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SOME RELATIONSHIPS BETWEEN INTERNAL PARASITES AND BROWN TROUT FROM MONTANA STREAMS

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Abstract.— Forty-five percent of 306 brown trout from 16 Montana streams were infected with one or more of the nematodes *Cystidicoloides salvelini*, *Bulbodacnitis globosa*, *Rhabdochona* sp., and *Eustrongylides* sp. The relationships between incidence and intensity of nematode infections and age and sexual maturity of the host fish were studied. Generally, sexually mature female brown trout had a higher rate of infection and had more nematodes per infected fish than immature female brown trout. Higher incidence and intensity of infection in sexually mature fish was attributed to more aggressive feeding behavior leading to more exposure to the intermediate hosts (mayflies) of the nematode parasites.

Numerous parasitological surveys of trout in North America have been reported; however, few have included information on the parasites of brown trout (*salmo trutta*). Van Cleave and Mueller (1934) studied 13 brown trout from Oneida Lake, New York, and 3 from one of its tributary streams. Fifty-eight Wisconsin brown trout were studied by Bangham (1946) and Fischthal (1947a, 1947b, 1950, and 1952), with 54 originating from streams. In the western geographic region of the United States the studies of Bangham (1951), Hugghins (1959), Alexander (1961), and Fox (1962) include information on the parasites of brown trout. In these studies a total of 55 brown trout were examined: 51 from lakes and 4 from streams. Heckmann (1971) examined 28 brown trout from Montana for blood parasitism.

This study is an attempt to examine some relationships between internal parasites, brown trout, and the fish's stream habitat. It is based on the necropsy of 306 brown trout collected from 17 sites on 16 streams in south and western Montana. The specimens were collected in early September through October (1972 and 1973) just prior to and during the spawning seasons. According to Van Cleave and Mueller (1934), fish are most heavily parasitized in the summer season when they are most actively feeding. Since Fox (1962) found nematode infections in Montana brown and rainbow trout (*Salmo gairdneri*) highest in August and September. these findings may be indicative of near maximum parasite infections for brown trout in Montana streams.

Methods and Materials

All fish were collected by use of electrofishing gear described by Vincent (1967). Collecting sites were selected to reflect a wide range of geographic locations (Fig. 1), and physical and chemical conditions (Table 1). Collections were taken on both sides of the Continental Divide from streams belonging to the Clark Fork of the Columbia, Yellowstone, and Missouri River drainages. At least one fall, winter, and summer measurement of conductivity and alkalinity was made on each stream. These field measurements were averaged with the available yearly conductivity and alkalinity averages obtained from Water Resources Data for Montana (USGS 1972). Discharge values were obtained by averaging available yearly values from the above USGS records with values measured or estimated by fisheries biologists of the Montana Department of Fish and Game. The streams sampled varied in average discharge from 5 cubic feet per second to 1,409 cubic feet per second, in average conductivity from 70 to 1,387 micromhos /cm at 25 C., and in alkalinity from 49 to 221 ppm $CaCO_3$. Ecologically the streams are diverse although they all support naturally reproducing populations of brown trout.

Immediately after capture the fish were preserved in 10 percent formalin, washed in water and stored in 40 percent isopropyl alcohol for later examination. Parker (1963) indicates fish shrink about 3-4 percent in length and gain between 5 and 12 percent in weight when preserved in formalin. About three to eight months after collection fish were individually

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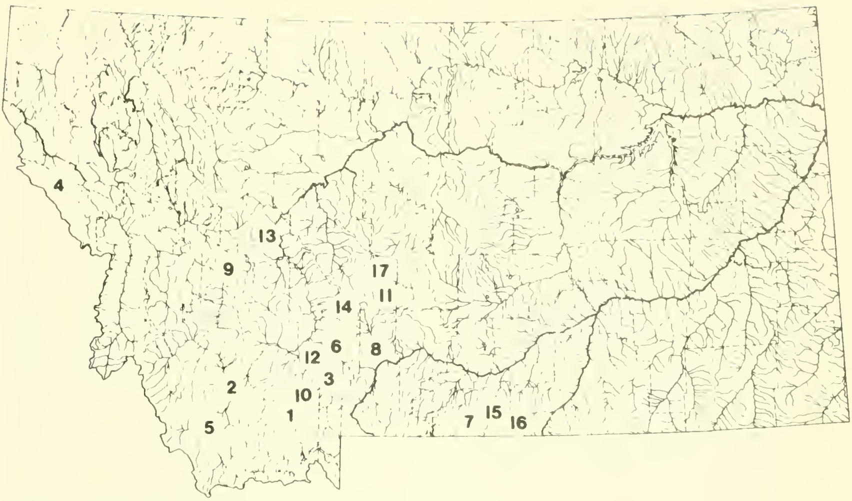

Fig. 1. Map showing location of collecting sites.

TABLE 1. Selected physical and chemical characteristics of 16 Montana streams and the incidence and intensity of nematode infections in brown trout from them.

Collection site no.[1]	Stream	Stream discharge	Cond.	Alk.	# Fish	% Par.	Ave. # worms par./fish
1	Madison R.	1409	249	107	13	100	68.7
2	Big Hole R.	1125	207	117	19	100	14.3
3	W. Gallatin R.	791	230	118	17	100	21.7
4	St. Regis R.	555	80	51	22	14	1.7
5	Beaverhead R.	405	521	193	14	43	1.7
6	E. Gallatin R.	400*	360	195	15	87	3.9
7	Rock Cr.	169	70	49	16	63	3.4
8	Shields R.	159	402	221	11	18	1.5
9	L. Blackfoot R.	105	612	188	28	21	1.2
10	O'Dell Cr.	100*	348	167	11	46	3.0
11	So. F. Musselshell R.	83	561	243	13	8	1.0
12	Baker Cr.	70*	317	154	28	39	1.9
13	L. Prickley Pear Cr.	69	358	195	21	5	1.0
14	16 Mile Cr.	50*	522	195	13	0	0
15	Bluewater Cr.[2]	28	1387	214	27	56	2.1
16	Bluewater Cr.[3]	18	798	209	22	77	3.7
17	Flagstaff Cr.	5*	405	197	16	0	0

*Estimated by fisheries biologists of the Montana Department of Fish and Game.
[1]See Figure 1
[2]Section below Bluewater Fish Hatchery
[3]Section above Bluewater Fish Hatchery

measured and weighed, and scale samples were taken for age determinations. The ovaries were removed for an unrelated fecundity study (Lockard 1974) and consequently were not included in this necropsy. Also, the heart and gas bladder were excluded because they were either mutilated or lost when the ovaries were removed. The procedure for necropsy was as follows. The gills and external body of the fish were examined for ectoparasites and fluke metacercaria, although the preserving and handling procedures greatly reduced the chances of discovering parasitic copepods, leeches, or monogenetic flukes. After removal of the remaining internal organs, the liver was dissected into small pieces, placed in a jar with water, and put on a mechanical shaker for 5-10 minutes. The contents were then washed onto a 200-mesh collecting screen and examined in an illuminated tray (Barber and Lockard 1973). The gastrointestinal tract was opened and its component parts scraped and placed with their contents in jars of water. After 5-10 minutes on the mechanical shaker, the contents of each jar were examined in the illuminated tray. The kidney and testes were examined grossly, and observed abnormalities checked microscopically. Recovered nematodes were placed in 70 percent alcohol-5 percent glycerine and later mounted in glycerine.

Results

Parasites were found throughout the upper digestive tract from the esophagus to the pyloric caeca. The examinations revealed that 45 percent of the 306 brown trout were infected with one to four genera of nematodes. Table 2 lists the occurrence of each taxon in a given stream. Identification of *Cystidicoloides salvelini*, *Bulbodacnitis globosa*, and *Rhabdochona* sp. was confirmed by Dr. James R. Adams, University of British Columbia (personal correspondence). The *Rhabdochona* sp. apparently is a new species and has been submitted to Dr. Morovec in Prague, Czechoslovakia, for further identification.

Inspection of Table 1 indicated an apparent relationship between the size of stream discharges, the percent parasitism (incidence) in fish and average number of worms per parasitized fish (intensity). Regression analyses were performed to test these relationships. The percentage of fish parasitized regressed on stream size was found to be correlated ($R^2=0.46$; T test $P=0.003$). The average number of nematodes per parasitized fish regressed on stream discharge was found to be highly correlated ($R^2=0.68$; T test $P=0.00004$).

The 306 fish used for this study ranged from 6.4 to 20.7 inches (16.3 to 52.6 cm) in total length and from 0.11 to 3.90 pounds (49.9 to 1769.0 grams) in weight with the mean length and weight being 12.3 inches (31.2 cm) and 0.93 pounds (421.8 grams). To test for a possible correlation between length of fish and intensity of parasitism, a regression of number of nematodes per infected fish on fish length was made on fish from the three collections with the highest percent parasitism (Table 1). Fish from each stream were tested individually to compensate for varying intensities of parasitism and differences in mean size of fish between streams. There was no significant correlation at the 0.5 level between number of parasites and length of host in fish from the Madison River, Big Hole River, and the West Gallatin River.

The relationship of fish age to the incidence and intensity of parasitism is shown in Table 3. Differences in the percent of infected fish between age classes

TABLE 2. Occurrence of nematode genera in brown trout from 16 Montana streams.

Collection site		*Rhabdochona*	*Bulbodacnitis*	*Cystidicoloides*	*Eustrongylides*
1	(Madison R.)	x	x	x	x
2	(Big Hole R.)	x	x	x	
3	(W. Gallatin R.)	x	x	x	
4	(St. Regis R.)	x	x		
5	(Beaverhead R.)	x	x		
6	(E. Gallatin R.)	x		x	
7	(Rock Cr.)	x		x	
8	(Shields R.)	x			
9	(L. Blackfoot R.)	x			
10	(O'Dell Cr.)	x		x	
11	(So. F. Musselshell R.)		x		
12	(Baker Cr.)	x	x	x	
13	(L. Prickley Pear Cr.)	x			
14	(16 Mile Cr.)				
15	(Bluewater Cr.)[1]	x	x		
16	(Bluewater Cr.)[2]	x	x		
17	(Flagstaff Cr.)				

[1]Section above Bluewater Fish Hatchery
[2]Section below Bluewater Fish Hatchery

TABLE 3. Incidence and intensity of parasitism in age classes of brown trout.

Age class	# Fish	% Infected	Ave. # worms/ infected fish
I	58	50	2.4
II	137	38	9.1
III+	111	52	21.3
Total (ave.)	306	(45)	(12.8)

were tested by a method of Arkin and Colton (1972) with results showing no significant differences between age classes I and II, and I and III$^+$ at the 0.05 level. Although the difference in the percent of fish infected in age classes II and III$^+$ was statistically significant ($P = 0.028$) it was not considered to be biologically significant. As the age of the fish increased the average number of worms per infected fish also increased (Table 3). These differences in the intensity of parasitism between age classes shown in Table 3 were significant at the 0.05 level.

The relationship of incidence and intensity of parasitism to age and sexual maturity in brown trout is given in Table 4. Significantly (0.05 level) more mature fish than immature fish in age classes I and II and in the overall total were infected. However, there was no significant difference between the incidence of parasitism in mature and immature fish in age class III$^+$. Mature fish in age classes II and III$^+$ and the overall total also had a significantly higher number of worms per fish than immature fish. In age class I there were no significant differences in the average number of worms in mature and immature brown trout.

Tests were made to determine the relationship of the chemical productivity of each stream with the degree of parasitism in its fish. No significant (0.05 level) correlations were found when percent parasitism and average number of worms per parasitized fish were regressed on stream conductivities and alkalinities.

In the five streams (Big Hole River, Baker Creek, Little Prickley Pear Creek, Bluewater Creek, and Flagstaff Creek) from which the 48 males were collected, there was no significant difference between their rate of infection (45.8 percent) and that of females from the same streams (48.2 percent).

DISCUSSION

Incidence of parasitism in brown trout varies with species of parasite and with habitat of the host fish. Fox (1962) found 30 brown trout from Meadow Lake, Montana, infected with fluke metacercaria of *Bolbophorus confusus*. Five of the 30 brown trout had immature stages of the nematode *Eustrogylides* sp. encysted within the body and 1 of the 30 had an unidentified nematode in its digestive tract. Van Cleave and Mueller (1934) examined 13 brown trout from Oneida Lake and 3 collected from Black Creek about one mile from its confluence with Oneida Lake, New York. The stream-inhabiting brown trout had the nematode *Cystidicoloides hardwoodi* exclusively, whereas the lake-inhabiting brown trout had the nematode *Spinitectus gracilis* and never *C. hardwoodi*. In over 1,000 fish from the lake *C. hardwoodi* was never taken; thus it was probably limited to streams.

In correlating parasitism to habitat, Van Cleave and Mueller (1934) conclude "that in fishes of wide range through a variety of environmental types, the type of parasitism is more or less closely correlated with the habitat from which the fish is taken." Bangham (1951) states "the fact that there were not many different types of habitats limited the numbers of various parasite species." Stream habitat may not favor the intermediate hosts of many lake parasites, i.e., cestodes

TABLE 4. Incidence and intensity of parasitism related to sexual maturity and age of brown trout.

Age class	# Fish	% Sex. Mat.	% Infected		Ave. # worms/ infected fish	
			Sex. mat.	Sex. imm.	Sex. mat.	Sex. imm.
I	58	19	82	43	2.1	2.5
II	137	51	47	28	11.0	5.9
III+	111	88	52	54	23.7	4.4
Total (Ave.)	306	(60)	(53)	(34)	(17.1)	(4.2)

(copepods), trematodes (snails), acanthocephalans (crustacea). Parasitic copepods and monogenetic flukes not common in streams may be favored by the lake environment. This would partially explain why nematodes were the only parasites found in these brown trout from cold water stream habitats.

Hugghins (1959) found no parasitism in four brown trout from Black Hills streams in South Dakota. Van Cleave and Mueller (1934) classified the frequency of occurrence of six species of parasites in brown trout as "occasional" based on a scale of abundant, common, occasional, and rare. Forty-one percent of 58 brown trout from Wisconsin streams and ponds were parasitized (Bangham 1946, and Fischthal 1947a, 1947b, 1950, 1952). This is comparable to the 45 percent incidence of parasitism found in this study.

The correlation of size of stream with incidence and intensity of parasitism was shown in Table 1. It can be seen from Table 2 that large streams have a greater diversity of species of nematodes than small streams. It would be expected in a large river with diverse habitat niches that the chance of intermediate and definitive hosts for a certain parasite existing together would be greater than in a smaller stream with a more restricted type of habitat.

Fox (1962) states that, in general, the longer the trout, the greater the number of individual parasites and kinds of parasites it contained. This is related to longer exposure time to parasitism, since the body length is generally determined by age. Woodbury (1940) summarized 12 previous investigations and reported that the longer fish had greater numbers of parasites in nine of these studies. Conversely, Langlois (1936) and Hubbs (1927) found shorter fish the most heavily parasitized. In this study no correlation between fish length and intensity of infection was found in fish from the three streams with 100 percent parasitism. However, the fish in these streams were not proportionately representative of all age classes; thus these results do not rule out a relationship between age and intensity of infection. This study did not show that older fish were generally more likely to be infected than younger fish (Table 3). However, it can be seen from Table 3 that as the age of the fish increases, so does the average number of worms per infected fish. This could be related to the older fish having more exposure time to parasites than the younger ones do.

The relationships of incidence and intensity of infection to feeding aggressiveness of fish as expressed by sexual maturity was examined. A higher percentage of mature fish was parasitized than immature fish in the overall total and for age classes I and II (Table 4). The difference between infection rates between mature and immature fish in the overall total could be attributed to older mature fish having more exposure time to the parasites than younger fish do. However, the differences in infection rates between mature and immature fish within age classes I and II could be the result of the fastest-growing (most-aggressive) fish in an age class reaching sexual maturity before less-aggressive fish. Bagenal (1969) fed different quantities of food to two groups of brown trout and found that the more aggressive of the under-fed fish took more than their share of the food. Consequently, the more aggressive of the starved fish had growth comparable with that of the well-fed fish. He also found that more of the better-fed fish were mature than the under-fed fish. There were no significant differences (0.05 level) between mature and immature fish in the percent infected for age class III^+. Nielson (1953) noted that brown trout in California began a shift in feeding habits from strictly aquatic invertebrate forms to partial diets of fish in the third year of life. An explanation for the similar percent infections for mature and immature age class III^+ fish (Table 4) could be this change in feeding habits in which the parasite intermediate hosts (mayflies) would be preyed upon less by the larger mature fish.

McFadden, Cooper, and Anderson (1965) state that perhaps some combination of chronological age and growth rate (or the factors which determine growth rate), a "physiological age", determines the age of sexual maturity. One factor which influences growth rate and thus age at sexual maturity is the feeding aggressiveness of a fish. If sexually mature fish feed more actively than sexually immature fish, then mature fish of a given age would be larger than the immature fish in that age class and would have more exposure to parasitism through their aggressive feeding habits. The following is a comparison of mean lengths of mature and immature female brown trout within age classes. In age class I, only the Bluewater Creek collections contained mature females, and they had a mean length of 8.0 inches while the immature females from Bluewater Creek were 7.5 inches in mean length. Mature female fish from all streams of age classes II and III+ had mean lengths of 13.3 and 15.1 inches, respectively; while the immature females from these age classes had mean lengths of 11.0 and 12.9 inches, respectively. Thus sexually mature fish within an age class are larger than sexually immature fish. This could be the result of more aggressive feeding habits. The most actively feeding fish would have more chances to encounter the intermediate hosts (mayflies, Hoffman 1967) of these nematode parasites (*Cystidicoloides* sp. and *Rhabdochona* sp. were 99.4 percent of all worms found) and thus more of them would be infected.

This theory to explain differences in infection rates between mature and immature fish within age classes is reinforced by inspection of the average number of worms per parasitized fish in age classes (Table 4). The mature fish in age classes II and III+ and for the overall total have a higher average number of worms per fish than the immature fish. This suggests that the more actively feeding mature fish within an age class are exposed more to parasitism by their feeding habits than less actively feeding immature fish.

In age class I (Table 4) there was no significant difference (0.05 level) between mature and immature brown trout in the average number of worms per infected fish, possibly because exposure time was too short for significant differences to be expressed.

Fox (1962) found little relationship between incidence of parasitism and condition of trout. He states that possibly ". . . analysis of fecundity will show that parasite incidence does effect some host conditions." Comparison of the findings of this study with those of a fecundity study on the same fish (Lockard 1974) indicates that no general relationship between parasitism and fecundity exists. Table 1 shows the Madison and West Gallatin rivers were highly parasitized; in the above fecundity study they had the highest fecundity (steepest slopes of the regressions of number of eggs on fish length for a stream). Thus parasitism apparently did not adversely affect the fecundity of infected fish.

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