

FINAL REPORT
PREDICTION OF RESISTANCE AND RESILIENCE
OF STREAM ECOSYSTEMS

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INTRODUCTION

One of the goals of the National Park Service (NPS) is to establish monitoring programs with the intent of detecting changing conditions. Prior to the initiation of such a program for aquatic systems,, it is first necessary to devise a method to measure stream health. It is our contention that to effectively appraise the health of any ecosystem it is necessary to enumerate the biotic diversity of the system.

Historically, water quality was assessed through the measurement of physical and chemical parameters; and thus it was assumed that an increase in biological quality would follow observed improvement in nonbiological parameters (Karr et al. 1987). Consequently, the assessment of ecosystems has evolved from the presentation of flora and fauna lists to a series of classification schemes, which include species-area curves (Gleason 1922), diversity indices (Shannon and Weaver 1949, Margalef 1958, Wilhm and Dorris 1968, Cairns et al. 1968, among others), autotrophic-heterotrophic ratios (Weber 1973), saprobian designations (Bick 1958, Cairns 1977), and biotic indices (Weber 1973, Karr et al. 1986). While these classification schemes have been used to rank the biological health or integrity of various ecosystems, they do not enable managers of land and water ecosystems to establish an effective, generalized monitoring system. To effectively appraise the health of any ecosystem with the intention of devising a monitoring plan, it is necessary to enumerate the biotic diversity of the system, as accomplished by the aforementioned schemes, and to integrate these data bases with information on the physical parameters of each system

and the types of stresses that threaten a particular system. The purpose of this report is to suggest and describe different methods of assessing the health of streams associated with four national parks in Pennsylvania: Upper Delaware Scenic and Recreational River (UPDE), Gettysburg National Military Park (GETT), Hopewell Furnace National Historic Site (HOFU), and Valley Forge National Historical Park (VAFO).

Toward this end, we determined the species richness of both the fish and macroinvertebrate communities of the aquatic systems within and adjacent to each of the parks. To effectively compare the aquatic communities of separate ecosystems we subjected the data to Detrended Correspondence Analysis, which permits one to assess similarity in a simple, graphical manner. It is generally accepted that mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) are particularly pollution-sensitive compared to other aquatic insects. Therefore, we calculated the differences in the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa between those sites located within park boundaries and the adjacent sites. Although this index may provide some indication of ecosystem health, it is to a certain extent stress specific. For example, stoneflies are generally more tolerant of low pH than many dipteran (true flies) species, although the latter are usually considered to be more tolerant to a wider range of pollutants. Thus, we calculated inertia and elasticity indices as conceived by Cairns and Dickson (1977) in order to predict the amount of stress a particular system can assimilate and the

potential of a system to recover once a structural or functional change of the biota was effected. Stauffer et al. (1978) and Stauffer and Hocutt (1980), using fishes, examined the feasibility of using the concepts of inertia and elasticity to classify the Youghiogheny River (Monongahela River System) and Conowingo Creek (Susquehanna River), respectively. Both of these studies concluded that the most important parameter upon which inertia is based is structural and functional redundancy.

METHODS

Site Selection

Table 1 describes the locality of all of the streams selected for each of the four parks (Figure 1). We attempted to choose sites on park streams and to find streams adjacent to, but outside of park boundaries that were close to the parks and were comparable in physical characters to study sites. The sites located inside the parks were chosen from those that had the most diverse habitat. We attempted to find sites that had an assortment of riffles, runs, and pools within a 100 m stretch and were without a preponderance of any one habitat type. In some instances this was difficult; site G1 at GETT did not have diverse habitats, but it was one of very few sites in the park that was collectible.

We chose reference sites outside of the parks, so that we could make assess the conditions of the streams in order to compare their fauna with the fauna inhabiting

Table 1. Sites collected for fishes and macroinvertebrates in the summers of 1990, 1991, and 1992 in and adjacent to four national parks in Pennsylvania

Upper Delaware National Scenic and Recreational River (UPDE)

- D2 Delaware River at National Park Service HQ in Wayne County, PA
- D3 Delaware River just upstream of Cortese Landfill, Sullivan County, NY
- D4 Delaware River just downstream of Cortese Landfill, Sullivan County, NY
- D5 Delaware River along railroad tracks, Sullivan County, NY
- D6 Delaware River at railroad bridge, Sullivan County, NY
- D7 Delaware River just upstream from Barryville, Sullivan County, NY

Gettysburg National Military Park (GETT)

- G1 Plum Run at Crawford Road bridge off Wheatfield Road within GETT
- G2 Willoughby Run at Water Works Road bridge within GETT
- G3 Willoughby Run at Route 30 bridge
- G4 Marsh Creek at Redrock Road bridge at mouth of Willoughby Run
- G5 Rock Creek at US Route 15 bridge south of junction with PA Route 97
- G6 Unnamed tributary to Rock Creek at US Business Route 15 just north of junction with Weaner Road
- G7 Conococheague Creek at Township Route T520 (Woodstock Road) near West Fayetteville

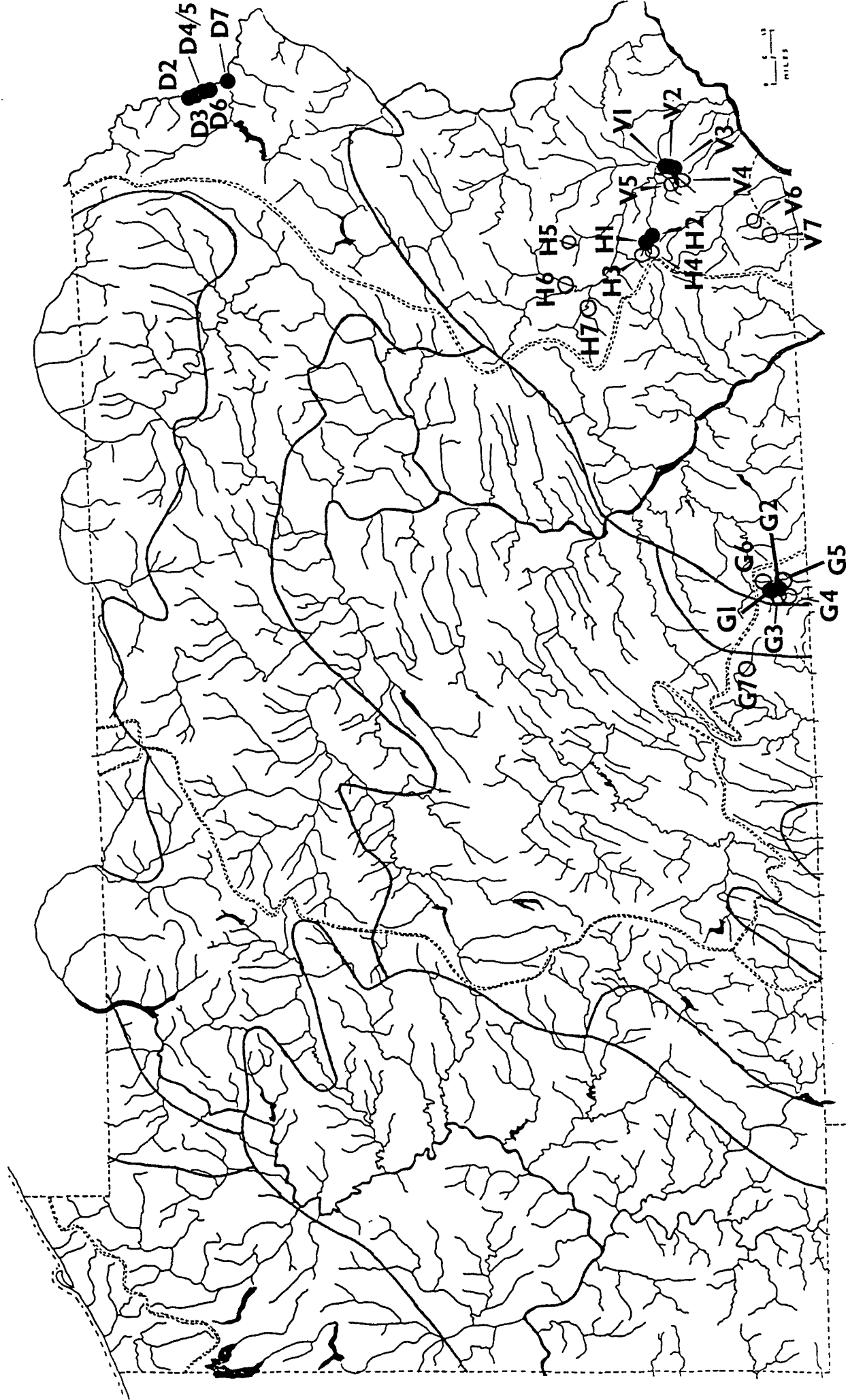
Hopewell Furnace National Historic Site (HOFU)

- H1 French Creek at Route 345 bridge within HOFU
- H2 French Creek at Harmonyville Road bridge, downstream of HOFU, just east of Bethesda Road
- H3 Scott's Run at park road bridge, French Creek State Park between Scott's Run Lake and Hopewell Lake
- H4 Pine Creek at Harmonyville Road bridge, downstream of swamp
- H5 Pine Creek at bridge on state route 1023, below Lobachsville
- H6 Maiden Creek along Wiley's Road, 0.7 miles upstream of Route 61
- H7 Tulpehocken Creek at state route 3008 bridge

Valley Forge National Historical Park (VAFO)

- V1 Valley Creek at mouth, just below Route 23 bridge, within VAFO
- V2 Valley Creek at Footbridge along Route 252, within VAFO
- V3 Valley Creek at Wilson Road bridge, within VAFO
- V4 Valley Creek at Church Road bridge
- V5 Pickering Creek at Charlestown Road bridge
- V6 Red Clay Creek at Marshall Road bridge, at confluence with West Branch
- V7 Middle Branch White Clay Creek at Crawford Road bridge off Wheatfield Road

Figure 1. Map of Pennsylvania indicating stations collected for fishes and macroinvertebrates. Closed circles indicate stations located within a national park while open circles indicate comparison stations outside national parks.



the streams within each park. To choose reference sites for each park, we examined streams within an approximately 50 km radius of each park that drained the same landform or, in one case (i.e. UPDE), chose a site within the park, but upstream of a known stress. We tried to avoid streams that looked as if they might have been affected by environmental problems; this, however, is difficult in areas such as suburban Philadelphia. Most sites seemed to have some form of degradation. The study and reference sites associated with UPDE were the same sites used in a previous study in which Stauffer (1987) analyzed the effects of Cortese Landfill leachate on the biota of the Delaware River. Here, site D2 was a reference site, sites D3 and D4 were park sites directly above and below the landfill, respectively, and sites D5, D6, and D7 were park sites located at an increasing distance downstream of the landfill. At GETT the park sites were G1 and G2. Sites H1 and H2 were park sites at HOFU. Finally, the park sites at VAFO were V1, V2, and V3. Table 2 lists the collection dates of all sites.

Collection of Organisms

Fish and macroinvertebrate collections were made during the summers of 1990, 1991, and 1992 at all sites (Figure 1). Macroinvertebrate samples were not taken at site G1 because of inappropriate habitat. Reference site H4 was abandoned after the first year because the habitat had been radically changed.

Table 2. List of the collection dates for all sites.

Site	1990	1991	1992
D2	11 July	13 June	15 June
D3	11 July	13 June	15 June
D4	11 July	13 June	15 June
D5	11 July	13 June	15 June
D6	11 July	14 June	15 June
D7	11 July	14 June	16 June
G1	18 July	15 May	23 June
G2	18 July	15 May	23 June
G3	19 July	15 May	24 June
G4	18 July	15 May	23 June
G5	14 September	16 May	24 June
G6	14 September	15 May	24 June
G7	14 September	15 May	24 June
H1	16 July	15 May	16 June
H2	16 July	15 May	16 June
H3	16 July	15 May	16 June
H5	16 July	15 May	17 June
H6	17 July	15 May	17 June
H7	17 July	15 May	17 June
V1	17 July	13 May	17 June
V2	17 July	13 May	17 June
V3	17 July	13 May	17 June
V4	17 July	13 May	17 June
V5	17 July	13 May	17 June
V6	17 July	14 May	18 June
V7	17 July	14 May	18 June

Fishes were collected at each site with a DC electrofisher. All existing habitats were thoroughly sampled over a stream reach of approximately 100 m. Fishes were tentatively identified in the field and sampling continued until it was thought that further efforts would yield no additional species. Fishes were preserved in 10% formalin, returned to the laboratory for positive identification, and permanently stored in 50% isopropyl alcohol. Specimens were catalogued into the Pennsylvania State University Fish Museum as voucher specimens; most game fishes were identified in the field and released.

Macroinvertebrates were collected within the same reach as the fishes using a D-frame kick net as described by Frost et al. (1971) at 9 places in the riffle section of each site. The collector stood directly upstream of the net and disturbed the substrate for 20 seconds. Benthic invertebrates were dislodged and swept into the net. The net's contents were pooled at each site and the invertebrates were separated from the detritus and inorganic material in the laboratory. A stereo-microscope and standard taxonomic keys were used to identify the invertebrates to the lowest practical taxon (usually genus). Macroinvertebrates were permanently stored in the Frost Entomological Museum at Penn State.

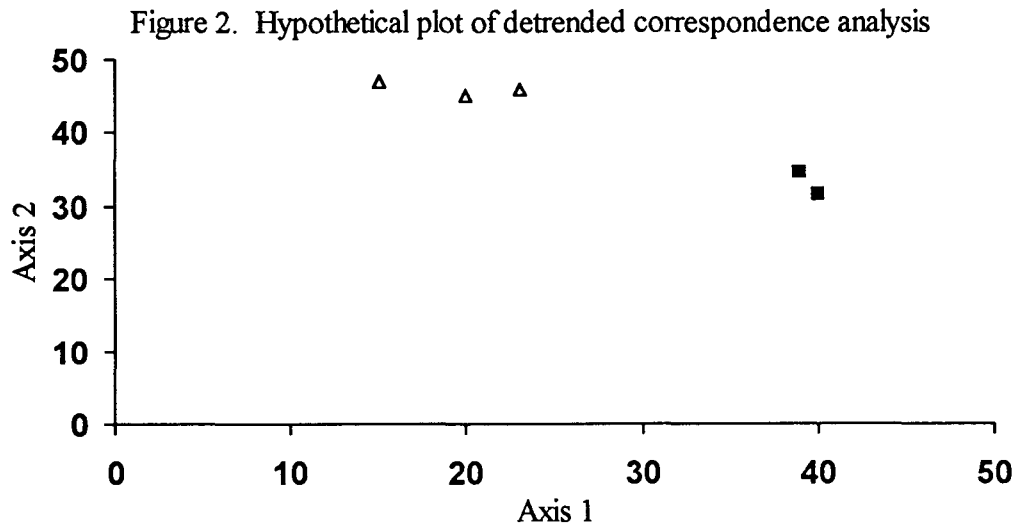
Data Analysis

Macroinvertebrate and fish data sets were analyzed separately. Data from each year were treated as a replicate.

Species Richness: Differences in the number of species among sites were determined using analysis of variance and Tukey's pairwise comparison ($P < 0.05$). These techniques indicate which sites are more diverse in a rigorous statistical manner.

Detrended Correspondence Analysis: Detrended Correspondence Analysis was calculated separately for fishes and macroinvertebrates using the data collected. The technique generates 'axis scores' for each site, which are then plotted on an X-Y coordinate system. Whereas numerous axes are generated, the most useful information is located in the scores for axes 1 and 2 and thus these axes are usually the only axes plotted. Scores in close proximity to each other on the graph have a similar faunal assemblage. In the example below, the triangles and the squares represent the plotting of axes scores from some hypothetical faunal assemblages. Here, the triangles would have fauna that are more similar to each other than to the squares.

Comparison of Ephemeroptera, Plecoptera, and Trichoptera (EPT) Taxa: Organisms differ in their sensitivity to pollution. It is generally accepted that mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) are particularly pollution-sensitive compared to other aquatic insects. Therefore, it is interesting to compare levels of these three taxa in park sites and reference sites in an effort to discern differences in water quality. ANOVA was used to determine



whether differences in the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa existed between each park site and its reference sites ($P < 0.05$).

Ecosystem Inertia and Elasticity: The concepts of ecosystem inertia and elasticity (Cairns and Dickson 1977) attempt to predict the amount of stress a particular system can assimilate (inertia) and the potential of a system to recover (elasticity) if a structural or functional change of the biota was effected.

Inertia is defined as the ability of a stream to withstand a particular stress without eliciting a structural or functional change (Cairns and Dickson 1977). Cairns and Dickson (1977:38-39) argued that the inertia of the system is based on the following parameters:

- Ia) whether the indigenous organisms are accustomed to highly variable environmental conditions;
- Ib) the structural and functional redundancy of the streams;
- Ic) stream order, flow dependability, and flushing capacity;
- Id) the presence of hard, well-buffered water antagonistic to toxic substances;
- Ie) how close the system is to a major ecological transitional threshold; and
- If) the presence of a drainage basin management group with a water quality monitoring program.

Cairns and Dickson (1977:33-35) defined the elasticity of a system as the ability to recover after a structural or functional displacement has occurred. The following parameters are considered important in the development of an elasticity index:

- Ea) existence of nearby epicenters, which can serve as refugia from which organisms can re-invade a damaged ecosystem;
- Eb) mobility of any propagules of the organisms present;
- Ec) conditions of habitat following the stress;
- Ed) presence of residual toxicants;
- Ee) chemical-physical environmental quality after a toxic stress; and
- Ef) management or organizational capabilities for immediate control of the damaged area.

Inertia and elasticity indices were developed for both park and nearby reference sites.

Calculation of Inertia Indices: Each of the aforementioned parameters was rated on a scale of 1 to 3 for each site (1 = poor, 2 = moderate, 3 = good) to calculate the index:

$$\text{Inertia Index} = I_a \times I_b \times I_c \times I_d \times I_e \times I_f$$

For parameter Ia, larger values were given for streams that were expected to experience variable environmental conditions. Small urban streams (e.g., Valley Forge Sites V1-V3; Table 1) that are subject to severe fluctuations in flow during

storm events would receive a higher score. Conversely, small streams with heavily wooded drainage areas would be less likely to have differing environmental conditions and thus the organisms living there would not be adapted to changing conditions; hence, they would receive a lower score for this category. Examples of small, high order streams with these characteristics are sites H1 through H5 at Hopewell Furnace (Table 1).

Parameter Ib is an evaluation of structural and functional redundancy of the systems. For each year of data collection, three groups of sites were analyzed: UPDE, GETT, and a combination of the HOFU and VAFO. The HOFU and VAFO sites form a natural group because they are in the same physiographic province and drainage systems. Structural redundancy is essentially a measure of taxonomic redundancy. For fishes, each family (Appendix A) with more than one species for all years and over all sites within a particular park site and associated reference sites was used to calculate structural redundancy. For macroinvertebrates, instead of calculating the values using number of species within a family, structural redundancy was calculated using genera within families (Appendix B). This was done because most, if not all, keys available for identifying aquatic insects only identify them to the generic level.

Using the data from UPDE sites as an example, structural redundancy for fishes was calculated using the four families that were represented by more than one species in 1990: Cyprinidae, Catostomidae, Centrarchidae, and Percidae (Appendix A). Site

Table 3. Trophic levels of fishes collected in and around four national parks in Pennsylvania. An X in a trophic level column indicates that the fish on that row feeds at that trophic level sometime in its life.

Trophic Level	I	II	III	IV	Trophic Level	I	II	III	IV
Petromyzontidae					<i>Hypentelium nigricans</i>	X	X		
<i>Petromyzon marinus</i>	X	X	X	X	Ictaluridae				
Anguillidae					<i>Ameiurus natalis</i>	X	X	X	X
<i>Anguilla rostrata</i>		X	X	X	<i>Ameiurus nebulosus</i>	X	X	X	X
Clupeidae					<i>Noturus insignis</i>		X		
<i>Alosa sapidissima</i>	X	X			Salmonidae				
Cyprinidae					<i>Oncorhynchus mykiss</i>		X	X	X
<i>Campostoma anomalum</i>	X	X			<i>Salmo trutta</i>		X	X	X
<i>Carassius auratus</i>	X	X			<i>Salvelinus fontinalis</i>		X	X	X
<i>Clinostomus funduloides</i>	X	X			Esocidae				
<i>Cyprinella analostana</i>	X	X			<i>Esox a. americanus</i>		X	X	X
<i>Cyprinella spiloptera</i>	X	X			<i>Esox lucius</i>		X	X	X
<i>Cyprinus carpio</i>	X	X	X		<i>Esox niger</i>		X	X	X
<i>Ericymba buccata</i>	X	X			Fundulidae				
<i>Exoglossum maxillingua</i>	X	X			<i>Fundulus diaphanus</i>	X	X		
<i>Hybognathus regius</i>	X	X			Centrarchidae				
<i>Luxilus cornutus</i>	X	X			<i>Ambloplites rupestris</i>		X	X	X
<i>Margariscus margarita</i>	X	X			<i>Lepomis auritus</i>		X		
<i>Notemigonus crysoleucus</i>	X	X			<i>Lepomis cyanellus</i>		X	X	
<i>Notropis amoenus</i>	X	X			<i>Lepomis gibbosus</i>		X	X	
<i>Notropis bifrenatus</i>	X	X			<i>Lepomis macrochirus</i>		X	X	
<i>Notropis hudsonius</i>	X	X	X		<i>Micropterus dolomieu</i>		X	X	X
<i>Notropis procne</i>	X	X			<i>Micropterus salmoides</i>		X	X	X
<i>Notropis rubellus</i>	X	X			<i>Pomoxis annularis</i>		X	X	X
<i>Pimephales notatus</i>	X	X			Percidae				
<i>Pimephales promelas</i>	X	X			<i>Etheostoma blennioides</i>		X		
<i>Rhinichthys atratulus</i>	X	X			<i>Etheostoma flabellare</i>		X		
<i>Rhinichthys cataractae</i>		X			<i>Etheostoma olmstedii</i>		X		
<i>Semotilus atromaculatus</i>	X	X	X		<i>Perca flavescens</i>	X	X	X	
<i>Semotilus corporalis</i>	X	X	X		<i>Percina peltata</i>		X		
Catostomidae					Cottidae				
<i>Catostomus commersoni</i>	X	X			<i>Cottus bairdi</i>		X		
<i>Erimyzon oblongus</i>	X	X			<i>Cottus girardi</i>		X	X	

Trophic Level I

Fish that eat plants

Trophic Level II

Fish that eat planteaters, macroinvertebrates

Trophic Level III

Fish that eat fish that eat plants

Trophic Level IV

A top carnivore at some point in its life; it eats primarily other fishes

D2 had three of eight (0.375) cyprinids, one of two (0.5) catostomids, one of three (0.333) centrarchids, and one of two (0.5) percids for a mean of 0.427. Structural redundancy was similarly calculated for macroinvertebrates.

Functional redundancy is the overlap of ecosystem function among different co-occurring taxa. It was evaluated for fishes in terms of overlap of spawning habitats (or reproductive guilds) and trophic level interactions. The trophic levels at which each species interacted were determined using Carlander (1969), Scott and Crossman (1973), Stauffer et. al. (1995) and our knowledge of food habits for these species. We considered four trophic classes in this study: I) primary consumers, those fishes that eat algae and plants; II) secondary consumers, those fishes that eat animals (not including other fishes) that eat algae and plants; III) piscivores, fishes that eat other fishes and carnivorous macroinvertebrates; and IV) top carnivores, those fishes, which at some point in their lives, eat mostly other fishes (Table 3). A species can feed at more than one trophic level during its life. For example, it may start out as an algivore, move to a diet of aquatic insects, and eventually consume primarily other fishes. Again using the 1990 Delaware River site D2 as an example, there were five of ten (0.500) species found in the Delaware River from trophic level I, nine of 19 (0.474) from level II, four of seven (0.571) from level III, and two of five (0.400) from level IV. The trophic redundancy at D2 is 0.486.

In addition to functional redundancy of trophic levels, functional redundancy values for reproductive guilds were also calculated for fishes. Five spawning guilds

were designated: I) fishes that guard their young; II) fishes that guard their eggs; III) fishes that build nests; IV) fishes that lay eggs on specific substrate; and V) fishes that broadcast their eggs into the water column (Table 4). Using a similar method as that described for trophic redundancy, a spawning redundancy of 0.560 was calculated for site D2 in 1990. The mean (0.523) of the trophic redundancy and the spawning redundancy, is the functional redundancy of fishes for site D2 in 1990.

Calculations for functional redundancy of macroinvertebrates consisted of placing taxa into feeding modes and dispersal guilds. Macroinvertebrate feeding modes are as follows: I) collectors, organisms that collect particulate matter to ingest; II) predators, organisms that eat other animals; III) shredders, organisms that shred plant matter, usually leaves; IV) piercers, organisms that suck fluids out of living plants; and V) parasites, organisms that attach to other living animals and prey on blood and other bodily fluids (Table 5). Dispersal guilds are based on a taxon's ability to fly, which would determine the likelihood that the group would re-invade a disturbed habitat from a nearby healthy one. Dispersal guilds of macroinvertebrates include: I) sedentary organisms (e.g., worms), those that do not leave the water; II) flyers, those that may leave the water, but are limited in flight range (e.g., mayflies); and III) good flyers, organisms capable of prolonged flight (e.g., dragonflies) (Table 6). Feeding mode redundancy and dispersal mode redundancy for macroinvertebrates are calculated using similar methods as those used for trophic redundancy and spawning redundancy for fishes.

Table 4. Spawning habits of fishes (designated by an x) collected in and around four national parks in Pennsylvania

Spawning habits	I	II	III	IV	V	Spawning habits	I	II	III	IV	V
Petromyzontidae						<i>Hypentelium nigricans</i>				X	
<i>Petromyzon marinus</i>			X			Ictaluridae					
Anguillidae						<i>Ameiurus natalis</i>	X				
<i>Anguilla rostrata</i>					X	<i>Ameiurus nebulosus</i>	X				
Clupeidae						<i>Noturus insignis</i>	X				
<i>Alosa sapidissima</i>					X	Salmonidae					
Cyprinidae						<i>Oncorhynchus mykiss</i>		X			
<i>Campostoma anomalum</i>			X			<i>Salmo trutta</i>		X			
<i>Carassius auratus</i>				X		<i>Salvelinus fontinalis</i>		X			
<i>Clinostomus funduloides</i>			X			Esocidae					
<i>Cyprinella analostana</i>				X		<i>Esox a. americanus</i>					X
<i>Cyprinella spiloptera</i>				X		<i>Esox lucius</i>					X
<i>Cyprinus carpio</i>				X		<i>Esox niger</i>					X
<i>Ericymba buccata</i>						Fundulidae					
<i>Exoglossum maxillingua</i>		X				<i>Fundulus diaphanus</i>				X	
<i>Hybognathus regius</i>				X		Centrarchidae					
<i>Luxilus cornutus</i>			X			<i>Ambloplites rupestris</i>	X				
<i>Margariscus margarita</i>				X		<i>Lepomis auritus</i>	X				
<i>Notemigonus crysoleucus</i>					X	<i>Lepomis cyanellus</i>	X				
<i>Notropis amoenus</i>						<i>Lepomis gibbosus</i>	X				
<i>Notropis bifrenatus</i>						<i>Lepomis macrochirus</i>	X				
<i>Notropis hudsonius</i>				X		<i>Micropterus dolomieu</i>	X				
<i>Notropis procne</i>				X		<i>Micropterus salmoides</i>	X				
<i>Notropis rubellus</i>				X		<i>Pomoxis annularis</i>		X			
<i>Pimephales notatus</i>		X				Percidae					
<i>Pimephales promelas</i>		X				<i>Etheostoma blennioides</i>				X	
<i>Rhinichthys atratulus</i>			X			<i>Etheostoma flabellare</i>		X			
<i>Rhinichthys cataractae</i>		X				<i>Etheostoma olmsted</i>		X			
<i>Semotilus atromaculatus</i>			X			<i>Perca flavescens</i>				X	
<i>Semotilus corporalis</i>			X			<i>Percina peltata</i>		X			
Catostomidae						Cottidae					
<i>Catostomus commersoni</i>				X		<i>Cottus bairdi</i>		X			
<i>Erimyzon oblongus</i>				X		<i>Cottus girardi</i>		X			

Spawning Habit I	Fish that guard their young
Spawning Habit II	Fish that guard their eggs
Spawning Habit III	Fish that build nests
Spawning Habit IV	Fish that lay eggs on specific substrate
Spawning Habit V	Fish that broadcast eggs into water column

Table 5. Feeding modes of macroinvertebrates (designated by an x) collecting in and around four national parks in Pennsylvania

Taxon	Collector	Predator	Scraper	Shredder	Piercer	Parasite	Taxon	Collector	Predator	Scraper	Shredder	Piercer	Parasite
Platyhelminthes							<i>Ameletus</i>	X					
Planariidae	X						Tricorythidae						
Nematoda	X						<i>Tricorythodes</i>	X					
Annelida							Odonata		X				
Oligochaeta	X						Anisoptera		X				
Hirudinea	X	X				X	Cordulegastridae		X				
Hydracarina		X				X	<i>Cordulegaster</i>		X				
Isopoda							Gomphidae		X				
Asellidae							<i>Arigomphus</i>		X				
<i>Asellus</i>	X						<i>Erpetogomphus</i>		X				
Amphipoda							<i>Gomphus</i>		X				
Gammaridae							<i>Lanthus</i>		X				
<i>Gammarus</i>	X						<i>Ophiogomphus</i>		X				
Ephemeroptera							Libellulidae		X				
Baetidae	X		X				Zygoptera		X				
<i>Baetis</i>	X		X				Aeshnidae		X				
<i>Cloeon</i>	X		X				<i>Boyeria</i>		X				
<i>Pseudocloeon</i>	X		X				<i>Nasiaeshna</i>		X				
Caenidae	X		X				Calogperygidae		X				
<i>Caenis</i>	X		X				<i>Hetaerina</i>		X				
Ephemerellidae							Coenogrionidae		X				
<i>Attanella</i>	X						<i>Amphiagrion</i>		X				
<i>Danella</i>	X						<i>Argia</i>		X				
<i>Drunella</i>	X						<i>Enallagma</i>		X				
<i>Ephemerella</i>	X		X				Plecoptera						
<i>Eurylophella</i>	X						Capniidae		X				
<i>Serratella</i>	X						<i>Allocapnia</i>		X				
Ephemeridae	X						Chloroperlidae						
Heptageniidae	X		X				<i>Alloperla</i>	X	X				
<i>Epeorus</i>	X		X				<i>Haploperla</i>	X	X				
<i>Cinygmula</i>	X		X				Leuctridae	X	X				
<i>Leucrocuta</i>	X		X				<i>Leuctra</i>	X	X				
<i>Stenonema</i>	X		X				Nemouridae						
<i>Stenacron</i>	X		X				<i>Amphinemura</i>	X				X	
Leptophlebiidae							Peltoperlidae					X	
<i>Chloroterpes</i>	X		X				<i>Peltoperla</i>					X	
<i>Leptophlebia</i>	X						Perlidae		X				
Oligoneuridae							<i>Acroneuria</i>		X				
<i>Isonychia</i>	X						<i>Agnetina</i>		X				
Potomanthidae	X						<i>Claassenia</i>		X				
<i>Potomanthus</i>	X						<i>Eccoptura</i>		X				
Polymatarcyidae	X						<i>Neoperla</i>		X				
<i>Ephoron</i>	X						<i>Perlesta</i>		X				
Siphonuridae							<i>Perlinella</i>		X				

Table 5. (cont.) Feeding modes of macroinvertebrates (designated by an x) collected in and around four national parks in Pennsylvania.

Taxon	Collector	Predator	Scraper	Shredder	Piercer	Parasite	Taxon	Collector	Predator	Scraper	Shredder	Piercer	Parasite
<i>Phasgonophora</i>		X					<i>Ochrotrichia</i>	X					
Perlodidae		X					Lepidostomatidae				X		
<i>Isoperla</i>		X					<i>Lepidostoma</i>				X		
<i>Tallaperla</i>		X					Leptoceridae						
Pteronarcyidae	X	X		X			<i>Ceraclea</i>	X	X		X		
<i>Pteronarcys</i>	X	X		X			<i>Leptocerus</i>				X		
Hemiptera	X						<i>Mystacides</i>	X			X		
Corixidae	X						<i>Nectopsyche</i>	X	X		X		
<i>Palmacorixa</i>	X						<i>Oecetis</i>	X			X		
<i>Trichocorixa</i>	X						<i>Setodes</i>	X	X				
Gerridae	X						<i>Triaenodes</i>	X					
<i>Rheumatobates</i>	X						Limnephilidae						
<i>Trepobates</i>	X						<i>Apatania</i>	X		X			
Veliidae	X						<i>Goera</i>			X			
<i>Rhagovelia</i>	X						<i>Hydatophyla</i> X	X			X		
Megaloptera	X						<i>Neophyla</i> X			X			
Corydalidae	X						Molannidae	X	X	X			
<i>Chauliodes</i>	X						<i>Molanna</i>	X	X	X			
<i>Corydalus</i>	X						Odontoceridae						
<i>Neohermes</i>	X						<i>Psilotreta</i>	X		X			
<i>Nigronia</i>	X						Philopotamidae	X					
Sialidae	X						<i>Chimarra</i>	X					
<i>Sialis</i>	X						<i>Dolophilodes</i>	X					
Neuroptera					X		Polycentropodidae	X					
Sisyridae					X		<i>Cyrnellus</i>	X					
<i>Climacia</i>					X		<i>Neureclipsis</i>	X					
<i>Sisyra vicaria</i>					X		<i>Nyctiophyla</i> X	X					
Trichoptera							<i>Polycentropus</i>	X					
Brachycentridae	X		X				Psychomyiidae	X					
<i>Brachycentrus</i>	X		X				<i>Psychomyia</i>	X					
<i>Micrasema</i>	X		X				Rhyacophilidae		X				
Glossosomatidae			X				<i>Rhyacophila</i>		X				
<i>Agapetus</i>			X				Lepidoptera					X	
<i>Glossosoma</i>			X				Noctuidae					X	
Helicopsychidae			X				<i>Archana</i>					X	
<i>Helicopsyche</i>			X				Pyalidae					X	
Hydropsychidae	X						<i>Acentria</i>					X	
<i>Cheumatopsyche</i>	X						<i>Petrophila</i>					X	
<i>Hydropsyche</i>	X						Coleoptera						
<i>Macronema</i>	X						Chrysomelidae				X		
<i>Potamyia</i>	X						Curculionidae					X	
Hydroptilidae							<i>Emphyastes</i>					X	
<i>Hydroptila</i>	X		X				Dytiscidae		X				
<i>Leucotrichia</i>	X		X				<i>Agabus</i>		X				

Table 5. (cont.) Feeding modes of macroinvertebrates (designated by an x) collected in and around four national parks in Pennsylvania.

Taxon	Collector	Predator	Scraper	Shredder	Piercer	Parasite
<i>Hydaticus</i>		X				
<i>Hydroporus</i>		X				
<i>Laccornis</i>		X				
<i>Matus</i>		X				
Elmidae						
<i>Dubiraphia</i>	X		X			
<i>Optioservus</i>	X		X			
<i>Promoresia</i>	X		X			
<i>Stenelmis</i>	X		X			
Gyrinidae		X				
<i>Dineutus</i>		X				
Haliplidae						
<i>Haliphus</i>				X		
<i>Peltodytes</i>				X		
Hydrophilidae		X				
<i>Berosus</i>		X				
<i>Helophorus</i>		X				
<i>Lacobi</i>		X				
Psephenidae						
<i>Ectopria</i>			X			
<i>Psephenus</i>			X			
Diptera						
Athericidae		X				
<i>Atherix</i>		X				
Blephariceridae			X			
<i>Blepharicera</i>			X			
Ceratopogonidae		X				
Chironomidae	X					
Empididae		X				
<i>Chelifera</i>		X				
<i>Hemerodromia</i>		X				
Simuliidae	X					
<i>Prosimulium</i>	X					
<i>Simulium</i>	X					
Tabanidae		X				
<i>Chrysops</i>		X				
<i>Merycomyia</i>		X				
<i>Tabanus</i>		X				
Tipulidae						
<i>Antocha</i>	X					
<i>Dicranota</i>		X				
<i>Hexatoma</i>		X				
<i>Limnophila</i>		X				

Table 6. Dispersal guilds of macroinvertebrates (designated by an x) collected in and around four national parks in Pennsylvania.

Taxon	sedentary	flyers	good flyers	Taxon	sedentary	flyers	good flyers	Taxon	sedentary	flyers	good flyers
Platyhelminthes	X			Siphonuridae	X			<i>Perlesta</i>	X		
Planariidae	X			<i>Ameletus</i>	X			<i>Perlinella</i>	X		
Nematoda	X			Tricorythidae	X			<i>Phasgonophora</i>	X		
Annelida	X			<i>Tricorythodes</i>	X			Perlodidae	X		
Oligochaeta	X			Odonata			X	<i>Isoperla</i>	X		
Hirudinea	X			Anisoptera			X	<i>Tallaperla</i>	X		
Hydracarina	X			Cordulegastridae			X	Pteronarcyidae	X		
Isopoda	X			<i>Cordulegaster</i>			X	<i>Pteronarcys</i>	X		
Asellidae	X			Gomphidae			X	Hemiptera	X		
<i>Asellus</i>	X			<i>Arigomphus</i>			X	Corixidae	X		
Amphipoda	X			<i>Erpetogomphus</i>			X	<i>Palmacorixa</i>	X		
Gammaridae	X			<i>Gomphus</i>			X	<i>Trichocorixa</i>	X		
<i>Gammarus</i>	X			<i>Lanthus</i>			X	Gerridae	X		
Ephemeroptera		X		<i>Ophiogomphus</i>			X	<i>Rheumatobates</i>	X		
Baetidae		X		Libellulidae			X	<i>Trepobates</i>	X		
<i>Baetis</i>		X		Zygoptera			X	Veliidae	X		
<i>Cloeon</i>		X		Aeshnidae			X	<i>Rhagovelia</i>	X		
<i>Pseudocloeon</i>		X		<i>Boyeria</i>			X	Megaloptera			X
Caenidae		X		<i>Nasiaeshna</i>			X	Corydalidae			X
<i>Caenis</i>		X		Calogperygidae			X	<i>Chauliodes</i>			X
Ephemerellidae		X		<i>Hetaerina</i>			X	<i>Corydalus</i>			X
<i>Attanella</i>		X		Coenogronidae			X	<i>Neohermes</i>			X
<i>Danella</i>		X		<i>Amphiagrion</i>			X	<i>Nigronia</i>			X
<i>Drunella</i>		X		<i>Argia</i>			X	Sialidae			X
<i>Ephemerella</i>		X		<i>Enallagma</i>			X	<i>Sialis</i>			X
<i>Eurylophella</i>		X		Plecoptera		X		Neuroptera		X	
<i>Serratella</i>		X		Capniidae		X		Sisyridae		X	
Ephemeridae		X		<i>Allocaenia</i>		X		<i>Climacia</i>		X	
Heptageniidae		X		Chloroperlidae		X		<i>Sisyra vicaria</i>		X	
<i>Epeorus</i>		X		<i>Alloperla</i>		X		Trichoptera		X	
<i>Cinygmula</i>		X		<i>Haploperla</i>		X		Brachycentridae		X	
<i>Leucrocota</i>		X		Leuctridae		X		<i>Brachycentrus</i>		X	
<i>Stenonema</i>		X		<i>Leuctra</i>		X		<i>Micrasema</i>		X	
<i>Stenacron</i>		X		Nemouridae		X		Glossosomatidae		X	
Leptophlebiidae		X		<i>Amphinemura</i>		X		<i>Agapetus</i>		X	
<i>Chloroterpes</i>		X		Peltopteridae		X		<i>Glossosoma</i>		X	
<i>Leptophlebia</i>		X		<i>Peltopterla</i>		X		Helicopsychidae		X	
Oligoneuridae		X		Perlidae		X		<i>Helicopsyche</i>		X	
<i>Isonychia</i>		X		<i>Acroneuria</i>		X		Hydropsychidae		X	
Potomanthidae		X		<i>Agnetina</i>		X		<i>Cheumatopsyche</i>		X	
<i>Potomanthus</i>		X		<i>Claassenia</i>		X		<i>Hydropsyche</i>		X	
Polymatarcyidae		X		<i>Eccoptura</i>		X		<i>Macronema</i>		X	
<i>Ephoron</i>		X		<i>Neoperla</i>		X		<i>Potamyia</i>		X	

Table 6. (cont.) Dispersal guilds of macroinvertebrates (designated by an x) collected in and around four national parks in Pennsylvania.

Taxon	sedentary	flyers	good flyers	Taxon	sedentary	flyers	good flyers	Taxon	sedentary	flyers	good flyers
Hydroptilidae		X		Curculionidae			X	<i>Antocha</i>			X
<i>Hydroptila</i>		X		<i>Emphyastes</i>			X	<i>Dicranota</i>			X
<i>Leucotrichia</i>		X		Dytiscidae			X	<i>Hexatoma</i>			X
<i>Ochrotrichia</i>		X		<i>Agabus</i>			X	<i>Limnophila</i>			X
Lepidostomatidae		X		<i>Hydaticus</i>			X	<i>Prionocera</i>			X
<i>Lepidostoma</i>		X		<i>Hydroporus</i>			X	<i>Tipula</i>			X
Leptoceridae		X		<i>Laccornis</i>			X	Gastropoda	X		
<i>Ceraclea</i>		X		<i>Matus</i>			X	Pelecypoda	X		
<i>Leptocerus</i>		X		Elmidae			X	Sphaeridae	X		
<i>Mystacides</i>		X		<i>Dubiraphia</i>			X	Ancylidae	X		
<i>Nectopsyche</i>		X		<i>Optioservus</i>			X	Decapoda	X		
<i>Oecetis</i>		X		<i>Promoresia</i>			X	Cambaridae	X		
<i>Setodes</i>		X		<i>Stenelmis</i>			X				
<i>Triaenodes</i>		X		Gyrinidae			X				
Limnephilidae		X		<i>Dineutus</i>			X				
<i>Apatania</i>		X		Haliplidae			X				
<i>Goera</i>		X		<i>Haliplus</i>			X				
<i>Hydatophylax</i>		X		<i>Peltodytes</i>			X				
<i>Neophylax</i>		X		Hydrophilidae			X				
Molannidae		X		<i>Berosus</i>			X				
<i>Molanna</i>		X		<i>Helophorus</i>			X				
Odontoceridae		X		<i>Lacobiis</i>			X				
<i>Psilotreta</i>		X		Psephenidae			X				
Philopotamidae		X		<i>Ectopria</i>			X				
<i>Chimarra</i>		X		<i>Psephenus</i>			X				
<i>Dolophilodes</i>		X		Diptera			X				
Polycentropodidae		X		Athericidae			X				
<i>Cyrnellus</i>		X		<i>Atherix</i>			X				
<i>Neureclipsis</i>		X		Blephariceridae			X				
<i>Nyctiophylax</i>		X		<i>Blepharicera</i>			X				
<i>Polycentropus</i>		X		Ceratopogonidae			X				
Psychomyiidae		X		Chironomidae			X				
<i>Psychomyia</i>		X		Empididae			X				
Rhyacophilidae		X		<i>Chelifera</i>			X				
<i>Rhyacophila</i>		X		<i>Hemerodromia</i>			X				
Lepidoptera		X		Simuliidae			X				
Noctuidae		X		<i>Prosimulium</i>			X				
<i>Archana</i>		X		<i>Simulium</i>			X				
Pyalidae		X		Tabanidae			X				
<i>Acentria</i>		X		<i>Chrysops</i>			X				
<i>Petrophila</i>		X		<i>Merycomyia</i>			X				
Coleoptera			X	<i>Tabanus</i>			X				
Chrysomelidae			X	Tipulidae			X				

The formula for Ib at one site for one year is as follows, f=fish,
m=macroinvertebrates, SR=structural redundancy, FR = functional redundancy
(tr=trophic, sp=spawning, fm=feeding mode, d=dispersal):

$$I_b = \frac{(SR(f) + SR(m))}{2} + \frac{[ER(tr,f) + ER(sp,f)]/2 + [ER(fm,m) + ER(d,m)]/2}{2}$$

For parameters Ic and Id, each site was given the score of 2 because of lack of necessary information on flow dependability, flushing capacity, and buffer levels. Parameter Ie is an evaluation of how close the system is to a major ecological threshold. In this study the only parameter considered was temperature. Sites V1 through V4 at Valley Forge were given a value of 1, because all these sites are located on Valley Creek, which is at a “warm water” and “cold water” faunal boundary (Table 1). Sites V5-V7 were assigned a value of 2. Since all the sites sampled were located within or in close proximity to a national park, they were all given a value of 3 for parameter If, the presence of someone to monitor water quality.

Calculation of Elasticity Indices

As for the calculation of Inertia Indices, each of the aforementioned parameters was rated on a scale of 1 to 3 for each site (1 = poor, 2 = moderate, 3 = good) to calculate the index:

$$\text{Elasticity Index} = E_a \times E_b \times E_c \times E_d \times E_e \times E_f.$$

Only three of the parameters can be differentiated when calculating elasticity indices at sites that have had no known major pollution event: (Ea) existence of nearby

epicenters for providing organisms to re-invade a damaged ecosystem; (Eb) mobility of any propagules of the organisms present; and (Ef) management or organizational capabilities for immediate control of the damaged area.

In order to assign a value for Ea, we examined the drainage map for a particular region and determined the existence of refugia from which recolonization of a given site could occur after a structural or functional displacement had occurred. For example, using the data from VAFO, all of the sites located on Valley Creek were assigned a value of 1.5, while those sites located on Pickering Creek, Red Clay Creek and Middle Branch White Clay Creek were assigned a value of 2.0. Valley Creek empties directly into the Schuylkill River, which, at that location does not support a diverse macroinvertebrate or fish fauna. Moreover, the head waters of Valley Creek are characterized by a depauperate fauna. On the other hand the tributaries and surrounding waters of the other three sites support a moderately more diverse fauna.

Again using data from VAFO as an example, we assigned a value of 2.0 for Eb at all sites. Although the recolonization of fishes involves migration through connecting water bodies, which are impacted in varying degrees, the majority of the macroinvertebrate fauna could recolonize these sites relatively rapidly because they have an aerial state as one of their life stages.

Finally, as stated previously, all sites associated with all of the parks were assigned a value of 3.0 for Ef because the association with a national park does, to a certain

extent, imply the presence of a management or organizational capability for control of any damaged area.

At Valley Creek (V1-V7) and on the main channel Delaware River (sites D2-D7) there have been pollution events that allow the assigning of values to parameters Ec (condition of habitat following stress), Ed (presence of residual toxicants), and Ee (chemical-physical environmental quality after toxic stress). At the remaining sites, a score of 3 was given to each of these latter three parameters.

RESULTS

Species Richness

The raw data for fishes and macroinvertebrates are included in appendices A and B, respectively. Common names of fishes are given in Appendix C. To quantify the differences in species richness among sites, we compared values from each of the sampling years as replicates. Analysis of variance was used to test for significant differences among sites ($P < 0.05$). When there was a significant difference found, Tukey's pairwise comparison method was used to find the sites that differed. Because there were two faunal groups, fishes and macroinvertebrates, and four parks, there were eight ANOVA computations.

The following combinations yielded no significant differences among sites: UPDE fishes, GETT macroinvertebrates, and HOFU macroinvertebrates. All the other combinations were statistically significant overall; multiple comparison analyses were

done. For the UPDE macroinvertebrates, there was one pairwise difference; site D5 had higher species richness than site D6. For HOFU fishes, site H3 had a significantly lower number of species than sites H1, H2, H6, and H7. There were many pairwise differences at Valley Creek sites for both macroinvertebrates and fishes, and at the Gettysburg sites for fishes (Tables 7-9). The site across the top of each of the three tables is compared to the site down the left border; for example, site V1 has lower species richness than site V3. Dashed lines indicate redundant comparisons and empty cells indicate the lack of a significant difference.

Table 7. Valley Forge Macroinvertebrates - ANOVA Table

Site	V1	V2	V3	V4	V5	V6
V2		-	-	-	-	-
V3	<		-	-	-	-
V4				-	-	-
V5		<	<	<	-	-
V6					>	-
V7			<			<

Table 8. Valley Forge Fishes - ANOVA Table

Site	V1	V2	V3	V4	V5	V6
V2		-	-	-	-	-
V3	>		-	-	-	-
V4	>			-	-	-
V5	<	<	<	<	-	-
V6		<	<	<	>	-
V7	<	<	<	<		

Table 9. Gettysburg Fishes - ANOVA Table

Site	G1	G2	G3	G4	G5	G6
G2	<	-	-	-	-	-
G3	<		-	-	-	-
G4	<	<	<	-	-	-
G5	<	<		>	-	-
G6	<			>		-
G7	<	<		>		

Detrended Correspondence Analysis

Plots of the results of Detrended Correspondence Analysis are shown for macroinvertebrates (Figure 3) and fishes (Figure 4) for each of three years. For the fishes in 1991, site G1 was excluded from the plot as it caused a severe shifting of the rest of the data because of the depauperate fish fauna. As stated earlier, G1 had a low diversity of habitats and a concomitant low diversity of fishes. The resulting axes for these data from G1 are very skewed, causing a compression of the plots from other sites, which in turn could lead to the masking of interesting data relationships.

Comparison of Ephemeroptera, Plecoptera, and Trichoptera (EPT) Taxa

No differences existed between the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa between each park site and its reference sites ($P < 0.05$) for any of the years in which data were collected.

Ecosystem Inertia and Elasticity

Inertia: The values assigned to Ia, whether the indigenous organisms are accustomed to highly variable environmental conditions, are subjective and for the

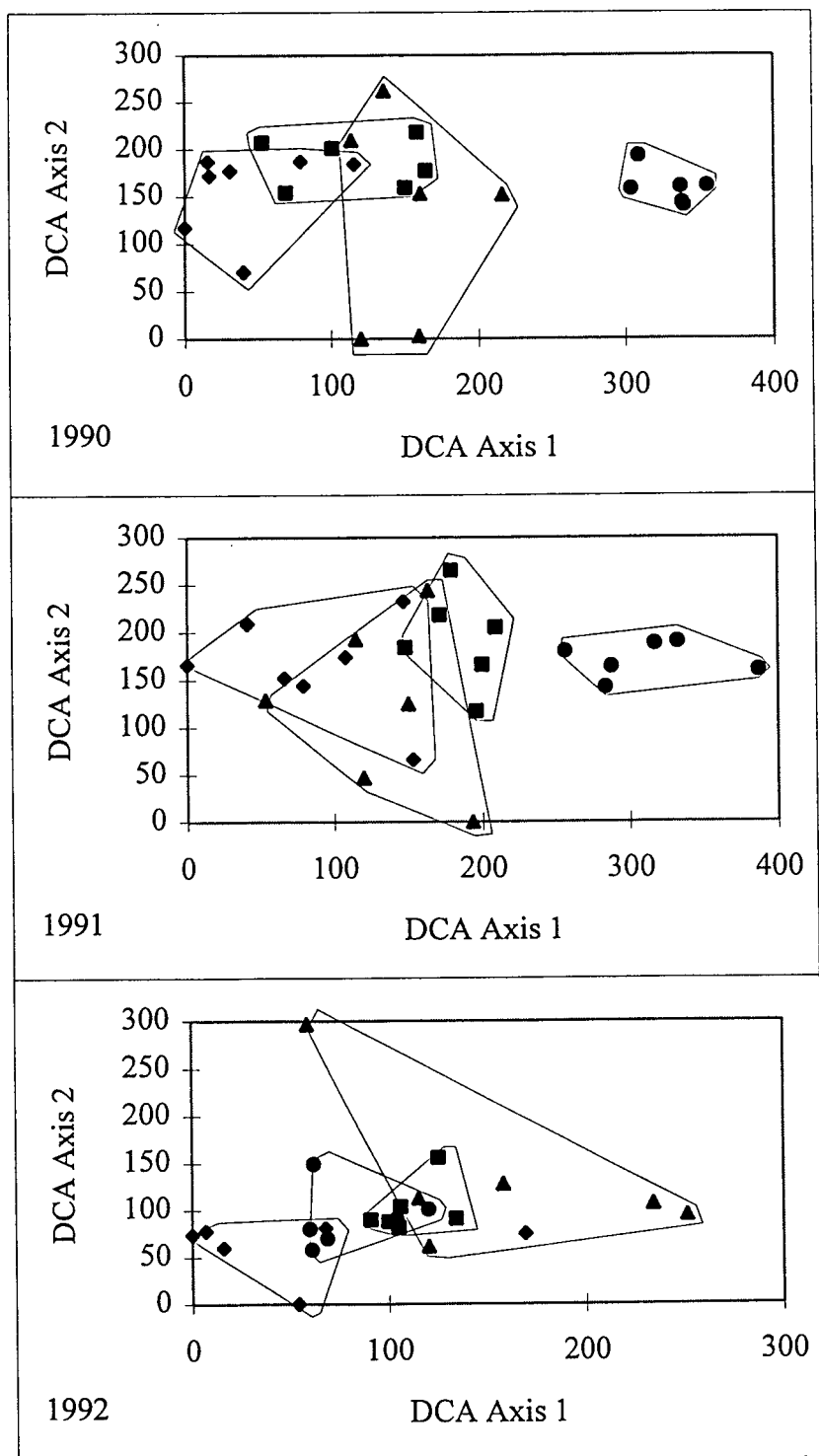


Figure 3. Plots of Axis 1 vs. Axis 2 from the Detrended Correspondence Analysis for the macroinvertebrate data. (●=UPDE, ■=GETT, ▲=HOFU, ◆=VAFO)

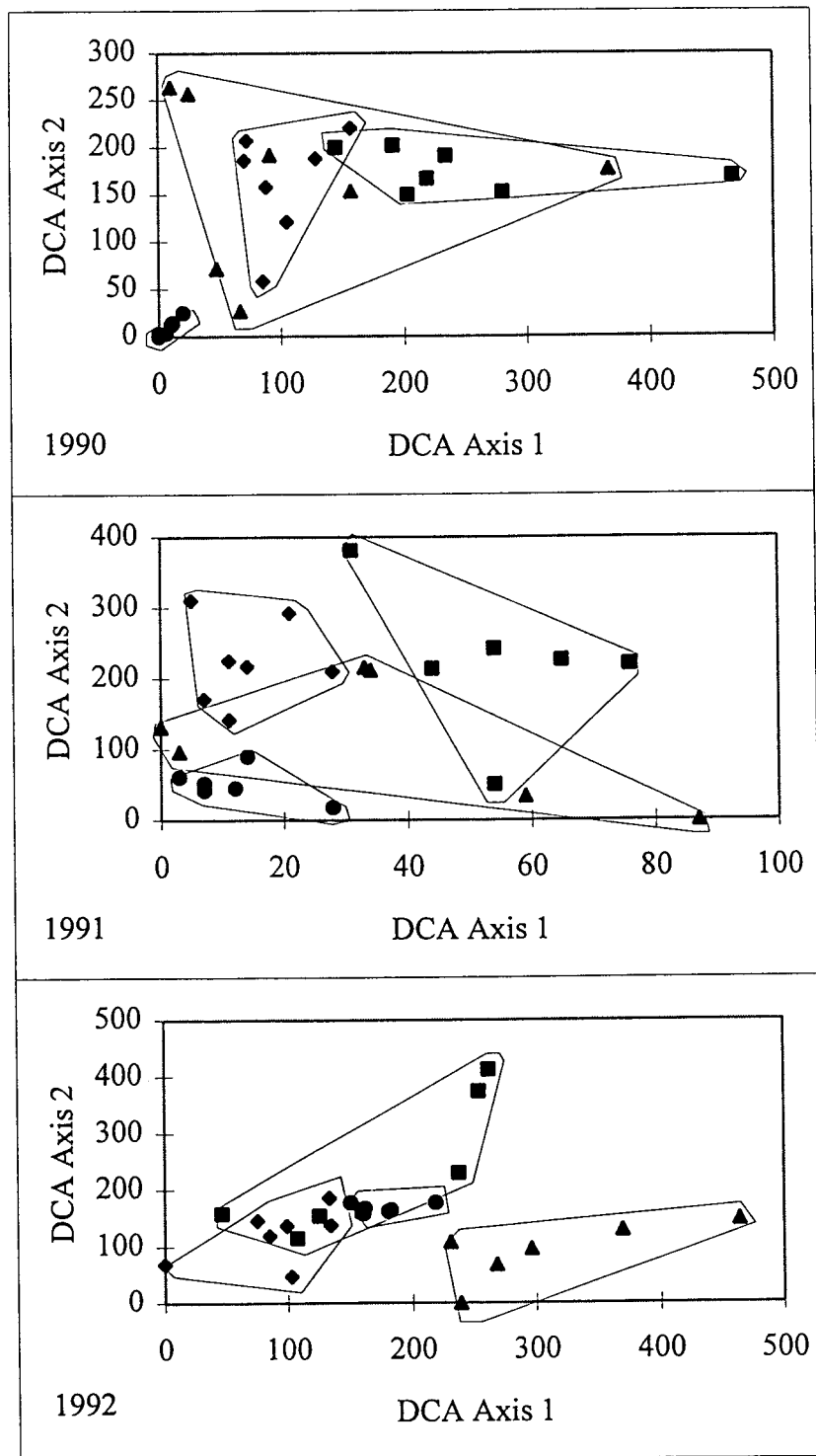


Figure 4. Plots of Axis 1 vs. Axis 2 from the Detrended Correspondence Analysis for the fish data.
 (●=UPDE, ■=GETT, ▲=HOFU, ◆=VAFO)

purposes of this study ranged between 1.5 and 2.0. Small spring-fed streams with heavily wooded drainage areas would be less likely to undergo rapid changes in water flow and temperature when compared to larger streams, which drain urban/industrialized areas. Theoretically, the fauna inhabiting the former environments would be less likely to experience highly variable environmental conditions than the fauna inhabiting the latter; hence the small spring-fed streams would be assigned a smaller value for Ia.

The values assigned to Ib, the structural and functional redundancy of the streams, were calculated using both the fish and macroinvertebrate data bases (Table 10 and Table 11). Structural redundancy is essentially a measure of taxonomic redundancy. For fishes, these values ranged from a low of 0.081 at V4 in Valley Creek (VAFO) in 1990 and 1991 to a high of 0.8 at D3 in the Delaware River (UPDE) in 1991 (Table 10). Structural redundancy of the macroinvertebrate community ranged from a low of 0.091 at V3 in Valley Creek (VAFO) in 1990 to a high of 0.933 at D5 in the Delaware River (UPDE) in 1991 (Table 11).

Functional redundancy values for fishes (Table 10) were analyzed using trophic levels (Table 3) and spawning habits (Table 4). It was determined that for the species found during this study at some point in their life state, 31 species interacted at trophic level I, 54 at level II, 23 at level III, and 14 at level IV. With respect to spawning habits, 10 species were assigned to spawning guild I, 13 to guild II, seven to guild III, 15 to IV, and six to V. Functional redundancy values reported for fish are

Table 10. Redundancy values for fishes collected from streams in and around four national parks in Pennsylvania. Functional redundancy is the mean of trophic and spawning redundancy.

Site	1990			1991			1992		
	Structural	Trophic	Functional	Structural	Trophic	Spawning	Structural	Trophic	Functional
D2	0.427	0.486	0.560	0.550	0.554	0.467	0.425	0.457	0.400
D3	0.500	0.464	0.580	0.800	0.716	0.800	0.550	0.446	0.487
D4	0.729	0.713	0.620	0.475	0.418	0.550	0.625	0.599	0.607
D5	0.667	0.611	0.690	0.500	0.488	0.650	0.725	0.490	0.633
D6	0.667	0.488	0.640	0.550	0.566	0.700	0.500	0.482	0.547
D7	0.594	0.783	0.710	0.775	0.894	0.700	0.675	0.580	0.647
G1	0.065	0.140	0.149	0.065	0.093	0.279	0.041	0.066	0.242
G2	0.238	0.248	0.323	0.238	0.365	0.256	0.265	0.394	0.247
G3	0.258	0.365	0.414	0.258	0.302	0.318	0.255	0.298	0.311
G4	0.536	0.613	0.617	0.536	0.636	0.425	0.541	0.534	0.462
G5	0.345	0.398	0.460	0.345	0.366	0.369	0.296	0.351	0.422
G6	0.322	0.198	0.326	0.322	0.353	0.385	0.197	0.251	0.471
G7	0.512	0.466	0.456	0.512	0.455	0.433	0.517	0.467	0.378
H1	0.473	0.409	0.460	0.390	0.332	0.444	0.268	0.323	0.414
H2	0.412	0.431	0.517	0.412	0.342	0.427	0.299	0.306	0.382
H3	0.142	0.128	0.107	0.059	0.194	0.190	0.224	0.246	0.229
H5	0.150	0.318	0.366	0.150	0.199	0.249	0.268	0.348	0.402
H6	0.258	0.249	0.337	0.236	0.306	0.437	0.403	0.508	0.473
H7	0.152	0.332	0.326	0.119	0.137	0.118	0.260	0.467	0.521
V1	0.260	0.237	0.291	0.260	0.294	0.301	0.265	0.304	0.290
V2	0.199	0.256	0.264	0.199	0.195	0.207	0.225	0.212	0.214
V3	0.153	0.143	0.157	0.153	0.162	0.184	0.172	0.123	0.160
V4	0.081	0.147	0.182	0.081	0.133	0.140	0.221	0.211	0.191
V5	0.493	0.519	0.563	0.493	0.414	0.457	0.410	0.500	0.455
V6	0.255	0.381	0.446	0.255	0.240	0.316	0.260	0.358	0.311
V7	0.325	0.237	0.530	0.225	0.430	0.488	0.343	0.365	0.399

Table 11. Redundancy values for macroinvertebrates collected from streams in and around four national parks in Pennsylvania. Functional redundancy is the mean dispersal redundancy.

Site	1990				1991				1992			
	Structural	Trophic	Dispersal	Functional	Structural	Trophic	Dispersal	Functional	Structural	Trophic	Dispersal	Functional
D2	0.491	0.353	0.778	0.566	0.700	0.667	0.598	0.632	0.479	0.418	0.529	0.474
D3	0.676	0.479	0.562	0.520	0.600	0.413	0.719	0.566	0.438	0.371	0.669	0.520
D4	0.361	0.147	0.333	0.240	0.667	0.362	0.621	0.492	0.260	0.279	0.342	0.311
D5	0.657	0.495	0.540	0.517	0.933	0.524	0.700	0.612	0.719	0.780	0.669	0.724
D6	0.435	0.235	0.518	0.376	0.433	0.164	0.330	0.247	0.344	0.287	0.316	0.302
D7	0.463	0.405	0.540	0.473	0.667	0.449	0.626	0.538	0.771	0.871	0.562	0.717
G2	0.333	0.418	0.436	0.427	0.392	0.532	0.494	0.513	0.310	0.370	0.510	0.440
G3	0.225	0.274	0.345	0.310	0.292	0.316	0.482	0.399	0.232	0.333	0.392	0.363
G4	0.467	0.546	0.613	0.580	0.467	0.258	0.438	0.348	0.423	0.301	0.472	0.387
G5	0.583	0.310	0.532	0.421	0.400	0.263	0.382	0.323	0.381	0.383	0.538	0.461
G6	0.433	0.229	0.390	0.310	0.417	0.396	0.493	0.444	0.327	0.246	0.392	0.319
G7	0.408	0.339	0.364	0.352	0.275	0.327	0.459	0.393	0.619	0.356	0.454	0.405
H1	0.251	0.155	0.306	0.230	0.295	0.178	0.293	0.235	0.135	0.081	0.187	0.134
H2	0.449	0.305	0.389	0.347	0.559	0.564	0.495	0.530	0.442	0.248	0.325	0.287
H3	0.321	0.238	0.186	0.212	0.644	0.446	0.482	0.464	0.481	0.251	0.294	0.273
H5	0.313	0.389	0.305	0.347	0.238	0.142	0.291	0.217	0.314	0.239	0.336	0.287
H6	0.177	0.335	0.343	0.339	0.152	0.296	0.379	0.338	0.321	0.284	0.365	0.324
H7	0.300	0.239	0.390	0.315	0.150	0.119	0.321	0.220	0.288	0.269	0.401	0.335
V1	0.215	0.126	0.277	0.202	0.243	0.130	0.297	0.213	0.276	0.197	0.340	0.268
V2	0.144	0.172	0.184	0.178	0.263	0.137	0.331	0.234	0.231	0.131	0.239	0.185
V3	0.091	0.053	0.164	0.109	0.150	0.102	0.130	0.116	0.179	0.116	0.235	0.175
V4	0.100	0.156	0.227	0.192	0.180	0.124	0.271	0.198	0.231	0.322	0.308	0.315
V5	0.251	0.196	0.405	0.300	0.416	0.206	0.368	0.287	0.417	0.242	0.396	0.319
V6	0.172	0.113	0.187	0.150	0.131	0.191	0.248	0.219	0.212	0.190	0.152	0.171
V7	0.302	0.167	0.311	0.239	0.323	0.144	0.259	0.202	0.346	0.179	0.278	0.229

the means of trophic and spawning redundancy and ranged from a low of 0.117 at H3 in Scott's Run (HOFU) in 1990 to a high of 0.797 at D7 in the Delaware River (UPDE) in 1991 (Table 10).

Functional redundancy values for macroinvertebrates (Table 11) were analyzed using feeding modes (Table 5) and dispersal guilds (Table 6). It was determined that for the taxa found during this study at some point in their life stage, 103 taxa were collectors, 77 at some point were predators, 30 were scrapers, 15 were shredders, eight were piercers, and two were parasites (Table 5). With respect to dispersal guilds, 19 taxa were categorized as sedentary, 128 as flyers, and 80 as good fliers (Table 6). Functional redundancy values reported for macroinvertebrates are the means of feeding mode redundancy and dispersal guild redundancy and ranged from a low of 0.116 at V3 in Valley Creek (VAFO) to a high of 0.724 at D5 in the Delaware River (UPDE) in 1992 (Table 11).

The values assigned to Ic, a characterization of stream order, flow dependability, and flushing capacity, for the purposes of this study were somewhat subjective and were based primarily on stream size for sites within and adjacent to a specific park. Values cannot be compared among the parks. For example, the value for this variable was 2.5 for all sites in the Delaware River (UPDE), but varied from 1.0 to 2.5 at those sites associated with the Gettysburg National Military Park (GETT) (Table 12); however, a stream with the value of 2.5 in GETT is much smaller in size and flushing capacity than any of the sites located in UPDE.

The values assigned to Id, the presence of hard, well-buffered water antagonistic to toxic substances, was assigned a value of 2.0 for all sites associated with all parks with the exception of those in and adjacent to the Valley Forge National Historical Park (VAFO), where they ranged from 2.0 - 3.0 (Table 12).

The values assigned to Ie, how close the system is to a major ecological transitional threshold, ranged from 1.0 at all of the UPDE sites to between 1.0 - 2.0 at the sites associated with the other parks (Table 12).

A value of 3.0 for If, the presence of a drainage basin management group with a water quality monitoring program, was assigned for all sites, since they were selected for being within or adjacent to a national park; thus there would be a monitoring/management group present for each of the sites.

Elasticity: The score of parameter Ea, existence of nearby epicenters, which can serve as refugia from which organisms can re-invade a damaged ecosystem, was based on the number and condition of the tributaries to each section and the diversity of the fauna in neighboring stream sections (Table 13). For example, the sites on the Delaware River (D2-D7) were given high scores of 2.5 since any loss of fauna due to a pollution event at these sites could be replenished from upstream. Valley Creek sites (V1-V7) were given low scores because all its tributaries had lower diversity than Valley Creek and therefore could not easily replenish the fauna of Valley Creek following a loss of fauna due to a toxic event. The Schuylkill River, which Valley

Table 12. Inertia component scores and index values for sites in and around four national parks in Pennsylvania.

Site	Ia	Ib	Ic	Id	Ie	If	Index
D2	1.5	1.6	2.5	2.0	1.0	3.0	36.0
D3	1.5	1.7	2.5	2.0	1.0	3.0	38.3
D4	1.5	1.5	2.5	2.0	1.0	3.0	33.8
D5	1.5	2.0	2.5	2.0	1.0	3.0	45.0
D6	1.5	1.4	2.5	2.0	1.0	3.0	31.5
D7	1.5	2.0	2.5	2.0	1.0	3.0	45.0
G1	2.0	0.3	1.0	2.0	1.0	3.0	3.6
G2	1.5	1.0	2.0	2.0	1.0	3.0	18.0
G3	1.0	0.9	1.5	2.0	1.0	3.0	8.1
G4	1.5	1.5	2.0	2.0	1.0	3.0	27.0
G5	1.5	1.2	2.0	2.0	1.0	3.0	21.6
G6	1.0	1.0	1.5	2.0	1.0	3.0	9.0
G7	2.0	1.3	2.0	2.0	2.0	3.0	62.4
H1	1.0	0.9	2.0	2.0	1.0	3.0	10.8
H2	1.0	1.2	2.0	2.0	1.0	3.0	14.4
H3	1.0	0.8	2.0	2.0	1.0	3.0	9.6
H5	1.0	0.8	2.0	2.0	2.0	3.0	19.2
H6	1.5	0.9	2.5	2.0	1.0	3.0	20.3
H7	1.5	0.8	2.5	2.0	2.0	3.0	36.0
V1	2.0	0.8	2.0	3.0	1.0	3.0	28.8
V2	2.0	0.6	2.0	3.0	1.0	3.0	21.6
V3	2.0	0.4	2.0	3.0	1.0	3.0	14.4
V4	2.0	0.5	2.0	3.0	1.0	3.0	18.0
V5	1.5	1.2	2.5	2.0	2.0	3.0	54.0
V6	1.5	0.7	2.5	2.0	2.0	3.0	31.5
V7	1.5	0.9	2.5	2.0	2.0	3.0	40.5

Creek enters, would not contribute much of the fauna, since it is very polluted and has low diversity.

Parameter Eb is dependent on the mobility of any propagules of the organisms present. Although fishes are relatively mobile organisms, they are not as mobile as most aquatic insects and poor water quality, such as that found in the Schuylkill River would block migration, which would be essential to recolonization. Thus, fishes were assigned a value of 1.0 and macroinvertebrates, most of which have an aerial stage sometime throughout their life, were assigned a value of 3.0, resulting in an overall score of 2.0 (Table 13.) The value for this parameter may change, once the extent of the stress was known. For example, in reference to the UDEP sites, if the hypothetical damage to the ecosystem occurred from the park downstream to Philadelphia, colonization by the fishes would be very slow. If, however, the damage was in a more restricted zone (i.e. 1 km above and below Narrowsburg), the fish fauna would recover quickly.

Parameter Ec reflects the condition of the stream after a stress. Valley Forge (VAFO) sites V1-V 7 have responded well since the contamination of PCB's, therefore they have been given a score of 2.5 (Table 13). The other sites for Valley Forge have not been contaminated so receive a score of 3.0. The Delaware River (UPDE) has not shown an effect on the fauna of the Cortese Landfill, hence all Delaware River sites receive a 3.0 for Ec. No specific stress affecting sites at HOFU or GETT have been identified, hence they all received a value of 3.0 for this analysis.

Table 13. Elasticity component scores and index values for sites in and around four national parks in Pennsylvania.

Site	Ea	Eb	Ec	Ed	Ee	Ef	Index
D2	2.5	2.0	3.0	3.0	3.0	3.0	405
D3	2.5	2.0	3.0	3.0	3.0	3.0	405
D4	2.5	2.0	3.0	3.0	3.0	3.0	405
D5	2.5	2.0	3.0	3.0	3.0	3.0	405
D6	2.5	2.0	3.0	3.0	3.0	3.0	405
D7	2.5	2.0	3.0	3.0	3.0	3.0	405
G1	2.0	2.0	3.0	3.0	3.0	3.0	324
G2	2.0	2.0	3.0	3.0	3.0	3.0	324
G3	2.0	2.0	3.0	3.0	3.0	3.0	324
G4	2.0	2.0	3.0	3.0	3.0	3.0	324
G5	2.0	2.0	3.0	3.0	3.0	3.0	324
G6	2.0	2.0	3.0	3.0	3.0	3.0	324
G7	2.0	2.0	3.0	3.0	3.0	3.0	324
H1	2.0	2.0	3.0	3.0	3.0	3.0	324
H2	2.0	2.0	3.0	3.0	3.0	3.0	324
H3	2.0	2.0	3.0	3.0	3.0	3.0	324
H5	2.0	2.0	3.0	3.0	3.0	3.0	324
H6	2.0	2.0	3.0	3.0	3.0	3.0	324
H7	2.0	2.0	3.0	3.0	3.0	3.0	324
V1	1.5	2.0	2.5	1.0	2.0	3.0	45
V2	1.5	2.0	2.5	1.0	2.0	3.0	45
V3	1.5	2.0	2.5	1.0	2.0	3.0	45
V4	1.5	2.0	2.5	1.0	2.0	3.0	45
V5	2.0	2.0	3.0	3.0	3.0	3.0	324
V6	2.0	2.0	3.0	3.0	3.0	3.0	324
V7	2.0	2.0	3.0	3.0	3.0	3.0	324

Valley Creek (VAFO) is the only stream with known residual toxicants, so its sites receive the lowest scores for parameter Ed, chemical-physical environmental quality after a toxic stress has occurred (Table 13).

The proximity of all the sites to a national park resulted in all sites being assigned a 3 for parameter Ef, management or organizational capabilities for immediate control of the damaged area (Table 13).

The UDEP sites had a highest potential to recover should there be a structural or functional change in the aquatic fauna, primarily because it is the largest river system and in close proximity to high quality streams from which recolonization can originate. The sites outside of the Valley Creek drainage (V5-V7), the GETT sites, and the HOFU sites were also rated with a high potential to recover from a biota alteration. The sites located within Valley Creek (V1-V4) had the lowest potential to recover because of the absence of nearby epicenters from which recolonization could occur, the conditions of the habitat following earlier contamination, and the presence of residual toxicants in the stream bed itself.

DISCUSSION

Species Richness

One of the primary goals of this report was to determine the 'health' of the streams in four national parks in Pennsylvania. The location of the sites in the Upper Delaware National Scenic and Recreational River (UPDE) had been determined

prior to the start of this study. Stauffer (1987) had done a study for the NPS from 1984-1987 to examine the effects of Cortese Landfill leachate on the fauna of the upper Delaware River. Although Stauffer (1987) indicated that there was initially a depression in the number and diversity of the macroinvertebrates immediately below the landfill, he concluded that recovery of the system had occurred. Inertia of the UPDE sites were comparable, and in fact the sites immediately downstream of the landfill had higher values than the upstream site; thus it was concluded that the data reported herein support Stauffer's (1987) contention that there is no major effect of the landfill leachate on the stream biota.

As previously stated, site G1 in Gettysburg National Military Park (GETT) was not sampled for macroinvertebrates because of inappropriate habitat. This site was a pond-like section of Plum Run that was probably filled primarily by groundwater. Its lack of habitat diversity and interchange with other streams, at least in the summer, have most likely led to its depauperate fish fauna. The fish diversity of site G1 was significantly lower than most of the other sites, attesting to the site's low habitat diversity. Fish diversity at site G2 also was lower than at sites G4, G5, and G7, reflecting its low habitat diversity. Consistently, Site G4 had the highest diversity of fishes in all three years and may be the best site to use as a reference for park sites.

Compared to sites outside of the park, sites within Hopewell Furnace National Historic Site (HOFU) were quite diverse with respect to fishes. Sites H1 and H2 were significantly ($P < 0.05$) higher in fish diversity than site H3. Site H6, Maiden

Creek, has the highest mean fish species count and would therefore be a good candidate as a reference to compare sites within Hopewell Furnace. Maiden Creek is highest in fish diversity primarily because it has the greatest diversity of habitats.

Site H2, French Creek downstream of HOFU, is a relatively smaller stream than Maiden Creek. In Pennsylvania, and perhaps most places, the larger a stream is, the more likely it is to have been exposed to some kind of environmental stress. French Creek, being isolated from roads and industry, is less likely to have experienced a toxic spill or some industrial accident, which may in part explain the higher macroinvertebrate diversity than that found in Maiden Creek.

Valley Creek, located in the Valley Forge National Historical Park (VAFO) is unique in southeastern Pennsylvania; it is a limestone spring creek fed mostly by groundwater. The increase in the number of fish species from headwaters to the mouth is predicted because of the relative increase in habitat types. The diversity of fishes seems low, however, when compared to other similarly sized streams in southeastern Pennsylvania that I have collected over the last 10 years.

Valley Creek has had some serious environmental problems. Its polychlorinated biphenyl (PCB) levels are very high, a result of contamination from Paoli Rail Yards. Numerous other spills have occurred, most notably cyanide from National Rolling Mills. The mill dam in VAFO creates unsuitable habitat for stream fishes by allowing silt to accumulate. This silt adversely influences egg survival by restricting oxygenated water from aerating them (Gutowski et. al., 1994). Pickering Creek, site V5

(reference site outside the park), supports more fishes and macroinvertebrate taxa than the Valley Creek sites. It may take Valley Creek quite a while to recover from these historical effects.

Detrended Correspondence Analysis

Detrended Correspondence Analysis illustrates (Figures 3 and 4) that the aquatic fauna present in UPDE is clearly different from that found in or adjacent to the other parks. The observed differences are most likely caused by the fact that the upper Delaware River is a much larger stream than those sampled in the other parks. Also evident in figures 3 and 4, VAFO and HOFU sites were more closely clustered with each other than either was to the GETT sites. This clustering pattern was obtained with both macroinvertebrate and fish data and again can be explained by differences in size and physical characters of the streams that drain the respective parks. Those streams in GETT are generally slower moving and smaller than the ones sampled in VAFO and HOFU. Finally, some differences may be explained by the fact that GETT streams are part of the greater Susquehanna River system, while those in VAFO and HOFU are tributaries to the Delaware River.

Ephemeroptera, Plecoptera, and Trichoptera (EPT) Taxa

These data indicated there was no difference between park sites and reference sites with respect to EPT taxa. These taxa are often used in bio-monitoring of streams because they have been shown to be particularly sensitive to certain types of

pollution. Comparison of EPT taxa among sites is not feasible, because of the differences in sizes and drainages of the aquatic habitat.

Inertia and Elasticity Scores

Inertia and elasticity scores were calculated for each site (Tables 9 and 10). As stated previously, the inertia scores indicate how likely it is that a particular system can assimilate stress. The potential of a system to recover from a stress is indicated by the elasticity index.

The sites along the Delaware River are obviously very similar. The only parameter that differs among sites is Ib, the structural and functional redundancy. These differences are enough to give sites D5 and D7 slightly higher inertia scores. Therefore, these sites would be more likely to survive an ecosystem stress. The elasticity scores for all the Delaware River sites are equivalent (Table 10).

The structural redundancy values for the fishes and macroinvertebrates were generally congruent and data presented herein supported Stauffer's (1987) contention that the aquatic community below the Cortese landfill had recovered, if indeed any impact had occurred. Data collected at station D4 in 1992, however, indicate that the structural redundancy of the macroinvertebrate community was reduced, although the fish community was not noticeably affected. Perhaps the greater mobility of fishes permits them to move into and out of this area depending upon the concentration of leachate. Functional redundancy values yielded similar results. Stauffer and Hocutt (1980) suggested that structural redundancy implies functional redundancy and

perhaps only a measure of structural redundancy is necessary. The data reported herein support this contention.

Only fishes were used in previous applications of the inertia and elasticity concepts (Stauffer et al. 1978, Stauffer and Hocutt 1980). Stauffer and Hocutt (1980) argued that since fishes occupy the top of the food chain in most stream systems their presence implies the presence of many other phyletic groups. Data for the upper Delaware, however, indicated that the macroinvertebrate community had a more rapid response, which may be related to their vagility. Moreover, because some macroinvertebrates have an aerial state during their life history, additional information not available by analyzing a fish data set, is accessible. For example, it was possible to distinguish among no aerial stage, flyers, and good flyers for the invertebrate taxa. The paucity of information on dispersal rates of fishes limits the application of this Eb.

The situation is very different for the GETT sites. The low inertia score indicate that there are three sites that are very vulnerable to stress: G1, G3, and G6 (Table 9). Plum Run (G1) is unique because it appears entirely fed by groundwater. Without a nexus to other bodies of water, the potential of re-invasion of organisms is reduced should a pollution event occur. This is a possible explanation for the low richness of fish species, which would result in low inertia indicies. The other two sites' low diversity is undoubtedly related to their smaller size. Small streams usually have lower diversity; this means that they contain fewer taxa performing each ecosystem

function; thus their inertia would be lower. Therefore, the loss of a few taxa is more likely to result in the loss of ecosystem function. This makes small streams, almost de facto, less resistant to stresses. The elasticity scores for all the GETT sites are equivalent (Table 10).

As with GETT sites, the HOFU sites that are on larger streams tend to have higher inertia indices (Table 9). These larger streams would include sites H6, Maiden Creek, and H7, Tulpehocken Creek. Sites H5, Pine Creek in Lobachsville, and H7 are both trout streams. They occur close to a major ecological transitional threshold, the shift from a cold water stream to a warm water stream. For this reason, they receive a lower value for parameter I_e in the Inertia index (Table 9). Site H3, Scott's Run between Scott's Run Lake and Hopewell Lake, does not have many connections to other lotic water systems. Organisms cannot migrate to this stream freely, except those organisms from the two lakes surrounding it. The elasticity scores for all the HOFU sites are equivalent (Table 10).

The VAFO sites have strong contrasts among them. Sites V1-V4 are located on Valley Creek, a limestone spring-fed trout stream. It has lower structural redundancy measures due to its typical limestone stream fauna and past environmental problems (Table 9). Stresses experienced include cyanide spills, PCB contamination, and contamination from road runoff. Working in Valley Creek's favor is that it has well-buffered water; acid rain, for example, should not be a problem here. Conversely, Valley Creek is unfortunately close to an ecological threshold. Valley Creek sites

(sites V1-V4) are uniformly lower than non-Valley Creek sites in inertia scores (Table 9). Since Valley Creek has had numerous environmental problems, its elasticity scores are lower than those of the other sites' (Table 10).

RECOMMENDATIONS

Species richness: The first task in the development of a comprehensive monitoring system is to establish a checklist of the fauna in question. Appendices A and B provide such a list for the four parks inventoried in this study (Table 1). It is recommended that a voucher collection containing specimens of all taxa collected in or adjacent to each of these parks be prepared and stored at park headquarters. It is further advised that macroinvertebrate and fish surveys be made annually. Fish should be collected sometime during July and August of each year, after most of the fishes have spawned. The collection of young-of-the-year specimens will assure park officials that reproduction in park waters is continuing. Fishes should be identified, enumerated, and placed in permanent storage. Species richness can be compared among sites and years, thus providing a baseline to assess whether further analyses are needed.

Macroinvertebrates should be collected in late fall or early winter at all sites identified herein. If collections are made during the spring or summer, they might miss important components of the macroinvertebrate community due to emergence. Macroinvertebrates collections should be sorted, but not identified or enumerated.

Should an analysis of the fish collections indicate that fish populations are declining, the macroinvertebrate samples will be available for further analysis.

Detrended Correspondence Analysis: Detrended Correspondence Analysis is a useful tool when comparing faunal assemblages among parks in different drainages or in water bodies that differ in size. It is suggested that for each park, the drainage and size of the water bodies be determined and expected faunal lists compiled. A Detrended Correspondence Analysis between two or more parks located in different drainages would inform park managers if comparison of faunal lists from different parks is justified. For example, based on the data collected from this study, Detrended Correspondence Analysis indicates that comparison of the fauna between sites located in the Hopewell Furnace National Historic Site (HOFU) and the Valley Forge National Historical Park (VAFO) is valid. Conversely, a comparison of the fauna from either of these sites with that located in the Upper Delaware National Scenic and Recreational River (UPDE) is not justifiable. Thus, it would be rational to compare ecosystem "health" between sites located in the Hopewell Furnace National Historic Site with those located in the Valley Forge National Historical Park. In effect, sites at one park could serve as reference sites for those at the other.

Ephemeroptera, Plecoptera, and Trichoptera (EPT) Taxa

Historically the abundance of these taxa has been used to compare levels of stress-induced perturbations to the health of aquatic ecosystems. These taxa, while particularly pollution-sensitive to certain disturbances, are pollution tolerant to

others. For example, collections in other sections of Pennsylvania have shown that stoneflies (Plecoptera) may be tolerant of streams with low pH. Thus, it is recommended that this index not be used as a general indicator of the health of the aquatic systems associated with the parks. It could be used on a site specific basis. For example the EPT taxa would be an excellent benchmark to monitor recovery, after a particular site has been subjected to a perturbation that lowers dissolved oxygen.

Ecosystem Inertia and Elasticity

Based on the data presented herein and elsewhere (Stauffer et al. 1978, Stauffer and Hocutt 1980), the concept of inertia as conceived by Dickson and Cairns (1977) prove to be useful index to rank and compare the health of aquatic ecosystems. In essence, inertia can be used to predict the amount of stress a particular system can assimilate. Elasticity has limited usefulness before a stress has occurred, but can provide some insight into the potential of a system to recover if and when the assimilative capacity is exceeded. Of all the parameters suggested by Cairns and Dickson (1977) for the prediction of ecosystem inertia, parameter Ib, the structural and functional redundancy of the system, is without a doubt, intuitively the single most important parameter upon which inertia is based. Because inertia is defined as the ability of a system to withstand a stress without eliciting a structural or functional change, it follows that the greater the redundancy in structure or function, the less chance a stress has of creating a measurable shift in the fauna. Furthermore, the

inclusion of functional redundancy in the calculation of inertia permits comparisons among different drainages, which have disparate faunal complexes. One could argue that irrespective of the species present, a system could be classified as healthy if in fact, the ecosystem was functioning to assimilate nutrients, supporting the species that utilize food at the higher trophic levels, recycling nutrients and energy, maintaining genetic diversity, and propagating its disseminules. Such a classification would permit managers to compare the state of health of selected ecosystems.

The above discussion raises the question of why structural redundancy values are included in the analysis. Obviously, it would be ideal to study each organism in such a fashion that its niche (*sensu* Hutchinson 1957) could be described. If a representation of each niche could be plotted in multidimensional space, overlap or redundancy could be precisely analyzed. For many species, the information needed for such a functional analysis is not known, thus we are in forced to rely to a certain extent on structural redundancy.

If we assume a multidimensional niche concept as conceived by Hutchinson (1957), then it follows that taxonomic groupings are intimately related to niches. In fact, as indicated by the Gause principle, no two species can coexist for long if they occupy a very similar niche (Schoener 1974). An organism's niche is therefore species specific and it appears, based on assumptions reviewed by Stauffer and Hocutt (1980), that those taxa that are more closely related to one another occupy more

similar niches than those not closely related phylogenetically. There are of course exceptions to this statement due to convergent and divergent evolution.

Structural redundancy is also important if rare, threatened, or endangered species are present in a given ecosystem. Certainly a manager cannot justify a selected strategy that would extirpate or drive to extinction a given species because some other taxa can replicate its function.

Elasticity indices as proposed by Cairns and Dickson (1977) cannot be determined until such time that an environmental perturbation has occurred. As suggested by Stauffer and Hocutt (1980), however an index that measures the potential for a system to recover can be determined by using parameters E_a , the existence of nearby epicenter, which can serve as refugia from which organisms can re-invade a damaged ecosystem, E_b , the mobility of any propagules of the organisms present, and E_f , management or organizational capabilities for immediate control of the damaged area. Should additional stresses occur within any of the parks, a complete elasticity index could be calculated in an effort to direct clean-up operations and to predict recovery time and probability.

Based on the data provided herein, it is recommended that the inertia and modified elasticity index of the fish communities be calculated using the fish data collected in the annual inventory of each park. As stated previously, if this initial analysis suggests that a perturbation has occurred and thus that a more detailed study is warranted, the macroinvertebrate data will be available for analyses.

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	1990						1991						1992					
	D2	D3	D4	D5	D6	D7	D2	D3	D4	D5	D6	D7	D2	D3	D4	D5	D6	D7
Petromyzontidae																		
<i>Petromyzon marinus</i>	12		2	1		1	1						1	1	1			
Anguillidae																		
<i>Anguilla rostrata</i>	2	9		14	13	17		6	5	5	26	13	15	3	1	5	8	31
Clupeidae																		
<i>Alosa sapidissima</i>																1	1	1
Cyprinidae																		
<i>Campostoma anomalum</i>			2															
<i>Carassius auratus</i>																		
<i>Clinostomus funduloides</i>																		
<i>Cyprinella analostana</i>	12	3	5	16	1		2	7	6	51		6			5	4	1	
<i>Cyprinella spiloptera</i>			2												1			
<i>Cyprinus carpio</i>																		
<i>Ericymba buccata</i>																		
<i>Exoglossum maxillingua</i>	16	9	9	17	9	26	47	30	28	35	22	20	39	49	34	103	60	76
<i>Hybognathus regius</i>																		
<i>Luxilus cornutus</i>						1		3		3	4			1	1			4
<i>Margariscus margarita</i>																		
<i>Notemigonus crysoleucus</i>																		2
<i>Notropis amoenus</i>																		
<i>Notropis bifrenatus</i>																		
<i>Notropis hudsonius</i>								15		16	1							
<i>Notropis procne</i>							1											
<i>Notropis rubellus</i>																		
<i>Pimephales notatus</i>			1															1
<i>Pimephales promelas</i>																		
<i>Rhinichthys atratulus</i>											1					1		
<i>Rhinichthys cataractae</i>		16		9	2			9		2	3			7		8	1	
<i>Semotilus atromaculatus</i>															2			
<i>Semotilus corporalis</i>	8	64	94	39	7	5	14	22	17	17	18	4			2	9	1	
Catostomidae																		
<i>Catostomus commersoni</i>	77	18	56	77	20	58	30	10	27	11	9	33		2	2	1		15
<i>Erismyzon oblongus</i>																		
<i>Hypentelium nigricans</i>		3										1				1		
Ictaluridae																		
<i>Ameiurus natalis</i>																		
<i>Ameiurus nebulosus</i>								1										
<i>Noturus insignis</i>	38	35	19	48	13	16	28	40	32	20	15	4	19	15	39	31	6	5
Salmonidae																		
<i>Oncorhynchus mykiss</i>																		
<i>Salmo trutta</i>																		
<i>Salvelinus fontinalis</i>																		
Esocidae																		
<i>Esox a. americanus</i>																		
<i>Esox lucius</i>																		
<i>Esox niger</i>																		

Appendix A. (cont.) Fishes collected at sites associated with Upper Delaware Scenic and Recreational River.

	1990						1991						1992					
	D2	D3	D4	D5	D6	D7	D2	D3	D4	D5	D6	D7	D2	D3	D4	D5	D6	D7
Fundulidae																		
<i>Fundulus diaphanus</i>			1	5		2	13	3	30	5	3	10	1	2	29	20	2	13
Centrarchidae																		
<i>Ambloplites rupestris</i>							2	1	5			2	12	2	5	2	3	16
<i>Lepomis auritus</i>	11		3	2	11	23	18	12	15	10	13	21	3	6	4	7	15	43
<i>Lepomis cyanellus</i>																		
<i>Lepomis gibbosus</i>						1												
<i>Lepomis macrochirus</i>												4						8
<i>Micropterus dolomieu</i>			5	8	6	2	2	1			9	5	2					1
<i>Micropterus salmoides</i>																1		
<i>Pomoxis annularis</i>																		
Percidae																		
<i>Etheostoma blennioides</i>																		
<i>Etheostoma flabellare</i>																		
<i>Etheostoma olmstedii</i>	47	7	28	29	16	6	15	29	23	10	19	8	58	9	38	30	44	24
<i>Perca flavescens</i>																		
<i>Percina peltata</i>			1	2	2			4				2	2	2	1	9	3	4
Cottidae																		
<i>Cottus bairdi</i>																		
<i>Cottus girardi</i>																		
Number of taxa	9	10	14	12	11	12	12	16	10	12	13	14	10	12	15	15	13	15
Number of individuals	223	165	232	262	100	158	173	193	188	185	143	133	152	99	165	232	146	244

Appendix B. (cont.) Fishes collected at sites associated with Gettysburg National Military Park.

	1990							1991							1992						
	G1	G2	G3	G4	G5	G6	G7	G1	G2	G3	G4	G5	G6	G7	G1	G2	G3	G4	G5	G6	G7
Fundulidae																					
<i>Fundulus diaphanus</i>		218	30	4		5		165	29	17			22		343	26	15	9	6		
Centrarchidae																					
<i>Ambloplites rupestris</i>				6			7			17	1			6			10	1			1
<i>Lepomis auritus</i>		12	6	12	3	24		8	11	5	9	37			29	18	19	5			
<i>Lepomis cyanellus</i>	32	3	10		3				8		1	2		15	1	5	1				
<i>Lepomis gibbosus</i>		1				3	2	1	3								2		18		
<i>Lepomis macrochirus</i>		1	1	5	6		7	2		5	1		1		1	1	7		16	17	
<i>Micropterus dolomieu</i>				4						6					2						
<i>Micropterus salmoides</i>			4	2	2			7		4					2		4				1
<i>Pomoxis annularis</i>																					
Percidae																					
<i>Etheostoma blennioides</i>		1		34	47	1				41	126	1			19		46	41			
<i>Etheostoma flabellare</i>			7	7		4	14		15	13		6	15			42	10	1		31	
<i>Etheostoma olmsted</i>				2	1						1						2				
<i>Perca flavescens</i>																					
<i>Percina peltata</i>																					
Cottidae																					
<i>Cottus bairdi</i>							77						74							89	
<i>Cottus girardi</i>							3						2							15	
Number of taxa	5	10	12	20	15	12	15	3	10	10	17	12	13	14	3	11	12	20	17	11	15
Number of Individuals	120	327	454	233	436	236	274	39	250	330	179	310	429	168	19	441	288	241	361	231	239

	1990						1991						1992					
	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7
Petromyzontidae																		
<i>Petromyzon marinus</i>																		
Anguillidae																		
<i>Anguilla rostrata</i>	3	1		2		1	1	7					1	25		4	2	5
Clupeidae																		
<i>Alosa sapidissima</i>																		
Cyprinidae																		
<i>Campostoma anomalum</i>																		
<i>Carassius auratus</i>																		
<i>Clinostomus funduloides</i>	3	110					19	30					22	26				
<i>Cyprinella analostana</i>											145	29						
<i>Cyprinella spiloptera</i>																	3	
<i>Cyprinus carpio</i>						11												1
<i>Ericymba buccata</i>																		
<i>Exoglossum maxillingua</i>	7	6		27		1	4	4		18			4	3		31		4
<i>Hybognathus regius</i>																		
<i>Luxilus cornutus</i>		28		25			4	5		25	2	19	8	7		12		3
<i>Margariscus margarita</i>																		
<i>Notemigonus crysoleucus</i>											3				1			
<i>Notropis amoenus</i>																		
<i>Notropis bifrenatus</i>																		
<i>Notropis hudsonius</i>																	3	2
<i>Notropis procne</i>																		
<i>Notropis rubellus</i>																		
<i>Pimephales notatus</i>					2						6	1				12		1
<i>Pimephales promelas</i>					1						1							
<i>Rhinichthys atratulus</i>	1	3	6	101	2		10	6	1	108	3		11	2	3	37	1	1
<i>Rhinichthys cataractae</i>				2	1					1	11					3	5	7
<i>Semotilus atromaculatus</i>		2		2	2	9	1			7	1		9			2		1
<i>Semotilus corporalis</i>	34	7		17			26	7		10			19	11		7		1
Catostomidae																		
<i>Catostomus commersoni</i>	3	8		14	3	59	4	19	1		1	2	2	9	2	49	5	24
<i>Erismyzon oblongus</i>																		
<i>Hypentelium nigricans</i>																		
Ictaluridae																		
<i>Ameiurus natalis</i>	1		7						7						12		3	
<i>Ameiurus nebulosus</i>																		
<i>Noturus insignis</i>	13						8	7					10					
Salmonidae																		
<i>Oncorhynchus mykiss</i>				1								1						
<i>Salmo trutta</i>				34						3		1				17		
<i>Salvelinus fontinalis</i>		2						3						12				
Esocidae																		
<i>Esox a. americanus</i>	1							1						1				
<i>Esox lucius</i>																	1	
<i>Esox niger</i>		1					1		2									

Appendix C. (cont.) Fishes collected at sites associated with Hopewell Furnace National Historic Site.

	1990						1991						1992					
	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7
Fundulidae																		
<i>Fundulus diaphanus</i>					1	5					6						2	8
Centrarchidae																		
<i>Ambloplites rupestris</i>					3	11											2	10
<i>Lepomis auritus</i>		1				3						1						2
<i>Lepomis cyanellus</i>	4		37		2				21						15	2	1	1
<i>Lepomis gibbosus</i>	12	6	7		2	1	1	1	26		1	1	2			2	3	
<i>Lepomis macrochirus</i>	4	6			6	1	3	3			2		4	2	17		7	1
<i>Micropterus dolomieu</i>						1										1		1
<i>Micropterus salmoides</i>	3	2			1							4	2		6		2	
<i>Pomoxis annularis</i>																	3	
Percidae																		
<i>Etheostoma blennioides</i>																		
<i>Etheostoma flabellare</i>																		
<i>Etheostoma olmstedi</i>	3	8			5	3	17	11		4	1	1	5	3		6	6	22
<i>Perca flavescens</i>											1				2			
<i>Percina peltata</i>																		
Cottidae																		
<i>Cottus bairdi</i>																		
<i>Cottus girardi</i>																		
Number of Taxa	14	15	4	11	13	11	13	13	6	8	14	10	13	11	8	13	17	18
Number of Individuals	92	191	57	230	29	103	99	104	58	176	184	50	99	101	58	173	61	95

Appendix D. Fishes collected at sites associated with Valley Forge National Historical Park.

	1990							1991							1992						
	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7
Petromyzontidae																					
<i>Petromyzon marinus</i>																					
Anguillidae																					
<i>Anguilla rostrata</i>	1					1	3	1						34	57					3	18
Clupeidae																					
<i>Alosa sapidissima</i>																					
Cyprinidae																					
<i>Campostoma anomalum</i>																					
<i>Carassius auratus</i>				1													2				
<i>Clinostomus funduloides</i>						7	10						2	50					18	36	
<i>Cyprinella analostana</i>					22		10							8				16	1	4	
<i>Cyprinella spiloptera</i>					2	12	2														2
<i>Cyprinus carpio</i>												2							1		
<i>Ericymba buccata</i>																					
<i>Exoglossum maxillingua</i>		18			17	55	13		14	2		7	20	20		17	5		20	53	46
<i>Hybognathus regius</i>																					
<i>Luxilus cornutus</i>					6	16	16	3					1	34		1			30	20	21
<i>Margariscus margarita</i>																					
<i>Notemigonus crysoleucus</i>												2									
<i>Notropis amoenus</i>																					
<i>Notropis bifrenatus</i>						171	29						12	24				8	109	1	
<i>Notropis hudsonius</i>					2	4	1					2	12	6				12	5	54	
<i>Notropis procne</i>																					
<i>Notropis rubellus</i>																					
<i>Pimephales notatus</i>												1							3		
<i>Pimephales promelas</i>																					
<i>Rhinichthys atratulus</i>	2	40	27	8	16	15	43		30	48	5	59	5	36	6	28	68	2	18	13	65
<i>Rhinichthys cataractae</i>	1	4	6		15	67	11	6	2	5		7	17	18	10	7	8		16	71	
<i>Semotilus atromaculatus</i>		1		1	1	2	1											1		12	5
<i>Semotilus corporalis</i>					3								2	3					2		
Catostomidae																					
<i>Catostomus commersoni</i>	11	18	1	4	23	8	14	11	64	12	16	64	16	59	1	116	22	14	21	140	61
<i>Erimyzon oblongus</i>																					
<i>Hypentelium nigricans</i>																					
Ictaluridae																					
<i>Ameiurus natalis</i>															1					1	
<i>Ameiurus nebulosus</i>																					
<i>Noturus insignis</i>							2							2							2
Salmonidae																					
<i>Oncorhynchus mykiss</i>							2							20							
<i>Salmo trutta</i>	14	11	73				10	24	19	35	45			25		10	54	47	11		4
<i>Salvelinus fontinalis</i>																		1			
Esocidae																					
<i>Esox a. americanus</i>					1																
<i>Esox lucius</i>																					
<i>Esox niger</i>																					

Appendix D. (cont.) Fishes collected at sites associated with Valley Forge National Historical Park.

	1990							1991							1992						
	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7
Fundulidae																					
<i>Fundulus diaphanus</i>																					
Centrarchidae																					
<i>Ambloplites rupestris</i>	1	3			10			2	3			11			3	3			12		
<i>Lepomis auritus</i>	1							13				2			3						
<i>Lepomis cyanellus</i>	4		2		11	3		1				8			1				8		
<i>Lepomis gibbosus</i>		2		4	5	4	2		2	1	2	3	2	5		2		2		1	1
<i>Lepomis macrochirus</i>		2	1	2	6			5		1	1	3		1	1				17		
<i>Micropterus dolomieu</i>					1			3				1			3				1		
<i>Micropterus salmoides</i>					4	2	1					3							3		
<i>Pomoxis annularis</i>																					
Percidae																					
<i>Etheostoma blennioides</i>																					
<i>Etheostoma flabellare</i>																					
<i>Etheostoma olmstedii</i>	8	7			3	15	13	3	1			2	2	21	1	4	2		23	26	20
<i>Perca flavescens</i>																					
<i>Percina peltata</i>	1				2							5							8		
Cottidae																					
<i>Cottus bairdi</i>																					
<i>Cottus girardi</i>																					
Number of Taxa	10	10	6	6	19	15	18	11	8	7	5	17	11	17	11	9	6	7	19	14	15
Number of Individuals	44	106	110	20	150	382	183	72	135	104	69	182	91	366	87	188	159	69	230	473	340

[illegible]

Appendix E. Macroinvertebrates collected at sites associated with Upper Delaware Scenic and Recreational River.

[illegible]

Appendix E. (cont.) Macroinvertebrates collected at sites associated with Upper Delaware Scenic and Recreational River.

	1990							1991							1992						
	D2	D3	D4	D5	D6	D7		D2	D3	D4	D5	D6	D7		D2	D3	D4	D5	D6	D7	
Tricorythidae																					
<i>Tricorythodes</i>	21			9						11	32	35	1								
Odonata																					
Anisoptera																					
Corddulegastridae																					
<i>Cordulegaster</i>																					
Gomphidae																					
<i>Arigomphus</i>																					
<i>Erpetogomphus</i>																					
<i>Gomphus</i>																					
<i>Lanthus</i>																					
<i>Ophiogomphus</i>								1							1	1		1		1	
Libellulidae																					
Zygoptera																					
Aeshnidae																					
<i>Boyeria</i>																					
<i>Nasiaaeshna</i>																					
Calogperygidae																					
<i>Hetaerina</i>																					
Coenogrionidae																					
<i>Amphiagrion</i>																					
<i>Argia</i>																		2		2	
<i>Enallagma</i>								2					13								
Plecoptera																1					
Capniidae																					
<i>Allocapnia</i>																					
Chloroperlidae																					
<i>Alloperla</i>																					
<i>Haploperla</i>																					
Leuctridae																					
<i>Leuctra</i>																					
Nemouridae																					
<i>Amphinemura</i>																					
Peltoperlidae																					
<i>Peltoperla</i>																					
Perlidae				14											1						
<i>Acroneuria</i>	30	58	21	8	9	3		2	8	9	15	7	6		6	7	4	11	11		
<i>Agnetina</i>		6			1			6			2					3					
<i>Claassenia</i>																					
<i>Eccoptura</i>																					
<i>Neoperla</i>					2																
<i>Perlesta</i>															2		1	8	2	1	
<i>Perlinella</i>																		2			
<i>Phasgonophora</i>		3				9															

Appendix E. (cont.) Macroinvertebrates collected at sites associated with Upper Delaware Scenic and Recreational River.

[illegible]

Appendix E. (cont.) Macroinvertebrates collected at sites associated with Upper Delaware Scenic and Recreational River.

[illegible]

Appendix E. (cont.) Macroinvertebrates collected at sites associated with Upper Delaware Scenic and Recreational River.

	1990						1991						1992					
	D2	D3	D4	D5	D6	D7	D2	D3	D4	D5	D6	D7	D2	D3	D4	D5	D6	D7
<i>Laccornis</i>																		
<i>Matus</i>																		
Elmidae	4	1		2									4			4		19
<i>Dubiraphia</i>				1			8	2	13		4					1		
<i>Optioservus</i>	1	12		3		2	4		13				3	1		4		92
<i>Promoresia</i>																		
<i>Stenelmis</i>	8	14	5	4	7	4	14	59	4	3	53	12	19	6	1	26	3	9
Gyrinidae																		
<i>Dineutus</i>							1											
Haliplidae																		
<i>Haliplus</i>																		
<i>Peltodytes</i>																		
Hydrophilidae																		
<i>Berosus</i>							8	2	4	2	7					1		
<i>Helophorus</i>																		
<i>Lacobi</i>																		
Psephenidae																		
<i>Ectopria</i>																		
<i>Psephenus</i>	1	3	1	7		1	1	18	8	31	13		5	10	4	39		
Diptera																		
Athericidae																		
<i>Atherix</i>																		
Blephariceridae																		
<i>Blepharicera</i>																		
Ceratopogonidae																		
Chironomidae	15	43		47		2	261	5			33		1	13		252		313
Empididae																		
<i>Chelifera</i>																		
<i>Hemerodromia</i>																		1
Simuliidae						3	3				8							1
<i>Prosimulium</i>		2		5														
<i>Simulium</i>														1		1		
Tabanidae																		
<i>Chrysops</i>																		
<i>Merycomyia</i>																		
<i>Tabanus</i>																		
Tipulidae																		
<i>Antocha</i>																		
<i>Dicranota</i>																		
<i>Hexatoma</i>																		
<i>Limnophila</i>																		
<i>Prionocera</i>																		
<i>Tipula</i>																		
Gastropoda	10	42	65	16	24	138	241	13	19	61	48	5				31		

Appendix E. (cont.) Macroinvertebrates collected at sites associated with Upper Delaware Scenic and Recreational River.

	1990						1991						1992					
	D2	D3	D4	D5	D6	D7	D2	D3	D4	D5	D6	D7	D2	D3	D4	D5	D6	D7
Pelecypoda	3		2	51	9	78	18	16	8	63		34						
Sphaeridae																		
Ancylidae													4	3	1	16	2	5
Decapoda																		3
Cambaridae																		
Number of Taxa	28	37	19	36	21	27	24	24	26	29	15	23	25	25	13	39	14	40
Number of Individuals	450	1548	527	607	435	697	530	815	664	710	407	353	149	153	46	843	68	982

Appendix F. Macroinvertebrates collected at sites associated with Gettysburg National Military Park.

	1990						1991						1992					
	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7
Platyhelminthes																		
Planariidae	4		95	3			40	5	2	2		9	130		5	106		2
Nematoda																		
Annelida																		
Oligochaeta	115	33	142	10		12	88	58	26	82	37	9	19	18	10	12	15	5
Hirudinea	7	1	1	4			6	3		21	5		2	4		21	61	
Hydracarina			1									4						
Isopoda																		
Asellidae																		
Asellus			2	9						98						17		
Amphipoda																		
Gammaridae																		
Gammarus								6					1	55	58	3	13	
Ephemeroptera						2												
Baetidae		1																
Baetis				153	116		5	49	45	224	246	31		46	159	369	221	8
Cloeon																		
Pseudocloeon																		68
Caenidae																		
Caenis	30	1		8	2		275	27	3	23	8		4	1	5	6		
Ephemerellidae												59						
Attanella																		
Danella																		
Drunella							1		19		1	48						19
Ephemerella									111			121			6			6
Eurylophella										1								
Serratella			48						338			28						
Ephemeridae																		
Heptageniidae																		
Epeorus																		
Cinygmula																		
Leucrocuta															7			
Stenonema	3		106	62	63	55			26		7					5		
Stenacron				27	28		3	69	45	16	152	33		4	105	6	8	5
Leptophlebiidae									1									
Chloroterpes					1													
Leptophlebia								12			24							
Oligoneuridae																		
Isonychia		1	110	27	2	151			31	5	1	1			293	27		8
Potomanthidae																		
Potomanthus																		
Polymataarcyidae																		
Ephoron																		
Siphonuridae													1					
Ameletus													23					

Appendix F. (cont.) Macroinvertebrates collected at sites associated with Gettysburg National Military Park.

	1990						1991						1992					
	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7
Perlodidae																		
<i>Isoperla</i>												1						4
<i>Tallaperla</i>						1												
Pteronarcyidae																		
<i>Pteronarcys</i>												2						1
Hemiptera						1												
Corixidae																		
<i>Palmarcorixa</i>																	5	
<i>Trichocorixa</i>																		
Gerridae																		
<i>Rheumatobates</i>																		
<i>Trepobates</i>						3												
Veliidae																		
<i>Rhagovelia</i>		1				9					8			3		1		
Megaloptera																		
Corydalidae																		
<i>Chauliodes</i>									1									
<i>Corydalus</i>					2				2	1					6	4		
<i>Neohermes</i>																		
<i>Nigronia</i>												1						1
Sialidae																		
<i>Sialis</i>	16	4	1	2	3								14	1		10	2	
Neuroptera																		
Sisyridae																		
<i>Climacia</i>											2			1				
<i>Sisyra vicaria</i>	1																	
Trichoptera			43			2	1	4	6		6	1	3		3	2		4
Brachycentridae																		
<i>Brachycentrus</i>																		
<i>Micrasema</i>																		
Glossosomatidae																		
<i>Agapetus</i>											8							1
<i>Glossosoma</i>																		5
Helicopsychidae																		
<i>Helicopsyche</i>																		
Hydropsychidae			206															
<i>Cheumatopsyche</i>		24	103	145		128	47	4	81	21	6	5	54	165	169	237	232	23
<i>Hydropsyche</i>		2	154	51	7	17			4	93	2				5	81		10
<i>Macronema</i>					125								1					
<i>Potamyia</i>												9						
Hydroptilidae	1																	
<i>Hydroptila</i>			2				12											
<i>Leucotrichia</i>																		
<i>Ochrotrichia</i>																		

Appendix F. (cont.) Macroinvertebrates collected at sites associated with Gettysburg National Military Park.

	1990						1991						1992					
	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7
Lepidostomatidae																		
<i>Lepidostoma</i>																		
Leptoceridae																		
<i>Ceraclea</i>							1											1
<i>Leptocerus</i>	1																	
<i>Mystacides</i>																		
<i>Nectopsyche</i>																		
<i>Oecetis</i>																		
<i>Setodes</i>																		
<i>Triaenodes</i>	1																	
Limnephilidae																		
<i>Apatania</i>																		
<i>Goera</i>																		
<i>Hydatophylax</i>																		
<i>Neophylax</i>																		7
Molannidae																		
<i>Molanna</i>																		
Odontoceridae																		
<i>Psilotreta</i>																		
Philopotamidae																		
<i>Chimarra</i>			137	5	59	59	3	5	51		13	9	3	106	12	4	5	66
<i>Dolophilodes</i>						2												2
Polycentropodidae																		
<i>Cyrnellus</i>																		
<i>Neureclipsis</i>																		
<i>Nyctiophylax</i>																		
<i>Polycentropus</i>																		1
Psychomyiidae																		
<i>Psychomyia</i>											1							
Rhyacophilidae																		
<i>Rhyacophila</i>						6												1
Lepidoptera															1			
Noctuidae																		
<i>Archanara</i>																		
Pyalidae																		
<i>Acentria</i>							1											
<i>Petrophila</i>			1															
Coleoptera																		
Chrysomelidae													1					
Curculionidae																1		
<i>Emphyastes</i>																		
Dytiscidae														8				
<i>Agabus</i>																	2	
<i>Hydaticus</i>							6	17			4						1	
<i>Hydroporus</i>								2			1							

Appendix F. (cont.) Macroinvertebrates collected at sites associated with Gettysburg National Military Park.

	1990						1991						1992					
	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7
<i>Laccornis</i>										1								
<i>Matus</i>										3								
Elmidae	32	57	40	226	175	1	119	143	22	159	305	3	132	134	63	133	128	
<i>Dubiraphia</i>							2											
<i>Optioservus</i>			235	22	2	5	1		16				1		59	1		4
<i>Promoresia</i>			3			1			3									1
<i>Stenelmis</i>	183	346	42	507	216		463	408	22	92	98		350	190	252	735	259	
Gyrinidae																		
<i>Dineutus</i>																		1
Halipidae																		
<i>Halipus</i>											2							
<i>Peltodytes</i>	2						26	12					2					
Hydrophilidae	2																	
<i>Berosus</i>	4						4		1			3	12		2			
<i>Helophorus</i>																		
<i>Lacobi</i>																		
Psephenidae																		
<i>Ectopria</i>	1	1	3				10						2					
<i>Psephenus</i>	121	69	91	268	460	19	134	312	38	165	263	22	205	72	112	144	12	10
Diptera						5												
Athericidae																		
<i>Atherix</i>																		
Blephariceridae																		
<i>Blepharicera</i>												2						
Ceratopogonidae							21	6				12	1	1			2	1
Chironomidae	18	23	141	621	173	90	695	1020	177	318	330	28	68	50	327	282	446	161
Empididae													5					
<i>Chelifera</i>																		
<i>Hemerodromia</i>									1	1								
Simuliidae						9						6	14		25	1		
<i>Prosimulium</i>													1					
<i>Simulium</i>					1		82	348	7	65	53		1	2	251	7	18	61
Tabanidae																9		
<i>Chrysops</i>				7							1							
<i>Merycomyia</i>				9														
<i>Tabanus</i>					1					1								
Tipulidae													1					
<i>Antocha</i>			1	6		11						6				3		13
<i>Dicranota</i>			2				4								2	6	1	
<i>Hexatoma</i>																		1
<i>Limnophila</i>														1				
<i>Prionocera</i>																		
<i>Tipula</i>		2						3		1								
Gastropoda	109	19	99	1	9	4	71	337			2	2	112	108	19	2	264	11

Appendix F. (cont.) Macroinvertebrates collected at sites associated with Gettysburg National Military Park.

	1990						1991						1992					
	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7	G2	G3	G4	G5	G6	G7
Pelecypoda																		
Sphaeridae	57	120	233	61	14		68	81	1		4	2		4	2	32	1	
Ancylidae			10	6	1			61			2		187	7	84	88	1	
Decapoda													9					
Cambaridae	2	4	5	4	4	2	3	8	4	3	4			2	3	4	16	2
Number of Taxa	23	18	32	27	24	24	34	27	31	24	32	31	35	23	31	33	23	36
Number of Ind.	718	709	2079	2251	1479	585	2201	3024	1114	1399	1632	469	1377	983	2075	2367	1718	537

Appendix G. (cont.) Macroinvertebrates collected at sites associated with Hopewell Furnace National Historic Site.

	1990							1991							1992						
	H1	H2	H3	H5	H6	H7		H1	H2	H3	H5	H6	H7		H1	H2	H3	H5	H6	H7	
Tricorythidae																					
<i>Tricorythodes</i>				1	93	33							291						1023	810	
Odonata																					
Anisoptera																					
Cordulegastridae																					
<i>Cordulegaster</i>																	1				
Gomphidae																					
<i>Arigomphus</i>									4												
<i>Erpetogomphus</i>						1															
<i>Gomphus</i>																					
<i>Lanthus</i>			6							3							3				
<i>Ophiogomphus</i>		11		2														7			
Libellulidae																					
Zygoptera																					
Aeshnidae																					
<i>Boyeria</i>			2														2				
<i>Nasiaeshna</i>	3																				
Calogperygidae																					
<i>Hetaerina</i>																	1				
Coenogrionidae																					
<i>Amphiagrion</i>																					
<i>Argia</i>															1					1	
<i>Enallagma</i>																					
Plecoptera																					
Capniidae																1					
<i>Allocapnia</i>				6					1	4								1			
Chloroperlidae																					
<i>Alloperla</i>								1									22				
<i>Haploperla</i>										1											
Leuctridae																					
<i>Leuctra</i>		40																			
Nemouridae																					
<i>Amphinemura</i>									3	9	1										
Peltoperlidae																					
<i>Peltoperla</i>		13								13											
Perlidae																					
<i>Acroneuria</i>		19	22	7				1	14	25						4	25	5			
<i>Agnetina</i>		15						3									1				
<i>Claassenia</i>										6											
<i>Eccoptura</i>										25											
<i>Neoperla</i>																					
<i>Perlesta</i>		3							7	9					5	2	2			11	
<i>Perlinella</i>								1		1											
<i>Phasgonophora</i>			1	47																	

Appendix G. (cont.) Macroinvertebrates collected at sites associated with Hopewell Furnace National Historic Site.

	1990							1991							1992						
	H1	H2	H3	H5	H6	H7		H1	H2	H3	H5	H6	H7		H1	H2	H3	H5	H6	H7	
Perlodidae																					
<i>Isoperla</i>								1	5						2			1			
<i>Tallaperla</i>																					
Pteronarcyidae																					
<i>Pteronarcys</i>		1	6	1						4					1	3	2				
Hemiptera																					
Corixidae																					
<i>Palmacorixa</i>																					
<i>Trichocorixa</i>								1													
Gerridae																					
<i>Rheumatobates</i>																					
<i>Trepobates</i>																					
Veliidae																					
<i>Rhagovelia</i>		5	1																		
Megaloptera						1															
Corydalidae																					
<i>Chauliodes</i>			3							1					2						
<i>Corydalus</i>	2					1												1	4	2	
<i>Neohermes</i>				1																	
<i>Nigronia</i>		10							7	3					2	9	1				
Sialidae																					
<i>Sialis</i>																					
Neuroptera																					
Sisyridae																					
<i>Climacia</i>																					
<i>Sisyra vicaria</i>					1	1															
Trichoptera	5	3		13	44	56		5			7	220		1	2		4	2	1		
Brachycentridae																					
<i>Brachycentrus</i>																5					
<i>Micrasema</i>										1											
Glossosomatidae						50															
<i>Agapetus</i>									24	7											
<i>Glossosoma</i>		8	6	10				2	3	2	1			2			2	7			
Helicopsychidae																					
<i>Helicopsyche</i>																					
Hydropsychidae					39																
<i>Cheumatopsyche</i>	50	20	84	32	882	1321		7	11	116	6	581	1187	18	2	16	26	472	1347		
<i>Hydropsyche</i>	20	243	81	245	31	45		64	15	33	4		25	5	11	3	15	3	4		
<i>Macronema</i>	1																				
<i>Potamyia</i>	3																				
Hydroptilidae																					
<i>Hydroptila</i>		20						1													
<i>Leucotrichia</i>																					
<i>Ochrotrichia</i>																					

Appendix G. (cont.) Macroinvertebrates collected at sites associated with Hopewell Furnace National Historic Site.

	1990						1991						1992					
	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7
Lepidostomatidae																		
<i>Lepidostoma</i>			2				7	11										
Leptoceridae																		
<i>Ceraclea</i>			10								125						3	
<i>Leptocerus</i>																		
<i>Mystacides</i>																		
<i>Nectopsyche</i>	1						1											
<i>Oecetis</i>					1													
<i>Setodes</i>																		
<i>Triaenodes</i>																		
Limnephilidae																		
<i>Apatania</i>																		
<i>Goera</i>		3					4											
<i>Hydatophylax</i>							3											
<i>Neophylax</i>		1	1				2								1	2		
Molannidae																		
<i>Molanna</i>																		
Odontoceridae																		
<i>Psilotreta</i>																		
Philopotamidae																		
<i>Chimarra</i>	2	67	8												4			
<i>Dolophilodes</i>		1		9					68					1	5			
Polycentropodidae				5														
<i>Cyrnellus</i>									3					2				
<i>Neureclipsis</i>																		
<i>Nyctiophylax</i>																		
<i>Polycentropus</i>									3									
Psychomyiidae																		
<i>Psychomyia</i>			1				6								1	3		
Rhyacophilidae																		
<i>Rhyacophila</i>		4	11	1			2	3						3	3	5		
Lepidoptera																		
Noctuidae																		
<i>Archanara</i>					1													
Pyralidae																		
<i>Acentria</i>																		
<i>Petrophila</i>																		1
Coleoptera	3																	
Chrysomelidae																		
Curculionidae																		
<i>Emphyastes</i>																		
Dytiscidae																		
<i>Agabus</i>																		
<i>Hydaticus</i>																		
<i>Hydroporus</i>																		

Appendix G. (cont.) Macroinvertebrates collected at sites associated with Hopewell Furnace National Historic Site.

	1990						1991						1992					
	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7
<i>Laccornis</i>																		
<i>Matus</i>																		
Elmidae		137		31		17	3	144	2	136	6	25	1	41	3	1	16	13
<i>Dubiraphia</i>					1													
<i>Optioservus</i>	2	28	13	23	3	2	3	29	1	358	13	1			1		2	
<i>Promoresia</i>		26	27					1	5									
<i>Stenelmis</i>		24	1	3	9	204		19	15	33	13	421		1			65	341
Gyrinidae																		
<i>Dineutus</i>		1																
Haliplidae																		
<i>Haliplus</i>																		
<i>Peltodytes</i>								1										
Hydrophilidae																		
<i>Berosus</i>	1				2	1					1						6	
<i>Helophorus</i>																		
<i>Lacobi</i>						1												
Psephenidae																		
<i>Ectopria</i>			1					1			1				2			
<i>Psephenus</i>		38		19		10		4		8		63				7		74
Diptera		2																
Athericidae																		
<i>Atherix</i>				3				1										
Blephariceridae																		
<i>Blepharicera</i>																		
Ceratopogonidae				1				2	1		1						3	
Chironomidae	12	137	33	144	217	574	687	69	39	900	647	486	29	142	7	301	815	1456
Empididae																		
<i>Chelifera</i>						2												
<i>Hemerodromia</i>						9		1										
Simuliidae	15			2		4				16	171	15						5
<i>Prosimulium</i>									1									
<i>Simulium</i>		2	1	1	49	12		3		10				2		4	69	17
Tabanidae																		
<i>Chrysops</i>																		
<i>Meryomyia</i>																		
<i>Tabanus</i>																		
Tipulidae																		
<i>Antocha</i>	2	11		17		6	1	16	1	112		4		2		17	2	6
<i>Dicranota</i>		4		3	4				5		12				1			
<i>Hexatoma</i>		3		5			2		4						3		1	
<i>Limnophila</i>																		
<i>Prionocera</i>						4			1									
<i>Tipula</i>	1	3	3		17			2	3		1					1		2
Gastropoda	42				227	6	16				19	2	16	1			19	5

Appendix G. (cont.) Macroinvertebrates collected at sites associated with Hopewell Furnace National Historic Site.

	1990						1991						1992					
	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7	H1	H2	H3	H5	H6	H7
Pelecypoda						1							8					
Sphaeridae	49	210			9		2		1		1	7				6		5
Ancylidae		2						1			3	5					22	1
Decapoda										1								
Cambaridae	1			1		1	1									1		
Number of Taxa	28	40	23	35	23	31	27	48	50	21	23	20	14	31	30	29	25	27
Number of Ind.	326	1353	324	704	1718	2536	940	772	980	2249	2341	2697	143	297	135	577	2756	4459

Appendix H. Macroinvertebrates collected at sites associated with Valley Forge National Historical Park.

	1990							1991							1992						
	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7
Platyhelminthes																					
Planariidae	2	2		84	9	63		2	11		353		4		68	3	10	19			2
Nematoda					3		1						5						1		1
Annelida																					
Oligochaeta	9		17	30	17		9	48	17		6	86	115	78	12	23	24	18	59		11
Hirudinea		1		1														1			
Hydracarina													2		1					1	
Isopoda																					
Asellidae																					
Asellus	9		9	132	5	1		23	2	5	336	3		1	15	4	1	299	2		
Amphipoda																					
Gammaridae																					
Gammarus	114	254	118	22	7			339	998		89				152	113	43	311	1		
Ephemeroptera							1														
Baetidae																					
Baetis	436	93		333	38	22	44	352	357	310	415	115	63	335	127	43	26	54	53	4	16
Cloeon																					
Pseudocloeon														5							
Caenidae																					
Caenis						1	1					1									1
Ephemerellidae							2														
Attanella												1									
Danella																					
Drunella												29		1					1		
Ephemerella	1							486	595	196	138	275		27					5		42
Eurylophella																				1	
Serratella					19		1		2			6	1	43					35		28
Ephemeridae	1																				
Heptageniidae																					
Epeorus																					1
Cinygmula																					
Leucrocuta																					
Stenonema	1				2		73												1		
Stenacron												5		56					5		18
Leptophlebiidae																					
Chloroterpes																					
Leptophlebia																			1		
Oligoneuridae																					
Isonychia					75		42					17		6					6		49
Potomanthidae																					
Potomanthus																					
Polymatarcyidae																					
Ephoron																					
Siphonuridae																					
Ameletus																					

Appendix H. (cont.) Macroinvertebrates collected at sites associated with Valley Forge National Historical Park.

	1990							1991							1992						
	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7
Perlodidae																					
<i>Isoperla</i>																					
<i>Tallaperla</i>																					
Pteronarcyidae																					
<i>Pteronarcys</i>																					
Hemiptera																					
Corixidae																					
<i>Palmarcorixa</i>																					
<i>Trichocorixa</i>																					
Gerridae																					
<i>Rheumatobates</i>																					
<i>Trepobates</i>																					
Veliidae																					
<i>Rhagovelia</i>							3														
Megaloptera																					
Corydalidae																					
<i>Chauliodes</i>							2	1	1			2	1		4		2				
<i>Corydalis</i>		2					2														
<i>Neohermes</i>							5														
<i>Nigronia</i>						1														2	
Sialidae																					
<i>Sialis</i>					1																
Neuroptera																					
Sisyridae																					
<i>Climacia</i>																					
<i>Sisyr vicaria</i>																					
Trichoptera	15	8			15		28	35	5	16	41	66		5	16	2	4		6		
Brachycentridae																					
<i>Brachycentrus</i>												5									
<i>Micrasema</i>																			2		
Glossosomatidae																					
<i>Agapetus</i>																					
<i>Glossosoma</i>					1		10		3	1		10		5		2		4	4		
Helicopsychidae																					
<i>Helicopsyche</i>																					
Hydropsychidae																					
<i>Cheumatopsyche</i>	17			7	13	2	21	3	8	8	2	37		4	58	5		2	19	1	3
<i>Hydropsyche</i>	281	140		22	95		134	273	226	327	295	87		38	538	135	198	18	71		27
<i>Macronema</i>																					
<i>Potamyia</i>																					
Hydroptilidae																					
<i>Hydroptila</i>	7						4	3	3	1											
<i>Leucotrichia</i>							92														
<i>Ochrotrichia</i>																					

Appendix H. (cont.) Macroinvertebrates collected at sites associated with Valley Forge National Historical Park.

[illegible]

Appendix H. (cont.) Macroinvertebrates collected at sites associated with Valley Forge National Historical Park.

	1990							1991							1992						
	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7
<i>Laccornis</i>																					
<i>Matus</i>																					
Elmidae	113			78	8	3	27	246	357	1	146	17	2	1	379	53	96	186	16		5
<i>Dubiraphia</i>		2																			
<i>Optioservus</i>	36	99		91	26	16	63	189	349	3	293	2	5	13	268	34	232	127	8		7
<i>Promoresia</i>																					
<i>Stenelmis</i>	55	162	10	9	5	3	26	125	94		27	6	1	8	168	62	55	21		3	
Gyrinidae																					
<i>Dineutus</i>																					
Haliplidae																					
<i>Haliphus</i>																					
<i>Peltodytes</i>																					
Hydrophilidae							1														
<i>Berosus</i>																					
<i>Helophorus</i>																				1	
<i>Lacobi</i>																					
Psephenidae																					
<i>Ectopria</i>																					
<i>Psephenus</i>	2	3	2		1	1	4	9	7					7	4	1		1	2		1
Diptera	1																				
Athericidae																					
<i>Atherix</i>																					
Blephariceridae																					
<i>Blepharicera</i>																					
Ceratopogonidae												2	1						1		
Chironomidae	239	92	122		86	602	172	929	37	13	1403	151	628	31	310	72	157	140	92	258	175
Empididae																					
<i>Chelifera</i>																					
<i>Hemerodromia</i>	12							5					9	1							
Simuliidae	9			11		8	1						229	9	1			2			4
<i>Prosimulium</i>		2						3					278	8							
<i>Simulium</i>	50		9	80	25	141	1		1		164	2			2		2	279	3	104	19
Tabanidae																					
<i>Chrysops</i>																					
<i>Merycomyia</i>																					
<i>Tabanus</i>																					
Tipulidae																					
<i>Antocha</i>	28	12		7	5	23	46	14	82	4	20	46	1	3	163	11	39	1	4	8	9
<i>Dicranota</i>						2	13		1			2		1	1					1	
<i>Hexatoma</i>							3														
<i>Limnophila</i>																					
<i>Prionocera</i>																					
<i>Tipula</i>						1					6					1	1	3		7	1
Gastropoda									1		1				1						

Appendix H. (cont.) Macroinvertebrates collected at sites associated with Valley Forge National Historical Park.

	1990							1991							1992						
	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7	V1	V2	V3	V4	V5	V6	V7
Pelecypoda																					
Sphaeridae					1			27				2							1		
Ancylidae							1					1									
Decapoda																					
Cambaridae			2		2			1													
Number of Taxa	27	14	9	14	31	17	30	21	23	13	18	34	16	24	22	16	15	20	32	12	22
Number of Ind.	1439	872	290	907	477	891	832	3090	3184	888	3736	1025	1345	713	2290	564	890	1488	422	391	423

Appendix I. Scientific and common names of fishes collected in this study.

<u>SCIENTIFIC NAME</u>	<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>COMMON NAME</u>
Petromyzontidae	lampreys	Ictaluridae	catfishes
<i>Petromyzon marinus</i>	sea lamprey	<i>Ameiurus natalis</i>	yellow bullhead
Anguillidae	eels	<i>Ameiurus nebulosus</i>	brown bullhead
<i>Anguilla rostrata</i>	American eel	<i>Noturus insignis</i>	marginated madtom
Clupeidae	shads, herrings	Salmonidae	trouts, salmon
<i>Alosa sapidissima</i>	American shad	<i>Oncorhynchus mykiss</i>	rainbow trout
Cyprinidae	minnows	<i>Salmo trutta</i>	brown trout
<i>Campostoma anomalum</i>	central stoneroller	<i>Salvelinus fontinalis</i>	brook trout
<i>Carassius auratus</i>	goldfish	Esocidae	pikes
<i>Clinostomus funduloides</i>	redside dace	<i>Esox a. americanus</i>	redfin pickeral
<i>Cyprinella analostana</i>	satinfin shiner	<i>Esox lucius</i>	northern pike
<i>Cyprinella spiloptera</i>	spotfin shiner	<i>Esox niger</i>	chain pickeral
<i>Cyprinus carpio</i>	carp	Fundulidae	killifishes
<i>Ericymba buccata</i>	silverjaw minnow	<i>Fundulus diaphanus</i>	banded killifish
<i>Exoglossum maxillingua</i>	cutlips minnow	Centrarchidae	sunfishes
<i>Hybognathus regius</i>	eastern silvery minnow	<i>Ambloplites rupestris</i>	rock bass
<i>Luxilus cornutus</i>	common shiner	<i>Lepomis auritus</i>	redbreast sunfish
<i>Margariscus margarita</i>	pearl dace	<i>Lepomis cyanellus</i>	green sunfish
<i>Notemigonus crysoleucus</i>	golden shiner	<i>Lepomis gibbosus</i>	pumpkinseed sunfish
<i>Notropis amoenus</i>	comely shiner	<i>Lepomis macrochirus</i>	bluegill sunfish
<i>Notropis bifrenatus</i>	bridle shiner	<i>Micropterus dolomieu</i>	smallmouth bass
<i>Notropis hudsonius</i>	spottail shiner	<i>Micropterus salmoides</i>	largemouth bass
<i>Notropis procne</i>	swallowtail shiner	<i>Pomoxis annularis</i>	white crappie
<i>Notropis rubellus</i>	rosyface shiner	Percidae	perches
<i>Pimephales notatus</i>	bluntnose minnow	<i>Etheostoma blennioides</i>	greenside darter
<i>Pimephales promelas</i>	fathead minnow	<i>Etheostoma flabellare</i>	fantail darter
<i>Rhinichthys atratulus</i>	blacknose dace	<i>Etheostoma olmstedii</i>	tessellated darter
<i>Rhinichthys cataractae</i>	longnose dace	<i>Perca flavescens</i>	yellow perch
<i>Semotilus atromaculatus</i>	creek chub	<i>Percina peltata</i>	shield darter
<i>Semotilus corporalis</i>	fallfish	Cottidae	sculpins
Catostomidae	suckers	<i>Cottus bairdi</i>	mottled sculpin
<i>Catostomus commersoni</i>	white sucker	<i>Cottus girardi</i>	Potomac sculpin
<i>Erismyzon oblongus</i>	creek chubsucker		
<i>Hypentelium nigricans</i>	hogsucker		

Delaware 1990

Catalog #	within park		outside park			
	2359	2358	2357	2360	2361	2362
<u>Petromyzon marinus</u>	12		2	1		1
<u>Anguilla rostrata</u>	2	9		14	13	17
<u>Campostoma anomalum</u>			2			
<u>Cyprinella analostana</u>	12	3	5	16	1	
<u>Cyprinella spiloptera</u>			2			
<u>Exoglossum maxillingua</u>	16	9	9	17	9	26
<u>Luxilus cornutus</u>						1
<u>Pimephales notatus</u>			1			
<u>Rhinichthys cataractae</u>		16		9	2	
<u>Semotilus corporalis</u>	8	64	94	39	7	5
<u>Catostomus commersoni</u>	77	18	56	77	20	58
<u>Hypentelium nigricans</u>		3				
<u>Noturus insignis</u>	38	35	19	48	13	16
<u>Fundulus diaphanus</u>		1	5			2
<u>Lepomis auritus</u>	11		3	2	11	23
<u>Lepomis gibbosus</u>						1
<u>Micropterus dolomieu</u>			5	8	6	2
<u>Etheostoma olmsted</u>	47	7	28	29	16	6
<u>Percina peltata</u>			1	2	2	
Individuals	223	165	232	262	100	158
Species	9	10	14	12	11	12

2359 Delaware River at National Park Service HQ in Wayne County, PA

2358 Delaware River just upstream of Cortese Landfill, Sullivan County, NY

2357 Delaware River just downstream of Cortese Landfill, Sullivan County, NY

2360 Delaware River along railroad tracks, Sullivan County, NY

2361 Delaware River at railroad bridge, Sullivan County, NY

2362 Delaware River just upstream from Barryville, Sullivan County, NY

Hopewell Furnace 1990

	in park		outside park				
Catalog #	2368	2369	2370	2371	2372	2373	2374
<u>Anguilla rostrata</u>	2	1		2	1		1
<u>Esox a. americanus</u>	1			1			
<u>Esox niger</u>		1					
<u>Salvelinus fontinalis</u>		1					
<u>Clinostomus funduloides</u>	3	110	121				
<u>Cyprinus carpio</u>							1
<u>Exoglossum maxilllingua</u>	7	6		20	27		1
<u>Luxilus cornutus</u>		28				25	
<u>Pimephales notatus</u>							2
<u>Pimephales promelas</u>							1
<u>Rhinichthys atratulus</u>	1	3	6	45	101	2	
<u>Semotilus atromaculatus</u>		2		2	2	1	
<u>Semotilus corporalis</u>	34	7			2	2	9
<u>Catostomus commersoni</u>	3	8		3	17		
<u>Ameiurus natalis</u>	1		7				
<u>Noturus insignis</u>	13			2			
<u>Fundulus diaphanus</u>						1	5
<u>Ambloplites rupestris</u>						3	11
<u>Lepomis auritus</u>		1					3
<u>Lepomis cyanellus</u>	4		37			2	
<u>Lepomis gibbosus</u>	12	6	7	3		2	1
<u>Lepomis macrochirus</u>	4	6				6	1
<u>Micropterus dolomieu</u>							1
<u>Micropterus salmoides</u>	2	1		2		1	
<u>Etheostoma olmsted</u>	3	8		6	5	3	
Individuals	90	189	57	214	194	29	93
Species	14	15	4	12	9	13	11

2368 Sta 1 French Creek at Route 345 bridge within Hopewell Furnace National Historical Park, Berks County, 16 July 1990

2369 French Creek at Harmonyville Road bridge, downstream of Hopewell Furnace National Historical Park, just east of Bethesda Road, Chester County, 16 July 1990

2370 Scott's Run at park road bridge, French Creek State Park between Scott's Run Lake and Hopewell Lake, Berks County, 16 July 1990

2371 Pine Creek at Harmonyville Road bridge, downstream of swamp, Chester County, 16 July 1990

2372 Pine Creek at bridge on state route 1023, below Lobachsville, Chester County, 16 July 1990

2373 Maiden Creek along Wiley's Road, 0.7 miles upstream of Route 61, Berks County, 17 July 1990

2374 Tulpehocken Creek at state route 3008 bridge, Berks County, 17 July 1990

Gettysburg 1990

Catalog #	in park		outside park				
	2378	2379	2380	2381	2447	2448	2449
<u>Campostoma anomalum</u>		9	33	80	90	23	
<u>Cyprinella analostana</u>						4	
<u>Cyprinella spiloptera</u>		19		20	8		
<u>Ericymba buccata</u>					1		
<u>Hybognathus regius</u>						2	
<u>Luxilus cornutus</u>				2			
<u>Margariscus margarita</u>							1
<u>Notemigonus crysoleucus</u>	82						
<u>Notropis amoenus</u>				1			
<u>Notropis hudsonius</u>			19	13	32		1
<u>Notropis rubellus</u>				17			
<u>Pimephales notatus</u>	1	52	89	12	149	6	
<u>Rhinichthys atratulus</u>			99	8	18	161	115
<u>Rhinichthys cataractae</u>					64		33
<u>Semotilus corporalis</u>	1						
<u>Catostomus commersoni</u>						1	4
<u>Erimyzon oblongus</u>						2	
<u>Hypentelium nigricans</u>							3
<u>Ameiurus natalis</u>		11	2	2	3		3
<u>Ameiurus nebulosus</u>				1			
<u>Noturus insignis</u>				1			
<u>Fundulus diaphanus</u>		218	30	4		5	
<u>Ambloplites rupestris</u>				6			7
<u>Lepomis auritus</u>		12	6	12	3	24	
<u>Lepomis cyanellus</u>	32	3	10		3	7	
<u>Lepomis gibbosus</u>		1				3	2
<u>Lepomis macrochirus</u>		1	1	5	6		7
<u>Micropterus dolomieu</u>				4			
<u>Micropterus salmoides</u>			4	2	2		
<u>Etheostoma blennioides</u>		1		34	47	1	
<u>Etheostoma flabellare</u>			7	7		4	14
<u>Etheostoma olmsted</u>				2	1		
<u>Cottus bairdi</u>							77
<u>Cottus girardi</u>							3
Individuals	120	327	454	233	436	325	272
Species	5	10	12	20	15	14	14

- 2378 Plum Run at Crawford Road bridge off Wheatfield Road, Adams County, 18 July 1990
- 2379 Willoughby Run at Water Works Road bridge, Adams County, 18 July 1990
- 2380 Willoughby Run at Route 30 bridge, Adams County, 18 July 1990
- 2381 Marsh Creek at Redrock Road bridge at mouth of Willoughby Run, Adams County, 18 July 1990
- 2447 Rock Creek at US Route 15 bridge south of junction with PA Route 97, Adams County, 14 September 1990
- 2448 Unnamed tributary to Rock Creek at US Business Route 15 just north of junction with Weaner Road, Adams County, 14 September 1990
- 2449 Conococheague Creek at Township Route T520 (Woodstock Road) near West Fayetteville, Franklin County, 14 September 1990

Valley Forge 1990

Catalog #	inside park			outside park			
	2363	2364	2365	2366	2367	2375	2376
<u>Anguilla rostrata</u>						1	3
<u>Esox a. americanus</u>					1		
<u>Salmo trutta</u>			1				
<u>Carassium auratus</u>				1			
<u>Clinostomus funduloides</u>						7	10
<u>Cyprinella analostana</u>					22		10
<u>Cyprinella spiloptera</u>					2	12	2
<u>Exoglossum maxillingua</u>		18			17	55	13
<u>Luxilus cornutus</u>					6	16	16
<u>Notropis hudsonius</u>					2	4	1
<u>Notropis procne</u>						171	29
<u>Rhinichthys atratulus</u>	2	40	27	8	16	15	43
<u>Rhinichthys cataractae</u>	1	4	6		15	67	11
<u>Semotilus atromaculatus</u>		1		1	1	2	1
<u>Semotilus corporalis</u>					3		
<u>Catostomus commersoni</u>	11	18	1	4	23	8	14
<u>Noturus insignis</u>							2
<u>Ambloplites rupestris</u>	1	3			10		
<u>Lepomis aurtus</u>	1						
<u>Lepomis cyanellus</u>	4		2		11	3	
<u>Lepomis gibbosus</u>		2		4	5	4	2
<u>Lepomis macrochirus</u>		2	1	2	6		
<u>Micropterus dolomieu</u>					1		
<u>Micropoters salmoides</u>					2	2	1
<u>Etheostoma olmsted</u>	8	7			3	15	13
<u>Percina peltata</u>	1				2		
Individuals	29	95	38	20	148	382	171
Species	8	9	6	6	19	15	16

2363 Valley Creek at mouth, just below Route 23 bridge, in Valley Forge National Historical Park, Chester County, 12 July 1990

2364 Valley Creek at Footbridge along Route 252, in Valley Forge National Historical Park, Chester County, 12 July 1990

2365 Valley Creek at Wilson Road bridge, in Valley Forge National Historical Park, Chester County, 12 July 1990

2366 Valley Creek at Church Road bridge, Chester County, 12 July 1990

2367 Pickering Creek at Charlestown Road bridge, Chester County, 12 July 1990

2375 Red Clay Creek at Marshall Road bridge, at confluence with West Branch, Chester County, 17 July 1990

2376 Middle Branch White Clay Creek at Crawford Road bridge off Wheatfield Road, Chester County, 17 July 1990