Scott Tindal Shelton. THE AGE, GROWTH AND FOOD HABITS OF THE WINDOWPANE FLOUNDER, SCOPHTHALMUS AQUOSUS (MITCHILL) IN THE LOWER CAPE FEAR RIVER ESTUARY AND ADJACENT OCEAN. (Under the direction of Frank J. Schwartz and Charles O'Rear).

The age, growth and food habits of Scophthalmus aquosus were examined from January through November, 1976. The lower 35 km of the Cape Fear River and adjacent ocean provided the specimens for analysis. Neomysis americanus, a mysid shrimp, was the dominant food source throughout the year. Based on the literature, Scophthalmus aquosus has a split spawning period in North Carolina waters, starting in April and recommencing in the Fall. No sexually ripe individuals were collected during the study period, but based on the literature, it is believed that young-of-the-year fish captured in late winter (February) and early spring (March) were spawned during the fall. Scales were examined to determine age and growth. Young-of-the-year (age class 0) fish dominated the catches, but age classes 1-3 were also observed. The length-weight relationship was $W = 0.578 \times 10^{-4}(L)^{2.82}$ or $\log W = -4.60 + 2.82 (\log L)$.

THE AGE, GROWTH AND FOOD HABITS OF THE WINDOWPANE FLOUNDER, *SCOPHTHALMUS AQUOSUS* (MITCHILL) IN THE LOWER CAPE FEAR RIVER ESTUARY AND ADJACENT OCEAN

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by

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THE AGE, GROWTH AND FOOD HABITS

OF THE WINDOWPANE FLOUNDER, *SCOPHTHALMUS AQUOSUS* (MITCHILL)

IN THE LOWER CAPE FEAR RIVER ESTUARY AND ADJACENT OCEAN

by

Scott T. Shelton

APPROVED BY:

CO-SUPERVISOR OF THESIS ______________________
Charles W. O'Rear, Ph.D.

CO-SUPERVISOR OF THESIS ______________________
Frank J. Schwartz, Ph.D.
Department of Zoology
University of North Carolina - Chapel Hill

THESIS COMMITTEE ______________________
Edward P. Ryan, Ph.D.

____
Clifford B. Knight, Ph.D.

ACTING CHAIRPERSON OF THE DEPARTMENT OF BIOLOGY

____
Edward P. Ryan, Ph.D.

DEAN OF THE GRADUATE SCHOOL

____
Joseph G. Boyette, Ph.D.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The windowpane flounder, *Scophthalmus aquosus* (Mitchill, 1815), is one of twenty-five species of Bothids occurring in North Carolina marine waters. *S. aquosus* is the only species of the genus inhabiting western Atlantic coastal waters. Three other species, *S. maximus* (Linnaeus), *S. maeoticus* (Pallus), and *S. rhombus* (Linnaeus), occur in portions of the northeastern Atlantic and other European waters (Lythgoe and Lythgoe 1975).

Bigelow and Schroeder (1953) reviewed the contributions made by various investigators toward the biological understanding of *S. aquosus*, which dealt with its spawning, age and growth, and feeding habits. Moore (1947) investigated the life history aspects of *Scophthalmus aquosus* in New York, and placed special emphasis on age determination by means of scales and otoliths. Aside from these investigations, most reports of *S. aquosus* have been repeated species descriptions along with distribution and abundance information (Hildebrand and Schroeder 1928; Leim and Scott 1966; Dahlberg 1975). *S. aquosus* has also been studied in ichthyofaunal surveys of the southeast coast of the United States (Anderson 1968; Dahlberg and Odum 1970; Kerr 1975; Shealy, Meglesease, and Joseph 1974). Although the zoogeography of *S. aquosus* may be well known, there is a dearth of life history information for most regions in which it occurs.

The purpose of this study was to investigate various life history aspects of *S. aquosus* collected in 1976 in the lower Cape Fear River estuary and adjacent ocean of North Carolina. Specimens were examined for their food habits and age and growth. Measurements of various physical and chemical aspects of the environment were also taken to possibly correlate their influence with biological data obtained from the fish sampled.

TAXONOMY AND DISTRIBUTION

Scophthalmus aquosus was first described by Mitchill (1814) from specimens collected from bays and coves near New York City, New York. Recognizing the fish as a flounder, he ascribed it the name *Pleuronectes maculatus*, (1814) which he later changed to *Pleuronectes aquosus*,(1815). Since then, the taxonomic name of the windowpane flounder has been changed several times by several different authors, such as *Rhombus aquosus*, *Lophopsetta maculata*, *Bothus maculatus*, *Lophosetta aquosus*, and *Scophthalmus aquosus* (Moore, 1947).

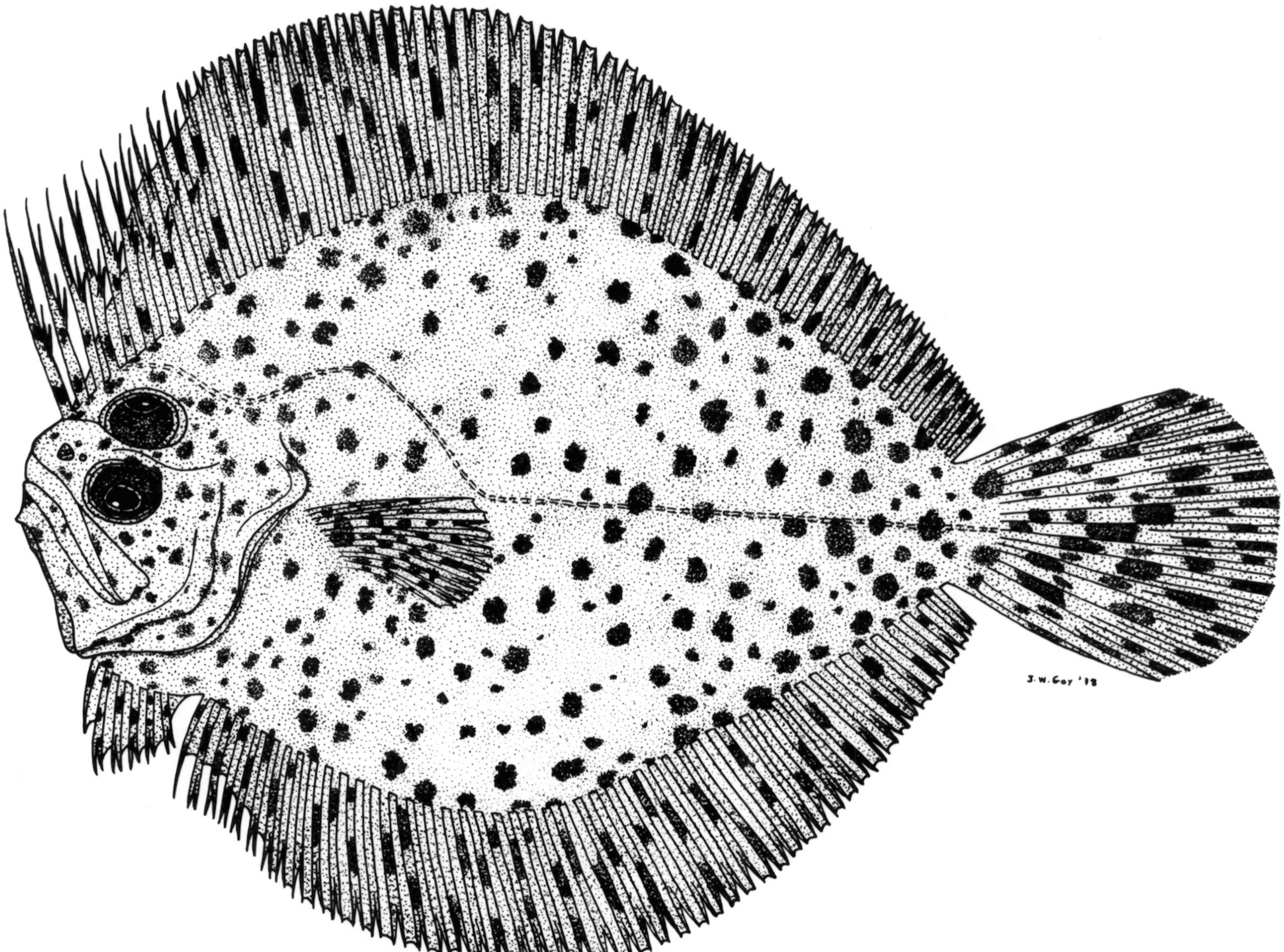
Gill (1878) reported mainly on fish collected in New Jersey and New York waters, but gave the distribution of *Scophthalmus* as from Cape Cod, Massachusetts to Cape Hatteras, North Carolina. Smith (1907) further extended the range of *S. aquosus* from Maine to South Carolina; also reporting it being common on sand bars of Beaufort, North Carolina. Yarrow in 1877, was the first to record this species in North Carolina, listing it under the taxonomic name *Lophosetta maculata* (Smith 1907). Moore (1947) used the fish as the subject matter of a rather extensive life history study in the vicinity of Long Island Sound, New York. Moore indicated that the distribution range of *S. aquosus* was in shoal waters extending from the Gulf of St. Lawrence to South Carolina. Bigelow and Schroeder (1953) gave the same general distribution pattern, as Moore (1947), in their study of the species in the Gulf of Maine. According to Gutherz (1967), the present geographic range for *Scophthalmus aquosus* is the Atlantic coast of North America from the Gulf of St. Lawrence, Nova Scotia to Florida. Even though, it is considered a shallow water species by many of the authors mentioned above, its depth distribution has been reported to be from the shoreline to 73 m, but found most abundantly in water less than 46 m deep (Martin and Drewry 1978).

DESCRIPTION

Scophthalmus aquosus is distinguished from other members of the genus *Scophthalmus,* primarily European species, by its large number of gill rakers (22 to 26), its pellucid body and cycloid scales (Figure 1). The pelagic eggs of *S. aquosus* and the developmental stages of both larval and juvenile specimens have been described by Moore (1947) and Martin and Drewry (1978). Adult meristics, morphometrics and color characteristics have been well described by several authors (Jordan and Evermann 1898; Bigelow and Schroeder 1953; Gutherz 1967). *S.* aquosus has been reported to have attained a maximum length of 404 mm (Moore 1947); however, the largest specimen examined in this study was 153 mm standard length (SL). Because of its small size, thinness of body, and lack of status as a game or food fish, *S. aquosus* presently has little commercial or recreational value, except possibly as a "scrap" fish. However, a market did develop for them during the war years (1944 and 1945) in New York, as a human food source (Moore 1947).

Although the accepted common name is windowpane flounder (Bailey *et al*. 1970), *Scophthalmus aquosus* has been called New York plaice, spotted flounder, sand dab, spotted turbot, sand flounder, and brill (Bigelow and Schroeder 1953; Leim and Scott 1966).

Fig. 1. Illustration of a 168 mm SL Scophthalmus aquosus from the Cape Fear study area.


J.W. Goy '78

STUDY AREA

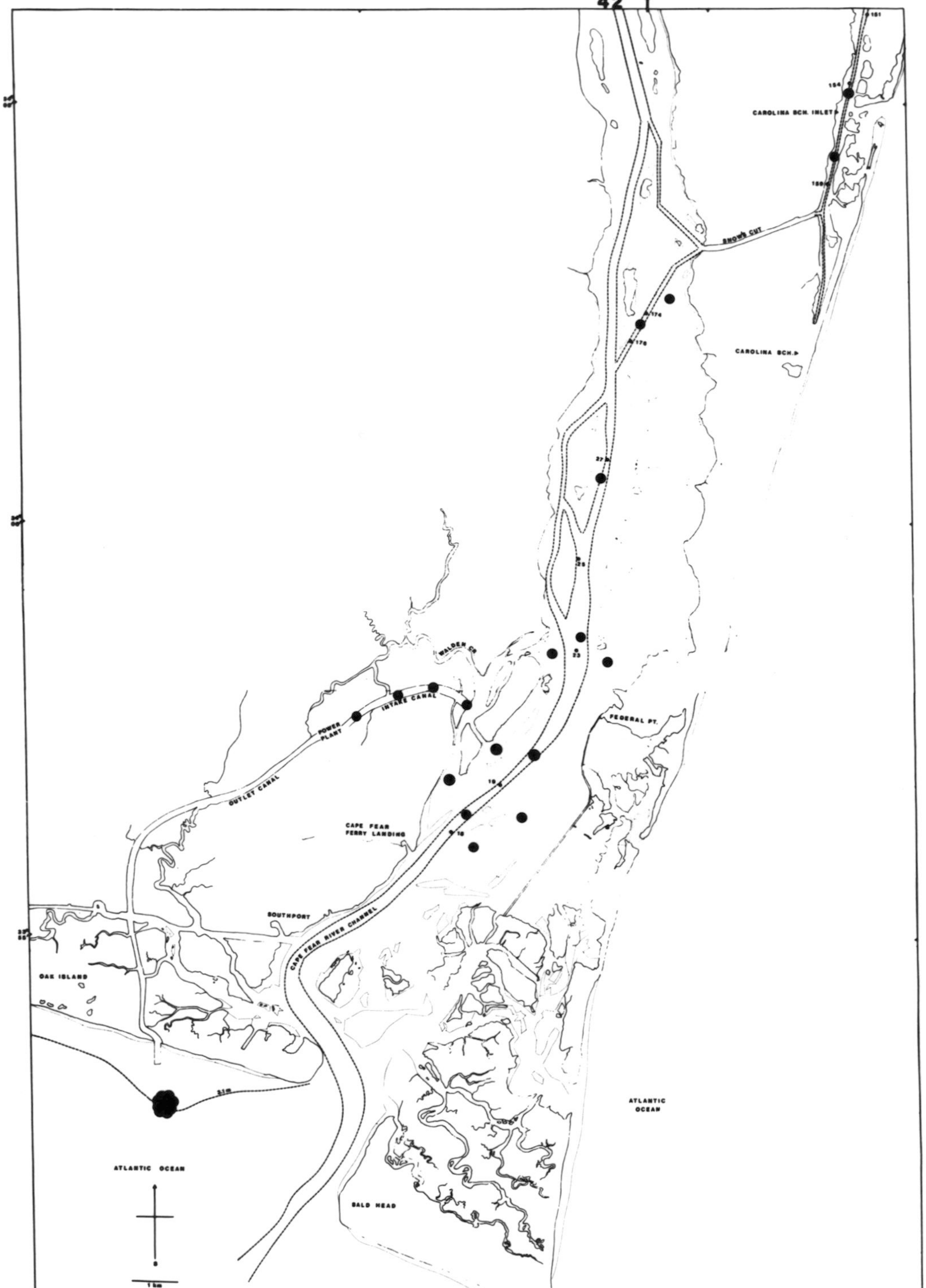
Scophthalmus aquosus were collected as part of a concentrated study in the lower 35 km of the Cape Fear River and adjacent ocean, including Carolina Beach Inlet from January through November 1973-1978. Details of the Cape Fear River estuary and nearby ocean, indicating sampling stations, are depicted in Figure 2.

Since 1973, an intensive survey of the physical, chemical, and biological characteristics of the lower Cape Fear River and adjacent ocean has yielded the basic data for a nuclear power plant (Carolina Power and Light, Brunswick Steam Electric Plant) environmental impact study. The hydrology of the area has been fairly well documented (Carpenter 1979; Hobbie 1971; Wells 1944; Wilder 1967; Schwartz et al. 1979), but the biological information has been meager (Copeland, Birk head, and Hodson 1974).

The topography, as well as the sedimentation in the study area vary as one progressed upriver from the mouth and/or ocean station. The ocean bottom (maximum depth 14.7 m, approximately 4.8 km offshore) was uniform, containing mostly sediments of fine sand and mud. The river bottom varied in depth (2 to 15 m) and sediment varying from sand and clay, but mainly mud. The water chemistry of the study area was greatly influenced by both freshwater from the river and salt water inflow from the ocean, which varied depending on wind and tidal conditions.

Fig. 2. Study area and sampling stations in the lower Cape Fear River and adjacent ocean. Sampling stations denoted by circles.

42


CAROLINA BCH. INLET
SNOWS CUT
CAROLINA BCH.
WALDEN CR
INTAKE CANAL
POWER PLANT
OUTLET CANAL
FEDERAL PT.
CAPE FEAR FERRY LANDING
SOUTHPORT
CAPE FEAR RIVER CHANNEL
OAK ISLAND
ATLANTIC OCEAN
BALD HEAD
ATLANTIC OCEAN
1 km

FIELD MATERIALS AND METHODS

Establishment of Stations

Twenty-two sampling stations (Figure 2) were established between 1973 and 1978 in the lower Cape Fear River and adjacent ocean and were sampled during this study from January through November, 1976. Three stations, 42E, 42, and 42W, were added to the study in September, 1976. All stations were established in conjunction with an extensive environmental impact study conducted by Dr. Frank J. Schwartz, University of North Carolina, Institute of Marine Sciences, Morehead City, for the Carolina Power and Light Company, in relation to the nuclear powered Brunswick Steam and Electric Plant (CP&L, BSEP). Station selection was designed to include a large enough area of the river and adjacent ocean to adequately sample the macroinvertebrates and ichthyofauna that might be affected by the operation of the Brunswick facilities.

Sampling stations were divided into one overall ocean station (OC, which was comprised of four sampling sites) and fifteen river stations: 42E (East), 42, 42W (West), Snow's Cut (SC), 174, 27 23E, 23, 23W, 19E, 19, 19W, 18E, 18, and 18W. Six stations exclusive of the ocean and river proper were also sampled. These included four localities in the power plant intake canal: Canal Screens (CS), Canal First Bend (CB1), Canal Second Bend (CB2), and Canal Mouth (CM), and two near Carolina Beach Inlet, one north (CBI-N) and one south (CBI-S) of the inlet. The east and west river stations (i.e. 18E or 18W) were shallow estuarine river stations (depth range 2 to 5 m) and the other sampling stations were considered deep water stations (depth range 12 to 15 m).

Sampling Schedule

Weekly sampling was maintained at all stations from mid-February through May and from September through November, 1976. Monthly samples were taken during January, June, July, and August; with no sampling being conducted during December. The Cape Fear ocean stations were sampled one day of each new sampling week with repetitive trawling. This station was usually occupied in the mornings, but a few afternoon collections were made. Time of sampling for the other Cape Fear stations (river) varied during daylight hours. No night collections were attempted for *Scophthalmus*.

Every third week from mid-February until November, 1976 (except one sample in 5-7 January) during the sampling schedule, specimens of *Scophthalmus aquosus*, if caught, were returned to the laboratory for analysis. During other sampling weeks specimens were measured, recorded, tagged or returned to the river or other habitats as part of other ongoing studies.

Equipment and Techniques

A semi-balloon otter trawl [12.5 m (41 ft) head rope, 15.2 m (50 ft) ground rope, 50 mm (2 in) stretch mesh in body, with a 38.1 mm (1.5 in) stretch mesh in cod end] was the most important piece of sampling gear used for collecting *S. aquosus*. The Institute of Marine Sciences 12.2 m, 2.9 m beam, 1.0 m draft *R/V Sarah Helen*, round stern trawler, was utilized exclusively for ocean and deep water channel stations, including CBI-North and -South. The Institute's 14.2 m, 3.9 m beam, 1.5 m draft *R/V Machapunga*, stern trawler, was used on occasions when breakdowns occurred on the *R/V Sarah Helen*. Since both trawlers used the same size and type sampling gear they were considered equal collectors, even though boat size was slightly different. Stations in the Cape Fear River and in the intake canal were occupied by the R/V Sarah Helen and a 6.1 m research trimaran skiff which towed a 7.6 m semi-balloon otter trawl of 19.0 mm stretch mesh. Sampling tows were of 15 minutes duration in the river as obstructions, etc. did not safely permit longer tows, while ocean tows were 30 minutes long. Nets were usually towed with the tide at a speed of 1-2 knots, or naturally faster during some swift ebb river tides, using a 3:1 tow cable: depth ratio. Nine 91.5 m gill nets were established at the following shallow river stations: 18E, 18W, 19E, 19W, 23E, 23W, Snow's Cut, 42E, and 42W. These nets did not contribute to any of the Scophthalmus caught during this study, and will not be discussed further.

All S. aquosus that were caught and returned to the laboratory were preserved in the field in approximately 10% formalin and seawater. Standard lengths and weights were recorded in the field for a number of specimens, but only the more accurate laboratory data was relied upon for final analysis.

Environmental Parameters

Physical and chemical data were collected at each station through out the entire sampling period. Surface water samples were obtained with a 11.4 liter plastic bucket. A 3.1 liter Kemmerer water sampler was used to collect bottom water. Salinities of surface and bottom water were measured to the nearest part per thousand (ppt) in the field, using a direct reading, American Optical refractometer. Water temperatures and dissolved oxygen observations were recorded using a Yellow Spring Instrument Co. oxygen/temperature meter (YSI, Model 51).

Water temperature, salinity, and dissolved oxygen content were recorded at the beginning of each new tow for each new station. Only surface and bottom readings were taken for Ocean (OC) and deep water stations (18, 19, 23, 27, CB1, CB2, Snow's Cut, CBI-N, and CBI-S). Bottom readings were not taken at shoal stations (18E, 18W, 19E, 19W, 23E, 23W, 42E, 42W) since extensive observations conducted by the project revealed that uniform mixing occurred at all the shoal stations.

LABORATORY MATERIALS AND METHODS

A meter measuring board, graduated in millimeters was used to obtain standard length (SL) for each Scophthalmus. All Scophthalmus measurements were made to the nearest millimeter from the tip of the lower jaw to the posterior edge of the hypural plate, where a crease was formed when bending the tail upwards (Hubbs and Lagler 1964). Fish weights were determined to the nearest 0.1 g using an Ohaus triple beam balance with a capacity of 200 g graduated in 0.1 g, and a "Mettler PL 3000" balance, graduated in 0.1 g. All fish studied were blotted semi-dry with a paper towel before weighing to insure a consistent degree of wetness. One hundred specimens, if available, from each sampling station were measured and weighted in the laboratory, of which ten specimens were saved for food and age and growth analysis.

Food Habits

During the one-year study (1976), 293 of 315 fish from the collections made throughout all stations were available for food habit analysis. An attempt was made to examine 10 specimens per third sampling week from each locality. The specimens were chosen randomly to represent all sizes (unbiased) of fish available in the monthly catches from a particular station.

In the laboratory, each stomach was dissected from the fish by cutting from the esophagus to pylorus, then cut open, and contents placed under a binocular microscope. During this process the percent fullness of the stomach was estimated visually. Food items were identified to the lowest possible taxa, and related items were grouped to obtain the percent composition for each food item. This procedure of stomach analysis follows closely that of June and Carlson (1971),Darnell (1958), McHugh (1940), and Hynes (1950).

Food data were analysed to determine the percent frequency of occurrence and relative percent volume of each food item by fish length (5 mm intervals), by month, and by station. The total number of stomachs analyzed and the number of empty stomachs were recorded. Average percent fullness of all stomachs in the three categories mentioned above were calculated. The percent frequency of occurrence of each food item was found using the following formula:

$$\%\ \text{Frequency of Occurrence } x = \frac{(\text{Number of stomachs containing } x)}{\text{Total Number of Stomachs Containing Food}}\ (100)$$

where x = food item. The total frequency of each food, x, was the number of times that item occurred in the sample. The relative percent volume was calculated by the following method:

$$\%\ \text{Relative Volume } x = \frac{(\text{Total Volume})}{\text{Total Number of Stomachs Containing Food}}\ (100)$$

where x = food item. The total volume of each food item, x was the percent volume of that food item visually calculated that occupied each stomach in the sample added together.

Age and Growth

Several scales were removed from 315 Scophthalmus for aging studies prior to stomach analysis. The scales were removed from an area just under the anterior portion of the dorsal fin and above the lateral line of the left side, dried, and stored in coin envelopes until examined. Ten to 15 scales from each envelope were cleaned by soaking in a one-tenth solution of phenol to help remove chromatophores and integument. Scales were then mounted wet between glass microscope slides and projected on a Eberbach projector screen at a magnification of 83x. Annulus and scale edge measurements were taken on unregenerated scales along an axis from the center of the focus to the middle of the anterior margin with a ruler graduated in 1 mm units. This measurement axis contained the clearest delineation of annuli and circuli. Repetitive readings were made on one key scale to ensure accuracy.

The number of annuli on a scale determined the age class (0,I,II, etc.) designation. Several criteria were used to determine annual marks and to avoid confusing them with false checks (marks caused by factors other than cessation of growth such as spawning). The three commonly used criteria for locating annuli were: spacing of the circuli, continuity of the radii, and crossing over of circuli. Discussion on annular delineation may be found in Berg and Grimaldi (1967), Chugnova (1963), Lagler (1956), Tesch (1968), and Van Oosten (1929).

Aging S. aquosus by vertebral examination was attempted on 315 fish. Vertebrae columns containing about 5-7 vertebrae were removed from under the mid lateral line, dried, and stored in coin envelopes. An unsuccessful attempt was made to read the anterior and posterior ends of vertebrae (even after polishing both ends) under a binocular microscope. Therefore, aging the fish by vertebrae was abandoned. Otoliths were also not used, as preservation in formalin rendered them unreadable for aging.

Fish lengths, at the time of annulus formation, were back calculated by the Lee method which involved the use of a correction factor. This method of back calculation is elaborated upon in the age and growth section.

DEFINITION OF TERMS

Annulus: A dark ring on a scale that is deposited once a year during a period of slow or no growth. The number of annuli, with some modification, conforms with the age of the fish.

Marginal increment: Distance between the focus and the scale edge in age class 0 fish; in older fish the distance from the last annulus to the edge.

Age class (age group): A group of fish with the same age in years (0-3 for *Scophthalmus*). Age classes were assigned according to the number of annuli on the scale. Age class 0 *Scophthalmus* (no annuli) were less than or equal to one year old, age class 1 were between one and two years old (1 annulus) etc. The split spawning season of *Scopthalmus* caused overlap in age classes such that fish in a particular age class were somewhat younger than that age class implied.

Young-of-the-year: Age class 0 fish that were less than or equal to one year old.

RESULTS AND DISCUSSION

Hydrography

Hydrographic parameters can govern the types and amounts of organisms present in an estuarine ecosystem. Temperature and salinity gradients have long been cited as causes for organism distribution and control in estuaries (Copeland and Bechtel 1971; Gunter 1961; and Pearse and Gunter 1957). Dissolved oxygen is also a serious limiting factor when its concentrations reach a low value (Copeland, Birkhead, and Hodson 1974). The mean bottom readings were emphasized because I felt they best represented the benthic environment which *Scophthalmus aquosus* occupied.

Temperature - Bottom water temperatures, in the study area, varied between a low of 8.5°C at the ocean station during January to a high of 28.5°C at station CM during July (Table 1). January was the month that exhibited the lowest mean bottom water temperature (9.5°C) (range 8.5-11.0°C), and July had the highest mean bottom water temperature at 27.5°C (range 26.0 to 28.0°C). By station, CM had the highest yearly mean bottom water temperature at 20.2°C and station 27 had the lowest at 19.1°C.

Dissolved oxygen - Mean bottom dissolved oxygen concentrations ranged from 4.7 ppm at station CBI-N during January to a high of 9.8 ppm at station CBI-North and -South in February (Table 2). Saturation values for dissolved oxygen were generally above acceptable levels, and were quite stable throughout the sampling year. The average bottom dissolved oxygen value did not vary more than 3.3 ppm during each month,

Table 1. Monthly surface water temperature means for Cape Fear River stations sampled 1976. Effort is noted in parenthesis ( ).

STATION	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	MEAN
42E									25.8 (14)	18.4 (9)	11.4 (12)	
42								26.0 (1)	25.6 (9)	19.8 (9)	12.8 (5)	
42W									26.1 (15)	18.6 (10)	11.4 (11)	
CBI-N	9.5 (2)	13.0 (5)	16.7 (14)	18.7 (10)	21.7 (10)	24.0 (2)	28.0 (2)	26.0 (2)	25.9 (14)	18.9 (13)	12.8 (11)	19.4
CBI-S	9.5 (2)	13.0 (5)	16.6 (14)	19.0 (10)	20.7 (11)	25.5 (2)	27.5 (2)	26.0 (2)	25.6 (14)	19.2 (13)	12.4 (11)	19.0
174	9.5 (2)	14.8 (4)	17.9 (9)	20.1 (7)*	22.1 (8)	25.5 (2)	28.5 (2)	26.5 (2)	25.1 (9)	19.6 (12)	13.6 (7)	19.9
SC		13.5 (6)	15.5 (15)	18.9 (12)	21.3 (11)				27.0 (12)	18.4 (11)	11.5 (10)	
27	7.0 (2)	14.2 (4)	17.9 (9)	20.5 (8)	21.5 (6)	25.5 (2)	28.5 (2)	26.5 (2)	25.0 (10)	19.2 (11)	13.1 (7)	19.7
23E		14.3 (6)	15.9 (15)	19.6 (11)	21.7 (11)				26.7 (15)	18.5 (12)	11.6 (11)	
23	9.5 (2)	15.2 (4)	18.1 (9)	20.0 (7)	21.8 (8)	26.0 (3)	28.5 (2)	26.7 (3)	25.1 (13)	21.1 (15)	13.4 (9)	20.5
23W		13.8 (6)	15.8 (15)	20.3 (11)	21.8 (11)				26.9 (14)	18.1 (10)	11.6 (10)	
19E		13.8 (6)	15.7 (13)	20.0 (11)	20.9 (11)				25.8 (13)	18.4 (12)	11.7 (10)	
19	10.0 (2)	14.8 (6)	18.1 (10)	20.5 (8)	22.1 (9)	25.7 (3)	28.0 (2)	26.3 (3)	25.2 (14)	19.9 (14)	13.2 (10)	20.1
19W		14.8 (6)	16.4 (14)	20.6 (11)	21.5 (11)	25.0 (1)	28.0 (1)		27.3 (14)	18.6 (12)	12.3 (11)	
CS		15.0 (6)	16.7 (13)	21.0 (10)	22.0 (9)				26.9 (12)	18.7 (7)	12.1 (10)	
CB1	10.0 (1)	15.2 (6)	18.3 (9)	19.9 (8)	22.1 (9)	26.3 (3)	28.0 (2)	28.7 (3)	25.8 (13)	17.0 (14)	13.7 (7)	20.2
CB2		16.0 (1)	18.0 (5)	19.2 (6)	21.7 (6)				27.4 (9)	17.3 (6)	12.7 (6)	
CM	10.0 (1)	15.3 (6)	16.5 (13)	21.0 (10)	22.1 (12)	25.7 (3)	28.5 (2)	27.3 (3)	25.9 (14)	21.3 (10)	13.3 (10)	20.4
18E	11.0 (2)	14.6 (8)	16.6 (20)	20.8 (16)	21.5 (14)	26.5 (2)	28.0 (2)	28.7 (3)	25.3 (22)	19.0 (25)	12.5 (15)	19.5
18	11.5 (2)	14.5 (6)	18.4 (11)	20.9 (8)	21.9 (9)	25.0 (2)	27.0 (2)	27.3 (3)	25.0 (12)	19.6 (15)	12.9 (10)	19.8
18W		14.0 (6)	16.3 (14)	20.5 (11)	21.6 (11)				26.8 (13)	18.4 (12)	12.3 (10)	
Ocean	10.0 (2)	13.2 (4)	17.1 (8)	19.2 (5)	22.3 (6)	23.0 (1)	28.3 (3)	28.0 (2)	25.4 (5)	21.0 (5)	13.3 (3)	19.9
MEAN	9.8	14.3	16.8	20.1	21.7	25.5	28.1	27.1	26.0	18.1	12.4	

Monthly bottom water temperature means for Cape Fear River stations sampled 1976.

STATION	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	MEAN
42E												
42								26.0 (1)	25.3 (9)	19.6 (9)	12.6 (5)	
42W												
CBI-N	9.5 (2)	12.8 (4)	16.9 (9)	17.8 (7)	20.5 (6)	24.0 (2)	27.5 (2)	26.0 (2)	25.5 (10)	19.5 (11)	12.8 (7)	19.4
CBI-S	9.5 (2)	12.5 (4)	17.1 (9)	20.1 (7)	20.8 (6)	25.5 (2)	27.0 (2)	26.0 (2)	25.2 (10)	20.1 (11)	12.9 (7)	19.5
174	9.0 (2)	13.8 (4)	17.4 (9)	19.3 (7)	22.0 (6)	25.5 (2)	27.5 (2)	27.0 (2)	25.0 (9)	19.4 (12)	12.9 (7)	19.4
SC												
27	7.0 (2)	14.0 (4)	17.9 (9)	17.2 (8)	21.8 (6)	25.5 (2)	28.0 (2)	27.0 (2)	24.9 (10)	19.1 (11)	12.5 (7)	19.2
23E												
23	9.5 (2)	14.0 (4)	17.9 (9)	19.4 (7)	21.6 (8)	25.7 (3)	28.0 (2)	27.3 (3)	25.1 (13)	19.4 (15)	13.1 (9)	19.9
23W												
19E												
19	10.5 (2)	13.8 (6)	17.6 (10)	19.9 (8)	21.9 (9)	25.7 (3)	27.5 (2)	27.3 (3)	25.1 (14)	19.6 (14)	12.9 (10)	19.8
19W												
CS												
CB1	10.0 (1)	14.3 (6)	17.9 (9)	19.6 (8)	21.9 (9)	26.0 (3)	27.5 (2)	26.7 (3)	25.3 (11)	19.0 (11)	13.4 (6)	19.3
CB2		15.0 (1)		19.0 (6)	21.0 (6)				26.0 (3)	15.8 (3)	10.4 (2)	
CM	10.0 (1)	14.8 (6)	18.1 (8)	21.5 (2)	23.3 (3)	25.7 (3)	28.5 (2)	27.3 (3)	25.4 (9)	20.4 (9)	13.5 (8)	20.2
18E	10.5 (2)	14.7 (3)	17.6 (10)	20.2 (8)	21.9 (8)	26.0 (2)	27.5 (2)	27.3 (3)	24.8 (12)	19.5 (15)	12.9 (8)	20.0
18	11.0 (2)	14.0 (6)	18.2 (11)	19.9 (8)	21.9 (9)	25.0 (2)	27.0 (2)	28.0 (3)	25.0 (12)	19.6 (15)	12.6 (10)	19.6
18W												
Ocean	8.5 (2)	13.0 (3)	16.5 (8)	18.6 (5)	22.2 (6)	23.0 (1)	27.5 (2)	28.0 (2)	25.4 (5)	21.4 (5)	13.3 (3)	19.6
MEAN	9.5	14.9	17.6	19.3	21.7	25.4	27.6	27.1	25.2	19.5	12.9	

Table 2 Monthly surface oxygen means for Cape Fear River stations sampled 1976. Effort is noted in parenthesis ( ).

STATION	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	MEAN
42E									6.4 (14)	6.8 (7)	7.2 (12)	
42								5.0 (1)	6.1 (9)	7.1 (9)	8.7 (5)	
42W									6.1 (14)	6.8 (8)	7.2 (11)	
CBI-N	6.5 (2)	9.0 (5)	7.1 (14)	8.2 (10)	7.8 (10)	7.4 (2)	5.5 (2)	7.0 (2)	6.9 (14)	7.3 (13)	8.3 (11)	7.5
CBI-S	5.9 (2)	9.2 (5)	7.6 (14)	8.0 (10)	7.1 (10)	7.3 (2)	5.4 (2)	6.6 (2)	6.6 (14)	7.4 (12)	8.4 (11)	7.5
174	6.1 (2)	9.4 (4)	8.2 (9)	8.0 (7)	7.8 (8)	7.2 (2)	6.0 (2)	6.2 (2)	6.5 (9)	7.5 (12)	8.7 (7)	7.7
SC		7.9 (6)	8.4 (15)	7.7 (12)	7.7 (11)				6.2 (12)	6.9 (9)	6.7 (10)	
27	6.2 (2)	8.4 (4)	7.8 (9)	8.0 (8)	7.4 (6)	7.1 (2)	5.2 (2)	6.9 (2)	6.4 (10)	7.3 (11)	8.7 (7)	7.4
23E		7.5 (6)	8.6 (15)	8.1 (11)	7.3 (11)				6.0 (15)	6.7 (8)	6.9 (11)	
23	6.2 (2)	9.5 (4)	8.1 (9)	7.8 (7)	7.4 (8)	7.0 (3)	6.3 (2)	6.3 (3)	7.0 (13)	7.2 (15)	8.4 (9)	7.5
23W		7.4 (6)	8.3 (15)	8.4 (11)	7.5 (11)				5.8 (14)	7.2 (8)	7.0 (10)	
19E		7.0 (6)	7.6 (13)	8.2 (10)	7.3 (11)				5.7 (13)	7.3 (9)	7.1 (10)	
19	6.6 (2)	9.4 (6)	7.2 (10)	7.6 (8)	7.4 (9)	7.3 (3)	6.0 (2)	6.4 (3)	6.5 (14)	7.0 (14)	8.6 (10)	7.4
19W		7.0 (6)	7.6 (14)	8.2 (11)	7.6 (11)	6.0 (1)	8.2 (1)		5.8 (13)	6.8 (9)	7.0 (11)	
CS		7.1 (6)	7.3 (13)	8.1 (10)	7.4 (8)				5.6 (12)	7.2 (5)	6.4 (10)	
CB1	6.0 (1)	9.3 (6)	7.5 (9)	7.8 (8)	7.2 (9)	7.7 (3)	5.6 (2)	6.5 (3)	6.6 (13)	7.5 (14)	8.6 (7)	7.5
CB2		9.0 (1)	7.3 (5)	7.6 (6)	7.2 (6)				6.2 (9)	8.2 (5)	7.1 (6)	
CM	6.0 (1)	9.2 (6)	8.4 (11)	8.3 (10)	7.6 (12)	7.0 (3)	5.9 (2)	6.3 (3)	6.2 (14)	6.2 (9)	8.5 (10)	7.5
18E	6.4 (2)	8.3 (8)	8.2 (20)	7.9 (16)	7.3 (14)	7.6 (2)	6.0 (2)	6.5 (3)	6.6 (22)	7.4 (22)	8.1 (15)	6.3
18	7.5 (2)	9.3 (6)	7.5 (11)	7.4 (8)	7.1 (9)	6.7 (2)	6.9 (2)	6.4 (3)	6.8 (12)	6.9 (15)	8.6 (10)	7.4
18W		7.0 (6)	8.0 (14)	8.2 (11)	7.5 (11)				5.8 (13)	6.9 (9)	7.0 (10)	
Ocean	6.2 (2)	9.6 (4)	8.3 (8)	7.5 (5)	7.6 (6)	7.8 (1)	6.5 (3)	5.5 (2)	6.7 (5)	7.1 (5)	8.8 (3)	7.6
MEAN	6.4	8.4	7.9	8.0	7.4	7.2	6.0	6.4	6.3	7.1	7.7	

Monthly bottom oxygen means for Cape Fear River stations sampled 1976.

STATION	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	MEAN
42E												
42								5.0 (1)	6.4 (9)	6.9 (9)	9.0 (5)	
42W												
CBI-N	4.7 (2)	9.8 (4)	7.7 (9)	8.0 (7)	7.5 (6)	7.1 (2)	5.6 (2)	6.6 (2)	6.6 (10)	7.1 (11)	9.0 (7)	7.7
CBI-S	5.8 (2)	9.8 (4)	6.5 (9)	7.2 (7)	7.7 (6)	7.0 (2)	5.4 (2)	6.5 (2)	6.6 (10)	7.1 (11)	8.8 (7)	15.8
174	7.2 (2)	9.4 (4)	8.5 (9)	7.6 (7)	7.2 (6)	7.4 (2)	6.0 (2)	6.3 (2)	6.5 (9)	7.4 (12)	8.7 (7)	7.6
SC												
27	6.5 (2)	8.9 (4)	9.1 (9)	7.5 (8)	7.0 (6)	8.0 (2)	6.0 (2)	6.7 (2)	6.6 (10)	7.2 (11)	8.6 (7)	7.6
23E												
23	6.3 (2)	9.6 (4)	8.9 (9)	7.5 (7)	7.0 (8)	7.1 (3)	6.7 (2)	6.1 (3)	6.8 (13)	7.1 (15)	8.4 (9)	9.1
23W												
19E												
19	7.0 (2)	9.3 (6)	8.5 (10)	7.3 (8)	6.8 (9)	7.3 (3)	6.2 (2)	6.0 (3)	6.7 (14)	7.0 (14)	8.4 (10)	7.4
19W												
CS												
CB1	7.2 (1)	9.4 (6)	6.3 (9)	7.1 (8)	6.2 (9)	7.4 (3)	5.7 (2)	6.3 (3)	6.5 (11)	7.1 (11)	8.6 (6)	7.4
CB2		8.8 (1)		6.9 (6)	5.8 (6)				5.9 (3)	7.7 (3)	8.8 (2)	
CM	7.2 (1)	9.4 (5)	7.5 (6)	7.6 (2)	7.2 (3)	7.7 (3)	6.2 (2)	6.3 (3)	6.7 (9)	6.9 (9)	8.5 (8)	7.5
18E	6.4 (2)	9.6 (3)	7.8 (10)	7.4 (8)	7.0 (8)	7.9 (2)	5.9 (2)	6.5 (3)	6.8 (12)	7.3 (15)	9.0 (8)	7.5
18	6.3 (2)	9.3 (6)	8.2 (11)	7.4 (8)	6.8 (9)	7.4 (2)	7.0 (2)	5.9 (3)	6.8 (12)	7.0 (15)	8.6 (10)	7.5
18W												
Ocean	5.4 (2)	8.8 (3)	8.1 (8)	7.2 (5)	7.2 (6)	5.8 (1)	5.8 (2)	5.2 (2)	6.7 (5)	6.9 (5)	8.7 (3)	7.2
MEAN	6.3	9.4	7.9	7.4	6.9	7.4	6.0	6.2	6.6	7.1	8.7	

Table 3. Monthly surface salinities means for Cape Fear River stations sampled 1976. Effort is noted in parenthesis ( ).

STATION	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	MEAN
42E									9.9 (14)	10.6 (9)	9.3 (12)	
42								0.0 (1)	10.7 (9)	12.6 (9)	11.0 (5)	
42W									9.3 (15)	11.4 (10)	9.5 (11)	
CBI-N	30.5 (2)	23.4 (5)	25.8 (13)	27.5 (10)	30.4 (10)	24.0 (2)	13.0 (2)	32.0 (2)	28.8 (14)	26.8 (13)	26.5 (11)	27.9
CBI-S	18.5 (2)	20.8 (5)	18.6 (13)	24.3 (10)	25.2 (11)	7.5 (2)	6.5 (2)	22.5 (2)	23.7 (14)	27.3 (13)	21.1 (11)	22.3
174	0.5 (2)	5.0 (4)	7.2 (9)	14.9 (7)	17.0 (8)	5.0 (2)	8.0 (2)	10.0 (2)	18.3 (9)	18.4 (12)	17.6 (7)	19.9
SC		5.0 (6)	7.7 (14)	13.3 (12)	16.3 (11)				15.0 (12)	16.6 (12)	14.7 (10)	
27	0.0 (2)	7.2 (4)	10.8 (9)	15.0 (8)	17.8 (6)	9.0 (2)	10.0 (2)	12.0 (2)	18.4 (10)	20.8 (11)	20.1 (7)	15.4
23E		10.7 (6)	11.4 (14)	16.2 (11)	20.1 (11)				20.2 (15)	19.3 (12)	18.1 (11)	
23	4.0 (2)	8.8 (4)	11.4 (9)	17.1 (7)	19.6 (8)	14.7 (3)	7.0 (2)	13.7 (3)	23.3 (13)	21.9 (15)	20.7 (9)	17.9
23W		11.2 (6)	12.4 (15)	16.8 (11)	20.6 (11)				20.1 (14)	20.8 (8)	18.6 (10)	
19E		12.2 (6)	16.7 (13)	19.8 (10)	23.1 (11)				22.7 (13)	22.6 (9)	22.8 (10)	
19	6.5 (2)	13.2 (6)	14.9 (10)	19.9 (8)	22.2 (9)	15.7 (3)	10.5 (2)	16.0 (3)	24.1 (14)	23.3 (14)	22.6 (10)	24.7
19W		13.3 (6)	16.0 (14)	17.7 (11)	23.5 (11)	20.0 (1)	10.0 (1)		24.1 (14)	22.1 (12)	21.6 (11)	
CS		11.7 (6)	14.2 (12)	19.4 (10)	19.2 (9)				21.5 (12)	21.3 (7)	21.4 (10)	
CB1	7.0 (1)	10.8 (6)	13.2 (9)	19.5 (8)	21.9 (9)	17.0 (3)	8.0 (2)	14.0 (3)	23.2 (13)	21.2 (14)	21.3 (7)	18.7
CB2		10.0 (1)	15.2 (4)	19.0 (6)	21.8 (6)				22.1 (9)	20.7 (6)	21.7 (6)	
CM	7.0 (1)	10.6 (6)	12.5 (13)	19.3 (10)	22.1 (12)	15.0 (3)	8.5 (2)	13.3 (3)	23.0 (14)	24.1 (10)	17.8 (10)	17.7
18E	8.0 (2)	15.2 (8)	17.2 (20)	23.0 (16)	24.6 (14)	24.0 (2)	9.5 (2)	18.0 (3)	25.2 (22)	24.4 (25)	23.5 (15)	21.4
18	6.0 (2)	18.0 (6)	17.2 (11)	21.2 (8)	22.6 (9)	25.0 (2)	14.0 (2)	16.7 (3)	26.5 (12)	24.8 (15)	25.8 (10)	21.9
18W		12.2 (6)	15.5 (13)	20.0 (11)	23.3 (11)				23.7 (13)	23.1 (12)	9.0 (10)	
Ocean	25.0 (2)	24.2 (4)	28.0 (8)	31.2 (5)	29.7 (6)	28.0 (1)	27.0 (3)	5.5 (2)	30.8 (5)	30.8 (5)	30.7 (3)	28.8
MEAN	10.6	12.9	15.6	19.6	22.2	16.3	11.3	15.1	21.1	21.4	19.1	

Monthly bottom salinities means for Cape Fear River stations sampled 1976.

STATION	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	MEAN
42E												
42								0.0 (1)	14.2 (9)	14.7 (9)	16.2 (5)	
42W												
CBI-N	30.5 (2)	25.0 (4)	26.6 (9)	29.4 (7)	30.0 (6)	25.0 (2)	27.5 (2)	33.0 (2)	30.7 (10)	31.0 (11)	28.0 (7)	29.0
CBI-S	29.5 (2)	22.0 (4)	25.1 (9)	28.3 (7)	28.3 (6)	11.5 (2)	21.0 (2)	32.0 (2)	29.6 (10)	28.2 (11)	25.6 (7)	26.7
174	4.0 (2)	7.2 (4)	12.8 (9)	19.1 (7)	18.3 (6)	6.5 (2)	10.5 (2)	18.0 (2)	20.8 (9)	20.2 (12)	20.0 (7)	19.4
SC												
27	10.5 (2)	12.0 (4)	17.0 (9)	19.2 (8)	20.2 (6)	12.0 (2)	13.5 (2)	19.0 (2)	22.9 (10)	23.4 (11)	23.0 (7)	19.5
23E												
23	11.5 (2)	17.5 (4)	18.4 (9)	23.3 (7)	23.1 (8)	17.7 (3)	17.0 (2)	20.0 (3)	26.4 (13)	24.6 (15)	24.6 (9)	22.5
23W												
19E												
19	17.0 (2)	18.3 (6)	18.4 (10)	23.9 (8)	26.1 (9)	18.3 (3)	13.5 (2)	22.7 (3)	27.1 (14)	26.1 (14)	25.2 (10)	22.4
19W												
CS												
CB1	15.0 (1)	14.8 (6)	18.4 (9)	22.9 (8)	23.7 (9)	19.0 (3)	13.5 (2)	17.0 (3)	25.2 (11)	23.0 (11)	24.0 (6)	22.3
CB2		10.0 (1)		22.7 (6)	23.8 (6)				28.7 (3)	20.0 (3)	22.0 (2)	
CM	15.0 (1)	14.2 (5)	18.0 (8)	25.0 (2)	22.8 (3)	16.7 (3)	12.5 (2)	19.3 (3)	24.4 (9)	24.4 (9)	24.2 (8)	21.0
18E	30.0 (2)	17.3 (3)	17.7 (10)	23.0 (8)	23.8 (8)	26.0 (2)	11.0 (2)	21.3 (3)	27.3 (12)	25.0 (15)	26.0 (8)	23.4
18	18.0 (2)	22.2 (6)	21.3 (11)	24.5 (8)	25.7 (9)	25.5 (2)	16.0 (2)	27.0 (3)	27.9 (12)	27.3 (15)	26.2 (10)	25.0
18W												
Ocean	30.0 (2)	25.7 (3)	29.2 (8)	30.6 (5)	31.0 (6)	32.0 (1)	27.5 (2)	5.2 (2)	31.2 (5)	25.0 (5)	29.7 (3)	29.2
MEAN	19.6	17.5	20.2	24.0	24.8	18.4	16.7	19.7	25.8	24.5	24.4	

and less than 1.0 ppm at each station over the entire sampling period. The mean bottom dissolved oxygen concentration for the study area, as a whole, were generally lower during the warmer months and higher during the colder months. The only notable exception was January (Table 2).

Salinity: Bottom salinities for the Cape Fear River estuary and adjacent ocean, in 1976, ranged between a low of 0.0 ppt at station 42 and a high of 33.0 ppt at station CBI-N during the month of August (Table 3). Salinity concentrations were found to be highest during the Spring and Fall months (March, April, May and September, October, November) and lowest during the Winter and Summer months (January, February and June, July, August) as shown in Table 3. July produced the lowest monthly mean bottom salinities (16.6 ppt) and September the highest (25.7 ppt).

Differences in bottom salinity concentration between stations were also noted. The Ocean and Carolina Beach Inlet-North station had the highest and basically the same salinity throughout the year (29.2 ppt and 29.0 ppt, respectively). Station 42 with a mean bottom value of 14.2 ppt was the lowest noted throughout the sampling period.

Discussion: Bottom water temperature, like salinity concentrations, exhibited a seasonal trend or low-high throughout the sampling year. The lowest temperatures were recorded during the winter months and the highest temperatures were during the summer months (Table 1). Surface and bottom mean water temperatures did not vary more than 0.8°C during each month. The monthly mean bottom water temperature at each station did not vary more than 1.0°C over the entire sampling period. The phenomenon of tidal-temperature influence was not examined in this study, but may account for the extreme variations from the mean noted for water temperature (Table 1). Tide along with wind, evaporation, and river discharge, may account for extreme variations from the mean for all physico-chemical data measured during this study.

Observed values for mean bottom dissolved oxygen were generally high throughout the sampling year (range 6.2-9.4). According to Copeland, Birkhead, and Hodson (1974), dissolved oxygen is strongly influenced by photosynthesis and respiration, which is a function of the time of the day the samples are taken. It is believed that strong tides, river flow, and extreme river turbulence may also have had an influence on the dissolved oxygen values.

Salinity values were similar for surface and bottom waters from all stations. The maximum salinity difference between surface and bottom was 4.4 ppt at station CBI-South (Table 3). Only two stations of the 22 sampled had a higher overall mean surface salinity value than mean bottom value. These two stations were 19 and CBI-S (Table 3). The remaining stations exemplified the typical salt wedge effect which is characterized in many estuarine environments (Copeland, Birkhead, and Hodson 1974).

Salinity concentrations were found to be lowest during the winter and summer months. This trend of low-high seasonal salinity concentrations were probably a reflection of heavy rains during winter and summer with low rainfall during the spring and fall. Tidal influence may also be an important factor influencing the salinity concentration in the lower Cape Fear estuary and adjacent ocean. Copeland, Birkhead, and

Hodson (1974) and Ross (1978) reported tides to have an affect on salinity and water temperature in the Cape Fear River and adjacent ocean. Tidal influence, depending on station location, may be the reason for higher salinity values for the Ocean and Carolina Beach Inlet stations versus lower salinity readings in the upper river stations (ex. 42E, 42, 42W).

Food Habits

Stomachs of 293 *Scophthalmus aquosus* between 33-153 mm (standard length) collected in the lower Cape Fear River and adjacent ocean over a nine month period (March-November 1976) were analyzed for their content Twenty-one different kinds of food items were found in the stomachs of *S. aquosus* and were expressed in both frequency of occurrence and percent volume, by month, station, and size length (Tables 4, 5, 6).

Emphasis was placed on percent volume rather than frequency of occurrence in this food habit study for all comparisons between stations, months, and size lengths. I felt that determining the amount of each food item consumed by *S. aquosus* (percent volume) rather than the regularity of a food item in the fishes diet (percent frequency) permitted a more meaningful conclusion concerning the relative importance of that food item.

Fish Size and Food Habits: Stomach contents of *Scophthalmus* specimens in the size range of 5 mm intervals were analyzed both by percent volume and frequency of occurrence (Table 4). Young *S. aquosus* (mostly 0^+ or young-of-the-year) were captured in the Cape Fear River and adjacent ocean station. *S. aquosus* 51-115 mm SL represented 90% of the fish stomachs containing food.

Neomysis americana was found to be the predominate food item eaten by all sizes of Scophthalmus (74.1% volume). Fish were also found to be an important food source of small Scophthalmus (36-55 mm SL) (Table 4). The chief consumers of calanoid copepods were fish between 71-80 mm SL. Whereas, Acetes americanus were eaten largely by individuals 96-120 mm in SL. The problem of too few stomachs containing food at small or extremely large sizes made it difficult to establish feeding preferences throughout the range of specimens studied.

Station and Food Habits: The food habits of Scophthalmus aquosus examined in relation to stations sampled in the Cape Fear River and adjacent ocean, including CBI-North and -South are noted in Table 5. Of the 22 sampling stations, 19 provided Scophthalmus for stomach analysis, and only nine stations had greater than 10 fish stomachs containing food items. These nine major food habitats (Ocean, 19E, 19W, 23E, 23W, 174, SC, CBI-N, and CBI-S) accounted for 93% of the stomachs analyzed, and were emphasized along with percent volume in determining what foods may be important in the S. aquosus diet. The station with fish containing the greatest array of food items (13) was CBI-N, and the station with fish containing the fewest food items (0) was 23 (Table 5).

Neomysis americana was the predominant food by percent volume for the nine major food stations, mentioned above. Calanoid copepods were also important food items at both Ocean (21.6% volume) and CBI-N (14.9%) stations, whereas fish were important in the diet at stations 19E, 23E, 23W, SC, CBI-N, and CBI-S (range 7.3% to 35.7% volume). Fish were not found in any Scophthalmus stomachs (N=53) analyzed at the Ocean station.

Table 4. Percent frequency and volume of all food items ingested by 293 *S. aquosus* by fish size (5 mm intervals) caught in the Cape Fear River and adjacent ocean, 1976.

Species / Food Item — Length (mm)	30-35 F*	30-35 V*	36-40 F	36-40 V	41-45 F	41-45 V	46-50 F	46-50 V	51-55 F	51-55 V	56-60 F	56-60 V	61-65 F	61-65 V
INVERTEBRATES														
Mollusca														
Bivalvia														
Geukensia demissus														
Aschelminthes														
Nematoda														
Annelida														
Polychaeta									5.90	2.30			4.10	1.70
Arthropoda														
Copepoda														
Calanoida					14.30	2.90	12.50	1.60	11.80	1.80	22.20	1.80	20.80	4.40
Amphipoda														
Gammaridea														
Gammarus sp.														
Mysidacea														
Neomysis americana			100.00	40.00	71.40	45.70	100.00	48.50	60.00	27.10	88.90	78.80	91.70	73.90
Decapoda														
Natantia														
Natantia zoea									5.90	0.60	11.10	2.80	16.70	6.20
Penaeidae														
Penaeus sp.									5.90	5.90	11.10	11.10		
Acetes americanus									5.90	5.90				
Reptantia														
Brachyura														
Brachyura zoea													4.10	2.10
Brachyura megalops														
VERTEBRATES														
Pisces														
Fish larvae					57.10	37.10	12.50	11.00	17.60	17.60				
Micropogonias undulatus							25.00	12.40	5.90	1.80			4.10	2.50
Leiostomus xanthurus									5.90	5.90				
Anchoa sp.							12.50	10.40						
Synodus sp.									5.90	2.90			4.10	0.80
Unidentified fish			100.00	60.00	14.30	14.30	25.00	16.10	35.30	28.20	22.20	5.50	4.10	4.20
Miscellaneous														
Digested organic matter													4.10	4.20
Plant material														
Detritus														
Number examined	1		1		9		9		19		10		26	
Number empty	1		0		2		1		2		0		2	
Number examined with food	0		1		7		8		17		10		24	

*F = Frequency of Occurrence (%)
*V = Volume (%)

Table 4. (cont.)

Species / Food Item	Length (mm) 66-70 F	V	71-75 F	V	76-80 F	V	81-85 F	V	86-90 F	V	91-95 F	V	96-100 F	V	101-105 F	V
INVERTEBRATES																
Mollusca																
Bivalvia																
Geukensia demissus											4.50	0.10				
Aschelminthes																
Nematoda							4.80	0.10	5.80	0.10						
Annelida																
Polychaeta																
Arthropoda																
Copepoda																
Calanoida	16.70	7.50	46.10	27.60	28.00	21.80	9.50	3.90	35.30	12.20	36.40	9.20	23.50	9.20	6.20	0.20
Amphipoda																
Gammaridea																
Gammarus sp.	4.10	1.00	15.40	7.70	20.00	6.20	9.50	1.80			13.60	2.90	17.60	1.20		
Mysidacea																
Neomysis americana	83.30	73.90	61.50	53.30	72.00	55.40	86.00	79.40	88.20	81.00	91.00	71.20	100.00	69.50	93.70	77.50
Decapoda																
Natantia																
Natantia zoea																
Penaeidae																
Penaeus sp.							4.80	2.40							6.20	0.30
Acetes americanus							4.80	4.80	5.80	0.60			23.50	15.60	12.50	12.20
Reptantia																
Brachyura																
Brachyura zoea	8.30	1.70	7.60	0.08	8.00	0.30										
Brachyura megalops			23.00	2.00	4.00	0.40					4.50	1.60	5.90	0.30		
VERTEBRATES																
Pisces																
Fish larvae																
Micropogonias undulatus							4.80	1.60								
Leiostomus xanthurus	4.10	1.70														
Anchoa sp.																
Synodus sp.	4.10	1.30														
Unidentified fish	12.50	4.60	7.60	5.80	16.00	7.40	9.50	0.70			4.50	2.50			6.20	0.30
Miscellaneous																
Digested organic matter	12.50	7.50	15.40	3.10	20.00	8.40	4.80	0.50	12.00	6.10	36.40	12.50	23.50	3.20	6.20	6.20
Plant material	4.10	0.40													12.50	3.30
Detritus	4.10	0.40	7.60	0.40	4.00	0.04	9.50	4.80								
Number examined	27		15		29		23		19		22		19		16	
Number empty	3		2		4		2		2		0		2		0	
Number examined with food	24		13		25		21		17		22		17		16	

*F = Frequency of Occurrence
*V = Volume (%)

Table 4. (cont.)

Species / Food Item — Length (mm)	106-110 F	106-110 V	111-115 F	111-115 V	116-120 F	116-120 V	121-125 F	121-125 V	126-130 F	126-130 V	131-135 F	131-135 V	136-140 F	136-140 V	141-145 F	141-145 V	146-150 F	146-150 V
INVERTEBRATES																		
Mollusca																		
Bivalvia																		
Geukensia demissus																		
Aschelminthes																		
Nematoda	6.20	0.10																
Annelida																		
Polychaeta																		
Arthropoda																		
Copepoda																		
Calanoida					20.00	3.80					100.00	10.00						
Amphipoda																		
Gammaridea																		
Gammarus sp.	6.20	0.10			20.00	0.20					100.00	5.00						
Mysidacea																		
Neomysis americana	87.30	88.20	84.60	76.90	100.00	77.00	100.00	100.00	100.00	100.00	100.00	65.00	100.00	99.00	100.00	100.00	100.00	100.0
Decapoda																		
Natantia																		
Natantia zoea																		
Penaeidae																		
Penaeus sp.																		
Acetes americanus	18.70	7.80	15.40	10.00	20.00	17.00					100.00	20.00						
Reptantia																		
Brachyura																		
Brachyura zoea																		
Brachyura megalops																		
VERTEBRATES																		
Pisces																		
Fish larvae																		
Micropogonias undulatus																		
Leiostomus xanthurus																		
Anchoa sp.																		
Synodus sp.																		
Unidentified fish					20.00	2.00												
Miscellaneous																		
Digested organic matter	12.50	3.70	30.80	13.10														
Plant material	6.20	0.30											100.00	1.00				
Detritus																		
Number examined	19		14		6		1		2		1		2		1		1	
Number empty	3		1		1		0		0		0		1		0		0	
Number examined with food	16		13		5		1		2		1		1		1		1	

*F = Frequency of Occurrence
*V = Volume (%)

Table 5. Percent frequency and volume of all food items ingested by 293 S. aquosus caught at sampling stations during the study year 1976, in the Cape Fear River and adjacent ocean.

Species Stations	OCEAN F*	OCEAN V*	18E F	18E V	18 F	18 V	18W F	18W V	19E F	19E V	19 F	19 V
INVERTEBRATES												
Mollusca												
Bivalvia												
Geukensia demissus												
Aschelminthes												
Nematoda	2.00	0.03										
Annelida												
Polychaeta												
Arthropoda												
Copepoda												
Calanoida	42.10	21.60	33.30	16.70								
Amphipoda												
Gammaridea												
Gammarus sp.	12.50	2.00										
Mysidacea												
Neomysis americana	70.70	45.50	100.00	83.30			100.00	80.00	92.90	89.60	100.00	100.00
Decapoda												
Natantia												
Natantia zoea												
Penaeidae												
Penaeus sp.												
Acetes americanus	31.20	19.50										
Reptantia												
Brachyura												
Brachyura zoea	6.20	0.20										
Brachyura megalops	14.50	1.70										
VERTEBRATES												
Pisces												
Fish larvae												
Micropogonias undulatus									3.60	1.20		
Leiostomus xanthurus												
Anchoa sp.												
Synodus sp.												
Unidentified fish									14.30	9.20		
Miscellaneous												
Digested organic matter	33.30	9.50			100.00	100.00	50.00	20.00				
Plant material												
Detritus	2.00	0.02										
Number examined	53		3		3		2		32		1	
Number empty	5		0		2		0		4		0	
Number examined with food	48		3		1		2		28		1	

*F = Frequency of Occurrence (%)
*V = Volume (%)

Table 5. (cont.)

Species / Stations	19W		CM		CB2		CB1		CS		23E		23	
	F	V	F	V	F	V	F	V	F	V	F	V	F	V
INVERTEBRATES														
Mollusca														
Bivalvia														
Geukensia demissus														
Aschelminthes														
Nematoda	7.10	0.10												
Annelida														
Polychaeta														
Arthropoda														
Copepoda														
Calanoida	7.10	0.20	25.00	1.30							10.50	2.20		
Amphipoda														
Gammaridea														
Gammarus sp.														
Mysidacea														
Neomysis americana	100.00	97.30	100.00	98.70	100.00	100.00	100.00	100.00	66.70	66.70	89.50	78.70		
Decapoda														
Natantia														
Natantia zoea														
Penaeidae														
Penaeus sp.														
Acetes americanus														
Reptantia														
Brachyura														
Brachyura zoea														
Brachyura megalops														
VERTEBRATES														
Pisces														
Fish larvae														
Micropogonias undulatus														
Leiostomus xanthurus														
Anchoa sp.														
Synodus sp.											21.00	7.90		
Unidentified fish														
Miscellaneous	14.30	2.10							33.30	33.30	10.50	10.50		
Digested organic matter											5.20	0.50		
Plant material	7.10	0.30									5.30	0.20		
Detritus														
Number examined	14		4		1		2		4		22		2	
Number empty	0		0		0		0		1		3		2	
Number examined with food	14		4		1		2		3		19		0	

*F = Frequency of Occurrence
*V = Volume (%)

Table 5. (cont.)

Species / Stations	23W		174		SC		42W		CBIN		CBIS	
	F	V	F	V	F	V	F	V	F	V	F	V
INVERTEBRATES												
Mollusca												
Bivalvia												
Geukensia demissus									2.00	0.20		
Aschelminthes												
Nematoda									2.00	0.10		
Annelida												
Polychaeta									4.00	1.40		
Arthropoda												
Copepoda												
Calanoida	4.90	0.20	7.10	0.10					48.00	14.90	4.80	4.00
Amphipoda												
Gammaridea												
Gammarus sp.									10.00	0.60	47.60	15.90
Mysidacea												
Neomysis americana	92.60	85.90	99.90	95.10	81.80	54.60	100.00	20.00	88.00	55.80	66.70	34.90
Decapoda												
Natantia												
Natantia zoea									12.00	4.20		
Penaeidae												
Penaeus sp.					27.30	22.70						
Acetes americanus											4.80	4.70
Reptantia												
Brachyura												
Brachyura zoea									2.00	1.00		
Brachyura megalops									2.00	0.80		
VERTEBRATES												
Pisces												
Fish larvae									16.00	13.00	4.80	4.20
Micropogonias undulatus									4.00	2.00	9.50	4.30
Leiostomus xanthurus											9.50	6.70
Anchoa sp.					9.10	7.70						
Synodus sp.											14.30	4.80
Unidentified fish	17.10	7.30	14.30	1.00	27.30	15.00	100.00	80.00	2.00	1.50	19.00	15.70
Miscellaneous												
Digested organic matter	12.20	3.70							6.00	4.50	14.30	4.80
Plant material	7.30	0.20	14.30	3.80								
Detritus	4.90	2.70										
Number examined	43		15		12		1		55		24	
Number empty	2		1		1		0		5		3	
Number examined with food	41		14		11		1		50		21	

*F = Frequency of Occurrence
*V = Volume (%)

Two crustaceans Acetes americanus (19.5% volume) and a gammeriad amphipod (Gammarus sp.) (15.9% volume) were found to be of relative importance as food items at stations Ocean and CBI-S, respectively.

Months and Food Habits: The monthly food habits of Scophthalmus aquosus caught in the Cape Fear study area are tabulated in Table 6. No food data were available for the months of January and February, because specimens were either not caught or they were tagged and released into the estuary. During the entire sampling year, except for the month of September, Neomysis americana was the predominant food item. Acetes americanus was the major food item (77.2% volume) in the diet of 10 fish analyzed in September. Fish were also found to be an important food source for specimens caught in March (36.9% volume) and November (26.7% volume). April and May contributed specimens with the largest percent volume of calanoid copepods in their stomachs (13.8% and 10%, respectively).

Table 6. Percent frequency and volume of all food items ingested by 293 S. aquosus by month for the whole study year, 1976, caught in the Cape Fear River and adjacent ocean.

Species / Food Items (Month)	Jan F*	Jan V*	Feb F	Feb V	Mar F	Mar V	Apr F	Apr V	May F	May V	Jun F	Jun V	Jul F	Jul V	Aug F	Aug V	Sep F	Sep V	Oct F	Oct V	Nov F	Nov V
INVERTEBRATE																						
Mollusca																						
Bivalvia									0.90	0.02												
Geukensia demissus																						
Aschelminthes																						
Nematoda									2.80	0.06												
Annelida																						
Polychaeta					3.00	1.00																
Arthropoda																						
Copepoda																						
Calanoida					15.10	2.30	21.10	13.80	26.50	10.00	28.60	0.70	30.00	3.30							33.30	3.30
Amphipoda																						
Gammaridea																						
Gammarus sp.									16.00	4.10	42.80	1.30									33.30	1.60
Mysidacea																						
Neomysis americana					81.80	52.90	76.90	74.80	88.60	75.40	100.00	94.40	100.00	87.70	99.90	84.50	100.00	4.80	100.00	100.00	100.00	61.70
Decapoda	NO		NO																			
Natantia																						
Natantia zoea	DATA		DATA		9.10	3.30																
Penaeidae																						
Penaeus sp.							5.80	4.80														
Acetes americanus					1.50	1.50							10.00	1.00	44.40	15.00	90.00	77.20			33.30	6.70
Reptantia																						
Brachyura																						
Brachyura zoea					1.50	0.50			0.90	0.06												
Brachyura megalops									0.90	0.40					11.10	0.50						
VERTEBRATES																						
Pisces																						
Fish larvae					13.60	11.20																
Micropogonias undulatus					7.60	3.40																
Leiostomus xanthurus					3.00	2.20																
Anchoa sp.					1.50	1.30																
Synodus sp.					4.50	1.20																
Unidentified fish					25.70	17.60	1.90	0.50	6.60	1.40											33.30	26.70
Miscellaneous																						
Digested organic matter					1.50	1.50	3.80	3.80	19.80	7.90	14.30	3.60	50.00	8.00			50.00	18.00				
Plant material									4.70	0.60												
Detritus					1.50	0.10	5.80	2.30	1.90	0.06												
Number examined					77		55		112		13		10		10		11		1		4	
Number empty					11		3		6		6		0		1		1		0		1	
Number examined with food					66		52		106		7		10		9		10		1		3	
% fullness of stomachs with food					48.20		55.80		57.20		32.10		57.00		37.80		54.30		90.00		53.30	

*F = Frequency of Occurrence (%)
*V = Volume (%)

Discussion: The windowpane flounder, *Scophthalmus aquosus*, has a varied diet by consuming small crustacenas, annelids, mollusks, isopods, and other fishes (Bigelow and Schroeder 1953; Hildebrand and Schroeder 1928; Leim and Scott 1966; Moore 1947; and Smith 1907). Moore (1947) reported the mysid shrimp, *Neomysis americana*, as the predominant food item eaten in all months of the year by 654 fish collected in Long Island Sound. *N. americana* was also the major prey organism of 120 *S. aquosus* (size range 58-264 mm) captured in the vicinity of Northport, New York (Hickey 1975). Bigelow and Schroeder (1953) indicated that judging from the large mouth of *Scophthalmus* it would probably be a fish eater, and Hickey (1975) reported fish as an important dietary item for older *S. aquosus* (age 2^+ to 4^+) in the Northport New York area. However, Moore (1947) concluded that the few fishes found in stomachs of her specimens were not enough to classify *Scophthalmus* as a fish eater. Fishes were also not reported in the diets of *S. aquosus* collected by Richards (1963) in Long Island Sound.

Much of the literature above suggested that the euryhaline shrimp, *N. americana* was a major food for *S. aquosus* collected along the Eastern United States coast. In this study, *N. americana* was the most important food item by both percent volume and frequency of occurrence over the entire sampling year. According to Ross (1978), *Neomysis* found in the turbid waters of the lower Cape Fear River estuary may be negatively phototactic and remain on or near the bottom during most of the day. Since *Scophthalmus*, a benthic dweller, has been reported to be an active feeder during the daylight hours (Hickey 1975), it possibly feeds on mysids at times of high light intensity (late morning, midday, or early afternoon) when mysids may be on or near the bottom.

I could not determine whether Scophthalmus caught in the Cape Fear estuary were selective or opportunistic feeders, based on the limited data available for the abundance, distribution, and behavior of prey items in the study area (Copeland et al. 1974). However, Hickey (1975) concluded from his study that S. aquosus appeared to be a rather selective feeder, with a preference for shrimps, Neomysis americana and Crangon spetemspinosa. No Crangon were found ingested in 1976 by Scophthalmus.

The food habits of Scophthalmus did not seem to change markedly with the fishes' growth. N. americana was the predominant food item for almost all size fish (5 mm intervals) examined. Only a few small individuals (36-55 mm SL) had fishes as the main constituent of the diet rather than N. americana, which probably was a reflection of the small number of stomachs containing food (n=16) in that size range (Table 4). Calanoid copepods, the smallest food item, were also preferred by many of the smaller size fish (range 40-100 mm SL). Similar to my findings, Hickey (1975) reported 0^+ or young-of-the-year Scophthalmus eating almost exclusively small crustaceans (copepods and Neomysis). N. americana was also the major food item for all months sampled, except September, where a few stomachs (10) revealed Acetes americanus to be the dominant food (77.2% volume) (Table 6). Williams (1965) indicated

Acetes americanus to be abundant in early fall along North Carolina waters, which might possibly account for A. americanus being prevalent in the diet of the Cape Fear River fish caught in September.

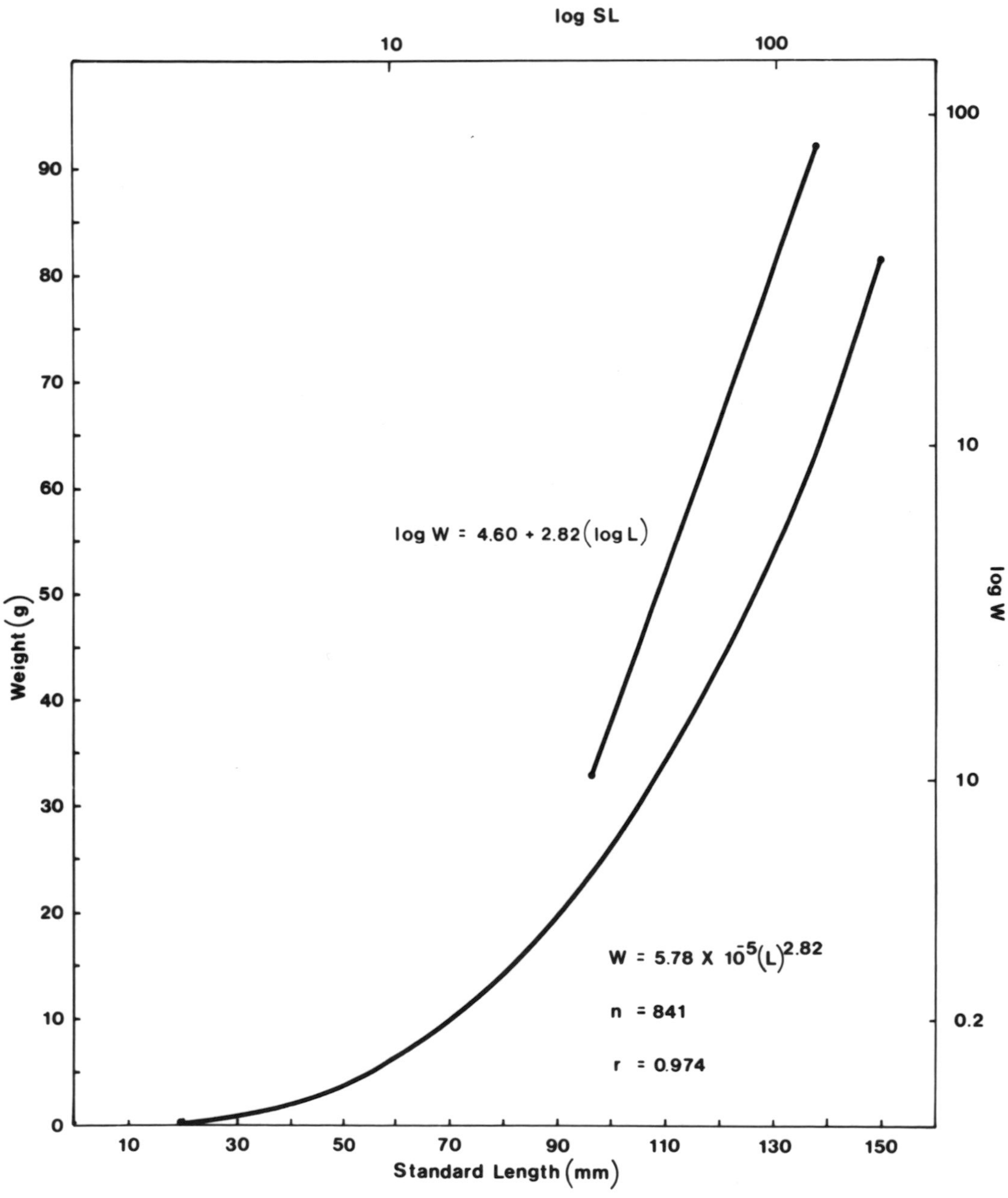
When the food habits of the windowpane flounder were examined by station, N. americana was the predominant food item by percent volume for all stations (Table 5). Copeland et al. (1974) reported N. americana occurring during the fall in both the Cape Fear estuary and adjacent ocean. Only nine of the 22 stations sampled had over 10 stomachs containing any food items which made it difficult to determine any pattern between each station.

Length-Weight Relationship

The relationship between body length (L) and weight (W) was expressed by the equation $W = KL^b$, logarithmically $\log W = \log K + b \log L$, where K and b are constants derived by regressing length by weights (Hile 1970; Lagler 1956; Tesch 1968). Fish lengths and weights are generally highly correlated and can be related in one of two ways. When the exponent b equals 3, all parts of the fishes body increase at the same rate, isometric growth. But when the value of b differs from 3 (usually between 2-4) indications are that allometric growth is occurring.

Sex data were combined and a Student t test [$t_{(0.05)(2),145} = 1.976$] indicated no significant difference between males or females. The length-weight relationship for 841 S. aquosus was calculated (Figure 3) as $W = 5.78 \times 10^4 (L)^{2.82}$, logarithmically, $\log W = -4.60 + 2.82 (\log L)$. The correlation coefficient of $r = 0.974$ indicated

Fig. 3. Length-weight relationship for 841 *S. aquosus* (sexes combined) captured in the Cape Fear River and adjacent ocean, 1976.



log SL
10
100
100
90
80
70
10
60
log W = 4.60 + 2.82(log L)
50
log W
Weight (g)
40
30
10
20
W = 5.78 X 10^-5 (L)^2.82
10
n = 841
0.2
r = 0.974
0
10
30
50
70
90
110
130
150
Standard Length (mm)

a good relationship between the Length-Weight variables. These data indicated isometric growth because the value of the exponent (2.82) *b* in the above equation was close to 3. These data may favor younger fish, since there were more smaller specimens available for calculation.

Moore (1947) reported length-weight relationship for *S. aquosus* (n = 1,322, size range 160 to 370 mm TL) in the Gulf of Maine. Her data were calculated from specimens larger than I encountered. Moore found that males lagged behind females in weight beginning at 300 mm body length (TL), but weighed basically the same in fish up to 300 mm body length.

Age and Growth

Time of Annulus Formation: The mean scale marginal increments of *Scophthalmus* growth were calculated for each 1976 sample week specimens for age classes 1, 2, and 3 (Table 7). Mean marginal increments of scales were smallest for yearlings collected 10-12 May. Based on limited data, I propose that annulus formation in yearling *S. aquosus* took place in late spring (early May). The difference between early May (10-12) and late May (24-25) increments (2.8 mm) indicated rather rapid growth soon after annulus formation. Unfortunately, there were too few yearling fish collected throughout the year (except May) to permit accurate conclusions regarding annulus formation. The marginal scale increments for age classes 2 and 3 were variable and accuracy in interpretation was lost because of the small sample sizes (Table 7).

An increase in the proportion of age class I fish during the month of May and a corresponding decrease in young-of-the-year starting in June is evident in Table 8. Assuming that age I fish were not migrating

Table 7. Mean marginal scale increment for 83 Scophthalmus aquosus captured in the Cape Fear River and adjacent ocean, 1976.

	AGE CLASS					
	I		II		III	
Sample Date	N	Average Increment	N	Average Increment	N	Average Increment
8-10 Mar	-	-	1	30.00	-	-
29-30 Mar	-	-	1	11.70	-	-
19-21 Apr	-	-	-	-	-	-
10-12 May	16	4.60	1	20.00	1	5.00
24-26 May	23	7.40	-	-	-	-
21-23 June	9	7.60	-	-	-	-
11-13 July	5	8.40	-	-	-	-
16-18 Aug	7	5.00	2	6.00	-	-
7-9 Sep	9	5.60	-	-	-	-
18-20 Oct	1	8.00	-	-	-	-
15-17 Nov	-	-	-	-	4	7.50

within the study area and young-of-the-year were not migrating out of the study area, then the increase in numbers of age I Scophthalmus during May suggested that the annuli formed during this time, which supported the data from the study of marginal scale increments (Table 7).

Body Length to Scale Radius Relationship: Age and growth analysis of fish based on scales (or bones) depends, in part, on the knowledge of the relationship between scale and fish body size (Hile 1970; Schuck 1949; Van Oosten 1929; Whitney and Carlander 1956). The method of least squares regressions was used to determine the characteristics of this relationship (Figure 4). The linear regression of 315 Scophthalmus was expressed as Y = 0.6394 x -12.084 (Figure 4), where Y = the scale radius (83X) and X = the standard length of the fish. A correlation coefficient (r) of 0.9606 suggested a good relationship between proportional growth of the scale over the entire range (33-153 mm) of the fish lengths studied. The data used to perform this regression are presented in Table 9. The average scale radii, and standard lengths were calculated in 10 mm intervals. Annuli readings and measurements were taken from the scale focus straight to the middle of the anterior edge (Figure 5).

Age Class Determination: Scales from 315 fish were used for analysis of S. aquosus age class structure. The fish were first divided into 10 mm SL size groups, and than a subsample of 25 individuals (when possible) was used in each size group for analysis (Ketchen 1950).

Table 8. Sample week (month) frequency of *S. aquosus* age classes. Age determined from scale aging of 1976 caught specimens from the Cape Fear River and adjacent ocean.

Age Class	MONTH													
	J	F	M*	M**	A	M^{+}	M^{++}	J	J	A	S	O	N	Total
0	-	-	33	54	54	47	32	4	5	3	-	-	-	232
I	-	-	-	-	-	16	23	9	5	7	9	1	-	70
II	-	-	1	4	-	1	-	-	-	-	2	-	-	8
III	-	-	-	-	-	1	-	-	-	-	-	-	4	5
Total			34	58	54	65	55	13	10	10	11	1	4	315

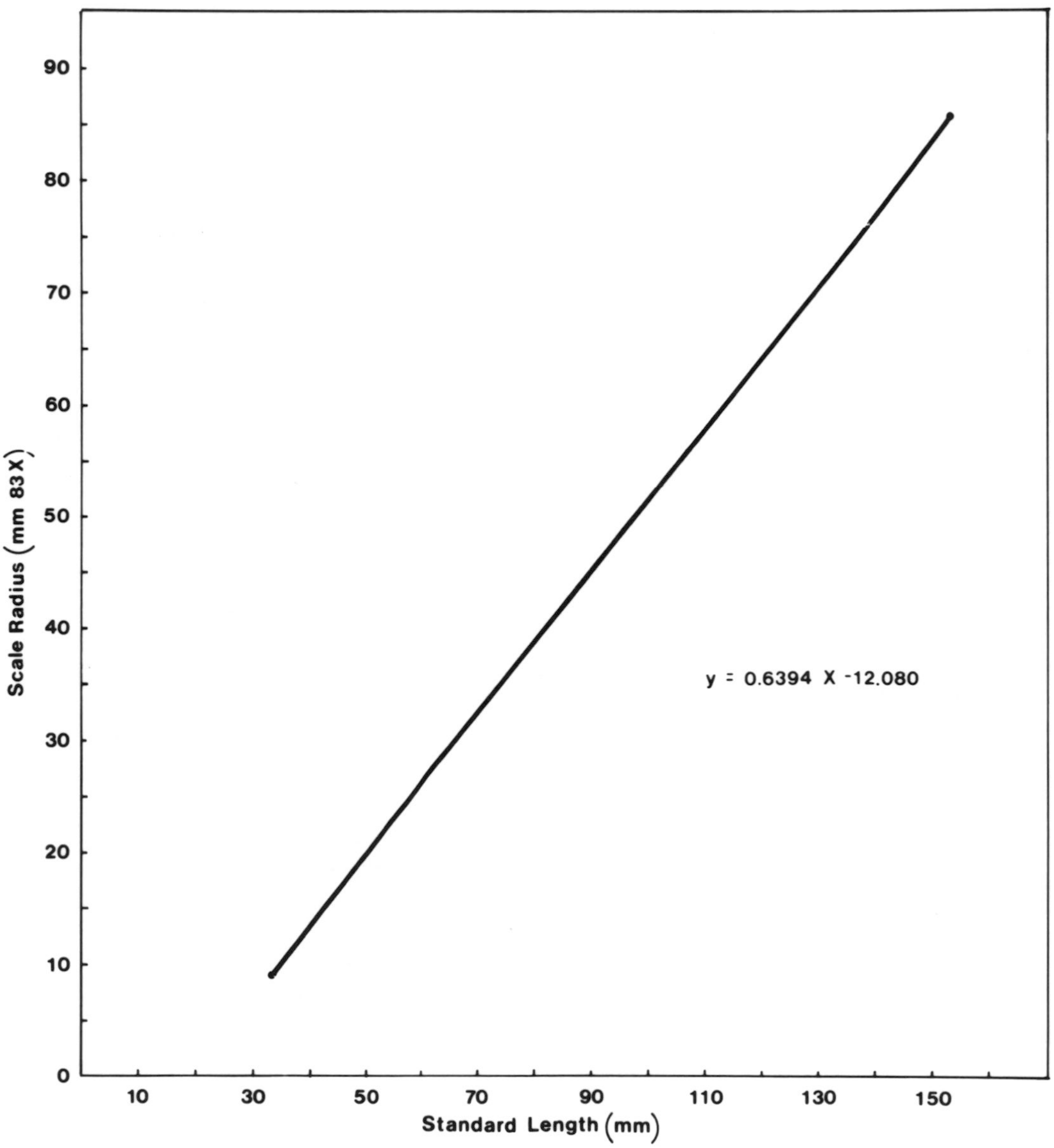
M* = 8-10 Mar
M** = 29-30 Mar
M+ = 10-12 May
M++ = 24-26 May

Age classes were assigned according to the number of annuli present, with each annulus representing 1 year of growth or age (Table 10). The absence of mature females (ripe with eggs) in the collection made it difficult to assign any simple date or month, as the birth date of S. aquosus collected in the Cape Fear study area. According to Smith, Sibunka, and Wells (1975), Scophthalmus has a split spawning season in offshore waters of North Carolina based on larval distributions. They indicated the first spawning period occurred April-June and the second spawning began in late fall. Smith, Sibunka and Wells (1975) also reported Scophthalmus larvae being present only during November and December and not occurring April through June in waters off Cape Lookout, North Carolina, which suggested a fall spawning occurring in those offshore waters.

The presence of small Scophthalmus (less than 30 mm) during late winter (February) and early spring (March) during 1976 in the Cape Fear study area (Figure 6), and the absence of small individuals of comparable sizes during the summer suggested that these fish were probably spawned in late fall or early winter. There could also be the possibility of spring spawned individuals living within the study area, but my data did not indicate such an occurrence.

If S. aquosus collected, during the 1976 sampling period, laid down their annuli in the late spring (10-12 May) based on marginal scale increments (Table 7), then fish showing one annuli on their scales were probably less than a year old when their annuli was formed. But since fish are generally categorized as 1 year olds (age I) when the annulus was formed, then fish collected during the study were given the same

Fig. 4. Standard length (mm) to scale radius (mm 83x) relationship for 315 *S. aquosus* captured in the Cape Fear River and adjacent ocean, 1976.



Scale Radius (mm 83 X)
90
80
70
60
50
40
30
20
10
0
10
30
50
70
90
110
130
150
Standard Length (mm)
y = 0.6394 X -12.080

Table 9. Mean scale radius (x83), mean standard length, and range of scale radii for 315 S. aquosus captured in the Cape Fear River and adjacent ocean, 1976.

Class Range SL in mm	N	MEAN Scale Radius (mm x83)	SL (mm)	Scale Radius Range (x83)
10-19	-	-	-	-
20-29	-	-	-	-
30-39	2	10.50	35.00	10-11
40-49	17	18.70	45.10	14-26
50-59	34	23.10	54.20	18-29
60-69	56	29.00	65.30	18-40
70-79	41	34.30	74.50	28-43
80-89	43	42.10	83.60	32-55
90-99	43	48.20	94.10	40-60
100-109	39	53.90	103.70	45-62
110-119	28	59.10	113.80	50-73
120-129	2	70.50	125.00	69-72
130-139	5	76.60	133.00	72-80
140-149	4	84.70	144.20	76-90
150-159	1	88.00	153.00	-

connotation, even though they probably had lived less than 12 months (age) when the first annulus appeared.

A problem sometimes encountered in aging *Scophthalmus* by scales was the formation of more than one growth mark (annulus) per year (Moore 1947). No *S. aquosus* scales possessed more than one annulus per year of growth and no pattern of secondary mark formation was visible. When an annulus was obscured or unreadable, it was easy to misinterpret a secondary as a true annulus. A scale with 3 annuli is illustrated for a typical age 3 *Scophthalmus aquosus* captured in the Cape Fear River estuary (Figure 5).

Age class 0 comprised the largest percentage of aged fish (73.7%), followed in decreasing order age class I (22.2%), II (2.5%), and III (1.6%). The mean observed standard length increased with the increasing age of the fish (Table 10).

Monthly Length-Frequency Distribution: Monthly length-frequencies of *Scophthalmus aquosus* collected at all stations from January to November 1976 are depicted in Figure 6. Young *S. aquosus* (young-of-the-year) occurred in much greater abundance than larger, possibly older, individuals within the estuarine complex sampled. The young-of-the-year fish were abundant from March through October with some specimens showing up earlier in February. The abundance of young individuals in the Cape Fear River estuary and adjacent ocean may imply that *S. aquosus* used the area as a nursery ground. Bigelow and Schroeder (1953) reported that young individuals tend to settle in shallow inshore waters and migrate offshore, as they grew older. A few large specimens (130 mm SL, N=27)

Table 10. Frequency distributions of observed standard lengths for each age class of S. aquosus aged by scales (sexes combined) captured in the Cape Fear River and adjacent ocean, 1976.

Length Interval (mm)	AGE CLASS (Ring Group)			
	0	I	II	III
10-19				
20-29				
30-39	2			
40-49	17			
50-59	34			
60-69	56			
70-79	41			
80-89	43			
90-99	35	8		
100-109	4	35		
110-119		26	2	
120-129		1	1	
130-139			3	2
140-149			2	2
150-159				1
Total	232	70	8	5

Fig. 5. Scale illustration from an age 3 *Scophthalmus aquosus* of 153 mm SL. Arrows 1-3 point out the 3 annuli. F = focus

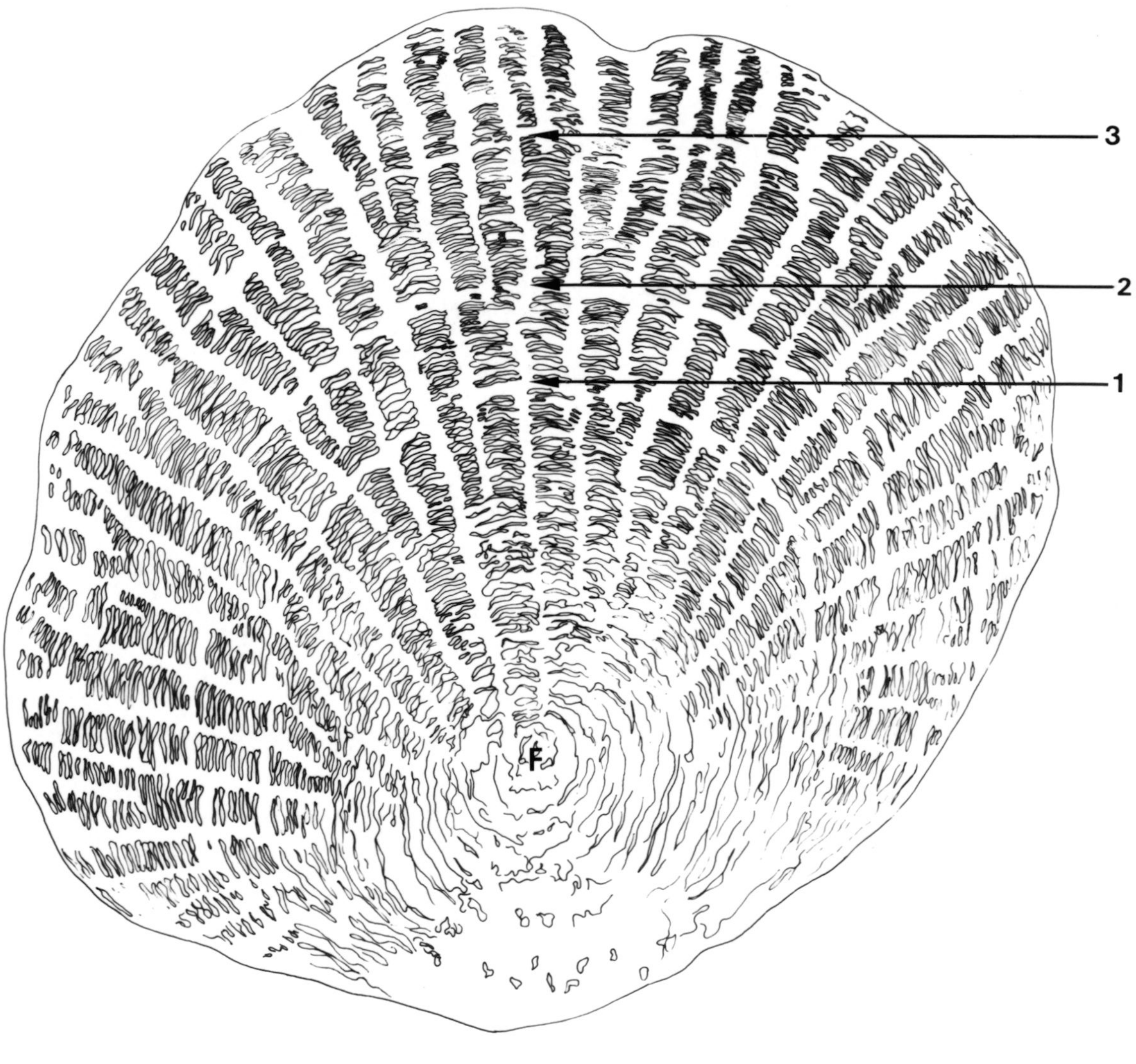

3
2
1
F

Fig. 6. Photograph of Scophthalmus scale illustrating 3 annuli.

were collected during the sampling year. The spawning season for Scophthalmus is temperature dependent, starting in April south of the Chesapeake Bay and moving northward to New Jersey and New York during the summer, not peaking there until the fall, at which time (Fall) breeding recommences in Virginia and North Carolina waters (Smith, Sibunka, and Wells 1975). The early appearance (February and March) of small S. aquosus (33 mm SL) in the Cape Fear study area suggested that they could possibly be the result of late fall or winter spawning (see Age Class Determination).

Validation of Annuli: Van Oosten (1929) established the following criteria that must be met before check marks on scales or bones can be considered annuli: (1) Scales or bones must remain constant in number and identity throughout the life of the fish, (2) growth of the scale or bone must be proportional to the overall growth of the fish, (3) growth check marks must be formed at approximately the same time each year, and (4) back-calculated lengths should agree with empirical lengths of younger age groups.

Evidence used to confirm that annuli were deposited once a year which could be used for valid age determination for S. aquosus was as follows: (1) A high correlation between scale radius (r = 0.9606) and body length, (2) reasonable assurance that the annulus formed at the same time each year (late spring), (3) a general agreement between back-calculated lengths and empirical body lengths (see Back-Calculation of Lengths and Discussion), and (4) an agreement between length-frequency peaks and mean lengths of age classes established by scale readings.

Fig. 7. Monthly length-frequency data for S. aquosus in study year, 1976.

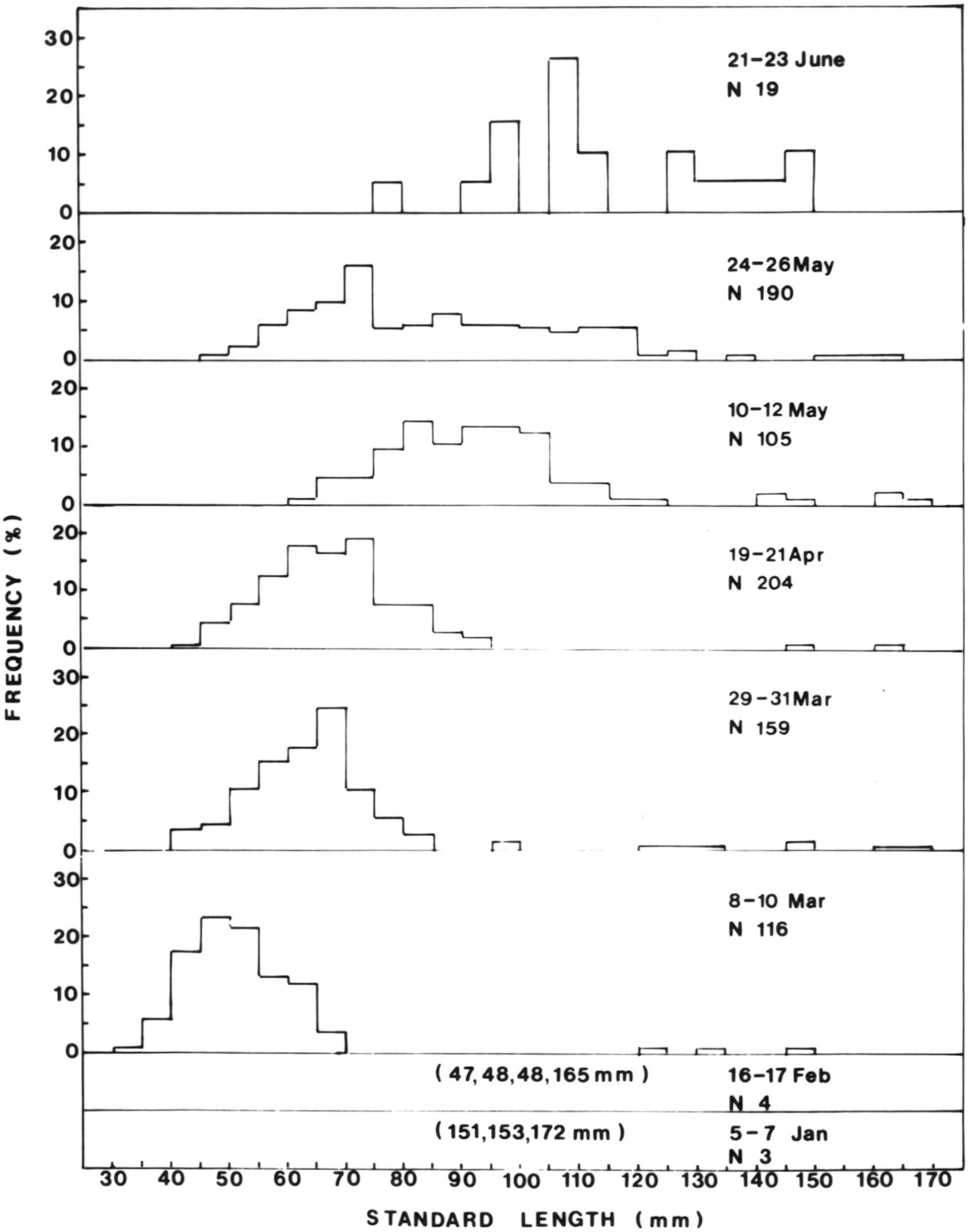
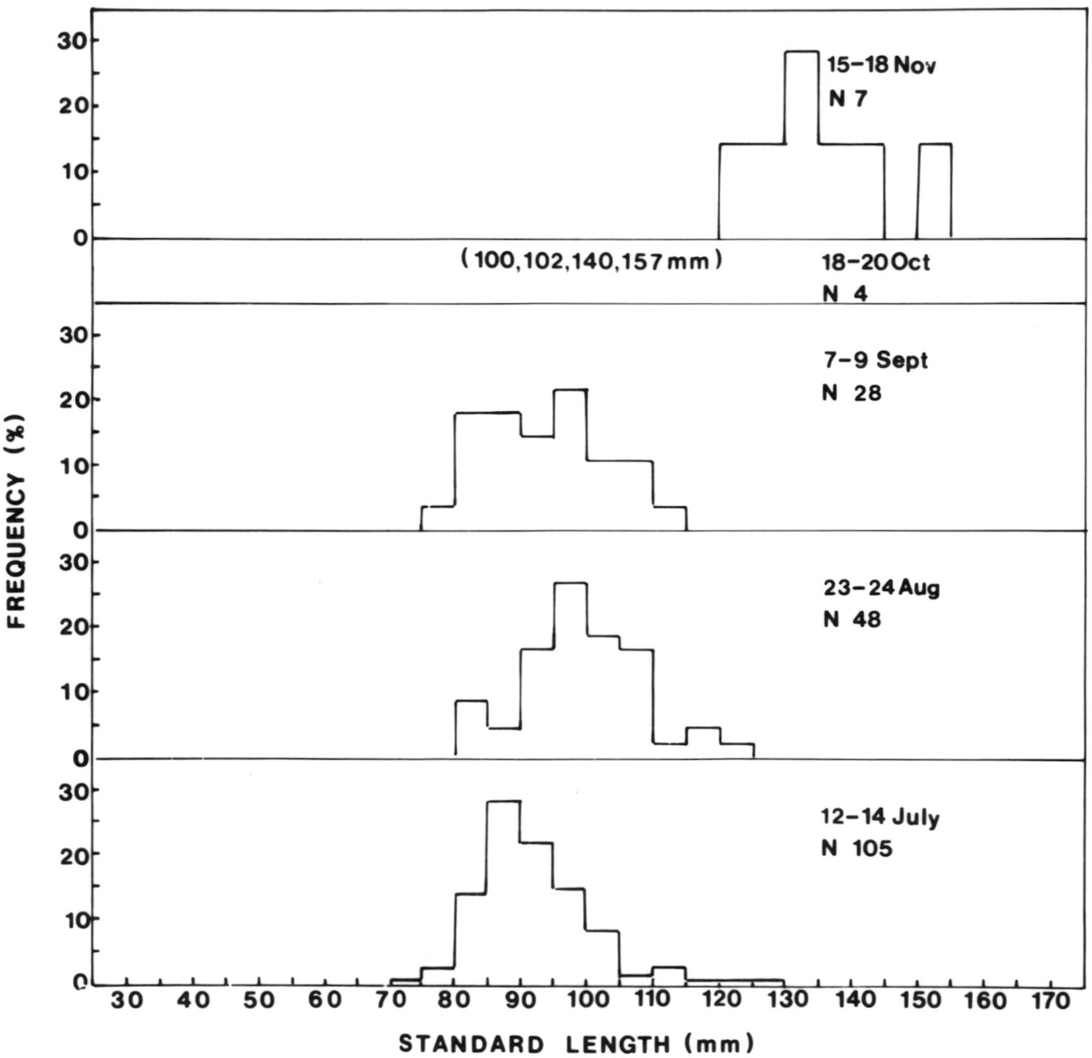

21-23 June
N 19
24-26 May
N 190
10-12 May
N 105
19-21 Apr
N 204
29-31 Mar
N 159
8-10 Mar
N 116
(47, 48, 48, 165 mm)
16-17 Feb
N 4
(151, 153, 172 mm)
5-7 Jan
N 3
FREQUENCY (%)
STANDARD LENGTH (mm)
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170

Fig. 7. Continued.



FREQUENCY (%)
30
20
10
0
15-18 Nov
N 7
(100,102,140,157 mm)
18-20 Oct
N 4
7-9 Sept
N 28
23-24 Aug
N 48
12-14 July
N 105
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
STANDARD LENGTH (mm)

Back-Calculation of Lengths: The relationship between scale radius and body length was examined earlier, and the formula for describing this relationship was derived by the method of least squares (Figure 4 and Table 9). The relationship between scale radius and standard length were linear (Figure 4) and intercepted the abscissa (SL axis) at a positive value (see below). This indicated that back-calculation by the Lee method should be used, and correction factors (CF) need to be computed and subtracted from the observed and calculated lengths in the Lee formula. The correction factor (abscissa intercept) was calculated from scale data using the equation from Figure 4 with Y = 0 being 18.89. The correction factor was then inserted into the Lee formula:

$$L_x - CF = S_x/S\ (LCF)$$

or

$$L_x = CF + S_x/S\ (LCF),$$

where L_x = standard length when annulus x was formed,
L = standard length at time fish was captured,
S_x = radius of annulus x,
S = total scale radius at time of fish capture,

and back-calculations were performed (Everhart *et al*. 1953; Nikolsky 1963; Tesch 1968). Distritution of back-calculated lengths are presented in Table 11. The observed size range of age class I *S. aquosus* was 91-121 mm (Table 10), and the calculated range 83-112 (Table 11). Data for all age class II fish yielded an observed length range of 111-147 mm (Table 10) and a calculated range of 101-121 (Table 11). Observed lengths in age class III from scale examinations ranged from 131 to

Table 11. Frequency distribution of back-calculated standard lengths at the time of annulus formation for *S. aquosus* captured in the Cape Fear River and adjacent ocean, 1976.

Standard Length (mm)	AGE CLASS		
	I	II	III
10-19			
20-29			
30-39			
40-49			
50-59			
60-69			
70-79			
80-89	14		
90-99	47		
100-109	18	7	
110-119	4	4	
120-129		2	3
130-139			1
140-149			1
150-159			
Total	83	13	5

Table 12. Average calculated and observed standard lengths and length increments for Scophthalmus using scales.

Age Class	N	Standard Length: Mean (mm)	Standard Length: Range (mm)	Mean Calculated SL for Ages: I	II	III
0	232	72.10	33-103	-	-	-
I	70	107.10	91-121	97.10	-	-
II	8	130.50	111-147	90.20	110.40	-
III	5	140.40	131-153	91.80	110.30	130.10
Total N				83	13	5
Mean Weighted Calculated SL				96.10	110.30	130.10
Mean Annual Calculated Increments of Growth (based on age classes I-III)				96.10	19.50	19.80

153 mm (Table 10) and the calculated lengths 116 to 145 mm (Table 11). The calculated length ranges were found to be lower than the observed ranges for age classes I-III.

Growth: Growth calculations were based on 315 specimens collected during the 1976 sampling period. The fish size range available for study was from 33 to 153 mm SL, with specimens from all but two months (January and February) of the study year represented in the analysis. Both sex and localities were combined to yield a larger sample size of all age classes.

The mean standard length increase from one age to another progressed from 72.1, age 0, to 107.1 mm, age I, to 130.5 mm, age II, 140.4, at age III (Table 12). The observed average annual growth increments were from 35.0 mm, at age 0-I, 23.4 mm, at age I-II, and 9.9 mm at age II-III. The mean calculated increments of each age class derived from back-calculated length data was noted in Table 12. The back-calculated data was similar to the observed data in that it indicated the most rapid growth of *S. aquosus* occurred during the first year of life when a size increment of 96.1 mm was attained. Age classes II and III exhibited a lesser growth rate, with size increment values of 19.5 mm and 19.8 mm, respectively.

Discussion (Age and Growth): There have been no published reports on the age and growth of *Scophthalmus aquosus* collected in North Carolina waters. However, Moore (1947) conducted a very extensive age and growth study (using scales and otoliths) on *S. aquosus* collected in southern New England waters. She indicated in her study that *Scophthalmus* grew most rapidly during its second, third, and fourth years of growth (age), which was contrary to my findings of the largest increment of growth occurring in 0-I age fish (Table 12). These differences could possibly be the result of sampling entirely different fish populations in different zoogeographical areas, and also that my II and III aged classes were poorly represented (N=13). I also recognize that the age and growth parameters calculated with the present data may not be accurately representative to *Scophthalmus* populations of other years and areas. Even in stable fish populations age and growth characteristics change over time and by locality (Everhart *et al*. 1953; Ricker 1975).

The back-calculated body length data indicated that the observed length range was larger than the calculated length range (Tables 10,11). Since the observed range noted the length of the fish at a particular age, after their capture, and the calculated range is the length of the fish at annulus formation. Then fish of an observed age would most likely be larger than the back-calculated aged fish to permit the annulus to be visible enough to be read.

As indicated earlier, the growth rate of *Scophthalmus*, especially young individuals (0-I) seemed greatest in the spring concurrently with rising water temperatures (hydrography section) and the greatest concentration of food in the fishes' stomachs (food habits section). However, *Scophthalmus* being primarily a cooler water species, based on their abundance north of the Chesapeake Bay area (Moore 1947; Smith, Sibunka, and Wells 1975), seemed to use the Cape Fear estuary primarily as a nursery ground for young-of-the-year fish. Based on my data, the young-of-the-year fish became 1 year olds in the early May and began moving out of the estuary during summer and fall when water temperatures were at their highest peak (hydrography section). Dahlberg and Odum (1970) reported finding *S. aquosus* only from January to May within an estuary in Georgia. Also according to Bigelow and Schroeder (1953) young *Scophthalmus* found in shallow inshore areas tend to move offshore into deeper water as they grew older. This may be the situation for *Scophthalmus* found in the Cape Fear estuary.

SUMMARY AND CONCLUSIONS

1. The food habits of *Scophthalmus* aquosus did not seem to change markedly with the fishes' growth. *N. americana* was the predominant food item for almost all size fish (36-153 mm SL) examined. Only a few small individuals (36-55 mm SL) had fishes as the main constituent of the diet, which probably was a reflection of the small number of stomachs containing food (N=16) in that size range (Table 4). Calanoid copepods, the smallest food item, were also preferred by many of the smaller size fish (range 40-100 mm SL).

2. When the food habits of the windowpane flounder were examined by station, *N. americana* was the predominant food item by percent volume for all stations (Table 5). Only nine of the 22 stations sampled had over 10 stomachs containing any food items which made it difficult to determine any pattern between each station.

3. *N. americana* was also the major food item for all months sampled, except September, where a few stomachs (10) revealed *Acetes americanus* to be the dominant food (77.2% volume).

4. The length-weight for 841 *S. aquosus* was calculated as $W = 5.78 \times 10^{4}(L)^{2.82}$, logarithmically, $\log W = 4.60 + 2.82 (\log L)$. The correlation coefficient of $r = 0.974$ indicated a good relationship between the lengthweight variables. These data indicated isometric growth because the value of the exponent (2.82) *b* in the above equation was close to 3.

5. The mean scale marginal increments of Scophthalmus growth were calculated to aid in determining time of annulus formation. Mean marginal increments of scales were smallest for yearlings collected 10-12 May. Based on limited data, I propose that annulus formation in yearling S. aquosus took place in late spring (early May).

6. The standard length scale radius relation was seen to be linear with a correlation coefficient (r) of 0.9606 suggesting a good relationship between proportional growth of the scale over the entire range (33-153 mm) of the fish lengths studied.

7. The presence of small Scophthalmus (less than 30 mm) during late winter (February) and early spring (March) during 1976 in the Cape Fear study area, and the absence of small individuals of comparable sizes during the summer suggested that these fish were probably spawned in late fall or early winter. Smith, Sibunka and Wells (1975) reported Scophthalmus larvae being present only during November and December and not occurring April through June in waters off Cape Lookout, North Carolina, which also suggested a fall spawning occurring in those offshore waters.

8. If S. aquosus collected, during the 1976 sampling period, laid down their annuli in the late spring (10-12 May) based on marginal scale increments (Table 7), then fish showing one annuli on their scales were probably less than a year old when their annuli were formed. But since fish are generally categorized as 1 year olds (age I) when the annulus was formed, then fish collected during the study were given the same connotation.

9. Monthly length frequencies of *Scophthalmus aquosus* collected at all stations from January to November, 1976 indicated that young-of-the-year fish occurred in much greater abundance than larger, possibly older, individuals within the estuarine complex sampled. The abundance of young individuals in the Cape Fear River estuary and adjacent ocean may imply that *S. aquosus* used the area as a nursery ground.

10. Moore (1947) concluded in her study that *Scophthalmus* grew most rapidly during its second, third, and fourth years of growth (age), which was contrary to my findings of the largest increment of growth occurring in 0-I age fish (Table 12). The differences could possibly be the result of sampling entirely different fish populations in different zoogeographical areas, and also that my II and III aged classes were poorly represented (N=13).

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