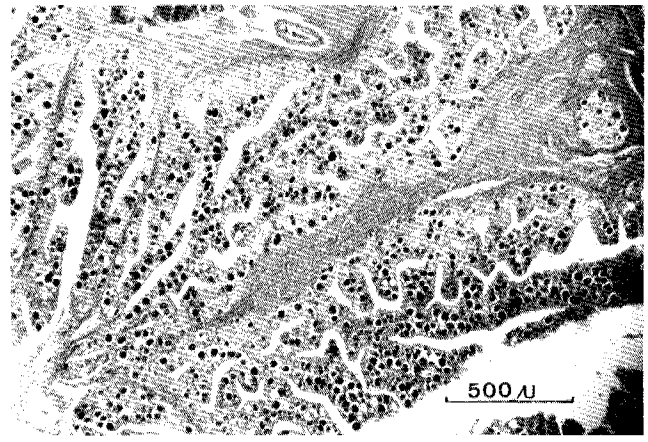

Figure 18. Early oogenesis in the immature ovary. Stage I oocytes forming into rows (or lamellae) are round and weakly to strongly basophilic. From a 4.4 kg specimen taken off Palm Beach in December, 1970.

subsequent primary oocytes remained temporarily in a pre-perinuclear phase. Ovaries at this stage weighed less than 40 gm.

In females 90 to 110 cm (35.4 to 43.3 in) TKL and approximately 5 to 10 kg (11 to 22 lb) primary oocytes (transitive at approximately 40 to 50 μ) began differentiating into resting (stage II) oocytes (Figure 19). Major septa occasionally

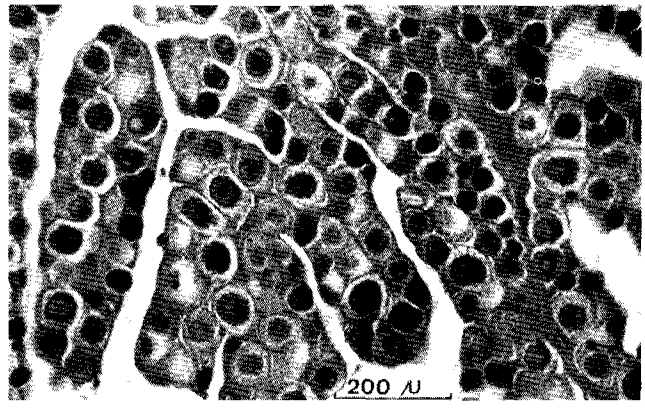

Figure 19. Resting stage II oocytes in the immature ovary. There is no evidence of rejuvenation. From an 8.2 kg specimen taken off Miami in July, 1970.

remained joined centrally even in larger specimens (Figure 20). A lumen often developed but was almost always surrounded by a variably thick connective tissue characteristic of immature specimens (Figure 21). This peculiarity was absent in post-spawning adults. Primary and secondary oocytes formed tightly packed rows or lamellae (Figures 19 & 20). These lamellae remained distinct in all young adult and mature resting specimens. During maturation lamellae became progressively less organized.

Maturation from young adult and mature resting stages was similar to that described by Merrett (1970). Stage I and Stage II oocytes were present in ovaries all year. In early maturation degenerating oocytes were uncommon.

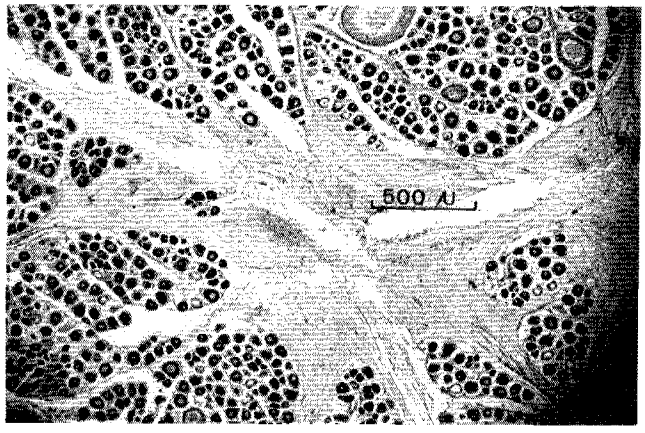

Figure 20. Prelumen phase in an active yet immature ovary showing connective tissue joined centrally. Most of the oocytes are resting stage II's. Note the variably basophilic characteristic of the inner and outer layers of cytoplasm. The oocytes remain tightly packed into lamellae. From a 15.6 kg specimen taken off Miami in August, 1971.

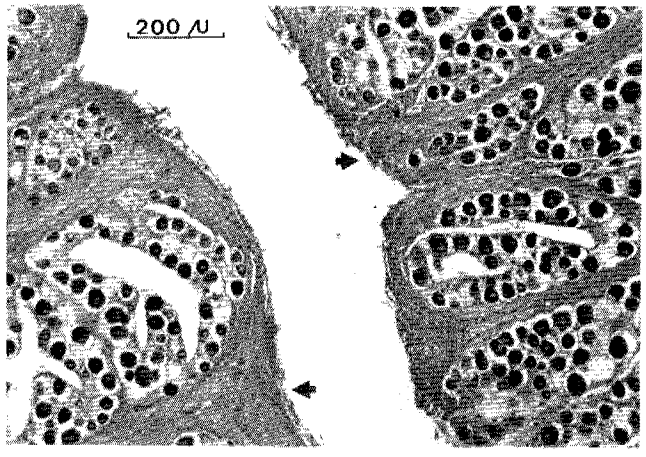

Figure 21. Varibly thick connective tissue surrounding the lumen of an immature ovary. Most oocytes are in stage I, mean diameter 26μ. From a 6.6 kg specimen taken off Stuart in February, 1971.

Vitellogenic (primary yolk forming; stage III) oocytes (Figure 22) first appeared in March and were visible to the naked eye. During March through June maturing oocytes changed the color of the ovary from pink to yellowish-orange. Secondary yolk forming oocytes (stage IV) formed as early as April and were prominent in adults during May through September (Figure 22). During secondary yolk formation lamellar integrity continued to lessen and gross weight of the ovary sharply increased, solely due to growth of existing oocytes. Ovaries in this active condition constituted approximately 1 to 9% of total body weight.

Ripe ovaries with stage V oocytes (Figure 23) were first observed in May but became prominent during June through September. Whole ripe ovaries weighed about 2 to 4 kg (4 to 9 lb), represented 8 to 13% ($\bar{x} \cong 10\%$) of total body weight and occupied most of the body cavity (Figure 24). At this stage maturing and ripe oocytes dominated the ovary and could be seen through a thinly stretched ovarian tunic. As in many ripe teleostean ovaries, ovulated translucent stage V oocytes were found flowing within the lumen. Their diameters ranged from 838 to 1357 μ ($\bar{x}$ = **1161**). This was approximately 140 μ smaller than the size of unpreserved ripe oocytes reported from Indian Ocean sailfish by Merrett (1970). Unovulated stage V oocytes from sectioned and stained tissue of Atlantic specimens measured 550 to 1300 μ in diameter ($\bar{x}$ = 885μ). Ripe ovaries occasionally contained evidence of preovulatory oocyte degeneration, and internal lamellar integrity was

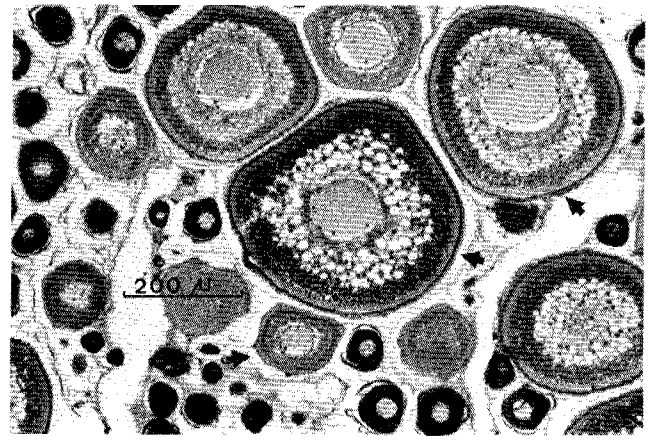

Figure 22. Developing stage III (lower arrow) and stage IV oocytes (upper arrows) in the active ovary. Cytoplasm with a globular yolk that stains acidophilic; nucleus is prominent during early phases but becomes less distinct and displaced (nuclear encroachment) in late stage IV (not shown). Zona radiata (chorion) is strongly acidophilic and composed of several layers (radial striae) which increase in diameter throughout stages III and IV. From a 21.0 kg specimen taken off the Florida Keys in early May, 1971.

completely lost, indicating that spawning was imminent.

Ovulation in shortbill spearfish, *Tetrapturus angustirostris* Tanaka, took place first centrally and progressed radially (Merrett, 1970) with the central core of ovary becoming a lumen. This also occurred in Atlantic sailfish but some ovulation occurred simultaneously throughout the entire ovary. Ovaries in various phases of spawning were observed from May through October. They were always running ripe and internal structure was much disorganized. Two distinct characteristics of ovaries in final stages of spawning included a dramatic reduction in ovary - total body weight ratio in the running ripe phase and an almost complete absence of late stage III and stage IV oocytes (Figure 25).

As spawning progressed, collapsed and buckled septa and empty follicles, cellular debris

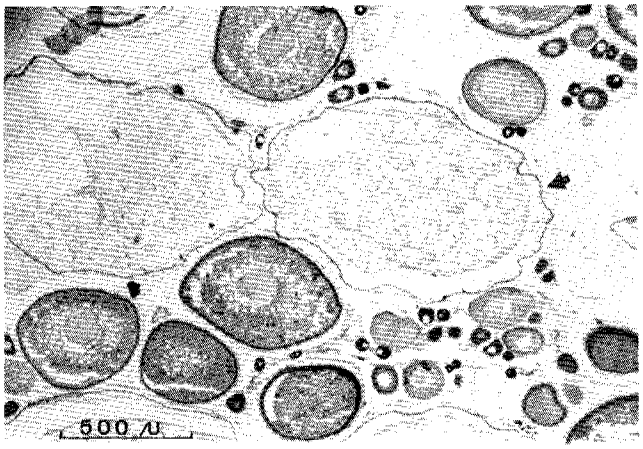

Figure 23. Ripe stage V oocytes (arrow) often amoeboid in shape after histological preparation. Cytoplasm with yolk finely granular and lightly acidophilic. Nucleus never apparent. Zona radiata comparatively thinner than during stage IV phase. Note the relative abundance of stage III and stage IV oocytes and complete loss of lamellar integrity. From a 28.0 kg pre-spawning, ripe specimen taken off Palm Beach in August, 1971.

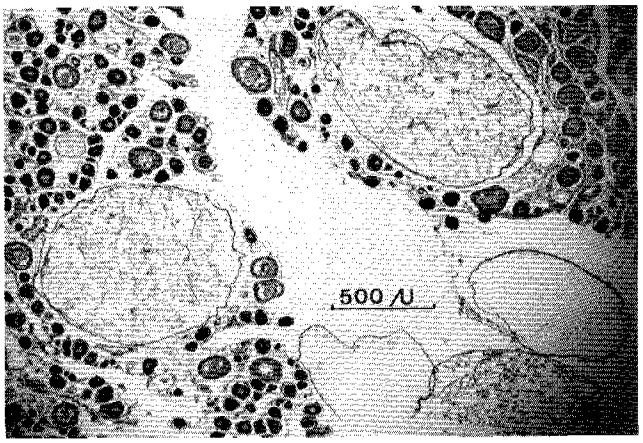

Figure 25. Partially spent ovary with stage V oocytes still flowing in the lumen. Note the complete absence of late stage III and all stage IV oocytes; degenerating oocytes are present and cellular debris is scattered throughout tissue. Lamellar integrity is beginning to reappear. From a 19.0 kg specimen in final stages of spawning taken off Miami in August, 1971.

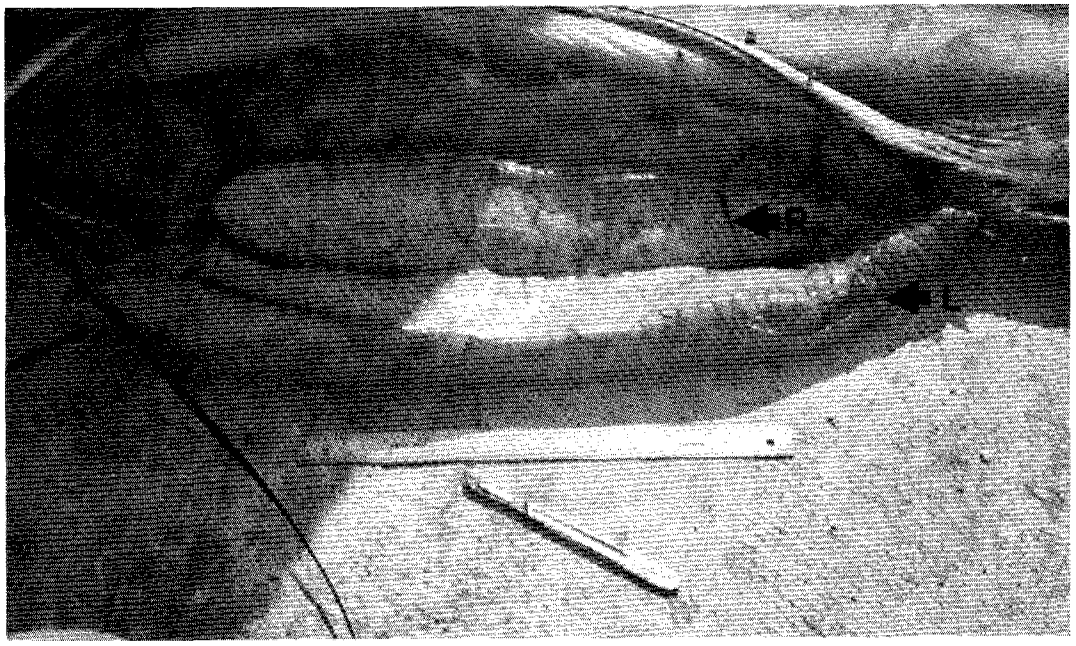

Figure 24. Running ripe ovary which occupied 80% of the body cavity and weighed about 2.2 kg. Note unequal length of left and right ovaries (arrows). From a 22.0 kg specimen taken off Boynton Beach in July, 1975.

and degenerating oocytes were regularly observed (Figure 26).

In common with other fishes, spent and early recovering ovaries of sailfish were flaccid and deep red in color. An expanded, empty lumen with rough, pitted appearance characterized the tissue. Reappearance of lamellar integrity took place rapidly as did a thickening of the ovarian tunic. Degeneration and absorption of advanced unovulated eggs were common at this time. Rejuvenation (partial resorption) of late stage II and early stage III oocytes probably took place (Figure 27), but I believe that some evidence of rejuvenation may have been a processing artifact. However, rejuvenation has recently been described for Indian Ocean billfish (Merrett, 1970), king mackerel (Beaumariage, 1973) and Spanish mackerel (Powell, 1975).

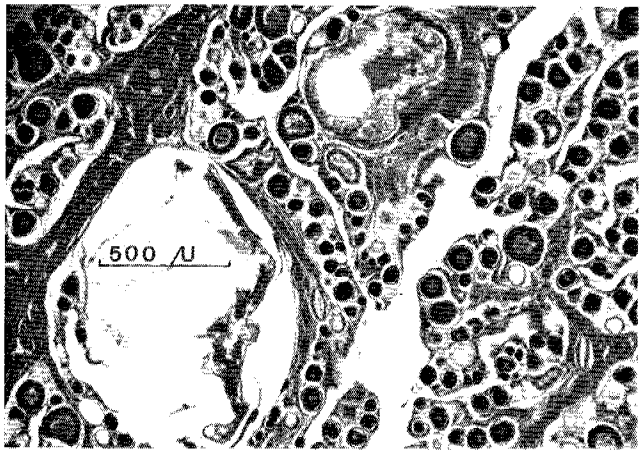

Figure 26. Spent and recovering ovary showing empty follicle, absorption of degenerating oocytes (arrow) and reappearance of lamellar integrity. Note the absence of late stage oocytes. From a 16.0 kg specimen taken off Miami in July, 1970.

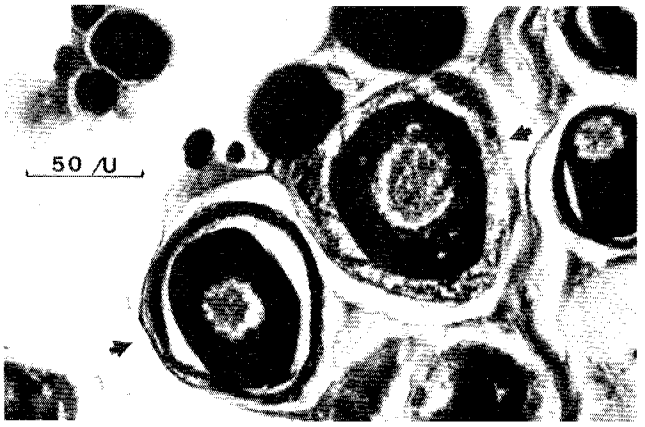

Figure 27. Examples of advanced stage II (upper arrow) and rejuvenated stage II (bottom arrow) oocytes. Note the "capping" phenomenon (lower arrow) produced during partial resorption of cytoplasm. Such a phenomenon was commonly observed in adult resting ovaries during winter (non-spawning) months. Rejuvenated and residual underdeveloped oocytes plus development of new oocytes provide the fund for future spawnings. From a 17.0 kg specimen taken off Palm Beach in early February, 1971.

Some young female sailfish 11 to 16 kg (25 to 36 lb) simulated gonadal maturation of spawning adults but did not lose their lamellar integrity nor reach the necessary stage of development to induce spawning similar to observations in young flounder, *Liopsetta obscura* (Herzenstein) by Yamamoto (1956) and young king mackerel (Beaumariage, 1973). Although non-spawners did not produce the great numbers of advanced vitellogenic oocytes as spawning adults (Figure 28) their recovering ovaries frequently contained greater numbers of degenerating oocytes than spawned out adults. This was a consequence of not shedding the maturing oocytes.

Maturation of Atlantic sailfish testes was similar to that observed by Merrett (1970) in Indian Ocean billfishes. Gross examinations of 591 males revealed year-round presence of milt in some testes. Similarly, microscopic evaluations of testicular tissues from 188 males revealed that spermatozoa were present in testicular crypts and spermatic ducts of some adults each month. Spermatids and spermatozoa were slightly more abundant during April through October.

Active and ripe testes did not become noticeably swollen or completely differentiated into spermatozoa; maximum weight was <0.2 kg (0.5 lb). This condition contrasted with the swollen testes and complete differentiation noted in Spanish mackerel (Dion Powell, personal communication), bonefish (Bruger, 1974) and sturgeon (Huff, 1975). Such evidence is further proof that spermatogenesis in sailfish is a

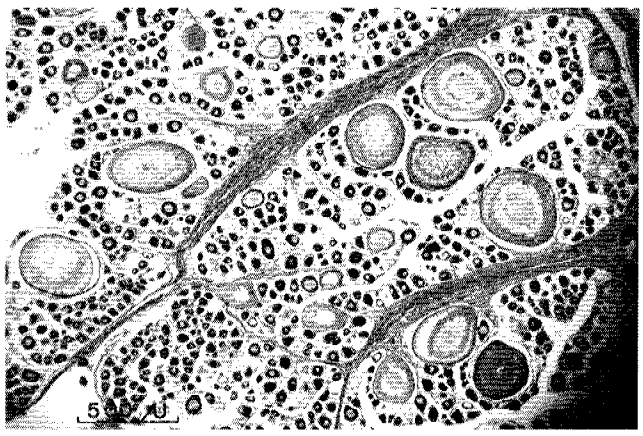

Figure 28. An immature sailfish that simulated gonadal maturation but did not spawn. Note the development of many advanced oocytes which are well surrounded by stage II oocytes and maintenance of good lamellar integrity. From a 15.6 kg specimen taken off Miami in August, 1971.

continuous process as originally suggested by Merrett (1970). During the spawning season sperm are probably stored and then expelled by contraction of a muscular seminal vesicle (Merrett, 1970:362).

SIZE AND AGE AT MATURITY

Maksimov (1971) suggested that Atlantic sailfish matured at 120 cm (47 in) EF or about 110 cm (43 in) TKL and 10 kg (22 lb) during the third year like most other tropical Scombroidei. Voss (1972) suspected maturity occurred at approximately 84 to 90 in (213 to 229 cm) TL. My data (Table 5) showed that females reached maturity at between 13 and 18 kg (30 to 40 lb) or approximately 120 cm (47 in) TKL (approximately 82 in TL). The smallest ripe female weighed 13 kg (29 lb) and measured 115 cm (45 in) TKL. Using results from dorsal fin spines, initial age of maturity corresponded primarily to ages III and IV. Major spawning classes of females measured 121 to 146 cm (about 48 to 58 in) TKL.

Immature females weighed up to 16 kg (36 lb) and measured 129 cm (51 in) TKL.

Males weighing only 5.4 kg (12.0 lb) were found with testes actively producing spermatids and spermatozoa. Whether spawning actually occurred in such specimens was not known. Immature males weighed up to about 8 kg (18 lb) and measured 100 cm (39 in) TKL. Most males appeared to mature by 10 kg (22 lb) and at an earlier age than females, as in king mackerel (Beaumariage, 1973).

TIME OF SPAWNING

Spawning occurred primarily during late May through early September (Figure 29 and Table 5). Minor spawning probably took place as early as April and continued into October. Abundance of istiophorid larvae (mostly sailfish) collected during Florida Department of Natural Resources east coast plankton surveys was greatest during June through August (Figure 30). Data on vertical distribution of these larvae by time of day suggested that they were most abundant on or near the surface during daylight hours (also see Ueyanagi, 1964:520-521). Time of spawning was further supported by earlier reports of gravid females and larvae during this period (Voss, 1953; Gehringer, 1956; deSylva, 1957; and Dr. William Richards, NOAA-NMFS, personal communication).

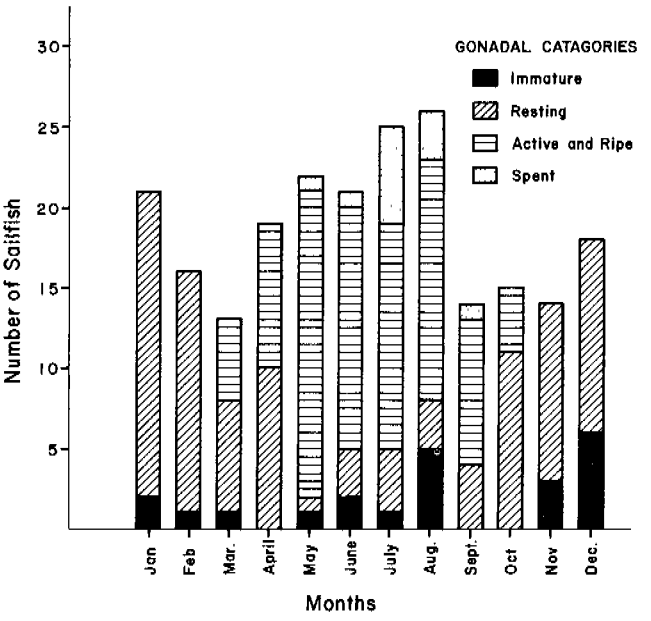

Figure 29. Reproductory activity of 224 Atlantic sailfish expressed as monthly relative prominence of each developmental ovarian category (collections 1970-71 combined; microscopic evaluations only).

TABLE 5. SUMMARY OF ATLANTIC SAILFISH SIZE AT MATURITY (FEMALES ONLY) USING MICROSCOPIC GONADAL EVALUATIONS

	GONAD CLASSIFICATIONS		
	Immature (N=40)	Very Active and Ripe (N=44)	Spent (N=12)
WEIGHT (kg)	0.4-15.8	13.2-38.0	13.2-29.6
MEAN (kg)	8.8	21.6	19.8
TKL (cm)	44.0-129.0	118.0-155.0	114.5-145.5
MEAN (cm)	101.0	132.0	132.5
TIME	— — —	April-October	May-September

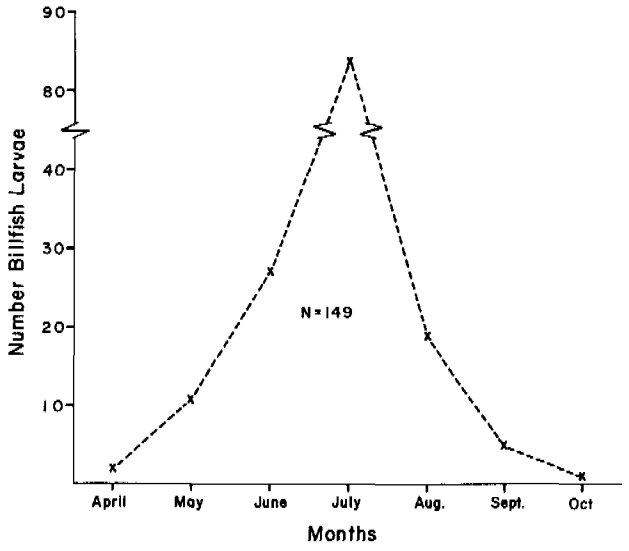

Figure 30. Monthly relative abundance of istiophorid larvae taken during Florida east coast plankton surveys, 1962-74.

FRACTIONAL SPAWNING

Fractional or multiple spawning has been reported for such species as Pacific albacore, *Thunnus alalunga* (Bonnaterre) by Otsu and Uchida (1959); dolphin, *Coryphaena hippurus*, by Beardsley (1967); king mackerel by Beaumariage (1973); California sheephead, *Pimelometopon pulchrum* (Ayres) by Warner (1975); and Spanish mackerel by Powell (1975). Such a phenomenon was also observed in Atlantic sailfish and was first indicated by differences in oocyte density (ripe ova per gram weight of ovary) and variation in percent of total body weight of ripe ovaries (Jolley, 1974).

Three distinct groups of maturing oocytes were found in prespawning ripe ovaries (Figure 31), and such evidence is characteristic of fishes with a protracted spawning season and fractional spawning by individuals during each season (Yamamoto and Yamazaki, 1961).

Two groups of stage IV oocytes were also distinguished in ripe sailfish ovaries examined during May through August (Figure 32). Frequency distribution of stage IV mean diameters taken semimonthly was polymodal (Figure 33). In several spent ovaries few stage IV oocytes were found, suggesting most developed into stage V's and had been shed (see Figures 25 and 26).

Simultaneous presence of stage III, IV and V oocytes in running ripe ovaries revealed that not all developing oocytes reached maturity at the same time and suggested at least three or four batches of eggs could be shed during one spawning season. According to Maksimov (1971) up to 12 batches of eggs may be shed. Although present data are insufficient to determine actual time between spawning intervals, it may be quite short.

FECUNDITY

Using stage V oocytes for fecundity estimates, I found that fecundity increased slightly with fish size (N = 10; weight 17.2 to 33.4 kg). Differential maturation of oocytes and fractional spawning indicated that spawning capacity is related at least to the number of developing stage IV and ripe stage V oocytes. Assuming at least three spawning intervals with equal batches of eggs, a 33.4 kg sailfish could release up to 4.8 to 10^6 ova per season. Therefore, total spawning capacity does appear similar to earlier fecundity estimates given by Voss (1953). Absolute fecundity (total ova) as described by Ovchinnikov (1970) would be much greater, but according to Merrett (1970), less than half of all oocytes in developing sailfish ovaries reach maturity and are shed. My observations agree.

SPAWNING BEHAVIOR

Pairing of male and female Pacific sailfish during spawning was reported by Nakamura (1949). Voss (1953, 1972) believed that Atlantic sailfish spawned inshore over shallow sandy bars and rocky reefs. Some spawning apparently occurs further offshore (Gehringer, 1956). Maksimov (1971) stated that a female accompanied by one or two males will spawn right at the surface with dorsal fins raised. Swimming movements at this particular time were described as sluggish (Voss, 1953; and Maksimov, 1971).

Reliable witnesses reported similar behavior of sailfish during the spawning seasons of 1970-74 along Florida's southeast coast. Captain Gary Stuve (West Palm Beach, Florida, personal communication) photographed sailfish exhibiting such behavior over flats in the Bahama Islands in 1971. My personal observations also support Voss' (1953) theory that such behavior in May through September may be attributed to spawning.

STOMACH CONTENTS

Voss (1953), Ovchinnikov (1970) and Maksimov (1971) found that fish were the most common remains found in adult Atlantic sailfish stomachs. Cephalopods (squid and octopus) were also prominent. Similar results on the feeding habits of Pacific sailfish were presented by Evans and Wares (1972) and Eldridge and Wares (1974).

I found teleost fishes excluding bait occurred in approximately 85% of stomachs with identi-

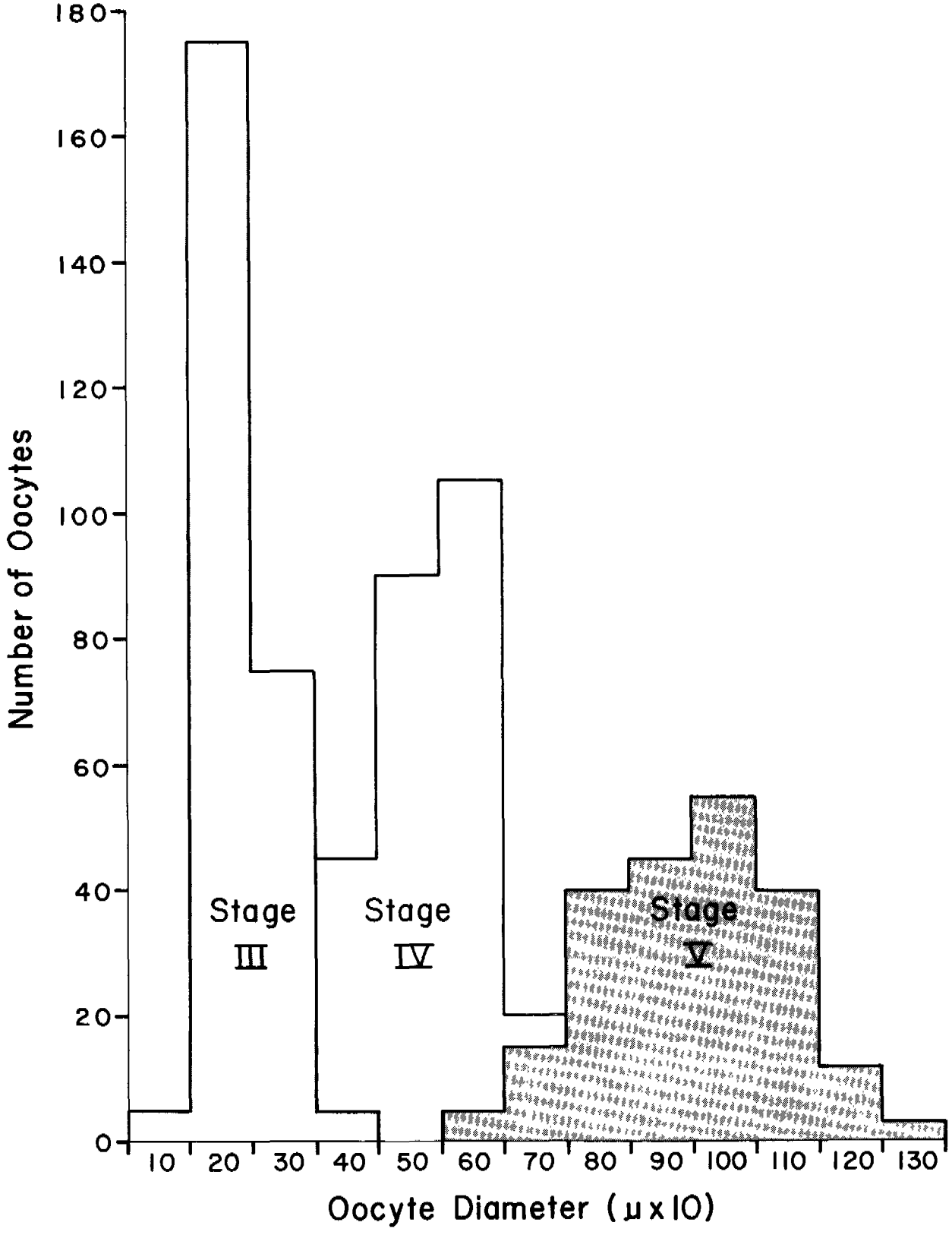

Figure 31. Size frequency of maturing oocytes in pre-spawning, ripe ovaries of 12 Atlantic sailfish.

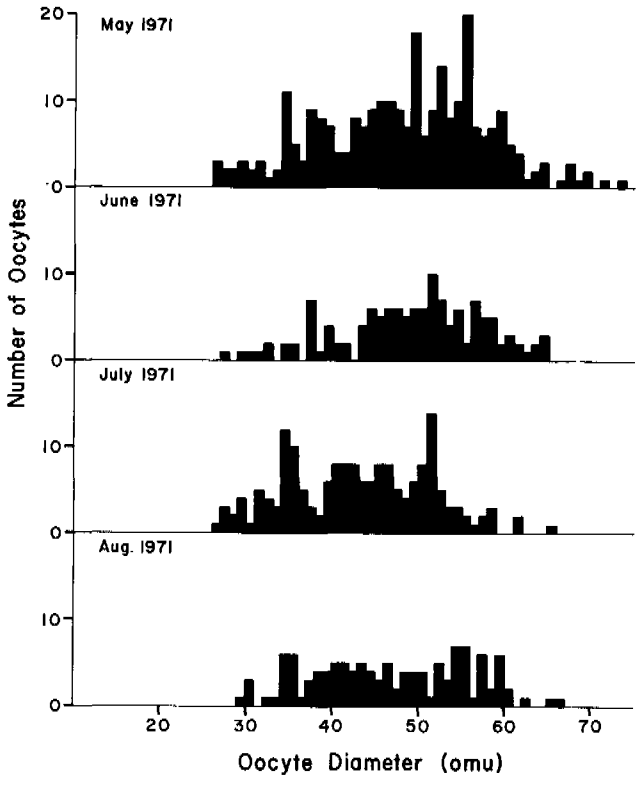

Figure 32. Size frequency of stage IV oocytes in ripe ovaries of 18 Atlantic sailfish examined during summer of 1971, 1 o m u = 10 μ.

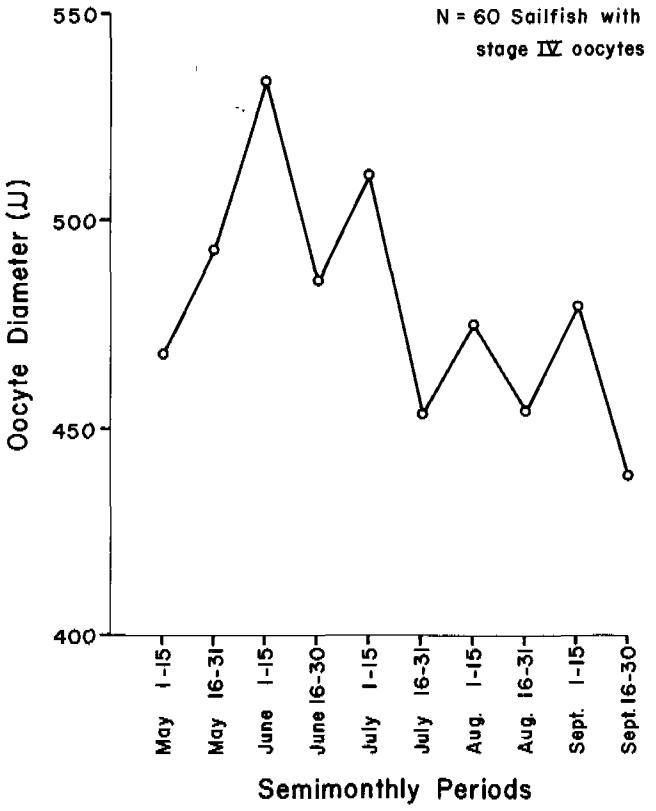

Figure 33. Semimonthly mean size of stage IV oocytes observed in active and ripe specimens during the combined spawning seasons of 1970-71.

fiable food items (Table 6). Most appeared to have been swallowed head first. Scombridae, primarily little tunny, *Euthynnus alletteratus* (Rafinesque), were the single most common food. Exocoetidae (mostly halfbeaks), Carangidae (jacks), Belonidae (needlefishes) and Clupeidae (herring) also occurred commonly. Benthic species were found least frequently.

Cephalopods were the most common invertebrates and were second only to scombrids in occurrence. Similarity of these results with those reported by Voss more than 20 years ago reveals that sailfish have not changed their diet and remain dependent upon the availability of such species in southeast Florida for food. Several previously unreported western Atlantic food species were Acanthuridae (surgeonfishes), Lobotidae (tripletails), Scaridae (parrotfishes), Scorpaenidae (scorpionsfishes), Serranidae (seabasses) and Syngnathidae (pipefishes and seahorses). Frequency of occurrence of such items in stomachs of sailfish was small.

Halfbeaks (*Hemiramphus* spp.) and boned white (silver) mullet, *Mugil curema* Valenciennes, were the most popular baits trolled by southeast Florida's marine anglers and were prevalent in sailfish stomachs. Baits of squid and belly strips from little tunny were found less often.

Use of live bait has become popular in recent years. Most commonly found in sailfish stomachs were blue runner, *Caranx crysos* (Mitchill), bigeye scad (goggle-eye), *Selar crumenophthalmus* (Bloch). Mullet, little tunny, pinfish and various herring species were also used as live bait. Selection and use of a particular live bait is often influenced by its relative abundance, time of year and an angler's ability to catch and keep his bait alive.

TIME OF FEEDING

All sailfish examined were caught during daylight, and only three reports have been received concerning specimens taken after dark. Strike and catch rates in western Atlantic sport fisheries appeared greatest during morning and afternoon (Beardsley, 1974; Rivas, 1973, 1974; and FDNR, unpublished). Ovchinnikov (1970) reported stomach fullness of eastern Atlantic sailfish increased from "morning through evening". Presumably fullness peaked between 4:00 P.M. and 8:00 P.M. Maksimov (1971) also considered sailfish to feed primarily during daylight. However, some feeding also occurs at night during the full moon.

TABLE 6. STOMACH CONTENTS FROM 778 SALIFISH EXAMINED FROM MAY 1970 - MARCH 1974.

FOOD ITEMS (in order of importance)		*OCCURRENCE*
Vertebrates:		
Scombridae (Tunas and mackerels)		71
Exocoetidae (halfbeaks and flying fishes)		41
Carangidae (jacks and pompanoes)		30
Mugilidae (mullets)[1]		26
Belonidae (needlefishes)		25
Clupeidae (herrings)		25
Balistidae (triggerfishes and filefishes)		8
Syngnathidae (pipefishes and seahorses)		4
Coryphaenidae (dolphins)		3
Trichiuridae (cutlassfishes)		3
Stomateidae (butterfishes)		2
Acanthuridae (surgeonfishes)		1
Atherinidae (silversides)		1
Engraulidae (anchovies)		1
Gerreidae (mojarras)		1
Lobotidae (tripletails)		1
Ophichthidae (smake eels)		1
Pleuronectiformes (flounders)		1
Pomadasyidae (grunts)		1
Scaridae (parrotfishes)		1
Scorpaenidae (scorpionfishes)		1
Serranidae (sea basses)		1
Triglidae (searobins)		1
Other unidentified fish remains		197
	Subtotal =	447
Invertebrates:		
Cephalopoda		63
Decapoda (squid)		(42)
Octopoda (octopus)		(5)
Unidentified cephalopod remains		(16)
Crustacea		20
Penaeidae		(13)

TABLE 6. STOMACH CONTENTS FROM 778 SAILFISH EXAMINED FROM MAY 1970 - MARCH 1974. (Continued)

FOOD ITEMS (in order of importance)		*OCCURRENCE*
Portunidae		(3)
Copepoda		(1)
Unidentified		(3)
	Subtotal =	83
	Grand Total =	530
Other classifications:		
Empty stomachs		210
Unidentified remains		30
Sargassum sp. (sea weed)		3
Thalassia sp. (turtle grass)		1
Eichornia crassipes (water hyacinth)		1
Bait:		
Exocoetidae (halfbeaks only)		37
Mugilidae (mullets)		25
Carangidae (blue runner and scads)		16
Scombridae (little tunny)		3
Clupeidae (herrings)		1
Cephalopoda (squid)		1
Sciaenidae (drums)		1

[1] — Most mullet in sailfish stomachs were probably bait.

DAMAGE TO FISHES CAUSED BY ANGLING METHODS

Sportsmen have long been concerned about fish damage or death caused by angling techniques. Hooks by themselves caused recognizable damage to tissues and vital organs of sailfish. Specimens were only occasionally "gut hooked" or hooked in the gill area. Twenty-seven out of 848 sailfish had everted stomachs when examined but few resulted from hooks penetrating esophagus or stomach walls. Everting the stomach did not cause any evident damage.

Only three specimens showed evidence of having been hooked previously. One contained an 8-0 Mustad hook that penetrated the esophagus and lodged between the liver and pericardial cavity. This hook was coated with scar tissue and was apparently causing no additional trauma.

Hooks frequently damaged eyes and surrounding nerve and muscle tissues. One hundred and thirty-four out of 848 sailfish (15.8%) sustained probable eye damage. This usually resulted from barbs entering the right or left roof of the mouth which is soft. Damage was recognized by perforations and/or blood in the eye. Often dissections revealed severed or partially torn optic nerves and eye muscles.

ABNORMALITIES, ULCERS AND PARASITES

Broken and deformed spears were the most common abnormalities. Fresh breaks were easily recognized and usually resulted during handling. Sailfish with scar tissue (bills that had healed) confirmed that damage had occurred prior to capture. Such injuries may result from specimens impaling boats and other fishes. One sailfish caught off Cape Canaveral in 1974 possessed a "split bill" (Figure 34).

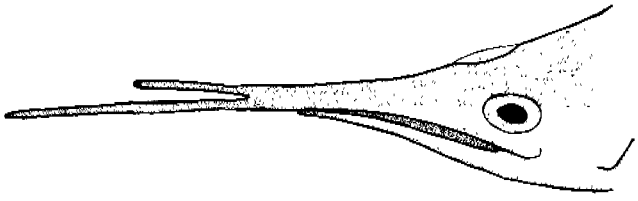

Figure 34. Unusual "split bill" on a 23.0 kg sailfish taken off Cape Canaveral in January, 1974.

Deformed fins and spines occurred occasionally. Dorsal fin damage on one specimen resulted from shark attack at a younger age. Most peculiar was growth of an additional caudal lobe on a sailfish from Palm Beach in 1973 (Figure 35).

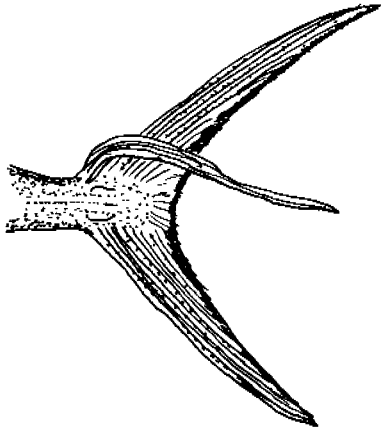

Figure 35. Rare additional caudal lobe of a 13.0 kg sailfish taken off Palm Beach in October, 1973.

Thomas and Raju (1964) described certain gonadal abnormalities in Scombroid fishes from the Indian Ocean but none for billfishes. Recently, Eldridge and Wares (1974) observed such gonadal anomalies in Pacific billfish. I also examined abnormal gonads in several Atlantic sailfish. A male measuring 118.5 cm (46 in) TKL and weighing 18 kg (40 lb) had only a single, but apparently normally functioning testis. Two females suffered gonadal atrophy. The severest case was in a ripe 22 kg (49 lb) specimen examined in June 1971. The left ovary had grown to twice its normal weight, 2.2 kg (5.0 lb), and represented 10% total body weight (Figure 36). Fecundity was about normal, 8.9×10^5 ripe ova.

Iversen and Kelley (1974) reported high occurrences of stomach ulcers in marlins from Hawaii. I also found stomach and intestinal ulcers occasionally in Atlantic sailfish. Close scrutiny for such conditions was not practiced, and incidence of ulcers in Atlantic specimens was believed greater. The causes for these ulcers and effects of stomach and intestinal parasites on such conditions were not known. However, Evans and Wares (1972) speculated that injuries from spines of prey fishes could have caused ulcers in sailfish stomachs and parasites may aggravate such conditions.

Parasitism varied greatly among individual sailfish, and both external and internal forms were common. At least 15 different parasites including forms similar to those described on sailfish by Ward (1954); Silas (1967); Silas and Ummerkutty (1967); and Williams (1967) were distinguished on specimens examined by Robert Richardson (Boca Raton, Florida, personal communication).

CONCLUDING REMARKS AND EVALUATION OF PREVIOUS AGING TECHNIQUES

Age and growth estimates of Atlantic sailfish based upon TL and TKL frequency analyses (Petersen's method) suggested rapid growth, about 9 kg (20 lb) per year, a short natural life span of two to three years, 90% mortality at age IV and two age groups comprising the sports fishery. Koto and Kodama (1962) applied similar techniques to commercial landings of Pacific sailfish with these results (three age groups, 140-175 cm, 175-195 cm, and 195-210 cm EF) but could not assign each group to a specific age in years.

Based upon deSylva's (1957) age and growth estimates (Figure 6) and my observations of size at maturity (Table 5), most females would mature in 18 to 24 months, spawn once and die. This does not appear typical of many tropical Scombroidei (see Schaefer, Broadhead and Orange, 1963; Shomura and Keala, 1963; Beaumariage, 1973; and Powell, 1975) most of which reach maturity at ages II, III, and IV and have maximum life spans exceeding 5 to 10 years.

A short life span hypothesis for Atlantic sailfish was not similar to estimates of a more closely related species, white marlin, which has a maximum life span of 10 to 12 years (deSylva and Davis, 1963). Estimated mortality rates of tagged and released white marlin (Mather, Jones and Beardsley, 1972) supported this theory.

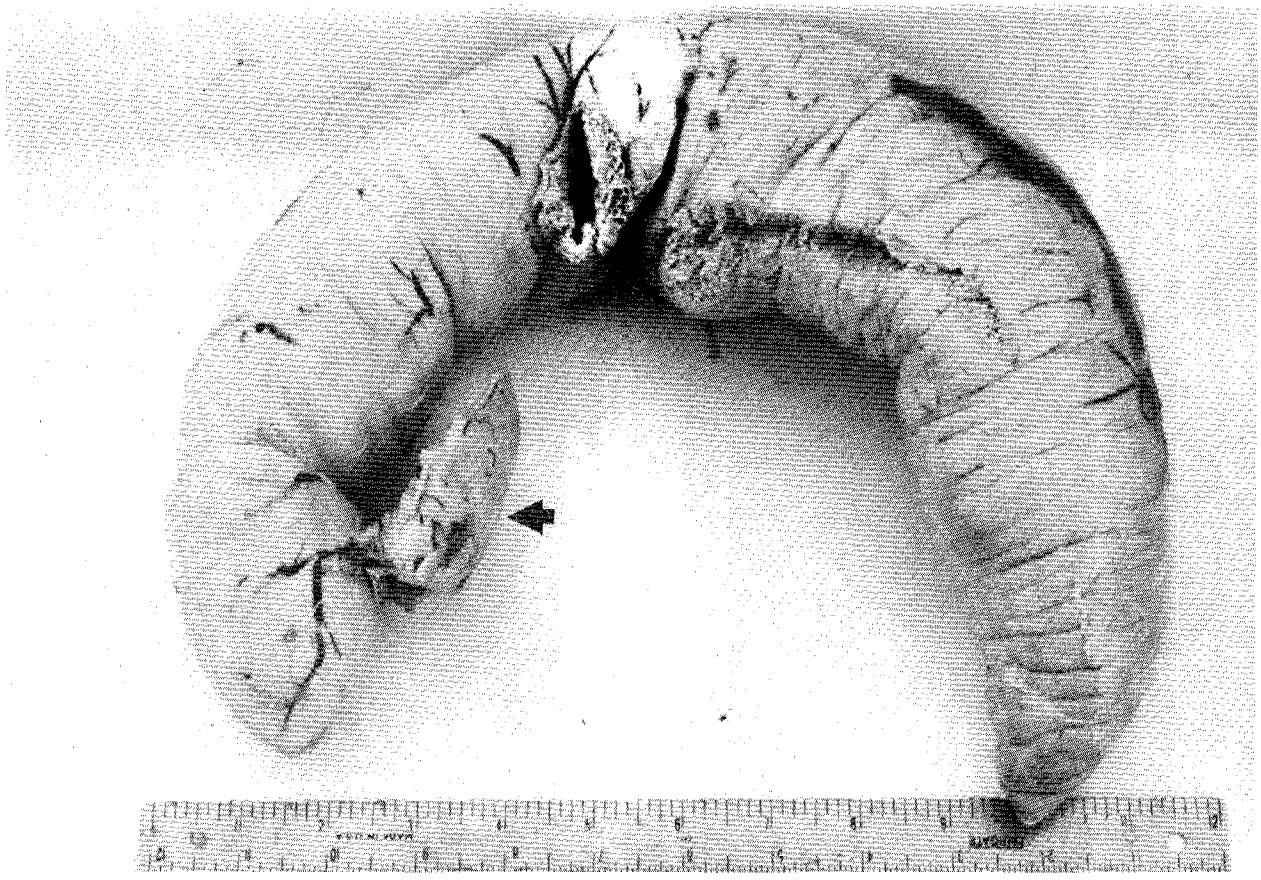

Figure 36. Gonadal atrophy in a ripe female examined during June 1971.

Unfortunately, age and growth estimates of sailfish from tag returns remain inconclusive (Mather, et al., 1974) because specimens were not measured before tagging and release. However, one sailfish tagged in 1966 and estimated to weigh about 21 kg (47 lb) was recaptured 54.8 months later and weighed only 27 kg (60 lb) (Mather, et al., 1974). This evidence was definitely contrary to the fast growth and short life span hypothesis and was evidence that sailfish live at least six or seven years.

In a paper on problems for biological fishery survey and techniques for their solution, Parrish (1958) stated that Petersen's method of age analysis relies heavily upon two principles: 1) lengths of individuals of each age group in a population of fish having a single restricted spawning season are approximately "normally" distributed; 2) growth is such that the modes of length distributions of successive age groups in a sample from the population are separated along the length axis. In addition, Lagler (1956) pointed out that a prerequisite for aging by the Petersen method was collection of a large sample from the population over a relatively short time period (preferably a single day). Sampling of sailfish in this manner has not been practical.

According to Parrish (1958) the principles underlying Petersen's method are seldom completely satisfied. 1) Protraction of spawning season, mixing of growth types and gear selectivity can produce "non-normal" length frequency data for constituent age groups. This yields size groupings not indicative of year classes (also see Rounsefell and Everhart, 1953). 2) Progressive reduction in growth rate with age causes overlapping of length frequencies of successive age groups amongst older fishes. 3) There is difficulty in gauging age of the smallest length group and of insuring that all ages are represented in the sample.

DeSylva (1957) recognized that such conditions could exist in aging sailfish by the length frequency method and suggested that annular marks be used to check his findings. Dr. Donald deSylva, University of Miami, (personal communication), also began examining various bony structures but was unable to continue this work. Evans (1969) reported exploring suitability of billfish fin ray sections. And, by 1972 Paul Wares (NOAA-NMFS, personal communication) indicated that substantial progress had been made using anal and dorsal fin spine sections to age striped marlin,

Tetrapturus audax (Philippi) and Pacific sailfish. Jolley (1974) subsequently reported methods and first attempts to age Atlantic sailfish using concentric rings in dorsal fin spines. Examination of fin spines of Pacific and Atlantic specimens has since revealed similar ring patterns for each of these species. Attempts are presently under way to age Atlantic blue and white marlins using the same technique (Chester Buchanan, NOAA-NMFS, personal communication).

I have presented evidence that certain biological conditions exist in sailfish sampled from southeast Florida that make age analysis by Petersen's method questionable. I believe that protraction of the spawning season, reduction in growth rate with age, and differential growth rates and/or mortality between the sexes exist, and such conditions create difficulty in determining successive age groups by length frequencies.

SUMMARY

1. From May, 1970 through June, 1974 sailfish primarily from southeast Florida, were examined for age, growth, size composition, sex ratio and size differential, seasonal gonadal development, spawning time and frequency, fecundity, diet, abnormalities and several aspects about the fishery.
2. Dorsal and anal fin spines were chosen for aging because they were easily extracted and exhibited distinct circuli which increased in number with fish size. Major translucent circuli were counted as "annuli". Ages were based on total annuli and margin status (translucent or opaque). Specimens with translucent margins (ring forming) were designated as age N+ and represented age class N+1 in all calculations; specimens with opaque margins fell into age class N. All measurements were taken from the fourth (IV) dorsal fin spine. Six hundred thirty-five sailfish were assessed by this method. Twenty-four percent (149) were legible. Ages 0 through VIII were represented; mean age for both sexes was about four years. Maximum age may be IX or X because the oldest aged sailfish (VIII) was not the largest examined.
3. Weight (kg) was used for measuring absolute growth. Mean weight attained at ages I through III was about one half that previously reported. Analysis of covariance between the age-weight relationships of males and females was significant ($P = .05$). Growth rates were not fully analyzed and analysis of additional data is planned to further test these findings.
4. Use of the fourth dorsal fin spine for aging was tentatively validated: dorsal fin spines developed in the larval stage; width of fourth dorsal fin spine was proportional to TKL; and evaluation of margin status revealed that translucent circuli (annuli) formed primarily during fall and winter. Back calculations of theoretical weights (or lengths) for comparison with empirical data were not attempted because of present sample size.
5. Mean size of males and females was 15 and 19 kg (120 and 127 cm TKL), respectively. Combined mean size was 17 kg and 124 cm TKL. About 80% of sample weighed between 8.4 and 27.8 kg and measured 110.0 to 139.5 cm TKL. Similarity of 1970-1971 and 1973-74 length frequency data and that collected about 20 years ago suggests that the biological status of southeast Florida sailfish stocks remains healthy.
6. Body length, eye to fork length and total length on trunk length regressions were linear. The following equations describe each relationship: BL = 1.09 + 1.25 TKL; EF = 1.56 + 1.07 TKL; TL = 16.44 + 1.53 TKL.
7. Sex ratio favored females by 1.2 to 1. At sizes $\geqslant$ 18 kg females were much more prevalent. Female sailfish attained greater size and were heavier than most males at a given length.
8. Maturation and seasonal gonadal development were described from microscopic examination of gonadal tissues. Oogonia and primary oocytes had differentiated in females weighing as little as 2.5 to 5.0 kg. Specimens weighing 5 to 10 kg showed resting (stage II) oocyte development. Connective tissue observed surrounding lumen of immature females was absent in post-spawning adults, and arrangement of oocytes in tightly packed rows or lamellae became less well organized during maturation. Such phenomena were useful in determining maturity.
9. Vitellogenesis was first marked by appearance of primary yolk forming (stage III) oocytes in March. Secondary yolk forming (stage IV) oocytes were observed as early as April. During maturation weight of the ovary increased due to growth of existing oocytes and constituted 1 to 9% of total body weight.
10. Prespawning ripe ovaries represented approximately 8 to 13% ($\bar{x} \cong 10\%$) of total body weight and were dominated by stage III, IV and V oocytes. Fresh, ovulated (stage V) oocytes were frequently found flowing within the lumen and mean diameter was 1161μ; unovulated (stage V) oocytes from preserved and stained samples were smaller, $\bar{x} = 885\mu$.
11. Ovulation progressed radially from center of ovary but some ovulation occurred simul-

taneously throughout entire ovary. In final stages of spawning ovaries showed reduction in ovary-total body weight ratio and almost complete absence of late stage III and IV oocytes.

12. Degeneration and absorption of unovulated eggs was observed. Rejuvenation of oocytes apparently took place but evidence existed that some of this may have been a processing artifact.
13. Some females weighing 11 to 16 kg simulated gonadal maturation of adults but did not spawn. Consequently, their recovering ovaries frequently contained greater numbers of degenerating oocytes than spawned out adults.
14. Spermatogenesis appeared to be a continuous process although some seasonality was noted. Spermatozoa were observed in testes each month and appeared slightly more abundant during April-October. Active and ripe testes did not become noticeably enlarged or completely differentiated into spermatozoa.
15. Females reached first maturity at between 13 and 18 kg and 120 cm TKL and primarily at ages III and IV. Major spawning classes measured 121 to 146 cm TKL. Males appeared mature by about 10 kg and at an earlier age than females.
16. Most spawning occurred during late May through early September and was documented by gravid females in landings and abundance of larvae during this period.
17. The presence of three distinct groups of maturing oocytes in ripe ovaries revealed that oocyte development was asynchronous, and that fractional or multiple spawning took place. Up to 4.8 x 10^6 ova may be shed in three batches by a 33.4 kg female during one spawning season.
18. Sailfish often move inshore into shallow water and spawn. A female swimming sluggishly with one or more males may spawn near the surface with dorsal fins extended.
19. Approximately 85% of identifiable food items in stomachs were teleost fishes. Scombridae, Exocoetidae, Carangidae, Belonidae and Clupeidae occurred most frequently. Squid were second only to scombrids in frequency of occurrence. This indicated that diet had not changed, and sailfish remain dependent upon the same basic food source reported 20 years earlier. Previously unreported Atlantic food fishes found were: Acanthuridae, Lobotidae, Scaridae, Scorpaenidae, Serranidae and Syngnathidae.
20. White mullet and halfbeaks were the most common trolling baits found in sailfish stomachs. Blue runner and bigeye scad were the most prevalent live baits.
21. All sailfish examined were caught during daylight. This is the time when most feeding occurs. Only a few reports were received about catches after dark.
22. Most significant damage caused by angling methods was by hooks perforating eyes or tearing optic nerves and eye muscles.
23. Broken and deformed spears and damaged fins were most common abnormalities. Several unusual gonadal conditions occurred. Stomach and intestinal ulcers were also observed. Parasites were found on most specimens and at least 15 different types were noted.
24. Problems concerning sailfish aged by Petersen's length frequency method were discussed. Conditions precluding reliability of this method are: a protracted spawning season, collection of data over several years rather than one short interval, possible changes in growth rate with advanced age and differential growth and/or mortality rates between sexes.

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