Woods Hole Oceanographic Institution

WHOI-80-31

MATAMEK
RESEARCH STATION

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MATAMEK ANNUAL REPORT FOR 1979

by

Robert J. Naiman

June 1980

TECHNICAL REPORT

*Prepared by the Woods Hole Oceanographic
Institution and the Department of Recreation,
Fish and Game of the Province of Quebec.*

WOODS HOLE, MASSACHUSETTS 02543

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Approved for Distribution:

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ABSTRACT

This report describes activities associated with the Matamek Research Program in 1979. Research was conducted on biological, chemical, and physical factors of lakes and rivers, principally in the Moisie and Matamek River watersheds, and on salmonid ecology and sea-ranching of brook trout in the Matamek River. Canadian universities, the Quebec government and the Woods Hole Oceanographic Institution cooperated in this program.

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INTRODUCTION

The scientific research of the Matamek Research Program currently has two long range objectives. These are: (1) to describe major structural and functional properties of river ecosystems of boreal areas in a watershed perspective and, (2) to explore means of directly increasing the production and yield of salmonids. These seemingly separate objectives will be combined in subsequent years into a single program in which salmonid production will be related to the river ecosystem (watershed) supporting the fishery. Eventually the consequences of experimental manipulations on the riverine community will be examined in a manner which will allow sound management decisions to be made with regard to the salmonids and their riverine habitat.

In 1979 the Matamek Research Program focused on three major areas. These were: (1) an integrated analysis of large watersheds, (2) sea-ranching of brook trout (Salvelinus fontinalis), and (3) monitoring of the Atlantic salmon (Salmo salar) population. In addition to these core programs, continuing studies of lake fertilization and salmonid behavior were completed.

The integrated ecosystem analysis of streams and rivers included metabolism and production, characterization of drifting organic matter, decomposition dynamics of leaves and woody debris, and monitoring the hydrogen ion concentration and buffering capacity of precipitation and stream water. These studies will be largely completed during the 1980 field season. The watershed analysis will continue in other areas, forming a major portion of the Matamek Research Program in subsequent years.

The experimental sea-ranching project completed the second year of a proposed five year study. In 1979 the project continued to explore the feasibility of directly enhancing salmonid production through sea-ranching. This phase of the field program is now finished. Studies in 1980 will emphasize the comparative life histories of natural and artificially induced sea trout, movements of sea trout within a river system relative to season and food availability, and the role of size and age in determining osmo-regulatory ability.

Studies of Atlantic salmon consisted of measuring growth and population size of the parr in selected areas, estimating the size of the smolt migration, the time of their seaward migration, and correlating smolt movements with water temperatures and discharge. Returning adults and grilse were counted, scales taken for age and growth, and an estimate made of the number of fish returning. These studies provide a continuance with studies of previous years.

Field studies of behavioral interactions between juvenile brook trout and Atlantic salmon, and of phytoplankton ecology, resulting from lake fertilization by Canadian graduate students were completed this year. The results of these and other canadian graduate student projects are amplified in the following research summaries.

The Matamek Research Program offers a unique 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 an opportunity for strong programs that

can continue indefinitely. The cooperation this program has received from researchers of 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 in many ways by the Quebec government and our Canadian colleagues.

Robert J. Naiman

Coordinator, Matamek Research
Program

INTRODUCTION

Les travaux de recherches scientifiques poursuivis par le Programme de Recherches de Matamek ont actuellement deux objectifs à longue portée. Ce sont: (1) de décrire les principales propriétés structurelles et fonctionnelles des systèmes écologiques des cours d'eau des régions boréales, en ce qui concerne le bassin fluvial, (2) d'explorer les moyens d'augmenter directement la production et le rendement des salmonidés. Ces deux objectifs qui, au premier abord, paraissent si différents, vont se joindre dans les années suivantes pour ne faire qu'un seul programme. Dans ce programme la production des salmonidés sera reliée au système écologique fluvial (bassin fluvial) dont dépendent les établissements de pêche. On examinera à la longue les effets de la manipulation expérimentale sur la communauté fluviale, et on fera cette étude de façon à arriver à de saines décisions pour les salmonidés et leur habitat fluvial.

En 1979 le Programme de Recherches de Matamek a concentré ses études sur trois domaines principaux: (1) une analyse complète des grands bassins fluviaux, (2) la pisciculture maritime de l'omble de fontaine (Salvelinus fontinalis), et (3) le recensement de la population des saumons Atlantiques (Salmo salar). En plus de ces programmes de base, on a complété les études en cours sur la fertilisation des lacs et sur le comportement des salmonidés.

L'analyse complète du système écologique des rivières et des fleuves comprenait le métabolisme et la production, la caractérisation des matières organiques charriées par les eaux, la dynamique de la décomposition des feuilles et de déchets de bois, et le contrôle de la concentration des ions

d'hydrogène, et aussi l'observation des eaux de pluie et des eaux fluviales par rapport à leur faculté de maintenir un équilibre chimique. On complètera ces études, du moins en grande partie, pendant la période de recherches de 1980. L'analyse du bassin fluvial se poursuivra dans d'autres domaines et formera, dans les années consécutives, une partie importante des travaux effectués par le Programme de Recherches de Matamek.

Le projet expérimental de pisciculture maritime a complété sa seconde année d'études qui s'étendront sur une période de cinq ans. En 1979 le projet a continué à étudier la possibilité d'augmenter directement par cette pisciculture la production des salmonidés. Cette phase du programme est maintenant terminée. En 1980 on étudiera surtout la vie des truite de mer en comparant celles qui sont nées dans les rivières et celles qui ont été créées artificiellement; on étudiera les déplacements de l'omble de fontaine à l'intérieur du système fluvial, selon la saison et la nourriture disponible; on examinera l'influence de la taille et de l'âge pour déterminer la capacité osmo-régulatoire.

Les études du saumon Atlantique consisteront à mesurer le développement et le nombre des tacons dans des régions prédéterminées, à estimer l'étendue de la migration des saumoneaux, l'époque de leur migration vers l'océan et la corrélation entre les déplacements de ces poissons, et la température et le débit des rivières. On a procédé à un calcul des poissons adultes qui remontent la rivière et des grilse qui reviennent pour la première fois; on a établi des échelles selon leur âge et le niveau de leur croissance et on a évalué le nombre des poissons revenus. Ces études font suite à celles qui ont été poursuivies les années précédentes.

On a terminé cette année-là (1979) les observations faites sur les interactions dans le comportement entre les jeunes ombles de fontaine et les jeunes saumons Atlantiques; on a aussi complété les études sur l'écologie du phytoplancton résultant de la fertilisation des lacs entreprise par des étudiants universitaires canadiens. Les abrégés suivants s'étendent sur les résultats de ces derniers projets et d'autres exécutés également par des étudiants universitaires canadiens.

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

Coordinator

LIST OF PERSONNEL

Woods Hole Oceanographic Institution

R.J. Naiman
F.G. Whoriskey
W.L. Montgomery
E.M. Ellis
Vickey Cullen
James Mitchell

Universite du Quebec a Chicoutimi

Francois Garneau
Denis Larribee
Jean-Luc Simard

University of Guelph

Thomas Dickson
Hugh MacCrimmon
Jacqueline McGlade

University of Toronto

Nancy Williams
Dudley Williams

University of Waterloo

Patricia Chou
Hamish Duthie
Authur Harrison
Gary Kramer
Phil Ross

Universite de Laval

Marcel Frenette

Others

James Critchley
Peter Heinerman
Sandra George
M. Evrade Boudreault
Gloria Blair
Richard Sears
Lise Paquin

MATAMEK CANADIAN AWARDS - 1979
25/4.01

Principal Investigator	Affiliation	Title of Proposal	Award C\$
Marcel Frenette	University of Laval	Synthesis of Chemical and Physical Studies of the Matamek River	C \$ 3,000
Hamish Duthie	University of Waterloo	Changes in Phytoplankton Biomass, Size Structure and Species Composition Following Low-Level Fertilization in Lower Baie Phillippe, Lake Matamek, Quebec	4,700
Hugh MacCrimmon	University of Guelph	Comparative Growth and Behavior of <u>Salvelinus fontinalis</u> and Juvenile <u>Salmo salar</u> in the Matamek River	6,996
			<hr/>
TOTAL AWARDS			C \$ 14,696

PUBLICATIONS - 1979
Scientific Papers

Matamek Contribution
No.

- 34 Janus, L.L., and H.C. Duthie. 1979. Phytoplankton and primary production of lakes in the Matamek watershed, Quebec. *Int. Rev. ges. Hydrobiol.* 64: 89-98.
- 35 Dubois, J.-M. Geomorphologie du littoral de la cote nord du Saint-Laurent: Analyse sommaire. IN: The Coastline of Canada: Littoral Processes and Shore Morphology.
- 36 Randall, R., and G. Power. Atlantic salmon (Salmo salar) of the Pigou and Bouleau Rivers, Quebec. *Envir. Biol. Fish.* 4(2): 179-184.
- 37 Boers, J.J., and J.C.H. Carter. The life history of Cyclops scutifer Laro (Cyclopoida: Copepoda) in a small lake of the Matamek River system, Quebec. *Can. J. Zool.* (In Press).
- 38 Williams, N.E., and D.D. Williams. Distribution and Feeding Records of the Caddisflies (Trichoptera) of the Matamek River Region, Quebec. *Can. J. Zool.* 57: 2402-2412.
- 39 Dubois, J.-M., and D. Clavet. La photo-interpretation et l'aménagement de la faune aquatique au Quebec. Exemple des rivières à saumon. (Accepted).
- 40 Carter, J.C.H. Zooplankton of the lower Matamek River, Quebec. *Naturaliste Canadien* (In Press).
- 41 Janus, L.L. and H.C. Duthie. 1979. Phytoplankton composition and periodicity in a northeastern Quebec lake. *Hydrobiologia* 63: 129-134.
- 42 Gibson, R.J. and F.G. Whoriskey. An experiment to induce anadromy in wild brook trout in a Quebec river on the North Shore of the Gulf of St. Lawrence. *Naturaliste Canadien*, (accepted pending revision).
- 43 Desmarais, G. and J.-M. Dubois. Paleogeographic holocene de la Cote Nord du Saint-Laurent. *Geographic physique et Quaternaire*. (In Press).

Thesis

DESMARAIS, G. Morpho-sédimentologie et evolution paleogeographic du bassin de la Rivière Matamek. M.Sc., Université de Sherbrooke.

Popular Article

Gibson, R.J. Ten years of research at the Matamek Research Station. *Atlantic Salmon Journal*.

RESEARCH SUMMARIES

RIVER ECOSYSTEM STUDIES

WATERSHED ANALYSIS

R.J. Naiman and J. Critchley

During 1979 considerable effort was expended selecting permanent sampling locations, physically characterizing each watershed, and attempting to place our current research programs into historical perspective with regard to climate and hydrologic patterns. In the end five permanent stations were selected. These are located on First Choice Creek, Beaver Creek, Muskrat River, Matamek River, and the Moisie River (Fig. 1).

CLIMATE

Climate and meteorologic events exert considerable influence on the biome in terms of degree-days, solar radiation and discharge patterns. Weather cycles of temperature and precipitation are well known and, because of this, it is important to consider current stream research in a meteorologic perspective.

The mean annual temperature of Sept Iles, Quebec is 10°C. Maximum mean monthly temperature for the period 1944-1970 was ~20°C (July) while the minimum mean monthly temperature (January) was about -20°C (Fig. 2). Only from May to October is the mean monthly minimum temperature >0°C.

The mean monthly temperature has had a regular oscillation of about -15°C to 15°C between 1944 and 1976 with no long term changes evident (Fig. 3). Occasionally some winters have been $5-8^{\circ}\text{C}$ warmer than others, but these appear to be sporadic events.

Precipitation at Sept Iles for the period 1944-1970 was fairly evenly distributed throughout the year, averaging 6-10 cm per month (Fig. 4). Most precipitation occurs as snow from mid-September to May, with a maximum of ~ 100 cm in January. Rain predominates from May through the summer with maximum amounts of ~ 10 cm per month.

Total monthly precipitation at Sept Iles was highly variable between 1944 and 1976 but no long or short-term trends were evident (Fig. 5). Monthly precipitation ranged from ~ 1 to ~ 25 cm.

An analysis of the departure from normal precipitation is often used to detect any gradual changes in the precipitation pattern. These data, shown in Fig 6 for the period 1957-1976, also indicate directed changes in the weather patterns are not occurring, and that month to month precipitation is highly variable.

DISCHARGE

Precipitation and air temperature strongly influence the magnitude of water flow as well as its annual pattern. In turn, both magnitude and pattern have considerable influence on the biota, export of nutrients and organic matter from the system, and community structure. Discharge magnitude and its pattern are important in the short term (annual, daily) by

influencing the immediate community response, and in the long term (multi-year) by influencing accumulation of organic matter in the system. For example, during a continuous series of relatively dry years organic matter would probably accumulate in the watershed as opposed to being moved downstream.

The only relatively long-term discharge record useful to us at this time is from the Moisie River (1964-1978). During that period it has shown regular annual oscillations with a strong spring freshet in April-May, occasionally minor freshets in July-September, and minimum flows from December to April (Fig. 7). The regularity of this pattern is striking, with mean monthly discharge during the spring freshet approaching $1800 \text{ m}^3 \text{ s}^{-1}$. Nearly 75 percent of the annual discharge occurs during the freshet. Minimum winter discharge will often be $<100 \text{ m}^3 \text{ s}^{-1}$.

The discharge pattern for the Moisie River in 1979 was unusual in that a secondary freshet occurred in June of $2200 \text{ m}^3 \text{ s}^{-1}$, which nearly equaled the $\sim 2500 \text{ m}^3 \text{ s}^{-1}$ discharge during the May freshet, and three other substantial freshets occurred during the summer (Fig. 8).

A pattern similar to that of the Moisie River also occurred for the Matamek River (Fig. 9). Other than discharge volume the only difference between these two major rivers is that ice breakup occurs about a month earlier on the Matamek River, usually near the end of March, but the full spring freshet does not occur until May.

Figure 10 shows the combined discharge of the Matamek and Muskrat Rivers. We have not had time to calculate only the Muskrat River discharge; however, it has a seasonal pattern similar to the other rivers.

PHYSICAL ANALYSES OF THE WATERSHEDS

The first step in drainage basin analyses is designation of stream orders following a system introduced by Horton (1945) and slightly modified by Strahler (1957). Canadian Geological Survey topographic maps (scale 1:50,000) were used to assign stream orders, calculate river profiles, measure basin areas, and determine number and lengths of streams of each order. Stream orders were field checked for accuracy where possible, especially for small streams. Methods used in these analyses are standard geomorphological techniques as described by Strahler (1957), Leopold et al. (1964) and Dunne and Leopold (1978).

The Moisie River watershed (19,811 km²) contains an estimated 49,564 streams with a total length of 32,341 km (Table 1). This is a density of 2.5 streams km⁻². If combined, the total length of all streams would reach 79 percent of the way around the earth's equator. Of the total number of streams, 98.9 percent are very small (order 1-3) making up 87.3 percent of the total length. The Matamek and Muskrat River watersheds have a similar pattern while Beaver Creek and First Choice Creek watersheds are too small to provide a meaningful analysis (Table 1).

Usefulness of the stream order system depends upon the premise that on the average, if a sufficiently large sample is treated, order number is directly proportional to size of the contributing watershed, to channel dimensions, and to stream discharge. After the drainage-network elements have been assigned order numbers, segments of each order are counted to

Table 1: Physical, Chemical and Biological Characteristics
of the Sampling Locations

Parameter	First Choice Creek	Beaver Creek	Muskrat River	Matamek River	Moisie River
Stream Order	1	2	5	6	9
Mean Width (m)	0.3	1.7	20	50	460
Mean Depth (m)	0.05	0.3	2	1.8	2.5
Discharge (m ³ ·s ⁻¹)					
Maximum	0.016	0.064	50	117	3820
Mean Annual	0.013	0.033	8.4	13.7	466.1
Minimum	0.006	0.008	0.4	0.9	58.9
Stream Gradient (%)	10	5	0.14	1.33	0.16
Watershed Area (km ²)	0.25	1.83	207	673	19811
Elevation (m)	10	18	15	15	5
Nutrients (mg · L ⁻¹)					
NO ₂	0.0003	0.0016	0.0015	0.0012	0.0008
NO ₃	0.1175	0.0525	0.0765	0.1160	0.0920
NH ₄	0.0053	0.0100	0.0077	0.0092	0.0064
Total N	0.3215	0.2615	0.2130	0.2620	0.2575
PO ₄	0.0029	0.0004	0.0005	0.0005	0.0005
Total P	0.0343	0.0048	0.0056	0.0039	0.0126
Silicates	0.5771	0.1739	0.0258	0.0170	0.3289

Table 2: A Detailed Physical Watershed Analysis For The Five Permanent Sampling Sites

Order	No. of Streams	% Total	Total km	% Total	$\frac{\text{Streams}}{\text{km}^2}$	$\frac{\text{km}}{\text{km}^2}$	Bifurcation Ratio	$\frac{\bar{x}}{\text{Length}}(\text{km})$	Length Ratios
Moisie River (19,810.7 km ²)									
1	38,770	78.2	16,142	49.9	1.957	0.815		0.416	
2	8,400	16.9	8,249	25.5	0.424	0.416	1:4.76	0.982	1:0.433
3	1,855	3.7	3,842	11.88	0.094	0.194	1:4.53	2.071	1:0.474
4	415	0.84	1,879	5.81	0.021	0.095	1:4.47	4.828	1:0.457
5	95	0.19	1,072	3.32	0.005	0.054	1:4.37	11.294	1:0.401
6	19	0.04	471	1.46	0.001	0.024	1:5.00	24.798	1:0.455
7	7	0.014	340	1.05	0.000	0.017	1:2.71	48.571	1:0.511
8	2	0.004	292	0.90	0.000	0.015	1:3.50	146.000	1:0.333
9	1	0.002	54	0.17	0.000	0.003	1:2.00	54.000	1:2.704
Total	49,564		32,341		2.502	1.633		$\bar{x} = 0.653$	
Matamek River (672.5 km ²)									
1	1,960	78.5	762	49.7	2.915	1.133		0.389	
2	414	16.6	322	34.95	0.616	0.568	1:4.95	0.923	1:0.402
3	94	3.77	176	11.50	0.140	0.262	1:4.40	1.872	1:0.493
4	23	0.92	92	6.01	0.034	0.137	1:4.09	4.000	1:0.468
5	4	0.16	95	6.21	0.006	0.141	1:5.75	23.750	1:0.168
6	1	0.04	26	1.70	0.001	0.039	1:4.00	26.000	1:0.913
Total	2,496		1,532		3.712	2.278		$\bar{x} = 0.614$	

Table 2: A Detailed Physical Watershed Analysis For The Five Permanent Sampling Sites

Order	No. of Streams	% Total	Total km	% Total	Streams $\frac{\text{km}}{2}$	$\frac{\text{km}}{2}$	Bifurcation Ratio	$\bar{x}/\text{Length}$ (km)	Length Ratios
Muskrat River (207.4 km ²)									
1	464	78.4	234	51.2	2.287	1.128		0.504	
2	99	16.7	112	24.5	0.477	0.540	1:5.05	1.131	1:0.422
3	22	3.72	51	11.2	0.106	0.246	1:4.50	2.318	1:0.488
4	6	1.01	25	5.47	0.029	0.121	1:3.67	4.167	1:0.556
5	1	0.17	35	7.66	0.005	0.169	1:6.00	35.000	1:0.119
Total	592		457		2.854	2.203		$\bar{x} = 0.772$	
Beaver Creek (1.83 km ²)									
1	7	87.5	2	50.0	3.825	1.093		0.286	
2	1	12.5	2	50.0	0.546	1.093	1:7.00	2.000	1:0.143
Total	8		4		4.372	2.186		$\bar{x} = 0.50$	
First Choice Creek (0.25 km ²)									
1	1	100.0	0.25	100.0	4.000	1.000		0.250	

yield the number of streams of a given order. It is obvious that the number of stream segments of any given order will be more numerous than for the next highest order. The ratio of number of segments of a given order (N_u) to the number of segments of the higher order ($N_u + 1$) is termed the bifurcation ratio. The ratio will not be the same from one order to the next because of chance variations in watershed geometry, but will tend to be a constant throughout the series. Bifurcation ratios characteristically range between 3.0 and 5.0 for watersheds in which geological structures do not distort the drainage pattern. This is true, to a large extent, for our study sites (Table 1). When logarithm of number of streams is plotted against order, drainage networks characteristically show a linear relationship, with small deviation from a straight line. This is also the case for our study sites (Fig. 11).

Horton (1945) postulated that the mean lengths of stream segments of each successive order of a basin tend to approximate a direct geometric sequence. A plot of logarithm of mean stream length as a function of order should normally yield a set of points lying essentially along a straight line (Fig. 12). However, at higher orders the relationship for our sites is distorted with the larger rivers being either slightly truncated (Moisie River) or elongated (Muskrat River).

As with stream length, the regression of logarithm of basin area on order should be linear. This is certainly the case with the three larger watersheds, but Beaver Creek and First Choice Creek do not fall on this line (Fig. 13). The size of their watersheds is slightly smaller than what would be predicted from stream order.

Assuming the validity of the laws of stream lengths and basin areas, in which both properties are related in an exponential function with order, length should be related to area by a power function. For our study sites both the total stream length and the number of streams in each watershed are perfectly correlated ($r = 1.00$) with basin area (Fig. 14).

Calculation of the constant of channel maintenance gives the area of watershed surface required to sustain one linear km of channel. For each of our basins the points fall on a straight line of 45° slope, indicating that a linear relationship may be used (Fig. 15). When the logarithm of the intercept is read at $\log [\text{stream length}] = 0$ and the antilog of this intercept taken, the constant of channel maintenance (C) for the whole basin is obtained. For the Moisie River $C = 0.66$, for the Matamek River it is 0.66, and for the Muskrat River it is 0.60. This means that, on the average, 0.60 – 0.66 km^2 of surface is needed to support each linear km of channel.

Using data supplied by the Quebec Ministere des Richesses naturelles we have established a rating curve for mean annual discharge as a function of basin area for rivers along the North Shore of the Gulf of St. Lawrence (Fig. 17). Using this relationship we can predict with good accuracy ($r^2 = 0.98$) the annual discharge by a given stream or river based on watershed area. We are still developing other relationships similar to this, such as mean annual flood; these should be ready in a few months.

The elevational profile of the main channel of the Moisie, Matamek, and Muskrat Rivers are shown in Fig. 17, 18, and 19. In all cases the slopes are relatively gentle, compared to western mountainous regions,

with gradients ranging from 0.13 to 0.94 percent. The lower courses of all rivers have very gentle slopes with much of the water's potential energy dissipated at waterfalls.

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Horton, R.E. 1945. Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. Bull. Geol. Soc. Am. 56: 275-370.

Stahler, A.N. 1957. Quantitative analysis of watershed geomorphology. Trans. Am. Geophy. Union. 38: 913-920.

Figure Captions - Watershed Analysis

- Fig. 1. Map of the study sites showing their location and relative sizes.
- Fig. 2. Maximum and minimum mean monthly air temperatures at Sept Iles, Quebec, between 1944-1970.
- Fig. 3. The continuous record of mean monthly air temperatures at Sept Iles, Quebec, between 1944-1976.
- Fig. 4. Mean monthly precipitation as rain and snow at Sept Iles, Quebec, between 1944-1970.
- Fig. 5. Monthly precipitation at Sept Iles, Quebec, between 1944 and 1976.
- Fig. 6. Mean monthly departure from normal precipitation at Sept Iles, Quebec, between 1957 and 1976.
- Fig. 7. Mean monthly discharge of the Moisie River, Quebec, between 1964-1979.
- Fig. 8. Daily discharge of the Moisie River, Quebec, in 1979.
- Fig. 9. Daily discharge of the Matamek River in 1979 at the outlet of Matamek Lake.
- Fig. 10. Daily discharge of the Matamek River, Quebec, below the confluence of the Muskrat River.
- Fig. 11. Numbers and total stream lengths as a function of stream order for the five study sites.
- Fig. 12. Mean stream length as a function of stream order for the five study sites.
- Fig. 13. Basin area as a function of terminal stream order for the five watersheds.
- Fig. 14. Total stream length and total number of streams as a function of watershed basin area.
- Fig. 15. Calculation of constant of channel maintenance for the Muskrat, Matamek, and Moisie River watersheds.
- Fig. 16. Mean annual discharge as a function of basin area for 15 major rivers on the North Coast of the Gulf of St. Lawrence. The rivers are: 1) Manicouagan-C, 2) Hart Jaune, 3) Toulnostovc, 4) Manicouagan-C2, 5) Manicouagan-C3, 6) Matamek-Lake Outlet, 7) Des Rapides, 8) Moisie, 9) Pekans, 10) Au Toinnerre, 11) Magpie, 12) Magpie - Rt. 138, 13) Romaine, 14) Romaine-Station 2, and 15) Muskrat.

Fig. 17. Elevational profile for the Muskrat River, Quebec.

Fig. 18. Elevational profile for the Matamek River, Quebec.

Fig. 19. Elevational profile for the Moisie River, Quebec.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

Figure 12

Figure 13

Figure 14

Figure 15

Figure 16

$$\text{LOG(M.A.D.)} = 0.87 \text{ LOG(AREA)} - 1.17$$
$$r = 0.99$$

Figure 17

Figure 18

Figure 19

COMMUNITY METABOLISM

R.J. Naiman and P. Heinermann

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 1979b, 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 plays 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. Naiman and Sedell (1979a,b, 1980) and their colleagues have investigated metabolic processes in streams and rivers from different geographical regions in an attempt to construct a

conceptual framework adequately describing metabolic changes occurring as small streams gradually coalesce to form large rivers. These efforts are based upon streams differing in community structure and geological age from those in the North Shore region, and all are more productive than the Matamek River System. Because of the low pH, scarcity of nutrients, and short growing season in the Matamek area, studies of these rivers and streams are providing an interesting contrast to rivers upon which existing hypotheses of river metabolism are based.

From June 1 to October 20, 1979 data were collected on metabolism by the various major components of each stream and river segment: coarse particulate organic matter (CPOM: >1 mm), fine particulate organic matter (FPOM: $0.5\text{ }\mu\text{m}$ – 1 mm), pool periphyton, riffle periphyton, macrophytes, and plankton. The method used is described by Naiman and Sedell (1980). These data provide the basis for the proposed studies of nutrient enrichment and effects of light manipulation scheduled to be conducted in 1980. In 1980 we will continue the basic metabolic measurements in order to encompass the ice-breakup and spring flood period (April–May), and the latter part of autumn (October 15 – November 15) just before ice formation, which were not sampled in 1979.

WATER CHEMISTRY

At approximately three week intervals water samples were taken from First Choice Creek, Beaver Creek, Muskrat River, Matamek River, Moisie River, Piquou River, Tortue River, and the Manitou River, frozen, and brought to Woods Hole for chemical analysis. Methods are summarized in Table 1; results are in Table 2. All streams and rivers which were examined had extremely low concentrations of nutrients. No seasonal trends were evident.

Table 1. Methods Used in Water Chemistry Analysis

NH₄: Solorzono, Lucia. 1969. Determination of ammonia in natural waters by the phenolypochlorite method. *Limnol. Oceanogr.* 14: 799.

NO₃: Wood, E.P., F.A.J. Armstrong and F.H. Richards. 1967. Determination of nitrate in sea water by cadmium - copper reduction to nitrate. *J. Mar. Biol. Assn. U.K.* 47: 23-31.

Total N: D'Elia, C.F., P.A. Steudler, and N. Corwin. 1977. Determination of total nitrogen in aqueous samples using persulfate digestion. *Limnol. Oceanogr.* Vol. 22, No. 4.

PO₄: Murphy, J. and J.P. Riley. 1962. A modified single solution method for determination of phosphate in natural waters. *Anal. Chem. Acta*, 26: 31-36.

Total P: Menzel, D.W. and N. Corwin 1965. The measurement of total phosphorus in sea water based on the liberation of organically bound fractions by persulfate oxidation. *Limnol. Oceanogr.* 10:280-283

Silicates: Determined colorimetrically as described by Strickland, J.D. and T.R. Parsons. 1968. *A Manual for Sea Water Analysis*. Bulletin No. 167, Fisheries Research Board of Canada.

Table 2. Water chemistry (mg/l) Analysis for the Major Sampling Locations.

Date	NH ₄	NO ₃	NO ₂	TOTAL N	PO ₄	TOTAL P	SI
FIRST CHOICE CREEK							
31 May 79	0.006	0.178	0.001	0.395	0.003	0.057	0.224
27 Jun 79	0.015	0.063	0.001	0.109	0.003	0.006	0.930
4 Jul 79	0.026	0.021	0.001	0.104	0.004	0.008	0.597
24 Jul 79	0.015	0.024	0.001	0.106	0.003	0.007	0.816
13 Aug 79	0.014	0.028	0.001	0.101	0.005	0.015	0.270
18 Sep 79	0.010	0.034	0.001	0.056	0.001	0.007	1.776
8 Oct 79	0.017	0.050	0.001	0.769	0.005	0.015	1.072
22 Oct 79	0.005	0.057	0.001	0.248	0.003	0.011	0.930
1 Dec 79	0.010	0.111	0.001	0.176	0.006	0.012	1.089
BEAVER CREEK							
31 May 79	0.006	0.088	0.002	0.298	0.001	0.004	0.055
4 Jul 79	0.008	0.012	0.005	0.362	0.001	0.008	0.096
8 Aug 79	0.012	0.012	0.004	0.540	0.001	0.013	0.098
27 Aug 79	0.012	0.008	0.005	0.646	0.001	0.011	0.099
18 Sep 79	0.020	0.009	0.003	0.396	0.001	0.010	0.098
22 Oct 79	0.014	0.017	0.002	0.225	-0-	0.005	0.293
1 Dec 79	0.010	0.030	0.001	0.319	0.003	0.015	0.143
MUSKRAT RIVER							
9 Jun 79	0.006	0.137	0.001	0.188	0.001	0.004	0.016
18 Jul 79	0.012	0.008	0.002	0.157	0.001	0.011	0.030
7 Aug 79	0.008	0.009	0.004	0.468	0.001	0.022	0.046
28 Aug 79	0.006	0.032	0.004	0.319	0.001	0.010	0.036
18 Sep 79	0.004	0.008	0.003	0.351	0.001	0.008	0.034
8 Oct 79	0.007	0.006	0.003	0.277	0.001	0.011	0.033
22 Oct 79	0.009	0.016	0.002	0.238	0.001	0.077	0.036
MATAMEK RIVER							
10 Jun 79	0.006	0.209	0.001	0.314	0.001	0.004	0.016
26 Jun 79	0.024	0.009	0.007	0.170	0.001	0.008	0.032
27 Jun 79	0.012	0.014	0.003	0.258	0.001	0.006	0.026
6 Aug 79	0.013	0.010	0.002	0.202	0.001	0.008	0.027
7 Aug 79	0.015	0.007	0.002	0.181	0.001	0.005	0.023
27 Aug 79	0.010	0.007	0.003	0.234	0.001	0.007	0.025
27 Aug 79	0.006	0.008	0.003	0.178	0.005	0.006	0.030
17 Sep 79	0.010	0.010	0.003	0.218	0.001	0.008	0.020
8 Oct 79	0.019	0.020	0.002	0.178	0.002	0.010	0.032
22 Oct 79	0.012	0.023	0.001	0.210	0.001	0.003	0.018
1 Dec 79	0.005	0.030	0.001	0.232	0.003	0.007	0.033
MOISIE RIVER							
5 Jun 79	0.006	0.108	0.001	0.283	0.001	0.019	0.214
26 Jun 79	0.026	0.054	0.002	-	0.020	0.036	0.111
23 Jul 79	0.026	0.029	0.002	0.178	0.001	0.019	0.412
24 Jul 79	0.023	0.030	0.002	0.237	0.001	0.015	0.349
24 Jul 79	0.028	0.024	0.002	0.261	0.001	0.012	0.610
24 Jul 79	0.025	0.021	0.001	0.242	0.001	0.001	0.619
6 Aug 79	0.008	0.043	0.002	0.260	0.001	0.029	0.140
27 Aug 79	0.016	0.043	0.002	0.154	0.006	0.007	0.044
17 Sep 79	0.012	0.039	0.002	0.180	0.002	0.008	0.349
23 Sep 79	0.032	0.022	0.002	0.220	0.002	0.001	0.757
8 Oct 79	0.043	0.083	0.002	0.269	0.003	0.020	0.277
22 Oct 79	0.007	0.076	0.001	0.232	0.001	0.006	0.444
PIGOU RIVER							
3 May 79	0.010	0.018	0.002	0.162	0.001	0.011	0.031
25 Jun 79	0.009	0.007	0.000	0.114	0.002	0.008	0.035
16 Jul 79	0.007	0.013	0.001	0.190	0.002	0.009	0.127
6 Aug 79	0.004	0.013	0.000	0.309	0.003	0.062	0.057
27 Aug 79	0.008	0.004	0.004	0.351	0.001	0.011	0.036
17 Sep 79	0.008	0.005	0.003	0.213	0.002	0.007	0.029
8 Oct 79	0.004	0.003	0.000	0.252	0.005	0.015	0.035
22 Oct 79	0.012	0.027	0.003	0.223	0.001	0.010	0.083
TORTUE RIVER							
4 Jun 79	0.005	0.011	0.001	0.068	0.003	0.005	0.025
25 Jun 79	0.009	0.008	0.001	0.133	0.004	0.005	0.036
16 Jul 79	0.013	0.014	0.001	0.148	0.009	0.010	0.073
6 Aug 79	0.006	0.009	0.001	0.078	0.002	0.006	0.036
27 Aug 79	0.008	0.002	0.000	0.129	0.003	0.006	0.045
17 Sep 79	0.008	0.004	0.001	0.136	0.001	0.006	0.023
8 Oct 79	0.006	0.010	0.001	0.100	0.002	0.008	0.036
22 Oct 79	0.007	0.024	0.001	0.099	0.001	0.006	0.080
MANITOU RIVER							
4 Jun 79	0.006	0.043	0.001	0.176	0.002	0.006	0.036
25 Jun 79	0.006	0.014	0.001	0.122	0.002	0.006	0.041
16 Jul 79	0.008	0.033	0.000	0.153	0.002	0.005	0.034
6 Aug 79	0.013	0.028	0.001	0.121	0.003	0.004	0.066
27 Aug 79	0.009	0.021	0.001	0.096	0.008	0.008	0.070
17 Sep 79	0.008	0.004	0.002	0.120	0.002	0.006	0.048
8 Oct 79	0.022	0.030	0.000	0.085	0.004	0.009	0.042
22 Oct 79	0.014	0.040	0.002	0.122	0.001	0.005	0.049
AMORY COVE							
27 Jun 79	0.010	0.008	0.006	0.197	0.011	0.023	0.274
24 Jul 79	0.030	0.006	0.001	0.662	0.024	0.086	0.034
13 Aug 79	0.032	0.050	0.003	0.367	0.030	0.048	0.224
27 Aug 79	0.014	0.002	0.000	0.190	0.010	0.019	0.086
18 Sep 79	0.030	0.046	0.004	0.230	0.020	0.029	0.148
8 Oct 79	0.016	0.070	0.001	0.319	0.024	0.034	0.173
22 Oct 79	0.018	0.106	0.000	0.280	0.029	0.035	0.271
MATAMEK ESTUARY							
10 Jun 79	0.004	0.005	0.001	0.167	0.003	0.007	0.038
4 Jul 79	0.010	0.009	0.001	0.172	0.017	0.005	0.047
24 Jul 79	0.008	0.032	0.001	0.216	0.003	0.007	0.088
13 Aug 79	0.006	0.006	0.001	0.244	0.007	0.010	0.038
28 Aug 79	0.006	0.005	0.000	0.309	0.002	0.009	0.029
18 Sep 79	0.014	0.009	0.001	0.315	0.006	0.037	0.215
8 Oct 79	0.015	0.030	0.001	0.251	0.013	0.028	0.400
22 Oct 79	0.014	0.021	0.000	0.172	0.003	0.008	0.036
MATAMEK RAIN GUAGE							
6 Aug 79	0.031	0.030	0.000	0.182	0.002	0.036	0.005

COMPARATIVE PRODUCTIVITY

In an attempt to put our intensive metabolic studies of the Matamek and Moisie River watersheds into a wider perspective we measured relative productivity of several rivers using accumulation rates on plexiglas plates. In June, 1979, plexiglas plates (20x20 cm) were attached to concrete blocks and five units were placed in the Moisie River, Matamek River, Pigou River, Tortue River, and the Manitou River in similar physical settings (Table 3). Every three weeks from June to September the plates were scraped clean and half of the sample area (200 cm²) used for chlorophyll analysis (Strickland and Parsons 1972), and the other half dried at 80°C, weighed, and ashed at 525° for 2-4 hr to determine organic content. Nutrient concentrations for each stream are very similar (Table 2).

Suprisingly, only the Matamek River had consistently high concentrations of chlorophyll; in the Manitou, Tortue, and Pigou Rivers it was nearly undetectable (Fig. 1). The amount of chlorophyll $\cdot \text{gAFDW}^{-1}$ was also relatively greater in the Matamek River but other sites had similar concentrations at times. The accumulation rate of material on plates is a measure of an increase in total organic matter (e.g. periphyton, detritus, insects, etc.) over time. The Pigou, Moisie and Matamek Rivers have relatively high accumulation rates but they reflect different aspects of the stream community. Most of the accumulation in the Pigou River was blackfly larvae (Simuliidae) attaching to the plates; in the Moisie River the two larger values were an accumulation of fine detritus on one or two of the plates; in the Matamek River the accumulation was nearly all periphyton.

Table 3. Physical Characteristics of the Sampling Sites (Plexiglass Blocks). Symbols are Manitou River (MUR)
Tortue River (TER), Pigou River (PUR), Moisie River (MOR), and Matamek River (MTK)

DATE	TEMPERATURE (°C)						WATER DEPTH (cm)						CURRENT SPEED (cm sec ⁻¹)					
	MUR	TER	PUR	MOR	MTK		MUR	TER	PUR	MOR	MTK		MUR	TER	PUR	MOR	MTK	
4 Jun 79	7.6	16.5	15.8	12.5	15.2		~122	~122	~104	~122						87.1		
26 Jun 79	11.1	10.0	9.9	13.7	15.6		121.9	91.4	78.7	99.1	91.4		95.3	95.3	95.2	76.2	66.3	
16 Jul 79	17.6	17.6	16.4	20.0	18.6		91.4	66.0	38.1	76.2	55.8		42.3	47.9	43.4	32.8	18.6	
6 Aug 79	18.4	18.4	15.5	18.1	19.5		63.5	83.8	94.0	182.9	63.5		32.3	56.0	57.2	65.3	26.1	
27 Aug 79	16.7	16.4	13.9	15.5	15.3		42.2	73.7	81.3	55.9	71.1		23.5	41.6	57.2	28.6	33.9	
17 Sep 79	12.8	9.8	8.8	10.6	10.4		76.0	91.0	60.0	~200.0	110.0		45.0	85.0	63.0	~63	72.0	

BENTHIC METABOLISM

General approach – The major metabolic components of each stream were measured separately because a natural section of substrate could not be accommodated by the metabolic chambers. The autotrophic component was either mosses or periphyton on rocks; periphyton was further identified depending as to whether the rocks were from a riffle or pool. The heterotrophic component consists of animals and microbes associated with detritus. Animal metabolism is usually a small percentage of the total community metabolism (Naiman 1976) and was not measured in this study.

Detritus was separated according to size; woody debris (CPOM) was cones, bark, leaves, needles, and wood >1 mm diameter. Fine particulate organic matter (FPOM) was considered to be smaller debris, generally <1 mm diameter. Total stream metabolism will eventually be estimated for each site by combining all metabolic components on an areal basis.

In these streams large woody debris >10 cm diameter (bole wood) is the major detrital component, appearing to comprise over 75 percent of the detrital standing crop. Nearly all of this material is in the form of trees up to 0.5 m in diameter. Metabolism associated with this material was not measured because: (1) much of it is in the stream channel but not under water, (2) it could not be realistically sampled and placed in the chambers, (3) and, although it is an important structural component of streams, it has a low biological activity, decomposing over very long time periods (Anderson et al. 1978, Naiman and Sedell 1979b).

Techniques and procedures - Periphyton, moss, macrophytes, and detritus were collected, placed in separate sealed recirculating plexiglass metabolic chambers (volume: 14 L), and oxygen changes monitored with YSI oxygen meters connected to a strip chart recorder (Naiman and Sedell 1980). All chambers were placed in the stream from which the samples had been collected. Metabolic parameters were measured by the diel oxygen method (Bott et al., 1978) using the following equations:

1. Gross primary production (GP) = Net community primary production plus community respiration during photo-period.
2. Net community primary production (NCP) = $GP - R_{pp}$
3. Community respiration (R) = Total respiration during photoperiod (pp) or diel period (24).
4. Net daily metabolism (NDM) = $GP - R_{24}$. The net change caused by community metabolism over a diel period.
5. P:R ratio = $GP \div R_{24}$.

Five chambers were run simultaneously for 24 hr periods. All chambers were flushed every 4 to 8 hr in an attempt to avoid oxygen, nutrient, and CO₂ depletion stress. Metabolism of microbes on the plexiglas was <5% (n = 4) of samples placed in the chambers, even after four days of continuous submergence. Incident radiation at the substrate was measured continuously with a LiCor model 185A quantum radiometer, or at the water surface with a Matrix Solarimeter on a few occasions when the radiometer was malfunctioning.

After each experiment the chamber contents were returned to the laboratory and frozen. The ash-free dry weight (AFDW) of material in each chamber was determined by drying to a constant weight at 80°C and ashing a subsample at 550°C for 4 hr. Prior to drying, chlorophyll was extracted by immersion in 1 L of 100% acetone for 24 hr. Water associated with the samples reduced the final acetone concentration to about 90%. Chlorophyll a was calculated using the equation of Lorenzen (1967). Surface area of rocks was measured by wrapping each rock with aluminum foil, weighing the foil, and converting to area using the weight of foil per unit area. Of the total rock area, about 50% is photosynthetically available and 25% is available when viewed as a horizontal plane from above the stream (T.D. Bott, pers. comm.; Gregory 1980, Naiman and Sedell 1980). Therefore, multiplying total rock area by 0.25 gives the photosynthetic area in m² of stream bottom.

It was not possible to measure metabolism of the intact benthic community because of the wide range of particle sizes encountered, turbulence of the water, and spatial distribution of metabolic components. In chambers with only detritus, metabolism was measured in g O₂·g AFDW⁻¹ of detritus per day. This value will be combined with measurements of the seasonal standing stock of detritus <10 cm diameter to be made in 1980, in order to estimate total detrital metabolism in g O₂ m⁻² day⁻¹. This value will be added to metabolic measurements of the autotrophic community to estimate total community metabolism. In 1979 nearly 275 individual metabolic measurements were made. During 1980 it is anticipated another 90-110 measurements will be made during the spring freshet and again just before ice formation in October and November.

Results - Preliminary results on metabolic rates of periphyton, moss, macrophytes, and detritus are presented in Tables 4a-e by sampling site. Rather than present a detailed analysis before the 1980 data are available only general trends will be discussed at this time.

Seasonal changes for most metabolic components were evident with highest metabolic rates occurring during June, July and August when water temperatures and sunlight were near maximal. Mosses were the most metabolically active, followed by periphyton. When more data is available on macrophyte standing crops a definitive statement on their relative metabolic importance in the larger rivers can be made. They have high specific production rates but without the seasonal standing crop data these specific rates cannot be converted to an areal basis for comparison. Periphyton in these streams are not especially productive when compared to rates measured in other biomes (Naiman and Sedell 1980).

Coarse and fine detritus have vastly different specific metabolic rates for most metabolic parameters (Tables 4a-e). This is most likely a function of the surface area to volume ratio (Hargrave 1972, Naiman and Sedell 1980), and has been observed in other systems.

There are strong downstream trends in the level of autotrophic production in these streams (Fig. 2). As the streams increase in size the autotrophic community increases in quantity and diversity. First Choice Creek has only a small riffle periphyton component; in Beaver Creek this is composed of pool and riffle periphyton; mosses begin to appear in the

Table 4a. 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						
25-28 Jun 79	6	0.117	0.013	0.153	- 0.036	0.76
31 Jul - 2 Aug 79	4	0.172	0.022	0.237	- 0.065	0.74
3-6 Sep 79	6	0.091	0.012	0.142	- 0.051	0.63
8-11 Oct 79	5	0.082	0.017	0.136	- 0.061	0.57
Periphyton ²						
25-27 Jun 79	3	201.5	71.6	190.1	11.4	1.01
30 Jul - 2 Aug 79	5	228.7	122.1	167.2	61.5	1.31
3-6 Sep 79	6	153.8	52.8	182.1	-28.3	0.90
8-11 Oct 79	7	144.2	51.9	198.6	-58.0	0.75
Fine Detritus ¹						
25-28 Jun 79	3	0.381	0.123	0.378	0.003	0.95
30 Jul - 2 Aug 79	3	0.441	0.234	0.325	0.116	1.30
3-6 Sep 79	3	0.328	0.121	0.372	- 0.044	0.86
8-11 Oct 79	3	0.265	0.052	0.459	- 0.194	0.59

1) mgO₂ · gAFDW⁻¹ · day⁻¹

2) mgO₂ · m⁻² · day⁻¹

Table 4b. 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 $\bar{x} \pm SE$
Riffle Periphyton ¹						
4-7 Jun 79	6	1146.1	772.8	553.9	592.2	1.98
9-12 Jul 79	5	671.6	177.5	736.6	-66.7	0.89
8-11 Aug 79	7	438.2	206.0	374.5	63.7	1.23
17-20 Sep 79	6	161.1	59.9	195.2	-34.0	0.83
Pool Periphyton ¹						
4-5 Jun 79	1	500.9	292.2	308.7	192.2	1.62
9-10 Jul 79	1	501.9	244.6	383.6	118.3	1.31
Fine Detritus ²						
6-7 Jun 79	1	0.858	0.251	0.899	-0.041	0.96
9-12 Jul 79	3	1.819	0.131	2.517	-0.698	0.72
8-11 Aug 79	2	0.760	0.159	0.967	-0.207	0.79
17-20 Sep 79	3	0.328	0.013	0.622	-0.295	0.53
Coarse Detritus ²						
4-7 Jun 79	4	0.282	0.051	0.342	-0.060	0.83
9-12 Jul 79	6	0.286	0.017	0.401	-0.115	0.72
8-11 Aug 79	6	0.244	0.030	0.345	-0.101	0.70
17-20 Sep 79	6	0.114	0.011	0.198	-0.084	0.58

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 4c. 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											
28-31 May 79	4	0.109	0.025	0.016	0.008	0.142	0.028	- 0.033	0.005	0.76	0.03
2-5 Jul 79	4	0.191	0.046	0.016	0.007	0.257	0.063	- 0.066	0.019	0.75	0.02
13-16 Aug 79	4	0.153	0.026	0.028	0.008	0.200	0.032	- 0.047	0.008	0.77	0.03
10-15 Sep 79	3	0.089	0.033	0.009	0.008	0.156	0.054	- 0.067	0.255	0.57	0.07
Fine Detritus ¹											
29-31 May 79	2	0.631	0.399	0.091	0.124	0.812	0.414	0.181	0.015	0.75	0.11
3-5 Jul 79	2	3.468	4.112	0.992	0.988	3.679	4.562	- 0.192	0.479	1.08	0.23
14-16 Aug 79	2	0.524	0.120	0.128	0.024	0.634	0.231	- 0.110	0.111	0.85	0.12
10-15 Sep 79	2	0.508	0.483	0.106	0.073	0.746	0.756	- 0.238	0.273	0.73	0.09
Moss Rocks (Fontinalis) ²											
29-31 May 79	2	451.8	68.1	190.9	63.0	391.9	8.5	59.9	59.6	1.16	0.15
2-5 Jul 79	5	999.2	755.5	430.7	240.3	836.2	784.2	162.9	115.0	1.80	1.25
6-16 Aug 79	8	838.9	367.1	459.1	145.3	607.7	362.9	231.3	48.1	1.64	0.64
10-14 Sep 79	2	577.2	383.8	279.5	305.3	380.0	150.3	207.3	233.6	1.47	0.44
Periphyton ²											
28-31 May 79	3	405.0	57.8	225.3	51.1	324.9	155.3	80.0	99.2	1.48	0.74
2-5 Jul 79	3	326.4	78.0	237.5	62.0	130.9	23.5	195.4	54.6	2.48	0.15
6-16 Aug 79	4	380.0	191.9	212.6	132.8	267.8	104.5	112.2	101.1	1.41	0.29
10-15 Sep 79	3	234.3	140.9	164.2	120.0	131.9	101.6	102.4	119.9	2.06	1.02
Periphyton ²											
28-31 May 79	4	353.7	151.8	168.4	60.6	279.1	149.5	74.6	39.0	1.34	0.21
4-5 Jul 79	1	554.2	-	126.3	-	631.3	-	-77.1	-	0.88	-
10-15 Sep 79	5	350.6	52.7	205.4	38.0	272.6	45.2	78.1	37.7	1.30	0.17
Total Periphyton											
28-31 May 79	6	386.4	131.6	175.9	56.0	316.7	129.7	69.7	41.0	1.28	0.20
2-5 Jul 79	6	925.0	699.8	380.0	248.3	802.1	706.4	122.9	142.1	1.65	1.18
6-16 Aug 79	8	838.9	367.1	459.1	145.3	607.7	362.9	231.3	48.1	1.64	0.64
10-15 Sep 79	7	415.4	196.5	255.1	154.0	300.4	85.9	115.0	118.0	1.35	0.24

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

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

Table 4d. 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 $\bar{x} \pm SE$
Periphyton¹						
12-14 Jun 79	3	360.9	266.3	139.1	221.8	2.60 0.04
16-20 Jul 79	4	1467.0	895.1	874.7	592.3	1.66 0.09
20-21 Aug 79	2	260.4	114.0	246.9	13.5	1.06 0.02
26-27 Sep 79	1	455.4	247.3	418.0	37.4	1.09 -
Pool Periphyton¹						
11-13 Jun 79	2	633.9	340.2	431.8	202.1	1.47 0.23
18-20 Jul 79	2	1009.1	620.5	588.6	420.5	1.73 0.11
22-23 Aug 79	2	737.1	439.6	507.2	230.0	1.44 0.22
Moss Rocks (Fontinalis)¹						
11-14 Jun 79	4	1660.4	878.2	1149.7	510.7	1.52 0.32
16-20 Jul 79	3	2595.5	1432.3	1757.4	838.1	1.48 0.29
20-23 Aug 79	4	1283.7	718.8	957.5	326.2	1.33 0.15
24-27 Sep 79	5	799.2	428.7	739.6	59.6	1.10 0.10
Sparangium²						
16-19 Jul 79	3	269.813	270.275	94.248	175.565	2.75 2.45
20-23 Aug 79	3	79.053	59.214	78.224	0.029	1.11 0.17
24-27 Sep 79	3	46.609	8.981	54.624	- 8.015	0.87 0.08
Coarse Detritus²						
11-13 Jun 79	2	0.272	0.118	0.300	- 0.028	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	0.296	- 0.044	0.84 0.06
24-27 Sep 79	3	0.097	0.033	0.130	- 0.034	0.74 0.09
Fine Detritus²						
13-14 Jun 79	1	2.420	-	1.993	0.427	1.21 -
16-20 Jul 79	3	0.739	0.775	0.517	0.222	1.32 0.21
20-22 Aug 79	2	0.375	0.085	0.222	- 0.154	0.71 0.01
24-28 Sep 79	3	0.252	0.206	0.347	- 0.095	0.66 0.16

1) mgO₂ · m⁻² · day⁻¹

2) mgO₂ · gAFDW⁻¹ · day⁻¹

Table 4e. 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 $\bar{x} \pm SE$
Riffle Periphyton¹						
19-20 Jun 79	2	876.4	445.2	559.2	267.7	1.29 0.27
23-25 Jul 79	2	1076.9	728.8	538.5	538.4	1.78 0.57
3-4 Oct 79	3	496.2	391.9	217.1	279.0	2.26 0.15
Pool Periphyton¹						
20-21 Jun 79	2	559.6	319.2	351.8	207.8	1.85 1.17
23-25 Jul 79	3	1005.5	771.9	608.7	396.8	1.87 0.60
27-28 Aug 79	2	840.6	6704.3	414.3	426.3	2.11 0.43
Moss Rocks (Fontinalis)¹						
23-26 Jul 79	2	1994.6	1385.5	936.6	1057.9	2.17 0.52
27-30 Aug 79	3	2347.1	1565.8	1364.9	982.2	1.72 0.09
1-3 Oct 79	4	1062.2	846.3	446.5	615.7	2.42 0.31
Total Periphyton¹						
19-20 Jun 79	2	876.4	445.2	559.2	267.7	1.29 0.27
23-26 Jul 79	4	1535.7	1057.1	737.6	798.2	1.97 0.50
27-30 Aug 79	3	2347.1	1565.8	1364.9	982.2	1.72 0.09
1-4 Oct 79	7	819.6	651.4	348.2	471.4	2.35 0.25
Sparangium²						
23-27 Jul 79	3	113.323	59.017	10.716	29.869	1.36 0.03
27-30 Aug 79	3	61.930	38.103	25.350	20.257	1.44 0.24
Potamogeton²						
23-26 Jul 79	3	416.589	251.511	167.603	163.255	2.33 1.01
27-30 Aug 79	3	42.478	27.747	8.653	16.713	1.65 0.17
2-4 Oct 79	3	39.328	22.740	24.104	15.355	1.68 0.55
Coarse Detritus²						
18-21 Jul 79	6	0.210	0.066	0.257	- 0.034	0.76 0.77
25-26 Jul 79	1	0.116	0.025	0.141	- 0.025	0.82 -
28-30 Aug 79	2	0.267	0.094	0.340	1.167	0.89 0.04
1-3 Oct 79	3	0.072	0.026	0.125	0.041	0.57 0.05
Fine Detritus²						
18-20 Jun 79	2	1.431	0.163	1.531	- 0.100	0.94 0.09
24-25 Jul 79	1	3.119	1.485	2.510	0.609	1.24 -
28-30 Aug 79	2	1.746	0.660	1.707	0.039	1.03 0.02
1-4 Oct 79	2	1.003	0.562	1.326	- 0.324	0.73 0.18

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

Muskrat River and reach their maximum development in the Moisie River; macrophyte communities are strongly developed in the Matamek River and less so in the Moisie. This is paralleled by the metabolic activity of the autotrophs (Fig. 2), which generally increase in a downstream direction for both gross production and net daily metabolism. In all streams for each autotrophic component, $P:R \geq 1.0$ when averaged for the 1979 season.

Metabolism by the microbial community associated with coarse detritus, and the P:R ratio, remain the same regardless of stream order (Fig. 3). Gross production by fine detritus generally increases with order, while net daily metabolism is strongly negative in Beaver Creek and the Muskrat River, indicating considerable decomposition. The P:R ratio is similar for all sites.

In an attempt to understand differences in metabolic rates between streams, correlation coefficients were calculated for each metabolic parameter as a function of light, chlorophyll μm^{-2} , chl μgAFDW^{-1} of detritus, and the amount of detritus used in each experiment (Tables 5-6). Results of these first analyses were encouraging, but significant ($p \leq 0.05$) correlation coefficients generally ranged between 0.3 and 0.7 explaining only a small percentage of the variability. It is anticipated that when the entire data sets are complete (e.g. including 1980 data) the relationships will be stronger since a wider range of measurements will have been made.

Chlorophyll - The amount of chlorophyll associated with periphyton is generally very low (Table 7). However, it does increase in a downstream direction from First Choice Creek to the Matamek River, and then

Table 5. Correlation coefficients (r), significance (p), and best equation of relationships between light, chlorophyll and the metabolic parameters of the autotrophic communities. Only relationships with $p < 0.05$ are shown.

Component	Variable	Sample Size (n)	Gross Production (r)	Net Community Production (r)	Diel Respiration (p)	Net Daily Metabolism (r)	P:R Ratio (r)	(p)
Riffle Periphyton	Light ($\mu E \times 10^5 \text{ m}^{-2} \text{ day}^{-1}$)	72	0.43 $\text{LOG}(\text{GP}) = 2.09 + 0.257 \text{ LOG}(\text{L})$	0.52 $\text{LOG}(\text{NCP}) = 1.50 + 0.399 \text{ LOG}(\text{L})$	0.001 $\text{LOG}(R_{24}) = 2.15 + 0.163 \text{ LOG}(\text{L})$	0.001 $\text{LOG}(\text{NDM}) = 0.988 \text{ LOG}(\text{L}) - 0.42$	0.51 $\text{LOG}(\text{PR}) + 0.145 \text{ LOG}(\text{L}) - 0.185$	0.001
	Chlorophyll ($\text{Chl } a \text{ m}^{-2}$)	72	0.38 $\text{LOG}(\text{GP}) = 2.40 + 0.271 \text{ LOG}(\text{C})$	0.48 $\text{LOG}(\text{NCP}) = 1.97 + 0.433 \text{ LOG}(\text{L})$	0.001	0.51 $\text{LOG}(\text{NDM}) = 0.76 + 1.065 \text{ LOG}(\text{C})$	0.58 $\text{PR} = 1.04 + 0.030 \text{ (C)}$	0.001
	Chlorophyll ($\text{Chl } a \text{ m}^{-2}$)	28	0.42 $\text{LOG}(\text{GP}) = 2.59 + 0.195 \text{ LOG}(\text{C})$	0.39 $\text{LOG}(\text{NCP}) = 2.36 + 0.200 \text{ LOG}(\text{C})$	0.001 $\text{LOG}(R_{24}) = 2.36 + 0.214 \text{ LOG}(\text{C})$	0.017 $\text{LOG}(\text{NDM}) = 1.91 + 0.382 \text{ LOG}(\text{C})$		
Moss	Chlorophyll ($\text{Chl } a \text{ m}^{-2}$)	42	0.46 $\text{LOG}(\text{GP}) = 2.69 + 0.249 \text{ LOG}(\text{C})$	0.52 $\text{LOG}(\text{NCP}) = 2.39 + 0.292 \text{ LOG}(\text{C})$	0.001 $\text{LOG}(R_{24}) = 2.52 + 0.236 \text{ LOG}(\text{C})$	0.007		
	Light ($\mu E \times 10^5 \text{ m}^{-2} \text{ day}^{-1}$)	24	-0.55 $\text{LOG}(\text{GP}) = 4.35 - 0.993 \text{ LOG}(\text{L})$	-0.51 $\text{LOG}(\text{NCP}) = 4.52 - 1.178 \text{ LOG}(\text{L})$	0.005 $\text{LOG}(R_{24}) = 3.25 - 0.619 \text{ LOG}(\text{C})$	-0.41 $\text{NDM} = 140.77 - 0.268 \text{ (L)}$	0.023 $\text{LOG}(\text{PR}) = 1.09 - 0.378 \text{ LOG}(\text{L})$	0.014
Riffle and Pool Periphyton	Light ($\mu E \times 10^5 \text{ m}^{-2} \text{ day}^{-1}$)	100	0.42 $\text{LOG}(\text{GP}) = 2.14 + 0.230 \text{ LOG}(\text{L})$	0.53 $\text{LOG}(\text{NCP}) = 1.56 + 0.394 \text{ LOG}(\text{L})$	0.001 $\text{LOG}(R_{24}) = 2.19 + 0.132 \text{ LOG}(\text{C})$	0.014 $\text{LOG}(\text{NDM}) = 0.924 \text{ LOG}(\text{L}) - 0.22$	0.50 $\text{LOG}(\text{PR}) - 0.143 \text{ LOG}(\text{L}) - 0.16$	0.001
	Chlorophyll ($\text{Chl } a \text{ m}^{-2}$)	100	0.39 $\text{LOG}(\text{GP}) = 2.44 + 0.260 \text{ LOG}(\text{C})$	0.45 $\text{LOG}(\text{NCP}) = 1.38 + 0.008 \text{ (L)}$	0.001	0.46 $\text{LOG}(\text{NDM}) = 1.05 + 0.904 \text{ LOG}(\text{C})$	0.40 $\text{LOG}(\text{PR}) + 0.01 + 0.136 \text{ (L)} - 0.12$	0.001
	Light ($\mu E \times 10^5 \text{ m}^{-2} \text{ day}^{-1}$)	142	0.43 $\text{LOG}(\text{GP}) = 2.15 + 0.276 \text{ LOG}(\text{L})$	0.53 $\text{LOG}(\text{NCP}) = 1.60 + 0.409 \text{ LOG}(\text{L})$	0.001 $\text{LOG}(R_{24}) = 2.17 + 0.190 \text{ LOG}(\text{L})$	0.001 $\text{LOG}(\text{NDM}) = 0.925 \text{ LOG}(\text{L}) - 0.01$	0.43 $\text{LOG}(\text{PR}) = 0.122 \text{ LOG}(\text{L}) - 0.12$	0.001
Riffle and Pool Periphyton, and Moss	Chlorophyll ($\text{Chl } a \text{ m}^{-2}$)	142	0.59 $\text{LOG}(\text{GP}) = 2.45 + 0.351 \text{ LOG}(\text{C})$	0.61 $\text{LOG}(\text{NCP}) = 2.08 + 0.446 \text{ LOG}(\text{C})$	0.001 $\text{LOG}(R_{24}) = 382.32 + 7.800 \text{ (C)}$	0.001 $\text{LOG}(\text{NDM}) = 1.15 + 0.80 \text{ (LOG}(\text{C}))$	0.35 $\text{LOG}(\text{PR}) = 0.01 + 0.009 \text{ LOG}(\text{C})$	0.001
	Light ($\mu E \times 10^5 \text{ m}^{-2} \text{ day}^{-1}$)	142						

Table 6. Correlation coefficients (r), significance (p), and equation of relationships between light, chlorophyll, and the metabolic parameters of the detrital components. Only relationships with p<0.05 are shown.

Component	Variable	Sample Size (n)	Gross Production (r)	Gross Production (p)	Net Community Production (r)	Net Community Production (p)	Diel Respiration (r)	Diel Respiration (p)	Net Daily Metabolism (r)	Net Daily Metabolism (p)	P:R Ratio (r)	P:R Ratio (p)
Coarse Detritus	Light ($\mu E \times 10^5 \text{ m}^{-2} \text{ day}^{-1}$)	78			0.32	0.002			0.38	0.001	0.28	0.006
	Chlorophyll (Chl a $\mu gFDW^{-1}$)	78	0.24	0.017	$NCP = 0.002 + (5.3 \times 10^{-5}) (L)$ $GP = 0.156 + 30.38 (C)$	0.001			$NDM = (8.6 \times 10^{-1})(1) - 0.007$ -0.70 $LOG(NDM) = 0.006 - 263.1 (C)$	0.001	$LOG(PR) = (1.2 \times 10^4)(L) - 0.175$ 0.46 $PR = 0.688 + 71.15 (C)$	0.001
Fine Detritus	Chlorophyll (Chl a $\mu gFDW^{-1}$)	45	0.55	0.001	0.50	0.001	0.47	0.001	-0.39	0.004	0.40	0.003
			$LOG(GP) = 0.15 + 0.187 LOG (C)$	$LOG(NCP) = 0.272 LOG (C)$	$LOG(NCP) = 0.272 LOG (C)$	$-0.37 LOG(R_{24}) = 0.14 + 0.148 LOG(C)$			$LOG(NDM) = 0.74 - 0.207 LOG(C)$		$PR = 0.85 + 4.491 (C)$	
Coarse and Fine Detritus	Light ($\mu E \times 10^5 \text{ m}^{-2} \text{ day}^{-1}$)	123			0.24	0.003			0.20	0.013	0.19	0.018
	Chlorophyll (Chl a $\mu gFDW^{-1}$)	123	0.63	0.001	0.55	0.001	0.59	0.001	-0.41	0.001	0.43	0.001
			$LOG(GP) = 0.01 - 0.233 LOG(C)$	$LOG(NCP) = 0.323 LOG(C)$	$LOG(NCP) = 0.323 LOG(C)$	$LOG(R_{24}) = 0.01 - 0.195 LOG(C)$			$LOG(NDM) = 0.64 - 0.164 LOG(C)$		$LOG(PR) = 0.004 LOG(C) - 0.01$	

Table 7. Chlorophyll Concentrations of Periphyton (mg Chl m^{-2}).

FIRST CHOICE CREEK				
SUBSTRATE	DATE	SAMPLE SIZE (n)	$\bar{x}$	SE
Riffle Periphyton	25-27 Jun 79	3	4.37	1.32
	30 Jul-2 Aug 79	5	2.02	0.83
	3-6 Sep 79	6	1.03	0.32
	8-11 Oct 79	7	1.83	0.72
BEAVER CREEK				
Riffle Periphyton	4-7 Jun 79	6	18.83	3.29
	8-12 Jul 79	5	2.25	0.81
	8-11 Aug 79	7	1.13	0.34
	17-20 Sep 79	6	1.77	0.53
Pool Periphyton	4-5 Jun 79	1	8.9	-
	9-10 Jul 79	1	1.4	-
MUSKRAT RIVER				
Riffle Periphyton	28-31 May 79	4	1.80	0.30
	4-5 Jul 79	1	3.46	-
	10-15 Sep 79	5	4.06	0.45
Pool Periphyton	28-31 May 79	3	2.23	0.48
	2-5 Jul 79	3	4.37	1.05
	13-16 Aug 79	4	3.53	1.45
	10-15 Sep 79	3	1.53	1.00
Moss	29-31 May 79	2	8.80	-
	2-5 Jul 79	5	9.88	3.49
	6-7 Aug 79	2	31.05	-
	13-16 Jul 79	6	11.68	2.46
	10-14 Sep 79	2	6.70	-
MATAMEK RIVER				
Riffle Periphyton	12-14 Jun 79	3	41.77	15.53
	16-20 Jul 79	4	13.10	4.09
	20-21 Aug 79	2	6.45	-
	26-27 Sep 79	1	29.49	-
Pool Periphyton	11-13 Jun 79	2	12.25	-
	18-20 Jul 79	2	44.30	-
	22-23 Sep 79	2	11.10	-
Moss	11-14 Jul 79	4	34.90	8.29
	16-20 Jul 79	3	51.10	22.67
	20-23 Aug 79	4	25.80	7.33
	24-27 Sep 79	5	87.78	22.96
MOISIE RIVER				
Riffle Periphyton	19-20 Jun 79	2	1.00	-
	23-25 Jul 79	2	2.70	-
	3-4 Oct 79	3	6.90	0.67
Pool Periphyton	20-21 Jun 79	2	0.50	-
	23-25 Jul 79	3	4.03	0.78
	27-28 Aug 79	2	4.10	-
Moss	23-26 Jul 79	2	22.45	-
	27-30 Aug 79	3	58.53	9.44
	1-3 Oct 79	4	56.50	14.64

decreases in the Moisie River. Moss covered rocks have considerably more chl $\cdot m^{-2}$ than periphyton in the three rivers in which they occur together. Chlorophyll concentrations for all sites are some of the lowest reported, even lower than many oligotrophic salmonid streams of the Pacific Northwest (Naiman and Sedell 1980).

MACROPHYTES

Aquatic macrophytes are generally an important component of saline and fresh water ecosystems, being prevalent worldwide in oceanic coastal zones, littoral regions of lakes, and in medium to large rivers (e.g., 5th to 10th order). In rivers they are often regarded as more of a nuisance than as a significant component of the ecosystem structure and function. In no area is the production ecology of this diverse group well characterized, and river communities are the least well known of all.

Submerged macrophytes in rivers perform several important functions: (1) they provide seasonal structure to the community for habitat and shelter, (2) they act as a retention device to regulate the flow of water and seston, (3) they act alternately as a sink and source for chemical compounds, and (4) they provide a large input of fine detritus to the system upon death in autumn and winter. Critical examination of these important functions is generally lacking in North American rivers.

Most of the limited knowledge existing on the submerged and floating aquatic macrophytes of rivers has been centered around taxonomy, measurements of the standing crop and its productivity, factors affecting the standing crop and species composition, and how this biomass affects the oxygen balance of downstream reaches (Westlake 1975 and references therein). Nearly all previous studies have been conducted in Europe where aquatic macrophytes are, for various reasons, prevalent.

Direct grazing on aquatic macrophytes by animals is unusual; it appears the plants contribute to the food web only after death. At that time they fragment to smaller particles of a size actively fed upon by filter-feeding invertebrates. Harrison and Mann (1975a, b) have extensively studied this process, and the chemical changes occurring during the growing season in marine eelgrass (Zostera), whereas only a few limited studies exist for macrophyte decomposition in lake water (Wetzel 1975, and references therein). To my knowledge no studies have been conducted on the decomposition of macrophytes in streams and rivers or the chemical changes occurring through the growing season which may influence the availability of this material to higher trophic levels. By comparison, the production ecology and decomposition dynamics of leaf litter in small streams is much better understood.

In the Matamek and Moisie River macrophytes are a significant component of the autotrophic community. They have an extensive distribution, being clustered not only near to the shore, but throughout the river channel where hydrologic conditions are favorable. They appear to have a maximum standing crop in late summer.

Using 0.25 m² quadrats we sampled macrophytes in the Matamek River for species composition, distribution, and standing crop in August, 1979 across seven transects (Fig. 4). These studies will be expanded in 1980 to encompass the entire growing season, as well as the Moisie River.

Eight species were identified in the Matamek River (Table 8). In most cases maximum biomass was within 10 m of shore, but in locations with favorable currents, depth, and substrate the plants distributed

Table 8. Species of Macrophytes and Microalgae Found in the Moisie and Matamek Rivers*.

MACROPHYTES

Sparangium sp. 1
Sparangium sp. 2
Potamogeton sp.
Nuphar varegatum
Sagittaria (Either S. latifolia or S. aventa)
Isoetes sp.
Callitriche vermae
Equisetum fluviatile

PERIPHYTON

Scapania nemorosa (liverwort)
Spirogyra
Fragilaria
Tabellaria flocculosa
Frustulia rhomboides
Diatoma spp.
Synedra vaucheriaeu
Peridinium inconspicuum
Cryptomonas erosa
Oscillatoria sp.
Merismopedia punctata

SESTON (MOISIE RIVER ONLY)

Tabullaria flucculosa
Fragilaria coristrunes
Navicula
Synedra

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

themselves across the river (Fig. 4). The most abundant plant is Sparangium; its long tapelike leaves can be seen floating at the surface over extensive areas (Table 9). It comprises 33-79% of the biomass for all transects. Local clusters of Isoetes, Sagittaria, Equisetum, and Callitriche do occur but generally do not make up the bulk of the biomass over large areas. Compared to other river systems of similar size, the biomass in the Matamek River is relatively low.

This effort was merely to survey the plants and test our methods. In 1980-81 a considerable effort will be made to measure seasonal standing crops and productivity, map distribution, and describe substrate relationships, the role of discharge, and decomposition dynamics.

Table 9. Macrophytes, Percent Composition by Weight.

TRANSECT NO.	ISOETES	MOSS	SPARANGIUM Sp. 1	SPARANGIUM Sp. 2	SAGITTARIA	POTAMOGETON	EQUISETUM	CALLITRICHE
1	18.7	2.4	78.8		0.2			
2	6.2	7.8	40.8	2.2	11.4	0.1	31.5	
3	0.1	0.1	12.2	21.3	46.8			19.8
4	12.9	2.3	48.6	1.3	12.5	9.9	12.4	
5	66.7		33.3					
6	24.4	0.3	67.4			7.9		
7	16.2	0.7	42.5		11.6	12.4	16.5	0.2

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Figure Captions - Community Metabolism

- Fig. 1. Relative productivity of the five rivers is compared for chlorophyll density and the accumulation rate of organic matter at three-week intervals in 1979.
- Fig. 2. Mean gross production, net daily metabolism, and the P:R ratio of each autotrophic component are shown as a function of stream order for 1979. Symbols are First Choice Creek (FCC), Beaver Creek (BVC), Muskrat River (MRR), Matamek River (MTK), and Moisie River (MOR).
- Fig. 3. Mean gross production, net daily metabolism, and the P:R ratio of each detrital component are shown as a function of stream order for 1979. Symbols for stream sites are the same as in the previous figure.
- Fig. 4. The lower Matamek River, Quebec, showing the location of transects for the measurement of the standing crop of macrophytes.
- Fig. 5. Distribution of macrophyte dry weight as a function of river width for each transect in the previous Figure.

Figure 1

Figure 2

Figure 3

Figure 4

MATAMEK RIVER, QUEBEC
AUGUST, 1979
MACROPHYTE TRANSECTS
O — START

Figure 5

MACROPHYTES, MATAMEK RIVER
AUGUST, 1979

SESTON DYNAMICS

R.J. Naiman, Sandra George, and F.G. Whoriskey

Transport of organic detritus by streams and rivers is a conspicuous component of their ecosystem structure but has seldom been adequately characterized for potential food quality, relative proportion of size fractions, or basic differences inherent between stream orders in a given watershed (Naiman and Sedell 1979a). Seston is important to invertebrates, especially filter feeders, and can be of considerable significance to estuarine communities.

In 1979 drifting organic detritus was characterized in the five streams of different order. 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 particulate organic matter (CPOM: >1 mm) and fine particulate organic matter (FPOM: 0.45 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 >0.45 μ m were estimated by measuring specific respiration rates associated with discrete sizes (>1 mm; 53 μ m to 1 mm; 0.45 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, however, was after the ice breakup - spring freshet period (April-May) when about 60-80% of annual discharge occurs. We will intensively sample this period in 1980, as well as the period

preceeding ice formation (October–November), using the same techniques and criteria as in 1979. Once completed, concentration data from 1979–1980 will be related to physical characteristics of stream order such as watershed area, discharge regime, retention structures, and stream power. 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.

Methods – Samples were collected using Miller high speed plankton samplers (106 μm mesh; food quality only) and calibrated pumps (concentrations only). Concentrations in $\text{mg AFDW}\cdot\text{m}^{-3}$ were estimated, after any large invertebrates were removed, by dividing sample ash-free dry weight (AFDW) by the volume of water filtered. For particles in the 0.45–53 μm size fraction, 4 L of water was first sieved through a 53 μm screen and then filtered onto a preweighed and precombusted (550°C, 2–4 hr) Gelman A/E glass fiber filter.

To investigate food quality, a large sample of drifting organic detritus was collected from each site, divided into size classes, and the invertebrates removed. A portion of each size class was used for determination of chlorophyll a, respiration, and carbon to nitrogen (C:N) ratio. Chlorophyll a mg AFDW^{-1} , corrected for phaeophyton, was estimated by extraction in 10 ml of 90% acetone for 24 hr (Lorenzen 1967). After chlorophyll extraction, detritus was weighed and ashed at 550°C. Respiration was determined in the laboratory with YSI self stirring B.O.D. probes. Samples were placed in sealed vials, kept at ambient stream temperatures,

and respiration rates measured over at least a 6 hr period. Three respiration estimates were made for each size class where enough material could be collected. Samples were then ashed and weighed. C:N was determined with a Perkin-Elmer Elemental Analyser. Samples were dried (80°C) and divided into two portions; one was used for C:N analysis and the other ashed.

Additional samples were taken in June and August for analysis with a scanning electron microscope (SEM). Samples were critically point dried and examined at the United States Geological Survey Laboratory in Woods Hole.

RESULTS AND DISCUSSION

Concentration - Regardless of stream site, seston concentrations are quite similar, ranging within an order of magnitude (200–2000 mg AFDW·m⁻³). Beaver Creek and the Muskrat River were consistently higher and have wider seasonal fluctuations than the other sites (Fig. 1). The Matamek and Moisie Rivers have minimal fluctuations over the season.

Dissolved organic carbon (DOC) concentration are highest in the Muskrat River and Beaver Creek (range: 6–16 mg C·L⁻¹) and generally ≤ 8 mg C·L⁻¹ at the other sites (Fig. 2). Only Beaver Creek and the Muskrat River show seasonal changes with higher concentrations in late summer. DOC:POC ratios are generally >10 for all sites except First Choice Creek (Table 1); there ratios are usually ≤ 5 .

Table 1. Seston concentrations (POC; $\text{mgC} \cdot \text{m}^{-3}$), size composition, dissolved organic carbon (DOC) concentrations ($\text{MgC} \cdot \text{m}^{-3}$). DOC:POC ratios, and discharges are shown for each site and sampling date.

DATE	TOTAL POC		SIZE COMPOSITION			DOC		DOC:POC	DISCHARGE m ³ s ⁻¹
	x	SE	>1 mm	53µm - 1mm	.45 - 53µm	x	SE		
FIRST CHOICE CREEK									
5 Jun 79	785.1	379.5	10.3	63.0	26.5	1,783.3	285.4	2.27	0.012
26 Jun 79	480.2	206.0	19.1	47.5	33.3	1,423.3	313.7	2.97	0.014
13 Jul 79	191.1	33.6	7.3	30.9	61.7	1,243.3	325.0	6.51	0.014
27 Jul 79	729.4	558.2	12.2	32.4	55.4	2,736.7	436.2	3.75	0.016
16 Aug 79	406.1	126.8	10.1	33.2	56.4	1,946.7	195.5	4.79	0.014
6 Sep 79	372.3	67.6	4.2	26.8	60.6	1,857.0	389.0	4.99	0.015
21 Sep 79	563.7	385.4	9.8	35.0	55.2	1,316.7	207.4	2.33	0.013
11 Oct 79	375.2	60.3	3.2	14.9	81.9	3,890.0	1,069.3	10.37	0.006
BEAVER CREEK									
4 Jun 79	641.7	128.5	6.1	16.4	77.4	9,023.3	257.0	14.08	0.043
23 Jun 79	385.0	67.0	0.4	7.8	91.7	9,396.7	473.4	24.41	0.008
11 Jul 79	691.4	286.8	0.7	8.4	90.7	9,416.7	617.8	13.62	0.021
3 Aug 79	1,565.9	736.2	0.3	2.9	96.7	14,936.7	1,241.7	9.54	0.038
18 Aug 79	682.8	101.3	0.3	4.4	95.5	14,016.7	1,361.5	20.53	0.032
2 Sep 79	924.5	102.7	0.4	4.3	95.2	12,833.3	1,187.8	13.89	0.024
22 Sep 79	702.3	47.1	2.7	4.0	93.2	12,260.0	877.3	17.46	0.062
6 Oct 79	1,407.6	563.1	2.8	7.7	89.5	10,300.0	828.1	18.29	0.036
MUSKRAT RIVER									
28 May 79	475.8	15.9	0.4	2.0	97.7	8,545.0	7.1	17.96	21.3
12 Jun 79	1,220.4	161.9	1.2	8.2	90.6	9,530.0	3,087.1	7.81	19.1
3 Jul 79	1,685.0	162.3	0.3	2.1	97.6	8,273.3	824.4	4.91	4.2
18 Jul 79	1,950.3	86.5	0.1	0.8	99.1	6,676.7	361.2	3.42	7.1
11 Aug 79	948.1	127.9	0.2	1.4	98.4	14,356.7	1,055.5	15.14	12.8
25 Aug 79	1,368.3	210.3	0.7	1.6	97.7	12,350.0	3,418.6	9.03	3.89
13 Sep 79	954.9	175.6	2.9	4.0	93.1	13,686.7	564.4	14.34	22.0
26 Sep 79	1,005.2	161.2	0.4	0.7	98.9	10,833.3	66.7	10.78	14.3
MATAMEK RIVER									
29 May 79	329.2	11.3	1.5	2.6	95.7	6,440.0	618.0	19.56	28.3
19 Jun 79	496.0	25.2	4.2	7.3	88.5	7,290.0	256.3	14.70	44.2
5 Jul 79	608.7	35.1	3.3	7.4	89.5	6,810.0	510.0	11.19	16.6
25 Jul 79	524.1	24.6	0.2	2.5	97.3	7,323.3	808.8	13.97	5.05
10 Aug 79	543.4	21.4	0.7	5.7	93.6	7,813.3	650.1	14.38	17.0
31 Aug 79	533.7	41.9	0.4	2.6	97.0	5,346.7	266.9	10.03	9.49
14 Sep 79	552.4	90.8	1.1	5.6	93.5	7,060.0	223.4	12.79	21.5
5 Oct 79	507.4	108.5	0.5	1.2	98.2	7,916.7	626.9	15.61	11.4
MOISIE RIVER									
11 Jun 79	924.2	91.4	< 0.1	2.6	97.4	5,080.6	99.9	5.50	1,100.
28 Jun 79	387.8	85.2	0.4	10.3	89.2	5,113.3	660.6	13.19	741.
19 Jul 79	788.7	363.3	0.2	4.2	95.6	4,463.3	371.7	5.66	458.
1 Aug 79	529.2	43.3	0.6	13.0	86.4	5,823.3	522.9	11.00	780.
24 Aug 79	418.4	18.1	1.4	3.7	95.0	4,770.0	1,070.4	11.40	359.
7 Sep 79	480.5	46.2	2.9	9.4	87.7	4,036.7	160.1	8.41	467.
27 Sep 79	328.9	38.6	0.4	8.9	90.6	3,980.0	461.1	12.10	460.
12 Oct 79	370.3	35.7	0.4	3.5	95.9	4,740.0	775.5	12.81	396.

The distribution of particle sizes is strongly skewed towards the smaller sizes. This can be readily seen with the high DOC:POC ratios. The same is true for particulate organic matter; the 0.45-53 μm size class comprises the majority of transported particles by weight (Table 1). This size fraction makes up >85 - 90% of the particle weight in larger streams, whereas in First Choice Creek only 26-62% is transported in this size fraction. First Choice Creek also transports a higher percentage of CPOM (>1 mm), and FPOM (53 μm - 1mm) than the larger streams. In larger streams these sizes are generally a miniscule part of the seston, but in First Choice Creek CPOM ranges from 3-20% and FPOM ranges from 15-63% of the drifting POC (Table 1).

Food Quality - Chlorophyll associated with drifting detritus can take several forms. Chlorophyll contained in particles >1 mm is generally associated with leaves from terrestrial plants; chlorophyll in particles between 53 μm and 1 mm are either leaf fragments or have an associated periphyton; chlorophyll from particles <53 μm generally tend to be from either microalgae and diatoms. Chlorophyll associated with the smaller sized particle is thought to enhance its potential food quality by virtue of its protein and lipid content.

During the normal course of growth and decay, periphyton sloughs a considerable amount of material to downstream reaches (Naiman and Sibert 1978, Naiman and Sedell 1979a). In First Choice Creek relatively little chlorophyll is transported downstream (Table 2). In the larger streams more chlorophyll is associated with the seston but there are no strong downstream trends for increasing chlorophyll concentrations. They are

Table 2. Seston Chlorophyll Concentrations by Size Class (mg Chl a·gAFDW⁻¹)

DATE	>16mm	4 mm	1 mm	500 µm	250 µm	125 µm	53 µm	0.45 µm
FIRST CHOICE CREEK								
5 Jun 79	-	-	0.021	-	-	-	0.093	0.409
26 Jun 79	-	0.075	0.037	0.034	0.043	-	0.021	0.146
13 Jul 79	-	0.017	0.033	0.008	0.023	0.012	0.016	-0-
27 Jul 79	-	0.047	0.019	-0-	0.022	0.040	0.040	0.049
16 Aug 79	-	0.248	0.015	0.010	0.024	0.014	0.034	0.154
6 Sep 79	-	0.011	0.053	0.031	0.038	0.059	0.071	0.046
21 Sep 79	-	0.101	0.075	0.008	0.011	0.015	0.020	0.138
11 Oct 79	-	0.282	0.096	0.027	0.040	0.062	0.071	0.092
BEAVER CREEK								
4 Jun 79	-	-	0.161	-	-	-	0.440	0.482
23 Jun 79	-	0.134	1.730	0.535	0.891	0.709	0.348	-0-
11 Jul 79	1.628	0.050	0.017	0.021	0.059	0.204	0.019	0.099
3 Aug 79	0.516	0.460	0.084	0.233	0.315	0.198	0.181	0.165
18 Aug 79	2.028	0.051	0.737	0.132	0.606	0.124	0.150	0.288
3 Sep 79	0.993	0.835	0.123	0.111	0.585	0.313	0.351	0.433
21 Sep 79	0.566	0.297	3.066	0.127	1.165	0.469	1.139	0.144
6 Oct 79	0.398	1.037	0.246	0.371	0.657	0.291	0.259	0.340
MUSKRAT RIVER								
31 May 79	-	-	0.262	-	-	-	0.246	0.300
12 Jun 79	-	-	1.200	-	-	-	-	0.202
3 Jul 79	0.080	0.138	0.039	0.196	0.193	0.111	0.016	0.279
16 Jul 79	0.361	0.249	0.144	0.380	0.103	-0-	0.059	0.253
11 Aug 79	1.117	0.084	0.087	0.185	0.273	0.349	0.324	0.481
25 Aug 79	0.690	0.240	0.310	0.261	0.453	0.239	0.095	0.190
13 Sep 79	0.210	0.221	0.050	0.193	0.464	0.146	0.085	0.497
26 Sep 79	0.500	0.109	0.213	0.504	0.818	0.201	0.392	0.208
MATAMEK RIVER								
31 May 79	-	-	-0-	-	-	-	-	0.464
19 Jun 79	-	0.052	0.514	1.094	0.869	0.765	0.021	0.265
7 Jul 79	1.504	0.857	0.039	0.467	0.265	0.427	0.214	0.073
25 Jul 79	0.168	0.573	0.627	0.061	0.891	0.961	-0-	0.424
11 Aug 79	-	1.253	0.374	0.748	1.645	1.069	0.870	0.567
31 Aug 79	1.360	0.319	0.400	-	0.904	1.180	0.934	0.459
14 Sep 79	0.159	0.046	0.232	0.434	1.351	1.660	0.229	0.851
5 Oct 79	0.031	0.157	0.210	0.581	2.110	1.697	0.703	0.435
MOISIE RIVER								
16 Jun 79	-	-	0.054	0.184	0.187	0.382	0.374	0.235
28 Jun 79	1.714	0.867	0.014	0.145	1.026	0.046	0.099	0.083
19 Jul 79	-	2.372	0.170	0.448	0.271	0.134	0.102	0.282
1 Aug 79	4.286	1.265	0.668	0.291	0.068	0.152	0.050	0.614
24 Aug 79	-	4.911	1.788	1.337	0.273	0.146	0.155	0.387
7 Sep 79	-	9.714	0.068	0.732	0.334	0.466	0.214	0.592
29 Sep 79	7.484	5.815	1.420	0.145	0.183	0.194	0.315	0.344
12 Oct 79	1.827	0.251	1.111	0.437	0.720	1.276	0.540	0.430

generally highest in the Matamek River but of nearly equal magnitude at the other sites (Table 2). Likewise there are no strong trends at any site for chlorophyll concentration to increase in the smaller particle sizes as found by Naiman and Sedell (1979a).

Russell-Hunter (1970) indicated that a C:N ratio of about 17 or less is necessary for efficient feeding and growth in most aquatic organisms. First Choice Creek and Beaver Creek generally export particles with higher C:N ratios than the larger streams. In the Matamek and Moisie Rivers most particle sizes have C:N ratios ≤ 20 whereas, in the other streams, they are usually ≥ 20 except for the very smallest size class ($0.45 \mu\text{m} - 53 \mu\text{m}$) (Table 3). The C:N samples are only partially analysed at this time, a full analysis will be presented in the 1980 report.

Respiration rates of CPOM and FPOM are generally low in First Choice Creek but higher for the remaining sites (Table 4). For all sites respiration rates of microbes associated with VPOM are generally an order of magnitude greater than CPOM and FPOM. Respiration rate - particle size relationships are similar to that found by Hargrave (1972) and Naiman and Sedell (1979b) for benthic detritus, but do not compare to relationships found for seston (Naiman and Sedell 1979a). Hargrave (1972) found rates for a wide variety of sediments to range from 0.1 to $10 \text{ mg O}_2 \cdot \text{gAFDW}^{-1} \cdot \text{hr}^{-1}$. In our experiments most rates for CPOM and FPOM were in this range. VPOM, however, normally ranged from 20 to $120 \text{ mg O}_2 \cdot \text{gAFDW}^{-1} \cdot \text{hr}^{-1}$ (Table 4). These experiments will be continued through the ice-breakup-spring freshet period in Spring 1980 and a full analysis presented next year.

Table 3. Carbon:Nitrogen Analyses for Seston^a; in percent.

Particle Size	FIRST CHOICE CREEK			BEAVER CREEK			MUSKRAT RIVER			MATAHEK RIVER			MOISTE RIVER		
	N	C	C:N	N	C	C:N	N	C	C:N	N	C	C:N	N	C	C:N
	5 Jun 79			4 Jun 79			31 May 79			31 May 79			16 Jun 79		
>16 mm															
4 mm															
1 mm	1.1	41.4	38.0	1.2	43.5	35.4				1.6	48.3	29.5			
500 µm							0.2	3.9	23.1				0.1	2.8	25.3
250 µm							0.1	2.7	29.9				0.1	5.5	55.2
125 µm	0.6	13.0	21.7	0.7	13.2	20.0	0.3	6.0	23.1	0.1	1.8	17.9	0.1	1.5	29.6
53 µm	-	-	16.2	-	-	14.2	0.8	15.3	20.1	-	-	12.7	-	-	14.8
0.45 µm															
	16 Aug 79			18 Aug 79			25 Aug 79			31 Aug 79			24 Aug. 79		
>16 mm															
4 mm															
1 mm	1.1	46.7	43.2	1.8	32.7	18.5	2.9	50.9	17.7	2.0	51.4	25.4	2.6	41.0	15.8
500 µm	0.8	24.8	31.4	1.3	43.0	33.6	1.9	53.4	28.1	2.3	49.0	21.6	2.6	42.8	16.2
250 µm	0.5	11.0	22.4	1.1	48.2	44.2	1.7	47.8	28.8	1.4	51.9	36.5	0.9	17.9	19.5
125 µm	0.2	5.5	24.0	0.3	6.8	27.4	0.6	12.6	20.3	1.4	20.3	14.4	1.0	20.6	21.2
53 µm	0.3	7.4	23.2	1.2	25.5	22.2	0.1	1.3	25.8	0.6	8.7	13.7	1.0	20.2	19.4
0.45 µm	0.5	9.6	20.8	1.0	22.3	23.0	0.5	11.3	21.3	1.5	21.9	14.3	0.8	14.8	17.6
				0.9	20.0	22.5	0.7	14.7	21.0	1.3	19.1	14.6	-	-	9.4
				-	-	16.5	-	-	15.1	-	-	11.5	-	-	

a) Blank spaces indicate that not enough material could be collected for analysis.

Table 4. Respiration Rates of Drifting POC ($\text{mg O}_2 \cdot \text{gAFDW}^{-1} \cdot \text{hr}^{-1}$)

Date	CPOM		FPOM		VPOM		Temp. Range °C
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	
FIRST CHOICE CREEK							
5 Jun 79	1.38	0.70	1.04	0.01	21.68	4.57	4.0 - 14.0
26 Jun 79	1.04	0.87	0.68	0.09	94.72	38.18	6.2 - 15.0
13 Jul 79	0.85	0.51	0.57	0.13	-	-	8.8
27 Jul 79	1.30	1.35	1.23	0.13	244.56	-	9.3 - 9.5
16 Aug 79	3.02	-	2.51	-	-	-	8.0 - 9.0
6 Sep 79	3.17	1.21	5.09	3.95	-	-	8.0
21 Sep 79	1.51	2.14	1.84	1.67	-	-	8.7
11 Oct 79	4.25	2.33	3.75	1.18	79.40	2.50	5.9 - 6.5
BEAVER CREEK							
4 Jun 79	6.62	4.21	2.38	1.75	28.08	19.36	4.3 - 16.9
23 Jun 79	0.07	0.09	24.67	30.12	58.77	20.58	8.9 - 16.8
11 Jul 79	3.32	0.32	2.17	0.09	45.33	26.42	12.3 - 19.5
3 Aug 79	19.97	1.12	9.40	5.34	37.37	21.44	20.2 - 21.5
18 Aug 79	2.62	1.72	6.95	1.24	76.42	26.71	10.0 - 13.4
1 Sep 79	9.84	5.89	6.81	1.04	28.80	-	15.0 - 16.0
22 Sep 79	4.44	0.51	15.17	9.09	-	-	10.4 - 12.0
6 Oct 79	9.48	2.80	13.33	7.48	-	-	8.9 - 10.2
MUSKRAT RIVER							
30 May 79	DATA LOST	-	-	-	-	-	-
12 Jun 79	15.01	18.33	1.39	1.16	30.86	5.81	10.0 - 16.0
3 Jul 79	3.05	3.21	4.14	0.16	19.16	0.15	8.9 - 12.9
16 Jul 79	8.59	1.27	11.86	4.10	31.51	-	18.1 - 18.6
7 Aug 79	3.57	1.06	5.59	0.90	56.69	-	10.6
25 Aug 79	4.85	1.21	5.04	0.19	-	-	17.0
13 Sep 79	5.11	1.51	6.55	0.24	-	-	12.0 - 13.8
26 Sep 79	3.80	1.17	45.80	8.20	-	-	8.7
MATAMEK RIVER							
2 Jun 79	1.40	-	1.78	-	-	-	-
19 Jun 79	23.57	28.53	2.56	0.16	19.76	12.09	9.0 - 13.6
5 Jul 79	4.05	0.19	9.34	0.40	38.97	10.88	8.0 - 15.2
25 Jul 79	9.43	0.52	50.63	14.15	86.09	51.56	18.3 - 20.6
10 Aug 79	9.28	3.22	18.95	0.08	109.90	1.71	17.5 - 18.0
31 Aug 79	6.06	0.45	20.75	1.52	114.93	79.14	16.0 - 16.4
14 Sep 79	2.90	1.66	7.30	3.62	-	-	12.0 - 13.0
5 Oct 79	4.89	1.40	27.13	5.10	34.37	18.32	8.0 - 10.8
MOISIE RIVER							
16 Jun 79	-	-	4.66	0.07	28.59	17.35	12.7 - 17.5
28 Jun 79	2.47	1.68	4.52	0.90	38.72	19.19	6.0 - 14.4
19 Jul 79	2.00	0.71	3.56	1.47	-	-	5.8 - 6.7
1 Aug 79	-	-	6.38	1.13	44.64	16.24	17.8 - 18.0
24 Aug 79	5.07	2.66	4.49	0.66	119.12	50.08	17.0
7 Sep 79	10.92	4.02	15.21	12.87	-	-	13.0 - 14.5
29 Sep 79	11.93	6.79	1.66	0.43	102.63	-	8.0 - 8.8
12 Oct 79	9.89	5.43	10.41	3.82	-	-	5.0

Scanning Electron Microscope (SEM) Studies - Seston is composed of many different organic materials theoretically contribute varying amounts, and reflect various stages of decomposition, depending upon river size, proximity to the source of the material, hydrologic regime, and the environmental setting. As part of the food quality studies this material is analysed chemically by size class, site, and season to discern its character. With the SEM study we are visually examining this material for the specific character of individual particles, and changes occurring during transport downstream. Only by SEM studies can individual particles be characterized.

We have examined particles between 53 μm - 1 mm and 0.45 μm - 53 μm for the five streams and rivers to date. Samples were taken in early June immediately after the spring freshet and again during low water in August. In general, results from the two sampling dates are not very different. The 0.45 - 53 μm size class for all streams was dominated by fractured particles of all sorts which, as will be seen, were the major components of invertebrate fecal pellets. The 53 μm - 1 mm was biologically the most interesting, and forms the majority of this discussion.

Seston in First Choice Creek was mostly woody debris, fecal pellets, a woody-like fiber, and occasionally some diatoms (Fig. 3). Woody debris, in nearly all cases, had a rich microbial coating on the matrix between its structural framework. Fecal pellets were tightly bound, containing particles of unknown origin. The woody-like fibers were nearly devoid of any evidence of decomposition, although in some cases they appeared to

have some microbial flora attached to them. In general, the seston was microbially rich and appeared to be in the initial stages of decomposition. There was some colloidal material in the 0.45 - 53 μm size fraction.

Fecal pellets and woody debris still dominated in Beaver Creek (Fig. 4). Woody debris was further decomposed; there was little matrix left, relatively few microbes, and the structural framework which was more resistant to decomposition was usually all that remained. Fecal pellets were similar to those in First Choice Creek except that more animal and diatom remains were evident. Chrysophytes and desmids were present in low numbers. The woody-like fibers seen in First Choice Creek were rare but still did not show any sign of decomposition. Considerable colloidal material was present in the 0.45 - 53 μm size class.

The Muskrat River transported few particles $>53 \mu\text{m}$ (Fig 5). Woody-like fibers were beginning to decompose but still had sparse microbial flora. The 0.45 - 53 μm size class was most interesting here. There were large populations of microflagellates, chrysophytes, and microbes, and considerable colloidal material. Microalgae, woody debris, and fecal pellets were notable by their relative absence.

The Matamek River had an abundant and varied seston (Fig. 6). Fecal pellets, woody debris, microalgae (Tabularia), and zooplankton (Bosmina) were common. Wood was predominantly structural with no matrix or attached microflora. The fecal pellets were compacted woods debris, microalgae, inorganic particles, and what appeared to be parts of chitinous exoskeletons. The 0.45 - 53 μm fraction was rich in microbes, colloidal particles, and pieces of diatoms and chrysophytes.

The Moisie River had the most diverse seston (Fig. 7). Wood debris in various stages of decomposition, fecal pellets, microalgae, and animal parts were common. For wood usually only the structural components remained but an occasional piece was observed with the matrix intact and a rich microbial coating. Fecal pellets were similar to those described from the Matamek River. Extruded insect skins were common, as were tube-like structures which could not be specifically identified. Microalgae were mainly Tabillaria. The wood-like fibers were beginning to decompose. The 0.45 - 53 μm fraction was rich with considerable diatom frustules, microflagellates, bacteria, and colloidal material.

In summary, woody debris with its matrix intact was densely covered with microbes. This was especially so in First Choice Creek. In downstream reaches most woody debris was structural components resistant to decomposition. Fecal pellets were prevalent in all reaches except the Muskrat River. They were composed of particles $<53 \mu\text{m}$ with the exact composition depending upon local availability of finer particles. Microbes, microalgae, and microfauna were most prevalent in downstream reaches where primary production and environmental heterogeneity were maximal.

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Figure Captions - Seston Dynamics

- Fig. 1. Concentrations of particles $>0.45 \mu\text{m}$ in the five streams and rivers from May to October, 1979. $\bar{x} \pm \text{SE (n)}$.
- Fig. 2. Seasonal variation in concentration of dissolved organic carbon ($<0.45 \mu\text{m}$) in the five streams and rivers.
- Fig. 3. Scanning electron microscope photography of seston in First Choice Creek. A) Overview of sample containing considerable wood particles, fibers, and fecal pellets. B) Overview of sample with many compact fecal pellets and inorganic particles. C) Wood particle with intact matrix. D) Closeup view of wood particle showing the rich microbial coating in the wood matrix. The scales are given on the photographs.
- Fig. 4. SEM photographs of seston in Beaver Creek. A) Fecal pellets and a chrysophyte. B) Wood particle lacking a matrix; note the absence of microbes. C) Closeup view of a fecal pellet containing pieces of diatoms, wood, animal(?) tubes, and other miscellaneous material. D) Desmids (Starella). Scales are given in each photograph.
- Fig. 5. SEM photographs of seston in the Muskrat River. A) Wood-like fiber; note the relative absence of other particles. B) Closeup of the wood-like fiber; the microflora is extremely sparse and there is little evidence of decomposition. C&D) Chrysophytes, colloidal particles, and bacterial are common. Most material in this river appears to be in the $0.45\text{--}53 \mu\text{m}$ range. Scales are given in each photograph.
- Fig. 6. SEM photographs of seston in the Matamek River. A) Overview of the diversity of particles; woody debris, wood-like fibers, and fecal pellets are common. B) Closeup view of a typical fecal pellet containing a diversity of smaller particles. C&D) Most wood particles lacked a matrix and had few associated microbes. Scales are given in each photograph.
- Fig. 7. SEM photographs of seston in the Moisie River. A) A fecal pellet containing a wide variety of smaller particles. B) Woody debris with only the structural components remaining. C) A few wood particles with the matrix intact were found; all had a rich microbial coating. D) Unidentified animal (?) tubes were common, as were diatoms. Scales are on each photograph.

Figure 1

Figure 2

Figure 3

Figure 5

Figure 6

Wood decomposition dynamics as a function of quality of material and
stream order in Quebec¹

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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 1980; 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 alternately 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 involved 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 fresh water and marine 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, estuary, coastal waters 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; and
- (3) To determine the nitrogen 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 (alder, birch, aspen, black spruce, and black fir) was felled, debarked, sawed into short lengths, and chipped using a power jointer. Chips from each species were air dried and sorted into two size classes by sieving. The larger size class consisted of those chips that would not pass through a 1.52 cm sieve, and the smaller class of those that would not pass a 0.75 cm sieve.

Five samples were randomly taken from each species-size class combination for determination of initial moisture content, ash content, % total Kjeldahl nitrogen, and % lignin. Approximately 20 grams of material from one size class of 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 ten species-size class combinations were strung together on a monofilament line.

Five lines of 50 bags were transported to each of the seven sites for field placement (see Table 1). Bags were anchored on the sediment at each aquatic site using bricks or concrete blocks, and were staked on the forest floor at the terrestrial site. One line of bags was collected from each site after three 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 70°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.

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 (0.317%) and black spruce, a species commonly found in nitrogen poor sites, has the lowest nitrogen concentration (0.035%). The lignin contents of the wood of 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 were less than 1.0%.

Immediately after placement of the litterbags in the coastal waters site, the bags were destroyed by sea urchins. To date we have made only one litterbag collection (after three months of field "incubation") at the six remaining sites. We have this far processed collected materials from the first, second, sixth and ninth order streams and the estuary. The materials collected from the terrestrial site have not been processed. Material collected after three months of field "incubation" exhibited several interesting trends. In the first and second order streams, wood chips of deciduous tree species decomposed more rapidly than wood chips of coniferous tree species. Rates of decomposition were relatively uniform among all materials in the sixth and ninth order streams. The existing data expressed as percentage of organic matter remaining appears in Figure 1.

An exponential decay model is 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 and the estuary appears in Table 3.

Alder wood chips incubated in the first order stream decomposed most rapidly with a k of 0.94. Alder chips lost 46% of their original weight during the three-month period in the first order stream. If the exponential decay model appropriately describes the decay process, we would predict a residence time 1.06 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. 1980) 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. 1980.

The lignin:nitrogen ratios (Table 2) of the materials range as an order of magnitude; from 42 for alder to 647 for spruce. In Figure 3 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 lower order streams than in higher order streams. In fact, litter quality appears to exert very little control over decomposition rates in higher order streams.

During the three-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 817% for aspen wood litter incubating in the second order stream to a low of 144% of alder wood litter incubating in the ninth order stream (Table 4). 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 the nitrogen input to decaying woody material in streams (Buckley and Triska, MS).

Nitrogen fixation rates were not monitored in the present study. It is likely that at least some fraction of the absolute increase of nitrogen observed in the litter bags in the present study resulted from trapping of nitrogen-rich fine particulate matter in the bags. The ash content of the bags analyzed after three months of incubation in the streams was as high as 50%, whereas the original ash content of the woody material was always less than 1%. Using the "ash contamination" of incubated bags as an index of fine particulate trapping, it is apparent that the trapping rate was high. We are currently reanalysing carefully cleaned woody tissues from the three-month collection to attempt to sort out the possible contamination factor.

Table 1. Field Sites

<u>Site</u>	<u>Description</u>
Forest	Black spruce
First Choice Creek	1st order stream
Beaver Creek	2nd order stream
Matamek River	6th order stream
Moisie River	9th order stream
Estuary	-----
Coastal waters	Gulf of St. Lawrence

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

<u>Species</u>	<u>% Nitrogen</u>	<u>% Lignin</u>	Lignin:Nitrogen
Alder	0.315	13.1	42
Birch	0.144	0.143	57
Aspen	0.090	0.073	150
Fir	0.058	0.052	471
Spruce	0.041	0.035	647

Table 3. k values for woody material

Species	INCUBATION SITE			
	1st Order Stream	2nd Order Stream	6th Order Stream	9th Order Stream
Alder	2.16	1.10	0.00	-0.04
Birch	1.97	0.94	0.01	-0.02
Aspen	1.53	0.77	0.12	-0.01
Fir	0.29	-0.22	-0.25	0.00
Spruce	0.25	0.15	-0.20	-0.08

Table 4. Absolute nitrogen increase in incubated bags expressed as a % of original.

Species	INCUBATION SITE				All Site Mean
	1st Order Stream	2nd Order Stream	6th Order Stream	9th Order Stream	
Alder	266	196	172	144	194
Birch	456	464	227	175	330
Aspen	722	816	526	562	582
Fir	462	658	401	270	448
Spruce	732	686	453	291	540

Figure 1

Figure 2

ACID RAIN

R.J. Naiman, J. Critchley, and F.G. Whoriskey

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.

Every three weeks from June to October water samples were collected in stoppered vials from First Choice Creek, Beaver Creek, Matamek River, Moisie River, Pigou River, Tortue River, and the Manitou 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 (Talling 1973).

Despite being a considerable distance from major industrial centers the Matamek Research Station received acidic precipitation throughout the field season, usually averaging ~ 5.5 pH units. On one occasion a pH of 3.8 was recorded (Fig 1). The pH of the Matamek River water remained

between 5 and 6 for most of the season (Fig. 1); that of First Choice Creek ranged from 6 to about 7; the Moisie River ranged from 6 to ~7.5; Beaver Creek usually remained between 6 and 7; the Pigou, Tortue, and Monitou River had the widest seasonal oscillations. Their pH ranged from 4.5 to 6.5 (Fig. 1)

Alkalinity was difficult to measure in all waters and negative values were often recorded. Despite extensive checking of our methodology this problem persisted. For all sites, however, the general trend was for alkalinity to slightly increase from June to October coinciding with an increase in the alkalinity of the precipitation (Fig. 2).

The implications of these observations are not yet clear. We plan to continue monitoring alkalinity and pH precipitation at First Choice Creek, Beaver Creek, Matamek River, and the Moisie River during 1980 on a regular basis. Results of the first year are intriguing in that acid precipitation is occurring in this region, and it can be of a seriously low pH. The watersheds, however, seem to be able to buffer the low pH's to some extent, since several of the streams have higher pH's than the precipitation. Rather than speculate at this time on the consequences of acid precipitation, or the mechanisms by which the watershed may be buffering it, discussion will be deferred until the end of the 1980 field season when considerably more data will be available.

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Figure Captions - Acid Rain

Fig. 1. Acidity of precipitation and stream water from several sites near the Matamek Research Station in 1979.

Fig. 2. The alkalinity (buffering capacity) of precipitation and stream water at several sites near the Matamek Research Station in 1979.

Figure 1

HP

Figure 2

ATLANTIC SALMON STUDIES (Salmo salar) L.)

THE ADULT SALMON RUN

F.G. Whoriskey, R.J. Naiman, J. Critchley

The Atlantic salmon run in the Matamek River is composed of 2 sea year maiden fish and 1 sea year grilse. World wide, the 2 sea year return of Atlantic salmon was poor in 1979 and the Matamek River run was no exception. In addition, there was a poor return of grilse.

For the first time the salmon ladder bypassing the 1st waterfall was open and operational for the entire adult run. Salmon entering the lower area of the ladder below the trap were counted daily. All fish entering the trap were measured for fork length, tagged with a yellow floy tag, a scale sample taken for age, and then released on the upstream side of the trap. Many of these fish were recaptured in a trap-net set above the 2nd falls, which allowed a population estimate to be made. The salmon migrate upstream as far as the 3rd and 4th waterfalls, where gravel bars at the bases of these falls provide the probable spawning grounds. The 4th waterfall marks the upstream limit of the natural salmon range in the river.

Daily movements of salmon and grilse into the fish ladder are shown in Fig. 1. The first returning fish appeared on July 2nd. The run appeared to peak about July 17th, and the number of fish entering the fish ladder dropped off slowly after this. The seven 2 sea-year fish which returned in 1979 all entered the fish ladder trap between July 3rd and July 28th. Entry dates were evenly distributed throughout the month. The

grilse run stretched out into early September. There was no doubt that these were fresh run fish as they were quite silver and had copepod parasites. Late running grilse were also captured at the Provincial fishway at Riviere aux Rochers (Pierre Bertrand, personal communication). The season was characterized by spates in June, July, August and September of this year (Fig. 2), contrasting with the trends of the past few years for even flows during the summer months. In addition to high discharges in mid June and early August, sharp temperature changes also occurred (Fig. 3). The combination of these two factors may account for the extension of the adult run into September this year. The bulk of the run entered the river during a period of descending (low) discharge at the end of July. The water temperature was relatively high (21°C) at this time.

Few adults were observed attempting to jump the 1st falls this year. They were first seen on July 17th, and rarely after that. This was probably a function of the high water levels and the availability of the fishway from the start of the run.

The population estimate for the grilse was 47 (95% confidence limits: 43-51). We did not recapture any tagged 2 sea-year fish in the trap-net above the 2nd falls due to high water levels. We did take some untagged 2 sea-year fish, however. By treating the salmon and grilse together as a population and subtracting the grilse population estimate, we estimate that a total of 10 adult salmon returned this year. Scale readings indicate that the grilse were all 3⁺ smolts with 1 sea-year. This would make them progeny of the run in 1974. The adult salmon, with the exception of a single individual, were also all 3⁺ smolts with 2⁺ sea

years. These fish would have been progeny of the 1973 run. The one exception was a 2⁺ smolt, 2⁺ sea year fish. This would have been progeny of the 1974 run, identical with the grilse. The mean fork lengths ($\bar{x} \pm \text{SE}$) for the adult salmon and grilse were 71.7 ± 1.7 and 51.4 ± 0.50 cm, respectively.

We do not dare sacrifice any adults for sex ratios or egg counts while the runs are so low. However, a few fish die in passage each year, and fish entering the trap net are generally starting to assume secondary sexual characteristics. Based on these data it appears that the 2 sea-year fish remain predominantly female (100%) while the grilse run is predominantly male (80%). This differs from the results of Scheifer (1971) who found 2 sea-year fish were 65% female and grilse 6% female. This shift in grilse towards a higher percentage of females may help to offset the steady decline of salmon in the Matamek River by increasing yearly egg depositions.

In summary, the adult salmon run continues to decline. Estimates of total number of adults in recent years are presented in the Table 1.

Table 1 Population Estimates of Atlantic Salmon (Adults Grilse) in the Matamek River, Quebec.

<u>Year</u>	<u>Population Estimate $\bar{x}$, 95 CI)</u>	<u>References</u>
1969	500	Karl Scheifer, 1971
1976	70 (50-110)	Gibson, 1977
1978	80 (46-139)	Whoriskey, 1979
1979	61 (54-68)	This report

REFERENCES

Gibson, R.J. 1977. Matamek Annual Report for 1976. W.H.O.I. 116pp.

Scheifer, Karl. 1971. Ecology of Atlantic salmon with special reference to occurrence and abundance of grilse in north shore of Gulf of St. Lawrence Rivers. Ph.D. Thesis, Univ. of Waterloo (Ontario, Canada) 129pp.

Whoriskey, F.G. 1979. Matamek Annual Report for 1978. W.H.O.I. 100pp.

Figure Captions - Adult Salmon

- Fig. 1. Return of adult salmon and grilse to the Matamek River fishladder by date.
- Fig. 2. Daily water levels measured at the 2nd Falls. Water levels here are positively correlated with discharge.
- Fig. 3. Daily maximum and minimum water temperatures measured at the 2nd Falls.

Figure 1

Figure 2

Figure 3

The Smolt Run

F.G. Whoriskey, R.J. Naiman and J. Critchley

Atlantic salmon smolts migrating from the Matamek River are a combination of fish produced in the Matamek River itself, and in the tributary Muskrat River. The Muskrat River is a slow flowing, unproductive waterway, and consequently its contribution to the number of smolts migrating is probably low.

Smolts were caught and tagged at two locations in the Matamek River this year, as in previous years. Starting on May 23rd fish caught in the basin below the 2nd Falls (including the base of the Muskrat River 1st falls) were tagged with a green Carlin tag (modified Canadian version) and released. On June 5th, seining was started in the estuary. Untagged fish were given the same model tag, and recaptures of any previously tagged fish were noted. Recaptured fish bearing a 2nd Falls tag were used in a Petersens' estimate of the smolt population size for this year.

A total of 542 smolts were tagged, the largest number since the start of smolt tagging operations at the Matamek Research Station. Of the 542 fish, 134 were tagged at the 2nd Falls and 408 in the estuary.

Ten smolts tagged at the 2nd Falls were recaptured in the estuary. This gives a population estimate of 6,257 smolts (95% confidence limits: 8140-3918). Population estimate results for the last six years are presented in Table 1.

TABLE 1 SMOLT POPULATION ESTIMATES

<u>Year</u>	<u>No. of Smolts</u>	<u>95% Confidence Limits</u>	<u>Source</u>
1974	8,300(b)	(10,980 - 5,620)	Gibson (1974)
1975	8,600(a) 2,500(b)	(15,400 - 1,800) (3,800 - 1,800)	Gibson (1976)
1976	4,720(b) 2,600(a)	(5,670 - 3,050) (4,850 - 1,500)	Gibson (1977)
1977	1,580(b)	(3,330 - 820)	Gibson (1978)
1978	10,248(a)	(17,388 - 3,108)	Whoriskey (unpublished)
1979	6,257(a)	(8,140 - 3,918)	This Study

(a) Petersens' mark/recapture method with fish Carlin tagged at the 2nd falls and recaptured in the Estuary.

(b) Petersens' mark/recapture estimate based on fin clips given to parr of 10 cm fork length the previous year. Does not include overwinter mortality.

The first smolt was tagged at the 2nd falls on May 23rd, at a water temperature of 5.5°C. By May 29-30 smolt activity had increased markedly, and schools of smolts were observed rising under the foam at the base of the 1st Falls in the Muskrat River. By June 4th, relatively large numbers of smolts had started moving into nets at the base of the Matamek 2nd Falls. The 31st of May and 4th of June corresponded to maximum and minimum water temperatures of 9.4°C - 8.3°C and 11.1°C - 10°C, respectively.

Although live trapping continued at the 2nd Falls through the end of July the last smolt taken was on the June 20th. Presumably all smolts had migrated at least as far as the estuary at this time.

The ten 2nd Falls tagged smolts recovered in estuary had a mean time between tagging and appearance in the estuary of 15.4 days (S.E. = 3.1 days; range = 1-33 days).

Seining started in the estuary on June 5th, and apparently part of the run had already passed by that time (Fig. 1). This was somewhat surprising as smolts at the 2nd Falls were just becoming active. Seining continued until July 10th when the run appeared to have finished.

In the estuary 68 of the fish tagged there were recaptured at least one time, and 15 of them were multiple recaptures (range 2 to 5 times). The mean number of days between the date of tagging and final recapture was 5.3 days (S.E. = 0.67 days). It appears the smolts linger in the estuary before migration. This pattern is currently being further analyzed.

As part of the experiment on the sea ranching of brook trout a large number of trout were removed from the 2nd Falls study area was depopulated of brook trout in 1978. We expected to see an enhancement of the juvenile salmon populations due to the removal of competition with the brook trout. None of our data documents an increase in smolt production from the 2nd Falls study area.

Mean fork length of smolts tagged at the 2nd Falls in 1978 and 1979 were identical (Table 2). It is possible that a lag time will exist between a response of the population to the removal of competition. Hopefully the continuing studies underway will help clarify this question.

Table 2. Matamek Smolts - Mean Fork Lengths (cm) of Atlantic salmon smolts in the Matamek River ($\bar{x}$, range)

<u>Year</u>	<u>2nd Falls</u>	<u>Estuary</u>	<u>Reference</u>
1974	-	14.2 (12.2 - 17.9) n = 283*	Gibson (1974)
1975	14.9 (11.8 - 18.3) n = 180	15.7 (12.3 - 21.4) n = 306	Gibson (1975)
1976	-	14.9 (12.0 - 17.9) n = 80	Gibson (1977)
1977	14.5 (11.2 - 20.5) n = 74	14.9 (10.7 - 19.7) n = 144	Gibson (1978)
1978	13.8 (11.3 - 18.8) n = 103	14.4 (11.0 - 19.0) n = 197	Whoriskey (1979)
1979	13.8 (9.8 - 16.8) n = 134	15.2 (10.8 - 19.4) n = 466	This Study

*Includes 80 smolts measured at the second falls.

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Figure Caption - The Smolt Run

Fig. 1. Number of Atlantic salmon smolts taken per seine haul in the Matamek River Estuary during June and July, 1979.

Figure 1

1979 MATAMEK RIVER
SMOLTS CAUGHT PER
SEINE HAUL IN ESTUARY

SECOND FALLS POPULATION ESTIMATES OF ATLANTIC SALMON AND BROOK TROUT

F.G. Whoriskey, R.J. Naiman, P. Heinerman, and L. Paquin

In the early part of the season most brook trout present at the 2nd Falls were removed and planted in the estuary as part of the sea ranching program. It was anticipated that removal of the brook trout would result in an enhancement of the Atlantic salmon population in the area through a reduction of interspecific competition. Unfortunately, data from 1978 are not yet available. In 1979, in comparison with the years 1976 and 1977, an augmentation of the numbers of 2+ salmon parr, and an increase in mean fork length and weight of the 0+, 1+, and 2+ parr occurred (Tables 1, 2).

Estimates of the trout population at the 2nd Falls from 1971-1979 are presented in Table 3. The 2+ trout population had nearly recovered to the previous level estimated for years preceding the sea ranching experiment. The 3+ and older year classes had fewer numbers of fish than in preceding years. The lack of recaptures of marked brook trout of the 1+ year class, and the variations which occurred in estimates of this year class between 1971-1979, make it difficult to interpret trends for the 1+ group.

We feel certain that the removal of brook trout from the second falls area was reasonably complete. At the time we stopped fishing in both years, the catch per unit effort had fallen off dramatically. In 1978 the number of fish removed was close to the estimation of the trout population. Despite this fishing pressure on the trout population, the younger year classes had substantially recovered in 1979. In the case of the trout, downstream migration from over the second waterfall and upstream migration

TABLE 1. 2nd Falls Atlantic Salmom Parr Population Estimates. Values are No. of individuals/ha; 95 percent confidence limits in brackets.

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*

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

TABLE 2. Mean Fork Lengths and Weights of Atlantic Salmon Parr at the 2nd Falls., 1967-1979
($\bar{x} \pm SE$). Data from 1967 from Scheifer 1971. Data from 1971-1977 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	9.7 (0.57)	10.5 (1.74)	13.7 (0.16)	29.6 (1.09)	15.7 (0.15)	43.6 (0.80)

TABLE 3. Brook Trout Population Estimates at the 2nd Falls. Values are No. of individuals/ha; 95 confidence limits in brackets. Estimates were made by Petersens' mark/recapture method. Data for 1971-1977 from Gibson (1976, 1977).

YEAR	AGE			
	<u>1+</u>	<u>2+</u>	<u>3+</u>	<u>4+</u>
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)	-

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

from the section of river between the 1st and 2nd Falls probably occurred. The river habitat between the 1st and 2nd Falls is deep and slow flowing, suitable for trout but not as favorable for salmon. Although we do not know fish densities in this area, from limited sampling it appears that trout were more abundant than salmon in this area.

More extensive analysis of these trends will occur when the 1978 information is processed, and after the 1980 field season when a third years data are available.

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ARTIFICIAL STOCKINGS OF ATLANTIC SALMON

F.G. Whoriskey, R.J. Naiman, T. Dickson and P. Heinermann

About 12,00 salmon fry from Matamek River X St. Marguerite River stock were planted in two areas of the Matamek watershed during July. One area, the Tchinicanman River was high on the Canadian shield and devoid of all fishes except Atlantic salmon stocked there in previous years. The second area was at the base of the Matamek fifth falls, an area in which the salmon would be competing with a brook trout population.

Due to time and budget constraints only the fifth falls area could be sampled at the end of the 1980 growing season. Survival of salmon fry appeared poor. The 1+ parr from the previous years stocking at the fifth falls had tremendous growth but were not abundant.

SEA TROUT STUDIES (Salvelinus fontinalis)

Research on Sea Trout (Salvelinus fontinalis) had two main objectives: 1) a repetition of the previous years sea ranching experiment to demonstrate its reproducibility, and 2) start collection of data on the natural sea trout population in the Moisie River to provide comparisons to the results of the sea ranching project. Reports on these two studies follow:

EXPERIMENTAL SEA RANCHING OF BROOK TROUT, Salvelinus fontinalis

F.G. Whoriskey, R.J. Naiman, J. Critchley, and P. Heinermann.

Results of both years of this experiment are currently under preparation for publication. Here we present a brief description of the results for 1979 and a comparison with the previous years work. Data from 1978 are taken from Gibson and Whoriskey (in preparation), and Whoriskey (unpublished).

Materials and Methods – Techniques in 1979 were essentially the same as in 1978 (Whoriskey 1979). Wild brook trout were trapped at the base of the Matamek River 2nd Falls in early summer and transported into the estuary. Fish were anesthetized, fork length and weight were determined, and the fish tagged for identification before release. An impassable waterfall 0.7 km upstream from the estuary prevented upstream migration of tagged fish beyond this point. We modified the tagging procedure in 1979 after the first years results indicated deleterious effects had occurred from the Floy tags, especially in smaller fish. Fish with fork lengths <10 cm

were fin clipped. Fish with fork lengths between 10 cm and 12.5 cm were marked with a Canadian tag (modified Carlin tag). Fish larger than 12.5 cm received a Floy anchor tag. Fish were recaptured from late August to mid-October by angling or with seines. Captured fish were examined for fork length, weight, sex, food habits and age.

Results and Discussion – Good percentage returns of transplanted fish were achieved in both years of the study (Table 1). Strongest returns were in the 2+ and 3+ year classes, with low recoveries of the 1+ and 4+ fish. More 1+ fish were caught in 1979 than in 1978, which might be a function of a slightly longer time spent sampling in 1979 than 1978, and also of the modification of the tagging procedures.

There was a bimodal response in the returns of each year class, with only a certain percentage of the fish developing a sea run response. Percentages of sea trout in the returned fish were similar in the two years, and trends were noted towards increasing numbers of sea trout in larger and older year classes (Table 1). Sea-run fish and river dwelling fish were all at liberty for approximately the same amount of time (Table 2).

Growth rates (Fig. 1) and condition factors (Table 3) were higher in sea-run fish than fish which remained in the river. Only in 1979 (Fig. 1) did the growth rates of sea trout approach the rates of non-manipulated populations of trout in the Matamek River. Samples of natural sea trout from the small population which existed in the Matamek estuary (Whoriskey, unpubl.) indicated that growth rates of sea trout are usually higher than those of river fish. We feel the depression of growth rate is due in large part to the tagging procedure.

Evident in the 1979 sea run trout, as compared to the river response fish, was a suppression of maturation (Table 4). This was also observed in 1978, but to a lesser extent (Table 5). Maturation levels in river response fish were also suppressed compared to undisturbed brook trout populations (Gibson et al., 1976). This suppression is a positive characteristic for sea trout from our point of view, as development of sexual maturity coincides with a loss of osmoregulatory ability, a decrease in growth rates, and a decline in flesh quality (Sutterlin et al., 1976).

Some fish released in 1978 evaded capture in that year and overwintered in the estuary (about 3 percent of the total population planted). Data from their recaptures during final sampling in 1979 are presented in Table 6. There appeared to be no augmentation of growth rates in the second season as compared to the first.

We know little about potential predators and competitors of sea trout. Potential predators include mergansers, loons, ospreys, gulls and terns. The first three never occurred in large numbers in 1979. We observed ospreys occasionally feeding but they appeared to be concentrating on marine flatfish. We did not observe feeding of loons and mergansers. Gulls and terns occurred in large numbers in the area and observations of their feeding indicated they were concentrating on sand lance (Ammodytes spp.). Inspection of the roosting areas of these birds turned up no tags.

The most abundant fish in the Matamek estuary is probably the tomcod (Microgadus tomcod). An analysis of stomach contents taken from a sample of tomcods in late August indicated these fish were utilizing the same

food resource as sea trout, and could be a potential competitor (Table 7). Another potential predator could be the cod (Gadus morhua) but they do not occur frequently in the estuary and we have no information indicating they feed on sea trout (Whoriskey, unpubl.).

In summary, the sea ranching experiment resulted in high returns and good growth, which probably would have been better if fish had not been subjected to tagging. Straying was low; <1% of the planted fish for both years were taken outside the Matamek River system.

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TABLE 1
RELEASE AND RECOVERY STATISTICS

RETURNS OF ALL PLANTED FISH

AGE	NO. OF FISH PLANTED		NO. OF FISH RECOVERED		PERCENT RECOVERED	
	1978	1979	1978	1979	1978	1979
1+	190	320	10	62	5.3	19.3
2+	451	309	167	150	30.8	48.5
3+	193	150	104	106	55.4	70.7
4+ 5+	97	42	16	6	16.5	18.8

INDUCTION OF ANADROMY IN RETURNS

AGE	NO. SEA RUN		TOTAL RECOVERIES		PERCENT SEA RUN FISH	
	1978	1979	1978	1979	1978	1979
1+	10	62	0	3	0	4.8
2+	167	150	22	21	13	14.0
3+	104	106	38	13	36	12.3
4+	12	6	9	0	75	0
5+	4	-	3	-	75	-

TABLE 2. MEAN DAYS AT LIBERTY $\pm$ SE; NUMBER OF FISH IN PARENTHESES

AGE	RIVER FISH		SEA RUN	
	<u>1978</u>	<u>1979</u>	<u>1978</u>	<u>1979</u>
1+	67 $\pm$ 3 (10)	98 (59)	-	94 (3)
2+	76 $\pm$ 2 (118)	86 $\pm$ 2 (117)	73 $\pm$ 4 (22)	79 $\pm$ 4 (17)
3+	73 $\pm$ 2 (65)	76 $\pm$ 2 (88)	79 $\pm$ 3 (33)	81 $\pm$ 5 (12)
4+	63 $\pm$ 3 (3)	71 $\pm$ 10 (6)	76 $\pm$ 6 (9)	-
5+	83 (1)	-	88 $\pm$ 9 (3)	-

TABLE 3 MEAN CONDITION FACTOR $\pm$ SE: NUMBER OF FISH IN SAMPLE IN PARENTHESES.

AGE	1978		1979	
	RIVER FISH	SEA RUN	RIVER FISH	SEA RUN
1+	0.92 $\pm$ 0.02(10)	-	1.04 $\pm$ 0.01(59)	1.06 $\pm$ 0.05(3)
2+	0.95 $\pm$ 0.01(111)	0.99 $\pm$ 0.01(20)	0.99 $\pm$ 0.01(128)	1.15 $\pm$ 0.06(20)
3+	1.00 $\pm$ 0.08(82)	1.04 $\pm$ 0.02(25)	1.02 $\pm$ 0.01(88)	1.08 $\pm$ 0.02(13)
4+	1.05 $\pm$ 0.03(3)	1.12 $\pm$ 0.03(9)	1.09 $\pm$ 0.04(6)	-
5+	1.16 (1)	1.04 $\pm$ 0.02(3)	1.09 (1)	-

TABLE 4. 1979 SEA RANCHING EXPERIMENT - SEXUAL CHARACTERISTICS NUMBER OF FISH IN SAMPLE IN PARENTHESES

<u>FISH WITH SEA RUN RESPONSE</u>				
<u>AGE</u>	<u>F:M</u>	<u>PERCENT FISH MATURE</u>	<u>PERCENT MALES MATURE</u>	<u>PERCENT FEMALES MATURE</u>
1+	2.00 (3)	0	0 (1)	0 (2)
2+	2.17 (19)	0	0 (6)	0 (13)
3+	3.33 (3)	31	0 (3)	40 (10)

<u>FISH WITHOUT SEA RUN RESPONSE</u>				
<u>AGE</u>	<u>F:M</u>	<u>PERCENT FISH MATURE</u>	<u>PERCENT MALES MATURE</u>	<u>PERCENT FEMALES MATURE</u>
1+	0.59 (59)	0	0 (37)	0 (22)
2+	0.83 (128)	10	9 (70)	12 (58)
3+	0.77 (87)	49	39 (49)	63 (38)
4+	0.50 (6)	100	100 (4)	100 (2)
5+	-	100	-	100 (1)

TABLE 5. 1978 SEA RANCHING EXPERIMENT - SEXUAL CHARACTERISTICS
NUMBER OF FISH IN PARENTHESES

<u>FISH WITH SEA RUN RESPONSE</u>				
<u>AGE</u>	<u>F:M</u>	<u>PERCENT FISH MATURE</u>	<u>PERCENT MALES MATURE</u>	<u>PERCENT FEMALES MATURE</u>
2+	1.00 (22)	18	18 (11)	18 (11)
3+	1.37 (38)	39	7 (16)	64 (22)
4+	0.50 (9)	78	67 (6)	100 (3)
5+	0.50 (3)	67	50 (2)	100 (1)

<u>FISH WITHOUT SEA RUN RESPONSE</u>				
<u>AGE</u>	<u>F:M</u>	<u>PERCENT FISH MATURE</u>	<u>PERCENT MALES MATURE</u>	<u>PERCENT FEMALES MATURE</u>
1+	1.50 (11)	0	0	0
2+	0.95 (131)	14	6 (67)	23 (164)
3+	1.23 (67)	54	47 (30)	59 (37)
4+	2.00	100	100 (1)	100 (2)
5+	-	100	-	100 (1)

TABLE 6. OVER WINTERED FISH, 1978-1979: GROWTH AND SEXUAL CHARACTERISTICS

2+		3+		4+	
PERCENT TOTAL GROWTH (N=6)		PERCENT TOTAL GROWTH (N=4)		PERCENT TOTAL GROWTH (N=1)	
<u>1978</u>	<u>1979</u>	<u>1978</u>	<u>1979</u>	<u>1978</u>	<u>1979</u>
34 ± 13	36 ± 10	52 ± 8	71 ± 25	74	10

SEX RATIOS	
<u>AGE</u>	<u>F/M</u>
2+	3.00
3+	2.00
4+	- (1 Female)

TABLE 7. FOOD HABITS: TOMCOD (MICROGADUS TOMCOD): Sampled Aug 31, 1979

MEAN LENGTH (CM $\pm$ SE)	STOMACH FULLNESS PERCENT	PERCENT STOMACH CONTENTS				
		<u>AMPHIPODA</u>	<u>MYSIDACEA</u>	<u>SAND LAUNCE</u>	<u>ALGAE</u>	<u>WOOD DEBRIS</u>
9.5 $\pm$ 0.1 (100)	75 (27)	96	-	-	1	3
17.0 $\pm$ 0.2 (50)	75 (14)	90	1	8	-	2

Figure Caption - Sea Ranching

Fig. 1. Total growth and growth rate are compared by age group for sea trout and river trout in 1978 and 1979 and trout taken in previous years in the Matamek River and Matamek Lake.

Figure 1

MOISIE RIVER SEA TROUT

F.G. Whoriskey, R.J. Naiman, J. Critchley, P. Heinermann,
Linn Montgomery, and L. Paquin

The Moisie River supports a relatively large population of sea trout, although the actual size of the population is unknown. The sea trout are reported to migrate into the estuary from upstream sites in early summer, and return in the fall to overwintering and spawning areas upstream (M. Mitchell Campbell, personal communication).

Two major spawning areas are known. The first is Riviere a la Truite approximately 11 km upstream from the estuary, the second is in a series of gravel bars slightly upstream from the Moisie Salmon Club main camp (approximately 20 km upstream from the estuary). Little else is known of the biology or movements of these fish.

Recently, exploitation has caused a major decline in the population of sea trout (Mitchell Campbell, personal communication). Currently the sea trout support a recreational fishery and a native peoples food fishery within the estuary of the Moisie River. If Atlantic salmon stocks continue to decline more intense fishing pressure is likely to be applied to the existing sea trout stocks (M. Pierre Bertrand, personal communication), leading to further declines in numbers of sea trout.

In July of 1979 we started preliminary work on a major research effort dealing with the population of sea trout in the Moisie River. The major objectives are: 1) to describe the biology and migration patterns of sea trout for effective management of the resource, and 2) to provide

comparative information between a natural sea trout population from the Sept Iles area and the sea ranching experiment described elsewhere in this report.

Methods – Sampling of sea trout started in July of 1979. Sampling sites were located in Riviere a la Truite, within the boundaries of the Moisie Salmon Club, and in the estuary of the Moisie River. We sampled by seining, angling, and gill netting, and determined fork length, weight, sex and age of collected fish. Gill nets were only used successfully at Riviere a la Truite. We took the direction from which a fish entered a gill net to indicate the direction of movement. Gill nets spanning Riviere a la Truite had stretch mesh sizes of 2", 1-1/2", and 1" and were deployed in an upstream direction, respectively.

Results and Discussion – We caught sea trout in the Moisie estuary from July 20th to August 16th, but an intensive sampling effort on September 4th produced no sea trout. During the period from July 20th to August 16th, sea trout appear to occur over a wide area of the estuary. Samples of fish from progressive upstream stations contained fewer and fewer sea trout. The sea trout component of the samples were replaced at first by brook trout, then a mixture of brook trout and Atlantic salmon parr at our most upstream estuary station. Further studies in 1980 will be directed at this zonation pattern.

Our samples suggest that most of the year's growth for all year classes of brook trout and sea trout was finished by the end of July

(Fig. 1). Brook trout of year classes 2+ and 3+ were larger than sea trout of the same year classes. We cannot explain this apparent anomaly at this time.

Migration of sea trout from the estuary to upstream sites appears to have started by August 13th, which corresponded with the first appearances of sexually maturing fish in estuary samples. The start of the migration was indicated by a maturing male sea trout, the first taken at an upstream site, which was captured on this day at the Moisie Club site. Sea trout were taken on October 3rd, 9th, and 16th at Riviere a la Truite. Indicating the sea trout migration spans at least two months. We can not tell from our data when the peaks of migration occur, if they exist.

Immature, mature, and post spawned brook trout and sea trout moved into Riviere a la Truite during October (Table 1). If we assume these movements are directed (not random) Riviere a la Truite appears to serve as both a over-wintering area for post spawned and immature fish, and as a spawning site for mature individuals. Captured sea trout had fewer mature fish than did sampled brook trout. This agrees with our sea ranching study (this report) and Sutterlin et al. (1976) that a period of sea life suppresses sexual maturity. There is also a trend towards larger numbers of sea trout females moving into Riviere a la Truite at the time of our sampling. This may reflect sampling error, or may indicate a difference of migration times for males and females. The latter idea is supported by samples of sea trout taken in the estuary of the Moisie River (Table 2). Due to sample sizes only the 2+ and 3+ year classes are comparable. In these year classes the ratio of males to females was approximately equal or biased towards the males.

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Table 1

RIVIERE A LA TRUITE
BROOK TROUT AND SEA TROUT
SEXUAL CHARACTERISTICS

Fish sampled between October 3 and October 16, 1979.
Number of fish in sample in parentheses

BROOK TROUT

Age	Percent Females	Percent Upstream Movement	Percent Immature	Percent Mature	Percent Post Spawning
0+	-	-	-	-	-
1+	-	-	-	-	-
2+	-	-	-	-	-
3+	87 (14)	83	7	14	79
4+	87 (8)	100	12	25	63
5+	100 (2)	100	-	50	50

SEA TROUT

0+	-	-	-	-	-
1+	-	-	-	-	-
2+	62 (16)	73	100	-	-
3+	58 (26)	73	92	8	-
4+	100 (3)	100	-	67	33
5+	-	-	-	-	-

Table 2

MOISIE ESTUARY SEA TROUT
SEXUAL CHARACTERISTICS

Fish sampled between July 20th and August 13th, 1979.
Number of fish in parentheses.

Age	Percent Females	Percent Immature	Percent Mature	Percent Post Spawn
0+	67 (3)	100	-	-
1+	60 (48)	96	4	-
2+	52 (50)	100	-	-
3+	37 (19)	95	5	-
4+	100 (1)	100	-	-
5+	-	-	-	-

Figure 1

On the Occurrence of Stray Salmonids on the North Coast of the
St. Lawrence River.

F.G. Whoriskey, R.J. Naiman, P. Heinermann and J. Critchley

Two tagged Atlantic salmon (Salmo salar) and 14 steelhead trout (sea run rainbow trout, Salmo gairdneri) were recovered during the late summer and early fall of 1979 in the vicinity of the Matamek Research Station.

The salmon were both tagged as hatchery reared smolts, one originating in Maine the other from the eastern shore of Nova Scotia. The Maine fish was trapped in a gill net and given to us by a commercial herring fisherman. The fish from Nova Scotia passed through our fishway and migrated upstream. On Sept. 21, 1979 this fish was once again taken in a seine haul in the estuary of the Matamek River presumably a washdown over the 1st falls. The fish had a brown "river coloration" and seemed quite healthy. It is unlikely that he had spawned as spawning in the Matamek River by Atlantic salmon has not been observed before late October.

Steelhead trout were taken in the Matamek River and the Moisie River. Within the Province of Quebec steelhead were also taken on the South shore of the Saint Lawrence River, and further west along the North Coast at Riviere aux Rochers (Pierre Bertrand, personal communication).

In previous years two other steelhead have been taken at the Matamek River. One was in 1974 the other in 1976. The rainbow trout occupies an ecologically similar niche to the Atlantic salmon and recent experiments (Gibson 1979) indicate that in competition rainbow trout displace

Atlantic salmon and brook trout (Salvelinus fontinalis) to less favorable habitats. In the Moisie River establishment of rainbow trout could result in a severe reduction of the population of Atlantic salmon in one of the finest salmon rivers on the North Coast. The Matamek River and several other rivers along the coast are probably safe from colonization as waterfalls short distances upstream from their estuaries provide substantial barriers to further upstream migration.

We are currently trying to track down the source of these steelhead trout.

REFERENCES

Gibson, R.J. 1979. Behavioural interactions between coho salmon (Oncorhynchus kisutch), Atlantic salmon (Salmo salar), brook trout (Salvelinus fontinalis) and steelhead trout (Salmo gairdneri), at the juvenile fluvatile stages. In F.G. Whoriskey Matamek Annual Report for 1978, 100pp.

Insect Colonization and the Diets of Salmonids in the Matamek River

F.G. Whoriskey, R.J. Gibson, Jean-Yves Charette, M. Winsor

P. Heinermann, and F. Cotton.

During the summers of 1976 and 1977, artificial substrate samplers (colonization baskets) constructed of Vexar screening (1/4" mesh size, 785 cm³ volume in 1976, 393 cm³ volume in 1977) and filled with rocks of approximately 3.8 cm radius were installed at the bases of the second, third, fourth and fifth falls of the Matamek River, and at the outlet of Matamek Lake into the Matamek River. The colonization baskets were sampled at approximately three week intervals. All rocks were gently rubbed free of insects, and the insects returned to the laboratory for identification, enumeration, and weight determinations. In cases where large numbers of insects in a sample prevented sorting all the insects present individually, subsamples were taken either with a plankton splitter, or through the use of the technique devised by Allanson (1961). Water velocities and depths were recorded for each colonization basket at the time of its placement and retrieval. On occasion, additional measurements were taken during intermediate periods.

On the dates the baskets were cleaned samples were taken of salmon and trout (or trout alone in sites upstream of the fourth falls which marks the limit of the salmon range) for determination of feeding habits. Fork lengths, weights, and sexes were recorded and a sample of scales taken for age determinations. The stomachs of the fish were preserved and later the contents identified, and percent compositions of food organisms estimated by the method of Hynes, 1950.

An in depth analysis of the data has not been conducted (raw data is presented in the following tables), but a few general points may be raised. The dominant insects in terms of numbers and volumes in the samples during the early summer were simuliid larvae. These were replaced in numerical dominance later in the season by chironomid larvae and a weight dominance of trichoptera larvae, especially hydropsychids. The outlet area from Matamek Lake appears to be a very productive region in June. The largest number of insects and largest weight of insects in the entire study were recorded there. Productivity appears to taper off later in the season, however.

A cursory examination of the contents of the stomach suggest that larger fish selected for larger food organisms, sometimes ignoring completely the dominant insect groups present during a particular season. A good example of this is the diet of brook trout at the fifth falls in June.

Further analysis of the data is currently underway.

REFERENCES

- Allanson, B.R. and J.E. Kerrick. 1961. A statistical method for estimating the numbers of animals found in field samples drawn from polluted rivers. Verh. Internat. Verein. Limnol. 14: 491-494.
- Hynes, H.B.N. 1950. The food of fresh water sticklebacks (Gasterosteus aculeatus and Pygosteus pungitius), with a review of methods used in studies of the foods of fishes. J. Anim. Ecol., 19: 32-58.

FOOD HABITS
BROOK TROUT - 3rd FALLS
Values expressed as mean percent stomach contents

METHOD OF CAPTURE DATE OF CAPTURE NO. OF STOMACHS EXAMINED AGE	n=5 1+	ANGLING 15/VIII/76 n=11 2+	n=2 3+
FOOD ITEM			
DIPTERA			
Simulidae adults		0.2	
Simulidae larvae		0.9	2.5
Simulidae pupae			
Chironomidae larvae		1.4	1.3
Chironomidae pupae	0.7		
Tabanidae	17.5		
COLEOPTERA		15.4	
HYMENOPTERA		2.7	15.0
HOMOPTERA		4.5	1.5
TRICHOPTERA			
Adults			2.5
Hydropsychidae larvae		5.9	3.7
Case Building larvae		20.0	15.5
Unidentified and debris*	41.8	32.5	6.0
Mean percent Stomach Fullness	14.5	35.5	37.5
Number Stomachs Empty	2	1	0

*Includes sticks, rocks, and spruce needles

FOOD HABITS
SALMON PARR - 3rd FALLS
Values expressed as mean percent stomach contents

METHOD OF CAPTURE		ANGLING	
DATE OF CAPTURE		15/VIII/76	
NO. OF STOMACHS EXAMINED	n=7	n=27	n=3
AGE	1+	2+	3+
<hr/>			
FOOD ITEM			
DIPTERA			
Simuliidae adults	2.8	1.7	0.3
Simuliidae larvae		0.9	7.5
Chironomidae adults		1.3	0.3
Chironomidae larvae	4.2	5.5	10.0
Chironomidae pupae	0.4	0.7	
Rhagionidae larvae		0.9	
Tabanidae adults		1.8	
Tabanidae larvae		1.0	3.3
Ceratopogonidae larvae		0.2	
Empididae larvae		1.1	0.4
COLEOPTERA	17.1	2.4	
HYMENOPTERA	4.3	9.3	4.0
PLECOPTERA			
Larvae	2.1		
TRICHOPTERA			
Adults	11.4	9.8	
Hydropsychidae larvae	6.3	8.1	50.0
Case Building larvae	11.4	9.9	4.2
Rhyacophyllidae larvae	0.1	0.1	
Unidentified larvae		0.4	
ARACHNIDA		1.6	3.3
HOMOPTERA	5.7	4.0	
HEMIPTERA		0.5	
EPHEMEROPTERA			
larvae	0.1	1.3	

FOOD HABITS
SALMON PARR - 3rd FALLS (Cont.)
Values expressed as mean percent stomach contents

METHOD OF CAPTURE		ANGLING	
DATE OF CAPTURE		15/VIII/76	
NO. OF STOMACHS EXAMINED	n=7	n=27	n=3
AGE	1+	2+	3+
<hr/>			
FOOD ITEM			
ODONATA			
adults		1.8	
larvae		2.4	
MECOPTERA			1.1
COLLEMBOLLA		0.1	
Debris and Unidentified*	33.7	17.7	15.0
Mean Percent Stomach Fullness	85.5	55.5	60.0
Number Stomachs Empty	0	2	0

*Includes sticks, rocks and spruce needles

FOOD HABITS
SALMON PARR - 2nd FALLS
Values expressed as mean percent stomach contents

METHOD OF CAPTURE	SEINING AND ANGLING			SEINING			SEINING			ANGLING		
DATE OF CAPTURE	21/VI/76			7/VII/76			13/VIII/76			5/IX/76		
NO. OF STOMACHS EXAMINED	n=8	n=2		n=17	n=6	n=1	n=7	n=6	n=1	n=6	n=12	n=5
AGE	1+	2+		1+	2+	3+	1+	2+	3+	1+	2+	3+
FOOD ITEM												
DIPTERA												
Simuliidae adults		22.5		1.1				0.8	1.0		5.4	
Simuliidae larvae	32.2	2.0				0.4	1.4		1.0	1.7		
Simuliidae pupae												0.1
Chironomidae adults				0.3						1.8	1.1	
Chironomidae larvae	14.0	0.5		2.0		1.3	1.6			2.9	0.8	0.2
Chironomidae pupae	0.1			22.3	35.0	35.0				2.5		
Rhagionidae larvae	1.1											
Ceratopogonidae larvae	0.3			0.1				0.2				
Tabanidae larvae				1.5								1.0
Empididae larvae				0.5					1.7	7.9	3.0	
Unidentified												
COLEOPTERA												
Adults		5.0		2.7	0.2		10.7	0.8	2.0	3.3	0.8	6.0
Larvae							18.6	10.0				
HYMENOPTERA												
							2.1	22.3	65.0		9.6	5.0
PLECOPTERA												
Adults							3.6					
Larvae	3.1									8.3		
TRICHOPTERA												
Adults		32.5		11.1	19.7		6.4	22.5	10.0			6.0
Hydropsychidae larvae	4.1						2.1		1.0	13.3	6.2	25.0
Case Building larvae		1.0		10.2	6.3	50.0	8.2	8.3		20.8	10.0	9.0
Rhyacophyllidae larvae											1.7	
Pupae	10.6			12.6	20.0	10.0						
Unidentified								0.9				

FOOD HABITS
SALMON PARR - 2nd FALLS (Cont.)
Values expressed as mean percent stomach contents

[illegible]

FOOD HABITS
BROOK TROUT - 5th FALLS
Values expressed as mean percent stomach contents

METHOD OF CAPTURE DATE OF CAPTURE NO. OF STOMACHS EXAMINED AGE	ANGLING 19/VI/76			ANGLING 6/VII/76			ANGLING 13/VIII/76		
	n=1 1+	n=3 2+	n=9 3+	n=3 4+	n=1 5+	n=4 1+	n=15 2+	n=2 3+	n=1 4+
FOOD ITEM									
DIPTERA									
Simuliidae adults		1.7	1.9	2.0	10.0		0.5	1.7	0.5
Simuliidae larvae	50.0	56.6		0.6		85.6	80.2	68.2	2.0
Simuliidae pupae	1.0					0.1	0.3		
Chironomidae larvae	1.0	0.6				0.2			3.2
Chironomidae pupae						0.5			1.5
Rhagionidae adults									0.5
Rhagionidae larvae		3.3	0.9		15.0		0.7		3.3
Tabanidae adults							1.6	1.5	0.4
Tabanidae larvae						0.2	0.3		1.6
Tipulidae larvae				28.0			3.3		1.0
Empididae larvae							0.1		
Unidentified						0.1			2.0
COLEOPTERA		5.3	22.7	16.6	15.0		2.0		2.2
HYMENOPTERA			1.3	3.3	1.0		0.1	0.5	16.0
TRICHOPTERA									
Adults		1.7	0.3		4.0				10.5
Hydropsychidae larvae	15.0	3.3		1.0		1.2	1.3	0.5	3.0
Case building larvae		6.6					0.6	3.5	4.0
									48.0
ARACHNIDAE		0.3	0.3	1.6					0.2
HOMOPTERA			0.1						3.0
HEMIPTERA			0.9						2.0

[illegible]

FOOD HABITS
BROOK TROUT - LAKE OUTLET
Values expressed as mean percent stomach contents

METHOD OF CAPTURE	ANGLING			
DATE OF CAPTURE	6/VII/76			
NO. OF STOMACHS EXAMINED	n=3	n=8	n=11	n=1
AGE	1+	2+	3+	4+
<hr/>				
FOOD ITEM				
DIPTERA				
Simulidae adults	10.0	13.1	46.2	0.5
Simulidae larvae	44.3	35.6	14.0	0.5
Simulidae pupae	51.0	49.9	32.4	99.0
Chironomidae larvae	0.3	0.1		
Rhagionidae larvae	0.3			
Debris and Unidentified		1.2	7.1	
Mean Percent Stomach Fullness	71.5	100.0	82.0	100.0
Number Stomachs Empty	0	0	0	0

FOOD HABITS
BROOK TROUT - 2nd FALLS
Values expressed as mean percent stomach contents

METHOD OF CAPTURE DATE OF CAPTURE NO. OF STOMACHS EXAMINED AGE	ANGLING 20/VI/76 n=11 2+	n=3 3+	n=2 4+	SEINING 7/VII/76 n=3 1+	n=8 2+	n=3 3+	SEINING 14/VIII/76 n=6 2+	n=4 1+	SEINING 5/IX/76 n=3 2+
FOOD ITEM									
DIPTERA									
Simuliidae adults	2.4	0.3						2.5	
Simuliidae larvae	22.5	5.3					0.2		
Chironomidae larvae	1.0	0.3			0.1		0.2		
Chironomidae pupae	0.1	0.1		1.0	7.7	8.3	0.2		
Tipulidae adults					6.3				
Rhagionidae adults		0.1							
Rhagionidae larvae				0.1			11.7		
Ceratopogonidae larvae		3.3							
Tabanidae larvae									
COLEOPTERA									
Adults	13.6	7.5		3.3	10.0	6.3	1.7		
Larvae	4.2	1.2			0.3		3.7		
HYMENOPTERA									
	0.6	1.7	10.0		4.3	3.3	42.5	18.3	30.0
PLECOPTERA									
Adults	1.8								
Larvae	2.0	3.3							
TRICHOPTERA									
Adults	0.6	0.3	2.5		1.9	5.7	20.0	33.0	7.5
Hydropsychidae larvae	1.7				0.6		8.8	0.5	
Case building larvae	16.2	13.7	5.0	40.0	13.1	2.5	12.7		13.3
Pupae					7.8	35.0			
Unidentified larvae					0.3				

FOOD HABITS
BROOK TROUT - 2nd FALLS (Cont.)
Values expressed as mean percent stomach contents

METHOD OF CAPTURE DATE OF CAPTURE NO. OF STOMACHS EXAMINED AGE	ANGLING 20/VI/76 n=11 2+ 3+ 4+	SEINING 7/VII/76 n=3 1+ 2+ 3+	SEINING 14/VIII/76 n=4 1+ 2+ 3+	ANGLING 5/IX/76 n=3 2+
FOOD ITEM				
ARACHNIDA	1.7			
HOMOPTERA		1.6 1.9 0.3		
LEPIDOPTERA Larvae		8.3 21.8 19.1		
EPHEMEROPTERA Larvae	8.6 7.0			
ODONATA Larvae	1.8			
AMPHIPODA		1.6		
Unidentified a Debris	21.7 41.8 75.0	44.0 22.7 18.7	10.8 30.5 12.5	19.9
Mean Percent Stomach Fullness	81.5 75.0 100.0	83.5 100.0 100.0	43.5 79.0 75.0	16.5
Number Stomachs Empty	0 0 0	0 0 0	0 0 1	2

COLONIZATION BASKETS
1976 2nd Falls

Sample Date	16/VI/76	1/VIII/76	16/VII/76	9/VIII/76	29/VIII/76	1/X/76
No. of Baskets	3	3	4	4	4	4
Mean Current Velocity (cm/sec)	31 + 7	26 + 8	28 + 5	54 + 11	40 + 4	41 + 6
Mean Basket Depth (cm)	49 + 9	41 + 3	39 + 3	44 + 5	40 + 3	48 + 4
Method of Preparation	2 Picked For All 1 Plankton Split	3 Picked For All	2 Allenson 2 Picked For All	2 Allenson 2 Picked For All	1 Allenson 1 Picked For All 2 Plankton Splits	3 Allenson 1 Picked For All
TAXON	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)
DIPTERA						
Chironomidae	709	0.07	6848	0.86	1743	0.55
Simuliidae	5432	4.57	112	0.04	124	0.17
Tipulidae			1	<0.01	1	0.01
Rhagionidae	1	0.02	143	0.40	4	<0.01
Others	2	<0.01			1	<0.01
TRICHOPTERA						
Net Spinning-	46	0.21	942	1.08	2990	2.14
Case Building	8	0.25	4	<0.01	1	<0.01
Free Living	4	0.04	1	0.03	10	0.01
Unidentified			400	0.03	1591	0.32
PLECOPTERA						
Setipalpia	12	0.09	28	0.10	16	0.05
Filipalpia	15	0.01	3	<0.01	2	<0.01
Unidentified			4	<0.01	16	<0.01
			1	<0.01	47	0.09

COLONIZATION BASKETS
1976 2nd Falls (Cont.)

<u>TAXON</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>
EPHEMEROPTERA	3	0.01	8	0.10	18	0.05	3	<0.01	5	<0.01	9	0.03
ODONATA												
COLEOPTERA					1	<0.01	14	<0.01	2	<0.01	2	<0.01
ARTHROPODA*	3	<0.01			147	0.01	16	<0.01				
COLLEMBOLLA					2	<0.01	3	<0.01			1	<0.01
HIRUDINEA												
Others	2	<0.01	28	0.01	16	<0.01	5	0.13	44	0.01	10	<0.01
TOTALS	6,237	5.27	609	1.67	8,664	2.6	6,453	1.56	5,033	2.9	1,984	1.67

*Mostly Hydracarina

Sample Date	31/V - 5/VI/76	15/VI/76	3-4/VI/76	17-18/ VII/76	10-11/ VIII/76	30-31/ VIII/76	4-5/X/76
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Sample Date	31/V - 5/VI/76	15/VI/76	3-4/VI/76	17-18/ VII/76	10-11/ VIII/76	30-31/ VIII/76	4-5/X/76
No. of Baskets	5	4	4	4	6	6	6
Mean Current Velocity (cm/sec)	36 + 4 —	30 + 9 —	29 + 3 —	17 + 5 —	35 + 7 —	22 + 3 —	37 + 4 —
Mean Basket Depth (cm)	31 + 3 —	65 + 11 —	44 + 6 —	40 + 9 —	46 + 7 —	34 + 2 —	52 + 5 —
Method of Preparation	5 Picked For All	4 Picked For All	3 Allenson 1 Picked For All	4 Allenson	6 Allenson	2 Plankton Splits 3 Picked For All 1 Allenson	6 Allenson

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TAXON	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)
DIPTERA										
Chironomidae	166	0.01	613	0.04	3227	0.07	6559	1.25	2326	0.11
Simuliidae	4575	1.12	1119	0.60	119	0.13	5	0.01	106	0.05
Tipulidae	1	0.01					1	<0.01		
Rhagionidae	1	0.01	3	<0.01	3	<0.01	61	0.08	20	0.04
Other			1	<0.01	1	<0.01	15	<0.01	2	<0.01
TRICHOPTERA										
Net Spinning	12	0.14	29	0.13	172	2.04	58	<0.01	1023	1.38
Case Building	1	0.20	6	<0.01	1	0.12	20	<0.01	46	0.01
Free Living	1	0.02	1	0.16	1	0.03	295	0.02	16	<0.01
Unidentified										
PLECOPTERA										
Setipalpia	7	0.10	34	0.43	25	0.54	8	0.03	12	0.06
Filipalpia	1	0.01			1	<0.01	1	<0.01		
Unidentified			7	<0.01						

COLONIZATION BASKETS
1976 3rd Falls (Cont.)

TAXON	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)
EPHEMEROPTERA			6	0.04	7	0.06	32	0.02	10	0.03	15	0.06		
ODONATA														
EMPIDIDAE	2	<0.01	8	<0.01	5	<0.01	44	<0.01	11	<0.01	7	<0.01	7	<0.01
ARTHROPODA*	3	<0.01	31	0.04										
COLLEMBOLLA			1	<0.01	1	<0.01	1	<0.01			1	<0.01		
HIRUDINAE							2	<0.01						
Others	3	<0.01	2	0.01	32	<0.01	35	0.01	8	<0.01	34	0.01	1	<0.01
TOTALS		1.63	1,861	1.44	3,395	2.99	7,137	1.42	3,586	1.68	3,641	1.19	2,643	2.63

*Mostly Hydracarina

COLONIZATION BASKETS
1976 4th Falls

Sample Date	6/VII/76	19/VII/76	12/VIII/76	2-3/IX/76	7/X/76
No. of Baskets	1	2	4	4	4
Mean Current Velocity (cm/sec)	18 $\pm$ 1	29 $\pm$ 7	28 $\pm$ 4	51 $\pm$ 11	40 $\pm$ 6
Mean Basket Depth (cm)	52 $\pm$ 27	43 $\pm$ 12	71 $\pm$ 12	72 $\pm$ 5	79 $\pm$ 5
Method of Preparation	Picked For All	-	2 Allenson 2 Picked For All	4 Plankton Splits	4 Allenson

TAXON	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)
DIPTERA										
Chironomidae	901	0.2	10,837	1.13	2766	0.18	931	0.05	2878	0.08
Simuliidae	7	0.2	4	<0.01	280	0.07	33	0.01	698	0.16
Tipulidae									1	0.07
Rhagionidae	1	<0.01	18	0.04	17	<0.01			23	0.08
Others					1	<0.01				
TRICOPTERA										
Net Spinning	5	0.02	851	1.32	1477	1.23	2024	1.48	375	2.01
Case Building	5	0.62	2	<0.01	13	0.08	4	0.01	28	0.01
Free Living					12	0.05	38	0.10	12	0.05
Unidentified					52	<0.01	9	<0.01	52	<0.01
PLECOPTERA										
Setipalpia	10	0.53	10	0.64	1	<0.01	32	0.20	85	0.60
Filipalpia			3	0.03			1	0.03	8	0.02
Unidentified							10	<0.01	56	<0.01

COLONIZATION BASKETS
1976 4th Falls (Cont.)

<u>TAXON</u>	<u>No. of Insect</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>
EPHEMEROPTERA	36	0.53	33	0.01	28	0.03	19	0.07	26	0.20
ODONATA	2	0.15								
COLEOPTERA	5	<0.01			3	<0.01	1	<0.01	3	<0.01
ARTHROPODA*					27	<0.01			3	<0.01
COLLEMBOLLA							1	<0.01	1	<0.01
HIRUDINEA										
Others	3	<0.01			35	0.05	96	0.02	2	<0.01
TOTALS	975	2.27	11,758	3.17	4,712	1.71	3,199	1.97	4,251	3.28

*Mostly Hydracarina

COLONIZATION BASKETS
1976 5th Falls

Sample Date	1-3/VI/76	15/VI/76	4/VIII/76	20/VI/76	12/VIII/76	2/IX/76	6/X/76	
No. of Baskets	2	2	1	2	2	2	2	
Mean Current Velocity (cm/sec)	34 + 3	49 + 17	13 + 13	23 + 7	28 + 7	33 + 4	35 + 10	
Mean Basket Depth (cm)	33 + 1	44 + 6	35 + 15	35 + 6	47 + 12	56 + 9	53 + 12	
Method of Preparation	1 Plankton Split 1 Picked For All	1 Plankton Split	Plankton Split	1 Picked 1 Allenson	1 Allenson 1 Plankton Split	2 Allenson	2 Allenson	
TAXON	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)
DIPTERA								
Chironomidae	79	<0.01	697	0.03	5072	0.26	2846	0.11
Simuliidae	9368	1.29	14200	8.06	36	0.02	575	0.04
Tipulidae					76	0.12		
Rhagionidae			8	0.04	104	0.20	72	0.21
Other								
TRICHOPTERA								
Net Spinning	12	0.01	48	0.34	2846	4.46	2512	3.42
Case Building	1	<0.01			28	0.04	44	0.01
Free Living			4	0.12	15	0.07	20	<0.01
Unidentified					40	<0.01	48	-
PLECOPTERA								
Setipalpia	1	0.01			169	0.01	72	0.40
Filipalpia	1	<0.01	13	0.10			81	1.04
Unidentified	1	<0.01	3	<0.01	19	<0.01	40	<0.01

COLONIZATION BASKETS
1976 5th Falls (Cont.)

TAXON	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)	No. of Insects	wt (gms)
EPHEMEROPTERA			5	0.04	10	0.09	4	<0.01	19	0.06	52	0.09	56	0.08
ODONATA														
COLEOPTERA							4	<0.01	24	<0.01	40	<0.01	25	0.01
ARTHROPODA*														
COLLEMBOLLA														
HIRUNIDAE														
Others	16	<0.01	4	<0.01	46	0.02	64	0.05	31	<0.01	14	<0.01	1	<0.01
TOTALS	9,479	1.91	14,966	8.63	11,440	0.80	5,943	2.82	10,088	5.43	7,786	4.04	4,269	2.76

*Mostly Hydracarina

COLONIZATION BASKETS
1976 Outlet

Sample Date	18/VI/76		20/VIII/76		13/VIII/76		3/IX/76		18/X/76	
No. of Baskets	2		2		1		2		1	
Mean Current Velocity (cm/sec)	33 $\pm$ 6		23 $\pm$ 9		47 $\pm$ 23		48 $\pm$ 14		43 $\pm$ 17	
Mean Basket Depth (cm)	32 $\pm$ 7		47 $\pm$ 14		65 $\pm$ 35		62 $\pm$ 10		95 $\pm$ 25	
Method of Preparation	2 Allenson		2 Allenson		Picked For All		3 Picked For All		Allenson	
<u>TAXON</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>
DIPTERA										
Chironomidae	244	<0.01	6232	0.32	368	0.06	139	0.01	107	0.01
Simuliidae	90,308	71.2	5	0.01	242	0.06	70	0.09	255	0.16
Tipulidae										
Rhagionidae										
Other										
TRICHOPTERA										
Net Spinning	32	0.52	494	1.31	847	0.42	102	0.17	16	0.15
Case Building			1	<0.01						
Free Living							2	0.01		
Unidentified									1	<0.01
PLECOPTERA										
Setipalpia	20	0.01	1	<0.01	26	<0.01	30	0.01	3	<0.01
Filipalpia			6	0.03						
Unidentified			19	0.01						

COLONIZATION BASKETS
1976 Outlet (Cont.)

<u>TAXON</u>	<u>No. of</u> <u>Insects</u>	<u>wt</u> <u>(gms)</u>	<u>No. of</u> <u>Insects</u>	<u>wt</u> <u>(gms)</u>	<u>No. of</u> <u>Insects</u>	<u>wt</u> <u>(gms)</u>	<u>No. of</u> <u>Insects</u>	<u>wt</u> <u>(gms)</u>	<u>No. of</u> <u>Insects</u>	<u>wt</u> <u>(gms)</u>
EPHEMEROPTERA										
ODONATA										
COLEOPTERA									2	<0.01
ARTHROPODA*										
COLLEMBOLLA										
HIRUNIDAE										
Others	4	<0.01	106	0.46	48	<0.01	14	0.02		
TOTALS	90,608	71.73	6,864	2.14	1,531	0.54	357	0.29	384	0.32

*Mostly Hydracarina

COLONIZATION BASKETS
1977 2nd Falls

Sample Date	15/VI/77	19/VII/77	27/VIII/77	23/IX/77				
No. of Baskets	1	4	4	4				
Mean Current Velocity (cm/sec)	-	51 $\pm$ 6	60 $\pm$ 8	76 $\pm$ 13				
Mean Basket Depth (cm)	37	35 $\pm$ 3	33 $\pm$ 3	34 $\pm$ 6				
Method of Preparation	Allenson	4 Allenson	4 Allenson	2 Allenson 2 Picked For All				
<u>TAXON</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>	<u>No. of Insects</u>	<u>wt (gms)</u>
DIPTERA								
Chironomidae	448	<0.01	3,770	0.45	1,079	0.05	121	0.04
Simuliidae	10,904	11.68	106	0.12	79	0.08	13	<0.01
Tipulidae			4	0.05	21	0.13		
Rhagionidae					2	<0.01	5	0.07
Other								
TRICHOPTERA								
Net Spinning			179	0.79	337	0.53	67	0.15
Case Building	24	<0.01	3	0.05	31	<0.01	1	<0.01
Free Living			1	0.03	9	0.03	3	0.03
Unidentified					44	<0.01	4	<0.01
PLECOPTERA								
Setipalpia	32	<0.01	36	0.04	7	0.01	2	<0.01
Filipalpia			4	<0.01	1	<0.01		
Unidentified			12	<0.01	4	<0.01		
EPHEMEROPTERA			10	0.01	15	<0.01	2	<0.01
ODONATA								
COLEOPTERA			1	<0.01	7	<0.01		
ARTHROPODA*			1	<0.01				
COLLEMBOLLA								
HIRUNIDAE								
Others	16	<0.01	23	<0.01	77	<0.01	4	<0.01
TOTALS	11,424	11.68	4,171	1.54	1,713	0.85	222	0.29

*Mostly Hydracarina

COLONIZATION BASKETS
1977 5th Falls

Sample Date	18/VII/77	26/VIII/77	24/IX/77
No. of Baskets	4	4	2
Mean Current Velocity (cm/sec)	47 $\pm$ 6	49 $\pm$ 5	59 $\pm$ 9
Mean Basket Depth (cm)	51 $\pm$ 4	47 $\pm$ 3	48 $\pm$ 6
Method of Preparation	4 Allenson	4 Allenson	2 Allenson
<u>TAXON</u>	<u>No. of Insects</u> <u>wt (gms)</u>	<u>No. of Insects</u> <u>wt (gms)</u>	<u>No. of Insects</u> <u>wt (gms)</u>
DIPTERA			
Chironomidae	11,556 1.18	2,957 0.13	980 0.04
Simuliidae	30 0.02	54 0.02	27 0.01
Tipulidae			
Rhagionidae	28 0.36	3 0.01	7 0.15
Other			
TRICHOPTERA			
Net Spinning	112 0.26	1,430 6.86	600 2.52
Case Building	4 <0.01	8 <0.01	1 <0.01
Free Living	2 0.02	7 <0.01	20 0.19
Unidentified		70 <0.01	
PLECOPTERA			
Setipalpia		22 0.40	23 0.15
Filipalpia			
Unidentified		2 <0.01	
EPHEMEROPTERA	112 0.10	2 <0.01	6 0.05
ODONATA			
COLEOPTERA	34 <0.01	2 <0.01	
ARTHROPODA*	4 <0.01		
COLLEMBOLLA		2 <0.01	
HIRUNIDAE			
Others	8 <0.01	21 <0.01	7 <0.01
TOTALS	11,900 1.94	4,580 7.42	1,671 3.11

*Mostly Hydracarina

COLONIZATION BASKETS
1977 Outlet

Sample Date	17/VII/77	25/VIII/77	25/IX/77
No. of Baskets	4	4	4
Mean Current Velocity (cm/sec)	32 $\pm$ 4	31 $\pm$ 2	34 $\pm$ 4
Mean Basket Depth (cm)	94 $\pm$ 5	54 $\pm$ 5	53 $\pm$ 7
Method of Preparation	4 Allenson	4 Allenson	4 Allenson
<u>TAXON</u>	<u>No. of Insects</u> <u>wt (gms)</u>	<u>No. of Insects</u> <u>wt (gms)</u>	<u>No. of Insects</u> <u>wt (gms)</u>
DIPTERA			
Chironomidae	4,917 0.31	805 0.06	566 <0.01
Simuliidae	42 0.09	196 0.20	9 0.01
Tipulidae			
Rhagionidae			
Other	9 <0.01	1 <0.01	
TRICHOPTERA			
Net Spinning	3 0.17	340 0.70	128 0.50
Case Building		1 <0.01	
Free Living		6 <0.01	8 0.03
Unidentified		14 <0.01	
PLECOPTERA			
Setipalpia	1 <0.01	6 <0.01	12 0.01
Filipalpia	1 <0.01	10 <0.01	
Unidentified			
EPHEMEROPTERA	91 0.13	10 <0.01	
ODONATA			
COLEOPTERA	28 <0.01	22 <0.01	
ARTHROPODA*	2 <0.01	33 <0.01	
COLLEMBOLLA	1 <0.01	1 <0.01	
HIRUNIDAE	31 1.30	16 0.31	3 0.14
Others	115 <0.01	30 <0.01	
TOTALS	5,241 2.00	1,491 1.30	726 0.69

*Mostly Hydracarina

THE INTERACTION OF JUVENILE ATLANTIC SALMON
(Salmo salar L.)
AND BROOK TROUT
(Salvelinus fontinalis [Mitchell])

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The pattern of cohabitation in eastern North American rivers by Atlantic salmon (Salmo salar) and brook trout (Salvelinus fontinalis) varies from complete separation (Power, 1969; Gibson, 1966) to overlap and interaction (Gibson, 1973). One river in which this overlap has been well documented is the Matamek River, part of a small watershed on the north shore of the St. Lawrence River.

The juveniles of the two species cohabit the river for up to three years before the salmon smoltify and leave (Schiefer, 1969). In areas in which they are sympatric, the salmon displace the trout from below the riffles as food becomes scarce [middle of July each year (Gibson and Galbraith, 1975)]. This shift in habitat by the trout is called 'interactive segregation' (Brian, 1966). Gibson (1973), from his studies on larger juveniles, postulated this phenomenon to be the result of the more aggressive nature of the salmon and its more efficient behavior in fast water.

Observations on pairs of other salmonid species in stream cohabitation show that the species winning the competitive interaction had the best growth (Egglishaw, 1970; Frost, 1960; Jones, 1970; McCarthy, 1972; Stein et al., 1972). However, this is not the case in the Matamek River where, at any given time when the two species co-exist, trout are typically larger than the salmon. Thus the question arises: why are the trout larger than salmon of equal age, if the salmon win the interaction?

To answer this question, experiments were conducted in 1978 and 1979, on both juvenile Atlantic salmon and brook trout living in sympatry. Testing was done in a stream tank using fish 7.5 through 10.0 cm (F.L.) in 1978 followed by fish 3.5 through 5.0 cm (F.L.) in 1979, and on underyearlings in experimental enclosures in Trappers Cabin Creek during both years. From insights gained through these experiments, a hypothesis has been developed regarding

salmon-trout interactions in the Matamek River.

As many authors have found differences (growth and behavior) between hatchery-reared and wild-reared salmonids (Bams, 1967; 1972; Miller, 1958; Moyle, 1969; Sosiak et al., 1979; Vincent, 1960; White and Huntsman, 1938). The present study has included a comparison of hatchery-reared and wild-reared Atlantic salmon fry with the interaction of brook trout using both the stream tank and the Trappers Cabin Creek facilities.

MATERIALS & METHODS

STREAM TANK

To facilitate working with 0⁺ year class fish (3.5 through 5.0 cm F.L.), the stream tank was modified from that used in previous experiments (MacCrimmon and Dickson, 1979). The flumes were narrowed and three sections created in each (60 x 150 cm) to maintain natural densities at a manageable number of fish (six). Barriers between sections were vexar screening (3.2 mm mesh). Sand and gravel covered the bottom (approximately 10.0 cm), with 30 cm ($\pm$ 1.0 cm) of water over this. No artificial cover was used as the narrower sections provided sufficient areas of shade.

With nine sections in the stream tank (and only six population types) several types could be duplicated (Table 1) in each of the six replicates (Table 2). The sections in the stream tank in which each test population was to be placed was chosen using a random number table.

Salmon (wild) alevins were the result of natural reproduction, which hatched and developed in the river. Trout and salmon (wild) were obtained by seining and with fyke nets below the 2nd and 3rd falls of the Matamek River. Salmon (hatchery) were the progeny of wild parents, but were raised to post emergent size in a hatchery (same as Moyle's (1969) F₁-wild trout). These fry were the product of Matamek females (captured September 1978 above the 2nd falls) and males from the Saquenay River. They were raised at the Quebec Government Fish Culture Station at Tadoussac and returned to the Matamek Research Station July 5, 1979.

The methods were essentially the same as in 1978. The fish were hot branded on the caudal fin using a 25 w soldering pencil (McNicol and Noakes, 1979). Shrimp used for food was prepared as in 1978, then put in a blender with water and reduced to a slurry. The fish were fed each evening at a

ration level of 1.0 g of shrimp per fish per day.

TRAPPERS CABIN CREEK

The methods were the same as those used in 1978 (MacCrimmon and Dickson, 1979). A new area was added which enabled two complete replicates to be run simultaneously in each experiment (Table 3). Vexar screening was replaced with ACE nylon netting (3.2 mm). Two new areas were added in experiment #2, for populations of salmon (wild) and salmon (wild)/trout (Table 3). The wild salmon were seined below the third falls of the Matamek River.

ANALYSIS OF DATA

Stream Tank

The data from individuals (both growth and behavior) were averaged by tank within each replicate, then averaged by species and treatment type for the whole experiment. Analysis of variance in growth and behavior displays used was conducted within each species or variety for treatment effects and between each species or variety for differences between each using a statistical program package (2V, BMDP). The statistical model used in 1979 the model was a completely randomized block design. Equal sample sizes were required, therefore datum points (and duplicate populations) were chosen, with the aid of a random number table, from each replicate. Each 'F' ratio was evaluated at 90% and 95% levels of significance. It was not possible to statistically compare the data with past years due to the differences in statistical models.

All other behavior analysis (# of interactions/individual, distance to nearest neighbour, and percent wins in interspecific populations) were averaged by species and population type (duplicates averaged) within each replicate, then all replicates averaged for each experiment.

The distance to nearest neighbour was measured for each fish in each observation from the maps made each observation, then averaged by species/population type. The number of interactions per individual and the percent wins by each species in mixed tanks, were calculated from the interaction data transcribed after each observation on the tanks.

Trappers Cabin Creek

The growth data was averaged by stream section and species (individual growth couldn't be measured). The data was then averaged by species and treatment.

The distribution of each species was summarized by experiment, one area per acetate sheet. The three distribution sheets (one for each population type) were compared with each other and the acetate overlays for water depth and velocity. Any trends within an area were compared with the data from the other areas.

No statistical analysis was possible with the growth and distribution data from the two salmon (wild) populations (exp - #2/79), except comparison with general trends in the salmon (hatchery) data. The data from area 6, exp. #1/79 and exp. #2/79, was not used as on both occasions the area was invaded by many brook trout fry.

RESULTS

STREAM TANK

Wild salmon and trout occupied positions in the stream tank similar to those of the larger juveniles as observed in 1977 (Dickson and Gibson, 1978) and 1978 (MacCrimmon and Dickson, 1979). Hatchery-reared salmon, however, appeared to spend more time just off the bottom, a position intermediary to the trout and salmon (wild). Apart from this behavior of hatchery-reared salmon juveniles could not be distinguished from that of the wild fish.

Growth was not significantly different between each species (or variety) (Table 4). Variation due to treatment effects (population mix) was not significant within species (or varieties) (Table 4), but trends were obvious in the growth summaries (especially in weight) (Table 5). The average growth increased for both species in mixed populations, except when the two salmon varieties were combined.

Behavior displays of the underyearlings were similar to those of the larger juveniles. Analysis of variance, on all the allopatric populations, shows a significant variation between the salmon (wild and hatchery-reared) and trout in the use of 'Approach' and 'Frontal display' ('Charge and chase' at the 90% level of significance) (Table 6). It was determined, using Tuckey's Multiple Mean Test (Steel and Torrie, 1960), that the trout varied significantly from both wild and hatchery-reared salmon (which didn't vary from each other) in the use of 'Approach'. The same was true of 'Frontal display'. The salmon (wild) differed significantly from the hatchery salmon and the trout in the use of 'Charge and chase'. As was observed in 1978, both species moved towards the other's percent use, in mixed populations, for those behavioral displays which they used at a significantly different rate in allopatric populations (Table 7). Analysis of variance demonstrated that growth observations on fish in a tank were not independent

and could not be considered as replicates. We were correct in designating the tanks as replicates.

Average distance to nearest neighbour remained constant under all treatments for the wild and hatchery-reared salmon, except when the two varieties were in sympatry (Table 8). The average number of interactions was greatest in allopatric trout and less, but equal in hatchery-reared salmon/trout and wild-reared salmon/hatchery-reared salmon populations (Table 9). The interspecific interactions further illustrated that hatchery-reared salmon interacted more with wild-reared salmon and trout than the latter two interacted against each other (Table 10). These three behavioral measures (Table 8,9,10) indicated the intermediary position of hatchery-reared salmon to the wild-reared salmon and trout.

Many of the monitored environmental variables varied seasonally. Water temperature (daily high °C) ($r > 0.95$), photoperiod ($r > 0.95$), and water velocity (Table 11) all correlated significantly with the replicate number (season). As the water temperature decreased a drop in the number of interactions per observation was observed, but it was not significant. The same was true of increasing water velocity. This could be because of the normally low rate of interactions used by the underyearlings compared with the larger juveniles. The growth in weight not only varied seasonally (Table 11), but it correlated significantly with three environmental variables which varied seasonally.

The basic repertoire of behavioral displays used by each species remained constant over the three years (size classes) of observations. The trout exhibited marked changes in the percent use of some behavioral displays, while the salmon showed less pronounced changes (Table 13). There was an increase in the rate of aggression in the larger juveniles of both species.

TRAPPERS CABIN CREEK

Growth in weight exhibited the same trends as 1978, the trout had the best growth in mixed populations while the opposite was true of the hatchery-reared salmon (Table 14). In the stream tank studies the growth of both species increased in mixed populations (Table 5). Whereas in the stream tank the fish were approximately equal in fork length at the start of each replicate, the trout were (on the average) three millimeters longer than the salmon in the Trappers Cabin Creek experiments (Table 14). The populations in Trappers Cabin Creek were a closer representation of the natural populations. When the salmon emerge from the gravel in the Matamek River the trout are larger than the salmon. The trout win the interspecific interactions aided by this size advantage. The two wild-reared salmon populations exhibited similar growth rates and patterns to the hatchery-reared salmon in the creek situation.

CONCLUSIONS

The results of the last three years research has led to the following explanation of the observed pattern of interactions between juvenile Atlantic salmon and brook trout in the Matamek River. The trout emerge from the gravel approximately one month before the salmon, thus giving the trout a growth advantage for the following reasons. The food is most plentiful in the Matamek River in June and the early part of July (Gibson and Galbraith, 1975). The trout emerge near the beginning of this burst of food, while the salmon emerge near the end of it. This means that the trout not only get a month longer to feed the first year, but it is when the food is most abundant. Mason and Chapman (1965) concluded that those individuals (in coho salmon populations) which emerged early had an advantage by 'settler's rights' to the best territories. Finally, the trout would benefit from a greater experience in the environment (ie. greater number of search images for food, better developed anti-predator and aggressive behavior). Alevins of both species interact with an equal chance of winning when the same size, but by the time the salmon emerge the trout are larger. The trout maintain this size advantage to the end of the first season of growth and with it are able to displace the salmon in interspecific interactions. In the larger juveniles the situation changes, the 2⁺ salmon are a little larger than the 1⁺ trout and are able to displace them with a more aggressive nature. Gibson (1973) illustrated this with estimates of salmonid populations in the Matamek River. There was an 80% drop in the number of 1⁺ trout in sympatric (with salmon) versus allopatric trout populations. The growth advantage attained in the 0⁺ year class is enough to maintain the trout's size advantage for the rest of the time the two species cohabit the river.

The difference between the preferred habitats of the juveniles of the two species has been shown in the other rivers (Gibson, 1966; Keenleyside,

1962; Power, 1969) and laboratory experiments (Gibson, 1973) with the salmon seeming to prefer faster, shallower water than the trout. In the stream tank dominants of each species did not interact, while the subordinates in each tank overlapped in demands on the environment, interacting with each other and the dominants. Therefore, in salmon rivers lacking good habitat (as the Matamek River), the interaction will be much more intense, with limited scope for habitat partitioning. In these rivers the presence of trout may not reduce salmon growth, but they will reduce population size as they overlap with salmon in habitat demands. In this situation the early emergence of trout is a significant factor in the relative age-size distribution of each species.

In the stream tank study both species grew at similar rates. Although no significant differences were observed due to population mixes, growth (weight) tended to be greater for both species in sympatric populations. Salmon and trout used the same behavioral displays but the relative occurrence of each was different. Both species exhibited shifts in behavioral displays to the other species relative occurrence, in mixed populations. This was observed in the behavioral displays that the two species used to a significantly different rate (in allopatric populations). When population density was increased a nonsignificant increase in growth was measured, but there were no constant changes in the use of behavioral displays.

Over the three size ranges of fish used in the Matamek stream tank there was a change in both the levels of aggression and percent of each display used. The larger fish were more aggressive than the 0^+ year class individuals. The shift in percent use of each behavioral display was greatest in the trout, with minor shifts in the salmon.

The growth of 0^+ year class salmon was not altered by hatchery rearing,

while major shifts were observed in the behavior of these fish. They tended to sit more off the bottom in a position intermediary to salmon (wild) and trout. The number of interactions per individual (by treatment type) further illustrated the intermediate nature of their position. The low success of planted salmon was attributed to this shift in behavior. In these experiments, it was not possible to separate the effect of stock differences and rearing experience.

This study will aid in the understanding of Atlantic salmon and brook trout interactions, not only in the Matamek River, but in all eastern North America. It may also have implications for the management of rivers such as the Matamek. Finally, further studies could pursue the effect of hatchery rearing on the survival of planted salmon underyearlings.

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Table 1. The number of each population type in each replicate, at the stream tank at the 2nd falls of the Matamek River, 1979.

Replicate #	Population Type					
	SW*	SW/T*	SW/SH*	T	SH	SH/T
1	-	-	-	3	3	3
2	1	1	-	3	2	2
3	2	2	1	2	1	1
4	2	2	2	1	1	1
5	2	2	2	1	1	1
6	2	2	2	1	1	1

* SW - Salmon (wild)
SH - Salmon (Hatchery)
T - Trout

Table 2. Particulars of each experiment completed at the stream tank at the 2nd falls of the Matamek River, 1979, and summaries of environmental variables.

Exp. #	Date of Experiment		Temperature (°C)		Photoperiod Hrs : Min
	Start	Finish	Maximum	Minimum	
1	06/07/79	20/07/79	20	17	16 : 02
2	30/07/79	03/08/79	22	19	15 : 30
3	03/08/79	17/08/79	19	18	14 : 48
4	13/08/79	31/08/79	18	16	14 : 03
5	31/08/79	14/09/79	16	15	13 : 09
6	14/09/79	28/09/79	13	12	12 : 18

Table 3. Particulars of each experiment from Trappers Cabin Creek, 1979, with the length of each experiment area, distance to the next area and temperature ranges.

Experiment	Start	Finish	Area	Species	Temperature(°C) Maximum Minimum	Length of Each Area(m)	Distance to Next Area(m)
1	11/07/79	9/08/79	1	T*	13 11	4.3	14.0
			2	SH*		3.4	9.5
			3	SHT		3.7	22.3
			4	T		4.0	9.5
			5	SHT		4.0	11.4
			6	SH		3.1	
2	10/08/79	8/09/79	1	SH	12 10	4.3	14.0
			2	SHT		3.4	9.5
			3	T		3.7	10.4
			A	SW*		3.1	8.8
			4	SH		4.0	9.5
			5	T		4.0	11.4
			6	SHT		3.1	28.0
			B	SWT		2.9	

* T - Trout
SW - Salmon Wild
SH - Salmon Hatchery

Table 4. Sources of significant variation (at 90% and 95% levels) from analysis of variance on the growth of salmon (wild and hatchery reared) and trout, and a comparison of all three, from the Matamek stream tank, 1979.

	Fork Length (cm)	Weight (g)
Salmon Wild		
Seasonal	*	-
Population Mix	-	-
Salmon Hatchery		
Seasonal	-	**
Population Mix	-	-
Trout		
Seasonal	-	-
Population Mix	-	-
Salmon Wild/ ¹ Salmon Hatchery/ Trout		
Seasonal	**	**
Population Mix	-	-

** - 95%

* - 90%

¹ - using allopatric populations only

Table 5. Summaries of growth (% increase on initial measurement/fish/day) by experiment and population type, with averages for the summer, from the Matamek stream tank, 1979. (standard deviation given in brackets).

A) growth in fork length (cm)
B) growth in weight (g)

		1	2	3	4	5	6	$\bar{X}$	(s)
(A)	SW*	-	1.6	0.7	0.8	0.3	0.4	0.8	(0.51)
	SW/T*	-	1.4	1.0	0.7	0.6	0.3	0.8	(0.40)
	SW/SH	-	-	1.2	0.4	0.4	0.4	0.6	(0.43)
	SH*	0.6	1.2	0.9	0.5	0.6	0.6	0.7	(0.25)
	SH/T	0.9	1.4	0.8	0.9	0.4	0.3	0.8	(0.38)
	SH/SW	-	-	1.0	0.5	0.5	0.5	0.6	(0.26)
	T	1.3	0.7	0.6	0.6	0.5	0.1	0.6	(0.39)
	T/SH	1.5	0.5	0.6	1.2	0.2	0.5	0.7	(0.50)
	T/SW	-	1.5	0.7	0.7	0.6	0.1	0.7	(0.49)
	SW	-	8.10	3.55	2.85	1.20	1.50	3.40	(2.78)
	SW/T	-	8.30	5.75	2.35	2.55	1.25	4.0	(2.91)
	SW/SH	-	-	6.20	1.15	1.10	1.40	2.5	(2.50)
(B)	SH	4.40	5.20	4.60	3.0	2.9	1.6	3.6	(1.35)
	SH/T	6.2	6.1	4.2	4.3	2.9	1.0	4.1	(1.98)
	SH/SW	-	-	6.7	2.0	2.95	1.65	3.3	(2.33)
	T	8.3	3.47	2.25	2.6	2.5	-0.1	3.2	(2.78)
	T/SH	8.4	1.75	2.7	4.4	0.4	2.8	3.4	(2.78)
	T/SW	-	9.5	2.6	3.1	2.25	0.5	3.6	(3.45)

* - SW - Salmon Wild
- SH - Salmon Hatchery
- T - Trout

Table 6. Sources of significant variation (at 90% and 95% levels) from analysis of variance on the behaviour of salmon and trout, with comparison, from the Matamek stream tank, 1979.

CHARGE AND CHASE	APPROACH	DRIFT	NIP	LATERAL DISPLAY	FRONTAL DISPLAY	PRESENCE	SUPPLANT
Salmon Wild							
seasonal	-	-	-	-	-	-	-
population mix	-	-	-	-	-	-	-
Salmon Hatchery							
seasonal	-	-	-	-	-	-	-
population mix	-	-	-	-	-	-	-
Trout							
seasonal	-	-	-	-	-	-	-
population mix	*	-	-	-	-	-	-
Salmon Wild/ ¹							
Salmon Hatchery/ Trout							
seasonal	-	-	-	-	-	-	-
population mix	*	**	-	-	**	-	-

¹ - allopatric populations only

Table 7. Percentage use of each display (averaged by population mix) by salmon (hatchery and wild) and trout and averages ($\bar{x}$) for each species or variety, in the Matamek stream tank, 1979.

1979	CHARGE AND CHASE	APPROACH	DRIFT	NIP	LATERAL DISPLAY	FRONTAL DISPLAY	PRESENCE	SUPPLANT
<u>SALMON</u> (wild)								
alone	42.9	4.9	0	43.5	7.3	0	0.9	0
mixed/T	41.1	13.3	0	37.9	6.0	0	1.8	0
mixed/SH	40.0	8.5	0	40.8	8.7	0	2.1	0
($\bar{x}$)	(41.3)	(8.5)	(0)	(40.7)	(7.3)	(0)	(1.6)	(0)
<u>SALMON</u> (hatchery)								
alone	39.4	5.6	0	42.0	12.4	0	0.7	0
mixed/T	36.2	10.4	0.2	38.4	12.9	0	2.0	0
mixed/SW	42.2	4.8	0	41.7	9.4	0	2.0	0
($\bar{x}$)	(39.3)	(6.9)	(0.1)	(40.7)	(11.6)	(0)	(1.6)	(0)
<u>TROUT</u>								
Alone	24.4	29.0	0	36.8	9.1	1.8	0.6	0
mixed/SW	22.5	27.5	1.3	39.3	7.1	0.7	0.7	0
mixed/SH	19.7	34.3	0	34.4	8.6	2.4	1.2	0
($\bar{x}$)	(22.2)	(30.3)	(0.4)	(36.8)	(8.3)	(3.7)	(0.8)	(0)

Table 8. The distance to nearest neighbour for salmon (wild and hatchery origin) and trout, by population mix from the Matamek stream tank, 1979.

	1	2	3	4	5	6	$\bar{x}$	s
SW++	-	6.5	5.7*	5.2*	6.6*	6.3*	6.1	(0.58)
SW/T++	-	6.3	5.6*	6.6*	7.3*	5.5*	6.2	(0.74)
SW/SH++	-	-	5.6	5.9*	5.3*	5.2*	5.5	(0.34)
SH	7.6+	6.2*	5.4	5.6	6.3	5.5	6.1	(0.82)
SH/T	5.8+	6.3*	7.2	6.8	6.6	4.5	6.2	(0.96)
SH/SW	-	-	6.4	6.6*	5.6*	6.0*	6.1	(0.43)
T	4.3+	5.0+	5.0*	5.3	6.2	5.4	5.2	(0.62)
T/SH	4.3+	4.9*	3.4	3.4	5.7	5.4	4.5	(0.98)
T/SW	-	4.1	4.9*	3.5*	4.5*	4.6*	4.3	(0.56)

* - weighted mean from two tanks

+ - weighted mean from three tanks

++ - SW - Salmon Wild

SH - Salmon Hatchery

T - Trout

Table 9. Number of interactions per experiment by salmon (wild or hatchery) and trout, and population mix, with the average number per individual from the Matamek stream tank, 1979.

	2	3	4	5	6	$\bar{x}$ (s)	x/IND
SW	70	50	69.5	16	22.5	44.6 (25.5)	7.6
SW/T	10	16.5	30.5	52.5	15	24.9 (17.2)	8.3
SW/SH	-	52	25.5	22.5	36.5	34.1 (13.4)	11.4
SH	52.5	25	51	32	8	33.7 (18.7)	5.6
SH/T	43.5	39	44	71	5	40.5 (23.5)	13.5
SH/SW	-	32	24	79	10	36.3 (29.9)	12.1
T	237	135.5	161	197	175	181.1 (38.4)	30.2
T/SH	39.5	14	22	28	76	35.9 (24.3)	12.0
T/SW	3	30.5	61.5	23	7.5	25.1 (23.2)	8.4

Table 10. The total number of interactions in the mixed tanks, with breakdown by species and within species to inter/intraspecific interactions (with percentages) from the Matamek stream tank, 1979.

	INTER		INTRA		TOTAL	SUB TOTALS	
	S	T	S	T		S	T
$\frac{+}{+}$ SW/T							
$\bar{x}$	12.6	13.6	12.4	11.5	50	25.0	25.1
(s)	(9.7)	(12.9)	(7.4)	(13.9)	(33.9)	(17.0)	(23.2)
n	5	5	5	5	5	5	5
%	48.1	51.9	-	-	-	49.9	50.1
$\frac{+}{+}$ SH/T							
$\bar{x}$	14.4	20.9	26.1	15.0	76.8	40.5	35.9
(s)	(9.3)	(9.7)	(20.4)	(20.3)	(17.3)	(23.5)	(24.3)
n	5	5	5	5	5	5	5
%	40.8	59.2	-	-	-	53.0	47.0
$\frac{SW}{SH}^*$							
$\bar{x}$	22.8	24.8	6.9	11.5	65.9	29.6	36.3
(s)	(16.7)	(24.9)	(1.9)	(6.6)	(33.0)	(15.2)	(29.9)
n	4	4	4	4	4	4	4
%	47.9	52.1	-	-	-	44.9	55.1

* (only reps 3-6)

+ SW - Salmon Wild

SH - Salmon Hatchery

T - Trout

Table 11. The correlation (r) of water current, percent increase in fork length per fish per day (by species/population mix), percent increase in weight per fish per day (by species/population mix), and number of interactions per experiment (by species/population mix) versus experiment number (season) from the Matamek stream tank, 1979.

	n	Level of Significance		Water Speed	Average Percent Increase on Initial Measure/fish/day		Average Number of Interactions/fish/exp.
		99%	95%		fork length (cm)	weight (g)	
SW ⁺	9	0.735	0.602	0.636	-0.764	-0.856	-0.717
SW/T	9	0.735	0.602	0.803	-0.898	-0.850	-
SW/SH	7	0.798	0.666	-	-0.671	-	-
SW(all)	25	0.487	0.381	0.586	-0.795	-0.799	-
SH ⁺	9	0.735	0.602	0.741	-	-0.618	-
SH/T	9	0.735	0.602	0.855	-0.634	-0.860	-
SH/SW	7	0.798	0.666	-	-	-0.667	-
SH(all)	25	0.487	0.381	0.789	-0.576	-0.749	-
T ⁺	11	0.684	0.553	0.811	-0.851	-0.799	-
T/SH	9	0.735	0.602	0.855	-0.629	-0.6502	-
T/SW	9	0.735	0.602	0.803	-0.829	-0.800	-
T(all)	29	0.456	0.355	0.831	-0.752	0.740	-

⁺ SW - Salmon (wild)

SH - Salmon (hatchery)

T - Trout

Table 12. The correlation (r) of water temperature (daily high °C), water current, and photoperiod versus percent increase in weight per fish per day (by species/population mix) from the Matamek stream tank, 1979.

	n	Level of Significance		Water Speed	Water Temperature	Photoperiod
		99%	95%			
SW	9	0.735	0.602	-	-0.835	-0.832
SW/T	9	0.735	0.602	-	0.827	0.807
SW/SH	7	0.798	0.666	-	-	-
SW (all)	25	0.487	0.381	-	0.753	0.748
SH	9	0.735	0.602	-	0.703	0.616
SH/T	9	0.735	0.602	-0.628	0.764	0.872
SH/SW	7	0.798	0.666	-	-	-
SH (all)	25	0.487	0.381	-0.440	0.726	0.740
T	11	0.684	0.553	-0.690	-	0.801
T/SH	9	0.735	0.602	-	-	0.647
T/SW	9	0.735	0.602	-0.820	0.833	0.797
T (all)	29	0.456	0.355	-0.553	0.513	0.741

+

SW - Salmon (wild)

SH - Salmon (hatchery)

T - Trout

Table 13. Average use of each behavior display by all population types at natural densities for each year, from the Matamek stream tank, 1977, 1978, 1979.

	CHARGE AND CHASE	APPROACH	DRIFT	NIP	LATERAL DISPLAY	FRONTAL DISPLAY	PRESENCE	SUPPLANT
<u>SALMON</u> <u>(wild)</u>								
1977	45.5	8.9	0.7	31.1	9.5	0.5	3.3	0.7
1978	45.2	8.4	0	38.9	5.4	0.2	1.7	0.1
1979	41.3	8.9	0	40.7	7.3	0	1.6	0
<u>TROUT</u>								
1977	48.0	11.0	0.3	32.3	2.5	0.1	5.6	0.2
1978	42.7	17.5	0.1	34.7	2.2	0.9	1.9	0.1
1979	22.2	30.3	0.4	36.8	8.3	3.7	0.8	0

Table 14. Summaries of growth (% increase on initial measurement/fish/day) by population mix, for salmon (wild and hatchery) and trout, from Trappers Cabin Creek.

	Starting fork length	% Increase on initial measurement/ fish/day fork length (cm)	weight (g)
Salmon(Hatchery) *n =	3.8 3	0.5	2.6
Salmon(Hatchery) / Trout n =	3.8 3	0.4	1.3
Trout n =	4.2 4	0.3	0.8
Trout/Salmon (Hatchery) n =	4.3 3	0.6	3.0
Trout/Salmon (wild) n =	4.2 1	0.4	1.7
Salmon(wild) n =	3.8 1	0.2	1.4
Salmon(wild)/ Trout n =	3.9 1	0.1	-0.6

* n = Total number of populations

Taxonomic congruence in three populations of Quebec brook trout
Salvelinus fontinalis*

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The degree of taxonomic congruence between three methods of classification is examined for three Quebec populations of wild brook trout, Salvelinus fontinalis, from the Matamek-Moisie watersheds. The three methods utilize morphometric, meristic, and electrophoretic characters. Electrophoretic comparison is also made between the Quebec samples and brook trout from the Dorion Hatchery, Ontario. Using discriminant function analysis on data for the three Quebec populations, a subset of nine morphometric measurements was identified with between 84.0 and 92.6 percent correct classification, and a meristic subset of four characters, including mandibular pores, and between 72.5 and 95.0 percent correct classification. Electrophoretic analysis has identified a number of newly defined alleles at four loci from five tissues. The meristic and electrophoretic analyses show congruence in the order of similarity and, therefore, are considered the most suitable methods for classification of the brook trout. Morphometric analysis provides an insight into localized adaptation particularly in response to habitat and resource utilization. An understanding of the taxonomic status of populations of brook trout requires not only a definition of individuals in terms of meristic and electrophoretic profiles, but also morphological characterization, to increase our understanding of their ecology and response to other faunal components.

ANALYSES OF ZOOPLANKTON GRAZING EXPERIMENTS IN LAC MATAMEC, 1978.

by

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Introduction

In 1978 Lower Baie Philippe (LBP) was separated from the rest of Lac Matamec by a polypropylene "limno-curtain". We then fertilized LBP by weekly additions of mono-ammonium phosphate, and we used Upper Baie Philippe (UBP) as a control station. Besides producing an overall increase in phytoplankton biomass, the fertilization of LBP also lead to a change in the size structure of the phytoplankton community. As well as increasing in absolute biomass, plankters in the 15 μ m to 64 μ m size range accounted for proportionally more of the total biomass (Ross, Chow and Duthie, 1979).

The 1978 grazing experiments were designed to investigate what effect this change in size structure had on the size structure of the food ration of the dominant zooplankton species. Values are here reported for Keratella taurocephala, the dominant rotifer species; for Bosmina longirostris, the dominant cladoceran; and for four different developmental stages of Diaptomus minutus, the dominant copepod.

This report presents only experimental results not described in previous reports. It will be the final progress report on the work we began at Matamec in 1976.

Methods

In the 1978 experiments we employed a triple-labelled radioactive food source (Ross and Duthie, 1978) to simultaneously measure grazing on three different size classes (smaller than $15\mu\text{m}$, the ultraplankton; $15\mu\text{m}$ to $27\mu\text{m}$, the smaller nanoplankton; and $27\mu\text{m}$ to $64\mu\text{m}$, the larger nanoplankton) of naturally occurring phytoplankton. We excluded the study of the net plankton (larger than $64\mu\text{m}$) because previous experiments (Ross and Duthie, 1978) had determined that this size class is virtually never eaten by the zooplankton species that we studied.

To compensate for the effects of differential leaching and decay rates of the three isotopes used (which leads to differential losses in activity between the end of the experiment and the subsequent scintillation counting), we ran each experiment with three different isotope combinations in a matrix-type design (Table 1,) and then summed the results of the three combinations for each food size-class. For each of the three isotope-size class combinations we replicated the experiment eight times. Thus each study reported below represents $8 \times 3 = 24$ individual grazing experiments performed within a three-hour period at the same site on the same day.

We performed all experiments at the same depth, 1.5 metres. We held the grazing time constant at six minutes, less than the previously determined gut-passage times of the organisms studied, so that the experiments reported

Table 1. Design of zooplankton feeding experiments using a triple-labelled food source: Three isotopes (P = ^{32}P - orthophosphoric acid; C = ^{14}C - sodium bicarbonate; H = $^3\text{H}_2\text{O}$) supplied exclusively to three size classes of algae in three combinations. Each size class received each isotope in one of the three combinations (0, X and +).

Isotope	Phytoplankton size classes		
	<15 μm	15 μm -27 μm	27 μm -64 μm
P	0	+	X
H	X	0	+
C	+	X	0

here measure only ingestion rates, and not assimilation rates (for details see Ross and Duthie, 1978.)

Results and Discussion

We performed seven pairs of studies in 1978. Each pair of studies was completed on the same day, one in LBP and one in UBP. The first three pairs of studies (22 June, 02 July and 12 July) we ran before we had begun to fertilize in LBP. The 20 July pair came just after the start of the fertilization and the last three (10 August, 20 August and 30 August) after it was well under way.

Table 2 shows the results of these seven pairs of studies. The post-fertilization studies in LBP show an increase in the utilization of the 27 μ m to 64 μ m size class by all zooplankton species studied. Use of this fraction in UBP, and in LBP before fertilization, was minimal (Fig. 1) but became quite substantial in LBP after fertilization (Fig. 2.)

Thus we conclude that the observed increase in phytoplankton biomass in the 15 μ m to 64 μ m range (Ross, Chow and Duthie, 1979) was partly used by the dominant zooplankton species. This dictates a negative evaluation of one of our original hypothesis, i.e. that fertilization would result in a phytoplankton biomass increase, but mainly an increase in "ungrazeable" forms. In fact, the increase in net plankton biomass was not significant (Ross, Chow and Duthie, 1979,) and it seems that the zooplankton community was able to utilize the nanoplankton increases.

Our fertilization programme was a low-level one, and we do not wish to suggest that a high-level increase in nutrient loading would not lead to a

preponderance of ungrazeable forms, including net plankton. Furthermore, it is quite possible that, had our nutrient additions continued for several years, a succession process toward net plankton might have taken place, perhaps accompanied by a shift to larger species of zooplankton.

These qualifications notwithstanding, our results should encourage the pursuit of further research on controlled, low-level nutrient additions to dystrophic Shield lakes to increase productivity and, hopefully, fish yield.

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List of figures and their legends

Figure 1. The percentage of the total food ration for zooplankton contributed by each of three size classes of phytoplankton in a grazing study at Lac Matamec on 20 August, 1978. Values given for Keratella taurocephala, Bosmina longirostris, and for four age classes of Diaptomus minutus, where N refers to naupliar instars and C to copepodites. Upper Baie Philippe (UBP).

Figure 2. The percentage of the total food ration for zooplankton contributed by each of three size classes of phytoplankton in a grazing study at Lac Matamec on 20 August, 1978. Values given for Keratella taurocephala, Bosmina longirostris, and for four age classes of Diaptomus minutus, where N refers to naupliar instars and C to copepodites. Lower Baie Philippe (LBP).

lower: <15 μ m middle: 15 - 27 μ m upper: 27-64 μ m

D. minutus

B.l.

K.t.

N1-3

N4-6

C1-3

C4-6

% of food ration

100
80
60
40
20

-215-

Figure 1

UBP 20/08/78

Figure 2

lower: <15 μ m middle: 15 - 27 μ m upper: 27 - 64 μ m

D. minutus

LBP 20/08/78

PHYTOPLANKTON RESPONSE TO FERTILIZATION IN
LOWER BAIE PHILLIPPE, LAC MATAMEC, QUEBEC.
A PRELIMINARY REPORT ON STUDIES IN 1979

by

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INTRODUCTION

The 1979 field season at Lower Baie Phillippe (LBP) Lac Matamec, was a continuation of the weekly low-level fertilization which began in the latter part of 1978. A total of 960 kg of mono-ammonium phosphate, dissolved in lake water was similarly dispensed as cited in the 1978 Annual Report (1978 Ross et al) over fourteen weeks. The control basin, Upper Baie Phillippe (UBP) was initially separated from LBP by a polypropylene limnocurtain which had been installed in 1978, but the curtain was damaged beyond repair after a storm in mid-June. However, the natural barrier, a 6m deep sill, and the minimal mixing between the 2 basins rendered them essentially discreet water bodies. Both basins were sampled intensively each week to study the changes in ambient nutrient concentrations and trends in phytoplankton species succession, using UBP as the control. In addition, biweekly depth series were undertaken to study vertical distribution of the phytoplankton over the sampling season.

RESULTS

Fertilization commenced on the first day of June in LBP. When compared with UBP, both light transmissivity and secchi disc depths were nominally lower in LBP over the course of fertilization. The ambient phosphorus concentrations in LBP were substantially higher than that in UBP (Fig. 1). The differences in corresponding N-nitrate concentrations were only notable at the Spring and Autumn overturns. (Fig. 2). Dissolved inorganic carbon and organic carbon (DIC and DOC) concentrations did not vary greatly from 1978 values obtained for both basins, with DIC concentrations ranging from 0.31 to 1.73 mg l⁻¹ in LBP and 0.31 to 1.80 mg l⁻¹ in UBP, and DOC concentrations ranging from 5.3 to 7.2 mg l⁻¹ in LBP and 5.3 to 7.1 mg l⁻¹ in UBP. Mean summer pH for both basins was 5.5, individual values ranging from 4.85 to 5.85 throughout the season. In response to the fertilization, chlorophyll-a concentrations rose sharply in LBP relative to UBP at the beginning and maintained a constant margin of difference throughout the season. (Fig. 3) A corresponding increase in biomass was also observed in LBP following enrichment, and this is well-illustrated in Fig. 1.

The dramatic increase in biomass in LBP after the onset of fertilization, almost 4X that of UBP, is consistent with the findings in 1978. A Mann-Whitney Test for detecting significant differences in paired data yielded a probability of less than 0.01 that the differences between the two basins could be a random occurrence. The largest percent contributor to the biomass in both basins was Tabellaria fenestrata, which was responsible for up to 95% of the total biomass on one sampling date in LBP. (Fig. 4) Note, however,

that a student's t-test did not show any significant differences between LBP and UBP in respect to the percent total biomass for Tabellaria fenestrata. On the other hand, a similar analysis on Cryptomonas erosa revealed a significant difference at the 95% level. It appears then, that the greatest relative increase in biomass was contributed by C. erosa, a very common nanoplankter. The trends displayed by both species in 1978 indicate that there was a rather sudden and dramatic increase in biomass immediately following nutrient addition in late July, although the results are not conclusive for C. erosa. However, it is clear from the 1979 study that the biomass for this nanoplankter was consistently and noticeably higher in LBP throughout the season, probably due to the additions of P and N. Table 1 summarizes the contributions in biomass (mg m^{-3}) made by the major species in response to nutrient enrichment. The vertical distribution of the phytoplankton in LBP and UBP is represented by the four biomass-depth profiles which were taken over the course of the fertilization period in 1978 and 1979. (Fig. 5) It appears that the standing crop in a vertical column is concentrated between 1m and 5m. Fertilization seems to greatly enhance the productivity in the top 5 meters of the water, but beyond 7.5 to 10 m in all cases, the light seems to be the limiting factor.

DISCUSSION

That fertilization enhanced the standing crop in LBP is well-illustrated in Fig. 1 and 3. In agreement with findings in 1978, there is further evidence that the nanoplankton (15-64 μm) as a group is contributing most of the biomass to LBP relative to UBP.

Although T. fenestrata responded well to the P and N additions in LBP, it was equally prominent in UBP this season. In fact, the appearance of the dominant species in LBP almost always coincided with those in UBP, the major difference being that the standing crop of LBP for a particular species or as a whole, was of one or more magnitudes greater than that of UBP. It seems, then, that this low-level cultural eutrophication was instrumental in bringing about a 3 to 4-fold increase in biomass without jeopardizing the trends in species succession or upsetting the natural regimes of the phytoplankton community. The growth of the dominant species which responded to the enrichment was not at the expense of the less competitive species.

The direction of the project now is towards elucidating trends in species succession by examining in detail the seasonal variations and vertical distribution of certain species in the 1978 and 1979 field seasons, as well as investigating the nature of the response to fertilization displayed by the dominant species in LBP. Laboratory experiments using continuous culture techniques have been planned for 1980 to study growth kinetics of relevant species under nutrient limitation, in order to answer questions regarding the physiological capabilities of certain species to compete in various nutrient regimes in natural waters.

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Table 1. Contributions in biomass (mg m⁻³) made by dominant species in LBP and UBP from May to September 1979.

Julian day	<u>Tabellaria fenestrata</u>		<u>Peridinium inconspicuum</u>		<u>Cryptomonas erosa</u>		<u>Mallomonas pumillio</u>	
	LBP	UBP	LBP	UBP	LBP	UBP	LBP	UBP
138	---	3.95	0.57	3.65	0.37	0.49	---	---
152	23.67	57.12	2.51	1.71	3.42	1.75	1.04	1.31
159	174.53	54.23	3.91	1.64	10.73	3.80	3.48	5.22
166	589.83	184.65	1.98	---	23.41	2.31	12.40	7.57
173	2269.00	509.25	2.18	---	29.03	5.99	20.66	32.38
187	1146.65	1041.80	---	4.01	32.66	10.88	22.33	48.55
194	2440.50	774.55	4.33	4.29	33.47	8.52	17.74	23.99
200	2470.00	716.90	2.00	1.50	27.68	4.06	16.15	4.99
208	839.60	817.45	45.58	21.48	30.56	10.96	16.19	9.88
216	643.30	689.50	24.83	24.52	108.04	17.04	17.81	8.03
221	1368.70	782.90	33.14	1.44	54.17	3.07	10.71	3.18
229	517.95	492.50	64.70	34.49	31.85	14.09	17.02	27.74
236	209.60	350.85	44.34	11.27	1.64	2.01	8.57	5.15
242	207.7	244.70	9.92	6.49	26.29	6.58	11.00	13.26

List of Figures and Legends

- Fig. 1. A comparison of Total P concentrations as mg m^{-3} from May to September 1979 in LBP (o----o) and UBP (+-----+), with the total biomass as mg m^{-3} from May to September 1979 in LBP (o——o) and UBP (+——+) in Lac Matamec, Quebec.
- Fig. 2. N-Nitrate as mg m^{-3} from May to September 1979 in LBP (o——o) and UBP (+——+) in Lac Matamec, Quebec.
- Fig. 3. Chlorophyll-a concentrations as mg m^{-3} from May to September 1979 in LBP (o——o) and UBP (+——+) in Lac Matamec, Quebec.
- Fig. 4. The proportion, as %, of the total phytoplankton biomass contributed by T. fenestrata and C. erosa from May to September 1978 and 1979 in LBP (o——o) and UBP (+——+) in Lac Matamec, Quebec.
- Fig. 5. The distribution of phytoplankton biomass as mg m^{-3} with depth (m) on 8 June 79, 22 June 79, 05 August 78 and 02 Sept 78 in LBP (o——o) and UBP (+——+) in Lac Matamec, Quebec.

○ LBP Seasonal biomass profile
 ○ LBP Seasonal phosphorus profile
 + UBP Seasonal biomass profile
 + UBP Seasonal phosphorus profile

Fig. 1

1979 JULIAN DAYS

o---o LBP Seasonal N-NO₃ profile
 +---+ UBP Seasonal N-NO₃ profile

Fig. 2

1979 JULIAN DAYS

Fig. 3

Tabellaria fenestrata

Fig. 4

BIOMASS-DEPTH PROFILES

Fig. 5

Progress Report on Zoobenthos Research at Lake Matamek (1979)

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G.R. Kreamer - Associate Investigator

Department of Zoology

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Research during 1979 was largely directed at completion of identifications of invertebrates collected during previous years and preparation of the Associate Investigator's MSc. Thesis, summarizing and detailing three years of study on the zoobenthos of Lake Matamek.

Some new research was conducted during two weeks following the new thaw to investigate further the phenomenon of preemergence aggregation of the large red chironomid, Sergentia coracina, a typical inhabitant of the bottom fauna of northern lakes and by far the most common and abundant macroinvertebrate in the Lake Matamek profundal benthos. Bottom sampling during the previous two springs has indicated ten to twenty times higher densities of late-instar larvae (up to 5000/m²) in the 15-20m depth zone at the lake outlet, relative to other times of year and parts of the lake surveyed.

Sergentia spp., particularly coracina, have been reported to exhibit nocturnal planktonic activity in late instars (Wulker, 1961; Mundie, 1964; and Hamilton, 1965), presumably resulting in shoreward displacement of preemergence populations in the spring; and a similar phenomenon has been observed in other chironomids (Spence, 1971; Davies, 1976; and Barton and Hynes, 1978), as well as in the well-known semi-planktonic dipteran Chaborus flavicans (Wood, 1956 and Parma, 1971). Such knowledge, in conjunction with our finding that C. flavicans was also present in substantially greater numbers in the spring outlet benthic samples, led us to speculate

that movement into the plankton at this time of year, and probably subsequent dispersal by currents (enhanced by elevated thaw discharges), could result in the observed aggregations of S. coracina in the outlet area, where the lake narrows and rises sharply in depth.

To investigate this possibility, a series of plankton samples were taken around and above the outlet area in four depth zones (surface, 5-10m, 10-20m, and lower), and at different times (midnight, dawn, afternoon and dusk) over a two day period approximately one week after ice had left the lake. Results of these studies are strongly indicative of a nocturnal migration of S. coracina into the plankton throughout the lake profundal. Larvae were taken in plankton tows as far up as near the surface over water as deep as 100m, but were most commonly found about 10-20m below the surface. This incidentally coincided with the outlet depth zone at which larvae were found to be aggregated and increasing in density over week-long intervals during this and the previous spring.

Thus it would indeed appear that a planktonic, nocturnal "drift" mechanism of dispersal could account for the observed benthic aggregations of both S. coracina and C. flavicans in Lake Matamek. We can also speculate that much movements should be beneficial to the species in that, by effectively concentrating otherwise sparsely distributed profundal populations into a given area prior to emergence, greater opportunities for subsequent reproductive success might be facilitated.

In any event, this information regarding S. coracina (and other chironomid species taken in the Lake Matamek plankton), though of a preliminary, indirect nature, does contribute to the growing body of evidence

(reviewed in Davies, 1976 and Wiley and Mozley, 1978) that planktonic behavior might be a relatively widespread dispersal phenomenon in lentic chironomid species, and specifically in this case, could constitute a quite important feature of the species ecology. A publication dealing with this aspect of the research is in preparation.

Aside from the above, laboratory work during 1979 was mostly directed toward completing taxonomic examination of the benthic organisms collected during the previous two years of sampling. Identifications of thousands of dissected, slide-mounted larval, adult and pupal Chironomidae were finalized, and a representative lot deposited in the Canadian National Collection at Ottawa. As a result of these efforts, at least 100 species of chironomids are now known from Lake Matamek, several of which (particularly in the larval states) are undescribed and, in a few cases, new to science. Descriptions and photomicrographs of some key taxonomic characters of these species will be included in the aforementioned thesis, along with available distributional and ecological information.

The identity and ecology of other groups represented in the Lake Matamek benthos were also considered, though at a generally more superficial level. The table following gives the breakdown of number of taxa (generally species) recognized from each of the major benthic groups collected during this survey.

Number of taxa identified from the Lake Matamek zoobenthos

Chironomidae	100	
Chaoboridae	3	
Ceratopogonidae		(Several)
Trichoptera	10	
Ephemeroptera	10	
Odonata	5	
Other Insecta	12	
Ostracoda	10	
Cladocera	24	
Copepoda	12	
Amphipoda	1	
Hydracarina	27	
Mollusca (<u>Pisidium</u>)	5	
Oligochaeta	20	(At least)
Hirudinea	2	
Nemata	34	
Miscellaneous taxa	15	

Except for the larger aquatic insects and Pisidium, and the numerically unimportant Hirudinea and Amphipoda, all of the groups listed required preparation of slide mounts (generally in polyvinyl lactophenol) for species and usually generic determination. As with the Chironomidae, a few species of the above groups appear to be new to science, including at least one Oligochaeta (Naididae), Nemata (Monochidae) and Ostracoda (Paracandona) species; and many others represent new distributional records for this part of Canada.

In any case, now that the taxonomic and ecological character of the Lake Matamek zoobenthos is sufficiently known, comparisons can be made with lakes of various types, both within and outside of the Shield. As such this study could conceivably serve a baseline purpose for lakes in the virtually unstudied North Shore (Eastern Quebec) area, where potential alterations associated with acid rainfall and/or deforestation are ominous.

These and other attributes of the Lake Matamek zoobenthos will be described in detail in the Associate Investigator's MSc. Thesis, which is to be completed by April.

Acknowledgements

Successful completion of this study would not be possible without the generous support of the Woods Hole Oceanographic Institution and their Matamek Research Station coordinators Mr. F.G. Whoriskey, Jr. and Dr. R.J. Naiman. Special thanks are also expressed to the various authorities (too numerous to list here), particularly Dr. D.R. Oliver and Ms. M.E. Roussel, who contributed to the taxonomic resolution of the research, and to Mr. David Levin who assisted during the spring field work.

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STUDIES OF CADDISFLIES, AND JUVENILE SALMON AND TROUT

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The purpose of the June 1979 visit to Matamek was threefold. The primary function was to collect and observe, in situ, newly emerged brook trout and atlantic salmon fry in order to determine their first diets and feeding behaviour. Although sufficient numbers of trout were collected, the abnormal river conditions towards the end of the month postponed and severely depressed the salmon emergence, resulting in no specimens. Benthic and drift samples were simultaneously collected in areas where fry congregated and the invertebrates in these will be compared with those in the guts. Analyses of these samples has begun. Underwater observations were made of the fry feeding, and digestion rates were determined in the lab.

The second purpose of the visit was to take cores of substrate at depths of up to 100 cm across a transect of the Matamek River bed. The aim was to determine the three-dimensional distribution of the benthic invertebrates, the first study of its kind in a large, northern, brown-water river. Unfortunately, the abnormally high flow conditions of the river in June prevented the project from getting underway.

The third purpose of the visit was to collect caddisflies (Trichoptera) from areas and habitats not sampled on a previous visit. This has resulted in the following publication: Williams, N.E. and D.D. Williams. (1979) Distribution and feeding record of the caddisflies of the Matamek River region, Quebec. Can. J. Zool. 57: 2402-2412

Tides and Water Movements in the Moisie River Estuary
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INTRODUCTION

Success of the brook trout sea-ranching program at the Matamek Research Station must rest in part on an understanding of the biology of migrating trout in saline waters. As a preface to a major program on movements and feeding of brook trout within the Moisie River, I undertook a short study of water characteristics within the Moisie estuary on different tidal phases. The primary objectives were to determine (a) the distance that sea water intrudes into the river at high tide, (b) the degree of vertical mixing of salt and freshwater, (c) whether seawater intrudes as a well-defined front or in some other pattern, and (d) the degree to which tides influence river depth upstream.

Although the results are clearly not definitive, they identify the regions of the river feeling the influence of marine waters during late summer non-flood periods, document the slight degree of mixing of water masses from river and sea, suggest complex patterns of seawater movements on rising or falling tides, and indicate that large changes in tide height are rapidly damped upstream. These insights provide a background for design of studies of movements of brook trout and their food supplies within the estuary.

MATERIALS AND METHODS

Four transects were established that traversed the Moisie River Estuary. Transect no. 1 comprised two stations and crossed the mouth of the estuary. Transect no. 2 had seven stations and ran from a dock along the western bank to a point on the eastern bank. Transect no. 3, with nine stations, crossed the widest portion of the estuary. It began on the western shore near a boat-launching ramp a few hundred meters north of the military base and ended near the base of the first hills to rise from sea level along the eastern shore. Transect no. 4, with six stations, crossed the river just below the first major turn it takes upstream.

Stations were marked with numbered buoys anchored by cement blocks. We attempted to place buoys equidistant from each other by timing travel between stations at constant throttle speed. Stations were approximately 150-200 m apart.

Stations were surveyed on 11 and 12 August 1979. At each of the 24 stations we recorded time, depth, temperature, salinity ($^{\circ}/_{\infty}$) and conductivity; data were collected for surface, bottom and thermocline. On 11 August, surveys were conducted on both the rising and falling phases of a single tidal cycle; on 12 August a single set of surveys were made at or near high tide. Times and heights of tides were calculated for Moisie Bay following guidelines in tide tables for the east coast of North America.

RESULTS AND DISCUSSION

Figure 1 diagrams the approximate shape of tidal waves predicted for Moisie Bay during 11 and 12 August 1979, as well as the time and tide height of transect surveys. Most discussion will center on Transects 3 and 4 because (a) we completed 3 surveys for each transect, (b) they are the two transects farthest upstream, and (c) results span the greatest tidal range. Transect 1 is ignored; salinity and temperature data for the station within the channel are incomplete because our probe reached to only 3 m in the 7 m channel.

Depth profiles of the river for Transects 2, 3 and 4 indicate that the major river channel follows the west bank of the estuary (Figure 2), and that the influence of tidal variation on river depth decreases rapidly between Transects 3 and 4. A low-to-high tide range of 1.6 m (5.3 feet) produced a change in river depth on Transect 3 averaging 1.5 m (4.9 feet), but a tide range of 1.9 m (6.25 feet) produced a changed river depth by only 0.7 m (2.3 feet) on transect 4. Thus at Transect 3, 1.2 km upstream from the river mouth, increase in river depth was 94 percent of the estimated tidal range; 2.9 km farther upstream, at Transect 4, the increase in depth was only 37 percent of tidal range.

Influence of tides on river depth extends far above actual incursion of seawater (Table 1). Seawater never reached Transect 4 and occurred at Transect 3 only on high or intermediate tides. The highest tide studied here is only 0.4 m (1.4 feet) below the highest tide for the months of July, August and September, which suggests that Transect 4 would rarely, if ever, experience a large increase in salinity during the summer months.

Mixing of salt and freshwater in the zone of seawater intrusion is slight (Table 1). On all transects, surface waters over a seawater lens exhibited low salinity, regardless of depth. In Transect 3 (Table 2), which averaged a depth of only 2 m at high tide, salinity differences as high as 22.5 ‰ per 1.75 m depth (12.9 ‰ m^{-1}) were recorded. These were not smooth salinity gradients. Thickness of thermoclines was estimated by noting the depth range over which temperatures dropped from river temperature (15–16°C) to the temperature of the seawater stratum (7–9°C). This distance was roughly 0.25m in virtually all cases. Changes in salinity paralleled changes in temperature. Also, the depth of the freshwater layer ($\bar{x} = 1.55 \text{ m}$, $SD = 0.43$, $N = 20$) was quite uniform within the estuary (Transects 2–3).

The shape of the seawater lens appears complex rather than a simple front which moves in and out with the tide. The position of thermoclines at high (2.25 m) and intermediate (1.62 m) tides on Transect 2 (Figure 3) supports the expectation that seawater moves first into the deeper channels. On a falling tide, pockets of seawater apparently remain behind in troughs flanked by shallows. For example, positions 14, 21 and C of Transect 3 (Table 2) are troughs, and each retained saline water on a falling tide (Tide approx. 4'). There is a direct correlation between depth of water and salinity: troughs are ranked C–14–21 in order of both increasing depth and increasing salinity. This suggests that saline waters drain from shallows into deeper channels. The salinity "front" would appear as fingers extending into the complex of small channels, rather than as a

consolidated internal bore or wave, and would produce very patchy habitat comprising a mosaic of pockets of water differing in temperature and salinity.

SUMMARY

The Moisie River Estuary is a physically complex habitat. Depths at high tide range to 7 m; temperatures range from 7-9° to 15-16°C, and usually change rapidly within sharp thermoclines; salinities range from approximately 0‰ to 26‰ or more, and while most gradients are steep (paralleling thermoclines), there is some mixing near the head of a seawater incursion; seawater intrudes in complex patterns rather than as a well-defined front; the seawater intrusion reaches less than 4 km upstream, but tidal changes in river depth occur beyond that due to backing up of river flow.

Table 1. Summary of salinities recorded on Transects 2, 3 and 4, Moisie River Estuary.
The time and height of tides during each transect survey are diagrammed in Figure 1.

	High Tide		Intermediate Tide		Low Tide	
	Surface	Bottom	Surface	Bottom	Surface	Bottom
<u>Transect 2</u>						
x	0.5	22.4	0.5	21.8	-	-
SD	0.3	1.8	0	3.4	-	-
Range	0.25-1.00	19 - 24	(0.5)	16-26.5	-	-
N	7	7	7	7	-	-
<u>Transect 3</u>						
x	0.4	17.2	1.3	6.1	0.5	0.4
SD	0.1	8.8	0.8	7.5	0.1	0.1
Range	0.25-0.5	0.25-24	0.5-2.5	0.5-19	0.3-0.5	0.3-0.5
N	9	9	8	8	6	6
<u>Transect 4</u>						
x	0	0	0.1	0.1	0	0
SD	0	0	0.2	0.2	0	0
Range	0	0	0-0.5	0-0.5	0	0
N	6	6	6	6	6	6

Table 2. Salinity data for Transect 3, Moisie River estuary. Tides are those calculated for Moisie Bay from tide tables, salinities are in parts per thousand (‰), and stations 22 through 10 to represent individual stations in order from west to east. Stations marked with asterisks (*) were troughs, low points flanked by shallower zones.

Stations	7.8 ft.		4.0 ft.		2.5 ft.	
	Tide Surface	Bottom	Tide Surface	Bottom	Tide Surface	Bottom
22	0.5	23.0	1.5	2.5	0.3	0.3
17	0.5	24.0	-	-	0.5	0.3
14*	0.5	23.0	0.5*	17.0*	0.5	0.5
15	0.5	23.0	2.0	1.5	0.5	0.5
21*	0.5	22.0	2.5*	19.0*	0.5	0.5
9	0.5	16.0	2.0	2.0	Exposed	
C*	0.5	19.0	0.5*	6.0*	0.5	0.5
11	0.25	4.5	0.5	0.5	Exposed	
10	0.25	0.25	0.5	0.5	Exposed	

FIGURE LEGENDS

- Figure 1 Tidal cycles in Moisie Bay for 11 and 12 August 1979. Transects (1-4) were surveyed at the time and tide height indicated by numbered points.
- Figure 2 Cross sections of the Moisie River on different tide heights. Transect 4 was farthest upstream. Water depths are given in meters; tide height in Moisie Bay given in feed to match Figure 1.
- Figure 3 Behavior of thermocline at Transect 2 in the Moisie River estuary. Depths in meters off bottom; tide heights in feed to match Figure 1.

STUDIES ON MARINE ORGANISMS

We are offering, here, a brief account of the 1979 research activities on the North Shore.

This report is structured along the same line as the preceding report covering

- I) Studies on reproduction
- II) Studies on larval settling
- III) The biology of Buccinum undatum
- IV) Studies on natural products of marine organisms
- V) The development of a bioassay

I) Studies on reproduction (D. LARRIVÉE*)

We continued the structural studies of the changes in the formation of the gametes in Strongylocentrotus droebachiensis. We looked more specifically at the ultrastructure of oogenesis in three identified periods (see previous report) preceding the maturation of the gametes in order to characterise more precisely the period of gametogenesis.

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We also made quantitative studies of the gametes. We intended to show that the cycle of growth and the cycle of gametogenesis of these animals are in some way asynchronized. This was therefore accompanied by experimental studies whereby animals sampled during these periods of elaboration were deprived of specific food. This led to early and incomplete spawning. The aspects of growth have not been fully analysed.

II) Studies on larval settling (D. LARRIVEE, J.L. SIMARD*)

We have completed the sampling of larval settling in Amory Cove. The objective here was two-fold

- 1) obtain a picture of the situation, temporally and spatially, concerning this aspect of productivity;
- 2) study larval adaptation to settling conditions.

The qualitative and quantitative analysis of settling distribution in Amory Cove is under completion. In this regard we have obtained images of the settling surfaces and tried to correlate the organization of the surfaces with settling preferences. The adaptation studies have been restricted to structural aspects in the most common species, Balanus crinoides and Mytilus edulis.

III) The biology of *Buccinum undatum* (D. LARRIVÉE*)

We have pursued the ultrastructural analysis of shell formation in *Buccinum undatum*. We looked at the periods covering the early shell laying. We have been unable to complete the biochemical analysis of the carbonic anhydrase synthesis and activity. Analysis of gonad index has been undertaken, which permits the determination of the peak of egg laying in this species.

IV) Studies on the natural products of marine organisms

(F.X. GARNEAU, J.L. SIMARD, O. HARVEY*; J. APSIMON, M. GIRARD**)

We pursued our investigation regarding the identification of certain secondary metabolites of marine organisms with the studying the influence of these substances on the equilibrium of marine coastal communities. We have progressed in our structural elucidation of major saponin (toxic defense substance) of the sea cucumber *Psolus fabricii* to the point where we can now propose the following partial structure:

** Dept. Chemistry, Carleton University, Ottawa.

The exact location of the endocyclic double bond and the relative quantities of the sugars as well as their order of attachment are presently under active study.

We have recently purified the major saponin of Cucumaria frondosa collected from Amory Cove. This product turns out to be a different type of saponin whose structure differs from the one illustrated above.

A crystalline substance was obtained from the hexane and ether extracts of the red algae Ptilota serrata collected on the beach in front of the main building and the boathouse of the Matamek research station. This substance appears to be similar to taraxerol, a triterpene found in abundance in terrestrial flora and one of the very few triterpenes so far found in marine organisms. This algae is known to be unpopular as a source of food with the sea urchin Strongylocentrotus drobachiensis and it may be that either this triterpene or other substances we have isolated from Ptilota act as a feeding deterrent. We plan to carry out experiments to verify this possibility.

V) The development of a bioassay (D. LARRIVÉE, F.X. GARNEAU, J.L. SIMARD*)

The bioassay for testing properties of bioactive compounds based on the use of sea urchin early development has been analysed along two lines:

- a) the determination of a predictive curve relating concentration to the number of cell division;
- b) the ultra structural aspects of cell surface disorganization as observed previously.

We have obtained transmission and scanning electron microscope images indicating that the disappearance of the cell surface villi is accompanied by a change in the distribution of the hyaline layer of the egg surface.

OBSERVATIONS OF CETACEANS ALONG THE NORTH SHORE
OF THE GULF OF ST. LAWRENCE

AUGUST 1979

R. SEARS

MINIGAN ISLAND CETACEAN STUDY
E. FALMOUTH, MA 02536

ABSTRACT

A large number of at least four species of cetaceans are found to summer in the Gulf of St. Lawrence. This includes the fin, blue, and minke whales as well as the white-sided Dolphin. The occurrence of other cetacean species in the Gulf is documented, however, the data on their numbers is ambiguous (Michell, 1973). There is at least one resident population of beluga whales that has been documented, (Pippard, L. 1978). Due to lack of data, observations of cetaceans is of major interest in this area. A study on cetaceans was carried out on the North Shore of the Gulf of St. Lawrence from 11 August to 30 August in 1979. The study area consisted of 175 miles of coastal waters between Sept-Iles ($66^{\circ} 31'W$ $50^{\circ} 06'N$) and Havre St. Pierre ($63^{\circ}36'W$ $50^{\circ} 15'N$). The main body of observations were made in Moise Bay ($65^{\circ}57'W$ $50^{\circ} 13'N$) and the Minigan islands ($64^{\circ}10'W$ $50^{\circ}, 13'N$). Aerial surveys were carried out at least once a week over the full distance between Sept.-Iles and Havre St. Pierre.

INTRODUCTION

During the summer of 1976, cetaceans were observed in Moisie Bay and at the Mingan Islands, which set the groundwork for this year's study (Sears, R. 1976). Due to the fact that the coastal waters between Sept-Iles and Havre St. Pierre are frequented by a considerable number of cetaceans, we decided to carry out a more intensive study of the area. Until this time, no one had taken a close look at cetaceans in this area. There have, however, been several studies conducted in the Gulf of St. Lawrence at the Saguenay River, by Mitchell (personal communication). Sergeant has carried out research in the St. Lawrence Estuary as well, on more pelagic stocks of cetaceans (Sergeant, D. E., 1977).

Due to the lack of hard data on cetacean movements and populations within the Gulf, we felt that more extensive observations were needed. Behavioral studies and a census of cetaceans were also essential.

Large whales having been hit by shipping, it was of interest to study their movements within the heavy traffic area around Sept-Iles.

A watch was carried out in Moisie Bay because it seems to be an important stopover point for cetaceans. Another important sector within the study area was that of the Mingan Islands. One week was devoted to observations at these islands, and additional time was spent over this location during flights.

METHODS

The observation period was from 11 August to 30 August and the area studied was from Sept-Iles to Havre St. Pierre. The main watch was carried out from the Matamek Research Station, a Woods Hole Oceanographic Institution lab on Moisie Bay.

Using Swift 7 X 50 wideangle binoculars, the observer was positioned approximately 12 meters above sea level. When cetaceans were sighted, a 15 ft. zodiac (inflatable rubber boat) powered by a 25 hp. Johnson outboard was used as a platform for taking photographs and for closer behavioral observation. The same methods were used at the Mingan Islands from 17 August to 21 August. At this, latter location camp was set up at Longue Pointe de Mingan ($64^{\circ}10'W$ $50^{\circ}15'N$). All observations recorded at the Mingan Islands were taken between and around Ile Nue and Iles aux Perroquets ($64^{\circ}10'W$ $50^{\circ}13'N$).

When using the zodiac, we were careful not to travel at high speeds near cetaceans. This reduced the chance of stressing the animals due to high-pitch noise. If the individuals being studied remained in one area, we found it preferable to turn off the motor and drift. In doing this, there is less chance of altering behavior. To cover the whale study area, 3 hr. flights were flown from Sept-Iles airport to Havre St. Pierre and back. Due to costs of flights the plane was flown parallel to the coast, instead of transects, at an altitude of 1000 ft. and varied from 2 to 12 kilometers from shore. When there was need for a closer look we would descend to 300 ft. The plane used was a four-passenger Piper Cherokee. However, it is better to use a Cessna 172 as the wing is out of the downward viewing area.

Cameras used were 3 Pentaxes: an Mx, an ME, and a KX with power winders. Lenses used were: a 50 mm Pentax, a 135 mm vivitar, a 200mm Pentax, and a 400mm Vintar. Polarizing filters were used when taking pictures from the air.

On days of heavy fog or rain, visibility being poor, the time spent watching was reduced.

In an attempt to gain additional sightings and information on cetacean behavior near fishing boats, many conversations were held with local shrimp fisherman.

RESULTS

The total number of cetaceans sighted are as follows: white sided dolphin, Lagenorhynchus acutus, 200-250; harbour porpoise, Phocoena phocoena, 40; minke whale, Balaenoptera acutorostrata; 140, fin whale, Balaenoptera physalus, 104, blue whale, Balaenoptera musculus, 23, and unidentified large balaenopterines, 13. Many of these sightings could be repeats. The first cetaceans sighted were 12 August, and from that point on they were sighted each day of clear weather. The aerial surveys yielded the best results. During the flights between Sept-Iles and Havre St. Pierre, we never saw less than thirty animals. The use of the plane allowed us to observe interesting feeding behavior which would have been much more difficult to observe while at sea. A plane is a more efficient surveying tool because a large area can be covered in a short time. Also, when cetaceans are present, there is less chance of not spotting them.

Blue Whales (B. musculus)

This species was seen throughout the study area, however, most were observed 15 kilometers west of the Mingan Islands in an area known as the Banc Rouge (64°31'W 50°11'N). It was at this location that blue whales were in close proximity to fin whales. Both species were feeding in the same area, at times not more than a few meters apart. We observed much side-feeding (whale breaks surface on its side, jaws wide open) and lunge-feeding (rushing to the surface, jaws open with most of the head emerging) over this bank. It was not clear what this species was feeding on, although schools of sand lance were observed in the immediate vicinity.

In Moisie Bay, most of the blue whales observed were generally near the mouth of the Moisie river. The most important aspect of the blue whales' behavior in the study area was that they were observed to raise their flukes almost perpendicular to the surface when diving. The ventral surface of the fluke can be used in the same manner as that of the humpback whale, for identification purposes. The pattern on the underside of the fluke is not as distinct as the humpback, however, there is enough detail so as to positively identify individuals.

Blue whales were found in the shipping lanes to the southwest of Sept-Iles and at the time there were two large ships (100,000+ tons) within 2 kilometers. It would be hard to state whether the whales were affected by the ships or not. However, in 1977, two fin whales were struck by shipping in that region (Sergeant, D. E, per. communication).

Finback Whale

Fin whales were fairly evenly distributed throughout the study area with as many as twenty per pod over Banc Rouge. It is at this location that this species was most actively feeding. Much lunge and side feeding was observed here. Individuals would rise to the surface, let some air out through the blowhole, roll on their sides, and break the surface with their jaws wide open (see photos). The animals would then roll back with belly down and milky fluid would come out of the mouth. There would then be 2-5 breaths at the surface followed by a short dive (2-4 min), and the whole process would begin again. While feeding, we saw 3-5 whales in very tight formations not more than a few meters from each other, at times dangerously close to colliding. These whales were at times observed feeding not more than 20-30 meters from fishing boats actively

fishing over the Banc Rouge. These fishermen are generally fishing for Cod (Gadus morhua), (personal communication with fishermen)) using gill nets.

Minke Whale (acutorostrata)

Minke whales were found in greatest numbers at the Mingan Islands. In the rest of the study area only a few single specimens were sighted. However, the 3 kilometer span of water between Ile Nue and Ile aux Perroquets seemed to be the most frequented location. In each of the observations, there were between fifteen and twenty minkes in the area. They were observed to be feeding on shrimp (species unknown) and sand launce. As with the balaenopterines, there was much lunging through the surface. They appeared to be using the surface film as a barrier against which to trap their prey. There were occasions when minkes would thrash around at the surface with flippers and flukes in the air, however, it was not clear what was happening at those moments.

When the outboard was turned off, the minkes would come up within two meters of the boat. One individual came right up to boat from directly below, perhaps curious about us, and when we moved away under power, it followed us for a good fifteen minutes. On one occasion two minkes breached several times, again the cause was not clear. There were no other boats but ours, and we were not using the motor at the time. The ventral side of the minke was seen when they breached and it was white, with a slight-pinkish pigmentation posteriorly.

In the evening, the minkes as a whole would move closer toward the mainland and feed as close as 50 meters from the shore on sand launce. Though there were many individuals in this area, only once did we see two swimming in tight formation within two meters of each other.

Individuals of this species were identified by marks on their backs or dorsal fins. There were two with extensive white scarring on their backs, possibly caused by net entanglements. Local fishermen told us of minkes getting entangled in their nets and then escaping carrying large wounds on their backs.

Harbor porpoise (*Phocoena phocoena*)

Harbor porpoise were sighted in Moisie Bay and in the same region as the minkes. They were abundant around the Mingan Islands. However, this species of cetacea is very shy of boats and will seldom venture close to a boat even when the motor is turned off. When seen, they were in groups of 3 to as large as 8, including some very small individuals which were probably juveniles.

White-sided Dolphin (*Lagenorhynchus acutus*)

A herd of 200-250 white-sided dolphin, moving east to west, 5 kilometers from shore was sighted in the Moisie Bay. The dolphin covered an area 1 kilometer by 1/2 a kilometer and swam in pods of 3 to 10 individuals. There were eight calves seen within the herd. Several dolphin rode in our wake and, at times, would come right up to the boat. Many individuals leapt out of the water at varying distances from us, some as close as 1/2 meter away.

Many dolphins were distinguished by marks on them, usually white scars on their backs or dorsal fins. On several specimens, there were notches in the dorsal fin.

SIGHTINGS MINGAN ISLANDS

DATE	TIME	LOCATION	SPECIES	NUMBER	METER SIZE	HRS. WATCHED	KTS WIND	KILOM VIS	WEATHER CONDITIONS	SEASTATE	COMMENTS
8/17	11:00	64° 10'W 50° 14'N	minke B. acutorstrata	2	6-7m 25-30	9	5-10 SW	7-10	1		Minkes staying area throughout the day.
	12:00	64° 10'W 50° 14'N	minke	2 3	8-10 6-7						
	13:00	50° 14'W	minke	6	6-7						
	14:30	50° 14'W	harbor porpoise phocoena	20-25	1-2						Heading East
	15:00	64° 07'W 50° 16'N	minke	1	6-7						Heading East
8/18	16:00	64° 10'W 50° 14'N	harbor porpoise	9-10	1-2						Heading East
	17:30	64° 10'W	minke	12-15	6-10						Feeding in area not moving away.
	20:00										
8/19	12:00	64° 10'W 50° 14'N	minke	18-20	5-10	9	calm	10	clear	1	Staying in area
	12:00	64° 10'W 50° 14'N	minke	8-10	5-8	8	5-10E	10	clear	1	Staying in area
	13:00	64° 12'W 50° 14'N	minke	6	6-9						
	18:00	64° 07'W 50° 15'N	minke	6-8	5-10						
8/20	13:30	64° 09'W 50° 15'N	minke	6-8	6-10	5	5-10E	6	Light Rain	1	Moving back and forth offshore
	18:30	64° 09'W 50° 15'N									

MOISIE BAY SIGHTINGS (A)

DATE	TIME	POSITION	SPECIES	NUMBER	METER SIZE	HRS. WATCHED	KTS WIND	KILOM VIS	WEATHER CONDITIONS	SEASTATE	COMMENTS
8/12	08:50	66° 04'W 50° 10'N	B.sp.	3		13	10-20SW	12	clear	3	Tall Spouts on horizon heading west
8/13	07:30	66° 04'W 50° 10'N	B.sp.	2	18+	12	10-15E	9	cloudy	2	Large balaenopterive breached once.
	11:30	60° 04'W 50° 10'N	blue B. musculus	3	18-22						In outflow of Moisie River. Blues raised flukes when diving. Good identification markings.
	15:15	60° 04'W 50° 10'N	fin B. physalus	1	18-20			5	rain	3	General heading of all whales to the west.
8/14	No sightings					12					
8/15	06:00	65° 54'W 50° 16'N	harbor porpoise	3-5	1-2	12	calm	11	clear	1	Heading east
	06:30	65° 54'W 50° 16'N	fin	3	18-20						
	07:00	65° 54'W 50° 16'N	blue	1	21-23						Stayed in area until 17:00 and then headed east.
8/21	No sightings					12	10-15E	300yds.	Fog/Heavy Rain	2	
8/22	09:15	66° 00'W 50° 16'N	fin	2-3	20-22	12	10-15SW	9	clear	2	Heading west
8/23	No sightings in pm					6	5SW	11	clear	1	Morning flight to Havre St. Pierre Sep.
8/24	No sightings										Heavy Rains & Thick Fog

MOISIE BAY SIGHTINGS (B)

DATE	TIME	POSITION	SPECIES	NUMBER	METER SIZE	HRS. WATCHED	KTS WIND	KILOM VIS	WEATHER CONDITIONS	SEASTATE	COMMENTS
8/25	11:00	65° 58'W 50° 17'N	minke	1	6-8	13	10-20SW	10	clear	3	Heading east
	15:00	65° 56'W 50° 17'N	minke	1	7-9						Heading east
8/26	No sightings					8	5-10NW	11	clear	1	
8/27	07:30	65° 57'W 50° 13'N	fin	5-7	19-22	10	5NW	12	clear	1	Heading west
	09:35	65° 57'W 50° 13'N	B.sp.	4	18-23						Heading west
	10:05	65° 57'W 54° 14'N	fin	1	20-22						Heading west
	10:32	66° 03'W 50° 11'N	B.sp.	1	18-23		10-15SW	11	clear	2	Heading west
8/28	07:15	65° 57'W 50° 12'N	L. acutus	200-250	1-2.5	12	5SW	12	clear	calm	Heading west/southwest
	10:00	66° 04'W 50° 11'N	fin	2	20-22		10-15SW		clear	2	Staying in area
	10:10	66° 04'W 50° 11'N	B.sp.	1	21-24						Staying in area
8/29	No sightings					5	15-20E	100m			Heavy rain and fog.
8/30	No sightings					5	15-20	100m			Heavy rain and fog.

AERIAL SIGHTINGS (A) ALL FLIGHTS ORIGINATE FROM SEPT-ILES.

DATE	TIME	POSITION	SPECIES	NUMBER	METER SIZE	HRS. WATCHED	KTS WIND	KILOM VIS	WEATHER		COMMENTS
									CONDITIONS	SEASTATE	
8/15	13:00	65° 38'W 50° 04'N	fin	1	20-22	1	10-15SW	20	clear	2	Flight to Anticosti and back. 1000 ft.
	18:15	No sightings				1	8-10SW	20	clear	2	Flight to Anticosti and back. 100 ft.
8/16	07:45	65° 40'W 50° 13'N	fin	1	19-22	3	5SW	24	clear	1	Heading west. Flight to Havre St. Pierre-3-12 kilometers from shore
	07:55	65° 15'W 50° 14'N	fin	1	18-21						Heading East
	08:05	64° 57'W 50° 11'N	fin	1	18-22						Heading Northeast
	08:10	64° 44'W 50° 12'N	B.sp. minke	1 1	20-23 6-8						Heading East Heading East
	08:15	64° 43'W 50° 14'N	minke	1	6-8						Heading Northeast
	08:30	64° 20'W 50° 14'N	fin	1	19-21						Heading West
	08:40	64° 10'W 50° 13'N "	fin minke "	5-6 16-20	19-29 5-10						Staying in area side-feeding Staying in area
	08:55	64° 02'W 50° 16'N	minke	1	7-8						Heading West
	09:15	63° 58'W 50° 16'N	minke	1	8-9						Heading North
	09:20	64° 01'W 50° 16'N	minke	1	7-8						Heading West
	09:35	64° 31'W 50° 16'N	minke	1	7-9						Heading West
	09:55	65° 22'W 50° 14'N	blue	1	21-23						Heading North

AERIAL SIGHTINGS (B) ALL FLIGHTS ORIGINATE FROM SEPT-ILES

DATE	TIME	POSITION	SPECIES	NUMBER	METER SIZE	HRS. WATCHED	KTS WIND	KILOM VIS	WEATHER CONDITIONS	SEASTATE	COMMENTS
8/23									part. cldy	1	
	07:40	65° 30' W 50° 13' N	fin	1	20-23	3	5-10SW	24			Flight to Havre St. Pierre and back. Heading Northeast
	07:45	64° 47' W 50° 12' N	fin	1	20-22						Heading East
	08:05	64° 16' W 50° 10' N	fin	5	20-22						Heading West
	08:15	64° 10' W 50° 14' N	minke	8-10	6-9						Staying in area
	08:30	64° 07' W 50° 15' N	minke	10-12	6-9						Staying in area
	09:30	64° 13' W 50° 12' N	minke	1	6-8						Heading West
	09:45	64° 18' W 50° 11' N	fin	9-10	18-22						Heading West
	09:50	64° 46' W 50° 13' N	fin	3	20-22						Heading West
	10:00	64° 54' W 50° 13' N	fin	1	22-23						Heading West
	10:10	65° 15' W 50° 14' N	fin	2	20-22						Heading East
8/26	16:45	65° 14' W 50° 13' N	fin	7-8	18-22	3	5-10SW	25	clear	2	Flight to Havre St. Pierre and back. Heading Northeast
	16:50	64° 59' W 50° 13' N	fin	1	20-22						Heading North
	17:20	64° 37' W 50° 13' N	blue	4	21-24						Heading Northwest
	17:35	64° 31' W 50° 12' N	fin	15-20	18-23						Heading North
	18:00	64° 21' W 50° 12' N	fin	3	19-22						Heading North

ALL FLIGHTS ORIGINATE FROM SEPT-ILES

AERIAL SURVEY (C)

DATE	TIME	POSITION	SPECIES	NUMBER	METER SIZE	HRS. WATCHED	KTS WIND	KILOM VIS	WEATHER CONDITIONS	SEASTATE	COMMENTS
8/28	17:20	66° 31'W 50° 05'N	fin	2	20-22	1.5	10-15SW	20	clear	2	Flight over shipping channels Sept-Iles Harbor Whales heading West-Southwest Heading West-Southwest
	17:50	66° 31'W 50° 05'N	blue	3	22-24						
	18:15	66° 03'W 50° 11'N	fin	1	20-22						Heading West-Southwest
		" "	B. sp.	1	22-24						Heading West

8/29	07:20	65° 38'W 50° 14'N	blue	1	22-25	3	5-8E	20	part.cldy.	1	Heading West Flight to Havre St. Pierre and back.
	08:10	64° 29'W 50° 15'N	fin	2	20-22						Heading Northwest
	08:15	64° 22'W 50° 14'N	fin	12-15	20-23						Staying in area.
		" "	minke	3-4	7-9						Staying in area.
		" "	blue	4-6	22-24						Staying in area
	09:15	64° 22'W 50° 16'N	minke	1	6-8						Staying in area
	09:37	65° 39'W 50° 12'N	blue	2	22-24		15-20E	10	fog/rain	3	Heading West
		" "	fin	1	20-23						Heading West

Discussion

This summer's study though brief, helped more clearly define the areas in which we must concentrate further studies. Both the Banc Rouge and the Mingan Islands seem to be important feeding grounds for cetaceans. The Moisie estuary in the Moisie Bay also seems to be an important feeding area.

It has been suggested that in the western portion of the Gulf of St. Lawrence, the currents cause a "nutrient pump" mechanism to form, and it is here that the highest primary production is found. (El. Sabh, 1976). From the air, many varying current patterns and packets of what appear to be internal waves, can be seen between the Banc Rouge and the Mingan Islands. It would appear that further hydrographic studies would be important in this region.

We have found that the ventral side of the blue whale's flukes can be photographed for positive identification.

Our study indicates that by mid to late August there is a general movement of cetaceans west. To illustrate this point, by the end of August few minke whales were seen around the Mingan Islands, but were strung out along the coast to the west and moving in that direction. The movements of other cetaceans were not as striking.

If one was able to identify individual animals of each species, as with humpbacks, more definite data could be gathered on cetacean movements in the Gulf. A catalogue of identification should be put together. With such a guide, more structure could be brought to the study of both cetacean movements and population studies. There is a need for a greater number of experienced observers to work together on such a catalogue. Placing observers on iron-ore ships between Sept-Îles and

Quebec City would be a very useful manner by which data could be collected. Fishermen can be a good source of information. The use of uniform sight-sheets would be of great help, as these could be handed out to pleasure boaters and fishermen. It would take time to organize a network of good observers, however, without this, knowledge on cetaceans will remain fragmented.

A matter of considerable importance has been made clear while working in the Mingan Islands. These islands should be protected from any industrial interests that may be concerned with mining the limestone of which these islands are made. The consequences of exploitation of these islands for their limestone would cause serious damage to both terrestrial and sealife.

There has been no comprehensive study made of this area. This should be carried out by a scientific organization with the means to take a serious look at these islands.

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