THE UNIVERSITY OF MANITOBA

ENVIRONMENTS OCCUPIED, INDICES OF MATURITY, FEEDING ECOLOGY, SHOALING BEHAVIOUR AND INTERACTIONS WITH OTHER SPECIES BY PEARL DACE, *SEMOTILUS MARGARITA* (COPE) IN MANITOBA

BY

ROSS FRANKLIN TALLMAN

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ENVIRONMENTS OCCUPIED, INDICES OF MATURITY, FEEDING ECOLOGY, SHOALING BEHAVIOUR AND INTERACTIONS WITH OTHER SPECIES BY PEARL DACE, SEMOTILUS MARGARITA (COPE) IN MANITOBA

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A thesis submitted to the Faculty of Graduate Studies of
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ABSTRACT

Pearl dace were present only in the headwaters of the Brokenhead River. Males were less abundant than females and the number of males to females decreased from May to November, 1978. Indices of sexual maturity rose steadily from May to November, 1978. From May to August the age classes were separated in horizontal distribution from the youngest (Age 0) in shallow waters to the oldest (Age 2^+) in deep waters and the Age 1 dace intermediate between the two. In September and November all ages appeared mainly in pools deeper than 50cm, with the youngest of age groups at the surface and older groups near the bottom.

Pearl dace are omnivorous with a diet consisting of insects, insect larvae and other invertebrates, along with plant material and detritus. Much of this material is allochthonous. Overlap of diet between ages was limited. Mouth size differed markedly between age groups. Choice of feeding sites differed among age groups but there was no obvious age dependent difference in feeding times.

Interactions with other species were minimized by a lack of dietary overlap and vertical zoning in multispecies schools.

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INTRODUCTION

The pearl dace, Semotilus margarita (Cope) is widely distributed in most of Canada south of the tundra from the Maritime Provinces to the Peace River System of British Columbia (Hubbs and Lagler 1958; McPhail and Lindsey 1970; Scott and Crossman 1973), southward through Montana and east to the northern portion of the Great Lakes region (Blair et al. 1957) and then south along the Atlantic slope to Pennsylvania and Virginia (Eddy 1969). Four subspecies, S.m. margarita (Cope 1869), S.m. nachtriebi (Cox 1896), S.m. koelzi (Hubbs and Lagler 1949), and S.m. athabascae (Bajkov 1927) are recognized (Scott and Crossman 1973). In spite of this wide distribution, pearl dace are rarely found to be abundant (Fava and Tsai 1974; Loch 1969).

Scott and Crossman (1973) report the habitat of the pearl dace in Canada as cool, clear headwater streams in the south, bog drainage streams, ponds and small lakes in the north. S.m. nachtriebi also favor small, clear, oligotrophic lakes in the Canadian Shield (Beamish et al. 1976; Lalancette 1977) and the tributaries of rivers (W. Boyd, personal communication; Fava and Tsai 1974). Generally Semotilus is considered to be adapted for headwater environments (Hynes 1970, Kuehne 1962).

Both sexes may live to age four (Lalancette 1977).

Females grow faster, live longer on the average, and reach a greater maximum length than males (Loch 1969; Fava and Tsai 1974). Age 0 fish have the greatest growth rate and over 75% of growth takes place from May to November (Fava and Tsai 1974; Lalancette 1977). Sex ratios (male:female) vary from 2:1 (Fava and Tsai 1974) to 1:1 (Lalancette 1977).

Langlois (1929) observed spawning northern pearl dace (S.m. nachtriebi) in Michigan, June 12, 1928, at water temperatures from 17.2 - 18.3°C. Fava and Tsai (1974) found southern pearl dace (S.m. margarita) spawned from mid-April to early May at temperatures from 13 to 15°C.

Pearl dace have a varied diet of insects, zooplankton, fish, detritus, and vegetable matter (Nall 1930; Lalancette 1977; McPhail and Lindsey 1970).

There is no information on intraspecific resource partitioning of space and food by pearl dace or on its ecological relationships with other species of fish. Life history data on the stream existence of pearl dace in Canada is not available.

Northern pearl dace are used as baitfish in Alberta (Scott and Crossman 1973) and in Northwestern Ontario where they are the principal species in an industry estimated to have a cash value greater than or equal to the Lake Manitoba commercial fishery (Beamish et al. 1976).

The widespread distribution of pearl dace in Canada, its importance in headwater ecosystems, the gaps in ecological information available and the commercial importance of Northern pearl dace prompted formation of an overall objective to gather ecological data on the species in a Manitoba stream.

The sub-objectives of this study were: to describe the distribution and abundance of pearl dace along the Brokenhead River; to determine an age-length relationship, sex ratio, time of spawning, and how the age classes utilize and partition habitat, food and time; and briefly to compare the similarity of diet between pearl dace and co-existing species.

MATERIALS AND METHODS

A. Distribution, Abundance and Age-Length Relationship

To describe the distribution and abundance of northern pearl dace along its length, the Brokenhead River (Fig. 1) was divided into five zones as follows:

Zone	Length (km)	Substrate (Hynes, 1970)	Surrounding Vegetation	Channel Width (m)	Channel Depth (m)	Mean Gradient (m/km)
Upper	10	Sand	Forest (Coniferous-Deciduous)	1-10	0.1-3.0	2
Middle	15	Silt	Marshland-Bogs	1-15	0.2-3.0	2
Lower	60	Silt-Pebbles-Cobbles	Cultivated	5-20	0.3-5.0	2
Delta	5	Silt	Marshland	20-10	1.0-5.0	1
Hazel Creek	45	Silt-Sand-Pebbles	Marshland-Bogs	2-10	0.1-2.0	2

The winding upper zone has three separate courses, each consisting of riffles, channels, and pools with scattered, small beaver dams. The three km long Brokenhead Swamp separates this from the rest of the river. The middle zone is principally a straight, high banked, man-made ditch blocked occasionally by large beaver dams. The lower zone has wide, unobstructed rapids, channels and pools, while the delta is a slow moving, wide channel. Hazel Creek starts as a shallow, wide channel and enters the Brokenhead River as a high banked narrow channel.

Density of dace in each zone by age group was determined by seining (nets: 2m x 1.5m, 6.0mm mesh; 10m x 1.5m, 6.0mm mesh) a minimum of $200m^2$. Three age groups were distinguished throughout spring, summer and autumn based on visual inspection of length frequency histograms.

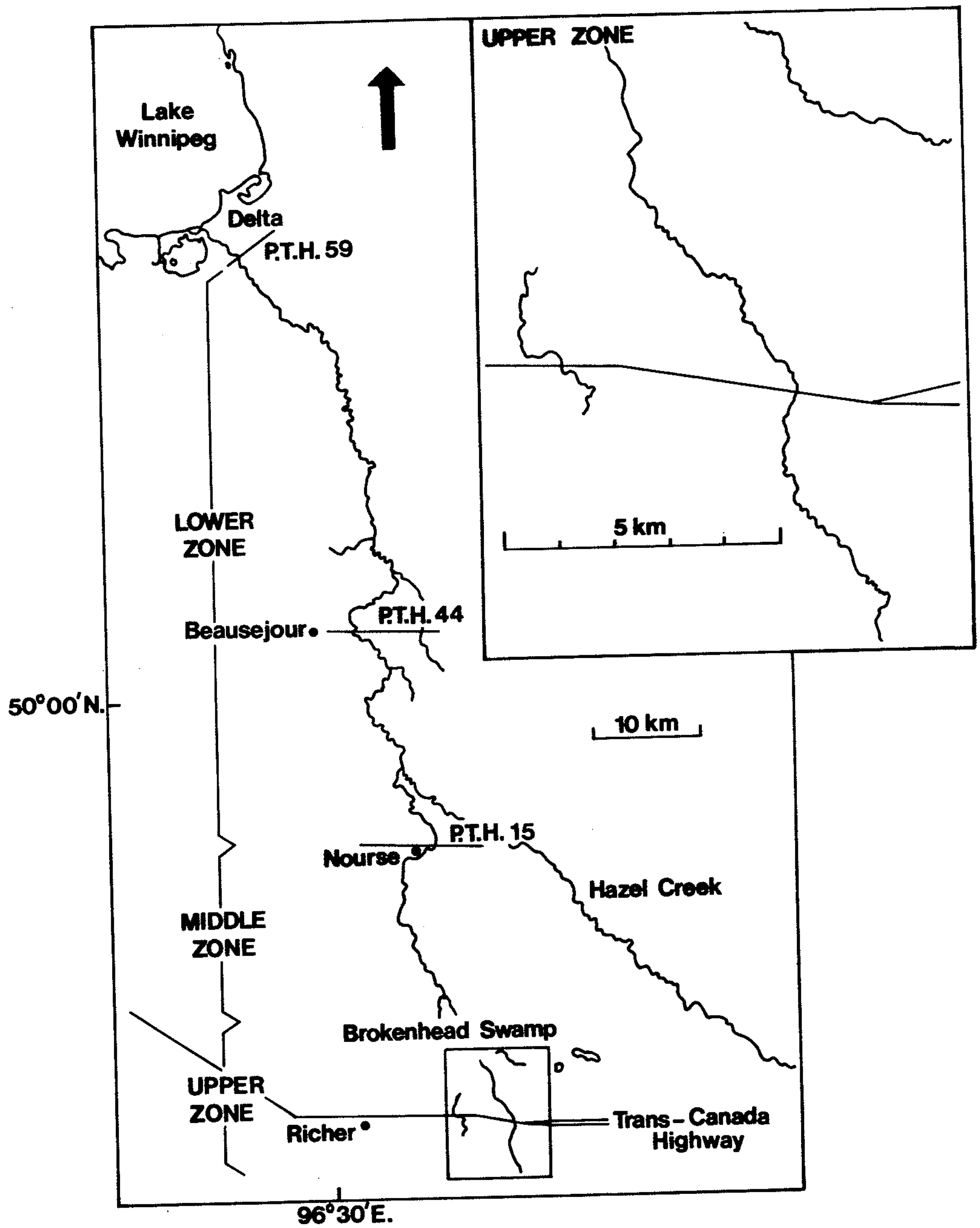
B. Environments Occupied

To describe environments occupied, five environments were defined in the upper zone by depth and surface water velocity as follows: rapids and riffles ($<$25 cm, $>$45 cm. sec^{-1}); shallow channels ($<$50 cm, 5-45 cm sec^{-1}); shallow pools ($<$50cm, $<$ 5 cm sec^{-1}); deep channels ($>$50 cm, 5-45 cm sec^{-1}): deep pools ($>$50 cm, $<$ 5 cm sec^{-1}). Densities of dace by age group in each zone was estimated by thrice monthly samples at several sites. Fishes were preserved in 10% formalin for later morphological measurements and analysis of diet and sexual development. When very large numbers were encountered, a portion of the catch was released after species identification and standard length (Hubbs and Lagler 1958) measurement.

C. Sex Ratio and Indices of Sexual Maturity

Sex ratios were calculated monthly (May-September and November, 1978) to determine if there was a difference

Fig. 1. The Brokenhead River Drainage


UPPER ZONE
5 km
Lake
Winnipeg
Delta
P.T.H. 59
LOWER
ZONE
Beausejour
P.T.H. 44
50°00'N.
10 km
P.T.H. 15
Nourse
Hazel Creek
MIDDLE
ZONE
Brokenhead Swamp
UPPER
ZONE
Richer
Trans-Canada
Highway
96°30'E.

in mortality between males and females.

To determine time of reproduction the indices of sexual maturity (total gonad weight as a percentage of the body weight (± 0.001 g)) were calculated for female dace. Fish were "dried" with paper towel before weighing ("blot-dried"). Then gonads were removed, "dried" with paper towel and weighed. Indices were measured on six dates from May 5 to June 14 (the anticipated time of spawning) and independently on a monthly basis (May-September and November) in 1978.

D. Feeding Ecology

At monthly intervals, contents of the anterior two-thirds of the gut were analyzed from a sample of 20 of each age group of pearl dace. Animals in the gut contents were identified at least to order. The occurrence, numbers, and (blot dry) weights (±0.001g) methods described by Hynes (1950) were used. Per cent occurrence, % numbers, and % weights were added together and divided by three to obtain an importance value (I) for each food item except plant material and detritus. For these no accurate numerical estimate could be made so % occurrence and % weight were added and divided by two. The "I" values were then adjusted to add to 100 by dividing them by their cumulative total and multiplying by 100. Fish for each sample were selected for analysis according to the relative frequency of occurrence in each environment.

Similarity of diet between ages and from month to month was determined by Morisita's (1959) Index of Overlap (C_{λ}).

A value greater than 0.50 meant diets were similar. Dietary separation of ages due to size differences was estimated by calculating a "mouth diameter ratio". The mean mouth diameter of 20 fish of the older age was divided by the mean diameter of 20 of the next younger age in the comparison for each month (i.e. age 2+ ÷ age 1).

To determine the pattern of feeding activity and the site of feeding attempts, monthly (May-August, 1978) observations of feeding behaviour of each age of pearl dace were made using a face plate and snorkel in each of eight, two-hour time periods from 0600 to 2200. A fish was chosen at random from the shoal and observed for five minutes. Six fish of each age were observed per two hour time period each month. Feeding areas were classified into four categories: 1) surface; 2) bottom; 3) water column; and 4) aquatic vegetation. Attempts in the water column could be either on food drifting horizontally or dropping to the bottom. Eating plants and picking food off plants was considered utilization of aquatic vegetation.

E. Interactions with Other Species

Distribution within shoals of pearl dace and other species was determined by observing shoaling behaviour monthly (May-August, 1978) using face plate and snorkel. Species, lengths, numbers and distances from the stream bottom of members of shoals containing ages 1 and 2+ pearl dace were recorded for intervals of 30 minutes. Fish in each shoal were classified as occurring in one of five equal vertical layers and the frequency of occurrence of length classes of each species calculated for each layer. Similar data were recorded for shoals containing age 0 pearl dace except that the distance from the surface was measured instead of the distance from the bottom.

Similarity of diet between pearl dace and white sucker, *Catastomus commersoni*, redbelly dace, *Chrosomus* (*Phoxinus*) *eos* and finescale dace, *Chrosomus* (*Phoxinus*) *neogaeus* was studied by comparing diet analysis for the four species during the month of August, 1978, when there was greatest spatial overlap. Comparisons between age groups of pearl dace and those of the other species were done by calculating Morisita's Index.

RESULTS

A. Distribution, Abundance, and Age-Length Relationship

Only the upper zone contained pearl dace. The average density was 7.34 fish/$10m^2$ (Appendix I). Length frequency data from 2014 fish showed three (Table 1) and some months four age groups (Appendix II). Females were slightly larger on the average and reached a greater maximum length than males (Appendix II).

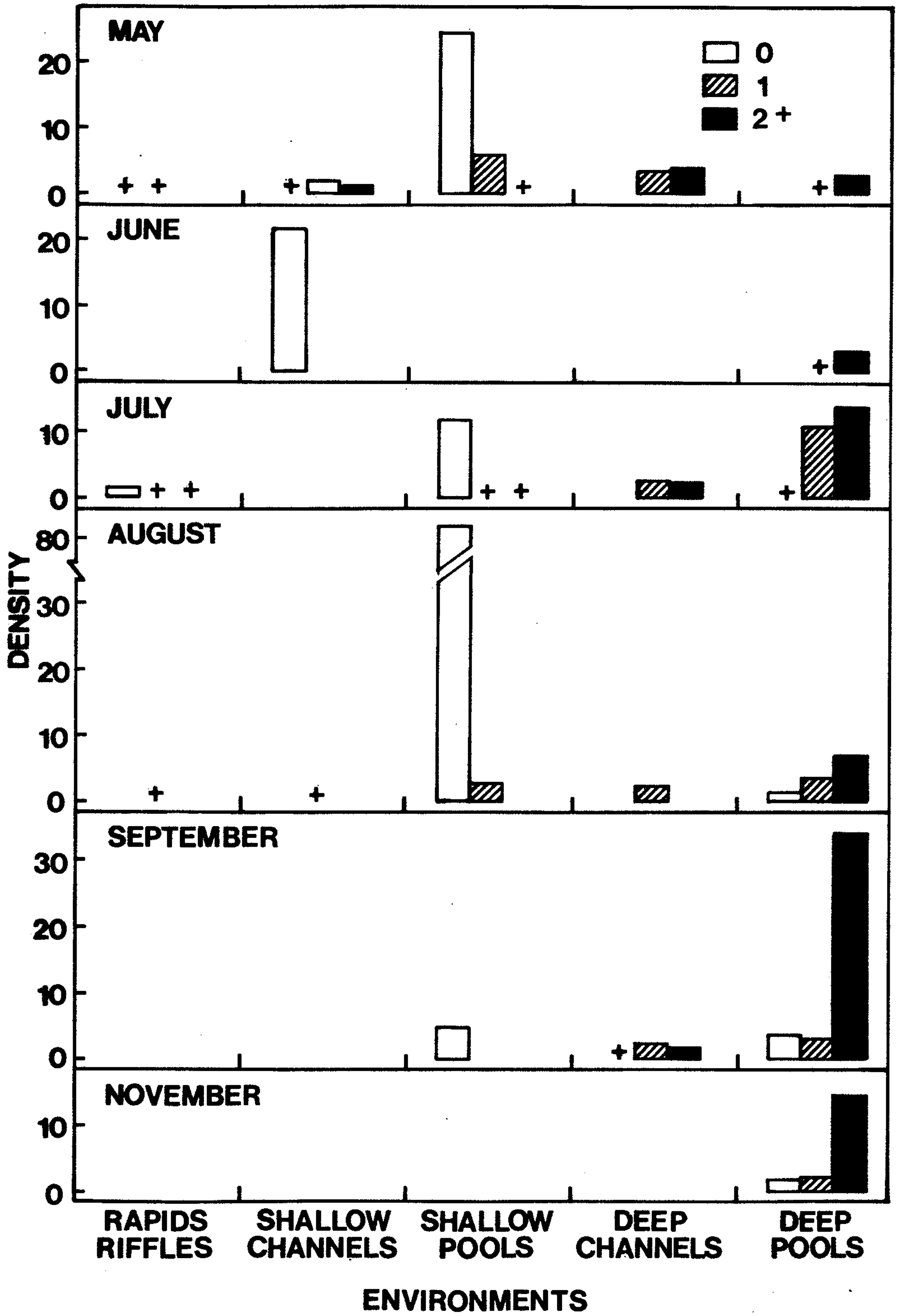
B. Environments Occupied

Dace of different age groups occupied particular environments at different times of the year. Age 0 fish were first observed in May in shallow pools (Fig. 2). From June to August they were found mostly in shallow slow moving water (pools or channels) but in September began to distribute into the deeper sections of the stream. Ages 1 and 2^+ were widely distributed about channels and pools in May (Fig. 2). Age 1 occupied mainly deep channels and pools throughout the summer, while age 2^+ were most abundant in deep pools. In September all ages began marshalling in the deeper waters and by November they were almost exclusively in deep pools.

TABLE 1. Ranges of standard length (mm) for age classes of pearl dace during May-September and November, 1978

Month	Age Class 0	1	2+
May	< 25	30-59.9	55-110
June	< 30	35-50	55-90
July	< 35	40-59.9	60-110
August	< 39.9	40-59.9	60-120
September	30-44.9	45-59.9	60-125
November	30-49.9	50-59.9	60-95

Fig. 2. Densities (numbers of fish per $10m^2$) of pearl dace in various environments in the upper zone, May-September, November, 1978.



MAY
JUNE
JULY
AUGUST
SEPTEMBER
NOVEMBER
0
1
2+
DENSITY
RAPIDS RIFFLES
SHALLOW CHANNELS
SHALLOW POOLS
DEEP CHANNELS
DEEP POOLS
ENVIRONMENTS

C. Sex Ratio and Indices of Sexual Maturity

The mean sex ratio was 0.48:1.00. For each female the number of males declined from 0.89:1.00 in May to 0.33:1.00 in November (Appendix III). Both sexes began to mature at the end of their second summer. The maturity indices of females increased slightly from the beginning of May to mid June (Table 2). Results from each month show a steady rise in % gonad weight/body weight from May to November, 1978, so time of reproduction appears to be before the beginning of May.

D. Feeding Ecology

Diet varied by month and age of fish. Most of the animals consumed were arthropods, the most important group being insects. Annelids and molluscs were occasionally eaten. The only vertebrate material consumed was fish eggs. A total of 32 different types of food item were consumed (Tables 3, 4, and 5).

Flying insects (Thysanoptera, Hymenoptera, and Diptera) were the dominant food category for age 0 fish in May and July and were important in June, August, and September (Fig. 3 and Table 3). Aquatic insects both adults and immatures (adult Coleoptera; larval Diptera, families Simuliidae and Chironomidae) were dominant in June and from August to November. Terrestrial insects (Hymenoptera) were important in July. Isopods were also important in July and August.

TABLE 2. Mean indices (n=10-14) maturity in age 2^+ female pearl dace May 5-June 14 and May-September and November, 1978

		Gonad Wt./Body Wt. X 100		
Date/Month	n	Mean	Standard Deviation	Range
May 5	10	1.32	0.36	0.317-1.623
May 10	10	1.42	0.14	1.215-1.613
May 20	10	1.54	0.20	1.216-1.820
May 26	10	1.69	0.39	0.974-2.184
May 30	10	1.58	0.33	1.064-1.990
June 14	10	1.71	0.29	1.260-2.170
May	12	1.42	0.43	0.32-1.94
June	14	1.82	0.30	1.53-2.37
July	13	3.02	0.35	2.51-3.81
August	10	5.53	0.63	4.79-6.22
September	10	11.11	1.26	9.25-13.60
November	11	13.60	1.28	11.63-15.09

TABLE 3. Importance values (I) of food items of age group 0 pearl dace May-September, November, 1978.((A) adult; (I) immatures)(n=20 stomachs/month)

Food Item	Importance Value					
	May	June	July	August	September	November
Flying Insects	83.05	21.41	41.72	17.74	25.35	0.00
(A) Thysanoptera	65.24	-	-	-	3.94	-
(A) Hymenoptera	17.81	1.84	14.57	5.62	9.83	-
(A) Diptera	-	19.57	27.15	12.12	11.58	-
Terrestrial Insects	0.00	0.00	18.57	3.85	4.41	0.00
(A) Hymenoptera	-	-	18.57	-	4.41	-
(I) Lepidoptera	-	-	-	3.85	-	-
Aquatic Insects	0.00	76.90	3.80	33.99	47.13	85.20
(A) Coleoptera	-	-	-	19.39	36.45	22.40
(I) Chironomidae	-	15.17	3.80	-	-	62.80
(I) Simulidae	-	58.25	-	-	-	-
(I) Tabanidae	-	-	-	6.61	-	-
(I) Dytiscidae	-	-	-	-	3.73	-
(I) Ephemeroptera	-	-	-	-	1.64	-
(I) Plecoptera	-	3.48	-	2.82	5.31	-
(I) Odonata (dragonfly)	-	-	-	5.17	-	-
Isopods	-	-	17.95	9.69	-	-
Unidentified Animals	11.70	1.69	4.95	5.96	3.09	7.00

TABLE 3 (Cont'd)

	Importance Value					
Food Item	May	June	July	August	September	November
Plant Material	2.62	-	-	-	4.00	3.90
Detritus	2.62	-	13.00	21.89	14.38	3.90
Empty Stomachs	3	2	2	2	1	3

TABLE 4. Importance values (I) of food items of age group 1 pearl dace, May-September, November 1978. ((A) adult; (I) immatures) (n=20 stomachs/month)

Food Item	Importance Value					
	May	June	July	August	September	November
Flying Insects	61.56	33.22	24.64	28.32	24.61	1.93
(A)Thysanoptera	31.46	-	-	-	-	-
(A)Hymenoptera	17.89	4.86	9.29	6.39	16.74	-
(A)Ephemeroptera	10.71	15.06	-	3.98	3.21	-
(A)Diptera	1.50	13.30	15.35	17.95	4.46	1.93
Terrestrial Insects	0.00	0.00	9.29	6.09	0.00	0.00
(A)Hymenoptera	-	-	9.29	6.09	-	-
Aquatic Insects	8.69	30.65	19.56	11.40	13.90	95.40
(A)Coleoptera	-	-	2.17	9.44	4.26	7.13
(I)Chironomidae	1.50	10.37	7.12	-	-	34.03
(I)Simulidae	-	7.63	-	-	-	-
(I)Dytiscidae	3.25	-	-	1.96	-	-
(I)Ephemeroptera	3.94	8.17	4.07	-	3.21	22.00
(I)Trichoptera	-	-	2.46	-	-	18.27
(I)Plecoptera	-	4.48	3.74	-	3.41	13.97
(I)Odonata (dragonfly)	-	-	-	-	3.02	-
Others	0.00	1.73	3.74	0.00	0.00	1.80
Hirudinea	-	-	-	-	-	1.80
Arachnida	-	1.73	-	-	-	-
Pelecypoda	-	-	3.74	-	-	-

TABLE 4 (Cont'd)

Food Item	Importance Value					
	May	June	July	August	September	November
Unidentified Animals	7.98	14.58	5.41	9.40	4.46	0.80
Plant Material	-	-	7.17	26.52	-	-
Detritus	21.78	19.89	29.09	18.04	57.06	-
Empty Stomachs	1	1	1	0	2	2

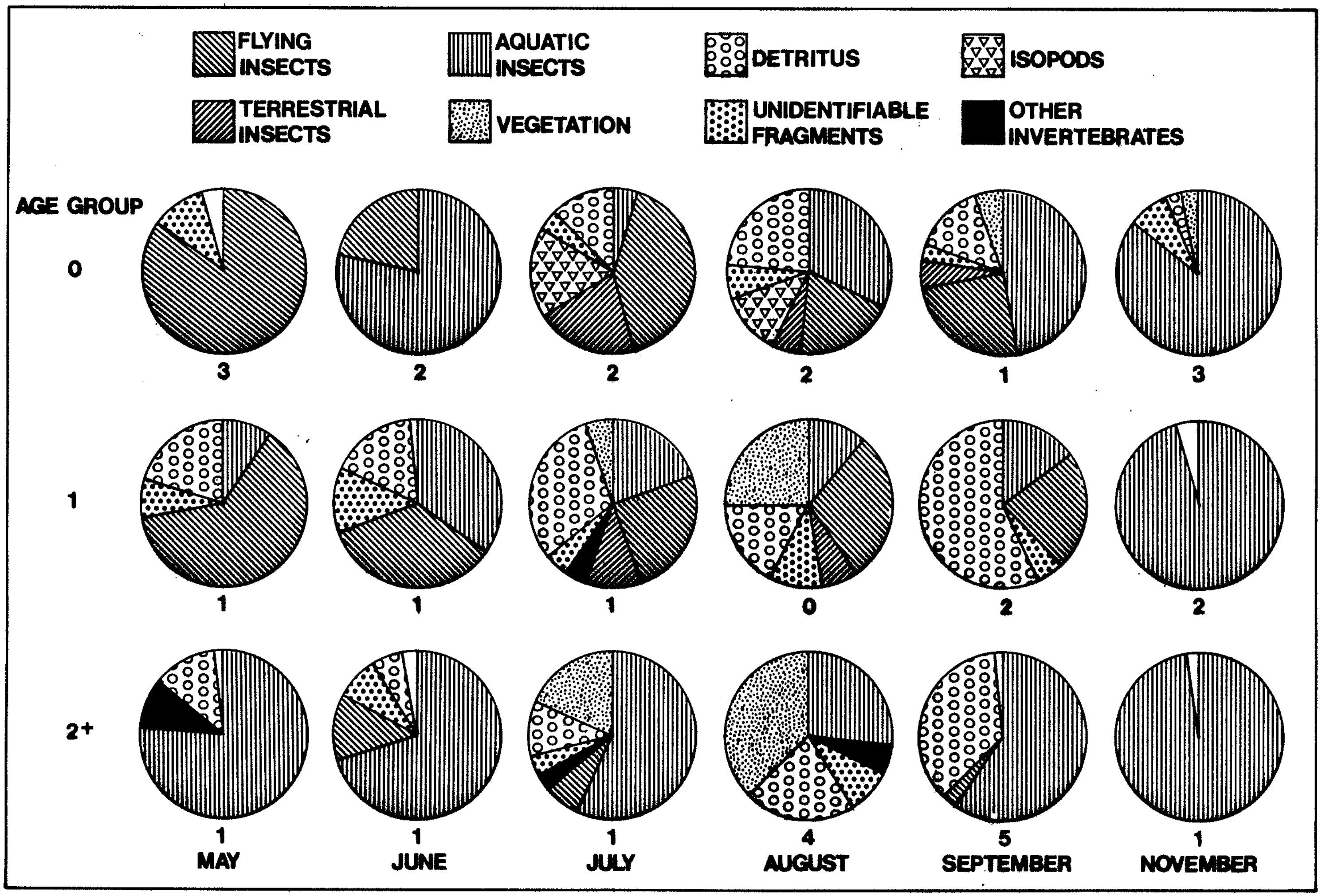
TABLE 5. Importance values (I) of food items of age group 2^+ pearl dace, May-September, November, 1978. ((A) adult; (I) immatures) (n=20 stomachs/month)

Food Item	Importance Value					
	May	June	July	August	September	November
Flying Insects	0.00	11.83	6.27	0.00	3.93	0.00
(A)Hymenoptera	-	1.34	-	-	3.93	-
(A)Trichoptera	-	5.75	-	-	-	-
(A)Orthoptera	-	4.74	-	-	-	-
(A)Lepidoptera	-	-	6.27	-	-	-
Aquatic Insects	74.33	71.83	58.06	28.62	58.79	98.25
(A)Coleoptera	-	4.02	2.60	-	6.69	4.47
(I)Chironomidae	16.73	39.10	7.21	4.72	-	6.40
(I)Simulidae	21.48	1.30	17.85	4.98	5.34	-
(I)Tipulidae	12.89	-	12.54	-	36.79	32.67
(I)Tabanidae	1.33	-	-	-	-	-
(I)Dytiscidae	1.24	-	-	5.88	3.73	-
(I)Neuroptera	1.40	1.56	-	-	-	-
(I)Ephemeroptera	2.35	1.75	-	7.28	3.49	4.57
(I)Plecoptera	-	1.93	1.91	2.43	-	8.90
(I)Trichoptera	16.92	19.38	15.95	-	-	38.27
(I)Odonata (dragonfly)	-	2.79	-	3.33	2.75	2.67

TABLE 5 (Cont'd)

Food Item	Importance Value					
	May	June	July	August	September	November
Others	9.41	7.00	3.96	5.88	0.00	0.00
Oligochaeta	2.95	-	-	-	-	-
Hirudinea	1.17	1.29	-	2.43	-	-
Amphipoda	3.96	-	-	-	-	-
Fish Eggs	-	5.71	-	-	-	-
Gastropoda	1.33	-	2.00	-	-	-
Pelecypoda	-	-	1.96	3.45	-	-
Unidentified Animals	1.30	1.85	3.34	8.32	9.90	0.90
Plant Material	-	-	18.02	38.55	-	-
Detritus	14.97	7.48	10.37	18.64	37.39	1.85
Empty Stomachs	1	1	1	4	5	1

Fig. 3. Diet of pearl dace by age group, May-September, November, 1978. Circles, Importance (I) value of food items; open sections of circles, categories contributing less than 3% of total I value of food; numerals, numbers of empty stomachs out of 20.



FLYING INSECTS
AQUATIC INSECTS
DETRITUS
ISOPODS
TERRESTRIAL INSECTS
VEGETATION
UNIDENTIFIABLE FRAGMENTS
OTHER INVERTEBRATES
AGE GROUP
0
1
2+
3
2
2
2
1
3
1
1
1
0
2
2
1
1
1
4
5
1
MAY
JUNE
JULY
AUGUST
SEPTEMBER
NOVEMBER

Age 1 pearl dace also relied on flying insects (Thysanoptera, Ephemerotera, Hymenoptera, and Diptera) from May to September (Fig. 3 and Table 4). They utilized aquatic insect adults and immatures (Chironomidae, Ephemeroptera, Plecoptera, and Trichoptera) throughout the summer. Terrestrial insects (Hymenoptera) were consumed in July and August.

Aquatic insect adults and immatures were the main food consumed by age 2^+ dace throughout the spring, summer and autumn with the exception of August (Fig. 3 and Table 5). Of the eleven taxa recorded, larval Diptera (Chironomidae, Simuliidae, and Tipulidae) and Trichoptera were the most important.

Plant material and detritus were important dietary components for all ages during July, August and September. Plant materials, consisting of grain, berries and aquatic vegetation, was the dominant component of the August diet of age 2^+ dace while detritus was dominant in the July and September diet of age 1. Age 1 dace also utilized detritus heavily in May and June.

Allochthonous material comprised the majority of the May diet of ages 0 and 1 (83.05% and 61.56%) (Table 6). From June to September allochthonous food varied in importance from 20% to 80% of the monthly diet for age 0 and 20% to 35% for age 1. By November all ages feed almost exclusively on aquatic animals and plants.

TABLE 6. The percentage of allochtonous material in the diet of each age group of pearl dace for May to September and November 1978.

Age Group	May	June	July	August	September	November
0	83.05	21.41	78.24	27.43	29.76	0.00
1	61.05	34.93	33.93	34.11	24.61	1.93
2^{+}	0.00	11.83	6.27	0.00	3.93	0.00

The Index of Dietary Overlap, C_λ , for comparisons between ages 0 and 1 is greater than 0.5 in May, July, August and November (Appendix IV). C_λ is greater than 0.5 in August and September between ages 1 and 2^+. The most divergent pairing, ages 0 and 2^+, did not have a C_λ value greater than 0.40.

"Mouth diameter ratios" between ages 0 and 1 and ages 1 and 2^+ were greater than 1.30 (Table 7).

Feeding activity of all ages was variable but continuous throughout the day. Age 0 had fewer attempts per time period than other ages in June but otherwise ages were similar in feeding pattern. There was a trend in May, June and July for lowest activity from 0600-1000 (Fig. 4).

Age 0 dace chose food predominantly from the surface in June and July but in August utilized the water column and the bottom more frequently (Fig. 5). Age 1 fed mostly from water column and bottom. Age 2^+ fed equally from bottom and water column in May and mainly on the bottom afterwards. The major feeding areas changed from upper sites to lower ones (i.e. surface to water column or water column to bottom) from May to August. Age 0 fish generally chose higher feeding sites than age 1, which chose higher sites than age 2^+.

TABLE 7. Mean ratios of mouth diameters for ages 0 and 1 and 1 and 2^{+} pearl dace, 1978. (n=120)

0-1	1-2
2.275	1.480

Fig. 4. Mean feeding attempts (5 min)$^{-1}$ by month and time of day for pearl dace: triangles, means for 6 age 0; open circles means for 12 age 1 and 2^+ combined; solid circles, means for 18 ages 0, 1 and 2^+ combined; vertical lines, 2 standard deviations. Symbols represent midpoints of 2 hour time period (from 0600-2200h).

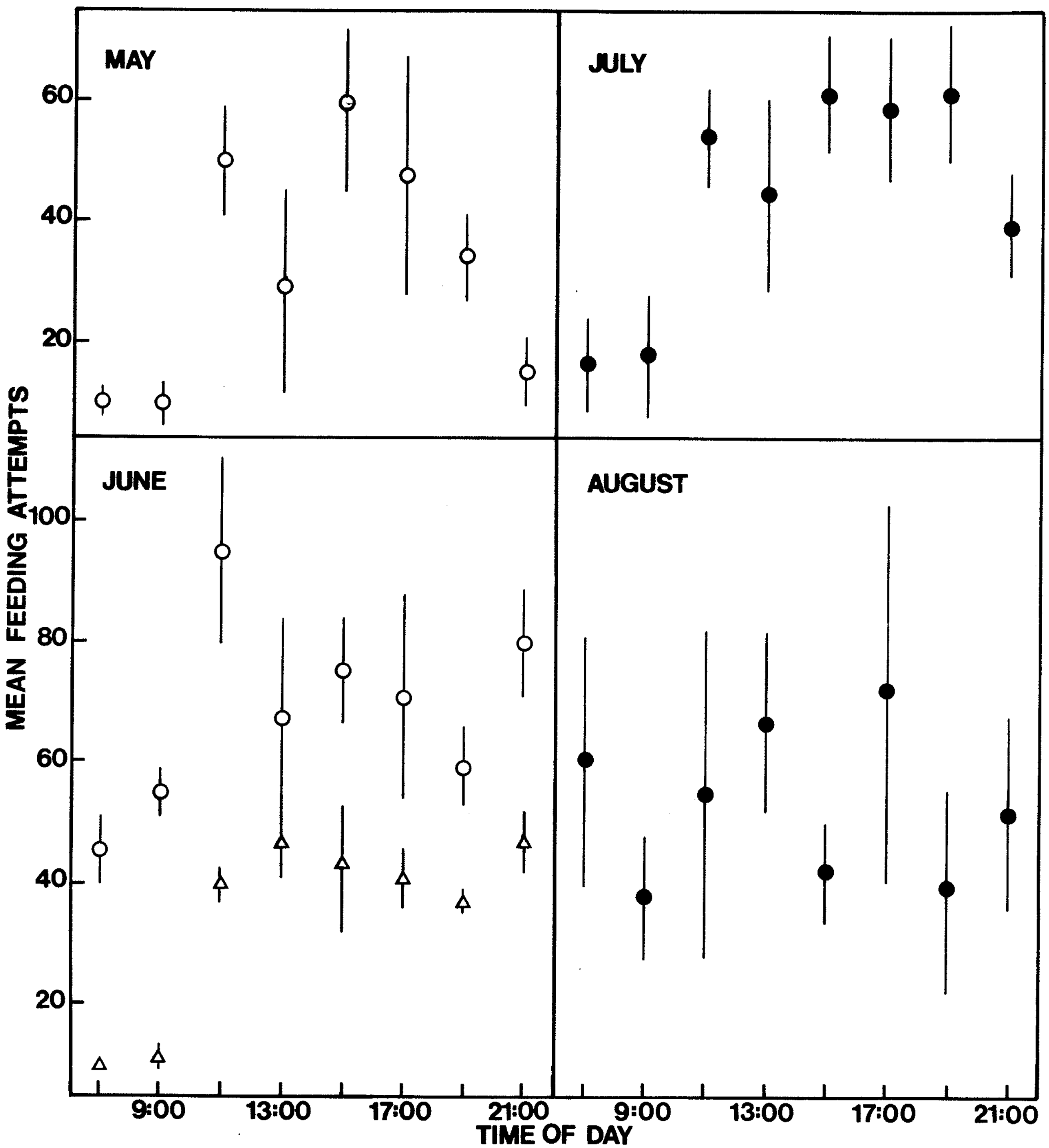
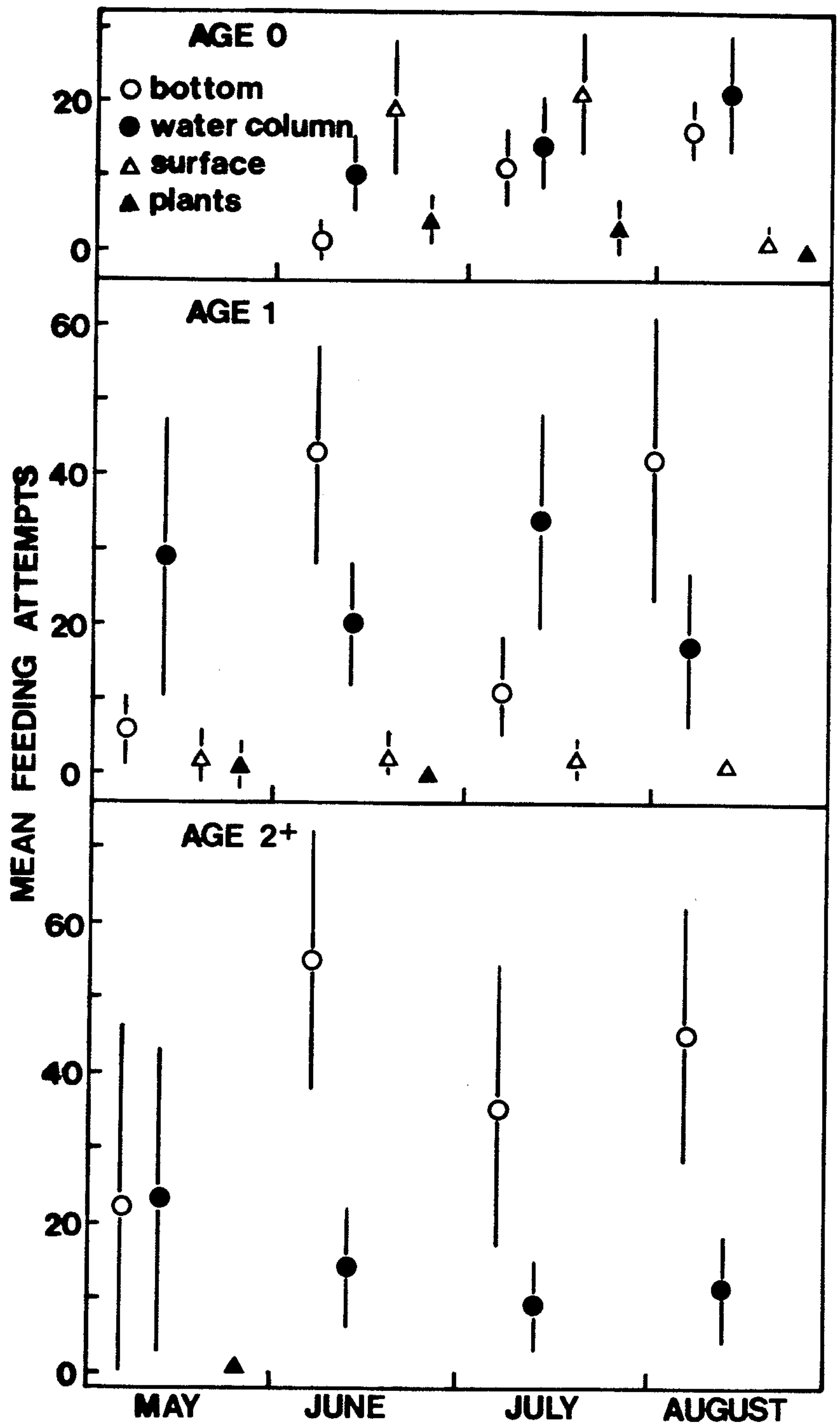

MAY
JULY
JUNE
AUGUST
MEAN FEEDING ATTEMPTS
60
40
20
100
80
60
40
20
9:00
13:00
17:00
21:00
9:00
13:00
17:00
21:00
TIME OF DAY

Fig. 5. Mean (n=48) feeding attempts at various sites $(5min)^{-1}$ for ages 0, 1 and 2^{+} pearl dace for May-August, 1978: triangles and circles are means, vertical lines are 2 standard deviations.


AGE 0
bottom
water column
surface
plants
AGE 1
AGE 2+
MEAN FEEDING ATTEMPTS
0
20
40
60
MAY
JUNE
JULY
AUGUST

E. Interactions with Other Species

Distribution within shoals. Redbelly and finescale dace generally occupied the uppermost zones in shoals with ages 1 and 2^+ pearl dace in the lower zones (Fig. 6). Older dace were more benthic than age 1. White sucker, when present, almost always occupied the lowermost portion of the shoal. Finescale dace and white sucker made up only a small portion of the shoals with age 1 and 2^+ pearl dace. Finescale dace were present during all months (May-August, 1978) and their relative frequency of occurrence in the shoal ranged from 2% in May to 6.7% in August. White sucker was absent in May and showed maximum relative frequency in August of 8.7%. Redbelly dace were relatively abundant in May (41.0%) and August (36.4%) but were scarce in June (3.4%) and July (1.8%). In June a low proportion of the shoals contained more than one species (36.4% compared to 85.4% in May, 81.9% in July, and 80.0% in August).

The average shoal size and the number of species in shoals increased sharply in August (Appendix V).

Age 0 pearl dace formed shoals at the surface with young of the year white sucker, redbelly dace, finescale dace, and fathead minnow, *Pimephales promelas* (Table 8).

Similarity of diet. Morisita's index was high (≥ 0.50) between age 1 and 2^+ pearl and finescale dace in August. Age 0 pearl dace ate a variety of items but mainly adult Coleoptera and detritus and so did not overlap heavily with finescale and redbelly dace which relied on adult Diptera and plant material, and white sucker which ate solely detritus (Table 9).

Age 1 pearl dace ate a wide variety of items, mainly adult Ephemeroptera, detritus, and plant material. Age 1 finescale dace overlapped with pearl dace by virtue of a mutual interest in plant material and some items of lesser importance value. White sucker and redbelly dace did not overlap with pearl dace since the former relied on larval Chironomidae and detritus and the latter were entirely herbivorous.

Age 2^+ pearl dace consumed mainly plant material as did age 2^+ finescale dace. Seventy per cent of the stomachs of age 2^+ finescale dace were empty.

Fig. 6. Position by relative frequency of species in schools containing pearl dace May-August, 1978. Each zone (1-5) represents 20 per cent of the depth of the school. The +'s represent relative frequency of $<0.5\%$.

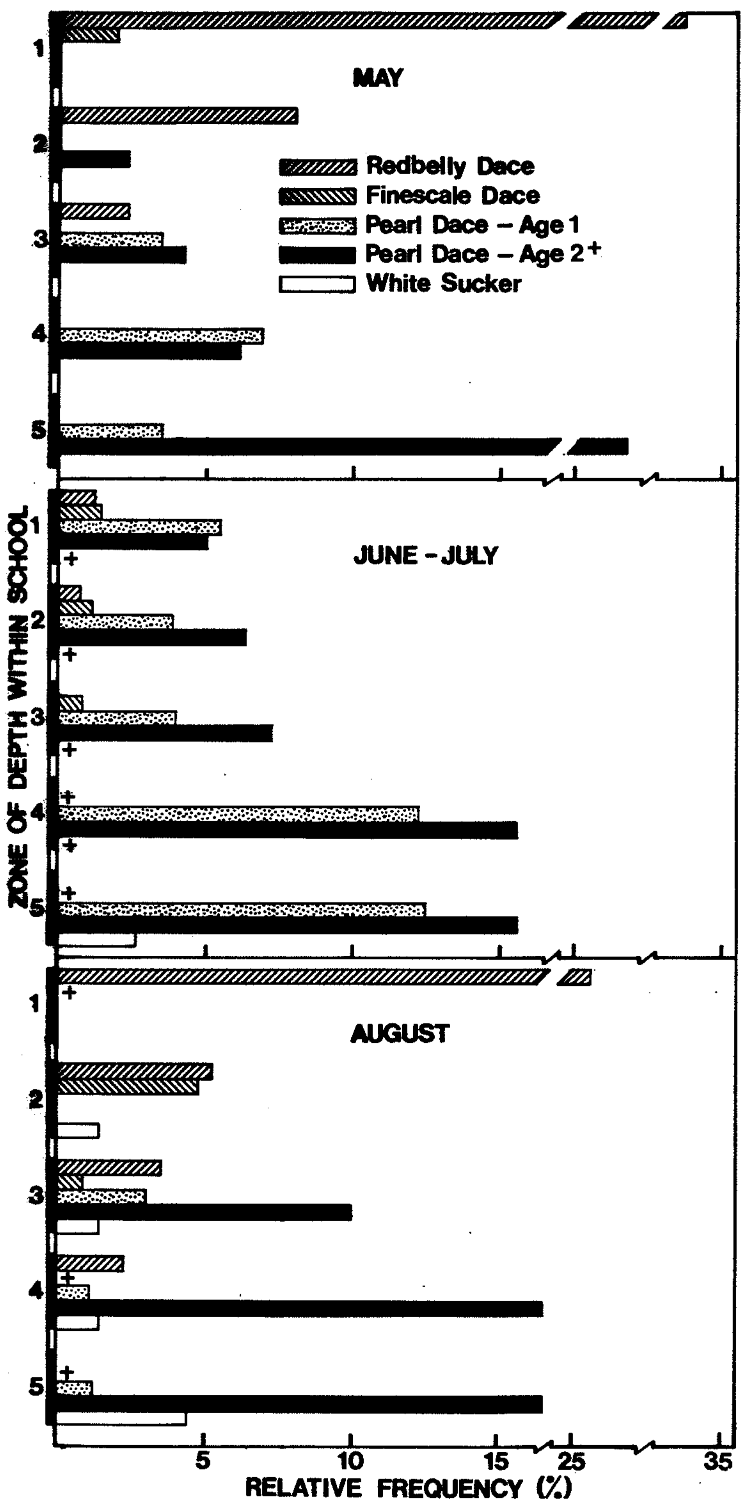

MAY
Redbelly Dace
Finescale Dace
Pearl Dace – Age 1
Pearl Dace – Age 2+
White Sucker
JUNE - JULY
AUGUST
ZONE OF DEPTH WITHIN SCHOOL
1
2
3
4
5
5
10
15
25
35
RELATIVE FREQUENCY (%)

TABLE 8. Range of distance (mm) from the surface June-August, 1978 and relative frequency in schools of fry (Age 0 fish) (number of schools observed = 3/month)

	Distance from Surface (mm)			
Species	June	July	August	Relative Frequency
Pearl dace	0-10	0-10	0-15	32.10%
Redbelly dace	0-5	0-10	0-10	32.89%
Finescale dace	0-10	0-10	0-15	21.58%
White sucker	0-15	0-20	0-25	9.74%
Fathead minnow	0-10	0-10	0-10	3.68%

TABLE 9. Diet analysis: Importance values for age groups of pearl dace (PD), redbelly dace (RB), finescale dace (FS) and white sucker (WS) for August, 1978.

Food Item	Age 0				Age 1 or 1+				Age 2+	
	PD	RB	FS	WS	PD	RB	FS	WS	PD	FS
(A)Coleoptera	19.4	-	-	-	9.4	-	-	-	-	-
(A)Diptera	12.1	35.5	47.8	-	17.7	-	4.3	-	-	-
(A)Ephemeroptera	-	-	-	-	4.0	-	-	-	-	-
(A)Hemiptera	-	-	-	-	-	-	26.0	-	-	-
(A)Hymenoptera(Flying)	5.6	-	11.7	-	6.4	-	-	-	-	21.8
(A)Hymenoptera(Ant)	-	-	12.8	-	6.1	-	-	-	-	-
(I)Chironomidae	-	-	-	-	-	-	-	49.9	4.7	-
(I)Simulidae	-	-	-	-	-	-	-	-	5.0	-
(I)Tabanidae	6.6	-	-	-	-	-	-	-	-	-
(I)Tipulidae	-	-	5.2	-	-	-	-	-	-	-
(I)Dytiscidae	-	-	-	-	2.0	-	-	2.6	5.9	-
(I)Ephemeroptera	-	-	-	-	-	-	-	-	7.3	-
(I)Lepidoptera	3.9	-	-	-	-	-	-	-	-	-
(I)Odonata	5.2	-	-	-	-	-	-	-	3.3	-
(I)Plecoptera	2.8	-	-	-	-	-	-	-	2.4	-
(I)Trichoptera	-	-	-	-	-	-	-	8.3	-	-
Isopoda	9.7	-	-	-	-	-	-	-	-	-
Hydracarina	-	-	-	-	-	-	-	-	2.4	-
Pelecypoda	-	-	-	-	-	-	-	-	3.5	-
Fragments	6.0	-	-	-	9.4	-	7.2	1.7	8.3	8.5

TABLE 9 (Cont'd)

Food Item	Age 0				Age 1 or 1^+				Age 2^+	
	PD	RB	FS	WS	PD	RB	FS	WS	PD	FS
Plant Material	-	64.5	19.6	-	26.5	100.00	60.0	1.5	38.6	69.7
Detritus	21.9	-	2.9	100.00	18.0	-	2.5	36.0	18.6	-
Sample Size	20	10	20	10	20	10	20	10	20	20
Empty Stomachs	2	1	0	0	0	0	3	2	4	14

Morisita's Index of Overlap:

age 0) PD-RB=0.1280; PD-FS=0.3289; PD-WS=0.3873; RB-FS=0.7029

age 1) PD-RB=0.4566; PD-FS=0.5965; PD-WS=0.2532; RB-FS=0.8361

age 2^+) PD-FS=0.7376

DISCUSSION

A. Distribution, Abundance and Age-Length Relationship

Pearl dace were present only in the headwaters (Upper Zone) and there were at least three age groups discernable by length frequency analysis.

Pearl dace may be abundant in the upper zone because of the absence of northern pike, *Esox lucius*. Beamish *et al.* (1976) found pearl dace to be the most abundant and most widely distributed species occurring in 72 of a total of 109 lakes samples in the Experimental Lakes Area (ELA) in northwestern Ontario. They found northern pike in 15 lakes, all except two barren of pearl dace. These two had only very low numbers. They proposed that pike predation seriously affected pearl dace populations in ELA lakes. When frightened, pearl dace dart to the vegetation along the edges of the stream and thus would be easy prey for a lurking predator such as pike. Pike and other predators are present in all other zones of the Brokenhead River but do not occur above the Brokenhead Swamp. Of all other streams of southeastern Manitoba, pearl dace occurred only in the Bog River, which contains no piscivorous fish. Pearl dace were absent in the Hanson, Rennie, Sand, Whitemouth, Whiteshell and Winnipeg Rivers, all of which contained pike. The nearby Rennie River, which seemed ideal pearl dace habitat was sampled intensively. The presence of all the species of the Upper Zone of the Brokenhead River except pearl dace suggests that pike may be a factor in limiting dace distribution.

The age-length relationship was similar to that of Loch (1970) and Lalancette (1977) except that the maximum age may be closer to three than four. Possibly the fluctuating nature of the prairie climate (causing both summer and winterkills) prevent many dace from reaching age 4. Differential growth rates between the sexes is an advantage for foraging in a varied habitat (Smouse 1971). Sexual dimorphism in size could prevent intensive intraspecific competition in diet. Smaller, more manoeuverable males might be able to take smaller, quicker prey than the larger females. There may also be a reproductive advantage in the size differences. The greater size of females can be more efficient because larger fish can produce more eggs (Breder and Rosen 1966). Males, on the other hand, must be more manoeuverable in courtship (Langlois 1929) and so smaller size is favored.

B. Environments Occupied

From May to August age 0 dace were found near the surface with fry of other species in slow moving shallow water. Ages 1 and 2^+ dace were usually in shoals with other species and distributed in pools and channels in May. From June to August age 1 occupied deep channels and pools while age 2^+ were in deep pools. In the fall all ages moved to deep waters and shoal sizes increased.

Habitat partitioning has been shown for different species of fish (Keast 1966; Lister and Genoe 1970; Mendelson 1975; Ross 1977) but rarely for different age classes within a species. Simon and Middendorf (1976) reported that the lizard, Sceloporous garrovi showed intra-specific differences in microhabitat usage. Moshenko and Gee (1970) showed that different ages of creek chub, Semotilus atromaculatus, were found in different habitats.

Age 0 pearl dace probably require a more complete separation of resources from May to August in order to survive. By occupying a separate habitat the young avoid interaction with the stronger, more experienced juveniles and adults. Marshalling of all ages to deep pools in September and November may be related to requirements other than feeding. Association with regions of low velocity and greater depth, as shown by creek chub and pearl dace, can be a mechanism for gaining shelter and remaining in suitable or non-winter killing reaches of stream over winter (Hartman 1963).

C. Sex Ratio and Indices of Sexual Maturity

Males were less abundant than females. The proportion of the population composed of males declined from May to November. Mortality in males may be greater because their active courtship and bright colors draw attention to them. This effect could be present from May to November since males were observed with spawning colors and exhibiting courtship behaviour. Another possible source of "increased male mortality" (or decreased female mortality) could be a predator who could not swallow the larger females.

The index of sexual maturity rose steadily from May to November. Changes in indices of sexual maturity suggest S.m. nachtriebi like the southern subspecies, spawns from mid to late April. This idea was reinforced by the presence of mature eggs in the oviducts of females in first collections of May, 1978.

Dace began maturing at the end of their second summer. Age of sexual maturity was similar to that recorded by Fava and Tsai (1974) and Lalancette (1977).

D. Feeding Ecology

Ages 0 and 1 ate mainly flying insects, aquatic insects and larvae and detritus (Age 1), and to a lesser extent terrestrial insects and plant material. Age 2^+ utilized mainly aquatic insects and larvae except in August when plant material was the dominant food item. Allochthonous material was an important component of the diets of ages 0 and 1 except in November.

Daytime temporal separation of feeding between ages was not marked but there was separation by feeding sites. Ages 0 and 1 and 1 and 2^+ showed dietary overlap by Morisita's Index during some months.

Hynes (1970) states that most species of stream fish have fairly specialized diets: they eat plants or mostly plants; or invertebrates or mostly invertebrates; or fish; or detritus. Pearl dace are exceptions in that plants, detritus and invertebrates are all important in the diet at one time or another.

Unlike the lacustrine pearl dace studied by Lalancette (1977) Brokenhead River fish consumed no zooplankton, took a wide range of insects and relied on detritus as a food source. These differences probably reflect differing food availability and feeding adaptation to streams. The major disagreement is that Lac Gamelin dace consumed white sucker fry whereas Brokenhead River dace ate no vertebrates despite the continual presence of small fish. Moshenko and Gee (1970) found a similar situation with creek chub. The chub did not consume any of the smaller cyprinids associated with them even though they appear to be easily accessible. They concluded that the fright pheromone (von Frisch 1938, 1941; Pfeiffer 1962, 1963; Reed 1969) present in the cyprinid skin prevented chub from consuming them. On the other hand, Newsome and Gee (1978) found that chub actually preferred cyprinids as food but concluded that they were protected from chub by countershading on their bodies which made them less visible. For some species such as brook stickleback, _Culaea inconstans_, defensive armament is sufficient deterrent but it is uncertain whether dace do not eat cyprinids due to a triggering of an alarm reaction in themselves or because other minnows are not visible to them. Lac Gamelin dace may eat fish because other food sources are insufficient.

Pearl dace could be considered a "fine grained", unspecialized feeder (Holling 1966) or a "temperate generalist" (Hyatt 1979). Selective feeding is poorly adapted for areas of low food density, such as energy impoverished headwaters and so a generalist would have the advantage over a specialist (Emlen 1966, Ivlev 1961). Diet plasticity and the ability to incorporate a large amount of allochthonous material in their diet allows pearl dace to inhabit a wide variety of habitats (Loch 1969; Lalancette 1977), and accounts for their success in relatively unproductive headwater streams.

Another advantage of a broad diet is that a species can be opportunistic and take advantage of seasonal changes in the biota (Hynes 1970). A flexible food regime prevents fish from having a fixed "search image" when seeking food (Brown 1975; Hyatt 1979). Detritus, plant material and terrestrial insects are least abundant in May so dace rely on flying and aquatic insects. In June the emerging Simuliids and Chironomids cause feeding emphasis to be placed on aquatic insects. In July and August there is a buildup of plant material, detritus, and terrestrial invertebrates and so these are incorporated as important dietary components. In September the plants begin dying, so detritus is more available and plant material less so. By November the fall of leaf litter has diminished and all non-aquatic insects have ceased activity so diet is dominated by aquatic insect larvae.

The small amount of overlap between age groups in resource utilization is a reflection first, of their differences in preferred habitat, and second, their differences in size.

Younger fish have more access to smaller prey than the older ages (Allen 1942). It is common for young of the year to be completely carnivorous even if the adults consume detritus and plant material (Hynes 1970).

It has been documented for a wide variety of co-existing animals (e.g. invertebrates--Brian 1957, Kohn 1971; reptiles--Schoener 1968, Pianka 1969; birds--Lack 1944, Ashmole 1968; mammals--Rosenzweig and Sterner 1970, Brown and Lieberman 1973) that size differences, especially in trophic structures, often facilitate partitioning of resources. Such partitioning of resources is usually regarded as support for Gause's (1934) competitive exclusion principle.

The idea that size differences between congeneric species might be a means of achieving ecological isolation was initially proposed by Huxley (1942) and later documented by Lack (1944). However, Hutchison (1959) was the first to give an estimate of how large a size difference is needed for two species to co-occur. His tentative estimate of the minimum mean ratio in linear dimensions of trophic structures needed for co-existence was 1.28. This type of reasoning could be applied to intraspecific comparisons.

Ricker (1937) proposed that intraspecific competition could come into play between different age classes of fish.

The only cases where diet was similar were between ages 0 and 1 and 1 and 2^+. The mean ratio of mouth diameter between these exceeds Hutchison's number. Thus, where diet is similar morphology or size difference may permit co-existence. Although according to dietary analysis certain taxa are of similar importance, two species or ages of fish may be taking different sizes of items within these taxa due to a measurable difference in the size of their feeding apparatus. Even very small differences in the size of the feeding apparatus can result in great dietary differences (Hyatt 1979). Svardson (1949) suggested that strong intraspecific competition tends to bring about uniformity in size of individuals in the population. The wide size range of pearl dace at each age class suggests competition is not important.

Although dace did not partition by feeding at different times, they did show partitioning of the microsites of feeding. Age 0 fish had distinctly different feeding habits from ages 1 and 2^+. Age 1 concentrated more on the drift than did age 2^+ but in June and August their feeding behaviour was quite similar. Choosing food from different sites would allow fish to have very similar diets without competing. The separation of age 0 fish by their feeding behaviour would allow them to avoid direct competition with the other ages.

Pearl dace are a shoaling fish, a behaviour characteristic of the Cyprinidae (Hynes 1970). There are a number of advantages to aggregations such as shoals or flocks. Nikolsky (1963) and Moynihan (1962) suggest that the function of shoals is the protection of the individual; the presence of a large number of specimens tends to confuse predators, and when one fish in the shoal is damaged the rest disperse to safety. The coevolution of the fright pheromone in the skin of cyprinids has made this a particularly effective defense. Radakov (1973) found that fish were captured more easily by Cod (_Gaddus_ _Sp_.) if they were solitary than in a group. Radakov showed that schools have specific escape behaviours which will thwart a predator. Other advantages in aggregation are: improved food gathering efficiency (Krebs _et_ _al_. 1972); the improvement of feedback information concerning local population density (Wynne-Edwards 1962); and reducing aggression to aggrevated individuals from solitary ones (Barash 1974). Multispecies schools may not be as cohesive as single species ones but food competition among the members would be less severe (Mendelson 1975).

E. Interactions with Other Species

Dietary overlap in August between pearl dace and corresponding ages of other species was minimal except between ages 1 and 2^+ pearl dace and finescale dace. Vertical spatial separation was found in shoals of pearl dace, finescale dace, redbelly dace and white sucker. White sucker and finescale dace were relatively rare in shoals compared to pearl dace and redbelly dace.

Schools with age 1 and 2^+ pearl dace can be characterized by the presence or absence of certain species. The absence of white suckers in May coincides to their spawning period (Scott and Crossman 1973). Redbelly dace are greatly reduced in June and July and may also remove themselves to spawn during these months. In August all four species are present. Possibly the larger schools composed of many species are a result of fish coming into close proximity due to movements to avoid low water levels and high temperatures or to find winter shelter. The resulting close association of all four species would cause interspecific competition to be at its maximum in August.

Similarity of diet was low. Thus, I conclude pearl dace occupy a separate dietary niche from the other species. Complete separation of age 0 dace from other species fry allows unstructured surface shoals to exist without competition. The vertical separation in shoals and low densities of finescale dace allow the coexistence of ages 1 and 2^{+} pearl dace with finescale dace despite their similarity of diet.

Northern pearl dace are found only in the Upper Zone of the Brokenhead River and have an average density of 7.34 fish per $10m^2$. Three age groups are evident by length. The overall sex ratio was 0.48:1.00 (male:female) and spawning appeared to take place in the early spring. They maintain themselves in the headwaters by being active, unspecialized opportunistic feeders, who partition habitat and food resources intraspecifically and avoid competition for resources with member species of their shoals by differing in vertical distribution and diet.

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APPENDIX I. Density of pearl dace in 5 zones of the Brokenhead River.

TABLE 1. Density of pearl dace in 5 zones of the Brokenhead River.

Zone	Number Caught	Area Seined (m^2)	Density Fish/$10m^2$
Upper	3816	5199	7.34
Middle	0	202	0
Lower	0	220[(1)]	0
Hazel Creek	0	202[(1)]	0
Delta	0	210	0

[(1)]Collections supplemented by those of K. Martin.

APPENDIX II. Length frequency data for pearl dace, 1978.

TABLE 2. Length frequency data of pearl dace by month (May-September and November, 1978).

Standard Length (mm) (Hubbs and Lagler, 1958)	Month					
	May	June	July	August	September	November
25	41(I)	-	29(I)	14(I)	-	-
25-29.9	-	64(I)	29(I)	102(I)	-	-
30-34.9	26(I)	-	3(I)	32(I)	1(I)	-
35-39.9	20(I)	7(I)	-	23(I)	59(I)	-
40-44.9	32(I)	10(I)	12(I)	9(I)	114(I)	16(I)
45-49.9	16(I)	3(I)	41(I)	17(I)	17(I)	4(I)
50-54.9	8(I)	-	26(I)	41(I)	30(I)	14(I)
55-59.9	1(M) 4(F)	8(M)	11(I)	18(I)	17(I)	9(I)
60-64.9	20(M) 3(F)	20(M) 1(F)	15(M) 2(F)	4(M) 4(F)	9(M) 5(F)	9(M) 8(F)
65-69.9	23(M) 10(F)	8(M) 13(F)	22(M) 9(F)	14(M) 2(F)	10(M) 2(F)	12(M) 11(F)
70-74.9	3(M) 18(F)	6(M) 17(F)	11(M) 12(F)	16(M) 10(F)	40(M) 18(F)	17(M) 17(F)
75-79.9	12(F)	12(F)	3(M) 13(F)	8(M) 10(F)	50(M) 24(F)	5(M) 33(F)
80-84.9	4(F)	7(F)	11(F)	11(F)	8(M) 108(F)	1(M) 41(F)
85-89.9	1(F)	8(F)	2(M) 6(F)	3(M) 13(F)	62(F)	18(F)
90-94.9	-	-	5(F)	12(F)	58(F)	7(F)
95-99.9	-	-	4(F)	6(F)	11(F)	-
100-104.9	-	-	-	6(F)	35(F)	-
105-109.9	1(F)	-	3(F)	3(F)	2(F)	-
110-114.9	-	-	-	2(F)	9(F)	-
115-119.9	-	-	-	1(F)	3(F)	-
120-125	-	-	-	-	2(F)	-

Note: (I) = Immature; (M) = Male; (F) = Female

TABLE 3. Mean length of immature (ages 0 and 1) and adult (age 2^+) pearl dace by month (May-September and November, 1978).

Month	Mean length (mm) ± s x t.025			
	Age 0	Age 1	Age 2^+	
			Males	Females
May	23.4 ± 2.4	40.7 ± 10.1	65.6 ± 6.5	72.0 ± 13.6
June	25.4 ± 0.6	43.1 ± 4.8	63.9 ± 9.4	75.5 ± 13.8
July	27.4 ± 5.3	47.1 ± 8.7	68.4 ± 11.4	80.3 ± 21.5
August	31.0 ± 6.2	50.5 ± 6.7	71.9 ± 12.1	86.3 ± 25.0
September	38.3 ± 4.9	53.4 ± 7.2	74.5 ± 11.9	88.0 ± 20.2
November	43.7 ± 3.0	55.7 ± 4.0	69.9 ± 10.2	78.8 ± 15.0
Overall	32.2 ± 11.1	47.5 ± 9.8	70.9 ± 13.2	84.2 ± 21.6

APPENDIX III. Sex ratios of pearl dace adults (age 2^{+}).

TABLE 4. Monthly sex ratios for pearl dace (May-September, November) 1978.

Month	Sex	Number	Sex Ratio (♂ : ♀)
May	♂	47	0.89: 1.00
	♀	53	
June	♂	42	0.67:1.00
	♀	62	
July	♂	53	0.84:1.00
	♀	63	
August	♂	45	0.56:1.00
	♀	80	
September	♂	117	0.36:1.00
	♀	329	
November	♂	45	0.33:1.00
	♀	135	
Total	♂	349	0.48:1.00
	♀	722	

APPENDIX IV. Similarity of diet for pearl dace by ages and months.

TABLE 5. Similarity of diet by Morisita's (1959) Index of overlap between age classes of pearl dace, May-September and November 1978.

	Ages compared		
Month	0-1	1-2	0-2
May	0.74076	0.21722	0.01761
June	0.34285	0.36708	0.22280
July	0.70832	0.41111	0.11503
August	0.60584	0.77470	0.39681
September	0.44658	0.68929	0.35396
November	0.68174	0.47609	0.14263

TABLE 6. Month to month measure of dietary similarity for age 0 pearl dace by Morisita's (1959) Index of Overlap, May-September and November, 1978.

	Month					
Month	May	June	July	August	September	November
May	1	0.012	0.107	0.075	0.1566	0.022
June	0.012	1	0.213	0.100	0.091	0.225
July	0.107	0.213	1	0.575	0.091	0.102
August	0.075	0.100	0.575	1	0.795	0.193
September	0.157	0.091	0.091	0.795	1	0.284
November	0.221	0.226	0.102	0.193	0.284	1

TABLE 7. Month to month measure of dietary similarity for age 1 pearl dace by Morisita's (1959) Index of Overlap, May-September and November, 1978.

	Month					
Month	May	June	July	August	September	November
May	1	0.527	0.520	0.364	0.580	0.070
June	0.527	1	0.755	0.566	0.580	0.359
July	0.520	0.755	1	0.768	0.765	0.262
August	0.364	0.560	0.768	1	0.498	0.057
September	0.580	0.580	0.765	0.4831	1	0.055
November	0.070	0.359	0.262	0.568	0.055	1

TABLE 8. Month to month measure of dietary similarity for age 2^+ pearl dace by Morisita's (1959) Index of Overlap, May-September and November, 1978.

	Month					
Month	May	June	July	August	September	November
May	1	0.638	0.801	0.366	0.537	0.584
June	0.638	1	0.422	0.222	0.135	0.441
July	0.801	0.422	1	0.648	0.465	0.560
August	0.366	0.222	0.648	1	0.376	0.068
September	0.537	0.135	0.465	0.376	1	0.476
November	0.584	0.441	0.560	0.068	0.476	1

APPENDIX V. The number of species in shoals and the size of shoals containing ages 1 and 2^{+} pearl dace.

Note on procedure: The numbers of each species were estimated to the nearest multiple of five.

TABLE 9. The number of species in shoals containing ages 1 and 2^+ pearl dace by month for 1977-78. Means (X) and Standard Deviations (SD). Other species are white sucker, redbelly dace and finescale dace.

Year	Month	No. of Shoals Sampled	Number of Species $\bar{X}$	Number of Species SD
1977	June	6	2.00	0.89
1977	July	21	1.88	0.83
1977	August	10	3.73	0.65
1978	May	8	2.00	0.54
1978	June	10	1.30	0.48
1978	July	14	2.21	1.05
1978	August	10	4.00	0.00

TABLE 10. Size of shoals containing ages 1 and 2^+ pearl dace by month for 1977-78. Mean (X) and Standard Deviations (SD).

Year	Month	No. of Shoals Sampled	School Size $\bar{X}$	School Size SD
1977	June	6	84.49	72.60
1977	July	21	37.32	35.71
1977	August	10	147.50	63.65
1978	May	8	62.13	44.55
1978	June	10	26.60	8.96
1978	July	14	61.36	45.21
1978	August	10	146.00	15.21

APPENDIX VI. Data on the other species in the upper zone.

TABLE 11. Densities of the fish species in the Upper Zone (5199 m^2 seined)

Species	Total Number of Fish	Density Fish/10m^2
Pearl Dace	3816	7.34
Redbelly Dace	5226	10.05
Finescale Dace	1086	2.09
White Sucker	1456	2.80
Fathead Minnow	223	0.43
Mudminnow	681	1.31
Brook Stickleback	2542	4.89
Brook Trout	41	0.08

TABLE 12. Length frequency data for redbelly dace, finescale dace and white sucker in August 1978.

Standard Length (mm)	Redbelly Dace	Finescale Dace	White Sucker
<20	137	-	-
20-24.9	54	-	1
25-29.9	118	2	2
30-34.9	142	30	15
35-39.9	89	14	-
40-44.9	79	21	-
45-49.9	16	49	2
50-54.9	13	11	6
55-59.9	11	14	15
60-64.9	-	10	28
65-69.9	-	3	10
70-74.9	-	1	5
75-79.9	-	-	-
80-84.9	-	-	-
85-89.9	-	-	6
90-94.9	-	-	12
95-99.9	-	-	12
100-104.9	-	-	13
105-109.9	-	-	11
110-114.9	-	-	11
115-119.9	-	-	11
>120	-	-	40

TABLE 13. Densities (nos per $10m^2$) in different environments August, 1978, for redbelly dace, finescale dace and white sucker by ages.

	Redbelly dace		Finescale dace			White sucker			
Environment	0	1^+	0	1	2^+	0	1	2	3
Rapids, Riffles	-	-	-	-	-	-	-	-	-
Shallow Channels	1.54	0.66	0.66	0.11	0.44	-	-	-	-
Shallow Pools	102.43	4.14	4.86	1.86	0.57	-	0.43	-	-
Deep Channel	4.04	7.93	-	0.88	0.70	1.05	1.73	-	-
Deep Pools	10.9	7.1	0.3	3.1	0.50	0.7	2.2	2.3	2.8