METAZOAN PARASITES OF FUNDULUS HETEROCLITUS (LINNAEUS, 1766) FROM INSULAR NEWFOUNDLAND

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METAZOAN PARASITES OF *FUNDULUS HETEROCLITUS* (LINNAEUS, 1766) FROM INSULAR NEWFOUNDLAND

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ABSTRACT

Seven hundred and twenty-eight fish of five species (cyprinodonts and gasterosteids) from four locations on the west coast of insular Newfoundland were examined for metazoan parasites, using conventional parasitological techniques.

Eleven genera of parasites were recovered (two Monogenea, four Digenea, two Cestoda, one Acanthocephala, two parasitic Crustacea). Six genera of parasites were recorded from *Fundulus heteroclitus*, 1 genus from *F. diaphanus*, 5 genera from *Pungitius pungitius*, 7 genera from *Gasterosteus aculeatus* and 4 genera from *Apeltes quadracus*. Two Canadian records, 2 Newfoundland records and 3 host records were noted.

It was found that the parasite burden of *F. heteroclitus* was not homogenous for sample areas, sex of host (Monogenea), and length of host (*Gyrodactylus prolongis, G. stephanus, Urocleidus angularis, Homalometron pallidum* and *Proteocephalus* sp.). Significant differences in the preferred site of attachment of the three species of Monogenea were noted. Seasonal variations in incidence and intensity were noted for all parasite species of *F. heteroclitus*. No seasonal differences in length of worms and fecundity were observed.

Seasonal cycles were related to seasonal variations in selected environmental factors, and possible changes in host diet and physiology.

Significant differences in the occurrence of particular species of parasites in cyprinodonts and gasterosteids were noted.

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INTRODUCTION

The genus *Fundulus* (fam. Cyprinodontidae) is widespread throughour eastern North America (Bigelow and Schroeder, 1953), where it has diversified into a wide variety of species and subspecies, as shown by Miller (1955) and Brown (1957). Two species of this genus, the mummichog *Fundulus heteroclitus* (Linnaeus, 1766), and the banded killifish *Fundulus diaphanus* (Le Sueur) have been recorded from the west coast of Newfoundland (Halkett, 1913; Johansen, 1926; Scott and Crossman, 1964; Leim and Scott, 1966; Van Vliet, 1970; Scott and Crossman, 1973). Hudson (1973, pers. comm.) has extended the known northern and eastern geographic range limits of *F. heteroclitus* and the known eastern limits of *F. diaphanus*.

The parasitofauna of members of this genus has been studied, primarily in the United States, from a qualitative aspect with regard to both naturally occurring parasite burdens and artificially induced infections under laboratory conditions (Dillon, 1966). The only reports of parasites from members of the genus in Eastern Canada are those of Gowanloch (1927) from New Brunswick, and Fantham and Porter (1947) from Nova Scotia. Check lists of parasites from members of the genus are given by Dillon (1966) and Hoffman (1967).

In May 1973, a study was initiated to determine the occurrence, distribution and seasonal dynamics, in relation to selected environmental factors, of the metazoan parasites of *F. heteroclitus* and *F. diaphanus* in the insular waters of Newfoundland. The opportunity was also taken to compare the parasitofauna of *Fundulus* species with that of other fish genera (fam. Gasterosteidae) collected in the same sample areas.

MATERIALS AND METHODS

Sampling was carried out at approximately monthly intervals in four areas.

A. Sample Areas

The sample areas, or parasite "macro-environments" (Pavlovskii, 1934), were chosen on the basis of four criteria, namely, as being representative of the known range (recorded and unrecorded) of *F. heteroclitus* in Newfoundland; to represent one area where *F. heteroclitus* and *F. diaphanus* co-exist; to exhibit as wide a range of environmental variation as possible; and to be easily accessible by road for rapid sampling in the short time periods available. Sampling was only possible in the period May-December 1973, due to adverse environmental conditions in the other months.

The insular locations of the sample areas are shown in Fig. 1, and details of the individual areas in Plates (I-IV).

Area 1. Clark's Brook (Plate I). (49°46'N, 58°08'W). This sample area, together with Area 2, extends the previously recorded northern geographic limits of *F. heteroclitus*, described by Van Vliet (1970) as Port-au-Port Bay. Both Areas 1 and 2 were discovered while investigating local reports of *F. heteroclitus* in the Bay of Islands area.

F. heteroclitus was found extensively throughout all parts of the brook estuary, with particularly large concentrations in a semi-stagnant backwater. The water was approximately 1 m. deep with a mud

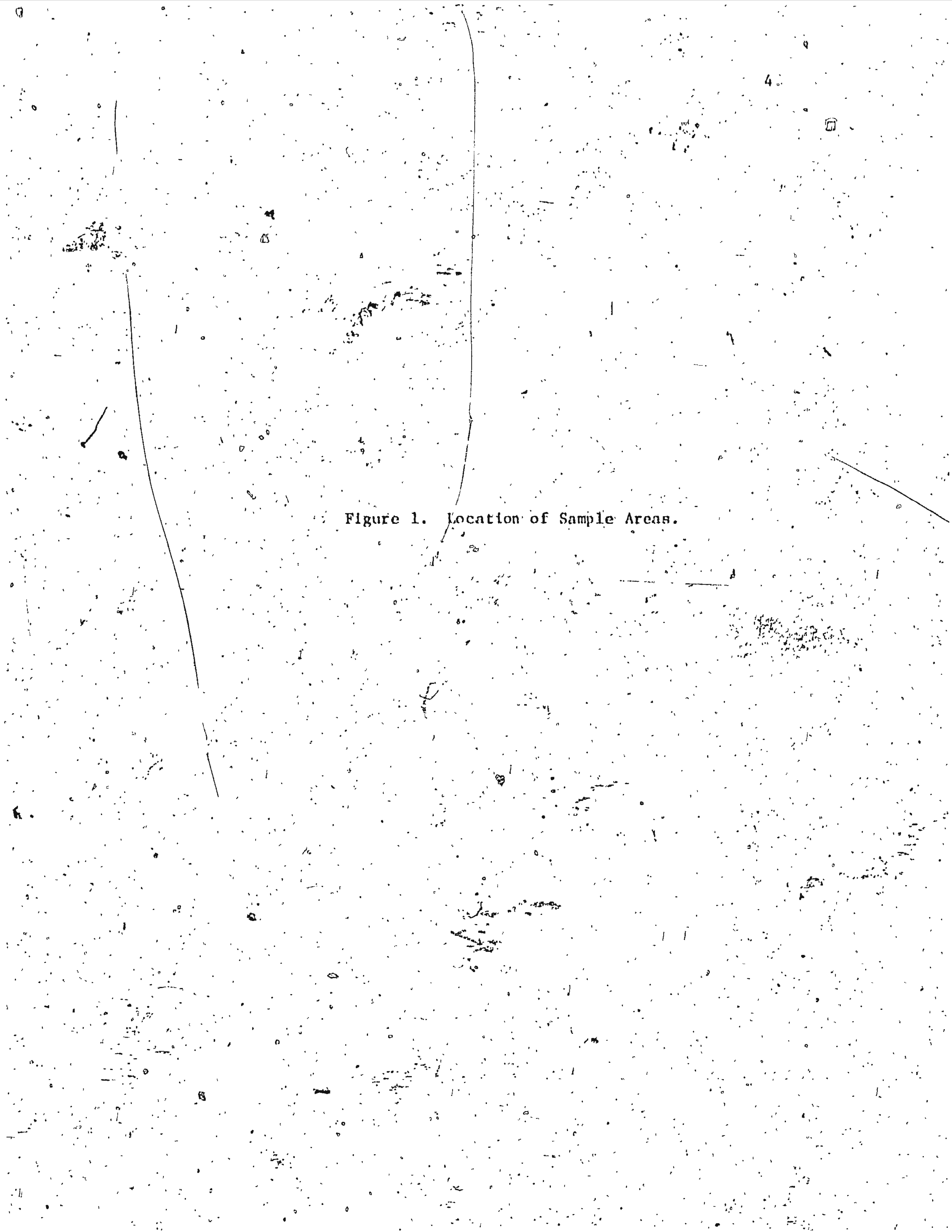

Figure 1. Location of Sample Areas.

2
1
4
3
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48km.

bottom, which was practically devoid of vegetation. The backwater was apparently isolated from tidal action, and in July the outlet from the area had been blocked, probably by local children, thus effectively producing a closed population. Gasterosteids were also abundant. In December, the water was frozen to a depth of approximately 10 cms.

Area 2. Frenchman's Cove. (Plate II). (49°03'N, 58°11'W). The sample area was a pond 1-2 m. deep in a grass meadow, situated approximately 75 metres from the low water mark. The pond was subject to tidal influence during high fall and winter tides. There was slight drainage from the pond via a small overgrown stream, which dried up in the summer months again effectively producing a closed population for this period of time. Gasterosteids were present but scarce. According to the owner of the property in which the pond was situated, *F. heteroclitus* was introduced into the pond from the Codroy Valley, approximately twenty years previously to provide food for domesticated ducks. The pond was frozen to a depth of approximately 10 cms. in December.

Area 3. Mummichog Park. (Plate III). (47°46'N, 59°16'W). Located approximately 45 km. north-east of Port-aux-Basques in the Codroy Valley, this Provincial Park is constructed around an inlet of the Little Codroy River known as Muddy Hole. A small lagoon extension of Muddy Hole supports a population of *F. heteroclitus*. The depth of the water in the lagoon is from 1-3 m. with a soft mud bottom, from which grows dense clumps of *Zostera* sp. The lagoon contains large concentrations of bacteria which are said to be responsible for the

Plate I. Clark's Brook Sample Area.

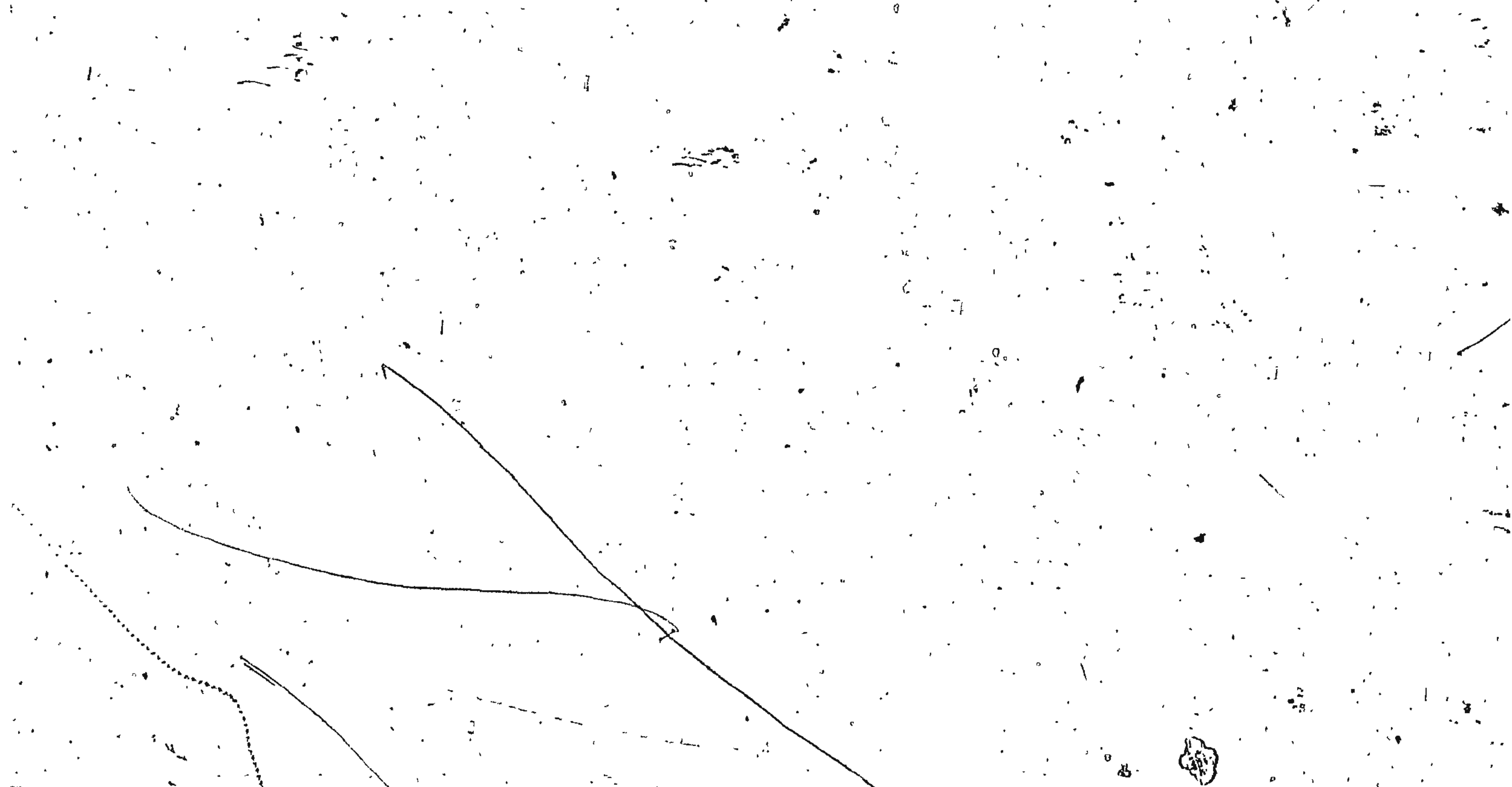
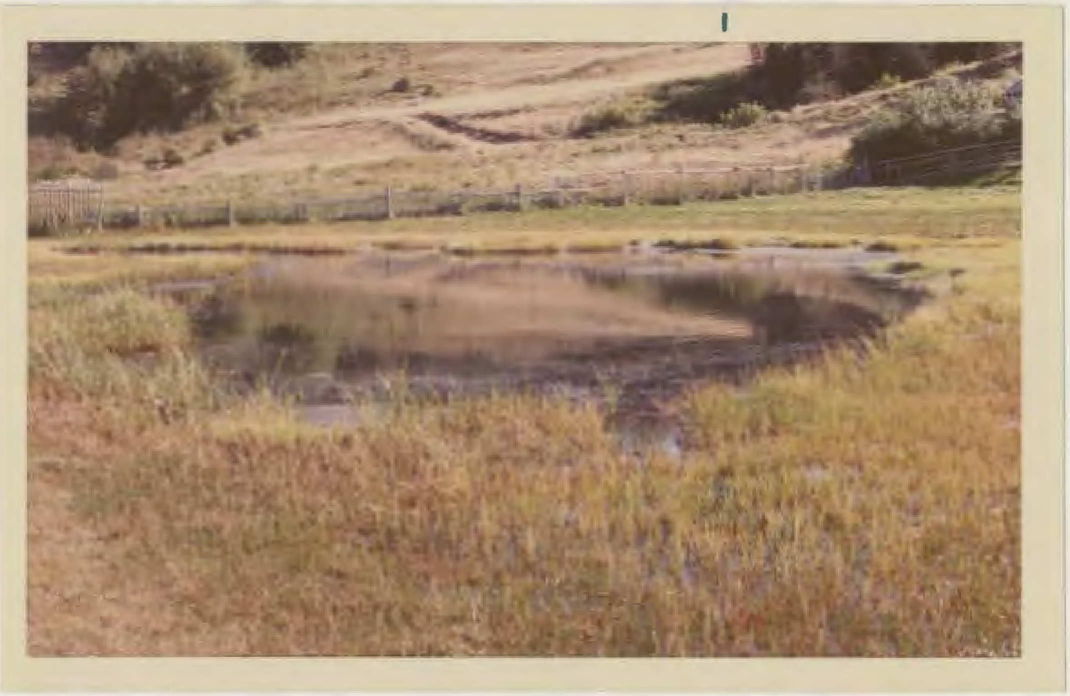


Plate II. Frenchman's Cove Sample Area.



high rate of decay and odour produced during the summer months. (Anon, Pub. 6). In June, algal growth had occurred to such an extent that the surface of the lagoon was covered with dense floating mats, which eventually united to form a thick algal scum around the shoreline. Analysis of the algal scum (Whittick, pers. comm., 1973) revealed the presence of Chlorophyceae, (*Monostomo grevillei, Enteromorpha intestinalis, Percusaria percusaria*), Phaeophyceae (*Ectocarpus siliculosus*) and Cyanophyceae (*Oscillatoria* sp.; *Phormidium* sp.).

Area 4. Seal Cove Brook. (Plate IV). (47°48'N, 58°28'W.). This area, located west of the town of Stephenville Crossing, off the Port-au-Port Peninsula highway, was the site of previous recordings of *F. heteroclitus* and *F. diaphanus* (Scott and Crossman, 1964). The brook flows through a coniferous forest area, across a salt-marsh characterised by the presence of *Spartina maritima*, and finally opens into Bay St. George. Sampling was possible only at low tide, when the water was slow running and approximately 1 m. deep. At high tide, and during periods of heavy rainfall when the run-off from the surrounding hills was high, the depth and speed of flow of water in the brook prevented sampling. Sampling was performed at a point approximately 100 m. upstream from the mouth of the brook. *F. diaphanus* was taken in June, and to a lesser extent in July, but was entirely absent from the sampling area in September and the following months. The reason for this is not known. A thin layer of surface ice occurred on the water in December.

Plate III. Mummichog Park Sample Area.

Plate IV. Seal Cove Sample Area.

B. Procedures

Sampling was carried out by driving the fish into a 10 m. seine net, (4 mm. on the diagonal mesh). Attempts were made to sample each area at monthly intervals. This was not always possible however, on account of high water conditions which resulted from floods or tidal influence, the fish not being present in the area at the time of sampling, or in one instance (August, 1973) due to the author being stranded in Cape Breton as a result of the Canadian National Railways strike. In the latter instance, a sample was taken in early September in an attempt to compensate for the sample missed.

A sample of 30 *F. heteroclitus* was arbitrarily chosen as the sample size, to represent a mid-range number between the 15 proposed by Dogiel (1933) and the 40 to 50 proposed by Petrushevskii and Petrushevskaya (1960). Consequently fish in excess of this number were taken to allow for mortality during transportation and laboratory holding.

The samples were transported back to the laboratory in a manner similar to that described by Abbott (1968). The samples from each area were placed in separate polythene bags, each containing a small amount of water from that sample area. The bags were then placed in separate polythene buckets, and each bag inflated with oxygen to its' fullest extent. The necks of the bags were then tied off, a lid placed securely on each bucket, and the sample transported back to the laboratory by road or air.

A water sample from each area, collected at the time of fishing, was also brought back for analysis by the Water Analysis Unit of Memorial

University. Specific conductance measurements were made using a standard conductivity bridge, and pH was determined using a Radiometer M52 digital pH meter. The surface water temperature was recorded at the time of fishing using a standard laboratory thermometer.

On arrival at the laboratory, the fish were placed in separate, cooled holding tanks to await examination. Cooling of the tanks was accomplished by use of a commercial cooling unit inserted into the tanks, or by means of a continuous flow of cool tap water passing through thin walled plastic tubing in the tank. This latter method proved to be somewhat unsatisfactory during the latter part of June and the month of July, when the air temperatures in the laboratory proved too high for the cooling system to overcome.

Autopsy of the fish commenced the day following arrival back at the laboratory, and was generally completed within a two-week period. In most months, sufficient fish survived transport and holding to allow for an autopsy sample of 30 fish per sample area. However, in the early summer months (June and July), high pre-autopsy mortality was experienced due to failure to oxygenate the samples immediately after capture, and inability to keep the samples cool during transport and laboratory holding.

Prior to autopsy, each fish was weighed to the nearest 0.5 gm. on an Ohaus Triple Beam balance. The total length of the fish was measured to the nearest 0.5 cm. The fish were then autopsied using standard parasitological techniques (Fernando *et al.*, 1972).

Samples of Monogenea were obtained by agitating individual gills and fins in 1:4,000 formalin (Putz and Hoffmann, 1963) as modified by

Parker and Haley (1960). Agitation caused the Monogenea to detach from the gill or fin, whereupon they were collected from the solution using the flattened end of a fine hypodermic syringe needle, which proved to be easier and more efficient than the mounted insect pins usually employed. The Monogenea were mounted in Ammonium-picrate-glycerin, and the edges of the cover slip sealed with Noyer's Solution (Malmberg, 1970). In addition to preserving a sample of the host monogenean fauna, the total numbers of Monogenea present on the gills, fins and body surface was recorded. For recording purposes, the gills on either side of the body were numbered I-IV in an antero-postero direction.

Intestinal helminths were relaxed in 1% ethyl carbamate and stored in 5% formalin, followed by staining in Semichon's acetic-carmine (Meyer and Olsen, 1971).

Gill metacercariae were excysted prior to generic identification using the method of McDaniel (1966), followed by storage in 5% formalin. Attempts were made to determine the specific nature of the adult form by orally infecting laboratory goldfish, ducks and mice with fresh, infected gills, followed by autopsy at periodic intervals up to 60 days.

Identification of the parasites was facilitated by reference to Yamaguti (1963), Dillon (1966), Hoffman (1967). Measurements of the Monogenea follow the scheme of Malmberg (1970).

Identification of the fish was aided by reference to Scott and Crossman (1964), while the nomenclature follows the format recommended by the American Fisheries Society (1970).

Raw data analyses were carried out by either chi-square or student's "t" tests (Scheffer, 1969), using ($p = 0.05$) as the minimum acceptable level of significance.

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RESULTS

1. The Host. (*F. heteroclitus*)

From Table 1 it can be seen that no significant difference ($p > 0.05$) occurs in the mean monthly lengths of *F. heteroclitus*, from the Frenchman's Cove and Seal Cove samples. Significant differences ($p < 0.05$) are noted between the mean lengths of the June-July-September (1) and October-November samples from Clark's Brook. A significant difference occurs between the May and June-September (2) samples from Mummichog Park. The fish from Seal Cove and Mummichog Park have significantly greater total mean lengths ($p < 0.001$) than fish from the other areas sampled.

The length of the fish will be used as an indicator of age, since no method is available specifically for the age determination of *F. heteroclitus*. According to Hildebrand (in Cullinan, 1945) a *Fundulus* of approximately 5 cms. is considered to be approximately one year old, although considerable variation in growth rate due to environmental conditions will obviously occur.

The numbers of *F. heteroclitus*, in various length classes from the four areas sampled are shown in Table 2.

2. The Physical Nature of the Host Environment

Tables 3 and 4 show variations in selected environmental parameters on an area and mean basis for the sampling period. Cyclic fluctuations in surface water temperature and salinity (as indicated by specific conductivity) are noticeable, reaching summer peaks in both

TABLE 1

Mean lengths of *F. heteroclitus* from four sample areas on the west coast of Newfoundland, 1973

Sample Area	Mean Length (cms.)								
	May	June	July	Sept. (1)	Sept. (2)	Oct.	Nov.	Dec.	Total Mean
Clark's Brook	-	4.0	6.5	5.4	6.2	7.1	5.3	4.9	4.9
Frenchman's Cove	-	4.9	5.4	5.7	6.0	6.0	5.8	5.2	4.8
Mummichog Park	7.9	4.4	-	-	4.2	-	-	-	5.7
Seal Cove	-	-	7.2	7.0	7.2	-	-	-	7.1

- = no sample taken.

TABLE 2

Numbers of *F. heteroclitus* per length class from the four areas sampled during the present study

Length Class (cms.)	Sample Area				
	Mummichog Park	Seal Cove	Clark's Brook	Frenchman's Cove	Total
3- 3.9	14	1	17	6	38
4- 4.9	23	2	63	47	135
5- 5.9	17	14	34	63	128
6- 6.9	5	26	23	25	79
7- 7.9	4	12	32	38	86
8- 8.9	3	21	13	14	51
9- 9.9	6	8	7	0	21
10-10.9	3	5	5	1	14
11-11.9	4	1	0	0	5
Totals	79	90	194	194	557

TABLE 3

Selected environmental parameters, according to month and sample area

Month	Sample Area											
	Clark's Brook			Frenchman's Cove			Mummichog Park			Seal Cove		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
May	-	-	-	14	6.9	159	14	7.3	12,927	14	7.0	959
June	19	7.3	149	20	6.8	449	18	7.2	21,068	16	-	-
July	22	7.6	22,036	26	7.3	9,165	-	-	-	20	6.7	201
September (1)	23	7.5	1,591	21	7.4	8,072	-	-	-	18	7.0	2,637
September (2)	11	8.5	786	18	7.2	12,746	19	8.4	25,179	14	7.3	18,553
October	7	7.4	36,126	8	7.7	11,529	-	-	-	8	7.4	36,126
November	3	7.8	8,670	2	7.6	642	4	7.0	160	3	7.3	11,910
December	0	8.5	9,128	1	7.5	674	-	-	-	2	7.1	1,176

(a) = Surface water temperature, °C. (b) = pH. (c) = Specific conductivity, micromhos/cm^3 @ 20°C.

TABLE 4

Mean monthly values for selected environmental parameters (sample areas combined)

Month	(a)	(b)	(c)
May	14	7.1	4,681
June	20	7.1	7,228
July	22	7.2	10,467
September (1)	20	7.3	12,300
September (2)	15.5	7.8	14,316
October	7.5	7.5	27,927
November	3	7.4	5,345
December	1	7.7	3,659

(a) = Mean surface water temperature °C. (b) = Mean pH. (c) = Mean specific conductivity, micromhos/cm^3 @ 20°C.

cases. Little variation occurs in the monthly pH values, either within or between the sample areas. The specific conductivity values obtained for Seal Cove may be suspect as to their representative value due to the high degree of tidal activity experienced in this area, compared to the other sample areas.

According to Dartnall (1972), a sample is considered to be freshwater if the conductivity reading is less than 800 micromhos/cm^3 (0.4%), and to be sea-water if the reading is at least 47,000 micromhos/cm^3 (34.3%).

3. The Parasites

The host species examined, and the metazoan parasite species recovered are listed in Table 5.

Single host species specificity was observed in *F. heteroclitus* (3 genera and species of parasite), and in *Gasterosteus aculeatus* (2 genera and species). Three genera and species of parasites were common to both the host families Cyprinodontidae and Gasterosteidae, whereas 3 genera and species were restricted to the Cyprinodontidae, and 5 genera and species to the Gasterosteidae. Such observed patterns of parasite/host specificity may be due to ecological factors such as the failure of a prospective host and parasite to come into contact, or to immunity on the part of a particular fish species.

Emphasis will be placed on the population dynamics of the metazoan parasites of *F. heteroclitus*, comparisons with other host and parasite species being made where appropriate.

TABLE 5

Details of infection of *F. heteroclitus*, *F. diaphanus*, *P. pungitius*, *G. aculeatus* and *A. quadracus* with metazoan parasites from Newfoundland

Species	*F. heteroclitus*			*F. diaphanus*			*P. pungitius*			*G. aculeatus**			*A. quadracus*		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Monogenea	56	6	1-73	53	3	1-25	-	-	-	-	-	-	-	-	-
Gyrodactylus prolongis Hargis, 1955	33(x)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. stephanus Mueller, 1937	26(x)	-	-	-	-	-	12	3	1-6	-	-	-	-	-	-
Urocleidus angularis Mueller, 1934	28(x)	-	-	100(y)	-	-	-	-	-	-	-	-	-	-	-
Unidentified metacercariae	z	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Homalometron pallidum Stafford, 1904	22	1.9	1-8	-	-	-	-	-	-	-	-	-	-	-	-
Brachyphallus crenatus Rudolphi, 1802	-	-	-	-	-	-	5	3	1-5	3	50	20-80	-	-	-
Derogenes varicus (Mueller, 1784)	-	-	-	-	-	-	-	-	-	4	30	20-50	20	3	2-4
Eubothrium sp.	-	-	-	-	-	-	-	-	-	1.5	1	0-1	-	-	-
Proteocephalus sp.	35	2.0	1-16	-	-	-	1.4	2	0-1	5.8	1.3	1-2	10	2	0-2

TABLE 5 (Continued)

Species	*F. heteroclitus*			*F. diaphanus*			*P. pungitius*			*G. aculeatus**			*A. quadracus*		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Neoechinorhynchus rutili (Mueller, 1780)	1	9.6	1-32	-	-	-	45	5	1-15	1.4	3	0-3	10	1	0-1
Thersatina gasterostei (Pagenstecher, 1861)	-	-	-	-	-	-	31	4	1-18	29	11.9	1-44	10	1	0-1
Argulus canadensis	-	-	-	-	-	-	-	-	-	1.4	1	0-1	-	-	-
# Fish examined	557			28			64			69			10		

(a) = incidence of occurrence (%). (b) = mean infestation. (c) = range of infestation. (x) = based on sample of 45% of total Monogenea. (y) = based on sample of 27% of total Monogenea. (z) = common occurrence, no counts made. * = 3 specimens (4.4%) of *G. aculeatus* infested with *Icthyophthirius multifilis*.

3. (a). Monogenea

Examination of Table 6 showed that the 3-3.9 cm. length class was significantly less infested ($p < 0.05$) than all other length classes. A significant increase ($p < 0.001$) in the incidence of infestation occurred between the 4-4.9 cm. and the 5-5.9 cm. length classes.

When the monthly data from all sample areas was combined (Table 7) the total incidence of infestation showed significant declines from May to September (1) ($p < 0.025$) and July to September (1) ($p < 0.05$). Seasonal increases were noted from September (1) to November ($p < 0.025$). The total mean intensity of infestation also declined from May to June ($p < 0.001$) and September (1) to September (2) ($p < 0.05$).

Examination of the data on the basis of sample area (Table 8) revealed seasonal variation in the total incidence of infestation of the Frenchman's Cove samples, decreasing from June to July ($p < 0.01$) and increasing from September (1) to September (2) ($p < 0.025$), September (2) to October ($p < 0.005$) and October to November ($p < 0.05$). The Clark's Brook samples showed a decline in the total incidence of infestation from July to September (1) ($p < 0.025$).

Similar fluctuations in the intensity of infestation were noted for the individual sample areas, decreases occurring in Clark's Brook from July to September (1) ($p < 0.025$), in Frenchman's Cove from June to July ($p < 0.05$) and June to September (1) ($p < 0.025$), and for Mummichog Park from May to June ($p < 0.001$). An increase was noted for the Clark's Brook samples from October to December ($p < 0.025$).

TABLE 6

Occurrence of Monogenea on *F. heteroclitus* by length class of host (all months and sample areas combined)

Length Class (cms)	# Fish	# Infested	% Infestation	Mean # parasites per infested fish	Range of Infestation
3- 3.9	38	14	36.8	4.8	1-16
4- 4.9	134	66	49.2	4.3	1-28
5- 5.9	128	91	71.0	5.5	1-33
6- 6.9	80	54	67.5	7.3	1-73
7- 7.9	86	54	62.8	4.1	1-27
8- 8.9	50	34	68.0	7.1	1-31
9- 9.9	21	17	80.9	8.5	1-31
10-10.9	15	11	73.3	7.3	1-24
11-11.9	5	3	60.0	16.6	1-10

TABLE 7

Occurrence of Monogenea on male and female *F. heteroclitus*
(all sample areas combined)

	May	June	July	Sept.(1)	Sept.(2)	Oct.	Nov.	Dec.
# fish in sample	29	71	75	86	116	60	60	60
% infestation	72.4 (21)	60.5 (43)	62.6 (47)	44.1 (38)	45.6 (53)	58.3 (35)	66.6 (40)	60.0 (36)
Mean # parasites per infested fish	19.7	8.3	8.3	5.0	2.7	2.3	2.8	3.9
Range of infestation	1-73	1-33	1-48	1-31	1-20	1-17	1-8	1-21
# males in sample	14	33	47	44	61	30	28	34
% infestation	57.1 (8)	60.6 (20)	68.0 (32)	47.7 (21)	57.3 (35)	83.3 (25)	75.0 (21)	73.5 (25)
Mean # parasites per infested fish	17.7	6.4	8.0	6.3	2.3	1.9	3.4	4.2
Range of infestation	1-29	1-22	1-27	1-31	1-9	1-5	1-8	1-21
# females in sample	15	38	28	42	55	30	32	26
% infestation	86.6 (13)	60.5 (23)	53.5 (17)	40.4 (17)	47.2 (25)	66.6 (20)	75.0 (24)	73.0 (19)
Mean # parasites per infested fish	28.0	9.7	9.0	4.1	3.3	2.9	2.2	4.1
Range of infestation	1-73	1-33	1-48	1-24	1-20	1-17	1-4	1-15

( ) = numbers of fish infested.

TABLE 8

Occurrence of Monogenea on *F. heteroclitus*, all areas and months

	May				June				July				September (1)				September (2)				Octobe	
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)
Number of fish in sample	-	29	-	-	22	25	24		24	23	-	28	28	26	-	32	30	30	26	30	30	30
% infestation		72.4 (21)			4.5 (1)	76 (19)	95.8 (23)		87.5 (21)	13 (3)		89.2 (25)	50 (14)	3.8 (1)		71.8 (23)	86.6 (18)	33.3 (10)	26.9 (7)	60 (18)	40 (12)	76.6 (23)
Mean # parasites per infested fish		19.7			2.0	6.4	9.5		3.9	2.5		12.4	2.3	1.0		6.4	2.8	1.8	2.1	3.6	1.8	2.9
Range		1-73			-	1-15	1-33		1-13	1-5		1-48	1-5	-		1-31	1-9	1-6	1-4	1-20	1-6	1-17
Number of males in sample		14			8	13	12		15	12		20	17	9		18	18	16	11	16	12	18
% infestation		57.1 (8)			-	61.5 (8)	100 (12)		86.6 (13)	8.3 (1)		90 (18)	58.8 (10)	- (-)		61.1 (11)	94.4 (17)	25 (4)	27.2 (3)	68.7 (11)	91.6 (11)	77.7 (14)
Mean # parasites per infested fish		16.3			-	4.0	8.2		3.5	1.0		11.7	2.0	-		8.6	2.7	2.7	2.3	1.8	1.6	2.2
Range		1-29			-	1-7	1-22		1-8	-		1-27	1-4	-		1-31	1-9	1-6	1-4	1-4	1-3	1-5
Number of females in sample		15			14	12	12		9	11		8	11	17		14	12	14	15	14	18	12
% infestation		86.6 (13)			7.1 (1)	91.6 (11)	91.6 (11)		88.8 (8)	18.1 (2)		87.5 (7)	36.3 (4)	5.8 (1)		85.7 (12)	75.0 (9)	42.8 (6)	26.6 (4)	50 (7)	61.1 (11)	75.0 (9)
Mean # parasites per infested fish		21.8			2.0	9.2	10.0		4.6	3.0		14.7	3.0	1.0		4.4	3.0	1.1	2.0	6.5	2.0	4.
Range		1-73			-	2-15	1-33		1-13	1-5		1-48	2-5	-		1-24	1-7	1-2	1-4	1-20	1-6	1-1

(a) = Clark's Brook. (b) = Frenchman's Cove. (c) = Mummichog Park. (d) = Seal Cove. (#)= Number of fish.

TABLE 8

Occurrence of Monogenea on *F. heteroclitus*, all areas and months

	June				July				September (1)				September (2)				October				November				December			
d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
-	22	25	24		24	23	-	28	28	26	-	32	30	30	26	30	30	30	-	-	30	30	-	-	30	30	-	-
	4.5 (1)	76 (19)	95.8 (23)		87.5 (21)	13 (3)		89.2 (25)	50 (14)	3.8 (1)		71.8 (23)	86.6 (18)	33.3 (10)	26.9 (7)	60 (18)	40 (12)	76.6 (23)			63.3 (14)	86.6 (26)			60 (18)	60 (18)		
	2.0	6.4	9.5		3.9	2.5		12.4	2.3	1.0		6.4	2.8	1.8	2.1	3.6	1.8	2.9			2.5	3.1			5.3	2.5		
	-	1-15	1-33		1-13	1-5		1-48	1-5	-		1-31	1-9	1-6	1-4	1-20	1-6	1-17			1-8	1-8			1-21	1-10		
	8	13	12		15	12		20	17	9		18	18	16	11	16	12	18			14	14			18	16		
	-	61.5 (8)	100 (12)		86.6 (13)	8.3 (1)		90 (18)	58.8 (10)	- (-)		61.1 (11)	94.4 (17)	25 (4)	27.2 (3)	68.7 (11)	91.6 (11)	77.7 (14)			71.4 (10)	78.5 (11)			94.4 (17)	50 (8)		
	-	4.0	8.2		3.5	1.0		11.7	2.0	-		8.6	2.7	2.7	2.3	1.8	1.6	2.2			3.2	3.7			5.4	1.7		
	-	1-7	1-22		1-8	-		1-27	1-4	-		1-31	1-9	1-6	1-4	1-4	1-3	1-5			1-8	1-8			1-21	1-3		
	14	12	12		9	11		8	11	17		14	12	14	15	14	18	12			16	16			12	14		
	7.1 (1)	91.6 (11)	91.6 (11)		88.8 (8)	18.1 (2)		87.5 (7)	36.3 (4)	5.8 (1)		85.7 (12)	75.0 (9)	42.8 (6)	26.6 (4)	50 (7)	61.1 (11)	75.0 (9)			56.2 (9)	93.7 (15)			75 (9)	71.4 (10)		
	2.0	9.2	10.0		4.6	3.0		14.7	3.0	1.0		4.4	3.0	1.1	2.0	6.5	2.0	4.0			1.7	2.6			5.2	3.2		
	-	2-15	1-33		1-13	1-5		1-48	2-5	-		1-24	1-7	1-2	1-4	1-20	1-6	1-17			1-3	1-4			1-15	1-10		

) = Frenchman's Cove. (c) = Mummichog Park. (d) = Seal Cove. (#)= Number of fish.

Examination of the data on the basis of sex of host and combining all monthly samples failed to reveal any significant difference between the incidence and intensity of infestation of males and females. Similarly, examination of the combined monthly data for each sample area showed that only in the fish from Clark's Brook was there any significant difference, males having a higher incidence of infestation than females, ($p < 0.005$).

On a monthly basis, females were found to have a significantly greater incidence of infestation than males in May (Mummichog Park, $p < 0.025$), and June (Frenchman's Cove, $p < 0.01$). Females also showed significantly greater mean intensities of infestation than males in June (Frenchman's Cove, $p < 0.01$), July and September (2) (Seal Cove, $p < 0.05$). Male fish showed a significantly greater mean intensity of infestation than females in November (Clark's Brook, $p < 0.05$). Monthly variation in incidence and mean intensity of infestation were also apparent on a sexual basis.

Seasonal declines in the incidence of infestation of the males occurred from June to July (Frenchman's Cove, $p < 0.025$), and seasonal increases from May to June (Mummichog Park, $p < 0.05$), and September (2) to October (Frenchman's Cove, $p < 0.01$, and combined sample area data, $p < 0.05$). Similar fluctuations occurred with regards to the females, seasonal declines occurring from June to July (Frenchman's Cove, $p < 0.005$), and Clark's Brook, $p < 0.025$), June to September (2) (Mummichog Park, $p < 0.005$). A seasonal increase was noted in the combined sample area data from September (2) to October ($p < 0.01$). The mean intensity of infestation of the males showed a decline from

September (1) to September (2) ($p < 0.025$) in the Seal Cove samples.

The distribution of the Monogenea between the gills and fins showed a significant ($p < 0.005$) variation, 80.9% (1122) occurring on the gills, and 19.1% (265) occurring on the fins. No significant preferences were noted for the various gill arches on the left or right side of the body (Table 9). Arch I on each side was a less preferred site ($p < 0.005$) than the other arches, between which no significant preferences occurred. In single parasite gill infestations, no significant preference was noted for any gill arch (gill arch I. 20.4% of Monogenea recovered; II, 20.6%; III, 26.8%; IV, 32.2%).

No preferences existed between the incidence of occurrence of Monogenea on the dorsal, anal and caudal fins (Table 10). The pectoral fins were significantly less infested ($p < 0.005$).

Analysis of the total mean intensity of infestation of each fin showed that the caudal fin was subject to a greater mean parasite load ($p < 0.005$) than the other fins, and that the pectoral fins were the least infested of the infested fins ($p < 0.005$).

Monogenea were significantly more prevalent ($p < 0.005$) on the fins of the fish from Clark's Brook than from any other sample area, whereas they were the least prevalent ($p < 0.005$) on the fish from Seal Cove.

Analysis of the sample area data showed fish from Mummichog Park and Seal Cove to have a significantly greater mean fin parasite load ($p < 0.005$) than fish from the other sample areas.

Microscopic examination of the monogenean fauna of *F. heteroclitus* revealed the presence of three species belonging to two genera, namely

TABLE 9

Distribution of Monogenea on the gills of *F. heteroclitus*

	Gill arch number				
	I	II	III	IV	Total
# Monogenea on right side (% infestation)	112 (19.1)	159 (27.1)	175 (29.9)	140 (23.9)	586 (52.2)
# Monogenea on left side (% infestation)	107 (20.0)	128 (23.9)	152 (28.3)	149 (27.8)	536 (47.8)
Total numbers (% infestation)	219 (19.5)	287 (25.6)	327 (29.1)	289 (25.8)	1122

TABLE 10

Distribution of Monogenea on the fins of *F. heteroclitus*, monthly data combined

Sample Area		Dorsal	Anal	Caudal	Pectorals	Total
Clark's Brook	(a)	15.4	20.1	17.0	-	38.5
	(b)	30	39	33	-	102
	(c)	1.4	1.5	2.1	-	2.1
Frenchman's Cove	(a)	14.4	15.9	9.2	0.5	29.4
	(b)	28	31	18	1	78
	(c)	1.8	1.9	1.2	2.0	2.5
Mummichog Park	(a)	26.5	24.0	21.5	1.3	21.9
	(b)	21	19	17	1	58
	(c)	3.2	4.9	14.2	1.0	13.7
Seal Cove	(a)	10.0	10.0	10.0	-	10.2
	(b)	9	9	9	-	27
	(c)	1.5	2.5	3.4	-	3.7
Total	(a)	15.7	17.5	13.8	0.3	-
	(b)	88	98	77	2	265
	(c)	2.0	2.4	4.7	1.5	-

(a) = incidence of occurrence (%). (b) = # of Monogenea. (c) = mean # of worms per fin.

Gyrodactylus prolongis Hargis, 1955; *Gyrodactylus stephanus* Mueller, 1937 and *Urocleidus angularis* Mueller, 1934. Linton (1940) reported a *Gyrodactylus* sp. from *F. heteroclitus*, Hargis (1955) describing *G. prolongis* from the same host. Williams and Rogers (1971) have recently redescribed the species from new evidence regarding the morphology of the peduncular bar. Hanek and Fernando (1971) established the Canadian record for the species by reporting it from *F. diaphanus* in Ontario. *G. prolongis* was not recovered from *F. diaphanus* in the present study. The recovery of *G. prolongis* from *F. heteroclitus* in this survey represents a new record for the waters of insular Newfoundland.

Comparative measurements with those obtained during the present study are given in Table 11. It should be noted that in previous work, confusion occurs as to what constitutes the length and width of the principal connecting bar.

Gyrodactylus stephanus Mueller, 1937. First described by Mueller (1937) from *F. heteroclitus*, the species was later redescribed by Hargis (1955) from *F. grandis* on account of lack of detail in the original work.

The recovery of *G. stephanus* from Newfoundland waters represents a Canadian record for the species, while *P. pungitius* is a new host.

Comparative measurements are given in Table 12.

It should be noted that a *Gyrodactylus* sp. was recorded by Gowanloch (1927) from *F. heteroclitus* in New Brunswick. According to the author, the species did not meet any of the available specific descriptions, and was supposed to be described later. However, no such

TABLE 11

Comparison of morphological criteria of *Gyrodactylus prolongis*, Hargis 1955

Morphological criteria	Hargis (1955)		Williams and Rogers (1971)	Hanek and Fernando (1971)	Present study	
Body length	0.348	(0.312-0.376)	(0.290-0.435)	(0.600-0.696)	0.453	(0.332-0.582)
Body width (max.)	0.076	(0.057-0.089)	(0.080-0.083)	(0.084-0.096)	0.075	(0.059-0.100)
Pharynx length	0.022	(-)	(-)	(0.060-0.072)	0.032	(0.025-0.046)
Pharynx width	0.027	(-)	(-)	(0.036-0.039)	0.028	(0.022-0.036)
Haptor length	0.081	(0.076-0.084)	(0.062-0.089)	(0.086-0.110)	0.079	(0.69 -0.081)
Haptor width	0.049	(0.044-0.051)	(0.062-0.089)	(0.082-0.096)	0.058	(0.050-0.081)
Peduncle width	-	(-)	(-)	(-)	0.060	(0.051-0.081)
Anchor length	0.075	(0.074-0.076)	(0.067-0.077)	(0.071-0.076)	0.084	(0.075-0.086)
Basal part length	-	(-)	(-)	(0.041-0.043)	0.030	(0.030-0.033)
Point length	-	(-)	(0.017-0.020)	(0.023-0.025)	0.026	(0.022-0.030)
Inner root length	-	(-)	(-)	(0.036-0.030)	0.041	(0.035-0.045)
Principal connecting (ventral) bar width	0.019	(0.018-0.023)	(0.021-0.023)	(0.023-0.025)	0.024	(0.022-0.025)
Principal connecting (ventral) bar length	0.006	(0.005-0.007)	0.009	(0.007-0.008)	0.007	(0.005-0.007)
Auxiliary connecting (dorsal) bar width	0.011	(0.011-0.014)	(0.021-0.022)	(0.014-0.018)	0.011	(0.010-0.016)
Auxiliary connecting (dorsal) bar length	0.007	(0.005-0.008)	(0.003-0.004)	(0.001-0.002)	0.001	(0.001-0.002)

TABLE 11 (Continued)

Morphological criteria	Hargis (1955)	Williams and Rogers (1971)	Hanek and Fernando (1971)	Present study
Length of marginal hook and shaft	0.041 (-)	(-)	(0.047-0.048)	0.043 (0.040-0.047)
Length of hook	- (-)	(0.005-0.007)	(0.006-0.007)	0.006 (0.006-0.007)
Length of shaft	- (-)	(0.033-0.036)	(-)	- (-)
Length of membrane	- (-)	(-)	(-)	0.024 (0.017-0.035)

(#) = range of measurements; all measurements in mm.

TABLE 12

Comparison of morphological criteria of *G. stephanus* Mueller, 1937

Morphological criteria	Hargis (1955)	Present study (*F. heteroclitus*)	Present study (*G. aculeatus*)
Body length	0.328 (0.299-0.357)	0.347 (0.228-0.494)	0.337 (0.312-0.390)
Body width (max.)	0.044 (0.038-0.051)	0.060 (0.046-0.104)	0.065 (0.052-0.072)
Pharynx (diam.)	0.019 x 0.016	0.028 x 0.023	0.026 x 0.024
Haptor length	0.048 (0.044-0.051)	0.056 (0.056-0.062)	-
Haptor width	0.038 (0.032-0.044)	0.047 (0.037-0.056)	-
Peduncle	-	0.036 (0.033-0.042)	-
Head Organ	-	0.014 (0.012-0.018)	-
Length of Anchors	0.042 (0.039-0.044)	0.035 (0.032-0.041)	0.035 (0.034-0.037)
Basal part length	-	0.014 (0.010-0.018)	0.015 (0.011-0.019)
Point length	-	0.014 (0.011-0.017)	0.014 (0.011-0.017)
Inner root length	-	0.007 (0.006-0.016)	0.008 (0.007-0.011)
Principal connecting (ventral) bar width	0.020 (0.019-0.020)	0.016 (0.013-0.017)	0.003 (0.003-0.004)
Principal connecting (ventral) bar length	0.004	0.003 (0.002-0.005)	0.016 (0.013-0.020)
Auxiliary connecting (dorsal) bar width	0.016	0.015 (0.013-0.017)	0.015 (0.014-0.017)
Auxiliary connecting (dorsal) bar length	0.001	0.001 (0.001-0.002)	0.001 (0.001-0.002)

TABLE 12 (Continued)

Morphological criteria	Hargis (1955)	Present study (*F. heteroclitus*)	Present study (*G. aculeatus*)
Length of marginal hook and shaft	-	0.022 (0.020-0.025)	0.020 (0.020-0.022)
Length of hook	-	0.004 (0.004-0.006)	0.005 (0.004-0.005)
Length of shaft	-	-	-
Length of membrane	-	0.013 (0.012-0.017)	- -

(#) = range of measurements; all measurements in mm.

later description appears to have been made.

Urocleidus angularis Mueller, 1934. The species was originally described by Mueller (1934) from *F. diaphanus*.

The present recovery from *F. heteroclitus* constitutes a new host record. The occurrence of this parasite in *F. diaphanus* from Newfoundland waters represents a Canadian record for the species. Comparative measurements are given in Table 13.

A significant difference existed ($p < 0.005$) between the total incidence of occurrence of *G. stephanus* and *U. angularis*. No significant difference in incidence of occurrence existed between *G. stephanus* and *G. prolongis* (Table 14).

In the Clark's Brook sample, *G. stephanus* showed a significantly greater incidence of occurrence than *G. prolongis* ($p < 0.005$), whereas in the Frenchman's Cove sample, although *G. stephanus* was significantly more frequent in occurrence than *G. prolongis* ($p < 0.005$), there was no significant difference in incidence of occurrence between *G. stephanus* and *U. angularis*. In the Mummichog Park sample, *G. prolongis* and *U. angularis* were significantly more frequent in occurrence ($p < 0.005$) than *G. stephanus*, whereas in the Seal Cove sample, *U. angularis* occurred more frequently than *G. stephanus* and *G. prolongis*.

Examination of Table 15 showed that for *G. prolongis* and *U. angularis* there were well defined seasonal incidence cycles. *G. prolongis* showed a significant decline ($p < 0.005$) from a spring maximum in May to a summer minimum in early September, followed by a significant increase in incidence to a fall maximum in October ($p < 0.01$).

TABLE 13

Comparison of morphological criteria of *U. angularis* Mueller, 1934.

Morphological criteria	Mueller, 1934	Present Study
Body length	(0.260-0.420)	0.387 (0.286-0.442)
Body width	(0.069-0.075)	0.070 (0.052-0.088)
Pharynx (max. diam.)	0.025	0.026 (0.020-0.030)
Haptor length		0.044 (0.037-0.050)
Haptor width		0.072 (0.062-0.093)
Peduncle		0.052 (0.046-0.062)
Length of Anchors	0.019	0.022 (0.022)
Length of Basal part		0.012 (0.010-0.013)
Length of Point		0.008 (0.005-0.010)
Length of Inner root		0.006 (0.005-0.010)
Length of connecting bar		0.003 (0.003-0.005)
Width of connecting bar		0.022 (0.020-0.027)
Marginal hooks and shaft length		0.015 (0.015)
Marginal hooks length		0.003 (0.003)

1. All measurements in mm. 2. Figures in parentheses represent range of measurements.

TABLE 14

Occurrence of three species of Monogenea from four sample areas, monthly data combined

Sample Area	# Monogenea in sample	*G. prolongis*		*G. stephanus*		*U. angularis*	
		(a)	(b)	(a)	(b)	(a)	(b)
Clark's Brook	183	28.5	52	71.5	131	-	-
Frenchman's Cove	137	24.0	33	60.5	83	15.5	21
Mummichog Park	179	56.4	101	7.8	14	35.8	64
Seal Cove	111	16.2	18	5.4	6	78.4	87
Total	610	33.4	204	38.4	234	28.2	172

(a) = incidence of occurrence (%) of parasite in monogenean sample. (b) = # Monogenea.

1 of

TABLE 15

Monthly occurrence of three species of Monogenea from four sample areas

Sample Area	May				June				July				Sept. (1)				Sept. (2)				Oct	
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)
Clark's Brook	–	–	–	–	1	–	1 (100)	–	30	3 (10)	27 (90)	–	9	1 (12)	8 (88)	–	38	11 (29)	27 (71)	–	24	10 (42
Frenchman's Cove	–	–	–	–	29	4 (14)	25 (86)	–	1	–	1 (100)	–	–	–	–	–	6	3 (50)	1 (17)	2 (33)	26	7 (14
Mummichog Park	106	89 (84)	11 (10)	6 (5.6)	69	12 (17)	2 (3)	55 (80)	–	–	–	–	–	–	–	–	4	–	1 (25)	3 (75)	–	–
Seal Cove	–	–	–	–	–	–	–	–	66	9 (14)	–	57 (86)	29	1 (4)	–	28 (96)	26	8 (30)	6 (23)	12 (46)	–	–
Total	106	89 (84)	11 (10)	6 (6)	99	16 (16)	28 (28)	55 (56)	97	12 (12)	28 (29)	57 (59)	38	2 (5)	8 (21)	28 (74)	64	22 (30)	35 (47)	17 (23)	50	17 (34

(#) = incidence of occurrence (%). (a) = total number of parasites examined. (b) = *Gyrodactylus prolongis*

TABLE 15

Monthly occurrence of three species of Monogenea from four sample areas

ıy		June				July				Sept. (1)				Sept. (2)				October				November				December			
(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
-	-	1	-	1 (100)	-	30	3 (10)	27 (90)	-	9	1 (12)	8 (88)	-	38	11 (29)	27 (71)	-	24	10 (42)	14 (58)	-	30	13 (44)	17 (56)	-	51	14 (27)	37 (73)	-
-	-	29	4 (14)	25 (86)	-	1	-	1 (100)	-	-	-	-	-	6	3 (50)	1 (17)	2 (33)	26	7 (14)	14 (86)	5	44	7 (16)	31 (70)	6 (14)	31	12 (39)	11 (25)	8 (36)
11 (10)	6 (5.6)	69	12 (17)	2 (3)	55 (80)	-	-	-	-	-	-	-	-	4	-	1 (25)	3 (75)	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	66	9 (14)	-	57 (86)	29	1 (4)	-	28 (96)	26	8 (30)	6 (23)	12 (46)	-	-	-	-	-	-	-	-	-	-	-	-
11 (10)	6 (6)	99	16 (16)	28 (28)	55 (56)	97	12 (12)	28 (29)	57 (59)	38	2 (5)	8 (21)	28 (74)	64	22 (30)	35 (47)	17 (23)	50	17 (34)	28 (56)	5 (10)	74	20 (27)	48 (65)	6 (8)	82	26 (32)	48 (58)	8 (10)

urrence (%). (a) = total number of parasites examined. (b) = *Gyrodactylus prolongis*. (c) = *G. stephanus*. (d) = *U. angularis*

U. angularis showed a seasonal maximum incidence of occurrence in early September, declining to seasonal minima in May ($p < 0.001$) and November ($p < 0.001$).

For *G. stephanus*, a significant increase ($p < 0.005$) occurred between May and November. It is possible that the insignificant decline between the November and December populations may have been the beginning of a winter decline to the May incidence level.

Examination of Table 16 failed to reveal any seasonal cycles in the incidence of occurrence of embryos in *G. prolongis* and *G. stephanus*. Similarly, there were no significant differences between the incidence of occurrence of embryos on a monthly basis, with the exception of the December samples where *G. prolongis* showed a significantly greater incidence of occurrence of embryos than did *G. stephanus* ($p < 0.025$).

Significant site preference on the host was noted, *G. prolongis* preferring the fins ($p < 0.005$), whilst, *G. stephanus* and *U. angularis* exhibited a preference for the gills ($p < 0.005$). *G. prolongis* showed less preference for the dorsal fin than for the anal and caudal fins ($p < 0.05$), there being no preference between the latter. *G. stephanus* and *U. angularis* did not show a preference for any particular fin or gills (Table 17).

From Table 18 it can be seen that significant monthly differences existed ($p < 0.001$) between the frequency of occurrence of Monogenea on the gills and fins. In May and June, the fins showed the highest incidence of infestation, whereas in the remaining months the gills were more frequently infested.

TABLE 16

Variation in monthly occurrence of embryos in two species of *Gyrodactylus* from *F. heteroclitus*, all sample areas combined

Month	*G. prolongis*			*G. stephanus*		
	(a)	(b)	(c)	(a)	(b)	(c)
May	89	54	60.6	11	8	72.7
June	16	11	68.7	28	13	46.4
July	12	8	66.6	28	16	57.1
Sept.(1)	2	1	50.0	9	6	66.6
Sept.(2)	22	15	68.1	35	22	62.8
October	17	9	52.9	28	15	53.5
November	20	13	65.0	48	27	56.2
December	26	22	84.6	48	26	54.1
Total	204	133	65.1	235	133	56.5

(a) = # worms examined. (b) = # worms with embryos.
(c) = % worms with embryos.

TABLE 17

Site preference of three species of Monogenea on *F. heteroclitus* from four sample areas in insular Newfoundland

Sample Area	Number Monogenea in sample	Dorsal fin			Anal fin			Caudal fin			Gills		
		(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Clark's Brook	184	10 (5.4)	5 (2.7)	-	20 (10.8)	4 (2.1)	-	22 (11.9)	9 (4.8)	-	-	114 (61.9)	-
Frenchman's Cove	133	13 (9.7)	4 (3.0)	-	12 (9.0)	7 (5.2)	-	5 (3.9)	-	-	3 (2.2)	68 (51.3)	21 (15.7)
Mummichog Park	176	17 (9.6)	-	2 (1.1)	30 (17.0)	-	-	53 (30.1)	1 (0.5)	-	1 (0.5)	13 (7.3)	59 (33.5)
Seal Cove	120	6 (5.0)	-	-	6 (5.0)	1 (0.8)	-	4 (3.3)	-	-	1 (0.8)	5 (4.1)	97 (80.8)
Total	613	46 (7.5)	9 (1.4)	2 (0.3)	68 (12.0)	12 (1.9)	-	84 (13.7)	10 (1.6)	-	5 (0.8)	200 (33.6)	177 (28.8)

(#) = incidence of occurrence (%) in Monogenea sample. (a) = *Gyrodactylus prolongis*. (b) = *G. stephanus*. (c) = *U. angularis*.

TABLE 18

Monthly distribution of Monogenea on *F. heteroclitus*, with regard to variation in mean environmental temperature (data from all sample areas combined)

Month	Mean °C.	Gill Monogenea	Fin Monogenea	Total
May	14	74 (17.9)	341 (82.1)	415
June	20	75 (35.0)	139 (65.0)	214
July	22	349 (82.1)	76 (17.9)	425
September (1)	20	160 (90.9)	16 (9.1)	176
September (2)	15.5	106 (61.6)	66 (38.4)	172
October	7.5	67 (61.4)	42 (38.6)	109
November	3	89 (70.6)	36 (29.4)	126
December	0	115 (58.9)	70 (41.1)	185

(#) = incidence of occurrence (%).

No pattern existed with regard to the mean water temperature and the preferred site of infestation.

Examination of Table 19 showed that *G. prolongis* exhibited minimum incidence of occurrence in the 3-3.9 cm. and 10-11.9 cm. length classes ($p < 0.005$) and maximum occurrence in the 5-5.9 cm. length class ($p < 0.05$). *G. stephanus* showed minimum infestation in the 3-3.9 cm. and 9-10.9 cm. length classes ($p < 0.005$) and maximum infestation in the 5-5.9 cm. length class ($p < 0.001$). In *U. angularis*, the 3-3.9 cm., 7-7.9cm. and 9-10.9 cm. host length classes were least infested ($p < 0.005$) whilst the 4-4.9 cm. length class showed maximum infestation.

The mean intensity of infestation with each species of Monogenea did not show any significant trend with increasing length of host. However in the case of *G. prolongis*, the 9-9.9 cm. and 11-11.9 cm. length classes were more heavily infested ($p < 0.005$) than all other length classes.

3. (b). Digenea

A. Metacercariae. Encysted Metacercariae were frequently found on the gill filaments of *F. heteroclitus* from Frenchman's Cove and Mummichog Park. Fish from the latter area were more heavily infested.

Identification of the excysted metacercariae was not possible due to distortion and poor preservation. No adults were obtained from the experimentally infected hosts.

Stunkard and Uzmann (1955) found the metacercariae of *Ascocotyle (Phagicola) diminuta* Stunkard and Haviland, 1924 to be encysted in the

TABLE 19

Occurrence of three species of Monogenea on *F. heteroclitus* by length class of host, all month and sample area data combined

Host Length Class (cms.)	*G. prolongis*			*G. stephanus*			*U. angularis*		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
3- 3.9	5	2.6	1.6	7	3.3	1.7	4	2.3	1.3
4- 4.9	17	8.8	1.2	36	15.9	1.7	51	28.9	2.5
5- 5.9	51	26.4	2.3	73	32.0	1.8	34	19.3	2.0
6- 6.9	16	8.3	1.2	37	16.3	1.7	28	15.9	2.1
7- 7.9	38	19.7	1.9	30	13.2	1.4	9	5.1	1.8
8- 8.9	23	11.9	2.1	32	14.1	2.3	26	14.8	3.2
9- 9.9	32	16.6	4.6	4	1.7	1.0	13	7.4	2.2
10-10.9	6	3.1	2.0	8	3.5	2.6	11	6.3	3.6
11-11.9	5	2.6	5.0	–	–	–	–	–	–

(a) = number of parasites. (b) = incidence of occurrence (%). (c) = mean intensity of infestation.

gills of *F. heteroclitus*. The adult forms were previously found in the intestines of wild rats (Stunkard and Haviland, 1924). Yamaguti (1971) states that *A. (P.) diminuta* is synonymous with *Phagicola angrensis* (Travassos, 1916).

Lillis and Nigrelli (1965) fed infected gill filaments from *F. heteroclitus* to various hosts, and in each case recovered, after thirty-five days, adult *Echinochasmus schwartzi*, which had previously been reported from the muskrat and dog (Price, 1931) in areas where the final hosts have access to bodies of water of varying salinity. The parasite is said to possess a natural euryhalinity and lack of host specificity.

Unidentified metacercariae were reported from the brain of *F. heteroclitus* by Abbott (1968). None were found in the same location in the present study.

B. *Homalometron pallidum* Stafford, 1904. The recovery of this parasite from the intestine of *F. heteroclitus* from Frenchman's Cove, Mummichog Park and Seal Cove represents the first record of the species in Newfoundland waters.

The genus *Homalometron* was erected by Stafford (1904) to contain a new species, *H. pallidum*, from the intestine of *F. heteroclitus* from Wood's Hole, Massachusetts. There was no description or figure in his original report, the species designation being based on a description and figure by Linton (1901) of a *Distomum* sp. The material from Stafford's collection was later redescribed by Miller (1941). Manter (1926) reported *H. pallidum* in *F. heteroclitus* from Maine, while

Fantham and Porter (1947) reported it from Nova Scotia.

Stunkard (1964) discussed the historical background and the systematic problems associated with the genus, and identified the life cycle of the species. The larval stages occur in the bivalve *Hydrobia minuta*, the metacercarial stages being encysted in the gastropod *Gemma gemma*, and *H. minuta*. *G. gemma* does not however occur in Newfoundland waters (D. H. Steele, pers. comm. 1974).

Table 20 details comparative measurements for the species.

The measurements obtained for *H. pallidum* in the present study differ from those of previous authors, particularly in the overall body dimensions and the dimensions of the genitalia. This may be due to the fact that since the host is at the limits of its recorded geographic range, environmental conditions such as water temperature may be below that required for optimum growth and sexual development of the parasite, resulting in smaller individuals than those from warmer regions. It is also possible that the local population of *H. pallidum* may represent a smaller race of the parasite peculiar to this area, and infecting a particular race of *F. heteroclitus*. According to (Brown, 1957) extensive recordings of structural variations of *F. heteroclitus* over its zoogeographic range are lacking, but would be valuable in considerations of intrageneric subspecific designations. Kok Leng Tay and Garside (1972) have found evidence of meristic variations in *F. heteroclitus* from Sable Island and mainland Nova Scotia, which they attribute to salinity variation in the areas sampled.

Examination of Table 21 showed a significant decrease in the total incidence of infection from September (2) to October ($p < 0.05$),

TABLE 20

Comparison of morphological criteria of *H. pallidum* Stafford, 1904

Morphological criteria	Author			
	Linton, 1901	Linton, 1940	Miller, 1941	Present study
Body length	2.72	2.99	1.90	1.56
Body width (at acetabulum)	0.89	0.70	0.50	0.25
Oral Sucker (max. diam.)	0.26	0.26	0.18	0.18
Acetabulum (max. diam.)	0.29	0.27	0.23	0.21
Pharynx length	-	0.12	0.095	0.10
Ovary (max. diam.)	0.21	-	-	0.12
Testes	0.33/0.39	-	-	0.17/0.14
Egg size	0.11/0.07	-	0.92-0.11/0.54	0.11/0.06

TABLE 21

Occurrence of *H. pallidum* in male and female *F. heteroclitus*

	May	June	July	Sept. (1)	Sept. (2)	Oct.	Nov.	Dec.
# fish in sample	29	49	51	58	86	30	30	30
% infection	37.9 (11)	18.3 (9)	5.8 (3)	18.9 (11)	23.2 (20)	3.3 (1)	36.7 (11)	46.6 (14)
Mean # parasites per infected fish	1.5	1.4	1.6	1.0	2.4	1.0	2.0	2.6
Range of infection	1-4	1-2	1-2	1-4	1-7	0-1	1-3	1-8
# males in sample	14	25	32	27	43	18	14	15
% infection	35.7 (5)	12.0 (3)	10.0 (2)	7.4 (2)	20.9 (9)	5.5 (1)	21.4 (3)	53.3 (8)
Mean # parasites per infected fish	1.6	1.3	1.5	2.2	2.9	1.0	1.7	2.0
Range of infection	1-4	1-2	1-2	1-4	1-7	0-1	1-2	1-4
# females in sample	15	24	19	31	43	12	16	14
% infection	40.0 (6)	24.0 (6)	12.5 (1)	3.2 (1)	25.5 (11)	- -	50.0 (8)	40.0 (6)
Mean # parasites per infected fish	1.5	1.5	2.0	2.3	1.6	-	1.9	3.0
Range of infection	1-3	1-2	0-2	1-4	1-4	-	1-3	1-8

(#) = numbers of fish infected.

and a significant increase from October to November ($p < 0.05$). A significant increase in the incidence of infection of the females occurred between September (1) and September (2) ($p < 0.025$). No other significant differences were noted.

Examination of Table 22 showed that for the September (2) samples, the fish from Frenchman's Cove had a lower incidence of infection ($p < 0.05$) than those from Mummichog Park or Seal Cove. However, the total mean intensity of infection of fish from Seal Cove was significantly greater ($p < 0.05$) than Mummichog Park and Frenchman's Cove.

Table 23 revealed the 10-11.9 cm. host length class to have a significantly greater ($p < 0.005$) incidence of infection than the 3-4.9 cm. length class. No significant differences in the mean intensity of infection per fish were detected.

Analysis of Table 24 revealed no significant differences in monthly mean parasite length, or in the percentage of parasites with eggs.

3. (c). Cestoda

A. *Proteocephalus* sp. Immature *Proteocephalus* sp. were found in the intestine of *F. heteroclitus* and the Gasterosteids examined. Due to the lack of sexually mature individuals, it was not possible to identify the parasite to the specific level.

Measurements of specimens recovered from *F. heteroclitus* during the present study are as follows: Body length 1.47 mm. (0.36-6.18); maximum body width 0.16 mm. (0.08-0.36), maximum scolex width 0.19 mm.

TABLE 22

Occurrence of *H. pallidum* in *F. heteroclitus*, by month and sample area

	May			June			July			Sept. (1)			Sept. (2)			October			Nove
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)
# fish in sample	-	29	-	25	24	-	23	-	28	26	-	32	30	26	30	30	-	-	30
% infected	-	37.9 (11)	-	-	37.5 (9)	-	-	-	39.3 (3)	-	-	34.3 (11)	6.6 (1)	26.9 (7)	36.6 (11)	3.3 (1)	-	-	36.7 (11)
Mean # worms per infected fish		1.5			1.4				1.6			2.2	1.0	1.4	3.5	1.0			2.0
Range of infection		1-4			1-2				1-2			1-4	0-1	1-3	1-7	0-1			1-3
# males in sample	-	14	-	13	12	-	12	-	20	9	-	18	16	11	16	18	-	-	14
% infection	-	35.7 (5)	-	-	25.0 (3)	-	-	-	10.0 (2)	-	-	11.1 (2)	6.2 (1)	18.1 (2)	37.5 (6)	5.5 (1)	-	-	21.4 (3)
Mean # worms per infected fish		1.6			1.3				1.5			2.2	1.0	2.0	3.8	1.0			1.7
Range of infection		1-4			1-2				1-2			1-4	0-1	1-3	1-7	0-1			1-2
# females in sample	-	15	-	12	12	-	11	-	8	17	-	14	14	15	14	12	-	-	16
% infected	-	40.0 (6)	-	-	50.0 (6)	-	-	-	12.5 (1)	-	-	7.1 (1)	7.1 (1)	33.3 (5)	35.7 (5)	-	-	-	50.0 (8)
Mean # worms per infected fish		1.5			1.5				2.0			2.3	1.0	1.3	2.2				1.9
Range of infection		1-3			1-2				0-2			1-4	0-1	1-2	1-4				1-3

(#) = numbers of fish. (a) = Frenchman's Cove. (b) = Mummichog Park. (c) = Seal Cove.

TABLE 22

Occurrence of *H. pallidum* in *F. heteroclitus*, by month and sample area

May			June			July			Sept. (1)			Sept. (2)			October			November			December		
(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
-	29	-	25	24	-	23	-	28	26	-	32	30	26	30	30	-	-	30	-	-	30	-	-
-	37.9 (11)	-	-	37.5 (9)	-	-	-	39.3 (3)	-	-	34.3 (11)	6.6 (1)	26.9 (7)	36.6 (11)	3.3 (1)	-	-	36.7 (11)	-	-	46.6 (14)	-	-
	1.5			1.4				1.6			2.2	1.0	1.4	3.5	1.0			2.0			2.6		
	1-4			1-2				1-2			1-4	0-1	1-3	1-7	0-1			1-3			1-8		
-	14	-	13	12	-	12	-	20	9	-	18	16	11	16	18	-	-	14	-	-	15	-	-
-	35.7 (5)	-	-	25.0 (3)	-	-	-	10.0 (2)	-	-	11.1 (2)	6.2 (1)	18.1 (2)	37.5 (6)	5.5 (1)	-	-	21.4 (3)			53.3 (8)		
	1.6			1.3				1.5			2.2	1.0	2.0	3.8	1.0			1.7			2.0		
	1-4			1-2				1-2			1-4	0-1	1-3	1-7	0-1			1-2			1-4		
-	15	-	12	12	-	11	-	8	17	-	14	14	15	14	12	-	-	16			14		
-	40.0 (6)	-	-	50.0 (6)	-	-	-	12.5 (1)	-	-	7.1 (I)	7.1 (1)	33.3 (5)	35.7 (5)	-	-	-	50.0 (8)			40.0 (6)		
	1.5			1.5				2.0			2.3	1.0	1.3	2.2				1.9			3.0		
	1-3			1-2				0-2			1-4	0-1	1-2	1-4				1-3			1-8		

(a) = Frenchman's Cove. (b) = Mummichog Park. (c) = Seal Cove.

TABLE 23

Distribution of *H. pallidum* in various length classes of *F. heteroclitus*, months and sample areas combined

Length class (cms.)	# fish in class	# infected	% infection	# worms	mean # worms per infected fish
3- 3.9	38	2	5.2	2	1.00
4- 4.9	135	12	8.8	21	1.75
5- 5.9	128	26	20.3	53	2.03
6- 6.9	79	12	15.1	23	1.91
7- 7.9	86	10	11.6	21	2.10
8- 8.9	51	8	15.6	25	3.12
9- 9.9	21	3	14.2	3	1.00
10-10.9	14	5	35.7	8	1.60
11-11.9	5	2	40.0	7	3.50

TABLE 24

Monthly variation in mean length (mm.) and fecundity of *H. pallidum*, from *F. heteroclitus*, all sample areas combined

Month	# worms measured	Mean length (mm)	# with eggs	# without eggs	% total with eggs
May	15	1.75	17	21	44.0
June	9	1.51	6	11	35.2
July	4	0.99	1	4	20.0
September (1)	14	1.35	10	14	41.6
September (2)	20	1.68	16	24	40.0
October	1	0.63	1	1	50.0*
November	16	1.48	9	19	32.1
December	27	1.21	17	28	37.7

*The October figures may not be a true reflection of the situation obtaining due to the small sample size.

(0.11-0.27), maximum sucker diameter 0.08 mm. (0.05-0.11), maximum apical organ diameter 0.02 mm. (0.02-0.04).

Examination of Tables 25 and 26 revealed no significant differences in the incidence of infection of males and females on a total or monthly basis. However, the fish from Seal Cove showed a greater incidence of infection than those from Clark's Brook ($p < 0.01$) and Frenchman's Cove ($p < 0.005$). Significant declines in the incidence of infection occurred in Clark's Brook between June to July ($p < 0.01$) and June to September (1) ($p < 0.005$). A similar decline occurred between July to September (1) ($p < 0.005$) in the Frenchman's Cove samples. Significant declines in the incidence of infection for the data for all areas combined were apparent from May to November ($p < 0.025$).

Examination of Table 27 revealed the 5-5.9 cm. and 9-9.9 cm. host length classes to be significantly less infected ($p < 0.01$) than the 3-3.9 cm. and 10-11.9 cm. length classes. The mean intensity of infection in the 9-9.9 cm. and 11-11.9 cm. length classes was significantly greater ($p < 0.005$) than all other length classes with the exception of the 8-8.9 cm. class.

No other differences in incidence or intensity of infection were noted.

Analysis of Table 28 failed to reveal any significant monthly and area variations in the mean length of the parasites recovered.

TABLE 25

Occurrence of *Proteocephalus* sp. in *F. heteroclitus*, all sample areas combined

	May	June	July	Sept. (1)	Sept. (2)	Oct.	Nov.	Dec.
# fish in sample	29	71	99	86	116	60	60	60
% infection	41.3 (12)	39.4 (28)	30.3 (30)	32.5 (28)	41.7 (48)	21.6 (13)	16.6 (10)	28.3 (17)
Mean # parasites per infected fish	2.7	2.5	2.3	3.0	3.4	2.4	2.1	1.4
Range of infection	1-12	1-8	1-6	1-16	1-15	1-7	1-5	1-2
# males in sample	14	33	47	44	61	30	28	33
% infection	42.8 (6)	48.4 (16)	38.2 (18)	34.0 (15)	37.7 (23)	23.3 (7)	25.0 (7)	36.3 (12)
Mean # parasites per infected fish	3.5	2.0	2.1	3.9	3.9	3.1	2.5	1.4
Range of infection	1-12	1-8	1-6	1-16	1-14	1-7	1-4	1-2
# females in sample	15	38	52	42	55	30	32	27
% infection	40.0 (6)	31.5 (12)	23.0 (12)	30.9 (13)	45.4 (25)	20.0 (6)	9.3 (3)	18.3 (5)
Mean # parasites per infected fish	1.8	3.0	2.5	1.9	2.9	1.6	1.0	1.4
Range of infection	1-4	1-4	1-4	1-4	1-15	1-3	0-1	1-2

(#) = number of fish infected.

1 of

TABLE 26

Occurrence of *Protzocephalus* sp. in *F. heteroclitus,* by month and sample area

	May				June				July				Sept. (1)				Sept. (2)				October				N
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)
# fish in sample	–	–	29	–	22	25	24	–	24	23	–	28	28	26	–	32	30	30	26	30	30	30	–	–	30
% infection	–	–	41 (12)	–	59 (13)	32 (8)	29 (7)	–	25 (6)	44 (10)	–	50 (14)	14 (4)	4 (1)	–	72 (23)	27 (8)	23 (7)	54 (14)	63 (19)	23 (7)	20 (6)	–	–	10 (3)
Mean # worms per infected fish			2.7		3.0	1.5	3.0		2.2	2.3		2.0	5.0	3.0		3.0	2.6	1.3	4.0	4.0	2.0	3.0			1.3
Range of infection			1–12		1–8	1–4	1–6		1–4	1–5		1–6	1–3	0–5		1–16	1–5	1–3	1–15	1–14	1–4	1–7			1–2
# males in sample	–	–	14	–	8	13	12	–	15	12	–	20	17	9	–	18	18	16	11	16	12	18	–	–	14
% infection	–	–	42 (6)	–	62 (5)	46 (6)	41 (5)	–	20 (3)	41 (7)	–	40 (8)	12 (2)	11 (1)	–	67 (12)	33 (6)	19 (3)	45 (5)	56 (9)	33 (4)	17 (3)	–	–	14 (2)
Mean # worms per infected fish			3.5		3.0	1.0	2.2		2.0	1.2		2.0	2.0	5.0		4.3	3.1	1.0	2.4	5.0	2.5	4.0			1.5
Range of infection			1–12		1–7	0–1	1–6		1–4	1–5		1–6	1–3	0–5		1–16	1–5	0–1	2–8	1–14	1–4	2–7			1–2
# femles in sample	–	–	15	–	14	12	12	–	9	11	–	8	11	17	–	14	12	14	15	14	18	12	–	–	16
% infection	–	–	40 (6)	–	57 (8)	17 (2)	17 (2)	–	33 (3)	46 (3)	–	75 (6)	18 (2)	–	–	79 (11)	17 (2)	28 (4)	60 (9)	71 (10)	17 (3)	25 (3)	–	–	9 (1)
Mean # worms per infected fish			1.8		3.0	3.0	3.5		2.3	3.0		2.0	1.5			2.0	1.0	1.5	3.8	3.0	1.3	2.0			1.0
Range of infection			1–4		1–8	2–4	3–4		1–4	1–3		1–4	1–2			1–4	0–1	1–3	1–15	1–9	1–2	1–3			0–1

(#) = numbers of fish. (a) = Clark's Brook. (b) = Frenchman's Cove. (c) = Mummichog Park. (d) = Seal Cove.

TABLE 26

Occurrence of *Proteocephalus* sp. in *F. heteroclitus*, by month and sample area

	June				July				Sept. (1)				Sept. (2)				October				November				December			
(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
-	22	25	24	-	24	23	-	28	28	26	-	32	30	30	26	30	30	30	-	-	30	30	-	-	30	30	-	-
-	59 (13)	32 (8)	29 (7)	-	25 (6)	44 (10)	-	50 (14)	14 (4)	4 (1)	-	72 (23)	27 (8)	23 (7)	54 (14)	63 (19)	23 (7)	20 (6)	-	-	10 (3)	23 (7)	-	-	40 (12)	17 (5)	-	-
	3.0	1.5	3.0		2.2	2.3		2.0	5.0	3.0		3.0	2.6	1.3	4.0	4.0	2.0	3.0			1.3	2.4			1.4	1.4		
	1-8	1-4	1-6		1-4	1-5		1-6	1-3	0-5		1-16	1-5	1-3	1-15	1-14	1-4	1-7			1-2	1-4			1-2	1-2		
-	8	13	12	-	15	12	-	20	17	9	-	18	18	16	11	16	12	18	-	-	14	14	-	-	18	15	-	-
-	62 (5)	46 (6)	41 (5)	-	20 (3)	41 (7)	-	40 (8)	12 (2)	11 (1)	-	67 (12)	33 (6)	19 (3)	45 (5)	56 (9)	33 (4)	17 (3)	-	-	14 (2)	36 (5)	-	-	50 (9)	20 (3)	-	-
	3.0	1.0	2.2		2.0	1.2		2.0	2.0	5.0		4.3	3.1	1.0	2.4	5.0	2.5	4.0			1.5	3.0			1.3	1.7		
	1-7	0-1	1-6		1-4	1-5		1-6	1-3	0-5		1-16	1-5	0-1	2-8	1-14	1-4	2-7			1-2	1-4			1-2	1-2		
-	14	12	12	-	9	11	-	8	11	17	-	14	12	14	15	14	18	12	-	-	16	16	-	-	12	15	-	-
-	57 (8)	17 (2)	17 (2)	-	33 (3)	46 (3)	-	75 (6)	18 (2)	-	-	79 (11)	17 (2)	28 (4)	60 (9)	71 (10)	17 (3)	25 (3)	-	-	9 (1)	13 (2)	-	-	25 (3)	13 (2)	-	-
	3.0	3.0	3.5		2.3	3.0		2.0	1.5			2.0	1.0	1.5	3.8	3.0	1.3	2.0			1.0	1.0			1.6	1.0		
	1-8	2-4	3-4		1-4	1-3		1-4	1-2			1-4	0-1	1-3	1-15	1-9	1-2	1-3			0-1	0-1			1-2	0-1		

(a) = Clark's Brook. (b) = Frenchman's Cove. (c) = Mummichog Park. (d) = Seal Cove.

TABLE 27

Occurrence of *Proteocephalus* sp. in different length classes of *F. heteroclitus*

Host length class (cms.)	# Fish	# Infected	% Infection	# worms	Mean Intensity of Infection	Range of Infection
3- 3.9	38	18	47.3	45	2.5	1-7
4- 4.9	135	41	30.3	100	2.4	1-8
5- 5.9	128	30	23.4	73	2.5	1-15
6- 6.9	79	25	31.6	70	2.8	1-14
7- 7.9	86	27	31.3	59	2.2	1-5
8- 8.9	51	19	37.2	63	3.3	1-9
9- 9.9	21	5	23.8	29	5.8	1-16
10-10.9	14	8	57.1	13	1.6	1-4
11-11.9	5	3	60.0	15	5.0	1-12

TABLE 28

Variation in mean body length (mm.) of *Proteocephalus* sp. by month and area, from *F. heteroclitus*

Area	May	June	July	Sept.(1)	Sept.(2)	Oct.	Nov.	Dec.	Total Mean
Clark's Brook	–	1.33	1.04	1.55	1.88	2.57	1.93	0.84	1.62
Frenchman's Cove	–	1.51	1.15	0.69	0.87	1.13	0.92	–	1.06
Mummichog Park	1.81	1.42	–	–	0.86	–	–	–	1.67
Seal Cove	–	–	1.13	1.35	2.24	–	–	–	1.54
Total monthly mean length.	1.81	1.42	1.10	1.34	1.83	1.79	1.07	0.84	1.47

3. (d). Acanthocephala

A. *Neochinorhynchus rutili* (Mueller, 1780). This species has been described from a wide variety of fish throughout North America (*vide* Hoffman, 1967), and from gasterosteids in Newfoundland waters by Hanek and Threlfall (1970).

The occurrence of the parasite in *F. heteroclitus* from Clark's Brook represents a new host record, probably arising as a result of cross infection from the population of *P. pungitius* in the same area.

Table 29 shows the occurrence of *N. rutili* in *F. heteroclitus* from Clark's Brook. Seasonal incidence is apparent in that infection commenced in November. No significant differences in the incidence or intensity of occurrence within or between the two monthly samples was noted, probably due to the small size of the samples.

TABLE 29

Occurrence of *N. rutili* Mueller, 1780, in *F. heteroclitus* from Clark's Brook.

	Nov.	Dec.
# fish in sample	30	30
% infection	13.4 (4)	3.4 (1)
Mean # parasites per infected fish	11.75	1.0
Range of infection	1-32	1
# Males in sample	14	18
% infection	21.4 (3)	5.6 (1)
Mean # parasites per infected fish	11.0	1.0
Range of infection	1-32	1
# Females in sample	16	12
% infection	6.3 (1)	-
Mean # parasites per infected fish	4.0	-
Range of infection	4	-

(#) = number of infected fish

DISCUSSION

The use of ecological principles in parasitological studies was pioneered by Pavlovskii (1934) in the USSR, who suggested that the parasite is influenced by two environmental habitats, the 'micro-environment' or immediate environment within the host, and the 'macro-environment' or environment of the host. Pavlovskii (1937) further stated that the basic subject of ecological parasitology is the study of all parasites inhabiting the host organism, where they form a parasitofaunal aggregation or 'parasitocoenosis'. Dogiel (1941) thus summarised ecological parasitology as being concerned with the study of the relationships existing between the parasite fauna treated as a unit on the one hand, and changes in the environment and physiological condition of the host on the other.

Fischthal (1953) considered limnological factors in relation to parasitism in lake fishes, and pointed out that any consideration of the influence of a single factor on the organism is merely a necessary method of approach, and that as Welch (1935) had suggested "conditions within an environment are, to a great extent, mutually dependant, and in nature factors are always operating in the presence of others".

According to Noble (1960) the modern approach to parasitology is to envisage an ecological complex, formed by the parasite, the host, and various factors of the host's environment, and that the total parasite fauna and flora of an animal be termed it's 'parasite-mix'.

Kennedy (1970) stated that the ecology of fish parasites may be studied using a systems theory concept, involving input to and output from the system. He suggested that two basic systems models may be formulated, a fish intermediate-host system and a fish definitive host system; input to and output from these systems being influenced by abiotic and biotic factors of the parasites' micro- and macro- environments. If the factor balance is such that it results in a simultaneous input to and output from the system, this will result in the parasite population being in a state of dynamic equilibrium, a view also subscribed to by Chubb *et al.*, (1964).

Kennedy (1972) further suggested that the factors controlling the flow of parasites through a host-parasite system may be divisible into three groups, those influencing input e.g. host diet and availability of infective larvae, those influencing output e.g. host response and natural mortality, and climatic factors which may influence the host's condition, and hence the first two sets of factors. He states that temporal variations in the abiotic and biotic factors will lead to seasonal patterns of parasite population change, and that if there is variation in the extent of change of the appropriate factors in different places, this will result in local differences in the pattern of flow of parasites through the same host-parasite system.

Seasonal cycles in the occurrence and reproduction of fish parasites have often been directly linked with seasonal changes in the host's environment. According to Dogiel (1958), annual cycles in parasitofauna are "particularly widespread in the parasites of freshwater fishes, being an adaptation to the seasonal fluctuations in water temperatures". Similarly, Wisniewski (1958) suggested that the characteristics of a body of water influence and determine the nature and cyclic fluctuations of its parasite fauna.

Variations in the host's ecology throughout the year, such as changes in the host diet have also been found to cause seasonal differences in intensity and incidence of infection (Hopkins, 1959; Chubb, 1963), whilst Kennedy and Walker (1969) have speculated on the relationships between seasonal incidence cycles and seasonal changes in the resistance of fish to infection.

According to Halvorsen (1972), is seasonal changes in the physiology of the fish host are the main factors influencing the parasites, then one would expect to find a comparable seasonal relationship for the same host-parasite system in localities with comparable seasonal climatic cycles. If, on the other hand, ecological mechanisms are the main factor, one would expect to find large differences in the patterns of cyclic fluctuations between localities. Differences in the composition and function of the ecosystems would give the parasite different possibilities to infect the host throughout the year, thus causing differences in seasonal cycles.

Bychowsky (1957) stated that "relatively little is known of the way in which a population of monogenean parasites is related to the behaviour and physiology of their hosts, or how such a population varies in composition over the year".

A seasonal cycle in the incidence of occurrence of Monogenea on *F. heteroclitus* is apparent, the total population decreasing in the summer and increasing in the fall months, parallelling fluctuations in the surface water temperatures. In Seal Cove, a region of little water temperature fluctuation during the months sampled, no cyclic fluctuation

Ma	
(b)	(a)
29	-
37.(11	-
1.	
1-	
14	-
35.(5)	-
1.	
1-	
15	-
40.(6)	-
1.	
1-	

(a) =

occurred in the frequency of occurrence of Monogenea.

Dogiel (1964) suggests that if a seasonal cycle is apparent in Monogenea, ~~it will~~ either show a peak in summer, totally disappearing in winter, or a peak in summer, partially disappearing in winter.

In the present study, a sample of Monogenea from the total *F. heteroclitus* sample examined reveals that for *G. stephanus*, the frequency of occurrence of the parasite increases from a minimum in May at a mean water temperature of 14°C to a maximum in November at a mean water temperature of 3°C. It is possible however that the insignificant decline experienced to the December level could be the beginning of a downward winter trend to the May level. *G. prolongis* and *U. angularis* appear to exhibit well-defined seasonal cycles in the samples examined. *G. prolongis* shows maximum frequency of occurrence in May and October at 14°C and 7.5°C and a minimum occurrence in early September at 20°C. *U. angularis* shows maximum occurrence in early September at 20°C and minimum occurrences in May (14°C) and November (3°C).

Anthony (1969) found that temperature influenced the distribution of *G. elegans* on *Cyprinus auratus*, a seasonal peak occurring in April and May at 9-11°C. Chappell (1969) found that *G. rarus* reached a peak of occurrence in Spring, whilst Mackenzie (1970) found that *G. unicopula* reached a peak in July on *Pleuronectes platessa*. Dartnall (1972) found unidentified *Gyrodactylus* sp. to have a low incidence of occurrence in summer and a high incidence in winter. Rawson and Rogers (1972) studying the Ancyrocephalinean Monogenea of the bluegill, *Lepomis machrochirus* found cyclic fluctuations with a trend towards increasing intensity of infestation in the fall months when the water temperature was declining from an approximate maximum of 30°C. The highest populations of *Urocleidus acer* and *U. dispar* occurred at temperatures of approximately 10°C.

Thus, it seems likely that the seasonal fluctuations in the Monogenea of *F. heteroclitus* from the areas samples are related to seasonal fluctuations in the water temperature, either by a possible retardation of the growth rate and delay in the onset of sexual maturity in the adult (Allée *et al.*, 1949) or by affecting the development of eggs and larvae.

Llewellyn (1957) stated that examination of egg production in several species of Monogenea showed that at 3-7°C adult worms survived for 2-3 weeks, but little egg production took place below 8°C. At 13°C, egg production generally ceased after 4 days, suggesting that the adult worms rapidly degenerate at this temperature. At 18°C, the parasites did not survive longer than 24 hrs.; egg production continuing for the first 12 hrs.; and at 20°C the parasites died within 12 hrs.; generally without egg capsules being produced.

It is therefore possible that a temperature controlled series of events similar to those described above could be responsible for the cyclic fluctuations observed in the *G. prolongis* samples.

The cyclic fluctuations in *U. angularis* may be explained in a manner similar to that proposed by Paling (1965) for *Discocotyle sagittata* on *Salmo trutta*. At the low winter temperatures experienced, any eggs that are present probably remain dormant. As the temperature rises in spring, hatching commences, and the oncomiracidia invade the host population. At 15°C and above, the parasites have a high rate of egg production and the incubation period is short, resulting in a mid-summer peak. The water temperature falls in the autumn, and consequently the speed of egg production and incubation decreases, until the low winter temperatures cause cessation of larval development.

It is possible that seasonal incidence cycles in parasites may be related to the effect of the water temperature on the physiology of the host. Cushing (1942) found that in *Cyrenius carpio* and *Carassius auratus* the rate of antibody production was greater in warm water (28°C) than in cold water (14°C). Thus, at high environmental temperatures, the high rate of host antibody production will lead to a decline in the host's parasite load, the reverse occurring in the cool fall and winter conditions, thus leading to an incidence cycle similar to that observed for *Gyrodactylus prolongis*.

A seasonal cycle has also been demonstrated (Chappell, 1969a) for the occurrence of developed embryos of *G. rarus*, which showed an increase in incidence over a September–June period. However, no such seasonal cycle was noted in *G. prolongis* or *G. stephanus* during the present study. Hoffman and Putz (1964) have indicated that *G. machrochiri* has an optimum reproduction temperature of 12°C. As to whether a similar temperature optimum applies to *G. prolongis* and *G. stephanus* is uncertain, since in the present survey, embryonated individuals were recovered with similar frequency during all seasons.

Little information is available on the effect of salinity changes on seasonal cycles in Monogenea. Bychowsky (1957) and Polyanskii (1958) both state that the salinity of the water exercises great influence on the incidence and intensity of occurrence of Monogenea. Gowanloch (1925) showed that *Gyrodactylus* sp. from *F. heteroclitus* was unaffected by the lowering of the salinity down to freshwater. However, exposure to the action of fresh or distilled water caused the rapid migration of the parasites off the host, followed by their subsequent death. Such an effect may be partially responsible for the seasonal decline in incidence of *U. angularis* during the spring and fall months, when the water salinities are declining from their summer maxima. According to Mueller (1936), the genus *Ancyrocephalus* (= *Urocleidus*) is essentially marine in nature.

Prost (1959) in a study of the effects of salinity in different reservoirs on the monogenean fauna concluded that those species which have not acquired phylogenetic resistance to high salinities are adversely affected by increasing the salinity of the medium, the degree of adverse effect varying with the species involved. Isakov (1970) showed that ectoparasites of *Gasterosteus pungitius* (= *Pungitius pungitius*) and *G. aculeatus*, including *Gyrodactylus arcuatus*, exhibit paranecrosis during gradual changes in the salinity of the water from fresh to marine. It is thus conceivable that the seasonal incidence of *G. prolongis* may decline during the summer months due to the increased salinity of the environment. Dartnall (1972) however states that the *Gyrodactylus* sp. (or spp.) that he recovered from *G. aculeatus* exhibited a wide range of tolerance to salinity changes. Unfortunately, as he did not identify the parasites to the species level, and it being possible that several species were involved, each having differing salinity tolerances, his assumptions are therefore questionable.

The relationship between incidence and intensity of infestation and length (age) of host has been studied by several workers. Gorbunova (1936) suggests that, as a consequence of work done on pike and roach, that the relationship between the incidence of infestation and the age of the host may follow any one of three patterns, the parasite incidence may be independent of the age of the host, or may decrease or increase with the age of the host.

Dogiel (1964) suggests that the latter case is most frequent in freshwater fish, and in the case of endoparasites, it may be due either to an increase in the quantity of food consumed by larger fish, and hence an increase in the intake of eggs and larvae. The accumulation of the parasite fauna over a period of years may also be a contributing factor. In the case of ectoparasites, an increase in the available surface area for the settling of the larval stages may also be partially responsible for increasing incidence and intensity of infestation.

Noble *et al.*, (1936) showed that the incidence of occurrence of *G. elegans* on *Gillichthyes mirabilis* to be non significant with increasing length (age) of the host. Aderounmu (1966) found that *Gyrodactylus* sp. decreased in incidence and intensity of infestation with age (length) of the host *Salmo trutta*. Chappell (1969b) found that *G. rarus* decreased in incidence of infestation with length of the host *G. aculeatus*, but the intentisy of infestation showed an initial increase followed by a decrease in larger fish, Mackenzie (1970) showed no significant change in the intensity of infestation of *Pleuronectes platessa* with *G. unicopula*, with increased length (age) of the host.

The monogenean fauna of *F. heteroclitus* shows no significant increases in incidence of infestation above the 5 cm. length class, suggesting that age immunity to increased parasite infestation has been developed. However, examination of samples of each species of Monogenea indicates that the incidence of infestation of each species is at a minimum in short (young) and long (old) fish. No definite trend was noticed towards increased intensity of infestation with each species and increasing length of *F. heteroclitus*.

In general, no significant difference in intensity and incidence of infestation with regard to the sex of the host was noted. However, in the samples from Clark's Brook, combination of the monthly data showed males to be more heavily infested than females. Paling (1965) suggested that such a situation is due to females having a greater physiological resistance to infestation than males. Lees and Bass (1960) showed that the host sex hormones are a contributing factor to parasitization in frogs, and Dobson (1961) showed that the female sex hormone increases the host's resistance while the male hormones cause decreased resistance. However, when the samples of *F. heteroclitus* are examined on a monthly basis, females from Mummichog Park and Frenchman's Cove were found to show a significantly greater incidence of infestation than males in May and June respectively. Examination of the female gonads in these months indicated all the females to be gravid, which was not the case in later months. Thomas (1964) proposes several reasons why female fish are more heavily infested than males in the spawning season. The condition factor of the females may be less than that of the males during and after spawning, since they contribute relatively more reproductive material, expend more energy and eat less food than the males, thus making them physiologically less resistant. Also, the state of stress induced in the females by the males during the spawning will contribute to the lowering of the physiological resistance of the females. According to Read (1958) stresses of various kinds, in mammals at least, stimulate the release of adrenocorticotrophic hormones from the anterior pituitary, which in turn could result in the production of adrenal glucocorticoids which are believed to be a contributing factor in the lowering of an organism's immune response.

Also, the ripe ovarian follicles would cease to produce estrogen after ovulation, thus depriving the fish of one of its resistance mechanisms.

The distribution of Monogenea on the host has been studied by Anthony (1969), who found that the temperature of the water influenced the distribution of *G. elegans* on the body and gills of *Cyprinus auratus*, the number of parasites on the body of the fish in cold water being higher than the number on the gills, whereas the reverse was true in warm water. However, although there was a significant monthly variation in the relative proportions of Monogenea on the gills and fins of *F. heteroclitus*, the distribution did not conform to any such pattern.

In the sample of *G. prolongis* examined, a preference was noted for the dorsal fin of *F. heteroclitus*, at the expense of all other fins and gills, whilst *G. stephanus* failed to demonstrate any fin preferences. Anthony (*op. cit.*) showed that *G. elegans* exhibited significant lack of preference for the anal fin of *C. auratus*, but no preference for any other fin. He demonstrated, however, that distribution of *G. elegans* on the fins is related to the area of the fin, the anal fin possessing the least percentage (7%) of the total fin area, yet possessing the highest number of parasites per mean area (1.3), whilst the caudal fin occupying 41% of the total fin area showed the lowest (0.7) number of parasites per mean area. This would appear to be in direct contrast to the present study, where the very small pelvic fins showed neglible infestation, whereas the large dorsal fin showed high intensities of infestation.

The relationship between mean intensity of infestation and fin area is further seen by reference to the fish from Mummichog Park and Seal Cove, which have a significantly greater mean intensity of infestation than fish from the other sample areas. These fish also have significantly greater mean lengths, and hence fin areas, than fish from the other sample areas, due either to a greater amount of available food in these areas, or to a lower population density of fish, which may in either case possibly result in a faster growth rate.

The differences in incidence of infestation of the fins of fish from the various sample areas may be explained on the basis of host population densities. Gyrodactyloidea are primarily distributed throughout a host population by transfer during physical contact of the host (Bychowsky, 1957). Hence the incidence of occurrence of fin Monogenea is significantly greater in Clark's Brook, due possibly to the smaller size of the habitat and the probable greater population density of the host, thus facilitating contact and transfer of the parasites.

Conversely, in Seal Cove, the population density of *F. heteroclitus* appears lower than in other areas, and hence a significantly lower frequency of occurrence of fin Monogenea results. The lack of a significant difference in incidence of occurrence between Frenchman's Cove and Mummichog Park is less apparent, since the Mummichog Park inlet covers a much larger area than the Frenchman's Cove pond. However, it was noticeable that *F. heteroclitus* tended to school in a particular region of the inlet which was of approximately the same type and surface area as the Frenchman's Cove pond. Hence in effect, since sampling at Mummichog Park was carried out in an area of similar size to that of Frenchman's Cove, it is possible that the population densities of the host, and hence the incidence of occurrence of fin Monogenea might be similar.

The distribution of Monogenea on the gill arches of the host has been studied by several authors. Mackenzie (1970) showed that *Pleuronectes platessa* carried significantly less *G. unicopula* on the fourth gill arch on both sides than on the other three. Tedla & Fernando (1970) showed that *Urocleidus adspectus* on *Perca flavescens* occurs in approximately equal numbers on both sides of the fish, and shows maximum infestation on Arch II and minimum on Arch IV. In the present study, *G. stephanus*, *G. prolongis* and *U. angularis* showed a lack of preference for Arch IV, and no significant preference for any other arch. Similarly, there was no preference for arches on either side of the body.

In an attempt to account for specificity of distribution of Monogenea on particular gill arches, Llewellyn (1956) suggested that infective larvae are swept involuntarily over the gills by the gill ventilation current. Any variations in the volume of water passing over the gill arches might thus be reflected in the number of opportunities for the parasite to become attached. However, the greater numbers of larvae brought to those gills receiving the greater ventilation would themselves be committed to a life-long struggle for existence against the greater current, and the survival rate would be correspondingly lower than on the less well ventilated gills. Paling (1968) working with *Salmo trutta*, and using glochidia of *Anodonta cygnea* as indicators, determined that the greatest volume of water in the gill ventilation current passed over the 2nd and 3rd arches. The first arch received the next greatest volume, and the 4th arch the least volume of water.

Arme and Halton (1972) showed a preference of *Diclidophora merlangi* for Arch I of whiting, followed by Arches III and IV in high intensity infections, there being no significant difference between either side of the body. They suggest that Llewellyn's (1956) hypothesis for parasite distribution could be appropriate in the case of single worm infections, but that in multiple worm infections other factors may be important in governing the distribution of the parasite. Possibly an established infection may influence the distribution of further parasites by increasing the mucus production on a particular gill, thus producing an unfavourable micro-habitat, so that Arch I becomes unsuitable for adult or larval occupation. They further suggest that newly acquired larvae may attach to Arch I, and then either migrate posteriorly or displace established parasites on Arch I. Izunova (1953) has noted that under conditions of lowered oxygen tension, *Dactylogyrus solidus* migrates over the gills to positions of maximum aeration on Arches I and IV, contradictory to the statement of Paling (1968).

In the present study however, no significant preference for any arch or side of the body is noted in single worm infections, and thus the possibility exists that initial and low intensity infection is a random occurrence.

It has frequently been shown (Kabata, 1963, Mackenzie, 1968) that the composition of the parasite fauna of a host species may vary over the geographic range of the host. Such a situation is found in *F. heteroclitus* with regard to the occurrence of Digenea in different sample areas. Metacercariae were of common occurrence on fish from Frenchman's Cove and Mummichog Park, but were totally absent on fish from Clark's Brook and Seal Cove, probably due to the first intermediate host being absent from those areas. It is of interest to note that the *F. heteroclitus* population from Frenchman's Cove was supposed to have originated in the Codroy Valley, possibly in some location adjacent to Mummichog Park, and thus the common presence of metacercariae in the samples may be used as an indicator of the origin of a particular population of the host species, in the manner of a "biological tag" (Kabata, 1963).

The absence of *Homalometron pallidum* from Clark's Brook may also be explained on a similar basis to the above. The significant differences in incidence of occurrence between areas where *H. pallidum* does occur may be due to differences in the incidence of occurrence of the intermediate hosts, whereas the significantly greater mean intensity of infection of the Seal Cove fish is probably due to a greater rate of ingestion of intermediate hosts, associated with the need for the larger fish from this area to take in greater amounts of food. Similar criteria could also explain the significantly greater incidence of infection found in the 10-10.9 cm. and 11-11.9 cm. length classes than in the 3-3.9 cm. and 4-4.9 cm. classes of host.

Significant fluctuations in the incidence of infection were noted between Sept. (1) and November, and non-significant variations occurred in other months, indicating the existence of a seasonal cycle for *H. pallidum* in *F. heteroclitus* with spring and fall peaks. Seasonal cycles have been found in other Digenea. Thomas (1958) showed an increase in winter and a decline in summer of *Crepidostomum metoecus* and *C. farionis* in *Salmo trutta* and *S. salar* and suggested that the summer decline was due to periodicity in the swarming of the cercariae, which in turn was governed by the life cycle of the clam.

The possible effects of changes in the salinity of the water on the seasonal incidence of Digenea has been investigated by Standen (1951), who showed that the salinity of the medium has a marked effect on the hatching of the eggs of *Schistosoma mansoni*, the process being almost totally inhibited by a 0.6% NaCl solution, extensive hatching not occurring until a dilution of 0.1% NaCl is reached, thus ensuring that eggs in the blood, gut contents or urine of the definitive host will only hatch on dilution with water.

The effect of environmental temperature variation may be exerted on all or several stages of the digenean life-cycle. Rawcliffe and Ollerenshaw (1960) showed that the eggs of *Fasciola hepatica* have a critical hatching range temperature from 10-30°C, above and below which there is increased inhibition of hatching. Similarly, Varma (1961) noted that the miracidia of *Cotylophoron cotylophum* hatch in fifteen days at 28-30°C, and at lower and higher temperatures, hatching is increasingly delayed. Vernberg and Hunter (1961) demonstrated the susceptibility of adult trematodes to variations in environmental temperature by studying changes in the respiration rates of the parasites, and showed that for *Saccocoelium beauforti* from *Mugil cephalus* there is an increase in respiration rate up to 34°C, after which a decrease occurs, leading to the death of the parasite at 41°C.

Seasonal variation in length and state of maturity of the parasite have been recorded for *Phyllodistomum folium* from *Gasterosteus aculeatus* L., 1958 (Chappell, 1969a), the smallest worms being found in mid-summer when a high proportion of newly hatched fish were found in the population. At the same time, the percentage of worms containing eggs was at a minimum, increasing over the fall and winter months.

In *H. pallidum*, the shortest mean worm lengths were noted in July and October, indicating the possibility of two generations of worms, although the differences were not significant from other months. No significant differences were observed in the monthly incidence of occurrence of eggs, signifying that in *H. pallidum*, the effect of temperature and salinity variation may act directly upon other stages in the life-cycle, or indirectly by affecting the occurrence of the intermediate molluscan hosts.

The majority of the *Proteocephalus* sp. found in *F. heteroclitus* were recovered from the rectum. As to whether this the parasites' permanent habitat in the definitive host, or a temporary position as a result of decreased feeding whilst in the holding tanks is not known. Mackenzie and Gibson (1970) found that the distribution of *Podocotyle* sp. in the intestine of *Platichthys flessus* varies with the time between capture and analysis, nearly all the parasites having moved down the intestine to the rectum after six days.

Seasonal incidence cycles have been reported for several species of *Proteocephalus* (Connor 1953; Hopkins 1959; Kennedy and Hine 1969). As with *Proteocephalus* sp. from *F. heteroclitus* in the present study, maximum incidences of infection occur in the spring and fall months. Kennedy and Hine (1969) also demonstrated a seasonal cycle in the intensity of infection of *Leuciscus leuciscus* with *P. filicollis*, but Chappell (1969a) was unable to demonstrate a cycle for the same parasite in *G. aculeatus*. Dartnall (1972) however, showed a winter decline in intensity of infection for the same host/parasite relationship. In the present study, no seasonal cycle in intensity of infection of *F. heteroclitus* with *Proteocephalus* sp. was observed.

It has been suggested (Dogiel, 1958) that seasonal incidence and intensity cycles may be due to seasonal variation in the availability of infective larvae, host feeding habits and physiological resistance of the host. Several authors (Hopkins, 1959; Chubb 1963, 1967; Awachie, 1966) have suggested that water temperature is the common causal factor in seasonal cycles of cestodes. It will be noted that in the present survey, the decrease in incidence of occurrence of *Proteocephalus* sp. parallels an increase in water temperatures.

Kennedy and Hine (1969) demonstrated a seasonal cycle in the mean length and maturation state of *P. torulosus* in *L. leuciscus*, the mean length of the worm increasing in the spring and fall and decreasing after April, coinciding with decreases and increases in water temperature. Sexual maturation accompanied the period of increase in worm length, genital rudiments appearing when the worms were less than 10 mm. long. Gravid worms did not however form a significant part of the populations until after March. No relationship between egg production and water temperature was observed, eggs being produced over a wide range of temperatures from 5.5-14.4°C.

No such cycle of sexual maturation and increase in mean worm length was noted in the present study. Sexually mature worms were totally absent from the samples throughout the whole of the sample period, and no significant variation in mean monthly length of the adults was noted. It is possible that sexual maturation did not occur due to environmental temperatures failing to reach a necessary minimum for maturation to occur. Chappell (1969a) has suggested that the duration of the low water temperatures rather than the absolute minimum reached may be of vital importance.

Kennedy and Hine (1969) suggest, however, that the water temperature does not directly stimulate egg production, the possibility existing that the stimulus for maturation is supplied by the host. The nature of the stimulus is in doubt, but seasonal variation in the endocrine balance of the host has been suggested as an initiator of the annual maturation rhythm in parasites, which is supported by Kennedy's (1968, 1969) discoveries that the commencement of infection of *Leuciscus leuciscus* with *Caryophyllaeus laticeps* is correlated with the commencement of gonad maturation in the host.

Kennedy and Walker (1969) have shown that at low temperatures, *C. laticeps* is better able to establish in *L. leuciscus* than at high temperatures, probably due to an active rejection of the parasite on the part of the host. Kennedy (1971) using *C. laticeps* in *L. idus* has shown that above a critical temperature of 18°C, only temporary survival of the parasite occurs, and that there is a simultaneous disappearance of all parasites after three days, rather than a gradual loss over a short period. The recovery of dead parasites from the rectum, and the failure to recover rejected parasites from the holding tank suggests that the parasite is being killed rather than merely being eliminated from the intestinal tract, and that the dead tapeworm is digested during its passage down the alimentary canal. The possibility of an immunogenic response on the part of the fish is considered to be consistent with what is known about antibody production in fish, which is closely dependant on temperature, increasing sharply above 12°C (Cushing, 1942). The rate of response to the parasite is extremely rapid (three days), and no fish has yet been shown to produce specific antibodies to either parasites or injected antigens within a period of less than seven days (Cushing, 1942; Orr, Hopkins and Charles, 1969). Thus Kennedy (1971) suggests that the temperature controlled death and rejection of the parasites may be an immunological response, but it is unlikely to be of the classical type involving the presence of circulating antibodies specifically directed against the parasite, since antibodies were not able to be demonstrated in the serum.

The effect of salinity on the occurrence of endoparasites has received little attention. Dartnall (1972) suggests that the sodium content of the intestinal fluids remains fairly constant regardless of the external environment, thus making it of minimal value in cestode and digenean seasonal cycles.

There is thus the distinct possibility that the seasonal cycles and lack of sexual maturity exhibited in *Proteocephalus* sp. from *F. heteroclitus* are controlled by the temperature of the environment and by host physiological factors similar to those postulated above.

The distribution of *Proteocephalus* sp. with regard to the length class of *F. heteroclitus* showed the 3-3.9 cm. and 10-11.9 cm. length classes to have a significantly greater frequency of infection than other length classes, particularly the 5-5.9 cm. and 9-9.9 cm. length classes. The mean intensity of infection is also significantly greater in fish of the 8-11.9 cm. length classes than in smaller fish. Hopkins (1959) showed the lower length classes of *G. aculeatus* to have a greater incidence of infection than the higher length classes in the fall, the heterogeneity of infection becoming less marked in the spring. Kennedy and Hine (1969) demonstrated that both the incidence and intensity of infection with *P. torulosus* increased with increase in length of *Leuciscus leuciscus*. Chappell (1969b) noted no significant variation in the incidence of occurrence of *P. fillicolis* with the length of the host, *G. aculeatus*. Dartnall (1972) however showed a decrease in incidence and intensity of infestation of *P. fillicolis* with increased length of *G. aculeatus*.

Dogiel (1958) regards such patterns as being due to changes in the physiology or diet of the host. However, Titova (1955) found that the lower thermal death limit of *Diphyllobothrium latum* plerocercoids depended upon the size of the fish host, the parasites of smaller fish succumbing more rapidly than those of larger fish. Conversely, Hilliard (1959) found that in *Osmerus dentax*, *Diphyllobothrium* sp. succumbed more rapidly in older fish.

No significant difference was observed between the incidence and intensity of occurrence of *Proteocephalus* sp. in male and female *F. heteroclitus*. Kennedy (1968) found male and female *L. leuciscus* to be similarly infected with *C. laticeps* except in the breeding season, when female fish became more heavily infected.

Seasonal occurrence of *Neoechinorhynchus rutili* was noted in the samples from Clark's Brook, the parasite being totally absent until November. However, no significant differences between the November and December samples were noted with regard to incidence and intensity of infection and the sex of the host.

Walkey (1967) demonstrated the occurrence of incidence cycles in mature and immature worms, a high incidence of immatures being present in summer, autumn and winter, and a high incidence of mature forms in spring. He suggests that such cycles may be due to changes in the endocrine balance of the host, or more likely to environmental temperature fluctuations. Similarly, he showed that the distribution of *N. rutili* is non-random with regard to the length of the host, there being an increase in incidence and intensity of occurrence with increase in length of the host. He speculates that this may be due to a difference in feeding habits of the larger fish, which eat more and are thus able to take in more larvae, or to cumulative infection as a result of the secure mode of anchorage of the worm. Similar results were found by Bibby (1972) from *Phoxinus phoxinus*.

Of the twelve species of metazoan parasites recorded in this survey from sympatric populations of Cyprinodonts and Gasterosteids, only three species (*G. stephanus*, *Proteocephalus* sp. and *N. rutili*) were common to both host families.

In all cases it would appear that one family is the "right" or normal host, and one family the "wrong" or abnormal host family. *G. stephanus* appears to be specific primarily for *F. heteroclitus*, secondarily infecting *P. pungitius*, whereas *N. rutili* appears to be primarily specific for Gasterosteids especially *P. pungitius*, secondarily infecting *F. heteroclitus*. Although *Proteocephalus* sp. appears to be primarily specific for *F. heteroclitus*, secondarily infecting Gasterosteids, it is possible that two or more species of *Proteocephalus* which were impossible to identify to the species level due to the lack of sexually mature adults, may be involved.

Species specificity occurs within the Cyprinodontidae of the seven recorded parasite species infecting *F. heteroclitus*, only one *G. stephanus*, occurs in *F. diaphanus*.

These differences may be explained in terms of differences in host immune reactions, or in terms of differences in the feeding habits of the fish in the case of those parasite species utilising intermediate invertebrate hosts.

As to the nature of the immune mechanisms operating in this parasite-host community, they may be of the classic antibody-antigen reaction, or a modification thereof.

Bråten (1966) showed *Schistocephalus solidus* could not survive in hosts other than *G. aculeatus*. No evidence of antigen-antibody reactions was obtained, and the time of death of the parasite from implantation in the new host was too short to allow for antibody production. Since the outer tegument of the worm was observed to rapidly degenerate, the author suggested that enzymic digestion of the "foreign" proteins of the worm occurred. However, Orr *et al.*, (1969) suggested that the failure of *S. solidus* to develop in experimentally infected *P. pungitius* was due to an immune rejection response, the degenerative changes in the tegument indicating the presence of a cytotoxic antibody.

Whatever the nature of the factors controlling the heterogeneous distribution of parasites throughout the host populations, the end result has important consequences in that severe damage and mortality is confined to a relatively small proportion of the host population (Kennedy, 1972).

SUMMARY

1. Conventional parasitological examination of 728 fish (557 *Fundulus heteroclitus*, 28 *F. diaphanus*, 64 *Pungitius pungitius*, 69 *Gasterosteus aculeatus* and 10 *Apeltes quadracus*) from four sample areas on the west coast of insular Newfoundland revealed the presence of 11 genera and 12 species of metazoan parasites.

2. Six genera and seven species were recorded from *F. heteroclitus* (*Gyrodactylus prolongis*, 33% infestation; *G. stephanus*, 26%; *Urocleidus angularis*, 28%; unidentified metacercariae; *Homalometron pallidum*, 22% infection; *Proteocephalus* sp., 35%; *Neoechinorhynchus rutili*, 1%); 1 genus and species from *F. diaphanus* (*U. angularis*, 100%;) 5 genera and species from *P. pungitius* (*G. stephanus*, 12%; *Brachyphallus crenatus*, 5%; *Proteocephalus* sp. 1.4%; *N. rutili*, 45%; and *Thersitina gasterostei*, 31%); 7 genera and species from *G. aculeatus* (*B, crenatus*, 3%; *Derogenes varicus*, 4%; *Eubothrium* sp., 1.5%; *Proteocephalus* sp., 6%; *N. rutili*, 1.4%; *T. gasterostei*, 29% and *Argulus canadensis*, 1.4%); and 4 genera and species from *Apeltes quadracus* (*D. varicus*, 20%; *Proteocephalus* sp., 10%; *N. rutili* 10%; and *T. gasterostei* 10%).

3. Host records are established for *G. stephanus* (*P. pungitius*), *U. angularis* (*F. heteroclitus*) and *N. rutili* (*F. heteroclitus*). Canadian records are noted for *G. stephanus* and *U. angularis* and Newfoundland records for *G. prolongis* and *H. pallidum*.

4. Differences in the parasitofauna of *F. heteroclitus* are

evident between the sample areas. Of the 3 species of Monogenea, *G. stephanus* is most common from Clark's Brook, *G. stephanus* and *U. angularis* from Frenchman's Cove, *G. prolongis* and *U. angularis* from Mummichog Park and *U. angularis* from Seal Cove. Gill metacercariae were found only in Mummichog Park and Frenchman's Cove, whilst *H. pallidum* was absent from Clark's Brook. *N. rutili* was found only in Clark's Brook, whereas *Proteocephalus* sp. was common to all areas.

5. Non-random distributions of parasites with regard to length and sex of host were noted for *F. heteroclitus*. *G. prolongis* showed least infestation in the 3-3.9 cm., and 10-11.9 cm. host length classes, *G. stephanus* exhibited minimum infestation in the 3-3.9 cm., and 9-10.9 cm. classes and *U. angularis* showed minimum occurrence in the 3-3.9 cm., 7-7.9 cm. and 9-10.9 cm. length classes. The 10-11.9 cm. length class was more infected with *H. pallidum* than other length classes, whilst *Proteocephalus* sp. showed maximum incidence of occurrence in the 9-9.9 cm. and 11-11.9 cm. classes.

Males were more infested with Monogenea than females in Clark's Brook, whereas females were more infested than males in May (Mummichog Park) and June (Frenchman's Cove), and showed greater intensities of infestation in June (Frenchman's Cove), July and Sept. (2) (Seal Cove). No differences in the intensity or incidence of infection of males and females were noticed for *H. pallidum*, *Proteocephalus* sp. and *N. rutili*.

6. Seasonal incidence cycles were demonstrated for several species of parasite from *F. heteroclitus*, showing peaks of occurrence

in spring and fall (*G. prolongis*, *H. pallidum*, and *Proteocephalus* sp.), peak occurrences in the summer (*U. angularis*), and peak occurrence in the fall (*N. rutili*). An increase in incidence was noted for *G. stephanus* from spring to fall.

7. No significant monthly variations in body length and incidence of occurrence of larvae and/or eggs in *G. prolongis*, *G. stephanus*, *H. pallidum* and *Proteocephalus* sp. were noted.

8. Specific site preference of Mongenea on *F. heteroclitus* was observed, *G. prolongis* preferring the fins whilst *G. stephanus* and *U. angularis* preferred the gills. No preference was noted for a particular gill arch, although Arch IV was significantly less infested than all other arches. The pectoral fins were the least infested of the infested fins, and the caudal fin showed the greatest intensity of infestation. Fish from Seal Cove and Mummichog Park showed a greater mean intensity of infestation than fish from other areas. No seasonal variation was noted in the relative distribution of Monogenea on the gills and fins.

9. The physical nature of the fishes' environment was noted with regard to surface water temperature, pH and salinity (specific conductivity).

10. Factors which may be responsible for seasonal cycles and heterogeneity of distribution of the parasites in the communities studied were discussed, with particular reference to the effects of host diet, physiology and the effect of selected abiotic environmental factors such as salinity and surface water temperature.

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