CURRITUCK SOUND FISH POPULATIONS BEFORE AND AFTER INFESTATION BY EURASIAN WATER-MILFOIL

JAMES C. BORAWA[a], North Carolina Cooperative Fishery Research Unit, North Carolina State University, Raleigh, NC 27650

J. HOWARD KERBY, North Carolina Cooperative Fishery Research Unit, North Carolina State University, Raleigh, NC 27650

MELVIN T. HUISH, North Carolina Cooperative Fishery Research Unit, North Carolina State University, Raleigh, NC 27650

ANTHONY W. MULLIS, North Carolina Wildlife Resources Commission, 512 N. Salisbury Street, Raleigh, NC 27611

Abstract: Data collected from rotenone samples of 3 coves before (1959-65) and after (1977) infestation by Eurasian water-milfoil (*Myriophyllum spicatum*) were compared to document changes in the fish populations. Using the mean of the 3 areas for comparison, both weight and number per hectare increased after water-milfoil infestation. The average weight per individual decreased from 0.02 kg (1959-65) to 0.008 kg (1977). The species were separated into 7 groups. Six of the groups had higher mean numbers per hectare and all groups had higher mean weights per hectare. Multivariate analyses of variance showed that the population structure had changed for numbers and weights per hectare. Ictalurids and yellow perch (*Perca flavescens*) had the greatest proportionate increases in numbers, whereas largemouth bass (*Micropterus salmoides*) and white perch (*Morone americana*) had the greatest proportionate decreases. Ictalurids and centrarchids, other than largemouth bass, exhibited the greatest proportionate increases in weights per hectare, while largemouth bass and other fish showed the greatest proportionate decreases. Numbers of young-of-the-year and older largemouth bass per hectare were not significantly different between pre- and post-water-milfoil samples.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 32: 520-528

Currituck Sound, a major sport fishing area on the east coast, is known for its excellent largemouth bass fishing and yields an estimated 85,000 largemouth bass annually. According to the Bass Anglers Sportsmen Society (B.A.S.S.), tournament fishermen caught an average of 0.55 largemouth bass and 0.44 kg per hour in the Sound in 1975. Both number and weight ranked fourth in 49 tournaments held from March 1972 to February 1978 at 33 locations throughout the nation (Harold Sharp, B.A.S.S. tournament director, personal communication). Fishermen and waterfowl hunters contributed almost $3 million to the local economy in 1976 (Dennis McCornac, North Carolina Sea Grant Office, personal communication).

Since 1968 the infestation of Currituck Sound by Eurasian water-milfoil (*Myriophyllum spicatum*) and its influence on the biota have been of concern. Changes in the species composition of plants used by waterfowl since the infestation are known (Florshutz 1972), but information about changes in fish populations is lacking. In October 1965 an area of about 40 ha was estimated to be heavily infested, and initial establishment had occurred in 200-400 ha (Kearson 1976). Areas covered by loose blankets of water-milfoil on the surface were considered heavily infested; areas of initial establishment were defined as those with sparse stands not extending to the surface. In 1966 more than 3,200

[a]Present address: North Carolina Wildlife Resources Commission, 512 N. Salisbury Street, Raleigh, NC 27611.

ha were heavily infested and initial establishment had occurred in an additional 27,115 ha of the Sound (Crowell et al. 1967). Since 1966 water-milfoil has continued to cover large surface areas, making boating and fishing difficult. Fishing is limited to areas where vegetation does not break the surface or is sparse. Commercial fishing with haul seines and gill nets has decreased.

A fishery investigation based on samples taken with rotenone during July was conducted from 1959 through 1963 before the infestation of water-milfoil (Sincock et al. 1965). The North Carolina Wildlife Resources Commission continued the work from 1964 thru 1966 immediately before and during the establishment of water-milfoil. Since aquatic vegetation control and harvest are currently practiced in the United States, an understanding of how fish population structures are affected by aquatic macrophytes could contribute to an understanding of the ramifications of such programs. The purpose of the present study was to compare fish population data obtained before (1959-65) and after (1977) extensive water-milfoil infestation and to document changes in population structure.

We thank the personnel of the North Carolina Wildlife Resources Commission, members of the North Carolina Cooperative Fishery Research Unit (jointly sponsored by North Carolina State University, North Carolina Wildlife Resources Commission, and the U. S. Fish and Wildlife Service, Department of the Interior) and students of North Carolina State University who provided assistance and materials for the project. R. J. Monroe provided assistance in the statistical analyses and interpretation. N. Walker typed the manuscript.

Financial support was provided in part by the Office of Sea Grant, NOAA, U. S. Department of Commerce under Grant Number 04-6-158-44054, in part by the North Carolina Department of Administration, and in part by the North Carolina Wildlife Resources Commission and the U. S. Fish and Wildlife Service. The U. S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright that may appear hereon.

MATERIALS AND METHODS

Currituck Sound is a brackish water environment located in Currituck and Dare Counties in northeastern North Carolina (Fig. 1). It consists of 39,600 ha of open water and marsh ponds with a mean depth of 1.6 m (Crowell et al. 1967). The Sound receives water from North Landing River, Northwest River and Back Bay and discharges water into Albemarle Sound at its southern end. Salinities vary from freshwater in the northern portion of the Sound to 20°/oo in the southern portion. Wind tides and seasonal precipitation patterns cause salinity fluctuations.

Three coves, 0.69, 1.11, and 1.42 ha in area, were sampled during 15-19 August 1977 with 5% emulsifiable rotenone. The areas sampled were Knapp's Pond (R-1), Cedar Island Bay (R-2), and Hog Quarter Creek (R-5). These sites represent 3 of 6 coves sampled during July in the 1959-66 studies (Fig. 1). They were selected because of their north-south distribution in the Sound and variation in density of water-milfoil. Vegetation at areas R-1 and R-2 was very dense and included heavy growths of water-milfoil and *Najas* sp., while R-5 was virtually free of vegetation. Application rates of rotenone were 1 mg/l in R-1 and 2 mg/l in areas R-2 and R-5.

Block nets with a 2.54 cm (1 in) bar mesh were used to prevent fish from leaving or entering the areas. All fish (except some small centrarchids) recovered from the sample areas on the day of rotenone application and the following day were sorted to species, and numbers and weights of fish in each 2.54 cm length class were recorded. Unidentified fish and largemouth bass were preserved in 10% formalin for later identification, measurements and weights.

Recovery of fish on the second day was hindered in area R-2 because winds blew the dead fish into emergent vegetation along the shoreline. Subsampling was conducted by

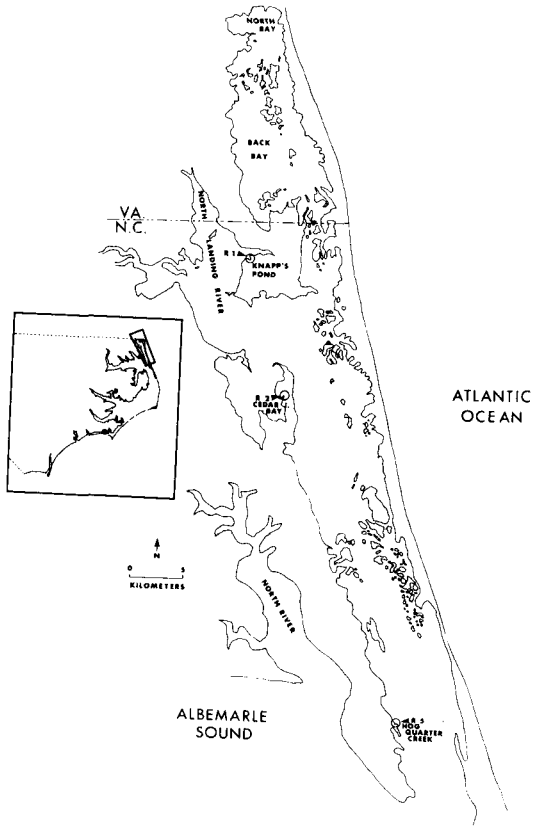

Fig. 1. Currituck Sound, North Carolina, showing the location of rotenone sampling sites R-1, R-2, and R-5.

dividing the shoreline into sections in which concentrations of dead fish were heavy, medium, or light. Concentrations of fish were heavy along 30% of the shoreline, medium along 40% and light along 30%. From each classification a 4.3 m subsample was taken. The data were later expanded to total numbers and total weights on the basis of shoreline length in each of the three categories. Total pickup was attempted at the other 2 areas. However, wave action over the block nets at area R-5 resulted in the loss of some fish between the first and second day of collection.

Univariate and multivariate analyses of variance and Student's t-tests (Barr et al. 1976) on the mean of the 3 areas were used to compare the 1977 data with the pre-water-milfoil data (1959-65). A standardized eigenvector was used in the multivariate analysis of variance to determine changes in the population structure. The 1966 data were excluded from analyses since water-milfoil had spread throughout the Sound by that time. Significant differences refer to $P < 0.05$, and highly significant differences to $P < 0.01$.

RESULTS

A total of 33 species were collected (Table 1). Numbers of fish per hectare were 11,135, 32,636, and 586 for areas R-1, R-2, and R-5, respectively, and weights per hectare

Table 1. Numbers and weight (kg) per hectare of different fish species and the corresponding percentages each species contributed to the total number and weight collected at three stations in Currituck Sound, August 15-19, 1977[a].

Species	Station R-1 (Knapp's Pond)				R-2 (Cedar Island Bay)				R-3 (Hog Quarter Creek)			
	Fish per hectare		% Total fish		Fish per hectare		% Total fish		Fish per hectare		% Total fish	
	No.	Wt. (kg)	No.	Wt.	No.	Wt. (kg)	No.	Wt.	No.	Wt. (kg)	No.	Wt.
Tidewater silverside (*Menidia beryllina*)	184	0.1	1.7	0.1	5348	3.7	16.4	2.6	59	T	10.0	0.1
Yellow perch (*Perca flavescens*)	4213	24.8	37.8	15.9	2230	20.9	6.8	14.9	52	4.2	8.9	5.5
Pumpkinseed (*Lepomis gibbosus*)	1132	7.2	10.2	4.6	1787	46.2	5.5	32.9	284	17.3	48.5	22.9
Bluespotted sunfish (*Enneacanthus gloriosus*)	1169	2.2	10.5	1.4	759	1.2	2.3	0.9	7	T	1.2	T
Fundulus spp.	37	0.1	0.3	0.1	1001	0.9	3.1	0.7				
Largemouth bass (*Micropterus salmoides*)	306	18.3	2.8	11.7	612	11.9	1.9	8.5	14	6.6	2.3	8.7
Golden shiner (*Notemigonus crysoleucas*)	557	4.7	5.0	3.0	445	12.3	1.4	8.7	2	0.1	0.3	0.1
Bluegill (*Lepomis macrochirus*)	197	3.4	1.8	2.2	12	2.7	T	1.9	4	0.5	0.6	0.6
Spot (*Leiostomus xanthurus*)	182	1.7	1.6	1.1	113	1.5	0.4	1.1	75	2.9	12.8	3.8
White perch (*Morone americana*)	81	1.4	0.7	0.9					14	1.6	2.5	2.1
Chain pickerel (*Esox niger*)	67	9.5	0.6	6.0	19	6.6	0.1	4.7	1	0.4	0.2	0.5
Striped mullet (*Mugil cephalus*)	60	0.3	0.5	0.2								
Brown bullhead (*Ictalurus nebulosus*)	51	3.0	0.5	1.9	22	1.6	0.1	1.1	4	2.2	0.6	2.9
Carp (*Cyprinus carpio*)	28	56.7	0.3	36.2	6	0.1	T	0.1	11	35.2	1.9	46.5
Atlantic needlefish (*Strongylura marina*)	4	T	T	T	28	0.1	0.1	0.1				
American eel (*Anguilla rostrata*)	27	0.9	0.2	0.6	20	0.1	0.1	0.1	8	0.1	1.4	0.1
Bay anchovy (*Anchoa mitchilli*)									23	T	4.0	T
Lake chubsucker (*Erimyzon sucetta*)	22	3.2	0.2	2.0	1	0.7	T	0.5				
Warmouth (*Chaenobryttus gulosus*)	3	0.2	T	0.1	14	1.0	T	0.7				
Alewife (*Alosa pseudoharengus*)	1	T	T	T					14	0.1	2.5	0.1
Channel catfish (*Ictalurus punctatus*)	11	11.0	0.1	7.0					3	2.7	0.5	3.6
Bowfin (*Amia calva*)	2	1.9	T	1.2	9	12.2	T	8.7				
Tadpole madtom (*Noturus gyrinus*)	6	T	0.1	T								
Black crappie (*Pomoxis nigromaculatus*)	6	1.4	0.1	0.9								
Yellow bullhead (*Ictalurus natalis*)	4	0.6	T	0.4	6	1.7	T	1.2				
White catfish (*Ictalurus catus*)	5	T	T	T								
Summer flounder (*Paralichthys dentatus*)	2	0.3	T	0.2					5	1.0	0.9	1.3
Longnose gar (*Lepisosteus osseus*)	4	0.2	T	0.1					1	0.9	0.2	1.2
Flier (*Centrarchus macropterus*)	3	0.1	T	T								
Pinfish (*Lagadon rhomboides*)									2	0.1	0.3	0.1
Menhaden (*Brevoortia tyrannus*)									2	T	0.3	T
Gizzard shad (*Dorosoma cepedianum*)	1	0.4	T	0.3								
American shad (*Alosa sapidissima*)								1	T	0.2	T	

Catfish spp.					400	0.7	1.2	0.5				
Centrarchid spp.	2770	3.2	24.9	2.0	19,804	14.6	60.7	10.4				
Totals	11,135	156.8	100.0	100.0	32,636	140.6	100.0	100.0	586	75.6	100.0	100.0

'In the body of the table, 1 less than 0.05 kg or 0.05%. The area sampled, salinity of the water, and the total numbers and weight of fish collected for each station were as follows:
R-1 - 1.42 ha (3.51 acres), 1.1" .... 15,890 fish, and 222.6 kg (490.7 lb);
R-2 - 0.69 ha (1.70 acres), 1.2 " .... 22,519 fish, and 97.04 kg (213.93 lb);
R-3 - 1.11 ha (2.74 acres), 4.0 " .... 650 fish, and 83.9 kg (187.4 lb).

were 156.7, 140.6, and 75.6 kg. The weighted overall standing crop estimate based on these 3 areas was 125.3 kg/ha. The largest numbers of fish per hectare in the 3 areas were contributed by yellow perch, tidewater silverside, pumpkinseed, and bluespotted sunfish. The most important species on a weight-per-hectare basis were carp, pumpkinseed, yellow perch, largemouth bass, and golden shiner.

Analysis of variance of the 1959-65 data revealed no significant differences in weights per hectare between years; thus we were able to use the mean of these years in further analyses. However, analysis showed that total numbers of fish per hectare were significantly different between years. Although the difference was attributed to the large number of fish collected in 1963, there was no apparent reason to exclude the 1963 data from the mean of the pre-water-milfoil data.

The weight of fish per hectare in 1977 was not significantly different from any pre-water-milfoil year. However, number of fish per hectare was significantly higher in 1977 than in any pre-water-milfoil year except 1963. The comparisons of individual years indicated a significant increase in numbers of fish per hectare after water-milfoil infestation, but no significant change in total weight of fish per hectare when the overall means were analyzed (Fig. 2). However, mean weight per individual decreased from 0.02 kg to 0.008 kg.

Two-way analysis of variance, with sample areas and presence and absence of water-milfoil as classes, confirmed a significant increase in total number of fish per hectare existed in 1977. Differences between sample sites were also shown. Salinity data did not influence the analyses and were eliminated from subsequent computations.

The data were divided into the following groups for population structure analysis: largemouth bass, yellow perch, white perch, golden shiner, carp, "other" centrarchids (excluding largemouth bass), ictalurids, and other fish. All groups were analyzed in univariate and multivariate analyses of variance for the effects of water-milfoil presence on numbers and weights of fish per hectare, with 2 exceptions: carp were analyzed for weight per hectare, and white perch for number per hectare because they were important only in those categories in 1977.

Multivariate analysis of variance revealed that numbers and weights per hectare in 1977 were significantly different from the values obtained during 1959-65 before heavy water-milfoil infestation occurred (Tables 2 and 3). This analysis utilized the mean of the 1959-65 data of the 3 sample areas combined.

The standardized eigenvector (which shows the proportionate change of the species groups) for mean numbers of fish per hectare indicated that ictalurids had the greatest proportionate increase in 1977 over 1959-65. Proportionate decreases in 1977 were greatest in largemouth bass and white perch. Ictalurids, "other" centrarchids, and yellow perch showed proportionate increases for weights per hectare, whereas largemouth bass and other fish showed the greatest proportionate decreases when compared with the 1959-65 mean (Tables 2 and 3).

Univariate analysis of variance of the mean number of each species group per hectare in 1977 showed only yellow perch and "other" centrarchids to be significantly different (P

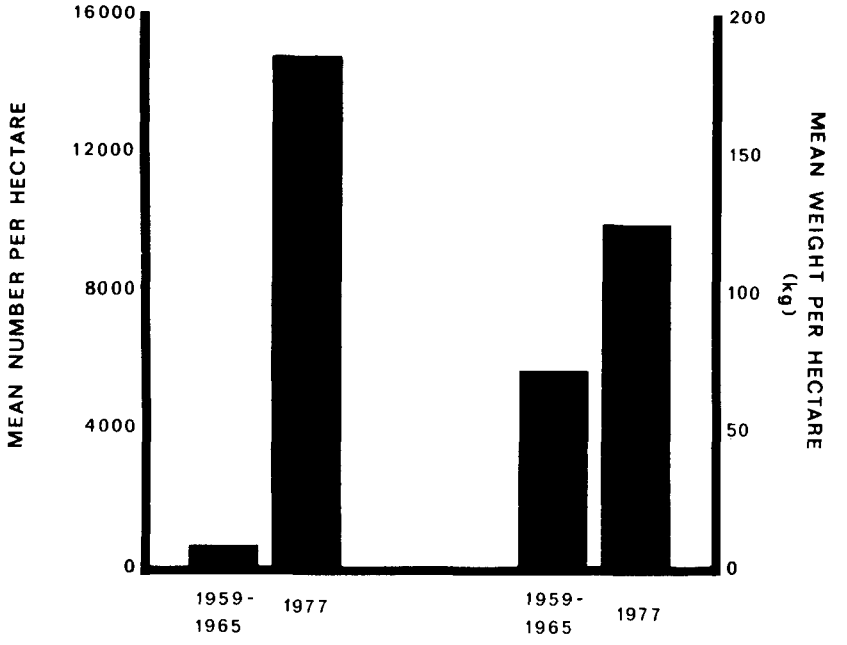

Fig. 2. Mean number and weight of fish per hectare at 3 stations in Currituck Sound, based on collections in 1959-65 and 1977.

Table 2. Results of univariate and multivariate analyses of variance on numbers of fish per hectare.

	Multivariate Analysis[a]	*Univariate Analysis*	
	Standardized	1959-1965	1977
Group	*eigenvector*	*Mean*	*Mean*
Largemouth bass	-0.8535	192	311
Yellow perch	+0.2669	538	2165[b]
White perch	-0.9970	77	32
Golden shiner	-0.1717	239	335
Other centrarchids	+0.0314	1341	9316[b]
Ictalurids	+1.0000	71	170
Other fish	-0.0090	1124	2455

[a]Hotelling-Lawley trace value 1.64
F approximation 3.74
Probability $> F$ 0.0137
[b]$P < 0.01$

Table 3. Results of univariate and multivariate analyses of variance on weights (kg) of fish per hectare.

Group	*Multivariate Analysis*[a] *Standardized eigenvector*	*Univariate Analysis* 1959-1965 *Mean*	1977 *Mean*
Largemouth bass	-0.6435	9.4	12.3
Yellow perch	+0.2723	10.9	16.6
Carp	-0.0144	12.2	30.7
Golden shiner	-0.1432	4.2	5.7
Other centrarchids	+0.6068	11.3	34.7[b]
Ictalurids	+1.0000	5.4	7.6
Other fish	-0.3972	17.0	17.6

[a]Hotelling-Lawley trace value 1.22
F approximation 2.80
Probability $> F = 0.0418$
[b]$P < 0.01$

< 0.01). Univariate analysis of mean weight per hectare showed only the "other" centrarchid group was significantly higher ($P < 0.01$) in 1977. Although numbers and weights of fish per hectare were not statistically different for most groups, the means of all groups increased in 1977 except number of white perch. A high degree of variability of the data was evident for all species groups (Figs. 3 and 4).

Neither number of young-of-the-year nor number of older largemouth bass per hectare, analyzed as separate groups, differed significantly before and after water-milfoil infestation.

DISCUSSION

Both freshwater and saltwater species were present in the standing crop estimate of 125.3 kg/ha for Currituck Sound. Carlander (1955) reported that standing crops for several types of lakes (areas from 667-642,460 ha) in the South ranged from 31.4 to 698.3 kg/ha with a mean of 287.2 kg/ha. The estimate for Currituck Sound is thus low in comparison.

The significant increase in total number of fish per hectare and the lack of a corresponding increase in total weight per hectare in 1977 indicates that more, but smaller, fish were present in 1977. Increases in numbers of smaller fish may have resulted from an increase in cover which allowed them to escape predators. Kearson (1976) estimated total dry weight of vegetation in Currituck Sound in August 1973 amounted to over 25.4 million kg of which 13.2 million kg was Eurasian water-milfoil. Mean total estimated dry weight of vegetation for the period 1959-63, before water-milfoil infestation, was 12.1 million kg. There was, however, an increasing trend of total dry weight of vegetation during the 1959-63 period, but no trend of increasing numbers of fish per hectare or decreasing mean weight per individual.

The multivariate analysis of variance indicates that, based on proportionate changes in total numbers of fish per hectare, a change occurred in the population structure of the 3 areas sampled. The large increase of numbers and weights of "other" centrarchids and yellow perch per hectare indicated that the habitat with water-milfoil was favorable to these groups. The decrease in the proportion of largemouth bass numbers may be a result of unusually high numbers being present before water-milfoil infestation.

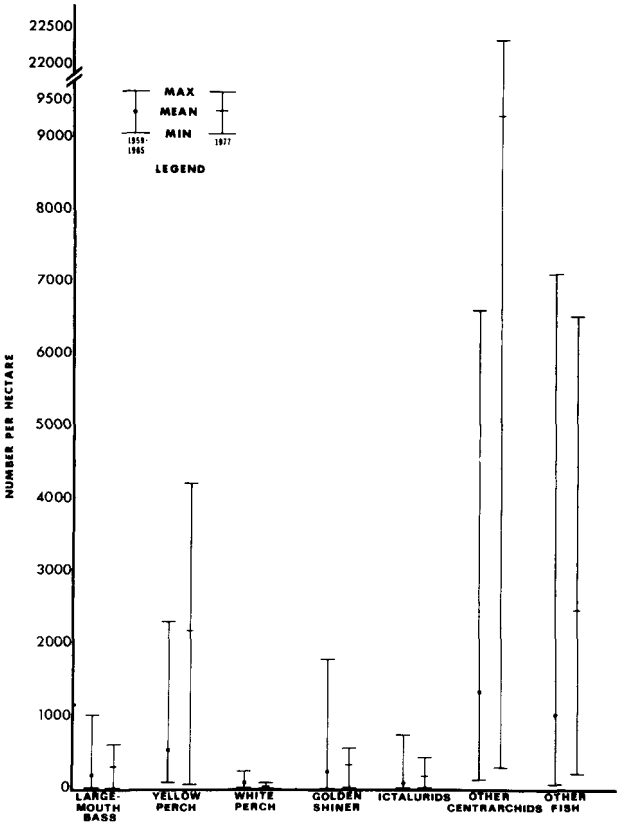

Fig. 3. Comparison of various fish groups before (1959-65) and after (1977) heavy infestation of water-milfoil in Currituck Sound, showing number of fish per hectare. Vertical lines = range (1959-65 at left; 1977 at right); short horizontal lines or dots = means for 1959-65 and 1977, respectively.

Groups that were shown to be positively significant in 1977 by univariate analysis were also positive by the multivariate analysis. This agreement lends confidence to the comparison based on 1 year's data after water-milfoil infestation. The lack of significant changes in numbers per hectare of young-of-the-year and older largemouth bass in a univariate analysis indicated they were not differentially affected.

Differences in the numbers and weights per hectare of the 3 areas indicate that each area should be analyzed separately to determine if they have changed at different rates or to different degrees. To analyze the individual areas additional samples are required.

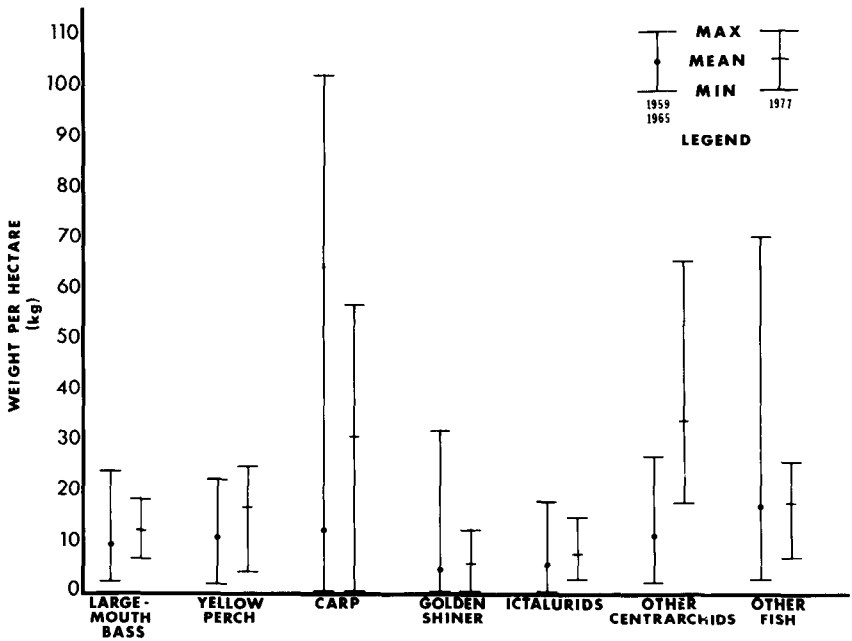

Fig. 4. Comparison of various fish groups before (1959-65) and after (1977) heavy infestation of water-milfoil in Currituck Sound, showing weight (kg) of fish per hectare. Vertical lines - range (1959-65 at left; 1977 at right); short horizontal lines or dots - means for 1959-65 and 1977, respectively.

LITERATURE CITED

Barr, A. J., J. H. Goodnight, J. P. Sall, and J. T. Helwig. 1976. A user's guide to SAS-76. SAS Institute Inc. Raleigh, North Carolina. 329 p.

Carlander, K. D. 1955. The standing crop of fish in lakes. J. Fish. Res. Board Can. 12:543-570.

Crowell, T. E., J. H. Steenis, and J. L. Sincock. 1967. Recent observations of Eurasian watermilfoil in Currituck Sound, North Carolina and other coastal southeastern states. North Carolina Wildlife Resources Commission, Raleigh. 8 p. (Unpublished).

Florshutz, O., Jr. 1972. The importance of Eurasian milfoil (*Myriophyllum spicatum*) as a waterfowl food. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 26:189-194.

Kearson, L. L. 1976. Observations of the flora of Currituck Sound during August, 1973. North Carolina Wildlife Resources Commission, Raleigh. 32 p. (Unpublished).

Sincock, J. L., K. E. Johnston, J. L. Coggin, R. E. Wollitz, J. A. Kerwin, and J. Grandy. 1965. Back Bay-Currituck Sound data report. U. S. Fish and Wildlife Service, North Carolina Wildlife Resources Commission, and Virginia Commission of Game and Inland Fisheries. 1600 p.