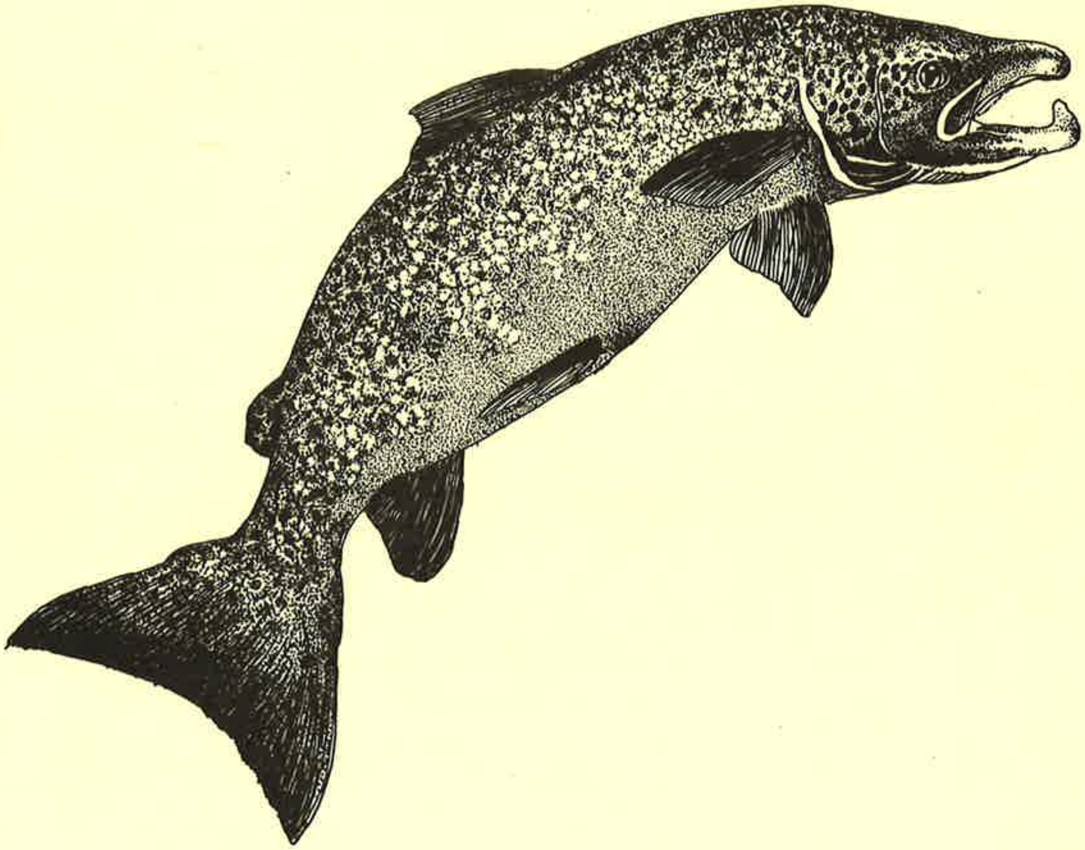
MATTAWAMKEAG RIVER STUDIES

I. BIOLOGICAL AND PHYSICAL FACTORS BEARING ON RESTORATION OF ATLANTIC SALMON

II. EFFECTS OF SEVIN INSECTICIDE ON FISH AND INVERTEBRATES IN 1976.



UNIVERSITY OF MAINE

MIGRATORY FISH RESEARCH INSTITUTE

AND

MAINE COOPERATIVE FISHERY RESEARCH UNIT

February 1978

FOREWORD

Efforts to restore the sea-run Atlantic salmon in New England are focused principally on the Penobscot, Connecticut, and Merrimack river systems. The Penobscot and Connecticut were designated as Model Rivers for salmon restoration a decade ago, and the progress made reflects increasing investment and effort by private organizations, the States, and agencies of the federal government. At present, specialists in research, culture, and management of Atlantic salmon are involved on each of the river systems.

The Penobscot, Connecticut, and Merrimack rivers have been greatly altered by man's activities since colonial times. It is impossible, of course, to return the rivers to pristine conditions, but their long-term degradation may be reversed sufficiently to permit restoration of self-perpetuating populations of salmon in some of the former range.

Although the three river systems are not far apart geographically, they do differ sharply in their basic physical and chemical characteristics and in the nature and degree of degradation suffered through man's activities. In their present condition, the Penobscot, Connecticut and Merrimack also differ greatly from rivers in eastern Canada and northern Europe where Atlantic salmon still maintain natural populations. Salmon interests have considerd it important, therefore, to characterize the physical, chemical, and biological, conditions of the Penobscot, Connecticut, and Merrimack to access their potentials for salmon restoration and to detect factors which may work for or against the fish. In this connection, the U.S. Fish and Wildlife Service awarded a three-year research contract to the University of Maine at Orono for a biological the biologists wished to compare the results of fry stocking in the Mattawamkeag with results of concurrent fry stockings in the upper tributaries of the Connecticut and Merrimack rivers.

A further complication to the survey arose in the spring of 1976 when State-federal efforts to suppress a widespread spruce budworm infestation by aerial application of insecticide were extended to portions of the Mattawamkeag drainage basin. The U.S. Fish and Wildlife Service awarded small additional funding to the University of Maine to expand the Mattawamkeag survey to include observations on the effect of the budworm insecticide on brook trout, landlocked salmon, and stream invertebrates.

In the first of the following reports, Principal Investigator Philip Hulbert presents the findings of the three-year survey of the Mattawamkeag River. In the second report, Mr. Hulbert presents data collected prior to and following the application of the insecticide SEVIN to suppress the spruce budworm in the Mattawamkeag drainage area.

It should be apparent to the reader that the following reports are not the last words on the status of the Mattawamkeag as a candidate for restoration of sea-run Atlantic salmon. The survey represents a major and important step, but only a step, in the lengthy and continuing process of evaluating a river's potential for supporting restored populations of the very fastidious salmon. The investigators believe that the continuing evaluation must be funded and accomplished lest the problems of restoring sea-run salmon be over-simplified in the eyes of administrators, managers, and the public.

Robert E. Lennon
Contract Project Officer
U.S. Fish and Wildlife Service
December 1977

University of Maine
Migratory Fish Research Institute
and
Cooperative Fishery Research Unit

I

BIOLOGICAL AND PHYSICAL FACTORS BEARING ON RESTORATION OF ATLANTIC SALMON IN MATTAWAMKEAG RIVER, PENOBSCOT RIVER SYSTEM, MAINE

(July 1974 through April 1977)

Final Report to U.S. Fish and Wildlife Service
FWS Contract No. 14-16-0008-842

by

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December 1977

ABSTRACT

A study to investigate limitations on the restoration of Atlantic salmon (Salmo salar) in the Mattawamkeag River, Maine, was conducted from 1974 to 1977. Physical characteristics such as water temperature, discharge, and habitat type were examined. Selected water quality parameters were monitored regularly. Biological investigations centered on relative abundance and length frequency distributions of resident fish species, performance of hatchery-reared salmon parr stocked into the Mattawamkeag drainage, and qualitative assessments of macroinvertebrate populations in selected areas of the drainage.

Suitable physical habitat for juvenile salmon was limited; most of the main stem consisted of flat water and deep pool habitats. Several of the larger tributaries contained abundant areas of favorable physical habitat.

Water quality was acceptable for salmon survival throughout the lotic areas of the Mattawamkeag drainage. Summer water temperatures were unfavorable for juvenile salmon during parts of two years and reached nearly lethal levels for several days in 1975. High water temperatures and the low water levels associated with drought conditions in 1975, apparently reduced survival of hatchery-reared salmon parr stocked into the Mattawamkeag River system. Abundant populations of chain pickerel (Esox niger), smallmouth bass (Micropterus dolomieui), and American eel (Anguilla rostrata)

should limit production of juvenile salmon. The migration and sport fishery harvest of adult salmon may be adversely affected by high water temperatures in the Mattawamkeag River.

The combination of biological and physical limiting factors indicate the Mattawamkeag River will be a marginal habitat for the restoration of Atlantic salmon.

INTRODUCTION

The U.S. Fish and Wildlife Service awarded Research Contract No. 14-16-0008-842 to the Migratory Fish Research Institute, University of Maine at Orono, in 1974 for a three-year study on the physical, chemical, and biological factors bearing on the restoration of Atlantic salmon (*Salmo salar*) in the Mattawamkeag River, Penobscot River system in Maine. Field research began on July 8, 1974 and ended on November 20, 1976. The results of the study are presented in this final report.

Many individuals from various organizations assisted me during the study, and I am grateful to them. In particular, I wish to acknowledge assistance received from personnel of the; U.S. Fish and Wildlife Service, Maine Cooperative Fishery Research Unit, Maine Department of Inland Fisheries and Wildlife, Maine Department of Environmental Protection, Maine Forest Service, and the Maine Atlantic Sea-Run Salmon Commission. The following research assistants were employed part-time on the project; Brian Tarbox,Edward Spear, Gary Poisson, Joan Trial, Bruce Grantham, Charles Peters, and Linda Rowell. In addition, valuable assistance was provided by George McCabe and Donald Williamson during the 1975 field season.

Historical background

The Penobscot River, the largest river in Maine, has four major sub-drainages; the Piscataquis River, the Mattawamkeag River, the West Branch Penobscot, and the East Branch Penobscot. Historically, the Penobscot and its sub-drainages supported anadromous Atlantic salmon, and commercial catches in the lower main stream ranged up to 15,000 salmon per year (Cutting 1963). Today, the Penobscot and the Piscataquis and Mattawamkeag sub-drainages are designated as a Model River for Atlantic Salmon Restoration (Everhart and Cutting 1968).

The Mattawamkeag River (Figures 1-3) was chosen for this study because of a specific request by the Maine Department of Inland Fisheries and Wildlife. The Mattawamkeag has a low gradient (approximately 0.1%), relatively warm water, and extensive flat water areas. The main stem of the Mattawamkeag River is 74 km long, and the East and West Branches of the Mattawamkeag aad 62.5 and 49.3 km long, respectively. Table 1, modified from Fenderson and AuClair (1956), presents several watershed characteristics of the Mattawamkeag River in relation to the other major tributaries to the Penobscot River. Other characteristics appear in Figures 4-7.

The Mattawamkeag River was reported to contain 20% of the total spawning and nursery area in the Penobscot system (Cutting 1963). Estimates of the size of former salmon runs in the Mattawamkeag are not available, but the Mattawamkeag salmon runs probably paralleled those in other parts of the Penobscot system.

Two predatory species, the chain pickerel (*Esox niger*) and the smallmouth bass (*Micropterus dolomieui*) were intro-

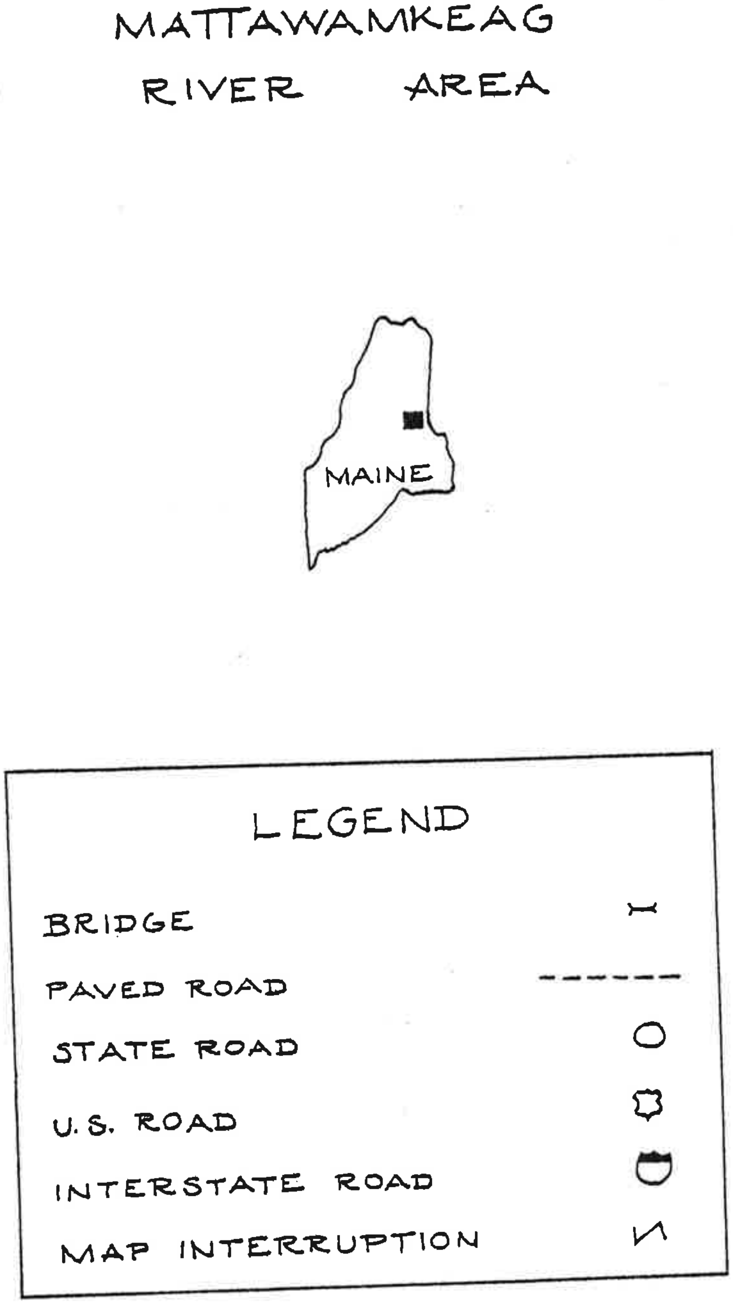


Figure 1. Map of study area and legend for maps shown in Figures 2-3.

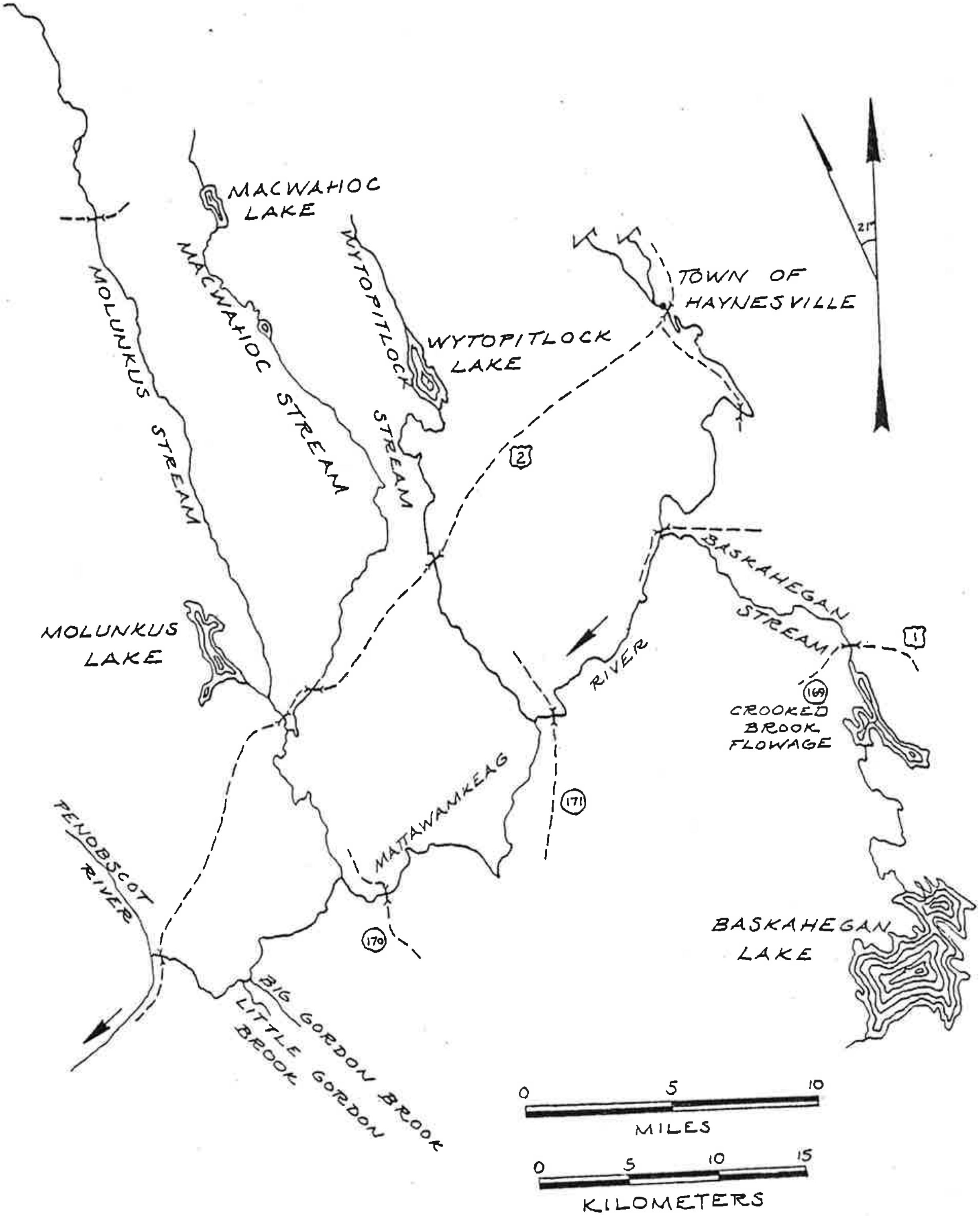


Figure 2. Map of the main stem of the Mattawamkeag River. Legend as shown in Figure 1. Short arrows indicate direction of flow.

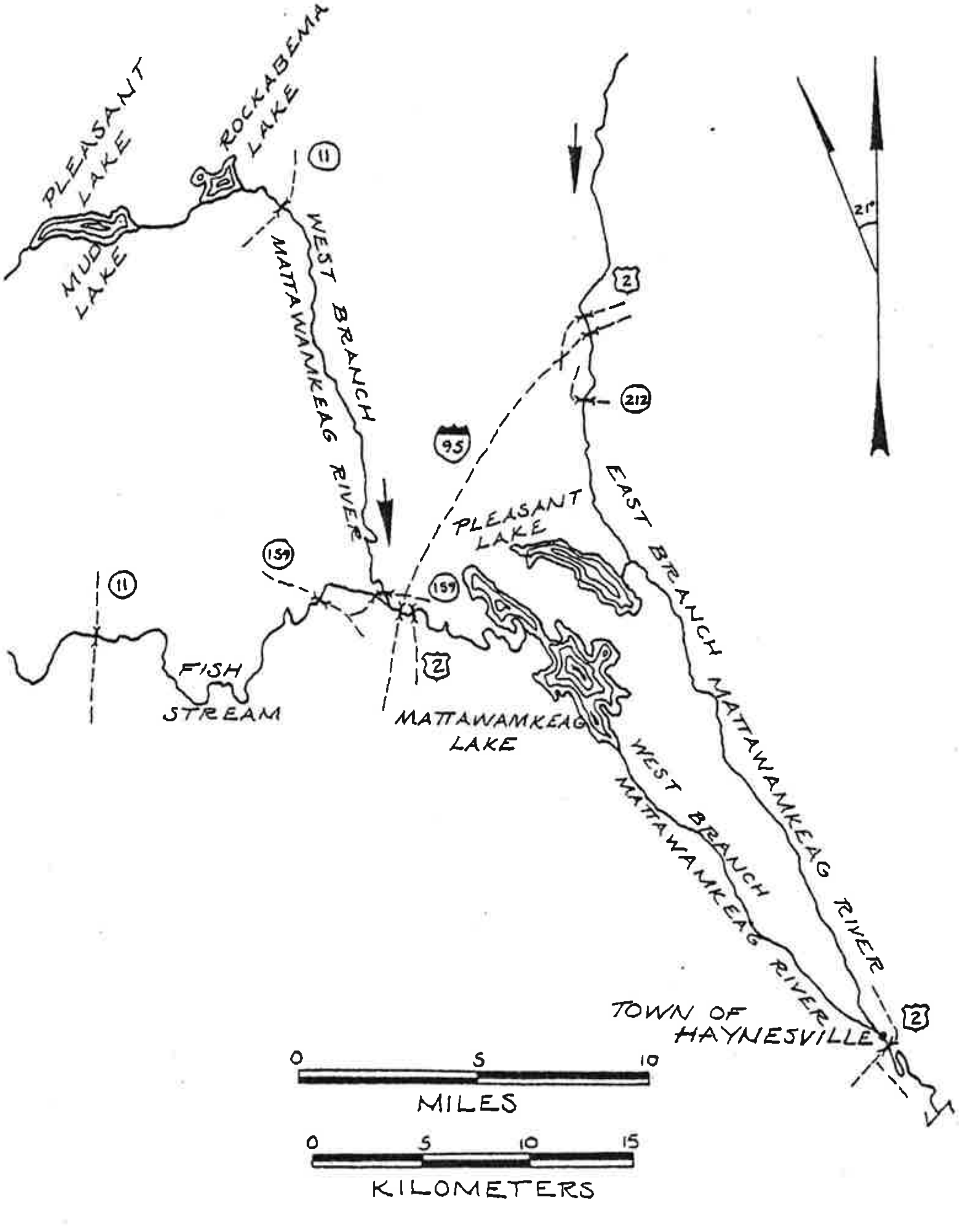


Figure 3. Map of the East and West Branches of the Mattawamkeag River. Legend as shown in Figure 1.

Table 1. Watershed characteristics of major Penobscot River tributaries.

River	Drainage area hectares	Lake area hectares	Stream discharge Station	Stream discharge Average daily m^3/sec	Stream discharge Minimum daily m^3/sec
Penobscot	3,140	100,539	West Enfield	334	46.2
West Br. Penob.	850	43,356	Medway	---	49.6
East Br. Penob.	445	16,170	Grindstone	55	2.2
Piscataquis	607	15,598	Medford	67	2.8
Mattawamkeag	615	10,376	Mattawamkeag	70	1.1
Passadumkeag	159	8,148	Lowell	14	0.1

Figure 4: Mattawamkeag River Drainage General Soils Map for the Penobscot County Area, Maine

Soil Associations

▤	Bangor-Dixmont-Thorndike association: Stony and stone-cleared, deep to shallow slaty soils of the uplands.
▧	Bangor-Howland-Plaisted association: Stony and stone-cleared, deep mainly slaty soils of the uplands; some have a compact layer.
▩	Hermon-Plaisted association: Stony and stone-cleared, deep mainly granitic soils of the uplands.
░	Monarda-Burnham-Dixmont association: Wet, dominantly very stony soils of the uplands.
□	Plaisted-Thorndike-Howland association: Stony and ledgy, deep to shallow, granitic and slaty soils of the uplands.
▒	Canaan-Thorndike-Hermon-Plaisted association: Mountainous land.
▨	Stetson-Machias-Allagash-Hadley association: Gravelly and sandy soils of the terraces and flood plains.
■	Water

Figure 4: Mattawamkeag River Drainage General Soils Map for the Penobscot County Area, Maine

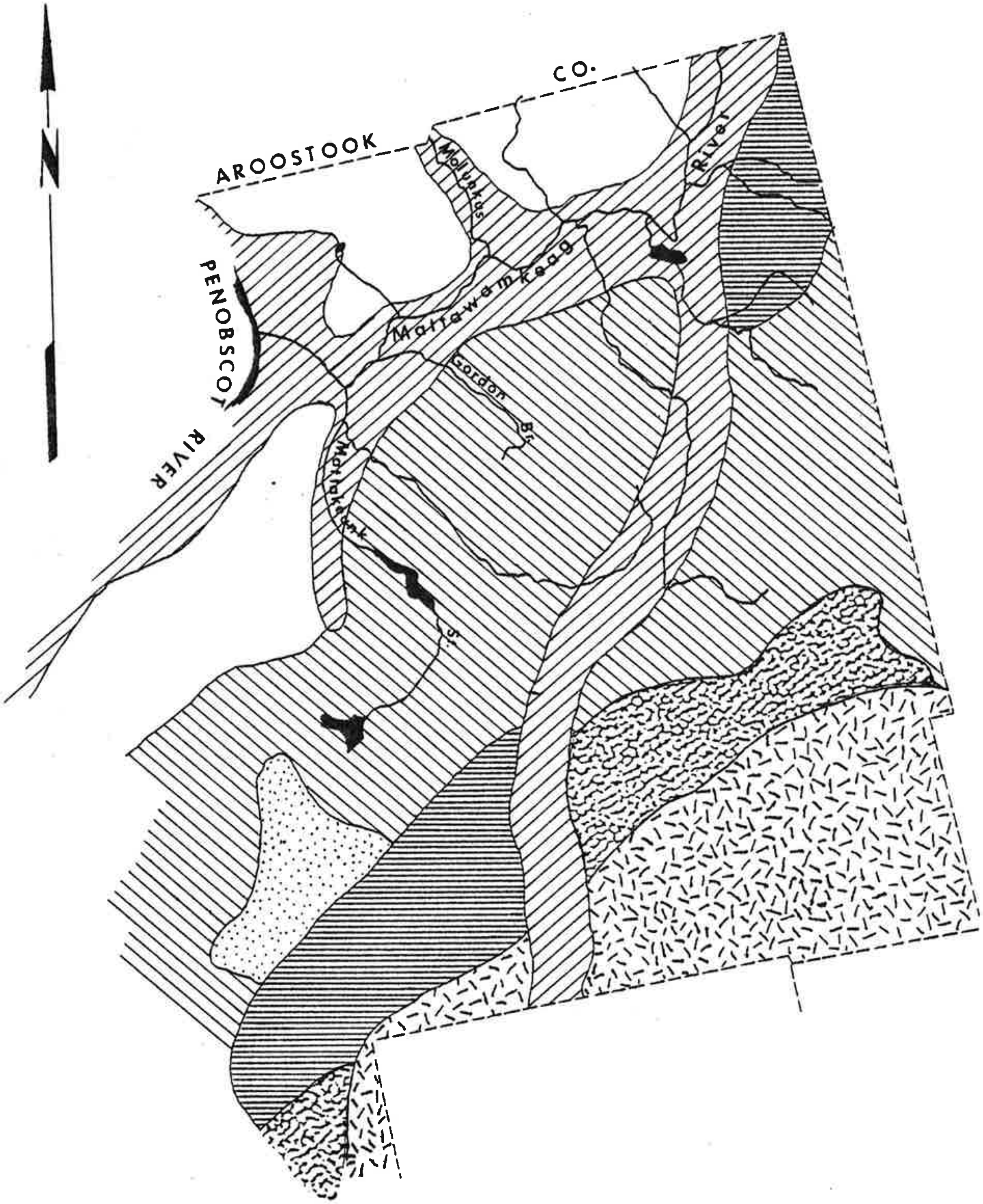


Figure 5: Mattawamkeag River Drainage General Soils Map for the Aroostook County Area, Maine

Soil Associations

▧ Caribou-Mapleton-Conant association: Gently rolling soils on till derived chiefly from linestone.

▤ Plaisted-Perham-Howland association: Smoothly sloping soils on till derived chiefly from acid rocks.

□ Thordike-Howland association: Irregularly sloping soils on till derived chiefly from acid rocks.

▨ Colton-Machias association: Nearly level to sloping soils on terraces, eskers, and glacial outwash.

░ Monarda-Burnham association: Nearly level to gently sloping, poorly drained soils on firm till.

■ Water

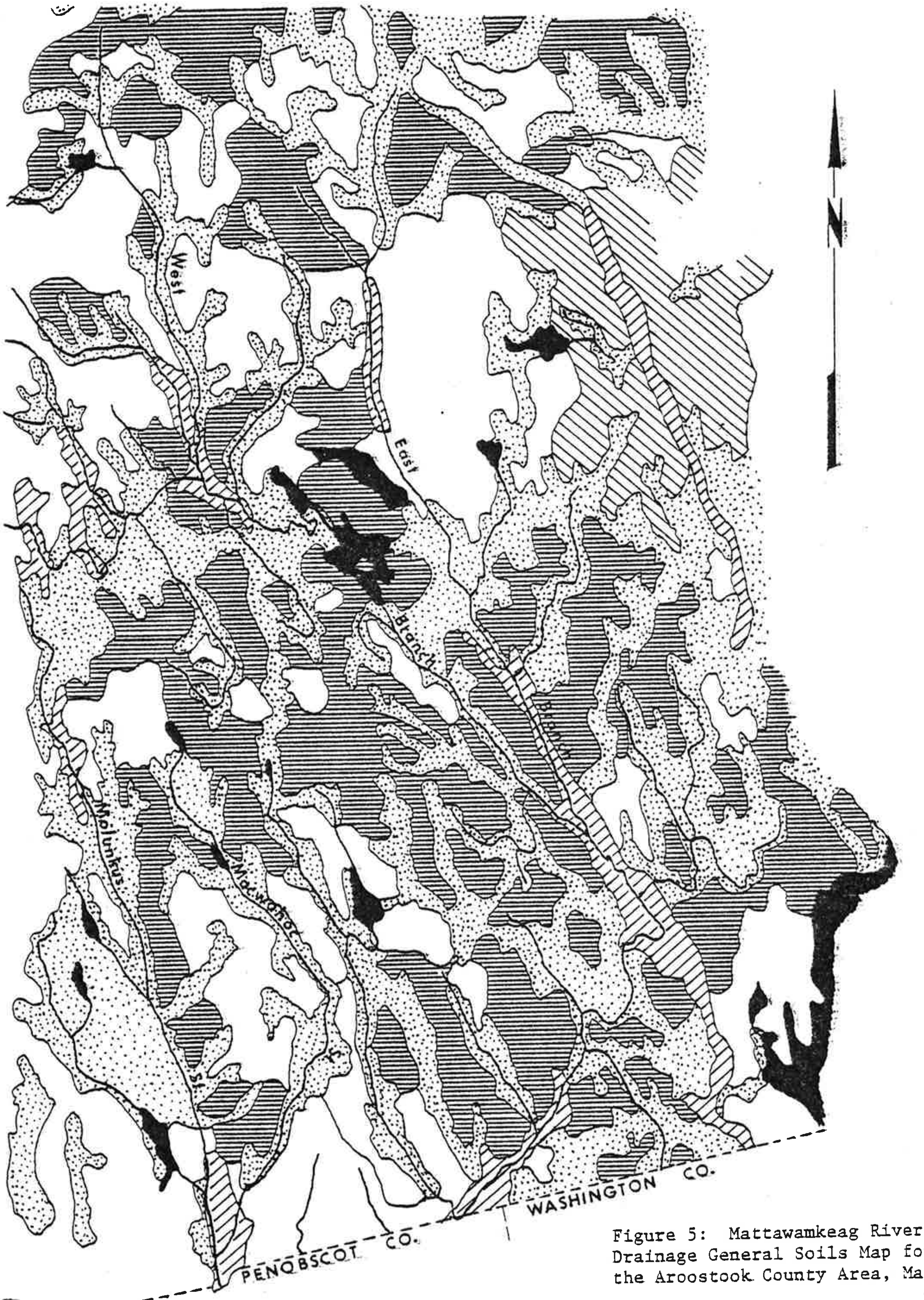


Figure 5: Mattawamkeag River Drainage General Soils Map for the Aroostook County Area, Maine

Figure 6. Mattawamkeag River Flowage General Bedrock Map for the Penobscot County Area, Maine.

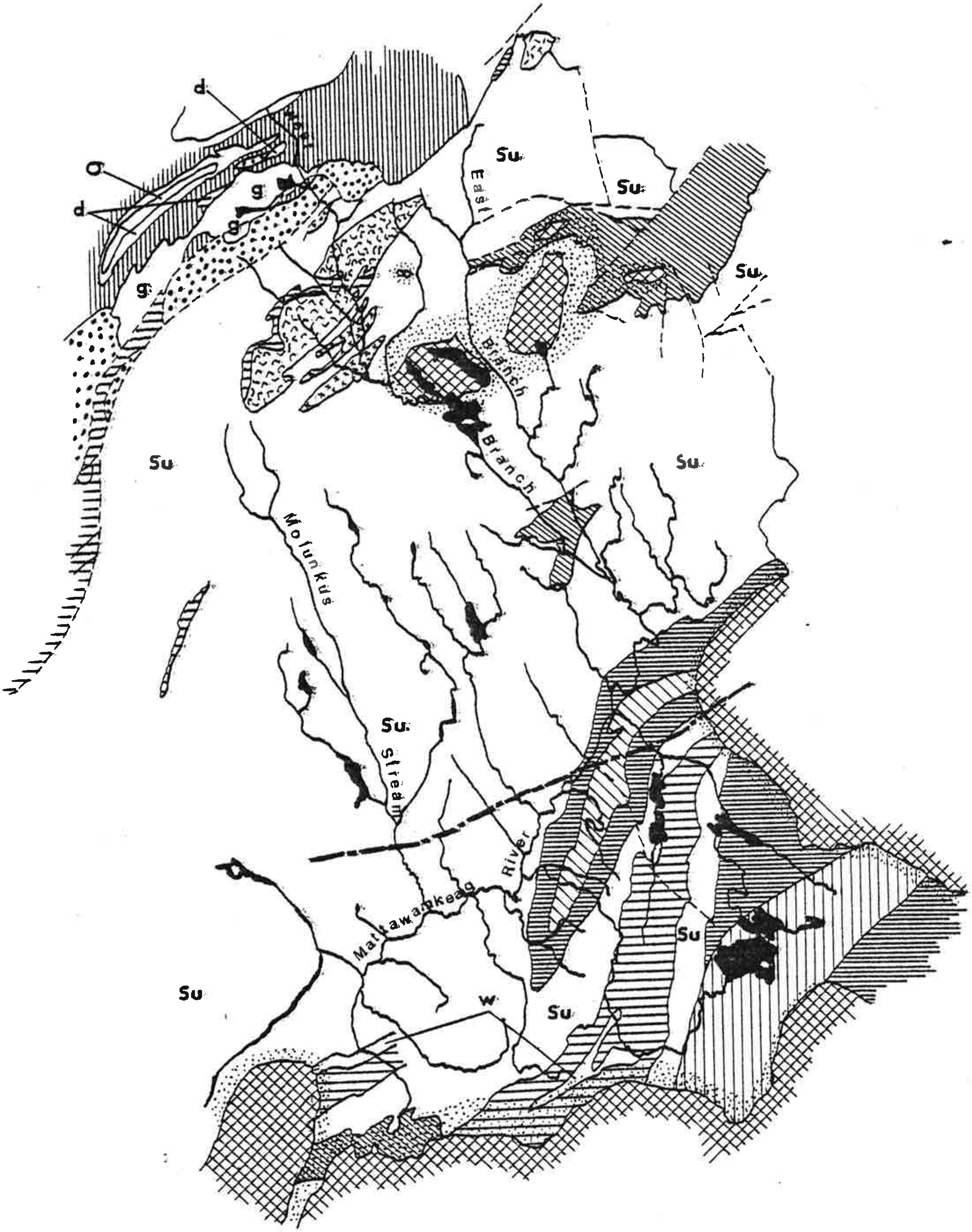
▬ ▬ ▬	Diabase dikes -- Devonian/younger
- - - - - -	Faults
▩	Biotite, biotite-muscovite granite, and quartz monzonite (includes some granodiorite and felsic intrusive rocks in Aroostook Co.) - Devonian New Hampshire Plutonic Series.
⁘	Shale and slate. Swamback Formation and unnamed units - Lower Devonian.
▧	Metamorphosed shale, siltstone, sandstone, and quartzite - Upper Silurian.
▤	Quartzite and metamorphosed conglomerate, shale, siltstone, and ferruginous slate. Daggett Ridge Formation - Upper Silurian.
Su	Metamorphosed gray and green siltstone, sandstone, shale, graywacke, conglomerate, sedimentary ironmanganese deposits. Smyrna Mills, Island Falls, and Allsbury Formation - Middle Silurian.
✕	Metamorphosed limestone, calcareous siltstone, and shale within the Island Falls Formation - Middle Silurian.
≋	Conglomerate, sandstone, and siltstone, includes Frenchville Formation - Lower Silurian.
g	Granitic and dioritic rocks - Silurian/Ordovician.
o	Diabase of Caradocian Age - Ordovician.

Figure 6. (continued)

∿	Slate and metagraywacke - Upper Ordovician.
▧	Metamorphosed limestone, calcareous sandstone, and shale. Carys Mills Formation - Middle Ordovician.
▤	Metamorphosed dark gray and black shale, chert, sandstone, and minor volcanic rocks, silicified in places - Middle Ordovician.
w	Conglomeratic quartzose metagraywacke - Middle Ordovician.
⁙	Metamorphosed felsic to mafic volcanic rocks with interbedded metasedimentary rocks - Middle Ordovician.
d	Metamorphosed felsic to intermediate tuff and tuffaceous. Includes Shin Brook Formation - Middle Ordovician.
▥	Slate, metasandstone, and quartzite, including green and black slate, and some metavolcanic rocks - Middle Ordovician.
▥	Interbedded quartzite, metasiltstone, and slate, including red and green varieties - Cambrian.

░	Indicates areas of contact metamorphism.

Figure 6. Mattawamkeag River Flowage General Bedrock Map for the Penobscot County Area, Maine.



COVER MAP
MATTAWAMKEAG RIVER
including the EAST BRANCH

Interpreted and Mapped by

Linda A. Wright

11 October 1977

PHOTOGRAPHY: Color infrared, 1:120,000, September 1973

MAP SCALE: Approximately 2 inches per mile

LEGEND:
▨ = Forested; more than 50% softwood
H = Forested; more than 50% hardwood
W = Wetland, bog, marsh
O = Open areas: residential, farm, clearcut, borrow pit

North arrow parallels long edge of map.

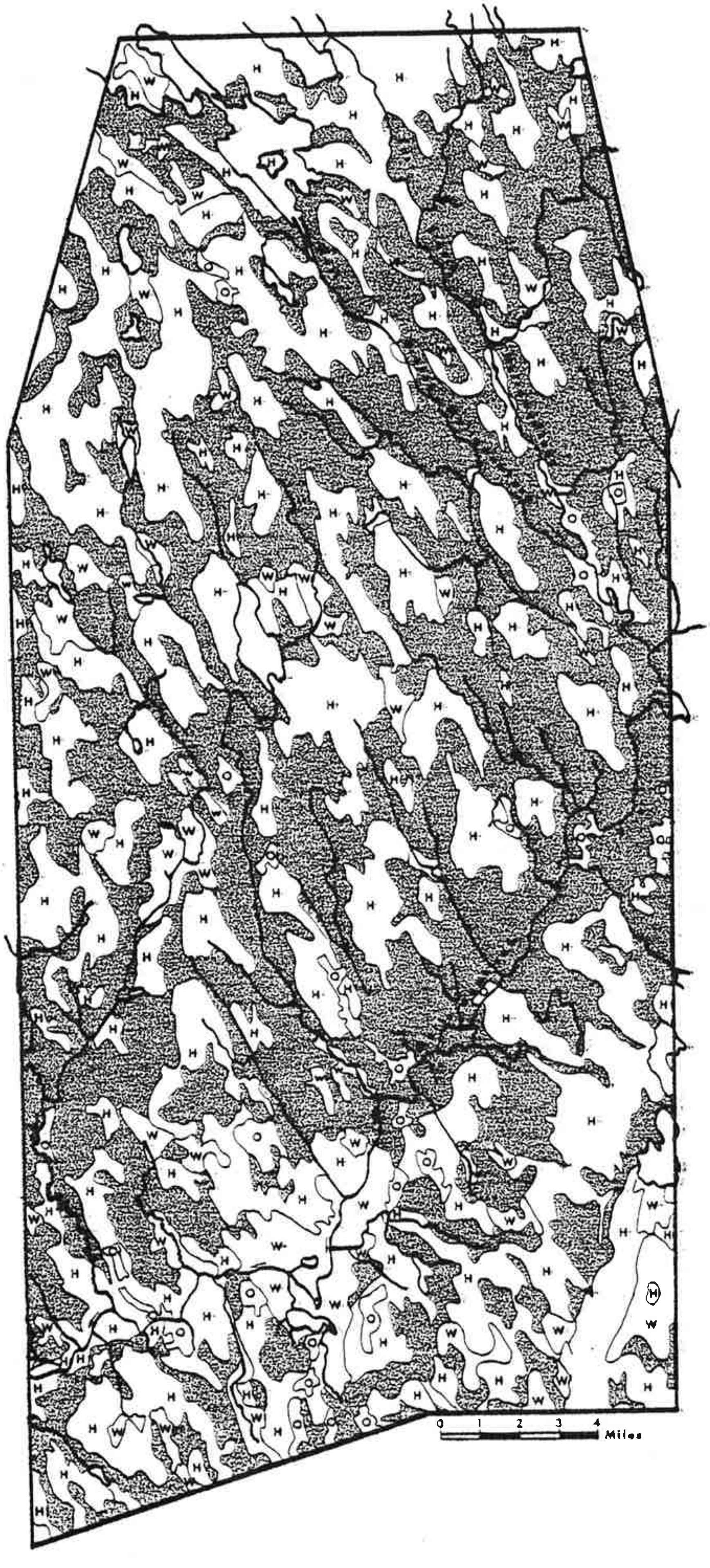


Figure 7. Map of the Mattawamkeag River including the East Branch, showing forest with more than 50% hardwood (H), and wetlands of bogs or marshes (W), and open areas (O).

duced into waters contiguous with the Mattawamkeag River in the Nineteenth Century. Pickerel were stocked into the upper Penobscot River in Lincoln in 1824 (Maine Commissioner of Fisheries 1867). In 1877 smallmouth bass were introduced into Mattaceunk Lake, which drains into the Penobscot River several kilometers upstream from the mouth of the Mattawamkeag (Maine Commissioner of Fisheries 1877). The impact of these introductions on the salmon population is not known. The distribution of bass and pickerel in the Mattawamkeag River may have been limited in the mid- and late-Nineteenth Century by three dams on the main stem of the Mattawamkeag below Kingman (Maine Commissioner of Fisheries 1873). Today bass and pickerel are widely distributed in the Mattawamkeag. Table 2 contains a list of the fish species captured in the Mattawamkeag River drainage during this study.

Adult Atlantic salmon were commonly seen below the dams on the Mattawamkeag River in the 1870's. Fishways were called for and were finally built in 1880, giving salmon access to most of the Mattawamkeag River (Maine Commissioner of Fisheries 1880). Unfortunately, developments on the lower Penobscot River doomed the Atlantic salmon runs of the Mattawamkeag.

The lumber industry along the Penobscot River expanded rapidly in the Nineteenth Century. Logs harvested in forests near the headwaters were floated down the Penobscot to be cut at many of the sawmills located close to Bangor. The combination of massive log drives and sawmill operations

Table 2. List of fishes captured by netting and electrofishing in the Mattawamkeag River drainage between July 8, 1974 and October 31, 1976.

Common name	Scientific name
American eel	*Anguilla rostrata*
Atlantic salmon	*Salmo salar*
Brook trout	*Salvelinus fontinalis*
Chain pickerel	*Esox niger*
Golden shiner	*Notemigonus crysoleucas*
Common shiner	*Notropis cornutus*
Blacknose dace	*Rhinichthys atratulus*
Creek chub	*Semotilus atromaculatus*
Fallfish	*Semotilus corporalis*
Longnose sucker	*Catostomus catostomus*
White sucker	*Catostomus commersoni*
Brown bullhead	*Ictalurus nebulosus*
Burbot	*Lota lota*
Threespine stickleback	*Gasterosteus aculeatus*
Ninespine stickleback	*Pungitius pungitius*
White perch	*Morone americana*
Redbreast sunfish	*Lepomis auritus*
Pumpkinseed	*Lepomis gibbosus*
Smallmouth bass	*Micropterus dolomieui*
Yellow perch	*Perca flavescens*

produced vast quantities of sunken logs, bark, and sawdust. This wood-waste pollution coated parts of the river bottom with a layer of oxygen-demanding material.

Many dams were constructed on waterways in the Penobscot River system to run the mills associated with the logging industry. Provisions for fish passage were not always included, and the proliferation of dams began to limit salmon runs. A major catastrophe occurred in 1887 when a dam spanning the Penobscot River at Great Works, 22.5 km upstream from head of tide, was torn down, including the State-owned fishway. Shortly after, a new dam was built with no fishway. The entire Penobscot River upstream run of salmon in 1890 was blocked because of this dam. Fish resting below the Great Works dam were subjected to poisonous wastes such as lime, soda, and sulfuric acid that were discharged from the adjacent pulp mill (Maine Commissioner of Fisheries 1889-1890). The deterioration of Penobscot River salmon runs due to pollution and inadequate fish passage progressed rapidly, and by 1900 only 200 salmon ascended the upper reaches of the Penobscot (Cutting 1963). From that point on, it is unlikely that sizeable numbers of Atlantic salmon were present in the Mattawamkeag River.

As stocks began to decline, the need for hatchery propagation of salmon was realized. Salmon stocking was initiated in the Penobscot River in 1872 and the following year salmon fry were released into the Mattawamkeag River (Maine

Commissioner of Fisheries 1873). Since then, the Mattawamkeag has received numerous plantings of juvenile salmon. Hatchery releases into the Penobscot drainage between 1872 and 1959 are summarized by Cutting (1963). Sea-run salmon stockings into the Mattawamkeag River during the span of this project, 1974 through 1976, are summarized in Tables 3 and 5.

Present status

Currently the Mattawamkeag River is comparatively free of man-made habitat alterations. No dams exist on the main stem or either of the branches. Low-head dams are found at the outlets of several lakes draining into the Mattawamkeag River, such as Rockabema and Mattawamkeag lakes. These dams were built primarily for log drives and to maintain water levels in the lakes for camp owners (Cutting 1963). Discharge is influenced by these dams, but strict flow control, as exemplified by the St. Croix River, does not exist in the Mattawamkeag River. Pollution is minimal and is essentially composed of domestic sewage from the few small towns along the river. Agricultural activities in the drainages include timber harvest and cultivation of potatoes, oats, corn, and hay. The East and West Branches Mattawamkeag River plus the Molunkus Stream drainage were estimated to contain 4,500 hectares of the non-timber crops mentioned above in 1974 (Kenneth Chapman, Cooperative Extension Service, personal communication). Recreational uses of the river are moderate and consist principally of fishing and canoeing. Increased

Table 3. Hatchery-reared sea-run Atlantic salmon released into main stem of Mattawamkeag River in 1974-1976.

Location	Date of release	Salmon stocked	Total length range mm	Remarks
Mattawamkeag to Haynesville	6/574	16,700	76-102	Age 1+ parr
Mattawamkeag	5/5-7/75	24,895	152-204	Age 2 smolts
	6/2/75	4,104	102-152	Age 1+ parr
Haynesville, confluence of E. and W. branches	7/22/76	6,539	102-152	Age 1+ parr
	9/15/76	5,816	102-152	Age 1+ parr
Haynesville, near village	5/7/76	4,961	140-178	Age 1 smolts
	9/13/76	4,181	102-152	Age 1+ parr
South Bancroft	7/23/76	5,424	102-178	Age 1+ parr
	9/13-17/76	6,960	102-152	Age 1+ parr
Wytopitlock	9/14-16/76	10,431	102-152	Age 1+ parr
Kingman	5/7/76	3,160	140-178	Age 1 smolts
	9/17-20/76	8,537	127-203	Age 1+ parr
Mattawamkeag	5/3-5/76	34,303	152-279	Age 2 smolts, LV clip
	9/17-21/76	11,427	127-203	Age 1+ parr

Totals in: 1974 - 16,700 parr
1975 - 24,895 smolts and 4,104 parr
1976 - 42,424 smolts and 59,315 parr

Table 4. Hatchery-reared sea-run Atlantic salmon released into tributaries of the Mattawamkeag River in 1974 and 1975.

Location	Date of release	Salmon stocked	Total length range mm	Remarks
	1974			
East and West branches, Haynesville	6/4	4,600	76-102	Age 1+ parr
Molunkus Stream, Molunkus	6/4	4,600	76-102	Age 1+ parr
Macwahoc Stream, Macwahoc	6/4	4,600	76-102	Age 1+ parr
Wytopitlock Stream, Reed	6/4	4,600	76-102	Age 1+ parr
	1975			
East Branch, Haynesville	6/2	1.534	102-152	Age 1+ parr
Wytopitlock Stream, Reed	6/2	1,200	102-152	Age 1+ parr

Totals in: 1974 - 18,400 parr
1975 - 2,734 parr

Table 5. Hatchery-reared sea-run Atlantic salmon released into tributaries of the Mattawamkeag River in 1976.

Location	Date of release	Salmon stocked	Total length range mm	Remarks
East Branch, Haynesville	7/21	8,341	101-152	Age 1+ parr
	9/14	4,572	102-152	Age 1+ parr
West Branch, Haynesville	7/19	11,245	76-152	Age 1+ parr
	7/20	8,725	76-152	Age 1+ parr
	9/15-16	12,209	102-152	Age 1+ parr
Molunkus Stream, Monarda Route 2	5/6	4,337	140-178	Age 1 smolts
	5/7	4,500	140-178	Age 1 smolts
Macwahoc Stream, Route 2A	5/6	2,000	140-178	Age 1 smolts
Wytopitlock Stream, Reed	5/6-7	1,500	140-178	Age 1 smolts
Wytopitlock Lake, Reed	9/22-29	10,509	178-254	Age 1+ parr
Hot Brook Lakes, Danforth	9/22-29	13,033	152-254	Age 1+ parr

Totals in 1976: 68,634 parr and 12,337 smolts use of the lower main stem is likely, due to the opening of the Mattawamkeag Wilderness Park in the Town of Mattawamkeag several years ago.

Because the Mattawamkeag is a tributary to the Penobscot River, conditions in the Penobscot will affect anadromous species originating in the Mattawamkeag River. Five dams, all on the Penobscot, are present between the mouth of the Mattawamkeag River and the Penobscot estuary. The dams range from 5 to 6 m in height, and all have fishways. The efficiency of several of these fishways, particularly at the Great Works, Milford, and West Enfield dams, has been questioned (Cutting 1963; Meister 1977), but quantitative studies have not been conducted. Some information on the upstream movements of adult salmon, including passage over dams, was obtained in 1976 in a radio-tracking study conducted by Dr. James McCleave, Migratory Fish Research Institute, University of Maine at Orono, and supported by the U.S. Fish and Wildlife Service.

When compared with most of the Penobscot River drainage, the Mattawamkeag River is unusual for its lack of environmental degradation. Two recent developments involving the use of chemical insecticides, however, may influence the future of Atlantic salmon populations. In 1976 the Forestry Bureau of the Maine Department of Conservation conducted an 8.6 million-hectare spraying operation to limit damage inflicted by the spruce budworm (<u>Choristoneura fumiferana</u>) on spruce-fir forests. Aerial applications of Sevin, a carbamate pesticide, were used on most operational areas, including headwater locations in the Mattawamkeag drainage. Results of a study conducted in 1976 to evaluate some effects of Sevin application on fish populations in parts of the Mattawamkeag drainage are included as an addendum to this report. In 1977 proposals are being finalized to conduct field tests of several chemicals for black fly (*Simulium* spp.) control. Parts of the Penobscot River may be included in these tests. Chemical treatments have been widely used in the past in conjunction with Maine's spruce budworm program and pressure to attempt chemical control of black flies is being applied by several municipalities within the Penobscot River drainage. The threat of potential damage to Atlantic salmon restoration efforts is real, particularly because the sub-lethal effects of chemical pesticides are poorly known.

Justification

Recent efforts to restore or augment North American stocks of sea-run Atlantic salmon have included local, state, federal, and international cooperation. The U.S. Fish and Wildlife Service is currently expending large amounts of manpower and funds toward the goal of restoration. Two National Fish Hatcheries in Maine, plus four others in nearby New England states, are propagating juvenile salmon for releases into suitable waters. The Maine Atlantic Sea-Run Salmon Commission, a State agency, has a full-time staff of five biologists working on management of salmon populations in Maine waters. The Penobscot River has an ultimate production goal of one million smolts per year under its Model River designation. Other New England rivers being investigated for Atlantic salmon potential include the St. Croix, Connecticut, and Merrimack rivers. Clearly, regional interest in New England salmon restoration is exceptionally high.

Habitat quality is crucial to the success of introduced species. Biological surveys should include sampling of different habitat types within a given river system. The Mattawamkeag River is representative of much of the lotic habitat available to Atlantic salmon in the Penobscot River drainage. Similarities and differences uncovered in surveys of the Connecticut and Merrimack rivers, when compared with the Mattawamkeag River results, may define factors which will influence the success of salmon introductions. A massive commitment to hatchery production, combined with environmental quality assessments, will enhance chances for achieving salmon restoration. Can the present habitat in the Mattawamkeag River still support large populations of anadromous Atlantic salmon? With that question in mind, the Mattawamkeag River study was undertaken.

Scope of study

Prior work centered on assessing spawning and nursery areas in the Mattawamkeag drainage (Cutting 1963). In the past, limited biological sampling was accomplished by personnel of the Maine Department of Inland Fisheries and Wildlife. The objective of the current study was to detect and examine physical, chemical, and biological factors which may affect restoration of Atlantic salmon in the Mattawamkeag River. Physical factors examined were water temperature patterns, stream discharge, and habitat type. The study of chemical factors centered on regular monitoring of selected water quality parameters. Biological factors included the relative abundance and length frequencies of major fish species, qualitative assessment of benthic macroinvertebrate populations, and the performance of hatchery-reared salmon stocked into parts of the Mattawamkeag drainage.

Principal field-oriented activities are listed below for the three years of this study.

FY 1974 1) reconnaisance of drainage
2) hydrothermographic monitoring
3) sampling of fish populations
4) initiation of monthly water quality surveys

FY 1975 1) hydrothermographic monitoring
2) water quality surveys
3) extensive surveys of fish populations

FY 1976 1) hydrothermographic monitoring
2) sampling of fish populations
3) intensive sampling of macroinvertebrates

PHYSICAL FACTORS

Water temperature and stream discharge- methods

Water temperatures were measured at numerous sites in the Mattawamkeag River drainage using Ryan Model D recording hydrothermographs, maximum/minimum thermometers, and laboratory thermometers. The sites included the main stem at the towns of Mattawamkeag, Wytopitlock, and Haynesville. Additional monitoring sites were the lower East and West Branches of the Mattawamkeag River, near the town of Haynesville. Temperature recording generally extended from early June through October, but one unit was maintained in the East Branch Mattawamkeag from October 19, 1974 to March 20, 1975.

Some observations from aircraft and ground were made on the extent and duration of ice cover on the main stem, East Branch, and part of the West Branch in the winter of 1974-1975.

Stream discharge was measured at several locations in the Mattawamkeag drainage in August 1975.

Water temperature and stream discharge- results

Water temperatures reached levels unfavorable for Atlantic salmon during portions of each summer from 1974-1976. This was most pronounced in 1975 and least severe in 1976. Mean daily water temperatures were 25 C or higher in the main stem at the Town of Mattawamkeag for a total of 29 days from June 1 to August 31, 1975. Daily temperature fluctuations at the lower main stem recording site averaged 2.2 C for those 29 days. During nine consecutive days in July 1975, mean water temperatures in the lower main stem did not fall below 25 C (Figure 8). No large influxes of cool water into the main stem were located. Two small tributaries to the lower main stem, Big Gordon and Little Gordon brooks,

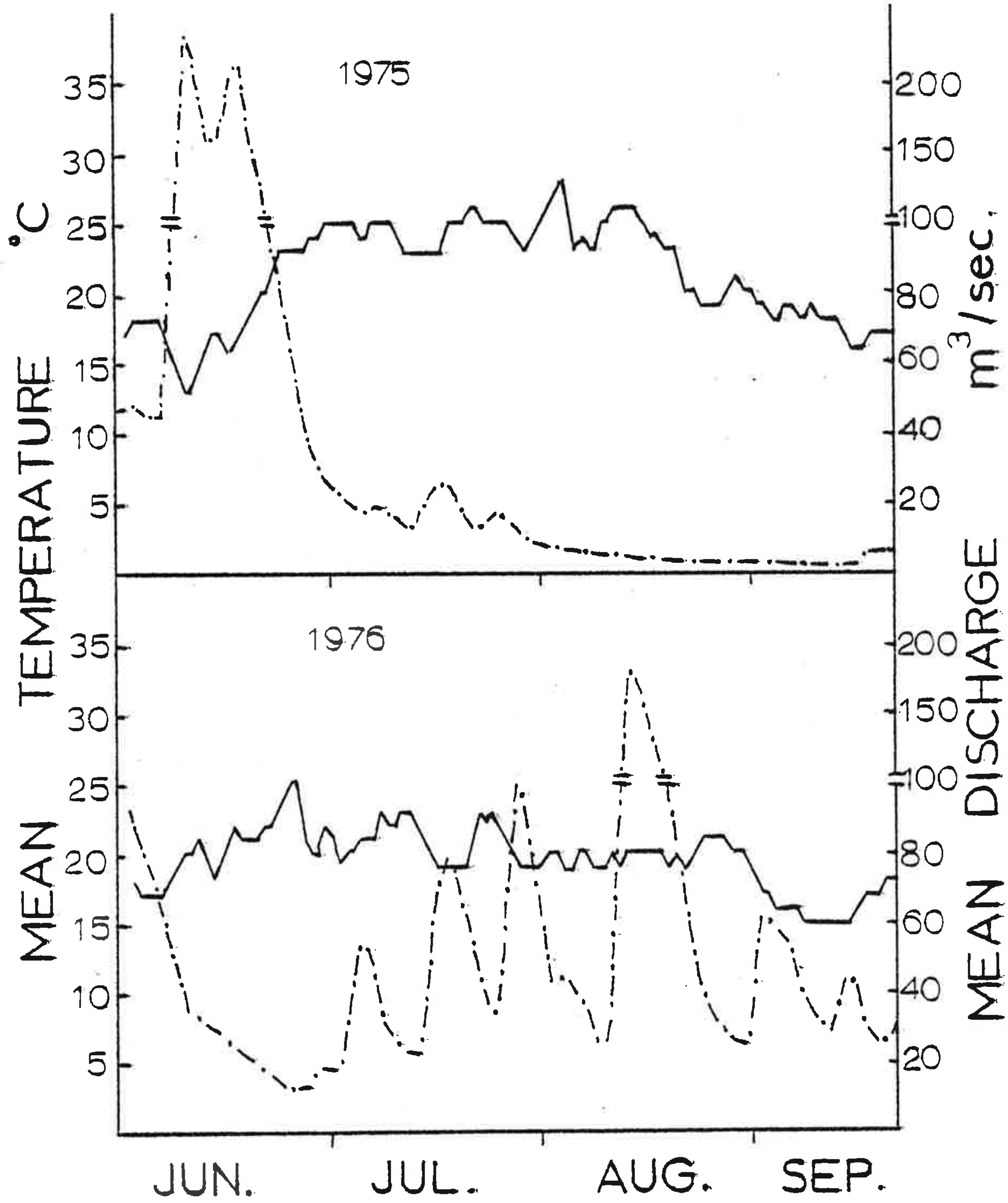


Figure 8. Changes in mean water temperature (solid line) and mean discharge (broken line) recorded at the Mattawamkeag River near the Town of Mattawamkeag, Maine from June 1 to September 20 in 1975 and 1976.

generally had day-time temperatures 3 to 5 C lower than the Mattawamkeag River.

High summer water temperatures were also common in the lower East and West Branches of the Mattawamkeag River. Daily maximum water temperatures often reached the same values recorded in the lower main stem. In early August 1975, water temperatures were 29 C for portions of two days at both branches and at the main stem (Table 6). Mean temperatures at the East and West Branches, however, were 2 to 4 C less than those at the main stem in the summer. Daily temperature ranges of 3 to 4 C were typical in the summer at the East Branch in 1975 and 1976 (Figures 9 and 10). Several cool-water tributaries to both the East and West Branches were located during reconnaissance float trips by canoe.

Water temperatures recorded in the fall at the Mattawamkeag drainage fluctuated widely between the 1975 and 1976 observations. In late October, mean water temperatures in the main stem and East Branch were 5 C less in 1976 than in 1975.

Aerial reconnaissance of the river on March 10, 1975 revealed major areas of open water on the main stem from Gordon Falls to Mattawamkeag Wilderness Park, near the town of Kingman, and at Ledge Falls between Bancroft and Haynesville. Other open water zones were located near the outlet of Pleasant Lake on the East Branch and, from the upper Webber Company Bridge to Mattawamkeag Lake on the West Branch. All of these ice-free areas contained some rapids,

Table 6. Results of water temperature monitoring at several sites in the Mattawamkeag River drainage from June 1 to September 20 in 1975 and 1976. Mean temperature (C) is listed first, followed by range in parentheses.

Sample period	Main stem, Town of Mattawamkeag	Main stem, Town of Wytopitlock	East Branch, Webber Road	West Branch, Webber Road
		1975		
June 1-10	16 (13-19)	14 (11-18)[a]	14 (10-17)	16 (14-18)
June 11-20	17 (13-21)	15 (12-17)	16 (13-20)[a]	N/A
June 21-30	23 (20-26)	20 (18-22)	21 (16-25)	21 (18-27)
July 1-10	23 (22-25)	25 (23-26)	23 (19-26)	22 (20-25)
July 11-20	23 (22-26)	24 (23-27)	23 (20-28)	22 (20-26)
July 21-31	24 (21-26)	25 (23-27)	23 (18-26)	23 (19-25)
August 1-10	24 (22-29)	24 (23-26)	23 (19-29)	24 (20-29)
August 11-20	24 (19-26)	23 (22-24)	22 (15-26)	22 (16-25)
August 21-31	19 (16-21)	20 (19-21)	17 (14-21)	17 (14-19)
September 1-10	18 (16-19)	19 (18-20)	16 (14-19)	16 (14-18)
September 11-20	17 (15-19)	N/A	16 (15-19)[a]	N/A

	Main stem, Town of Mattawamkeag		East Branch, Webber Road
		1976	
June 1-10	18 (16-21)		N/A
June 11-20	20 (18-22)		N/A
June 21-30	22 (19-26)		N/A
July 1-10	21 (19-24)		N/A
July 11-20	20 (18-24)		19 (16-24)[a]
July 21-31	23 (19-24)		21 (16-24)
August 1-10	19 (18-21)		19 (16-22)
August 11-20	20 (19-21)		19 (16-21)
August 21-31	20 (18-22)		19 (14-25)
September 1-10	16 (14-18)		14 (12-16)
September 11-20	16 (14-18)		16 (13-18)

N/A data not available

[a] data missing for 2 or more days

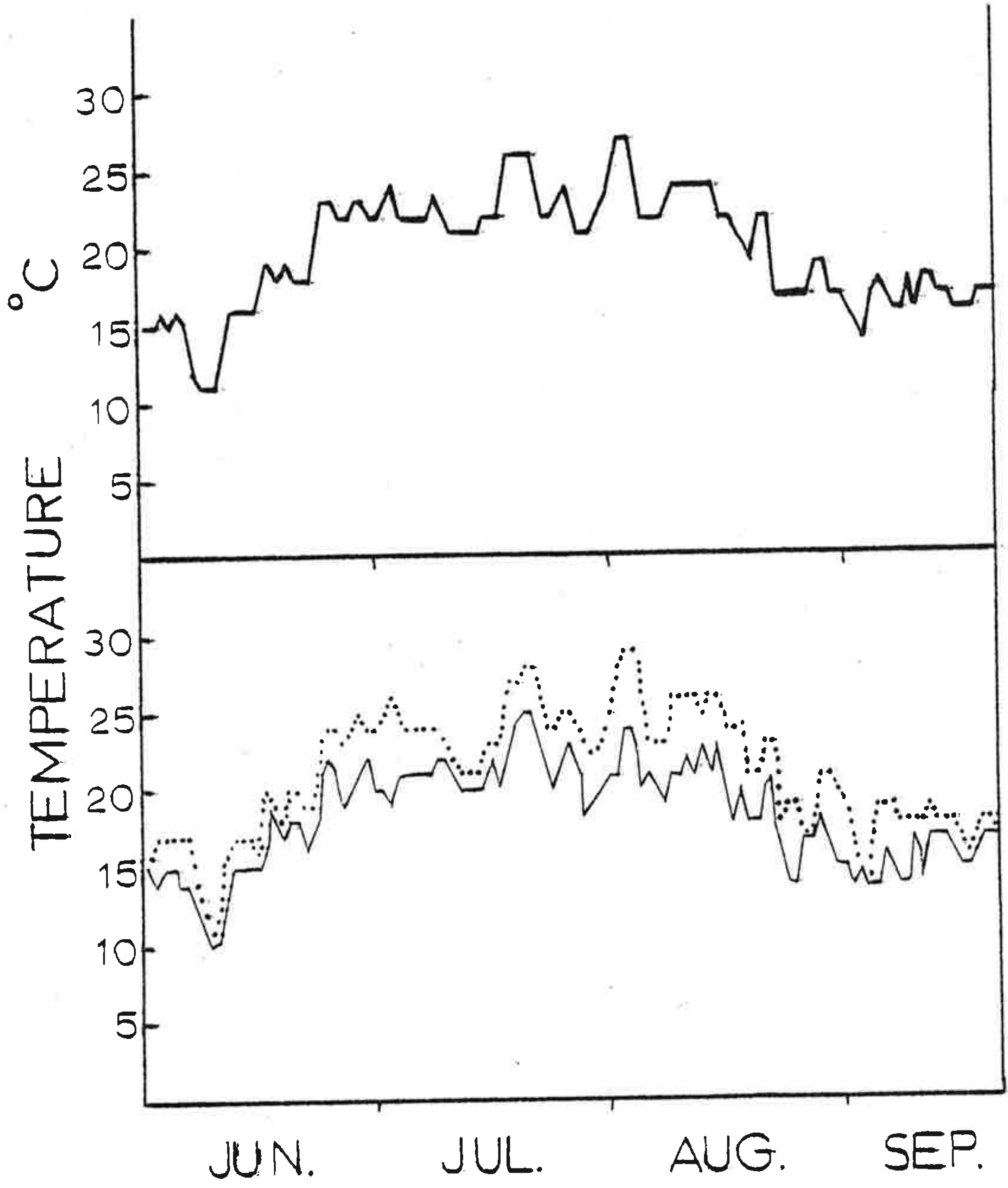


Figure 9. Water temperature patterns recorded at the East Branch Mattawamkeag River near Haynesville, Maine from June 1 to September 20, 1975. Upper graph shows mean daily temperature (heavy solid line). Lower graph shows maximum (dotted line) and minimum (light solid line) daily temperatures.

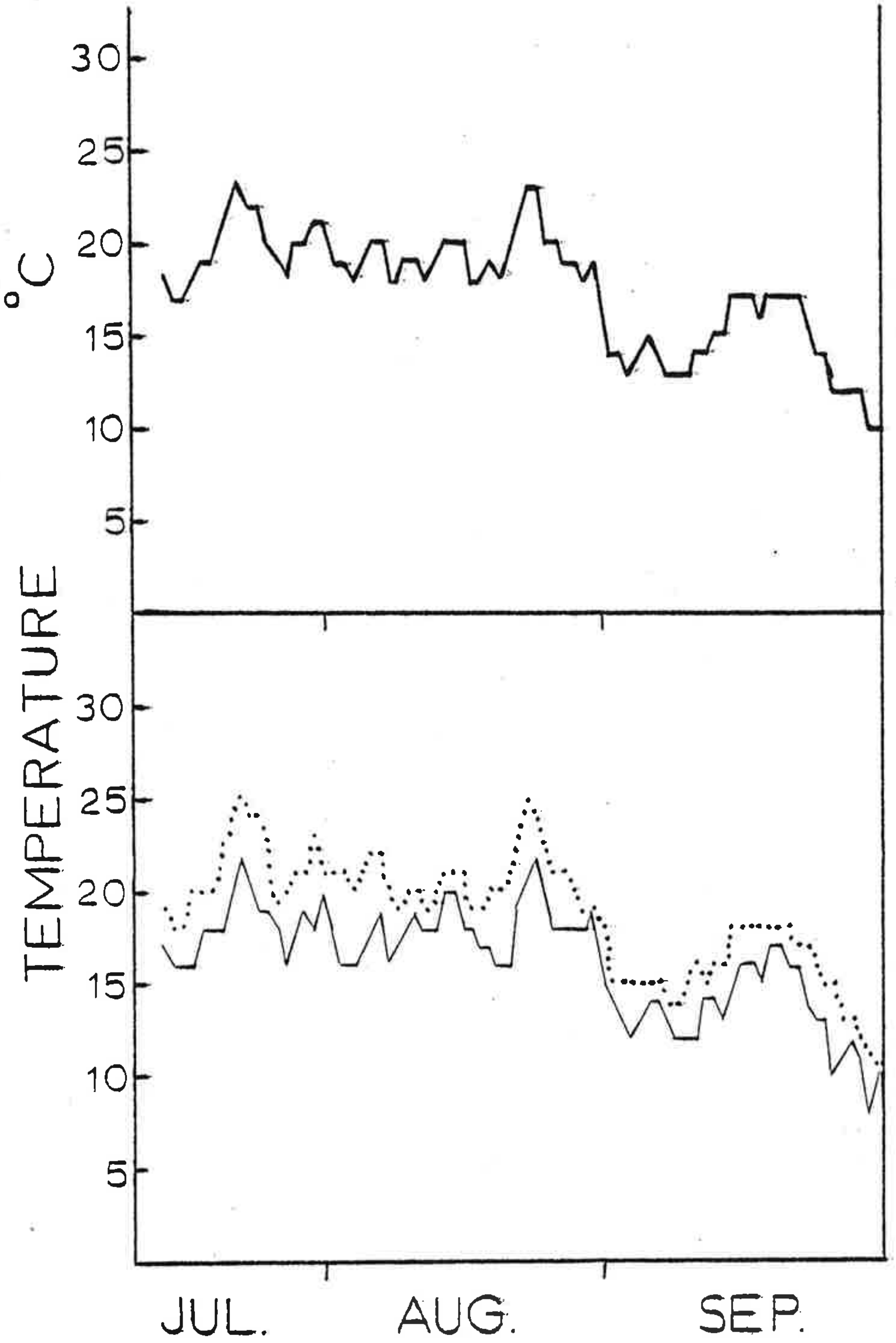


Figure 10. Water temperature patterns recorded at the East Branch Mattawamkeag River near Haynesville, Maine from July 11 to September 20, 1976. Legend as shown in Fig. 5

with vertical gradients ranging from approximately 1 to 4 m/km over each area. No major influxes of ground water were found in subsequent examinations of these sites.

Sporadic discharge measurements taken during the summer drought conditions in 1975 showed extreme habitat reduction occurred throughout the Mattawamkeag drainage. Discharge at the West Branch and East Branch temperature monitoring sites was 0.4 and 0.3 m^3/sec, respectively, on August 28, 1975. Flow reductions were particularly severe in some of the smaller tributaries like Wytopitlock Stream (Figure 11). At the lower main stem, the minimum flow recorded in 1975 was 1.7 m^3/sec, on September 3. Precipitation measured at the Houlton Airport, a site near the East Branch Mattawamkeag, was 1.2 cm in August 1975. This total was less than 15% of the average August rainfall recorded at Houlton since 1941 (Cooper and Lautzenheiser 1975). Total monthly precipitation and discharge data for June through September were substantially different in 1975 and 1976 (Table 7). High water temperatures in the Mattawamkeag River usually occurred when discharge was low (Figure 4).

Habitat types- methods

Assessments of the major habitat types in the main stem were made in conjunction with biological sampling trips. For descriptive purposes, habitats were classified as flat water, deep pool, or rapids. The following characteristics were assigned to those habitats:

flat water- surface unbroken; current slight; mud, sand, and

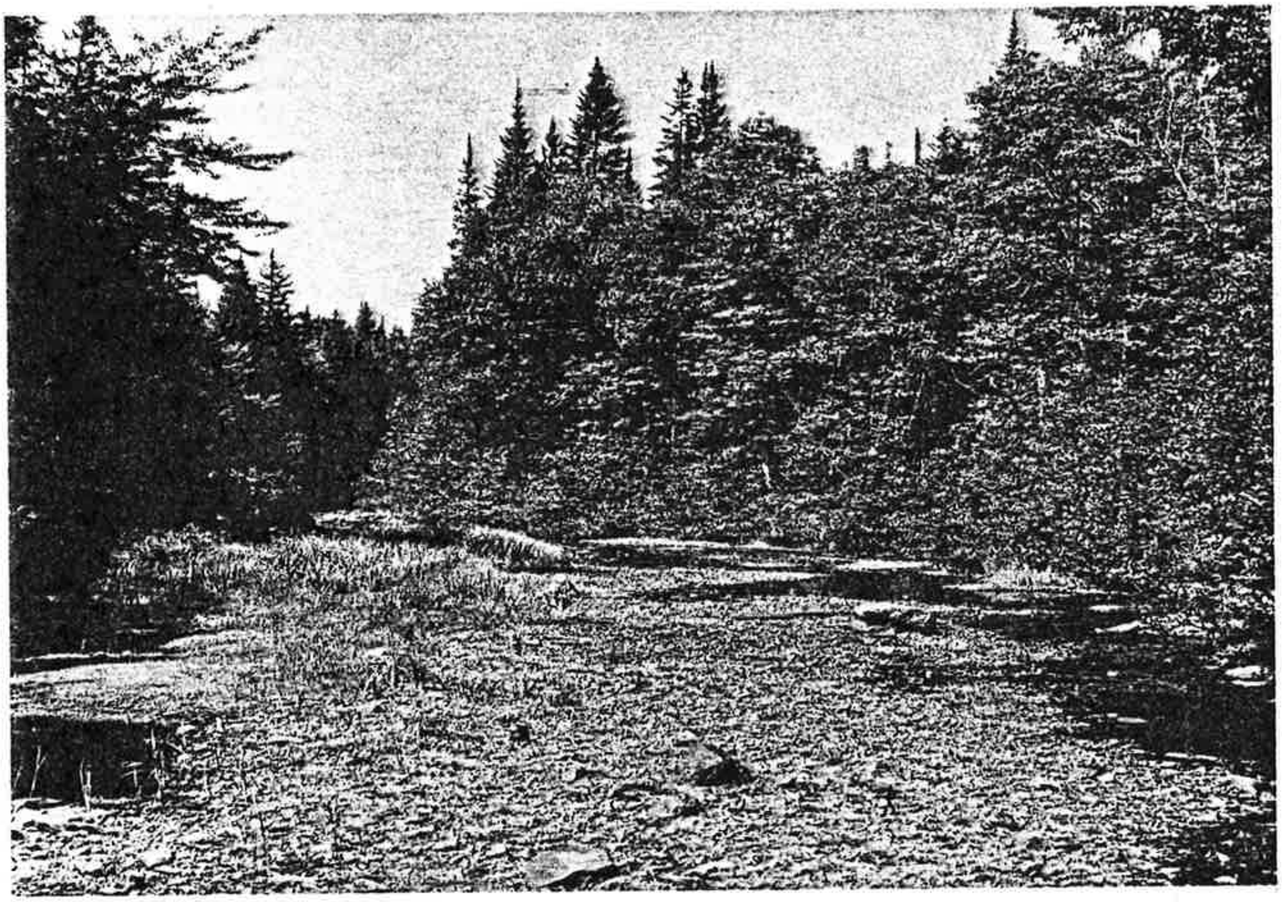


Figure 11. Photograph of Wytopitlock Stream near the Maine Route 2-A highway bridge on August 28, 1975. Stream flow was 0.0 m^3/sec (0.5 ft^3/sec) on this date.

Table 7. Short- and long-term total monthly precipitation and discharge data recorded during the summer in the Mattawamkeag River area. Precipitation was measured at the F.A.A. Airport in Houlton, Maine. Total discharge was recorded at the U.S.G.S. station on the lower main stem Mattawamkeag River.

	Total precipitation (cm)			
Year	June	July	Aug.	Sept.
1974	7.34	9.30	6.15	10.62
1975	9.47	8.98	1.25	11.55
1976	8.40	15.09	15.73	6.95
Mean from 1946-1976	8.21	9.81	9.09	9.58

	Total discharge (m^3/sec)			
Year	June	July	Aug.	Sept.
1974	3,477	1,621	444	368
1975	4,510	690	160	207
1976	1,400	2,173	2,788	1,641
Mean from 1946-1976	2,262	1,205	921	1,045

	gravel substrates predominate; rooted aquatic plants very common; depths rarely exceed 2 m
deep pool-	surface unbroken or slightly rippled; current slight to moderate; cobble, rubble, and boulder substrates predominate; rooted aquatic plants scarce; depths range to 3 m
rapids-	surface slightly to greatly rippled; current moderate to strong; gravel, rubble, and exposed bedrock substrates predominate; rooted aquatic plants scarce; depths rarely exceed 2 m

Habitat types were noted for the East and West Branches, but quantitative estimates were not made as some sections were not observed. Some remote areas on the East and West Branches were surveyed during float trips by canoe. On May 28-29, 1975 the West Branch was travelled from Route 11, below Rockabema Lake, to the Town of Island Falls. The East Branch, between the towns of Oakfield and Haynesville, was floated on September 3, 1976. Some of the larger tributaries encountered on these trips were briefly examined.

Habitat types- results

Based on the criteria used, the principal habitat type in the main stem is flat water, amounting to 50% of the total area. Extensive flat waters were located from Drew to Wytopitlock and from North Bancroft to Haynesville. Deep pools constituted approximately 30% of the main stem habitat. These areas were exemplified by the section between the Mattawamkeag highway bridge (U.S. Route 2) and the mouth of Mattakeunk Stream, although similar deep pools were interspersed from Kingman to Haynesville. Rapids were relatively scarce and comprised only 20% of the main stem area. Most rapids were found near the access road to Mattawamkeag Wilderness Park, in the Town of Kingman, and in the Bancroft area.

Estimates of habitat availability were not made for the East and West Branches because portions of them were not observed, but general habitat descriptions were made for the areas examined. The West Branch Mattawamkeag between Rockabema Lake and Mattawamkeag Lake contained extensive areas of salmonid habitat. At least one-half of this 25-km section was classified as rapids. Most of the flat water and deep pool zones were located near the Town of Island Falls. Below Mattawamkeag Lake, the West Branch flows 20 km before joining the East Branch at Haynesville. The first 5-km below Mattawamkeag Lake was mostly rapids. Downstream from this area, deep pools and some flat waters were common.

Approximately one-half of the total length of the East Branch Mattawamkeag was observed on a 17-km float trip between Oakfield (Red Bridge) and Haynesville (Webber Bridge). Nearly the entire section was rapids. The highest gradients were near the area of the Pleasant Lake outlet. Deep pools with many large boulders characterized the East Branch several kilometers above the Webber Bridge.

CHEMICAL FACTORS

Water quality surveys- methods

Some data on water quality were obtained during the summer of 1974, and monthly water chemistry surveys were initiated in November 1974 and continued until March 1976.

The surveys were taken at three sites on the main stem, two each on the East and West Branches, and one each in Molunkus, Macwahoc, and Wytopitlock streams. Water temperature, dissolved oxygen concentration, ambient conductance, pH, and total alkalinity were measured at each site. Dissolved oxygen concentrations were determined using the Alsterberg azide modification of the Winkler method (Brown et al. 1970). Percent oxygen saturation and carbon dioxide concentrations were derived using methods described in Brown et al. (1970). Ambient conductance values were converted to specific conductance at 25 C for reporting purposes.

Water quality surveys- results

All water quality parameters measured from 1974 to 1976 were within acceptable ranges for Atlantic salmon (DeCola 1970). Monthly water quality surveys revealed only small variations in pH, percent oxygen saturation, carbon dioxide concentration, specific conductance, and total alkalinity among the locations examined (Table 8). At a given site, carbon dioxide levels often ranged widely. Carbon dioxide concentrations were not directly measured, but were calculated from observed pH and total alkalinity values (Brown et al. 1970). Some of the differences, therefore, may have been an artifact of the method used to calculate carbon dioxide concentration.

Supplementary dissolved oxygen measurements taken during the summer in 1975 ranged from 90 to 98% saturation. Water temperatures usually exceeded 20 C when these oxygen

Table 8. Water quality data collected monthly at 10 sites from November 1974 to March 1976. Mean and standard deviation are followed by range in parentheses.

Stream Town	Specific conductance micromhos/cm	pH units	Dissolved oxygen		Carbon dioxide ppm	Total alkalinity ppm $CaCO_3$
			ppm	Percent saturation		
Mattawamkeag R.						
Mattawamkeag	57±10 (36-84)	6.7±0.2 (6.4-7.2)	12.5±2.5 (8.0-15.0)	98±5 (91-108)	3.5±2.2 (1.2-9.5)	10.6±2.6 (5.8-15.0)
South Bancroft	62±14 (41-84)	6.7±0.3 (6.2-7.3)	12.4±2.2 (8.0-14.8)	96±4 (91-104)	2.5±3.3 (0.7-9.6)	8.9±1.9 (5.8-12.2)
Haynesville	61±14 (33-83)	6.7±0.2 (6.2-7.1)	12.2±2.1 (8.4-14.8)	94±6 (80-103)	3.8±2.3 (1.6-10.9)	11.1±2.5 (8.3-16.4)
East Branch						
Haynesville, Webber Road	73±14 (52-111)	6.8±0.3 (6.3-7.4)	12.4±2.1 (8.4-14.6)	96±5 (82-100)	4.2±3.8 (0.8-15.6)	12.9±3.5 (7.5-19.1)
Smyrna Mills	65±20 (40-116)	6.8±0.3 (6.4-7.3)	12.8±2.1 (8.2-15.0)	98±3 (89-103)	3.5±2.8 (1.2-9.9)	12.4±3.6 (5.8-19.1)
West Branch						
Haynesville, Webber Road	68±12 (40-86)	6.8±0.2 (6.4-7.2)	12.3±2.1 (8.4-14.8)	96±5 (85-101)	3.4±2.1 (1.0-8.7)	12.1±3.4 (5.8-19.1)
Moro, Hall Cr. Road	39±7 (25-49)	6.6±0.3 (5.9-6.9)	12.9±2.2 (8.2-15.0)	98±3 (92-103)	2.9±2.1 (1.0-8.8)	5.6±1.6 (2.5-8.2)

Table 8. continued

Stream Town	Specific conductance micromhos/cm	pH units	Dissolved oxygen		Carbon dioxide ppm	Total alkalinity ppm $CaCO_3$
			ppm	Percent saturation		
Molunkus S. Molunkus, Route 2	87±11 (70-110)	6.9±0.3 (6.5-7.3)	12.0±2.1 (8.4-15.0)	93±7 (75-103)	4.3±3.6 (0.8-9.2)	14.5±5.7 (2.5-24.6)
Macwahoc S. Macwahoc, Route 2A	49±8 (36-61)	6.7±0.3 (6.2-7.1)	12.3±2.3 (8.2-14.8)	96±4 (84-102)	3.8±3.1 (0.7-10.9)	8.8±2.1 (5.8-13.7)
Wytopitlock S. Reed, Route 2A	39±8 (28-57)	6.6±0.3 (6.0-7.1)	12.2±2.3 (8.0-15.0)	95±4 (89-103)	3.5±2.8 (0.8-10.9)	6.1±1.6 (4.2-9.6)

measurements were taken. Dissolved oxygen levels,therefore, were consistently favorable for Atlantic salmon survival even during the periods when high water temperatures were encountered.

BIOLOGICAL FACTORS

Fish populations- methods

Fish populations were sampled in riffle areas throughout the drainage to obtain data on species composition, relative abundance, and size distribution. Most sampling was done with a DC electrofishing unit that was mounted in a small boat and towed by one of the crew. Only one pass was made through a given stream section. Blocking seines were not used. Catch and effort data were computed for the species captured.

Fish populations in flat water areas of the main stem and West Branch Mattawamkeag were sampled in 1974 and 1975 by trap nets, nylon gill nets, and monofilament gill nets. Details of net construction are described by McCabe (1976). The gill nets and trap nets were set perpendicular to shore in slack water zones, whereas they were set parallel to shore if river currents were evident.

Fish collected by netting and electrofishing were weighed and measured for total length. Group weights and ranges in total length were obtained for most young-of-the-year, especially cyprinids. Stomachs were removed from the larger American eels caught in 1975. Eel stomach contents were analyzed to indicate levels of piscivorous predation.

Sightings of adult sea-run Atlantic salmon in the Mattawamkeag River were recorded. Several areas along the main stem, East Branch, and Molunkus Stream were surveyed by wading to look for adults or spawning redds during the fall in 1975.

Fish populations- results

High water levels prevented effective electrofishing in the main stem except in 1975, hence most results were confined to that year. Resident fishes (Table 2) capable of competing with or preying on juvenile Atlantic salmon are abundant in the main stem rapids and they include American eel, smallmouth bass, burbot, and fallfish (Tables 9 and 10). All are known to be piscivorous (Scott and Crossman 1973). Stomach contents of 29 eels larger tham 500 mm in total length contained mostly aquatic insects (55%) and fish (35%), based on percentage of total volume of stomach contents. Young-of-the-year smallmouth bass frequently occupied areas within the rapids that were qualitatively judged to be suitable Atlantic salmon habitat. Large bass, however, were not abundant in the rapids.

White suckers were the most abundant species captured in gill nets and trap nets set in flat water areas, although chain pickerel and smallmouth bass were frequently captured there (Table 11). Approximately 35% of the pickerel sampled were greater than 370 mm in total length. Species that

Table 9. Relative abundance (catch/hr) of fishes, excluding cyprinids and salmonids, taken by electrofishing in the Mattawamkeag River drainage from July 1 to September 30, 1975.

Species	Location						
	1	2	3	4	5	6	7
American eel	12.0	51.7	30.0	7.3	28.4	9.3	18.2
Longnose sucker	0.3	----	----	----	2.1	1.3	----
White sucker	3.8	7.1	----	18.2	7.9	14.7	22.7
Brown bullhead	----	----	----	----	0.5	----	----
Burbot	6.8	20.8	12.9	1.8	12.6	26.0	18.2
Threespine stickleback	----	----	----	----	----	5.3	----
Ninespine stickleback	----	----	----	----	0.5	----	----
Redbreast sunfish	----	4.2	----	----	----	----	----
Pumpkinseed	----	----	----	----	0.5	----	4.5
Smallmouth bass-adult	2.5	3.0	2.1	7.3	6.3	0.7	4.5
Young-of-the-year	59.5	155.4	30.0	18.2	----	----	----
Yellow Perch	----	1.8	----	----	4.2	0.7	----
Hours fished	4.0	1.7	0.5	0.6	1.9	1.5	0.2
Area fished (m^2)	25,000	7,500	5,250	4,375	15,075	10,925	1,525

Location code

1. Main stem: Penobscot River confluence - Molunkus Stream
2. Main stem: Molunkus Stream - Wytopitlock Stream
3. Main stem: Wytopitlock Stream - Baskahegan Stream
4. Main stem: Baskahegan Stream - confluence E. Branch & W. Branch
5. West Branch Mattawamkeag: below Mattawamkeag Lake
6. East Branch Mattawamkeag: near Haynesville
7. Wytopitlock Stream: near U.S. Route 2-A

Table 10. Relative abundance (catch/hr) of cyprinids and salmonids taken by electrofishing in the Mattawamkeag River drainage from July 1 to September 30, 1975.

Species	Location						
	1	2	3	4	5	6	7
Atlantic salmon-parr	1.0[a]	----	----	----	4.7	19.3[a]	----
Young-of-the-year	0.8	----	----	----	----	----	----
Brook trout-adult	----	----	----	----	----	----	----
Young-of-the-year	----	----	----	----	----	2.0	----
Common shiner	14.3	13.1	2.1	49.1	3.2	----	31.8
Blacknose dace	2.5	4.2	2.1	----	2.1	22.0	9.1
Creek chub	----	----	----	----	0.5	4.7	----
Fallfish	61.3	125.3	53.6	56.4	14.2	23.3	----
Hours fished	4.0	1.7	0.5	0.6	1.9	1.5	0.2
Area fished (m^2)	25,000	7,500	5,250	4,375	15,075	10,925	1,525

Location code

1. Main stem: Penobscot River confluence - Molunkus Stream
2. Main stem: Molunkus Stream - Wytopitlock Stream
3. Main stem: Wytopitlock Stream - Baskahegan Stream
4. Main stem: Baskahegan Stream - confluence E. Branch & W. Branch
5. West Branch Mattawamkeag: below Mattawamkeag Lake
6. East Branch Mattawamkeag: near Haynesville
7. Wytopitlock Stream: near U.S. Route 2-A

[a] stocked sea-run salmon parr

Table 11. Length frequency distributions of the major fish species captured from the Mattawamkeag River with trap nets and gill nets in 1974 and 1975. All fish were measured for total length.

Size interval (mm)	Chain pickerel		White sucker		Smallmouth bass		Yellow perch	
	No. of fish	Mean length	No. of fish	Mean length	No. of fish	Mean length	No. of fish	Mean length
1-49	0	--	0	--	0	--	0	--
50-99	0	--	0	--	0	--	5	82
100-149	0	--	6	131	6	134	9	130
150-199	1	153	6	179	3	175	28	177
200-249	1	249	25	228	46	233	20	221
250-299	14	272	54	277	61	270	2	260
300-349	23	336	96	330	22	328	0	--
350-399	19	371	137	382	3	365	0	--
400-449	9	416	81	416	1	440	0	--
450-499	5	476	6	466	0	--	0	--
500-549	3	522	0	--	0	--	0	--
550-599	1	552	0	--	0	--	0	--
Total number of fish	76		411		142		64	

are common only in flat water areas include chain pickerel, golden shiner, brown bullhead, white perch, redbreast sunfish, pumpkinseed, and yellow perch.

Resident populations of landlocked Atlantic salmon are present in portions of the main stem and in both the East and West Branches of the Mattawamkeag. In the East Branch, salmon are most abundant within several kilometers of the outlet of Pleasant Lake and are scarce elsewhere. Salmon are common in the West Branch upstream from the upper Webber Bridge. Few landlocked salmon are found in the main stem, although several of state-hatchery origin were angled in 1974. These salmon were initially stocked into lakes draining into the main stem Mattawamkeag River. Only four young-of-the-year Atlantic salmon were taken during electrofishing surveys in the main stem in 1974 and 1975. Their origin was not determined.

Potential nursery areas for anadromous Atlantic salmon in tributaries such as the East and West Branches Mattawamkeag River and Molunkus Stream, contain most of the competitor fish species found in the main stem. Resident populations of American eel, burbot, and fallfish are abundant in all three locations. Smallmouth bass are known to overlap the present landlocked salmon habitat in the lower West Branch Mattawamkeag River (Table 9). Bass are present in the lower reaches of the East Branch and Molunkus Stream, but the upper limit of their distribution in those waters was not determined in this study. Brook trout are present in most tributaries to the main stem, especially in headwater locations, however they were rarely captured in electrofishing surveys conducted in the summer.

Short-term success of sea-run salmon parr stocked into the Mattawamkeag drainage seemed to be influenced by water levels. Population estimates were not made; however, survival of stocked parr was evident in 1974 and 1976. Drought conditions in 1975 apparently caused a high mortality of the parr stocked into the East Branch Mattawamkeag and Wytopitlock Stream (Table 12). Over-winter survival was not examined because high water levels in the spring lasted beyond the time of natural smoltification and emigration.

Hatchery-reared salmon parr stocked into the East Branch Mattawamkeag were sampled three times in 1976. Useful biological data were apparently being obtained in these samples. However, subsequent to the third sampling trip, we learned that the East Branch was stocked twice in 1976. Conclusions concerning relative growth and dispersal of these fish were obscured by the multiple stocking.

Whitish skin lesions were observed on salmon that were stocked in the summer of 1974 and sampled in the fall. Parr both with and without lesions were captured from similar habitats in the East Branch, Molunkus, Wytopitlock, and Macwahoc streams. These lesions may be carcinomae. Dr. Roger Herman, Histopathologist at the Eastern Fish Disease Laboratory in Leetown, West Virginia, stated, "Previous specimens from hatcheries have been deposited with the Registry of Tumors of Lower Animals as possible examples of

Table 12. Relative abundance (catch/hr) of species taken by electrofishing in the Mattawamkeag River drainage from October 1 to 31, 1975.

Species	Location code		
	6	7	8
Atlantic salmon	1.1	-	-
Brook trout	3.0	0.3	0.9
Common shiner	20.3	11.7	17.3
Blacknose dace	30.3	14.3	23.6
Creek chub	0.8	3.0	-
Fallfish	55.7	8.3	63.6
Longnose sucker	1.4	-	-
White sucker	24.7	22.7	39.1
Burbot	5.7	0.3	4.5
Threespine stickleback	1.4	-	-
Ninespine stickleback	0.3	-	-
Smallmouth bass-adult	-	-	-
Young-of-the-year	11.6	5.3	11.8
Yellow perch	-	-	0.9
Hours fished	3.7	3.0	1.1
Area fished (m^2)	11,967	5,904	5,532

Location code

6. East Branch Mattawamkeag: near Haynesville
7. Wytopitlock Stream: near U.S. Route 2-A
8. Molunkus Stream: near U.S. Route 2

carcinoma in situ" (personal communication). When it occurs, this condition appears in the fall and disappears sometime during early winter. Wild landlocked salmon with similar lesions were taken from Scott Brook, a tributary to the St. Croix River, in October 1975 (McCabe 1976).

Fin deformities were present in approximately 90% of all hatchery-reared parr captured from the East Branch Mattawamkeag in 1976. The pectoral and dorsal fins were most commonly eroded, and individual fin condition ranged from nearly normal to practically absent.

Adult sea-run Atlantic salmon were sighted in the lower main stem in 1974 and 1975, and four adult salmon were reportedly angled from the Mattawamkeag in 1975. Most observations occurred near the mouths of Big Gordon and Little Gordon brooks. Some adult salmon captured at Bangor Dam fishway on the Penobscot River were trucked upstream during each year of the study. These fish were released into the Penobscot between the towns of Costigan and Howland (Alfred Meister, Chief Biologist, Maine Atlantic Sea-Run Salmon Commission, personal communication).

Some of the adult salmon captured in the Mattawamkeag River system in 1975 swam distances up to 70 km and survived water temperatures over 25 C after their release in the Penobscot River. Their movements between the time of release below Howland and subsequent recapture were unknown. No spawning salmon or redds were located during three trips to the Mattawamkeag drainage between November 1 to 10, 1975.

In 1976 three adult salmon with internally placed radio tags were released into the Mattawamkeag River near Bancroft. This was part of a study on adult salmon movements conducted by Dr. James McCleave, Migratory Fish Research Institute, University of Maine at Orono. One of the fish was known to have been released into the Mattawamkeag River as a smolt. Movements of these fish were recorded for up to 30 days. Contact with all three salmon was lost by October 19, 1976 (James McCleave, personal communication). Their activity during the 1976 spawning season was unknown.

Macroinvertebrate populations-methods

Benthic macroinvertebrates were collected during November 1974 at all of the sites used for monthly water quality surveys except the main stem at Haynesville. Samples were taken using a kick net (0.3 mm mesh) in a riffle site. The sampling technique used was to dislodge bottom materials by kicking or digging with one or both feet. The net was held in position about 0.5 m downstream from the kick area, thereby capturing many of the invertebrates uncovered. Various sites within the riffle were sampled until 5 min had elapsed. Collections were identified by Dr. Charles Rabeni, Research Assistant, Entomology Department, University of Maine at Orono.

Macroinvertebrate populations-results

Most orders of aquatic insects were well represented in the kick net samples obtained in November 1974. A range of 18 to 34 aquatic insect genera was identified at the nine sampling sites (Table 13). The Diptera, Ephemeroptera, and Trichoptera comprised from 61 to 91% of the total numbers of aquatic insects collected in the samples.

Merganser sightings-methods

Sightings of American mergansers (*Mergus merganser americanus*) were recorded on days spent at the Mattawamkeag River. Information on the relative abundance of these birds in the drainage was desired because mergansers can be serious predators on salmon in Canadian rivers (Elson 1962).

Merganser sightings-results

American mergansers were sighted in the Mattawamkeag River system on several occasions each year of the study, mostly on the lower main stem. The largest single sighting consisted of 30 to 40 birds between Mattakeunk Stream and Lower Gordon Falls on November 17, 1975. No broods were seen during any of the summers.

IMPORTANCE OF FACTORS EXAMINED TO ATLANTIC SALMON

Physical and chemical factors

Because the main stem of the Mattawamkeag River is primarily composed of deep pools and flat water, natural production of Atlantic salmon will be concentrated in selected tributaries. In Canadian salmon rivers, rapids are the preferred habitat of juvenile salmon, although pool and deadwater areas support some salmon (Saunders and Gee 1964; Gibson 1966; Elson 1975). Salmon fry are most abundant in shallow, gravelly riffles near spawning sites, but salmon

Table 13. Results from kick net samples of stream macroinvertebrates collected at 9 sites in the Mattawamkeag River drainage in November 1974. Number of aquatic insect genera identified is listed in each row.

Order	Number of genera per order								
	Locations sampled								
	A	B	C	D	E	F	G	H	I
Trichoptera	4	6	5	3	6	5	5	7	5
Plecoptera	6	5	5	1	5	6	7	5	4
Ephemeroptera	5	4	6	6	6	8	4	6	4
Diptera	7	2	7	3	3	7	7	10	2
Coleoptera	2	4	3	3	3	4	4	3	3
Odonata	1	2	1	1	2	2	3	2	1
Megaloptera	0	1	0	1	0	1	2	2	0
Total number of genera per location	25	24	27	18	25	33	32	35	19

Location code

A. Main stem: Town of Mattawamkeag
B. Main stem: Town of Bancroft
C. East Branch Mattawamkeag: near Haynesville
D. East Branch Mattawamkeag: Town of Smyrna Mills
E. West Branch Mattawamkeag: near Haynesville
F. West Branch Mattawamkeag: Moro-Hersey line
G. Macwahoc Stream: near U.S. Route 2-A
H. Wytopitlock Stream: near U.S. Route 2-A
I. Molunkus Stream: near U.S. Route 2

parr seek deeper water with faster currents and coarser substrates (Elson 1975; Jones 1975). The East Branch Mattawamkeag River and Molunkus Stream contain extensive areas with the substrates and gradients most favorable for young salmon. Additional sites with suitable physical habitat are found in the main stem rapids, in the West Branch Mattawamkeag, and in several of the small main stem tributaries such as Mattakeunk and Macwahoc streams.

Summer water temperatures in the Mattawamkeag River were marginal for juvenile Atlantic salmon during parts of two years, 1974 and 1975. Water temperatures should rarely exceed 22 to 25 C for good growth of salmon parr (Elson 1975). Some parr move into spring seepage areas and abandon their normal territorial behavior when temperatures exceed 22 C (Gibson 1966). Increased vulnerability to predation can occur when parr desert their territories (Symons 1974). Water temperatures surpassed 25 C at various sites in the Mattawamkeag drainage in 1974 and 1975, and the maximum of 29 C measured in 1975 can be lethal for some stocks of salmon (Garside 1973). When day-time temperatures are high, night-time cooling is important for parr survival and growth (Elson 1975). Night-time cooling of 3 C commonly occurred at the East Branch Mattawamkeag, but less diurnal cooling was recorded in the main stem. Salmon can tolerate sudden changes which occur on a diurnal basis (Scott 1975). The high water temperatures observed during some summers can be tolerated by salmon, but they are not favorable for salmon production.

Temperature data are not available for Maine's other Atlantic salmon rivers during 1974 to 1976. Published records for the Narraguagus River from 1963 to 1965, however, showed mean water temperatures reached 25 C in only one year (Scott 1975). In that year, 1963, mean water temperatures were at least 25 C for a total of 5 days. A thermograph operated by the U.S. Geological Survey provided summer water temperature data for the Dennys River from 1959 to 1971. Mean daily temperatures were not tabulated, but maximum temperatures reached 25 C an average of 4 days (range 0 to 12 days) per summer during those 13 years (U.S. Geological Survey Records). In contrast, mean water temperatures in the Mattawamkeag River in 1975 were 25 C or higher for nearly 30 days. Rainfall was abnormally low in 1975 (Table 6) and comparisons among rivers in different years must be viewed cautiously. The data suggest, however, the Mattawamkeag River may experience higher water temperatures than other Maine salmon rivers.

Extreme fluctuations in water levels, with consequent habitat reduction in the summer, may adversely affect production of juvenile salmon (Huntsman 1973). The outlet dams on several of the lakes that which drain into the Mattawamkeag River do not regulate discharge significantly. Therefore, wide natural fluctuations in water level are expected, and they do occur.

Although an empirical relationship was not established, an association between low discharge and high water temperatures in the summer was indicated (Figure 4). The combination of reduced flows and high summer water temperatures probably contributed to the poor survival of hatchery parr stocked into Wytopitlock Stream and the East Branch Mattawamkeag in 1975. If emigration from the study areas in those streams occurred, the parr did not recolonize their former habitats when favorable conditions returned in the fall. Low summer flows were believed to be responsible for a periodic scarcity of Atlantic salmon in Canadian Maritime fisheries (Huntsman 1973). The low flows reduce survival of age 1+ parr, and corresponding adult returns for that year are diminished (Huntsman 1973). Low water in summer in some of the Mattawamkeag River tributaries was identified as a potential limiting factor on salmon productivity by Cutting (1963). Similar low summer flows were also considered a limiting factor in potential nursery areas in the Piscataquis River, another major tributary to the Penobscot (Fenderson and AuClair 1956).

Physical conditions in the winter might also limit salmon production in the Mattawamkeag River. Low winter flows are common in New Brunswick salmon rivers and may contribute to the high mortality of juvenile salmon in those waters (Redmond 1975). Parr become inactive at low water temperatures and may hide beneath rocks and gravel in the winter (Symons 1974). Habitat requirements for optimal over-winter survival of young salmon have not been adequately defined (Redmond 1975). Winter discharges, particularly in January and February, are often greatly reduced in the Mattawamkeag River. Moreover, the Mattawamkeag River area generally receives 10 to 20 cm less annual precipitation than coastal salmon rivers in Maine's Washington County (Cooper and Lautzenheiser 1975). Most of this difference occurs during the winter. In addition, more of the winter precipitation along the coast, when compared to inland areas in northern Maine, is likely to be rain. These factors could result in relative winter water levels being lower in the Mattawamkeag River than in Washington County streams such as the Machias or Narraguagus rivers. Further studies are needed to clarify the effects of winter river conditions on survival of salmon in North America.

Before reaching the Mattawamkeag River most adult salmon must perform a complicated migration. This includes ascending the Penobscot River estuary, entering the fish trap at Bangor Dam, being trucked to a release site in the Penobscot River below Howland, passing through the fish ladder at the West Enfield or Howland dams, and swimming 40 km to the mouth of the Mattawamkeag River. Cutting (1963) reported that the majority of the salmon runs in the latter half of the Twentieth Century reached Bangor after the peak of spring runoff had occurred. Entrance of the fish after peak runoff plus the questionable efficiency of several fishways on the Penobscot River, reduce the chances of salmon successfully reaching the headwaters of the Penobscot by natural means. This problem has been recognized by the Maine Atlantic Sea-Run Salmon Commission because most fish released upstream in the Penobscot River are trucked from Bangor to the Howland area. Further obstacles exist, as recent information indicates that adult salmon do not pass promptly through the West Enfield fishway (Meister 1977).

The migration of adult salmon into and through the Mattawamkeag River drainage may be adversely affected by summer water temperatures. Adult salmon may not enter Maine rivers when water temperatures exceed 23 C (DeCola 1970) or when water flows are abnormally low (Goodwin 1942). In New Brunswick, however, movement of adult salmon has occurred at temperatures above 25 C, occasionally resulting in mortality when temperatures reached 29 to 30 C (Elson 1975). Low summer flows are uncommon in the Mattawamkeag River before August, but water temperatures can reach 23 C by late June. Water temperatures at adult release sites in the Penobscot also may reach these high levels. For example, temperatures in the Penobscot at West Enfield were at least 23 C for an average of 21 days in July and August from 1968 to 1975 (U.S. Geological Survey). Some adult salmon, however, did move from the Penobscot River into the Mattawamkeag during the study in summers with high water temperatures, but the percentage of adults that were trucked upriver and subsequently entered the Mattawamkeag in 1974 to 1976 cannot be determined.

The potential sport fishery harvest of adult salmon from the Mattawamkeag River will probably be affected by summer water temperatures. Temperatures above 20 C reduce activity levels of Atlantic salmon and are not favorable for salmon angling (DeCola 1970). Approximately one week of water temperatures below 20 C is needed before the salmon will again be responsive to angling (DeCola 1970). In 1976, the year with the lowest summer water temperatures in this study, mean water temperatures in the main stem were at least 20 C during nearly all of June, July, and August (Table 6). The vulnerability of a salmon to capture by artificial flies also decreases with the amount of time spent in fresh water (Goodwin 1942). Goodwin studied the salmon run in the Dennys River in Maine and found that most fish were angled within several days of their entry into the river. Salmon reaching the Mattawamkeag River probably spend at least several days in fresh water completing their natural and artificial migration. Delays in ascending the fishway at West Enfield Dam (Meister 1977) may further reduce their willingness to strike artificial lures.

Cutting (1963) estimated that anglers could harvest 15 to 25% of the Penobscot River salmon runs. The percent of the known Penobscot River salmon runs captured by angling, below the Bangor Dam, was 4% in 1974, 7% in 1975, and 8% in 1976 (Baum 1976). Some fish were also captured in the upper sections of the Penobscot system in those years, but the total numbers caught are not known. The concentration of fish, plus the proximity to the Penobscot estuary, suggests that relative angling success should be high below the Bangor Dam. The publicity associated with the recent salmon runs and the fact that no license is required to fish in tidal waters in Maine, has ensured a high fishing effort below Bangor Dam. Given the conditions salmon will experience in the Mattawamkeag River, it is not realistic to expect percentage rod catches to surpass those recorded for the lower Penobscot River.

Biological factors

The data obtained for resident fish populations in fast water areas were limited by physical conditions in the river. Most main stem rapids were too deep to sample by electrofishing except during periods of very low discharge. When the main stem could be electrofished, poor conductivity and the dark color of the water probably increased the escapement of some fish. Small tributaries like Wytopitlock Stream could be sampled effectively by electrofishing during most flow regimes encountered from June to November. Population estimates were not attempted due to limitations in sampling the large waters quantitatively.

The relative abundance and length frequency data obtained from gill net and trap net catches were biased by gear selectivity. Nets set in littoral areas of the river in the summer may not adequately sample the chain pickerel and smallmouth bass populations due to reduced movements of these species during peak summer water temperatures (Scott and Crossman 1973). Mesh size in the nets was too large to capture juvenile warmwater game fish or small cyprinids. Eels, although extremely abundant in much of the Mattawamkeag River drainage, were rarely captured by netting. Despite these limitations, valuable information of the fish species that could compete with or prey on juvenile salmon was obtained.

American eels were frequently captured in electrofishing surveys conducted throughout the drainage. Predation by eels can cause important losses of salmon in Canadian rivers (Elson 1941). Some sections of rivers with high densities of eels produce fewer salmon fry than comparable sections with lower eel densities (Godfrey 1957). Eels also eat many of the invertebrate food organisms that are usable by young salmon (Elson 1941; Godfrey 1957), and eels and salmon often cohabit Canadian salmon rivers (Elson 1975). The large numbers of eels in the Mattawamkeag River could adversely affect salmon production.

Chain pickerel are likely to prey on salmon smolts moving through the flat waters of the Mattawamkeag. Pickerel larger than 370 mm total length preyed on smolts migrating through Beddington Lake on the Narraguagus River and apparently caused most of the 80% loss of marked smolts (Barr 1962). Pickerel large enough to eat salmon smolts are common in the slower sections of the Mattawamkeag River, but they are scarce in fast water areas. Pickerel spawning may overlap the time of salmon smolt migrations in the spring (Scott and

Crossman 1973). Predation may be reduced if a large proportion of the pickerel population has moved into the shallow areas of the river for spawning.

Young-of-the-year smallmouth bass dominated the catches in many of the areas electrofished. Competition with salmon for space, and for food (Neves 1973), could occur in fast-water stretches of the main stem, the areas of maximum juvenile bass abundance. Adult smallmouth bass are known to prey on stocked landlocked salmon parr (Warner 1972). In the Mattawamkeag River, large bass are not common in areas suitable as salmon habitat, thus losses due to bass predation should not be severe. Smallmouth bass are believed to be serious competitors in marginal salmon habitat (Cutting 1956), and bass are presently found throughout most of the potential salmon nursery areas sampled in the Mattawamkeag River drainage.

Burbot and fallfish are abundant in the drainage and are capable of preying on young salmon. Both species are piscivorous, and they remain active throughout the winter (Scott and Crossman 1973; Muth and Smith 1974). However, most burbot and fallfish captured in electrofishing samples were small, suggesting predation on young salmon by these species should not be severe.

The Mattawamkeag River supports a diverse fish fauna including many warm-water or transitional species such as chain pickerel, brown bullhead, redbreast sunfish, smallmouth bass, and yellow perch. Several of these fishes, the pickerel, bass, and yellow perch were not native to the Mattawamkeag. Even in New England, the upper tributaries of the Connecticut and Merrimack rivers, which have received plantings of juvenile Atlantic salmon, contain relatively few of the non-salmonid species found in the Mattawamkeag River.

Attempts to reduce populations of competitors and predators have preceded stockings of juvenile salmon in the past. In Europe, eels, brown trout (Salmo trutta), and northern pile (Esox lucius) have been removed from rivers prior to releases of salmon eggs, fry, and parr (Mills 1971; Arrignon 1973). Production of salmon parr and smolts increased greatly after a program to control populations of American mergansers, a piscivorous duck, was initiated on Canada's Pollett River (Elson 1975). Mergansers are not abundant in the Mattawamkeag, but competitor fish species are. Significant short-term reductions in populations of competitor fishes in the Mattawamkeag River could only be achieved at the expense of tremendous amounts of funds and manpower, if at all. Therefore, satisfactory growth and survival of juvenile salmon will have to be achieved in conjunction with an abundance of potential competitor and predator fish species.

The kick-net samples of stream invertebrates collected in 1974 indicated a diverse community of organisms was present in the areas sampled. Larval Ephemeroptera, Diptera, and Trichoptera are major components of the diet of young salmon (Goodwin 1942; Keenleyside 1967). Hoffman (1966) found 30 genera of Ephemeroptera, Diptera, and Trichoptera in drift and benthic samples collected at the Narraguagus River over an 11-month period. A total of 34 genera from the same taxa were identified from the Mattawamkeag River in one sampling period. Barring drastic alterations in water quality, populations of aquatic organisms important in the diets of juvenile salmon should remain well represented in the Mattawamkeag River drainage.

Based on the biological, chemical, and physical factors examined, the East Branch Mattawamkeag River and Molunkus Stream have the greatest potential for Atlantic salmon production in the Mattawamkeag River drainage. To help evaluate this potential, we proposed an experimental stocking of advanced sea-run salmon fry. Survival and growth of fry are essential if natural populations of salmon are to become established. Results from an experimental stocking would reduce the hypothetical nature of this study, as well as provide a valuable comparison with concurrent U.S. Fish and Wildlife Service studies involving salmon fry planted in the headwaters of the Connecticut and Merrimack river watersheds and experimental fry stocking by the Canadian Fisheries and Marine Service in the St. Croix River. The initial request for fry was made on April 30, 1975 and was approved at the Atlantic Salmon Research Committee Meeting on May 19, 1975. The fish were to be stocked in 1976. An attempt to finalize plans for the stocking with the Chief Biologist of the Maine Atlantic Sea-Run Salmon Commission was made on January 13, 1976. His response, while not an outright refusal, indicated inadequate brood stock was obtained in 1975 so there would be " a continuing deficit in production for the next 15 to 18 months," and results from such a stocking would " do little to enhance or add to our basic knowledge of the Atlantic salmon" (Alfred Meister, personal communication). No fry were furnished for stocking in 1976, and therefore an important element of this project was not realized.

SUMMARY

Production of juvenile salmon in the Mattawamkeag River will be limited primarily by physical habitat availability, summer water temperature and discharge patterns, and interactions with resident fish species. Of these factors, the effects of temperature and discharge should be the most variable, depending on climatic conditions.

The movements of adult salmon destined for the Mattawamkeag are probably being impeded by inadequate fish passage facilities at some of the Penobscot River dams. Physical conditions in the lower Penobscot River have necessitated the transport of adult salmon by truck from Bangor Dam fishway to release points upstream. The need for this man-assisted phase of the salmon's migration is likely to continue in the future. Those salmon entering the Mattawamkeag River may exhibit a reduced vulnerability to capture by legal angling methods due to high water temperatures and the length of time

spent in fresh water. A low sport fishery yield, even by Atlantic salmon standards, should be expected.

No single factor investigated will preclude the survival of Atlantic salmon in the Mattawamkeag River. The survival and abundance of salmon in the Mattawamkeag should not be viewed as an all-or-nothing phenomenon. Some production of juveniles, as well as a harvest of adults, can be expected in all years. The combined effects of the major limiting factors suggest, however, that the Mattawamkeag River be considered a marginal candidate for the restoration of Atlantic salmon from existing stocks.

PART II

University of Maine

Migratory Fish Research Institute

and

Cooperative Fishery Research Unit

II

EFFECTS OF SEVIN, A SPRUCE BUDWORM INSECTICIDE ON FISH AND INVERTEBRATES IN THE MATTAWAMKEAG RIVER IN 1976

Final Report to U.S. Fish and Wildlife Service

FWS Contract 14-16-0008-842

by

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INTRODUCTION

Aerial applications of insecticides have been periodically employed over the last two decades to limit damage inflicted by the spruce budworm, *Choristoneura fumiferana*, on spruce-fir forests in Maine. Although overall impacts are poorly understood, investigations into some of the effects of these pesticides on non-target fauna, including fish and stream macroinvertebrates, have been accomplished. Effects of DDT applications on brook trout growth and abundance in six streams were reported by Warner and Fenderson (1962). More recently, pesticides that are less persistent and less toxic to fish have been used in Maine. Marancik (1976) examined the effects of several pesticides, including Sevin 4-oil, on brain acetylcholinesterase activity levels in several fish species.

In 1976, headwater areas of the East and West Branches of the Mattawamkeag River were included in the Maine Bureau of Forestry's 9-million-hectare operational spruce budworm control program. The insecticide Sevin-4 was prepared at 0.84 kg/hectare, diluted with kerosene, and sprayed from aircraft at 2.25 liter/hectare. Sevin 4-oil was the principal pesticide used in the operational spray program. The Mattawamkeag River system was being studied as potential habitat for anadromous Atlantic salmon. The overlapping of the spruce budworm control program with headwater areas of the Mattawamkeag River provided the impetus for a separate investigation into some effects of the pesticide application on fish populations. The principal objectives of this study were:

1) To determine background pesticide residue concentrations in pre-spray fish samples

2) To determine changes in brain acetylcholinesterase levels over an extended post-spray period in several fish species

3) To compare growth of salmonids in sprayed and unsprayed streams during the summer

4) To determine if major changes in macroinvertebrate fish food populations occurred after pesticide application

Study area

Four sampling locations were included in this project; the West Branch Mattawamkeag River, West Hastings Brook, Meduxnekeag Stream, and Greenlaw Stream. The West Branch Mattawamkeag, which drains Rockabema Lake, was sampled about 4 km below the lake. West Hastings Brook flows into the West Branch Mattawamkeag 2 km below Rockabema Lake. Greenlaw Stream, the outlet of a 44-hectare lake in the Aroostook River watershed, had been previously examined by personnel of the Maine Department of Inland Fisheries and Wildlife. Meduxnekeag Stream was chosen as a control stream. Its source, Meduxnekeag Lakem has a surface area of 2,716 hectares and lies east of the East Branch Mattawamkeag River drainage. Meduxnekeag Stream is a tributary to the St. John River system. All of the streams, except Meduxnekeag, were in areas that were scheduled to be sprayed by the Maine Bureau of Forestry.

Project personnel were on site to observe the spraying at West Hastings Brook and the West Branch Mattawamkeag. These locations were sprayed from 1945-2030 EDT on June 3, 1976. Spraying was not observed at Greenlaw Stream; however, Bureau of Forestry records show that location was treated on the evening of June 6. Figure 1 indicates areas within the Mattawamkeag River drainage that were sprayed by the Bureau of Forestry.

The Meduxnekeag Lake area was at least 15 km from any scheduled spraying by the Bureau of Forestry. Unfortunately, a private operator reportedly sprayed a 15-hectare woodlot at the southern end of Meduxnekeag

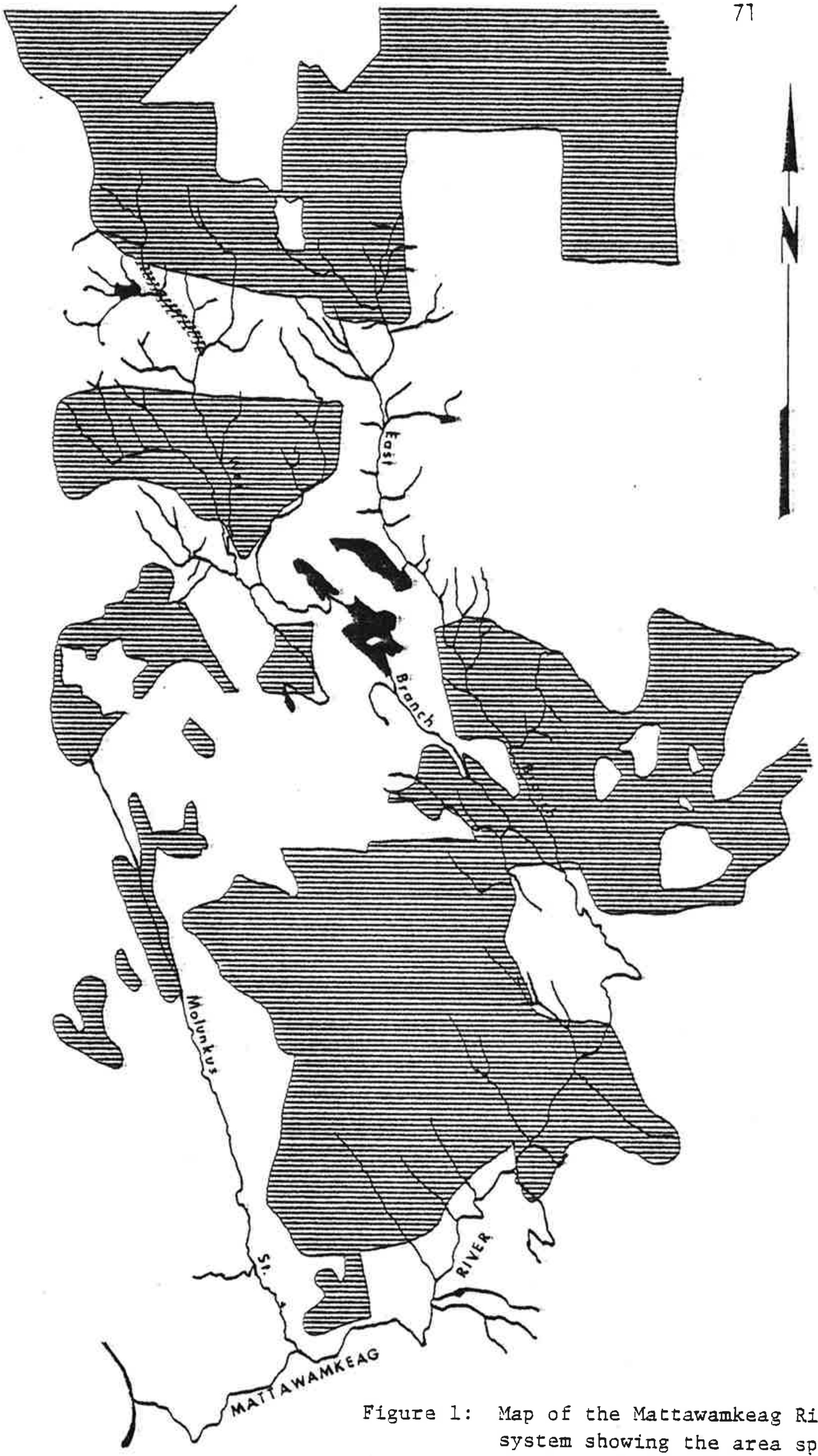

Figure 1: Map of the Mattawamkeag River system showing the area sprayed (horizontal lines) with Sevin 4-oil.

Lake on the evening of June 4. The reported dosage of 2.40 liter/hectare of Sevin was comparable to the levels used in the State's operational treatments.

MATERIALS AND METHODS

Water quality and temperature monitoring

Water samples were taken at all four streams prior to pesticide application. Post-spray collections were made approximately 24 hr after spraying at Greenlaw Stream, West Hastings Brook, and the West Branch Mattawamkeag River. Although it was not intended to be a post-spray sample, the second water collection taken from Meduxnekeag Stream occurred from 20-24 hr after that area was sprayed. All samples were analyzed for Sevin concentration by Mr. Ernie Richardson, Pesticide Residue Analyst, Maine Department of Human Services.

Water quality was examined in the study streams several times from May to October. The parameters measured were specific conductance at 25 C, total alkalinity, dissolved oxygen concentration, and pH. In addition, hydrothermographs were installed at West Hastings Brook and Meduxnekeag Stream on May 25 and 27, respectively. Both hydrothermographs were removed on October 31. Instantaneous water temperatures were taken each time water quality or biological data were obtained throughout the summer and fall.

Fish populations-chemical analyses

Two species of fish, including one salmonid, were sought from each stream for pesticide residue and brain acetylcholinesterase (AChE) analyses. Fish samples were generally obtained by electrofishing, but angling was employed when insufficient numbers of fish were captured by electrofishing. A general summary of pre- and post-spray sampling activities is contained in Table 1.

Table 1. General summary of sampling activities conducted to investigate some effects of aerial applications of Sevin 4-oil on fish and macroinvertebrate populations in four northern Maine streams in 1976.

PRE-SPRAY	POST-SPRAY
Water samples	Water samples
1. Analysis for Sevin	1. Analysis for Sevin
2. Measure water quality parameters	2. Measure water quality parameters
Fish samples	Fish samples
1. Analysis for tissue residues of Sevin, PCB's, organophosphate and organochlorine pesticides	1. Analysis for tissue residues of Sevin
2. Analysis for brain acetylcholinesterase activity levels	2. Analysis for brain acetylcholinesterase activity levels
3. Examine growth parameters in salmonids	3. Examine growth parameters in salmonids
4. Examine stomach contents in salmonids sacrificed for residue or brain analyses	4. Examine stomach contents in salmonids sacrificed for residue or brain analyses
Macroinvertebrate samples	Macroinvertebrate samples
1. Collect benthic organisms	1. Collect benthic organisms
2. Collect drifting organisms	2. Collect drifting organisms

At least five fish of the same species were used for a tissue residue sample, to obtain a minimum total weight of 50 g. Handling procedures for tissue residue analysis were similar to those used by Marancik (1976). Pre-spray fish collections were analyzed for residues of organochlorine and organophosphate pesticides, polychlorinated biphenyls (PCB's), and Sevin. Post-spray fish samples were analyzed for Sevin.

Brain AChE activity levels were measured in fish collected before and after pesticide application. Pre-spray samples were taken between May 17 and the actual time of spraying. Post-spray samples were collected at 24+, 48+, 96+, and 192+ hr after treatment. The samples included five fish per species whenever possible. All fish captured were kept in live cages until processing. The field surgical and freezing techniques were similar to those described by Marancik (1976). Fish brains were removed, and frozen by immersion in liquid nitrogen, within 60 sec of fish death. Fish brains were removed from the liquid nitrogen after about 15 sec. They were then placed in a cooler containing ice until the day's field work was completed, at which time all brain samples were placed in permanent freezing facilities. AChE activity levels were determined following the methods recommended by Coppage (1971). The individual brains from each collection date were pooled into a composite sample for the species tested. Fish sacrificed for pre-spray and 24+ hr post-spray AChE analysis were used in the tissue residue tests previously described.

Fish populations-biological data

Stomach contents were examined in those brook trout and landlocked salmon sacrificed for AChE or tissue residue analyses. Two to six stomachs were obtained per sampling day. Percentages of total stomach volume and frequency of occurrence of food items were determined for each sample of stomachs collected on a given day.

Fish populations were sampled monthly from May through October in the study streams. During most months, each stream was electrofished until a minimum of 25 brook trout or landlocked Atlantic salmon was obtained. In June, only the species needed for the postspray AChE analyses were captured and measured. All fish caught, except cyprinids and young-of-the-year salmonids, were anethetized with MS 222, weighed, measured, and released. Range in total length and group weights were obtained for young-of-the-year salmonids and most cyprinids. Condition factors for individual salmonids, excluding young-of-the-year, were computed using the following formula: $(\text{weight in g} \times 10^5) / (\text{length in mm})^3$. Meduxnekeag Stream was not electrofished after July because landlocked salmon were no longer present in numbers sufficient to warrant further investigation.

Macroinvertebrate populations

Aquatic macroinvertebrates in West Hastings Brook and Meduxnekeag Stream were collected using drift nets. Two drift nets, with 1-m square openings, were set in each stream. Details of the net construction and operation are described by Hoffman (1966). The nets were set near mid-channel in two riffle areas for 45 min per sampling time. Drift was collected at 0300, 0900, 1500, and 2100 hr. Prespray samples were obtained in May and monthly post-spray collections were taken from July through October. In addition, limited drift samples were collected in early June, shortly after spraying. Thirty-minute sets were made at 0900 and 1500 EDT at West Hastings Brook on June 4, 1976. These samples followed the Sevin spraying in that area by 13 and 19 hr, respectively.

Similarly, drift nets were set at Meduxnekeag Stream on June 7 at 0900 and 1500. The Meduxnekeag Lake area was sprayed on June 4. All invertebrates collected were preserved in 10% formalin.

Stream discharge measurements were taken with a Model 622, direct reading Gurley current meter in conjunction with the drift net samples. Total stream discharge and flow through the drift nets were measured at each net location two or three times per collection date.

Benthic macroinvertebrates were collected montly from May to October on the same days drift was sampled. Collections were made using a Surber sampler in qualitatively similar riffle areas in West Hastings Brook and Meduxnekeag Stream. These riffles were located downstream from the lower drift net sites. Different areas within the same riffle were sampled throughout the season. A monthly sample consisted of the combined contents of three 0.09 m^2 collections.

All macroinvertebrates were analyzed in the laboratory by Research Assistants Joan Trial and Bruce Grantham. Most aquatic insects were identified to the genus. In some cases, particularly with the Diptera, identifications were only made to family. Numbers of organisms were determined for the taxa identified. Wet weights of the major orders of aquatic insects were recorded.

RESULTS

Water quality and temperature monitoring

Detectable concentrations of Sevin were absent from all pre-spray water samples, but were present in all post-spray collections. Sevin concentrations ranged from 25.60 to 42.45 ppb at Greenlaw Stream, West Hastings Brook, and the West Branch Mattawamkeag. These streams were within areas sprayed by the Bureau of Forestry. Although only a small portion of the Meduxnekeag Lake area was sprayed, the concentration of Sevin in the outlet, Meduxnekeag Stream, was 2.82 ppb approximately 24 hr after treatment.

All water quality parameters examined were similar in the four study streams (Table 2). Specific conductance, total alkalinity, and pH levels were nearly identical at West Hastings Brook, Meduxnekeag Stream, and the West Branch Mattawamkeag. Values for these three parameters were consistently higher at Greenlaw Stream. Dissolved oxygen concentrations exceeded 8.2 ppm and 91% saturation throughout the sampling period.

Daily and seasonal water temperature differences were evident between West Hastings Brook and Meduxnekeag Stream. Diurnal fluctuations of 5 C often occurred at West Hastings, while maximum water temperatures did not exceed 20 C. Water temperatures were higher, but more stable at Meduxnekeag Stream (Table 3). Daily temperature ranges were rarely greater than 2 C at Meduxnekeag Stream. Mean water temperatures were at least 20 C from June 11 to August 31 at Meduxnekeag Stream. The temperature patterns reflect differences in the sources of the two streams. West Hastings Brook drains an area for heavily forested land, whereas Meduxnekeag Stream is fed by the epilimnetic waters of a large lake.

Fish populations-chemical analyses

Tissue samples from fish taken in all four streams contained background residues of DDT that ranged up to 106 ppb. DDT residues were highest in the fish taken from Greenlaw and Meduxnekeag streams. No detectable levels of organophosphate pesticides or PCB's were found in any of the fish tissues analyzed. Pre-spray collections contained no residues of Sevin. Post-spray analyses have not been completed.

Table 2. Water quality parameters measured in four northern Maine streams from May to October, 1976. Mean value is listed first in each column, followed by range in parentheses.

Location	Number of observations	Specific conductance at 25 C micromhos/cm	pH units	Dissolved oxygen		Total alkalinity ppm $CaCO_3$
				percent saturation	concentration ppm	
Meduxnekeag Stream	9	33 (30-37)	6.5 (5.6-7.1)	97 (93-99)	9.7 (8.2-12.0)	8.0 (4.1-4.6)
West Hastings Brook	9	29 (22-33)	6.4 (5.6-7.1)	97 (96-99)	10.4 (8.6-13.6)	6.8 (4.1-9.6)
West Branch Mattawamkeag River	9	30 (26-40)	6.5 (5.9-6.9)	98 (96-100)	9.7 (8.6-11.0)	6.8 (5.5-8.2)
Greenlaw Stream	9	60 (49-79)	6.9 (6.6-7.3)	97 (91-100)	9.8 (9.2-10.8)	20.2 (12.2-28.7)

Table 3. Record of water temperatures obtained at West Hastings Brook and Meduxnekeag Stream from June 1 to October 31, 1976. Mean temperature (C) is listed first, followed by range in parentheses.

	Location	
Sampling period	West Hastings Brook	Meduxnekeag Stream
June 1-10	13 (8-18)	18 (14-22)
June 11-20	15 (8-20)	22 (18-24)
June 21-30	N/A	22 (19-26)
July 1-10	N/A	22 (19-25)
July 11-20	15 (13-20)	21 (19-21)
July 21-31	16 (13-20)	22 (21-24)
August 1-10	14 (11-17)	21 (20-23)
August 11-20	15 (11-17)	21 (20-23)
August 21-31	15 (11-20)	22 (18-25)
September 1-10	11 (8-13)	17 (15-18)
September 11-20	12 (11-16)	17 (16-19)
September 21-30	10 (7-14)	15 (13-19)
October 1-10	9 (6-13)	13 (12-14)
October 11-20	6 (3-8)	10 (8-13)
October 21-31	3 (1-6)	6 (4-8)

N/A data not available due to equipment malfunction

Brain AChE levels were depressed in brook trout and salmon after spraying. The magnitude and duration of the depressions, up to 48 hr post-spray, appeared to be related to concentrations of Sevin in the water (Table 4). AChE activity levels returned to pre-spray values in most salmonids by 192 hr post-spray. White sucker brain AChE levels were elevated after pesticide application.

Water temperatures increased at all four streams during the period when fish were collected for AChE analyses. Post-spray instantaneous water temperatures were 2 to 13 C higher than pre-spray values. Water temperatures were negatively correlated with brain AChE levels in brook trout and landlocked salmon, and correlation coefficients (Zar 1974) ranged from -0.23 to -0.81. Although limited data were obtained for white suckers, brain AChE activity levels were positively correlated with water temperature at Meduxnekeag Stream (r=0.97).

Fish populations-biological data

Pesticide application apparently influenced the feeding activity of brook trout at Greenlaw Stream, West Hastings Brook, and the West Branch Mattawamkeag. Fish, oligochaetes, and larval Simuliidae were the principal food items consumed by trout at all three streams prior to spraying. Greatly increased feeding was evident in the 24 hr post-spray stomach samples, and larval Diptera, Ephemeroptera, and Plecoptera were the major organisms consumed. After 96 hr post-spray, immature aquatic insects were not major components of the trout stomach contents, and total stomach contents volume declined to pre-spray levels.

The West Branch Mattawamkeag River was stocked with hatchery-reared landlocked Atlantic salmon parr on May 26, 1976, two days before pre-spray fish collections were obtained at that location. Pre-spray stomach samples

Table 4. Changes in brain acetylcholinesterase activity levels in three species of fish captured in four northern Maine streams in 1976. All streams received aerial applications of Sevin 4-oil. Percent change from pre-spray activity levels is indicated in parentheses.

	Sevin concentration in water ppb		Brain acetylcholinesterase activity micromoles/mg/hr				
	Pre-spray	Post-spray 24 hr	Pre-spray	Post-spray 24 hr	48 hr	96 hr	192 hr
West Branch Mattawamkeag River	0.00	25.60					
Brook trout			0.18*	----	0.44	0.54	0.50
Landlocked salmon			0.57	0.37 (-35%)	0.35 (-39%)	0.53 (-7%)	0.24 (-58%)
White sucker			----	1.13	----	----	
Meduxnekeag Stream	0.00	2.82					
Landlocked salmon			0.48	----	0.35 (-27%)	----	0.58 (+21%)
White sucker			1.22	1.82 (+49%)	1.68 (+38%)	----	1.71 (+40%)
Greenlaw Stream	0.00	42.45					
Brook trout			0.48	0.39 (-19%)	0.31 (-35%)	0.30 (-37%)	0.36 (-25%)
West Hastings Brook	0.00	26.80					
Brook trout			0.54	0.44 (-19%)	0.44 (-19%)	0.48 (-11%)	0.48 (-11%)

* value not reliable due to analytical error

were not taken from salmon, but all post-spray salmon stomachs were analyzed. Nearly all post-spray salmon stomachs contained larval Ephemeroptera, Trichoptera, Diptera, and Plecoptera. The largest number and volume of these organism, however, was present in the 24- and 48 hr post-spray collections.

Brook trout and landlocked salmon growth, as indicated by condition factors, was not adversely affected by pesticide application in the study streams. Trout condition factors were generally highest in early summer, and they declined slightly in the fall (Table 5). A similar seasonal pattern was observed in the landlocked salmon captured from the West Branch Mattawamkeag River. Monthly condition factors were lower in salmon, however, than in brook trout.

Macroinvertebrate populations

Large numbers of immature aquatic insects drifted shortly after Sevin was sprayed at West Hastings Brook. Most of the drift in the June samples taken at West Hastings was composed of black fly, *Simulium* sp., larvae. Many Ephemeroptera and Trichoptera larvae were also captured.

Analysis of drift and benthic samples indicated no abnormal reductions in the aquatic insect orders most important to salmonids as food. The number of Ephemeroptera, Trichoptera, Plecoptera, and Diptera genera identified in fall collections compared favorably with pre-spray samples (Table 6). Except for the post-spray collections in June, drift at both Meduxnekeag Stream and West Hastings Brook was usually highest when stream discharges were also large. Within a monthly drift collection, samples taken at 2100 hr usually captured the largest number of macroinvertebrates.

Table 5. Condition factors for brook trout and landlocked salmon captured from three streams receiving aerial applications of Sevin 4-oil for spruce budworm control in 1976. Mean values are listed first in each column, followed by range in parentheses. All fish were sampled by electrofishing, except where noted.

Species, location	Date of sample	Number of fish	Condition factor (weight in g/length in mm^3) x 10^5
<u>Brook trout</u>			
West Branch	May 28	11	0.93(0.70-1.13)
Mattawamkeag River	June 5-12	11[a]	1.00(0.89-1.17)
	September 14	10	0.92(0.76-1.11)
	October 19	11	0.84(0.65-1.03)
West Hastings Brook	May 19	27	0.85(0.49-1.18)
	June 5-12	23	1.05(0.81-1.26)
	July 13	30	1.01(0.69-1.54)
	August 18	31	0.96(0.71-1.19)
	September 13	43	0.81(0.58-1.13)
	October 18	33	0.91(0.75-1.20)
Greenlaw Stream	May 17	25	0.96(0.64-1.66)
	June 8-15	24	0.96(0.66-1.20)
	July 21	24[b]	1.01(0.81-1.33)
	August 19	36	0.92(0.54-1.22)
	September 15	43	0.88(0.56-1.13)
	November 12	18	0.87(0.52-1.07)

Table 5. (continued)

Species, location	Date of sample	Number of fish	Condition factor (weight in g/length in mm^3) x 10^5
Landlocked salmon			
West Branch	May 28	15	0.76(0.55-0.90)
Mattawamkeag River	June 6-12	20	0.76(0.64-0.90)
	July 20	22	0.91(0.75-1.07)
	August 17	25	0.94(0.73-1.19)
	September 14	30	0.86(0.71-1.03)
	October 19	11	0.82(0.64-0.98)

[a] 6 fish angled

[b] 20 fish angled

Table 6. Number of Ephemeroptera, Trichoptera, Plecoptera, and Diptera genera identified in drift net and Surber sampler catches from two stream sprayed with Sevin 4-oil in 1976. Monthly collections consisted of the total combined catches from two drift nets and three 0.09 m^2 benthic areas.

Location, sampling period	Total drift net effort (hrs)	Mean stream discharge m^3/sec	Number of genera identified per order			
			Ephemeroptera	Trichoptera	Plecoptera	Diptera [a]
West Hastings Brook						
May	4.5	1.68	12	17	7	7
June	2.0	0.51	10	12	8	5
July	6.0	0.20	10	8	7	3
August	6.0	0.77	10	10	5	3
September	6.0	0.18	10	9	4	3
October	6.0	1.16	13	13	8	6
Meduxnekeag Stream						
May	4.5	2.68	10	7	6	2
June	2.0	0.98	8	6	3	2
July	6.0	0.16	10	8	3	2
August	6.0	2.30	12	20	5	2
September	6.0	0.48	8	9	3	1
October	6.0	1.79	11	15	4	8

[a] Diptera identified to family level are not included, i.e. Chironomidae

DISCUSSION

In recent years, measurements of brain AChE activity levels has been used to indicate exposure of various animals to pesticides. Esterase inhibiting pesticides bind to the active site of the AChE molecule, thereby disrupting synaptic transmission of nerve impulses (Coppage and Matthews 1974). Many organophosphate and carbamate pesticides produce reversible depressions of AChE activity in fish (Williams and Sova 1966; Holland et al. 1967; Coppage 1972). AChE reductions exceeding 80% of normal values can be lethal in fish (Coppage and Matthews 1974). Environmental factors can be influence this enzyme, as Hogan (1970) found that AChE acitvity in bluegill (Lepomis macrochirus) varied directly with water temperature.

Marancik (1976) reported AChE reductions lasting up to 48 hr post-spray in brook trout and landlocked Atlantic salmon taken from three northern Maine streams sprayed with Sevin in 1975. Although most AChE activities approached normal levels within 48 hr post-spray in the same species sampled in my study, the magnitude of the depressions recorded in 1976 generally exceeded those reported by Marancik. The 24 hr post-spray concentrations of Sevin in the operational spray areas were also larger in 1976 than in Marancik's 1975 study. The magnitude of the AChE depressions may have been related to the larger Sevin concentrations in the water, however, the degree of AChE inhibition is not always related to the amount of inhibitor present or to length of exposure (Gibson et al. 1969).

White suckers experienced AChE elevations after spraying in 1975 (Marancik 1976) and in 1976. Whereas water temperatures increased only slightly between Marancik's pre- and post-spray collections, a range of

13 C was recorded between the pre- and post-spray samples taken at Meduxnekeag Stream in 1976. Because white sucker AChE activities were elevated after spraying in both years, the effect of water temperature in this instance is not clear. AChE activity increases have not been reported in other species of fish exposed to pesticide application.

Fish exposed to Sevin accumulate only small amounts of the pesticide in their tissues (Korn 1973). Marancik (1976) reported no detectable residues of Sevin in fish tissues collected in Maine in 1975. In my study, Sevin was not detected in pre-spray fish collections, and it is not likely to be found when post-spray analyses are completed by the U.S. Fish and Wildlife Service's Fish Pesticide Research Laboratory in Columbia, Missouri.

The fish species examined in 1976 contained background levels of DDT in their tissues, but no organophosphate pesticides or PCB residues were detected. The toxicity of Sevin is increased in brook trout containing background concentrations of PCB (Aroclor 1254) (Schoettger and Mauck 1976), though synergistic relationships between Sevin and DDT have not been reported.

Atlantic salmon exposed to some organophosphate or organochlorine pesticides may experience increased vulnerability to predation (Hatfield and Anderson 1972), reductions in territorial behavior (Symons 1973), delayed behavioral development (Dill and Saunders 1974), and abnormal temperature selection (Oglivie and Miller 1976). Sevin is less toxic to salmonids than many organochlorine and organophosphate pesticides formerly used to control forest pests (Schoettger and Mauck 1976). Peterson (1976) found temperature selection was not altered in Atlantic salmon exposed to Sevin. Other effects of Sevin on fish behavior are not known.

Condition factors are useful for comparing the relative well being of fish populations (Everhart et al. 1975). Previous studies in Maine have reported condition factors for brook trout from unsprayed streams (Rupp 1953) and streams sprayed with DDT (LaBrie 1975). Rupp examined monthly condition factors for trout angled from May to August at Sunkhaze Stream, Penobscot County, Maine. He reported maximum condition factors in early summer and a slight decline in late summer. In all months examined, the trout from Sunkhaze Stream had condition factors 10-20% greater than those observed in the present study. LaBrie examined growth parameters in brook trout from 33 streams in northern Maine. Most of these streams had received aerial applications of DDT from 1950 to 1967, but some had not been sprayed during that interval. LaBrie classified the streams as controls, heavy, or medium treatments depending on their spray history, and he collected 5-11 trout from each stream by angling from June 16-30, 1970. He found that condition factors were not significantly different between the controls and two DDT treatment classes. The mean June condition factors ranged from 0.94 to 1.01 in LaBrie's study. In 1976, condition factors for brook trout captured in June from the three streams treated with Sevin ranged from 0.96 to 1.05.

Effects of Sevin on salmonid growth have not been examined prior to this study. Warner and Fenderson (1962) reported brook trout growth increased in several northern Maine streams one year after DDT spraying, possibly due to a reduced density of trout and other fishes in the sprayed streams. Differences in trout condition factors between my 1976 data and Rupp's (1953) may be largely due to factors other than pesticide application. These factors include differences in productivity of the streams, variations in environmental conditions among years, and differences in capture method. Some studies report higher condition factors in brook trout captured by angling than in those captured by electrofishing (Carlander 1969). All of Rupp's data came from fish that were angled whereas 98% of my trout were taken by electrofishing.

Water levels and temperatures were extremely favorable for salmonid survival in streams in northern Maine in 1976. It is assumed that growing conditions for trout were also favorable. Although data from this study are not conclusive, brook trout growth does not appear to have been affected in streams treated with Sevin 4-oil in 1976.

The effects of pesticide application on populations of stream macroinvertebrates are often difficult to assess. Dramatic changes in numbers of organisms collected in drift or benthic samples collected several days apart can occur in both treated and untreated streams (Dimond 1967; Rabeni and Gibbs 1976). Due to the uncertainties concerning changes in total numbers of insects, come investigators believe alterations in community structure provide better information on the effects of a pesticide on aquatic insects (Dimond 1967; Ide 1967).

In the present study, aerial applications of Sevin did not appear to adversely affect the diversity of the aquatic insect orders most important as food for juvenile salmonids. The short-term increase in the drift of larvae observed at West Hastings Brook was probably attributable to the spraying. Feeding levels of brook trout captured in West Hastings Brook suggest maximum drift occurred wihtin 48 hr post-spray and a return to "normal" drift levels was underway by 96 hr post-spray. Drift samples collected throughout the summer at West Hastings Brook and Meduxnekeag Stream showed that the normal pattern of increased drift after darkness established for many aquatic insects (Waters 1962) was not altered by spraying. Burdick et al. (1960) reported substantial reductions in aquatic insect populations based on benthic samples taken in two New York streams treated with Sevin. The dosage used in Burdick's study, 1.40 kg/hectare, was nearly twice that used in Maine in 1976. Based on the number of genera identified in pre- and post-spray samples, the quality of the aquatic insect community in the streams examined in 1976 was not adversely affected by the applications of Sevin.

CONCLUSION

The spraying of Sevin 4-oil for spruce budworm control in 1976 did not cause detectably significant harm to the salmonids and macroinvertebrates in the streams examined. Short-term brain AChE depressions occurred in brook trout and landlocked Atlantic salmon. Growth patterns during the open water season did not seem to be altered by the spraying, but water temperatures and flows were extremely favorable for salmonids in northern Maine stream in 1976. The diversity of aquatic insect populations was not reduced, although most orders of insects experienced increased drift rates immediately after apraying.

No potential effects of pesticide application on salmonid fry were investigated in this study. Future work should include this life stage because the continuation of naturally produced fish populations depends on growth and survival of young-of-the-year.

Few studies have been designed to assess the impact of sublethal AChE depressions in fish. Organophosphate pesticides are known to cause AChE depressions. Sub-lethal exposures to Fenitrothion, an organophosphate compound, have altered the behavior (Symons 1973) and reduced the survival (Hatfield and Anderson 1972) of juvenile Atlantic salmon.

Carbamate pesticides such as Sevin, produce AChE reductions, but their effects on fish behavior are generally unknown. Examination of the behavior of fish, particularly while they are experiencing a pesticide induced AChE reduction, are badly needed. Without this type of information, the ultimate effect of a pesticide on fish populations cannot be determined.

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