THE UNIVERSITY OF MANITOBA

ADAPTIVE STRATEGIES OF THE CENTRAL MUDMINNOW, UMBRA LIMI (KIRTLAND) IN SOUTHERN MANITOBA

by

KATHLEEN ANN MARTIN

A DISSERTATION

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ABSTRACT

The variation in the environmental factors encountered, the habitat occupied and preferred, patterns of activity, aspects of growth, reproduction and food consumption by the central mudminnow, *Umbra limi* were studied to illustrate the mudminnow's adaptations to the spatial and temporal pattern of its environment.

Mudminnows inhabit and show a preference for areas with cover which is consistent with their morphological, behavioural and physiological adaptations. Mudminnows showed variations in time of activity. Crepuscular, nocturnal and diurnal activities were observed at different times and places.

Enhanced survival of females is one of the life history strategies exhibited by mudminnows. Females (age 2+) were usually larger and more abundant than males. Age at first maturity was two for females and one for males. Time of spawning varied between years in the streams studied and some females did not spawn at all in 1979. Delayed spawning (particularly in smaller females) may be an important survival strategy in a variable environment. Larger females produced more eggs so that a strategy of increased growth in females may be selected. Gonad development in females occurred largely in winter when a piscivorous diet was observed. Variability in growth rates resulted in overlap in lengths which increased as the fish aged. All are indicative of a generalized life history strategy.

Feeding occurred in the vegetated areas of streams. Benthic, mid-water, surface and organisms attached to vegetation were included in the diet. Mudminnows were euryphagic carnivores and ate aquatic and terrestrial invertebrates and fish (which became more important as the temperature dropped). Utilization of all available food resources was accomplished by increased diet diversity with increased fish size, reduction in apparent overlap by a different microhabitat occupied by year classes and use of abundant food items (e.g. zooplankton and Chironomidae larvae by age 0 and 1 fish), the opportunistic strategy of switching to new resources as they became available, incorporation of allochthonous material in the diet, and feeding at different times.

The central mudminnow responds to a heterogeneous environment by specializing in habitat and generalizing in time of activity, life history and feeding strategies.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The central mudminnow, *Umbra limi* (Kirtland) reaches the northern limit of its range in southern Manitoba (Scott and Crossman 1973) and although much is known of its biology in southern populations (Westman 1941; Peckham and Dineen 1957; Jones 1973) little, apart from the work of Keast (Keast and Webb 1966; Keast 1966, 1968, 1970) is known from northern areas of its distribution. In addition, most researchers place little importance on the role of adaptive strategies in *U. limi*'s response to its environment. Gee (1980, 1981), one exception, discussed adaptive strategies in respiratory patterns and hydrostatic functions of the swimbladder of mudminnows.

At the northern end of its range, *U. limi* is found in the headwaters of small, slow-moving streams characterized by seasonal variation of temperature, oxygen, pH, conductivity, water velocity, presence of cover and availability of food. Adaptive strategies for such a variable environment should include the ability to occupy a broad niche in terms of either space, resources utilized or time (Mayr 1963; Selander 1966; Keast 1970, 1977).

The purpose of this study was to describe on a seasonal basis the variation in the environmental factors encountered by *U. limi*, the habitat occupied and preferred, patterns of activity, aspects of growth, reproduction and food consumption by *U. limi*. Such information would provide an understanding of the mudminnow's adaptations to the spatial and temporal pattern of its environment.

METHODS

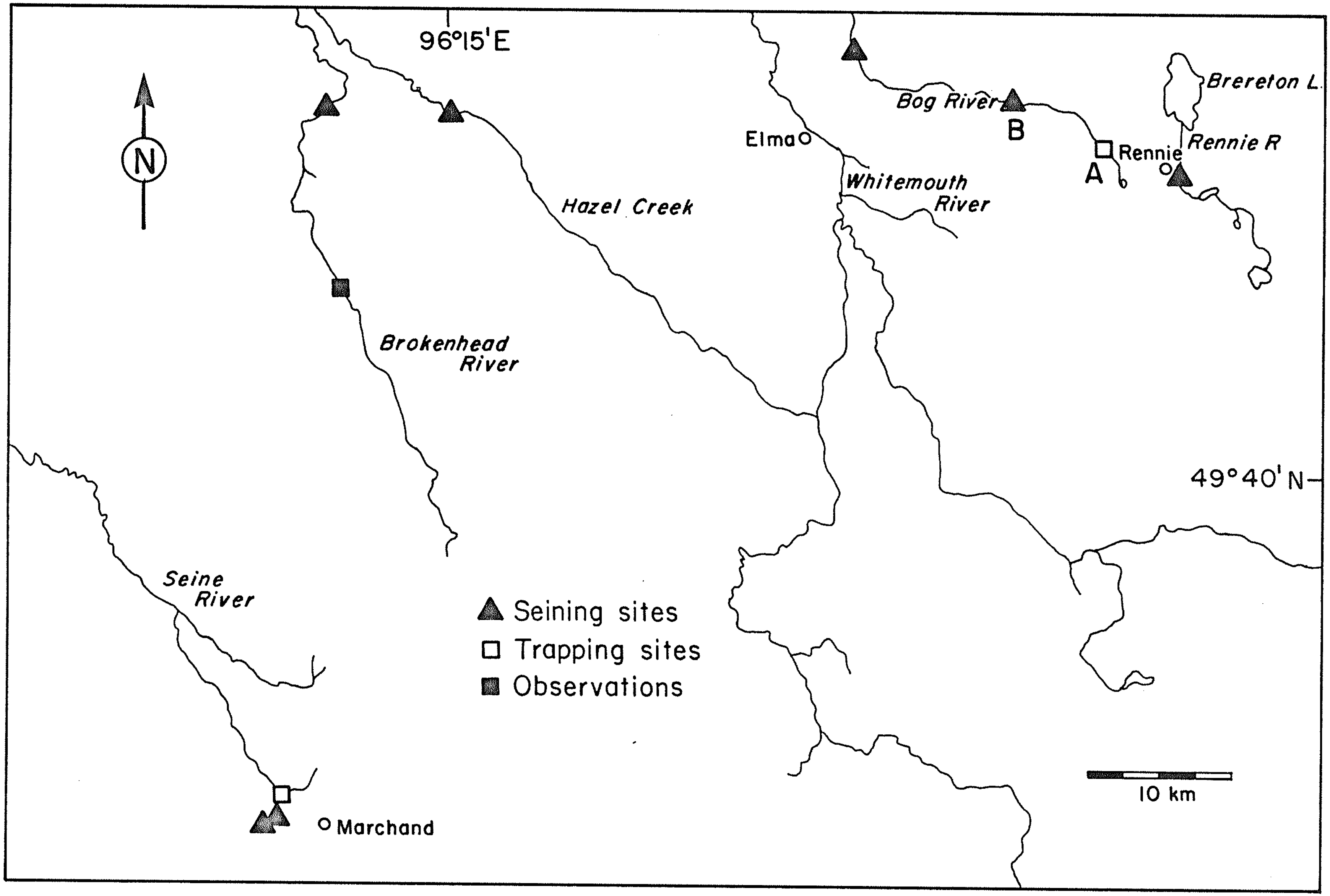
Study Area.

Measurements of environmental variables and collections of fish were made from streams in the Red River, Brokenhead and Winnipeg River drainage systems (Fig. 1) from April 1978 to August 1979. The Seine River was sampled intensively in 1978, the Rennie River in 1979 and the Bog River in both years. Variables measured included; dissolved oxygen (YSI model 54 oxygen meter), salinity, conductivity, temperature (YSI model 33 SCT meter) and pH (measured in the laboratory with a Corning Model 7 pH meter and a Corning triple purpose electrode). Water velocities were measured by timing a floating object over a 1-m interval at each collection site. Stream characteristics such as depth, substrate, percent of the area with cover and the type of cover were described for each collection in addition to the area sampled.

Fish Collections.

A 2.0-m X 1.4-m two-man seine with 2-mm square mesh and a heavily weighted lead line was used in sampling fish to describe distribution and abundance of mudminnows in particular environments and to provide collections of fish for age, reproduction and diet analysis. Collections were categorized into two environments: vegetated margins and pools and unvegetated or sparsely vegetated channels. In sparsely vegetated areas the net was hauled quickly upstream and raised within

Figure 1: River systems and sampling sites where mudminnows were collected in 1978 and 1979 in southern Manitoba.


96°15'E
Brereton L.
Bog River
B
Elma
Rennie
Rennie R
A
Whitemouth
River
Hazel Creek
Brokenhead
River
49°40'N
Seine
River
Seining sites
Trapping sites
Observations
10 km
Marchand

the same habitat. Vegetated areas along the stream edges were encircled by the net. The substrate within the net was disturbed by vigorous kicking, driving fish out of the substrate and vegetation as the net was hauled to shore and lifted. Collections were made through relatively uniform habitat and were repeated where necessary to ensure thorough sampling (removal of all mudminnows within the seined area). An attempt was made to remove at least 10 mudminnows per sample for feeding analysis at each site. Shallow water was sampled using a dip net to collect fry.

All fish collected were initially anaesthetized in <1% phenoxyethanol to prevent regurgitation of stomach contents and then preserved in 10% formalin for up to seven days after which they were transferred to 70% isopropanol to facilitate handling.

A 2.5-cm stretched mesh gill net (7.6m X 2.4m) was used to sample fish in deep water in the Seine River. The number and length of fish were recorded and the stomach contents of Esox lucius Linnaeus were preserved in 10% formalin.

Collections were made under the ice during winter and early spring of 1979 using floating plastic minnow traps (length 43cm; diameter 21cm) set in the Bog River. Attempts to sample in other areas were unsuccessful. Traps were sunk by attaching several lead weights where water level permitted, otherwise they were left to float beneath the ice. Traps were not baited and most were left up to four hours. Fish were preserved as previously described. Trap collections were used for feeding analysis only during winter and early spring when fish could not be collected by seining. Trapping was carried out during the summer to demonstrate seasonal changes in distribution in the Seine and Bog Rivers. Fish were preserved as previously described (early summer 1978) or captures were noted and fish were released.

The seasonal sampling regime was defined as: spring, 1 March to 31 May; early summer, 1 June to 30 June; midsummer, 1 July to 31 July; late summer, 1 August to 31 August; autumn, 1 September to 30 November; winter, 1 December to 28 February.

Attempts were made to observe U. limi under field conditions using a face-plate and snorkel. These attempts were generally unsuccessful because of the dense vegetation, the cryptic colouration of the fish and their secretive behaviour.

Habitat Preference.

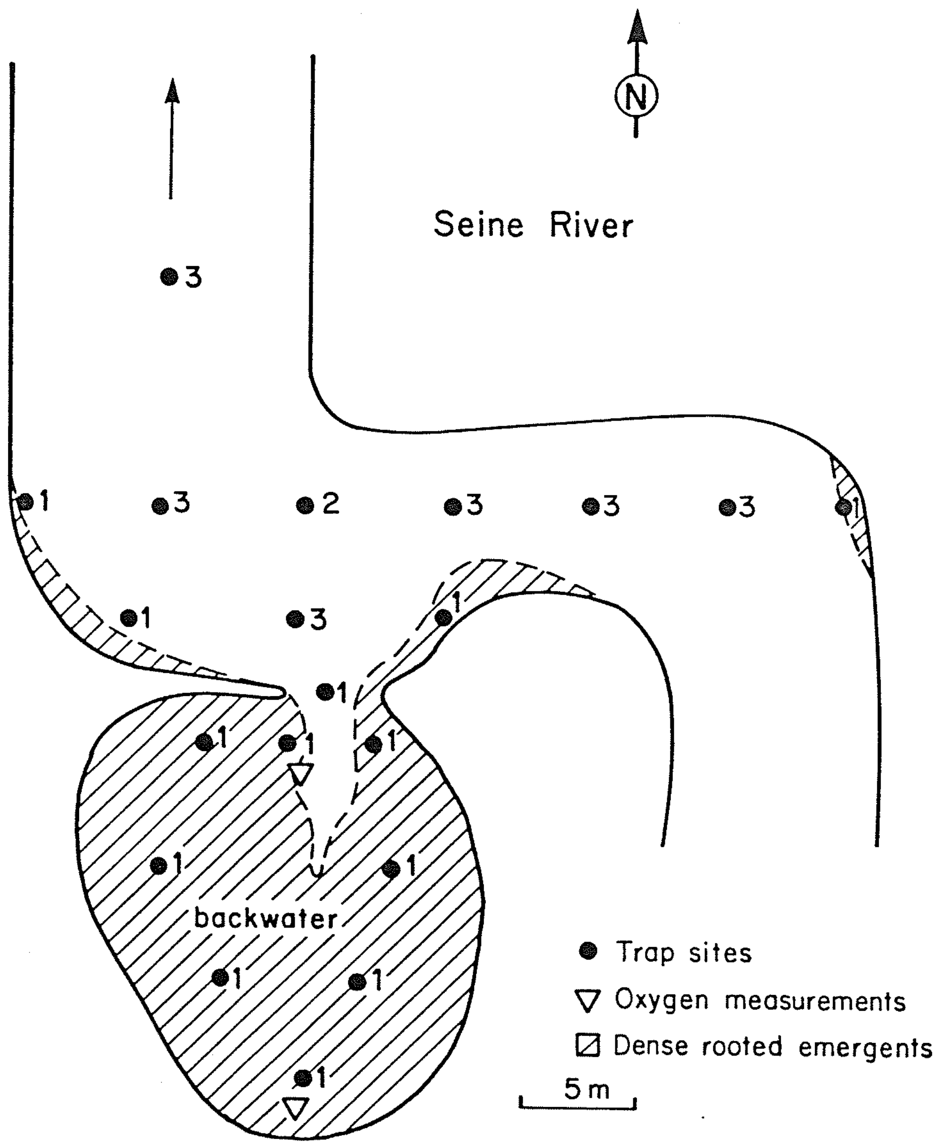
Laboratory experiments were carried out to assess habitat preference by U. limi. Fish were collected from the Bog River in late autumn 1979, held for two months prior to observation and tested in the laboratory at $25^{o}C$ under a photoperiod of 12L:12D. Observations were carried out in six aquaria (90cm X 45cm X 45cm) each of which was surrounded by black barriers and illuminated by an overhead light source (100-W bulb positioned 0.5m above the water surface). Fish were viewed through a slot (0.5m X 5.0cm) in the front panel. Initial observations were made in aquaria with no vegetation. Then four to six strands of Myriophyllum sp., collected from the Bog River, were tied to a lead weight and six to nine of these bundles were spaced evenly in one half of the aquarium as vegetation, the other half was left bare. Fish were introduced into the centre of the aquaria and were observed every 6min for 1h, after a 10-min and 24-h acclimation period as well as after 7-days (for groups of fish). Observations on choice of habitat were made on individual fish (52 fish in total) and fish held in groups of 10 (6 groups of 10 fish). The criterion used to assess choice of habitat for Cole's closed sequential test design (Cole 1962) was 8 of 10 observations within one habitat for the single fish and for groups of 10 fish, 8 of the 10 fish in one area. The number of observations in each area was also tested using a chi-square analysis.

Diurnal Activity.

To obtain information on time of activity, six series of collections were made over 24h at 4-h intervals in 1978 using minnow traps set in areas of the Bog and Seine Rivers. Frequency of capture was used as an index of time of activity.

The Seine River site had a protected backwater with access to the main river (Fig. 2). The river edge, the area near the backwater mouth and the backwater itself supported a mixed aquatic plant community including rooted emergents (e.g. *Typha* sp.) rooted non-emergents (e.g. *Myriophyllum* sp.) and floating plants (e.g. *Lemna* spp.). Vegetation was surveyed and its seasonal progression noted. Traps were set in the river and backwater in early and late summer 1978. For comparison with the Seine River, trapping was carried out during midsummer 1978 in the Bog River which had a much less diverse plant community (4 species were abundant as compared to 16 in the Seine River), confined to a smaller area along the river edge. Fish were either preserved as previously described (early summer 1978) or total lengths were measured and fish were released (mid- and late summer 1978).

Figure 2: A diagram of the trapping site on the Seine River, Manitoba. Points represent trap placement with numbers indicating the number of traps at each site. Direction of flow is marked by an arrow.



Seine River
N
3
1
3
2
3
3
3
1
1
3
1
1
1
1
1
1
1
backwater
1
1
1
Trap sites
Oxygen measurements
Dense rooted emergents
5 m

Age, Growth, Condition and Reproduction.

Total length, weight, sex and gonad weight were recorded for all *U. limi* collected and preserved. To age fish, otoliths were dryed and then cleared in benzyl benzoate for 15min to 12h and while still in the clearing solution, were examined through a dissecting microscope with reflected light against a dark background. Age was determined for a subsample (1197 fish) of the fish collected (2836 fish) following the interpretation of Jones and Hynes (1950). Estimated age for the remaining fish was based on these data in conjunction with length frequency information. For this study age change-over was said to occur at the New Year (age 0 fish became age 1 fish on 1 January 1979, etc.). Fry and age 0 fish are interchangeable terms.

Growth for each age class was calculated from mean lengths throughout all seasons. Coefficient of condition for age classes and sexes was calculated using Hile's (1936) index (Appendix 1). Percent sexual development (Appendix 1) was calculated (Luoma and Gee 1980) and sex ratios compared. Eggs were counted from samples of gravid females collected in 1978 and 1979.

Feeding Biology.

Time of feeding activity on both a seasonal and diurnal basis was investigated during several 24-h seining periods. Seasonal changes in feeding were indicated by the change in percent of fish with empty and full and distended stomachs. The change in the ratio of stomach content to body weight ($x10^3$) with time was the measure of diurnal feeding activity.

Diet was studied for age classes 0,1 and 2+ . Data for both years and all streams were combined. Hynes' (1950) point method was used to assess the importance of food items consumed. Each stomach was assessed seperately. Points were allotted to the stomach based on fullness (distended, 30; full, 20; 3/4 full, 15; 1/2 full, 10; 1/4 full, 5; trace, 2). These points were then subdivided amongst the various food items based on the estimated percent volume of each item present in the stomach. In some cases <1 point was assigned to minor quantities of small items. Points were then totalled for each item and presented as the percentage of the total points for each age group. Stomach samples were identified to Family for the Insecta (Borror et al. 1976; Merritt and Cummins 1978; Usinger 1956) and to Order for all others (Borror et al. 1976; Pennak 1953). Overlap in diet was calculated using Morisita's (1959) index as modified by Horn (1966) (Appendix 1). Diversity was calculated using MacArthur's index (1972) (Appendix 1).

RESULTS

Habitat Description.

The headwater regions sampled were generally narrow (<10m wide), shallow (<2m deep) meandering prairie streams with high humus content. Flow rate was irregular, rising sharply during spring flooding (max 60cm/s) and approaching 0 cm/s in mid- to late summer when vegetation impeded the flow (0 to 25 cm/s). In winter no flow was detectable.

Fig. 3 illustrates the progression of vegetational change typical of all sites. Submerged terrestrial vegetation in areas flooded by runoff was the major vegetated habitat observed in the spring. Undercut banks provided cover for fish particularly in areas of the Seine River. During early and midsummer aquatic vegetation started to develop in the main stream and became more dense along the stream margins. In the Bog River *Sparganium* sp. and *Myriophyllum* sp. were the dominant forms of aquatic vegetation. Overhanging terrestrial vegetation provided cover along the river edges. The plant community of the Seine River was more diverse particularly in and around the backwater. By late summer the water level had risen approximately 20 cm, in part due to the construction of a beaver dam near the trapping site (Seine River). Water flow was reduced and some terrestrial vegetation was submerged. The vegetation which had extended into deeper water in midsummer began to

Figure 3: Seasonal progression of vegetation in the Bog River, Manitoba at site A in spring(A), early summer(B), midsummer(C) and late summer (D). Note traps set in midsummer.

die back. Submerged portions of Valisnaria sp., Potomageton sp. and Nuphar sp. began to deteriorate while floating leaves formed a dense surface cover. In the backwater there were dense mats of rotting vegetation covered with a thick layer of Lemna spp. This deterioration occurred later in the Bog River.

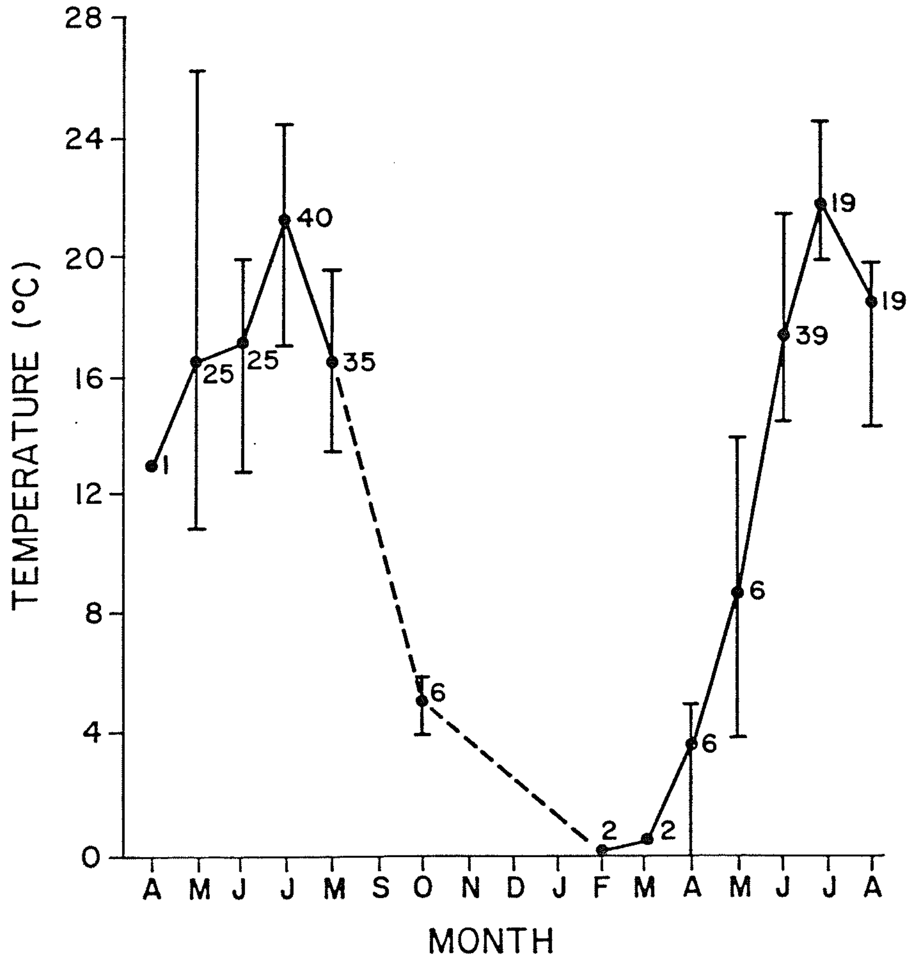
U. limi were subjected to large variations in seasonal temperatures (Fig. 4). Surface water temperature (sub-ice in winter) averaged $<5^{o}C$ for six months of the year and ice-cover extended from late October 1978 until late April 1979 in most of the areas studied.

During the spring when water flow increased the pH in the streams was moderately acidic (6.5), increased only slightly through midsummer (6.7) and by late summer the streams were slightly basic (7.2). The pH increased in the fall to 7.9 and continued to increase under ice-cover to 8.5 by March.

Conductance varied between streams and throughout the seasons. Low values correspond to input from meltwater in the spring and from precipitation in the fall. Values increased under ice-cover in winter and during the summer months. Mean values of conductance (μmos) were calculated for the Seine River (406.4), Brokenhead River (384.0), Hazel Creek (257.1), Rennie River (95.1) and Bog River (90.9) at the study sites.

Seasonal as well as diurnal changes in oxygen concentrations were apparent in habitats occupied by U. limi. During the spring when flow rate was high and vegetative production was low, oxygen levels were high (60 to 93% saturation). During the summer months the effects of

Figure 4: Mean monthly water temperatures (± range and number of observations) for all study sites combined. The period of infrequent sampling is indicated by a dashed line.



TEMPERATURE (°C)
28
24
20
16
12
8
4
0
1
25
25
40
35
6
2
2
6
6
39
19
19
A M J J M S O N D J F M A M J J A
MONTH

temperature and vegetation were evident. Areas of dense vegetation had higher concentrations of oxygen during the day (up to 139% O_2 saturation) and lower concentrations at night (down to 2% O_2 saturation). Extremes were greater in vegetated areas than in unvegetated areas and the surface waters were generally higher in oxygen than deeper water. During the autumn percent saturation of oxygen continued to show diurnal fluctuations (from 8% to 95%). Winter levels were low (2.9% to 14.3% O_2 saturation) and in previous years (1976-1977) dropped to the point that winterkill occurred (J.H. Gee personal communication).

Distribution and Abundance.

During spring, flooded stream margins, meltwater channels and ditches became accessible to gravid female and ripe male *U. limi*. Few mudminnows were found in the main channel. They moved up meltwater channels where spawning may have occurred and in some cases were 10m from the river. These areas were inhabited as long as water remained, usually for several weeks. In Hazel Creek however, *U. limi* remained in the drainage ditches along an abandoned highway until late summer when they presumably moved into the main stream.

In early summer mudminnows were captured in the main stream, along its edges and extending out from the backwater mouth in the Seine River. All fish were captured in traps set on the bottom in water from 25 to 110cm and all captures were made in vegetation. More intensive trapping was done in late June. Vegetation had developed further in the main stream and was much more dense than during the initial trapping. Mudminnows were collected from surface and midwater traps only at night. Activity had increased in all areas including the backwater during the night and in general was more extensive than in spring.

Encroachment of vegetation into deeper water became more evident in mid- to late summer with the distribution of mudminnows expanding to cover these areas. In midsummer, trapping was carried out in the Bog River. U. limi were largely found in vegetated areas and along edges with overhanging vegetation.

By late summer in the Seine River activity was found only in the backwater area. Oxygen concentrations were recorded over a 24-h period during this trapping session (Fig. 5). In dense vegetation oxygen dropped sharply at dusk and increased at dawn at the surface but remained low throughout at the substrate. Trap mortalities occurred in the backwater during the night when the traps were completely submerged.

A migration of U. limi fry was observed in the Brokenhead River in midsummer 1978. Fry swam along the edges of the river through the dense vegetation with upstream progress impeded by two cement culverts under a road. The fry swam through the culverts where a current of 30cm/s was recorded, directly into the edge vegetation at the upstream end. This was the only case where fry were not found in dense vegetation and when a number of mudminnows were found in moderate current.

During autumn U. limi moved into deeper water and in winter, congregations of fishes were found in isolated pools along the course of the streams. Occasionally U. limi were found frozen in the ice.

Densities of U. limi were calculated throughout the sampling period in the two habitats studied (Table 1). Overall mean densities in vegetated margins and pools was 1.83 fish/m^2 and in unvegetated channels

Figure 5: Diurnal fluctuations in oxygen concentration (% saturation) at the Seine River trap site in August 1978.

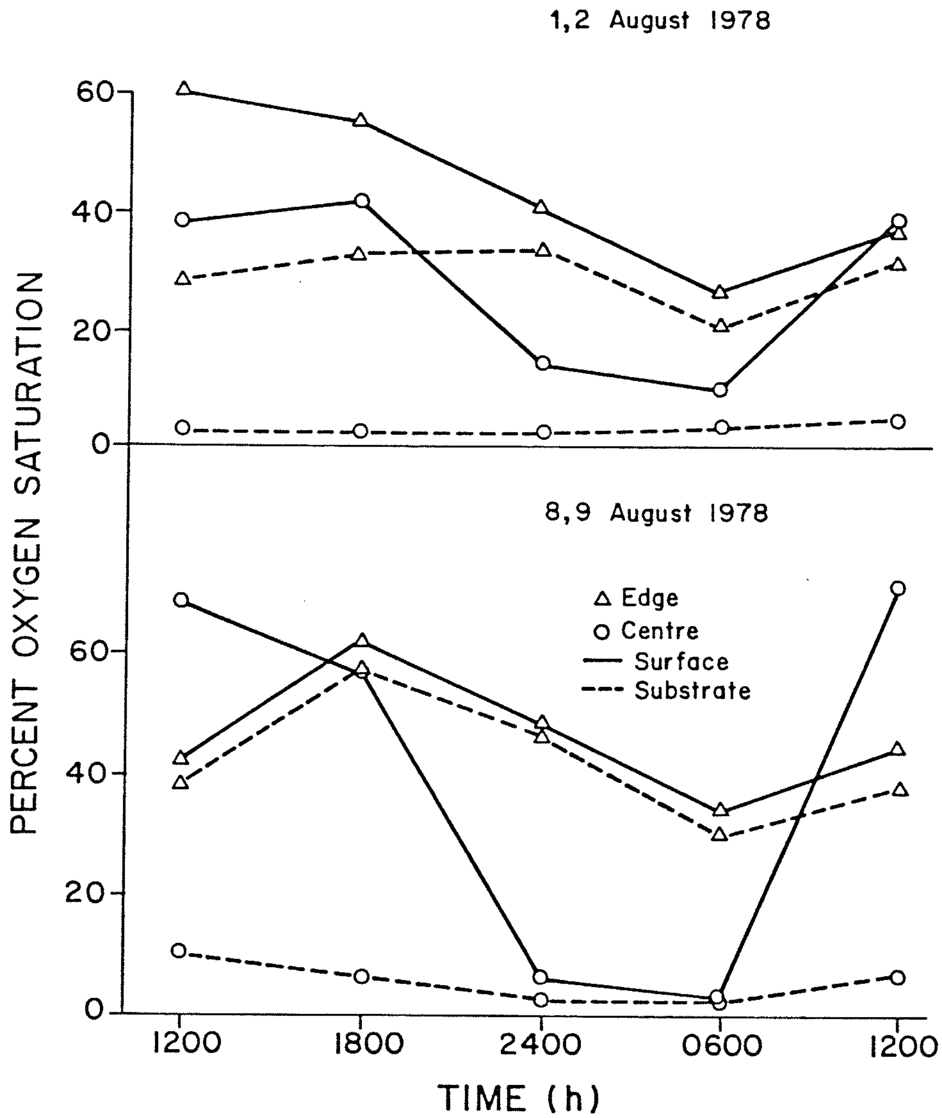

1,2 August 1978
8,9 August 1978
60
40
20
0
60
40
20
0
PERCENT OXYGEN SATURATION
Δ Edge
o Centre
— Surface
--- Substrate
1200
1800
2400
0600
1200
TIME (h)

Table 1. Distribution and abundance of mudminnows from all seine net collections made in 1978 and 1979.

Season	Vegetated margins and pools		Unvegetated channels	
	Area sampled (m^2)	Density (no./m^2)	Area sampled (m^2)	Density (no./m^2)
Spring	507.5	0.7	184.0	0.1
Early summer	172.0	2.4	183.0	0.8
Midsummer	185.0	3.0	201.0	0.1
Late summer	262.0	2.3	156.0	0.3
Autumn	160.8	2.6	-	-

was 0.32 fish/m^2 . Mudminnows were always significantly more abundant in vegetated margins and pools ($P<0.005$) than in unvegetated channels.

In the Seine River, fry were collected in dense vegetation in the backwater areas. Occasionally seine hauls contained fry although many may have been overlooked in the debris collected in the nets. A small inflow stream in a backwater of the Bog River yielded several U. limi fry on 4 July 1979. Close to the backwater large U. limi were collected in 10cm of water. Further upstream fry alone were found in water 3cm deep and several were found in 1cm of water. In the main stream fry were found along the edge in dense vegetation.

In general mudminnows were found in shallow water, 98.5% were seined from water less than 1m deep and 67.9% were seined from water less than 0.5 m deep in close association with vegetation.

Habitat Preference.

Observations of mudminnow behaviour were recorded in conjunction with habitat preference experiments. When introduced into a bare aquarium U. limi swam to the bottom and remained motionless, sometimes after a short period of frenzied activity. Smaller fish remained inactive longer than larger ones and fish tested singly remained inactive longer than when in groups. Fish were observed in the lower half of the aquarium for most of the observation period (90% of the observations on single fish and 85% of the observations on groups of 10 fish).

U. limi were always observed more often (> 65%) in vegetation in the laboratory preference experiments (Table 2), however from Cole's sequential analysis, single fish showed a preference for vegetation after a 10-min acclimation, but no preference after 24h. Groups of fish showed a preference for vegetation after 10min, 24h and 7 days.

Table 2. Habitat preference exhibited by mudminnows in laboratory experiments for single fish (A) and groups (B), N is the number of observations, PX and PY the percent of observations in and not in vegetation respectively.

	Acclimation	N	PX	PY	Cole's test	
					Results	trials
A.	10-min	52	72.3	27.7	Vegetation	14
	24-h	48	68.3	31.7	No preference	44
B.	10-min	60	69.5	30.5	Vegetation	25
	24-h	60	74.0	26.0	Vegetation	19
	7-d	60	72.0	28.0	Vegetation	13

Diurnal Activity.

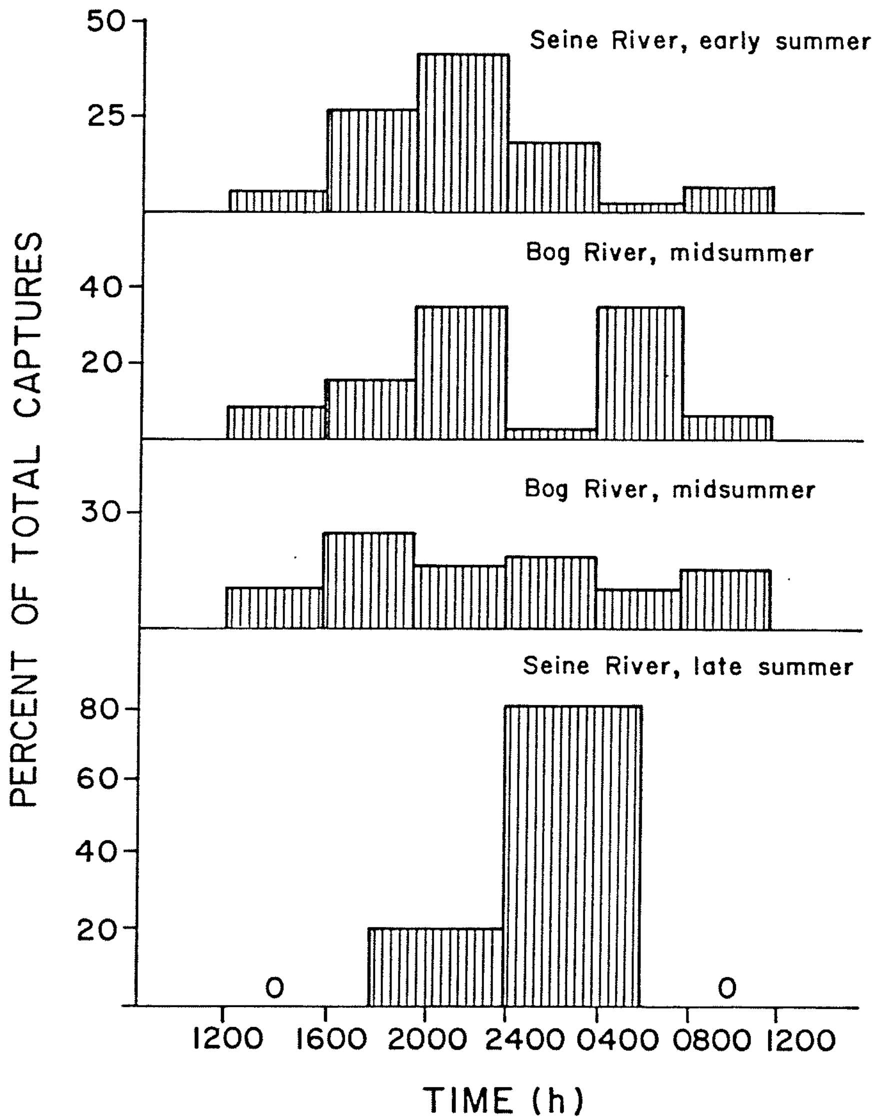
During early summer *U. limi* showed greatest activity from evening through to early morning (Fig. 6) regardless of moon phase. Two different activity periods were observed during midsummer on the Bog River. Crepuscular activity was observed during the new moon (Fig. 6) but a more uniform activity pattern was observed during the full moon (Fig. 6). In the Seine River in late summer *U. limi* also showed high levels of activity from 2400h to 0600h (Fig. 6). In winter activity was low but by March activity had increased as indicated by greater capture success in traps.

Age, Growth, Condition and Reproduction.

Length-frequency histograms were constructed for fish from each of the four streams (Fig. 7). Hazel Creek fish showed a bimodal frequency distribution, an indication of a missing year class (age 1 fish were scarce during 1978). The Seine, Rennie and Bog River fish had length frequency distributions which differed from Hazel Creek but were similar to each other.

There was little difference in mean lengths between male and female mudminnows of age 0 and 1 (Table 3). In the Bog River and Hazel Creek, age 2 females were larger than age 2 males. In all four streams females were larger than males in the age 3 group. Small sample sizes and high variability in length of 4+ fish mask any size differences between sexes.

Figure 6: Diurnal fluctuations in activity as measured by capture success (percent of total captures) from minnow traps.



Seine River, early summer
Bog River, midsummer
Bog River, midsummer
Seine River, late summer
50
25
40
20
30
80
60
40
20
0
0
PERCENT OF TOTAL CAPTURES
1200 1600 2000 2400 0400 0800 1200
TIME (h)

Figure 7: Length-frequency histograms for each stream from combined data for 1978 and 1979.

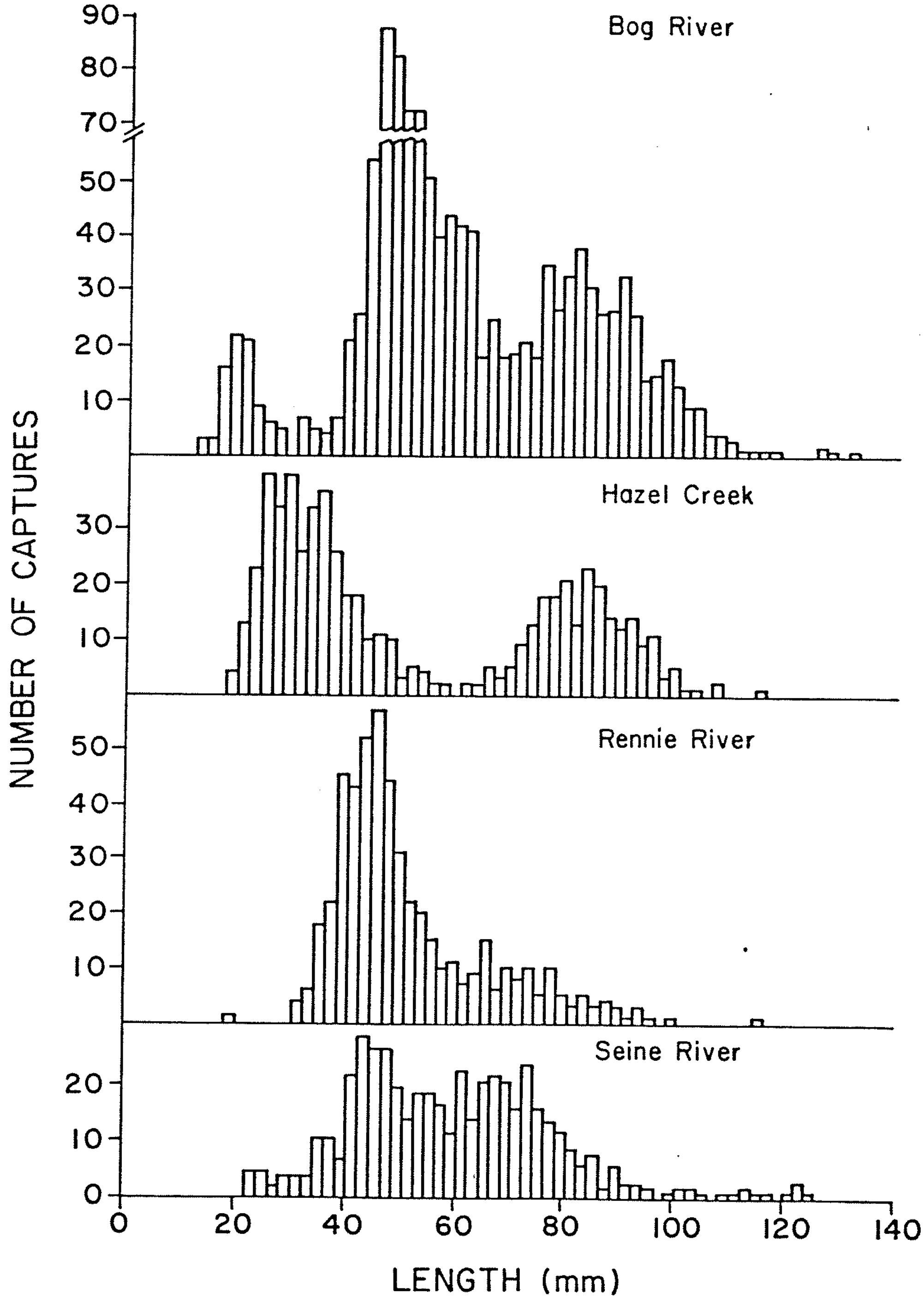

Bog River
Hazel Creek
Rennie River
Seine River
NUMBER OF CAPTURES
LENGTH (mm)
0
20
40
60
80
100
120
140
10
20
30
40
50
70
80
90

Table 3. Mean lengths (mm) of mudminnows calculated for each stream. N is the number of observations, standard deviation (S.D.), in parenthesis, follows the mean.

Age	Sex	Bog River			Hazel Creek			Rennie River			Seine River		
		Mean (mm)	S.D.	N	Mean (mm)	S.D.	N	Mean (mm)	S.D.	N	Mean (mm)	S.D.	N
0	♀	23.3	(5.9)	36	31.2	(6.3)	147	-	-	0	41.2	(7.6)	73
	♂	23.3	(5.0)	36	30.5	(5.6)	170	24.4	(14.4)	2	41.1	(8.2)	76
1	♀	50.6	(7.5)	349	47.2	(4.5)	20	45.2	(7.0)	203	58.7	(9.4)	109
	♂	50.1	(7.4)	304	47.8	(4.9)	22	44.4	(6.0)	191	58.8	(9.8)	108
2	♀	78.9*	(12.5)	165	80.8*	(9.1)	31	64.6	(6.0)	30	75.8	(6.0)	65
	♂	75.5*	(8.6)	141	75.7*	(6.0)	78	65.7	(7.2)	28	76.3	(6.9)	35
3	♀	92.6*	(10.3)	130	89.0*	(7.0)	61	79.2	(6.9)	23	97.9	(10.7)	16
	♂	83.3*	(6.4)	35	84.7*	(8.0)	49	76.6	(6.6)	14	90.7	(8.1)	8
4	♀	93.1	(7.1)	4	93.6	(1.8)	2	87.7	(10.2)	15	120.2	(5.1)	6
	♂	100.4	(10.7)	4	91.7	(1.0)	1	76.1	(4.8)	3	108.3	(5.5)	3

* Significant difference between male and female lengths ($P<0.05$) as determined by a F-test.