An Ecological Survey of the Helminths of *Notropis venustus* and *Notropis lutrensis* (Cyprinidae) From the Area of San Marcos, Texas

THESIS

Presented to the Graduate Council of
Southwest Texas State University
in Partial Fulfillment of
the Requirements

For the Degree of
MASTER OF SCIENCE

By

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San Marcos, Texas
December, 1976

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ACKNOWLEDGEMENTS

I wish to extend my appreciation and thanks to Dr. D. G. Huffman for the many hours of guidance and assistance he has contributed toward the completion of this research, and to Drs. D. W. Tuff and B. J. Yager for their constructive criticism of the manuscript.

I also wish to acknowledge G. L. Hoffman, U. S. Fish and Wildlife Service, Stuttgart, Arkansas (Trematoda) and G. L. Hendrickson, Iowa State University (Trematoda) for the assistance they gave in identification of specimens.

Special thanks are extended to my husband, James, who provided both assistance and encouragement throughout the course of this research.

CHAPTER I

INTRODUCTION

A survey of the helminths of the shiners, *Notropis venustus* (Girard) and *Notropis lutrensis* (Baird and Girard) was conducted during the period of November, 1974 through October, 1975 in the vicinity of San Marcos, Texas.

Primary objectives of this study were: (1) to identify and describe the helminth fauna of *N. venustus* and *N. lutrensis* in the area of San Marcos, Texas; (2) to correlate the ecology of the hosts with their helminth communities; (3) to determine helminth diversity within the two hosts; (4) to evaluate the effect of season on the helminth fauna of the two hosts; and (5) to determine the effect of host sex and size on the helminth community.

Choice of Host

Notropis venustus and *N. lutrensis* were selected as host species for this study because they are morphologically and ecologically similar and are found in intermixing populations in a variety of habitats; providing an excellent opportunity for investigating the effects of minute differences between the hosts upon various aspects of helminth parasitism. Due to their small size, large numbers of the hosts could be examined in a relatively short time. Since these small fish are generally abundant within their habitats, it was felt that they may prove to be important intermediate hosts of the helminth parasites of larger piscivorous animals in this area.

Literature Review

Prior to this study, 104 species of helminths had been reported from the genus *Notropis* in North America. There have been few studies involving the helminth fauna of *N. venustus* and *N. lutrensis*. The work which has been done has been limited to the inclusion of the two hosts in general surveys of fish parasites.

Two monogenetic trematodes (*Dactylogyrus banghami* and *D. moorei*) (Mizelle et al, 1969) and one digenetic trematode (*Neascus* sp.) (Meyer, 1958) have been reported from *N. lutrensis*. Parasites previously reported from *N. venustus* include four monogenetic trematodes (*Dactylogyrus venusti*, *D. banghami*, *D. moorei* and *Gyrodactylus baeacanthus*) (Rogers, 1967; Wellborn and Rogers, 1967), one digenetic trematode (*Pisciamphistoma stunkardi*) (Arnold and Schafer, 1968) and one acanthocephalan (*Neoechinorhynchus cylindratus*) (Arnold and Schafer, 1968).

No previous ecological studies have been conducted on the helminths of either of these fishes, although there have been previous studies concerning various aspects of the helminth ecology of other fish species. Studies which have dealt specifically with the seasonal distribution of helminths in other fishes include Bogtish (1958), Chubb (1963), Connor (1953), Kennedy (1975), Linton (1914), Pennycuick (1971), and Van Cleave (1916). Ecologically-oriented studies dealing solely with the problem of population dynamics of particular helminth species include Anderson (1974), Kennedy (1968, 1970, 1975), Kennedy and Hine (1969), Kohlweiss (1971), McDaniel (1969), Spall and Summerfelt (1970), and Stromberg and Crites (1975). Broad ecological studies on the helminths of fishes include Chubb (1963), Dogiel et al (1958), Fischthal (1953), Holl (1932), Lawrence (1970), McDaniel and Bailey (1974), Spall (1968), Spall and Summerfelt (1970), Van Cleave and Lynch (1950), Van Cleave and Mueller (1934), Ward (1911), and Whitlock (1966).

CHAPTER II

MATERIALS AND METHODS

Collection and Necropsy of Hosts

Notropis venustus and *N. lutrensis* were collected together from the San Marcos, Guadalupe and Blanco Rivers, while *N. venustus* was taken alone from Canyon Reservoir and *N. lutrensis* was taken alone from the Little Blanco River. Collections were made monthly near the area of San Marcos, Texas from November, 1974 through October, 1975. Every attempt was made to collect ten fish of each species each month from the collection stations. Spring flooding of two of the rivers and fluctuation of water height in Canyon Reservoir prevented the collection of complete samples at times.

Fish were captured with a 1.2-m, 1.9-cm mesh, straight, push seine from all stations. In addition to the seine, a throw net was used in the San Marcos River. Surface water temperatures were recorded in degrees Celsius. Live fish were transported back to the laboratory and placed in polystyrene buckets equipped with aeriators. All fish were examined within 36 hours after capture.

Fish were pithed, measured, and placed in pond water where fins, body, and gills were examined for cysts and ecto-parasites. Initially the eyes were examined, but this was discontinued after five months when no parasites were found. Following the external examination, a section of the abdominal wall was excised, the fish were sexed, and the surface of the viscera was examined. Organs were removed and placed in 0.75 percent saline solution, where they were dissected and examined for endoparasites. Identifiable food organisms within the stomach and intestine were recorded from January 1974 through October 1975.

Parasite Preservation and Identification

Metacercarial trematodes were removed by gently squeezing the cysts between flattened microprobes. Smaller cysts were frequently placed in distilled water prior to squeezing, to facilitate breaking the cyst wall. Encysted cestodes were removed from cysts with flattened microprobes and were evaginated in a weak solution of bile salts and distilled water.

Trematodes and leeches were flattened under coverslip pressure and fixed with AFA (Alcohol-Formalin-Acetic Acid). Acanthocephalans were placed in distilled water until distended, then fixed with AFA. Nematodes were dropped into bubbling hot AFA.

Digenetic trematodes, cestodes, and leeches were stained with Grenacher's Alcoholic Borax-Carmine, dehydrated in a graduated alcohol series, counter-stained with fast green, and cleared in xylene (Meyer and Olsen, 1972). Monogenetic trematodes, adhering to slides, were run through a graduated alcohol-dehydration and xylene coplin jar series and were not stained.

Nematodes were removed from AFA after 24 hours and placed in glycerinated alcohol.

All parasites, except nematodes, were mounted in Canada Balsam.

The major taxonomic keys utilized in this study included those of Hoffman (1967), Petrochenko (1956), Skrjabin et al (1967) and Yamaguti (1958, 1959, 1961, 1963, 1971).

Quantitative Methods Employed in This Study

Descriptive terminology has been reduced in this text for the convenience of the reader. The term incidence indicates the percentage of hosts infected by a specific parasite or group of parasites. The term intensity indicates helminth load, or mean number of helminths per fish examined.

Since only 75 of the 864 fish examined were males, data for both sexes were pooled to obtain a larger sample size for analysis.

Moving Average

To reduce the effects of sampling error upon incidence and intensity of helminth infection, a ten-percent moving average was utilized whenever these variables were plotted against standard host length and month of collection. The moving average technique produced a more readily interpreted representation of the effect of standard body length and season upon incidence and intensity of helminth infection, and had much the same effect as increasing the sample size at each class to the number of observations in the moving average interval.

Computer Programs

The data obtained in this study were analyzed with the DEC system-10 computer, using programs of the Biodat series written by D. G. Huffman and the Statistical Package for the Social Sciences (Nie et al, 1975), as well as original programs written in BASIC.

The major subroutine used in the analyses was Scattergram. This subroutine prints a two-dimensional plot of data points, where the coordinates of the points are the values of the two variables being considered. Statistics used were those usually associated with simple linear regression, including the intercept (a), regression coefficient (b), and Pearson product moment correlation coefficient (r).

Diversity Index

Shannon's (1948) index as described by Zar (1974), was incorporated in the Biodat series to compute helminth diversity:

$$\bar{d} = \frac{n * \log_2 (n) - \sum f_i * \log_2 (f_i)}{n}$$

where $\bar{d}$ is the helminth diversity (the distribution of individuals among species), n is the number of helminth species, and f is the number of helminths in species i. Maximum diversity exists if each individual belongs to a different species, and minimum diversity exists if all individuals belong to the same species.

<u>Description of the Study Area</u>

General Description

The study was conducted in the Guadalupe and Blanco river basins on the Edwards Plateau in the vicinity of Hays County, Texas (Figure 1). The Edwards Plateau rises to an elevation of 366 m in the hill country and is considered a physiographically discrete unit and a distinct biotic province. Most of the Balconian Province lies on Comanchean Cretaceous limestone. The topography of the eastern and southern parts of the area is rugged due to dissection of the limestone by rivers and their tributaries (Blair, 1950).

The climate is characterized by a decrease in rainfall from east to west. The eastern half of the province is classified as semiarid and mesothermic (Blair, 1950). The seasonal rainfall pattern in the area exhibits a peak in the spring and fall. The mean annual precipitation in the county is 83.3 cm with a mean annual temperature of 19.9°C.

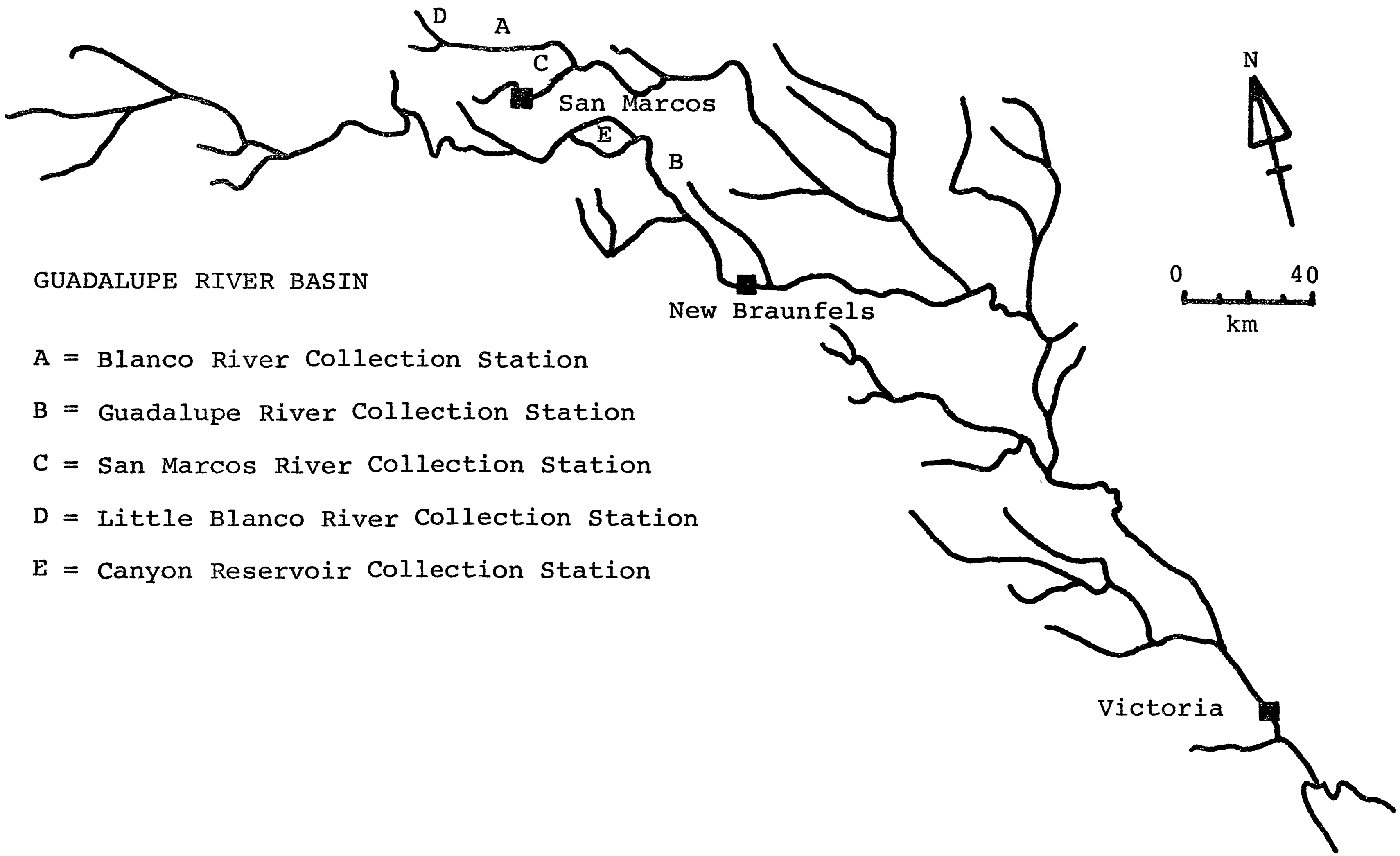

Figure 1. Map of the study area.

The Guadalupe River is the primary source of water for Canyon Reservoir, a major impoundment on the river. The river also accepts drainage from several major tributaries, including the San Marcos River. The San Marcos River forms a confluence with waters from the Blanco River and its tributaries.

Floodplains of the streams are occupied by a mesic forest of large live oaks, elms, hackberries, and pecans. Large cypress trees also fringe the stream banks in the southeastern portions of the province (Blair, 1950).

Description of Collection Stations

Stations A

Abiotic Features

Station A was located on the Blanco River below Five-Mile Dam. Physico-chemical conditions at this station were highly unstable, since the river fluctuated seasonally in depth and temperature. Flooding was frequent at this station. The water source was primarily from seepage springs. Stream width averaged 13 m. During the study period the surface temperature of the water ranged from 10°C to 33.5°C. Water flow was swift due to the steep gradient of the stream bed. Water depth varied from 0.5 m to 1.0 m.

The irregular shorelines formed many side-pools and backwater areas. Patches of rubble, gravel, and silt occurred in eddies and sand bars along the river. Mud-gravel mixtures were found along the banks of the river and silt-covered limestone occurred in backwater pools. Waters were clear except during flood conditions.

Biotic Features

Riverbanks were densely covered with trees. Rooted aquatic macrophytes were scarce.

Invertebrates previously reported in the literature and those observed in this study are listed in Table 1.

Thirty species of fish have been previously reported from the Blanco River (Young et al, 1973).

Other vertebrates observed in the area included *Rana pipiens*, *Natrix* sp., turtles, and raccoons.

<u>Station B</u>

Abiotic Features

Station B was located on the Guadalupe River, approximately 14 river km below the tailrace of Canyon Reservoir. The Guadalupe River originates in the Edwards Plateau at an elevation of 667 m and flows southeast to San Antonio Bay, over 800 km away. The river receives a constant water supply from springs and has the highest and most stable flow of any Texas stream (Young et al, 1973). On the Plateau the stream is swift and shallow with clear water. Composition of the stream bed was similar to that of the Blanco River (Station A).

Physico-chemical parameters fluctuated according to season and rainfall. Water depth varied from 0.25 m

TABLE 1.--Summary of the invertebrates reported from the collection stations by Young et al (1973), Kent (1971), Davis and Huffman (1975) and this study

Taxonomic Unit	Station*				
	A	B	C	D	E
Arthropoda					
Insecta					
Coleoptera			x	x	
Collembola				x	
Diptera			x		
Ephermeroptera (nymphs)	x	x	x	x	x
Hemiptera	x		x		
Megaloptera				x	
Odonata (nymphs)	x	x	x	x	x
Arachnida					
Hydracarina sp.			x		
Crustacea					
Decapoda					
Procambarus sp.	x	x	x	x	x
Ostracoda					
Hyallela azteca	x		x		x
Mollusca					
Gastropoda					
Basommatophora					

TABLE 1.--Continued

Taxonomic Unit	Station*				
	A	B	C	D	E
Physidae					
Physa halei			x		
Physa virgata	x				
Physa sp.		x	x	x	x
Planorbidae					
Planorbis trivolvis	x				
Helisoma anceps		x	x		
Helisoma sp.	x				
Lymnaeidae					
Lymnaea desidosa			x		
Lymnaea sp.			x		
Ancylidae					
Ferrissia sp.			x		
Thiaridae					
Thiara tuberculata			x		
Thiara granifera			x		
Prosobranchia					
Viviparidae			x		
Campeloma sp.			x		
Viviparus sp.			x		

TABLE 1.--Continued

Taxonomic Unit	Station*				
	A	B	C	D	E
Pleuroceridae					
Pleurocera sp.			x		
Goniobasis comalensis			x		
Goniobasis sp.		x	x		
Mesogastropoda					
Amnicolidae					
Amnicola peracuta		x	x	x	
Pelecypoda					
Eulamellibranchia					
Unionidae					
Unio tuberculatus			x		
Unio aureus			x		
Unio sp.	x	x			
Anodonta sp.	x				
Sphaeriidae					
Eupera sp.	x				
Pisidium nitidum		x			x
Cyrenidae					
Corbicula sp.		x	x		x
Annelida					
Oligochaeta			x	x	

TABLE 1.--Continued

Taxonomic Unit	Station*				
	A	B	C	D	E
Platyhelminthes					
Turbellaria					
Dugesia sp.		x	x		
Hirudenia			x		

*Stations: A = Blanco River below Five-Mile Dam
B = Guadalupe River, eight miles below tailrace of Canyon Dam
C = San Marcos River at Thompson's Island
D = Little Blanco River at Hwy 32 bridge
E = Canyon Reservoir at Potter's Creek Park

to 0.75 m in the shallows where collections were made. Water temperature during the time of collection ranged from 13°C to 28.5°C.

Biotic Features

The banks of the river were covered with dense grasses, bald cypress, willows, cottonwood, and sycamores. Aquatic vegetation was absent.

Invertebrates reported at this station are listed in Table 1.

Rana sp. were also observed.

Station C

Abiotic Features

Station C was located on the San Marcos River at Thompson's Island immediately upstream from the County Road bridge, within the city limits of San Marcos, Texas. The San Marcos River originates at a series of springs that issue from the Edwards Aquifer in San Marcos. The combined average flow of these springs is 47 m^3/sec and flooding is common. The river flows southeasterly for approximately 101 km where it empties into the Guadalupe River about six km west of Gonzales, Texas (Young et al, 1973). The headwaters of the river provide a constant physico-chemical ecosystem for the aquatic community within it.

Span of the river at the collection station varied between 2.0 m and 4.0 m, with a range in depth from 0.5 m to 1.0 m. Surface temperature of the water during the sampling time varied from 12.5°C to 28°C. Flow was moderate in pool areas and rapid in the mainstream area. A small dam was present next to the road, over which water entered the mainstream area.

Stream banks were composed of black and yellow clays with an occasional overlay of alluvium. Substratum varied from gravel and sand in the shallows, to silt and piles of decaying filamentous algae and macrophytes in deeper areas. Waters were generally clear, except during times of floods.

Biotic Features

The clear constant-temperature waters and high nutrient levels were conducive to plant growth. Rooted macrophytes covered the bottom in all areas except the swiftest riffles and mainstream of the river. Bald cypress and sycamore trees were common along the shorelines. The steeply sloping banks were densely overgrown with grasses. Dominant macrophytes included *Hydrilla* sp., *Ludwigia* sp., *Potamogeton* sp., and some *Eichornia* sp. Submerged and partially submerged filamentous algae were present in mats in shallow riffle areas.

Invertebrates reported from this station are listed in Table 1.

Longley (1975) stated that 52 species of fish had been reported from the San Marcos River.

Ranid frogs and turtles were also observed at this station.

Station D

Abiotic Features

Station D was located on the Little Blanco River beneath the Ranch Road 32 bridge. The highland creek is a tributary of the Blanco River. The spring-fed waters resemble the Blanco River in that they are subject to violent physico-chemical fluctuations.

Width of the station ranged from 4.0 m to 6.0 m and depth ranged from 0.3 m to 1.0 m, except during times of floods. Flow was moderate to rapid in riffle and mid-stream areas. Surface water temperature ranged from 14°C to 28°C during the study period.

The substratum consisted of small gravel and stones with sand and decaying organic matter in pooled areas.

Biotic Features

The sharply sloping banks were lined with large bald cypress trees which almost completely shaded the creek. Roots from the numerous trees along the banks often formed cavities where the water moved rather slowly and allowed sticks and leaves to accumulate. *Chara* sp. and filamentous algae formed mats in the shallows and along shorelines. *Hydrocotyle* sp. and *Dianthera americana* were common emergents along the banks.

Invertebrates reported from this station are listed in Table 1.

Turtles (sliders) and ranid frogs were also observed at this station.

Station E

Abiotic Features

Station E was located in the Potter Creek Park area of Canyon Reservoir. Canyon Reservoir is a deep-storage, bottom-draining reservoir with a surface area of approximately 3300 hectares and a volume of 500 million cubic meters. This major impoundment was a joint project of the U. S. Army Corp of Engineers and Guadalupe-Blanco River Authority and was completed in 1964. Maximum depth in the inundated riverbed is 40 m.

The shoreline of the station was irregular and protected areas were common, especially during periods of high water. Canyon Reservoir had a mud substratum in the deeper waters, but shallow areas had a substratum of rubble and gravel mixed with mud. Collections were made from the shallow, rocky substratum, just before it dropped off into deeper waters, a few meters out from the bank.

Due to wind action causing fluctuations in water height, waves were common and waters were generally turbid. Depth in the collection station ranged from 0.25 m to 1.5 m. Physico-chemical conditions fluctuated in the shallow areas. During the summer the monomectic reservoir was thermally stratified. Epilimnetic temperatures ranged from 16°C to 29°C during the study period.

Biotic Features

The rock and mud shoreline was densely covered with grasses, along with oak and blackwillow trees. Shallow waters contained patches of *Potamogeton* sp. and floating mats of green filamentous algae.

Invertebrates reported from this station are listed in Table 1.

According to Young et al (1973), 24 species of fish have been reported from this station.

Mallards and *Rana* sp. also frequented the station.

Summary of Collection Station Characteristics

A short summary of the habitat characteristics for each collection station is given in Table 2 for quick reference.

TABLE 2.--Summary of the distinguishing characteristics of the five stations sampled in this study

Station	Habitat	Months Sampled	Habitat Characterization
A	Blanco River at Five-Mile Dam	Nov. - Oct.	Shallow, steep gradient, hill country river; prone to drastic physico-chemical fluctuations
B	Guadalupe River	Nov. - April, June - Oct.	Moderately deep, fast flowing highland river; located below a deep-storage reservoir; fluctuating physico-chemical characteristics
C	San Marcos River at Thompson's Island	Nov. - Oct.	Fed by major spring; nearly constant physico-chemical conditions
D	Little Blanco River	Nov. - April, June - Oct.	Like Station A, but much smaller
E	Canyon Reservoir at Potter's Creek Park	Nov., Dec., Jan., Feb., June, July, Aug.	Large, deep-storage, man-made reservoir

CHAPTER III

RESULTS

Helminths of *N. venustus* and *N. lutrensis*

Three of the 104 helminth species previously reported from the genus *Notropis* have been reported from *N. lutrensis* and six have been reported from *N. venustus*. In the current study, 20 species of helminths were collected from *N. venustus* and 19 species from *N. lutrensis*, all of which are new host records (Table 3). Thirteen of the species collected from *N. lutrensis* and 15 of the species collected from *N. venustus* were larval forms. Helminths were found parasitizing almost every organ and tissue of both host fish.

Taxonomy of Helminths of *N. venustus* and *N. lutrensis*

Trematoda

Crassiphiala bulboglossa Vanhaitsma, 1925, identified using Hoffman's (1960) key and description, was found embedded in the epidermis under the scales and in the fins of the host fish. The specimens varied slightly from Hoffman's description in that the cysts were not completely covered with black pigmentation in all cases.

TABLE 3.--Helminth species collected from *N. venustus* and *N. lutrensis* from the area of San Marcos, Texas. (The number on the left represents *N. lutrensis* and the number on the right represents *N. venustus*)

Parasite	Number of Parasites Collected	Number of Fish Infected	Parasites Per Fish	Parasites Per Infected Fish	Percent Fish Infected
Trematoda:					
Crassiphiala bulboglossa	1491/26	48/7	3.2/0.06	31/3.7	10/1.7
Diplostomulum scheuringi	0/1	0/1	0/0.002	0/1	0/0.3
Gyrodactylus sp	4/0	3/0	0.01/0	1.3/0	0.65/0
Macroderoides spiniferus	31/55	22/26	0.07/0.14	1.4/2.1	4.8/6.4
Opisthorchis sp.	1/11	1/6	0.002/0.03	1/1.83	0.22/1.5
Plagioporus "A"	309/866	28/55	0.67/2.1	11/16	6.1/14
Plagioporus "B"	19/19	7/9	0.04/0.05	2.7/2.1	1.5/2.2
Posthodiplostomum minimum	97/642	33/129	0.21/1.6	2.9/4.9	7.2/32
Neascus "A"	1/0	1/0	0.002/0	1/0	0.22/0
Neascus "B"	0/2	0/2	0/0.01	0/1	0/0.5
Rhipidocotyle papillosum	50/12	25/7	0.11/0.03	2/1.7	5.5/1.7
Tetracotyle sp.	1/5	1/5	0.002/0.01	1/1	0.22/1.2

TABLE 3.--Continued

Parasite	Number of Parasites Collected	Number of Fish Infected	Parasites Per Fish	Parasites Per Infected Fish	Percent Fish Infected
Trematoda A	8/0	2/0	0.06/0	4/0	0.44/0
Trematode B	1/1	1/1	0.002/0.002	1/1	0.22/0.25
Trematode C	2/1	2/1	0.004/0.002	1/1	0.44/0.25
Cestoda:					
Proteocephalus "A"	33/47	14/24	0.07/0.12	2.4/1.9	3.1/5.9
Proteocephalus "B"	6/0	1/0	0.01/0	6/0	0.22/0
Acanthocephala:					
Echinorhynchidae	1/0	1/0	0.002/0	1/0	0.22/0
Pomphorhynchus bulbocolli	0/3	0/1	0/0.02	0/3	0/0.25
Hirudinea:					
Piscicola sp.	1/1	1/1	0.002/0.002	1/1	0.22/0.25

TABLE 3.--Continued

Parasite	Number of Parasites Collected	Number of Fish Infected	Parasites Per Fish	Parasites Per in-fected Fish	Percent Fish Infected
Nematoda:					
Camallanus sp.	0/3	0/3	0/0.011	0/1	0/0.74
Contracaecum sp.	0/1	0/1	0/0.002	0/1	0/0.25
Cystidicola sp.	0/8	6/2	0.02/0.02	1.3/4	1.3/0.5
Rhabdochona cascadilla	191/145	44/36	0.5/0.36	4.3/4	9.6/8.9
Spiroxys sp.	6/9	5/8	0.01/0.02	1.2/1.1	1.1/1.9
Totals	2261/1858	184/224			

Diplostomulum scheuringi Hughes, 1929 was identified with the aid of Hoffman's key (1967:170). The single specimen collected was found loose in the coelomic cavity of *N. venustus* rather than in the eyes as had been previously reported for most other fish species. Haderlie (1953) and Davis and Huffman (1975), however, did report *D. scheuringi* from the coelomic cavity of *Gambusia affinis* (Poecilidae).

Posthodiplostomum minimum (MacCallum, 1921), was identified in Hoffman (1967:175-176). Metacercariae were taken from the mesenteries surrounding the intestine of the host fish.

Macroderoides spiniferus Pearse, 1924, was keyed to genus in Hoffman (1967:151). The metacercariae were found embedded in the epidermis and in the mesenteries of the host fish. Specific identification was confirmed with the use of Leigh's (1956) description.

Plagioporus "A" was found in the gallbladder of *N. venustus* and *N. lutrensis* collected from the San Marcos River. The specimens corresponded closely to Hoffman's subgenus *Plagioporus*, since the vitillaria appeared to extend to the posterior extremity of the worm and testes were oblique in the midbody of the parasite. A series of specimens was sent to Dr. Glen Hoffman, who was unable to arrive at a specific determination, therefore, the worm will be referred to as *Plagioporus* "A" until a species determination can be made. Body measurements for this worm are given in Table 4.

Plagioporus "B" was found in the intestine of the host fish. The trematode corresponded closely to Hoffman's description of the subgenus *Caudotestis* (Hoffman, 1967: 157-158), in that the vitillaria extended into the fore-body but did not reach the posterior portion of the worm and testes were located near the extreme posterior end of the worm. Dr. Hoffman was unable to verify the subgenus determination. Body measurements for this parasite are given in Table 4.

Rhipidocotyle papillosum (Woodhead, 1929) was found encysted deep in caudal muscle tissue and in the mesenteries of the intestine. Hoffman's key (1967:178-181) was used to identify the gasterostome to genus. Subsequent identification to species was accomplished by comparison with Woodhead's (1929) description of the metacercariae.

Opisthorchis sp. was collected from the mesenteries surrounding the intestine of the host fish. The metacercariae were identified to genus by the use of Hoffman's key (1967:178-181). The parasite corresponded closely to *Opisthorchis tonkae* (Wallace and Penner, 1939) which was reported encysted in *N. deliciosus*. However, as the metacercariae of this species had not been described, specimens could not be assigned to this species with confidence. The helminths measured 752.5 microns by 183.8 microns. The width of the oral sucker and acetabulum averaged 98 microns and 70 microns, respectively.

TABLE 4.--Body measurements in microns for *Plagioporus* "A" collected from the gallbladder and *Plagioporus* "B" collected from the intestine of *N. venustus* and *N. lutrensis*. (The mean is represented by "$\bar{x}$" and the standard deviation is represented by "*s*")

Body Part	*Plagioporus* "A" $\bar{x}$ (*s*)	*Plagioporus* "B" $\bar{x}$ (*s*)
Total Length of Worm	600(165)	870(296)
Length of Acetabulum	175(50)	180(55)
Length of Ovary	45(7)	75(15)
Length of Testes	55(9)	135(35)
Width of Ovary	50(7)	80(23)
Width of Testes	55(7)	115(57)
Width of Oral Sucker	100(15)	135(36)
Width of Acetabulum	165(42)	175(44)
Width of Body	260(67)	375(384)
Distance Between Centers of Testes	84(8)	171(52)

TABLE 4.--Continued

Body Part	*Plagioporus* "A" $\bar{x}$ (*s*)	*Plagioporus* "B" $\bar{x}$ (*s*)
Egg Length	70(3)	62(3)
Egg Width	39(3)	36(3)
Sucker Ratio	3.10(0.15)	3.60(0.12)

Two *Neascus* species Hughes, 1927 were collected from the coelomic cavity of the host fish. *Neascus* "A" measured 357 microns by 840 microns and was found unencysted and active in the body cavity. *Neascus* "B" was found in a thick, golden, gelatinous cyst, between the eggs within the distended ovary. The encysted metacercariae measured 518 microns by 784 microns. Both *Neascus* species were identified to the larval genus by the use of Hoffman's key (1967:169).

Specimens of the larval genus *Tetracotyle* de Filippi, 1854 were found loose in the coelomic cavity. The parasite was identical to the description in Hoffman (1967:171-174), except that there was apparently no cyst surrounding the worm. The worm's body measured 490 microns by 739 microns.

The monogenetic trematode *Gyrodactylus* Nordmann, 1832 was collected from the anal fin of the host fish and was identified using Hoffman's (1967:74-76) description of the genus.

Three metacercarial trematodes, designated Trematodes "A", "B", and "C", could not be identified because the only specimens available were in poor condition.

Cestoda

Proteocephalus "A" Weinland, 1858 occurred as a procercoid larva in the mesenteries covering the stomach and intestine of the host fish. Identification to genus was made with the use of Hoffman's key (1967:218).

Proteocephalus "B" Weinland, 1858 was found in the liver of the host fish. These plerocercoid larvae were noticably more active than *Proteocephalus* "A" and were identified to genus with the use of Hoffman's key (1967:218). No attempt was made to key *Proteocephalus* "A" or "B" further, because keys which would allow the confident assignment of larval forms in this genus to species were not available.

Acanthocephala

One specimen of the family Echinorhynchidae Cobbold, 1876 was collected from the anterior portion of the intestine of the host fish. Identification to family was based on the male, using Hoffman's key (1967:272). Loss of the specimen prevented further specific identification.

Pomphorhynchus bulbocolli VanCleave, 1919 was collected from the intestine of *N. venustus*. The worms were identified to genus using Hoffman (1967:272). Specific identification was made using Petrochenko (1956).

Hirudinea

Two specimens of *Piscicola* sp. Blainville, 1818 were found attached beneath the pectoral fin of the host fish. The leech was identified to genus using Hoffman's key (1967:290-293).

Nematoda

Camallanus sp. Railliet and Henry, 1915 was identified using Hoffman (1967:242-245). The buccal cavity with two lateral chitinous valves with internal rib-like thickenings helped identify the worm to family. Further identification was made in accordance with Hoffman's illustrations and descriptions. The immature adults were found in the host's intestine.

Contracaecum sp. Railliet and Henry, 1912 was identified to genus in Hoffman (1967:245-246). The specimens were found in the intestinal mesenteries of the host fish. The immature adults were easily recognizable to genus by the presence of an anteriorly projecting intestinal caecum and a posteriorly projecting esophageal appendix.

Cystidicola sp. Fischer, 1798 was found in the intestine of the host fish. Identification was based on the anal papillae, spicules, and rounded tip of the tail of the male (Hoffman, 1967:242-245). No females were collected. Further specific identification was not made due to the poor condition of the specimens.

Rhabdochona cascadilla Wigdor, 1918 were collected in dense populations from the intestine of the host fish. Identification was based on adult male and female specimens. Hoffman (1967:242-245) was used for generic identification and Petrochenko (1956) was used for specific identification.

Spiroxys sp. Schneider, 1866 was identified according to Hoffman (1967:245-246). The nematodes were found encysted in the mesenteries and were distinguishable by the trilobed-lips and triangular appearance of the head. The larval nematode was not identified further since appropriate keys were unavailable.

Factors Affecting the Helminth Fauna of *N. venustus* and *N. lutrensis*

Diet of Host

The diet of *N. venustus* and *N. lutrensis* is probably a key factor in determining the helminth communities of these fishes since they are expected to be physiologically very similar. Food organisms found in the stomach and/or intestine of the host fishes are given in Table 5.

Habitat of Host

Figure 2 shows a comparison of the five collection stations with regard to the number of helminth species, helminth diversity, number of helminths, and number of fish infected for both host species. It should be noted that only relative comparisons between stations are possible, since equal host sample sizes were not possible among the five stations.

Figure 3 illustrates geometric intervals of the helminths most commonly found in *N. lutrensis* and *N. venustus* from the four river stations. Helminth loads for

TABLE 5.--Identifiable food remains taken from the stomach and/or intestine of *N. venustus* and *N. lutrensis* from the five collection stations from January 1975 through October 1975. (A = Blanco River, B = Guadalupe River, C = San Marcos River, D = Little Blanco River, E = Canyon Reservoir)

Month	*N. venustus*		*N. lutrensis*	
	Food Organism	Habitat	Food Organism	Habitat
January	Coleoptera	B, E	Coleoptera	B
	Odonata	B	Odonata	B
February	Collembola	A		
	Megaloptera	E		
	Ostracoda	A		
	Daphnia	A		
March	Coleoptera	B	Coleoptera	B
	Ephemeroptera	A	Odonata	B, C
	Odonata	A		
	Misc. Insects	A		
April	Megaloptera	A	Ephemeroptera	D
			Megaloptera	A
			Odonata	D
May	Megaloptera	A	Ephemeroptera	A
			Megaloptera	A
June			Ephemeroptera	D

TABLE 5.--Continued

Month	*N. venustus*		*N. lutrensis*	
	Food Organism	Habitat	Food Organism	Habitat
July	Megaloptera	C	Misc. Insects	D
	Tricoptera	C		
	Misc. Insects	A, C		
August	-	-	-	-
September	Coeloptera	C	Coleoptera	C
	Odonata	B, C	Odonata	B, C
	Spirogyra	C	*Spirogyra*	C
	Misc. Plants	C	Misc. Plants	C
October	Coleoptera	C	Coleoptera	C
	Diptera	C	Diptera	C
	Megaloptera	C	Megaloptera	C
	Odonata	C	Odonata	C

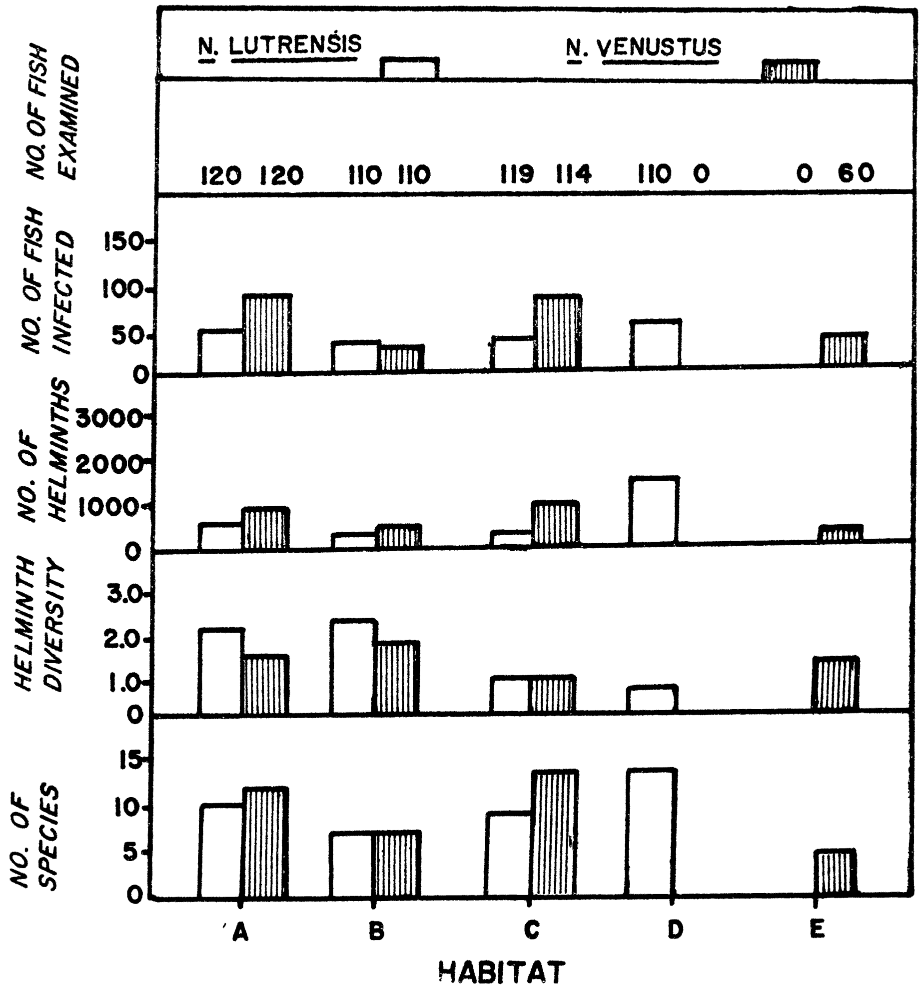

Figure 2. Comparisons of the number of helminth species, helminth diversity, number of helminths and number of infected *N. venustus* and *N. lutrensis* among the five stations. A = Blanco River, B = Guadalupe River, C = San Marcos River, D = Little Blanco River, E = Canyon Reservoir.

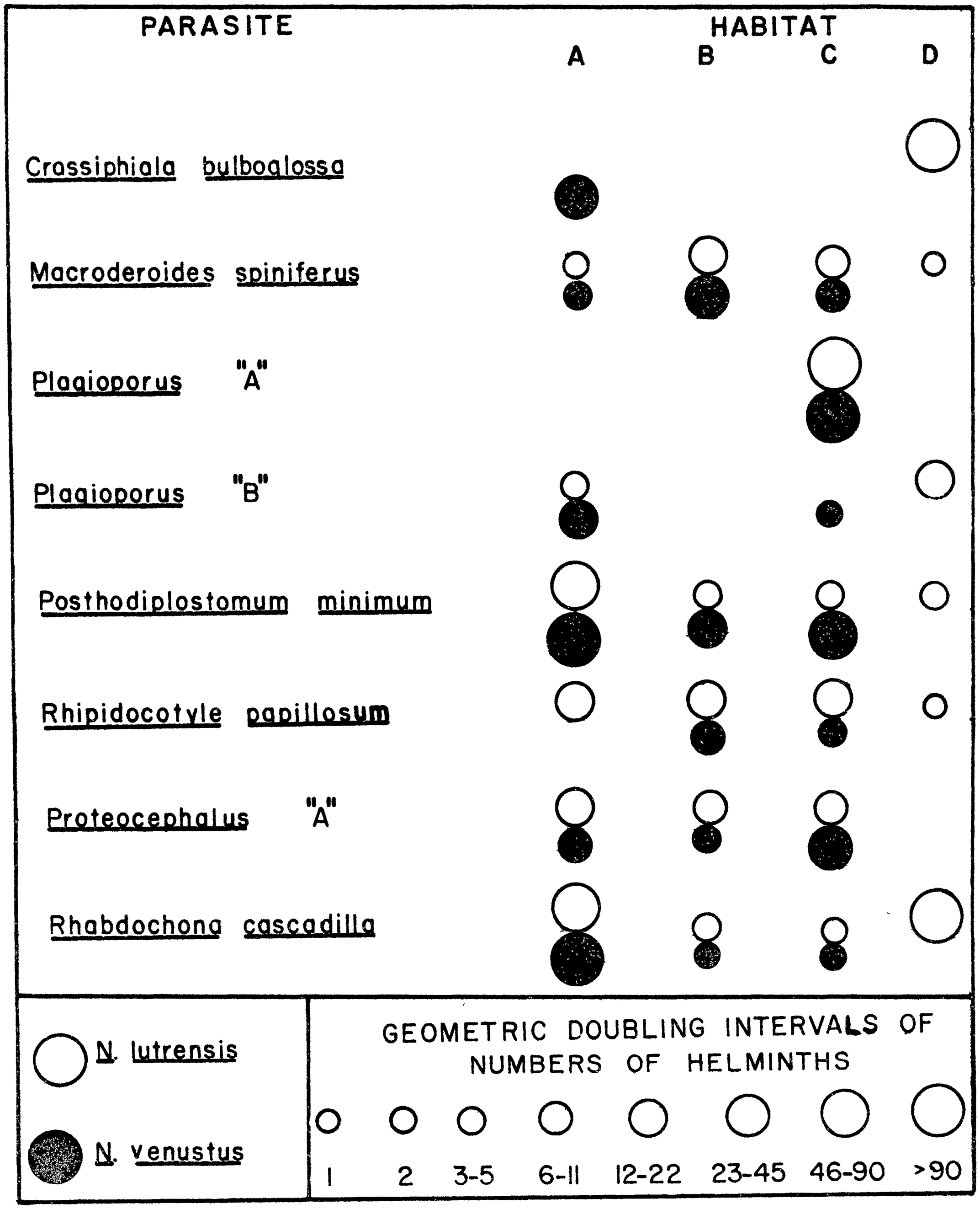

Figure 3. Geometric intervals of the number of trematodes, cestodes, and nematodes of each species which commonly infect *N. venustus* and *N. lutrensis* among the four river stations. A = Blanco River, B = Guadalupe River, C = San Marcos River, D = Little Blanco River.

the month of May were not included due to unequal host sample sizes at that time.

The number of circles in each vertical row represents the number of the most common trematode species occurring in that habitat. Relative abundance of each trematode in each habitat can be ascertained by comparing the overall area of each circle. More trematode species were found in *N. venustus* from the San Marcos River (Station C) than from any other station, while the Little Blanco River (Station D) seemed to favor the trematode group to a greater extent in *N. lutrensis*.

Comparison of circle sizes in a horizontal row shows the relative extent to which each habitat can support a given species. Thus, of the four stations, the Little Blanco River supported the densest population of *Crassiphiala bulboglossa*, while *Plagioporus* "A" occurred in both species of fish, but only those from the San Marcos River.

Consideration of the overall area of the circles in each vertical row indicates that *Posthodiplostomum minimum* was encountered more often in this study than any other helminth, while *Plagioporus* "B" was the least abundant of these parasites.

The larval cestode *Proteocephalus* "A" was found frequently in both host fish and in all habitats except the Little Blanco River (Figure 3). The absence of

Proteocephalus in fish from the Little Blanco River may be due to the lack of large fish that serve as definitive hosts.

Adults of the nematode species, *Rhabdochona cascadilla* were found in all four habitats, and were in greatest abundance in fish from the Blanco and Little Blanco Rivers (Figure 3).

Season of Collection

Seasonal Variation in Incidence and Intensity of Overall Helminth Infection

Data from the five collection stations were pooled by month for each host species to analyze the effect of season on incidence and intensity of overall helminth infection.

Incidence and intensity of helminth infection were highest in *N. venustus* during March and April and were lowest during September (Figures 4 and 5). Incidence of infected *N. lutrensis* remained relatively constant over the year (Figure 4). Intensity of helminth infection in *N. lutrensis* appears to have peaked the first part of March and dropped to a low the first part of June (Figure 5).

Seasonal trends for the two species may be the result of the dominance of adult fish in March. This is the time the spawning season begins (Laser and Carlander, 1971) and these fish have had an entire year to obtain parasites. Thus, when spawning was over, many overly

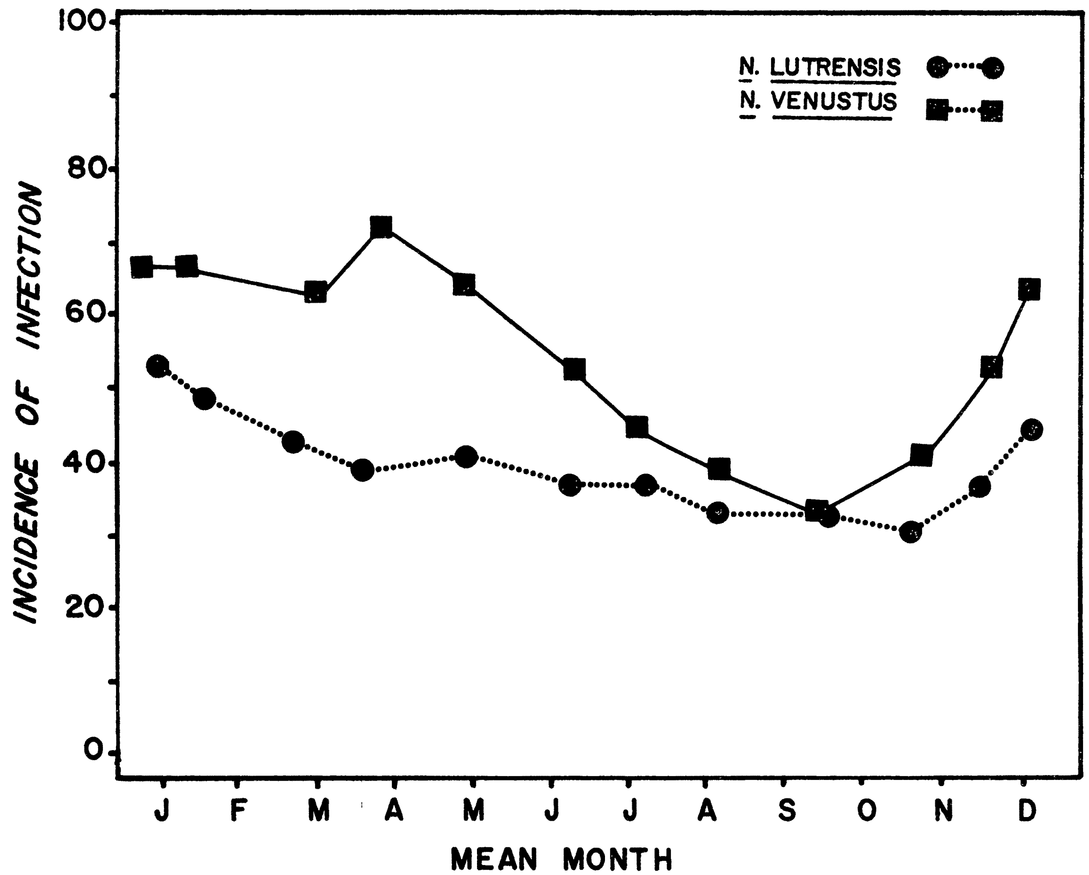

Figure 4. Incidence of overall helminth infection in *N. venustus* and *N. lutrensis* plotted against a three-month moving average.

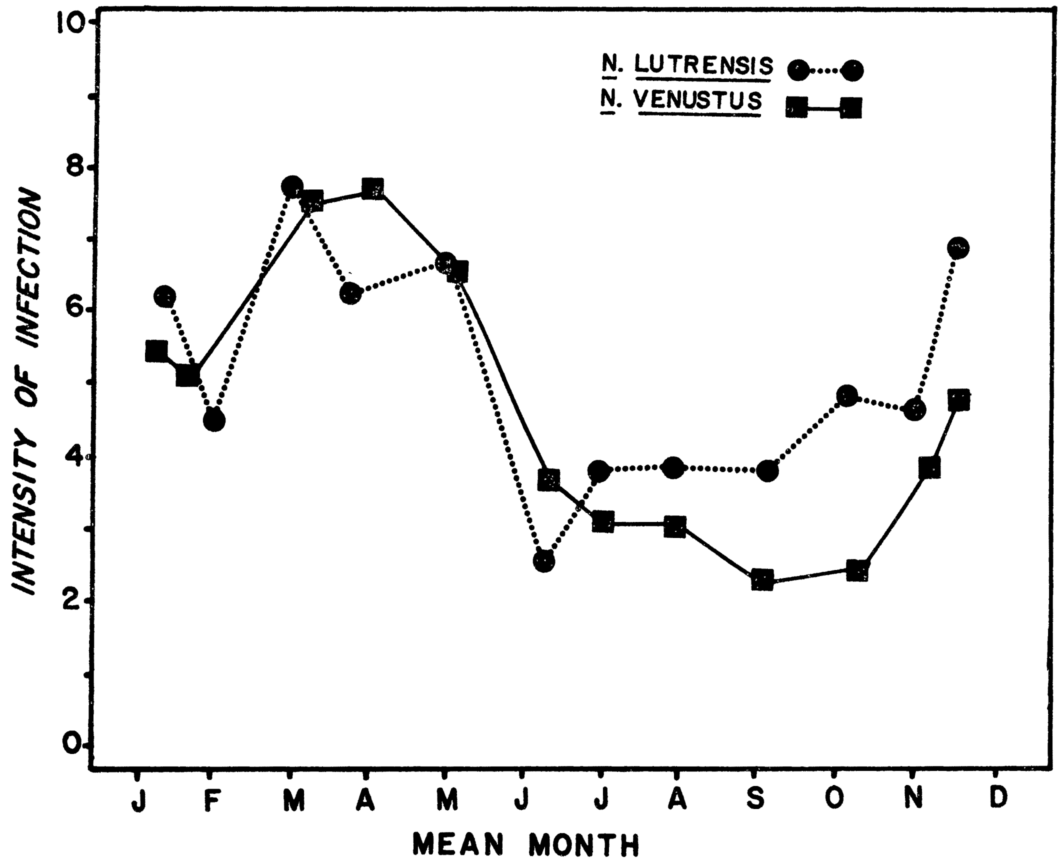

Figure 5. Intensity of overall helminth infection in *N. venustus* and *N. lutrensis* plotted against a three-month moving average.

stressed adult fish may have died and dilution by uninfected young may have occurred, effectively reducing the mean number of helminths per fish.

Seasonal Variation in Incidence and Intensity of Infection of Four Common Helminths

Incidence and intensity of *Posthodiplostomum minimum* infection were highest in *N. venustus* during the winter months and exhibited a low during October (Figures 6 and 7). Incidence and intensity of infected *N. lutrensis* remained relatively constant over the year (Figures 6 and 7) and at substantially lower levels than *N. venustus*. It is possible that the larger size of *N. venustus* increases the chances of cercarial penetration by this strigeoid.

Incidence of *Plagioporus* "A" infection peaked in late winter and early spring for both host species from the San Marcos River and was lowest in late summer (Figure 8). Intensity of *Plagioporus* "A" infection peaked in March for both host species (Figure 9). The intermediate host of many of the species in this genus is *Goniobasis* (Hoffman, 1967). Low incidence and intensity of helminth infection during the summer months may result from the inability of the fry to swallow the large gastropod. Adult fish, being proportionately the dominant age class in early spring, would have larger mouths which may effectively increase their chances of ingesting an infected snail.

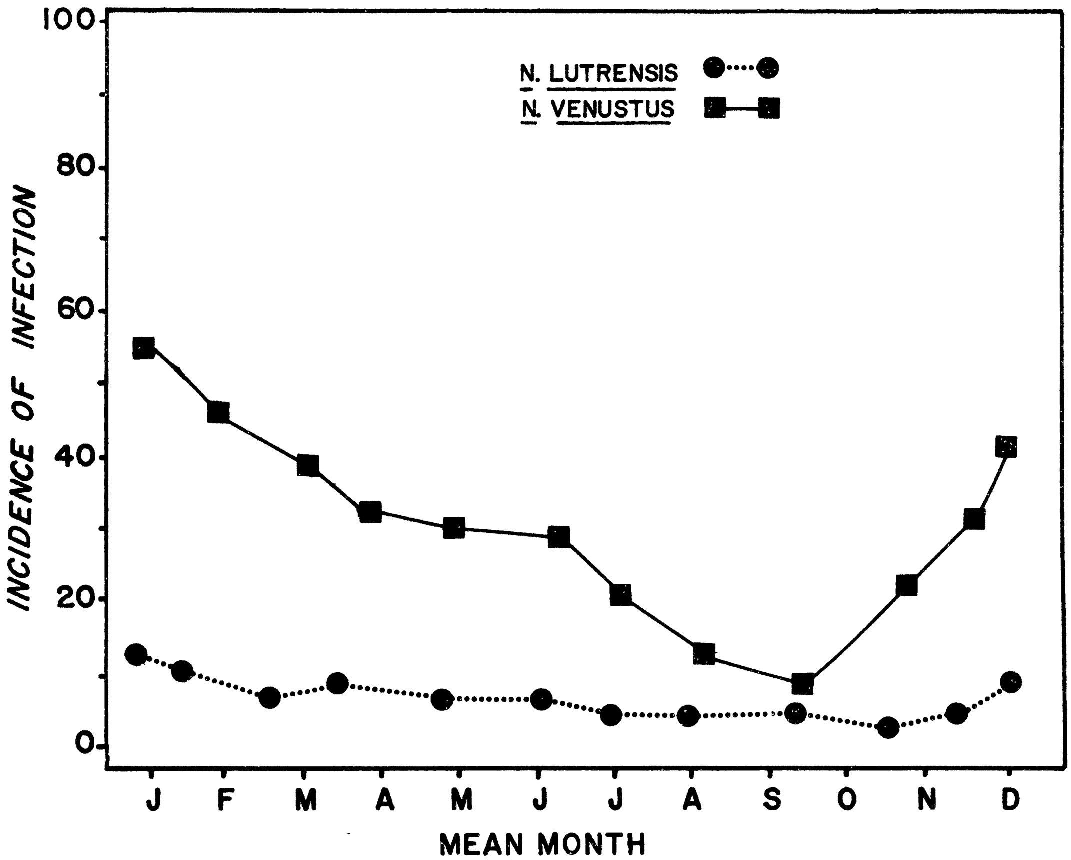

Figure 6. Incidence of *Posthodiplostomum minimum* infection in *N. venustus* and *N. lutrensis* plotted against a three-month moving average.

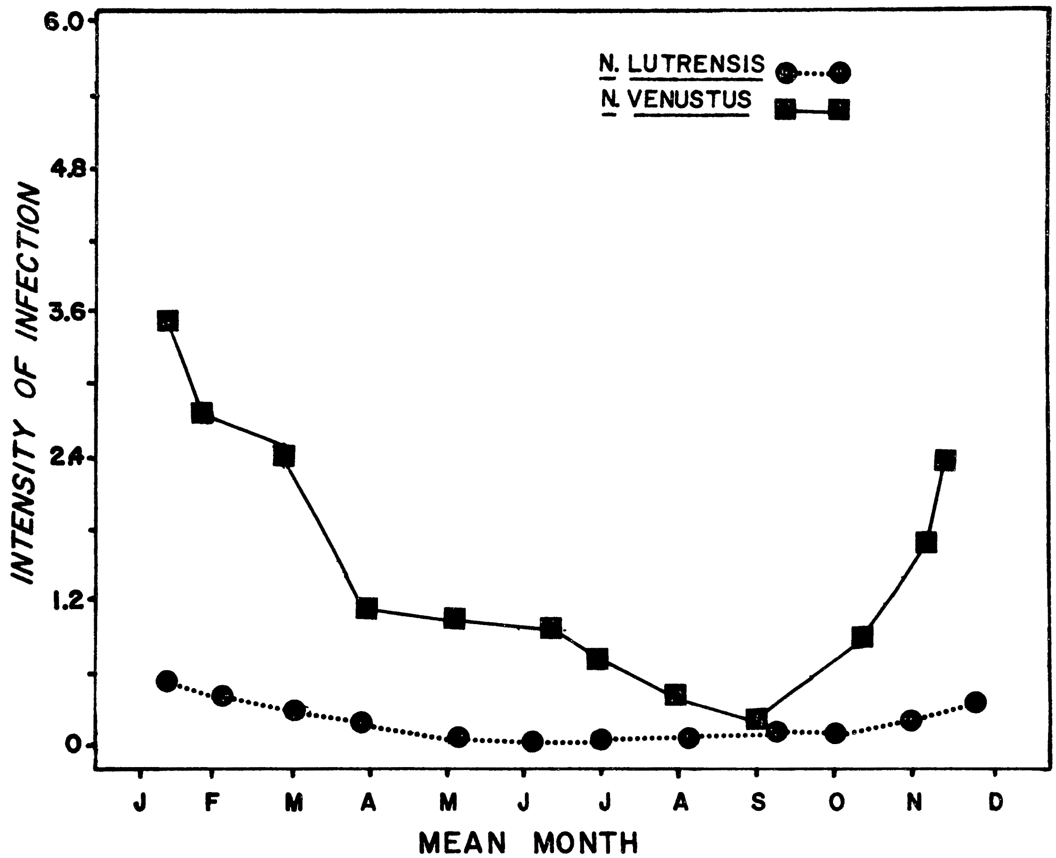

Figure 7. Intensity of *Posthodiplostomum minimum* infection in *N. venustus* and *N. lutrensis* plotted against a three-month moving average.

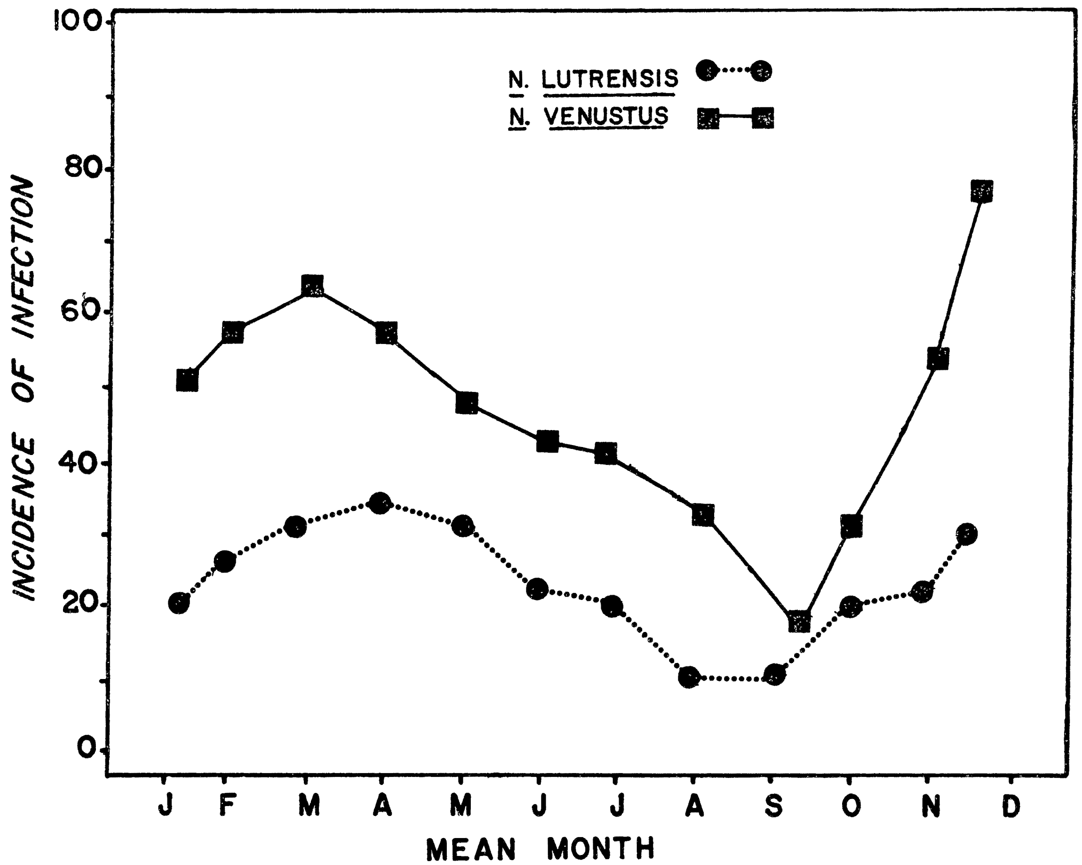

Figure 8. Incidence of *Plagioporus* "A" infection in *N. venustus* and *N. lutrensis* from the San Marcos River plotted against a three-month moving average.

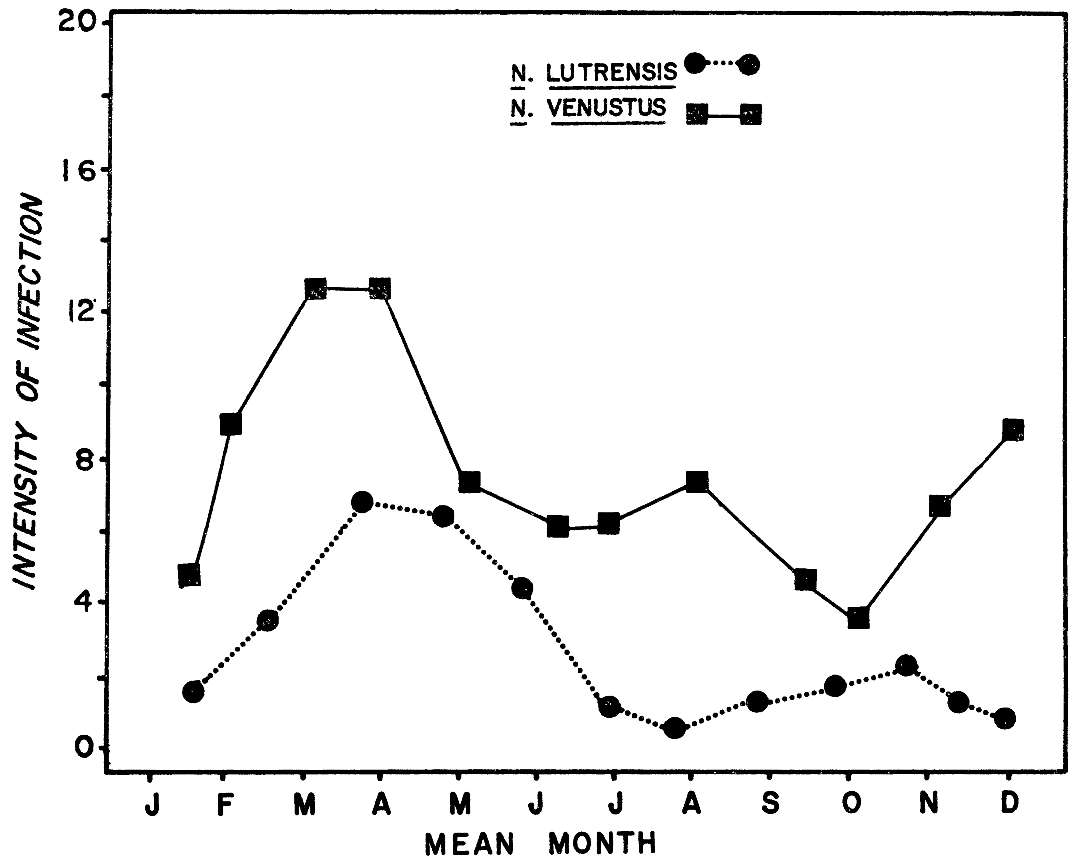

Figure 9. Intensity of *Plagioporus* "A" infection in *N. venustus* from the San Marcos River plotted against a three-month moving average.

Peaks in incidence and intensity of *Crassiphiala bulboglossa* infection occurred during the winter months in fish from the Little Blanco River (Figure 10).

Both host species exhibited a relatively low incidence of infection with *Rhabdochona cascadilla* (Figure 11). Intensity of infection with the nematode reached highest levels in *N. venustus* in May and exhibited low helminth loads over the rest of the year (Figure 12). *Notropis lutrensis* exhibited peak helminth intensity in late June, with low infection levels over the winter months (Figure 12).

Size of Host

Since fish tend to grow during their entire life, it is sometimes possible to compare the approximate ages of fish by comparing standard body lengths. Kennedy (1975) stated that the older the host is, the more time it has had to make contact with a parasite. Thus, for this study, longer (older) fish would be more likely to have a helminth infection than shorter (younger) fish.

The Relationship Between Incidence of Overall Helminth Infection and Host Length

Figure 13 is a plot of the incidence of hosts infected against standard host length for both fish species. Incidence of infection rose in both species as their length increased from 33 mm. This trend was highly significant for *N. venustus* ($p = 0.00156$; $a = 11.55842$, $b = 0.54362$, $r = 0.36883$) and the trend was very highly

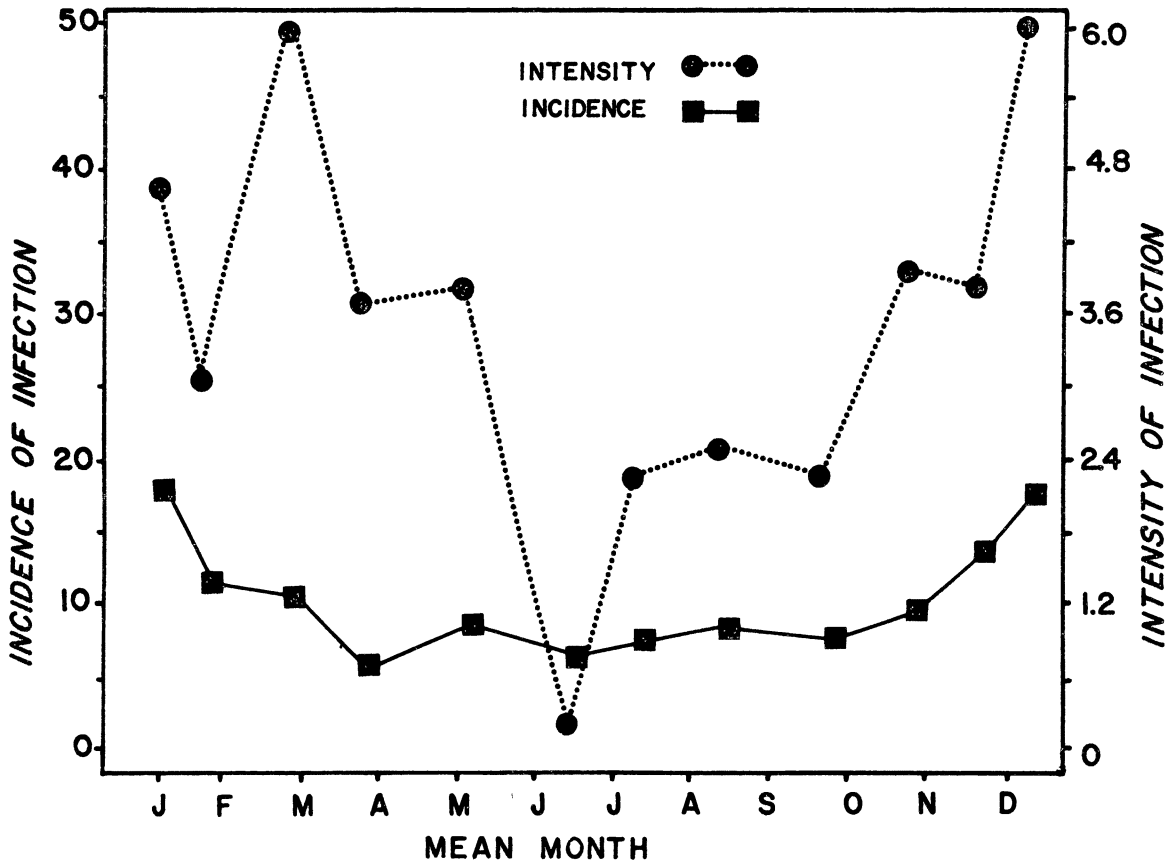

Figure 10. Incidence and intensity of *Crassiphiala bulboglossa* infection in *N. lutrensis* from the Little Blanco River plotted against a three-month moving average.

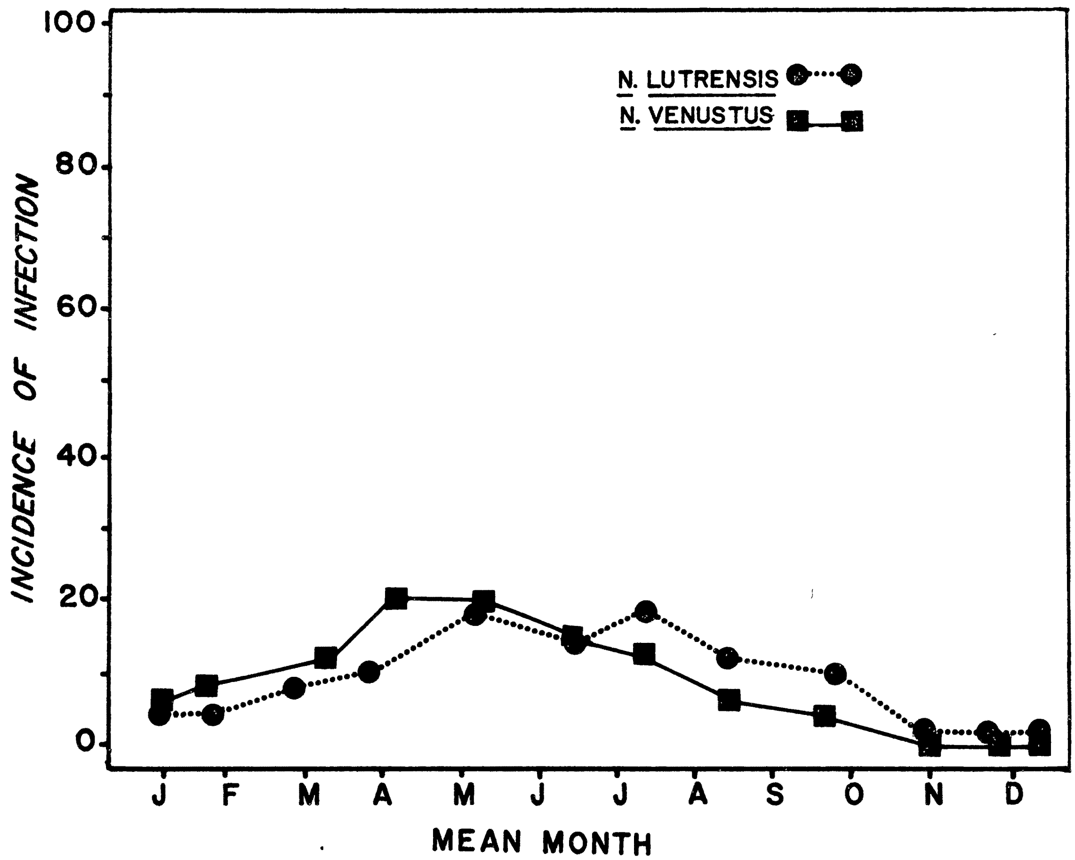

Figure 11. Incidence of *Rhabdochona cascadilla* infection in *N. venustus* and *N. lutrensis* plotted against a three-month moving average.

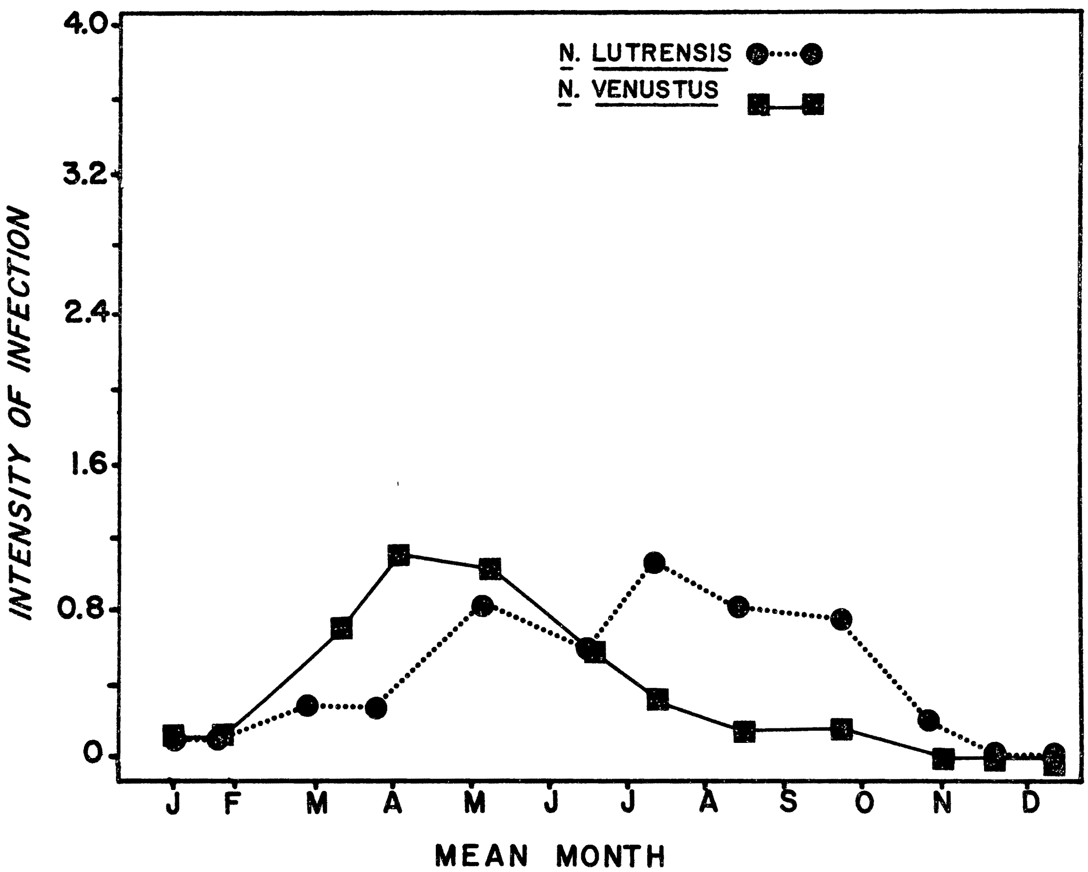

Figure 12. Intensity of *Rhabdochona cascadilla* infection in *N. venustus* and *N. lutrensis* plotted against a three-month moving average.

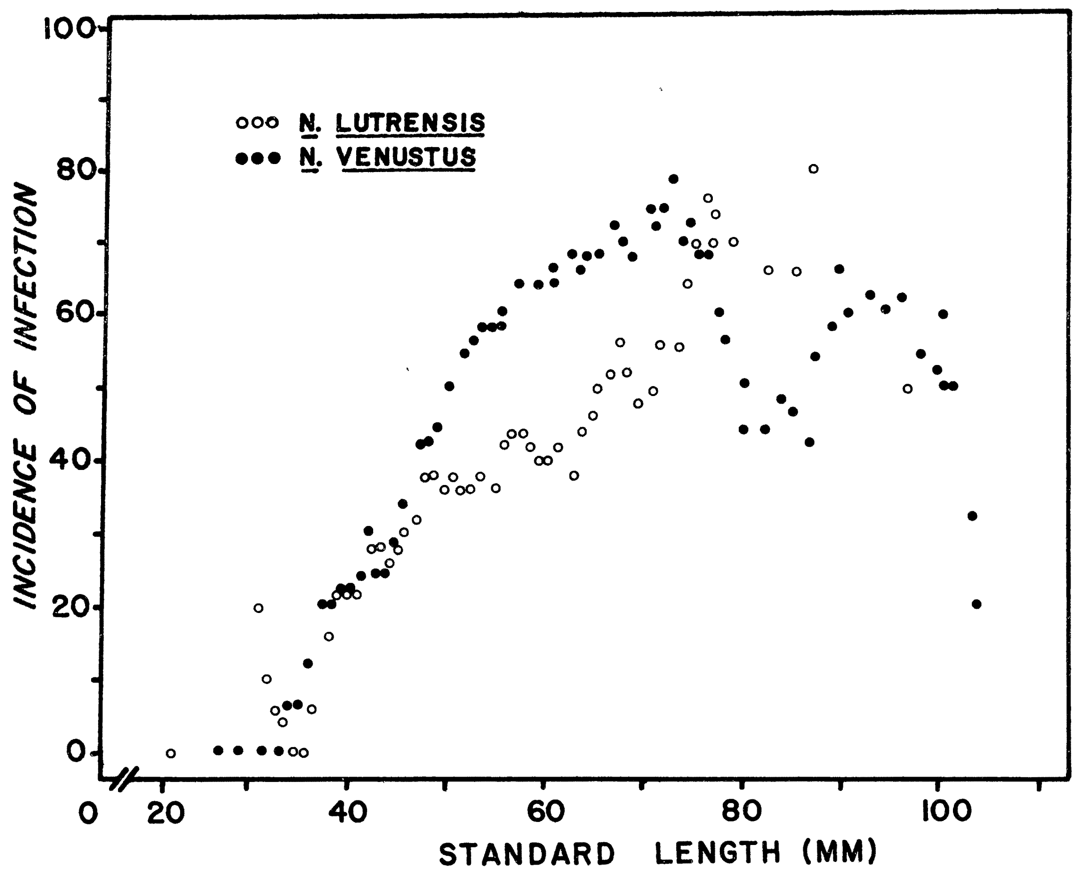

Figure 13. Incidence of overall helminth infection in *N. venustus* and *N. lutrensis* plotted against standard body length using a 9 mm moving average.

significant for *N. lutrensis* ($p = 0.00001$; $a = -21.38246$, $b = 1.07406$, $r = 0.62033$).

The Relationship Between Intensity of Overall Helminth Infection and Host Length

The effect of standard body length on intensity of helminth infection was determined for each host species. Intensity of overall infection increased linearly with host length from approximately 33 mm in both host species (Figure 14). This trend is evidenced in *N. venustus* by a highly significant regression coefficient ($p = 0.00989$; $a = -0.17208$, $b = 0.07284$, $r = 0.30010$). The same trend for *N. lutrensis* revealed a significant linear regression ($p = 0.03301$; $a = -19.65684$, $b = 0.49238$, $r = 0.27339$) between intensity of infection and host length. Thus increasing standard host length seemed to positively influence helminth load in both hosts. Intensity of infection tended to be higher in *N. venustus* than in *N. lutrensis*.

The Relationship Between Host Length and the Incidence and Intensity of Infection of Four Common Helminths

Incidence of *Posthodiplostomum minimum* infection peaked over the middle length classes of *N. venustus* (Figure 15). There was a highly significant linear relationship for incidence of infection to increase with host length for *N. lutrensis* ($p = 0.00270$; $a = -14.24367$, $b = 0.38937$, $r = 0.37757$). Intensity of infection also peaked over the middle length classes for *N. venustus* but remained at relatively constant low levels for *N. lutrensis*

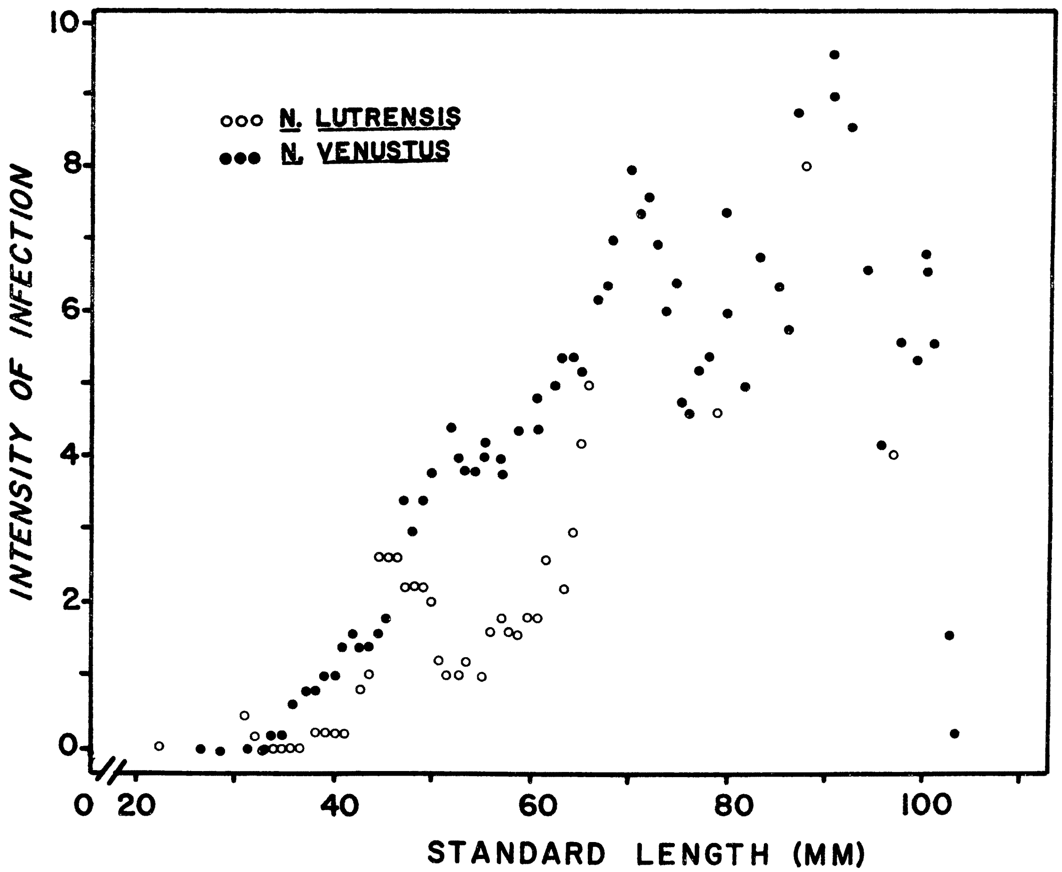

Figure 14. Intensity of overall helminth infection in *N. venustus* and *N. lutrensis* plotted against standard body length using a 9 mm moving average.

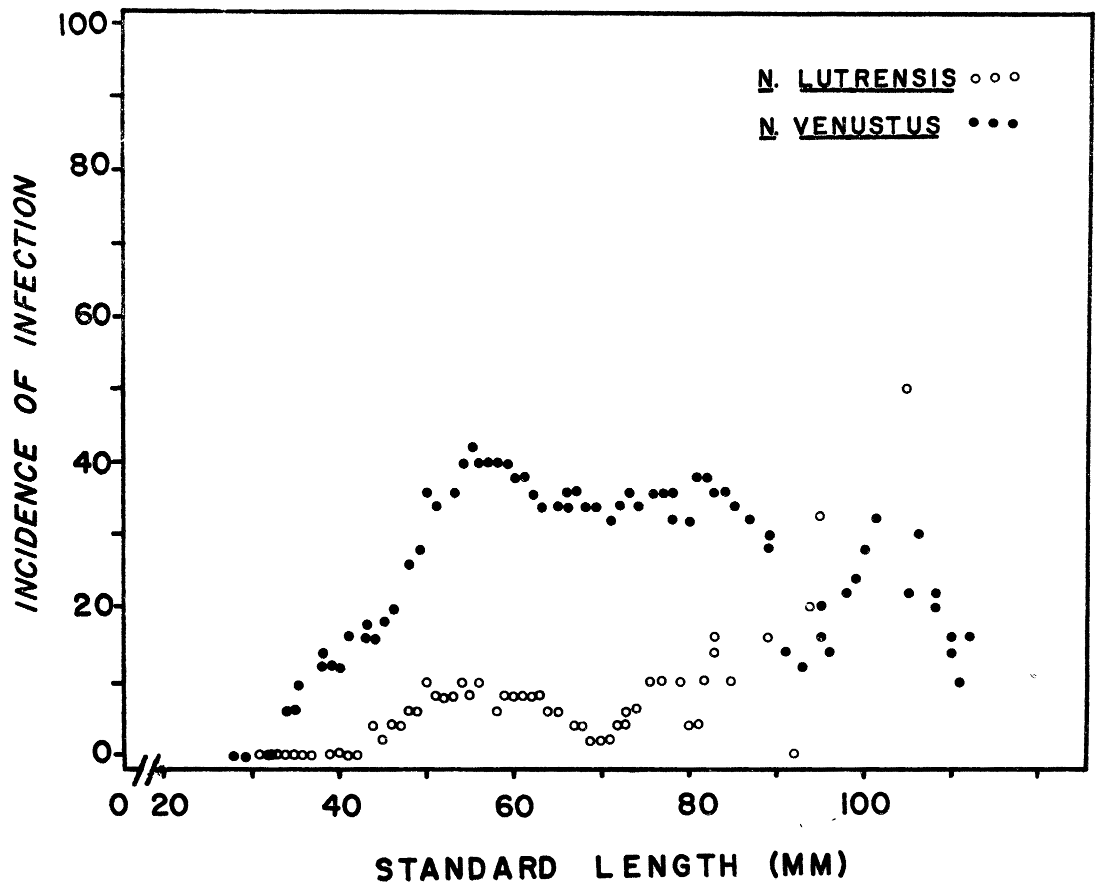

Figure 15. Incidence of *Posthodiplostomum minimum* infection in *N. venustus* and *N. lutrensis* plotted against standard body length using a 9 mm moving average.

(Figure 16).

Incidence of *N. venustus* infected with *Plagioporus* "A" rose and then remained constant over the middle length classes (Figure 17). *Notropis lutrensis* exhibited a significant linear trend for incidence of infection to increase with standard host length (p = 0.04377; a = -37.39048, b = 1.00549, r = 0.38381). In length classes where both host species were represented, the slope of the increase in incidence was virtually identical for both species, but the y-intercept for *N. venustus* appeared to be much lower than for *N. lutrensis*. Unfortunately, *N. lutrensis* greater than 70 mm were not collected from the San Marcos River, consequently, it was not possible to extend the comparison into longer length classes. Intensity of *Plagioporus* "A" infection in *N. venustus* and *N. lutrensis* from the San Marcos River increased linearly with body lengths greater than 46 mm and 57 mm, respectively (Figure 18). This trend was significant for *N. lutrensis* (p = 0.04225; a = -4.60048, b = 0.11056, r = 0.38639) but not for *N. venustus*.

Incidence of *N. lutrensis* from the Little Blanco River infected with *Crassiphiala bulboglossa* rose linearly from approximately 34 mm of standard host length and leveled off at approximately 55 percent beyond 50 mm (Figure 19). This trend exhibited a highly significant regression coefficient (p = 0.00307; a = -15.68800, b = 0.93217, r = 0.42709). Intensity of *Crassiphiala bulboglossa* infection also increased significantly with host length

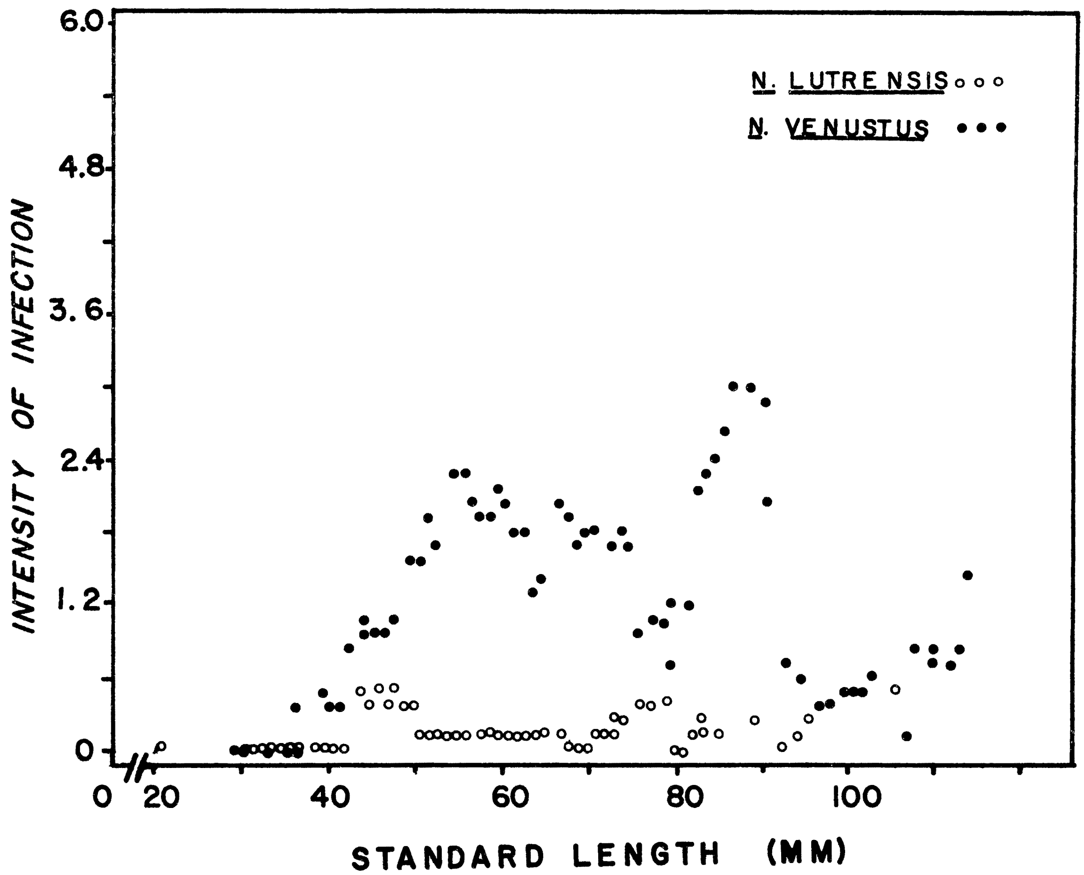

Figure 16. Intensity of *Posthodiplostomum minimum* infection in *N. venustus* and *N. lutrensis* plotted against standard body length using a 9 mm moving average.

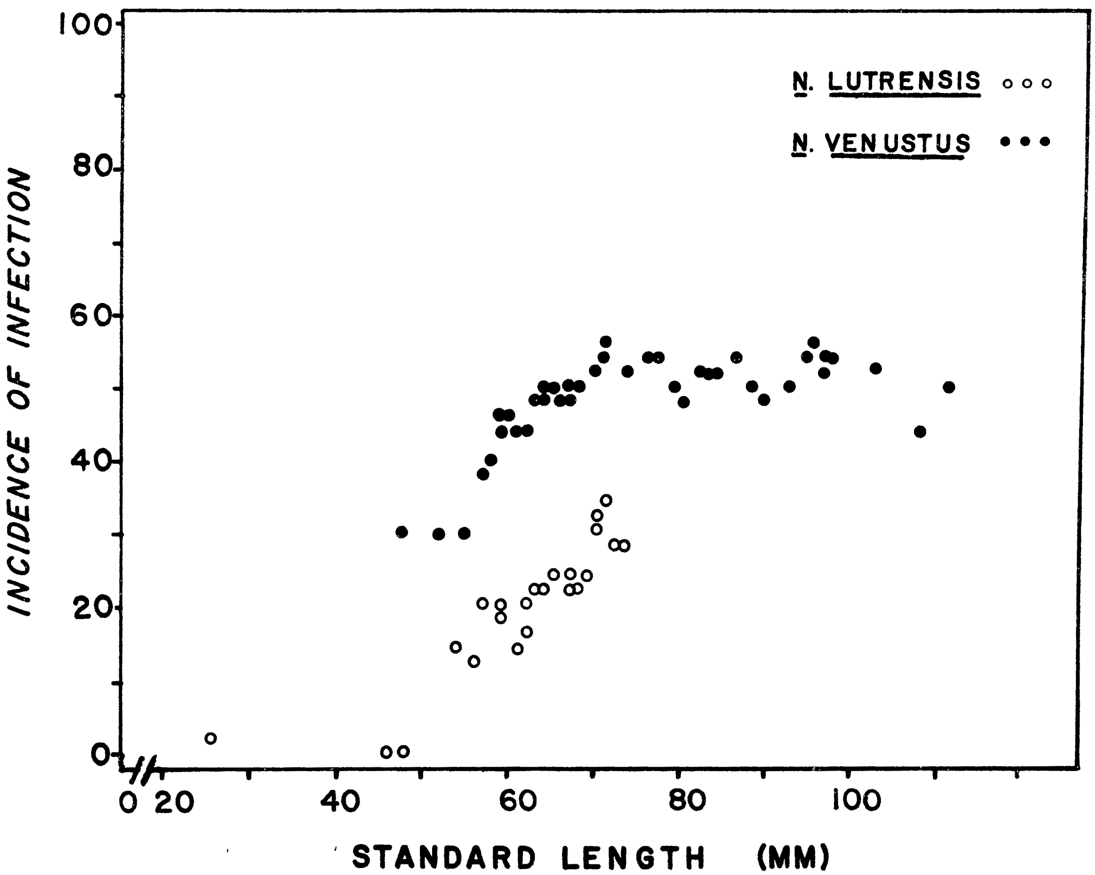

Figure 17. Incidence of *Plagioporus* "A" infection in *N. venustus* and *N. lutrensis* from the San Marcos River plotted against standard body length using a 15 mm moving average.

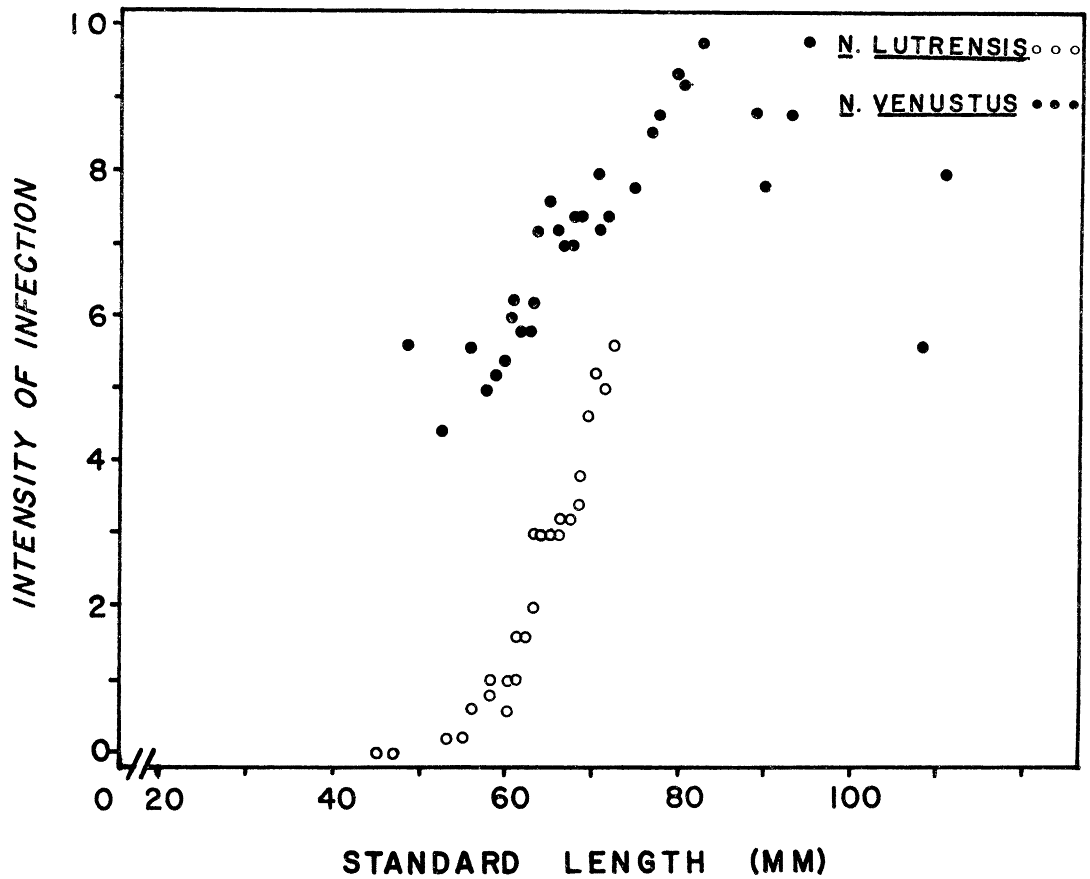

Figure 18. Intensity of *Plagioporus* "A" infection in *N. venustus* and *N. lutrensis* from the San Marcos River plotted against standard body length using a 15 mm moving average.

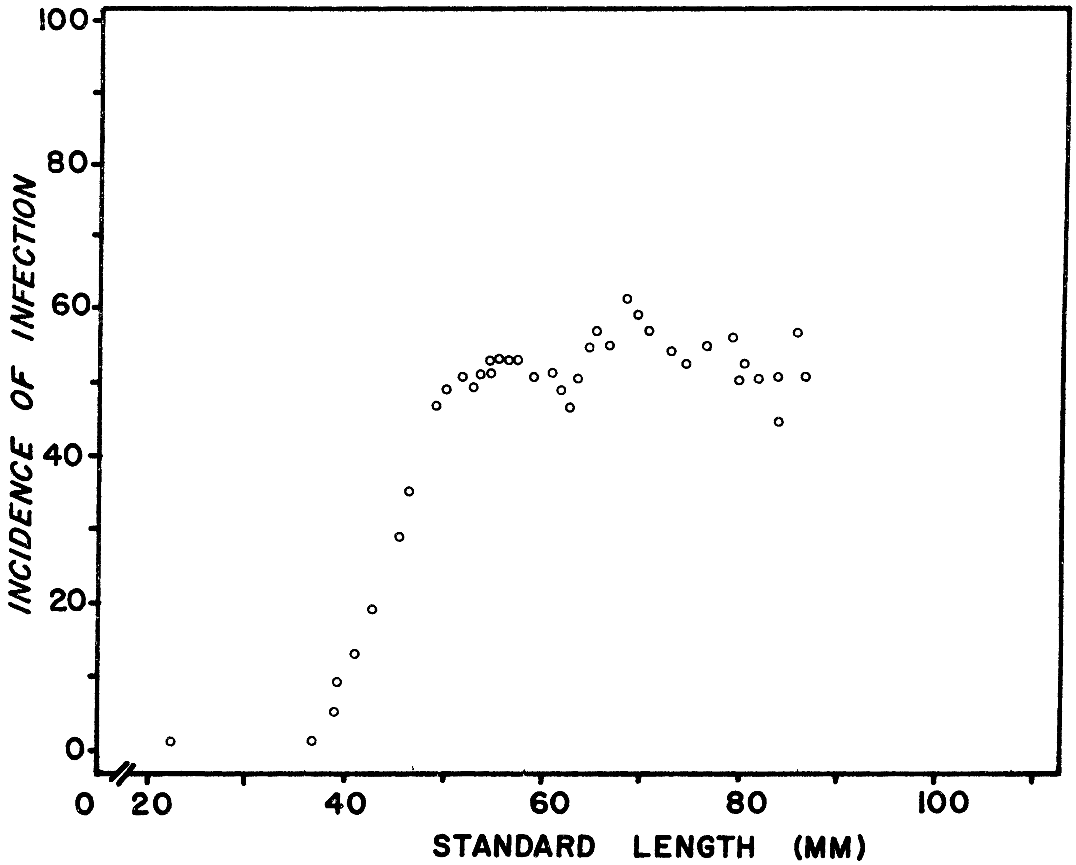

Figure 19. Incidence of *Crassiphiala bulboglossa* infection in *N. lutrensis* from the Little Blanco River plotted against standard body length using a 9 mm moving average.

(Figure 20) (p = 0.04966; a = -30.16811, b = 0.77535, r = 0.29112). A plot of worms per infected host against standard length revealed that the vast majority of worms were found in four fish present in the longer length classes (Figure 21), indicating a highly overdispersed distribution.

Infection of both fish species with *Rhabdochona cascadilla* began at approximately 39 mm of host length (Figure 22). However, while incidence continued to rise in *N. lutrensis*, it leveled off to a relatively constant ten-percent infection in *N. venustus*. The rise in incidence of helminth infection in *N. lutrensis* was very highly significant (p = 0.00004; a = -24.67187, b = 0.67918, r = 0.49838). Intensity of helminth infection in *N. lutrensis* rose with a very significant linear tendency (p = 0.00045; a = -3.05386, b = 0.07163, r = 0.43564) (Figure 23). Intensity of *R. cascadilla* infection in *N. venustus* exhibited no detectable relationship to host length.

Comparisons of the Numbers of Helminth Species From *N. venustus* and *N. lutrensis*

Numbers of helminth species rose in both host fish after a length of approximately 40 mm had been reached (Figure 24) The trend, however, for *N. venustus*, suggested an arch occurring over the middle length classes (approximately 34 mm to 93 mm). This arch was not immediately apparent for *N. lutrensis*, probably because of

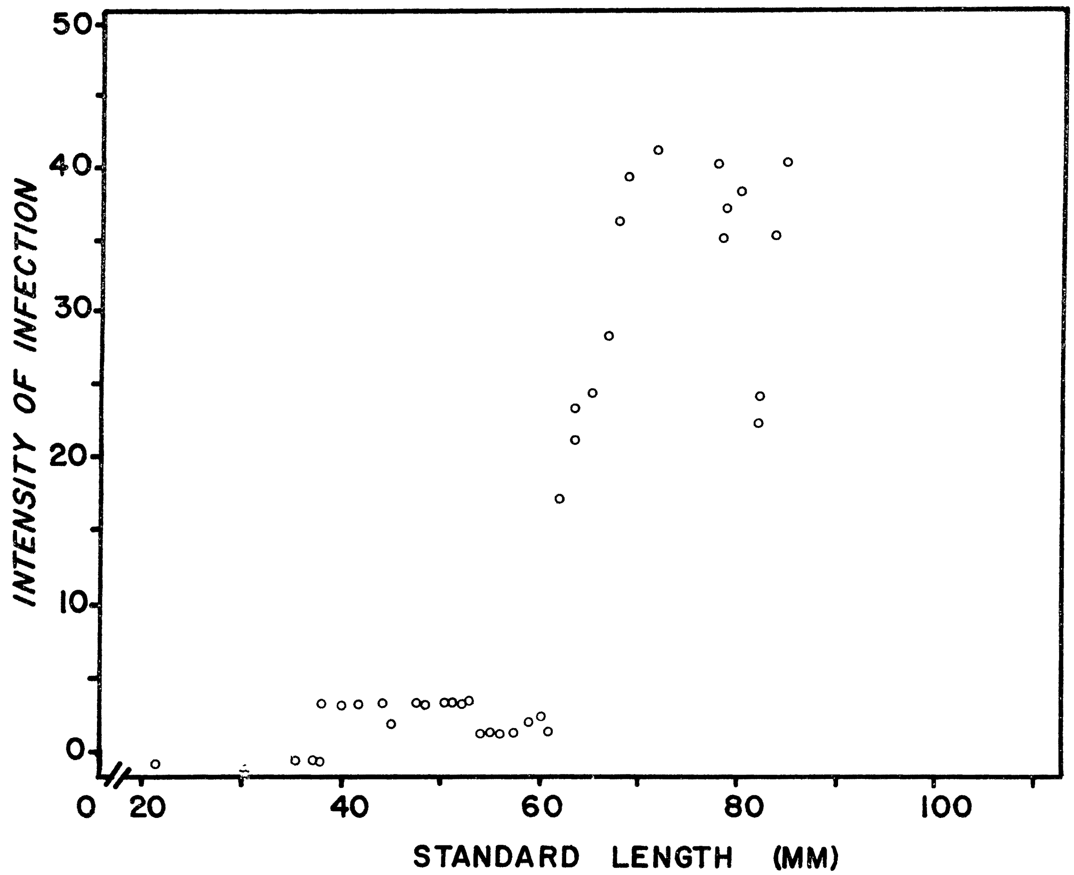

Figure 20. Intensity of *Crassiphiala bulboglossa* infection in *N. lutrensis* from the Little Blanco River plotted against standard body length using a 9 mm moving average.

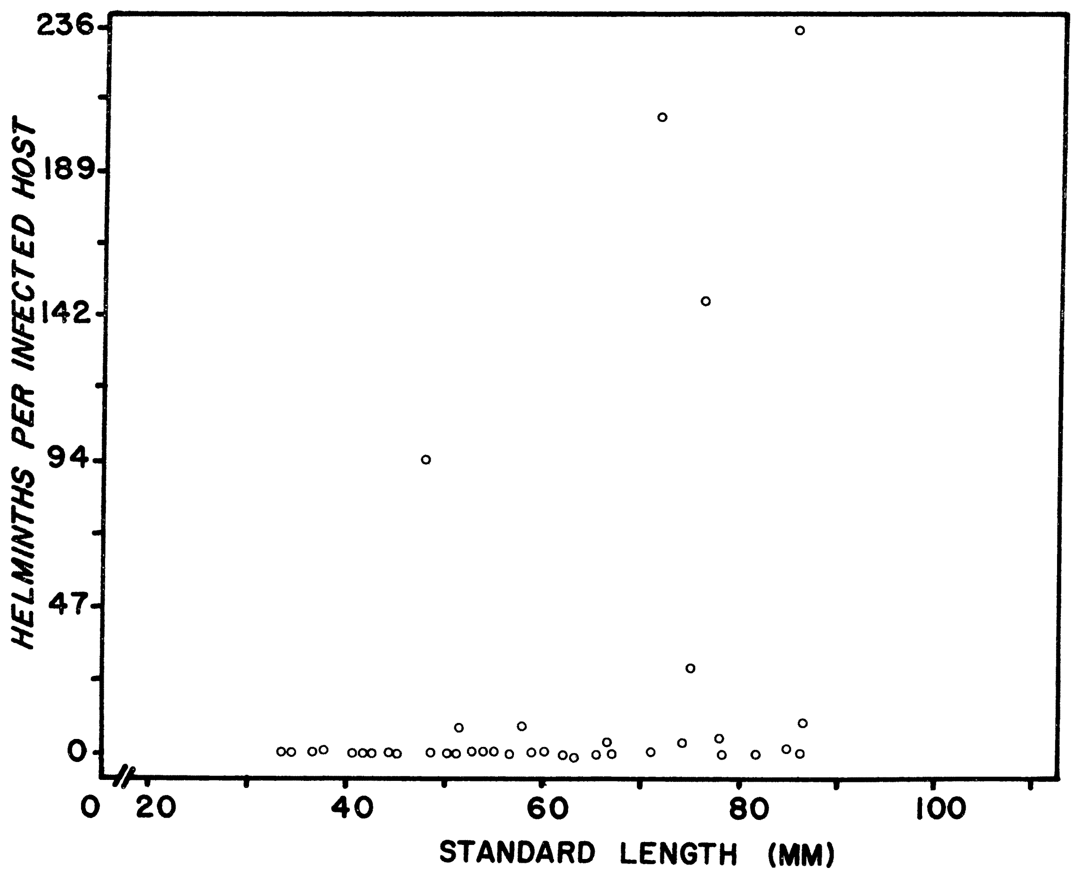

Figure 21. Number of *Crassiphiala bulboglossa* per infected *N. lutrensis* from the Little Blanco River plotted against standard body length.

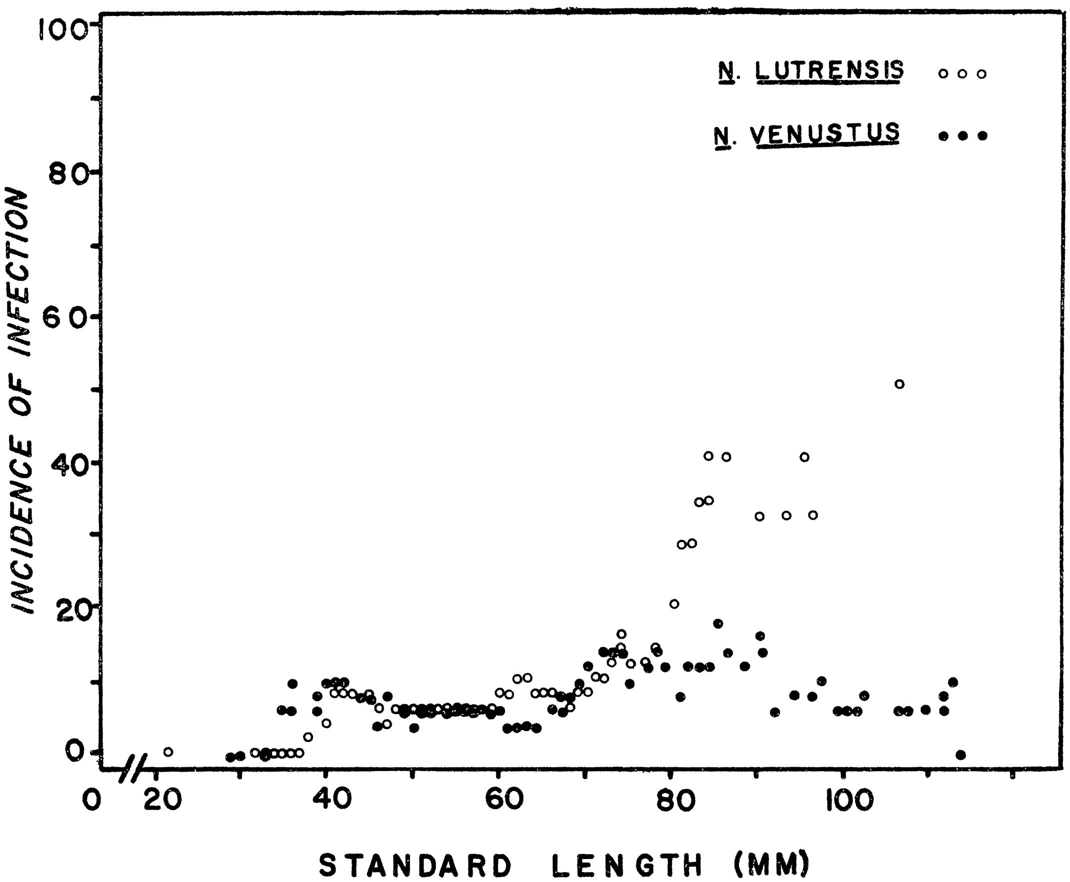

Figure 22. Incidence of *Rhabdochona cascadilla* infection in *N. venustus* and *N. lutrensis* plotted against standard body length using a 9 mm moving average.

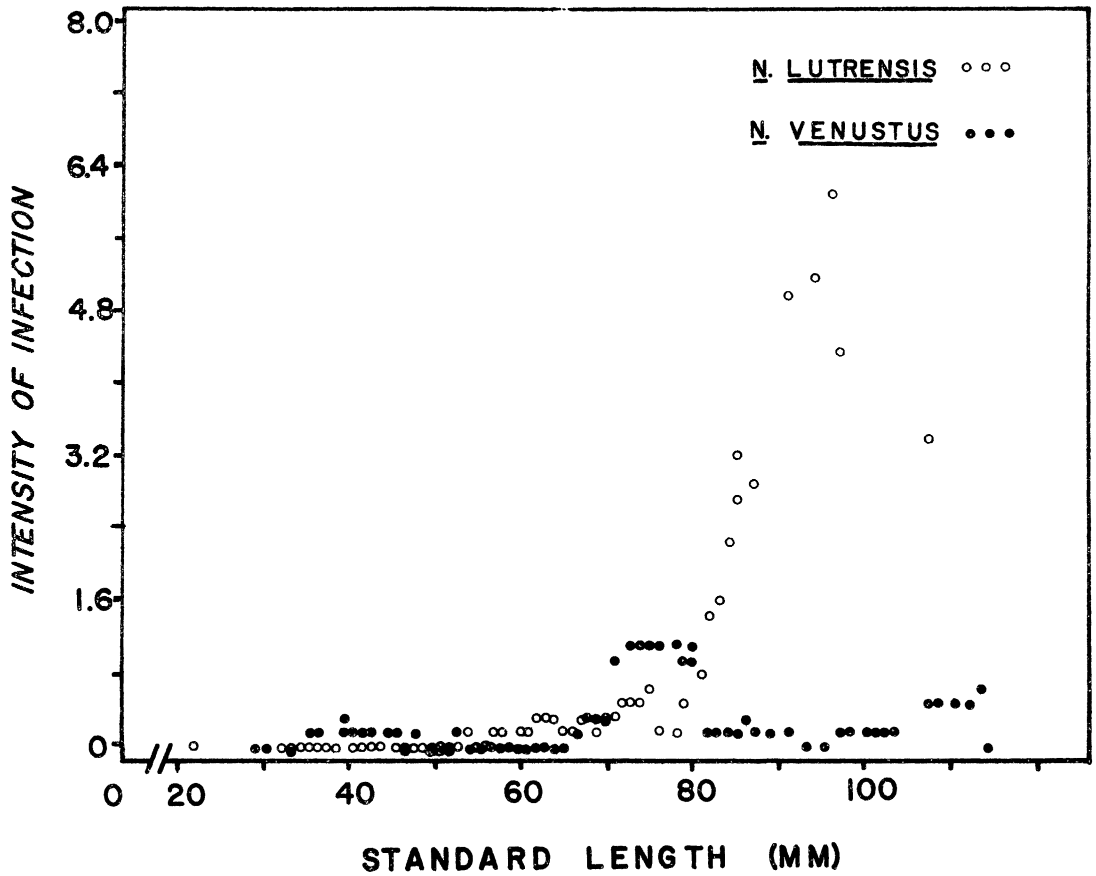

Figure 23. Intensity of *Rhabdochona cascadilla* infection in *N. venustus* and *N. lutrensis* plotted against standard body length using a 9 mm moving average.

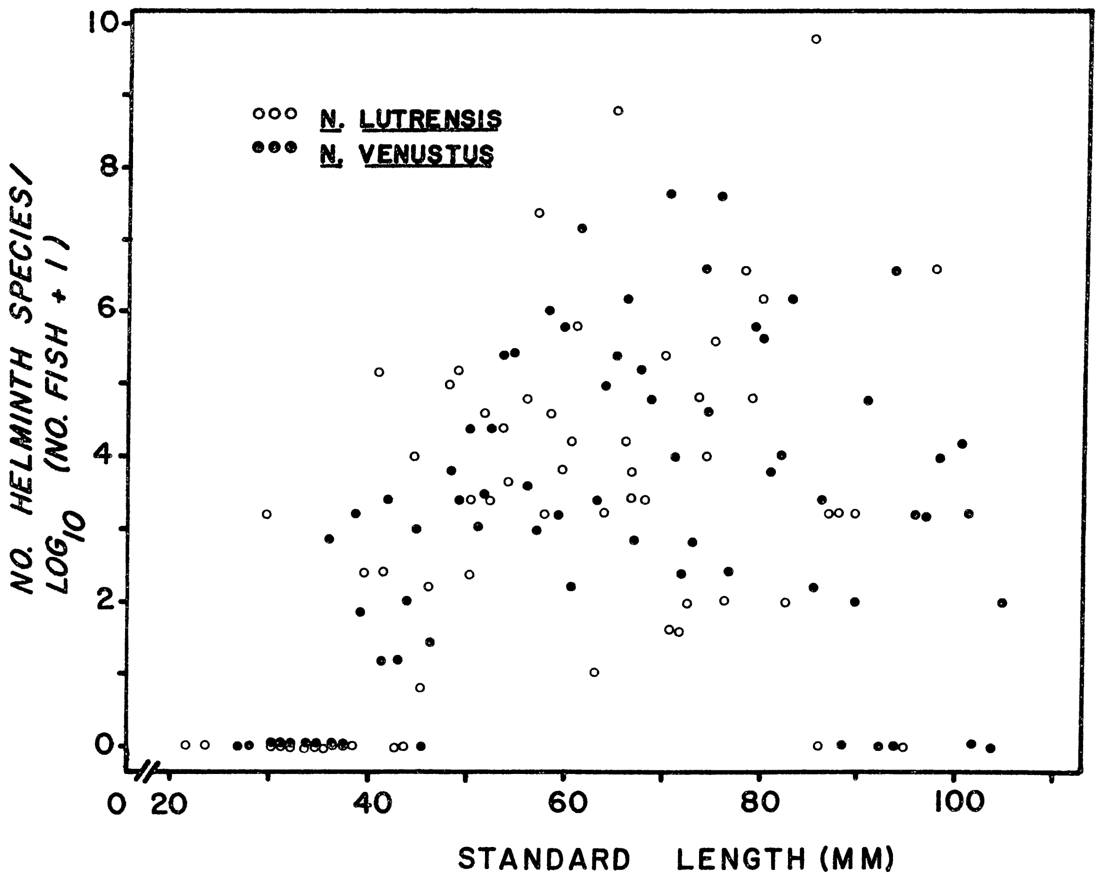

Figure 24. Number of helminth species divided by the $\log_{10}$ (No. hosts + 1) in *N. venustus* and *N. lutrensis* plotted against standard body length.

insufficient representation of this fish in longer length classes.

Comparisons of the Helminth Communities of *N. venustus* and *N. lutrensis*

Since *N. venustus* and *N. lutrensis* were found in close proximity of each other in the Blanco, Guadalupe, and San Marcos Rivers, differences between their helminth communities could be assumed due only to differences between the two host species.

Blanco River

Equal numbers of each host species were collected from the Blanco River over the twelve-month study period. The number of infected fish, number of helminths collected, and helminth diversity for each host fish are plotted against month in Figure 25.

There were more *N. venustus* infected than *N. lutrensis* in all months except September and October. The number of helminths collected for each species in each month followed a similar trend, with *N. venustus* sustaining the higher intensity of infection in all but two months. Helminth diversity was higher in *N. venustus* than *N. lutrensis* in all but four months of the study period. *Notropis venustus* maintained the generally higher number of helminth species over the study period (Figure 26).

Posthodiplostomum minimum and *Rhabdochona cascadilla* were the most abundant helminth species in both host fishes

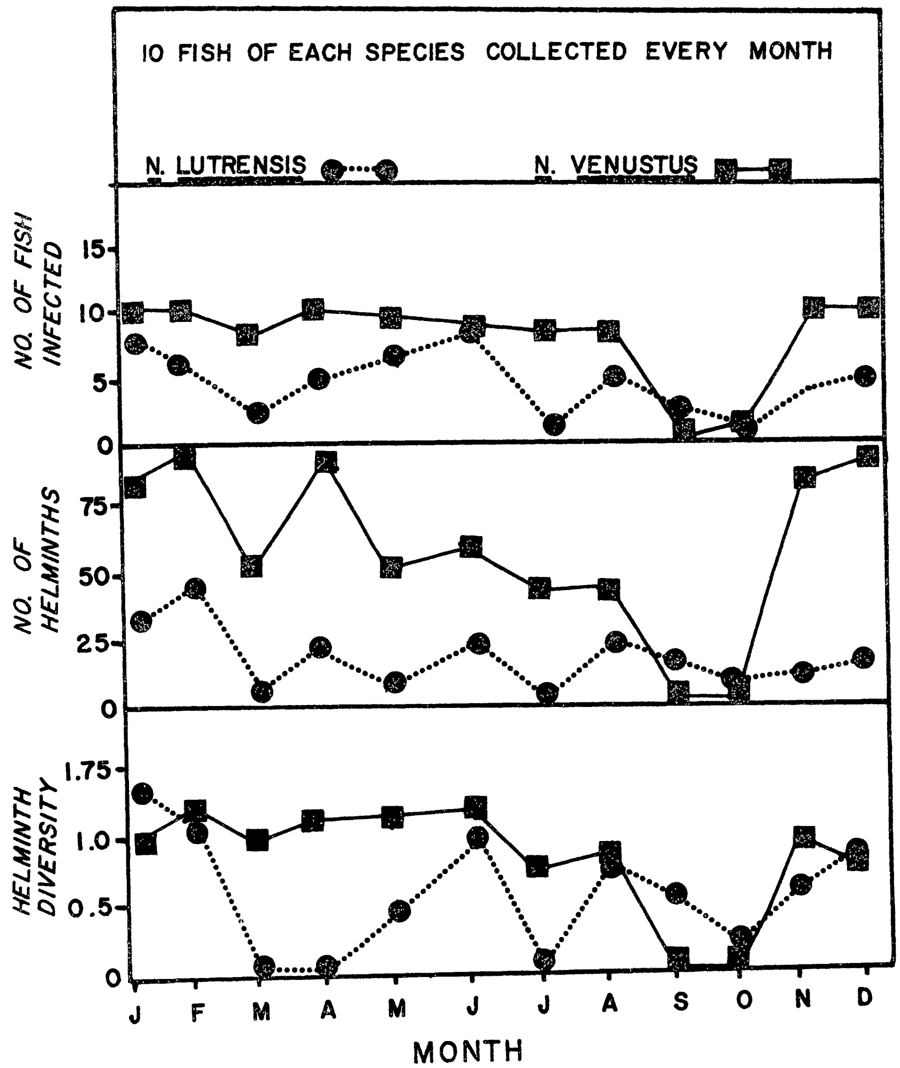

Figure 25. Monthly comparisons between Blanco River *N. venustus* and *N. lutrensis* regarding the number of fish infected, number of helminths and helminth diversity.

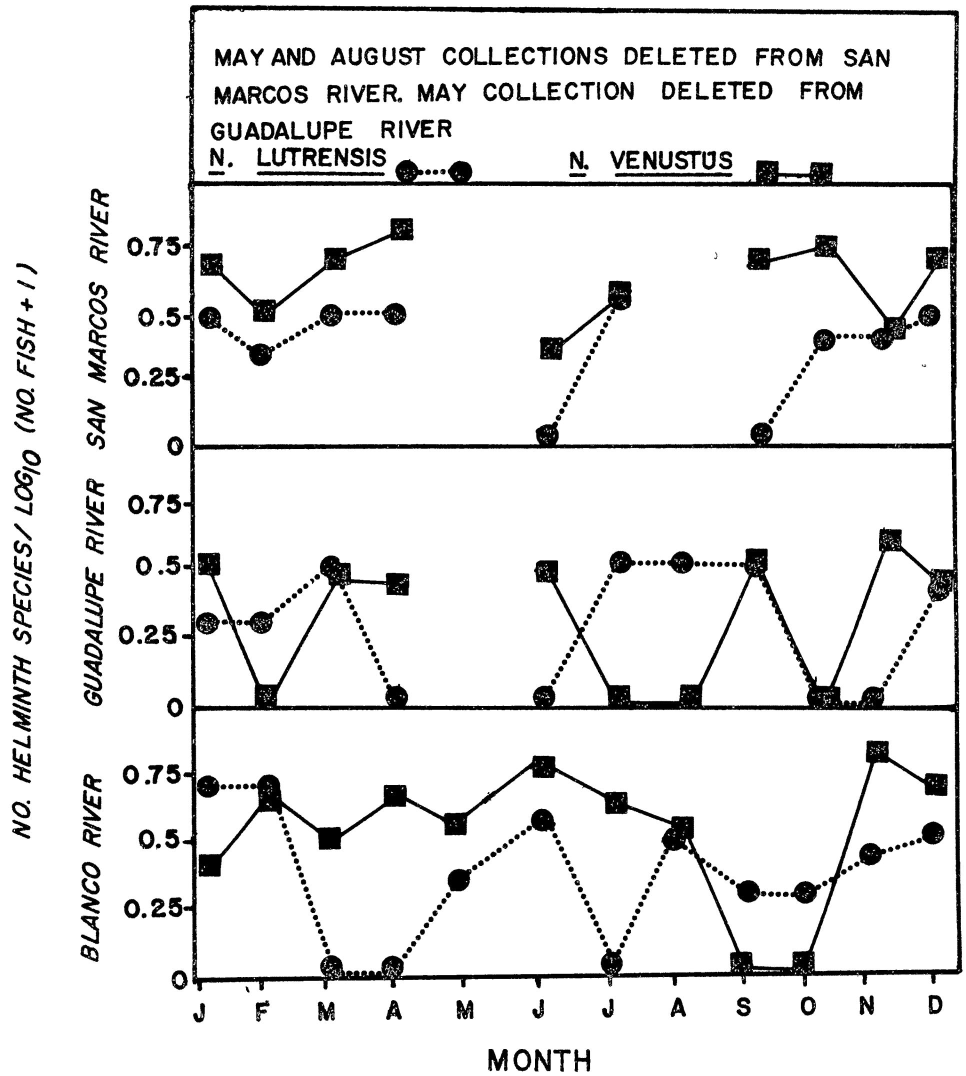

Figure 26. Monthly comparisons of the $\log_{10}$ of the number of helminth species which infect *N. venustus* and *N. lutrensis* from the San Marcos, Guadalupe, and Blanco rivers.

from the Blanco River (Table 6). *Notropis venustus* was more heavily infected than *N. lutrensis* by all but three of the helminths encountered in this habitat.

Guadalupe River

The number of fish infected, number of helminths collected, and helminth diversity for each month for each host species fluctuated greatly over the study period (Figure 27). These fluctuations suggest that no difference in helminth infections between the two host species exists at this station. The number of helminth species infecting the two fish hosts each month also fluctuated (Figure 26), again suggesting little difference between the two fish hosts.

Low intensity of infection was found in both host species at this station (Table 6).

San Marcos River

More *N. venustus* were infected than *N. lutrensis* in all months of collection (Figure 28). *Notropis venustus* maintained the higher intensity of infection in all months except June. Helminth diversity was higher in *N. venustus* than *N. lutrensis* in all but three months. *Notropis venustus* also maintained the higher number of helminth species in all months except July (Figure 26). Higher overall helminth infection levels in *N. venustus* than *N. lutrensis* may be due to *N. venustus* generally being the larger of the two fish at this habitat.

TABLE 6.--Number of helminths of each species collected from *N. venustus* and *N. lutrensis* from the Blanco, Guadalupe, and San Marcos Rivers. (*Notropis lutrensis* is represented by the number on the left and *N. venustus* is represented by the number on the right)

Parasite	Blanco River	Guadalupe River	San Marcos River
Crassiphiala bulboglossa	0/26		
Gyrodactylus sp.		1/0	2/0
Diplostomulum scheuringi	0/1		
Macroderoides spiniferus	2/5	22/37	6/11
Opisthorchis sp.		0/1	0/10
Neascus "B"	0/1		0/1
Plagioporus "A"			308/866
Plagioporus "B"	5/17		0/2
Posthodiplostomum minimum	81/478	6/20	5/88
Rhipidocotyle papillosum	20/0	16/8	14/4
Tetracotyle sp.	1/5		
Trematode B			0/1

TABLE 6.--Continued

Parasite	Blanco River	Guadalupe River	San Marcos River
Trematode C	2/1		
Proteocephalus "A"	17/11	6/3	10/23
Proteocephalus "B"			6/8
Piscicola sp.		1/0	
Camallanus sp.			0/3
Contracaecum sp.			0/1
Cystidicola sp.	2/4		0/4
Rhabdochona cascadilla	48/141	5/2	2/2
Spiroxys sp.	4/7	0/1	1/1

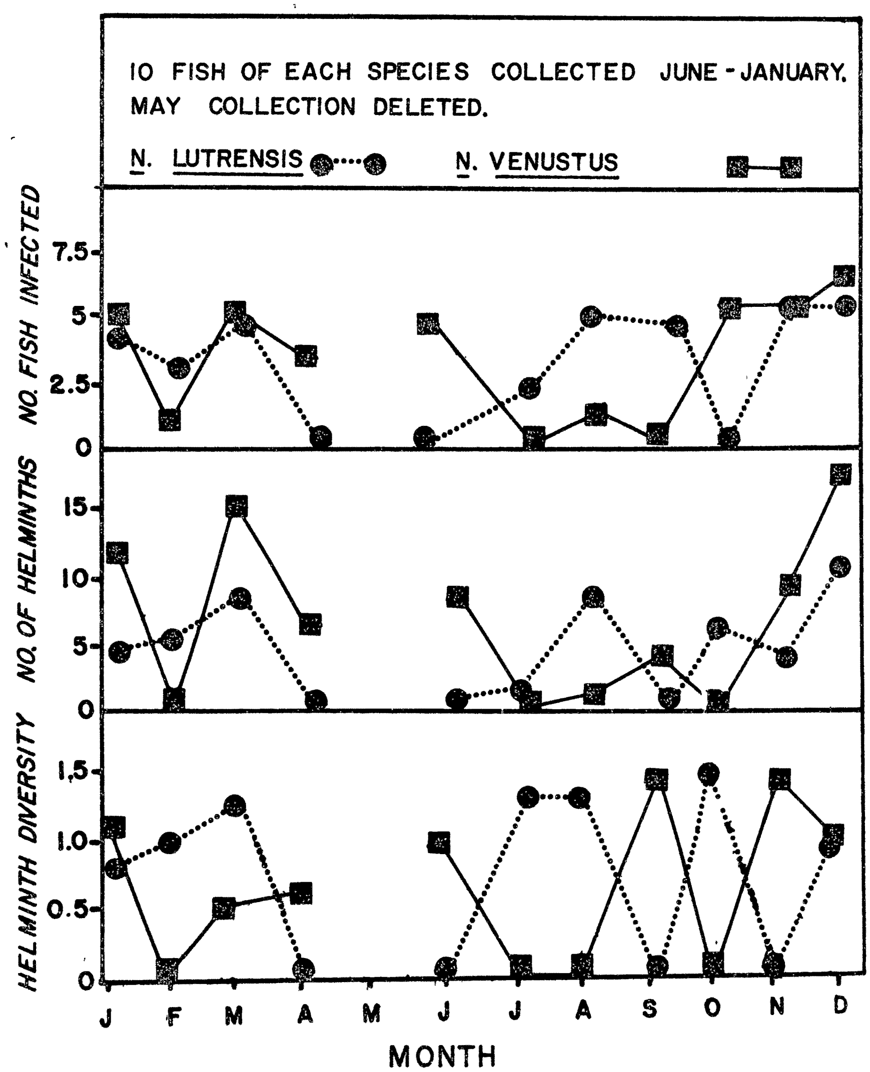

Figure 27. Monthly comparisons between Guadalupe River *N. venustus* and *N. lutrensis* regarding the number of fish infected, number of helminths, and helminth diversity.

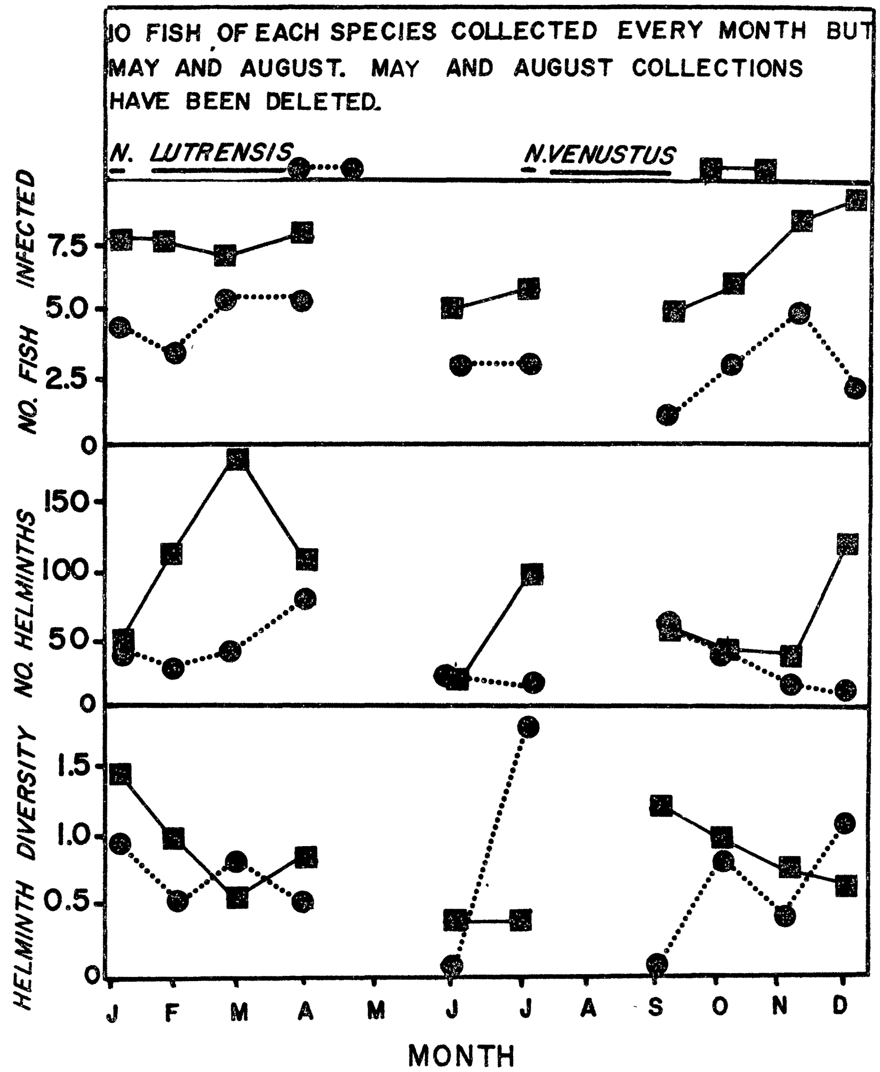

Figure 28. Monthly comparisons between San Marcos River *N. venustus* and *N. lutrensis* regarding the number of fish infected, number of helminths, and helminth diversity.

Notropis venustus sustained the higher intensity of infection with all but four helminth species (Table 6).

CHAPTER IV

DISCUSSION

Factors Influencing the Helminth Fauna of *N. venustus* and *N. lutrensis*

Movement of *N. venustus* and *N. lutrensis* in Their Habitat

Due to the movement of fish, absolute homogeneity of the monthly samples of fish was not possible. Those captured from Canyon Reservoir tended to swim out to deeper waters during the extreme hot or cold periods of the year. Flooding conditions also tended to upset the location of the host species, especially in the Blanco and Guadalupe Rivers, causing displacement and mixing of fish populations. These conditions could partially account for the diverse parasite communities found in the Blanco River. However, specific migration patterns in either species are apparently unknown. The movement of the fish in their habitat could also cause them to acquire a large variety of helminths due to greater exposure to a more diverse population of intermediate hosts.

Fish taken from Thompson's Island in the San Marcos River, were observed to move readily around the small island over the study period. These fish also contained a diverse parasite fauna. Dislocation of fish species due to host migration and flooding, should be taken into consideration whenever a study of this type is undertaken, as mixing host populations could possibly effect the helminth fauna.

Host Population Density

Cheng (1964) states that the abundance of the host influences the composition and particularly the abundance of the parasite fauna, for the latter is directly dependent on the former.

Data from this study suggest that incidence and intensity of helminth infection are particularly high in the San Marcos and Little Blanco Rivers. At these locations, the geography of the collection stations concentrated the number of potential hosts per unit volume of habitat, and thus increased the probability of infections. Additionally, the geography of the areas restricted use by birds to a few accessable areas, therefore resulting in a concentration of fecal material. Large numbers of both host species were also found in the Blanco and Guadalupe Rivers, but these much more spacious habitats allowed for increased area between individual fish and volumetric dilution of infective stages of parasites. This could partially account for lower intensity of infection per fish at these stations.

Habitat of Host

Knowing the affinity of helminth species for particular types of ecosystems may be of value for two reasons. First, knowing the habitat requirements of various helminths may possibly assist in predicting the helminth fauna of fish which have not been examined for parasites. Thus, a habitat which could not support specific intermediate or definitive hosts, would not contain fish with helminths which utilized those hosts. Second, knowledge of the habitat specificity of a helminth species may be of value in efforts to control the parasite. Each habitat, therefore, is made up of certain characteristics which interact to help determine the helminth fauna of the host fish.

It was noted that some of the more common helminth species exhibited a certain degree of habitat specificity (Figure 3). *Plagioporus* "A" was found only in San Marcos River fishes. Low infections of *Plagioporus* "B" were present in fish from the Blanco and Little Blanco Rivers. *Goniobasis*, the intermediate host of other species in this genus (Hoffman, 1967), has only been reported from the San Marcos River among the three *Plagioporus* habitats. The presence of *Plagioporus* "B" in the two *Goniobasis* deficient habitats suggests that this trematode species may be utilizing some other mollusk species. It is worth noting that one *N. venustus* among the 114 fish and 866 specimens of *Plagioporus* "A" removed from the San Marcos River, contained two specimens of *Plagioporus* "B".

Only one specimen of *Diplostomulum scheuringi* was collected. This worm was found in *N. venustus* from the Blanco River and is thought to represent a chance infection.

Opisthorchis sp. was found in very low numbers in fishes from the San Marcos and Little Blanco Rivers. Only one worm was taken from Guadalupe River fish. *Amnicola*, the first intermediate host (Hoffman, 1967), is abundant in the San Marcos River and present in the Little Blanco and Guadalupe Rivers. Low numbers of this parasite may indicate a low density of the necessary definitive hosts in this area.

Rhipidocotyle papillosum was found in fishes from the Guadalupe, San Marcos, and Blanco Rivers. Pelecypods acting as the first intermediate host for this bucephalid trematode (Hoffman, 1967) are found abundantly in the San Marcos and Guadalupe Rivers. However, the necessary mollusks may be present in small populations in the Blanco River, since low incidence of *R. papillosum* infection was present in this habitat. Davis and Huffman (1975) reported *Rhipidocotyle papillosum* in *Gambusia affinis* from the slough area of Spring Lake and the adjacent head waters of the San Marcos River.

Posthodiplostomum minimum was found in all habitats and in both species of fish, but was most abundant in the

Blanco River. This common strigeoid uses *Physa* sp. as the first intermediate host (Hoffman, 1958). Since *Physa* is most common in the San Marcos River, it would seem higher infections should be located there instead of the Blanco River. Analysis of the habitat, however, shows that the definitive host, the heron or kingfisher, would have a difficult time entering or diving in the rapid, shallow waters surrounding Thompson's Island on the San Marcos River. The steep river banks, which were covered with dense shading vegetation, hindered access by the definitive hosts. The Blanco River, although swift, had gently sloping banks on at least one side and many shallow back-pool areas easily accessible by wading birds. The Guadalupe River flowed extremely fast between steep banks at the collection station and this probably limited its use by the definitive host. The Little Blanco River was shaded with tree limbs and vegetation and did not present a favorable habitat for herons, although it would seem that kingfishers would frequent the overhanging limbs.

The cestode, *Proteocephalus* "A" was found in small populations in both species of fish in all habitats except the Little Blanco River. The Little Blanco River is generally shallow in the vicinity of the collection station and the large fish hosts that *Proteocephalus* requires to complete its life cycle did not occur there. The San Marcos River, where *Proteocephalus* "A" occurred in greatest numbers, supports a diverse community of these larger fishes. Davis and Huffman (1975) found heavy *Proteocephalus* infection in the Spring Lake slough adjacent to the San Marcos River and also in the Blanco River.

The most abundant nematode, *Rhabdochona cascadilla*, was found in every habitat except Canyon Reservoir. Conditions at Canyon Reservoir were not favorable to the growth of the mayfly intermediate host (Hoffman, 1967), since the lake was very deep and contained little vegetation. The Little Blanco River, however, favored the development of dense populations of ephemeropteran nymphs. The shallowness of this stream possibly increased the chance of encounter between definitive and intermediate hosts. The largest numbers of these worms were found in fish from this collection station (Figure 3). The worms were also abundant in fishes from the Blanco River, a similar ecosystem.

Season of Collection

Overall Helminth Infection

The breeding season for *N. lutrensis* begins in March and may continue through the month of August (Laser and Carlander, 1971). Fry would be abundant in the fall and would reach maturity over the winter months. This study reveals that relatively high incidence and intensity of helminth infection occurred during the winter months when adult fish were common (Figures 4 and 5). These fish would have had time to accumulate helminths over the year. The trend was the same for *N. venustus* (Figures 4 and 5). It has been shown by several workers that many fish accumulate parasites as they age (Dogiel et al, 1958; Lawrence and Murphy, 1967; McDaniel and Bailey, 1974; Spall and Summerfelt, 1970). Lowest intensities were found in late summer and early fall, after the spawning season of the hosts. Low intensities at this time may be due to the death of overly stressed adults and/or dilution by young fish.

Incidence and Intensity of *Posthodiplostomum minimum* Infection

Posthodiplostomum minimum infection peaked in incidence and intensity in both host fish during the winter months, with the lowest infection levels occurring over the summer months (Figures 6 and 7). Davis and Huffman (1975) reported that peak abundance of *P. minimum* in *Gambusia affinis* from the San Marcos River occurred in February and McDaniel and Bailey (1974) reported peak *P. minimum* abundance in sunfish in Oklahoma in January.

The following hypothesis is presented as an explanation for the winter peaks: (1) the definitive host, the heron, arrives in March and begins releasing trematode eggs in its feces; (2) snails consequently become infected and cercariae probably begin emerging four to six weeks later; (3) the herons continue to provide a source of infection for the snails through the month of October, after which the birds depart; (4) metacercarial infections of the fish would probably peak shortly thereafter.

Hoffman (1958) stated that *P. minimum* cercariae can be released and be infective to fish in a temperature range of 18°C to 28°C. Thus, winter water temperatures in the south, falling within this range, could also account for the abundance of metacercariae during those months. Since *Physa*, the intermediate host, is common throughout the year, a survey of trematode dynamics in the snail population would be necessary before definite conclusions could be reached regarding the observed dynamics in the fish hosts.

Size of Host

Incidence and Intensity of Overall Infection

Host size may be a major factor in determining incidence and intensity of helminth infection in *N. venustus* and *N. lutrensis*, since both variables rose significantly with increasing host body length. *Notropis venustus*, the larger of the two species studied, sustained the generally higher overall incidence and intensity of infection.

Three factors which may contribute to the increasing probability that a fish will acquire a helminth infection as it ages and grows are as follows: first, the period of exposure to infective helminths; second, the enlarging body surface of a growing fish; and third, the increased consumption of potentially infected intermediate hosts.

Incidence and Intensity of *Posthodiplostomum minimum* Infection in *N. venustus*

The arch seen in Figures 15 and 16 formed over the middle length classes of *N. venustus* (40 mm to 84 mm) by incidence and intensity of *P. minimum* infection, raises some interesting points for speculation. This same phenomenon was also noted by Davis and Huffman (1975) in *Gambusia affinis* from the San Marcos River. In that case, however, the arch occurred over 27 mm (20 mm and 35 mm) which was near the middle length class for *G. affinis*, a much smaller fish. The fact that this same trend should occur over such different length classes in *Notropis* suggests that this arch over the middle length classes is a function of host age and independent of absolute length.

The observed decreases in incidence and intensity of *P. minimum* infection in *N. venustus* after the middle length classes have been reached may result from two factors. First, the trematode's cercariae may not be able to penetrate the tough epidermal layers and thickened scales of older fish. Second, the cercariae may be able to penetrate the body wall, but may be unable to become established in the host once it has entered. The inability of the parasite to become established may depend on normal physiological changes in the maturing fish, or acquired immunity, which could be stimulated by threshold infection in the younger and middle age classes and then result in decreasing infections as immunity develops with the age of the fish.

CHAPTER V

SUMMARY

An ecological survey was conducted to determine the helminth fauna of *N. venustus* and *N. lutrensis* in the area of San Marcos, Texas. Twenty species of helminths were collected from *N. venustus* and 19 from *N. lutrensis* all of which are new host records.

Posthodiplostomum minimum, *Crassiphiala bulboglossa* and *Rhabdochona cascadilla* were the helminths collected in greatest abundance from the fish hosts.

Notropis venustus generally maintained the higher incidence and intensity of infection than *N. lutrensis*. These differences were attributed to the larger size of *N. venustus*, which might effectively increase the chances of infective intermediate host consumption and/or the possibility of cercarial penetration of the host's body. Overall incidence and intensity of infection were found to exhibit highly significant linear trends over increasing standard host length.

Incidence and intensity of helminth infection plotted against season was higher in *N. venustus* than *N. lutrensis* where the two fish existed together. High intensities of infection during the winter months were

attributed to definitive host migration patterns and the higher average age of fish collected at that time, most of which had had a year to accumulate parasite infections.

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