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An Evaluation of the Fishery Resources of the Thames River Watershed, Connecticut

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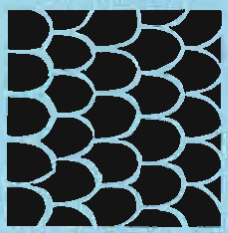

Edited by Richard L. Hames
Connecticut Department of Environmental Protection

STORRS AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE AND NATURAL RESOURCES
THE UNIVERSITY OF CONNECTICUT, STORRS, CONNECTICUT 06268

EDITOR'S FOREWORD

The Thames River system is located in a section of southern New England that has escaped the extreme alterations of the industrial revolution and later urbanization. It has, unfortunately, suffered the consequences of dam construction causing the disappearance of anadromous fish, and industrial and domestic pollution which degraded water quality in some areas to a marginal fisheries habitat. Enough unspoiled areas are left, unaltered by dams, pollution and the developer, to reward the knowledgeable observer with a glimpse of what it was and what it could be again.

As part of the program for restoration of anadromous fish to the Thames River system, it was decided to make a general biological survey of the system to document present conditions. This included predictions of anadromous runs, comparisons of various habitat types, investigation and monitoring of pollution and its effect on fish and the aquatic environment and a survey of the various pathogens present in the fish population. Dr. Whitworth and his students did the bulk of the field work and reports; the section on pathobiology was contributed by Dr. Wolke of the University of Rhode Island.

The estimates of the anadromous fish runs should not be considered indicative of historic runs or as specific goals for the restoration program but more of an indication of what we could expect if fish were not so capricious about ignoring the wishes of biologists and so determined about deciding their own fate.

Richard L. Hames
Department of Environmental Protection
Hartford, Connecticut

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A general survey of the fisheries resources of the Thames River Watershed, Connecticut

Walter R. Whitworth, Dave R. Gibbons, John H. Heuer, Warren E. Johns and Robert E. Schmidt[1]

INTRODUCTION

The purpose of this study was to make a general fisheries survey of the Thames River Watershed as part of an overall project of the Department of Environmental Protection to introduce or reintroduce anadromous fishes into that watershed. The Thames Watershed (Fig. 1) encompasses approximately 3818 km^2, of which 3010 km^2 is in eastern Connecticut, 650 km^2 is in south-central Massachusetts, and 158 km^2 is in northwestern Rhode Island; statistics obtained from Randall et al. (1966), Thomas et al. (1967), and Thomas et al. (1968). Two major tributaries, the Quinebaug (1924 km^2) and the Shetucket (1331 km^2) Rivers, were considered by the Department of Environmental Protection (Anon., 1962) to have great potential for increasing anadromous fish populations in Connecticut.

Messrs. Wayne Swingle, Steve Goodbred, Charles Suprenant, Edward Nottage, Jay Flynn, Earl Morse, Elwyn Eaton, Scott Sauter, Miss Peggy Marsh, Mrs. Mary Parham, and Messrs. Joseph Piza, Peter Minta, and Richard Hames, fishery biologists and the conservation officers and supervisors of Regions 3 and 4, Department of Environmental Protection, assisted with many phases of the work. Mr. Joseph Brumbach, NOAA climatologist, provided published and unpublished records of precipitation and the USGS provided flow data for the Thames River. This study was supported, in part, by (1) Anadromous Fish Act (P.L. 89-304) funds through the Bureau of Sport Fisheries and Wildlife, and (2) the Connecticut Department of Environmental Protection.

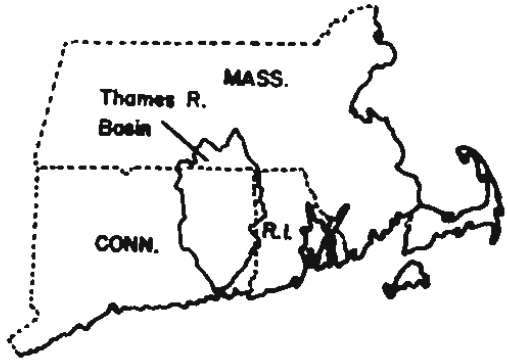

Fig. 1. The Thames River Watershed.

[1]Associate Professor, Fisheries, University of Connecticut, Storrs, Connecticut; Research Assistant, University of Washington, Seattle, Washington; Fisheries Biologist, TVA, Muscle Schools, Alabama; Fisheries Biologist, Raytheon Corporation, Portsmouth, Rhode Island; and Research Assistant, University of Connecticut, Storrs, Connecticut, respectively.

MATERIALS AND METHODS

Three areas selected for comprehensive sampling were (1) the Quinebaug River from Danielson, Connecticut, to the Thames Estuary (formed by the junction of the Quinebaug and the Yantic Rivers at Norwich, Connecticut), (2) the Shetucket River from its formation in Willimantic, Connecticut, to its junction with the Quinebaug in Taftville, Connecticut, and (3) the Thames Estuary from its formation to Long Island Sound at New London, Connecticut. The areas in the Quinebaug and Shetucket Rivers were further subdivided into 3 and 2 units respectively and sampling locations established at which artificial-substrate fauna, plankton, and water samples were periodically collected, returned to the laboratory, and usually analyzed immediately. Locations are shown in Fig. 2, and the intervals at which they were sampled are summarized in Table 1.

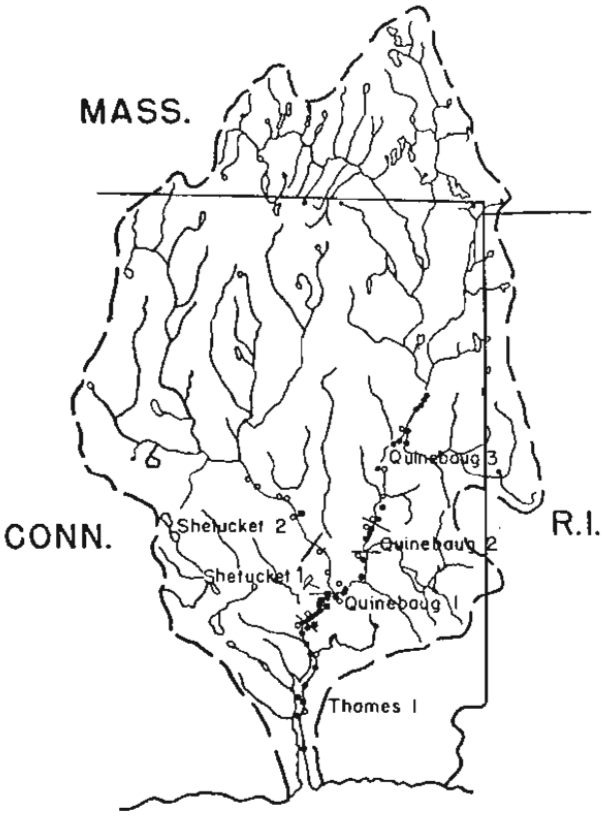

Fig. 2. Sampling areas and station locations in the Thames Watershed. Closed circles indicate stations sampled from July-September 1969; open circles represent stations also sampled from October-December 1968; and closed squares represent the stations sampled from September 1969-October 1970.

Table 1. Sampling locations and number of stations in the Thames River System. Sampling period 1 was 10/68 to 12/68; period 2 was 7/69 to 9/69; and period 3 was 9/69 to 10/70.

	Sampling Periods		
Sampling Area	1*	2**	3**
Quinebaug 1	12-15	9	3
Quinebaug 2	3	3	1
Quinebaug 3	11	11	3
Thames 1	12	12	3
Shetucket 1	-	-	4
Shetucket 2	-	-	5

* 4-week sampling interval
** 3-week sampling interval

Twenty-eight profiles of salinity, specific conductance, temperature, dissolved oxygen, pH, and total alkalinity were made in the Thames Estuary between July 1969 and August 1970. Three similar diel profiles were made in August and September 1970. Sampling locations are shown in Fig. 3. Profiles were also made during the summers of 1969 and 1970 in most of the major impoundments of the Quinebaug and Shetucket Rivers.

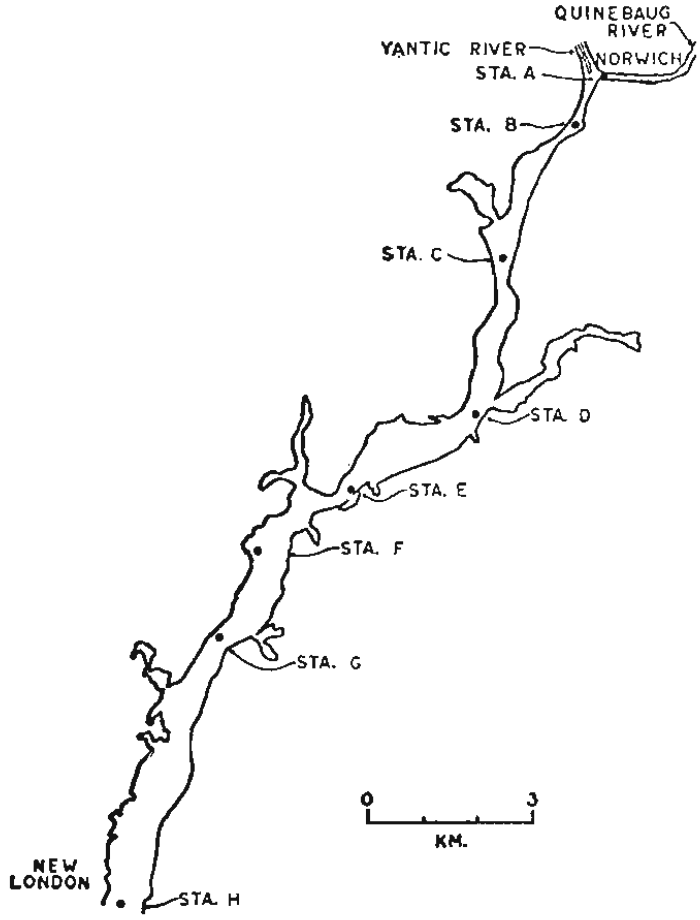

Fig. 3. The Thames River Estuary. Sampling locations of profiles are represented by Stations A through H.

Surface water samples were collected at all but the profile stations in 0.3 and 1.0 liter glass bottles, returned to the laboratory, and analyzed within 2 hours. Profile water samples were usually taken (Kemmerer bottle) in the main channel (during winter occasionally near shore through the ice) of the Thames Estuary or at 3-5 locations at random in the impoundments, from the nearest odd meter above the bottom to the surface at odd meter intervals. An aliquot was immediately withdrawn from the Kemmerer bottle from each depth and dissolved oxygen measured by the azide modification of the Winkler method (APHA et al., 1965). Another water sample was withdrawn into a glass bottle and returned to the shore or laboratory and usually analyzed within 2 hours. Specific conductance was obtained by measuring temperature (mercury thermometer) and resistivity (a Wheatstone bridge or conductivity meter utilizing platinum dip electrodes having constants of 1, 10, or 50) and calculating specific conductance (μmhos/cm at 25 C) as follows:

$$\text{Sp. Cond.} = \frac{1{,}000{,}000}{\frac{\text{Resistance (ohms)}}{\text{Prob Constant}} \times [1.0 + 0.0226\ (\text{temp}-25)]}.$$

Salinity was calculated as follows:

$$\text{Salinity (ppt)} = -0.0649 + 0.549(\text{Sp. Cond.}/1000) + 0.00278(\text{Sp. Cond.}/1000)^2 - 0.0000123(\text{Sp. Cond.}/1000)^3;$$

constants were calculated by applying a third degree polynomial to Tiphane's (1962) salinity-specific conductance data. A Corning pH meter was used to measure the pH of a 100 ml sample of water which was then titrated to a pH of 4.3 with 0.02N sulfuric acid to estimate total alkalinity; expressed as mg/liter of equivalent $CaCO_3$ (APHA et al., 1965).

Mean values of specific conductance, salinity, pH, and total alkalinity were calculated for each sampling date for each area. Mean values of salinity, specific conductance, temperature, dissolved oxygen, pH, and total alkalinity were calculated for each depth at each profile location in the Thames Estuary (1) each day, (2) seasonally (winter was December through February, spring was March through May, summer was June through August, and fall was September through November), and (3) monthly. Mean values in other areas were calculated only for each day. Data were analyzed graphically.

Temperature was normally monitored continuously from March 1968 to October 1970 by 1-5 Ryan thermographs placed at selected locations in the rivers; the Quinebaug River close to the Highway 12 bridge in Norwich was monitored much of this time. Thermographs were placed on the bottom in 0.3-2 m of water and either anchored in place with rocks or tied to stakes driven into the bottom. Average hourly temperature values interpreted from the tapes were summed and mean daily and weekly values obtained. Mean weekly values for the Quinebaug and Shetucket Rivers at Norwich were used as indications of the annual temperature fluctuations. Temperatures were also measured (mercury thermometer) each time an area was visited.

Total flow (m^3/month) of the Thames River was obtained from USGS monthly releases of estimated stream discharge of rivers entering Long Island Sound. Monthly flows were analyzed graphically. Tidal information was obtained from U.S. Coast and Geodetic Survey publications for 1969 and 1970.

Total precipitation falling on the Thames Watershed was estimated by arbitrarily dividing the watershed into 4 regions (Fig. 4), multiplying the average rainfall for the reporting stations in the Watershed (Region 1 was 2, 2 was 2 or 3, 3 was 4 or 5, and 4 was 5 or 6) by the approximate land surface in the area (area 1 was 455,793 m^2, area 2 was 933,361 m^2, area 3 was 1,378,982,160 m^2, and area 4 was 1,170,042,330 m^2), and summing the 4 regions; rainfall was obtained from U.S. Climatological Data - New England (1968, 1969, and 1970) or from monthly reports of the stations.

Plankton samples were obtained by pouring 18-40 liters of water taken at random at the surface of each station using a 3.7 liter vessel into a #20 mesh plankton net; concentrates were analyzed within 6 hours. Numbers, individuals, or colonies of selected groups (filamentous green, colonial green, unicell green, diatom, desmid, filamentous blue-green, non-filamentous blue-green, protozoa, rotifer, miscellaneous invertebrate, golden brown, and others) were estimated by counting (at random) 10 fields (using a calibrated Whipple disc) of each of 2 one ml samples contained in a Sedgwick Rafter using a monocular microscope (160X in 1968 and 200X in 1969 and 1970).

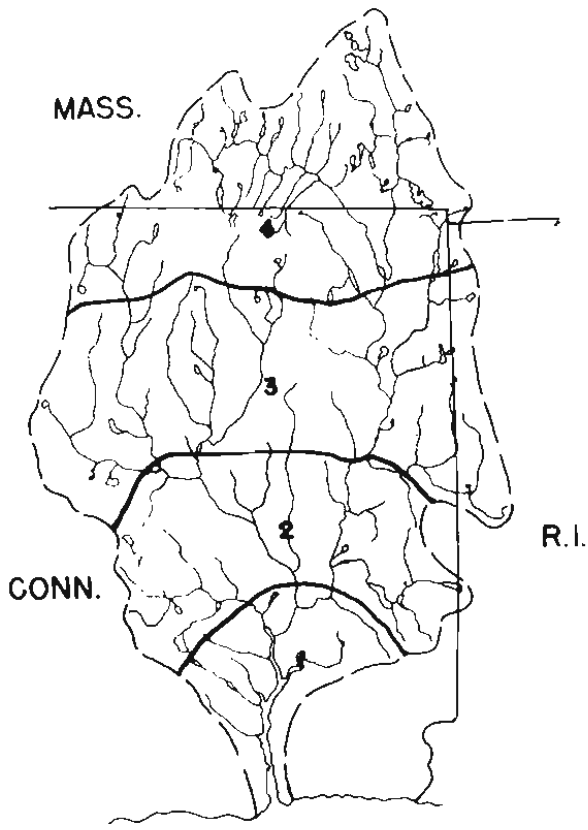

Fig. 4. Precipitation areas of the Thames River Watershed. Approximate area percentages are area 1, 12%; area 2, 24%; area 3, 35%; and area 4, 30%.

Populations were estimated as follows:

$$\text{No./ml} = \frac{\text{No. Fields/Counting Cell}}{\text{No. Fields Counted}} \times \frac{\text{ml of Concentrate}}{\text{ml of Original Sample}} \times \text{No. Organisms Counted}$$

Numbers of specimens of each group and of all groups combined were determined for each sampling date for each area and a taxon index (No. of species having 10% or more of the total number of species sampled at each station/total number of species sampled at that station) calculated for each area by monthly intervals. Data were interpreted graphically.

Artificial-substrate fauna samples were obtained by suspending plate samplers (three 75 mm squares of masonite separated by two 25 mm squares held together by cord) about 15 cm off the bottom (1968) or approximately on the bottom (1969 and 1970) from trees, pilings, or stakes driven into the river bed for the period between two sampling dates (3 or 4 weeks). The outside of the samplers were scraped when necessary to remove organisms and the samplers placed in plastic bags, returned to the laboratory, and all macroscopic invertebrates found within the sampler enumerated (approximately 24 hours after collection in 1968 and within 4 hours in 1969 and 1970). Populations of selected groups (polychaete, oligochaete, other worms, leech, clam, snail, barnacle, amphipod, isopod, water penny, midge, other diptera, net caddis, case caddis, odonate, mayfly, stonefly, and others) were estimated in numbers/dm^2. Numbers of specimens of each group and of all groups combined were calculated for each sampling date for each area and a taxon index (same as plankton) calculated for each area by monthly intervals. Data were interpreted graphically.

Samples of fishes were obtained at irregular times and places throughout the watershed with (1) 5 and 6 mm knotless nylon seines (0.5 to 16 m long X 0.9 to 3.1 m deep) from June 1968 to December 1970; (2) gill nets (20 to 110 mm stretch mesh, 15 to 91.5 m long X 2 to 4 m deep) from September 1968 to December 1970; (3) trap nets (approximately 80 mm stretch mesh about 1-1.5 m in diameter X 5 m long) from June 1968 to December 1970; (4) a fishermen survey in Thames 1 and Quinebaug 1 from June to November 1968; (5) diurnal and nocturnal electrofishing in Quinebaug 2 during October 1969 and August 1970; and (6) rotenone samples once in Thames 1, Quinebaug 2, and Quinebaug 3 during the period July to August 1969.

Juvenile fish were sampled (seines and tow nets) once a week (random times within the week) in Quinebaug 1-3 and Thames 1 from 5 July to 20 August 1971 (a few irregular samples were taken through September 1971, and one sample was taken on 21 June 1971).

Random samples of fishes collected in the comprehensive study areas were returned to the laboratory fresh; rarely preserved in 10% formalin. Varying numbers of each species (usually no more than 15 specimens after July 1969) were measured (total and usually standard lengths in cm), weighed to the nearest 0.01 g on a direct-reading balance or to the nearest 0.5 g on a beam balance for fish over 1.3 kg, sexed if possible (1969 and 1970), and the stomach and often part of the intestine inspected with the aid of a binocular dissection microscope; food organisms present were recorded by category (insect, oligochaete, midge, caddis, fish, snail, arthropod, vascular plant, nonvascular plant, detritus, and others). Scales or spine samples were taken from all specimens analyzed except American eel. Scales were removed from the area between the lateral line and the anterior base of the dorsal fin and usually the left pectoral spine (occasionally both) removed from ictalurid fishes.

The relationship between total length and standard length for each species was obtained by fitting all total and standard length values by the least squares method and calculating the values of A, B, and a correlation coefficient; $SL = A + B(TL)$.

The relationship between total length and weight for each species was obtained by (1) fitting all total length and weight values by the least squares method and calculating the values of A, B, and a correlation coefficient [log weight = log A + B(log TL)] and (2) calculating a condition index [Condition Index = weight (g) X 10^5/length^3 (mm).

Covariance analysis (Snedecor and Cochran 1967) was used to compare effects of sex, space, and time within each species.

Growth of juvenile fish was obtained by fitting all standard length and growth day values (21 June was considered day 1 of juvenile growth) by the least squares method, calculating the values of A, B, and a correlation coefficient, and determining the average standard length at 10 day intervals for most of the summer.

Food habits of each species were expressed as the percent occurrence of each food item in the total number of specimens examined that contained any food in the stomach.

Age and growth estimates of scaled fish were obtained (1) by placing scales either between glass slides or on acetate slides (approximately 25 X 75 X 1 mm), in the latter case making impressions with a roller press (Michigan type); (2) magnifying the scales or impressions with a microprojector; (3) recording total scale length (center of focus to center of anterior scale margin) and length from the center of the focus to each annulus (along the same center line used to measure total scale

length); and (4) calculating total length at the time of each annulus formation: TL = a + Annulus Length X (Total Length of Fish When Captured - a)/Total Scale Length, where a was a constant chosen to approximate the total length of the fish when scales first appeared.

Values of a used were 0.7 (Alosa pseudoharengus, Semotilus corporalis, Notemigonus crysoleucas, and all Notropis), 0.8 (Catostomus commersoni, Erimyzon oblongus, and all Lepomis), 0.9 (all Morone, Perca flavescens, and Pomoxis nigromaculatus), 1.0 (Cyprinus carpio, Esox niger, and all Micropterus), 2.3 (Osmerus mordax), and 2.5 (all Ictalurus).

Age and growth estimates were performed similarly with ictalurid fishes using spines. Each pectoral spine was sectioned (0.5 or 0.3 mm with a mounted jewelers saw, constructed by the University of Connecticut Research Shop), as close to the groove at the base of the spine as possible, cleared in 5% acetic acid for 4 hours, magnified with a micro-projector, and interpreted as were scales. Annuli were thin dark lines separated by broad clear areas and were consistently read on the dorsal side of the spine just anterior to the posteriorily projecting ridge. Back calculations were performed as with scale measurements, substituting total spine length (center of spine to dorsal margin just anterior to the posteriorily projecting ridge) for total scale length, and measuring annuli length along that same line.

Ovaries of ripe females of some species collected in the fall of 1969 and spring of 1970 were removed, split open, and placed in Gilson's solution for at least 2 days. Ovarian tissue, eggs, and Gilson fluid were then poured on filter paper with as much ovarian tissue discarded as possible, and all eggs weighed to the nearest 0.0001 g on a Mettler analytical balance. A random sample of 50 eggs was then weighed and the total number of eggs calculated by direct proportion [Egg No. = Ovary Weight/(Weight of 50/50)]. The relationship between egg number and (1) total length and (2) total weight for each species was calculated by fitting egg number and both total length and total weight values by the method of least squares and calculating the values of A, B, and a correlation coefficient [Egg No. = A + B(total length or total weight)].

CHEMICAL-PHYSICAL CHARACTERISTICS

Seasonal trends and a general indication of an upstream-downstream progression of mean values of pH, total alkalinity, and specific conductance (Fig. 5) were occasionally (in the former) and often (in the latter) obscured by "polluted" water masses (Table 2 documents 2 examples). These water masses were probably of sufficiently different density so they stayed together for some distance and covered only part of the area of the stream. Generally the Quinebaug River decreased in total alkalinity, specific conductance, and pH as it flowed downstream through the study area until it joined the Shetucket River above Norwich, Connecticut; probably as the effluents introduced above Danielson were diluted by the less polluted tributary streams and ground water sources. The Shetucket River did not show these downstream trends, probably due to a lower inflow of tributary waters. The "slug-type" pollution often indicated in the rivers was superimposed on an obviously constant oxygen-demand effluent in two areas, Taftville impoundment on the Shetucket River (Table 3) and the upper end of the Thames Estuary (Table 4 and Appendices A and B).

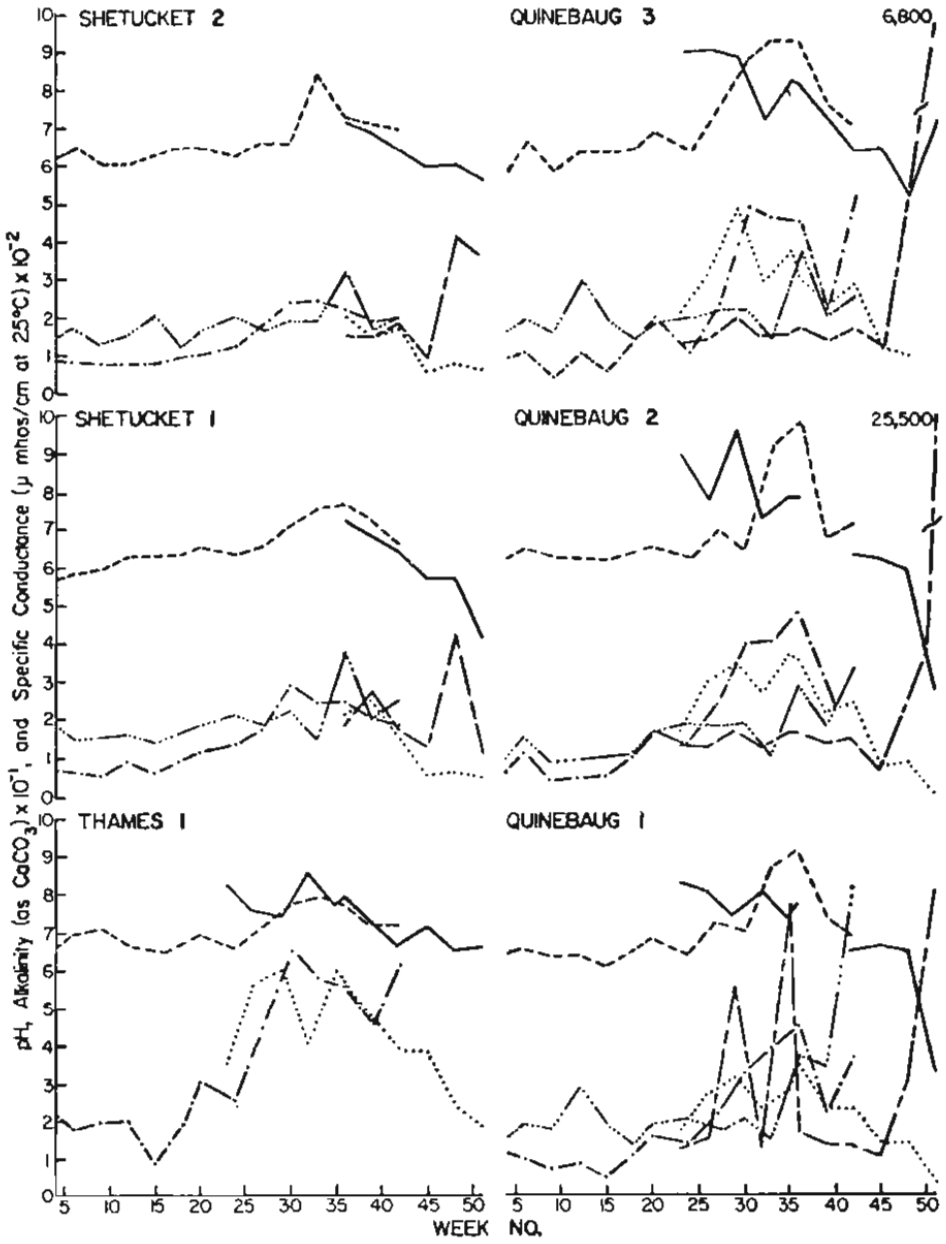

Fig. 5. Mean pH, total alkalinity, and specific conductance measurements in the Thames River System. Total alkalinity is represented by ····· 1969 and -·-·- 1970; pH by ——— 1969 and ---- 1970, and specific conductance by —·—·- 1969 and ···—··· 1970.

Vertical and longitudinal stratificiations of salinity, specific conductance, temperature, dissolved oxygen, pH, and total alkalinity in the Thames Estuary, evident throughout the year, showed monthly, seasonal (Table 5), and tidal (Table 4 and Appendices A and B) effects of a saltwater wedge which was usually present to Norwich, 24 km from the mouth of the river. The saltwater wedge exerted a buffering effect on the temperature regime of the estuary during times of rapid change of air and surface temperatures in the spring and fall (Appendix C).

Table 2. Examples of "polluted" water masses in the Thames River System.

Downstream Distance (km)	12 December 1969 Time	Water Temp. (C)	Sp. Cond. (umhos/cm at 25 C)	Tot. Alk. (equiv. $CaCO_3$)	pH	22 December 1969 Time	Water Temp. (C)	Sp. Cond. (umhos/cm at 25 C)	Tot. Alk. (equiv. $CaCO_3$)	pH
Wauregan, Conn. Quinebaug River										
0	0845	3.0	733	0.0	3.7	0810	1.0	105	13.2	6.5
9.2	0905	3.0	391	14.1	6.5	0840	1.0	6495	0.0	2.1
17.7	0920	3.0	416	5.2	5.4	0900	0.5	13673	>340.0	13.5
18.4	0930	3.0	390	9.1	6.0	0905	0.0	25481	0.0	2.8
22.8	0945	3.0	369	18.5	6.7	0925	0.3			
34.0	1000	3.0	272	11.0	6.3	0940	0.6	1460	0.0	0.4
39.5	1030	3.0	251	11.4	6.4	1000	1.0	136	6.4	6.0
Norwich, Conn. Thames Estuary										
0	1040	3.0	2102	15.4	6.4	1010	1.3	3594	14.0	6.4
5.7	1100	5.0	3016	21.7	6.6	1030	2.7	7430	21.0	6.7
12.7	1115	5.0	7763	34.0	6.6	1045	2.7			
Willimantic, Conn. Shetucket River										
0	1330	3.0	423	4.5	6.3	1245	0.9	121	9.7	6.7
2.7	1320	3.0	408	8.1	6.1	1230	1.0	127	0.0	3.1
5.0	1310	3.0	384	12.0	6.4	1215	0.4	539	8.2	6.4
7.5	1300	3.0	413	6.5	5.9	1200	0.4	905	4.8	5.9
8.7	1240	3.0	414	9.9	6.3	1150	0.8	97	8.8	6.4
15.5	1230	2.5	522	1.5	4.5	1135	0.8	97	6.5	5.9
19.5	1220	2.5	284	12.2	6.5	1130	0.3	108	6.5	6.1
21.1	1210	3.0	474	4.8	5.0	1120	0.4	112	0.0	1.9
24.8	1000	3.0	391	9.2	6.3	0940	0.7	110	6.5	5.9

Table 3. Summary of vertical profiles in the Quinebaug and Shetucket Rivers in 1969 and 1970.

Date	Area	Number of Stations	Depth (M)- # Sample Averaged	pH	O_2 (mg/liter)	Temp. (C)	Sp. Cond.*	Total Alk.**
8-07-69	Tunnel Dam Impoundment Quinebaug River	1	Surface-1	7.4	6.2	25.0	183	26.0
			1-1	7.5	6.5	25.2	198	28.0
8-07-69	Quinebaug-Shetucket below junction of Shetucket River	1	Surface-1	6.7	5.6	25.4	173	17.1
8-07-69	Greenville Dam Impoundment Quinebaug-Shetucket River	3	Surface-3	6.7	6.1	25.8	124	20.8
			1-1	6.9	5.9	25.5	121	20.8
			2-2	6.7	6.0	25.8	128	21.8
			3-1	6.8	5.8	25.7	118	21.1
			5-3	6.8	5.9	25.7	125	21.5
8-07-69	Quinebaug-Shetucket between Greenville Dam & last canal discharge	2	Surface-1	6.8	6.4	27.4	124	20.1
			2-1	6.9	6.1	27.0	122	20.2
			3-2	6.8	6.4	26.7	124	20.2
8-11-69	Aspinook Pond Quinebaug River	9	Surface-9	9.0	8.5	26.1	177	25.2
			1-9	8.6	8.0	25.5	134	25.5
			2-3	7.8	7.2	25.4	131	25.3
			3-6	7.6	7.4	25.4	130	25.3
			4-1	7.4	6.1	24.5	194	24.8
			5-3	7.5	6.5	25.0	129	24.7
7-23-70	Taftville Impoundment Shetucket River	3	1-3	6.4	5.5	25.3	155	24.8
			3-3	6.4	4.5	25.0	170	24.7
			5-2	6.2	0	24.4	160	29.9
7-23-70	Aspinook Pond Quinebaug River	4	1-4	7.9	9.1	26.5	177	44.1
			3-4	7.3	6.5	25.4	176	40.1
			4-3	6.7	4.2	25.3	172	40.5
			5-1	6.9	1.7	25.1	167	39.4
8-18-70	Taftville Impoundment Shetucket River	3	1-3	6.5	1.9	26.4	255	19.7
			3-3	6.5	1.1	26.1	367	20.6
			5-2	6.3	0	25.0	264	34.1

*µmhos/cm at 25 C **mg/liter equivalent $CaCO_3$

Seasonal trends of temperature, precipitation falling on the Thames Watershed, and discharge of the Thames Estuary into Long Island Sound (Fig. 6 and Appendix D) correlated well with the seasonal trends of pH, total alkalinity, and specific conductance and revealed that precipitation falling on the Thames basin in the winter, spring, and late fall showed substantial effects on streamflow compared to summer and early fall precipitation; heavy rains in June 1968 delayed low water flow but apparently did not significantly increase the level of the summer low. Vertical and longitudinal fluctuations of the saltwater wedge were directly correlated with stream discharge (Table 5).

Table 4. Diel profiles of temperature, dissolved oxygen, and salinity for September 9-10 in the Thames Estuary, Connecticut.

Tidal Stage		rising			high			falling			low			rising			rising			high			falling		
Time		1200			1500			1800			2100			2400			0300			0600			0900		
Variables*		T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S
Area**	Depth																								
0	1m	19.7	5.9	4	20.6	1.1	20	19.9	6.6	3	19.7	4.7	3	19.7	4.8	2	20.0	0.5	12	19.7	2.6	3	20.1	2.7	7
	3m	20.9	0	31	20.2	0	35	20.3	0	35	20.2	0	32	20.2	0	30	20.3	0	33	20.0	0	34	20.7	0	35
	5m	20.2	0	34	19.8	0	34	20.0	0	37	19.9	0	37	19.7	0	-	19.9	0	33	19.9	0	34	20.1	0	37
	7m	19.7	0	36	19.8	0	37	19.7	0	37	19.8	0	37	19.8	0	-	19.8	0	34	19.9	0	34	20.0	0	36
	9m	19.7	0	37	19.8	0	37	19.7	0	32	19.7	0	34	19.7	0	30	19.7	0	32	19.7	0	35	20.0	0	37
1.0	1m	20.3	3.6	13	20.1	3.5	15	19.5	4.0	10	19.6	3.8	7	19.6	4.7	6	20.0	1.6	10	19.6	2.7	6	20.0	1.3	8
	3m	20.3	0	36	20.3	0	34	20.7	0	-	20.4	0	35	20.4	0	30	20.4	0	32	20.5	0	32	20.9	0	34
	5m	20.0	0	36	20.0	0	37	20.3	0	35	20.0	0	37	19.9	0	30	20.0	0	33	20.0	0	34	20.5	0	36
	7m	19.6	0	34	19.8	0	38	19.9	0	37	19.6	0	37	19.7	0	40	19.8	0	33	19.9	0	35	20.2	0	34
5.2	1m	20.0	3.2	20	19.2	5.5	18	19.5	5.4	18	19.6	3.6	18	19.5	6.9	13	19.7	4.6	20	19.8	3.5	24	20.1	2.2	26
	3m	20.4	0	32	20.1	0.3	34	20.1	0	36	20.1	0	33	20.3	0	33	20.2	0	31	20.2	0.4	29	20.4	0	33
	5m	19.9	0	38	19.9	0.6	37	19.8	0.4	38	19.7	0	35	19.9	0	34	20.1	0	32	20.1	0	31	20.3	0	36
	7m	19.6	0.8	39	19.6	0.9	38	19.8	0.4	37	19.7	0	35	19.7	0.3	34	19.9	0.4	34	19.9	0	33	20.2	0.1	37
10.4	1m	19.4	3.0	27	19.9	6.3	31	19.8	4.0	30	19.7	3.7	30	19.6	4.7	26	20.2	5.4	30	19.9	3.8	28	19.8	5.0	28
	3m	19.7	1.9	36	19.9	2.4	37	20.1	1.4	34	20.0	1.7	32	19.9	1.9	28	20.0	2.4	33	20.0	3.3	30	20.1	1.1	36
	5m	19.5	1.7	38	19.4	3.5	38	19.7	1.3	36	19.7	0.7	36	19.8	1.7	34	19.7	1.9	32	19.8	2.0	34	20.0	0.6	37
	7m	19.4	1.3	39	19.5	3.2	37	19.6	2.0	38	19.5	1.0	38	19.6	1.3	34	19.6	1.5	33	19.7	1.3	32	20.0	0.8	37
14.3	1m	19.4	5.1	31	19.6	6.4	33	19.7	4.1	35	20.4	3.9	32	20.1	5.4	31	19.6	5.7	32	20.5	4.7	30	20.7	3.9	32
	3m	19.6	2.9	34	19.6	5.2	34	19.7	1.0	34	20.7	2.2	33	20.0	5.0	31	19.6	5.2	33	19.7	4.5	32	20.4	4.3	33
	5m	19.2	2.5	37	19.2	4.3	38	19.5	1.8	38	19.8	1.5	34	19.5	3.3	35	19.5	4.2	34	19.6	4.4	32	20.0	2.7	35
	7m	19.0	2.8	38	19.7	3.7	38	19.0	2.0	36	19.3	1.5	38	19.3	4.3	34	19.2	3.6	36	19.5	3.4	34	19.7	2.7	37

*T=Temperature (C), O=Dissolved oxygen (mg/l), and S=Salinity (ppt).

** Distance downstream from Norwich, Conn. (km).

Table 5. Seasonal means of temperature, dissolved oxygen, and salinity in the Thames Estuary, Conn.

Distance From Norwich (km)	0			1.0			5.2			7.7			10.4			12.6			14.3			19.7		
Variables	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S
Seasons / **Depth**																								
Winter																								
1m	1.1	13.7	1	1.3	12.5	1	3.3	14.2	5	0.7	13.1	2	1.5	13.4	2	1.7	12.0	7	6.6	10.6	5	2.0	12.9	8
3m	1.4	13.6	4	1.1	12.8	3	3.0	12.2	20	1.3	10.7	22	1.5	13.4	2	2.0	10.5	40	7.2	6.5	17	2.0	12.6	12
5m	2.2	11.6	17	2.3	10.9	25	3.2	10.3	31	2.0	9.6		1.5	12.6		2.0	10.0	39	8.5	4.0	35	2.1	10.5	35
7m	2.2	11.0	22	2.3	10.2	25	2.8	9.8	30	1.9	8.3	38	1.9	10.1	28	1.9	10.0	37	8.5	4.2	36	2.1	10.5	34
9m	1.8	11.1	7	2.0	13.7			5.5	23				1.5	13.2	7	2.2	10.3	38	8.5	5.5	37	2.1	10.2	39
Spring																								
1m	8.8	10.9	0	8.5	12.3	3	6.2	11.0	4	10.2	10.5	6	6.2	10.8	8	10.2	10.4	9	15.5	8.0	15	8.3	10.7	22
3m	8.4	9.9	14	7.8	11.6	7	5.7	9.8	17	8.9	9.7	17	6.3	10.3	13	9.6	9.9	20	10.4	7.6	31	6.5	9.8	32
5m	6.4	8.7	28	6.3	10.0	24	5.5	9.2	28	7.2	9.5	27	5.1	10.0	34	7.1	9.6	33	9.5	7.4	33	6.0	9.8	37
7m	6.4	8.6	28	6.4	9.7	26	5.4	8.8	33	6.8	8.9	34	5.0	10.3	37	6.9	9.5	35	10.7	7.5	33	6.0	9.9	37
9m	2.0	9.4	38	3.0	9.7	39	2.8	10.5	39										9.9	8.0	34	5.9	9.7	37
Summer																								
1m	23.3	4.8	7	23.8	4.9	8	23.8	6.1	10	23.5	7.2	13	23.5	5.5	16	23.4	4.3	23						
3m	19.3	1.2	22	20.1	1.5	19	20.4	1.7	22	20.4	2.6	27	20.2	3.5	28	20.8	3.1	23						
5m	18.2	0.4	23	18.1	0.3	23	19.1	0.9	28	19.2	1.7	27	18.3	3.3	33	19.8	3.3	29						
7m	18.2	0.2	25	18.3	0.2	24	18.7	0.5	29	18.8	2.3	28	17.7	3.2	34	19.4	3.8	30						
9m	17.7	0.1	22	17.3	0.2	31	19.4	0	27	20.0	2.1	31	16.2	3.3	34	19.4	3.7	33						
Autumn																								
1m	11.8	9.1	2	17.5	6.5	5	12.1	7.7	7	12.8	9.3	7	18.3	5.9	22				13.6	7.3	32			
3m	13.0	6.4	15	18.5	1.9	30	12.6	5.4	16	13.0	6.1	16	18.4	4.5	23				13.8	5.4	33			
5m	11.9	6.0	22	18.8	0.7	31	12.6	3.6	24	13.1	3.7	30	18.5	2.3	33				14.2	3.4	35			
7m	12.7	4.2	26	18.9	1.1	32	13.5	2.3	30	14.8	2.9	30	18.5	1.4	32				14.1	3.5	37			
9m	12.7	3.2	26	18.3	0.8	21																		

T = Temperature (C) O = Dissolved Oxygen (mg/l) S = Salinity (ppt)

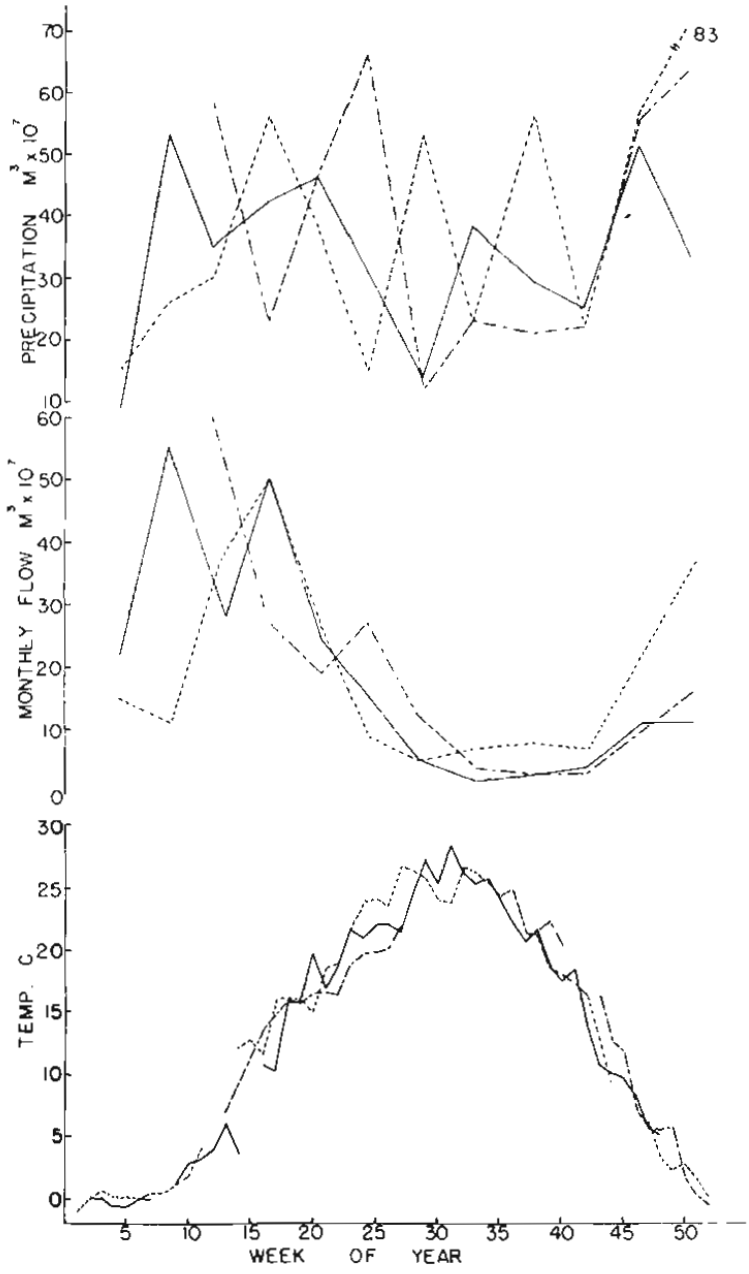

Fig. 6. Estimated precipitation falling on the Thames Watershed, discharge of the Thames River into Long Island Sound, and temperature of the surface waters of the Quinebaug River in Norwich, Connecticut. Longest broken lines represent 1968, smallest broken lines are 1969, and solid lines are 1970.

ARTIFICIAL-SUBSTRATE FAUNA AND PLANKTON

Artificial-substrate fauna and plankton populations were generally similar throughout the watershed (Fig. 7 shows seasonal trends of the total number of organisms in each area). The large numbers of bottom organisms in the Thames Estuary during the fall of 1969 and spring of 1970 were a result of large populations of amphipods. The average number of taxons generally was highest in the fall and most areas revealed that fall was the time of the bloom organisms because species indices increased (Fig. 8). Because pollution in the Thames Estuary apparently increased in 1970, or the effects of pollution were greater, this increase was not evident in the fall of 1970.

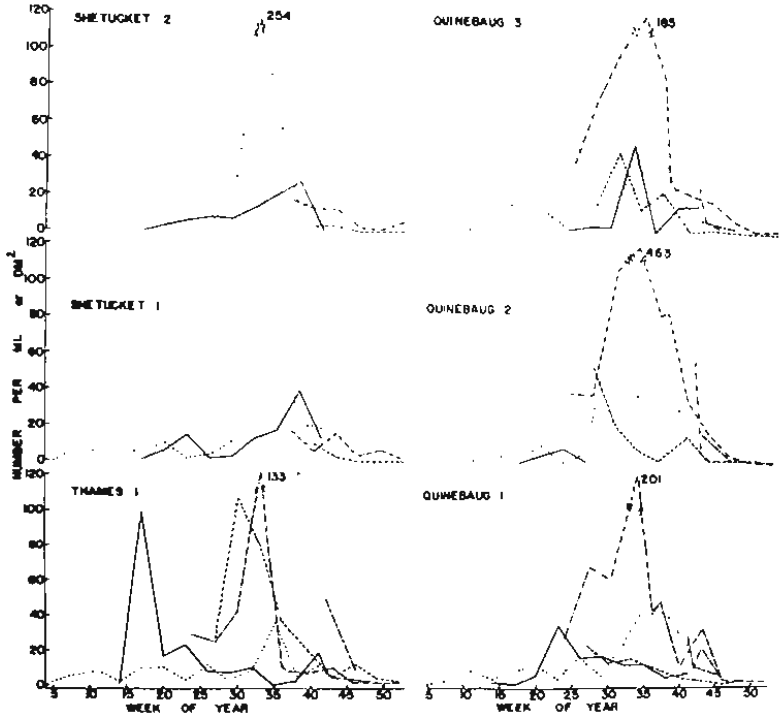

Fig. 7. Bottom fauna and plankton populations in the Thames River Watershed. Bottom fauna populations are represented by ———1968, - - - - - 1969, ———1970; plankton populations are represented by ·····1968, -·-·-1969, ····· ··1970.

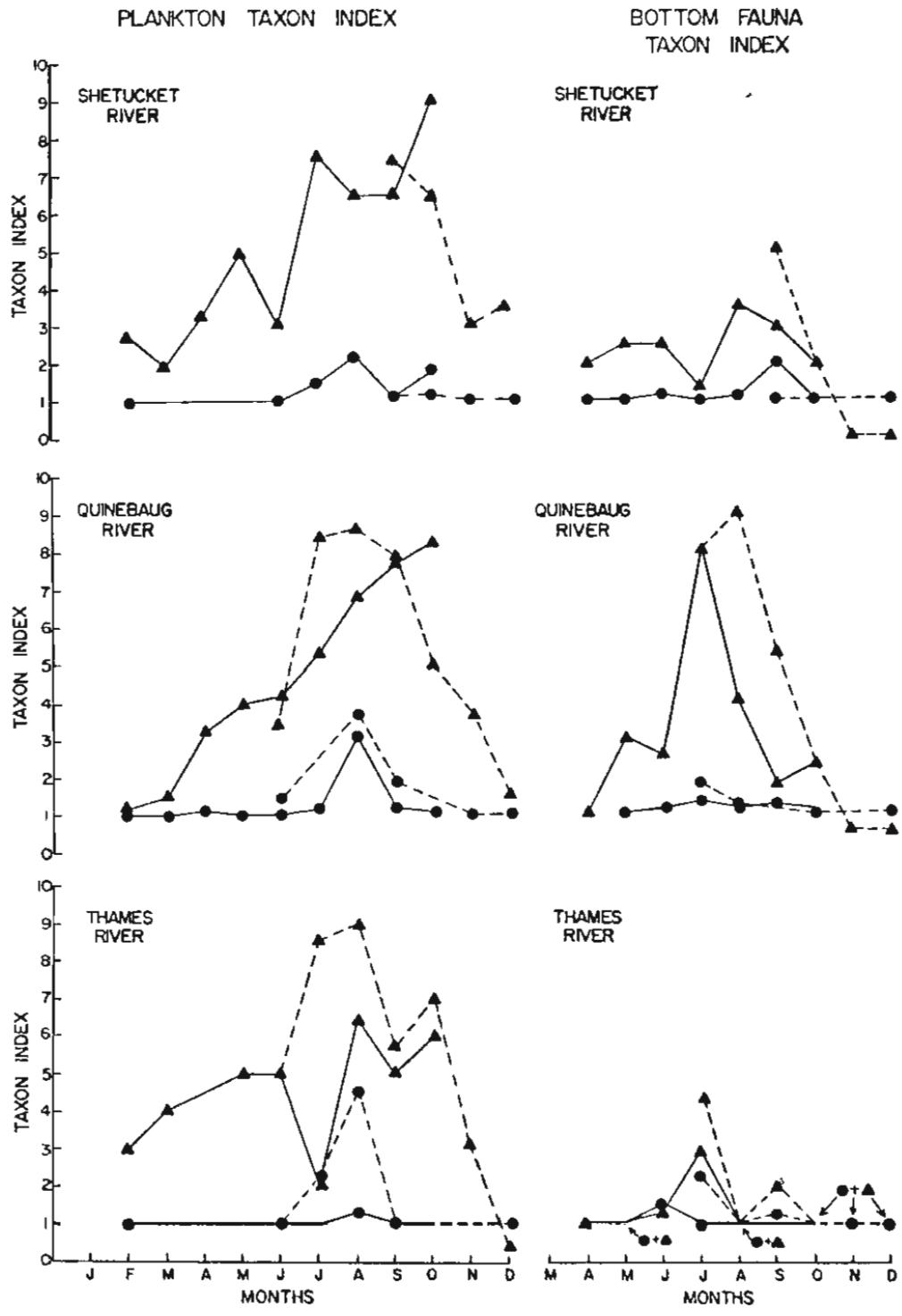

Fig. 8. Monthly plankton and bottom fauna taxon indices for the Thames River System, Connecticut. ---- represents 1969, —— represents 1970, ▲ represents average number of taxons, and ● represents species index.

ANNOTATED LIST OF FISHES

Acipenser oxyrhynchus Mitchill — Atlantic sturgeon

Only one specimen was captured (gill net on 10-31-68) in the Thames River near Stoddard Hill State Park. Parasites were examined by Dr. L. Penner, University of Connecticut.

Alosa aestivalis (Mitchill) — blueback herring

SL = -0.26151 + 0.85160 TL; R = 0.999, N = 86.
Log Wt = -2.42525 + 3.29876 Log TL; R = 0.989, N = 61.
Mean K = 1.98, Mean TL = 7.8 cm (4.6 - 28.5)

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Thames 1	4.5	4.2	4.0	3.8	-0.2011	45

There was no correlation in growth of juvenile fish with time, suggesting that once young blueback herring reached a certain size, they either moved out of the estuary or into water masses which were not sampled.

Primary food items eaten (58 individuals were examined, 4 were empty) were non-vascular plants (78%) and arthropods, mostly amphipods (35%). Detritus (13%), miscellaneous items (11%), and snails and insects (each <5%) were also found.

Adult fish were first captured in the Thames River in June and were observed in the tributary streams and under Greenville Dam and Norwich Falls. Young were found in the main river until late fall and one and two year old fish were occasionally captured during the summer in the lower estuary.

Alosa mediocris (Mitchill) — hickory shad

Hickory shad were captured by gill nets and hook and line in the fall (1969 and 1970) in Norwich Harbor and near Stoddard Hill State Park. They were piscivorous and supported a small sport fishery in the fall.

Alosa pseudoharengus (Wilson) — alewife

SL = -0.07086 + 0.82121 TL; R = 0.998, N = 358.
Log Wt = -1.98141 + 2.95454 Log TL; R = 0.998, N = 357.
Mean K = 1.39, Mean TL = 21.8 cm (2.8 - 35.5).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Thames 1	3.5	4.2	4.8	5.4	5.8	0.671	41

Calculated TL (cm)/Number in Sample

Age			
1	2	3	4
15.4/57	22.5/52	25.7/39	27.6/29

The following food items were preferred (223 were examined and 40 were empty): arthropods, mostly amphipods (65%), nonvascular plants (37%), miscellaneous items [fish eggs (21%), detritus (6%) and insects, fish, snails, and vascular plants (<5% each)].

Alewives were primarily limited to the Thames River Estuary. Some unconfirmed reports of alewives below Tunnel Dam were received from fishermen, and one juvenile specimen was captured above Aspinook (some ponds in the river system have been stocked with land-locked alewives).

Adults appeared in the river in late April and spawned in tributary streams and the main rivers below Norwich Falls and Greenville Dam. Some remained until October. Juveniles were distributed throughout the estuary during summer and fall. Adults were captured in some streams for bait (live or frozen) and human consumption (pickled or smoked).

Alosa sapidissima (Wilson) American shad

SL = 0.07575 + 0.79170 TL; R = 0.996, N = 44.

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971)									Correlation Coefficient	Number in Sample
	6-20	6-30	7-10	7-20	7-30	8-9	8-19	8-29	9-8		
Quinebaug 2			4.6	6.0	7.2	8.4	9.4	10.4		0.943	5
Quinebaug 3	1.1	2.9	3.8	4.5	5.1	5.6	6.0			0.918	33
All	1.0	3.0	4.1	4.9	5.5	6.1	6.6	7.1	7.5	0.903	41

Eggs of American shad were stocked in June 1971. Differences in growth (similar in slope but different in height) between the areas were probably a result of the early or rapid movement of the faster growing individuals downstream.

Stomachs of 15 juvenile specimens (5.9 - 9.0 cm TL) were examined and all were eating larval aquatic insects (caddis, midge, stonefly, mayfly, and dragonfly), adult insects (40%), detritus (35%), clams (33%), and larval fish (8%).

An adult specimen was captured in the Norwich area of the Thames Estuary and sportsmen catches (verified by J. Piza) were reported in the Quinebaug River below Greenville Dam during spring 1969. Numerous one and two year old specimens were captured in various areas of the Estuary in summer and fall of 1969, 1970, and 1971.

Ammodytes americanus DeKay American sand lance

SL = 0.54196 + 0.88164 TL; R = 0.997, N = 11.
Log Wt = -2.78129 + 3.31560 Log TL; R = 0.984, N = 11.
Mean K = 0.40, Mean TL = 14.6 cm (12.9 - 16.5).

All specimens analyzed were captured at the mouth of the Thames River (12 June 1969). Primary food items (11 specimens examined) were fish eggs (91%) and arthropods (45%).

Anochoa mitchilli (Valenciennes) bay anchovy

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Thames 1	1.1	2.4	3.1	3.7	4.4	0.791	29

Adult anchovies were occasionally captured in the lower estuary (Stoddard Hill and south) during the summer and early fall, and juveniles remained in the estuary when sampling ceased in September.

Anguilla rostrata (Lesueur) American eel

Log Wt = -3.12741 + 3.24902 Log TL; R = 0.985, N = 69.
Mean K = 0.30, Mean TL = 49.4 cm (7.0 - 89.0).

The following food items were preferred (62 specimens were examined and 24 were empty): nonvascular plants (75%), fish (74%), arthropods (39%), and vascular plants (26%).

Adults were collected in all areas in all seasons. Juveniles were present in Norwich Harbor in the spring and large numbers were observed below Greenville Dam in June 1971. There is a small commercial fishery in the Thames River for this species.

Apeltes quadracus (Mitchill) fourspine stickleback

SL = -0.03668 + 0.86889 TL; R = 0.980, N = 65.
Log Wt = -1.77079 + 2.57066 Log TL; R = 0.827; N = 55.
Mean K = 1.0, Mean TL = 4.0 cm (3.0 - 5.6).

Sixteen specimens were examined for food preference (2 were empty) and contained: polychaetes (71%), arthropods (43%), and nonvascular plants (21%).

Fourspine sticklebacks, although abundant throughout the Thames Estuary, were most numerous in the lower estuary. Gravid females were commonly collected in early spring.

Brevoortia tyrannus (Latrobe) Atlantic menhaden

SL = 0.01076 + 0.81253 TL; R = 0.995, N = 175.
Log Wt = -2.23621 + 3.29872 Log TL; R = 0.972, N = 154.
Mean K = 1.51, Mean TL = 7.5 cm (3.2 - 12.5).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-20	7-30	8-9	8-19	8-29	9-8	Correlation Coefficient	Number in Sample
Thames 1	3.6	3.7	3.8	3.8	3.8	3.9	0.07316	87

The lack of correlation of growth of juvenile fish with time is probably a result of continual migration of young fish (from late spawning adults) into the estuary.

Stomachs of 99 fish were examined (1 was empty) and contained: nonvascular plants (91%), detritus (25%), arthropods (13%), and vascular plants, fish, and midges (3% each).

Juveniles were probably the most important forage fish in the estuary, and were distributed in the surface layers as far upstream as the first rapids above the harbor. Adults were occasionally captured in the estuary in the summer and fall in small numbers until 1970. The yearly fluctuations in abundance of this species probably exert great influence on the abundance of predatory fishes.

Caranx hippos (Linnaeus) crevalle jack

SL = -0.12866 + 0.81365 TL; R = 0.983, N = 29.
Log Wt = -1.51493 + 2.74022 Log TL; R = 0.994, N = 29.
Mean K = 1.9, Mean TL = 10.1 cm (4.4 - 14.6).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-19	Correlation Coefficient	Number in Sample
Thames 1	4.1	4.6	4.9	5.4	0.33165	22

Calculated growth rates did not show good correlation in this species (as in B. tyrannus) due to their influx from saltwater. They appeared in the estuary in July and were still present in early winter.

Stomachs of 28 fish were examined (1 was empty) and 96% ate fish, 11% nonvascular plants, and less than 5% fed on midges.

Catostomus commersoni (Lacépède) white sucker

SL = -0.00296 + 0.83440 TL; R = 0.994, N = 644.
Log Wt = -1.93023 + 2.97589 Log TL; R = 0.997, N = 366.
Mean K = 1.69, Mean TL = 27.3 cm (5.1 - 49.0).
Egg No. = 17,585 + 293.3 Wt; R = 0.506, N = 6.
Egg No. = 9909 + 445.9 TL; R = 0.171, N = 6.

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 6-30	7-10	7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Thames 1	3.3	4.0	4.6	5.0	5.3	5.6	5.9	0.771	52
Quinebaug 1	2.8	4.2	5.3	6.2	7.0	7.7	8.5	0.835	29
Quinebaug 2	3.2	4.4	5.3	6.0	6.6	7.1	7.7	0.985	6
Quinebaug 3	3.6	4.4	5.0	5.5	5.9	6.2	6.5	0.899	57
All	3.6	4.4	5.0	5.4	5.8	6.2	6.5	0.888	152

Calculated TL (cm)/Number in Sample

Age				
1	2	3	4	5
10.1/343	21.5/322	30.0/236	34.3/68	36.0/10

Stomachs of 274 specimens were examined (21 were empty) and 63% contained detritus, 59% nonvascular plants, 32% miscellaneous, 10% midges, 9% vascular plants, 8% other insects, 7% caddis, 6% arthropods, and 5% snails.

This species was ubiquitous in the Thames River system and was taken in the estuary as far downstream as Stoddard Hill.

Clupea harengus Linnaeus — Atlantic herring

SL = -0.38884 + 0.87504 TL; R = 1.0, N = 2.
Log Wt = -4.47260 + 4.51679 Log TL; R = 1.0, N = 2.
Mean K = 0.64, Mean TL = 31.7 cm (30.5 - 32.9).

Stomachs of 2 specimens were examined and both contained amphipods and marine shrimp, indicating they had recently entered the upper estuary.

Cynoscion regalis (Bloch and Schneider) — weakfish

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971)						Correlation Coefficient	Number in Sample
	7-20	7-30	8-9	8-19	8-29	9-8		
Thames 1	1.8	2.8	3.9	5.1	6.5	7.9	0.858	76

This species utilized the estuary as a nursery area and was first taken during the summer of 1971 in the Stoddard Hill area.

Cyprinodon variegatus Lacépède — sheepshead minnow

SL = -0.35439 + 0.89504 TL; R = 0.915; N = 28.
Log Wt = -1.91423 + 3.81808 Log TL; R = 0.995, N = 3.
Mean K = 3.21, Mean TL = 30 cm (2.5 - 3.3).

This species was occasionally captured in the estuary as far upstream as Norwich.

Cyprinus carpio Linnaeus — carp

SL = 0.39380 + 0.81265 TL; R = 0.982, N = 185.
Log Wt = -1.69741 + 2.92246 Log TL; R = 0.996, N = 120.
Mean K = 2.6, Mean TL = 33.4 cm (6.3 - 68.0).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Thames 1	2.0	3.5	5.1	6.9	8.8	0.696	39
Quinebaug 1	2.2	3.8	5.4	7.8	9.1	0.846	12

Calculated TL (cm)/Number in Sample

Age 1	2	3	4	5	6	7	8	9
15.1/147	26.3/120	34.4/100	40.7/71	45.2/50	49.3/36	52.2/26	55.0/19	55.2/13

Stomachs of 91 specimens were examined (35 were empty) and 66% contained nonvascular plants, 6% fish, and 5% each insects and snails.

Erimyzon oblongus (Mitchill) creek chubsucker

SL = 0.04958 + 0.83944 TL; R = 0.999, N = 4.
Log Wt = -3.08779 + 3.85422 Log TL; R = 0.997, N = 3.
Mean K = 1.4, Mean TL = 26.5 cm (23.5 - 28.0).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Quinebaug 1	2.6	3.5	4.4	5.1	5.9	6.6	0.911	17

Calculated TL (cm)/Number in Sample

Age 1	2	3
9.7/5	20.0/4	26.0/2

Stomachs of 2 specimens were examined and both contained nonvascular plants and detritus and one contained snails.

This species was only collected in the Quinebaug River.

Esox niger Lesueur chain pickerel

SL = -0.89467 + 0.89717 TL; R = 0.999, N = 115.
Log Wt = -1.84896 + 2.79174 Log TL; R = 0.968, N = 93.
Mean K = 0.90, Mean TL = 32.5 cm (10.2 - 57.6).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 6-30	7-10	7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Thames 1	7.3	8.8	9.9	10.7	11.4	12.0	12.5	0.861	10
Quinebaug 1	5.8	7.6	9.0	10.0	10.9	11.7	12.4	0.572	8
All	7.2	8.6	9.6	10.3	11.0	11.5	12.0	0.787	25

Calculated TL (cm)/Number in Sample

Age 1	2	3	4	5	6
15.2/79	23.7/65	25.5/53	30.8/39	35.5/27	37.4/12

Stomachs of 42 specimens were examined (19 were empty) and they contained: fish (83%) and arthropods and miscellaneous (9% each). This species is widely distributed in the Thames System and was taken as far south in the estuary as Station C.

Etheostoma olmstedi Storer — tessellated darter

SL = -0.38913 + 0.89518 TL; R = 0.995, N = 16.
Log Wt = -2.56174 + 3.73615 Log TL; R = 0.953, N = 16.
Mean K = 1.1, Mean TL = 5.1 cm (3.8 - 6.8).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 6-30	7-10	7-20	7-30	8-9	Correlation Coefficient	Number in Sample
Quinebaug 1	2.1	2.5	2.8	3.0		0.623	21
Quinebaug 3		2.5	2.8	3.0	3.2	0.460	35
All	2.1	2.5	2.8	3.0	3.2	0.590	62

Stomachs of 16 specimens were examined and 81% contained midges, 29% detritus, 25% caddis, 19% oligochaetes, and 14% arthropods.

Fundulus diaphanus (Lesueur) — banded killifish

SL = -0.10419 + 0.83931 TL; R = 0.991, N = 20.
Log Wt = -1.86546 + 2.88414 Log TL; R = 0.980, N = 17.
Mean K = 1.3, Mean TL = 6.6 cm (4.5 - 10.4)

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Thames 1	1.9	2.4	3.0	3.5	3.9	4.3	0.686	22
Quinebaug 3	No correlations						-0.066	17
All	2.2	2.5	2.7	2.9	3.0	3.1	0.240	39

Poor correlation in Quinebaug 3 was probably because of an extended spawning season and samples were obtained from different sources.

Stomachs of 14 specimens were examined (one was empty) and 92% ate arthropods, 17% nonvascular plants, and 8% each midges and miscellaneous items.

There were three populations in the Thames River System: (1) Norwich Harbor to Stoddard Hill, (2) Region 3 in the Quinebaug, and (3) Scotland Impoundment on the Shetucket River.

Fundulus heteroclitus (Linnaeus) mummichog

SL = -0.32375 + 0.87649 TL; R = 0.996, N = 354.
Log Wt = -1.94586 + 3.20944 Log TL; R = 0.949, N = 276.
Mean K = 3.1, Mean TL = 9.0 cm (2.6 - 13.6).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-5	7-15	7-25	8-4	8-14	Correlation Coefficient	Number in Sample
Thames 1	2.3	2.4	2.5	2.6	2.7	0.249	45

Poor correlation and apparent slow growth of juveniles is probably due to an extended spawning period. Females with extrusable eggs were taken from May through July.

Stomachs of 121 specimens were examined for food (14 were empty) and 70% contained arthropods (amphipods), 32% miscellaneous, 12% nonvascular plants, 11% detritus, and 5% or less each insects, midges, and snails.

Fundulus majalis (Walbaum) striped killifish

SL = -0.20961 + 0.86133 TL; R = 0.994, N = 65.
Log Wt = -1.79352 + 2.96354 Log TL; R = 0.994, N = 63.
Mean K = 1.9, Mean TL = 10.1 cm (3.2 - 14.8)

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-20	7-30	8-9	8-19	8-29	9-8	Correlation Coefficient	Number in Sample
Thames 1	2.3	2.9	3.5	4.0	4.5	5.0	0.712	15

Stomachs of 34 specimens were examined and 100% contained miscellaneous items (mainly polychaetes), 71% arthropods, 50% nonvascular plants, 32% detritus, 29% snails, and 6% each insects and midges.

Striped killifish were not found in the estuary as frequently as their congenitors and apparently are only able to withstand freshwater for short periods of time.

Gasterosteus aculeatus Linnaeus — threespine stickleback

SL = -0.11863 + 0.87390 TL; R = 0.996, N = 4.
Log Wt = -2.14445 + 3.17373 Log TL; R = 0.928, N = 4.
Mean K = 1.0, Mean TL = 5.8 cm (5.2 - 7.1).

This species was only captured occasionally in the estuary (Trading, Stoddard Hill, and Poquetanuck Coves).

Ictalurus catus (Linnaeus) — white catfish

SL = -1.49799 + 0.88666 TL; R = 0.991, N = 644.
Log Wt = -2.27181 + 3.23850 Log TL; R = 0.980, N = 473.
Mean K = 1.55, Mean TL = 25.6 cm (5.1 - 50.4).
Egg No. = 2142 + 646.3 Wt; R = 0.971, N = 15.
Egg No. = 6113.8 + 371.1 TL; R = 0.963, N = 15.

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 6-30	7-10	7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Thames 1	1.7	2.3	2.8	3.2	3.5	3.7		0.784	54
Quinebaug 1		2.7	3.3	3.7	4.2	4.6	5.0	0.738	35
Thames 1, Quinebaug 1 & 2	1.6	2.4	2.9	3.4	3.9	4.3	4.6	0.788	92

Calculated TL (cm)/Number in Sample

Age 1	2	3	4	5	6	7	8	9	10
13.5/227	18.4/223	22.8/195	26.3/149	29.8/91	33.6/62	35.9/48	39.4/25	41.0/18	42.7/

Juveniles in Quinebaug 1 were larger but grew at the same rate, suggesting an earlier spawning time.

Stomachs of 271 fish were examined (108 were empty) and 36% contained arthropods, 31% nonvascular plants, 26% fish, 14% detritus, 6% each vascular plants and miscellaneous, and <5% each insects, midges, caddis, and snails.

Ictalurus nebulosus (Lesueur) — brown bullhead

SL = -0.40506 + 0.86199 TL; R = 0.961, N = 259.
Log Wt = -1.77657 + 2.89118 Log TL; R = 0.944, N = 186.
Mean K = 1.30, Mean TL = 21.9 cm (4.7 - 34.2).
Egg No. = 857 + 281 Wt; R = 0.640, N = 8.
Egg No. = 7671 + 511.5 TL; R = 0.681, N = 8.

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 6-30	7-10	7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Thames 1		2.6	3.4	4.1	4.8	5.4		0.863	23
Quinebaug 1	1.9	2.7	3.4	4.0	4.5	5.0	5.5	0.784	69
All	1.4	2.3	3.1	4.0	4.7	5.4	6.1	0.825	124

Calculated TL (cm)/Number in Sample

Age 1	2	3	4
9.9/98	15.5/97	20.8/50	23.0/12

Stomachs of 116 specimens were examined (86 were empty) and 56% contained detritus, 51% nonvascular plants, 43% miscellaneous, 34% arthropods, 29% midges, 21% vascular plants, 16% insects, 13% fish, and <5% each oligochaetes, caddis, and snails.

White catfish seem to be dominating this species in the Quinebaug and Thames Rivers.

Lepomis gibbosus (Linnaeus) pumpkinseed

SL = -0.14168 + 0.82023 TL; R = 0.982, N = 320.
Log Wt = -1.72671 + 3.07651 Log TL; R = 0.971, N = 216.
Mean K = 2.56, Mean TL = 12.7 cm (4.6 - 19.7).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Quinebaug 1	1.4	2.0	2.5	3.0	3.4	0.916	46
Quinebaug 2	1.0	1.7	2.5	3.4	4.3	0.801	8
All	1.4	2.0	2.5	3.0	3.5	0.905	65

Calculated TL (cm)/Number in Sample

Age 1	2	3	4	5
5.2/250	10.2/225	12.4/128	13.1/35	14.7/12

Stomachs of 154 specimens were examined (32 were empty) and 43% had nonvascular plants, 41% detritus, 40% midges, 39% insects, 30% caddis, 20% arthropods, 12% each vascular plants and miscellaneous, and <5% fish, snails, and oligochaetes.

Lepomis macrochirus Rafinesque — bluegill

SL = -0.07983 + 0.81165 TL; R = 0.996, N = 874.
Log Wt = -1.80501 + 3.08968 Log TL; R = 0.991, N = 316.
Mean K = 2.9, Mean TL = 13.4 cm (1.7 - 27.8)

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Quinebaug 1	1.3	1.8	2.3	2.9	3.4	3.8	0.850	75
Quinebaug 2	1.3	1.7	2.0	2.4	2.6	2.9	0.441	61
Quinebaug 3	1.5	1.9	2.2	2.5	2.7		0.544	48
All	1.3	1.8	2.2	2.6	3.0	3.3	0.593	191

Calculated TL (cm)/Number in Sample

Age 1	2	3	4	5	6
6.0/412	11.4/388	14.6/318	15.7/115	16.8/30	17.5/7

Growth of juveniles suggests that Quinebaug 2 and 3 samples were influenced by extended spawning and then recruitment, whereas Quinebaug 1 samples consisted of one population. Growth rate of specimens in Quinebaug 3 was significantly different from Quinebaug 1.

Stomachs of 242 specimens were examined (48 were empty) and 48% consumed insects, 34% nonvascular plants, 23% detritus, 21% each midges and vascular plants, 19% each arthropods and caddis, 13% fish, and < 5% each snails and oligochaetes.

Lucania parva (Baird) — rainwater killifish

SL = -0.24498 + 0.87947 TL; R = 0.943, N = 7.
Log Wt = -1.82067 + 3.22623 Log TL; R = 0.811, N = 7.
Mean K = 1.89, Mean TL = 2.5 cm (2.3 - 2.8).

This species was collected occasionally in the estuary, usually in the Stoddard Hill area.

Menidia beryllina (Cope) — tidewater silverside

SL = -0.12813 + 0.85854 TL; R = 0.994, N = 125.
Log Wt = -2.16126 + 3.04328 Log TL; R = 0.984, N = 108.
Mean K = 1.0, Mean TL = 5.9 cm (2.1 - 9.1).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Thames 1	1.1	1.8	2.4	3.0	3.7	0.854	60

Stomachs of 44 specimens were examined (11 were empty) and 61% ate arthropods (amphipods), 33% miscellaneous items, 18% each nonvascular plants and insects, and <5% each ate midges and snails.

This species was collected earlier in spring and was generally smaller, more numerous, and more widely distributed in the estuary than its congenitor. Spawning probably occurred in mid-spring.

Menidia menidia (Linnaeus) Atlantic silverside

SL = -0.22599 + 0.85679 TL; R = 0.992, N = 72.
Log Wt = -1.89276 + 2.67473 Log TL; R = 0.987, N = 33.
Mean K = 0.70, Mean TL = 8.9 cm (4.7 - 12.8).

Stomachs of 15 specimens were examined (2 were empty) and 85% ate miscellaneous organisms, 54% arthropods (amphipods), and 15% nonvascular plants.

This species was only occasionally captured upstream of the Stoddard Hill area.

Microgadus tomcod (Walbaum) Atlantic tomcod

Log Wt = -2.05202 + 3.01984 Log TL; R = 0.988, N = 257.
Mean K = 1.16, Mean TL = 19.4 cm (4.3 - 32.0).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 6-30	7-10	7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Thames 1	6.0	7.0	7.6	8.1	8.5	8.9	0.516	30

Stomachs of 55 specimens were examined (4 were empty) and 82% ate arthropods, 33% miscellaneous items, and <5% ate insects.

Large numbers of tomcod migrate into the estuary sometime during the fall (September-December) to spawn although there are usually some present in the estuary as far upstream as Norwich all year.

Micropterus salmoides (Lacépède) largemouth bass

SL = 0.00535 + 0.83909 TL; R = 0.999, N = 145.
Log Wt = -1.99703 + 3.14278 Log TL; R = 0.997, N = 127.
Mean K = 6.49, Mean TL = 12.2 cm (2.9 - 48.5).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Thames 1	3.5	4.2	4.7	5.2	5.7	6.1	0.545	14
Quinebaug 1	3.7	4.3	4.8	5.2	5.6	5.9	0.450	78
Quinebaug 2	3.5	4.4	5.1	5.7	6.3	6.9	0.953	58
Quinebaug 3	3.0	3.8	4.6	5.3	6.0	6.6	0.781	30

Calculated TL (cm)/Number in Sample

Age				
1	2	3	4	5
7.5/37	17.1/21	23.7/21	27.2/15	31.5/7

Stomachs of 111 specimens were examined (26 were empty) and 44% contained fish, 27% nonvascular plants, 25% arthropods, 22% oligochaetes, 21% detritus, 6% vascular plants, and <5% each insects and snails.

Lower correlation coefficients indicate different spawning dates which was revealed by plotting sizes of all fish on each sampling date. Fewer distinct spawnings were seen in Quinebaug 1 (last group showed up on 8-10-71).

Morone americana (Gmelin) white perch

SL = -0.35128 + 0.84332 TL; R = 0.988, N = 753.
Log Wt = 0.00919 + 3.19073 TL; R = 0.988, N = 709.
Mean K = 1.94, Mean TL = 22.8 cm (3.7 - 35.8).
Egg No. = -74,155 + 4448.6 Wt; R = 0.868, N = 9.
Egg No. = -377,534 + 0.87035 TL; R = 0.870, N = 9.

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971)					Correlation Coefficient	Number in Sample
	7-10	7-20	7-30	8-9	8-19		
Quinebaug 2	3.0	4.0	4.9	5.7	6.4	0.957	26
Thames 1	2.7	3.6	4.5	5.4	6.2	0.820	6

Calculated TL (cm)/Number in Sample

Age					
1	2	3	4	5	6
9.1/410	15.9/354	20.4/259	23.8/138	25.6/53	26.1/14

Stomachs of 400 specimens were examined (106 were empty) and 57% ate arthropods, 24% fish, 21% miscellaneous items, 9% nonvascular plants, and 5% each ate insects, oligochaetes, snails, and vascular plants.

White perch were extremely common in the estuary and ripe individuals were often observed in the spring. A spawning run was apparent in the Quinebaug River from Norwich to Greenville Dam. Because few young fish were observed in 1969-71 in the estuary, it must be (1) that the young migrated elsewhere, (2) they could not survive the low oxygen conditions present in the upper estuary since they do not live in the upper water levels (as do young Alosa spp), or (3) they occupied a habitat not sampled. This problem definitely needs more study.

Morone saxatilis (Walbaum) striped bass

SL = 0.88995 + 0.82995 TL; R = 0.990, N = 67.
Log Wt = -1.79924 + 2.90836 Log TL; R = 0.989, N = 67.
Mean K = 1.35, Mean TL = 58.6 cm (20.2 - 92.6).

Calculated TL (cm)/Number in Sample

Age						
1	2	3	4	5	6	7
14.4/79	26.7/77	37.0/68	45.9/51	53.9/31	62.2/20	70.2/10

Stomachs of 50 specimens were examined (22 were empty) and 90% ate fish, 13% arthropods, and <5% contained miscellaneous items.

This species entered the estuary at various times of the year, probably following food fishes.

Myoxocephalus octodecemspinosus (Mitchill) longhorn sculpin

Log Wt = 0.11257 + 2.28338 Log TL; R = 0.517, N = 3.
Mean K = 1.03, Mean TL = 28.2 cm (27.8 - 28.8).

This sculpin was occasionally captured in the estuary during spring and fall.

Notemigonus crysoleucas (Mitchill) golden shiner

SL = -0.20885 + 0.83486 TL; R = 0.989, N = 513.
Log Wt = 0.00540 + 3.30026 Log TL; R = 0.973, N = 296.
Mean K = 1.49, Mean TL = 17.6 cm (5.0 - 24.1).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971)						Correlation Coefficient	Number in Sample
	6-30	7-10	7-20	7-30	8-9	8-19		
Quinebaug 1	1.0	1.7	2.4	3.0	3.7	4.2	0.938	35
Quinebaug 2	2.1	3.0	3.7	4.3	4.8	5.3	0.957	24
Quinebaug 3	No Correlation						-0.175	17
All	1.6	2.1	2.5	2.8	3.0	3.3	0.740	82

Calculated TL (cm)/Number in Sample

Age				
1	2	3	4	5
7.2/297	13.0/277	16.4/165	18.0/62	18.2/14

Stomachs of 227 specimens were examined for food (40 were empty) and 66% contained nonvascular plants, 45% detritus, 36% miscellaneous items, 21% arthropods, 19% vascular plants, 10% insects, and <5% each oligochaetes and caddis.

Notropis cornutus (Mitchill) common shiner

SL = -0.17486 + 0.83838 TL; R = 0.997, N = 79.
Log Wt = -2.26988 + 3.29676 Log TL; R = 0.989, N = 79.
Mean K = 1.36, Mean TL = 9.6 cm (5.2 - 14.0).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	8-29	Correlation Coefficient	Number in Sample
Quinebaug 1	2.5	3.1	3.7	4.2	4.6	5.0	0.860	50
Quinebaug 2 & 3	2.5	3.1	3.7	4.1	4.6	5.0	0.853	54

Calculated TL (cm)/Number in Sample

Age 1	2	3
6.3/36	7.8/22	9.5/10

Stomachs of 66 specimens were examined (2 were empty) and 63% contained nonvascular plants, 43% detritus, 33% insects, 17% arthropods, 12% miscellaneous items, 6% each oligochaetes, caddis, and vascular plants and 5% midges.

Notropis hudsonius (Clinton) spottail shiner

SL = -0.05821 + 0.81640 TL; R = 0.993, N = 313.
Log Wt = -2.29625 + 3.24066 Log TL; R = 0.972, N = 248.
Mean K = 1.1, Mean TL = 9.1 cm (4.0 - 12.6).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 6-20	6-30	7-10	7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Thames 1	1.0	2.0	2.5	2.8	3.1	3.3	3.5	0.858	95
Quinebaug 1	0.7	2.0	2.7	3.2	3.7	4.1	4.4	0.901	119
Quinebaug 2	0.9	2.1	2.8	3.3	3.7	4.0	4.3	0.902	76
Quinebaug 3	1.0	2.0	2.4	2.7	2.9	3.1	3.2	0.821	103

Calculated TL (cm)/Number in Sample

Age 1	2	3	4
5.0/123	7.3/79	9.3/39	10.1/16

Stomachs of 126 specimens were examined (12 were empty) and 61% contained nonvascular plants, 42% detritus, 25% arthropods, 21% insects, 17% miscellaneous items, 14% midges, and <5% each caddis, vascular plants, and fish.

The spottail shiner was common throughout the areas sampled except in the lower estuary. Because it occurred downstream of the Stoddard Hill area, it must be fairly tolerant of medium to high salinities.

Oncorhynchus kisutch (Walbaum) coho salmon

SL = 0.55220 + 0.81733 TL; R = 0.931, N = 36.
Log Wt = -1.45496 + 2.50571 Log TL; R = 0.868, N = 36.
Mean K = 0.91, Mean TL = 16.0 cm (12.0 - 18.5).

This species was introduced into selected areas of the Quinebaug and Shetucket Rivers in the springs of 1968-1971. Some specimens were recaptured in the Thames River Estuary near Norwich. Stomachs of 23 specimens were examined (4 were empty) and 68% contained arthropods, 37% miscellaneous items, and 5% insects. Amphipods were the most abundant food item at the time of smolt migration through the Norwich area.

Osmerus mordax (Mitchill) rainbow smelt

SL = 0.15001 + 0.86855 TL; R = 0.973, N = 292.
Log Wt = -2.54976 + 3.31219 Log TL; R = 0.961, N = 282.
Mean K = 0.77, Mean TL = 18.6 cm (7.1 - 27.6).
Egg No. = -11,275 + 4753.1 Wt; R = 0.962, N = 19.
Egg No. = -161,302.5 + 10,659.1 TL; R = 0.927, N = 19.

Calculated TL (cm)/Number in Sample

Age		
1	2	3
9.7/57	15.5/43	19.1/6

Stomachs of 15 specimens were examined (12 were empty); 67% contained arthropods and 33% miscellaneous items. A significant difference in height of the lines for TL-Wt relationships of male and females was obtained.

Perca flavescens (Mitchill) yellow perch

SL = -0.40914 + 0.86472 TL; R = 0.998, N = 131.
Log Wt = -2.02872 + 3.09792 Log TL; R = 0.996, N = 120.
Mean K = 1.94, Mean TL = 17.4 cm (6.4 - 33.0).
Egg No. = -45,080 + 4889.7 Wt; R = 0.992, N = 4.
Egg No. = -178,675.4 + 9504.8 TL; R = 0.979, N = 4.

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971)							Correlation Coefficient	Number in Sample
	6-20	6-30	7-10	7-20	7-30	8-9	8-19		
Thames 1	1.5	3.4	4.4	5.0	5.6	6.0	6.4	0.981	11
All	1.4	3.5	4.5	5.3	5.9	6.4	7.0	0.971	20

Calculated TL (cm)/Number in Sample

Age					
1	2	3	4	5	6
8.4/103	11.9/73	14.8/52	16.9/34	20.6/21	21.7/8

Stomachs of 87 specimens were examined for food (21 were empty) and 67% ate arthropods, 33% detritus, 18% each caddis, fish and nonvascular plants, 14% miscellaneous items, 12% each vascular plants and midges, 11% insects and <5% each snails and oligochaetes.

Pomatomus saltatrix (Linnaeus) bluefish

SL = -0.29398 + 0.83505 TL; R = 0.986, N = 150.
Log Wt = -2.38015 + 3.31060 Log TL; R = 0.992, N = 150.
Mean K = 1.16, Mean TL = 15.5 cm (9.8 - 23.6).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	8-29	9-8	Correlation Coefficient	Number in Sample
Thames 1-Group 1	5.5	7.4	9.1	10.6	12.1			0.929	55
Thames 1-Group 2					4.8	5.8	7.0	0.574	67

Stuart Wilk, Sandy Hook, New Jersey (personal communication), reported two populations of bluefish, one that spawns off North Carolina and one that spawns off New Jersey. Their progeny would correspond to groups 2 and 1, respectively. The lower correlation in group 2 was probably caused by the inclusion of some fish from group 1.

Stomachs of 150 specimens were examined (52 were empty) and 98% contained fish, 15% arthropods, and <5% miscellaneous items.

Pomoxis nigromaculatus (Lesueur) black crappie

SL = -0.03795 + 0.79928 TL; R = 0.987, N = 351.
Log Wt = -1.96862 + 3.12158 Log TL; R = 0.991, N = 154.
Mean K = 1.98, Mean TL = 18.0 cm (4.4 - 27.1).
Egg No. = 5813 + 267.1 Wt; R = 0.154, N = 9.
Egg No. = -23,077 + 1491.1 TL; R = 0.354, N = 9.

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 6-30	7-10	7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Quinebaug 2	2.0	2.8	3.4	3.9	4.3	4.7	0.379	31
Quinebaug 3	2.3	3.1	3.7	4.2	4.6	5.0	0.876	16
Quinebaug 1-3	2.2	2.9	3.4	3.9	4.3	4.6	0.538	52

Calculated TL (cm)/Number in Sample

Age 1	2	3	4	5
6.9/242	12.7/232	18.0/179	21.4/55	23.0/16

Stomachs of 131 specimens were examined (42 were empty) and 38% contained fish, 34% arthropods, 33% insects, 17% nonvascular plants, 13% miscellaneous items, 12%

detritus, 9% vascular plants, 7% midges, and 6% caddis.

Abundance of this species during the period studied was extremely variable. One year many large black crappies were captured whereas other years yielded few. Young specimens were seen in large numbers one year.

Pseudopleuronectes americanus (Walbaum) winter flounder

SL = 0.31148 + 0.77674 TL; R = 0.996, N = 129.
Log Wt = -1.87068 + 2.94293 Log TL; R = 0.994, N = 113.
Mean K = 1.64, Mean TL = 19.5 cm (3.9 - 41.0).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 6-30	7-10	7-20	7-30	8-9	8-19	8-29	9-8	Correlation Coefficient	Number in Sample
Thames 1	2.7	3.4	3.8	4.1	4.4	4.6	4.8	5.0	0.597	51

Stomachs of 20 specimens were examined and 80% ate arthropods, 10% detritus, and 5% each contained miscellaneous items and oligochaetes.

This species was commonly collected in the upper end of the estuary, especially in spring, winter, and late fall when dissolved oxygen levels were high.

Rhinichthys cataractae (Valenciennes) longnose dace

Calculated SL (cm) of Juvenile Fish

Area	7-10	7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Quinebaug 1	3.5	3.8	4.0	4.1	4.3	0.715	10

Longnose dace were collected only in the Quinebaug River.

Salmo trutta Linnaeus brown trout

SL = -0.69019 + 0.88626 TL; R = 0.997, N = 11.
Log Wt = -1.73380 + 2.80600 Log TL; R = 0.997, N = 6.
Mean K = 1.16, Mean TL = 30.0 cm (12.0 - 40.0).

Stomachs of 3 specimens were examined and 33% each ate insects, fish, and vascular plants. Specimens obtained were probably hold-overs from the state stocking program.

Scomber scombrus Linnaeus Atlantic mackerel

SL = 0.14249 + 0.84711 TL; R = 0.994, N = 15.
Log Wt = -0.30358 + 1.67794 Log TL; R = 0.961, N = 3.
Mean K = 0.94, Mean TL = 20.4 cm (16.0 - 23.5).

Stomachs of 11 specimens were examined; 100% contained fish and 9% arthropods.

Scophthalmus aquosus (Mitchill) windowpane

SL = 3.46804 + 0.47297 TL; R = 0.748, N = 12.
Log Wt = -1.61832 + 2.73776 Log TL; R = 0.999, N = 3.
Mean K = 2.70, Mean TL = 13.4 (6.3 - 26.2).

Windowpanes were collected occasionally in the estuary in winter.

Semotilus corporalis (Mitchill) fallfish

SL = -0.11413 + 0.84220 TL; R = 0.997, N = 42.
Log Wt = -2.00380 + 2.97786 Log TL; R = 0.992, N = 42.
Mean K = 1.23, Mean TL = 8.8 cm (4.4 - 14.1).

Calculated SL (cm) of Juvenile Fish

Area	Dates (1971) 7-10	7-20	7-30	8-9	8-19	Correlation Coefficient	Number in Sample
Quinebaug 1	3.3	4.0	4.7	5.2	5.7	0.894	17
Quinebaug 1 & 3	3.3	4.1	4.7	5.2	5.7	0.893	19

Fallfish were calculated to be 6.4 cm (TL) at age 1 (N = 9).

Stomachs of 41 specimens were examined (2 were empty) and 62% contained insects, 59% detritus, 51% midges, 49% nonvascular plants, 38% caddis, 15% arthropods, and 8% miscellaneous items.

Syngnathus fuscus Storer northern pipefish

SL = 0.16870 + 0.95167 TL; R = 0.999, N = 5.
Log Wt = -3.3495 + 3.00929 Log TL; R = 0.968, N = 5.
Mean K = 0.10, Mean TL = 17.6 cm (13.6 - 23.6).

This species was occasionally taken in the estuary.

Tautoga onitis (Linnaeus) tautog

SL = -1.14301 + 0.89821 TL; R = 0.993, N = 18.
Log Wt = -1.64789 + 3.01107 Log TL; R = 0.992, N = 18.
Mean K = 2.6, Mean TL = 23.4 cm (17.2 - 35.1).

Spring collections in the estuary occasionally contained this species.

Tautogolabrus adspersus (Walbaum) cunner

SL = 0.84106 + 0.80066 TL; R = 0.990, N = 7.
Log Wt = -1.44844 + 2.74084 Log TL; R = 0.963, N = 7.
Mean K = 2.4, Mean TL = 15.8 cm (7.5 - 23.9).

Stomachs of 5 specimens were examined and 60% contained arthropods, 40% detritus, and 20% nonvascular plants.

Trinectes maculatus (Bloch and Schneider) hogchoker

SL = -0.42079 + 0.86590 TL; R = 0.994, N = 23.
Log Wt = -1.63809 + 2.92338 Log TL; R = 0.993, N = 24.
Mean K = 2.6, Mean TL = 13.0 cm (5.8 - 22.1).

Stomachs of 9 specimens were examined (1 was empty) and 88% contained unidentified items, 25% arthropods, and 12% fish.

Urophycis chuss (Walbaum) red hake

SL = -0.61928 + 0.91459 TL; R = 0.999, N = 4.
Log Wt = -1.82672 + 2.72695 Log TL; R = 0.999, N = 4.
Mean K = 2.2, Mean TL = 11.8 cm (5.5 - 28.1).

This species was occasionally collected in the estuary in winter.

GENERAL EVALUATION OF THE FISHERIES

Currently there is a fishery for bluefish, Atlantic mackerel, Atlantic tomcod, striped bass, winter flounder, white catfish, American eel, rainbow smelt, alewife, and white perch in the Thames Estuary from Stoddard Hill to Norwich. Certain areas of the Shetucket and Quinebaug Rivers are utilized for put-and-take trout fishing. They are also fished for largemouth bass, chain pickerel, black crappie, white perch, bluegill, pumpkinseed, brown bullhead, white catfish, yellow perch, carp, and white suckers. We feel there are no major fisheries in the Quinebaug and Shetucket Rivers in the areas we studied that compare in magnitude to those in the Thames Estuary.

Poor populations of "game" fishes are the primary factors responsible for the low utilization of fish in the Quinebaug and Shetucket Rivers. We feel there are many factors that contribute to the inability of populations of "game" fishes to flourish in the Shetucket and Quinebaug Rivers (although the Quinebaug River is definitely superior to the Shetucket River). Both rivers have been dumping grounds for organic and toxic materials and the Shetucket, in many areas, is subjected to tremendous fluctuations in water level twice a day during the low flow months (in response to hydroelectric demands). During periods of low flow, toxic effluents, alone or in combination with high temperature and low dissolved oxygen, cause many fish kills.

Since there are fewer "game" fishes in the tributary streams compared to "forage" fishes there would be a lag in the former in repopulating an area from the tributaries after a fish kill. Populations of forage fishes are in a more favorable position to recruit a substantial number of young into the first age class during the summer. Some species spawn over an extended period in many areas of the river (spottail shiners, golden shiners, blacknose dace, fallfish, and common shiners) and some are broadcast spawners, or they spawn early and the young are larger, more widely distributed, and better able to avoid toxic water masses than "game" fishes (many white suckers spawn in April). Centrarchids, in contrast, spawn in nests during the months when low flows often occur, and chain pickerel require aquatic vegetation. Because many adult "forage" fishes reside in areas in which "game" fishes spawn, predation of eggs and early young of "game" fishes is often high (almost all fishes eat fish eggs and young when available).

Years in which favorable water flows and discharges of toxic water masses do not

adversely affect recruitment of "game" fish populations result in strong year classes of "game" fishes that grow well. For example, we collected good numbers of "catchable" black crappie, sunfishes, and chain pickerel in certain areas in some years. A comparison of age and growth estimates with state averages for lakes and ponds (Whitworth and Sauter 1973) showed that Thames River System chain pickerel, pumpkinseed, bluegill, and largemouth bass grew about the same for the first few years and then slower; yellow perch and black crappie always slower, and golden shiners and white perch faster. Because of the effects of the primary factors we would expect that after a certain size was reached in many areas there would be a limitation of growth as a result of the physical environment, basically water volume. We would also also expect white perch to grow faster because the populations sampled were mainly an estuarine (possibly anadromous) population, rather than the land-locked populations reported in the state averages. The overall lower growth of black crappie and yellow perch was probably due to a bias in the specimens used (both space and time). The fine growth of golden shiners was also expected because of the lack of competition of "game" fishes and large populations of plankton.

The fisheries of the Thames Estuary exist because many species of fish migrate into the estuary for feeding (adults and juveniles) or spawning. Numerous toxic water masses passed through the estuary and most of the water volume from Norwich to the State Hospital was devoid of oxygen for most of the summer and early fall. Most of the fish kills were rarely noticed in this area, with certain exceptions. For example, during the fall of 1971 tremendous numbers of adult Atlantic menhaden entered the estuary and moved upstream to Norwich and large numbers died. Although we have no logical explanation for their movement into the estuary, in such numbers, it is quite possible that because they could not utilize much of the water volume (low dissolved oxygen) and their tolerance of freshwater is not great, that any combination of disease, parasites, moderately toxic water masses, or temperature changes could have affected them. The fall of 1971 also was unique in that adult bluefish entered the estuary in numbers and penetrated as far as the Atlantic menhaden. Both species again entered in the fall of 1972, although the Atlantic menhaden numbers were not as great as 1971, however, only moderate numbers of Atlantic menhaden died.

The numbers of fish kills that we saw in progress, or investigated shortly after they happened, were greater in 1969 and 1970 than in 1971 and 1972 (highest in 1970). Artificial-substrate fauna, plankton, and water chemistry data suggest that toxic water masses were more numerous in 1970 than in 1969. Since water flows were higher in 1971 and 1972 there is not any way to determine if there was a significant reduction in the number of toxic water masses added to the Quinebaug and Shetucket Rivers.

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Appendix A. Diel profiles of temperature, oxygen, and salinity for 13–14 August 1970 in the Thames Estuary, Connecticut.

Tidal Stage		Falling			Low			Rising			Rising			High			Low			Rising			Falling		
Time		0800			1100			1400			1700			2000			2300			0200			0600		
Variables		T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S
Area*	Depth																								
0	1m	23.3	2.9	6	26.1	5.6	4	26.1	2.6	10	26.8	6.5	33	26.3	3.3	1	24.0	5.6	3	24.4	5.6	2	22.4	0.5	28
	3m	20.2	0	29	20.7	0	29	22.0	0	28	20.7	0	30	20.5	0	31	19.9	0	23	20.5	0	29	19.9	0	30
	5m	19.4	0	31	20.6	0	31	21.4	0	29	20.3	0	33	20.0	0	34				19.5	0	29	19.3	0	31
	7m	19.2	0	31	20.3	0	31	21.4	0	30	20.0	0	32	19.5	0	34	19.6	0	32	19.3	0	30	19.1	0	33
	9m	19.4	0	31	20.6	0	33	21.6	0	31										19.3	0	29	19.2	0	32
1.0	1m	22.3	1.3	22	24.0	1.9	19	26.4	4.1	13	27.7	8.9	13	26.4	6.7	12	25.3	5.2	9	24.8	6.0	6	23.9	1.2	21
	3m	20.1	0	30	21.3	0	28	22.1	0	29	21.0	0	31	20.7	0	31	20.3	0	32	20.5	0	28	20.4	0	29
	5m	19.6	0	31	20.5	0	34	21.5	0	31	20.2	0	32	20.2	0	34	19.6	0	33	19.5	0	30	19.3	0	32
	7m	20.0	0	31	20.6	0	31	21.1	0	33	20.0	0	33	20.3	0	35	19.9	0	33	19.5	0	31	19.6	0	33
	9m				20.7	0	32	21.4	0	31	20.5	0	33	20.3	0	34	20.0	0	34						
5.2	1m	23.2	4.1	16	24.4	4.7	18	24.7	4.5	23	24.6	7.7	25	24.6	8.5	25	24.9	8.8	20	24.8	5.5	19	24.8	5.9	18
	3m	20.0	0.1	29	21.4	0	29	21.6	0	29	20.8	0.4	32	21.2	0	23	22.2	0.5	28	19.8	0	29	20.3	0	31
	5m	20.1	0	31	21.2	0	29	20.9	0	32	20.3	0	32	20.4	0		19.9	0	34	19.5	0	33	19.7	0	33
	7m	20.0	0	32	21.0	0	32	21.0	0	33	20.4	0		20.7	0	35	19.9	0	31	19.5	0	33	19.7	0	32
7.7	1m	22.2	3.1	26	25.1	5.3	23	26.3	11.8	23	24.4	8.3	26	24.0	11.0	28	24.2		26	24.3	5.8	22	23.2	6.2	26
	3m	21.0	0.4	30	22.4	1.4	29	21.6	0.8	31	21.9	3.6	30	20.1	0.6	34	20.6		27	22.8	1.2	26	22.5	1.9	30
	5m	20.5	0.8	31	20.9	0.2	31	20.9	0.3	32	20.9	1.0	33	20.0	0.4	34	20.1		34	19.9	0	32	20.4	0.2	31
	7m	20.2	0.8	32	21.1	0.4	32	20.9	0.4	32	21.1	0.5	32	20.5	0.6	34	20.0		33	19.6	0	31	19.9	0	33
12.6	1m	23.1	5.8	26	25.0	9.3	25	25.2	7.8	29	24.0	7.8	31	23.4	7.8	30	23.4		27	23.0	4.8	20	23.3	2.5	31
	3m	23.1	4.1	29	21.4	2.2	30	22.2	4.9	30	22.5	6.3	30	21.4	3.3	33	23.5		30	22.5	3.2	31	21.4	3.5	31
	5m	20.7	2.7	32	20.8	3.0	32	20.7	2.1	34	20.3	2.7	32	20.1	3.1	35	20.4		30	21.2	2.5	32	20.2	2.5	34
	7m	20.4	3.4	32	20.9	2.9	31	20.8	3.3	33	20.2	4.6	32	20.1	3.1	36	19.8		36	20.4	2.5	31	19.8	3.0	32

T=Temperature (C), O=Oxygen (mg/liter), S=Salinity (ppt).

*Distance downstream from Norwich (km).

Appendix B. Diel profiles of temperature, oxygen, and salinity for 26-27 August 1970 in the Thames Estuary, Connecticut.

Tidal Stage		Low			Rising			High			Falling			Falling			Low		
Time		1200			1500			1800			2100			2400			0300		
Variables		T	O	S	T	O	S	T	O	S	T	O	S	T	O	S	T	O	S
Area*	Depth																		
0	1m	23.4	8.7	0	24.7	8.7	6	24.5	9.5	0	23.8	6.5		23.0	6.0	0	23.2	6.0	0
	3m	23.0	0	30	22.4	0	19	22.0	0	22	21.0	0		21.2	0	31	21.9	0	30
	5m	21.4	0	28	21.5	0	26	20.8	0	26	20.5	0		20.4	0	35	20.6	0	32
	7m	21.7	0	40	21.4	0	31	20.8	0	32	20.7	0		20.5	0		20.3	0	35
	9m				22.5	0	38	21.3	0	28	20.7	0		20.6	0	34			
1.0	1m	25.2	7.6	3	25.2	10.3	3	24.9	11.0	3	24.3	9.1		23.6	6.8	1	23.4	6.5	1
	3m	22.4	0	24	23.0	0	25	22.0	0	31	21.6	0		22.3	0	28	21.9	0	30
	5m	21.6	0	21	21.7	0	30	21.0	0	12	20.6	0		20.7	0		20.8	0	34
	7m	22.5	0	22	22.0	0	34	21.5	0	32	21.0	0		21.1	0	35	20.8	0	35
5.2	1m	24.8	3.7	13	25.5	6.8	1	25.4	11.0	14	24.8	9.3		24.0	9.2	8	24.1	6.6	12
	3m	22.5	0	12	23.2	0.5	28	22.5	0.2	27	22.1	0		22.3	0	29	21.8	0	31
	5m	22.4	0	33	22.4	0.2	30	21.5	0.1	32	21.4	0		21.2	0	34	21.3	0	32
	7m	22.0	1.2	32	22.1	0.3	30	21.3	0.1	32	20.9	0.5		20.8	0.7	38	20.7	0.3	35
7.7	1m	24.6	7.6	8	24.9	9.7	18	24.6	6.0	21	24.2	9.6		23.9	8.0	19			
	3m	22.5	0.5	29	22.7	0.2	31	22.0	0.5	21	22.3	0.5		23.5	2.6	25			
	5m	22.5	0.3	32	22.1	0.6	31	21.5	0.3	32	21.4	0.2		21.4	0	35			
	7m	21.9	1.1	29	21.8	0.9	22	20.9	0.7	29	20.8	0.9		20.9	0.4	35			
12.6	1m	25.4	6.0	29	24.0	3.4	24	25.5	3.0	20	23.6	4.8		23.4	5.4	28			
	3m	23.9	2.5	34	23.5	3.3	27	23.6	3.5	30	23.5	3.0		23.5	4.1	29			
	5m	22.2	2.0	31	21.3	1.5	34	20.6	1.8	30	21.1	1.3		21.4	0.9	34			
	7m	21.5	2.7		21.7	2.0	33	20.4	3.0	25	20.4	2.0		20.4	1.8	36			

T=Temperature(C), O=Oxygen (mg/liter), S=Salinity (ppt)

*Distance downstream from Norwich (km).

Appendix C. Selected temperature profiles in the Thames Estuary, Connecticut.

Dates	7 October 1969				21 October 1969					7 November 1969				24 November 1969		
Distance from Norwich (km)	0	1.0	5.2	7.7	0	1.0	5.2	7.7	10.4	0	5.2	7.7	10.4	0	5.2	7.7
Depths																
1m	18.0	17.0	18.0	19.2	15.0	15.5	16.0	16.5	16.8	9.0	9.5	10.0	10.4	4.7	5.1	5.7
3m	18.5	18.5	18.6	18.5	15.0	16.0	16.5	16.5	17.0	9.5	9.5	10.0	10.5	8.5	5.7	6.9
5m		18.5				17.5	17.5	17.0	17.0	10.5	10.5	12.0	13.5	11.4	10.5	10.4
7m		18.5	18.5	18.5		18.0		17.0	17.0	13.5		13.0		11.5	10.6	10.8
9m		18.5				18.0				13.5				11.4		

Dates	8 April 1970					22 April 1970				15 May 1970						24 June 1970			
Distance from Norwich (km)	0	1.0	5.2	7.7	12.6	0	1.0	5.2	10.4	0	5.2	7.7	12.6	14.3	19.7	0	1.0	5.2	7.7
Depths																			
1m	6.6	6.5	6.9	7.2	8.0	9.5	8.9	8.9	9.9	19.1	18.2	17.5	17.5	15.5	13.7	22.2	21.8	21.7	21.4
3m	6.5	6.6	6.4	7.3	7.5	8.9	8.6	7.9	9.5	18.7	15.2	14.5	16.4	10.4	10.5	20.2	19.8	17.3	17.4
5m	6.4	6.6	6.5	6.5	5.9	7.4	7.0	7.2	7.5	10.8	10.2	10.5	10.3	9.5	9.5	16.1	16.0	15.8	16.1
7m	6.5	6.6	6.0	6.0	5.4	7.2	7.0	7.3	7.3	10.5	10.3	10.5	10.2	10.7	9.4	14.7	14.9	15.0	16.7
9m														9.9	9.3		14.8		

Appendix D. Precipitation and discharge of the Thames River into Long Island Sound.

Months	Precipitation (m^3)				Total Precipitation (m^3)	Total Surface Flow into Long Island Sound of Thames (m^3)
	Area 1	Area 2	Area 3	Area 4		
Mar 1968	178,611,642	187,039,624	141,735,492	74,556,858	581,943,616	559,736,516
Apr	78,161,168	74,255,431	49,782,665	25,353,963	227,553,227	265,702,359
May	140,571,226	154,115,046	106,420,127	59,043,475	460,149,874	191,129,542
Jun	225,864,971	249,386,166	139,365,334	50,939,468	665,555,939	273,776,187
Jul	44,281,422	40,980,592	24,649,651	8,567,092	118,478,757	116,801,387
Aug	64,193,202	95,621,381	50,958,413	23,848,933	234,621,929	36,253,936
Sep	49,630,856	77,057,523	65,890,413	22,228,132	214,806,924	26,570,237
Oct	56,763,434	76,357,000	51,195,429	30,795,224	215,111,087	29,276,192
Nov	174,450,971	174,780,473	125,855,429	73,399,143	548,486,016	103,149,277
Dec	177,422,879	199,999,298	159,985,715	96,900,761	634,308,643	156,999,267
Jan 1969	46,658,948	57,442,881	31,760,127	17,597,271	153,459,227	149,414,761
Feb	95,101,041	73,905,170	40,529,714	46,308,608	255,844,533	112,348,548
Mar	80,241,503	98,773,734	78,215,238	39,478,088	296,708,563	366,331,622
Apr	166,129,630	206,304,005	131,069,778	52,907,584	556,410,997	499,109,403
May	111,149,341	138,003,019	86,036,762	42,140,833	377,329,955	265,457,697
Jun	41,012,324	58,843,927	33,182,222	14,355,668	147,394,143	94,683,990
Jul	152,458,856	175,831,257	139,602,350	62,516,620	530,409,083	47,023,935
Aug	76,080,832	85,463,798	42,188,826	31,258,310	234,991,866	72,052,803
Sep	206,844,763	199,999,298	106,657,143	41,677,747	555,178,951	80,738,286
Oct	61,221,295	79,159,092	52,380,508	26,858,992	219,619,887	69,019,001
Nov	173,262,208	184,587,794	133,676,953	69,925,997	561,452,952	219,461,340
Dec	241,913,272	277,056,822	195,301,080	111,835,287	826,106,461	365,573,171
Jan 1970	36,257,272	30,122,486	20,383,365	6,714,748	93,477,871	219,192,213
Feb	174,153,781	177,582,565	116,611,810	57,422,673	525,770,829	549,411,802
Mar	105,341,251	111,733,408	71,104,762	61,821,991	350,001,412	277,592,906
Apr	128,683,596	159,368,968	77,030,159	54,759,928	419,842,651	503,513,309
May	146,515,041	155,516,092	113,293,588	47,119,008	462,443,729	242,704,180
Jun	103,719,572	104,728,179	68,023,556	30,679,453	307,150,760	145,328,040
Jul	53,197,145	36,076,931	29,864,000	20,028,473	139,166,549	45,507,000
Aug	108,771,815	153,764,785	83,666,604	33,342,197	379,545,401	21,236,600
Sep	68,353,873	110,332,363	68,497,588	43,877,406	291,061,230	33,029,100
Oct	80,241,503	79,159,092	61,861,143	33,573,741	254,835,479	40,956,300
Nov	124,820,116	167,074,721	133,202,921	82,197,778	507,295,536	107,895,060
Dec	109,069,006	109,982,101	68,734,603	44,340,492	332,126,202	111,492,150

An evaluation of the Thames River Watershed, Connecticut using estimates of community metabolism

John H. Heuer[1]

INTRODUCTION

The purposes of this study were to evaluate (1) a diurnal oxygen technique of estimating community metabolism and (2) various areas of the Thames River Watershed, Connecticut, based on these estimates.

Community metabolism (rate of gross storage and loss of energy) can be estimated by measuring (1) gross primary productivity, in most communities usually equivalent to gross photosynthesis, and (2) total respiration, the sum of respiratory and direct oxidative requirements of a community (Copeland 1963, 1967). Community metabolism can be estimated by measuring rate of change of either a product or raw material of the photosynthetic reaction in either a discrete sample of the community, or in the community over a diurnal period. The light-dark bottle oxygen method, the most common example of the former approach, has the limitations of (1) possible inhibitory effects of confining a community to a small volume container, (2) sampling error due to spacial differences in distribution of the biota, and (3) elimination of possible interactions with the benthic community (Odum and Hoskin 1958; Pratt and Berkson 1959; Pomeroy 1961; Saijo and Ichimura 1961; Cassie 1962; Lyford and Phinney 1968). The main advantages of this technique are that it requires a minimum of time and equipment, and is not affected by exchanges of gases with the atmosphere. Examples of the second approach would be the measurement of dissolved oxygen (Odum 1956; Odum and Hoskin 1957, 1958) or carbon dioxide (Verduin 1956; Copeland 1966) in the environment. The major limitations of this approach are it is difficult to estimate the effects of diffusion of atmospheric gases, especially under turbulent conditions (Pomeroy 1961; Gorden and Kelley 1962) and it requires extensive diurnal sampling or expensive equipment. Application of this approach to flowing waters requires the accurate measurement of flow, a serious limitation in situations with rapidly fluctuating flow characteristics.

Since the rivers on which the study was performed exhibited large, rapid fluctuations in discharge during the summer months due to flow demands by hydroelectric peaking power plants, the two approaches were combined. The size of the discrete sample was greatly increased in order to reduce the limitations due to confinement and unrepresentative sampling, and the communities in the samples were exposed to the atmosphere and a constant current. Theoretically, combining the two approaches should provide a better estimate of community metabolism in rivers having variable discharge.

This study was supported, in part, by funds provided by the Anadromous Fish Act (P.L. 89-304) through the Connecticut Department of Environmental Protection.

[1]Research Biologist TVA, Muscle Shoals, Alabama

MATERIALS AND METHODS

Eight locations in the Thames River system were sampled once a week for at least 5 successive weeks from 6/1/70 to 9/21/70. Locations and sampling times are shown in Fig. 1 and Table 1. Temperature was usually measured (using a standard mercury thermometer) to the nearest 0.1 C at each location at the time of sample collection. Surface water samples were collected in 19 liter glass bottles having a 12 cm opening. The bottles were usually rinsed at least once in the river water before a sample was taken. Samples from 6 locations were taken every Monday and returned to the laboratory, and all samples (including a deionized water sample) were randomly assigned to 7 of 8 positions on a low, wooden table. Magnetic stirrers were placed under each sample, a 4.1 cm teflon-coated stirring bar was placed in each sample, and all stirring bars were rotated at approximately the same speed. Two lights, each containing four 40-watt standard cool-white fluorescent bulbs, and suspended 0.56 m apart and 1.22 m above the table's surface, were the only source of light. The photoperiod was 14 hours of light and 10 hours of darkness (dawn at 0600 hours and dusk at 2000 hours). Temperature was maintained at 23.0 $\pm$ 1.0 C within the 6 m by 7 m by 3 m laboratory. A YSI galvanic oxygen probe, thermister, and a siphon (to facilitate the taking of dissolved oxygen samples) were placed at about mid-depth in each uncovered bottle. Six oxygen probes, connected to a sequential relay device and a Rustrax Model 88 recorder, and all thermisters connected to a YSI Model 47 Scanning Tele-thermometer and a Bausch and Lomb V.O.M.-5 laboratory recorder were activated by a time clock for two 3-hour periods centered at dawn and dusk. The remaining oxygen probe (determined by random selection) was monitored continuously by a Rustrax Model 88 recorder. The galvanic oxygen probes were standardized each day by dissolved oxygen samples following the Azide modification of the Winkler method (APHA et al. 1965) except that the 300 ml BOD bottles were overflowed only one volume in order to conserve water in the sample.

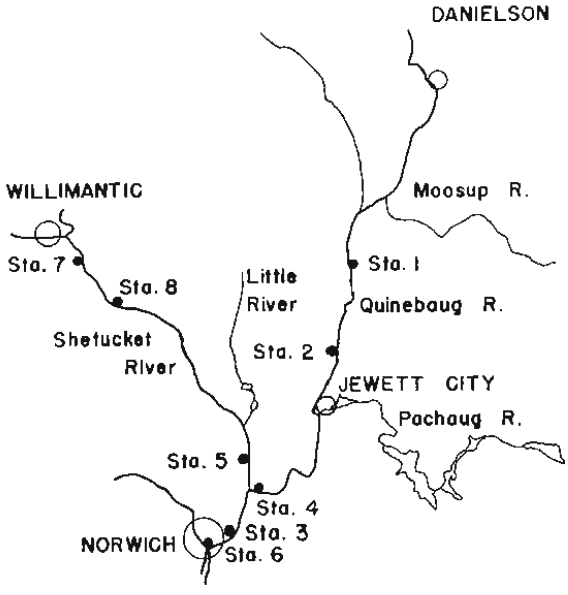

Fig. 1. Map of study area of the Thames River system. Sta. 1-8 represent sampling locations.

Table 1. Sampling locations in the Thames River System.

Area	Location	Location #	Weeks Sampled
Quinebaug River	immediately below Route 14 bridge.	1	1-17
Quinebaug River	at access area, west bank of Aspinook impoundment.	2	1-17
Quinebaug River	at canal inlet, west bank of Greenville impoundment.[1]	3	1-17
Quinebaug River	immediately above spillway of the dam, west bank of Tunnel impoundment.	4	6-17
Shetucket River	approximately 0.5 km above dam, southwest bank of Taftville impoundment.	5	1-17
Thames Estuary	west bank at beginning of Thames River estuary.	6	8-17
Shetucket River	at U.S.G.S. gaging station near Plains Rd. Bridge.	7	1-5
Shetucket River	at Windham Fish & Game Club access, northeast bank of Scotland impoundment.	8	1-7

[1]Sample taken in canal, about 15 m from impoundment.

Collection of data used to estimate community metabolism began on Tuesday dusk and was continued until dusk on Saturday. The bottles were thoroughly washed using a strong solution of HTH and deionized water and allowed to air dry at the end of each test. Gross primary productivity and community respiration, not corrected for diffusion, were estimated following the three-value method (McConnell 1962 as described in Whitworth and Lane 1969; hereafter referred to as Method I) beginning at dusk. A reaeration coefficient was obtained by plotting the changes of dissolved oxygen against time of all samples of deionized water (one that was recorded continuously and ten that were recorded at dusk and dawn) on semilog paper (dissolved oxygen on the log scale). A straight line was fitted by eye to the data of each sample and a reaeration coefficient was obtained by solving for r in the equation, $\underline{r} = (\Delta R/\Delta T)/\overline{D}$ (where ΔR = the amount of reaeration in a given time interval, ΔT; $\overline{D}$ = average concentration deficit for the time interval, ΔT; and r = reaeration coefficient). The mean value of r (0.05/hr) for all curves was used to correct the community metabolism estimates. Community metabolism estimates were corrected for diffusion as shown in the example.

Sample calculations:

Dissolved oxygen at dusk, dawn, dusk = 7.5, 6.0, 7.3 mg/liter, respectively

Uncorrected primary productivity = 3.1 g/M^3/day

Uncorrected community respiration = 3.3 g/M^3/day

Average temperature = 23.0 C

Oxygen saturation = 8.4 mg/liter

Concentration deficit at dusk = [(7.5 mg/liter)/(8.4 mg/liter) - 1.0] x 8.4 mg/liter = -1.0 mg/liter

Concentration deficit at dawn = [(6.0 mg/liter)/(8.4 mg/liter) - 1.0] x 8.4 mg/liter = -2.4 mg/liter

Average concentration deficit for dusk to dawn time interval = [(-1.0 mg/liter) + (-2.4 mg/liter)]/2 = -1.7 mg/liter

Rate of reaeration during darkness = $r\bar{D}$ = (0.5/hr)(-1.7 mg/liter) = 0.08 mg/liter/hr

Community respiration corrected for diffusion = uncorrected community respiration + (rate of diffusion during night x hours of darkness) = 3.3 g/m^3/day + (0.08 mg/liter x 10 hr) = 4.1 g/M^3/day

Concentration deficit at second dusk = [(7.3 mg/liter)/(8.4 mg/liter) - 1.0] x 8.4 mg/liter = -1.1 mg/liter

Average concentration deficit from dawn to second dusk time interval = [(-2.4 mg/liter) + (-1.1 mg/liter)]/2 = -1.8 mg/liter

Rate of reaeration during day = $r\bar{D}$ = (0.05/hr)(-1.8 mg/liter) = -0.09 mg/liter/hr

Primary productivity corrected for diffusion = uncorrected primary productivity + (rate of reaeration during day x hours of day) = 3.1 g/M^3/day + (-0.09 mg/liter/hr x 14 hours) = 1.8 g/M^3/day

Community metabolism estimates were also converted to g of O_2/M^2/day by multiplying the estimates in g of O_2/M^3/day by 0.33 m (the average depth of the experimental vessels) to facilitate comparisons with other studies.

Method I was evaluated by (1) determining the reproducibility of daily primary productivity and community respiration by analysis of variance using a randomized complete block design (7 replicate samples were collected on Monday, 9/28/70, from location 6); (2) comparing observed gross changes in zooplankton and phytoplankton populations in the sample with the trends of daily primary productivity, community respiration and the ratio of primary productivity divided by community respiration (P/R); and (3) comparing the community metabolism estimates (obtained from continuous records for 16 tests) with an alternate method (Odum 1957, except that my reaeration coefficient was used to correct for diffusion). Calculations of this method (hereafter referred to as Method II) were performed using a FORTRAN IV computer program that constructed the rate of change curves from hourly dissolved oxygen values. Methods I and II were evaluated by ranking the daily community metabolism estimates for each of the 16 tests (based on Method I), dividing these estimates into four equal groups, obtaining the quotient of the average difference of Method I minus Method II for each group, and comparing the average difference/group by graphical intrepretation of the average daily estimate of productivity, respiration, and the ratio of production to respiration.

RESULTS AND DISCUSSION

Community metabolism estimates obtained by Method I were reproducible (tab. F = 2.66, P = 0.95; calculated F = 1.02), and were of the same order of magnitude as other laboratory studies (Table 2). Estimates obtained by Method I were generally lower than Method II, although the differences decreased as the magnitude of the Method I estimate increased (Table 3). Evaluation of estimates obtained by Methods I and II were similar. Trends of community metabolism did follow the observed changes in zooplankton and phytoplankton populations, i.e., large numbers of zooplankton in station 2, week 8, changed respiration estimates of approximately 2 g O_2/M^3/day in week 7 (average zooplankton populations) to 9 g O_2/M^3/day; production remained at approximately 0 g O_2/M^3/day. Mean daily community metabolism (Table 4) also showed the deleterious effect of industrial pollution at station 5; water at this station often had a turbid grayish appearance and fish kills were occasionally observed.

Table 2. Comparison of community metabolism estimates.

reference	range of primary productivity in g of O_2/M^2/day	range of community respiration in g of O_2/M^2/day
present study	0.0–1.4	0.4–2.5
McConnell 1962[A]	0.86–1.89	
Beyers 1963	1.72–2.11	1.88–2.18
Butler 1964[B]	1.0–9.2	1.0–9.1
McIntire et al. 1964	2.9–4.7	1.6–3.3
Kevern & Ball 1965	0.5 (mean value)	0.3 (mean value)
Kemmerer et al. 1968	0.2–1.60[C]	
Kemmerer et al. 1968	0.0–6.52[D]	
Kemmerer 1969	0.03–38.20	

[A] in Butler (1964)

[B] expressed in g of CO_2/M^2/day

[C] phytoplanktonic community only

[D] phytoplanktonic and benthic community

Table 3. Comparison of methods of estimating community metabolism

Group	Productivity		Respiration		P/R	
	A	B	A	B	A	B
1	2.2	−0.2	3.4	−0.6	0.8	+0.1
2	0.8	−0.6	2.1	−1.0	0.5	−0.2
3	0.3	−1.0	1.5	−0.7	0.2	−0.3
4	0.0	−0.8	1.1	−0.8	0.0	−0.3

A = average Method I estimate in g of O_2/M^3/day

B = average difference (Method I − Method II)

Table 4. Comparison of mean daily estimates of community metabolism of major areas of the Thames Watershed, Connecticut.

	Quinebaug River			Shetucket River			Quinebaug-Shetucket River	Upper Thames Estuary
Locations	1	2	4	5	7	8	3	6
Mean P	1.1	0.3	0.8	0.3	0.2	0.3	0.8	0.9
Mean R	2.2	2.7	1.9	2.0	1.5	1.4	1.8	1.4
Mean P/R	0.05	0.1	0.4	0.2	0.1	0.2	0.4	0.6
# of Wks	17	17	12	16	5	7	17	9

Community metabolism estimates showed that the areas were generally heterotrophic and that the Shetucket River had less primary production than either the Quinebaug River or the Upper Thames Estuary (Table 4).

Assuming the Upper Thames Estuary should have had higher community metabolism estimates than the upstream areas because it received upstream enrichment plus possible nutrients from salt water, I think it might have been influenced by inhibitory influences from industrial or municipal effluents. Community metabolism of one area in the Quinebaug (location 2) may have been affected by limitations of Method I, undetected industrial pollution, or adverse effects of a substantial drawdown of the impoundment during the summer previous to this study.

Method I should be useful in future studies in which an index that is reproducible and detects general trends of community metabolism in the natural environment is desired. The reaeration coefficient calculated in this method was in close agreement with reaeration coefficients calculated by Kevern and Ball (1965) for an artificial stream (0.4-.07/hr), and eliminated the difficulty encountered in calculating reaeration coefficients under field conditions. Method I also would be useful in studies operating on a limited budget on a large river system or on several river systems since it requires only one person for about 20 hours per week to obtain the same information that probably no less than 3 men working shifts for 24 hours a day for 4 days could obtain sampling in the field, and requires about one-third the recording equipment necessary in field studies. Method I could be made even less expensive by eliminating all recording equipment, using larger experimental vessels, and determining three oxygen values per day by direct measurement (saving time spent in interpreting tape records of dissolved oxygen), and using a computer program to calculate community metabolism estimates corrected for diffusion (possibly saving time and increasing accuracy).

The principal limitations of Method I were that it did not adequately assess low levels of community metabolism. This may have been due to elimination of the opportunity for the sample community to interact with a benthic biota, and differential influences of important environmental factors on the sample communities, e.g., light (Butler 1964; Maddux and Jones 1964; Copeland 1965; Soeder 1965), temperature (Aruga 1966), and current (Odum and Hoskin 1957; Whitford and Schacher 1961; Owens and Maris 1964). The magnitude of possible inhibitory or stimulatory effects of these factors could be tested in future studies by an experimental approach using factorial arrangement of treatments.

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An evaluation of the Thames River Watershed, Connecticut, using growth of fishes

Walter R. Whitworth and Robert M. Goldstein[1]

INTRODUCTION

The primary purpose of this study was to evaluate the ability of part of the Thames Watershed to support populations of fishes. Theoretically, if differences in the populations of fishes occur, this would indicate either differences in man's effect on the watercourses or basic physical-chemical differences in the watersheds. Since documentation of some of the physical-chemical (Anon. 1954; Anon. 1964; Randall et al. 1966; and Thomas et al. 1967) and biological characteristics (Whitworth et al. 1974) of the Quinebaug and Shetucket Rivers (the two main tributaries of the watershed) were not greatly different, this evaluation of the growth of the fish populations was undertaken.

This study was supported, in part, by funds provided by the Andromous Fish Act (P.L. 89-304) and the Connecticut Department of Environmental Protection and the Institute of Water Resources, University of Connecticut. Computer time was supplied by the University of Connecticut Computer Center.

MATERIALS AND METHODS

The areas of the Thames Watershed in Connecticut evaluated were (1) the Quinebaug River from Danielson to the junction of the Shetucket River, (2) the Shetucket River from its formation to its junction with the Quinebaug River, and Mansfield Hollow Reservoir and Willimantic Reservoir on the Natchaug River, (3) the Quinebaug-Shetucket from its formation to Greenville Dam, and (4) the Quinebaug-Shetucket from below Greenville Dam to the Thames Estuary and the upper 500 m of the Thames Estuary. These areas were arbitrarily divided into either stream or impoundment (each impoundment was considered separately except those on the Natchaug River which were combined) and the stream areas were lumped into Shetucket (all in the Shetucket River), Quinebaug (all in the Quinebaug River), and Thames (all in the Quinebaug-Shetucket River and Thames Estuary). The mainstream lengths of the Shetucket and Quinebaug Rivers were 20.6 and 36.8 km and the ratio of this to their drainage area was 0.02006 and 0.02178, respectively. The mean distance between impoundments was 12.3 km on the Quinebaug River whereas a mean of only 5.2 km separated impoundments on the Shetucket River. Impoundments are characterized in Table 1.

Age and growth estimates of fishes that were common in several areas were determined following methods described in Whitworth and Sauter (1973); values of a (intercept) used were: Catostomus commersoni (Lacépède), 0.9; Cyprinus carpio Linnaeus, 1.0; Esox niger Lesueur, 1.0; Lepomis gibbosus (Linnaeus), 0.8; L. macrochirus Rafinesque, 0.8; Micropterus salmoides (Lacépède), 1.0 (only age classes I and II were used). Notemigonus crysoleucas (Mitchill), 0.7; Notropis hudsonius (Clinton), 0.7; Perca flavescens (Mitchill), 0.9; and Pomoxis nigromaculatus (Lesueur), 0.9. Fishes obtained by any sampling method were utilized.

[1]Both of the Department of Plant Science, The University of Connecticut, Storrs, Connecticut 06268

Table 1. Selected characteristics of the impoundments in the study area.

Impoundment	River System	Length (km)	Surface Area ($m^3 \times 10^6$)	Volume ($m^3 \times 10^6$)	Surface Area/ Volume	Dam Usage
Mansfield Hollow	N-S	4.0	1.78	5.13	0.569	flood control
Willimantic Res.	N-S	1.3	0.34	0.47	0.710	water supply
Scotland	S	3.7	0.54	1.66	0.326	power
Occum	S	0.5	-	-	-	power
Taftville	S	1.9	0.43	1.23	0.351	power
Aspinook	Q	4.6	1.35	3.57	0.378	power (defunct)
Tunnel	Q	0.5	0.12	0.62	0.188	power
Greenville	Q-S	1.9	0.32	0.30	1.093	power

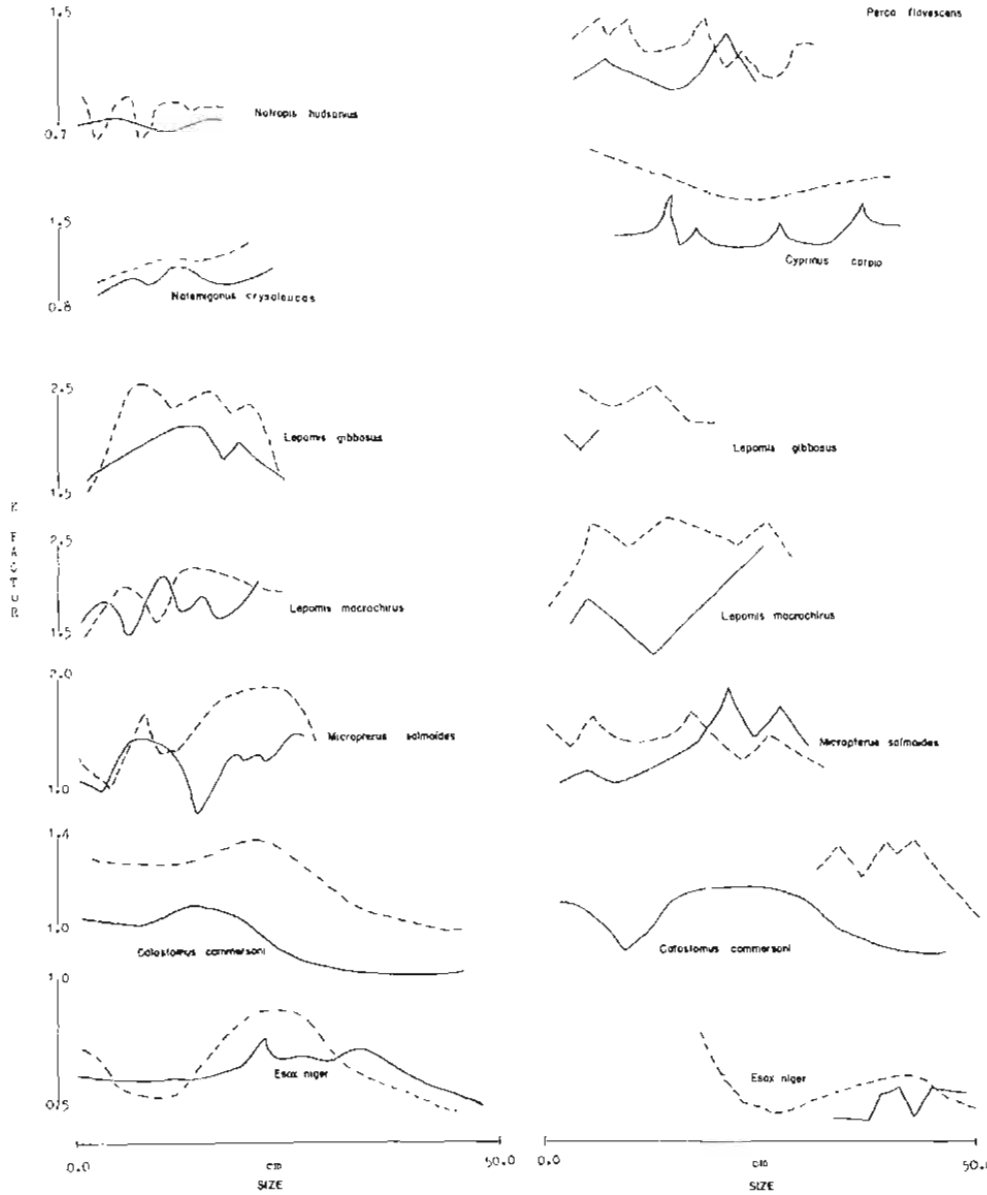

Fig. 1. Comparison of condition factors (K) of fishes in mainstream areas and impoundments in the Shetucket River and the Quinebaug River. Solid line is the Shetucket River and broken line the Quinebaug River (left series of graphs) and solid line in Scotland Impoundment and broken line is Aspinook Pond (right series of graphs).

Relationships between total length (TL) and wet weight (Wt) of fishes sampled in each of the areas were obtained by (1) fitting all TL and Wt values by the least squares method and calculating values of A, B, and a correlation coefficient [log Wt = log A + B (log TL)] and (2) calculating condition factors (K) described in Carlander (1969). All calculations were done using Fortran IV programs and an IBM 360/65 computer.

Evaluation was accomplished by graphical interpretation of age and growth and length-weight relationships of (1) mainstream and Scotland Impoundment of the Shetucket River compared with mainstream and Aspinook Pond of the Quinebaug River, (2) Natchaug Impoundments with Scotland Impoundment and Aspinook Pond, and (3) all areas (mainstream and impoundments) based on their upstream-downstream location.

RESULTS

Most fishes in the mainstream of the Shetucket River and Scotland Impoundment had lower condition factors (Fig. 1), higher length-weight slopes (Table 2), and lower growth rates (Table 3) than those in the Quinebaug River and Aspinook Pond. Fishes in the Natchaug Impoundments had faster growth and were heavier than those in Scotland Impoundment and Aspinook Pond (Tables 2 and 3).

Overall evaluation of the system showed a general decrease in growth after the Natchaug Impoundments in the Shetucket River, reduction of growth after the Quinebaug and Shetucket Rivers joined, and an increase in growth in the upper Thames Estuary (Tables 2 and 3, Fig. 1). Estuaries are noted for high productivity and turnover. The favorable conditions (for those species with a salinity tolerance) seem to out-weigh the deleterious effects of the Quinebaug-Shetucket River water.

DISCUSSION

Theoretically, since the Shetucket River has more readily accessible impoundments with less mainstream distance between them than the Quinebaug River, the fishes of the Shetucket River should have better growth dynamics (more cover, more deep water, and more feeding area). Since good growth was observed only in the Natchaug Impoundments, it may be that man's effect is more pronounced in the Shetucket River than in the Quinebaug River. One of the Natchaug Impoundments (Mansfield Hollow Dam Reservoir) is usually lowered in the fall which probably means either an increase or decrease in the growth of fishes. Because the Willimantic River and the Willimantic Sewage Treatment Plant are the only additions to the Natchaug flow, they would seem to be the logical cause of the poor growth conditions at Scotland Impoundment and in the Shetucket River. At this time the effects of the Willimantic River and the sewage treatment plant cannot be separated. Either or both probably have a negative effect on fish growth. Power generation in the Shetucket usually varies water depth at least one meter twice daily during low flow periods. This phenomenon alone (flooded and dried nesting sites, feeding areas, and cover) or in combination with effluents from the Willimantic River and the Willimantic Sewage Treatment Plant may also account for the reduced growth dynamics of the fishes in the Shetucket River.

Since there is good growth in the Thames Estuary, if the effluents were stopped there would theoretically be better growth. This would increase productivity of the estuary residents, probably at all taxonomic levels. The marine species that utilize the estuary as feeding, spawning, or nursery areas would also benefit, thus leading to an increased sport fishery and possibly a commercial fishery.

Table 2. Comparison of selected areas of the Thames River Watershed by slope of the length-weight relationships.

Area	*Catostomus commersoni* Slope	No.	*Cyprinus carpio* Slope	No.	*Lepomis gibbosus* Slope	No.	*Lepomis macrochirus* Slope	No.	*Perca flavescens* Slope	No.
Natchaug Imps.					3.158754	20	3.027274	50	3.267905	32
Scotland Imp.	2.911804	22	2.901565	46	2.882121	6	3.085521	5	3.134848	14
Occum Imp.	2.928819	24			3.293842	14	3.401608	10	2.536337	4
Aspinook Pond	2.539713	110	2.928596	11	2.875008	37	3.097867	135	2.942717	44
Tunnel Imp.	2.759387	9	2.826886	9	3.250085	13	3.140942	22		
Greenville Imp.	2.985587	31	2.829212	10	3.149517	44				
Shetucket River	2.922084	66	3.036044	3	3.185707	64	3.091627	39	2.987807	14
Quinebaug River	2.952759	132	2.948686	15	3.206912	45	3.134925	135	2.881911	15
Thames Estuary	2.970913	64	2.851033	57	3.042889	46			3.049981	43

Area	*Notemigonus crysoleucas* Slope	No.	*Notropis hudsonius* Slope	No.	*Micropterus salmoides* Slope	No.	*Pomoxis nigromaculatus* Slope	No.	*Esox niger* Slope	No.
Natchaug Imps.					3.078526	9			3.147977	10
Scotland Imp.	3.45947	30	2.768965	10	3.390759	12	3.162325	14	3.130032	9
Occum Imp.	3.243927	3	2.720616	11	3.218228	6			3.214549	4
Aspinook Pond	3.335788	132	2.506282	35	3.021825	54	3.046213	49	2.501124	16
Tunnel Imp.	3.615105	11					2.266241	12		
Greenville Imp.	3.556485	66					3.388007	9	2.434807	49
Shetucket River	3.180953	158	2.297321	65	3.099113	29	3.21694	13	3.172989	31
Quinebaug River	3.342533	30	3.185172	116			3.147109	50	3.049334	9
Thames Estuary	3.182724	75	3.576118	75	3.047051	15	2.905600	23	3.096964	8

Table 3. Comparison of selected areas of the Thames River Watershed by calculated total length (cm).

Area	*Catostomus commersoni*				*Cyprinus carpio*				*Lepomis gibbosus*				*Lepomis macrochirus*			
	I	N	II	N	I	N	II	N	I	N	II	N	I	N	II	N
Natchaug Imps.	15.5	38	22.4	38					5.0	25	8.8	24	7.1	51	11.4	35
Scotland Imp.	9.9	29	14.1	8					4.6	13			5.6	5	8.3	5
Occum Imp.	10.4	17	18.9	6					5.3	10	9.1	7				
Aspinook Pond	9.9	161	22.0	158					4.6	29	9.2	29	5.7	109	10.6	98
Tunnel Imp.	9.5	8	21.9	8					4.8	26	10.1	25	6.6	42	11.6	42
Greenville Imp.	11.9	29	20.5	25					4.8	68	8.4	54	4.3	23	9.3	23
Shetucket River	7.5	65	15.8	36	11.0	61	13.8	57	4.1	65	7.5	43	4.1	32	8.2	33
Quinebaug River	10.2	69	20.4	68	15.8	31	29.6	30	4.6	45	9.6	41	4.9	210	10.0	198
Thames River	10.6	58	23.6	49					5.9	78	11.8	72	7.5	27	13.9	23

Area	*Notemigonus crysoleucas*				*Notropis hudsonius*				*Micropterus salmoides*				*Pomoxis nigromaculatus*			
	I	N	II	N	I	N	II	N	I	N	II	N	I	N	II	N
Natchaug Imps.	11.0	19	15.4	18					12.1	14	23.6	6				
Scotland Imp.	6.1	150	9.5	129					11.3	15	19.6	7	7.7	12	14.2	11
Occum Imp.	8.8	3							9.0	3						
Aspinook Pond	8.7	135	15.0	129					7.0	17	17.6	11	7.0	77	13.7	77
Tunnel Imp.																
Greenville Imp.	6.4	45	11.4	38									7.4	34	12.7	29
Shetucket River	6.7	64	10.6	56	5.0	36	7.4	25	10.0	19	12.7	8	6.8	23	13.4	13
Quinebaug River	5.3	41	11.6	40	4.3	33	6.3	19	8.5	7	18.4	6	6.3	63	12.0	61
Thames River					5.1	44	7.4	30					6.7	55	11.8	52

Area	*Esox niger*				*Perca flavenscens*			
	I	N	II	N	I	N	II	N
Natchaug Imps.					7.8	48	12.4	30
Scotland Imp.					6.7	19	12.0	9
Occum Imp.								
Aspinook Pond	12.6	14	23.0	13	7.7	35	10.0	22
Tunnel Imp								
Greenville Imp.	12.3	33	17.0	29	7.3	12	9.7	10
Shetucket River	13.6	38	21.5	23	7.4	12	13.0	6
Quinebaug River	9.8	6	12.5	4	7.1	8	12.0	5
Thames River					10.4	35	14.6	28

N is the number of spacimens in each age class

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Theoretical population estimates and dynamics of three species of Alosa in the Thames River Watershed, Connecticut

Christopher G. Clark[1]

INTRODUCTION

Alosa sapidissima (American shad), Alosa pseudoharengus (alewife), and Alosa aestivalis (blueback herring) are anadromous clupeids that spawn in Connecticut in the spring (Whitworth et al. 1968; Thomson et al. 1971). These fish were undoubtedly important to the early settlers because in May 1715, the colony of Connecticut passed an act "to prevent nuisances by Hedges, Wears and other Incumbrances, obstructing the passage of fish in rivers in the spring of the year," and specifically named the "Quinabaug" and "Shoutucket" Rivers (Hoadly 1870). They continued to be important food fishes until "the building of so many dams across the river, ended the days of shad fishing," in particular the dam at Norwich (Greenville Dam) which blocked passage to both the Quinebaug and Shetucket Rivers (upper Thames River system) (Anon. 1893). One seine haul (1830) in the Willimantic River (Shetucket River system) contained 31 shad weighing from 3 to 5 pounds (Anon. 1893). At the present time blueback herring and alewife spawn in the Thames River system (Loesch 1969) and have been caught at the base of the Greenville Dam.

The purpose of this study was to estimate the size of the spawning populations of American shad, alewife, and blueback herring that could be supported in the Quinebaug and Shetucket-Natchaug Rivers and determine how each population was affected by changing the percent survival (egg to spawning adult), sex ratio, and percentage of repeat spawners.

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MATERIALS AND METHODS

Study Area

The Quinebaug and Shetucket Rivers join at Taftville, Connecticut, and flow into the Thames River at Norwich, Connecticut. The Quinebaug River originates in the vicinity of Southbridge, Massachusetts; the portion from Putnam, Connecticut, to the mouth was considered in this study. The Shetucket River begins at the junction of the Willimantic and Natchaug Rivers in Willimantic, Connecticut; the total Shetucket River and the Natchaug River north to Bigelow Brook, in the vicinity of Phoenixville, Connecticut, was considered. The two Rivers (Quinebaug and Shetucket-Natchaug) were divided into 6 sections corresponding to the numbers of dams in each. Each of these sections was then separated into stream and impoundment areas to separate the spawning habitats of the alewife from those of the American shad and blueback herring. The alewife selects areas of relatively slow flow (Kissil 1969) whereas American shad (Leim 1924; Marcy 1972) and blueback herring select those of relatively fast flow (Loesch 1969).

[1]Department of Plant Science, The University of Connecticut, Storrs, Connecticut 06268.

Surface area (acres) of each section was determined by measuring midstream length and estimating average width (most frequent width per increment of length) from aerial photographs taken in March and April 1970 (Table 1). These photographs are on file in the State Office Building, Hartford, Connecticut.

Table 1. Surface area (acres) utilized to estimate spawning populations of 3 species of Alosa.

River Section	Impoundment	Stream	Total
Quinebaug			
1 Greenville Dam to Tunnel Dam	61		61
2 Tunnel Dam to Aspinook Dam	167	53	220
3 Aspinook Dam to Wauregan Dam	314	261	575
4 Wauregan Dam to Danielson Dam	346	276	622
5 Danielson Dam to Rogers Dam	367	285	652
6 Rogers Dam to Putnam, Conn.	393	456	849
Shetucket-Natchaug			
7 The mouth to Taftville Dam		25	25
8 Taftville Dam to Occum Dam	87	50	137
9 Occum Dam to Scotland Dam	143	154	297
10 Scotland Dam to Willimantic Res. Dam	231	256	487
11 Willimantic Res. to Mansfield Hollow Dam	345	256	601
12 Mansfield Hollow Dam to Bigelow Brook	407	353	760
Connecticut			
1 Haddam, Conn. to Mass. State Line			6297
2 Haddam, Conn. to Enfield Dam			5804
3 Rocky Hill to Enfield Dam			2937

Population Estimates

Population estimates of American shad were based on the total surface areas of the Quinebaug and Shetucket-Natchaug Rivers compared to three areas and their populations of American shad in the Connecticut River. The Connecticut River areas were primarily selected on the basis of egg collections by Marcy (1972). Surface area was determined as for the Quinebaug and Shetucket-Natchaug Rivers (Table 1 describes these areas). Estimates of the number of American shad in the Connecticut River were obtained by averaging the population estimates for the years 1965–1970 (Leggett 1972) and assuming that all the American shad (681,000) were produced in areas 1, 2, and 3. The estimate for area 3 was reduced by 10% to approximate 90% of the production in this area; Marcy (1972) reported 11 times the number of American shad eggs collected/hour in this area, compared to the other two areas. Since population estimates for alewife and blueback herring in the Connecticut River were not available, young of the year sampling totals (1967 and 1968) for the three species of Alosa reported by Loesch (1969) in the Connecticut River were averaged and the relative number of alewife and blueback herring compared to American shad obtained (2 and 109, respectively). Population estimates in the Quinebaug and Shetucket-Natchaug (Q and S-N) were obtained as follows:

1. Est. of Amer. shad in Q or S-N = $\frac{\text{Total area (Q or S-N)}}{\text{Area 1 Conn. River}}$ X Pop. Est. Amer. shad in Area 1 Conn. Riv.

2. Est. of Amer. shad in Q or S-N = $\frac{\text{Total area (Q or S-N)}}{\text{Area 2 Conn. River}}$ X Pop. Est. Amer. shad in Area 2 Conn. Riv.

3. Est. of Amer. shad in Q or S-N = $\frac{\text{Total area (Q or S-N)}}{\text{Area 3 Conn. River}}$ X Pop. Est. Amer. shad in Area 3 Conn. Riv.

Population estimates of alewife and blueback herring were obtained by multiplying each population estimate of American shad by 2 and 109, respectively.

Population Dynamics

A general model was constructed to represent that year's population of females of each species that would be available to spawn.

$$Y.C. = \sum[(\%\ V.\ \text{in}\ A.C.)(\bar{x}\ V.F.) + (\%\ R.\ \text{in}\ A.C.)(\bar{x}\ R.F.)]\ (S.)\ (S.R.)$$

where V. = virgin spawners, A.C. = age class, V.F. = virgin fecundity, R. = repeat spawners, R.F. = repeat fecundity, S.R. = sex ratio factor (S.R. = fraction of females in the population), S. = % survival (egg to spawning adult) to achieve a stable population, and Y.C. = females in year class surviving to spawn. Spawning populations (S.P.) were obtained by summing the numbers in each age class producing this year's Y.C. Theoretical percentage survival for a stable population of blueback herring (0.001%), alewife (0.00051%), and American shad (0.00057%) were calculated as follows:

$$S. = 1/[(\%\ V.)(\bar{x}\ V.F.) + (\%\ R.)(\bar{x}\ R.F.)]\ (S.R.)$$

Estimates for age structure (% virgins and % repeat spawners in each age class), sex ratio, and fecundity were obtained from the literature (Table 2).

The population model and its various parameters (Table 2) for the three species of Alosa were incorporated in a computer program (Fortran IV) and a stable population (original population) simulated for 70 years (IBM 360/65). Nine successive simulations (70 years) were performed changing three parameters (% survival, sex ratio, and percentage of repeat spawners); each parameter was varied in a single year and multiple years (Table 3). The effects of each parameter change on the spawning and year class populations of each species were evaluated graphically by determining: (1) the % change from the original population [(changed population/original population) X 100], (2) % change in the spawning population from the original population when annual fluctuations were less than 5% (long term change), (3) year of maximum change, and (4) magnitude of maximum fluctuation (Table 3).

Table 2. Characteristics of the spawning populations of three species of Alosa.

Species	Age	Virgin(%)	Repeat(%)	Fecundity $\bar{x}$	Sex Ratio (M:F)
Blueback herring[a]	3	9.0		virgin 124,000	2:1
	4	74.6			
	5	16.4	40		
	6		28	repeat 216,700	
	7		16		
Alewife[b]	4	32.5			1:1
	5	67.5	12	virgin 207,000	
	6		39		
	7		24	repeat 238,800	
	8		2		
American shad[c]	4	26.0			1:1
	5	68.0	20	virgin 263,000	
	6	6.0	8		
	7		3	repeat 282,000	
	8		1		

[a]Loesch 1969, Marcy 1968; [b]Kissil 1969, Marcy 1968; [c]Leggett 1969

RESULTS

Total population estimates of American shad, alewife, and blueback herring, ranged from 82,129 to 158,583; 164,258 to 317,166; and 8,952,061 to 17,285,547, respectively in the Shetucket-Natchaug and 91,867 to 177,402; 183,734 to 354,804; and 10,013,503 to 19,336,818, respectively in the Quinebaug.

The American shad population fluctuates more on an annual basis than either the alewife or blueback herring populations, unless the number of repeat spawners was lowered (Tables 4-12). When survival was changed, the resultant long term (30 or 70 years) change in population numbers were approximately the same for all species (Tables 4-8 and 12). A change in sex ratio has the same effect as a change in survival; this is best illustrated by the blueback herring population comparing Tables 5 and 8. The three populations have the ability to withstand extreme stress as indicated in Table 7 and 12 (no survival for three years and six years of lowered survival and decreased numbers of repeat spawners). Generally, the year class and spawning population fluctuations of all three species were minimum and maximum in the same year (Table 2), except for the blueback herring (when population parameters were changed in a single year, the year class population's greatest fluctuation was one year later than the spawning population's largest change).

Table 3. Summary of population changes and their effects on the populations of the three species of Alosa. B. = blueback herring, A. = alewife, S. = American shad, Y.C. = year class, and S.P. = spawning population.

Changes in population parameters	Species	Year and % of maximum change		Long term change
		S.P	Y.C.	S.P. (%)
(1) Twice survival rate in 1 year.	B.	4/43	5/38	20
	A.	5/43	4/41	17
	S.	6/67	5/65	25
(2) Half survival rate in 1 year.	B.	4/19	5/18	10
	A.	5/27	5/22	9
	S.	5/34	5/34	10
(3) No survival in Y.C. 2 consecutive years.	B.	5/71	5/66	39
	A.	6/67	6/68	38
	S.	5/86	5/86	41
(4) No survival in Y.C. 3 consecutive years.	B.	6/87	6/86	59
	A.	6/86	6/85	55
	S.	6/97	6/97	59
(5) Sex ratio change by 1 in 1 year.	B.	4/20	5/17	10
	A.	5/14	5/15	6
	S.	5/23	5/23	9
(6) Sex ratio change by 1 in 3 consecutive yrs.	B.	6/43	6/42	29
	A.	6/28	6/29	18
	S.	6/32	6/32	18
(7) Half repeat spawners in 1 year.	B.	4/12	5/11	7
	A.	5/9	5/9	3
	S.	5/7	5/7	0
(8) Half repeat spawners in 3 consecutive yrs.	B.	6/26	6/25	17
	A.	6/19	6/20	13
	S.	6/12	6/12	7
(9) Year 1 & 4 no survival; Year 2 & 5 half survival; Year 3 & 6 half repeat spawners.	B.	–	–	64
	A.	–	–	62
	S.	–	–	62.

Table 4. Effects of doubling the survival rate in one year on the spawning and year class population of the three species of Alosa. Percentages of original population are rounded.

Year	Blueback herring		Alewife		American shad	
	S.P.	Y.C.	S.P.	Y.C.	S.P.	Y.C.
0	100	205	100	195	100	200
1	100	100	100	100	100	100
2	100	100	100	100	100	100
3	105	105	100	100	100	100
4	143	133	118	115	120	119
5	132	138	143	141	167	165
6	116	120	121	122	111	110
7	113	114	113	114	102	103
8	116	111	104	103	105	104
9	126	125	115	114	126	126
10	126	127	126	125	148	149
30	120	120	117	117	125	125

Table 5. Effects of reducing the survival rate in one year by 50% on the spawning and year class population of the three species of Alosa. Percentages of original populations are rounded.

Year	Blueback herring		Alewife		American shad	
	S.P.	Y.C.	S.P.	Y.C.	S.P.	Y.C.
0	100	52	100	49	100	50
1	100	100	100	100	100	100
2	100	100	100	100	100	100
3	98	99	100	100	100	100
4	81	85	91	91	90	90
5	85	82	78	78	66	66
6	93	89	89	88	94	94
7	95	93	93	93	100	99
8	93	93	98	97	100	100
9	88	88	93	93	87	86
10	89	88	86	87	75	75
30	90	89	91	91	90	89

Table 6. Effects of no survival in year class for two consecutive years on the spawning and year class population of the three species of Alosa. Percentages of original populations are rounded.

Year	Blueback herring		Alewife		American shad	
	S.P.	Y.C.	S.P.	Y.C.	S.P.	Y.C.
0	100	0	100	0	100	0
1	100	0	100	0	100	0
2	100	100	100	100	100	100
3	95	97	100	100	100	100
4	55	66	82	83	80	81
5	29	34	37	39	14	14
6	54	45	33	32	23	23
7	73	66	64	61	87	86
8	74	75	83	81	93	92
9	60	67	80	80	70	69
10	51	52	57	58	25	26
70	61	60	62	63	59	60

Table 7. Effects of no survival in year class for three consecutive years on the spawning and year class population of the three species of Alosa. Percentages of original population are rounded.

Year	Blueback herring		Alewife		American shad	
	S.P.	Y.C.	S.P.	Y.C.	S.P.	Y.C.
0	100	0	100	0	100	0
1	100	0	100	0	100	0
2	100	0	100	0	100	0
3	95	97	100	100	100	100
4	55	66	82	83	80	81
5	24	31	37	39	14	14
6	13	14	14	15	3	3
7	42	31	19	19	21	21
8	58	55	61	58	82	82
9	48	52	66	66	68	68
10	36	41	53	54	20	21
70	41	40	45	44	41	40

Table 8. Effects of sex ratio changed by 1 in one year on the spawning and year class population of the three species of Alosa. Percentages of original population are rounded.

Year	Blueback herring		Alewife		American shad	
	S.P.	Y.C.	S.P.	Y.C.	S.P.	Y.C.
0	100	149	100	66	100	66
1	100	100	100	100	100	100
2	100	100	100	100	100	100
3	103	102	100	100	100	100
4	120	116	94	93	93	94
5	115	117	86	85	77	77
6	108	109	93	92	96	96
7	106	106	95	95	99	99
8	108	105	99	98	99	99
9	112	111	95	95	92	91
10	113	113	90	90	83	95
30	110	110	94	93	91	93

Table 9. Effects of sex ratio changed by 1 for three consecutive years on the spawning and year class population of the three species of Alosa. Percentages of original population are rounded.

Year	Blueback herring		Alewife		American shad	
	S.P.	Y.C.	S.P.	Y.C.	S.P.	Y.C.
0	100	152	100	66	100	66
1	100	152	100	66	100	66
2	100	152	100	66	100	66
3	103	102	100	100	100	100
4	123	117	94	93	93	94
5	138	134	79	80	72	71
6	143	142	72	71	68	68
7	129	133	73	73	74	73
8	121	122	87	85	94	94
9	125	124	88	88	89	90
10	132	130	85	85	73	74
30	129	130	82	81	82	83

Table 10. Effects of reducing the number of repeat spawners in one year by 50% on the spawning and year class population of the three species of Alosa. Percentages of original population are rounded.

Year	Blueback herring		Alewife		American shad	
	S.P.	Y.C.	S.P.	Y.C.	S.P.	Y.C.
0	77	70	79	76	89	88
1	100	100	100	100	100	100
2	100	100	100	100	100	100
3	98	98	100	100	100	100
4	88	91	96	95	97	97
5	90	89	91	91	93	93
6	96	94	96	94	98	98
7	97	95	98	96	100	100
8	95	95	100	98	100	100
9	93	92	97	96	98	98
10	93	92	95	96	96	96
30	93	94	97	96	100	100

Table 11. Effects of reducing the number of repeat spawners for three consecutive years by 50% on the spawning and year class population of the three species of Alosa. Percentages of original population are rounded.

Year	Blueback herring		Alewife		American shad	
	S.P.	Y.C.	S.P.	Y.C.	S.P.	Y.C.
0	77	70	79	76	89	88
1	77	70	79	76	89	88
2	77	70	79	76	89	88
3	99	98	100	100	100	100
4	87	91	96	95	97	97
5	77	80	86	85	89	90
6	74	75	81	80	88	88
7	83	80	82	81	90	90
8	87	86	90	90	98	97
9	85	86	92	92	96	96
10	81	83	88	88	90	91
70	83	82	87	86	93	93

Table 12. Effects of no survival, reducing survival by 50%, reducing repeat spawners by 50%, alternating for six consecutive years, on the spawning and year class population of the three species of Alosa. Percentages of original population are rounded.

Year	Blueback herring		Alewife		American shad	
	S.P.	Y.C.	S.P.	Y.C.	S.P.	Y.C.
0	100	0	100	0	100	0
1	100	52	100	49	100	49
2	77	70	79	76	89	88
3	95	0	100	0	100	0
4	57	34	82	41	80	40
5	36	34	28	29	20	20
6	53	50	51	49	53	53
7	31	36	46	46	65	64
8	31	31	31	32	19	18
9	33	32	35	34	32	33
10	38	35	32	31	28	28
11	40	40	42	43	50	51
12	36	52	42	43	53	54
13	34	35	38	40	27	27
14	34	33	35	36	31	32
15	37	35	35	34	33	33
16	37	37	38	38	49	48
70	36	35	38	37	38	38

DISCUSSION

American shad population estimates in the Quinebaug and Shetucket-Natchaug Rivers are conservative estimates because: (1) the survival rate of 0.001% reported by Leggett (1969) indicates a growing (or attempting to grow) population of American shad (when contrasted to a 0.00057% theoretical stable population survival rate);

and (2) the Quinebaug and Shetucket-Natchaug Rivers have more spawning sites (as characterized by Leim 1924) per area than the Connecticut River comparison areas; therefore, I would assume my highest estimates to be minimum estimates.

Additional mortality because of dams in the Quinebaug and Shetucket-Natchaug Rivers (Bell and Holmes (1962) estimated a survival rate of 75% to 90% for young American shad passing through turbines), was not considered in the population estimates because the distance of migration was approximately half the distance reported in the Connecticut River (Watson 1968). This would allow less mortality for late spawning adults due to high temperatures and low water flow, which should increase the total spawning population (virgin and repeat spawners) and offset the increased mortality of young American shad. Further, it is not unlikely that the technological problem of reducing the mortality of juvenile American shad passing through turbines will be achieved.

The major implications for management of American shad are threefold:

1. The total size of the spawning population should be evaluated rather than a particular emphasis on the percentage of repeat spawners because the effect on the population of decreasing the percentage of repeat spawners was minimal.

2. Estimates of the size of both the spawning and resultant year class populations should be made. The population model is based on the assumption that a population that reaches a steady state (fills its available niche) has a survival rate that allows each member of that population to replace itself in the future, and if that population decreases there would be a rise in the survival rate (Slobodkin 1961). Therefore, if the spawning population decreases, the resultant year class population may not decrease proportionally.

3. Management plans should be based on the average size of the spawning population for five years. The three populations of Alosa had approximately equal long term changes (30 or 70 years), but the American shad had the largest annual fluctuations. The average fluctuation for five years (starting with the year the spawning population was affected by a change in the survival rate) resulted in differences between the three populations of less than 6%. Because each spawning population is composed of individuals in five age classes, it would seem reasonable to manage for five year average changes, rather than single year fluctuations.

The economic impact of the restoration of this fishery to Connecticut would be significant. The commercial American shad fishery in the Connecticut River had an estimated capitalized value of $7,000,000 (Bampton 1964). Assuming a population of 350,000 American shad in the Quinebaug and Shetucket-Natchaug Rivers, the capitalized value would be approximately $3,500,000. If we consider the value of the blueback herring and alewife populations (combined) to be worth only 50% of the American shad value, then the total resource in these rivers would have a capitalized value of $5,250,000. A resource of this value should be inducement enough to either remove the dams, or build fishways in the Quinebaug and Shetucket-Natchaug Rivers.

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Capability of the Thames River Watershed in Connecticut to support anadromous salmonids

Walter R. Whitworth, Ernest E. Beckwith, Jr., and Richard L. Hames[1]

INTRODUCTION

The purposes of this study were to (1) estimate the potential spawning areas for three species of anadromous salmonids (coho salmon, Oncorhynchus kisutch; Atlantic salmon, Salmo salar; and sea-run brown trout, Salmo trutta) in the Thames River Watershed of Connecticut and (2) estimate the sizes of potential spawning runs in selected areas of the Watershed.

Historical records show that Atlantic salmon provided excellent fishing in the Quinebaug River until the early 1800's (Larned 1880, Bayles 1889) and in the Shetucket River until about 1830 (Larned 1880). Atlantic salmon migration into the Thames River system probably ceased after the building of the "great dam at Greenville" in the 1830's (Netboy 1968).

This study was part of a program of the Connecticut Department of Environmental Protection to introduce or reintroduce an anadromous salmonid into the Thames River Basin. Funds were provided, in part, by the Department of Environmental Protection and the Anadromous Fish Act (P.L. 89-304) through the Bureau of Sport Fisheries and Wildlife.

MATERIALS AND METHODS

The Thames River Basin drains an area of approximately 3818 km^2 in eastern Connecticut, south-central Massachusetts, and northwestern Rhode Island. This basin was arbitrarily divided into four major streams, the Quinebaug, Shetucket, Yantic, and Thames Rivers. Most of the tributaries of these major streams in Connecticut, considered large enough for anadromous salmonids to spawn, and the Yantic and Shetucket Rivers were walked during September 1971 to September 1972 from their mouths upstream to the points considered too small for salmonids to pass or spawn (Table 1 lists the streams). Certain streams that were low-grade, contained little gravel, or had many dams were inspected from cars and only walked in those areas having potential spawning sites for anadromous salmonids; these streams are so designated in Table 1. The Quinebaug River was evaluated by canoeing from the Massachusetts border to Danielson and the Thames River was not evaluated.

Potential spawning areas for anadromous salmonids were identified (criteria utilized are listed in Table 2), and their lengths and widths estimated. Gravel size, percent sand, silt, and mud of bottom materials, and water velocity were estimated; estimates were checked periodically. The height of dams and other obstructions to anadromous salmonids was also estimated (nearest 0.5 m). Length of streams walked was estimated by use of map measurers and the appropriate U.S.G.S. topographic sheets (average of three trials). Total potential spawning area of each stream between each obstruction was calculated by summing the individual areas (length X width).

[1]Associate Professor, Fisheries, University of Connecticut; QLM Laboratories, Inc., New York; and Connecticut Department of Environmental Protection.

Table 1. Streams evaluated in the Thames River Basin

Stream	Major Stream	Length Evaluated from Mouth Upstream (km)	Approximate Height (m) of Dam (from Mouth Upstream)
Hunts Brook	Thames River	10.0	2.5, 9, 1.5
Oxoboxo Brook	Thames River	Auto-walk	9 dams, not suitable
Poquetanuck Cove Br.	Thames River	6.9	
Stony Brook	Thames River	6.6	3, 8, 3
Trading Cove Brook	Thames River	10.8	3.5
Abington Brook	Quinebaug River	2.1	1
Blackwells Brook	Quinebaug River	14.0	1, 1, 4.5
Broad Brook	Quinebaug River	7.6	1
Cady Brook	Quinebaug River	1.3	2
Fivemile River	Quinebaug River	24.0	3, 2.5, 4.5, 4.5, 2
French River	Quinebaug River	Auto-walk	6 dams, not suitable
Kitt Brook	Quinebaug River	5.1	2, 1.5
Little River	Quinebaug River	6.3	4.5
Mashamoquet Brook	Quinebaug River	12.1	1.5
Moosup River	Quinebaug River	19.2	1, 6, 2.5
Pachaug River	Quinebaug River	8.4	2.5, 3.5, 6, 6, 2.5, 6, 2.5
Quaduck Brook	Quinebaug River	18.7	1.5
Snake Meadow Brook	Quinebaug River	8.4	2, 1
Whetstone Brook	Quinebaug River	2.4	2, 6
Beaver Brook	Shetucket River	7.0	
Bigelow Brook	Shetucket River	6.5	
Bungee Brook	Shetucket River	Auto-walk	not suitable
Coventry Brook	Shetucket River	Auto-walk	not suitable
Crystal Lake Brooks	Shetucket River	Auto-walk	3 dams, not suitable
Eagleville Brook	Shetucket River	Auto-walk	not suitable
Fenton River	Shetucket River	17.0	3
Furnace Brook	Shetucket River	8.0	3, 7.5, 4.5, 4.5
Hop River	Shetucket River	24.0	2
Frog Brook	Shetucket River	2.5	2 dams. not suitable
Knowlton Brook	Shetucket River	Auto-walk	
Little River	Shetucket River	32.0	3.5, 7.5, 2, 4.5, 4.5, 3, 3
Merrick Brook	Shetucket River	7.0	
Middle River	Shetucket River	8.0	3 dams, not suitable
Mt. Hope River	Shetucket River	25.0	2.5
Natchaug River	Shetucket River	28.0	6, 2, 21.5
Negro Brook	Shetucket River	Auto-walk	not suitable
Roaring Brook	Shetucket River	Auto-walk	not suitable
Sawmill Brook	Shetucket River	Auto-walk	not suitable
Skungamung River	Shetucket River	15.5	1, 9, 1
Still River	Shetucket River	8.0	3
Stonehouse Brook	Shetucket River	Auto-walk	
Tenmile River	Shetucket River	8.9	
Willimantic River	Shetucket River	43.0	3, 6, 6, 6, 6, 3
Bartlett Brook	Yantic River	8.0	3
Deep River	Yantic River	Auto-walk	15
Gardner Brook	Yantic River	Auto-walk	1
Pe e Brook	Yantic River	9.7	
Sl. man Brook	Yantic River	Auto-walk	1
Susquetonscut Brook	Yantic River	16.0	
Quinebaug River			3, 5, 8, 7, 2, 3, 5, 5, 12
Shetucket River			8, 4, 8
Yantic River			3, 2.5, 5, 3.5, 2.5

Table 2. Criteria used to identify potential spawning areas for anadromous salmonids.

Gravel size	1/4–6 in	Belding 1934; Briggs 1953; Burner 1951; Jones 1959
% sand, silt & mud of bottom	0–15%	Burner 1951; Foye et al. 1969; Warner 1963
Water depth	0.33–4 ft	Andrew & Green 1960; Belding 1934; Briggs 1953; Burner 1951; Foye et al. 1969
Water velocity	1–4 ft/sec	Briggs 1953; Burner 1951; Jones 1959

The number of female salmon/m^2 of potential spawning area was calculated as follows:

No. females = 1/Avg. redd area X Inter-redd factor

The average redd areas were: coho salmon, 2.84 m^2 (Burner 1951); Atlantic salmon, 2.76 m^2 (Belding 1934); and sea-run brown trout, 2.4 m^2 (Hardy 1963); and the average inter-redd space factor was 4 (Burner 1951). Rounded off to the nearest 0.1, the average number of spawning females was 0.1 for the three species of anadromous salmonids.

The number of smolts produced that would survive and go to sea was obtained by assuming a 0.01 survival of the eggs of Atlantic salmon and sea-run brown trout and a 0.02 survival of the eggs of coho salmon as follows:

Smolt Production = 0.01 or 0.02 X (# females/area) X (Avg. # eggs/female),

where the average number of eggs/female was coho salmon, 2750 (Allen 1958, Rousenfelt 1957, Salo and Bayliff 1958, Staufer 1970); Atlantic salmon, assuming 10 to 16% of the run would be repeat spawners, 11,500 (Baum and Meister 1971, Rousenfelt 1944, Warner 1963); and sea-run brown trout, assuming 10 to 16% of the run would be repeat spawners, 11,800 (Hardy 1963).

The total size of the spawning run was obtained by assuming 0.03 survival of the smolts and was divided into (1) the spawning population [No. females/area X 2 + 20% No. females/area X 2 (the latter factor to insure that all redds are utilized)] and (2) the harvestable population (total run - spawning population).

Possible effects of fall discharge fluctuations on the potential spawning runs were estimated by evaluating the mean monthly discharges of the Thames River into Long Island Sound (data obtained from U.S.G.S. monthly releases) for the September-January period with these same estimates for the last 20 years. Based on our observations of stream conditions (velocity and depth) we arbitrarily assumed that any month in the past 20 years that had more than 60% reduction in discharge compared to the period Sept 1971-Jan 1972 would have the potential of seriously reducing the number of spawning areas.

RESULTS

Most of the potential spawning areas for anadromous salmonids were above the major dams on the Quinebaug and Shetucket Rivers. Fig. 1 shows the total number of potential spawning areas in relation to obstructions. All of these major dams, except Jewett City on the Quinebaug River, are for power generation and subject to

licensing by the Federal Power Commission. A potential spawning run that could be developed (Table 3) may be significantly larger if the Quinebaug River between Danielson and Canterbury were utilized for spawning. Potential spawning areas frequently could be reduced because of low flows during fall and winter because two consecutive months of low flow occurred approximately every four years, three consecutive months every five years, and all months once in the last twenty years.

DISCUSSION

The potential spawning runs we propose allow anadromous salmonids access to areas in the Moosup and Fivemile Rivers of the Quinebaug River Watershed,and Merrick Brook and the Natchaug, Fenton, and Mount Hope Rivers of the Shetucket River Watershed. Since the first two dams on the Quinebaug and the first three dams on the Shetucket River are associated with power generation and much of the potential run must pass over them, we shall discuss them first. Large fishways would have to be constructed over these dams to accommodate, not only an anadromous salmonid run, but also large runs of alewife, blueback herring, and American shad that would utilize them (Clark 1973). There would probably be no competition for the large volumes of water required to operate these fishways in spring, but there often would be in fall. Assuming the fishways would have priority during fall, there could be reduced power generation, even using a flexible generation schedule, during months of low flow.

Large fishways or other fish passage facilities would also have to be constructed on the last major dam on the Quinebaug River (at Jewett City) and the two dams on the Natchaug River. There would be no competition for water in the fall on the latter two dams because the upstream dam (Mansfield Hollow) is a flood control dam and is drawn down in the fall.

We recommend the Alaskan steeppass fishway, a modified denil, for all of the other fishways. They have successfully passed coho salmon in Michigan (Borgeson 1970) and king salmon in Alaska (Zeimer 1962) and being a denil type will pass American shad, alewife, and blueback herring (Decker 1967). This type of fishway would be the most economical as the high cost of onsite construction would be reduced because it is made in prefabricated sections (aluminum alloy) and would be easily transportable.

The potential spawning runs we estimated could be obtained are probably minimum because (1) marginal areas were not included, (2) many additional areas will be available when all pollution control facilities (presently required) are complete, and (3) additional areas can be developed by construction of stream improvement structures. We also feel that if young fish utilize the Quinebaug and Shetucket Rivers as nursery areas that greater numbers will survive this freshwater stage than if they remain in the tributary stream in which they were spawned. Notwithstanding the fact that consecutive months of low water flow could periodically reduce the population, we feel our estimates are much lower than can be expected.

Development of an Atlantic salmon or sea-run brown trout fishery would probably require stocking to (1) supplement natural reproduction in years of poor smolt survival or loss of spawning areas due to low waters, and (2) increase the harvestable stock for fishing once a demand for the fishery was created. A coho salmon fishery would require stocking just to sustain itself (assuming our survival figures are reasonable). Since harvest could be controlled, within limits, a fishery should be closely monitored.

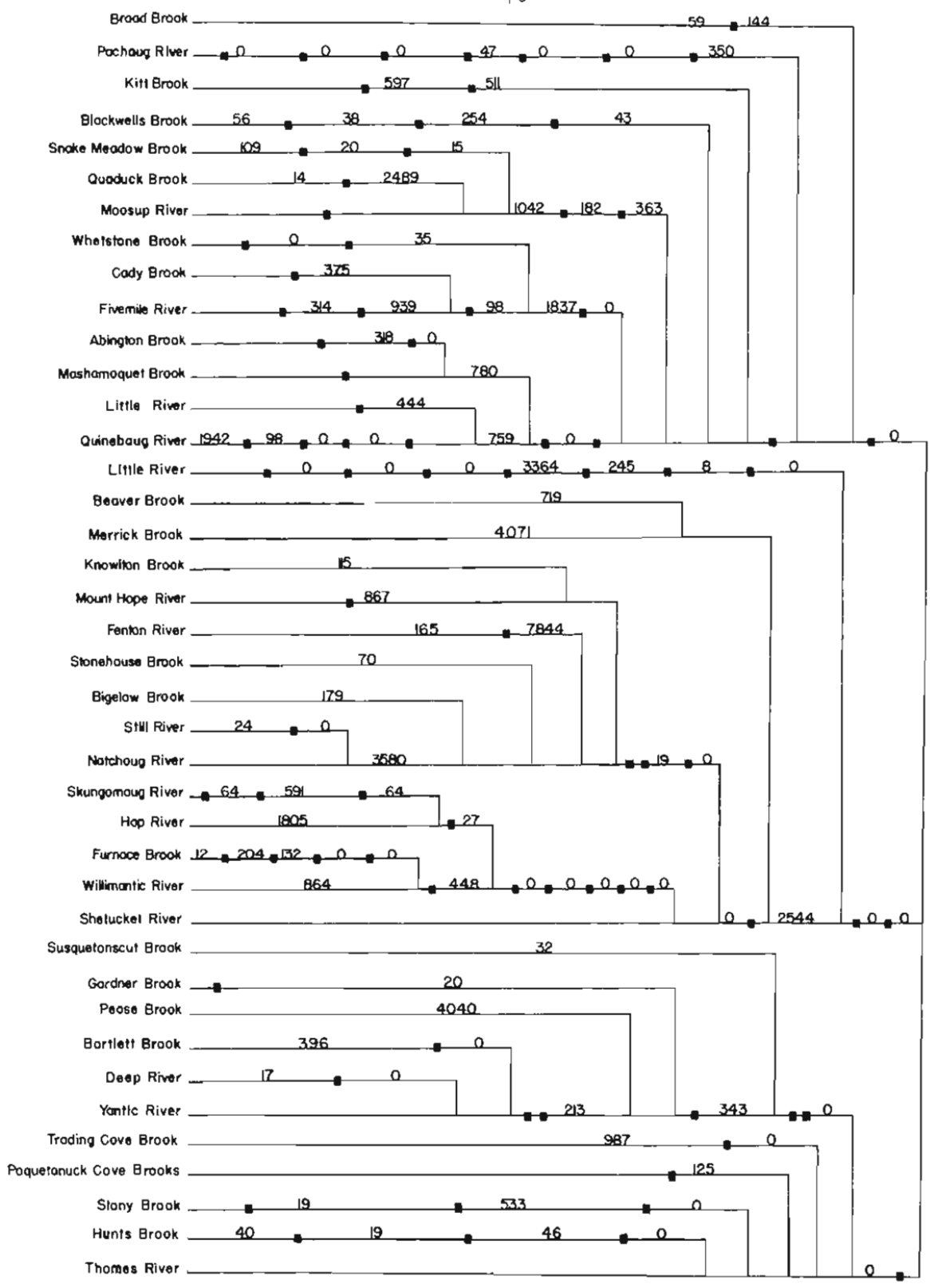

Fig 1. Potential spawning areas for anadromous salmonids in the Thames River Watershed of Connecticut. Dams are shown in solid vertical bars and spawning areas are in m^2.

Table 3. Potential spawning runs of anadromous salmonids in selected areas of the Thames River Watershed.

Stream (Ascending Order from Mouth of Thames Estuary)	No. of Smolts Produced			Total Spawning Run			Harvestable Population**	
	AS*	SRB*	CS*	AS*	SRB*	CS*	AS*	SRB*
Poquetanuck Cove Brooks	1,495	1,534	715	45	46	21	14	15
Broad Brook	1,610	1,652	770	48	50	23	15	17
Pachaug River	4,025	4,130	1,925	121	124	58	37	40
Kitt Brook	12,765	13,098	6,105	383	393	183	157	167
BlackwellsBrook	460	472	220	14	14	7	5	5
Moosup River	18,285	18,762	8,745	549	563	262	167	181
Snake Meadow Brook	230	236	110	7	7	3	2	2
Quaduck Brook	28,635	29,382	13,695	859	881	411	261	283
Fivemile River	33,005	33,866	15,785	990	1,016	474	301	327
Cady Brook	4,370	4,484	2,090	131	135	63	40	44
Merrick Brook	46,805	48,026	22,385	1,404	1,441	672	427	464
Beaver Brook	8,280	8,496	3,960	248	255	119	75	82
Natchaug River	41,400	42,480	19,800	1,242	1,274	594	378	410
Fenton River	90,160	92,512	43,120	2,705	2,775	1,294	823	893
Mt. Hope River	10,005	10,266	4,785	300	310	144	89	99
Knowlton Brook	1,380	1,416	660	41	42	20	12	13
Stonehouse Brook	805	826	385	24	25	12	8	9
Bigelow Brook	2,070	2,124	990	62	64	30	20	22
Totals	305,785	313,762	146,245	9,173	9,415	4,390	2,831	3,073

*AS indicates Atlantic Salmon; SRB indicates Sea-run Brown Salmon; and CS indicates Coho Salmon.

**Since the spawning population of coho salmon required is 6382 fish, this population cannot perpetuate itself.

Although we believe the native Atlantic salmon should be the anadromous salmonid introduced into the Thames Watershed, this is impractical in the foreseeable future because the State of Connecticut is committed to reintroducing them into the Connecticut River and all Atlantic salmon produced are required for that project. Both of the exotic species have been tried in the Northeast, with varying degrees of success, and, assuming certain problems are solved, could be successfully introduced into the Thames Watershed. The choice of species should be dependent on the kind of fishery that is desired in relation with the other fisheries currently in the Watershed and the proposed recreational uses of the area.

We recommend that this resource be developed immediately because (1) the effluent sources in the Thames River System are being controlled, and (2) this area of Connecticut still has much undeveloped and state controlled land in the areas we proposed to devote to anadromous fishes. Many other recreational activities could be carried out on the same areas utilized by anadromous fishes.

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A survey of the diseases and parasites of fishes of the Thames River Watershed, Connecticut

Richard L. Wolke[1]

INTRODUCTION

A study of the diseases of fish occurring in their natural environment has not been conducted in the State of Connecticut since the investigation of Hunter (1942). This excellent work concerned itself primarily with the parasitic diseases due to helminths and protozoans. No histopathological survey was conducted nor were diseases due to other infectious, toxic, or physical agents considered.

The field of Ichthyopathology is presently in its infancy. Although a few specific diseases of economic importance have been intensively studied no large scale histopathological survey of naturally occurring fish diseases has been attempted. For this reason such a survey was envisioned by the author in conjunction with an ongoing survey of fish present in the Quinebaug-Thames River System, Connecticut.

The justifications for such a disease study are obvious. Fish are an important recreational and food resource. Failure to study disease processes in so important an aquatic animal would be to omit from consideration a key variable in the conservation of our existing aquatic environment. Information regarding this variable has as its immediate reward knowledge of processes which may cause decreases in numbers of these animals. Such decreases may be evidenced by subsequent decreases in higher vertebrates (birds and mammals) which use fish as a major food source and by lowered angler productivity.

Of less obvious significance, studies of disease among fish populations yield information which aid diagnosis and control of diseases in aquaculture projects, aid the pathologist in classification of pathological reactions and their pathogenesis in poikilothermic vertebrates, and which may uncover model-systems of importance in the study of diseases of man. Furthermore, these investigations elucidate both the relationship of pollution to disease processes with the possible use of fish as pollution monitors and, the role of fish in zoonoses.

With these justifications in mind, the objectives of this study were twofold:

1. To obtain a qualitative and quantitative survey of the diseases and parasites present in the fish of the Quinebaug-Thames River System, Connecticut.

2. To obtain normal and pathological histological sections of varying species of freshwater and anadromous fishes which might serve as base data for later investigations and allow description of the manner in which these animals react to pathological processes.

[1]Assistant Professor of Animal Pathology, University of Rhode Island, Kingston, Rhode Island 02881.

MATERIALS AND METHODS

Thirty species of fish were obtained (Tables 1 and 2) from the Thames River Watershed for one year (1969-70). Bacteriological, gross, and histopathological examinations were conducted on a total of 331 fish.

Necropsy Examination

Specimens were necropsied immediately or stored at 8 C for a period not exceeding 24 hours prior to necropsy. All organs were examined grossly and representative sections of major organs were fixed in 10% formalin for histopathological examination.

Fixed tissue was embedded in paraffin, sectioned at 6 microns, and routinely stained with heamotoxylin and eosin. Special stains included Wolbach Giemsa, Lugols Iodine, Toluidine Blue-O, Periodic Acid-Schiff, Brown-Bren, Grocott, Ziehl-Neilsen, Feulgen, Methyl Green-pyronin Y, and Mallorys PTAH.

Formalin-fixed material used for electron microscopy was washed in 0.1 M sodium phosphate buffer, treated for 1 1/2 hours in a 2 per cent solution of osmium tetroxide in the same buffer, dehydrated in alcohol, and embedded in Epon-Araldite. Thin sections were cut with glass knives using the LKB ultramicrotome III, double stained with uranyl acetate and lead citrate and examined with the JEM T6S electron microscope.

Sections approximately 1 micron in thickness were also cut from the same Epon-Araldite embedded material, double stained with paragon multiple stain and toluidine blue and examined by light microscopy.

Bacteriological Examination

Each fish necropsied was opened aseptically by means of a flamed scalpel and the following organs cultured: peritoneum, spleen, liver, and kidney. Initial bacterial isolation was made on tryptose agar plates and incubated at 37 C for 16 to 24 hours. Lesions apparent on gross observation were cultured separately on tryptose or blood agar.

Portions of the hind gut were placed routinely in SBG Sulfa enrichment broth for Salmonella sp isolation and incubated at 43 C for 24 hours. Growths were then plated on BG Sulfa agar and incubated at 37 C for 24 hours. Characteristic Salmonella colonies were picked and TSI Agar slants inoculated. If TSI slants were positive, urea, dulcital and lysine decarboxylase media were in turn inoculated. Final identification was made by serological methods.

Parasitological Examination

The external surface of all fish was examined with a hand lens. Samples of gill, liver, foregut, and hindgut were placed in tap water and examined within four hours. Recovered parasites were fixed in A-F-A (alcohol-formalin-acetic acid) fixative, dehydrated, stained (trematodes, cestodes, and acanthocephalids) with Harris' haemotoxylin and mounted after the method of Meyer and Penner (1962).

Table 1. Fish examined from the Thames River Watershed, Connecticut.

	# males examined	# females examined	# unknown sex examined	# normal	# not examined for parasites
Alosa pseudoharengus (Wilson) alewife	11	9		15	
Anguilla rostrata (Lesueur) American eel		5	7	1	
Caranx hippos (Linnaeus) crevalle jack	1			1	
Catostomus commersoni (Lacépède) white sucker	13	21	1	25	1
Cyprinus carpio Linnaeus carp	14	7	2	8	2
Erimyzon oblongus (Mitchill) creek chubsucker		1			
Esox niger Lesueur chain pickerel	3	10		9	
Fundulus heteroclitus (Linnaeus) mummichog		2		1	1
F. majalis (Walbaum) striped killfish	3				1
Ictalurus catus (Linnaeus) white catfish	13	8	1	10	1
I. nebulosus (Lesueur) brown bullhead	10	6		9	1
Lepomis gibbosus (Linnaeus) pumpkinseed	7	2	1	2	
L. macrochirus Rafinesque bluegill	2	1			
Microgadus tomcod (Walbaum) Atlantic tomcod	3	3		3	
Micropterus salmoides (Lacépède) largemouth bass	2	6			1
Morone americana (Gmelin) white perch	31	34		16	1
M. saxatilis (Walbaum) striped bass	11	6		1	1
Myoxocephalus octodecemspinosus (Mitchill) longhorn sculpin	2			2	
Notemigonus crysoleucas (Mitchill) golden shiner	7	4	2	6	
Notropis cornutus (Mitchill) common shiner	7		2	4	
N. hudsonius (Clinton) spottail shiner	1		5	6	
Osmerus mordax (Mitchill) rainbow smelt	3	4		3	
Paralichthys dentatus (Linnaeus) summer flounder		1		1	
Perca flavescens (Mitchill) yellow perch	9	9		7	
Pomatomus saltatrix (Linnaeus) bluefish	1		1	2	1
Pomoxis nigromculatus (Lesueur) black crappie	7	3		5	1
Pseudopleuronectes americanus (Walbaum) winter flounder		1	1	1	
Salmo trutta Linnaeus brown trout	1	1		2	
Semotilus corporalis (Mitchill) fallfish			1	1	1
Syngnathus fuscus Storer northern pipefish		1		1	
	162	145	24	142	13

Table 2. Number of fishes by months and rivers.

Months	Rivers							
	Thames	Quinebaug[1]	Quinebaug[2]	Quinebaug[3]	Shetucket[4]	Shetucket[5]	Yantic	Totals
1969								
Mar-Jul	3	0	0	3	0	0	0	6
Aug	21	7	10	5	0	0	0	43
Sep	10	0	11	0	3	9	0	33
Oct	6	30	6	0	11	6	0	59
Nov	12	12	0	0	0	0	0	24
Dec	11	0	0	0	5	0	0	16
1970								
Feb	0	0	0	6	0	0	0	6
Mar	24	0	0	6	1	5	0	36
Apr	24	0	0	6	0	0	0	30
May	18	12	0	0	0	6	6	42
Jun	12	6	0	0	0	0	6	24
Jul	0	12	0	0	0	0	0	12
	141	79	27	26	20	26	12	331

[1]Quinebaug River from the mouth upstream to Jewett City.

[2]Quinebaug River from Jewett City to Butts Bridge Road.

[3]Quinebaug River from Butts Bridge Road to Danielson.

[4]Shetucket River from mouth upstream to Baltic.

[5]Shetucket River from Baltic to Willimantic.

PATHOLOGICAL FINDINGS

Lesions of the Brain

Lesions of the brain were rare. In only 5 of 327 brains examined were abnormalities noted. These pathological changes were classified either as inflammatory reactions (non-suppurative) or physical disorders (cysts and space-occupying lesions).

Focal non-suppurative encephalitis. Focal non-suppurative encephalitis was present in 3 brains and was associated with Aeromonas liquefaciens septicemia in 2 of these instances. The lesion was characterized by focal accumulations of microglia cells with occasional lymphocytes resembling the glial nodules so characteristic of viral encephalitidies of higher vertebrates (Fig. 1). Some of the reactive microglia cells were hypertrophied, vesicular in appearance, and in relation to areas of necrosis. Perivascular cuffs and satellitosis were also present in conjunction with the focal gliosis. The etiology of this condition is unknown but its occurrence with a known Aeromonas septicemia in 2 of 3 cases appears more than coincidental.

Parasitic cavitations and cysts. Parasitic infestations of the brain were present in two Morone americana and one Morone saxatilis In all three instances, the causitive agents were unidentified metacercaria and the reactions elicited were of two types: (1) simple microcavitations or space-occupying lesions and (2) microcavitations surrounded by some inflammatory response. In the first instance metacercaria were present surrounded by a clear area bounded in turn by displaced parenchyma. No cyst wall or inflammatory reaction was present. In the second instance, reactive cells were present at the periphery of the displaced tissue. These cells included accumulations of microglia cells (rod cells and gitterzellen), lymphocytes and a few granular leucocytes (heterophiles). Many of the gitter cells contained a yellow-brown pigment resembling hemosiderin though little hemorrhage was observed (Fig. 2). It is probable that these reactive foci were products of the inflammatory response to metacercarial migration tracts. Parasitic microcavitations of the brain without inflammatory response are not unusual in higher vertebrates.

In one case a true microsporidial cyst was present in the optic tectum of a Morone americana. The cyst was filled with pansporoblasts and mature spores of an organism resembling Glugea. The cyst wall was thin (approximately 1 micron), hyaline and acidophilic. No inflammatory reaction was elicited (Fig. 3).

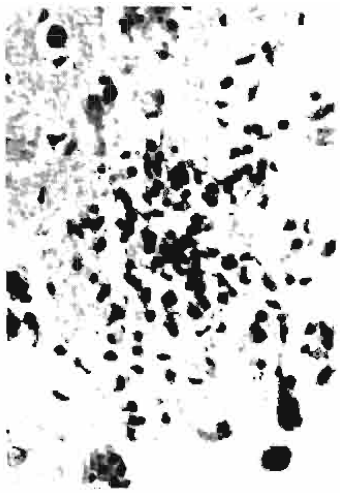

Fig. 1. Brain. Focus of microglial cells & lymphocytes. H&E X400.

Fig. 2. Brain. Metacercaria eliciting mixed inflammatory response with pigment filled phagocytes. H&E X160

Fig. 3. Brain. The optic tectum contains a microsporidial cyst (arrow). Note lack of inflammatory response. H&E X25.

Lesions of the Gill

Lesions observed in the gill included circulatory changes (congestion and hemorrhage), inflammatory processes (necrosis and mononuclear cell response), growth disturbances (hypertrophy, hyperplasia), and physical disorders (cyst formation).

Congestion. Congestion of the branchial vessels was a common finding in all species of fish and was apparent as a swelling of the branchial afferent and efferent vessels due to excessive numbers of red blood corpuscles. In a few instances a

peculiar manifestation of congestion was seen characterized by collections of red blood cells in the lamellar capillaries resulting in localized globoid swellings of the lamella. These swellings occurred at any point along the lamellar capillary and were random in their lamellar distribution (Fig. 4). The lesion resembled hemorrhagic gill disease described by Wood and Yasutake (1957) and lamellar capillary aneurysms secondary to ammonia toxicity (Bullock 1972). The etiology of the erythrocytic globoid accumulations could not be determined; however, in one instance the lesion was seen in conjunction with branchial trematodiasis.

Hemorrhage. Hemorrhagic lesions were present with some frequency and appeared due to trauma from gill nets or other causes. Rupture of vessels resulted in the accumulation of blood cells between lamellae and between gill filaments.

Necrosis. Frank necrosis of lamellae was seldon observed. When present, the necrosis was of the coagulation type with pyknosis and resulted in a complete loss of normal gill architecture. The inflammatory response was predominantly lymphocytic with a scattering of histiocytes (Fig. 5). This necrosis was of unknown etiology.

Hypertrophy and hyperplasia. By far the most common lesions observed in the gill were hypertrophy and hyperplasia of the lamellar epithelial cells, often in conjunction with mucous cell hypertrophy and proliferation. Under normal circumstances lamellar epithelial cells are present as a single layer, flattened and in close contact with the underlying capillary endothelium. The first manifestation of the lesion was a swelling and hollowing of the epithelial cell. This was followed by obvious hyperplasia of the epithelium resulting in layers of cells which, due to their proliferation, were often responsible for lamellar fusion (Fig. 6). The hyperplasia appeared to begin most commonly at the base of lamellae and to progress outward.

Fig. 4. Gill. Distal lamellae are swollen, globose & filled with blood cells. H&E X160.

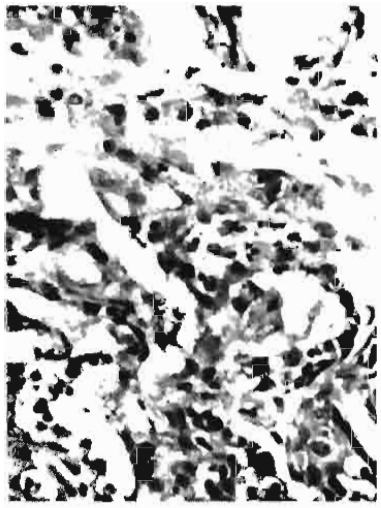

Fig. 5. Gill. Necrosis of distal lamellae with mild lymphocytic influx. Filament at bottom. H&E X400.

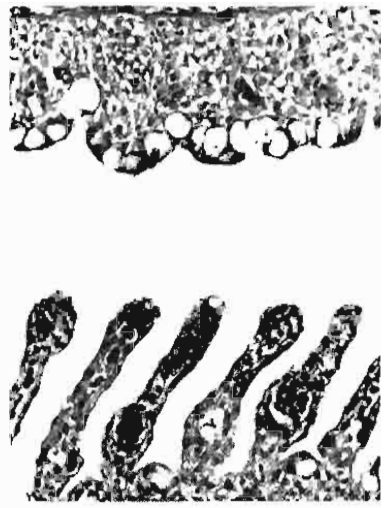

Fig. 6. Gill. Epithelial hyperplasia & hypertrophy resulting in lamellar fusion in filament at top. Lamellar epithelium of bottom filament is mildly hyperplastic. H&E X160.

Branchial epithelial hypertrophy and hyperplasia was observed in conjunction with Trematodiosis (Microcotyle sp, Podocotyle sp, Tetranochus sp, Ascocotyle sp, Heterophyidae and Echinostomidae), Trichodiniasis, Chilodeneliasis and Epitheliocystis (Fig. 7). The lesion was often present in the absence of any etiological agent. It is however, a common sequellae to the myxobacteria (Cytophaga sp, Soprocytophaga sp) causative agents of bacterial gill disease.

Cysts. Bedsonial, protozoal, and helminth agents were present within the gill tissue in sacs best classified as cysts.

Epitheliocystis disease, first described by Hoffman et al. (1969) and later by Wolke et al. (1970) is caused by a Bedsonial agent and was responsible for cysts of the lamellae in 8 Morone saxatilis and 5 Morone americana. Machiavello positive organisms were present early in the course of the disease within budding and hypertrophic epithelial cells. Later large aggregates of basophilic organisms (50 μ) were present at the tip of affected lamellae (Fig. 8). These aggregates were surrounded by a hyaline, acidophilic basement lamina of varying thickness which contained multiple nuclei. An epithelial layer 3 to 4 cells thick, bordered the whole structure. Electron microscopic examination revealed these organisms to possess a cell wall and membrane and to be of the Chlamydiae or psittacosis/lymphogranuloma-venereum/trachoma group (Fig. 9).

Protozoal cysts were Myxosporidial in origin. They were found primarily within gill lamellae. When stained with hematoxylin and eosin dyes, their cyst wall was composed of a hyaline acidophilic material at the periphery of which were flattened basophilic nuclei resembling the nuclei of endothelial cells. In the process of growth these cysts pushed the neighboring lamellae to one side (Fig. 10). The cysts did not elicit any inflammatory response. Generic identification was not always possible by means of histological examination but was greatly aided by the use of Giemsa and Periodic acid-Schiff stains.

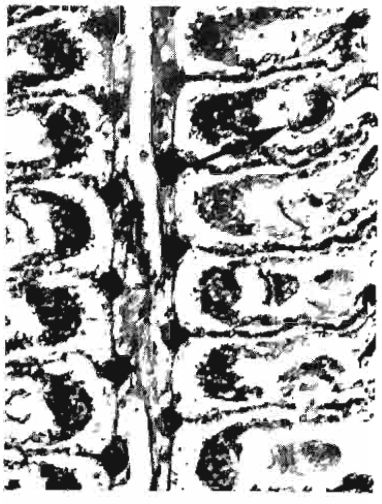

Fig. 7 Gill. Trichodina sp between lamellae (arrows). H&E X60.

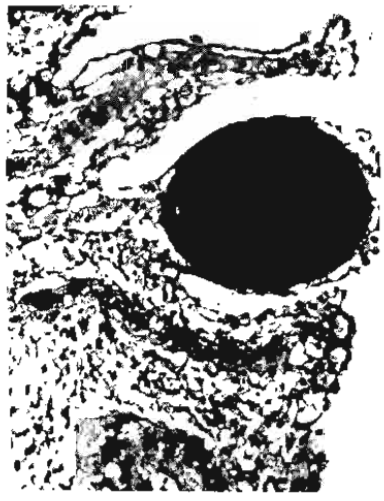

Fig. 8. Gill. Mass of strongly basophilic amorphous encapsulated organisms occupying swollen tip of lamellae. Epitheliocystis (Bedsonia). H&E X160.

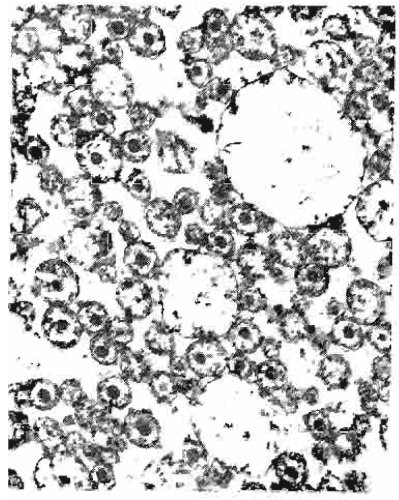

Fig. 9. Gill. Electron micrograph of intracellular epitheliocystis organisms. Uranyl acetate X17,040.

Helminth cysts of branchial tissue were due to penetrating metacercaria and were observed in gill filaments only. The cysts were large, often apparent to the unaided eye and lined by a flattened epithelium. They were present only within the gill filaments. Metacercaria occupied 50 to 75% of the total cyst area. They elicited little or no inflammatory response after encystment.

Lesions of the Liver

Liver lesions were common in all species of fish examined. Examples of inflammatory processes (granulomas, non-purulent reactions, necrosis and fibrosis), metabolic disorders (fatty metamorphosis, nodular hyperplasia), growth disturbances (bile duct proliferation), and physical disorders (cyst formations) were observed.

Focal necrosis. An acute focal necrosis with diffuse distribution was present in the liver of a Cyprinus carpio, a Fundulus heteroclitus, and a Morone americana. Two of these fish, C. carpio and M. americana, were collected simultaneously and cultures of peritoneal swabs yielded Aeromonas liquefaciens. The lesion was characterized by coagulation necrosis of hepatocytes and pyknosis and centrally, a loss of cellular outline. The lesion resembled acute "typhoid nodules" of salmonellosis in higher vertebrates (Fig. 11).

Non-purulent inflammations. Focal collections of mononuclear cells diffusely distributed throughout the liver parenchyma (Fig. 12) or with a pericanicular distribution were present with some frequency. These collections were composed of uniform cells with vesicular nuclei and poorly outlined cytoplams. The cells resembled immature members of the lymphocytic series but could not be classified as true reticuloendothelial cells.

Necrotic hepatocytes were often observed in the center of the mononuclear foci. Occasional granulocytic leucocytes were also present about the periphery of the lesion. No cause for this lesion was found.

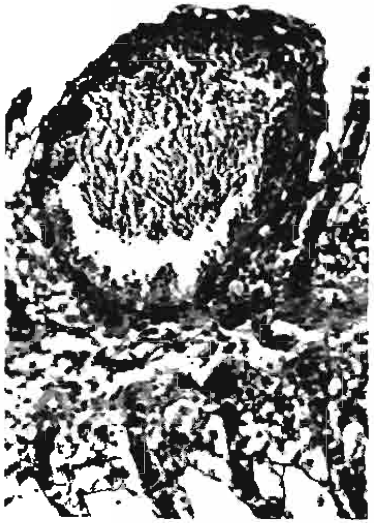

Fig. 10. Gill. Intralamellar myxosporidial cyst eliciting some epithelial hyperplasia. Organisms are readily apparent within cyst walls. H&E X160.

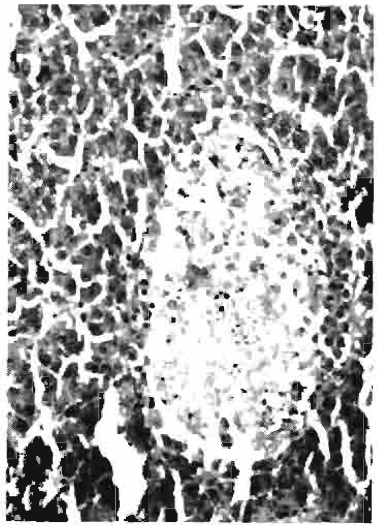

Fig. 11. Liver. Focus of coagulation necrosis. H&E X160.

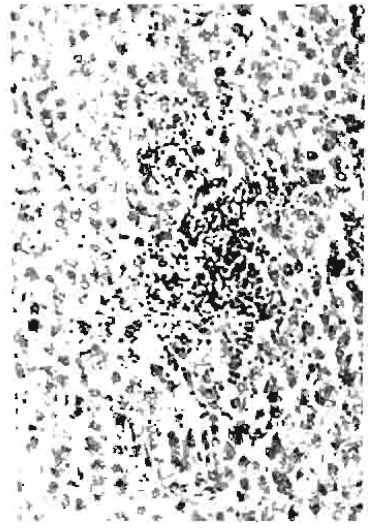

Fig. 12. Liver. Focus of mononuclear cells within liver parenchyma. H&E X160.

Granulomatous inflammation. Fish appear capable of responding with granulomatous inflammatory processes similar in tissue and cellular components to that of homeothermic vertebrates. These granulomas may be divided into foreign body and infectious types, depending on the agent eliciting the response. Fish examined in this survey had granulomas of the infectious type.

The infectious granulomas observed were parasitic in origin. Aberrant larval forms of Pomphorynchus sp elicited severe reactions as did the larval forms of Proteocephalus ambloplites. While viable parasites were capable of eliciting this reaction, granulomas were more frequent in response to degenerating parasites. Degeneration often led to calcification or to the formation of structures resembling cholesterol clefts (Fig. 13). Surrounding the parasite was a zone of fibroblasts, epithelial cells and reticulo-endothelial cells (histiocytes). At the periphery of this reaction lymphocytes and occasional granulocytic leucocytes (heterophiles, eosinophiles) were present. The degree of reaction appeared directly related to the degree of parasite degeneration. In instances where the parasite was completely destroyed the central area was occupied by whirling fibroblasts. No giant cells were present.

A granuloma of characteristic histologic appearance was present in the livers of 14 Morone americana and 2 Morone saxatilis. The granuloma was of uncertain etiology but was apparently related to helminth migrations. Grossly the lesion was often present as a brownish-black waxy material within the hepatic parenchyma. In a number of instances the liver tissue could be removed from elongated (4-5 cm) branching tubular collection of this material which was reminiscent of a bile duct cast. Microscopically, even in its acute manifestations, the granuloma was well walled off from the hepatic parenchyma. Stained with hematoxylin and eosin it was characterized by a central eosinophilic, granular, amorphous material containing collections of hemosiderin pigment. This area was in turn bounded by a mature fibrous capsule. Lying outside the capsule was an area of epithelioid and reticulo-endothelial cells. Surrounding these reactive cells was a thin, immature fibroblastic wall with diffusely distributed heterophiles (eosinophiles) among the fibroblasts (Fig. 14). This double fibrous encapsulation was unique. The amorphous material occupying the center of the granulomas was acid-fast using the Ziehl-Neilsen technique. The lesion, however, did not resemble piscine tuberculosis nor were colonies of acid-fast bacteria apparent. In two or three instances the center of the granuloma was occupied by helminth fragments of uncertain identification. Parasites recovered from the liver of Morone americana included only these few fragmented unidentifiable encysted helminths and some streigeid trematodes.

Fibrosis. Cirrhosis is defined as a diffuse progressive fibrosis of the liver parenchyma. Focal fibrosis of the parenchyma is not considered in the strict sense as cirrhosis. The livers of the fish examined in this survey were not affected by diffuse fibrosis but focal scarring was present.

Focal fibrosis was present in one instance in the absence of a known etiologic agent. The whirling fibroblasts had replaced hepatocytes and in turn were surrounded by liver cells undergoing fatty metamorphosis (Fig. 15). Other areas of this liver contained collections of hepatocytes with lipid droplets but degeneration had not progressed to frank necrosis or post-necrotic scarring. The relationship between fatty change and subsequent cirrhosis is well known and it is interesting to speculate that the case observed here may have been an early stage in the development of this condition.

Fig. 13. Liver. Focal granuloma, the center of which contains structures resembling cholesterol clefts. H&E X160.

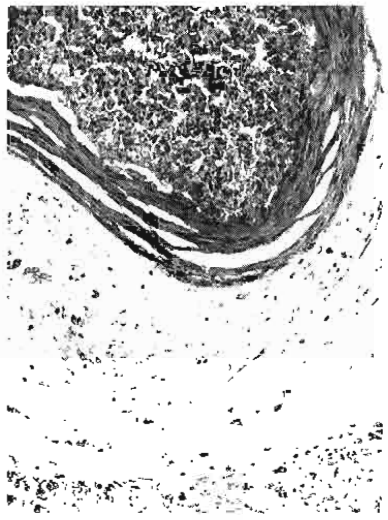

Fig. 14. Liver. Granuloma, with a double connective tissue encapsulation. Note zone of inflammatory cells between connective tissue walls. H&E X160.

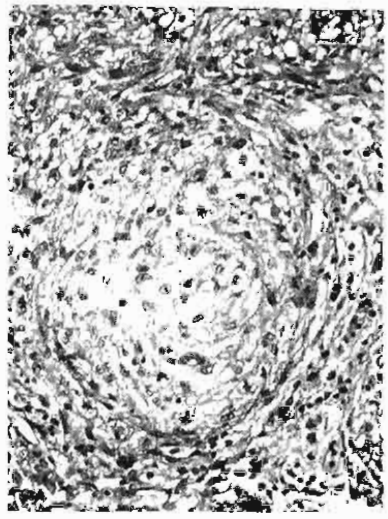

Fig. 15. Liver. Focus of fibrosis surrounded by lipid laden hepatocytes. H&E X160.

Other instances of focal fibrosis (scarring) were present as healing processes following degeneration of parasites within cysts and granulomas.

Fatty metamorphosis. In strict pathological terms, fatty metamorphosis or fatty change indicates an abnormal accumulation of fats within hepatocytes and is of multiple etiology. Heavily lipid laden hepatocytes were observed in a number of fish in this survey, especially Anquilla rostrata. The degree of lipid accumulation appeared seasonal with greatest incidence in the fall. Affected hepatocytes were swollen and clear. Discrete lipid droplets were not apparent. Differentiation from glycogen infiltration was possible only be means of special stains.

A fatty metamorphosis of this nature observed in higher vertebrates would be classified as a lesion but it appears to be a physiological change associated with normal fat metabolism in the fish. Further studies are needed to determine the true significance of this histological change.

Nodular hyperplasia. One example of nodular hyperplasia was present in the liver of a 70.0 cm Anquilla rostrata collected in October 1969. The lesion was apparent grossly as a raised one centimeter diameter mass on the right anterior portion of the organ. Histologically, it was characterized by discrete rounded masses of proliferating hepatocytes which were larger than surrounding cells, more densely stained and with a distinct morula architecture. These cells were observed to compress and push to one side surrounding parenchyma. Nodular hyperplasia in higher vertebrates is usually associated with hepatic lipidosis and is a form of regeneration. In this case no lipidosis was present and the cause of the hyperplasia could not be determined. Differentiation of this lesion from hepatic adenoma is extremely difficult because of the well known capacity of the liver to regenerate following injury. It is, therefore, possible that this nodular hyperplasia may be an example of early adenoma (Dawe et al., 1964).

Adenomatous hyperplasia of the bile duct. Bile duct proliferation, best described as adenomatous hyperplasia, was present in the livers of four Morone americana (Fig. 16). Two of these fish were collected simultaneously. The lesion was similar to the cholangiomatous change described in conjunction with salmonid hepatoma and that previously described in Catostomus commersoni (Yasutake and Rucker 1967; Dawe et al., 1964). It was not apparent, however, on gross examination. Focal areas of proliferating bile ducts in a fibrous network were diffusely scattered throughout the liver parenchyma. Epithelial cells lining the ducts were 3 to 4 cells thick and in some instances obliterated the livers of the resulting ductule. Mitotic figures were present but sparse. In one instance a protozoal organism resembling Eimeria sp was present within epithelial cells.

Parasitic cysts. Cysts containing parasites were common. They were simply microcavitations or space-occupying lesions and elicited no inflammatory reaction (Fig. 17). Trematode matacercaria such as Posthodiplostomum minimum were often the eliciting agents. The cyst wall was composed of a thin layer of mature fibrous tissue lined in turn on its inner surface with a pale staining eosinophilic hyaline material. Unidentified parasites were found on occasion within the bile ducts of Esox niger. No reaction was present.

Lesions of the Heart

Lesions of the heart were relatively frequent and included pericarditis (mononuclear, diffuse, and granulomatous), myocarditis (mononuclear, diffuse and granulomatous), myocardial necrosis and protozoal infections.

Diffuse pericarditis. The pericardium of the fish under normal circumstances is a relatively cellular organ containing both granulocytic and mononuclear cells. Diagnosis of inflammation is, therefore, subjective. In a number of instances an increase in all cellular elements was observed, which was classified as a diffuse pericarditis characterized by a mixed inflammatory response and occasionally hypertrophy and hyperplasia of the lining mesothelial cells. In one instance this reaction was present with a parasitic infiltration of the tissue surrounding the bulbus arterious which appeared continuous with the pericardium. The parasitic cysts contained unidentifiable debris.

Focal mononuclear pericarditis. Focal infiltrations of the pericardium by mononuclear cells was present in a specimen of Lepomis gibbosus. The cells packed the pericardium in these areas pushing the sac away from the myocardium. Both mature lymphocytes and larger mononuclear cells with vesicular nuclei were present. In its most severe manifestation mononuclear infiltrations of the underlying myocardium was observed (Fig. 18). The etiology of this lesion could not be determined histologically.

Granulomatous pericarditis. Focal granulomas of the pericardium were present in response to migrating parasites.

Metacercaria of Posthodiplostomum minimum minimum in their acute infective phase lacked both parasite and host capsules and elicited a severe epithelioid response with heterophiles (Fig. 19). In more chronic infestations, encapsulation occurred and the granulomatous response persisted.

A unique granuloma characterized by a central zone of acid fast material surrounded in turn by a fibrous capsule bounded by epithelioid cells, heterophiles, and finally surrounded by an outer thinner fibrous capsule was also present within the

pericardium (Fig. 20). This lesion was similar to that seen in the livers of Morone americana and was of uncertain cause, probably helminth in origin.

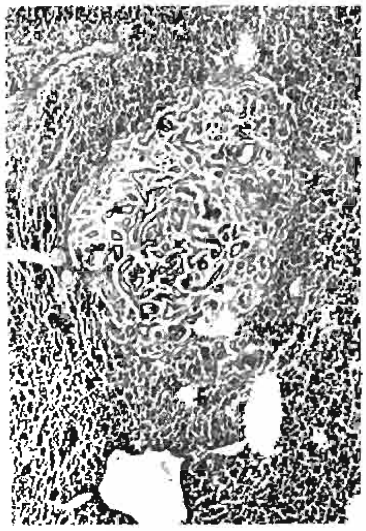

Fig. 16. Liver. Adenomatous hyperplasia of the bile ducts. H&E X60.

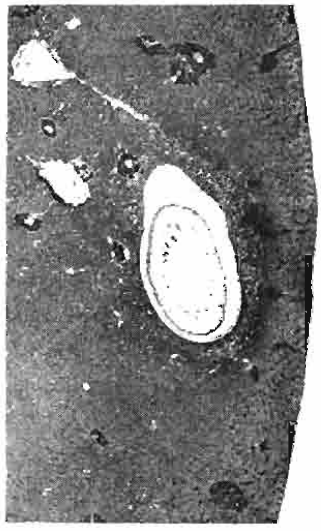

Fig. 17. Liver. Parasitic cyst within parenchyma. Note absence of inflammatory response. H&E X25.

Fig. 18. Pericardium. Focal mononuclear pericarditis of unknown etiology. H&E X160.

Myocardial necrosis. Necrosis of myocardial muscle characterized by broken and swollen fibers undergoing hylinization was observed in the heart of a female Perca flavescens, 20.5 cm in length. The lesion was not apparent at gross examination. Histologically, transverse sections of muscle bundles were quite acidophilic and greatly swollen. Mallory's PTAH stains indicated a loss of striations in affected fibers. Little inflammatory reaction or regeneration was apparent. The lesion was confined to auricular musculature and resembled Zenker's necrosis seen in homeotherms (Fig. 21).

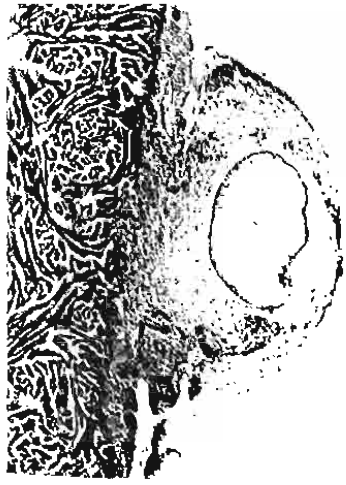

Fig. 19. Pericardium. Focal granuloma containing metacercaria. H&E X25.

Fig. 20. Pericardium. Heavily encapsulated granuloma with acid fast central zone. H&E X160.

Fig. 21. Myocardium. Necrosis with broken and swollen fibers undergoing hylinization. Mallory's PTAH X160.

Focal mononuclear myocarditis. Focal myocardial infiltrations of lymphocytes and larger mononuclear cells with vesicular nuclei and poorly outlined cytoplasm were present in the myocardium below areas of pericarditis. A similar infiltration located in the area of the atrioventricular valves and also involving the endocardium was present in the heart of a Morone americana. These lesions were classified as instances of focal mononuclear myocarditis.

Diffuse myocarditis. Inflammatory conditions must be diagnosed by subjective evaluation of the relative increase in white blood cells and by myocardial necrosis. Increases in the number of polymorphonuclear leucocytes in peripheral blood have been reported in cases of infectious dropsy (Arlacher 1961). It was of interest, therefore, to note an increase in these cells (heterophiles) in the myocardium of Cyprinus carpio with Aeromonas liquefaciens septicemia. This lesion was classified as a diffuse myocarditis,and was seen only in conjunction with cases of proven infectious dropsy (hemorrhagic septicemia; Aeromonas septicemia).

Granulomatous myocarditis. Granulomatous reactions were elicited in myocardial tissue by both viable and degenerating parasites. The lesion was characterized by a fibrous capsule immediately surrounding the invading parasite in turn bounded by epithelioid cells and often hemosiderin laden macrophages.

Lesions of the bulbus arteriosus. The bulbus arteriosis was more frequently involved in pathological processes than was either the pericardium or the myocardium. Focal granulomas of the bulbus, like the pericardium, were due to migrating parasites. Parasitic invasion resulted in simple fibrous encapsulating or more severe reactions with the presence of epithelioid cells. Granulomas with double fibrous encapsulation and heterophiles were also present.

Protozoal cysts due to both Microsporida and Myxosporida were also observed. In one instance endothelial involvement by Glugea sp was quite severe resulting in a marked decrease of bulbar lumenal diameter. Fibrous encapsulation of some Microsporida cysts was also noted.

Lesions of the Gastrointestinal Tract

Lesions were classified as occurring in one of three areas, the gastric area, foregut area, or hindgut, and included acute, mononuclear and granulomatous reactions, and necrosis.

Acute gastroenteritis. Peracute inflammation as evidenced by severe edema and swelling of the gastric lamina propria was noted in a specimen of Ictalurus catus. The lamina propria was thickened and the collagen fibers were widely separated by proteinaceous fluid. Both blood vessels and lacteals were greatly dilated, especially in the area of the transverse muscularis. In one section focal granulomas due to degenerating parasites were noted. Such granulomas were present, however, in other instances in the absence of such a peracute reaction. The cause of this lesion was not determined.

Acute reactions characterized by excessive heterophile infiltrations of the intestinal lamina propria of fish with an Aeromonas sp septicemia were commonly observed. Both the fore and hindgut were involved. The villi were swollen with histiocytes and some lymphocytes but the major inflammatory cell was granulocytic. No necrosis of the mucosa was present in conjunction with the infiltration of inflammatory cells (Fig. 22).

Gastric mucosal necrosis. A small focal area of gastric mucosal necrosis was observed in the stomach of Ictalurus nebulosus. The lesion resembled the acute erosion of histamine toxicity in rodents. There was a loss of mucosal cell outline, pyknosis and karyorrhexis. Paneth cells underlying the area were absent and were replaced by histocytes and frank hemorrhage.

Mononuclear gastritis. The gastric lamina propria of a mature Ictalurus catus was found to be infiltrated with lymphocytes in one quadrant. The infiltration was purely lymphocytic and confined to the base of the villi. No etiologic agent capable of eliciting such a reaction was seen.

Granulomatous enteritis. Granulomas were the most common response to irritation in the piscine gastrointestinal tract. The majority of these lesions were due to viable and degenerating parasites which had invaded intestinal tissue. Parasitic lesions were present in all areas of the gut but were most severe in the hindgut due to penetration by acanthocephalids. Such infestations in Morone saxatilis, Morone americana, and Anquilla rostrata were caused by Pomphorynchus rocci, an ubiquitous parasite, which in all instances elicited a severe reaction. Grossly, the unopened serosal surface of the last 6 cm of the hindgut occupied by P. rocci was covered with 1 mm raised yellowish cysts. The intestine was thickened and firm in consistency. When opened the lumen was found to be filled with masses of adherent yellow acanthocephalids 5 to 6 cm long. Histologically a massive granulomatous reaction was present surrounding the area of parasitic attachments (Fig. 23). The parasite's thorny head was surrounded by an acidiphilic fibrous capsule of varying thickness which in turn was bounded by weakly basophilic, vesicular epitheloid cells. The zone of epitheloid cells was uniform and often 300-400 μ thick. The outer capsule was composed of loose fibrous tissue with a mixed inflammatory response composed of lymphocytes and heterophiles. Granulomas of this nature were found in all areas of the intestinal wall including the subserosa. Penetrations of the intestine occurred leading to peritonitis. Mucosal necrosis and generalized inflammation of the lamina propria was present in conjunction with the focal granulomas.

Other focal granulomas throughout the length of the tract were present in the muscularis and lamina propria of many fish. Often the offending parasite could not be identified due to degeneration. In other instances, larval nematodes were identified within the granulomas found in the transverse and longitudinal muscularis.

A third case of granulomatous enteritis was noted in a Catostomus commersoni (Wolke and Trainor, 1971). The lesion was characterized by a diffuse granulomatous reaction reminiscent of Johnels disease (paratuberculosis) in cattle. The villi were shortened, thickened and swollen to such an extent that the crypts that normally exist between these structures were obliterated and their previous existence was discernable only by the persistence of the lining mucosal cells lying at right angles to the gut lumen. The submucosa was packed with uniform, acidophilic polygonal reticulo-endothelial cells. Giant cells of both the Langhans and foreign body type were dispersed among the reticulo-endothelial cells of the submucosa. Present within the cytoplasm of at least one-half of the giant cells were ovoid or rectangular striated refractile bodies varying in length from 5-10 μ. These organisms were identified as diatoms (Eurotica, Cocconeis, Melosira, Cyclotella, Cymbella, Gomphoneura, Fragilaria, Nitzschia, and Syndia) (Fig. 24).

Coccidiosis. Gastrointestinal coccidiosis is a documented condition of freshwater and marine fish (Amlacher 1961; Lom 1970). A Morone americana had oocysts containing four banana shaped sporozoites within the mucosal cells of the foregut. The organisms were identified as members of the genus Eimeria. Advanced postmortem autolysis prevented proper evaluation of the inflammatory response.

Fig. 22. Hindgut. Massive mixed inflammatory cell influx in lamina propria. Mucosal surface at left. H&E X160.

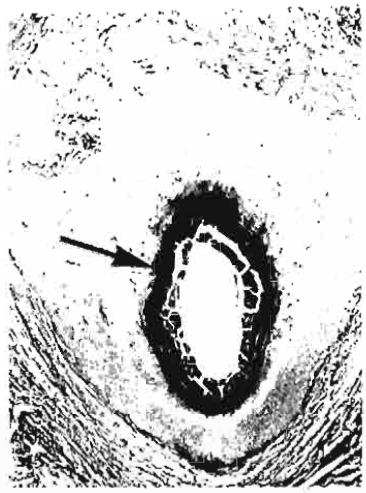

Fig. 23. Hindgut. Massive, well encapsulated granuloma surrounds probosous of Pomphorynchus sp (arrow). H&E X25.

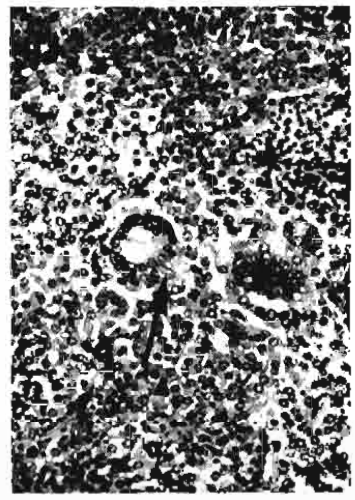

Fig. 24. Hindgut. Diffuse granulomatous reaction within lamina propria. Note foreign body giant cells containing diatoms (Arrow). H&E X160.

Lesions of the Kidney

Interstitial nephritis is a difficult condition to diagnose and this fact must be taken into consideration when pointing out that no instances of diffuse nephritis were observed in this survey. Pathological processes noted included renal tubular dilatation, granulomas, parasitic microcysts, protozoal cysts and trichodiniasis.

Renal tubular dilatation. Approximately one-third of all Cyprinus carpio kidneys examined had lesions of renal tubular dilatation. The dilatation was also noted in Catostomus commersoni and one Pseudopleuronectes americanus. The lesion was characterized by a diffuse distribution of renal tubules containing acidophilic, hyaline proteinaceous casts (Fig. 25). The tubules varied in size from 20-200 μ in diameter. Tubular epithelium was so flattened against its basement membrane that identification of tubule type was impossible, even in instances of beginning dilatation.

Granulomatous nephritis. Granulomas of the kidney were observed in conjunction with degenerating parasites. These lesions were characterized by a central zone of degenerating debris (parasite), a surrounding zone of epitheloid cells and macrophages bounded by a fibrous capsule (Fig. 26). No examples of tuberculous granulomas were noted.

Parasitic cysts. Parasitic microcysts were present in the kidney parenchyma of fish heavily infected with trematode metacercaria (diplostomiasis of Lepomis macrochirus). Little reaction was elicited by these space occupying lesions though zones of hemorrhage, probably marking migration paths, were present (Fig. 27).

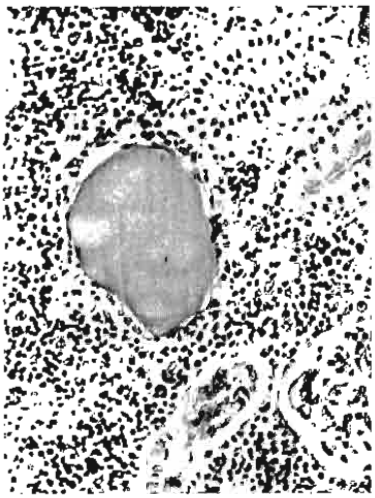

Fig. 25. Kidney. Dialated tubules with acidophilic proteinaceous casts. H&E X160.

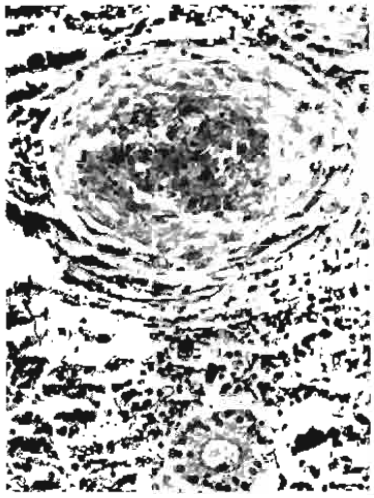

Fig. 26. Kidney. Granulomatous nephritis. H&E X160.

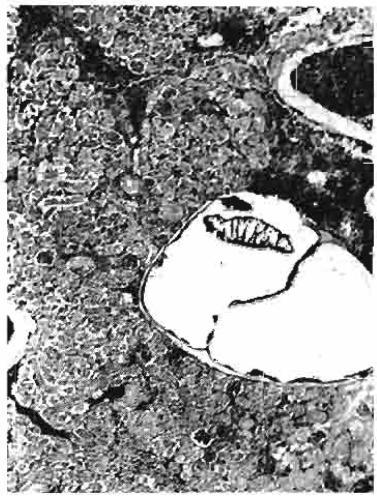

Fig. 27. Kidney. Metacercarial interstitial cyst eliciting no reaction. H&E X25.

Protozoal cysts. Five kidneys contained protozoal cysts and one kidney had Trichodina present in the Wolffian ducts. Examples of both myxosporidiosus and microsporidiosus were observed. The protozoal cysts were round in shape, varied in size to 500 μ in diameter, and contained developing stages of the organisms. The cysts were surrounded by a thin hyaline capsule in turn bounded by narrow connective tissue septae. In one case (Myxosporida) there was a clear zone 20–30 μ in width between the cyst capsule and the fibrous wall (Fig. 28). This zone was occupied by sparsely distributed mononuclear cells with poorly outlined cytoplasm. Protozoal organisms in some instances failed to stain with hemotoxylin and eosin dyes and required Giemsa stain for proper differentiation.

A Wolffian (mesonephiric) duct of a Esox niger contained numerous organisms identified as Trichodina sp. No reaction was noted. This parasite has previously been reported in the bladder of fish (van Duijn 1967) but not to the author's knowledge in the Wolffian ducts (Fig. 29).

Lesions of the Spleen

Changes noted included follicular hypertrophy, granulomatous inflammation, and cyst formation.

Follicular hypertrophy. Hypertrophy of splenic corpuscles was noted in a number of instances (Fig. 30). The significance of this hypertrophy is not known and it is thought to be physiological. In instances of follicular hypertrophy the cells of the follicles resemble undifferentiated members of the reticulo-endothelial system and in some instances these cells contained hemosiderin pigment. In higher vertebrates follicular hypertrophy of this type may be stimulated by disease processes of multiple etiology but no positive relationship between known disease processes and hypertrophy were apparent in this survey.

Fig. 28. Kidney. Encapsulated myxosporidial cyst (arrows) with no inflammatory cell response. X160.

Fig. 29. Kidney. Masses of Trichodina sp within Wolffian duct. Kidney parenchyma at top. H&E X160.

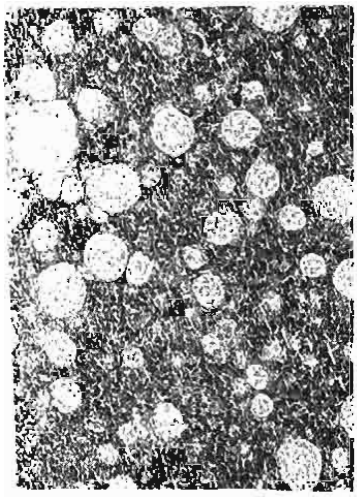

Fig. 30. Spleen. Follicular hyperplasia. H&E X25.

Parasitic granulomas were elicited only by degenerating organisms. Epithelioid cells surrounded the non-viable parasite and were in turn bounded by a fibrous capsule of varying thickness. Double walled granulomas with acid-fast centers as described in the livers of Morone americana were seen on occasion within the splenic parenchyma.

Cysts. Microcavitations due to viable metacercaria (P. minimum) were noted in a number of spleens. There was no apparent reaction to encysted organisms and damage due to migration was not observed.

Protozoal cysts were present in a spleen taken from a Notropis cornutus (Fig. 31). Cysts varied in size from 50-800 μ in diameter. The larger cysts were bounded by a thin connective tissue wall and contained round structures (pansporoblasts) with groups of immature spores. Isolated structures of this type were often seen in follicles of pigment laden reticulo-endothelial cells and were outlined by an extremely thin hyaline acidophilic material. The organisms were identified as members of the order Myxosporida.

Lesions of the Gonads

Abnormalities of only the ovary were noted.

Granulomatous oophoritis. A grossly distended abdomen was found in a Morone americana. Abdomenal distension was due to enlarged ovaries with two gross abnormalities. The ventral portion of both ovaries was whitish in color and of firm consistency. There was a sac 4 mm by 1 mm containing a brownish fluid in the distal ventral portion of the left ovary. Microscopically the hardened portions of the ovaries were found to consist of fibrous tissue and of degenerating ova

with irregular walls which contained an acidophilic proteinaceous fluid. Scattered diffusely through the fibrous septa were focal granulomas and numerous macrophages (Fig. 32). The centers of these granulomas often contained an acid-fast material. However, no bacteria could be identified and lesions were not similar to those seen in piscine tuberculosis. The cyst observed grossly was lined by a thin connective tissue wall and contained a basophilic amorphous debris.

Parasitic granulomas due to larvae of the cestode Proteocephalus ambloplites were observed in the ovary of Micropterus salmoides. The reaction was severe with many heterophils (eosinophils) infiltrating a fibrous syncytium surrounding both viable and degenerating parasites. Large segments of the ovary normally containing ova were involved in the inflammatory process. Histocytic cells and lymphocytes were also present (Fig. 33).

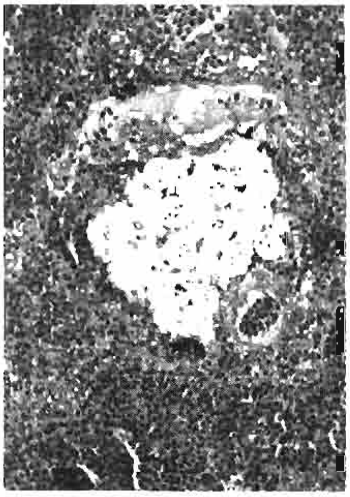

Fig. 31. Spleen. Focus of protozoal organisms within melaninmacrophage center. H&E X60.

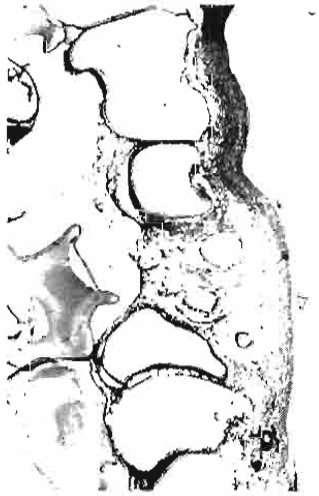

Fig. 32. Ovary. Granulomatous reaction within fibrous tissue separating ova. H&E X25.

Fig. 33. Ovary. Focal heterophilic granuloma containing larval segment of Proteocephalus ambloplites. H&E X25.

Ovarian microsporidial cysts. Cysts of the microsporida, Glugea sp were present in the ovary of an Osmerus mordax. The cysts varied in size from 50–500 μ and were bounded by a loose fibrous network which contained histiocytes and lymphocytes. The cysts and contents were weakly acidophilic aiding in differentiation from developing ova (Fig. 34). Although mature spores could be identified in haematoxylin and eosin stained sections, the morphology of the organisms was more easily seen with Giemsa stain. The abnormality is best classified as a space occupying lesion and elicited little inflammatory response. Microsporida are intracellular parasites but it was not possible to determine if the organisms had invaded and were causing hypertrophy of the ova or other cells.

Lesions of the Skin and Skeletal Musculature

Lesions observed in the skin presented a spectrum of pathological responses from simple congestion to granulation tissue and cell hypertrophy. These lesions often included the underlying musculature. Pathological processes with primary site of origin in the skeletal musculature were also observed.

Dermal congestion and hemorrhage. Frequent examples of ecchymosis were present in the skin of various species. Grossly the areas were discolored (red to black), occurred on all areas of the body, and often underlaid an area of scale loss. Histologically, there was congestion of the dermal vessels, edema, and in severe cases, frank hemorrhage. These lesions might have arisen from trauma either during capture or, in the instance of Alosa sp, from injuries incurred during spawning migrations.

Dermal ulceration and necrosis. Focal lesions, characterized grossly and microscopically by ulceration and necrosis, were present in some of the fish surveyed. Bacterial cultures of these areas were positive for Aeromonas liquefaciens. Grossly these lesions were composed of a central area of frank ulceration with necrosis of the dermis and underlying musculature surrounded by a zone of hemorrhage, blue to black in color. Microscopically, the periphery was overlain by an intact epidermis with dermal hemorrhage, edema, and an influx of mixed inflammatory cells in both the epidermis and dermis. In the central portion of the lesion there was usually a complete loss of integument with necrosis of the skeletal musculature. Fungal hyphae of the genus Saprolegnia are commonly present in such lesions but in the cases examined the fungus was absent. Fish have been examined from the Thames River Watershed that were infected by agents causing Saprolegniasis and its absence is felt to be coincidental.

In one instance, an ulceration of the caudal fin epidermis of a Micropterus salmoides was surrounded by a raised, pinkish tissue. Sections of this lesion revealed a healing process with peripheral granulation tissue and inflammatory cells overlying intact epidermis (Fig. 35). The lesion was chronic in nature (proliferative) and microfractures of the caudal fin bones were present.

Lymphocystis disease. The classical dermal lesions of lymphocystis disease were observed in one Morone saxatilis. Grossly the skin and fins were covered by a raised granular pinkish-white tissue. Microscopically, these granular areas were characterized by a complete loss of epidermis and replacement by hypertrophied (100-200 μ), rounded fibroblastic cells (Fig. 36). The cell cytoplasm was vacuolated, foamy, varying in basophilia and contained a peripheral intensely basophilic granular material. This material was often horseshoe shaped and was composed of Feulgen positive viral particles. The nucleus was swollen, vacuolated, and contained a single nucleolus. The affected cells were present in a vascular, thin, connective tissue framework.

Dermal cysts. Cysts observed in the skin of captured fish were metacercarial (diplostomiasis) in origin. To the unaided eye, these appeared as small black spots (approximately 1.0-1.5 mm in diameter) randomly distributed on the skin and fins. Histologically, the lesions were situated in the dermis and contained trematode metacercaria surrounded by a non-cellular hyaline acidophilic wall in turn bounded by a thin fibroblastic wall. These cysts elicited a collection of black pigment cells (melanophores) about their periphery.

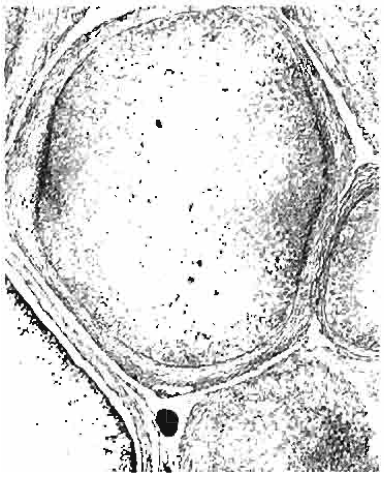

Fig. 34. Ovary. Normal parenchyma has been replaced by massive cysts containing Glugea sp. H&E X25.

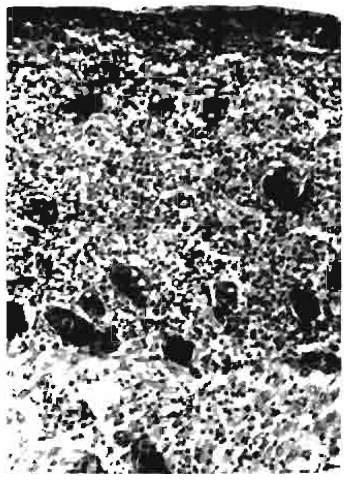

Fig. 35. Skin. Granulation tissue and inflammatory cells overlying area of ulceration. H&E X60.

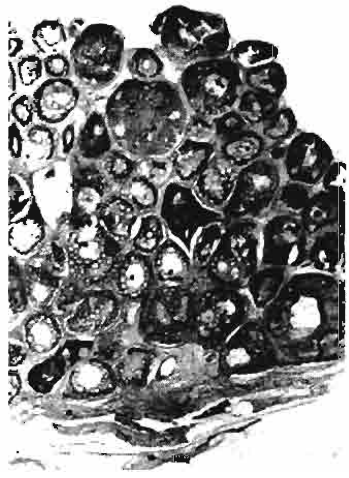

Fig. 36. Skin. Hypertrophied fibroblasts containing lymphocystis virus. Note complete loss of epidermis. H&E X25.

Necrotic myositis. Necrosis of skeletal muscle fibers underlying zones of dermal ulceration secondary to Aeromonas sp infection was observed (Fig. 37). Muscle fibers were swollen and there was a loss of normal striation. In severe lesions the fibers were broken and the isolated segments were undergoing coagulation necrosis. The fibers were surrounded by a mixed inflammatory cell influx composed primarily of mononuclears and hemorrhage.

In two instances the body musculature of Morone americana was found to be invaded by a protozoan (order Myxosporida). This organism resembled Unicapsula muscularis in morphology, was non-encapsulated and diffusely distributed between muscle bundles. Its presence resulted in pressure necrosis with absence of inflammatory response (Fig. 38).

Granulomatous myositis. Focal granulomas of parasitic origin were occasionally observed in skeletal muscles. This was especially true in the pharyngeal muscles of Catostomus commersoni. The unidentified encysted parasite was surrounded by epithelioid cells and bounded by a thin fibrous cyst wall. No reaction to the parasite was apparent outside the fibrous capsule.

Miscellaneous Lesions

Lesions of the Eye. Two fish were found to have lesions of the eye. Probable congenital anophthalmia was noted in a 40 cm Ictalurus catus that was apparently in good condition. Both eyes were absent and the orbits were covered with normal skin. The fish was in good physical condition. Histological examination revealed normal optic nerves with remnants of pigment epithelium and the retinal layer of rods and cones. This condition has previously been reported in Ictalurus nebulosus from Dog Lake, Oregon (Weisel and McLaury 1964).

Phithis bulbi in conjunction with a retrobulbar cyst was present in a second Ictalurus catus. The lesion involved the left eye only and was apparent grossly as a fluctuating 3 cm swelling behind a shrunken white mass in the area of the left orb. The cyst was filled with approximately 15 cc of an aseptic, clear watery fluid. Histologically the glove was collapsed and replaced by fibrous tissue. The cyst was lined by a low cuboidal epithelium.

Lesions of the Bone. Only one lesion of bone was noted. A Micropterus salmoides had focal 1-2 cm raised red ulcerated areas on the caudal fin. Underlying bone was fractured and at microscopic examination sequestration and necrosis was present (Fig. 39). Increased osteoblastic and osteoclastic activity were noted in areas of fracture healing.

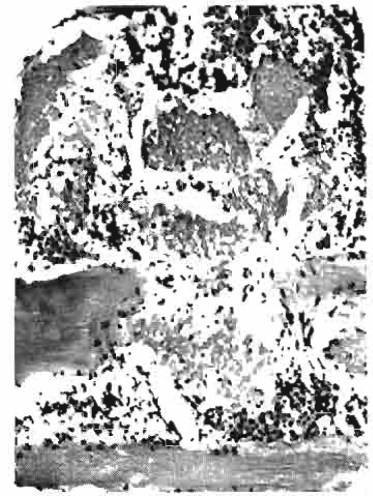

Fig. 37. Muscle. Necrotic myositis with fiber destruction and hemorrhage. H&E X60.

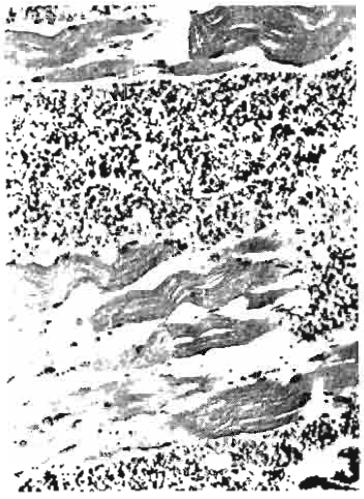

Fig. 38. Muscle. Massive infiltration of myxosporidia between muscle bundles. H&EX60.

Fig. 39. Bone. Primary sequestrum (arrow) in dermis. H&E X25.

Lesions of the Pancreas. Histological examination of a Notropis cornutus revealed protozoal cysts in the disseminated mesenteric pancreas. These organisms were morphologically identical to those noted in the spleen of a member of the same species and previously described with lesions of that organ.

Lesions of the Peritoneum and Mesentery. Lesions of these tissues included parasitic granulomas and cysts of Microsporida. The mesentery was involved more often than the parietal or visceral peritoneum. In only one instance was a lesion of parietal peritoneum noted. The lesion was due to a Glugeal cyst which arose dorsolateral to the kidney and displaced the adjoining kidney and air bladder.

Degenerating parasites elicited granulomas and simple fibrous encapsulations within mesenteric sheets. Calcifying granulomas were noted in one case.

As in other organs the presence of a granuloma with an acid-fast center and double fibrous encapsulation was noted within the peritoneum.

Bacteriologic Findings

The bacteria most consistantly recovered from both clinically and histologically normal fish, as well as diseased specimens, was of the genus Aeromonas. These ubiquitous bacteria when associated with disease were of the species A. liquefaciens and resulted in localized dermal lesions as well as septicemias characterized by enteritis, hepatitis, and encephalitis. Fish which had died in trap and gill nets or were held overnight for necropsy, often had organs containing bacteria at time of culture.

In a few instances a gram positive coccus identified as Micrococcus sp was recovered from the liver and spleen. These were not associated with any lesions and were felt to be contaminants. A yeast resembling Candida sp was recovered from the liver of an Ictalurus catus.

The intestines of 331 fish were cultured for Salmonella sp in SBC Sulfa enrichment broth. No Salmonella were recovered.

RESULTS AND DISCUSSION

This survey, the first of its kind to be conducted in the State of Connecticut, was undertaken to determine the incidence and kinds of diseases of fish. The overall incidence of disease processes was 45% (Table 1). Positive conclusions regarding incidence of disease and parasites (Table 2) in this study is difficult due to the small numbers of fish and their distribution through space and time. This study indicates further investigations would be of decided value because of the incidence of lesions in Morone saxatilis (16 of 17 fish), Morone americana (49 of 65 fish), Cyprinus carpio (15 of 23 fish), and Perca flavescens (11 of 18 fish).

Incidence of lesions by causative agents and organ involvement is summarized in Tables 4 and 5. No cause could be determined in 38% of the lesions found. It is probable that the majority of these lesions were due to helminths since the most common inflammatory response was the granuloma. Thirty-three percent of the lesions were attributed to both adult and larval helminths, the vast majority of these lesions due to larval forms. Protozoa elicited lesions in 17% of the affected fish while lesions of positive bacterial cause were responsible for only 6%. Miscellaneous agents such as Bedsonia, diatoms, trauma, etc., were involved in 6% of the lesions observed.

Incidence of lesion type is summarized in Table 4. Inflammatory responses comprised approximately 50% of all the lesions observed and had the following distribution: granuloma 30%, mononuclear response 7.8%, necrosis 6.3%, heterophilic response 3.1%, ulceration and fibrosis each 1.4%. It is evident from this data that the fish seldom responds with a granulocytic response (heterophilic, eosinophilic, neutrophilic), but tends rather to produce a granuloma often successfully walling off the invasive organism. The granulocytic inflammation was present most frequently in Aeromonas sp infections. It is also of interest to note that the presence of foreign body or Langhan's type giant cells within the granuloma are rare. Giant cells were present in only one instance and were elicited in response to diatoms invading the lamina propria of the gut. Cysts with little or no inflammatory response comprised 25.4% of the lesions. The vast majority of these cysts were in response to larval helminths such as the metacercaria of the digenetic trematodes. Hyperplasia and hypertrophy of various cells were observed in 57 of

Table 2. Number of occurrences of parasites (number of occurrences, mean number/occurrence, and range).

	Stomach and Hindgut	Hindgut	Gills	Liver	Kidney	Peritenum
Ascocotyle sp. metacercariae			1-50			
Bothriocephalus sp.	3-2(1-4)	1-3				
B. claviceps	3-2(1-3)	6-9.3(1-40)				
Camallanus oxycephalus larvae		1-1				
Camallanus sp.	1-2	2-2(1-3)				
Carophyllidae		4-2(1-4)				
Carophyllidae larvae	6-3.8(1-8)			1-7		
Carophyllidae immature	1-1					
Contracaecum sp.	8-5.5(1-15)	6-3(1-10)				
Corallobothrium sp.		1-1				
Corallobothrium sp. plerocercoids				1-2		
Crepidostomum sp.	1-30*	1-5		1-2		
Dacnitoides sp.	5-17.2(10-37)	4-5.2(2-10)				
Echinostomatidae larvae			2-37(25-50)			
Ergasilus sp.	1-24	1-70	4-27.7(1-79)			
Eustrongylides sp. larvae						6-22(1-8)
Glaridacris catostomi	1-2					
G. sp.	2-3(1-5)					
Hemiurus levinseni		2-40.5(31-50)				
Heterophyidae larvae			1-50			
Homalometron sp.		1-1		1-1		
Leptorhynchoides thecatum		3-1.3(1-2)				
Macroderoididae metacercariae	1-2	2-6				
Microcotyle sp.			2-9 (8-10*)			
Neoechinorhynchus cylindratum	4-27.2(1-100*)	4-6.8 (1-13*)				
Philonema sp.	1-1					
Podocotyle olssoni	3-4.7(1-7)	2-3.5(1-6)				
Podocotyle sp.		2-37(4-70)				
Pomphorhynchus bulbocolli	1-10*	5-13.4 (1-50*)				
P. bulbocolli larvae	1-2	1-30				
P. rocci	5-2.8(1-6)	17-19.6 (1-100*)				
P. rocci larvae		2-12.5(11-14)				
P. sp.	2-50 (1-100)	9-24.5 (1-100*)		1-2		
Proteocephalus ambloplites plerocercoid	2-2.5(1-4)	3-17.0 (2-30*)		3-1.7(1-2)		
P. sp. plerocercoid	5-6.4(1-14)	14-12.8(1-80)		4-2(1-4)		
P. sp.		2-6(1-11)				
Posthodiplostomum centrarchi minimum				7-9.9 (2-50*)	2-30 (10 -50*)	
P. minimum minimum metacercariae		1-100		5-12(1-38)		
Spinitectus sp.	1-7	1-7				
Spiroxys sp. larvae		4-2.9(1-5)				
Stephanostomum sp.		1-1				
Stephanostomum tenue	2-1	5-1.6(1-4)				
Tanaorhamphus ambigous	1-1	4-2(1-4)				
T. longirostris cystocanth	1-4	2-2.5(1-4)				
T. sp.	5-8.4(2-10*)	3-7.3 (1-10*)				
Tetraonchus sp.			2-7(4-10)			
Trematode sp.	1-2		1-25*			
Triganodistomum sp.	2-8(2-14)					
Unknown	1-1	1-1				

*after a mean denotes that the exact number of one of the occurrences was not given.

Table 3. Incidence of Lesions.

Species	Epitheliocystis F	Epitheliocystis L	Trichodina F	Trichodina L	Myxosporidia F	Myxosporidia L	Microsporidia F	Microsporidia L	Coccidia F	Coccidia L	Chilodinella F	Chilodinella L	Helminths F	Helminths L	Aeromonas sp. F	Aeromonas sp. L	Miscellaneous F	Miscellaneous L	Unknown F	Unknown L
Alosa pseudoharengus													1	1			4	4		
Anguilla rostrata			2	2											1	2			2	2
Catostomus commersoni					2	2							4	4	1	2	1	1	6	6
Cyprinus carpio													1	1	3	13			12	15
Caranx hippos																				
Esox niger													4	5					2	2
Erimyzon oblongus			1	1															1	1
Fundulus heteroclitus																			2	2
F. majalis													3	3					2	2
Ictalurus catus					1	1							5	7	1	2			6	8
I. nebulosus													1	1					6	9
Lepomis gibbosus													7	14					4	6
L. macrochirus													2	3					1	1
Morone americana	5	5	21	21	1	1	3	5	1	1	3	3	29	11	15	30			25	39
M. saxatilus	10	10	2	2									12	18			1	1	6	9
Microgadus tomcod							3	4					1	1					1	2
Micropterus salmoides							2	2					5	9					4	9
Myoxocephalus octodecimspinosus																				
Notemigonus crysoleucas			2	2			1	1					4	4					3	4
Notropis cornutus					5	5													1	1
N. hudsonius																				
Osmerus mordax							2	5					2	2					1	1
Paralichthys dentatus																				
Perca flavescens			1	1									6	9					4	6
Pomatomus saltatrix																				
Pomoxis nigromaculatus													2	2					3	4
Pseudopleuronectes americanus			1	1															1	2
Salmo trutta																				
Semotilus corporalis																				
Syngnathus fuscus																				
Total	15	15	30	30	9	9	11	17	1	1	3	3	75	114	21	49	6	6	93	132

Table 4. Incidence of lesion type.

Species	Granuloma	Heterophilic	Mononuclear	Fibrosis	Necrosis	Mineralization	Hyperplasia & Hypertrophy	Cyst	Ulcer	Miscellaneous
Alosa pseudoharengus	2									3
Anguilla rostrata					1		4			1
Caranx hippos										
Catostomus commersoni	5	2		1			4	3		
Cyprinus carpio	3	9	4		2		2			9
Esox niger	1							2		4
Erimyzon oblongus							1	1		
Fundulus heteroclitus					1		1			
F. majalis	2							3		
Ictalurus catus	5		2		1		1	7	1	2
I. nebulosus	1		1		1		5	1		1
Lepomis gibbosus	7		3		1	1		6		2
L. macrochirus							1	3		
Microgadus tomcod	1				1		1	4		
Micropterus salmoides	3		1	1	2		1	9	1	2
Morone americana	41		10	1	4	1	28	18	2	
M. saxatilis	17		6	1			4	11	1	
Myoxocephalus octodecimspinosus										
Notemigonus crysoleucas	2			2		3	4			
Notropis cornutus				1		5				
N. hudsonius										
Osmerus mordax	2			1	1		4			
Paralichthys dentatus										
Perca flavescens	9				3	1	1	1		1
Pomatomus saltatrix										
Pomoxis nigromaculatus	1			1		1		3		
Pseudopleuronectes americanus								3		
Salmo trutta										
Semotilus corporalis										
Syngnathus fuscus										
Total	102	11	27	9	18	12	62	75	5	25

Table 5. Incidence of organ involvement (number of fish) and percent.

Species	Brain	Eye	Pancreas	Heart	Gill	Stomach	Intestines	Peritoneum	Liver	Bile Duct	Kidney	Ovary	Testes	Skin	Muscle	Bone	Spleen
Alosa pseudoharengus							1		1					3			
Anguilla rostrata					3				1					1	1		
Caranx hippos																	
Catostomus commersoni				1	6		1	3	2						1		1
Cyprinus carpio	2			2	4		4	2	3		10						
Erimyzon oblongus					1												
Esox niger							1		2	3	1						
Fundulus heteroclitus									1								1
F. majalis					3			2									
Ictalurus catus		2			4	2	1	2	5					1	1		
I. nebulosus				1	7	1			1								
Lepomis gibbosus				3		1	2		8		5						
L. macrochirus					1				1		1						1
Microgadus tomcod				3	3		2										
Micropterus salmoides					4	1	1	1	4		4	1		1		1	1
Morone americana	3			16	31	4	7	9	14	2	4	1		3	5		3
M. saxatilis	4			3	14	2	11	4	2	1		2					
Myoxocephalus octodecimspinosus																	
Notemigonus crysoleucas					4				4		1			2			
Notropis cornutus			1						1		1	1			2		1
N. hudsonius																	
Osmerus mordax					1		2	2			1						
Paralichthys dentatus																	
Perca flavescens				1	3		5	5									1
Pomatomus saltratrix																	
Pomoxis nigromaculatus				4		1		1									
Pseudopleuronectes americanus					1		1				1						
Salmo trutta																	
Semotilus corporalis																	
Syngnathus fuscus																	
Totals	9	2	1	34	90	12	39	31	50	6	29	5		11	10	1	9
Percents	2.4	0.6	0.3	10.1	26.7	3.6	9.8	9.2	16.3	1.8	8.6	1.5		3.2	3.0	0.3	2.4

the total 346 lesions (16.4%). The area most commonly involved in this response was the branchial epithelium. Such hypertrophy and hyperplasia could occur with such severity that complete lamellar fusion resulted with destruction of gill function. Mineralization of older granulomas and cysts was present in 1.4% of the lesions, and miscellaneous lesions (hemorrhage, etc.) were present in 5.7% of the cases.

Aeromonas liquefaciens is a bacteria involved in acute mortalities of fish (Meyer 1968). Decreased oxygen levels and increased water temperature appear directly related to increased disease incidence, hence the disease is most commonly seen during summer months when water levels are low or severely polluted (Ojala, 1968). Outbreaks of this disease were observed in July 1969.

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Barriers to anadromous fishes and stream bank use in the Thames River Watershed, Connecticut

Robert E. Schmidt[1]

INTRODUCTION

The purposes of this project were to delineate dams on the Thames River Watershed that are barriers to potential anadromous fish spawning areas and describe the uses made of the stream banks in these areas. The project was undertaken as part of the State of Connecticut's anadromous fish introduction program and was supported, in part, by funds provided through the Anadromous Fish Act (P.L. 89-304), and the Connecticut Department of Environmental Protection.

MATERIALS AND METHODS

The Thames River Watershed was divided into (1) the Thames and Yantic River System, (2) the Shetucket River System, excluding the river in Norwich, and (3) the Quinebaug River System, including the river flowing into Norwich. The dams blocking potential spawning areas of anadromous fishes listed by Whitworth, Beckwith, and Hames (in this publication) were evaluated during the summer of 1973. Notes on location, construction, and size of the dams were made by observation. Ownership and water rights were determined by examining the assessor's and town clerk's records in the town where the dam was located. Present use of the dam and pond was determined by contacting the owner by telephone or by field observations. Dams are described by river system in order from the mouth of the river upstream.

The streams which could support anadromous fish populations were measured to determine the present use of the land adjacent to the stream by tracing the river courses on the 1:24,000 1970 Connecticut land use maps, measuring the length of each category of land use on each bank with a map measurer, and converting this figure to percent of river length. Land use categories were (1970 Connecticut Land Use Directory): (A) residential, (B) light manufacturing, (C) heavy manufacturing, (D) transportation, communication, and utilities, (E) trades and services, (F) cultural entertainment, recreation, (G) resource use, and (H) undeveloped land including forest.

RESULTS AND DISCUSSION

Thames and Yantic River System

Hunt's Brook has its mouth at Smith's Cove, Thames River. There are 3 dams and no other barriers deny access to this brook.

The first dam is just west of Smith's Cove on Old Mill Road, and is made of concrete (8 ft X 35 ft) with a "flood control" channel on the east side. The Town of Waterford owns the west side of Hunt's Brook (including pond and dam) and the east side

[1]Research Assistant, University of Connecticut, Storrs, Connecticut.

of the pond. Frank Terranova (210 Jefferson Avenue, New London) owns the east side of the brook and dam. The owner shall permit flow as presently constituted and keep the dam in repair. The pond is very small and shallow and has no present use (historically it was a mill pond).

The second dam, Miller Pond dam, south of Route 52, is made of concrete and dressed stone with iron supports (25 ft on west side, 30 ft on east side X 150 ft) and with large slabs of bedrock sloping from west to east. The spillway is a 2 ft square hole on the west side. Schact, Saunders, and the Waterford Country School, Inc., are the owners and they have all riparian rights and interests. The pond is large and used for recreation.

The third dam, Cuheca Pond dam, north of Route 52, is made of concrete and stone (4 ft X 40 ft) with 2 spillways, one with a removable gate. The group that owns the second dam also owns this one and has the same rights. The pond is shallow and is used for recreation.

Stony Brook has its mouth in Horton's Cove, Thames River. There are 2 dams and no other barriers deny access to this brook.

Johnson Pond dam is the first dam and is located below the east edge of the Route 32 bridge, Uncasville. It is made of large rocks with a concrete and wooden top (10 ft X 35 ft) and is broken on the north edge. Theodore Wisniewski (Box 326, Uncasville) has the right to maintain the dam (which he hasn't) and build another (12 ft high) downstream, and the riparian right to flow over the spillway. The pond is small and shallow and was historically used for ice-cutting.

The second dam forms Stony Brook Reservoir near Montville Center. The dam is made of fieldstone (Whitworth, personal comm.). The present use is water supply for the city of Norwich. The City of Norwich (Water Dept., 34 Shetucket Street, Norwich) owns the dam, they have all riparian rights, and don't have to guarantee flow.

Trading Cove Brook has its mouth in Trading Cove, Thames River. There is one dam and no other barriers deny access to this brook.

This dam is located under the Route 32 bridge, Montville, and is made of concrete with a wooden top (10 ft X 15 ft, sloping). The pond is small and shallow and there is a gate and raceway on the north side. Louise Dupont (790 W. Thames St., Norwich) is presently selling to Norwich Chemical Co., who doesn't intend to use the pond. She had all rights to the dam and pond.

Yantic River has its mouth in Norwich Harbor, Thames River. There are 5 dams and no other barriers deny access to this river.

The first dam is located at Norwich Falls, Yantic St., Norwich, and is erected on top of a natural falls. It is made of concrete (5 ft X 50 ft). The Falls Corp., Norwich owns the dam but has no explicit rights. The pond is narrow and deep, and is presently not used.

The second dam is located 0.2 of a mile upstream of the first and is made of dressed stone (8 ft X 60 ft). The Falls Corp., Norwich, also owns this dam with no explicit rights. The pond is shallow and is not used.

The third dam, Fitchville Reservoir, is at the junction of old Route 2 and Route 163, and is made of concrete (12 ft X 30 ft). Seymour Sand and Stone, Inc. (RFD #1, Fitchville) owns all flowage rights, but does not intend to maintain the dam and will sell to the state.

The fourth dam, the Gilman dam in Gilman, is made of concrete (10 ft X 80 ft), perpendicular). The Gilman Bros. Mfg. Co., owns the dam with no explicit rights and the pond is used for power (Bozrah Light and Power Co.) and industry.

The fifth dam is above Waterman Road Bridge, 0.5 miles upstream of Gilman, and is made of dressed stone (8 ft X 40 ft). The Einhorn Feed and Grain Co., owns the dam with no explicit rights. The pond is used presently for recreation (state fishing area).

Bartlett Brook has its mouth in the Yantic River upstream of Gilman. There are 2 dams, the upper one is now abandoned and is not a barrier. The 5 dams on the Yantic River deny access to this brook.

Savin Lake dam is just north of old Route 2, and is made of concrete (7 ft X 25 ft) with dirt banks. A. I. Savin owns the dam with no explicit rights. The pond is used for watering stock.

Deep River has its mouth in Yantic River upstream of Bartlett Brook. There is one dam and the 5 dams on the Yantic River also deny access to this brook.

Deep River Reservoir dam is made of concrete (55 ft X 1500 ft). It is owned by the City of Norwich with no explicit rights and is a public water supply.

Shetucket River System

Shetucket River has its mouth in the Quinebaug River at Taftville. There are 3 dams. Greenville dam (on the Quinebaug River) denies access to this river.

The first is Taftville dam in Taftville, and it is made of stone and concrete (25 ft X 100 ft). The Connecticut Light and Power Co. (CL&P) owns the dam and the right to flow through the turbines. The pond was originally used for industrial water supply but now is used for power generation.

The second, Occum dam, is located in Occum and is made of stone and concrete with a wooden platform at the base. The Norwich Gas and Electric Co., owns the dam and has the right to maintain the dam. Water is used for power generation.

The third, Scotland dam, is in Scotland and is made of concrete (30 ft X 200 ft). CL&P owns the dam and has riparian rights and the right to maintain the dam. Water is impounded to generate power.

Little River has its mouth in the Shetucket River just below Occum dam. There are 3 dams and Taftville dam and Greenville dam deny access to this river.

The first, Versailles Pond dam, is near Krusman Road, Occum. The sloping dam is made of concrete and stone (8 ft X 30 ft). Federal Paperboard, Inc., owns the dam and has all pondage, flowage, and riparian rights of any nature to the pond, Little River, and the Shetucket River. The pond was originally used for milling and industry but now is a settling basin for effluents from Federal Paperboard and Domino Sugar.

The second, Papermill Pond dam, is in the Federal Paperboard factory complex, and was not seen by me. It is made of concrete (25 ft X 80 ft). Ownership and rights are the same as the first dam. Present use is industrial.

The third dam forms Hanover Reservoir and is located near Hanover. The dam is a "step-type" made of rock and concrete (5 ft X 60 ft) with an apron and a low gradient natural falls below the dam. Angus Park Woolen Co., owns the dam and has all imaginable rights to the dam and pond. The pond is used as a public water supply and for industry.

Merrick Brook has its mouth in the Shetucket River below Scotland dam. There is one dam but this dam is not a barrier except during June-August. Occum dam, Taftville dam, and Greenville dam deny access to this brook.

Natchaug River has its mouth in the Shetucket River at Willimantic. There are 3 dams and the 3 dams on the Shetucket River and Greenville dam deny access to this river.

The first dam forms Willimantic Reservoir in Willimantic, and is made of concrete (15 ft X 150 ft). The City of Willimantic owns the dam and has all flowage and pondage rights. The pond is used for public water supply.

The second dam is an old mill dam, located on Mansfield Hollow Road. It is made of stone (6 ft X 40 ft) and is no longer used. The State of Connecticut owns the dam with no explicit rights.

The third is Mansfield Hollow dam in Mansfield. The sloping dam is made of concrete (70 ft X 700 ft). The U.S. Corps of Engineers owns the dam with no explicit rights. The impoundment is a flood control reservoir.

Fenton River has its mouth in Mansfield Hollow Reservoir below the Route 87 bridge. There is one dam and the 3 dams on the Natchaug River, the 3 dams on the Shetucket River and Greenville dam deny access to this brook.

The dam is located at the Daleville School Road bridge, and is made of concrete (10 ft X 40 ft). Claire M. Berg, Willington and Allen W. Stone, own the dam with no explicit rights. The pond has no present use.

Still River joins Bigelow Brook to form the Natchaug River about 1 mile south of Phoenixville on Route 198. There is one dam and the 3 dams on the Natchaug River, 3 on the Shetucket River and Greenville dam deny access to this brook.

Carter dam is about 0.25 miles upstream of the Junction of Route 198 and Westford Road, Eastford. The dam is made of concrete (6 ft X 30 ft) with old gates and channels. The Tatum Mfg. Co., Eastford, owns the dam and has all flowage rights and water privileges. The pond is small and unused.

Willimantic River has its mouth at the Shetucket River in Willimantic. There are 6 dams and the 3 dams on the Shetucket River and Greenville dam deny access to this river.

The first 4 dams are owned by American Thread Co., with all rights and privileges. The first dam is north of the recreation field in Willimantic, and is made of concrete (15 ft X 300 ft). The pond is not used at present.

The second dam is located about 200 yards south of the Route 32 bypass bridge, Willimantic, and is made of concrete (20 ft X 200 ft). The pond is not used at present.

The third dam is just upstream of the Route 32 bypass bridge, Willimantic, and is made of concrete (20 ft X 100 ft). A small amount of water is used for turbine cooling.

The fourth dam is located 200 yards upstream of the third, and is made of concrete (20 ft X 150 ft). Water is used for processing and dyeing.

The fifth dam is 100 ft south of the Route 32 Bridge, Willimantic, and is made of concrete (20 ft X 200 ft) and the east end is partially broken. Boland Oil Co., owns the dam with no explicit rights. The pond is not used.

The sixth dam forms Eagleville Reservoir, located in Eagleville, and is made of stone and concrete (8 ft X 60 ft). The State of Connecticut owns the dam and has flowage rights and privileges. The pond is used for some recreation.

Hop River has its mouth in the Willimantic River about 0.5 miles upstream from the Route 6 bridge. There is one dam and the lower 5 dams on the Willimantic River, the 3 dams on the Shetucket River, and Greenville dam deny access to this brook.

The dam is located upstream of the Hop River Road bridge, and is made of concrete (6 ft X 50 ft) with a 6 ft wide concrete top. The Bushnell Co. (25 Lewis St., Hartford) owns the dam and has all rights to water power, flowage, and all other water rights and privileges. The pond is small and unused.

Skungamaug River has its mouth in the Hop River, 2 miles north of Andover. There are 2 dams and the dam on Hop River, the 5 dams on the Willimantic River, the 3 dams on the Shetucket River, and Greenville dam deny access to this brook.

The first dam is located at the Times Farm Camp. The sloping dam is made of concrete (3 ft X 25 ft) and is owned by the Almada Lodge, Times Farm Corps, Hartford, with no explicit rights. The small pond is used for recreation.

The second dam is the Sykes Falls dam, located at South St. and River Rd., Coventry, and is made of concrete and stone (30 ft X 30 ft). Roberta S. Bynes (South St., Coventry) owns the dam and has the right to maintain dam and all "water privileges." No present use was seen.

Furnace Brook has its mouth in the Willimantic River at Stafford Springs. There are 4 dams and the 6 dams on the Willimantic River, 3 dams on the Shetucket River, and Greenville dam deny access to this brook.

The first dam is located near the factory, Furnace Ave., Stafford Springs, and is made of stone and concrete (8 ft X 60 ft) with a concrete top and 5 ft apron. The Hale Mfg. Co., Cyril Johnson Mills Div. (22 Furnace Ave., Stafford Springs) owns the dam and flowage rights. Present use is industrial.

The second, Warren pond dam, is located 0.3 miles upstream of the first dam, and is made of dressed stone and concrete (20 ft X 60 ft). Warren Woolen Co. (99 Furnace Ave., Stafford Springs) owns the dam with no explicit rights. Present use is industrial.

The third, Glenville Pond dam, is located 0.5 miles upstream of the second dam, and is made of concrete (12 ft X 60 ft). The ownership and rights are the same as in the second dam. It is not used at present.

The fourth dam is located under the Leonard Road bridge, Stafford Hollow, is made of stone (11 ft X 40 ft), and is partially a natural falls. North American Printed Circuit (Box 145, Stafford) owns the dam and has pond rights of flowage and all privileges. Presently it is used for industry.

Quinebaug River System

Quinebaug River has its mouth in the Thames River at Norwich. There are 8 dams and no other barrier denies access to this river.

The first, Greenville dam, is located in Norwich. The dam is wooden with rock fill (15 ft X 100 ft). Atlantic Carton Corp., owns the dam and leases the mill rights to Norwich Gas and Electric Co. Water is used for power generation.

The second, Tunnel dam, is located in Taftville. The sloping dam is made of concrete (20 ft X 50 ft). CL&P owns the dam and has all water power rights and privileges. Water is used for power generation.

The third, Aspinook Pond dam, is located in Jewett City. Wyre Wynd Corp., Jewett City, owns the dam and has flowage rights. Water is used for recreation and industry.

The fourth dam is in Danielson, below the Route 6 bridge, and is made of stone and concrete (20 ft X 80 ft). The Rosen Realty Co., owns the dam and has the right to maintain dam and flow water through the canal. The impoundment apparently is not used.

The fifth, Rogers dam, is in Rogers, and is made of stone (5 ft X 100 ft). The Rogers Corp., owns the dam and has all rights to the dam and flowage. Water is used by industry.

The sixth dam is located 300 ft upstream of the Route 44 bridge, Putnam. There are two concrete dams (10 ft X 30 ft and 5 ft X 55 ft) on top of a natural falls. Hale Mfg. Co., Putnam, owns the dam and has all water rights. The water is used by industry.

The seventh dam is located 0.5 miles upstream of the sixth dam, and is made of rock and concrete (15 ft X 20 ft). Raymond Rosenfield (New England Chemical) owns the dam and has all flowage rights. The water is used for power generation.

The eighth dam is located 300 ft upstream of the Route 171 bridge, Putnam, and is made of stone and concrete (15 ft X 60 ft). Shaw-Mac, Inc., owns the dam and has all water rights. A small amount of water is used for industry.

Broad Brook has its mouth in the Quinebaug River about 2 miles downstream of the Route 52 bridge. There is one dam and Tunnel and Greenville dams deny access to this brook.

Lewis Pond dam is located near the junction of Lewis Road and Route 165, Preston, and is made of loose rock and concrete (4 ft X 20 ft). Natale Pellegrino (RD #3, Norwich) owns the dam with no explicit rights. The pond is small and unused.

Pachaug River has its mouth in the Quinebaug River at Jewett City. There are 3 dams and Tunnel and Greenville dams deny access to this river.

The first dam is about 100 ft upstream of the Route 12 bridge in Jewett City. The sloping dam is made of concrete (5 ft X 60 ft) with a 5 ft apron. United Merchants and Mfg. Corp. (Wilmington, Delaware) owns the dam and has flowage rights and use of water for fire. The pond is small and unused.

The second, Slater dam, is located about 50 ft upstream of the Route 138 bridge in Jewett City, and is made of stone (12 ft X 50 ft). William A. Slater, III (Tiburon, California) owns the dam and the land under water, and can maintain or raise the dam. The pond is small and used for recreation.

The third, Ashland Pond dam, is located about 250 ft upstream of the Ashland Road bridge, Jewett City, and is made of concrete (15 ft X 50 ft) with a 5 ft apron. United Merchants and Mfg. Corp. (Wilmington, Delaware) owns the dam and have all rights to flowage. The pond is presently used for recreation.

Kitt Brook has its mouth in the Quinebaug River about 1.5 miles upstream of Butts bridge. There is one dam and Aspinook, Tunnel, and Greenville dams deny access to this brook.

Edith White Fletcher's dam is located about 0.25 miles upstream of the Route 169 bridge, and is made of dressed stone (8 ft X 20 ft) with a concrete top. Albert M. and Eleanor M. Gilman (Canterbury) own the dam with no explicit rights. The pond is very shallow and weedy and is not used presently.

Blackwell's Brook has its mouth in the Quinebaug River above the Route 14 bridge. There are 3 dams and the 3 lower dams on the Quinebaug River deny access to this brook.

The first is a beaver dam, located about 500 yards downstream of the Wauregan Road bridge. This obstruction was reported to be 3 ft X 20 ft but it was not seen by me. The State of Connecticut owns the land in this area.

The second dam forms Bassett (Lawton) Pond, located about 300 yards downstream of the Tatnic Road bridge, and is made of dressed stone (9 ft X 50 ft). Alice E. Shaw owns the dam and all water rights. The pond is now unused.

The third obstruction is located upstream of the Route 6 bridge at the end of a cleared field. The dam is made of bulldozed rocks and sticks (3 ft X 35 ft X 6 ft wide) and capped with concrete. A. W. and K. L. Anderson own the land at this point. The pond is miniscule and unused.

Moosup River has its mouth in the Quinebaug River about one mile upstream of the Route 14A bridge. There are 2 dams (the rest are considered passable) and the 3 lower dams on the Quinebaug River deny access to this brook.

The first dam is about 500 ft upstream of the Route 12 bridge, Central Village (behind the A&P), and is made of rock and logs (6 ft X 60 ft) with a concrete top. The Hale Mfg. Co., owns the dam and has all flowage rights. No use is made of the pond at present.

The second dam is about 0.25 miles downstream of the Route 14 bridge, Moosup, and is a concrete step-type (15 ft X 150 ft). The Brunswick Worsted Co. (Moosup) owns the dam and has all rights and privileges. The water is used for industry.

Snake Meadow Brook has its mouth in the Moosup River 0.5 miles east of Moosup. There are 2 dams and the dams on the Moosup River and the 3 lower dams on the Quinebaug River deny access to this brook.

The first dam is located 500 ft above the Snake Meadow Road bridge, and is made of concrete and rock (5 ft X 20 ft) with a removable gate. The Snake Meadow Club, Inc., owns this dam and the second with no explicit rights. The pond is used for recreation.

The second dam is 0.5 miles upstream of the first and is made of concrete (4 ft X 15 ft) with gates. The pond is used for recreation.

Quaduck Brook has its mouth in the Moosup River about 2 miles from Moosup. There is one dam and the 2 dams on the Moosup River and the 3 lower dams on the Quinebaug River deny access to this brook.

The dam is about 200 ft upstream of Sawmill Hill Road bridge (upper), and is made of stone and concrete (3 ft X 20 ft) with wooden flashboards. The State of Connecticut owns the dam and has all flowage rights. The pond is large and is used for recreation.

Fivemile River has its mouth in the Quinebaug River at Danielson, 0.25 miles downstream of the Route 6 bridge. There are 5 dams and the 3 lower dams on the Quinebaug River deny access to this brook.

The first dam is near Water Street in Danielson, and is made of dressed stone (8 ft X 75 ft) with a concrete top. The D. R. Holding Co. (12 Main St., Danielson) owns the dam and has flowage rights. The pond is extensive and is not used at present.

The second dam is located north of Route 101 bridge in Dayville, and is made of stone (8 ft X 40 ft). It was not seen by me. William Prym, Inc. (Dayville) owns the dam and has flowage rights. Use of the pond is industrial.

The third dam is located 500 ft upstream of the Route 12 bridge, Attawaugan, and is made of stone and concrete (15 ft X 50 ft). The A. L. Realty Co. (c/o Louis Hand, 5761 Collins Ave., Miami Beach, Florida 72644) owns the dam with no explicit rights. The pond is small and unused.

The fourth dam is 50 ft upstream of the Ballouville Road bridge, Ballouville, and is made of concrete (15 ft X 25 ft). Hale Mfg. Co., owns the dam and has all water power, dam, and flowage rights. The pond is moderate in size and the water is used for industry.

The fifth dam is located 100 ft upstream of a bridge on a dirt road joining River Road. The dam is a step-type made of dressed stone and concrete (6 ft X 30 ft). Ownership and rights were not determined. The pond is moderate in size and presently unused.

Most of the stream banks were over 80% undeveloped and only one stream, the Pachaug River, has less than 50% undeveloped land along its banks (Table 1). Although much of the watershed is undeveloped, consideration must be given to the changes that are being made or contemplated in decisions regarding priorities in development of anadromous fish runs.