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THE MATAMEK RESEARCH PROGRAM:
ANNUAL REPORT FOR 1980

by

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WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts 02543

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TECHNICAL REPORT

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Quebec; for the University of Waterloo, Waterloo, Ontario.*

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ABSTRACT

This report briefly describes activities associated with the Matamek Research Program in 1980. Research was conducted on biological, chemical, and physical characteristics of streams and rivers, principally in the Moisie and Matamek River watersheds, and on salmonid ecology and the natural history of sea trout. Canadian universities, the Quebec government, and the Woods Hole Oceanographic Institution cooperated in this program.

TABLE OF CONTENTS

	Page
Introduction (English).....	1
Introduction (French).....	3
List of Personnel.....	6
Canadian Research Grants.....	7
Publications (1980).....	8
<u>Research Summaries</u>	
River Ecosystem Studies.....	10
Community Metabolism.....	11
Seston Dynamics.....	47
Decomposition Dynamics of Woody Debris.....	60
Rainwater Chemistry.....	70
Allochthonous Inputs.....	74
Periphyton Production Dynamics.....	75
Atlantic Salmon Studies (<u>Salmo salar</u>).....	93
The Adult Salmon Run.....	94
2nd Falls Parr and Trout.....	101
Artificial Stocking of Atlantic Salmon.....	106
Changes in Stock Composition of Juvenile Salmon.....	112
Pigou River Survey.....	124
Sea Trout Studies (<u>Salvelinus fontinalis</u>).....	127
Sea Trout in the Moisie River.....	128
Parasites as Indicators of Movements.....	147
Biology of <u>Salmincola</u> on Brook Trout.....	149
Size, Age, and Osmoregulation.....	150
Juvenile Brook Trout and Riparian Vegetation.....	153
Other Studies.....	158
Growth and Behavior of Juvenile Salmonids.....	159
Non-Salmonid Fishes of the Lower Moisie River.....	163
Response of Phytoplankton to Fertilization.....	164
Ecology of a Small Stream During Summer.....	179
Geomorphologique - Potentiel d'Accueil Salmonicole.....	180
Hydro-Physiques du Bassin Matamec.....	201
Characteristics of Peatlands.....	205
Natural Products of Marine Organisms.....	207
Possible Blue Whale Sighting.....	210

INTRODUCTION

In 1980 the Matamek Research Program continued to focus on three related areas: (1) an integrated analysis of the structure and function of large watersheds, (2) the biology of sea trout (Salvelinus fontinalis), and (3) monitoring of the Atlantic salmon (Salmo salar) population. In addition to these core programs studies of geographical variations in the life history of salmon, the early life history of brook trout, and osmoregulation by brook trout were initiated.

The integrated ecosystem analysis of streams and rivers included metabolism and production, characterization of drifting organic matter, decomposition dynamics of wood and leaves, nature and quantity of allochthonous inputs, monitoring rainwater chemistry, and the chemistry of stream water. Several of these studies were mostly completed during the 1980 field season (e.g. pattern of metabolism, seston dynamics). The watershed analysis is continuing in the other areas, forming a major portion of the present research program. These studies are, in essence, exploring the trophic basis for salmonid production in this region and will be eventually used to suggest enhancement procedures or to predict the effects of perturbation.

The brook trout sea-ranching project completed the third year of a proposed five year study. In 1980 the project explored in detail the natural history of a native sea trout population in the lower Moisie River. Data were collected on timing of migration, movements, exploitation of the food supply, growth, and parasites. A new project was

initiated with funds from the NOAA Sea Grant office to examine physiological relationships between age, size, and osmoregulatory ability.

Studies of Atlantic salmon consisted of measuring, and population sizes of parr in selected areas and monitoring returning adults and grilse at the fishladder. Scales were taken for age and growth of returning fish. These programs provide a continuence with studies of previous years.

Canadian graduate student projects included a comparative life history study of Atlantic salmon populations on the North Shore, jointly funded with the Atlantic Salmon Association, and periphyton production dynamics as a function of stream order. Student interns investigated the early life history of brook trout as related to their use of riparian vegetation and the ecology of a small stream during the summer low water period.

The Matamek Research Program offers an unusual opportunity for Canadian and American researchers and students to join in a common scientific effort. The location of the Matamek Research Station in close proximity to a variety of pristine lakes and rivers, in conjunction with the endowed nature of the program, provides a unique opportunity for development of strong programs of long duration. The cooperation this program has received from scientists at Canadian universities and the Quebec Ministry of Recreation, Fish and Game has been exceptional. We are most grateful for the continued support and assistance given us by the Quebec government and our Canadian colleagues.

Robert J. Naiman
Coordinator,
Matamek Research Program

30 March 1981

Introduction

En 1980 le Programme de Recherches de Matamek a poursuivi ses travaux dans les trois domaines suivants: (1) l'analyse intégrée de la structure et de la fonction des grands bassins fluviaux, (2) la biologie de l'omble de fontaine de la mer (Salvelinus fontinalis), et (3) le recensement de la population du saumon Atlantique (Salmo salar). En plus de ces programmes essentiels, on a entrepris des études sur les variations géographiques de la biologie du saumon, sur l'histoire naturelle des jeunes ombles de fontaine, et sur les processus d'osmorégulation chez l'omble de fontaine anadrome.

L'analyse intégrée des écosystèmes fluviaux impliquait les études suivantes:

- étude du métabolisme et de la production,
- caractéristiques de matières organiques en dérive,
- décomposition du bois et des feuilles,
- nature et quantité des apports provenant des sources allochtones,
- chimie des pluies et de l'eau de ruisseau.

Plusieurs de ces études ont été achevées pendant la saison estivale de 1980 (e.g. un modèle de métabolisme, la dynamique du seston). Cependant, l'analyse du bassin fluvial se poursuit dans les autres domaines, occupant ainsi la majeure partie du programme de recherche actuel. Ces études portent essentiellement sur deux objectifs: (1) la détermination de la base

trophique de la production des salmonidés et, (2) ultérieurement, l'élaboration des procédures pour favoriser la production des salmonidés et prévoir les effets de perturbations.

Une étude expérimentale de la pisciculture maritime de l'omble de fontaine se poursuivait en 1980, complétant la troisième année d'un projet d'une durée de cinq ans. En 1980 on a étudié en détail l'histoire naturelle de la population indigène de l'omble de fontaine anadrome dans la rivière Moisie. On a recueilli des données sur la synchronisation des migrations, les mouvements, l'alimentation, la croissance et les parasites des salmonidés. Un nouveau projet a été mis sur pied grâce à des fonds provenant de NOAA Sea Grant Office dans le but d'examiner les relations physiologiques entre l'âge, la taille et la capacité d'osmorégulation chez l'omble de fontaine anadrome.

L'étude du saumon Atlantique portait sur la détermination de la croissance, du dénombrement des tacons, ainsi que le recensement du retour des saumons adultes à la barrière de comptage. Des écailles ont été prélevées afin de déterminer l'âge et la croissance des saumons revenant de la mer. Ce programme poursuit les activités des années précédentes.

Des étudiants gradués canadiens travaillent sur deux projets: l'étude comparative des populations du saumon Atlantique le long de la Côte Nord avec l'aide financière de l'Atlantic Salmon Association; et la dynamique de la production du périphyton en relation avec l'ordre du cours d'eau. Des étudiants visitants la Station de Recherche de Matamek ont initié des études sur l'écologie des jeunes ombles de fontaine en relation avec la présence de végétation riveraine et sur l'écologie d'un ruisseau pendant la période estivale de faible débit.

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Le Programme de Recherches de Matamek offre à des savants canadiens et américains, ainsi qu'à des étudiants l'occasion unique de collaborer à un effort scientifique commun. L'emplacement de la Station de Recherches de Matamek, qui se trouve à proximité d'une variété de lacs et de rivières intacts, soit à l'état vierge, et le caractère de ce programme largement subventionné, offrent la possibilité d'études approfondies qui peuvent se poursuivre indéfiniment. Les savants des universités canadiennes et le Ministère du Loisir, de la Chasse et de la Pêche du Québec ont accordé à notre programme une aide tout à fait exceptionnelle. Nous leur en sommes profondément reconnaissants, ainsi que de l'appui que nous ont apporté le gouvernement du Québec et nos collègues canadiens.

Robert J. Naiman
Coordinateur

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Francois Garneau
Jean-Luc Simard

University de Quebec a
Chicoutimi

* In Memorium Nov. 24, 1920 - April 11, 1980

** Present Address

Matamek Canadian Awards - 1980
25/4.01

Principal Investigator	Affiliation	Title of Proposal	Award \$C
Marcel Frenette	University of Laval	Caracteristiques hydro-physiques du Bassin de la Riviere Matamec	\$C 3,000
Hamish Duthie	University of Waterloo	Stream Periphyton Studies in the Matamek and Moisie Watersheds, Quebec	\$ 4,930
Geoff Power	University of Waterloo	Salmon of the North Shore of the Gulf of St. Lawrence	\$ 6,000

Publications - 1980
Scientific Papers

Matamek Contribution
No.

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- Ross, P. Role of the ultraplankton in the ecology of a Pre-Cambrian Shield Lake. University of Waterloo. Ph.D. Dissertation.
- Chow-Fraser, P. Phytoplankton response to low-level fertilization of a dystrophic shield lake. University of Waterloo. M.Sc. Thesis.
- Kreamer, G. The Macrozoobenthos of a deep, ultraoligothrophic, humic acid lake in the eastern Canadien shield with special reference to the Chironomidae. University of Waterloo. M.Sc. Thesis.
- Dickson, T.A. Growth and behavior of juvenile Salmo salar and Salvelinus fontinalis in allopatry and sympatry. University of Guelph. M.S. Thesis.

RESEARCH SUMMARIES

RIVER ECOSYSTEM STUDIES

THE PATTERN OF METABOLISM IN A LARGE BOREAL FOREST WATERSHED

R.J. Naiman

Woods Hole Oceanographic Institution

The relative proportion of total metabolism contributed by autotrophic and detrital components of running waters is principally a function of stream width. Normally, small headwater streams in forested areas are heavily shaded and contain considerable terrestrially derived detritus associated with the substrate (Naiman and Sedell 1979, 1980). As stream size increases, corresponding higher discharge rates move much of the detritus out of the stream channel or downstream, the forest canopy opens slightly allowing more light to reach the water surface, and extensive periphyton and macrophyte communities usually develop. In these areas the metabolic importance of detritus to total stream metabolism is less than in the headwaters (Naiman and Sedell 1980). Further downstream, as the forest canopy opens completely and the river becomes deep and turbid, the autotrophic component is reduced mainly to a plankton community. In these reaches the metabolic activity of fine detritus being transported plus a larger role (Vannote et al. 1980).

Past studies of community metabolism in streams have, for the most part, been restricted to a single location, emphasized either primary production or total metabolism, or been largely conducted on small streams because of sampling ease. Gross physical analyses of large watersheds are relatively easy to accomplish and, when combined with studies of stream segments of various orders, can be a powerful tool for understanding the

basic structural and functional properties of large complex ecosystems. When physical and biological studies are combined, the relative importance, abundance, activity, and distribution of biological components can be readily examined at the watershed level.

In 1979 and 1980 data were collected on metabolism of the various components of each stream and river segment: coarse particulate organic matter (CPOM: > 1mm), fine particulate organic matter (FPOM: 0.5 μ m - 1 mm), pool and riffle periphyton, macrophytes, and seston. The method used is described by Naiman and Sedell (1980, 1981). These data are being interfaced with physical characterization of the watersheds to provide an overview of the spatial and temporal patterns of metabolism. The data are presented in the following tables and figures. A manuscript summarizing this study is being prepared and will be available for distribution by the end of the year

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- Naiman, R.J. and J.R. Sedell. 1979. Benthic organic matter as a function of stream order in Oregon. *Arch. Hydrobiol.* 87: 404-422.
- Naiman, R.J. and J.R. Sedell. 1980. Relationships between metabolic parameters and stream order in Oregon. *Can. J. Fish. Aquat. Sci.* 37: 834-847.
- Naiman, R.J. and J.R. Sedell. 1981. Stream ecosystem research in a watershed perspective. *Verh. Internat. Verein. Limnol.* 21: In press.
- Vannote, R.J., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. *Can. J. Fish. Aquat. Sci.* 37: 130-137.

Figure Captions

Fig. 1. Location and relative sizes of the watershed used in this and other studies of ecosystem dynamics.

Fig. 2. Total number and lengths of streams in each watershed as a function of stream order.

Fig. 3. Total number and length of streams as a function of basin size using data from the five key watersheds.

Fig. 4. River width is shown as a function of stream order. Widths were measured in the field or from aerial photographs.

Fig. 5. Total degree days for each site by month for 1980.

Fig. 6. Areal metabolism of fine particulate organic matter by site and sampling period. FPOM standing stock was measured separately and combined with specific metabolic rates in previous table.

Fig. 7. Areal metabolism of coarse particulate organic matter by site and sampling period. CPOM standing stock was measured separately and combined with specific metabolic rates in previous table.

Fig. 8. Estimated annual metabolism by each metabolic component for each stream.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Table 1. Physical and Chemical Characterization of the Quebec Study Sites.

Parameter	First Choice Creek	Beaver Creek	Muskrat River	Matamek River	Moisie River
Stream Order	1	2	5	6	9
Watershed Area (km ²)	0.25	1.83	207	673	19,811
Mean Width (m)	0.3	2.0	21.9	51.7	208.7
Mean Depth (m)	0.05	0.3	2.0	1.8	2.5
Mean Annual Discharge (m ³ · s ⁻¹)	0.013	0.033	8.4	13.7	466.1
Gradient (%; lower reaches)	1.5	1.0	0.14	1.33	0.16
Substrate	Detritus	Sediment/cobble	Sediment/cobble	Gravel/cobble	Sand/cobble
Temperature range (°C)	0.4-11.0	0.0-19.0	0.0-19.5	0.1-19.8	0.1-21.8
Annual Degree Day (°C · yr ⁻¹)	1702	2069	2157	2225	2219
Nutrient range (µg · L ⁻¹)					
NO ₃ -N	17-199	5-135	3-91	1-76	25-87
Total N	49-234	211-623	170-382	148-341	134-392
PO ₄ -P	2-8	1-7	1-5	1-17	1-11
Total P	7-29	6-26	6-22	5-16	4-22
Alkalinity range (meq · L ⁻¹)	0.097-0.253	0.039-0.368	0-0.085	0-0.076	0.044-0.338
pH range	6.2-7.2	6.0-7.0	4.9-6.1	4.8-6.0	6.3-7.1
Mean Dissolved Organic Carbon (mgC · L ⁻¹)	4.1	12.9	12.3	11.3	6.8
Benthic Chlorophyll Range (mg Chl a · m ⁻²)	0.2-5.7	0.4-17.4	1.0-4.2	3.7-30.0	0.0-7.0
Forest Canopy Development	Closed	Mostly Closed	Mostly Open	Open	Open
Benthic Organic Matter (gAFDW · m ⁻²)	712	526	516	252	481

Table 2. Physical Characterization of the Moisie River Watershed, Quebec (19,811 km²).

Stream Order	No. of Streams	%Total	Total Length of Streams (km)	%Total	Width (m)	Estimated Surface Area (m ² x 10 ⁶)	%Total
1	38,770	78.2	16,142	49.9	0.3	4.8	2.3
2	8,400	16.9	8,249	25.5	2.1	17.3	8.4
3	1,855	3.7	3,842	11.9	6.7	25.7	12.5
4	415	0.84	1,879	5.8	15.6	29.3	14.3
5	95	0.19	1,072	3.3	30.1	32.3	15.8
6	19	0.04	471	1.5	51.3	24.2	11.8
7	7	0.014	340	1.1	80.6	27.4	13.4
8	2	0.004	392	0.9	119.1	34.8	17.0
9	1	0.002	54	0.2	168.2	9.1	4.4
TOTAL	49,564		32,341			204.9	

Table 3. Water Chemistry ($\text{mg} \cdot \text{L}^{-1}$) Analyses for the Major Sampling Locations.

Date	NH ₄	NO ₃	NO ₂	Σ N	PO ₄	Σ P	Si
FIRST CHOICE CREEK							
9 Apr 80	.005	.144	0	.185	.007	.012	1.283
21 Apr 80	.006	.163	.0008	.222	.006	.011	1.436
5 May 80	.007	.105	.001	.190	.005	.029	.829
19 May 80	.010	.199	.001	.214	.003	.011	1.509
2 Jun 80	.006	.133	.001	.185	.002	.013	2.520
16 Jun 80	.004	.055	.001	.108	.004	.014	1.656
30 Jun 80	.005	.024	0	.088	.005	.009	2.165
14 Jul 80	.011	.017	0	.234	.004	.011	.602
28 Jul 80	.004	.019	.0004	.049	.005	.008	2.089
11 Aug 80	.005	.024	.0006	.095	.003	.007	1.131
25 Aug 80	.004	.017	.0006	.075	.005	.008	1.142
8 Sep 80	.011	.019	.0009	.128	.008	.020	1.585
22 Sep 80	.008	.017	.001	.122	.006	.012	.970
6 Oct 80	.012	.022	.0007	.104	.007	.010	2.898
20 Oct 80	.008	.041	.0004	.101	.008	.009	3.528
3 Nov 80	.020	.079	.0005	.229	.008	.010	3.024
BEAVER CREEK							
9 Apr 80	.114	.135	.001	.623	.003	.015	1.288
22 Apr 80	.022	.022	.002	.274	.001	.012	.092
5 May 80	.003	.012	0	.217	.002	.026	.047
19 May 80	.016	.006	.002	.211	.003	.012	.082
2 Jun 80	.007	.025	.001	.248	.002	.015	.165
16 Jun 80	.017	.009	.002	.248	.001	.010	.118
30 Jun 80	.015	.046	.001	.332	.002	.011	.169
14 Jul 80	.006	.009	.003	.287	.001	.008	.126
28 Jul 80	.012	.063	0	.422	.003	.012	.008
11 Aug 80	.004	.010	.0002	.320	.002	.008	.154
25 Aug 80	.002	.007	.0003	.257	.002	.012	.753
8 Sep 80	.008	.012	0	.388	.007	.011	.015
22 Sep 80	.006	.014	0	.376	.006	.022	.087
6 Oct 80	.011	.005	0	.309	.003	.009	.194
20 Oct 80	.034	.076	.0005	.471	.002	.006	.442
3 Nov 80	.008	.019	.0006	.252	.003	.007	1.131

Table 3. (cont).

Date	NH ₄	NO ₃	NO ₂	-ΣN	PO ₄	ΣP	Si
MUSKRAT RIVER							
10 Apr 80	.047	.091	.001	.382	.002	.010	.067
21 Apr 80	.012	.049	0	.306	.002	.017	.032
5 May 80	.012	.023	0	.323	.004	.014	.068
19 May 80	.006	.016	.002	.175	.004	.014	.025
2 Jun 80	.004	.018	.001	.238	.002	.022	.023
16 Jun 80	.006	.004	0	.222	.002	.007	.013
30 Jun 80	.002	.005	.001	.189	.002	.018	.049
14 Jul 80	.004	.006	.001	.227	.001	.010	.054
28 Jul 80	.005	.010	.0004	.215	.002	.007	.064
11 Aug 80	.003	.003	0	.340	.002	.012	.048
25 Aug 80	.005	.005	.0004	.200	.002	.008	.081
8 Sep 80	.005	.010	0	.273	.002	.009	.199
22 Sep 80	.004	.006	0	.302	.002	.009	.060
6 Oct 80	.004	.009	.0005	.170	.005	.013	.149
20 Oct 80	.003	.014	.0003	.211	.002	.007	.076
3 Nov 80	.011	.022	.0003	.265	.002	.006	.068

MATAMEK RIVER

9 Apr 80	.024	.076	.001	.242	.002	.014	.047
21 Apr 80	.019	.063	0	.341	.002	.015	.043
5 May 80	.012	.037	0	.293	.002	.016	.030
19 May 80	.016	.032	.002	.186	.001	.011	.030
2 Jun 80	.007	.033	0	.195	.002	.013	.029
16 Jun 80	.004	.026	.001	.175	.001	.006	.028
30 Jun 80	.005	.011	.001	.174	.002	.011	.029
14 Jul 80	.005	.015	.002	.203	.002	.011	.038
28 Jul 80	.005	.010	0	.191	.002	.005	.035
11 Aug 80	.002	.008	.0007	.263	.002	.007	.112
25 Aug 80	.003	.007	.0004	.148	.002	.005	.075
8 Sep 80	.004	.001	0	.218	.002	.010	.038
22 Sep 80	.015	.014	0	.321	.010	.034	.060
6 Oct 80	.009	.011	.0005	.165	.017	.027	.108
20 Oct 80	.016	.032	.0004	.220	.002	.005	.072
3 Nov 80	.014	.028	.0005	.248	.002	.009	.060

Table 3. (cont).

Date	NH ₄	NO ₃	NO ₂	Σ N	PO ₄	Σ P	Si
MOISIE RIVER							
9 Apr 80	.026	.087	0	.227	.001	.022	1.189
21 Apr 80	.010	.086	0	.200	.004	.009	.942
5 May 80	.018	.054	.002	.392	.002	.088	.375
19 May 80	.003	.033	.001	.194	.002	.021	.112
2 Jun 80	.010	.045	.001	.252	.001	.012	.174
16 Jun 80	.004	.033	.001	.159	.006	.016	.454
30 Jun 80	.002	.030	0	.148	.002	.008	.501
14 Jul 80	.006	.025	.001	.134	.001	.007	.325
28 Jul 80	.015	.042	0	.177	.002	.007	1.031
11 Aug 80	.002	.032	.0004	.211	.002	.006	.459
25 Aug 80	.011	.032	.0010	.188	.002	.006	.899
8 Sep 80	.002	.035	.0010	.164	.002	.005	1.005
22 Sep 80	.011	.033	.002	.181	.002	.005	.577
6 Oct 80	.008	.046	0	.234	.003	.006	.400
20 Oct 80	.018	.046	.0004	.211	.002	.004	.736
3 Nov 80	.005	.057	.0004	.209	.005	.007	.960
MATAMEK ESTUARY							
9 Apr 80	.008	.052	.002	.365	.021	.032	.300
MATAMEK RAIN GAUGE							
9 Apr 80	.081	.066	0	.441	.007	.046	.014
13-14 Apr 80	.067	.041	.0004	Pink	.017	.246	.003
15-16 Apr 80	.154	.177	0	.337	.004	.044	.002
8-9 Apr 80	.051	.033	.0002	.113	.005	.012	.013
18-19 May 80	.021	.108	0	.421	.067	.106	.028
8-10 Jun 80	.107	.118	0	.251	.009	.011	.004
2 Jul 80	.069/.082	.065/.046	0/0	.538/.319	.011/.017	.013/.029	.002/.004
5-6 Jul 80	.015	.027	.001	.077	.004	.010	.009
11-12 Jul 80	.192	.137	.0005	.443	.009	.012	.008
13-14 Jul 80	.106	.200	0	.356	.006	.011	.044
30 Aug 80	.041	.130	.0005	.593	.038	.047	.059
17-18 Sep 80	0	.314	0	.816			
20-21 Sep 80	.055	.092	.0002	.206		.046	
23 Sep 80	.028	.064	.0005	.112	.002	.002	.008
30-1 Sep-Oct 80	.026	.052	0	.149	.004	.004	.018
2-3 Oct 80	.005	.006	.0006	.642	.002	.008	.048
17-18 Oct 80	.447	.844	.0008	1.304	.011	.014	.032

Table 4. Daily light regime ($\mu E \times 10^5 \cdot m^{-2} \cdot d^{-1}$) at the submerged metabolic chambers for each sampling location during the experiments. Sampling periods are: (1) April-early May, (2) June, (3) July, (4) August, (5) September-early October, and (6) late October-November.

Sampling Period	First Choice Creek		Beaver Creek		Muskrat River		Matamek River		Moisie River	
	$\bar{x} \pm SE$	n	$\bar{x} \pm SE$	n	$\bar{x} \pm SE$	n	$\bar{x} \pm SE$	n	$\bar{x} \pm SE$	n
1	15.3 $\pm$ 1.4	3	55.9 $\pm$ 20.4	3	57.4 $\pm$ 10.3	3	219.2 $\pm$ 26.5	3	553.8 $\pm$ 91.3	3
2	6.9 $\pm$ 1.2	3	46.9 $\pm$ 8.9	3	317.4 $\pm$ 81.3	3	70.6 $\pm$ 35.8	3	279.2 $\pm$ 26.1	3
3	23.7 $\pm$ 6.4	3	19.5 $\pm$ 0.2	3	87.6 $\pm$ 57.2	3	266.0 $\pm$ 76.4	4	241.7 $\pm$ 35.2	3
4	14.4 $\pm$ 6.7	3	21.2 $\pm$ 0.5	3	330.0 $\pm$ 105.6	3	339.2 $\pm$ 149.9	3	464.8 $\pm$ 122.8	3
5	22.0 $\pm$ 13.8	3	34.0 $\pm$ 17.7	3	295.0 $\pm$ 102.9	3	338.0 $\pm$ 70.9	3	290.3 $\pm$ 55.8	3
6	7.7 $\pm$ 3.9	3	31.1 $\pm$ 4.3	3	76.8 $\pm$ 25.3	3	47.3 $\pm$ 7.7	3	42.3 $\pm$ 18.2	3

Table 5. Mean concentration ($\text{mg} \cdot \text{m}^{-2}$) of chlorophyll *a*, and ratio of optical density at 665 nm before and after acidification for periphyton, mosses, and detritus in each stream during the various sampling periods. Sampling periods are given in Table for the light regime.

Sampling Period	First Choice Creek				Beaver Creek				Muskrat River			
	Periphyton		Detritus		Periphyton		Detritus		Periphyton		Detritus	
	n	$\bar{x} \pm \text{SE}$	%	665/665a	n	$\bar{x} \pm \text{SE}$	%	665/665a	n	$\bar{x} \pm \text{SE}$	%	665/665a
1 Periphyton	2	0.2 ± 0.2	33	1.00	6	0.6 ± 0.2	60	0.95	4	1.0 ± 1.0	24	1.24
Detritus	12	0.4 ± 0.1	66	1.44	9	0.4 ± 0.1	40	1.21	8	3.1 ± 2.5	76	1.14
Total		0.6				1.0				4.1		
2 Periphyton	3	4.4 ± 1.3	96	1.46	7	17.4 ± 3.1	98	1.63	7	2.0 ± 0.3	80	1.52
Detritus	9	0.2 ± 0.1	4	1.54	5	0.4 ± 0.2	2	1.84	6	0.5 ± 0.2	20	1.51
Total		4.6				17.8				2.5		
3 Periphyton	5	2.0 ± 0.8	71	2.08	6	2.1 ± 0.7	84	1.43	4	4.2 ± 0.8	88	1.47
Detritus	7	0.8 ± 0.4	29	1.31	9	0.4 ± 0.2	16	1.43	6	0.6 ± 0.5	12	1.37
Total		2.8				2.5				4.8		
4 Periphyton	6	1.0 ± 0.3	77	1.64	7	1.1 ± 0.3	85	1.35	4	2.4 ± 1.5	92	1.45
Detritus	9	0.3 ± 0.1	23	1.37	8	0.2 ± 0.1	15	1.33	6	0.2 ± 0.1	8	1.32
Total		1.3				1.3				2.6		
5 Periphyton	7	1.8 ± 0.7	82	1.50	6	1.8 ± 0.5	86	1.41	8	3.1 ± 0.6	91	1.31
Detritus	8	0.4 ± 0.1	18	1.49	9	0.3 ± 0.3	14	1.12	5	0.3 ± 0.2	9	1.30
Total		2.2				2.1				3.4		
6 Periphyton	4	5.7 ± 5.2	77	1.30	6	0.4 ± 0.2	57	0.92	3	1.2 ± 0.6	33	1.35
Detritus	11	1.7 ± 1.0	23	1.11	9	0.3 ± 0.1	43	1.05	7	2.4 ± 2.0	66	1.21
Total		7.4				0.7				3.6		

Table 5. (Cont.)

Matamek River				Moisie River			
Periphyton and Detritus		Mosses		Periphyton and Detritus		Mosses	
n	x ± SE	%	665/665a	n	x ± SE	%	665/665a
4	5.7 ± 5.6	88	1.29	3	8.5 ± 3.9	1.38	
7	0.8 ± 0.6	12	1.12				
	<u>6.5</u>						
5	30.0 ± 11.2	93	1.49	4	35.2 ± 8.4	1.38	
3	2.1 ± 1.6	7	1.57				
	<u>32.1</u>						
6	23.2 ± 9.3	67	1.55	3	51.1 ± 26.7	1.63	
4	11.4 ± 9.7	33	1.48				
	<u>34.6</u>						
4	8.8 ± 1.4	98	1.47	4	25.8 ± 7.3	1.57	
4	0.2 ± 0.3	2	1.42				
	<u>9.0</u>						
1	29.5	99	1.59	5	87.8 ± 23.0	1.67	
6	0.3 ± 0.1	1	1.42				
	<u>29.8</u>						
3	3.7 ± 2.1	54	1.44	3	27.3 ± 13.1	1.39	
9	3.1 ± 1.0	46	1.32				
	<u>6.8</u>						

Table 6. Species of Macrophytes Found in the Moisie and Matamek Rivers*.

MACROPHYTES

Sparganium sp.
Potamogeton epihydric
Potamogeton sp.
Lobelia dortmanna
Sagittaria latifolia
Callitriche vermae
Equisetum fluviatile
Nuphar variegatum

*Identification by H. Duthie, I.K. Morton (University of Waterloo).

Table 7. Macrophyte Standing Crop Summary for The Matamek River. Weight data are gAFDW m^{-2} ($\bar{x} \pm SE$)

Transect	August 1979						June 1980					
	Sample Size (n)	Standing Crop	Sparganium (%)	Sagittaria (%)	Lobelia (%)	Others (%)	Sample Size (n)	Standing Crop	Sparganium (%)	Sagittaria (%)	Lobelia (%)	Others (%)
1	16	12.70 $\pm$ 5.67	78.8	0.2	18.7	2.3	29	5.58 $\pm$ 2.60	3.4	0	96.6	0
2	9	33.16 $\pm$ 7.18	43.0	11.4	6.2	39.4	21	23.43 $\pm$ 17.57	39.0	0	18.0	43.0
3	8	10.06 $\pm$ 8.52	33.5	46.8	0.1	19.6	14	0.22 $\pm$ 0.21	18.2	0	4.5	77.3
4	9	25.45 $\pm$ 9.69	49.9	12.5	12.9	24.7						
5	10	0.33 $\pm$ 0.25	33.3	0	66.7	0	9	0.82 $\pm$ 0.30	0	0	95.1	4.9
6	6	3.65 $\pm$ 2.59	67.4	0	24.4	8.2	18	0.84 $\pm$ 0.42	0	0	92.9	7.1
7	9	10.58 $\pm$ 2.28	42.5	11.6	16.2	29.7	16	0.71 $\pm$ 0.57	94.4	0	0	5.6
<hr/>												
	$\bar{x}$	13.70	49.8	11.8	20.7	17.7	$\bar{x}$	5.27	25.8	0	51.2	23.0
	SE	4.42	6.5	6.3	8.2	5.6	SE	3.72	15.0	0	19.7	12.6

Table 7. (Cont.)

August 1980						September 1980					
Sample Size (n)	Standing Crop	Sparganium (%)	Sagittaria (%)	Lobelia (%)	Others (%)	Sample Size (n)	Standing Crop	Sparganium (%)	Sagittaria (%)	Lobelia (%)	Others (%)
16	14.40 <u>±</u> 4.46	45.3	0	53.8	0.9	16	5.62 <u>±</u> 2.58	95.0	0	5.0	0
13	16.72 <u>±</u> 4.09	56.0	13.9	29.1	1.0	15	12.72 <u>±</u> 2.29	71.7	17.6	10.7	0
12	7.00 <u>±</u> 3.67	10.3	36.7	0	53.0						
15	1.44 <u>±</u> 1.11	87.5	0	12.5	0	16	1.08 <u>±</u> 1.03	96.6	0	0.9	2.5
12	3.28 <u>±</u> 1.79	0	62.0	38.0	0	10	1.59 <u>±</u> 1.13	99.4	0	0.6	0
						14	3.66 <u>±</u> 1.50	11.5	79.0	9.5	0
$\bar{x}$	8.57	39.8	22.5	26.7	11.0	$\bar{x}$	4.93	74.8	19.3	5.3	0.5
SE	3.01	15.9	11.9	9.4	10.5	SE	2.11	16.6	15.3	2.1	0.5

Table 8. Macrophyte standing crop summary for the Moisie River. Weight data are gAFDW $\cdot$ m⁻² ($\bar{x}$ $\pm$ SE)

Transect	June 1980					July-August 1980					September 1980				
	Sample Size (n)	Standing Crop	Potamogeton (%)	Moss (%)	Other (%)	Sample Size (n)	Standing Crop	Potamogeton (%)	Moss (%)	Other (%)	Sample Size (n)	Standing Crop	Potamogeton (%)	Moss (%)	Other (%)
1	15	0.22±0.13	100.0	0	0	15	7.11± 5.38	100.0	0	0	12	0.12±0.12	0	0	100.0
2	11	8.45±4.56	100.0	0	0	11	27.93± 9.26	99.8	0	0	12	2.92±2.92	94.4	3.6	0
3	20	0.11±0.07	0	72.7	27.3										
4						10	14.61± 5.48	89.0	0	11.0	12	4.58±2.80	100.0	0	0
5						20	46.27±15.79	95.7	4.3	0	10	12.47±4.49	84.2	15.8	0
6						12	53.44± 9.42	100.0	0	0	12	10.01±5.64	100.0	0	0
<hr/>															
	$\bar{x}$	2.93	66.7	24.2	9.1	$\bar{x}$	29.87	96.9	0.9	2.2	$\bar{x}$	6.02	76.1	3.9	20.0
	SE	2.76	33.3	24.2	9.1	SE	8.89	2.1	0.9	2.2	SE	2.28	19.3	3.1	20.0

Table 9a. Benthic Metabolism Summary for 1st Choice Creek.

Date	Sample Size (n)	Gross Production $\bar{x} \pm SE$	Net Community Production $\bar{x} \pm SE$	Diel Respiration $\bar{x} \pm SE$	Net Daily Metabolism $\bar{x} \pm SE$	P:R Ratio $\bar{x} \pm SE$
Coarse Detritus ¹						
21-24 Apr 80	5	0.186	0.036	0.013	0.058	0.83
25-28 Jun 79	6	0.117	0.013	0.010	0.153	0.76
31 Jul - 2 Aug 79	4	0.172	0.022	0.003	0.237	0.74
3-6 Sep 79	6	0.091	0.012	0.013	0.142	0.63
8-11 Oct 79	5	0.082	0.017	0.008	0.136	0.57
10-13 Nov 80	6	0.131	0.010	0.004	0.315	0.42
Fine Detritus ¹						
21-24 Apr 80	7	0.945	0.363	0.110	0.984	0.98
25-28 Jun 79	3	0.381	0.123	0.165	0.378	0.95
30 Jul - 2 Aug 79	3	0.441	0.234	0.162	0.325	1.30
3-6 Sep 79	3	0.328	0.277	0.127	0.372	0.86
8-11 Oct 79	3	0.265	0.103	0.037	0.459	0.59
10-13 Nov 80	5	1.742	0.672	0.189	3.347	0.55
Periphyton ²						
21-24 Apr 80	2	87.5	38.6	13.5	82.8	1.05
25-27 Jun 79	3	201.5	71.6	57.5	190.1	1.01
30 Jul - 2 Aug 79	5	228.7	122.1	108.2	167.2	1.31
3-6 Sep 79	6	153.8	52.8	13.6	182.1	0.90
8-11 Oct 79	7	144.2	51.9	23.4	198.6	0.75
10-13 Nov 80	4	340.8	100.4	27.5	626.4	0.56

1) mgO₂ · gAFDW⁻¹ · day⁻¹

2) mgO₂ · m⁻² · day⁻¹

Table 9b. Benthic Metabolism Summary for Beaver Creek.

Date	Sample Size (n)	Gross Production $\bar{x} \pm SE$	Net Community Production $\bar{x} \pm SE$	Diel Respiration $\bar{x} \pm SE$	Net Daily Metabolism $\bar{x} \pm SE$	P:R Ratio $\bar{x} \pm SE$
Coarse Detritus ²						
12-15 May 80	6	0.063	0.025	0.017	0.018	0.014
4-7 Jun 79	4	0.282	0.110	0.051	-0.060	0.029
9-12 Jul 79	6	0.286	0.067	0.017	-0.115	0.037
8-11 Aug 79	6	0.244	0.128	0.030	-0.101	0.029
17-20 Sep 79	6	0.114	0.032	0.011	-0.084	0.022
20-23 Oct 80	4	0.076	0.011	0.003	-0.075	0.015
Fine Detritus ²						
12-15 May 80	3	0.242	0.079	0.115	0.042	0.048
6-7 Jun 79	1	0.858	-	0.251	-0.041	0.048
9-12 Jul 79	3	1.819	0.361	0.131	-0.698	0.057
8-11 Aug 79	2	0.760	0.148	0.159	-0.207	0.007
17-20 Sep 79	3	0.328	0.042	0.013	-0.295	0.105
20-23 Oct 80	5	0.850	0.151	0.302	-0.415	0.153
Pool Periphyton ¹						
12-15 May 80	1	365.3	-	101.3	-57.1	0.86
4-5 Jun 79	1	500.9	-	292.2	192.2	1.62
9-10 Jul 79	1	501.9	-	244.6	118.3	1.31
20-23 Oct 80	3	70.3	9.3	21.7	-41.2	0.62
Riffle Periphyton ¹						
12-15 May 80	5	338.1	85.0	44.4	-130.2	0.74
4-7 Jun 79	6	1146.1	602.0	772.8	592.2	1.98
9-12 Jul 79	5	671.6	218.9	177.5	-66.7	0.89
8-11 Aug 79	7	438.2	165.0	206.0	63.7	1.23
17-20 Sep 79	6	161.1	23.6	59.9	-34.0	0.83
20-23 Oct 80	3	91.0	11.9	21.6	-68.9	0.58

1) mgO₂ · m⁻²·day⁻¹
 2) mgO₂ · gAFDW⁻¹·day⁻¹

Table 9c. Benthic Metabolism Summary for the Muskrat River.

Date	Sample Size (n)	Gross Production $\bar{x} \pm SE$	Net Community Production $\bar{x} \pm SE$	Diel Respiration $\bar{x} \pm SE$	Net Daily Metabolism $\bar{x} \pm SE$	P:R Ratio $\bar{x} \pm SE$
Coarse Detritus ¹						
5-8 May 80	4	0.044	0.005	0.062	- 0.011	0.72 0.02
28-31 May 79	4	0.109	0.016	0.142	- 0.033	0.76 0.03
2-5 Jul 79	4	0.191	0.046	0.257	- 0.066	0.75 0.02
13-16 Aug 79	4	0.153	0.026	0.200	- 0.047	0.77 0.03
10-15 Sep 79	3	0.089	0.033	0.156	- 0.067	0.57 0.07
13-16 Oct 80	4	0.112	0.084	0.242	- 0.130	0.50 0.03
Fine Detritus ¹						
5-8 May 80	4	6.725	2.903	6.780	- 0.055	1.10 0.11
29-31 May 79	2	0.631	0.399	0.812	0.181	0.75 0.11
3-5 Jul 79	2	3.468	4.112	3.679	- 0.192	1.08 0.23
14-16 Aug 79	2	0.524	0.120	0.634	- 0.110	0.85 0.12
10-15 Sep 79	2	0.508	0.483	0.746	- 0.238	0.73 0.09
13-16 Oct 80	3	0.300	0.012	0.482	- 0.183	0.65 0.09
Pool Periphyton ²						
5-8 May 80	2	228.6	75.8	193.1	35.4	1.15 0.16
28-31 May 79	3	405.0	57.8	324.9	80.0	1.48 0.74
2-5 Jul 79	3	326.4	78.0	130.9	195.4	2.48 0.15
6-16 Aug 79	4	380.0	191.9	267.8	112.2	1.41 0.29
10-15 Sep 79	3	234.3	140.9	131.9	102.4	2.06 1.02
13-16 Oct 80	3	217.9	31.1	232.5	-14.6	0.96 0.11
Riffle Periphyton ²						
5-8 May 80	2	177.0	-	208.0	-30.5	0.85 -
28-31 May 79	4	353.7	151.8	279.1	74.6	1.34 0.21
4-5 Jul 79	1	554.2	-	631.3	-77.1	0.88 -
10-15 Sep 79	5	350.6	52.7	272.6	78.1	1.30 0.17

Table 9d. Benthic Metabolism Summary for the Matamek River.

Date	Sample Size (n)	Gross Production $\bar{x} \pm SE$	Net Community Production $\bar{x} \pm SE$	Diel Respiration $\bar{x} \pm SE$	Net Daily Metabolism $\bar{x} \pm SE$	P:R Ratio $\bar{x} \pm SE$					
Coarse Detritus ²											
28-1 Apr 80	4	0.091	0.022	0.021	0.005	0.117	0.032	- 0.026	0.010	0.80	0.05
11-13 Jun 79	2	0.272	0.118	0.067	0.018	0.300	0.200	- 0.028	0.082	1.00	0.27
18-19 Jul 79	1	0.332	-	0.126	-	0.312	-	0.020	-	1.06	-
21-23 Aug 79	2	0.252	0.119	0.078	0.049	0.296	0.119	- 0.044	0.000	0.84	0.06
24-27 Sep 79	3	0.097	0.033	0.031	0.018	0.130	0.035	- 0.034	0.014	0.74	0.09
27-30 Oct 80	4	0.059	0.007	0.012	0.001	0.113	0.017	- 0.054	0.010	0.53	0.02
Fine Detritus ²											
28-1 Apr 80	3	0.263	0.098	0.088	0.029	0.290	0.130	- 0.027	0.043	0.96	0.15
13-14 Jun 79	1	2.420	-	1.067	-	1.993	-	0.427	-	1.21	-
16-20 Jul 79	3	0.739	0.775	0.396	0.443	0.517	0.501	0.222	0.274	1.32	0.21
20-22 Aug 79	2	0.375	0.085	0.063	0.022	0.529	0.108	- 0.154	0.023	0.71	0.01
24-28 Sep 79	3	0.252	0.206	0.079	0.103	0.347	0.203	- 0.095	0.004	0.66	0.16
27-30 Oct 80	5	0.590	0.166	0.239	0.087	0.843	0.205	- 0.253	0.064	0.67	0.05
Pool Periphyton ¹											
28-1 Apr 80	3	78.0	25.0	38.1	13.1	66.1	19.7	11.9	5.3	1.53	0.05
11-13 Jun 79	2	633.9	91.6	340.2	94.5	431.8	3.4	202.1	95.0	1.47	0.23
18-20 Jul 79	2	1009.1	206.7	620.5	102.6	588.6	158.6	420.5	48.0	1.73	0.11
22-23 Aug 79	2	737.1	222.6	439.6	176.9	507.2	78.0	230.0	144.6	1.44	0.22
27-30 Oct 80	3	90.4	30.9	43.3	17.0	112.6	66.4	-22.2	44.1	1.11	0.41

Table 9d (Cont.)

Riffle Periphyton¹

28-30 Apr 80	1	73.3	-	37.8	-	60.5	-	13.9	-	1.23
12-14 Jun 79	3	360.9	74.5	266.3	54.5	139.1	29.6	221.8	45.0	2.60
16-20 Jul 79	4	1467.0	433.8	895.1	274.9	874.7	222.7	592.3	211.9	1.66
20-21 Aug 79	2	260.4	18.2	114.0	10.6	246.9	12.8	13.5	5.4	1.06
26-27 Sep 79	1	455.4	-	247.3	-	418.0	-	37.4	-	1.09

Moss Rocks (*Fontinalis*)¹

28-1 Apr 80	3	349.0	82.5	182.0	66.1	276.3	61.4	72.6	65.3	1.34
11-14 Jun 79	4	1660.4	307.0	878.2	131.7	1149.7	343.9	510.7	136.3	1.52
16-20 Jul 79	3	2595.5	436.5	1432.3	545.9	1757.4	103.9	838.1	472.0	1.48
20-23 Aug 79	4	1283.7	554.1	718.8	335.3	957.5	383.2	326.2	193.6	1.33
24-27 Sep 79	5	799.2	310.7	428.7	154.6	739.6	318.9	59.6	47.1	1.10
27-30 Oct 80	3	335.6	91.1	215.4	76.4	288.5	39.3	49.4	59.4	1.13

Sparganium²

16-19 Jul 79	3	269.813	270.275	207.344	257.546	94.248	58.379	175.565	253.229	2.75
20-23 Aug 79	3	79.053	59.214	32.808	18.536	78.224	70.341	0.029	13.655	1.11
24-27 Sep 79	3	46.609	8.981	19.235	2.025	54.624	14.271	-	8.015	0.87

- 1) $\text{mgO}_2 \cdot \text{m}^{-2} \cdot \text{day}^{-1}$
 2) $\text{mgO}_2 \cdot \text{gAFDW}^{-1} \cdot \text{day}^{-1}$

Table 9e. Benthic Metabolism Summary for the Moisie River.

Date	Sample Size (n)	Gross Production $\bar{x} \pm SE$	Net Community Production $\bar{x} \pm SE$	Diel Respiration $\bar{x} \pm SE$	Net Daily Metabolism $\bar{x} \pm SE$	P:R Ratio $\bar{x} \pm SE$
Coarse Detritus ²						
19-22 May 80	7	0.03	0.009	0.001	0.014	0.006
18-21 Jun 79	6	0.210	0.066	0.021	0.051	0.054
25-26 Jul 79	1	0.116	-	0.025	-	-
28-30 Aug 79	2	0.267	1.135	0.040	1.167	0.382
1-3 Oct 79	3	0.072	0.026	0.011	0.041	0.017
3-6 Nov 80	4	0.018	0.004	0.002	0.009	0.006
Fine Detritus ²						
19-22 May 80	5	0.989	0.283	0.127	0.253	0.065
18-20 Jun 79	2	1.431	0.163	0.368	0.020	0.143
24-25 Jul 79	1	3.119	-	1.485	-	-
28-30 Aug 79	2	1.746	0.660	0.772	0.681	0.039
1-4 Oct 79	2	1.003	0.562	0.364	0.440	0.324
3-6 Nov 80	8	2.954	1.233	0.964	2.227	1.941
Pool Periphyton ¹						
19-22 May 80	3	81.6	15.9	31.1	8.2	3.9
20-21 Jun 79	2	559.6	128.1	319.2	154.9	207.8
23-25 Jul 79	3	1005.5	124.1	7.719	317.9	396.8
27-28 Aug 79	2	840.6	129.0	6704.3	144.6	426.3
3-6 Nov 80	3	68.8	20.9	21.3	35.6	-50.4
Riffle Periphyton ¹						
19-20 Jun 79	2	876.4	1040.6	445.2	679.7	360.9
23-25 Jul 79	2	1076.9	1052.0	728.8	417.4	634.6
3-4 Oct 79	3	496.2	139.5	391.9	47.4	92.3

Table 9e (Cont.)

Moss Rocks (Fontinalis)¹

23-26 Jul 79	2	1994.6	194.7	1385.5	280.4	936.6	135.3	1057.9	330.0	2.17	0.52
27-30 Aug 79	3	2347.1	413.9	1565.8	297.6	1364.9	209.3	982.2	222.0	1.72	0.09
1-3 Oct 79	4	1062.2	283.4	846.3	218.2	446.5	142.9	615.7	153.9	2.42	0.31

Total Periphyton¹

19-20 Jun 79	2	876.4	1040.6	445.2	559.2	608.7	779.7	267.7	360.9	1.29	0.27
23-26 Jul 79	4	1535.7	813.8	1057.1	709.2	737.6	342.1	798.2	510.4	1.97	0.50
27-30 Aug 79	3	2347.1	413.9	1565.8	297.5	1364.9	209.3	982.2	222.0	1.72	0.09
1-4 Oct 79	7	819.6	371.7	651.4	295.3	348.2	161.2	471.4	217.0	2.35	0.25

Sparganium²

23-27 Jul 79	3	113.323	21.207	59.017	10.716	83.455	16.061	29.869	5.436	1.36	0.03
27-30 Aug 79	3	61.930	34.747	38.103	25.350	41.672	17.316	20.257	18.386	1.44	0.24

Potamogeton²

23-26 Jul 79	3	416.589	368.519	251.511	167.603	253.333	310.672	163.255	65.261	2.33	1.01
27-30 Aug 79	3	42.478	12.667	27.747	8.653	25.765	7.651	16.713	5.811	1.65	0.17
2-4 Oct 79	3	39.328	21.437	22.740	24.104	23.973	9.904	15.355	16.300	1.68	0.55

1) mgO₂ · m⁻²·day⁻¹
2) mgO₂ · gAFDW⁻¹·day⁻¹

Table 10. Mean gross production per milligram of chlorophyll a in the periphyton and moss components, for each stream by sampling period. Units are $\text{mgO}_2 \cdot \text{mgchl}^{-1} \cdot \text{d}^{-1}$; Sampling periods are given in Table 4.

Sampling Period	First Choice Creek	Beaver Creek	Muskrat River	Matamek River	Moisie River
Periphyton					
1	437.7	1172.2	405.6	26.6	*
2	45.8	94.7	379.4	33.2	1305.5
3	114.4	558.8	209.7	106.7	595.0
4	153.8	398.4	158.3	113.4	205.0
5	80.1	89.5	188.7	15.4	70.9
6	59.8	175.8	181.6	24.4	36.2
Moss					
1	NS	NS	122.2	40.1	NS
2	NS	NS	50.2	45.5	NS
3	NS	NS	100.9	50.8	88.7
4	NS	NS	50.8	49.8	40.1
5	NS	NS	86.2	9.1	18.8
6	NS	NS	26.6	12.3	NS

*No chlorophyll detected;
NS = no sample or not present.

Table 11. Correlations between chlorophyll *a* concentrations and metabolic parameters for the periphyton, moss, and macrophyte community in all streams where they occur. Metabolic parameters units are $\text{mgO}_2 \cdot \text{m}^{-2} \cdot \text{d}^{-1}$, for periphyton and mosses $\text{mgO}_2 \cdot \text{gAFDW}^{-1} \cdot \text{d}^{-1}$ for macrophytes; chlorophyll *a* $\cdot \text{m}^{-2}$. * $p < 0.05$; ** $p < 0.01$.

Metabolic Parameter	Sample Size (n)	Correlation Coefficient (r)	Equation
Periphyton			
Gross Production (GP)	132	0.43**	$\text{Log}_{10}(\text{GP}) = 2.32 + 0.32 \text{ Log}_{10}(\text{CHL})$
Net Community Production (NCP)	132	0.50**	$\text{Log}_{10}(\text{NCP}) = 1.90 + 0.48 \text{ Log}_{10}(\text{CHL})$
Diel Respiration (R24)	132	0.22*	$\text{Log}_{10}(\text{R24}) = 2.31 + 0.16 \text{ Log}_{10}(\text{CHL})$
Net Daily Metabolism (NDM)	132	0.49**	$\text{Log}_{10}(\text{NDM}) = 0.81 + 0.99 \text{ Log}_{10}(\text{CHL})$
P:R Ratio	132	0.41**	$\text{Log}_{10}(\text{PR}) = -1.59 + 0.16 \text{ Log}_{10}(\text{CHL})$
Mosses			
Gross Production (GP)	60	0.65**	$\text{Log}_{10}(\text{GP}) = 2.41 + 0.38 \text{ Log}_{10}(\text{CHL})$
Net Community Production (NCP)	60	0.65**	$\text{Log}_{10}(\text{NCP}) = 2.11 + 0.43 \text{ Log}_{10}(\text{CHL})$
Diel Respiration (R24)	60	0.59**	$\text{Log}_{10}(\text{R24}) = 2.31 + 0.34 \text{ Log}_{10}(\text{CHL})$
Net Daily Metabolism (NDM)	60	0.33**	$\text{Log}_{10}(\text{NDM}) = 1.39 + 0.53 \text{ Log}_{10}(\text{L})$
P:R Ratio	60	0.18	
Macrophytes			
Gross Production (GP)	24	0.89**	$\text{Log}_{10}(\text{GP}) = 28.45 + 28.99 \text{ Log}_{10}(\text{CHL})$
Net Community Production (NCP)	24	0.75**	$\text{Log}_{10}(\text{NCP}) = 23.12 + 16.31 \text{ Log}_{10}(\text{CHL})$
Diel Respiration (R24)	24	0.95**	$\text{Log}_{10}(\text{R24}) = 11.22 + 19.41 \text{ Log}_{10}(\text{CHL})$
Net Daily Metabolism (NDM)	24	0.54**	$\text{Log}_{10}(\text{NDM}) = 16.62 + 9.50 \text{ Log}_{10}(\text{CHL})$
P:R Ratio	24	0.18	

Table 12. Relationship between metabolic parameters for periphyton, mosses, and macrophytes and photosynthetically available sunlight received by each experiment for all sites where the autotrophs were found. Sunlight units are $\mu\text{E} \times 10^5 \cdot \text{m}^{-2} \cdot \text{d}^{-1}$; metabolic units are $\text{mgO}_2 \cdot \text{m}^{-2} \cdot \text{d}^{-1}$ for mosses and periphyton and $\text{mgO}_2 \cdot \text{gAFDW}^{-1} \cdot \text{d}^{-1}$ for macrophytes, * $p < 0.05$; ** $p < 0.01$.

Metabolic Parameter	Sample Size (n)	Correlation Coefficient (r)	Equation
Periphyton			
Gross Production (GP)	132	0.27**	$\text{Log}_{10}(\text{GP}) = 2.14 + 0.17 \text{ Log}_{10}(\text{L})$
Net Community Production (NCP)	132	0.38**	$\text{Log}_{10}(\text{NCP}) = 1.51 + 0.32 \text{ Log}_{10}(\text{L})$
Diel Respiration (R ₂₄)	132	0.07	
Net Daily Metabolism (NDM)	132	0.53**	$\text{Log}_{10}(\text{NDM}) = -0.45 + 0.91 \text{ Log}_{10}(\text{L})$
P:R Ratio	132	0.51**	$\text{Log}_{10}(\text{PR}) = -0.26 + 0.17 \text{ Log}_{10}(\text{L})$
Mosses			
Gross Production (GP)	60	0.31**	$\text{Log}_{10}(\text{GP}) = 2.20 + 0.29 \text{ Log}_{10}(\text{L})$
Net Community Production (NCP)	60	0.35**	$\text{Log}_{10}(\text{NCP}) = 1.77 + 0.37 \text{ Log}_{10}(\text{L})$
Diel Respiration (R ₂₄)	60	0.24*	$\text{Log}_{10}(\text{R}_{24}) = 2.20 + 0.22 \text{ Log}_{10}(\text{L})$
Net Daily Metabolism (NDM)	60	0.33**	$\text{Log}_{10}(\text{NDM}) = 0.36 + 0.76 \text{ Log}_{10}(\text{L})$
P:R Ratio	60	0.17	
Macrophytes			
Gross Production (GP)	24	0.55**	$\text{Log}_{10}(\text{GP}) = 4.35 - 0.99 \text{ Log}_{10}(\text{L})$
Net Community Production (NCP)	24	0.51**	$\text{Log}_{10}(\text{NCP}) = 4.52 - 1.18 \text{ Log}_{10}(\text{L})$
Diel Respiration (R ₂₄)	24	0.38*	$\text{Log}_{10}(\text{R}_{24}) = 3.25 - 0.62 \text{ Log}_{10}(\text{L})$
Net Daily Metabolism (NDM)	24	0.34	
P:R Ratio	24	0.45*	$\text{Log}_{10}(\text{PR}) = 1.09 - 0.38 \text{ Log}_{10}(\text{L})$

Table 13. Correlations between mean period chlorophyll a concentrations and mean period metabolic parameters for periphyton, moss, and macrophytes. Metabolic units are $\text{mgO}_2 \cdot \text{m}^{-2} \cdot \text{d}^{-1}$ for periphyton and moss; $\text{mgO}_2 \cdot \text{gAFDW}^{-1} \cdot \text{d}^{-1}$ for macrophytes. Chlorophyll is $\text{mgChl } a \cdot \text{m}^{-2}$. * $p < 0.05$; ** $p < 0.01$.

Metabolic Parameter	Sample Size (n)	Correlation Coefficient (r)	Equation
Periphyton			
Gross Production (GP)	30	0.52**	$\text{Log}(\text{GP}) = 2.38 + 0.452 \text{ Log}(\text{C})$
Net Community Production (NCP)	30	0.56**	$\text{Log}(\text{NCP}) = 2.01 + 0.556 \text{ Log}(\text{C})$
Diel Respiration (R24)	30	0.43**	$\text{Log}(\text{R24}) = 2.40 + 0.292 \text{ Log}(\text{C})$
Net Daily Metabolism (NDM)	30	0.57**	$\text{Log}(\text{NDM}) = 0.86 + 1.181 \text{ Log}(\text{C})$
P:R Ratio	30	0.48**	$(\text{PR}) = 1.49 + 0.991 \text{ Log}(\text{C})$
Mosses			
Gross Production (GP)	15	0.82**	$\text{Log}_{10}(\text{GP}) = 2.14 + 0.639 \text{ Log}(\text{C})$
Net Community Production (NCP)	15	0.78**	$\text{Log}_{10}(\text{NCP}) = 1.89 + 0.621 \text{ Log}(\text{C})$
Diel Respiration (R24)	15	0.90**	$\text{Log}_{10}(\text{R24}) = 1.96 + 0.693 \text{ Log}(\text{L})$
Net Daily Metabolism (NDM)	15	0.92**	$\text{NDM} = 26.38 + 14.37 (\text{C})$
P:R Ratio	15	-0.41	
Macrophytes			
Gross Production (GP)	6	-0.08	
Net Community Production (NCP)	6	-0.10	
Diel Respiration (R24)	6	0.11	
Net Daily Metabolism (NDM)	6	-0.22	
P:R Ratio	6	-0.14	

Table 14. Relationship between mean period metabolism for periphyton, mosses, and macrophytes and mean period photosynthetically available radiation received by each experiment for all sites where the autotrophs occur. Sun light units are $\mu\text{E} \times 10^5 \cdot \text{m}^{-2} \cdot \text{d}^{-1}$; metabolic units are $\text{mgO}_2 \cdot \text{m}^{-2} \cdot \text{d}^{-1}$ for mosses and periphyton and $\text{mgO}_2 \cdot \text{gAFDW}^{-1} \cdot \text{d}^{-1}$ for macrophytes. * $p < 0.05$; ** $p < 0.01$.

Metabolic Parameter	Sample Size (n)	Correlation Coefficient (r)	Equation
Periphyton			
Gross Production (GP)	30	0.37*	$\text{Log}_{10}(\text{GP}) = 2.01 + 0.306 \text{ Log}_{10}(\text{L})$
Net Community Production (NCP)	30	0.47**	$\text{Log}_{10}(\text{NCP}) = 1.44 + 0.437 \text{ Log}_{10}(\text{L})$
Diel Respiration (R24)	30	0.22	
Net Daily Metabolism (NDM)	30	0.55**	$\text{Log}_{10}(\text{NDM}) = -0.66 + 1.094 \text{ Log}_{10}(\text{L})$
P:R Ratio	30	0.53**	$\text{Log}_{10}(\text{PR}) = -0.24 + 0.241 \text{ Log}_{10}(\text{L})$
Mosses			
Gross Production (GP)	15	-0.35	
Net Community Production (NCP)	15	-0.35	
Diel Respiration (R24)	15	-0.35	
Net Daily Metabolism (NDM)	15	-0.12	
P:R Ratio	15	0.16	
Macrophytes			
Gross Production (GP)	6	0.83*	$\text{Log}_{10}(\text{GP}) = 1.36 + 0.708 \text{ Log}_{10}(\text{L})$
Net Community Production (NCP)	6	0.76*	$\text{Log}_{10}(\text{NCP}) = 1.20 + 0.796 \text{ Log}_{10}(\text{L})$
Diel Respiration (R24)	6	0.85*	$\text{Log}_{10}(\text{R24}) = 2.41 + 1.512 \text{ (L)}$
Net Daily Metabolism (NDM)	6	0.59	
P:R Ratio	6	0.36	

SESTON DYNAMICS

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In 1979 and 1980 drifting organic detritus was characterized in five streams ranging from 1st to 9th order (see metabolic section for locations). We examined concentrations, percentage organic matter, carbon to nitrogen ratios, chlorophyll a, and respiration rate by size class. Concentrations, processing (oxidation) rates, and potential food quality of coarse (CPOM: >1 mm) and fine particulate organic matter (FPOM: 0.5 μ m to 1 mm) drifting at each site were measured over a 24-hour period at 2-week intervals from June to late October. Oxidation rates of particles >0.5 μ m were estimated by measuring specific respiration rates associated with discrete sizes (>1 mm; 53 μ m to 1 mm; 0.5 μ m to 53 μ m). Potential food quality was ascertained by measuring carbon:nitrogen ratios, ash content, chlorophyll a, invertebrate biomass, and respiration rates associated with particles of various known sizes. The sampling period continued from just before the ice breakup - spring freshet period (April-May) when about 60-80% of annual discharge occurs, to the period just preceeding ice formation (November) using the same techniques and criteria as in 1979 (see 1979 Matamek Annual Report for methods). Concentration data are being related to physical characteristics of stream order such as watershed area, discharge regime, retention structures, and stream power, as well as the effects of storms. Food quality data will eventually be compared to the distribution and abundance of invertebrate functional feeding groups, providing the basis for future studies of invertebrate nutrition.

The data are currently being prepared for publication; a manuscript will be ready by the end of the year. Pertinent results from the study are presented in last years annual report and in the following figures.

Figure Captions

- Fig. 1. The annual hydrograph is shown for each sampling location. Note change in scale for each site.
- Fig. 2. The annual pattern for the suspended inorganic sediment load for each site is shown. Note that highest concentrations are during the spring freshet, that there is considerable day-to-day variability at that time, and that summer and autumn loads are negligible.
- Fig. 3. The annual cycle of suspended particulate organic matter is shown for each site. Note that the increase during the spring freshet is small; that the scale is the same as in the inorganic sediment figure; and that all sites are similar have a similar pattern.
- Fig. 4. Concentrations of dissolved organic carbon are relatively low and uniform during the spring freshet but increase during the productive summer and autumn months. Note that all sites show a similar pattern.
- Fig. 5. The annual cycle of the DOC:POC ratio is shown to vary widely on a daily basis for most streams examined. Ratios tend to be greatest during summer and autumn and lowest during the spring freshet. The coefficient of variation for a sample on one day is <5 .
- Fig. 6. The percentage of particulate organic matter in the seston varies considerably from day-to-day for all sites, thus influencing the apparent food quality.
- Fig. 7. The ratio of particulate inorganic matter to organic matter in the seston is greatest and most variable during the spring freshet, and lowest and most uniform during summer and autumn for all sites.
- Fig. 8. The effects of storms on seston transport are shown for DOC ($\bullet$), POM (Δ), and inorganic material (o). The hydrograph for each stream is not yet available.
- Fig. 9. The annual cycle of respiration rates ($\bar{x} \pm SE$) by drifting CPOM (>1 mm), FPOM ($53 \mu\text{m} - 1$ mm), and VPOM ($0.5 \mu\text{m} - 53 \mu\text{m}$) are shown by site. Note that rates increase as particle size decreases. Data for 1979 are depicted by (o); for 1980 (Δ).
- Fig. 10. The annual pattern of drifting chlorophyll concentrations by size class are shown for each site. Data for 1979 are depicted by (o); for 1980 (Δ).

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

STORM SERIES 4-8 AUGUST 1980

Fig. 8

Fig. 9

WOOD DECOMPOSITION DYNAMICS AS A FUNCTION OF QUALITY OF MATERIAL
AND STREAM ORDER IN QUEBEC

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INTRODUCTION

Large woody debris is a major and persistent component of the detrital standing stock in many streams (Naiman and Sedell 1979, Anderson and Sedell 1979, Bilby 1979). Recent research has begun to elucidate the functions of the large woody mass in stream ecosystems. From studies conducted in temperate evergreen forests of the Pacific Northwest and in hardwood forests of northern New England, the following functions of large woody material in streams have been identified: (1) it promotes physical stability in streams (Swanson et al. 1976, Keller and Swanson 1979); (2) it creates a variety of habitats for aquatic organisms (Sedell et al. 1975, Anderson et al. 1978, Anderson and Sedell 1979); (3) it increases the retention time of organic matter within streams thus allowing more complete utilization of this material (Bilby 1979, Likens and Bilby 1980, Bilby and Likens MS); (4) it may serve as a constant source of fine particulate organic matter utilized by consumers in downstream communities (Naiman and Sedell 1979, Wallace et al 1977); and (5) it serves as an important site for nitrogen fixation (Buckley and Triska 1978).

To date, the ability of large woody debris and fine particulate organic matter of wood origin to influence the chemistry of stream water has not been extensively studied. These materials may influence solution

chemistry in at least two ways: (1) they may act alternatively as sinks and sources of inorganic ions as the woody material moves through the immobilization and mineralization phases of decomposition; and (2) they may serve as an important source of dissolved organic compounds that are solved in supporting the heterotrophic component of stream communities.

The study described in this report is designed to explore various aspects of the decomposition process for woody materials in stream ecosystems in eastern Quebec. More specifically, the study has three objectives:

- (1) To determine the rates of decomposition in various types of woody material along a stream continuum in the Matamek River watershed;
- (2) To determine the influence of initial litter quality (i.e., lignin:nitrogen ratio) on decomposition rates along the continuum;
- (3) To determine nitrogen, lignin, and cellulose dynamics during decomposition of each type of woody material along the continuum.

METHODS

One live stem from each of five important tree species in the Matamek River watershed (red alder, paper birch, trembling aspen, black spruce, and balsam fir) was felled, debarked, sawed into short lengths, and chipped using a power jointer. Chips from each species were air dried and sieved. Chips that passed through a 1.52 cm sieve, but would not pass a 0.75 cm sieve, were used in this study.

Five samples were randomly taken from each species for determination of initial moisture content, ash content, % total Kjeldahl nitrogen, and % lignin. Approximately 20 grams of material from a single species were placed in each of 175 sewn mesh bags. The bags were made of fiberglass screening with a mesh size of 2.0 mm, and were approximately 25 x 25 cm square. Bags were weighed before and after filling (nearest 0.1 g). After weighing, bags were sewn closed, and five bags from each of the five species were strung together on a monofilament line.

Five lines of 25 bags were transported to each of the four sites for field placement (see Table 1). Bags were anchored on the sediment at each aquatic site using bricks or concrete blocks. One line of bags was collected from each site after three, nine and sixteen months. Upon collection, sediment material was washed from bags as completely as possible, but in some cases it was necessary to repeat this task after the bags had been returned to the laboratory.

Laboratory analysis consisted of air-drying the collected bags, and then drying the bags to constant weight in an oven at 50°C. Oven-dry bags were weighed, and subsampled for tissue analysis. Subsamples were ground to pass a 20-mesh screen in a Wiley mill, stored in sample vials, and later used for determinations of moisture loss at 105°C, % ash, nitrogen, % lignin and % cellulose.

The chemistry of the streamwater was monitored throughout the study. Measurements were made of concentrations of ammonium, nitrate plus nitrite, and phosphate.

RESULTS AND DISCUSSION

The original nitrogen concentrations of the various types of woody material (mean of both chip sizes) appear in Table 2. Alder, the only nitrogen fixing species used in the study has the highest nitrogen concentration (0.31%) and black spruce, a species commonly found in nitrogen poor sites, has the lowest nitrogen concentration (0.038%). The lignin content deciduous tree species is on average a factor of two less than the lignin content of the wood of coniferous species. Ash content of all materials was less than 1.0%.

After sixteen months of field "incubation", weight loss for all materials was generally fastest in the first-order stream. Regardless of stream size, wood chips of deciduous tree species decomposed more rapidly than wood chips of coniferous tree species.

An exponential decay model was used to estimate the rate of annual weight loss for each litter type at each site.

$$X/X_0 = e^{-kt}$$

where X = weight remaining at time t , X_0 = original weight, e is the base of natural logarithms and k is the decomposition constant (Jenny et al. 1949, Olson 1963). The annual decomposition constant (k) for each of the five wood chip types decomposition in each of the four streams appears in Table 3.

Alder wood chips incubated in the first order stream decomposed most rapidly with a k of -1.37 . Alder chips lost 81% of their original weight during the sixteen-month period in the first order stream. If the exponential decay model appropriately described the decay process, we would predict 95% of the material to disappear in about 2 years for alder woodchips in the first order stream.

Litter quality, as defined by lignin:nitrogen ratio, has proved to be a good prediction of decomposition rate of forest leaf litter material decomposing on the forest floor (Melillo et al. 1981) and aquatic macrophytes tissue decomposing in laboratory cultures (Jensen and Melillo 1980). In these studies the lower the lignin:nitrogen ratio, the higher the decomposition rate (k value) of a material. This relationship was linear in the forest leaf litter decomposition study Melillo et al. 1981.

The lignin:nitrogen ratios (Table 2) of the materials range over an order of magnitude; from 42 for alder to 647 for spruce. In Figure 1 we have examined the relationship between the lignin:nitrogen ratios of the original materials and k values for each of the five wood chip types decomposing in each of the four streams. Litter quality, as defined by lignin:nitrogen ratio, is a better predictor of k in the first order streams than in higher order streams. In fact, litter quality appears to exert very little control over decomposition rates in higher order streams.

The reason why litter quality appears to be an important controlling factor for decomposition in first order streams but not in the higher order streams has not been established. It is interesting to note that

the $\text{PO}_4\text{-P}$ concentration is an order of magnitude higher in the first order stream than in the others. Phosphorus is considered to be a limiting factor for net primary production in fresh water systems. Perhaps it is also the factor limiting decomposition rates in the stream systems of eastern Quebec.

At some time during the sixteen-month incubation period in the stream ecosystems, all types of woody material apparently functioned as nitrogen sinks, regardless of stream order. Absolute increases in nitrogen content ranged from a high of 1151% for spruce wood litter incubation in the second order stream at 16 months to a low of 134% for alder wood litter incubation in the second order stream at 3 months. These absolute increases may be attributed to one or more of the following mechanisms:

(1) immobilization of inorganic and/or dissolved organic nitrogen in ambient waters by microorganisms colonizing the woody tissue; (2) nitrogen fixation of gaseous nitrogen by microorganisms colonizing the woody tissues; and (3) trapping of nitrogen-rich fine particulate matter in the litter bags. Immobilization of nitrogen by microbes is commonly found in laboratory and terrestrial field studies of nitrogen dynamics of wood fragments decomposing in terrestrial sites (e.g. Viljoen and Fred 1923; Roberts and Stephenson 1948; McKenzie 1958; Allison 1963). Nitrogen fixation is reported to be an important source of nitrogen input to decaying woody material in streams (Buckley and Triska 1978).

Aber and Melillo (1980) have demonstrated an inverse linear relationship between % organic matter remaining and % N in the remaining residue during decomposition of leaf and wood litter in terrestrial

ecosystems, and leaf litter in stream ecosystems. For each wood type, all data, regardless of site, were analyzed on single graph and the results were found to conform to the previously established pattern. This would suggest that regardless of location, a particular litter type will have characteristic dynamics in both weight loss and nitrogen. In Figure 2 we plot the decomposition data for paper birch in this way. Note that the litter from First Choice Creek in farthest down the line at the end of the sixteen months, whereas the litter from the Moisie has made it only about a third of the way down the line after sixteen months.

Table 1. Characteristics of the sites used for the wood decomposition experiment.

Site	Stream Order	Streamwater Chemistry ($\mu\text{g} \cdot \text{L}^{-1}$)		
		NH_4	$\text{NO}_3 + \text{N}_2\text{O}$	PO_4
First Choice Creek	1st	5.3	118	2.9
Beaver Creek	2nd	10.0	54	0.4
Matamek River	6th	9.2	117	0.5
Moisie River	9th	6.4	93	0.5

Table 2. Original Nitrogen and Lignin Concentrations of Woody Materials (%) and Lignin:Nitrogen Ratios.

Species	Nitrogen	Lignin	Lignin:Nitrogen
Alder	0.315	13.1	42
Birch	0.144	8.2	57
Aspen	0.090	12.0	150
Fir	0.058	25.9	471
Spruce	0.041	24.6	647

Table 3. Annual decomposition rates for each wood species by site.

Species	First Choice Creek	Beaver Creek	Matamek	Moisie
Alder	-1.37	-0.39	-0.24	-0.11
Birch	-1.16	-0.45	-0.37	-0.29
Aspen	-0.64	-0.44	-0.24	-0.15
Spruce	-0.29	-0.17	-0.11	-0.05
Fir	-0.25	-0.10	-0.15	-0.06

Fig. 1

Fig. 2

RAINWATER CHEMISTRY

Silvaine Zimmerman and R.J. Naiman
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Acid precipitation in eastern Canada and the United States is a serious ecological problem. It is thought to be responsible for the disappearance of fishes in many lakes either through the direct influence of pH on tissues or through the release of toxic heavy metals such as aluminum. Water courses draining the North Shore of the Gulf of St. Lawrence are naturally acidic due to an inherently high content of humic acids caused by close contact with the granitic rocks of the Canadian Shield. In June 1979 we began a low effort monitoring program to document acidity of precipitation and the buffering capacities of river water in this region and this was carried through the 1980 season.

Every two weeks from April to November water samples were collected in stoppered vials from First Choice Creek, Beaver Creek, Muskrat River, Matamek River, and Moisie River. In addition, precipitation was collected from a rain gauge in an open area next to the laboratory. All samples were kept at the original stream temperature, hydrogen ion was measured with a Coleman Model 80 pH meter, and alkalinity (meq L^{-1}) by Gran titration. The results are presented in the following figures.

In addition, precipitation throughfall was collected over the season under alder, paper birch, trembling aspen, black spruce, and balsam fir. Samples were analysed for DOC, NO_2 , NO_3 , NH_4 , Total N, PO_4 , and Total P. Results are not ready for presentation at this time.

Figure Captions

- Fig. 1. The pattern of acidity in precipitation and stream water is presented for each site. Note that pH was relatively constant throughout the year.
- Fig. 2. The pattern of alkalinity in precipitation and stream water is presented for each site. Note that buffering capacity decreased during ice breakup to low but constant levels for the remainder of the sampling period.

Fig. 1

Fig. 2

ALLOCHTHONOUS INPUTS

R.J. Naiman and D. LaChance

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Organic inputs from the forest to the aquatic environment are a significant contribution to the trophic base which vary by season and by stream size in quantity and chemical composition. In April 1980 we began to examine the magnitude and nature of these inputs in First Choice Creek, Beaver Creek, Muskrat River, and the Matamek River. A large array of litter baskets and lateral traps were placed either in the stream or along the shore. In the rivers, baskets were placed in a matrix array various distances from shore in order to examine the distribution of inputs to a large body of water as a function of distance from shore.

From April to mid August baskets and traps were sampled monthly; from the late August to November leaf fall period they were emptied weekly. Materials were separated into leaf and needle species, woody debris, miscellaneous categories, and dried (60°C) and ashed (525°C for 4 h). This program will continue at least through October 1981. At that time allochthonous inputs will be mathematically modelled for amounts and character by stream order and distance from shore.

PERIPHYTON PRODUCTION DYNAMICS

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The extensive studies on detrital metabolism in headwater streams has shown that allochthonous sources of energy are very important to the river ecosystem (Hynes, 1975). When total metabolism is considered it is apparent that the importance of allochthonous and autochthonous inputs varies with the physical parameters of the stream (Naiman and Sedell, 1979, 1980, and Naiman, 1980). Vannote et al (1980) have summarized these current ideas into the River Continuum Concept which sets up guidelines for the predictive estimates of community metabolism in temperate watersheds.

A re-examination of periphyton metabolism is now needed to determine the role of this plant group in the river community. Using the diel oxygen method developed by Bott et al (1978), Naiman (1980) found that riffle periphyton has a small energy contribution in headwater streams which increases in importance as the stream order increases. This study is part of Naiman's Matamek and Moisie Watershed investigation. The focus of this work is towards the species-specific interactions which take place within the riffle periphyton community. The hypotheses to be tested are: 1) that the periphyton under optimal growing conditions contributes a measureable amount of biomass to the stream ecosystem, 2) certain periphyton species are much more productive and are therefore very important as energy contributors to the system, and 3) storm events create stress conditions which may limit potential periphyton growth.

METHODS

The flow chart (Figure 1) outlines the design of this study. Base-line data collection represents the characterization of 5 selected riffle sites from 5 different streams. Weekly collections at these sites were made for biochemical parameters and periphyton biomass. The biochemical data for acid precipitation were collected according to the guidelines outlined by the Ontario Ministry of Environment (1979). Periphyton biomass samples were collected using a modified Douglas sampler (Douglas, 1958); three surface scrubs from a single rock were combined together to make a single sample. Usually one sample was collected from each site however, sporadically 5 samples were collected for analysis of periphyton diversity. Using the procedures of Lorenzen (1967), chlorophyll a was measured once a week at each of the sites. The physical parameters have been studied by Naiman. Track autoradiography will be used to measure the species-specific production of riffle periphyton from June and August (1980) samples; ^{14}C samples were also used to determine ^{14}C uptake per cm^2/hr . (Smythe, 1974).

Natural periphyton colonization experiments were set up in May and June at the 5 sites: biomass samples were collected at weekly intervals. The stream tank was also used for a controlled periphyton colonization experiment. From the tank 5 samples were collected weekly for biomass and chlorophyll a. Small granitic stones approximately 1 cm x 1 cm x 5 mm were initially placed in the tank and selectively removed by row for track autoradiography and SEM examination during colonization.

Two storm events were studied during late August and early September. They were chosen because they caused a noticeable increase in stream discharge. Phytoplankton samples from First Choice Cr., Beaver Cr., and Matamek R. were collected every 3 hours for a 48 hour period during and after the rain event. Water discharge measurements for the storm are being compiled by Robert Naiman.

RESULTS AND DISCUSSION

The preliminary results are presented in this section. General observations are put forward with some discussion about future interpretations of the complete data set.

1) Acid Precipitation

The data from Table 1 represents four of the six minimum parameters necessary in determining the susceptibility of these rivers to acid rain. The Ontario Ministry of Environment (1979) has published a set of minimum values for acid tolerant systems; these values can be used in the initial assessment of raw data to characterize acid intolerant watersheds.

All the streams except First Choice Cr. show conductivities below the accepted value of 35% mho/cm at 25 degrees centigrade. Only the Matamek and Muskrat Rivers showed pH values consistently below 6.00. All the rivers showed alkalinity (Meq/L) values half the accepted minimum of 0.3 and all the rivers had dissolved inorganic carbon levels much lower than the accepted 15 mg/L.

Conductivity, alkalinity, and dissolved inorganic carbon levels all indicate that these Canadian Shield rivers have very low mineral and HCO_3 levels. A comparison with the Experimental Lakes Area of Northern Ontario shows that these levels are among the lowest ever recorded for North America (Armstrong and Schindler, 1971, and Ross, 1980). This low buffering capacity is probably due to high annual precipitation levels, high humic acid content of surrounding soils and the watershed's northern location (Janus and Duthie, 1979). The future analysis of Al and Mn should show high concentrations of these toxic elements, which are true indicators of acid rain intolerance.

Table 2 represents the pH of seven precipitation events from June to September (1980). The average pH of these events falls below the 4.8 average recorded at the airport (Ross, per comm.). The very low pH levels in the precipitation creates stress on the buffering strength of the rivers under study. The relatively high summer pH levels of the rivers suggests at the present time the rivers are buffering the acid precipitation. Further analysis of the complete data set by the Ministry of Environment will hopefully yield new insights into the status of the Matamek and Moisie watersheds.

2) Riffle Periphyton Production

Preliminary results presented in Figure 2 and Figure 3 represent estimates of standing crop over a seven week period from June to the middle of July (1980). The chlorophyll a estimates (Figure 2) of the Matamek and Muskrat Rivers are much higher than the estimates of Beaver

Cr. and First Choice Cr. (Figure 2b). The chlorophyll a data of the Matamek and Muskrat Rivers are also higher than those of the Moisie R. (Figure 2c).

Biomass ($\% \text{ g/cm}^2$) estimates for the 5 rivers are presented in Figure 3. Again the Matamek and Muskrat Rivers show higher standing crop than the low order First Choice Cr., Beaver Cr. and high order Moisie River. The initially high biomass in First Choice Cr. (Figure 3b) is indicative of the spring bloom which quickly disappeared when the summer leaves emerged around June 16, 1980. The drop in Beaver Cr. biomass at the end of the month was also caused by the emergence of summer leaves. The drop in Muskrat R. biomass is due to a counting error of Bactrachospermum sp. which has many different forms. A recount of these samples now shows much higher biomass estimates for this river.

The Moisie R. had a comparatively late ice breakup and high spring discharge. This delayed the establishment of visible summer periphyton communities. The delay could be of some importance in reducing annual or summer estimates of periphyton energy production from this river.

Uptake experiments using ^{14}C were conducted in June and August. At this time the data are not presentable, however a first estimate of ^{12}C fixation in the Muskrat, Matamek and Moisie Rivers (Table 3) would suggest that the Matamek and Muskrat Rivers are more productive. When compared to the productivity of the Speed R. in Southern Ontario we find productivity levels much lower. This initially suggests that periphyton in these streams are not highly productive.

This limited available data base for summer riffle periphyton standing crop and production indicates that the mid-order streams (Matamek R. and Muskrat R.) are more productive than the low order streams (First Choice Cr. and Beaver Cr.) and the high order stream (Moisie R.). The Moisie R. data presented above is not in agreement with the production estimates (diel oxygen experiments) made by Naiman. These differences are probably due to sampling site differences. Further work this summer should clarify my production estimates on the Moisie R.

3) Periphyton Colonization Experiment

Biomass estimates are presented in Figure 4. Over the 25 day experiment exponential growth was quite evident. Tabellaria flocculosa and T. fenestrata by the end of the colonization period comprised 93% of the total biomass. In the Matamek R. it appears that Tabellaria consistently dominates the riffle community through the summer. Termination of the experiment was premature and completion of this part of the work will be attempted in the summer of 1981. Track autoradiography and SEM analysis of colonization samples should give a complete story for the periphyton development of riffles in the Matamek R.

4) Storm Event

Figure 5 presents the phytoplankton biomass of First Choice Cr. and Beaver Cr. during the August 7th 1980 storm event. As expected the larger Beaver Cr. showed a maximum biomass 4.6 times that of First Choice Cr. at peak discharge. First Choice Cr. showed a instantaneous biomass increase at the initiation of the event which returned to normal levels after 6

hours. Analysis of the species composition indicates that Eunotia pectinalis and Gomphonema angustatum were the main contributors to the phytoplankton biomass. Biomass in the Beaver Cr. peaked approximately 4 hours after the initiation of the storm event. Analysis of the species composition showed that Mougeotia sp., Frustulia spp., Pinnularia spp., and Eunotia spp. were the main contributors to the elevated biomass. For both First Choice Cr. and Beaver Cr. the main contributors to the increased biomass are periphyton species. This supports the idea that a storm event can have a strong effect on the stability of the periphyton community. In future analysis we would like to evaluate the actual stress in terms of percent biomass removed.

Figure 6 represents the phytoplankton biomass counts for the Matamek R. during the Sept. 3, 1980 storm event and during a normal 24 hour period (Aug. 26, 1980). The biomass peaked approximately 8 hours after the initiation of the rain event. Like First Choice Cr. and Beaver Cr. the increased biomass occurred over a very short period of time. The diel data during a normal 24 hour period showed stable phytoplankton base-line levels.

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Figure Captions

- Fig. 1. Research flow chart for the data collected during the spring and summer of 1980.
- Fig. 2. Chlorophyll a measurements over an eight week period from June to July 1980. Samples were taken from all 5 sites.
- Fig. 3. Periphyton biomass estimates over an eight week period from June to July 1980. Samples were taken from all 5 sites.
- Fig. 4. Periphyton colonization study at the stream tank on the Matamek River. The experiment was conducted in August and had a duration of 25 days. Standard errors of the means are so small that error bars could not be shown on the graph.
- Fig. 5. Storm event: phytoplankton biomass changes during and after a moderate rain storm (August 7, 1980).
- Fig. 6. Storm event: phytoplankton biomass changes during and after a heavy rain and during a normal 24 hour period. The storm occurred Sept. 3, 1980 and the diel study was done on August 26, 1980.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

TABLE 1. Water acidity data for the 5 sampling sites through the summer.

	DATE	CONDUCTIVITY (u mho/cm)	pH	ALKALINITY (Meq/L)	DISSOLVED INORGANIC CARBON (mg/L)
FIRST CHOICE CR.	5 May 80	110.1	6.54	0.1590	1.8
	19 May 80	157.0	6.28	0.1450	1.6
	2 June 80	126.0	6.45	0.1186	1.6
	16 June 80	78.0	6.69	-----	---
	8 July 80	69.0	6.52	0.1409	1.8
	22 July 80	77.0	6.20	0.1314	---
	4 Aug. 80	75.0	6.50	0.1560	2.1
	25 Aug. 80	68.0	6.50	0.1645	2.1
	1 Sept. 80	68.0	6.60	0.1765	---
BEAVER CR.	5 May 80	21.3	5.95	0.0532	1.0
	19 May 80	20.0	5.81	0.0575	0.8
	2 June 80	24.9	6.35	0.1035	0.8
	16 June 80	24.9	6.65	-----	---
	8 July 80	27.0	6.61	0.1645	1.2
	22 July 80	26.0	6.20	0.1407	0.4
	4 Aug. 80	34.0	6.71	0.2314	3.1
	25 Aug. 80	36.9	6.89	0.2541	2.5
	1 Sept. 80	42.8	6.90	0.3160	---
MUSKRAT R.	5 May 80	20.0	4.80	-0.0058	0.8
	19 May 80	16.1	4.90	-0.0054	0.6
	2 June 80	17.2	5.20	0.0130	0.6
	16 June 80	20.5	5.50	-----	---
	8 July 80	20.1	5.61	0.0175	0.4
	22 July 80	19.0	5.70	0.0328	0.4
	4 Aug. 80	19.8	6.29	0.7644	1.0
	25 Aug. 80	21.1	6.20	0.0607	0.8
	1 Sept. 80	26.0	6.42	0.0870	---
MATAMEK R.	5 May 80	18.2	5.20	0.0158	0.6
	19 May 80	15.3	5.10	0.0059	0.4
	2 June 80	16.6	5.10	0.0185	0.4
	16 June 80	18.0	5.21	-----	---
	8 July 80	14.0	5.43	0.0340	0.2
	22 July 80	19.0	5.40	0.0230	0.6
	4 Aug. 80	12.5	5.60	0.0183	---
	25 Aug. 80	13.9	5.52	0.0092	---
	1 Sept. 80	15.0	5.50	0.0095	---
MOISIE R.	5 May 80	19.0	6.23	0.0992	1.2
	19 May 80	17.4	6.20	0.0960	---
	2 June 80	21.1	6.28	0.1112	1.2
	16 June 80	22.2	6.67	-----	---
	8 July 80	25.5	6.80	0.1512	1.6
	22 July 80	23.7	6.61	0.1518	1.6
	4 Aug. 80	22.0	6.80	0.1965	1.9
	25 Aug. 80	26.0	6.60	0.1746	1.8
	1 Sept. 80	31.2	6.72	0.1740	---

TABLE 2. Acidity measures of rain water throughout the summer.

DATE	pH	ALKALINITY (Meq/L)
6 June 80	4.20	-0.0459
16 June 80	4.80	-0.0287
24 June 80	4.38	-----
2 Aug. 80	4.00	-0.1305
9 Aug. 80	4.20	-0.0625
15 Aug. 80	4.69	-0.0030
3 Sept. 80	5.18	-0.0004

TABLE 3. ^{12}C fixation (productivity) experiments conducted in Aug. 1980.

RIVER	^{12}C FIXED (mg/hr.)
Matamek R.	4.96
Muskrat R.	3.29
Moisie R.	0.91
Speed R. (southern Ont.)	46.81

SOME OBSERVATIONS ON THE ADULT SALMON (*Salmo salar*)
RUN OF THE MATAMEK RIVER, QUEBEC

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ATLANTIC SALMON STUDIES
(*Salmo salar*)

Whoriskey, F.G. Jr., and R.J. Natman. Some observations on the
adult salmon (*Salmo salar*) run of the Matamek River, Quebec, Can. J.
Fish. Aquat. Sci. Manuscript.

Despite the absence of freshwater exploitation the adult salmon run in
the Matamek River, Quebec, declined during 1975-1980 to only 23% of the
level estimated prior to 1967. Returns in 1979 and 1980 of adults tagged
as smolts were 1.02 and 0.92, respectively. Numbers of migrating smolts
and their corresponding adult returns are not significantly correlated,
although we observed a trend towards more precise (1 sea year fish) return-
ing with larger numbers of migrating smolts. An increase in the fraction
of adults since 1967 which smolted at age 2+ was noted.

Key Words: Atlantic salmon, *Salmo salar* population dynamics.

Matamek River

SOME OBSERVATIONS ON THE ADULT SALMON (Salmo salar)
RUN OF THE MATAMEK RIVER, QUEBEC

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Whoriskey, F.G. Jr., and R.J. Naiman. 1981. Some observations on the adult salmon (Salmo salar) run of the Matamek River, Quebec. Can. J. Fish. Aquat. Sci. Manuscript.

Despite the absence of freshwater exploitation the adult salmon run in the Matamek River, Quebec, declined during 1975-1980 to only 23% of the level estimated prior to 1967. Returns in 1979 and 1980 of adults tagged as smolts were 1.0% and 0.9%, respectively. Numbers of emigrating smolts and their corresponding adult returns are not significantly correlated, although we observed a trend towards more grilse (1 sea year fish) returning with larger numbers of migrating smolts. An increase in the fraction of adults since 1967 which smolted at age 2+ was noted.

Key Words: Atlantic salmon, Salmo salar population dynamics,
Matamek River

Table 1. River temperature and discharge characteristics during the peak of the adult run.

Year	Date of Migration Peak	Temperature		Discharge	
		Range (°C)	Rate of Change (°C/day)	Range (m ³ /s ⁻¹)	Rate of Change (m ³ /s ⁻¹ d ⁻¹)
1979	13-17 July	21.7-20.5	-0.3	21.0-16.3	-4.7
1980	5-12 July	19.7-14.5	-0.6	25.3-10.0	+2.2

Table 2. Population estimates of salmon and grilse for each year the fishladder has been in operation

YEAR	SALMON		METHOD	GRILSE		SOURCE
	NO. OF FISH	95% CONF. LIMITS		NO. OF FISH	95% CONF. LIMITS	
1975	30	-	1	130	70 - 180	Gibson 1978a
1976	30	20 - 50	2	90	50 - 190	Gibson 1977
1977	No Data	No Data		No Data		-
1978	12	4 - 23	1	68	42 - 116	Whoriskey 1979
1979	10	-	1	47	43 - 51	This study
1980	18	-	3	65	-	This study

1. Ratio of salmon to grilse in fishladder
2. Schnabel multiple census
3. Direct count in fishway; value is a minimum estimate
4. Peterson estimate
5. Adjusted Petersen estimate

Table 3. Values used in calculating correlation coefficients.

Year	Smolts		Salmon		Grilse	
	No. Estimated	$\bar{x}$ FL (cm)	Source	Year	No. Estimated	Source
1974	8300	14.2	Gibson 1974	1976	30	Gibson 1977
1975	5550*	15.7	Gibson 1975	1977	N.D.	
1976	3660*	14.9	Gibson 1977	1978	12	Whoriskey 1979
1977	1580	14.9	Gibson 1978	1979	10	This Study
1978	10248	14.4	Whoriskey 1979	1980	18	This Study
1979	6257	15.2	This Study	-	-	

*Average of two values reported.

N.D. = No Data.

Table 4. Mean fork length (FL) and standard deviation in centimeters of returning salmon and grilse by year; n = sample size.

YEAR	SALMON			GRILSE			SOURCE
	$\bar{x}$	SD	n	$\bar{x}$	SD	n	
1975	73.7	3.5	17	51.8	3.1	67	Whoriskey and Gibson (unpubl.)
1976	71.9	4.4	9	50.2	2.3	19	Whoriskey and Gibson (unpubl.)
1977	70.5	-	23	50.1	-	6	Gibson 1977
1978	74.5	6.0	2	51.7	2.8	28	Whoriskey 1979
1979	71.3	4.9	8	51.6	3.0	34	This Study
1980	73.1	4.9	17	55.7	3.3	65	This Study

Table 5. Percentages of returning of salmon and grilse smolting at given ages; number of fish are in parentheses

YEAR	SALMON			GRILSE		
	2+	3+	4+	2+	3+	4+
1967	20 (9)	75 (33)	5 (2)	4 (2)	80 (35)	16 (7)
1975	0	100 (17)	0	5 (3)	90 (60)	6 (4)
1976	0	100 (9)	0	0	84 (16)	16 (3)
1977	-	-	-	-	-	-
1978	0	100 (1)	0	20 (3)	73 (11)	7 (1)
1979	12 (1)	88 (7)	0	12 (4)	88 (30)	0
1980	23 (4)	77 (13)	0	6 (4)	92 (60)	1 (1)

Table 6. Sexual characteristics of salmon and grilse. Sex determined in 1975-1980 by examination of accidental mortalities or from fish recaptured in the trap net after development of obvious secondary sexual characteristics.

YEAR	SALMON			GRILSE			SOURCE
	% MALE	% FEMALE	n	% MALE	% FEMALE	n	
1967	37	63	43	96	4	47	Scheifer (1967)
1975	0	100	1	100	0	4	Whoriskey and Gibson (unpubl.)
1976	29	71	7	80	20	5	Whoriskey and Gibson (unpubl.)
1977	No Data		—	No Data		—	
1978	0	100	2	83	17	23	Whoriskey and Gibson (unpubl.)
1979	0	100	3	82	18	17	This Study
1980	—	—		100	0	3	
<hr/>							
TOTAL 1975–1980	15	85	13	85	15	52	

SALMON PARR AND BROOK TROUT POPULATION ESTIMATES

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In 1980 we continued our monitoring of salmonids in the 2nd Falls study area. Fall population estimates were made of Atlantic salmon parr and brook trout, as well as samples of fish taken for further study.

In June and July of 1978 and 1979 we manipulated the salmonid populations in this site by removing most of the brook trout and transplanting them to another section of the Matamek River. Food is postulated as a limiting resource for salmonids in this area, especially in late summer (Gibson, 1973) and we anticipated the removal of brook trout would enhance the salmon parr population. We feel confident most brook trout were removed as the number of fish captured closely matched our population estimates from previous years.

Though the data from 1978 are still being processed it appears from the 1979 and 1980 population estimates that significant enhancement of parr numbers did not occur (Table 1). In contrast the brook trout population especially in the 1+ and 2+ year classes had recovered almost to pre-manipulation levels, possibly through immigration of brook trout into the site from other areas (Table 2).

The mean sizes of salmon parr increased in 1979 and 1980 when compared with our last available samples (Table 3). The mean size of parr in this area has been increasing for some years, presumable through greater food availability for individual fish due to declining parr populations caused by falling adult returns (Gibson 1978b). Thus identifying a beneficial effect of trout removal on the parr population does not appear possible.

Table 1. 2nd Falls Atlantic Salmon Parr Population Estimates. Values are numbers of individuals/ha; growth 95% confidence limits in parentheses. Estimates were made by the Petersen mark-recapture method. Data for 1971-1977 from Gibson (1976, 1977).

Year	AGE		
	1+	2+	3+
1971	200 (140-320)	590 (510-700)	-
1972	All year Classes	2020 (1700-2500)	-
1973	510 (300-1600)	1750 (1420-2290)	20 (10-50)
1974	260 (200-360)	450 (350-630)	150 (60-380)
1975	-	-	-
1976	140 (110-200)	230 (220-260)	96 (40-190)
1977	690 (510-920)	430 (320-600)	9*
1978	-	-	-
1979	42 (30-55)	703 (449-956)	26*
1980	159 (145-173)	84 (68-99)	11*

*No marked fish were recaptured. Value represents a minimum value.

Table 2. Brook Trout Population Estimates at the 2nd Falls. Values are No. of individuals/ha with 95% confidence limits in parentheses. Estimates were made by Petersens' mark/recapture method. Data for 1971-1977 from Gibson (1976, 1977).

YEAR	AGE			
	1+	2+	3+	4+
1971	410 (240-1290)	560 (480-710)	100 (80-130)	70 (60-90)
1972	-	-	-	-
1973	300 (130-750)	510 (380-860)	180 (140-230)	50 (30-80)
1974	400 (220-810)	400 (320-540)	140 (110-190)	80 (50-130)
1975	-	-	-	-
1976	20 (16-40)	250 (200-310)	90 (70-120)	70 (50-90)
1977	290 (150-590)	310 (200-430)	130 (90-120)	60 (40-90)
1978				
1979	29*	347 (125-570)	38 (29-48)	-
1980	537 (29-1045)	140 (55-780)	12**	

*No marked fish were recaptured. Value represents a minimum value.

** One recapture.

Table 3. Mean Fork Lengths and Weights of Atlantic Salmon Parr at the 2nd Falls., 1967-1980 (SE in parentheses. Data for 1967 from Scheifer 1971. Data for 1971-1978 from Gibson 1977.

Year	AGE							
	0+		1+		2+		3+	
	<u>FL(cm)</u>	<u>Wt(gms)</u>	<u>FL(cm)</u>	<u>Wt(gms)</u>	<u>FL(cm)</u>	<u>Wt(gms)</u>	<u>FL(cm)</u>	<u>Wt(gms)</u>
1967	3.5 (0.94)	-	7.2 (0.34)	4.5	10.5 (0.16)	12.9 (0.16)	12.6 (1.40)	21.5 (1.15)
1971	3.9 (0.08)	-	8.0 (0.10)	5.6 (0.11)	11.6 (0.10)	16.4 (0.45)	15.8 (0.27)	49.1 (2.70)
1973	4.3 (0.18)	0.7 (0.11)	7.6 (0.18)	4.7 (0.35)	11.5 (0.21)	15.5 (0.49)	-	-
1974	4.3 (0.10)		7.6 (0.13)	4.8 (0.26)	11.8 (0.22)	17.2 (0.92)	-	-
1975	4.0 (0.05)		8.8 (0.45)	7.5 (1.17)	12.7 (0.17)	22.0 (0.82)	14.9 (0.41)	40.7 (2.48)
1976	4.4 (0.06)		9.8 (0.18)	10.5 (0.51)	12.8 (0.14)	23.5 (0.78)	15.7 (0.30)	48.8 (3.33)
1977	-		8.2 (0.13)	6.6 (0.36)	12.2 (0.22)	21.3 (1.23)	-	-
1978	-	-	-	-	-	-	-	-
1979	5.7	2.0 (1)	9.7 (0.57)	10.5 (1.74)	13.7 (0.16)	29.6 (1.09)	15.7 (0.15)	43.6 (0.80)
1980	4.5 (0.13)	1.0 (0.13)	9.7 (0.16)	10.5 (0.52)	13.3 (0.32)	27.8 (2.00)	16.2 (0.85)	5.80 (13.29)

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THE IMPACT OF AN INTRODUCTION OF JUVENILE ATLANTIC SALMON
(Salmo salar) ON AN INDIGENOUS POPULATION OF BROOK TROUT
(Salvelinus fontinalis) IN THE MATAMEK RIVER, QUEBEC

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Whoriskey, F.G. Jr., and R.J. Naiman. The impact of an introduction of juvenile Atlantic salmon (salmo salar) on an indigenous population of brook trout (Salvelinus fontinalis) in the Matamek River, Quebec. Can. J. Fish. Aquat. Sci. 38:000-000

In 1979 approximately 5,000 Atlantic salmon (Salmo salar) fry were released into an area of the Matamek River, Quebec, devoid of salmon but having a population of native brook trout (Salvelinus fontinalis). Our objective was to study ecological impacts of the artificial introduction on each species in a field situation. Overwinter survival of fry appeared good. By 1980 parr occupied primarily two areas within the study site: a shallow riffle previously devoid of trout and a deeper area at the riffle base where they were outnumbered by trout. In 1980 trout of age 1+ were significantly smaller than 1+ trout captured in 1979. No significant difference was noted for older trout. Salmon parr growth was excellent. Competition for food may explain the 1+ trout size differences. Seventy one percent of the male parr sampled were mature.

Key Words: Competition, enhancement, growth, Atlantic salmon, brook trout

Figure Caption

Fig. 1. The study site. Diving transects are indicated by lines T1-T4.

Fig. 1

Table 1. Distribution of salmon parr and brook trout at the 5th Falls of the Matamek River in 1980.

Survey Date	Site	Method	No. of Parr	No. of Trout	Water Velocity (cm s ⁻¹)	Depth (cm)
8 Sep.	In riffle	Angling	11	2	-	-
8 Sep.	Riffle base	Angling	10	71	-	-
11 Sep.	In riffle	Angling	12	1	38-43	15- 61
11 Sep.	Riffle Base	Angling	8	22	0-48	90-120
11 Sep.	Other	Angling	3	0	-	-
11 Sep.	Transect 1	Diving	4	45	0-48	90-120
11 Sep.	Transect 2	Diving	2	17	0-48	90-120
11 Sep.	Transect 3	Diving	2	76	20-70	30- 90
11 Sep.	Transect 4	Diving	13	9	57-76	30- 60

Table 2. Mean fork lengths of brook trout and salmon parr sampled at the 5th Falls of the Matamek River. Fish in 1979 sampled on 2 and 9 September, those in 1980 sampled on 8 and 11 September. Data from 1971 and 1974 from Gibson (1973b) and Gibson et al. (1976) respectively.

Age	BROOK TROUT FL (cm)						SALMON PARR FL (cm)					
	1971	1974	1979			1980			1980			
	$\bar{x}$	$\bar{x}$	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	
1+	10.5	10.8	12.4	0.3	15	11.6	0.1	62	12.1	0.1	43	
2+	15.5	15.5	16.7	0.3	32	17.0	0.2	27				
3+	20.0	19.4	21.5	0.5	11	21.3	0.4	7				
4+	-	23.4	24.4	0.05	2	-	-					

Table 3. Sexual characteristics of parr and trout sampled at the 5th Falls. Data for 1974 from Gibson et al. (1976). M:F is ratio of males to females.

BROOK TROUT								
YEAR	AGE	MALES			FEMALES			M:F
		% IMMATURE	% MATURE	n	% IMMATURE	% MATURE	n	
1974	1+	59	41	49	100	0	29	1:0.6
	2+	63	37	43	19	81	37	1:0.9
	3+	31	69	13	0	100	24	1:1.8
	4+	0	100	1	12	88	8	1:8.0
1979	1+	70	30	10	100	0	5	1:0.5
	2+	6	94	17	20	80	15	1:0.9
	3+	17	83	6	0	100	4	1:0.7
	4+	-	100	1	0	1	1	1:1.0
1980	1+	75	25	44	94	6	18	1:0.4
	2+	33	67	15	0	100	12	1:0.8
	3+	25	75	4	33	67	3	1:0.7
	4+	-	-	-	-	-	-	-
SALMON PARR								
1980	1+	29	71	17	100	0	26	1:1.5

PRELIMINARY INDICATIONS OF CHANGE IN STOCK COMPOSITION
OF JUVENILE ATLANTIC SALMON (*Salmo salar* L.)
IN SOME RIVERS OF THE QUEBEC NORTH SHORE

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INTRODUCTION

The Atlantic salmon is the most important fishery resource on the Quebec North Shore, and its presence has a direct impact on the lives of many people in the region. Its aesthetic, recreational and economic qualities are well documented, and it is hardly surprising that the deterioration of Canadian stocks has aroused widespread concern.

For a variety of reasons, the status of most North Shore stocks is unknown. Indications of a steady decline in salmon abundance in at least one river, the Matamek, (Gibson, 1978) prompted a study to compare the present composition of stocks in a variety of rivers with that described by Schiefer (1971) (the only other major survey of North Shore salmon).

Preliminary results of comparisons that changes in stock composition, possibly due to decreased spawning escapement, have taken place in a number of North Shore rivers.

METHODS

Salmon parr were sampled from the Moisie, St. Jean, Carneille, Mingan, Manitou and Nibisipi rivers (see Fig. 1) by seining during August. Salmon smolts were collected from the Moisie estuary, throughout the duration of the run, in the course of routine sampling by Matamek personnel engaged in the Moisie Sea Trout project. Data obtained from all juveniles included fish lengths, weights, sexes and states of maturity.

Adult salmon were sampled throughout the season from the catches of angling clubs on the Moisie, St. Jean, Mingan, Corneille and Olomane rivers. A sample of the catch from a commercial net set adjacent to the mouth of the Nibisipi river was also obtained. Adult data provided lengths, weights, sexes and dates and places of capture.

Age determinations of all juvenile scales are complete, but only one reading of adult scales has been undertaken to date. Mean smolt ages were calculated from the adult data except in the case of the Moisie where both smolt (N=105) and adult (N=129) samples were considered. Some preliminary statistical analysis has been carried out to provide 95% confidence intervals about the mean and to lump data from different sample sites where appropriate.

RESULTS

Table I indicates that there has been a decrease in mean smolt age for five of the six rivers compared, and a slight increase for one. The St. Jean figure is suspect because, due to collecting difficulties, the small sample is probably not representative of the total salmon run. Table II shows differences in smolt age distribution, for the Corneille and Moisie, concomitant with changes in mean smolt age. Complete analysis of the data is expected to provide further evidence of smolts migrating at an earlier age in the other rivers. Figure II shows the change in growth of salmon parr at the fourth falls of the Matamek river between 1967 and 1975. Figures III-VI illustrate growth curves for other North Shore rivers where comparative data are now available. A general increase in parr size is

evident for the Moisie, St. Jean and Nibisipi rivers. The converse situation obtains for the Corneille. For the Mingan River and its tributary, the Manitou, only 2+ parr were sampled in 1970 which makes any interpretation of differences difficult (2+ parr were significantly smaller (at $p = 0.05$) in 1980 than in 1970 for both rivers). Intersampling site differences in growth rates of 1+ Moisie parr are now evident (Figure IIIa); such differences were not found by Schiefer (1971). Growth rates are lowest upstream and highest in the lower reaches, a situation which also exists on the St. Jean (Figure IVa).

DISCUSSION

Gibson (1978) attributed changes in the Matamek salmon stock either to natural factors or increased exploitation at sea. He ruled out the possibility of human interference in the river because of the "undeveloped" conditions and game reserve status of the Matamek basin. He suggested that a possible indication of depletion of salmon stocks in rivers of the North Shore might be an increase in mean fork length and mean weight of the parr year classes. It appears from our preliminary results that this is so for length at least, our study having revealed a number of differences in growth rates over the last decade. These trends are not exclusively unidirectional, and are thus unlikely to be due to a "global" shift in growth patterns of all North Shore stocks, such as could be influenced, for example, by climatic factors. Analysis of Sept Iles region meteorological data by the Matamek Station (Naiman 1980) indicates that directed changes in weather patterns are not occurring in the area,

a conclusion that can be extrapolated for the North Shore with some confidence. It is our opinion that the observed differences can be explained, in part, in terms of recent changes in North Shore accessibility, as well as by continuing commercial netting pressures. Both these factors are contributing to decreased spawning escapement which is in turn reflected in increased parr growth rates, differential growth within rivers such as the Moisie and St. Jean, and eventually age at smoltification.

Increased accessibility to the North Shore has brought with it demands from all quarters for a share in the salmon resource. It has also facilitated its illegal taking and disposal, and it is inevitable that these factors have contributed to direct pressures on the individual stocks themselves. Supporting evidence for this comes from the status of the Corneille stock which is, at the least, holding up well as indicated by decreased parr growth rates and increased mean smolt age. We attribute this to the river's continued relative inaccessibility and the sound stewardship exercised by the lease-holding angling club. The former renders poaching difficult, the latter has meant that management measures taken have included ones to increase spawning escapement: the leasing of one of two estuarine nets and the removal of a large boulder which hindered upstream migration were two such measures.

CONCLUSIONS

There are indications that many North Shore rivers may now be below their carrying capacity for salmon. The bulk of the historical scientific data available for the area comes from work at the Matamek Station. The lack of long data series is disturbing, because in the absence of these, important stock management decisions are based mainly on angling and commercial catch statistics which, in view of the open access status of many rivers, may be incomplete.

ACKNOWLEDGEMENTS

This study was supported by the Woods Hole Oceanographic Institution, the Atlantic Salmon Association and the Association for the Protection of the River Moisie Inc. Special and heartfelt thanks are due to so many people that space precludes mentioning them all here. Suffice it to say that the 1980 field season could not have been as successful as it was without their time, knowledge and assistance. Martin Silverstone good humouredly and capably put up with the rigours of life as a field assistant.

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List of Tables and Figures

Table I	Preliminary results of mean smolt age comparisons for North shore rivers.
Table II	Changes in smolt age composition for the Moisie and Carneille rivers.
Figure I	Study area - Quebec North Shore.
Figure II	Salmon Parr Growth, R. Matamek 4th Falls (After Gibson, 1979. Bars represent a S.E. either side of the mean).
Figure III	Salmon Parr Growth, R. Moisie.
Figure IIIa	Growth of 1+ parr sampled at different locations, R. Moisie.
Figure IV	Salmon Parr Growth, R. St. Jean.
Figure IVa	Growth of Salmon Parr sampled at different locations R. St. Jean. (Figure after Lalonde et al. 1979. S _{5,6,7} upper reaches, S ₄ lower reaches).
Figure V	Salmon Parr Growth, R. Corneille
Figure VI	Salmon Parr Growth, R. Nabisipi

Note: For Figures III-VI, bars represent 95% confidence limits around the mean.

Table I Preliminary results of mean smolt age comparisons
for North Shore rivers

RIVER	MEAN SMOLT AGE (YEARS)		
	1970	1980 (N)	% CHANGE
MOISIE	3.7	3.4 (234)	-8.1
ST JEAN	4.6	3.7 (34)	-20.4
MINGAN	3.5	3.3 (108)	-5.1
CORNEILLE	3.0	3.1 (98)	+3.0
OLOMANE	3.8*	3.6 (53)	-7.3
NABISIPI	3.8**	3.7 (51)	-5.0

*1972 (1970 and 1972 data after Schiefer - 1971 and unpublished).

**1961 (after Power and Shooner, 1966).

Table II Changes in smolt age composition for
the Moisie and Corneille Rivers

RIVER	1970			1980		
	SMOLT AGE (%)					
	2+	3+	4+	2+	3+	4+
MOISIE	2	34	60	4	59	36
CORNEILLE	6	88	6	7	75	13

Figure I

Figure II

Figure III

Figure IIIa

Figure IV

Figure IVa

COURSES DE CROISSANCE DES TACONS-1978

Figure V

Figure VI

A SURVEY OF THE PIGOU RIVER IN 1980

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In 1972-1973 Randall and Power (1979) conducted a study of the salmon populations of the Pigou and Bouleau Rivers, approximately 60 and 68.5 km east of Sept-Iles, and concluded both rivers had "healthy" stocks. Up to and including 1980, fishing in these rivers was regulated by laws applied to salmon rivers. In 1980 the Ministere du Loisir, Chasse et Pêche, suspecting runs of adult salmon no longer existed in these rivers, began to consider changing the status of these rivers from salmon to non-salmon thereby opening the rivers to greater exploitation. We conducted a brief survey of the Pigou River in late summer of 1980 to determine if Atlantic salmon were still present.

Sporadically, from 27 July - 3 August 1980, we collected scales of returning adult salmon captured by sportsfishermen in the Pigou River. Four of the total of 11 adults we examined were re-released after tagging, the remaining seven were taken by the sportsfishermen. In addition two divers spent 30 mins. each making snorkeling transects to count parr in a 100 m² basin located at the base of a 9 m waterfall 1.7 km upstream from the sea. This fall marks the upstream limit of salmon distribution.

We sampled no two sea year fish (salmon) in 1980, possibly a function of a lack of intensive sampling and/or a decrease in numbers. The mean size of grilse does not appear to have changed significantly since 1973 (Table 1) but mean smolt age has decreased (Table 1). In the Matamek

River we found a decrease in smolt age was closely related to and paralleled a decrease in adult returns (Gibson, 1978, Whoriskey and Naiman, this report). A similar situation may be occurring in the Pigou River. Randall and Power (1978) also reported grilse in the Pigou River where 100% male while salmon were 86% female. The lack of salmon in our samples could indicate a decline in potential egg deposition although we have noted a recent increase in the number of female grilse returning to the Matamek River. Unfortunately we were unable to determine the sex of grilse examined at the Pigou.

In the diving transects we counted 18 parr (age 1+–3+) in the 100 m² site. These densities fall within those reported by other workers for salmon producing rivers in the maritime provinces (Cameron and Gray 1979).

In conclusion there appears to be a reasonable grilse run still returning to the Pigou River, and juvenile (parr) densities which in at least one section of the river fall within densities reported for other productive salmon rivers. The declassification of the Pigou River as a salmon river at this time appears to be unwarranted.

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Table 1. Fork lengths (FL) of grilse, and smolt ages of fish sampled in the Pigou River. Data from 1973 from Randall and Power 1979. Smolt ages for 1973 from samples of migrating smolts, post smolts, and returned adults. While those in 1980 are from adult scales. Number of fish in smolt sample in brackets.

	GRILSE		
	Mean FL (cm)	SD	n
1973	53.1	2.3	5
1980	53.5	3.5	11

	MEAN SMOLT AGES, (%)		
	2+	3+	4+
1973	15(4)	78(21)	7(2)
1980	78(7)	22(2)	0

BIOLOGY OF ANADROMOUS BROOK TROUT (*Salvelinus fontinalis*)
IN THE NOBLE RIVER AND ITS ESTUARY

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SEA TROUT STUDIES
(*Salvelinus fontinalis*)

BIOLOGY OF ANADROMOUS BROOK TROUT (Salvelinus fontinalis)
IN THE MOISIE RIVER AND ITS ESTUARY

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During April–November 1980 we monitored movements, feeding, growth, and population characteristics of brook trout, as well as physical characteristics of the habitats, in both the Moisie River estuary and Riviere a la Truite, the largest tributary of the lower Moisie River. We incidentally sampled an additional 26 species of fishes (Table 1).

Brook trout departed Riviere a la Truite for the estuary during late May and early June (Table 2, Weeks 7–10), and returned in August and September (Weeks 17–25). Recaptures of tagged or fin-clipped trout indicate that fish tend to remain at the site of original capture once they reach the estuary (Table 3). Fish move rapidly from Riviere la Truite to the estuary, remain in the estuary for mid-summer months, and return to the river (Tables 4 and 5).

All trout were classified as either "river" trout, with coloration characteristic of resident river fish, or "sea" trout, with a silver sheen (similar to that of salmon smolts) from guanine crystal deposition. The fraction of sea trout in fish departing Riviere la Truite in Spring dropped from May (54.8%) to June (17.1%; Table 6). There was a tendency in the estuary for the fraction of sea trout to increase throughout the summer, and fish returning to the river in Fall were largely sea trout.

Trout exiting Riviere a la Truite in Spring tend to be larger than those moving upstream during the same period or those resident in the river during mid-summer (Table 7). Our beach seining techniques in the estuary generally failed to capture fish larger than about 15-17 cm fork length, even though fish above this size clearly left the river in Spring and returned in the Fall.

Growth rates of tagged fish depended heavily on the length of time between tagging and recapture (Table 8). The strongest effect was evident in the 30 days following tagging, when growth averaged 1.48% body weight per day. Thereafter growth rates averaged 4.27% per day.

Condition factors were low in emigrants from Riviere a la Truite and in June arrivals in the estuary, and increased in subsequent samples (Table 9). Conditions factors also demonstrated a tag effect. Of the 26 fish with less than 30 days between tagging and recapture, 14 (53.9%) experienced a loss in condition (recapture CF < initial CF); only 3 of the 25 fish out more than 30 days had negative changes in condition.

We captured trout up to age 5+ (Table 10), although most were in the 1+ to 3+ range. Fish from the lower estuary generally exhibited a larger maximum size than those from middle and upper sections. Age 2+ specimens from Riviere a la Truite had a much broader upper size range than expected. We captured few 3+ and older fish in the estuary, but these were significant components of immigrants to Riviere a la Truite.

Fish classified as sea trout tended to be older than river trout (Table 11) and the relative prevalence of older river trout (2+, 3+)

declined as the summer progressed. A similar loss of 3+ sea trout is evident when estuary samples are compared to emigrants from Riviere a la Truite, but this and older age groups are well-represented in fish returning to the river.

Sea trout emigrants from Riviere a la Truite are primarily females, as are June arrivals in the estuary; the corresponding river trout samples are male dominated (Table 12). The sex ratio for all emigrating brook trout is 1.06 (N=60). Estuary sea trout apparently experience a disproportionate loss of females from June to July. August immigrants to Riviere a la Truite, however, were once again dominated by females.

Analysis of Variance indicates that females tend to be larger than males. Maturing immigrants are larger than immature immigrants to Riviere a la Truite; similar differences were not detected in maturing vs. immature fish from the estuary.

Trout moving downstream in May were all immature (Table 13). No general increase in percent maturing with time was noted. The apparent drop in percent maturing in the estuary during September may reflect an earlier departure of maturing fish. Trout returning to Riviere a la Truite in August contained a larger fraction of maturing fish than did the September samples, again suggesting an earlier return of maturing fish.

Results of food habits studies are not reported in detail. Marine foods (amphipods, mysids, sand lance) are available from at least mid-April to early November, and are abundant during most of that period. Specimens from the lower estuary appear to have fed more frequently on marine foods than specimens from the middle estuary, even though such

foods were available in the middle estuary at high tides. There is very little apparent correlation between contents of surface or bottom plankton tows and stomach contents.

SUMMARY

Both river trout and sea trout morphs depart Riviere a la Truite (and a second upstream tributary ignored here) in late May-early June. Early departures are dominated by larger, older sea trout, and later departures by river trout. Sea trout emigrants are predominately female.

Fish arriving in the estuary exhibit about the same age and sex structure as emigrants from the river, but larger fish were not evident in estuary samples. Throughout the summer, we failed to capture many fish over 15-17 cm FL. In addition, sex ratios of estuary trout shift from female-skewed to slightly male-skewed.

Growth of tagged fish averaged about 4.5% per day (weight) following a roughly 30 day period when the suppressive effect of tagging was very evident. Condition factors were lowest in Spring emigrants, and increased through the summer. Changes in conditions factors also reflected an effect of tagging. Our techniques effectively sampled estuary trout of ages 0+ and 1+, but larger specimens of older age groups escaped our detection.

Fish returning to Riviere a la Truite in August were primarily sea trout and again females dominated. The larger fish were maturing, but a significant component of younger, smaller fish were not. By September, the dominance of females was lost and the fraction of maturing immigrants was down.

Our beach seining techniques doubtless yielded an incomplete sample of estuarine trout, as they sampled only the upper ~2 m of the water column. In the highly stratified Moisie estuary, this upper lens is almost pure river water. Our failure to capture larger fish probably reflects a size-dependent ability to enter saline waters, which allows the fish to enter the deeper, saline sections of the estuary; emigrants and immigrants exhibit a much larger size range than any estuary samples. This phenomenon may also account for the June-July drop in sex ratios, as females are significantly larger than males and should enter seawater earlier.

Table 1. List of fishes caught in Moisie River system, April-October 1980, with earliest and latest dates of capture in Riviere la Truite and estuary. Occurrence codes: Z - Zorich Creek, T - Riviere la Truite, E - Moisie estuary. Question mark preceding scientific name indicates tentative identification make in the field. The order and nomenclature follows Bailey et al. (1970).

Family and Species	Common Name	Occurrence Code	Capture Dates (mo/day)		
			Estuary	Truite	Latest
			Earliest	Earliest	Latest
Petromyzontidae <u>Petromyzon marinus</u>	Sea lamprey	T	-	5/28	8/19
Anguillidae <u>Anguilla rostrata</u>	American eel	TE	6/10	5/27	9/3
Clupeidae <u>Alosa pseudoharengus</u> Other clupeids	Alewife	TE E	6/8 6/25	7/1 9/30	6/21 -
Salmonidae <u>Prosopium cylindraceum</u> <u>Salmo salar</u> <u>Salvelinus fontinalis</u>	Round whitefish Atlantic salmon Brook charr	TE	6/10 6/6 5/25	9/9 9/10 9/30	- 10/28 10/28
Osmeridae <u>Mallotus villosus</u> <u>Osmerus mordax</u>	Capelin Rainbow smelt	E ZE	6/19 5/24	7/8 9/30	- -
Esocidae <u>Esox lucius</u>	Northern pike	T	-	7/14	-
Cyprinidae <u>Couesius plumbeus</u> <u>Rhinichthys cataractae</u>	Lake chub Longnose dace	ZT ZT	- -	5/21 6/26	6/21 -
Catostomidae <u>Catostomus catostomus</u> <u>Catostomus commersoni</u>	Longnose sucker White sucker	ZTE ZTE	6/8 5/24	9/16 -	9/6 6/21

	Burbot	ZT	-	9/1	-
	Tomcod	TE	5/24	5/23	5/31
Gasterosteidae					
<u>Apeltes quadracus</u>	Fourspine stickleback	E	9/16	-	-
<u>Culaea inconstans</u>	Brook stickleback	E	5/14	-	-
<u>Gasterosteus aculeatus</u>	Threespine stickleback	E	5/24	-	-
<u>Gasterosteus wheatlandi</u>	Baldspotted stickleback	E	6/23	-	-
<u>Pungitius pungitius</u>	Ninespine stickleback	TE	4/23	5/18-5/24	-
Ammodytidae					
<u>Ammodytes sp.</u>	Sand lance (launce)	E	4/28	-	-
Cottidae					
<u>Cottus bairdi</u>	Mottled sculpin	T	-	5/24	6/15
<u>Myoxocephalus scorpius</u>	Southern sculpin	E	8/18	-	-
Plueronectidae					
<u>Limanda ferruginea</u>	Yellowtail flounder	E	7/7	-	-
<u>Liopsetta putnami</u>	Smooth flounder	E	5/14	-	-
<u>Pseudopleuronectes americanus</u>	Winter flounder	E	7/24	-	-

Table 2. Captures of brook trout in Riviere a la Truite and the Moisie River estuary, 1980, by week. Effort was approximately equal for a given week within the river (captures in hoop nets facing upstream and downstream) and estuary (duplicate seine hauls at each of 6 stations).

#	Week	Date Began	Riviere a la Truite		Moisie Estuary		
			Individuals Moving:		Day-Time Captures	Only	
			Downstream	Upstream	Upper	Middle	Lower
0-5	Apr.	13	0	0	0	0	0
6	May	18	0	0	...	...	...
7		25	279	3	...	...	...
8	June	1	643	18	11	82	3
9		8	89	13	10	26	15
10		15	74	5	38	291	65
11		22	9	0	46	301	265
12		29	1	0	14	147	43
13	July	6	...	...	15	135	77
14		13	0	0	4	53	3
15		20	...	...	4	77	22
16		27	...	...	9	225	28
17	Aug.	3	0	8	...	...	...
18		10	10	44	4	45	5
19		17	2	57	17	40	26
20		24	0	119	2	16	0
21		31	0	18	10	174	1
22	Sept.	7	0	7	8	70	0
23		14	17	19	0	177	0
24		21	0	10	...	...	...
25		28	0	0	0	1	0
26	Oct.	5	0	0			
27		12	0	1			
28		19	1	8			
29		26	0	1			
30	Nov.	2	...	0			
31		9	...	0			

Table 3. Records for fish clipped and recaptured within the estuary. Diagonals (underlined) demonstrate that fish tend to be recaptured where they were originally marked.

		Clipped at Station:					
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>6</u>	<u>7</u>
Recaptured At Station:	1	8	7	0	0	1	0
	2	<u>7</u>	<u>146</u>	1	1	2	1
	3	0	<u>4</u>	7	2	1	0
	4	0	0	<u>0</u>	<u>21</u>	1	0
	6	1	4	0	<u>2</u>	<u>7</u>	0
	7	0	1	0	0	<u>0</u>	<u>0</u>

Table 4. Days elapsed between tagging and recapture of trout within the Moisie River system. Data are for fish captured by Matamek Research Station personnel during routine sampling.

Tagged at: Recaptured at:	R. Truite Estuary	Estuary Estuary	Estuary R. Truite	R. Truite* R. Truite
Mean =	16.75	19.71	50.86	71.38
S.D. =	10.06	13.47	13.50	16.15
Max. =	37	60	88	87
Min. =	2	1	46	61
N =	12	34	7	13

* - fish that made Spring to Fall round trip.

Table 5. Mean number of days elapsed between tagging and recapture of brook trout by anglers in the Moisie River system. Sample sizes are in parentheses.

Tagged at: Recaptured at:	R. Truite Estuary	Estuary Estuary	Estuary R. Truite	R. Truite R. Truite
<u>Month Tagged</u>				
May	52.7 (11)	...	...	84.0 (8)
June	56.6 (20)	37.4 (16)	61.8 (21)	76.9 (9)
July	...	27.0 (2)	37.3 (3)	...
August	0	0	0	7.3 (23)

Table 6. Percent of trout that exhibited "sea trout" coloration, Moisie River system, 1980

Location		May	June	July	August	September	October
Riviere a la Truite							
Moving downstream	%	54.8	17.1	0	0	76.5	0
	N	279	818	1	12	17	1
Moving upstream	%	0	13.9	...	94.0	85.2	66.7
	N	3	36	...	234	54	3
Moisie Estuary:							
Upper	%	...	55.2	76.6	68.8	91.7	...
	N	...	125	77	32	36	...
Middle	%	...	79.1	93.7	91.1	97.9	...
	N	...	847	492	101	422	...
Lower	%	...	97.9	99.5	100	100	...
	N	...	422	213	92	8	...

Table 7. Length frequency distributions of brook trout from Moisie River system, 1980. Values are percent of total sample.

Fork length(cm)		Riviere a la Truite			Estuary	Riviere a la Truite
		May - June		July-August	June-Sept.	August - October
From	To	Moving Downstream	Moving Upstream	Remaining		Returning
< 3		0.1	2.6	1.0	2.7	0.3
3	4			24.3		
4	5			26.2	<0.1	
5	6	0.5	2.6	9.7	0.2	1.3
6	7	2.5	7.7	4.9	0.5	1.4
7	8	8.0	5.1	9.7	1.5	1.7
8	9	12.2	18.0	7.8	5.6	
9	10	15.6	18.0	5.8	11.2	2.1
10	11	13.0	15.4	7.8	19.5	1.4
11	12	12.6	23.1		20.0	4.1
12	13	9.2	5.1	2.9	16.0	5.8
13	14	6.4			8.9	3.8
14	15	3.6			6.2	5.2
15	16	1.8			2.7	4.5
16	17	2.2			1.8	3.8
17	18	2.0	2.6		1.4	8.3
18	19	1.3			0.7	5.5
19	20	2.5			0.4	5.8
20	21	1.7			0.2	7.2
21	22	2.0			0.1	4.1
22	23	1.4			0.1	3.8
23	24	0.6			0.1	3.8
24	25	0.5			<0.1	3.4
25	26	0.3				4.5
26	27	0.1			0.1	4.1
27	28				<0.1	2.1
28	29					2.1
29	30				<0.1	2.8
30	31				<0.1	1.4
31	32					3.1
32	33					1.0
33	34					0.3
34	35					
	>35	0.1			<0.1	
N =		1097	39	103	28.67	291

Table 8. Growth (% initial body weight per day) of tagged fish from the Moisie River system, 1980. Data subdivided by days between tagging and recapture; summary demonstrates probable effect of tagging on growth.

Days Elapsed Between Tagging and Recapture						Summary	
0-19	20-29	30-49	50-69	≥ 70		<30	≥ 30
-2.62	-0.16	0.84	0.93	2.64			
-0.79	0.23	1.46	3.24	2.89			
-0.21	1.43	2.86	3.51	2.90			
-0.16	1.69	3.44	3.51	3.06			
0.19	2.34	4.22	3.60	4.39			
0.19	2.47	5.40	5.83	4.40			
0.24	2.53	6.44	6.17	4.45			
0.25	3.94		6.18	5.64			
0.30	4.45		6.54	12.20			
0.35							
0.78							
1.82							
2.00							
2.09							
3.78							
4.38							
6.92							
X = 1.15	2.10	3.52	4.39	4.73		1.48	4.27
S.D. = 2.23	1.52	2.02	1.89	2.98		2.03	2.32
N = 17	9	7	9	9		26	25

Table 9. Condition factors (100 WT/L³) of trout in the Moisie River system, 1980. Note that August-October samples in Riviere a la Truite were dominated by returning sea trout.

	May-June	July	August-October
R. Truite			
MEAN =	0.94	1.24	1.09
S.D. =	0.20	0.18	0.13
N =	818	59	306
Estuary			
MEAN =	0.95	1.03	1.08
S.D. =	0.11	0.11	0.16
N =	560	378	342

sample sizes are in parentheses.

Age	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35
0+	UUUUUUUUUUUUUU (13)																
	TTT (1)																
	LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL (35)																
1+	UUUUUUUUUUUUUUUUUUUUUUUUUUUU (82)																
	TTTTTTTTTTTTTTTT (17)																
	LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL (43)																
2+	UUUUUUUUUUUUUUUUUUUUUUUUUUUU (18)																
	TT (39)																
	LLLL (1)																
3+	UUUU (1)																
	TT (20)																
4+	TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT (9)																
5+	TTT (1)																

Table 11. Comparisons of age structure for brook trout and sea trout.

Location	Age	Brook Trout	Sea Trout
Riviere a la Truite (May-June) Emigrants	0+	0	0
	1+	12	1
	2+	10	11
	3+	3	21
	4+	0	2
	5+	0	0
Estuary (June) All Sites	0+	0	0
	1+	10	13
	2+	4	123
	3+	0	35
	4+	0	2
	5+	0	0
Estuary (August-September)	Lower	0+	0
		1+	35
		2+	42
		3+	1
		4+	0
		5+	0
	Middle Upper	0+	1
		1+	72
		2+	18
		3+	1
		4+	0
		5+	0
Riviere a la Truite (August-September) Immigrants	0+	1	0
	1+	5	12
	2+	0	39
	3+	0	20
	4+	1	8
	5+	0	1

Table 12. Sex ratios for river trout and sea trout in Moisie River system, 1980.

	Riviere a la Truite				Moisie Estuary - All Sites*		
	Emigrants (May)	Residents (July)	Immigrants (August)	Immigrants (September)	(June)	(July)	(August) (September)
River Trout							
F/M =	0.56	1.27	1.00	1.50	0.50	0.63	3.00
N =	25	50	2	5	15	13	4
							...
							0
Sea Trout							
F/M =	1.69	...	1.36	1.00	1.42	0.97	0.79
N =	35	0	59	22	174	301	118
							0.93
							54

*No river trout were sampled from the lower estuary; there were only 10 river trout in our entire summer sample of 735 trout.

Table 13. Percent of sampled fish that appeared to be maturing, by month and location.

Site	May		June		July		August		September	
	%	N	%	N	%	N	%	N	%	N
Riviere a la Truite										
Moving downstream:	0	60	...	...	...	...	...	...	41.2	17
Moving upstream:	...	...	...	...	...	...	75.0	60	37.0	27
Moisie Estuary:										
Lower:	...	...	14.9	47	8.3	97	26.3	80	...	...
Middle and Upper	...	...	9.2	142	6.9	217	9.5	42	1.9	54

PARASITES AS INDICATORS OF MOVEMENTS OF ANADROMOUS BROOK CHARR
(Salvelinus fontinalis)

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Black, G.A. 1981. Parasites as indicators of movements of anadromous brook charr (Salvelinus fontinalis). Can. J. Zool.

Changes in the numbers of metazoan parasites of anadromous brook charr, Salvelinus fontinalis, during the summer 1980 were determined by examining 220 fish at different times and localities in the Moisie River, Quebec. The marine trematode Brachyphallus crenatus remained in brook charr during their movements into fresh water. Differences in the prevalence of this parasite between sampling localities in late July indicated that some charr which undergo smoltification do not go to sea although others do. Also, infection with B. crenatus enabled an estimate to be made of the percentage of charr entering a tributary in late August which had been to sea. Brook charr were also infected with Crepidostomum cooperi, Diplostomum spathaceum, Eubothrium salvelini, Proteocephalus sp., Metechinorhynchus lateralis, Echinorhynchus gadi complex, Cystidicoloides tenuissima, Thynnascaris sp., Anisakis simplex, Acuarioidae: Seuratiinae gen. sp., Salmincola edwardsii and glochidia larvae.

Key words: Brook charr, sea charr Salvelinus fontinalis, biological tag,
Brachyphallus crenatus

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Table 1. Parasites recovered from brook charr in the Moisie River and Riviere a la Truite in the summer, 1980.

	Sample Time and Locality			
	June River Mouth	July-Aug. Upstream	July-Aug. River Mouth	Aug.-Sept. la Truite
Brook charr				
Sample size	59	58	59	44
Fork length (mm)	133 ± 35 ^a (84 - 261)	118 ± 15 (80 - 168)	145 ± 20 (111 - 201)	161 ± 28 (96 - 219)
Age (yr)	2.2 ± 0.6 (1 - 4)	1.3 ± 0.5 (1 - 3)	1.5 ± 0.5 (1 - 2)	2.0 ± 0.6 (1 - 3)
Trematoda				
<i>Crepidostomum cooperi</i> (Hopkins, 1931)	68(1-354) ^b 17.2 ± 56.4	64(1-88) 5.9 ± 14.1	51(1-50) 6.8 ± 10.9	45(1-15) 4.0 ± 3.7
<i>Brachyphallus crenatus</i> (Rudolphi, 1802)	2 22.0	3(24-28) 26.0 ± 2.8	86(1-172) 43.2 ± 45.2	64(1-289) 50.9 ± 78.5
<i>Diplostomum spathaceum</i> ^c (Rudolphi, 1819)	3 1.0	3(1-3) 2.0 ± 1.4	2 1.0	11(1-16) 5.6 ± 6.2
Cestodoidea				
<i>Eubothrium salvelini</i> (Schrunk, 1790)	22(1-5) 2.1 ± 1.4	5(1-3) 1.7 ± 1.2	8 1.0	5 1.0
<i>Proteocephalus</i> sp. (Weinland, 1858)	0	0	0	2 1.0
Acanthocephala				
<i>Metechinorhynchus lateralis</i> (Leidy, 1851)	31(1-18) 3.5 ± 4.3	81(1-9) 2.5 ± 2.1	83(1-23) 4.3 ± 4.3	73(1-17) 4.9 ± 4.6
<i>Echinorhynchus gadi</i> complex (Zoega in Muller, 1976)	3(1-3) 2.0 ± 1.4	12(1-4) 1.4 ± 1.1	7 1.0	16(1-7) 1.9 ± 2.3
Nematoda				
<i>Cystidicoloides tenuissima</i> (Zeder, 1800)	24(1-4) 1.4 ± 0.9	14(1-2) 1.1 ± 0.4	14(1-3) 1.5 ± 0.8	39(1-5) 2.2 ± 1.3
<i>Thynnascaris</i> sp. <i>adunca</i> ^d (Rudolphi, 1802)	5 1.0	2 1.0	5 1.0	7 1.0
<i>Anisakis simplex</i> ^d (Rudolphi, 1809)	0	0	12(1-2) 1.3 ± 0.5	7(1-5) 2.3 ± 2.3
Acuarioidea:Seuratiinae gen. sp. ^d	3 1.0	0	0	7 1.0
Copepoda				
<i>Salmincola edwardsii</i> (Olsson, 1869)	10(1-2) 1.3 ± 0.5	10(1-3) 1.5 ± 0.8	36(1-6) 1.4 ± 1.1	25(1-3) 1.3 ± 0.6
Mollusca				
Glochidia ^e	5	0	0	0

a Mean ± S.D. subtended by range.

b Prevalence (range in infected fish) subtended by mean ± S.D.

c Metacercariae.

d Larvae.

e Not enumerated.

THE BIOLOGY OF Salmincola edwardsii (OLSSON, 1869) IN THE MOISIE
RIVER SYSTEM, QUEBEC

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ABSTRACT

We examined the biology of Salmincola edwardsii (Olsson, 1969) (Copepoda: Lernaeopodidae) in the Moisie River and its tributary, Riviere a la Truite, during 1980. This copepod was specific to brook charr, Salvelinus fontinalis. In single and double infections the preferred site of infestation was the area on and around the adipose fin. At higher intensities of infestation the majority of copepods were located in the region of the dorsal fin and the percentage occurring on the ventral surface increased. This apparent displacement from the preferred site may be a regulating mechanism in populations of Salmincola spp.

The preferred site of S. edwardsii on brook charr apparently changes with host size. Almost all fish examined here were <200 mm long and over 99% of all copepods occurred on the body surface. In other studies on brook charr >300 mm long this copepod infested the gill filaments almost exclusively.

Prevalence and intensity of S. edwardsii was higher on brook charr <140 mm long than in larger fish. The copepod was most abundant on fish leaving Riviere a la Truite in late spring and on fish resident in this stream during mid-summer. The copepod occurred less frequently on fish in the main river and on fish re-entering Riviere a la Truite in the fall suggesting that the smaller tributary is a more conducive environment for the transmission of this normally lacustrine parasite.

DETERMINING THE OSMOREGULATORY ABILITY OF ANADROMOUS BROOK TROUT

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Sea-run brook trout (Salvelinus fontinalis) may obtain growth rates that are four to five times that of their cohorts remaining in freshwater. This fact, in combination with an exceptionally high rate of return of brook trout to their parent stream, has generated keen interest in the use of this species in fish farming, ranching and population enhancement programs (Gibson and Whoriskey 1981; Whoriskey et al. in prep.). For any such program designed to grow brook trout in salt water, the determination of optimal size and age for introduction of young brook trout into sea water is an important first step. Research in our laboratory is designed to answer this and other key questions concerning salmonid smoltification.

In order to determine the relative importance of size and age in determining the osmoregulatory ability of brook trout, it is necessary to grow a large number of fish of a single age class. 20,000 brook trout fry obtained as eggs from the Massachusetts State Hatchery are being grown in culture facilities in the Shore Laboratory at the Woods Hole Oceanographic Institution. Photoperiod has been shown to have a profound effect on salinity tolerance in salmonids (Clarke et al., 1979), one which could mask the effects of size and age. In order to control for the possible effects of photoperiod half of the fish are under a natural daylength light regime while the remainder experience a photoperiod which is three months out of phase with normal day length. In order to develop fish of

different sizes at any given age, half of the fish are being grown at a maximal rate, with the remainder being fed a lesser amount and growing submaximally.

Beginning in spring 1981 the fish currently being cultured will be used for monthly sea water exposure experiments. Fish obtained as fingerling from the Massachusetts State Hatchery at Sandwich and grown to different sizes have already undergone salinity tolerance tests. In these experiments brook trout are gradually acclimated to sea water (30⁰/oo) over a 4 day period at constant temperature in 100 liter aquaria. Fish are kept in seawater for several weeks during which survival and growth relative to freshwater controls will be the major criteria by which the relative role of size, age and photoperiod are judged. In addition to growth and survival, several potential physiological changes are investigated. These include plasma ions and osmotic concentration, gill $\text{Na}^+ + \text{K}^+$ ATPase, gill histology and levels of thyroxine in the blood.

Results from his study will show the relative roles of size and age in determining the ability of brook trout to osmoregulate in sea water. This information will be valuable in determining successful seawater stocking procedures for brook trout and other salmonids. In addition our examination of physiological changes will detect physiological parameters that might be used to predict the ability of a population to enter sea water as well as increase our understanding of the process of salmonid smoltification.

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EARLY LIFE HISTORY OF BROOK TROUT IN THE MATAMEK RIVER, QUEBEC:
SUMMARY OF METHODS AND PRELIMINARY RESULTS

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From early June to mid-August 1980 we studied the early life history of brook trout in the Matamek River. We were particularly interested in the food selection, growth and use of riparian habitat by the brook trout fry. The study area selected was in the vicinity of the island below the 3rd Falls.

Collections of fry commenced in early June, just after swim-up, and continued weekly throughout the summer until the 8th of August. Fry to be used for stomach content analysis were fixed in 10% formalin, then preserved in 70% ethanol. Fry to be used for growth analysis were placed directly in 70% ethanol to avoid damaging the otoliths. Fry were captured initially with handnets and later by seining. Drift samples were also taken weekly from areas where fry were captured and were examined alive the same day. Size ranges of drifting organism and food items in stomachs were ascertained throughout.

HABITAT

To explore the importance of the riparian zone, a map was made to scale of the study area shoreline and categorized into segments as follows: alder overhangs with various water depths beneath (0-20 cm; 20-30 cm; 30-50 cm and >50 cm); conifer shaded undercut bank; open canopy with

sand or mud substrate; exposed cobble; grass clumps; and rock ledge. This was accomplished between 31 July and 4 August representing a late-summer condition. We feel the following generalization is reasonable: the percent of shoreline comprised of alder overhangs decreases from early to late summer as the average amount of water beneath these overhangs decreases. During late summer we estimated alder overhangs to comprise approximately 45% of the total shoreline as compared to approximately 76% in early to mid June.

We see four main effects of alder overhangs on the riparian zone and possible effects on underyearling brook trout:

1. Creating cover - protection from both air and water borne predation and competition.
2. Supplement to feeding - terrestrial insects falling into water from alder leaves and branches.
3. Slowing of current velocity - quiet resting places amongst the branches.
4. Shade - may be important during certain developmental stages.

No predictable patterns emerged with respect to location of fry. Parameters such as varying water levels, availability of food, time of day, amount of cloud cover, varying terrestrial and aquatic plant growth, size of fry, water turbidity, current speed, temperature fluctuations and other factors probably combine to govern where the fry will be at any one time.

We offer the following scenario as being a reasonable hypothesis: Shortly after swim-up, water levels are high and the fry are found hugging the banks in shallow water or associated with alder only where the overhangs are in shallow water. Most of the alder overhangs in deeper water appear to be unsuitable habitat; reasons may include excessive current velocity, lack of proper food or the overhangs having enough water beneath them to be suitable habitat for potential fry predators. Our observations suggest that there is a "right" amount (depth) of water beneath alder overhangs for fry at any given size which increases as fry size increases. During the first half of the summer, alder overhangs become increasingly important fry habitat areas; as the fry get larger they seek deeper water cover and at the same time, decreasing water levels mean that more and more alder overhang areas are becoming suitable habitats (e.g. having the "right" depth of water underneath). Perhaps also, larger fish (potential predators) may be forced away from the riparian zone into deeper water by the steadily decreasing water level. At some point in time the overhang-depth relationship is such that alder overhangs are by far and away the most important habitat for the fry. After this point the fry begin to outgrow this habitat type as it becomes less and less suitable (because of increasing fry size and decreasing water depth beneath alders). This change occurs when submerged macrophytes are becoming larger and more abundant in littoral areas. The increasingly mobile fry begin to be found in these submerged macrophyte areas especially if deep alder overhangs are located nearby.

There is no doubt that the riparian zone and particularly the role of alder overhang areas can be demonstrated as being important for the early life history of for these fish.

GROWTH

Instantaneous growth rates and a growth equation for these fry are currently being investigated but are not yet available.

FOOD

Of the organisms identified we divided them into 16 taxa, plotted both the mean number of organisms per stomach and the mean percentage of those organisms per fish stomach against time. A considerable amount of each sample (13.5 to 32.5%) was unidentifiable and ignored. We did not plot five insect orders which were present (Coleoptera, Megaloptera, Lepidoptera, Homoptera, Hymenoptera) because they occurred infrequently or in small amounts. Adults and pupae of the prevalent invertebrate were identified only to order, except for larvae of the Diptera which were identified to family and plotted separately. Some obvious interpretations to make at this point are:

1. Early in June (after swim up), Copepods and Cladocerans may be important as a first food for the fry.

2. Chironomid larvae and simuliid larvae are important from mid-June through early-July and seem to be selected for. An interesting note is that chironomid larvae tend to become more and more abundant throughout the summer in my samples, yet the fry stopped feeding on them despite their abundance in early-July (probably because of the availability of Trichoptean pupae which appear to be the preferred food).
3. Diptera and Trichoptera form the staple food source for the fry with dipterans (in larval, pupal and adult stages) being most important in the first part of the summer, and trichopterans (mostly in the pupal stage) being most important later in the summer.

DRIFT

Analysis of data on drifting organisms is currently being conducted and is not ready for presentation at this time.

2. Chironomid larvae and simuliid larvae are important from mid-June through early-July and seem to be selected for. An interesting note is that chironomid larvae tend to become more and more abundant throughout the summer in my samples, yet the fly stopped feeding on them despite their abundance in early-July.

OTHER STUDIES

(probably because of Trichoptera pupae which appear to be the preferred food).

3. Diptera and Trichoptera form the staple food source for the fly with dipterans (in larval, pupal and adult stages) being most important in the latter part of the summer, and trichopterans (mostly in the pupal stage) being most important later in the summer.

DRIFT

Analysis of data on drifting organisms is currently being conducted and is not ready for presentation at this time.

GROWTH AND BEHAVIOR OF JUVENILE Salmo salar and
Salvelinus fontinalis IN ALLOPATRY AND SYMPATRY

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The interaction of juvenile Atlantic salmon (Salmo salar L.) and brook trout (Salvelinus fontinalis [Mitchill]) was studied to determine why juvenile Atlantic salmon were smaller, both in length and weight, than equivalent age class brook trout in the Matamek River, Quebec.

Three questions were posed: a) Are the growth rates and behavioral patterns of juvenile Atlantic salmon and brook trout significantly different in allopatric and sympatric populations? b) Does population density affect the growth rate of either species? c) Does their earlier emergence from the gravel accord the juvenile brook trout an advantage in either growth or behavior over the juvenile Atlantic salmon?

Test populations of both species were examined in two stream tank facilities: one exposed to natural stream variables in the Matamek River, the other within a controlled laboratory environment. Concurrent studies examined fish released into restricted areas of a Matamek tributary and natural populations in the Matamek River.

The larger juvenile salmon held station in contact with the substrate using their pectoral fins to maintain position, while the larger juvenile trout were usually found midwater in the stream tank. Both species grew at similar rates in allopatry. The behavioral repertoire was the same for

both species, although the frequency with which individual behavioral components were employed varied between the species, e.g. "Approach" was used by trout more, "Lateral display" by salmon. With only two replicates completed the statistical tests were not sensitive enough to determine significant sources of variation. Nearest neighbour distances decreased significantly in high density populations for salmon but not for trout.

Behavioral patterns of smaller juveniles generally were similar to those exhibited by the larger juveniles. Growth rates of smaller juveniles did not vary significantly between the species in allopatry, or within species in allopatric or sympatric populations. The species employed a significantly different proportion of "Lateral display" and "Approach". In sympatry, the smaller juvenile salmon significantly increased their use of those behavioral displays more characteristic of trout, a similar shift was not significant for trout. In all population types salmon were more aggressive than trout. The dominant individual of each species in sympatric populations interacted more with the subordinates than the other dominant individual; the subordinates interacted with each other and the dominant of either species. Salmon were more successful in interspecific interactions than the trout. The general behavioral trends observed were similar in the laboratory stream tank, but with only two replicates the results could not be statistically tested. Growth in weight and the number of interactions correlated significantly with photoperiod, water temperature and velocity, which all varied seasonally. Also, the number of interactions per observation correlated significantly with water temperature and velocity for several population types.

The hatchery-reared salmon occupied a position just off the substrate in the stream tank, which was intermediate to the position of wild salmon (bottom) and trout (midwater), in agreement with observations from Trappers Cabin Creek (TCC). The habitats of salmon and trout in TCC overlapped, but in sympatric populations the trout displaced the salmon from the area of overlap. The growth rates of hatchery-reared salmon, wild salmon, and trout in the stream tank were not significantly different in allopatry. Alternatively, in TCC the trout, which were larger than the salmon at the start of each experiment, grew better in sympatric populations while the salmon grew better in allopatric populations. Salmon and trout used a significantly different percent of several displays employed in the stream tank. Nearest neighbour distances and the number of interactions per individual were similar for hatchery-reared salmon whether in sympatry with wild salmon or trout, and the latter increased for wild salmon in sympatry with hatchery-reared salmon. Trout had an advantage over hatchery-reared salmon in interspecific interactions, while in the other two sympatric populations participants were equally successful.

It is concluded that the lack of preferred salmon habitat in the Matamek River limits the possibility for habitat separation as observed in other salmon rivers in eastern Canada. The dominant individuals of each species occupied their preferred habitat, while the subordinants overlapped in distribution and interacted aggressively.

When the population density was increased to the point that territoriality broke down, the mean growth rate did not increase significantly for either species in either the Matamek stream tank or an environmentally-controlled facility at Woods Hole.

Behavioral patterns of hatchery-reared salmon underyearlings are intermediate to those of wild salmon and brook trout. The shift in the behavior of hatchery-reared salmon may explain the lack of success in Atlantic salmon planted in other rivers. Therefore, before more plantings of hatchery-reared salmon are undertaken, the rearing procedures should be evaluated.

Later emergence than brook trout is a significant feature of the early life history of juvenile Atlantic salmon. As a result, the underyearling trout are larger than equal age class salmon and can displace the salmon from areas of habitat overlap in the first year of cohabitation. The early emergence is only a significant feature in rivers such as the Matamek River, in which there is a lack of preferred habitat for salmon. The growth advantage gained in the 0⁺ year-class by the trout is enough to maintain the size differential in their favour for the rest of the time the trout cohabit with the salmon.

NON-SALMONID FISHES OF THE LOWER MOISIE RIVER, QUEBEC

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Twenty seven species of fishes were recorded from the lower Moisie River system in April-October 1980. In late May to early June, longnose suckers, white suckers, lake chubs, and juvenile sea lampreys, as well as salmon parr and smolt and anadromous brook charr, exit tributaries to the lower Moisie River in a highly synchronized and explosive emigration. Activity, and perhaps population densities, of fishes remain low during mid-summer. Only brook charr returned in August-October, coincident with a small influx of adult sea lampreys. The emigrations of lake chub and longnose and white suckers are similar; 3-4 major peaks of migratory activity occur, each separated by approximately three days from other peaks and each succeeding peak lower than the previous. Salmonids, although exhibiting a period of migration virtually identical with that of non-salmonids, show no clear peaks of activity and catches per day increase as the run progresses. With the exception of sea lampreys, onset of the emigration occurred with dropping water levels shortly after the peak of Spring runoff; the sea lamprey exodus may correlate with periods of increasing water temperature. The remarkable synchrony in timing of a run including 5 species of fishes suggests that such simple environmental cues may not account for the phenomenon in toto. Perhaps social interactions resulting from migratory restlessness or downstream movements may stimulate other fishes, producing a chain reaction that generates the synchronous and cyclic nature of the run.

RESPONSE TO PHYTOPLANKTON ON LOW-LEVEL FERTILIZATION
OF LOWER BAIE PHILIPPE, MATAMEK LAKE

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In 1974 Dr. Duthie and his co-workers began an investigation of the primary productivity of lakes in the Matamek watershed and the controlling factors. After three field seasons considerable information had been gained on the primary productivity of lakes Matamek, Gallienne and Randin (Janus and Duthie, 1979a) and of the phytoplankton composition, biomass and periodicity (Janus and Duthie, 1979b). In 1976 and 1977 the extent of phosphorus limitation of phytoplankton growth in Matamek Lake was measured using ^{32}P (Duthie and McLachlan, 1977). In 1977 a phosphorus budget was calculated for Lower Baie Philippe by Martin (1978). This basin had been selected for experimental work and the low-level fertilization project described here was conducted during the 1978 and 1979 field seasons. The fertilization project was carried out for three main reasons:

- (1) To test Vollenweider's (1968) model relating lake productivity to mean depth phosphorus loading in an acid dystrophic Shield lake. This would have significance in any future cultural activities in the watershed such as logging, road building or habitation, and would have relevance in any further attempts to increase fish yields (Chow-Fraser, 1981).

- (2) To conduct experiments on the importance of ultraplankton and the effects of enrichment on phytoplankton-zooplankton trophic relationships (Ross, 1980).
- (3) To determine in detail the temporal and spatial response of the phytoplankton community to low-level fertilization.

This report deals mainly with part 3.

In previous schemes one reason for whole-lake fertilization was to increase the phytoplankton stock in a lake nursery, for example the Great Central Lake project in British Columbia (Parsons, et al. 1972). There is substantial evidence in support of the premise that an increased phytoplankton stock would lead ultimately to an increased fish stock in the lake. However, this premise is heavily underlined by the condition that the dosage of nutrient additions be kept at low levels. Otherwise, nuisance blue-green algae may proliferate which may actually be damaging to the fish stock instead of enhancing it.

With these aims in mind, a low-level enrichment with monoammonium phosphate was implemented on an ultra-oligotrophic basin of Lake Matamek, Quebec, while a contiguous basin was monitored as a control (Figure 1). These two basins lie on the Precambrian Shield in the Matamek watershed and are characterized by dystrophic, moderately acidic waters. The two basins, Lower Baie Philippe (LBP) and Upper Baie Philippe (UBP) are of almost equal size with similar chemical and physical characteristics, and are separated by an island-sill structure. To effect total separation between these two basins, a polypropylene curtain was installed across the sill in the summer of 1978.

In 1977, a phosphorus budget, that is, the total amount of phosphorus input from all sources, was calculated for LBP. Using Vollenweider's model, we related this budget to the phytoplankton biomass (Figure 2) and hypothesized that if the budget could be increased artificially by P-additions, to a point just below the "dangerous level" for LPB as indicated by this model, then, we may also maximize the phytoplankton biomass without causing the system to become eutrophic. We further hypothesized that this increase in primary productivity would not be accompanied by a change in species succession and community structure. This meant that the calculated ambient phosphorus loading of about 22 kg of total P would be increased to a loading of 135 kg in the treatment basin by weekly additions of commercial fertilizer. Table 1 shows the amounts and duration of additions of fertilizer in the summers of 1978 and 1979. The fertilizer was first dissolved in lake water and was dispensed slowly from the platform of a motor-drive catamaran.

The changes in biomass, chlorophyll-a and phosphorus concentrations in both treatment and control basins were monitored weekly from the beginning of the ice-free season until the end of the summer in 1978 and 1979. These changes through time are summarized in Table 2. Note that before fertilization, total phosphorus concentrations between LBP and UBP were not significantly different. At the onset of nutrient enrichment, there was a three-to-four-fold increase in LBP in both years. When fertilization commenced, there was a drastic increase in the chlorophyll-a concentration in the treatment basin in 1978, which coincided with the sharp rise in phosphorus concentrations. The relative increase was not as

noticeable in 1979 which may be attributed to the fact that chlorophyll-a is not an accurate measure of the phytoplankton standing stock for oligotrophic lakes where diatoms and chrysophytes dominate. A much better estimate of standing stock is the phytoplankton biomass. Note that there is essentially no difference between both basins before fertilization, but there is a four-fold increase in the fertilized basin after enrichment in 1978. Again in 1979, there was a sharp increase in LBP over UBP after fertilization. These figures indicate that when N and P were added, there was a concurrent three-to-four-fold increase in biomass standing stock and phosphorus concentrations. This then verified the first part of our hypothesis.

The second hypothesis was that species succession and community structure would not be altered. To verify this, we examined the relative composition of the phytoplankton community with respect to taxonomic divisions in both treatment and control. The seasonal composition of the total biomass for the major taxonomic groups were presented in Figure 3 and demonstrate that the community structure in the fertilized basin was not significantly altered over the period of enrichment. These represent percentages of the daily total biomass contributed by the phytoplankton groups from May to September. Note that trends in succession for both basins were similar. At Spring overturn, the cooler temperatures favored the growth of the dinoflagellates and the flagellated Chrysophytes. The diatoms gained prominence only after the thermocline was established at the beginning of June and remained dominant throughout the summer. Both

the chlorophytes and the cryptophytes stayed at low levels over the entire summer. Therefore, no changes in the community structure with respect to taxonomic distinctions occurred with P-additions.

We also considered the distribution of the total biomass for three different size-classes irrespective of the taxonomic differences (Figure 4). These results also indicated that nutrient addition in LBP did not change the size-class distribution after enrichment.

Next, we examined the distribution with depth (Figure 5). This analysis suggests that there are differences in the depth distribution between treatment and control basins concerning groups 4, 5 and 6, which are the phytoflagellates and the diatoms, but these differences are only apparent below 5 m in the water column in most cases. From this study, it appears that the phytoflagellates, especially the cryptomonads, benefitted disproportionately from the fertilization and selectively occupied the lower depths, probably in response to zooplankton grazing in the upper waters.

Table 3 is a summary of the species which responded positively to the enrichment. Note that of the 20, 16 are flagellates, 11 of which belong to the group Cryptophyceae. Of these 11, 7 species are also found consistently at the lower depths of the water column. This high frequency of flagellate forms displaying a positive response to fertilization probably reflect their competitive advantage in escaping to the lower waters during periods of heavy grazing in the epilimnion. The preponderance of net plankters such as dinoflagellates and diatoms is probably a reflection of their inedibility to the filter-feeding zooplankton. There is also reason

to believe that the hour of fertilization selectively benefitted these net plankters as well, since they have been observed to contribute increasingly to community carbon fixation during the afternoon and evening. Therefore, enrichment in the afternoon in the present study may have unintentionally encouraged the diatoms to proliferate.

In summary then the low-level nutrient additions of N and P were able to elicit concomitant increases in phytoplankton biomass and phosphorus concentrations in the fertilized basin. The diatom, Tabellaria fenestrata was responsible for the greatest portion of the community biomass in both basins. Despite this, the group which displayed the highest relative biomass increase was the phytoflagellates, either small nanoplankton or large ultraplankton, which appeared to contribute disproportionately to the community biomass in the lower depths of the water column. Since grazing data were too tentative for conclusions to be drawn, the extent to which the energy flowed directed from phytoplankton to zooplankton to fish could not be assessed. There is some evidence to suggest, however, that neither of the groups which responded favourably to fertilization enter the food web directly through zooplankton grazing, vis a vis, the diatoms seem to be inedible to filter-feeders and the phytoflagellates appeared to have predator-avoidance strategies through vertical migration. If this is true, then energy transfer through the action of zoobenthic communities in the sediment is implicated. If the productivity of higher trophic levels is partially dependent on the productivity of lake benthic communities, then assessment of the effects of fertilization on the fish stock would be premature without analysis of the sediment composition and

benthic productivity. Future directives for consideration would be to 1) study the portion of the fish diet which would be composed primarily of plankton forms (including the planktivorous fishes which become food for piscivores) and 2) to investigate the portion of the fish diet which is dependent on the benthic community. Much of the untold story in lake tropho-dynamics in Matamek might be revealed through sediment cores, analysis of which may help us further elucidate the role of sedimented plankton in the eutrophication process.

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Fig. 1

Fig. 2. Vollenweider's (1968) model and Lower Baie Philippe (LBP).

Table 1

Amounts and duration of additions of $\text{NH}_4\text{H}_2\text{PO}_4$ (fertilizer) to LBP

YEAR	PERIOD OF ENRICHMENT	KG OF FERTILIZER	P	N
1978	7 weeks	500	135	61
1979	15 weeks*	960	265	116

*includes a two-week period during which no fertilizer was added

TABLE 2

Summary of 1978 observed $[P_{spr}]$, mean $[P_T]$, $[Chlor a]$,
phytoplankton biomass (mg m⁻³) before and after
fertilization in LBP and UBP

BASIN	$[P_{spr}]$	$[P_T]$		$[Chlor a]$		BIOMASS	
		Before	After	Before	After	Before	After
LBP	10.13	8.68	28.27	0.993	3.740	97.49	409.67
UBP	7.53	7.46	5.53	0.849	1.833	148.57	250.50

Fig. 3

Fig. 4. Effect of fertilization on phytoplankton size classes. Solid line = fertilized basin, broken = control.

Fig. 5. Depth distribution of phytoplankton. Solid = fertilized, stippled = control.

Table 3. Summary of the species which responded positively to the enrichment

Edible	Group	Size-Class	Genus & Species	Depth Distribution
Yes	2	Ultra-	<u>Scourfieldia complanata</u>	E
Yes	2	Ultra-	<u>Tetraedron minimum</u> (early)	E
Yes	4	Ultra-	<u>Dinobryon suecicum</u>	E
Yes	6	Ultra-	<u>Chroomonas caudata</u>	E & H
Yes	6	Ultra-	<u>Chr. acuta</u>	E & H
Yes	6	Ultra-	<u>Rhodomonas minuta</u>	E
Yes	6	Ultra-	<u>Rh. minuta</u> v. <u>nanno-planctica</u>	E & H
Yes	6	Ultra-	<u>Cryptomonas caudata</u>	E & H
Yes	6	Ultra-	<u>Katablepharis ovalis</u>	E & H
?	2	Nanno-	<u>Ankistrodesmus falcatus</u> v. <u>acicularis</u> (early)	E
Yes	4	Nanno-	<u>Dinobryon bavaricum</u>	E
?	4	Nanno-	<u>Mallomonas majorensis</u>	E
Yes	6	Nanno-	<u>Cryptomonas erosa</u>	E & H
Yes	6	Nanno-	<u>Cr. erosa</u> v. <u>reflexa</u>	E
Yes	6	Nanno-	<u>Cr. erosa</u> (small form)	E & H
Yes	6	Nanno-	<u>Cr. ovata</u>	E
Yes	6	Nanno-	<u>Cr. brevis</u>	E
Yes	6	Nanno-	<u>Cr. reflexa</u>	E
No	7	Nanno-	<u>Peridinium inconspicuum</u>	E
No	5	Net-	<u>Asterionella formosa</u>	E
No	5	Net-	<u>Tabellaria fenestrata</u>	E & H

For groups see Fig. 5. E = epilimnion, H = hypolimnion.

RIVIERE A LA TRUITE: A STUDY OF A SMALL STREAM DURING THE
SUMMER LOW WATER PERIOD

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Comparative behavior and habitat selection by salmonids were examined in Riviere a la Truite, a tributary of the Moisie River, during the summer low water period. Prior to the summer low flow period, a large percentage of the fish fauna emigrates to the sea leaving behind a remnant population of mostly small individuals. The objective of this study was to examine the ecological relationships between the remaining brook trout (Salvelinus fontinalis) and Atlantic salmon (Salmo salar) juveniles and to present a profile of their activities, habitat selection, and diets in relation to the physical, chemical, and biological characteristics of the stream channel. Results were equivocal; further examination of this system is needed.

APPROCHE GEOMORPHOLOGIQUE DANS LA DETERMINATION
DU POTENTIEL D'ACCUEIL SALMONICOLE DES RIVIERES
DES PRINCIPALES REGIONS PHYSIOGRAPHIQUES DU QUEBEC

par

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ABSTRACT

This research began in 1975 at the Matamek Station. The main objective was to determine by means of aerial photo-interpretation and to map geomorphic processes in regards to physical aspects of potential salmon habitat on the Matamek river. In 1976, this approach was tested on a bigger river, the Moisie and in 1977, these potential sites were ground truthed by biologists. Other rivers were then studied in the James Bay area, in Gaspésie and in the Eastern Townships. Salmon and trout habitats were mapped and the percentage of error from the photo-interpretation was determined in each case.

The importance and the influence of geomorphic environments on salmonid habitats are determined for different physiographic regions.

This method is a contribution to the knowledge of salmon habitat and it gives a new approach for evaluating salmon river capacities.

RESUME

Cette étude débuta en 1975 à la station de recherche Matamek. Son but principal était de lever par photo-interprétation et de cartographier des éléments hydro-géomorphologiques influant sur l'habitat du saumon atlantique sur une petite rivière de la Côte Nord: la rivière Matamek. En 1976, la méthode a été appliquée sur une grande rivière, la Moisie. En 1977, les habitats potentiels pour le saumon, déterminés au cours des années antérieures, ont été visités par des biologistes. D'autres rivières

res ont, par la suite, fait l'objet d'une telle étude à la Baie James, en Gaspésie et dans les Cantons de l'Est. Ces relevés ont permis: dans un premier temps de dégager l'importance et l'influence de différents environnements géomorphologiques sur l'habitat du saumon et dans un deuxième temps, de mettre au point une technique d'inventaire pour évaluer la capacité d'accueil d'une rivière à saumon, avec un degré d'efficacité éprouvé.

Les buts:

A la suite des travaux d'inventaires hydromorphologiques effectués sur une grande et sur une petite rivière à saumon de la Côte Nord du Saint-Laurent, il a été possible de définir clairement les étapes nécessaires à la détermination du potentiel d'accueil salmonicole des principales régions physiographiques du Québec. Ces buts sont de quatre ordres: 1) déterminer les caractéristiques hydromorphologiques des rivières types des principales régions physiographiques du Québec; 2) perfectionner l'outil de travail qu'est la photo-interprétation; 3) voir quelles sont les interrelations entre les différents environnements géomorphologiques et les types d'habitats qu'ils peuvent supporter; 4) dégager les environnements géomorphologiques propices à des habitats de reproduction, de migration et d'élevage pour les salmonidés.

La démarche:

L'inventaire des facteurs hydromorphologiques a été cartographié à l'échelle du 1: 50 000 pour les rivières types des quatre régions physio-

graphiques, soit: la rivière Saint-Jean, en Gaspésie, la rivière Matamek sur la Côte Nord du Saint-Laurent, la rivière Papaskwasati sur le territoire de la Baie James et la rivière au Saumon dans les Cantons de l'Est (figure 1).

Dans un premier temps, le relevé des facteurs hydromorphologiques (figure 2) a été fait par photo-interprétation à l'échelle du 1: 15 000 et un contrôle sur le terrain, pour chaque rivière. Ce contrôle a corrigé et complété l'information obtenue par photo-interprétation, de même qu'il a fourni une expertise sur la qualité des habitats aquatiques potentiels qui avaient été déduits. Dans un deuxième temps, l'inventaire hydromorphologique a été effectué sur la rivière au Saumon, dans les Cantons de l'Est, en utilisant des photographies aériennes avec diverses émulsions réfléchissant dans le vert, le rouge et l'infra-rouge (noir et blanc et fausse couleur). Cet aspect a été étudié dans l'optique d'une recherche sur l'interprétation optimale des facteurs hydromorphologiques.

Les résultats:

- Hydromorphologie et potentiel d'accueil salmonicole

La première étape consiste à comparer les caractéristiques hydromorphologiques des rivières et les habitats aquatiques qui en découlent aux unités géomorphologiques qu'elles recourent. Lors de la deuxième étape, il est possible de déterminer l'importance des environnements géomorphologiques sur les habitats potentiels pour salmonidés, dans différentes régions physiographiques (tableau 1).

RÉGIONS À L'ÉTUDE

Figure 1

LÉGENDE HYDROMORPHOLOGIQUE

BERGE

Morphologie

Talus

Dépôts

Organiques

Limons argiles

Sables

Graviers-galets

Dynamique

Érosion: - Fluviale

- Par glissement

Accumulation

Stable

Végétation

Alnus rugosa

Picea mariana

Abies balsamea

Betula papyrifera

& Populus tremuloides

Culture

LIT

Morphologie

Largeur

0-3 m

3-6 m

6-200 m

Tracé conforme

Chute

Franchissable
Infranchissable

Rapide

Fosse

Seuil

Sédiments

Limons-argiles

Sables

Graviers

Galets-blocs

Roc

Remblaiement

Végétation

AMÉNAGEMENTS

Pont

Quai

Barrage de béton

Digue de castor

Passe migratoire

EXEMPLE DE REPRÉSENTATION

0-200 m

Tracé
Conforme

Dynamique

Végétation

Dépôts

Sédiments

Dynamique

Sédiments

ZONE FAVORABLE À LA

FRAYE DU SAUMON

0-200m

Tracé
Conforme

Figure 2

REGION PHYSIOGRAPHIQUE (rivière type)	HABITATS POTENTIELS		ENVIRONNEMENT GEOMORPHOLOGIQUE	
	Fosse	Frayère		
A. GASPESIE (Appalaches) (rivière Saint-Jean)	x	-	1o	Substratum rocheux
	-	x	2o	Milieu fluvial
	x	x	3o	Deltaïque proglaciaire
	-	-	4o	Deltaïque fluvial
	x	-	4o	Fluvio-glaciaire
	x	-	5o	Glaciaire
B. CÔTE NORD (Bouclier canadien) (Rivière Matamek)	x	-	1o	Substratum rocheux
	x	-	2o	Milieu fluvial
	-	x	3o	Lacustre et marin (littoral)
	x	x	4o	Fluvio-glaciaire
	-	-	5o	Glaciaire
C. BAIE JAMES (Hautes terres) (rivière Papaskwasati)	-	-	1o	Substratum rocheux
	-	-	2o	Milieu fluvial
	-	x	3o	Deltaïque (actuel)
	x	x	4o	Trainée proglaciaire et alluviale
	x	x	5o	Fluvio-glaciaire
	-	-	6o	Glaciaire
D. CANTONS DE L'EST (Appalaches) (Rivière au Saumon)	-	-	1o	Substratum rocheux
	-	-	2o	Milieu fluvial
	x	x	3o	Lacustre (ancien)
	x	x	4o	Fluvio-glaciaire
	x	x	5o	Glaciaire
	-	-		

x = Présence - = Absence

TABLEAU 1 : IMPORTANCE DES DIFFÉRENTES RÉGIONS PHYSIOGRAPHIQUES ET DE LEUR ENVIRONNEMENT
GEOMORPHOLOGIQUE SUR LES HABITATS POTENTIELS POUR LES SALMONIDES

A partir de l'analyse des différents environnements géomorphologiques, on peut donc évaluer quel milieu offre la ou les meilleures aptitudes à supporter un potentiel d'accueil salmonicole.

Des quatre rivières types à l'étude, le milieu aquatique dans le substratum rocheux s'est avéré propice à la présence de fosses sur les rivières de la Gaspésie et de la Côte Nord. Bien que le modelé structural de ces deux régions soit différent, sa vulnérabilité à l'érosion en est la principale cause.

Le milieu fluvial, bien qu'il soit présent sur les quatre rivières types, est dans la majorité des cas associé au substrat rocheux, exception faite pour la rivière Saint-Jean en Gaspésie, où la présence de matériaux détritiques est dominante. En Gaspésie, ce milieu favorise la présence de frayères, grâce à la répartition granulométrique idéale des sédiments. Ailleurs, ce milieu est non propice à de bons habitats.

L'environnement deltaïque ancien est présent en Gaspésie. Ce milieu est apte à supporter un potentiel d'accueil. La dynamique fluviale qui remanie ces sédiments principalement composés de graviers crée de bonnes fosses et de bonnes frayères.

Le milieu deltaïque actif ou actuel se retrouve dans deux régions à l'étude: la Gaspésie et la Baie James. Ce milieu n'offre aucun bon potentiel dans une limite estuarienne comme la rivière Saint-Jean. En milieu lacustre, il peut toutefois exister un faible potentiel de frayères pour la truite, prenant l'exemple de la rivière Papaskwasati où l'on retrouve des seuils sableux et graveleux.

L'environnement lacustre ou marin (littoral), qu'il soit présent à la Baie James, sur la Côte Nord ou dans les Cantons de l'Est, n'offre qu'un faible potentiel de fosses sur la rivière au Saumon (Cantons de l'Est) et un faible potentiel de frayères sur les rivières au Saumon et Matamek (Cantons de l'Est et Côte Nord). Les matériaux sont trop fins et ils contribuent dans la majorité des cas au colmatage des sites qui pourraient exister.

Dans un environnement à traînée proglaciaire, la morpho-sédimentologie des cours d'eau est telle qu'on y retrouve de très bons habitats de reproduction et d'élevage pour les truites. Ce milieu sédimentaire apparaît couramment sur le territoire de la Baie James mais souvent le courant est trop faible pour que les truites y soit présentes.

Le milieu fluvio-glaciaire, qu'il soit de contact glaciaire ou de fusion, offre un très bon potentiel pour l'accueil des salmonidés dans trois des quatre régions étudiées. En Gaspésie, la granulométrie diffère des autres régions; ses caractéristiques plus grossières, ainsi que la difficulté des sédiments à être érodés, dû à la grande compaction du dépôt, en font un milieu peu propice à la formation de frayères. Il peut toutefois y avoir de bonnes fosses relativement stables.

Le milieu d'origine glaciaire est présent dans les quatre régions étudiées. En Gaspésie et dans les Cantons de l'Est, les formations glaciaires sont propices à la création de fosses. Ce milieu offre un bon potentiel pour la présence de frayères à truites dans les Cantons de l'Est, lorsqu'il est peu remanié ou lessivé. Grâce à la présence de matériaux dont la granulométrie est hétérogène et le plus souvent grossière, le domaine

glaciaire offre de bons sites d'élevage sur toutes les rivières étudiées.

- La photo-interprétation

L'efficacité de la photo-interprétation a pu être déterminée car les habitats aquatiques des rivières étaient inventoriés au préalable par des biologistes. Les résultats, de même que l'efficacité obtenue pour la détection des fosses et des frayères sur les différentes rivières, sont présentés aux tableaux 2 à 6.

- La photographie aérienne panchromatique

La principale limite est l'échelle de la couverture aérienne. Considérant qu'il faut habituellement utiliser les documents usuels qui sont toujours disponibles et qui sont donc les moins coûteux, il est recommandé d'employer des photographies panchromatiques noir et blanc au 1: 15 840. A cette échelle, la majorité des facteurs sont identifiables par un photo-interprète moyen. Les difficultés s'amenuisent avec une échelle plus grande, si disponible, mais elles augmentent d'une façon exponentielle avec des échelles plus petites comme le 1: 20 000 par exemple.

Deux autres limites reliées à la prise de vues sont importantes à connaître: ce sont l'heure et le temps de l'année où ont été prises les photographies. Il arrive parfois que des prises de vue se font vers l'heure du midi, alors que le soleil est au zénith: l'émulsion photographique enregistre alors la réflexion sur les plans d'eau qui deviennent blanchâtres et qui ne peuvent plus transmettre d'informations. Idéalement, il faudrait aussi utiliser des couvertures aériennes prises en temps de frai, entre la mi-octobre et le début de novembre et en dehors d'une période de crue ou de

TABEAU 2 - LEVÉS DES FOSSES DE LA RIVIÈRE SAINT-JEAN EN GASPÉSIE

Secteurs	Levés de terrain			Correspondant à des zones connues		Correspondant à des zones connues		Ne correspondant pas à des zones connues		Ne correspondant pas à des zones connues		Fosses connues non identifiées	
	Connues du NTCP en 1977	Connues en 1979	Total	Princ.	Sec.	Photo 1977	Photo 1979	Princ. et sec.	Photo 1977	Princ. et sec.	Photo 1979	Princ.	Sec.
Aval	7	7	7	4	0		6			1		1	0
Club	29	27	28	12	0		23			2		4	0
Amont	19	17	24	13	0		16		10	2		1	6
Sanctuaire et Saint-Jean-Sud	11	10	11	4	0		8		1	0		2	1
Total	66	61	70	33	0		53		17	5		8	7

TABLEAU 3 - LEVÉS DES FRAYÈRES DE LA RIVIÈRE SAINT-JEAN EN GASPÉSIE

Secteurs	Levés de terrain			Correspondant à des zones connues Photo 1977		Correspondant à des zones connues Photo 1979		Ne correspondant pas à des zones connues Photo 1977		Ne correspondant pas à des zones connues Photo 1979		Prayères connues non identifiées Photo 1979
	Connues du MTCP en 1977	Connues du MTCP en 1979	Total	Princ.	Sec.	Princ.	Sec.	Princ.	Sec.	Princ.	Sec.	
Aval	2	5	7	0	0	4	2	0	0	0	0	1 0
Club	7	10	18	3	0	8	5	6	3	3	3	2 3
Amont	11	12	23	6	0	7	5	6	4	4	6	5 6
Sanctuaire et St-Jean-Sud	3	3	5	1	0	2	0	4	0	0	2	1 2
Total	23	30	53	10	0	21	12	16	7	9	11	

SECTEUR	TERRAIN		PHOTO-INTERPRÉTATION					
	Zones connues du M.T.C.P.		Correspondant à des zones connues		Ne correspondant pas à des zones connues*		Ne correspondant pas à des zones connues et non visitées	
	Fosses	Frayères	Fosses	Frayères	Fosses	Frayères	Fosses	Frayères
Rivière Matamek	12	5	12	5	0	0		6
Rivière aux Rats-musqués	0	0	0	0	0	1	10	1
Ruisseau Thom	0	0	0	0	0	1		
Rivière Tchinicaman	0	0	0	0	0	0	12	1
Total	12	5	12	5	0	2	22	8

* Les fosses et les frayères ne correspondant pas à des zones connues qui ont été vérifiées sur le terrain se sont avérées inefficaces.
Validité: 100% des fosses entre 53 et 87% des frayères

TABEAU 4 : LEVÉS DES FOSSES ET DES FRAYÈRES SUR LE BASSIN DE LA RIVIÈRE MATAMEK

SECTEUR	TERRAIN		PHOTO-INTERPRÉTATION			
	Zones connues du M.T.C.P.		Correspondant à des zones connues		Ne correspondant pas à des zones connues*	
	Fosses	Frayères	Fosses	Frayères	Fosses	Frayères
Rivière au Saumon	19	3	10	3	8	4
Ruisseau à la Loutre	-	-	1	-	14	6
Ruisseau Bown	1	-	1	-	16	4
Rivière Ditton	-	-	4	1	18	10
Rivière Chesham	1	1	1	2	12	0
Total	21	4	17	6	68	24

* Ces fosses et ces frayères qui ne correspondent pas à des zones connues n'ont pas été vérifiées.

Validité: Fosses: 57%
Frayères: 100%

TABLEAU 6 : LEVÉS DES FOSSES ET DES FRAYÈRES SUR LE BASSIN DE LA RIVIÈRE AU SAUMON

SECTEUR	TERRAIN		PHOTO-INTERPRÉTATION		
	Frayères potentielles	Zones connues Fosses	Frayères	Fosses	Zones connues non identifiées
Rivière Papaskwasati	9	40	9	40	0
Rivière Neilson	-	-	1	9	0
Ruisseau Holton	-	-	1	2	0

Validité : 100% des frayères
100% des fosses

TABLEAU 5 : LEVÉS DES FOSSES ET DES FRAYÈRES SUR LE BASSIN DE LA RIVIÈRE PAPASKWASATI

trop grand étiage. Les débits extrêmes ne permettent pas d'apprécier avec assez d'exactitude l'emplacement et l'état d'émersion des bancs de gravier qui servent de frayère.

Dans le cas d'une couverture aérienne adéquate, les deux problèmes majeurs d'identification sont les fosses et la texture des matériaux.

La localisation des fosses est facile dans la plupart des régions mais lorsque leur profondeur dépasse 1,5 à 2 m, cette dernière ne peut être évaluée avec certitude que sur le terrain. Au contraire, en Gaspésie, la transparence de l'eau, due au fait qu'il n'y a pratiquement pas de production de sédiments fins, permet une forte pénétration de l'émulsion et ne permet de localiser avec certitude que les fosses de plus de 2 m de profondeur.

L'identification de la texture des matériaux, surtout les graviers, est primordiale dans ce genre d'étude. Sur les berges, la texture n'est identifiable qu'à partir des ensembles géomorphologiques homogènes, à partir de l'allure de la topographie et des talus, ainsi qu'à partir de la reconnaissance des formes d'érosion caractéristiques de chacune des textures. Sur le lit des cours d'eau, elle n'est observable que dans les secteurs de rapides et de seuils, avec l'aide d'un binoculaire 3X. Dans la majorité des régions, on distingue les secteurs rocheux et les principales catégories de texture, mais il faut souvent s'aider de la nature des berges. En Gaspésie, l'homogénéité de couleur des roches et, par le fait même des matériaux produits, rend la granulométrie des sédiments grossiers difficilement appréciable parce que l'on n'y trouve pas, contrairement à d'autres régions, d'éléments foncés donnant un bon contraste parmi des éléments

généralement pâles. De la même façon, il est difficile de distinguer le roc émergé de ces sédiments parce que le roc est fortement altéré en surface et parce qu'il produit des matériaux meubles d'une même couleur homogène. Le roc immergé, cependant, se distingue très bien parce qu'on peut y déceler un réseau orthogonal de fractures.

- La photographie aérienne multi-spectrale

L'utilisation de photographies multi-spectrales a été expérimentée dans les Cantons de l'Est sur un segment de la rivière du Nord, affluent de la rivière Eaton. Le choix de ce secteur repose sur la disponibilité des documents et sur les nombreuses recherches qui ont été menées, soit par l'Université de Sherbrooke, soit par le gouvernement du Québec, dans le cadre des études intégrées du bassin versant de la rivière Eaton.

Cette vérification compare le degré d'identification des facteurs hydromorphologiques d'une photographie panchromatique (0,5-0,7 μ) usuelle par rapport à d'autres photographies dans diverses bandes spectrales réfléchissant dans le vert (0,5-0,6 μ), dans le rouge (0,6-0,7 μ), dans l'infra-rouge noir et blanc (0,7-0,9 μ) et dans l'infra-rouge couleur (0,9-1,3 μ). La date de la photographie est prise en considération au même titre que les bandes spectrales. L'échelle moyenne de la photographie panchromatique est de 1: 15 840 et celle des autres bandes, de 1: 40 000. Ces photographies ont été observées, dans le cas de la première bande, avec un facteur de grossissement de 10X, donc à l'échelle de 1: 1 600 approximativement. Dans le deuxième cas, un facteur de grossissement de 13X a été utilisé, pour une observation à l'échelle de 1: 3 000 approximativement.

L'observation à grande échelle similaire des photographies permet d'en tirer des résultats significatifs et non biaisés.

En se référant au tableau 7, il est possible de dégager les résultats suivants:

1^o La photographie panchromatique prise au printemps permet une identification facile de la sédimentologie du lit ainsi que des fosses. Le roc est facilement identifiable, de même que la dynamique des berges. Par ailleurs, la nature des berges est plus difficilement identifiable et doit être déduite de la géomorphologie terrestre. La végétation est identifiable, mais cela nécessite une clef d'interprétation bien définie, compte tenu du faible contraste du couvert végétal et de sa densité.

2^o La bande réfléchie dans le vert n'offre aucune interprétation du milieu aquatique au printemps, sauf pour la dynamique des berges et pour la végétation, qui sont facilement identifiables. Les prises de vue en été et en automne sont similaires, quoique les blocs et les graviers dans le lit sont identifiables à cause de la faible profondeur d'eau. En été, la végétation y est bien difficilement identifiable.

3^o La bande réfléchie dans le rouge au printemps n'offre aucune vision des facteurs rattachés au lit du cours d'eau; par ailleurs, la nature des berges est identifiable, de même que leur dynamique et leur végétation. En été, les blocs et les graviers sont identifiables comme dans la bande verte. La végétation des berges est peu visible.

4^o L'infra-rouge noir et blanc, dû à son faible contraste et à sa forte absorption dans l'eau, ne laisse voir aucun facteur hydromorphologique rattaché au lit, mais il est possible d'identifier la nature des

TABEAU 7 : LIMITES DE LA PHOTOGRAPHIE AERIENNE MULTISPECTRALE

BANDE SPECTRALE	LIT				BERGES								VEGETATION
	SEDIMENTOLOGIE			FOSSES	NATURE				DYNAMIQUE				
	Blocs	Gravier	Sables		Roc	Blocs	Sables	Limon- argile	Erosion	Accumulation			
P E A	● -- --	● -- --	○ -- --	● -- --	○ -- --	○ -- --	○ -- --	○ -- --	● -- --	● -- --	○ -- --		
P E A	● ○ ○	● ○ ○	● ○ ○	● ○ ○	● ○ ○	● ○ ○	● ○ ○	● ○ ○	● ○ ○	● ○ ○	● ○ ○		
P E A	● ○ --	● ○ --	● ○ --	● ○ --	○ ○ --	○ ○ --	○ ○ --	○ ○ --	● ○ --	● ○ --	● ○ --		
P E A	● ● ●	● ● ●	● ● ●	● ● ●	○ ○ ○	○ ○ ○	○ ○ ○	○ ○ ○	○ ○ ○	○ ○ ○	○ ○ ○		
P E A	○ ○ --	● ● --	● ● --	● ● --	○ ○ --	○ ○ --	○ ○ --	○ ○ --	● ● --	● ● --	● ○ --		

P Printemps
 E Eté
 A Automne
 ● Facilement identifiable
 ○ Identifiable
 ● Peu ou pas visible
 -- Non disponible

berges à partir des caractéristiques de drainage des dépôts en bordure de celles-ci. Dans ce cas, les meilleurs résultats correspondent à des prises de vue en été.

5° L'infra-rouge couleur, dont la fenêtre spectrale (0,5-0,7 μ) capte le visible, offre une vision facile de la nature et de la dynamique des berges au printemps et en été. La végétation est facilement identifiable au printemps, comparativement à l'été. Les fosses sont faciles à identifier durant cette saison; par ailleurs, la sédimentologie du lit l'est moins.

Dans le cadre de ce relevé, la photographie panchromatique donne une vision optimale pour le milieu aquatique. L'utilisation de l'infra-rouge couleur permet une identification plus précise des fosses, en été et de la végétation des berges, en automne.

A une échelle moyenne de 1: 15 000, les photographies aériennes noir et blanc et couleur procurent de très bonnes informations sur le milieu aquatique en général. Pour une meilleure résolution, l'échelle du 1: 1 000 ou voisine, sur émulsion infra-rouge couleur, permet l'identification précise du milieu aquatique, tout particulièrement pour la végétation.

Conclusion

Pour l'ensemble des régions étudiées, les environnements géomorphologiques susceptibles d'offrir des habitats propices aux salmonidés se résument ainsi: les aires de reproduction et de séjour se retrouvent principalement dans des environnements deltaïques proglaciaires et à traînées proglaciaires ou fluvioglaciaires. Les aires d'élevage se retrouvent prin-

principalement sur des formations d'origine glaciaire ou typiquement fluviales.

Les niveaux d'efficacité de la photo-interprétation ont été obtenus par des relevés sur des rivières dont on connaissait les habitats.

. Gaspésie:	86% des fosses sont détectées
75% des frayères sont détectées
. Côte Nord:	100% des fosses sont détectées
de 53 à 87% des frayères sont détectées
. Baie James:	100% des fosses sont détectées
100% des frayères sont détectées
. Cantons de l'Est:	57% des fosses sont détectées
100% des frayères sont détectées.

Cette méthode d'inventaire du milieu aquatique permet d'identifier et d'évaluer les habitats avec un niveau d'efficacité éprouvé. Son utilisation dans la classification des cours d'eau peut, d'une part, servir à comparer le potentiel d'accueil de différentes rivières et, d'autre part, contribuer à l'évaluation de la productivité d'un cours d'eau.

INTRODUCTION

UNIVERSITÉ LAVAL
DÉPARTEMENT DE GÉNIE CIVIL

RECUEIL DE DONNÉES SUR LES CARACTÉRISTIQUES
HYDRO-PHYSIQUES DU BASSIN DE
LA RIVIÈRE MATAMEC

en rapport avec la subvention de
recherche accordée par

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Objectifs

par

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Mars 1980

INTRODUCTION

La station de recherche de Matamec est située à l'embouchure de la rivière du même nom, à quelques 18 milles à l'est de Sept-Iles. Elle possède une longue histoire au niveau de la recherche en biologie. Dès 1931, sous les auspices de monsieur Copley Amory, se tenait une conférence sur la périodicité biologique de la rivière. Bien que depuis lors, l'activité de la station fut périodiquement interrompue, les recherches biologiques ont pris un regain de vigueur depuis 1969. En plus du personnel de "Woods Hole Oceanographic Institution" directement impliqué à la station, plusieurs groupes universitaires canadiens s'y sont impliqués depuis. Il en résulte que l'information biologique présentement disponible est volumineuse et variée. Cependant, l'information concernant le milieu physique et l'interrelation existant entre les paramètres physiques et biologiques est longtemps demeurée à l'état embryonnaire. Ce rapport vise à combler cette défaillance en tentant de rassembler dans un seul rapport les données éparses contenues dans différents rapports individuels.

Objectifs

L'objectif de la présente étude consiste donc à établir une image des principales caractéristiques physiques du bassin versant et de la rivière Matamec principalement en rapport avec l'hydro-biologie et la morphologie du cours d'eau.

Ce rapport synthèse vise à regrouper l'information appartenant à des domaines aussi diversifiés que: la physiographie, la climatologie, la foresterie, la géologie, la géomorphologie, la morphologie, l'hydrologie, l'hydraulique et la sédimentologie; la géologie et géomorphologie ayant fait l'objet d'une étude à part réalisée par J.M. Dubois et G. Demarais, Université de Sherbrooke.

Approche

Les relevés effectués sur le bassin de la rivière Matamec se partagent en quatre parties principales. La première partie contient l'information générale relative au bassin versant dans une perspective comparative du bassin étudié avec l'ensemble des bassins versants de la Côte nord. Les caractéristiques hydrologiques du bassin versant de la Matamec sont présentées dans la seconde partie du rapport. Une étude de corrélation entre les débits journaliers des bassins versants ayant montré une certaine affinité avec celui de la rivière Matamec est alors élaboré afin de reconstituer les statistiques de débit de la Matamec.

Dans la troisième partie du rapport, les données relatives à l'aspect physique du tronçon de la rivière Matamec compris entre l'embouchure et la 5ième chute (6,4 km) sont présentées en relation avec l'aspect hydro-morphologique de la rivière et également en vue d'études hydro-biologique. La dernière partie, rattachée à l'aspect hydraulique, sert de lien entre les deux parties précédentes en indiquant les relations existant entre les caractéristiques physiques, et hydrauliques de la rivière.

Limites du rapport

L'objectif visé par les auteurs étant de présenter un inventaire de données physiques à l'intention des ingénieurs et biologistes effectuant des recherches à Matamec, **Le** rapport doit être considéré comme un recueil de données plutôt qu'un rapport de recherche dans le sens étymologique du mot. Les recherches découlant des différentes données ci-jointes ont fait l'objet de publications distinctes.

CHARACTERISTICS OF PEATLANDS OF THE SEPT-ILES AREA

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During July, 1980, ten peatlands in the Sept-Iles area were examined for their vegetation peat characteristics and chemical properties. This work was part of a preliminary survey of peatlands in northeastern Quebec, with a similar study being undertaken at Schefferville.

Although they exhibited different shapes, sizes and morphologies, the peatlands showed little variation in their surface vegetation characteristics. Species diversity was low and most of the peatlands fell into the DEI and EI types of Radforth's (1973) classification. Depth of peat material was variable, up to 7 m, but in nearly all cases, the peat was poorly decomposed, being H2 to H4 on the Van Post humification scale. This slow degree of decomposition is related, in part, as a suspension, varied from 3.0 to 4.3, whilst surface water samples had pH values in the range of 4.1 to 4.5. The oligotrophic nature of these peatlands is indicated further by the low concentrations of calcium, magnesium and sodium in surface waters. Concentrations of calcium and magnesium were very low (generally < 0.5 ppm), whilst sodium concentrations ranged from 0.7 to 9 ppm, the highest values being recorded in the peatlands closest to the sea, reflecting the importance of atmospheric inputs of sea salt. Those peatlands close to the shore also tended to have high pH values in surface water and peat samples.

Thus, the peatlands of the Sept-Iles area show remarkably uniform oligotrophic characteristics, with the only major chemical difference associated with distance from the sea shore. By comparison, the peatlands of the Schefferville area, although less extensive and shallower, show a wider range from minerotropic to oligotrophic, reflecting the influence of dolomitic rocks beneath the peatlands.

STUDIES ON THE NATURAL PRODUCTS OF MARINE ORGANISMS

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This report indicates the progress that has been realized on the structural elucidation of certain secondary metabolites of marine organisms collected along the north coast of the Gulf of the St-Lawrence. Our studies have dealt with the saponins (toxic defense substances) of the sea cucumbers Psolus fabricii and Cucumaria frondosa as well as the natural products of the red alga Ptilota serrata.

In regard to the major saponin (Psoluthurin A) of P. fabricii, we have identified the aglycone and the four sugars. We have also determined the relative quantities of the latter as being equimolecular and have detected the presence of a sulfate group. The following structure is proposed:

The sequence of the sugars as well as the location of the sulfate group is presently under active study. Initial results indicate 3-O-Meglucose or glucose as the terminal sugar.

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We have isolated five saponins from C. frondosa collected from Amory cove. The relative quantities of the sugar moieties for these toxins are shown in the following table:

SUGARS	A	FRONDOSIDES SAPONINS		
		B ₁ + B ₂	C ₁	C ₂
XYLOSE	3	2	2	2
QUINOVOSE	1	1	1	1
3-O-MeGLUCOSE	1	1	1	1
GLUCOSE	0	1	1	1

A positive rhodizionate test (sulfate group) was observed for the frondosides. The following partial structure is proposed for Frondoside A:

β -Sitosterol and palmitic acid were isolated from the hexane extracts of the red alga P. serrata collected in part along the shore facing the Matamek Research Station. A third substance has been tentively identified as a close derivative of taraxerol, one of the few triterpenes found in marine organisms. Experiments are planned in 1981 to search for feeding deterrents in this alga as it is an unpopular food source with the sea urchin Strongylocentrotus droebachiensis.

A new area of study is presently underway dealing with the effect of predation of the starfish Leptasterias polaris on the subtidal community of the north coast of the St-Lawrence. This project is in collaboration with John Himmelman presently with the Ministry of Fisheries and Oceans of the government of Canada.

A BLUE WHALE (Balaenoptera musculus)(1) SIGHTING IN EARLY APRIL IN
THE GULF OF ST. LAWRENCE NEAR SEPT-ILES, QUEBEC.

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Historically, the blue whale Balaenoptera musculus, occurred in the Gulf of St. Lawrence and St. Lawrence River estuary though the size of the pre whaling population is uncertain (Leatherwood et al. 1976; Sergeant 1966). Catch records from whaling stations within the Gulf indicate the greatest concentrations of blue whales occurred in June and July (Sergeant 1966), although some whales entered in Spring with "ice out" and remained through November (Leatherwood et al. 1976). Severe over-exploitation of whale stocks drove North Atlantic blue whales to near-extinction by the 1920's (Jonsgard 1955). Present North Atlantic blue whale populations at the upper limit are estimated at 2000, though the population could be considerably smaller (MacIntosh 1972). Leatherwood et al. (1976) feels enough animals are present to support continued growth of populations, barring renewed exploitation. Here we report what we believe to be the earliest spring sighting of a blue whale in the Gulf of St. Lawrence in recent years. Mr. Richard Sears (Mingan Island Cetacean Study) and Mr. Wyb Hoek (Arctic Biological Station) identified the whale as a blue whale from our photographs, but Dr. William Schevill (Woods Hole Oceanographic Institution) was unwilling to confirm the identification on the basis of our photographs and field notes.

We first sighted the whale at about 1600 h, 14 April 1980, approximately 22 km east of Sept-Iles, Quebec, and 5 km offshore. We observed and photographed the animal for 50 minutes from a 6 m long skiff. The weather was sunny and calm, and the whale appeared neither interested in nor disturbed by our presence. Most observations were made from distances less than 100 m, and we approached on occasion to within 10 m.

From comparisons with our skiff we estimated the whale's length to be at least 18 m; the breadth of the portion of the back out of water as the whale exhaled and dove was 2-2.5 m. The dorsal fin was smoothly falcate (Leatherwood et al. 1976) and the color of the back was mottled blue-black. We noticed no scars or irregularities in the outline of fin.

The whale was alone, which is consistent with tendencies for blue whales to travel alone or in pairs (Ruud 1956). During the 50 min period of observation, the whale remained within approximately 1 km of its initial location. Although we detected no specific pattern of movement, the animal changed direction frequently and moved slowly (we were able to keep pace with the whale at low throttle). Dives lasted 5-7 minutes (4 timed dives). The flukes were never raised above the surface and the angles at which the whale submerged indicated shallow dives. The whale's movements within a circumscribed area suggested it might be feeding; we observed dense patches of mysids throughout the area, and noted a Minke whale (Balaenoptea acutorostrata) exhibiting similar meandering behavior within 1-2 km of the blue whale. During April we frequently sighted Minke whales in areas characterized by dense patches of mysids.

During one period while the whale was on the surface, we saw it roll on its side and raise one flipper out of the water. Somewhat later the whale rolled onto its back and extended both flippers above the surface. We have found no other reports of similar behavior by blue whales to date.

The pre-whaling population of blue whales in the Gulf of St. Lawrence and Newfoundland/Labrador region was estimated at 1500 (Sergeant 1966). Whaling activities centered in Newfoundland and Sept-Îles itself (where 28 blue whales were taken from 1911-1915; Sergeant 1966) made sightings of blue whales in the Gulf a relatively rare event (Sergeant 1970). Hunting of blue whales anywhere is currently prohibited by the International Whaling Commission. Our sighting of a blue whale in early April, and the recent report by Sears (1980) of Right whales (Eubalaena glacialis) in the Gulf of St. Lawrence after their absence, may reflect increases in population size and/or return to pre-whaling patterns of movements by whales in this area.

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