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CHANGE IN GENETICS STUDENTS' UNDERSTANDING OF THE NATURE OF SCIENCE: EVALUATION AND PREDICTION

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ABSTRACT

The purpose of this study was to evaluate the effectiveness of a college-level genetics course in developing student understanding of the nature of science and to develop a predictive model for possible use in situations where direct measurement of student understanding of the nature of science is impossible or undesirable.

Results of this study support the following conclusions: 1) a suitably designed genetics course can effectively promote student understanding of the nature of science; 2) predictive equations can be developed which permit relatively accurate estimates of change in student understanding of the nature of science; 3) students are more likely to make significant gains in understanding the nature of science when they perceive a course to be consistent with the philosophy and rationale of BSCS curricula, are female, are *not* concurrently enrolled in two or more science courses, and have *not* completed a large number of college-level science courses.

INTRODUCTION

Science courses which reflect the "nature of science" include those which provide an opportunity for students to explore science actively as a *process of inquiry* as well as to understand it as a body of accumulated, but not infallible, knowledge. Furthermore, they provide ample opportunity for students to examine and reflect upon the philosophical assumptions and limitations which underlie the inquiry process.

Cary and Stauss (1970) have stated that "it is imperative that science courses at all levels of instruction, *including the college level* (italics this author's), reflect the nature of science." In recent years, journals such as the *Science Teacher* and the *Journal of College Science Teaching* have carried numerous articles advocating greater emphasis on objectives pertaining to the nature of science. Despite this, few attempts have been made to evaluate courses in terms of the actual degree to which these objectives are being attained.

The few evaluations which have been reported indicate that a wide variety of experiences in science (Welch & Walberg, 1968), the history of science (Lavach, 1968), science education (Cary & Stauss, 1968; Carey & Stauss, 1970; Lucy, 1974; Billeh & Hasan, 1975), and philosophy (Kimball, 1968) can produce significant increases in pupil and/or teacher understanding of the nature of science.

PURPOSE

The purposes of this study were (1) to evaluate the effectiveness of an introductory genetics course in developing student understanding of the nature of science and (2) to develop a predictive model for possible use in estimating changes in student understanding of the nature of science.

METHOD

Subjects participating in this study included individuals enrolled in two sections (N=34) of introductory genetics at Middle Tennessee State University during the spring semester, 1976. All subjects were science majors, most of whom plan careers in either teaching or a biomedical field. The course was developed and taught by the author. Throughout the course an attempt was made to depict genetics as an on-going, self-correcting process of inquiry.

Several techniques were employed to promote student understanding of the nature of science. These included: (1) investigative laboratory activities, (2) invitations to inquiry, (3) assigned readings pertaining to the philosophical assumptions and limitations of scientific inquiry as a method of establishing truth, (4) lectures involving the historical treatment of contemporary genetic concepts, and (5) group discussions involving societal problems which result from the application of genetic knowledge.

The *Biology Classroom Activities Checklist* (BCAC) was administered as a posttest in an attempt to measure the degree to which subjects perceived the course as reflecting the philosophy and rationale of BSCS curricula. This instrument was specifically designed for this purpose and has a reported reliability of .96 (Mayer, 1974).

A pretest/posttest procedure was employed to evaluate the course in terms of its effectiveness in promoting student growth in understanding the nature of science. The *Wisconsin Inventory of Scientific Processes* (WISP) was chosen as the measure of understanding of the nature of science. This instrument has a maximum score of 93 and a reported reliability of .82 (Mayer, 1974). Pretest/posttest data were analyzed by means of a repeated measures analysis of variance to determine if the posttest mean was significantly greater than the pretest mean.

Six predictor variables were selected and used in developing a series of linear regression equations for predicting the criterion of change in student understanding of the nature of science. The variables used are listed below.

Y = *WISP Gain Score.* (For purposes of data analysis, Y was calculated by subtracting each subject's pretest score from his posttest score, thereby obtaining a value designated Y^1. This value was then substituted into the equation $Y = Y^1 + 10$ to obtain a Y value for each subject. This transformation of raw scores made it possible to avoid the use of signed numbers.)

X_1= *Sex of Subjects.* (For purposes of data analysis, male subjects were assigned a score of one while females were assigned a score of two.)

X_2= *American College Test (ACT) Natural Science Subtest Score.*

X_3= *Number of College-Level Science Courses Completed.*

X_4= *BCAC Score.* (100 percent maximum)

X_5= *Final Course Average.* (100 percent maximum)

X_6= *Concurrent Enrollment in Science Courses Other Than Genetics.* (For purposes of data analysis, subjects not enrolled in science courses other than genetics were assigned a score of one while subjects concurrently enrolled in one or more science courses other than genetics were assigned a score of two.)

Data pertaining to variables X_1, X_3, and X_6 were collected from information supplied by students at the beginning of the course. Information supplied by students at the beginning of the course. Information related to the other variables was obtained at the end of the course.

RESULTS AND DISCUSSION

Evaluation

Data collected from the posttests administration of the BCAC instrument gave a mean score of 66.51 with a standard deviation of 8.11. This mean was considerably higher than the mean reported (Mayer, 1974) for high school courses taught by non-BSCS teachers ($\bar{X}$=50.50; SD=5.90) and slightly higher than the mean for biology courses taught by experienced BSCS teachers ($\bar{X}$=65.70; SD=8.14). It was therefore interpreted as indicating that the course was taught in a manner consistent with the BSCS rationale and philosophy.

WISP pretest scores ranged from 54 to 78 (93 possible) with a mean of 66.24 and a standard deviation of 6.01. Posttest scores ranged from 55 to 79 with a mean of 69.09 and a standard deviation of 5.27. The repeated measures analysis of variance performed on the data indicated that the posttest mean was significantly greater than the pretest mean (F=10.22; P<.01). A summary of the repeated measures analysis is given in Table 1.

TABLE 1: *Summary of the repeated measures analysis of variance performed on WISP scores.*

Source of Variation	SS		df		MS	F
Between Subjects		1546.50		33		
Within Subjects		582.50		34		
Treatment	137.73		1		137.73	10.22*
Error	444.77		33		13.48	
Total		2129.00		67		

*p < .01

The significant pretest-to-posttest gain in WISP score probably indicates a significant gain in student understanding of the nature of science. It could be inferred that this gain was due to the effects of the genetics course. However, this inference must be made with caution since a control group was not used.

Prediction

Six linear regression equations of the general form $Y = b_0 + \Sigma b_i X_i$ were generated by computer. These equations included from one to six predictor variables. These variables were used to predict the criterion of WISP Gain Score (transformed). A summary of the means and standard deviations for the criterion and the various predictor variables is given in Table 2.

TABLE 2: *Summary of the means and standard deviations for the criterion and predictor variables.*

Variable	$\bar{X}$	SD
(Transformed) WISP Gain Score (Y)	12.85	5.28
Sex of Subject (X_1)	1.56	0.50
ACT Natural Science Subtest Score	26.21	9.88
Number of College-Level Science Courses Completed (X_3)	5.76	3.00
BCAC Score (X_4)	66.41	8.11
Final Course Average (X_5)	85.53	9.29
Concurrent Enrollment in Science Courses Other Than Genetics (X_6)	1.53	0.51

Product-moment correlations between the criterion (Y) and the predictor variables are given in Table 3. Inspection shows that significant correlation coefficients (.05 level) ranged from −.39 to .45.

The −.39 correlation between variable X_6 and the

TABLE 3: *Product-moment correlation matrix for the predictor variables and criterion.*

Variable	Y	X_1	X_2	X_3	X_4	X_5	X_6
Y	1.00	0.43**	−0.06	−0.35*	0.45**	−0.04	−0.39*
X_1		1.00	−0.25	−0.07	0.05	−0.10	−0.36*
X_2			1.00	−0.03	0.27	0.18	0.26
X_4				1.00	−0.22	0.37*	0.36*
X_5					1.00	0.21	−0.00
X_6						1.00	0.18
							1.00

*p < .05
**p < .01

criterion indicates that subjects were more likely to make gains in understanding the nature of science when they were *not* concurrently enrolled in science courses other than genetics. The magnitude of this correlation coefficient was an anticipated result. However, the negative sign was something of a surprise. It implies that the various science courses involved actually may have impeded student progress in understanding the nature of science.

The .45 correlation between BCAC Score (X_4) and the criterion indicates that subjects who perceived the course as reflecting the rationale and philosophy of BSCS curricula were more likely to make gains in understanding the nature of science than subjects who did not.

At least three other coefficients given in Table 3 are noteworthy. The .43 correlation observed between variable X_1 (Sex of Subject) and the criterion indicates that female subjects made greater gains in understanding the nature of science than male subjects. Another noteworthy coefficient is the −.35 correlation between variable X_3 (Number of College-Level Science Courses Completed) and the criterion. This correlation may indicate that the more science a student has had, the more difficult it is to change that student's perception of the nature of science. If this is true, it implies that courses encountered early in a student's educational career have greater influence on his understanding of the nature of science than those encountered later. Crumb and Abegg (1967) have reported a similar finding. In their study, students enrolled in a college-level physical science course made significant gains in understanding the nature of science provided they had not had either physics or chemistry in high school. Students who had had both physics and chemistry did not make significant gains.

A final coefficient of interest is the −.04 correlation between variable X_5 (Final Course Average) and the criterion. Final course averages were computed from grades made on tests designed to measure knowledge of certain facts, principles, and theories of genetics. Therefore, this small negative correlation supports Olstad's (1969) finding that the acquisition of knowledge of the products of science is not necessarily accompanied by increased understanding of the nature of science, Consequently, measurement of student knowledge of the nature of science must be given special consideration in courses which stress understanding of the nature of science as an objective.

The stepwise multiple-regression analysis employed for purposes of developing predictive equations began with BCAC Score (X_4), which had the highest positive product-moment correlation with the criterion. Variable X_1 (Sex of Subject) was added in the second step, while variables X_6 and X_3 were added in the third and fourth steps, respectively. Variables were added until all six predictors were taken in combination with the criterion. Variables added after the fourth step failed, however, to increase the multiple correlation (R) appreciably. The combination of variables X_4, X_1, X_6, and X_3 produced a multiple correlation of .675 with the criterion, compared to .677 for all six variables. Table 4 summarizes the results of the regression analysis.

TABLE 4: *Summary of the multiple-regression analysis.*

Step Number	Regression Equation	Multiple Correlation (R)	Standard Error of Measurement
1	$Y = -6.581 + 0.293X_4$	0.450	4.784
2	$Y = -12.300 + 0.279X_4 + 4.270X_1$	0.607	4.326
3	$Y = -6.447 + 0.281X_4 + 3.217X_1 - 2.880X_6$	0.659	4.159
4	$Y = -4.515 + 0.258X_4 + 3.358X_1 - 2.218X_6 - 0.285X_3$	0.675	4.150
5	$Y = -4.397 + 0.265X_4 + 3.280X_1 - 2.126X_6 - 0.289X_3 - 0.021X_2$	0.676	4.219
6	$Y = -5.116 + 0.261X_4 + 3.297X_1 - 2.118X_6 - 0.306X_3 - 0.023X_2 + 0.013X_5$	0.677	4.294

The equation generated in the fourth step of the analysis ($Y = -4.515 + 0.258X_4 + 3.358X_1 - 2.218X_6 - 0.285X_3$) had the lowest standard error of measurement and should, therefore, be regarded as the best overall predictive equation. The standard error of measurement was 4.159. The equation produced an R^2 of .46. This indicated that 46 percent of the criterion score (Y) variability could be accounted for in terms of variations in the four predictor variables. The remaining 54 percent of the criterion variance was, of course, attributed to variables not included in the regression equation.

CONCLUSIONS

Results of this study support the following conclusions. First, a suitably designed genetics course can effectively promote student understanding of the nature of science. Second, predictive equations permitting relatively accurate estimates of change in student understanding of the nature of science can be developed. Finally, students are more likely to make significant gains in understanding the nature of science when they: (1) perceive the course to be consistent with the philosophy and rationale of BSCS curricula, (2) are female, (3) are *not* concurrently enrolled in two or more science courses, and (4) have *not* completed a large number of college-level science courses.

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A SURVEY OF HELMINTH PARASITES FROM TURTLES IN RUTHERFORD COUNTY, TENNESSEE

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ABSTRACT

From July, 1974 through September, 1975, 102 turtles—*Chelydra serpentina, Graptemys geographica, Chrysemys scripta elegans, Sternothaerus odoratus, Trionyx spinifer, Terrapene carolina,* and *Kinosternon subrubrum* were collected along or near the Stones River, Rutherford County, Tennessee. Thirteen species of parasites were identified including six trematodes, five nematodes, and two acanthocephalans. Helminths parasitized 67.6% of the turtles.

INTRODUCTION

Monogenetic and digenetic trematodes, cestodes, acanthocephalans, and nematodes have been reported from North American turles. Leidy (1851), Stafford (1900), Stunkard (1915), Ward (1921), and Byrd (1939) have made the most important contributions to the study of these worms. However, only a few reports of helminth parasites of turtles from Tennessee have been published. Byrd (1938, 1939) reported 16 species of blood flukes from turtles from Reelfoot Lake Biological Station, Tennessee. The incidence of infection for all turtles examined was 85%. Reiber (1941) reported three species of turtle nematodes.

The purpose of this study was to enumerate the helminth parasites in turtles in Rutherford County, Tennessee.

MATERIALS AND METHODS

A total of 102 turtles of 7 species—*Chelydra serpentina* (15), *Graptemys geographica* (1), *Chrysemys scripta elegans* (35), *Sternothaerus odoratus* (24), *Trionyx spinifer* (7), *Terrapene carolina* (5), and *Kinosternon subrubrum* (15)—were collected by hand and with wire funnel traps from various localities of Stones River, Rutherford County, Tennessee (Fig. 1). They were killed as soon as practical after collection and examined for parasites immediately. Helminths found while examining viscera grossly and with a stereomicroscope were removed and placed in 0.7% saline solution.

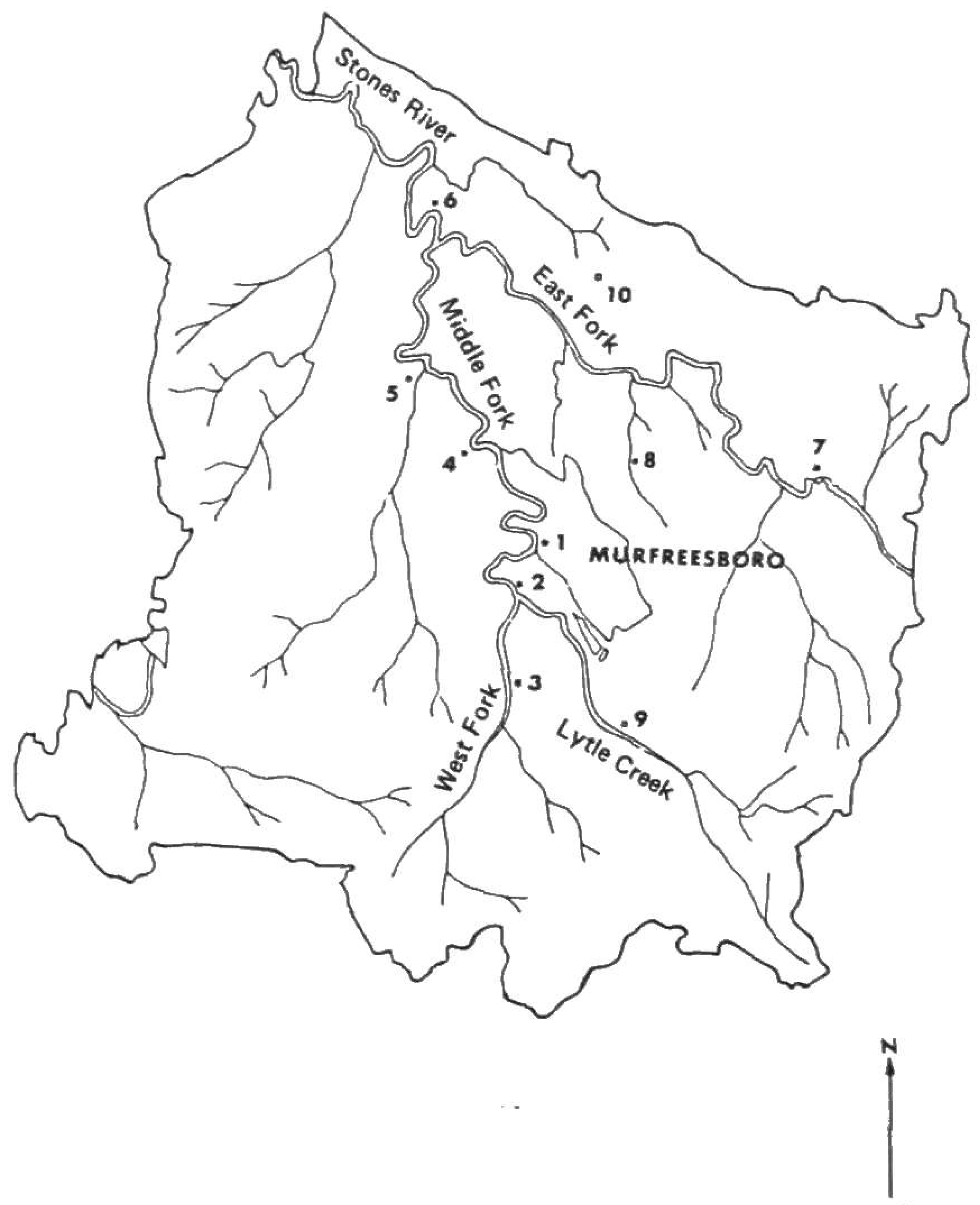

FIG. 1: *Map of Rutherford County, showing localities where collections were made.*

Preliminary studies of helminth gross morphology were made before they were killed. Measurements and observations were made from living unstained specimens under the gentle pressure of the cover glass and from fixed stained ones. Flattened trematodes were killed and fixed with Bouin's solution. Specimens were stained with Semichon's carmine. Unstained nematodes and acanthocephalans were cleared with glycerine alcohol.

TABLE 1: *Species of Helminths from Turtles Collected at Various Localities in Rutherford County, Tennessee.*

Location	Parasites
(1) West Fork, Stones River, Highway 96	*Amphimerus ovalis* Barker 1911
	Telorchis robustus Goldberger 1911
	Spirorchis haematobium (Stunkard 1922)
	Camallanus trispinosus (Leidy 1851)
	Spironoura chelydrae Harwood 1932
	Spiroxys contorta (Rudolphi 1819) Schneider 1866
	Neoechinorhynchus pseudemydis Cable and Hopp 1954
	Neoechinorhynchus chrysemydis Cable and Hopp 1954
(2) West Fork, Stones River, Highway 99	*Neopolystoma orbiculare* (Stunkard 1916)
	Amphimerus ovalis Barker 1911
	Telorchis robustus Goldberger 1911
	Camallanus trispinosus (Leidy 1851)
	Spironoura chelydrae Hardwood 1932
	Dracunculus globocephalus (Mackin 1927
	Neoechinorhynchus pseudemydis Cable and Hopp 1954
	Neoechinorhynchus chrysemydis Cable and Hopp 1954
(3) West Fork, Stones River, Barfield	*Amphimerus ovalis* Barker 1911
	Telorchis robustus Goldberger 1911
	Camallanus trispinosus (Leidy 1851)
	Spironoura chelydrae Harwood 1932
	Unidentified Spiruroidea
	Neoechinorhynchus chrysemydis Cable and Hopp 1954
	Neoechinorhynchus pseudemydis Cable and Hopp 1954
(4) West Fork, Stones River, Thompson Lane	*Neopolystoma orbiculare* (Stunkard 1916)
	Macrovestibulum orbicaudatum Mackin 1930
	Amphimerus ovalis Barker 1911
	Telorchis robustus Goldgerger 1911
	Camallanus trispinosus (Leidy 1851)
	Spironoura chelydrae Harwood 1932
	Dracunculus globocephalus (Mackin 1927)
	Neoechinorhynchus pseudemydis Cable and Hopp 1954
	Neoechinorhynchus chrysemydis Cable and Hopp 1954
(5) Overall Creek	*Neopolystoma orbiculare* (Stunkard 1916)
	Camallanus trispinosus (Leidy 1851)
	Spironoura chelydrae Harwood 1932
	Spiroxys contorta (Rudolphi 1819) Schneider 1866
	Neoechinorhynchus pseudemydis Cable and Hopp 1954
	Neoechinorhynchus chrysemydis Cable and Hopp 1954
(6) East Fork, Stones River	*Telorchis robustus* Goldberger 1911
	Camallanus trispinosus (Leidy 1851)
	Spironoura chelydrae Harwood 1932
	Neoechinorhynchus psuedemydis Cable and Hopp 1954
(7) East Fork, Stones River	*Camallanus trispinosus* (Leidy 1851)
	Spironoura chelydrae Harwood 1932
	Neoechinorhynchus pseudemydis Cable and Hopp 1954
(8) Bushnell Creek	*Camallanus trispinosus* (Leidy 1851)
	Neoechinorhynchus pseudemydis Cable and Hopp 1954
(9) Middle Fork, Stones River, Elm Road	*Camallanus trispinosus* (Leidy 1851)
	Spironoura chelydrae Harwood 1932
	Neoechinorhynchus pseudemydis Cable and Hopp 1954
(10) Private pond on Holly Grove Road	*Heronimus chelydrae* MacCallum 1902
	Neoechinorhynchus pseudemydis Cable and Hopp 1954
	Spironoura chelydrae Harwood 1932

TABLE 2: *Infection Records of Turtle Hosts.*

Localities	Turtle Hosts	Number Examined	Number with Parasites	Percentage Infected
(1)	*Chelydra serpentina*	3	3	100.0
	Chrysemys scripta elegans	3	3	100.0
	Sternothaerus odoratus	4	0	00.0
	Kinosternon subrubrum	2	2	100.0
	Trionyx spinifer	1	1	100.0
(2)	*Chelydra serpentina*	2	2	100.0
	Chrysemys scripta elegans	4	4	100.0
	Sternothaerus odoratus	8	1	12.5
	Terrapene carolina	1	1	100.0
	Kinosternon subrubrum	3	2	66.6
	Trionyx spinifer	1	1	100.0
	Graptemys geographica	1	1	100.0
(3)	*Chelydra serpentina*	2	2	100.0
	Chrysemys scripta elegans	3	3	100.0
	Sternothaerus odoratus	1	0	00.0
	Kinosternon subrubrum	1	1	100.0
(4)	*Chelydra serpentina*	3	3	100.0
	Chrysemys scripta elegans	9	9	100.0
	Sternothaerus odoratus	5	1	20.0
	Kinosternon subrubrum	3	2	66.6
	Trionyx spinifer	2	2	100.0
(5)	*Chelydra serpentina*	1	1	100.0
	Chrysemys scripta elegans	5	5	100.0
	Sternothaerus odoratus	4	0	00.0
	Kinosternon subrubrum	2	0	00.0
	Trionyx spinifer	1	1	100.0
(6)	*Chelydra serpentina*	1	1	100.0
	Chrysemys scripta elegans	2	2	100.0
	Terrapene carolina	1	0	00.0
	Kinosternon subrubrum	1	0	00.0
	Trionyx spinifer	1	0	00.0
(7)	*Chelydra serpentina*	1	1	100.0
	Chrysemys scripta elegans	2	2	100.0
	Sternothaerus odoratus	2	0	00.0
	Terrapene carolina	1	1	100.0
	Kinosternon subrubrum	1	0	00.0
(8)	*Chrysemys scripta elegans*	2	2	100.0
	Kinosternon subrubrum	1	0	00.0
(9)	*Chrysemys scripta elegans*	2	2	100.0
	Terrapene carolina	1	1	100.0
	Kinosternon subrubrum	1	0	00.0
(10)	*Chelydra serpentina*	3	3	100.0
	Chrysemys scripta elegans	3	3	100.0
	Trionyx spinifer	1	0	00.0
TOTALS		102	69	67.6

INFECTION RECORDS AND DISCUSSION

Thirteen species of helminth parasites were recovered from the turtles (Tables 1 and 2). *Neoechinorhynchus pseudemydis*, *Camallanus trispinosus*, and *Spironoura chelydrae* were the most common helminths found in Rutherford County (Table 3). *N. pseudemydis* was collected at all locations, while *C. trispinosus* and *S. chelydrae* were found from 9 of 10 locations.

Results indicated variation in parasitims of the different species of turtles (Table 4). *Chrysemys scripta elegans* and *Chelydra serpentina* showed 100% infection; however, the percentage for *Sternothaerus odoratus* was low—only 8.3%. The average infection rate was 67.6%. Turtles in Rutherford County are infected rather heavily. Nematodes were most frequently found, infecting 45.1% of the specimens. Monogenetic trematodes parasitized only 6.9%, digenetic trematodes, 23.5%, and acanthocephala, 26.5%

TABLE 3: *Frequency of Parasites in Turtles.*

	Chelydra serpentina	*Chrysemys scripta elegans*	*Sternothaerus odoratus*	*Terrapene carolina*	*Kinosternon subrubrum*	*Trionyx spinifer*	*Graptemys geographica*	TOTALS
Number of Hosts Examined	15	35	24	5	15	7	1	102
	Number of Hosts Infected							
Trematoda								
Monogenea								
Neopolystoma orbiculare	0	7	0	0	0	0	0	7
Digenea								
Macrovestibulum obtusi caudatum	0	2	0	0	0	0	0	2
Amphimerus ovalis	4	0	0	0	7	1	0	12
Telorchis robustus	0	8	0	0	0	0	0	8
Heronimus chelydrae	0	1	0	0	0	0	0	1
Spirorchis haematobium	0	1	0	0	0	0	0	1
Nematoda								
Camallanus trispinosus	1	21	2	0	0	3	1	28
Spironoura chelydrae	13	2	0	4	0	0	0	19
Spiroxys contorta	0	1	0	0	0	1	0	2
Dracunculus globocephalus	2	0	0	0	0	0	0	2
Unidentified Spiruroidea	0	1	0	0	0	0	0	1
Acanthocephala								
Neoechinorhynchus pseudemydis	2	18	0	0	0	0	0	20
Neoehinorhynchus chrysemydis	0	12	0	0	0	0	0	12

TABLE 4: *Degree of Helminth Infection of Seven Species of Turtles from Rutherford County.*

Host Species	Number Examined	Number Parasitized	Percentage Parasitism	Number of Turtles Infected			
				Monogenea	Digenea	Nematoda	Acanthocephala
Chelydra serpentina	15	15	100.0	0	5	13	2
Chrysemys scripta elegans	35	35	100.0	7	11	21	25
Sternothaerus odoratus	24	2	8.3	0	0	2	0
Terrapene carolina	5	4	80.0	0	0	4	0
Kinosternon subrubrum	15	7	46.7	0	7	0	0
Trionyx spinifer	7	5	71.4	0	1	5	0
Graptemys geographica	1	1	100.0	0	0	1	0
TOTALS	102	69	67.6	7	24	46	27

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