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Analysis of Morone saxatilis and Morone americanus Spawning and Nursery Area in the York-Pamunkey River, Virginia

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ANALYSIS OF *Morone saxatilis* AND *Morone americanus* SPAWNING AND NURSERY AREA IN THE YORK-PAMUNKEY RIVER, VIRGINIA

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Ronald Gilbert Rinaldo

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APPROVAL SHEET

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Master of Arts

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ABSTRACT

Spawning and nursery areas in the York-Pamunkey River for striped bass, *Morone saxatilis* (Walbaum), and white perch, *M. americanus* (Gmelin), are described. Abundance and distribution of prolarvae, larvae and juveniles were investigated by meter net sampling. Both species utilized the main stream of the Pamunkey River 35 to 55 miles upstream from the mouth of the York River as spawning and nursery areas. Movements of early stages within the nursery ground are also described.

Associated physical and biological data for spring 1966 are related to the early life history of both species. Water temperature was 16 C during striped bass spawning, while white perch spawned when temperatures were 11-16 C. Both species spawned in fresh water and utilized low salinity areas as a nursery ground. Growth rates for both species were essentially the same during the first two months; after which striped bass grew much more rapidly than white perch. Gut content analyses of larvae and recently transformed juveniles indicated a similar diet in the two species. Food of older juveniles differed between the two species. Striped bass became piscivorous at an early age.

ANALYSIS OF MORONE SAXATILIS AND MORONE AMERICANUS SPAWNING AND NURSERY AREA IN THE YORK-PAMUNKEY RIVER, VIRGINIA

INTRODUCTION

The striped bass, *Morone saxatilis* (Walbaum), has been an economically important species since the 17th century (Wood, 1634), rivaling the cod as a food source in early North American history, and later becoming an important game fish as well. Bass were abundant until 1885, scarce to 1920, and then striped bass populations began to increase in size. In some years there were striking peaks of abundance shown in catch records. These peaks result from the so-called "dominant year class phenomenon", i.e. occasional dramatically successful spawning and survival not necessarily associated with a large spawning population.

Raney (1952), in reference to this phenomenon, indicated the need for detailed study of biological, chemical and physical conditions at a number of known spawning areas to determine which factors are essential for a large striped bass year class. He presented suggestions for studies on young striped bass, including stomach analyses, meteorological and oceanographic observations.

Young white perch, Morone americanus (Gmelin), are often associated with young striped bass. The white perch is also a valuable and abundant food fish, especially in the Chesapeake Bay region. Chesapeake Bay catch records of perch show no marked annual fluctuations or dominant year class phenomenon; however, the steady but low commercial demand may obscure changes in population level.

Mansueti (1961) gave an excellent account of the morphometric and meristic differences between early developmental stages of white perch and striped bass. He recommended further ecological research on the spawning areas and early life history. Prolarvae and larvae of both species develop into juveniles in an estuarine nursery area. Little is known of their ecology at this stage of development. McHugh (1966) commented that complex life histories of many estuarine fish require unusually detailed ecological knowledge as a basis for management.

The present thesis was undertaken in the hope that studying both species during early life history stages might give some indication of the conditions essential for a large year class in striped bass and the apparent constant success of white perch year classes. Striped bass life history has been described by Raney (1952) and Blunt (1962). White perch life history has been presented by Thoits (1958) and Mansueti (1961, 1964).

Several studies on striped bass and white perch have been made on the York River and its tributaries. Tresselt

(1952) identified spawning areas in the Pamunkey and Mattaponi rivers. Massmann, Joseph and Norcross (1962) collected the larvae of both species from the Pamunkey River. Massmann and Pacheco (1961) described migrations in Virginia waters, including the York River system. Woolcott (1962) studied white perch from the Atlantic Coast, and found significant differences in meristic characters between collections from the Pamunkey and the nearby James and Chickahominy rivers.

The York-Pamunkey River system was selected for this study because of regular sampling by the staff of the Virginia Institute of Marine Science (VIMS). A section of this river system had been identified as a nursery area for striped bass and shad after extensive experimental trawl surveys that were initiated in the early 1950's by the Institute.

The purpose of this study was to characterize hydrographically those river areas used by striped bass and white perch as spawning and nursery areas. Consideration was also given to the utilization of these areas in terms of distribution, abundance, growth and feeding habits of these congeneric species.

METHODS AND MATERIALS

The study area included the York River and the lower 30 miles of the Pamunkey River. In accordance with a station designation system in use at the Virginia Institute of Marine Science, stations are coded according to their distance from the York River mouth (Figure 1). For example, Y20 is 20 miles upstream from the mouth of the York River, and P30 is in the Pamunkey River, 30 miles from the mouth of the York River.

The York-Pamunkey system was sampled on the following dates.[1]

1) April 13, 14, 1966; seven stations, Y10, Y20, Y25, P30, P40, P45, P50, including a 24-hour anchor station at P35, plus a 12-hour anchor station at P53.
2) April 21, 1966; five stations, P35-P60.
3) April 27, 28, 1966; eight stations, P30-P60, plus six anchor stations at P53.
4) May 10, 1966; nine stations, P30-P60.
5) May 16, 17, 18, 1966; thirteen stations, Y10-P60, plus a 24-hour anchor station at P35.
6) June 3, 1966; seven stations, P30-P60.

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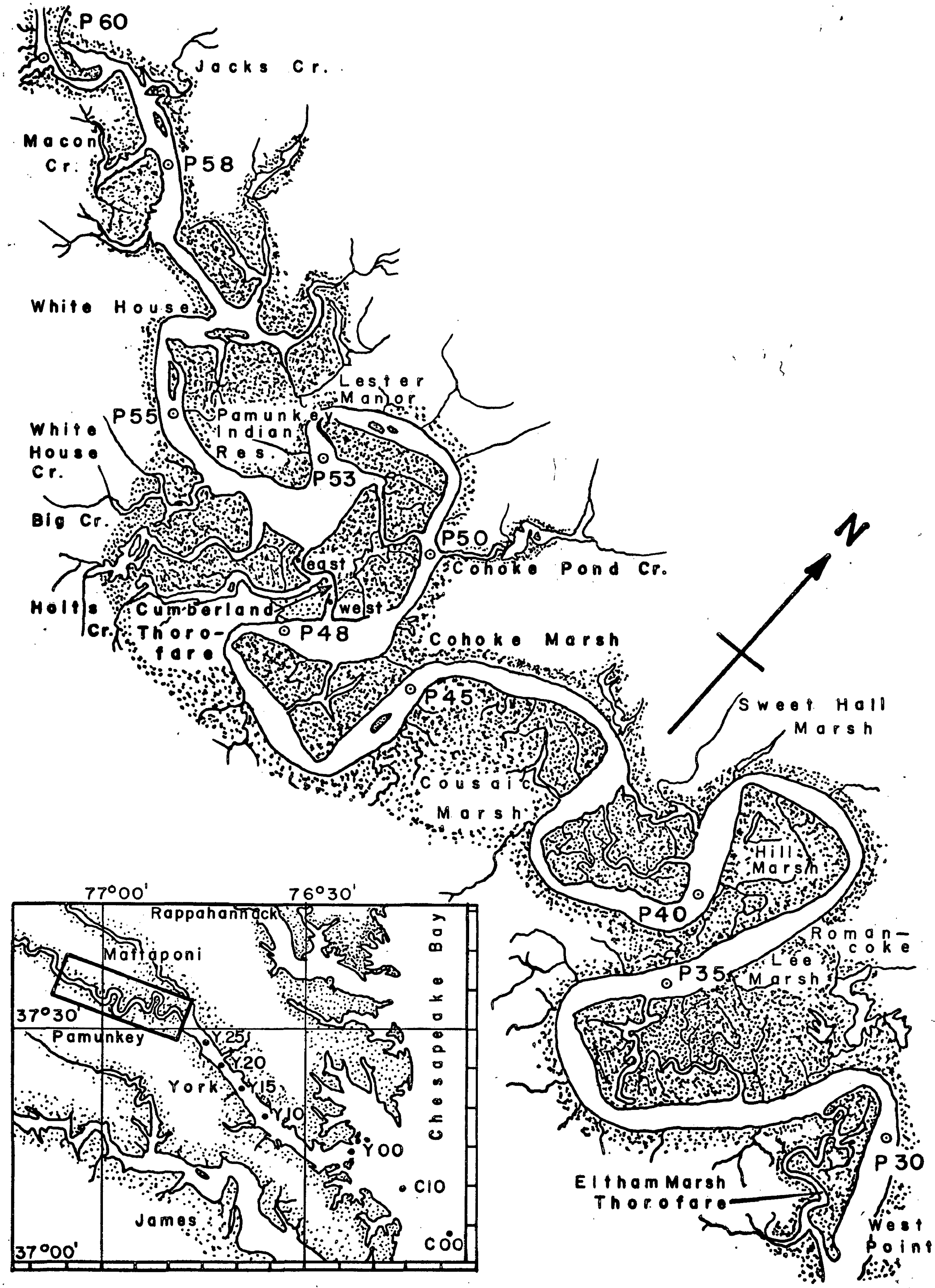
[1]Data were collected monthly by the Virginia Institute of Marine Science on Research Contract 14-17-007-531 under the Fisheries Research and Development Act (88-309). Research was co-ordinated with this project resulting in biweekly collections for the purpose of this thesis (Van Engel and Joseph, 1968).

FIGURE 1

York-Pamunkey River Sampling Stations



P 60
Jacks Cr.
Macon Cr.
P58
White House
Lester Manor
P55
Pamunkey Indian Res.
White House Cr.
P53
Big Cr.
P50
east
Cohoke Pond Cr.
Holts Cr.
Cumberland Thorofare
west
N
P48
Cohoke Marsh
P45
Sweet Hall Marsh
Cousaic Marsh
Hill Marsh
77°00'
76°30'
Rappahannock
Chesapeake Bay
Mattaponi
37°30'
Pamunkey
Y25
Y20
York
Y15
Y10
Y00
C10
James
C00
37°00'
P40
Romancoke
Lee Marsh
P35
P30
Eltham Marsh Thorofare
West Point

7) June 15, 16, 1966; eight stations, Y10-P50, plus a 24-hour anchor station at P35.

8) July 20, 21, 22, 1966; seven stations, Y10-P53, plus a 24-hour anchor station at P35.

9) August 17, 18, 19, 1966; seven stations, Y10-P53 plus a 24-hour anchor station at P35.

These stations were sampled, surface and bottom, with a meter net having a 0.7 to 0.8 mm mesh. Five-minute tows were made from the R/V Langley, an 85-foot converted ferry boat, or from a 14-foot Boston Whaler. A meter net or a ¼-meter net was towed in many small freshwater and tidal tributaries of the Pamunkey on May 10, 17, 18 and June 3, 1966. Eltham Thorofare, Lee Marsh, Sweet Hall Marsh, Cohoke Pond Creek, Cumberland Thorofare East (CTE), Holts Creek, Cumberland Thorofare West (CTW), Big Creek, White House Creek, Macon Creek, and Jacks Creek were also sampled (Figure 1).

Since white perch eggs are adhesive and demersal it was necessary to take Petersen grab samples and examine shoreline vegetation. This was done on April 13 and 21.

Beach seine samples were taken irregularly from June to October at Gloucester Point with a ½-inch stretch-mesh, 50-foot seine. Two collecting trips were made along the north shore of the York River, June 29 and August 17. Samples using the same beach seine, or a 16' semi-balloon trawl with a 1¼-inch stretch-mesh were obtained by others. These samples were used to indicate the presence or absence of early stages, and were not interpreted further. All samples were preserved in 5-10% formalin in the field.

A Folsom plankton splitter was used to obtain sub-samples small enough to examine in the available time but without losing significant information. All fish eggs, larvae and juveniles were removed from the sub-samples. Striped bass and white perch were identified using meristic and morphometric characteristics given by Mansueti (1958, 1964).

Individuals from each sub-sample were counted, and the whole sample number was calculated. The volume of water strained by each tow was calculated and whole-sample numbers were converted to numbers of eggs or larvae per 1000 cubic meters.

Hydrographic data were collected simultaneously with the biological material. Temperature and salinity of surface and bottom waters at each station were measured with either an Induction Salinometer (RS5) or an Induction-Conductivity-Temperature-Indicator (ICTI). Water samples were taken in order to check the accuracy of the ICTI or RS5 and to obtain dissolved oxygen determinations. Salinity of the water samples was determined with an Induction Salinometer (RS7-A), temperature with a stem thermometer, and dissolved oxygen by a modified Winkler titration. Current was measured with an OEC/HYDRO Portable Current Speed and Direction Measuring and Recording System (HYDRO Current Meter). Hydrographic data collected hourly at P35 usually over a 24-hour period once each month by Van Engel and Joseph (1968) were used to describe the hydrography of the study area. A cross-sectional profile of each Pamunkey River station was obtained with a lead line and the shoreline type was recorded; all other geomorphology was taken from the most recent USC&GS charts.

Stomach contents of larval and early juvenile stages of white perch and striped bass were analyzed. Specimens from each sample were randomly selected using a marked dish from which 1/16 of the specimens were removed and measured in length to the nearest 0.5 mm. The stomach contents were removed, identified, and counted as a group for all larvae in a length frequency sub-sample.

All hydrographic and biological data were recorded on IBM cards, sorted, and print-outs made. No computer analysis was attempted.

The developmental stages referred to in this thesis are defined as follows: prolarvae are recently hatched individuals which still have a yolk sac; larvae are individuals still undergoing transformation, from final absorption of oil and yolk in the gut through the attainment of adult body conformation; individuals resembling adults but still in their first year of life are termed juveniles.

Description of the Study Area

The York River System is the fifth largest contributor of fresh water to Chesapeake Bay. Average daily river discharge approximates 2,200 c.f.s. (cubic feet per second) of fresh water from 2,660 square miles of watershed. The York River is formed by the confluence of the Pamunkey and Mattaponi rivers 28.5 miles from the mouth. The two chief tributaries of the Pamunkey River are the North Anna and South Anna rivers, which originate in the Blue Ridge Mountains. The multiannual mean daily discharge of the Pamunkey is approximately 950 c.f.s. (calculated from USGS runoff data at Hanover) (Galstoff, 1947).

The Pamunkey River has a narrow channel 3-9 meters deep meandering through low marsh and swampland ½ to 2 miles wide on either side of the river (Figure 1). It flows into the upper York River, characterized by broad shallow flats, with a relatively narrow channel about 10 meters deep, which broadens and reaches a depth of 15-20 meters in the lower river. Current and salinity data from the study area indicate the York River may have a two layer circulation pattern (Van Engel and Joseph, 1968). Tidal influence extends beyond the upper limit of the study area to Bassett Ferry on the Pamunkey River. The current and tide advance upriver in the York as a progressive wave requiring about 2 hours to travel from the mouth to West Point (USC&GS tide and current tables).

RESULTS AND DISCUSSION

I. Spawning and nursery areas of striped bass and white perch in the York-Pamunkey River System

Striped Bass

Since spawning striped bass are capable of escaping trawl nets and are seldom taken in early spring cruises by VIMS, the spawning areas utilized by striped bass in 1966 were identified indirectly from egg and prolarval concentrations.

Pearcy (1962) and Mansueti (1964) in addition to Tresselt (1950) have employed egg and larval collection data to identify spawning areas. Pearcy described the ecology of winter flounder from field collections of eggs, larvae and juveniles. Mansueti used field collections of white perch to support laboratory data.

A sampling program, using meter and ¼ meter plankton nets, was designed to determine spawning locations by capturing eggs and newly hatched larvae. Ninety-four surface and bottom meter net tows were made between April and August from Y10 to P60. Twenty-one ¼ meter net samples were taken in fresh water and tidal marsh creeks along the river (Figure 1).

Although plankton collections are subject to bias, they can be quantitatively accurate provided the population distribution is limited (Cassie, 1968). No striped bass or white perch were taken below P30 in meter net collections. Early stages were absent in all fresh water and tidal marsh creek tows. These data delimit distribution to the main channel of the Pamunkey. The volume of water sampled by a five minute meter net tow was calculated and catch was converted to number per 1000 cubic meters (Tables 1 and 2). Escapement and non-random distribution were considered to be nonsignificant.

Eggs hatched in about 48 hours (Mansueti, 1958) at water temperatures (15-16C) similar to those recorded in mid-April, 1966 on the York-Pamunkey River system (Figure 2). They represent the most valid picture of spawning distribution, since they are a direct result of spawning and remain subject to tidal drift for less than two days. Eggs were found from P35 to P60 (Table 1). The greatest concentrations occurred at P40, indicating this was the center of the spawning area. There appeared to be no significant difference (X^2=1.25) between concentrations of eggs on April 27 and May 10.

Similar results were obtained when prolarval distribution was considered. Prolarvae were a maximum of 5 days old. Their distribution pattern supports the conclusion that P40 is the area where heaviest concentration of spawning occurred. A greater percentage of

TABLE 1

<u>MORONE</u> <u>SAXATILIS</u> CONCENTRATIONS FOR EACH STATION

(NUMBER/1000 METER^3)

	April			May		June	July	
	13	21	27	10	16	3	15	20
Eggs								
P30	0	-	0	0	0	0	0	0
P35	0	0	11.5	0	0	0	0	0
P40	3.6	0	31.5	29.0	0	0	0	0
P45	0	0	6.0	8.5	-	0	0	-
P48	-	0	0	0	0	-	-	-
CTW	-	-	-	4.8	-	-	-	-
P50	0	0	4.8	-	0	0	0	0
P53	0	-	0	0	0	-	-	-
P55	-	0	0	0	0	0	0	0
P60	-	0.3	2.4	0	0	0	-	-
Prolarvae								
P30	0	-	0	0	0	0	0	0
P35	0	0	37.6	92.1	0	0	0	0
P40	2.4	0	392.7	43.6	0	0	0	0
P45	0	0	0	0	-	0	0	-
P48	-	0	0	1.2	24.2	-	-	-
CTW	-	-	-	0	-	-	-	-
P50	0	0	1.4	-	0	0	0	0
P53	0.6	-	2.4	0	0	-	-	-
P55	-	0	1.2	0	0	0	0	0
P60	-	0	0	0	0	0	-	-
Larvae								
P30	0	-	0	0	0	19.1	0	0
P35	0	0	0	0	273.6	129.4	90.8	0
P40	0	0	0	0	115.5	114.8	38.3	0
P45	0	0	0	15.8	-	77.9	0	-
P48	-	0	0	6.6	63.4	-	-	-
CTW	-	-	-	73.9	-	-	-	-
P50	0	0	0	-	211.5	0	1.6	0
P53	0	-	5.3	0	49.7	-	-	-
P55	-	0	0	0	5.3	0	1.9	0
P60	-	0	0	0	5.3	0	-	-
Mean larval length (mm)			8.6	6.3	7.8	11.5	16.0	

TABLE 2

<u>MORONE</u> <u>AMERICANUS</u> CONCENTRATIONS FOR EACH STATION

(NUMBER/1000 METER^3)

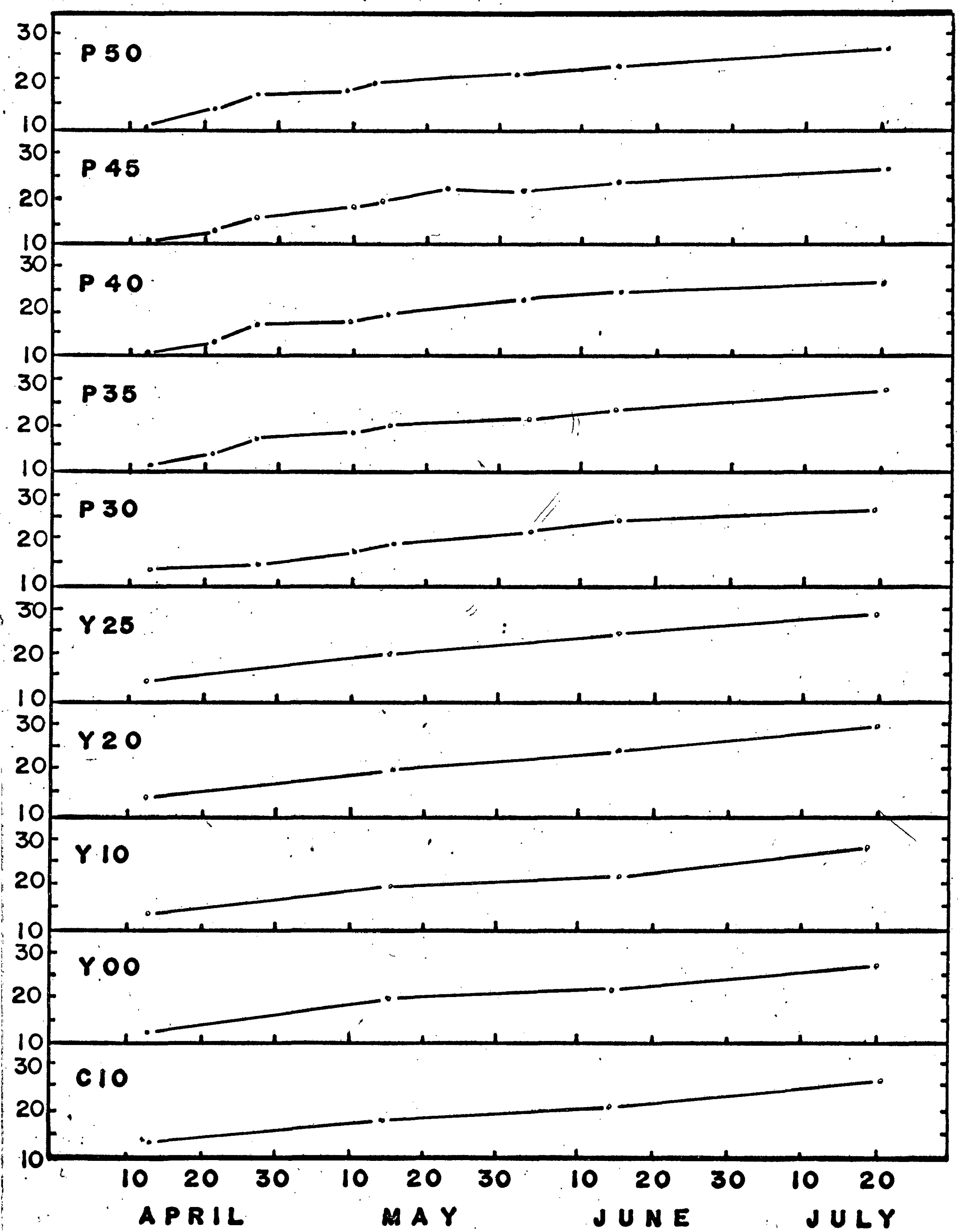
	April			May		June		July
	13	21	27	10	16	3	15	20
Prolarvae								
P30	0	-	0	2.4	0	0	0	0
P35	4.8	0	202.4	0	0	0	0	0
P40	509.1	0	608.5	0	0	0	0	0
P45	0	0	49.9	0	-	0	0	-
P48	-	0	0	0	0	-	-	-
CTW	-	-	-	43.6	-	-	-	-
P50	593.1	5.2	0	-	0	0	0	0
P53	49.7	-	61.3	0	0	-	-	-
P55	-	1.2	0	2.4	0	0	0	0
P60	-	2.1	9.7	0	0	0	-	-
Larvae								
P30	0	-	0	0	0	21.8	0	0
P35	0	0	0	5.3	3.2	110.9	42.2	2.6
P40	0	0	0	15.8	112.8	133.3	465.9	0
P45	0	0	617.8	35.6	-	282.5	0	-
P48	-	0	0	33.3	628.0	-	-	-
CTW	-	-	-	42.2	-	-	-	-
P50	0	0	87.0	-	1468.8	19.1	23.7	0
P53	0	-	227.0	329.6	121.6	-	-	-
P55	-	0	19.8	39.6	14.5	15.2	13.2	0
P60	-	0	0	0	2.6	8.9	-	-
Mean larval length (mm)			7.1	5.5	6.2	11.0	19.0	

FIGURE 2

Temperature Observations at Each Station

Surface Temperatures, °C on Figure

Bottom Temperatures, °C on Overlay


P 50
P 45
P 40
P 35
P 30
Y 25
Y 20
Y 10
Y 00
C 10
30
20
10
10 20 30 10 20 30 10 20 30 10 20
APRIL
MAY
JUNE
JULY

prolarvae were observed on the bottom on April 27 indicating that these were recently hatched. Mansueti (1958) reported newly hatched fish settling to the bottom "despite swimming efforts". These data indicate that spawning was initiated during the latter part of April and the first part of May, possibly from April 24 (±2 days) through May 13 (±2 days).

The larval nursery area for this species appears to be essentially the same as the spawning area. A nursery is that particular area which is suited to nourish, protect, and foster the early stages of a given species. The nursery for larval striped bass is the area above P30. No larvae were taken below that point. Larvae were found from P30 to P60 during May and June (Table 1). Concentrations were significantly greater at P35, P40 and P50 in May, but only at P35 and P40 in June.

Striped bass young remained in the spawning area throughout larval development, but as juveniles they appeared further downstream. Beach seine samples were taken periodically at Gloucester Point (Y05) and a single striped bass, 34 mm fork length, was collected June 13. Two weeks later 5 specimens averaging 45 mm fork length were taken. A large sample was obtained on July 8 (48 mm mean fork length) at P35 in a beach seine collection (Table 3).

TABLE 3

SEMI-BALLOON TRAWL AND BEACH SEINE COLLECTIONS
SHOWING CATCH IN NUMBERS AND MEAN FORK LENGTHS OF JUVENILES

Date	P40		P35		P30	P28	Y25	Y17	Y05
1966	Trawl	Seine	Trawl	Seine	Trawl	Seine	Trawl	Seine	Seine
Morone saxatilis									
June 13	-	-	-	-	-	-	-	-	1 34mm
June 29	-	0	-	0	-	0	-	0	5 45mm
July 8	-	-	-	81 48mm	-	-	-	-	-
July 20-21	2 38mm	-	43 55mm	-	4 56mm	4 54mm	0	0	-
August 17	0	0	0	0	0	1 85mm	1 131mm	1 60mm	7 89mm
September 1	0	-	0	-	0	-	0	-	-
October 4	-	-	-	-	-	-	-	-	1 133mm
Morone americanus									
June 13	-	-	-	-	-	-	-	-	0
June 29	-	0	-	0	-	0	-	0	0
July 8	-	-	-	0	-	-	-	-	-
July 20-21	54 46mm	-	36 50mm	-	0	4 47mm	0	0	-
August 17	0	0	0	27 49mm	0	0	0	0	0
September 1	0	-	0	-	6 76mm	-	0	-	-
October 4	-	-	-	-	-	-	-	-	0

<u>White Perch</u>

White perch eggs are dense and adhesive. They settle to the bottom adhering to themselves and to fixed objects in the water (Mansueti, 1964). The spawning area should then be easily located with bottom grabs; but no evidence of eggs was discovered due to late or inadequate sampling of the bottom and shoreline vegetation. Therefore it was necessary to estimate spawning locations based on concentrations of prolarvae (Table 2). Heaviest concentrations of prolarvae were located at P40 and P50. These prolarvae were judged to be less than 3 days old based on their stage of development and ambient temperatures.

Prolarvae were collected during the first sampling period of April 13. Assuming a maximum of 3 days for egg development and 4 days for prolarval development, the spawning of these individuals took place, at the earliest, during the first week in April. Another concentration of prolarvae was collected on the 27th of April. These were probably spawned in late April. A few prolarvae were also taken in early May. Spawning of the white perch therefore occurred throughout April with spawning peaks of equal intensity (X^2=0.64) early and late in the month.

The nursery area for white perch larvae was the same as the general spawning area. Concentrations of white perch larvae in May were one order of magnitude greater at P50 than in the lower or upper river areas. By June larvae had moved downriver and concentrations were greatest from P35 to P45. Although there was a general downstream drift of larvae, the nursery area was essentially the same as the spawning area; from P30 to P60 with heaviest concentrations at P40-P50.

White perch juveniles were not taken below West Point (P28) with seine or trawl. They stayed above P30 in shallow water near shore and in the channel, as evidenced by beach seine and trawl collections. Large samples of juvenile white perch, 45-50 mm in length were taken at P35 and P40 in July and August (Table 3).

II. Hydrography of the study area

Spring and early summer runoff in 1966 was below the 25 year mean (1942-1966) (Table 4). Mean estimates of tidal excursion and net flow at P35 were based on single tidal cycle sections of 24-hour velocity profiles (Van Engel and Joseph, 1968). The mean net surface flow was 2.8 miles on the ebb each tidal cycle and the mean net bottom flow was 0.6 miles on the ebb.

Maximum surface ebb and flood current velocities exceeded maximum bottom current velocities. The bottom layer shifted from ebb to flood about ½ hour before the surface layer, but both layers shifted to ebb about the same time (Figure 3; from Van Engel and Joseph, 1968).

At P53 in April, during a 12-hour velocity profile, the lengths of time for ebb and flood, surface and bottom were about the same (Figure 4). Tidal excursion was 3.5

TABLE 4

25-YEAR MONTHLY RECORD OF AVERAGE DAILY DISCHARGE IN SECOND-FEET ON THE PAMUNKEY RIVER NEAR HANOVER, VIRGINIA (U. S. Coast and Geodetic Survey)

Year	April	May	June	July
1942	720	335	281	639
1943	1,126	787	375	363
1944	1,359	547	260	271
1945	828	907	395	2,697
1946	1,269	2,570	758	1,076
1947	1,074	642	419	407
1948	2,743	1,953	692	315
1949	1,335	1,297	659	1,568
1950	855	1,504	630	531
1951	1,550	764	1,272	330
1952	2,169	1,509	501	340
1953	1,738	956	579	183
1954	787	734	230	143
1955	938	428	441	319
1956	953	364	328	875
1957	1,541	474	387	91
1958	2,304	1,375	607	358
1959	1,624	437	502	555
1960	2,285	1,015	498	216
1961	2,089	1,849	789	442
1962	2,141	1,051	1,022	582
1963	694	416	830	123
1964	1,091	602	254	241
1965	1,001	474	365	295
1966	535	751	242	101
Mean	1,390	950	533	525
Minimum	535	335	230	91
Maximum	2,743	2,570	1,272	2,697

FIGURE 3

Typical 24-Hour Station Data at P35

(May 17-18, 1966)

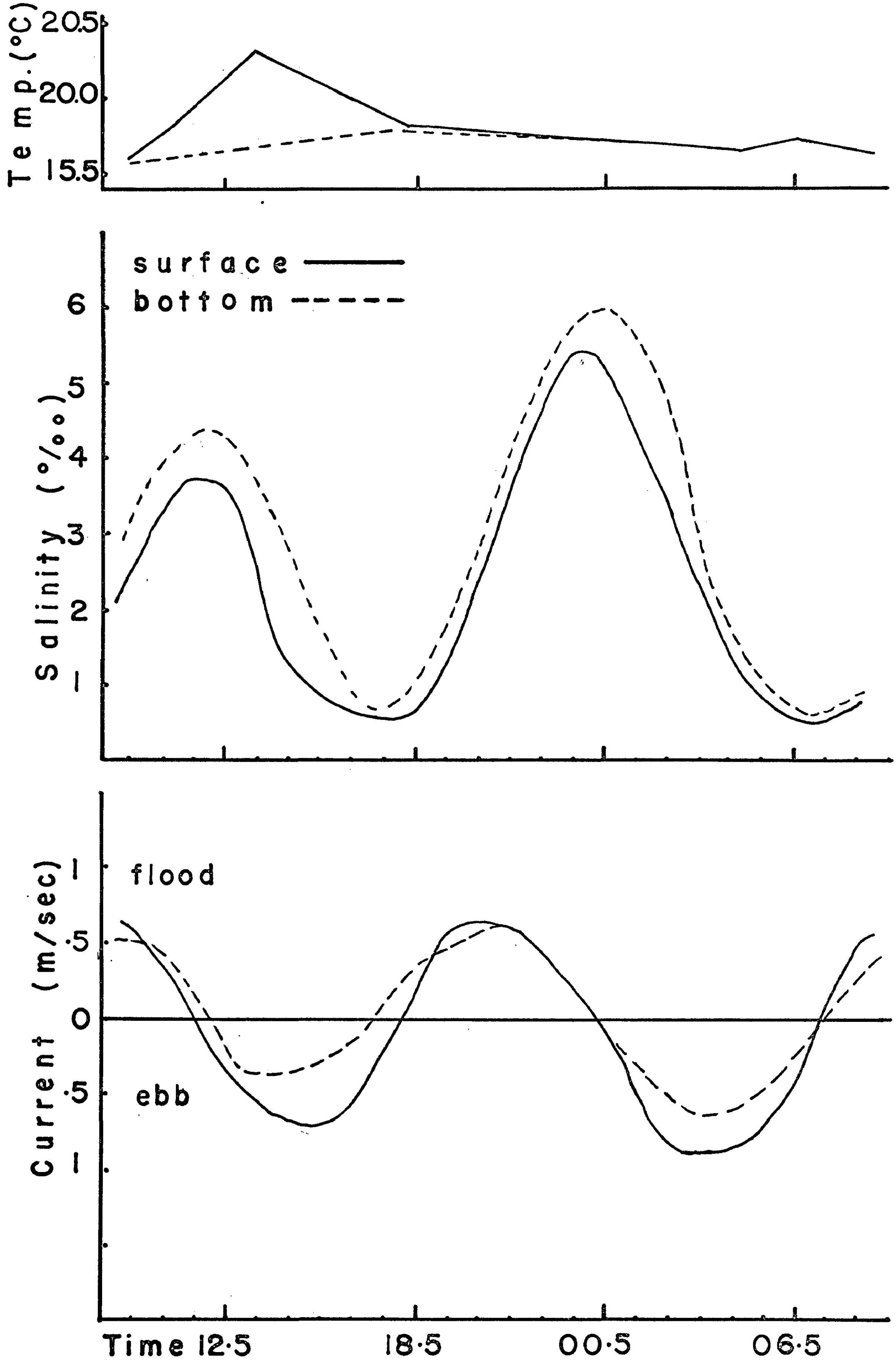
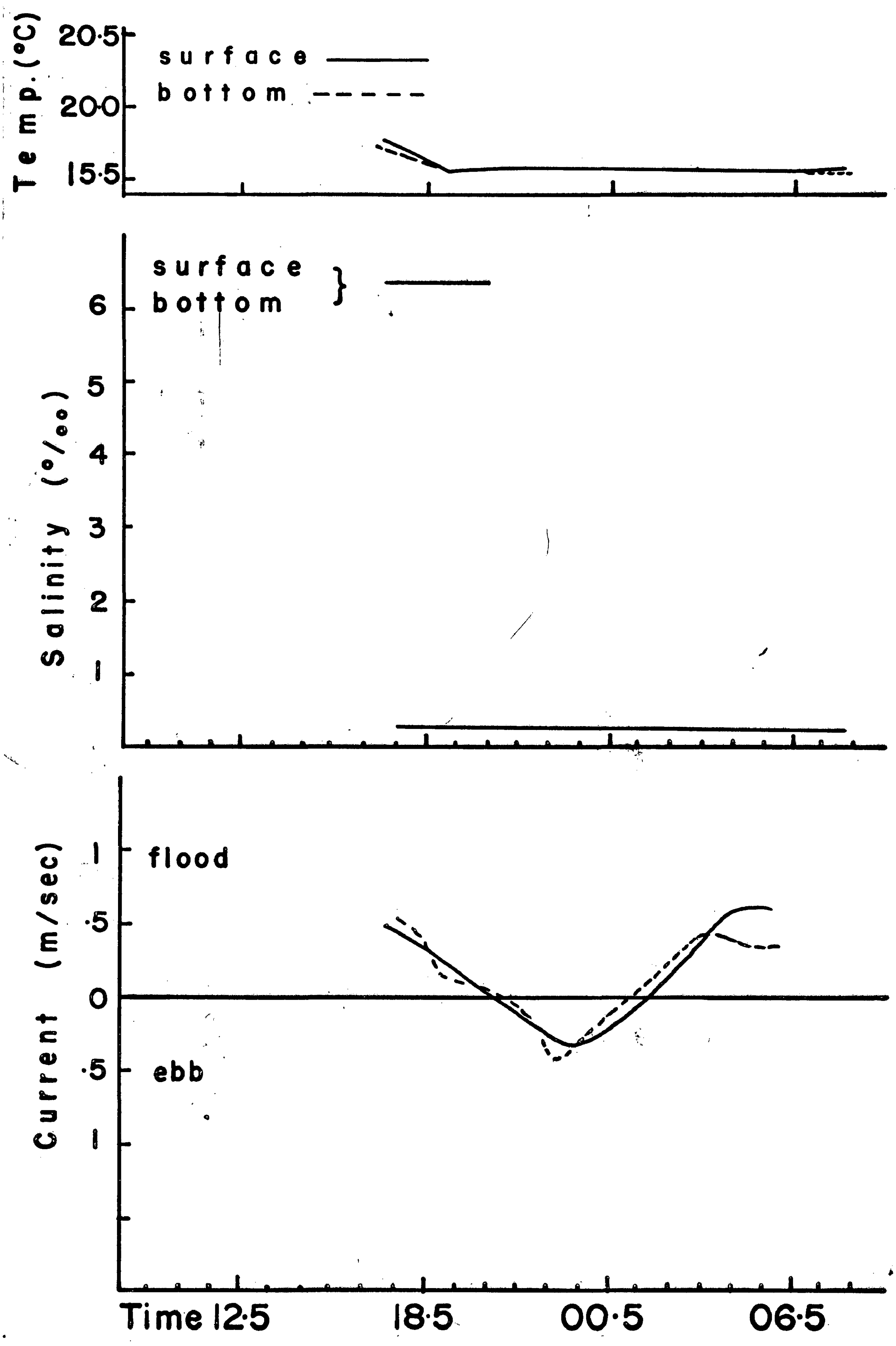

Temp.(°C)
20.5
20.0
15.5
surface
bottom
Salinity (°/oo)
6
5
4
3
2
1
Current (m/sec)
1
flood
·5
0
·5
ebb
1
Time 12·5
18·5
00·5
06·5

FIGURE 4

12-Hour Station Data at P53

(April 28, 1966)


Temp. (°C)
20·5
20·0
15·5
surface
bottom
Salinity (°/oo)
6
5
4
3
2
1
surface
bottom
Current (m/sec)
1
·5
0
·5
1
flood
ebb
Time 12·5
18·5
00·5
06·5

miles ebb and 3.3 miles flood. Surface excursion was 4.3 miles ebb and 4.0 miles flood. Maximum velocity was 0.5 meters per second for both ebb and flood.

Salinity at P35 was dependent upon tide and runoff with mean values near 5 o/oo in April and 3 o/oo in May and June (Table 5). Mean salinities rose to 7 o/oo in July, reflecting the lower runoff. Highest salinities in the Pamunkey were recorded at P30 during high slack water. Salinities from P40 to P60 remained less than 3.5 o/oo. P50 can be defined as the approximate upper limit of the York-Pamunkey estuary. Mean salinity there for the year 1966 was 0.2 o/oo, with lowest salinities occurring in late winter and early spring. Twelve-year quarterly and monthly salinity profiles for the York-Pamunkey system are shown in Figures 5 and 6.

Water temperatures in mid-April from P30 to P53 ranged from 12.3 to 10.5 C, the cooler temperatures being recorded upriver. Water temperature rose steadily to 16 C in late April and to 25 C in mid-June. Bottom water temperatures remained as much as 3 C below surface temperatures. From late April on, temperatures were higher in the upstream portion of the sampling area. Twelve-year quarterly and monthly temperature profiles for the York-Pamunkey system are shown in Figures 2 and 6. Bottom waters in May and June were 2-3 C cooler than average, and at near record lows for the 12-year period.

TABLE 5

HYDROGRAPHIC SUMMARY FOR 24-HOUR STATIONS, P35

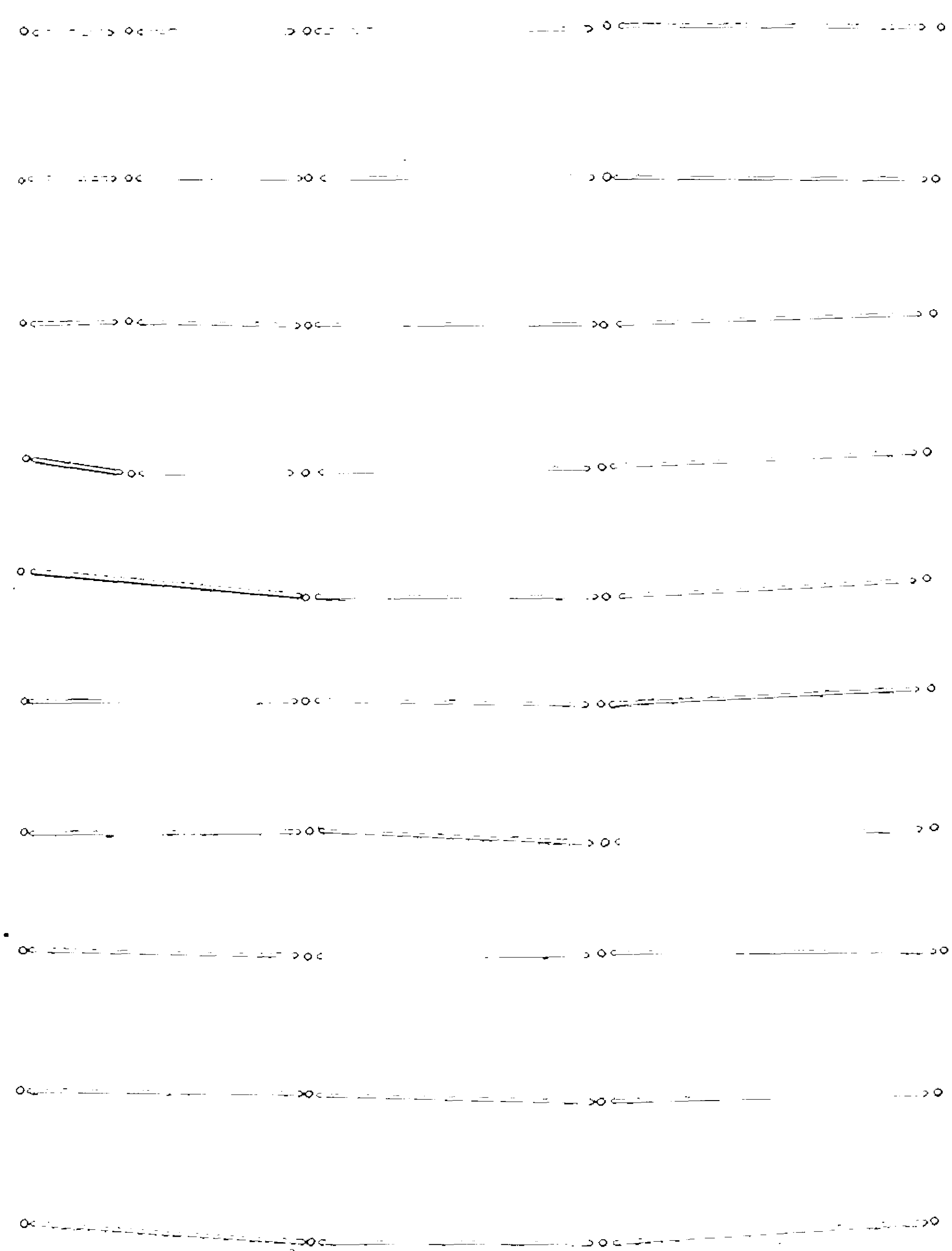
Date	Depth	Temperature °C		Salinity ‰		Dissolved O_2 mg/liter	
		Mean	Range	Mean	Range	Mean	Range
April 1966	Surface	11.3	10.5-12.0	4.08	1.83-7.23	7.4	6.6-8.2
	Bottom	11.2	10.8-11.5	4.89	2.32-8.15	7.4	6.8-8.1
May 1966	Surface	19.0	18.3-21.7	2.27	0.50-5.31	7.3	6.3-8.4
	Bottom	18.6	18.2-19.0	2.90	0.58-5.74	7.0	6.3-8.0
June 1966	Surface	24.4	23.2-25.0	2.56	0.47-5.68	5.8	5.0-6.7
	Bottom	24.4	23.7-25.0	2.92	0.62-5.89	5.7	4.9-6.8
July 1966	Surface	28.1	27.3-28.8	6.23	3.12-9.78	4.3	2.8-5.7
	Bottom	28.1	27.2-28.5	6.86	3.44-10.36	4.1	2.7-5.1

FIGURE 5

Salinity Observations at Each Station

Surface Salinities, o/oo on Figure

Bottom Salinities, o/oo on Overlay



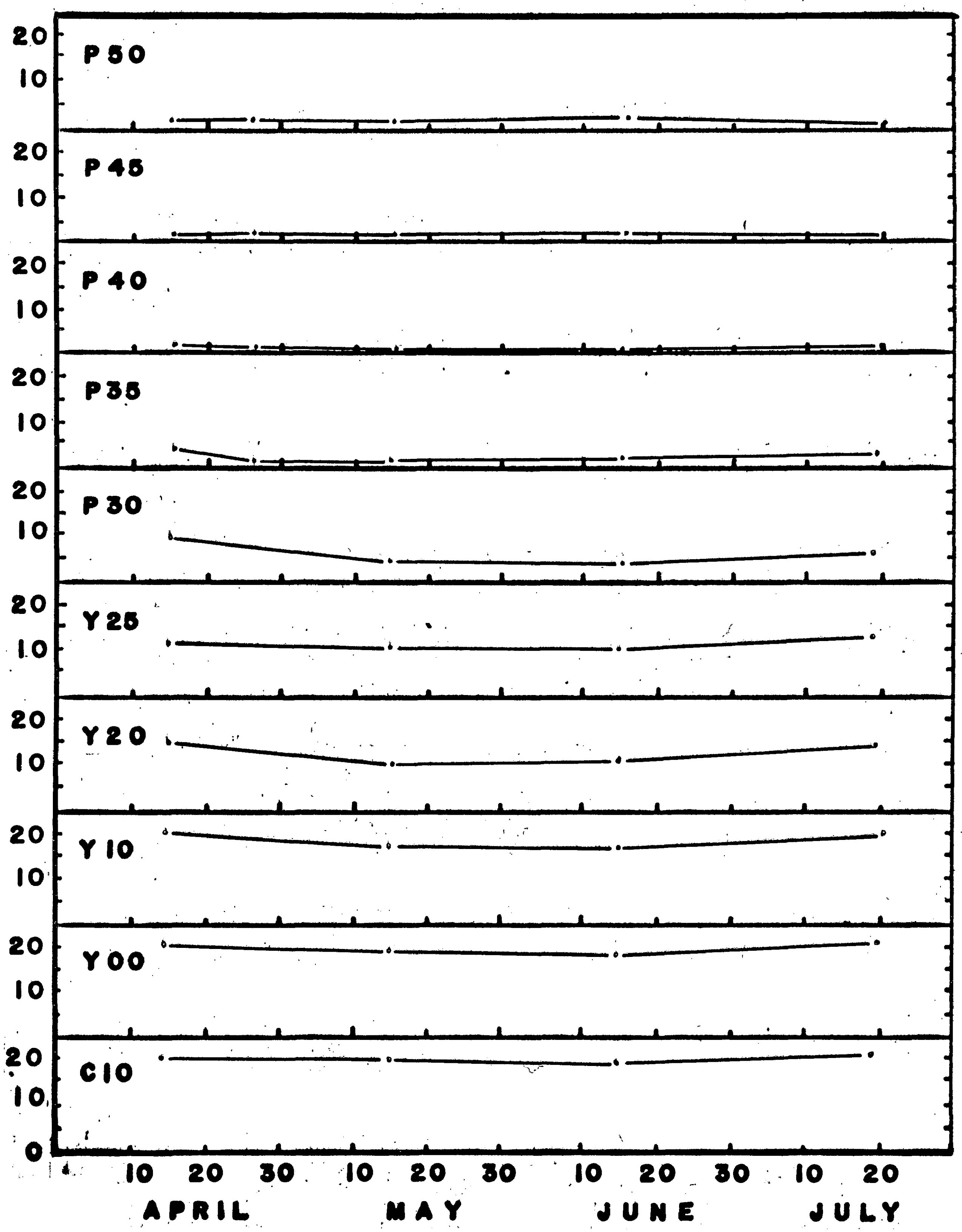

P50
P45
P40
P35
P30
Y25
Y20
Y10
Y00
C10
0
10
20
30
10
20
30
10
20
30
10
20
APRIL
MAY
JUNE
JULY

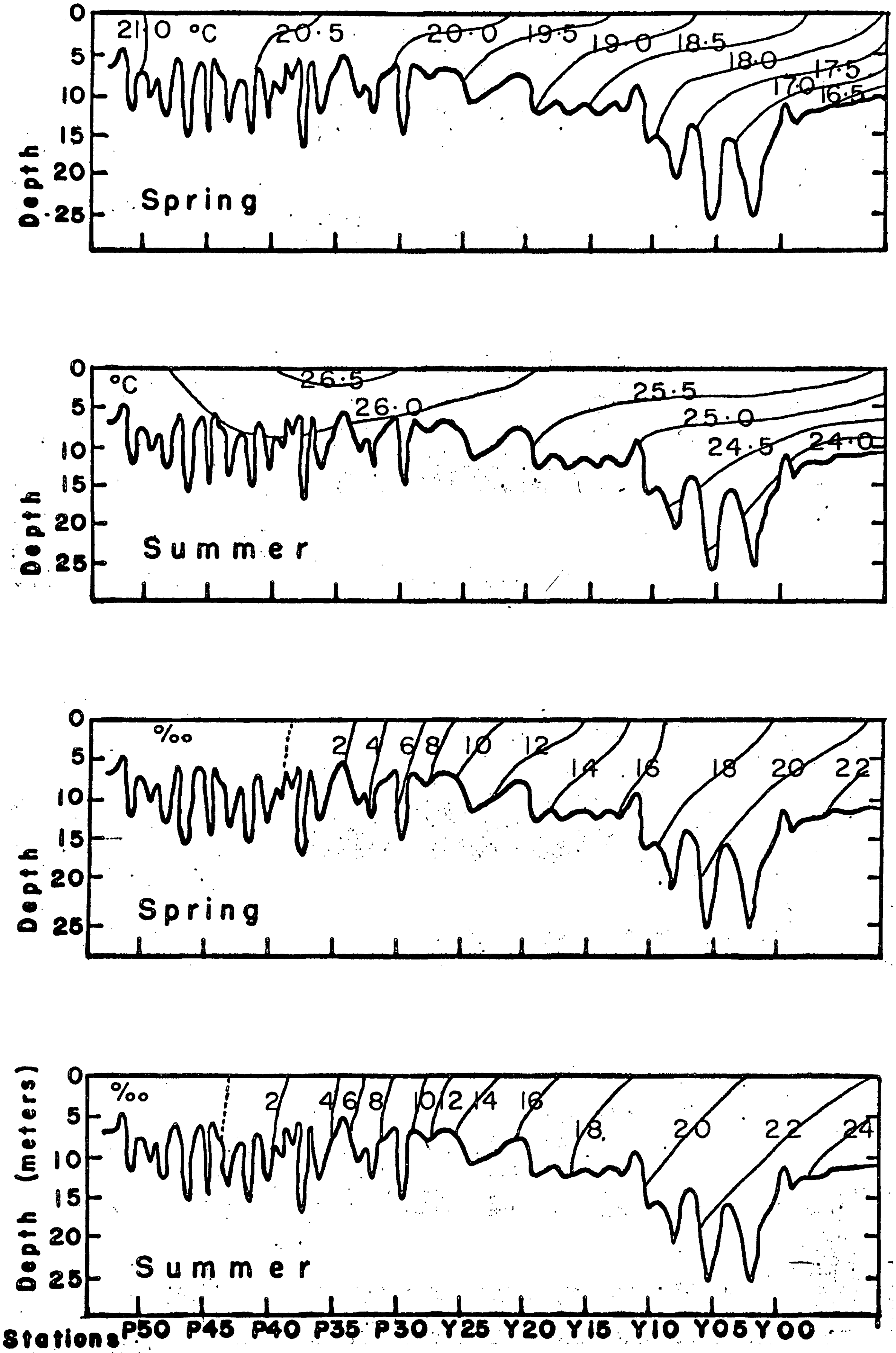
FIGURE 6

Spring and Summer Profiles

of Temperature ^{o}C and

Salinity o/oo

(after Van Engel and Joseph, 1968)



0
5
10
15
20
25
Depth
21·0 °C
20·5
20·0
19·5
19·0
18·5
18·0
17·5
17·0
16·5
Spring
°C
26·5
26·0
25·5
25·0
24·5
24·0
Summer
‰
2
4
6
8
10
12
14
16
18
20
22
24
Depth (meters)
Stations
P50
P45
P40
P35
P30
Y25
Y20
Y15
Y10
Y05
Y00

Profiles of quarterly mean dissolved oxygen, expressed in mg/liter and percent saturation, for the year 1966 are shown in Figure 7. Minimum dissolved oxygen, 4.6 mg/liter, and minimum percent saturation, 60% occurred in summer between P30 and P35 in the nursery area. Stations in the lower York River, and at P50 were near 100% saturation thoughout the year. Lowest values for the entire river in April, May and June occurred during slack after flood. Highest values occurred at slack after ebb.

Light penetration, as determined by Secchi disk readings, was least in the middle nursery area, P30-P45. Secchi disk disappearance depth from April through July was less than ½ meter from P30 to P53, and less than 1 meter at P53 to P60.

River width increased between Hill and Sweet Hall marshes (P40) and Cousaic and Cohoke marshes (P45). The current slows there because of the increased cross-sectional area of the river.

III. Hydrography relative to striped bass and white perch early development.

Striped bass

Greatest concentrations of striped bass eggs were in water with temperatures ranging from 16 C to 19 C. This is the range referred to as optimum by Talbot (1966) and agrees with spawning conditions described by Farley (1966).

FIGURE 7

Spring and Summer Profiles of

Dissolved Oxygen Concentration, mg/liter

and Percent Saturation

(after Van Engel and Joseph, 1968)

Farley studied spawning in the San Joaquin Delta, and reported that bass swam upriver until water temperatures reached 15.6 C, at which time they commenced spawning.

Water temperature increased rapidly from April 13 to April 27, at which time it became more stable, but increased steadily through May. This constant temperature increase assured spawning and eliminated the possibility of a cessation due to a sudden temperature drop, as reported by Mansueti and Hollis (1963).

Tresselt (1950) reported striped bass spawning in the Pamunkey River, although he collected only a few eggs. The only location at which he captured eggs was Island Reach, which is about one mile below the confluence of the main channel and Cumberland Thorofare (about P48). I converted data obtained from his stationary nets to an equivalent of the data presented in this paper and derived concentrations of only 1.5 eggs / 1000 m^3. Temperature during April 6-13, 1950, ranged from 13.0 to 13.6 C; salinities were reported as 0.5 to 1.2 o/oo. The difference in egg abundance from 1950 to 1966 is probably a reflection of temperature being at suboptimal or optimal levels at the time of sample collection in the two years. Tresselt collected large concentrations of eggs in the adjacent Mattaponi River a week later when the temperature was 16 C.

Striped bass spawning temperatures have been reported by many investigators. Talbot (1966), in summarizing these reports, states that the number of eggs collected diminishes greatly or to zero when temperatures drop below 14.4 C. Eggs (3.5/1000m^3) and prolarvae (2.4/1000m^3) were collected at P40 on April 14 at 10.4 C. This represents twice the concentration reported by Tresselt at 13.0-13.6 C. Although spawned and hatched at these low temperatures these individuals may not have survived to contribute to the population.

All striped bass eggs were collected at salinities below 1.5 o/oo. Salinity does not seem to be as critical as temperature in the determination of spawning grounds. Albrecht (1964) reported salinities of 4.6 o/oo and greater were detrimental to striped bass eggs under laboratory conditions. Above P35 salinities were below this concentration. No eggs were taken downstream from P35.

Current plays an important part in striped bass streams. Merriman (1941) characterizes spawning rivers as large, swift flowing streams. In the York-Pamunkey, tidal action creates the flow necessary for egg suspension; observe the velocities at ebb and flood during the P35 24-hour station (Figure 3). Spring runoff creates a flow though marshland supplying fresh water and creating increased productivity. Van Engel and Joseph (1968) point to this as a two layered system creating a zone of entrapment about P35, where tidal action meets net downstream flow. Above this, at P40 there is a greater cross-sectional river area through which the river flows more slowly.

This area of reduced flow often contained the greatest concentrations of early stages of both species. Net flow on both surface and bottom was downstream (Table 6). Simple calculations will show that two weeks is sufficient time for current to carry neritic organisms out of the sample area. Although the slower flow through the P40 area would not be sufficient to retain the eggs and larvae, it would undoubtedly retard downstream drift. Emery and Stevenson (1957) state that larvae are not lost in the net downstream flow because of factors opposing the dispersing effect of turbulence. The "factors" of course vary with the organism involved. I was unable to correlate distribution to any special factors, other than the availability of more larvae at slack before flood and early flood stages of the tide (Table 7). The larvae of both species were absent from side creeks and thorofares, and apparently remained in the main channel above P30 until they had transformed into juveniles. Perhaps this area of low net flow is important to larval development. More research is needed to investigate this idea in greater detail.

Striped bass larvae apparently utilize the area above P35 as a nursery ground and move downstream when they reach the juvenile stage into the higher salinity area. The presence of all larvae in salinities of 2.1 o/oo or less indicate salinity might be a determining factor for a suitable larval nursery area. A separate nursery area in the York River may

TABLE 6

TIDAL EXCURSION AND NET TRANSPORT, IN MILES, AT P35, PAMUNKEY RIVER, VIRGINIA, 1966 (after Van Engel and Joseph, 1968)

	Surface			Bottom		
	Flood	Ebb	Net	Flood	Ebb	Net
April	4.1	7.0	-2.9*	4.4	4.7	-0.3
May	6.0	8.9	-2.9	5.2	6.6	-1.4
June	6.9	9.4	-2.5	5.4	5.6	-0.2
Mean	5.7	8.4	-2.8	5.0	5.6	-0.6

*Negative numbers indicate transport downstream

TABLE 7

NUMBER OF TIMES LARVAE APPEARED IN SAMPLES TAKEN AT VARIOUS STAGES OF THE TIDE

Month	Tide	Stage	No. of times *Morone saxatilis* collected: Surface	No. of times *Morone saxatilis* collected: Bottom	Total number of stations sampled	No. of times *Morone americanus* collected: Surface	No. of times *Morone americanus* collected: Bottom
	Flood	Slack	2	2	2	2	2
		Early	2	0	2	2	2
April		Maximum	0	0	5	3	4
		Late	0	0	3	1	1
	Ebb	Slack	0	1	2	1	1
		Early	0	0	2	0	1
		Maximum	1	1	3	2	1
		Late	-	-	0	-	-
	Flood	Slack	2	4	4	4	4
		Early	0	1	2	1	2
May		Maximum	1	2	4	2	2
		Late	0	1	3	1	1
	Ebb	Slack	-	-	0	-	-
		Early	-	-	0	-	-
		Maximum	1	1	2	1	1
		Late	3	4	7	2	5
	Flood	Slack	2	5	7	3	7
		Early	0	0	2	0	1
June		Maximum	0	1	2	0	1
		Late	0	1	2	0	2
	Ebb	Slack	0	0	1	0	0
		Early	0	0	1	0	0
		Maximum	-	-	0	-	-
		Late	-	-	0	-	-

exist for juvenile striped bass that remain in the river during the first winter (Van Engel and Joseph, 1968). No transformed bass were taken at P35 or above in June when salinities were 3 o/oo, but a large sample was collected in July when salinities were higher (5-8 o/oo). This one sample indicates the presence of juveniles in higher salinity water, hence further downstream than the larvae.

White perch

Mansueti (1963) reported white perch spawning at 10-15 C and stated that spawning takes place over a week or more. These are essentially the findings of this study: 11-16 C were the temperatures at peak spawnings. This is in agreement with Bigelow and Schroeder (1953) and Thoits (1958). Spawning began in early April and continued into late April.

Spawning was concentrated at P40, where optimum conditions prevail for striped bass, and P50, which is similar to P40 in some respects. The current at P50 slows because a portion of the water mass moving downstream from P55 to P49 goes through Cumberland Thorofare (Figure 1). There is an expanse of marshland above and below P50 which could supply the nutrient base for developing larvae.

The salinity at P40 and P50 is 1.5 o/oo or less. Mansueti (1964) collected early prolarvae in slightly brackish water and stated that prolarvae can apparently survive salinities up to 8 o/oo before transformation.

Prolarvae and larvae are more dependent upon the current than are juveniles. The largest concentration of these early stages was at P40 and P50. In this area of the river at the bottom, it would take a week to transport a water mass, hence the prolarvae or larvae, one mile downstream. More individuals were found on the bottom than in the surface in these areas. This was consistant with findings at other stations. Juveniles on the other hand are able to escape the net, and can apparently move freely within the nursery area. White perch remain in the low salinity area above P35 as young juveniles. Numbers of juveniles above and below P35 were significantly different (X^2=51.5).

IV. Comparison of physical and biological factors for nursery stages of white perch and striped bass.

Hydrographic and biological data were collected simultaneously in an attempt to explain distribution and movement of the various developmental stages in terms of physical and biological conditions. Analysis of temperature, salinity, growth and food did yield some definite relationships.

Hydrography

Temperature may be a critical factor for spawning of striped bass and white perch. Both species have different optimum ranges, but spawning for both was initiated at temperatures about 10 C and continued through 17-19 C.

Although small concentrations of striped bass eggs and larvae were present in cool water (10-11 C) peak spawning occurred at 16-19 C for striped bass. White perch spawning peak occurred between 11-15 C. Distribution in relation to temperature reflects the progressive temperature increase throughout the season. Because of the time factor, later stages of development were invariably collected in warmer water. Once the fish had attained larval stages the river had almost a uniform temperature.

Salinities at which both species spawn are low (0.0 - 1.5 o/oo) but fresh water does not appear to be required. Each successive developmental stage of striped bass was collected in slightly higher salinity water, but white perch for the most part seemed to maintain themselves in salinities below 3 o/oo (Figure 8).

Early striped bass stages were collected in areas of low salinity. All striped bass eggs were collected in water of salinities less than 1.5 o/oo. All larvae were taken from areas of 2.1 o/oo or less. Juveniles were taken downstream in much higher salinities (about 17 o/oo), but all juveniles smaller than 30 mm were collected in water having salinities of 4.5 o/oo or less.

White perch larvae were taken in areas where salinities were less than 1.5 o/oo except for a single sample collected in May at P30. Most juveniles were also taken in low salinity waters (less than 3 o/oo) although a few scattered samples were collected in higher salinity water (Figure 8).

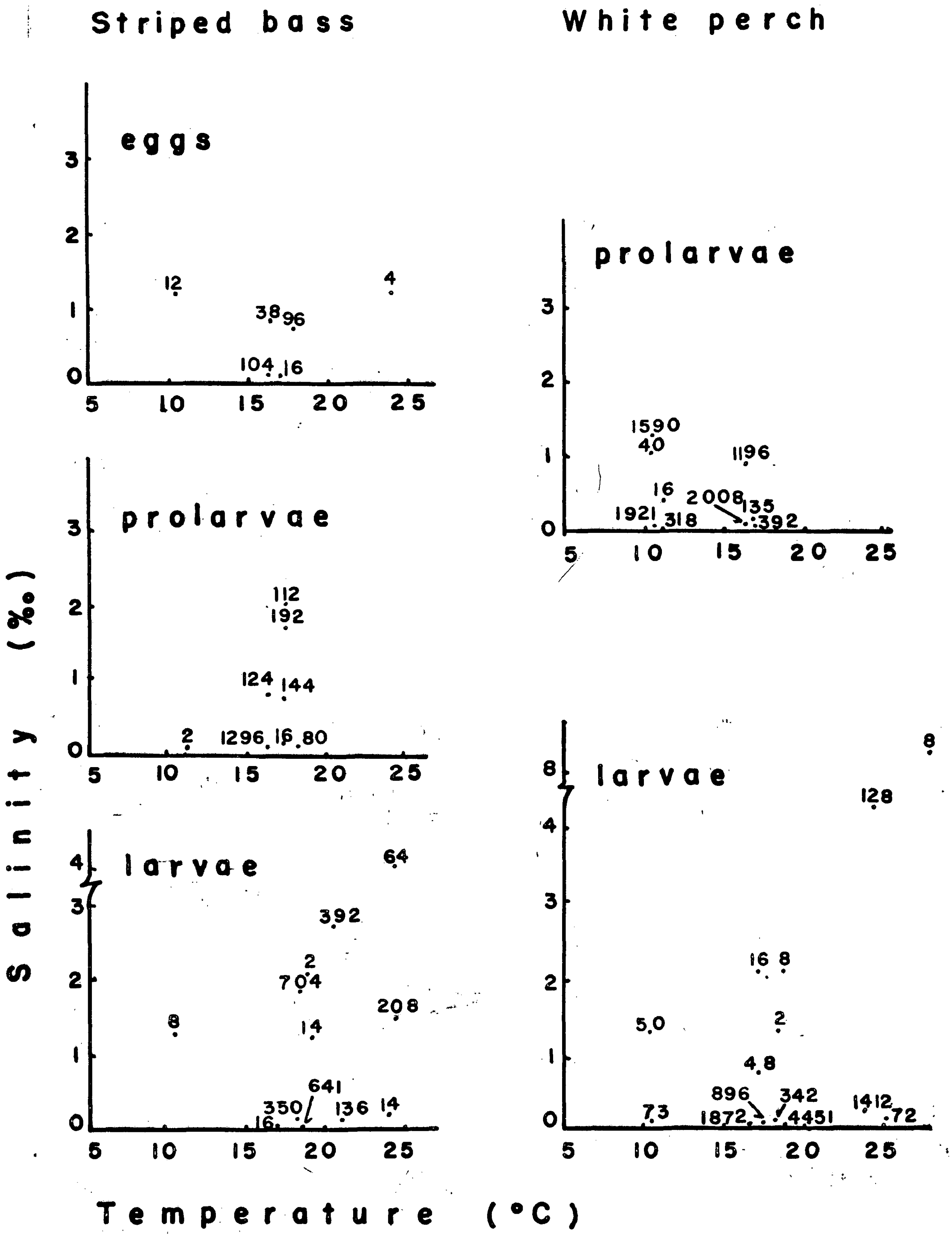
White perch began spawning 1-2 weeks earlier than striped bass but the peak spawning period for each species was little more than a week apart. White perch spawning terminated first. Essentially the same spawning area was used, P35 through P60, and neither species appeared to use the tributary creeks or thorofares. Both species spawned in fresh or slightly brackish water but at different temperatures, white perch in cooler water, 9-16 C, and striped bass in warmer waters, 16-19 C.

Both species remained on the nursery grounds above P35 until they reached a length of 20-30 mm. Striped bass then began to move downstream into the high salinity nursery grounds (10-17 o/oo), while the white perch remained in fresh to brackish water (0-7 o/oo).

Four times as many white perch as striped bass were obtained in the sum of all plankton collections. This represents a real difference in abundance, (X^2=75.2) but not necessarily in this proportion. Although patchy distribution of ichthyoplankton may cause a sampling bias, it is slight because the sampling area is limited by the absence of early stages below P30 and in tributary creeks. The presence of early stages in Cumberland Thorofare can be attributed to the large size of the thorofare and the tidal current, which could bring early stages in on the ebb or flood tide. Samples taken of eggs, prolarvae and

FIGURE 8

Abundance Diagrams for White Perch and Striped Bass at Each Stage



Striped bass
White perch
eggs
prolarvae
larvae
prolarvae
larvae
Salinity (‰)
Temperature (°C)

larvae are probably representative of their true numerical proportions but juveniles of both species could apparently escape the meter net, since few juveniles were taken compared to the number of larvae available for transformation.

Merriman (1941) reported a significant correlation between striped bass year class success and below normal water temperatures on the Atlantic Coast. Tiller (1950) found exception to this in the 1942 and 1943 year classes of upper Chesapeake Bay. Raney (1952) suggested a closer look at chemical, physical, and biological factors which might influence the success or failure of a year class. Hydrographic observations are important if causes of successful year classes are to be discovered. The present study was of only 1-year duration and therefore could produce little direct information on year class success. However, there are a few points that can be made as a result of this study. Recent tagging studies at VIMS indicate the 1966 striped bass year class was relatively successful. It was produced in a year when runoff was extremely low, and temperatures were below normal in the York River. Trent (1961) reported a complete failure of the 1958 year class in Albermarle Sound, N. C., while other investigators report it to be one of great magnitude (Shearer, Ritchie and Frisbie, 1962 and Mansueti and Hollis, 1963) in Chesapeake Bay. I think the importance of locally collected data over a period of years is therein obvious.

Talbot (1966) reports that greatest production of striped bass is generally in streams with large volumes of flowing water. But in Chesapeake Bay successful runs are maintained in streams with low average flows, where tidal action creates the large volumes of flowing water and spring runoff supplies the necessary fresh water. Since tidal action is relatively constant from year to year it seems logical that spring runoff may affect a particular year class. Farley (1966) concludes that the spawning population migrates further upriver in years of heavy runoff because the waters remain cool and the striped bass spawn later where temperatures were 14-15 C. In years of low runoff the 14-15 C temperature is reached early in the migration and spawning takes place early. But in an area like Chesapeake Bay low runoff and high temperatures do not necessarily go together, especially in years of below normal temperatures. Since early stages are at the mercy of the current, a successful year class would need adequate time to develop at ambient temperatures before leaving the area, which would afford the optimum conditions for growth and survival. In a tidal nursery area the net current should be slow enough to permit the larvae to develop before leaving the protected area. One alternative might be portions of the stream where the current slows enough to retard downstream transport of the eggs and larvae. In large swift flowing streams the spawning area would have to be a sufficient distance upstream to provide time for the transported eggs and larvae to develop before reaching the higher salinity estuary. An ample supply of zooplankters is also an important factor but it does not appear to be a limiting factor in the highly productive marsh area of the York-Pamunkey River System.

Many data were collected in an attempt to discover factors contributing to the success or failure of a year class. Therefore factors which I was unable to correlate with distribution and abundance may contribute to the general knowledge of both species early life history. Each stage of both species was analyzed with respect to oxygen concentrations, flow rates, pH, presence of other larvae, presence of zooplankton, shoreline type, and Secchi disk depth. In all cases there was no obvious direct correlation. Only salinity and temperature showed some limiting range of distribution, although unrelated to concentrations. An attempt was then made to convert these temperature and salinity findings into a density-related phenomenon, with no success in either surface or bottom waters. The amount of particulate organic detritus was unrelated to disk visibility and neither one showed a relationship to early stage abundance, even when consideration was also given to tidal stage.

Growth

Striped bass and white perch growth rates were essentially the same the first two months, then striped bass continued to grow rapidly while the white perch growth rate decreased. As larvae, both species followed an exponential growth curve:

$$l = ae^{rt}$$

where;

l = length in millimeters
a = length at hatching (in mm)
r = rate of growth
t = time in days (age)

<u>Morone</u> <u>saxatilis</u> --- $l = 3.30\ e^{.027\ t}$

<u>Morone</u> <u>americanus</u> -- $l = 2.75\ e^{.028\ t}$

(Figure 9)

This relationship broke down when both species reached early juvenile stages at about 70-80 days. No relationship was found which would include both larvae and juveniles.

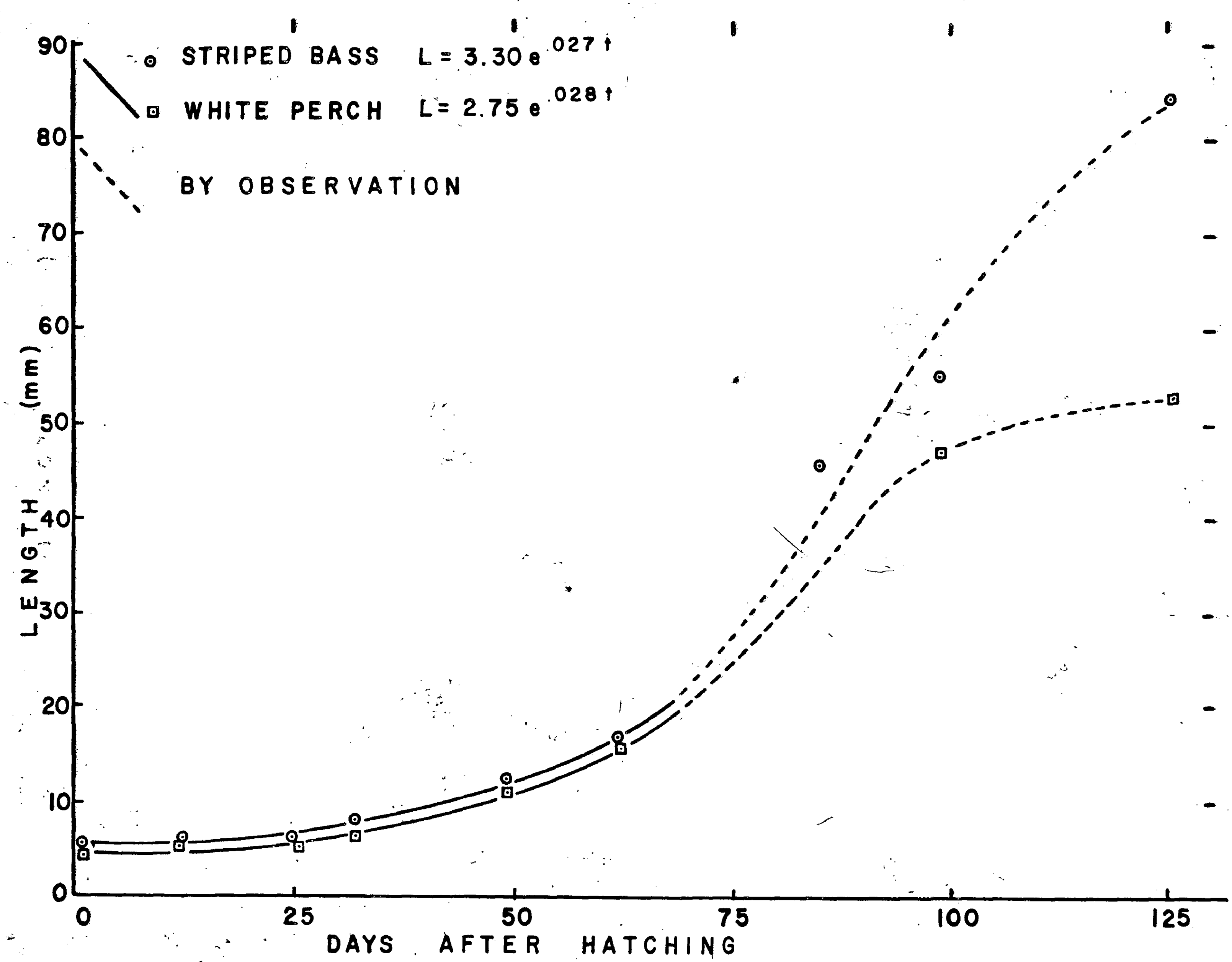
Growth was calculated from 5,589 striped bass length measurements and 22,774 white perch length measurements. Mean size and standard deviations were calculated for each sample date and the growth curve was fitted to these data.

It has been established (above) that striped bass move out of the upper nursery area as they become juveniles, while white perch remain in the area. The difference in growth slightly precedes this change in habitat.

Striped bass mortality was greater than white perch mortality for the same period of time. Instantaneous rate of mortality for the period April 27 to June 15 was 0.396 in striped bass and 0.177 in white perch. Mortality was

FIGURE 9

Growth of White Perch and Striped Bass


STRIPED BASS L = 3.30 e .027 t
WHITE PERCH L = 2.75 e .028 t
BY OBSERVATION
LENGTH (mm)
90
80
70
60
50
40
30
20
10
0
0
25
50
75
100
125
DAYS AFTER HATCHING

calculated for this period from larval and juvenile mean concentrations. Sample sizes were inadequate to calculate mortality for shorter periods.

Gulland (1965) states that natural mortality can be gauged by growth patterns. Species which have a rapid growth rate have a higher natural mortality. This is useful information in determining if a species will have a dominant natural mortality or fishing mortality. It is not surprising then to find that striped bass mortality is greater than white perch mortality for the larval and early juvenile period. These differences in growth and mortality provide a plausible explanation for differences in adult population abundance of these two species.

Feeding habits

The stomachs of 176 striped bass larvae and 228 white perch larvae were examined. Only seven striped bass stomachs and three white perch stomachs were empty, indicating that the smaller stages do not gorge and fast as has been described for larger individuals of striped bass (Merriman 1941). Food items were generally mixed within a stomach, so that few individual stomachs contained a single food type. This is not shown in Table 8 because stomachs were examined in length-frequency groups from each sub-sample. There was a notable change in food preference between fish less than 12 mm length and fish of more than 12 mm length (X^2 = 70.8). Stomachs of both species contained

TABLE 8

PERCENTAGE COMPOSITION OF GUT CONTENTS*

Organism	P30-P45		P48-P60		Total	
	< 12mm	≥ 12mm	< 12mm	≥ 12mm	< 12mm	≥ 12mm
			Morone saxatilis			
Cladocerans	62.0	25.8	59.0	0	60.5	24.7
Copepods	31.0	58.0	13.5	71.5	21.5	58.5
Daphnids	0	2.0	0	0	0	1.9
Ostracods	0	0	21.6	0	11.6	0
Amphipods	0	6.8	0	0	0	6.5
Mysids	0	2.0	0	0	0	1.9
Fish	0	0.7	0	14.3	0	1.3
Crustacean Material	0.6	4.8	1.6	14.3	1.2	5.2
Unidentified	6.3	0	4.3	0	5.2	0
			Morone americanus			
Cladocerans	72.6	38.9	83.5	40.0	80.2	39.3
Copepods	26.6	60.3	16.2	14.7	19.2	53.3
Daphnids	0	0	0	0	0	0
Ostracods	0	0	0.3	15.3	o.3	6.3
Amphipods	0	0.8	0	0	0	4.8
Mysids	0	0	0	0	0	0
Fish	0	0	0	0	0	0
Crustacean Material	0.7	0	0	0	0.3	0
Plant Material	0	+	+	0	+	+

* Grouped by size because of significant difference in gut contents above and below 12mm total length.

cladocerans, copepods, large daphnids, ostracods, amphipods, unidentifiable material. Some white perch stomachs contained semi-digested plant material, and some striped bass stomachs contained mysid shrimp and fish (Table 8). The major food items for both species were cladocerans and copepods.

Although both species consumed essentially the same food, striped bass 19 mm and larger became more diverse in their feeding habits. While amphipods, mysid shrimp, and fish appeared in the diet, copepods and cladocerans were still the primary source of food. The piscivorous nature of the striped bass was expressed very early. One 25 mm striped bass stomach contained an 8 mm alosid-like larvae.

Cladocerans, copepods, and small crustacean food items show similar relationships in both the upper (P49-P60) and lower (P30-P45) Pamunkey River samples. Other food organisms do not. Ostracods play a more important food role in the larvae of both species obtained upriver. Lower river samples contained amphipods, mysids, and fish in striped bass. White perch seem to be consistent in their preference for cladocerans, copepods, small crustaceans and ostracods, in both upper and lower river areas. Plankton samples indicate cladocerans, copepods and amphipods were the major zooplankters in the sample area. Cladocera were present in greater numbers in the plankton samples of the lower area, but were more abundant in white perch stomachs from the upper area (Table 9).

TABLE 9

ORGANISMS IN STOMACHS AND PLANKTON OF UPPER(ABOVE P45) AND LOWER(THROUGH P45) PAMUNKEY RIVER

Stations Fish Size	No. Fish Examined	Cladocerans	Copepods	Daphnids	Ostracods	Amphipods	Mysids	Fish	Crustacean Material	Unidentified	Plant Material
	Number of organisms in stomachs of *M. saxatilis*										
P35-P45											
< 12mm	62	98	49	0	0	0	0	0	1	10	
≥ 12mm	40	38	85	3	0	10	3	1	7	0	
P48-P60											
< 12mm	62	109	25	0	40	0	0	0	3	8	
≥ 12mm	4	0	5	0	0	0	0	1	1	0	
Total											
< 12mm	124	207	74	0	40	0	0	0	4	18	
≥ 12mm	44	38	90	3	0	10	3	2	8	0	
	Number of organisms in stomachs of *M. americanus*										
P35-P45											
< 12mm	64	98	36	0	0	0	0	0	1	0	0
≥ 12mm	14	47	73	0	0	1	0	0	0	0	+
P48-P60											
< 12mm	179	253	49	0	1	0	0	0	0	0	0
≥ 12mm	11	34	38	0	13	0	0	0	0	0	+
Total											
< 12mm	243	351	85	0	1	0	0	0	1	0	0
≥ 12mm	25	81	111	0	13	1	0	0	0	0	2+

No. of organisms in bottom meter net - 5 min. tows

P30-P40	Cladocerans	Copepods	Ostracods	Amphipods	Mysids
3 stations	98,624	2,336,145	0	51,046	297,136
P50					
1 station	28,264	48,544	70,272	1,024	0

In this study it was found that both species feed primarily on cladocerans and copepods. White perch and striped bass are very similar morphologically in the early stages of development. They are also quite similar ecologically, as the result of this investigation shows. Both species are distributed essentially in the same areas, and inhabit the same habitat. The adults spawn in the same sections of the river, and their spawning seasons overlap. There is also a great deal of similarity in their feeding niche, especially in the earliest stages up to 12 mm. The same four food items appear repeatedly in nearly the same proportions in stomachs of both species (X^2 = 4.6).

Basic differences in feeding changed for individuals of both species above 12 mm, when copepods become the major source of food. White perch continue to feed primarily on the same zooplankters, whereas striped bass above 19 mm began to diversify and feed on amphipods, mysid shrimp, and fish. Up to this size however, both species are so similar in habitat and niche that some competition might exist between the two species. This could easily become a critical factor if food items should become limited in any way. There is scant information available on the feeding habits of very early stages of Morone. The food items found to be ingested by white perch were consistent with those reported by Thoits (1958). Striped bass are reported to begin feeding on young-of-the-year striped bass and threadfin shad in their second summer (Stephens, 1966). The present study found fish remains in two of 176 stomachs examined. These are a year younger than Stephens reported, but represent a very small percentage of total food items.

SUMMARY AND CONCLUSIONS

1. Time and location of spawning and larval development in the York-Pamunkey River is presented for striped bass and white perch. Associated physical and biological data for spring 1966 is related to the early life history of both species.

2. Striped bass spawning area extended from 35 to 60 miles upriver from the mouth of the York and was centered at 40 miles upriver. Spawning occurred from April 24 through May 13.

White perch spawning area extended from 30 to 60 miles upriver from the mouth of the York and was centered at 40-50 miles upriver. Spawning occurred throughout the month of April.

3. Striped bass nursery area for prolarvae and larvae was essentially the same as the spawning area, with the center of concentration 40 miles upriver. As juveniles the bass moved downstream and were distributed from the mouth of the York to 40 miles upriver.

White perch nursery area was also essentially the same as the spawning area, for all early stages, as perch juveniles remained in the Pamunkey.

4. Abundance of white perch was four times that of striped bass from the early prolarval stages through transformation.

5. Water temperature during early April when white perch were spawning was 11-16 C. Striped bass spawned when temperatures reached 16 C. Throughout larval development water temperature steadily rose to 25 C.

6. Both species spawned in fresh water (<1.5 o/oo). Prolarvae of striped bass remained in areas where salinities were 2.1 o/oo or less and white perch prolarvae remained in areas where salinities were 1.5 o/oo or less. As larvae both species were still collected at these low salinity levels, although samples of both species were occasionally collected at slightly higher salinities.

7. Growth rates from hatching through the first two months of life were essentially the same. As transformed juveniles, striped bass began to grow more rapidly than transformed white perch.

8. Food items ingested by the larvae of both species are presented. Both species ingested the same items until they reached 12 mm total length, then striped bass feeding became more diverse. The piscivorous nature of the striped bass was expressed soon after transformation.

9. It is difficult to ascertain specific causal relationships for year class abundance in a single season study. I therefore suggest the following relationships as possible factors of year class success. Year class strength: white perch were four times as abundant as striped bass from early prolarval stages through transformation. At approximately 12 mm total length

feeding habits of striped bass changed more dramatically than those of white perch. Immediately following this change in feeding striped bass grew more rapidly. At this point the natural mortality of striped bass was greater than that of white perch. Striped bass juveniles moved further downriver, following the change in growth pattern, into the less protective higher salinity areas of the estuary. The 1966 year-class was produced in a year of low runoff, which might decrease the transport of early larval stages downriver toward the higher salinity areas of the estuary.

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