AGE, GROWTH AND REPRODUCTION OF AMERICAN EELS, *ANGUILLA ROSTRATA*, (LESUEUR), FROM THE CHESAPEAKE BAY AREA

A THESIS

Presented to

The Faculty of the School of Marine Science

The College of William and Mary

In partial fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Marion Yvonne Hedgepeth

1983

APPROVAL SHEET

This thesis is submitted in partial fulfillment of
the requirements for the degree of

Master of Arts

Marion Y. Hedgepeth

John V. Merriner, Ph.D., Chairman

John A. Musick, Ph.D.

Herbert M. Austin, Ph.D.

Evon P. Ruzecki, Ph.D.

Charles A. Wenner, Ph.D.
South Carolina Div. Marine Resources
Charleston, S.C.

ACKNOWLEDGMENT

The author wishes to express her appreciation to Dr. John Merriner, under whose guidance this investigation was conducted, and for his patient guidance and criticism throughout the investigation.

This project was partially the result of support by NOAA, U.S. Department of Commerce, Grant No. NA81 AA-D-00025, Project R-CF-9 to the Virginia Division Graduate Marine Science Consortium Sea Grant.

I also would like to thank my friends and colleagues who assisted me in the field and Patrice Mason for her assistance in the histological aspects of this study, and Debbie Velix for typing the manuscript.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS ii

LIST OF TABLES iv

LIST OF FIGURES v

ABSTRACT vi

INTRODUCTION 1

MATERIALS AND METHODS 5

Age and Growth 7
Reproduction 7
Statistical Analysis 9

RESULTS 11

Age and Growth 11
Reproduction 14

DISCUSSION 17

Age and Growth 17
Reproduction 21

LITERATURE CITED 24

APPENDIX 57

VITA 61

LIST OF TABLES

Tables Page

1. Range, mean and standard deviations of observed size-at-age .. 33

2. Observed and theoretical sizes expressed as relative growth .. 34

3. Mean length-at-age of American and European eels 35

4. Size of American eels and ovarian width 37

LIST OF FIGURES

Figure	Page
1. Study area and James River Estuary	38
2. York River Estuary	39
3. Age determination from an otolith	40
4. Fish length on total otolith radius	41
5. Theoretical growth for lengths-at-age	42
6. Estimates of $L\infty$	43
7. Mean observed and theoretical weights-at-age	44
8. Mean marginal increment widths on otoliths	45
9. CPUE for total number of eels collected	47
10. CPUE for total weight of eels collected	48
11. Macroscopic view of a normal eel ovary	49
12. Relationship between ovary width and fish size	50
13. Ovary of a female silver eel	51
14. Lobe-shaped sex organ of a transforming female	52
15. Undifferentiated tissue from a transforming female	52
16. Photomicrograph of a Stage II Ovary	53
17. Photomicrograph of a Stage IV Ovary	55
18. Photomicrograph of an Early Stage III testes	56

ABSTRACT

American eels, ANGUILLA ROSTRATA, (elvers through silver stages) were collected between January and September 1981 from tributaries of the Chesapeake Bay and the eastern shore of Maryland. Age Groups I through IX were encountered. Age Group III was the most abundant age group among the yellow eels. Observed lengths and weights-at-age were quite variable. The von Bertalanffy equation : $lt = 797.24\ (1-e^{-0.1953(t-0.8528)})$ described theoretical growth in length. American eels from the Chesapeake Bay area were longer at a given age than European eels, ANGUILLA ANGUILLA, and American eels from areas north of the Chesapeake Bay and tropical and subtropical areas, presumably due to the effects of extremely high and low water temperatures on feeding periodicity. Also, American eels from the Chesapeake Bay area appeared to mature and migrate at an earlier age than eels from northern areas. It was estimated that female eels became silver and migrated by the age of six or seven years or approximately 550 millimeters in total length , while male eels became silver and migrated by the age of five to seven or approximately 300 millimeters total length.

Fishing pressure appeared to be the greatest factor in determining the size distribution of eels in a given area. Also, water temperatures had a great effect on CPUE during the course of the study. Mean catch-per-unit-effort for total numbers of eels collected was highest during the months of May and July,while mean

CPUE values for total weights were highest during the months of July and September. CPUE values for both total numbers and total weights were highest at water temperatures of 25 to 29.9 degrees C. and in salinities 20 to 24.9%. Mean marginal increment widths on otoliths of eels peaked in mid to late spring when eels were most active. The average size of yellow eels in the samples was 400 millimeters and 242 grams (Age Group V), while the most preferred market size is 450 grams or one pound. A commercial eelpot mesh size of 1" by 1/2" diameter was recommended for use in Virginia waters.

Macroscopic and histological observations of gonadal tissue examined in this study showed no advanced sexual products present. Most ovaries of yellow eels were Stage II . Eight transforming female eels which had been collected from the lower James River were examined and found to contain non-overlapping gonads similiar to the organs of Syrski. A female silver eel had a Stage IV Ovary and a testes from a male silver eel was classified as Early Stage III. The testes contained crypts of primary and secondary spermatocytes which had not been photographed from eels before under natural conditions.Reproductive maturation data supported the hypothesis that the production of more advanced sexual products must occur during migration or just prior to spawning.

INTRODUCTION

The American eel, ANGUILLA ROSTRATA, is a catadromous fish which spawns in the western North Atlantic Ocean in the southern Sargasso Sea. They grow to an adult stage in inland lakes, streams and coastal areas bordering most of the western Atlantic Ocean north to southern Greenland, Newfoundland island and the Gulf of St. Lawrence south to approximately the mouth of the Amazon River in Brazil (Vladykov, 1964). Young A. ROSTRATA develop into transparent larvae, leptocephali, which are passively transported by ocean currents to coastal areas wherein they transform into elvers or glass eels.

Elvers generally arrive in the Chesapeake Bay during March and April; however, they have been collected from late December through mid-May (VIMS, unpublished). Elvers transform into yellow eels and may remain in this juvenile stage for 5 to 20 years (Tesch,1977). According to Bertin (1956) and Schwartz (1961), eels in freshwater areas are usually females while males apparently stay in brackish or salt water. Most researchers now agree that male eels remain near the coast in salt, brackish or freshwater. Dolan and Power (1977) and Passakas and Tesch (1980) reported that male yellow eels (juvenile) may transform into females and migrate considerable distances inland. Older yellow eels develop into sexually maturing silver eels and migrate downstream towards the sea from late August through mid-November. They are guided presumably by electronavigation to the Sargasso Sea where the adults die after spawning (Bertin, 1956).

Early growth studies of anguilloid eels used scales for age determination (Gemzoe,1908; Bertin,1956; Sinha and Jones,1967 and 1975; Gray and Andrews,1971; and Voronin et al.,1971. Scales were subsequently shown to be poor aging structures for eels; because, they do not appear until several years after birth. Otoliths are presently preferred for age determination although methods of preparation and interpretation vary (Ogden,1970; Moriarty, 1973 and 1979; Liew, 1974; Williams et al.,1974; and Benech, 1975). Growth rates for wild and cultured eel populations have been published (Bellina, 1910; Frost, 1945; Bertin, 1956; Gunning and Shoop, 1962; Vladykov, 1970; Bieder, 1971; Tesch, 1971 and 1977; Ord, 1978 and Rasmussen et al., 1979).

The sagitta, largest of the otoliths, has been considered the most reliable structure for aging eels (Tesch, 1971 and Williams et al. 1974). Periods of fast and slow seasonal growth can be distinguished on otoliths by their different structural and chemical characteristics (Liew, 1974). Supernumary or subsidary zones have been described from eel otoliths (Liew, 1974, Deeldler, 1976, Moriarty et al., 1979 and Jellyman 1977). Under laboratory conditions, the formation of these zones correlated with periods of starvation induced by low temperatures, sudden temperature changes or following periods of handling (Liew, 1974). Jellyman (1977) noted that there was little growth beyond the last annulus on otoliths of New Zealand eels (sacrificed monthly) during winter months when temperatures ranged between 2 C and 10 C, while marginal increment widths increased rapidly during spring, summer and fall. Slight decreases in growth rates were observed during late spring and mid-summer when water temperatures reached 22 C.

Environmental factors such as temperature, salinity and over crowding may play an important role in the growth, sex determination and distribution of eels. Somatic growth and gonadal differentiation in eels were accelerated to some extent in culture experiments by elevating temperatures (D'Ancona, 1959 and Kuhlman, 1979). Water temperatures above 28 C or below approximately 5 C (varies by species) caused a loss of appetite and periods of little or no growth in eels (Usui, 1974). Sinha and Jones (1975) noted empty stomachs in the few eels collected during winter months in Danish waters. Abundance of eels in trawl collections was low during winter months in Virginia and was supportive of the suggestion that eels may overwinter by burrowing into mud (Wenner and Musick, 1975). Thus, catch records of eels and mean monthly marginal increment widths on otoliths may be correlated with changes in seasonal water temperature.

The reproductive biology of anguilloid eels has been extensively studied. Since the time of Aristotle, Modini (1777), Syrski (1874) and other researchers have speculated on the sexuality of eels. Reproductive aspects that have been investigated include: sex ratio, size-sex differentiation and gonad maturation (Goode, 1881; Hermes, 1881; Fontaine, 1936; Bertin, 1956; D'Ancona, 1959; Satoh, 1962; Egusa et al., 1973; Winn and Richkus, 1975; Sinha and Jones, 1975; Tesch, 1977; Rossi; et al. 1979 and Moriarty, 1979); migration of silver eels (Wenner, 1972 and 1973; Wenner and Musick, 1974 and Westin et al., 1977); and artifical induction of maturation, embryology, and sex reversal (Fish, 1926; Satoh, 1962; Boetius et al., 1967 and 1980; Meske, 1973; Ghittino et al., 1975; Yamamoto et al., 1975 and Bieniarz et al., 1981.)

Tesch (1977) reported that in several European and American studies silver eels were sexed by size alone (ie. females > 500 mm., males < 500 mm.). Recent aquaculture experiments have reported sex reversal in eel culture ponds due to over crowding and/or starvation. Passakas and Tesch (1980) demonstrated that European eels may be phenotypically male and karyotypically female: "our results indicate that the genotypical glass eel females, which probably enter the continental waters at a normal sex ratio, stay in estuarine areas over crowded with eels - evidently, they then develop male gonads so that the number of male yellow eels is disproportionately high". Thus the influence of age, size, season and salinity on the rate of gonadal development and the eventual phenotypic expression of the sex organs (including descriptions of oogenesis and spermatogenesis) in wild populations of eels warrants further study.

The objectives of my investigation are (1) to determine the age and annual growth rates of eels from Virginia waters, (2) to correlate catch records and growth increments from eel otoliths with trends in seasonal water temperatures and salinities, (3) to define macroscopically and histologically the stages of gonadal development of American eels from wild populations in the Chesapeake Bay region, and (4) to relate the rate of sexual development of eels to the age, size, season of capture and preference of habitat (ie. salinity regime).

MATERIALS AND METHODS

Twenty-eight collections consisting of 533 American eels (elver through silver stages) were obtained between the months of January and September 1981. A total of 216 elvers were collected with a meter net, japanese fyke net and dipnets during March and April. Sampling stations for elvers included a culvert that drains Lake Maury on the lower James River, the dam on Wormley Creek, the culvert on Bracken's Pond and the main channel of the York River. Yellow eels were sampled from Lake Maury and the lower James River, lower Potomac River, Mattaponi River, Pamunkey River, Poropotank River and York River (Figs. 1 and 2). Thirty foot and 16 foot semi-balloon trawls (9.1 and 4.9 meter), and baited eelpots were used to collect yellow eels. One silver female was taken in a trawl in February from the upper York River. Four male silver eels were obtained from Mr. John Foster of the Maryland Department of Natural Resources in Wye Mills, Maryland. These eels were captured in November of 1980 in a fish trap placed below a spillway on Turvil Creek (freshwater) near Ocean City, Maryland.

Most of the eels in this study were obtained during a VIMS-Sea Grant Project on eelpot gear efficiency. Catch records from this study are given in Appendix A. A total of 29 sets of approximately 25 eelpots per set were made between May and September, 1981 in the York River and some of its' tributaries (Fig 2). Rectangular and cylindrical eelpots constructed of galvanized wire or vinyl-coated galvanized wire and hung with 1/2" by 1/2" or 1" by 1/2" mesh were used to capture eels. The number of eelpots fished in a set ranged from 19 to 25 due to the loss of pots just before or during a set. Eelpots were fished at a location for a 12-hour day and a 12-hour night period; however, during intervals of bad weather or at the approach of bad weather, fishing periods were shortened or lengthened. Therefore, an adjusted total catch for a 12-hour fishing interval was calculated for each set. Four sets were deleted from any final analysis; because, their fishing periods had greatly overlapped day-night intervals. Catch-per-unit-effort (CPUE) was calculated by dividing total number or total weight of eels collected in a set by the number of eelpots fished during the set.

Age and Growth

Total length in millimeters, wet weight in grams, sex, stage of gonad development and age were recorded for each eel. Sagittae were removed and stored in glycerine. Prior to taking radial measurements, otoliths were polished on a grinding stone and read in glycerine under a dissecting microscope equipped with reflected light, a dark background and an ocular micrometer. Measurements of the opaque and transparent zones were made on otoliths where annuli were clearly visible. An age of one was assigned to elvers. Therefore, age represented the total number of years spent inshore plus one as illustrated in Figure 3.

Water temperatures (degrees Centigrade) were taken on station with a stem thermometer. Salinity (‰) and dissolved oxygen (mg/l) were sampled in the field and later analyzed by the VIMS Ecology and Pollution Department. Additional water temperatures (1952-1981) were obtained from a computer listing of water temperature records maintained for the VIMS pier site on the York River.

Reproduction

Gonads of yellow and silver eels were examined macroscopically to determine sex and stage of gonadal development. Samples of gonadal tissue from approximately 30 eels of various sizes were removed for histological examination. Tissue samples were preserved in 10% buffered formalin, Davidson's solution or Bouin's Fixative, and were stained with Harris's Hematoxylin and counterstained with eosin Y. In sexually developing females, the width of the gonad was measured macroscopically to the nearest millimeter to estimate the macroscopic condition of the gonad.

Identification of maturity stages in eels corresponded to those used by Kesteven (1960) with some modifications.

Stage I. Virgin-immature. Sexual organs not visible.

Stage II. Maturing virgin- Sexual organs have just begun to develop. Oocyte stages I and II are present.

Stage III. Developing virgin- Increase in the width of the ovary. Oocyte stages I-IV may be present. Testes still very undeveloped or transforming into female sex organ (ie. lobes are becoming ribbon-shaped).

Stage IV. Developing silver phase- ovary is whitish with reddish blood capillaries. Oocyte stages IV-VI prevalent. Testes appears as a white narrow band. Nests of secondary spermatocytes prevalent. Body of eel is characterized by enlarged eyes, black fins and overall silvery appearance.

Classification of oocyte stages corresponded to the six maturation intervals described by Smith (1966) and Combs (1969). The stages of spermatogenesis were classified according to Hyer (1969).

Statistical Analysis

Means and standard deviations for observed and theoretical lengths and weights and gonadal widths-at-age were computed for an analysis of growth rates. Relative growth (h) per year was calculated from an equation in Everhart and Youngs (page 74, 1981).

Regression analyses of length on weight, length on otolith radius and length and weight on gonadal width were computed with a curve fitting program provided by Hewlett-Packard for the Model HP-67 calculator. The program provided least squares regression analysis for linear, exponential, logarithmic and power fits. The coefficient of determination (r**2), y-intercept (a) and slope (b) were provided in the output.

The theoretical growth equation for length-at-age of eels was obtained by fitting observed mean length-at-age data to the von Bertalanffy growth equation (Ricker, 1975):

$$l_t = L_\infty (1-e^{-K(t-t_o)})$$

Where L_∞ = maximum size which the length of the average fish is tending

K = Brody growth coefficient which measures the rate at which length approaches L_∞

t_o = a parameter that indicates the hypothetical time at which the fish would have been zero size if it had always grown according to the above equation

Growth parameters L_∞, K, t_o were calculated from the Walford plot of l_{t+1}, plotted against l_t for estimates of L_∞, and by the Beverton Method in which age is plotted against $\ln(L_\infty - l_t)$, (Ricker, 1975). Since the weight of an eel was so variable from year to year, an equation for a Gompertz type "S" curve was used to describe theoretical growth of American eels in terms of weight (Everhart and Youngs, 1981):

wt = wo e**gt

where wt = weight at time t

wo = a growth coefficient for a time interval

e = base of the natural logarithms

and where gt = ln wt/wo.

RESULTS

Age and Growth

Age Groups I through IX were encountered among the 433 eels aged (Table 1). A female silver eel was assigned an age of 13 years during the first reading;but after multiple examinations, they were rated as too poor for age determination and the fish was deleted from the sample. Storage of otoliths in glycerine for several months resulted in a vagueness of the opaque zones on many otoliths. As a result, radial measurements on otoliths were obtained from only 72 eels.

A linear relationship for fish length vs otolith radius (Fig. 4) existed for American eels from the Chesapeake Bay area. The equation : Total Otolith Radius = 10.78 + 0.10 (Length) was obtained for this relationship and the correlation coefficient (r) was 0.90.

Observed lengths and weights-at-age of the eels examined were variable beyond the elver stage (Table 1). The equation : ln W = 0.0255 + 3.33 (ln L) and an r value of 0.98 described the relationship between the length and weight of American eels from the Chesapeake Bay area.

Relative growth (h) values (Table 2) revealed that the most substantial growth in length of eels occured during the first 3 or 4 years of life, while the most substantial growth in weight continued into the 5th or 6th year of life. Mean observed and theoretical lengths and weights were most variable between Age Groups III and VI which may be a reflection of the onset of sexual maturation.

Theoretical growth for length-at-age (Fig. 5) was described by the von Bertalanffy equation: lt = 797.24 (1 - e**-0.1053 (t - 0.8528)). Estimates of L_∞ by the Walford Plot and Beverton Method are illustrated in Figure 6. The Beverton Method provided the most accurate estimate of L_∞ . The theoretical mean length of elvers (Age Group I) was underestimated perhaps due to the lack of substantial growth data for leptocephali (Age Group 0) and "pencil" eels (Age Group II).

Theoretical weight was described by the equation: wt = 0.05 e**gt. The variable, wo, was assigned a value of 0.05 grams or approximately one fourth of the mean weight of an elver. Values for gt were calculated for each age group present. Utilizing this method, mean values obtained for the theoretical weights of eels were very similar to mean observed weights-at-age data (Fig. 7). These data suggest that growth in weight of American eels is curvilinear.

Observed mean lengths-at-age from the present study and other eel studies (Table 3.) generally indicated that American eels in the Chesapeake Bay area were longer at a given age than eels from areas north of the Chesapeake Bay and reported size-at -age for European eels , (A. ANGUILLA). Age Groups from the present study were adjusted to concur with the age designations of other eel studies. Data from my study most closely resembled the data of Harrell and Loyacano (1980) ,South Carolina Wildlife and Marine Resources Department (1981), and Hansen (1981). Their data were collected from the Cooper River System in South Carolina. American eels collected in Bermuda and aged by Boetius and Boetius (1967) were shorter at a given age than eels from the Chesapeake Bay area and South Carolina; however, they were slightly longer at a given age than eels from more northern states. Insufficent data were available to test for size differences of eels between sampling areas used in the current study.

Water temperature and salinity showed some trends with growth ; however, these trends were not conclusive. Monthly marginal increment widths from the otoliths of 72 eels, peaked in mid to late spring when eels appeared to be the most active and temperatures were still below 20 C (Fig. 8). Mean monthly CPUE values for total numbers of eels collected in the VIMS-Sea Grant Eelpot Gear Efficiency Study were highest during the months of May and July, while mean CPUE values for total weights were highest during the months of July and September (Figs. 9A and 10A and Appendix A). Values for CPUE were also high when water temperatures were 25 to 29.9 C. and at salinities of 20 to 24.9 ‰. (Figs. 9B and 10B). CPUE values in 1981 drastically declined when water temperatures averaged 30 C. in June and 29 C. in August.

Reproduction

Most developing ovaries appeared as the familiar whitish ribbon-like organs illustrated by Hermes (1881) and Bertin (1956), (Fig. 11). Ovaries developed in vertically crenulated patterns with mostly connective tissue between the folds. Growth was generally outward from the base of the vertebrae and downward into the ventral body cavity. Larger and more sexually advanced eels had more crenulations in their ovaries (ie. increases in thickness) than smaller eels as previously reported by Dolan and Power (1977). Most of the eels collected in my study were of Maturity Stage II (maturing virgin). From a histological perspective, oocyte stages I through IV were encountered (Appendix B). A Stage IV ovary was present in the female silver eel (922 mm, 1870 g).

Ovarian maturation, width of developing ovaries, was correlated with increasing fish size. A regression analysis of fish length, weight, and age on ovarian width produced correlation coefficients of 0.876, 0.841 and 0.647, respectively. Developing sex organs were not macroscopically visible in eels less than approximately 250 millimeters or 30 grams (Figs. 12A and 12B). Widths of ovaries increased as the size of the eels increased. The ovary of the female silver eel was 25 millimeters wide. Therefore, American eels with ovaries approaching 20 millimeters in width may be nearing the silver phase of development (ie. Maturity Stage IV) and may correspond to Age Groups VI and VII. Data were insufficient to assess seasonal variations in ovarian width.

Five migratory silver eels (1 female and 4 males) were examined. The female silver eel (922mm and 1870g) had a Stage IV gonad which was milky white with small reddish capillaries throughout (Fig. 13). Testes of silver eels from Turvil Creek in

Maryland appeared as very narrow white bands (Stage III). A massive amount of testicular development must occur at sea as suggested by Wenner (1974). These males ranged from 278 to 301 mm and 34.0 to 42.0 g. They ranged in age from 5 to 7 years.

Of the 533 American eels examined, eight were also designated as transforming females based upon the description of Dolan and Power (1977). These posessed non-overlapping lobed gonads somewhat similar to the male sex organ, the organs of Syrski (Figures 14 and 15). These eels were collected on separate occasions in April and July from the Deep Water Shoals area in the James River and ranged from 278 millimeters (34.8g) to 368 millimeters (85.7g). Gonad widths were from 1 to 3 millimeters. Transparent zones at the tips of the lobes consisted of undifferentiated tissue (Fig. 15). Thus development must proceed dorsally to ventrally.

Histological examination of gonadal tissue (Appendix B) revealed oocyte stages I through IV in ovaries and primary plus secondary spermatocytes were evident in testicular tissue. Thus, production of more advanced sexual products must occur at sea during migration or just before spawning. The histological features of a Stage II ovary included oocyte Stages I and II (Figures 16A and 16B). These oocytes were very small and darkly stained with hematoxylin. Protovitellonucleoli (PVN) which will develop into the nucleolus of the cell were evident in the lighter stained nuclear material. Protovitellonucleoli were more evident around the inner sides of the nuclear membrane in Stage IV oocytes (Fig. 16 A &B). During this stage the outer cell wall, sometimes called the zona radiata or vitelline membrane, and yolk platlets were developing. Stage IV oocytes were encountered almost exclusively in the silver eel (Fig. 17 A & B). Testes of a silver eel from Turvil Creek in Maryland contained crypts of primary spermatocytes and darker stained secondary spermatocytes as described by Hyder (1969) (Stage III testes, Figs. 18a & 18b). Unlike the gonads of most fishes which may exhibit all stages of oocyte or sperm production simultaneously during the course of a single year (once maturity is reached),both the male and female sexual products of eel gonads were generally in a relatively homogenous stage. This would be consistent with the rapid gonadal maturation and once in a life time reproductive strategy adopted by this group of fishes.

DISCUSSION

Age and Growth

Mean lengths at age of American eels from the Chesapeake Bay region most closely resembled those reported from South Carolina, (Harrell and Loyacano,1980; South Carolina Wildlife and Marine Resources Department,1981; and Hansen, 1981.) These data indicated that American eels from the southeastern region of the United

States were longer at a given age than both European eels ,ANGUILLA ANGUILLA, and American eels from the northeastern region of the United States. Canadian studies have primarily dealt with eels from inland freshwater lakes where they appear to live longer and grow larger than those in brackish water or other coastal areas. Eels from the Chesapeake Bay appear to grow faster, mature earlier and migrate at a younger age (ie. live for a shorter period of time) than those of other published age and growth studies. Perhaps the large size achieved by eels from inland systems is due to delayed sexual maturation wherein assimiliated food energy continues to be shifted to growth and maintanence. Also, differences in current and past fishing pressures and the availability of food are factors which could contribute substantially to variations in age distributions and growth rates in wild populations of eels.

In this study, female eels showed the first signs of sexual maturation at an age of three (approximately 250 millimeters or 30 grams). They advanced to the silver stage at approximately six or seven years of age or 550 millimeters total length. Vladykov (1970) reported silver female eels from Quebec, Canada which ranged from 711-750 millimeters in total length and ranged in age from 14 to 18 years. No male eels were identifiable in the current study ;however, male silver eels examined from Maryland were age five to seven years. Male silver eels examined from the Cooper River System in South Carolina ranged from 250-318 millimeters in total length and had a mean age of three years, (Harrell and Loyacano, 1980). Therefore, American eels from southern areas do mature and migrate at an younger age than eels from northern areas.

In previous age and growth studies on eels other workers have all reported difficulties in assigning ages to individual fish. Facey (1980) was unable to compute a von Bertalanffy growth equation for eels from Lake Chaplain, Vermont; since, he found poor coefficients of determination (0.27 and 0.29 for length-at-age and weight-at-age, respectively). Those fish ranged from 43 to 90 centimeters total length,120 to 1665 grams and 8 to 23 years of age. No published reports which included theoretical growth in weight for American eels were found. Rasmussen and Therkildsen (1979) reported von Bertalanffy growth parameters for A. ANGUILLA from a small Danish stream (L_∞=59.83cm, K=-0.1194 and to =0.5683). Von Bertanlaffy growth parameters for ANGUILLA ROSTRATA from the Chesapeake Bay area were: L_∞=79.72cm, K=-0.1953 and to =0.8528. A. ANGUILLA at 450 millimeters was estimated to be 10 years of age, while a 450 millimeter A. ROSTRATA was estimated at 5 years old. Therefore, some problems still exist in the accurate interpretation of growth zones on otoliths and age designations of both species of ANGUILLA from wild populations. One problem is the accurate recognition of supernumary zones which appear to occur with high frequency on otoliths of eels. These zones may form during periods of high or low water temperatures (ie. below 5 and above 20 C) low oxygen, salinity fluctuations etc. Such events appear to coincide with reduced eel growth and feeding. Future studies should focus more on validation of annual markings on otoliths and growth rates of "wild" eel populations from a regional or local perspective. For example, a tetracycline marking study, in which true growth of individual eels could be calculated, would probably answer many of the questions about eels that have plaqued scientists for centuries.

Mean catch per unit of effort for eelpots was highest during May, July and September. VIMS trawl survey data between 1955 and 1982 indicate that catch-per-unit-of-effort of eels in the York River is generally highest in mid-spring (VIMS, unpublished). Local commercial fishermen set eelpots in spring when water temperatures approach 10 C and temporarily cease fishing when water temperatures above 25 C are reported. In Maryland, Brody and Foster (1981) reported that total catch (ie. weight) of eels in eelpots peaked at 19 C and decreased at higher water temperatures. Water temperature had,by far, the greatest effect on CPUE during the course of the present study. High CPUE during spring may be attributed to very active feeding after a long period of starvation during winter months. Therefore, eels are more vulnerable to baited fishing gears. In the Maryland eelpot study, total catches of eels were higher in the Sassafras River which is under tidal influence, than in the Susquehanna River where water flow is controlled by a dam. Eels in the York River were most abundant in the mesohaline reach (3.0 to 16.5‰); but, eels of marketable size were found at the river mouth (Guinea Marshes) and well into the fresh water reaches of the Pamunkey and Mattaponi Rivers. Eels are rarely taken directly from Chesapeake Bay waters except during the fall emigration of silver eels.

Reproduction

Macroscopic and histological examinations of gonadal tissues from eels collected during this study demonstrated that production of spermatid, spermatozoa, sperm and oocyte Stages V and VI must occur during migration or just prior to spawning. The condition of ovarian and testicular tissues was generally similiar throughout the gonad of an eel. This supports the hypothesis of a one time , mass spawning period by American eels. Photomicrographs from the female silver eel revealed a Stage IV ovary, similiar to those illustrated by Wenner (1974), and Bertin (1956) ,(although maturation stages were not identified in their text). Testicular tissue from silver eels in Maryland contained primary and secondary spermatocytes (Early Stage III Testes). Photomicrographs from other studies revealed nests of only primary spermatogonia from male silver eels. Therefore, the male silver eels from the present study were more sexually advanced (by one stage) than male yellow eels of Bertin (1956) and male silver eels of Wenner (1974).

Histological comparisons of sexual development in A. ROSTRATA for silver eels migrating from different latitudes are still needed to confirm if eels migrating from northern regions are less mature histologically than eels migrating from southern regions as proposed by Wenner (1973). At this time, advanced stages of gonadal maturation of A. ANGUILLA and A.JAPONICA have been documented only from artificial induction studies (Satoh,1962; Boetius and Boetius,1967 and 1980; Meske,1973; Ghittino et al.,1975; Yamamoto et al.,1975; and Bieniarz et al., 1981.

Fishing pressure is probably the greatest factor determining the size distribution of eels in a given area. During the 1950's, Local eel fishermen reportedly landed eels over 90cm in length which would correspond to Age Group XV and older (Table 3). Therefore, an estimate of L_∞ (79.7cm) may be an indication of the first signs of heavy exploitation rates in the Chesapeake Bay region. Concern has been expressed over the trend toward smaller sizes of eels landed in Virginia by Mr. George Robberecht, the largest eel shipper in the United States. Smaller eels usually bring substantially lower prices or are not salable. Mr. Robberecht endorses the prohibition of eelpots constructed with 1/2" by 1/2" wire mesh (personal communication). He feels a regulation is necessary in order to conserve the eel resources ,as well as assure a good future economic return from Virginia fishery resources. The average size of yellow eels in this study was 40 centimeters and 242 grams (Age Group V). European markets prefer eels weighing 450 grams or 60 centimeters (Age Groups VII and VIII). Therefore , eelpots constructed of 1" by1/2" wire mesh which allow smaller eels (< 350 mm) to escape would be the best mesh size to use in Virginia waters at this time.

LITERATURE CITED

Bellina, A. 1910. Aalzucht-Versuche. Z. Fisch. 15,136-81.

Benech, V. 1975. Note on the preparation of otoliths, particularly those of eel. Ann. Hydrobiol. 6:2,173-178.

Bertin, Leon. 1956. Eels: A Biological Study. Cleaver-Hume Press Ltd.,London , 192p.

Bieder, Richard C. 1971. Age and growth of the eels in Rhode Island. Masters Thesis. University of Rhode Island.

Bieniarz, Krzysztof, P. Epler, B. Malczewski, and T. Passakas. 1981. Development of European eel (ANGUILLA ANGUILLA L.) gonads in artificial conditions. Aquaculture 22:53-66.

Boetius, Inge and Jan Boetius. 1967. Studies on the European eel ANGUILLA ANGUILLA (L.) Experimental induction of the male sexual cycle, its relation to temperature and other factors. Meddelelser fra Denmarks Fiskeri-og Havundersogelser 4:11,339-405.

------------------------------ 1980. Experimental maturation of female silver eels,ANGUILLA ANGUILLA.

Estimates of fecundity and energy reserves for migration and spawning. Dana 1:1-28.

Brody, Robert W. and John W. S. Foster III 1981. American eel investigations-
Sassafras and Susquehanna Rivers,Spring 1981. Maryland Dept. Nat. Res.,Tidal Fisheries Division, Annapolis, Maryland, 30p.

Combs, R. M. 1969. Embryogenesis, histology and organology of the ovary of BREVOORTIA PATRONUS. Gulf Res. Rep. 2:333-434.

D'Ancona, Umberto. 1959. Distribution of the sexes and environmental influence in the European eel. Arch. Anat. Micro. Morph. Exp. 48:61-71.

Deelder, C. L. 1976. The problem of the supernumary zone in otoliths of the European eel (ANGUILLA ANGUILLA, Linnaeus,1758). a suggestion to cope with it. Aquaculture 9:373-379.

Dolan, J. A., and G. Power. 1977. Sex ratio of American eels, ANGUILLA ROSTRATA, from the Matanek River system, Quebec, with remarks on problems in sexual identfication. J. Fish. Res. Bd. Canada 34:294-299.

Egusa, Synzo and Hitomi Hirose. 1973. Further notes on sex and growth of European eels in culture ponds. Bull. of Japan. Soc. of Sci. Fish. 36:6,611-616.

Everhart, W. H. and W.D. Youngs. 1981. Principles of Fishery Science. 2nd Edition, Cornell Univ. Press, Ithaca, New York, 349p.

Fish, Marie Poland. 1926. Contributions to the embryology of the American eel (ANGUILLA ROSTRATA, LeSueur). Zoologica 8:5,289-323.

Fontaine, M. 1936. Sur la maturation complete des organes genitaux de l'anguille male et l'emission spontanee de ses produits sexuels. C.R. Acad. Sci., Vol. CCII.

Foster, John W. S. III 1982 (unpublished) . The American eel in Maryland: a situation report., Maryland Dept. Nat. Res., Tidal Fisheries Division, Annapolis, Maryland, 15p.

---------------------- and R. W. Brody 1982. Status report : The American eel fishery in Maryland, 1982., Maryland Dept. Nat. Res.,Tidal Fisheries Division, Annapolis, Maryland, 27p.

Frost, W. E. 1945. The age and growth of eels (ANGUILLA ANGUILLA) from the Windermere Catchment Area. J. Animal Ecol. 14:26-36.

Gemzoe, K. J. 1908. Age and rate of growth of the eel. Report of the Danish Biological Station 14:10-39.

Ghittino, P., J.S. Glenn, and F.G. Smith. 1975. Studies on hormonal induction of gonadal development in American eels (ANGUILLA ROSTRATA). Riv. It. Piscis. Ittiop-A 10:3,75-85.

Goode, G.B. 1881. Notes on the life history of the eel, chiefly derived from a study of recent European authorities. Bull. U. S. Fish. Comm. 1:71-130.

Gray, R. W. and C. W. Andrews. 1971. Age and growth of the American eel, ANGUILLA ROSTRATA, LeSueur, in Newfoundland waters. Can. J. Zool. 49:121-128.

Gunning, G. E. and C. R. Shoop. 1962. Restricted movements of the American eel ANGUILLA ROSTRATA (LeSueur) , in freshwater streams, with comments on growth rates. Tulane Studies in Zoology 9:265-272.

Hansen, Richard 1981. Age, growth and sex ratio of the American eel (ANGUILLA ROSTRATA) in brackish water portions of Cooper River, South Carolina. Masters Thesis, Clemson University.

Harrell, Reginal M. and Loyacano Jr. 1980. Age ,growth and sex ratio of the American eel in the Cooper River, South Carolina. Proc. Ann. Conf. S. E. Assoc. Fish. & Wildl. Agencies 34:349-359.

Hermes, Otto. 1881. On the mature male sexual organs of the Conger eel ,(CONGER VULGARIS), with some observations on the male of the common eel , (ANGUILLA VULGARIS, Fleming). Bull. U. S. Fish. Comm. 1:100-126.

Hyder, M. 1969. Histological studies on the testes of TILAPIA LEUCOSTICA and other species of the genus TILAPIA (Pices: Teleostei). Trans. Am. Microsc. Soc. 88: 211-231.

Jellyman, D. J. 1977. Summer upstream migration of juvenile freshwater eels in New Zealand. New Zealand

J. Mar. Freshwater Res. 11:1,61-71.

Kesteven, G. L. (ed.) 1969. Manual of field methods in fisheries biology. F. Fish.Sci. No. 1, 152p.

Kuhlmann, H. 1979. The influence of temperature, food, initial size, and origin on the growth of elvers (ANGUILLA ANGUILLA, L.) Rapp. Riv. Re'un. Cons.Int. Explor. Mer. ,174:59-63.

Liew, Peter, K. L. 1974. Age determination of American eels based on the structure of their otoliths: IN, Ageing of Fish, T. B. Bagenal (ed.) ,Unwin Brothers Ltd., Surry, England,p.124-136.

Meske, C. 1973. Experimentally induced sexual maturity in artifically reared male eels (ANGUILLA ANGUILLA). IN, Genetics and Mutagenesis of Fish,J. H. Schroder (ed.) ,Springer-Verlag, Berlin,p.161-176.

Mondini, C. 1777. De anguillae ovariis. Comment. Acad. Bologna (1783),p.406.

Moriarty, C. 1973. A technique for examining eel otoliths. J. Fish. Biol. 5:183-184.

----------- 1979. Biological studies of yellow eels in Ireland. Rapp. P-V. Reun. Cons. Int. Explor. Mer., 174:16-21.

----------- and B. Steinmetz 1979. On age determination of eels. Rapp. P.- V. Re'un Cons. Int. Explor. Mer., 174:70-74.

Ogden, J. C. 1970. Relative abundance,food habits,and age of the American eel, ANGUILLA ROSTRATA (LeSueur) in certain New Jersey streams. Trans. Amer. Fish. Soc. 99:54-59.

Ord, Bill 1978. Habitat determines sex and size of eels. IN Australian Fisheries, February 1978,p.13.

Passakas, Teresa and F. W. Tesch. 1980. Karyological and gonadal sex of eels ANGUILLA ANGUILLA) in the German Bight and the lower River Elbe. Helgolander Meersunter. 34:159-164.

Rasmussen, Gorm and Birgit Therkildsen. 1979. Food, growth and production of ANGUILLA ANGUILLA L. in a small Danish stream. Rapp. P-V. Re'un Cons. Int. Explor. Mer.,174:32-40.

Ricker, W. E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Fish. Res. Bd. Canada, No. 191.

Rossi, Remigio and Ginseppe Colombo. 1979. Some observat- ations on age, sex and growth of silver eels (ANGUILLA ANGUILLA L.) in North Adriatic Lagoons. Rapp. P-V. Reun. Cons. Int. Explor. Mer.,174:64-69.

Satoh, Hideo, N. Nakamura and T. Hibiya. 1962. Studies on the sexual maturation of the eel:I. On the sex differentiation and the maturing process of the gonads. Bull.of Japan. Soc.of Sci. Fish., 28:6,579-588.

Schwartz, Frank 1961. Lampreys and eels. Maryland Conser.

,Vol.38 ,5p.

Sinha, V. R. P. and J. W. Jones 1967. On the age and growth of the freshwater eel (ANGUILLA ANGUILLA) . J. Zool. ,London, 153:99-117.

------------------------------ 1975. The European Freshwater Eel., Liverpool Univ. Press, Liverpool, England,146p.

Smith, C. L. 1966. The patterns of sexuality and the classification of serranid fishes . Am. Mus. Nov., No. 2207, 19p.

South Carolina Wildlife and Marine Resources Department 1981. American eel investigation : Completion report for the period March 1977-July 1978., 311p.

Syrski, A. 1874. Uber die Reproduktions- Organe der Aale. Sber. Akad. Wiss. Wien. 69:1,315.

Tesch, F. W. 1971. Age and growth. IN, Methods for Assessment of Fish Production in Freshwaters., W. E. Ricker (ed.) ,p.98-130.

------------- 1977. The Eel: Biology and Management of Anguillid Eels., Chapman and Hall, London,434p.

Usui, A. 1974. Eel Culture. Fishing News Books Ltd., London, 186p.

Vladykov, V. D. 1964. Quest for the true breeding area of the American eel (ANGUILLA ROSTRATA, LeSueur). J. Fish. Res. Bd. Canada, 21:1523-1530.

---------------- 1970. American eel (ANGUILLA ROSTRATA) studies in Canada. Industrial Development Branch, Dept. of Fish and Forestry,Ottawa Canada Report No. 32, 98p.

Voronin, F. N. and N. Rusetskaya. 1971. Determination of the age and growth of the European freshwater eel (ANGUILLA ANGUILLA , L.) from the scales. J. Ich. 11:717-724.

Wenner, Charles A. 1972. Aspects of the biology and systematics of the American eel,ANGUILLA ROSTRATA, LeSueur, V.I.M.S. Masters Thesis.

------------------ and J. A. Musick 1974. Fecundity and gonad observations of the American eel, ANGUILLA ROSTRATA, migrating from Chesapeake Bay, Virginia. J. Fish. Res. Bd. Canada 31:1387-1391.

------------------------------------ 1975. Food habits and seasonal abundance of the American eel, ANGUILLA ROSTRATA, from the lower Chesapeake Bay. Chesapeake Sci.16:62-66.

Westin, Lard and L. Nyman. 1977. The migrations of silver eels: when, where and how.Zool. Revy. 39:1,2-11.

Williams, T. and B. C. Bedford. 1974. The use of otoliths for age determination. IN, Ageing of Fish, T. B. Bagenal (ed.), p.114-136.

Winn, H. E., W. A. Richkus and L. K. Winn. 1975. Sexual dimorphism and natural movements of the American eel (ANGUILLA ROSTRATA) in Rhode Island streams and estuaries. Hegulander Wiss. Meeresenthers 27:156-166.

Yamamoto, K. and K. Yamauch. 1975. Sexual maturation of Japanese eels and the production of eel larvae in the aquarium. Nature 251:220-221.

Table 1

Range, mean and standard deviations of observed total length (mm), and weight-at-age (g) for American eels from the Chesapeake Bay area.

Age	Mean	Standard Deviation	N	Range
		TOTAL LENGTH (mm)		
1	59.2	6.0	216	53-67
2	137.9	24.3	39	96-186
3	274.0	42.7	97	158-354
4	340.1	46.7	35	204-492
5	425.4	78.5	27	290-546
6	552.0	55.6	10	431-620
7	556.0	45.4	3	505-592
8	571.0	-	1	-
9	642.5	48.3	4	585-689
		TOTAL WEIGHT (g)		
1	0.2	0.1	216	0.1-0.3
2	3.4	2.5	39	0.6-7.9
3	37.9	17.8	97	6.5-90.2
4	78.9	36.6	35	36.6-198.0
5	165.5	101.1	27	35.0-367.7
6	340.4	96.4	10	157.6-454.2
7	398.5	24.7	3	381.0-416.0
8	433.9	-	1	-
9	718.4	172.9	4	534.4-877.7

Table 2

Observed and theoretical sizes expressed as relative growth (h).

Age (years)	Mean Length (mm)	Relative Growth Length	Mean Weight (g)	Relative Growth Weight
		Observed		
1	59.2		0.2	
		1.33		16.0
2	137.9		3.4	
		0.99		10.15
3	274.0		37.9	
		0.24		1.08
4	340.1		78.9	
		0.25		1.10
5	425.4		165.5	
		0.30		1.06
6	552.0		340.4	
		0.01		0.17
7	556.0		398.5	
		0.03		0.09
8	571.0		433.9	
		0.13		0.66
9	642.5		718.4	
		Theoretical		
1	22.5		0.2	
		6.08		16.0
2	160.0		3.4	
		0.71		10.1
3	273.1		37.9	
		0.34		1.07
4	366.1		78.6	
		0.21		1.09
5	442.6		164.7	
		0.14		1.05
6	505.5		338.4	
		0.1		0.17
7	557.3		397.1	
		0.08		0.94
8	599.8		434.5	
		0.06		0.65
9	634.8		716.4	

Table 3

Comparison of mean lengths-at-age (cm) obtained for American and European eels.

Study	Location	AGE GROUP 0	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Present Study*	Virginia	-	14	27	34	42	55	56	57	64						
Facey 1980	Vermont	-	-	-	-	-	-	-	-	43	57	58	60	61	61	63
Bieder 1971	Rhode Is.	-	-	-	-	35	42	42	44	45	46	53	56			
Ogden 1970	N.Jersey	-	-	-	-	17	19	28	34	37	45	45	50	55	61	67
Foster 1982	Maryland	-	-	10	20	36	35	37	36	39	42	47	51	54	67	64
		-	-	-	28	30	31	31	31	35	-	36				
Harrell 1980	S.Carolina	-	15	22	25	34	40	49	54	60	61	64	61	68	69	-
Hanson 1981	S.Carolina	-	-	29	36	41	46	48	51	58	51	61	-	-	55	
Boetius 1967	Bermuda	-	-	23	33	42	47	49								
Smith 1955	Canada	-	-	-	24	29	35	37	39	46	50	55				
Gray 1970	Canada	-	-	17	22	27	32	40	46	53	62	71	84			
Hurley 1972	Canada	-	-	-	-	31	-	51	50	53	53	66	79	79	84	85
Frost**1945	England	-	9	15	20	23	26	32	38	41	43	49	52	56	58	80
Sinha**1975	England	-	15	18	22	27	31	35	39	46	47	54	62	63	70	
Rasmussen**1952	Denmark	-	-	-	-	-	-	-	-	53	56	55	56	58	58	59

Table 3 conti.

AGE GROUP

Study	Location	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII
Present Study*	Virginia								
Facey 1980	Vermont	65	70	72	73	77	75	77	81
Bieder 1971	Rhode Is.								
Ogden 1970	N.Jersey	68	69	72	74	87			
Foster 1982	Maryland	69	58						
Harrell 1980	S.Carolina	83							
Hanson 1981	S.Carolina								
Boetius 1967	Bermuda								
Smith 1955	Canada								
Gray 1970	Canada								
Hurley 1972	Canada	91	92	97	91				
Frost**1945	England	77	83	93					
Sinha**1975	England								
Rasmussen**1952	Denmark	59	69						

*Adjusted age,elvers= Age Group 0
**Anguilla anguilla study.

Table 4

Size of American eels and width of the ovary by collection period.

Date month/day	Mean Length (mm)	Standard Deviation	Mean Weight (g)	Standard Deviation	Mean Gonad Width (mm)	Standard Deviation	N
04/1-15	345.0	-	71.6	-	3.0	-	1
04/16-30	344.5	9.19	72.9	9.33	3.0	-	2
06/1-15	304.1	35.70	54.4	18.50	1.9	2.49	20
06/16-30	433.9	73.40	170.2	93.90	7.4	3.96	32
07/1-15	481.8	101.80	253.3	188.80	11.8	6.67	12

Fig.1

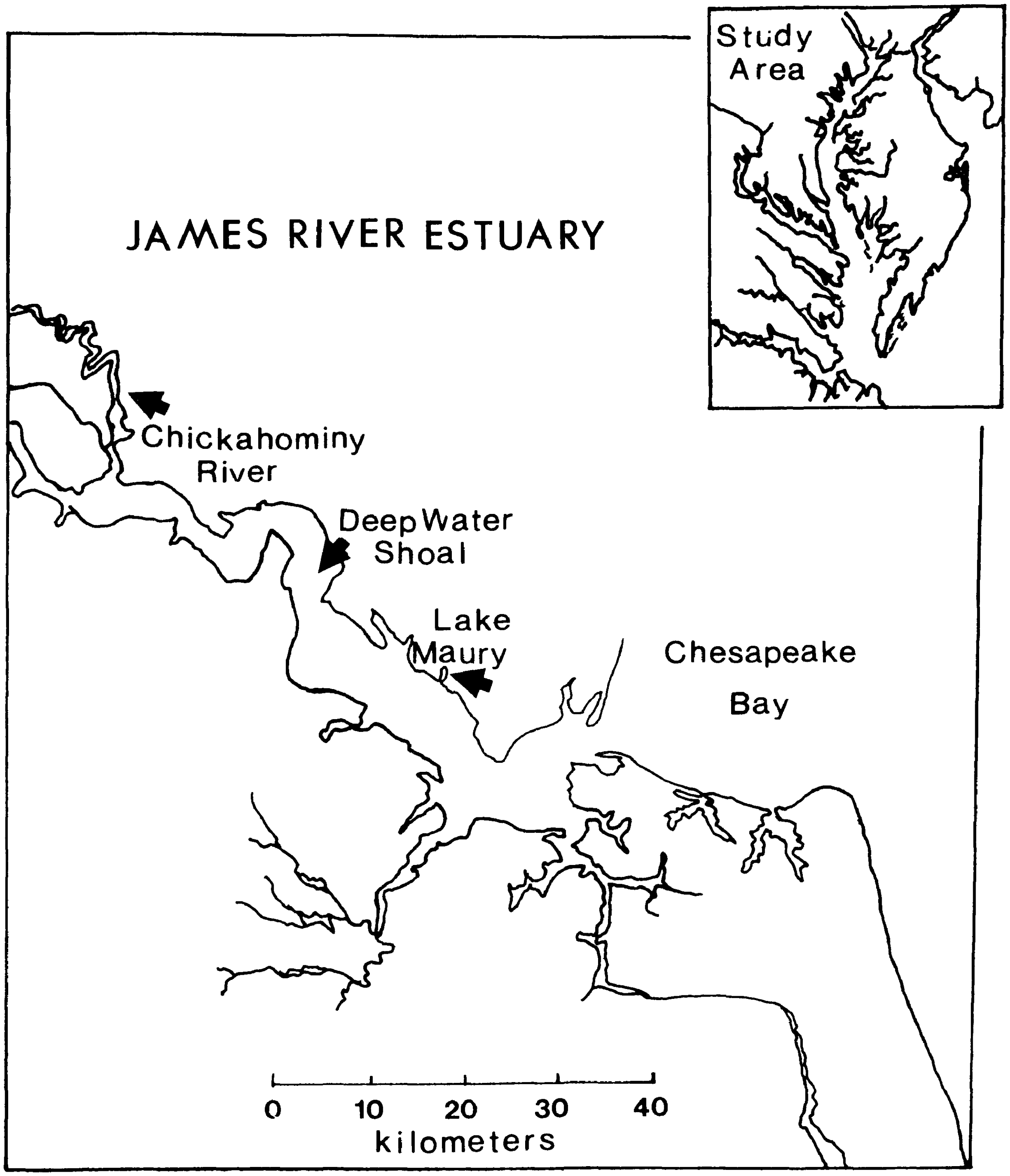
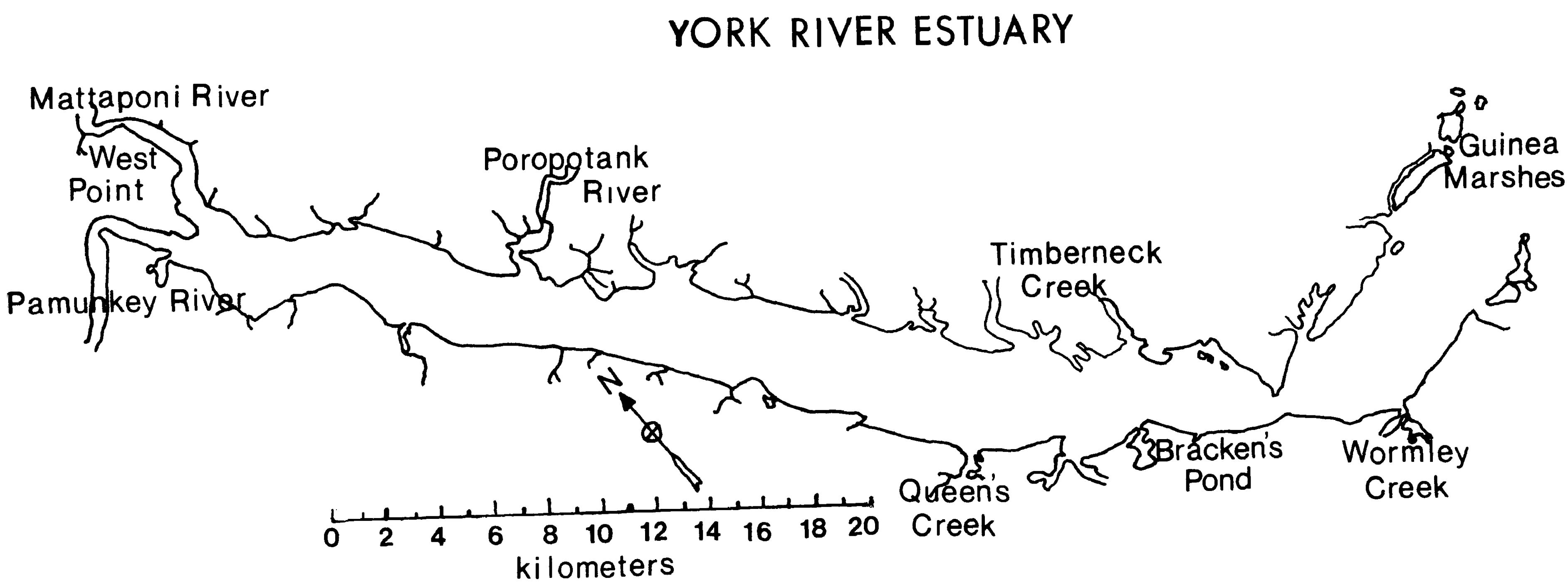
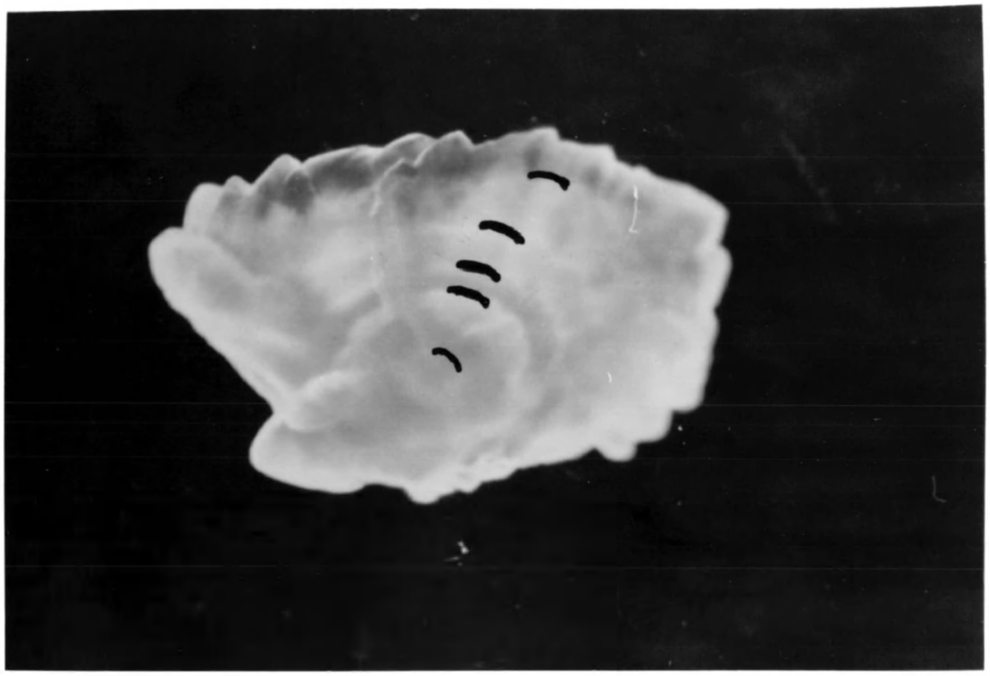

Study
Area
JAMES RIVER ESTUARY
Chickahominy
River
Deep Water
Shoal
Lake
Maury
Chesapeake
Bay
0 10 20 30 40
kilometers

Fig. 2



YORK RIVER ESTUARY
Mattaponi River
West Point
Pamunkey River
Poropotank River
Timberneck Creek
Guinea Marshes
Queen's Creek
Bracken's Pond
Wormley Creek
N
0 2 4 6 8 10 12 14 16 18 20
kilometers

Fig. 3 Age determination from an otolith of a 5+ age American eel (309mm , 64g).



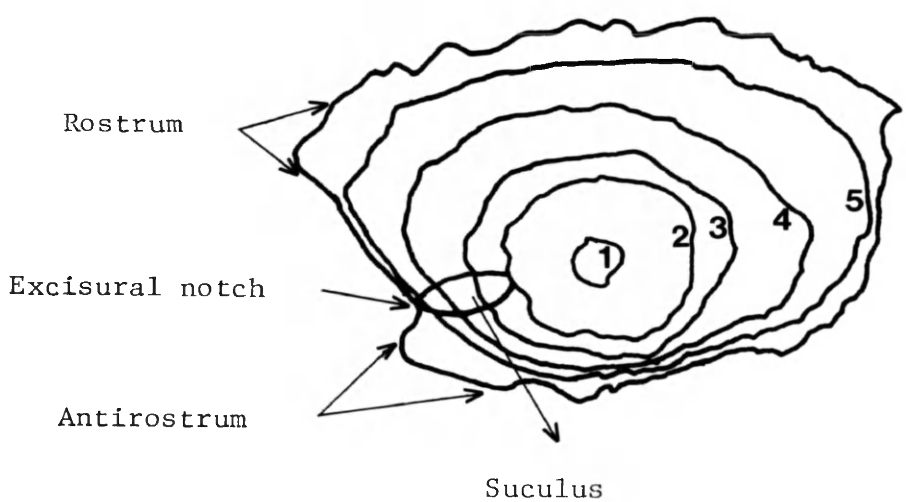


Fig. 4 Relationship between fish length (mm) on total otolith radius (400 micrometer units= 1mm) for American eels from the Chesapeake Bay area.

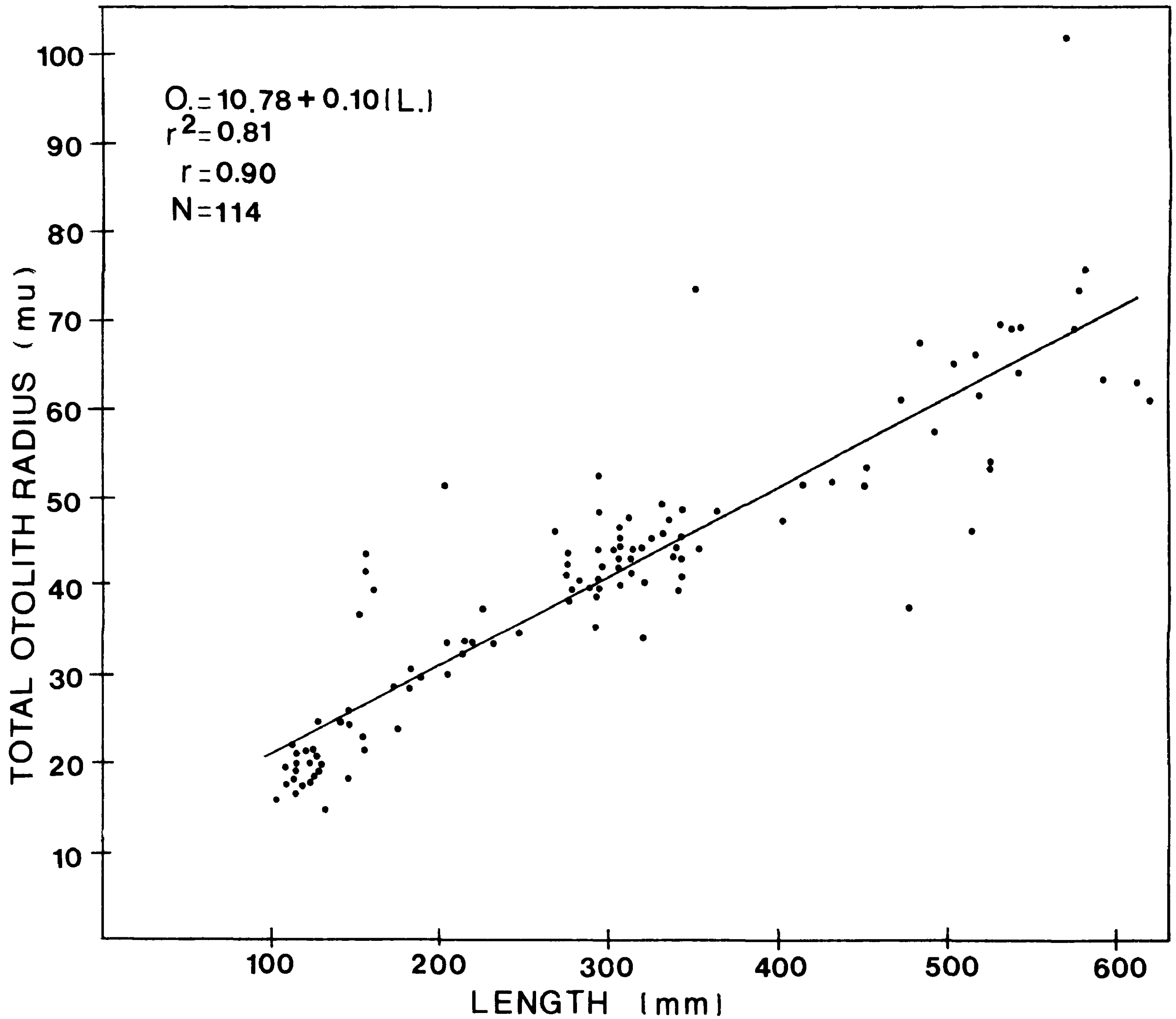


Fig. 5 Growth curves for observed and theoretical length-at-age of American eels from the Chesapeake Bay area.

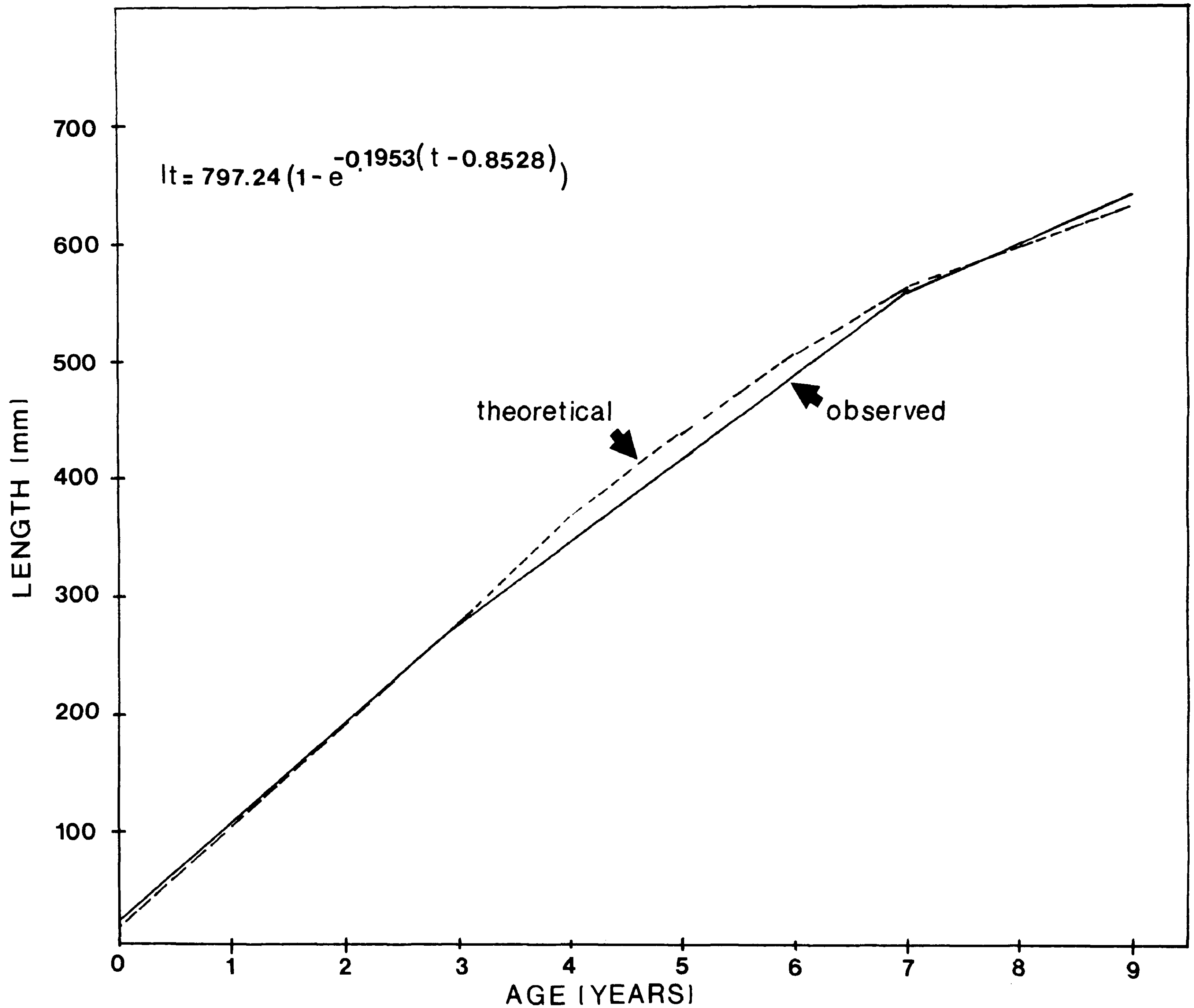


Fig. 6 Estimates of L_{∞} by the Walford Plot and Beverton Method.

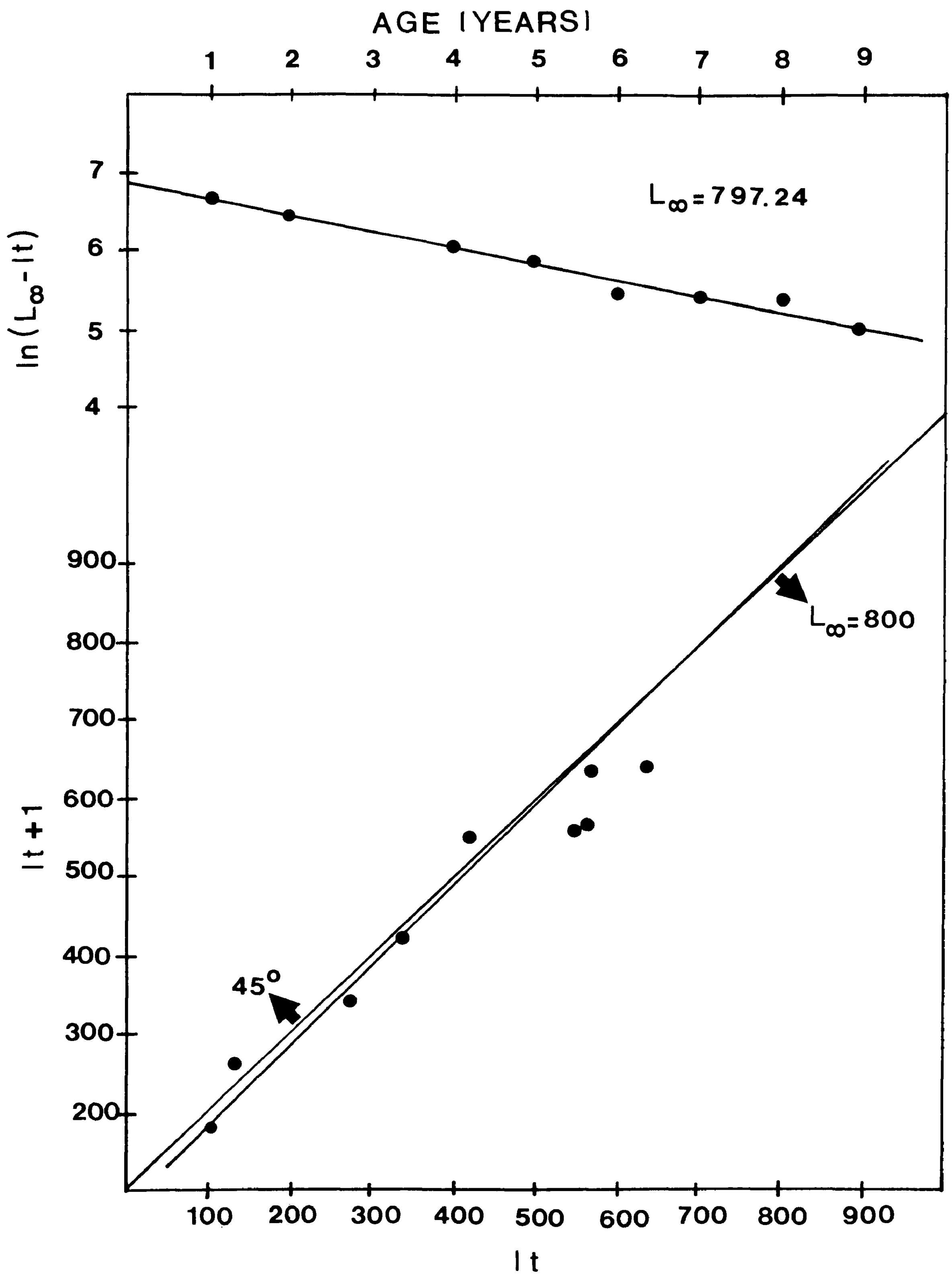


Fig 7 Observed and theoretical growth curves for weight of American eels from the Chesapeake Bay area.

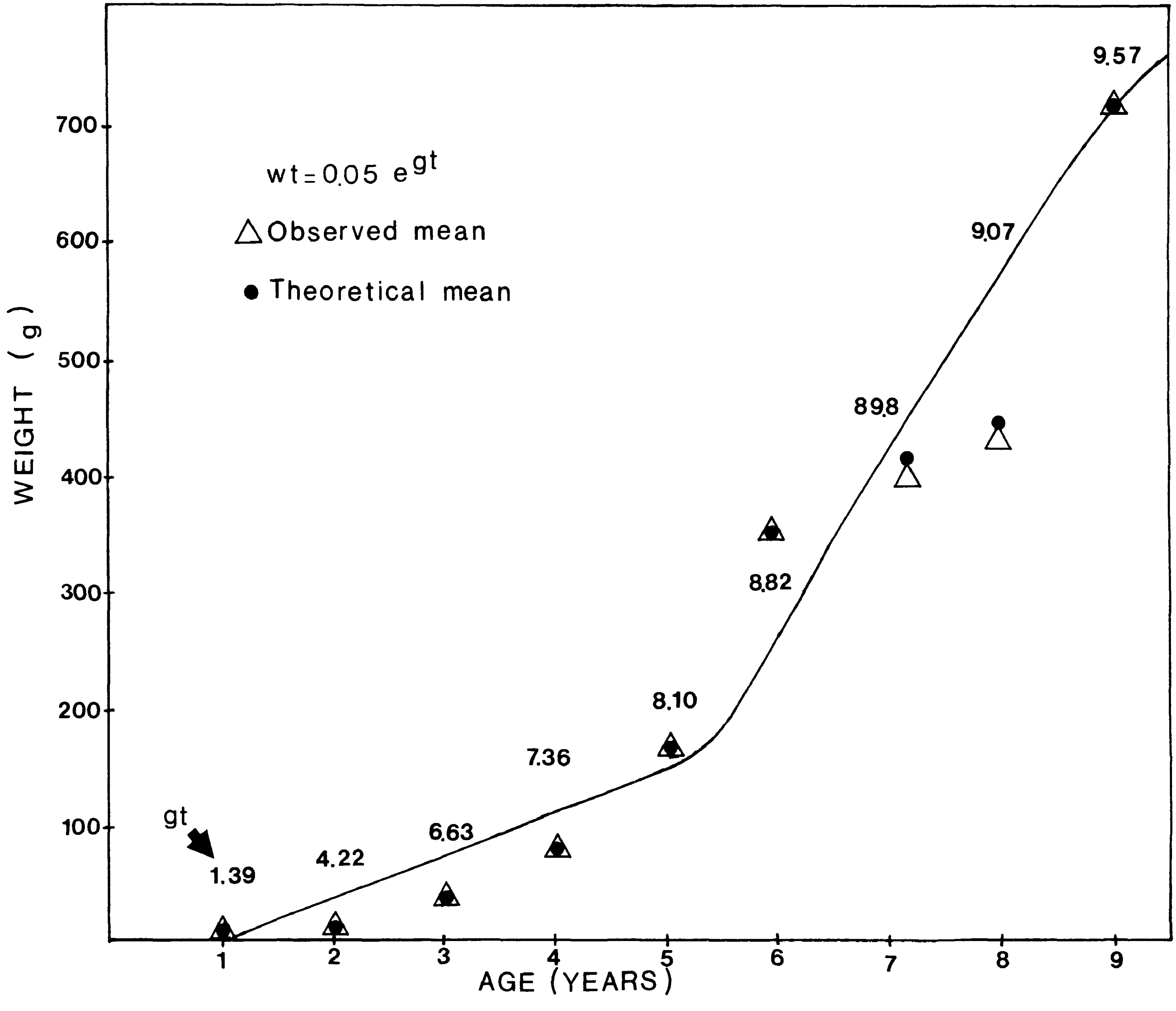


Fig. 8 Relationship between marginal increment widths on otoliths from 72 eels and mean monthly water temperatures from December 1980 through July 1981.

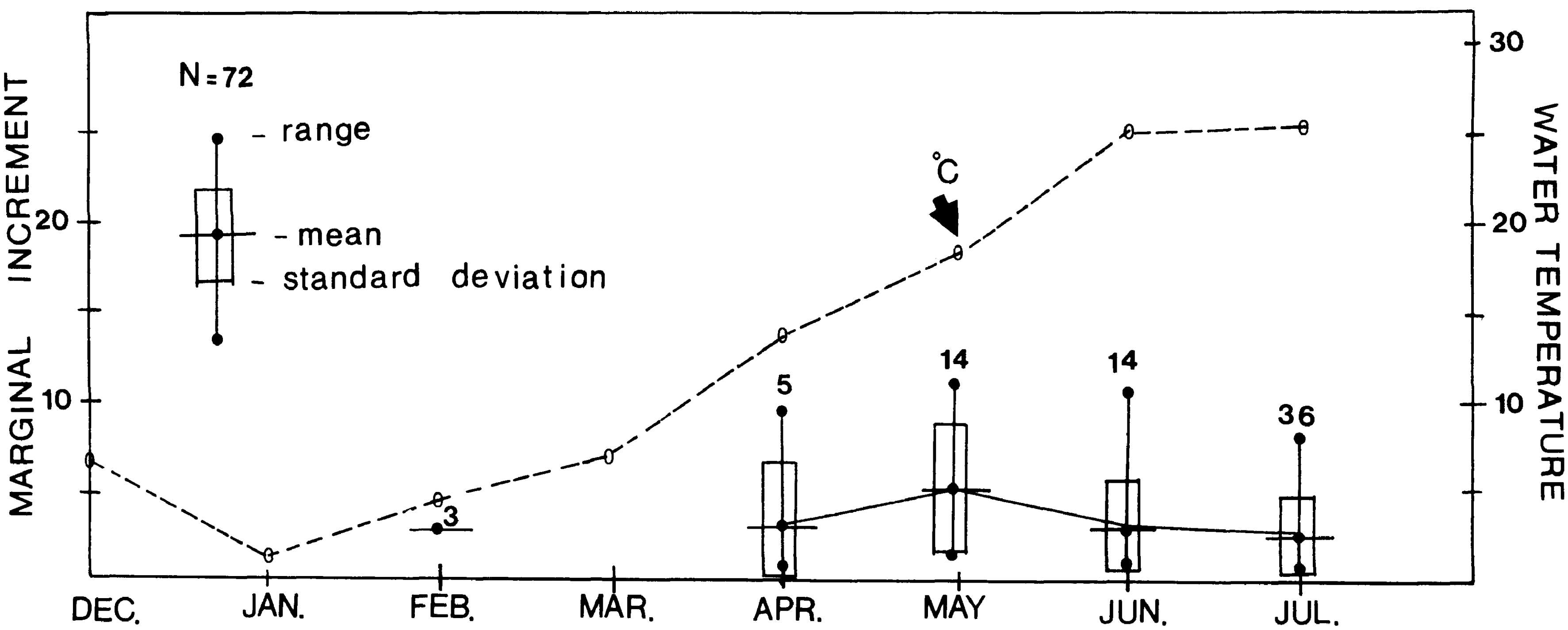


FIG. 9 & 10. Catch-per-unit-of-effort of American eels by month, and water temperature and salinity intervals. Data was obtained from the VIMS-Sea Grant Eelpot Gear Efficiency study in the York River and its' tributaries (May through September 1981).

TOTAL NUMBER

Fig. 9A

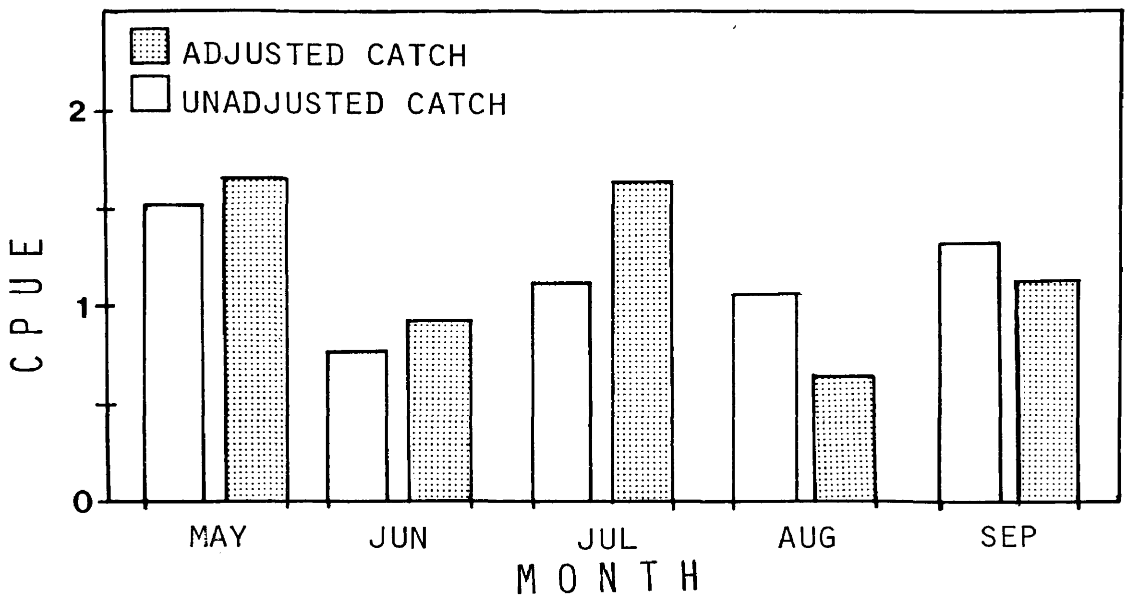
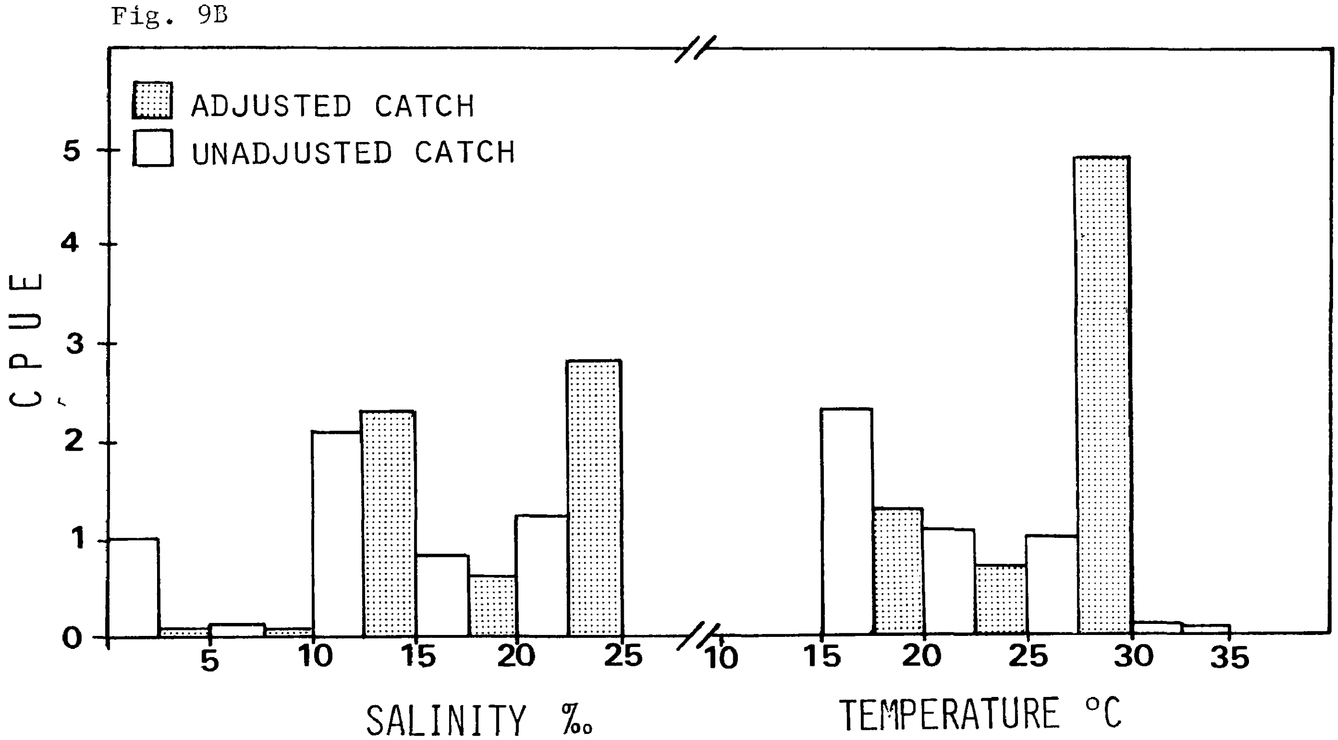


Fig. 9B



TOTAL WEIGHT

Fig. 10A

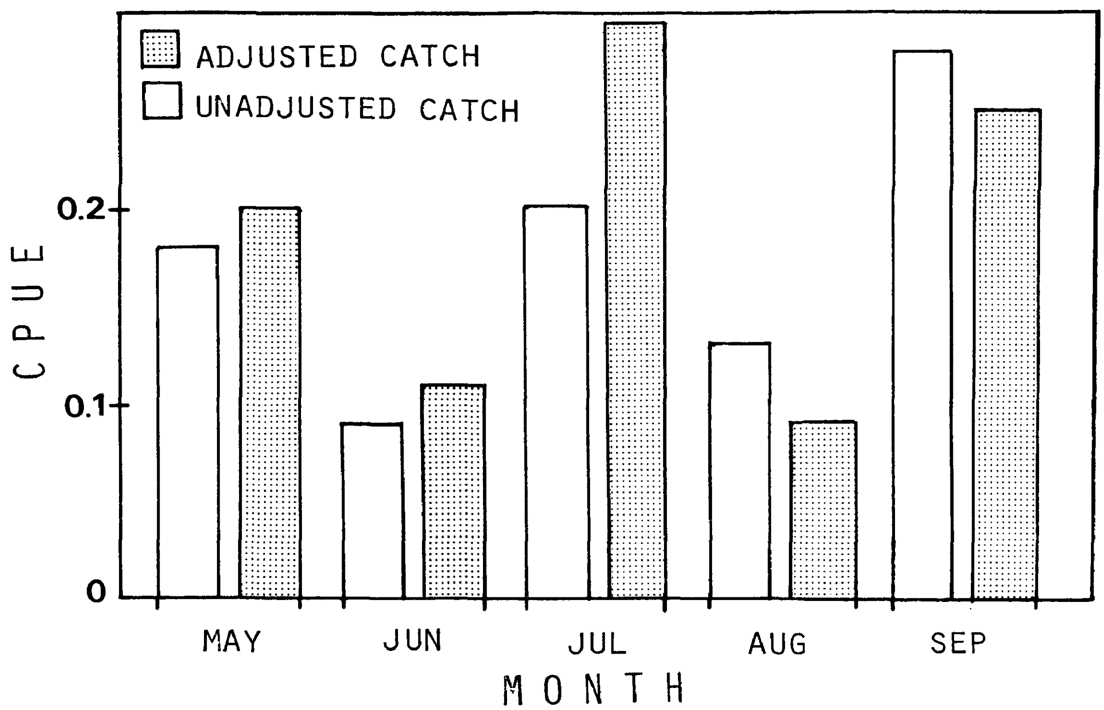


Fig. 10B

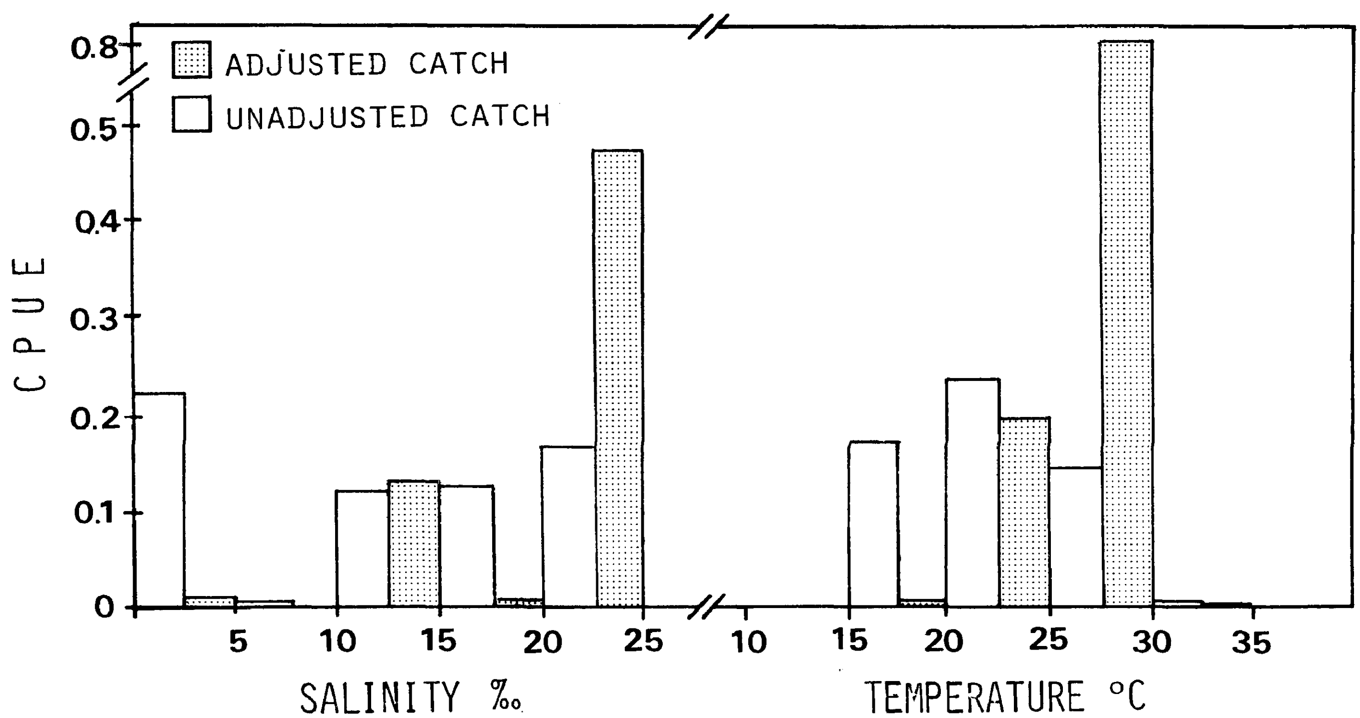


Fig. 11 Photograph of a normal ribbon-shaped ovary of an eel (601mm, 396g) from Queens Creek on the York River. The gonad width was 12mm.

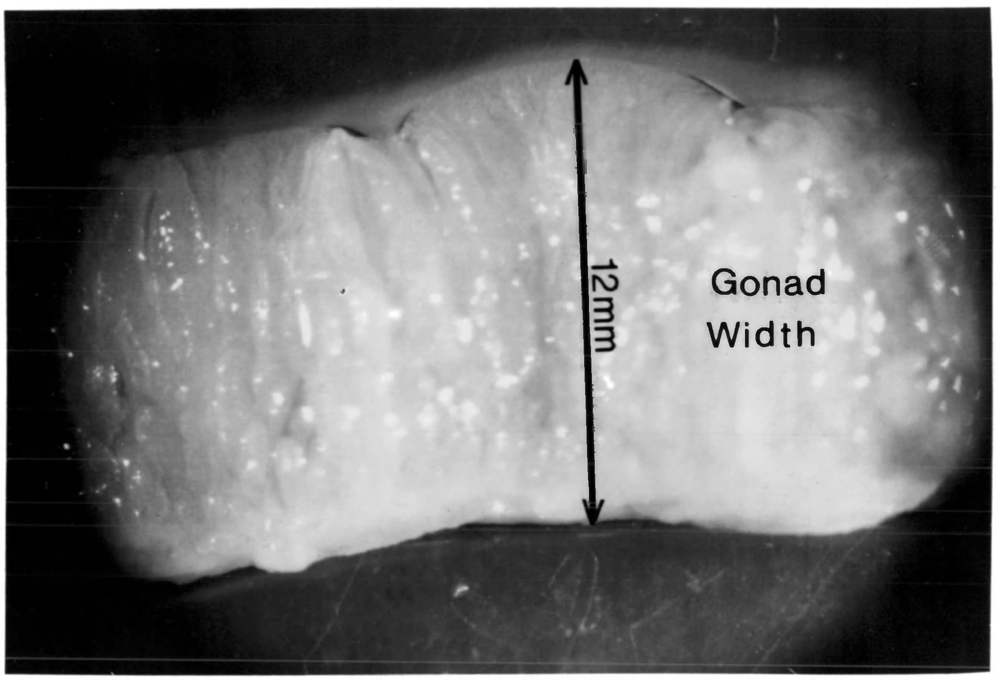


Fig.12 Diagrams of the relationships between ovary width, fish size (length, panel A; weight, panel B) and the time of capture for American eels from the Chesapeake Bay area.

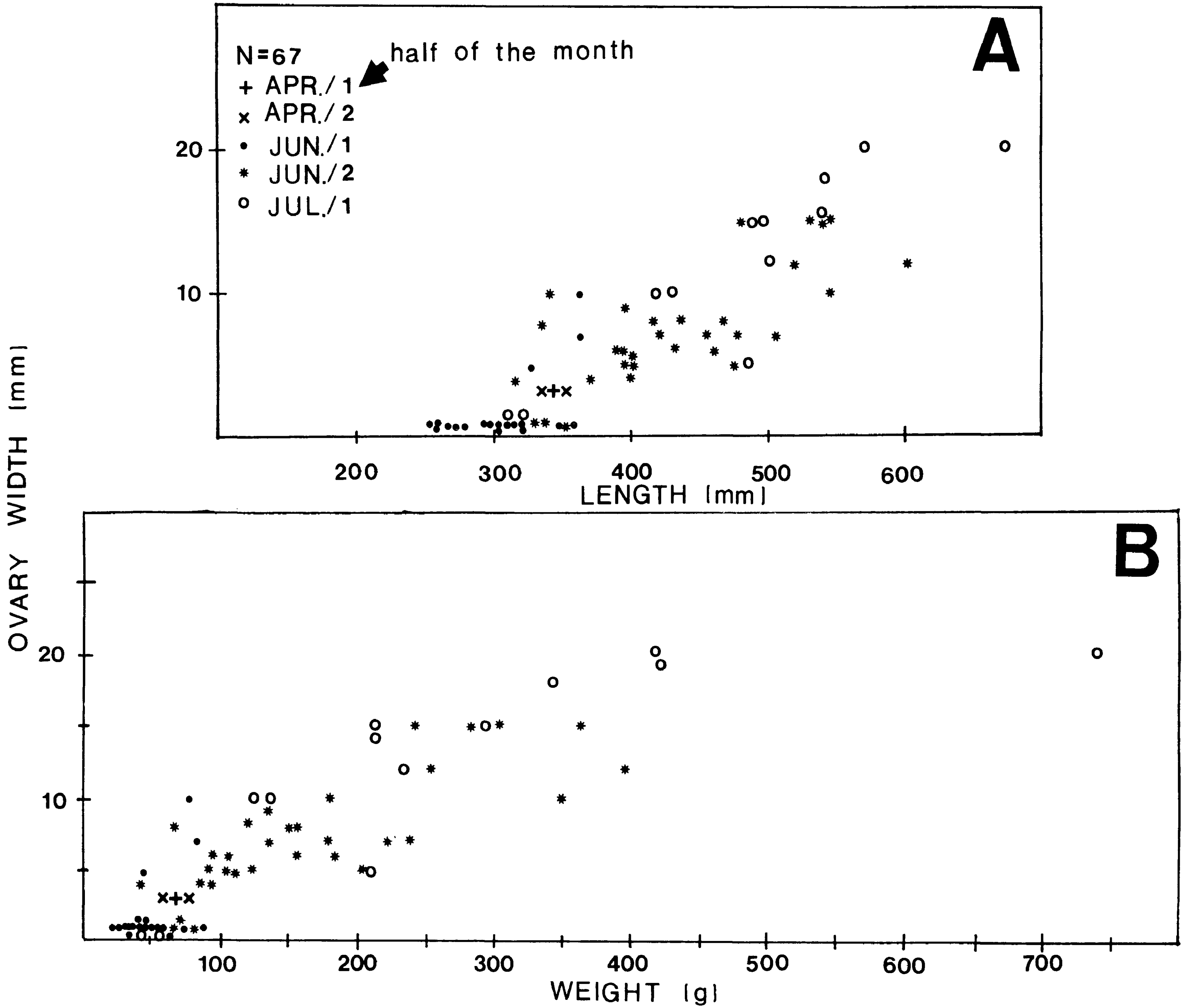


Fig. 13 Ovaries of a silver eel (922mm, 1870g) captured in a trawl in the upper York River during February 1981. Each ovary weighed approximately 55 grams. The ovary width was 25mm. This eel was initially aged as 13+ years. Note the degenerating stomach, the three lobed liver, and black fin. The left ovary was somewhat shorter than the right ovary.

Fig. 14 Photograph of a lobe-shaped sex organ resembling the organ of Syrski of male eels. This eel was possibly a transforming female (334mm, 75.3g). Gonad width ranged from 3mm at the top of the lobe to 2mm at the point of overlap between two lobes.

Fig. 15 Photograph of another possible transforming female eel (311mm, 46.2g) captured at Deep Water Shoal on the lower James River. Gonad width was 1mm. Note the upper portions of the lobes appear transparent apparently due to the presence of undifferentiated tissue.

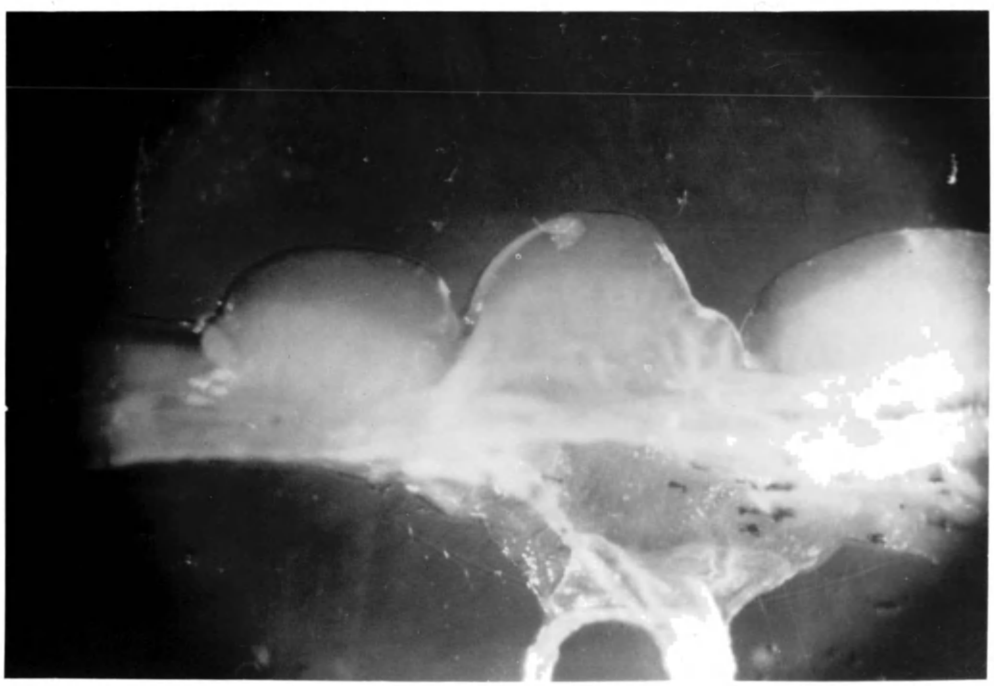


Fig. 16A Photomicrograph of a Stage II Ovary (400X) from an American eel (591mm, 405.9g and age 6).

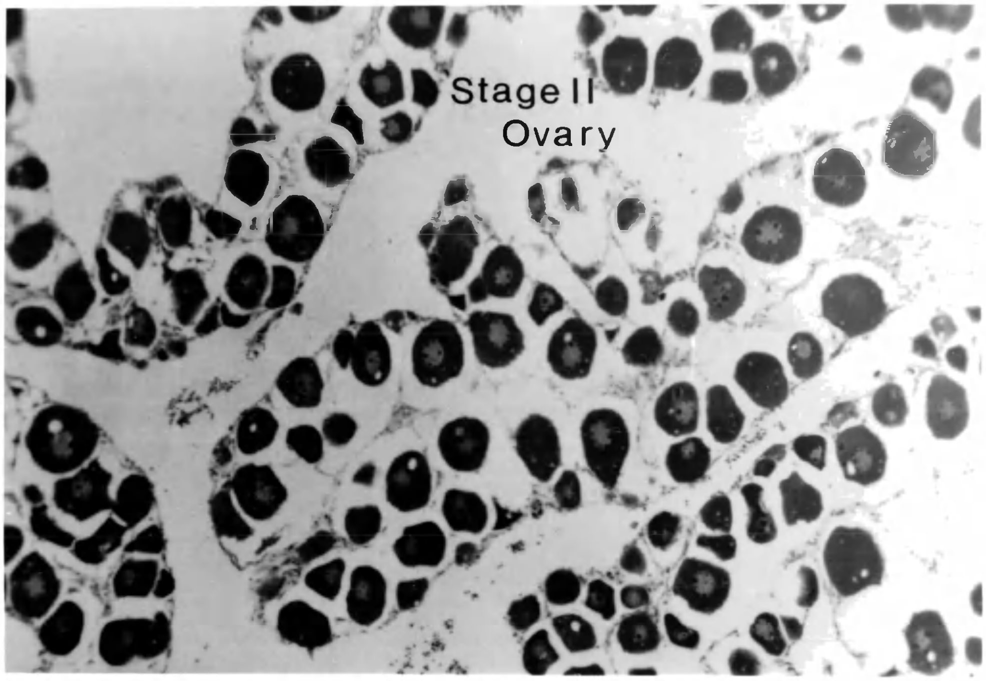


Fig. 16B Photomicrograph of Stage I and II oocytes (1000X) present in a Stage II Ovary (PVN=protovitellonucleoli).

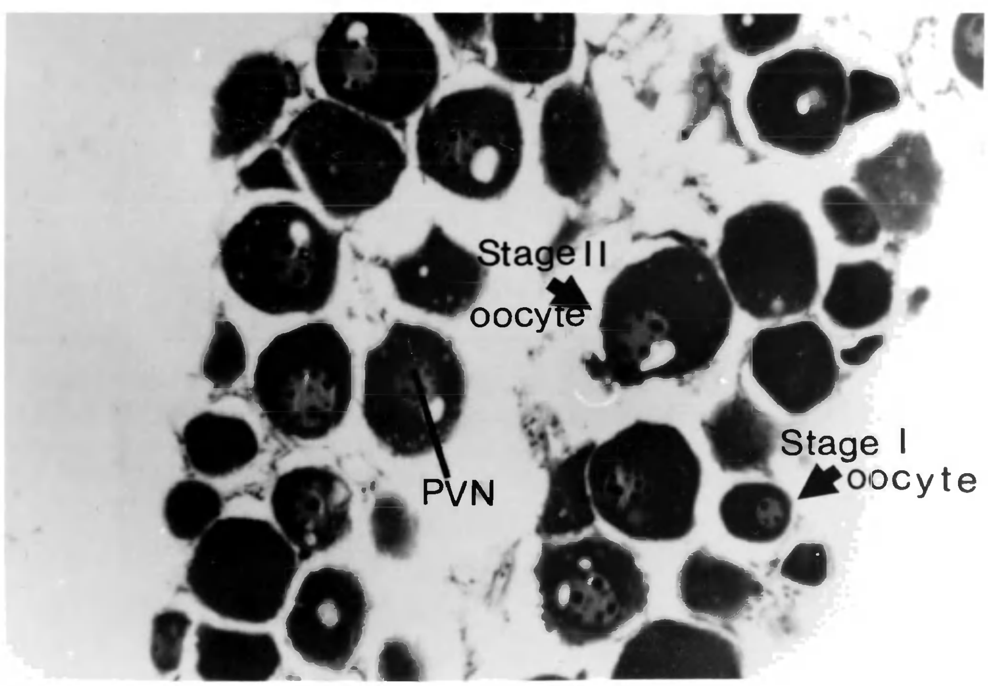
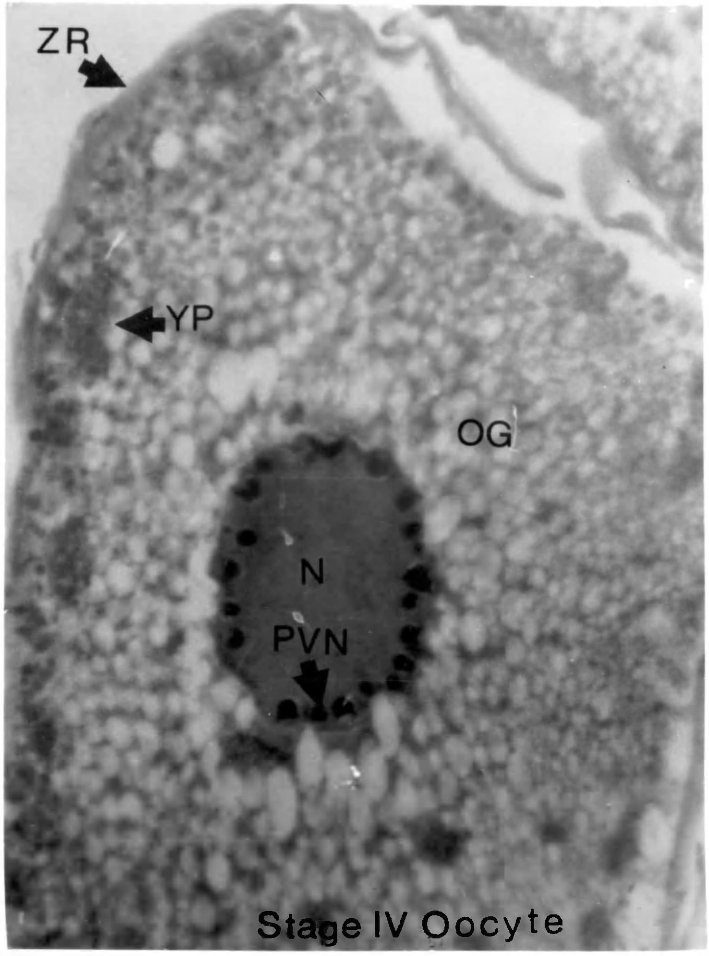


Fig. 17A Photomicrograph of a Stage IV oocyte at 1000X (YP=yolk platelets, ZR=zona radiata, N=nucleus, OG=oil globules and PVN=protovitellonucleoli or basophilic inclusions). The yolk platelets were just beginning to form.

Fig. 17B Photomicrograph of a Stage IV ovary from a silver-stage American eel. Note that essentially all oocytes appear to be in the same stage.

17A



17B

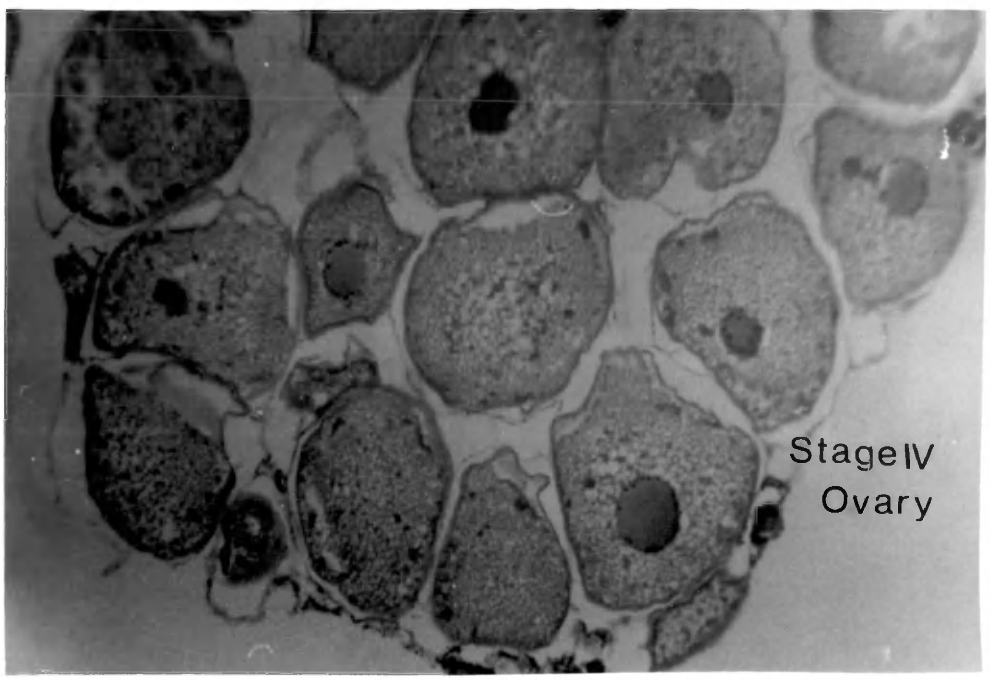
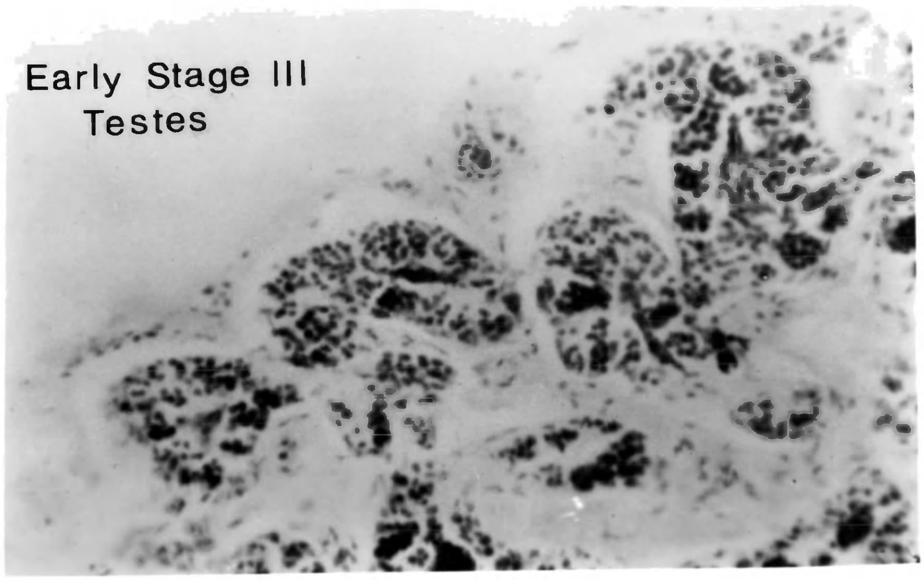
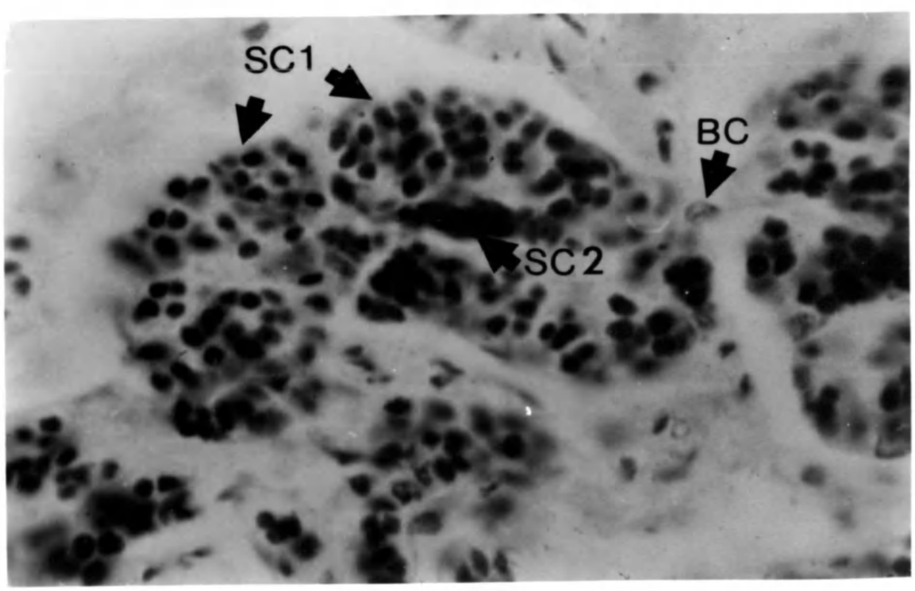


Fig. 18A & B Photomicrograph of the testes of a silver eel (278mm, 34g, age 6-7) from Turvil Creek in Maryland. Note the crypts of darkly stained spermatocytes (1000X, 1500X).





Appendix A

Catch data from the VIMS-Sea Grant Eelpot Gear Efficiency Study, 1981.

			TOTAL NUMBER				TOTAL WEIGHT (kg)			
Month	Set No.	No. of Pots	Total Catch	CPUE	Adj. Catch	CPUE	Total Catch	CPUE	Adj. Catch	CPUE
May	1	24	16	0.67	19	0.79	3.58	0.15	4.25	0.18
"	2	25	27	1.08	27	1.08	5.40	0.22	5.40	0.22
"	3	25	97	3.88	90	3.60	5.55	0.22	5.12	0.20
"	4	25	54	2.16	79	3.16	3.15	0.13	4.61	0.18
"	5	24	23	0.96	21	0.88	6.22	0.26	5.70	0.24
"	6	25	9	0.36	12	0.48	2.89	0.12	3.85	0.15
June	7	19	2	0.11	4	0.21	0.39	0.02	0.78	0.04
"	8	24	14	0.58	9	0.38	2.20	0.09	1.41	0.06
"	9	24	2	0.08	3	0.12	0.16	0.01	0.24	0.01
"	10	24	43	1.79	37	1.54	3.80	0.16	3.26	0.14
"	11	23	2	0.09	2	0.09	0.23	0.01	0.23	0.01
"	12	23	3	0.13	*	-	0.42	-	-	-
"	13	25	10	0.40	12	0.48	1.88	0.08	2.26	0.09
"	14	25	70	2.80	62	2.48	8.44	0.34	7.50	0.30

Appendix A (conti.)

July	15	25	64	2.56	87	3.48	10.24	0.41	13.96	0.56
"	16	25	27	1.08	22	0.88	3.64	0.14	2.97	0.12
"	17	25	10	0.40	13	0.52	4.24	0.17	5.53	0.22
"	18	24	33	1.37	*	-	5.55	-	-	-
"	19	25	5	0.20	*	-	1.00	-	-	-
August	20	25	3	0.12	4	0.16	0.47	0.02	0.63	0.03
"	21	25	82	3.28	*	-	7.25	-	-	-
"	22	25	0	0.00	0	0.00	0.00	0.00	0.00	0.00
"	23	25	3	0.12	2	0.08	0.45	0.02	0.30	0.01
"	24	25	49	1.96	39	1.56	6.32	0.25	5.02	0.20
"	25	25	27	1.08	34	1.36	4.24	0.17	5.36	0.21
September	26	25	70	2.80	53	2.12	11.73	0.47	8.91	0.36
"	27	25	4	0.16	6	0.24	1.48	0.06	2.22	0.09
"	28	24	53	2.21	49	2.04	13.39	0.56	12.36	0.52
"	29	23	2	0.09	2	0.09	0.76	0.03	0.76	0.03
Total			804		688		115.09		102.63	

* Deleted set due to day/night period overlap.

Appendix B

Histological data summary.

Specimen Number	L. (mm)	W. (g)	Age (yrs.)	Location	Date	Gonad Stage	Oocyte Stage 1	2	3	4	5
E001	495	213.7	-	JA	01/28/81	II	x	xx			
E003	412	107.2	-	"	"	II	x	x			
E007*	922	1870.0	-	YK	02/10/81	IV			x	xx	
E029	255	27.5	3	PT	03/11/81	II	x				
E031	358	68.7	5	"	"	II	x	x			
E028	525	256.4	6	"	"	II or III	x	x	xx		
E384	621	534.4	9	WC	05/27/81	III	x	xx	xx		
E385	610	552.1	-	"	"	III	x	x	xx		
E386	546	350.8	5	"	"	II	x	xx			
E387	591	405.9	6	"	"	II	x	xx			
E388	476	215.1	-	"	"	II	x	xx	x		
E389	520	298.5	-	"	"	II	x	x	xx		
E390	488	233.4	5	"	"	II	x	xx			
E391	460	199.4	5	"	"	II	x	x	xx		
E410	362	80.5	4	"	"	II	x	x			

Appendix B (conti.)

* silver phase
x oocyte stage present
xx most abundant stage present

JA= James River
YK= York River
PT= Potomac River
WC= Wormley Creek (York River)

VITA

<u>Marion Yvonne Hedgepeth</u>

The author was born in Newport News, Virginia on December 31,1952. She graduated from Denbigh High School in that city , June 1971. She attended Old Dominion University in Norfolk, Virginia as a biology major between 1971 and 1973. In March of 1975, she obtained a Bachelor of Science Degree in Marine Science from the University of West Florida in Pensacola, Florida. After graduation, the author returned to the state of Virginia, and worked as technician, marine scientist and graduate research assistant at the Virginia Institute of Marine Science, Department of Ichthyology.

In 1978, the author entered the College of William and Mary, School of Marine Science.

The author is currently a marine biologist for the Florida Department of Natural Resources, Marine Research Laboratory in West Palm Beach, Florida.