WHOI-82-29

Woods Hole
Oceanographic
Institution

THE MATAMEK RESEARCH PROGRAM:
ANNUAL REPORT FOR 1981

by

Robert J. Naiman

June 1982

TECHNICAL REPORT

WOODS HOLE, MASSACHUSETTS 02543

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Prepared for the Woods Hole Oceanographic Institution, Matamek Research Program and Education Program; for NOAA, Office of Sea Grant under Grant NA 80AA-D-00077; for the National Scientific and Engineering Research Council of Canada; for the Atlantic Salmon Association; for the Department of Recreation, Fish and Game of the Province of Quebec; for the University of Waterloo, Waterloo, Ontario.

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Approved for Distribution:

John M. Teal, Chairman
Department of Biology

ABSTRACT

This report summarizes activities associated with the Matamek Research Station in 1981. Research was conducted on the biological, chemical, and physical environment of streams and rivers, principally in the Moisie and Matamek River watersheds, on the effects of beaver in shaping aquatic ecosystems, on salmonid ecology, and on interactions between riparian vegetation and juvenile salmonids. Canadian universities, the Quebec government, and the Woods Hole Oceanographic Institution cooperated in this program.

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INTRODUCTION

In 1981 the scientific program at the Matamek Research Station was the largest and most comprehensive to date. Investigations continued to emphasize river ecosystem dynamics and salmonid ecology, but the depth and quality of these studies were far superior to those previously undertaken. The research group was large, up to 26 persons at any one time, and with a diverse array of interests. These are amplified in the research summaries.

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

The salmonid ecology program continued to monitor adult and juvenile life history characteristics. This provides a continuity with studies conducted in previous years. We continued to investigate the relative roles of size, age and photoperiod in determining the osmoregulatory ability of brook trout, as well as the influence of riparian vegetation on the ecology of brook trout fry.

Canadian graduate student projects included a comparative life history study of Atlantic salmon populations along the North Shore, jointly funded with the Atlantic Salmon Association, and periphyton production dynamics as a function of stream order. Student interns investigated interactions between brook trout fry and sticklebacks.

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 development of significant programs of long duration. The cooperation this Program has received from scientists at Canadian universities and the Quebec Ministry of Recreation, Fish and Game has been exceptional. We are most grateful for the continued support and assistance given us by the Quebec Government and our Canadian colleagues.

Robert J. Naiman
Coordinator,
Matamek Research Program

28 April 1982

INTRODUCTION

En 1981, le programme scientifique de la Station de Recherche Matamek était de loin le plus vaste et le plus complet. Les recherches scientifiques se sont poursuivies au niveau de la dynamique des cours d'eau et l'écologie des salmonidés, mais l'intensité et la qualité de ces études étaient supérieures à celles déjà enterprises dans le passé. De nombreuses personnes formaient le groupe de recherche, qui a impliqué jusqu'à 26 personnes à une certaine période et l'éte. Ces dernières présentaient une grande diversité d'intérêts dans divers domaines de recherche.

L'analyse intégrée des écosystèmes fluviaux incluaient cette année:

- la dynamique du périphyton
- la caractérisation des matières organiques en dérive
- la décomposition du bois et des feuilles
- la nature et la quantité des apports provenant des sources allochtones
- le rôle des castors dans les écosystèmes aquatiques
- l'analyse chimique des pluies
- la composition chimique des cours d'eau.

Plusieurs de ces études se sont poursuivies pendant la saison estivale de 1980 et furent complétées en 1981 (e.g. la décomposition des feuilles, la dynamique du seston). Cependant, l'analyse du bassin fluvial se poursuit dans d'autres domaines, occupant ainsi la majeure partie du programme de recherche actuel. Ces études portent essentiellement sur deux objectifs: 1) la détermination de la base trophique des salmonidés et 2) ultérieurement, l'élaboration des procédures pouvant favoriser la production des salmonidés et prévoir les effets de perturbation.

Le programme sur l'écologie des salmonidés poursuit le recensement annuel des populations des salmonidés ainsi que les caractéristiques biologiques du saumon adulte et juvénile. Ceci fourni une certaine continuité aux études entreprises dans le passé. Nous avons poursuit notre étude sur l'importance de la taille, de l'âge et de la photopériode en déterminant la capacité osmorégulatoire de l'omble fontaine. D'ailleurs, nous avons étudié l'influence de la végétation riveraine sur l'écologie des alevins de l'omble fontaine.

Les projets des étudiants gradués canadiens portaient 1) sur l'étude comparative des populations du saumon Atlanique le long de la Côte Nord, avec l'aide financière de l'Atlantic Salmon Association et 2) sur la dynamique de la production du périphyton en relation avec l'ordre des cours d'eau. Les étudiants internes ont investiqué les intéractions entre les épinoches et les alevins de l'omble fontaine.

Le Programme de Recherches de Matamek offre à des scientifiques canadiens et américains ainsi qu'aux étudiants, l'occasion unique de collaborer à un effort scientifique commun. L'emplacement de la Station de Recherche Matamek, qui'se trouve à proximité d'une variété de lacs et rivières à l'état vierge, et le caractère de ce programme largement subventionné, offrent la possibilité d'études approfondies qui peuvent se poursuivre indéfiniment. Les scientifiques de différentes universités canadiennes et le Ministère des Loisirs, de la Chasse et de la Pêche ont accordé à notre programme une aide exceptionnelle. Nous sommes très reconnaissants envers le Gouvernement du Québec et nos collèques canadiens pour leur support continuel.

Robert J. Naiman
Coordinateur

1981 PROGRAM PERSONNEL

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Matamek Canadian Awards - 1981
27/4.01

Principal Investigator	Affiliation	Title of Proposal	Award $C
Marcel Frenette	University of Laval	Characteristiques hydro-physiques du Bassin de la Riviere Matamec	$C 1,500
Hamish Duthie	University of Waterloo	Stream Periphyton Studies in the Matamek and Moisie Wateseds, Quebec	$ 8,000
Geoff Power	University of Waterloo	Salmon of the North Shore of the Gulf of St. Lawrence	$ 10,000

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Manuscript Reports

1981 Frenette, M. and P. Julien. Recueil de donnees sur les caracteristiques hydro-physiques de la Riviere Matamec Quebec, Canada. Rapport GCS-81-03. Universite Laval.

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RESEARCH SUMMARIES

RIVER ECOSYSTEM STUDIES

CHARACTERISTICS OF SEDIMENT AND ORGANIC CARBON EXPORT FROM PRISTINE BOREAL FOREST WATERSHEDS

Robert J. Naiman
Woods Hole Oceanographic Institution

SUMMARY

Estimates of the amount of material moving annually from terrestrial ecosystems to the ocean are largely based on an incomplete understanding of events occurring throughout the hydrologic year, and only a vague comprehension of in-stream processes controlling that export. This paper describes sediment and organic carbon export throughout an annual hydrologic cycle from five pristine watersheds in the boreal forest of Quebec, Canada. Discharge, suspended sediment, particulate organic matter (POM: >0.5 μm), and dissolved organic carbon (DOC: <0.5 μm diameter), and the percentage of organic matter were measured from 1979 to 1981 in First Choice Creek (1st order; watershed area: 0.25 km^2), Beaver Creek (2nd order; 1.83 km^2); Muskrat River (5th order; 204 km^2), Matamek River (6th order; 673 km^2); and the Moisie River (9th order; 19,871 km^2). All streams, with the exception of First Choice Creek, have a strong spring freshet when 43 to 55% of the annual discharge occurs. During this two month period 71 to 92% of the annual sediment load is exported but only 59-65% of the annual POM load and only 47-51% of the annual DOC load. Sediment yield is relatively constant between watersheds (1.5-7.6 $g \cdot m^{-2} \cdot yr^{-1}$), as is POM export (1.0-6.7 g AFDW $\cdot m^{-2} \cdot yr^{-1}$); however, export of DOC varies from 3.1 g $C \cdot m^{-2} \cdot yr^{-1}$ in First Choice Creek to 48.4 g $C \cdot m^{-2} \cdot yr^{-1}$ in Beaver Creek. There appears to be rapid loading of carbon between 1st and 2nd order streams in boreal forests, followed by biological and physical processing as watershed area increases. Thus, for the Moisie River watershed, export of TOC is reduced to only 4.7 g $C \cdot m^{-2} \cdot yr^{-1}$. Export of coarse particulate organic matter (CPOM: >1 mm) is negligible (normally <0.1 mg/L), as is oxidation of the suspended load (<0.3%/d). Effects of summer storms, natural diel variations, and depth

of sample from the water column have minimal importance. Rating curves (kg/d vs. discharge) are developed to estimate the annual yield of sediment, POM, and DOC.

Conclusions - Results suggest that in-stream retention devices have a strong influence on organic carbon concentrations in pristine streams, regardless of watershed size, while discharge and stream power have little effect. Both the spring freshet and summer storms have been shown to have little control over organic carbon concentrations. Sediment movement responds to discharge patterns, suggesting that export of sediment and organic material are controlled by two different processes: retention characteristics and the water's potential energy. Annual yields ($g \cdot m^{-2} \cdot yr^{-1}$) reported here are similar to those reported previously for boreal forests but differ slightly in response to watershed size. The particulate organic material being exported has been efficiently processed, regardless of stream size, as evidenced by the dominance of VPOM (0.5-53 μm), the minor contribution of CPOM, and the fact that only 0.3-0.5% of the POM is oxidized daily during movement. These data emphasize that retention and processing of organic matter within the pristine watershed are important and complicated phenomenon, and that the downstream movement of this material cannot be easily described just in terms of fluid dynamics. Further studies of an experimental nature are needed to quantify the relative importance of specific in-stream retention devices before a working model for predicting sediment and organic carbon concentrations can be constructed.

FIGURE CAPTIONS

Fig. 1. This map shows the location of the five watersheds in eastern Quebec, Canada. The photographs are of each site used in this study.

Fig. 2. Mean monthly precipitation received as rain and snowfall between 1944–1970 at Sept Iles, Quebec, are shown by month. Total monthy precipitation received at Sept Iles varies greatly from month to month, but since 1944 no long term cycles are evident.

Fig. 3. Discharge at the five sites had the same general pattern between 1979 and 1981. In each year there was a strong spring freshet with a secondary freshet in late summer or autumn.

Fig. 4. The Moisie River is the only site for which relatively long-term discharge data are available. Shown here is the mean monthly discharge since 1965; note the regular annual pattern.

Fig. 5. The percentage of organic matter, and sediment and POM concentrations were sampled in a matrix array for the Moisie River during the ice-free season in 1980. Shown above are the contour intervals generated from these data.

Fig. 6. The annual pattern of the suspended inorganic sediment concentration is shown for each site. Note that highest concentrations are during the spring freshet with considerable day-to-day variability at that time, and that summer and autumn loads are negligible.

Fig. 7. The annual cycle of suspended particulate organic matter is shown for each site. Note that the increase during the spring freshet is small; the scale is the same as in Fig. 6; and that all sites have a similar pattern.

Fig. 8. Concentrations of dissolved organic carbon are relatively low and uniform during the spring freshet but increase during the productive summer and autumn months. Note that all sites show a similar pattern.

Fig. 9. Concentrations of suspended CPOM are generally low in all streams; however, during autumn leaf fall the concentration can occasionally increase. Compared to FPOM and DOC, the amount of CPOM exported is negligible.

Fig. 10. The ratio of particulate inorganic matter to organic matter in the seston is greatest and most variable during the spring freshet, and lowest and most uniform during summer and autumn for all sites.

Fig. 11. The annual pattern of the DOC:POM ratio varies widely on a daily basis for most streams. Ratios tend to be greatest during summer and autumn and lowest during the spring freshet. The coefficient of variation for a sample on one day is probably <5%.

Fig. 12. The percentage of particulate organic matter in the seston fluctuates considerably from day-to-day for all sites, thus influencing the apparent food quality of drifting material.

Fig. 13. The size composition of suspended particulate organic matter shifts quickly to very small particles as stream size increases. Over 90% of drifting POM in streams larger than 2nd order is <53 μm diameter.

Fig. 14. Data from all sites are combined and regressed against discharge for percentage organic matter, sediment, POM, DOC, sediment to POM ratio, and DOC to POM ratio. The resulting relationships are weak with <40% of the variation in each case attributable to discharge.

Fig. 15 The effect of summer storms on the hydrologic regime, and sediment, POM, and DOC concentrations is shown for each site. During this period 3.58 cm of rain fell in two storms.

Fig. 16. Rating curves (kg/d) as a function of discharge are developed for sediment, POM, and DOC using all available data. For each case >80% of the daily load can be estimated from discharge.

Fig. 17. The monthly pattern of total sediment, POM, and DOC export for 1980 is given for each site. Most sediment is exported during the spring freshet; whereas, total POM and DOC export follow the annual hydrograph.

Fig. 18. Total annual export of sediment, POM, DOC, and TOC can be reliably predicted from either watershed area or total annual discharge. In both cases all coefficients of determination (r^2) are >0.94.

Fig. 19. The average annual percentage of POM oxidized daily remains essentially constant as stream size increases; however, the annual oxidation pattern varies according to the specific characteristics of each stream ecosystem.

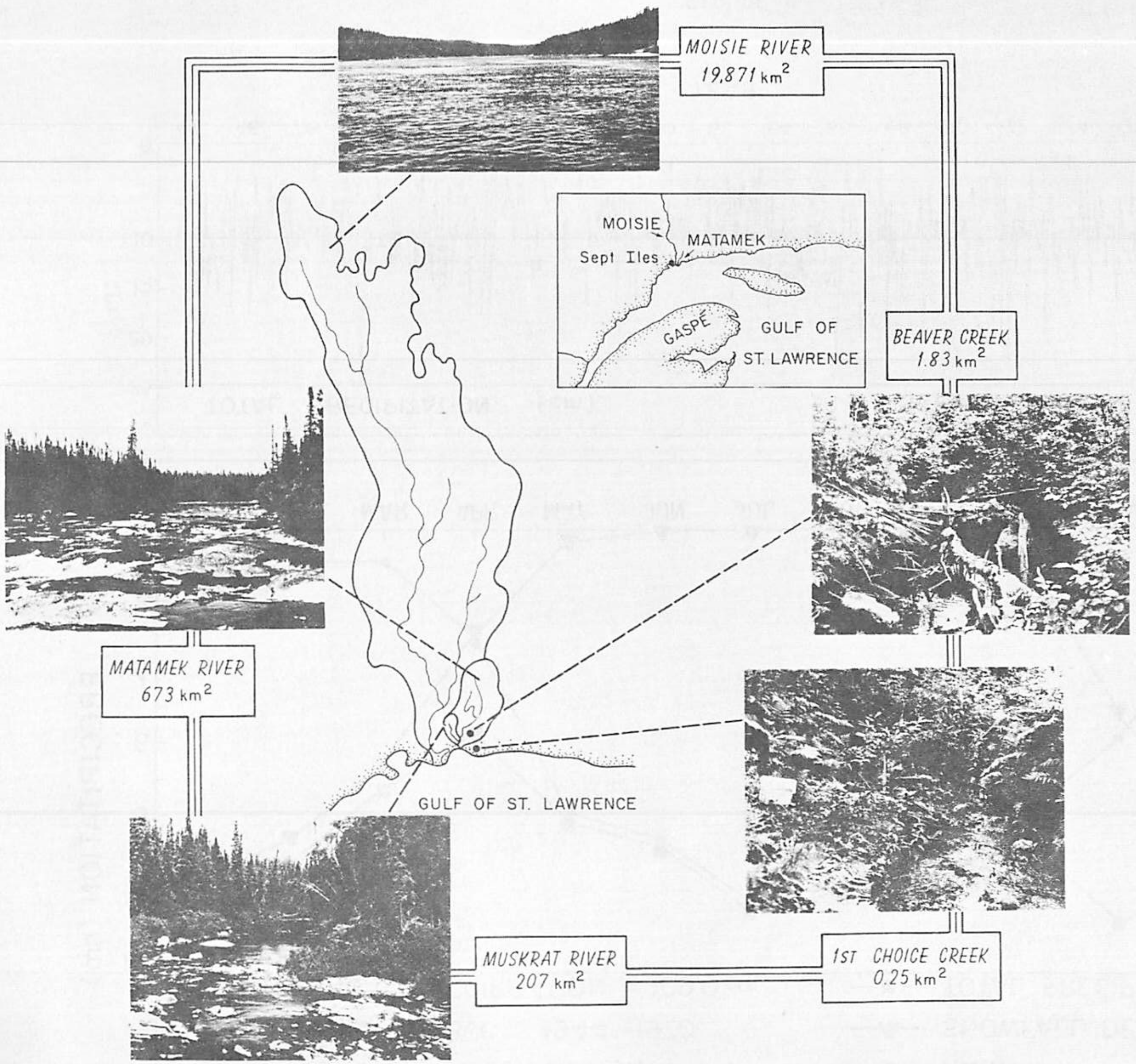

MOISIE RIVER
19,871 km²
MOISIE
MATAMEK
Sept Iles
GASPÉ
GULF OF
ST. LAWRENCE
BEAVER CREEK
1.83 km²
MATAMEK RIVER
673 km²
GULF OF ST. LAWRENCE
MUSKRAT RIVER
207 km²
1ST CHOICE CREEK
0.25 km²

Figure 1

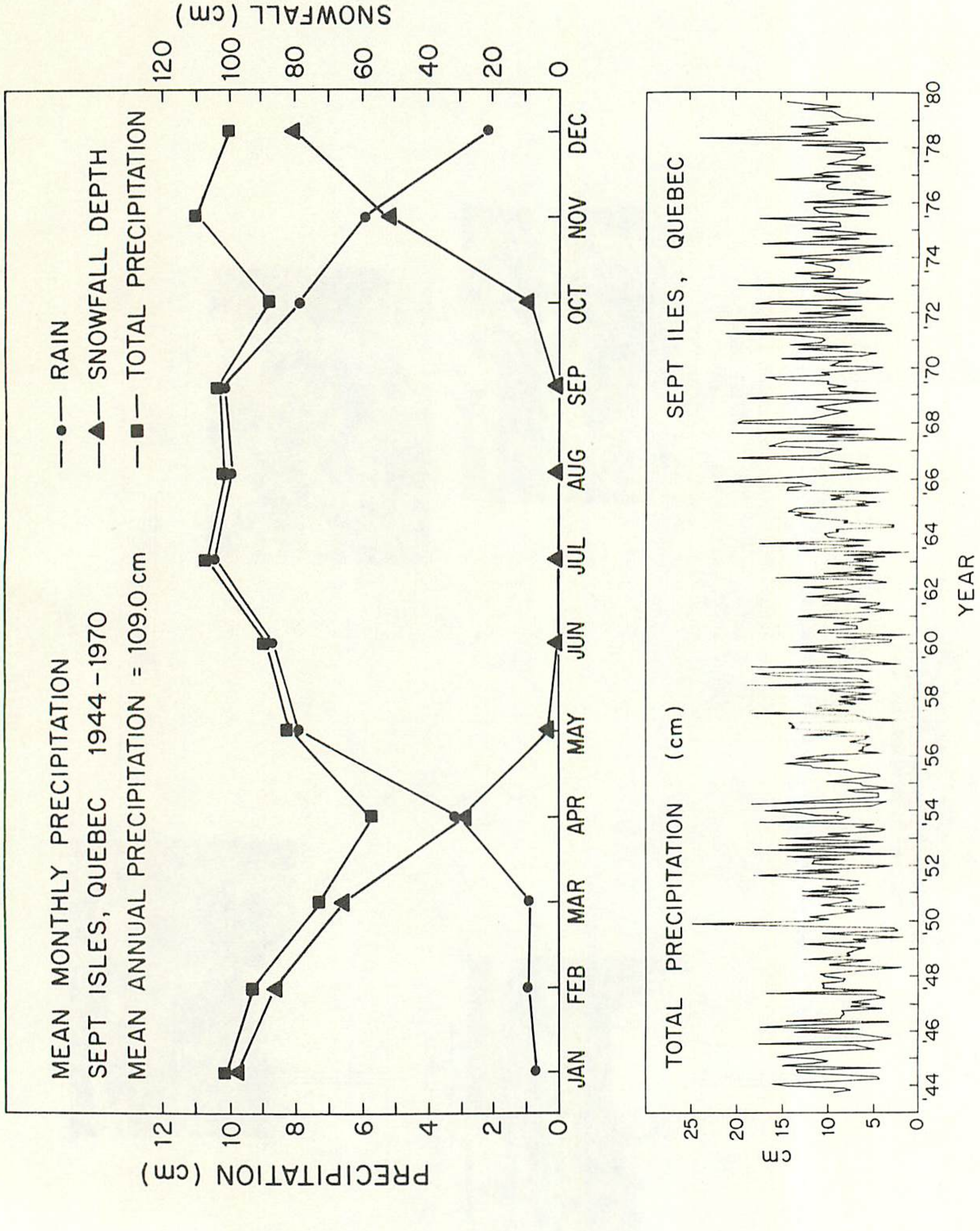

MEAN MONTHLY PRECIPITATION
SEPT ISLES, QUEBEC 1944 - 1970
MEAN ANNUAL PRECIPITATION = 109.0 cm
RAIN
SNOWFALL DEPTH
TOTAL PRECIPITATION
PRECIPITATION (cm)
0
2
4
6
8
10
12
SNOWFALL (cm)
0
20
40
60
80
100
120
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
TOTAL PRECIPITATION (cm)
SEPT ILES, QUEBEC
cm
0
5
10
15
20
25
'44
'46
'48
'50
'52
'54
'56
'58
'60
'62
'64
'66
'68
'70
'72
'74
'76
'78
'80
YEAR

FIGURE 2

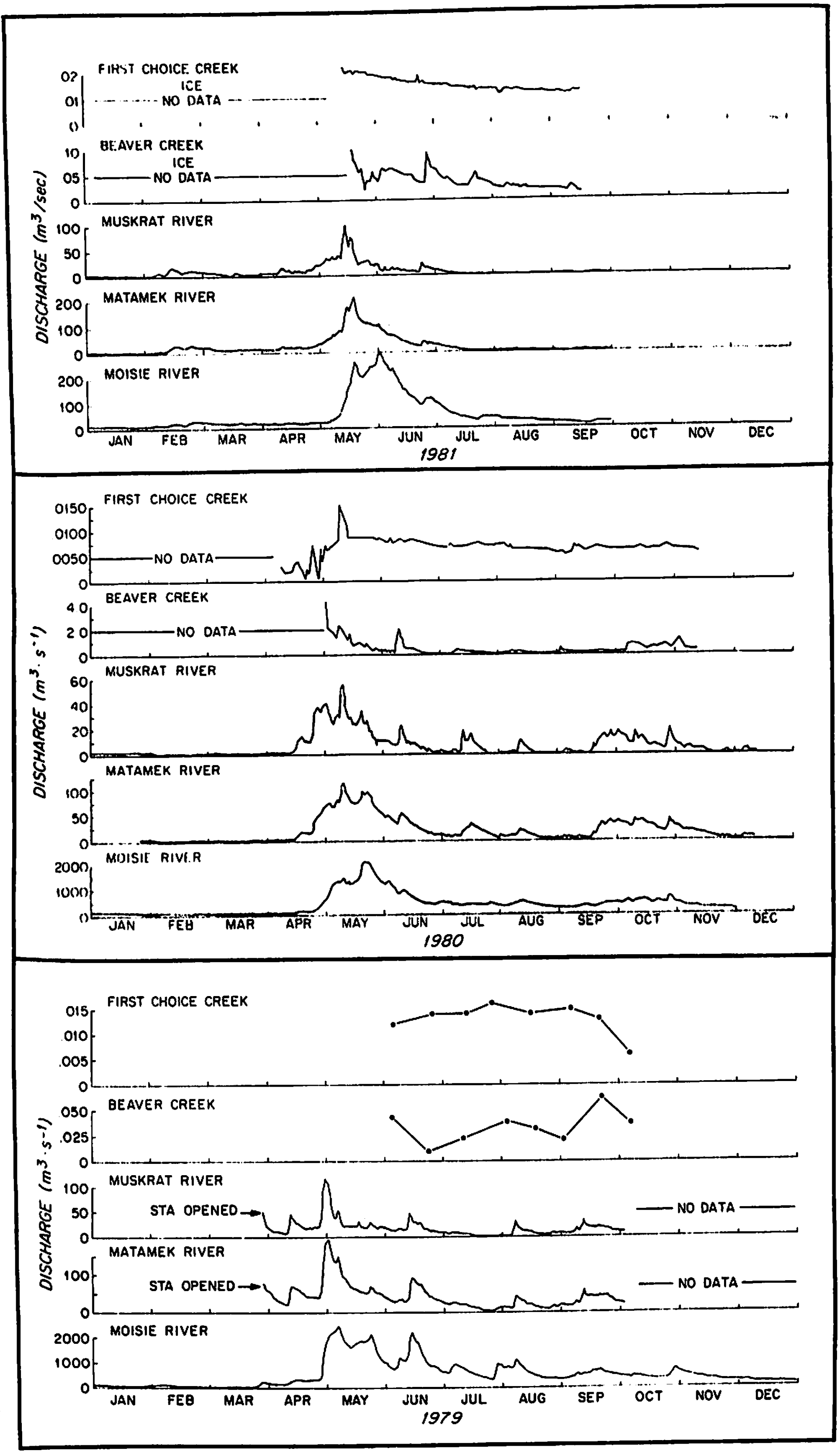

FIRST CHOICE CREEK
ICE
NO DATA
BEAVER CREEK
ICE
NO DATA
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
DISCHARGE (m^3/sec)
02
01
0
10
05
100
50
200
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981
FIRST CHOICE CREEK
0150
0100
0050
NO DATA
BEAVER CREEK
4 0
2 0
NO DATA
MUSKRAT RIVER
60
40
20
MATAMEK RIVER
MOISIE RIVER
2000
1000
DISCHARGE ($m^3 \cdot s^{-1}$)
1980
FIRST CHOICE CREEK
.015
.010
.005
BEAVER CREEK
.050
.025
MUSKRAT RIVER
STA OPENED
NO DATA
MATAMEK RIVER
STA OPENED
NO DATA
MOISIE RIVER
DISCHARGE ($m^3 \cdot s^{-1}$)
1979

FIGURE 3

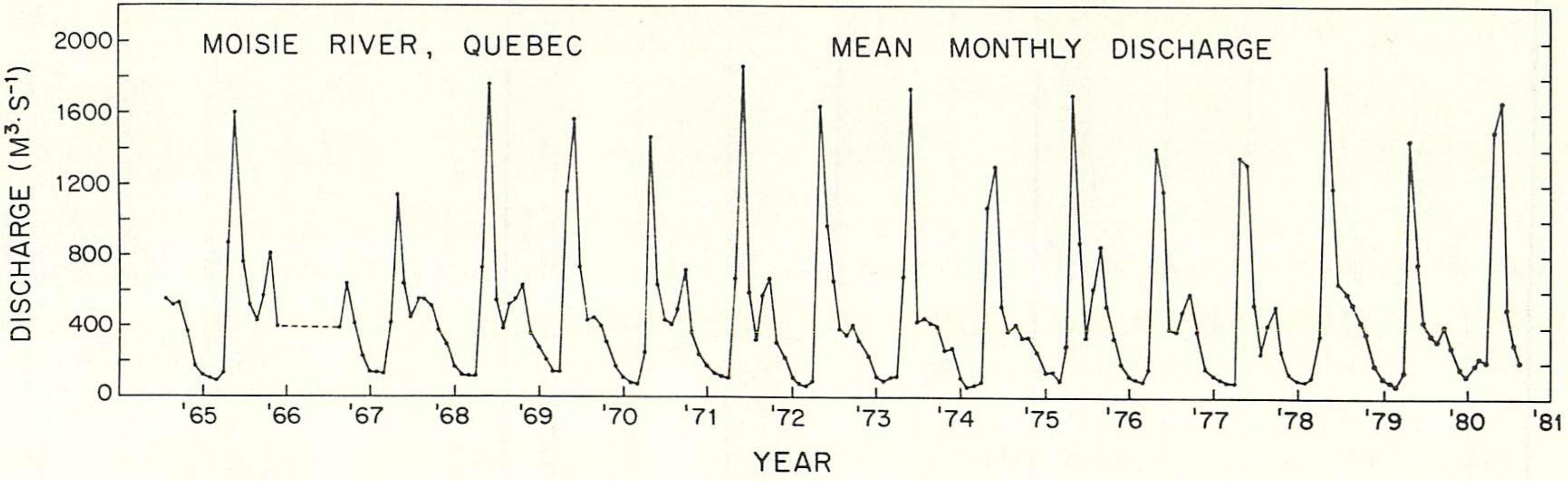

MOISIE RIVER, QUEBEC
MEAN MONTHLY DISCHARGE
DISCHARGE (M^3·S^{-1})
2000
1600
1200
800
400
0
'65
'66
'67
'68
'69
'70
'71
'72
'73
'74
'75
'76
'77
'78
'79
'80
'81
YEAR

FIGURE 4

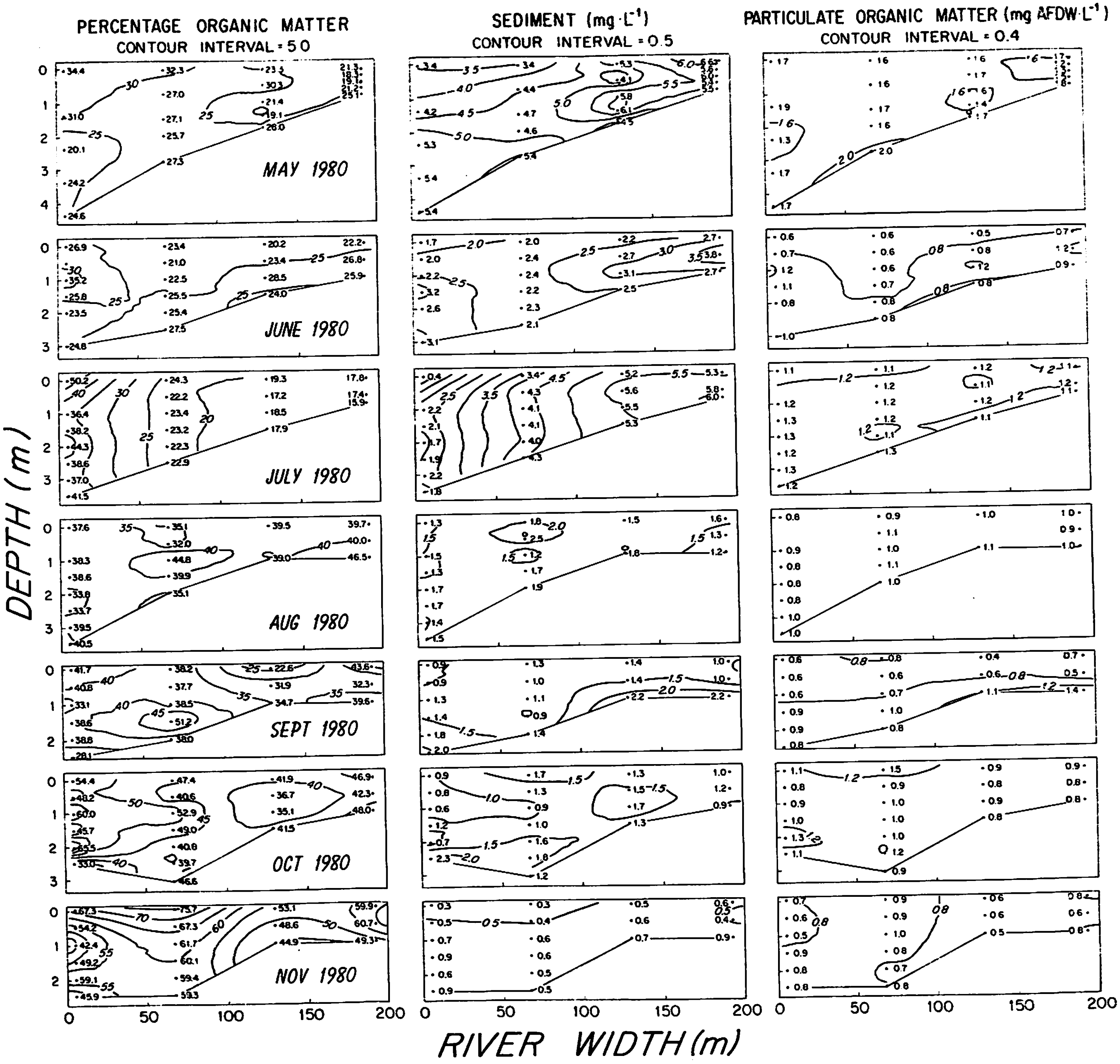
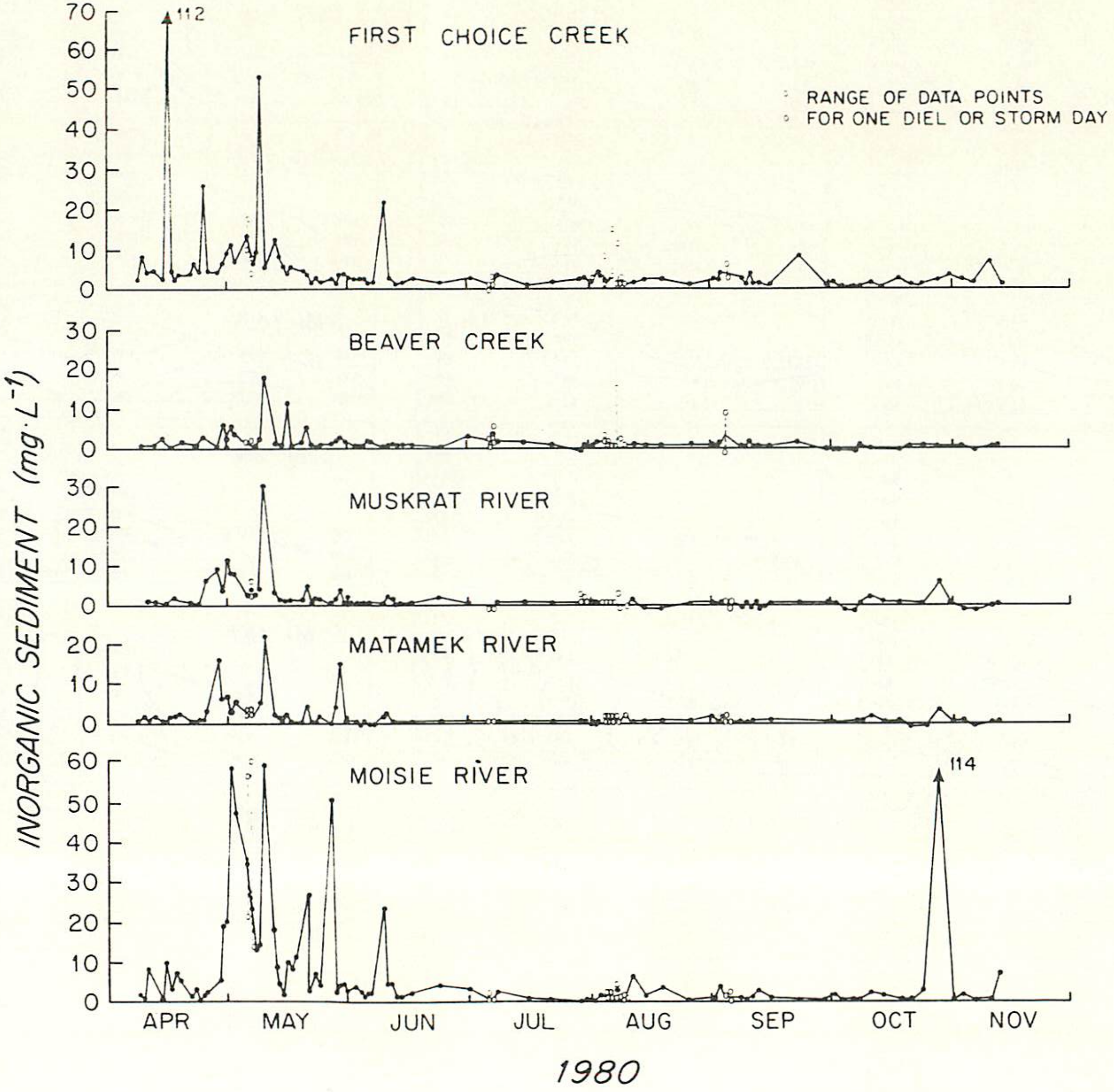

PERCENTAGE ORGANIC MATTER
CONTOUR INTERVAL = 5.0
SEDIMENT (mg·L⁻¹)
CONTOUR INTERVAL = 0.5
PARTICULATE ORGANIC MATTER (mg AFDW·L⁻¹)
CONTOUR INTERVAL = 0.4
MAY 1980
JUNE 1980
JULY 1980
AUG 1980
SEPT 1980
OCT 1980
NOV 1980
DEPTH (m)
RIVER WIDTH (m)
0
50
100
150
200

FIGURE 5


FIRST CHOICE CREEK
BEAVER CREEK
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
RANGE OF DATA POINTS
FOR ONE DIEL OR STORM DAY
112
114
INORGANIC SEDIMENT (mg·L⁻¹)
70
60
50
40
30
20
10
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
1980

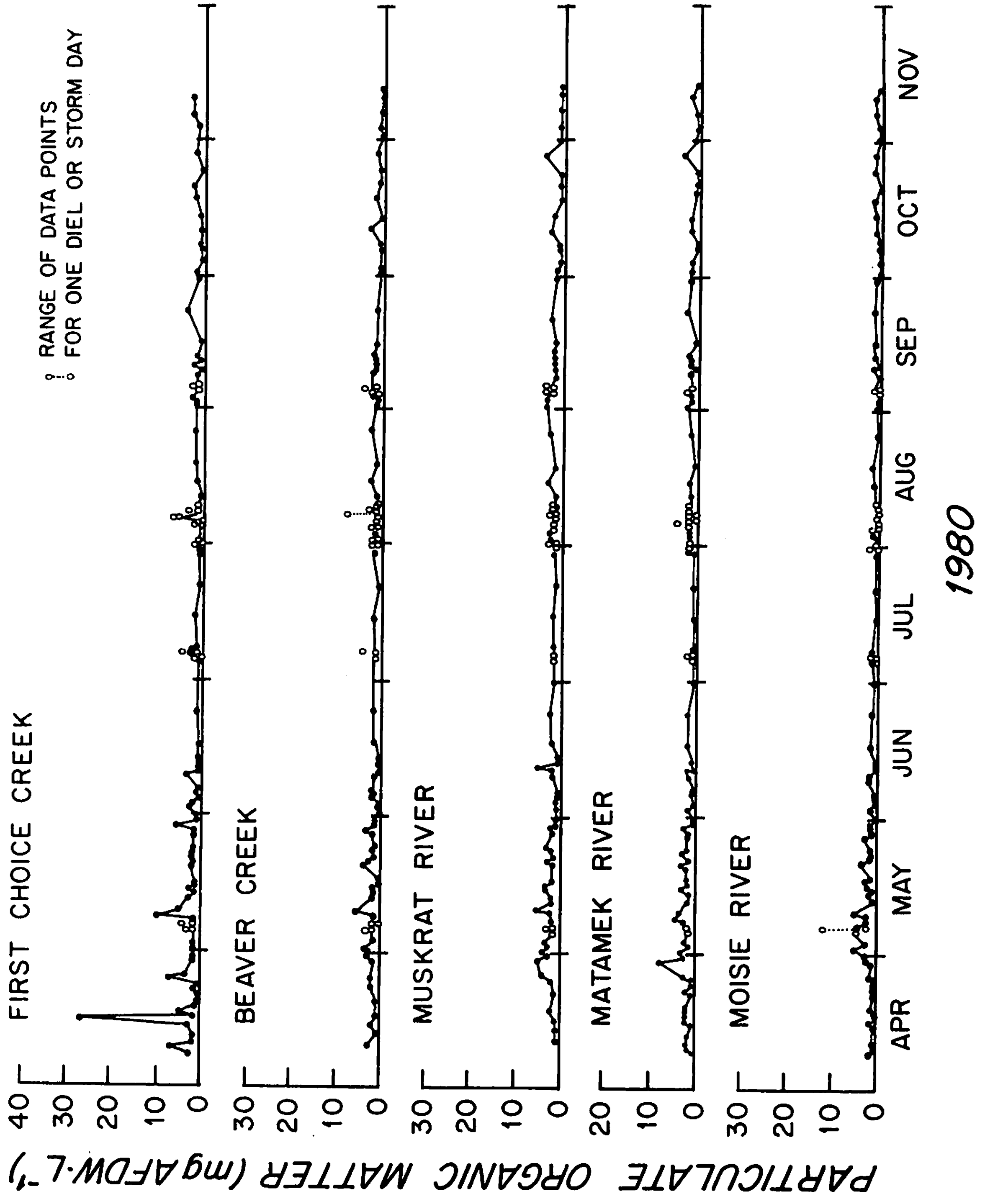

FIRST CHOICE CREEK
BEAVER CREEK
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
RANGE OF DATA POINTS
FOR ONE DIEL OR STORM DAY
PARTICULATE ORGANIC MATTER (mg AFDW·L⁻¹)
40
30
20
10
0
30
20
10
0
30
20
10
0
20
10
0
30
20
10
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
1980

FIGURE 7

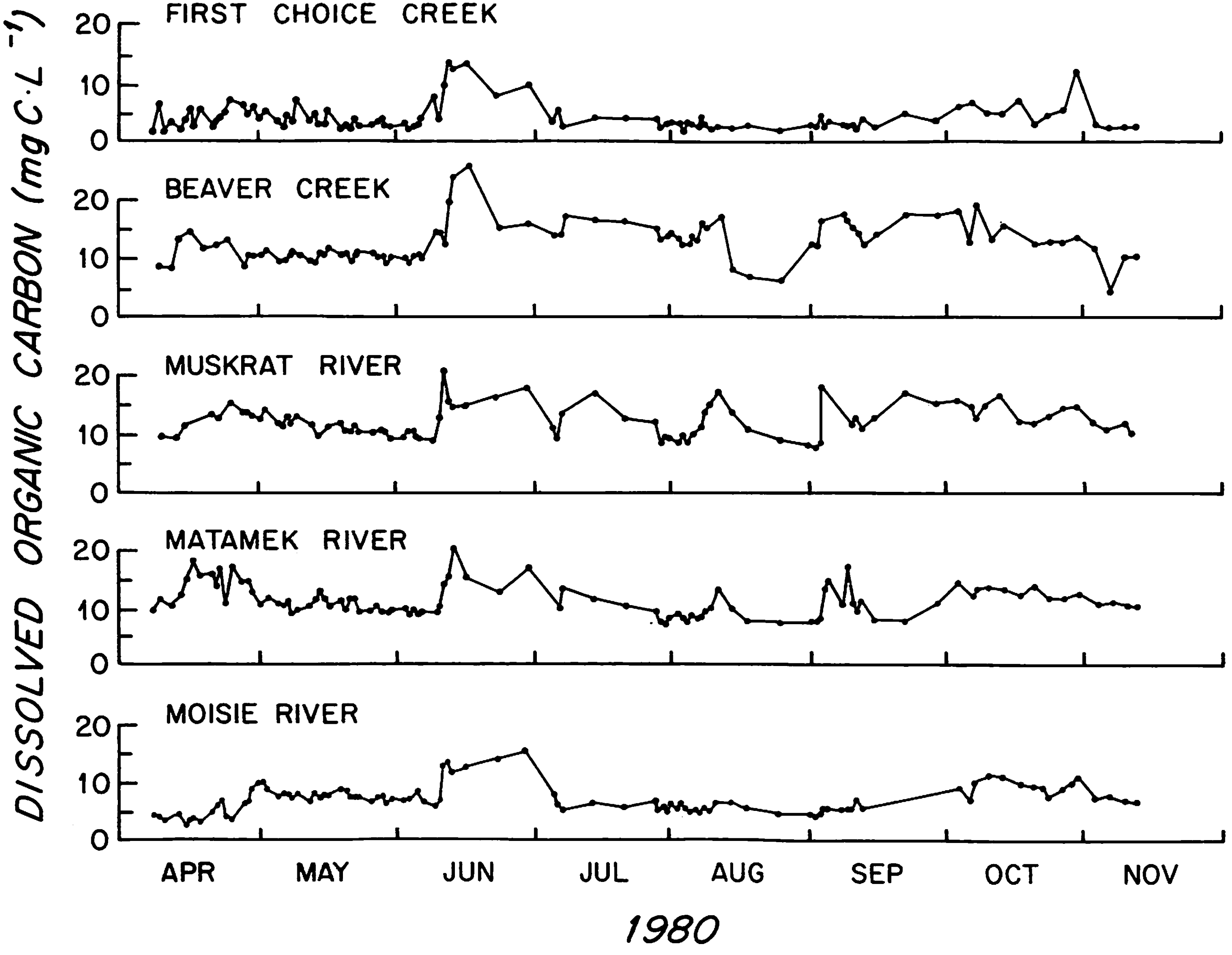

DISSOLVED ORGANIC CARBON (mg C·L⁻¹)
FIRST CHOICE CREEK
BEAVER CREEK
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
20
10
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
1980

FIGURE 8

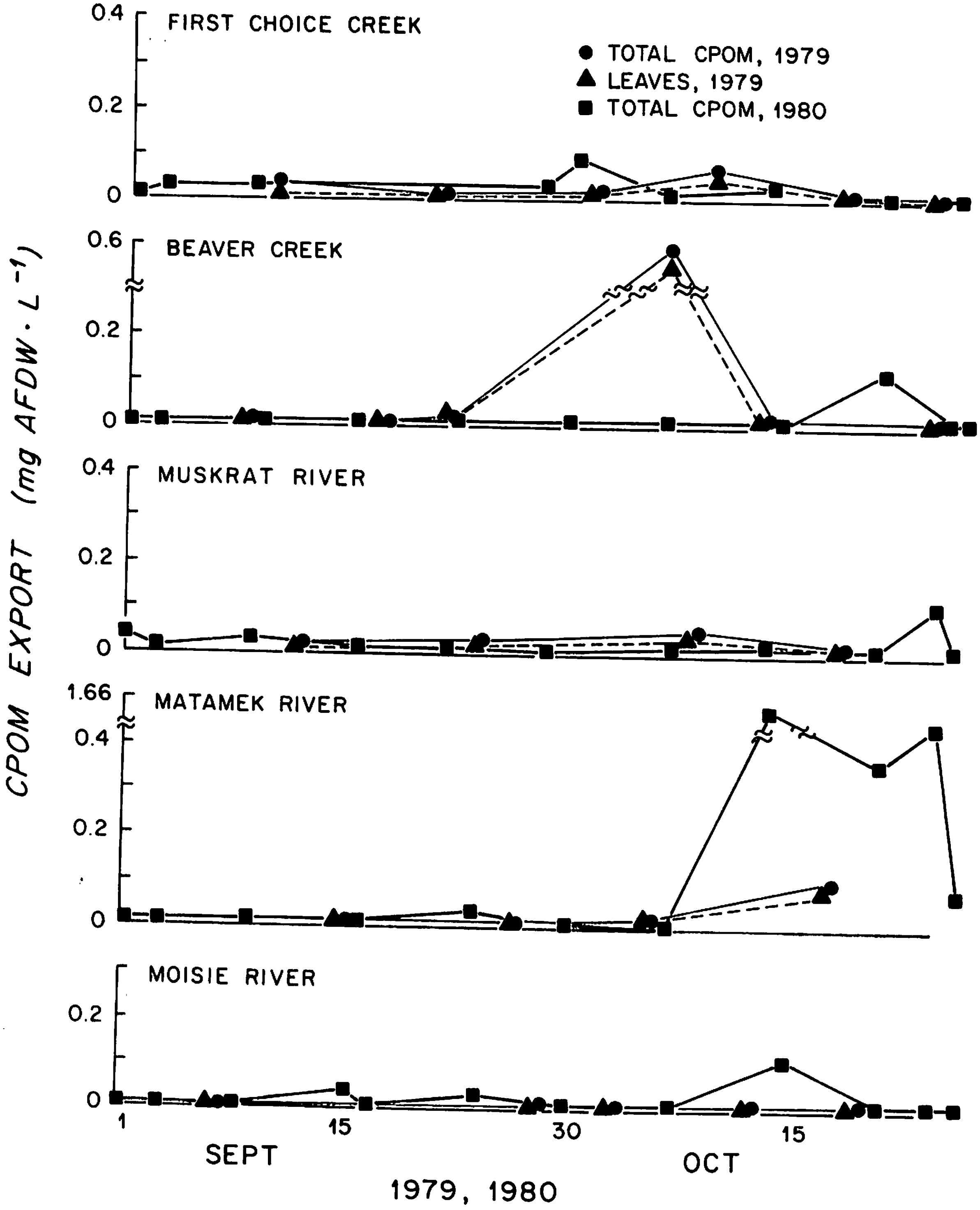

FIRST CHOICE CREEK
● TOTAL CPOM, 1979
▲ LEAVES, 1979
■ TOTAL CPOM, 1980
0.4
0.2
0
BEAVER CREEK
0.6
0.2
0
MUSKRAT RIVER
0.4
0.2
0
MATAMEK RIVER
1.66
0.4
0.2
0
MOISIE RIVER
0.2
0
CPOM EXPORT (mg AFDW · L⁻¹)
1
15
30
15
SEPT
OCT
1979, 1980

FIGURE 9

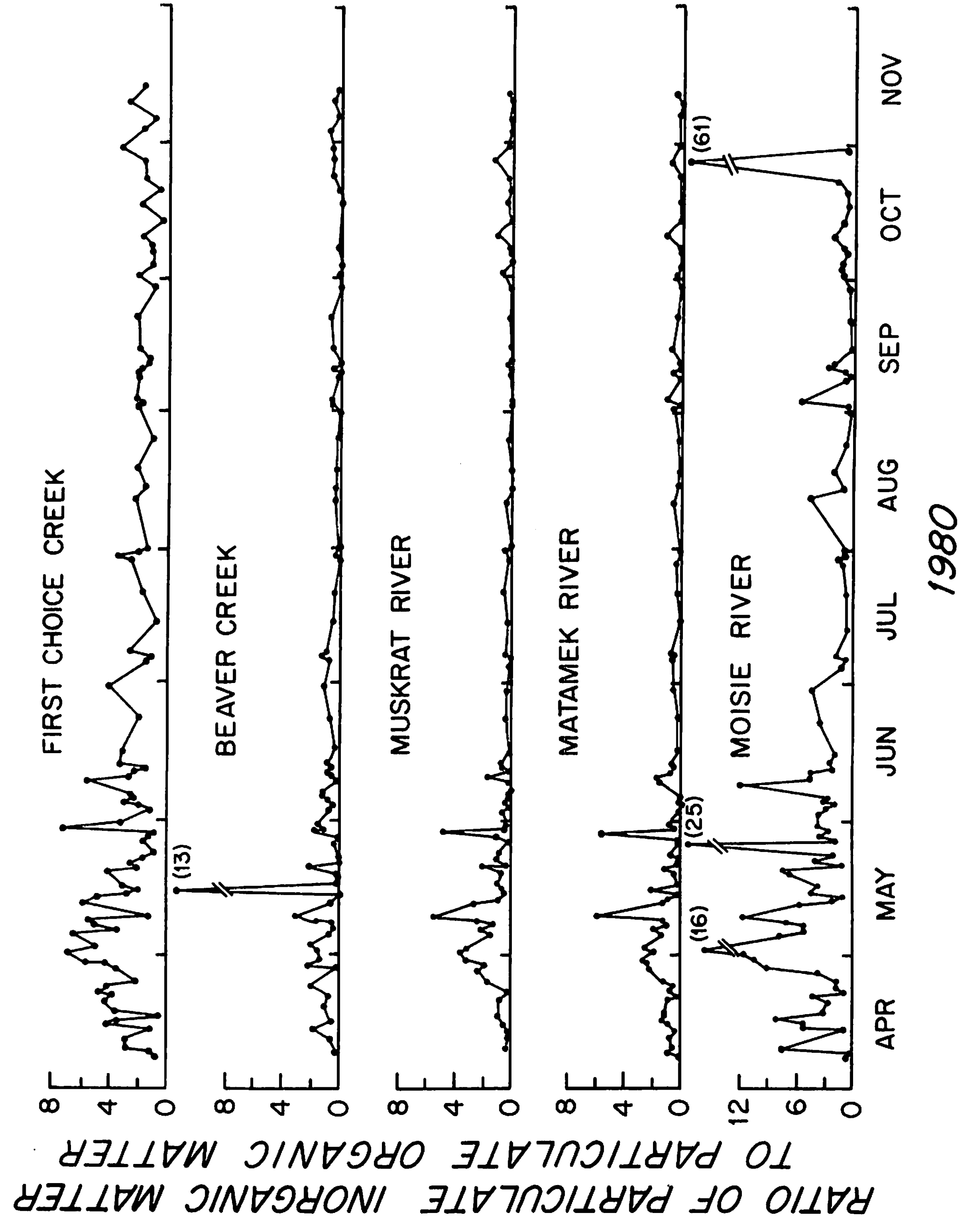

FIRST CHOICE CREEK
BEAVER CREEK
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
(13)
(16)
(25)
(61)
8
4
0
8
4
0
8
4
0
8
4
0
12
6
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
1980
RATIO OF PARTICULATE INORGANIC MATTER
TO PARTICULATE ORGANIC MATTER

FIGURE 10

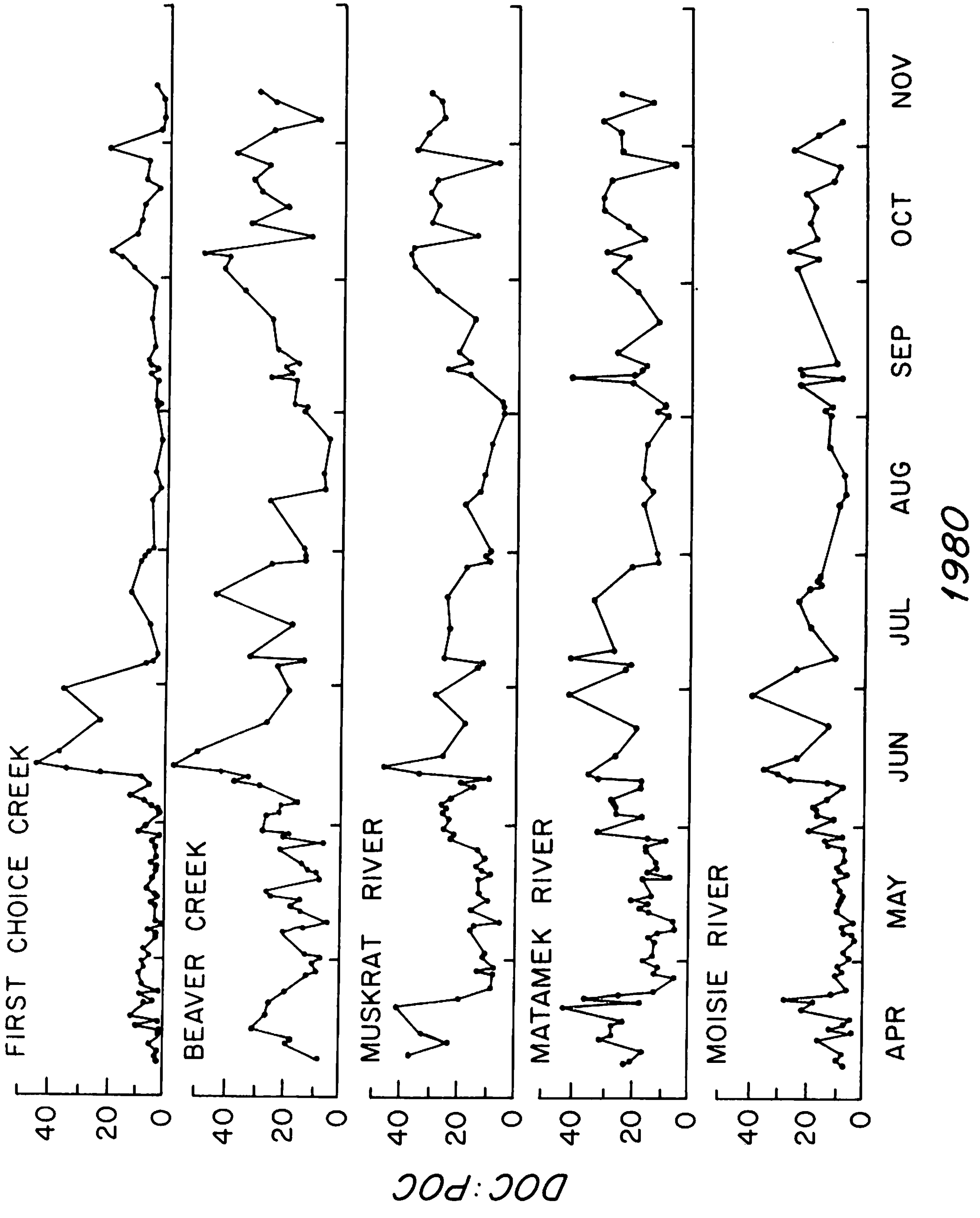
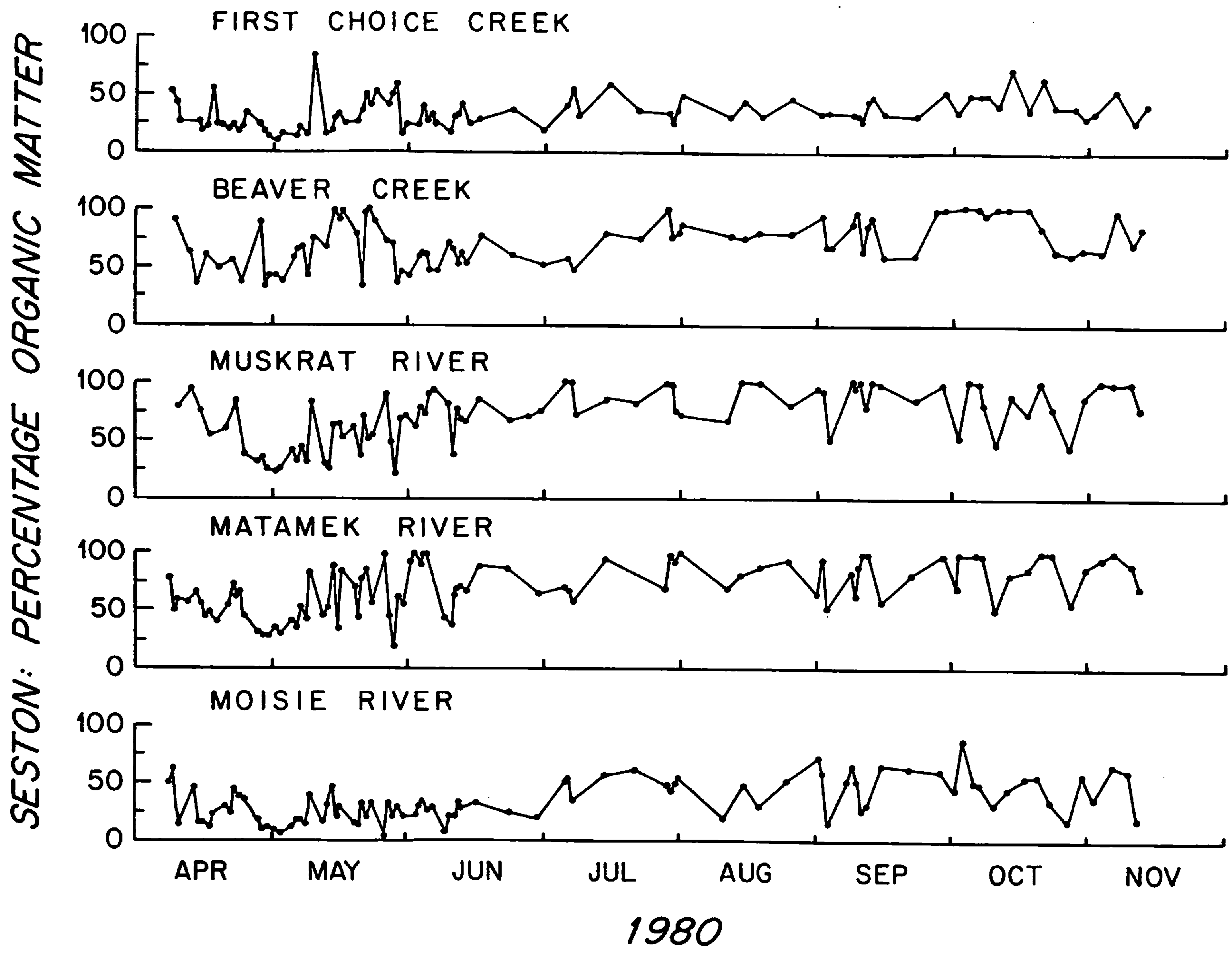

FIRST CHOICE CREEK
BEAVER CREEK
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
40
20
0
DOC:POC
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
1980

FIGURE 11



SESTON: PERCENTAGE ORGANIC MATTER
FIRST CHOICE CREEK
BEAVER CREEK
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
100
50
0
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
1980

FIGURE 12

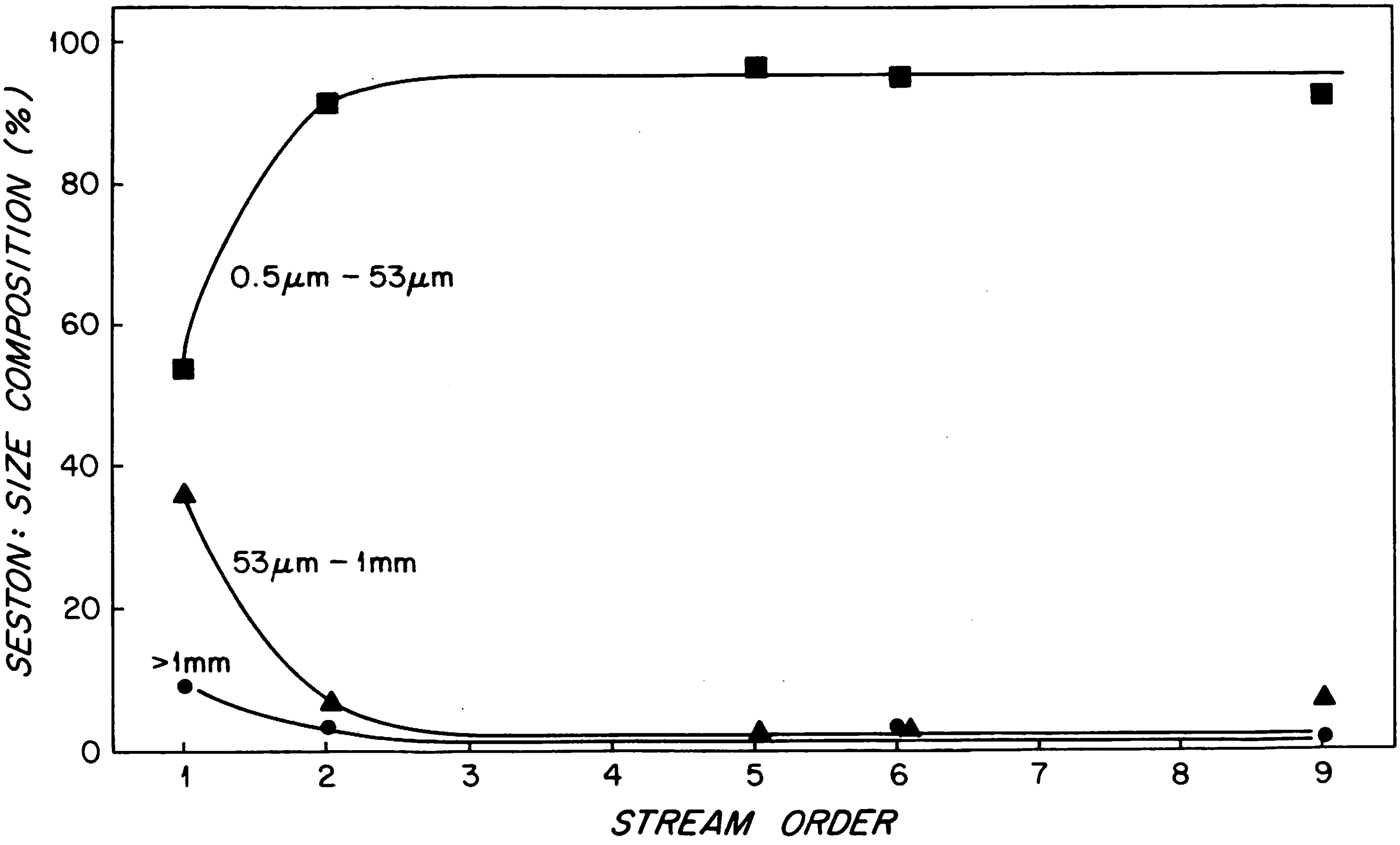

SESTON: SIZE COMPOSITION (%)
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
STREAM ORDER
0.5μm – 53μm
53μm – 1mm
>1mm

FIGURE 13

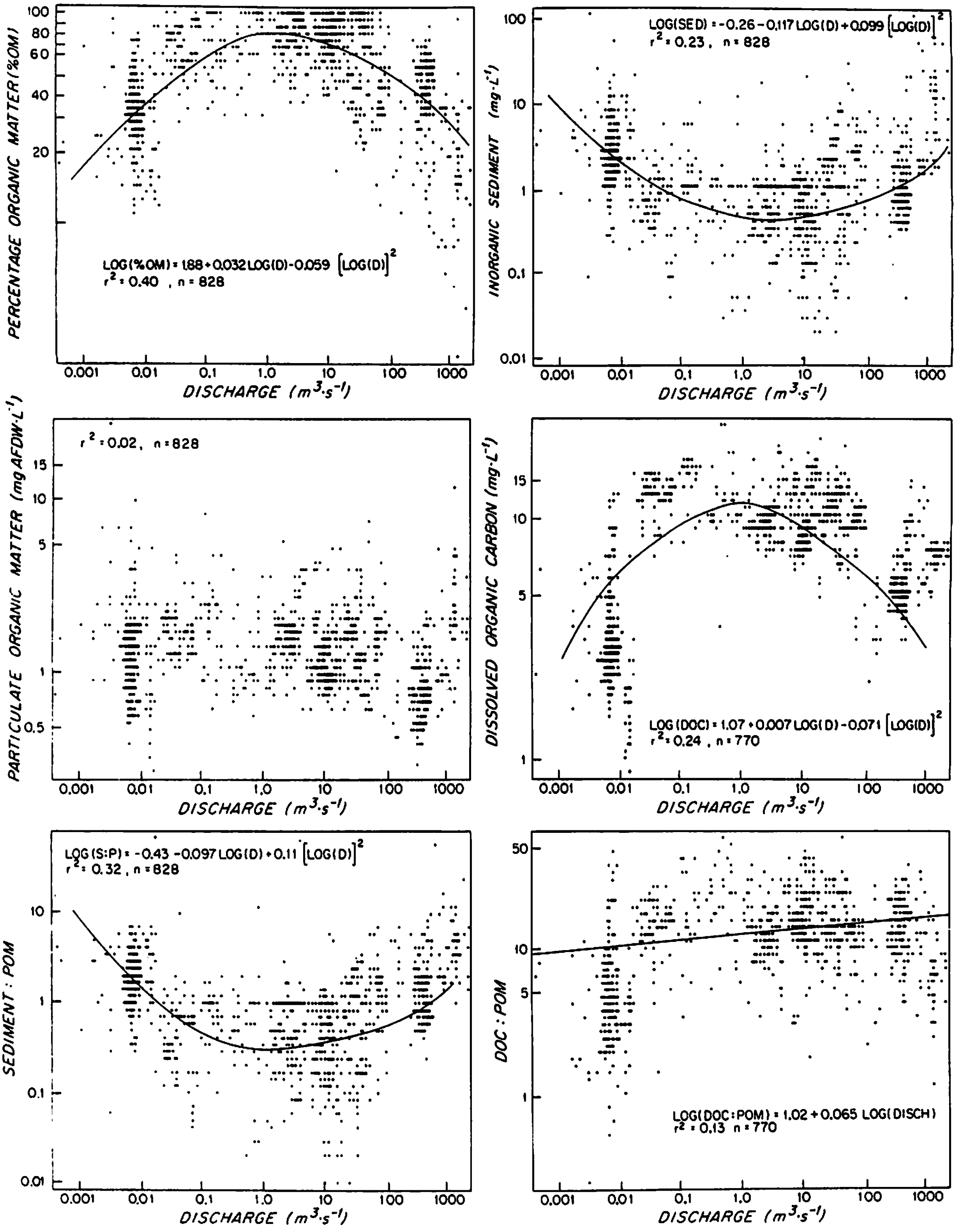

PERCENTAGE ORGANIC MATTER (%OM)
100
80
60
40
20
LOG(%OM) = 1.88 + 0.032 LOG(D) - 0.059 [LOG(D)]²
r² = 0.40 , n = 828
INORGANIC SEDIMENT (mg·L⁻¹)
LOG(SED) = -0.26 - 0.117 LOG(D) + 0.099 [LOG(D)]²
r² = 0.23 , n = 828
100
10
1
0.1
0.01
PARTICULATE ORGANIC MATTER (mg AFDW·L⁻¹)
r² = 0.02 , n = 828
15
10
5
1
0.5
DISSOLVED ORGANIC CARBON (mg·L⁻¹)
LOG(DOC) = 1.07 + 0.007 LOG(D) - 0.071 [LOG(D)]²
r² = 0.24 , n = 770
15
10
5
1
SEDIMENT : POM
LOG(S:P) = -0.43 - 0.097 LOG(D) + 0.11 [LOG(D)]²
r² = 0.32 , n = 828
10
1
0.1
0.01
DOC : POM
LOG(DOC:POM) = 1.02 + 0.065 LOG(DISCH)
r² = 0.13 n = 770
50
10
5
1
0.001
0.01
0.1
1.0
10
100
1000
DISCHARGE (m³·s⁻¹)

FIGURE 14

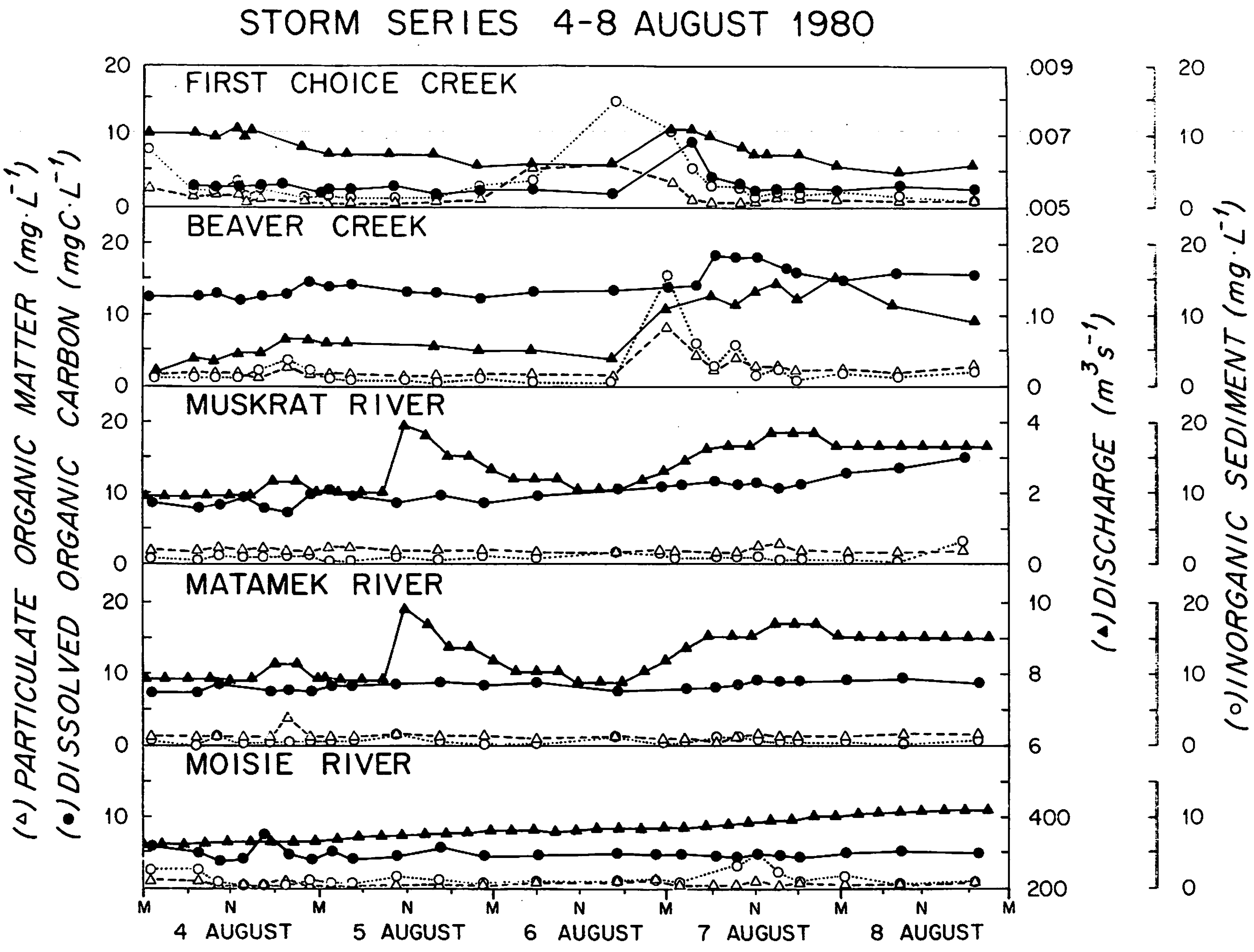

STORM SERIES 4-8 AUGUST 1980
FIRST CHOICE CREEK
BEAVER CREEK
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
(△) PARTICULATE ORGANIC MATTER (mg·L-1)
(●) DISSOLVED ORGANIC CARBON (mgC·L-1)
(▲) DISCHARGE (m3s-1)
(○) INORGANIC SEDIMENT (mg·L-1)
20
10
0
.009
.007
.005
.20
.10
4
2
8
6
400
200
M
N
4 AUGUST
5 AUGUST
6 AUGUST
7 AUGUST
8 AUGUST

FIGURE 15

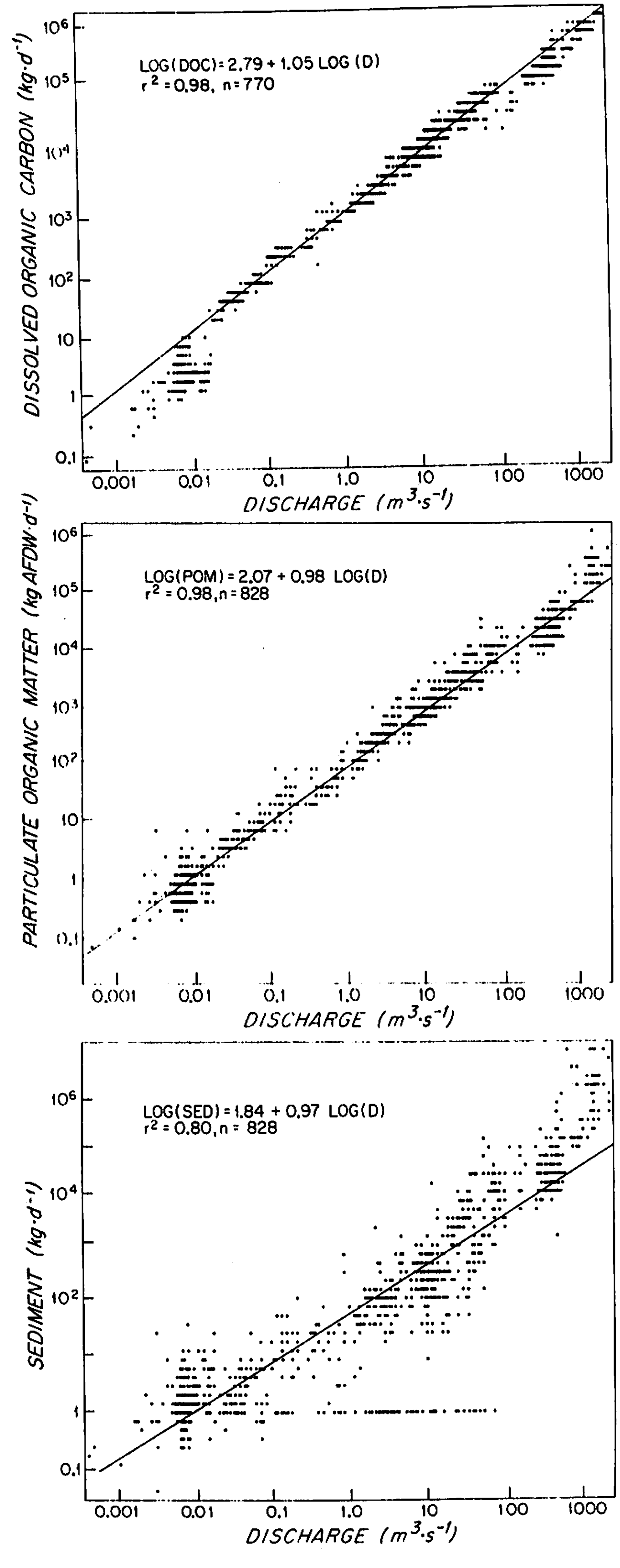

LOG(DOC)=2.79+1.05 LOG(D)
r² = 0.98, n=770
DISSOLVED ORGANIC CARBON (kg·d⁻¹)
10⁶
10⁵
10⁴
10³
10²
10
1
0.1
0.001
0.01
0.1
1.0
10
100
1000
DISCHARGE (m³·s⁻¹)
LOG(POM)=2.07+0.98 LOG(D)
r² = 0.98, n=828
PARTICULATE ORGANIC MATTER (kg AFDW·d⁻¹)
10⁶
10⁵
10⁴
10³
10²
10
1
0.1
0.001
0.01
0.1
1.0
10
100
1000
DISCHARGE (m³·s⁻¹)
LOG(SED)=1.84+0.97 LOG(D)
r² = 0.80, n= 828
SEDIMENT (kg·d⁻¹)
10⁶
10⁴
10²
1
0.1
0.001
0.01
0.1
1.0
10
100
1000
DISCHARGE (m³·s⁻¹)

FIGURE 16

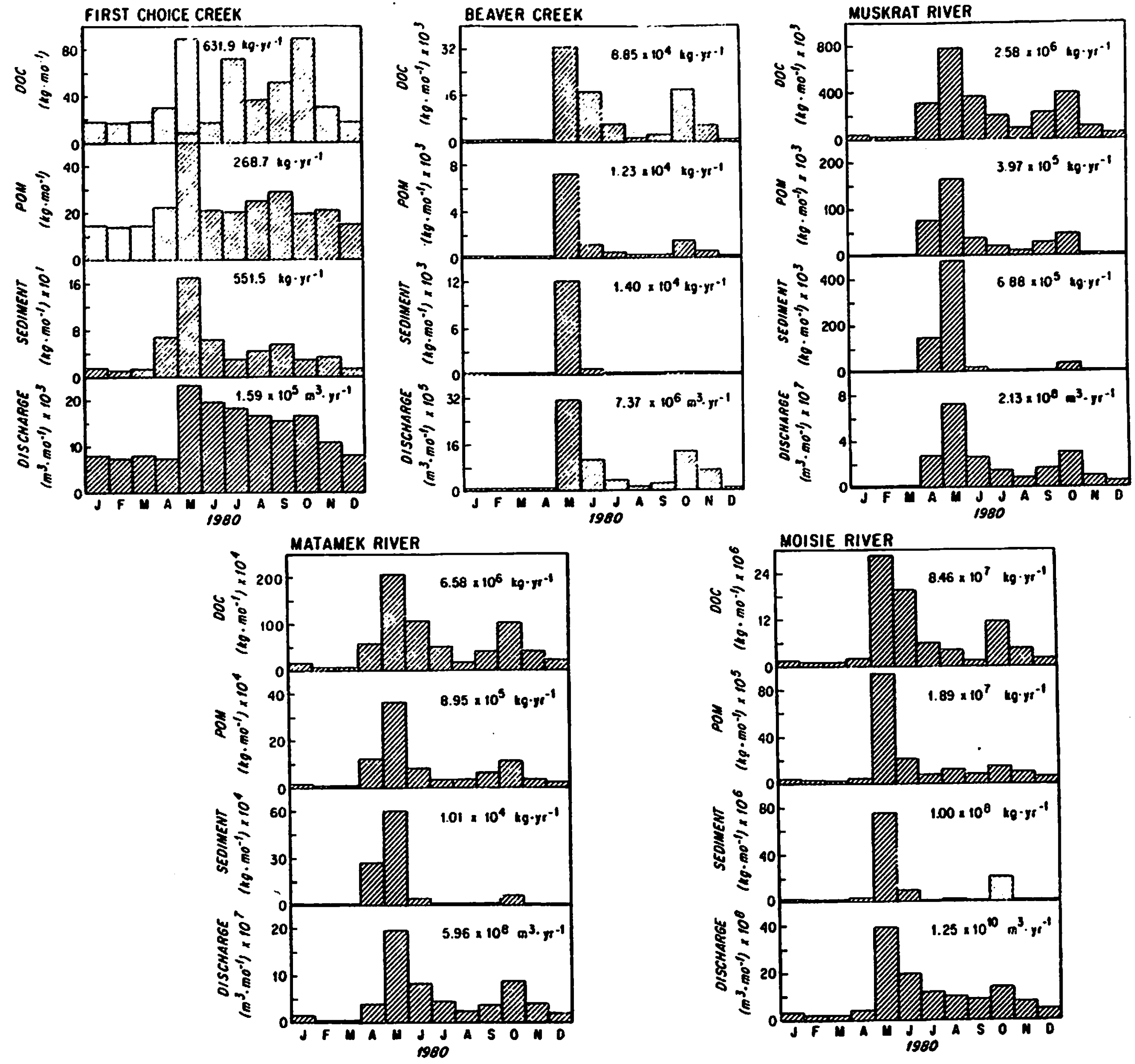

FIRST CHOICE CREEK
DOC (kg·mo⁻¹)
631.9 kg·yr⁻¹
POM (kg·mo⁻¹)
268.7 kg·yr⁻¹
SEDIMENT (kg·mo⁻¹) x 10¹
551.5 kg·yr⁻¹
DISCHARGE (m³·mo⁻¹) x 10³
1.59 x 10⁵ m³·yr⁻¹
BEAVER CREEK
DOC (kg·mo⁻¹) x 10³
8.85 x 10⁴ kg·yr⁻¹
POM (kg·mo⁻¹) x 10³
1.23 x 10⁴ kg·yr⁻¹
SEDIMENT (kg·mo⁻¹) x 10³
1.40 x 10⁴ kg·yr⁻¹
DISCHARGE (m³·mo⁻¹) x 10⁵
7.37 x 10⁶ m³·yr⁻¹
MUSKRAT RIVER
DOC (kg·mo⁻¹) x 10³
2.58 x 10⁶ kg·yr⁻¹
POM (kg·mo⁻¹) x 10³
3.97 x 10⁵ kg·yr⁻¹
SEDIMENT (kg·mo⁻¹) x 10³
6.88 x 10⁵ kg·yr⁻¹
DISCHARGE (m³·mo⁻¹) x 10⁷
2.13 x 10⁸ m³·yr⁻¹
MATAMEK RIVER
DOC (kg·mo⁻¹) x 10⁴
6.58 x 10⁶ kg·yr⁻¹
POM (kg·mo⁻¹) x 10⁴
8.95 x 10⁵ kg·yr⁻¹
SEDIMENT (kg·mo⁻¹) x 10⁴
1.01 x 10⁴ kg·yr⁻¹
DISCHARGE (m³·mo⁻¹) x 10⁷
5.96 x 10⁸ m³·yr⁻¹
MOISIE RIVER
DOC (kg·mo⁻¹) x 10⁶
8.46 x 10⁷ kg·yr⁻¹
POM (kg·mo⁻¹) x 10⁵
1.89 x 10⁷ kg·yr⁻¹
SEDIMENT (kg·mo⁻¹) x 10⁶
1.00 x 10⁸ kg·yr⁻¹
DISCHARGE (m³·mo⁻¹) x 10⁸
1.25 x 10¹⁰ m³·yr⁻¹
J F M A M J J A S O N D
1980

FIGURE 17

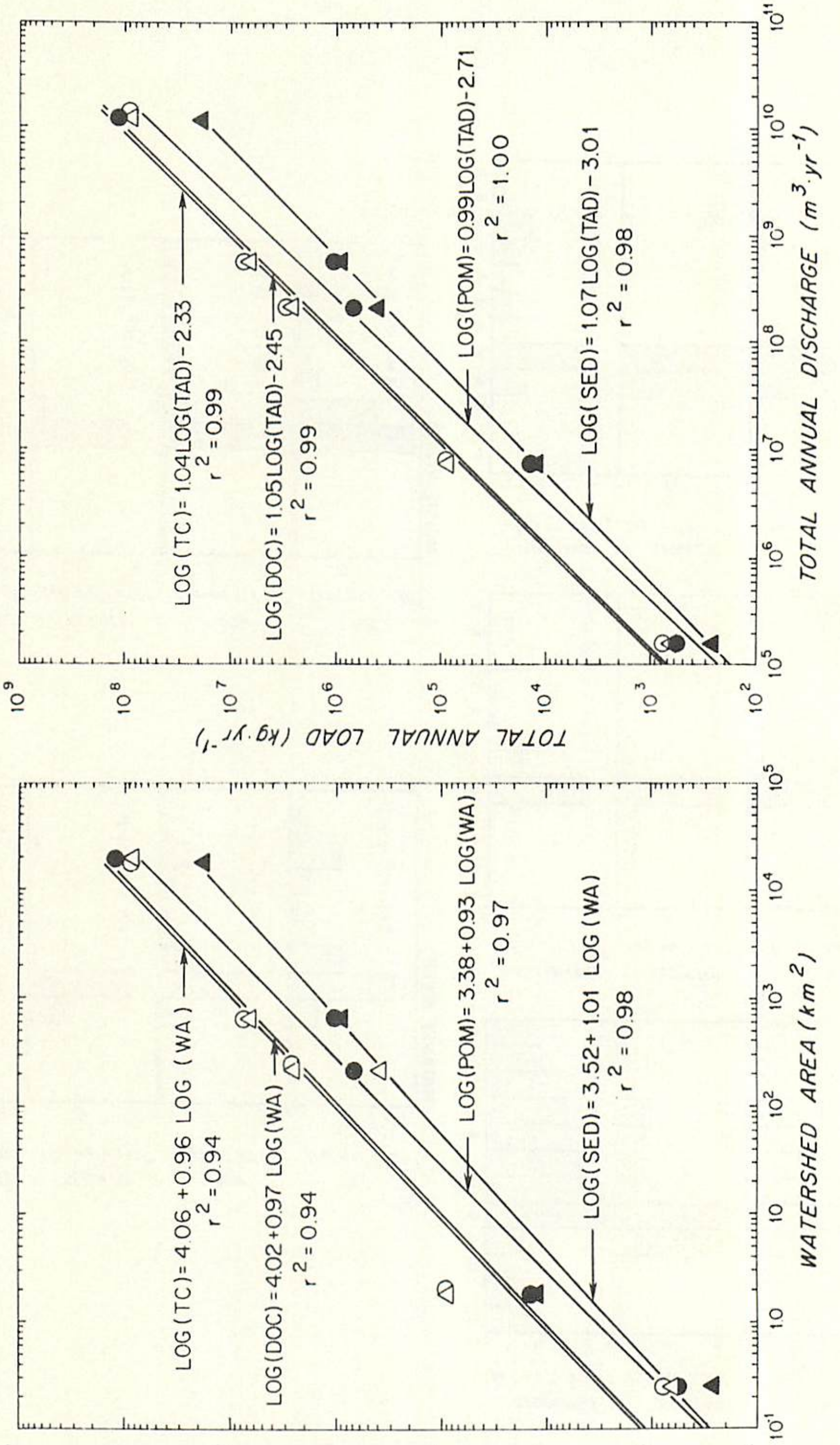

TOTAL ANNUAL LOAD (kg·yr-1)
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
WATERSHED AREA (km²)
10^-1
10
10
10²
10³
10^4
10^5
LOG (TC) = 4.06 + 0.96 LOG (WA)
r² = 0.94
LOG (DOC) = 4.02 + 0.97 LOG (WA)
r² = 0.94
LOG (POM) = 3.38 + 0.93 LOG (WA)
r² = 0.97
LOG (SED) = 3.52 + 1.01 LOG (WA)
r² = 0.98
TOTAL ANNUAL DISCHARGE (m³·yr-1)
10^5
10^6
10^7
10^8
10^9
10^10
10^11
LOG (TC) = 1.04 LOG (TAD) - 2.33
r² = 0.99
LOG (DOC) = 1.05 LOG (TAD) - 2.45
r² = 0.99
LOG (POM) = 0.99 LOG (TAD) - 2.71
r² = 1.00
LOG (SED) = 1.07 LOG (TAD) - 3.01
r² = 0.98

FIGURE 18

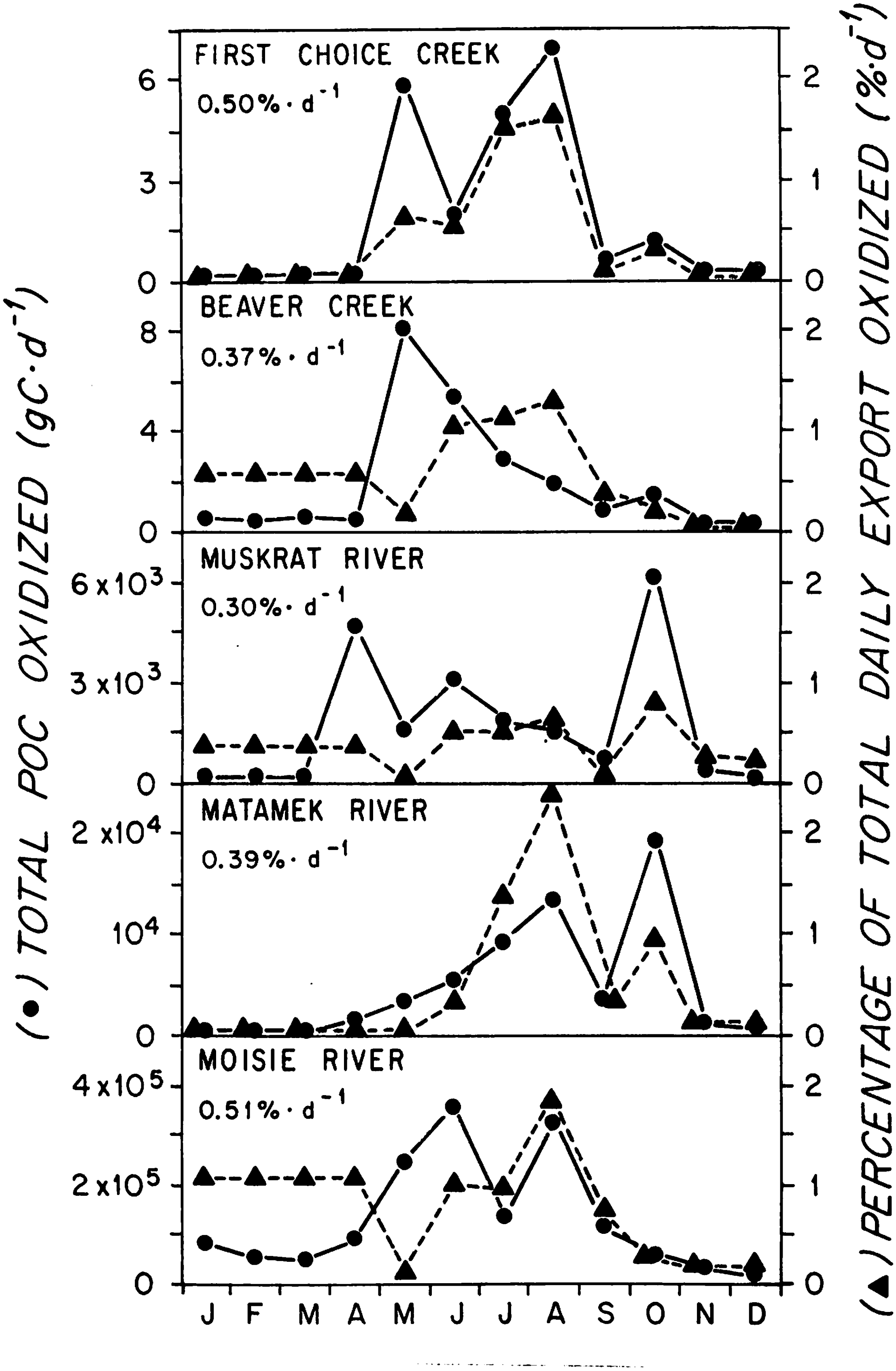

FIRST CHOICE CREEK
0.50%·d⁻¹
BEAVER CREEK
0.37%·d⁻¹
MUSKRAT RIVER
0.30%·d⁻¹
MATAMEK RIVER
0.39%·d⁻¹
MOISIE RIVER
0.51%·d⁻¹
(●) TOTAL POC OXIDIZED (gC·d⁻¹)
(▲) PERCENTAGE OF TOTAL DAILY EXPORT OXIDIZED (%·d⁻¹)
0
3
6
0
4
8
0
3 x10³
6 x10³
0
10⁴
2 x10⁴
0
2 x10⁵
4 x10⁵
0
1
2
J
F
M
A
M
J
J
A
S
O
N
D

FIGURE 19

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

Parameter	First Choice Creek	Beaver Creek	Muskrat River	Matamek River	Moisie River
Stream Order	1	2	5	6	9
Watershed Area (km^2)	0.25	1.83	207	673	19,871
Mean Width (m)	0.3	2.0	21.9	51.7	208.7
Mean Depth (m)	0.05	0.3	2.0	1.8	2.5
Mean Annual Discharge ($m^3 \cdot s^{-1}$)	0.013	0.033	8.4	13.7	466.1
Gradient (%; lower reaches)	1.5	1.0	0.14	1.33	0.16
Substrate	Detritus	Sediment/ cobble	Sediment/ cobble	Gravel/ cobble	Sand/cobble
Temperature range (°C)	0.4–11.0	0.0–19.0	0.0–19.5	0.1–19.8	0.1–21.8
Annual Degree Days(°C yr^{-1})	1702	2069	2157	2225	2219
Nutrient Range ($\mu g \cdot L^{-1}$)					
NO_3–N	17–199	5–135	3–91	1–76	25–87
Total N	49–234	211–623	170–382	148–341	134–392
PO_4–P	2–8	1–7	1–5	1–17	1–11
Total P	7–29	6–26	6–22	5–16	4–22

Table 1 (continued)

Alkalinity Range (meq $\cdot L^{-1}$)	0.097–0.253	0.039–0.368	0–0.085	0–0.076	0.044–0.338
pH range	6.2–7.2	6.0–7.0	4.9–6.1	4.8–6.0	6.3–7.1
Mean Dissolved Organic Carbon (mg $C \cdot L^{-1}$)	4.1	12.9	12.3	11.3	6.8
Forest Canopy Development	Closed	Mostly closed	Mostly open	Open	Open
Benthic Organic Matter (gAFDW $\cdot m^{-2}$)	712	526	516	252	481

Table 2. The mean concentration and coefficient of variation of diel sample series are given by date for sediment, POM, and DOC concentrations at each site.

Site/Date	Sediment (mg·l^{-1})		POM (mgAFDW·l^{-1})		DOC (mgC·l^{-1})	
	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)	$\bar{x}$	CV(%)
First Choice Creek						
5-6 May 80	8.83	48	2.05	38	3.02	9
5-6 Jul 80	1.38	52	1.38	87	5.23	58
29-31 Jul 80	1.67	31	0.99	23	2.98	33
4-5 Sep 80	3.12	47	1.53	30	3.02	26
Beaver Creek						
5-6 May 80	0.78	65	1.41	23	9.52	4
5-6 Jul 80	1.76	102	1.53	45	13.93	9
29-31 Jul 80	0.56	24	2.07	10	14.11	9
4-5 Sep 80	1.53	283	2.49	41	-	-
Muskrat River						
5-6 May 80	3.37	39	1.73	10	11.54	6
5-6 Jul 80	0.03	500	1.56	12	10.04	12
29-31 Jul 80	0.57	99	1.86	12	9.33	9
4-5 Sep 80	0.03	-	3.09	12	18.82	18
Matamek River						
5-6 May 80	2.81	14	1.63	13	10.27	4
5-6 Jul 80	0.48	56	0.97	12	10.11	13
29-31 Jul 80	0.36	157	1.46	14	7.88	4
4-5 Sep 80	0.81	70	1.97	11	14.38	12
Moisie River						
5-6 May 80	27.41	65	4.78	60	7.86	2
5-6 Jul 80	0.77	62	0.73	37	7.22	27
29-31 Jul 80	0.66	35	0.68	34	5.27	17
4-5 Sep 80	1.47	42	0.83	17	5.48	7

Table 3. Correlations between the concentrations or ratios of suspended material being carried by each stream and discharge or stream power.

Stream	Parameter	Sample Size (n)	DISCHARGE Coefficient of Determination (r^2)	DISCHARGE Significance (p)	STREAM POWER Coefficient of Determination (r^2)	STREAM POWER Significance (p)
First Choice Creek	%OM	172	0.03	0.05	0.03	0.05
	SED	172	0.01	NS	0.01	NS
	POM	172	0.07	0.01	0.07	0.01
	DOC	168	0.14	0.01	0.13	0.01
	S:P	172	0.11	0.01	0.11	0.01
	D:P	168	0.00	NS	0.00	NS
Beaver Creek	%OM	164	0.03	0.05	0.06	0.05
	SED	164	0.08	0.01	0.03	0.05
	POM	164	0.03	0.05	0.02	NS
	DOC	146	0.06	0.01	0.02	NS
	S:P	164	0.04	0.05	0.04	0.05
	D:P	146	0.04	0.05	0.04	0.05
Muskrat River	%OM	164	0.40	0.01	0.39	0.01
	SED	164	0.69	0.01	0.69	0.01
	POM	164	0.14	0.01	0.14	0.01
	DOC	144	0.10	0.01	0.10	0.01
	S:P	164	0.53	0.01	0.54	0.01
	D:P	144	0.05	0.05	0.05	0.05
Matamek River	%OM	172	0.14	0.01	0.14	0.01
	SED	172	0.15	0.01	0.15	0.01
	POM	172	0.09	0.01	0.09	0.01
	DOC	165	0.01	NS	0.01	NS
	S:P	172	0.12	0.01	0.13	0.01
	D:P	165	0.05	0.05	0.05	0.05

Table (Continued)

Moisie River	%OM	170	0.18	0.01	0.18	0.01
	SED	170	0.34	0.01	0.33	0.01
	POM	170	0.36	0.01	0.36	0.01
	DOC	161	0.32	0.01	0.32	0.01
	S:P	170	0.19	0.01	0.20	0.01
	D:P	161	0.14	0.01	0.07	0.01
All Streams	%OM	842	0.40	0.01	0.02	0.01
	SED	842	0.23	0.01	0.01	0.05
	POM	842	0.02	0.01	0.03	0.01
	DOC	784	0.29	0.01	0.03	0.01
	S:P	842	0.32	0.01	0.02	0.01
	D:P	784	0.12	0.01	0.05	0.01

Table 4. Percentage of the total annual export occurring during the spring freshet, 15 April to 14 June, 1980.

Stream	Discharge	Sediment	POM	DOC
First Choice Creek	24.0	60.6	31.2	26.9
Beaver Creek	55.0	90.3	65.4	51.4
Muskrat River	52.0	91.9	64.6	48.1
Matamek River	48.0	89.7	59.2	49.2
Moisie River	43.0	70.6	58.5	47.3

Table 5. Annual export of sediment and carbon per unit area for the five watersheds in 1980. POM is assumed to be 50% carbon.

Stream	Watershed Area (km^2)	Sediment ($g \cdot m^{-2} \cdot yr^{-1}$)	POM ($gAFDW \cdot m^{-2} \cdot yr^{-1}$)	DOC ($gC \cdot m^{-2} \cdot yr^{-1}$)	Total Carbon ($gC \cdot m^{-2} \cdot yr^{-1}$)
First Choice Creek	0.25	2.21	1.08	2.53	3.07
Beaver Creek	1.83	7.62	6.73	48.38	51.75
Muskrat River	207	3.32	1.92	12.44	13.40
Matamek River	673	1.50	1.33	9.78	10.45
Moisie River	19,871	5.99	0.95	4.26	4.74

Table 6. Total annual export from all streams of a particular order is compared to the amount of detritus available in the watershed annually. Total organic input is the sum of FPOM standing crop, areal litter and laterial inputs >1 mm diameter, and net annual primary production. Geomorphological data are based on the Moisie River watershed; FPOM standing crop and net annual primary production data are from Naiman (1982) and allochthonous input data are from Conners and Naiman (unpublished).

Stream	Stream Order	No. of Streams	Total Organic Input (kg AFDW·yr^{-1})	Total Annual POM Export (kg AFDW·yr^{-1})	POM Export/ Total Input
First Choice Creek	1	38,770	0.4×10^{7}	1.0×10^{7}	2.5
Beaver Creek	2	8,400	1.2×10^{7}	1.0×10^{8}	8.3
Muskrat River	5	95	4.6×10^{7}	2.7×10^{7}	0.6
Matamek River	6	19	5.1×10^{7}	1.7×10^{7}	0.3
Moisie River	9	1	6.6×10^{7}	1.9×10^{7}	0.3

WOOD DECOMPOSITION STUDIES

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Woods Hole Oceanographic Institution

J.D. Aber
University of Wisconsin

J. Hobbie
Ecosystems Center, Marine Biological Laboratory

and M. Francis
Woods Hole Oceanographic Institution

During the past year we have continued to work on the wood decomposition study described in the Matamek Annual Reports for 1979 and 1980. In this study we have been following the decomposition of wood chips of speckled alder, paper birch, trembling aspen, black spruce and balsam fir in four streams and at a terrestrial site. A litter bag technique is being used in this study. We now have data taken over a 27 month period on weight loss patterns, and changes in the concentrations of nitrogen, lignin and cellulose for the five materials at four of the five sites. We only have data through 16 months for material in the Moisie River.

We have analysed the 0-16 month data on weight loss and nitrogen dynamics for the materials in the streams and have submitted a paper for publication on this aspect of the study. We are currently analysing the remainder of the weight loss and nitrogen data and we are working with the cellulose and lignin data. Patterns of organic matter, cellulose, lignin and nitrogen dynamics through time appear in the attached Figures (1-11).

In June 1981 we initiated two new studies of wood decomposition, one in the field and one in laboratory microcosms. The field study is designed to test two hypotheses:

H1: Fine woody litter will decompose more rapidly in beaver ponds than in low order, free-flowing streams.

H2: Substrate quality as defined by lignin:nitrogen ratio will be inversely related to decomposition rate regardless of site.

Preliminary data on weight loss and cellulose and lignin dynamics appear in Figures 12-15.

The laboratory microcosm study is designed to test the following hypothesis.

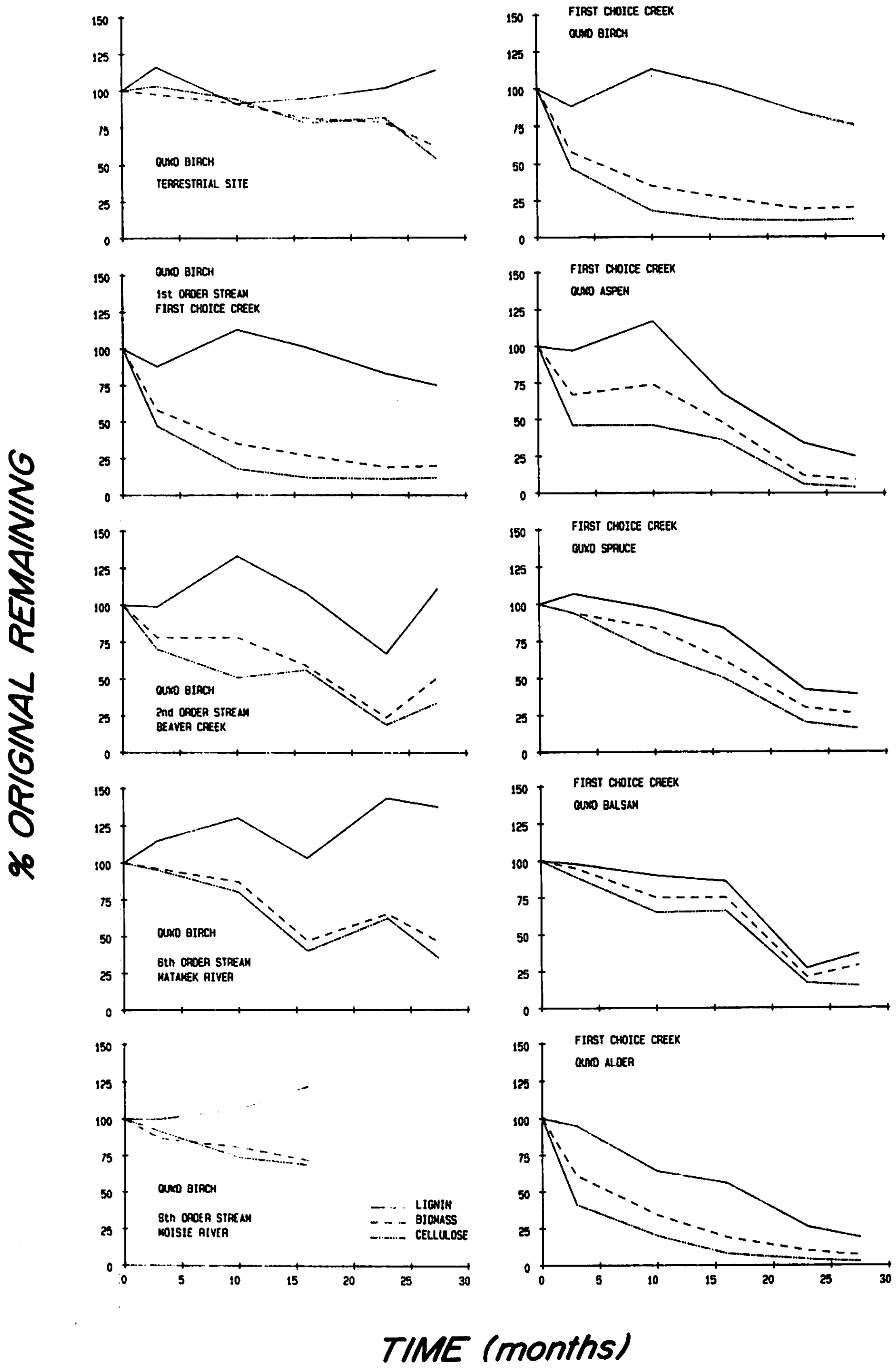
H3: Decomposition rate of fine woody litter is increased by the addition of inorganic N and P.

The design of the laboratory microcosms (chambers) appears in Figure 16. The chambers are glass filter tubes with a narrow stem drawn at the bottom. Coarsely chopped litter is retained within the chamber of a square of fiberglass screening supporting a thin layer of glass wool. Water containing a specific nutrient matrix is delivered to the top of the chamber, drains through the litter and down the stem, where it bifurcates either to the recirculating or to the outflow limb. The height of the outflow limb determines the water level in the chamber, which for our purposes is set at the glass wool, so that the litter is moist but not waterlogged. The recirculating limb operates as an airlift, such that the pressure head in the stem pushes water past a "Y"-shaped function, where an air-stream bubbles it up and over into the top of the chamber again. The inflow and outflow rates are slow and equal each other (~17 ml/hr), resulting in a steady-state with respect to water level. Water flows in from above the chambers by means of a Marriot bottle and a siphon that achieves constant flow independent of water level.

Results are not yet available from the microcosm studies.

FIGURE LEGENDS

Figures 1-10.	Quebec Wood (QUWD) Decay Dynamics. % organic matter remaining, % lignin remaining, % cellulose remaining vs time. Fig. 1-5, birch at 5 sites. Fig. 6-10, 5 wood species at First Choice Creek.
Figure 11.	Phase plane plot. Quebec wood decomposition dynamics - organic matter remaining vs. % N in the remaining tissue.
Figures 12-15	Preliminary decomposition dynamics of wood for new 1981 field study. % original remaining biomass, lignin, cellulose vs. time.
Figure 16.	Laboratory microcosm for experimental decomposition studies.


% ORIGINAL REMAINING
TIME (months)
QUKD BIRCH
TERRESTRIAL SITE
FIRST CHOICE CREEK
QUKD BIRCH
QUKD BIRCH
1st ORDER STREAM
FIRST CHOICE CREEK
FIRST CHOICE CREEK
QUKD ASPEN
QUKD BIRCH
2nd ORDER STREAM
BEAVER CREEK
FIRST CHOICE CREEK
QUKD SPRUCE
QUKD BIRCH
6th ORDER STREAM
MATAMEK RIVER
FIRST CHOICE CREEK
QUKD BALSAM
QUKD BIRCH
9th ORDER STREAM
MOISIE RIVER
FIRST CHOICE CREEK
QUKD ALDER
LIGNIN
BIOMASS
CELLULOSE
0
25
50
75
100
125
150
0
5
10
15
20
25
30

FIGURES 1-10

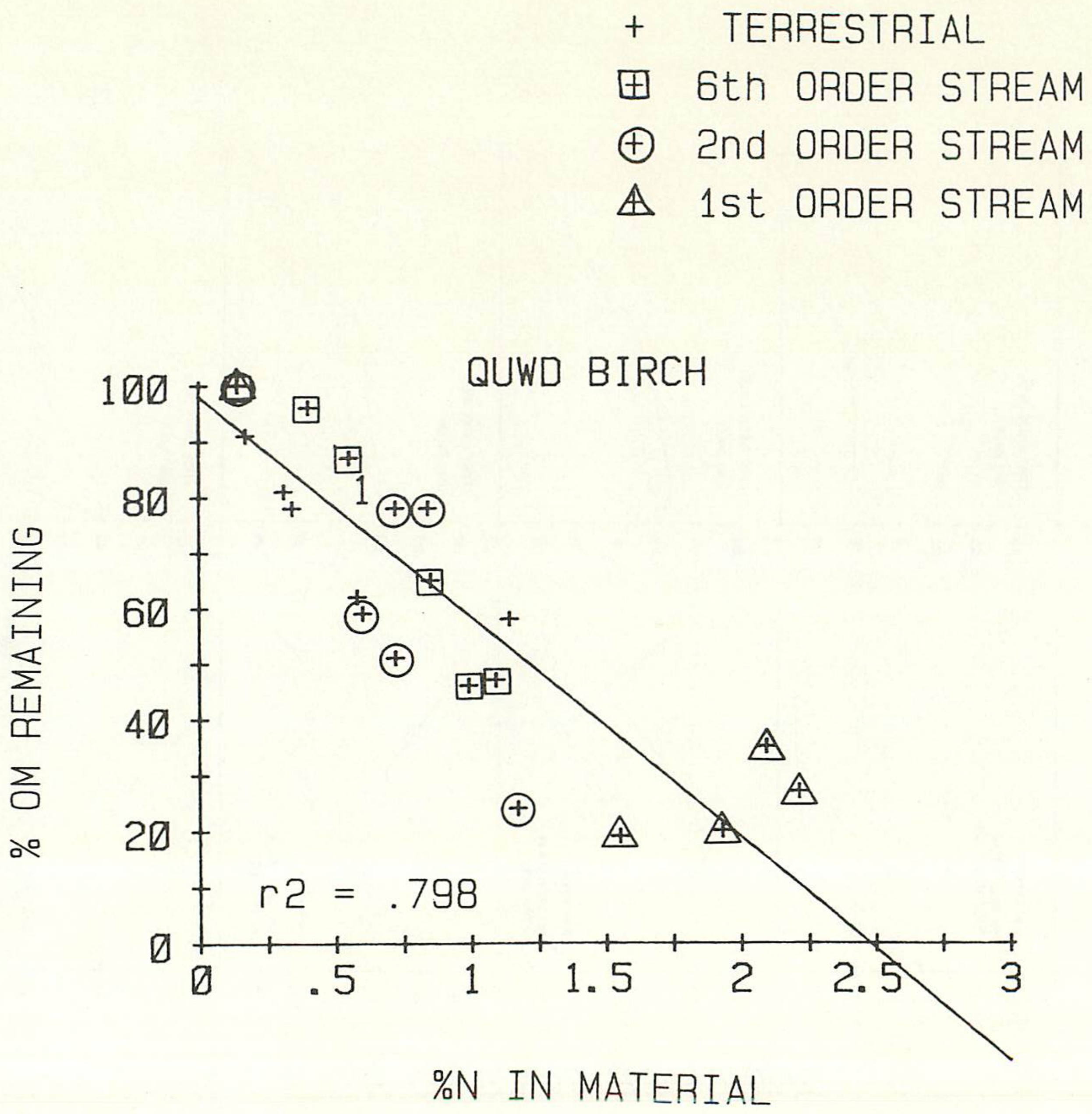
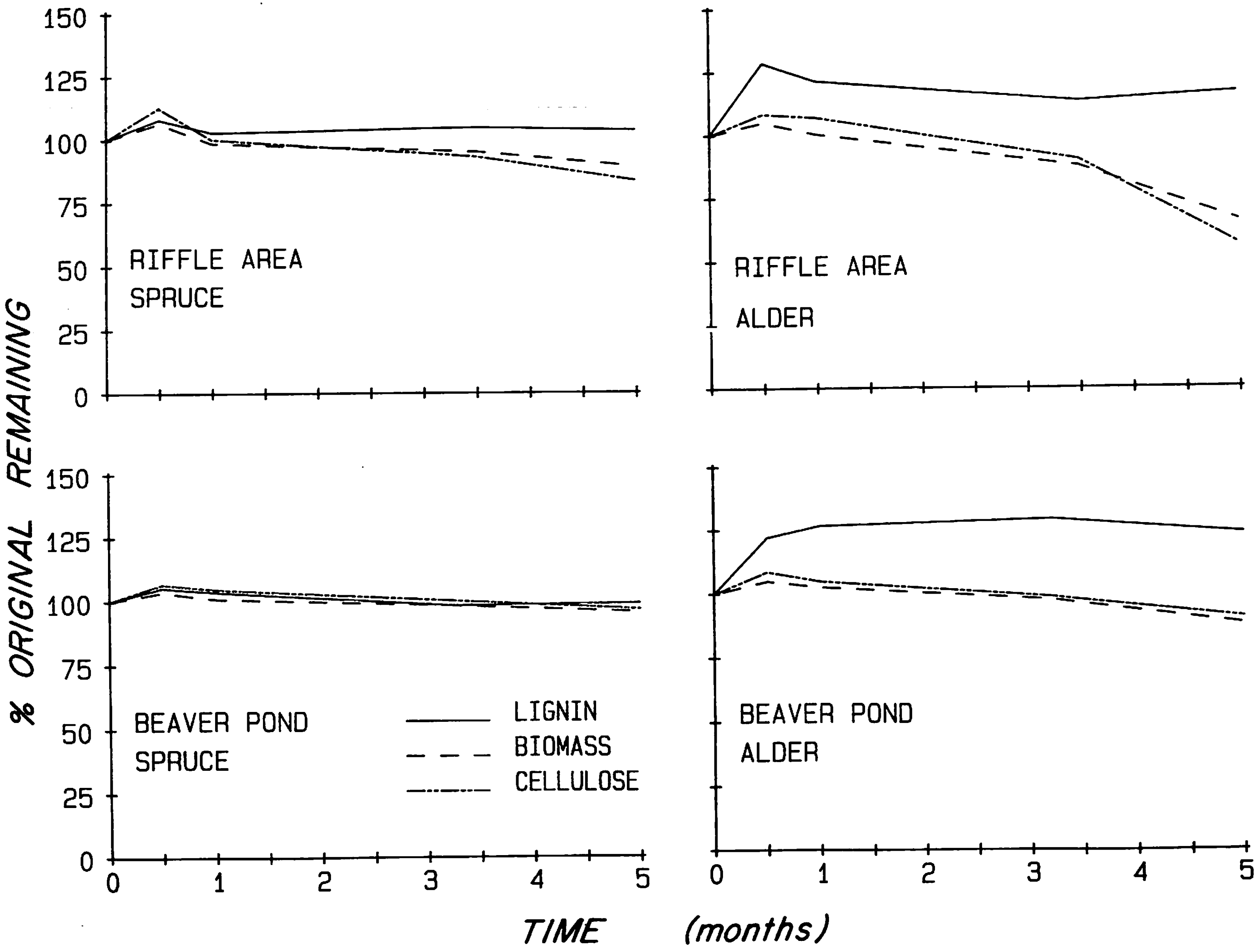

+ TERRESTRIAL
⊞ 6th ORDER STREAM
⊕ 2nd ORDER STREAM
△ 1st ORDER STREAM
QUWD BIRCH
% OM REMAINING
100
80
60
40
20
0
r2 = .798
1
0
.5
1
1.5
2
2.5
3
%N IN MATERIAL

FIGURE 11



FIGURES 12-15

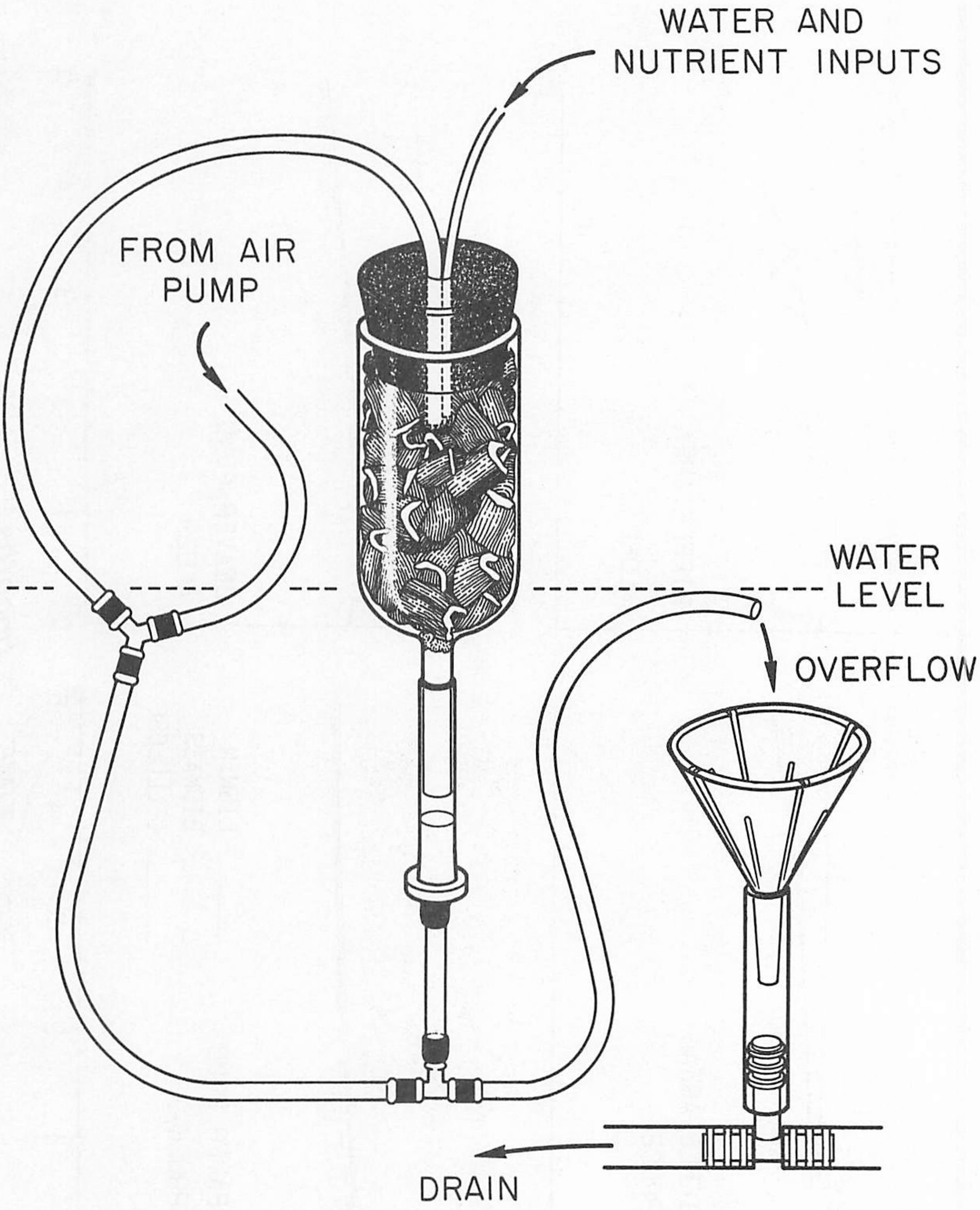

WATER AND
NUTRIENT INPUTS
FROM AIR
PUMP
WATER
LEVEL
OVERFLOW
DRAIN

FIGURE 16

LEAF LITTER DECOMPOSITION IN STREAMS AND ON LAND

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Much of the life in streams is powered by energy-rich carbon compounds from adjacent terrestrial environments. A large fraction of this carbon enters forest streams as leaf litter, but energy locked in the leaf litter is not directly accessible to stream animals. Through the process of decomposition, bacteria and fungi "repackage" this energy and make it available to other stream organisms. Understanding factors controlling leaf litter decay in streams, then, is basic to understanding stream energetics.

Nutrients also enter streams in leaf litter. The nutrient dynamics of decomposing leaf litter depends on initial chemistry. Decomposition of leaves with narrow carbon to nutrient ratios generally result in a continuous release of nutrients into surrounding water, while decomposition of leaves with wide carbon to nutrient ratios often exhibit an absolute accretion of nutrients from surrounding water before nutrient release. The absolute increases in nutrient mass are presumably associated with increases of microbial biomass and the accumulation of extracellular microbial products on the litter-microbe complex. During the early phases of decomposition of leaves with wide carbon to nutrient ratios, there is competition for nutrients between microorganisms and stream autotrophs. From this brief discussion it is apparent that we must know the nutrient dynamics in decomposing leaf litter if we wish to understand nutrient cycling patterns in streams.

A major factor of the leaf litter mass entering streams in the boreal forest zone, comes from alders and birches. During the past year we have been conducting a study of alder and birch leaf litter decay in three streams, and a terrestrial site in the Matamek River Drainage Basin using the litter bag technique. The stream sites are: 1) First Choice Creek, a first order stream; Beaver Creek, a second order stream; and the Matamek River, a sixth order stream. The terrestrial site is an undisturbed birch forest stand adjacent to First Choice Creek.

During the study we have been monitoring a large number of parameters including; weight loss, ash content, total Kjeldahl nitrogen concentration, and the concentrations of lignin and cellulose. To date, we have completed the chemistry and data analysis on materials collected over the first 10 months of the experiment. Below we briefly discuss some of the results.

1) Alder had higher concentrations of nitrogen and lignin than did birch. The cellulose content of birch was slightly higher than alder (Table 1).

2) We observed a rapid leaching of carbon and nitrogen from both litter types during the first three days at all sites. Carbon leaching ranged from 5-10% of original, and nitrogen leaching ranged from 5-15% of original.

3) We used an exponential decay model to estimate the rate of annual weight loss for each litter type at each site. The model has the following form:

$$\frac{X}{X_o} = e^{-kt}$$

where X = weight remaining at time t, X_o = original weight, e is the base of natural logarithms, and k is the decomposition constant. For both litter types, decay rate was slowest at the terrestrial site and the decay rate increased with decreasing stream order (Table 2). Alder leaf litter decomposed more rapidly in all sites except the second order stream where the pattern was reversed.

4) Aber and Melillo (*Can. J. Bot.* 58: 416-421) have demonstrated that an inverse linear relationship exists between percent organic matter remaining and percent nitrogen in the remaining residue during decomposition of leaf and fine wood litter in terrestrial ecosystems, and leaf litter in stream ecosystems. We have tested this relationship with data for the alder and birch leaves and the relationship holds in most instances (Figures 1-7).

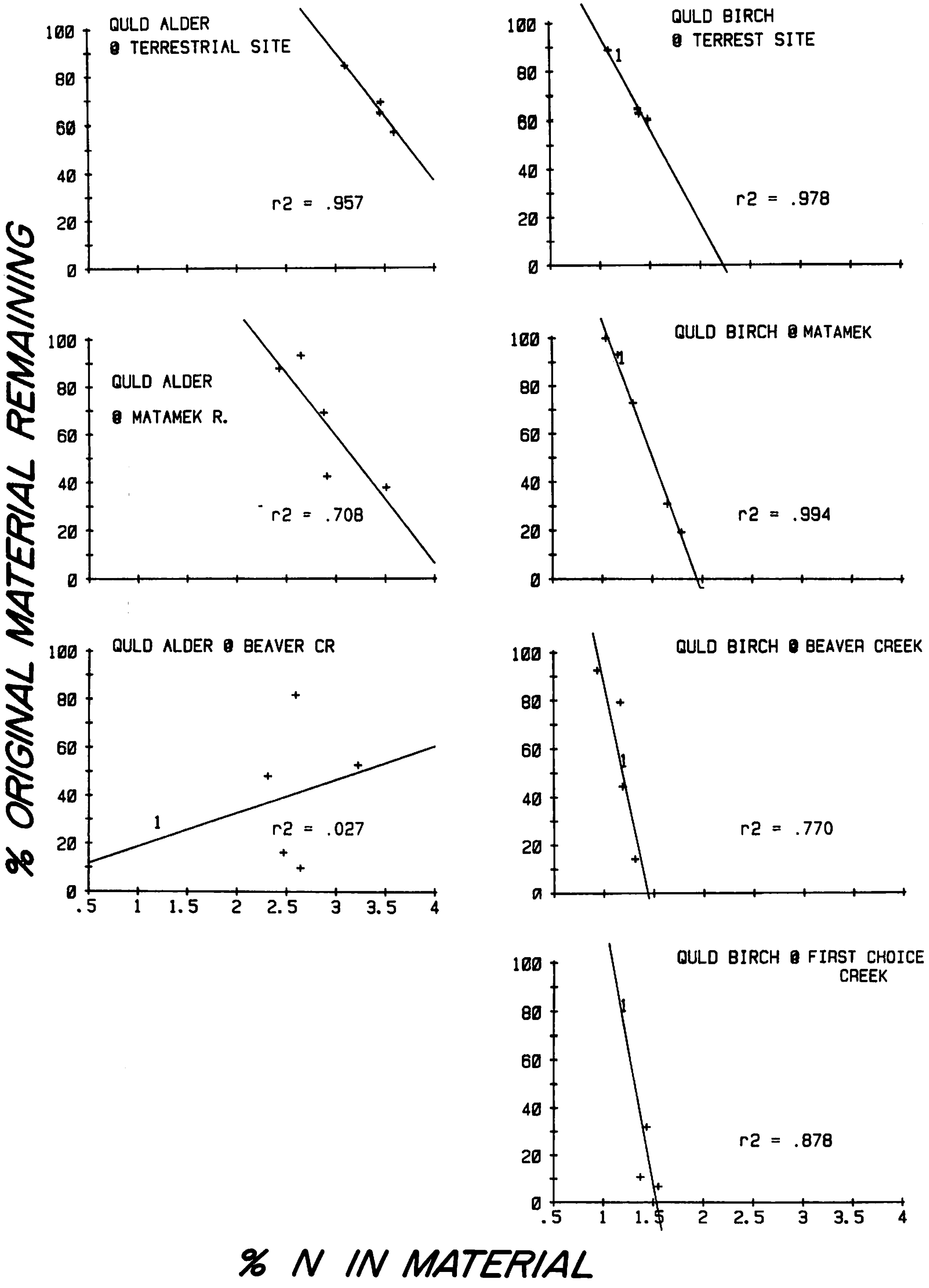
Using this simple relationship we can calculate the maximum nitrogen immobilization potential of a given mass of initial litter by using the following relationship developed by (Aber and Melillo, *Can. J. Bot.*, in press):

$$\frac{\frac{b^2}{-4 * m} - [100 * N]}{10} = \frac{\text{mg N immobilized}}{\text{g initial material}}$$

where b is the intercept of the inverse linear function relating organic matter remaining to nitrogen concentration in the residue, m is the slope of that function, and N is the initial nitrogen concentration. An analysis of our data using this approach indicates that alder leaf litter immobilizes nitrogen in the terrestrial site only. Birch leaf litter immobilized nitrogen in all but the terrestrial site.

FIGURE CAPTION

Figures 1-7 Quebec leaf (QULD) litter decay dynamics - % organic matter remaining vs. % N in the remaining tissue.


% ORIGINAL MATERIAL REMAINING
QULD ALDER
@ TERRESTRIAL SITE
r2 = .957
QULD BIRCH
@ TERREST SITE
r2 = .978
QULD ALDER
@ MATAMEK R.
r2 = .708
QULD BIRCH @ MATAMEK
r2 = .994
QULD ALDER @ BEAVER CR
r2 = .027
QULD BIRCH @ BEAVER CREEK
r2 = .770
QULD BIRCH @ FIRST CHOICE CREEK
r2 = .878
0
20
40
60
80
100
.5
1
1.5
2
2.5
3
3.5
4
1
% N IN MATERIAL

FIGURES 1-7

Table 1. Initial Plant Chemistry

	Alder	Birch
% N	2.72	1.02
% Cellulose	14.81	16.49
% Lignin	25.32	19.87

Table 2 Annual exponential decay constant (K) calculated from linear regressions for alder and birch leaves at five sites in the Matamek drainage basin. Numbers in ( ) refer to r^2 values for best fits to linear approximations of K versus time.

	Alder	Birch
First Choice Creek	-	-3.28 (0.87)
Beaver Creek	-2.52 (0.90)	-2.21 (0.92)
Matamek River	-1.12 (0.90)	-1.86 (0.90)
Terrestrial Site	-0.95 (0.99)	-0.50 (0.98)

Table 3. Maximum immobilization potential. mg N immobilized/g initial tissue

	Alder	Birch
First Choice Creek	0	3.0
Beaver Creek	0	0.2
Matamek River	0	0.6
Terrestrial Site	2.2	0

DECOMPOSITION OF PAPER BIRCH AND RED ALDER LEAF LITTER IN A SEAWATER ENVIRONMENT

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Abstract

Decomposition dynamics of paper birch (Betula papyrifera) and red alder (Alnus rubra) leaves were studied in a seawater environment. Trends observed in the nitrogen, carbon, lignin, cellulose and acid detergent cell wall (ADCW) fraction of the litter over time were similar to those reported for freshwater systems, but decomposition rates in this study were much slower than expected. Even after 140 days (1090 degree days), approximately 70% of the original material remained. Although the two species differ significantly in presumed substrate quality, decay rate coefficients (k) were virtually identical ($k = 0.0013 \cdot d^{-1}$ for birch leaves; $0.0012 \cdot d^{-1}$ for alder). Correlations previously reported between k and percent nitrogen, C:N ratio, percent lignin, and lignin: nitrogen ratio for terrestrial and freshwater systems failed to predict both the slow rates of decomposition and the striking similarity between species. The absence of significant fungal colonization is postulated to have resulted in the slow decomposition rates.

Conclusion

Decomposition of terrestrial leaf litter in seawater, as observed in this study, differs from decomposition of similar material in freshwater in a number of ways. Decomposition rates in seawater are much slower than those generally reported in freshwater. Furthermore, we were unable to discern any significant differences between rates of decomposition or patterns of change in litter quality between alder and birch leaves, despite their marked dissimilarity in traditionally important chemical parameters. While temperature, season, litter quality, and experimental artifacts may all be important factors in controlling decomposition, they are probably insufficient to explain differences between our results and those reported for freshwater. Freshwater studies involving temperature regimes similar to ours, and those using mesh litter bags, still resulted in much higher decomposition rates than we found.

Decomposition rates of mangrove leaves and eel grass in estuarine environments appear similar to leaves in freshwater studies, although less data for estuarine systems are available (Burkholder and Doheny, 1968; Fell et al., 1980). In contrast, many studies have shown that Spartina litter in estuaries decomposes at rates comparable to those reported here for terrestrial litter (Burkholder and Bornside, 1957; Rublee et al., 1978).

The lack of fungal colonization in our study may have limited the decay rate. Lee et al. (1980), who reported a relatively high rate of decomposition for Spartina, also reported fungal biomass at least an order of magnitude greater than what we observed. In freshwater, leaf litter decomposition has been viewed as a successional process, whereby microbial settlement and "conditioning" precedes attack by various specialized invertebrates (Petersen and Cummins, 1974; Sedell et al., 1975). Fungi are considered important pioneer settlers in this process, allowing bacteria access to the interior plant tissue by disrupting the leaf cuticle (Kaushik and Hynes, 1971; Suberkropp and Klug, 1974, 1976). It is not yet clear whether decomposition of leaf debris in the marine environment follows a similar pattern. Newell (1973) reported a comparable succession in decaying mangrove seedlings, as did Gessner et al. (1972) in Spartina. However, Morrison et al. (1977) concluded that for oak leaves in a Florida estuary, bacteria dominated the microbial community during the early stages of decomposition. Although our study was not specifically designed to examine microbial conditioning and succession, our results support the idea that fungi may be less important in decomposition of terrestrial litter in seawater than in other systems. It is important to note, however, that despite low fungal activity during initial stages of decomposition, Morrison et al. (1977) report a decomposition rate for oak litter comparable to rates reported in freshwater studies, and significantly higher than rates we observed for alder and birch.

General conclusions concerning decomposition of terrestrial leaf litter in marine environments cannot yet be formulated, though it is clear that simple extrapolation of freshwater decomposition processes to marine systems is not advisable. More information about the decomposition process in seawater is essential for understanding coastal ecosystems where the input of terrestrial plant litter is important.

Arch. Hydrobiol. (In press).

FIGURE LEGENDS

Fig. 1. Percent of original AFDW remaining as a function of time. Each point is a value for a single litter bag; lines are least squares fits. (a) birch; (b) alder.

Fig. 2. Chemical composition as percent of AFDW and percent of initial remaining as a function of time. Solid circles= birch; open circles= alder; asterisks= initial values (not included in regressions). In (a) and (b) each point is the mean ± SE (n=3); in (c) through (h) each point is the measured value for a single bag; lines are least squares fits. (a) percent nitrogen of AFDW; (b) percent nitrogen remaining; (c) percent lignin of AFDW; (d) percent lignin remaining; (e) percent cellulose of AFDW; (f) percent cellulose remaining (regression not significant for alder; points are mean ± SE, n=2); (g) percent acid detergent cell wall (ADCW) of AFDW; (h) percent ADCW remaining.

Fig. 3. The number of bacteria per g AFDW as a function of time. Each point is the mean of ten microscope fields from one leaf; bars represent 95% confidence intervals. Lines are least squares regression fits of means. (a) birch; (b) alder.

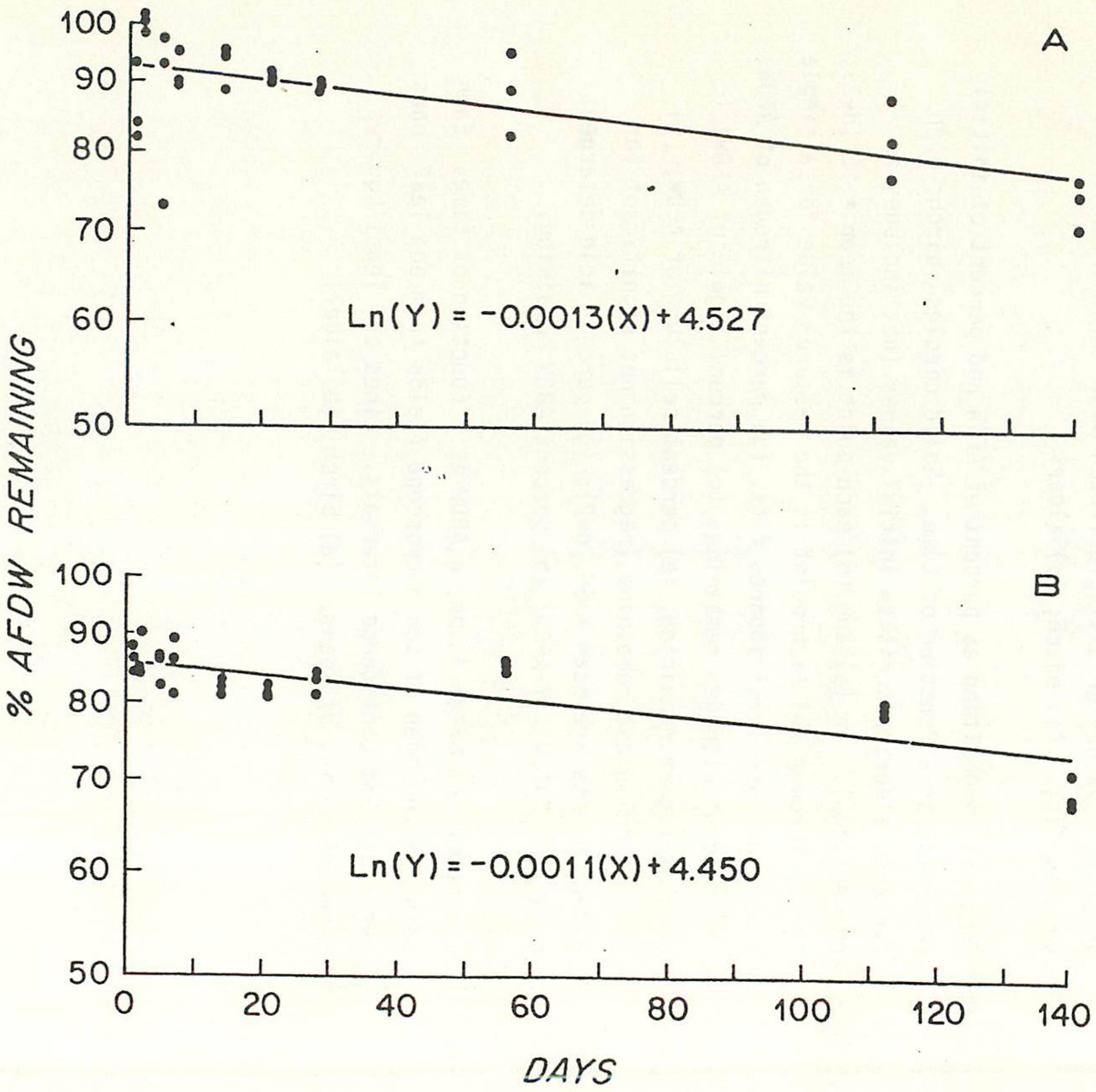

A
Ln(Y) = -0.0013(X) + 4.527
B
Ln(Y) = -0.0011(X) + 4.450
% AFDW REMAINING
100
90
80
70
60
50
0
20
40
60
80
100
120
140
DAYS

FIGURE 1

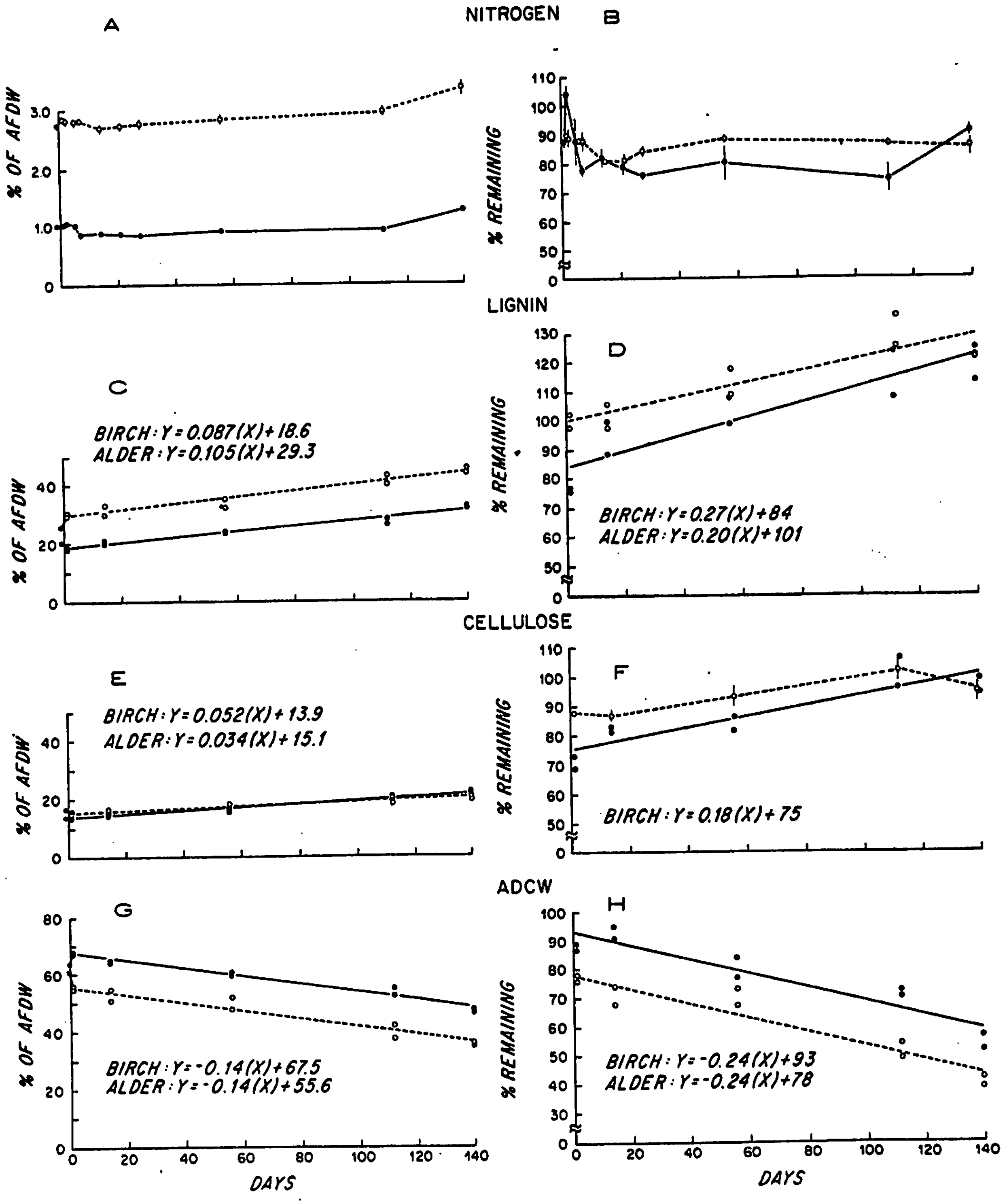

NITROGEN
A
B
3.0
2.0
1.0
0
% OF AFDW
110
100
90
80
70
60
50
0
% REMAINING
LIGNIN
C
BIRCH: Y=0.087(X)+18.6
ALDER: Y=0.105(X)+29.3
40
20
0
% OF AFDW
D
130
120
110
100
90
80
70
60
50
0
% REMAINING
BIRCH: Y=0.27(X)+84
ALDER: Y=0.20(X)+101
CELLULOSE
E
BIRCH: Y=0.052(X)+13.9
ALDER: Y=0.034(X)+15.1
40
20
0
% OF AFDW
F
110
100
90
80
70
60
50
0
% REMAINING
BIRCH: Y=0.18(X)+75
ADCW
G
80
60
40
20
0
% OF AFDW
BIRCH: Y=-0.14(X)+67.5
ALDER: Y=-0.14(X)+55.6
0
20
40
60
80
100
120
140
DAYS
H
100
90
80
70
60
50
40
30
0
% REMAINING
BIRCH: Y=-0.24(X)+93
ALDER: Y=-0.24(X)+78
0
20
40
60
80
100
120
140
DAYS

FIGURE 2

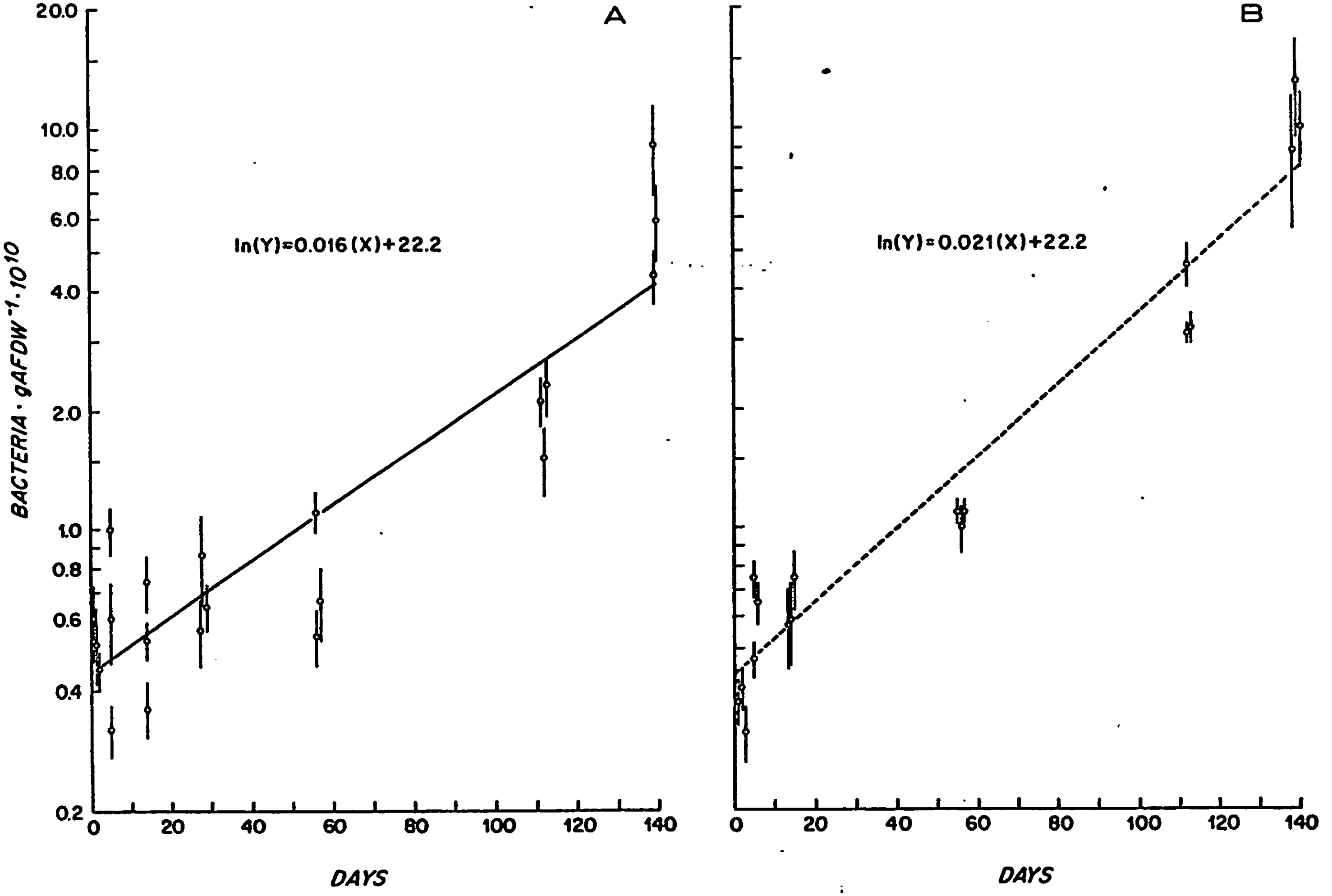

A
B
ln(Y)=0.016(X)+22.2
ln(Y)=0.021(X)+22.2
BACTERIA · gAFDW⁻¹ · 10¹⁰
20.0
10.0
8.0
6.0
4.0
2.0
1.0
0.8
0.6
0.4
0.2
0
20
40
60
80
100
120
140
DAYS
DAYS

FIGURE 3

Table 1. Initial Chemical Composition of the Leaf Litter

Parameter	Birch	Alder
% Nitrogen (of AFDW)	1.02	2.72
% Carbon (of AFDW)	49	51
C:N (atomic)	56	22
% Lignin (of AFDW)	19.8	25.2
% Cellulose (of AFDW)	16.5	14.8
% ADCW (of AFDW)	63.6	60.7
Lignin: Nirogen	19.4	9.3

Table 2. Regression of Decomposition Parameters as a Function of Time

Parameter	Sample Size (N)	Coefficient of determination (r^2)	Significance of regression	Slope ± SE	Significance of slope[3,4]	Significance of difference between slopes [2,4]
% AFDW remaining						
birch	30	.45	$p < 0.01$	-.111 ± .0273	$p < 0.01$	NS
alder	30	.65	$p < 0.01$	-.089 ± .0189	$p < 0.01$	
ln (AFDW remaining)						
birch	30	.45	$p < 0.01$	-.0013 ± .0003	$p < 0.01$	NS
alder	30	.66	$p < 0.01$	-.0011 ± .0003	$p < 0.01$	
% N in residue						
birch	30	.15	NS	-	-	-
alder	30	.58	$p < 0.01$	.0031 ± .0007	$p < 0.01$	
% N remaining						
birch	30	.02	NS	-	-	-
alder	30	.02	NS	-		-
% Lignin in residue						
birch	10	.96	$p < 0.01$	.087 ± .009	$p < 0.01$	NS
alder	10	.94	$p < 0.01$	.105 ± .009	$p < 0.01$	
% Lignin remaining						
birch	10	.79	$p < 0.05$	.269 ± .053	$p < 0.05$	NS
alder	10	.76	$p < 0.05$	.200 ± .049	$p < 0.05$	
% Cellulose in residue						
birch	10	.98	$p < 0.01$	.052 ± .004	$p < 0.01$	NS
alder	10	.90	$p < 0.01$	.034 ± .004	$p < 0.01$	
% Cellulose remaining						
birch	10	.79	$p < 0.05$	.181 ± .044	$p < 0.05$	-
alder	10	.48	NS	-		-
% ADCW in residue						
birch	10	.98	$p < 0.01$	-.140 ± .011	$p < 0.01$	NS
alder	10	.94	$p < 0.01$	-.140 ± .012	$p < 0.01$	
% ADCW remaining						
birch	10	.88	$p < 0.05$	-.243 ± .045	$p < 0.05$	NS
alder	10	.91	$p < 0.01$	-.244 ± .037	$p < 0.01$	
ln (bacteria per g AFDW)						
birch	21	.82	$p < 0.01$	.0160 ± .0023	$p < 0.01$	NS
alder	21	.94	$p < 0.01$	.0210 ± .0017	$p < 0.01$	

(1) Day 0 values excluded; (2) F-test
(3) T-test; (4) NS = $p > 0.05$

Table 3. Meters of Fungal Hyphae per g AFDW

Sample Day	Birch Fields Counted	Birch Mean ± SE	Alder Fields Counted	Alder Mean ± SE
1	40	580 ± 184	42	77 ± 4
	40	190 ± 109	40	130 ± 88
28	40	220 ± 59	40	140 ± 58
	42	260 ± 94	40	76 ± 29
56	43	350 ± 105	40	110 ± 58
	40	340 ± 108	40	56 ± 29
112	40	430 ± 141	40	770 ± 162
	41	230 ± 90	40	150 ± 56
140	40	600 ± 162	40	14 ± 8
	40	310 ± 123	40	44 ± 27
Overall mean		351 ± 46		156 ± 70
Signifificance of differences between days (1)		NS ($p > 0.75$)		NS ($p > 0.25$)
Significance of difference between species (2)			$p < 0.05$	

(1) nested ANOVA (F-test)
(2) simple ANOVA of overall means (F-test)

ALLOCHTHONOUS INPUTS IN THE MATAMEK WATERSHED: PRELIMINARY RESULTS

M. Elizabeth Conners and Robert J. Naiman
Woods Hole Oceanographic Institution

During 1980 and 1981 data were collected to study the timing, magnitude, and composition of allochthonous inputs to four streams in the Matamek Watershed. Presented here is a brief summary of the initial analysis of these data; a complete analysis is currently in preparation and will be included in next year's report.

Inputs of terrestrially formed leaf litter, wood fragments, and other organic debris form the base of the detrital food web within streams, acting as an external source of reduced carbon compounds and as substrate for microbial colonization. This energy source is considered to be especially important for small, densely canopied streams where autochthonous production is limited by shading; its influence becomes less crucial downstream as macrophytes and periphytic algae become more productive (Vannote et al. 1980; Naiman and Sedell 1980). Quantitative information on allochthonous organic carbon supplies, combined with geomorphological data and stream metabolism, transport, and decomposition studies, should yield valuable insight into the production dynamics of streams in the Matamek Watershed.

Five locations were studied: the regular sampling sites at First Choice Creek, Beaver Creek, and the Muskrat River (the regular study site on Beaver Creek will be referred to as the "metabolic area"), and a broad area just downstream of the Third Falls in the Matamek River. In addition, Beaver Creek was sampled in a pond area upstream of the second beaver dam; this location is identified as "Beaver Creek Dam". At each study site both direct fall of materials into the stream and lateral wash-in from the banks were collected. Litter traps consisted of plastic washtubs with a collection area of 0.0891 m^2; those samplers placed in the water were set inside innertubes and either tied to bank vegetation or moored with cement blocks. Lateral samplers were triangular in cross section and 0.40 m long; backs and bottom were 0.5 cm galvanized screening with the open side facing away from the stream. At First Choice Creek and Beaver Creek litter traps were also set within the forest 20-40 m from the stream. In the rivers, in-stream litterfall samplers were moored in a matrix array to investigate differences between inshore and midchannel input levels. Figure 1 shows the placement of traps at each site and the locations of the study sections.

The six to ten replicate traps of each type per site were emptied and re-set at intervals throughout the year. A total of 2,748 collections were made over the two year study. Material accumulated in the samplers was collected on a 1 mm mesh net and preserved by freezing. In the laboratory thawed samples were sorted into leaf, wood, bark, and needle fractions and identified to species whenever possible. Fractions were then dried at 80°C and weighed to the nearest 0.01 g. Subsamples of major species were ashed at 525°C for 2-4 hours to measure organic content. The information gathered was put onto the WHOI computer system and distilled into total input averages for each site, trap type, and collection date. These averages were used to compute annual estimates of total input; these estimates are presented in Table 1.

The seasonal regularity of the input averages is striking. Figures 2-4 are histograms of the average total input of material at the different sites. The form of the autumn leaf pulse is consistent for all sites, even over large changes in maximum height of the peaks. More frequent sampling and a strong storm that accounted for most leaf fall in early October 1980 gave better peak resolution for this year than in the fall of 1981, but both the distinct and the rounded patterns are apparent in all data sets except the very low-volume samples from the mid-river locations. These patterns quantitively confirm the long-standing hypothesis of the importance of the autumn leaf pulse in annual allochthonous input schedules. In both litter and terrestrial traps at First Choice Creek and Beaver Creek and in Trap 1 in the Matamek River, greater than 74% of the total annual input for May 1, 1980 to April 30, 1981 occurred between September 1 and November 1. The same period in 1981-82 accounted for over 60% of total income at these sites. Lateral traps in the smaller streams and both lateral and nearshore litter traps in the Muskrat River all received approximately 50% of their annual income during the fall pulse in both years. The midchannel traps in the rivers and Beaver Creek Dam and Matamek River lateral traps had sporadic pulse to annual ratios; these traps also showed the highest variance and most year to year variation. In general the differences in annual estimates from one year to the next at First Choice and Beaver Creeks could be accounted for in the September-November period, the variation coming from November-September in the rivers and in the litter traps at Beaver Creek Dam.

Another positive result is the close match of the averages from litter and terrestrial traps at First Choice Creek and Beaver Creek (Figure 1). These data imply that for very small streams the stream surface is effectively just a patch of forest floor, and that realistic estimates of allochthonous inputs could be made from collectors in either location.

The averages for lateral inputs to all sites have higher variances than those for the direct fall traps due to small sample volumes and patchy distributions, but they also reflect the fall pulse patterns. The major difference in seasonality between the litter and lateral traps is in the elevated input to lateral traps over the winter. This effect occurs at all sites and is most pronounced in the Matamek River. In this latter case the high lateral inputs are probably associated with spring snowmelt and bank overflow. Collection of the 1982 overwinter samples will help to confirm this result.

The importance of lateral inputs relative to direct litterfall varies from site to site, but does not seem to be a function of stream order. Consider a section of stream 1m long. At First Choice Creek, where the average stream width is only 0.3 m, the combined lateral input from both banks is approximately equal to the direct fall into the segment. The percentage of total annual input per meter of stream that occurs as lateral input declines to 15-25% at Beaver Creek (mean width 2.0 m) and

5-6% in the Muskrat River (mean width 21.9 m). In the Matamek River, however, lateral inputs account for 12-13% even though it is an average of 51.7 m wide. This result is probably related to the relative magnitude of the overwinter lateral pulse; differences in spring flood patterns, bank slopes, and local vegetation should be examined.

There is a strong correlation with stream order when we look at the maximum height of the fall input peaks. There is a steady decline from a maximum input average of 21 gAFDW/m^2/day at First Choice Creek to less than 5 gAFDW/m^2/day in the nearshore traps in the Muskrat and Matamek rivers. Figure 5 shows the exponential decline of annual litter input with increasing stream order. This decline is not apparent in the lateral traps, which seem to consistently have maximum input averages form 1.0 to 1.5 gAFDW/m/day and annual inputs from 30 to 70 gAFDW/m/year. The First Choice Creek and Beaver Creek metabolic sites are very similar in their lateral input levels, with the Beaver Creek dam and Muskrat River sites showing the lowest annual lateral input. The Matamek River lateral traps had the highest annual input for reasons mentioned above.

The annual litterfall figure for 2nd order streams used in the regression of Fig. 5 is that from the metabolic area of Beaver Creek; for both individual-year regressions the total input at the dam site is that expected of a 3rd order stream. The creek in this area is broader and slower-flowing than the riffle at the metabolic site because of the presence of the beaver dam; riparian vegetation has also been cleared of trees for up to 7 m on either side of the stream near the dam by feeding and building activities. This supports the assertion that the overall effect of beaver activity is to increase the order of a stream (Naiman, unpublished data).

Other relationships derived from the data describe surface litterfall to large streams as a function of distance from shore. The decline in annual input with increasing distance of the trap from the closest bank is roughly exponential, but the coefficients of this decline are different for the Muskrat and Matamek rivers. The litter array traps in the Muskrat

River followed the equation $y = 275 \exp(-0.496x)$, while those from the Matamek were best fit by $y = 65 \exp(-0.109x)$. These relationships will be more thoroughly investigated during the final data analyses.

In summary, the primary results to date quantify long-standing hypotheses of stream ecology rather than suggest new concepts. Estimates drawn from thorough sampling of allochthonous inputs provide reliable figures for particulate carbon loading from terrestrial sources. The importance of the autumn leaf fall to all stream sites and the large contribution of lateral inputs to very small streams are numerically confirmed. A preliminary hypothesis on the effects of beaver activity in stream ecosystems is supported. The similarity of litterfall to canopied streams and forest floor is illustrated. The declining influence of litterfall as streams grow larger is quantitavely described and a first approximation is made toward a numerical description of the spatial pattern of inputs to larger rivers.

FIGURE CAPTIONS

Fig. 1. The Matamek River System, Quebec, Canada.

A) Placement of samplers at First Choice Creek

C) Placement of samplers at Beaver Creek

D) Placement of samplers in the Muskrat River. Average input figures for in-stream array were calculated across A–E for each trap number.

E) Placement of samplers in the Matamek River. Average input figures for in-stream array were calculated across A–E for each trap number.

Fig. 2. Total organic matter inputs to First Choice Creek and Beaver Creek terrestrial and in-stream collectors. Vertical bars show standard errors. X-axis tics are the first of each month.

Fig. 3. Total organic matter collected in lateral traps at each site. Vertical bars show standard errors. X-axis tics are the first of each month.

Fig. 4. Total organic matter collected in river arrays. In the Muskrat River, traps 1 and 4 are an average of 0.9 and 1.4 m from each bank, respectively, while traps 2 and 3 are each approximately 7 m from the nearest shore. In the Matamek traps 1 and 5 average 1 m from shore, trap 2 averages 17 m from the eastern bank, and traps 3 and 4 are 34 and 32 m from the eastern and western shores, respectively. See Fig. 1 for exact location of traps. Vertical bars show standard errors. X-axis tics are the first of each month.

Fig. 5. Estimates of total annual direct-fall inputs vs stream order. Dashed lines follow exponential regressions for individual years.

1980-1981: $y = 1070 \exp(-0.639\ x)$ $r^2 = .986$.

1981-1982: $y = 589 \exp(-0.524\ x)$ $r^2 = .998$.

Where y is the annual input estimate in gAFDW/m_2/year and x is stream order (1-6).

The solid line is the exponential regression for all data combined: $y = 794 \exp(-0.582\ x)$ $r^2 = .975$

For both years, the calculated stream order from input levels at the Beaver Creek dam site is 3.2.

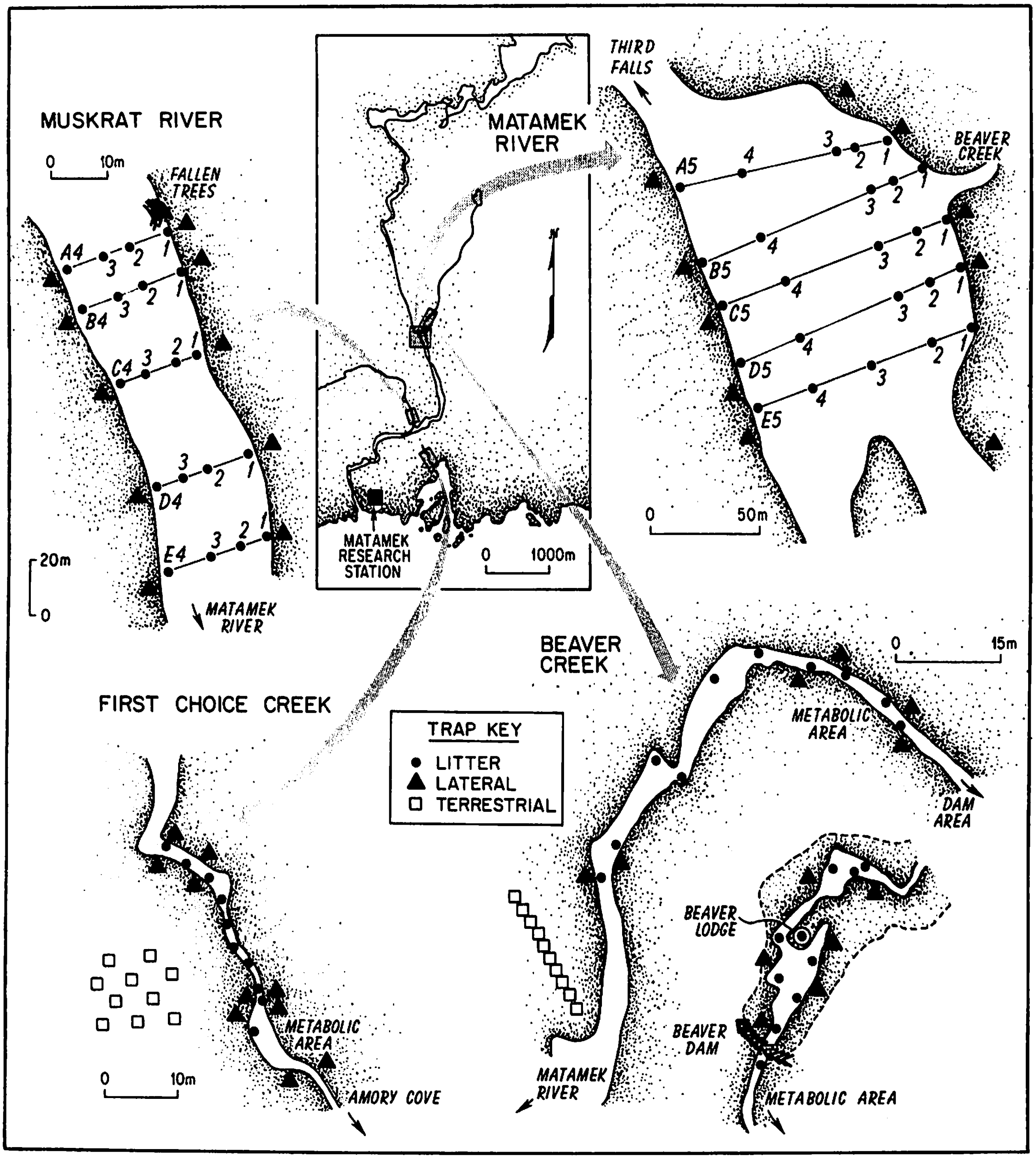

MUSKRAT RIVER
0 10m
FALLEN TREES
A4 3 2 1
B4 3 2 1
C4 3 2 1
D4 3 2 1
E4 3 2 1
20m
0
MATAMEK RIVER
MATAMEK RIVER
MATAMEK RESEARCH STATION
0 1000m
THIRD FALLS
BEAVER CREEK
A5 4 3 2 1
B5 4 3 2 1
C5 4 3 2 1
D5 4 3 2 1
E5 4 3 2 1
0 50m
BEAVER CREEK
0 15m
METABOLIC AREA
DAM AREA
BEAVER LODGE
BEAVER DAM
METABOLIC AREA
MATAMEK RIVER
FIRST CHOICE CREEK
TRAP KEY
● LITTER
▲ LATERAL
□ TERRESTRIAL
METABOLIC AREA
AMORY COVE
0 10m

Figure 1

TOTAL ALLOCHTHONOUS INPUTS

MAY 1980 TO NOV 1981

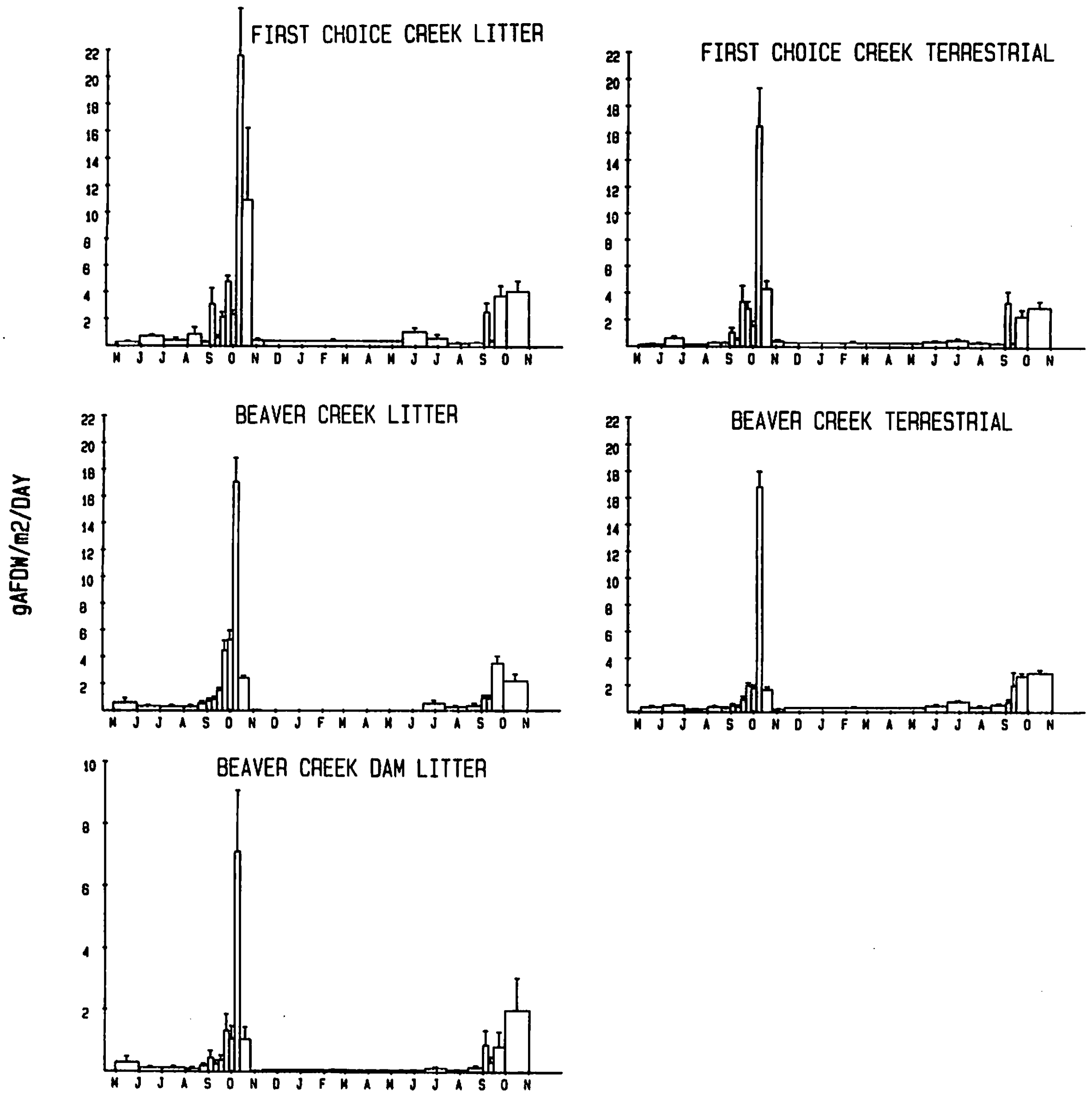


FIGURE 2

TOTAL ALLOCHTHONOUS INPUTS - LATERAL TRAPS

MAY 1980 TO NOV 1981

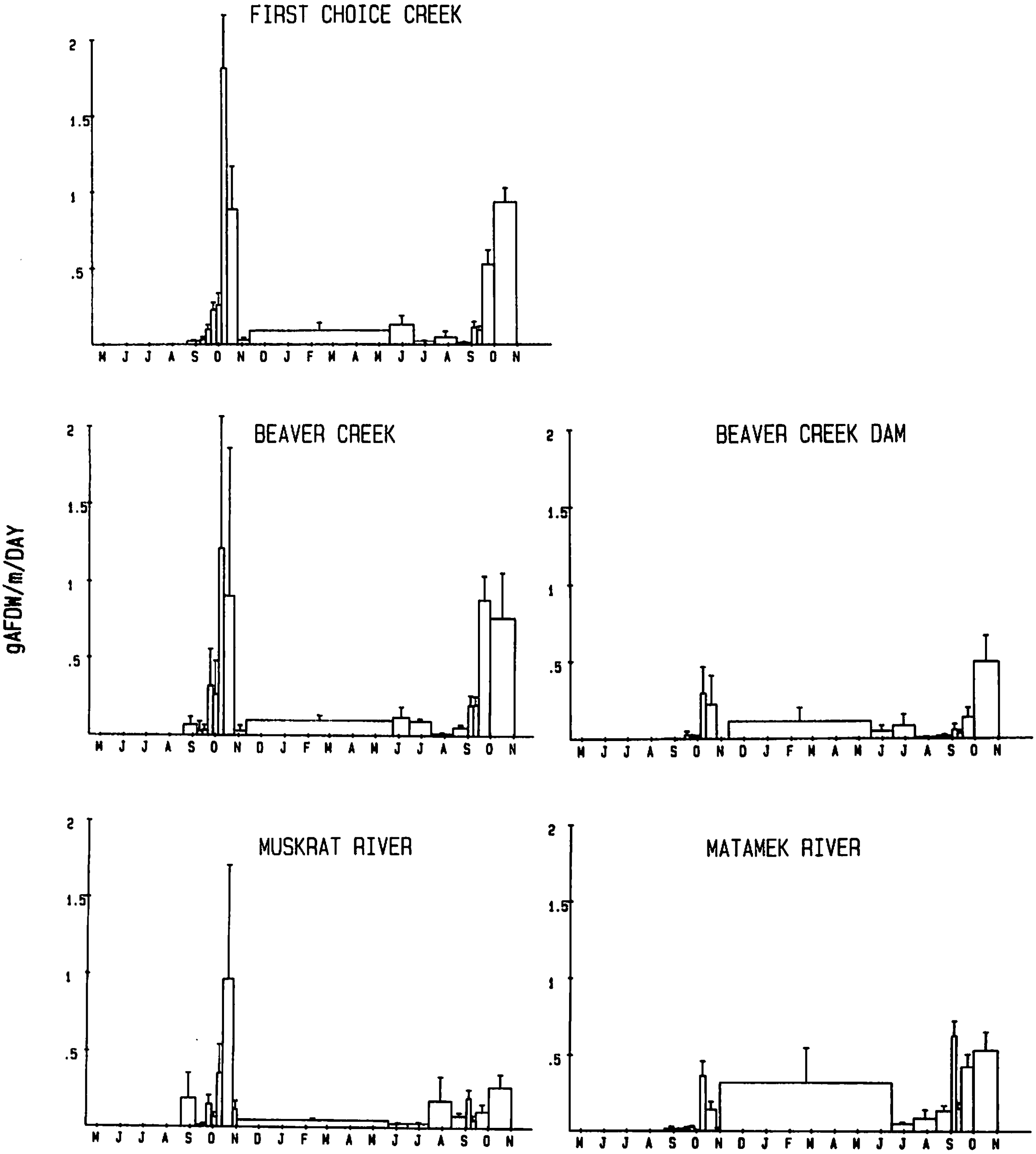


FIGURE 3

TOTAL ALLOCHTHONOUS INPUTS - ARRAY TRAPS

MAY 1980 TO NOV 1981

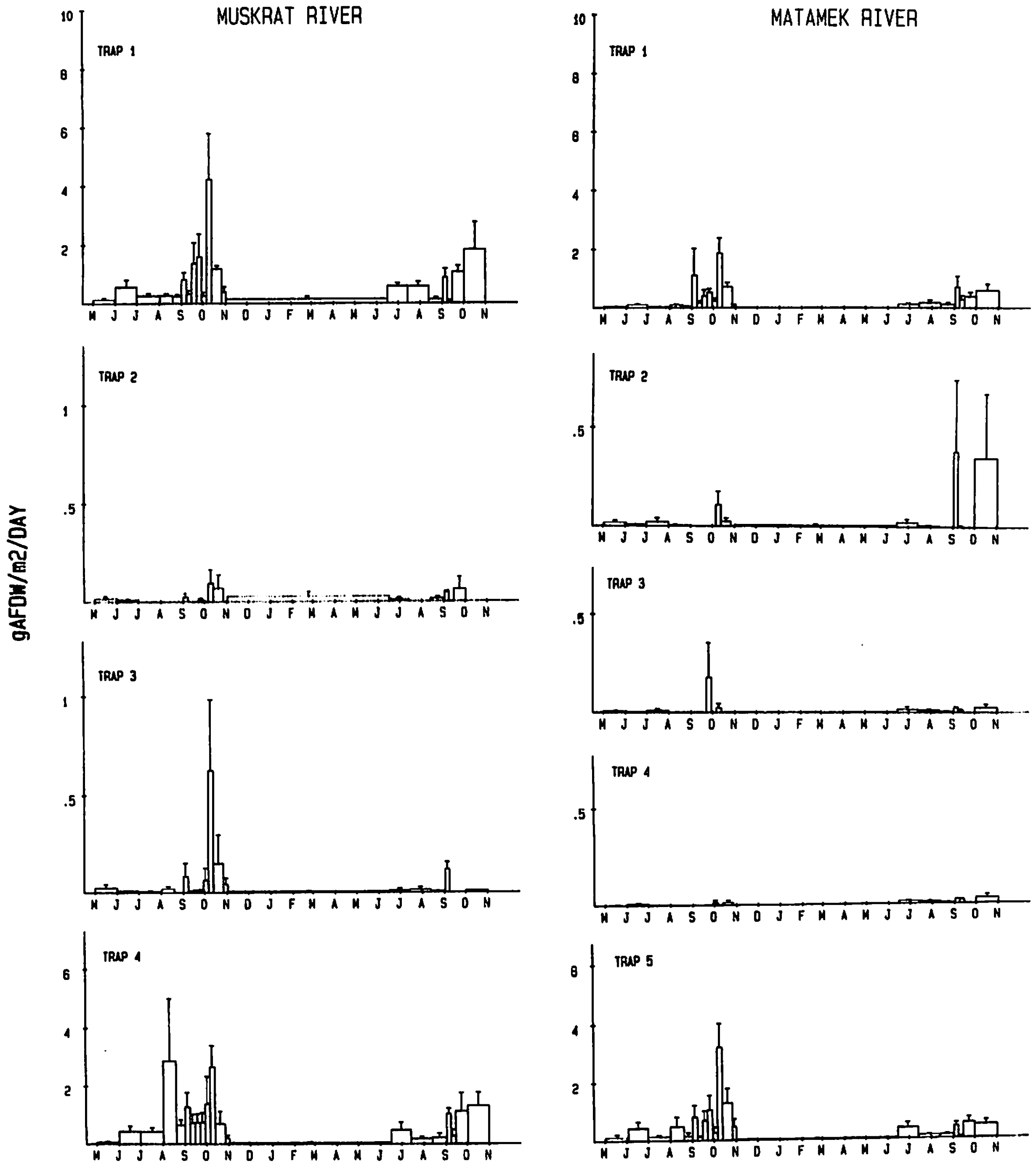


FIGURE 4

ANNUAL LITTERFALL ESTIMATES

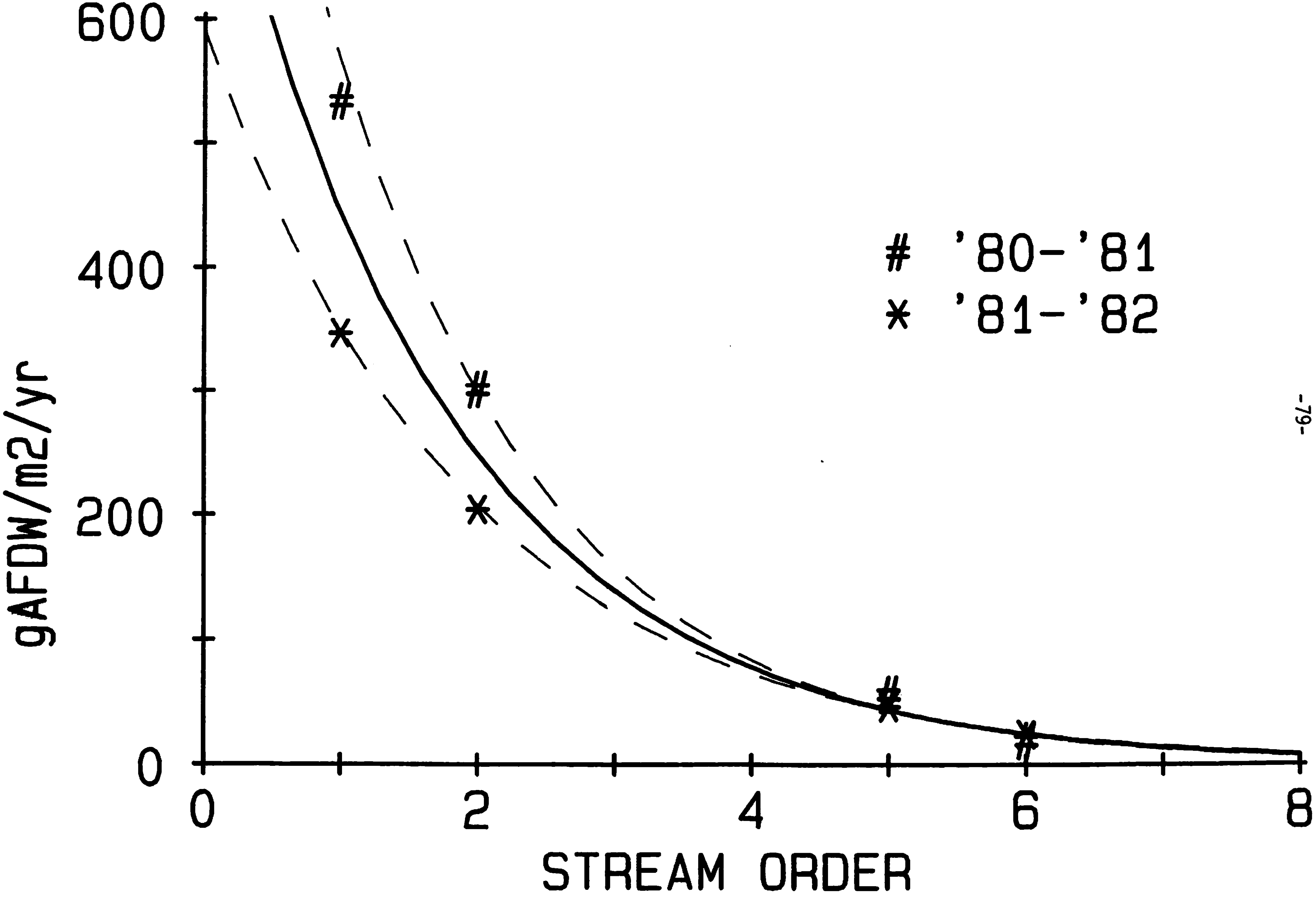


FIGURE 5

TABLE LEGENDS

Table 1. Annual (May 1 - April 30) estimates of total allochthonous input to the locations studied. Note that the November-May portion of the second year is estimated from data taken for the first year, since May 1982 collections had not yet been taken at the time of this writing.

ANNUAL ALLOCHTHONOUS INPUT

		May'80-May'81	May'81-May'82
LITTER TRAPS	gAFDW/m2/yr		
First Choice Creek		534	347
Beaver Creek	metabolic area	301	204
	dam area	133	110
Muskrat River		56	46
Matamek River		19	24
TERRESTRIAL TRAPS			
	gAFDW/m2/yr		
First Choice Creek		327	250
Beaver Creek		240	278
LATERAL TRAPS	gAFDW/m/yr		
First Choice Creek		53	62
Beaver Creek	metabolic area	52	67
	dam area	29	44
Muskrat River		38	28
Matamek River		70	94

ENVIRONMENTAL MONITORING PROGRAM

Robert J. Naiman, Barbara Farr, Maggie Francis, and Lisa Wolfe
Woods Hole Oceanographic Institution and the Matamek Research Station

In 1981 data were routinely collected on water chemistry, precipitation, discharge, water temperatures, and particulate and dissolved seston concentrations. These are presented in the following tables and figures without comment. Methods of collection and analysis can be found in the annual reports for 1979 and 1980

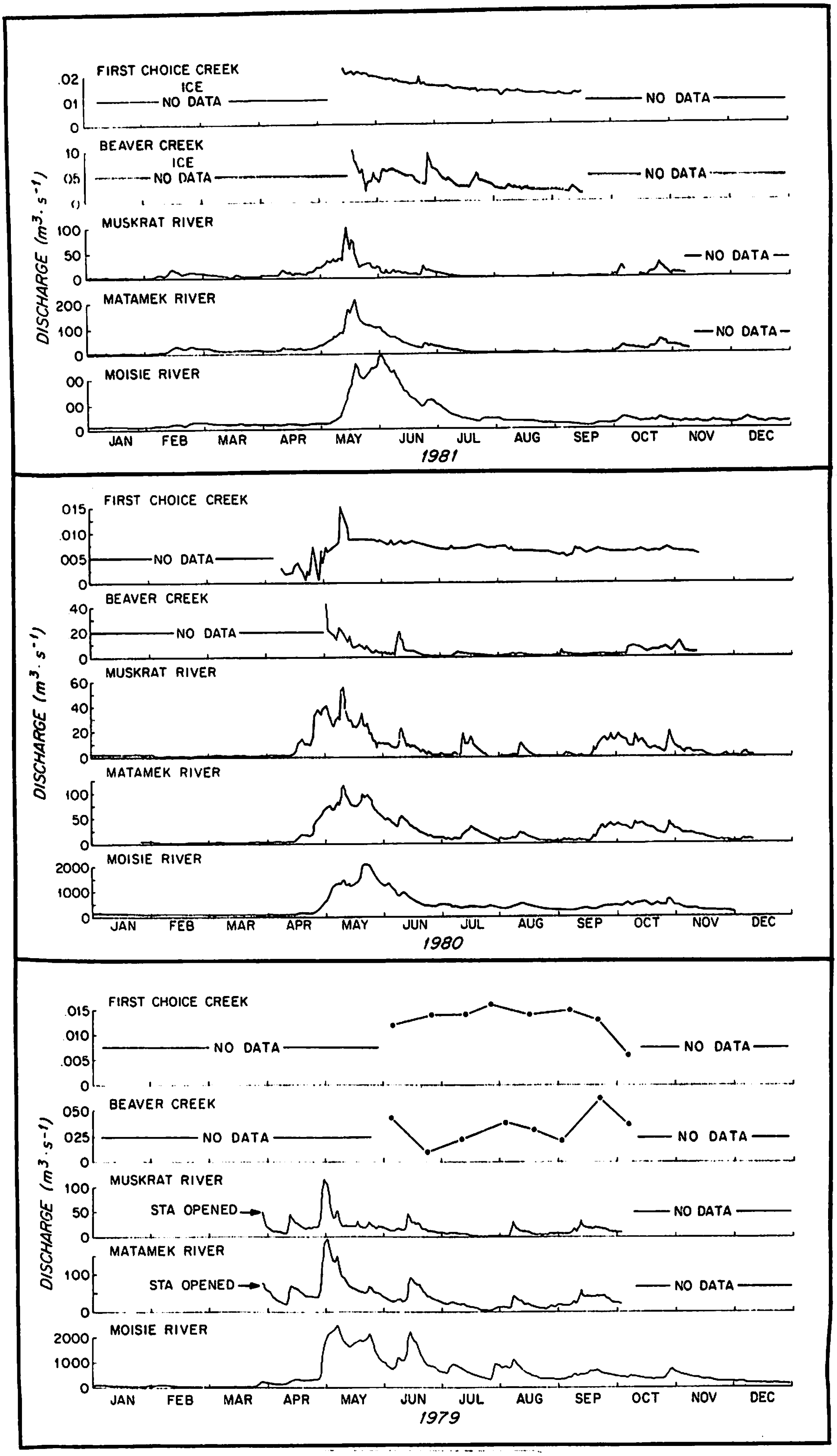

FIRST CHOICE CREEK
ICE
NO DATA
NO DATA
BEAVER CREEK
ICE
NO DATA
NO DATA
MUSKRAT RIVER
NO DATA
MATAMEK RIVER
NO DATA
MOISIE RIVER
DISCHARGE (m³·s⁻¹)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981
FIRST CHOICE CREEK
NO DATA
BEAVER CREEK
NO DATA
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
1980
FIRST CHOICE CREEK
NO DATA
NO DATA
BEAVER CREEK
NO DATA
NO DATA
MUSKRAT RIVER
STA OPENED
NO DATA
MATAMEK RIVER
STA OPENED
NO DATA
MOISIE RIVER
1979

Figure 1

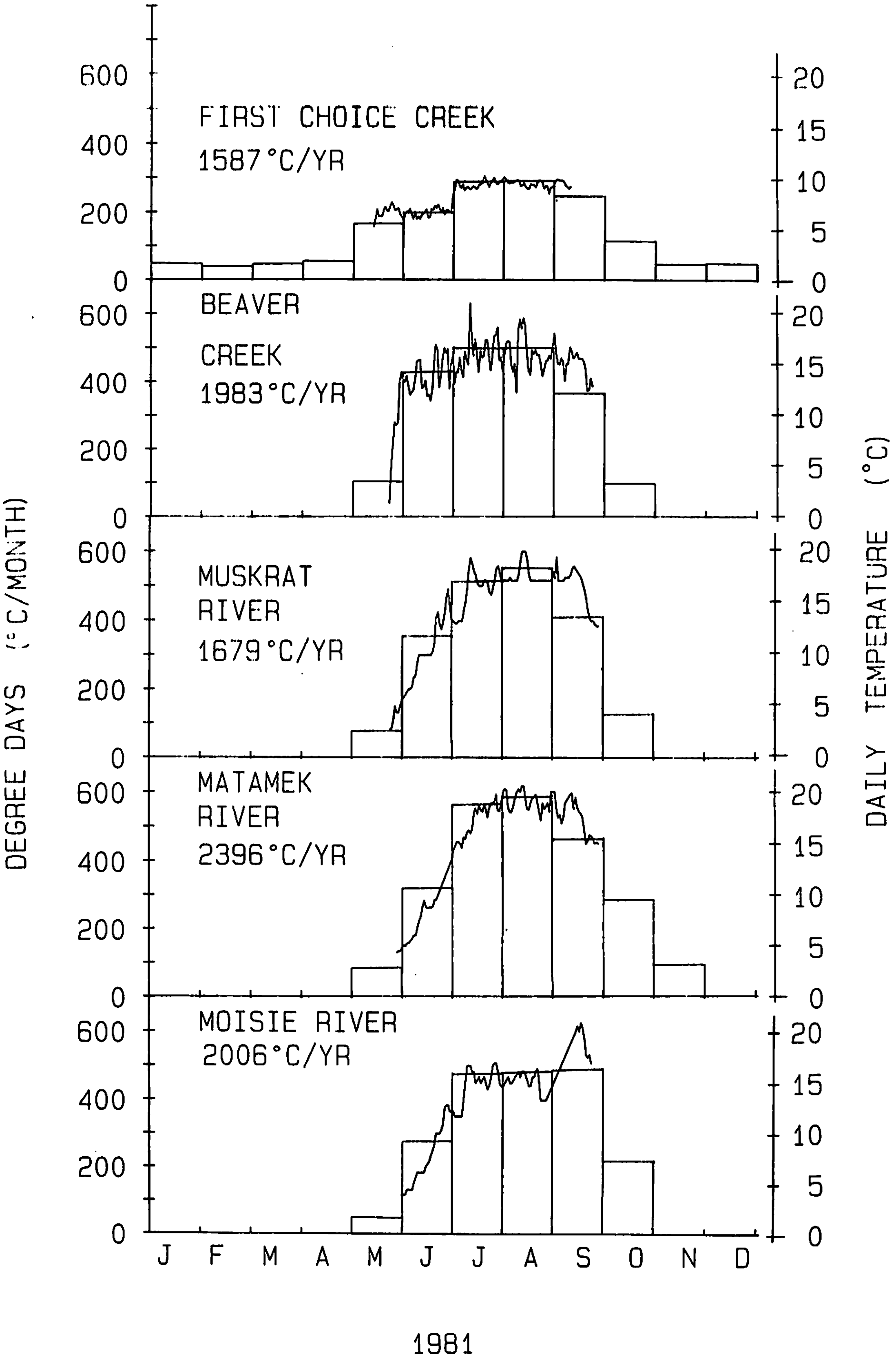

FIRST CHOICE CREEK
1587°C/YR
BEAVER
CREEK
1983°C/YR
MUSKRAT
RIVER
1679°C/YR
MATAMEK
RIVER
2396°C/YR
MOISIE RIVER
2006°C/YR
DEGREE DAYS (°C/MONTH)
DAILY TEMPERATURE (°C)
0
200
400
600
0
5
10
15
20
J
F
M
A
M
J
J
A
S
O
N
D
1981

Figure 2

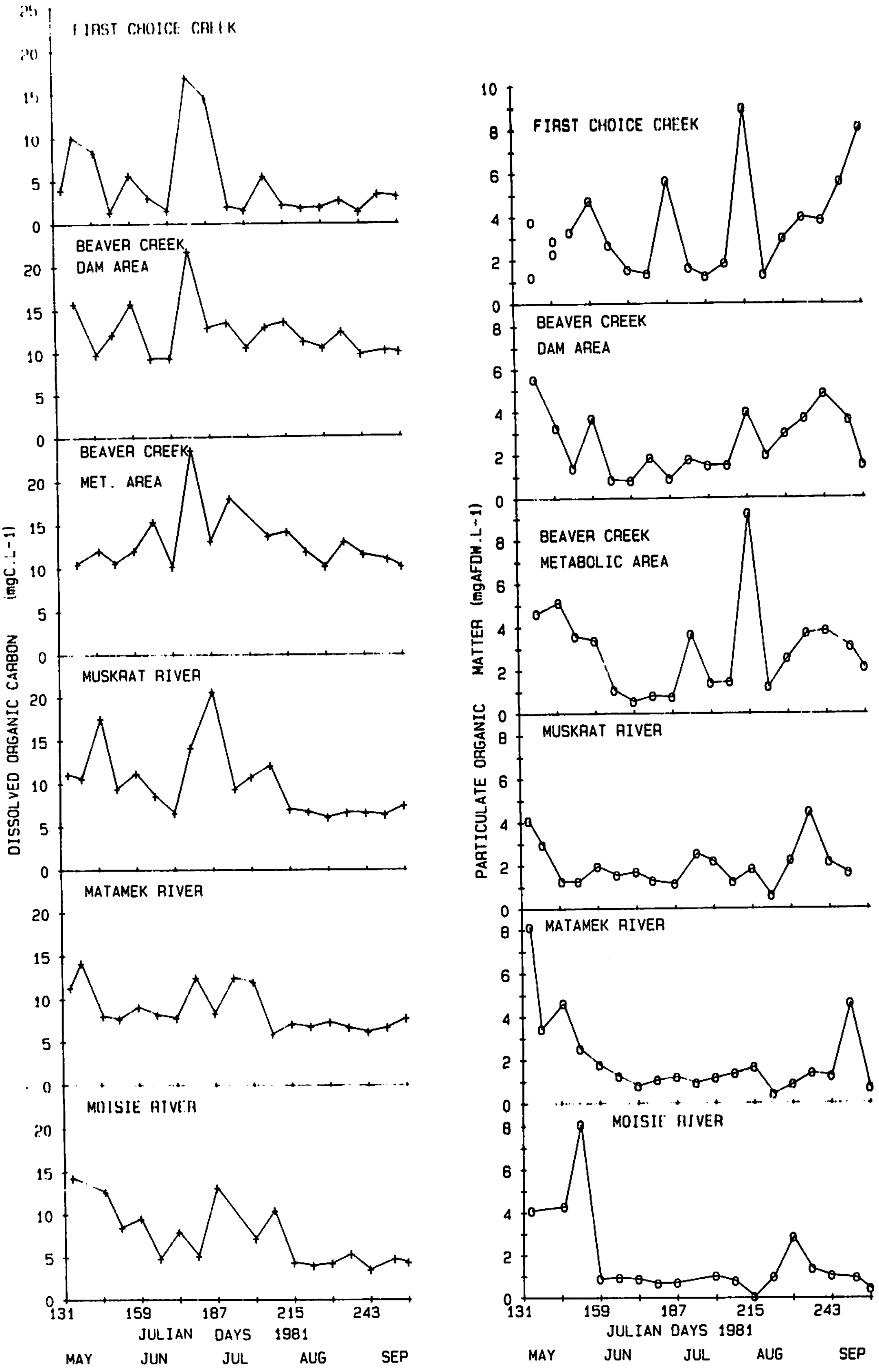

FIRST CHOICE CREEK
BEAVER CREEK DAM AREA
BEAVER CREEK MET. AREA
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
DISSOLVED ORGANIC CARBON (mgC.L-1)
0
5
10
15
20
25
131
159
187
215
243
JULIAN DAYS 1981
MAY
JUN
JUL
AUG
SEP
FIRST CHOICE CREEK
BEAVER CREEK DAM AREA
BEAVER CREEK METABOLIC AREA
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
PARTICULATE ORGANIC MATTER (mgAFDW.L-1)
0
2
4
6
8
10
131
159
187
215
243
JULIAN DAYS 1981
MAY
JUN
JUL
AUG
SEP

Figure 3

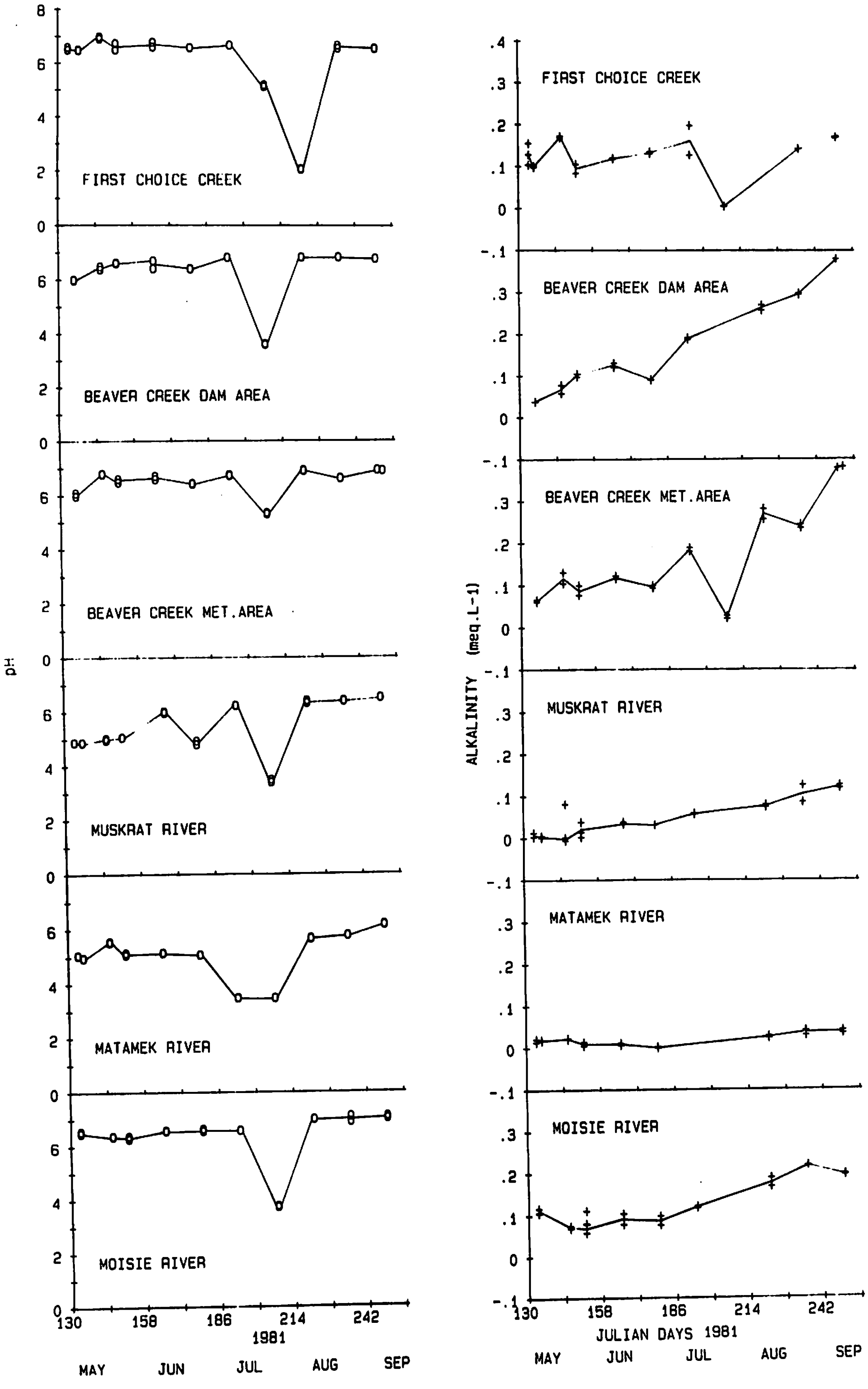

pH
FIRST CHOICE CREEK
BEAVER CREEK DAM AREA
BEAVER CREEK MET.AREA
MUSKRAT RIVER
MATAMEK RIVER
MOISIE RIVER
0
2
4
6
8
130
158
186
214
242
1981
MAY
JUN
JUL
AUG
SEP
ALKALINITY (meq.L-1)
-.1
0
.1
.2
.3
.4
JULIAN DAYS 1981

Figure 4

Table 1. Water Chemistry (mg· L^{-1}) Analyses for the Major Sampling Locations.

Date	NH_4	NO_3	NO_2	ΣN	PO_4	ΣP	Si
FIRST CHOICE CREEK							
14 May 81	.011	.119	.001	.232	.005	.007	.319
18 May 81	.002	.130	.001	.188	.005	.006	.462
1 Jun 81	.006	.092	.001	.182	.004	.005	.157
15 Jun 81	.003	.004	.001	.076	.004	.007	.140
29 Jun 81	.011	.015	.001	.084	.005	.007	.188
14 Jun 81	.004	.013	.001	.117	.004	.006	.248
27 Jul 81	.011	.008	.001	.111	.005	.007	.193
24 Aug 81	.026	.008	.001	.092	.013	.014	.461
7 Sep 81	.011	.008	.001	.082	.005	.006	1.545
2 Oct 81	.002	.003	.001	.081	.005	.006	.466
5 Nov 81	.003	.014	.002	.238	.006	.012	.497
BEAVER CREEK							
18 May 81	.004	.005	.001	.155	.001	.003	.013
1 Jun 81	.002	.005	.001	.160	.001	.002	.060
15 Jun 81	.008	.025	.001	.238	.002	.003	.108
29 Jun 81	.014	.010	.001	.235	.002	.003	.042
13 Jul 81	.020	.076	.001	.359	.001	.003	.113
27 Jul 81	.022	.101	.001	.349	.002	.003	.181
10 Aug 81	.033	.070	.001	.403	.002	.003	.176
24 Aug 81	.034	.103	.001	.352	.002	.004	.390
9 Sep 81	.035	.028	.001	.301	.002	.004	.260
1 Oct 81	.008	.007	.001	.259	.004	.007	.014
6 Nov 81	.014	.001	.001	.241	.052	.057	.058
BEAVER DAM							
18 May 81	.003	.005	.001	.182	.002	.003	.016
1 Jun 81	.005	.006	.001	.182	.001	.003	.051
15 Jun 81	.005	.011	.001	.221	.034	.040	.090
29 Jun 81	.014	.014	.001	.241	.003	.005	.039
13 Jul 81	.031	.034	.001	.320	.011	.014	.011
27 Jul 81	.017	.057	.001	.322	.002	.004	.157
10 Aug 81	.036	.101	.001	.361	.002	.003	.181
24 Aug 81	.058	.032	.001	.393	.002	.006	.307
9 Sep 81	.053	.087	.001	.316	.002	.004	.512
1 Oct 81	.007	.008	.001	.246	.003	.004	.021

Table 1. (cont).

Date	NH_4	NO_3	NO_2	ΣN	PO_4	ΣP	Si
MUSKRAT RIVER							
14 May 81	.004	.013	.001	.147	.004	.007	.013
19 May 81	.005	.016	.001	.156	.003	.005	.008
1 Jun 81	.002	.008	.001	.133	.001	.001	.016
15 Jun 81	.013	.019	.001	.152	.002	.004	.041
29 Jun 81	.019	.003	.001	.240	.003	.003	.014
14 Jul 81	.004	.003	.001	.187	.001	.003	.018
27 Jul 81	.007	.004	.001	.172	.004	.005	.009
10 Aug 81	.017	.007	.001	.187	.002	.004	.070
24 Aug 81	.011	.001	.001	.150	.002	.004	.027
7 Sep 81	.011	.003	.001	.129	.001	.002	.123
2 Oct 81	.007	.018	.001	.346	.014	.018	.011
11 Nov 81	.011	.018	.001	.188	.002	.004	.041
MATAMEK RIVER							
18 May 81	.009	.030	.001	.189	.003	.004	.012
1 Jun 81	.012	.026	.001	.225	.002	.002	.016
15 Jun 81	.010	.017	.001	.135	.002	.002	.013
29 Jun 81	.031	.012	.001	.185	.002	.002	.013
13 Jul 81	.012	.008	.001	.142	.001	.002	.008
27 Jul 81	.010	.009	.001	.122	.002	.002	.013
10 Aug 81	.010	.008	.001	.135	.001	.003	.007
24 Aug 81	.012	.005	.001	.151	.002	.003	.013
7 Sep 81	.009	.001	.001	.111	.002	.002	.014
2 Oct 81	.010	.021	.001	.027	.005	.008	.021
6 Nov 81	.009	.001	.001	.136	.027	.033	.056
MOISIE RIVER							
14 May 81	.008	.049	.001	.201	.004	.007	.044
26 May 81	.003	.032	.001	.201	.002	.003	.036
1 Jun 81	.005	.027	.001	.177	.002	.005	.052
15 Jun 81	.003	.036	.001	.182	.004	.004	.063
29 Jun 81	.010	.021	.001	.167	.002	.002	.080
13 Jun 81	.002	.026	.001	.111	.004	.004	.010
18 Jul 81	.004	.014	.001	.158	.002	.002	2.006
24 Aug 81	.014	.011	.001	.153	.020	.026	.997
7 Sep 81	.012	.008	.001	.118	.002	.002	.659
2 Oct 81	.002	.045	.001	.182	.003	.004	.035

Table 1. (cont).

Date	NH_4	NO_3	NO_2	ΣN	PO_4	ΣP	Si
MATAMEK RAIN GAUGE 2ND FALLS							
No date	.349	.413	<.001	.760	.024	.030	.001
3 Aug	.088	<.001	-	.660	.083	.100	.055
8 Aug	.170	.097	-	1.253	.236	.275	.007
9 Sep	.102	.086	-	.650	.058	.104	.004

THE ROLE OF BEAVERS IN SHAPING AQUATIC ECOSYSTEM DYNAMICS

R.J. Naiman, B. Farr, and M. Francis
Woods Hole Oceanographic Institution

and J. Melillo and J. Hobbie
Ecosystems Center, Marine Biological Laboratory

Beaver (Castor canadensis) provide an important link between terrestrial and aquatic ecosystems throughout North America. Through feeding and dam building activities they act to significantly influence the geomorphology, production dynamics, and the community structure of streams. In 1981, with funds provided by the National Science Foundation, we instigated a two year study of the effects of beaver on aquatic ecosystem dynamics. During the first field season we intensively surveyed and mapped streams in the Matamek and Moisie River watersheds for beaver activity and wood accumulations, we measured insect emergence from beaver ponds and a riffle, measured oxygen metabolism of FPOM (0.5 µm-1 mm) and CPOM (>1 mm) sediments from beaver ponds and compared it to sediment metabolism from riffles, and measured the amount of nitrogen fixation associated with beaver pond sediment and the five major wood species in the Matamek watershed.

Surveys - Preliminary results of the surveys are given in Tables 1 and 2 and Figures 1-4. We sampled 10 streams, ranging in size from 1st to 9th order. Significant beaver activity was found at all sites with the exception of First Choice Creek. Dam building was extensive in 2nd to 4th order streams, relatively rare in 5th order streams, and absent in the larger streams. In most cases strong associations were found between dam building activity and creation of high quality habitat for moose and other game species.

In addition, we compared low gradient sites in Quebec to high gradient streams in the Rocky Mountains of western Montana. There we examined 53 sites for beaver activity, either recent or historical, finding activity on >95% of the localities examined. A separate report is in preparation on this comparison.

Wood Accumulations - The amount of wood in streams can be impressive (Figs. 5-14). Particles >10 cm diameter provide nearly 40 kg AFDW/m^2 in Beaver Creek, exclusive of dams and wood buried in sediments. Other sites range between 2 and 16 kg AFDW/m^2. Wood <10 cm diameter contributes up to 3.5 kg AFDW/m^2, but is usually <2 kg AFDW/m^2.

The composition of the standing stock and the means by which it became part of the stream environment vary by stream order and level of beaver activity. Beaver usually require about 1000 kg of wood per individual per year for growth and maintenance. Each lodge averages six beavers, and in small streams (2-4th order) there may be an active lodge every 100-200 meters or less. Beaver prefer species rich in nitrogen and low in lignin which decompose rapidly (such as alder, willow, and trembling aspen). Thus, the standing crops measured represent the residual biomass accumulated over a period of years. Many faster decomposing species have undergone biotic processing (either microbial or through digestion) or have been buried in the sediments. The relative composition of the standing stock and its probable cause of deposition and shown by site in Figs. 6 to 14.

Insect Emergence - Traps were used to compare emergence from an older pond on Beaver Creek with a riffle upstream (Figs. 15 to 17). In general, the results show that (1) total biomass emerging was much greater from the riffle area throughout the summer, (2) in both areas chironomids made up only a small percentage of the total emergent weight, and (3) more insect families emerged from the riffle but the diversity (H) and equitability (H_{max}) were generally highest in the beaver pond.

Sediment Metabolism - Beaver have a significant effect on the metabolism of sediments by opening of the forest canopy (Fig. 18). This allows more light to reach the substrate, resulting in increased sediment temperatures and increased primary production by periphyton assemblages. A full analysis of this aspect will be presented in next years report.

Nitrogen Fixation - Rate of acetylene reduction by nitrogen fixing organisms colonizing river sediment and decaying wood were measured at a variety of stream sites in the Matamek River watershed. The amount of acetylene (C_2H_2) reduced to ethylene (C_2H_4) by organisms in a given time period is evidence of activity of the enzyme nitrogenase, and thus representative of the potential nitrogen fixing ability of such organisms. Quantitative amounts of ethylene produced (μmoles gAFDW^{-1} $\cdot$hr^{-1} for sediment; μmoles cm^{-2} hr^{-1} for wood samples) during field sample incubations in 5% acetylene were measured by gas chromatography (flame ionization detector).

Nitrogen fixing organisms function as a part of the nutrient recycling process of the Matamek watershed. Factors appearing to affect fixation rates include temperature, quality of substrate available for colonizing fixing organisms, depth of substrate in the water, and stream order.

Cores from older and relatively new beaver ponds were analyzed for reduction rates as a function of sediment depth. Organisms inhabiting the sediment probably constitute a relatively stable situation. Thus, any increases in fixation rate during the summer are presumably caused by environmental changes (i.e temperature) and not by new populations of nitrogen fixing organisms colonizing the substrate. Reduction rates increased over time for all core depths throughout the summer sampling period (Fig. 1). Rates for all sites at the final sample period ranged from 7×10^{-6} to 5×10^{-5} μmoles gAFDW^{-1} $\cdot$hr^{-1}. Sediment depth was not an influential variable except perhaps for a distinction between surface (aerobic) and subsurface (anaerobic) regions. Initial studies show no patterned differentiation, based on stream order or beaver activity, for reduction rates among sites per sediment sampling period (Fig. 19).

In contrast, substantial acetylene reduction rates were measured for nitrogen fixing organisms colonizing locally abundant wood species which commonly enter river systems through beaver activity. Five species of wood (black, spruce, red alder, trembling aspen, balsam fir and paper birch) placed at five sites (1st, 2nd, 3rd and 6th order streams with varying degrees of beaver activity) were analyzed for the reduction rates of organisms colonizing them. Rates were affected by fluctuations in water temperature and stream flow. An initial lag and then overall progressive increase in acetylene reduction rates for all wood species occurred throughout the sampling period (Fig. 20). Increasing populations of N_2-fixing organisms on the wood species, as well as temperature, appear to be important factors for rate increases. Final reduction levels for all species in all sites ranged from 5×10^{-4} to 7.7×10^{-3} μmoles cm^{-2} hr^{-1} (Table 3). Wood species inherently low in nitrogen (e.g., birch) consistently showed a higher level of acetylene reduction per site than species higher in nitrogen content (e.g. alder) (Fig. 20). This suggests that, in the former case, organisms are fixing the required nitrogen that is not readily available to them in the wood.

Depth of substrate and stream order appear to influence nitrogen fixation rates. Reduction levels for wood species in First Choice Creek (1st order stream without beaver activity) and Beaver Creek (2nd order stream with beaver activity) were the highest of the sampling season. Substrates being studied in these rivers were in shallow (8-30 cm) water. Wood substrates in Cran Carre Creek (3rd order stream with beaver activity) and the Matamek River (6th order stream without activity) were in relatively deep (10-20 cm) water and their subsequent reduction rates were comparatively low. First Choice Creek shows the greatest increase of acetylene reduction levels for most wood species during the sampling period (Fig. 21). First Choice Creek is known to promote rapid wood decomposition rates which could lend explanation to such high levels of fixation there.

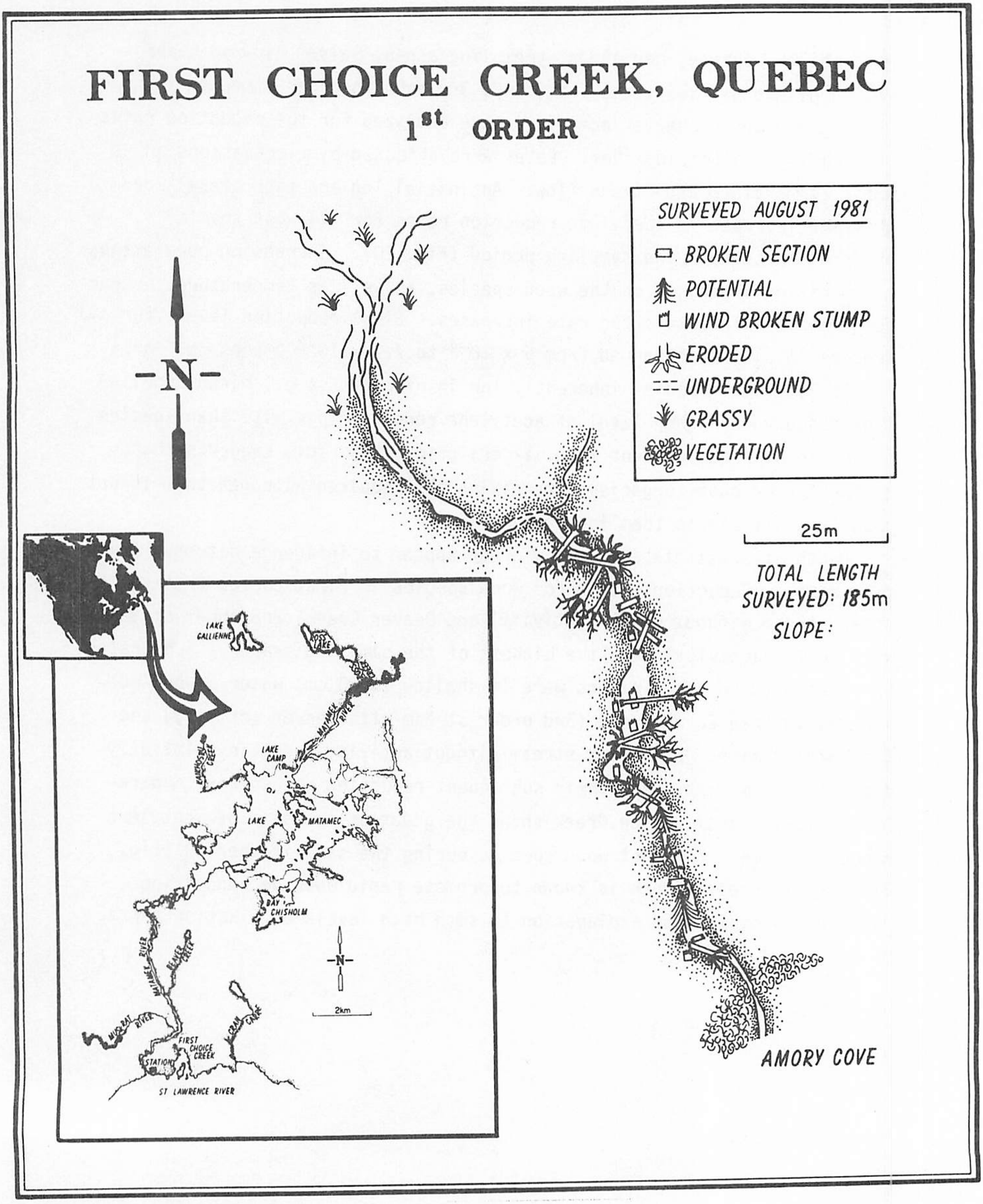

FIRST CHOICE CREEK, QUEBEC
1st ORDER
SURVEYED AUGUST 1981
BROKEN SECTION
POTENTIAL
WIND BROKEN STUMP
ERODED
UNDERGROUND
GRASSY
VEGETATION
N
25m
TOTAL LENGTH SURVEYED: 185m
SLOPE:
AMORY COVE
LAKE GALLIENNE
ROSS LAKE
MATAMEK RIVER
CREEK
LAKE CAMP
LAKE MATAMEC
BAY CHISHOLM
MATAMEK RIVER
BEAVER CREEK
MUSKRAT RIVER
FIRST CHOICE CREEK
STATION
CRAN CARRE
ST LAWRENCE RIVER
N
2km

Figure 1

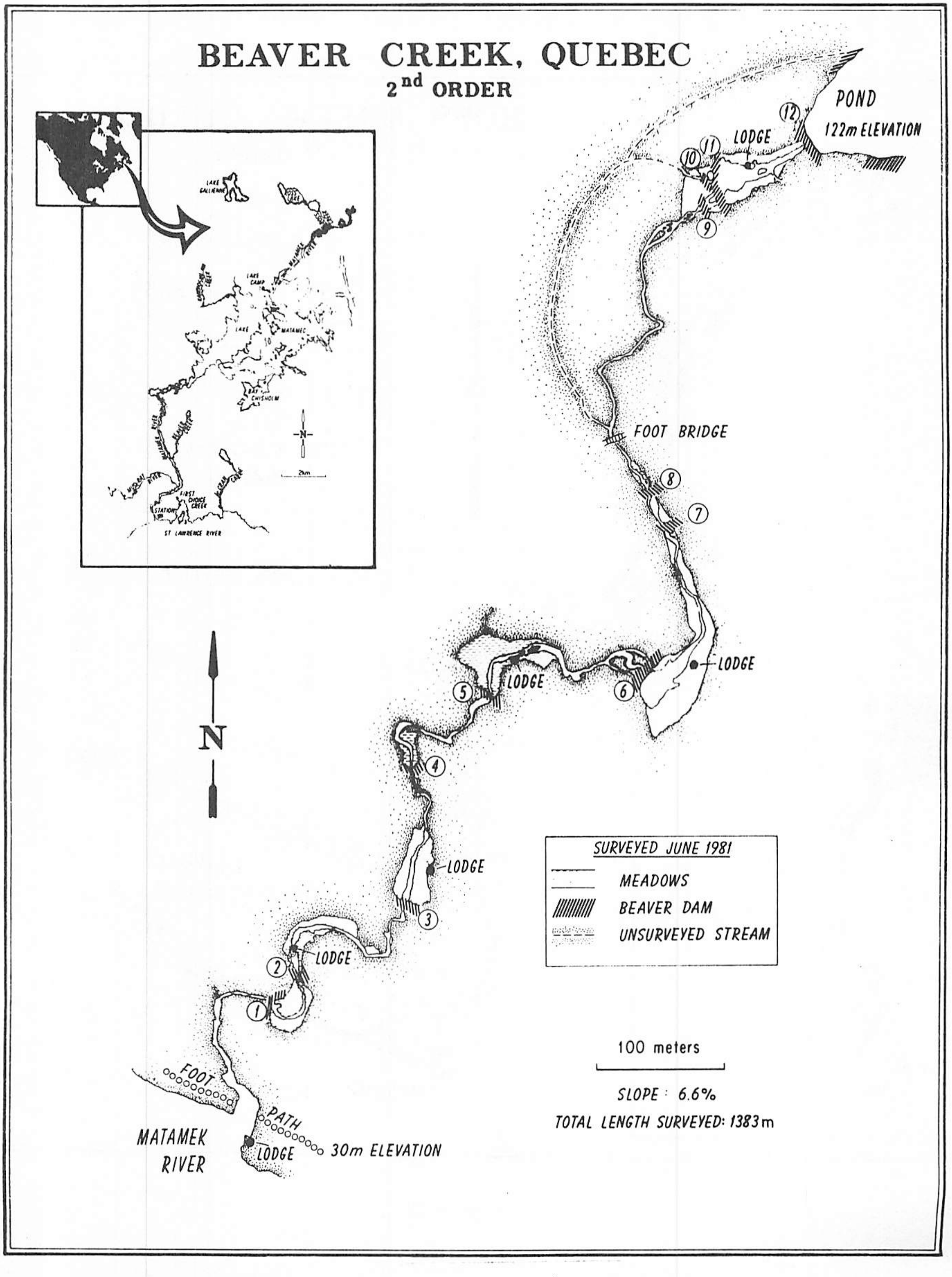

BEAVER CREEK, QUEBEC
2nd ORDER
LAKE GALLIENNE
MATAMEC RIVER
LAKE CAMP
LAKE
MATAMEC
BAY CHISHOLM
MATAMEK RIVER
BEAVER CREEK
MOISRAI RIVER
FIRST CHOICE CREEK
STATION
CRAN CREEK
ST LAWRENCE RIVER
-N-
2km
POND
122m ELEVATION
LODGE
FOOT BRIDGE
N
SURVEYED JUNE 1981
MEADOWS
BEAVER DAM
UNSURVEYED STREAM
100 meters
SLOPE : 6.6%
TOTAL LENGTH SURVEYED: 1383m
FOOT PATH
MATAMEK RIVER
30m ELEVATION
1
2
3
4
5
6
7
8
9
10
11
12

Figure 2

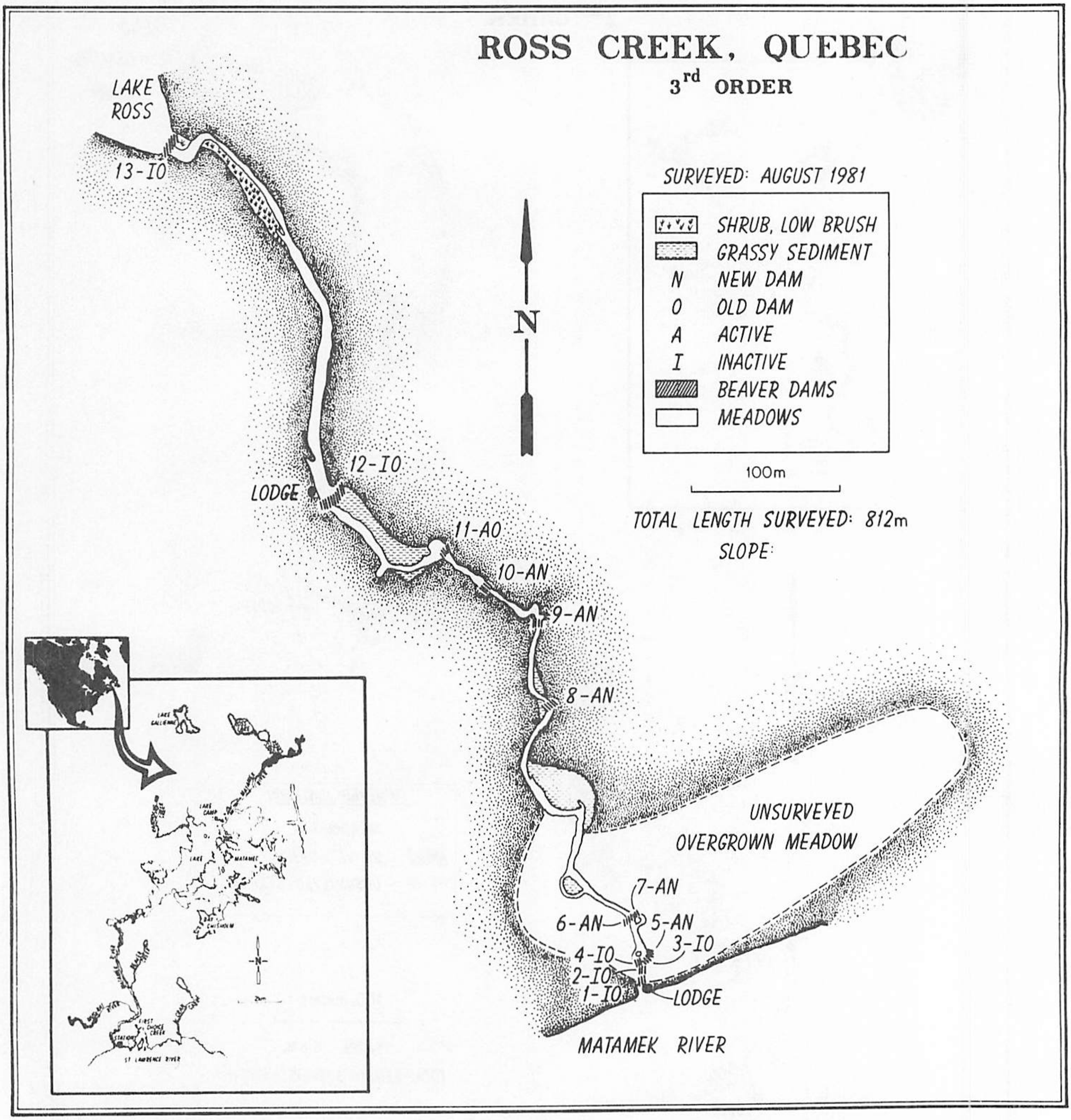

ROSS CREEK, QUEBEC
3rd ORDER
SURVEYED: AUGUST 1981
SHRUB, LOW BRUSH
GRASSY SEDIMENT
N NEW DAM
O OLD DAM
A ACTIVE
I INACTIVE
BEAVER DAMS
MEADOWS
100m
TOTAL LENGTH SURVEYED: 812m
SLOPE:
N
LAKE ROSS
13-IO
12-IO
LODGE
11-AO
10-AN
9-AN
8-AN
UNSURVEYED OVERGROWN MEADOW
7-AN
6-AN
5-AN
3-IO
4-IO
2-IO
1-IO
LODGE
MATAMEK RIVER
LAKE GALLIENNE
LAKE CAMP
LAKE
MATAMEC
BAY CHISHOLM
MATAMEK RIVER
FIRST CHOICE CREEK
STATION
ST LAWRENCE RIVER
N
2km

Figure 3

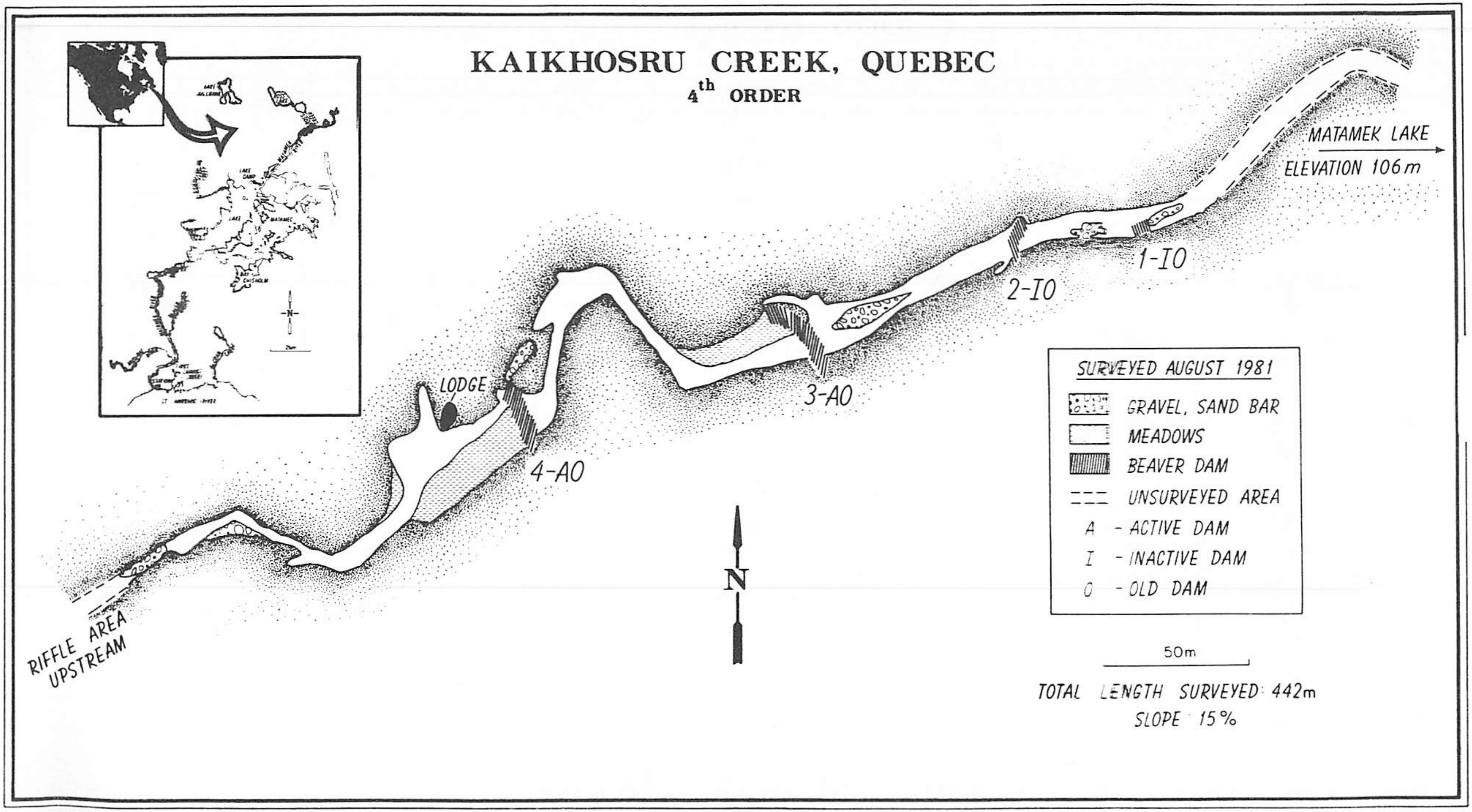

KAIKHOSRU CREEK, QUEBEC
4th ORDER
MATAMEK LAKE
ELEVATION 106 m
1-IO
2-IO
3-AO
4-AO
LODGE
RIFFLE AREA
UPSTREAM
N
SURVEYED AUGUST 1981
GRAVEL, SAND BAR
MEADOWS
BEAVER DAM
UNSURVEYED AREA
A - ACTIVE DAM
I - INACTIVE DAM
O - OLD DAM
50m
TOTAL LENGTH SURVEYED: 442m
SLOPE 15%

Figure 4

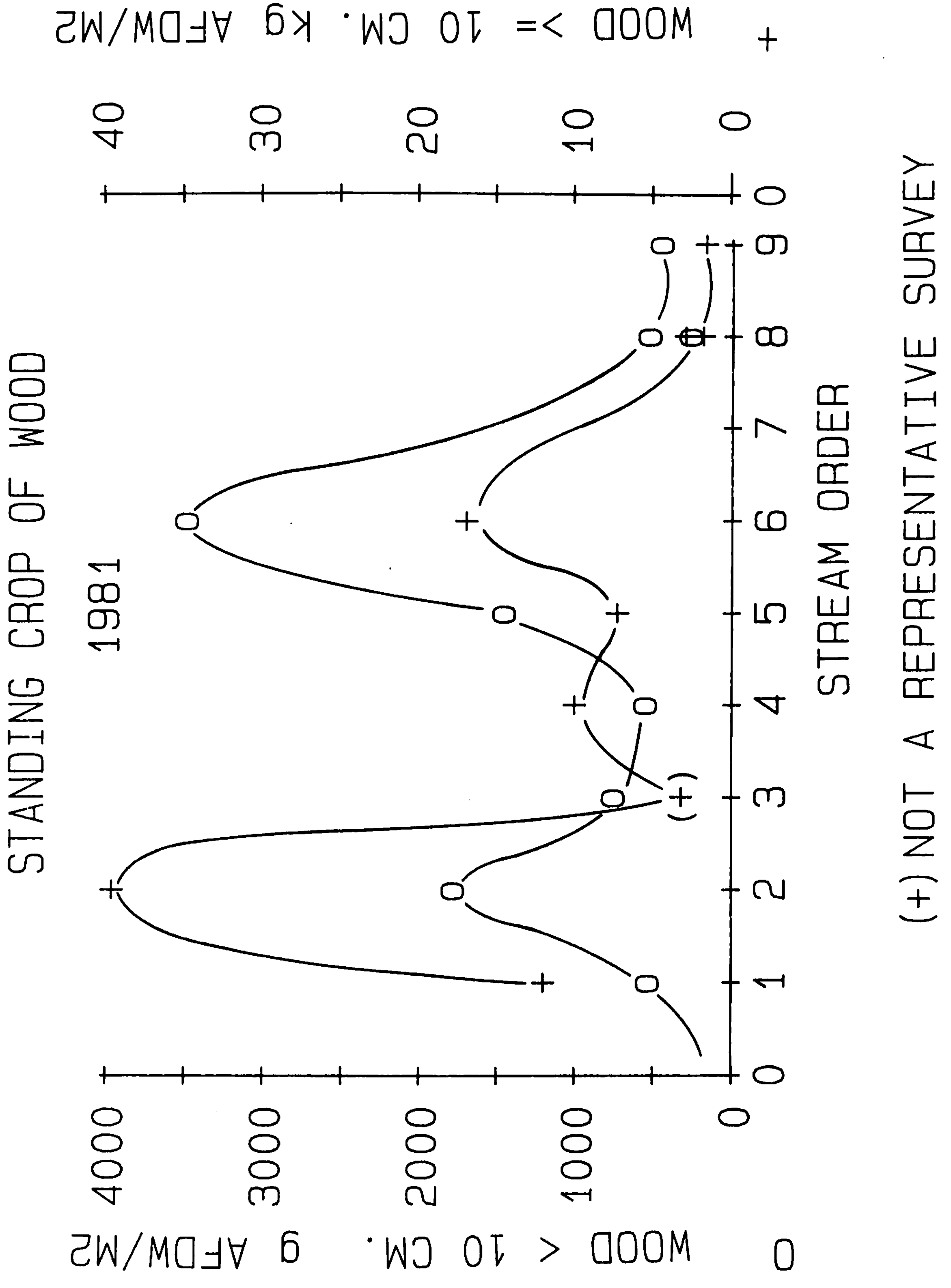

STANDING CROP OF WOOD
1981
STREAM ORDER
0
1
2
3
4
5
6
7
8
9
0
1000
2000
3000
4000
0
10
20
30
40
O WOOD < 10 CM. g AFDW/M2
+ WOOD >= 10 CM. kg AFDW/M2
(+)
(+) NOT A REPRESENTATIVE SURVEY

Figure 5

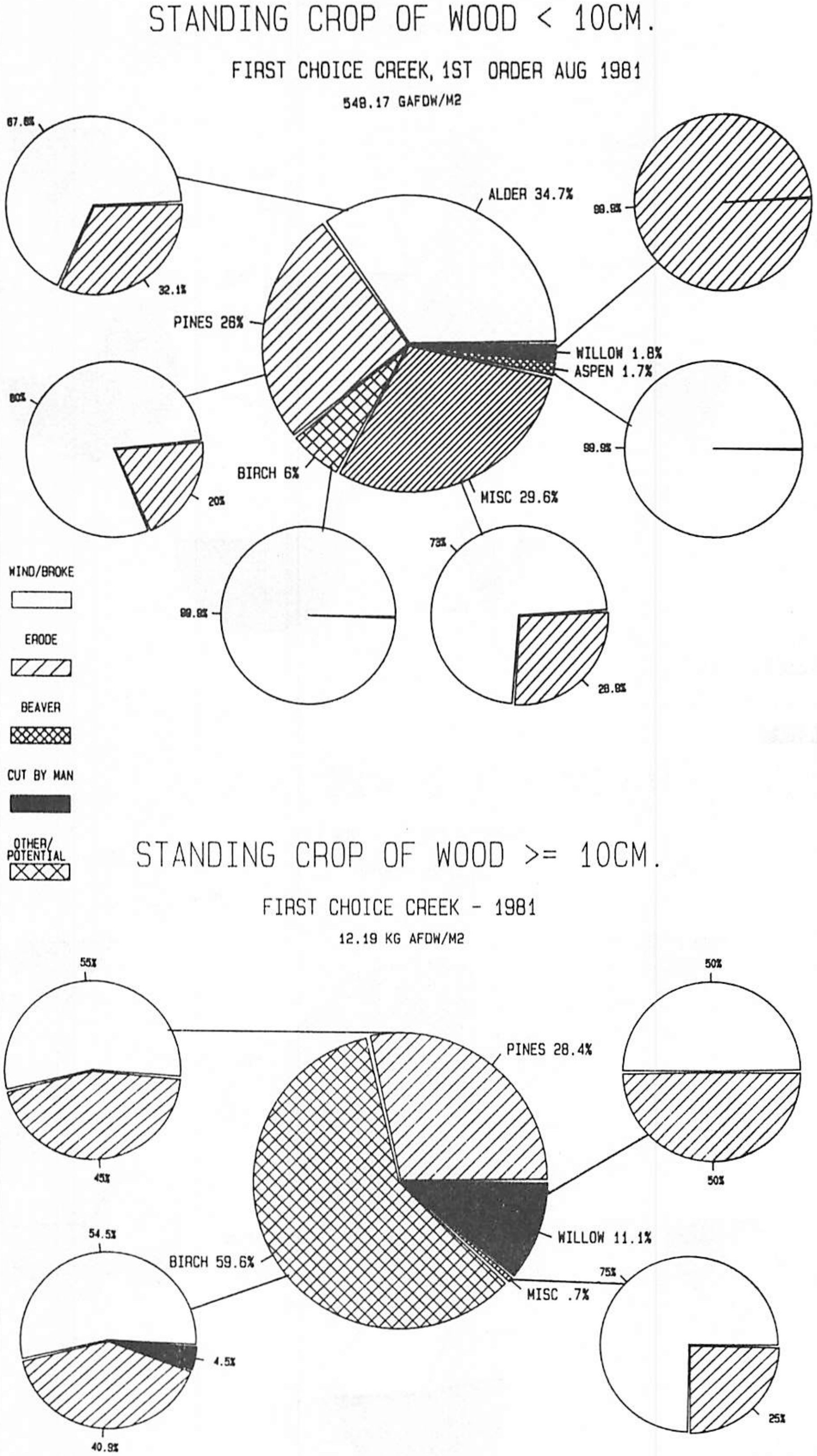

STANDING CROP OF WOOD < 10CM.
FIRST CHOICE CREEK, 1ST ORDER AUG 1981
549.17 GAFDW/M2
67.8%
32.1%
ALDER 34.7%
99.9%
PINES 26%
WILLOW 1.8%
ASPEN 1.7%
80%
20%
99.9%
BIRCH 6%
MISC 29.6%
73%
99.9%
26.9%
WIND/BROKE
ERODE
BEAVER
CUT BY MAN
OTHER/
POTENTIAL
STANDING CROP OF WOOD >= 10CM.
FIRST CHOICE CREEK - 1981
12.19 KG AFDW/M2
55%
50%
PINES 28.4%
45%
50%
54.5%
WILLOW 11.1%
BIRCH 59.6%
MISC .7%
75%
4.5%
25%
40.9%

Figure 6

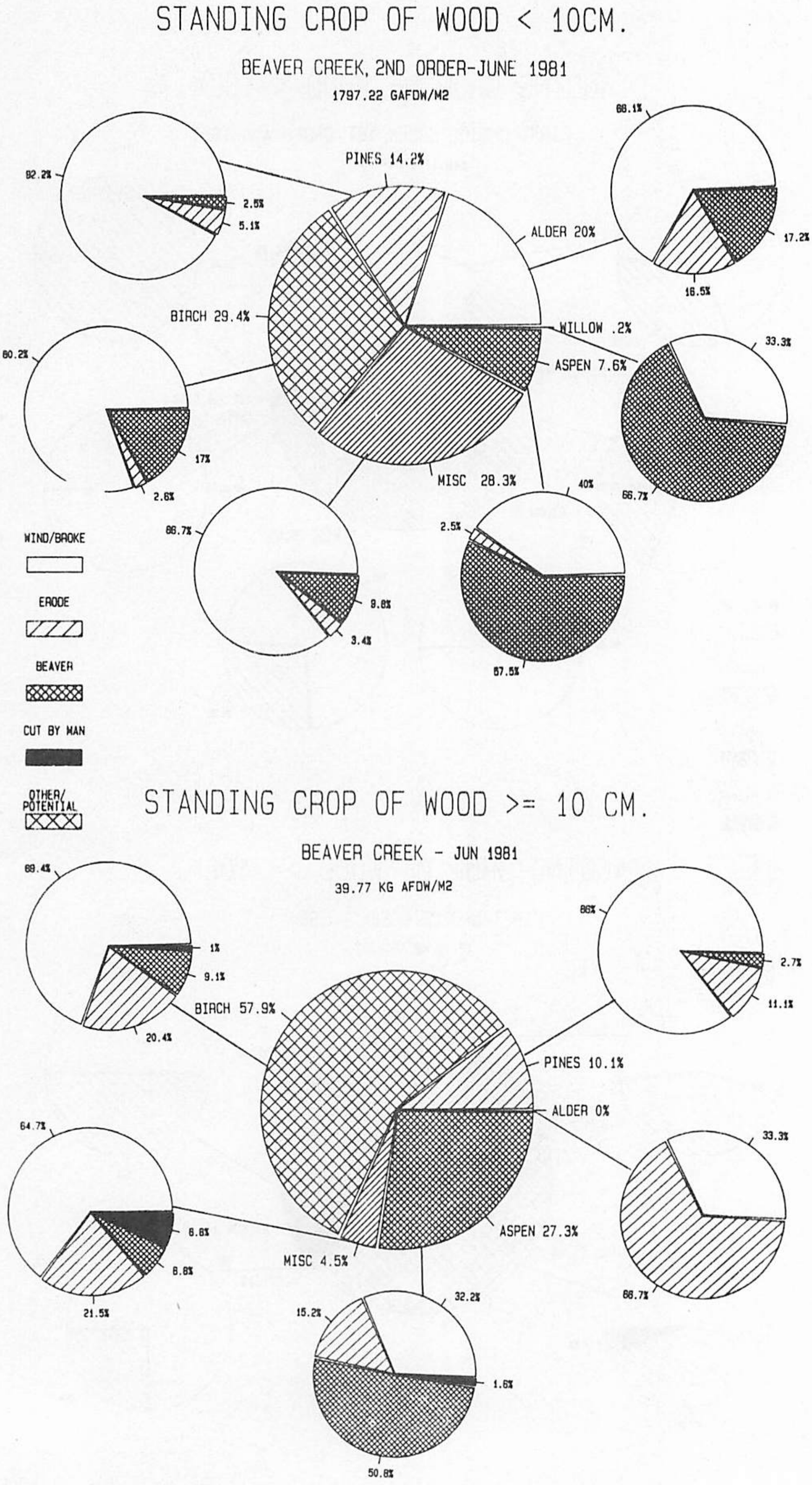
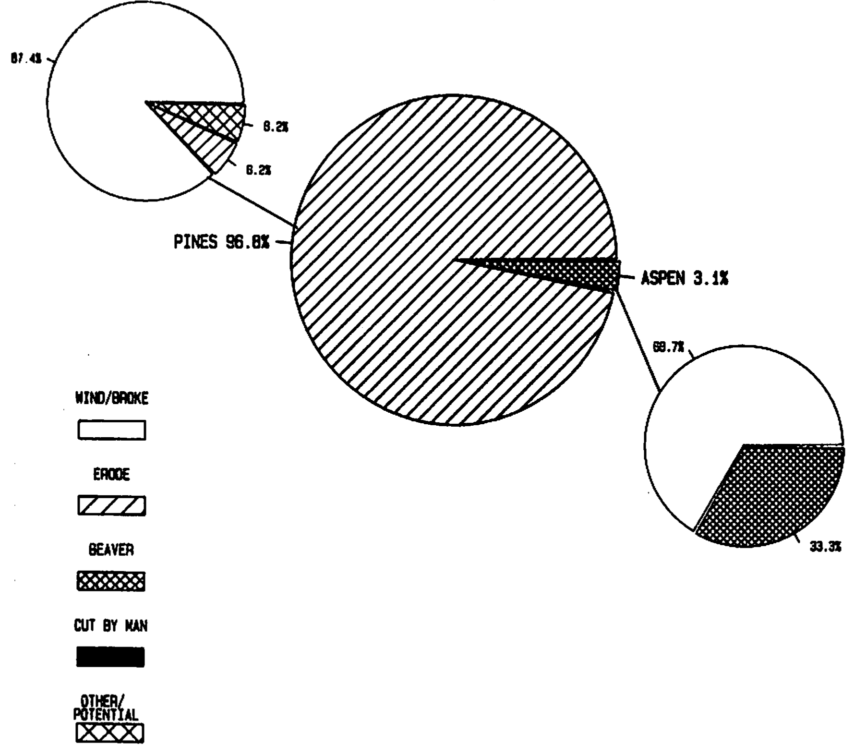

STANDING CROP OF WOOD < 10CM.
BEAVER CREEK, 2ND ORDER-JUNE 1981
1797.22 GAFDW/M2
PINES 14.2%
ALDER 20%
WILLOW .2%
ASPEN 7.6%
MISC 28.3%
BIRCH 29.4%
92.2%
2.5%
5.1%
66.1%
17.2%
16.5%
80.2%
17%
2.6%
33.3%
66.7%
86.7%
9.8%
3.4%
40%
2.5%
57.5%
WIND/BROKE
ERODE
BEAVER
CUT BY MAN
OTHER/POTENTIAL
STANDING CROP OF WOOD >= 10 CM.
BEAVER CREEK - JUN 1981
39.77 KG AFDW/M2
BIRCH 57.9%
PINES 10.1%
ALDER 0%
ASPEN 27.3%
MISC 4.5%
69.4%
1%
9.1%
20.4%
86%
2.7%
11.1%
64.7%
6.8%
6.8%
21.5%
33.3%
66.7%
32.2%
15.2%
1.6%
50.8%

Figure 7

STANDING CROP OF WOOD < 10CM.

ROSS CREEK, 3RD ORDER-AUG 1981

768.13 GAFDW/M2



STANDING CROP OF WOOD >= 10 CM.

ROSS CREEK - AUG 1981

3.40 KG AFDW/M2

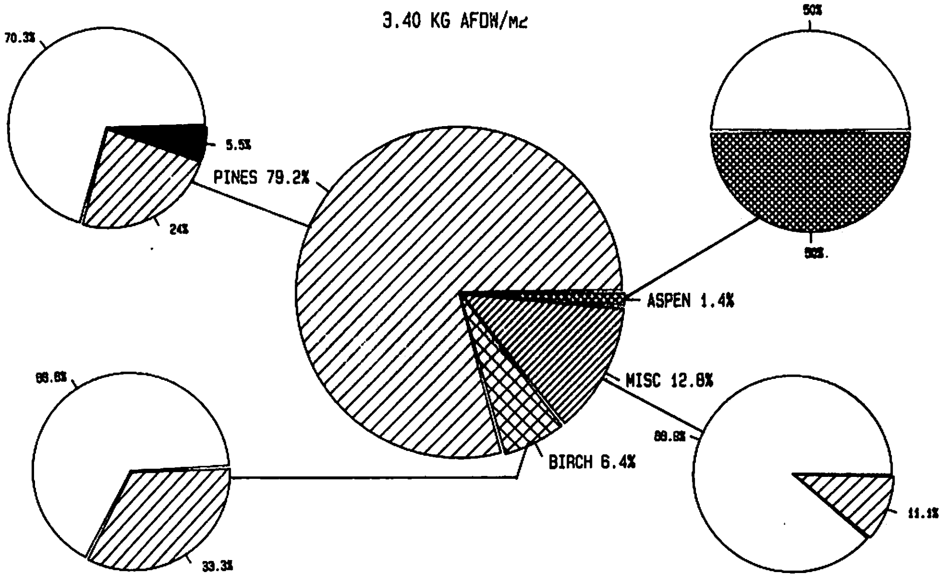


Figure 8

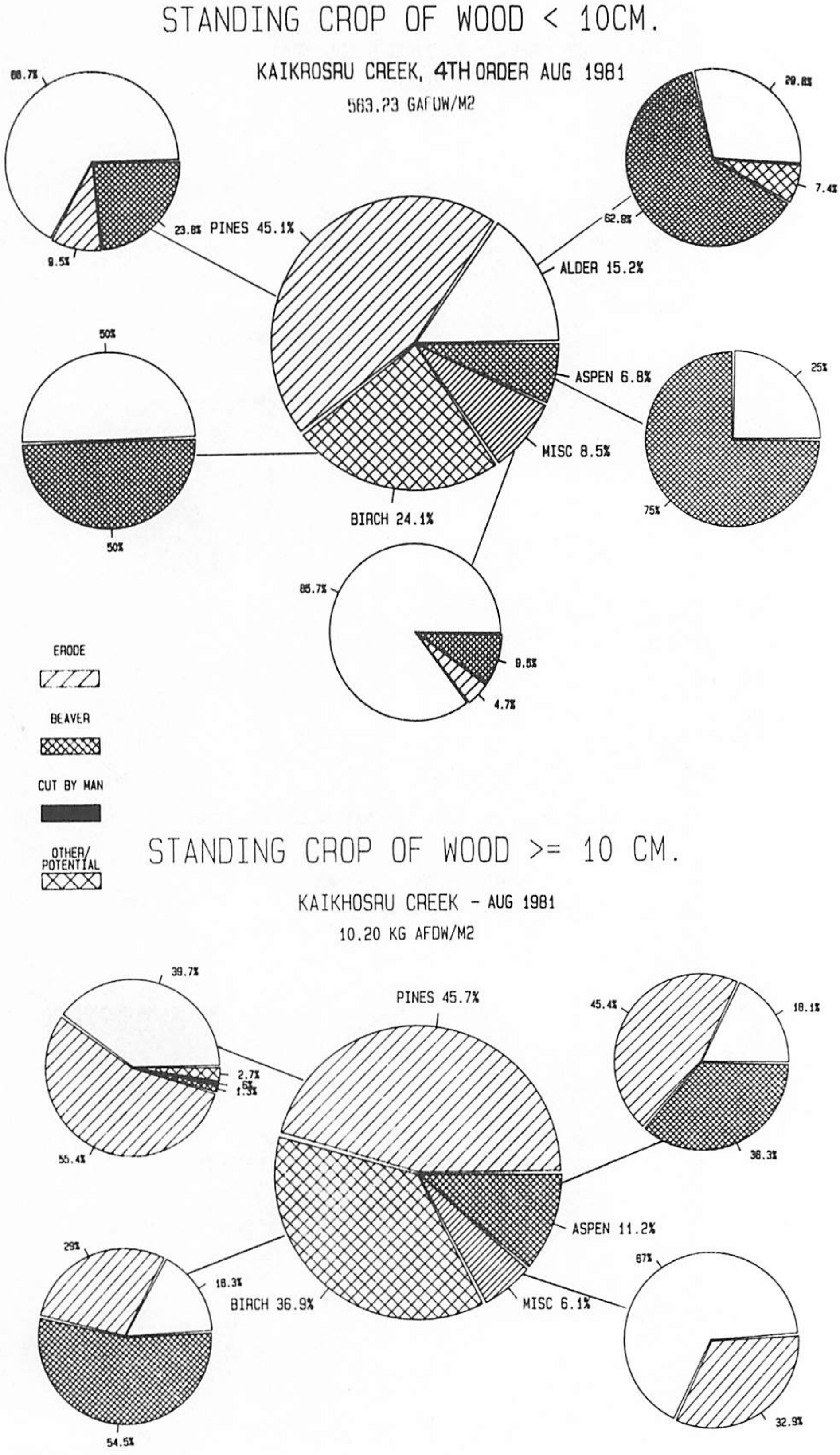

STANDING CROP OF WOOD < 10CM.
KAIKROSRU CREEK, 4TH ORDER AUG 1981
563.23 GAFDW/M2
66.7%
23.8%
9.5%
PINES 45.1%
29.8%
7.4%
62.8%
ALDER 15.2%
50%
50%
ASPEN 6.8%
25%
75%
MISC 8.5%
BIRCH 24.1%
85.7%
9.5%
4.7%
ERODE
BEAVER
CUT BY MAN
OTHER/
POTENTIAL
STANDING CROP OF WOOD >= 10 CM.
KAIKHOSRU CREEK - AUG 1981
10.20 KG AFDW/M2
39.7%
2.7%
.6%
1.3%
55.4%
PINES 45.7%
45.4%
18.1%
36.3%
ASPEN 11.2%
29%
16.3%
54.5%
BIRCH 36.9%
MISC 6.1%
67%
32.9%

Figure 9

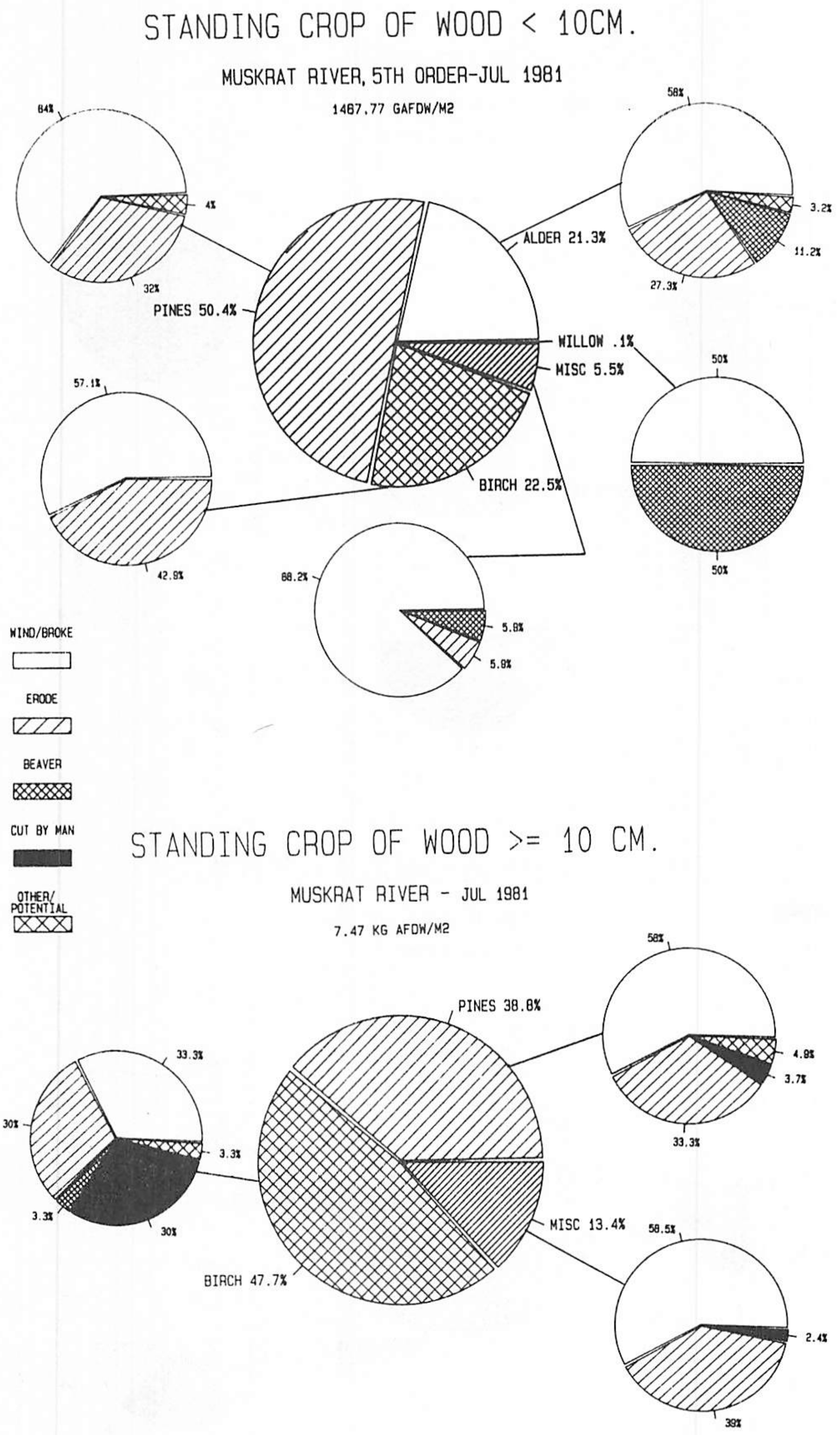

STANDING CROP OF WOOD < 10CM.
MUSKRAT RIVER, 5TH ORDER-JUL 1981
1487.77 GAFDW/M2
64%
4%
32%
PINES 50.4%
58%
3.2%
11.2%
27.3%
ALDER 21.3%
WILLOW .1%
MISC 5.5%
50%
50%
57.1%
42.9%
BIRCH 22.5%
88.2%
5.9%
5.9%
WIND/BROKE
ERODE
BEAVER
CUT BY MAN
OTHER/
POTENTIAL
STANDING CROP OF WOOD >= 10 CM.
MUSKRAT RIVER - JUL 1981
7.47 KG AFDW/M2
58%
PINES 38.8%
4.9%
3.7%
33.3%
33.3%
30%
3.3%
3.3%
30%
MISC 13.4%
58.5%
2.4%
39%
BIRCH 47.7%

Figure 10

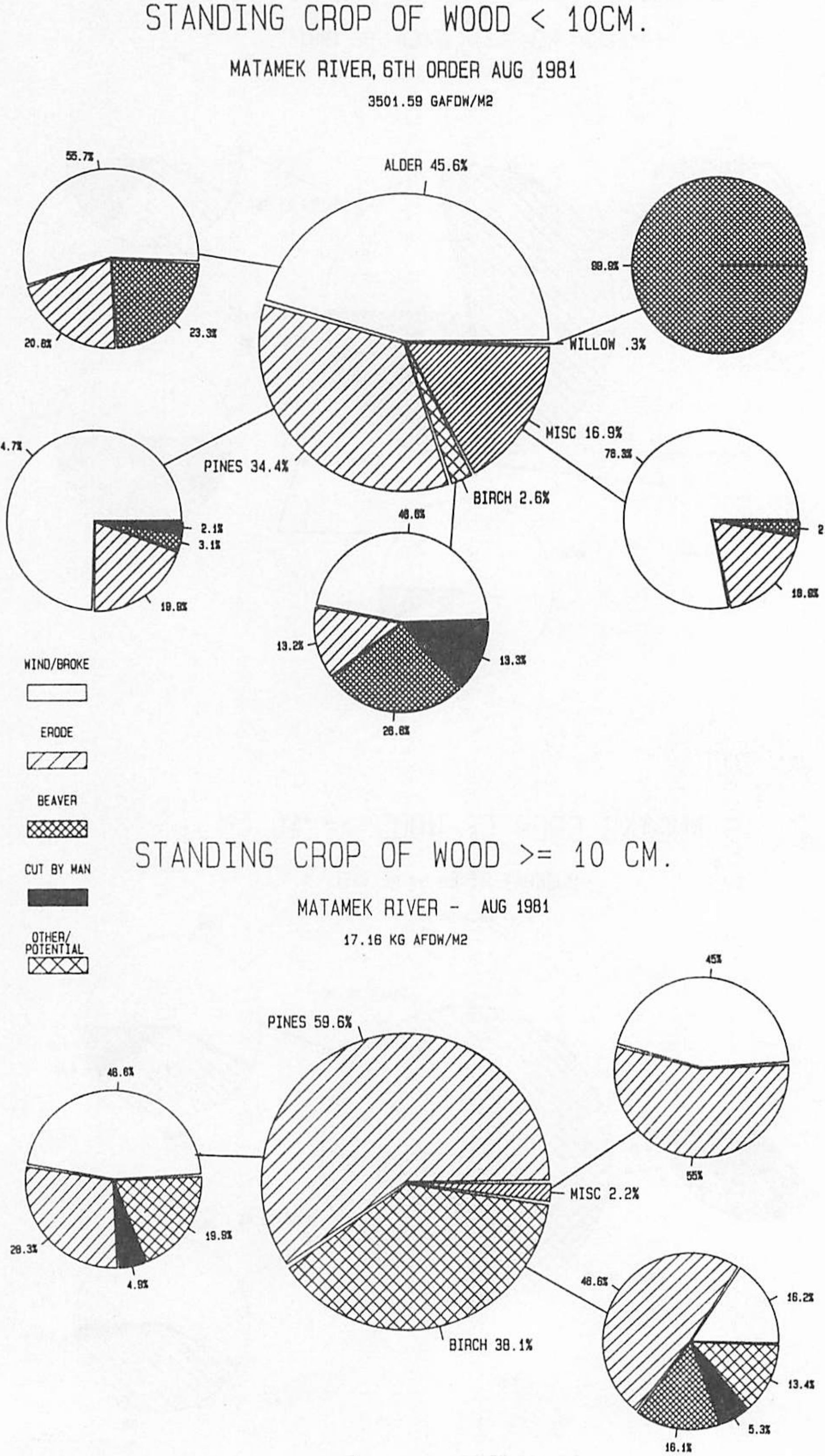

STANDING CROP OF WOOD < 10CM.
MATAMEK RIVER, 6TH ORDER AUG 1981
3501.59 GAFDW/M2
ALDER 45.6%
55.7%
20.8%
23.3%
99.9%
WILLOW .3%
MISC 16.9%
PINES 34.4%
BIRCH 2.6%
74.7%
2.1%
3.1%
19.8%
78.3%
2.7%
18.8%
46.6%
13.2%
13.3%
26.6%
WIND/BROKE
ERODE
BEAVER
CUT BY MAN
OTHER/ POTENTIAL
STANDING CROP OF WOOD >= 10 CM.
MATAMEK RIVER - AUG 1981
17.16 KG AFDW/M2
PINES 59.6%
MISC 2.2%
BIRCH 38.1%
46.6%
28.3%
4.9%
19.9%
45%
55%
48.6%
16.2%
13.4%
5.3%
16.1%

Figure 11

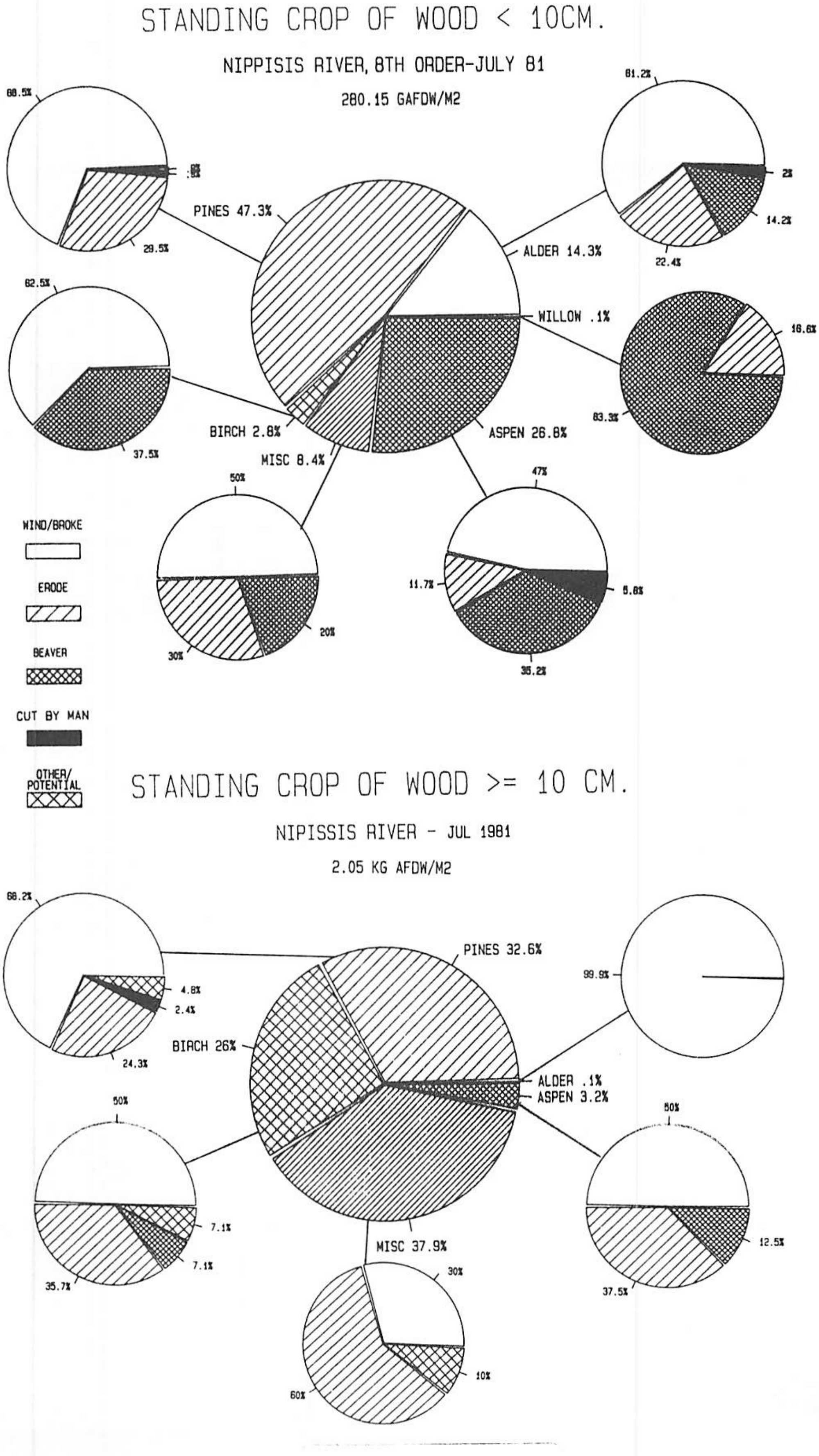

STANDING CROP OF WOOD < 10CM.
NIPPISIS RIVER, 8TH ORDER-JULY 81
280.15 GAFDW/M2
68.5%
.8%
29.5%
PINES 47.3%
81.2%
2%
14.2%
22.4%
ALDER 14.3%
WILLOW .1%
16.6%
83.3%
62.5%
37.5%
BIRCH 2.8%
MISC 8.4%
ASPEN 26.8%
50%
30%
20%
47%
11.7%
5.8%
35.2%
WIND/BROKE
ERODE
BEAVER
CUT BY MAN
OTHER/POTENTIAL
STANDING CROP OF WOOD >= 10 CM.
NIPISSIS RIVER - JUL 1981
2.05 KG AFDW/M2
68.2%
4.8%
2.4%
24.3%
PINES 32.6%
99.9%
BIRCH 26%
ALDER .1%
ASPEN 3.2%
50%
7.1%
7.1%
35.7%
50%
12.5%
37.5%
MISC 37.9%
30%
10%
60%

Figure 12

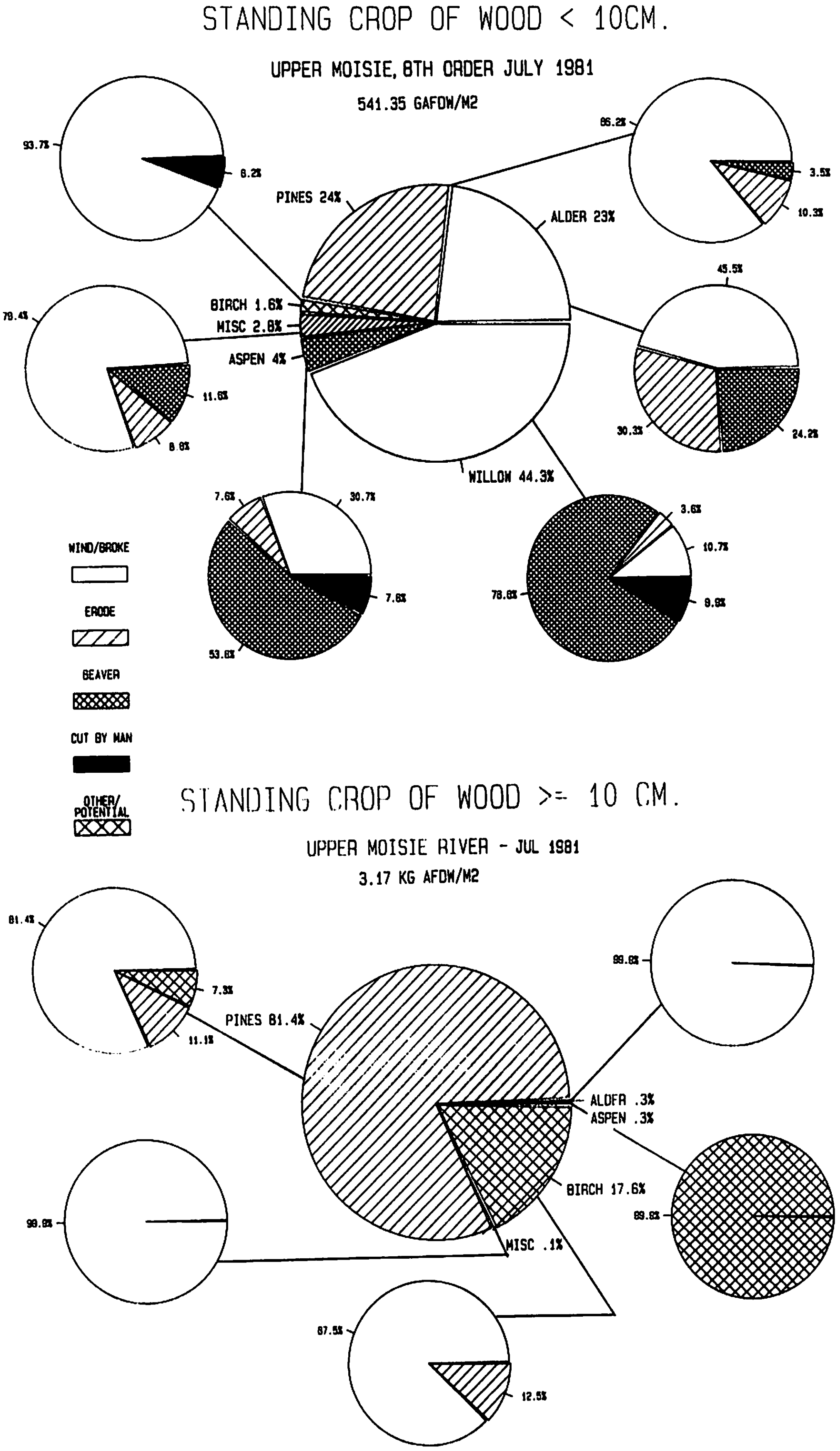

STANDING CROP OF WOOD < 10CM.
UPPER MOISIE, 8TH ORDER JULY 1981
541.35 GAFDW/M2
93.7%
6.2%
PINES 24%
86.2%
3.5%
10.3%
ALDER 23%
45.5%
30.3%
24.2%
BIRCH 1.6%
MISC 2.8%
ASPEN 4%
79.4%
11.6%
8.8%
WILLOW 44.3%
7.6%
30.7%
7.6%
53.8%
3.6%
10.7%
78.8%
9.9%
WIND/BROKE
ERODE
BEAVER
CUT BY MAN
OTHER/ POTENTIAL
STANDING CROP OF WOOD >= 10 CM.
UPPER MOISIE RIVER - JUL 1981
3.17 KG AFDW/M2
81.4%
7.3%
11.1%
PINES 81.4%
99.8%
ALDER .3%
ASPEN .3%
BIRCH 17.6%
99.8%
99.8%
MISC .1%
87.5%
12.5%

Figure 13

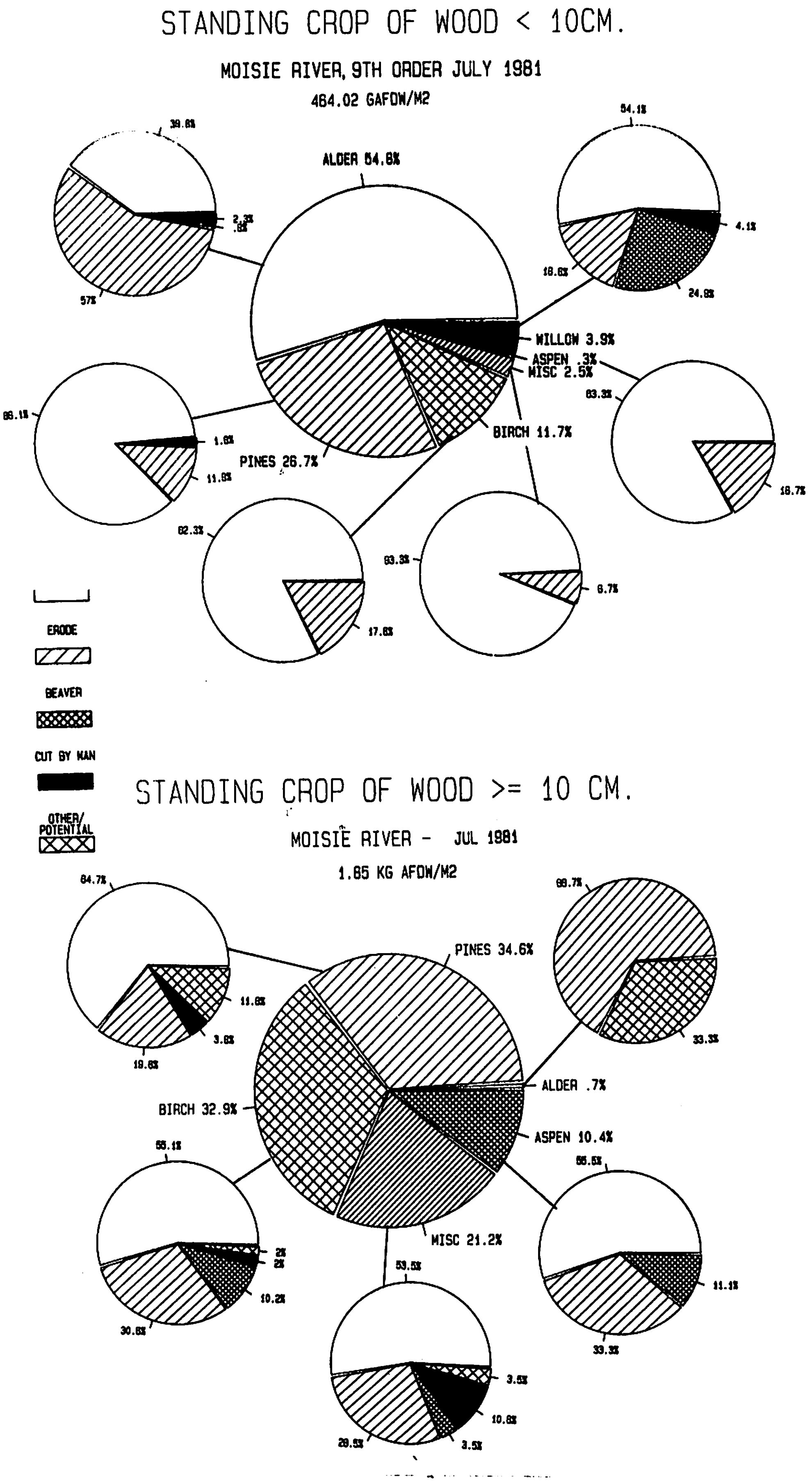

STANDING CROP OF WOOD < 10CM.
MOISIE RIVER, 9TH ORDER JULY 1981
464.02 GAFDW/M2
ALDER 54.8%
WILLOW 3.9%
ASPEN .3%
MISC 2.5%
BIRCH 11.7%
PINES 26.7%
39.8%
2.3%
.8%
57%
54.1%
4.1%
16.8%
24.9%
86.1%
1.6%
11.9%
83.3%
16.7%
82.3%
17.6%
93.3%
6.7%
ERODE
BEAVER
CUT BY MAN
OTHER/
POTENTIAL
STANDING CROP OF WOOD >= 10 CM.
MOISIE RIVER - JUL 1981
1.85 KG AFDW/M2
PINES 34.6%
ALDER .7%
ASPEN 10.4%
MISC 21.2%
BIRCH 32.9%
64.7%
11.8%
3.9%
19.6%
66.7%
33.3%
55.1%
2%
2%
10.2%
30.6%
53.5%
3.5%
10.6%
3.5%
28.9%
55.5%
11.1%
33.3%

Figure 14

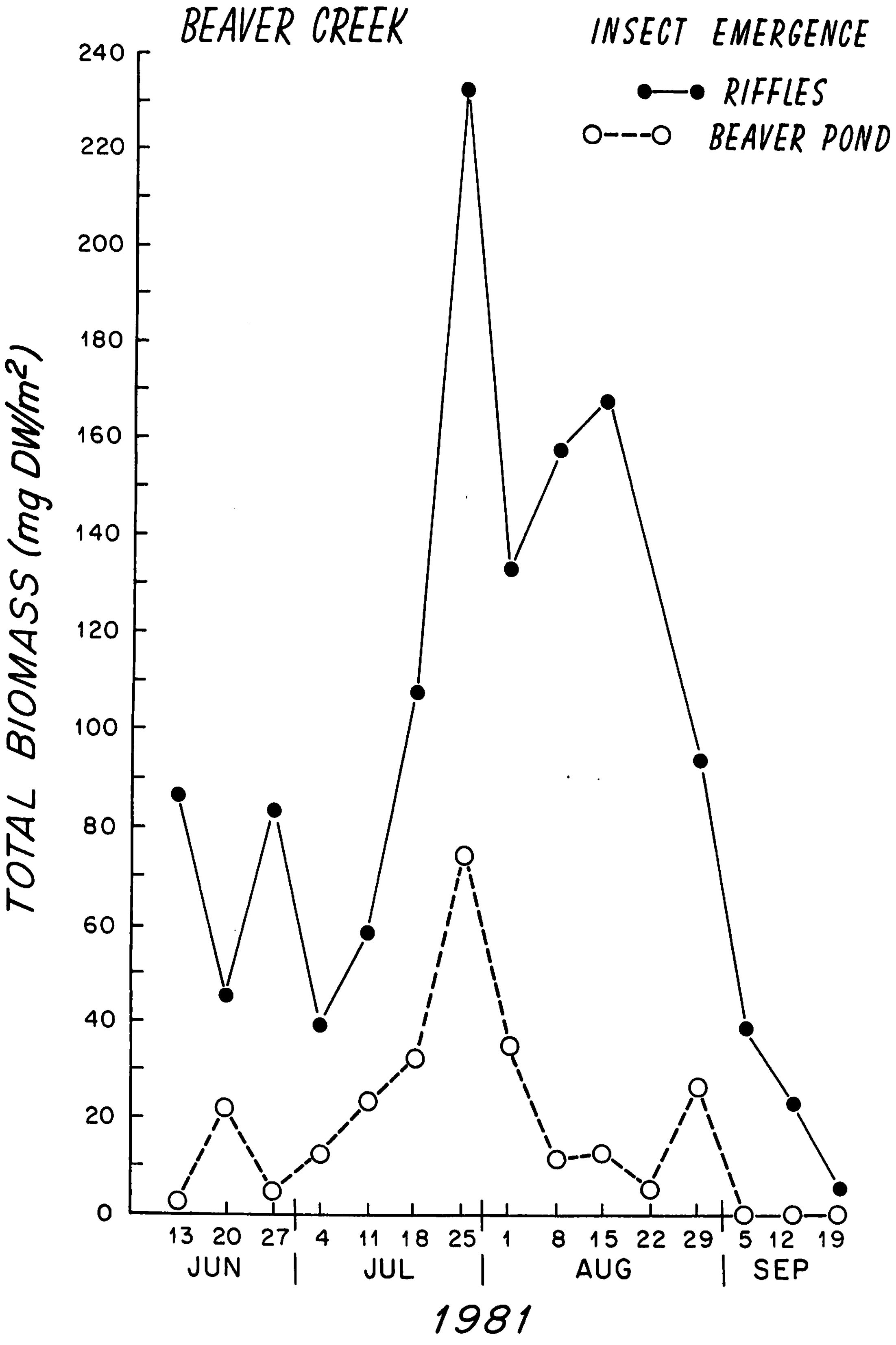

BEAVER CREEK
INSECT EMERGENCE
●—● RIFFLES
○---○ BEAVER POND
TOTAL BIOMASS (mg DW/m²)
240
220
200
180
160
140
120
100
80
60
40
20
0
13
20
27
4
11
18
25
1
8
15
22
29
5
12
19
JUN
JUL
AUG
SEP
1981

Figure 15

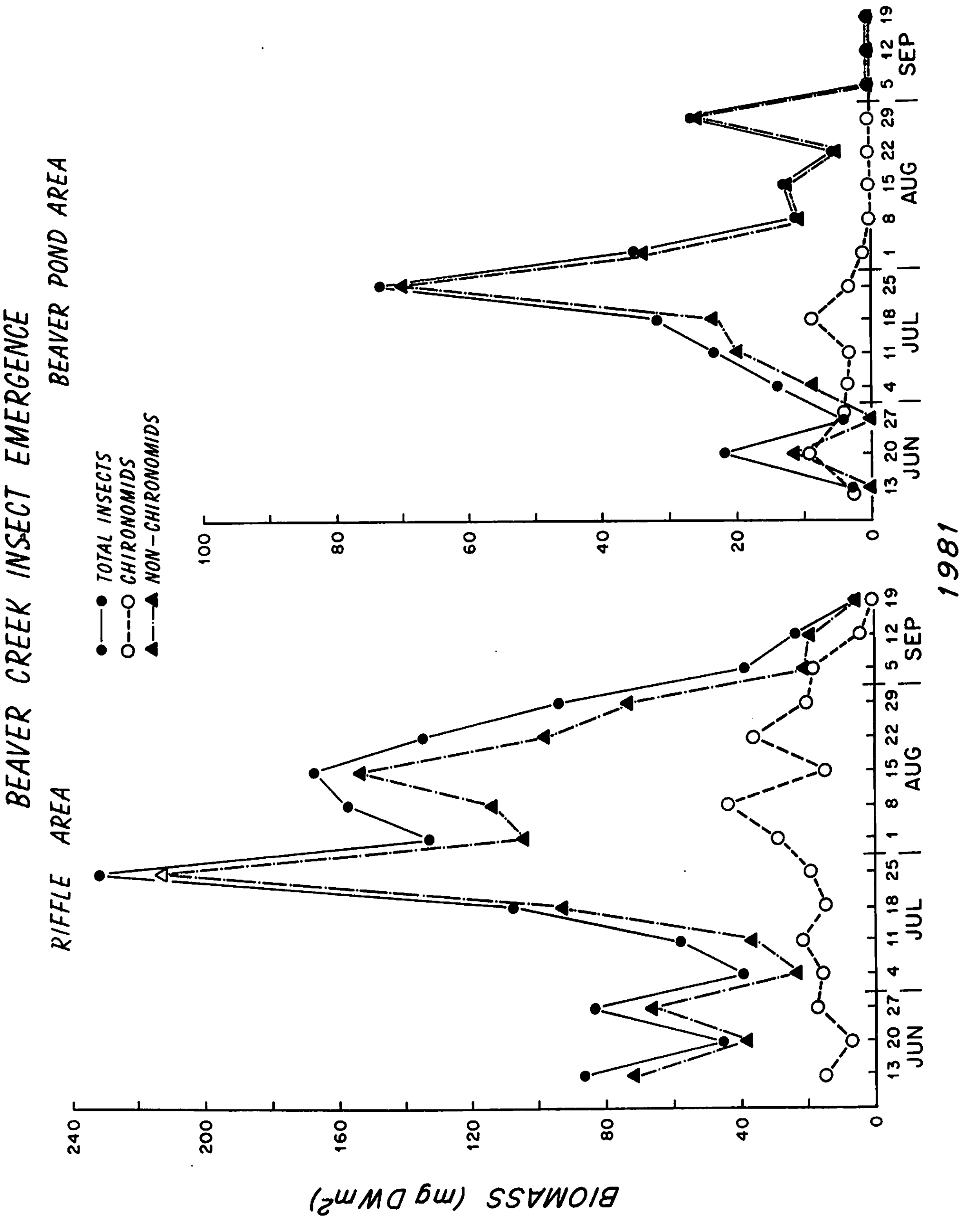

BEAVER CREEK INSECT EMERGENCE
RIFFLE AREA
BEAVER POND AREA
TOTAL INSECTS
CHIRONOMIDS
NON-CHIRONOMIDS
BIOMASS (mg DW m²)
240
200
160
120
80
40
0
100
80
60
40
20
0
13 20 27
JUN
4 11 18 25
JUL
1 8 15 22 29
AUG
5 12 19
SEP
1981

Figure 16

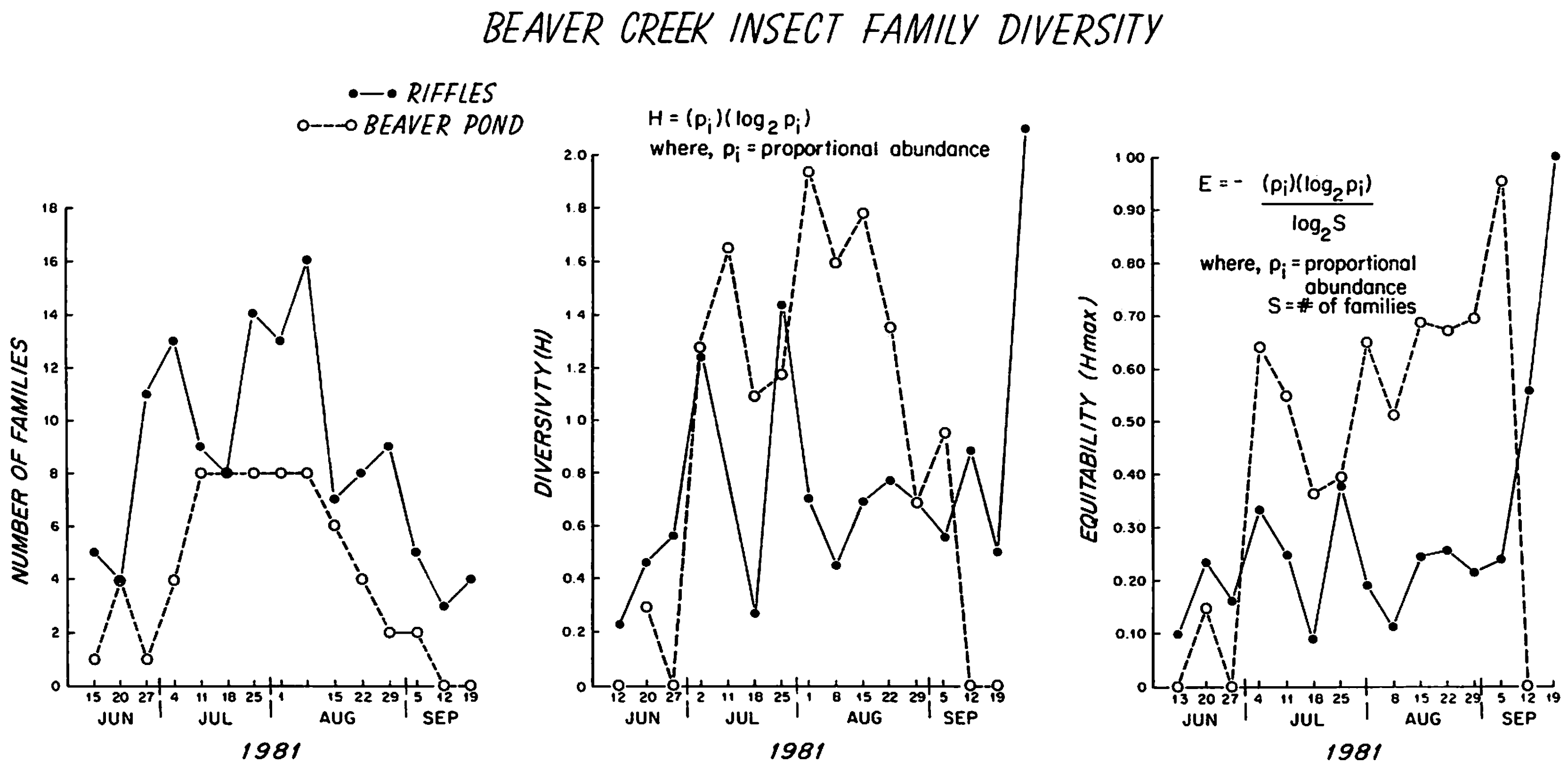
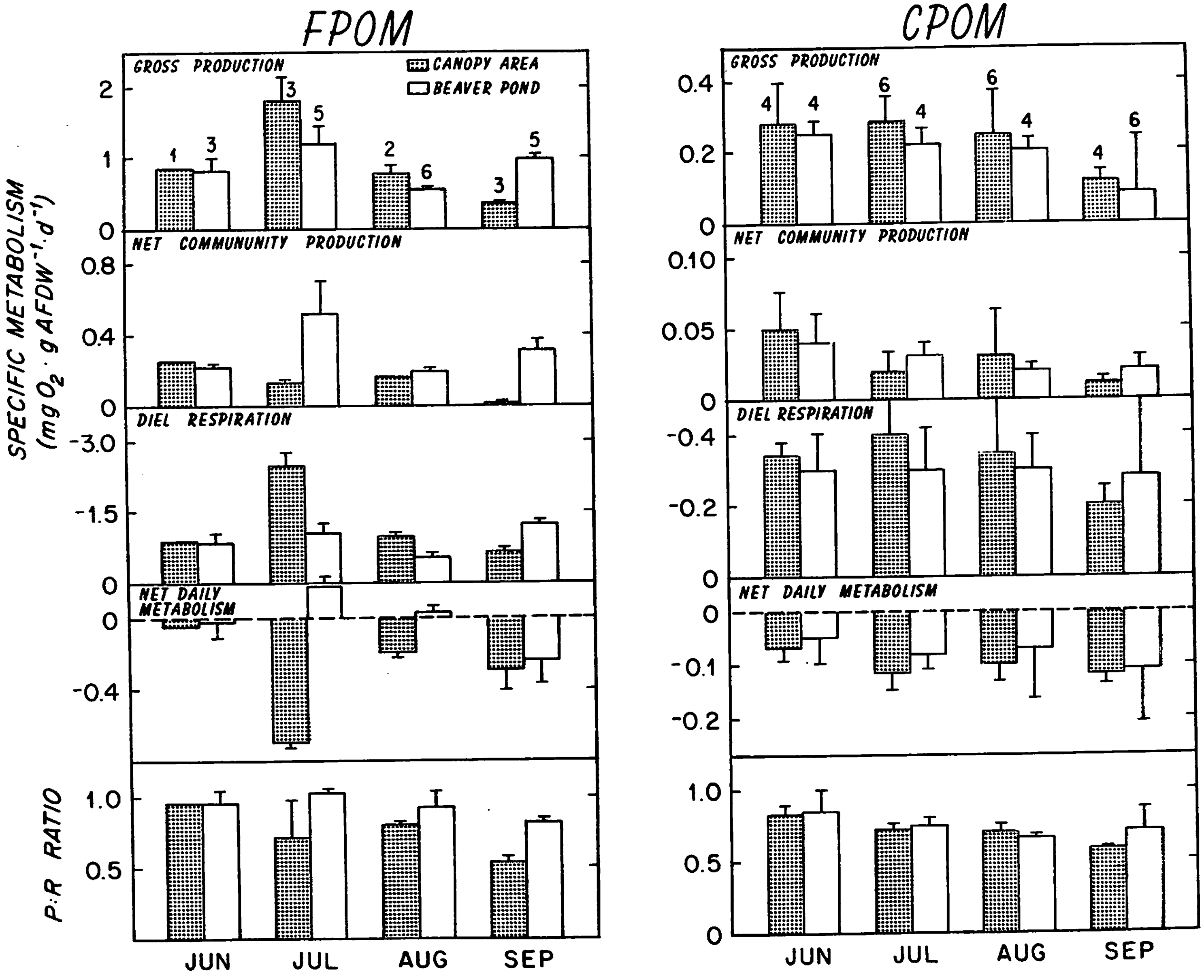

BEAVER CREEK INSECT FAMILY DIVERSITY
●—● RIFFLES
○---○ BEAVER POND
NUMBER OF FAMILIES
0
2
4
6
8
10
12
14
16
18
15 20 27 4 11 18 25 1 15 22 29 5 12 19
JUN JUL AUG SEP
1981
H = (p_i)(log_2 p_i)
where, p_i = proportional abundance
DIVERSIVTY (H)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
12 20 27 2 11 18 25 1 8 15 22 29 5 12 19
JUN JUL AUG SEP
1981
E = - (p_i)(log_2 p_i) / log_2 S
where, p_i = proportional abundance
S = # of families
EQUITABILITY (Hmax)
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
13 20 27 4 11 18 25 8 15 22 29 5 12 19
JUN JUL AUG SEP
1981

Figure 17



1981

Figure 18

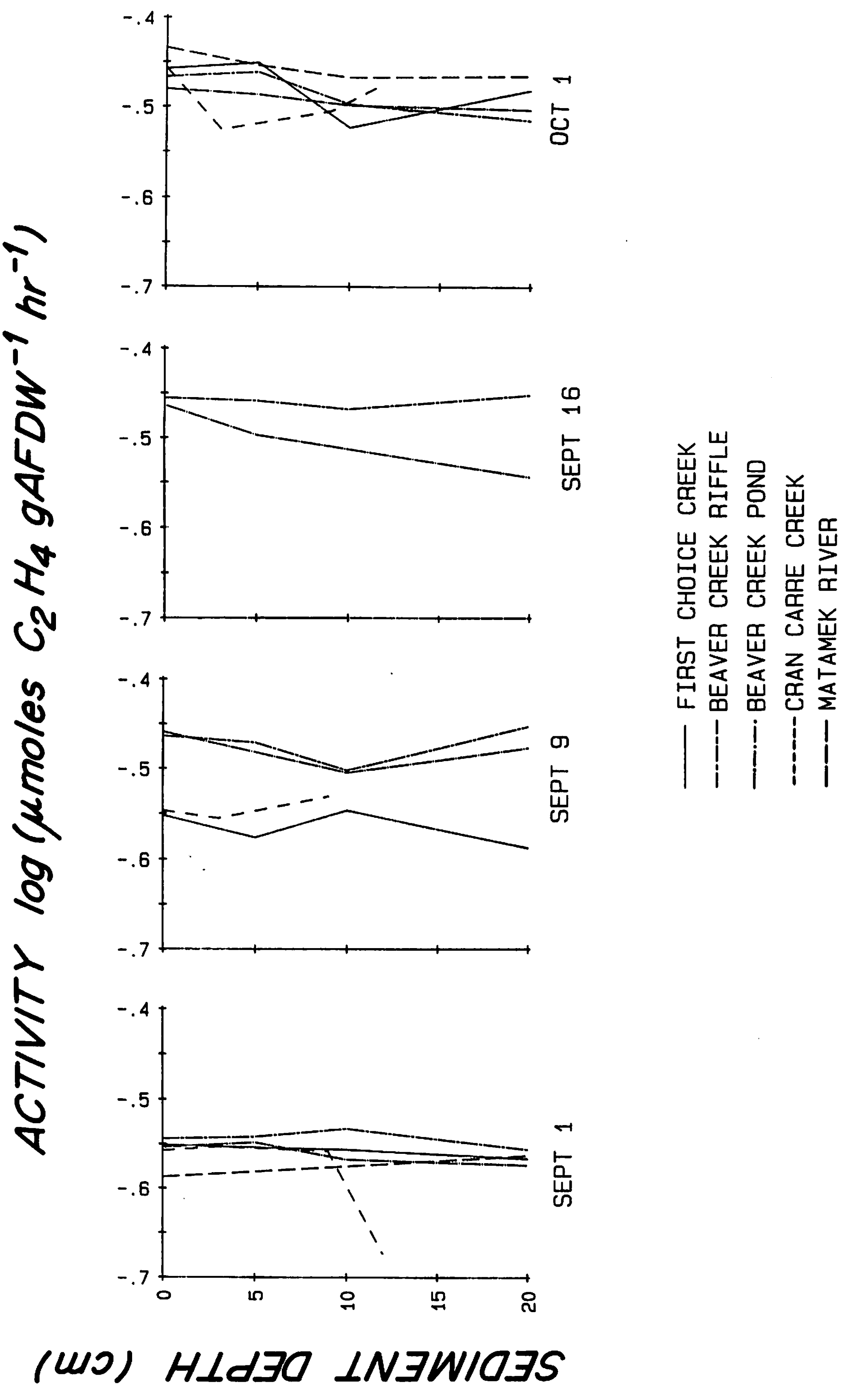

ACTIVITY log (μmoles C_2H_4 gAFDW^{-1} hr^{-1})
-.4
-.5
-.6
-.7
OCT 1
SEPT 16
SEPT 9
SEPT 1
0
5
10
15
20
SEDIMENT DEPTH (cm)
FIRST CHOICE CREEK
BEAVER CREEK RIFFLE
BEAVER CREEK POND
CRAN CARRE CREEK
MATAMEK RIVER

Figure 19

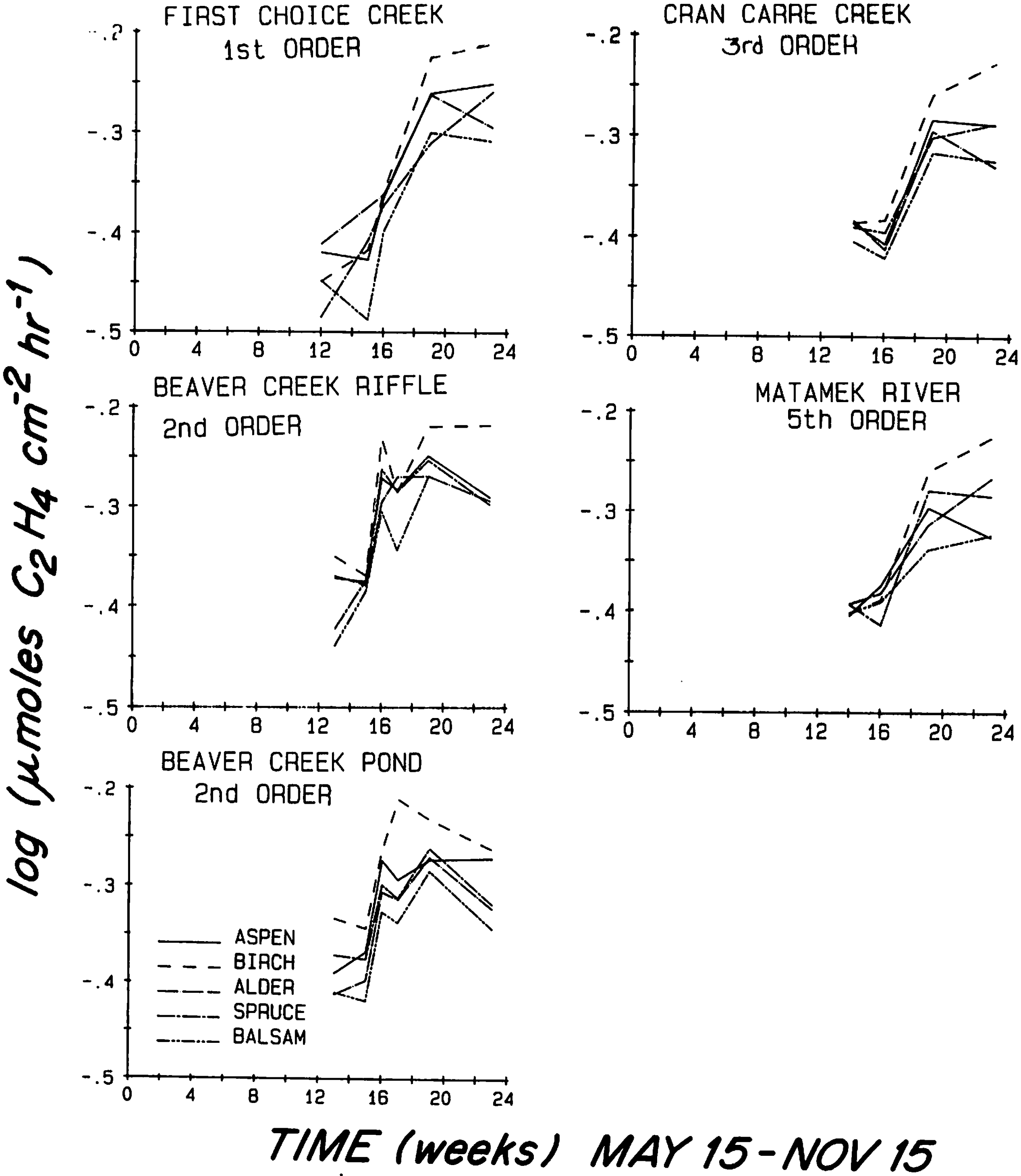

FIRST CHOICE CREEK
1st ORDER
CRAN CARRE CREEK
3rd ORDER
BEAVER CREEK RIFFLE
2nd ORDER
MATAMEK RIVER
5th ORDER
BEAVER CREEK POND
2nd ORDER
-.2
-.3
-.4
-.5
0
4
8
12
16
20
24
ASPEN
BIRCH
ALDER
SPRUCE
BALSAM
log (µmoles C_2H_4 cm^{-2} hr^{-1})
TIME (weeks) MAY 15 - NOV 15

Figure 20

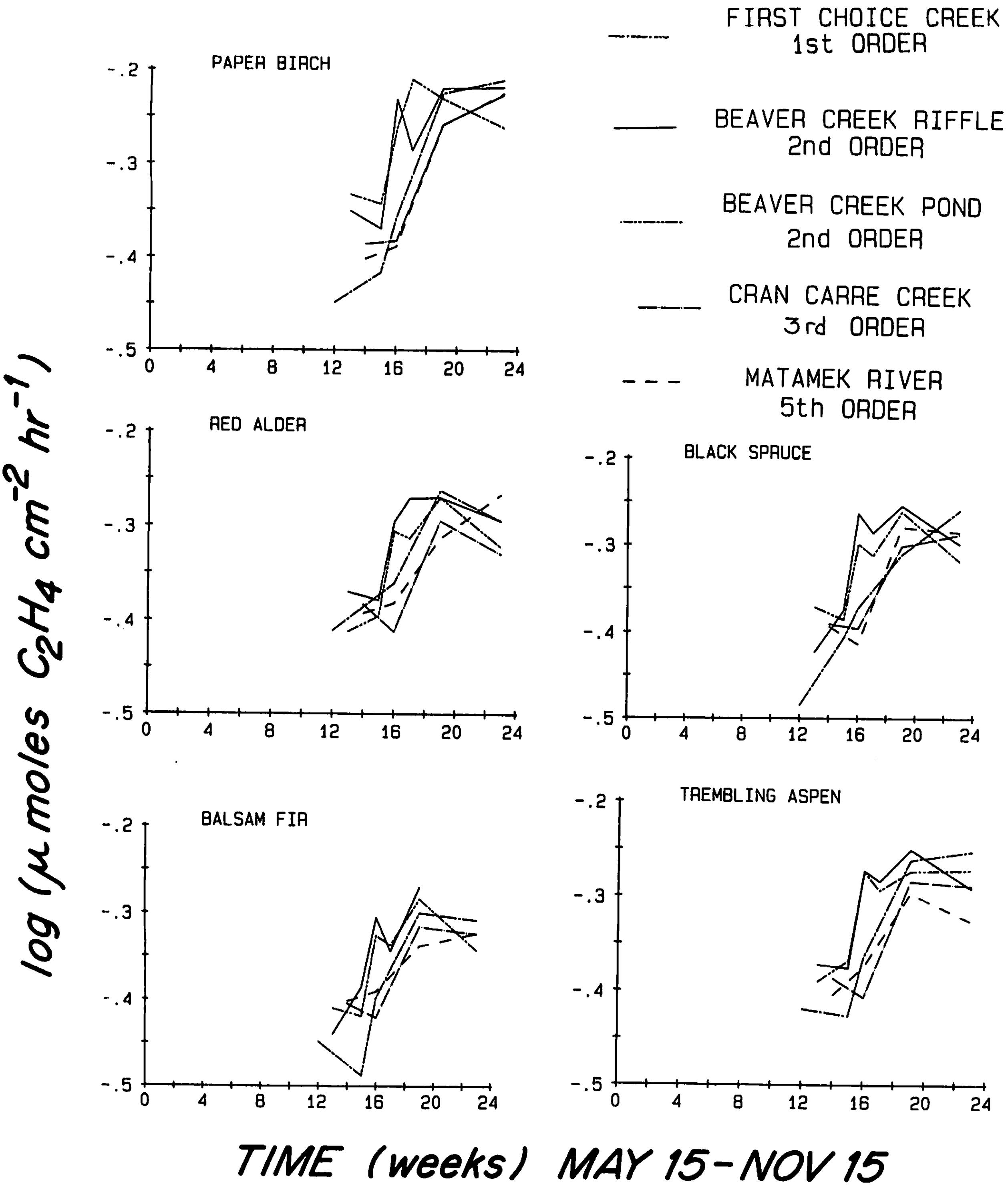

FIRST CHOICE CREEK 1st ORDER
BEAVER CREEK RIFFLE 2nd ORDER
BEAVER CREEK POND 2nd ORDER
CRAN CARRE CREEK 3rd ORDER
MATAMEK RIVER 5th ORDER
PAPER BIRCH
RED ALDER
BLACK SPRUCE
BALSAM FIR
TREMBLING ASPEN
-.2
-.3
-.4
-.5
0
4
8
12
16
20
24
log (μ moles C_2H_4 cm^{-2} hr^{-1})
TIME (weeks) MAY 15-NOV 15

Figure 21

Table 1. Survey Summary - 1981

Site	Stream Order	Date	Wood <10 cm		Wood ≥ 10 cm
			Transect Type	Total Length Surveyed (m)	Total Length Surveyed (m)
First Choice Creek	1	Aug	1-10-1-10	18	185
Beaver Creek	2	Jun	1-10-1-10	27	1383
Ross Creek	3	Aug	1-10-1-10	20	812
Kaikhosru Creek	4	Aug	1-10-1-10	10	442
Muskrat River	5	Jul	1-25-1-25	30	500
Matamek River	6	Aug	1-25-1-25	25	500
Nipissis River	8	Jul	20-50-20-50	60	367
Upper Moisie River	8	Jul	20-50-20-50	80	447
Lower Moisie River	9	Jul	20-50-20-50	180	964

Table 2. Survey 1981: Beaver Creek Summary

Water surface area in normal stream channels - 2229 m^2 Average width-3.3 m
Water surface area of ponds - 3073 m^2 Average width-4.8 m
Sediment surface area - 8371 m^2

	Dam Volume (m^3)	Sediment Behind Dam (m^3)
Dam 1	8.37	355.2
Dam 2	7.06	201.6
Dam 3	9.97	579.6
Dam 4	10.32	93.4
Dam 5	86.23	753.6
Dam 6	92.89	795.2
Dam 7	7.52	35.3
Dam 8	5.64	33.6
Dam 9	-	-
Dam 10	-	-
Dam 11	131.43	287.2
Dam 12	25.80	-

Table 3. Final sampling period $C_2H_2 \rightarrow C_2H_2$ reduction rates for wood species. Data are in µmoles cm^{-2} ·h^{-1}.

Wood Species	First Choice Creek	Beaver Creek Riffle Area	Beaver Creek Pond Area	Matamek River	Cran Carre Creek
Birch	7.71×10^{-3}	6.28×10^{-3}	4.88×10^{-3}	5.55×10^{-3}	5.40×10^{-3}
Aspen	3.07×10^{-3}	3.20×10^{-3}	1.88×10^{-3}	5.51×10^{-4}	1.31×10^{-3}
Spruce	2.54×10^{-3}	2.88×10^{-3}	2.46×10^{-3}	1.43×10^{-3}	1.35×10^{-3}
Alder	1.13×10^{-3}	2.00×10^{-3}	1.99×10^{-3}	2.17×10^{-3}	5.01×10^{-4}
Balsam	8.18×10^{-4}	1.97×10^{-3}	1.44×10^{-3}	5.79×10^{-4}	5.70×10^{-4}

AN EXPERIMENTAL APPROACH TO PERIPHYTON COLONIZATION

P.B. Hamilton and H.C. Duthie
University of Waterloo

INTRODUCTION

The colonization of periphyton on macrophytes and artificial substrates in lentic and lotic systems has been well studied. From early epiphytic colonization studies it was proposed that bacteria and algae act as primary colonizers modifying the substrate by covering it with accumulated cells, organic matter and detritus (Zobell and Allen 1935, Allen 1971). Using the scanning election microscope, Paul et al. (1977), Greesey et al. (1978) and Lock and Wallace (1979) have confirmed the idea of substrate modification by the accumulation of bacteria and algae on both natural and artificial substrates. It is currently throught that substrate type makes an initial difference in primary colonization, however through time the substrate is modified with cells, organic matter and detritus accumulation and similar communities can subsequently be observed on a variety of different substrates (Blinn et al. 1980).

The process of periphyton colonization, especially during spring bloom periods has been well studied in temperate regions. Lund and Talling (1957) however, are quick to point out that the duration of a colonization period is still not predictable. In more recent papers Backhaus (1967), Tuchman and Blinn (1979), Blinn et al. (1980) and Munteanu and Maly (1981) have found using natural and artificial substrates that an exposure period of 3 weeks or greater is necessary to achieve a sample community representative of the natural community. During the initial days of colonization, Cattaneo (1978) and Silver (1978, 1980) have found an accumulation of cells around the edges of leaves. Cattaneo also found that this edge effect was present on artificial leaves and concluded that the attraction to cells to the leaf edge was the result of physical, not biological factors. Munteanu and Maley (1981) using glass in lotic waters also noted this strong edge effect. In addition to this edge effect Dickman and Gochnauer (1978) have observed the accumulation of motile diatoms in hollow depressions on tile surfaces during colonization.

Of particular interest is the cellular production changes which occur throughout colonization. Naiman (1976), Naiman and Gerking (1975), Naiman and Sedell (1980) and Naiman (1981) have used seasonal production levels to estimate total community production, however, only Duffer and Doris (1966) and Cattaneo and Kalff (1979) have looked at primary production on a short term scale under controlled experimental conditions.

This study examined the process of colonization of flat stone surfaces. We attempted to measure the rate of growth and the attachment pattern for periphyton. In addtion to this we examined the changes in cellular production levels during the colonization period.

METHODS

One channel from the Matamek River artificial stream chambers were used in this study. During the study period the current varied from 0.23 m/s to 0.1 m/s. Rocks with large flat surfaces were cleaned and placed down the center of the channel. This was done to standardize the amount of light received by each rock. A small stone pile was placed at the upstream end of the channel to prevent coarse particulate organic matter from disrupting the experiment and to help stabilize the current flow.

Replicated samples for biomass and chlorophyll a were collected from the stones at weekly intervals throughout the experiment.

Species Interactions and Net Production Studies

Small stone sections approximately 1 cm x 1 cm x 1mm were cut from granite. Prior to the experiment the stone sections were autoclaved. At the initiation of the experiment the stones were glued to a flat glass surface in offsetting rows of four, allowed to dry and then submerged in the channel. On days 1, 4, 8, 9, 13, 16, 23 and 27 rows of 4 stones were removed starting at the upstream edge. Two stones were used for SEM examination, one for chlorophyll *a* analysis and one was used in a species-specific net production study.

SEM Examination

The stones were prepared for examination using the procedure described by Lock and Wallace (1979). To ensure that bacterial contamination would not be a problem, half the stones were stored in fixative during transit, while the other stones were dehydrated and stored in 70% ethanol.

A total of 11 transects were constructed over each stone surface: four transects were along the edges and 7 were constructed across the stone surface. Observations of species types and growth densities were recorded along each transect. Twenty stones were examined using over 85 hours of SEM examination time.

Species-Specific Net Production

After removal from the channel, one stone section was immediately glued to a large flat stone and placed in a recirculating plexiglass metabolic chamber and incubated from 1 to 4 hours with 50 μCi of ^{14}C. After incubation the stone was placed in a small vial and preserved in Lugol's solution. Integrated light readings were taken during each incubation period. The track autoradiography analysis developed by Knoechel (1976) was used to study the gross production changes of *Tabellaria flocculosa* during the colonization period.

RESULTS AND DISCUSSION

Logarithmic growth was observed throughout the twenty-five day study period (Fig. 1,2). Both biomass and chlorophyll *a* measured had high correlation coefficients with linear regressions of almost identical slopes. In this study both biomass and chlorophyll *a* are good measures of growth. Poor correlations between biomass and chlorophyll *a* have created numerous problems in the literature and even in other parts of this study. However, under controlled experimental conditions Douglas sampler samples for both chlorophyll and biomass are consistent measures of biotic growth.

SEM Examination

During the colonization period there was a definite edge effect observed. Seventeen of the twenty stones observed, showed that the upstream edge of the stones had more cell clusters than the other edges. Thirteen of twenty stones showed the downstream edge to be the next most important edge for cell growth. These results are in agreement with the findings of Cattaneo (1978), Silver (1980) and Munteanu and Maly (1981).

All thirteen stones less than sixteen days showed the development of surface colonies in depression areas (Fig. 3). Twelve of the twenty stones examined showed a distinct increase in the number of colonies present towards the upstream edge. Other observations also suggest that rough surfaces are good areas for cell growth.

Stone surface roughness and current flow are the most important factors determining colonization patterns. Munteanu and Maly (1981) have suggested the current flow is reduced at the upstream and downstream edges by circulating eddies. These eddies create higher phytoplankton settling rates at the edge which allows for faster colonization. Reduced current flow in depressions along the stone surface also allows for the accumulation of floating plankton, thus, enhancing the colonization rate in these areas.

Species-Specific Production during Colonization

T. flocculosa showed an increase in the gross production during the colonization period (Fig. 4). This is surprising because we expected to see a decrease in cellular production due to competition stress. The fact that there is an increase in the amount of carbon being fixed suggests that intraspecific competition (if present) does not negatively affect the net production of individual cells. Is intraspecific competition for nutrients present at all? More experimental work is needed to confirm these results and further questions the ideas of intraspecific competition in developing plant communities.

SUMMARY

Under controlled experimental conditions periphyton colonization showed logarithmic growth over the 25 day experimental study. Initial growth along the upsteam, downstream edges and colony development in hollow depressions along the surface were observed. These results confirm the idea of an edge effect reported by Cattaneo (1978). In lotic systems surface structure and current stream to be the main factors determining the pattern of periphyton colonization. Changes in T. flocculosa gross production levels suggest that there is an increase in cellular production during colonization. The concept of intraspecific competition for inorganic carbon and nutrients is questioned.

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Backhaus, D. 1969. Okologische Untersuchunger an der Aufwuchsalgan der obsersten Donau and ikier Quellflusse. Arch. Hydrobiol/suppl. 30(4): 364-399.

Blinn, D., A. Fredericksen, and V. Korte. 1980. Colonization rates and community structure of diatoms on three different rock substrata in a lotic systems. Br. Phycol. J. 15: 303-310.

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FIGURE CAPTIONS

Fig. 1.	Periphyton biomass ($\mu g/cm^2$) as a function of colonization days.
Fig. 2	Chorophyll a (mg/m^2) accumulation as a function of colonization days.
Fig. 3.	Pattern of colonization over the stone surface. Visual depiction of SEM observations. The edge towards the bottom of the page is the upstream edge of the stone.
Fig. 4.	Gross production measured by carbon fixed (pg $cell^{-1}$ 1000 μ^{-1} m^{-2} sec-hr^{-1}) as a function of colonization days.

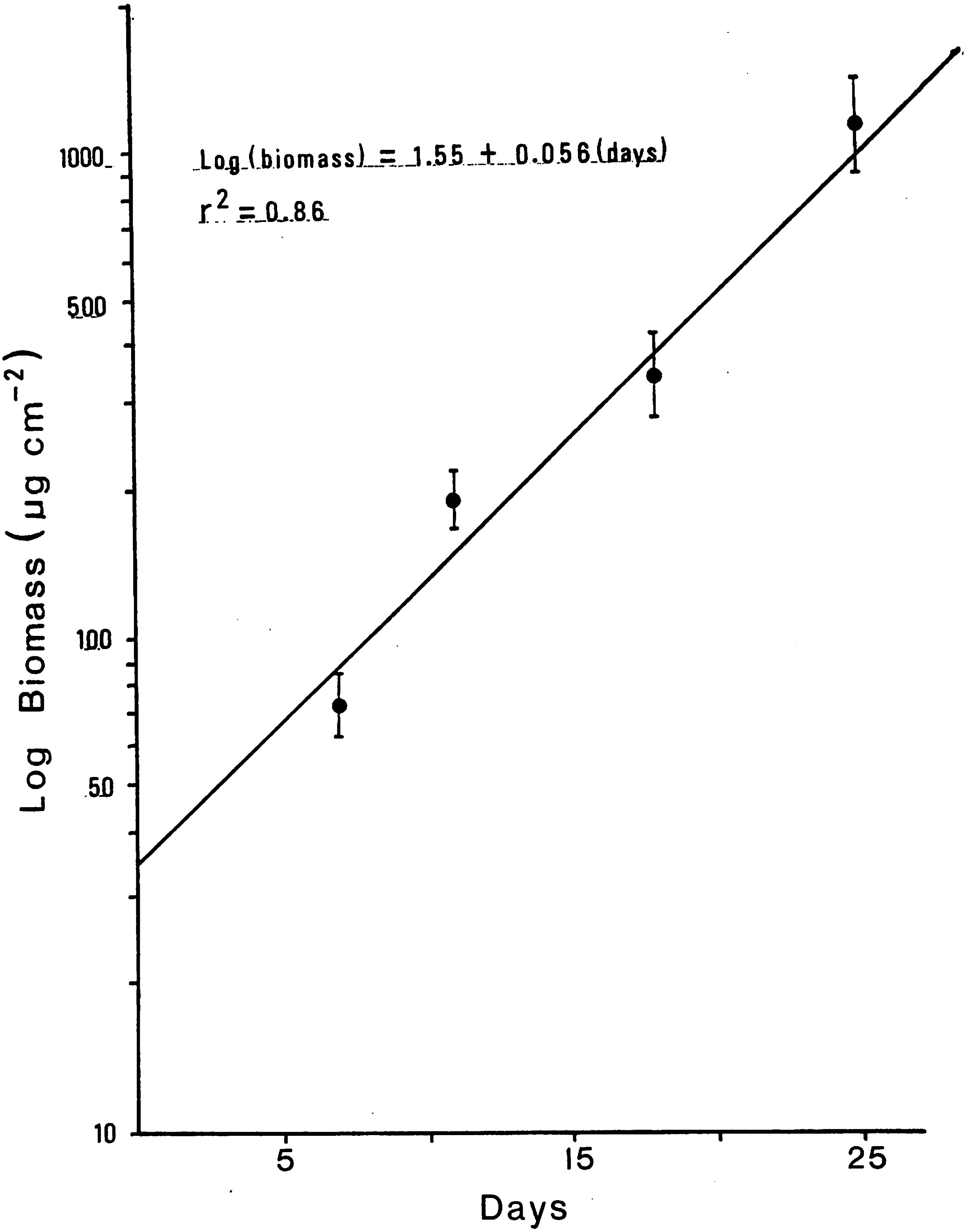
Log (biomass) = 1.55 + 0.056 (days)
$r^2 = 0.86$
1000
500
100
50
10
Log Biomass (µg cm^{-2})
5
15
25
Days

FIGURE 1

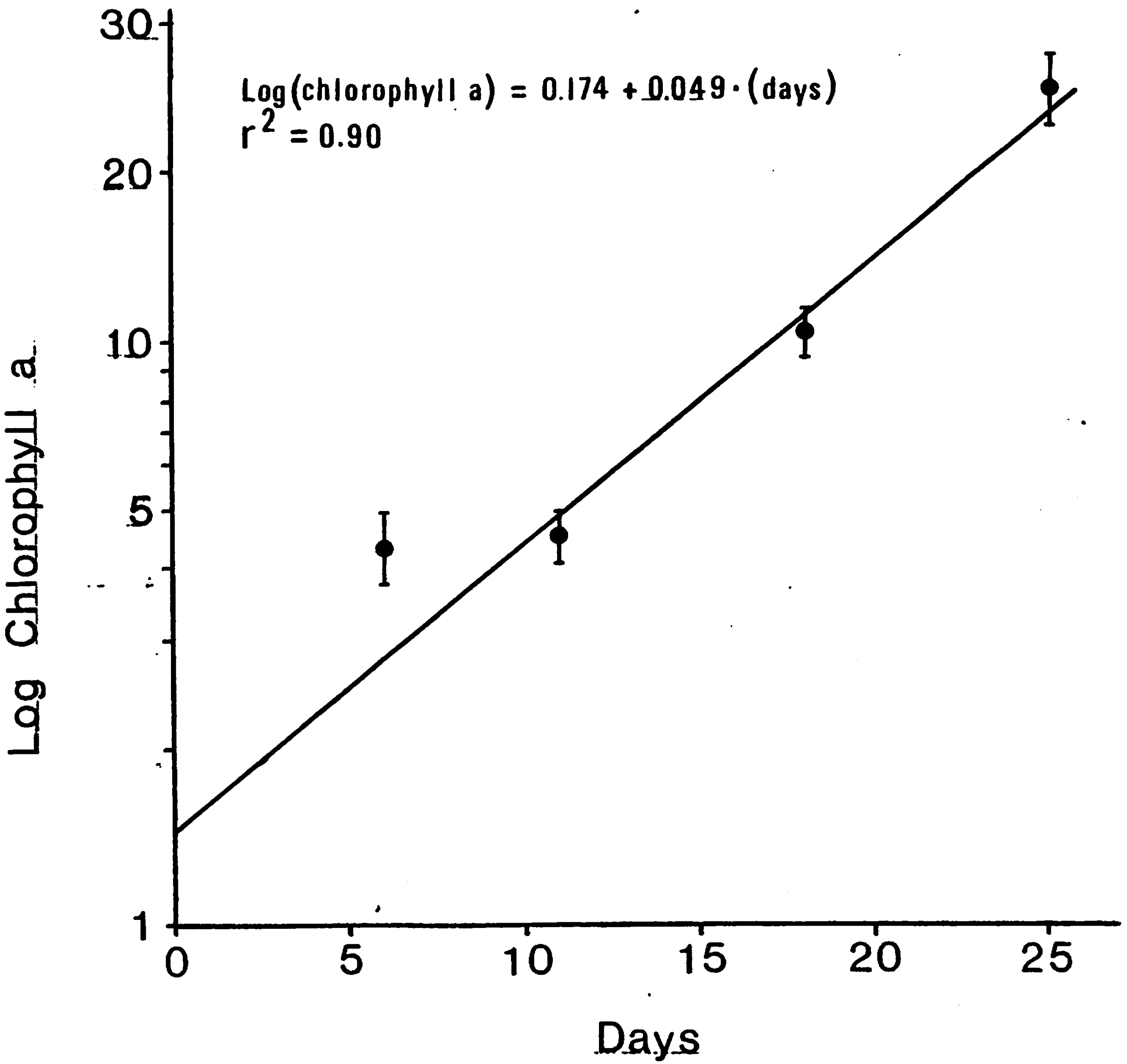
Log(chlorophyll a) = 0.174 + 0.049 · (days)
r^2 = 0.90
Log Chlorophyll a
30
20
10
5
1
0
5
10
15
20
25
Days

FIGURE 2

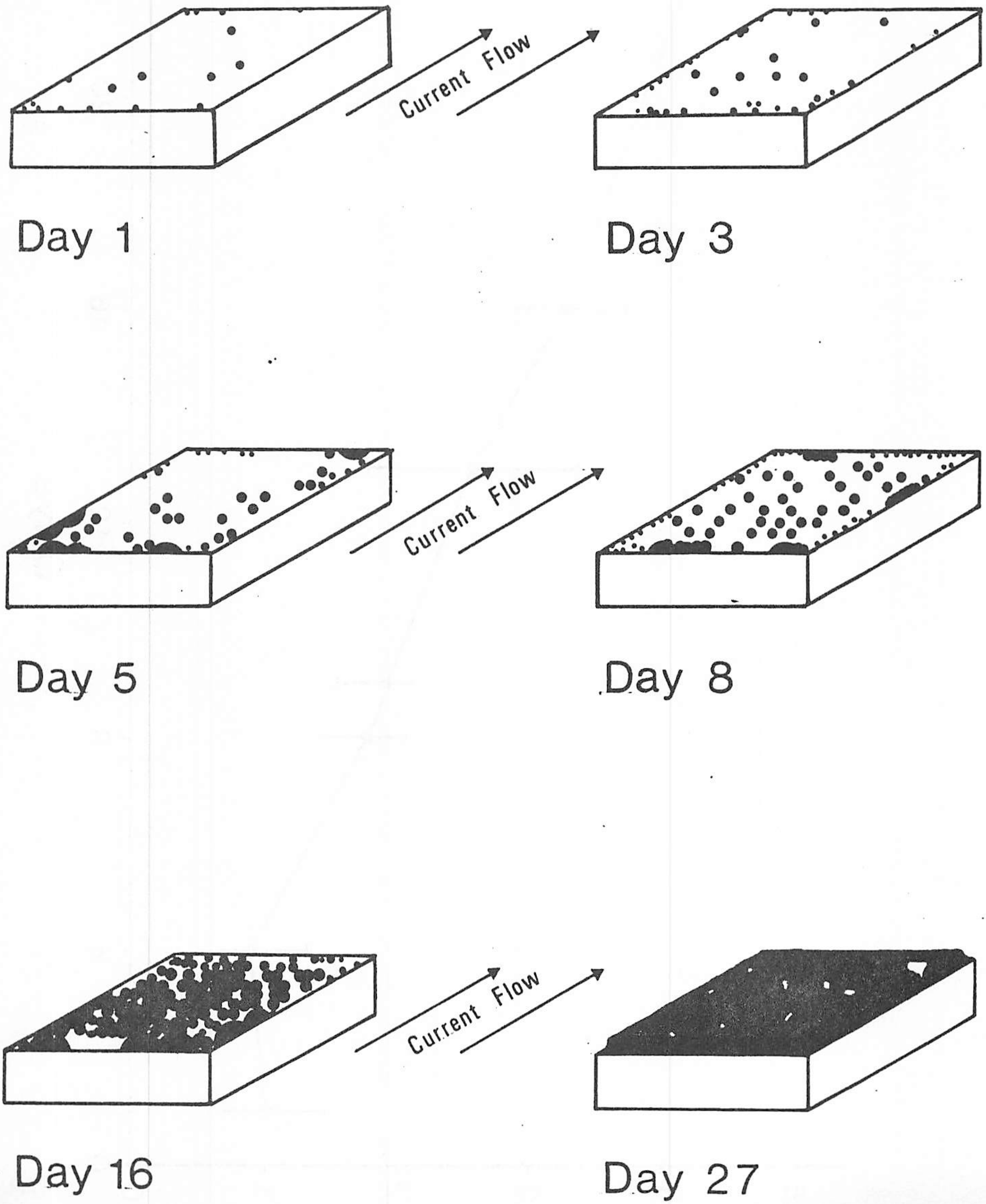
Current Flow
Day 1
Day 3
Current Flow
Day 5
Day 8
Current Flow
Day 16
Day 27

FIGURE 3

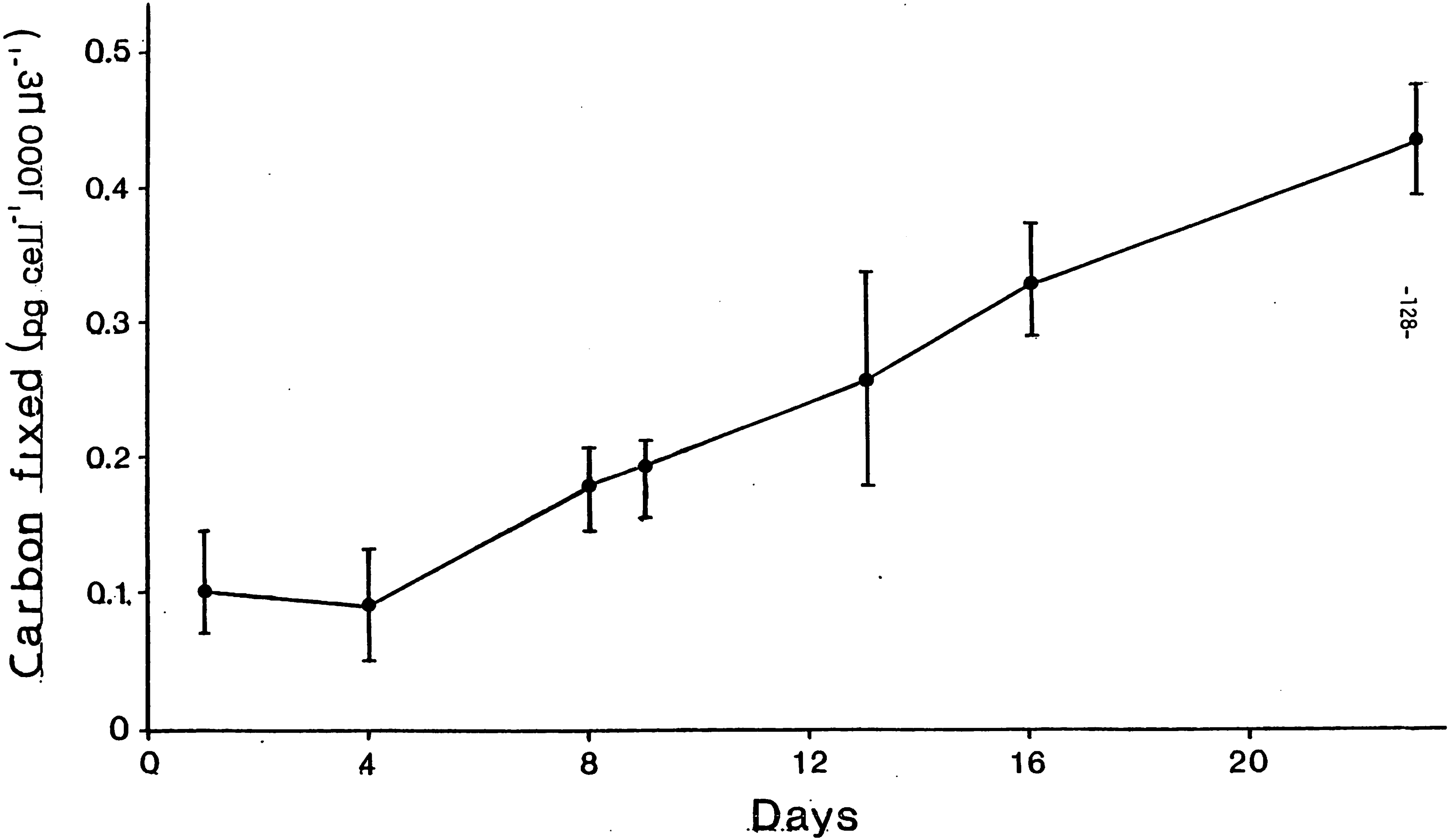

FIGURE 4

GEOGRAPHIC ANALYSIS OF THERMAL EQUILIBRIA

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Stroud Water Research Center
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RD 1, Box 512
Avondale, PA 19311

The overall objective of our research project on aquatic insects is to test and refine a theoretical model (Vannote and Sweeney, 1980) that describes the effects of natural and altered temperature regimes on the growth rate of insect larvae and adult size and fecundity. Our central hypothesis is that the stability of a given population (i.e. the ability to recover from serious reduction in numbers by environmental perturbations or fluctuations) within the geographic range of a species reflects mainly a dynamic equilibrium between temperature and individual growth, metabolism, reproductive potential, and generation time. In this context, a thermal regime is viewed as optimum for a species when individual body weight and fecundity is maximized. Our model predicts that geographic range extension away from a location with an optimum thermal regime would be associated with temperature induced changes in the rate and efficiency of energy use, developmental processes, and generation time. The net result of these changes would be altered life history patterns and reduced reproductive effort.

To test and refine our model, we proposed to study the growth, development, metabolism, and reproduction of a large number of aquatic species in an array of rivers distributed along a natural thermal gradient from northern Florida to the Province of Quebec. As part of this on-going project, we selected eight sites near the Matamek Research Station and initiated field studies in June 1981. A total of sixteen species of aquatic insects, largely belonging to the orders Ephemeroptera and Trichoptera, were studied intensively from June through August 1981 (Table 1). Although many more species occur and were collected at these sites, we only initiated detailed studies on those species that we had previously obtained comparative growth and fecundity data at more southern latitudes (Florida to Vermont).

Field data for each species were collected on the rate and magnitude of larval growth, timing of adult emergence, and the size and fecundity of adults. In addition, the larvae of many species were reared to the adult stage at the Matamek Research Station. These reared adult specimens were used for taxonomic verification and detailed population genetic studies (i.e. gel electrophoresis studies of 18 loci for at least 30 adult specimens per species).

Results of these studies are tentative and need further confirmation during 1982. In general, however, most species emerge significantly later in the spring and summer at the eight study sites relative to rivers at more southern latitudes. There was also good evidence that the life history of at least two species, *Eurylophella verisimilis* and *Eurylophella funeralis*, was significantly different (i.e. $\geq$ 1 year longer) in rivers near the Matamek Station. Adult size and fecundity of many species appeared to be consistently lower (i.e. relative to more southern populations) at the eight study sites but this needs to be confirmed with more extensive collections in 1982. Electrophoretic analyses of specimens reared from the Matamek area are near complection but detailed statistical evaluation is needed for proper interpretation.

Table 1 - A list of insect species and collection locations in 1981 for population structure, growth and fecundity studies.

	Study Sites*							
Species	CHO1	TRA2	BEA2	PIG6	TRU4	CRA3	LOU6	MAT7
Litobrancha recurvata				X				
Ephemerella aurivillii		X		X	X			
Drunella cornutella				X			X	
Eurylophella funeralis		X	X					
Eurylophella verisimilis				X		X	X	X
Baetisca laurentina								X
Leptophlebia cupida		X		X				X
Arthroplea bipunctata								X
Epeorus fragilis				X				
Epeorus vitreus				X				
Heptagenia pulla			X					
Siphlonuris sp.				X				X
Ameletus sp.				X				
Siphlopecton basale				X				
Pycnopsyche gentilis		X						
Neophylax sp.	X							

*CHO1 = First Choice Creek, TRA2 = Trapper Cabin Creek, BEA2 = Beaver Creek, PIG6 = Pigou River, TRU4 = Riviere la Truite, CRA3 = Cran Carre River, LOU6 = Loup Marin River, MAT7 = Matamek River

SALMONID STUDIES

FISH MONITORING OF SALMONIDS IN THE MATAMEK RIVER 1981

Roderick Morin, Robert J. Naiman, W. Linn Montgomery,
Francine Lafontaine, John Pirie, and Michel Legault
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An important part of the Matamek program consists of monitoring long term changes in salmonid populations. The objectives of the monitoring program are:

(1) to establish the yearly population size of migrant adult Atlantic salmon and smolts and of resident populations of salmon parr and brook trout located at the base of each set of falls on the lower Matamek River.

(2) to record the characteristic size, age and sex composition of each monitored population.

Sampling periods and peak runs during 1981 are shown in Table 1. In spite of intense effort to tag and recapture smolts (approximately 70 man-days), high water levels during May and early June prevented sufficient tagging of smolts to generate a population estimate. The mean fork length of smolts sampled during 1981 was 15.6 cm (SE=0.25; n=40). Mean age was 3.08 years (SE=0.08; n=40) with three smolts aged 2^+ years; 32 smolts aged 3^+ years; four smolts aged 4^+ years and one aged 5^+ years. Male smolts formed 20% of our sample.

The First Falls salmon ladder operated during the entire salmon run. A total of 81 adult salmon (69 grilse and 12 two-sea-year salmon) passed through the ladder. Each fish was measured, a scale sample removed for age determination and a Floy anchor tag affixed before release. From adult salmon recaptured 2.5 km upriver in a trap net, population size was estimated by a Schnabel estimate (Ricker 1975).

The mean fork length of returning grilse was 53.8 cm (SE=0.35; n=97) and of two-sea-year salmon 73.7 cm (SE=1.90; n=13). The total population of grilse was estimated at 142 (95% confidence limits: 95; 228). Two-sea-year salmon were estimated at 14 (95% c.l.: 7; 32). Females formed 51% of the grilse run; sex was determined by the presence or absence of a kype on adult salmon caught in the trap net. Two returning adult salmon had been tagged as smolts in previous years, representing a return of 2.5% on tagged smolts. A two-sea-year salmon tagged at the ladder on July 12 was recaptured below the Fifth Falls on September 4 while angling for trout. This represents the first record of Atlantic salmon from above the Fourth Falls. This salmon belongs to the 1976 year class and therefore could not have originated from salmon introduced to that site for spawning in the autumn of 1976 (Gibson 1977).

These data reveal several important changes in the Matamek salmon population. A sharp rise in total population occurred in 1981 (Figure 1); however, grilse now form 91% of the adult population, a significant change from 55% in 1967. Changes in the sex ratio of adult salmon are related to increased precocity of male parr. While female grilse now form 51% of the return (4% in 1967, Figure 1), females are also increasingly dominant in smolt populations (Figure 2). The mean fork length of smolts has not changed appreciably, but the mean age of smoltification has (changed notably) since 1967 (Figure 2). These changes appear to result from commercial exploitation causing intense pressure on the two-sea-year component of the population and selecting for precocious spawning of male salmon parr (Naiman et al. MS).

Table 2 presents population estimates of salmon parr and brook trout located at the bases of the second to fifth falls of the Matamek River. Parr and trout were collected by angling and seining. Fish were anethetized, measured, weighed and fin clipped. Population estimates were made by the Petersen method or by the Schnabel method when more than four sample days were required. Calculations of population size and 95% confidence limits were made according to methods described by Ricker (1975) with Chapman corrections applied to all formulae.

One Arctic charr (Salvelinus alpinus) was seined at the mouth of the Matamek River on June 25. It measured 44.0 cm (fork length). On August 19 two steelhead trout (Salmo gairdneri, FL: 28.1 cm, 33.5 cm) were angled by fly casting at the base of the First Falls of the Matamek River. Identification were confirmed by D.E. McAllister and specimens catalogued in the ichthyological collection of the National Museum of Natural Sciences, Ottawa.

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FIGURE CAPTIONS

Figure 1.	The number of adult salmon returning to the Matamek River and the percentage of grilse and female grilse shown by year.
Figure 2.	Characteristics of the Atlantic salmon smolts determined by year.
Figure 3.	Diel pattern of adult salmon entering ladder on the Matamek River during 1981. Outer numbers indicate the hours of the day. The salmon ladder was checked at 7:00 h, noon, 17:00 h and 21:00 h daily. Radius of each shaded area indicates total number of salmon entering ladder between checks. Total number is also indicated within each shaded area.

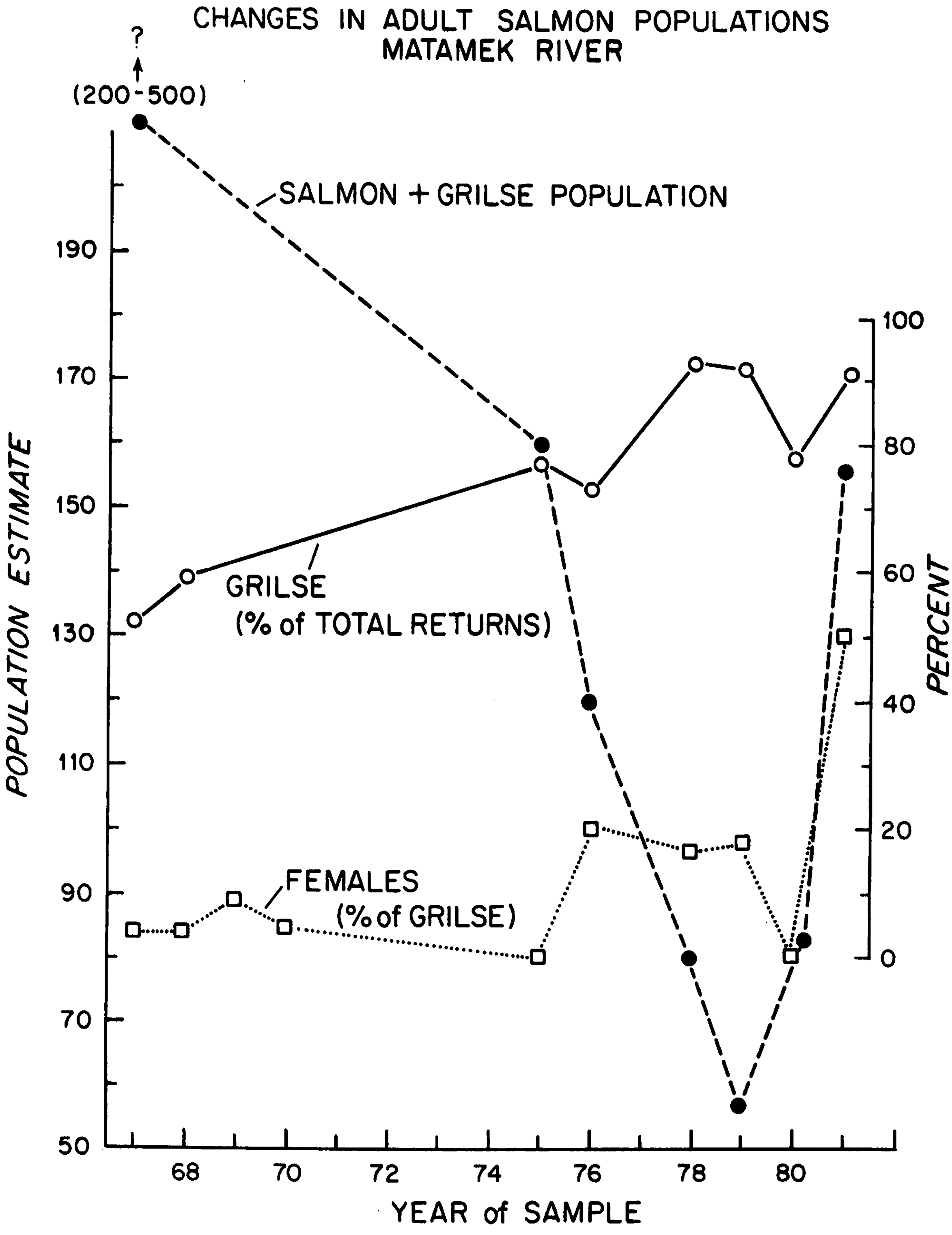
CHANGES IN ADULT SALMON POPULATIONS
MATAMEK RIVER
?
(200-500)
SALMON + GRILSE POPULATION
GRILSE
(% of TOTAL RETURNS)
FEMALES
(% of GRILSE)
POPULATION ESTIMATE
PERCENT
YEAR of SAMPLE
190
170
150
130
110
90
70
50
100
80
60
40
20
0
68
70
72
74
76
78
80

Figure 1

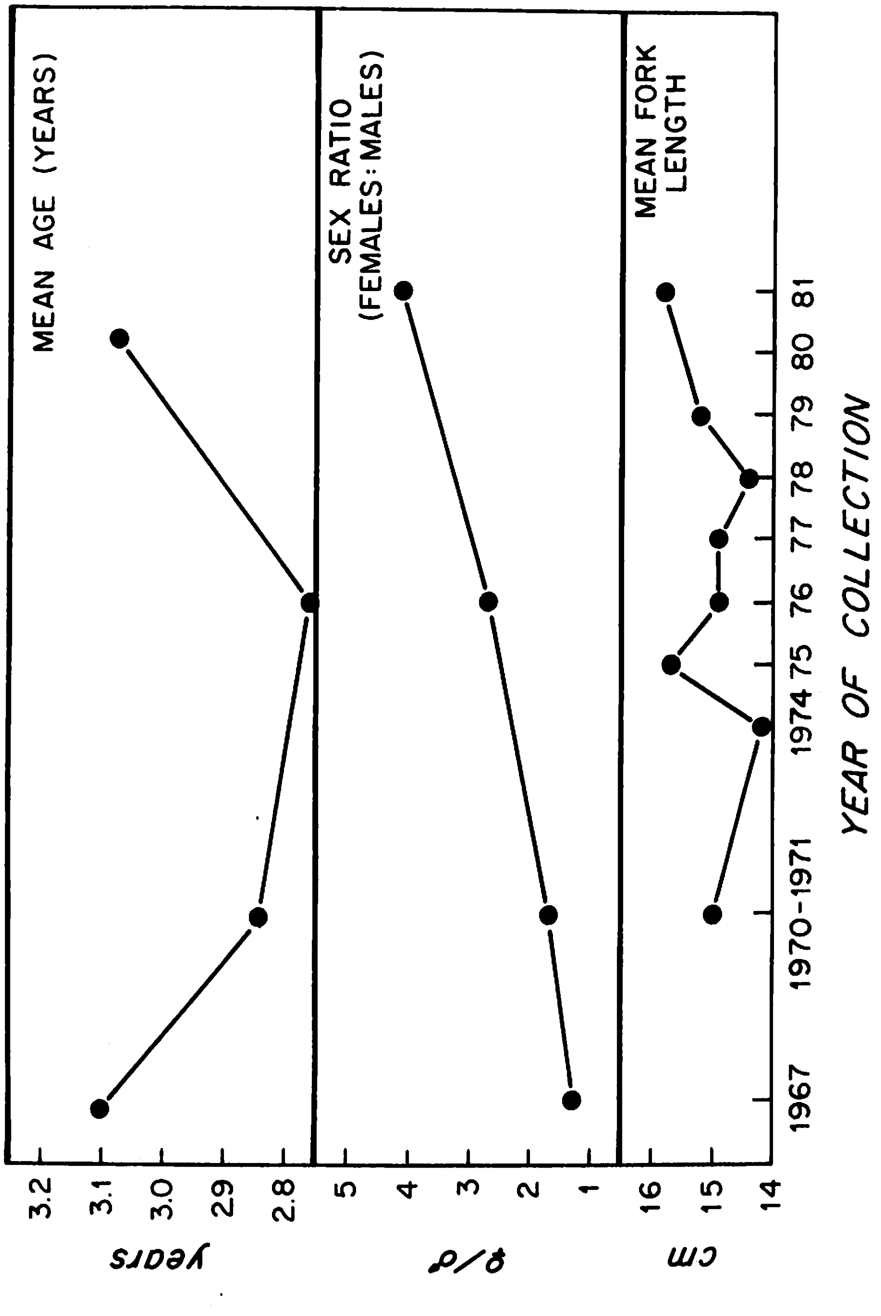
MEAN AGE (YEARS)
SEX RATIO
(FEMALES: MALES)
MEAN FORK
LENGTH
years
3.2
3.1
3.0
2.9
2.8
♀/♂
5
4
3
2
1
cm
16
15
14
1967
1970-1971
1974
75
76
77
78
79
80
81
YEAR OF COLLECTION

Figure 2

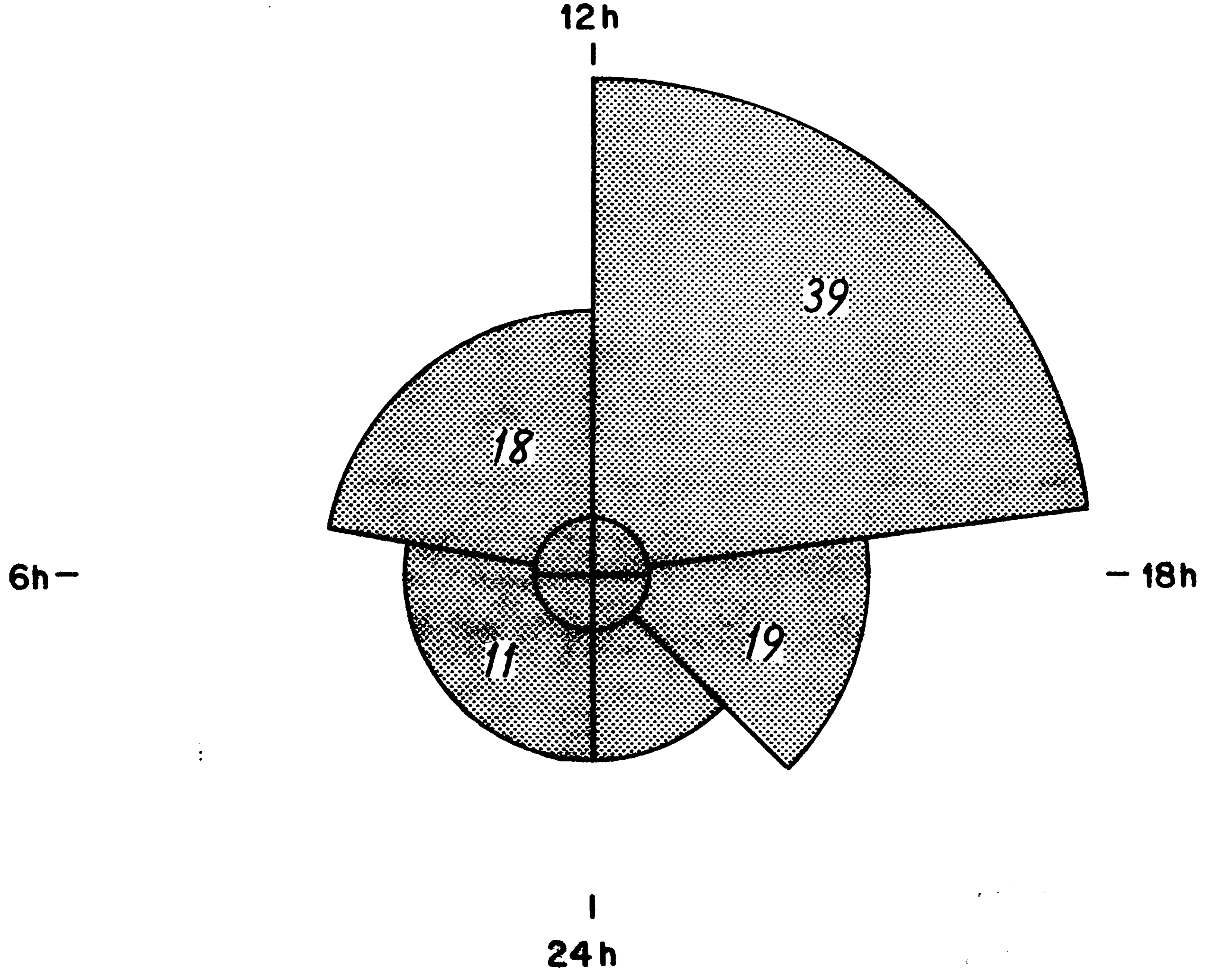

Figure 3

Table 1. Sampling times and migration periods in salmon monitoring program, Matamek River 1981.

	Sampling	MIGRATION Beginning	MIGRATION End	MIGRATION Peak
Smolts	May 18 - July 4	May 25	June 29	June 25
Adults (Ladder)	June 16 - August 27	June 23	August 25	July 22-27
(Trap Net)	July 30 - September 14	August 4	September 14	August 11-13

Table 2. Salmon parr and brook trout population estimates along the Matamek River. Estimates are based on sampling conducted between 18 August and 7 September, 1981.

Location	Population estimates (95% confidence limits) Parr	Population estimates (95% confidence limits) Trout
2nd Falls	315 (247; 402)	113 (73; 184)
3rd Falls	237 (166; 351)	261 (132; 614)
4th Falls	35 (16; 69)	359 (273; 484)
5th Falls	*	566 (446; 742)

*Two parr angled at base of Fifth Falls.

BIOLOGY OF ATLANTIC SALMON PARR

W.L. Montgomery, Francine LaFontaine, John Pirie, Tandy Miller
Anna Brzeski and Rod Morin
Woods Hole Oceanographic Institution and Matamek Research Station

Studies of parr in 1981 focussed on distribution, length-weight relationships and the dynamics of precocious sexual maturation among males. Although ages of all sampled parr are not yet available, when length distributions for all sampled and released parr are compared with lengths of aged parr collected in July by A. Brzeski, A. Bielak and J. Noble, it becomes clear that 1+ and 2+ fish dominate all populations (Fig. 1). There is no clear indication that fish of a given age are larger as one goes upstream, with the possible exception of 4th Falls fish compared to 2nd and 3rd. Seven parr collected below 5th Falls were quite large (15.0-17.8 cm), and may be remnants of plantings in 1979. If this is the case, they would be age 2+. This remains speculative, however, since capture of a Salmon (tagged No. 468 on 12 July at First Falls, 78.2 cm FL) immediately below Fifth Falls and observations of a grilse successfully jumping at least the lower portion of Fifth Falls on 4 September make it possible that salmon have historically penetrated to or above Fifth Falls.

As previously noted, virtually all male parr in the Matamek River now mature sexually (Table 1). Comparisons of sex ratios between upstream and downstream sites for July and September (Table 2) did not yield clear-cut evidence for directional movements by maturing parr, as suggested elsewhere (R. Saunders, B. Glebe, pers. comm). When fractions of mature males are considered alone, however, it is clear that mature males increase in prevalence at upstream locations from July to September, likely due to immigration of maturing fish and/or maturation of resident immatures (Table 3). During the same period, however, the prevalence of mature males declines in downstream locales; this suggests migration of maturing males to upstream sites.

Condition factors were lowest in May-June, and generally rose to their highest levels in September (Table 4). As expected, condition factors for maturing males exceeded those for immature males in 7 of 8 comparisons and for females in 11 of 13 comparisons. There are no consistent indications of greater condition at upstream sites, although fish below 4th Falls (16A-C) tend to have high condition factors in all months.

Rapid testes growth in maturing males began in early August, and reached 12-18% of total body weight by early September (Fig. 2). Immature males captured during August-September all had testes comprising <1% of total body weight; conversely, all points at <1% were immature males (Fig. 2).

Gibson (1975) summarized information on unusually large ($\geq$16 cm FL) or old (4+-6+) parr from the Matamek River. In 1981, we collected 27 parr 16.0-20.1 cm in length (Table 5). Although ages are not yet available, several features of these fish are noteworthy. First, their condition factors were high (1.13-1.37). Second, all sacrificed fish (14 of 27) were precociously mature males (13) or had previously matured (1). Third, relative gonad weight increased dramatically between late July and early September (also see Fig. 2); linear regression of % body weight on day (where 21 July = Day 1) gave $\%DW = -0.20 + 0.26\,(Day)$, $r = 0.89$, $n = 13$.

REFERENCES

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FIGURE CAPTIONS

Figure 1. Length-frequency distributions for all parr examined during August-September 1981.

Figure 2. Growth of testes in male salmon parr, Matamek River, 1981. Points represent individual fish; circled points represent 2-4 specimens. Females are excluded.

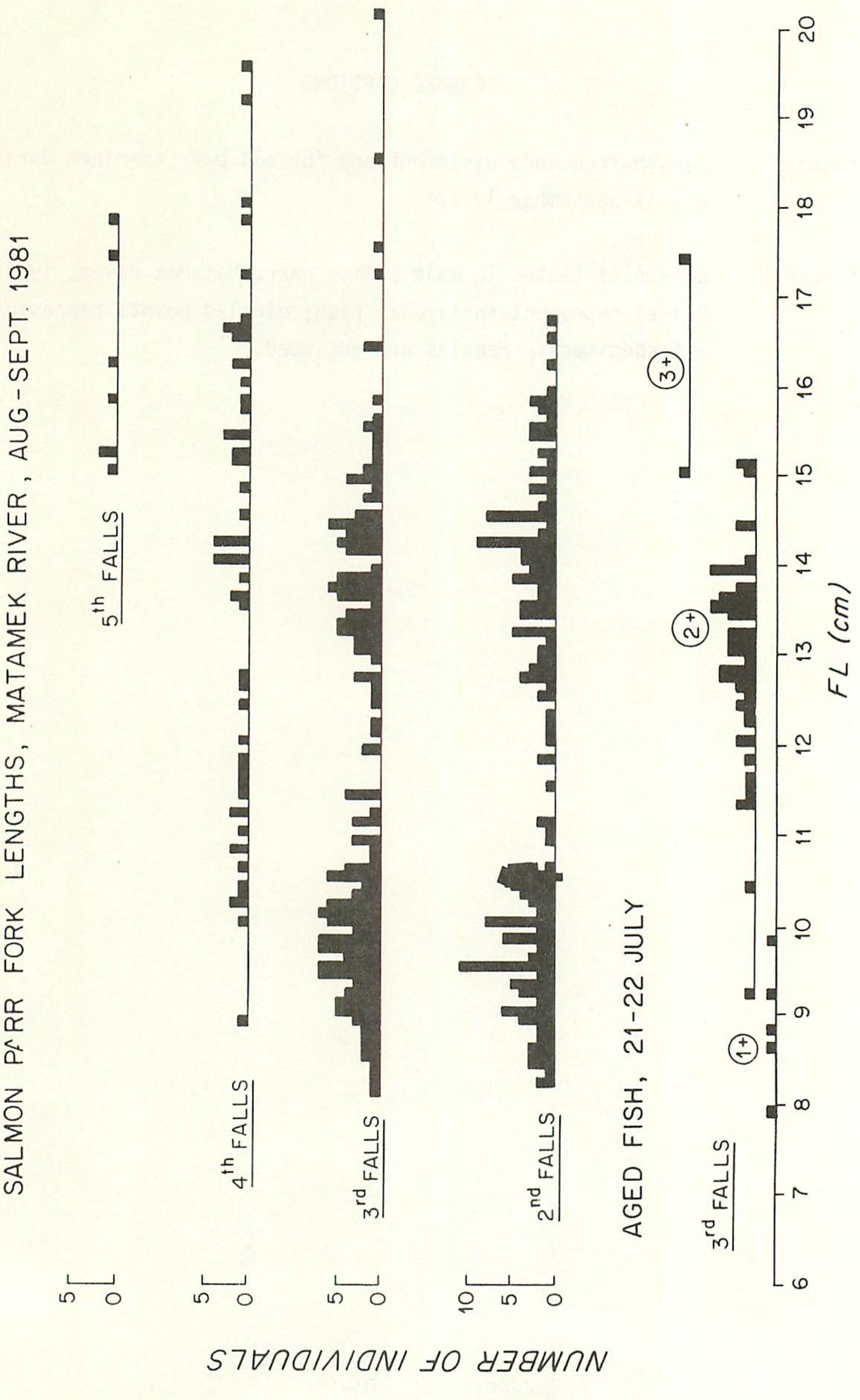
SALMON PARR FORK LENGTHS, MATAMEK RIVER, AUG-SEPT 1981
5th FALLS
4th FALLS
3rd FALLS
2nd FALLS
AGED FISH, 21-22 JULY
3rd FALLS
1+
2+
3+
NUMBER OF INDIVIDUALS
5
0
5
0
5
0
10
5
0
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
FL (cm)

Figure 1

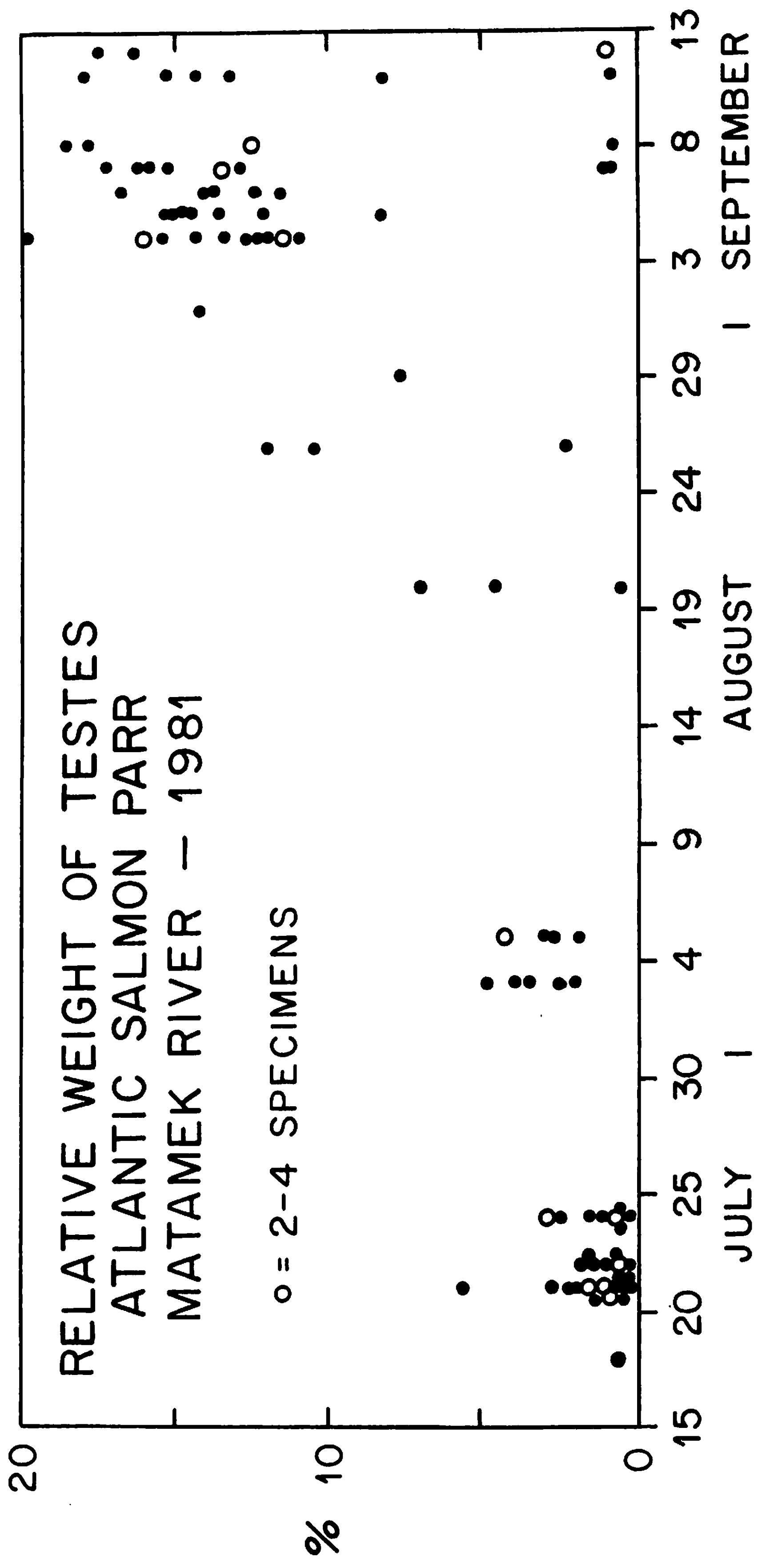
RELATIVE WEIGHT OF TESTES
ATLANTIC SALMON PARR
MATAMEK RIVER — 1981
○ = 2–4 SPECIMENS
%
20
10
0
15
20
25
30
4
9
14
19
24
29
3
8
13
JULY
AUGUST
SEPTEMBER

Figure 2

Table 1. Sexes and maturation of male parr in the Matamek River, August-September 1981.

Location	Female	Immature Male	Mature Male	% Mature Male
2nd Falls	5	0	16	100
3rd Falls	6	2	7	78
4th Falls	5	0	15	100
5th Falls	1	0	2	100

Table 2. Percent composition of parr samples from different segments of the Matamek River, Summer 1981.

Location	July			September		
	Female	Im Male	Mat Male	Female	Im Male	Mat Male
Below 3rd Falls						
Downstream, slow water	56.3	3.1	40.6	40.0	25.0	35.0
Upstream, fast water	42.9	11.4	45.7	40.0	13.3	46.7
Below 4th Falls						
Downsteam, slow water	0	0	100	8.3	16.7	75.0
Upstream, fast water	28.6	14.3	57.1	36.4	0	63.6

Table 3. Percent of all males that were mature

Location	July	September
Below 3rd Falls		
Downstream, slow water	93	58
Upstream, fast water	80	78
Below 4th Falls		
Downstream, slow water	100	82
Upstream, fast water	80	100

Table 4. Condition factors ($K = \frac{W}{L^3} \times 100$) for female, immature male, and mature male salmon parr in the Matamek River, Quebec, Summer 1981. Values are means (n). Location codes increase upstream (see below).

Months	Location Codes	Female	Immature Male	Mature Male
May/June	5,6,7	1.02 (1)	0.75 (1)	–
	10,11	0.92 (3)	–	0.90 (1)
	12,13	0.98 (2)	1.03 (1)	1.14 (1)
July	10,11	1.18 (18)	1.24 (1)	1.20 (13)
	12,13	1.10 (15)	0.98 (4)	1.20 (16)
	16A,B	–	–	1.32 (5)
	16C	1.18 (2)	1.12 (1)	1.29 (4)
August	5,6,7	–	–	1.42 (4)
	14A	1.03 (2)	0.99 (1)	1.17 (5)
	16C	1.12 (1)	–	1.27 (8)
September	5,6,7	1.20 (5)	–	1.36 (12)
	10,11	1.05 (8)	1.05 (5)	1.17 (7)
	12,13	1.11 (6)	1.17 (2)	1.22 (7)
	16A,B	1.32 (1)	1.09 (2)	1.30 (4)
	16C	1.23 (4)	–	1.45 (7)
	17	1.26 (1)	–	1.33 (2)

Location	
1	Matamek estuary
2	Estuary to and including 1st falls fish ladder
3	1st falls to 1st sharp bend in river (downstream of old road crossing)
4	1st bend to mouth of Muskrat River
5	Bay below 2nd falls: southern edge (right bank, facing upstream)
6	Riffle at base of 2nd falls + Falls
7	Bay below 2nd falls: northern edge (left bank, facing upstream
8	Muskrat Rive: below 1st falls
9	Muskrat River: above 1st falls
10	Matamek River, 2nd falls to first island (left side facing upstream)
11	First small island to area of quiet, branching backwaters along east shore (right bank facing upstream: includes trap net)
12	Backwater along east shore to mid-river island (including island)
13	Upstream end of island to base of rapids
14	base of rapids to bse of 3rd falls
15	Above 3rd falls to top of rapids (to start of quiet water below 4th)
16	Quiet water below 4th falls; to base of 4th
17	4th falls to base of 5th

Table 5. Summary of data on unusually large (≥16.0 cm FL) parr, Matamek River, 1981.

Date	Falls	FL (cm)	Wt (g)	K	Sex	Maturity	Gonad as % Body Wt.
July 21	3rd	17.4	64.4	1.22	Male	Mat.	1.1
24	4th	17.5	67.0	1.25	Male	Mat.	0.8
24	4th	16.1	47.8	1.15	Male	Prev. Mat.	0.2
24	4th	16.0	52.9	1.29	Male	Mat.	2.8
24	4th	16.3	50.6	1.17	-	-	-
Aug. 3	3rd	20.1	95.3	1.17	Male	Mat.	3.8
3	3rd	17.2	59.9	1.18	Male	Mat.	3.4
5	4th	19.5	95.9	1.29	Male	Mat.	4.2
5	4th	16.5	52.4	1.17	Male	Mat.	2.9
21	2nd	16.7	-	-	-	-	-
22	2nd	16.2	48.3	1.14	-	-	-
22	2nd	16.5	53.8	1.20	-	-	-
25	4th	19.2	87.8	1.24	-	-	-
25	4th	16.5	54.2	1.21	-	-	-
26	4th	16.6	52.9	1.16	Male	Mat.	2.2
26	4th	16.2	58.4	1.37	Male	Mat.	10.5
27	4th	17.8	63.8	1.13	-	-	-
27	4th	16.6	-	-	-	-	-
27	4th	16.6	46.3	1.23	-	-	-
Sept. 2	3rd	16.4	54.1	1.23	-	-	-
5	3rd	17.5	62.5	1.17	-	-	-
5	3rd	18.5	77.2	1.22	-	-	-
5	3rd	16.4	49.9	1.13	-	-	-
6	4th	17.2	61.4	1.21	Male	Mat.	11.7
6	4th	16.0	55.3	1.35	Male	Mat.	13.7
6	4th	18.0	66.8	1.15	Male	Mat.	12.3
8	4th	16.7	57.7	1.24	Male	Mat.	18.5

SPAWNING OF PRECOCIOUS MALE PARR: SPAWNING CHAMBER OBSERVATIONS AT NOEL PAUL'S BROOK, NEWFOUNDLAND

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Recent shifts in salmon life history include dramatic increases in the fractions of male parr that mature sexually. Although it is clear that mature parr spawn as satellites in competition with adults, virually no information exists on either individual reproductive success or reproductive effort, and few details are available on parr reproductive behavior. In October 1981, I conducted pilot studies of parr spawning in a spawning chamber at the Fisheries and Oceans hatchery on Noel Paul's Brook, a tributary of Newfoundland's largest river, the Exploits River.

RESULTS AND DISCUSSION

1. Parr distribution in nature. Water from the Noel Paul's Brook spawning channel spills over a concrete dam approximately 1 m in height and into the brook. The dam blocks movement of parr from the river into the channel. Seine hauls on several occasions demonstrated that parr massed within 1 m of the foot of the dam (water depth <0.05 m) during the day. Some moved into the shallows (depth <0.2 m) at night. For example, two hauls with a 15 m seine on 28 October (±1600 h) at between ~10 and 40 m from the dam yielded only 2 parr for an estimated 150-200 m^2 area; two subsequent hauls within 2 m of the dam produced 14 parr (area covered ±20 m^2).

2. Parr size, condition and maturity. I captured a total of 59 parr ranging in size from 6.2 to 15.2 cm FL (Table 1). Forty-eight of these were checked by abdominal pressure for maturity; 39 (81%) were running ripe males. Only 10 fish were sacrificed, and these included no females. The smallest ripe male was 7.1 cm in length, although most unripe fish were less than 8.5 cm in length. Condition factors were unexpectedly low

(x=0.98, sd=0.09, n=59) considering the tendency for maturing parr from the Matamek and other rivers to have exceptionally high condition at the end of the growing season.

3. Pre-spawning behavior. Parr stationed themselves about the redd and oriented toward the redd rather than into the current. Except for occasional changes in position or flight from adult or parr attack, parr remained totally immobile among the rock. Parr coloration differs from that common to Matamek parr in Summer and early Fall; some exhibit a weakly-defined, broad, lateral stripe while other sport 1-3 faint vertical bars below the dorsal fin, nape or adipose fin. Both patterns tend to obliterate parr marks. Parr-parr aggression was uncommon. Adult attacks on parr were common only in an experiment with a single adult male and a single female. In experiments involving 2 or more adult males, virtually all aggression was between adults.

4. Spawning behavior. When courting, adult males perform a high-frequency, low-amplitude lateral quiver, parr dash to positions immediately beneath the female's vent. The quiver is both a courtship maneuver and the earliest obvious motor pattern in the spawning sequence. Under the spawning adults, parr twirl about, gape and quiver. Eggs are often released directly onto spawning parr; parr position suggests they may contribute significantly to fertilization.

5. Post-spawning behavior. After spawning, parr immediately resume their posts outside the redd, from which they rush to eat eggs dislodged into the water column by the digging adult female. Eggs are not eaten if they come in contact with the substrate, so that only eggs likely to be swept out of the redd are eaten.

SUMMARY

Parr may be quite effective in fertilizing eggs, as they are much closer to spawned eggs than is the adult male's vent. Further, during spawning the vent of the adult male actually rises from proximity to the female, as if jet-propelled by the explosive discharge of milt. Ingestion of eggs by parr may be very significant. Six stomachs of post-spawning parr of fork lengths 8.9, 9.4, 11.6, 12.3, 13.7 and 14.8 cm contained 3, 5, 9, 27, 28, and 17 eggs, respectively. At least two critical questions become apparent from these observations. First, what is the individual and aggregate reproductive success enjoyed by parr? Second, how does the ingestion of eggs affect subsequent survival and growth of precociously mature parr?

Table 1. Lengths, weights, condition factors, and maturing of parr from Noel Paul's Brook, Newfoundland, October 1981. NC = not checked, R = running ripe , blank = checked but not running ripe, K = 100 W/L3. No fish were sacrificed during these initial samplings. ID specimens recaptured later from the chamber (8.9-14.9 cm) were all males.

Specimen	FL (cm)	WT (g)	Maturity	K
1	6.2	2.8		1.17
2	6.3	2.7		1.08
3	6.8	2.7		0.86
4	6.8	3.6	NC	1.14
5	7.0	3.5		1.02
6	7.1	3.8	R	1.06
7	7.1	3.4		0.95
8	7.2	3.8	R	1.02
9	8.3	5.6	NC	0.98
10	8.3	5.0	R	0.87
11	8.3	4.9		0.86
12	8.3	5.4	R	0.94
13	8.8	7.3	R	1.07
14	8.8	7.6	R	1.12
15	8.9	6.7	R	0.95
16	8.9	6.6	R	0.94
17	9.1	7.6	NC	1.01
18	9.1	7.8	R	0.90
19	9.1	7.1	R	0.94
20	9.2	7.6	R	0.98
21	9.2	7.4	R	0.95
22	9.3	7.5	R	0.93
23	9.3	7.8	NC	0.97
24	9.4	7.0	R	0.84
25	9.5	6.6		0.77
26	9.5	8.8	R	1.03
27	9.5	9.8	NC	1.14
28	9.5	6.8		0.79
29	9.6	7.6	NC	0.86
30	9.7	9.0	R	0.99
31	9.8	9.6	R	1.02
32	9.8	9.6	NC	1.02
33	9.9	9.7	R	1.00
34	10.2	10.4	R	0.98
35	10.3	11.1	R	1.02
36	10.3	10.7	NC	0.98
37	10.4	12.2	R	1.08
38	10.5	11.6	R	1.00
39	10.7	9.5		0.78

Table 1 (Cont.)

Specimen	FL (cm)	WT (g)	Maturity	K
40	10.8	10.2	NC	0.78
41	11.3	14.8	R	1.03
42	11.4	15.2	R	1.03
43	11.6	15.8	R	1.01
44	11.7	16.1	R	1.01
45	11.8	15.9	R	0.97
46	11.8	16.2	R	0.99
47	12.3	20.8	R	1.12
48	12.3	20.6	R	1.11
49	12.3	18.5	R	0.99
50	12.4	19.6	R	1.03
51	12.8	22.5	R	1.07
52	12.9	23.6	NC	1.10
53	13.2	23.6	R	1.03
54	13.3	24.5	R	1.04
55	13.7	22.9	R	0.89
56	13.9	28.2	R	1.05
57	14.9	31.0	NC	0.94
58	14.9	29.8	R	0.90
59	15.2	32.6	R	0.93

Table 2. Summary of maturity and condition for Noel Paul's Brook parr, by 1 cm size class.

Size Class (cm)	Examined Fish that were Running Ripe %	N	Condition Factor $\overline{x}$	sd	N
6.0–6.9	0	3	1.06	0.14	4
7.0–7.9	50	40	1.01	0.05	4
8.0–8.9	86	7	0.97	0.09	8
9.0–9.9	83	12	0.95	0.09	17
10.0–10.9	80	5	0.95	0.12	7
11.0–11.9	100	6	1.01	0.02	6
12.0–12.9	100	5	1.07	0.05	6
13.0–13.9	100	4	1.00	0.08	4
14.0–14.9	100	1	0.92	0.03	2
15.0–15.9	100	1	0.93	-	1
TOTAL	81	48	0.98	0.09	5

ADAPTIVE LIFE HISTORY STRATEGIES IN NORTH SHORE GULF OF ST. LAWRENCE STOCKS OF ATLANTIC SALMON: A PROGRESS REPORT

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ABSTRACT

The need exists for a more powerful model, than currently available, to describe the ecology of North Shore Salmon. An integrated approach is under development to examine stock characteristics such as smolt age, occurrence of male precocity and age and size at first (adult) maturity, in relation to differences in river basin geomorphology. Considerable progress was made in a number of areas during and subsequent to the 1981 field season.

PROGRESS REPORT

1. An excellent general data base has been established (see Table 1); some 3,100 angled adult salmon from 10 rivers have now been sampled. 2,700 salmon parr were also obtained from various sample sites on these rivers over the past two field seasons. The data base for the comparative component of the study (Bielak and Power 1981) was generally consolidated after identification of gaps in the data. Good representative samples of the St. Jean and Godbout Salmon runs (juveniles also in the latter case) were collected thus allowing comparison with Schiefer's (1971) data. A sample of parr from the upper Nabispi will allow a comparison with Shooner's (1967) figures. The previously unstudied Grand Watchichou was sampled for both adults and parr. Unfortunately, adult sexes were not generally obtained, a situation which will hopefully be rectified in 1982.
2. The Natashquan River was comprehensively sampled to determine Salmon distribution and juvenile growth rates throughout the system. Salmon

parr were collected from all the major tributaries accessible to adults, and a report is under preparation to separately describe this aspect of the project. The penetration of adult salmon into the Natashquan river is far more extensive than previously thought, juveniles having been found above the Quebec-Labrador border, a distance of over 150 miles from the Gulf of St. Lawrence.

Although some 120 adult fish were also sampled (bringing the total adult sample for the river to 240), there is a lack of confidence in certain of the recorded data making it imperative to return to the river to obtain a truly representative sample. (This was also done on the St. Jean in 1981 because of small sample size in 1980.) It is hoped that the two angling clubs on the Natashquan will provide logistic support to facilitate scale collection.

3. A variety of river systems between the Nabisipi and Etamamiou were mapped to establish river order using the same methods as employed by Naiman and Critchley (1980).

A considerable effort was expended in this exercise, and the information will be used in establishing an index of river harshness. The ordering of the Natashquan system was used to establish sampling sites in 1981 on a systematic rather than random basis.

4. Two salmonid research projects by undergraduate students (John Noble, University of Waterloo and Anna Brzeski , Macdonald College) were instigated and supervised during the course of the summer. Details of each project appear elsewhere in the Annual Report.

PLAN OF WORK IN 1982

Field work planned for 1982 will complete the data base established in 1980 and 1981. Priority consideration will be given to obtaining a fully representative sample of the Atlantic Salmon runs (adult and smolt) of the Natashquan river. Supplemental data (as identified by analysis of available data prior to the field season) will be collected where necessary.

ACKNOWLEDGEMENTS

As in 1980 a great number of people contributed to the general success of the field season. It would be unfair to single any one of them out. Field Assistants, John Noble and Anna Brzeski worked very hard, often under difficult conditions, and did a fine job both for us, and in the successful completion of their own projects.

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Table 1. Data Base, Adult and Juvenile Atlantic Salmon.

River	Adults Sampled			Juveniles Sampled		
	Year			Year		
	1980	1981	Total	1980	1981	Total
Godbout	--	130	130	--	120	120
Moisie	131	400	531	691	--	691
Mingan/Manitou	118	129	237	106/34	--	106/34
St. Jean	34	250	284	243	--	243
Corneille	97	75	172	163	--	163
Gt Watchichou	--	125	125	--	115	115
Nabisipi	41	--	41	85	61	146
Natashquan	119	120	239	28	500	528
Olomane	53	60	113	182	30	212
Etamamiou	225	400	665	254	54	308
Gros Mecatina	200	433	633	48	--	48
Total	1018	2122	3140	1834	880	2714

VARIATION IN BODY MORPHOLOGY OF JUVENILE ATLANTIC SALMON (*Salmo salar*) OF THE MATAMEK RIVER, QUEBEC

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INTRODUCTION

Both heredity and environment play an important role in the development of an organism, but there has been much discussion over the degree of environmental and genetic influence on any particular characteristic. Morphological characteristics of fish vary considerably depending on conditions during development (Ricker 1972). Riddell and Leggett (1981a,) found consistent differences in body and fin morphology between juvenile Atlantic salmon (*Salmo salar*) from two rivers differing in average flow velocities. They demonstrated a genetic basis to this interpopulation variation (1981a) as well as an adaptive basis (1981b). Yevsin (1977) suggested similar morphological differences in summer-run sea trout (*Salmo trutta*) entering one river at different flow velocities. Thus, not only the spatial but also the temporal aspects of genetic variability have been considered.

However, it is possible that similar differences may exist in relation to micro-habitat heterogeneity (Calaprice 1969). The purpose of this study was to determine whether there is any significant difference in body morphology between juvenile Atlantic salmon of the same genetic stock found in fast-flowing water and those found in slow-flowing water.

METHODS

Atlantic salmon parr were sampled in two different areas of the Matamek River, a slow-flowing section (10.3 cm/s on July 28) and a riffle area (87.6 cm/s on July 28). Even during the driest part of the summer the two sections remained distinguishable; the fast-flowing section, although less turbulent at the end of August than earlier in the summer, nevertheless remained a riffle area. Both areas occur between the second and third falls of the river, the former being above the only major tributary into which salmon could enter. Thus salmon parr from the two sample sites are considered to be the same single Matamek genetic stock. It is assumed that the parr were resident in their respective sections of the river as many studies of salmonid movements indicate that they do establish homes within a river, straying little from them (Fausch and White, 1981; Rimmer, 1980; Saunders and Gee, 1964; LeCren, 1958) though movement away from such homes may occur (Gee et al., 1978).

Salmon parr were sampled by fly-fishing and trolling over 2 days (July 21-22). Twelve morphometric traits were measured to the nearest 0.01 mm. These were, following the criteria of Hubbs and Lagler (1970), pectoral and pelvic fin lengths (PEC and PEL, respectively), length of dorsal and anal fin base (DOR and ANAL), body depth (BD), body width (BW), head length (HL), head depth (HD), and head width (HW), and fork length (FL), snout to the anterior insertion of the pectoral fins (SNAP) and pelvic fins (SNAPE). Each fish were also weighed, sexed, and aged (by scale-reading). Only 2^+ parr were used in the analysis, 30 in each category of water velocity.

RESULTS

A t-test was performed to test for differences between the means of the males and females within each section of the river. Since some of the variances were significantly different (F-test, $p>0.05$), these results were confirmed with the Wilcoxon test which makes no assumptions about equal variances. The results were identical; there was no significant difference found in any of the twelve morphological characteristics (see Table 1). The data were then pooled and tested to compare parr from the fast-flowing with those from the slow-flowing section. Anal fin base was significantly longer in the parr from the riffle area (t-test, $p<0.05$) and body width was significantly larger in the parr from the slow-flowing section (t-test, $p<0.05$). Means for pectoral fin length and head length were greater in the riffle fish although not significantly so (Table 2).

Prior to performing multivariate discriminant function analysis (D.F.A.), an intercorrelation matrix comprising all variables was examined to identify highly related morphological characteristics (Table 3). Virtually all variables were highly correlated, thus variables to be used in D.F.A. were those having significantly different means (BW, ANAL) and variables having intercorrelated coefficients less than 0.05.

Initially, all variables were included in the D.F.A. and subsequently the number of variables was reduced while maximizing classification success and keeping the relevant variables indicated above. Elimination of 7 variables was possible, leaving 5 (Table 4) to discriminate between the 2 river sections with a classification success of 88.33 (Table 5). These variables were fork length, length of anal fin base, body width, head length, and snout to anterior insertion of pectoral fin. There is a tendency for fish from slow-moving water to have wider bodies and a larger snout to anterior insertion of pectoral fin, and fish from fast-moving water to have longer anal fin bases and longer heads.

DISCUSSION

These results indicate that based on a combination of variables, it is possible to discriminate between 2+ salmon parr from the fast and slow sampling stations of the Matamek River. This distinction agrees with Riddell and Leggett's hypothesis (1981a) that differences in fish body morphology are adaptive responses to long-term flow condition.

Riddell and Legett (1981a) as well as Yevsin (1977) found that fish from faster moving waters were shallower and had more fusiform bodies. Juvenile salmon also had longer pectoral and pelvic fin lengths as well as longer heads. The differences in fin size were attributed to the energetic cost of maintaining feeding positions on the substrate by extending paired fins as hydrofoils; larger fins would be more effective in creating the negative lift required to maintain a position in higher flows (Riddell and Leggett, 1981a). Although fin lengths were greater in parr from faster water of the Matamek River, these differences were not significant. However, having the pectoral fin inserted further forward may help in balance and maneuverability in the stronger flows. (SNAP, one of the 5 variables included in the D.F.A., is greater in fish from fast-flowing water.)

Rimmer (1980), studying movements of salmon parr, found that not only pectoral and pelvic, but also anal fins were used in anchoring salmon to the substrate. The anal fin was significantly longer in the riffle-inhabiting parr of the Matamek River (Table 2); a longer fin would be more effective in controlling stability in turbulent water. When a salmon parr swims quickly forward the paired fins and dorsal fin are folded against the body but the anal fin remains partly extended, thus the later may also be used to provide thrust for swimming (Power, pers. comm.).

Body width is significantly smaller in riffle-inhabiting parr and it is also one of the variables which help to discriminate between the two river sections; narrower fish offer less resistance to higher flow.

Thus, a combination of certain morphological traits of juvenile Atlantic salmon parr are significant in distinguishing between populations inhabiting different areas of the same river.

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Table 1. Means (X) and standard errors (S.E.) of the 12 morphological characteristics measured (mm) for male and female salmon parr (2+) from fast and slow sections of the Matamek River, Quebec.

Morphological Characteristics	Fast Water (87.6 cm/sec)			
	Male		Female	
	X	S.E.	X	S.E.
FL	129.07	3.07	130.97	1.73
PEC	23.71	1.18	22.44	0.36
PEL	16.01	0.30	15.76	0.25
DOR	16.44	0.37	16.54	0.27
ANAL	10.11	0.26	10.22	0.19
BD	27.77	0.62	27.91	0.41
BW	15.98	1.57	15.84	0.27
HL	28.47	0.59	28.37	0.28
HD	18.12	0.64	18.09	0.26
HW	13.59	0.33	13.35	0.26
SNAP	26.57	0.54	26.79	0.34
SNAPE	62.92	1.54	64.14	0.92

Morphological Characteristics	Slow Water (10.3 cm/s)			
	Male		Female	
	X	S.E.	X	S.E.
FL	129.55	3.13	130.09	2.64
PEC	22.53	0.50	22.44	0.46
PEL	15.92	0.34	15.84	0.31
DOR	16.28	0.28	16.34	0.39
ANAL	9.57	0.31	9.62	0.29
BD	28.26	0.74	27.92	0.59
BW	17.09	0.47	17.23	0.76
HL	28.03	0.54	28.11	0.54
HD	18.21	0.40	17.96	0.39
HW	13.47	0.32	13.49	0.29
SNAP	26.93	0.53	26.88	0.57
SNAPE	65.05	1.35	64.00	1.55

Table 4. Standardized coefficients associated with each of 5 variables comprising the function used to discriminate between Salmon parr found in fast and slow moving water.

Variable	Standardized discriminant function coefficient
FL	1.95
ANAL	-1.40
BW	0.52
HL	-2.99
SNAP	1.94

Table 5. Results of the discriminant analysis based on 5 variables of Salmon parr from fast vs slow flowing water, Matamek River, Quebec.

	Fast Water		Slow Water
Centroid in reduced space	-0.939		0.939
Difference in fast and slow centroids		1.879	
Number of cases correctly classified	27 (90.0%)		26 (87.7%)
Classification success for the population		88.33%	

A STUDY OF SCALE REGENERATION IN SALMON FROM THE ST. JEAN AND GROS MECATINA RIVERS

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ABSTRACT

Scale samples of Salmo salar were taken from 97 pre-spawned specimens from the St. Jean River and 10 specimens from the Gros Mecatina. The scales were examined for incidence of regeneration at three life cycle stages; river, smolt and ocean. The greatest scale loss ocurred during the river stage, apparently before parr attained an age of three years. Thereafter increased age was an insignificant factor in occurrence of scale regeneration. For the St. Jean sample a mean of 84.8-91.8% scale regeneration occurred in 3-5 year old parr. (The equivalent figure for the Gros Mecantina was 74.4-79.7%).

River regeneration percentages were significantly higher than smolt and ocean regeneration percentages, which did not differ significantly. Total scale regeneration was not significantly different between the St. Jean and Gros Mecatina rivers, although this conclusion is only tentative given the small sample number in the latter case.

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OSMOREGULATION IN THE BROOK TROUT, (Salvelinus fontinalis)

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Migration of brook trout (Salvelinus fontinalis) into sea water can result in exceptional growth and high return rates, making this a potentially valuable species for sea ranching, fish farming and enhancement programs. Sea ranching experiments conducted at the Matamek Research Station indicate the prevalence of these qualities under conditions of artificial transplantation. Economic development of commercial ventures will require knowledge of optimum sea water stocking procedures. To this end, we have investigated the role of size, age and photoperiod in determining the ability of brook trout to osmoregulate and grow in sea water.

Ten thousand fry were divided into fast and slow growing groups using feeding rate to control growth. Fish were further divided into two photoperiods; one of normal (annually cycling) daylength and a second three months out of phase with normal. Fish from each group were exposed to seawater using a step-wise acclimation procedure (10→20→32°/oo). Growth and survival were monitored for 20 days. Osmoregulatory ability was judged by changes in plasma concentrations of Na^+, Cl^-, K^+, Mg^{++}, osmotic concentration and gill Na^+-K^+ ATPase after 4 and 20 days in sea water.

Increased size results in increased sea water survivorship and osmoregulatory ability (see Figures 1 and 2). Growth rate and age have no detectable effect on osmoregulation. Photoperiod effects osmoregulation by controlling maturation; ripe males have significantly decreased survival time (Figure 3) and increased plasma osmotic concentrations (Table 1). Plasma osmotic concentration after 4 days in seawater correlate with sea water surivorship and can be used to predict osmoregulatory ability of experimental groups or natural populations of brook trout (see Figure 1). The predominant role of size in determining osmoregulatory ability indicates that accelerated growth rates, which produce larger fish at any age, will result in individuals that can more successfully adapt to sea water.

Activity of gill Na^+-K^+ ATPase in brook trout in freshwater is similar to other freshwater teleosts, ranging from 5 to 12 μM P_i ·mg $prot.^{-1} \cdot hr^{-1}$. Enzyme activity increases with increasing body size, until a maximum freshwater value is reached. Unlike smolting salmonids, no spring-time peak in activity is present. Thyroxine levels in slow growing fish are lower than fast growers at all sampling periods. Gill Na^+-K^+ ATPase levels increase under hypersaline conditions, rising at rates similar to other euryhaline teleosts, to levels of 40-60 μM P_i ·mg $prot.^{-1} \cdot hr^{-1}$ after 20 days in 32 ^{o}/oo seawater.

Method of sea water acclimation had a significant effect on survivorship. Fish acclimated at intermediate salinities (one week in 10^o/oo, one week in 20^o/oo) had higher mean survival times, greater percentage survival and lower plasma osmotic concentrations after 24 hours in sea water, relative to fish transferred directly to sea water. Gill Na^+-K^+ ATPase activity increased from 10 to 17 μM P_i ·mg $prot.^{-1} \cdot hr^{-1}$ when fish are acclimated for one week in 20^o/oo. These results indicate that an increased acclimation time in intermediate salinities result in increased physiological preparedness and sea water survivorship for every size class.

Within group variations in osmoregulatory ability exist and cannot be explained by variations in size or sex. This indicates a considerable natural genetic variation that could provide a basis for selective breeding of sea-run brook trout. Attempts are being made to preserve a broodstock consisting of individuals with exceptional osmoregulatory ability.

The results cited above have important implications for sea water stocking of brook trout. Large fish will adapt more readily to sea water, so that increased growth will result in greater sea water survival. However, during a declining photoperiod, increased size will also lead to greater percentages of maturing fish which has a negative effect on osmoregulatory ability and sea water survival. Acclimation at intermediate salinities elevates gill Na^+-K^+ ATPase and increases survival in full strength sea water.

Several questions still remain: (1) the physiological basis for differences in osmoregulatory ability between mature males and females may provide insight into mechanisms controlling osmoregulation in salmonids and implies sexual differences in migratory behavior and life history strategy. (2) Stress due to freshwater readaptation (hyperosmoregulation) needs to be investigated for its possible effect on returning stocks of sea-run brook trout. (3) What are the physiological differences, if any, that exist between anadromous (e.g. Moisie River) and non-anadromous (e.g. Matamek River) stocks of brook trout? Continued research and data analysis in our laboratory should help answer these and other basic questions related to salmonid osmoregulation.

Figure Caption

Figure 1. Size at time of sea water exposure, mean survival time in seawater and plasma osmotic concentration after 4 days in 32 o/oo seawater versus age at time of seawater entry. All fish were acclimated to 32o/oo seawater in a stepwise fashion (see text). Closed circles represent fast growing fish and closed triangles represent slow growing fish.

Figure 2. Body size versus mean survival time in seawater. All fish were acclimated to 32o/oo seawater in a stepwise fashion. Duration of exposure was 20 days which represented maximum seawater survival time.

Figure 3. Mean seawater survival time for brook trout maintained under two photoperiod regimes. Experiments were conducted in November and both groups were in a declining photoperiod. The female category represents both mature and immature females.

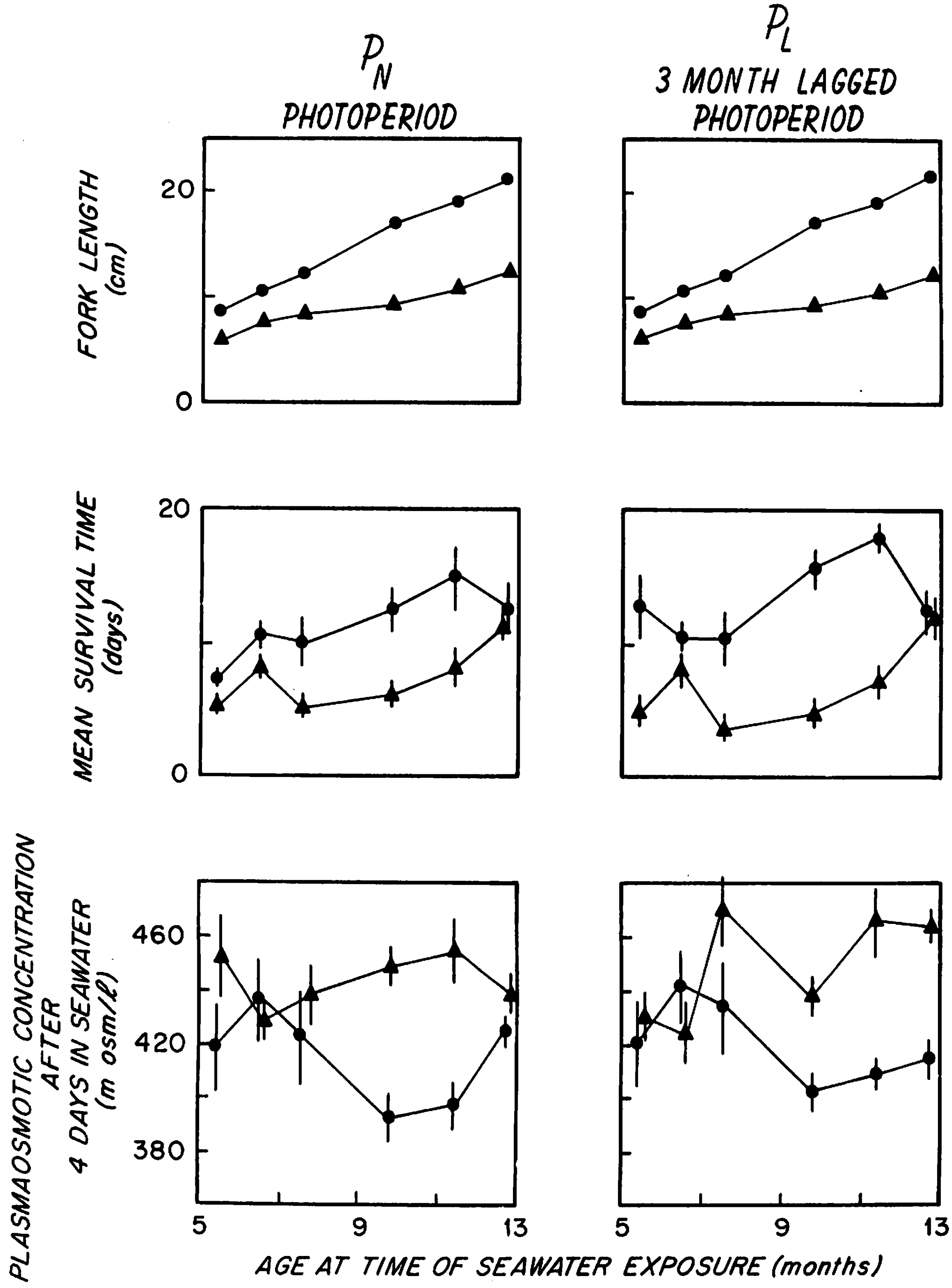

P_N
PHOTOPERIOD
P_L
3 MONTH LAGGED PHOTOPERIOD
FORK LENGTH (cm)
20
0
MEAN SURVIVAL TIME (days)
20
0
PLASMAOSMOTIC CONCENTRATION AFTER 4 DAYS IN SEAWATER (m osm/ℓ)
460
420
380
5
9
13
5
9
13
AGE AT TIME OF SEAWATER EXPOSURE (months)

FIGURE 1

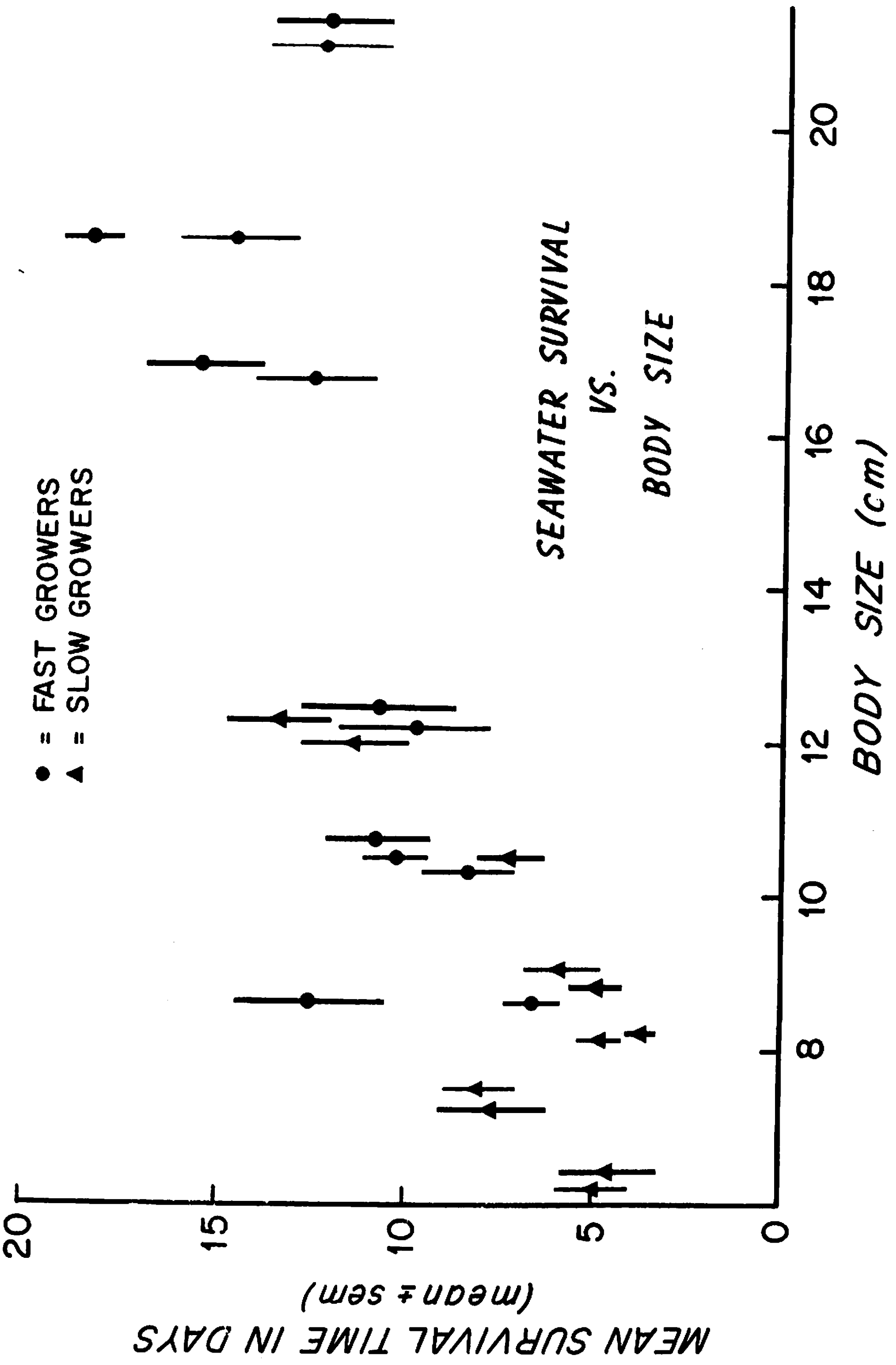

● = FAST GROWERS
▲ = SLOW GROWERS
SEAWATER SURVIVAL
VS.
BODY SIZE
MEAN SURVIVAL TIME IN DAYS
(mean ± sem)
0
5
10
15
20
8
10
12
14
16
18
20
BODY SIZE (cm)

FIGURE 2

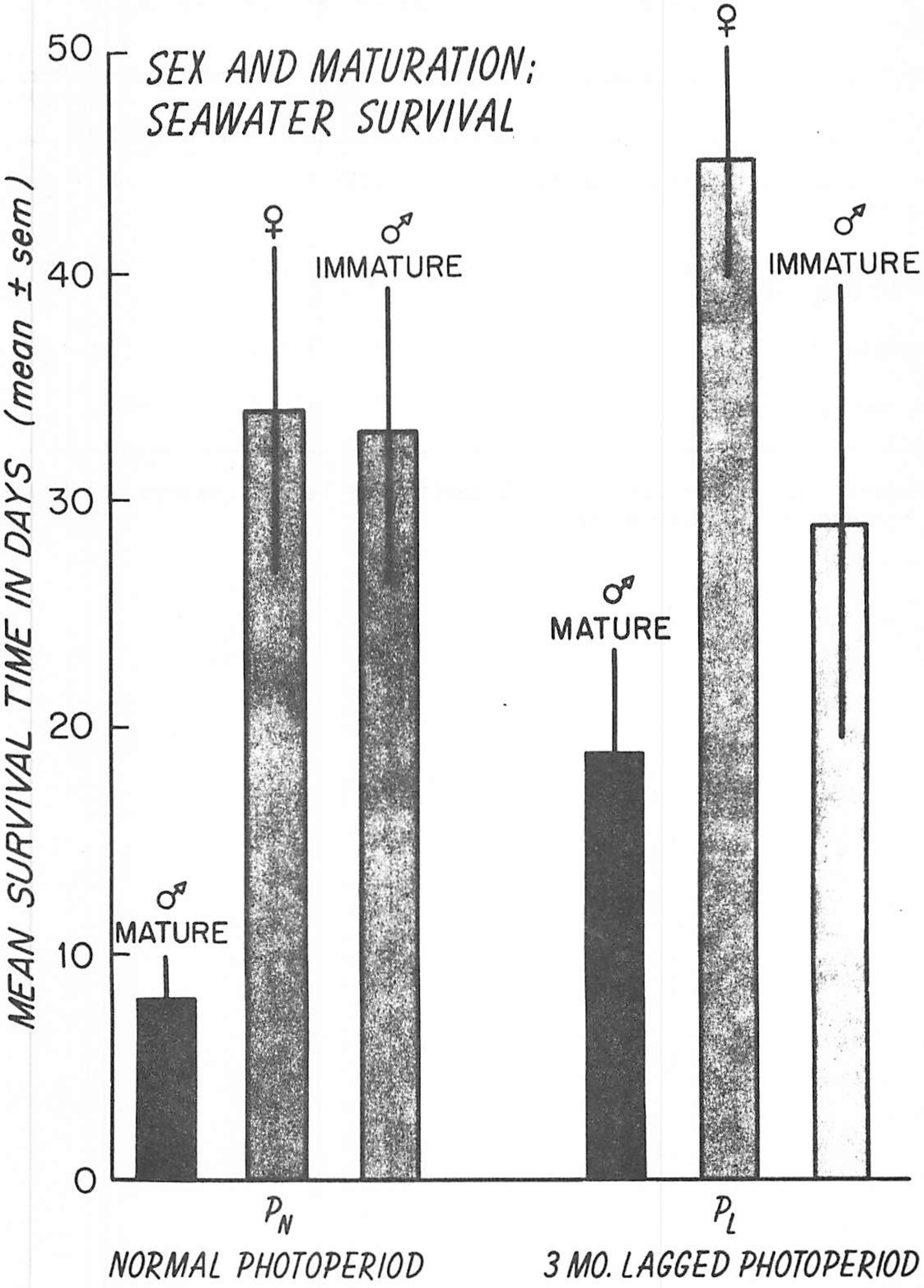

SEX AND MATURATION;
SEAWATER SURVIVAL
MEAN SURVIVAL TIME IN DAYS (mean ± sem)
0
10
20
30
40
50
♂
MATURE
♀
♂
IMMATURE
♂
MATURE
♀
♂
IMMATURE
P_N
NORMAL PHOTOPERIOD
P_L
3 MO. LAGGED PHOTOPERIOD

FIGURE 3

Table 1. Physiological comparison of mature females and mature males after 4 days in 32o/oo seawater. Fish were acclimated to 32o/oo sea water in a stepwise fashion (see text).

	Males	Females
Plasma Osmotic Concentration (mOsm/l)	427* ± 8.7	401* ± 4.0
Gonadosomatic Index (% body wt)	2.8 ± 0.2	9.0 ± 2.4
Length (cm)	21.4 ± 0.4	21.0 ± 0.3
Weight (g)	109.2 ±10.4	105.3 ± 8.5

*Significantly different at 95% confidence level. Values are expressed as means ± standard errors.

INFLUENCE OF RIPARIAN VEGETATION AND WOODY DEBRIS ON THE ECOLOGY OF BROOK TROUT FRY, Salvelinus fontinalis

Roderick Morin, Robert J. Naiman and Michel Legault
Woods Hole Oceanographic Institution, and the Matamek Research Station

Brook trout are widely considered to respond favorably to physical structures in the stream environment that provide shade, cover, or a physically complex environment. For this to be true of the early life stages of brook trout, the following predictions should apply to trout fry in streams:

- fry should be more abundant in areas with riparian vegetation and woody debris;
- fry should be distributed through the water column in a manner that reflects association with riparian vegetation and woody debris;
- fry should be bigger or grow faster in areas with riparian vegetation and woody debris;
- fry should consume a greater number of terrestrial invertebrates in areas of riparian vegetation and should feed off of woody debris where present.

During 1981 these predictions were tested by experimental removal of riparian vegetation and woody debris from equal sections of the Matamek River (Figure 1).

Weekly observations of abundance and spatial distribution were made by snorkeling. Biweekly removals of trout fry were made in a separate set of treatments and reference sections for the analysis of growth and feeding. Growth was described for each treatment and for reference sections by regressing body weight on julian days and comparisons made by analysis of covariance. Diet composition was analysed by determining for each taxon consumed, the % relative abundance, % frequency of occurrence and % wet weight in fry stomachs. These measures were combined in an index of the relative importance of each taxon by the method of George and Hadley (1973). The diet composition of fry was compared between treatments and reference sections by contingency analysis of functional groupings of taxa. Behavioral observations of trout fry were made both in the Matamek River experimental site and in Rivière à la Truite (Figure 1).

Results of habitat manipulations in the Matamek River did not consistently support hypotheses based on the predicted beneficial influence of riparian vegetation and woody debris. Analyses of the abundance and spatial distribution of trout fry in treatments and references indicate that fry initially selected denuded areas and were distributed in shallow water close to the shoreline (Figures 2-5). Where fry were found in association with riparian vegetation they were located close to the edge of the riparian zone and, therefore, in deeper water (Figure 3). Decreasing mean water depth and mean distance from shore, observed in reference areas and the debris treatment during June and July, are due to dropping water levels and the association of trout fry with the riparian edge. Riparian vegetation may be selected for in mid-August (Figure 2); however, this was more apparent in reference areas than in treatments, due to the reduction of the riparian zone within the experimental site as water level decreased. Growth in treatments and references was similar for the slopes and elevations of all regressions (Table 1, $P<.05$ for all comparisons).

Trout fry feeding was opportunistic in the Matamek River, with a diverse array of organisms consumed, and with no apparent relationship to habitat. Fry consumed organisms proportionately unrelated to available prey in drift (Figure 7, data from R. Dubois, 1980) or on woody debris. Terrestrial insects and winged adult aquatic insects were prominent throughout treatments and reference areas (Tables 2 and 3), indicating the importance of surface feeding.

Trout fry behavior in the Matamek River differed from fry in Rivière à la Truite. Trout fry in the study site on the Matamek occurred in mobile groups with scattered, loose assemblages, whereas fry in Rivière à la Truite more frequently occupied territories. Tagging experiments at both locations indicated that fry in the study site on the Matamek River moved between habitats, while fry in Riviere a la Truite showed a high degree of fidelity to their stream position. These differences in behavior are attributed to higher fry density and faster water flow in Rivière à la Truite. These results illustrate the importance of social organization in relation to the ecology of fish species, determining patterns of resource utilization and habitat association. On the basis of these results we suggest that in smaller, high-gradient streams territoriality stabilizes fry distribution in relationship to habitat.

References

George, E.L. and W.F. Hadley. 1979. Food and habitat partitioning between rock bass (_Ambloplites rupestris_) and smallmouth bass (_Micropterus dolomieui_) young of the year. Trans. Am. Fish. Soc. 108: 253-261.

FIGURE CAPTIONS

Figure 1. Map of North Shore of St. Lawrence River showing location of study sites, Matamek River and Rivière à la Truite. Insets show the location of experimental habitat manipulations on the lower Matamek River.

Figure 2. Relative abundance of trout fry in treatments and reference sections during 1981. Abundance is expressed as the percent occurrence of fry in treatment or reference section relative to all treatments and references for each sampling period. Stippled lines show expected percent occurrence if trout fry were distributed equally throughout all treatments and references.

Figure 3. Mean depth of water column of trout fry observed in habitat treatment and reference sections during biweekly intervals in 1981. Letters appearing above mean values indicate the ranking of mean water depth for treatments and references. Vertical lines joining letters indicate non-significantly different mean water depths according to Student-Neuman-Keuls tests ($P<.05$).

Figure 4. Mean distance of trout fry from shoreline in treatment and reference sections during biweekly intervals in 1981.

Figure 5. Mean distance of trout fry from water surface in treatment and reference sections during biweekly intervals in 1981.

Figure 6. Mean fork lengths and trout fry in the Matamek River during 1980 and 1981 and in Rivière à la Truite in 1980. Growth curves for Matamek data were drawn by eye.

Figure 7. Percent frequency of chironomid and simulid larvae appearing in drift (darkened columns) and in trout fry diet (open columns) in the Matamek River, 1980.

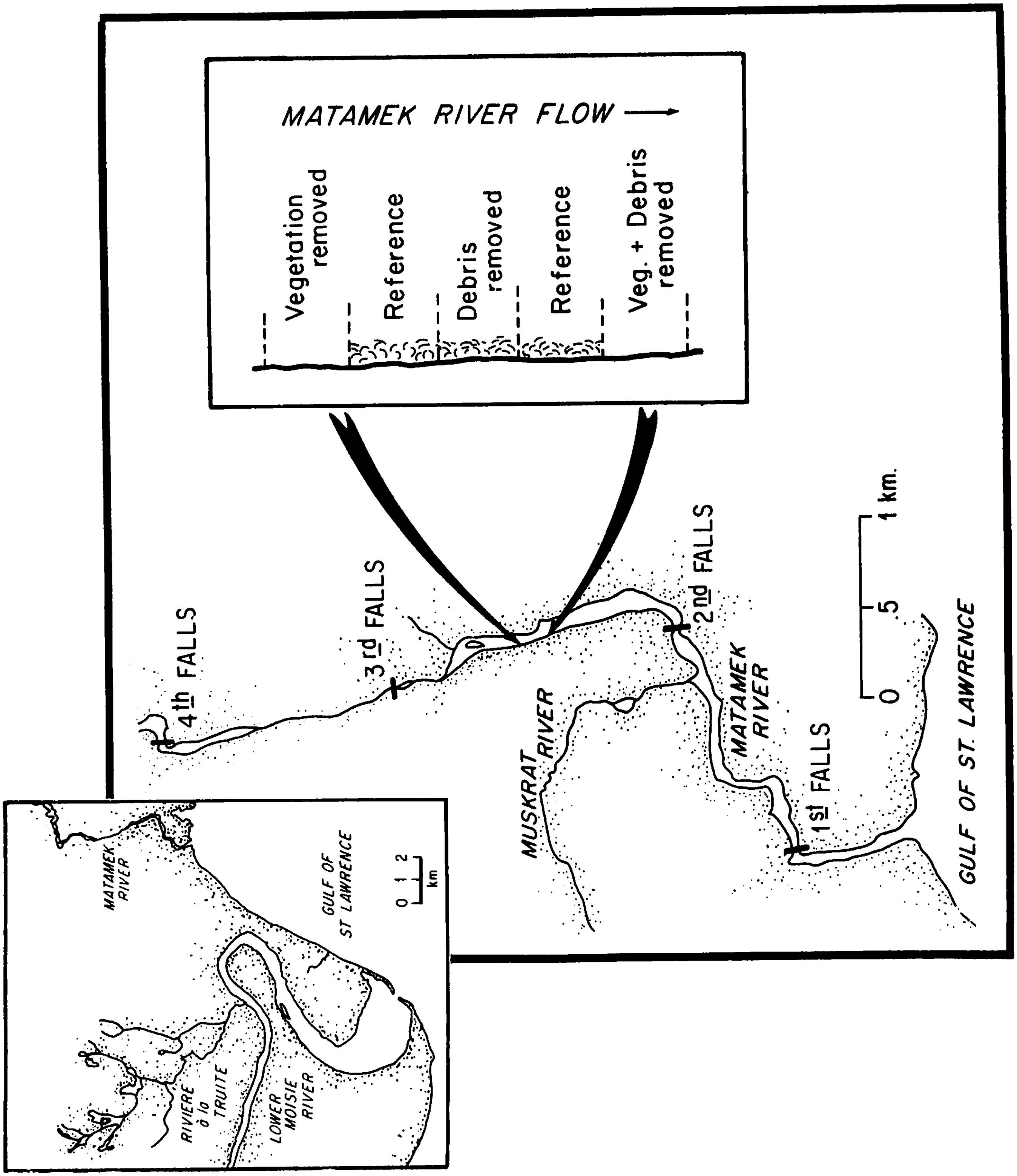

MATAMEK RIVER FLOW →
Vegetation removed
Reference
Debris removed
Reference
Veg. + Debris removed
4th FALLS
3rd FALLS
2nd FALLS
1st FALLS
MUSKRAT RIVER
MATAMEK RIVER
GULF OF ST. LAWRENCE
0 .5 1 km.
MATAMEK RIVER
GULF OF ST LAWRENCE
0 1 2 km
RIVIERE à la TRUITE
LOWER MOISIE RIVER

Figure 1

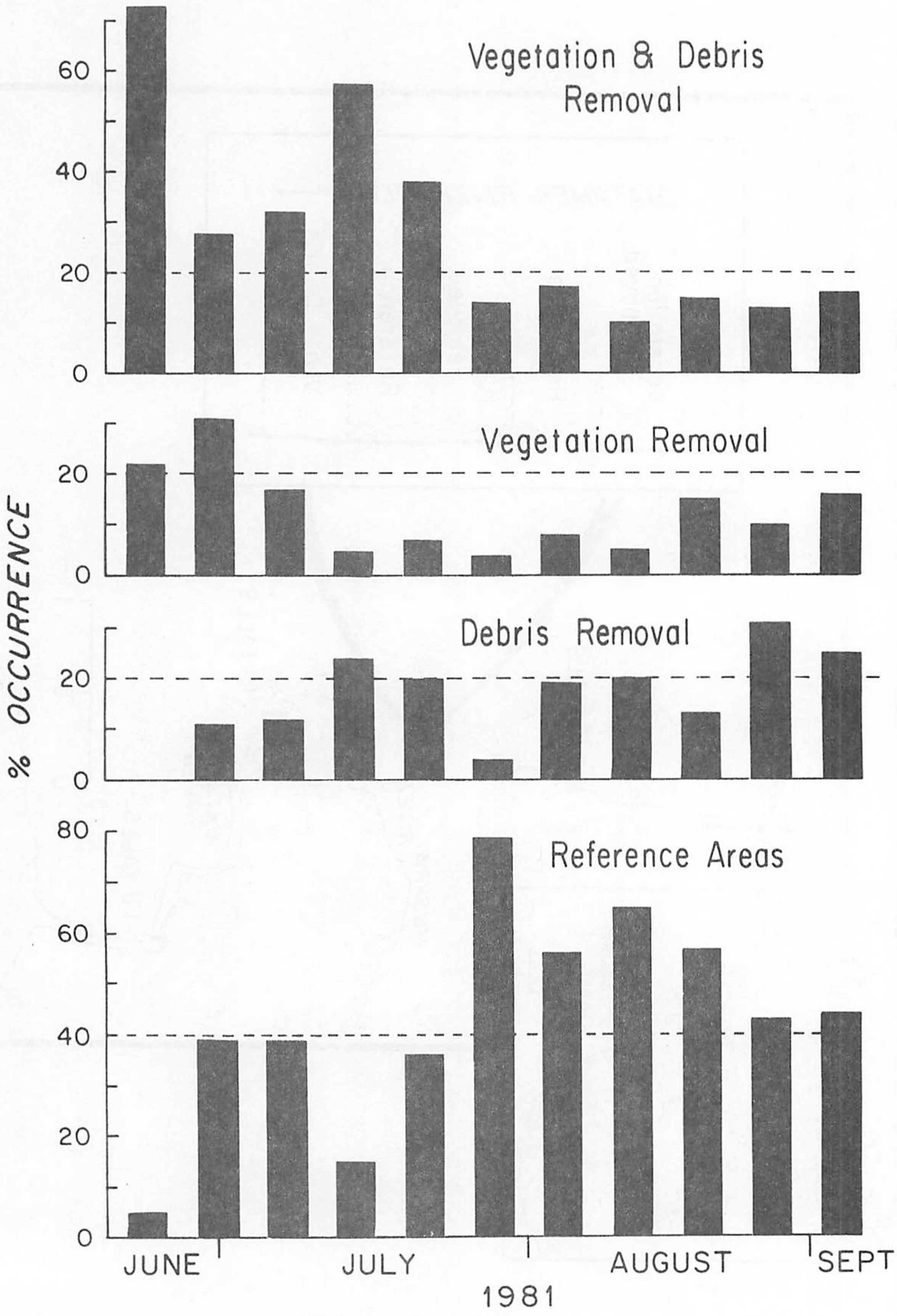

Vegetation & Debris Removal
Vegetation Removal
Debris Removal
Reference Areas
% OCCURRENCE
0
20
40
60
80
JUNE
JULY
AUGUST
SEPT
1981

Figure 2

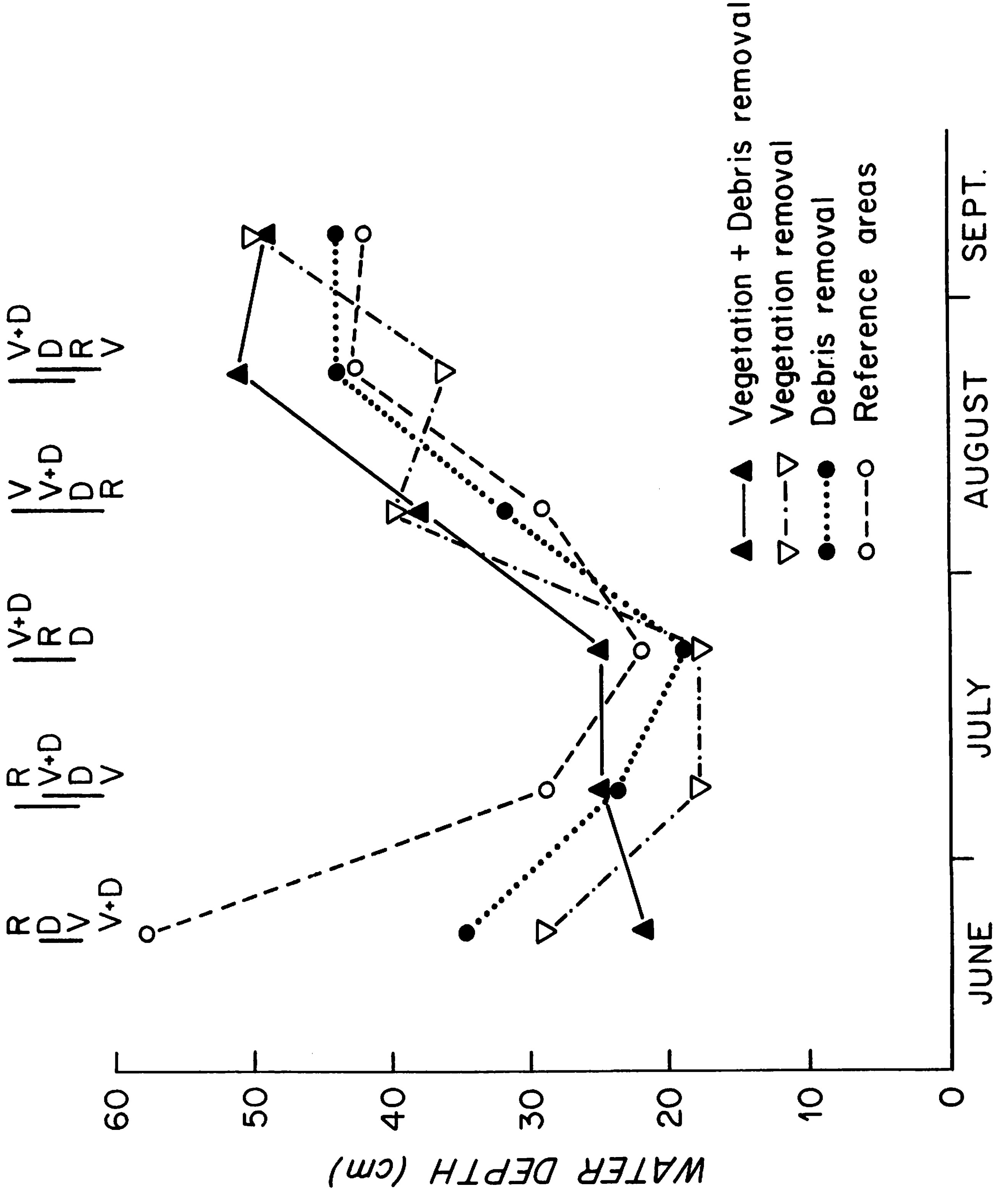

WATER DEPTH (cm)
0
10
20
30
40
50
60
JUNE
JULY
AUGUST
SEPT.
R
D
V
V+D
R
V+D
D
V
V+D
R
D
V
V+D
D
R
V+D
D
R
V
Vegetation + Debris removal
Vegetation removal
Debris removal
Reference areas

Figure 3

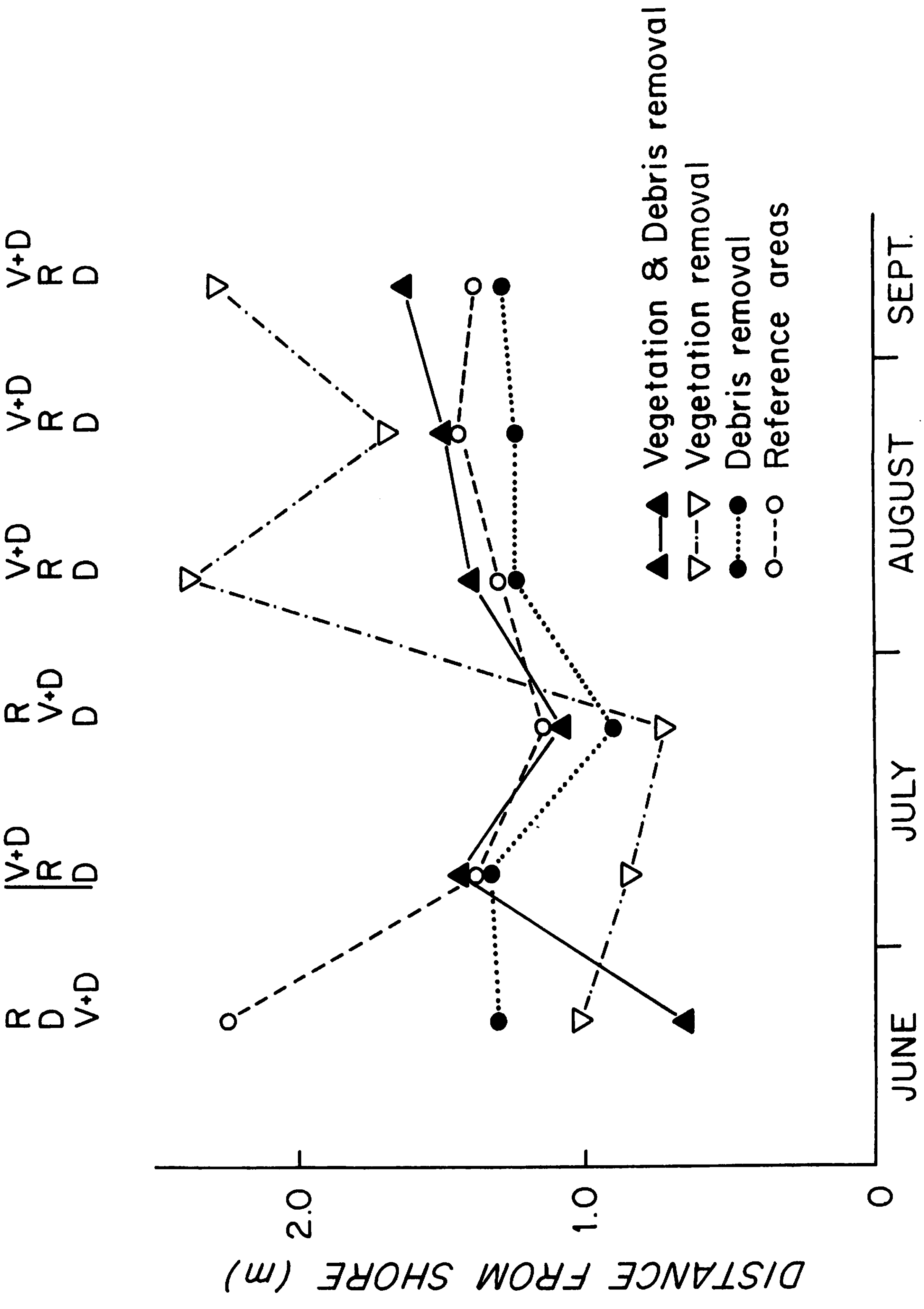

DISTANCE FROM SHORE (m)
0
1.0
2.0
JUNE
JULY
AUGUST
SEPT.
R D V+D
V+D R D
R V+D D
V+D R D
V+D R D
V+D R D
Vegetation & Debris removal
Vegetation removal
Debris removal
Reference areas

Figure 4

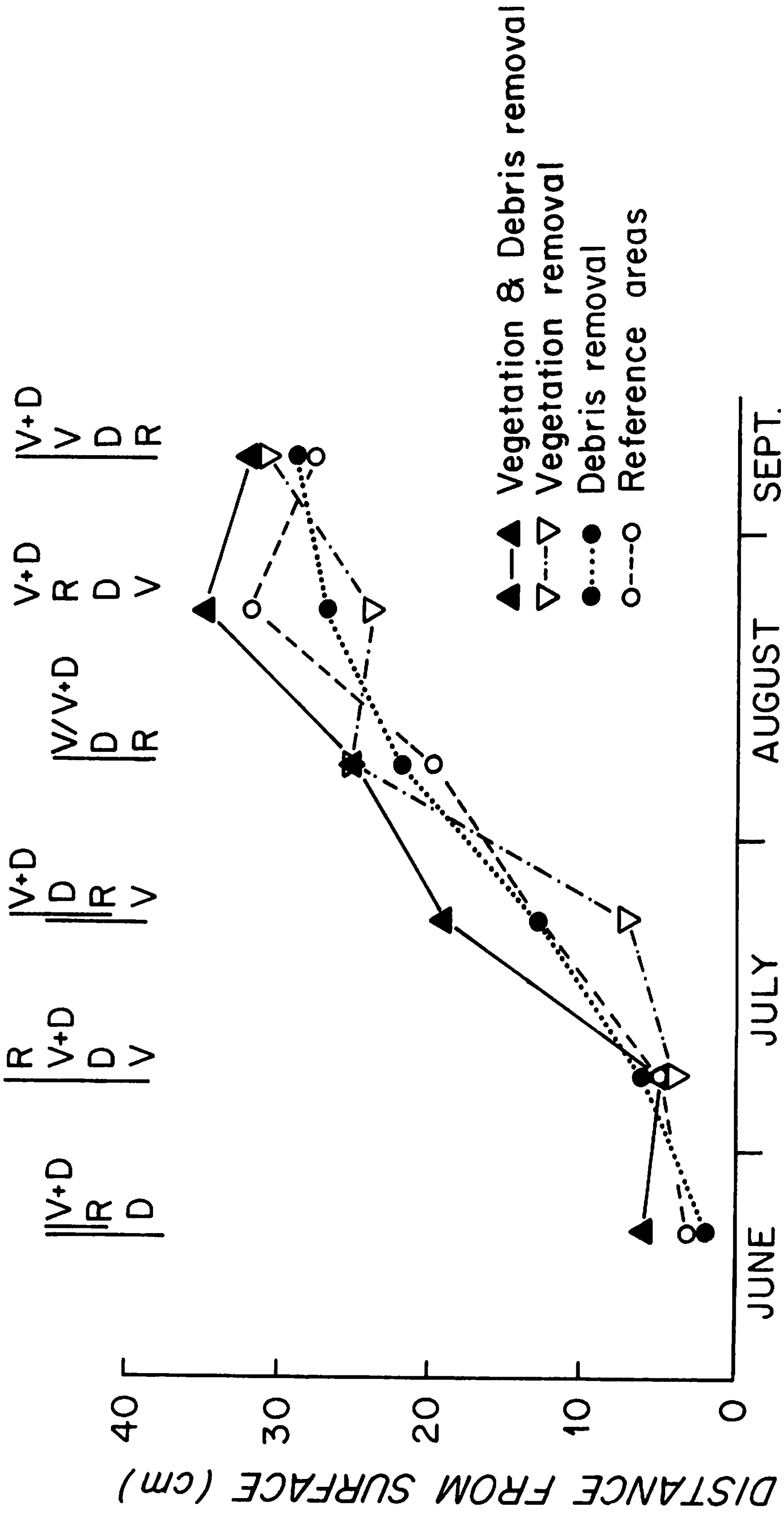

DISTANCE FROM SURFACE (cm)
40
30
20
10
0
JUNE
JULY
AUGUST
SEPT.
V+D R D
R V+D D V
V+D D R V
V/V+D D R
V+D R D V
V+D V D R
▲—▲ Vegetation & Debris removal
▽-·-▽ Vegetation removal
●·····● Debris removal
○---○ Reference areas

Figure 5

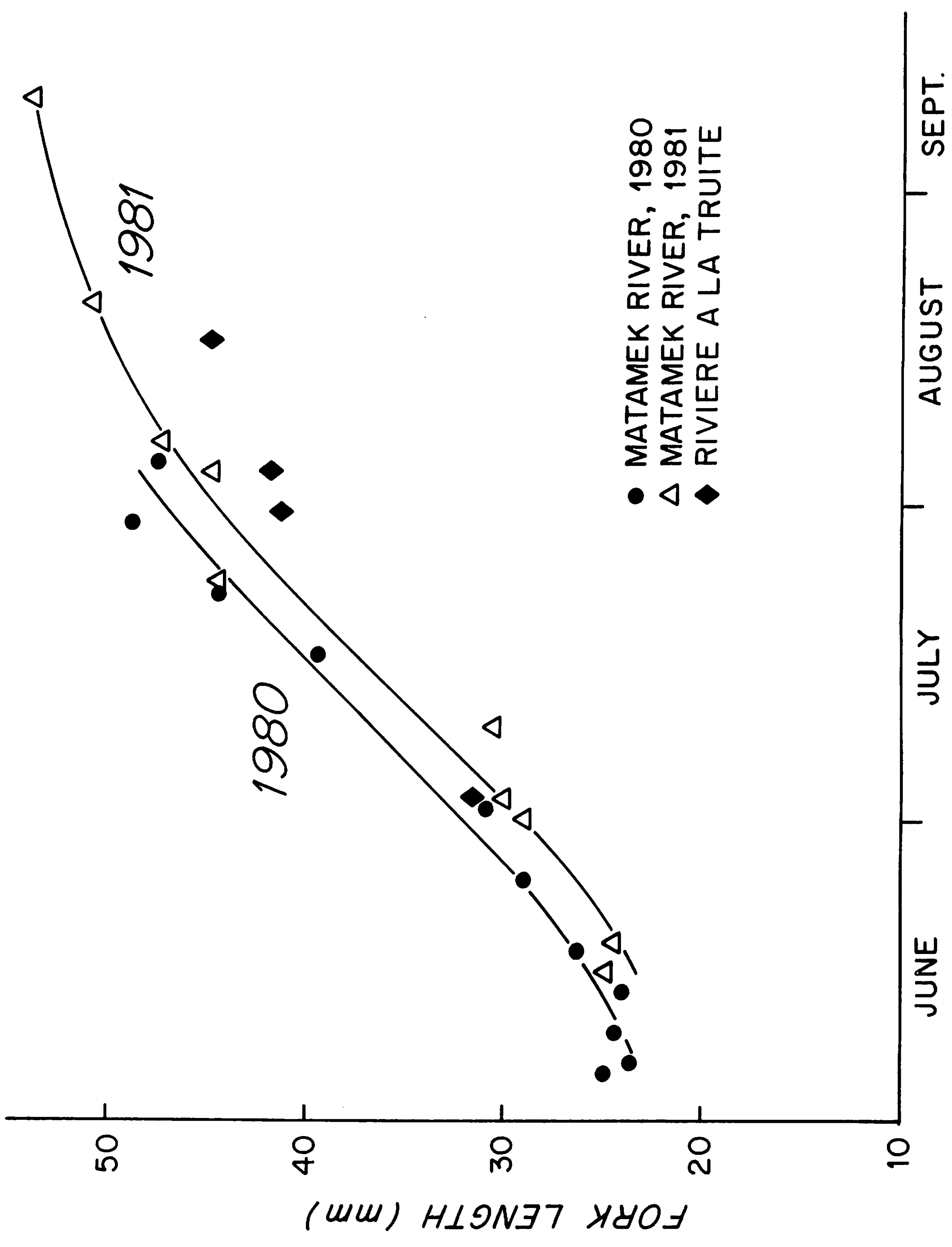

FORK LENGTH (mm)
10
20
30
40
50
JUNE
JULY
AUGUST
SEPT.
1980
1981
● MATAMEK RIVER, 1980
△ MATAMEK RIVER, 1981
◆ RIVIERE A LA TRUITE

Figure 6

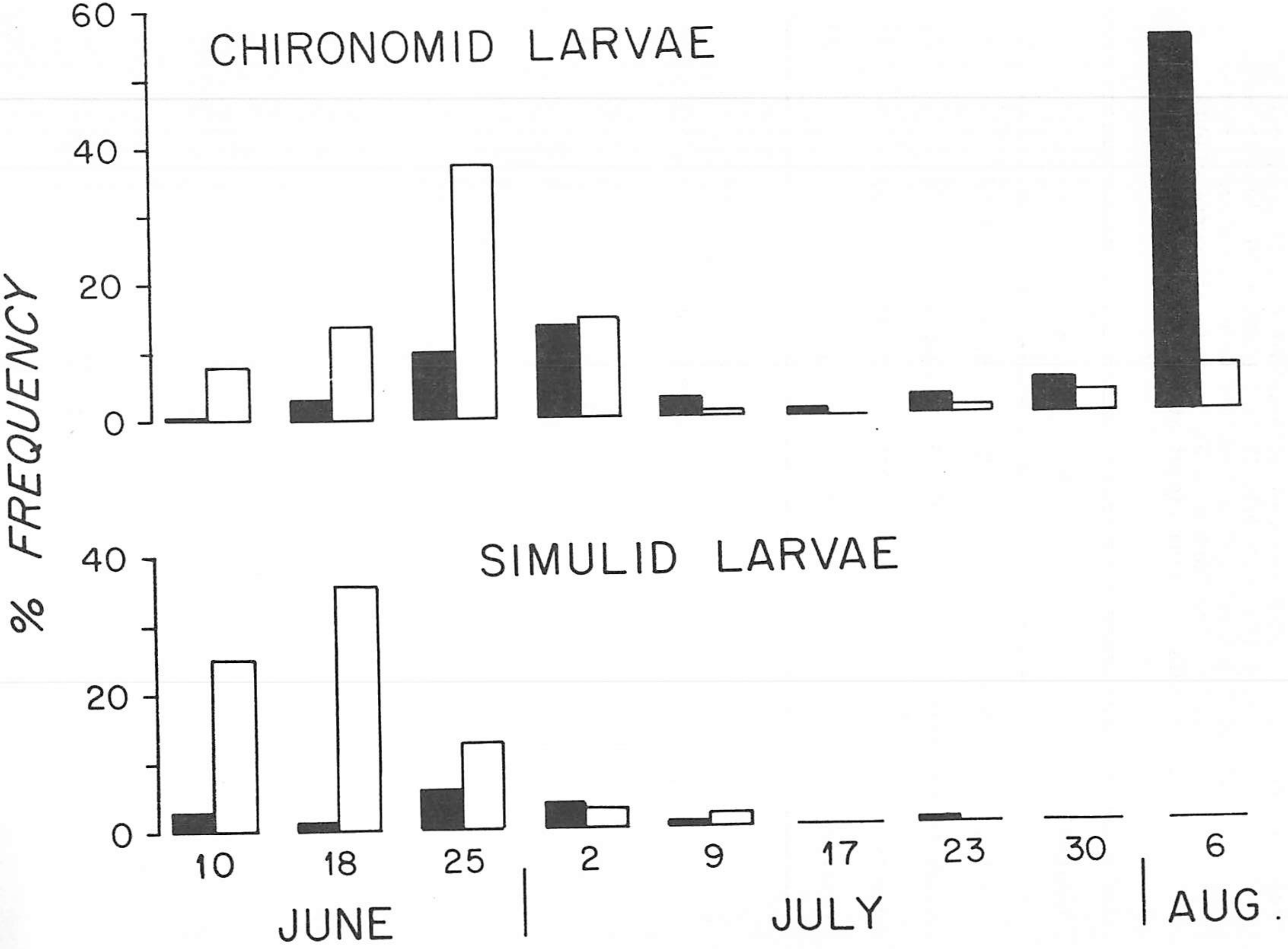

% FREQUENCY
CHIRONOMID LARVAE
60
40
20
0
SIMULID LARVAE
40
20
0
10
18
25
2
9
17
23
30
6
JUNE
JULY
AUG.

Figure 7

Table 1. Summary of regressions of body weight (Wt) in grams against julian days (t) from July 10 to September 10, 1981 in each habitat treatment and in combined reference areas. Regression lines are of the form $Wt = bt + a$ with all correlation coefficients (r) significant at the .01 level.

Treatment	b	a	r	n
vegetation-debris removal	0.028	-5.016	0.87	14
vegetation removal	0.023	-3.894	0.72	22
debris removal	0.026	-4.563	0.87	17
references	0.022	-3.617	0.70	47

Table 2. Relative importance indices of taxa in brook trout fry diet during 1981 for given treatments and reference sections. Treatments refer to the removal of riparian vegetation, woody debris, or both. Sample size is indicted in parentheses.

Taxa	Vegetation-Debris (15)	Vegetation (23)	Debris (11)	References (38)
Annelida	1.2			
Arachnida	1.4	2.2		0.5
Hydracarina	1.3			1.5
Cladocera			1.6	
Copepoda	1.2			
Collembola		0.7	1.6	2.1
Diptera-adult, terrestrial	13.1	10.4	13.0	11.1
Chironomidae - adult	11.8	10.8	14.2	7.1
- pupa	5.6	6.6	3.2	6.8
- larva	6.6	5.9	6.8	6.3
Simulidae - adult	1.2	0.8	8.8	2.3
- pupa				0.5
- larva	1.2			
Culicidae - adult			1.6	1.1
- pupa			4.2	0.7
- larva	1.2			
Ceratopogonidae - larva				0.5
Tipulidae - larva	2.2	0.7		1.2
Hemiptera		3.0		
Heteroptera		1.4		2.0
Homoptera - adult	6.3	10.6	5.8	9.1
- imm.				0.5
Hymenoptera-adult, terrestrial	8.4	5.0	2.8	5.8
Chalcidoidea	2.8	1.4		3.2
Braconidae		0.8	1.8	
Ichneumonidae		0.7		
Mymaridae		2.5	0.5	0.5
Odonata				
Libellulidae			0.6	
Ephemeroptera - adult				0.5
- nymph	4.7	4.2	1.6	4.9
Trichoptera - adult	7.9	5.3	4.9	10.6
- larva	1.2	2.2	3.6	1.4
Hydroptilidae - adult	1.4	4.0	5.5	5.6
- larva	1.2	2.4		1.4
Plecoptera - adult		3.6		3.7
- nymph				0.5
Lepidoptera - adult		4.4		2.8
- larva		1.3		
Coleoptera-adult, terrestrial		1.5		
Dytiscidae			2.1	0.5
Thysanoptera - adult	16.4	7.6	16.9	4.5
- larva				0.5
Fish fry - *P. pungitius*	1.7			

Table 3. Contingency table for functional invertebrate taxa in diet of trout fry during 1981. Column numbers indicate for each treatment and reference section the observed frequency of each taxon in trout fry stomachs based on the number of organisms consumed. Numbers in parentheses indicate the expected frequency for taxa based on the relation of the number of organisms of all taxa in a given treatment or reference to the total number of organisms of all treatments and reference sections. Underlined frequencies indicate taxa that appear with greater than random probability.

Functional Taxa	Vegetation-Debris (.232)	Reference (.146)	Debris (.139)	Reference (.216)	Vegetation (.267)
Terrestrial insects + Arachnida[1]	.500	.504	.492	.261	.484
Minute aquatic invertebrates[2]	.014	.022	.016	.050	.013
Aquatic Diptera - adults	.220	.178	.297	.095	.207
- larvae + pupae	.112	.178	.094	.111	.093
Aquatic Hymenoptera	.089	-	.008	.191	.053
Adult aquatic insects[3]	.033	.044	.063	.226	.102
Other aquatic insects[4]	.033	.074	.031	.065	.049

[1] includes adult Diptera, Thysanoptera, Hemiptera, Hymenoptera, Coleoptera, Lepidoptera, Arachnida.

[2] includes Annelida, Hydracarina, Cladocera, Collembola.

[3] includes winged adult Ephemeroptera, Trichoptra, Plecoptera, Odonata.

[4] includes nymphs of Ephemeroptera and Plecoptera, Trichoptera larvae, and Dytiscidae (Coleoptera).

OTHER STUDIES

RECUEIL DE DONNEES SUR LES CHARACTERISTIQUES HYDRO-PHYSIQUES DE LA RIVIERE MATAMEC, QUEBEC, CANADA

M. Frenette and P. Julien
Université Laval

CONCLUSIONS GENERALES

Ce rapport synthèse est destiné à l'usage des ingénieurs et biologistes effectuant des recherches sur l'hydro-biologie de la rivière Matamec. Ce document résume l'ensemble des relevés et des études entreprises par l'équipe de l'Université Laval sous la direction de Marcel Frenette, Dr-ing., depuis 1974 et il se divise en quatre parties intitulées:

- Partie A: Caractéristiques generales du bassin de la rivière Matamec;
- Partie B: Caractéristiques hydrologiques du bassin de la rivière Matamec;
- Partie C: Caractéristiques physiques de la rivière Matamec;
- Partie D: Caractéristiques hydrauliques de la rivière Matamec.

Dans la première partie montrant une vue générale du bassin de la rivière Matamec, l'analyse de représentativité, basée sur les caractéristiques physiographiques excluant l'aspect géomorphologique, démontre que le bassin de la rivière Matamec est peu représentatif de l'ensemble des bassins versants de la Côte-Nord. C'est donc avec réserve que les résultats des recherches effectuées sur la rivière Matamec peuvent être transposes aux autres rivières à saumon de la Côte-Nord. Toutefois, les bassins des rivières des Rapides et au Tonnerre montrent une grande affinité physiographique avec celle de la rivière Matamec et il faut ajouter que ces deux rivières possèdent une longue période d'enregistrement des débits.

Dans la deuxième partie sont présentées les principales caractéristiques physiographiques des sous-bassins de la rivière Matamec. La reconstitution des statistiques de débit à la sortie du lac Matamec et à l'embouchure de la rivière a été possible en effectuant la corrélation des débits observés à ces stations avec ceux des rivières des Rapides et au Tonnerre. Les hydrogrammes journaliers et la courbe des débits journaliers classés ont par la suite été reconstitués.

La troisième partie résume de façon descriptive l'ensemble des données recueillies lors des campagnes de mesure concernant le morphométrie, la sédimentologie et les profils de vitesse de la rivière Matamec pour chacune des sections transversales inventoriées et plus spécialement au pied des chutes en raison du potentiel de frai plus élevé dans ces secteurs. Plus particulièrement, l'analyse des niveaux d'eau dans les zones de dépôts de gravier a permis de mettre en évidence le risque de gel des frayères lors des périodes hivernales d'étiage. Ce fait prouve la relation très étroite qui existe entre les aspects biologiques et les conditions physiques de même que la nécessité de réaliser des études conjointes.

La quatrième partie du rapport complète les deux parties précédentes en exprimant la relation existant entre les caractéristiques physiques et les caractéristiques hydrauliques. Ainsi, à partir des courbes niveau - débit de chacun des tronçons, la variation des paramètres (la profondeur, le périmètre mouillé, la section d'écoulement et la vitesse moyenne) en fonction du débit est maintenant connue pour chacune des sections transversales ainsi que de façon globale pour chacun des tronçons. L'analyse des forces tractrices sur chacun des troncons a permis d'évaluer, en fonction de la dimension des particules, le débit nécessaire pour provoquer l'entraînement des sédiments vers l'aval.

Voilà l'essentiel de ce recueil de données qui, rappelons-le, ne constitue pas une recherche en tant que tel, mais plutôt un inventaire des données recueillies à l'intention des ingénieurs et biologistes confrontés avec les problèmes hydro-biologiques de la rivière Matamec.

Référence: Université Laval
Faculté de Sciences et de Génie
Département de Génie Civil
Section Hydraulique
Rapport GCS-81-03
Juillet 1981

SEASONAL DYNAMICS OF *Schistocephalus solidus* IN THE THREESPINE STICKLEBACK *Gasterosteus aculeatus* OF MATAMEK LAKE

J.A. Holloway and M.A. Curtis
Institute of Parasitology, McGill University

RATIONALE

The study of the population dynamics of parasites may provide insight as to how regulation of such populations occurs. A wide variety of density dependent and density independent control mechanisms determine the size of a parasite population, and these mechanisms operate at various phases in the life-cycle. From seasonal studies, which follow a given parasitic stage over an extended period of time, it is possible to estimate important population rate processes such as immigration rate (recruitment into the population) and emigration and death rates (loss from the population). These rate parameters may then be related to environmental variables.

Populations of parasite species spending the greater proportion of their life-cycles in a poikilothermic environment are undoubtedly influenced by temperature. This is true for many species which include fish in their life-cycles, as either intermediate or definitive hosts, and the potential role of temperature as a control mechanism in the regulation of these parasite populations must be considered.

In recent years much interest has been generated in the use of theoretical modelling as a tool in determining how control of parasite populations may occur. Simply, this involves selecting a variable (e.g. temperature), predicting mathematically how a population will respond to changes in that variable and then comparing predictions with data obtained in the field. Such methodology has been used successfully in ascertaining the relative importance of some environmental variables in the regulation of parasite populations.

The *Schistocephalus*/*Gasterosteus* system provides an excellent parasite/host system for the study of seasonality in parasites of fish. The life history and physiology of *Schistocephalus* and *Gasterosteus* are well documented. The infection is widespread and thus the comparison of seasonal data from different geographical localities is possible. From such comparative studies we may gain insight into how climatic conditions may affect the population dymamics of the species. Due to the longevity of the plerocercoid stage and the apparent absence of control by the host on this population, plerocercoids accumulate in their hosts, and probably remain for the life span of the fish. The tremendous growth of this parasitic stage in the perivisceral cavity of the threespine stickleback results in pathology to this host, especially in multiple infections where total worm mass may exceed fish mass. This pathology may include decreased condition, organ displacement, decreased swimming ability, nutritional stress and castration of the host. Abdominal distension is characteristic of heavy infections with *Schistocephalus* (See Fig. 1 and 2).

Matamek Lake provides an ideal location for the study of this host/parasite system. The three spine stickleback is very abundant and the prevalence and intensity of *Schistocephalus* are very high (~72% of fish infected; $\bar{x} \doteq 5.2$ (1-23) worms per fish). This is probably a reflection of minimal predation pressure on the infected population by fish in the lake. Piscivorous fish are unsuitable final hosts for the adult parasite, the definitive hosts are piscivorous birds (see Fig. 3). Of the other fish present at Matamek Lake, only brook trout have been reported to feed on threespine sticklebacks, and these comprise a very minor part of the diet. These fish feed preferentially on the ninespine stickleback. This lack of predation pressure is very important as the pathological effects exerted upon the sticklebacks by their parasites render them far more susceptible to predation. In a situation where predation pressure is high both fish and parasite populations are severely culled. This is not the case at Matamek Lake.

Finally, the cold climate of the study area constrains the growing season for Schistocephalus; thus it is interesting to compare the seasonality exhibited by the parasite population of Matamek, in relation to temperature, with that seen in seasonal studies carried out in the U.K.

Resume of the study

Briefly, the present study involves:

1. A seasonal study of the Schistocephalus/Gasterosteus system in Matamek Lake, near Sept Iles, Quebec.
2. Laboratory studies to asertain the precise association between plerocercoid growth and temperature.
3. The integation of data derived from field and laboratory studies into a model for predicting the seasonality of a plerocercoid population under different temperature conditions.

The seasonal study

i) Report for 1981.

Samples, ranging from 40-350 fish, were collected, using seine and dip nets, at 2-4 weekly intervals from early July to late October. On one occasion a large sample of 2,000 sticklebacks was collected for a more detailed analysis. In addition approximately 500 fish were collected over the season, kept alive, and sent to the Institute of Parasitology at McGill to be maintained for experiments. Temperature records were maintained throughout the season.

The seasonally collected sticklebacks, stored in 70% alcohol are presently being analysed for the following variables: fish age (otoliths), fork length, sex, eviscerated dry weight; parasite prevalence, intensity and dry weight. This information will be analysed using multivariate statistical techniques and polymodal analysis of parasite size frequency distributions.

ii) Preliminary plans for 1982.

During the ice-free season (May to November) in 1982 we should like to resume sampling sticklebacks (approx. 200 fish/sample) and recording temperature at two-week intervals at the North Camp at Matamek Lake. Continued sampling in 1982 would provide data (May-July) to complete last year's seasonal survey plus a duplicate survey (July-November) to verify the findings of 1981. We also hope to collect live sticklebacks to maintain aquarium stocks at McGill for further laboratory studies.

The completed seasonal study combined with the laboratory study would generate sufficient data to test our model, of the population dynamics of the Schistocephalus/Gasterosteus system, in the cold temperate climate of Quebec.

FIGURE CAPTIONS

Fig. 1. A dead, heavily parasitized stickleback collected from Matamek Lake. Large arrow: a plerocercoid of *Schistocephalus solidus* removed from body cavity of the fish. Small arrows: other plerocercoids *in situ*. (Scale in cm).

Fig. 2. Abdominal distension is characteristic of infections of *Schistocephalus solidus* in the threespine stickleback. The infection is found in all age groups of the stickleback. Infected fish are denoted by an asterix -- compare with less heavily infected or uninfected fish above in each case. (Scale in cm).

Fig. 3. When an infected stickleback is eaten by a piscivorous bird the plerocercoids mature to become adults in the intestine of the bird. The adults release eggs which are passed into the water with faeces. The eggs hatch to release free-swimming coracidia. When a coracidium is ingested by a copepod the coracidium penetrates the gut wall and enters the coelomic cavity where it develops into a procercoid. The procercoid develops into a plerocercoid when an infected copepod is eaten by a threespine stickleback, thus the life-cycle is completed.

Fig 1

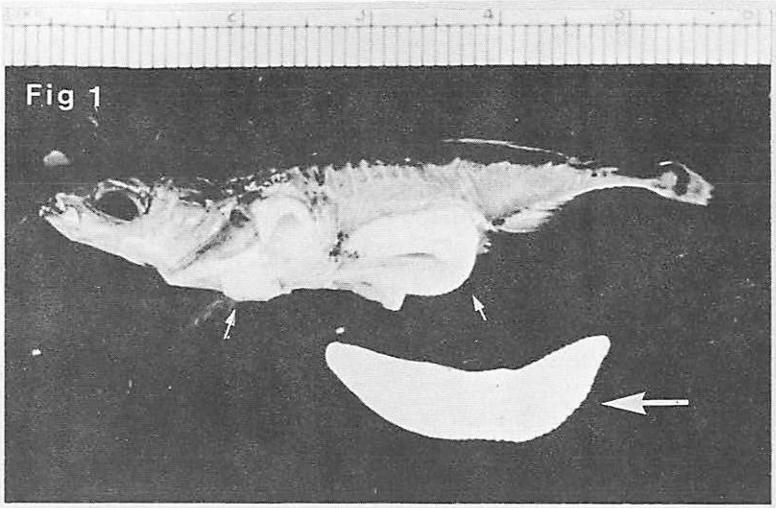


Fig 2

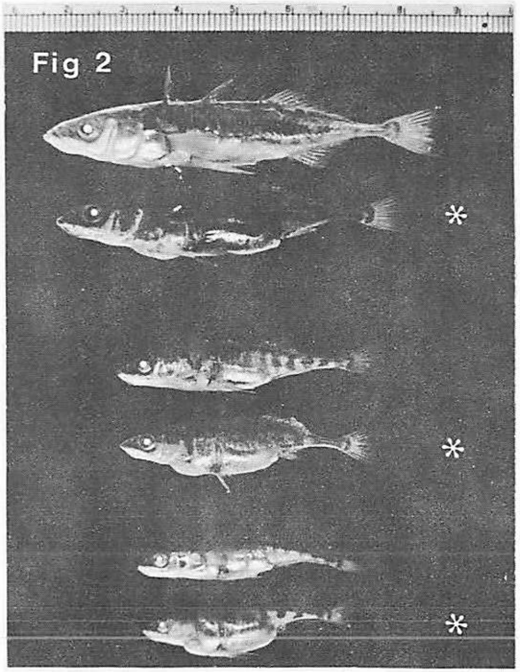
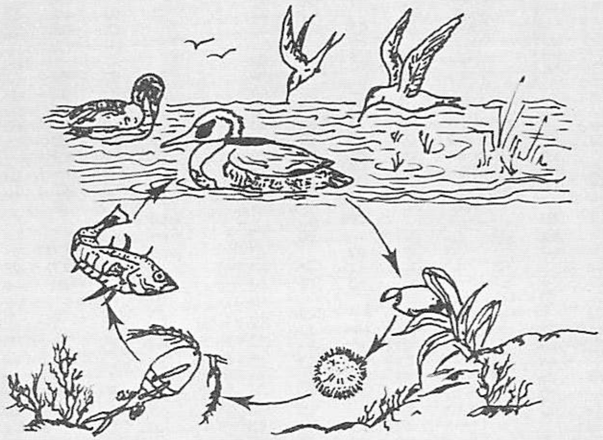


Fig 3



The life cycle of Schistocephalus.

BEHAVORIAL INTERACTIONS BETWEEN STICKLEBACKS AND BROOK CHARR FRY

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Brook charr fry (Salvelinus fontinalis) and ninespine sticklebacks (Pungitius pungitius) cohabitate in the Matamek River. Data from a salmonid fry growth study, which was done by Matamek personnel during the summer of 1981, indicate that sympatric populations of brook charr fry and ninespine sticklebacks are common in the Matamek River (8 out of 13 sites samples included Pungitius pungitius). Brook charr fry and ninespine sticklebacks overlap during the late spring and summer months (June through August) in habitat, times of major daily activity and possibly food preferences. Little research has been done to examine interactions between salmonid fry and non-salmonid fishes. The first three months of the brook charr's life is a critical time in terms of growth and survival. The period of sympatry also includes the spawning season of Pungitius pungitius. Observations of natural sympatric populations indicated that these species exhibited interspecific aggressive behaviour.

The purpose of this project was to investigate interspecific aggressive interactions between ninespine sticklebacks and brook charr fry. Experimental stream tanks (located just below the second falls of the Matamek River) were used to observe the two species in allopatry and sympatry and at different densities. The raceway was divided into three equal sections (1 m x 1 m), with allopatric fry in the upstream section, allopatric stickbacks in the middle and sympatric populations in the downstream section. Observations of both aggressive and feeding acts were made during 5-minute intervals on 1 to 3 (depending on the density) marked (fin-clipped) individuals. Feeding acts were broken down into bites at substrate, water column and surface. Data recorded on aggressive acts included charges, chases and nips. "Tilt" was recorded for sticklebacks, a behaviour not exhibited by charr. Allopatric and sympatric populations were observed at 12, 8, 6 and 2 individuals/m.

In allopatric charr populations, total aggression declined with increased densities and sympatry depressed total aggression at higher densities. Intraspecific aggression by charr in sympatric populations declines with increasing density, whereas interspecific aggression increased. Intraspecific aggression by sticklebacks in sympatry increased with density and intespecific aggression declined.

Successful breeding occurred, during the month of July, in a separate allopatric stickleback section. Data were recorded on feeding acts and aggressive interactions between stickleback fry, stickleback adults and brook charr fry. The brook charr ate all the stickleback fry smaller than ~22.50 mm.

In another section, separate from the density treatments, stickleback adults were added to established brook charr fry populations. Within 24 hours, the sticklebacks were successfully able to establish territories in the middle of the section.

All of the stream tank populations exhibited territorial behaviour or dominance hierarchies. Only the largest charr were successful at maintaining territories in sympatry. Escalated stickleback intraspecific aggressive interactions resulted in ritualized "spiral fights". Brook charr do not exhibit that behaviour, and interspecific fights involved prolonged periods of nipping and biting. I observed the death of two charr (~2.17 cm. smaller than the stickleback) as a result of interspecific fights. However, later in the summer, smaller sticklebacks reacted to the charr fry (larger than the sticklebacks by ~1.10 cm.) by hiding in the gravel. Individual brook charr may dominate certain individual sticklebacks, and vice versa. This seems especially likely in sympatric populations of sticklebacks and salmonid fry, where a variety of intermediate sizes of individual members of each species occur. Salmonid fry populations will exhibit particularly high levels of size variation due to the fact that the individuals emerge at various times during the summer months and exhibit rapid growth patterns during this time.

Total Agressive Acts (per 5 min)

Density	Charr Allopatry	Charr Sympatry	Sticklebacks Allopatry	Sticklebacks Sympatry
2	1.6	--	3.0	--
6	4.6	4.8	3.8	3.7
8	8.8	5.7	5.3	2.1
12	7.8	5.1	5.3	4.0

Intra- and Interspecific Agression in Sympatry (per 5 min)

Density	Charr Intra	Charr Inter	Sticklebacks Intra	Sticklebacks Inter
2	--	0.5	--	2.2
6	4.1	0.7	0.4	3.3
8	3.1	2.6	0.8	1.3
12	2.6	2.5	2.8	1.2

Specific Aggressive Acts Percent of Total Acts

Interaction	Charr Density	Charge	Chase	Nip
Allopatric	2	78	13	10
	6	47	29	24
	8	53	20	26
	12	54	16	30
vs. Charr	2	--	--	--
	6	45	23	32
	8	68	14	18
	12	38	34	28
vs. Sticklebacks	2	57	28	15
	6	92	0	8
	8	85	8	7
	12	52	12	36

Feeding Location

Species	Density	Percent of Feeding Acts Bottom	Midwater	Surface
Charr - Allopatry	2	51	41	8
	6	50	36	13
	8	53	39	8
	12	69	21	10
Sticklebacks - Allopatry	2	76	24	0
	6	43	54	4
	8	76	24	0
	12	77	23	0
Charr - Sympatry	2	43	57	0
	6	67	17	17
	8	70	24	6
	12	36	51	14
Sticklebacks - Sympatry	2	70	27	3
	6	82	18	0
	8	61	39	0
	12	51	47	2

AN ATTEMPT TO ADAPT AN ELECTROFISHING METHOD FOR SAMPLING RIVERS WITH LOW CONDUCTIVITY

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Electrofishing remains one of the most effective means of sampling fishes in fluvial systems. It may be used for qualitative surveys but is also frequently used in quantitative estimates; however, one important limit for using this method is the low conductivity of water. The conductivity of water in the Matamek River drainage basin is low (~20 µS). According to Harley and Alabaster (1962) below 200 µS efficiency declines proportionally to the decrease in conductivity. Taking into consideration the results of Bruschek (1967), experiments conducted in an Apline silicate zone, electrofishing cannot be successful below 30 µS conductivity. Nevertheless, it is common opinion that by using a current of high voltage it is possible to improve remarkably the efficiency of this method even, in low conductivity water.

An important goal of the Matamek Research Program is to analyse the structure and function of fish populations. Having an efficient sampling technique is a condition for successful research. Therefore, we attempted some experiments with electrofishing during 1981.

For this purpose an A.C. generator was adapted by combining with a transformer to obtain 500 V. Because captured fishes would later be used for experiments in stream tanks or for mark and recapture population estimates, we decided to modify the current by using a four diode bridge changing alternating current to a D.C. two wave pulsating current which gives sufficient galvanotaxis but with a lower fish mortality (Fig. 1).

The first test was conducted in a closed chamber of the salmon ladder, where we put brook trout (Salvelinus fontinalis) captured by angling. In shallow transparent water and a small area (about 3 x 3 m) the results obtained were good with fish showing a pronounced galvanotaxis. After many variants of experimentation they were still alive.

The next test was conducted on the Matamek River. All equipment was loaded on a plastic (!) boat and three crew members took part in the experiment (Fig. 2). This experiment was unsuccessful; schools of trouts were seen but were usually 5-10 m from the approaching boat; our active electromagnetic field was less than 2 meters from the active electrode (anode). We collected only eels, which were hidden in the bottom substrate.

We conclude that electrofishing, even with high voltage, will not be a successful method for collecting salmonids in a large river with low conductivity. Fish were wary and able to avoid the electric field which is active for only a short distance in these conditions.

On the basis of observations in salmon ladder and during the test on the Matamek River we expect that electrofishing can be useful in only narrow and shallow stream sections which can be closed by blocking nets.

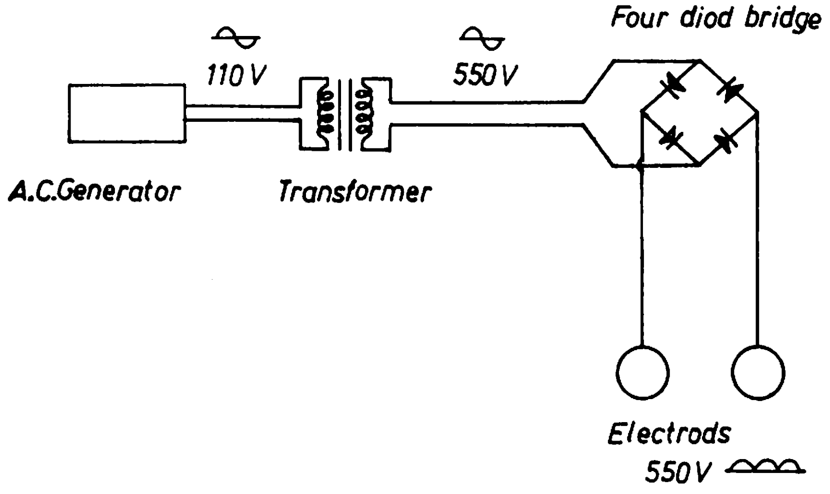
110 V
550 V
Four diod bridge
A.C.Generator
Transformer
Electrods
550 V

Fig. 1

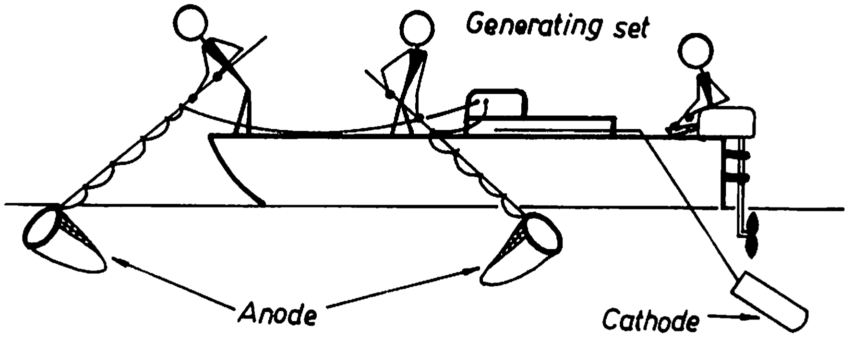
Generating set
Anode
Cathode

Fig. 2

GROWTH AND BIOLOGY OF Catostomus catostomus (FORSTER) FROM DIFFERENT ENVIRONMENTS NEAR MATAMEK

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Catostomus catostomus (Forster) is an important component of fish communities in salmonid rivers and lakes of North America.

Physiological characteristics of the family Cyprinidae, of which C. catostomus is a member, suggest this group of fish to be warm water organisms. Most are herbivores or detritivorus but some species during otogeny change their diet to invertebrates, becoming more energetically efficient. It is rare among cyprinids to find a typical predator. Feeding specialization is related to anatomical and physiological features, such as length of digestive tract. Vegetation feeders usually occur in warmwater ecosystems because this less energetically efficient food needs a high digestion rate which, according to the digestive enzyme characteristics, is only possible at relatively high temperatures. Therefore, having a relatively long digestive tract, combined with the invertebrate diet of C. catostomus, suggests a hypothetical explanation of why this species is so successful in invading cold water ecosystems.

The first step in verifying this hypothesis is collecting data describing the life history, feeding and growth of C. catostomus in different types of coldwater ecosystems.

STUDY AREAS

Fishes were collected from four sites:

1. An unnamed lake approximately 200 miles NE of the Matamek Research Station. The collection was made by Hydro-Quebec investigators.
2. The Moisie River estuary using a salmon trap with the help of Chasse et Peche personnel, and with a seine 3 km above the mouth of estuary.

3. Rivière à la Truite about 1 km above the confluence with the Moisie River.
4. Between the 1st and 2nd Falls on the Matamek River and below the 1st Falls on the Muskrat River.

Characteristics of materials collected are contained in Table 1.

METHODS AND MATERIALS

The best age determinations were obtained from opercular bones, relative to scales or otoliths. In the case of older fish, which are known to lose the first years' ring, we collected fishes one year old and compared their operculum with those of older fish. All measurements for back calculation of age were done on the central axis where the bone is most transparent (Fig. 1).

For comparison, condition factor was used with a modified coefficient (K') which eliminates the effect of allometic growth by using the calculated value of the slope (b) from the logarithmic length-weight relations for each population, i.e. $K' = (w/l^b)\ 100$.

Two populations presented too small of a size range for accurately calculating <u>b</u>. For Rivière à la Truite we used unpublished data on the length-weight relationship from Montgomery (1980); for the lake population we used an unmodified coefficient of $\underline{b} = 3.00$.

Analyses of stomach contents were completed on materials fixed in 5% formalin. Fecundity was determined gravimetrically.

RESULTS

I. Growth

The following equations describe the length-weight relationships:

1) For the Moisie River population:

$$\log_{10}(w) = 2.998\ [\log_{10}(l)] - 4.966;\ r = 0.998$$

2) For the Muskrat River population:

$$\log_{10}(w) = 2.945\ [\log_{10}(l)] - 4.850;\ r = 0.997$$

The comparison of growth rate for C. catostomus from the four different environments is contained in Table 2. Best growth rate and probable life span are represented by fishes from lake. A shortest life-span and slowest growth are by fishes from the Moisie estuary. The shortest lifespan is exhibited by populations from Rivière à la Truite and the Muskrat River but the pattern of growth is different at these two locations. Juvenile fish from Rivière à la Truite are growing slow but slightly better than fishes from Muskrat River. However, when mature the growth rate dramatically decreases (R. Truite) but in the case of fishes from the Muskrat River it is remarkably accelerated. It may be caused by differences in diet (see below), a low density of mature specimens in the Muskrat River and a much lower temperatures in Riviere a la Truite. Mature specimens assimilate most food energy into gonads rather than somatic tissue. If we assume lower temperatures slow the digestion rate then there will be less assimilation per unit time.

Calculated sizes of one year old specimens are exaggerated because of the effect of the inside bone growth. For this comparison it is necessary to collect fry and juveniles from each location.

On the basis of marginal growth, the opercular bone analyzed for annual pattern of growth during the herbivore/detritivore feeding period is given as a percent of annual growth increment (Table 3). Knowing that spawning occured in the Muskrat River between 25 and 30 June and that the creation of the annual ring is usually near spawning, we can precisely compare the annual growth pattern in each locality. From these data we see growth beginning on July 7 and 9 is similar among stations except for Rivière à la Truite, but high standard deviations there suggest some influence of migration. Lowest standard deviations are from Lake Matamek and correspond with the most stabilized growth conditions.

Data from Moisie River and Muskrat River were used to compare males and females. Females have a better growth rate using paired comparisons (Bailey 1959), which display a statistical significant difference at the level $p \geq 0.02$, $t = 3.499 > t \ = 3.143$.

The best condition factors are from the Muskrat River. This value is stabilized during the intensive period of growth. Populations from Moisie River and Rivière à la Truite had lower values. Data for lake population cannot be directly compared to the others because they were calculated as a K coefficient.

II. Fecundity

Studies were conducted on the Muskrat River population. Results are preliminary because only few mature females were collected before spawning. Females start to be mature after age 5; some specimens after 6 years of life. Size of egg immediately before spawning is between 2.4 - 2.8 mg. Absolute fecundity is between 3,400 (5^+) to 14640 (8^+). Period of spawning was determined on the basis samples taken to occur between 25 and 30 June.

III. Food

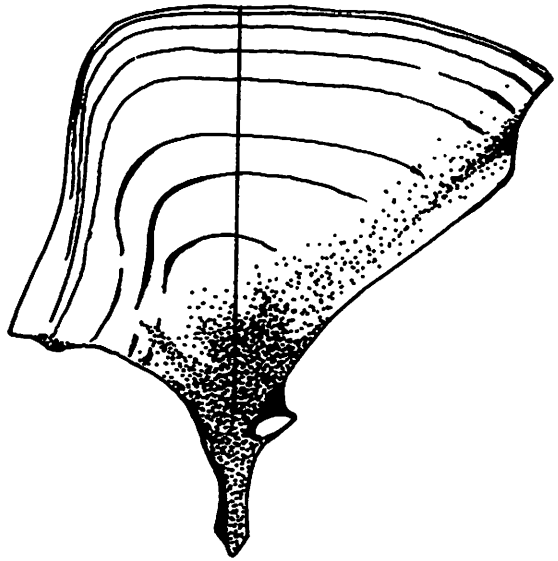
The length of the digestive tract (DT) is strongly correlated with body size: $r = 0.998$; $\log_{10}(l) = 3.571 \log_{10}(DT) - 242.01$.

Basic components of the diet of _C. catostomus_ are similar in all locations but proportions eaten are different.

1) Lake: stomachs were full, 40-60% of capacity were small moluscs (Bivalvia) 0.5 - 2 mm diameter; Chironomidae 30-40%; also a few Odonata and Ephemeroptera.
2) Rivière à la Truite: stomachs contained only insects; Chironomidae, Ephemeroptera, Trichoptera and Simulidae.

3) Muskrat River: There were interesting differences in the quality of food between juvenile and adult specimens. Small fish had only insects with mostly Trichoptera and Chironomidae; there were a few Ephemeroptera and Simulidae as well as some unidentified imago stages of insects. Large fish had numerous small molluscs (Bivalvia). This suggests that *C. catostomus* tends to change main food component from insects to moluscs during ontogeny. Lack of moluscs in the stomachs of fish captured in Rivière à la Truite and the reduced rate of growth in older specimens there, which did not exceed 300 mm, suggests that lack of suitable food supply rather than inefficient digestion at low temperatures may be influencing the migrations observed by Montgomery et al. (unpublished data).

Photographs of operculare bones from fishes captured at each location illustrate and confirm data. However, it is necessary to state that conducted studies are preliminary and require more precise explanation with future research.



OPERCULAR BONE OF *Catastomus catastomus* (Forster)
WITH MEASUREMENT AXIS

FIG. 1

Table 1. Characteristics of materials.

Station	Fishing Gear	Number of Fish	Size Range (fork length, cm)
Lake	Gill net	8	32.6 - 43.2
Moisie River	Gill net	19	28.6 - 33.8
	Sein net	12	6.2 - 27.7
Rivière à la Truite	Fyke net	13	18.8 - 23.7
Muskrat River/ Matamek River	Fyke net	36	4.4 - 29.4

Table 2. Growth rate *Catostomus catostomus* (Forster) from different types of environments, on the basis back-calculation from opercular bones, expressed as fork length. M.- mean, S - standard deviation, V - variance.

Station	Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lake	M	8.29	10.69	13.85	16.75	20.00	23.30	25.69	28.66	21.18	33.52	35.78	38.24	40.42	43.0
	S	0.39	0.76	1.42	0.85	0.92	1.16	0.67	1.06	0.74	1.00	0.85	0.45	0.77	0.
	V	0.14	0.51	1.76	0.60	0.75	1.17	0.39	0.97	0.44	0.85	0.60	0.16	0.40	0.
Moisie River	M	7.42	10.38	13.39	16.10	19.43	22.59	25.08	27.29	29.34	32.17				
	S	0.99	0.90	0.87	0.82	0.79	0.99	0.79	0.55	1.03	0.21				
	V	0.94	0.83	0.74	0.65	0.60	0.93	0.59	0.28	0.94	0.02				
Rivière à la Truite	M	6.48	9.2	12.03	14.87	17.15	19.23	21.00	22.42						
	S	0.80	0.68	0.72	0.72	0.53	0.72	0.37	0.43						
	V	0.59	0.43	0.48	0.48	0.26	0.49	0.33	0.15						
Muskrat River	M	5.75	8.47	11.31	14.33	16.84	20.56	24.0	27.82						
	S	1.02	0.86	0.75	1.07	0.45	1.14	-	-						
	V	0.99	0.71	0.53	1.07	0.18	0.66	-	-						

Table 3. Condition factor (K') and pattern of growth during period of herbivory/detritivory of *Catostomus catostomus* (Forster) from different types of environments. Data are based on measurements of marginal growth the opercular bones, expressed as percentage of annual body growth increment. S - standard deviation, V - variance.

Station	Number of Fish	Date	Condition factor	S	V	Percentage of annual growth increment	S	V
Lake	8	7 July	1.35	0.12	0.01	18.58	3.59	11.28
Moisie River	10	9 July	1.05	0.09	0.01	22.71	11.45	116.56
Rivière à la Truite	5	9 July	1.01	0.10	0.01	40.33	19.85	315.07
	5	26 July	0.93	0.14	0.02	51.15	20.56	317.48
	3	2 August	1.03	0.04	0.00	58.20	28.28	533.10
Muskrat River	7	7 July	1.26	0.11	0.01	25.82	14.13	171.25
	8	23 July	1.23	0.05	0.00	60.65	15.67	214.82
	5	1 August	1.25	0.07	0.00	71.48	9.71	75.44

A CONTINUUM OF ABIOTIC-BIOTIC FACTORS AS A REGULATOR OF FISH COMMUNITIES IN RIVERS

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ABSTRACT

By comparing riverine fish communities occurring in major geographical areas of the world, it is evident that a continuum of abiotic and biotic factors is regulating the structure and dynamics of fish communities through the relative importance of these factors at a particular site. We demonstrate that abiotic factors are of primary importance in many situations, but where the environment becomes stable or predictable, the role of biotic factors gradually increase in importance. In our analysis we considered abiotic factors such as fluvial geomorphology, geology, and climate; and biotic factors such as competition, predation, and productivity. Within this framework we then examined fish diversity, reproductive strategies, pertinent physiological adaptations, and behavior, concluding that certain important abiotic-biotic factors, to a large extent, regulate the existance of a continuum of fish communities in rivers. This fish community continuum responds mainly to (1) stream order, which expresses a degree of environmental diversity and a degree of stabilization, (2) the temperature regime, which strongly influences the physiological performance of the fish and ecosystem productivity, and (3) the slope of the river which appears to greatly modify the previous two considerations. In order to explore the concept further, a three dimensional graphical model describing the abiotic-biotic continuum is introduced. A manuscript is now in preparation describing this study in greater detail.

MARINE ALGAE IN THE VICINITY OF THE MATAMEK RESEARCH STATION

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An impressive algal population with high diversity and density flourishes in the shallow subtidal waters off the Matamek Research Station and nearby Amory Cove. Algal specimen were gathered during August 1981 while snorkeling and SCUBA diving. In the laboratory, samples were identified, numbered, preserved in vials, mounted on slides and/or dried for the herbarium.

Distinct community-group patterns were evident from the 0 meter tide level to -8 meters in the subtidal zone. *Chordaria*, *Desmarestia*, *Dumontia*, *Fucus* with epiphytic *Ectocarpus*, and *Ascophyllum* with epiphytic *Elachistea* inhabited the shallowest areas. Verdant fields of *Ulva* interspersed with *Laminaria* and *Alaria* occurred between depths of 3 and 5 meters. Smaller red algae formed an understory beneath this canopy. In deeper water *Agarum* grew as well as *Plumaria* with epiphytic *Membranoptera*.

During this survey we found examples of the classic sea urchin-algae interaction. Phalanxes of grazing urchins roam the subtidal zone leaving expanses of rocky bottom vegetated only by crustose coralline algae. The forests of *Ulva* and *Laminaria* abruptly abut the "pink rocks" at the front line of the advancing urchins.

Another interesting observation was the presence of multitudes of amphipods (*Calliopius laeviusculus* and *Gammarus oceanicus*) and small gastropods on the shallow-living *Chordaria* and *Desmarestia*. Why was the density of these organisms concentrated on these two seaweeds Are these invertebrates herbivorous

The documentation of several macroalga-epiphyte associations, such as *Membranoptera* growing on *Plumaria*, *Elachistea* growing on *Ascophyllum*, and *Ectocarpus* colonizing *Fucus* and *Dumontia*, was quite exciting, especially as it relates to my future thesis research. What is the nature of these interrelationships? How do the epiphytes affect host plant growth and viability?

The physical factors existing in this marine environment near the Matamek Research Station present topics for further investigation. Often we noticed an upper layer of humic acid-colored river runoff water. How does this freshwater influx affect the algal community and other biota? How does the ice and snow of Canadian winters alter the distribution of seaweeds? How does the Matamek marine community compare to other locations along the St. Lawrence Seaway (e.g. Mingan Islands), and on the more exposed Atlantic Coast?

This preliminary examination of the marine algae and the new herbarium collection establishes a framework for continued exploration and research in the Matamek area marine ecosystem.

Annotated List of Marine Algae

CHLOROPHYCEAE (Green Algae)

Chaetomorpha melagonium (Weber et Mohr) Kutzing.

Attached to *Alaria* haptera at Amory Cove. Plant unbranched with disk-like holdfast. Cells long with peripherally arranged plastids.

Enteromorpha sp.

Common in low intertidal zone.

Ulva lactuca Linnaeus.

Green and leafy. 2 cell layers thick, close-packed in surface view. Found 3-5 m deep with *Alaria* and *Laminaria*.

PHAEOPHYCEAE (Brown Algae)

Agarum cribrosum (Mertens) Bory.

Perforate blade with heavy midrib. Single flat blade on long stalk. Found in drift algae and at 6-7 m depth.

Alaria esculenta (Linnaeus) Greville.

Base of blade tapering to stalk. Prominent midrib. Mixed with *Laminaria* and *Ulva* at 3-5 m. Also in drift algae on beach.

Ascophyllum nodosum (Linnaeus) Le Jolis.

Plants erect from discoid holdfast. Vesicles present. Epiphytized by *Elachistea*. Found in shallow subtidal zone.

Chordaria flagelliformis (Muller) C. Agardh.

Like brown spaghetti. In cross-section, colorless matrix with assimilatory filaments evident. Often covered with amphipods. Found in shallow water (1-2 m).

Desmarestia viridis (Muller) Lamouroux.

Plant erect, light brown. Branching opposite. Ultimate branches very fine. Covered with amphipods and small gastropods. Found in water 1-2 m deep.

Ectocarpus confervoides (Roth) Le Jolis.

Branching opposite. Gametangia lateral on short stalks. Gametangia tapering, but not acute, not hair-tipped; like baby corn-on-the-cob. Ribbon-like plastids. Heavily epiphytic on *Scytosiphon*.

Elachistea lubrica Ruprecht.

Lower part forming thick basal holdfast. Paraphyses straight. Upper cells of assimilator filaments nearly cylindrical. Epiphytic on *Ascophyllum*.

Fucus edentatus De la Pylaie.

Flattened, forked receptacles. Intertidal zone.

Fucus vesiculosus Linnaeus.

Prominent vesicles. Swollen receptacles not winged. Low intertidal to shallow subtidal.

Laminaria saccharina (Linnaeus) Lamouroux.

Lanceolate blade with mucus ducts present. Solid stalk. Growing with *Alaria* and *Ulva* at 3-5 m deep. Also in drift algae.

Phyllaria dermatodea (De la Pylaie) Le Jolis.

Conical disk holdfast. Long oblanceolate blade on a long stalk. Paraphyses abundant in cryptostomata on frond. Found at Amory Cove.

Punctaria latifolia Greville.

Small brown understory alga. In cross-section about 7 cells thick. Ribbon-like blades from basal disks, with short stalks. No marginal hairs present.

Scytosiphon lomentaria (Lyngbye) C. Agardh.

Cylindrical fronds with constrictions and hollow parts. Heavily epiphytized by Ectocarpus. In shallow subtidal.

RHODOPHYCEAE (Red Algae)

Cystoclonium purpureum (Hudson) Batters.

All branches cylindrical. Thallus corticated. The cross-section cortex cells radially seriate. Dark red-purple, bushy plant, 10 cm tall. Prominent main axis with numerous tapering lateral branches. Found at Amory Cove.

Dumontia incrassata (Müller) Lamouroux.

Red brown thallus except where bleached at tips. Main axis and secondary branches hollow. Some branch tips clavate, some acute. Cortex of large cells. Epiphytized by Elachistea and Ectocarpus. Common in shallow subtidal zone.

Membranoptera denticulata (Montagne) Kylin.

Foliaceous with serrated blades with minute lateral veins. Rose-colored plant. Epiphytic on Plumaria pectinata, sometimes larger than host alga.

Plumaria pectinata (Gunner) Ruprecht.

Bushy, bilateral branching. Ultimate branches flattened and alternately unequal in size. Sporangia on stalk with little filaments. Frequently epiphytized by *Membranoptera*. Found 3-7 meters deep.

Polysiphonia variegata (C. Agardh) Zanardini.

Red. 6 pericentral cells. Tetrasporangia present, seriate in branches. Found in Armory Cove.

Corallinaceae

Crustose coralline algae on rock substrate, especially in sea urchin grazing zone. Present as ground cover beneath *Laminaria* and *Alaria*.

AQUATIC ANGIOSPERMS OF THE MATAMEC AREA, QUEBEC

Karla J. McDermid
Woods Hole Oceanographic Institution

A brief but intensive survey of aquatic vascular plants or macrophytes was conducted during the month of August, 1981 at Lac Matamec, Rivière Matamec and Lac à la Croix in Québec. Samples were collected from ten study sites by hand (see Fig. 1). Specimens were identified to species whenever possible, dried, prepared for mounting, and sometimes sketched (see Fig. 2). Our herbarium collection now contains over 30 species of macrophytes.

Several distributional patterns were noted during this survey. Nuphar rubrodiscum was a dominant member of the littoral zone community in the lakes. This species seemed most adapted to shallow, calmer waters with mud-sand substrate. However, spindly, non-flowering Nuphar were also found in sparse stands off exposed points with rocky bottoms. Sparganium spp. and Potamogeton spp. were most prevalent in the river. The beaver ponds behind beavers' dams created unique habitats for several of the more delicate species including Callitriche, Hippuris, Myriophyllum and Utricularia. One rich and varied collection was made at a boggy peninsula on the northeast shore of Lac Matamec. Here distinct zones of vegetation were evident: Nuphar beds spread out in shallow water near shore, but then were replaced by well-mixed Lobelia and Eriocaulon; Juncus pelocarpus appeared on the sandy shore with dwarfed forms of Lobelia and Eriocaulon; dense stands of Carex and some Equisetum stood on the upper shore ground; and finally on the uppermost level grew Campanula, Eupatorium and Solidago.

Seasonality of plant fruiting was a minor limiting factor in species identification. Sometimes the key characteristic nutlet or flower was absent. Further specimen collections should be made in spring and early summer.

This study introduces areas for future research. What factors are involved in the ontogeny of a single species stand of macrophytes? At Lac Matamec are pure Nuphar beds the result of simple first-come-first-served or competition or defense mechanisms? Is the frequent close association between Eriocaulon and Lobelia just incidental? How do such factors as light, water level, nutrients, substrate, water turbulence and plant density influence the heteromorphism observed in Sparganium angustifolium, Lobelia dortmanna, Eriocaulon septangulare and Potamogeton spp.? How do grazing moose, muskrats and beavers affect the macrophyte communities? Often at Lac Matamec we saw traces of moose herbivory: shredded macrophytes and hoof prints in the mud. What insect chews up the Nuphar so efficiently, making lily pad doilies? While seining in Lac Matamec and Rivière Matamec above the lake, the only trout captured were from macrophyte beds. Perhaps these young fish were demonstrating a pattern of habitat selection. What happens to the aquatic plants and the associated biotic community in Rivière Matamec, Lac Matamec and Lac à la Croix during the winter freeze-up and spring flood?

This 1981 survey and herbarium collection provides an essential foundation for the investigation of these problems.

Annotated List of Macrophytes

BRYOPHYTES (Mosses and Leafy Liverworts)

Fontinalis sp.

Plants with long stems flowing out from point of attachment. Leaves in 3 rows. Found on unnamed creek west of Gallienne Creek.

Scapania sp.

Plants with rather short stems, approximately 2 cm. Leaves on sides of stems, giving a flattened appearance. Much organic material caught in plant mat. Found on unnamed creek adjacent to Gallienne Creek.

EQUISETACEAE (Horsetail Family)

Equisetum fluviatile forma Linnaeanum (Doll) Broun.

Erect stem 40 to 65 cm tall. Unbranched. Stem with large central cavity and barely visible side cavities. Stems of lower portion approximately 4.5 mm diameter. Teeth at stem joints completely black. Found on shores of Lac à la Croix and Lac Matamec among Eleocharis and Carex.

SPARGANIACEAE (Bur Reed Family)

Sparganium fluctuans (Morong) Robinson.

Leaves flat and floating, some narrow, some broad. Multiple staminate heads. Pistillate heads with single stigmas borne in leaf axils. Found in flowing river water.

Sparganium angustifolium Michx.

Single stigmas on supra-axillary pistillate heads. Leaves rounded on back, some with slightly inflated sheathing bases. Leaf nerves no more than .8 mm apart. Nutlets non-ribbed, 3 mm long with pinkish base. Found on muddy shores of Lac à la Croix and on Rivière Matamec above 2nd Falls.

NAJADACEAE (Pondweed Family)

Potamogeton gramineus L.

Floating leaves tapered at base with 14 nerves. Leaf margins non-dentate. Submersed leaves non-petioled, up to 15 cm long. Found in river and beaver ponds.

Potamogeton confervoides Reichenb.

Leaves all thread-like and submerged. Spikes with 4 tiers of pods on peduncles about 15 cm tall. Stipules free from leaf base. Found in Lac à la Croix.

ALISMACEAE (Water Plantain Family)

Sagittaria cuneata Sheldon.

Plants with 2 leaf forms: submerged rosettes (3 cm long) and floating arrowheads (3 cm long). Floating leaf lobes pointed with petiole from lower margin of blade. Main central vein and all other veins branch from point of leaf-petiole junction. No flowers or nutlets present. Found among Sparganium above 2nd Falls.

GRAMINEAE (Grass Family)

Glyceria canadensis (Michx.) Trin.

Spikelets several-flowered and ovate. Lemmas obscurely nerved. Found in old beaver meadow of Beaver Creek.

Calamagrostis canadensis (Michx.) Beauv.

Tall slender grass. Inflorescence open. Found in old beaver meadow of Beaver Creek.

CYPERACEAE (Sedge Family)

Eleocharis palustris var. major Sonder.

Tall 40 cm stems (3 mm diameter). Solitary spikelets terminating the stems. Scales of spike easily removed. 2 sterile scales at base of spike. Nutlet 2-angled with tubercle higher than broad (1.9 mm long) Found on muddy shores of Lac à la Croix with Equisetum.

Eleocharis robbinsii Oakes.

Leaves from one point at plant base. Leaves thread-like with cross-striations visible with back light. No tuber apparent. Up to 40 cm tall. Found in beaver pond off Rivière Matamec.

Eleocharis acicularis R S

Stems forming a turf on wet shore. Spikelets sparsely flowered. About 2.5 cm tall. Understory vegetation on muddy shores of Lac à la Croix.

Scirpus microcarpus var. rubrotinctus (Fernald) Jones.

Spikelets (2 mm thick) with leaf extending beyond. Plant 50 cm tall. Involucre of 2 or more leaves (3-5 mm). Nutlets with 4 bristles. Solitary upright stems from root stocks. Lower sheaths reddish. Found on sandy banks of Rivière Matamec.

Carex spp.

Spikelets present with 1 involucral leaf extending beyond. Stem rounded in cross-section, not completely hollow. Spikelets 3-7 tiered with 3-angled nutlets. Found in dense stands in upper shore ground of Bog Peninsula.

ARACEAE (Arum Family)

Calla palustris L.

Lobed leaves on long petioles arising from root stock end. Lobe veins not heavy. Blade heart-shaped with finger-like tip. Found in Rivière Matamec above lake.

ERIOCAULACEAE (Pipewort Family)

Eriocaulon septangulare With.

Rossette of leaves at base. Leaves (4 cm long) tapering, pointed with cross-striations. Roots with cross lines. Sooty grey flower in button-like heads on tips of slender stalks above water. Some plants tall (30 cm), some dwarfed (3 cm). Found in cove of Bog Peninsula and on sandy shore.

JUNCACEAE (Rush Family)

Juncus pelocarpus Mey.

Spike-like dark green leaves. Tiny flowers borne singly. Thin runners join plants. Inflorescence terminating the stem with one involucral leaf extending beyond. 4 cm tall. Found on very shallow sandy bank at mouth of Gallienne Creek.

Juncus pelocarpus forma submersus Fassett.

Similar to J. pelocarpus but sterile. Very thin dark green leaves with reddish tinged leaves. Definite horizontal connecting stems. 6 cm tall. On sandy shore of Bog Peninsula.

MYRICACEAE (Sweet Gale Family)

Myrica gale L.

Shrub with flat, wedge-shaped leaves, toothed toward rounded tip. Leaves fragrant (minty laurel smell). Underside of leaf sprinkled with yellow resinous dots and white hairs. Little buds in each leaf axil. On boggy shores of Lac à la Croix.

NYMPHAEACEAE (Water Lily Family)

Nuphar rubrodiscum Morong.

Yellow flowers with cupped sepals. Lemony odor. Rhizome thick with petiole and flower stalk scars. Flowers 3-4 cm wide with 10-13 stigma rays. Many stamens. Notch 1/2 length of leaf midrib. Submerged leaves thin, reddish. Common in Lac Matamec and in beaver ponds.

CRUCIFERAE (Cress Family)

Subularia aquatica L.

Small tufted plants forming a turf. Slender, pointed leaves 2 cm tall. Tiny white flowers in green pods (2 mm long). No horizontal connecting stem. Growing in mud bank upriver of 2nd Falls between Carex patch and Sparganium stand.

CALLITRICHACEAE (Water Starwort Family)

Callitriche heterophylla Pursh.

Delicate plants with slender, limp stems. Thin submersed leaves and floating leaves forming a rosette at water surface. Fruits in leaf axils less than 1 mm, as high as broad with non-keeled lobes. Found in beaver pond off upper Rivière Matamec and in creek west of Gallienne Creek.

HALORAGIDACEAE (Water Milfoil Family)

Hippuris vulgaris L.

Non-petioled leaves in a whorl with about 10 leaves to a level. Distance between whorl less than leaf length. Submersed leaves limp 2-3 cm long. Upper emersed leaves short rigid (.5 cm long) Stem pink above water, green with striations below. Found in beaver pond off upper Rivière Matamec.

Myriophyllum verticillatum L.

Thread-like compound leaves borne in whorls with regular forking. Rachis of leaves broader at base. Pinkish stem. No flowers present. Found in beaver pond off upper Rivière Matamec.

LENTIBULARIACEAE (Bladderwort Family)

Utricularia gemniscapa Benj.

Many well-developed bladders on scattered leaves. Irregularly forked, compound leaves thread-like without spiny margins. Bladder-bearing leaves forked at base with straight rachis. Top bud 5 mm diameter. Found in beaver ponds off Rivière Matamec above lake.

CAMPANULACEAE (Bluebell Family)

Campanula uliginosa Rydb.

Blue, bell-shaped flowers with 5 lobes. Leaves less than 1 cm wide. Leaves alternate with branching vein pattern. 40 cm tall. Found on upper ground of Bog Peninsula.

LOBELIACEAE (Lobelia Family)

Lobelia dortmanna L.

Aerial, white flowers on tall, semi-naked stem leaves in a basal rosette. Leaves consisting of 2 tubes joined side by side. Found in Bog Peninsula Cove (40 cm tall) and on lake bank (13 cm tall).

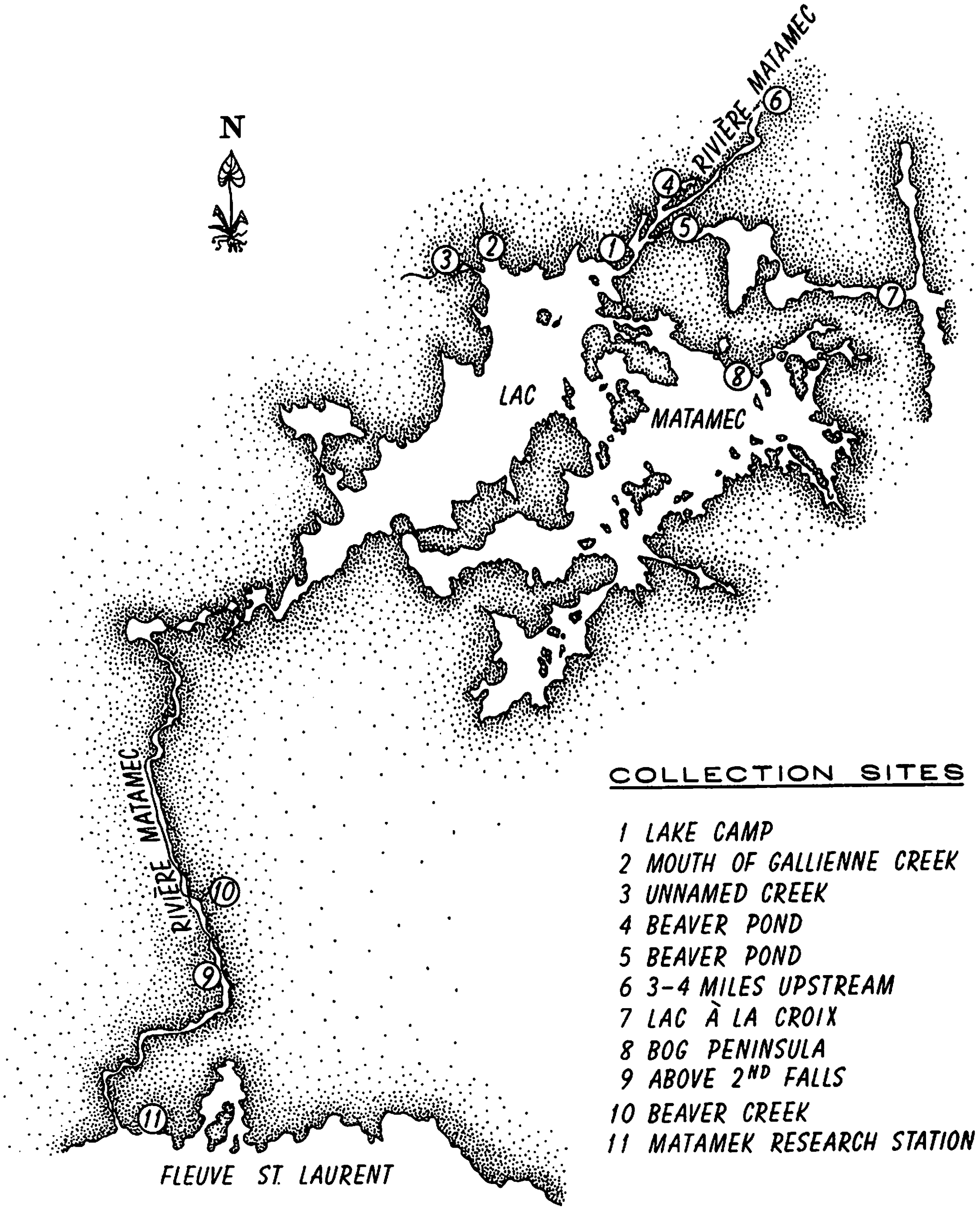
COMPOSITAE (Composite Family)

Eupatorium maculatum L.

Toothed leaves whorled in fours. Red-purplish stems round and hollow in cross-section. Leaves tapered to petiole with almost uniform side veins. Purple flowers. Uppermost leaves shorter than inflorescence. Found on upper ground of Bog Peninsula.

Solidago graminifolia L. Solisb.

Non-petioled leaves with minute saw-toothed edges. Leaves alternate with main midrib. Yellow, clustered flowers, 35 mm tall. On upper ground of Bog Peninsula.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COLLECTION SITES
1 LAKE CAMP
2 MOUTH OF GALLIENNE CREEK
3 UNNAMED CREEK
4 BEAVER POND
5 BEAVER POND
6 3-4 MILES UPSTREAM
7 LAC À LA CROIX
8 BOG PENINSULA
9 ABOVE 2ND FALLS
10 BEAVER CREEK
11 MATAMEK RESEARCH STATION

FIGURE 1

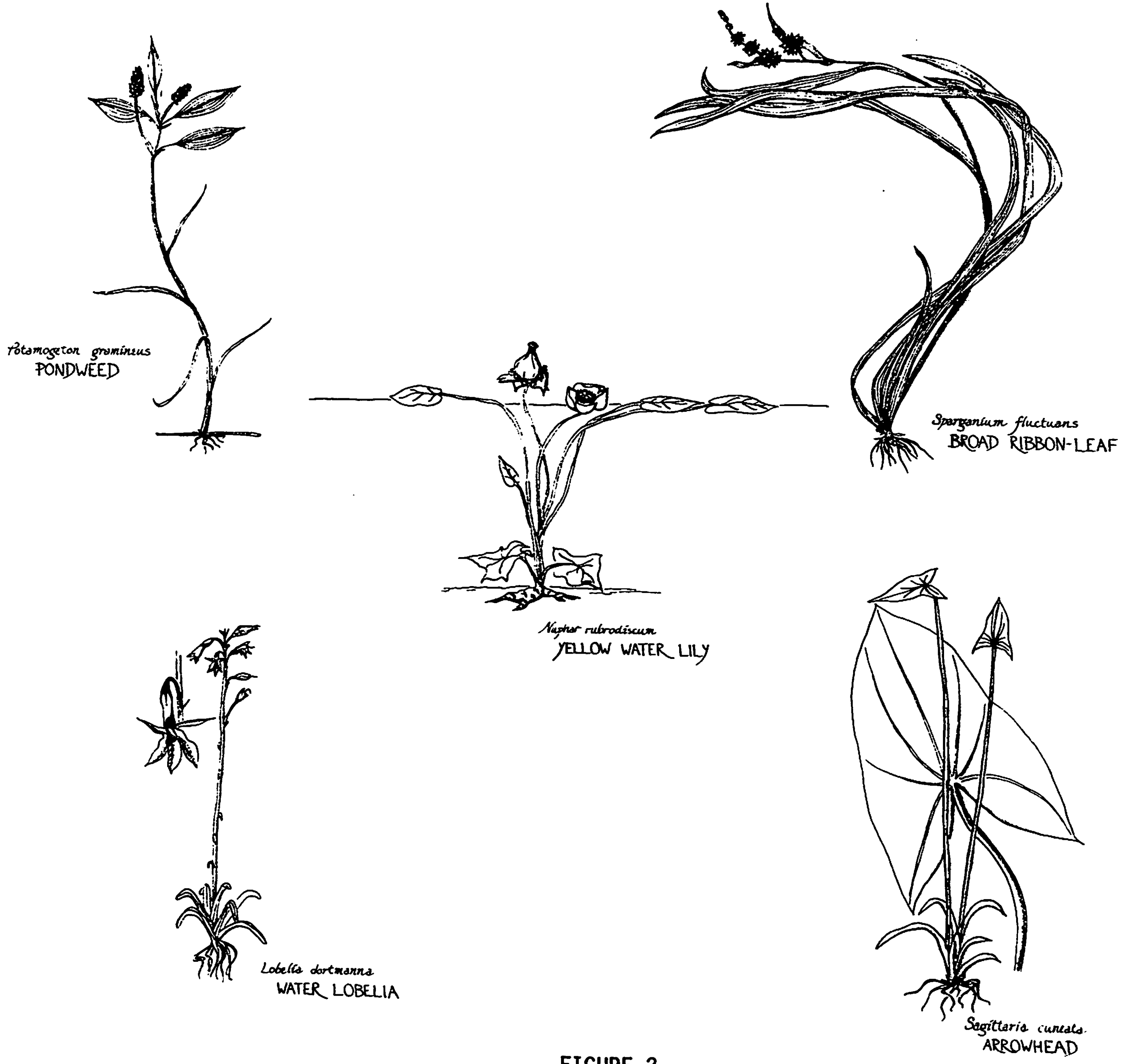
Potamogeton graminius
PONDWEED
Nuphar rubrodiscum
YELLOW WATER LILY
Sparganium fluctuans
BROAD RIBBON-LEAF
Lobelia dortmanna
WATER LOBELIA
Sagittaria cuneata
ARROWHEAD

FIGURE 2

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This report summarizes activities associated with the Matamek Research Station in 1981. Research was conducted on the biological, chemical, and physical environment of streams and rivers, principally in the Moisie and Matamek River watersheds, on the effects of beaver in shaping aquatic ecosystems, on salmonid ecology, and on interactions between riparian vegetation and juvenile salmonids. Canadian universities, the Quebec government, and the Woods Hole Oceanographic Institution cooperated in this program.

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