THE UNIVERSITY OF MANITOBA

ECOLOGICAL DIVERGENCE BETWEEN EMERALD AND SPOTTAIL SHINERS (*NOTROPIS*) IN LAKE MANITOBA

BY

DONALD JEAN BERNARD

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ABSTRACT

In Lake Manitoba two cyprinid species (Notropis) occur sympatrically and show ecological divergence. In July and August the fry of emerald shiners were near the surface in the limnetic zone while spottail shiners appeared to be littoral. By September both species were most abundant near shore and overlapped in vertical distribution. Emerald shiner fry fed on plankton, and spottail shiner fry on plankton and bottom foods. Emerald shiners of age I and older in May and June were mainly in offshore surface waters and at shoal edges occupying the whole water column. Spottail shiners of age I and older were near the bottom onshore in the shoal waters. As the season progressed, spottail shiners appeared to move offshore and off the bottom, while emerald shiners moved on to shoal waters but were most abundant near the surface or midwater. Emerald shiners showed a diel onshore-offshore movement, which occurred at irregular times in June, July and August, and a diel vertical movement to the surface at night in June and July. Spottail shiners showed no diel movements but appeared to be inactive between dusk and dawn. The diet of both species reflected their spatial distribution. Emerald shiners fed primarily on plankton, and spottail shiners ate

mainly bottom food but both shared a common diet of Diptera larva in July.

The ecological segregation between the two cohabiting congeneric species is possibly due to selective segregation.

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INTRODUCTION

The emerald shiner, *Notropis atherinoides* Rafinesque, and the spottail shiner, *Notropis hudsonius* (Clinton), are cyprinids whose geographical ranges overlap. They occur sympatrically in the Mackenzie River system (south of the lower Liard River), and most of the river systems from Alberta east to Quebec including the upper Mississippi River system and the Great Lakes drainages (Trautman 1957; McPhail and Lindsey 1970; Paetz and Nelson 1970). The purpose of this study is to provide comparative ecological information in an area of sympatric occurrence. No such information is available although each species has been the object of separate studies. The most recent of these are studies on the life history of the emerald shiner (Campbell and MacCrimmon 1970; Flittner MS 1964; Fuchs 1967) and its diet (Gray MS 1942; Manny MS 1928). Similar information on the spottail shiner is provided by Griswold (1963), McCann (1959), Smith and Kramer (1964) and Price (1963).

When two congeneric species occur in sympatry there is a potential for a simultaneous demand by both on resources in the environment. If the potential demand exceeds the supply, then according to the principle of Gause (1934), each species must utilize different portions of the resources available if they are to coexist. This study provides information during the ice-free period on the relative abundance and distribution of emerald and spottail shiners, both horizontally (distance from shore) and vertically (depth in the water column) and on food consumed. Hence this study seeks to describe the ecological divergence between the two species that allows their coexistence.

MATERIALS AND METHODS

A. Study Area

Lake Manitoba is a large (4,706 km^2), shallow (5 m mean depth), saline (1412 mg/l dissolved solids), turbid (0.25 - 1 m sechi disc), homothermic lake.

The study area was located near the University Field Station--Delta Marsh, where shiners were collected in 1969-70 at the south end of the lake along a transect which had eight stations of differing distance from shore. Physical variables at each station were as follows:

Station Number	1	2	3	4	5	6	7	8
Distance from shore (km)	0.15	0.20	0.26	0.80	1.61	3.22	4.83	8.05
Depth (m)	0.9	1.5	2.4	3.7	4.3	4.3	4.6	4.9
Substrate	sand	sand	sand	silt-clay	silt-clay	silt-clay	silt-clay	silt-clay

B. Distribution and Relative Abundance of Fry (Young of the Year)

Fry were collected from July to September, 1970, to determine their relative abundance, horizontal, and vertical distribution. Initially a modified plankton net (Faber 1968) was used, but after Aug. 9 a semi-ballon trawl, modified for sampling surface and bottom waters (Trent 1967) was used, eliminating the possibility of net avoidance by larger fry.

Two plankton nets (3 m long, 0.5 m mouth diam., 2 mm mesh, nitex screen bucket 10 meshes/cm) were towed from one boat with the nets suspended from either side of the bow by a V-shaped boom (Plates 1 and 2), the arms of which extended approximately 60° from the tip of the bow. For sampling at various depths, a galvanized steel wedge-shaped depressor (45 x 30 x 8 cm) of about 5 kg was attached to the net by two movable brass brackets (Plate 3). Desired depths were sampled by adjusting the length of tow line and the angle of the depressor to the net. A lazy line (Faber 1968) was used to prevent contamination of the sample when retrieving the net at the end of a haul. These nets were towed for 5 min at approximately 0.8 m/sec.

The semi-ballon trawl had the following specifications: height and width of mouth - 1.2 and 4.9 m, body - 3.8 cm stretch mesh, codend - 3.2 cm stretch mesh, inner liner of codend 2 mm stretch mesh knotless nylon netting. The trawl doors were 0.6 x 0.3 m and rigged with 30.5 m of nylon rope. The trawl was towed for 5 min parallel to shore at a speed of about 1.3 m/sec.

Four replicate tows for the plankton net at stations 3, 5 and 7 and three for the semi-ballon trawl at stations 3, 6 and 8 were collected when possible, for each depth. Each station was sampled between 800-1000, 1400-1600, and 2000-2200 hours.

Plate 1. Plankton tow nets used for collecting fry (young of the year).

Plate 2. Boom mounted on bow for towing plankton nets.

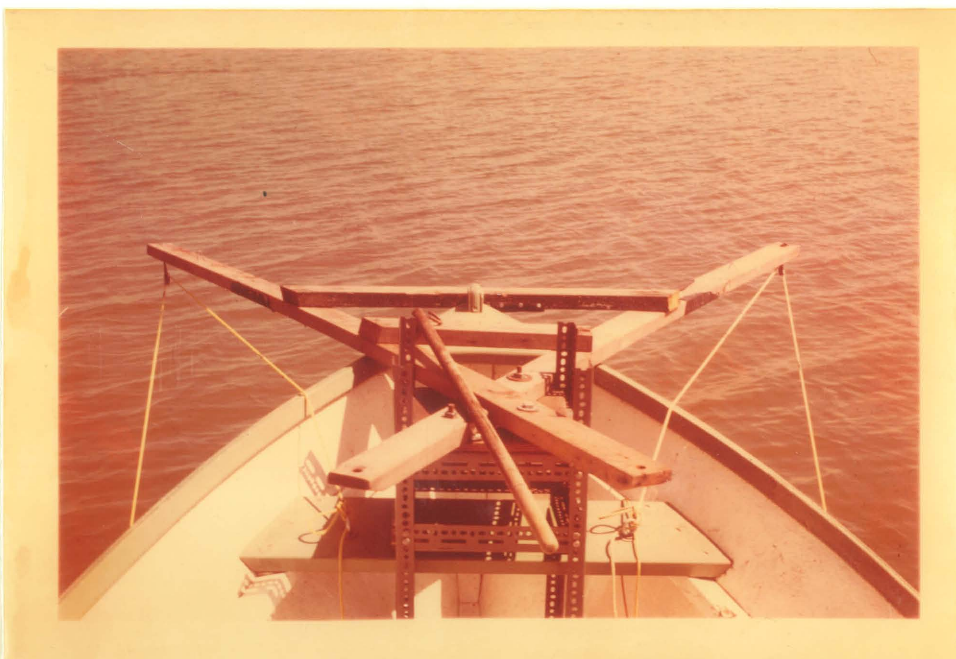


Plate 3. The depressor used for towing at various depths.

C. Distribution and Relative Abundance of Age I and Older Shiners

Relative abundance, vertical and horizontal distribution of shiners, age I and older, were determined, using catches taken from monofilament nylon gillnets. These nets were each 15.24 m long and designed as continuous vertical curtains of different depths for various stations. Each set consisted of two nets (12.70 m and 19.05 m stretched mesh) tied together and set parallel to shore. Narrow horizontal white bands at intervals of 0.5 m marked nets into panels and permitted the recording of depth of capture. Netting was conducted in 1969 and 1970 at stations 1, 2, 3 and 5 for two hours at five different times, 800-1000, 1400-1600, 2000-2200, 2400-200 and 400-600 hours. In October the time intervals for the netting program were:

Station	Oct.18, hours	Oct.18-19, hours	Oct.19, hours
1, 2, 3 and 5	1400-1600	2100-900	
	1700-2100		
3 and 5			900-1300

While in December, fishing underneath the ice, the time intervals were:

Station	Dec.28-29, hours	Dec.29-30, hours	Dec.30-31, hours
3	1400-1400	1100-1000	1200-1000
7	1500-1100	1500-1100	
8			1000-900

Nets containing fishes were taken ashore and placed in a cool (5-10 C) water bath. They were removed from the nets and the numbers of each species captured at each depth interval were recorded. All shiners were then preserved in 10% formalin for later analysis of stomach contents.

On July 15-16, 1970 a comparison of day and night gillnetting with trawling was made to determine the efficiency of gillnets in capturing spottail shiners at night. Gillnets were set for two hours at stations 1 and 2 at 1400 and 2400 hours. While nets were fishing three bottom trawls were made at station 2.

D. Diet

To compare the diet of both species, a sample of up to 15 fish of age I and older was selected from each station (station 1 and 2 pooled because of similar diet) at each period of sampling. The diet of fry of less than 12 mm total length could not be determined quantitatively by the method adopted. Therefore only a sample of 25 emerald shiner fry collected by the plankton tow net on July 30 could be used. Those captured by the semi-ballon trawl were large enough and a sample of 25 fry was taken at station 3 and the most offshore station sampled for the months of July (spottail shiner only), August and September (both species).

For fish of age I and older, the contents of the anterior one-third of the alimentary canal were removed, blotted dry, weighed (± 1 mg) excluding undigestable material such as caddis-cases, and identified to genus where possible. The food was separated into items, then the total weight of each food item in all stomachs in the sample was taken. Fry were analyzed in the same procedure except that weight of food present in individual stomachs was not taken.

Three methods were used to assess differences in diet between species. In each, fish with empty stomachs were excluded. 1. Occurrence, the number of stomachs in which each food item occurred. 2. The weight of each food item expressed as a percentage of total weight of food consumed. 3. Consumption index (Godfrey 1955) which provided a value of the relative importance of each food item. This value was found by taking the square root of the product of the number of fish in the sample that consumed a specific food item times the average weight of that food item in all stomachs.

RESULTS

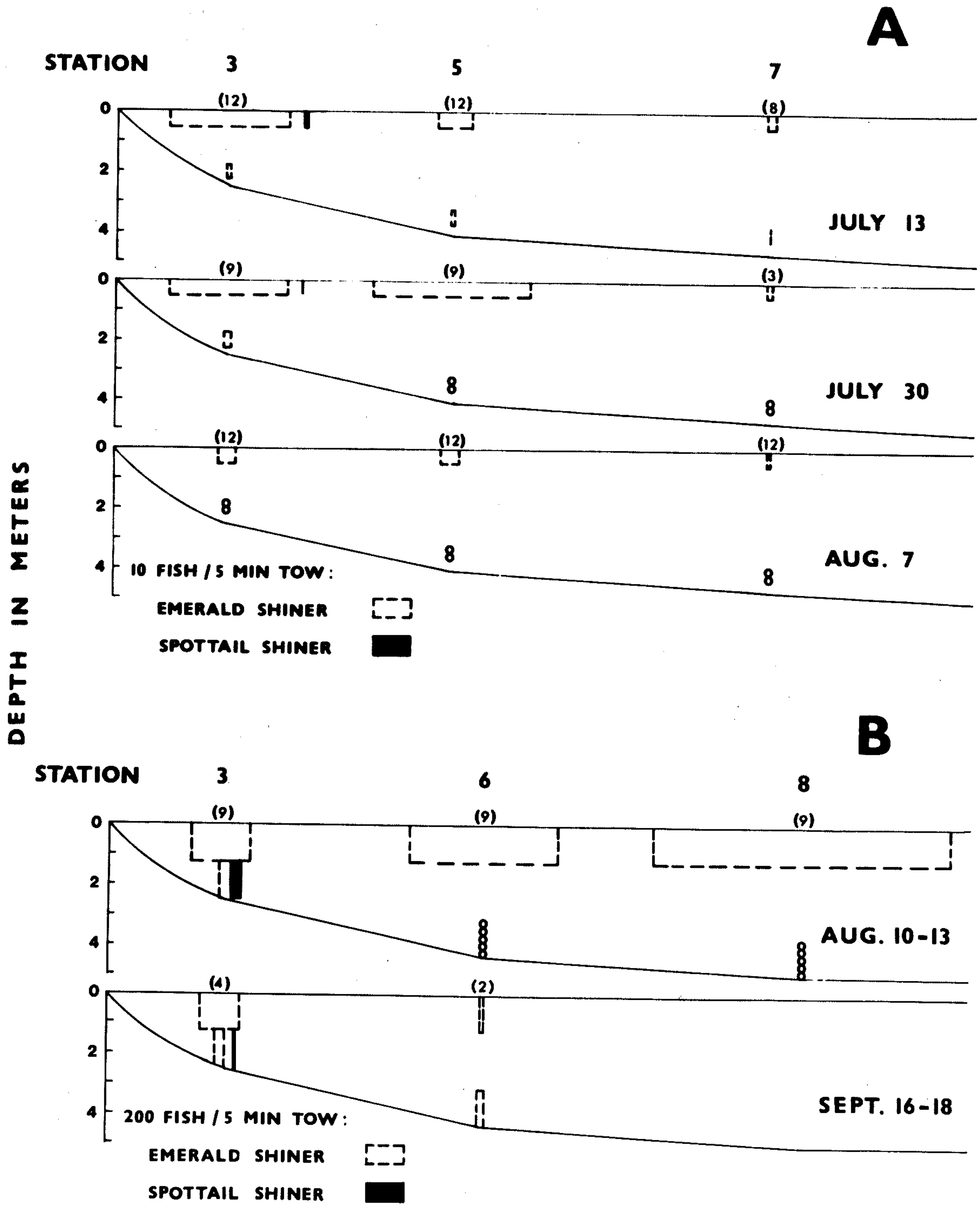
A. Distribution and Relative Abundance of Fry (Young of the Year)

There were no vertical or horizontal changes in catch per unit of effort within or between stations over a 24 hour period, hence the results within each period were combined. However, there were differences in catch per unit of effort at different stations which did vary between months. On July 13 the greatest catch per unit of effort of emerald shiner fry was in surface waters at all stations (Fig. 1A), and was greatest near shore (station 3). Catch per unit of effort differed significantly between all stations ($P < 0.05$ from analysis of variance). By July 30 and August 7 the greatest catch per unit of effort of these fry occurred in surface waters but it increased offshore, mainly at station 5 (Fig. 1A). No significant differences in catch per unit of effort in surface waters between stations were found. Spottail shiner fry were scarce. By August 10-13 the catch per unit of effort of emerald shiner fry was greatest in surface waters. Significant differences in catch per unit of effort in surface waters between stations 3, 6 and 8 were found (F, $P < 0.05$) and they were caught in greatest numbers offshore at station 8 (Fig. 1B). Spot-

Fig. 1. The horizontal and vertical distribution of emerald and spottail shiner fry expressed as numbers/5 min tow. The vertical depth that the gear sampled is illustrated by depth of the squares. Numbers in parenthesis refer to number of 5 min tows. Open circles signify that no shiners were caught at that depth. Station 8 in September 16-18 was not sampled.

A. - plankton tow net catches

B. - semi-ballon trawl catches


A
STATION
3
5
7
(12)
(12)
(8)
0
2
4
JULY 13
(9)
(9)
(3)
8
8
JULY 30
(12)
(12)
(12)
8
8
8
AUG. 7
10 FISH / 5 MIN TOW:
EMERALD SHINER
SPOTTAIL SHINER
DEPTH IN METERS
B
STATION
3
6
8
(9)
(9)
(9)
AUG. 10-13
(4)
(2)
SEPT. 16-18
200 FISH / 5 MIN TOW:
EMERALD SHINER
SPOTTAIL SHINER

tail shiner fry were captured only near the bottom near shore at station 3 at this time and on September 16-18. Emerald shiner fry in September were not restricted to surface waters and they were found at all depths sampled, but they appeared to be more abundant near shore at station 3.

B. Distribution and Relative Abundance of Age I and Older Shiners

a) Relative abundance

The relative abundance of each species of shiner, expressed in terms of catch per unit of effort (numbers/ m^2/hr), was calculated monthly from May to October (Table 1). The greatest catch per unit of effort occurred in June and July along the transect. Emerald shiners dominated the catch in all months except May. In December, however, only three fish (two emerald and one spottail shiners) were captured though the fishing effort was 15,904.5 m^2 of net hours.

TABLE 1. The monthly catch per unit of effort of emerald and spottail shiners (age I and older) caught by gillnets from May to October 1969-70.

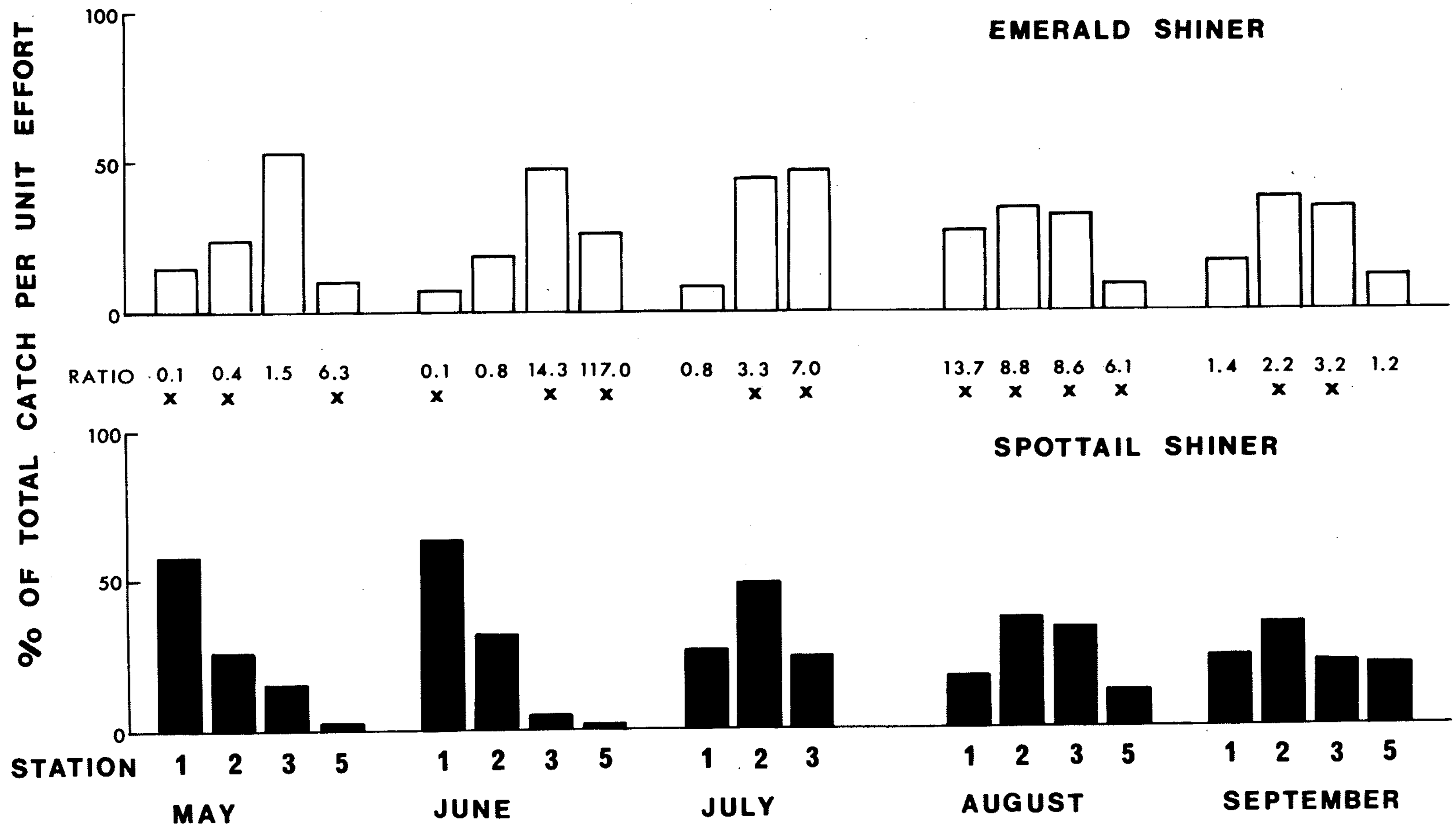
	1970		1969			
	May 23-24	June 26-27	July 25-26	Aug.20-21,24	Sept. 8-9	Oct. 18-19
Numbers/m^2/hr						
Emerald shiner	0.0339	0.5011	0.8016	0.2722	0.0806	0.0008
Spottail shiner	0.0799	0.3434	0.2188	0.0310	0.0394	0.0004
Effort-m^2/hr	2973.0	2378.4	1189.3	4756.8	2378.4	6837.9
Age Groups						
Emerald shiner	II$^+$	II$^+$	II$^+$	II$^+$	I, II$^+$	I, II$^+$
Spottail shiner	II$^+$	I, II$^+$	I, II$^+$	I, II$^+$	I, II$^+$	I, II$^+$

b) Horizontal distribution

During May and June the highest proportion of spottail shiners captured was inshore at station 1 (Fig. 2), and they were significantly more abundant than emerald shiners which were present in the highest proportion offshore at station 3. From July to September spottail shiners increased in proportion offshore, eventually reaching similar values at stations 1,2, 3 and 5. In August a similar proportion of emerald shiners was found at stations 1, 2 and 3, and this species was significantly more abundant than spottail shiners at stations 1, 2, 3 and 5. By September the greatest proportion of emerald shiners was offshore at stations 2 and 3 where it was the most abundant shiner.

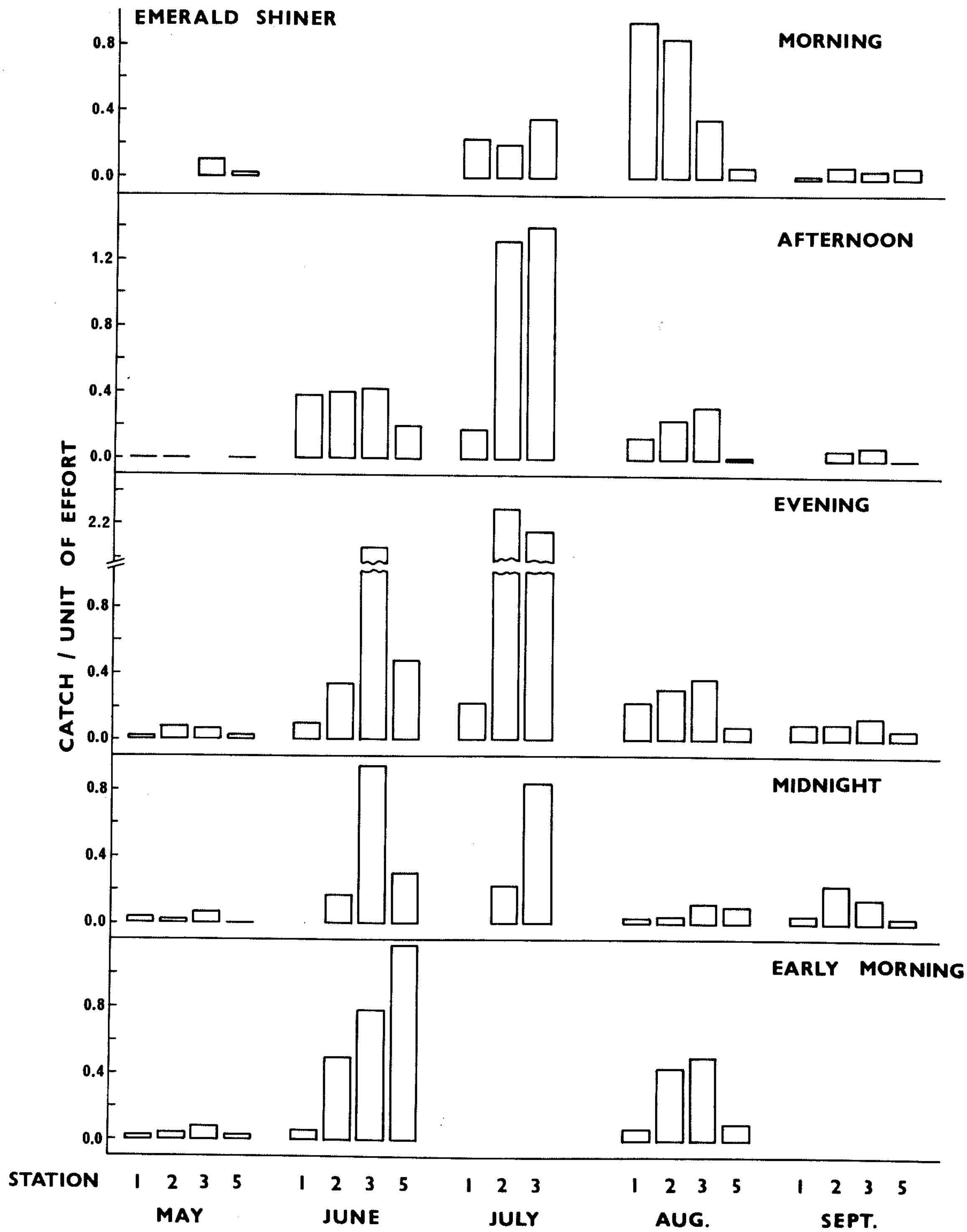
There were marked changes in the catch per unit of effort of emerald shiners at stations 1, 2, 3 and 5 over a 24 hour period in June, July and August (Fig. 3). But this was not observed in May and September when low catches per unit of effort were obtained. In June, the catch per unit of effort in the afternoon was similar at stations 1, 2 and 3, but from evening to early morning the greatest catch per unit of effort was found offshore at stations 3 and 5. In July, a similar catch per unit of effort was found at stations 1, 2 and 3 in the morning with an increased catch per unit of effort at stations 2 and 3 from afternoon to

Fig. 2. The horizontal distribution of emerald and spottail shiners (age I and older) from May to September at stations 1, 2, 3 and 5. The catch per unit of effort at each station is expressed as a percentage of the total monthly catch per unit of effort for each species. The ratio is the number of emerald shiners for every spottail shiner. The difference between the number of spottail and emerald shiners at each station was tested with a chi-square test (x denotes significance at 5% level).



% OF TOTAL CATCH PER UNIT EFFORT
EMERALD SHINER
SPOTTAIL SHINER
100
50
0
RATIO 0.1 0.4 1.5 6.3 0.1 0.8 14.3 117.0 0.8 3.3 7.0 13.7 8.8 8.6 6.1 1.4 2.2 3.2 1.2
STATION 1 2 3 5 1 2 3 5 1 2 3 1 2 3 5 1 2 3 5
MAY
JUNE
JULY
AUGUST
SEPTEMBER

Fig. 3. The diel horizontal distribution of emerald shiners (age I and older) caught by gillnets from May to September 1969-70. The number of shiners caught at each station at different times within a 24 hour period of a particular month is expressed as numbers/m^2/hr. Areas not sampled are morning of June, early morning of July and September, and station 5 in July.



EMERALD SHINER
MORNING
AFTERNOON
EVENING
MIDNIGHT
EARLY MORNING
CATCH / UNIT OF EFFORT
0.0
0.4
0.8
1.2
2.2
STATION
1 2 3 5
1 2 3 5
1 2 3
1 2 3 5
1 2 3 5
MAY
JUNE
JULY
AUG.
SEPT.

midnight. But in August the greatest catch per unit of effort in the morning was onshore at stations 1 and 2.

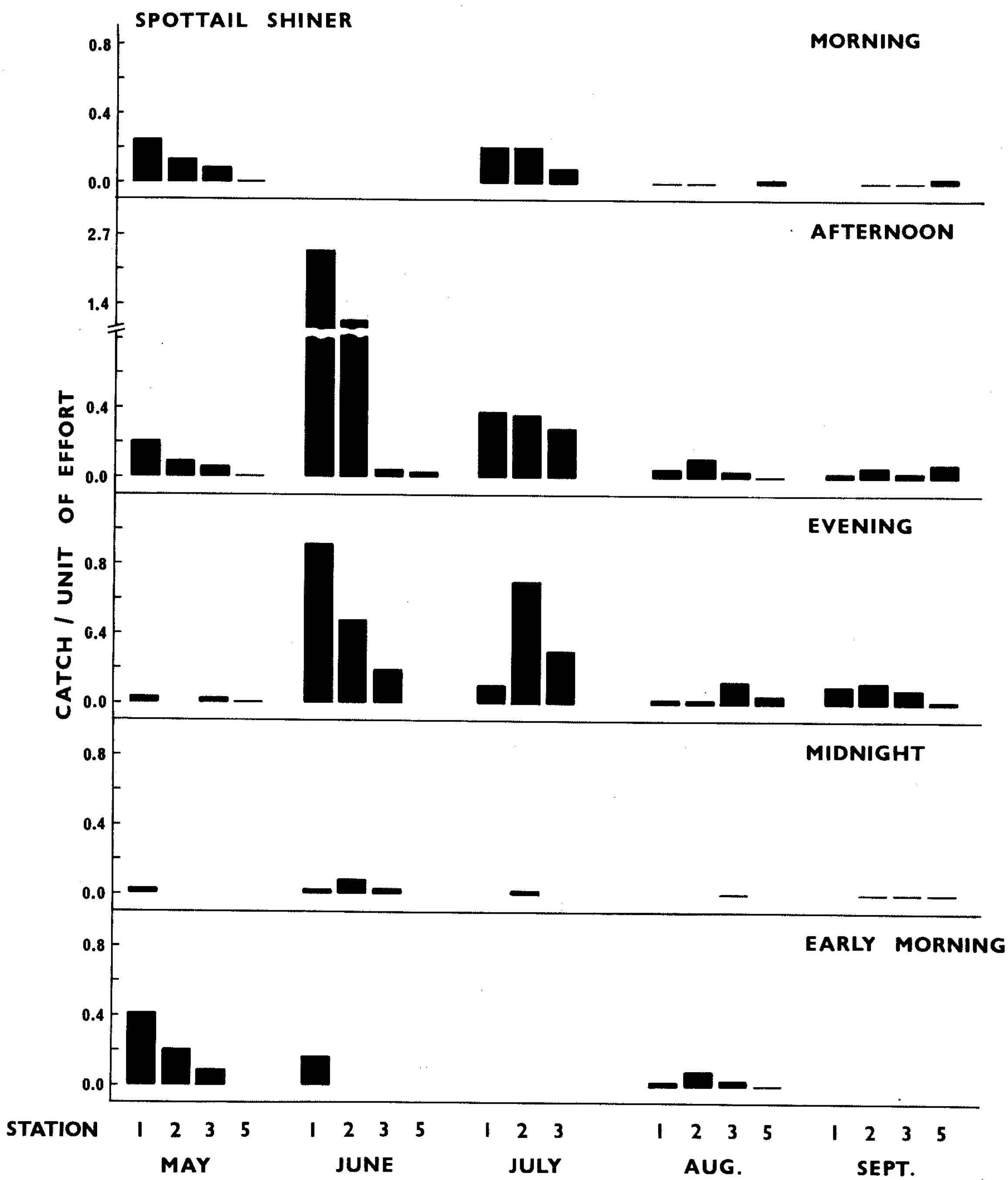
In the afternoon and evening a similar catch per unit of effort was found at stations 1, 2 and 3. However, by early morning the catch per unit of effort was largest at stations 2 and 3. Although there were changes in the horizontal distribution of emerald shiners within a 24 hour period in June, July and August, they occurred at different times each month.

Spottail shiners (Fig. 4) did not show such marked changed in diel horizontal distribution, but the catch per unit of effort at midnight and early morning (except for May) were generally the lowest. To determine if spottail shiners were present in the transect after sunset but were not being caught by gillnets, simultaneous gillnetting and bottom trawling were conducted during the day and at night. The following catches of spottail shiners were recorded:

	Gillnets (stations 1 + 2)	Bottom trawl (station 2)			
		Replicates			Total
		1	2	3	
Day	37	57	74	136	267
Night	7	89	40	18	147

The results showed that spottail shiners were present in the area at night and more were caught relative to those during the day by trawling than by gillnets. But it is impossible to compare catches by gillnets during day and night with the total catch caught by trawl because the ratios of the catch at the three sites varied by more than chance.

Fig. 4. The diel horizontal distribution of spottail shiners (age I and older) caught by gillnets from May to September 1969-70. The number of shiners caught at each station at different times within a 24 hour period of a particular month is expressed as numbers/m^2/hr. Areas not sampled are morning of June, early morning of July and September, and station 5 in July.



SPOTTAIL SHINER
MORNING
AFTERNOON
EVENING
MIDNIGHT
EARLY MORNING
CATCH / UNIT OF EFFORT
0.8
0.4
0.0
2.7
1.4
STATION
1 2 3 5
1 2 3 5
1 2 3
1 2 3 5
1 2 3 5
MAY
JUNE
JULY
AUG.
SEPT.

c) Vertical distribution

The vertical distribution of both species showed considerable overlap (Fig. 5) but several features are evident. When present at station 1, spottail shiners generally had a uniform vertical distribution. In deeper water at stations 2 and 3 the catch per unit of effort was greater near the bottom except for September where they were present throughout the water column. Emerald shiners were caught throughout the water column although at stations 1 and 2, from June to September, more were caught in surface waters. Offshore at station 5 emerald shiners were found mainly from midwater to surface from May to September. At this station few spottail shiners were caught in early summer but in August and September they were present throughout the water column.

There was no evidence of a change in vertical distribution of spottail shiners over a 24 hour period within any month (May to September). In June and July emerald shiners (Fig. 6) were caught throughout the water column at stations 1, 2 and 3 during the daylight hours (800-2200 hr). But offshore, at station 5, in June, they were only present from midwater to surface. After sunset (2400-600 hr) at stations 2, 3 and 5 the greatest catch per unit of effort was in the surface waters.

Fig. 5. The vertical distribution of emerald and spottail shiners (age I and older) caught by gillnets at stations 1, 2, 3 and 5 for May, June, July, August and September (from top to bottom). Shiners are expressed as numbers/m^2/hr times 10. Station 5 in July was not sampled. The open and closed triangles are values of less than 0.3 for emerald and spottail shiners respectively.

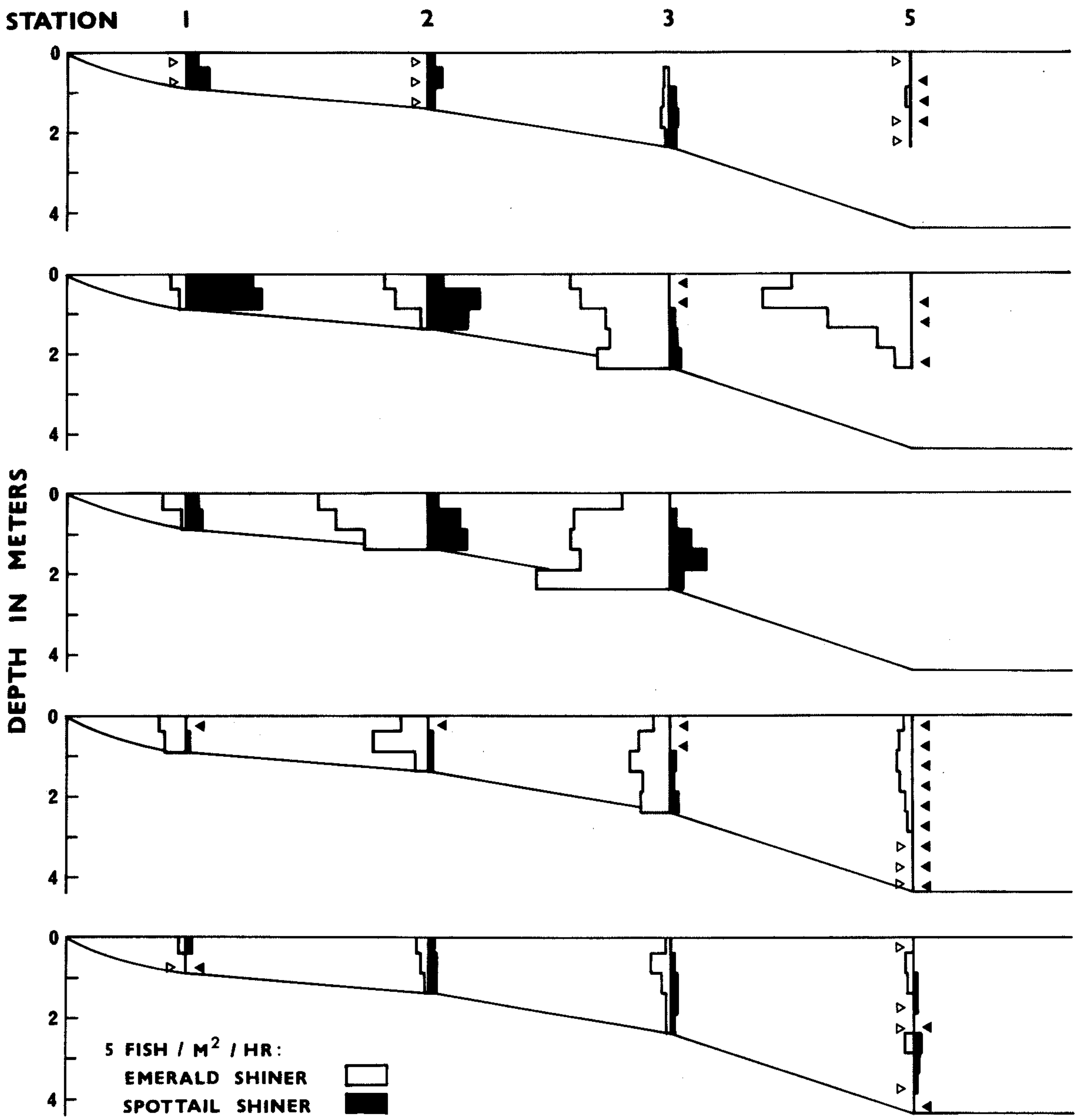
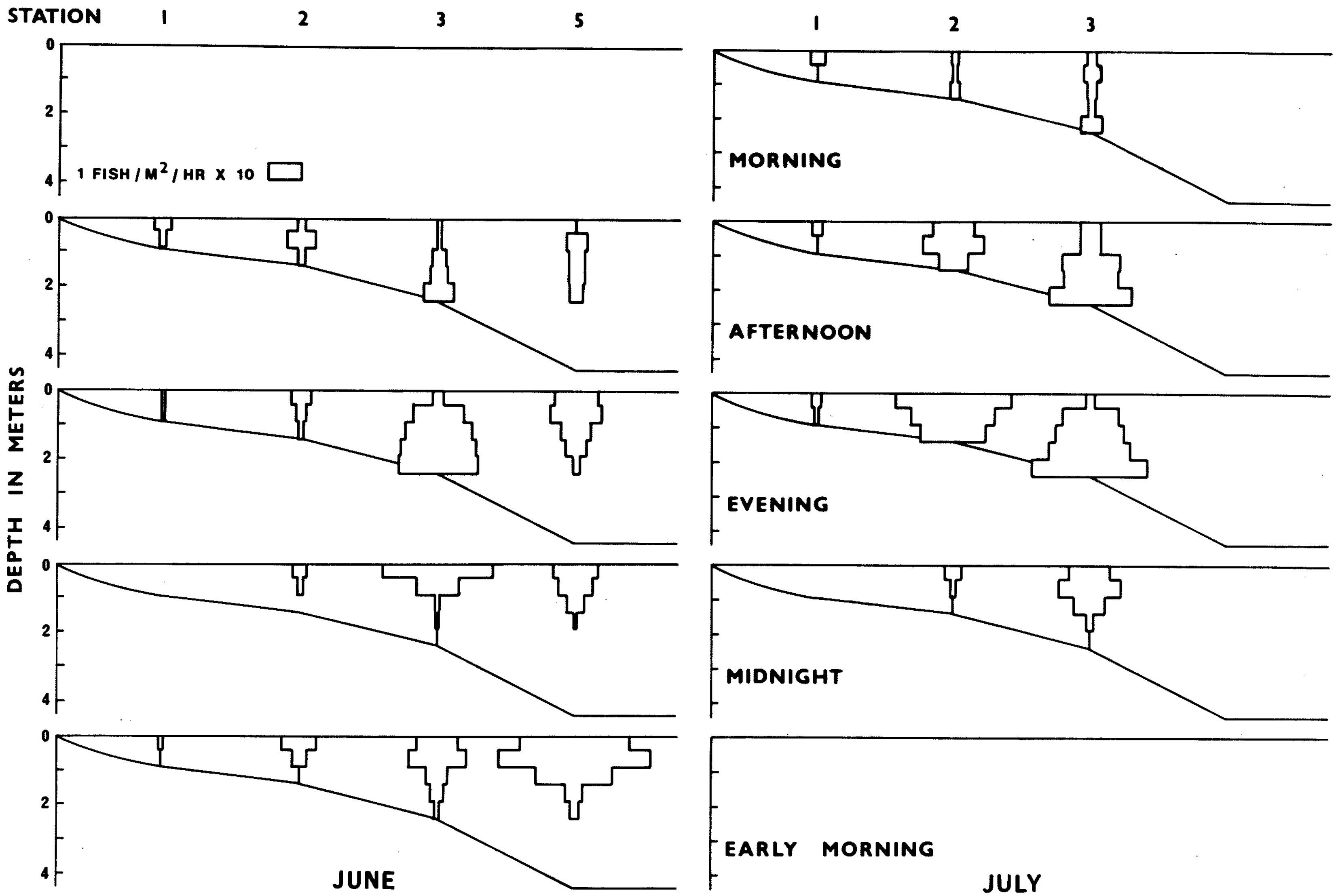

STATION
1
2
3
5
DEPTH IN METERS
0
2
4
5 FISH / M² / HR:
EMERALD SHINER
SPOTTAIL SHINER

Fig. 6. The diel vertical distribution of emerald shiners (age I and older) caught by gillnets at stations 1, 2, 3 and 5 for June 26-27/70 and July 25-26/69. Shiners are expressed as numbers/m^2/hr times 10. Morning in June, early morning and station 5 in July were not sampled.


STATION
1
2
3
5
1 FISH / M2 / HR X 10
DEPTH IN METERS
0
2
4
MORNING
AFTERNOON
EVENING
MIDNIGHT
EARLY MORNING
JUNE
JULY

Though both species overlap in distribution, gillnetting indicates:

1. Shiners are most abundant along the transect in June and July, and emerald shiners dominate the catch during most of the ice-free period.
2. During early summer, spottail shiners are the dominant shiner onshore, while emerald shiners are found mainly offshore.
3. Catch per unit of effort of both species declines throughout the transect by September.
4. Spottail shiners are found mainly near the bottom, showing no marked change in diel horizontal or vertical distribution except that few are caught between sunset and sunrise.
5. Emerald shiners are generally present throughout the water column onshore, and from midwater to surface offshore except in June and July when they are found at the surface at night.
6. Emerald shiners show marked changes in diel horizontal distribution, but the timing of these events is irregular.

C. Diet

The diet of emerald and spottail shiners was similar in that both species fed to a large extent on the same items (Table 2). But differences were evident in the quantity and time of year that particular items were consumed. To facilitate the explanation of these differences, food items were placed into three categories: plankton food, bottom food and surface food. Food items composing each category are listed in Table 2. To compare the diet of the two species at particular stations at particular times, a coefficient of similarity (Whittaker and Fairbanks 1958), based on the percent contribution of the consumption index for each food item, was calculated.

The coefficient of similarity was not used for fry of either species due to the difficulty of separating different cladocerans for weight determinations of which some cladocerans were eaten by both species and others were eaten exclusively by either species. In the case of age I and older shiners, the composition of the cladoceran food item was completely different between the two species, justifying the use of the coefficient of similarity.

TABLE 2. Food and the three food categories of fry, age I and older emerald and spottail shiners in Lake Manitoba, 1969-70

Food items	Food of shiners emerald	Food of shiners spottail	Food categories surface	Food categories plankton	Food categories bottom
Algae	#	#		X	
Cladocera					
Daphnia sp.	#	#		X	
Latona setifera		#		X	
Diaphanosoma sp.	#	#		X	
Leptodora kindti	#	#		X	
Others	#	#		X	
Copepoda	#	#		X	
Ostracoda	#	#			X
Amphipoda	#	#			X
Decapoda		#			X
Hydracarina	#	#			X
Flying insects (adults)					
Odonata	#	#	X		
Megaloptera	#	#	X		
Trichoptera	#		X		
Diptera	#	#	X		

TABLE 2. (cont'd).

Food items	Food of shiners emerald	Food of shiners spottail	Food categories surface	Food categories plankton	Food categories bottom
Aquatic insects (adults)					
Hemiptera	#				X
Corixidae	#	#			X
Coleoptera	#	#			X
Aquatic larvae, pupae, nymph					
Ephemeroptera	#	#			X
Trichoptera	#	#			X
Diptera larvae	#	#			X
pupae	#	#	X		
Mollusca (Sphaeriidae)		#			X
Fish eggs	#	#			X
Unidentifiable matter	#	#			
Number of fish	608	394			

a) Diet of fry

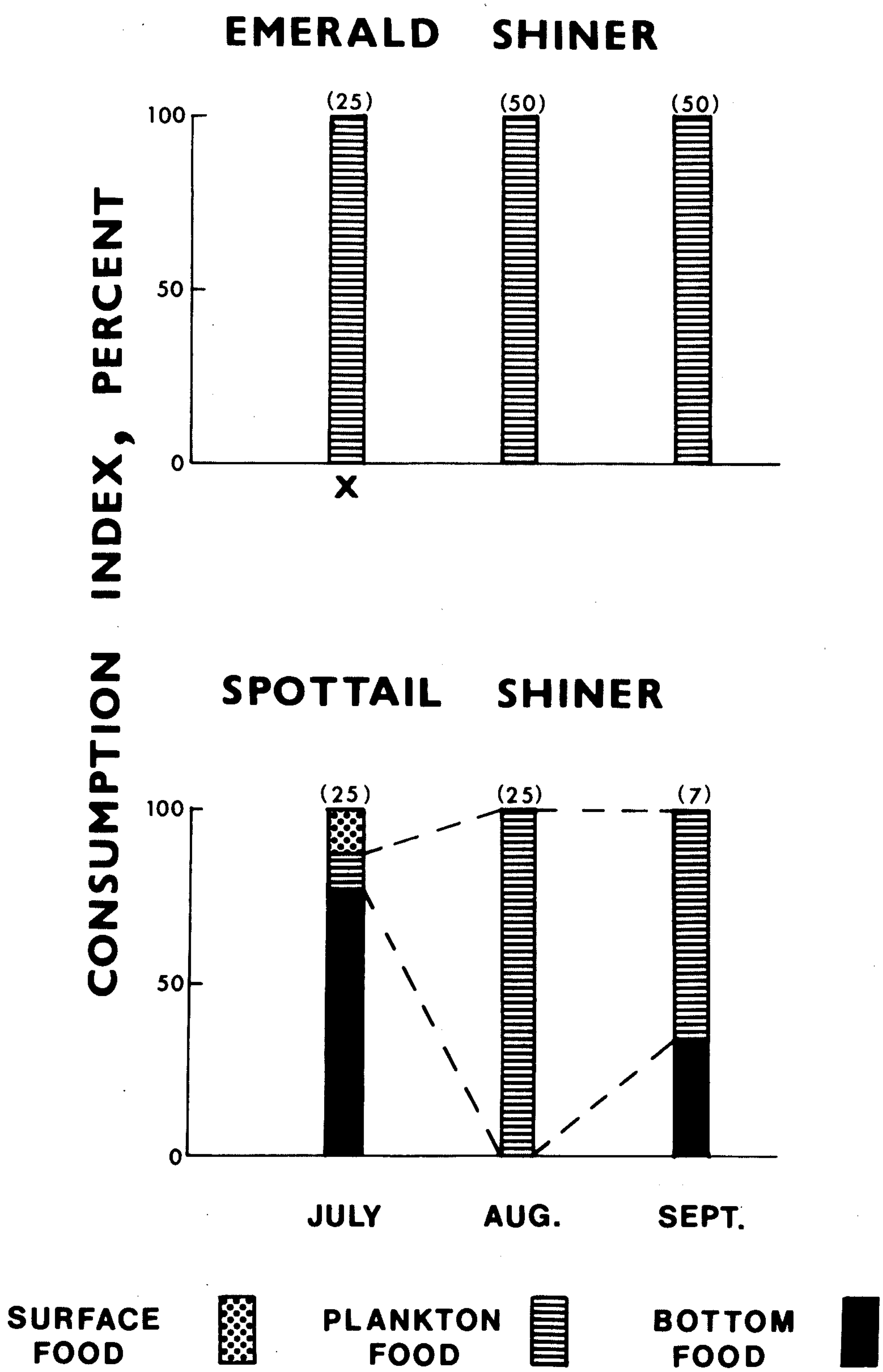
Bottom food, composed mainly of Diptera larvae, dominated the diet of spottail shiners in July. Emerald shiners in July fed only on plankton food. The diet of both species in August and September consisted mostly of plankton (Fig. 7) with *Daphnia* sp. and other cladocerans common to both species. *Latona setifera* and *Diaphanosoma* sp. were exclusive to spottail and emerald shiners respectively. (See Appendix G for further details.)

b) Diet of age I and older shiners

An examination of the diet of age I and older emerald and spottail shiners (Fig. 8) revealed the following points:

1. Diet of both species varied seasonally.
2. Spottail shiners consumed more bottom food than emerald shiners while the latter consumed more plankton food than the former.
3. Surface food is eaten by both species, particularly in June and July.
4. Of the bottom food consumed by emerald shiners, more is consumed at stations nearest shore.
5. The greatest percentage of similarity of food consumed occurred in July when both species consumed Diptera larvae.

Fig. 7. Diet of emerald (stations 3 and 8 combined) and spottail shiner fry (station 3 only) caught by semi-ballon trawl, 1970. Numbers in parentheses are the sample size. The X denotes emerald shiner fry caught by plankton tow nets at stations 3 and 7 on July 30.

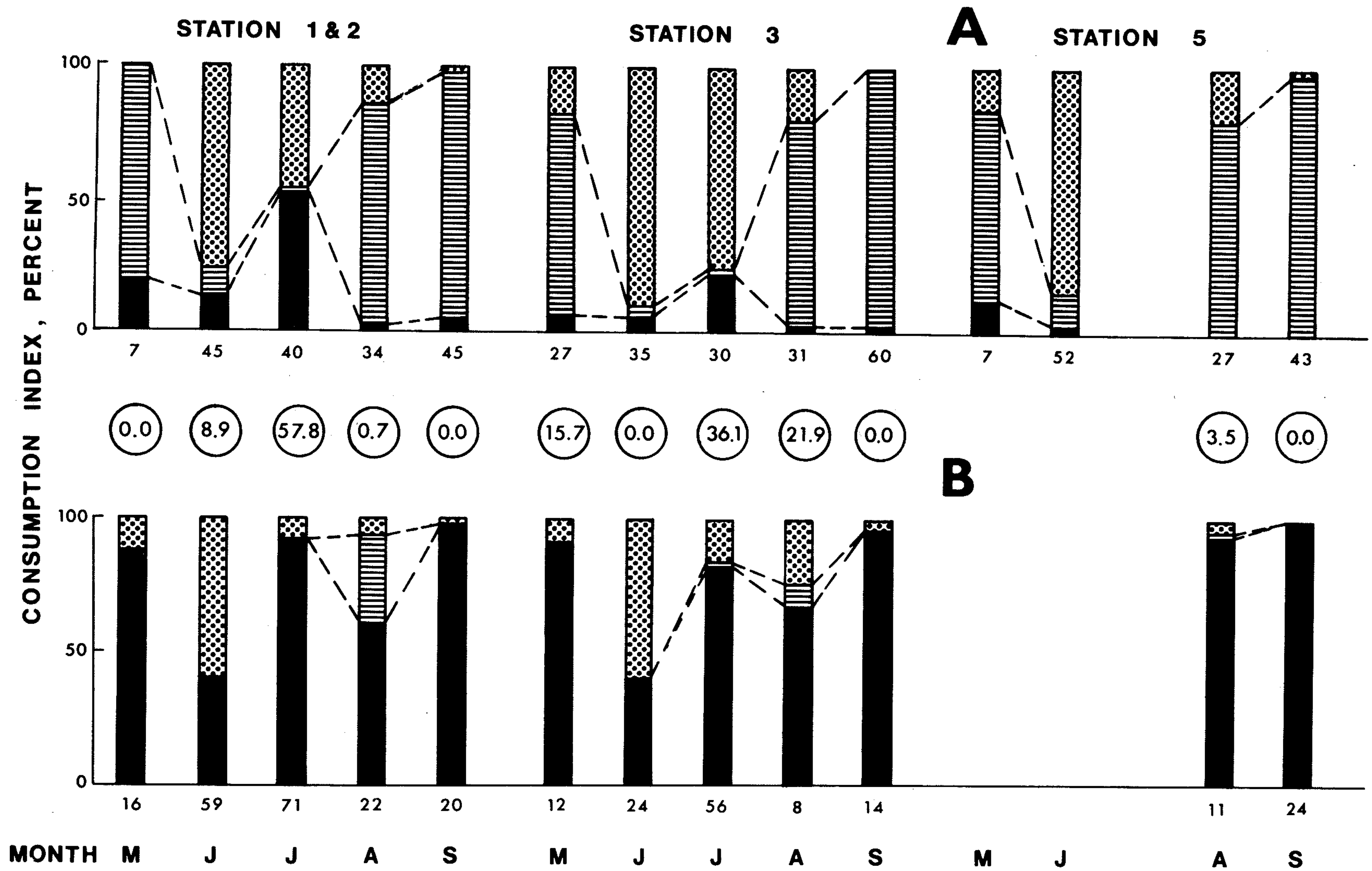


EMERALD SHINER
SPOTTAIL SHINER
CONSUMPTION INDEX, PERCENT
100
50
0
(25)
(50)
(50)
X
(25)
(25)
(7)
JULY
AUG.
SEPT.
SURFACE FOOD
PLANKTON FOOD
BOTTOM FOOD

Fig. 8. Diet of emerald and spottail shiners (age I and older) caught by gillnets 1969-70. The numbers encircled are the percentage similarity of diet between each species for each station of each month. The numbers are the number of fish examined, excluding those with empty stomachs. Stations 1 and 2 are combined because of similar diet. At station 5 there was only one spottail shiner in June and none in May, and in July this station was not sampled. The legend is as given in Fig. 7.

A - Emerald Shiner

B - Spottail Shiner



A
B
STATION 1 & 2
STATION 3
STATION 5
CONSUMPTION INDEX, PERCENT
100
50
0
7 45 40 34 45 27 35 30 31 60 7 52 27 43
0.0 8.9 57.8 0.7 0.0 15.7 0.0 36.1 21.9 0.0 3.5 0.0
16 59 71 22 20 12 24 56 8 14 11 24
MONTH M J J A S M J J A S M J A S

Seasonal variation in diet is most pronounced among emerald shiners. It is characterized by a shift from plankton food (copepods) in May to surface food (Diptera adults) in June and July, and with a return to plankton food (*Daphnia* sp. and *Leptodora kindtii*) in August and September. The diet of spottail shiners changed from bottom food (Diptera larvae) in May to surface food (Diptera pupae) in June, reverting to bottom food (Diptera larva and sphaeriids) in July, August and September. They also fed to some extent on plankton (exclusively *Latona setifera*) in August.

DISCUSSION

Spottail shiners, age I and older, were most abundant near shore in early summer and appeared to move offshore from July to September but showed no diel movements. They appeared to be inactive between dusk and dawn. During the day they occurred near the bottom, except in shallow water (< 1.5 m), and fed mainly on bottom food. In contrast, emerald shiners were most abundant offshore in early summer, moving inshore by July and August and returning to offshore waters by September. They showed a diel onshore-offshore movement which occurred at irregular times between the months of June, July and August. They showed a diel vertical movement to the surface at night in June and July. Although they occupied the whole water column when near shore, they were found from midwater to surface offshore, feeding mainly on plankton food. Both species shared a common diet (Diptera larvae) in July.

Emerald shiner fry were found in the limnetic zone in July and August, but in September they were present throughout the water column and appeared to concentrate near shore. They fed only on plankton. Spottail shiner fry were found inshore near the surface in July and near the bottom in August and September, feeding on plankton and bottom foods.

Recently emerged fry of many lake-dwelling fishes migrate to the limnetic region and may remain there for several weeks (Faber 1967; Heard 1965; Hubbs 1921; Sinclair 1968; Werner 1969). The occurrence of recently emerged emerald shiner fry in this zone could be due to: (1) the eggs being spawned offshore and remaining there; or (2) spawning occurring elsewhere and the fry being carried offshore by local wind-generated currents. The latter is most likely in Lake Manitoba since spawning occurs in shoal areas (corresponding to stations 1, 2 and 3) and fry at that stage are not capable of any active long distance movements (Flittner MS 1964). This area offers few predators and abundant food. Such dispersal may serve as a mechanism to dampen density effects (Johnson 1965). Similar concentrations of emerald shiner fry inshore in September have been observed by Flittner (MS 1964) and Campbell and MacCrimmon (1970). The latter inferred a preference for warmer inshore waters as a cause for the change in distribution.

The scarcity of spottail shiner fry in July and August, despite extensive sampling with tow nets, is difficult to interpret. This may be due to several factors. First, spottail shiners spawned earlier than emerald shiners as indicated by gonad development (Appendix E).

By July the fry may have been large enough to escape the tow nets as Noble (1970) found for yellow perch fry. Secondly, spottail shiner fry may remain inactive near the bottom and so avoid capture. Many larval fishes are caught in greater numbers at night than during the day (Bridger 1956 and Isaacs 1964 for marine larval fish; Faber 1967 and Noble 1970 for freshwater fish). This may well be correlated with activity of fry since Werner (1969) has shown that bluegill fry undergo a diel activity pattern with peak activity at dusk and dawn. Thirdly, they may occupy a different area than that sampled. McCann (1959) and Griswold (1963) found spottail shiner fry to be most abundant at night in areas of moderate emergent and submergent vegetation. However, Peer (MS 1961) did not find any fry below 19 mm total length on the shores of Nemeiben Lake but suggested that they may be found off-shore. Though few spottail shiner fry of less than 19 mm fork length were found, larger fry were inshore and near the bottom in August and September. It appears most likely that spottail shiner fry are found close to shore in waters too shallow to sample with tow nets.

The seasonal movements of spottail shiners (age I and older) between onshore and offshore waters are probably related to spawning. Spawning occurs on shoal areas in either May, June or July, depending on the latitude, Peer (1966). In Lake Manitoba some ripe spottail shiners (age II^+) were caught in or near shoal areas (stations 1, 2 and 3) in May, but most age II^+ fish captured in June were ripe (Appendix E). Following spawning there was an increase in catches offshore which probably reflect a breaking up of spawning aggregations and a movement into deeper water, as observed by Reckahn (1970) and Peer (1966). But the distribution is complicated by the presence of immature age I spottail shiners after May which seemed to be dispersed throughout the transect.

The catch of spottail shiners in gillnets during the ice-free period at midnight and early morning was greatly reduced. But catches by trawling indicated their presence, possibly in reduced numbers. McCann (1959) suggests that increased catches by seining at night in shallow waters indicates a movement into such places or a greater susceptibility to seining at night. However, Hubbs (1921) suggests a movement offshore at night. Such movements were not observed in Lake Manitoba, or by Peer (MS 1961). Based on gillnet catches, several investigators hypothesized that some fishes are active at different times of the day (Carlander and Cleary 1949; Hart 1931; Lawler 1969; Scott 1955; Sieth and Parsons 1950; Spoor and Schloemer 1939; and others). It appears most likely that spottail shiners are inactive at night and some may move into shallow waters at dusk.

Emerald shiners show a more complex pattern of movement and migration which appears to be related in part to spawning. They have a prolonged spawning season from June to August and spawn in areas slightly offshore of an exposed shoreline in water of 2 m or deeper (Flittner MS 1964; Campbell and MacCrimmon 1970). A large proportion of emerald shiners captured in June and July were ripe (Appendix E). This corresponds to the large aggregations of spawning emerald shiners which Flittner (MS 1964) and Campbell and MacCrimmon (1970) found near exposed shorelines. By August and September in Lake Manitoba the relative abundance in onshore waters decreased, possibly reflecting a breakdown of spawning aggregations followed by offshore movements as suggested by Flittner (MS 1964).

According to McNaught and Hasler (1961) the diel vertical migration of emerald shiners may be a response to light intensity, or the following of a food source, or a preferred spawning place. Analysis of the feeding activity (Appendix C) during this time suggested that feeding, which begins between 2400 and 500 hours, might be involved. During this time the diet consisted mainly of surface food. Light intensity may also be involved as indicated by Narver (1970) for underyearling sockeye salmon and Northcote et al (1964) for peamouth chub. But light may act indirectly on fish by affecting the migration of the food source (McNaught and Hasler 1961). In Lake Manitoba the migration could be related to spawning since in June and July emerald shiners are ripe and they spawn at night near the surface (Flittner MS 1964).

The irregular occurrence of the diel onshore-offshore movements of emerald shiners did not appear to be correlated with diel changes in illumination. The situation is obviously complex and it may be attributed as Northcote (1967) suggests to "localized semi-discrete populations with varying amounts of movement and interchange between adjacent or nearby populations." Wind action could also be an important factor as Lorz and Northcote (1965) found for mature kokanee salmon where diel fluctuations in onshore-offshore movements were related to differences in wind action.

The diet of the two congeneric species was considerably different. Fry of emerald shiners fed only on plankton while spottail shiners fed on a variety of foods. However, the plankton component of the diet of spottail shiners was composed in part of a cladoceran, *Latona setifera*, not consumed by emerald shiner fry. Pennak (1953) states that *Latona setifera* is commonly found among submergent vegetation, suggesting that spottail shiner fry feed in the littoral zone. Emerald shiners, age I and older, were primarily plankton feeders while spottail shiners were mainly bottom feeders. Flexibility in diet occurred in both species but it was more evident for emerald shiners. In June and July they shifted from plankton to surface and bottom foods. Similarity in diet between species occurred in July where both fed on Diptera larvae. This would be explained by what Nilsson (1955) and Keast (1965) refer to as superabundance of food, or perhaps a combination of superabundance of a particular food with a low availability of preferred food. Fuchs (1967) found that emerald shiners eat more insects when *Daphnia* sp. were scarce. Though the available food was not measured, large hatches of Diptera adults were observed in June and July and a few qualitative bottom samples suggested an abundance of Diptera larvae in July. Similarity in diet was more pronounced near shore and this could be due to an abundant supply of Diptera larvae in onshore waters.

Hartley (1948) and Larkin (1956) imply that amongst cohabiting freshwater fishes flexibility and adaptability is the rule rather than the exception. However, specialization in morphology may be important in determining feeding habits of coexisting species. Northcote (1954) discusses the importance of mouth size of two species of cottids, and Keast and Webb (1966) investigated the mouth and body form of fourteen co-habiting species of fish in Lake Opinicon. They concluded that structural specialization gives certain advantages while still allowing for flexibility in feeding. Emerald shiners have a slight dorso-terminal mouth and a compressed fusiform body, and spottail shiners have a slightly subterminal and slightly oblique mouth and a moderately compressed fusiform body. These differences relate closely to the spatial differences and diet observed. Emerald shiners appear particularly suited for a pelagic mode of life while spottail shiners are better adapted as a bottom-dwelling species. Another difference is the number of gillrakers. Emerald shiners have a total of 9-12 and spottail shiners 4-9 gillrakers (Paetz and Nelson 1970). This may have some bearing on diet, as more gillrakers may aid in capturing plankton. However, the relationship of food to numbers of gill-rakers, length and space between them, may be complex as in coregonids (Kliewer 1970).

Gause (1934) states that two or more species cannot utilize similar resources in their environment but if they are to coexist they must segregate and utilize different portions of the environment. The most notable work in this field on fishes is by Nilsson (1955, 1960, 1961, 1963, 1965) on the competitive interaction between arctic char (Salvelinus alpinus) and the brown trout (Salmo trutta). Emerald and spottail shiners are spatially segregated. In early summer emerald shiners are mainly in offshore surface waters and at shoal edges occupying the whole water column. Spottail shiners are near the bottom onshore on the shoal waters. As the season progresses, spottail shiners move offshore and off the bottom while emerald shiners move on to shoal waters but are most abundant near the surface or midwater areas. Diel horizontal and vertical movements of emerald shiners (mainly in June and July), and spottail shiners' apparent state of inactivity at night, reinforces spatial segregation between the two species. The least amount of spatial segregation was found in September. Similarly the fry of both species are most abundant onshore in September but in July and August the fry of emerald shiners are limnetic and near the surface, and spottail shiners appear to be littoral. The temporal and spatial changes in distribution would support the view of Nilsson

(1967), and Andrusak and Northcote (1971) that spatial segregation between cohabiting species can be of seasonal occurrence.

Both species show food segregation at times. Emerald shiners fed primarily on plankton and spottail shiners on bottom food. This breaks down in July when both species of age I and older shiners feed to some extent on Diptera larvae. Other studies, Nilsson (1960) on arctic char and brown trout, Andrusak and Northcote (1971) on adult cutthroat trout and dolly varden, Gee and Northcote (1963) on leopard and longnose dace, have described a similar situation.

The cause of this segregation could be the result of either interactive or selective segregation (Brian 1956). In the former, slight ecological differences between species in food consumed, or space occupied are magnified by competition and/or predation. Selective segregation is the end process of interactive segregation whereby phylogenetically distant or closely related species have evolved differences, either in sympatry or allopatry, which are great enough to result in segregation. But as Lindström and Nilsson (1962) point out, one must compare closely related species when living allopatrically and sympatrically in different combinations in order to determine the cause of segregation.

However, the differences in position of the mouth and general body form, which are adaptive to differing modes of life, strongly suggests that selective segregation is the cause of ecological differences resulting in the sympatric occurrence of the two species with little interaction.

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APPENDIX A. Statistical Analysis of Fry Distribution.

TABLE 1. The results of the analysis of variance and Duncan's new multiple-range test for the horizontal distribution of emerald shiner fry caught with plankton tow nets at stations 3, 5 and 7 in Lake Manitoba, July-August, 1970. Data in log (x + 1) values.

Date	Source	Degrees of freedom	Mean Square	F value	Treatment means Station 3	5	7	Duncan's test
7/13	Place	2	1.5697	5.2976*	1.1354	0.8833	0.3314	Sta 3 vs. Sta.6*
	Error	29	0.2963					Sta 3 vs. Sta.4*
	Total	31						Sta 4 vs. Sta.6*
7/30	Place	2	0.7645	1.5685				
	Error	18	0.4874					
	Total	20						
8/7	Place	2	0.1341	0.5886				
	Error	30	0.2278					
	Total	32						

*Significant at 5% level.

Ho: no difference ($P < 0.05$) between stations.

TABLE 2. The results of the analysis of variance and Duncan's new multiple-range test for the horizontal distribution of emerald shiner fry caught with the semi-ballon trawl at the surface at stations 3, 6 and 8 in Lake Manitoba, August 10-13, 1970. Data in x + 1 values.

Source	Degrees of freedom	Mean Square	F value	Treatment means Station 3	6	8	Duncan's test
Place	2	1292.062	6.62**	14.17	24.01	38.01	Sta 7 vs. Sta 3*
Time	2	162.895	0.82				Sta 7 vs. Sta 5*
Interaction	4	124.260	0.64				Sta 3 vs. Sta 5
Error	18	195.293					
Total	26						

*Significant at 5% level.

**Significant at 1% level.

Ho: no significant difference between stations and time of day.

Appendix B. The Offshore Gillnetting Series for the Summer of 1970 .

The object of this sampling program was to determine the extent of the offshore distribution (vertical and horizontal) of both species.

Gillnets (previously described) were set at stations 3, 6 and 8 and were fished for two hours in the morning 800-1000 hr, afternoon 1400-1600 hr and the evening 2000-2200 hr during the summer of 1970.

The results of the netting program are given in Table 3. Spottail shiners were found to be more abundant per unit of effort near shore. Emerald shiners, however, were found to be more abundant per unit of effort than spottail shiners and they were distributed throughout the transect.

Numbers of fish for each species were totaled for the depth intervals of 0-2 m and 2-4.5 m for station 6 and 0-2.5 m and 2.5-5.0 m for station 8. Since the vertical distribution of each species was sufficiently consistent throughout the summer, data were pooled for all sets. Chi-square tests were applied to test the null hypothesis that there were no differences ($P < 0.05$) in the numbers of emerald shiners caught between the two depth intervals of station 6 and similarly for station 8. The same null hypothesis was tested for spottail shiners. Emerald shiners were found to be significantly more abundant 0-2 m interval at station 6 and 0-2.5 m interval at station 8. Spottail shiners were significantly more abundant in the 2-4.5 m and 2.5-5.0 m interval at stations 6 and 8 respectively. At station 3 both species were distributed as described in the result section, with emerald shiners present throughout the water column and spottail shiners concentrating in the bottom meter of the water column.

TABLE 3. The catch per unit of effort (numbers/m^2/hr) of both species for the offshore gillnetting program of 1970.

Date and time	Station 3		Station 6		Station 8	
	Emerald	Spottail	Emerald	Spottail	Emerald	Spottail
June 2						
Morning	0.351	0.036	0.136	0.003	0.025	0.0
Afternoon	0.148	0.019	0.112	0.003	0.068	0.004
Evening	0.147	0.322	0.060	0.007		
Average	0.215	0.126	0.103	0.004	0.046	0.002
June 20						
Morning	0.589	0.015	0.204	0.011	0.379	0.005
Afternoon	0.143	0.025	0.124	0.008	0.848	0.010
Evening	0.431	0.117	0.470	0.0	0.598	0.0
Average	0.531	0.052	0.266	0.006	0.608	0.005
July 26-27						
Morning	0.151	0.042	0.190	0.059	0.182	0.0
Afternoon	0.168	0.081	0.031	0.039	0.157	0.006
Evening	0.385	0.992	0.097	0.006	0.147	0.005
Average	0.235	0.372	0.106	0.035	0.162	0.004
August 14-19						
Morning	1.627	0.026	0.794	0.038		
Afternoon	1.268	0.226	0.042	0.007	0.144	0.0
Evening	0.563	0.565	0.635	0.005	0.527	0.033
Average	1.153	0.272	0.491	0.017	0.336	0.016

Appendix C. Feeding Activity of Both Species, Age I and Older.

Feeding activity of emerald and spottail shiners, caught by gillnets 1969-70, was determined as follows:

$$\text{F.A., \%} = \frac{\text{Weight of food content (blotted dry)}}{\text{Total body weight of fish (blotted dry)}} \times 100$$

The feeding activity for the stomach content and for the intestine content was determined. Intestine activity was calculated to determine the rate of food passage through the alimentary tract.

A random sample of 15 fish, including fish with empty stomachs, for each species was selected for each sampling period within a 24 hour period from May to September. The techniques for weighing are previously discussed in method and material. The results are given in Table 4 and age-groups were combined because of similar feeding activity.

TABLE 4. The feeding activity of emerald and spottail shiners (age I and older).

Date, species and time		Sample size	Stomach Mean %	Stomach Range %	Stomach % Empty	Intestine Mean %	Intestine Range %	Intestine % Empty
May 23-24/70								
Emerald	Morning	15	0.025	0-0.210	80.00	0.053	0-0.272	60.0
	Afternoon	4	0.095	0-0.338	50.00	0.079	0-0.145	25.0
	Evening	18	0.064	0-0.199	22.2	0.062	0-0.147	33.3
	Midnight	17	0.080	0-0.335	47.0	0.077	0-0.194	29.4
	Early morning	17	0.033	0-0.168	64.7	0.071	0-0.268	41.2
Spottail	Morning	15	0.070	0-0.592	60.0	0.074	0-0.247	26.7
	Afternoon	16	0.164	0-2.129	81.3	0.105	0-0.491	56.3
	Evening	8	0.033	0-0.261	87.5	0.017	0-0.139	87.5
	Midnight	3	0.054	0-0.161	66.7	0.023	0-0.048	33.3
	Early morning	15	0.019	0-0.206	73.3	0.051	0-0.263	53.3
June 26-27/70								
Emerald	Afternoon	15	1.141	0-2.881	6.7	0.571	0.037-1.379	0.0
	Evening	15	0.193	0-0.773	20.0	0.225	0-0.485	6.7
	Midnight	15	0.172	0-0.965	53.3	0.137	0-0.483	26.7
	Early morning	15	0.708	0-5.012	6.7	0.236	0-1.112	33.3
Spottail	Afternoon	30	1.089	0.043-5.174	0.0	0.394	0.030-1.236	0.0
	Evening	30	0.419	0-1.756	10.0	0.262	0-0.766	13.3
	Midnight	8	0.035	0-0.222	75.0	0.063	0-0.301	50.0
	Early morning	8	0.032	0-0.258	87.5	0.025	0-0.143	62.5

TABLE 4.(cont'd).

Date, species and time		Sample size	Stomach Mean %	Stomach Range %	Stomach % Empty	Intestine Mean %	Intestine Range %	Intestine % Empty
June 20/70								
Emerald	Morning	15	1.129	0.303-2.992	0.0	0.430	0.107-0.741	0.0
	Afternoon	15	0.620	0-1.935	6.7	0.343	0.078-0.806	0.0
	Evening	15	0.359	0-1.966	46.7	0.152	0-0.422	40.0
Spottail	Morning	2	0.579	0-1.159	50.0	0.146	0.138-0.154	0.0
	Afternoon	4	0.060	0-0.128	50.0	0.144	0-0.339	50.0
	Evening	10	0.494	0-1.545	30.0	0.231	0-0.727	20.0
July 25-26/69								
Emerald	Morning	30	1.264	0-3.358	10.0	0.335	0-1.151	6.7
	Afternoon	30	0.467	0-3.696	13.3	0.278	0-0.830	3.3
	Evening	30	0.007	0-0.089	90.0	0.008	0-0.083	83.3
	Midnight	30	0.153	0-2.034	50.0	0.063	0-0.779	66.7
Spottail	Morning	20	1.061	0.193-2.973	0.0	0.375	0-1.119	10.0
	Afternoon	46	1.248	0-4.877	8.7	0.599	0-1.700	8.7
	Evening	53	0.488	0-1.829	18.9	0.353	0-1.110	11.3
	Midnight							

TABLE 4.(cont'd).

Date, species and time		Sample size	Stomach Mean %	Stomach Range %	Stomach % Empty	Intestine Mean %	Intestine Range %	Intestine % Empty
August 21-22/69								
Emerald	Morning	4	0.448	0.195-0.813	0.0	0.353	0.275-0.464	0.0
	Afternoon	24	0.915	0.202-2.309	0.0	0.418	0-1.085	4.2
	Evening	38	1.203	0-2.872	5.3	0.477	0-0.966	5.3
	Midnight	22	0.198	0-1.277	45.5	0.172	0-0.498	9.1
	Early morning	45	0.080	0-0.956	66.7	0.045	0-0.372	57.8
Spottail	Morning	4	0.238	0-0.376	25.0	0.369	0.196-0.473	0.0
	Afternoon	33	0.270	0-1.616	24.2	0.207	0-0.553	24.2
	Evening	16	0.336	0-1.333	50.0	0.287	0-0.898	43.8
	Midnight	2	0.0	-	100.0	0.0	-	100.0
	Early morning	15	0.117	0-0.531	66.7	0.087	0-0.619	73.3
Sept. 8-9/69								
Emerald	Morning	27	0.235	0-1.124	11.1	0.119	0-0.597	40.7
	Afternoon	16	0.586	0-1.108	6.3	0.378	0-0.760	6.3
	Evening	30	0.279	0-0.953	13.3	0.143	0-0.867	23.3
	Midnight	26	0.149	0.043-0.314	0.0	0.141	0-0.493	7.7
Spottail	Morning	6	0.349	0.039-0.772	0.0	0.361	0-0.960	16.7
	Afternoon	21	0.332	0-1.172	33.3	0.389	0-0.992	9.5
	Evening	27	0.463	0-2.289	22.2	0.267	0-0.746	18.5
	Midnight	3	0.0	-	100.0	0.199	0-0.380	33.3

Appendix D. The Diet of Emerald and Spottail Shiners Caught by Gillnets, July 1969 to June 1970.

The determination of diet is essentially as described in the materials and methods except that fish with empty stomachs are excluded and the occurrence of food items in the intestine was recorded. Age groups of both species were pooled unless the percentage of similarity was less than 70%. However, stations and time of day were pooled.

The results are given in Tables 5 and 6 for emerald and spottail respectively.

An explanation of terms used in these tables is as follows:

O. - occurrence - number of stomachs containing the organism.

I.O. - occurrence in intestine - number of intestines containing the organism.

W. - total weight (in mg) of the organisms of all stomachs.

%,W. - percentage by weight - weight of the organism expressed as a percentage of the total weight of food consumed by all the fish.

C.I. - consumption index - for explanation, see materials and methods.

S. - sample size, excluding empty stomachs.

a - adult form

l - larvae

p - pupae

n - nymph

T - trace amount

U.M. - unidentifiable material.

The numbers in parentheses refer to the occurrence of each cladoceran group.

TABLE 5. Diet of emerald shiners, age I and older.

	May 23-24/70				S-41	June 26-27/70				S-132
Food	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Cladocera	9		T			30	31	165	3.2	6.1
Copepoda	32	36	72	81.8	7.5	13	3	34	0.7	1.8
Ostracoda						1	1	T		
Hydracarina	2	2	2	2.3	0.3					
Flying insects, a.	9	5	5	5.7	1.0	3	1	70	1.3	1.3
Odonata, a.						1		25	0.5	0.4
Diptera, a.	2		2	2.3	0.3	105		4626	88.8	60.7
Hemiptera (Corixidae)	1	3	5	5.7	0.4	8	2	135	2.6	2.9
Aquatic Nymph						1		21	0.4	0.4
Ephemeroptera, n.						1	1	21	0.4	0.4
Trichoptera, l.							3			
Diptera, l.	2		1	1.1	0.2	5	2	11	0.2	0.6
Diptera, p.						2	2	7	0.1	0.3
Eggs						2	1	74	1.4	1.1
U.M.	1	3	1	1.1	0.1	2	5	18	0.4	0.5

TABLE 5.(cont'd).

	July 25-26/69				S-70	Aug. 21-22/69				S-92
Food	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Cladocera	5	1	9	0.6	0.8	79	76	1509	81.7	36.0
Copepoda						11		1	0.1	0.3
Amphipoda	1		1	0.1	0.1					
Flying insects, a.						19	11	189	10.2	6.2
Megaloptera, a.						9		42	2.3	2.0
Trichoptera, a.	3		26	1.7	1.1					
Piptera, a.	51	45	505	32.3	19.2					
Hemiptera (Corixidae)	4	2	15	1.0	0.9	1		7	0.4	0.3
Coleoptera	1	1	1	0.1	0.1					
Diptera, I.	18	12	978	62.5	15.9	2		8	0.4	0.4
Diptera, p.	8	8	20	1.3	1.5					
U.M.	3	2	10	0.6	0.7	8	1	92	5.0	2.8

TABLE 5. (cont'd).

	Sept.8-9/69		Emerald Age I		S-112	Sept.8-9/69		Emerald Age II		S-36
Food	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Algae	2	5	11	1.7	0.4	13	19	102	28.7	6.0
Cladocera	110	89	630	97.07	24.9	32	15	194	54.7	13.1
Copepoda	2	T	T							
Amphipoda	1		2	0.3	0.1	1	1	20	5.6	0.8
Flying insect, a.	1		T			1	2	4	1.1	0.3
Diptera, a.						1	1	4	1.1	0.3
Hemiptera (Corixidae)						1		T		
Coleoptera						1		20	5.6	0.8
Trichoptera, I.							1			
U.M.	2		6	0.9	0.3	6	2	11	3.1	1.3

TABLE 6. Diet of Spottail shiners, age I and older.

	May 23-24/70 S-28					June 26-27/70 S-83				
Food	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Cladocera	2	1	3	1.2	.5	1	1	T		
Latona setifera						(1)	(1)	T		
Ostracoda						1	1	T		
Amphipoda	1		T							
Hydracarina	1		1	.4	.2	3	2	1	.04	.2
Flying insects, a.	3	5	21	8.5	1.5					
Diptera, a.						1	1	4	.2	.2
Hemiptera (Corixidae)						1	1	2	.1	.1
Coleoptera	6	4	23	9.4	2.2					
Aquatic nymph						1		5	.2	.2
Ephemeroptera, n.						2	2	87	3.3	1.5
Trichoptera, l.	2		3	1.2	.5	5	5	14	.5	.9

TABLE 6. (cont'd).

	July 25-26/69 S-127					Aug.21-22/69 Spottail Age I S-9				
Food	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Cladocera (<u>Latona</u> sp)	3	1	2	.1	.2	6	4	71	39.9	6.9
Ostracoda	1		T							
Amphipoda	1		1	.02	.1					
Decapoda	1		6	.1	.2					
Hydracarina	14	2	11	.3	1.1					
Odonata, a.	1		6	.1	.2					
Diptera, a.	24	8	174	4.1	5.7					
Hemiptera (Corixidae)	4		15	.4	.7					
Ephemeroptera, n.	4		5	.1	.4					
Trichoptera, l.	12	5	23	.5	1.5	3		3	1.7	.9
Diptera, l.	109	89	3786	89.5	57.0	5		8	4.5	2.1
Diptera, p.	18	2	51	1.2	2.7					
Mollusca						2		12	6.7	1.6
Eggs	1		21	.5	.4					
U.M.	30	7	131	3.1	5.6	6	4.	84	47.2	7.5

TABLE 6. (cont'd).

Food	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Diptera, l.	14	14	167	67.9	9.1	28	20	660	25.0	14.9
Diptera, p.						45	38	1648	62.3	29.9
Eggs						12	5	77	2.9	3.3
U.M.	2	5	28	11.4	1.4	29	28	147	5.6	7.2

TABLE 6. (cont'd).

	Aug.21-22/69		Spottail age II+		S-21	Sept.8-9/69				S-58
Food	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Cladocera	3	2	11	4.8	1.2	1		T		
<u>Latona setifera</u>	(3)	(2)				(1)				
Ostracoda	2		1	.4	.4	1		T		
Amphipoda						1		14	1.1	.5
Flying insect, a.	2		43	18.6	2.0	2	1	4	.3	.4
Diptera, a.						1		1	.1	.1
Hemiptera (Corixidae)	1		22	9.5	1.0	1	1	15	1.2	.5
Trichoptera, l.	6	5	9	3.9	1.5	23	18	27	2.1	3.3
Diptera, l.	12	8	67	29.0	6.2	40	29	554	42.5	19.5
Diptera, p.	2		8	3.5	.9					
Mollusca	3	1	28	12.1	2.0	11	8	172	13.2	5.7
U.M.	10	3	42	18.2	4.5	34	31	518	39.7	17.4

APPENDIX E. Relationship between Gonad Weight and Body Weight of Adult Male and Female Shiners.

The relationship between gonad weight and body weight of each fish of each species was determined as follows:

$$\frac{\text{Gonad weight (blotted dry)}}{\text{Total body weight (blotted dry)}} \times 100$$

The two species of shiners caught by gillnets in 1969-70 were used for this determination. Specimens used for stomach analysis were those used for gonad analysis. Table 7 gives the results as mean percent of gonad weight per total body weight.

TABLE 7. The relationship of gonad weight to body weight of adult male and female emerald and spottail shiners, expressed as a mean of the percent of gonad weight to total body weight.

Month	Female No.	Female Mean, %	Female Range, %	Male No.	Male Mean, %	Male Range, %
	Emerald Shiner F.L.* > 55 mm					
May/70	44	2.93	0.80-4.79	39	0.44	0.13-1.29
June/70	113	13.80	3.71-24.99	66	0.79	0.39-1.37
July/69	46	6.11	1.08-19.23	74	0.64	0.16-1.37
Aug./69	65	1.59	0.76-2.76	68	0.32	0.09-0.58
	Spottail Shiner F.L.* > 66 mm					
May/70	39	6.42	4.42-9.35	53	1.08	0.09-2.22
June/70	48	6.45	0.97-17.96	14	0.85	0.37-1.67
July/69	38	1.41	0.97-2.20	14	0.28	0.20-0.52
Aug./69	39	1.79	1.06-2.55	15	0.29	0.16-0.46

*F.L. is the fork length.

APPENDIX F. Results of Trawling Program for Shiners, 1969-70.

A trawling program was adopted in 1969-70 in order to collect additional information on the distribution and abundance of emerald and spottail shiners.

A modified semi-ballon trawl (see materials and methods for description) was used to sample the top and bottom 1.2 m of the water column. The sampling program followed is described in Table 8. The emerald and spottail shiners were sorted from the samples, enumerated and preserved in 10% formalin for length frequency and sexing.

The results of the fork length measurements are given in Table 9. All fish collected in 1969 were measured and all spottail shiners collected in 1970. For emerald shiners collected in 1970, only the first day of a complete transect study was used since numbers of fish collected for each replicate were very large.

The numbers collected and relative abundance of both species of different age groups are given in Tables 10 and 11 respectively, and statistical analysis of some of the data is presented in Table 12.

TABLE 8. The sampling program adopted for the semi-ballon trawl, 1969-70.

Date	Stations sampled	Number of 5 min tows/station		
		Morning	Afternoon	Evening
August 19-25/69	3	1	4	6
	6	3	5	6
June 13-15/70	3, 6, 8	3	3	3
July 20-23/70	3, 6, 8	3	2	2
August 10-13/70	3, 6, 8	3	3	3
Sept. 16-18/70	3	2	2	-
	6	1	1	-

TABLE 9. Length-frequency of emerald and spottail shiners collected by the semi-ballon trawl in 1969-70. (Sexes combined, modes are indicated by asterisks.)

Fork-length (millimeters)	Emerald Shiners Aug. 1969	Emerald Shiners June 1970	Emerald Shiners July 1970	Emerald Shiners Aug. 1970	Emerald Shiners Sept. 1970	Spottail Shiners Aug. 1969	Spottail Shiners June 1970	Spottail Shiners July 1970	Spottail Shiners Aug. 1970	Spottail Shiners Sept. 1970
12 - 13.9				2						
14 - 15.9				3						
16 - 17.9				13	2					
18 - 19.9				58	9			10*		
20 - 21.9				257	24	7		8		
22 - 23.9	10*			611	36	12		6	1	
24 - 25.9	7			925*	63	24		5	2	
26 - 27.9	6	6		547	68	50		3	4	
28 - 29.9		23	1	222	46	107		2	22	
30 - 31.9		63	1	34	143	119	1		47	1
32 - 33.9		196	7	3	326	139*	1		66	
34 - 35.9		230*	31		333*	121	2		77*	3
36 - 37.9		125	96		142	120			42	1
38 - 39.9		53	194		27	69			42	
40 - 41.9		10	222*		3	61	1		20	1
42 - 43.9			162	1	1	23	3	2	1	1
44 - 45.9			131	6		11	4*	7	2	
46 - 47.9			82	10	1		2	11	3	
48 - 49.9	2	1	50	24	6	3		16		
50 - 51.9	1		16	29	15			15	1	
52 - 53.9		4	13	37*	24	5		27	1	
54 - 55.9		5		28	49	6		35*	6	
56 - 57.9	2	7		23	71*	10		26	6	
58 - 59.9	17	9	2	10	66	22		27	21	
60 - 61.9	41	24	5	2	39	22		17	30	
62 - 63.9	55	59	19	1	10	42*	1	16	47	
64 - 65.9	72*	118*	45	5	12	40		15	75*	
66 - 67.9	53	92	70	13	15	33		5	52	

TABLE 9.(cont'd).

Fork-length (milli-meters)	Emerald Shiners Aug. 1969	Emerald Shiners June 1970	Emerald Shiners July 1970	Emerald Shiners Aug. 1970	Emerald Shiners Sept. 1970	Spottail Shiners Aug. 1969	Spottail Shiners June 1970	Spottail Shiners July 1970	Spottail Shiners Aug. 1970	Spottail Shiners Sept. 1970
68 - 69.9	58	113	85*	33	49*	17		1	62	1
70 - 71.9	43	100	84	34*	44	6			57	1
72 - 73.9	27	70	58	30	28	10	1	3	31	
74 - 75.9	21	51	30	23	31	9		4	24	2
76 - 77.9	14	20	19	10	17	10		4	16	2
78 - 79.9	3	19	17	11	4	15*		9*	3	
80 - 81.9	3	6	8	5	5	14	1	5	7	1
82 - 83.9			1	1	3	8	1	4	15*	
84 - 85.9						11	1	7	12	1
86 - 87.9						7	1	3	11	2
88 - 89.9						5		6	5	3
90 - 91.9						3	2	2	5	
92 - 93.9						1	3*		2	2
94 - 95.9						1		2*	1	
96 - 97.9						1		1	4*	
98 - 99.9							1			1
100 -101.9										
Total	435	1404	1449	3071	1712	1164	26	304	823	23

TABLE 10. The total monthly numbers and average numbers per 5 min tow of the different age groups of both species collected in 1970.

Date	Age	Station 3 Surface	Station 3 Bottom	Station 6 Surface	Station 6 Bottom	Station 8 Surface	Station 8 Bottom	Average Surface	Average Bottom
June 13-15									
Emerald Shiner	Age 0								
	I	615	2	563	2	55	78	45.7	3.0
	II+	320	390	102	455	15	267	16.2	41.2
Spottail Shiner	Age 0								
	I	1	32	1	7		3	< 0.1	1.6
	II+	1	55		9		1	< 0.1	2.4
July 20-23									
Emerald Shiner	Age 0								
	I	203	5	421	18	1417	86	97.2	5.2
	II+	139	83	34	172	75	201	11.8	21.7
Spottail Shiner	Age 0		34	1				< 0.1	1.6
	I		167		49		3		10.4
	II+		24		20		6		2.4

TABLE 10.(cont'd).

Date			Station 3 Surface	Station 3 Bottom	Station 6 Surface	Station 6 Bottom	Station 8 Surface	Station 8 Bottom	Average Surface	Average Bottom
Aug. 10-13										
Emerald Shiner	Age	0	2935	71	7169		14,226	4	901.1	2.8
		I	61	422	160	324	2	410	8.3	42.8
		II^+	42	205	11	534		275	1.9	37.6
Spottail Shiner	Age	0	7	317					0.3	11.7
		I	1	408		6		1	<0.1	15.4
		II^+		59		5		2		2.4
Sept. 16-18										
Emerald Shiner	Age	0	863	242	44	76			151.2	53.0
		I	29	11		239			4.8	41.7
		II^+	10	3	2	187			2.0	31.7
Spottail Shiner	Age	0		7						1.2
		I		2		2				0.7
		II^+		7		4				1.8

TABLE 11. The relative abundance of different age groups of emerald and spottail shiners taken in 81 surface and 81 bottom tows, 1970.

	Total # collected		Percent of total catch		Av. number /tow		No. of tow with		Percent frequency of occ.	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Emerald										
Age 0	25,237	393	85.48	6.56	311.57	4.85	31	8	38.27	9.88
I	3,526	1,597	11.94	26.65	43.53	19.72	52	37	64.20	45.68
II^{+}	750	2,772	2.54	46.26	9.26	34.22	52	65	64.20	80.25
Spottail										
Age 0	8	358	<0.1	5.97	0.10	4.42	4	17	4.94	20.99
I	3	680	<0.1	11.35	0.04	8.40	3	46	3.70	56.79
II^{+}	1	192	<0.1	3.21	0.01	2.37	1	45	1.23	55.56
Total	29,525	5,992								

TABLE 12. The analysis of variance and Duncan's new multiple-range test on some of the trawling data. The null hypothesis tested was, no significant difference ($P < 0.05$) between stations and time of day of collection. Duncan's test was tested for significance ($P < 0.05$) of the treatment means for stations and time of day. The horizontal bar underlining station numbers in the Duncan's test column signifies no significant difference between compared stations.

Species of shiner, age and date	Transformation	Source	Degrees of freedom	Mean square	F Value	Duncan's test
Emerald Age I						
June 13-15	log(x+ 1)	Place	2	1.305	1.86	Sta 3, 6, 8
		Time	2	0.212	0.30	
		Interaction	4	0.778	1.11	
		Error	18	0.702		
		Total	26			
July 20-22	log(x + 1)	Place	2	3.968	12.74**	Sta 3, 6, 8
		Time	2	0.287	0.92	
		Interaction	4	0.412	1.32	
		Error	9	0.312		
		Total	17			

TABLE 12.(cont'd).

Species of shiner, age and date	Transformation	Source	Degree of freedom	Mean square	F Value	Duncan's test
Spottail Age I June 13-15	log(x + 1)	Place	2	0.574	11.96**	Sta 3, 6, 8
		Time	2	0.015	0.32	
		Interaction	4	0.117	2.44	
		Error	18	0.048		
		Total	26			
July 20-22	none	Place	1	1045.333	15.15**	Sta 3, 6
		Time	2	183.083	2.65	
		Interaction	2	179.083	2.60	
		Error	6	69.000		
		Total	11			
Spottail Age II+ June 13-15	$\sqrt{x + 1}$	Place	2	4.959	11.84**	Sta 3, 6, 8
		Time	2	0.330	0.79	
		Interaction	4	1.004	2.40	
		Error	18	0.419		
		Total	26			
July 20-22	log(x + 1)	Place	2	0.271	4.12	Sta 3, 6, 8
		Time	2	0.087	1.32	
		Interaction	4	0.089	1.36	
		Error	9	0.066		
		Total	17			

*significant at 5% level.
**significant at 1% level.

Appendix G. The Diet of Emerald and Spottail Shiners Caught by Semi-ballon Trawl, 1970.

The diet of each age-group of both species (age determined by length-frequencies, see Appendix F) was determined for the trawl catches, collected from June to September, 1970.

A sample of not more than fifteen fish (excluding fish with empty stomachs) per station (depth and time of day pooled) was selected for each available age-group of each species. The method of food analysis and calculations were essentially the same as described in the materials and methods except that weight of individual stomachs was not determined and the occurrence of food items in the intestine was recorded. Stations were pooled when a percentage similarity in diet of 75% and over was obtained. Otherwise the stations examined were kept separate.

The results are given in Tables 13 to 15 for emerald shiners and Tables 16 to 18 for spottail shiners.

For explanation of terms used in the tables, see Appendix D.

TABLE 13. Diet of age 0 emerald shiners.

Food	July 30/70	Sta 3 + 7*			S-25	Aug.10-12/70		Sta 3 + 8		S-50
	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Cladocera	25	25	17	100.0	4.1	50	50	40	100.0	6.3
<u>Daphnia</u> sp.						(45)	(39)			
<u>Diaphanosoma</u> sp.	(20)	(21)				(32)	(28)			
<u>Leptodora kindti</u>						(4)	(2)			
Others	(5)	(3)				(2)	(1)			
Copepoda	3	1	T			1		T		
Ostracoda										

Food	Sept 16-18/70	Sta 3 + 6			S-50
Cladocera	40	40	191	99.5	12.4
<u>Daphnia</u> sp.	(40)	(31)			
<u>Diaphanosoma</u> sp.	(31)	(29)			
<u>Leptodora kindti</u>	(2)	(1)			
Others	(25)	(24)			
Copepoda	17		1	0.5	0.6
Ostracoda					

*Fry collected by the plankton net.

TABLE 14. Diet of age I emerald shiners.

Food	June 13/70		Station 3		S-15	June 13/70		Station 8		S-15
	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	6.3
Cladocera	10	8	12	16.9	2.8	6	3	T		
Copepoda	8	5	23	32.4	3.5	3	2	T		
Diptera, a.	8	5	21	29.6	3.4	13	15	23	100.0	4.5
Fish Fry	2		12	16.9	1.3					
U.M.	1	1	3	4.2	0.5					
Food	**July 20/70**		**Station 3 + 8**		**S-30**	**Aug.10-12/70**		**Station 3 + 8**		**S-30**
Cladocera	29		309	99.4	17.3	30	30	191	100.0	13.8
<u>Daphnia</u> sp.						(30)	(30)			
<u>Diaphanosoma</u> sp.										
<u>Leptodora</u> <u>kindti</u>						(2)				
Others										
Copepoda	2		T			1		T		
Diptera, a.	2	1	2	0.6	0.4					

TABLE 14.(cont'd).

Food	Sept.16-18/70	Station 3 + 6	S-30		
	O.	I.O.	W.	%,W.	C.I.
Cladocera	30	30	303	100.0	17.4
Daphnia sp.	(30)	(27)			
Diaphanosoma sp.	(26)	(25)			
Leptodora kindti	(7)	(4)			
Others	(16)				
Copepoda	9		T		
Diptera, a.					

TABLE 15. Diet of age II^{+} emerald shiners.

Food	June 13/70		Station 3		S-15	June 13/70		Station 8		S-15
	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Cladocera	7	5	68	11.6	5.6					
<u>Leptodora</u> <u>kindti</u>	(7)	(5)								
Copepoda	13	11	448	76.7	19.7	1		4	1.1	0.5
Araneae						2		3	0.8	0.6
Diptera, a.	3	5	65	11.1	3.6	12	10	200	53.2	12.7
Coleoptera							1			
Trichoptera, l.						1	1	2	0.5	0.4
Diptera, l.	1		2	0.3	0.4	2	2	55	14.6	2.7
Diptera, p.	1		T			3	6	74	19.7	3.9
Mollusca						1		38	10.1	1.6
Fish Fry	2		1	0.2	0.4					
Food	**July 20/70**		**Sta 3 + 8**		**S-30**	**Aug. 10-12/70**		**Sta 3 + 8**		**S-30**
Cladocera	22	19	499	47.1	19.1	30	30	879	100.0	29.7
<u>Daphnia</u> sp.		(14)				(29)	(28)			
<u>Diaphanosoma</u> sp.		(5)				(1)				
<u>Leptodora</u> <u>kindti</u>						(9)	(3)			
Others										
Copepoda	6		T			4		T		
Flying insect, a.										
Diptera, a.	11	10	401	37.8	12.1					
Diptera, l.	1		20	1.9	0.8					
Diptera, p.	7	7	140	13.2	5.7					

TABLE 15.(cont'd).

Food	Sept. 16-18/70 Sta 3 + 6 S-30									
	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Cladocera	30		708	99.9	26.6					
Daphnia sp.	(18)	(14)								
Diaphanosoma sp.	(24)	(15)								
Leptodora kindti	(17)	(11)								
Others	(15)	(11)								
Copepoda	12		1	0.1	0.9					
Flying insect, a.		2								

TABLE 16. Diet of age 0 spottail shiners.

Food	July 20-22/70 Station 3 S-25					Aug. 10-12/70 Station 3 S-25				
	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Oligochaetes	2		3	10.0	0.5					
Cladocera	6	4				22	22	73	100.0	8.0
Daphnia sp.						(22)	(22)			
Latona setifera	(6)	(4)	2	6.7	0.7	(3)	(3)			
Others						(3)	(1)			
Copepoda						2		T		
Ostracoda	3	3	1	3.3	0.4		1			
Diptera, l.	23	15	18	60.0	4.1					
Diptera, p.	3	3	5	16.7	0.8					
U.M.	2	4	1	3.3	0.3					

Food	Sept 16-18/70 Station 3 S-7				
Cladocera	5	3	14	73.7	3.2
Latona setifera	(3)	(2)			
Others	(2)	(1)			
Ostracoda	4	5	5	26.3	1.7

TABLE 17. Diet of age I spottail shiners.

Food	June 13/70		Station 3		S-7	July 20/70		Station 3		S-15
	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Cladocera						1		T		
Daphnia sp.						(1)				
Ostracoda						8	8	75	27.2	6.3
Trichoptera, l.						1		T		
Diptera, l.	7	7	78	100.0	8.8	2	2	4	1.5	0.7
Diptera, p.						6	6	148	53.6	7.7
Eggs						2		31	11.2	2.0
U.M.						3	2	18	6.5	1.9
Food	**July 20/70**		**Station 6**		**S-15**	**Aug.10-12/70**		**Station 3**		**S-15**
Cladocera						4		27	9.4	2.7
Daphnia sp.						(2)	(2)			
Latona setifera						(2)				
Others						(1)				
Ostracoda	3	2	27	12.9	2.3	5	4	112	39.0	6.1
Diptera, a.	1		4	1.9	0.5					
Trichoptera, l.	2	1	5	2.4	0.8	1		1	0.4	0.3
Diptera, l.	10	11	121	58.2	9.0	8	9	123	42.9	8.1
Diptera, p.	6	2	29	13.9	3.4	2	1	5	1.7	0.8
Mollusca	3	4	17	8.2	1.8					
U.M.	2	3	5	2.4	0.8	4	2	19	6.6	2.3

TABLE 18. Diet of age II^{+} spottail shiners.

Food	June 13/70 Station 3 S-6					July 20/70 Station 3 S-12				
	O.	I.O.	W.	%,W.	C.I.	O.	I.O.	W.	%,W.	C.I.
Ephemeroptera, n.	4	3	545	92.1	19.1	1	1	5	0.9	0.7
Trichoptera, l.	2	2	3	0.5	1.0	1	3	8	1.3	0.8
Diptera, l.	4		24	4.0	4.0	6	5	124	19.8	7.9
Diptera, p.	1	1	14	2.4	1.5	4	4	162	25.9	7.4
Eggs	1	3	6	1.0	1.0	4	1	307	49.1	10.1
U.M.		2				2	1	19	3.1	1.8
Food	**July 20/70 Station 6 S-15**					**Aug.10-12/70 Station 3 S-14**				
Cladocera						3		16	5.1	1.9
Daphnia sp.						(2)	(1)			
Latona setifera						(1)				
Ostracoda						5	5	73	23.3	5.1
Trichoptera, l.	8	13	75	13.7	6.3	1	1	31	9.9	1.5
Diptera, l.	13	7	251	45.8	14.8	7	7	101	32.3	7.1
Diptera, p.	4	3	40	7.3	3.3	1		11	3.5	0.9
Mollusca	8	3	176	32.1	9.7	1	1	47	15.0	1.8
U.M.	1		6	1.1	0.6	2	2	34	10.9	2.2

TABLE 18. (cont'd).

Food	Sept.16-18/70 Sta 3 + 6 S-14				
	O.	I.O.	W.	%,W.	C.I.
Cladocera	1	2	1	0.3	0.3
Ostracoda	1	1	1	0.3	0.3
Diptera, l.	11	9	330	98.8	16.1
Mollusca	1		T		
U.M.	2	4	2	0.6	0.5

APPENDIX H. Analysis of Day and Night Gillnetting and Trawling of Spottail Shiners.

The results are given in Tables 19 and 20.

TABLE 19. Summary of chi-square tests for day and night gillnet catches of spottail shiners of July 15-16, 1970.

	Mesh size, mm	Number of fish	Degrees of freedom	Chi-square	Ho: that the proportions are not different*
Proportions of spottails day and night catch station 2 and 3	12.7	Day 22 Night 0	1	22.0	Reject H_o
Proportions of spottails day and night catch station 2 and 3	19.0	Day 15 Night 7	1	2.9	Accept H_o
Proportions of spottails day and night catch station 2 and 3	12.7 and 19.0	Day 37 Night 7	1	20.4	Reject H_o

*significant at 5% level.

TABLE 20. Test for the independence in 3 x 2 table of the day and night trawl catch of spottail shiners. The null hypothesis tested was no difference ($P < 0.05$) between the ratio of day and night trawl catch of spottail shiners, from replicate to replicate.

Replicates	Day	Night	Total	$\hat{p}$ = Day/Total	$\hat{p}$ x Day
1	57	89	146	0.391	22.287
2	74	40	114	0.649	48.026
3	136	18	154	0.883	120.088
Total	267	147	414		190.401

$$\bar{\hat{p}} = 267/414 = 0.645$$

$$\chi^2 = \frac{\sum \hat{p} \times \text{Day} - \bar{\hat{p}} \times \sum \text{Day}}{\bar{\hat{p}}(1 - \bar{\hat{p}})} = \frac{190.401 - 172.215}{0.645\ (0.355)} = 79.415^{*}$$

*significant at 5% level.

Appendix I. Parasitism of Spottail Shiners by the Plerocercoid Larva of *Ligula intestinalis*

Spottail shiners were observed to be infected with *Ligula intestinalis*, the plerocercoid larval stage. To determine the extent of parasitism of the cestode, all spottail shiners collected by gillnets from July 1969 to June 1970 were examined in the following way: numbers of larva, weight of total number of larva (blotted dry) and weight of the gonads were recorded for each infected fish. The results are given in Tables 21, 22 and 23. Spottail shiners which were collected with the semi-ballon trawl in 1970 were also examined. However, only the percent occurrence and number of larva per fish of age I and II^+ were recorded. (See Table 24)

The plerocercoid larva was found in the coelom. In most cases it was loose or unattached to any organ in the coelom. However, in some cases it was coiled around the digestive tract and in two cases it had pushed its head into the stomach, puncturing it. In some fish the larva were surrounded by tissue which may have been a host tissue response.

It was observed that during the spawning season, infected adult (age II^+) spottail shiners had suppressed gonad development (Table 23). One or both ovaries in some were completely suppressed in development and in one case the ovaries had hardened. Similarly in males the testes were sometimes suppressed so that only a thin whitish thread could be detected.

Other parasites found in spottail shiners were the nematode Rhabdochona cascadilla (identified by Fred Austin) which was also found in emerald shiners, the Palaeacanthocephala, Leptorhychoides thecatus (identified by Robert Baron) and Argulus sp. In emerald shiners a small leech Myzobdella moorei (identified by Dr. R. W. Davis) was found attached in some on the operculum and in others on the pectoral fin.

TABLE 21. The occurrence of the plerocercoid larvae, Ligula intestinalis, in spottail shiners caught by gillnets, 1969-70.

Date and station	Numbers infected	Sample size	Percent occurrence	Number of larvae/fish
May 23-24/70				1.1
Station 1	5	49	10.2	
2	8	44	18.2	
3	1	37	2.7	
5	0	3	0.0	
Total	14	133	10.5	
June 26-27/70				1.2
Station 1	20	189	10.6	
2	29	159	18.2	
3	11	41	26.8	
5	1	5	20.0	
Total	61	394	15.5	
July 25-26/69				1.2
Station 1	9	43	20.9	
2	15	108	13.9	
3	15	114	13.2	
Total	39	265	14.7	
Aug. 21-22/69				1.0
Station 1	2	11	18.2	
2	10	33	30.3	
3	4	30	13.3	
5	3	22	13.6	
Total	19	96	19.8	
Sept. 8-9/69				1.3
Station 1	1	8	12.5	
2	4	22	18.2	
3	3	22	13.6	
5	4	43	9.3	
Total	12	95	12.6	
Grand Total	145	983	14.8	1.1

TABLE 22. The relationship of body weight to weight of the plerocercoid larvae, *Ligula intestinalis*, in spottail shiners caught by gillnets.

	Numbers of fish	Wt. of larvae (mg.) Mean	Wt. of larvae (mg.) Range	Larvae Wt./Body Wt., % Mean	Larvae Wt./Body Wt., % Range
May 23-24/70	14	239.7	68-835	4.09	1.39-13.59
June 26-27/70	46	233.21	10-1114	4.31	0.21-17.24
July 25-26/69	17	285.8	8-1459	4.38	0.41-16.32
Aug. 21-22/69	9	382.22	34-1103	5.21	0.49-11.79
Sept. 8-9/69	12	168.0	8-555	3.05	0.15-10.83

TABLE 23. The relationship of gonad weight to total body weight of infected and non-infected adult (age II^+) spottail shiners caught by gill-nets in 1970. [No. denotes sample size.]

Date and sex	Gonad Wt./Body Wt., %					
	Infected			Non-infected		
	No.	Mean	Range	No.	Mean	Range
May 23-24						
Female	7	5.08	3.19-6.22	39	6.42	4.42-9.35
Male	9	0.80	0.12-1.16	53	1.08	0.09-2.22
June 26-27						
Female	16	1.39	0.97-2.22	48	6.45	0.97-17.96
Male	9	0.26	0.15-0.38	14	0.85	0.37-1.67

TABLE 24. The occurrence of *Ligula intestinalis* in spottail shiners of age I and II^{+}, collected by the semi-ballon trawl, 1970.

Date and age of fish	Numbers infected	Sample size	Percent occurrence	Number of larvae/fish
June 13				
Age I	2	14	14.3	1.3
Age II^{+}	3	12	25.0	1.0
Total	5	26	19.2	1.2
July 20-22				
Age I	55	220	25.0	1.2
Age II^{+}	16	50	32.0	1.4
Total	71	270	26.3	1.2
Aug. 10-12				
Age I	108	434	24.9	1.3
Age II^{+}	15	62	24.2	1.3
Total	123	496	24.8	1.3
Sept.16-18				
Age I	5	8	62.5	1.0
Age II^{+}	6	8	75.0	1.3
Total	11	16	68.8	1.2
Total				
Age I	170	676	25.2	1.3
Age II^{+}	40	132	30.3	1.3
Grand Total	210	808	25.9	1.3