HELMINTH PARASITES OF AMERICAN EELS FROM BRACKISH WATER[1]

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Abstract: Two hundred fourteen of 218 American eel, *Anguilla rostrata*, from brackish portions of Cooper River, South Carolina, were infected with 1 or more of 22 helminth species representing 4 classes: Trematoda, Cestoda, Nematoda and Acanthocephala. Larval nematodes (*Contracaecum* sp.) predominated, infecting 95% of eels examined. Seasonal, size- and age-related variations in levels of parasitism by trematodes and cestodes are discussed. Six new host and 7 new locality records are established.

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The commercial fishery for American eel in the southeast United States is growing in response to market demand from Europe and Asia. The American eel, common in drainages of the western North Atlantic and northern Gulf of Mexico, serves as host for many parasite species throughout its range (Hoffman 1967). However, much of the known parasite fauna of American eel has been described from surveys conducted in northeastern and northcentral United States and Canada. Previous studies have surveyed parasites of fish, including eels, from a geographic region (e.g. Mueller 1934, Linton 1940, Bangham 1955), parasites of eels from a geographic region (Hanek and Threlfall 1970), and specific parasites or groups of parasites of eels (e.g. Van Cleave 1921). Scant information is available on the ecological aspects of eel-parasite interactions upon which fishery management decisions could be based. Therefore, an investigation was undertaken to determine the parasite fauna of American eel in a southern river system, and to identify host-related and seasonal differences in parasite occurrence and intensity. This paper presents the data collected on nematode, trematode, cestode and acanthocephalan parasites of yellow stage eels.

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METHODS

Yellow eels (n = 218) were caught with baited traps in the brackish portion (mean salinity = 5.3 g/l) of Cooper River, South Carolina, between Bushy Park

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boat landing (32° 57'20"N, 79° 56'13"W) and Wando River confluence (32° 49'23"N, 79° 56'52"W). Sampling began in July 1977 and was repeated at approximately 2-week intervals through June 1978. Ten eels were collected each sampling period when possible, placed on ice and transported to the laboratory for parasitological examination.

Eels were weighed to the nearest 0.1 g and measured to the nearest millimeter total length (TL). Age was determined from otoliths. Three eels with unreadable otoliths were omitted from calculations involving age.

Dissected visceral organs were placed in physiological saline and examined for helminth parasites under a dissecting microscope (30X). Pectoral fins were examined under a compound microscope (150X). Parasites were collected separately by type, fixed and preserved according to methods described by Rogers (undated) and Hoffman (1967).

Percentage of infected eels (% occurrence) and mean number of parasites per infected eel (intensity) were calculated for month of capture, age and 5-cm size group (e.g. 245 - 294 mm TL) of host. To evaluate relative strength of parasite species associations, % co-occurrence was calculated by dividing the number of times 2 species were found in the same host (i.e. in association) by the number of times the reference species occurred. Occurrences of a reference species during months an associating species was not found were omitted from calculations of % co-occurrence.

RESULTS

Marine and freshwater species of helminth parasites (Trematoda, Cestoda, Acanthocephala, Nematoda) infected 214 eels (Table 1). Nematodes, the most abundant group, occurred in 96% of eels examined. Trematodes (38%), cestodes (33%) and acanthocephalans (6%) were encountered less frequently.

Table 1. Occurrence and mean intensity of helminth parasites in 218 American eels from the brackish portion of Cooper River, South Carolina, including salinity preferences, sites of infection, and new host (H) and locality (L) records (status).

Parasite	% Occurrences	Mean Intensity (Range)	Salinity[a]	Site of Infection	Status
TREMATODA	38.1				
Opecoeloides fimbriatus	1.8	4.8 (1-15)	M	Intestinal lumen	H
Opecoeloides vitellosus	5.5	5.5 (1-8)	M	Intestinal lumen	H
Crepidostomum cornutum	13.2	3.8 (1-14)	F	Intestinal lumen	L
Lecithochirium microstomum	8.7	1.4 (1-3)	M	Stomach lumen	

Stephanostomum imparispine	19.3	3.0 (1-17)	M	Kidney, heart, pericardium, esophagus, mesentery & gill artery	H
CESTODA	32.6				
Bothriocephalus scorpii	0.9	1.5 (1-2)	M	Intestinal lumen	
Bothrimonus sturionis	0.5	1.0 (1)	M & F	Intestinal lumen	HL
Haplobothrium globuliforme	0.5	1.0 (1)	F	Intestinal lumen	L
Proteocephalus macrocephalus	1.4	1.7 (1-3)	F	Intestinal lumen	
Proteocephalus sp.	0.9	1.0 (1)	F	Intestinal lumen	
Tetraphyllidea[b]	28.4	283.5[c] (1->1000)	M	Intestinal lumen & gall bladder	
NEMATODA	96.3				
Philometra sp. larvae	31.2	52.3[c] (1-534)	F	Pectoral fin, gall bladder & mucus	
Philometra sp. adult	0.9	1.0 (1)	F	Coelom	
Contracaecum sp. larvae	95.0	45.6 (1-344)		[d]	
Contracaecum sp. adult	6.4	3.4 (1-24)		Intestinal lumen & wall, stomach & coelom	
Spirocamallanus cricotus	1.8	2.8 (1-5)	M	Intestinal lumen	HL
Spinitectus sp.	1.8	26.5 (1-91)	F	Stomach & intestinal lumen	
Spiruridea	1.4	1.0 (1)		Intestinal lumen	
Cucullanidae	0.5	1.0 (1)		Intestinal lumen	
ACANTHOCEPHALA	5.5				
Fessisentis friedi	0.5	2.0 (2)	F	Intestinal lumen	L
Illiosentis furcatus	0.5	2.0 (2)	M	Intestinal lumen	H
Leptorhynchoides thecatus	0.9	2.0 (1)	F	Intestinal lumen	L
Pomphorhynchus bulbicolli	3.2	1.6 (1-2)	F	Intestinal lumen	L

Unidentifiable remains	0.9	2.0 (1-3)	Mesentery & intestinal wall

[a] Salinity preference of known intermediate hosts: Marine, Freshwater (<0.5 g/l).
[b] Includes plerocercoids of three species (*Scolex pleuronectis, Echeneibothrium* sp. and *Phyllobothrium* sp.).
[c] Intensity determined from subsamples.
[d] Heart, spleen, liver, intestinal and stomach walls, esophagus, gall bladder, mesentery, gonad and urinary bladder.

Trematoda

Eels were infected with 5 species (4 adult and 1 larval form) of digenetic trematode (Table 1). New host records were established for *Stephanostomum imparispine, Opecoeloides fimbriatus* and *O. vitellosus*. This was the first reported occurrence in South Carolina of *Crepidostomum cornutum*.

Metacercariae of *S. imparispine* were encysted in germinal sacs in anterior kidneys, heart and associated tissues (Table 1). Ten small metacercariae were also found in bronchial blood vessels of gill filaments of 3 eels. The other digenean species occurred as adults in the alimentary canal.

Except for a single occurrence of *Lecithochirium microstomum* in September, adult digeneans were not found from July-October 1977 (Table 2). Highest levels of *O. fimbriatus, O. vitellosus* and *C. cornutum* occurred in February, while occurrence of *S. imparispine* peaked in May 1978. Mean intensity of *S. imparispine* was highest in August 1977, then declined as occurrence increased (Table 2). Mean intensities of adult digeneans varied but with no apparent seasonal pattern.

Occurrence and intensity of trematode parasites varied with length and age of host. *O. fimbriatus, O. vitellosus* and *C. cornutum* occurred more frequently in shorter and younger eels, while *S. imparispine* was more common in longer and older eels (Fig. 1). *S. imparispine* did not occur in eels younger than 3 years. Occurrence of *L. microstomum* increased with host length but decreased slightly with host age. This apparent contradiction was probably the result of small sample size (n = 19). Mean intensities of *O. fimbriatus, O. vitellosus, L. microstomum* and *S. imparispine* increased slightly with increasing length and age of host, while that of *C. cornutum* decreased.

Several trematode species associations were noted (Table 3). Percent co-occurrence was largest for *O. fimbriatus* - *S. imparispine* and *O. vitellosus* - *C. cornutum*, and smallest for *S. imparispine* - *O. vitellosus*. *O. fimbriatus* did not co-occur with either *O. vitellosus* or *C. cornutum*, nor did *O. vitellosus* co-occur with *L. microstomum*. *S. imparispine* co-occurred with all 4 alimentary tract trematodes. Low intensities of adult trematodes prevented more detailed analysis of parasite community structure and interactions. Intermediate hosts of trematode parasites are also listed in Table 3.

Cestoda

Adult cestodes were not common; 3 *Bothriocephalus scorpii* and 5 *Proteocephalus macrocephalus* occurred in 4 eels (Table 1). Plerocercoids or post-plerocercoids of

Table 2. Monthly percent occurrence and mean intensity (in parentheses) of trematode and cestode parasites found in American eel collected from Cooper River, South Carolina.

Parasite	1977 Jul	Aug	Sep	Oct	Nov	Dec	1978 Jan	Feb	Mar	Apr	May	Jun
TREMATODA												
S. imparispine	10.0 (1.0)	20.0 (7.8)		10.0 (5.0)	15.0 (4.3)		16.7 (3.5)	20.0 (1.5)	25.0 (1.5)	40.0 (2.8)	50.0 (2.4)	20.0 (2.0)
C. cornutum					10.0 (6.0)		16.7 (1.5)	30.0 (4.2)	18.8 (1.3)	25.0 (4.8)	22.2 (4.2)	20.0 (4.8)
O. fimbriatus							8.3 (1)	15.0 (6.0)				
O. vitellosus								20.0 (1.0)	18.8 (2.0)	20.0 (1.5)	5.6 (8)	
L. microstomum			7.1 (2)		10.0 (1.0)	11.1 (1.0)	16.7 (1.0)	5.0 (1)	18.8 (1.7)	5.0 (1)	16.7 (2.7)	20.0 (1.0)
CESTODA												
Tetraphyllidea[a]	5.0 (20)					5.6 (1)		35.0 (7.9)	87.5 (94.9)	90.0 (725.5)[b]	72.2 (237.8)[b]	40.0 (3.2)
Eels Examined	20	20	14	20	20	18	12	20	16	20	18	20

[a] Plerocercoids of at least 3 species: *Scolex pleuronectis, Phyllobothrium* sp., and *Echeneibothrium* sp.

[b] Calculations of mean intensity include 13 eels in April and 3 in May with estimated intensities >1000. Means were calculated using 1000 for these eels.

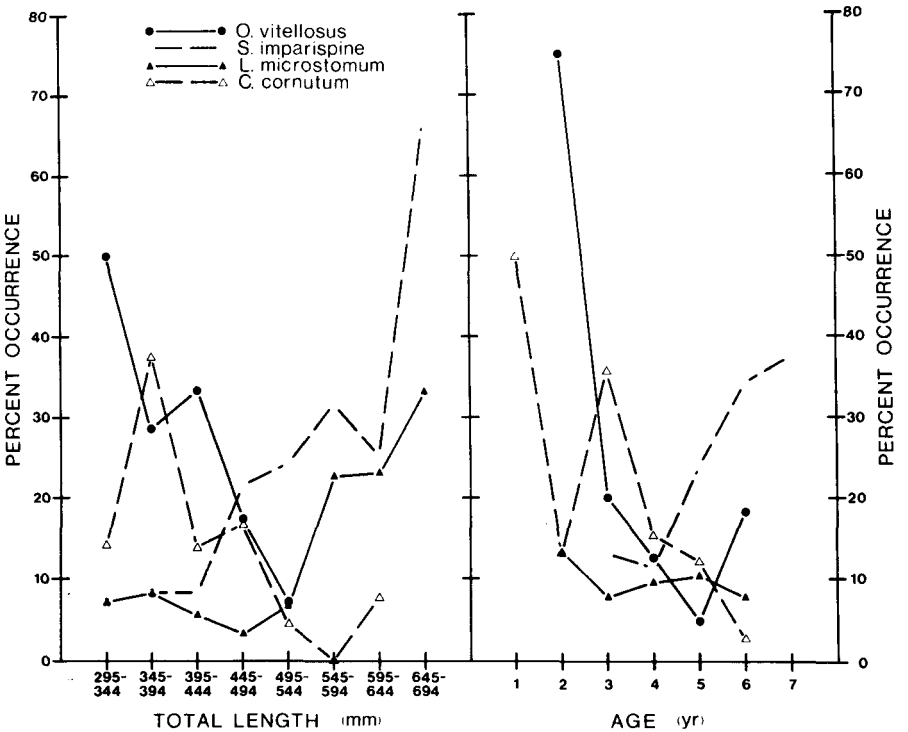

Fig. 1. Percent occurrence of 4 species of digenetic trematodes in American eel by 5-cm size group and age of host.

Proteocephalus sp., *Haplobothrium globuliforme,* and *Bothrimonus sturionus* were found in 7 eels. New host and locality records were established for *B. sturionus.*

Plerocercoids of 3 or more species of Tetraphyllidea accounted for most cestode occurrence and abundance (Table 1). Genera identified include *Scolex pleuronectis* (an undifferentiated form which may include early stages of many species), *Echeneibothrium* sp. and *Phyllobothrium* sp. Occurrence and intensity of larval tetraphyllideans rose to their highest levels (90%, 725.5) in April 1978 (Table 2). No clear relationship was detected between length or age of host and occurrence of tetraphyllidean cestodes.

Acanthocephala

Sixteen identifiable acanthocephalans belonging to 4 species were found in 11 hosts (Table 1). *Illiosentis furcatus* has not previously been reported from American eel, but has occurred in South Carolina coastal waters (Lawler 1978). New locality records were established for the other 3 species (Table 1).

Table 3. Percent co-occurrence and intermediate hosts of digenetic trematode parasites found in American eel collected from Cooper River, South Carolina.

Reference Species	Co-occurring Species	%	Intermediate Host (Citation)
Opecoeloides vitellosus	*C. cornutum*	42%	*Gammarus mucronatus* *Amphithoe longimana* (Hunninen and Cable 1941)
	S. imparispine	8%	
Opecoeloides fimbriatus	*S. imparispine*	75%	*Penaeus duorarum* *P. setiferus* (Kruse 1959)
	L. microstomum	25%	
Lecithochirium microstomum	*O. fimbriatus*	33%	Unknown
	S. imparispine	26%	
	C. cornutum	16%	
Crepidostomum cornutum	*O. vitellosus*	29%	*Cambarus* spp. (Hopkins 1934)
	S. imparispine	12%	
	L. microstomum	10%	
Stephanostomum imparispine	*O. fimbriatus*	50%	Marine gastropod (?) (Wolfgang 1955)
	L. microstomum	12%	
	C. cornutum	12%	
	O. vitellosus	4%	

Nematoda

Eels were heavily infected with nematodes. Encysted larval *Contracaecum* sp. were found throughout tissues and organs of the coelomic cavity (Table 1). Stomach wall and mesenteries were most frequently and intensely infected. Larval *Contracaecum* sp. occurred in 95% of eels examined. Monthly occurrences ranged from 83 to 100%, and monthly mean intensities varied from 22.7 to 78.8. However, no seasonal patterns in occurrence and intensity were detected.

Mature females of the genus *Philometra* were recovered from coelomic cavities of 2 eels and larval forms were found in subdermal tissues of the pectoral fins of 68 eels (Table 1). New host and locality records were established for *Spirocamallanus cricotus,* which occurred both as larvae and adults in 4 eels. *Spinitectus* sp. also occurred as larvae and adults in 4 eels. The other nematode fauna found in the digestive tract was not identified beyond the level shown in Table 1.

DISCUSSION

Changes in the endoparasitic fauna of vertebrates with respect to season or host size or age can be useful in identifying and characterizing aspects of a host's life history if inferences are made about its food habits (Polyanski 1970). Food habits of American eels vary with the availability of prey (McCord 1977). Seasonal variations in relative abundance of prey species and annual migrations to or from overwintering areas produce dietary changes in eels. These changes may be reflected in seasonal differences in parasite fauna, particularly parasites of the digestive tract.

Digenetic trematodes and tetraphyllidean cestodes varied seasonally (Table 2). The absence of digestive tract helminths during summer months and their presence and, in some cases, increase from fall through spring suggests eel diets shifted to include parasite intermediate hosts. These occurrence patterns also indicate that some eels in the population feed more actively in winter than previously believed (Wenner and Musick 1975, McCord 1977).

Among the more frequent parasites of the digestive tract of eel, all but *Crepidostomum cornutum* had intermediate hosts which required brackish or marine waters. Amphipod hosts of *Opecoeloides vitellosus*, including *Gammarus (= Carinogammarus) mucronatus*, would be most likely to occur in low salinity portions of Cooper River (Fox 1978). Wenner and Musick (1975) reported *G. mucronatus* among the amphipods found in stomachs of eels from brackish water in Chesapeake Bay. According to Kruse (1959), pink shrimp, *Penaeus duorarum*, a halophilic species, is the preferred host for *Opecoeloides fimbriatus*. However, *P. duorarum* occurs only occasionally in South Carolina waters, and then only in high salinity estuaries such as the mouth of Cooper River (Bishop and Shealy 1977). White shrimp, *P. setiferus*, a less suitable intermediate host of *O. fimbriatus*, undergoes postlarval development during summer and early fall in the low salinity reaches of Cooper River (Bishop and Shealy 1977). Unidentified penaeid shrimp were found in stomachs of several eels examined.

Although life cycles of *Lecithochirium microstomum* and the tetraphyllidean cestodes are not fully known, possible intermediate hosts can be inferred from what is known about closely-related species. Other hemiurid trematodes use marine copepods and other marine invertebrates for metacercarial development (Yamaguti 1975). Tetraphyllidean cestodes use either marine molluscs or crustaceans as 1st intermediate hosts, and mollusciverous gastropods or fish as 2nd intermediate hosts (Cake 1976). Cake (1976) considered mollusciverous gastropods ideal "cestode collectors." Gastropods may have been the source of the cestode infection in eel, considering that McCord (1977) found that the importance of gastropods in eel diets increased during spring when tetraphyllidean occurrence and intensity peaked.

Relationships between eel size and occurrence of *O. vitellosus* and *C. cornutum* may indicate that amphipods and crayfish are more common in the diets of smaller (<445 mm TL) than larger eels. Correspondingly, the intermediate host of *L. microstomum* may be more common in the diet of larger eels (>545 mm TL). Ogden (1970) pointed out a tendency for size of food items to increase with size of eel. If the relationship is valid, it may signify that the intermediate host of *L. microstomum* is a relatively large invertebrate or that a paratenic/transport host such as a fish is involved in transmission. McCord (1977) found fish (eels and clupeids) dominant in stomachs of eels examined during winter.

The relatively strong associations among trematodes (*Stephanostomum imparispine, O. fimbriatus* and *L. microstomum*) with marine intermediate hosts, and between trematodes (*C. cornutum* and *O. vitellosus*) with freshwater and oligohaline intermediate hosts indicate that the overwintering eel population in brackish portions of Cooper River included individuals from downstream high salinity areas and from upstream low salinity and freshwater areas. *C. cornutum* and *O. vitellosus* were weakly associated with some marine trematodes but neither co-occurred with *O. fimbriatus*. Eels from freshwater and those from high salinity waters may not venture beyond brackish water to feed during the overwintering period, explaining in part the absence of co-occurrence of trematodes from those areas. The fact that some of the other trematodes did not co-occur in eel hosts may be a product of several factors, including competitive interactions between trematodes or unequal access to intermediate hosts by eels.

Co-occurrence of *S. imparispine* with all 4 digestive tract trematodes serves to confirm an intermingling of eels from fresh and marine waters. According to Wolfgang (1955), *Stephanostomum* cercariae are shed by marine gastropod 1st intermediate hosts, then lie on bottom debris awaiting contact with a suitable 2nd intermediate host, usually a fish. Concentration of metacercariae of *S. imparispine* in and near the hearts of infected eels, and the occurrence of several metacercariae in gill filaments suggest that cercariae may burrow into gill tissue when eels seek food or cover in bottom muds.

Additional research on the parasites of American eel, especially from freshwater and marine systems, would be useful in further understanding the dynamics of eel populations and aid in their management.

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