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REVISED CHECKLIST OF THE TERRESTRIAL GASTROPODS OF NEW JERSEY (MOLLUSCA: GASTROPODA)

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ABSTRACT – A revised checklist of land snails and their county distributions presents 96 species known to occur in New Jersey. Lists of 14 species we regard as introduced to North America and reported in New Jersey and 24 species that may be found potentially in New Jersey are also included. Five species are presented as possible rarities for New Jersey based on Natural Heritage Program methodology. By preparing a revised checklist, we hope that a new interest in gathering additional information about the distribution, ecology, and status of land snails found in New Jersey will be generated.

Keywords: Gastropoda, terrestrial snails, slugs, New Jersey, U.S.A.

INTRODUCTION

Early research about the land snails of New Jersey contains rich information useful to developing checklists of species (Fox, 1891; Marshall, 1892; Pilsbry 1892, 1900, 1911; Tableman, 1919; Vanatta, 1919, 1926). Using Pilsbry's early and later (1939-1948) reports and his own field survey work and research (Alexander, 1947a, 1947b, 1952a), Alexander (1952b,) pioneered the first inventory of land mollusks with distribution data for New Jersey. His report included 74 species and subspecies of native and introduced land snails. For unknown reasons, he did not report occurrences of three Limacidae reported previously (Alexander, 1947a, 1947b): *Deroceras laeve, D. reticulatum,* and *Limax maximus* in his 1952 checklist. Moreover, he (Alexander 1952) did not report the county distributions of *Philomycus carolinianus,* and *P. flexuolaris.*

In 1953, Freed noted four species found in Essex County, New Jersey, including a new record for *Discus rotundatus.* After, Freed (1957) reported on the land and freshwater mollusks of Union County, New Jersey. His checklist included 13 species of terrestrial mollusks not previously reported for Union County. He also reported a new state record for *Zonitoides nitidus.* Freed (1966a) produced a checklist of the land snails of New Jersey but did not include distribution data. Other reports during the 1940s through 1960s include the accounts of field trips (Eddison, 1966; Freed, 1966b; Lee, 1966), new records (Jacobson, 1965), species of agricultural interest

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(Quakenbush, 1955), and habitat and ecology (Rapp Jr. & Rapp, 1945).

Dundee (1974) listed sixteen introduced but not established species for New Jersey. Hubricht (1985) provides the most recent account of lands snails known from New Jersey based on his personal collection and Pilsbry (1939-1948). Hubricht's monograph contains range maps detailing the county occurrences for 67 native species found in the state. He adds seven new records of species to the previous lists of Alexander: *Cochlicopa lubricella, Strobilops texasianus, Succinea campestris, Succinea wilsoni, Glyphyalinia luticola, Neohelix major,* and *Stenotrema barbatum.* His report, however, does not include 13 species listed by Alexander (1952b): *Gastrocopta corticaria, G. tappaniana, Vertigo morsei, Strobilops labyrinthicus, Helicodiscus inermis, H. singleyanus, Philomycus flexuolaris, Succinea indiana, Euconulus chersinus, Glyphyalinia indentata, G. rhoadsi, Deroceras laeve* and *Neohelix solemi.*

Because discrepancies about the species and their county occurrences exist among the above references and changes in nomenclature have taken place, a revised checklist is warranted. Our checklist is provided to the researcher as a tool to aid in planning field surveys, identifying species, and reporting records.

METHODS

This revised checklist is based on the species and their county occurrences reported by Alexander (1947a; 1947b; 1952b), Dundee (1974), Eddison (1966), Fox (1891), Freed (1953, 1957, 1966b), Hubricht (1985), Jacobson (1965), Lee (1966), Pilsbry (1892, 1900, 1911, 1939-1948), Rapp Jr and Rapp (1945), Tableman (1919), and Vanatta (1919, 1926). Additional records include the collections by Bogan and museum specimens of the Hubricht Collection, Field Museum of Natural History. Whenever possible, we note records from primary sources (*e.g.*, Vanatta 1919, 1926) rather than reports included in later sources (*e.g.*, Alexander 1952b). Moreover, we avoided questionable identifications such as Marshall's (1892) report of *Succinea avara* that Pilsbry (1900) reexamined. The systematic order and scientific names presented follow Turgeon *et al.* (1988) and the revised, unpublished edition. The taxonomy of the Polygridae is revised according to Emberton (1995).

We provide additional species to Alexander's (1952a) and Dundee's (1974) lists of introduced land snails. A list of potential species of land snails that may be found in New Jersey is based on information from the range maps of Hubricht (1985) and a survey of the mollusk collection in the Department of Malacology at the Academy of Natural Sciences, Philadelphia. We defined a "potential species" as one for which documented occurrences adjacent to New Jersey exist, or as a species that based on known distributions in the northeastern United States is likely to be found in the state through additional field investigations.

RESULTS

The present list (Table 1) includes 96 species representing 20 families of land snails known to occur in New Jersey. The order Gastropoda is represented by two suborders: Basomatophora, represented by the family

Carychidae, and the suborder Stylommatophora, represented by 19 families, beginning with Cochlicopidae in Table 1.

Table 2 presents 14 species representing eight families we regard as introduced to North America and reported in New Jersey. However, reports of land snails introduced to New Jersey suffer from two problems. First, arionid, limacid and malacid slugs are under-reported and are much more widespread than is reported in the literature or museum collections. Second, reports of introduced species are often vague. For example, Pilsbry (1939-1948) noted that *Limax maximus* is found in many localities in New Jersey and only lists the eastern United States for *Deroceras reticulatum*. Alexander (1952b: 56) reported *Philomycus carolinianus, P. flexuolaris, Deroceras laeve, D. reticulatum, Limax flavus* and *L. maximus* as "fairly common and widespread," although in our county checklist these species are under-represented. Not included in Table 2 are the species, *P. carolinianus, P. flexuolaris,* and *Triodopsis hopetonensis,* and *Xolotrema fosteri.* These snails are native to North America, but can be considered as introduced to New Jersey (Alexander 1952b; Jacobson, 1965; Turgeon *et al.*, 1988).

A total of 24 species representing 10 families are presented as occurring or potentially occurring in New Jersey (Table 3).

DISCUSSION

The rarity of terrestrial gastropods found in New Jersey can be assessed using Natural Heritage Program methodology which standardizes how to determine and prioritize the conservation needs of particular species. The rarity of species is based on many considerations including the number of known and estimated occurrences, the estimated abundance of the species, the range of the species in the state, population trends, the number of protected sites, and the threats to the species (The Nature Conservancy, 1982). Using these criteria, we determined that five species may be rare in the state because of their limited distribution in or adjacent to New Jersey: *Gastrocopta pellucida, Helicodiscus singleyanus, Catinella vagans, Succinea campestris* and *Neohelix major.* These species either reach their northeastern most range limit in New Jersey or have been recorded only in the state. Moreover, the estimated occurrence of these species is limited to less than 100 occurrences in New Jersey. A short summary for each of these species follows.

Gastrocopta pellucida is known to occur in Cape May County (Alexander, 1952b), the species' northeastern-most range limit (Hubricht, 1985). Hubricht (1985) shows records from one county in Maryland, one county in Virginia, and from Georgia south to Florida. This species can be found

TABLE 1. Revised checklist of the native lands snails of New Jersey. Letters correspond to the references supporting county distribution: A (Alexander, 1947a, 1947b, 1952a; 1952b); B (Bogan collection record); D (Dundee, 1974); E (Eddison, 1966); F (Freed, 1953, 1957, 1966b); H (Hubricht, 1985); J (Jacobson, 1965); L (Lee, 1966); M (museum record from Hubricht Collection, Field Museum of Natural History); P (Pilsbry, 1892, 1900, 1911, 1939-1948); [table legend continued on top of facing page]

County Family Species	A T L	B E R	B U R	C A M	C A P	C U M	E S S	G L O	H U D
CARYCHIIDAE									
Carychium exiguum			AH	AHV	AH			AX	
Carychium exile				A				A	
COCHLICOPIDAE									
Cionella lubrica	AP		A		A		HF		H
Cochlicopa lubricella	H				H				
PUPILLIDAE									
Columella edentula				AV		A			
Gastrocopta armifera			A	AV					
Gastrocopta contracta	A		A	AV	A	A	H	AV	
Gastrocopta corticaria				AV					
Gastrocopta pellucida					AHP				
Gastrocopta pentodon	A		A	AV	AP	A		A	
Gastrocopta tappaniana		A		A					
Pupilla muscorum	AHP								
Pupoides albilabris	AH		AH	AHV	AHMP	AH		AH	H
Vertigo gouldi									
Vertigo milium	AH		AH	AHV	AHP				
Vertigo morsei									
Vertigo ovata		H	AH		AH	HM	H	A	H
Vertigo pygmaea			AH	V	AH				
Vertigo tridentata				AHV					
VALLONIIDAE									
Vallonia costata	AH								
Vallonia excentrica	AH		AH	AH	AH	AH		AH	
Vallonia perspectiva	AHP								
Vallonia pulchella				AHV	AHP		AF		
STROBILOPSIDAE									
Strobilops aenea		H	AHP						
Strobilops affinis									
Strobilops labyrinthicus	A		A	A	A	A		A	
Strobilops texasianus	H		H	HV	H			H	
FERUSSACIIDAE									
Ceciliodes acicula									
Ceciliodes apertus									
SUBULINIDAE									
Lamellaxis gracillis			M						
HAPLOTREMATIDAE									
Haplotrema concavum			AH						
PUNCTIDAE									
Punctum munutissimum			AH	AH	AH	AH		AHX	
Punctum vitreum				AH					
HELICODISCIDAE									
Helicodiscus inermis	A		A	A				A	
Helicodiscus parallelus	A		AH	AHV	AH	A		AHX	
Helicodiscus singleyanus			P	A					

[table legend continued from facing page] R (Rapp Jr & Rapp, 1945); T (Tableman, 1919); V (Vanatta, 1919, 1926); and X (Fox, 1891). New Jersey county abbreviations are defined at the end of the table. Questionable occurrences are identified with a question mark (?). All species native, except those identified as introduced to North America [I] and non-native to New Jersey [N].

HUN	MER	MID	MON	MOR	OCE	PAS	SAL	SOM	SUS	UNI	WAR
									HL		AH
									AHL		AV
									AHL	F	
				H							
									AHL		AV
	H						A		AHL		AV
									A		
					A				AHL		AV
										A	
							AH		HL		A
		A	H						A	H	A
									AH		AV
											A
	AH		H					H			A
											AHV
	AH										V
	A	A					A				
		A					AH			F	
											AHP
					A			A			A
							H				
	D										
	AD										
	AH							AH			
									AHL		AH
									AH		AH
	A			A	A				AH	F	AV

TABLE 1 (continued)

County	A	B	B	C	C	C	E	G	H
Family	T	E	U	A	A	U	S	L	U
Species	L	R	R	M	P	M	S	O	D
DISCIDAE									
Anguispira alternata		AH	AH	AH	AH				
Anguispira fergusoni		AH	AH	AV					
Discus catskillensis		H	AH						
Discus cronkhitei			AH	AHV				X	
Discus rotundatus							DF		
ARIONIDAE									
Arion fasciatus		D							
Arion subfuscus								B	
PHILOMYCIDAE									
Philomycus carolinianus		HP	HP						
Philomycus flexuolaris			P	P	P				
SUCCINEIDAE									
Catinella vagans				A?	AHP				
Catinella vermeta			A	A	AH	A		AX	
Oxyloma decampi									
Oxyloma effusum				AH					
Oxyloma retusum			A	A					
Oxyloma subeffusum			AH	AH					
Succinea campestris					HMP				
Succinea indiana	A				A	A			
Succinea ovalis		AH	AH	AHV	AH			AHV	
Succinea wilsonii				H	HM				
HELICARIONIDAE									
Euconulus chersinus	A			A					
Euconulus fulvus				AV					
Guppya sterkii						A			
ZONITIDAE									
Glyphyalinia indentata	A		A	AV	A	A		AX	
Glyphyalinia luticola			H						
Glyphyalinia rhoadsi								A	
Glyphyalinia wheatleyi			AH	AH		AH		AH	
Hawaiia alachuana				AHV					
Hawaiia minuscula	A		A	AV	AP	A		AX	
Mesomphix cupreus									
Mesomphix inornatus									
Nesovitrea electrina			AH	AV	A	H		AHX	
Oxychilus alliarius							AD		
Oxychilus cellarius			D		AD		DF		
Oxychilus draparnaudi				AD					
Striatura exigua					AH				
Striatura meridionalis	AH		AH	AH	AH	A			
Striatura milium									
Ventridens ligera			AHM	AH	AH			AHX	
Ventridens suppressus			AH	AH	AH	AH		AHX	
Zonitoides arboreus	A	A	A	AV	AHP	A	F	AX	
Zonitoides nitidus							F		
LIMACIDAE									
Deroceras laeve				V	AP				
Deroceras reticulatum			D		A				
Limax flavus			DP	DP					
Limax maximus			D		A				

HUN	MER	MID	MON	MOR	OCE	PAS	SAL	SOM	SUS	UNI	WAR
	AH			A		H			AHL	F	AHV
H									AHL		AH
					AH				AHL		AH
										D	
	J	RP									
P	P								P		P
											AV
									L		
				A					H		AV
										F	
AH	AH			AH		H			AHL	F	AH
				A					A		
									HL		AV
									AH		AV
				A					AL		AV
	A								A		A
				AH					A		AH
									AHL		AV
H									AHL	F	AHV
	AH										
			H						AHL		AHV
			A		D	D				DF	
				HM							
				AH					L		AH
H	A								AHL		AHV
	A	A	AP	A	A			A	AHL	F	AHV
									HL	F	

TABLE 1 (continued)

County Family Species	A T L	B E R	B U R	C A M	C A P	C U M	E S S	G L O	H U D
MILACIDAE									
Milax gagates									
POLYGYRIDAE									
Euchemotrema fraternum		AH							
Mesodon thyroidus	AH	AH	AH	AHV	AH	AH	AHT	AHX	AA
Neohelix albolabris		AH	AH	AHV	AP		T	AHX	
Neohelix major					H				
Neohelix solemi	A				AP				
Stenotrema barbatum									
Stenotrema hirsutum									
Triodopsis fallax				AHV				AH	
Triodopsis hopetonensis									
Triodopsis juxtidens			AH						
Triodopsis tridentata		AH	AH						AH
Xolotrema denotata		AH							
Xolotrema fosteri			AHJ					A	
HELICIDAE									
Capaea nemoralis			AD						

New Jersey County Key: ATL (Atlantic); BER (Bergen); BUR (Burlington); CAM (Camden); CAP (Cape May); CUM (Cumberland); ESS (Essex); GLO (Gloucester); HUD (Hud- [table footnote continued at the bottom of the table on the facing page]

in open fields, woods, or sandy areas (Hubricht, 1985). The species has a generalized habitat, is limited in state range, and is known now from one county in New Jersey.

Helicodiscus singleyanus is known from Camden County (Alexander, 1952b). Pilsbry (1939-1948) reports a single specimen from Riverton, Burlington County, New Jersey; the specie's northeastern most range limit. Hubricht (1985) shows that this species is most likely common in Delaware and Maryland. He also reports that this species can be found in open, grassy fields and meadows, and along roadsides and railroads. The species has a generalized habitat, may be limited to the Delaware River drainage, and is known now from two counties in New Jersey.

Catinella vagans is known from the type locality in Cape May Point, Cape May County, New Jersey (Hubricht, 1978). A questionable occurrence, not reported by Hubricht, exists for Camden County (Alexander, 1952b). The habitat of this species appears to be coastal plain ponds located in sand beach or back dune communities (Hubricht, 1985; Pilsbry, 1939-1948). The species may be restricted to the Cape May peninsula, has specialized habitat, is known now from a single location and county

HUN	MER	MID	MON	MOR	OCE	PAS	SAL	SOM	SUS	UNI	WAR
						D					
AH	AH			AH					AHL		AHV
AH	AH		AHP	AH	AHP		AH		AHL	FH	AHV
	AH	AH	AH	AH			AH		AHL	F	AHV
			E								
									H		
AH	AH	H						H	AHL		AHV
		J									
AH	AH					H			H	F	AH
A											
					D						

[continued from facing page] son); HUN (Hunterdon); MER (Mercer); MID (Middlesex); MON (Monmouth); MOR (Morris); OCE Ocean); PAS (Passaic); SAL (Salem); SOM (Somerset); SUS (Sussex); UNI (Union); and WAR (Warren).

in New Jersey, and has a limited range.

Succinea campestris is an Atlantic coast species with Cape May County, New Jersey as its northeastern most range limit (Hubricht, 1985). The habitat for this species is described by Hubricht (1985) as beach dune areas. The species may be restricted to Cape May County, has a specialized habitat requirement, and is known now from one county in New Jersey.

Neohelix major is known from Cape May County which is the northeastern most range limit of this species. This species can be found along the Atlantic Coast south to Florida (Hubricht, 1985). *Neohelix major* is found in general habitats such as wooded hillsides, ravines, along roadsides and railroads, and urban areas (Hubricht, 1985). This species has a generalized habitat, is limited in state range, and is known now from one county in New Jersey.

CONCLUSION

With this revision of the checklist of land snails of New Jersey, we hope to stimulate interest in gathering additional information on the distribu-

TABLE 2. Land snail species introduced to North America and reported for New Jersey including Alexander (1952a) and Dundee (1974).

Family Ferussaciidae	*Oxychilus alliarius* (J.S. Miller 1822)
Ceciliodes acicula (Müller 1774)	*Oxychilus cellarius* (Müller 1774)
Cecilioides apertus (Swainson 1840)	*Oxychillus draparnaudi* (Beck 1837)
Family Subulinidae	Family Limacidae
Lamellaxis gracilis (Hutton 1834)	*Deroceras reticulatum* (Müller 1774)
Family Discidae	*Limax flavus* Linnaeus 1758
Discus rotundatus (Müller 1776)	*Limax maximus* (Linnaeus 1758)
Family Arionidae	Family Milacidae
Arion fasciatus (Nilsson 1823)	*Milax gagates* (Draparnaud 1801)
Arion subfuscus (Draparnaud 1805)	Family Helicidae
Family Zonitidae	*Cepaea nemoralis* (Linnaeus 1798)

tion, ecology, and status of the species presented. Surveys for land snails in New Jersey should begin with the five species we presented as possibly rare in the state: *Gastrocopta pellucida, Helicodiscus singleyanus, Catinella vagans, Succinea campestris,* and *Neohelix major.* Determining a factual conservation status of these five species demands further field and museum investigation.

As land development pressures become greater in New Jersey and open space is lost, the need for thorough invertebrate surveys increases. This is particularly true for rare species of land snails. However, before New Jersey can plan for the preservation of rare land snails, additional information on their biology and ecological role is needed. General snail surveys should begin by focusing on the rare ecological communities reported by Breden (1989) to determine which, if any, species are habitat-restricted and can be used in characterizing communities. The production of complete habitat and vegetation descriptions for land snail species found in New Jersey would also assist in identifying areas that are rich in snail diversity or contain rare species.

Occurrences of the species we present as rare will be tracked as "elements" of New Jersey's natural diversity by the New Jersey Natural Heritage Program. The Program tracks the occurrences of over 300 other rare invertebrates from New Jersey. A report on the status of rare invertebrate species is available from the Program. The invertebrates of New Jersey not only have research and educational potential but also aesthetic and cultural value that deserve our attention and preservation.

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TABLE 3. Land snail species that potentially occur in New Jersey after Hubricht (1985).

Family Cochlicopidae	*Philomycus togatus* (Gould 1841)
Cochlicopa morseana (Doherty 1878)	Family Succinidae
Cochlicopa nitens (Gallenstein 1848)	*Catinella oklahomarum* (Webb 1953)
Family Pupillidae	Family Helicarionidae
Columella simplex (Gould 1841)	*Euconulus dentatus* (Sterki 1893)
Vertigo bollesiana (E.S. Morse 1865)	Family Zontidae
Family Valloniidae	*Nesovitrea binneyana* (E.S. Morse 1864)
Planogyra asteriscus (E.S. Morse 1857)	*Paravitrea multidentata* (A. Binney 1840)
Family Helicodiscidae	*Striatura ferrea* Morse 1864
Helicodiscus shimeki (Say 1962)	*Ventridens cerinoideus* (Anthony 1865)
Family Discidae	*Ventridens intertextus* (A. Binney 1841)
Discus patulus (Deshayes 1830)	Family Polygridae
Family Philomycidae	*Allogona profunda* (Say 1821)
Megapallifera mutabilis (Hubricht 1951)	*Appalachina sayanus* (Pilsbry 1906)
Pallifera dorsalis (A. Binney 1842)	*Euchemotrema leai* (A. Binney 1841)
Pallifera fosteri F.C. Baker 1939	*Mesodon zaletus* (A. Binney 1837)
Pallifera secreta (Cockerell 1900)	*Neohelix dentifera* (A. Binney 1837)

with a preliminary checklist of the terrestrial gastropods of New Jersey based on Pilsbry (1939-1948). Dr. Rüdiger Bieler and John Slapcinsky (Division of Lower Invertebrates, Field Museum of Natural History, Chicago) kindly provided county data from the Hubricht Collection for this project. Dirrigl would like to thank Tom Breden (New Jersey Natural Heritage Program) and Dr. Larry Master and Melissa Morrison (The Nature Conservancy) for their continued support and friendship. Also, Dirrigl always appreciates the encouragement and advisement provided by Drs. Jane O'Donnell and David Wagner (The University of Connecticut) towards his invertebrate fieldwork and studies. This paper benefited from Timothy Pearce's review of the manuscript, and we are grateful for his assistance and time. We take sole responsibility for any errors or omissions in this paper and would appreciate notification of any necessary corrections and additional records.

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INVERTEBRATES EXPLOITING TERRESTRIAL AND FRESHWATER MOLLUSKS

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ABSTRACT – The literature was surveyed for records of invertebrates occupying empty land and freshwater shells. Animals employ mollusks for substrate, transportation or building material. In addition, inquilines of shells and predators have been observed. Inquilines include pseudoscorpions, spiders, mosquitoes and bees. Some flies, coleopterans and hemipterans prey on mollusks. New records include a juvenile *Humboldtiana* sp., a diplopod, and a beetle.

Key words: invertebrates, mollusk shells, phoresis, building material, inquilines, predators, *Humboldtiana*.

RESUMEN – Se revisó la literatura en relación con el uso de conchas por animales terrestres y dulceacuícolas. Hay animales que utilizan a los moluscos como substrato, medio de transporte o como material de construcción. Además existen inquilinos en las conchas y predadores. Los inquilinos son seudoescorpiones, arañas, mosquitos y abejas. Entre los predadores están moscas, coleópteros y hemípteros. Nuevos registros incluyen un caracol juvenil de *Humboldtiana*, un diplópodo y un escarabajo.

INTRODUCTION

Much is known on the use of shells by marine invertebrates and algae; however, little has been investigated for terrestrial and freshwater invertebrates. I reviewed the literature, for the last 12 years, on the use of shells by terrestrial and freshwater invertebrates. For the first time a compilation on the theme is presented.

The information gathered from the literature indicates that shells can serve as shelter, nests or breeding places, a way of transportation and as building material for a variety of terrestrial and freshwater invertebrates. The findings encountered are organized below under several headings according to the type of use.

Substrate

Trichoptera

Caddisflies occupy mussel shells or snails as pupation sites. This phenomenon has occurred with the change of the normal conditions

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of a river, which was dammed. Since caddisflies need a hard surface on which to pupate, and as the hard substrate provided by rocks (changed to a soft bottom) is unavailable, the larvae find bivalve shells suitable to their needs (Anderson & Vinikour, 1984).

Phoresis

Diptera

Another type of association between mollusks (live) and invertebrates is phoresis (White *et al.*, 1980), where one of the partners transports the other. White *et al.* observed in Wildcat Creek, South Carolina, that the freshwater snail *Elimia acutocarinata* (Prosobranchia) carries on the shell an average of two (0-4) Chironomidae larvae of *Rheotanytarsus* spp. Vinikour (1982) has also reported *Rheotanytarsus* sp., *Thienemanniella* sp. (Chironomidae), *Simulium tuberosum* (Simulidae) and *Ochrotrichia* (Hydroptilidae, Trichoptera) on shells of *Elimia carinifera;* the most common association was seen between *Rheotanytarsus.* Other associations were uncommon.

Building Material

Trichoptera

The caddisfly *Philarctus quaeris* often builds its larval cases with freshwater shells of snails and small bivalves (Sphaeriidae) along with rocks and sedge seeds. *Grensia praeterita* apparently uses snail opercula among other building materials for its larval case (Wiggins, 1977). A unique example was found where a caddisfly of the species *Glossosoma intermedium* built its case with *Physa gyrina* shells. This is a rare event, since other trichopterans of the same family (Glossosomatidae) usually construct their cases with pieces of rocks (Anderson & Vinikour, 1980).

Inquilines

Arachnidae

Araneida. So far the only spiders known to get shelter from an empty shell are species of the genus *Phonognatha* (Ana Hoffman, pers. comm.). The spider *Phonognatha graeffi* from a private garden in Victoria, Australia was observed in a shell of *Helix aspersa* (Hewish & Hewish, 1990).

Scorpionida. Taylor *et al.* (1977) believed that pseudoscorpions use shells as shelter during molting and to get protection from extreme weather conditions.

Biantennata

Decapoda. Terrestrial hermit crabs (Anomura) mainly of the genera *Coenobita* and *Birgus* utilize empty gastropod shells (Powers & Bliss, 1983). Powers & Bliss have emphasized the importance of the shell in the adaptations of the terrestrial hermit crabs to a land existence. The shell provides protection, shelter from predators, protection of the eggs, and helps in the conservation of water (Hazlett, 1981), also providing thermal insulation (McMahon & Burggren, 1979), but allows for a somewhat confined locomotion (Hazlett, 1981). On the other hand, the shell has allowed land hermit crabs, *e.g., Coenobita,* to move inland while still possessing a marine ionic balance (Powers & Bliss, 1983). Nonetheless, even inland populations need to migrate to the sea to spawn (Hazlett, 1981). Hazlett (1981) reviews several of the features that have been related to the association of hermit crabs with shells: daily movements, reproduction, crab fitness, population, shell exchange, epifauna, competition, coexistence, and hermit behavior. "The adopted shell (of *Coenobita* sp.) may have allowed these animals to enter the terrestrial habitat with less modification than the more exposed forms" (McMahon & Burggren, 1979).

Insecta

Diptera. To mosquitoes, shells are natural cavities for breeding, and various mosquito genera lay their eggs in molluscan shells. In Tanzania, *Aedes aegypti* is associated with *Culex fatigans* and *C. nebulosus* (Ramachandra *et al.,* 1973), and all three species breed in land shells. In the same area, Trpis (1973) observed that 11-35% of *Achatina fulica* shells examined had larvae of *Aedes aegypti, A. simposoni* and *Eretmapodites quinquevittatus.*

Coleoptera. Sigida (1987) has reported beetles of the genus *Carabus* inhabiting shells.

Hymenoptera. Bees were reported to nest in shells by Belloveye (1870), including the genera *Osmia, Ashmeadiella, Hoplitis,* and some species of *Rhodanthidium* that occupy empty gastropod shells as nests. Most of the known genera found employing shells as nests are distributed in Eurasia, and *Ashmeadiella* is the only one registered from America.

Bees built cells in the shells by using diverse material (leaf mastic, sheep or rabbit dung, saliva, resin and snail shell fragments – O'Toole & Raw, 1991). The number of cells in which the carapace is divided depends on the size of it, only one cell is found in *Cepaea nemoralis* and *C. hortensis,* up to 10 in the shell of *Helix pomatia* (Belloveye, 1870; Westrich, 1990; O'Toole & Raw, 1991).

Predators

Insecta

Diptera. Several families of flies (Sciomyzidae, Phoridae, Anthomyidae, Borboridae, Calliphoridae, Chironomidae, Dryomyzidae, Ephydridae, Muscidae, Psychodidae, Sarcophagidae, Sepsidae and Tabanidae) have been observed to prey or feed on dead terrestrial and freshwater mollusks (Berg, 1953; Knutson *et al.*, 1967; Disney, 1973a, 1973b, 1976, 1982; Blackith, 1984; Vala & Gasc, 1990). Flies breed in living or freshly killed snails [there is an obligate malacophagy by Sciomyzidae larvae] (Berg, 1953). Some flies leave the shell before pupation *(e.g., Paraspiniphora maculata),* while others apparently pupate within the snail shell *(e.g., Hydrotaea occulta* and *Hylemya strenua,* Disney, 1973a). Other flies finish pupation in the shell closed by a calcareous plate built by themselves *(e.g., Pherbellia* and *Colobaea,* Chandler *et al.*, 1978).

Sciomyzidae larvae are predators (Berg, 1953) or parasitoids of either freshwater or terrestrial snails (Berg, 1961), which crawl and penetrate between the mantle and the shell. The snail will die in about two days, and the larvae will continue to eat the dead animal. The 2nd larval instar will also feed on the decaying snail; later it will prey on another snail. The 2nd and 3rd instar larvae eat their prey, killing several mollusks during their life span (Vala & Gasc, 1990). "Berg (1961) and Knutson (1962) listed *Hydromya dorsalis* as one of the Tetanocerinae whose larvae are adapted for aquatic life and feed as predators on pulmonate snails" (Knutson & Berg, 1963).

Predation and phoresis appear to exist among the larvae *Simulium (Thyrsopelma) orbitale* and *Simulium (Psaroniocompsa)* spp. of the Simuliidae and the freshwater snail *Asolene (Pomella) megastoma* from the Uruguai River in Brazil (Darwich *et al.*, 1989). *Sciomyza varia* breeds in grounded or aestivating *Stagnicola elodes* (Barnes, 1990). In addition, at least three genera of flies *(Renocera, Knutsonia* and *Glyptotendipes)* feed on freshwater sphaeriid bivalves (Foote & Knutson, 1970). The fly *Melinda itoi* (Calliphoridae) was observed to emerge after pupation from the slug *Incilaria bilineata* (Hori & Yamaguchi, 1984).

Coleoptera. Examples of coleopterans attacking mollusks include members of the families Lampyridae *(Lampyris, Phausis,* and *Zarhipis)* and Carabidae *(Abax, Carabus, Feronia* and *Scaphinotus).* All those genera prey on the slugs *Arion hortensis, A. ater, A. subfuscus, A. fasciatus* and *Milax gagates,* among other land mollusks (Stephenson & Knutson, 1966). The main component in the diet of *Carabus* and *Cychius* are slugs (Gruntal & Sergeeva, 1989); while for *Pterostichus oblongopunctatus* several invertebrates form part of its diet, among them slugs (Sergeeva & Gruntal, 1988). *Abax ater* (Carabidae) is also a predator of slugs (Loreau, 1983), and *Photuris* sp. is a predator and scavanger on soft bodied organisms such as snails and slugs (Buschman, 1984).

Hemiptera. Species of *Belostoma, e.g., B. flumineum* are predators on *Physa vernalis* and *Pseudosuccinea columella* (Kesler & Munns, 1989).

New Findings

Incidental observations over a 10-year period of collecting land snails has resulted in a small number of new records of invertebrates dwelling in or occupying snail shells. It is interesting to note that there are at least five orders of arthropods and one mollusk that use empty land shells (Table 1, see Appendix 1 for data).

Shells have been found occupied by pseudoscorpions, spiders, spider webs, Diplopoda larvae (dead), Diptera molts, a Lampyridae larva, a beetle *Plagiodera* sp. (Coleoptera), and a snail (Table 1).

Pseudoscorpions were inside *Sonorella.* Spider webs were found in *Orthalicus* sp., *Drymaeus* sp. and *Rabdotus* sp. Live Diptera larvae were encountered twice, on the genera *Drymaeus* and *Pomacea,* unfortunately after discovering them in mild detergent, they did not survive. It was possible to raise a fly larva found in a *Orthalicus* sp. shell to adulthood (Sarcophagidae). Diptera molts were found in *Succinea undulata, Helminthoglypta fieldi,* and *Rabdotus* sp. A millipede was found in a *Streptostyla* sp. shell. A Lampyridae was found in an apparently dormant *Drymaeus* sp. attached to a Convolvulaceae-like vine; however, the shell was empty. An individual of *Humboldtiana* sp. was once observed to shelter a dormant beetle of *Plagiodera* sp. (Chrysomelidae). The beetle was found on the umbilicus of a live snail estivating on a depression of a rock approximately 3 m high. A very young specimen of *Humboldtiana* sp. (see data on Appendix 1) was found estivating on an empty shell of the same species.

TABLE 1. New findings on molluscan shells occupied by invertebrates.

Inquilines	Predators									
	Hum	Dpa	Pse	Ara	Web	Col	Sar	Lar	Mlt	Lam
Pomacea								1		
Succinea									2	
Drymaeus					4			3,6		5
Orthalicus				8,9	8,9		7			
Rabdotus					10				10	
Microceramus									11	
Streptostyla		12								
Humboldtiana	15				14	13				
Helmintoglypta									16,17	
Sonorella			18							

Numbers indicate data of records from Appendix 1

Key of abbreviations used: Ara = Araneidae; Col = Coleoptera; Dpa = Diplopoda; Hum = *Humboldtiana*; Lam = Lampyridae; Lar = Diptera Larvae; Mlt = Diptera molts; Pse = Pseudoscorpion; Sar = Sarcophagidae; Web = Spider web.

There is one record on the use of an *Orthalicus* sp. terrestrial shell by a marine hermit crab, all other crabs on that beach were apparently using marine shells.

DISCUSSION

An assortment of animals utilize empty shells of terrestrial and freshwater snails for their particular needs in nature.

Flies can either take the shell as shelter or feed on live or dead snails at different stages of their life (Disney, 1973; Vala & Gasc, 1990), as in the case of Sarcophagidae found in *Orthalicus* sp., and the unidentified larvae in *Pomacea* cf. *flagellata* and *Drymaeus* sp.

Lampyridae, and some families of flies (Sciomyzidae) are known to feed on snails or dead material (Sarcophagidae, Phoridae).

The percentage of animal occupancy is low, 18 records in more than 10 years. It should be taken into account that during collection, invertebrates will crawl out when the shell is picked up.

Larvae of the marsh-flies (family Sciomyzidae) has been included in several investigations to test if these organisms are potential agents for schistosomiasis snail biocontrol (Knutson *et al.*, 1953; Appleton & Miller, 1993).

Investigations on the use of shells by land and freshwater fauna has been largely unexplored in comparison with similar studies of marine organisms. More information about the subject could lead to a greater ecological knowledge in the relations between mollusks or molluscan shells and other animals.

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APPENDIX 1. Data of land and freshwater Mollusca recorded with animal dwellers.

1. *Pomacea* cf. *flagellata* (Say, 1829). MEXICO, Michoacán. Municipio Coahuayana. Laguna Mezcales. El Ticuis. G. Casas-Andreu! 24 February 1992. No. shells 2, Diptera larvae 2.
2. *Succinea undulata* Say, 1829. MEXICO, Puebla. Tehuacán. No more data. MHNCH 265. No. shells 1, Diptera molt.
3. *Drymaeus* sp. MEXICO, Veracruz. Estación de Biología Los Tuxtlas. P. Guadarrama! 15 January 1992. No. shells 1, Diptera larva 1.
4. *Drymaeus* sp. GUATEMALA, Sitio Chivacabé. E. Naranjo-García! Former Pine Forest, now pasture fields. 14-15, & 18 April 1992. No. shells 1.
5. *Drymaeus* sp. MEXICO, Jalisco. Estación de Biología Chamela, Vereda Chachalaca and Arroyo Zarco. E. Naranjo-García! 12 November 1989. No. shells 1, glow worm (Lampyridae) 1.
6. *Drymaeus* sp. MEXICO, Puebla. 4 km on Hwy Apapantilla – Piedras Negras El Salto. *Ca.* 179 mbsl. E. Barrera & C. Mayorga! 12 July 1994. No. shells 1 of 2, Diptera larva 1.
7. *Orthalicus* sp. MEXICO, Colima, Sierra Minatitlán. E. Naranjo-García! July 1994. No. shells 1, Diptera larvae 3 (one of them reached adulthood: Sarcophagidae).
8. *Orthalicus* sp. MEXICO, Jalisco, Estación de Biología Chamela. Eje Central. E. Naranjo-García! 28 January 1992. No. shells 1, spider and spider webb.
9. *Orthalicus* sp. MEXICO, Jalisco, Estación de Biología Chamela. Camino Antiguo Norte. E. Naranjo-García! 1 February 1992. No. shells 2, spider and spider webb.
10. *Rabdotus* sp. MEXICO, Sonora, 12 km s, 13 km E Carbo near Cueva El Tigre (29 34' 30" N, 110 49' 15" W) on limestone hilltop, in crevices *Bursera* – *Pachycormus* – *Cercidium* Thornscrub. G.M. Ferguson! 6 November 1987. No. shells 2 of 7, spider webb and Diptera molt.
11. *Microceramus* sp. MEXICO, Veracruz, Cuitlahuac. Ma. T. Olivera, F. Guzmán, C. López, E. Naranjo-García! 21 August 1991. No. shells 3 of 15, Diptera molts 3.
12. *Streptostyla* sp. MEXICO, Veracruz. Estación de Biología Los Tuxtlas. R. Bonilla, P. Guadarrama, R. León, A. Rendón & E. Naranjo-García! 16 July 1991. No.

shells 1, Diplopoda 1.

13. *Humboldtiana* sp. MEXICO, Durango. Potrerillos. O.J. Polaco, F. Guzmán, R. Corral & E. Naranjo-García! 2 May 1994. No. shells 1, live *Humboldtiana* specimen with *Plagiodera* sp. (Coleoptera, Chrysomelidae) on umbilicus, both organisms were dormant.
14. *Humboldtiana* sp. MEXICO, Durango. Cajón El Potrero. O.J. Polaco, F. Guzmán, R. Corral & E. Naranjo-García! 3 May 1994. No. shells 1, spider webb.
15. *Humboldtiana* sp. MEXICO, Durango. *Ca.* 29 km from Santiago Papasquiaro to Topia. E. Naranjo-García! 26 November 1994. No. shells 1, juvenil specimen of *Humboldtiana*.
16. *Helminthoglypta fieldi* Pilsbry 1930. UNITED STATES, California, Santa Barbara Co., Ocean Beach. Santa Inez River. E. Naranjo-García! 1 July 1989. No. shells 7, Diptera molts.
17. *Helminthoglypta phlyctaena* (Bartsch, 1916). UNITED STATES, California, Santa Barbara Co. Gaviota Hot Springs State Park. E. Naranjo-García! 1 July 1989. No. shells 8, Diptera molts 7.
18. *Sonorella* sp. MEXICO, Sonora. E. Naranjo-García! Specimens collected between December 1983 and April 1987. Pseudoscopions given to Dave Zeh (pseudoscorpions specialist).

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THE UNIONIDAE (MOLLUSCA: BIVALVIA) OF THE WALHONDING RIVER, COSHOCTON COUNTY, OHIO, INCLUDING THE FEDERALLY ENDANGERED CATSPAW *(EPIOBLASMA OBLIQUATA OBLIQUATA)*, FANSHELL *(CYPROGENIA STEGARIA)*, AND CLUBSHELL *(PLEUROBEMA CLAVA)* MUSSELS

Michael A. Hoggarth

ABSTRACT – The purpose of this study was to determine the distribution of the Unionidae of the Walhonding River. It was known that this river once had a diverse community, but it was widely assumed that the fauna had been severely reduced by the construction of a flood control dam at Nellie by the Army Corps of Engineers in 1936. The river below the dam was presumably impacted by the increased siltation and substrate compaction associated with increased silt loads, while the river above the dam was supposedly impacted by the temporary closing of the dam and the flooding of the river channel. Collections by the author in 1983 appeared to confirm this assumption. However, because the river is one of two major tributaries of the Muskingum River (the other being the Tuscarawas River), and because both tributaries, and the main stem of the Muskingum River, once supported diverse unionid faunas, it was determined that a thorough study of the unionid fauna of the river should be done. The present study was begun in 1991 when the state was experiencing a mild drought. It was continued through the summers of 1992 and 1993. During the three years of the study, 8424 specimens representing 34 species or subspecies were collected. Included in this total were three species listed as endangered by the U.S. Fish and Wildlife Service and the Ohio Department of Natural Resources, Division of Wildlife *(Pleurobema clava, Cyprogenia stegaria,* and *Epioblasma obliquata obliquata),* five additional species listed as endangered in Ohio *(Quadrula cylindrica cylindrica, Fusconaia maculata maculata, Plethobasus cyphyus, Villosa fabalis,* and *Lampsilis ovata),* two species listed as threatened in the state *(Ligumia recta* and *Epioblasma triquetra*), and three species of special interest in Ohio *(Cyclonaias tuberculata, Pleurobema sintoxia* and *Lampsilis fasciola).* This represents the first time the federally endangered catspaw mussel *(E. o. obliquata)* has been collected in Ohio in 150 years. The total number of rare species, along with the large number of other species, and the densities of the mussels in this river place it among the richest streams in Ohio.

Key Words: Unionidae, Endangered Species, Walhonding River, Ohio.

INTRODUCTION

The Walhonding River is among the shortest rivers in the state. It begins in western Coshocton County at the confluence of the Mohican and Kokosing rivers and then flows to the west for a distance of 23.3

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miles before joining the Tuscarawas River to form the Muskingum River in the city of Coshocton. Over that distance the river changes very little. It remains about the same width throughout its length and has a diversity of habitats from headwaters to mouth.

Although no published report on the unionid fauna of the Walhonding River has been done, museum records indicate that it once supported a diverse fauna. This river had almost as many species as the Tuscarawas River which had a rich fauna second only to that of the Muskingum and Scioto rivers in Ohio (Sterki, 1894, 1900, 1907; Stansbery *et al.*, 1985). It is unfortunate that the Tuscarawas River has suffered so much degradation that only a remnant of that fauna remains.

The Walhonding River has not suffered this same level of development or degradation. Still some development has occurred within the first six and a half miles of the river behind Mohawk Dam, a mostly open flood control dam. Upstream of Mohawk Dam, the flood plain is in agricultural production, or in woods. State Route 715 crosses the stream at three locations upstream of the dam, but the most significant degradation occurs at the dam itself. Below the dam, which was completed in 1936, the stream flows through mostly agricultural areas and woodland habitats. Gravel mining occurs along the last ten miles of the river and the only significant residential development adjacent to the river occurs at the towns of Nellie and Warsaw. Sixmile Dam impounds the river in its lower reaches but the effects of this low head dam on the flow of the river are ameliorated within half of a mile upstream.

MATERIALS AND METHODS

Unionid mollusks were collected by hand from 18 June 1991 to 25 August 1993. Three prior collections, two on 15 July 1983, and one on 19 September 1989 were included in this study. Appendix 1 lists all of the site specific collection records for the study.

An attempt was made to locate all concentrations of unionid mollusks throughout the length of the river. This was done by sight collecting along the shore combined with searches for living mussels by sight and by hand. A canoe was used to increase accessibility to the river. Throughout the three years of the study, the entire length of the river was canoed at least once, and some reaches were canoed repeatedly. All living mussels, freshly dead shells, and old dead shells were collected. After being collected, the mollusks were identified, counted, and either returned (living mussels) or retained as vouchers (freshly dead shells and selected old dead shells). Specimens returned to the river were replaced posterior end up in the same area from which they were taken. The location of each mussel bed was indicated on an appropriate 7.5 minute topographic map and the location of each collection site was set by triangulation with nearby towns. Mussel beds were identified as large assemblages of mixed species of mussels located in clearly delineated reaches of the river. Fig. 1 shows the location and approximate length of each mussel bed.

RESULTS

Table 1 lists the composition of the unionid community of the Walhonding River. Since so many living mussels occur in this river, it became apparent, that most of the effort used in this study should be directed toward locating living mussels since this would be of greater informational value than the same type of data relative to dead shells. Hence, the collection of living mussels became the priority of the study and a large number of living mussels (7997) compared to dead and old dead (427) shells were taken. All freshly dead specimens found were collected and retained as vouchers, but only uncommon and rare old dead shells were retained on a regular basis. It should be noted that old dead shells of some otherwise more common species were taken if that species happened to be uncommon at the particular collection site (see Appendix 1, p. 165).

The abundance data for the Unionidae of the Walhonding River demonstrates that the fauna is dominated by the mucket *(Actinonaias ligamentina carinata)* and threeridge *(Amblema plicata plicata).* These species are not among the most common members of the unionid fauna of the state, but can be abundant in fairly high quality streams throughout their range. The third most abundant species, the white heelsplitter *(Lasmigona complanata complanata),* is quite adaptable, and can be found in fairly degraded water to fairly high quality water in larger streams. It is the only mussel the author found living in the Muskingum River at the mouth of the Tuscarawas River. Other species that comprised one percent of this fauna or greater were *Lampsilis radiata luteola* (6.44%), *Lasmigona costata* (6.26%), *Lampsilis cardium* (2.25%), *Strophitus undulatus undulatus (2.05%), Tritogonia verrucosa* (1.81%), *Cyclonaias tuberculata* (1.54%), *Pyganodon grandis* (1.36%), and *Quadrula pustulosa pustulosa* (1.13%). This group of species consists of some of the most common and tolerant species of Unionidae that occur in the state as well as some of the most sensitive and uncommon species. This relationship is characteristic of good water quality and a diversity of habitats.

Another important indicator of habitat quality and water resource integrity, was the occurrence of rare and endangered species. The Walhonding River supports many such species of Unionidae. Three species listed as endangered by the U.S. Fish and Wildlife Service and the Ohio Department of Natural Resources, Division of Wildlife

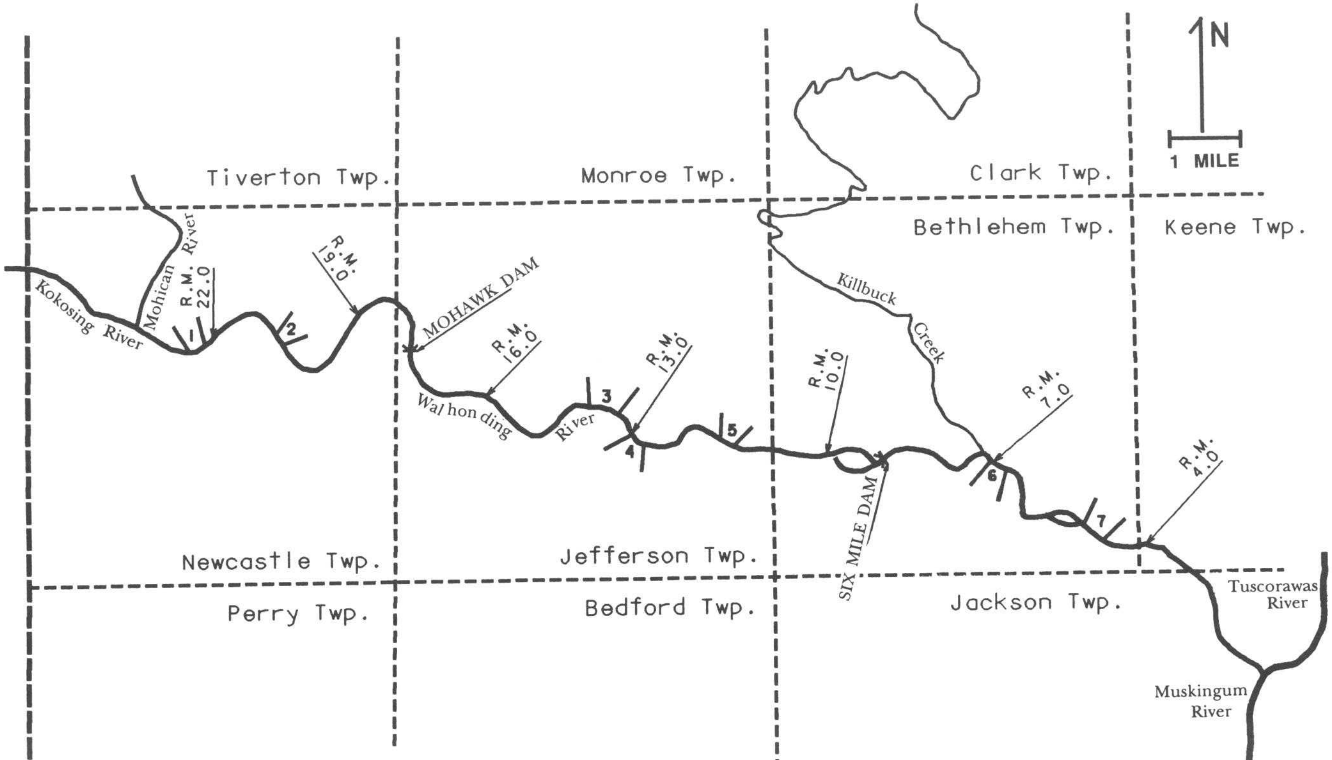

FIG. 1. Map of the Walhonding River in Coshocton County, Ohio, showing the distribution of mussel beds and major tributary rivers.

TABLE 1. Unionidae collected from the Walhonding River 1991-1993. Live = collected alive during this study. Dead = collected as freshly dead shells (dead approximately one year). Historic = collected as weathered or subfossil shells (dead longer than five years).

Species	Live		Dead	Historic	Total	
U. imbecillis	3	0.04%	1	0	4	0.05%
P. grandis	109	1.36%	9	4	122	1.45%
S. u. undulatus	164	2.05%	36	4	204	2.42%
A. marginata	47	0.59%	5	8	60	0.71%
L. c. complanata	1056	13.21%	18	2	1076	12.77%
L. costata	501	6.26%	9	14	524	6.22%
L. compressa	10	0.13%	2	3	15	0.18%
T. verrucosa	145	1.81%	2	10	157	1.86%
Q. quadrula	14	0.18%	0	2	16	0.19%
Q. c. cylindrica[a]	20	0.25%	0	15	35	0.42%
Q. p. pustulosa	90	1.13%	5	17	112	1.33%
A. p. plicata	1909	23.87%	16	6	1931	22.92%
F. m. maculata[a]	7	0.09%	0	16	23	0.27%
F. flava	37	0.46%	9	3	49	0.58%
C. tuberculata[b]	123	1.54%	4	5	132	1.57%
P. cyphyus[a]	5	0.06%	0	7	12	0.14%
P. clava[a,d]	0	0.00%	1	14	15	0.18%
P. sintoxia[b]	1	0.01%	0	4	5	0.06%
E. dilatata	16	0.20%	1	20	37	0.44%
P. fasciolaris	10	0.13%	3	11	24	0.29%
C. stegaria[a,d]	0	0.00%	0	13	13	0.15%
A. l. carinata	3187	39.85%	27	6	3220	38.22%
O. subrotunda	7	0.09%	1	12	20	0.24%
L. fragilis	25	0.31%	9	2	36	0.43%
P. alatus	2	0.03%	0	0	2	0.02%
L. recta[c]	24	0.30%	1	8	33	0.39%
V. fabalis[a]	1	0.01%	1	4	6	0.07%
V. i. iris	31	0.39%	2	2	35	0.41%
L. r. luteola	515	6.44%	20	1	536	6.36%
L. cardium	180	2.25%	8	6	194	2.30%
L. ovata[a]	8	0.10%	0	3	11	0.13%
L. fasciola[b]	42	0.53%	1	7	50	0.59%
E. triquetra[c]	8	0.10%	1	5	14	0.17%
E. o. obliquata[a,d]	0	0.00%	1	0	1	0.01%
Totals	7997		193	234	8424	

a - Endangered in Ohio; b - Special Interest in Ohio; c - Threatened in Ohio; d - Federally Listed Endangered Species.

(Pleurobema clava, Cyprogenia stegaria, and *Epioblasma obliquata obliquata)* were located in this river. Five additional species listed as endangered in Ohio (*Quadrula cylindrica cylindrica, Fusconaia maculata maculata, Plethobasus cyphyus, Villosa fabalis,* and *Lampsilis ovata*), two species listed

as threatened in the state *(Ligumia recta* and *Epioblasma triquetra)*, and three species of special interest in Ohio *(Cyclonaias tuberculata, Pleurobema sintoxia* and *Lampsilis fasciola)* also occur in this river. Rare species comprised 38% of the species that were found to occur in the river and represented 2.99% of the living unionids located during this study.

Many species were distributed throughout the length of the river. Some of these species were found in impressive numbers, mostly in the mussel beds identified in Fig. 1. Included in this group were *Lasmigona costata, Amblema plicata plicata, Cyclonaias tuberculata, Actinonaias ligamentina carinata, Lampsilis cardium* and *Lampsilis fasciola.* Other species were common but not usually found in mussel beds. These species were generally more abundant along the margin of the river in slowly moving to slack water and included *Pyganodon grandis, Strophitus undulatus undulatus, Lasmigona complanata complanata, Tritogonia verrucosa* and *Lampsilis radiata luteola.* Still other species were fairly uncommon but widely distributed including *Utterbackia imbecillis, Lasmigona compressa, Quadrula quadrula, Plethobasus cyphyus, Elliptio dilatata, Ptychobranchus fasciolaris* and *Obovaria subrotunda.* Some species were more common in the upper reaches *(Quadrula cylindrica cylindrica, Fusconaia maculata maculata, Fusconaia flava, Pleurobema clava,* and *Villosa iris iris)* while others were more common in the lower reaches *(Alasmidonta marginata, Quadrula pustulosa pustulosa, Leptodea fragilis, Potamilus alatus, Ligumia recta, Villosa fabalis, Lampsilis ovata, Epioblasma triquetra* and *Epioblasma obliquata obliquata).* The federally listed endangered fanshell, *Cyprogenia stegaria,* was once fairly abundant in the lower reaches of the Walhonding River but only old dead shells of this species were found during this study indicating that the species has been extirpated from the river.

The following species accounts are for all of the species of Unionidae that have been reported for the Walhonding River. All but *Quadrula metanevra, Pleurobema rubrum, Ligumia nasuta* and *Epioblasma rangiana,* were found during the present study. These species have been recorded for the Walhonding River, but they have not been found in the river in many years. Extant populations of all of the remaining species listed below, except *Cyprogenia stegaria,* were located. This list includes many species never before recorded for the Walhonding River (according to Stansbery *et al.*, 1985).

SPECIES ACCOUNTS

Utterbackia imbecillis (Say 1829) (paper pondshell) was sporadically encountered in the present study. It was located along the margin of the river away from the main current in a muck to silt substrate. It was generally found with *Pyganodon grandis* and *Lampsilis radiata luteola.*

Only four specimens of the paper pondshell were found during this study and the species only comprised 0.05% of the total number of unionid mollusks found. Within the Muskingum River system, literature records for this species indicate its occurrence only in the Muskingum and Tuscarawas rivers.

Pyganodon grandis (Say 1829) (giant floater) is one of the most widespread and abundant species in Ohio. Stansbery *et al.* (1985) state that museum records and literature accounts place this species throughout the Muskingum River system. The species occurred throughout most of the Walhonding River with a slightly larger population above Mohawk Dam (sites 1-7) than below the dam. The species comprised 1.45% of the unionids collected during this study with 109 living specimens found.

Strophitus undulatus undulatus (Say 1817) (squawfoot) was the sixth most abundant mollusk found during this study. It comprised 2.42% of all the mollusks found with 164 living and 36 freshly dead specimens collected. It was found at most of the collection sites with no clear center of abundance (either above or below Mohawk Dam). Literature accounts and museum records place this species throughout the Muskingum River system.

Alasmidonta marginata (Say 1818) (elktoe) is distributed throughout the Muskingum River system (museum records) although the scarcity of literature records for this species in the watershed would tend to suggest that it is rare. Within the Walhonding River, the elktoe is found only in the lowermost 13 river miles and is common only at a riffle at river mile 7.3. This species was found completely buried in firm sand, gravel, and cobble substrate within a well developed riffle that extended the entire length of the river. Only 60 specimens were found during the current study and the species comprised only 0.71% of the fauna collected during this study.

Lasmigona complanata complanata (Bames 1823) (white heelsplitter) was one of the most abundant species encountered during the present study and was particularly abundant at two sites (river mile 7.3 in a slack water area behind a sand-gravel bar adjacent to the riffle located at the site, and river mile 22.2 where it was widely distributed but was most common along the depositional bank away from the main current). Stansbery *et al.* (1985) state that this species is widespread in the system. It is tolerant of silt and is becoming more widespread and more abundant in the state. In the current study it comprised 12.77% of the unionid fauna with 1056 living specimens collected. The species was collected alive at every station on the river.

Lasmigona costata (Rafinesque 1820) (fluted-shell) was as widely distributed as the white heelsplitter but it was not as abundant. This species was generally encountered in swift current, in shallow (3 inches) to much deeper (3 feet) water. It was usually found almost entirely buried except that the posterior margin of the shell of older individuals was elevated an inch or more above the level of the substrate. Young individuals (less than 5 years of age) were generally completely buried. This species comprised 6.22% of the unionid fauna of the river with 501 living specimens collected. The species was most abundant at river mile 22.2 where it outnumbered the white heelsplitter in population density. Stansbery *et al.* (1985) found this to be a widespread species within the Muskingum River system.

Lasmigona compressa (Lea 1829) (creek heelsplitter) is not a common species in the Muskingum River system (Stansbery *et al.*, 1985) but it is relatively widespread. A few widely distributed specimens were found throughout the length of the Walhonding River with the most living individual encountered along the margin of the river at river mile 22.2. This species comprised 0.18% of the unionid fauna of the river and only 10 living specimens were found.

Tritogonia verrucosa (Rafinesque 1820) (pistolgrip) was widely distributed but not very common in the Walhonding River. It was collected at every site except near the mouth of the river and was most abundant at river mile 4.8 where it was taken from run habitats, partially buried in gravel and sand, and from slack water habitats in silt and sand. This species comprised 1.86% of the unionid fauna of the river with 145 living specimens collected. Stansbery *et al.* (1985) found this to be a widely distributed species within the Muskingum River system but not a common species.

Quadrula quadrula (Rafinesque 1820) (mapleleaf) is common throughout the length of the Muskingum River and the lower reaches of its larger tributaries, but it has not been recorded from the Walhonding River (Stansbery *et al.*, 1985). During the present study 14 living specimens of the mapleleaf were collected. This species comprised 0.19% of the unionid fauna of the river and was most abundant at river mile 4.8. It was only encountered at four sites, one above Mohawk Dam and the others near the mouth of the river.

Quadrula cylindrica cylindrica (Say 1817) (rabbitsfoot) is a state endangered species. Museum records indicate that it was once widely distributed in the Walhonding and Mohican rivers and although most Muskingum River records are for old dead shells, Bates (1970) and Stansbery and King (1983) record this species for the upper reaches of that river. In the present study the rabbitsfoot comprised 0.42% of the total unionid fauna collected and 0.25% of the living mussels found. It was most abundant upstream of Mohawk Dam with 12 living specimens found at river mile 22.2. Most of the specimens encountered were older individuals but two juvenile specimens were collected, one at river mile 22.2 and the other at river mile 15.4 below the dam.

Quadrula metanevra (Rafinesque 1820) (monkeyface) is a state endangered species. It was not taken during the present study but was reported from the Walhonding River by Lea (1862). Stansbery *et al.* (1985) stated that this record is of historic importance and that this species is restricted to the lower reaches of the main stem of the Muskingum River in Ohio.

Quadrula pustulosa pustulosa (Lea 1831) (pimpleback) occurred throughout the Muskingum River and the lower reaches of its larger tributaries (Stansbery *et al.*, 1985). In the present study this species was fairly common within the lower 7.5 miles of the river and was abundant at river mile 4.8 where it was found in swift current completely buried in sand, gravel, and cobble substrate. This species comprised 1.33% of the total unionid fauna of the river and 1.13% of the living mussels found with 90 living specimens collected.

Amblema plicata plicata (Say 1817) (threeridge) was the second most abundant mussel found during the present study (22.92% of the total fauna) with 1909 living specimens collected. Although common at every station except near the mouth of the river, this species was abundant upstream of Mohawk Dam in swift water in a cobble, gravel, and sand substrate to slack water in a silt and gravel substrate. Stansbery *et al.* (1985) state that this is a common and widespread species in the watershed.

Fusconaia maculata maculata (Rafinesque 1820) (long-solid) is an endangered species in Ohio. Stansbery *et al.* (1985) state that the present range of this species in Ohio may be limited to the lower reaches of the Muskingum River although there are records for the species in the larger tributaries of that river. During the present study, the long-solid was taken alive at two sites and as old dead shells at seven other sites. Although rare within the river, it was frequently found in the fast riffle and run habitats at river mile 22.2. This species comprised 0.27% of the unionid fauna of the river but only 0.09% of the living mussels collected.

Fusconaia flava (Rafinesque 1820) (Wabash pigtoe) occurs from the lower reaches of the Muskingum River to the smaller tributaries within this watershed (Stansbery *et al.*, 1985). In the present study the Wabash pigtoe was collected sporadically both upstream and downstream of

Mohawk Dam but was only common in the sand and gravel substrate of the run habitats at river mile 22.2. This species comprised 0.58% of the total fauna of the river with 37 living specimens collected.

Cyclonaias tuberculata (Rafinesque 1820) (purple wartyback) was widely distributed in the Walhonding River and was fairly common at four sites on the river (river miles 22.2, 13.7, 7.5, and 4.8). This species comprised 1.57% of the total fauna of the river and 1.54% of the living mussels taken with 123 specimens collected. Stansbery *et al.* (1985) state that the species occurred in the Walhonding River and that literature and museum records indicate that it was widely distributed in the system. This species is listed as Special Interest in Ohio.

Plethobasus cyphyus (Rafinesque 1820) (sheepnose) is a state endangered species. Literature records indicate that this species was present in the Tuscarawas River until the early 1900's (Sterki, 1907) and still exists in the lower Muskingum River (Stansbery and King, 1983). Stansbery *et al.* (1985) stated that, "...this species made up part of the high unionid diversity in the Mohican and Walhonding Rivers before the closing of Mohawk Dam during a period of high flow. It has not been seen living there since that time." During the present study, five living specimens were collected including one two year old specimen collected from a riffle habitat near White-Woman Rock, upstream of the C.R. 23 bridge. This species comprised 0.14% of the total unionid fauna and only 0.09% of the living mussels collected.

Pleurobema clava (Lamarck 1819) (clubshell) is listed as endangered in Ohio and by the U.S. Fish and Wildlife Service. Stansbery *et al.* (1985) state that museum records show that this species has recently lived in the Walhonding and Mohican rivers, but that no living or freshly dead specimens have been taken in the past decade from anywhere in the Muskingum River system. During the present study, one freshly dead specimen was collected from shallow water at river mile 22.2. The specimen had just recently died as the adductor muscles were still attached to the shell. This species was once common in the Walhonding River as the 14 old dead shells suggest, but it is very rare today.

Pleurobema sintoxia (Rafinesque 1820) (round pigtoe) is a widespread but uncommon species in the Muskingum River system (Stansbery *et al.*, 1985). Only one living specimen of this Ohio Special Interest species was collected, and only 4 other shells were taken from the entire river.

Pleurobema rubrum (Rafinesque 1820) (pyramid pigtoe) once occurred in the Ohio River and many of its larger tributaries in Ohio including the Muskingum, Scioto, Tuscarawas, Mohican and Walhonding rivers. It was not collected in the present study and has not been taken in any of these streams recently except the lower Muskingum River (Stansbery *et al.*, 1982). It is listed as endangered in Ohio.

Elliptio dilatata (Rafinesque 1820) (spike) is a widespread but uncommon species in the Muskingum River system (Stansbery *et al.*, 1985). This species comprised 0.44% of the unionid fauna of the Walhonding River but only 0.20% of the living specimens collected. It was widely distributed in the river and was most abundant at river mile 22.2.

Ptychobranchus fasciolaris (Rafinesque 1820) (kidneyshell) is a widespread but uncommon species in the Muskingum River system (Stansbery *et al.*, 1985). It was fairly widely distributed in the Walhonding River but it was not common at any one site. The kidneyshell comprised 0.29% of the total unionid fauna of the river and only 0.13% of the living mussels collected.

Cyprogenia stegaria (Rafinesque 1820) (fanshell) is an Ohio and Federal Endangered species. It was once fairly abundant in the Walhonding River at Camp Tonowanda (Site 10, river mile 13.7) but it has not been collected there since Mohawk Dam was constructed (Stansbery *et al.*, 1985). During the present study only thirteen old dead shells of this species were found. All of these shells were found from Camp Tonowanda downstream. This species has apparently been extirpated from the Walhonding River but still persists in the lower Muskingum River in Ohio.

Actinonaias ligamentina carinata (Barnes 1823) (mucket) has replaced its sister species *Actinonaias ligamentina ligamentina* over the last 100-150 years. Both subspecies were present in the Muskingum River system during the early 1800's but today only *A. l. carinata* persists in this drainage basin. This subspecies is widely distributed in the Muskingum River system (Stansbery *et al.*, 1985) and is widely distributed and abundant in the Walhonding River. It comprised the largest percentage of the unionid mollusks collected during the present study (38.22%) with 3187 living specimens found. This subspecies was common at many sites on the river, but was very abundant at river mile 22.2, river mile 13.7, and at river mile 4.8. At each location this mussel was found in fairly swift current in a substrate of cobble, gravel, and sand.

Obovaria subrotunda (Rafinesque 1820) (round hickorynut) was found sporadically from river mile 22.2 to river mile 0.0. It was never common, with one living specimen located at each of five sites, and two living specimens located at one site. This species comprised 0.24% of the total unionid fauna collected from the river. Stansbery *et al.* (1985) reported this species from the Muskingum River main stem, and Sterki (1894) found this to be a common species in the Tuscarawas River.

Leptodea fragilis (Rafinesque 1820) (fragile papershell) is common in the main stem of the Muskingum River (Stansbery *et al.*, 1985) but it had not been reported for any tributary of that river. This species comprised 0.43% of the unionid fauna found during this study with a total of 17 specimens taken between river mile 7.5 and 6.8. This species was found in the lower 7.5 miles of the Walhonding River. Its only known host is the freshwater drum *(Aplodinotus grunniens)* which is also probably limited to the lower reaches of this river (Hoggarth, 1992b).

Potamilus alatus (Say 1817) (pink heelsplitter) is another common main stem Muskingum River species that also has been found in some lower Muskingum River tributaries (Stansbery *et al.*, 1985). It apparently has not been recorded for the Tuscarawas River (Sterki, 1907; Ortmann, 1924) and has just recently moved into the Walhonding River. During the present study two living individuals were located at river mile 4.8. No other specimens of this species were taken. The species comprised only 0.02% of the total unionid fauna collected during this study. This is another species that uses the freshwater drum as host for its glochidia (Hoggarth, 1992b).

Ligumia recta (Lamarck 1819) (black sandshell) is an uncommon species in the Muskingum River (Stansbery *et al.*, 1985) but was fairly common in the Walhonding River. This species is listed as threatened by the state of Ohio. It comprised 0.39% of the total fauna collected during this study with 25 living specimens taken. It was found alive from the headwaters of the river to its mouth, but the largest number of individuals were taken near the C.R. 23 bridge at river mile 4.8. This species was commonly taken in six inch to one foot deep water, near the bank, in slack or slowly moving water. It was usually found slightly buried in the substrate with a large area of the posterior margin exposed. Both adult and juvenile specimens were taken. The younger specimens were generally found buried deeper in the substrate.

Ligumia nasuta (Say 1817) (eastern pondmussel) occurs in Lake Erie, the upper Cuyahoga River, and in Muzzy Lake of the Cuyahoga River drainage. It was once found in the Portage River but no recent records confirm its continued existence in that river. Sullivant (1838) recorded this species from the Walhonding River and Eggleston found it in the Muskingum River in 1929 (Stansbery *et al.*, 1982). This state endangered species has not been found in the Muskingum River system since.

Villosa fabalis (Lea 1831) (rayed bean) is listed as endangered in Ohio. This species was taken alive at only one site, at river mile 6.8 near a muskrat burrow. The freshly dead specimen collected at this same site had been eaten by the muskrat and the shell was discarded with other species near the mouth of this burrow. This species was reported for the Muskingum River system by Sterki (1894, 1900) and Ortmann (1919) but has not been recorded from the system since. This species is rare in the Walhonding River and only comprised 0.07% of the total fauna collected.

Villosa iris iris (Lea 1829) (rainbow) has been taken from Muskingum River tributaries but not the Muskingum River itself (Stansbery *et al.*, 1985). It has a fairly wide distribution in the Walhonding River but was only common in the shallow, slow water adjacent to the run habitats at river mile 22.2. This species comprised 0.41% of the unionids collected and was found alive at four sites.

Lampsilis radiata luteola (Lamarck 1819) (fatmucket) is one of the most common species of unionid mollusks in Ohio. It inhabits slow run to pool habitats and is often found along the margins of streams. This species comprised 6.36% of the total fauna collected with 515 live specimens found. This is a widespread species within the Muskingum River system (Stansbery *et al.*, 1985) and it was widely distributed in the Walhonding River as well.

Lampsilis cardium Rafinesque 1820 (plain pocketbook) was as widely distributed in the Walhonding River as the fatmucket but it was not as common. This specie comprised 2.30% of the unionids collected but it was not abundant except at river mile 22.2 and at river mile 4.8. This species was found in fairly swift to moderately flowing water in a substrate of gravel and sand. Specimens were often buried except for the posterior end of the shell. This species is widespread within the Muskingum River system (Stansbery *et al.*, 1985).

Lampsilis ovata (Say 1817) (pocketbook) is a state endangered species. It has been reported from the Muskingum River (Stansbery and King, 1983) and from the Walhonding and Mohican rivers (Putnam, 1971). It is still extant in the Walhonding River but it is not a common member of the fauna. It was taken alive at six sites on the river although the most taken at any one site was two individuals. The species comprised 0.13% of the fauna and only 8 living specimens were collected.

Lampsilis fasciola (Rafinesque 1820) (wavy-rayed lampmussel) is a special interest species in the state of Ohio. This species is widespread in the Muskingum River system but it is not common wherever it is found (Stansbery *et al.*, 1985). Forty two living specimens were collected during this study and the species comprised 0.59% of the unionids found. It was usually taken in very swift current, completely buried in the cobble and gravel substrate.

Epioblasma triquetra (Rafinesque 1820) (snuffbox) is a threatened species in Ohio. It is never a common member of the fauna and is quite often only found as single individuals. In the present study living snuffbox were collected at two sites, both in the lower reaches of the river. Two living specimens were taken at river mile 4.8 near the C.R. 23 bridge, and six living specimens were taken at river mile 6.8 near the mouth of Killbuck Creek. This species has been reported from the Tuscarawas and Muskingum rivers (Stansbery *et al.*, 1985) although it is questionable whether it is still extant in the Tuscarawas River given the age of the records (1890's and early 1900's) and the condition of the river.

Epioblasma rangiana (Lea 1839) (northern riffleshell) is listed as endangered by the U.S. Fish and Wildlife Service and by the Ohio Department of Natural Resources, Division of Wildlife. Stansbery *et al.* (1982) stated that this species has been found as subfossil shells in the Walhonding River. Today this species is apparently restricted to Big Darby Creek and Fish Creek in Ohio (U.S. Fish and Wildlife Service, 1993).

Epioblasma obliquata obliquata (Rafinesque 1820) (catspaw) is a federally listed endangered species. This species occurred in the Muskingum River and Ohio River well over 150 years ago (Stansbery *et al.*, 1982) and from the Licking River (in Ohio) around that same time period (Hoggarth *et al.*, 1995). During the present study a single freshly dead specimens was found. It was collected from a sand bar adjacent to a riffle at river mile 6.8, downstream of the mouth of Killbuck Creek. No other specimens (old dead, fresh, or living) were collected but abundant suitable habitat is present at this site, and downstream to support this species. Other populations of this species occur in two isolated sites on the Green River in Kentucky and the Cumberland River in Tennessee (Stansbery *et al.*, 1982). During the summer of 1994, a large population of this very rare species was found in Killbuck Creek, a tributary of the Walhonding River (Hoggarth *et al.*, 1995).

DISCUSSION

Recent studies of the Unionidae of complete river systems in Ohio have demonstrated that these rivers support a strikingly different fauna today than in the past (Hoggarth, 1990a, 1990b, 1991, 1992a; Watters, 1992). Generally, these studies have shown that the fauna is much less diverse today than in the past, that the tolerant members of the community have become dominant in the system, and that tolerant species have invaded areas from where they had not been previously recorded. This is not true to the same extent in Ohio's less disturbed watersheds which include Big Darby Creek and Fish Creek (Hoggarth, 1986; Watters, 1988, 1990). The Walhonding River appears to be among the latter group of streams.

The fauna of the Walhonding River today is similar to its historic assemblage of species. Thirty eight species have been reported from the Walhonding River (these collections, museum records, and literature records). Of this total fauna, 33 species still maintain extant populations in the river. Not only are many of its original species still part of its current fauna, but the Walhonding River supports a large number of rare and endangered species. Both of these aspects of the river's unionid fauna suggest that this river is among the most diverse and stable in the state.

Two sites on the river are particularly diverse. The river above the State Route 715 bridge immediately downstream of the confluence of the Kokosing and Mohican rivers, supports a large number of species and an impressive number of individuals. A well defined bed is located at this site. It begins at the head of a fast riffle that stretches across the entire length of the river and extends upstream for approximately one tenth of a mile. It is located along the southern boarder of the stream and extends approximately one half the width of the river throughout much of its length. A total of 24 species, all of them extant, were collected from this bed. This list included four state endangered species, one of which is also listed as endangered by the U.S. Fish and Wildlife Service.

The other diverse site is located downstream of the mouth of Killbuck Creek. This bed consists of a total of 25 species, all but three extant, including four state endangered species, one of which is listed as endangered by the U.S. Fish and Wildlife Service, and another that is currently being considered for listing. This bed is located on and adjacent to an extensive riffle that extends across the river. Many of the living mussels were taken from a run along the northern border of the riffle. Other specimens were taken from the riffle and from the extensive run habitats upstream of this riffle.

Other beds, located throughout the length of the river, were less diverse but were often quite densely populated by mussels. Many of these beds were dominated by *Actinonaias ligamentina carinata* and

Amblema plicata plicata, but were also found to contain rare and endangered species. Only very short reaches of the river were devoid of unionid mollusks. The longest reach, containing only silt tolerant species or no species, was the reach from Mohawk Dam to approximately one half mile downstream of the State Route 715 bridge (the first bridge upstream of the dam). The impoundment behind Sixmile Dam also was devoid of unionid mollusks. The unionid fauna recovers rapidly upstream of the head of that impoundment.

Given the large number of unionid species in this river, the number of rare and endangered species, the wide ranging distribution of many of these species, and the small number of threats to this riverine environment, this river and its fauna may provide many opportunities for studying the biology of the Unionidae.

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APPENDIX 1. Site specific collection records. These data are arranged from the headwaters of the Walhonding River to its mouth.

Site#1 – River Mile 23.3-21.9

Walhonding River, R.M. 23.3-21.9, from the confluence of the Mohican and Kokosing rivers to SR 715 bridge, 0.3 mi. SE of Walhonding, 3.8 mi. WNW of Nellie, Newcastle Twp., Coshocton Co., Ohio.

MAH:1991:41 1 September 1991 M.A. Hoggarth, Karen Cook-Hoggarth & Mark Hoggarth.

Pyganodon grandis	2 live
Strophitus undulatus undulatus	5 dead
Lasmigona complanata complanata	33 live, 3 dead
Lasmigona covtata	15 live, 4 dead
Lasmigona compressa	1 live
Tritogonia verrucosa	3 live, 1 weathered
Quadrula cylindrica cylindrica	2 live, 2 weathered
Amblema plicata plicata	100 live, 1 dead, 1 weathered
Fusconaia maculata maculata	2 weathered
Fusconaia.flava	1 live, 1 weathered
Cyclonaias tuberculate	1 live, 1 weathered
Elliptio dilatata	1 dead
Actinonaias ligamentina carinata	100 live, 4 dead
Ligumia recta	1 dead
Lampsilis radiata luteola	33 live, 1 dead
Lampsilis cardium	3 live

Site #2 - River Mile 22.2-22.1

Walhonding River, R.M. 22.2-22.1, upstream of SR 715 bridge, 0.3 mi. SE of Walhonding, 3.8 mi. WNW of Nellie, Newcastle Twp., Coshocton Co., Ohio.

MAH:1991:40 31 August 1991 M.A. Hoggarth.
MAH:1992:24 15 June 1992 M.A. Hoggarth and Mark Hoggarth.
MAH:1992:31 29 June 1992 M.A. Hoggarth and Mark Hoggarth.
MAH: 1992:33 3 July 1992 M.A. Hoggarth and Mark Hoggarth.
MAH: 1992:34 4 July 1992 M.A. Hoggarth.
MAH:1992:36 17 August 1992 M.A. Hoggarth.
MAH:1992:37 24 August 1992 M.A. Hoggarth and Dan Rice.
MAH:1992:41 12 September 1992 M.A. Hoggarth and Chuck Boucher.
MAH:1992:42 26 September 1992 M.A. Hoggarth, D. Best, L. Grieszmer & C. Mattingly.
MAH:1993:56 23 August 1993 M.A. Hoggarth, D. Rice, S. Lewis, C. Divolviss, Y. Alley.

Utterbackia imbecillis	1 live
Pyganodon grandis	16 live
Strophitus undulatus undulatus	17 live, 3 dead
Lasmigona complanata complanata	180 live, 1 dead
Lasmigona costata	216 live
Lasmigona compressa	4 live, 1 dead
Tritogonia verrucosa	19 live
Quadrula quadrula	3 live
Quadrula cylindrica cylindrica	10 live, 2 dead, 1 weathered
Quadrula pustulosa pustulosa	2 live
Amblema plicata plicata	673 live, 1 dead
Fusconaia maculata maculata	6 live
Fusconaia flava	23 live, 1 dead
Cyclonaias tuberculata	17 live, 1 dead
Plethobasus cyphyus	1 live

Pleurobema clava	1 dead
Elliptio dilatata	8 live, 1 weathered
Ptychobranchus fasciolaris	1 dead
Actinonaias ligamentina carinata	672 live, 4 dead
Obovaria subrotunda	1 live
Villosa iris iris	23 live
Lampsilis radiata luteola	134 live, 2 dead
Lampsilis cardium	37 live, 2 dead
Lampsilis fasciola	12 live

Site #3 - River Mile 21.9-20.5

Walhonding River, R.M. 21.9-20.5, from S.R. 715 bridge, 0.3 mi. SE of Walhonding, 3.8 mi. of Nellie, to S.R. 715 bridge, 1.2 mi. ESE of Walhonding, 2.7 mi. WNW of Nellie, Newcastle Twp., Coshocton Co., Ohio.

MAH:1992:42 1 September 1992 M.A. Hoggarth.

Pyganodon grandis	1 live, 1 dead
Strophitus undulatus undulatus	3 dead
Lasmigona complanata complanata	25 live, 2 dead
Lasmigona costata	7 live, 1 dead
Lasmigona compressa	1 dead
Tritogonia verrucosa	7 live, 1 weathered
Quadrula cylindrica cylindrica	2 live, 1 weathered
Amblema plicata plicata	100 live, 1 dead
Fusconaia maculata maculata	2 weathered
Fusconaia flava	1 live, 1 dead
Actinonaias ligamentina carinata	100 live, 3 dead
Obovaria subrotunda	1 weathered
Villosa iris iris	1 weathered
Lampsilis radiata luteola	33 live, 3 dead
Lampsilis cardium	2 live, 1 dead

Site #4 – River Mile 20.5-20.2

Walhonding River, R.M. 20.5-20.2, at S.R. 715 bridge, 1.2 mi. ESE of Walhonding, 2.7 mi. WNW of Nellie, Newcastle Twp., Coshocton Co., Ohio.

MAH:1983:15 15 July 1983 M.A. Hoggarth & G.T. Watters.
MAH:1991:45 9 September 1991 M.A. Hoggarth.

Utterbackia imbecillis	2 live
Pyganodon grandis	42 live, 1 dead
Strophitus undulatus undulatus	32 live
Lasmigona complanata complanata	83 live, 4 dead
Lasmigona costata	17 live, 1 dead
Lasmigona compressa	2 live, 2 weathered
Tritogonia verrucosa	3 live, 1 weathered
Quadrula cylindrica cylindrica	2 live, 8 weathered
Amblema plicata plicata	100 live, 4 dead
Fusconaia flava	1 live, 2 dead

Cyclonaias tuberculata	1 live
Plethobasus cyphyus	1 weathered
Pleurobema clava	4 weathered
Pleurobema sintoxia	1 weathered
Elliptio dilatata	4 weathered
Actinonaias ligamentina carinata	101 live, 4 dead
Obovaria subrotunda	4 weathered
Ligumia recta	2 weathered
Villosa iris iris	1 weathered
Lampsilis radiata luteola	53 live, 3 dead
Lampsilis cardium	6 live, 2 dead

Site #5 – River Mile 19.6-19.3

Walhonding River, R.M. 19.6-19.3, above S.R. 715 bridge, 2.4 mi. WNW of Nellie, 14.2 mi. WNW of Coshocton, Newcastle Twp., Coshocton Co., Ohio.

MAH:1993:55 20 August 1993 M.A. Hoggarth, Dan Rice & Stacy Xenakis.

Pyganodon grandis	6 live
Strophitus undulatus undulatus	11 live
Lasmigona complanata complanata	81 live
Lasmigona costata	16 live
Tritogonia verrucosa	1 live
Amblema plicata plicata	212 live
Fusconaia flava	5 live
Cyclonaias tuberculata	5 live
Plethobasus cyphyus	1 live
Actinonaias ligamentina carinata	270 live
Obovaria subrotunda	1 live
Ligumia recta	2 live
Villosa iris iris	1 live
Lampsilis radiata luteola	40 live
Lampsilis cardium	5 live
Lampsilis fasciola	4 live

Site #6 – River Mile 19.3-17.4

Walhonding River, R.M. 19.3-17.4, from S.R. 715 bridge, 2.1 mi. E. of Walhonding, 2.0 mi. WNW of Nellie, to Mohawk Dam, 3.0 mi. E. of Walhonding, 0.8 mi. NW of Nellie, Newcastle/Jefferson Twp., Coshocton Co., Ohio.

MAH:1991:47 15 September 1991 M.A. Hoggarth, K. Cook-Hoggarth, M. Hoggarth, *et al.*

Pyganodon grandis	12 live
Strophitus undulatus undulatus	3 live, 2 dead
Lasmigona complanata complanata	32 live, 4 dead
Lasmigona costata	13 live, 1 dead
Tritogonia verrucosa	2 live, 1 weathered
Quadrula cylindrica cylindrica	1 live
Amblema plicata plicata	59 live, 2 dead, 2 weathered
Ptychobranchus fasciolaris	1 weathered
Actinonaias ligamentina carinata	100 live

Lampsilis radiata luteola	15 live, 2 dead
Lampsilis cardium	3 live

Site #7 – River Mile 19.3-19.1

Walhonding River, R.M. 19.3-19.1, at S.R. 715 bridge, 2.4 mi. WNW of Nellie, 14.2 mi. WNW of Coshocton, Newcastle Twp., Coshocton Co., Ohio.

MAH:1983:17 15 July 1983 M.A. Hoggarth & G.T. Watters.

MAH:1989:123 19 September 1989 M.A. Hoggarth.

MAH:1991:16 18 June 1991 M.A. Hoggarth & James Koren.

Pyganodon grandis	2 live, 3 dead, 2 weathered
Strophitus undulatus undulatus	5 live, 3 dead
Lasmigona complanata complanata	15 live, 1 weathered
Lasmigona costata	1 live, 10 weathered
Tritogonia verrucosa	1 live, 1 weathered
Quadrula cylindrica cylindrica	5 weathered
Amblema plicata plicata	72 live, 3 dead, 2 weathered
Fusconaia maculata maculata	4 weathered
Fusconaia flava	1 live, 2 dead, 1 weathered
Cyclonaias tuberculat	1 live, 1 weathered
Plethobasus cyphyus	1 live, 3 weathered
Pleurobema clava	8 weathered
Pleurobema sintoxia	3 weathered
Elliptio dilatata	1 live, 12 weathered
Ptychobranchus fasciolaris	3 weathered
Actinonaias ligamentina carinata	102 live, 4 dead, 1 weathered
Obovaria subrotunda	1 live, 4 weathered
Ligumia recta	1 weathered
Villosa fabalis	2 weathered
Villosa iris iris	1 live
Lampsilis radiata luteola	20 live, 5 dead
Lampsilis cardium	2 live
Lampsilis fasciola	2 live, 1 weathered

Site #8 – River Mile 16.9-16.5

Walhonding River, R.M. 16.9-16.5, below Mohawk Dam, 1.3 mi. NW of Nellie, 4.7 mi. WNW of Warsaw, Jefferson Twp., Coshocton Co., Ohio.

MAH:1991:35 19 August 1991 M.A. Hoggarth, Dan Rice & Mac Albin.
MAH:1993:46 13 August 1993 M.A. Hoggarth, Dan Rice & Stacy Xenakis.

Pyganodon grandis	2 live
Strophitus undulatus undulatus	9 live
Lasmigona complanata complanata	29 live
Lasmigona costata	7 live
Tritogonia verrucosa	6 live
Amblema plicata plicata	46 live
Cyclonaias tuberculata	2 live
Ptychobranchus fasciolaris	1 live

Actinonaias ligamentina carinata	83 live
Lampsilis radiata luteola	10 live
Lampsilis cardium	6 live
Lampsilis fasciola	2 live

Site #9 – River Mile 15.5-15.4

Walhonding River, R.M. 15.5-15.4, below U.S.R. 36 bridge, 0.3 mi. NE of Nellie, 3.4 mi. W of Warsaw, Jefferson Twp., Coshocton Co., Ohio.

MAH:1993:47 13 August 1993 M.A. Hoggarth, Dan Rice & Stacy Xenakis.

Strophitus undulatus undulatus	5 live
Lasmigona complanata complanata	22 live
Lasmigona costata	10 live
Tritogonia verrucosa	3 live
Quadrula cylindrica cylindrica	2 live
Amblema plicata plicata	62 live
Fusconaia flava	1 live
Cyclonaias tuberculata	1 live
Actinonaias ligamentina carinata	134 live
Lampsilis radiata luteola	10 live
Lampsilis cardium	2 live

Site #10 – River Mile 13.7-13.3

Walhonding River, R.M. 13.7-13.3, at Camp Tonowanda, 1.5 mi. E of Nellie, 2.0 mi. W of Warsaw, Jefferson Twp., Coshocton Co., Ohio.

MAH:1991:38 26 August 1991 M.A. Hoggarth, Dan Rice, Dave Ross & Mac Albin.
MAH:1993:53 19 August 1993 M.A. Hoggarth, Dan Rice, Stacy Xenakis & Bob Gable.

Pyganodon grandis	3 live
Strophitus undulatus undulatus	17 live, 3 dead
Alasmidonta marginata	1 weathered
Lasmigona complanata complanata	66 live, 1 dead
Lasmigona costata	47 live
Tritogonia verrucosa	12 live, 1 weathered
Quadrula cylindrica cylindrica	3 live, 2 weathered
Quadrula pustulosa pustulosa	4 live, 1 weathered
Amblema plicata plicata	128 live
Fusconaia maculata maculata	4 weathered
Fusconaia flava	2 live
Cyclonaias tuberculata	33 live, 2 dead
Plethobasus cyphyus	1 weathered
Pleurobema clava	1 weathered
Elliptio dilatata	1 live, 1 weathered
Ptychobranchus fasciolaris	4 live, 1 dead
Cyprogenia stegaria	1 weathered

Actinonaias ligamentina carinata	549 live, 2 weathered
Obovaria subrotunda	1 weathered
Ligumia recta	2 live, 1 weathered
Lampsilis radiata luteola	16 live
Lampsilis cardium	4 live
Lampsilis ovata	1 live, 1 subfossil
Lampsilis fasciola	5 live

Site #11 – River Mile 13.0-12.9

Walhonding River, R.M. 13.0-12.9, off of C.R. 61, 2.2 mi. E of Nellie, 1.3 mi. W of Warsaw, Jefferson Twp., Coshocton Co., Ohio.

MAH:1991:53 28 September 1991 M.A. Hoggarth.
MAH:1992:40 12 September 1992 M.A. Hoggarth & Chuck Boucher.

Pyganodon grandis	4 live, 1 dead
Strophitus undulatus undulatus	35 live, 1 dead, 1 weathered
Alasmidonta marginata	2 live, 1 weathered
Lasmigona complanata complanata	52 live
Lasmigona costata	37 live
Tritogonia verrucosa	1 live
Amblema plicata plicata	105 live
Cyclonaias tuberculata	1 live
Plethobasus cyphyus	1 live, 2 weathered
Pleurobema clava	1 weathered
Elliptio dilatata	1 live
Ptychobranchus fasciolaris	1 weathered
Cyprogenia stegaria	1 weathered, 1 subfossil
Actinonaias ligamentina carinata	102 live
Obovaria subrotunda	1 live
Ligumia recta	1 weathered
Lampsilis radiata luteola	5 live
Lampsilis cardium	7 live
Lampsilis ovata	2 live, 1 weathered
Lampsilis fasciola	3 live
Epioblasma triquetra	1 weathered

Site #12 – River Mile 11.3-11.1

Walhonding River, R.M. 11.3-11.1, at S.R. 60 bridge, 0.3 mi. S of Warsaw, Bethlehem/Jefferson Twp., Coshocton Co., Ohio.

MAH:1991:49 22 September 1991 M.A. Hoggarth.
MAH:1992:38 5 September 1992 M.A. Hoggarth.

Pyganodon grandis	5 live
Strophitus undulatus undulatus	12 live, 1 dead, 1 weathered
Lasmigona complanata complanata	27 live
Lasmigona costata	28 live, 1 weathered

Tritogonia verrucosa	9 live, 1 weathered
Quadrula cylindrica cylindrica	1 live, 4 weathered
Amblema plicata plicata	47 live
Fusconaia maculata maculata	1 weathered
Cyclonaias tuberculata	5 live
Elliptio dilatata	1 live
Ptychobranchus fasciolaris	1 live, 1 weathered
Actinonaias ligamentina carinata	162 live
Villosa iris iris	1 weathered
Lampsilis radiata luteola	17 live, 1 dead
Lampsilis cardium	4 live, 1 weathered
Lampsilis fasciola	9 live, 2 weathered
Epioblasma triquetra	1 weathered

Site #13 – River Mile 11.1-10.0

Walhonding River, R.M. 11.1-10.0, from S.R. 60 bridge, 0.3 mi. S of Warsaw, to T.R. 384 bridge, 1.4 mi. E of Warsaw, Bethlehem/Jefferson Twp., Coshocton Co., Ohio.

MAH:1991:50 23 September 1991 M.A. Hoggarth & Dan Rice.

Pyganodon grandis	1 live
Strophitus undulatus undulatus	3 live, 4 dead
Alasmidonta marginata	1 live
Lasmigona complanata complanata	15 live
Lasmigona costata	27 live, 1 dead
Tritogonia verrucosa	5 live, 1 dead
Quadrula cylindrica cylindrica	2 weathered
Quadrula pustulosa pustulosa	1 weathered
Amblema plicata plicata	53 live, 3 dead
Fusconaia maculata maculata	1 weathered
Fusconaia flava	1 dead
Cyclonaias tuberculata	1 weathered
Elliptio dilatata	1 live, 1 weathered
Ptychobranchus fasciolaris	1 live, 1 weathered
Cyprogenia stegaria	3 weathered
Actinonaias ligamentina carinata	100 live, 6 dead
Obovaria subrotunda	1 weathered
Ligumia recta	1 weathered
Villosa iris iris	1 live, 1 dead
Lampsilis radiata luteola	17 live, 2 dead
Lampsilis cardium	3 live
Lampsilis fasciola	2 live, 1 weathered

Site #14 – River Mile 8.7-8.5

Walhonding River, R.M. 8.7-7.5, from Sixmile Dam 2.2 mi. E of Warsaw, to U.S.R. 36 bridge, 3.5 mi. ESE of Warsaw, 5.7 mi. NW of Coshocton, Bethlehem Twp., Coshocton Co., Ohio.

MAH:1992:39 6 September 1992 M.A. Hoggarth.

Lasmigona complanata complanata	8 live
Lasmigona costata	3 live
Tritogonia verrucosa	1 live
Amblema plicata plicata	9 live
Actinonaias ligamentina carinata	9 live
Ligumia recta	1 live
Lampsilis radiata luteola	2 live
Lampsilis cardium	3 live
Lampsilis ovata	1 live

Site #15 – River Mile 7.5-5.6

Walhonding River, R.M. 7.5-5.6, from U.S.R. 36 bridge 3.5 mi. ESE of Warsaw, 5.7 mi. NW of Coshocton, to C.R. 23 bridge, 5.5 mi. ESE of Warsaw, 3.5 mi. NW of Coshocton, Bethlehem Twp., Coshocton Co., Ohio.

MAH:1993:45 12 August 1993 M.A. Hoggarth, Dan Rice & Stacy Xenakis.

Pyganodon grandis	2 live
Alasmidonta marginata	3 live
Lasmigona complanata complanata	28 live
Lasmigona costata	8 live
Lasmigona compressa	1 live
Tritogonia verrucosa	14 live
Quadrula quadrula	1 live
Quadrula pustulosa pustulosa	10 live
Amblema plicata plicata	12 live
Cyclonaias tuberculata	13 live
Plethobasus cyphyus	1 live
Ptychobranchus fasciolaris	1 live
Cyprogenia stegaria	1 weathered
Actinonaias ligamentina carinata	10 live
Leptodea fragilis	2 live
Lampsilis radiata luteola	2 live
Lampsilis cardium	7 live
Lampsilis ovata	1 live
Lampsilis fasciola	1 live, 1 dead

Site # 16 – River Mile 7.5-6.8

Walhonding River, R.M. 7.5-6.8, below the U.S.R. 36 bridge, 3.5 mi. ESE of Warsaw, 5.7 mi. NW of Coshocton, Bethlehem Twp., Coshocton Co., Ohio.

MAH:1991:54 5 October 1991 M.A. Hoggarth.
MAH:1991:59 19 October 1991 M.A. Hoggarth, D.H. Stansbery & Dave Ross.
MAH:1992:35 17 August 1992 M.A. Hoggarth.

MAH:1993:11 30 June 1993 M.A. Hoggarth, Mark Hoggarth, Dan Rice & Stacy Xenakis.
MAE:1993:54 20 August 1993 M.A. Hoggarth, Dan Rice & Stacy Xenakis.

Utterbackia imbecillis	1 dead
Pyganodon grandis	4 live, 3 dead, 1 weathered
Strophitus undulatus undulatus	11 live, 2 dead
Alasmidonta marginata	30 live, 4 dead, 4 weathered
Lasmigona complanata complanata	77 live
Lasmigona costata	7 live, 1 dead
Lasmigona compressa	1 live, 1 weathered
Tritogonia verrucosa	9 live, 1 dead
Quadrula cylindrica cylindrica	1 weathered
Quadrula pustulosa pustulosa	10 live, 5 weathered
Amblema plicata plicata	4 live, 1 dead, 1 weathered
Fusconaia maculata maculata	1 live
Fusconaia flava	2 live, 2 dead, 1 weathered
Cyclonaias tuberculata	1 live
Pleurobema sintoxia	1 live
Elliptio dilatata	1 live
Ptychobranchus fasciolaris	2 weathered
Cyprogenia stegaria	2 weathered
Actinonaias ligamentina carinata	18 live, 1 dead, 1 weathered
Leptodea fragilis	11 live, 6 dead, 1 weathered
Ligumia recta	2 live
Villosa fabalis	1 live, 1 dead
Lampsilis radiata luteola	17 live
Lampsilis cardium	18 live, 1 dead, 1 weathered
Lampsilis ovata	1 live
Lampsilis fasciola	1 live, 1 weathered
Epioblasma triquetra	5 live, 1 dead
Epioblasma obliquata obliquata	1 dead

Site #17 – River Mile 4.8-4.6

Walhonding River, R.M. 4.8-4.6, at C.R. 23 bridge, 3.5 mi. NW of Coshocton, 5.5 mi. ESE of Warsaw, Bethlehem Twp., Coshocton Co., Ohio.

MAH:1991:51 23 September 1991 M.A. Hoggarth & Dan Rice.
MAH:1991:56 14 October 1991 M.A. Hoggarth & Dave Ross.
MAH:1993:57 24 August 1993 M.A. Hoggarth, Dan Rice & Stacy Xenakis.
MAH:1993:60 25 August 1993 M.A. Hoggarth, Dan Rice & Stacy Xenakis.

Pyganodon grandis	7 live
Strophitus undulatus undulatus	3 live
Alasmidonta marginata	5 live, 1 dead
Lasmigona complanata complanata	215 live, 1 dead
Lasmigona costata	35 live
Tritogonia verrucosa	34 live
Quadrula quadrula	10 live, 1 weathered
Quadrula pustulosa pustulosa	46 live, 5 dead

Amblema plicata plicata	117 live
Cyclonaias tuberculata	40 live, 1 dead, 2 weathered
Elliptio dilatata	2 live, 1 weathered
Ptychobranchus fasciolaris	2 live, 1 dead, 1 weathered
Cyprogenia stegaria	3 weathered
Actinonaias ligamentina carinata	470 live, 1 weathered
Obovaria subrotunda	2 live, 1 weathered
Leptodea fragilis	6 live
Potamilus alatus	2 live
Ligumia recta	14 live
Villosa fabalis	1 weathered
Lampsilis radiata luteola	74 live
Lampsilis cardium	55 live, 2 weathered
Lampsilis ovata	2 live
Lampsilis fasciola	1 live, 1 weathered
Epioblasma triquetra	2 live, 1 weathered

Site # 18 – River Mile 3.3-1.8

Walhonding River, R.M. 3.3-1.8, at and upstream of Lake Park, 1.6 mi. NW of Coshocton, Tuscarawas Twp., Coshocton Co., Ohio.

MAH:1991:46 14 September 1991 M.A. Hoggarth.
MAH:1993:59 25 August 1993 M.A. Hoggarth, Dan Rice & Stacy Xenakis.

Strophitus undulatus undulatus	2 weathered
Alasmidonta marginata	7 live
Lasmigona complanata complanata	28 live, 2 dead
Lasmigona costata	4 live, 3 weathered
Lasmigona compressa	1 live
Tritogonia verrucosa	3 live, 3 weathered
Quadrula quadrula	1 live, 1 weathered
Quadrula pustulosa pustulosa	18 live, 8 weathered
Amblema plicata plicata	5 live, 1 weathered
Fusconaia maculata maculata	2 weathered
Cyclonaias tuberculata	2 live, 1 weathered
Ptychobranchus fasciolaris	1 weathered
Cyprogenia stegaria	1 weathered
Actinonaias ligamentina carinata	51 live, 2 dead
Leptodea fragilis	3 live, 1 dead, 1 weathered
Ligumia recta	2 live, 1 weathered
Lampsilis radiata luteola	11 live, 1 weathered
Lampsilis cardium	14 live, 2 weathered
Lampsilis ovata	1 weathered
Lampsilis fasciola	1 weathered
Epioblasma triquetra	1 live, 1 weathered

Site #19 – River Mile 1.0-0.0

Walhonding River, R.M. 1.0-0.0, from Lake Park 1.6 mi. NW of Coshocton, to the mouth of the Walhonding River in Coshocton, Tuscarawas/Jackson Twp., Coshocton Co., Ohio.

MAH:1991:60 19 October 1991 M.A. Hoggarth, D.H. Stansbery & Dave Ross.
MAH:1993:58 25 August 1993 M.A. Hoggarth, Dan Rice & Stacy Xenakis.

Pyganodon grandis	1 weathered
Alasmidonta marginata	1 live, 2 weathered
Lasmigona complanata complanata	28 live, 1 weathered
Lasmigona costata	3 live
Quadrula quadrula	1 live
Quadrula pustulosa pustulosa	5 live, 1 weathered
Ptychobranchus fasciolaris	1 weathered
Cyprogenia stegaria	1 weathered
Actinonaias ligamentina carinata	54 live, 3 dead
Obovaria subrotunda	1 live, 1 weathered
Leptodea fragilis	3 live, 2 dead
Ligumia recta	1 live, 1 weathered
Villosa fabalis	1 weathered
Lampsilis radiata luteola	6 live, 1 dead
Lampsilis cardium	5 live, 2 dead
Lampsilis ovata	1 weathered
Epioblasma triquetra	1 weathered

Walkerana, 1995-1996, 8(20): 177-185

BIOLOGICAL ASSESSMENT OF PROPOSED UNITED STATES CORPS OF ENGINEERS NAVIGATION DREDGING AND DISPOSAL ON FRESHWATER MUSSELS AT SITES DOWNSTREAM FROM CORDELL HULL DAM, CUMBERLAND RIVER MILES 304.3-308.9

Steven A. Ahlstedt[1,2]

ABSTRACT — The United States Corps of Engineers (COE) conducts routine maintenance dredging on rivers for navigation. Sediment accumulations in the navigation channel of the upper Cumberland River have been periodically dredged over the last 20 years and spoil deposited on the backsides of islands. Four dredge sites and three spoil disposal areas were surveyed by divers in the Cumberland River for the presence of federally listed endangered species. The endangered Pink Mucket (*Lampsilis abrupta*) was found alive and the Dromedary Mussel (*Dromus dromas*) was reported as relict. Reproduction of mussel species in the upper Cumberland River is probably limited and/or non-existent because of thermal problems related to coldwater releases from tributary dams. The mussel fauna in the river appears old and non-reproducing. Recommendations were made to translocate *L. abrupta* to unaffected rivers in hope of reestablishing additional populations in accordance with United States Fish and Wildlife Service recovery plans.

Key words: Cumberland River, Unionidae, dredging, *Lampsilis abrupta, Dromus dromas, Plethobasus cooperianus, Pleurobema plenum.*

INTRODUCTION

The Nashville District Corps of Engineers (COE) contracted with the Tennessee Valley Authority (TVA) to conduct a mussel survey at proposed navigation dredging to be performed on the upper Cumberland River between miles 304.3-308.9. The purpose was to determine if federally listed mussel species would be impacted by this work.

Various sites in the upper Cumberland River have been dredged one or more times during the last 20 years. The COE indicated that at least 235,000 cubic yards of material was removed from the Cumberland (mile 300-313.5) between 1972 and 1976 in order to establish and maintain a nine-foot navigation channel.

Previous knowledge of the mussel fauna in the upper Cumberland River is limited to Wilson & Clark (1914) who reported 26 species near Goodall's Island (mile 307). They reported three species (*Dromus dromas, Lampsilis abrupta* and *Plethobasus cooperianus*) now listed endangered by the U.S. Fish

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and Wildlife Service. Farther downstream at Cedar Bluff (near mile 290), Wilson and Clark found an additional presently listed species, *Pleurobema plenum*. The Cumberland River was later impounded by Old Hickory Dam (mile 216) which closed in 1957. Farther upstream, Cordell Hull Dam (mile 313.5) was closed in 1973 and Center Hill Dam, located on the Caney Fork at mile 26.4, was closed in 1950.

Freshwater mussel surveys since the completion of the dams on the Cumberland and Caney Fork rivers are limited to those conducted by TVA (TVA, 1976, 1983) and Parmalee *et al.* (1980). Together these surveys documented 27 living species from the river between miles 270-297 and included four endangered species (*Dromus dromas, Lampsilis abrupta, Plethobasus cooperianus* and *Pleurobema plenum*). Quantitative data from these surveys indicate that *L. abrupta* is the most abundant of the endangered species in the Cumberland River, comprising somewhat less than one percent of the community at mile 285 and present throughout the remainder of the reach. Parmalee *et al.* (1980) brailed sites between miles 291 and 297 and found three live specimens of *Plethobasus cooperianus* and one live specimen of *D. dromas*. Neither species was found during TVA quantitative mussel sampling at mile 285 (TVA, 1983). Parmalee *et al.* (1980) found *Pleurobema plenum* only in commercial musseler's cull piles. Based on the age and measurement data of specimens they examined, Parmalee *et al.* concluded that *D. dromas* and *Plethobasus cooperianus* are not reproducing in this reach of the Cumberland River and that *L. abrupta* may be reproducing simply because of the number of specimens present.

METHODS AND MATERIALS

The four dredge sites and three spoil disposal areas proposed for this project were surveyed by TVA aquatic biologists during the period September 8-14, 1992. All sites were sampled by two divers using surface supplied air (hooka). Boat to diver radio communications were essential for keeping divers in the proposed dredge channel and for communicating instantaneous observations on substrate and water clarity. All live mussels found were collected and placed in nylon mesh bags. Relict shells were also collected because of the scarcity of mussels at some of the sites. Upon completion of the dive, mussels were taken to the dive boat for sorting, identification, and counting. All specimens of endangered species were aged, measured, and photographed before being returned to the river. Age determinations were made by counting the annular rings or growth rests on the outside of the shell.

RESULTS

The 13.3 man hours of diving effort yielded 17 species of freshwater mussels, of which 254 specimens were live and 44 were relicts (Tables 1 and 2). Six live specimens and three relicts of the endangered *Lampsilis abrupta*, and two relict specimens of *Dromus dromas* were reported during the survey (Fig. 1).

TABLE 1. Freshwater mussels present at proposed Cumberland River dredge sites, September 1992.

	Dredge Sites								
Species	305.4R	305.5R	306.3R	306.4R	306.5R	306.6–.7R	307.5-.6R	308.5-.9C	Totals
Actinonaias ligamentina	–	–	–	1r	–	–	–	–	1
Amblema plicata	–	–	–	–	–	–	–	–	0
Anodonta grandis	–	–	–	–	–	–	–	–	0
*Dromus dromas**	–	–	–	–	–	–	–	–	0
Ellipsaria lineolata	–	–	2r	2	–	–	–	–	4
Elliptio crassidens	–	–	–	–	2r	–	–	–	2
Elliptio dilatata	–	–	2	–	1r	–	–	–	3
*Lampsilis abrupta**	–	–	4	1	2r	–	–	–	7
Lasmigona complanata	–	–	–	–	–	–	–	–	0
Ligumia recta	–	–	1	–	–	–	–	–	1
Megalonaias nervosa	–	1	31	4r	5r	27	–	1	69
Obliquaria reflexa	–	–	–	4	1r	–	–	–	5
Pleurobema cordatum	–	–	5	1	–	–	–	–	6
Potamilus alatus	–	–	–	1	–	–	–	–	1
Ptychobranchus fasciolaris	–	–	2	–	–	–	–	–	2
Quadrula metanevra	–	–	1	3r	–	–		–	4
Quadrula pustulosa	–	–	7	–	2	–	–	–	9
Totals	0	1	55	17	13	27	0	1	114
Dive Time (minutes)	30	30	60	60	60	30	30	120	420

*Endangered

TABLE 2. Freshwater mussels present at proposed Cumberland River spoil dumping sites, September 1992.

Species	Spoil Sites							
	304.3R	304.4R	304.5-.7R	304.7-.9R	304.6-.8L	304.8-305.1L	306.1L	Totals
Actinonaias ligamentina	–	–	–	1	–	2	–	3
Amblema plicata	1r	1r	–	–	–	–	–	2
Anodonta grandis	–	–	1	–	–	–	–	1
*Dromus dromas**	–	2r	–	–	–	–	–	2
Ellipsaria lineolata	–	1r	–	–	–	1	–	2
Elliptio crassidens	2r	–	1	–	–	1	–	4
Elliptio dilatata	–	–	–	–	–	–	–	0
*Lampsilis abrupta**	1r	–	–	–	–	1	–	2
Lasmigona complanata	3	–	4	5	–	6	–	18
Ligumia recta	–	1r	–	–	1	–	–	2
Megalonaias nervosa	1r	–	1	5	32	86	1r	126
Obliquaria reflexa	1r	–	–	–	–	–	–	1
Pleurobema cordatum	4r	–	–	1r	–	1r	–	6
Potamilus alatus	–	2r	3	–	–	4	–	9
Ptychobranchus fasciolaris	–	–	–	–	–	–	–	0
Quadrula metanevra	–	1r	–	–	–	–	–	1
Quadrula pustulosa	–	1r	–	–	–	3	1r	5
Totals	13	9	10	12	33	105	2	184
Dive Time (minutes)	30	30	60	60	60	60	75	375

*Endangered

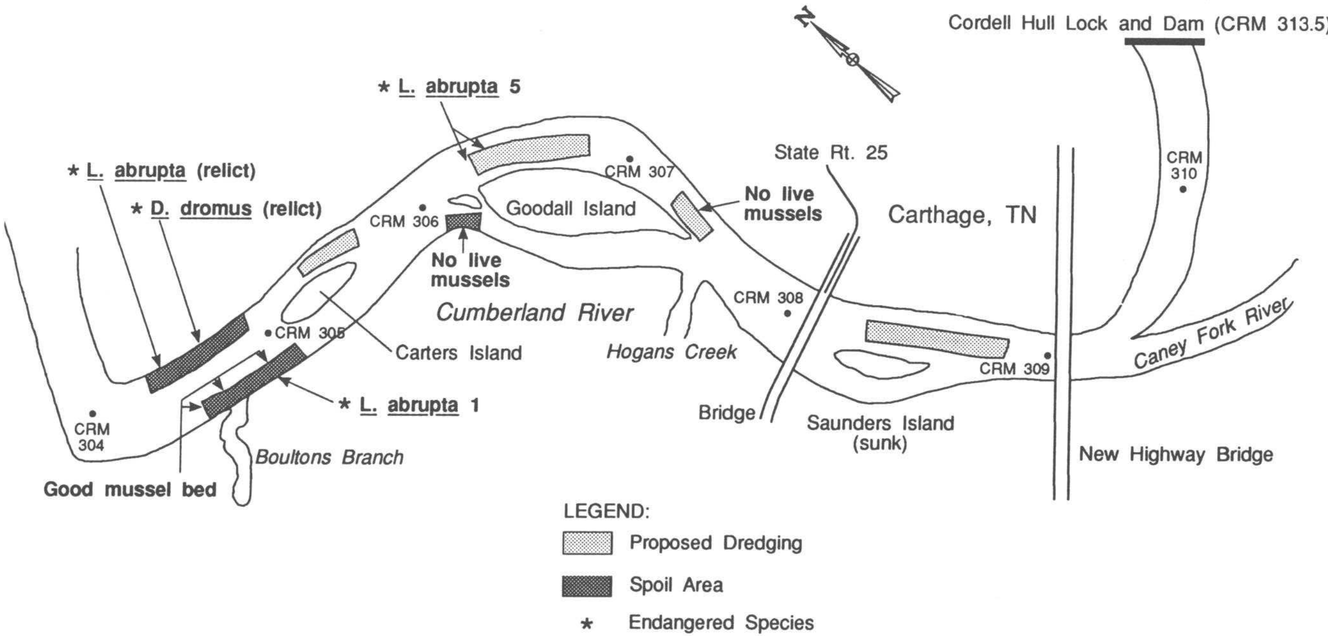

FIG. 1. Cumberland River mussel survey – U. S. Army Corps of Engineers proposed dredge and spoil dumping areas, September 1992.

The proposed dredging site at Goodall Island (CRM 306.3R-306.4R) maintained the most diverse mussel population with 12 species (138 individuals), including five live *Lampsilis abrupta.* At CRM 306.6-.7R, a bed of Washboards, *Megalonaias nervosa,* was discovered along the outside edge of the navigation channel close to Goodall Island. This bed should not be affected by dredging activities because of shallow water and its location outside the navigation channel. At remaining proposed dredge sites, mussels were non-existent, relict, or represented by only single live individuals.

Mussels were scarce in all proposed spoil dumping areas, with the exception of the lower downstream left side of Carters Island (CRM 304.6-.8L and 304.8-305.1L). A mussel bed found at this location included 10 species (138 individuals), with one live *Lampsilis abrupta.* Because of the presence of endangered species and total number of mussels found at this location, it is not recommended for dumping dredge spoil.

SPECIFIC SITE EVALUATIONS

Tables 1 and 2 include only mussel tabulations from specific areas proposed for dredging or spoil areas. Each site is considered individually because of the patchy distribution of mussels in this reach of the Cumberland River.

Dredging Sites

CRM 305.4R - No live or relict mussels found. Substrate consisted of shifting sand and gravel.

CRM 305.5R - One live mussel, *Megalonaias nervosa,* was reported from this site. Substrate consisted of shifting sand and gravel.

CRM 306.3R - Nine mussel species (53 live, 2 relicts), including four live *Lampsilis abrupta,* were found. The Armored Rock Snail, *Lithasia armigera,* was represented by 25 live individuals. This site is located in the middle of the navigation channel at the extreme lower end of proposed dredging. Substrate consisted of broken slabs of bedrock interspersed with sand and gravel. Specimens of *L. abrupta* would be adversely affected by silt from dredging activities immediately upstream.

CRM 306.4R - Eight mussel species (9 live, 8 relict) were reported, including one live *Lampsilis abrupta.* Substrate consisted of shifting sand and gravel with broken slabs of bedrock. *Lampsilis abrupta* would be impacted by the proposed dredging at this site.

CRM 306.6-.7R - No mussels were found at this site. Substrate in the main channel consisted of shifting sand and gravel. However, *Megalonaias nervosa* (27 specimens) were found along the outside edge of the navigation channel in shallow water close to the banks of Goodall Island. This population of mussels should not be affected due to location outside the area proposed for dredging.

CRM 307.5-.6R - No mussels were found at this site; substrate consisted of shifting sand and gravel.

CRM 308.5-.9C - Only one live *Megalonaias nervosa* was reported. Substrate consisted of shifting sand and gravel throughout the middle of the navigation channel, with large slabs of bedrock and sunken trees in the lower end of the channel.

Spoil Disposal Sites

CRM 304.3R - Seven mussel species (3 live, 10 relict) were reported and included one relict *Lampsilis abrupta.* This location is an extension of the proposed spoil dumping area originally proposed by the COE. Most of the specimens found consisted of relicts and no live endangered species were present. Substrate was a mixture of cobble, gravel, and silt with clay banks. This area is recommended for spoil deposition.

CRM 304.4R - Seven mussel species (all relicts) were found and included two relict *Dromus dromas.* This location is an extension of the proposed spoil dumping area originally proposed by the COE. All mussels found were reported as relicts and substrate consisted of bedrock, silt, and sand. This area is recommended for spoil deposition.

CRM 304.5-.7R - Five mussel species (10 live) were reported from this site and no endangered species were present. One specimen of the armored rock snail, *Lithasia armigera,* was found. The substrate consisted of bedrock, sand, and silt.

CRM 304.7-.9R - Four mussel species (11 live, 1 relict) were reported from this site. No endangered species were present. Substrate consisted of shifting rubble, gravel, and sand.

CRM 304.6-.8L - One mussel species, *Megalonaias nervosa* (33 live), was present at this site. This location is at the downstream end of a mussel bed which persists along the streambanks in this reach. Substrate consisted of sand, mud, and clay along the banks with numerous sunken trees. The deposition of dredge spoil in this reach is not recommended because of the presence of the mussel bed.

CRM 304.8-305.1L - Nine mussel species (104 live, 1 relict) were reported from this site and included one live *Lampsilis abrupta.* A mussel bed was identified at this site which extends downstream (see CRM 304.6-.8L) throughout this reach. Spoil dumping could eliminate the mussel fauna at this site.

CRM 306.1L - Two mussel species (all relicts) were reported from this site and no endangered species were found. Substrate consisted of silt over rubble and gravel. This area is recommended for spoil deposition.

DISCUSSION AND CONCLUSION

The upper 40 miles of the Cumberland River downstream from Cordell Hull Dam has been found to contain at least seven federally listed mussel species documented since the mid-1970s. All listed species are uncommon and appear to be isolated old individuals. Because of the widespread distribution and abundance of endangered *Lampsilis abrupta*, the possibility exists that some reproduction and recruitment may be occurring, but at extremely low levels. However, individuals of *L. abrupta* found during the present study were estimated at between 20 and 27+ years old. Reproduction of mussel species is probably limited and/or non-existent because of thermal problems related to cold-water releases from tributary dams. The fauna in the upper Cumberland River appears to be old and non-reproducing.

This survey of proposed dredge and spoil disposal sites between CRM 304.3-308.9 indicated that the mussel fauna consisted of 17 species, of which *Megalonaias nervosa* was the most abundant. The U. S. Fish and Wildlife Service recovery plan for *L.ampsilis abrupta* is to maintain and restore viable populations to a significant portion of its historic range (USFWS, 1985). Experimental transplants should be considered for the species and could include placement of specimens in the upper Clinch River or in streams which are in the process of recovery (*i.e.*, Holston and lower French Broad rivers).

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Walkerana, 1995-1996, 8(20): 187-258

APPLICATION OF INDEX OF BIOTIC INTEGRITY (IBI) TO FIXED STATION WATER QUALITY MONITORING SITES

Charles F. Saylor[1] and Steven A. Ahlstedt[1, 2]

INTRODUCTION

Biological monitoring aspects of Tennessee Valley Authority's (TVA) Surface Water Monitoring Strategy (SWMS) Fixed Station Ambient Monitoring Network include sampling and analysis of fish and benthic macroinvertebrate communities, laboratory bioassay of surface water and elutriates of sediments, chemical analysis of fish flesh to assess bioaccumulation, chlorophyl analysis, and basic chemical and physical water quality parameters taken in conjunction with biological samples. The principal objective of the biological monitoring portions of SWMS is to assess the "health" or quality of the aquatic environment in given stream reaches. This report deals with two aspects of biological monitoring, structural and physical characteristics of fish and benthic macroinvertebrate communities. These are considered relative to physical and chemical aquatic environmental conditions that may identify perturbations in aquatic biological communities. Specifically, fish are sampled to measure species richness, species composition, trophic structure, fish abundance, and condition following the Index of Biotic Integrity (IBI) methodology introduced by Karr (1981). Benthic macroinvertebrates are sampled to allow an assessment of species richness, taxonomic composition, and community structure.

Biological monitoring, incorporated into SWMS in 1986, was continued for the third year in 1988 with a repeat of 1986 sampling. This report presents 1988 findings and discusses differences between 1988 and 1987.

METHODS AND MATERIALS

Sampling stations for IBI and benthic macroinvertebrate monitoring and analyses were established on five streams of the Tennessee Valley in 1986 (Fig. 1 and Table 1).

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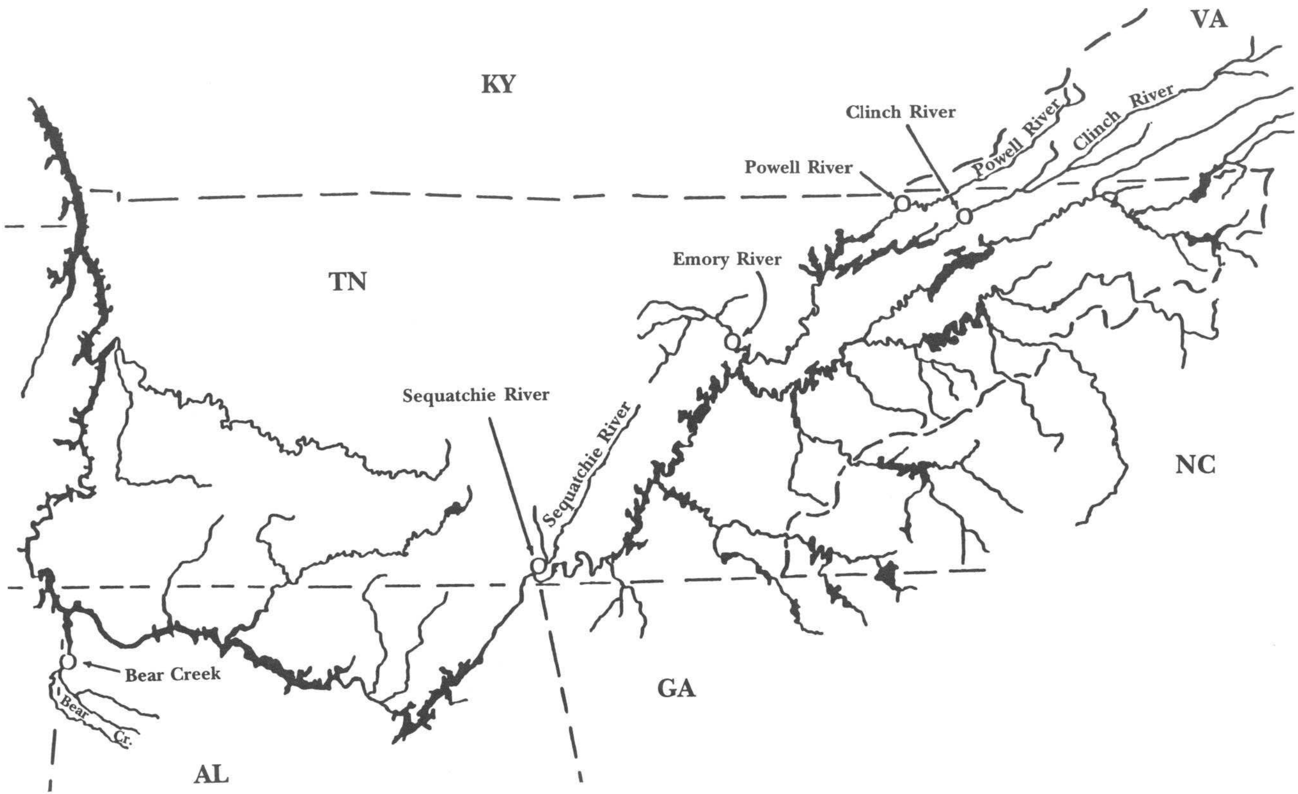

FIG. 1. Index of Biotic Integrity (IBI) stations on five Tennessee Valley streams sampled during May and July, 1986-1988.

TABLE 1. Locations of IBI stations.

Sequatchie River, RM 7.1 – USGS 7.5' topographic map (Sequatchie, 100-SE) Marion County, Tennessee; H. Millard Harris (property owner).

Powell River, RM 65.4 – USGS 7.5' topographic map (Middlesboro, 153-SW), Hancock County, Tennessee; public access upstream of 25 E bridge.

Clinch River, RM 172.3 – USGS 7.5' topographic map (Swan Island, 162-NE) Hancock County, Tennessee; at mouth of Swan Creek.

Emory River, RM 21.7 – USGS 7.5' topographic map (Camp Austin, 122-SE) Morgan County, Tennessee; public access at bridge.

Bear Creek, RM 25.2 – USGS 7.5' topographic map (Bishop, 26-NE) Colbert County, Alabama; access off Natchez Trace Parkway, USPS.

These same sites were worked in 1987 and 1988 from mid-May through early July.

Index of Biotic Integrity (IBI)

Development of an IBI based upon samples of fish populations yields a general assessment of stream condition at a given site by measuring certain aspects of species richness and composition, trophic structure, fish abundance, and individual condition. Each of the 12 metrics (Table 2), which reflects the condition of the fish community, is scored against findings expected under pristine conditions. Potential scores are 1-poor, 3-intermediate, or 5-the best to be expected. Scores for these 12 metrics are then summed to produce an index for a given site. The index is then classified using the system developed by Karr *et al.* (1986) (Table 3). An integral part of IBI is the judgment used in scoring the 12 metrics. These scores, and essentially the final index, rely upon the knowledge and experience of fisheries biologists in the study region.

Scoring criteria for the fish fauna metrics were set for each monitoring station and are presented with the results. Scores were adjusted during the study as our information and experience increased. Criteria for metrics 1 through 5 were set according to checklists of species either occurring or expected to occur (Table 4). This information was derived from various sources including Fitz (1968a, 1968b, and 1972), Wall (1968), TVA (1974), Masnik (1975), Lee *et al.* (1980), and unpublished TVA data. In 1988, fish species occurrence at Bear Creek, Emory, and Sequatchie river sites increased over expected species richness. Also, the status of white bass *(Morone chrysops)* and threadfin shad *(Dorosoma petenense)* in the Clinch and Powell rivers was corrected from native species to introduced species. These changes facilitated an adjustment in scoring criteria used in 1987 for metrics 1, 3, and 4.

Designations of trophic guilds and tolerance (metrics 6 through 9) were derived from ecological information presented by Pflieger (1975), Smith (1979), Lee *et al.* (1980), Etnier and Starnes (in press), and from experience and knowledge of TVA biologists. Scoring criteria for metrics 6 through 9 were derived from TVA quantitative fish data produced during the Cumberlandian Mollusk Conservation Program (CMCP) (Barr *et al.*, 1994). Scoring criteria for metric 7 used in 1987 was modified slightly to be more comparable to criteria used by other investigators (Karr, 1981) and (Ohio EPA, 1987). Criterion for a score of five for percentage of omnivores was in-

TABLE 2. List of metrics used in calculating Index of Biotic Integrity.

1. Number of native species
2. Number of darter species
3. Number of sunfish species (excluding *Micropterus* sp.)
4. Number of sucker species
5. Number of intolerant species
6. Proportion of individuals as tolerant species
7. Proportion of individuals as omnivores
8. Proportion of individuals as specialized insectivorous minnows and darters
9. Proportion of individuals as piscivores
10. Catch rate (average number/unit sampling effort)
11. Proportion of individuals as hybrids
12. Proportion of individuals with disease, tumors, fin damage, and other anomalies

*Each is assigned a value as follows: 1-poor, 3-intermediate, 5-the best to be expected. The IBI for a given site is the sum of those values.

creased from values less than 10 percent to include values less than 15 percent. Criteria for scoring catch rate, metric 10, were based on the least amount of existing data and may be subject to adjustment as additional catch rate data are compiled in future IBI sampling. Catch rate is presented as average catch per single seine haul (approximately 15 ft x 20 ft area) and five minutes of shocking. Criteria were set using data from the CMCP (Barr *et al.*, 1994), 1987 Holston River Fisheries Evaluation (unpublished TVA report), and Fixed Station IBI (TVA, 1988). Scoring criteria for metric 10 were adjusted downward for the Emory River because the Emory River drainage has primarily a sandstone substratum and is consequently not as potentially productive as most other streams in the region. Scoring criteria for presence of hybridized, diseased, or otherwise anomalous fish, metrics 11 and 12, follow those proposed by Karr *et al.* (1986). Metric scores and indices for 1986 and 1987 IBIs presented herein (Appendix) were recalculated to incorporate changes in scoring criteria noted above.

Selection of IBI Sampling Stations

Sample sites were selected in 1986 using the following procedures and criteria. Preliminary reconnaissance familiarized the crew leader with the various habitats in each stream reach and locations of stream access points. Selection of stations was dependent on four factors: habitat types present; suitability for assessment of the cumulative effects of pollutants entering the watershed; proximity to existing fixed surface water monitoring stations; and proximity of reservoirs or tributaries that might affect the number of fish species at the station due to immigration. A priority factor in selecting and delineating stations was the inclusion of habitat types characteristic of the

TABLE 3. Biotic integrity classes used in assessing fish communities along with general descriptions of their attributes (Karr *et al.*, 1986).

Class	Attributes	IBI Range
Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.	58-60
Good	Species richness somewhat below expectation, especially due to loss of most intolerant forms; some species with less than optimal abundances or size distribution; trophic structure shows some signs of stress.	48-52
Fair	Signs of additional deterioration include fewer intolerant forms, more skewed trophic structure (e.g., increasing frequency of omnivores); older age classes of top predators may be rare.	40-44
Poor	Dominated by omnivores, pollution-tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.	28-34
Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.	12-22
No fish	Repetitive sampling fails to turn up any fish.	

subject stream. Stream habitat in the Tennessee Valley can generally be classified as riffle, run, or pool. Each station included these gross habitat types. The need for more specific habitat features was left to the discretion of the crew leader. The length of stations sampled ranged from 0.3 to 0.5 miles. Stations were located in the lower reaches of the subject streams so the cumulative effect of pollutants from the entire watershed could be detected. This follows the strategy used in the selection of fixed surface water monitoring stations where samples for chemical and physical parameters are taken. Biological monitoring stations were located as near as possible to their corresponding water quality monitoring for better correlation of findings.

To minimize the effects of fish immigration on samples, which can mask the impacts of environmental degradation, stations were located as far as possible from reservoirs and large tributaries (fourth order or greater) while maintaining other sampling requirements. Stations were located at least two miles upstream of reservoir backwaters, except for Bear Creek, which was 1.5 miles from Pickwick Reservoir. Although smaller

TABLE 4. List of fish species expected to occur at five TVA fixed station IBI surveys (1986-1988) under impacted conditions. Symbols are as follows: O-species collected from site, E-species expected to occur, I-introduced species not counted in species richness, R-species rare due to factors other than environmental degradation, and not used in setting scoring criteria.

Scientific Name	Common Name	Tolerance*	Trophic** Guild	Bear Creek	Clinch River	Powell River	Emory River	Sequatchie River
Lampetra appendix	American brook lamprey		Pk	R				
Ichthyomyzon bdellium	Ohio lamprey		PS	E	0	0		
Ichthyomyzon castaneus	Chestnut lamprey		PS	0				0
Polydon spathula	Paddlefish		PK		E	E		
Amia clava	Bowfin	TOL	TC					0
Lepisosteus oculatus	Spotted gar		TC	0				0
Lepisosteus osseus	Longnose gar	TOL	TC	0	0	0	0	0
Dorosoma cepedianum	Gizzard shad	TOL	OM	0	0	0	0	0
Dorosoma petenense	Threadfin shad		PK		0	0		E
Hiodon tergisus	Mooneye		IN		0	E		E
Esox americanus vermicalutus	Grass pickerel		TC	0				
Esox masquinongy	Muskellunge		TC				E	
Esox niger	Chain pickerel		TC	E				
Campestoma anomalum	Central stoneroller		HB	0	0	0	0	0
Cyprinus carpio	Common carp	TOL	OM	I	I	I	I	I
Hybopsis amblops	Bigeye chub		SP	E	0	0		0
Hybopsis cahni	Slender chub		SP		E	0		
Hybopsis dissimilis	Streamline chub	INT	SP		0	0		
Hybopsis insignis	Blotched chub		OM		E	0		0
Hybopsis monacha	Spotfin chub		SP				0	
Nocomis leptocephalus	Bluehead chub		OM	0				
Nocomis micropogon	River chub	TOL	OM		0	0	E	0
Notemigonus crysoleucas	Golden shiner	TOL	OM	0			I	
Notropis ardens	Rosefin shiner		SP	E				
Notropis ariomus	Popeye shiner	INT	SP		0	0	E	E

TABLE 4. (cont.).

Scientific Name	Common Name	Tolerance*	Trophic** Guild	Bear Creek	Clinch River	Powell River	Emory River	Sequatchie River
Notropis atherinoides	Emerald shiner		SP	0	E			0
Notropis boops	Bigeye shiner	INT	SP	0				
Notropis chrysocephalus	Striped shiner	TOL	OM	0	0	0	0	0
Notropis coccogenis	Warpaint shiner		SP		0	0	0	E
Notropis emiliae	Pugnose minnow		SP	0				
Notropis fumeus	Ribbon shiner	TOL	SP	0				
Notropis galacturus	Whitetail shiner		SP		0	0	0	0
Notropis leuciodus	Tennessee shiner		SP		0	0	0	
Notropis photogenis	Silver shiner		SP		0	0	0	
Notropis rubellus	Rosyface shiner		SP	0	0	0		0
Notropis stramineus	Sand shiner		SP				0	
Notropis spilopterus	Spotfin shiner	TOL	SP	0	0	0	0	0
Notropis telescopus	Telescope shiner	INT	SP	E	0	0	0	E
Notropis venustus	Blacktail shiner		IN	0				
Notropis volucellus	Mimic shiner		SP	0	0	0	0	0
Notropis whipplei	Steelcolor shiner		SP	0	0			0
Notropis (undescribed)	"Sawfin" shiner		SP		0	0		0
Phenacobius mirabilis	Suckermouth minnow		SP	0				
Phenacobius uranops	Stargazing minnow		SP		0	0		
Pimephales notatus	Bluntnose minnow		OM	0	0	0	0	0
Pimephales promelas	Fathead minnow		OM		I			
Pimephales vigilax	Bullhead minnow		SP	0	0	E		0
Carpiodes carpio	River carpsucker		OM	0				
Carpiodes cyprinus	Quillback		OM	E	0	R		
Carpiodes velifer	Highfin carpsucker		OM		R			
Catostomus commersoni	White sucker		IN		E	E	E	E
Hypentelium nigricans	Northern hog sucker	INT	IN	0	0	0	0	0
Ictiobus bubalus	Smallmouth buffalo		OM	0				0

TABLE 4. (cont.).

Scientific Name	Common Name	Tolerance*	Trophic** Guild	Bear Creek	Clinch River	Powell River	Emory River	Sequatchie River
Ictiobus niger	Black buffalo		OM	0				0
Minytrema melanops	Spotted sucker		IN	0				0
Moxostoma anisurum	Silver redhorse		IN	0	0	E		0
Moxostoma carinatum	River redhorse		IN	0	0	0		0
Moxostoma duquesnei	Black redhorse		IN	0	0	0	0	0
Moxostoma erythrurum	Golden redhorse		IN	0	0	0	0	0
Moxostoma macrolepidotum	Shorthead redhorse		IN	0	0	0		0
Ictalurus natalis	Yellow bullhead		OM	E	0	0	E	0
Ictalurus punctatus	Channel catfish		OM	0	0	0	0	0
Noturus eleutherus	Mountain madtom	INT	IN		0	0		
Noturus miurus	Brindled madtom		IN	E				
Noturus nocturnus	Freckled madtom		IN	E				
Noturus stanauli	Pygmy madtom		IN					
Pylodictis olivaris	Flathead catfish		TC	E	0	0	0	0
Anguilla rostrata	American eel		TC	0				
Fundulus catenatus	Northern studfish		IN	0	0	0	0	E
Fundulus olivaceus	Blackspotted topminnow		IN	0				0
Gambusia affinis	Mosquitofish		IN	0				0
Morone chrysops	White bass		TC	E	I	I		E
Morone mississippiensis	Yellow bass		TC	0				E
Ambloplites rupestris	Rock bass		TC	E	0	0	0	0
Lepomis auritus	Redbreast sunfish		IN		I, R		I	I
Lepomis cyanellus	Green sunfish		IN	0			0	E
Lepomis gulosus	Warmouth		TC	E				0
Lepomis humilis	Orangespotted sunfish		IN	0				
Lepomis macrochirus	Bluegill		IN	0	0	0	0	0
Lepomis megalotis	Longear sunfish		IN	0	0	0	0	0
Lepomis microlophus	Redear sunfish		IN	0				0

TABLE 4. (cont.).

Scientific Name	Common Name	Tolerance*	Trophic** Guild	Bear Creek	Clinch River	Powell River	Emory River	Sequatchie River
Micropterus dolomieui	Smallmouth bass		TC		0	0	0	0
Micropterus punctulatus	Spotted bass		TC	0	0	0	0	0
Micropterus salmoides	Largemouth bass		TC	0	0	E	0	0
Pomoxis annularis	White crappie		TC	0	0	0		E
Pomoxis nigromaculatus	Black crappie		TC	E	E	E		0
Ammocrypta clara	Western sand darter		IN		E	E		
Etheostoma blennioides	Greenside darter		SP	E	0	0	0	0
Etheostoma camurum	Bluebreast darter	INT	SP		0	0	0	0
Etheostoma cinereum	Ashy darter		SP				E	
Etheostoma histrio	Harlequin darter		SP	0				
Etheostoma jessiae	Blueside darter		SP		0	0	E	0
Etheostoma kennicotti	Stripetail darter		SP				E	0
Etheostoma maculatum	Spotted darter		SP		0	E		E
Etheostoma nigrum	Johnny darter		SP	0				
Etheostoma rufilineatum	Redline darter		SP	0	0	0	0	0
Etheostoma simoterum	Tennessee snubnose darter		SP	E	0	0	0	0
Etheostoma stigmaeum	Speckled darter		SP	0				
Etheostoma tippecanoe	Tippecanoe darter	INT	SP		0			E
Etheostoma zonale	Banded darter		SP	E	0	0	E	0
Perca flavescens	Yellow perch		IN					I
Percina aurantiaca	Tangerine darter		SP		0	0	0	
Percina caprodes	Logperch		SP	0	0	0	0	0
Percina copelandi	Channel darter		SP		0	0		
Percina evides	Gilt darter	INT	SP	E	0	0	0	E
Percina phoxocephala	Slenderhead darter		SP	0				
Percina sciera	Dusky darter		SP	0	0	E		0
Percina shumardi	River darter		SP	E				0
Percina squamata	Olive darter		SP				0	

TABLE 4. (cont.).

Scientific Name	Common Name	Tolerance*	Trophic** Guild	Bear Creek	Clinch River	Powell River	Emory River	Sequatchie River
Percina tanasi	Snail darter		SP					0
Stizostedion canadense	Sauger		TC		E	0		0
Stizostedion vitreum	Walleye		TC		0	E		
Aplodinotus grunniens	Freshwater drum		IN	0	0	0	0	0
Cottus carolinae	Banded sculpin		IN	E	E	0	E	0
Labidesthes sicculus	Brook silverside		IN	0	0	E	0	0
	Maximum expected native species			74	69	64	47	71
	Total number of species			76	75	68	50	74

*Tolerance – TOL=Tolerant, INT=Intolerant

**Trophic Guild – PS=Parasite, PK=Planktivore, TC=Piscivore, HB=Herbivore, OM=Omnivore, SP=Specialized insectivore, and IN=Insectivore.

tributaries occurred within most sites, the IBI samples did not appear to be influenced by small stream fauna. Stations were delineated by setting permanent aluminum TVA bench markers in the riverbank at the upper and lower limits of sampling.

IBI (Fish) Sampling

Fish were sampled during late May through early July using a variety of methods. Hauling with a 20- by 6-foot seine of 3/16-inch mesh was performed in shallow backwaters, pools, and runs. The seine was also used in conjunction with a backpack electrofishing unit to sample riffles and runs. An area approximately 20'x 20' was shocked in a downstream direction to capture fish drifting or driven into the seine positioned stationary in the river. Backpack shocking and dip nets were used to collect fish from around logs, boulders, undercut banks, and brush piles in shallow water. Shocking with a boat-mounted, 230 volt generator was the primary method for sampling deep pool areas. Ten-minute shocking runs were made in a downstream direction, allowing stunned fish to rise to the surface in front of the boat. Sampling efforts were equally distributed between open water and shoreline habitats.

Fish were collected from all discernible habitat types within riffle, run, and pool areas (*i.e.*, sand and gravel, rubble, bedrock, vegetation, etc.). Pool areas sampled by boat shocker were treated as single predominant habitat type (deep pool). To assure that a high percentage of species present was collected and practical limits on sampling effort were set, predominant habitat types were sampled until a minimum of three consecutive seine hauls or shocking runs produced no new species for a given habitat type. Additional sampling was done if deemed necessary by the crew leader.

After each seine haul or shocking run, fish captured were sorted by species, counted, and recorded. Young-of-year (YOY) fish which could have affected the accuracy of the IBI were omitted from the fish count, but were noted in the comments section of the record sheet. Because YOY fish have been present for less than a year and are more likely to drift or be displaced than adult fish, they may not fully reflect perturbation. Before releasing or preserving fish, each specimen was examined for hybridization, anomalies, disease, and poor condition.

Occurrence of any of these conditions was recorded for each species. When large numbers of minnows or other small fish were encountered, a subsample was retained for examination for disease or other anomalies. Mild infestations of the parasite *Neascus* sp. (less than five parasites per fish) were not considered in the proportion of diseased, injured, or other anomalous fish (metric 12). The relationship between increased infestation of this parasite and degradation is not well known. Fish retained for subsampling or closer examination were preserved in an appropriately labeled jar of 10 percent formalin and taken to TVA's Aquatic Biology laboratory in Norris, Tennessee.

Benthic Macroinvertebrates

The benthic macroinvertebrate fixed station monitoring program was developed as an additional biological assessment of stream conditions. Macroinvertebrates are important, since they are one of the primary food sources for fish and are excellent indicators of localized stream conditions since many species have limited migration patterns or a sessile mode of life.

Bottom fauna sampling in 1988 was conducted at six fixed station ambient monitoring sites established in 1986. Four sites (Clinch, Powell, and Sequatchie rivers, and Bear Creek) corresponded with fish IBI sites. Benthic data from the other two rivers (Elk and Duck) are providing longterm baseline information for future IBI fish sampling. Quantitative and qualitative benthic samples were collected in order to define relative abundance and species occurrence. Quantitative sampling was completed in substrate types ranging from rubble to gravel in both riffle and pool habitats. Qualitative sampling was limited to a maximum of two hours (total time) per site, or was discontinued when redundancy in organisms being collected was observed.

Quantitative sampling consisted of both Hess and Surber bottom samplers. A total of eight Hess samples were taken (four in pool, four in riffle/run) at each site. An additional four quantitative samples were collected with a Surber sampler around emergent vegetation and shallow riffles in the Clinch, Powell, and Sequatchie rivers. Surber samples were limited to areas not exceeding the depth of the sampling frame.

Hess and Surber sampling consisted of physically disturbing the substrate inside the sampling frame to a depth of 2 to 4 inches. Organisms dislodged washed into a collection cup or net located on the downstream side of the sampling frame. The contents were then transferred into collection jars containing 10 percent formalin and appropriately labeled.

Qualitative sampling of bottom fauna organisms was completed using a D-net, Surber sampler, and hand-picking organisms from all habitats present. Benthic invertebrates obtained during fish IBI sampling with a seine were also retained. Specimens were preserved in 10 percent formalin solution containing an appropriate field identification label. All benthic samples were taken to TVA's Aquatic Biology Laboratory in Muscle Shoals, Alabama, for sorting. Additional sorting and identification of specimens was provided under contract to Fish and Wildlife Associates, Inc., Hickory, North Carolina.

Benthic samples processed under contract were washed in a 270 micron mesh sieve with water to remove the preservative. After washing, each sample was poured into a white enamel pan in small portions and all macroinvertebrates removed from detritus with forceps. Sorted organisms were transferred to vials containing 80 percent ethanol prior to being identified and counted. Identifications were made with a stereomicroscope (7X to 7OX). Benthic organisms from 1987 samples were identified to family/genus level. The level of identification for many organisms (especially dipterans), was much greater in 1988 than in the 1987 samples. However, for comparative purposes between the two surveys, dipteran midge larvae (chironomidae) were left at the family level. Species level of identifications were retained for all 1988 benthic samples so that they can be compared to the 1989 fixed station benthic samples.

Two aspects of the macroinvertebrate community (total number of taxa and total number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa) were used in comparing FY 1987 to FY 1988 benthic samples. These two measurements have been widely used in biomonitoring as demonstrated by North Carolina Department of Natural Resources (1988), Ohio Environmental Protection Agency (1987), Plafkin *et al.* (1987), and Shackleford (1987). Taxa richness has historically been a key component in most all evaluations of macroinvertebrate integrity. The underlying reason is the basic ecological principal that healthy, stable, biological communities have high species richness and diversity. The number of EPT taxa are generally considered to be pollution sensitive.

Classification and corresponding level of impact, listed below, are similar to those used by North Carolina Department of Natural Resources (1988). Criteria for classification of the total number of taxa and the total EPT scores are based on previous TVA benthological surveys throughout the Tennessee Valley and best professional judgment of TVA biologists. Following is a listing of the scoring system for total taxa and total EPT values:

Total Number of Taxa	Taxa	Total Number of EPT	Taxa
Excellent (No Impact)	>67	Excellent (No Impact)	>27
Good (Slight Impact)	53-67	Good (Slight Impact)	19-26
Fair (Moderate Impact)	35-52	Fair (Moderate Impact)	14-18
Poor (Severe Impact)	<35	Poor (Severe Impact)	<14

The health of the macroinvertebrate community was also assessed by examining and comparing percent composition of samples by major taxocenes (taxa groups) between years.

Water Quality Measurements

A Hydrolab Surveyor II was used to measure temperature, dissolved oxygen, pH, and conductivity at each station. Calibration and operation of equipment followed procedures in TVA's Natural Resource Engineering Procedures Manual, Vol. I.

CLINCH RIVER

Station Description

Approximately one-half mile of the Clinch River between Clinch River miles (CRM) 172.0 and 172.5 was sampled at Swan Island (Table 1). This station (designated as CRM 172.3) contained the greatest diversity of habitats of the five streams sampled for fish IBI. Substrate ranged from silty sand in quiet backwaters to large expanses of flat bedrock found at midstream in pool areas. Predominant substrates in runs and riffles were sand/gravel and cobble/rubble. Shoreline habitat ranged from gravel bars to deep undercut banks arranged in various combinations with water willow, root masses, overhanging brush, and heavier cover such as log jams or large boulders. The river is wide and open, but most of the shoreline is shaded by tree canopy. Stream gradient at CRM 172.3 is moderate, descending 1.75 feet per mile between CRMs 182.0 and CRM 170.6. There was little change in physical features since 1987. Flows during 1988, 1000 cfs, was greater than the 640 cfs worked in 1987, but was comparable to 1060 cfs encountered in 1986.

Apparently, increased flows helped cleanse the light siltation that had been observed in runs and shallow pools during 1987. The Clinch River drainage area at CRM 172.3 is about 1,300 square miles and is the largest of the five drainages sampled.

Results and Discussion

Sampling efforts in 1988 consisted of 64 seine hauls (including those in combination with a backpack shocker) and 120 minutes of boat shocking. This represents approximately 17% increase over 1987 sampling efforts. The additional sampling was by increased species richness. A total of 2,306 fish were collected including 60 native species, 3 introduced species (threadfin shad, common carp and redbreast sunfish), and no hybrids (Table 5). Priority species groups were represented by 13 darter species and 3 sunfish species (excluding redbreast sunfish, and *Micropterus* species). Seven intolerant species were found including streamline chub, popeye shiner, telescope shiner, northern hog sucker, mountain madtom, bluebreast darter, tippecanoe darter, and gilt darter. Tolerant species included longnose gar, gizzard shad, common carp, river chub, spotfin shiner, striped shiner, white sucker, and yellow bullhead. Eighty-eight anomalous or diseased fish were found among 19 species. Blackspot disease affected 33 minnows, two suckers, and one bass. Fin rot and/or skin lesions (most lesions appeared to be related to leech infestation) affected 36 suckers, two bass, three sunfish, and three minnows. Maladies affecting three or fewer fish included backbone deformity, gill fungus, whitespot disease, and leech infestation. Water quality measurements were normal (Table 6).

TABLE 5. Totals of all fish collected in IBI samples taken at Clinch River mile 172.3 on 6/11/86, 6/10/87 and 5/25-26/88.

Scientific Name	Common Name	Total 1986	Total 1987	Total 1988	Tolerance*	Trophic	Group
Ichthyomyzon bdellium	Ohio lamprey	0	0	7		Parasitic	Misc
Lepisosteus osseus	Longnose gar	4	1	3	TOL	Piscivore	Misc
Dorosoma cepedianum	Gizzard shad	37	81	18	TOL	Omnivore	Misc
Dorosoma petenense	Threadfin shad	1	26	0		Planktivore	Misc
Hiodon tergisus	Mooneye	0	1	7		Insectivore	Misc
Campestoma anomalum	Central stoneroller	14	25	24		Herbivore	Misc
Cyprinus carpio	Common carp	0	0	2	TOL	Omnivore	Misc
Hybopsis dissimilis	Streamline chub	11	20	26	INT	Specialist	Misc
Hybopsis amblops	Bigeye chub	42	27	23		Specialist	Misc
Nicomis micropogon	River chub	6	20	14	TOL	Omnivore	Misc
Notropis ariommus	Popeye shiner	53	40	24	INT	Specialist	Misc
Notropis coccogenis	Warpaint shiner	1	0	2		Specialist	Misc
Notropis galacturus	Whitetail shiner	14	60	46		Insectivore	Misc
Notropis leuciodus	Tennessee shiner	14	34	8		Specialist	Misc
Notropis photogenis	Silver shiner	0	11	1		Specialist	Misc
Notropis rubellus	Rosyface shiner	298	108	102		Specialist	Misc
Notropis spilopterus	Spotfin shiner	39	103	369	TOL	Insectivore	Misc
Notropis volucellus	Mimic shiner	0	102	37		Specialist	Misc
Notropis whipplei	Steelcolor shiner	0	53	23		Insectivore	Misc
Notropis chrysocephalus	Striped shiner	112	42	36	TOL	Omnivore	Misc
Notropis telescopus	Telescope shiner	0	0	13	IN	Specialist	Misc
Notropis (undescribed)	"Sawfin" shiner	19	199	26		Specialist	Misc
Phenacobius uranops	Stargazing minnow	14	15	38		Specialist	Misc
Pimephales notatus	Bluntnose minnow	25	56	62		Omnivore	Misc
Pimephales promelas	Fathead minnow	1	1	0		Omnivore	Misc
Pimephales vigilax	Bullhead minnow	0	13	1		Specialist	Misc
Carpiodes cyprinus	Quillback carpsucker	0	0	1		Omnivore	Suckers

TABLE 5 (cont.).

Scientific Name	Common Name	Total 1986	Total 1987	Total 1988	Tolerance*	Trophic	Group
Carpiodes velifer	Highfin carpsucker	0	0	1		Omnivore	Suckers
Hypentelium nigricans	Northern hog sucker	8	13	31	INT	Insectivore	Suckers
Catostomus commersoni	White sucker	0	0	1	TOL	Omnivore	Suckers
Moxostoma anisurum	Silver redhorse	0	0	4		Insectivore	Suckers
Maxostoma macrolepidotum	Shorthead redhorse	3	9	57		Insectivore	Suckers
Moxostoma carinatum	River redhorse	5	10	52		Insectivore	Suckers
Moxostoma duquesnei	Black redhorse	15	18	177		Insectivore	Suckers
Moxostoma erythrurum	Golden redhorse	20	35	97		Insectivore	Suckers
Ictalurus natalis	Yellow bullhead	0	0	1	TOL	Omnivore	Misc
Ictalurus punctatus	Channel catfish	4	7	15		Omnivore	Misc
Noturus eleutherus	Mountain madtom	1	2	23	INT	Insectivore	Misc
Pylodictis olivaris	Flathead catfish	1	0	2		Piscivore	Misc
Fundulus catenatus	Northern studfish	1	0	0		Insectivore	Misc
Ambloplites rupestris	Rock bass	3	28	89		Piscivore	Sunfish
Lepomis auritus	Redbreast sunfish	0	0	1		Insectivore	Sunfish
Lepomis macrochirus	Bluegill	4	8	2		Insectivore	Sunfish
Lepomis megalotis	Longear sunfish	76	149	319		Insectivore	Sunfish
Micropterus dolomieui	Smallmouth bass	6	24	32		Piscivore	Misc
Lepomis hybrid	Hybrid sunfish	1	0	0		Insectivore	Misc
Micropterus punctulatus	Spotted bass	3	15	22		Piscivore	Misc
Micropterus salmoides	Largemouth bass	1	1	5		Piscivore	Misc
Pomoxis annularis	White crappie	1	0	0		Piscivore	Sunfish
Etheostoma blennioides	Greenside darter	3	7	2		Specialist	Darters
Etheostoma camurum	Bluebreast darter	2	22	108	INT	Specialist	Darters
Etheostoma jessiae	Blueside darter	1	6	8		Specialist	Darters
Etheostoma maculatum	Spotted darter	0	0	1		Insectivore	Darters
Etheostoma rufilineatum	Redline darter	16	50	142		Specialist	Darters

TABLE 5 (cont.).

Scientific Name	Common Name	Total 1986	1987	1988	Tolerance*	Trophic	Group
Etheostoma simoterum	Tennessee snubnose darter	1	11	5		Specialist	Darters
Etheostoma tippecanoe	Tippecanoe darter	5	60	111	INT	Specialist	Darters
Etheostoma zonale	Banded darter	0	3	1		Specialist	Darters
Percina copelandi	Channel darter	0	0	1		Specialist	Darters
Percina evides	Gilt darter	12	25	62	INT	Specialist	Darters
Percina aurantiaca	Tangerine darter	0	1	8		Specialist	Darters
Percina caprodes	Logperch	0	4	5		Specialist	Darters
Percina sciera	Dusky darter	0	0	1		Specialist	Darters
Stizostedion vitreum	Walleye	0	1	3		Piscivore	Misc
Aplodinotus grunniens	Freshwater drum	0	2	1		Insectivore	Misc
Labidesthes sicculus	Brook silverside	2	2	2		Insectivore	Misc
		901	1551	2307			

*Tolerance – TOL=Tolerant, INT=Intolerant

The fish at CRM 172.3 rated an index of 52 and a classification "Good" (Tables 3 and 7). Species richness and composition showed only slight degradation with high scores produced for metrics 1, 2, 4, and 5 and moderate scores for metrics 3 and 6. Scoring for metric 3 was lowered by the absence of crappie sps, while scoring for metric 6 was affected primarily by large numbers of yearling spotfin shiners in backwater samples. Trophic structure received high scores in metrics 7 and 9, but showed a mild imbalance with a moderate score for metric 8, proportion of specialized insectivores. This imbalance occurred only among fishes sampled from pool areas. The cause of this is uncertain since macroinvertebrate sampling indicated that the food base for this feeding gild was only slightly disturbed. Fish abundance was satisfactory as catch rate (metric 10) met expectations. No hybrid fish were found resulting in a high score for metric 11. The proportion of injured, diseased, or otherwise anomalous fish (metric 12) was greater

TABLE 6. Water quality measurements in conjunction with IBI samples at five fixed stations during 1987 and 1988.

River	Year	Depth (m)	Temp. (C)	Cond. (umhos/cm)	D.O. (ppm)	pH (S.U.)	Remarks
Clinch River	1987	Surface	24.40	.342	6.70	7.97	
		3.2	24.40	.344	6.60	7.96	
	1988	Surface	20.95	.306	8.82	8.08	
		1.0	21.15	.306	8.82	8.08	
		1.7	21.16	.305	8.80	8.07	
Powell River	1987	Surface	23.80	*	6.30	7.90	*Problem with calibration of Hydrolab
	1988	Surface	22.02	.314	9.98	8.13	
		0.4	22.00	.313	9.51	8.15	
Emory River	1987	Surface	28.81	.171	6.56	7.11	
		3.0	27.36	.172	5.33	6.87	
		4.8	25.52	.174	0.56	6.57	
	1988	Surface	24.09	.156	7.88	6.12	
		1.0	23.58	.148	6.00	6.19	
		2.0	23.00	.150	5.88	6.21	
		3.0	22.83	.153	6.37	6.24	
		4.0	22.52	.147	3.21	6.12	
		5.0	19.68	.185	0.41	5.89	
Sequatchie River	1987	Surface	23.10	.230	6.70	7.60	
		0.7	23.10	.229	6.80	7.60	
	1988	Surface	20.90	.200	7.30	7.60	
		0.7	20.90	.199	7.50	7.60	
Bear Creek	1987	Surface	28.80	.098	7.00	7.30	
	1988**						**Data lost

TABLE 7. Index of Biotic Integrity (IBI) analysis for Clinch River mile 172.3, June 10, 1987, and May 25-26, 1988.

		Scoring		Scoring Criteria			Observed		Max. expected
		1987	1988	1	3	5	1987	1988	
Metric 1	Total number of native fish species	5	5	<22	22-43	>43	46	60	69
Metric 2	Number of darter species	5	5	<5	5- 8	>8	10	13	14
Metric 3	Number of sunfish species, less *Micropterus*	3	5	<2	2- 3	>3	3	4	5
Metric 4	Number of sucker species	3	5	<3	3- 5	>5	5	9	8
Metric 5	Number of intolerant species	5	5	<3	3- 5	>5	7	8	8
Metric 6	Proportion of individuals as tolerant species	3	3	>20%	20-10	<10%	15.9%	19.3%	
Metric 7	Proportion of individuals as omnivores	5	5	>30%	30-15	<15%	12.9%	6.5%	
Metric 8	Proportion of individuals as specialized insectivores	3	3	<25%	25-50	>50%	49.0%	33.0%	
Metric 9	Proportion of individuals as piscivores	3	3	<2%	2- 5	>5%	4.5%	6.8%	
Metric 10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	5	5	<8	8-16	>16	21.0	26.2	
Metric 11	Proportion of individuals as hybrids	5	5	>1%	1-Tr*	0	0	0	

TABLE 7 (cont.).

		Scoring		Scoring Criteria			Observed		Max. expected
		1987	1988	1	3	5	1987	1988	
Metric 12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	5	3	>5%	5- 2	<2%	0.9%	3.8%	
	IBI VALUE	50	52						

*Tr = Value between 0 and 1%

than expected and produced a moderate score. A high rate of anomalous or parasitized fish often reflects stress on fish related to environmental degradation.

In comparison to 1987 IBI findings, the overall integrity of the fish community in 1988 showed little improvement. After adjusting the 1987 IBI to 1988 modifications of IBI (noted on page 189), 1987 and 1988 sampling produced indices of 50 and 52, respectively. Both years attained a classification "Good" (Table 7). High scores for number of sucker species (metric 4) and proportion of piscivores (metric 9) were the only improved scores in 1988. These improvements were partly negated by a worsening of individual fish condition which lowered scoring for metric 12. Metrics 1, 2, 4, 5, 7, and 10 continued to receive high scores, and also exhibited improvements in metric values. These improved values, although not effecting higher metric scores, indicated a healthier fish community with improved species richness (including relatively pollution sensitive species), a lower proportion of omnivores and increased fish abundance. Problems in metrics 3, 6, and 8 persisted in 1988.

Modifications in scoring criteria 1988 (see Methods and Materials, page 3) had no affect on IBI classifications or indices reported in 1986 and 1987. Modifications did improve the 1987 score for metric 7 but decreased scoring for metric 4.

Benthic macroinvertebrates sampled at CRM 172.4 in 1988, resulted in a mean abundance of 2,656 organisms per square meter, 61 total taxa, and 27 EPT taxa (Table 8). This site had the greatest number of total taxa and EPT taxa found at any of the six fixed station ambient monitoring sites and ranked second in abundance of benthic organisms. Sampling in 1987 produced 2,497 organisms per square meter, 47 total taxa, and 22 EPT taxa (Table 9). A comparison between the five most abundant groups between sampling years are listed below:

1988	1987
Diptera – 42%	Ephemeroptera – 53%
Pleurocerid snails – 16%	Pleurocerid snails – 15%
Ephemeroptera – 15%	Coleoptera – 15%
Coleoptera – 11%	Trichoptera – 10%
Plecoptera – 8%	Diptera – 4%

Recovery in the macroinvertebrate community was reported in 1988 as both numbers of total taxa and EPT taxa increased since 1987. Total taxa (47) was classified "Fair" in 1987, improved to 61 and a classification "Good" in 1988 (see Methods and Materials, page 198). This was due primarily to increased numbers of intolerant EPT taxa. The number of EPT taxa (22) improved from a classification "Good" in 1987 to "Excellent" (27) in 1988. The recovery of total taxa and total EPT exceeds the degree of recovery reported in the fish community.

Another major change since 1987, was a shift in percent composition by major taxocenes. Ephemeropterans which comprised 53% of the organisms in 1987 declined to 15% in 1988, and were replaced by dipterans which dominated (42%) in 1988. This shift was due mainly to mean abundance of chironomids per square meter which increased from 97 in 1987 to 1,114 in 1988. A high percent composition of chironomids is generally associated with enrichment and/or siltation. However, the occurrence of a healthy number of intolerant taxa (EPT taxa) suggests that the degree of degradation was not severe. Pleurocerid river snails *(Leptoxis praerosa* and *Pleurocera uncialis)* were the second most abundant group in 1988 (15%) and 1987 (16%). The spiny riversnail *(Io fluvialis)*, an endemic riffle species considered intolerant to pollution, was also reported in low numbers during both sampling years. This once widespread, big river species is presently found only in the upper Clinch, Powell, Nolichucky, and North Fork Holston rivers. Coleopteran riffle beetles (11%) were the fourth most common group of organisms in 1988. In 1987, riffle beetles were the third most abundant group (15%). The most common riffle beetle found for both surveys was *Stenelmis* sp. Plecoptera (stoneflies), which are generally considered the most intolerant of EPT taxa, the fifth most

TABLE 8. Quantitative (mean number per square meter) and qualitative benthic macroinvertebrate samples from six fixed station ambient monitoring sites during mid-May and early July 1988.

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Plathyhelminthes												
Turbellaria												
Planariidae												
Cura foremanii									1			
Nematoda							2					
Oligochaeta												
Lumbriculidae												
Lumbriculus sp.				X			3		26		11	
Tubificidae	30	X	11	X	4	X	16		17		28	
Branchiura sowerbyi					8						26	
Hirudinea		X										
Glossiphoniidae				X								
Crustacea												
Isopoda												
Asellidae												
Lirceus fontinalis				X								
Amphipoda												
Gammaridae												
Gammarus sp.				X				X				
Decapoda			1					X	2	X	1	
Astacidae												X
Cambarus sp.		X					16					
Orconectes sp.			8	X				X		–		X

*RM = river mile.

TABLE 8 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Insecta												
Plecoptera												
Chloroperlidae										X	8	X
Leuctridae												
Leuctra sp.			1	X							1	
Perlidae			1									
Acroneuria sp.				X								
Neoperla clymene			4		99	X	1				17	X
Paragnetina sp.											1	
Perlesta placida		X					3	X	7	X	192	X
Agnetina capitata				1		3	X					
Pteronarcidae												
Pteronarcys dorsata			6	X			2		3			
Ephemeroptera												
Baetidae												
Baetis sp.		X	3	X	7	X	62	X	14	X	20	X
Centroptilium sp.					1							X
Pseudocloeon sp.									5		14	
Caenidae												
Caenis sp.	9	X	12	X	13	X	85		1	X	15	X
Ephemeridae												
Ephemera sp.		X			17	X		X				
Ephemerellidae												
Attenuella attenuata				X			4		4	X		
Drunnella sp.			4								3	
Ephemerella sp.									35			X

TABLE 8 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Eurylophella sp.			1							X		X
Serratella deficiens			13	X					32	X	152	
Heptageniidae												
Epeorus sp.									1			
Heptagenia	sp.					3						
Leucrocuta sp.						X			1		79	
Stenacron interpunctatum			15	X		X	5	X	1			
Stenonema sp.	19	X	114		121	X	53	X	13	X	20	X
Oligoneuriidae												
Isonychia sp.	3	X		X		X	5	X	10	X	4	X
Polymitarcyidae												
Ephoron leukon					12	X					22	
Potamanthidae												
Potomanthus distinctus			2	X	315	X	11			X	63	X
Tricorythidae		X										
Tricorythodes sp.	5	X	4	X	13	X	101	X				
Odonata												
Aeschnidae												
Boyeria vinosa		X		X			1			X		X
Coenagrionidae											1	
Argia sp.		X				X						
Enallagma sp.						X		X		X		X
Ischnura sp.								X				
Calopterygidae												X
Hetaerina sp.		X										
Corduliidae sp.												

TABLE 8 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Neurocordulia sp.								X				
Gomphidae						X	4					
Dromogomphus spinosus				X		X	1					
Gomphus sp.					1	X		X		X		
Hagenius brevistylus								X		X		
Macromiidae												
Didymops sp.		X										
Macromia sp.		X				X		X		X		X
Hemiptera												
Belostomatidae												
Belostoma sp.												X
Gerridae												
Gerris sp.				X								
Nepidae												
Ranatra sp.										X		
Veliidae												
Microvelia sp.												X
Rhagovelia obesa									1			
Megaloptera												
Corydalidae												
Corydalus cornutus		X	1				2	X	1	X		X
Nigronia serricornis									1			
Sialidae												
Sialis sp.		X	1	X	23	X	2					
Trichoptera												
Brachycentridae												

TABLE 8 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Brachycentus sp.							7	1	5			
Micrasema sp.							1					
Glossosomatidae												
Agapetus sp.									3		1	
Hydropsychidae												
Cheumatopsyche sp.	6	X	192	X	49	X	74	X	41	X	90	X
Hydropsyche sp.	1	X	175	X	2		1	X	64	X	10	X
Macronema zebratum												X
Hydroptilidae												
Hydroptila sp.		X		X		X	10				4	
Lepidostomatidae												
Lepidostoma sp.			1									
Leptoceridae												
Oecetis sp.		X										
Triaenodes injustus			11	X			4				1	
Limnephilidae												
Pycnopsyche sp.							1					
Philopotamidae												
Chimarra sp.	6	X					2				2	
Phryganeidae							1					
Polycentropodidae												
Polycentropus sp.		X	2				2	X				
Psychomyiidae							2					
Psychomyia flavida							2					

TABLE 8 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Lepidoptera												
Pyralidae												
Parapoynx sp.												
Coleoptera												
Dryopidae												
Helichus lithophilus									1	X		
Dytiscidae												
Hydaticus sp.												X
Elmidae												
Ancronyx varieghatus	1	X										
Dubiraphia sp.		X	4	X	3	X	25	X	3		2	X
Macronychus glabratus						X	1					
Microcylloepus pusillus			3									
Optioservus sp.	1	X		X		X			3	X		
Prymoresia elegans				X						X		
Stenelmis sp.		X	1411	X	279	X	323	X	276		282	X
Gyrinidae									1			
Dineutus sp.		X					6	X		X		X
Hydroporus sp.								X				
Haliplidae												
Peltodytes sexmaculatus								X		X		
Hydrophilidae												
Berosus sp.						X						
Psephenidae												
Ectopria nervosa				X								
Psephenus herricki			1	X			1				5	
Staphylinidae									1			

TABLE 8 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Diptera												
Ceratopogonidae		X										
Chironomidae	137	X	788	X	303	X	1414	X	238	X	1114	X
Empididae	1	X					1					
Simuliidae												
Simulium sp.	5	X	3	X			2		158		3	
Stratiomyiidae												1
Tanyderidae												
Tabanus sp.									1			X
Tipulidae												
Limnophila sp.											1	
Tipula sp.									5		3	X
Mollusca												
Gastropoda												
Ancylidae												
Ferrissia sp.						3						
Physidae												
Physella sp.												X
Planorbidae												
Helisoma sp.										X		
Planorbella sp.												X
Viviparidae												
Campeloma sp.							2			X		
Pleuroceridae							2					
Elimia laqueata			3619	X								
Euryacoelon anthyoni							1					

TABLE 8 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Io fluvialis									2	X	4	X
Leptoxis praerosa	9	X	291	X	11	X	55	X	950	X	372	X
Lithasia geniculata					105							
Lithasia verrucosa	26	X	51	X	1	X						
Pleurocera alveare			77									
Pleurocera canaliculata	16	X	285	X	47	X	146	X			1	
Pelecypoda						X						
Unionidae												
Actinonaias ligamentina												X
Cyclonaias tuberculata					1							
Ptychobranchus subtentum											1	
Quadrula pustulosa			*2*									
Sphaeriidae												
Sphaerium sp.					1	X	*2*					
Cyrenidae												
Corbicula fluminea	150	X	98	X	4	X	117	X	58	X	27	X
Number of Taxa	38		51		40		59		53		61	
Number of EPT Taxa	14		*22*		16		23		21		27	
Mean Number Per Square Meter	425		7216		1443		2580		2124		2656	

TABLE 9. Quantitative (mean number per square meter) and qualitative benthic macroinvertebrate samples from six fixed station ambient monitoring sites from mid-May to early July 1987.

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Platyhelminthes												
Turbellaria												
Catenulidae												
Dugesia tigrina							1	X	54	X		
Tricladia												
Planariidae			34	X			1	X			10	X
Nematoda				X	3	X			1	X		
Oligochaeta	10	X	29	X	18	X	9	X	15	X	15	X
Tubificidae												
Branchiura sowerbyi	2	X			2	X	2	X	21	X	4	X
Hirudinea	2	X		X								
Glossiphoniidae					2	x						
Crustacea												
Isopoda												
Asellidae												
Asellus sp.					18	X						
Lirceus sp.				X								
Amphipoda												
Gammaridae												
Crangonyx sp.				X								
Talitridae												
Hyalella azteca		X										
Decapoda				X		X						
Astacidae												
Oeconectes sp.		X	6	X		X	8	X	8	X	1	X

*RM = river mile.

TABLE 9 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Insecta												
Plecoptera				X								
Chloroperlidae						X						
Perlidae							1	X	1	X	2	X
Neoperla sp.			13	X	87	X			6	X	18	X
Perlesta sp.			15	X			5	X			4	X
Phasganophora sp,											1	X
Pteronarcidae												
Pteronarcys sp.			16	X					2	X		X
Leuctridae							3	X	1	X		
Ephemeroptera											1	X
Baetidae			150	X	2	X						
Baetis sp.		X				X	58	X	19	X	473	X
Pseudocloeon sp.							25	X	19	X		
Caenidae												
Caenis sp.	7	X	7	X	3	X	44	X	65	X	53	X
Ephemeridae												
Hexagenia sp.	3	X		X	2	X		X	X	X		
Rhithrogena sp.											4	X
Serratella sp.			23	X					2	X	2	X
Ephemerellidae												
Ephemerella sp.									1	X		
Eurylophella sp.						X		X				
Heptageniidae			2	X								
Leucrocuta sp.					9	X			1	X	16	X
Heptagenia sp.		X										

TABLE 9 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Stenacron sp.			38	X	38	X	8	X				
Stenonema sp.	10	X	193	X	64	X	79	X	109	X	131	X
Leptophlebiidae												
Paraleptophlebia sp.							1	X				
Polymitarcyidae												
Ephoron sp.					47	X					389	X
Potamanthidae												
Potomanthus sp.			6	X	131	X			1	X	60	X
Oligoneuriidae												
Isonychia sp.		X		X	3	X	30	X	77	X	19	X
Tricorythidae												
Tricorythodes sp.	3	X		X	5	X	53	X	152	X	176	X
Odonata												
Aeshnidae												
Boyeria vinosa		X		X		X	1	X				
Coenagrionidae												
Argia sp.		X	2	X		X		X		X		X
Enallagma sp.		X						X		X		
Calopterygidae												
Hetaerina sp.		X		X		X						
Calopteryx sp.									2	X		
Gomphidae												
Dromogomphus spoliatus						X						
Dromogomphus sp.			2	X				X				
Gomphus sp.		X		X		X	2	X		X		X
Ophiogomphus sp.											1	X

TABLE 9 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Stylogomphus sp.							1	X				
Hagenius brevistylus			X			X		X				X
Libellulidae								X				
Eurythemis sp.												X
Macromiidae												
Macromia sp.		X	2	X				X		X		
Didymops transversa												X
Hemiptera		X										
Corixidae						X						
Belostomatidae												X
Megaloptera												
Corydalidae												
Corydalus cornutus		X	3	X				X	3	X	2	X
Nigronia sp.											2	X
Sialidae												
Sialis sp.	3	X			32	X	4	X	2	X		X
Trichoptera												
Brachycentridae												
Brachycentrus sp.			12	X			2	X	2	X		
Micrasema sp.							16	X				
Hydropsychidae												
Cheumatopsyche sp.	2	X	137	X	7	X	303	X	347	X	189	X
Diplectrona sp.									3	X		
Hydropsyche orris					2	X						
Hydropsyche sp.		X	110	X	13	X	223	X	105	X	50	X

TABLE 9 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Hydroptilidae			3	X	2	X					6	X
Hydroptila sp.	3	X					4	X	9	X		
Orthotrichia sp.					2	X						
Leptoceridae												
Mystacides sp.					2	X						
Oecetis sp.	3	X			2	X	2	X				
Limnephilidae												
Hydatophylax sp.							1	X				
Neophylax sp.									1	X		
Pycnopsyche sp.						X						
Philopotamidae												
Chimarra sp.		X										
Polycentropodidae									1	X		
Polycentropus sp.		X									1	X
Psychomyiidae												
Cyrnellus fraternus		X										
Neureclipsis sp.		X		X		X			3	X		
Rhyacophilidae			20	X								
Glossosoma sp.							17	X	1	X	2	X
Coleoptera												
Gyrinidae								X				
Dineutus sp.		X			2	X	5	X	8	X		
Haliplidae												
Peltodytes sp.		X										
Hydrophilidae						X	2	X				
Berosus sp.		X										

TABLE 9 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Psephenidae												
Psephanus sp.			3	X		X	4	X			3	X
Elmidae	2	X					1	X	1	X		
Stenelmis sp.		X	194	X	348	X	178	X	397	X	379	X
Microcylloepus pusillus			6	X								
Optioservus sp.		X					5	X	2	X		
Dubiraphia sp.							13	X	3	X		
Ancyronyx sp.		X										
Diptera												
Chironomidae	126	X	1356	843	X	1411	X	401	X	97	X	
Ceratopogonidae	2	X		*X*	*2*	X			1	X		
Chaboridae												
Chaoborus sp.									1	X		
Rhagionidae												
Atherix sp.									1	X		
Simuliidae		X	16	X	2	X	569	X	25	X	5	X
Tabanidae					2	X						
Empididae												
Hemerodromia sp.					5	X	6	X	14	X	1	X
Tipulidae					1	X			5	X	3	X
Antocha sp.									3	X		
Hexatoma sp.											4	X
Gastropoda												
Lymnaeidae	X											
Planoribidae												
Helisoma anceps										X		

TABLE 9 (cont.).

	Bear Cr. RM* 25.2		Elk R. RM* 32.7		Duck R. RM* 15.8		Sequatchie R. RM* 7.1		Powell R. RM* 65.4		Clinch R. RM* 172.4	
	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Ancylidae												
Ferrissia sp.		X						X				
Pleuroceridae												
Pleurocera uncialis									198	X	76	X
Pleurocera alveare			28	X								
Pleurocera canaliculata	5	X	51	X	3	X	58	X				
Lithasia verrucosa	19	X					3	X				
Lithasia lima			69	X								
Lithasia geniculata					89	X						
Elimia laqueata			1626	X								
Leptoxis praerosa	3	X	111	X	4	X	19	X	590	X	284	X
Io fluvialis									5	X	3	X
Bithyniidae												
Somatogyrus sp.			2	X								
Pelecypoda												
Unionidae												
Quadrula quadrula		X										
Ptychobranchus subtentum											1	X
Sphaeriidae												
Sphaerium sp.				X	3	X	1	X				
Psidium sp.			10	X								
Cyrenidae												
Corbicula fluminea	131	X	26	X	23	X	50	X	329	X	9	X
Number of Taxa		46		52		53		54		54		47
Number of EPT Taxa		15		21		23		21		24		22
Mean Number Per Square Meter		336		4321		1823		3229		3018		249

dominant group (8 percent) in 1988, were not a major group in 1987. Of the six species of stoneflies reported for both surveys, the most abundant species was *Perlesta placida.* Overall, the total number of organisms per square meter were similar between the surveys.

Conclusion

Findings from 1988 indicate the overall integrity of the fish comunity at CRM 172.3 was slightly disturbed and experienced little improvement since 1987. The IBI increased from 50 in 1987 to 52 in 1988, maintaining a classification "Good." Scoring for numbers of sucker species and proportion of piscivores improved; however, these were partially negated as the proportion of fish with disease, tumors, fin damage, or other anomalies worsened. Number of native species, number of darter species, number of intolerant species, proportion of omnivores, and catch rate received high scores again and showed improvement in metric values. The absence of hybrid fish also continued to produce a high score. Slight problems persisted with low number of sunfish species, low proportion of specialized insectivores, and high proportion of tolerant fish.

Macroinvertebrate sampling in 1988 indicated greater recovery than that shown by the fish community since 1987. Total number of taxa increased from 47 in 1987 to 61 in 1988, improving the classification from "Fair" to "Good." Since 1987, the number of EPT taxa also increased from 22 to 27, improving the classification from "Good" to "Excellent." Shifts in percent composition by major taxa detected some degradation as well as faunal recovery. Evidence of enrichment and/or siltation were apparent since ephemeropterans which were dominant at 53% in 1987, were replaced by dipterans (42%), primarily chironomids, as the most abundant taxocenein 1988. However, an increase in stoneflies to the fifth most commn group in 1988, is an excellent indication that waterquality conditions are suitable for the colonization of this pollution intolerant group and that conditions have generally improved since 1987.

Water quality measurements taken in conjunction with ampling were comparable to parameters reported in 1987. Potential surces of environmental degradation include coal mining operations, agriculture, and municipal wastes. Eddies and back water areas were noted to be lightly silted. All water quality measurements were considered normal.

POWELL RIVER

Station Description

The Powell River sampling station included one-half mile of stream extending from Powell River mile (PRM) 65.0 to PRM 65.5 (Table 1). This site consisted mainly of run and pool habitat, and a limited area of riffle habitat. Substrates ranged from sand/gravel to bedrock; with sand/gravel making up most of the substrate in shallow water. Some coal fines and light-to-moderate siltation were noticeable in substrates of eddies and backwaters. Shoreline areas provided various habitats including an open gravel bar, deep undercut banks with roots and water willow cover, and shallow eddies. Tree canopy was heavy over the lower half of the site. Stream gradient in the lower Powell River is moderate, descending approximately 2.7 feet per mile between PRM 70.9 and PRM 63.5. Flows at PRM 65.5 during sampling was 488 cfs and the drainage area is 685 square miles (TVA, 1958). Minor changes in physical features were noted since 1987. Scattered growths of pond weed (*Potamogeton* sp.) were present in shallow pool areas, and river turbidity was greatly reduced since 1987.

Results and Discussion

Fish sampling efforts consisted of 61 seine hauls (including those in combination with a backpack shocker) and 130 minutes of boat shocking. This represents approximately 24% increase over 1987 sampling and was facilitated in part by increased species richness in 1988. A total of 2,625 fish were sampled representing 48 native species and one introduced species (Table 10). Priority species groups were represented by 10 darter, four sunfish (excluding *Micropterus* sp.), and five sucker species. Seven intolerant fish included streamline chub, popeye shiner, telescope shiner, northern hog sucker, mountain madtom, bluebreast darter, and gilt darter. Tolerant species included longnose gar, gizzard shad, river chub, striped shiner, and spotfin shiner. 63 diseased, injured, or deformed fish were observed among 19 species. The predominant disease was parasitic nematode infestation and "popeye" in the eyes of 21 bluegill and one spotted bass. Lesions or sores affected 14 fish (one minnow, five sunfish, and eight suckers), and blackspot disease infested 11 fish (five minnows and six darters). Other maladies included fin rot or damaged fin (one minnow, one sucker, and six sunfish), deformities (one minnow, three sunfish, and two sauger), and blindness (one sucker and one sunfish). Water quality measure-

TABLE 10. Totals of all fish collected in IBI samples taken at Powell River mile 65.4 on 6/10/86, 6/9/87, and 5/23-24/88.

Scientific Name	Common Name	Total			Tolerance*	Trophic	Group
		1986	1987	1988			
Ichthyomyozon bdellium	Ohio Lamprey	0	0	1		Parasitic	Misc.
Lepisosteus osseus	Longnose gar	0	0	2	TOL	Piscivore	Misc.
Dorosoma cepedianum	Gizzard shad	15	59	27	TOL	Omnivore	Misc.
Dorosoma petenense	Threadfin shad	0	1	0		Planktivore	Misc.
Campestoma anomalum	Central stoneroller	24	6	0		Herbivore	Misc.
Cyprinus carpio	Common carp	2	1	1	TOL	Omnivore	Misc.
Hybopsis cahni	Slender chub	2	0	0		Specialist	Misc.
Hybopsis dissimilis	Streamline chub	79	28	135	INT	Specialist	Misc.
Hybopsis insignis	Blotched chub	0	3	2		Omnivore	Misc.
Hybopsis amblops	Bigeye chub	217	110	32		Specialist	Misc.
Nocomis micropogon	River chub	11	6	5	TOL	Omnivore	Misc.
Notropis ariomus	Popeye shiner	26	27	17	INT	Specialist	Misc.
Notropis chrysocephalus	Striped shiner	56	90	15	TOL	Omnivore	Misc.
Notropis coccogenis	Warpaint shiner	1	16	2		Specialist	Misc.
Notropis galacturus	Whitetail shiner	104	156	51		Insectivore	Misc.
Notropis leuciodus	Tennessee shiner	4	26	16		Specialist	Misc.
Notropis photogenis	Silver shiner	2	1	69		Specialist	Misc.
Notropis rubellus	Rosyface shiner	9	21	11		Specialist	Misc.
Notropis spilopterus	Spotfin shiner	31	58	13	TOL	Insectivore	Misc.
Notropis telescopus	Telescope shiner	4	15	295	INT	Specialist	Misc.
Notropis volucellus	Mimic shiner	32	85	90		Specialist	Misc.
Notropis (undescribed)	"Sawfin" shiner	95	390	448		Specialist	Misc.
Phenacobius uranops	Stargazing minnow	20	24	38		Specialist	Misc.
Pimephales notatus	Bluntnose minnow	20	3	33		Omnivore	Misc.
Hypentelium nigricans	Northern hog sucker	12	19	61	INT	Insectivore	Suckers
Moxostoma carinatum	River redhorse	5	3	7		Insectivore	Suckers
Moxostoma duquesnei	Black redhorse	4	7	60		Insectivore	Suckers
Moxostoma erythrurum	Golden redhorse	16	6	27		Insectivore	Suckers
Moxostoma macrolepidotum	Shorthead redhorse	1	14	36		Insectivore	Suckers
Ictalurus natalis	Yellow bullhead	0	2	0	TOL	Omnivore	Misc.

TABLE 10 (cont.).

Scientific Name	Common Name	Total 1986	1987	1988	Tolerance*	Trophic	Group
Ictalurus punctatus	Channel catfish	1	15	8		Omnivore	Misc.
Noturus eleutherus	Mountain madtom	6	2	4	INT	Insectivore	Misc.
Pylodictis olivaris	Flathead catfish	0	3	1		Piscivore	Misc.
Fundulus catenatus	Northern studfish	94	16	39		Insectivore	Misc.
Morone chrysops	White bass	0	1	0		Piscivore	Misc.
Ambloplites rupestris	Rock bass	18	87	235		Piscivore	Sunfish
Lepomis macrochirus	Bluegill	1	3	115		Insectivore	Sunfish
Lepomis megalotis	Longear sunfish	16	55	265		Insectivore	Sunfish
Lepomis sp.	Hybrid sunfish	0	1	0		Insectivore	Misc.
Micropterus dolomieui	Smallmouth bass	12	29	82		Piscivore	Misc.
Micropterus punctulatus	Spotted bass	13	21	30		Piscivore	Misc.
Pomoxis annularis	White crappie	0	0	1		Piscivore	Sunfish
Ethiostoma blennioides	Greenside darter	3	6	10		Specialist	Darters
Etheostoma camurum	Bluebreast darter	0	1	3	INT	Specialist	Darters
Etheostoma jessiae	Blueside darter	0	0	2		Specialist	Darters
Etheostoma rufilineatum	Redline darter	10	74	161		Specialist	Darters
Etheostoma simoterum	Tennessee snubnose darter	1	0	1		Specialist	Darters
Etheostoma zonale	Banded darter	5	9	7		Specialist	Darters
Percina aurantiaca	Tangerine darter	1	2	1		Specialist	Darters
Percina copelandi	Channel darter	0	0	7		Specialist	Darters
Percina caprodes	Logperch	46	17	56		Specialist	Darters
Percina evides	Gilt darter	3	33	89	INT	Specialist	Darters
Stizostedion canadense	Sauger	0	2	5		Piscivore	Misc.
Stizostedion vitreum vitreum	Walleye	0	0	2		Piscivore	Misc.
Aplodinotus grunniens	Freshwater drum	1	4	7		Insectivore	Misc.
Cottus carolinae	Banded sculpin	1	0	0		Insectivore	Misc.
		1024	1558	2625			

*Tolerance – TOL=Tolerant; INT=Intolerant ments (Table 6) were normal.

IBI sampling at PRM 65.4 resulted in an index of 58 and a classification "Excellent" (Tables 3 and 11). Only metric 12 (proportion of fish with disease, tumors, fin damage, or other anomalies) received a moderate score. All other metrics met expectations and received high scores. A moderate score for metric 12 was due primarily to a high rate of nematode infestation in bluegills. During spring 1988, unusually high numbers of "popeyed" bluegill were also reported from other waters of the Tennessee Valley by other biologists. This disease was observed in bluegill from upper South Holston Reservoir by TVA field personnel (Dennis Baxter, Per. Com.) and in upper Fontana Lake by North Carolina Game and Fish biologist (Travis Whitson, Per. Com.). What appears to be a widespread, but spotty, increase in this disease suggests that it may in part be related to recent drought conditions.

IBI findings for 1988 showed notable improvement in the fish community since 1987. After adjusting 1987 findings to 1988 modifications of IBI (noted on page 3), 1987 and 1988 sampling produced indices of 52 and 58, and classifications "Good" and "Excellent" (Table 11). High scores for metrics 2 and 3 reflected recovery of darter and sunfish species that had been missing from pool and eddy habitats in 1987.

Moderate scores for these two metrics in 1987 were thought to be the result of deposition of coal fines and silt in pools and eddies (Saylor *et al.,* 1988). Silt deposits in these habitats persisted during 1988 sampling; however, turbidity seemed much reduced. High scores also resulted from a decreased proportion of tolerant fish and hybrid fish (metrics 6 and 11). A healthier fish community was further demonstrated by improvements in values for metrics 1, 7, 9, and 10, which had already received high scores in 1987. Metrics 4, 5, and 8 experienced little change in metric values and continued to score high. Only metric 12 worsened since 1987, and was the result of the high rate of parasitic nematode infestation in bluegill.

Modification of scoring criteria for metric 7 (noted on page 3) improved scoring for both 1986 and 1987 findings by two points and increased their IBIs from 48 and 50, to 50 and 52, respectively. IBI classifications for both years were not affected.

Benthic macroinvertebrates sampled at PRM 65.4 in 1988, resulted in a mean abundance of 2,124 organisms per square meter, 53 taxa, and 21 EPT taxa (Table 8). Sampling in 1987 produced a mean abundance of 3,018 organisms per square meter, 54 taxa, and 24 EPT taxa

TABLE 11. Index of Biotic Integrity analysis for Powell River mile 65.4, June 9, 1987, and May 23-24, 1988.

		Scoring		Scoring Criteria			Observed		Max-expected
		1987	1988	1	3	5	1987	1988	
Metric 1	Total number of native fish species	5	5	<21	21-40	>40	45	48	64
Metric 2	Number of darter species	3	5	<5	5-8	>8	7	10	13
Metric 3	Number of sunfish species, less *Micropterus*	3	5	<2	2-3	>3	3	4	5
Metric 4	Number of sucker species	5	5	<2	2-4	>4	5	5	7
Metric 5	Number of intolerant species	5	5	<2	2-4	>4	7	7	7
Metric 6	Proportion of individuals as tolerant species	3	5	>20%	20-10	<10%	13.5%	2.4%	
Metric 7	Proportion of individuals as omnivores	5	5	>30%	30-15	<15%	11.5%	3.5%	
Metric 8	Proportion of individuals as specialized insectivores	5	5	<25%	25-50	>50%	56.8%	56.8%	
Metric 9	Proportion of individuals as piscivores	5	5	<2%	2-5	>5%	9.2%	13.6%	
Metric 10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	5	5	<8	8-16	>16	22.3%	30.2%	
Metric 11	Proportion of individuals as hybrids	3	5	>1%	1-Tr*	0	0.1%	0.0%	
Metric 12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	5	3	>5%	5-2	<2%	0.5%	2.4%	
	IBI VALUE	52	58						

*Tr = Value between 0 and 1%

(Table 9). A comparison between the five most abundant groups between sampling years are listed below:

1988	1987
Pleurocerid snails – 51%	Pleurocerid snails – 26%
Diptera – 19%	Trichoptera – 16%
Coleoptera – 13%	Ephemeroptera – 15%
Ephemeroptera – 6%	Diptera – 15%
Trichoptera - 5%	Coleoptera – 14%

There was little change in the macroinvertebrate community in comparison to recovery seen among the fishes since 1987. Invertebrate samples from both 1987 and 1988 indicated essentially the same slight level of impact. The 53 total taxa identified in 1988 were slightly less than the 54 total taxa found in 1987 with the classification remaining "Good" for both years (see methods and materials page 10). Number of EPT taxa decreased by three taxa, 21 in 1988 and 24 in 1987, but also maintained a classification "Good." Another sensitive taxa present during 1988 was the spiny riversnail *(Io fluvialis)*, a riffle species very intolerant to water quality degradation. This species occurred during both sampling years in low densities and the Powell River remains one of the last refugia for this snail.

There were some noticeable shifts in percent composition of major taxocenes. How much these shifts in taxa reflect changes in environmental quality is not known. The most obvious change was the proportion of pleurocerid snails (primarily *Leptoxis praerosa* and *Pleurocera uncialis)* which increased from 26% in 1987, to 51% in 1988. Drought conditions may have favored the proliferation of snails by reducing turbidity (observed during sampling), and subsequently, enhancing the growth of attached macrophytes, algae, and periphyton that sustain snails. There was also a noted decline in the proportion of trichopterans which decreased 16% in 1987, to 5% in 1988. In 1987, trichopteran numbers consisted mainly of taxa that are primarily net spinning filter feeders, *Cheumatopsyche* sp., and *Hydropsyche* sp. Their decline in 1988 may have been influenced by drought conditions which reduced flows and suspended particles and plankton. Dipterans were the second most abundant organism increasing from 15% in 1987, to 19% in 1988. Major constituents of dipterans were chironomids (midges) and simulids (black flies). The increase in dipterans was facilitated by decreased numbers of other quality organisms such as trichopterans (caddisflies) and ephemeropterans (mayflies) rather than increased numbers of dipterans. Reduced proportions of these two taxocenes were due to deceases in their numbers. Ephemeropterans decreased from the second most abundant organism in 1987 (15%) to fourth (6 %) in 1988. Coleopteran riffle beetles (13%) were the third most common group in 1988, slightly lower than reported in 1987 (14%). The most common riffle beetle in both surveys was *Stenelmis* sp. Riffle beetles appear to be only moderately sensitive to pollution.

Conclusion

IBI sampling at PRM 65.4 revealed considerable improvement in the fish fauna since 1987 sampling, increasing from 52 to 58 and classification improving from "Good" to "Excellent." Recovery was seen in four metrics as numbers of sunfish and darter species attained expected levels, and tolerant and hybrid fish were less prevalent among fish sampled. Increases in sunfish and darter species included species that had been missing from pools and eddies during 1987 sampling. Other metrics reflecting species richness and composition, trophic structure, and catch rate continued to make high scores. Among these metrics, improved values were seen in the total number of native species, proportions of omnivores and piscivores, and catch rate. The only metric to worsen since 1987 was the proportion of fish affected by disease or other anomalies. This problem was based mainly on a high rate of infestation of bluegill by parasitic nematodes causing "Popeye." Reports of numerous "Popeyed" fish in other Tennessee Valley waters suggests that an increase in the parasite may inpart be related to drought conditions.

Macroinvertebrate sampling in 1988 indicated slight degradation and little change in the benthic fauna since 1987. A slight decrease in total number of taxa were reported, 54 in 1987 and 53 in 1988, but the classification "Good" remained the same. The number of EPT taxa decreased from 24 in 1987, to 21 in 1988, but continued to maintain a classification "Good."

Noticeable shifts occurred in percent composition by major taxocenes. These shifts, however, were not considered necessarily related to changes in environmental quality. Pleurocerid river snails increased from 26% to 54%, and ephemeropterans and trichopterans decreased from 15% and 16% to 6% and 5%, respectively. Changes in proportions of these three taxocenes may be the result of drought related conditions, specifically reductions in turbidity and flow.

Forms of water pollution which may have contributed to the mild suppression of fauna are sedimentation from coal mining and agricultural run-off. Moderate to light deposits of coal fines and silt were again observed in pools and eddies of the Powell; however, turbidity was reduced because of low flows (drought conditions). Water quality measurements taken in 1988 were comparable to those measured in 1987 and were considered normal.

EMORY RIVER

Station Description

The Emory River, from mile 21.4 to 21.7, was sampled at Deermont, Tennessee (Table 1). There was little change in physical features at this station since 1987. The sampling area included runs, pools, and riffles (cascades) having predominantly loose boulder substrate. Substrate in pool and run areas was coated with brown flocculent silt; however, deposits of ferric hydroxide, present in 1987 at the mouth of Crab Orchard Creek, were not observed. The river is bordered by forests, but low flows had caused the shoreline to recede from most canopy cover. Shorelines were covered by dense beds of water willow, *Justica americana*. Stream gradient was high (10.7 feet per mile between Emory River Mile (ERM) 26.9 and ERM 21.3), which is typical of the Emory and other streams flowing through the Cumberland Plateau escarpment. Low flows during sampling (13 cfs at ERM 18.3) was somewhat less than the 60 cfs reported in 1987. Flows in the river are extremely variable during June and July, and often less than 50 cfs during the summer. Drainage area at this station is 704 square miles (TVA 1958).

Results and Discussion

Sampling efforts at ERM 21.7 consisted of 31 seine hauls (including those in combination with a backpack shocker) and 110 minutes of boat shocking. This represents approximately 4% increase over 1987. Sampling in 1988 yielded 697 fish representing 34 native species, two introduced species (redbreast sunfish and golden shiner), and one hybrid (Table 12). Priority species groups were represented by eight darter, five sunfish, and two sucker species. Intolerant fish present included telescope shiner, northern hog sucker, bluebreast darter, and gilt darter. Tolerant species collected were gizzard shad, golden shiner, and spotfin shiner. 40 fish with injury, disease, or

TABLE 12. Totals of all fish collected in IBI samples taken at Emory River mile 21.7 on July 1, 1986, July 28-30, 1987, and June 30, 1988 through July 1, 1988.

Scientific Name	Common Name	Total 1986	1987	1988	Tolerance*	Trophic	Group
Lepisosteus osseus	Longnose gar	0	1	0	TOL	Piscivore	Misc
Dorosoma cepedianum	Gizzard shad	13	38	12	TOL	Omnivore	Misc
Campostoma anomalum	Central stoneroller	37	29	69		Planktivore	Misc
Cyprinus carpio	Carp	0	4	0	TOL	Omnivore	Misc
Hybopsis monacha	Spotfin chub	6	11	20		Specialist	Misc
Notemigonus crysoleucas	Golden shiner	0	0	1	TOL	Omnivore	Misc
Notropis chrysocephalus	Striped shiner	0	1	0	TOL	Omnivore	Misc
Notropis coccogenis	Warpaint shiner	2	3	0		Specialist	Misc
Notropis galacturus	Whitetail shiner	3	41	31		Insectivore	Misc
Notropis leuciodus	Tennessee shiner	8	23	20		Specialist	Misc
Notropis photogenis	Silver shiner	88	3	31		Specialist	Misc
Notropis spilopterus	Spotfin shiner	4	11	34	TOL	Insectivore	Misc
Notropis stramineus	Sand shiner	0	0	5		Specialist	Misc
Notropis telescopus	Telescope shiner	0	5	5	INT	Specialist	Misc
Notropis volucellus	Mimic shiner	2	16	22		Specialist	Misc
Pimephales notatus	Bluntnose minnow	1	7	5		Omnivore	Misc
Hypentelium nigricans	Northern hog sucker	11	17	13	INT	Insectivore	Suckers
Moxostoma duquesnei	Black redhorse	0	3	1		Insectivore	Suckers
Moxostoma erythrurum	Golden redhorse	0	5	0		Insectivore	Misc
Fundulus catenatus	Northern studfish	1	0	0		Insectivore	Misc
Ictalurus punctatus	Channel catfish	0	3	2		Omnivore	Misc
Pylodictis olivaris	Flathead catfish	0	5	6		Piscivore	Misc
Ambloplites rupestris	Rock bass	3	10	29		Piscivore	Sunfish
Lepomis auritus	Redbreast sunfish	12	10	24		Insectivore	Sunfish
Lepomis macrochirus	Bluegill	0	5	2		Insectivore	Sunfish
Lepomis megalotis	Longear sunfish	3	17	27		Insectivore	Sunfish
Lepomis sp.	Hybrid sunfish	0	1	0		Insectivore	Misc

TABLE 12 (cont.).

Scientific Name	Common Name	Total 1986	1987	1988	Tolerance*	Trophic	Group
Lepomis cyanellus	Green sunfish	0		1		Insectivore	Sunfish
Micropterus dolomieui	Smallmouth bass	1	2	2		Piscivore	Misc
Micropterus punctulatus	Spotted bass	0	10	9		Piscivore	Misc
Micropterus salmoides	Largemouth bass	1	1	2		Piscivore	Misc
Etheostoma blennioides	Greenside darter	60	11	51		Specialist	Darters
Etheastoma camurum	Bluebreast Darter	0	1	2	INT	Specialist	Darters
Etheostoma rufilineatum	Redline darter	49	41	72		Specialist	Darters
Etheostoma simoterum	Tennessee snubnose darter	5	1	7		Specialist	Darters
Etheostoma sp.	Hybrid darter	1	0	1		Specialist	Darters
Percina aurantiaca	Tangerine darter	22	29	165		Specialist	Darters
Percina caprodes	Logperch	13	3	19		Specialist	Darters
Percina evides	Gilt darter	6	1	2	INT	Specialist	Darters
Percina squamata	Olive darter	0	0	1		Specialist	Darters
Aplodinotus grunniens	Freshwater drum	0	6	2		Insectivore	Misc
Labidesthes sicculus	Brook silverside	0	2	2		Insectivore	Misc
		352	377	697			

*Tolerance – TOL=Tolerant, INT=Intolerant poor condition were found. Blackspot disease was the primary problem, affecting 30 fish (28 darters, one minnow, and one bass). Lesions or topical infection affected two bass, and one sucker. Fin rot or fin injury was found on one catfish and one bass. Leeches infested four darters, and extremely poor condition was exhibited by one bass. Water quality measurements (Table 6) revealed that stratification occurred in the deepest pool at this station, similar to findings in 1987. Dissolved oxygen ranged from 7.88 mg/l at the surface to an unusually low 0.41 mg/l at the bottom, 5 meters. Other water quality measurements were normal.

The fish fauna at ERM 21.7 rated an index of 52 and a classification "Good" (Tables 3 and 13). Species richness and composition reflected only limited disorder as the number of sucker species (metric 4) was only slightly below expectation. The number of native species (metric 1) and numbers of species of darter, sunfish, and intolerant fish (metrics 2, 3, and 5, respectively) were satisfactory. The low proportion of tolerant fish in the sample (metric 6) also indicated a healthy fauna.

Trophic structure (metrics 7-9) was well balanced at all levels. Catch rate (metric 10) met expectations; however, problems were found in the proportions of hybrid fish (metric 11) and fish with disease, tumors, fin damage, and other anomalies (metric 12). The occurrence of a single hybrid (redline darter-bluebreast darter) produced a moderate score for metric 11. Hybridization by these two species may reflect a reduction in suitable spawning habitat for both darter species due to reduced flows and siltation. Of the five fixed stations sampled for IBI, ERM 21.7 had the highest proportion of fish (5.7 percent) suffering from disease, injury, or poor condition. This resulted in a low score for metric 12. Maladies consisted mainly of blackspot disease which affected primarily tangerine darters collected from pool habitat. Although infestation by this parasite may not necessarily indicate stress on fish, its occurrence has been correlated with increased environmental degradation (Steedman, 1987). Other more serious defects (fin rot, lesions, or poor condition) occurred at a much lower rate.

Overall, findings from 1988 showed limited improvement over findings from 1987. After adjusting the 1987 IBI to 1988 IBI modifications (noted on page 3), 1987 and 1988 sampling produced indices of 48 and 52, respectively, with both samples rating "Good" classification (Table 13). Improvement was seen in species richness and composition (metrics 1-6). Number of darter species and propor-

TABLE 13. Index of Biotic Integrity analysis for Emory River mile 21.7, July 28-30, 1987 and June 30-July 1, 1988.

		Scoring		Scoring Criteria			Observed		Max. ex-
		1987	1988	1	3	5	1987	1988	pected
Metric 1	Total number of native fish species	5	5	<15	15-29	>29	34	34	47
Metric 2	Number of darter species	3	5	<4	4-7	>7	7	8	12
Metric 3	Number of sunfish species, less *Micropterus*	5	5	<2	2-3	>3	4	5	5
Metric 4	Number of sucker species	5	3	<2	2	>2	3	2	4
Metric 5	Number of intolerant species	5	5	<2	2	>2	4	4	4
Metric 6	Proportion of individuals as tolerant species	3	5	>20%	20-10	<10%	14.6%	7.0%	
Metric 7	Proportion of individuals as omnivores	5	5	>30%	30-15	<15%	14.1%	3.2%	
Metric 8	Proportion of individuals as specialized insectivores	3	5	<25%	25-50	>50%	39.3%	60.7%	
Metric 9	Proportion of individuals as piscivores	5	5	<2	2-5	>5%	7.7%	7.0%	
Metric 10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	3	5	<1	6-12	>12	7.4%	13.2%	
Metric 11	Proportion of individuals as hybrids	3	3	>1%	1-Tr	0	Tr	Tr	
Metric 12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	3	1	>5%	5-2	<2%	3.5%	5.7%	
	IBI VALUE	48	52						

tion of tolerant fish scored higher in 1988 sampling. This was slightly offset by the number of sucker species which dropped to a moderate score. Numbers of species of native fish, sunfish, and intolerant fish continued to receive high scores. Trophic structure (metrics 7-9) appeared healthier because of increased proportion of insectivores resulting in a higher score. Proportions of omnivores and piscivores continued to receive high scores. Catch rate (metric 10) increased to an expected level in 1988 and improved to a high score. This increase occurred primarily in shallow pool and run areas where fish caught per seine haul rose from 2.3 in 1987, to 12.3 in 1988. There was no visible improvement in habitat that might explain improved catch rate. Fish condition was slightly worse in 1988, which partially negated improved scoring in other metrics. A trace occurrence of hybridization continued to suppress metric 11 to a moderate score. An increase in the rate of blackspot disease reduced metric 12 to a low score.

Modification of scoring criteria for metric 7 (noted on page 189) improved 1987 findings increasing IBI from 46 to 48 and classification from "Fair-Good" to "Good." Unexpected species occurrence required an upward adjustment of scoring criteria for metric 1. This had no effect on 1986 or 1987 scoring.

Conclusion

The resultant index (52) and classification, "Good," of 1988 IBI sampling at ERM 21.7 indicated a slightly disturbed fish community. Signs of potential recovery since 1987 improved IBI from 48 to 52, but were not sufficient to change classification. Improvement was found in most aspects of the fish community. In species richness and composition, the number of darter species increased and the proportion of tolerant fish decreased. The numbers of native, sunfish, and intolerant species remained at expected levels; however, number of sucker species fell to a moderately low level. Trophic structure showed improvement as the proportion of insectivores increased to a healthy level. Proportions of piscivores and omnivores continued to meet expectations. Catch rate also improved to a satisfactory level, especially in shallow pool and run areas, where catch rate had been low in 1987. Problems persisted in fish condition as a trace of hybridization was found again, and the proportion of diseased, injured, or otherwise anomalous fish in pool areas increased.

Siltation from coal mines is a major concern in the Emory River watershed. Most physical and chemical evidence of environmental degradation, observed in 1987, persisted in 1988. These included siltation of run and pool habitats, and low dissolved oxygen concentrations in deeper pool areas. Other water quality measurements were normal. Ferric hydroxide deposits discharged from Crab Orchard Creek in 1987, were not present during 1988.

SEQUATCHIE RIVER

Station Description

Approximately 0.3 miles of the Sequatchie River were sampled, Sequatchie River mile (SRM) 6.8 to SRM 7.1, at Nickletown, Tennessee (Table 1). There was no change in physical habitat since 1987 sampling. A variety of habitats occurred including pools, runs, and riffle areas with substrates ranging from sand and gravel to rubble and boulder. Growths of stonewart *(Chara* sp.) were heavy on substrates in riffle and run areas. Shoreline habitat varied from open gravel bars to quiet eddies and backwater areas. The most abundant heavy cover was aquatic vegetation including water willow *(Justica* sp.) and pond weed *(Potamogeton* sp.). Log jams and brush piles also provided cover along shorelines. Land surrounding SRM 7.1 was forested, providing moderate-to-heavy canopy. Stream gradient in this section of the Sequatchie River is moderate (2.3 feet per mile) between SRM 5.4 and SRM 14.1. Stream flow during sampling was approximately 200 cfs at SRM 25.1. The Sequatchie River at SRM 7.1 has a drainage area of approximately 557 square miles (TVA 1958). The only physical sign of environmental degradation was siltation that coated substrate in eddies and backwaters, and accumulated up to several inches deep in some weed beds.

Results and Discussion

Sampling efforts in 1988 was equal to 1987 and consisted of 44 seine hauls (including those made in combination with a backpack shocker) and 120 minutes of boat shocking. Sampling produced 1,066 fish representing 49 native species, two introduced species (redbreast sunfish, and yellow perch), and no hybrid fish (Table 14). Priority species groups were represented by 12 darter, six sunfish, and eight sucker species. Three intolerant species present were northern hog sucker,

TABLE 14. Totals of all fish collected in IBI samples taken at Sequatchie River mile 7.1 on 6/6/86, 6/16-17/87, and 6/7-8/88.

Scientific Name	Common Name	Total			Tolerance*	Trophic	Group
		1986	1987	1988			
Ichthyomyzon castaneus	Chestnut lamprey	1	0	5		Parasitic	Misc.
Lepisosteus oculatus	Spotted gar	1	3	6		Piscivore	Misc.
Lepisosteus osseus	Longnose gar	0	0	5	TOL	Piscivore	Misc.
Amia clava	Bowfin	0	3	2	TOL	Piscivore	Misc.
Dorosoma cepedianum	Gizzard shad	12	11	30	TOL	Omnivore	Misc.
Campostoma anomalum	Central stoneroller	1	3	3		Herbivore	Misc.
Cyprinus carpio	Common carp	0	1	0	TOL	Omnivore	Misc.
Hybopsis insignis	Blotched chub	13	22	34		Omnivore	Misc.
Hybopsis amblops	Bigeye chub	23	5	56		Specialist	Misc.
Nocomis micropogon	River chub	15	20	19	TOL	Omnivore	Misc.
Notemigonus crysoleucas	Golden shiner	0	1	0	TOL	Omnivore	Misc.
Notropis atherinoides	Emerald shiner	6	0	0		Specialist	Misc.
Notropis galacturus	Whitetail shiner	19	16	10		Insectivore	Misc.
Notropis rubellus	Rosyface shiner	0	0	2		Specialist	Misc.
Notropis spilopterus	Spotfin shiner	25	102	139	TOL	Insectivore	Misc.
Notropis whipplei	Steelcolor shiner	26	103	20		Insectivore	Misc.
Notropis chrysocephalus	Striped shiner	28	29	23	TOL	Omnivore	Misc.
Notropis volucellus	Mimic shiner	1	0	0		Specialist	Misc.
Notropis (undescribed)	"Sawfin" shiner	0	1	7		Specialist	Misc.
Pimephales notatus	Bluntnose minnow	0	1	0		Omnivore	Misc.
Pimephales vigilax	Bullhead minnow	1	7	0		Specialist	Misc.
Hypentelium nigricans	Northern hog sucker	2	13	23	INT	Insectivore	Suckers
Ictiobus bubalus	Smallmouth buffalo	0	3	1		Omnivore	Suckers
Ictiobus niger	Black buffalo	1	1	0		Omnivore	Suckers
Minytrema melanops	Spotted sucker	0	4	1		Insectivore	Suckers
Moxostoma anisurum	Silver redhorse	1	1	3		Insectivore	Suckers
Moxostoma macralepidotum	Shorthead redhorse	1	2	5		Insectivore	Suckers
Moxostoma carinatum	River redhorse	0	4	3		Insectivore	Suckers

TABLE 14 (cont.).

Scientific Name	Common Name	Total 1986	Total 1987	Total 1988	Tolerance*	Trophic	Group
Moxostoma duquesnei	Black redhorse	4	9	21		Insectivore	Suckers
Moxostoma erythrurum	Golden redhorse	3	2	2		Insectivore	Suckers
Ictalurus natalus	Yellow bullhead	0	2	0	TOL	Omnivore	Misc.
Ictalurus punctatus	Channel catfish	2	3	3		Omnivore	Misc.
Pylodictis olivaris	Flathead catfish	1	0	1		Piscivore	Misc.
Fundulus olivaceus	Blackspotted topminnow	3	2	7		Insectivore	Misc.
Gambusia affinis	Mosquitofish	0	5	12	TOL	Insectivore	Misc.
Ambloplites rupestris	Rock bass	11	25	78		Piscivore	Sunfish
Lepomis gulosus	Warmouth	0	0	1	IN	Insectivore	Sunfish
Lepomis auritus	Redbreast sunfish	19	37	110		Insectivore	Sunfish
Lepomis macrochirus	Bluegill	11	45	53		Insectivore	Sunfish
Lepomis megalotis	Longear sunfish	20	4	94		Insectivore	Sunfish
Lepomis microlophus	Redear sunfish	7	30	14		Insectivore	Sunfish
Micropterus punctulatus	Spotted bass	4	8	11		Piscivore	Misc.
Micropterus salmoides	Largemouth bass	1	8	3		Piscivore	Misc.
Micropterus dolomieui	Smallmouth bass	0	1	0		Piscivore	Misc.
Pomoxis nigromaculatus	Black crappie	3	1	0		Piscivore	Sunfish
Etheostoma blennioides	Greenside darter	2	0	1		Specialist	Darters
Etheostoma camurum	Bluebreast darter	7	5	7		Specialist	Darters
Etheostoma jessiae	Blueside darter	2	0	6		Specialist	Darters
Etheostoma kennicotti	Stripetail darter	0	1	2		Specialist	Darters
Etheostoma rufilineatum	Redline darter	48	63	124		Specialist	Darters
Etheostoma simoterum	Tennessee snubnose darter	4	3	4		Specialist	Darters
Etheostoma tippecanoe	Tippecanoe darter	0	8	9	INT	Specialist	Darters
Etheostoma zonale	Banded darter	2	1	3		Specialist	Darters
Perca flavescens	Yellow perch	3	13	18		Insectivore	Misc.
Percina caprodes	Logperch	15	19	59		Specialist	Darters
Percina sciera	Dusky darter	4	1	10		Specialist	Darters

TABLE 14 (cont.).

Scientific Name	Common Name	Total 1986	1987	1988	Tolerance*	Trophic	Group
Percina shumardi	River darter	1	0	3		Specialist	Darters
Percina tanasi	Snail darter	0	0	1			Darters
Stizostedion canadense	Sauger	0	0	1		Piscivore	Misc.
Aplodinotus grunniens	Freshwater drum	3	2	3		Insectivore	Misc.
Cottus carolinae	Banded sculpin	3	0	5		Insectivore	Misc.
Labidesthes sicculus	Brook silverside	16	4	3		Insectivore	Misc.
		366	659	1066			

*Tolerance – TOL=Tolerant, INT=Intolerant

bluebreast darter, and tippecanoe darter. Tolerant species found were longnose gar, bowfin, gizzard shad, river chub, spotfin shiner, striped shiner, and mosquitofish. Maladies affected 19 fish including extremely poor condition (four minnows), lesions (three bass, one sunfish, and one sucker), deformed backbone (one minnow), twirled scales (one sucker), fin rot (one minnow and one sunfish), leech infestation (one catfish), and blackspot disease (three darters and two minnows). Water quality measurements were normal (Table 6).

The fish fauna at SRM 7.1 rated an index of 50 which corresponds to a classification "Good" (Tables 3 and 15). Moderate disturbance was found in species richness and composition. The low number of intolerant species resulted in a moderate score for metric 5, and the proportion of tolerant fish was unusually high, creating a low score for metric 6. This suggests that environmental degradation was adversely affecting intolerant species thus reducing competition with tolerant species. Total number of native species and numbers of darter, sunfish, and suckers were satisfactory and attained high scores for metrics 1, 2, 3, and 4, respectively. Trophic structure showed only limited imbalance. The proportion of specialized insectivores was less than expected, producing a moderate score for metric 8. Proportions of omnivores and piscivores were both at healthy levels scoring high for metrics 7 and 9. Catch

TABLE 15. Index of Biotic Integrity for Sequatchie River mile 7.1, June 16-17, 1987 and June 7-8, 1988.

		Scores		Scoring Criteria			Observed		Max. expected
		1987	1988	1	3	5	1987	1988	
Metric 1	Total number of native fish species	5	5	<23	23-44	>44	48	49	71
Metric 2	Number of darter species	3	5	<5	5- 8	>8	9	12	14
Metric 3	Number of sunfish species, less *Micropterus*	5	5	<3	3- 5	>5	6	6	8
Metric 4	Number of sucker species	5	5	<4	4- 6	>6	9	8	10
Metric 5	Number of intolerant.species	3	3	<2	2- 3	>3	3	3	6
Metric 6	Proportion of individuals as tolerant species	1	1	>20%	20-10	<10%	20.8%	21.6%	
Metric 7	Proportion of individuals as omnivores	5	5	>30%	30-15	<15%	14.3%	10.3%	
Metric 8	Proportion of individuals as specialized insectivores	1	3	<25%	25-50	>50%	17.3%	27.6%	
Metric 9	Proportion of individuals as piscivores	5	5	<2%	2- 5	>5%	7.1%	10.0%	
Metric 10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	3	3	<8	8-16	>8	9.7%	15.7%	
Metric 11	Proportion of individuals as hybrids	5	5	>1%	1-Tr*	0	0.0%	0.0%	

TABLE 15 (cont.).

	Scores		Scoring Criteria			Observed		Max. expected
	1987	1988	1	3	5	1987	1988	
Metric 12 Proportion of individuals with disease, tumors, fin damage, and other anomalies	5	5	>5%	5-2	<2%	1.5%	1.8%	
IBI VALUE	46	50						

*Tr = Value between 0 and 1%

rate was only slightly low, producing a moderate score for metric 10. Low catch rate occurred primarily in run and shallow pool habitat. An absence of hybrid fish and a low proportion of fish with disease, tumors, fin damage, and other anomalies produced high scores for metrics 11 and 12.

There was little improvement in the fish fauna since 1987. After adjusting 1987 findings to 1988 IBI modifications (noted on page 3), 1987 and 1988 sampling resulted in indices of 46 and 50 with classifications "Fair-Good" and "Good", respectively (Table 15). Improved scoring was represented by a high score for number of darter species (metric 2) and a moderate score for the proportion of specialized insectivores (metric 8). This represents recovery by some of the more pollution sensitive species. Catch rate (metric 10) also improved but was insufficient to effect a higher metric score. Metrics 1, 3, 4, 7, 9, 11, and 12 continued to receive high scores. Problems persisted as moderate scores were found for metrics 5 and 10, and a low score was given for metric 6.

Adjustment of 1987 findings to 1988 IBI modifications (noted on page 3) improved scoring for metric 7, increasing the index from 44 to 46, and improved the classification from "Fair" to "Fair-Good." Unexpected species occurrence for this site required an upward adjustment of scoring criteria for metric 1. This had no effect on 1986 or 1987 scoring.

Benthic macroinvertebrates sampled in 1988, resulted in a mean abundance of 2,580 organisms per square meter, 59 taxa, and 23 EPT taxa (Table 8). In 1987, benthic sampling produced a mean abundance of

3,229 organisms per square meter, 54 taxa, and 21 EPT taxa (Table 9). A comparison between the five most abundant groups between sampling years are listed below:

1988	1987
Diptera – 55%	Diptera – 62%
Coleoptera – 14%	Trichoptera – 18%
Ephemeroptera – 13%	Ephemeroptera – 9%
Pleurocerid snails – 8%	Coleoptera – 6%
Corbicula fluminea – 5%	Pleurocerid snails – 2%

Overall, the macroinvertebrate community reflected only slight degradation with minimal improvement since 1987. Total number of taxa reported in 1988, improved since 1987 (54); however, the classification remained "Good" for both years (see methods and materials page 10). Number of EPT taxa also improved from 21 in 1987, to 23 in 1988, and continued to rate a classification "Good." Percent composition by major taxocenes exhibited some minor shifts. The proportion of dipterans were dominant in 1987 (62%) and were the most abundant organism again in 1988 (55%). These large proportions were based on abundant chironomid midge larvae, approximately 1400 larvae per square meter for each year. An abundance of chironomids usually indicates degradation from enrichment and/or siltation. Coleopteran riffle beetles, whose tolerance to pollution is uncertain, were the second most abundant group (14%) in 1988, increasing from fourth (6%) in 1987. The most common riffle beetle for both surveys was *Stenelmis* sp. Trichoptera which was the second most abundant group (18%) in 1987, decreased to 4.5 percent in 1988, and were not ranked. Pleurocerid river snails (*Pleurocera canaliculata* and *Leptoxis praerosa*) increased from 2% in 1987, to 8% in 1988. This was similar to the faunal shift reported from the Powell River fixed station in 1988, where reduced numbers of filter feeding trichopterans and increased numbers of snails were suspected of being influenced by drought conditions. Theoretically, reduced turbidity associated with the drought would have enhanced growth of algae and periphyton (snail food) while reducing flow, and suspended particles and plankton required by filter feeding caddisflies. Ephemeropterans were the third most abundant group for both sampling years (13% and 9%), with slightly higher numbers reported in 1988. Dominant ephemeropteran taxa for both years were *Tricorythodes* sp., *Baetis* sp., and *Stenonema* sp. The Asian clam (*Corbicula fluminea*), increased from 1.5%in 1987 to 5% in 1988, to become the fifth most dominant group in 1988. This species is especially common throughout the Southeastern United States, and occurs in a wide range of habitats and water quality conditions. Unlike native freshwater mussels, the Asian clam is highly adapted and tolerant to stream perturbations and poor water quality. Large numbers of *Corbicula* sp. are generally signs of stream degradation.

Conclusion

IBI sampling at SRM 7.1 during 1988 indicated a slight disturbance of the fish community and minor improvement since 1987. Evidence of recovery was seen as the index increased from 46 in 1987, to 50 in 1988, raising the classification from "Fair-Good" to "Good." Recovery occurred among some of the more pollution sensitive species. The number of darters increased to an expected level, and the proportion of specialized insectivores improved metric scoring, but was still less than expected.

Catch rate increased considerably but did not improve over the 1987 score. Number of native species and numbers of species of sunfish, and suckers continued to look healthy. Upper and lower levels of tropic structure were also normal. There was no incidence of hybridization, and anomalous and diseased fish were present in low numbers. Problems continued to be reflected by moderate reduction in intolerant species, high proportion of tolerant fish, moderately low proportion of specialized insectivores, and moderately low catch rate.

Macroinvertebrates sampled from SRM 7.1 indicated some changes in dominant groups of taxa, but generally conditions improved since 1987. The number of total taxa collected in 1988 (59) was five taxa greater than reported in 1987 (54), resulting in a "Good" classification for both years. Number of EPT taxa improved from 21 in 1987, to 23 in 1988, and also rated a classification "Good." Percent composition by major taxocenes reported only minor changes. The proportion of dipterans, 55% in 1988 and 62% in 1987, continued to dominate the invertebrate community. Abnormally high numbers of the dipteran taxa Chironomidae are indicative of degradation, probably due to enrichment and/or siltation. The proportion of trichopterans decreased from 18% in 1987 to 4.5% in 1988. This was accompanied by an increase in proportion of pleurocerid river snails from 2 % in 1987, to 8% in 1988. The changes observed in proportions of these two taxocenes resemble a similar pattern observed in the Powell River during 1988, and is thought to be influenced by drought conditions resulting from reduced turbidity and flow. Increases in proportions of coleopteran riffle beetles and Asian clams, *Corbicula fluminea,* were also seen in 1988. Whether or not their success is related to changes in environmental stress or water quality degradation remains uncertain.

Primary forms of pollution in the Sequatchie River basin include siltation from coal mines, coal processing operations, and agriculture. Visible evidence of environmental degradation was moderate to heavy siltation in runs, eddies, and pools. Water quality measurements were considered normal.

BEAR CREEK

Station Description

Approximately 0.3 mile of Bear Creek, Bear Creek mile (BCM) 25.0 to BCM 25.3, was sampled at the confluence of Rock Creek (Table 1). Habitat at this station is typical of low-land streams in the Tennessee Valley. Runs and low gradient riffles were present with predominantly sand and gravel substrate. Some cobble was found in the main body of the riffles but no larger size substrates. Substrate in eddies and backwater areas consisted of silted sand and detritus. Since 1987, there had been some obvious shifts in gravel substrate in some areas, apparently the result of high flows. Shoreline habitat included open gravel bars and undercut clay banks. Log-jams provided heavy cover within the stream bed and along shorelines. The land adjacent to the stream was forested and most shoreline areas was partially covered by some tree canopy. Stream gradient is relatively low, approximately 1.8 feet/mile between BCMs 23.6 and 27.0. Flow at BCM 25.2 was approximately 292 cfs (combined discharge from three contributing reservoirs) during sampling. The drainage area of Bear Creek is approximately 670 square miles at BCM 25.2.

Results and Discussion

Sampling efforts at BCM 25.2 during 1988 was comparable to efforts in 1987, and included a total of 36 seine hauls (including those in combination with a backpack shocker) and 100 minutes of boat shocking. A total of 1,399 fish was collected including 43 native species, one introduced species (common carp), and no hybrid fish (Table 16). Priority species groups were represented by two darter, five sunfish, and six sucker species. Only one intolerant species, bigeye shiner,

TABLE 16. Totals of all fish collected in IBI samples taken at Bear Creek mile 25.2 on June 7, 1986, June 30, 1987, and June 9, 1988.

Scientific Name	Common Name	1986	Total 1987	1988	Tolerance*	Trophic	Group
Lampetra appendix	American brook lamprey	0	0	1		Herbivore	Misc.
Ichthyomyzon castaneus	Chestnut lamprey	0	1	0		Parasitic	Misc.
Lepisosteus oculatus	Spotted gar	1	0	0		Piscivore	Misc.
Lepisosteus osseus	Longnose gar	1	4	10	TOL	Piscivore	Misc.
Dorosoma cepedianum	Gizzard shad	3	15	9	TOL	Omnivore	Misc.
Dorosoma sp.	Hybrid shad	1	0	0		Planktivore	Misc.
Esox americanus	Grass pickerel	1	0	2		Piscivore	Misc.
Campostoma anomalum	Central stoneroller	5	3	8		Herbivore	Misc.
Cyprinus carpio	Common carp	5	5	14	TOL	Omnivore	Misc.
Nocomis leptocephalus	Bluehead chub	0	0	1		Omnivore	Misc.
Notemigonus crysoleucas	Golden shiner	1	1	0	TOL	Omnivore	Misc.
Notropis atherinoides	Emerald shiner	2	0	0		Specialist	Misc.
Notropis boops	Bigeye shiner	0	2	6	INT	Specialist	Misc.
Notropis fumeus	Ribbon shiner	1	0	0	TOL	Specialist	Misc.
Notropis spilopterus	Spotfin shiner	14	137	568	TOL	Insectivore	Misc.
Notropis venustus	Blacktail shiner	0	2	5		Insectivore	Misc.
Notropis volucellus	Mimic shiner	11	46	175		Specialist	Misc.
Notropis whipplei	Steelcolor shiner	27	236	262		Insectivore	Misc.
Notropis emilias	Pugnose minnow	0	1	1		Specialist	Misc.
Notropis chrysocephalus	Striped shiner	0	0	3	TOL	Omnivore	Misc.
Phenacobius mirabilis	Suckermouth minnow	0	0	1		Specialist	Misc.
Pimephales notatus	Bluntnose minnow	0	1	8		Omnivore	Misc.
Pimephales vigilax	Bullhead minnow	4	1	10		Specialist	Misc.
Carpiodes carpio	River carpsucker	0	0	4		Omnivore	Suckers
Hypenteium nigricans	Northern hog sucker	3	1	0	INT	Insectivore	Suckers
Ictiobus bubalus	Smallmouth buffalo	0	6	20		Omnivore	Suckers
Ictiobus niger	Black buffalo	0	0	1		Omnivore	Suckers
Minytrema melanops	Spotted sucker	0	1	1		Insectivore	Suckers
Moxostoma macrolepidotum	Shorthead redhorse	0	0	4		Insectivore	Suckers
Moxostoma carinatum	River redhorse	3	0	1		Insectivore	Suckers

TABLE 16 (cont.).

Scientific Name	Common Name		Total		Tolerance*	Trophic	Group
		1986	1987	1988			
Moxostoma duquesnei	Black redhorse	1	1	4		Insectivore	Suckers
Moxostoma anisurum	Silver redhorse	0	2	0		Insectivore	Suckers
Moxostoma erythrurum	Golden redhorse	1	6	3		Insectivore	Suckers
Ictalurus punctatus	Channel catfish	2	2	7		Omnivore	Misc.
Anguilla rostrata	American eel	1	0	0		Piscivore	Misc.
Fundulus catenatus	Northern studfish	0	1	2		Insectivore	Misc.
Fundulus olivaceus	Blackspotted topminnow	1	3	3		Insectivore	Misc.
Gambusia affinis	Mosquitofish	0	3	3	TOL	Insectivore	Misc.
Lepomis cyanellus	Green sunfish	1	2	6		Insectivore	Sunfish
Lepomis humilis	Orangespotted sunfish	0	1	0		Insectivore	Sunfish
Lepomis macrochirus	Bluegill	8	15	27		Insectivore	Sunfish
Lepomis megalotis	Longear sunfish	52	127	55		Insectivore	Sunfish
Lepomis microlophus	Redear sunfish	0	2	7		Insectivore	Sunfish
Lepomis hybrid	Hybrid sunfish	0	1	0		Insectivore	Sunfish
Morone mississippiensis	Yellow bass	0	0	1		Piscivore	Misc.
Micropterus punctulatus	Spotted bass	14	29	8		Piscivore	Misc.
Micropterus salmoides	Largemouth bass	0	1	1		Piscivore	Misc.
Pomoxis annularis	White crappie	0	1	2		Piscivore	Sunfish
Etheostoma histrio	Harlequin darter	0	0	2		Specialist	Darters
Etheostoma nigrum	Johnny darter	1	0	0		Specialist	Darters
Etheostoma rufilineatum	Redline darter	0	42	142		Specialist	Darters
Percina caprodes	Logperch	3	11	5		Specialist	Darters
Percina phoxocephala	Slenderhead darter	1	0	1		Specialist	Darters
Percina sciera	Dusky darter	0	0	1		Specialist	Darters
Aplodinotus grunniens	Freshwater drum	7	2	3		Insectivore	Misc.
Labidesthes sicculus	Brook silverside	10	3	1		Insectivore	Misc.
		186	718	1399			

*Tolerance — TOL=Tolerant, INT=Intolerant was collected, while seven tolerant fish were found: longnose gar, gizzard shad, common carp, spotfin shiner, striped shiner, mosquitofish, and green sunfish. Maladies affecting 18 fish included lesions (one shad, one shiner, three suckers, and two darters), blackspot disease (one bass, two crappie, and two darter), leech infestation (one darter), anchor worm (one minnow), fin rot (one shiner), white grubs (one topminnow), and twirled scales (two shiners). Water quality measurements were lost.

The fish fauna rated an IBI index of 40 and a classification "Fair" (Tables 3 and 17). Species richness and composition, and trophic structure were seriously disturbed. A low number of native species including darter and sunfish resulted in moderate scores for metrics 1, 2, and 3. The occurrence of only one intolerant fish caused a low score for metric 5, and an abundance of tolerant fish, mostly spotfin shiner, produced a low score for metric 6. The number of sucker species was at an expected level scoring high for metric 4. Trophic structure suffered from low proportions of specialized insectivores and piscivores, resulting in reduced scores for metrics 8 and 9, respectively. However, the proportion of omnivores (metric 7) was low and received a high score. This suggests that potential problems in the food base related to enrichment or siltation have been overridden by other forms of degradation. Fish abundance and fish condition (metrics 10-12) were healthy and received high scores.

Fish sampled in 1988 showed slight improvement over sampling in 1987. The resultant index increased from 36 in 1987, to 40 in 1988, and improved from "Poor-Fair" to "Fair." Species richness and composition (metrics 1-6) had a mixture of scoring changes that tended to offset one another (Table 17). While greater numbers of darter and sucker species improved scoring for metrics 2 and 4, slight reductions in numbers of sunfish and intolerant species were sufficient to lower scoring for metrics 3 and 5. Total number of native species (metric 1) increased in 1988 but continued to be moderately suppressed. Tolerant fish continued to dominate fish numbers creating a low score for metric 6. Trophic structure (metrics 7-9) showed no change in scoring. Low proportions of specialized insectivores and piscivores to indicate imbalance in the food chain. The proportion of omnivores, however, was at a healthy low level. A considerable increase in catch rate and an absence of hybrid fish improved metrics 10 and 11 to high scores. The proportion of fish with disease, tumors, fin damage, and other anomalies remained at a normal level, scoring high for metric 12.

TABLE 17. Index of Biotic Integrity analysis for Bear Creek mile 25.20, June 30, 1987, and June 9, 1988.

		Scoring		Scoring Criteria			Observed		Max. expected
		1987	1988	1	3	5	1987	1988	
Metric 1	Total number of native fish species	3	3	<23	23-46	>46	35	43	74
Metric 2	Number of darter species	1	3	<5	5-9	>9	2	5	13
Metric 3	Number of sunfish species, less *Micropterus*	5	3	<3	3-5	>5	6	5	9
Metric 4	Number of sucker species	3	5	<4	4-6	>6	6	8	11
Metric 5	Number of intolerant species	3	1	<2	2	>2	2	1	4
Metric 6	Proportion of individuals as tolerant species	1	1	>20%	20-10		<10%	23.3%	43.3%
Metric 7	Proportion of individuals as omnivores	5	5	>30%	30-15	<15%	4.2%	4.8%	
Metric 8	Proportion of individuals as specialized insectivores	1	1	<25%	25-50	>50%	14.3%	24.7%	
Metric 9	Proportion of individuals as piscivores	3	3	<2%	2-5	>5%	4.8%	2.1%	
Metric 10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	3	5	<8	8-16	>16	13.3%	25.4%	
Metric 11	Proportion of individuals as hybrids	3	5	>1%	1-Tr*	0	0.1%	0.0%	
Metric 12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	5	5	>5%	5-2	<2%	0.6%	1.3%	
	IBI VALUE	36	40						

*Tr = Value between 0 and 1

Unexpected species occurrence in 1987 sampling required a slight upward adjustment of scoring criteria for metric 1. The adjustments had no effect on 1986 or 1987 scores for this metric. Furthermore, a correction in scoring criteria for metric 3 increased 1987 scoring and index by two points and improved the 1987 IBI classification from "Poor" to "Poor-Fair." Modification of metric scoring criteria for metric 7 (noted on page 3) had no effect on 1986 or 1987 findings.

Benthic macroinvertebrates sampled in 1988, resulted in a mean abundance of 425 organisms per square meter, 38 taxa, and 14 EPT taxa (Table 8). During 1987, benthic sampling produced a mean abundance of 336 organisms per square meter, 46 taxa and 15 EPT taxa (Table 9). A comparison between the five most abundant groups between sampling years are listed below:

1988	1987
Corbicula fluminea – 35%	*Corbicula fluminea* – 39%
Diptera – 34%	Diptera – 38%
Pleurocerid snails – 12%	Pleurocerid snails – 8%
Ephemeroptera – 8%	Ephemeroptera – 7%
Oligochaeta – 7%	Oligochaeta – 4%

Contrary to improvements reported by fish IBI sampling in 1988, the macroinvertebrate fauna continued to reflect severe degradation and suppression of certain species in the benthic community. Mean number of organisms per square meter was slightly higher in 1988, but was still low. Mean density of benthic organisms for both years was at least three times lower than mean densities found at any of the other fixed stations. Considering the high productivity potential of large lowland streams in the Tennessee Valley, the low density of organisms was probably related to stream degradation. During 1988, losses were seen in numbers of total taxa and EPT taxa suggesting additional environmental degradation since 1987. Total taxa decreased from 46 in 1987, to 38 in 1988, but did not change the classification "Fair" (see Methods and Materials). Loss of taxa involved tolerant as well as intolerant taxa and occurred mainly in qualitative sampling. This suggests that habitats where qualitative sampling was concentrated (usually littorial or shoreline areas) had incurred additional degradation since 1987 or that 1988 qualitative sampling was less effective. The reduction in number of EPT taxa from 15 in 1987, to 14 in 1988, resulted in a borderline classification "Fair" to "Poor." Numbers of total taxa and EPT taxa were the lowest found at any of the fixed stations during 1987 and 1988.

Percent composition by major taxocenes continued to indicate a stressed invertebrate community and was consistent between years. The order of the five most abundant groups remained unchanged as proportions showed minimal variation since 1987. Mean numbers of organisms were dominated by *Corbicula fluminea* and dipterans, both considered tolerant of most forms of environmental degradation. Pollution tolerant oligochaets, which are often associated with enrichment and/or siltation, were the fifth most abundant organism. Pluerocerid river snails (*Pleurocera canaliculata* and *Leptoxis praerosa)* were third in dominance. Snails are considered to be at least moderately tolerant of siltation and pollution, especially *P. canaliculata.* Other species of snails *Leptoxis* sp. and *Lithasia* sp. generally occur in silt free riffle habitats. Ephemeropterans (*Caenis* sp., *Stenonema* sp., and *Tricorythodes* sp.) were the fourth most common taxocene for both surveys, and are the least tolerant of the five dominant taxa groups.

Conclusion

Findings from 1988 IBI sampling reveal that the fish community continues to be seriously depressed and showed limited recovery. The IBI and classification for this site in 1987, 36 and "Poor-Fair", improved to 40 and "Fair," in 1988. Changes in species richness and composition were generally encouraging but did not effect an improvement in IBI. Total number of native species increased but remained moderately impaired. Recovery was seen in increased numbers of darter and sucker species. However, this was offset by losses in numbers of sunfish and intolerant species. The proportion of tolerant fish in the population continued to be abnormally high. There was no improvement in metric scoring for trophic structure which continued to suffer from a moderately low proportion of piscivores and a low proportion of specialized insectivores. The proportion of omnivores remained at a healthy low level. This situation in trophic structure suggests that another form of water pollution continued to overshadow potential problems from enrichment or siltation. Recovery was found in fish abundance and proportion of hybrids as both improved to expected levels. The proportion of fish with disease or other anomalies was at a normal low level.

Macroinvertebrate sampling indicated a severely depressed benthic community, and in contrast to fish IBI findings, revealed a slightly more depressed benthic fauna since 1987. Mean abundance of organisms (425 per square meter) continued to be less than that found at any other fixed station, and was considered evidence of major environmental perturbation. Fewer total taxa (38) and EPT taxa (14) were collected from Bear Creek than from any other fixed station in 1988. These values were also less than numbers of total taxa (46) and EPT taxa (15) collected in 1987. Total taxa maintained a classification "Fair" (moderate impact) for both years, however EPT taxa was classified as borderline "Fair" to "Poor" (severe impact) in 1988. Cause or causes for this reduction in taxa are not known, however degradation of specific habitats or sampling error are possible explanations.

Percent composition of dominant taxocenes was essentially the same for both years. Two pollution tolerant groups, *Corbicula fluminea* and dipterans (chironomids), continued to dominate numbers of organisms (35 percent and 34 percent, respectively) followed by less tolerant plueroceri̇d river snails (12 percent) and ephemeropterans (8 percent). Oligochaets, which are often an indication of environmental degradation, were the fifth most abundant taxocene at 7 percent.

The source of pollutants depressing the benthic fauna at BCM 25.2 is uncertain. Agricultural runoff, which is notorious for degradating water quality and responsible for fish kills in this region, are suspect. The Bear Creek drainage is used heavily for agricultural production and is otherwise thinly populated. Agricultural runoff could be contaminated with pesticides, herbicides, defoliants, fertilizer, and silt. Instability of some substrates, which was noticed at this site during 1988, may have had some adverse affects on the fauna, such as temporary disruption of fish and macroinvertebrate habitat and loss of fish food organisms.

ELK RIVER

Station Description

Benthic macroinvertebrates were sampled from the Elk River at mile 32.7, approximately one mile downstream from the Tennessee-Alabama state line (Salem Quadrangle, Limestone County, Alabama, 60-NE). Samples were taken on the first riffle area upstream from the backwaters of Wheeler Reservoir. The drainage area of the Elk River is approximately 1,818 square miles (TVA, 1958).

Results and Discussion

Benthic macroinvertebrates sampled at ERM 32.7, in 1988, resulted in a mean abundance of 7,216 organisms per square meter, 51 total taxa, and 22 EPT taxa (Table 8). In 1987, sampling produced a mean abundance of 4,321 organisms per square meter, 52 taxa, and 21 EPT taxa (Table 9). A comparison between the five most dominant groups between sampling years are listed below:

1988	1987
Pleurocerid snails – 60%	Pleurocerid snails – 44%
Coleoptera – 20%	Diptera - 32%
Diptera – 11%	Ephemeroptera – 9%
Trichoptera – 5%	Trichoptera – 7%
Ephemeroptera – 2%	Coleoptera – 5%

Sampling at ERM 32.7 reported no sign of recovery in the macroinvertebrate community since 1987. For both years, numbers of total taxa rated a "Fair" classification, and numbers of EPT taxa rated "Good." The suppression of benthic fauna indicates slight-to-moderate degradation during both years. Notable shifts occurred in percent composition of major taxocenes. However, these provided no definite evidence of change in environmental quality. Pleurocerid snails, considered to be moderately tolerant of environmental degradation, continued to dominate numbers of organisms collected and increased their proportion from 44% in 1987 to 60% in 1988. This increase was the result of increase in snail abundance, especially *Elimia laqueata.* Riffle beetles, of undetermined tolerance, also increased in numbers in 1988, becoming the second most abundant taxocene at 20%. Tolerant dipterans (midge larvae) decreased in percent composition from 32% in 1987, to 11% in 1988, an indication that enrichment or siltation may have been more severe in 1987. Caddisflies and mayflies, considered intolerant taxocenes, continued to constitute less than 10% of organisms collected. Caddisflies (*Cheumatopsyche* sp.) were fourth in dominance in 1988 (5%) and 1987 (7%). Mayflies (*Stenonema* sp., *Stenacron* sp., and *Serratella* sp.) declined from 9% in 1987 to 2% in 1988. The most noticeable difference between the 1988 and 1987 sample was the considerable increase in mean abundance of organisms per square meter. This was due to increased numbers of pleurocerid river snails and coleopteran beetles. A relatively rare snail species (*Pleurocera alveare*), was reported from this site for both sampling years.

Conclusion

Macroinvertebrate sampling at ERM 32.7 indicated slight to moderate impairment. Minor differences between 1988 and 1987 surveys revealed no discernible change in the health of the macroinvertebrate community. In both years, number of total taxa rated a classification "Fair" (moderate impact), decreasing slightly from 52 in 1987, to 51 in 1988.

Similarly, number of EPT taxa maintained a "Good" (slight impact) classification for both sampling years, increasing from 21 in 1987, to 22 in 1988. Some shifts occurred in percent composition of major taxocenes. Overall, these changes did not represent any clear indication of faunal recovery or further disturbance of the fauna. The moderately tolerant pleurocerid snails increased and continued to be the dominate taxocene. Coleopteran riffle beetles also increased and were the second largest group of benthic organisms collected in 1988. Percent composition by dipterans (primarily tolerant midges) and intolerant mayflies both declined in 1988. Caddisflies, a relatively intolerant taxocene, maintained approximately the same proportion in both 1987 and 1988 samples. In addition to these changes, mean abundance of organisms per square meter was 60% greater in 1988 than in 1987, due to increased numbers of river snails and riffle beetles.

Suspected sources of environmental perturbation at ERM 32.7 include water level manipulations from Tims Ford Dam, and agriculture development throughout the river basin. Although this station is approximately 100 miles downstream from the dam, it is still subjected to fluctuations in flow regimes, shifting substrate, and abnormal lower seasonal temperatures caused by hypolimnetic releases from Tims Ford Dam. Land use in the river basin is primarily agriculture which may produce run-off containing pollutants such as fertilizer, insecticides, herbicides, silt, or animal wastes.

DUCK RIVER

Station Description

Benthic macroinvertebrates were sampled from the Duck River at mile 15.8, just downstream from Link Bridge (Hurricane Mills Quadrangle, Humphreys County, Tennessee, 31-NE). Samples were taken from the first riffle area upstream from the backwaters of Kentucky Lake. Drainage area of the Duck River at this site is 2,660 square miles (TVA, 1958).

Results and Discussion

Benthic macroinvertebrates sampled in 1988, resulted in a mean abundance of 1,443 organisms per square meter, 40 total taxa, and 16 EPT taxa (Table 8). In 1987, sampling produced a mean abundance of 1,823 organisms per square meter, 53 total taxa, and 23 EPT taxa (Table 9). A comparison between the five most abundant groups between sampling years are listed below:

1988	1987
Ephemeroptera – 35%	Diptera – 47%
Diptera – 21%	Coleoptera – 19%
Coleoptera – 20%	Ephemeroptera – 17%
Pleurocerid snails – 19%	Pleurocerid snails – 5%
Plecoptera – 7%	Plecoptera – 5%

The decrease in total mean number of organisms per square meter, total number of taxa, and total EPT taxa reflected in the 1988 samples was probably the result of sample spoilage (rotting specimens). Dipteran midge larvae were the most common group (47%) in 1987, but declined to the second most abundant taxocene (21%) in 1988. Mayflies were the most dominant group (35%) in 1988, and this represented a 50% increase in numbers since 1987 (17%).

This would suggest that an increase in pollution intolerant species to the most dominant taxocene in 1988 (Ephemeroptera) would also raise the total number of taxa and total EPT scores; however, sample spoilage and the rotting of specimens is the probable cause. The most common mayfly species reported for both surveys was *Potamanthus* sp. and *Stenonema* sp. Coleopteran riffle beetles were the third most common group (20%) in 1988, and were second (19%) in 1987. Virtually no change was noted between sampling years, with large numbers of *Stenelmis* sp. reported. Pleurocerid river snails were more abundant in 1988 (19%) than in 1987 (5%). A large number of *Lithasia geniculata* and *Pleurocera canaliculata* were found in 1988. The river snail fauna in 1987 consisted primarily of *Lithasia geniculata.* Plecopteran stoneflies were the fifth most common group of organisms in 1988 (7 percent) and 1987 (5 percent). Only one species of stonefly (*Neoperla clymene*) was reported for both surveys.

Conclusion

A lower mean total number of organisms per square meter, lower total number of taxa, and lower EPT were reported from the Duck River in 1988 than in 1987. However, this included a better quality group of organisms Ephemeroptera (mayflies) replacing dipteran midge larvae in 1988 as the most abundant organism. The relatively low number of taxa (40) reported from the Duck in 1988, rated a classification "Fair" (moderate impact). In 1987, the 53 taxa reported from the Duck rated "Good" (slight impact).

The EPT classification is probably a greater reflection of actual water quality conditions which affect pollution sensitive organisms in the Duck, since most EPT species are considered intolerant to water quality degradation. In 1988, the Duck River had an EPT of 16 and rated "Fair" (moderate impact). During 1987, the EPT total was much higher (23) and rated "Good" (slight impact). Since benthic macroinvertebrates are considered excellent indicators of water quality, the 1988 data did show a major shift in dominant taxocenes from dipterans (47%) in 1987, to pollution intolerant ephemeropterans (35%). Further, an increase was noted in pleurocerid river snails and pollution sensitive Plecoptera (stoneflies). The 1988 survey results do not support the scoring criteria that conditions have degraded in the Duck (which would account for the "Fair" classification) since 1987. Most likely, the 1988 scores were affected by specimens which were rotted and could not be identified because of spoilage. This would account for lower mean number of organisms, lower total taxa, and lower EPT totals.

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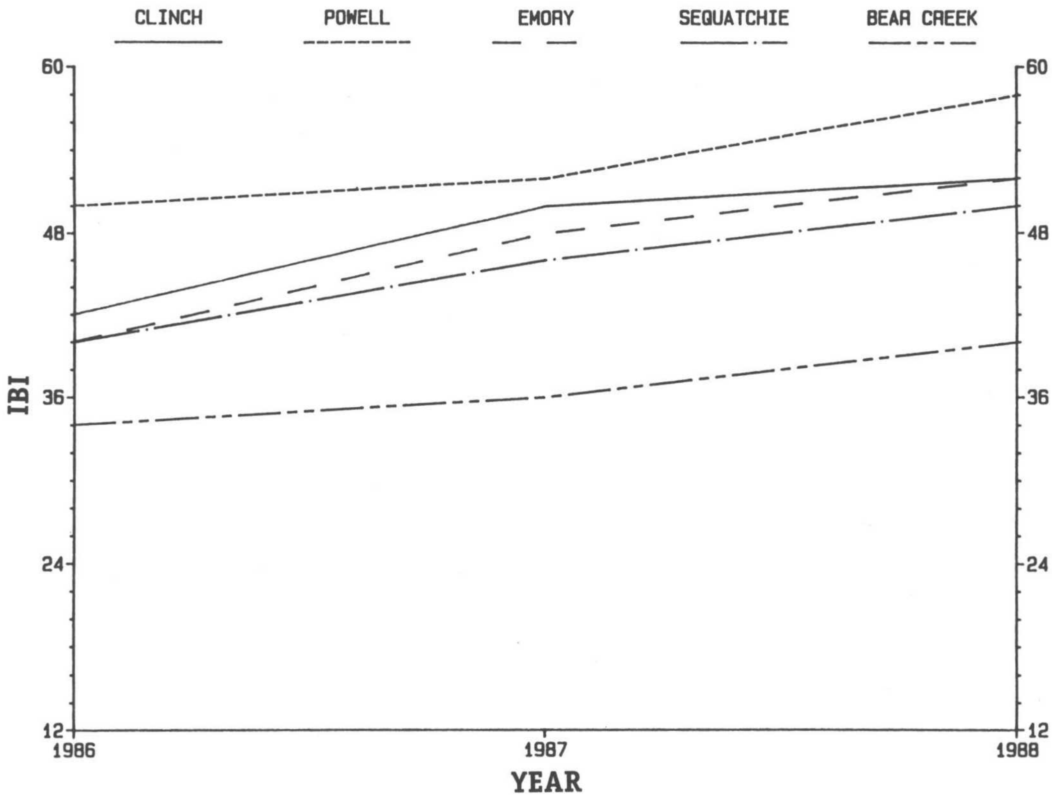
APPENDIX



Index of Biotic Integrity (IBI) classification and indices for five fixed stations, 1986-88.

Metric scores and indices for five IBI stations sampled in 1987 and 1988.

		Clinch CRM 172.3		Powell PRM 65.4		Emory ERM 21.7		Sequatchie SRM 7.1		Bear Creek BCM 25.2	
		1987	1988	1987	1988	1987	1988	1987	1988	1987	1988
Metric 1	Total number of native fish species	5	5	5	5	5	5	5	5	3	3
Metric 2	Number of darter species	5	5	3	5	3	5	3	5	1	3
Metric 3	Number of sunfish species, less *Micropterus*	3	3	3	5	5	5	5	5	5	3
Metric 4	Number of sucker species	3	5	5	5	5	3	5	5	3	5
Metric 5	Number of intolerant species	5	5	5	5	5	5	3	3	3	1
Metric 6	Proportion of individuals as tolerant species	3	3	3	5	3	5	1	1	1	1
Metric 7	Proportion of individuals as omnivores	5	5	5	5	5	5	5	5	5	5
Metric 8	Proportion of individuals as specialized insectivores	3	3	5	5	3	5	1	3	1	1
Metric 9	Proportion of individuals as piscivores	3	5	5	5	5	5	5	5	3	3
Metric 10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	5	5	5	5	3	5	3	3	3	5
Metric 11	Proportion of individuals as hybrids	5	5	3	5	3	3	5	5	3	5
Metric 12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	5	3	5	3	3	1	5	5	5	5
	IBI VALUE	50	52	52	58	48	52	46	50	36	40

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