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THE WEAKFISH *(CYNOSCION REGALIS)* IN NEW YORK WATERS[1]

Alfred Perlmutter Senior Aquatic Biologist (Marine)
New York State Conservation Department

William S. Miller Aquatic Biologist (Marine)
New York State Conservation Department

John C. Poole Aquatic Biologist (Marine)
New York State Conservation Department

ABSTRACT

A reported scarcity of weakfish in New York waters led to the initiation of a study of this species by the New York State Conservation Department in 1952. Based on data collected both by Nesbit in the early 1930's and by the present investigators, it was found that the resource of weakfish available to New York fishermen consists of both locally-spawned and southern-spawned fish. Weakfish are abundant in New York waters only when the southern-spawned stock is large. In recent years this stock has been smaller than ever before in the history of the fishery, and the New York fishery has depended mostly on locally-spawned fish. For New York to enjoy once more the abundant weakfish supply of the 1920's would necessitate an increase in the stock of southern-spawned fish. The feasibility of increasing this stock can only be determined through cooperative study by the conservation agencies of those states whose waters contribute, in important measure, to the weakfish resource.

The weakfish *(Cynoscion regalis)* is found from Massachusetts to the Carolinas and is an important commercial species in the Middle Atlantic area. On Long Island it is a prime recreational fish, particularly so in the Peconic Bays and, to a lesser extent, in Great South Bay. Smaller numbers are taken at times by surfcasters along

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-3-R.
In gathering the data for the present study, the authors were dependent largely on the good will and cooperation of both the commercial and recreational fishermen. We should like to thank all who assisted, and particularly wish to thank the Sunrise, Whitecap, and South Bay Fish Companies, as well as Fred Fiedler, John Troyon, John Flynn, Remson Haynes, John Boschler, Michael Altenkirch, Harry Tuthill, Howard King, Stanley Dykovitz, William Allen, Rodman Pell, Nathan Warner, William Januick, and Sam Petersen. We also extend our appreciation to the fisheries laboratories in Virginia, Maryland, Delaware, and New Jersey, and to the U. S. Fish and Wildlife Service.

the ocean shore and by rowboat fishermen in western Long Island Sound and in the southern bays of western Long Island.

In the Peconic Bays the height of the recreational fishery for weakfish is in May and June. While fish remain in these bays throughout the summer, they are not as concentrated nor do the anglers pursue them with the same fervor as in the spring. In Great South Bay angling for weakfish starts in July and may continue as late as October, depending on the weather. Most commonly, the fish are caught close to the surface having been lured there by continuous chumming. The grass shrimps, *Palaemonetes vulgaris* and *Palaemonetes carolinus,* have proven most effective as chum and are, in addition, often used as bait. The types of tackle used and fishing methods have been described in detail by Wisner (1953).

During the past several years, the recreational fishermen of Long Island have reported a scarcity of weakfish, and these reports have been borne out by the trend of the catch of the commercial fishery. Over the 20-year period from 1929 to 1948, the annual commercial catch of weakfish in New York waters fluctuated irregularly with a low of 649,000 pounds in 1929 and a high of 2,305,000 pounds in 1946. In 1949, the catch fell to 406,000 pounds, the smallest quantity ever taken by the New York commercial fishery in any one year up to that time. The annual catch declined even more drastically in subsequent years, averaging about 150,000 pounds from 1950 to 1952, and only slightly over 100,000 pounds in 1953.

In 1952, a 3-year investigation of the weakfish was undertaken to determine the reasons for its apparent decline in New York waters. The present report includes an analysis of data collected in the course of this investigation, together with data collected by R. A. Nesbit of the U. S. Fish and Wildlife Service in the late 1920's and early 1930's. Nesbit's data, both published and unpublished, have been reanalyzed and reinterpreted in the light of present information. In order to present the findings in a form readily available to those who can put them to practical use, this report has been divided into two sections.

SECTION I

In this section, the procedure followed, findings, and conclusions are briefly given without detailed presentation of substantiating data and their analyses. However, at appropriate places in the text reference is made to the topics in Section II under which these data are presented and discussed in more detail.

PROCEDURE

The possibility of the existence of races of weakfish had been suggested by the senior author (Perlmutter, 1939, p. 27) based on fragmentary original observations and data on egg size reported by Welsh and Breder (1924, p. 151). Nesbit (1954, p. 67) offered additional evidence of separate populations. If such races do exist, it is important to ascertain whether one or more of them are confined to Long Island or adjacent waters and, if so, how much it or they contribute to the Long Island fishery. Existence of a local race or races which contribute heavily to the Long Island population would mean that protective measures by New York could be effective in obtaining optimum utilization of the stock. However, should the Long Island population depend largely on fish migrating there from distant areas with local fish nonexistent or of relatively little importance, then little could be done by New York alone to effect most efficient utilization of the resource. Instead, it would be necessary for New York to depend on cooperation with the conservation agencies of other states where the weakfish is present to institute necessary conservation measures.

In making population studies, the data for young of the year and for older fish were analyzed separately. Methods used included fin ray counts, patterns on the surface of the scale (scale sculpturing), age and growth, and tagging.

POPULATION STUDIES OF YOUNG OF THE YEAR

In order to investigate the existence of races of weakfish, it was necessary to analyze data obtained from fish whose origin was known. Since it was probable that adult populations were composed of fish spawned in several different areas, it seemed advisable to study young-of-the-year fish. Such young of the year were assumed to have been the product of spawning in the particular area in which fall collections of them were made. (Young-of-the-year fish, or O-Group weakfish, are those collected prior to January 1.)

FIN RAY COUNTS[2]

Dorsal and anal spine and ray counts of young-of-the-year weakfish taken in Long Island waters in 1952 and 1953 were compared with similar counts of fish taken in Virginia in 1951, 1952, and 1953. There was no significant difference in the anal spine and ray counts of the

[2] For more detail see Studies of Fin Ray Counts in Section II.

fish from the two areas. The dorsal spine and ray counts were different, averaging higher for Virginia fish than for New York fish with a low degree of significance in the 1952 year class and a much higher degree of significance in the 1953 year class. Indications are that, despite year-class variations, the tendency is for southern-spawned fish to average a greater number of dorsal spines and rays than northern-spawned fish.

Scale Sculpturing[3]

The successive, concentric growth rings (circuli) of a fish scale produce a pattern known as sculpturing. Such sculpturing on the weakfish scales collected from 1930 to 1934 was intensively studied by Nesbit (1954). He found that the marginal circuli during the first year of life were further apart in fish spawned in New York waters than in those produced in Virginia and North Carolina waters. Further, scales taken from such young fish in both northern and southern New Jersey waters were similar in appearance to the scales of comparable New York fish. Limited data on scale sculpturing obtained in 1951 and 1952 from Virginia, when compared with similar data from New York for the period from 1951 to 1953, confirm Nesbit's findings.

Age and Growth[4]

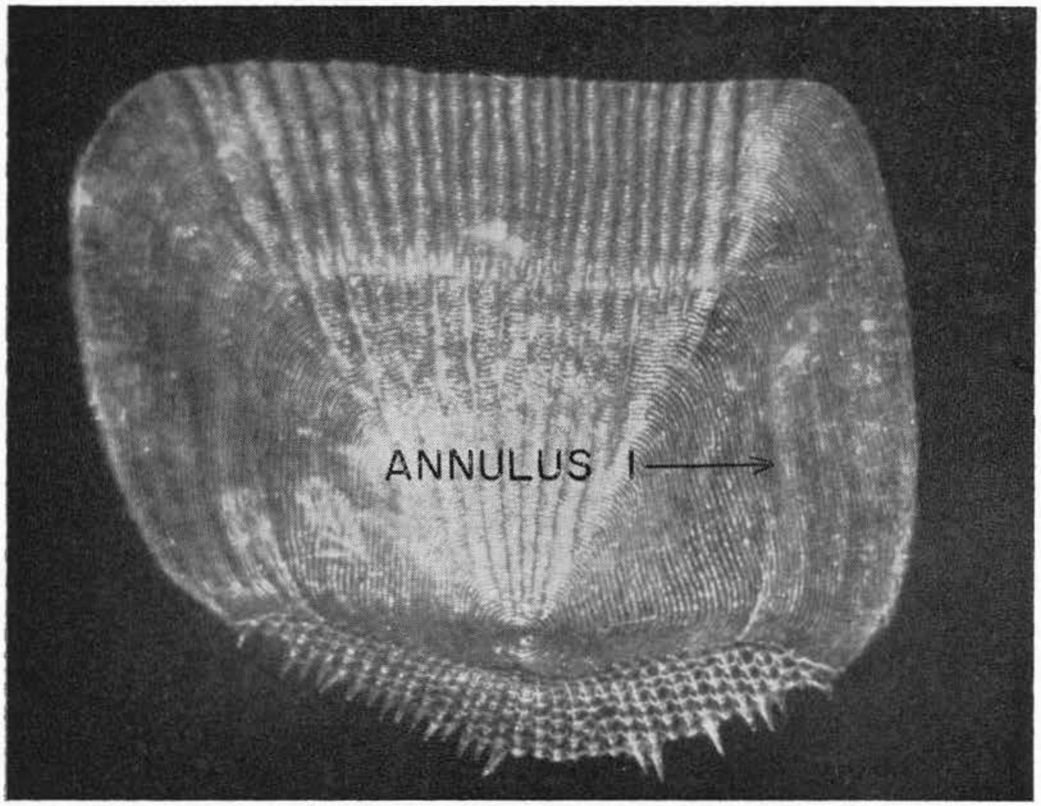
Because of the limitations of the investigation, it was not possible to make a comparative study of the rate of growth of young-of-the-year weakfish in southern and northern waters in recent years. However, unpublished data collected in 1929 by Nesbit in both New York and Virginia waters (Chesapeake Bay) were available for analysis. It was found that for each year from 1922 to 1928 growth to the time represented by the first annulus, or year mark, was greater in New York than in Virginia waters. The average for the 7-year period was slightly less than 8 inches in New York compared with 6⅗ inches in Virginia.

Discussion

Studies of the fin ray counts, scale sculpturing, and rate of growth of the young of the year indicate the existence of northern-spawned

[3] For more detail see Studies of Scale Sculpturing in Section II.

[4] For more detail see Studies of Age and Growth in Section II.



Scale of weakfish demonstrating annulus 1. (Taken in Great Peconic Bay on June 16, 1953)

and southern-spawned groups of weakfish. Whether these groups should be designated subspecies or races is of no importance to the present study. What is important is that there are two major population segments contributing to the total weakfish stock in New York waters, and that in the young of the year these segments are separate and identifiable. Fish spawned in New York and as far south as Wildwood, New Jersey, might be considered to belong to the northern group, and fish spawned south of Wildwood, New Jersey, to the southern group. A knowledge of the relative size of these population segments and the degree of intermixture of them as the fish become older is important in order to determine whether local conservation measures can be effective or whether cooperative measures among the agencies of other states interested in the weakfish are necessary. If the northern and southern groups remain separate, or if there is relatively little interchange between them, then local measures can be effective. However, mass intermixture of the two groups would mean that only cooperative measures could be used. Therefore, a study was made of the population of older fish.

POPULATION STUDIES OF OLDER FISH

Weakfish of a wide range of ages from Group I upward were studied to determine their origin and subsequent history of growth. Limited information on migration habits, obtained through tagging studies undertaken by Nesbit (1954), aided in this work.

SCALE SCULPTURING[5]

The origin, as interpreted from scale sculpturing, of weakfish comprising the commercial catch taken in New York and Virginia waters in the years from 1930 to 1934 was studied by Nesbit. These fish were mostly 1 year old or older. From an analysis of these data it was found that the southern-spawned fish in any one year may comprise a large part, estimated at 20 to 82 per cent, of the weakfish taken by the Long Island fishery, as well as most of the fish taken in Virginia.

AGE AND GROWTH[6]

Again, unpublished data collected by Nesbit in New York and Virginia (Chesapeake Bay) waters in 1929 were analyzed to determine the average length at each year mark and the rate of growth. For both the Virginia and New York fish, the calculated average size at each annulus from the second to the eighth for various year classes showed less regularity than that at the first year mark. There is still some indication that the Virginia fish average smaller for a given age, but the tendency was for the New York fish to show a progressive increase in average length at the time of each annulus from 1921 to 1928, and to have been even larger in the period from 1946 to 1951.

TAGGING EXPERIMENTS

Returns from tagging experiments during the project both on young of the year and adults are incomplete. However, fragmentary returns obtained by Nesbit (1954) show that there is an interchange of the northern and southern population segments. The degree of contribution of each of these population segments to the other cannot be determined from his experiments.

[5] For more detail see Studies of Scale Sculpturing in Section II.

[6] For more detail see Studies of Age and Growth in Section II.

DISCUSSION

Studies of first-year scale sculpturing, age and growth, and tagging for fish 1 year of age and for older fish show that, although two distinct population segments of weakfish exist among the young of the year, beyond this stage the fish from the two segments tend to intermix. The relative size of the two segments, together with the annual degree of intermixture, would determine the size of the population or the quantity of fish available to the Long Island fishery during a particular year or period. If the southern-spawned population segment were very large compared to its northern counterpart, then movement of fish from the south to the north, even in limited numbers, would result in a greater supply in New York waters than would normally result solely from locally-spawned fish, and any reduction in the numbers of these southern recruits would decrease the New York supply. On the other hand, if the northern-spawned segment were very large compared to its southern counterpart, then fluctuations in the degree of contribution of southern-spawned fish to the New York supply would have little effect. It can be expected that the relationship between the two population segments would be variable, changing from year to year, and over long periods of time would probably show different patterns. Unfortunately, continuous data are not available to portray these patterns from the beginning of the fishery to present times.

POPULATION PICTURES

From fragmentary early data and from more complete data collected by Nesbit and by the authors, it has been possible to sketch crude pictures of the weakfish population in the early days of the fishery, in the late 1800's, again in the 1930's, and, finally, at present.

LATE 1800's AND EARLY 1900's

Little information is available on the weakfish population during the early days of the fishery. Beginning in 1880, approximately annual canvass figures for the commercial catch of weakfish, first collected by the former U. S. Bureau of Fisheries and later by the U. S. Fish and Wildlife Service, serve as the only source of information (Figure 1). During this period New York and the other Middle Atlantic States, as well as the New England States, were taking a large per-

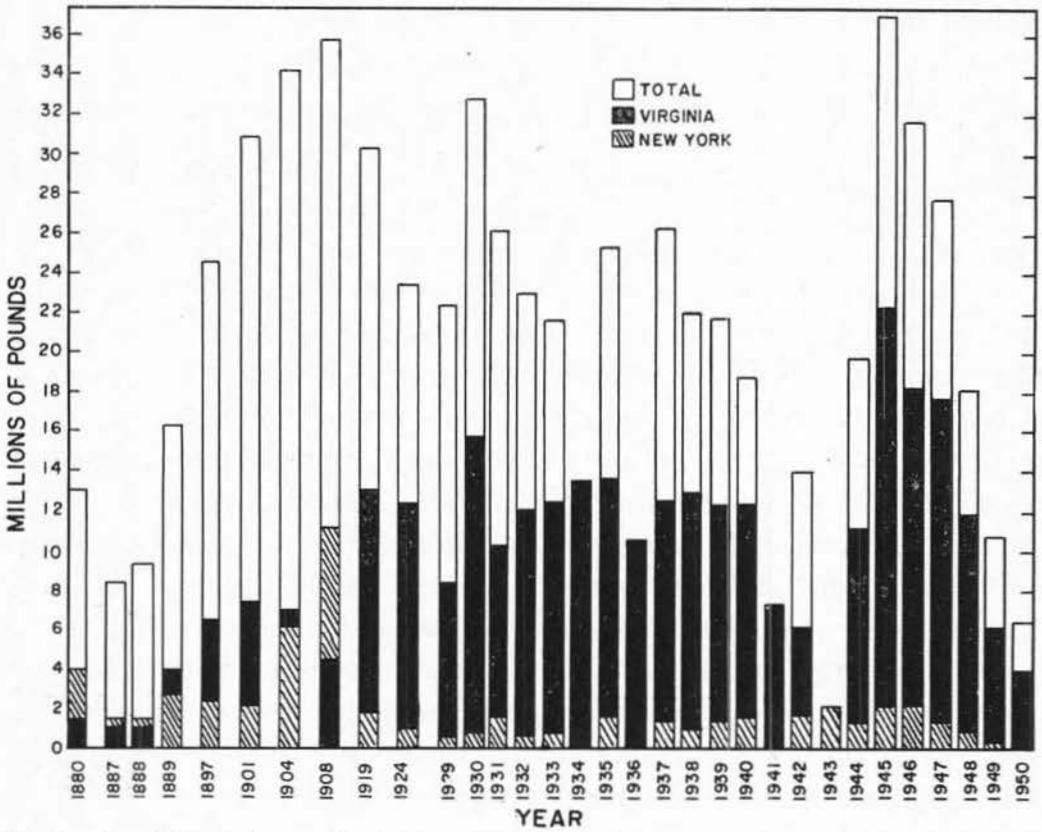


Figure 1. Comparison of the total commercial catch of weakfish along the whole coast with the catches in Virginia and New York waters in various years from 1880 to 1950.

centage of the total commercial catch of weakfish, while the catch of Virginia and its Chesapeake Bay fishery was relatively small. However, by the 1920's, the Virginia catch had increased so that it comprised almost half of the entire coastal catch while the latter remained at about the same poundage level. Historically, the Chesapeake Bay fishery has always depended on the smaller weakfish, those under 3 years of age, while the northern fishery has included large quantities of older, larger fish. Therefore, it is probable that the increase in the Virginia catch resulted in a decrease in the number of fish comprising the total weakfish population, since many more fish would have to be taken by the Virginia fishery than by the northern fishery to maintain the same total poundage level for the catch along the coast as a whole. A reduction in the total weakfish population, particularly when a large percentage of the fish was a product of southern spawning, would result in fewer of these fish being available to migrate to northern waters. That such a reduction in the number of southern-spawned fish contributing to the northern fishery occurred is indicated by the apparent increase in the average size of the Long

Island fish at each annulus for various year classes from 1921 to 1928 (see Figure 20). Such an increase in the average size of the weakfish in Long Island waters reflects smaller amounts of the slower-growing southern stock coming north to intermix with the faster-growing northern stock.

THE 1930's

During the 1930's, the weakfish fishery was more or less stabilized at a total catch level of 22 to 26 million pounds, with the Virginia fishery supplying a little over half of this catch (Figure 1). Based on Nesbit's data, it has been estimated that in the period from 1930 to 1934 some 20 to 82 per cent of the fish taken in New York waters in the spring and fall seasons were products of southern spawning (see Table 5).

1940 TO THE PRESENT

In the period from 1941 to 1943, the fishery was decreased by the impact of World War II. By 1944 the industry had returned to normal and the fishery again was producing at top efficiency. Stimulated by high prices and a good demand, as well as by ready availability of fish, the Virginia catches of 1945, 1946, and 1947 rose to the highest level in the history of the fishery, being about 22 million pounds, 18 million pounds, and 18 million pounds, respectively (Figure 1). This tremendous increase was followed by a marked decrease. Thus, in 1949 the Virginia catch fell to around 6 million pounds, in 1950 to 4 million pounds, and in 1951 to 2 million pounds. At the same time, the annual New York catch fell from an average of 2 million pounds in 1945, 1946, and 1947, to a little over 400,000 pounds in 1949, to an average of 150,000 pounds per year in 1950, 1951, and 1952, and to about 100,000 pounds in 1953.

Biological data on the weakfish in New York waters are not available for any year since 1940, except 1952 and 1953. The size composition of the catch by various types of gear in the important fishing areas in 1952 is shown in Figures 2 and 3. Similar data for 1953 are shown in Figures 4 and 5. A comparison of the size composition of the catch in the major fishing areas, weighted according to the relative importance of the commercial catch for these areas,[7]

[7] Statistics on the commercial catch used in weighting the length frequency were obtained by the Conservation Department's Bureau of Marine Fisheries.

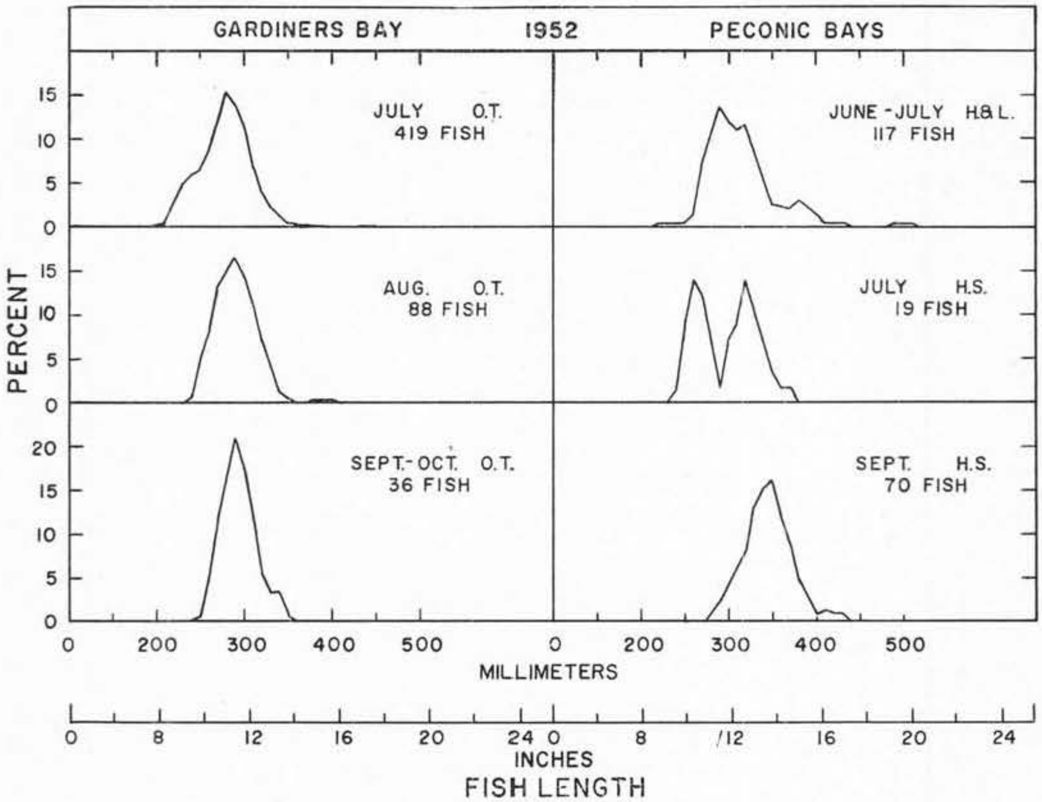


Figure 2. Length-frequency distributions of weakfish taken by various types of gear in Gardiners Bay and the Peconic Bays in 1952. (O.T., otter trawl; H. & L., hook and line or recreational fishery; H.S., haul seine)

is made in Figures 6 and 7 for the years 1952 and 1953, respectively. Also indicated for each year is a summary curve of the length-frequency distribution of the catch, and by inference of the weakfish population present, in the several areas combined. It is interesting to note that, on the basis of the total commercial catch of weakfish in Long Island waters, 54 per cent came from the Gardiners-Peconic Bays area in 1952, while 50 per cent came from there in 1953.

A comparison of the size composition of the catch in the major Long Island fishing areas, weighted according to age, is made in Figures 8 and 9 for the years 1952 and 1953, respectively. Also indicated for each year is a summary curve for all ages combined. From the study of scale sculpturing (see Tables 6 and 7) it appears that the 1- and 2-year-olds at least, which together comprised over 94 per cent and 70 per cent for the two years, respectively, of the weakfish taken

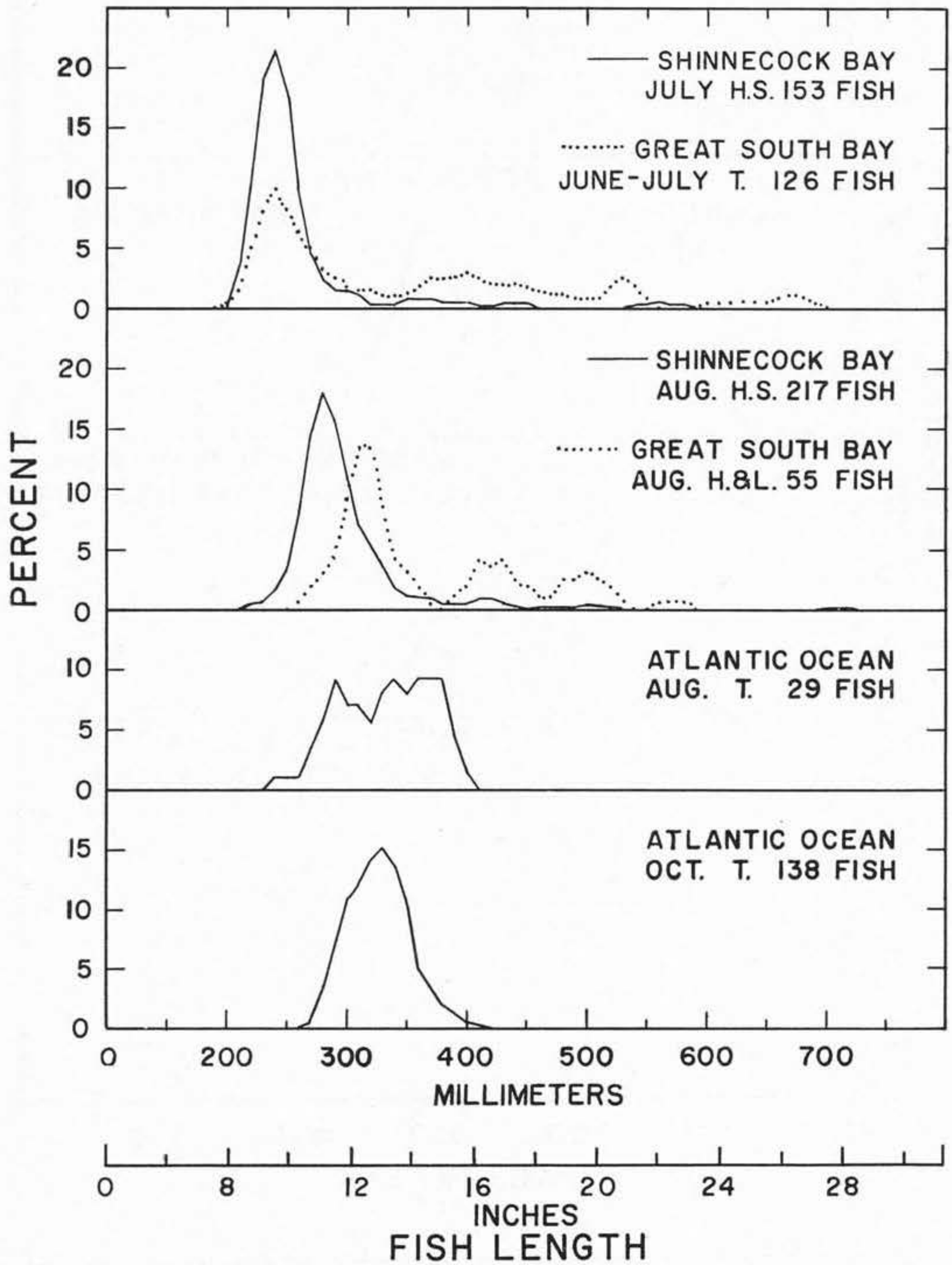


Figure 3. Length-frequency distributions of weakfish taken by various types of gear in Shinnecock Bay and Great South Bay, and in the Atlantic Ocean in 1952. (H. & L., hook and line or recreational fishery; H.S., haul seine; T., ocean trap)

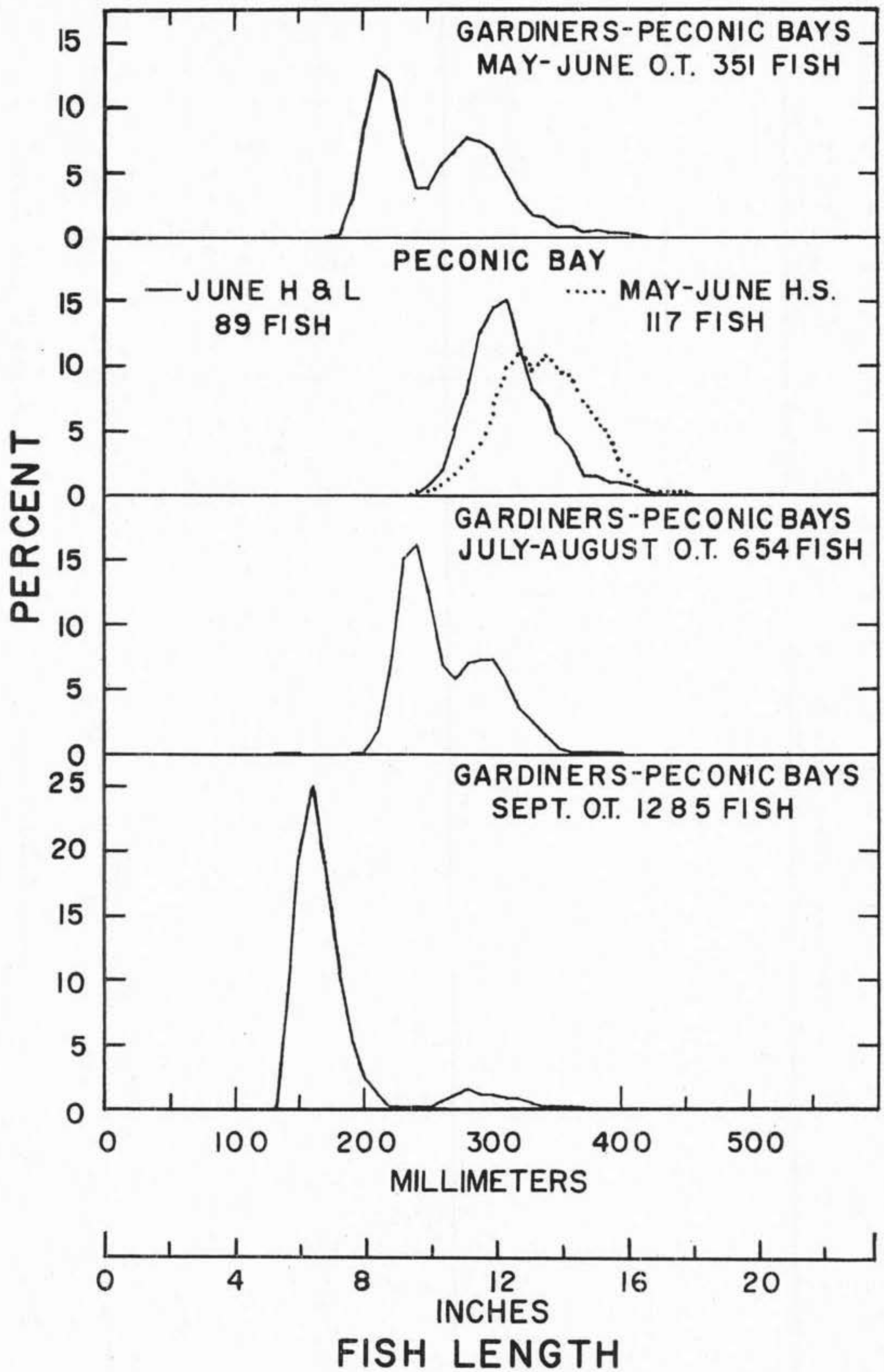


Figure 4. Length-frequency distributions of weakfish taken by various types of gear in the Gardiners-Peconic Bays in 1953. (O.T., otter trawl; H. & L., hook and line or recreational fishery)

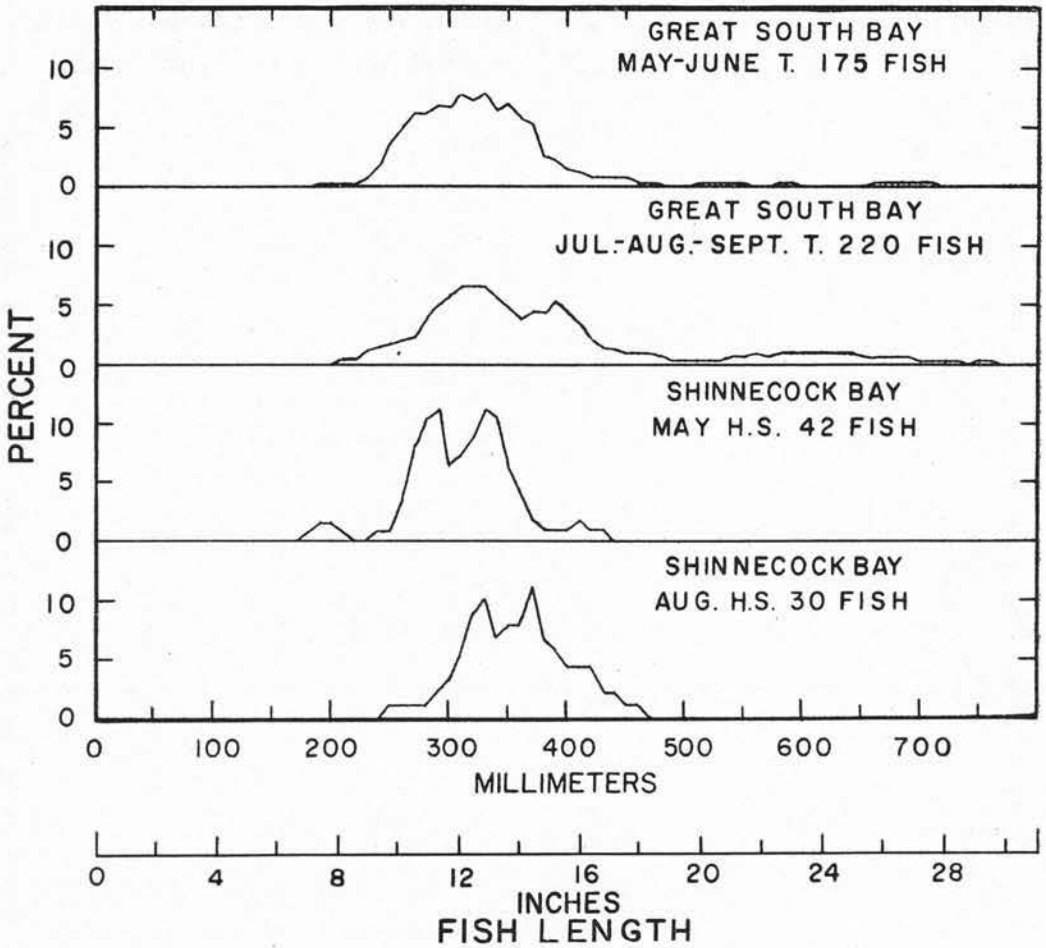


Figure 5. Length-frequency distributions of weakfish taken in Great South Bay and Shinnecock Bay by various types of gear in 1953. (H.S., haul seine; T., ocean trap)

by Long Island fishermen, were northern-spawned fish. However, some of the 3-year-old fish which made up 22.1 per cent of the catch probably came from southern waters.

DISCUSSION AND CONCLUSIONS

From the foregoing population pictures it is possible to theorize as to the reasons for the poor fishing for weakfish in New York waters both in the 1930's and in recent years. It is probable that the drop in the numbers of larger fish in Long Island waters in the 1930's, as reported by the fishermen, was due to the increased take of smaller fish by the southern fishery, particularly in the Chesapeake Bay area. As this fishery in Virginia became stabilized, the catch in northern waters remained at a more or less constant level from the 1930's until the late 1940's. The increased take of fish in the Chesapeake Bay area during 1945, 1946, and 1947 resulted in an upset in this stability.

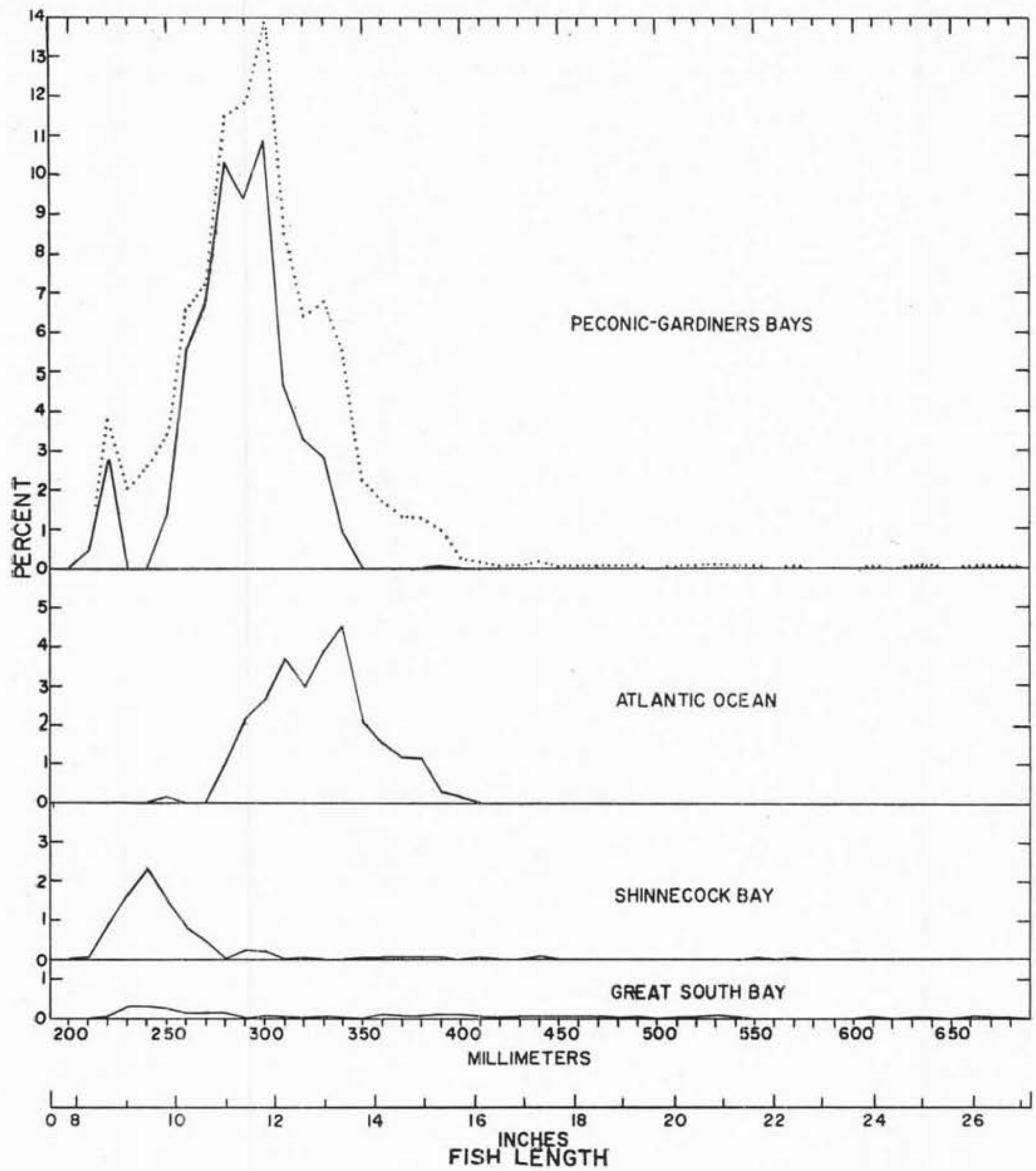


Figure 6. Length-frequency distributions of weakfish in 1952 for various New York waters weighted according to the relative importance of the commercial catch in each area as follows: Gardiners-Peconic Bays, 60 per cent; Atlantic Ocean, 28 per cent; Shinnecock Bay, 9 per cent; Great South Bay, 3 per cent (solid lines); and for all areas combined (dotted line).

Subsequently, from 1950 to the present time, the catch of weakfish, not only in New York but also along the entire coast, dropped drastically. This drop seems to indicate one of the lowest population levels in the history of the fishery.

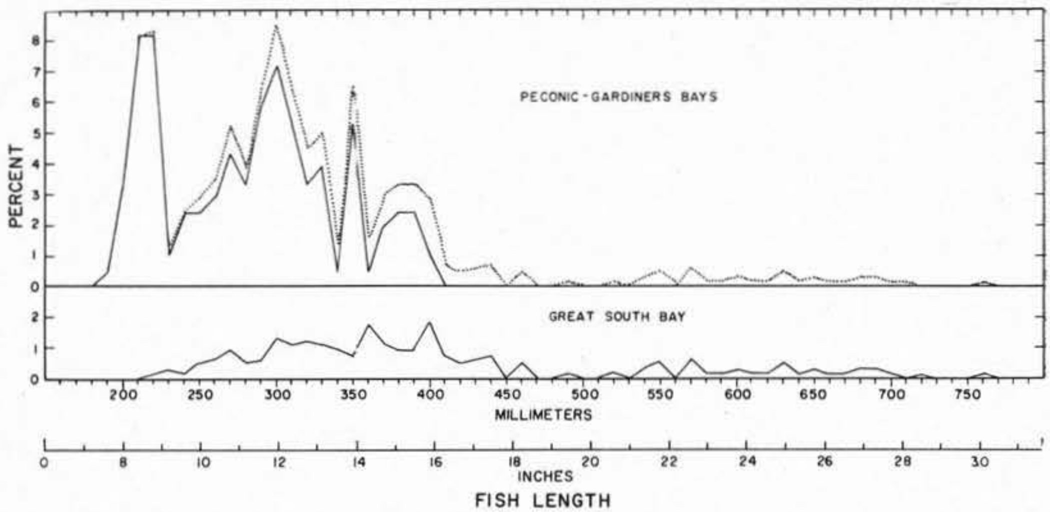


Figure 7. Length-frequency distributions of weakfish in 1953 for the two major New York waters (representing about 75 per cent of the total commercial catch) weighted according to the relative importance of the commercial catch in each area as follows: Gardiners-Peconic Bays, 76 per cent; Great South Bay, 24 per cent (solid lines); and for both areas combined (dotted line).

On the basis of past data, fragmentary as they are, as well as recent information collected in 1952 and 1953, it would thus appear that the northern fishery for weakfish is primarily dependent on the southern-spawned stock, and that the amount of fish produced locally in northern waters comprises but a relatively small part of the total population along the New York shore. Therefore, it is likely that there will never be the abundance of weakfish in New York waters that was prevalent in the 1920's until such time as the southern stock builds up to a greater density than at present. Whether this southern stock can be built up from its existing low level can only be determined by cooperative study and management of the weakfish by the conservation agencies of the various states in whose waters this fish is found.

SECTION II

In order to avoid obscuring the preceding discussions and conclusions with details of substantiating data and descriptions of methods used, it was considered advisable to present this more detailed information in a second section.

STUDIES OF FIN RAY COUNTS

Differences in fin ray counts are often used to distinguish various groups of fish within a given species. Such differences may be largely

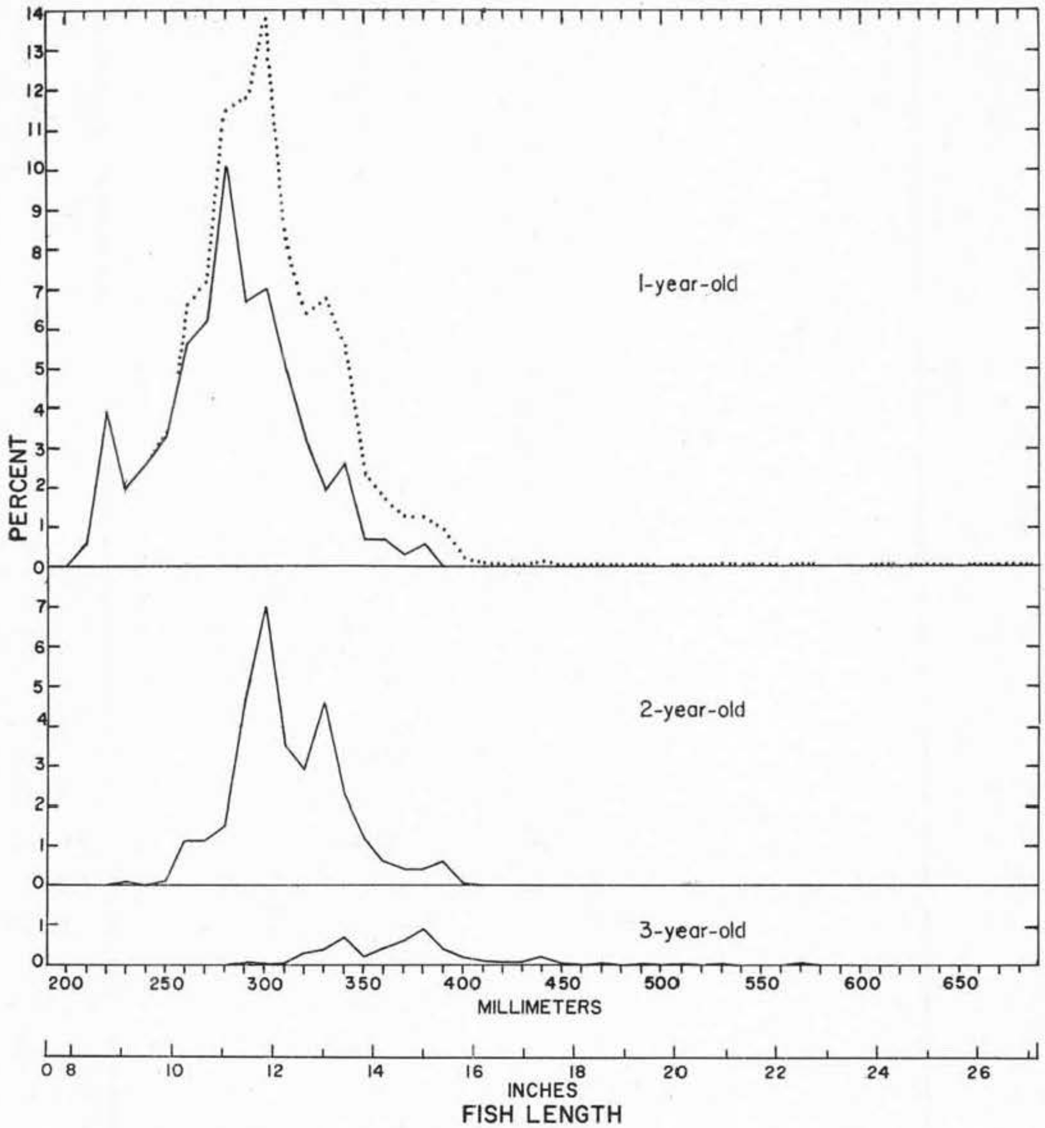


Figure 8. Length-frequency distributions of weakfish in 1952 for all New York waters weighted according to age as follows: 1-year-olds, 62.2 per cent; 2-year-olds, 32.1 per cent; 3-year-olds, 5.1 per cent (solid lines); and for all ages combined (dotted line). The 4-, 5-, and 6-year-olds, 0.6 per cent, not plotted separately.

genetic in character, or they may reflect variations of the environment during the embryonic development of the fish. For the present study, the reason for the differentiation, if it exists, is of less importance than the fact that the fin ray counts can be used to divide a population into its components.

The numbers of spines and rays in the dorsal and anal fins of samples of young-of-the-year weakfish taken in various waters of New York in 1952 and 1953 and in Virginia in 1951, 1952, and 1953 were

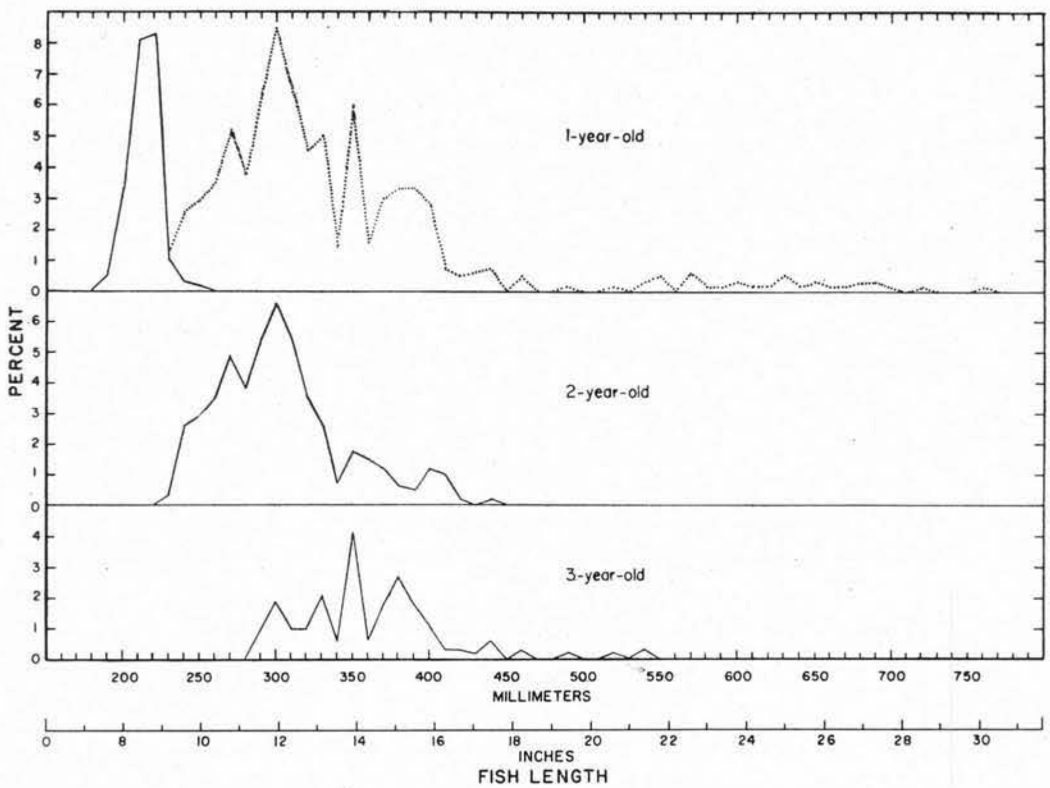


Figure 9. Length-frequency distributions of weakfish in 1953 for the two major New York waters (Gardiners-Peconic Bays and Great South Bay) weighted according to age as follows: 1-year-olds, 21.7 per cent; 2-year-olds, 49.0 per cent; 3-year-olds, 22.1 per cent (solid lines); and for all ages combined (dotted line). The 4-year-olds, 4.9 per cent, and the 5- and 6-year-olds, 2.3 per cent, not plotted separately.

counted under a dissecting microscope. In making these counts, for both the dorsal and anal fins, the last two rays which are joined at the base were considered as one.

The frequency distributions of the combined anal spine and ray counts, together with the means and number of fish in each sample, are shown in Table 1. In New York waters the mean ranged from 13.64 to 13.72, and in Virginia waters from 13.62 to 13.77. Simple inspection would indicate that there was no difference in the combined spine and ray count between the fish taken in New York and in Virginia.

The frequency distributions of the combined dorsal spine and ray counts, as well as the means, standard deviations, standard errors, and number of fish in each sample, are shown in Table 2. In New York waters the mean ranged from 37.96 to 38.15, and in Virginia from 38.28 to 38.37. A graphic analysis of the records according to

TABLE 1. NUMBER OF ANAL SPINES AND RAYS OF O-GROUP WEAKFISH* FROM NEW YORK AND VIRGINIA

Locality	Date	Number of fish	Number of anal spines and rays: 12	13	14	15	Mean
			New York				
Gardiners Bay.....	September, 1952....	68	..	22	44	2	13.71
	September, 1953....	61	..	18	42	1	13.72
Fire Island Inlet...	November, 1952....	50	..	18	31	1	13.66
Great South Bay...	October, 1953......	28	..	10	18	..	13.64
Total.............	1952–1953	207	..	68	135	4	13.69
			Virginia				
York River.......	October, 1951	29	..	9	20	..	13.69
	July, 1952.........	61	1	21	39	..	13.62
	August and September, 1953..	57	..	14	42	1	13.77
Total............	1951–1953.........	147	1	44	101	1	13.69

*Young of the year.

TABLE 2. NUMBER OF DORSAL SPINES AND RAYS OF O-GROUP WEAKFISH* FROM NEW YORK AND VIRGINIA

Locality	Date	Number of fish	Number of dorsal spines and rays: 35	36	37	38	39	40	41	Mean	Standard deviation	Standard error
			New York									
Gardiners Bay	September, 1952	68	..	2	10	35	18	3	..	38.15	0.69	0.08
	September, 1953	60	..	..	17	28	11	4	..	38.03	0.74	0.10
Fire Island Inlet	November, 1952	49	1	..	9	24	13	2	..	38.10	0.80	0.11
Great South Bay	October, 1953	28	..	2	5	13	8	..	..	37.96	0.78	0.15
Total..........	1952–1953	205	1	4	41	100	50	9	..	38.08	0.74	0.05
			Virginia									
York River.....	October, 1951	29	..	..	6	13	7	2	1	38.28	0.99	0.18
	July, 1952	61	..	..	15	17	23	6	..	38.33	0.92	0.12
	August and September, 1953	57	..	..	7	25	22	3	..	38.37	0.59	0.08
Total..........	1951–1953	147	..	..	28	55	52	11	1	38.33	0.80	0.07

*Young of the year.

the method suggested by Hubbs and Perlmutter (1942) indicates that in the 1952 data the difference in dorsal ray counts between the New York and Virginia fish was of a low level of significance, with the possibility of occurring by chance once in every 5 to 10 times. In the 1953 data, the difference between the fin ray counts of fish from the two areas was of a higher level of significance, with the possibility of occurring by chance about once in every 195 times (Figure 10).

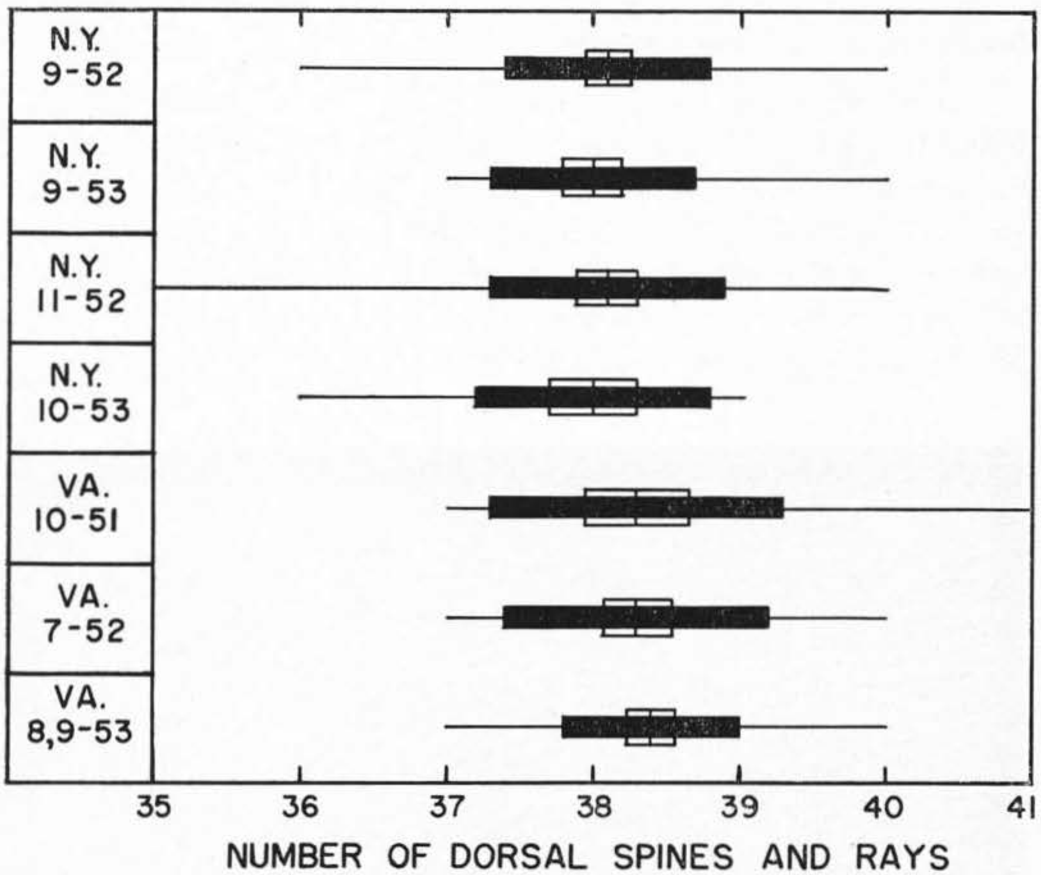


Figure 10. Graphic comparision of the number of dorsal spines and rays in young-of-the-year weakfish collected in New York and Virginia waters from 1951 to 1953.

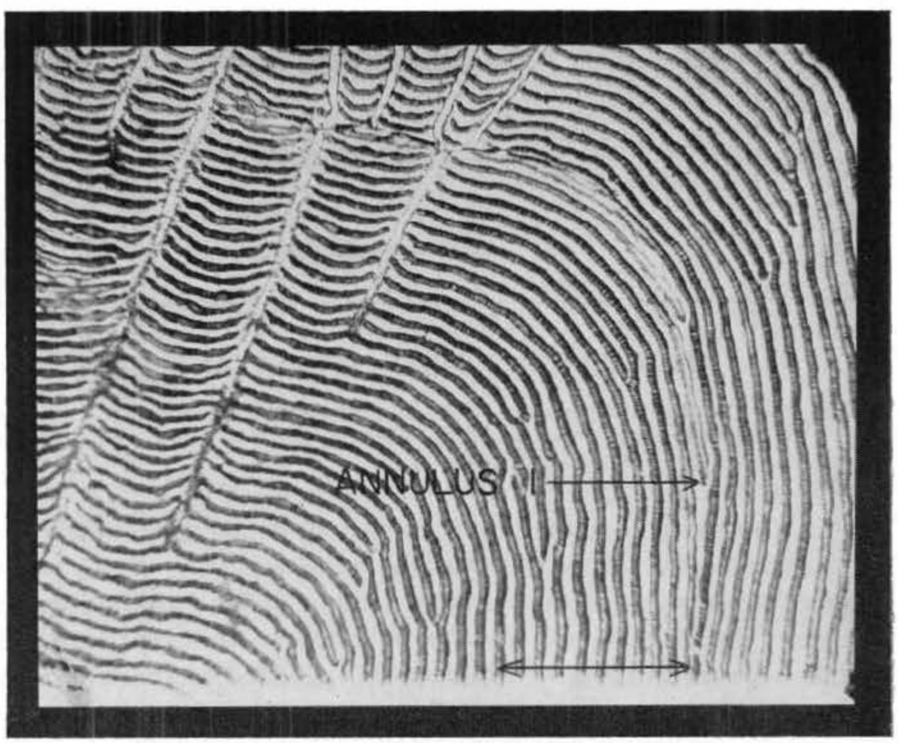
It is probable that the larger number of dorsal spines and rays, compared with the relatively fewer anal spines and rays, offers greater chance for variation in the number. Although the variation in the number of dorsal spines and rays was not large, northern-spawned and southern-spawned groups of weakfish are suggested by the difference in the counts recorded between the two areas. Also, the same population groups are further and more clearly delineated by differences in scale sculpturing and rate of growth.

STUDIES OF SCALE SCULPTURING

Differences in sculpturing due to the pattern of the circuli or other surface markings on the scale among groups of fish of a particular species may be useful to distinguish one group from another. Further, if seasonal intermixture occurs, such markings can assist in determining the extent to which each group contributes to the composition of the total population.

SCALE PATTERN, O-GROUP (1930-1934)

A difference in scale pattern between two groups of weakfish was found by Nesbit (1954, p. 64-65) who examined the last 10 circuli of the lateral margin region of the scale for young-of-the-year (O-Group) specimens from New York, New Jersey, Virginia, and North Carolina using material collected in fall months. Frequency distributions of the mean spacing between these 10 circuli were available for the Montauk (New York) area in 1930, 1931, 1932, and 1934, and



Section of weakfish scale demonstrating annulus 1 and measurement between 10 circuli.

statistical analysis showed that there was a significant difference among these year classes. However, an analysis of variance for the 1934 year class, for which data were available from New York, New Jersey, Virginia, and North Carolina, indicated that there was a greater difference in the sculpturing between groups of fish than between year classes. Two types of scale sculpturing were evident; one with circuli further apart found in New York and northern New Jersey specimens, and one with circuli closer together found in Virginia and North Carolina specimens.

The frequency distributions recorded by Nesbit for the mean spacing between the 10 marginal circuli of scales collected in October and November from O-Group weakfish in 1930 to 1934 were converted to cumulative percentage-frequency distributions (Table 3).

TABLE 3. CUMULATIVE FREQUENCY DISTRIBUTION OF O-GROUP WEAKFISH ACCORDING TO THE MEAN SPACING BETWEEN THE 10 MARGINAL CIRCULI OF THE LATERAL FIELD OF SCALES COLLECTED IN OCTOBER AND NOVEMBER, 1930-1934*

	New York				New Jersey					Virginia				
	(Montauk)				North		South (Wildwood)			Exmore		Chesapeake Bay	North Carolina	
Unit§	1930	1931	1932	1934	1930	1934	1930	1932	1934	1933	1934	1934	1933	1934
21	..	..	..	..	..	..	..	..	..	..	..	..	0.86	..
22	..	..	..	..	..	..	..	..	..	0.39	0.90	1.52	1.72	..
23	..	..	..	..	..	..	..	..	..	0.78	1.80	1.52	6.89	1.72
24	1.94	0.71	..	0.69	..	..	..	..	2.49	3.49	5.40	4.55	18.96	5.17
25	3.88	3.57	0.89	2.77	2.38	0.73	..	..	4.98	8.53	20.72	10.61	39.65	6.89
26	7.76	11.43	3.57	9.71	7.14	2.91	2.17	..	10.95	17.83	36.94	28.79	62.93	24.13
27	14.07	18.57	7.14	18.39	11.90	7.27	4.34	2.27	22.39	34.88	56.76	43.94	80.17	62.06
28	24.26	27.86	18.75	30.89	21.42	18.91	13.04	9.09	39.31	57.36	73.88	63.64	89.65	86.20
29	40.76	44.29	34.82	54.50	40.47	38.91	19.56	29.54	54.24	75.96	91.00	81.82	98.27	91.37
30	56.78	59.29	51.78	69.78	57.14	60.36	63.04	36.36	70.16	88.75	97.31	92.43	99.13	98.27
31	74.26	73.58	72.32	84.02	71.43	76.36	78.26	59.09	86.08	95.34	98.21	96.98	99.99	99.99
32	84.45	85.01	85.71	93.39	76.19	89.45	86.96	79.54	94.58	98.44	99.11	100.09	..	..
33	91.73	92.15	95.53	96.17	88.09	94.54	91.31	90.90	97.53	99.60	100.01	..	..	..
34	95.13	95.72	99.10	98.60	92.85	96.72	97.83	95.45	98.03	99.99	..	..	..	..
35	99.01	98.58	99.99	99.29	95.23	99.27	97.83	97.72	99.52	..	..	..	..	..
36	99.98	99.29	..	99.64	97.61	100.00	100.00	97.72	100.02	..	..	..	..	..
37	..	99.29	..	99.99	99.99	..	..	99.99	..	..	..	..	..	..
38	..	100.00	..	..	..	..	..	..	..	..	..	..	..	..
Number of fish..	206	140	112	288	42	275	46	44	201	258	111	66	116	58

*Based on data contained in Table 26 of Nesbit (1954, p. 68).
§Each unit equals 1/24,000 of an inch.

The cumulative percentage value at the 30-unit interval was arbitrarily selected to compare the various year classes taken in both the southern and northern areas. In the southern area (North Carolina and Virginia) the value at the 30-unit interval ranged from 88.75 to 99.13 and averaged 93.70. In the northern area (from Cape May, New Jersey, to Montauk, New York) the 30-unit interval ranged from 36.36 to 70.16 and averaged 61.23. The range of values in each of the areas probably can be ascribed largely to differences between year classes. If values at the 30-unit interval were available for the O-Group of each year class from both the northern and southern areas over an extended period of time, it would be possible to determine with a high degree of accuracy the extent of intermixture in New York waters and elsewhere of weakfish from these two areas each year. Lacking such data, a crude estimate of the degree of intermixture of the northern and southern stocks in New York can be obtained by assuming that the average value for the O-Group fish at the 30-unit interval for the several year classes available is fairly close to the actual value for any one year. Examination of Table 3 shows that, in the northern area where the 30-unit interval averaged 61.23, the values for the different year classes and for different localities varied less than 10 units, plus or minus, except for one small collection. In the southern area, where the average at the 30-unit interval was 93.70, variation from the average was less than 5 units, plus or minus.

Because of the relatively small amount of variation in the 30-unit interval values for the several year classes from the average of the values for the period studied, it has been considered feasible to use this average value as an estimated actual value for any one year. On this basis, the assumption was made that if the southern stock contributed nothing to the catch from northern waters, then the value at the 30-unit interval would be 61.2, while, if it contributed 100 per cent to the composition of the catch, the value would be 93.7. The values of the 30-unit interval for various intermediate degrees of contribution would be in proportion. These theoretical values were then calculated for the range of contribution from 1 to 99 per cent in 1 per cent intervals (Table 4).

SCALE PATTERN, COMMERCIAL CATCH (1930-1934)

Next, the frequency distributions recorded by Nesbit for the mean spacing between the 10 marginal circuli (representing the first

TABLE 4. PERCENTAGE CONTRIBUTION OF SOUTHERN STOCK TO NORTHERN STOCK OF WEAKFISH, CALCULATED FROM THE CUMULATIVE PERCENTAGE VALUE AT THE 30-UNIT INTERVAL*

Value at 30 units	Per cent	Value at 30 units	Per cent	Value at 30 units	Per cent	Value at 30 units	Per cent
61.2	0	69.3	25	77.5	50	85.6	75
61.5	1	69.7	26	77.8	51	85.9	76
61.9	2	70.0	27	78.1	52	86.2	77
62.2	3	70.3	28	78.5	53	86.6	78
62.5	4	70.7	29	78.8	54	86.9	79
62.8	5	71.0	30	79.1	55	87.2	80
63.2	6	71.3	31	79.4	56	87.5	81
63.5	7	71.6	32	79.7	57	87.9	82
63.8	8	72.0	33	80.1	58	88.2	83
64.2	9	72.3	34	80.4	59	88.5	84
64.5	10	72.6	35	80.7	60	88.8	85
64.8	11	72.9	36	81.0	61	89.2	86
65.1	12	73.2	37	81.4	62	89.5	87
65.5	13	73.6	38	81.7	63	89.8	88
65.8	14	73.9	39	82.0	64	90.2	89
66.1	15	74.2	40	82.3	65	90.5	90
66.4	16	74.5	41	82.7	66	90.8	91
66.7	17	74.9	42	83.0	67	91.1	92
67.1	18	75.2	43	83.3	68	91.5	93
67.4	19	75.5	44	83.7	69	91.8	94
67.7	20	75.8	45	84.0	70	92.1	95
68.0	21	76.2	46	84.3	71	92.4	96
68.4	22	76.5	47	84.6	72	92.7	97
68.7	23	76.8	48	85.0	73	93.1	98
69.0	24	77.2	49	85.3	74	93.4	99
....	..	....	..	....	..	93.7	100

*Based on Table 3.

growing season) of the scales of weakfish from commercial catches in the northern area for the spring and fall seasons from 1930 to 1934 were converted to cumulative percentage frequencies. The values at the 30-unit interval of these frequencies were referred to Table 4, and the corresponding percentage contribution of the southern stock to the northern catch determined. Thus, at Montauk (New York) in the spring of 1930, the cumulative percentage frequency was 75.2, and the southern contribution was 43 per cent. Estimated percentages of contribution of the southern stock to the population in various parts of the northern region, during the spring and autumn of the years from 1930 to 1934, have been summarized in Table 5. In New York, the southern stock contributed from 43 to 82 per cent of the total population available to the fishery in 1930 and 1931, while it contributed 35 and 20 per cent, respectively, to the population in the autumns of 1932 and 1934.

TABLE 5. CONTRIBUTION OF SOUTHERN STOCK TO NORTHERN STOCK OF WEAKFISH IN VARIOUS AREAS AND SEASONS FROM 1930 TO 1934, RELATED TO THE PERCENTAGE OF FISH IN GROUP I IN THE AGE FREQUENCY OF THE CATCH AND THE NUMBER OF YEAR CLASSES IN THE CATCH*

Locality	Year	Season	Value at 30 units	Percentage contribution§	Percentage of fish in age group I†	Number of year classes‡
New York						
Montauk....	1930	Spring	75.2	43	2.94	12
		Autumn	79.8	57	3.31	8
	1931	Spring	75.8	45	0.89	10
		Autumn	77.6	50	0.79	8
	1932	Spring	70.6	29	21.98	7
		Autumn	72.6	35	20.70	8
	1934	Autumn	67.9	20	0.00	3
Fire Island..	1930	Spring	76.2	46	0.00	9
		Autumn	80.2	58	3.84	10
	1931	Spring	85.6	75	0.00	12
		Autumn	87.8	82	0.00	8
New Jersey						
Northern						
waters....	1930	Autumn	81.8	63	1.85	8
	1931	Autumn	80.8	60	2.42	8
	1934	Autumn	74.5	41	0.25	6
Beach Haven	1930	Autumn	80.2	58	6.02	7
	1931	Spring	79.4	56	0.00	8
		Autumn	72.3	34	24.45	7
Wildwood...	1930	Autumn	82.2	65	7.38	6
	1934	Autumn	69.5	25	39.45	5

*Based on data published by Nesbit (1954, p. 70-73).
§Contribution of southern stock to northern stock.
†Percentage of Group I in the age frequency sample of the catch.
‡Includes the number of year classes in the age frequency sample of the catch exclusive of age group I.

In the same table are given the corresponding percentages of 1-year-old fish in the catch and the total number of year classes represented exclusive of age group I. Also, in Figures 11 and 12 the latter have been correlated with the percentage contribution of the southern stock to the northern total population.

From examination of Figure 11, it is apparent that on the whole, where the number of year classes was large, the corresponding values for the percentage contribution of the southern stock to the northern fishery were also large. When the number of year classes was small, the value for the percentage contribution of the southern stock tended also to be small. The correlation between number of year classes and

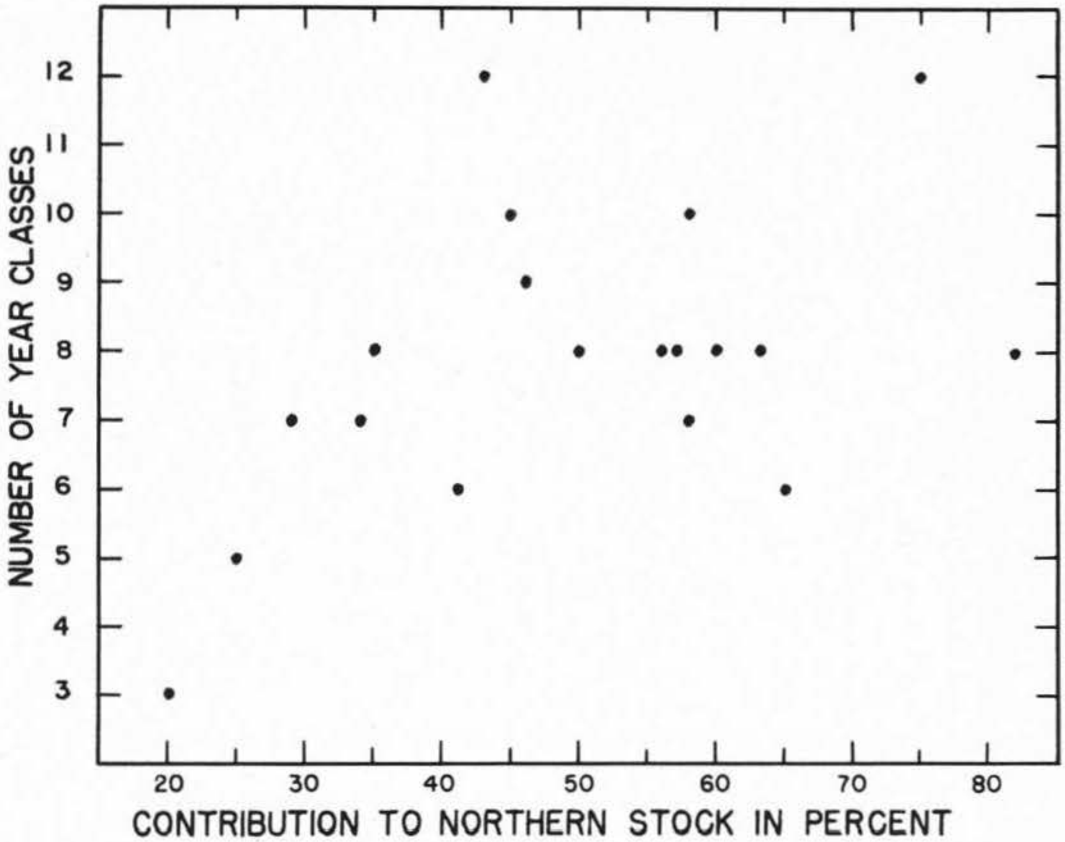


Figure 11. Percentage contribution of the southern to the northern stock of weakfish, in various areas and seasons from 1930 to 1934, correlated with the relative number of year classes in the catch, exclusive of age group I.

the extent of contribution of the southern stock to the northern fishery is further indicative of the influence of the southern fish on fluctuations in the supply in New York waters. A marked increase in the relative numbers of 1-year-old fish in the catch when the contribution of the southern stock to the northern fishery is small (Figure 12) would indicate a possible marked decrease in the total population.

SCALE PATTERN, O-GROUP (1951-1953)

An attempt was made to use the above approach to analyze recently collected data. Cumulative frequency distributions were obtained for O-Group weakfish from New York from 1951 to 1953, Maryland in 1952, and Virginia in 1951 and 1952 (Table 6). Effort was made to use the same criteria and measurements employed by Nesbit. Nevertheless, the values obtained at the 30-unit interval were considerably higher than those recorded by Nesbit for both the northern and southern areas. Probably this was due to slight differ-

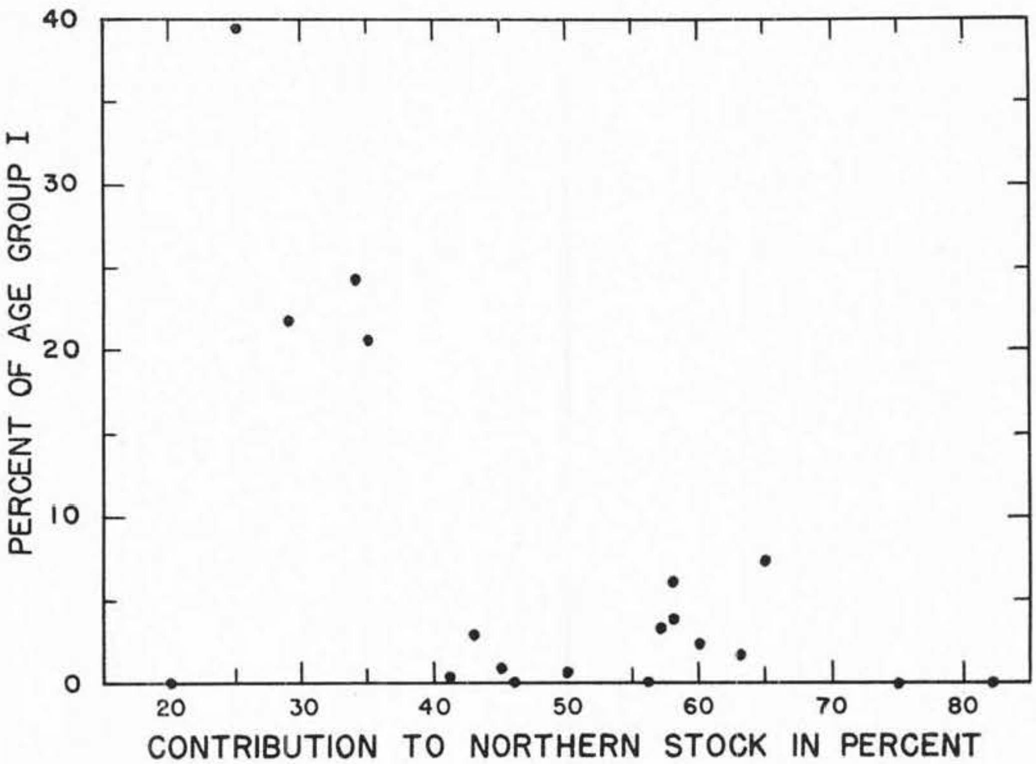


Figure 12. Percentage contribution of the southern to the northern stock of weakfish, in various areas and seasons from 1930 to 1934, correlated with the percentage of fish in age group I in the catch.

ences in technique, and as a result the data cannot be compared directly. For the more recent data, a 29-unit interval was used instead of the 30-unit interval. It will be noted that the values at this interval ranged from 63.16 to 81.33 in the years 1951 to 1953 for the northern stock as found around New York, and 91.67 to 100.00 in 1951 and 1952 for the southern stock as found around Virginia. Maryland specimens had a value at the 29-unit interval of 70.51 which fits into the northern stock range. A study of the combined dorsal spine and ray counts also indicated that this group of fish belonged to the northern stock.[8]

SCALE PATTERN, VARIOUS YEAR CLASSES (1952-1954)

Cumulative frequency distributions of the mean spacing between the 10 marginal circuli of the lateral field of the scale were obtained

[8] The frequency distributions of the combined dorsal spine and ray counts were as follows: 36-count, 2 fish; 37-count, 7 fish; 38-count, 19 fish; 39-count, 9 fish; 40-count, 2 fish; 41-count, 1 fish. The mean was 38.12, the standard deviation 1.05, and the standard error 0.17.

TABLE 6. CUMULATIVE FREQUENCY DISTRIBUTION OF O-GROUP WEAKFISH ACCORDING TO THE MEAN SPACING BETWEEN THE 10 MARGINAL CIRCULI OF THE LATERAL FIELD OF SCALES COLLECTED FROM SEPTEMBER TO NOVEMBER, 1951-1953

	New York					Maryland (Ocean City)	Virginia (York River)	
	Gardiners Bay				South Ocean			
Unit*	1951§	1952	1953	1953†	1952	1952	1951	1952
22	...	...	...	...	...	...	...	10.00
23	...	1.33	2.66	3.77	...	3.85	8.33	20.00
24	...	9.33	10.66	9.43	1.32	5.13	8.33	20.00
25	2.22	16.00	21.33	16.98	5.27	11.54	50.00	20.00
26	20.00	34.67	40.00	41.51	18.43	32.05	75.00	60.00
27	20.00	34.67	40.00	41.51	18.43	32.05	75.00	60.00
28	35.56	48.00	61.33	60.38	32.90	50.00	75.00	90.00
29	66.67	64.00	81.33	73.59	63.16	70.51	91.67	100.00
30	77.78	73.33	88.00	88.68	80.26	85.89	100.00	...
31	97.78	82.66	96.00	96.23	84.21	96.15	...	...
32	100.00	89.33	97.33	96.23	92.10	96.15	...	...
33	...	89.33	97.33	96.23	92.10	96.15	...	...
34	...	96.00	100.00	96.23	99.99	98.71	...	...
35	...	97.33	...	96.23	...	99.99	...	...
36	...	97.33	...	98.12	...	...	...	...
37	...	100.00	...	100.01	...	...	...	...
Number of fish	45	75	75	53	76	78	12	10

*Each unit equals 1/24,000 of an inch.
§1951 year class, measured in the summer of 1952 as Group I+ fish.
†1953 year class, measured in the spring of 1954.

by year class for the years 1952 to 1954 in the Gardiners-Peconic Bays region of New York (Table 7). For the 1951 year class, the 29-unit interval was 66.7 in 1952 for 1-year-old fish, presumably locally spawned, and was 47.3 and 47.1 in 1953 and 1954, respectively. For the 1952 year class, the 29-unit value was 64.0 in 1952, 68.2 in 1953, and 62.8 in 1954. The 1953 year class had a value at the 29-unit interval of 81.3 as young of the year, and of 73.6 the following year. Going back to the 1950 year class, the value at the 29-unit interval for 2-year-old fish in 1952 (60.9) is in agreement with the values for other northern-spawned fish, but in 1953 the value of 86.1 for 3-year-olds indicates that the latter included some migrants from the south. As can be seen, with the possible exception of the 1950 year class, the value at the 29-unit interval did not increase in the years following birth or the first year, as would have been expected if the southern stock was contributing extensively to these year classes in the northern

TABLE 7. CUMULATIVE FREQUENCY DISTRIBUTION OF WEAKFISH BY YEAR CLASS FOR VARIOUS YEARS IN THE GARDINERS-PECONIC BAYS REGION ACCORDING TO THE MEAN SPACING BETWEEN THE 10 MARGINAL CIRCULI OF THE LATERAL FIELD OF SCALE

	1950 year class§		1951 year class†			1952 year class			1953 year class	
Unit*	1952	1953	1952	1953	1954	1952	1953	1954	1953	1954
23	..	2.8	..	..	..	1.3	..	..	2.7	3.8
24	1.6	11.1	..	..	..	9.3	4.5	3.8	10.7	9.4
25	1.6	22.2	2.2	3.6	..	16.0	6.8	9.0	21.3	17.0
26	17.2	36.1	20.0	10.9	20.6	34.7	18.2	21.8	40.0	41.5
27	29.7	36.1	20.0	10.9	20.6	34.7	18.2	21.8	40.0	41.5
28	29.7	52.8	35.6	21.8	32.3	48.0	45.5	42.3	61.3	60.4
29	60.9	86.1	66.7	47.3	47.1	64.0	68.2	62.8	81.3	73.6
30	65.6	91.7	77.8	61.8	55.9	73.3	79.6	78.2	88.0	88.7
31	82.8	94.5	97.8	74.5	70.6	82.7	95.5	87.2	96.0	96.2
32	90.6	100.0	100.0	90.9	82.3	89.3	95.5	94.9	97.3	96.2
33	90.6	..	..	90.9	82.3	89.3	..	94.9	97.3	96.2
34	96.8	..	..	98.2	97.1	96.0	..	97.4	100.0	96.2
35	98.4	..	..	98.2	97.1	97.3	..	98.7	..	96.2
36	99.9	..	..	100.0	100.0	97.3	..	100.0	..	98.1
37	..	..	..	..	..	100.0	..	..	..	100.0
Number of fish..	64	36	45	55	34	75	44	78	75	53

*Each unit equals 1/24,000 of an inch.
§Data not available for 1950 and 1951.
†Data not available for 1951.

fishery. For all practical purposes, these data would indicate that few, if any, southern fish 2 or 3 years of age contributed to the population in the Gardiners-Peconic Bays region of New York during 1953 and 1954, but that most of the fish there were products of northern spawning.

STUDIES OF AGE AND GROWTH

Three different sets of data were used in studying the age and growth of weakfish. Included were materials collected by Nesbit in Great South Bay, New York, and in Chesapeake Bay, Virginia, in 1929, and by the authors in the various waters of Long Island during 1952 (Table 8 and Figure 13). Nesbit's data[9] were in the form of anterior radius measurements to each annulus and to the edge of the scale taken from the fish when caught, together with the total length of the fish when caught. These data were used directly to compute

[9] Through the courtesy of Gerald B. Talbot and the United States Fish and Wildlife Service, certain original data collected by Nesbit were made available.

TABLE 8. COLLECTIONS USED IN THE STUDY OF AGE AND GROWTH OF WEAKFISH IN 1952

Collection number	Date	Area		Total number of fish§
		Name	Map number*	
1	July 9	Gardiners Bay	1	8
2	July 15	Gardiners Bay	1	2
3	August 5	Gardiners Bay	1	53
4	August 19	Gardiners Bay	1	35
5	September 16	Gardiners Bay	1	22
6	October 8	Gardiners Bay	1	14
7	June 25	Peconic Bays	2	100
8	July 12	Peconic Bays	2	17
9	July 1	Shinnecock Bay	3	17
10	July 10	Shinnecock Bay	3	136
11	June 19	Great South Bay	4	100
12	July 8	Great South Bay	4	26
13	August 8	Great South Bay	4	10
14	August 12	Great South Bay	4	20
15	August 23	Great South Bay	4	35
16	August 27	Atlantic Ocean	5	29
17	October 2	Atlantic Ocean	5	55
18	October 17	Atlantic Ocean	5	83

*See Figure 12 for location of these areas.

§Scales from 762 fish were examined, 20 of which (9 specimens that had regenerated scales and 11 O-Group specimens that did not have any annuli) were excluded from the calculations of age and growth.

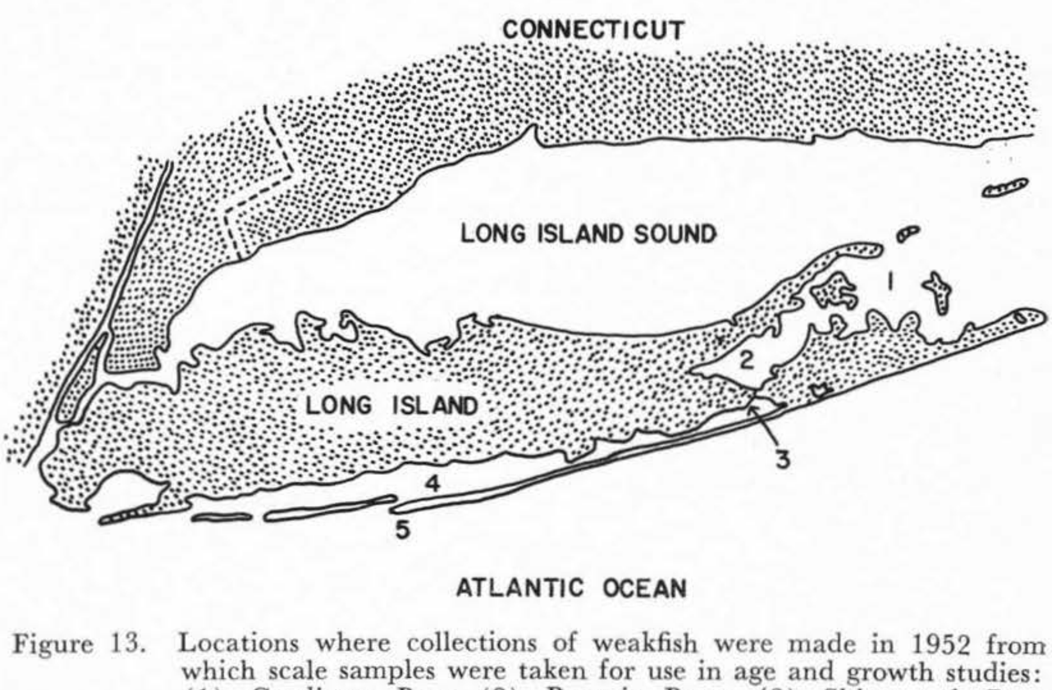


Figure 13. Locations where collections of weakfish were made in 1952 from which scale samples were taken for use in age and growth studies: (1) Gardiners Bay; (2) Peconic Bays; (3) Shinnecock Bay; (4) Great South Bay; (5) Atlantic Ocean.

the age and growth of weakfish in the Chesapeake and Long Island regions in the 1920's. The age and growth data collected by the authors in 1952 were analyzed in a more complete way. In the analysis of 1952 materials, it was considered advisable to check on certain aspects of the use of the scale in determining the age and growth of weakfish, such as the area of the body from which the scales should be taken and the structure and time of formation of the annulus.

The first step in determining the region of the body of the fish from which scales should be taken was to arbitrarily divide the body, exclusive of the head, into seven areas—three dorsal to the lateral line, and four ventral to it—as shown in Figure 14. Scales were then

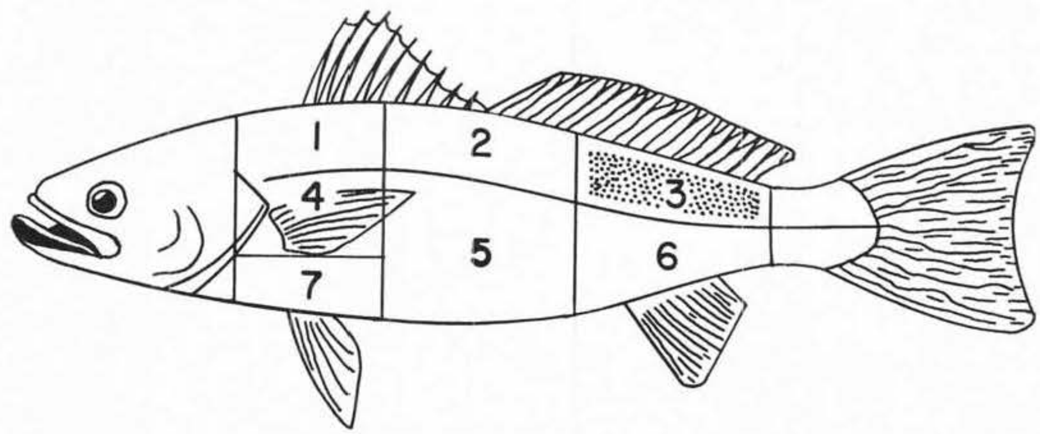


Figure 14. Diagram of a weakfish showing areas from which scales were studied to determine where scale samples should be taken. Area 3 was found to be the best.

taken from each of these areas from three different fish, total circuli counts made, and anterior radii measured. Area 3, in the region dorsal to the lateral line and extending beneath the posterior two-thirds of the second dorsal fin, had the highest circuli count (Table 9). Although the measurements of the anterior radii in this region were not the longest, they were sufficiently long, when coupled with the high circuli count, to indicate that scales from this region would reflect the maximum growth of the fish from the inception of scale formation to the time the fish was caught.

APPEARANCE AND FORMATION TIME OF ANNULUS

The following procedure was employed to check the structure and appearance of the annulus and the time of annulus formation. Taylor

TABLE 9. NUMBER OF CIRCULI AND LENGTH OF ANTERIOR RADIUS OF WEAKFISH SCALES FROM VARIOUS BODY AREAS

Number of circuli				Length of anterior radius*			
	Specimen				Specimen		
Area	1§	2†	3‡	Area	1§	2†	3‡
1	99	77	...	1	243	184	...
2	90	91	89	2	221	219	245
3	110	115	123	3	237	277	291
4	85	97	92	4	221	246	261
5	97	110	105	5	228	282	275
6	106	117	115	6	265	287	305
7	94	98	70	7	233	259	194

*In millimeters, magnified 76 times.
§Female, 218 millimeters, Great South Bay, May 1952.
†Male, 221 millimeters, Great South Bay, May 1952.
‡Female, 217 millimeters, Great South Bay, May 1952.

(1916) described the structure and appearance of the annulus of the weakfish. Using his criteria, a series of scales taken during different months of the year from June 1952, through July 1953, in the Gardiners-Peconic Bays and the Great South Bay areas of New York, was examined and the distance from the last annulus to the edge of the scale, which was designated the "terminal zone", was measured. Obviously, the terminal zone of the scale would be relatively small soon after the formation of this annulus, and would be relatively large immediately preceding the formation of a new annulus. Monthly frequency distributions of the measurements of the terminal zone for scales of fish taken in the Gardiners-Peconic Bays region in 1952 and 1953 are shown in Figure 15.

In June, 1952, the mode of the frequency distribution of the terminal zone was 80-99 millimeters. In July, the 80-99 millimeter mode still remained, but a secondary mode had appeared at 0-19 millimeters. By August, the distribution was once more unimodal, but at the 0-19 millimeter interval. The mode shifted in September to 20-39 millimeters, and in October to 60-79 millimeters. The change in the distribution from June to July, 1952, from a unimodal curve with a mode at 80-99 millimeters to a bimodal curve with the secondary mode at the lowest range of the terminal zone size-frequency distribution, would indicate the formation of a new annulus during July on the scales of some fish. The unimodality of the distribution in August, 1952, and the location of the mode at the lowest range of the terminal zone size-frequency distribution, indicates completion of

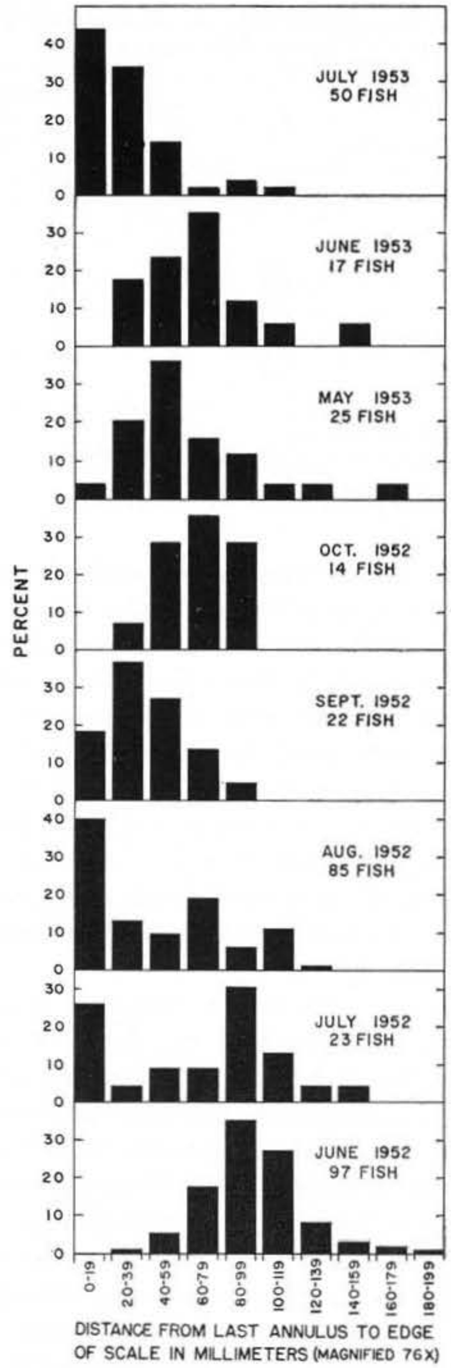


Figure 15. Percentage frequency distributions of measurements of the "terminal zone" of weakfish scales taken at various times of the year in 1952 and 1953 in the Gardiners-Peconic Bays area.

annulus formation. This is confirmed by the fact that in September and October of 1952 the modes of frequency progressively increased showing growth beyond the newly-formed annulus which had been laid down during July and August.

The data on the terminal zone for fish in the Gardiners-Peconic Bays area in 1953 show only unimodal curves during each of the months of May, June, and July. In May, the mode was at 40-59 millimeters, in June at 60-79 millimeters, and in July at 0-19 millimeters. The appearance in July of a very marked mode at the lowest range of the terminal zone size-frequency distribution, and the almost complete elimination of terminal margin measurements of 60-79 millimeters and over, indicates that all of the weakfish in the Gardiners-Peconic Bays area had a new annulus on their scales during July, 1953. As has been demonstrated for the previous year in the same area, only part of the fish had a new scale annulus in July and it was not until August that the entire population showed this structure.

Monthly frequency distributions of the measurements of the terminal zone of the scale of weakfish were also plotted for the Great South Bay area during 1952 and 1953 (Figure 16). Here again may be found months in which the mode shifted to the lowest range of the terminal zone size frequency (0-19 millimeters), and since no other modes were present, presumably a new annulus had formed. In 1952, the annulus was formed in June, and in 1953 in July.

Comparing these results with what was obtained in the Gardiners-Peconic Bays area, it is apparent that annulus formation does not occur necessarily at the same time from year to year in any one area, or in any one year, in the two areas studied. However, on the basis of this limited study, it may be concluded that annulus formation can take place anytime from June through August. Further, the regularity of the increase and decrease in the size of the terminal zone from the designated last annulus, and the repetition of this phenomenon in two different areas in each of two years, confirms the validity of the criteria for designation of an annulus on a weakfish scale developed by Taylor (1916) and followed in the present study.

DETERMINATION OF AGE AND GROWTH

The scales of weakfish can be relatively easily read and measured for age and growth determinations when mounted dry between two glass slides. They were studied using a scale projector of the type

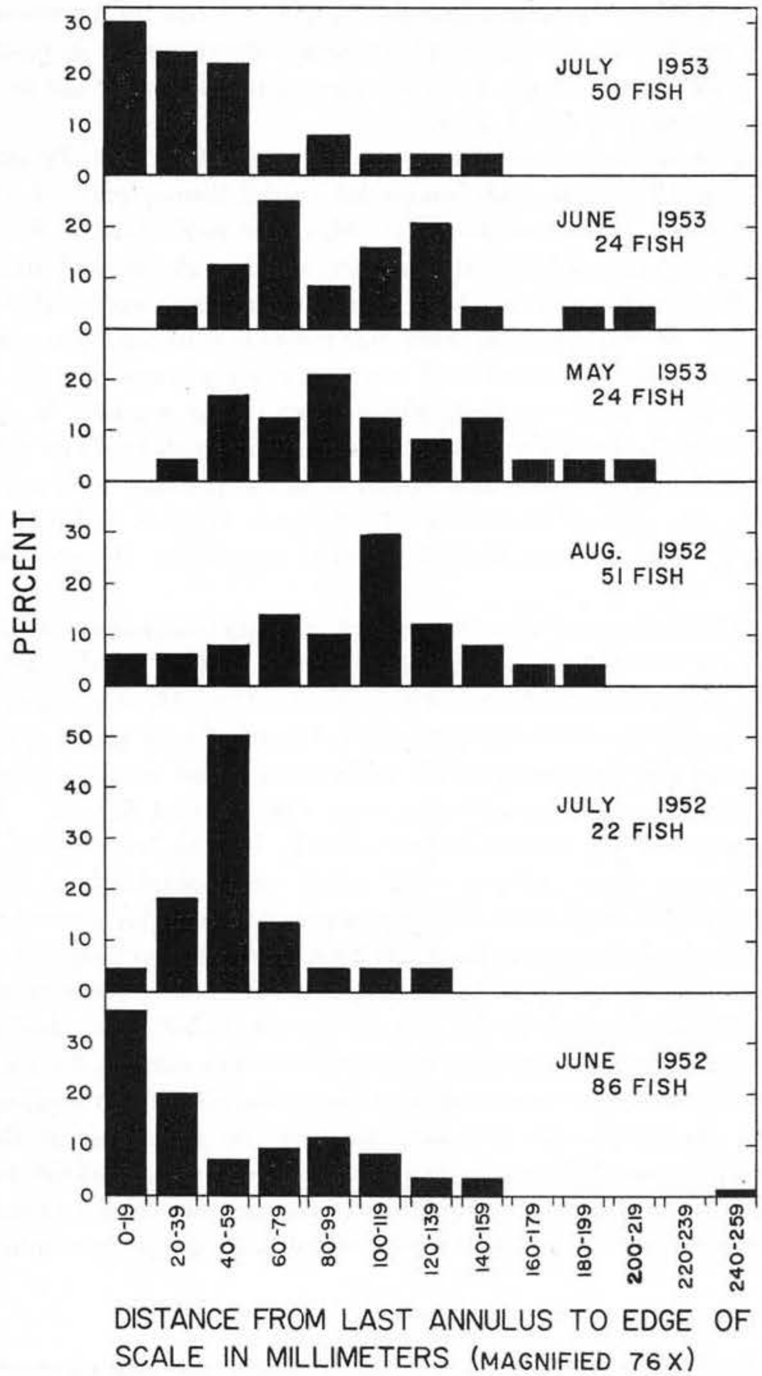


Figure 16. Percentage frequency distributions of measurements of the "terminal zone" of weakfish scales taken at various times of the year in 1952 and 1953 in Great South Bay.

described by Van Oosten, Deason and Jobes (1934). Scales from 762 fish collected in New York waters in 1952 were examined, of which 20 were not used because of regenerated centers or broken edges. To determine the rate of growth and to calculate the lengths of fish in a particular age group for various year classes, the initial step was to determine the relationship of scale radius to fish length (Figure 17).

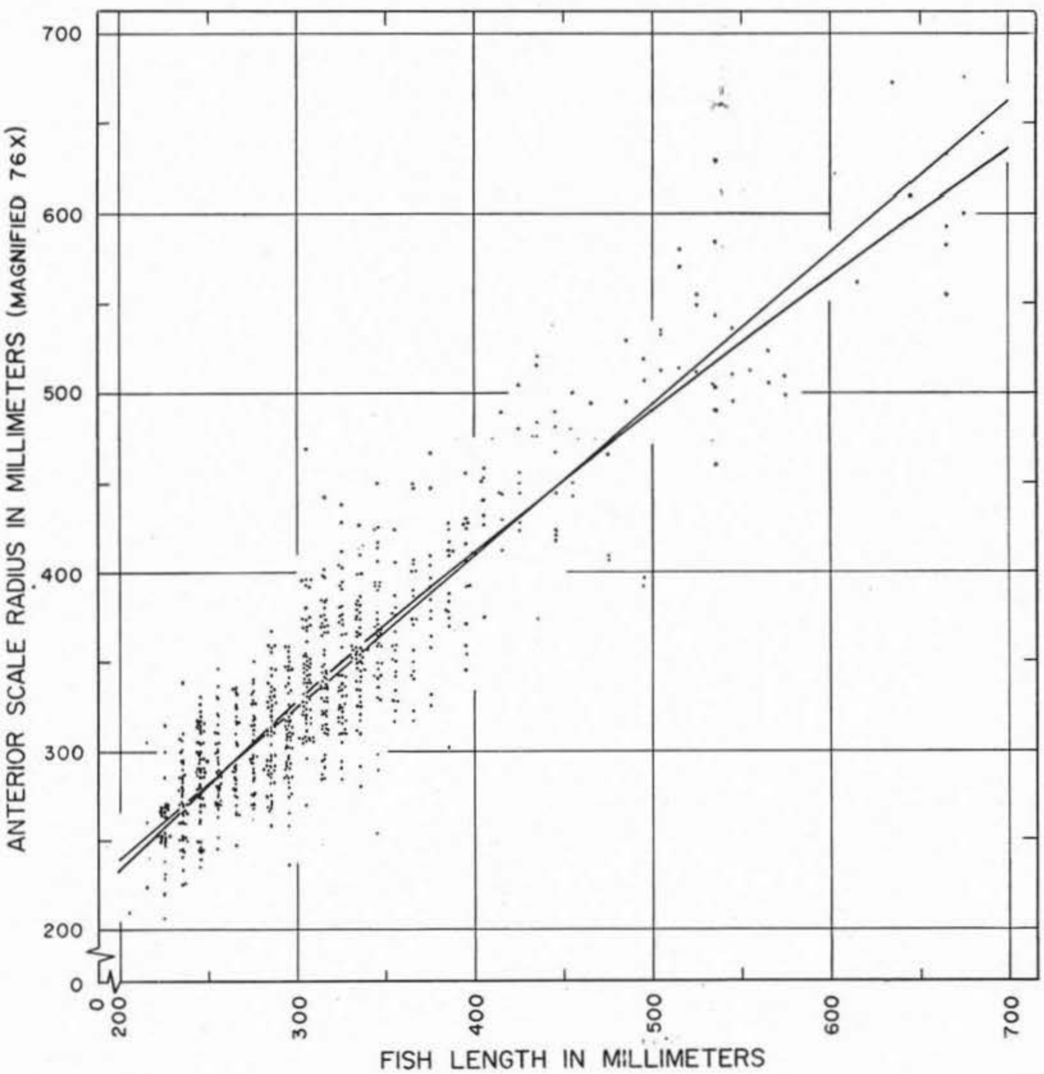


Figure 17. Relationship of the fork length to the anterior scale radius of 742 weakfish collected in New York waters in 1952. Straight line fit: $Y = 76.96 + 4.17X$. Curved line fit: $\log Y = 1.1144 + 7874X$; $C = -1.4152$.

It appeared that a slightly curvilinear relationship existed between the anterior scale radius and fish length. Since the logarithmic equation fit this relationship better than the arithmetic equation, logarithmic values were used in the following formula, by means of which fish lengths were computed from scale measurements:

$$Ln = C + \frac{Sn\ (L - C)}{S}$$

in which,

Ln = the logarithm of the computed fork length of the fish at the end of any year.

C = correction factor representing the intercept value at the X axis of a straight line fitting the data.

Sn = the logarithm of the anterior scale radius to any annulus.

L = the logarithm of the fork length of the fish when caught.

S = the logarithm of the anterior scale radius of the fish when caught.

The results of these calculations have been summarized in Table 10. The average length of weakfish at each annulus from one to six has been calculated for various year classes from 1946 to 1951. Figures for the male and female fish were computed separately and compared to see if there was a difference in the rate of growth between the sexes. Only the 1949, 1950, and 1951 year classes were available in large enough numbers to warrant comparison. Simple inspection of the data is enough to show that there was no consistent difference in the average size of the males and females. The calculated average lengths of weakfish for both sexes combined for the various year classes are also given in the table, and figures for the computed growth between the annuli are given in Table 11.

TABLE 10. CALCULATED AVERAGE LENGTH OF WEAKFISH IN MILLIMETERS AT EACH ANNULUS, BY YEAR CLASSES FROM 1946 TO 1951, COMPUTED FROM THE SCALES OF FISH TAKEN IN NEW YORK WATERS IN 1952

Year class	Number of fish		Annulus and sex																	
			1			2			3			4			5			6		
	Male	Female	M	F	T*	M	F	T*	M	F	T*	M	F	T*	M	F	T*	M	F	T*
1946	2	1	180	195	185	280	305	288	365	375	368	445	455	448	550	545	548	630	645	635
1947	2	4	195	185	188	260	285	277	310	350	337	400	448	432	525	560	548	...	...	...
1948	7	8	192	215	204	272	316	296	341	411	378	426	501	466	...	...	...	...	...	...
1949	36	36	200	192	196	266	264	265	358	351	355	...	...	...	...	...	...	...	...	...
1950	89	66	188	196	191	278	290	283	...	...	...	...	...	...	...	...	...	...	...	...
1951	205	286	206	211	209	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

*Combined males and females.

TABLE 11. CALCULATED AVERAGE GROWTH OF WEAKFISH IN MILLIMETERS BETWEEN ANNULI, BY YEAR CLASS FROM 1946 TO 1951, COMPUTED FROM THE SCALES OF FISH TAKEN IN NEW YORK WATERS IN 1952

Year class	Number of fish	Annuli					
		0—1	1—2	2—3	3—4	4—5	5—6
1946	3	185	108	82	85	102	85
1947	6	188	92	62	98	122	..
1948	15	204	93	85	92	..	..
1949	72	196	72	91	..	..	..
1950	155	191	94	..	..	..	..
1951	491	209	..	..	..	..	..

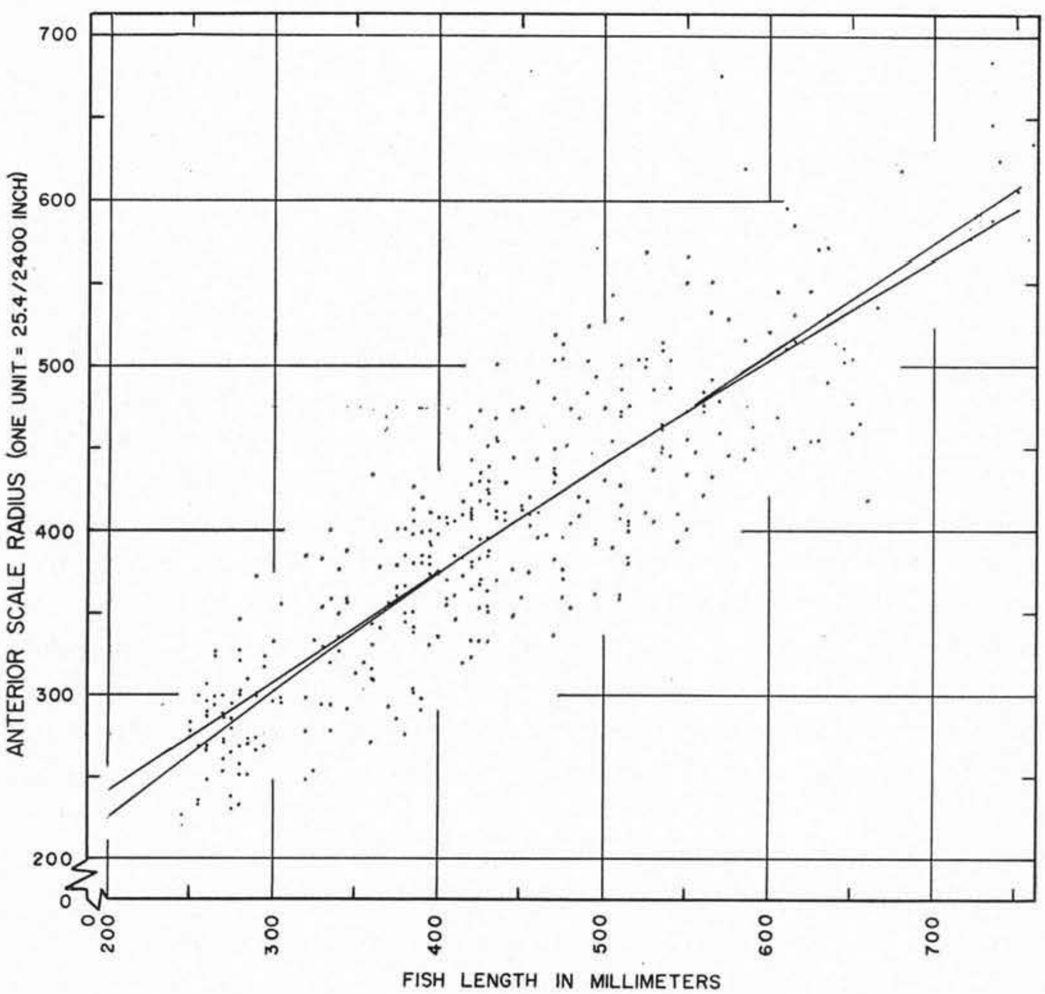


Figure 18. Relationship of the fork length to the anterior scale radius of 399 weakfish collected in Great South Bay in 1929. Straight line fit: $Y = 109.24 + 3.31X$. Curved line fit: $\log Y = 1.1733 + 0.7355X$; $C = -1.5952$.

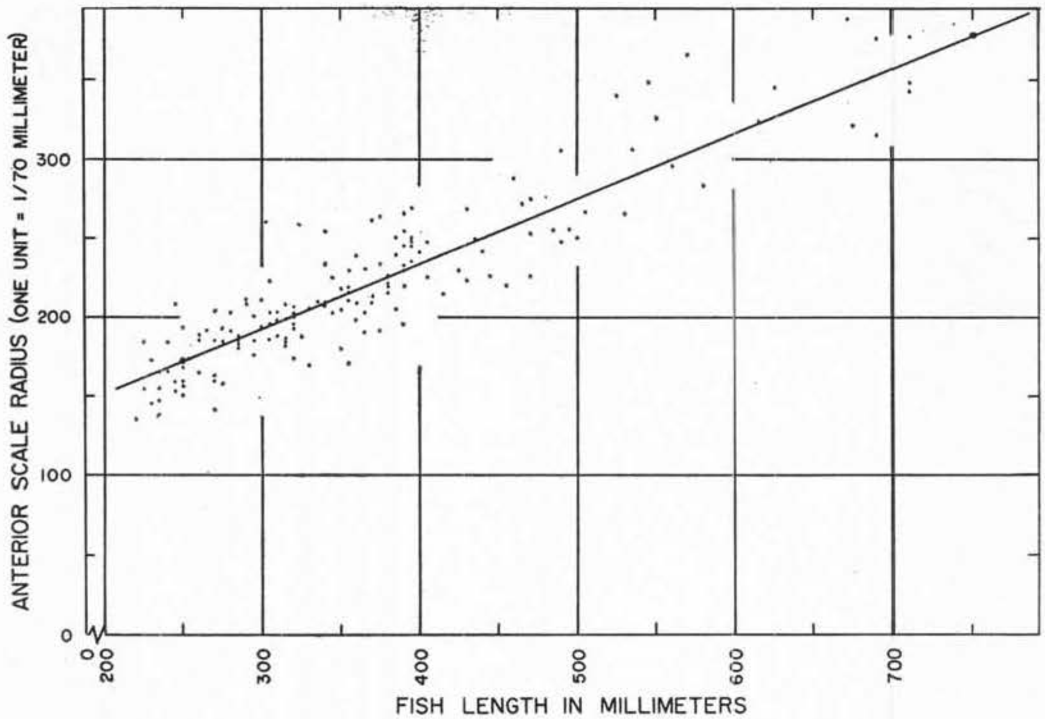


Figure 19. Relationship of the fork length to the anterior scale radius of 152 weakfish taken in Chesapeake Bay in 1929. Straight line fit: $Y = 69.53 + 2.06X$; $C = -33.75$.

The same technique as described in the preceding paragraphs was used to determine the age and growth of weakfish in Long Island waters (Great South Bay) and Virginia waters (Chesapeake Bay) from data collected by Nesbit in 1929. However, he used one type of unit in measuring the scales from the Long Island fish, and another type in measuring the scales from the Virginia fish, and both these units were different from that used in the present study. Therefore, separate analyses were made of the relationship of the anterior scale radius to the length of the fish for the New York and Virginia data collected in 1929, and curves fitted to these data (Figures 18 and 19) to obtain a constant term (C) for use in the formula already described.

Again, the average sizes of the male and female fish were computed separately for the New York data (Table 12). Inspection of the results appears sufficient to show that from the first to the seventh annulus there was no consistent difference between the average sizes of the males and females. At any annulus, in some year classes the males were slightly larger than the females, while in other year classes the reverse was true. These findings are in agreement with

TABLE 12. CALCULATED AVERAGE LENGTH OF WEAKFISH IN MILLIMETERS AT EACH ANNULUS, BY YEAR CLASS FROM 1921 TO 1928, COMPUTED FROM THE SCALES OF FISH TAKEN IN NEW YORK WATERS IN 1929*

Year class	Number of fish		Annulus and sex																							
			1			2			3			4			5			6			7			8		
	Male	Female	M	F	T§	M	F	T§	M	F	T§	M	F	T§	M	F	T§	M	F	T§	M	F	T§	M	F	T§
1921	10	7	167	166	166	215	226	219	256	262	259	286	291	288	324	315	320	378	345	364	443	385	419	523	439	488
1922	25	22	196	182	190	254	240	247	283	273	279	311	300	306	338	335	336	379	379	379	444	440	442	...	...	...
1923	32	27	206	204	205	255	261	258	291	300	295	323	325	324	371	379	375	435	447	440	...	...	...	...	...	...
1924	22	35	187	189	188	247	257	253	283	299	293	330	359	348	384	425	409	...	...	...	...	...	...	...	...	...
1925	15	23	209	179	191	277	254	263	318	310	313	361	368	365	...	...	...	...	...	...	...	...	...	...	...	...
1926	20	18	209	211	210	279	281	280	349	330	340	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1927	50	40	197	202	199	282	288	284	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1928	35	18	188	182	186	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

*Based on Nesbit's scale readings (unpublished data).
§Combined males and females.

TABLE 13. CALCULATED AVERAGE GROWTH OF WEAKFISH IN MILLIMETERS BETWEEN ANNULI, BY YEAR CLASS FROM 1921 TO 1928, COMPUTED FROM THE SCALES OF FISH TAKEN IN NEW YORK WATERS IN 1929*

Year class	Number of fish	Annuli							
		0—1	1—2	2—3	3—4	4—5	5—6	6—7	7—8
1921	17	166	53	40	29	32	38	55	71
1922	47	190	58	31	27	31	43	63	..
1923	59	205	54	38	30	50	65	..	..
1924	57	188	65	42	53	61	..	..	..
1925	38	191	71	51	55	..	..	..	..
1926	38	210	67	60	..	..	..	..	..
1927	90	199	80	..	..	..	..	..	..
1928	53	186	..	..	..	..	..	..	..

*Based on Nesbit's scale readings (unpublished data).

TABLE 14. CALCULATED AVERAGE LENGTH OF WEAKFISH IN MILLIMETERS AT EACH ANNULUS, BY YEAR CLASS FROM 1922 TO 1928, COMPUTED FROM THE SCALES OF FISH TAKEN IN CHESAPEAKE BAY IN 1929*

Year class	Number of fish	Annulus						
		1	2	3	4	5	6	7
1922	6	183	245	272	319	369	424	465
1923	21	174	251	280	321	367	418	...
1924	25	155	238	276	327	366	...	...
1925	25	167	249	290	331	...	...	...
1926	25	181	264	301	...	...	...	...
1927	25	169	252	...	...	...	...	...
1928	25	134	...	...	...	...	...	...

*Based on Nesbit's scale readings (unpublished data).

TABLE 15. CALCULATED AVERAGE GROWTH OF WEAKFISH IN MILLIMETERS BETWEEN ANNULI, BY YEAR CLASS FROM 1922 TO 1928, COMPUTED FROM THE SCALES OF FISH TAKEN IN CHESAPEAKE BAY IN 1929*

Year class	Number of fish	Annuli						
		0—1	1—2	2—3	3—4	4—5	5—6	6—7
1922	6	183	62	27	47	50	54	42
1923	21	174	77	30	41	46	50	..
1924	25	155	83	44	45	46	..	..
1925	25	167	82	41	41	..	..	..
1926	25	181	84	37	..	..	..	..
1927	25	169	84	..	..	..	..	..
1928	25	134	..	..	..	..	..	..

*Based on Nesbit's scale readings (unpublished data).

the results obtained from the previously described age and growth study of weakfish from New York waters in 1952. Computed growth between the annuli is shown in Table 13.

The calculated average lengths of weakfish from Chesapeake Bay, as computed from the 1929 material, are shown in Table 14, and the computed growth between the various annuli in Table 15.

DISCUSSION OF RESULTS

The calculated average lengths of weakfish for the combined sexes at various annuli for each year class, obtained from analysis of the New York and Virginia materials collected in 1929 and from the New York material collected in 1952 (as summarized in Tables 10, 12, and 14) have been plotted in Figure 20. One of the most striking things in this graph is the agreement in the values for the average length at the first annulus of the weakfish from New York waters in the periods from 1921 to 1928 and from 1946 to 1951. Also note-worthy is the smaller size of this age group from Virginia waters in the 1922-1928 period. It seems that in the 1-year-old fish, which were presumably products of local spawning, the rate of growth remained fundamentally the same over the years in the northern area. Also, where comparative data for both the northern and southern areas were available (1922-1928), it appears that the northern fish were faster growing than their southern-spawned counterparts.

From the first annulus on, the average length of the weakfish from New York waters at each annulus in the period from 1921 to 1928 in general became progressively greater for each new year class. However, this phenomenon was not true for the fish taken in Virginia waters in the same period. Instead, they had much the same values for average length at a particular annulus for various year classes. Also, the average lengths of fish from New York waters in the period from 1946 to 1951 showed no consistent year-class variation at a particular annulus.

The question rises as to what was responsible for the apparent progressive increase in the average size at each annulus beyond the first one for the various year classes of fish taken in New York waters from 1921 to 1928. A comparison of the average sizes of the fish at each annulus beyond the first in the New York area during the 1921-1928 period and during the 1946-1951 period shows that in the later period the fish were considerably larger at a particular annulus than they were in the earlier period. Thus, the average size at the

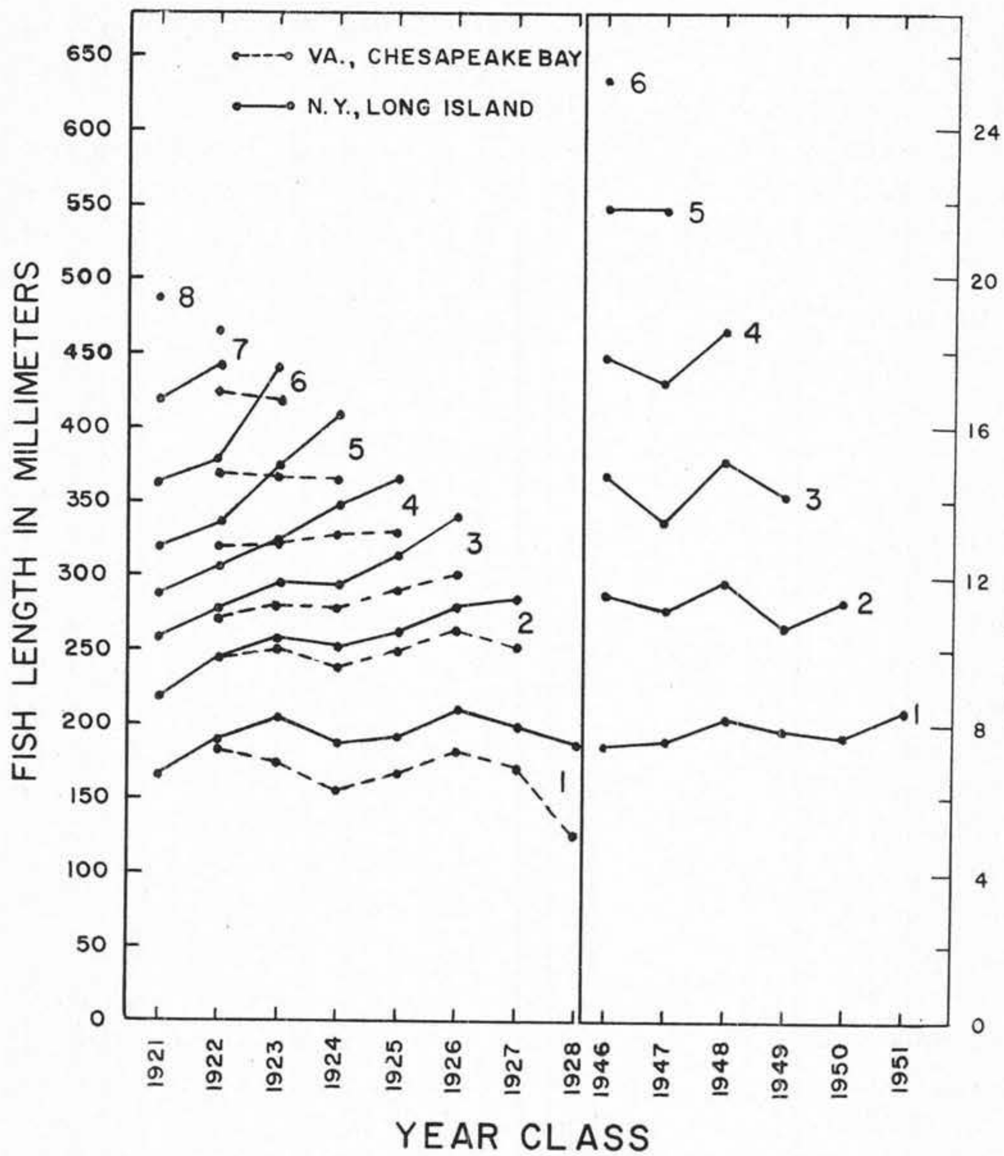


Figure 20. Comparison of the calculated average lengths of weakfish at various annuli for different year classes from 1921 to 1928 in Virginia and New York, and from 1946 to 1951 in New York.

fourth annulus from 1946 to 1948 was roughly equivalent to that at the seventh annulus in 1921 and 1922. Further, in the 1922-1928 period, it appears that the New York fish were larger at any given annulus than were the Virginia fish.

Based on these data alone, there is a logical explanation for the apparent progressive increase in the average size of fish at each annulus from year class to year class in New York during the 1921-1928 period. If the northern-spawned fish are faster growing than their southern counterparts, and there is no intermixture of the two, then a plot of the average size at an annulus for a series of year classes from each group would be similar to that shown at the first annulus for the 1921-1928 period (Figure 20). Minor fluctuations in size from year class to year class in the two groups would tend to parallel each other, but the two groups would still remain distinctive in size. Since the southern-spawned group grows more slowly, the more of these which come north to mix with the faster growing northern-spawned group, the greater will be their effect on the average rate of growth of the mixed northern population available to the fisheries, and the smaller will be the average sizes of the fish in the various age classes. Thus, the apparent progressive increase in the average size of fish from year class to year class at each annulus beyond the first in New York during the 1921-1928 period, and the uniformly large average size of fish from year class to year class at each annulus beyond the first in the 1946-1951 period, would indicate that the number of southern-spawned fish contributing to the northern population available to the fishery declined in each year from 1921 to 1928. Also, in the 1942-1951 period the southern contributions were very low compared to those in 1921 and 1922.

These conclusions are in agreement with the findings obtained in the studies of the scale sculpturing as reported under the preceding topic.

LITERATURE CITED

HUBBS, CARL L. and ALFRED PERLMUTTER. 1942. Biometric comparison with particular references to racial investigations. Amer. Nat. 76: 582-592.

NESBIT, ROBERT A. 1954. Weakfish migration in relation to its conservation. U. S. Fish and Wildl. Serv. Special Scientific Report, Fisheries No. 115.

PERLMUTTER, ALFRED. 1939. An ecological survey of young fish and eggs identified from tow-net collections. In: A Biological Survey of the Salt Waters of Long Island, 1938, Part II. N. Y. Cons. Dept. :11-71.

TAYLOR, HARDEN F. 1916. The structure and growth of the scales of the squeteague and the pigfish as indicative of the life history. Bull. U. S. Bur. of Fish. 34:285-330.

VAN OOSTEN, JOHN, H. J. DEASON, and FRANK W. JOBES. 1934. A microprojection machine designed for the study of fish scales. Journal du Conseil. 9(2):241-248.

WELSH, WILLIAM W. and C. M. BREDER, JR. 1924. Contributions to the life histories of Sciaenidae of the eastern United States coast. Bull. U. S. Bur. of Fish. 34:141-201.

WISNER, WILLIAM. 1953. The weak-jawed prince. Fishing Long Island Waters 4(6):17, 27-28.

SOME ASPECTS OF RED FOX AND GRAY FOX REPRODUCTION IN NEW YORK [1]

James N. Layne Assistant Professor of Biology
Department of Biology, University of Florida

Warren H. McKeon Assistant Game Research Investigator
New York State Conservation Department

ABSTRACT

Data on numbers, sex ratios, breeding seasons, and various aspects of fecundity were obtained for red foxes and gray foxes trapped during 1951, 1952, and 1953 in three environmentally distinct parts of the State. These regions, designated as northern, Lake Plain, and southern, differ from one another in topography, soils, climate, and other factors.

Red foxes and gray foxes were trapped in a ratio of about 10 to 1. There was no evidence of an appreciable change in abundance for either species during the 3-year interval. Red fox population indices averaged highest in the northern region, lowest in the Lake Plain, and intermediate in the southern region. For neither species did the population indices exhibit a consistent trend of reduction in counties trapped for consecutive years.

Estimates of proportion of barren females, ovulation rate, implantation success, and resorption were used to compare the reproductive success of the two species during the period of study. Further analysis on a yearly and regional basis was made of the red fox data. Mean litter sizes calculated from values obtained for these factors showed a reasonable correspondence with average litter sizes based on the direct evidence of fetal and placental scar counts. Average annual productivity of red foxes during the 3-year period was estimated to be about 214 per cent per adult as compared with 182 per cent for the gray fox. On a regional basis red fox productivity ranged from 180 per cent in the northern region to 320 per cent in the Lake Plain. The data suggest that a higher breeding potential is at least in some measure indicative of a more nearly optimum balance between the population density and the environmental capacity of the particular habitat.

The data pertaining to reproductive success appear to relate to the fox rabies control program in New York in at least two ways. First, the productivity values obtained probably provide a fairly accurate indication of the proportion of the population that must be eliminated if a net reduction in numbers is the goal. Second, if a significant relationship between population density, carrying capacity, and reproductive potential does exist, trapping may in some instances result in an increase in relative productivity. Nevertheless, it is felt that if, through trapping, fox populations can be prevented from attaining high density levels, the opportunity for rabies to spread can be reduced.

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The general features of the natural history of the red fox *(Vulpes fulva)* and gray fox *(Urocyon cinereoargenteus)* are comparatively well known. However, a more detailed knowledge of specific aspects of their biology is often necessary to evaluate fox management problems in particular situations or localities, and such data may be surprisingly meager when the number of foxes annually trapped or shot in many parts of the country is considered.

This study was conducted from April, 1951, to April, 1953, in order to obtain detailed and quantitative information pertaining to certain phases of reproduction in the two species in New York.

PROCEDURE

The findings presented result primarily from the analysis of material and records contributed by professional trappers employed by the State to reduce fox populations in specified areas as a rabies control measure. Nineteen counties are represented in the red fox sample and 15 in that for the gray fox (Figure 1).

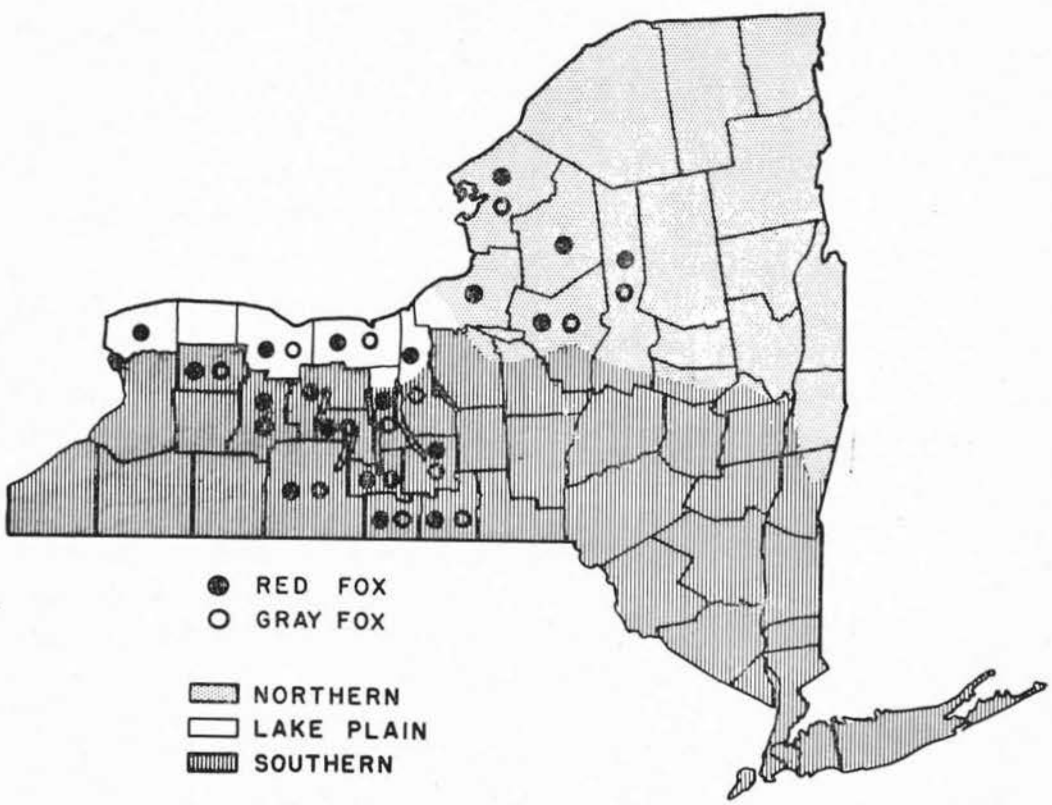

Figure 1. Limits of the northern, Lake Plain, and southern regions of New York as used in this study and location of counties from which fox reproductive material was obtained.

Information on numbers and sex ratios was extracted from the trappers' monthly reports in which the period of trapping, the number of traps set, and the fox take according to species, sex, and age (pup or adult) were recorded.

Data on reproduction were largely secured from gross study of female reproductive organs that had been removed from trapped animals by the trappers, tagged as to date and locality, and preserved in 10 per cent formalin. Approximately 1,150 reproductive tracts were collected from both species. Of this total, 1,091, including 1,003 red foxes and 88 gray foxes, yielded at least certain items of usable information.

Individual record cards were kept for each genital tract; and, in addition to species, date, and locality (county and township), the following items were recorded where possible:

1. Reproductive status (subadult, barren adult, or parous adult).
2. Appearance of reproductive tract (not enlarged, slightly turgid, fully turgid, pregnant, recent partum, or slightly enlarged).
3. Width of uterus (measured between uterine swellings, if present).
4. Width of vagina just below cervix.
5. Greatest length and width of both ovaries.
6. Number and disposition in right and left uterine horns of placental scars, uterine swellings, or fetuses, if present.
7. Presence or absence of macroscopic follicles in ovaries, and degree of development if present.
8. Total number and distribution in right and left ovaries of corpora lutea, if present.
9. Incidence of resorption and number of embryos affected.

Normal fetuses were aged according to a fetal growth curve of body weight established for captive silver foxes by Smith (1939) and provided data on breeding seasons through back-dating to the approximate time of conception.

DESCRIPTION OF STUDY AREA

The counties from which fox data were gathered represent three environmentally distinct parts of the State, which have been designated as the northern, Lake Plain, and southern regions (Figure 1).

The northern region has been denoted by Morton and Cheatum (1946) as that area north of the New York Central and Boston and Albany railroad tracks from Columbia County on the east to Oswego County on the west. This area is mainly comprised of three physiographic subregions: The Adirondack Highlands, the Tug Hill Plateau, and the St. Lawrence Lowland. The Adirondack Highlands, with elevations ranging from 1,000 to 5,300 feet, are located in the eastern and central part of the region and cover the most extensive area of the three subregions. Although generally mountainous throughout, their greatest elevations and most rugged topography are in the eastern section. Foxes are relatively scarce there; and, since the mountains apparently serve as a natural barrier to fox movements, no systematic trapping was conducted. The Tug Hill Plateau adjoins the Adirondack province on the west. It lies at an elevation of 1,000 to 2,000 feet and is in contact at its western and southern boundaries with lowlands averaging less than 500 feet in elevation. The St. Lawrence Lowland is a gently rolling plain some 25 or 30 miles wide that lies between the Tug Hill Plateau and the eastern end of Lake Ontario and extends northeastward along the St. Lawrence River.

Fox data representing northern populations were obtained from a block of five counties situated somewhat peripherally to the main part of the northern region. Although some stations were located in the St. Lawrence Lowland, the majority of the trap lines were maintained in the Tug Hill area and Adirondack foothills. The principal forest type in this region is beech, birch, maple, and hemlock. Characteristic soils include Gloucester loam, Merrimac fine sand, Worth stony fine sandy loam, and Ontario loam. With the exception of the latter, all are rated by Howe (1935) as being of low natural productivity.

The northern region as a whole is characterized by lower temperatures, shorter growing season, and greater annual precipitation than the remainder of the State. Average July temperatures in those counties from which foxes were trapped range from 65.1° to 70.8°F., and mean January temperatures from 16.3° to 23.1°F. (Kincer, 1941). The average growing seasons for the same counties are between 117 and 156 days, and annual precipitation averages between 37.2 and 51.4 inches.

The Lake Plain region is a low-lying district that borders the southern shore of Lake Ontario and extends southward some 30 or 40 miles to meet the Appalachian Plateau. For the purposes of this study, the Lake Plain was delimited as the first tier of counties south of Lake Ontario, including the northern parts of Seneca and Cayuga Counties and the southeastern corner of Oswego County. In this area forest cover is of the central hardwoods type, of which oak, hickory, elm, ash, sycamore, poplar, and basswood are typical. The highly productive Dunkirk silty clay loam and Ontario loam soils predominate; whereas soils of lower productivity are of more limited distribution (Howe, 1935). Average July temperatures in counties where fox trapping was conducted are 70.1° to 71.6°F., and mean January temperatures range from 24.9° to 25.9°F. (Kincer, 1941). The proximity of Lake Ontario has a significant moderating influence on the climate of the region, with the result that growing seasons in the Lake Plain are among the longest in the State, averaging from 160 to 178 days in the counties from which foxes were obtained. Mean annual precipitation varies from 27.0 to 36.2 inches.

The remainder of the State is included in the southern region which is principally a highlands area. The Appalachian Plateau constitutes a major portion, and data pertaining to foxes were obtained from 11 counties included wholly or in part within its limits in the central part of the State. The land surface in this area is deeply dissected, resulting in a characteristic topography of flat or broadly rounded hilltops and deep valleys. Elevations vary from about 1,200 to 2,000 feet. Northern hardwoods (beech, birch, maple, and hemlock) are typical of much of the region, although oak-hickory associations are not infrequent. Representative soils include Ontario loam, Langford silt loam, Mardin gravelly silt loam, Volusia silt loam, and Chenango gravelly loam (Howe, 1935). The soils of the southern region vary considerably in their degree of natural productiveness. In aggregate, they are probably somewhat less fertile than those of the Lake Plain. Mean July temperatures of the counties from which specimens were obtained are between 69.4° and 72.2°F., and average January temperatures lie between 22.7° and 28.7°F. (Kincer, 1941). Annual precipitation averages 26.9 to 36.8 inches, and mean length of growing season ranges from 136 to 162 days.

FOX POPULATIONS

The red fox apparently greatly outnumbers the gray fox in New York at the present time. Records of 1,353 gray foxes and 14,333 red foxes trapped over a major part of the State from 1951 to 1953 give a proportion of about 1 to 10. This ratio is considerably higher than that (1:3.1) based on the reported take in New York in 1940 (Seagears, 1944) and suggests that a significant shift may have occurred in the relative numbers of the two species in recent years. If a change in the status of red fox and gray fox populations has developed, it is not clear whether it is due to a decrease in gray foxes, an increase in red foxes, or a combination of both factors, although some trappers and other competent observers contend that gray foxes are actually less abundant now than they were 10 or so years ago.

Since the analysis of certain reproductive phenomena becomes more meaningful when considered in relation to population density, some index of fox abundance was desirable for the purposes of this study. The most satisfactory measure of population levels obtainable from the available trapping records appeared to be an index based on numbers of foxes taken per trap night (one trap set for one night equaling a trap night). Ideally, the best estimate of this sort for comparative purposes would be one calculated on the basis of data obtained during the same period from all areas. Such a refinement was not possible in the present study, as the sections of the State from which data came were at no time simultaneously trapped.

Population indices for each county have been obtained by dividing the number of foxes (weighted according to the skill of the individual trappers) taken in all townships in a county by the total number of trap nights involved. Only adults were considered, so that the take in different townships within the same county before and after pups have left the dens would be comparable. Data from September, October, and November were excluded, as this is the time of the annual "fall shuffle", and population estimates made during this period might not be truly representative of the specific area under consideration. In addition, only records for the second consecutive month of trapping in each township were used in calculating the index. There were two reasons for doing this: trappers in unfamiliar territory had generally completed exploratory work and were trapping efficiently by the second month; and the second month in a series of trapping records usually showed the highest trapping success ratio, indicating that populations may have been most vulnerable during this period. Furthermore, movements into and out of a trapped area of township size might have been sufficient to distort an index based on a longer trapping interval. Because of obvious variation in the skill of individual trappers, a further refinement in computing the index appeared to be justified. Trappers were rated as being 100, 75, or 50 per cent effective on the basis of their ability as compared with that of other trappers and as evaluated by supervisors, and their reported catches were weighted accordingly.

Yearly and regional population indices were based on the total weighted take and trap nights, obtained in the manner described above, in all townships for a given year or region.

No definite trend in red fox abundance is apparent over the 3-year interval. Yearly population indices for all counties show an increase from 1951 to 1952 (0.020 to 0.024) followed by a decrease in 1953 (0.015). The decline in 1953, if actually experienced by the population, may have been less marked than is suggested by the index, as the index for this year was based on data for the period January-March rather than December-August as in the other two years. Poor trapping conditions in late winter and early spring coupled with the fact that foxes, particularly gravid females, may range less extensively at this season may result in a lower catch per unit of effort during this period than at other times of the year.

Gray fox populations also appear to have been relatively stable from 1951 to 1953. The over-all index rose from 0.005 in 1951 to 0.007 in 1952 and 1953.

Red fox population indices during the 1951-53 period averaged higher in the northern and southern regions than in the Lake Plain (Table 1), a pattern of relative abundance that corresponds closely to that demonstrated by Seagears (1944). Population indices increased from 1951 to 1952 and dropped in 1953 in all regions. Only January to March data were available for calculation of the 1953 indices, and this must be considered in the interpretation of the values for the reasons already stated.

For neither the red fox nor the gray fox is there marked evidence of a consistent reduction in numbers in those counties that were trapped for consecutive years by professional trappers (Table 1). In 21 instances of two consecutive years of trapping for red foxes, the density the second year apparently was higher in 10 cases and lower in 11. Of the 14 instances of two consecutive years of trapping for gray foxes, the population index the second year was higher in 7 cases, lower in 6, and showed no change in the other.

SEX RATIOS

Sex ratios among the adults and pups of both species trapped from 1951 through 1953, and of fetuses recovered from pregnant

TABLE 1. RED FOX AND GRAY FOX POPULATION INDICES BY COUNTY AND REGION OF NEW YORK FROM 1951 TO 1953

County and region	Red fox			Gray fox		
	1951	1952	1953	1951	1952	1953
Allegany	...	0.041	...	...	0.008	...
Cayuga	0.010	0.013	0.011	0.008	0.010	0.002
Chemung	0.026	0.013	...	0.011	0.010	...
Herkimer	0.012	...	...	0.003	...	...
Jefferson	0.035	0.038	...	0.003	0.009	...
Lewis	0.033	0.029	0.012	0.004	0.004	...
Livingston	...	0.125	0.040	...	...	0.010
Monroe	0.020	...	...	0.011	...	...
Oneida	0.026	0.013	...	0.004	0.019	0.040
Ontario	0.018	...	0.017	0.006	...	...
Oswego	0.056	0.020	...	0.004	0.001	...
Schuyler	0.026	0.031	0.022	0.005	0.008	...
Seneca	0.007	0.017	0.019	0.007	0.015	0.012
Steuben	0.008	0.035	0.026	0.003	...	0.008
Tioga	0.027	0.036	0.018	0.007	...	0.005
Tompkins	0.013	0.136	0.036	0.004	0.003	...
Wayne	0.011	0.025	0.042	0.009	0.010	0.005
Yates	0.020	...	...	0.011	...	...
Northern	0.026	0.028	0.012*	...	...	...
Lake Plain	0.012	0.023	0.016*	...	...	...
Southern	0.015	0.025	0.021*	...	...	...

*Includes data from January to March only.

vixens during this interval, are given in Table 2. Pups can be easily distinguished from adults until October. After this month aging trapped animals on the basis of external examination is less reliable. Consequently, in calculating sex ratios all specimens taken after October have been considered adult.

Yearly and total sex ratios of 9,782 adult red foxes and 1,132 adult gray foxes show a consistent and significant (chi-squares exceeding 3.841) preponderance of males. Since a similar trend is not apparent in the sex ratios for pups, it might be assumed that the greater number of males among the adults caught was probably due in large part to the fact that males range more widely than females and thus have a greater probability of being captured.

It will be noted that in both species adult males outnumbered the females throughout the year. Sheldon (1949, 1950) believed the disparate sex ratio to be particularly prominent in the fall, when adult males and male pups are known to travel widely. He noted (1950) that the sexes of foxes caught in the Catskills of New York in January and February were reportedly about even. Richards and

TABLE 2. NUMBERS TAKEN AND SEX RATIOS ACCORDING TO AGE CLASS FOR RED FOXES AND GRAY FOXES COLLECTED IN NEW YORK FROM 1951 TO 1953

Age class and season	1951			1952			1953			Total		
	Number		Sex ratio*	Number		Sex ratio*	Number		Sex ratio*	Number		Sex ratio*
	M	F		M	F		M	F		M	F	
Red fox												
Adult	1,745	1,247	139.9	2,607	2,184	119.4	1,090	909	119.9	5,442	4,340	125.4
January–April	116	68	170.6	300	187	160.4	129	104	124.0	545	359	151.8
May–August	718	577	124.4	951	781	121.8	511	450	113.6	2,180	1,808	120.6
September–December	911	602	151.3	1,356	1,216	115.1	450	355	126.8	2,717	2,173	125.0
Pup (April–October)	715	754	94.8	795	774	102.7	698	815	85.6	2,208	2,343	94.2
Fetus	...	...	...	28	19	147.4	58	37	156.8	86	56	153.6
Gray fox												
Adult	255	137	186.1	274	214	128.0	136	116	117.2	665	467	142.4
January–April	41	16	256.2	32	18	177.8	15	13	115.4	88	47	187.2
May–August	118	63	187.3	82	64	128.1	40	41	97.6	240	168	142.9
September–December	96	58	165.5	160	132	121.1	81	62	130.6	337	252	133.7
Pup (April–October)	49	48	102.8	25	16	156.2	45	38	118.4	119	102	116.7
Fetus	12	9	133.3	5	5	100.0	...	...	...	17	14	121.4

*Males per 100 females.

Hine (1953) found the proportion of red fox males in Wisconsin to be higher (54 per cent) from September to December than from January to March (45 per cent). The present data indicate a somewhat different picture in that the preponderance of males in both species was highest in the January-April period and considerably less the rest of the year. This is apparently explained by the fact that during at least the latter part of the January-April period breeding females are probably more secretive and restricted in their movements than at any other time of the year, because of advancing pregnancy, whelping, and early postnatal care of the young. At this time the males, although possibly having a smaller home range than at other seasons, are probably even more mobile as compared to females than during the rest of the year. The more unbalanced sex ratio of gray foxes during the May-August period than in the fall and early winter months is assumed to be merely a reflection of the later breeding season of this species.

The sex ratios of 142 red and 31 gray fox fetuses in which the sex could be positively determined are also of interest. For the latter the sample is much too inadequate to be given much weight and does not depart significantly from a 50-50 ratio. However, the higher percentage of red fox male fetuses is significant and when compared to the almost even sex ratio of the pups is difficult to explain unless it is a rare vagary of sampling. A possible explanation may be that differential mortality during gestation or before the pups left the den favored the survival of females and accounted for the more or less even sex ratio of the pups. On the other hand, some peculiarity of movement among pups may have masked an actually greater number of males in the population. Although no definite conclusions can be drawn from the present information, the data do suggest the possibility that the observed unbalanced sex ratio of adults may not have been due entirely to differential sexual selectivity of trapping.

BREEDING SEASONS

The breeding season of the red fox is generally considered to extend from December to March and that of the gray fox to lag about a month behind. In a previous study of foxes in New York, Sheldon (1949) found evidence of red foxes mating from late December to the end of March, with 76 per cent of the matings occurring between mid-January and mid-February. For the gray fox his data indicated a breeding season from late January to May, with 71 per cent of the matings taking place between the last week in February and the middle of March. The breeding season of red foxes in southwestern Wisconsin (Richards and Hine, 1953) is in close agreement with Sheldon's results, although one litter recorded apparently had been conceived during the first week of April. Gray fox breeding took place between mid-February and late March. Hoffman and Kirkpatrick (1954) concluded that the minimum duration of red fox breeding in Indiana was from December to mid-February.

In this study, breeding dates of 80 red and 21 gray foxes were estimated to the nearest week on the basis of observed copulation or reproductive tracts in the fully turgid (near estrous) condition, and by back-dating from aged fetuses or genital tracts indicating very recent parturition (Table 3). Red fox breeding dates occurred from the second week of January to the third week of April, with the majority of matings (83.8 per cent) recorded from the third week of January to the first week of February. Peak breeding activity appeared to have occurred slightly later in the northern region than in either the Lake Plain or southern regions. In neither of the two latter areas were matings recorded after mid-February, whereas in the northern region seven (29.3 per cent) of the 24 estimated mating dates occurred later.

In line with previous observations, the height of breeding occurred about a month later in the gray fox, and the breeding season as a whole appeared to be more prolonged (Table 3). Estimated breeding dates extended from the third week of January to the end of May. Over half (52.5 per cent) of the matings were calculated to have taken place in March. The few northern records suggest that the later occurrence of breeding there may be even more pronounced in this species than in the red fox.

SEASONAL VARIATION IN THE FEMALE REPRODUCTIVE ORGANS

Information pertaining to variation in appearance of the female genital organs at different stages of the yearly sexual cycle was obtained by gross examination of hundreds of preserved reproductive tracts. Histological studies of the reproductive organs of the silver fox and English red fox have been published by Rowlands and Parkes (1935). The female reproductive tracts of both the red and the gray fox are essentially similar, although the organs of the gray fox tend to be somewhat smaller than those of the red at corresponding stages of the breeding cycle. The difference is particularly evi-

Table 3. Distribution of Breeding Dates to the Nearest Week for 80 Red Foxes and 21 Gray Foxes in Three Regions of New York from April, 1951, to April, 1953*

Month and week	Red fox				Gray fox			
	Northern	Lake Plain	Southern	Total	Northern	Lake Plain	Southern	Total
January								
1	..	..	..	..	..	..	..	..
2	..	1 (7.1)	1 (2.4)	2 (2.5)	..	..	..	..
3	2 (8.3)	5 (35.7)	10 (23.8)	17 (21.3)	..	1 (20.0)	..	1 (4.8)
4	7 (29.2)	6 (42.8)	25 (59.5)	38 (47.5)	..	..	3 (30.0)	3 (14.3)
February								
1	5 (20.8)	2 (14.3)	5 (11.9)	12 (15.0)	..	..	..	..
2	3 (12.5)	..	1 (2.4)	4 (5.0)	..	1 (20.0)	..	1 (4.8)
3	1 (4.2)	..	..	1 (1.2)	..	1 (20.0)	1 (10.0)	2 (9.5)
4	4 (16.7)	..	..	4 (5.0)	..	..	..	1§(4.8)
March								
1	..	..	..	..	..	2 (40.0)	2 (20.0)	4 (19.0)
2	1 (4.2)	..	..	1 (1.2)	3 (60.0)	..	2 (20.0)	5 (23.8)
3	..	..	..	..	..	..	2 (20.0)	2 (9.5)
4	..	..	..	..	..	..	..	..
April								
1	..	..	..	..	..	..	..	..
2	..	..	..	..	..	..	..	..
3	1 (4.2)	..	..	1 (1.2)	..	..	..	..
4	..	..	..	..	..	..	..	..
May								
1	..	..	..	..	..	..	..	..
2	..	..	..	..	1 (20.0)	..	..	1 (4.8)
3	..	..	..	..	..	..	..	..
4	..	..	..	..	1 (20.0)	..	..	1 (4.8)

*Percentages given in parentheses.
§A litter for which locality not known.

dent in the size of the ovaries. The average length and width of 30 red fox ovaries from pregnant or recently parous animals were 15.7 and 11.1 millimeters, respectively. Thirty gray fox ovaries at a similar stage of the reproductive cycle had corresponding mean measurements of 10.5 and 7.3 millimeters. Even the corpora lutea at comparable stages were found to be noticeably smaller in this species.

The degree of development of the tubal genitalia of 844 red fox and 77 gray fox females collected from January to June and from October to December is presented in Table 4. Since there was apparently no significant change in the reproductive status of females between June and October, tracts from July, August, and September have been omitted from Table 4 and subsequent tables concerning follicular and corpora luteal cycles.

In both species the genital organs of young of the year could generally be easily distinguished from those of anestrous adults

TABLE 4. PERCENTAGE OF SPECIMENS FOR VARIOUS MONTHS SHOWING CONDITION OF THE REPRODUCTIVE TRACT FOR 844 RED FOX AND 77 GRAY FOX FEMALES COLLECTED IN NEW YORK FROM APRIL, 1951, TO APRIL, 1953*

Month	Condition of reproductive tract					
	Not enlarged	Slightly turgid	Fully enlarged	Pregnant	Recent parturition	Slightly enlarged
			Red fox			
January....	23.3 (14)	48.3 (29)	28.3 (17)	..	..	..
February...	..	14.3 (1)	42.8 (3)	42.8 (3)	..	..
March.....	1.4 (1)	1.4 (1)	1.4 (1)	37.5 (27)	47.2 (34)	11.1 (8)
April......	42.5 (57)	..	0.7 (1)	..	9.0 (12)	47.8 (64)
May.......	77.4 (195)	..	..	..	0.4 (1)	22.2 (56)
June.......	89.5 (68)	..	..	..	..	10.5 (8)
October....	46.3 (19)	53.6 (22)	..	..	..	..
November..	72.0 (67)	28.0 (26)	..	..	..	..
December..	52.3 (57)	47.7 (52)	..	..	..	..
			Gray fox			
January....	77.8 (7)	22.2 (2)	..	..	..	..
February...	..	..	..	..	..	..
March.....	22.2 (2)	..	33.3 (3)	44.4 (4)	..	..
April......	10.0 (2)	10.0 (2)	5.0 (1)	35.0 (7)	35.0 (7)	5.0 (1)
May.......	..	..	10.0 (1)	10.0 (1)	30.0 (3)	50.0 (5)
June.......	26.7 (4)	6.7 (1)	..	..	..	66.7 (10)
October....	60.0 (3)	40.0 (2)	..	..	..	..
November..	..	§ (1)	..	..	..	..
December..	62.5 (5)	37.5 (3)	..	..	..	..

*Number of specimens given in parentheses.
§Percentage omitted because of low number of specimens for this month.

throughout the summer and early fall. The uterine horns of the pup or subadult are relatively short and narrow (Figure 2, A). They are smooth, rather firm, and usually a clear creamy-white in color. A considerable amount of fat is frequently present in the mesometrium, and the uterine blood vessels are inconspicuous. The reproductive organs of anestrous adults are markedly larger (Figure 2, B). The uterine horns, which usually contain well-defined placental scars (except in the case of barren females), are flattened and lax. They are usually somewhat discolored, and their surface may be scored by fine striae. There is generally little fat in the mesometrium, and the uterine blood vessels are usually prominent. The mean widths of preserved uterine horns and vaginae of 49 adult red foxes in the non-enlarged or anestrous condition were 3.8 millimeters (3 - 5) and 4.6 millimeters (3 - 6), respectively, while corresponding measurements for 20 subadults were 2.1 millimeters (2 - 3) and 3.2 millimeters (2 - 5). The mean widths of uterine horns and vaginae of six adult gray foxes in anestrous condition were 3.5 millimeters (3 - 5) and 4.5 millimeters (4 - 5), respectively, while corresponding measurements for four subadults were 3.0 millimeters (2 - 4) and 3.0 millimeters (2 - 4).

For both species, initial evidence of sexual activity in the genital organs occurred in late fall and early winter with a slight increase in the diameter and turgidity of the tubal genitalia and enlargement of the cervix. Fully enlarged and turgid reproductive tracts, indicative of estrus (or very early pregnancy), occurred from January to April in red foxes and from March to May in gray foxes. The estrous period in silver foxes varies from 1 to 6 days, according to Pearson and Bassett (1946). The ovaries of a few tracts classified as fully turgid still had Graafian follicles that were presumably near ovulation; but most were in a post-ovulatory stage, containing recently-formed corpora lutea. The condition of the uterine horns and vagina at this stage is characteristic (Figure 2, C). They are extremely turgid and almost circular in cross section. The cervix is conspicuous on the ventral aspect as a pear-shaped protuberance. The ramifications of the uterine blood vessels on the surface of the horns are distinct. Twenty red fox tracts in the fully turgid state had a mean uterine width of 5.6 millimeters (4 - 8) and vaginal width of 7.4 millimeters (5 - 13). Five gray fox tracts near estrus averaged 5.4 millimeters (4 - 7) in width of uterine horns and 5.6 millimeters (4 - 7) in vaginal diameter.

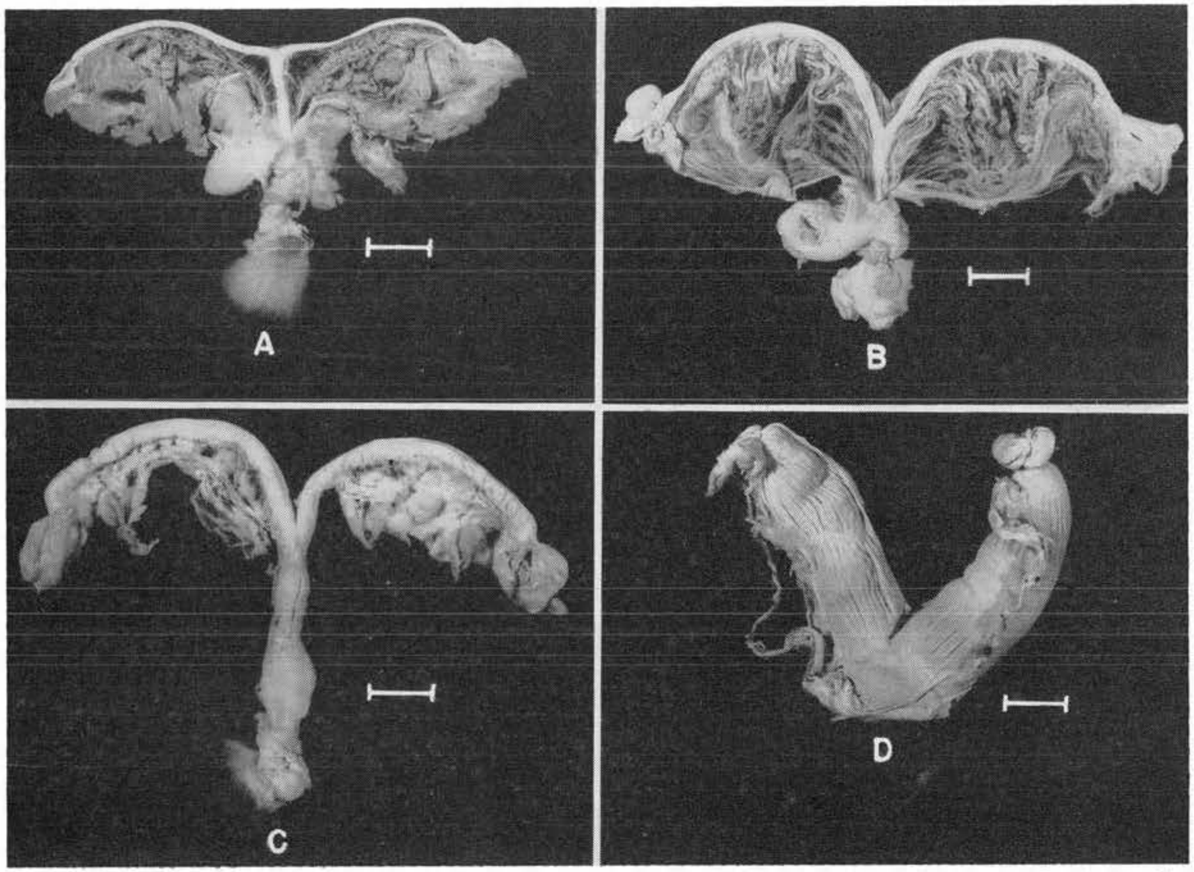

Figure 2. Genital tracts of female red foxes representing the following stages of the reproductive cycle: A. subadult in late summer; B. adult in late summer; C. near estrus; and D. shortly after parturition. Scale in each figure equals 2 centimeters.

During pregnancy the vagina becomes flaccid and enlarged. Internally a mucous plug is formed that extends from the cervix for as much as 2 inches caudad. Toward the end of gestation the uterine horns become greatly distended, exceeding 50 millimeters in width, and thin-walled.

The condition of the reproductive tract after parturition is unmistakable (Figure 2, D). The uterine horns are much shortened and swollen. Their walls are as much as 4 millimeters thick and deeply wrinkled on the surface. The uterine blood vessels are conspicuous and engorged with blood. Placental scars can scarcely be discerned externally but are distinctly marked internally as broad bands of villi encircling the uterine horn. The widths of the uterine horns and vaginae of 13 red fox vixens classed as being at or near partum (probably within 1 or 2 days) averaged 15.5 millimeters (8 - 24) and 9.3 millimeters (8 - 12), respectively. Similar measurements of six gray foxes shortly after the birth of young were 17.6 millimeters (12 - 23) and 10.4 millimeters (6 - 18).

Following parturition, the genital organs gradually regress to the quiescent state, probably reaching the typical anestrous condition before the termination of lactation. Over 90 per cent of the red fox reproductive tracts collected in April, May, and June were recorded as only slightly or non-enlarged. Because of the later breeding season, the majority of gray fox tracts were not thus classified until June.

The seasonal follicular cycle in the ovaries is indicated in Table 5. The development of follicles seems to have coincided with incipient enlargement of the tubal genitalia in fall and early winter in both species. In the red fox, numerous follicles ranging from approximately 0.5 millimeter to less than 2.0 millimeters were present in the majority of ovaries examined from October to January. A subadult (?) vixen collected December 7, with large follicles up to 3.5 millimeters in diameter in the ovaries but showing no other sign of sexual activity, was considered abnormal because no other reproductive tract was noted with such advanced follicular development without equally marked enlargement and turgidity of the uterine horns and vagina. Growth of the follicle appears to be gradual until just before estrus when there is a rapid increase to the mature size of about 5 or 6 millimeters.

Following ovulation and formation of corpora lutea, follicles virtually disappear from the ovaries. However, in pairs of ovaries that contain corpora lutea in only one of the pair, there are often small,

TABLE 5. PERCENTAGE OF SPECIMENS FOR VARIOUS MONTHS SHOWING DEVELOPMENT OF FOLLICLES IN THE OVARIES OF 651 RED FOX AND 59 GRAY FOX FEMALES COLLECTED IN NEW YORK FROM APRIL, 1951, TO APRIL, 1953*

Month	Size of largest follicles visible in bisected ovaries				
	None visible	Minute (under 0.5 mm.)	Small (0.5-1 mm.)	Medium (1-2.5 mm.)	Large (over 2.5 mm.)
Red fox					
January..	7.6 (4)	1.9 (1)	28.8 (15)	40.4 (21)	21.2 (11)
February.	§ (1)	..	§ (1)	..	..
March...	92.8 (26)	..	..	3.6 (1)	3.6 (1)
April.....	98.3 (118)	0.8 (1)	..	0.8 (1)	..
May.....	98.6 (210)	0.5 (1)	0.5 (1)	0.5 (1)	..
June.....	98.1 (53)	..	1.8 (1)	..	..
October..	5.3 (2)	13.2 (5)	31.6 (12)	50.0 (19)	..
November	9.2 (6)	9.2 (6)	41.5 (27)	40.0 (26)	..
December	3.8 (3)	6.3 (5)	63.3 (50)	26.6 (21)	..
Gray fox					
January..	14.2 (1)	28.5 (2)	42.8 (3)	14.2 (1)	..
February.	..	..	..	..	..
March...	66.7 (4)	..	16.7 (1)	..	16.7 (1)
April.....	88.2 (15)	5.9 (1)	5.9 (1)	..	..
May.....	87.5 (7)	..	..	..	12.5 (1)
June.....	100.0 (11)	..	..	..	..
October..	16.7 (1)	50.0 (3)	33.3 (2)	..	..
November	..	..	..	..	..
December	50.0 (2)	25.0 (1)	25.0 (1)	..	..

*Number of specimens given in parentheses.
§Percentage omitted because of low number of specimens for this month.

probably atretic, follicles in the other. Occasionally in pregnant or postpartum animals one or a few small visible follicles persist in the thin partitions separating the corpora lutea or at the periphery of the ovary.

In correlation with the later breeding season of the gray fox, it appeared that the advanced stages of follicle growth occurred about a month later in this species than in the red fox.

The cycle of the corpus luteum is protracted in both species (Table 6). Recently-formed corpora lutea in the ovaries of maximally enlarged and turgid red fox reproductive tracts usually vary in diameter from 5 to 6 millimeters, but may be as large as 8 millimeters. They measure about 4 to 5 millimeters in gray foxes. Many possess antra of varying size which, in the silver fox, are said to persist until 2 or more days after ovulation (Pearson and Enders, 1943). Occa-

TABLE 6. PERCENTAGE OF SPECIMENS FOR VARIOUS MONTHS SHOWING DEVELOPMENT OF CORPORA LUTEA IN THE OVARIES OF 651 RED FOX AND 56 GRAY FOX FEMALES COLLECTED IN NEW YORK FROM APRIL, 1951, TO APRIL, 1953*

Month	Average size of corpora lutea visible in bisected ovaries				
	Recently formed§	Large	Medium	Small	Trace
	Red fox				
	(5-6 mm.)	(5-6 mm.)	(4-5 mm.)	(1-3 mm.)	(under 1 mm.)
January	43.5 (10)	..	..	4.3 (1)	52.2 (12)
February	50.0 (3)	33.3 (2)	..	..	16.7 (1)
March	1.2 (1)	91.6 (76)	7.2 (6)	..	..
April	..	64.8 (83)	34.4 (44)	0.8 (1)	..
May	..	39.9 (101)	59.3 (150)	0.8 (2)	..
June	..	14.7 (11)	80.0 (60)	5.3 (4)	..
October	..	..	..	10.0 (1)	90.0 (9)
November	..	..	..	22.8 (8)	77.1 (27)
December	..	2.6 (1)	5.3 (2)	..	92.1 (35)
	Gray fox				
	(4-5 mm.)	(4-5 mm.)	(2-3 mm.)	(1-1.5 mm.)	(under 1 mm.)
January	..	..	..	..	† (1)
February	..	..	..	..	..
March	87.5 (7)	12.5 (1)	..	..	..
April	33.3 (5)	46.7 (7)	20.0 (3)	..	..
May	18.2 (2)	18.2 (2)	36.4 (4)	27.3 (3)	..
June	..	6.2 (1)	37.5 (6)	56.2 (9)	..
October	..	..	..	..	† (1)
November	..	..	..	..	..
December	..	..	..	..	100.0 (4)

*Number of specimens in parentheses.
§Uterus and vagina still fully turgid and uterine swellings not visible.
†Percentage omitted because of low number of specimens for this month.

sionally antra were noted in some of the corpora in ovaries of red fox vixens trapped more than 5 or 6 weeks after estrus.

The corpora persist through pregnancy with no apparent reduction in size from that at formation. They generally fill the ovary almost completely so that the substance of the latter is compressed into a thin peripheral layer and narrow partitions separating the individual corpora. The size of the latter seems to be at least partially a function of their number, since in pairs of ovaries those in the ovary containing the greater number usually average smaller. There is also a correspondence between the size of an ovary and the number of corpora lutea it contains.

Following parturition a gradual reduction in size of the corpora lutea takes place. Although persisting as definite bodies throughout the summer, they become progressively somewhat darker and more dense in appearance. From October on, the ovaries of most vixens bred during the current season contained only traces of hyalinized corpora lutea, which appear as small, irregular, dark yellowish or yellowish-brown patches. Traces were still discernible in the ovaries of some vixens in January and February but were not usually macroscopically evident after the ovaries had become active in the development of new follicles for the oncoming breeding season. A female collected March 29, a week or two past parturition, had large corpora lutea of the current breeding season in the right ovary and traces of those of the previous year in the left, suggesting that the latter gonad had been inactive during the breeding period just past. Unusually well-developed corpora lutea were found in the ovaries of three red foxes taken in December. These may be indicative of ovulation outside the normal breeding season.

PRODUCTIVITY

Among the important reproductive factors that influence productivity in mammalian populations are the proportion of adult females successfully becoming pregnant during the breeding season, the number of ova produced, the success of fertilization and implantation, and the percentage of embryos surviving to parturition. Information pertaining to these factors is of interest both to indicate the relative effect of each on the ultimate productivity of the populaion in question and to provide a means of comparing the reproductive behavior of different species or populations of the same species existing under different density levels or environmental situations. Where the characteristics of the populations and their environments have been well studied, it may further be possible to actually determine the relative effects of particular physical and biological features of the environment on reproductive success and perhaps even to link them with the specific factor or factors of reproduction that they affect.

Information relative to certain factors in reproductive success of red foxes and gray foxes in New York in 1951, 1952, and 1953 are presented in Table 7. Table 8 provides an additional summary of similar data for the red fox at a regional level. In the discussion of these particular components of reproduction that follows, a difference between means stated as "significant" implies that the difference in question is 1.96 or more times its standard error (P=.05). Differences between percentages are treated as significant when chi-squares equal or exceed 3.841 ($P=.05$).

BARREN FEMALES

Some reproductive tracts of females of both species collected subsequent to the respective breeding seasons contained well-developed corpora lutea in the ovaries, indicating ovulation during the current season, but showed no evidence of pregnancy or placental scars in the uterine horns. These specimens, which were classified as "barren", represent vixens that produced no young, either through failure to mate, failure of the eggs to be fertilized, or loss of the embryos prior to implantation or shortly thereafter. Barren females could be determined with reasonable accuracy until September in the red fox and October in the gray fox, since pregnancy or placental sites were readily discernible in successfully-bred individuals examined between the respective breeding seasons and these months. Calculation of the percentage of barren vixens was based upon genital tracts collected during these intervals only.

The proportion of barren females averaged considerably higher (11.5 per cent) among red foxes than among gray foxes (3.8 per cent), but the difference was not significant. Although yearly differences in the number of barren females were not statistically significant for the red fox, marked regional differences were apparent. The northern region evidenced a significantly higher proportion of barren females (16.6 per cent) than either the Lake Plain (2.1 per cent) or the southern region (2.1 per cent). Sheldon (1949) reported a proportion of 4.6 per cent barren females among 172 red fox vixens and 3.3 per cent in a sample of 90 gray fox females.

OVULATION RATE

Counts of corpora lutea contained in the ovaries were considered to provide a reliable estimate of the number of ova produced and ovulated. Any error due to polyovulation and fusion of corpora lutea is probably negligible when dealing with large samples. The relatively large size and persistence of the corpora in both *Vulpes* and *Urocyon* permit counts to be made on the basis of gross examination. Usually all corpora in an ovary of a pregnant or recently-parous vixen are revealed when the gonad is longitudinally bisected with a sharp scalpel or razor blade. It may be necessary to cut additional sections to either side when a large number or corpora are present or when the

Table 7. Incidence of Various Reproductive Characteristics in Red Foxes and Gray Foxes Collected in New York from April, 1951, to April, 1953*

Year	Reproductive characteristic						
	Percentage of barren females	Mean number of corpora lutea	Percentage of implantation	Percentage incidence of resorption	Percentage of fetuses affected by resorption	Mean number of fetuses	Mean number of placental scars
				Red fox			
1951	12.5 (272)	5.9 (216)	87.6 (179)	2.6 (155)	100.0 (14)	. .	5.4 (226)
1952	11.0 (300)	5.8 (268)	84.3 (208)	5.0 (262)	84.3 (51)	4.7 (10)	5.4 (245)
1953	10.4 (106)	5.8 (106)	87.5 (64)	12.8 (78)	76.5 (34)	4.5 (25)	5.4 (70)
Total...	11.5 (678)	5.9 (590)	86.1 (451)	5.4 (495)	83.8 (99)	4.6 (35)	5.4 (541)
				Gray fox			
1951	5.6 (36)	5.4 (27)	80.0 (17)	13.8 (29)	53.3 (15)	4.5 (6)	4.6 (20)
1952	0.0 (14)	5.2 (15)	74.5 (10)	13.3 (15)	50.0 (6)	5.0 (3)	4.1 (10)
1953	0.0 (3)	4.2 (5)	. .	. .	. .	3.0 (1)	3.5 (2)
Total...	3.8 (53)	5.2 (47)	78.1 (27)	13.6 (44)	52.4 (21)	4.5 (10)	4.4 (32)

*Number of specimens examined in each case given in parentheses.

Table 8. Incidence of Various Reproductive Characteristics in Red Foxes Collected in Three Regions of New York from April, 1951, to April, 1953*

Year	Reproductive characteristic: Percentage of barren females	Mean number of corpora lutea	Percentage of implantation	Percentage incidence of resorption	Percentage of fetuses affected by resorption	Mean number of fetuses	Mean number of placental scars
Northern region							
1951	17.7 (192)	5.5 (159)	86.7 (127)	2.6 (115)	100.0 (9)	..	5.0 (161)
1952	16.1 (192)	4.9 (166)	84.1 (114)	8.2 (158)	84.3 (51)	3.7 (6)	4.6 (132)
1953	14.0 (57)	5.7 (58)	89.0 (46)	0.0 (37)	..	5.3 (3)	5.4 (45)
Total...	16.6 (441)	5.3 (383)	86.1 (287)	5.2 (310)	86.7 (60)	4.2 (9)	4.9 (338)
Lake Plain region							
1951	0.0 (28)	7.0 (20)	91.4 (17)	0.0 (8)	..	..	6.2 (4)
1952	3.3 (61)	7.9 (57)	81.7 (54)	0.0 (58)	..	7.3 (3)	6.5 (61)
1953	0.0 (8)	6.6 (8)	84.6 (2)	0.0 (8)	..	6.6 (5)	6.4 (25)
Total...	2.1 (97)	7.6 (85)	83.9 (73)	0.0 (74)	..	6.9 (8)	6.4 (90)
Southern region							
1951	0.0 (52)	7.1 (37)	88.3 (35)	3.1 (32)	100.0 (5)	..	6.2 (40)
1952	0.0 (47)	6.8 (45)	89.0 (40)	0.0 (46)	..	3.0 (1)	6.2 (52)
1953	7.3 (41)	5.6 (40)	83.8 (16)	30.3 (33)	76.5 (34)	3.8 (17)	5.3 (19)
Total...	2.1 (140)	6.5 (122)	87.9 (91)	9.9 (111)	79.8 (39)	3.7 (18)	6.0 (111)

*Number of specimens examined in each case given in parentheses.

ovaries of animals taken late in the season are being examined. Questionable counts due to poor preservation or an advanced stage of regression of the corpora lutea were not included in the analysis of the data.

The mean number of 5.9 (2 - 12) corpora lutea recorded per red fox vixen was significantly greater than the average of 5.2 (2 - 9) per gray fox female. In Ohio, Gier (1947) has reported average numbers of corpora lutea of 7.2 and 5.2 for the red and the gray fox, respectively.

Yearly differences in ovulation rate were not pronounced in the red fox sample, but significant regional differences did exist. Ova production was apparently lowest in the northern region, highest in the Lake Plain, and intermediate in the southern region. The over-all differences between the rates for the northern region and either the Lake Plain or southern region were highly significant. The difference between the Lake Plain and southern regions was less marked.

Comparison of numbers of corpora lutea in each ovary with uterine swellings or placental sites in the corresponding horn of the uterus revealed a fairly high number of cases in which fewer corpora were present than embryos or placental sites on the same side. These discrepancies were assumed to represent instances in which ova had moved from one side to the other. The probable path of the ova is through the uterine horns rather than across the body cavity, since in both species the gonads are enclosed within bursae. Although polyovulation or fusion of corpora lutea may also result in a fewer number of corpora on a side as compared to implantation sites, the phenomena probably occur so infrequently in foxes that no serious error is introduced by attributing all such cases to ova transfer. Since trans-uterine migration can be detected only when the corpora lutea in a given ovary are actually fewer than the number of fetuses or placental scars present in the uterine horn of the same side, calculation of the extent of ova transfer by this method can be assumed to represent only the minimum frequency of its occurrence. A certain amount of ova migration probably takes place that does not result in an actual imbalance between corpora lutea and embryos or placental sites.

Of a total of 442 red fox reproductive tracts in which the disposition of corpora lutea and fetuses or placental scars was compared, 196 (44.3 per cent) showed evidence of trans-uterine migration of ova. Of this number, 116 (65.9 per cent) involved a minimum cross-over of a single ovum, 49 (27.8 per cent) a minimum of two ova, 10 (5.7 per cent) a minimum of three ova, and 1 (0.6 per cent) a minimum of four ova. Fourteen (53.8 per cent) of 26 gray fox reproductive tracts gave evidence of ova migration. A minimum of one ovum was involved in 12 cases (85.7 per cent), and a single instance each was recorded in which at least two and three ova crossed over.

IMPLANTATION SUCCESS

Comparison of the number of corpora lutea in the ovaries with the number of embryos or placental sites in matching uteri provides a measure of ovum wastage. Thus calculated, implantation success does not take into account total loss before or just after implanting, since uterine horns in such cases would show no sign of pregnancy or placental sites. This factor is not neglected, however, as such vixens would be considered as barren.

Although the percentage of implantation may actually have been higher in the red fox than in the gray, as the data in Table 7 suggest, the differences were not statistically significant on the basis of the samples available. The slight differences exhibited between years and regions for red foxes were in no case significant, suggesting that the proportion of ova successfully implanting may be more constant under varying conditions than certain other reproductive factors that have been measured.

RESORPTION

Many resorbing embryos or fetuses were easily identified in gravid uteri, as the uterine swelling containing the affected specimen was usually smaller than the others and contained a pasty black material. Occasionally, a shapeless hard "kernel" of the embryo was present. In one instance the mummified remains of a fetus at approximately 40 days of development was recovered from a tract containing three normal fetuses aged at 51 days. Sites of resorbed embryos were found to persist in some postpartum uteri as smooth swellings. Such instances probably represent resorption that began fairly late in pregnancy.

Evidence of resorption either in pregnant or postpartum specimens was not found after May in red foxes or June in gray foxes. Therefore, incidence of resorption was calculated on the basis of pregnant and postpartum specimens collected between the respective breeding seasons of the two species and these months.

The percentage of fetuses actually affected by resorption was obtained by dividing the number of resorbed or resorbing specimens by the total number of fetuses in reproductive tracts in which resorption was recorded. In the case of postpartum tracts, in which resorption was indicated by abnormal swellings, the number of fetuses surviving to parturition was assumed to be represented by the normal placental sites.

The two species did not differ significantly in the incidence of resorption or the proportion of fetuses affected, although a valid comparison is not possible in view of the small gray fox sample available. In the red fox, yearly differences approached the border line of significance only between 1951 and 1953. No evidence of resorption was encountered in a total of 74 specimens examined from the Lake Plain region during the 3-year period. In contrast, minimum resorption rates of 5.2 and 9.9 per cent were recorded for the northern and southern regions, respectively. The difference is not significant. Within the southern area, the percentage of resorption was significantly higher in 1953 than in either 1951 or 1952. Yearly differences for the northern area were not significant.

As there is evidence to suggest that prenatal mortality may be concentrated during the early embryonic stages in many mammals (Brambell, 1948), it is clear that the present method of determining resorption loss provides only a partial estimate of the total prenatal mortality experienced by a given population, since only those embryos resorbing during advanced stages of gestation are likely to be recorded. Resorption that occurred in early pregnancy may well pass undetected in advanced pregnancies or be indistinguishable from normal implantation sites in postpartum uteri. Furthermore, females that have experienced a partial or total loss of ova through failure of fertilization or implantation are entirely excluded from consideration. Therefore, it is necessary to take into account the percentage of barren females and implantation success as well as the incidence and extent of resorption to derive at least a minimum estimate of the total loss of ova from ovulation to parturition.

On the basis of the combined data for proportion of barren females, implantation success, and resorption, the total prenatal mortality for red foxes approximated at least 27 per cent of the ova produced. On a regional basis, a minimum estimate of ova loss is about

32 per cent in the northern sample, about 16 per cent in the Lake Plain sample, and about 20 per cent in the southern sample. Prenatal mortality in gray foxes for all years and regions may be similarly estimated at approximately 30 per cent.

Litter Size

Counts of placental sites, uterine swellings, and fetuses can be utilized to provide direct information as to the average number of young produced per female. Using these criteria, studies of foxes in Indiana (Hoffman and Kirkpatrick, 1954), Ohio (Gier, 1947), New York (Sheldon, 1949) and Wisconsin (Richards and Hine, 1953) gave 5.1 to 6.8 as the mean litter size of the red fox and 3.66 to 4.1 as that of the gray fox. Schoonmaker (1938), Switzenberg (1950), and Richards and Hine (1953) reported average numbers of red fox pups in dens to be 4.7, 4.92, and 5.1, respectively. Mean litter size based on counts of den young may be less reliable than that based on placental sites or embryos, since postpartum mortality, communal denning, or failure to recover all of the pups may introduce a degree of inaccuracy.

Fetal counts in which resorbing individuals are excluded probably provide the most accurate measure of litter size obtainable from ordinary field data. However, in this study relatively few pregnant females were obtained, owing to the fact that trapping operations were largely discontinued during the winter months and were not begun again until favorable weather arrived in spring. As a consequence many females had dropped their pups by the time the trapping program was underway for the season. This was particularly true for red foxes. Based on only 35 fetal counts for red foxes and 10 for gray foxes, the difference between a mean litter size of 4.6 (1 - 10) for the former and one of 4.5 (3 - 7) for the latter is insignificant.

Since placental scars remain conspicuous in the uterine horns for 4 or more months after parturition, a relatively large number of genital tracts containing this evidence of the number of young produced was obtained in comparison with gravid ones. Because of the number available and the fairly uniform distribution by years and regions, placental scar counts probably furnish the best single criterion of litter size in this instance. An estimate of mean litter size obtained by this means will undoubtedly be higher than the true value, unless a correction is made for the extent of prenatal mortality attributable to the resorption of embryos or fetuses.

The mean of 5.4 (1 - 12) placental scars per red fox vixen was significantly higher than that of 4.4 (3 - 7) per gray fox female. Yearly differences in placental scar numbers in red foxes from all regions were not apparent, but marked regional differences did exist. The northern region was characterized by having a significantly lower mean than either the Lake Plain or southern regions. Over-all differences between the latter were not significant. In the northern area differences between 1951 and 1952 and between 1951 and 1953 were not significant, whereas that between 1952 and 1953 was highly so. Yearly mean numbers of placental scars per female did not show significant variation in the Lake Plain populations. Differences between 1951 and 1952 in the southern zone were not significant, but the mean number of placental scars in 1953 was significantly lower than that in either of the preceding two years.

It is of interest to compare the data on mean numbers of fetuses and placental scars with mean litter sizes calculated directly from the values determined for ovulation rate, implantation success, and incidence and extent of resorption. Thus, in the red fox for all years and regions, 100 females would be assumed to produce 590 ova (mean number of corpora lutea 5.9) and 86.1 per cent would successfully implant. Resorption would occur in a minimum of 5.4 per cent of the 100 animals and account for a loss of at least 83.8 per cent of the susceptible embryos. Consequently, the 100 vixens would be expected to produce approximately 485 fetuses that would survive until birth, resulting in a mean litter size of 4.8.

Calculated mean litter sizes for red foxes in the northern, Lake Plain, and southern regions are 4.3, 6.5, and 5.3, respectively. Since significant inter-regional differences in implantation success were not demonstrated, the average of 86.1 per cent for all years and areas was employed. Similarly the average values of 6.4 and 83.8 per cent were used for the incidence and extent of resorption, respectively, in both the northern and southern regions, for regional differences in these characteristics were not significant. The calculated mean litter sizes in all instances lie between the mean fetal and placental scar counts. This rather close correspondence may be taken as evidence that the values for the various reproductive factors upon which the calculated mean litter sizes are based actually do approximate the respective population parameters.

Data for gray foxes gave a calculated mean litter size of 3.8. This figure is less reliable than those for red foxes because of the smaller samples involved. Furthermore, the lower ovulation rate and higher incidence of resorption used in the calculation for this species were not significantly different from corresponding values for red foxes.

By a method similar to the foregoing, to which is added the factor of the proportion of barren females in the population, a measure of productivity can be computed. On the basis of the data recorded, average annual productivity of the red fox for all years and regions was approximately 2.14 young (214 per cent) per adult. The northern region evidenced the lowest average productivity (180 per cent) and the Lake Plain the highest (320 per cent). In the southern region it was intermediate (259 per cent) but more nearly approached that of the Lake Plain. The same values for percentage implantation and incidence and extent of resorption were used as for the calculation of mean litter size.

Estimated average annual productivity of gray foxes during the period of the study was 182 per cent.

DISCUSSION

Although the period of the present study was too short to reveal long-range trends in reproductive capacity among New York foxes, and additional data on the various aspects of reproduction involved would be highly desirable, certain tentative conclusions appear justified on the basis of the evidence gathered.

Of the two species in the State, the gray fox appears to have a lower reproductive potential than the red, although the small sample available for the former rules out critical comparisons of specific factors in most instances.

Regional differences in certain reproductive characteristics and resultant productivity are readily apparent in the red fox, with average yearly reproductive success during the 1951-53 period having been lowest in the northern region, intermediate in the southern region, and highest in the Lake Plain. While statistically significant differences in some reproductive factors did occur between years within the same region, these variations were generally of lesser magnitude than those between regions. An exception occurred in the southern region in 1953 where productivity sharply declined from that of the previous years. This lowered fecundity was largely the result of a high proportion of barren females and incidence of resorption and a lower ovulation rate in a relatively large sample from Steuben, Tioga, and Livingston

Counties and may reflect poorer reproductive success in these particular localities rather than for the southern region as a whole.

These observed variations in reproductive behavior of red foxes in sections of the State differing in broad environmental features seems best explained as being primarily the result of an interaction between population density and the environmental capacity of the respective regions. Thus, whatever the specific ecological factor or factors may be that affect certain aspects of productivity, their action is probably largely associated with population density in such a way that when fox numbers exceed an optimal level for a given habitat there will be a reduction in fecundity. This relationship between reproductive potential and the number of individuals that a given environment can support has been amply demonstrated in other vertebrate and invertebrate species.

It can, therefore, be assumed that for the State as a whole the higher breeding potential of red foxes in the Lake Plain area is indicative of a more nearly optimum balance between population density and carrying capacity than exists in either the southern or northern regions, which were characterized by lower reproductive potentials. This contention is supported by a comparison of the calculated productivity of each region with the respective population indices over the 3-year period (Table 1) which shows a slight inverse relationship between reproductive capacity and population density. It should be emphasized, however, that such a negative correlation between productivity values and population levels is not actually necessary to support the hypothesis that fecundity is at least partially a function of population-environmental capacity relationships, since the population indices as calculated provide merely an expression of relative numbers of individuals and give no information concerning the *status* of the population with respect to the optimal density for the particular environment. Because of this fact, it appears that information relating to reproductive characteristics of the kind considered here, when obtainable, may be of considerably greater value as a measure of the relationship between a given population and its environment than is the mere enumeration of individuals per unit of area, time, or effort as provided by most census methods. In this connection, Errington (1954) has noted that data bearing on certain physiological (including reproductive factors) and psychological phenomena may yield more fruitful results in the interpretation of population "cycles" among muskrats than will records of gross fluctuations in numbers.

The possible effects of trapping on the reproductive potentials of the populations involved are of interest. If a relationship between fox density, environmental capacity, and fecundity does exist, then trapping may actually prove "beneficial" to fox populations in some cases by reducing numbers to more nearly optimum density levels at which reproductive potentials would be expected to increase. Although this would not necessarily negate the effects of the trapping, if it is assumed that subsequently increased population increments would be reflected in greater trap success per unit of effort, a compounding of the rate of increase over a sufficient interval might ultimately affect the efficacy of the trapping.

The foregoing considerations may have an important application to the present fox rabies control program in New York. By means of trapping, this program seeks to create "zones of fox scarcity" some 50 or more miles wide around areas having a high incidence of the disease and thus to reduce the probability of rabid foxes contacting uninfected animals and to restrict movements of foxes into and out of infected areas (Colson *et al.,* 1955). If trapping may be assumed to be the major factor in fox mortality in these zones, the present findings provide what is probably a reasonably accurate estimate of the magnitude of the annual population increment with which control measures must cope. Thus, for the conditions existing during the study, gray fox populations could theoretically be reduced about 64 per cent and red fox populations about 68 per cent annually and still be potentially able to effect a full recovery the following year. On a regional basis, red fox populations could support an annual harvest ranging from about 64 per cent (northern region) to 76 per cent (Lake Plain). In order to bring about an actual reduction in a given population in subsequent years it would be necessary to remove a proportion of animals in excess of these percentages. Available evidence suggests that this is seldom accomplished under the present rabies control program. Yearly population indices for counties trapped in 1951, 1952, and 1953 (Table 1) bear out this view, since there appears to be no marked trend of decrease in the indices for consecutive years of trapping.

Although there is little evidence as to how low density levels among rabies-exposed fox populations must be reduced in order to break the "chain" of transmission, there is a possibility that a sustained trapping program might hold numbers at a level low enough to decrease significantly the probabilities of transfer of the virus from infected to noninfected foxes without actually producing sustained scarcity in the population. Control at this level would appear to be most effective in areas experiencing the highest incidence of fox rabies.

In this regard, the fox reduction program in New York is presently being moved into the epidemic rabies counties in order to determine whether the elimination of the approximate annual increment within such areas will reduce the record of rabies incidence in the fox population being trapped. Consistent application of trapping adequate to remove the desired segment of the population in infected areas may demonstrate over a period of several years whether this method of "creaming off" annual surpluses will effectively reduce the frequency of rabies in the fox population.

LITERATURE CITED

BRAMBELL, F. W. 1948. Prenatal mortality in mammals. Biol. Reviews 23(4):370-407.

COLSON, RALPH, W. S. STONE AND DONALD J. DEAN. 1955. Rabies. N. Y. S. Conservationist 9(5):8-12.

ERRINGTON, PAUL L. 1954. On the hazards of overemphasizing numerical fluctuations in studies of "cyclic" phenomena in muskrat populations. Jour. Wildl. Mgt. 18(1):66-90.

GIER, HERSCHEL T. 1947. Populations and reproductive potentials of foxes in Ohio. Ninth Midwest Wildl. Conf. (mimeo.)

HOFFMAN, ROGER A. AND CHARLES M. KIRKPATRICK. 1954. Red fox weights and reproduction in Tippecanoe County, Indiana. Jour. Mammal. 35(4):504-509.

HOWE, FRANK B. 1935. Classification and agricultural value of New York soils. N. Y. S. Coll. Agr. Exp. Sta. Bull. 619.

KINCER, J. B. 1941. Climate and weather data for the United States. In: U.S.D.A. Yearbook of Agriculture (Climate and Man). U. S. Govt. Printing Off., Washington.

MORTON, GLENN H. AND E. L. CHEATUM. 1946. Regional differences in breeding potential of white-tailed deer in New York. Jour. Wildl. Mgt. 10(3):242-248.

PEARSON, OLIVER P. AND ROBERT K. ENDERS. 1943. Ovulation, maturation and fertilization in the fox. Anat. Rec. 85(1):69-84.

PEARSON, OLIVER P. AND CHARLES F. BASSETT. 1946. Certain aspects of reproduction in a herd of silver foxes. Amer. Nat. 80(786):45-67.

RICHARDS, STEPHEN H. AND RUTH L. HINE. 1953. Wisconsin fox populations. Wis. Cons. Dept. Tech. Wildl. Bull. No. 6.

ROWLANDS, I. W. AND A. S. PARKES. 1935. The reproductive processes of certain mammals.—VIII. Reproduction in foxes (*Vulpes* spp.). Zool. Soc. of London Proc. Pt. 4:823-841.

SCHOONMAKER, W. J. 1938. Notes on mating and breeding habits of foxes in New York State. Jour. Mammal. 19(3):375-376.

SEAGEARS, CLAYTON B. 1944. The fox in New York. N. Y. S. Cons. Dept. Bull.

SHELDON, WILLIAM G. 1949. Reproductive behavior of foxes in New York State. Jour. Mammal. 30(3):236-246.

————. 1950. Denning habits and home range of red foxes in New York State. Jour. Wildl. Mgt. 14(1):33-42.

SMITH, G. ENNIS. 1939. Growth of fox foetus and length of gestation period. Canadian Silver Fox and Fur (March).

SWITZENBERG, D. F. 1950. Breeding productivity in Michigan red foxes. Jour. Mammal. 31(2):194-195.

TOXICITY OF EMULSIFIABLE ROTENONE TO YELLOW PERCH

G. E. Burdick Senior Aquatic Biologist
New York State Conservation Department

Howard J. Dean Aquatic Biologist
New York State Conservation Department

Earl J. Harris Analytical Chemist
New York State Conservation Department

ABSTRACT

The toxicity of rotenone to yellow perch was studied under controlled laboratory conditions and a toxicity curve constructed. The effect of length on time for death was calculated and was found to be not significant. The means for time for death in the five concentrations used are plotted, as is the curve representing the equation for the regression of those means which tend to fall on a straight line. This is superimposed upon a graph depicting the comparative toxicity of rotenone to brown trout, rock bass, creek chub, smallmouth bass, common sucker and brown bullhead as determined by the authors.

The yellow perch *(Perca flavescens)* is generally considered an undesirable species in brook trout waters and the primary purpose of rotenone treatment of Adirondack ponds has been to eliminate it. At the time of a previous investigation of the toxicity of emulsifiable rotenone to fishes (Burdick *et al.* 1955) this species was not available at the laboratory in sufficient numbers to justify its inclusion in the study, in spite of the desirability of having information on the comparative susceptibility of perch to rotenone.

In the spring of 1955 it was found that a nearly pure culture of small perch could be obtained from an unused hatchery pond at Rome. Entrance had been gained through an uncreened pipe carrying water from Delta Lake. About 200 were removed from the pond and placed in a trough where they were acclimatized to the hatchery spring water for 3 weeks before use in experimentation. Temperature was maintained at 60° F. for a large part of this period.

GENERAL PROCEDURE

The general procedure and methods of chemical determinations were essentially the same as those used in the previous study and described by Burdick *et al.* (1955). Where any variation from these methods occurred, it is set forth in the text. Some trouble was encountered in the use of the Leeds and Northrop pH meter and certain values had to be determined colorimetrically as noted in the table.

The Rome Hatchery spring water was used throughout this study and routine chemical analyses were made. They are summarized in Table 1. A more complete chemical analysis of this water has been given by Burdick *et al.* (1954).

Time of turn-over (loss of equilibrium) and time for death were noted for all fish, as were length and weight. Only time for death[1] and length were used in the computations.

Controls in water from the same source showed no loss during the period of experimentation.

STATISTICAL TREATMENT

Since the previous study had shown the time for death to be logarithmically distributed, the logarithmic means were calculated and used in place of the arithmetic means. The regression of these means in the straight-line portion of the curve was calculated by the method of least squares described by Bliss (1952). Standard deviation and standard error have been expressed as a range, as in the previous paper.

A three-factor multiple regression was calculated by the method outlined by Snedecor (1940) to evaluate the effect of length which had been found significant in some of the other species which had been studied.

DISCUSSION

Fifty fish, selected at random, were used, 10 for each of five concentrations from 0.05 to 0.80 p.p.m. by volume of 5 per cent emulsifiable rotenone and vehicle. The length of these fish ranged from 58 to 107 millimeters, with an average of 82.1 millimeters.

For the 0.05 p.p.m. concentration, two sets of three fish each were placed in tanks containing 15 liters of solution and two sets of two fish each were placed in equal volumes. Two fish, one from each group, appeared to be extremely resistant to the action of the chemical and were twice transferred to a fresh solution before death occurred. The replacement insured that the time was not seriously affected by removal of rotenone from solution by the fish as suggested by Prévost, Lanouette and Grenier (1948). The divergence can be assumed to represent the spread in individual tolerance which can be expected as the minimum lethal dose is approached. The mean for this concentration deviated from the straight line and was not used in computing

[1] Lapsed time from the introduction of the specimen in the experimental solution until death.

TABLE 1. SUMMARY OF EXPERIMENTAL DATA FOR DIFFERENT ROTENONE CONCENTRATIONS AT 60° F. FOR YELLOW PERCH

Item	Concentration (in p.p.m.)				
	0.05	0.10	0.20	0.40	0.80
Range in pH	7.98	7.90-7.92	7.30-7.40*	7.80	7.50*
Range of oxygen from start to end of experiment (in p.p.m.)	10.0-9.6	9.6-9.4	10.0-9.0	9.5-9.4	10.2-10.0
Initial carbon dioxide content (in p.p.m.)	2.0	2.0	1.0	1.0	3.0
Initial methyl orange alkalinity (in p.p.m.)	94	92-94	96	96	96
Volume of solution per fish (in liters)	5-7½§	3	3	3	3
Number of fish	10	10	10	10	10
Average length of fish (in millimeters)	80.8	76.4	90.2	78.4	84.9
Range of lengths (in millimeters)	73-97	66-87	74-107	72-94	58-102
Range of times for death (in minutes)	201-945	108-180	79-134	60-79	33-53
Mean time for death (in minutes)	325.0†	142.0	98.3	67.6	40.7
Standard deviation of the mean (spread in minutes)	188-531	120-168	83.8-118	61.3-74.5	34.8-47.7
Standard error of the mean (spread in minutes)	278-379	135-150	92.8-104	65.6-69.7	38.8-42.8
Mean calculated from regression equation	†	146	96.6	64.1	42.4

*Due to failure of the electrometric pH meter, these values determined colorimetrically on a Hellige disc.
§Two fish subjected to two changes of water, 15 liters in each change.
†Mean deviates from straight line; not used in calculating the regression.

the regression equation. No lower concentration was tested, since, with one fish surviving for nearly 16 hours, it is evident that with only a slightly lower concentration some fish could be expected to survive for longer than a 24-hour period.

In the concentrations from 0.10 to 0.80 p.p.m. five fish were used per 15 liters of solution. No replacement was found necessary. Due to an error in adjusting the temperature of the dilution water, one set of fish in the 0.20 p.p.m. concentration had been started at a temperature of 62½° F. instead of the 60° F. ±½ degree used in all the other experiments. These were discarded because of failure to meet the criterion and a duplicate set was run at the properly adjusted temperature.

A summary of the data is given in Table 1.

The plotted logarithmic means fell in an approximately straight line and the regression of the means was calculated, giving the equation:

$$\log Y = 1.57018 - 0.59435 \log X$$

In this equation log X represents the common logarithm of the concentration.

From the table it can be observed that due to random selection the range of the mean length of the groups of fish used varied from 76.4 to 90.2 millimeters. As has been previously shown (Burdick *et al.* 1955), length has a significant effect upon the time for death in several species. Use of multiple regression to assess the function of this additional variable produced the following equation:

$$\log Y = 1.48639 - 0.55158 \log X_1 + 0.00130X_2$$

In this equation log X_1 represents the common logarithm of the concentration and X_2 is the length in millimeters.

Applying the *t*-test to determine the significance of the betas, that for concentration independent of length was found to exceed the 1 per cent level at 13.6, while that for length independent of concentration failed to reach significance at 1.03. With so small a slope for the possible effect of length on time for death, such a large increase in data would be required to determine whether it has an actual effect that the additional experimentation is not believed justified in view of the variability shown by the data presented. Also with so small a slope there can be little error involved in accepting the null hypothesis and assuming that, within the range covered, length has no significant effect in the case of yellow perch.

To facilitate comparison of the toxicity of rotenone to yellow perch and the other species studied, the final graph (Figure 7) of the previous paper has been used as a background and the experimental means and regression line for yellow perch have been plotted upon it (Figure 1). Use of the logarithmic scale permits direct reading of concentration against time for all species.

Yellow perch are shown to be rather easily destroyed, even at

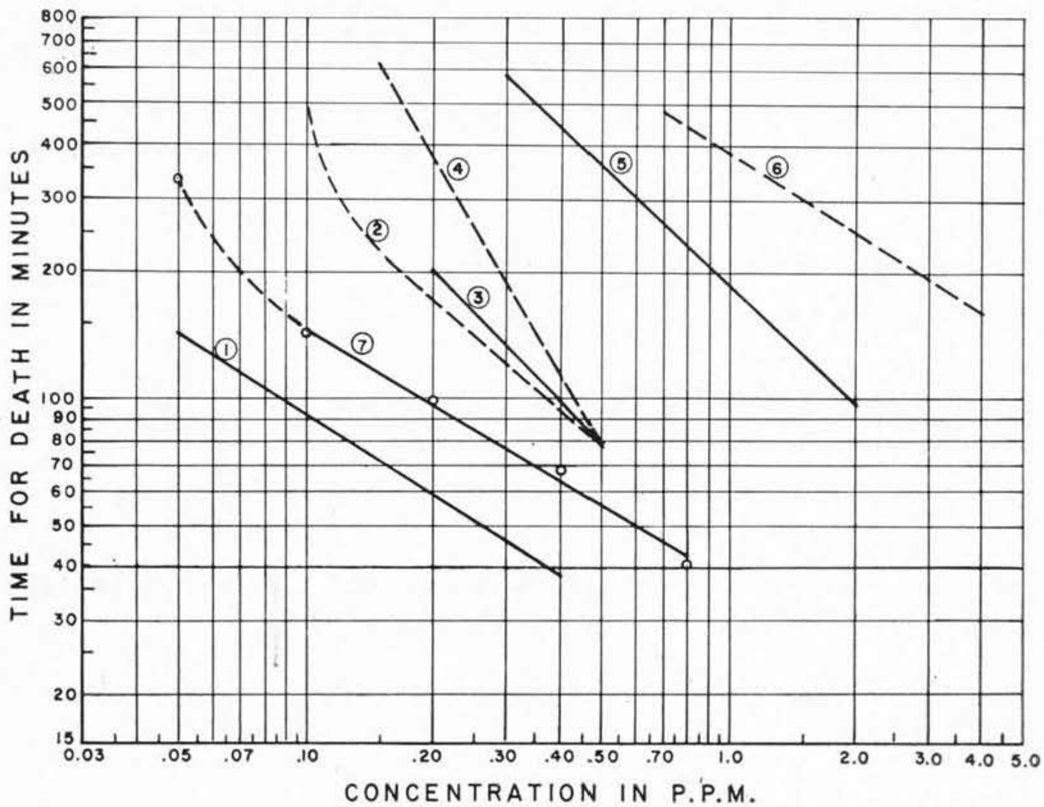

Figure 1. Toxicity curve for yellow perch (7) based on the regression of the means corrected to the mean length of 82.50 millimeters. Also shown for comparison are similar curves for: (1) brown trout (86.55 millimeters); (2) rock bass (41.10 millimeters); (3) creek chub (53.16 millimeters); (4) smallmouth bass (47.75 millimeters); (5) common sucker (60.43 millimeters); brown bullhead (46.60 millimeters).

relatively low concentrations of rotenone. Their sensitivity to the chemical is exceeded only by that of brown trout among the species studied. This can be considered to be confirmed by the data which are gradually being amassed as a result of the pond reclamation program in this State, which to date has not shown that yellow perch have survived in any treated pond, although some carry over of a few other species has sometimes occurred.

It was observed during this study that many of the males were ripe, but it is unknown whether this condition made them more or less susceptible to the toxicant, or had no effect.

LITERATURE CITED

BLISS, C. I. 1952. The Statistics of Bioassay. Academic Press, New York.

BURDICK, G. E., MORRIS LIPSCHUETZ, HOWARD J. DEAN AND EARL J. HARRIS. 1954. Lethal oxygen concentrations for trout and smallmouth bass. New York Fish and Game Jour. 1(1):84-97.

BURDICK, G. E., HOWARD J. DEAN AND EARL J. HARRIS. 1955. Toxicity of emulsifiable rotenone to various species of fish. New York Fish and Game Jour. 2(1):36-67.

PRÉVOST, G., C. LANOUETTE AND F. GRENIER. 1948. Effect of volume on the determination of DDT or rotenone toxicity of fish. Jour. Wildl. Mgt. 12(3):241-250.

SNEDECOR, GEORGE W. 1940. Statistical Methods. The Collegiate Press. Ames, Iowa.

HISTORY, MANAGEMENT, AND ECOLOGY OF WHITE-TAILED DEER IN ALLEGANY STATE PARK [1]

C. W. Severinghaus Game Research Investigator
New York State Conservation Department

ABSTRACT

White-tailed deer moved into Allegany State Park about 1920. The Park was a refuge and the deer increased rapidly. During the winter of 1939-40, losses due to starvation were very heavy. Since then deer have died of starvation every winter. The number of dead deer found each spring and the calculated total loss for each winter are reported.

Hunting was first permitted in 1944 and there has been an open season each year since then. The take by years is reported and compared to the losses from starvation.

The condition of the winter food supply was studied at 76 stations in 1945 and again in 1955. The average reduction in available browse was 83 per cent in one area and 85 per cent in the other. Twelve species were completely eliminated and the bulk of those remaining normally are seldom eaten except by starving deer.

Allegany State Park consists of about 65,000 acres of hilly land in southern Cattaraugus County, adjoining the Pennsylvania border and the Alleghany National Forest. The Park is primarily a forested area, although there are considerable acreages in old fields and plantations.

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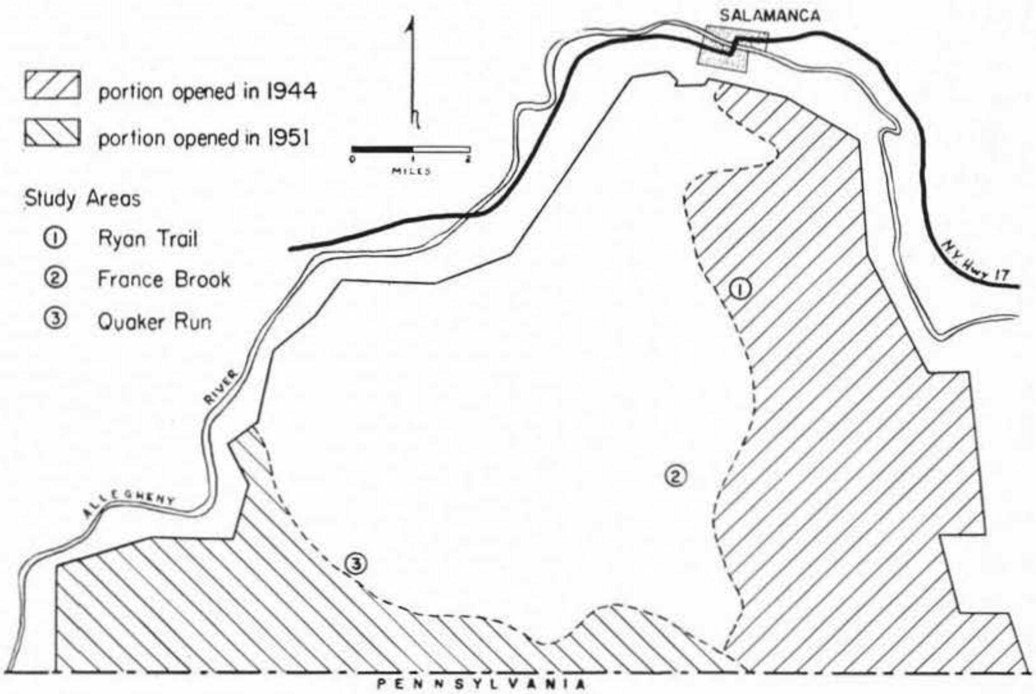
[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-28-R. The author is grateful to Oscar R. Lindberg, Chief Ranger at Allegany State Park, for the records on losses from starvation and deer legally harvested used in this paper, as well as to John E. Tanck who made the 1955 browse survey and H. F. Maguire who analyzed both the 1945 and 1955 browse data, both of the New York State Conservation Department.

The principal native tree species are sugar maple, hemlock, beech, and oak. Others include aspen and hornbeam. Various conifers have been planted, including scotch pine, red pine, white pine, and spruce.

Deer spread into Allegany State Park from Pennsylvania about 1920. Range conditions were excellent and their numbers grew rapidly. By the summers of 1936 and 1937 they were common and in good physical condition. They browsed heavily on jewelweed, brambles, and goldenrod, in addition to woody plants.

After a very heavy snowfall early in 1938, the deer concentrated in areas of coniferous shelter and localized overbrowsing of hemlock occurred. This was the beginning of range deterioration in the deer wintering areas of the Park. During the summer of 1938 browsing on brambles and goldenrod was much heavier and it was evident that the deer population had increased substantially.

The winter of 1938-39 was not particularly severe but browsing on hemlock was much more apparent and extended over a wider area than before. In the summer of 1939 browsing on brambles and goldenrod exceeded that of the previous year. Deer were much more numerous, being readily seen almost anywhere, and it became evident that the Park was overstocked.



Allegany State Park showing portions opened to deer hunting by gunners in 1944 and 1951, and location of browse study areas. Hunting in each portion has been permitted annually since it was opened.

TABLE 1. WINTER LOSSES FROM STARVATION AMONG DEER IN ALLEGANY STATE PARK (1940-55)

Year	Source of information	Number of deer found*	Estimated number lost§
1939-40	Shadle & Stullken (1942)	275	500–800
1940-41	Park Rangers	118	350
1941-42	" "	97	250
1942-43	" "	149	550
1943-44	" "	125	500
1944-45	" "	260	700
1945-46	" "	117	300
1946-47	" "	190	400
1947-48	" "	125	350
1948-49	" "	80	240
1949-50	" "	121	350
1950-51	" "	115	300
1951-52	" "	115	750
1952-53	" "	68	250
1953-54	" "	55	200
1954-55	" "	127	650
Total.	. . . .	2,137	6,940

*In compiling these figures care was taken to avoid duplication.
§Estimated totals based largely on area covered in surveys by the rangers in which field work was done chiefly in the territory adjacent to streams.

The winter of 1939-40 was severe. Deer concentrations were very heavy in all areas of coniferous shelter. The following spring, 275 deer were found that had died of starvation and it was estimated that between 500 and 800 had been lost in this way. The available natural winter food was largely exhausted. Browsing on hemlock and upon introduced evergreens (except spruce) was devastating. It was general and complete as high as deer could reach. Over wide areas hardly a living hemlock under 6 feet could be found. This was the first winter deer had died of starvation in the Park. Dr. Albert Shadle of the University of Buffalo and others recommended that surplus numbers be removed in order to prevent further excessive damage both to food sources and to the deer.[2]

Beginning with the winter of 1939-40 deer have died of starvation every year. Park rangers and other personnel have not been able in any one year to survey all wintering areas completely. They have, after each winter, made sample surveys. During these 16 surveys, 2,137 deer have been found that died of starvation and, from the sample areas covered, it has been calculated that the total number has exceeded

[2] The information in this and the preceding three paragraphs has been derived largely from Shadle and Stullken (1942).

6,940. The losses by year are presented in Table 1. This record demonstrates that the Park has been grossly overstocked with deer.

In the springs of 1944 and 1945, Department technicians made surveys of deer losses and natural food conditions in the Park. The reports submitted clearly stated that overbrowsing of the winter food supply had probably reduced the carrying capacity of the winter range below what it was in 1939-40, and that overbrowsing had caused distinct damage to many young trees, both natural and planted, the most noticeable damage having occurred on evergreen species (Severinghaus, 1945).

In 1944 deer hunting was permitted in a small section (approximately 17,000 acres) in the eastern portion of the Park. Both sexes were legal game and 223 deer (54 antlered and 169 antlerless) were taken. Because starvation losses occurred during the winter of 1944-45, this harvest provided an opportunity to determine whether the removal of deer in the fall would reduce such mortality.

Losses in the Quaker Run section (5 to 6 miles from the hunted area) were almost exactly the same as they had been in winters prior to the open season. Losses in the vicinity of Ryan Trail and Camp Carleton (adjacent to the hunted area) were below those of previous years. Losses at France Brook (1 to 2 miles from the hunted area) were equal to or below those of previous years. The comparison indicated that the fall harvest had reduced starvation losses in the area open to hunting and its immediate vicinity.

TABLE 2. TOTAL LEGAL TAKE OF DEER FROM ALLEGANY STATE PARK (1944-54)

Year	Number of deer taken			Number of permits*		
	Antlered	Antlerless	Total	Gunners	Archers	Total
1944	54	169	223	1,657	..	1,657
1945	33	..	33	1,226	..	1,226
1946	51	..	51	1,024	...	1,024
1947	41	..	41	790	85	875
1948	100	137	237	1,285	70	1,355
1949	116	..	116	1,258	119	1,377
1950	55	36	91	1,413	157	1,570
1951	241	..	241	3,701	157	3,858
1952	143	136	279	3,735	450	4,185
1953	94	20	114	2,792	824	3,616
1954	76	4	80	2,313	960	3,273
Total...	1,004	502	1,506	21,194	2,822	24,016

*In 1944 and 1945 daily permits were issued. Since then seasonal permits have been issued.

Including those in 1944 and 1954, there have been four open seasons for antlerless deer and the taking of antlered deer has been permitted during all 11 years. The take by years is presented in Table 2.

The contrast between the legal take of 1,506 and the calculated winter-kill of 6,940 is great. An adequate harvest of bucks and does throughout the Park each fall could have prevented these losses from starvation. One of the simplest ways of illustrating this is as follows: In the winter of 1951-52 there were obviously 750 more deer in the Park than could survive. These deer ate all the browse they could secure during December, January, and February, but they did not get enough nutrition to carry them through and they died in February and March after having eaten 2,250 deer-months of food and wasted it. Had 500 to 700 more deer been harvested in the fall of 1951 the remaining population would have had 1,500 to 2,100 more deer-months of food which would have been enough to prevent starvation in the Park.

The change in range conditions over the past 10 years has been as great as the contrast between legal take and starvation loss. In 1945, data on browse species, density and utilization of winter forage, and on deer density were recorded at 37 stations in the France Brook area and at 39 stations in the Ryan Trail area. Both are in the section where hunting was permitted. Similar data were taken at the same stations in 1955. The two sets of records for each area are compared in Tables 3 and 4.

The deer density index is the average number of piles of droppings per station. In the France Brook area a decrease of about 10 per cent was recorded and in the Ryan Trail area the decrease was about 30 per cent. The average for both areas was about 19 per cent.

On each area forage densities probably averaged five to seven units per station during the years prior to the winter of 1937-38. (No study was made at that time but pictures and descriptions provide a reasonably good idea of the conditions.) At France Brook, average forest density had been reduced to 1.14 units in 1945 and to 0.16 units in 1955. At Ryan Trail, the figures were 1.79 and 0.31 respectively.

Between 1945 and 1955 in the France Brook area five browse species were completely eliminated and two species were reduced to a trace, while an average reduction of 85.7 per cent occurred in forage density. During the same period in the Ryan Trail area, ten species completely disappeared and an average reduction of 83.0 per cent occurred in forage density.

In 1955, five species were recorded which had not been present in 1945 on the plots examined. Each was represented by only a few stems. Two of them (hawthorn and locust) will grow in areas severely

Example of heavy browsing on spruce, a species normally seldom eaten by deer. Spruce in Allegany State Park was heavily eaten between 1949 and 1953.

Example of heavy browsing on hemlock, a formerly important winter deer food in Allegany State Park. Before 1938 green branches of such trees reached the ground.

TABLE 3. COMPARISON OF BROWSE DENSITY AND DEER DENSITY IN THE RYAN TRAIL STUDY AREA OF ALLEGANY STATE PARK IN 1945 AND 1955*

Species	Index of density		Per cent change
	1945	1955	
Beech (*Fagus grandifolia*)	14.36	5.27	− 63.3
Briar (*Rubus* sp.)	11.00	1.04	− 90.5
Red pine (*Pinus resinosa*)	9.60	0.10	− 99.0
Blue beech (*Carpinus caroliniana*)	6.55	0.75	− 88.5
Hard maple (*Acer saccharum*)	6.10	0.73	− 88.0
Choke cherry (*Prunus virginiana*)	5.80	2.51	− 56.7
Hemlock (*Tsuga canadensis*)	4.55	....	−100.0
Apple (*Pyrus Malus*)	4.30	0.20	− 95.3
Scotch pine (*Pinus sylvestris*)	2.40	...	−100.0
Yellow birch (*Betula lutea*)	1.30	...	−100.0
Arrow-wood (*Viburnum acerifolium*)	1.20	...	−100.0
Hop hornbeam (*Ostrya virginiana*)	0.80	1.00	+ 25.0
Wild black cherry (*Prunus serotina*)	0.70	...	−100.0
Juneberry (*Amelanchier* sp.)	0.50	...	−100.0
Ash (*Fraxinus* sp.)	0.40	...	−100.0
Hobblebush (*Viburnum alnifolium*)	0.24	...	−100.0
Red-berried elder (*Sambucus pubens*)	0.18	...	−100.0
Bitternut hickory (*Carya cordiformis*)	0.02	...	−100.0
Hawthorn (*Crataegus* sp.)	...	0.16	+100.0
White pine (*Pinus strobus*)	...	0.10	+100.0
Locust (*Robinia* sp.)	...	0.04	+100.0
Total	70.00	11.90	− 83.0
Forage density per station	1.79	0.31	xxx
Deer density index per station	3.5	2.3	xxx

*A total of 39 browse stations, each having a 25-foot radius, were located in this area.

overpopulated by deer, and two (witch hazel and white pine) are heavily browsed only when deer are undernourished. Red maple, a reasonably good deer food, was found at one station and in all probability will be killed by overbrowsing.

The only species to increase its density during the past 10 years is hop hornbeam (*Ostrya virginiana*). As a deer food it is only eaten by starving deer. The forage depletion by deer in these two areas is amply demonstrated by the foregoing data. But their influence is emphasized even more when one considers that since 1945 there has been no invasion of the open fields by woody plants.

In 1945 there were 112 units of browse on both areas. Species of average or better quality as deer browse (hard maple, apple, hemlock, ash, hobblebush, elderberry, and hickory) constituted only 22 units (or 20.6 per cent) of the forage. In 1955 there were 17.9 units of browse on both areas. Species of average or better quality as browse (red

TABLE 4. COMPARISON OF BROWSE DENSITY AND DEER DENSITY IN THE FRANCE BROOK STUDY AREA OF ALLEGANY STATE PARK IN 1945 AND 1955*

Species	Index of density		Per cent change
	1945	1955	
Red pine (*Pinus resinosa*)	11.61	....	−100.0
Blue beech (*Carpinus caroliniana*)	10.55	3.40	− 67.8
Scotch pine (*Pinus sylvestris*)	8.94	0.75	− 91.6
Hard maple (*Acer saccharum*)	5.95	0.15	− 97.5
Beech (*Fagus grandifolia*)	3.10	1.33	− 57.1
Briar (*Rubus* sp.)	0.65	....	−100.0
Willow (*Salix* sp.)	0.45	....	−100.0
Apple (*Pyrus Malus*)	0.30	T	§
Choke cherry (*Prunus virginiana*)	0.25	....	−100.0
Juneberry (*Amelanchier* sp.)	0.10	T	§
Quaking aspen (*Populus tremuloides*)	0.10	....	−100.0
Witch hazel (*Hamamelis virginiana*)	....	0.20	+100.0
Red maple (*Acer rubrum*)	....	0.10	+100.0
Hawthorn (*Crataegus* sp.)	....	0.07	+100.0
Total	42.00	6.00	− 85.7
Forage density per station	1.14	0.16	xxx
Deer density index per station	5.8	5.2	xxx

*A total of 37 browse stations, each having a 25-foot radius, were located in this area.
§A decrease of 99.9 or more.

maple, hard maple, and apple) constituted only 6.6 per cent of the greatly reduced quantity.

It may be concluded that Allegany State Park has been severely overstocked with deer in relation to their winter food supply since about 1938. Heavy losses due to starvation have occurred during the 16-year period from 1939-40 to 1954-55. It is quite obvious that it has done no good to prohibit hunting on the greater part of the Park area with the hope of saving deer. This prohibition has actually caused a greater loss of deer than would have been the case if the harvest by hunters in the fall had been adequate because each deer that dies of starvation wastes about three deer-months of food.

LITERATURE CITED

SEVERINGHAUS, C. W. 1945. Deer winter conditions in certain parts of Allegany State Park, Cattaraugus County, New York. Pittman-Robertson Project 1-R, Suppl. C. Quarterly Report (October). N. Y. S. Cons. Dept.

SHADLE, ALBERT R. AND DONALD STULLKEN. 1942. The deer of Allegany State Park, New York. Jour. Wildl. Mgt. 6(1):27-30.

HUNTING ACCIDENTS IN RELATION TO TYPES OF DEER SEASONS [1]

C. W. Severinghaus Game Research Investigator
New York State Conservation Department

C. P. Brown Game Research Investigator
New York State Conservation Department

ABSTRACT

Records of deer hunting accidents in New York State during the period 1941-1954 were studied in relation to the number of man-days spent afield in areas where the taking of antlered deer only, antlerless deer only, or deer of either sex was permitted. It was found that the number of accidents per 100,000 man-days was 1.9 in areas where antlered deer only could be hunted, and 0.6 in areas where the taking of deer of either sex was permitted. No accidents occurred where the taking of antlerless deer only was permitted, but the number of man-days afield during such seasons was small. Tabulations revealed that, during three recent years for which detailed information is available, less than one-fourth of all deer hunting accidents were due to people having been mistaken for deer.

Hunting accidents, particularly fatal ones, receive a good deal of publicity in spite of the fact that time spent in hunting probably is less risky than an equal amount of time spent in driving an automobile. One of the chief arguments employed by early proponents of the "buck law" was the thesis that there would be fewer accidents due to mistaking people for deer if hunters had to see antlers before firing. This idea persists to the present day and hampers efforts to convince the public that good management includes occasional open seasons on antlerless deer. The present study was undertaken in an effort to learn the facts concerning the effects, if any, of the various types of open seasons on the incidence of accidents among deer hunters.

PROCEDURE

Records of deer hunting accidents (fatal and nonfatal) were secured from the files of the Bureau of Law Enforcement for the period from 1941 to 1954.[2] Through the date and county of occurrence in

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-28-R.

[2] Records of accidents associated with hunting for antlered deer only from 1941 to 1945, and for deer of either sex in 1944, are incomplete and were omitted.

each case these were correlated with the hunting regulations in effect at the time. Thus, it was possible to tabulate the number of accidents to deer hunters in areas where antlered deer only, antlerless deer only, or deer of either sex could be legally taken. This was done irrespective of the type of license held by a hunter involved. For example, any accident, occurring in an area where holders of regular big game licenses could hunt simultaneously with those having special licenses for antlerless deer only, was considered to have taken place in an area open to hunting for deer of either sex. These data were further correlated with the records of license sales to determine the frequency of such accidents.

Various degrees of overlap occurred in different years with respect to the areas where the taking of antlered deer only was permitted and those where other deer could be taken. In view of this, some explanation of the treatment of the license records is in order.

For 1941, the data represent a situation where hunting was permitted for antlerless deer only. The number of hunters is known because a special license was required.

In 1943, hunting for antlerless deer only was again permitted under special license. In 15 western and Catskill counties this took place after the regular season so no overlap occurred. On the other hand, in the Adirondacks it took place during the first 6 days of the buck season so that, in actuality, the situation amounted to an open season for deer of either sex, especially since most special license holders had regular licenses as well. Nevertheless, there were many hunters afield on these days who could legally take only antlered deer. In computing the accident rate, however, only the special licensees were considered—a conservative treatment from the standpoint of not minimizing this factor.

In 1946, hunting for antlerless deer was permitted in four western counties under circumstances similar to those in the Adirondacks in 1943 and the records have been treated accordingly.

In 1948, hunting deer of either sex under special license was permitted during a 6-day season in 10 western counties. There was no other deer season in this area and the special licenses were not valid elsewhere. Therefore, no overlap occurred in this year.

In 1950, the regulations were the same as in 1948 except that 24 counties were involved and the special license permitted taking deer of either sex on the last day of the season only, but was valid for antlered deer on the other 5 days. To be conservative, the figures for time spent hunting antlered deer only were not increased to compensate for that done by the special license holders.

In 1952, hunting deer of either sex was permitted under the regular big game license on 2 days within the open season for antlered deer in 5 Catskill and 24 western counties. Because no special license was issued it was necessary to estimate the number who hunted there on those 2 days. On the basis of the hunter distribution observed in previous years, it was felt that roughly half of those who purchased big game licenses would be a reasonable figure. Therefore, 200,000 was used.

Conversations with deer hunters during the past 14 years have indicated that the average hunter spends about 4 days afield during the open season, whether it is a 6-day, 16-day, or 37-day period. Therefore, for seasons of 4 or more days duration, the number of man-days spent afield was calculated by multiplying the number of licensees by four. For shorter seasons the actual number of days was used as the factor.

FINDINGS

Pertinent data for the period from 1941 to 1954 are presented in Table 1. Accident frequency is expressed as the number per 100,000 man-days. This rate was lower where the regulations permitted taking deer of either sex than where antlered deer only were legal game, the figures being 0.6 and 1.9, respectively. On the basis of accidents per 100,000 licensees, the rate was 7.7 in areas where antlered deer only were legal game and 1.4 where the taking of deer of either sex was permitted. It is of particular interest that no accidents were associated with hunting for antlerless deer or for deer of either sex in 1941, 1943, and 1950 despite the fact that some 171,000 hunters spent more than 222,000 man-days afield.

Information is available as to the cause of deer hunting accidents during 1952, 1953, and 1954 (Table 2). It is evident that less than one-fourth of all accidents during these years were due to mistaking people for deer. Since 4,430,268 man-days were spent afield by deer hunters during the 3-year period (Table 1) there were only 0.36 accidents per 100,000 man-days due to mistaking hunters for deer, and only 1.56 from all causes.

DISCUSSION

The data presented in Table 1 indicate that in New York there has been no more danger of being shot while hunting in areas where

TABLE 1. FREQUENCY OF DEER HUNTING ACCIDENTS IN NEW YORK IN RELATION TO REGULATIONS WITH RESPECT TO ANTLERED AND ANTLERLESS DEER (1941-54)

Year	Hunting pressure in areas where regulations permitted taking—						Number of accidents in areas where regulations permitted taking—			Accidents per 100,000 man-days of hunting where regulations permitted taking—		
	Antlered deer only		Antlerless deer only		Deer of either sex							
	Number of hunters	Man-days afield	Number of hunters	Man-days afield	Number of hunters	Man-days afield	Antlered deer only	Antlerless deer only	Deer of either sex	Antlered deer only	Antlerless deer only	Deer of either sex
1941	*	*	1,927	5,781§	..	..	*	0	..	*	0.0	..
1943	*	*	23,465	70,395§	15,643	62,572	*	0	0	*	0.0	0.0
1946	282,837	1,131,348	..	..	2,945	11,780	26	..	0	2.3	..	0.0
1947	295,700	1,182,800	..	..	..	..	22	..	..	1.9	..	..
1948	242,348	969,392	..	..	136,211	544,844	33	..	3	3.4	..	0.6
1949	313,955	1,255,820	..	..	..	..	33	..	..	2.6	..	..
1950	203,331	813,324	..	..	145,936	145,936†	14	..	0	1.7	..	0.0
1951	365,517	1,462,068	..	..	..	..	17	..	..	1.2	..	..
1952	201,612	806,448	..	..	200,000	400,000‡	26	..	4	3.2	..	1.0
1953	399,701	1,598,804	..	..	..	..	16	..	..	1.0	..	..
1954	406,254	1,625,016	..	..	..	..	23	..	..	1.4	..	..
Total.	2,711,255	10,845,020	25,392	76,176	500,735	1,165,132	210	0	7	1.9	0.0	0.6

*Omitted because number of accidents was not available.
§3-day season.
†1-day season.
‡2-day season.

TABLE 2. CAUSES OF DEER HUNTING ACCIDENTS IN NEW YORK (1952-54)

Cause	Number of accidents				Per cent of total
	1952	1953	1954	Total	
Carelessness	9	7	6	22	31.9
In line of fire	10	2	8	20	29.0
Mistaken for deer	5	5	6	16	23.2
Ricocheting bullet	5	1	2	8	11.6
Other	1	1	1	3	4.3
Total	30	16	23	69	100.0

the taking of deer of either sex was permitted than in areas where antlered deer only could be legally taken. In fact, the opposite seems to have been the case. Since open seasons for deer of either sex have resulted in concentrations of hunters similar to those of the first day or first weekend of a buck season, it may be that greater care than usual has been exercised by hunters. Another possible factor has been that open seasons for antlerless deer and deer of either sex in New York have been short (varying from 1 to 6 days in duration), with the result that the hunters "bear down" and concentrate on hunting, whereas during the longer buck seasons (37, 16, and 12 or 6 days in duration depending on the region) there has been a greater tendency for them to engage in target shooting and other activities, and become careless.

Mr. F. R. Butler, Game Commissioner for the Province of British Columbia, summarized the results of a questionnaire survey made in 1953 (personal communication, May 16, 1955). He found that, of 20 states and three provinces responding, not one considered that there were more accidents during deer-of-either-sex seasons than during buck seasons. These included such prominent deer states as Michigan, Minnesota, Wisconsin, and New York. Furthermore, only one state indicated that the possibility of an increased number of accidents was a major consideration when deciding on seasons for taking antlerless deer. In fact, as a result of the survey, it was concluded that hunters were safer during doe seasons than during buck seasons.

CONCLUSIONS

A study of deer hunting accidents in New York during the period from 1941 to 1954 indicates that there was less likelihood of being mistaken for a deer or injured by gun fire when deer of either sex were legal game, than during seasons when antlered deer only could be taken.

GROWTH IN RELATION TO SEX AMONG BROOK TROUT [1]

David C. Haskell Fish Hatchery Foreman
New York State Conservation Department

Robert Griffiths Fish Hatchery Helper
New York State Conservation Department

ABSTRACT

Unsorted samples of brook trout fingerlings had an approximately 50:50 sex ratio. Bar sorters, as used in hatcheries to grade trout into nearly even-sized groups, were shown to produce unbalanced sex ratios among the sorted groups, the larger fish being predominantly males. The effect seems too small to be of much importance unless only a few of the largest fish are sorted out, in which case there will be a very high proportion of males.

Length and weight data according to sex for a small group of brook trout were taken over a period of a year and a half. The rate of growth, as measured by increases in length or in the cube root of the weight, was found to be slightly higher for males than for females. It was nearly the same for the groups produced by sorting when allowance was made for differences in the sex ratio. Although the average growth rate was approximately the same for groups of different size, great variation was observed among individual fish, so that the effect of sorting was only temporary in producing groups of uniform size. Selection of the largest fish by length or weight at a given age was found to have little value in predicting their subsequent growth rate.

Many fish-culturists have seen instances when groups comprising the larger-sized individuals among hand-sorted brook trout have proved to be predominantly males. In 1937 one of the authors stocked a display pond with a dozen carefully selected fall fingerling brook trout. It later developed that all of these fish were males. This occurrence caused interest in the relative size of the sexes of brook trout, and the effect of sorting brook trout with the conventional bar sorter.

EFFECT OF BAR SORTER ON SEX RATIO

During 1938 five samples were taken, on different dates, from a lot of brook trout fingerlings. The fish in three of these samples were sorted into two groups with a bar sorter. Then, all the fish were killed and the sex of each was determined and recorded together with its length. In 1939 a second lot was sorted and sexed. Certain fish of this lot were selected for further study (see following topic) and for these sex was not determined until later, but the fact that they were tagged enabled the two sets of data to be correlated. Another lot was sampled for sex and length only in 1954.

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[1] The data analysis and preparation of this report are a contribution of Federal Aid in Fish and Wildlife Restoration Project F-11-R.

TABLE 1. SEX AND SIZE DISTRIBUTION IN UNSORTED LOTS OF BROOK TROUT

Sample	Date	Number male	Number female	Average length in inches	
				Male	Female
1	July 14, 1938	65	69	3.43	3.37
2	July 18, 1938	52	57	3.53	3.38
3	September 20, 1938	78	77	5.02	4.64
4	October 7, 1938	75	75	5.33	4.98
5	October 10, 1938	56	54	5.29	5.01
6	July 29, 1939	293	315	*	*
7§	July 29, 1939	29	31	3.88	3.73
	December 4, 1939	29	31	5.66	5.39
8	May 16, 1954	189	151	3.41	3.33

*Not recorded.
§Sample 7 comprised those fish of Sample 6 which were selected and held for further study. Data for them were taken on two dates as shown and, in addition, they are included in Sample 6.

TABLE 2. SEX DISTRIBUTION OF BROOK TROUT SORTED WITH BAR SORTER

Sample	Number of fish	Average length in inches	Percentage distribution			
			Smaller group		Larger group	
			Male	Female	Male	Female
			First sorting			
2	109	3.45	25.7	36.7	22.0	15.6
3	155	4.83	14.2	29.7	36.1	20.0
5	110	5.15	40.9	47.3	10.0	1.8
6	608	3.80	19.9	33.5	28.3	18.3
			Resorting*			
3a	87	5.24	31.0	20.0	5.1	0.0
3b	68	4.32	6.5	15.5	7.7	14.2
6a	283	§	15.1	14.0	13.2	4.3
6b	325	§	9.7	18.1	10.2	15.4

*For each of Samples 3 and 6 the two groups resulting from the first sorting were designated *a* (larger) and *b* (smaller) and were resorted. Percentages for the groups obtained by resorting, however, are in terms of the total sample in each case.
§Not recorded.

The overall composition of these samples is given in Table 1. The results, in terms of sex distribution, of separating the smaller from the larger fish are given in Table 2. With respect to Samples 3 and 6, the two groups resulting from the first sorting were each resorted. In Table 3 the sex ratios for the various groups are given in terms of the percentage of males. The data indicate that:

1. All of the unsorted samples had nearly a 50:50 sex ratio.
2. For each sample the larger of the two groups obtained by the first sorting contained a disproportionally high number of males.
3. The proportion of males was highest when only a few of the larger fish were selected, as in resorting the larger groups from the first sorting.
4. Sorting does not appear to upset the sex ratio sufficiently to have much biological importance unless a sorting is made in which only a very few of the largest fish are selected.

TABLE 3. EFFECT OF BAR SORTER ON SEX RATIO OF BROOK TROUT

Sample	Number of fish	Smaller group		Larger group	
		Number	Per cent male	Number	Per cent male
First sorting					
2	109	68	41.2	41	58.5
3	155	68	32.4	87	64.4
5	110	97	46.4	13	84.6
6	608	325	37.2	283	60.8
Resorting					
3a	87	79	60.8	8	100.0
3b	68	34	29.4	34	35.3
6a	283	177	52.0	106	75.5
6b	325	169	34.9	156	39.7

GROWTH RATE OF THE SEXES

During July 1939, a sample (Sample 6) of a lot of brook trout was taken containing 608 fish. Sorting and resorting these fish resulted in four groups as shown in Table 2. From each of these four groups a sample of about 25 fish was taken. Each fish was tagged and weighed, and its length was measured. The tagged groups were then put together and held until October, 1940 under hatchery conditions. Individual weights and lengths were taken at intervals, and sex was determined at the breeding season in the second year. At the end of the experiment random selections were made to obtain a sample in which each sex in each group appeared in the same proportion as in the original group of 608 fish. The number of fish of each sex in this sample is given in Table 4. The data on these fish were used for a

TABLE 4. SEX COMPOSITION OF FOUR SORTED GROUPS

Groups	Number of fish	Number	
		Male	Female
1 (largest)	11	8	3
2	17	9	8
3	15	6	9
4 (smallest)	17	6	11
Total.	60	29	31

detailed analysis of growth. The remainder of this paper covers that analysis.

The number of fish (60) in this sample was, of course, pitifully small. However, the authors place considerable confidence in the results, first, because this sample checks in all respects where comparisons are possible with the other samples included in Tables 1 to 3, and second, because several tests made on the data are statistically convincing.

All of the growth data may have been affected by the jaw tags. It is known that during the first summer the growth of the test fish in weight was only 80 per cent of that of the untagged group from which they had been selected.

Growth may be measured by several criteria. Three have been used to evaluate the data presented here: length, weight, and the cube root of the weight.

GROWTH AS MEASURED BY LENGTH

In Figure 1, the mean length of each of the four sorted groups is plotted against time, the data being the mean length of each group on six dates spread throughout the experiment. It will be noted that the four lines are nearly parallel throughout, although a close inspection reveals that they diverge slightly as they progress.

In Figure 2, the mean length of each sex is similarly plotted. It is apparent that the males not only were larger at the start of the experiment but in addition had a slightly faster growth rate over the entire period. A close inspection shows that the males outgrew the females in each of three of the five periods, their growth rate being slower only in the fall months of each year. It is suspected that this was in some way associated with the breeding season. It is further suspected that this was a reduction in the growth rate of the males rather than an increase in the growth rate of the females, since the

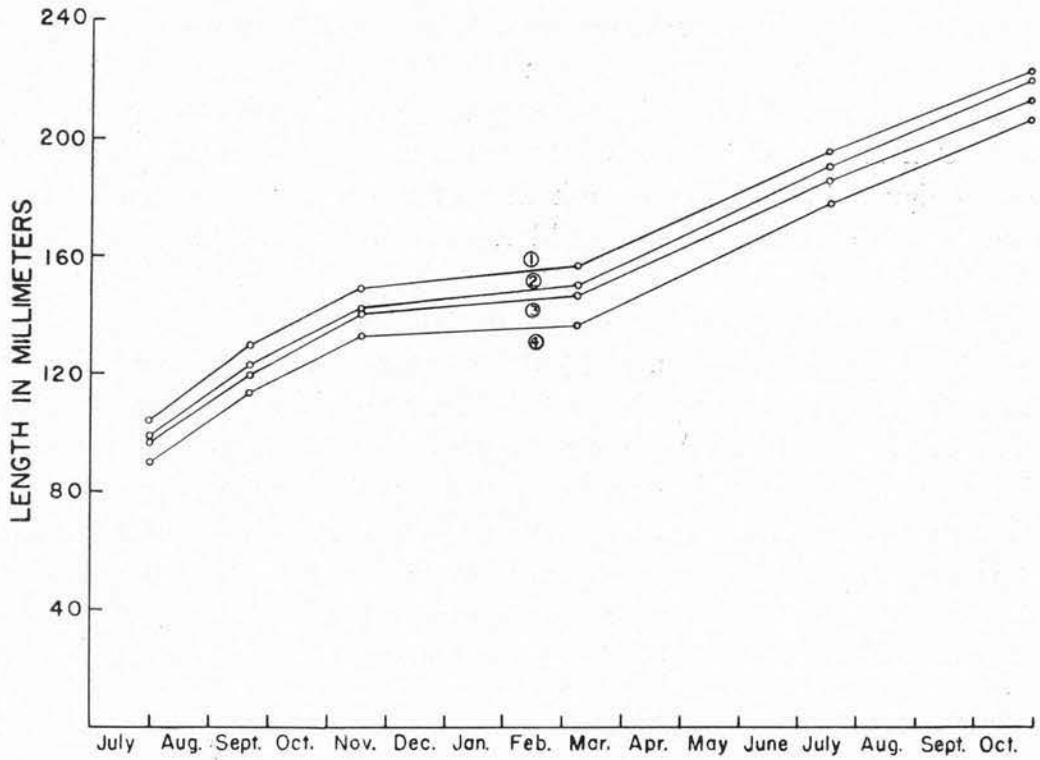

Figure 1. Growth of four sorted groups of brook trout according to the increase in the mean length of each.

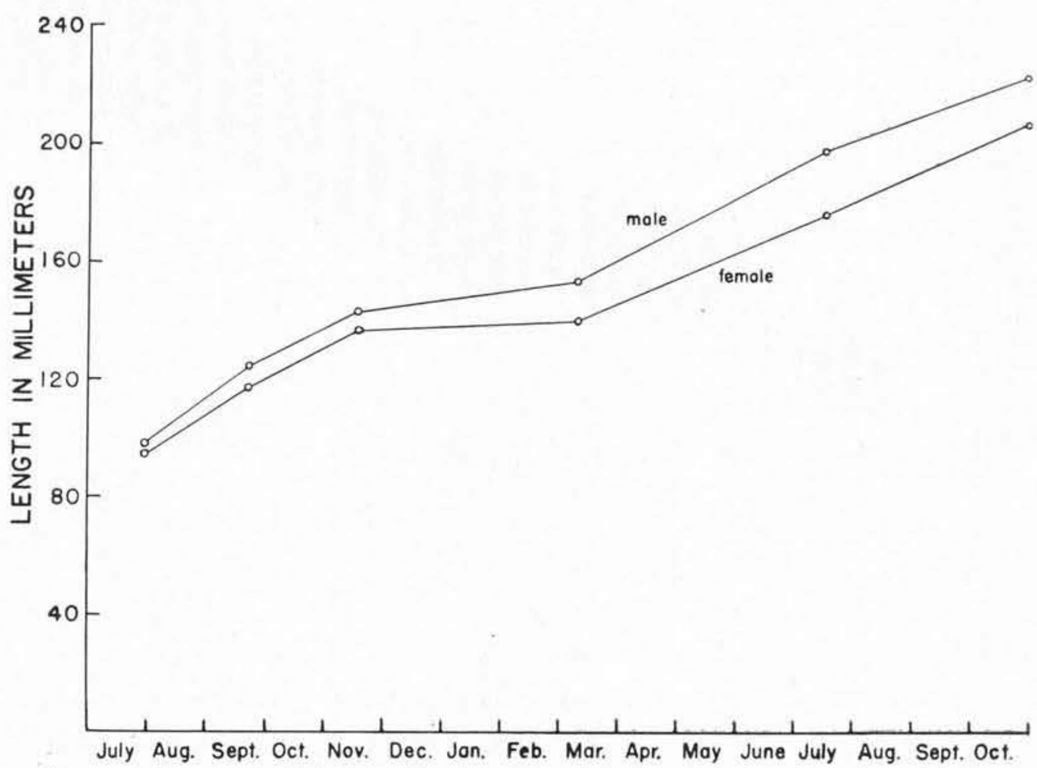

Figure 2. Growth of the two sexes of brook trout according to the increase in the mean length of each for the four groups combined.

males were ripe in the first year and females not until the second year so that spawning probably did not affect the growth of the females in the first year. The data supply no proof on this point, however.

Considering the fact that the two groups comprising larger-sized fish (Figure 1) had a predominance of males and the others a predominance of females, one would expect a slightly faster growth rate for the former, and this, it has been calculated, was sufficient to account for the slight divergence of the lines in the graph.

In Figure 3 an attempt has been made to show the variation in size and growth among the individuals comprising the four groups. The heavy lines give the mean length for each and the shaded bars indicate the range of variation represented by twice the standard deviation either side of the mean in each case. This spread would include approximately 95 per cent of the fish in a large population having the same variability as the sample studied. It is obvious from this graph why sorting produces uneven sex ratios, and why sorting

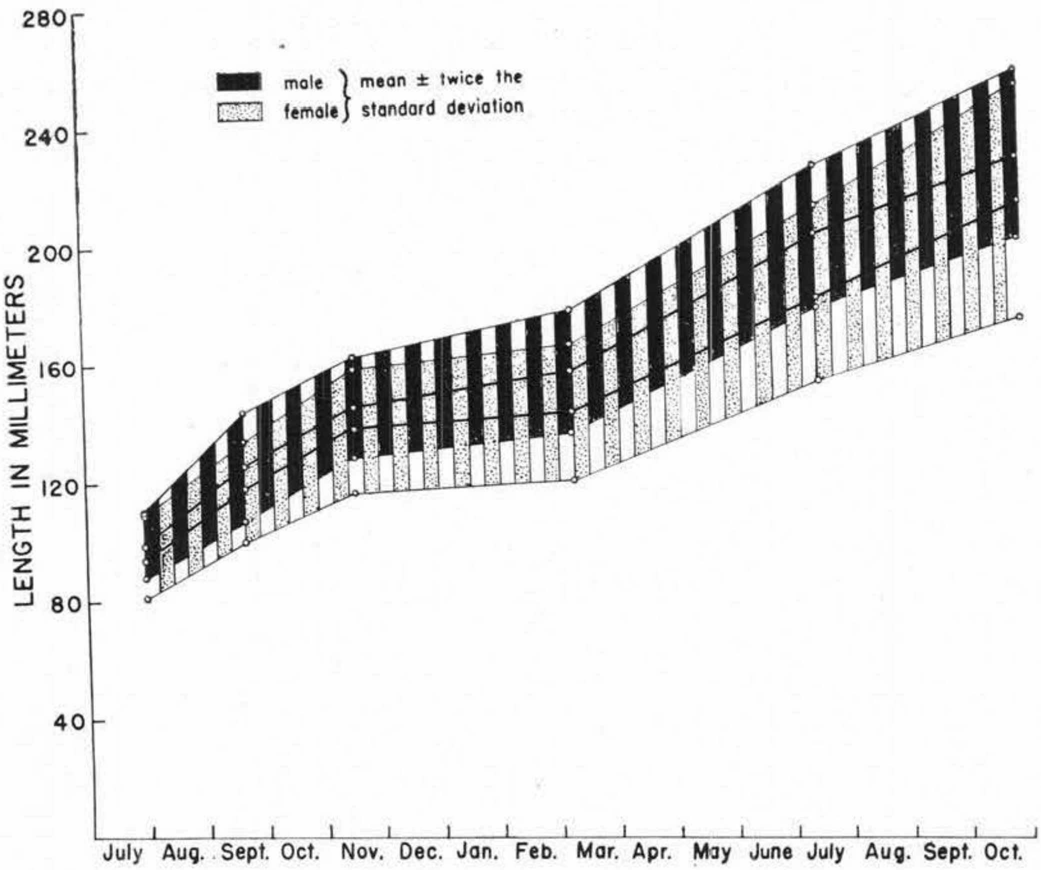

Figure 3. Variation in size and growth of the two sexes of brook trout according to the increase in the mean length and twice the standard deviation of each for the four groups combined. The heavy lines represent the means: (upper) male; (lower) female.

out only a few large individuals produces a predominance of males. It appears that a normal population of brook trout is actually a mixture of two populations having different growth potentialities, the two populations being the two sexes.

A study of the data for individual fish indicates little conformity in growth among specimens of the same initial length and sex. In fact it appears that the growth of an individual of a given sex was random. For example, considering the 10 largest individuals among all 60 fish at the start of the experiment, their ranks[2] in length at the end were: 31.5, 4.5, 1, 16.5, 35, 30, 37, 16, 7, and 52. A test of this observation was made by the chi square method (x^2r) proposed by Wilcoxon (1949). The test consists of determining whether the fish with the most rapid growth in one period had the most rapid growth in all periods.[3] The results strongly suggest that among the males growth was determined only by sex and randomness, while for the females there was a slight tendency for the most rapidly growing fish at one size to have the faster growth rate throughout. For the males $x^2r=32.23$, and with 28 degrees of freedom represents a probability of 0.27. For the females $x^2r=49.92$, and with 30 degrees of freedom represents a probability of 0.013.

In summation, sorting produces groups of fish of different mean lengths. If this difference is, for example, one-eighth inch at an average length of 4 inches, it will not be likely to be much greater when the fish are 10 inches long despite a progressively greater degree of individual variation.

It is concluded that selection of the largest fish at a given date, particularly among males, is a rather inefficient way of selecting those which will be largest at a later date. Sorting fish produced groups in which the variation was small. Subsequent growth rapidly increased variation, so that sorting was only a temporary expedient in producing fish of uniform size.

The continuous change in the size rank of individuals raises questions about selective breeding for rapid growth. If, for example, one wished to produce rapid-growing fish he might select those which at first breeding had attained the greatest size. Such a group, based on this experiment, would on the average contain relatively few individuals which had been among the largest at earlier ages.

[2] Ranks ending in 0.5 indicate ties, i.e., two fish of same length.

[3] There is some doubt regarding the applicability of this test since the variance of the lengths increased as the means increased.

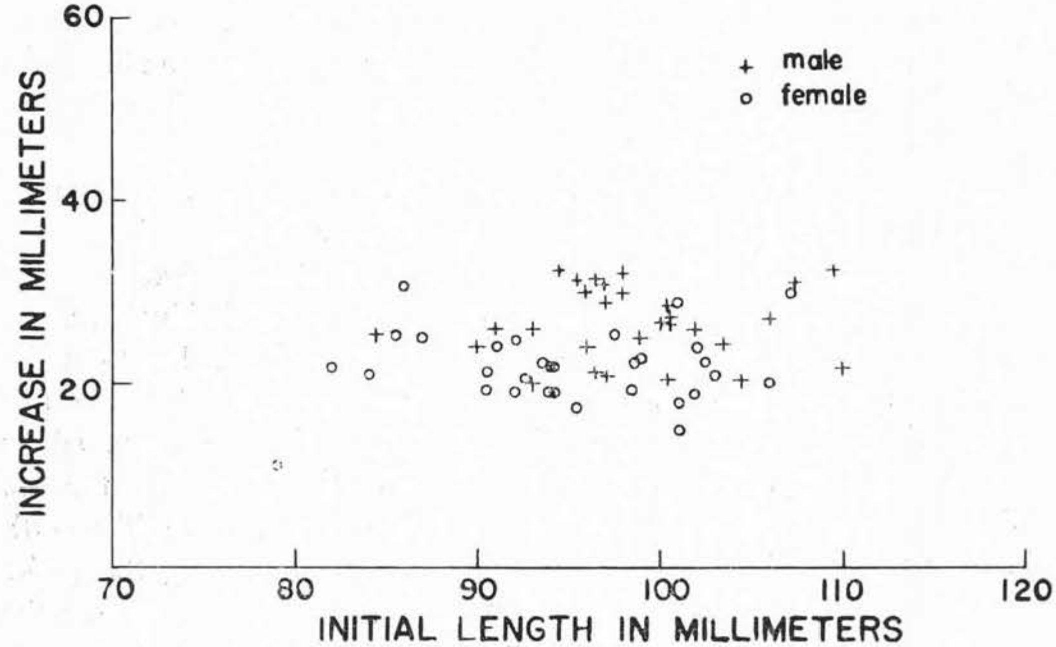

Figure 4. Comparison of initial length (on July 29, 1939) with degree of increase to September 20, 1939.

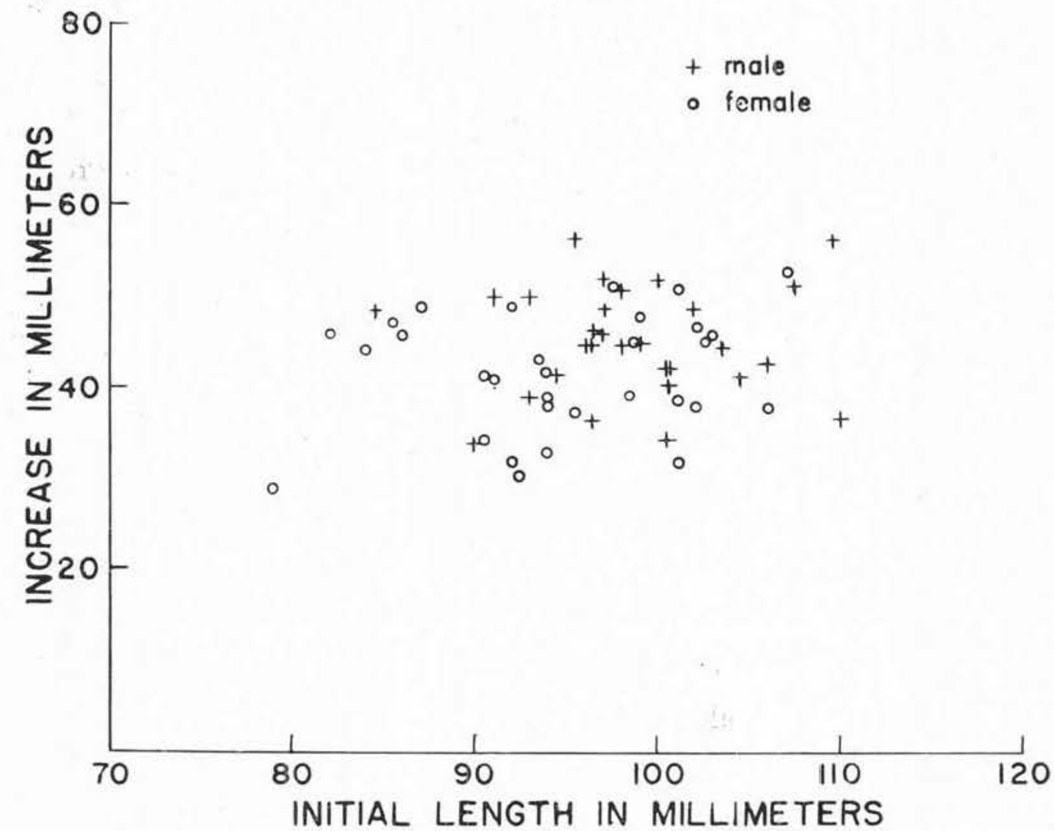

Figure 5. Comparison of initial length (on July 29, 1939) with degree of increase to November 16, 1939.

The relationship between initial length and subsequent growth is illustrated by Figures 4 to 8, in which the initial length of individual fish has been plotted against growth to the end of each of the several periods. It can be noted that the dependence of growth on initial length was not great and that the variation among individuals increased with time.

GROWTH AS MEASURED BY WEIGHT

The same comparisons of growth have been made using average weight instead of length. Figure 9 shows the growth rates of the four sorted groups, and Figure 10 the growth of the two sexes. In both instances the weight means diverged much more rapidly than did those for length. Using this measure of growth one would conclude that the

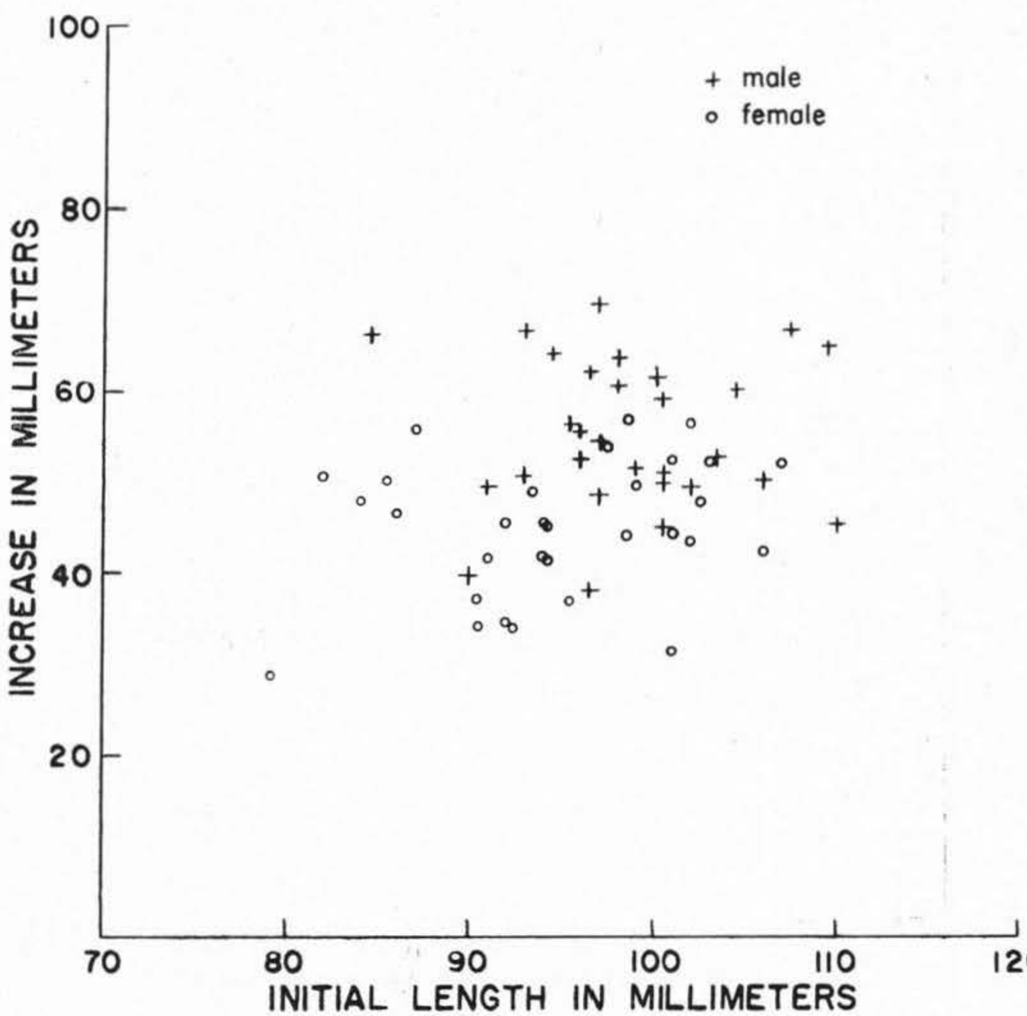

Figure 6. Comparison of initial length (on July 29, 1939) with degree of increase to March 7, 1940.

larger-sized groups had a faster growth rate and that the males had a considerably higher growth rate than the females. These data might appear to conflict with those for length. However, because weight increases in proportion to the volume of a fish (which may be represented by the cube of its length) it should, for example, take less

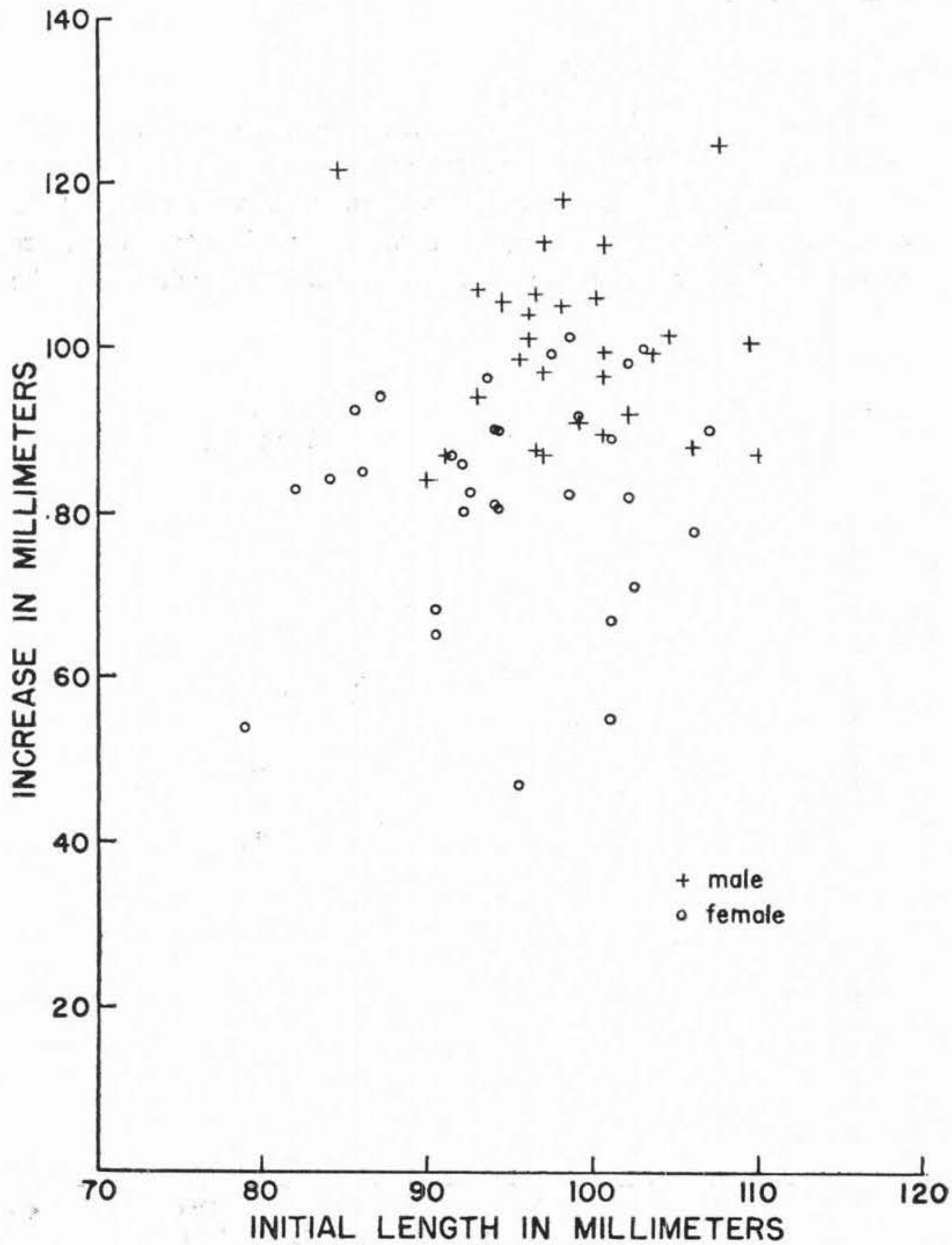

Figure 7. Comparison of initial length (on July 29, 1939) with degree of increase to July 15, 1940.

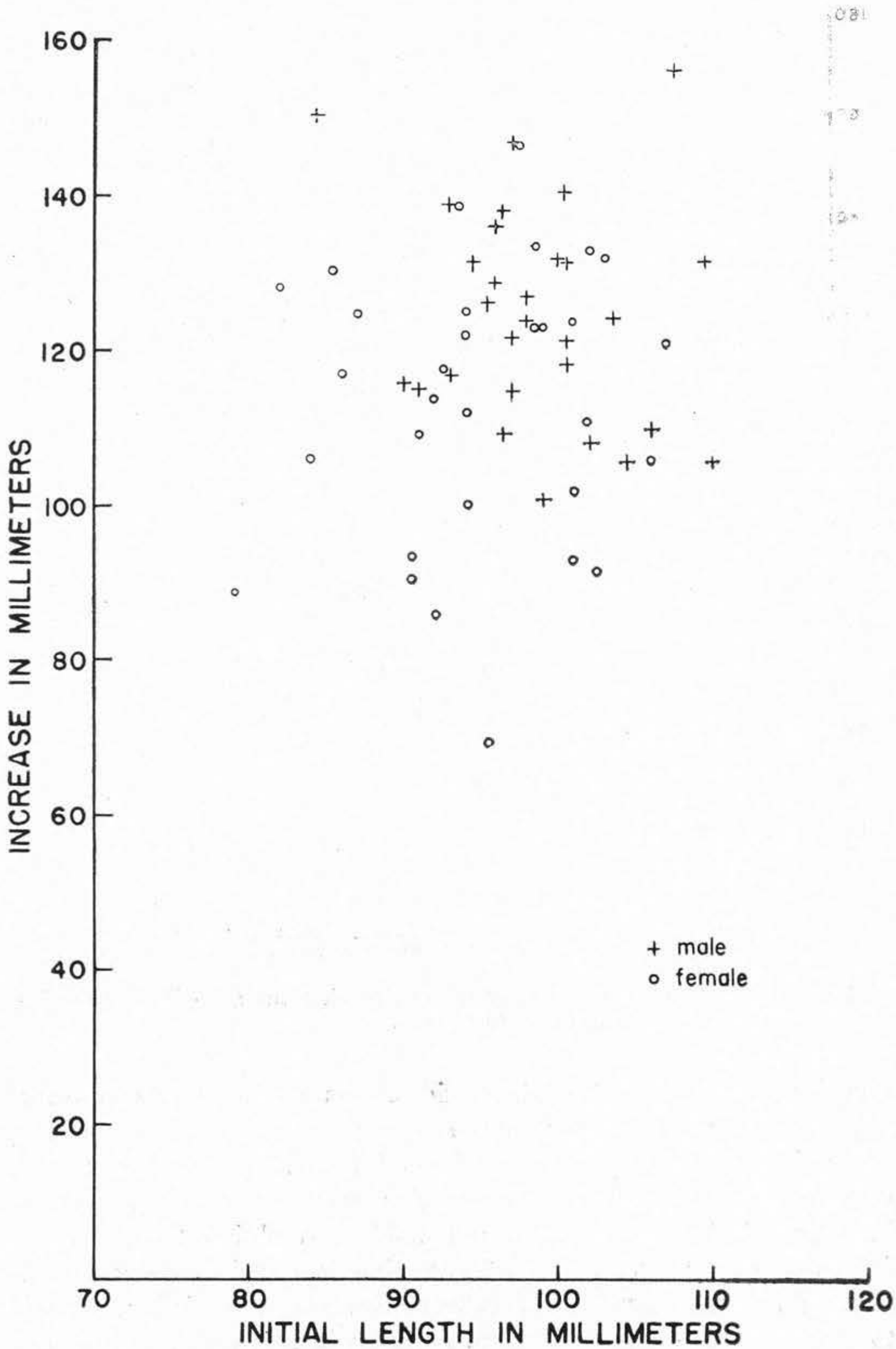

Figure 8. Comparison of initial length (on July 29, 1939) with degree of increase to October 28, 1940.

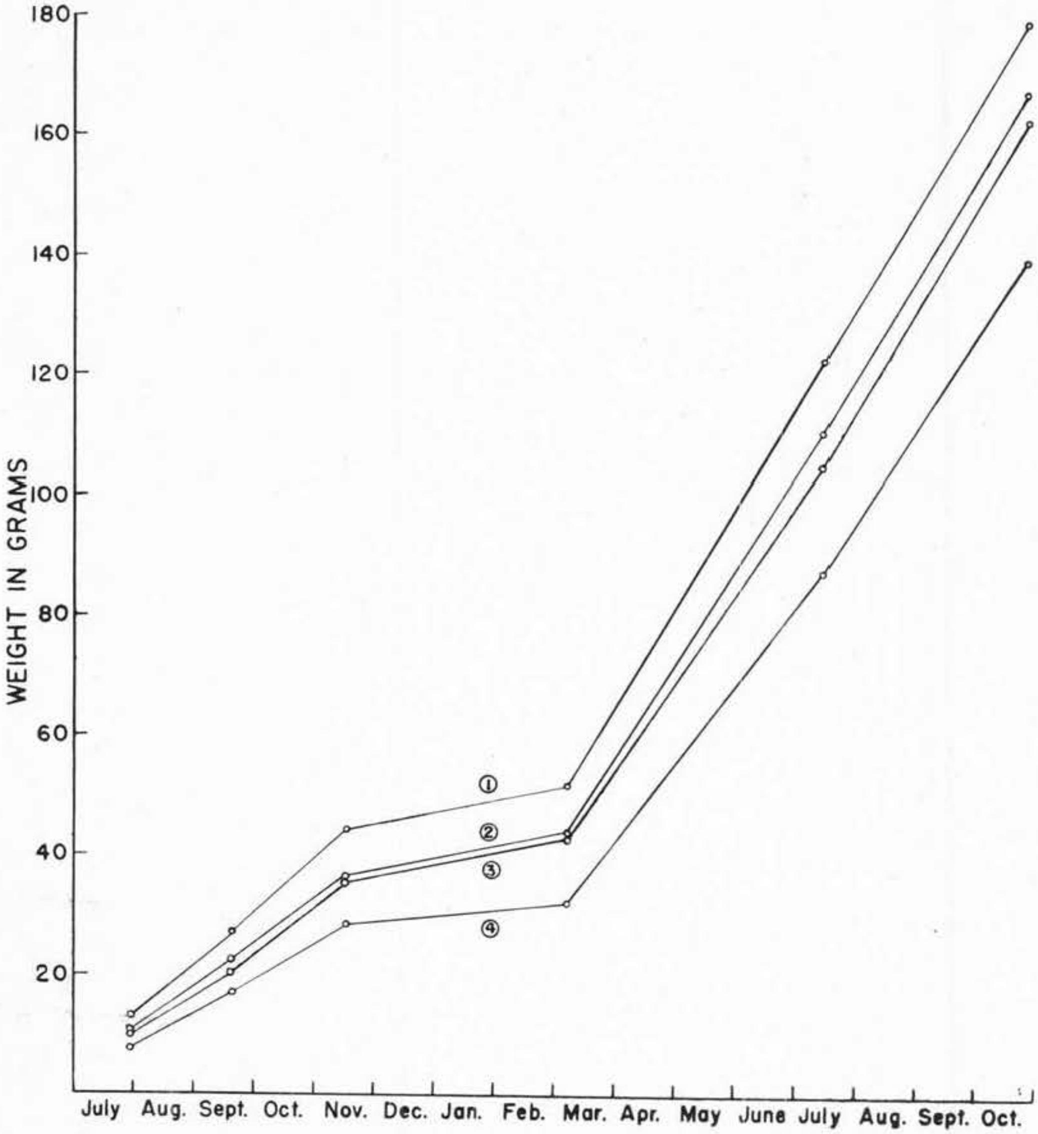

Figure 9. Growth of four sorted groups of brook trout according to the increase in the mean weight of each.

time for a one-half pound fish to add an ounce to its weight than for a one-quarter pound fish to do the same.

Before proceeding to the analysis of growth as measured by the cube root of the weight, a discussion of the measures of growth appears in order. Under even approximately uniform conditions the growth of fish as shown by weight in relation to time is a rapidly rising curved line. Thus, to compare the growth of two lots of fish it is necessary to evaluate the differences in two curves, which is difficult. For this reason various other measures of growth have been used, e.g., percentage gain and number per pound. In most lines of work where this

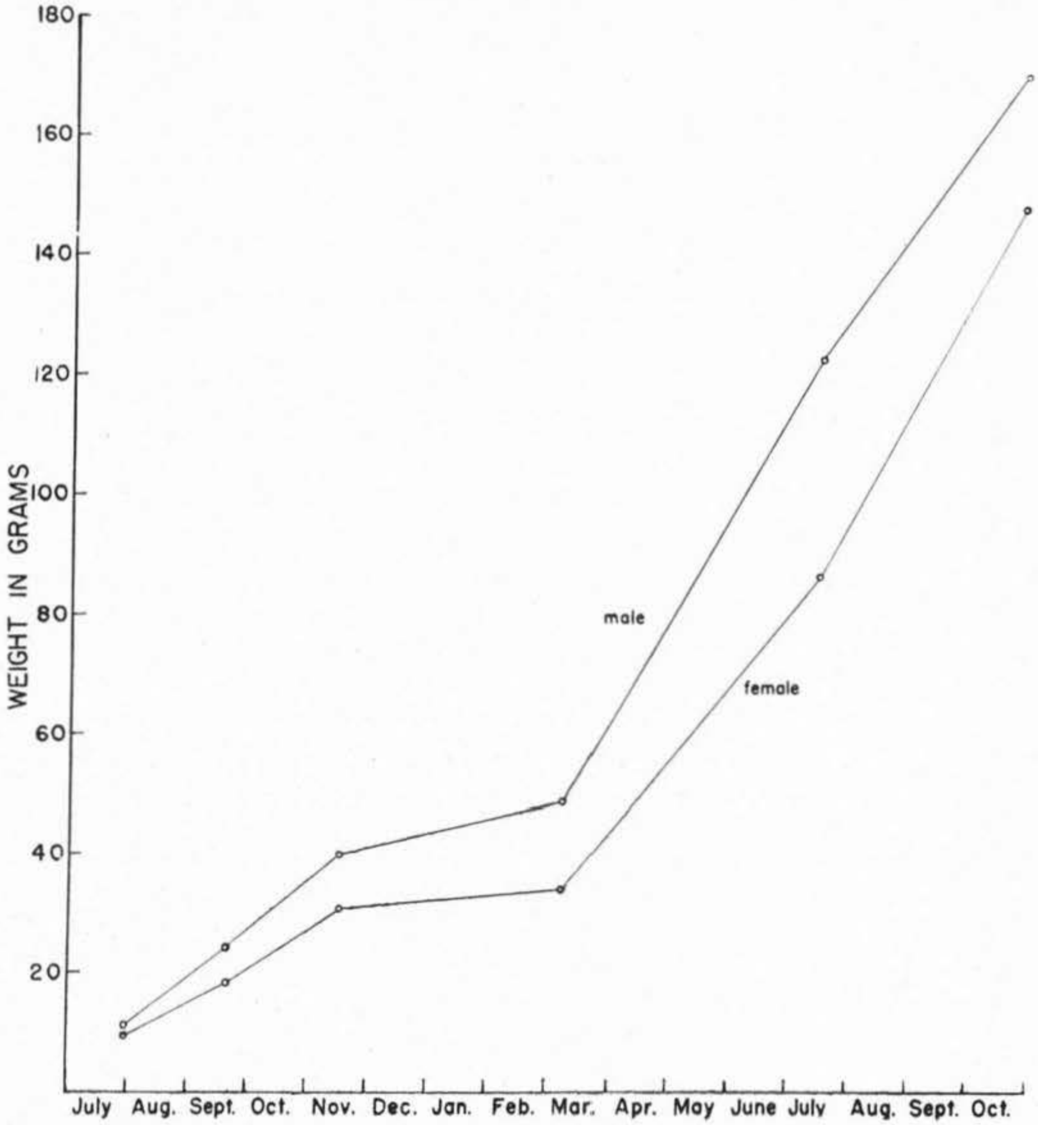

Figure 10. Growth of the two sexes of brook trout according to the increase in the mean weight of each for the four groups combined.

problem is encountered, an attempt is made to find a measure which is linear, i.e., produces a straight line. Haskell (1948) has shown that for brook trout the cube root of the weight produces a very close approximation of a straight line at constant temperature, at least until the first spawning season. From other experiments by the author there is good reason to believe that, with a succession of different temperatures, growth may be subdivided into segments for the period at each temperature, the cube root of the weight being linear in each case. It is for this reason that the cube root of the weight has been used in this study. Its use suggests some interesting implications. If it in-

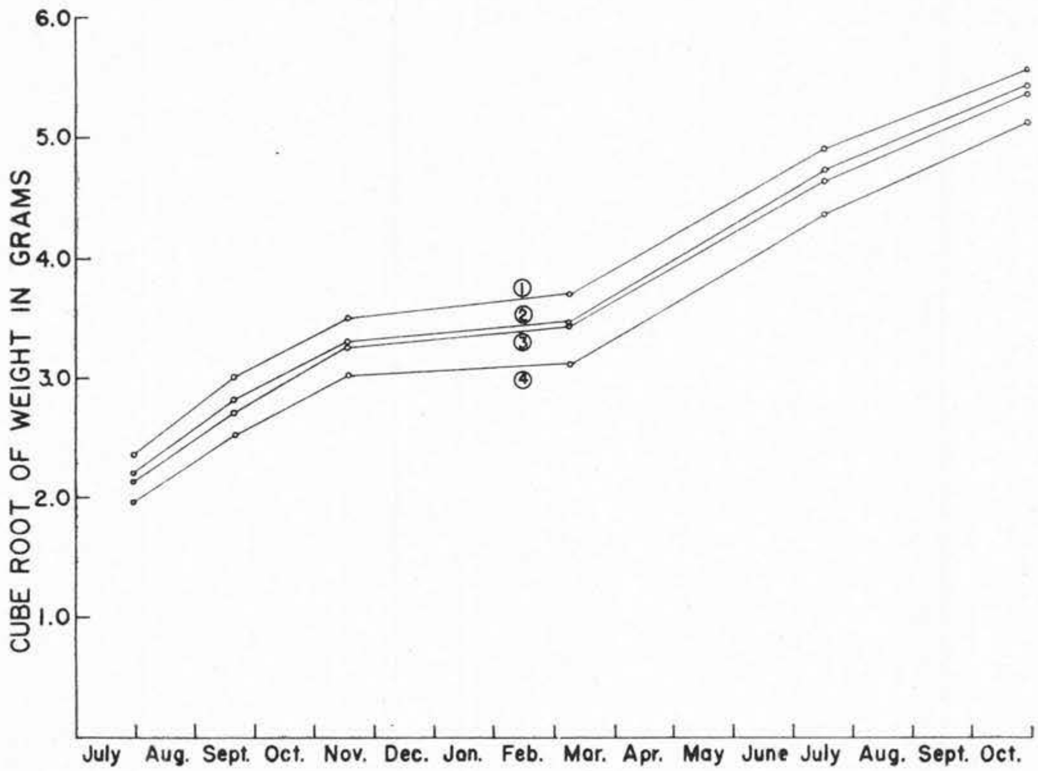

Figure 11. Growth of four sorted groups of brook trout according to the increase in the cube root of the mean weight of each.

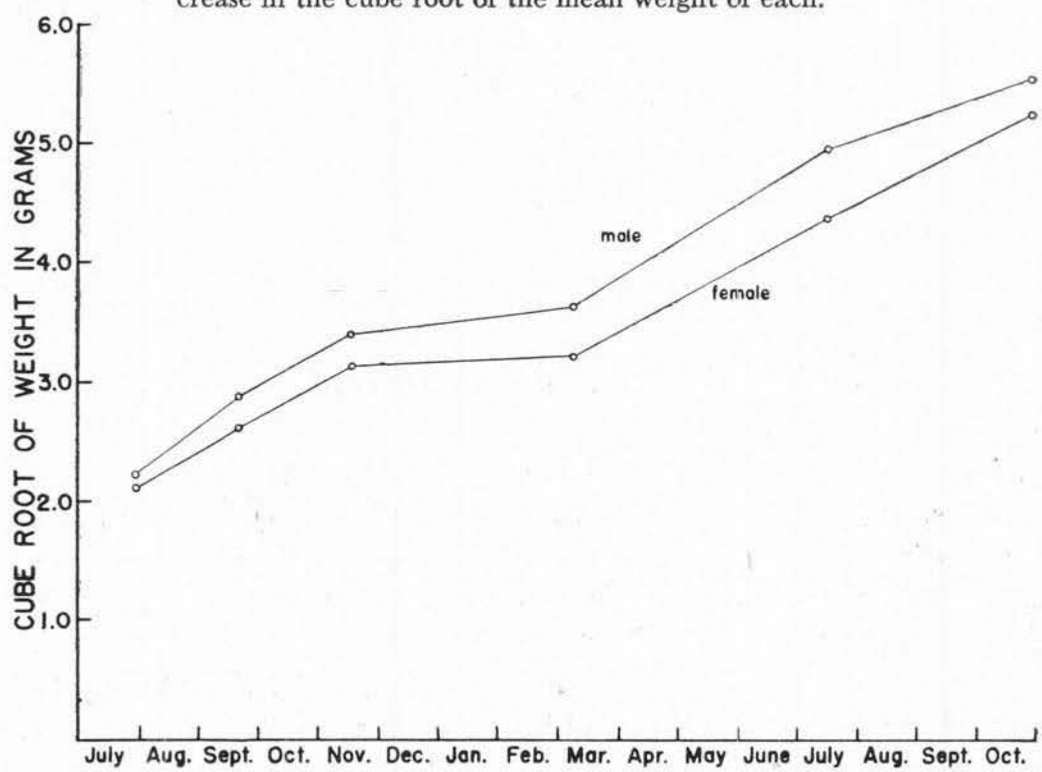

Figure 12. Growth of the two sexes of brook trout according to the increase in the cube root of the mean weight of each for the four groups combined.

creases linearly with age at constant temperature, and if the condition factor is constant, then the length will be expected to increase linearly with age since, under a constant condition factor, weight is proportional to the cube of the length. It is suspected, therefore, that under uniform conditions, including temperature, the mean length for a group of brook trout may be expected to increase at a constant rate.

GROWTH AS MEASURED BY CUBE ROOT OF MEAN WEIGHT

Figures 11 and 12 give the growth of the four groups and of the sexes according to the cube root of the mean weight. The similarity between these and similar data for length (Figures 1 and 2) is striking. All of the conclusions drawn for length seem to apply here as well.

It appears, both in this comparison and in that for length, that the larger fish did not have a faster growth rate than the smaller ones; in fact they were nearly equal when sex is taken into account. Nevertheless, many a fish-culturist is confident that had the small fish been separated from the large ones, and kept in a separate trough, they would have had a faster growth rate. This would be well worth an experiment but at least when kept together the growth rates were not much different.

LITERATURE CITED

HASKELL, DAVID C. 1948. Graphical method of presenting data on the growth of trout. The Prog. Fish-Cult. 10(2):59-61.

WILCOXON, FRANK. 1949. Some rapid approximate statistical procedures. American Cyanamid Co., New York.

THE EFFECT OF TEMPERATURE ON THE GROWTH OF BROOK TROUT [1]

David C. Haskell Fish Hatchery Foreman
New York State Conservation Department

Louis E. Wolf[2] Senior Fish Pathologist
New York State Conservation Department

Loyal Bouchard Fish Hatchery Helper
New York State Conservation Department

ABSTRACT

Growth data were collected on 16 lots of brook trout from a single original source. Two lots were assigned to each of eight hatcheries and reared under controlled conditions from a size of 1½ inches to one of 4¾ inches. The difference between hatcheries and the effect of temperature on growth rate were calculated from the data. It is shown that at a given temperature approximately the same number of days was required for each one-half inch of growth.

Water temperature is undoubtedly one of the most important factors affecting the propagation of trout. However, quantitative data measuring the effect of temperature on growth are meager. In the experiment to be described, temperature data under one set of conditions have been obtained.

PROCEDURE

In this experiment 16 lots of brook trout fingerlings were reared under uniform conditions at each of eight hatcheries. Work was started in March when the fish were about 800 per pound. Equal lots of 4,000 fish were randomly selected from a single source at the Rome Hatchery. Two of these lots were transferred to each participating hatchery: Bath, Caledonia, Chateaugay, Crown Point, Johnstown, Lake George, Randolph, and Rome. At each hatchery each lot was assigned an upper rearing trough, 10 cubic feet in capacity, in a battery receiving unused spring water. The flow was adjusted to 15 gallons per minute in each trough.

The troughs were cleaned twice daily, after the first and last feedings. A 2½ per cent salt bath for 15 minutes was given once a week the first thing in the morning, the first feeding being omitted on that day.

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[1] The data analysis and preparation of this report are a contribution of Federal Aid in Fish and Wildlife Restoration Project F-11-R.

[2] Deceased.

The feed used was "edible" liver, carefully skinned and trimmed. The grinding was standardized according to the size of the fish, both as to plate size and number of passes through the grinder.

All feeding was done with a perforated bottom dipper, the size being standardized for various sizes of fish.

The amount of feed as a percentage of body weight was the same for all lots at a particular size, but no account was taken of water temperature in determining the amount to feed. In general, the amount at least equalled the recommended amount at the hatchery having the highest temperature (Deuel *et al.*, 1937).

The weight of fish was adjusted weekly to maintain a maximum per trough at the start of each week. This weight was standardized for various sizes and increased from 10 pounds per trough for 1½-inch fish to 50 pounds for 5-inch fish.

The total weight of fish per trough was taken weekly. It was then adjusted, and the weight of feed per day for the following week was calculated.

ANALYSIS OF DATA

In total then, most of the known variables affecting trout growth were controlled. The two variables notably not controlled were: (1) hatchery, with differences in water chemistry; and (2) water temperature which varied as the experiment progressed, and from hatchery to hatchery.

An analysis of the data has been made based on the assumption that at any particular temperature the cube root of the weight of a fish increases linearly with time.

Unfortunately, it was impossible to test this assumption statistically since the data for successive periods were to an extent interdependent and did not provide degrees of freedom. On a nonstatistical basis the data seemed to follow the cube root very well, and the authors feel the assumption of the linearity of the cube root of the weight was warranted.

The cube root of the mean weight was calculated for each lot at the end of each 2-week period of the experiment. The increment for each period was calculated and correlated with the average water temperature for the period in the standard form for covariance analysis (Snedecor, 1940). Thus there were eight hatcheries each with two lots, making a total of 16 lots for nine periods each.

The "within lot" regression of the increments in relation to temperature was calculated and is plotted in Figure 1. Also plotted

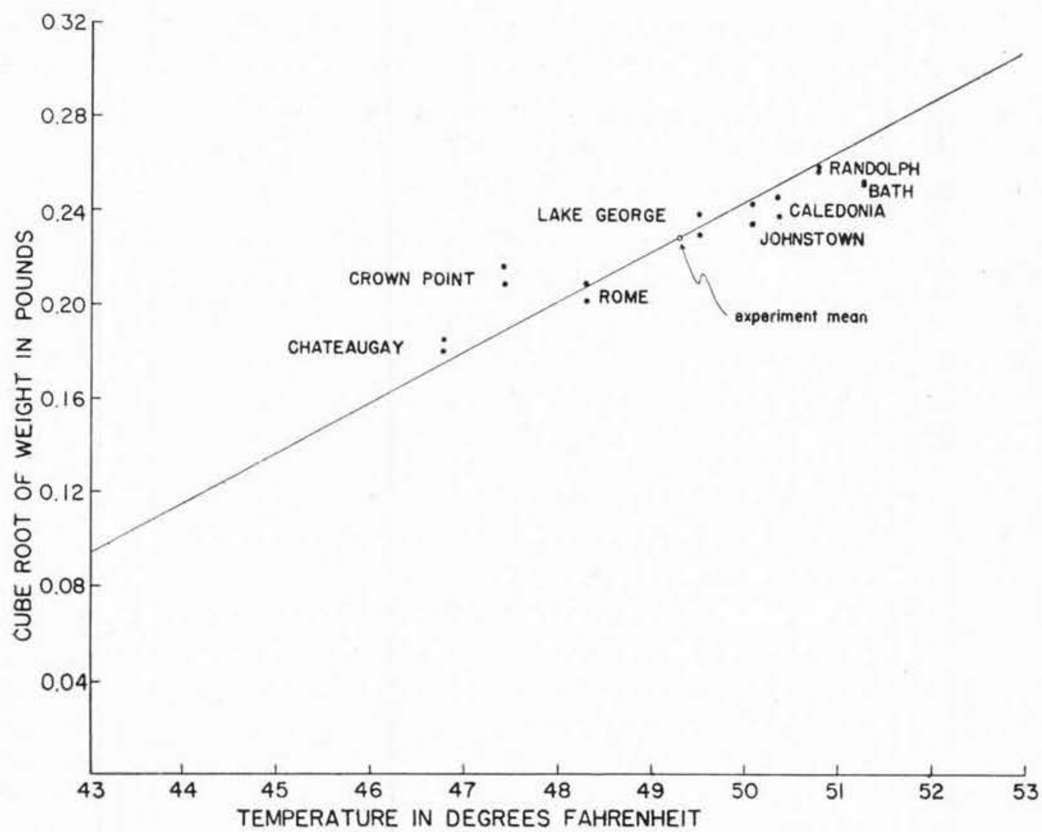

Figure 1. Mean increment in the cube root of the mean weight according to temperature for each of 16 lots of brook trout (two at each of eight hatcheries) derived from data recorded at the end of each of nine 2-week periods and the calculated "within lot" regression line for these data.

is the mean increment for each lot at each hatchery and the experiment mean. The hatcheries fit this line rather well. Nevertheless, statistical analysis shows a significant departure from the line for certain hatcheries, notably Bath and Crown Point. In the case of Bath it can be shown that growth did not come up to expectations during the first few weeks of the experiment but later reached a rate just about equal to the expected. At Crown Point growth seemed to be above the expected rate throughout.

Using the "within lot" regression equation, the expected percentage gain at various temperatures has been calculated and the figures are given in Table 1. While these data cannot be applied universally due to differences in strains, diets, etc., they give a measure under one set of conditions of the effect of temperature on the growth of brook trout.

The "within lot" regression predicts no growth at 38.6°F. While this is considerably below the temperatures in the experiment, and

TABLE 1. EXPECTED 31-DAY PERCENTAGE GAIN IN WEIGHT FOR BROOK TROUT AT DIFFERENT WATER TEMPERATURES*

Water temperature in degrees Fahrenheit	Size in inches and number per pound§									
	1½ 740	2 304	2½ 153	3 88.3	3½ 55.9	4 37.8	4½ 26.8	5 19.7	5½ 14.9	6 11.6
40	*19*	*14*	*11*	*9*	*8*	*7*	*6*	*5*	*5*	*4*
42	*53*	*37*	*29*	*23*	*20*	*17*	*15*	*14*	*12*	*11*
44	98	66	*50*	*40*	*34*	*29*	*25*	*23*	*20*	*19*
46	154	101	74	*59*	*49*	42	*37*	*32*	*29*	*26*
48	220	141	102	80	66	56	*48*	*43*	*38*	*35*
50	317	190	135	104	84	71	*62*	*54*	*48*	*44*
52	432	250	176	133	106	88	76	66	*59*	*53*
54	...	*319*	*215*	*160*	128	*106*	91	*79*	*70*	*63*

*Figures in italics are extrapolated values outside the range of the actual data recorded.
§Upper and lower figures, respectively.

therefore not very accurately determined, it is a rough indication of a threshold temperature for growth.

In Table 1, the italicized figures represent values outside either the size range or temperature range of the experiment and hence must be regarded as of low reliability.

Deuel *et al.* (1952) prepared a table, based on extensive measurements of hatchery fish, showing the number per pound for trout of various sizes. These data indicate a substantially constant condition factor. Combining the cube root and constant condition factor concepts, several interesting relationships can be developed. For example, the condition factor equation is $W=CL^3$. It follows, then, that $\sqrt[3]{W}=KL$ where K represents $\sqrt[3]{C}$. Thus, if the cube root of the weight increases at a constant rate, the length may be expected to do the same.

Using the table for number of fish per pound in relation to size in inches (Deuel *et al.*, 1952), the expected number of days required to produce an increase of one-half inch in length has been calculated for various temperatures and sizes, and the results are given in Table 2. The values were approximately the same for all size classes at a given temperature. In Table 3 are given for each temperature the average number of days required to produce one-half inch of growth for all sizes combined, and the expected number of inches of growth per month.

From purely mathematical considerations, with a constant condition factor and a uniform rate of increase in the cube root of the weight, it may be shown that the *daily* percentage gain is approxi-

TABLE 2. EXPECTED NUMBER OF DAYS REQUIRED FOR BROOK TROUT OF VARIOUS SIZES TO GAIN ONE-HALF INCH IN LENGTH AT DIFFERENT WATER TEMPERATURES*

Water temperature in degrees Fahrenheit	Size in inches									
	1–1½	1½–2	2–2½	2½–3	3–3½	3½–4	4–4½	4½–5	5–5½	5½–6
40	*181*	*185*	*181*	*186*	*179*	*183*	*164*	*173*	*175*	*167*
42	*73*	*74*	*75*	*74*	*72*	*71*	*72*	*71*	*69*	*68*
44	*46*	47	*46*	*46*	*45*	*45*	*43*	*44*	*45*	*43*
46	*33*	34	34	*34*	*33*	33	*32*	*31*	*33*	*31*
48	*27*	25	27	26	26	25	*25*	*25*	*25*	*25*
50	*22*	22	22	22	21	21	*21*	*21*	*21*	*20*
52	*18*	19	17	18	20	18	18	18	*18*	*17*
54	*16*	*16*	*16*	*16*	16	*16*	15	*15*	*16*	*15*

*Figures in italics are extrapolated values outside the range of the actual data recorded.

TABLE 3. CALCULATED GROWTH RATES AT DIFFERENT WATER TEMPERATURES FOR BROOK TROUT*

Item	Water temperature in degrees Fahrenheit							
	40	42	44	46	48	50	52	54
Expected number of days required for ½ inch growth....	179	71	45	33	26	21	18	16
Expected inches of growth per month.	0.087	0.218	0.344	0.470	0.596	0.738	0.861	0.969

*Average values for fish from 1½ to 6 inches in length.

mately inversely proportional to the length. Thus, if 5-inch fish made a daily percentage gain of 2 per cent, then 1-inch fish would be expected to make a gain of 10 per cent per day. It appears advisable for the fish-culturist to examine the daily percentage gains for various sizes at the same temperature. If some size falls short of others, proportionally, the feeding methods, diets, and care of the deficient size should be considered.

When trout growth is measured on the basis of a constant rate of increase in length, small fish are seen to grow at the same rate as large fish. Faster growth of small fish is a concept based on weight and percentage gain. Since fish have a specific gravity of one, concepts based on weight are essentially considerations of volume. Assuming that length, breadth, and depth all increase at a uniform rate, then volume will increase proportionally to length × breadth × depth, or proportionally to the cube of any one of the dimensions, e.g., length. Thus, a constant rate of increase in length presumes weight to be proportional to the cube of the length.

Several years have elapsed since the experimental data were collected. During the interval some of the findings were evident although the data had not been completely analyzed. An extrapolation of expected percentage gains for fish averaging 5,000 per pound at 50°F. indicated a monthly expected gain of over 1,000 per cent, and for fish averaging 2,500 per pound the indicated gain was over 750 per cent. If such a growth rate were possible it would require feeding an amount equivalent to approximately 25 per cent of the body weight of the fish per day at a conversion of 3. An attempt was made to feed at this level and it was found impossible to do this in an 8-hour day, although by feeding over a 24-hour day it was possible to feed this amount, admittedly with some waste. Gains equal to the expected values were not obtained but the actual values were considerably higher than had previously been obtained, so that the practice of heavy "overfeeding" has been found profitable until the fish reach about 1,000 per pound. For example, in one case brook trout starting to feed when they averaged 6,482 per pound reached a size of 3,525 per pound in 11 days, equivalent to a monthly gain of 455 per cent. Similar trials with brown trout failed to produce any unusual results.

LITERATURE CITED

DEUEL, CHARLES R., DAVID C. HASKELL AND A. V. TUNISON. 1937. The New York State Fish Hatchery Feeding Chart. New York State Cons. Dept., Albany.

DEUEL, CHARLES R., DAVID C. HASKELL, DONALD R. BROCKWAY AND O. R. KINGSBURY. 1952. The New York State Fish Hatchery Feeding Chart. Fisheries Res. Bull. No. 3., New York State Cons. Dept., Albany.

SNEDECOR, GEORGE W. 1940. Statistical Methods. The Collegiate Press, Ames, Iowa.

SOME ASPECTS OF LEUCOCYTOZOAN INVESTIGATIONS IN NEW YORK [1]

James R. Reilly Game Pathologist
New York State Conservation Department

ABSTRACT

Mallard ducklings exposed to blackflies in the presence of known carriers of the parasite became infected with *Leucocytozoon simondi.* Exposure of 3-day-old ducklings to a relatively limited source of infection produced a slowly developing low-grade parasitemia in 55.9 per cent of the specimens in 34 days. In a group of 5-week-old birds, exposed after a greater source had built up, an infection of 62.5 per cent developed in 12 days and resulted in the death of one individual. The pathology is described for this case. The clinical symptoms are also given. The relapse phenomenon was evident with the incidence of infection in blood films dropping to a low of 11.5 per cent in December and increasing to 41.8 per cent the following spring.

Wickware (1915), investigating an apparently infectious disease in ducks in Canada and unaware of the investigations of Mathis and Leger (1910, 1911), described *Leucocytozoon anatis* as the etiological agent which caused an exceptionally high mortality of about 65 or 70 per cent. Although he did not mention the duck species involved, he was probably working with a domestic strain. Herman (1938) reduced *L. anatis* to synonymy and established the priority of *L. simondi* which has since been generally accepted. O'Roke (1931) found the blackfly (*Simulium venustum*) to be the transmitting agent and reported a mortality of 90 per cent in wild black duck and mallard ducklings at Munuskong Bay, Michigan. He also pointed out the need for field studies to determine the seriousness of the disease on the nesting grounds.

Three other cases of mortality from this parasite have been reported in the literature, one in Maine involving domestic ducks (Nelson and Gashwiler, 1941), and two in New York involving artificially propagated mallards (Cheatum, 1948). Since the diagnosed mortalities in New York involved mallards from areas of high blackfly abundance and since certain species of ducks (i.e., black duck, wood duck, and teal) through selective survival appear to have developed a tolerance to the Leucocytozoan parasite, an experiment was initiated in 1949 to investigate the relative tolerance of the mallard, black duck, and wood duck.

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-35-R.

Unfortunately, it became impossible to obtain the necessary black ducks and wood ducks for the study as originally planned. Mallards were available, however, from State game farms and it was decided to study the tolerance of this species to a natural infection of Leucocytozoan disease.

METHODS AND MATERIALS

According to the design of the experiment, two groups of ducklings were to be held in outdoor enclosures in an area of high blackfly abundance. One group would be given no protection from blackflies, while the other would be screened as completely as possible from them. A source of infection would be insured by holding in an adjacent pen several adult ducks known to be carriers. After the field stage of the work was completed, any survivors of the experimental group would be held during the fall, winter, and spring for observation and periodic blood examination.

The Poplar Point Campsite on Piseco Lake (Hamilton County) which met all requirements, i.e., an abundant blackfly population, a competent caretaker, and a source of electric power for brooders, was selected as the site for the experiment. Here, two pens, one exposure and one control, were constructed. The exposure pen 28 x 42 x 5 feet in size was covered with ½-inch hardware cloth. The control pen 7 x 28 x 5 feet in size which necessarily had to be blackfly-proof was covered with 40-60 mesh, 4-denier, phosphorous bronze wire netting. To maintain the fly-proof condition of the control pen it was constructed with a fly-proof anteroom into which the operator could enter, spray to kill the flies which had accidentally gained access, and then enter the pen proper. The bronze netting used for this pen was obtained as scrap from a paper mill where it had been used to cover the initial rollers in the paper making process. Both pens included land and water portions.

To provide a known source of infection, wild black ducks trapped in connection with banding operations of P-R Project 39-R (Waterfowl Banding and Census) were used. Three ducks, determined from blood specimens to be positive for *Leucocytozoon,* were transferred to Piseco Lake and confined in a small pen adjacent to the exposure pen.

On June 9, 128 mallard ducklings, 3 days old, were transported to the pen site. Twenty-five of these were placed in the control pen and 103 in the exposure pen. On July 15, however, it became necessary to transfer the control ducks to the exposure pen because the lowering lake level had reduced the water portion of the control pen to an intolerably small area. Although this eliminated the control feature of the experiment, the opportunity remained to record the incidence of the disease and the degree of mortality, and to observe symptoms among birds exposed at an older age.

In order to determine the presence or absence of Leucocytozoan infection, blood samples were taken at intervals from the medial vein of the leg of each duckling. The blood films were dried, fixed with absolute methyl alcohol and stained with Giemsa's or Wright's stain. Giemsa's stain gave sharper differentiation and was used more generally. Thedane Blue solutions T-3 and T-5 (Methylene Blue-Sapoin) were used in staining heavier blood films without much success, probably because of the small number of gametocytes in the peripheral blood at the time these examinations were made. Each slide was examined using a 15× wide-field ocular and 8×, 40×, and 90× oil-emersion objectives. A minimum time of 15 minutes for examination of each film was required before a slide could be classified as negative.

The field phase of the study was terminated September 6, 1949. All birds surviving at that time were taken to the Wildlife Research Laboratory at Delmar where they were held for further observation. Blood samples were taken periodically and individuals which were found to be negative for two consecutive examinations were liberated.

FINDINGS

For the field phase of the study, the records are given in Table 1.

With respect to the group that was placed in the exposure pen at the start, Leucocytozoan infection was found in 55.9 per cent of those examined 34 days later. At the end of 48 days, those that had previously been negative (including the original controls) and those that had not been examined before showed an infection rate of 71.2 per cent.

Of interest are the data for the original control group (Table 2) which was not exposed to blackflies until the birds were 5 weeks old. These ducklings showed an infection rate of 62.5 per cent after only 12 days exposure. That the disease built up faster in this group than in those exposed earlier was probably a result of the fact that the source of infection was greater, i.e., the positive cases among the other group plus the adult carriers.

During this phase of the study, mortality among all the experimental ducklings was very low (3.1 per cent). Furthermore, of the four birds that died, Leucocytozoan disease was considered responsible in only one case—that among the group exposed at 5 weeks of age.

TABLE 1. INCIDENCE OF LEUCOCYTOZOAN INFECTION AND MORTALITY RECORDED AMONG MALLARD DUCKLINGS EXPOSED TO BLACKFLIES AT 3 DAYS OF AGE

Date	Age in days	Number in pen	Number examined	Infected		Mortality	
				Number	Per cent	Number	Per cent
June 9.....	3	103	0	..	..	0	0.0
21.....	15	103	41	0	0.0	0	0.0
July 13.....	37	102	102	57	55.9	1	1.0
27.....	51	125*	66§	47	71.2	2	1.6
August 5-24.	60-79	124	123	81	65.9	1	0.8

*Includes 25 ducklings transferred from control pen on July 15, which were negative at that time.
§Ducklings negative at first examination plus those from control pen.

TABLE 2. INCIDENCE OF LEUCOCYTOZOAN INFECTION AND MORTALITY RECORDED AMONG MALLARD DUCKLINGS FIRST EXPOSED TO BLACKFLIES AT 5 WEEKS OF AGE

Date	Age in days	Number in pen	Number examined	Infected		Mortality	
				Number	Per cent	Number	Per cent
July 13*....	37	25	25	0	0.0	0	0.0
27.....	51	25	24	15	62.5	0	0.0
August 5-8..	60-63	24	24	13	54.2	1	4.2

*Two days before transfer to exposure pen.

Two others were infected, however, and for one of these Leucocytozoan was considered as possibly responsible for death.

Following termination of the work at the Piseco Lake site, the 124 surviving birds were transported to the Wildlife Research Laboratory at Delmar, N. Y., where they were held for further observation. Blood examinations from time to time indicated that among the original exposure group apparent Leucocytozoan infection dropped to a low incidence of 12.3 per cent by December, increased to 39.4 per cent by April, 1950, and dropped again to 7.7 per cent in January, 1951. Among the other group, all birds were negative in January, 1950, but the apparent incidence of infection had increased to 28.6 per cent by the following April. There were no additional deaths attributable to the disease.

Clinical symptoms of the disease appeared to be loss of appetite, muscular weakness, and rumpled feathers. A limping gait and drooping wings seemed characteristic of ducks with mild infections. It was also noted that growth of the flight feathers appeared somewhat retarded.

The one specimen that succumbed to Leucocytozoan disease was a female from the original control group, which was exposed at 5 weeks of age on July 15 and was found dead on August 3, 19 days later. Pathological changes included: focal necrosis of the liver, which was thickly studded with lesions from pin-point size to 2 millimeters in diameter; hemorrhage in peritoneum on ventral surface of keel at junction with ribs and area of necrosis at this point; necrotic plaques extending length of both ceca; intramuscular hemorrhage along left rib insertions with sternum; intense bile staining of intestinal and gizzard contents; enlarged, dark spleen; anemic lungs with no congestion. A heart blood smear showed a heavy infection with *L. simondi*.

DISCUSSION

Of particular interest in connection with this experiment is the low degree of mortality compared with that recorded by O'Roke (1931). Of possible importance is the fact that blackflies were not abundant at the Piseco Lake site, a resort area, as a result of aerial spraying operations that had been carried on in the vicinity. Also, the experimental site was not near good duck nesting habitat. Therefore, the source of infection was very largely limited to the three carrier ducks penned there. Thus the opportunity for insect vectors in the immediate vicinity to become infected was slight and transmission to the exposed ducks was necessarily slow. Chernin (1952a) had pointed out that an arthropod vector secures an initial infection from a low-grade parasitemia in a carrier bird and, before an epizootic can be established, a larger reservoir of parasites must be available for transmission. Therefore, even though the simuliid population increased slightly shortly after the initial infection, transmission was probably still not rapid and the infections already present may have furnished an immunity to a heavier, mortality-producing superinfection. The possibility of superinfection upon low-grade parasitemias, which may have produced some resistance, should be considered. Fallis *et al.* (1951) pointed out that ducks develop some tolerance to the disease when they are subjected to repeated infections.

Bearing on the influence and magnitude of the source of infection is the fact that the ducklings exposed when 5 weeks of age all developed a heavier infection in 12 days than did those of the other group in 34 days. The reason for this probably was the greater possibility of transmission; i.e., most of the original exposure ducks had become infected and the blackfly population had increased somewhat by that time.

The seasonal fluctuation of the number of gametocytes in the peripheral blood of the host following the initial infection represents what has been termed the relapse phenomenon. This was noted in ducks by O'Roke (1934) and confirmed by Huff (1942). Chernin (1952b) demonstrated that the increase in spring is associated with the onset of reproductive activity in the avian host.

CONCLUSIONS

Mallard ducklings exposed to a natural source of infection are susceptible to Leucocytozoan disease. The rate and degree of infection appear to be related directly to the magnitude of the source of infection. It is probable that mortality is similarly related.

The relapse phenomenon in the avian host serves to overwinter the disease.

LITERATURE CITED

CHEATUM, E. L. 1948. Blackflies as Carriers of Leucocytozoan Disease in Game Birds. Pittman-Robertson Project 35-R Quarterly Report (October). N. Y. S. Cons. Dept.

CHERNIN, ELI. 1952a. The epizootiology of *Leucocytozoon simondi* infections in domestic ducks in northern Michigan. Am. Jour. Hyg. 56(1):39-57.

————. 1952b. The relapse phenomenon in the *Leucocytozoon simondi* infection of the domestic duck. Am. Jour. Hyg. 56(2):101-118.

FALLIS, A. M., D. M. DAVIES AND M. A. VICKERS. 1951. Life history of *Leucocytozoon simondi* Mathis and Leger, in natural and experimental infections and blood changes produced in the avian host. Can. Jour. Zool. 29(6):305-328.

HERMAN, C. M. 1938. *Leucocytozoon anatis* Wickware, a synonym for *L. simondi* Mathis and Leger. Jour. Parasit. 24(5):472-473.

HUFF, C. G. 1942. Schizogony and gametocyte development in *Leucocytozoon simondi* and comparisons with *Plasmodium* and *Haemoproteus*. Jour. Infect. Dis. 71(1):18-32.

MATHIS, CONSTANT AND MARCEL LEGER. 1910. Leucocytozoon d'une tourterelle *(Turtur humilis)* et d'une sarcelle *(Querquedula crecca)* du Tonkin. Compt. Rend. Soc. Biol. 68(3):118-120.

————. 1911. Recherches sur la Parasitologie et la Pathologie humaines et animals du Tonkin. Masson et Cie, Paris.

NELSON, E. C. AND JAY S. GASHWILER. 1941. Blood parasites of some Maine waterfowl. Jour. Wildl. Mgt. 5(2):199-205.

O'ROKE, E. C. 1931. A destructive waterfowl parasite. Trans. 18th Am. Game Conf. :248-251.

————. 1934. A malaria-like disease of ducks caused by *Leucocytozoon anatis* Wickware. Univ. of Mich. Sch. of For. and Cons. Bull. 4.

WICKWARE, A. B. 1915. Is *Leucocytozoon anatis* the cause of a new disease in ducks? Parasitol. 8(1):17-21.

NOTES ON THE DEVELOPMENT OF THE RED FOX FETUS [1]

James N. Layne Assistant Professor of Biology
Department of Biology, University of Florida

Warren H. McKeon Assistant Game Research Investigator
New York State Conservation Department

ABSTRACT

The gross aspects of red fox fetal development from about the 30th day of gestation until term are described on the basis of 160 specimens aged according to a fetal growth curve of body weight established for captive silver foxes.

Relative growth in crown-vent length is greater than that in body weight until about the 40th day of gestation, after which the latter exceeds. Of the four linear measurements taken, relative increase in crown-vent length is greatest, followed by that of the tail. The head and hind foot grow at a slower, and at approximately the same, rate. No apparent correlation was demonstrated between intra-litter variability in weight and either fetal age or size of litter. Sexual dimorphism was not marked.

The trenchant morphological features of the fetus are established by the 30th day of gestation. Subsequent to this stage changes are largely concerned with growth of the eyelids, retraction of the herniated portion of the intestine, changes in the proportions of different parts of the body and various organs, growth of the claws, increasing opacity of the skin, and development of pelage and external genitalia. The fetus is well furred at birth.

During the course of an investigation of certain phases of reproduction in the red fox *(Vulpes fulva)* and gray fox *(Urocyon cinereoargenteus)* in New York, 35 gravid red fox uteri containing 160 fetuses, were obtained from professional trappers employed by the Conservation Department's rabies control project. These specimens constituted an evenly distributed series from about the 30th day of gestation to term (assumed to be 53 days) and provided an opportunity to study the gross aspects of fetal development in the red fox over an interval approximating the terminal 37 per cent of the gestation period.

PROCEDURE

The ages of the fetuses were estimated by means of a fetal growth curve of body weight established by Smith (1939) for captive silver

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foxes *(Vulpes)*. His data were obtained by sacrificing pregnant vixens at known intervals of gestation. In the present study, the stage of gestation of a given litter was determined to the nearest day by plotting the mean weight of the fetuses, excluding any obviously abnormal ones, on a graph prepared from Smith's data on weights of known-age fetuses. The specimens, which were preserved in 10 per cent formalin, were carefully blotted to remove excess preservative prior to weighing. Individual weights were obtained to the nearest tenth of a gram, and the mean weight of the litter was then calculated. Although ages estimated in this manner are probably not exact to the day, it is felt that they are sufficiently accurate to permit description of the general features of fetal growth and development over the period of gestation represented by the sample.

In addition to body weight, the following measurements (recorded to the nearest millimeter) were made on each fetus:

Crown-vent length.	Measured in a straight line from the highest point of the crown to the edge of the anus, with the fetus on its back and the axis of the head perpendicular to the body axis. Care was taken so that all points of the dorsum were in contact with the surface when the measurement was made.
Head length.	Measured from the tip of the snout to the back of the head along a line projected from the end of the nose through the center of the eye.
Tail length.	Measured on the ventral surface from the edge of the vent to the tip of the caudal vertebrae.
Hind foot length.	Measured from the heel to the tip of the longest claw.

FINDINGS

Means and standard deviations for body weights and measurements of 156 normal fetuses at ages ranging from an estimated 30 days to term are given in Table 1. These data indicate that increase in crown-vent length is proportionately greater than increase in weight from 30 to about 40 days gestation, when a weight of approximately

TABLE 1. MEANS AND STANDARD DEVIATIONS OF WEIGHTS AND MEASUREMENTS OF 156 RED FOX FETUSES AT AGES ESTIMATED FROM 30 TO 53 (TERM) DAYS

Age in days	Number of litters	Number of fetuses	Weight in grams		Measurements in millimeters							
					Crown-vent length		Head length		Tail length		Hind foot length	
			Mean*	Standard deviation	Mean*	Standard deviation	Mean*	Standard deviation	Mean*	Standard deviation	Mean*	Standard deviation
30	2	10	0.56	0.07	20.3	0.94	9.7	0.47	4.5	0.58	2.8	0.47
34	1	4	2.00	0.00	32.2	0.58	13.8	0.58	7.5	0.58	5.5	0.58
36	1	3	3.83	0.16	42.7	1.22	16.0	0.00	11.7	0.58	7.0	0.00
37	1	4	4.30	0.18	44.2	0.58	16.0	0.00	10.8	0.58	7.2	0.58
38	1	1	(6.90)	..	(54.0)	..	(18.0)	..	(15.0)	..	(9.0)	..
39	1	5	11.20	0.59	62.0	2.45	21.0	1.00	21.0	1.00	11.2	0.50
40	1	7	18.57	0.90	74.7	1.58	24.1	0.41	27.3	1.26	13.6	0.58
41	1	3	20.53	1.82	75.3	1.22	26.0	0.00	30.3	0.71	14.7	1.22
42	2	8	28.59	6.21	85.8	7.93	28.9	1.00	35.8	1.51	17.1	0.84
44	2	6	36.25	2.30	91.5	2.72	30.0	0.89	39.2	1.18	18.7	0.77
45	2	10	44.43	1.42	93.3	2.00	31.5	0.88	40.1	1.10	18.6	0.67
46	3	17	46.82	2.90	95.5	3.94	32.5	1.12	44.0	2.47	20.1	1.06
47	4	27	55.71	3.64	104.0	3.61	34.7	1.04	48.6	2.17	22.2	0.86
48	1	7	59.30	1.74	106.6	2.00	36.0	1.00	50.0	1.73	22.8	0.71
49	1	1	(66.40)	..	(100.0)	..	(34.0)	..	(50.0)	..	(24.0)	..
50	3	9	69.16	8.34	109.2	4.74	36.7	1.12	47.9	2.42	24.1	1.17
51	2	13	73.80	6.16	112.3	2.90	37.6	1.12	54.3	2.63	24.6	0.64
53	6	21	99.91	13.28	121.2	5.07	40.8	1.80	57.5	3.17	28.0	1.90

*Parentheses indicate only one specimen involved.

18 grams is attained. Relative increase in body weight somewhat exceeds that of crown-vent length from that point on. Considering the four linear measurements recorded, relative growth of the body (crown-vent length) is of the greatest magnitude, followed by that of the tail. The head and hind foot grow at approximately the same rate, which is noticeably less than that of crown-vent and tail length.

Average coefficients of variation of these weights and measurements are, in order of decreasing magnitude: weight, 7.59; hind foot length, 5.72; tail length, 5.10; crown-vent length, 3.32; and head length, 2.77. There appears to be no apparent trend towards either increasing or decreasing variability of weight or measurements with respect to age in the over-all data. A more detailed analysis was performed to determine the relationship between variability of weight and both fetal age and litter size. Coefficients of variation of weight were calculated for 27 individual litters (128 specimens) comprising two or more normal fetuses and were plotted separately on estimated fetal age and litter size. The wide scatter of the resulting points in both cases was indicative of no significant correlation.

Sexual dimorphism in weight or length of fetuses was not marked. Males and females occurred together in 23 litters. In these, male fetuses averaged heavier than females in 17 and longer in 16, but the differences were not statistically significant on the basis of the sample involved.

The smallest red fox fetuses recovered from pregnant vixens were approximately 30 days of age. At this stage of development (Figure 1, A) the torso is nearly straight, but flexion of the head is still pronounced. The toes of the fore feet are distinctly separated at the tips, while those of the hind feet are still united by webs of skin. The liver prominence is marked, and the organ is visible through the thin translucent skin of the abdominal region. A segment of the intestine protrudes from the body cavity into the umbilical stalk. The mesencephalon produces a conspicuous bulge on the dorsal aspect of the head, and the spinal cord appears to lie at the surface of the back and is widely exposed throughout its length. The lids have not yet begun to grow over the eyes. The pinna stands out somewhat from the side of the head and only partially obscures the sealed external auditory meatus. No hair is visible on the body, although vibrissae follicles can be discerned on the jaws and wrists. The external genitalia do not yet show visible sex differences. Mammae are faintly evident.

Specimens estimated at 34 days of age (Figure 1, B) have the neck noticeably more elongate and the head less sharply flexed. The limbs are further developed, and soft white blunt claws have appeared on the fore and hind digits. The liver is still prominent, and the umbilical hernia persists. The mesencephalon is relatively reduced but still forms a marked swelling. Dorsal growth of skin, muscle, and vertebrae has partly roofed over the spinal cord. The upper and lower lids have grown over the eye, covering it except for a narrow slit at the center. The dark-colored iris remains distinctly visible through the overlying skin. The folded pinna now nearly conceals the external auditory meatus. Follicles of the supercilliary, genal, interramal, and carpal vibrissae are evident, although the hairs themselves are not yet visible. Sex can be determined by the relative distance between the urogenital papilla and anus. In the female, the posteriorly appressed urogenital papilla reaches the edge of the anus, while in the male it extends only about half the distance to the vent. Nipples are visible on individuals of both sexes.

The mesencephalon has assumed normal proportions in 36-day fetuses (Figure 1, C), and the spinal cord is completely obscured except in the sacral region where its margins remain faintly outlined. The liver prominence is less obvious, and the herniated portion of the gut has been withdrawn into the abdominal cavity. Fusion of the eyelids is complete, but the iris is still faintly visible. The pinna is larger and more tightly appressed to the side of the head and now completely conceals the external auditory meatus.

Between 36 and 39 days of fetal age the vibrissae appear and hair follicles become distinctly visible over the general body surface. The sexes are readily distinguished by the appearance of the external genitalia. In the males, the beginning of scrotal development is evident as a slight swelling at the caudal portion of the raphe.

At 40 to 41 days (Figure 1, D) the dorsal surface of the claws shows signs of keratinization. Vibrissae are visible without magnification, the posterior mystacials measuring about 1 millimeter in length. The skin appears generally thicker and more opaque than at 39 days. The iris is no longer visible through the eyelids nor does the dark coloration of the liver show through the abdominal wall. Dark pigment is faintly evident on the dorsum. A sparse covering of hair is present over the entire body, the hairs being more numerous and longer on the crown.

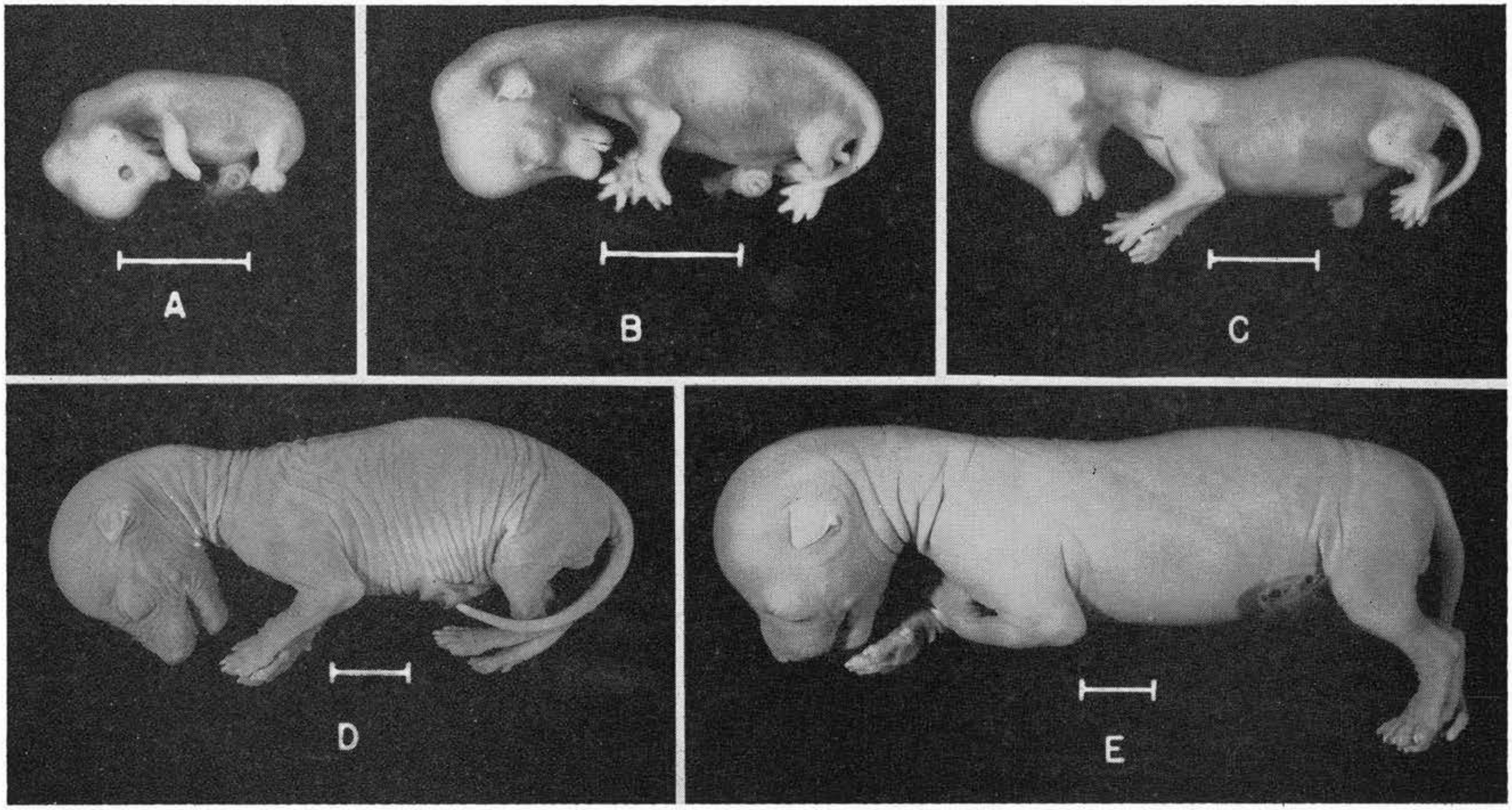

Figure 1. Stages in the development of the red fox fetus: A. about 30 days; B. about 34 days; C. about 36 days; D. about 40 days; E. about 46 days. The scale for each stage equals 1 centimeter.

Fetuses considered to be 42 days old have a more pronounced and uniform skin pigmentation. In contrast to the general dark dorsal coloration, a light mid-dorsal stripe extends the length of the body. It is most sharply defined on the crown and nape. The hair on the body is generally longer and denser, particularly on the back and upper sides. The scrotum of the male is larger and more vesicular in appearance.

Gross features of fetal development subsequent to this stage largely involve further growth and development of the pelage and changes in various body proportions. At 46 days (Figure 1, E) the coat has grown sufficiently to give the body a velvety aspect. The hair is thickest and longest on the crown and dorsal surface of the body. It is short and sparse on the limbs, sides of head, muzzle, and venter, and lacking on the pinna. The light mid-dorsal band is still distinct on the crown and nape. A light-colored oval patch, marking the site of the tail gland, is present on the dorsal surface of the tail about one-third of the distance to the tip. The tip of the tail is more lightly pigmented than the remainder.

In 48-day specimens the longer hairs on the flanks measure 3 to 4 millimeters, a few hairs have appeared on the pinna, and eyelashes are visible along the posterior two-thirds of the upper lid. There is still less development of hair on the rostrum, sides of head, and limbs below the elbows and knees. In addition to the longitudinal light stripe on the crown and nape, a transverse light band overlying the coronal suture has appeared. The hairs on the sides of the crown and neck are lighter in color than those on the remainder of the head and dorsal surface of the trunk. At 50 to 51 days (Figure 2) these areas have acquired a faint yellowish cast, as have the lower sides.

The pelage is well developed at birth (Figure 2). The hairs on the dorsal surface of the body and head are about 6 to 8 millimeters long. Those on the venter are approximately 5 millimeters in length, while the hairs of muzzle, chin, and lower limbs measure only 1 or 2 millimeters. The general coloration of the back and sides of the trunk is a dark grayish-brown. Numerous light yellow hairs are interspersed among the dark ones. The crown, temporal region, and sides of the neck just posterior to the ears are clothed with yellowish-buff hairs. These hairs are brightest on the temporal region. The anterior portion of the cheeks and forehead and the rear part of the lower jaw are dull black; whereas the muzzle and chin, which are covered with

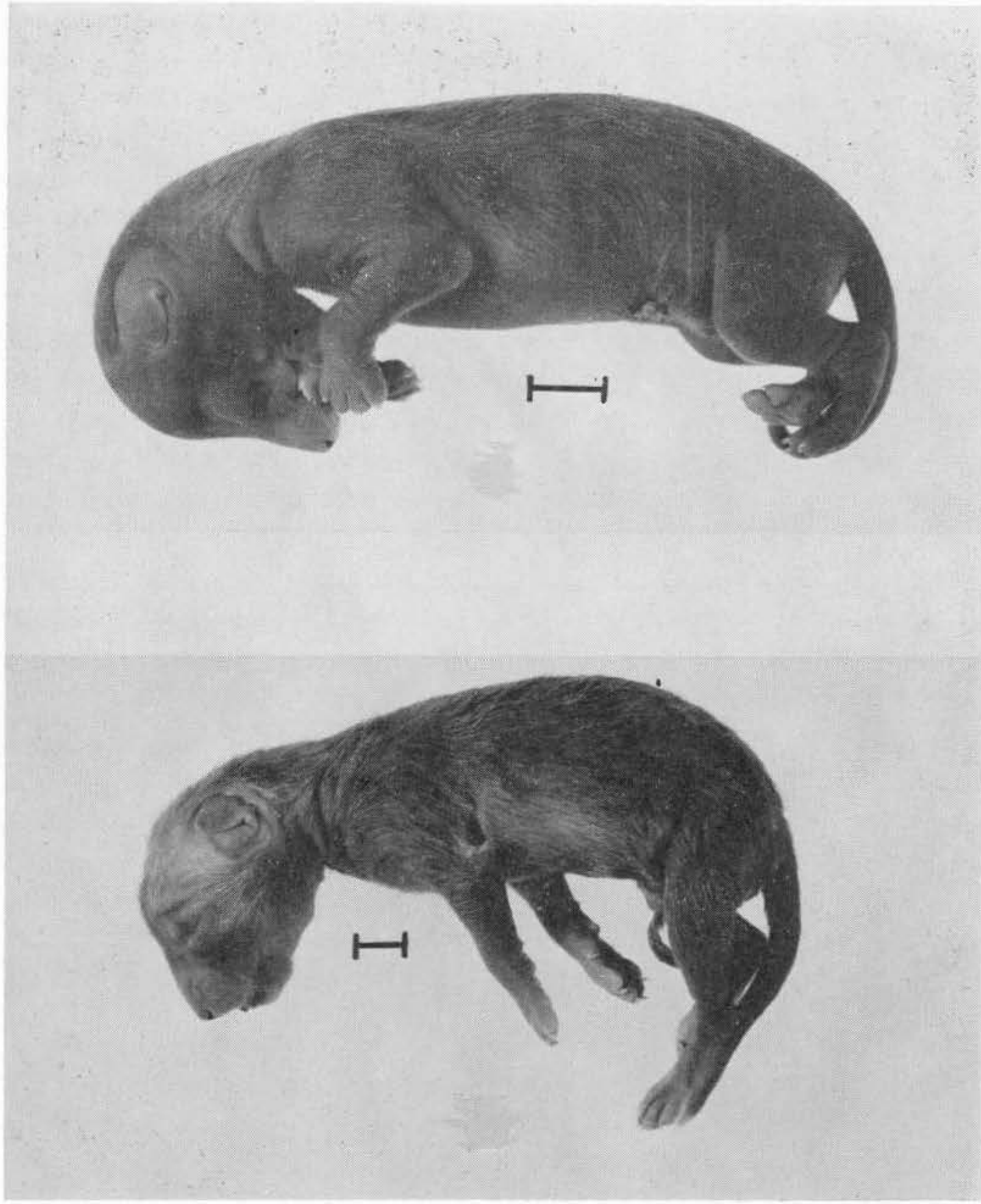

Figure 2. Stages in the development of the red fox fetus: (upper) about 50 days; (lower) at term, about 53 days. The scale for each stage equals 1 centimeter.

very short hairs, are the light gray color of the skin. The pinna is dark and bears only scattered hairs.

The lateral areas of the belly, between the fore and hind limbs, are straw-colored, while the midabdominal region, breast, throat, and inner surfaces of the limbs are covered with dark gray fur. The white hairs of the tail tip are prominent and extend 2 to 3 millimeters beyond the end of the vertebrae.

The plantar surfaces of the feet and the axillary and inguinal regions are more sparsely furred than the rest of the body. The claws and bottoms of the feet are nearly white. Other conspicuously light areas are present on the elbows, rear margins of the thighs, ventral surface of the base of the tail, and encircling the anus.

There were no easily recognizable features by which red fox and gray fox fetuses could be distinguished at estimated ages of 30, 38, and 40 days other than by the number of teats. Gray fox fetuses of about 45 days of age differed from red foxes of similar age in lacking the lighter tail tip and in having a light belly, breast, and throat in contrast to the darker tone of these parts in the red fox fetus. The dorsal coloration of the gray fox at term resembles that of the red fox closely, even to the presence of scattered yellowish hairs. The head, however, is darker. The crown and temporal regions are about the same color as the back, although the hairs behind the ears are yellowish as in the red fox. The pelage of the belly, breast, and throat is usually lighter than that of the red fox, and the prominent buffy wash present on the lower sides of the latter is not apparent.

A certain amount of variability in the number of teats was noted among the red fox fetuses. Of 79 specimens (49 males, 30 females) in which the number of nipples was recorded, 1 had six teats, 7 had seven, 64 had eight (the typical number for the species), 5 had nine, and 2 had ten. Eleven male gray fox fetuses and 9 females showed no variation from the six teats characteristic of the species.

LITERATURE CITED

SMITH, G. ENNIS. 1939. Growth of fox foetus and length of gestation period. Canadian Silver Fox and Fur (March).

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