THE BIOLOGY OF THE WHITE PERCH, *MORONE AMERICANA*, IN THE HUDSON RIVER ESTUARY

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ABSTRACT

White perch, *Morone americana*, are found throughout a 250 km region in the Hudson River from Manhattan north to Albany, New York. They represent a dominant species in most portions of the river, although they are of little importance in the commercial fishery. Life history information was determined for more than 7,500 white perch collected from a 15 km region of the Hudson River between Haverstraw and Bear Mountain, New York.

Annulus formation began by the first week in May and was completed by the end of July. Maximum age for both male and female white perch was 7 years. Most of the growth occurred in the first 3 years for both males and females, and represented 78% of the length attained by the seventh year. Most fish were sexually mature by their second year. The length-weight relationship observed for Hudson River white perch was Log $W = -4.743 + 3.093$ Log L. The mean fecundity was 50,678 eggs per female, with a range of 15,726-161,449.

The white perch, *Morone americana* (Gmelin), inhabits rivers, bays, and estuaries of the Atlantic coast from Nova Scotia to South Carolina (Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Leim and Scott 1966). The species has been introduced to freshwater lakes and reservoirs through migration, stocking, and by being landlocked in impoundments (Bigelow and Schroeder 1953; Mansueti 1961; Woolcott 1962). White perch has been reported in Lake Ontario (Sheri and Power 1969), Lake Erie (Larsen 1954; Trautman 1957), and the waters of Quebec (Scott and Christie 1963; Leim and Scott 1966). Most recently it has been introduced into the waters of Nebraska (Hergenrader and Bliss 1971).

White perch is found throughout a 250 km region in the Hudson River from Manhattan north to Albany, N.Y. It represents a dominant species in most portions of the river (McFadden[2]), although it is of little importance in the commercial catch (Sheppard[3]). The species is particularly abundant in the Hudson River from Nyack north to Catskill, N.Y. (Perlmutter 1967).

With the exception of a fecundity study (Holsapple and Foster 1975), no life history information for white perch in the Hudson River has been published. Site-specific data for white perch populations are available in reports (Raytheon Co.[4]; Lawler, Matusky and Skelly Engineers[5, 6]; Texas Instruments Inc.[7]). The present study was carried out to investigate the life history of white perch in the Hudson River estuary over a 15 km section, from Haverstraw to Bear Mountain, N.Y. This section of the Hudson River is a very stressful environment owing to frequent changes in salinity: On an annual basis, the region experiences one to several transitions between limnetic and oligohaline conditions (Abood 1974). The white perch is one of the highly adaptable species that can tolerate these changes. Along with the hogchoker, *Trinectes maculatus*, it is a dominant year-round resident of this portion of the Hudson region.

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[2]McFadden, J. T. 1978. Influence of the proposed Cornwall pumped storage project and steam electric generating plants on the Hudson River Estuary with emphasis on striped bass and other fish populations. Rep. for Consolidated Edison Co. of N.Y., Inc., 1179 p.

[3]D. J. Sheppard, New York State Department of Environmental Conservation, 50 Wolfe Road, Albany, NY 12223, pers. commun. March 1980.

[4]Raytheon Co. 1971. Indian Point ecological survey report II, January-June 1970. Submarine Signal Div., Portsmouth, R.I., 165 p.

[5]Lawler, Matusky and Skelly Engineers. 1974. Hudson River aquatic ecology studies at Roseton and Danskammer Point. Vol. III. Fish. Rep. to Central Hudson Gas and Electric Corp., N.Y., 114 p.

[6]Lawler, Matusky and Skelly Engineers. 1974. Hudson River aquatic ecology studies—Bowline Point and Lovett Generating Stations. Vol. IV, 445 p.

[7]Texas Instruments Inc. 1974. Hudson River ecological study in the area of Indian Point. 1973 Annu. Rep. to Consolidated Edison Co. of N.Y., Inc., 426 p.

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MATERIALS AND METHODS

We collected white perch at seven beach seining stations, nine trawling areas, and one experimental mesh gill net location between Haverstraw and Bear Mountain, N.Y., on the Hudson River from April through November 1970 (Fig. 1). Beach seine collections were made with a 30.4 m by 2.4 m seine (9.5 mm square mesh) or a 15.2 m by 1.5 m seine (6.5 mm square mesh), each with a central bag of 6.5 mm square mesh. The large seine was set from shore with the aid of a boat and retrieved in a semicircle. The 15.2 m seine was handhauled by pulling the seine parallel to the shore in water ~1.2 m deep. The large seine was fished in water ~2.4 m deep.

Bottom and surface trawls were made with a 7.6 m semiballon trawl, constructed with a 38.1 mm stretch mesh nylon body, with a 31.8 mm stretch mesh nylon cod end rigged with an inner liner of 6.5 mm stretch mesh nylon. Trawl doors were 1.1 m in length and 0.46 m in width. Tow

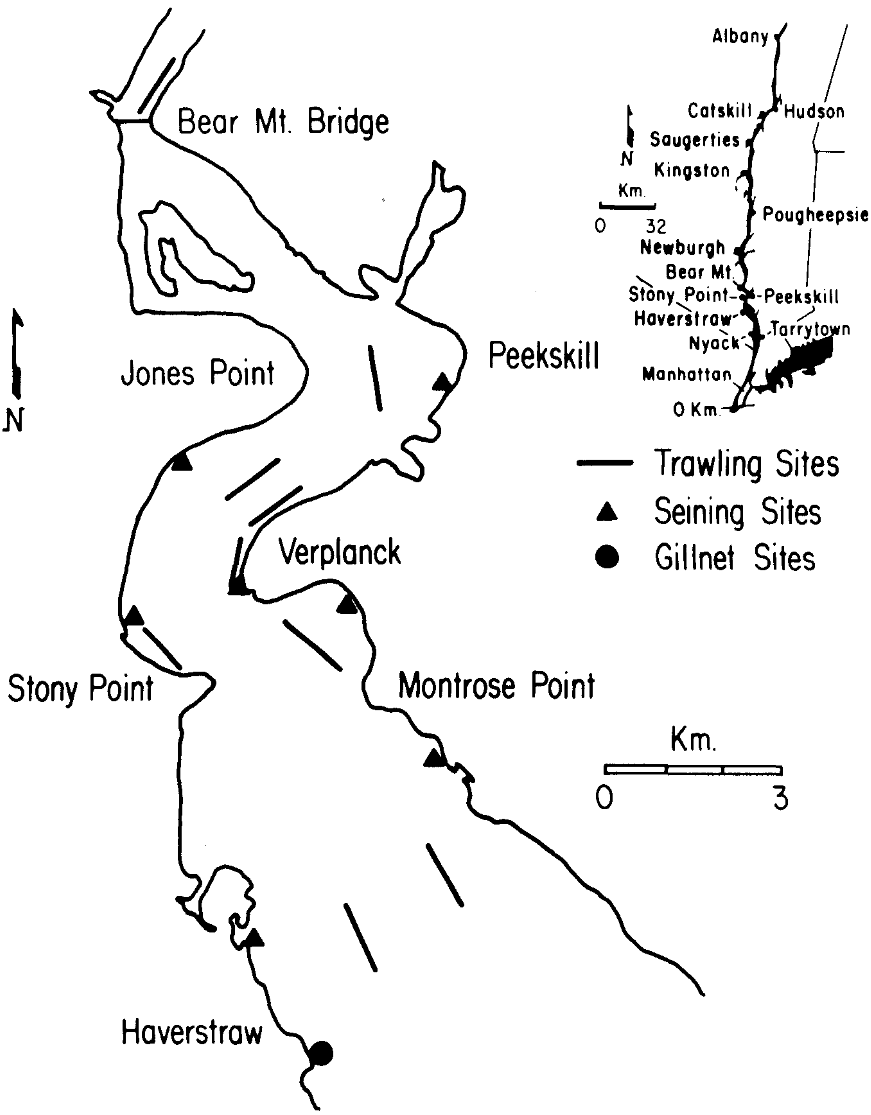

FIGURE 1.—Region of Hudson River from which white perch were collected.

speed for trawling was about 3.4 km/h. Details of the towing procedure are described in Bath et al. (1979).

The gill net was an experimental type with four panels of varying mesh size. The net measured 30.4 m by 1.8 m and contained 7.6 m each of 12.7, 25.4, 38.1, and 76.2 mm stretch mesh monofilament line. It was hung from 9.5 mm braided, polycore float line, with a bottom lead-coreline.

All fish collected at each site were immediately labeled and preserved in 10% Formalin[8] and returned to the laboratory for analysis. Each fish was measured (standard length (SL)) to the nearest millimeter, weighed to the nearest 0.1 g, and the sex was determined. A subsample of 310 fish was measured for fork length (FL) and total length (TL) to determine regression equations for comparison of Hudson River white perch populations with data from other river systems. Mature ovaries and testes were removed from selected individuals, weighed, and preserved in 10% Formalin. The ovaries were later transferred to Gilson's fluid for fecundity analysis (Ricker 1968). Stomachs were removed from randomly selected fish and preserved in 10% Formalin for later food analysis. Scales for age analysis were removed from behind the left pectoral fin (Rounsefell and Everhart 1953), cleaned, pressed, and sealed between glass microscope slides. The scales were read within 6 mo of the collection date.

[8]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

RESULTS

Time of Annulus Formation

Annulus formation began by the first week in May and was completed in all age groups by the end of July (Table 1). Younger fish (age groups 1 and 2) completed the annulus by the end of June.

TABLE 1.—Percentage of aged white perch, *Morone americana*, with a new annulus and with a given number of circuli beyond the new annulus during a given period.

Date collected	Age (winters of life)	No. spec.	Percent with new annulus	Percent with noted no. of circuli beyond new annulus					
				0	1-2	3-4	5-6	7-8	>8
May 22-June 2 (incl.)	1	11	73	64	9	0	0	0	0
	2	36	50	50	0	0	0	0	0
	3	36	39	39	0	0	0	0	0
	4	14	29	29	0	0	0	0	0
	5	14	0	0	0	0	0	0	0
	>5	31	0	0	0	0	0	0	0
June 9-June 16 (incl.)	1	7	100	14	14	29	14	29	0
	2	20	70	45	15	10	0	0	0
	3	17	47	41	0	6	0	0	0
	4	14	43	22	14	7	0	0	0
	5	13	39	31	8	0	0	0	0
	>5	21	0	0	0	0	0	0	0
June 19-June 30 (incl.)	1	5	100	0	0	0	40	20	40
	2	7	100	29	14	57	0	0	0
	3	8	50	50	0	0	0	0	0
	>3	9	33	33	0	0	0	0	0
July 1-July 17 (incl.)	1	3	100	0	0	0	0	0	100
	2	8	100	0	25	13	50	13	0
	3	17	88	24	35	29	0	0	0
	4 or 5	6	83	67	16	0	0	0	0
	>5	5	20	0	0	0	0	0	0
July 24-July 30	1	4	100	0	0	0	0	0	100
	2	10	100	0	0	0	20	20	60
	3 or 4	7	100	43	57	0	0	0	0
	>4	2	100	100	0	0	0	0	0
Aug. 1-Aug. 15	1	10	100	0	0	0	0	0	100
	2	21	100	0	0	0	10	14	76
	3	9	100	0	11	33	33	11	11
	4 or 5	12	100	8	17	58	17	0	0
	>5	2	100	50	50	0	0	0	0
Aug. 17-Aug. 31	1	15	100	0	0	0	0	0	100
	2	4	100	0	0	0	25	0	75
	3	6	100	0	0	17	50	0	33
	>3	6	100	0	17	67	17	0	0
Sept.-Oct.	1	15	100	0	0	0	0	0	100
	2	5	100	0	0	0	0	0	100
	3	6	100	0	0	0	17	17	67
	>3	2	100	0	0	0	100	0	0

White perch of age groups 3 and older completed the annulus ~2 wk later.

Length-Frequency and Age Distribution

During May and June, there were three modes in the length-frequency data, with peaks at 65.0-69.0, 105.0-109.0, and 140.0-144.0 mm (Figs. 2, 3). These peaks represent the 1-, 2-, and 3-yr age groups. From July to November the length frequencies ranged from 10.0-14.0 mm to 200.0-204.0 mm (Fig. 4). The prominent mode at 50.0-54.0 mm represents young-of-the-year fish (Fig. 5).

Growth

The relationship between anterior scale radius and standard length for white perch from all age groups was $L = 32.64 + 45.56\,(R)$, where L = standard length in millimeters and R = scale radius in millimeters. The coefficient of determination (r^2) was 0.88 (Fig. 6).

The standard lengths at the various annuli were back-calculated and the growth histories were constructed for each year class, along with growth increments for each age group (Tables 2, 3). The most rapid growth occurred in the first 3 yr of life, and accounted for 78.0% of the total growth at the maximum size observed. Subsequent average growth increments were uniform among year classes, but considerably smaller (Fig. 7). Similar growth histories were compiled for each year class for both male and female white perch (Tables 4-7). Females grew slightly larger in TL than males of the same age (Fig. 8).

Length Conversions

We calculated the relationship between total length, fork length, and standard length measurements taken on a subsample of 310 white perch, ranging in size from 30.0 mm to 182.0 mm SL. A linear regression was computed to obtain conversions between the three methods so that we could compare growth rates among the different white perch studies. (Fig. 6). The relationship between total length and standard length was $SL = -1.05 + 0.81\,TL$, $r^2 = 1.0$; the relationship between fork length and standard length was $SL = -0.99 + 0.86\,FL$, $r^2 = 1.0$.

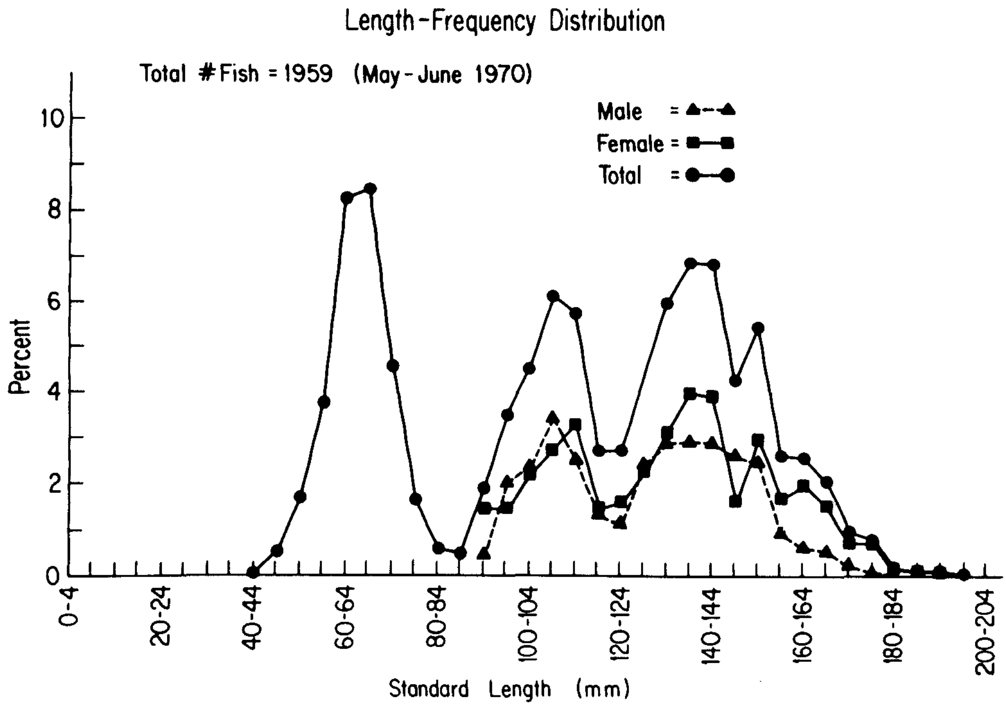

FIGURE 2.—Length-frequency distribution of white perch during May and June 1970, and for mature males and females during this same period.

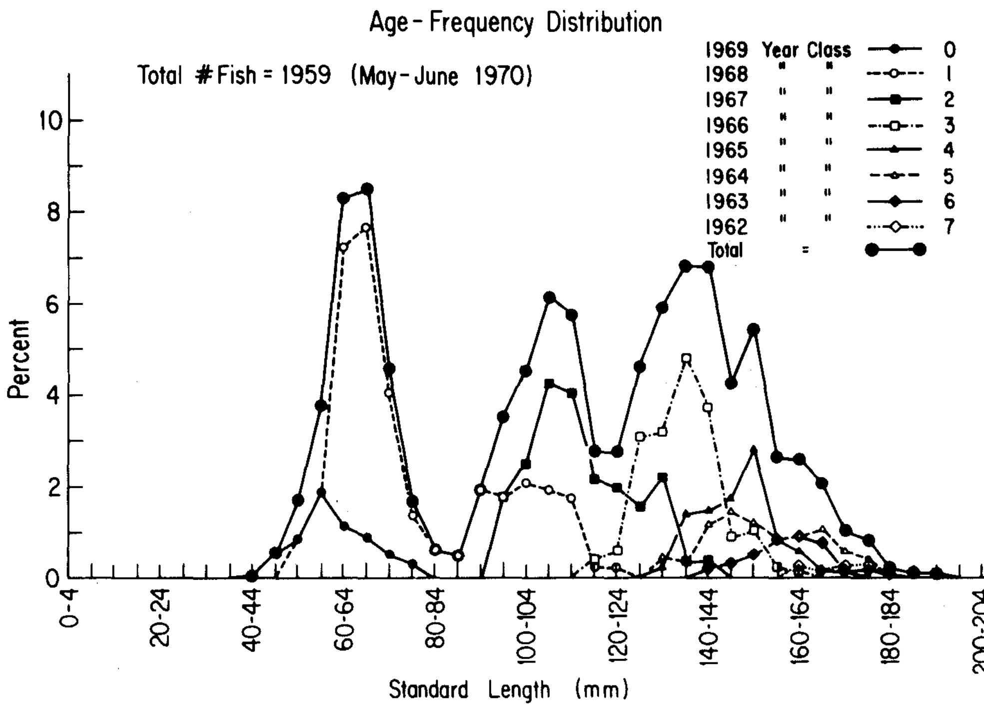

FIGURE 3.—Age-frequency distribution of white perch during May and June 1970.

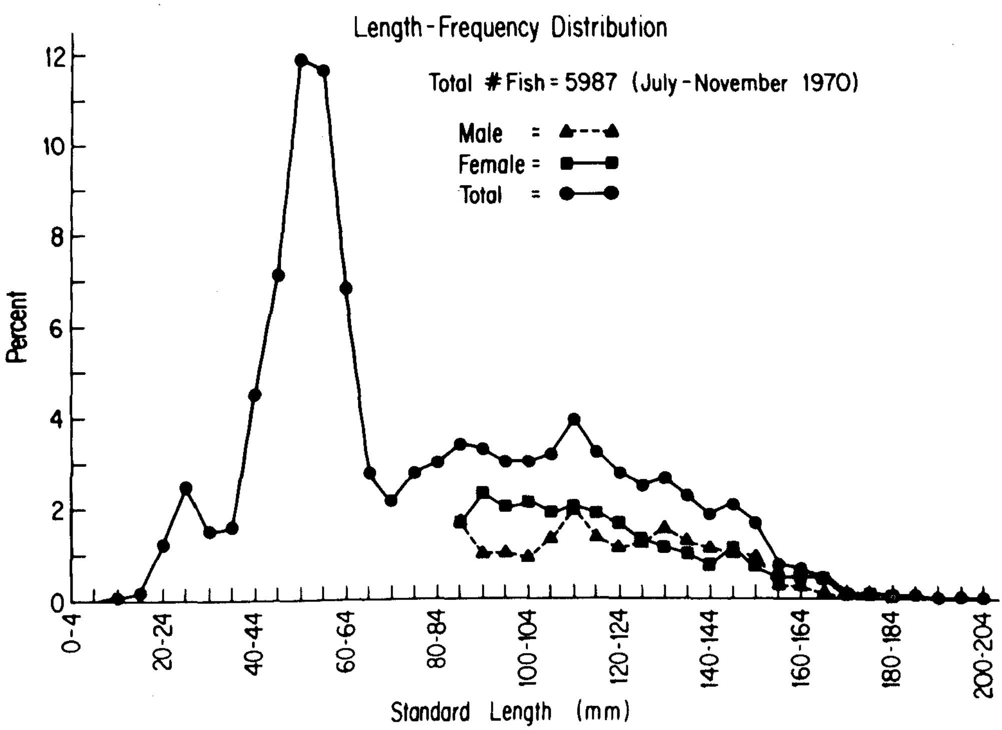

FIGURE 4.—Length-frequency distribution of white perch during July to November 1970, and for mature males and females during this same period.

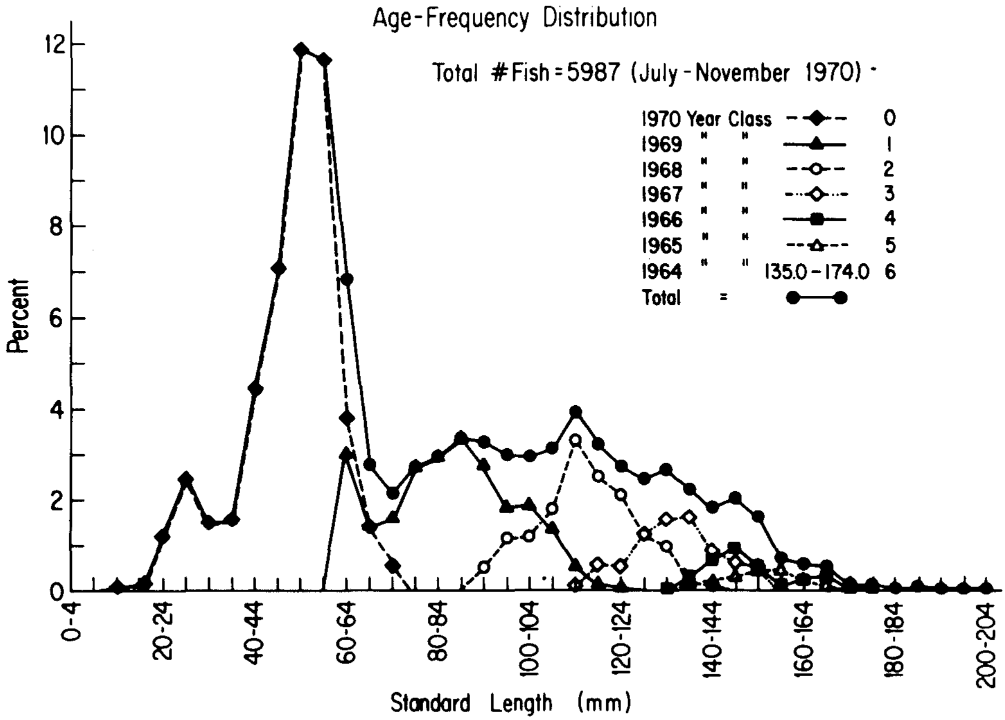

FIGURE 5.—Age-frequency distribution of white perch during July to November 1970.

TABLE 2.—Calculated growth of white perch in the Hudson River between Haverstraw and Bear Mountain, N.Y. (sexes combined), 1963-69.

Year class	No.	Calculated standard length (mm) at end of year 1	2	3	4	5	6	7
1963	12	69.2	119.2	150.1	164.2	176.2	185.9	194.1
1964	36	71.9	122.6	150.8	164.2	174.9	184.5	
1965	68	68.9	119.2	148.4	164.2	177.7		
1966	85	70.2	121.6	150.6	167.6			
1967	139	69.4	123.5	153.9				
1968	219	71.7	126.6					
1969	243	80.1						
Weighted mean		73.4	123.8	151.5	165.6	176.6	184.8	194.1
Increment		73.4	50.4	27.7	14.1	11.0	8.2	9.3
Percent of total growth		37.8	26.0	14.2	7.2	5.6	4.2	4.8
No.		802.0	559.0	340.0	201.0	116.0	48.0	12.0

Length-Weight Relationship

The length-weight relationship for Hudson River white perch was calculated using the least squares method (Ricker 1968). The relationship for males was Log $W = -2.262 + 1.925$ Log L, $r^2 = 0.706$. For females, the relationship was Log $W = -4.738 + 3.099$ Log L, $r^2 = 0.965$. The combined male and female length-weight relationship was Log $W = -4.743 + 3.093$ Log L, $r^2 = 0.952$. The values of the exponents 1.925 and 3.099 indicate females were heavier than males of the same length ($F_{1,20} = 4.97$; $\alpha = <0.05$). Graphically expressed (Fig. 9), it can be seen that this occurred for females over 140.0 mm (age group 2+ and older) and can be related to fatness and gonad development (Le Cren 1951).

Reproduction

Sixty-five female white perch collected during May and June (115.0 to 187.5 mm SL) and representing age groups 2 to 7 were analyzed for fecundity. An exponential curve was fitted to

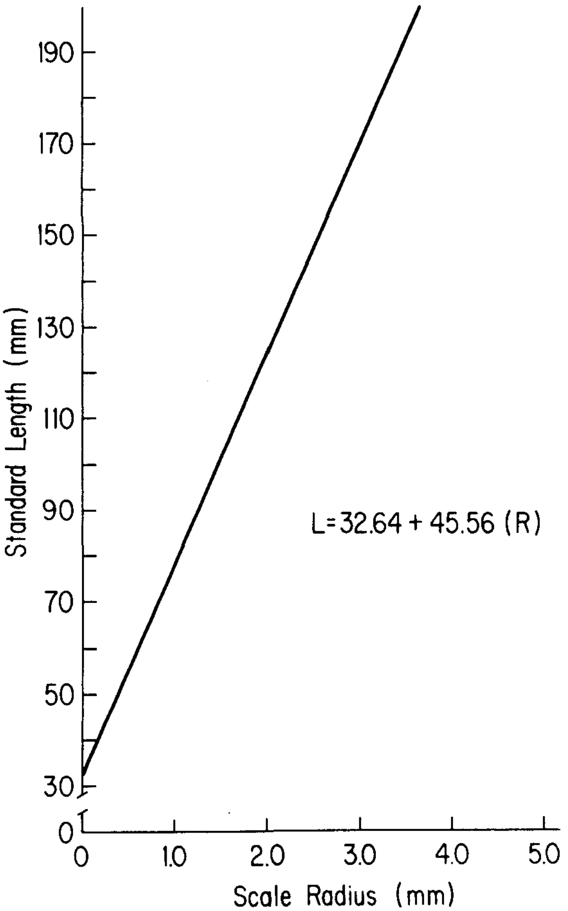

FIGURE 6.—Relationship between scale radius and standard length of white perch from the Hudson River between Nyack and Bear Mountain, N.Y. $r^2 = 0.88$.

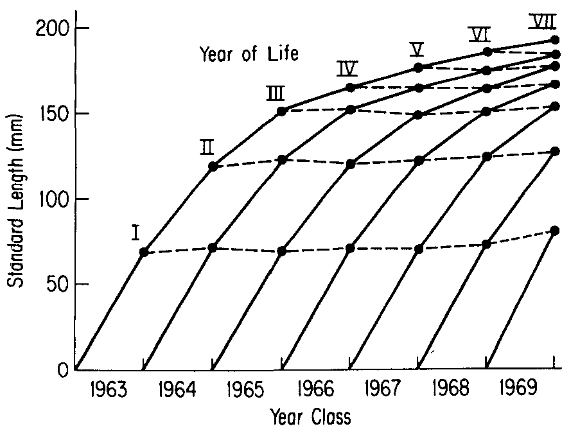

FIGURE 7.—Graphic representation of the growth histories of year classes of white perch from the Hudson River between Nyack and Bear Mountain, N.Y., 1963-69.

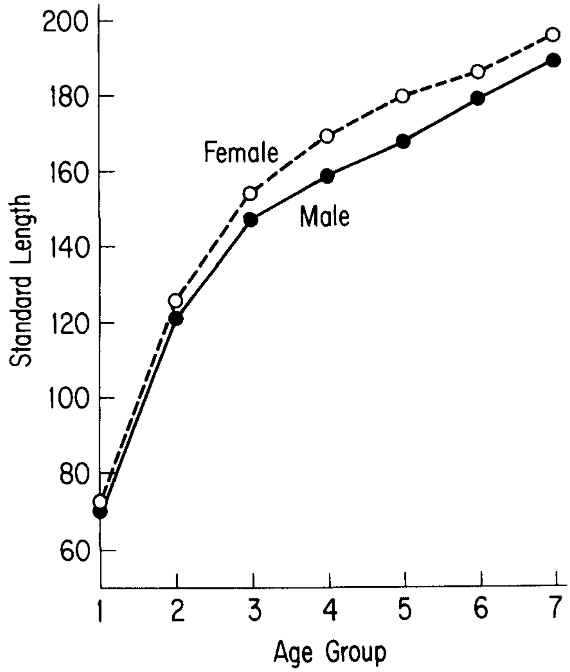

FIGURE 8.—Mean calculated standard lengths (mm) and increments of growth for each year of life of white perch from the Hudson River between Nyack and Bear Mountain, N.Y.

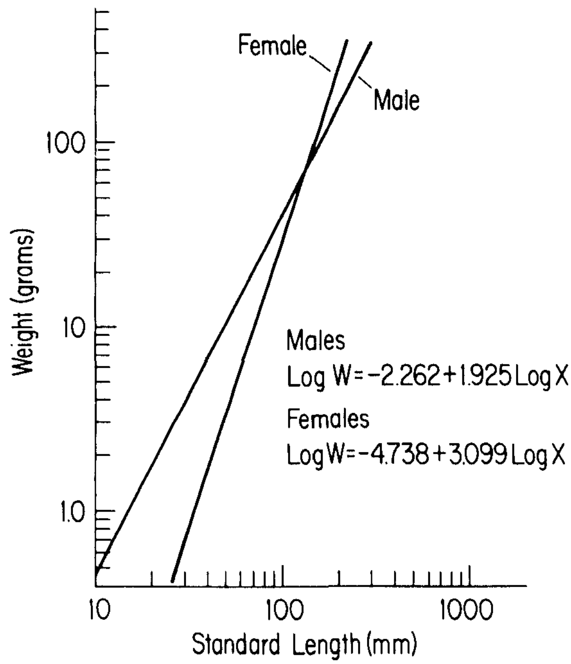

FIGURE 9.—Length-weight relationships of male and female white perch from the Hudson River between Nyack and Bear Mountain, N.Y. For males, $r^2 = 0.706$; for females, $r^2 = 0.965$.

fecundity data for May and June (Fig. 10). The egg-to-length relationship was $Y = 1,697.08e^{0.02} X$, where Y = number of eggs per fish and X = length, $r^2 = 0.39$. The white perch analyzed had a mean fecundity of 50,678 eggs/female with a range of 15,726-161,449.

The relationship between ovary weight and total body weight for 243 female white perch of known age collected from May to October is shown in Table 8. The changes in the ratio of ovary weight to body weight expressed as a percentage shows that spawning took place during June and was completed by July. Thereafter the ovaries are refractory and do not regain their weight until prior to the succeeding spawning season. The occurrence of the spawning season is further substantiated by the occurrence of white perch eggs and larvae in ichthyoplankton during June and July collections from the Hudson River (Lauer et al. 1974).

TABLE 3.—Growth history of the white perch in the Hudson River between Haverstraw and Bear Mountain, N.Y., 1963-69.

Growth period	Growth increment for indicated year of life						
	1	2	3	4	5	6	7
1963	69.2						
1964	71.9	50.0					
1965	68.9	50.7	30.9				
1966	70.2	50.3	28.2	14.1			
1967	69.4	51.4	29.2	13.4	12.0		
1968	71.7	54.1	29.0	15.8	10.7	9.7	
1969	73.4	54.9	30.4	17.0	13.5	9.6	8.2

TABLE 4.—Calculated growth of white perch males in the Hudson River between Haverstraw and Bear Mountain, N.Y., 1963-69.

Year class	No.	Calculated standard length (mm) at end of year						
		1	2	3	4	5	6	7
1963	2	66.9	115.2	142.3	156.8	169.3	179.7	189.1
1964	11	68.2	117.2	144.9	157.0	168.5	178.9	
1965	32	66.5	114.3	140.2	155.2	167.2		
1966	37	69.3	119.4	146.6	162.6			
1967	54	68.6	121.6	152.5				
1968	63	70.6	126.2					
1969	21	79.4						
Weighted means		70.0	121.2	147.2	158.8	167.6	179.0	189.1
Increment		70.0	51.2	26.0	11,6	8.8	11.4	10.1
Percent of total growth		37.0	27.1	13.8	6.1	4.6	6.0	5.3
No.		220.0	199.0	136.0	82.0	45.0	13.0	2.0

Sex Ratio

Of the 2,600 mature fish collected, 1,209 were males and 1,442 were females, giving an overall sex ratio of 0.83 to 1.0 in favor of females. This phenomenon has been observed for other fish populations in which females attain an older age

TABLE 5.—Growth history of the white perch males in the Hudson River between Haverstraw and Bear Mountain, N.Y., 1963-69.

Growth period	Growth increment for indicated year of life						
	1	2	3	4	5	6	7
1963	66.9						
1964	68.2	48.3					
1965	66.5	49.0	27.1				
1966	69.3	47.8	27.7	14.5			
1967	68.6	50.1	25.9	12.1	12.5		
1968	70.6	53.0	27.2	15.0	11.5	10.4	
1969	70.0	55.6	30.9	16.0	12.0	10.4	9.4

TABLE 6.—Calculated growth of white perch females in the Hudson River between Haverstraw and Bear Mountain, N.Y., 1963-69.

Year class	No.	Calculated standard length (mm) at end of year						
		1	2	3	4	5	6	7
1963	10	69.6	120.1	151.9	166.2	177.6	187.6	195.8
1964	25	73.2	124.4	151.4	165.8	175.6	185.6	
1965	29	70.4	121.9	152.8	170.1	183.8		
1966	41	70.6	123.2	154.6	171.7			
1967	67	70.5	125.6	156.2				
1968	98	73.0	128.6					
1969	35	78.8						
Weighted means		72.4	125.6	154.2	169.3	179.6	186.2	195.8
Increment		72.4	53.2	28.6	15.1	10.3	6.6	9.6
Percent of total growth		36.9	27.2	14.6	7.7	5.2	3.4	4.9
No.		305.0	270.0	172.0	105.0	64.0	35.0	10.0

TABLE 7.—Growth history of white perch females in the Hudson River between Haverstraw and Bear Mountain, N.Y., 1963-69.

Growth period	Growth increment for year of life						
	1	2	3	4	5	6	7
1963	69.6						
1964	73.2	50.5					
1965	70.4	51.2	31.8				
1966	70.6	51.5	27.9	14.3			
1967	70.5	52.6	30.9	14.4	11.4		
1968	73.0	55.1	31.4	17.3	9.8	10.0	
1969	72.4	55.6	30.6	17.1	13.7	10.0	8.2

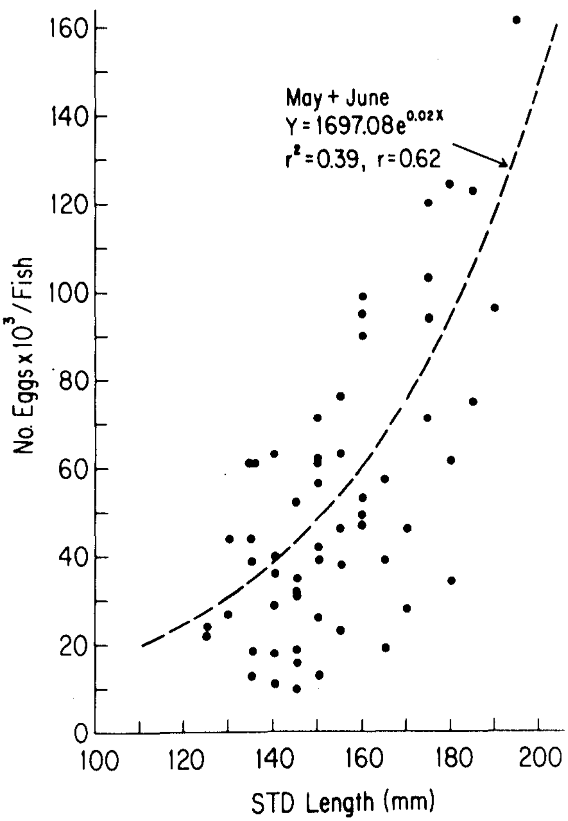

FIGURE 10.—Relationship between fecundity and standard length in female white perch collected during May and June from the Hudson River between Nyack and Bear Mountain, N.Y.

TABLE 8.—Mean ovary weight expressed as percentage of body weight.

Age	May	June	July	August	September	October
2	4.0	3.6	1.1	0.5	0.4	1.1
3	4.7	4.3	1.8	0.4	0.6	0.7
4	7.1	4.0	1.0	0.5	—	1.8
5	5.9	3.9	1.5	0.8	—	—
6	5.9	4.1	0.6	—	—	—
7	7.8	3.0	—	0.5	—	—
Total no. of fish 243						

than males (Elrod and Hassler 1969). Chi-square analysis of data from individual collections showed the difference to be significant ($x^2 = 132.1$; $P<0.001$). During May and June the population consisted of 70.1% mature males and females and 29.9% immature fish. From July to November the population consisted of 40.6% mature males and females and 59.4% immature fish. The change observed in the population between mature and immature individuals was due to the recruitment of young-of-the-year fish into the population sampled by our gear.

DISCUSSION

The growth and reproductive characteristics of white perch from the Hudson River compare favorably with data from other riverine systems. The maximum age attained in the Hudson River is about 7 yr, and maximum size is about 200 mm. Other data from the Hudson River (Lawler, Matusky and Skelly Engineers footnote 6; Texas Instruments Inc. footnote 7) show maximum age to be 7 and 9 yr, respectively, with a maximum size of from 200 to 222 mm. White perch from the Connecticut River, Conn. (Marcy 1976; Marcy and Richards 1974) attained a maximum age of about 8 yr, but grew to a maximum size of more than 280 mm. Wallace (1971) and Miller (1963) studied brackish water segments of the Delaware River estuary white perch populations and reported maximum ages of 8 and 10 yr, respectively. However, Wallace obtained a maximum size (~175 mm) smaller than found in Miller's (~257 mm) and smaller than in other riverine populations. White perch from the Patuxent River, Md., and the Roanoke River, N.C., had a greater maximum age, up to 10 yr; however, the size attained at 7 yr is approximately the same as in the Hudson River, from 190 mm to 205 mm (Conover 1958; Mansueti 1961). In Figure 11 we have plotted calculated standard lengths by age groups for white perch from five riverine systems. A similarity of growth rates for most populations is obvious except for the Connecticut River where perch grow more rapidly throughout their life span. Such rapid growth is more characteristic of white perch in freshwater impoundments than of riverine populations (Thoits 1958).

The rapid growth of perch in the Connecticut River may be attributed to a longer growing season; the onset of annulus formation occurs nearly 2 mo earlier than in the Hudson River. However,

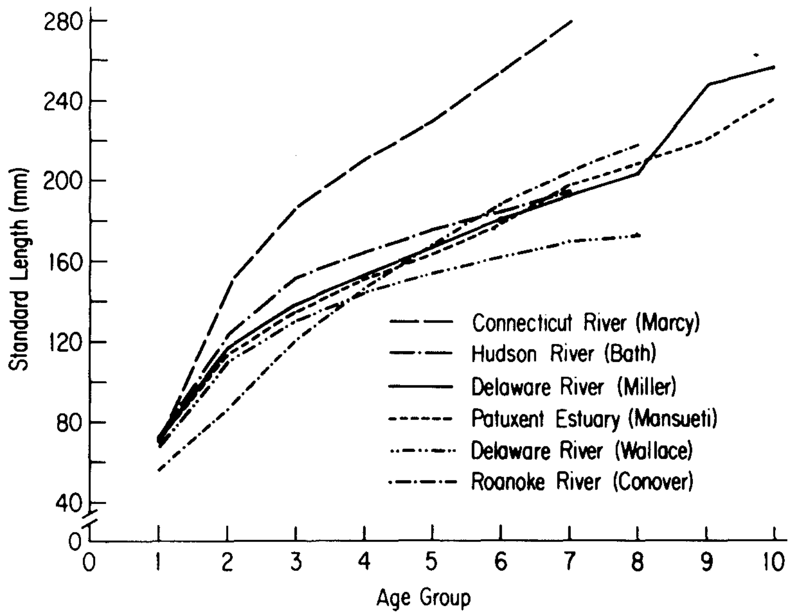

FIGURE 11.—Mean calculated standard lengths for white perch based on present and other studies.

this rapid growth rate estimate could be an artifact. Data from more recent year classes (1963-65) show lower rates of growth than observed from the 1959 through 1962 year classes (Marcy and Richards 1974). The Connecticut River population may be expanding rapidly and responding to increased population size with reduced rates of growth (Mansueti 1961).

White perch populations from south of the Hudson River show earlier onset and completion of the annulus. In the Chesapeake region, annulus formation begins in April (Mansueti 1961). In the estuarine portions of the Delaware River (Wallace 1971), the timing of annulus formation was shown to be complete by mid-June to early July. Lawler, Matusky and Skelly Engineers (footnote 5) reported that annulus formation in white perch from the Newburgh, N.Y., region of the Hudson River began in May and was completed by early July, essentially the same time observed in the present study. In Lake Ontario (Sheri and Power 1969) annulus formation was completed in July. The Connecticut River white perch (Marcy and Richards 1974) were anomalous in the apparent phenological trend of annulus formation, beginning in late March with completion during mid-May. This anomaly may be due to slightly higher average seasonal temperatures in the Connecticut River compared with those in the Hudson and Delaware Rivers, or it may be related to the fact that Marcy and Richards' (1974) studies were apparently carried out on a rapidly expanding population.

The basic reproductive potential for white perch, expressed as fecundity, appears to vary among the estuarine and freshwater populations studied. In estuarine and tidal rivers, fecundity values are similar throughout the range. White perch from the Roanoke River and Albemarle Sound, N.C., for example, had a mean fecundity of ~56,000 eggs/fish for age groups 3 and 4 (range 20,000-90,000; Conover 1958). Thoits (1958), in a generic study of white perch, estimated fecundity at 40,000 eggs/female. Hudson River fish fall close to this mean, with fecundity from three independent studies given as 21,000-135,000 (age groups 3 and 4; Holsapple and Foster 1975), 39,000-116,000 (Lawler, Matusky and Skelly Engineers footnote 6), and 16,000-161,000 with a mean of ~51,000 eggs/female in the present study. Variations in the data are most likely related to numbers of females sampled and the difficulty of obtaining fecundity data from a species which spawns over an extended period of time (Thoits 1958; Mansueti 1961; Taub 1969).

Freshwater lake populations of white perch may produce more eggs than similar groups in estuarine and tidal river systems. Au Clair (1956) estimated the fecundity of white perch from Sebasticock Lake, Maine, at 164,000 eggs/female. Taub (1969), studying white perch from Quabbin Reservoir, Mass., gave a mean fecundity value of 271,000 eggs/female for age groups 3 and 4 (range 190,000-321,000). These fecundities, which are at least double that found in riverine populations, may be related to environmental factors such as food supply, sample size, time of capture, or technique used (Taub 1969). Growth data for these populations show that the increased fecundity is primarily related to an increased growth rate for white perch in lacustrine systems, and attainment of a greater size for mature females (Thoits 1958; Taub 1969).

The white perch does not contribute substantially to the commercial fishery of the Hudson River and has declined sharply from the 590 t (1.3 million lb) observed for the New York Bight region in the 1901 statistics (McHugh and Ginter 1978). Sheppard[9] reported that for the Hudson River the average catch between 1913 and 1964 was ~19,073 lb, ranging from 2,249 to 60,522 lb. The average commercial catch during 1965-74 was 1,600 lb.

However, the species has ecological importance in cycling nutrients within estuarine food webs and thus contributes to populations of commercially important marine and anadromous fisheries. The juvenile white perch in the Hudson River are prey for yearling and older striped bass, *Morone saxatilis*; adult white perch; and presumably other species such as the bluefish, *Pomatomus saltatrix* (Bigelow and Schroeder 1953; Texas Instruments Inc. footnote 7, 1976[10]).

The adaptability of the species to waters of different quality and chemical characteristics, and the high plasticity of fecundity and growth rate under various conditions (e.g., brackish waters vs. freshwater impoundments) suggest potential importance of white perch as highly suited to temperate zone aquaculture.

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