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A BIOLOGICAL SURVEY OF THE  
NEW RIVER GORGE NATIONAL RIVER

Volume 1

Summary of Findings

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by

The Virginia Cooperative Fish and Wildlife Research Unit  
and the

Department of Fisheries and Wildlife Sciences

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Volume 2 - A Survey of Habitats and Wildlife

Volume 3 - Habitat Use by Fishes of the New River, West Virginia

Volume 4 - A Survey of Freshwater Mussels

Copies of Volumes 2, 3, and 4 are available in limited supply upon request from the Superintendent, New River Gorge National River, P.O.Box 1189, Oak Hill, WV 25901.

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## **PURPOSE AND JUSTIFICATION**

In 1983 the National Park Service contracted with the Virginia Co-operative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife Sciences, VPI&SU, to conduct a biological survey of the New River Gorge National River (NRGMR). The purpose of the survey was to provide the NFS with biological information about the National River in order to formulate management plans and make decisions concerning future uses of the NRGMR. The study was divided into three components; 1) Riparian habitats and wildlife; 2) Fisheries; and 3) Mussels.

The specific objectives of this study were:

- 1). To identify and describe the riparian habitats of the New River Gorge National River.
- 2). To survey these habitats for birds, mammals, reptiles, and amphibians occurring there.
- 3). To provide density indices, where possible, for wild vertebrate species.
- 4). To identify fish species inhabiting the New River and describe their habitat associations.
- 5). To identify the freshwater mussel species associated with the New River.
- 6). To provide a literature review of the potential impacts from fluctuating river flows on the above components of the New River system.

## THE EFFECTS OF FLOODING ON RIPARIAN HABITATS

### A REVIEW

Floodplains are productive and diverse ecosystems, capable of supporting a variety of plant and animal populations, as well as some of the most productive agricultural systems. Riparian habitats may be considered ecotones between the aquatic habitat of a river and the surrounding terrestrial habitats. They include flora and fauna from both, as well as some unique organisms of their own (Johnson 1978). Riparian habitats, by definition are lands which are periodically flooded, although they do not retain standing bodies of water.

Floodplains have historically been heavily utilized and impacted by man. Because of transportation and recently, recreation, these areas have been, favored as sites for human settlements (Teskey and Hinckley 1977). Haddock (1976) estimated that approximately 9.5% of all cultivated land and 16.5% of all urban land within the United States occurred within floodplains.

With these human demands on floodplains, it is not surprising that attempts have been made to restrict the flooding which naturally occurs on these lands. However, floodplains and river systems are intricately tied together and alteration of flow regime will impact the floodplain ecosystem. All too often, dams, channelization projects, and irrigation systems have been designed with little or no consideration given to the native habitats and wildlife affected by such actions.

Floodplain vegetation is adapted to natural flooding conditions. Those species found on floodplains are there because they are better adapted to the conditions than nearby upland species. A plant's tolerance to flooding is determined in part, by the growth of adventitious roots and new secondary roots under low oxygen conditions (Teskey and Hinckley 1977). Adventitious roots usually develop at or near the water surface where oxygen supply is the greatest. These flood-time root systems develop a more porous structure to facilitate gas exchange.

Even the main roots of floodplain species become dormant or die back immediately after flooding, and the trees which exhibit the greatest amount of adventitious root development also have the highest growth rates and greatest tolerance to flooded conditions (Hosner and Boyce 1962). Harris (1975) observed a higher mortality in red oak and black locust than willow, green ash, and boxelder in a newly impounded flood control lake. Exposure to air causes adventitious roots to die, thus rapid daily flow fluctuations are probably detrimental.

According to Teskey and Hinckley (1977), five factors are critical in determining a plant's response to changes in water level.

- 1). The time of year during which flooding occurs will affect growth and survival of floodplain species. Gill (1970) found that growth rates were reduced when flooding occurred in the growing season, while Hall and Smith (1955) found no harmful effects associated with flooding in the dormant season. During the latter period tree roots have a low requirement for oxygen (Yelenosky 1964). Associated with time of year is water temperature. Cool water is less damaging than warm water because the oxygen holding capacity of cool water is greater (Broadfoot and Williston 1973).

2). Flood duration is critical in species survival. Even with adventitious roots, most bottomland species cannot survive two years of continuous flooding (Broadfoot and Williston 1973). The locations of specific species are situated within boundaries formed by flood duration patterns. Teskey and Hinckley (1978) found that the survival of boxelder, silver maple, river birch, green ash, and sycamore was much greater than oaks, hickories, and other upland species. However, even they died after being exposed to total root submersion for the entire growing season. Teskey and Hinckley (1978) further stated that seedlings were more susceptible to flood duration, and were less likely to survive than mature trees.

Seedling tolerance to flooding is varied. Teskey and Hinckley (1978) found that sycamore and boxelder seedlings experienced 100% mortality after being exposed to 30 continuous days of root submersion during the growing season. River birch seedlings survived thi same experiment, but their growth was stunted. Silver maple seedlings were not used in this experiment, but were noted to display good adventitious root development. Black willow seedlings displayed 100% survival to the 30 day flooding, and it was noted that black willow seeds germinate in water.

3). Survival of herbaceous plants has been related to water depth at time of flooding. If flood waters are greater than a few centimeters above the soil surface, gas exchange through lenticels will be blocked (Armstrong 1968). In tree seedlings, those which have not leafed out will remain dormant until the waters recede. Leaves on seedlings which have already leafed out become chloric and drop off. Duration of the flood

will then decide survival (Hosner 1958). Harris (1975) recorded high mortality from flooding stress in most seedlings.

4). Siltation resulting from flood waters may have positive and negative impacts on the riparian community. Deposits of clay, silt, and sand impact seedling and herbaceous plant survival. Organic sediments have a high oxygen demand, thereby reducing floodwater oxygen content and putting stress on tree roots. However, flood discharges can rearrange sedimentary deposits (Petts 1984) and provide influx of nutrients which maintain the high primary productivity of riparian communities. New successional sites are often formed by the deposition of sediment in receding flood stages (Petts 1984).

5). Flood frequency has been found to influence the composition and diversity of herbaceous species. Bell (1974) found that as flood frequency decreased, herbaceous species diversity increased.

Severe frequent flooding during the growing season may decrease the growth of mature trees and decrease seedling survival. Depending on flood frequency, the duration and water temperature may also result in floodplain forest mortality. The lack of adaptability of upland species such as red oak, black locust, black cherry, beech, and hickories keeps them from becoming established in floodplain habitats,

A delicate balance exists between the flora and fauna of riparian habitats and the annual flood regime. Unusually high summer flows may scour beds of aquatic vegetation reducing cover for young of the year fish, turtles, and invertebrates. Summer destruction of these plant beds may affect waterfowl food supply and survival the following winter. Ill-timed artificial flows may destroy larvae of amphibians by flushing

them from pools and backwaters (Petts 1984). Eggs of reptiles buried -on sandbars and islands may be inundated and drown. Ground nesting birds in riparian habitats may also experience high mortality of nests and nestlings.

#### **EFFECTS OP REDUCED FLOWS ON RIPARIAN COMMUNITIES**

Just as altering the flood timing and duration may impact riparian ecosystems, so also will reducing the magnitude of flooding. Petts (1984) states that flood-control facilities (such as Bluestone Dam) reduce normally higher winter flows and increase normally low summer flows. Over the course of a one year cycle, these dams 'smooth out' the variation which naturally occurs in a flood and drought cycle. Elimination or reduction in frequency of flooding limits opportunities for exchanges between the river and its former floodplain, so that processes which cause channel migration and construction of new wetlands is inhibited (Frith 1977).

Reduced flows can result in loss of sediment deposition, which are key factors in retaining riparian habitats. Reduced flows can adversely affect the reproduction of floodplain species, such as black willow whose seeds germinate in water. Schneider et al. (1986) stated that seed dispersal, seed viability, seedling establishment, and seedling survivorship were all dependent on the timing and degree of riverine flooding, although several decades may pass before changes in riparian community structure are noticed. Schneider (pers. comm.) recommended comparing the forest

canopy species with the understory seedlings in an effort to assess changes in the structure of the vegetation.

Flow regulation may reduce habitat for wildlife, such as muskrat (Ondatra zibethica) and beaver (Castor Canadensis), because of changes in food supply and cover. Kellerhals and Gill (1973) found that ducks needed the continuous production of successional vegetation, and that lush shoot growth ceased when flows were stabilized. Overall, reduced soil moisture results in reduced vegetation density (Gill 1971). Reduced flooding of riparian habitats may also allow upland type species including oaks, black cherry, beech, and hickories to become established. In the aquatic habitat, reduced flows often result in reduced turbidity, allowing for increased algal and macrophyte growth.

Reduced flows can produce a vegetative Community where none existed before. In the lower Colorado River, a confined river, pre-dam conditions included high floods which raced through a steep narrow gorge, limiting the formation of a riparian plant community. Since dam completion, a riparian community has formed along the river although it is a community not designed to be flooded. With this plant community has come changes in the wildlife composition (Petts 1984). Kellerhals and Gill (1973) noted that in the absence of continued initiation of primary succession, biological productivity would eventually decrease.

In the southern section of the New River Gorge National River, a floodplain exists, while in the northern section the river channel is confined. From this review we can anticipate the types of changes likely to occur from artificial flows. Quantity, timing, and quality of flow discharges can produce a diverse range of responses in terms of

vegetational structure and composition. These changes will likely, be noticeable only through the initiation of long-term studies of the vegetation and wildlife populations. Riparian habitats have evolved in a cycle of flood and drought, but it is a system in which there is a natural repeating cycle of events. Artificial manipulation of the flow regime without an understanding of the effects can destroy the valuable riparian ecosystem, as well its inseparable riverine habitat.

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## THE EFFECTS OF FLUCTUATING FLOWS ON FISH

Dams have various effects on the downstream biota. The tailwater biota may be affected indirectly or directly in two principal ways. Either the downstream flow regime is altered or changes in physical or chemical water quality, due to storage of water in the reservoir, influence the downstream environment (Brooker 1981). The type and use of the impoundment will influence the magnitude of environmental changes downstream of the dam (Brooker 1981). The effects of dams on the downstream biota have been reviewed (Baxter 1977; Stanford and Ward 1979; Hildebrand 1980; Brooker 1981; Walburg et al. 1981). This paper will focus on the effects of rapid fluctuations in flow, due to peak power generation by hydroelectric dams, on the fish below impoundments.

Two general types of hydroelectric facilities can be identified; run-of-river and storage. A run-of-river operation generally has extremely limited water storage capacity and only uses normal river flow for power generation (Baxter 1977; Hildebrand 1980). A strict run-of-river facility usually does not change the normal water level fluctuations already present in the drainage basin (Hildebrand 1980), unless diversions are constructed to route the water to a powerhouse downstream.

A storage hydroelectric facility, on the other hand, is associated with a reservoir that is large enough to allow water storage from the wet season to the dry season (Hildebrand 1980; Walburg et al. 1981). The capacity for such storage can provide more consistent flows for hydroelectric generation. Such facilities are generally operated in a peaking

mode, in which discharge is varied in accordance with the demand for electricity. This generally results in high flows during weekdays and low flows at night and on weekends (Hildebrand 1980; Walburg et al. 1981).

The amplitude of fluctuations below hydropower dams and in unimpounded streams are essentially equivalent. However, flow fluctuations below hydroelectric facilities are more frequent and rapid (Hildebrand 1980; Walburg et al. 1981). In some hydropower tailwaters daily fluctuations can be as great as two meters (Holden 1979). Large daily fluctuations below hydropower dams usually have a destructive influence on tailwater biota by creating an unstable, highly variable downstream habitat (Walburg et al. 1981). In general, the most highly adapted species will sustain the greatest impact of flow regulation, due to their narrowly defined environmental requirements (Pfitzer 1963; Holden 1979; Walburg et al. 1981). Changes in flow cause changes in velocity, depth and wetted area c. a river, which consequently influence the survival and distribution of fish (Brooker 1981).

Large diurnal fluctuations in the tailwaters of hydropower dams can have several effects on the tailwater fisheries. Rapid flow reductions can disrupt spawning, strand fish and expose nests. Abrupt flow increases can sweep away eggs and fry as well as disrupt spawning. Kroger (1973) found rapid reduction in flow below Jackson Lake, Wyoming stranded sculpins (*Cottus sp.*) in the Snake River. Trout and salmon have also been found stranded below hydropower and diversion dams (Anderson 1972; Fowler 1978). Cyprinid eggs in Russia were exposed and desiccated due to fluctuating releases (Sharanov 1963; Chikova 1968). Fry and eggs of the European golden shiner have been destroyed as a result of dewatering

(Barannikova 1962). Also in Russia, pike spawning was disrupted and eggs and larvae were desiccated in the tailwaters of hydroelectric dams (Barannikova 1962; Eliseev and Chikova 1968). Corning (1969) found high stream flows, resulting from sudden water releases from a Colorado reservoir, disinterred 75% of artificially buried rainbow trout (Salmo gairdneri) eggs and the viability of the remaining eggs was apparently lowered. Also, since fish have preferred depths and velocities for spawning, spawning conditions may be met only for a short time each day (Bauersfield 1978). Few studies have documented the effects of fluctuating flows on fish in warmwater streams below impoundments. However, the effects on warmwater fish are probably similar to the above effects. For example flooding, which is similar to the rapid releases during power generation, terminated nesting, behavior, apparently destroyed nests and displaced fry of smallmouth bass (Micropterus dolomieu) in a small Ohio stream (Winemiller and Taylor 1982).

Diel fluctuations in flow alter fish habitat. Different life stages of fish have distinct preferences for various combinations of depth, velocity and other physical characteristics of a stream (Stalnaker 1981). Due to these preferences, each life stage may find a specific stream reach suitable or unsuitable at a given discharge and time (Stalnaker 1979, 1981). Low flows decrease habitat quality and quantity and fish become concentrated and redistribute to less suitable habitat (Walburg et al. 1981). Reduced habitat increases competition for food and space between and within species and can lead to increased susceptibility to predation (Corning 1969; Walburg et al. 1981; Stevens and Miller 1983). During maximum releases the tailwater may change from a typical pool-riffle as-

sociation to a deep, swift river (Walburg et al. 1981) and fish may be displaced downstream. Hubert (1981) found high flows, resulting from opening flood gates of a hydroelectric dam, displaced smallmouth bass downstream. When displaced, the fish generally moved into areas near the shoreline where eddies and rock cover created protection from the current. MacPhee and Brusven (1976) found that any alteration in flow displaced juvenile salmon downstream in a diversion channel used to simulate fluctuating flows below a power dam. High winter discharges probably disrupted tailwater habitat and forced bluegill (Lepomis macrochirus<sup>1</sup>). longear sunfish (Lepomis megalotis) and white crappie (Pomoxis annularis) to move downstream in a Kentucky tailwater (Hoyt and Kruskarap 1982). Only fish adapted to high velocities are able to sustain their populations below hydroelectric dams, (Walburg et al. 1981). High flows are less detrimental to fish if the tailwater has deep pools, sufficient cover and backwater areas (Walburg et al. 1981, 1983). As a result of daily discharge fluctuations, fish may experience greater physiological stress and fish production may decrease (Walburg et al. 1981). As an example, Austen (1984) found that in the New River in Virginia and West Virginia, growth and condition of smallmouth bass were generally higher in the tailwater of a flood-control dam (Bluestone dam) than below a hydroelectric facility (Claytor dam). Power generation by Claytor dam results in greater flow, a rise in water level, increased current velocity, and greater turbidity. However, the differences in fish growth and condition may have been attributable to factors other than the differences in discharge patterns (Austen 1984). Stream flow changes alter fish

habitat, but they may also change the composition and relative abundance of species (Neel 1963; Stalnaker 1981; Brocksen et al. 1982).

The high and low flows below peaking power facilities alternately inundate and expose portions of the streambed. This results in a permanent "zone of fluctuation" (Walburg et al. 1981), which has also been called a freshwater "intertidal zone" (Fisher and LaVoy 1972). This zone is the area of the streambed most affected by fluctuating flows and generally includes side channels, backwater areas, shallows and riffles (Ffitzer 1963; Walburg et al. 1981). Due to the periodic exposure of streambed during non-power cycles, little or no production takes place in this zone (Ffitzer 1963; Walburg et al. 1981). Changes take place in this zone as well as in other sections of the stream that may be detrimental to the fishery.

High flows following periods of low discharge result in increased streambed and bank instability and scouring of the substrate (Ward 1976). Erosion and sedimentation rates in the main channel may increase. Degradation of the main channel may increase rates of erosion and sedimentation in tributary streams as well, by lowering the erosional base level (Turner 1980). Erosion increases turbidity, which discourages streambank vegetation and streambed algal and higher plant growth by inhibiting photosynthesis (Walburg et al. 1981). A decrease in the amount of riparian vegetation leads to a reduction in allochthonous inputs (ie. plant litter and detritus), which are an important source of energy for stream ecosystems (Radford and Hartland-Rowe 1971; Cummins 1979). However, the influence of the riparian area decreases as the stream becomes larger (Cummins 1979). Streambank vegetation also provides habitat for

terrestrial insects, which are a source of food for some fish species (Ward 1976). In addition, scouring constantly flushes away any detritus and sediments that are present in the stream (Ward 1976). Bed and bank degradation and substrate scouring due to daily flow fluctuations, decrease streambank vegetation, streambed algae and higher plants, and detritus. This stresses the trophic structure of tailwaters and may critically limit the biota (Walburg et al. 1981).

Siltation can also affect the fish in tailwaters. Particles scoured from the streambed during high flows may be deposited downstream. Deposition may also occur during low flows, such as during lengthy non-power cycles. Silt gradually fills the interstices of gravel, which reduces invertebrate habitat and destroys fish spawning habitat (Wright and Szluha 1980). Thus, affecting the fishery indirectly and directly by reducing fish food organisms and fish abundance. Siltation may also occur at the mouths of tributaries during low flows (Brooker 1981).

Scouring, erosion and sedimentation change the substrate and channel morphology (Duma and Day 1977). Scouring involves flushing of the fine particles (detritus and sediment) and often results in an armored layer of coarse surface particles (Scullion 1983). Since substrate is an important habitat parameter, any change in substrate results in a change in invertebrate species (Sprules 1947). Any changes in channel configurations and substrate will change the complexity of fish and invertebrate habitat. Stream habitat complexity has been positively correlated with fish species diversity (Gorman and Karr 1978; Schlosser 1982). Thus, the potential for change in channel morphology and substrate below

impoundments is likely to influence the tailwater fishery (Hildebrand 1980; Brooker 1981).

Peaking power flows affect the invertebrates that are the foods of fish. Daily water level changes generally reduce invertebrate production, standing crop and diversity by eliminating the invertebrates (Fisher and LaVoy 1972; Trotzky and Gregory 1974) and their food base (Kroger 1973; Bovee 1975; Ward 1976; Ward and Short 1978). Insects become dislodged and may be destroyed during high flows, as well as being subject to stranding and desiccation during low flows (Powell 1958; Fisher and LaVoy 1972; Kroger 1973; Trotzky and Gregory 1974). However, the benthic community may tolerate brief exposure periods (Fisher and LaVoy 1972). Scouring of the substrate may reduce the numbers of insects by 50 percent (Sprules 1947). The abundance of epilithic algae and higher plants may be reduced by the scouring effects of irregular high flows below hydropower dams (Ward and Short 1978). For example, Kroger (1973) noted that each time an area of streambed was exposed algae and higher plants were destroyed. Until this food base is reestablished, invertebrates will not return in their former numbers (Waters 1964). The lack of clearly defined, permanent pools and riffles, resulting from fluctuating flows, inhibits the survival of most stream insects (Walburg et al. 1981). The insect groups which are generally regarded as quality fish food, including mayflies, stoneflies and caddisflies, are also the groups most affected by fluctuations in flow (Powell 1958; MacPhee and Brusven 1976). The insects that are able to withstand the flow fluctuations are generally smaller (Hildebrand 1980) and are considered to be of marginal food value for fish (Powell 1958; Bauer 1976). Powell (1958) showed that

invertebrate standing crops were consistently less below a Colorado-dam than in the stream above the reservoir. He also showed that the decrease in insects was detrimental to the downstream fishery.

Changes in current velocity resulting from fluctuating flows also influence the distribution and survival of invertebrates (Sprules 1947; Walburg et al. 1981). A change in current velocity may be the initial major influence of a change in discharge from a reservoir (Wright and Szluha 1980). Current velocities may have the greatest influence on the distribution and abundance of invertebrates in a stream (Chutter 1969; Giger 1973). Invertebrate drift has been shown to increase in response to flow reductions (Pearson et al. 1968; Radford and Hartland-Rowe 1971) and flow increases (Elliot 1971; Brusven et al. 1976). This may increase the availability of the invertebrates to fish. Any increase in availability might be regarded as beneficial to a fishery if the standing crop is not radically reduced (Brooker 1981; Walburg et al. 1981). For example, studies by Matter et al. (1981) demonstrated that the surge of water resulting from power generation by a coldwater release hydroelectric dam, may benefit the tailwater fishery by scouring the substrate and making benthic food more available. MacPhee and Brusven (1976) found flow reductions increased insect drift and ingestion by salmon. However, long term increases in drift probably will not occur because of reductions in standing crop. Therefore, the decrease in drift, resulting from a decrease in invertebrate density, would adversely affect diet, growth and behavior of stream fishes (MacPhee and Brusven 1976).

Rapid fluctuations in flow below hydropower dams can cause dramatic temperature changes in the tailwater. The release of large volumes of

cold, hypolimnetic water from bottom-release hydroelectric dams during power generation maintains cold tailwater environments below some southern reservoirs (Walburg et al. 1981). High flows carry tailwater temperatures far downstream (Stanford and Ward 1979). Investigators have shown reductions in warmwater species abundance and diversity resulting from coldwater discharge from hypolimnetic release reservoirs built on warmwater streams (Bendy and Stroud 1949; Brown et al. 1967; Pfitzer 1967; Edwards 1978; Holden 1979; Hoyt and Robison 1980; Eley et al. 1981). Pfitzer (1967) reported reductions of 10 to 15 degrees F along with power generation releases. During non-power generating periods however, the small volume of water being discharged may warm rapidly due to solar radiation and warm air temperatures (Stanford and Ward 1979; Walburg et al. 1981). The rapid changes in temperature may exceed the thermal tolerances of fish and invertebrates. If this is the case, the organisms either move out of the tailwater or die (Walburg et al. 1981). Also, for most fish species, timing of reproduction and sequencing of growth is thermally cued (Stanford and Ward 1979). Temperature changes associated with fluctuating flows may eliminate fish and invertebrate species, disrupt spawning of fish, affect growth rates and reduce abundance and diversity of fish and fish food organisms. Another effect of temperature change is it may mask the influences of flow and other factors on the tailwater biota (Walburg et al. 1981).

Another important influence of hydropower dams, as with any dam, is the potential for changes in water quality due to storage of water in the reservoir. The water quality of the tailwater is dependent upon the water quality within the reservoir at the level of water release (Walburg et

al. 1981). Chemical properties that may affect the tailwater biota are concentrations of dissolved gases such as oxygen and nitrogen, pH, particulate organic matter, nutrient availability, and reduced compounds (Walburg et al. 1981). If the water quality of the discharge is poor, it will stress and may eliminate some tailwater organisms.

The downstream effects of fluctuating flows, temperature and water quality decrease as the distance from the reservoir increases. The distance below a dam necessary for a river to return to a more natural environment is different for every project and depends on the time, volume, depth and water quality of releases (Walburg et al. 1981). Tributary and groundwater inflow, meteorological conditions, pools, riffles, substrate and other influences moderate the effects of the discharge (MacPhee and Brusven 1976; Walburg et al. 1981, 1983). Powell (1958) showed aquatic insects increased at greater distances downstream from a hydropower dam. In studies on several tailwaters, Walburg et al. (1983) found that the return to a more natural flow and temperature regime downstream allowed a greater variety of aquatic insects to colonize the communities. They also noted that warmwater fish species generally were more abundant downstream, than immediately below the dam, in three hydropower tailwaters.

Walburg et al. (1983) also compared the effects of hydropower facilities to those of flood-control projects. They found fish were more abundant in the tailwaters of flood-control dams and a small hydropower facility, than in large hydropower project tailwaters. They also found warm tailwaters had the greatest diversity of fish and invertebrates. They concluded that these differences were a result of differences in flow

regime, water temperature, and depth and volume of the reservoirs. They also found fish distribution below the hydropower dams was apparently related to daily changes in flow, temperature and habitat availability.

There is a paucity of information documenting the effects of peaking power flows on warmwater fish. Most of the literature that deals with hydroelectric facilities describes the influences of temperature reduction, due to coldwater discharges from deep-release dams, on warmwater streams. There is also an abundance of literature pertaining to the effects of flow fluctuations on coldwater fish. There are two principal reasons for the lack of data on the effects of peaking flows on the biota of warm tailwaters. 1) Many warm tailwaters of dams used for purposes other than hydropower, have been found to produce valuable fisheries without management (Fogle and Shields 1961; Pfitzer 1967). 2) Many hydroelectric dams have deep, coldwater releases. Hence the effects of temperature reductions, rather than fluctuating flows, on warmwater systems have been studied. Although little information exists on the influence of peaking power flows on warmwater fish, the effects are probably similar to those found in coldwater systems.

### **CONCLUSIONS**

There are two general types of hydroelectric facilities. Run-of-river operations usually do not change the normal water level fluctuations of a river. Storage hydroelectric facilities which are operated based on power demand, cause rapid and frequent flow fluctuations. These fluctuations have a destructive influence on the tailwater fishery by

creating changes in the physical- characteristics of the stream. Daily fluctuations can disrupt fish spawning, expose egg nests, strand fish, and displace eggs, fry and adults downstream. In addition, habitat quality and quantity is reduced. As a result, fish may experience greater stress which may lead to a decrease in fish production. Relative composition and abundance may change also.

Alternate inundation and exposure of portions of the streambed creates a "zone of fluctuation". This zone is the area most affected by flow fluctuations and little or no production takes place here.

Rapid flow changes increase streambed and bank instability and substrate scouring, resulting in erosion and sedimentation and the flushing away of organic material. Growth of streambank and streambed vegetation is discouraged. The decrease in these food bases stresses the trophic structure of the tailwater. Sedimentation destroys invertebrate habitat and fish spawning habitat. Changes in substrate and channel morphology cause changes in habitat complexity and are likely to influence the fishery also.

Peaking flows can reduce invertebrate production, standing crop and diversity. The insect groups most affected are the ones generally regarded as quality fish food. The decrease in such fish food organisms can be detrimental to the fishery in a hydropower tailwater.

Changes in temperature and water quality are often associated with hydroelectric dams. Rapid temperature changes can occur, which may eliminate fish and invertebrate species, disrupt fish spawning, affect growth of fish, and reduce the abundance of fish and fish food organisms. The water quality of the tailwater is dependent on the water quality in

the reservoir at the depth of water release. If the water quality is poor it will stress and may eliminate some organisms from the tailwater.

The downstream effects of fluctuating flows decrease as the distance from the dam increases. Tributary and groundwater inflow, meteorological conditions and other influences moderate the effects of the discharges. The distance required for a river to return to a more natural environment depends on the time, volume, depth and water quality of the releases.

Little information is available in the literature pertaining to the effects of fluctuating flows on warmwater fish. Most studies related to hydropower facilities have concentrated on the influences on coldwater species and on temperature reductions, caused by deep-release facilities, on warmwater streams. The effects of fluctuating flows on fish in warm hydropower tailwaters are probably similar to the effects found in coldwater systems.

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# THE EFFECTS OF FLUCTUATING FLOWS ON MUSSELS AND AQUATIC INSECTS

## INTRODUCTION

The construction and operation of dams for the control and use of flowing waters has been a part of human civilization for thousands of years. The benefits of this practice such as flood-control, irrigation, increased water supply, and hydroelectric power-generation are obvious. However, only in the latter half of this century has society become aware of the detrimental effects of such water manipulation. Of major importance are the effects of dams on the aquatic environment downstream of impoundments. The downstream biota is impacted through alterations in the abiotic components of the system including the flow regime, sediment load, water temperature, and water quality (Petts 1984). Changes in these factors lead to alterations in channel form, habitat suitability, and primary production, which directly affect invertebrate and fish community stability and function.

The type and magnitude of impacts on the fauna below an impoundment vary with the purpose and operation of the dam. The general effects of dams on the fauna and ecology downstream have been thoroughly reviewed (Baxter 1977; Langford 1983; tfalburg et al. 1981a; Petts 1984). These reviews have dealt mainly with impacts on fish and aquatic insects. This paper will address the potential impacts of hydroelectric power-generation dams on freshwater mussel (Unionidae) populations downstream. There is a paucity of information on the effect of hydroelectric dams on

downstream mussel faunas specifically, but the wealth of knowledge available on the impacts on aquatic insects provides insight into the possible consequences for mussel populations. Being sedentary filter-feeders, mussels are susceptible to many of the same problems experienced by other macroinvertebrates with similar life styles. Due to the lack of specific information on mussels, many of the inferences drawn in this paper will be based on known impacts on other macroinvertebrates.

#### **POTENTIAL IMPACTS ON MUSSELS**

A variety of habitat alterations are associated with hydroelectric power-generation (Walburg et al. 1981b; Petts 1984; Cushman 1985). Of importance to mussels are changes in substrate type and stability. Waters released from hydroelectric dams are often clear and free of sediment due to the settling out of materials within the reservoir. Clear-water discharges coupled with extreme fluctuations in flows may be extremely erosive and cause rapid degradation of the river bed and banks (Baxter 1985). Fine sediments are transported downstream and deposited, thus altering habitats not directly impacted by alterations in flow. Changes in current velocities and substrates, along with increases in suspended solids, can devastate invertebrate populations by interfering with critical life history stages (Lehmkuhl 1979; Petts 1984). The settling out of silts and other fine particles over mussel beds can lead to elimination of mussels through interference of gill functioning and the creation of unsuitable substrates (Fuller 1974). Sickel (1982) cited high silt loads, associated with extreme daily fluctuations in discharge through Barkley

Dam, Kentucky, as a possible contributing factor to poor recruitment of most mussel species below the dam. The erosional forces of increased flows may also damage the shells of mussels and ultimately affect mussel survival.

Scouring of the river bed caused by increased discharge volume and velocity can cause dislodgement and shifting of gravel and other coarse sediments. Since these substrates, in conjunction with moderate current velocities, provide ideal mussel habitat, removal or disturbance of gravels and other bottom materials can result in the destruction of mussel beds (Fuller 1974; Sickel 1982). Scouring may also eliminate aquatic macrophytes, resulting in unstable environments that are unsuitable for habitation by most aquatic invertebrates (Lehmkuhl 1979; Walburg et al. 1981b).

Excessively high current velocities alone may be detrimental to invertebrate populations due to dislodgement of individual organisms (Radford and Hartland-Rowe 1971; Trotzky and Gregory 1974; Matter et al. 1983). Only organisms highly specialized for torrential conditions are able to maintain large populations in waters with high current velocities (Ward 1976). In areas experiencing extreme fluctuations in flows, the fauna may become dominated by those species that can rapidly migrate into the substrate (Petts 1984). Thus, some species of mussels would be subject to dislodgement from the substrate and physical transport downstream. Such conditions could lead to the elimination of affected species from a given stretch of water.

Peaking power flows may subject mussels and other invertebrates to periods of stranding and desiccation. Fisher and LaVoy (1972) observed

that a freshwater "intertidal" zone was created by water level fluctuations below a dam on the Connecticut River. Along a transect from the low to high water mark within this zone, density and diversity of benthic invertebrates decreased markedly. Community composition shifted from mollusc predominance on the least exposed sites to chironomid-oligochaete predominance on the most exposed sites. Much of the change in biomass along the transect was attributed to the intolerance of unionid molluscs to exposure.

Changes in water quality resulting from releases of hypolimnetic waters can have adverse consequences on the benthos of the receiving stream. Lack of a diverse benthic fauna below many impoundments in the Tennessee Valley has been attributed to seasonally low oxygen tensions of hypolimnetic releases (Isom 1971). Relatively high concentrations' of hydrogen sulfide, iron, and manganese associated with anoxic hypolimnial releases have been identified as causes in faunal depletions below some dams (Petts 1984). Conversely, nutrient concentrations may be elevated in hypolimnial releases, and increased calcium/sodium ratios may favor reproductive success and ionic regulation in freshwater molluscs (Petts 1984).

Hydroelectric power-generation has been shown to affect feeding and growth of aquatic invertebrates (Radford and Hartland-Rowe 1971; Lehmkühl 1972; Petts 1984). Deep release dams may not provide an adequate supply of food for development or maintenance of a fauna that is dependent on micro-seson. Mussel growth may be impaired as a result of their remaining closed and not feeding for extended periods in response to high silt loads or poor water quality (Fuller 1974).

Although power-generation releases may substantially impact mussel populations through alteration and degradation of habitat, of possibly far greater importance are their potential consequences to mussel reproduction and recruitment. Nearly all freshwater mussel species use specific fish species as glochidial hosts in order to complete their life cycles (Fuller 1974). Alterations of fish habitat or fish behavior may disrupt these fish/mussel associations. Anthropogenic changes in fish faunas have been identified as one of the major threats to mussel populations (Fuller 1974). Operational procedures of hydroelectric power dams can have significant consequences for downstream fish populations by altering spawning conditions, eliminating prey items, providing flow and depth conditions unsuitable for certain life history stages, and stranding individual fish (Radford and Hartland-Rowe 1971; Lehmkuhl 1979; Walburg et al. 1983; Petts 1984). Thus, fish faunas below hydroelectric dams are often characterized by extirpation of some species, and changes in faunal composition, biomass and diversity. Loss of potential fish hosts can lead to reproductive failure of mussels and may be a causa of poor mussel recruitment below dams producing extreme fluctuations in discharge (Sickel 1982).

Dam operations may impact mussel reproduction in a second way by altering the thermal regime below impoundments. Hypolimnial discharges dampen natural seasonal and diurnal variations in temperature producing depressed summer and elevated winter temperatures (Lehmkuhl 1972; Baxter 1977). Thermal constancy and seasonal temperature patterns below deep-release reservoirs may not provide the thermal stimuli necessary for completion of some invertebrate life cycles (Lehmkuhl 1972; Matter et al.

1983). Temperature is a major determining factor in mussel spawning and subsequent glochidial development and discharge (Yokley 1972; Fuller 1974). Dampening of thermal variations may result in disruption of spawning cycles and/or failure of glochidial release or release under unfavorable conditions. Low temperatures will affect glochidial response to host contacts which may result in lower recruitment rates (Fuller 1974). The loss of mussel populations below Tims Ford Dam and Norris Dam in Tennessee has been attributed to depressed spring and summer water temperatures resulting from hypolimnial releases (Steve Ahlstedt, Tennessee Valley Authority, pers. comm.).

The effects of altered flows on downstream fauna, resulting from hydroelectric power-generation, are related to the pattern of reservoir releases, attributes of the water released, channel morphology, and substrate composition (Petts 1984). Impacts on benthic populations decrease as distance from the dam increases, but faunal depletions have been known to exist for 100 kilometers downstream of hypolimnial release dams (Lehmkuhl 1979). Volume of tributary and groundwater inflow, meteorological influences, and channel morphology help to moderate the effects of discharges and return the environment to a more natural state (Valburg et al. 1983). Downstream response to hydroelectric power-generation will vary according to site characteristics and dam operations, but in general the effect is to produce marked changes in the benthic community through shifts in species diversity and abundance.

## SUMMARY

The operation of hydroelectric dams for peak power generation produces a variety of environmental conditions that can adversely affect the survival and maintenance of freshwater mussel populations downstream. Major fluctuations in discharges can alter suitable mussel habitats by creating unstable substrates, increasing silt loads downstream, and scouring the river bed. Increased stream bank erosion and deposition of associated sediments may destroy existing mussel beds or impair recruitment. Elevated current velocities may eliminate invertebrates not adapted for rapid increases in flows, and cause mussels to be dislodged from the substrate and transported to potentially unsuitable habitats. Peaking power flows may subject mussels to periods of stranding and desiccation, effectively eliminating most species from periodically exposed sites.

Changes in downstream water quality are also associated with hydroelectric dams. Seasonally low dissolved oxygen levels below some dams have led to the elimination of mussels and other invertebrates. Mussel populations may also be adversely affected by relatively high levels of hydrogen sulfide, iron, and manganese associated with anoxic hypolimnial releases. Mussel growth may be inhibited through changes in food supply and feeding behavior in response to altered flow regimes or poor water quality.

A major concern involving mussels and hydroelectric power-generation is the potential impact on mussel reproduction and recruitment through alterations in the fish fauna, fish behavior, and the thermal regime for

spawning. Extirpation or reduction of available fish hosts can severely limit mussel recruitment and ultimately lead to elimination of affected species. Conditions of thermal constancy produced by hypolimnial releases may alter mussel spawning cycles and glochidial release periods. Dulled glochidial response associated with altered thermal regimes may also impair recruitment.

The type and magnitude of environmental impacts realized below a hydroelectric dam will be related to the pattern of reservoir releases, quantity and quality of water released, channel morphology, and substrate composition. Downstream effects decrease with increasing distance from the dam and are moderated by tributary and groundwater inflows, meteorological factors, and channel form. Negative impacts to mussel populations associated with altered flow regimes will vary depending on local conditions, but at least some shifts in-species abundance and diversity can be expected.

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## SUMMARY OF FINDINGS

### TERRESTRIAL HABITATS

Riparian sites in the southern section of the Gorge, Hinton to Meadow Creek, consist primarily of small floodplain forests with sycamore (Platanus occidentalis), river birch (Betula nigra), black willow (Salix nigra), and silver maple (Acer saccharinum) constituting most of the canopy. Much of the floodplain forest has been cleared or altered for farmland, industry, town sites, and homesites.

A few unusual riparian habitat types occur in the southern section of the Gorge including a site dominated by Virginia pine (Pinus virginiana) and quaking aspen, (Populus tremuloides) and a talus slope near the 164 bridge, dominated by eastern hemlock (Tsuga Canadensis) and upland hardwoods. An unusual floral community with several rare plant species occurs on an underlying sandstone ledge on the property of Union Carbide's Brooks Camp. Downstream from Meadow Creek, the river channel begins to narrow, the stream gradient increases, and wide floodplain habitats become sparser. Rock rip-rap habitats predominate, with only a single band of riparian hardwoods separating the river from the upland forest. Wider floodplains are found at the confluences of major tributaries, such as Glade Creek in Raleigh County. The gradient of the river continues to increase throughout the Gorge. Downstream from Thurmond, large talus blocks of sandstone from the cliffs above become the dominant riparian shoreline.

The plant communities along the NRGNR are diverse. In summary, riparian habitats are associated with floodplains in the southern part of the Gorge and steep rocky slopes in the northern part. Several habitats exist on non-flooded terraces between riparian and upland sites. These include farmland and old fields. Upland habitats include mixed hardwoods, tributary stream borders, and pine-dominated ridgetops. A general description of each NRGNR habitat as defined by us, including their dominant overstory and understory vegetative components, are found in Volumn 2 of this report.

#### **WILDLIFE**

Numerous species of songbirds breed and rear young in NRGNR habitats. The effects of flow changes on riparian songbird communities is unclear. High waters during the early summer nesting season might flood low level or ground nests. Heavy flooding scours the herbaceous understory cover of riparian communities and could deplete seed foods and insects on which many songbirds feed.

During summer 1984 and 1985, Canada geese (Branta canadensis), mallards (Anas platyrhynchos), and wood ducks (Aix sponsa) were the most conspicuous waterfowl species in the NRGNR. The waterfowl population on the New River peaked during mid-winter. Censuses were conducted between Bluestone Dan and Sandstone Falls several times each month during January-March 1985. Surveys conducted in northern areas of the Gorge indicated little use by waterfowl.

Concentration sites included the areas directly below Bluestone Dam and directly above Sandstone Falls. These areas are relatively shallow and provide dabbling (puddle) ducks accessibility to invertebrates and aquatic plants. Waterfowl species commonly observed were black ducks (A. rubripes), mallards, wigeon (A. Americana), and gadwall (A. strepera).

Diving ducks utilized the more open, deeper pools in the New River. Common winter species included flocks of goldeneye (Bucephala clangula) and hooded mergansers (Lophodytes cucullatus)

High flows in mid-winter would be detrimental to wintering dabbling duck populations. High flows may scour weed beds and submerge them below the surface and out of reach. Dabbling ducks were observed to congregate in beds of the emergent plant, water willow (Justica sp.), where they find food and cover. High flows scour these emergent weed beds as well. The effects of high flows on diving ducks is not certain, but since high flows and muddy water usually go together, it is probable that high flows would make it more difficult for diving ducks to capture fish and other food items. We identified 12 species of waterfowl in the NRGNR during the winter months.

Wading birds, such as green-backed herons (Butorides striatus) and great blue herons (Ardea herodias) utilized river banks for feeding and cover during the summer months.

Shorebirds, including spotted sandpipers (Actitus macularia) and killdeer (Charadrius vociferous) were frequently observed foraging along the muddy banks of the river.

Six species of hawks, 2 species of vultures, 3 species of owls, plus osprey (Pandion haliaetus) and golden eagle (Aquila chrysaetos) were observed at least once during the 2 year study period.

The occurrence of mammals in various habitats was determined by trapping, track and scat surveys, scent station visits, and sightings. During track surveys we observed tracks of 12 terrestrial mammalian species at 26 different sampled locations. Four species of squirrels were identified in the NRGNR during the study, and each inhabited a different habitat.

Aquatic furbearing mammals inhabiting the NRGNR include beaver (Castor Canadensis), muskrat (Ondatra zibethica), and mink (Mustela vison). All three species are common throughout.

In 1984 we only captured 2 species of small mammals in riparian habitats, while we captured 11 species in upland habitats. It is likely that with regular flooding, few small mammal species are able to quickly recolonize riparian habitats. A total of 3 species of mice, 3 species of voles, 4 species of shrews, 2 species of moles, plus the eastern woodrat (Neotoma floridana), eastern chipmunk (Tamias striatus), and eastern pipistrel bat (Pipistrellus subflavus) include all small mammals identified in the NRGNR during this study.

Few salamanders were found in riparian habitats and probably do not colonize sites that are frequently flooded. The greatest numbers and diversity of salamanders were found in the tributary streams. During this survey, we identified 15 species of salamanders, 9 species of frogs and toads, 10 species of snakes, 2 species of lizards, and 6 species of turtles. An in-depth population study of one turtle, the river cooter

(Pseudemys concinna) was conducted and the results were submitted to the National Park Service, separate from this report.

Table 1. List of vertebrate species identified during a biological survey of the New River Gorge National River, 1984-85.

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Gavia immer Common Loon

Fulica americana American Coot

Podilymbus podiceps Pied-billed Grebe

Podiceps auritus Horned Grebe

Phalacrocorax auritus Double-crested Cormorant

Ardea herodias Great Blue Heron

Butorides striatus Green-backed Heron

Cygnus olor Mute Swan

Branta canadensis Canada Goose

Aix sponsa Wood Duck

Anas rubripes Black Duck

Anas platyrhynchos Mallard

Anas strepera Gadwall

Anas americana American Widgeon

Aythya affinis Lesser Scaup

Bucephala clangula Common Goldeneye

Lophodytes cucullatus Hooded Merganser

Mergus merganser Common merganser

Mergus serrator Red-breasted Merganser

Oxyura jamaicensis Ruddy Duck

Coragyps atratus Black Vulture

Cathartes aura Turkey Vulture

Pandion haliaetus Osprey

Accipiter striatus Sharp-shinned Hawk

Accipiter cooperii Cooper's Hawk

Buteo lineatus Red-shouldered Hawk

Buteo platypterus Broad-winged Hawk

Buteo jamaicensis Red-tailed Hawk

Aquila chrysaetos Golden Eagle

Bonasa umbellus Ruffed Grouse

Meleagris gallopavo Wild Turkey

Charadrius vociferus Killdeer

Tringa flavipes Lesser Yellowlegs

Actitis macularia Spotted Sandpiper

Scolopax minor American Woodcock

Larus delawarensis Ring-billed Gull

Sterna hirundo Common Tern

Columba livia Rock Dove

Zenaida macroura Mourning Dove

Coccyzus americanus Yellow-billed Cuckoo

Otus asio Eastern Screech-Owl

Bubo virginianus Great Horned Owl

Strix varia. Barred Owl

Chordeiles minor Common Nighthawk

Chaetura pelagica Chimney Swift

Archilochus colubris Ruby-throated Hummingbird

Ceryle alcyon Belted Kingfisher

Melanerpes carolinus Red-bellied Woodpecker

Sphyrapicus varius Yellow-bellied Sapsucker

Picoides pubescens Downy Woodpecker

Picoides villosus Hairy Woodpecker

Colaptes auratus Northern Flicker

Dryocopus pileatus Pileated Woodpecker

Contopus virens Eastern Wood-Pewee

Empidonax virescens Acadian Flycatcher

Empidonax traillii Willow Flycatcher

Empidonax minimus Least Flycatcher

Sayornis phoebe Eastern Phoebe

Myiarchus crinitus Great Crested Flycatcher

Tyrannus tyrannus Eastern Kingbird

Tachycineta bicolor Tree Swallow

Stelaidopteryx serripennis No

Hirundo pyrrhonota Cliff Swallow

Hirundo rustica Barn Swallow

Cyanocitta cristata Blue Jay

Corvus brachyrhynchoa American Crow

Parus atricapillus Black-capped Chickadee

Parus carolinensis Carolina Chickadee

Parus bicolor Tufted Titmouse

Sitta canadensis Red-breasted Nuthatch

Sitta carolinensis White-breasted Nuthatch

Certhia americana Brown Creeper

Thryothorus ludovicianus Carolina Wren

Troglodytes troglodytes Winter Wren

Regulus satrapa Golden-crowned Kinglet

Regulus callendula Ruby-crowned Kinglet

Polioptila caerulea Blue-gray Gnatcatcher

Sialia sialis Eastern Bluebird  
Catharus fuscescens Veery  
Catharus ustulatus Swainson's Thrush  
Hylocichla mustelina Wood Thrush  
Turdus micratorius American Robin

Dumetella carolinensis Gray Catbird  
Mimus polyglottos Northern Mockingbird  
Toxostoma rufum Brown Thrasher

Bombycilla cedrorum Cedar Waxwing

Sturnus vulgaris European Starling  
Vireo ariseus White-eyed Vireo  
Vireo solitarius Solitary Vireo  
Vireo flavifrons Yellow-throated Vireo  
Vireo ailvus Warbling Vireo  
Vireo olivaceus Red-eyed Vireo

Parula americana Northern Parula Warbler  
Dendroica petechia Yellow Warbler  
Dendroica pennsylvanica Chestnut-sided Warbler  
Dendroica caerulescens Black-throated Blue Warbler  
Dendroica coronata Yellow-rumped Warbler  
Dendroica virens. Black-throated Green Warbler  
Dendroica fusea Blackburnian Warbler  
Dendroica dominica Yellow-throated Warbler  
Dendroica pinus Pine Warbler  
Dendroica castanea Bay-breasted Warbler  
Dendroica striata Blackpoll Warbler  
Dendroica cerulea Cerulean Warbler  
Mniotilta varia Black-and-white Warbler  
Setophaga ruticilla American Redstart  
Helmitheros vermivorus Worm-eating Warbler  
Seiurus aurocapillus Ovenbird  
Seiurus motacilla, Louisiana Waterthrush  
Oporornis formosus Kentucky Warbler  
Geothlypis trichas Common Yellowthroat  
Wilsonia citrina Hooded Warbler  
Icteria virens Yellow-breasted Chat

Piranga rubra Summer Tanager  
Piranga olivacea Scarlet Tanager

Spizella passerina Chipping Sparrow  
Spizella pusilla Field Sparrow  
Passerella iliaca Fox Sparrow  
Melospiza melodia Song Sparrow  
Zonotrichia albicollis White-throated Sparrow

Agelaius phoeniceus Red-winged Blackbird  
Sturnella magna Eastern Meadowlark  
Ouiscalus quiscalus Common Crackle

Molothrus ater Brown-headed Cowbird

Icterus spurius Orchard Oriole

Icterus galbula Northern Oriole

Passer domesticus House Sparrow

Spiza americana Dickcissel

Junco hyemalis Dark-eyed Junco

Cardinalis cardinalis Northern Cardinal

Carpodacus mexicanus House Finch

Hesperiphona vespertina Evening grosbeak

Carduelis tristis American Goldfinch

Passerina cyanea Indigo Bunting

Pheucticus ludovicianus Rose-breasted Grosbeak

Pipilo erythrophthalmus Rufous-sided Towhee

Napeozapus insignis Woodland jumping mouse

Peromyscus maniculatus Deer mouse

Mus musculus House mouse

Cleithromys gapperi Red-backed vole

Pitymys pinetorum Pine vole

Microtus pennsylvanicus Meadow vole

Blarina brevicauda Shorttail shrew

Sorex fumeus Smoky shrew

Sorex cinereus Masked shrew

Sorex dispar Long-tail shrew

Neotoma floridana Eastern woodrat

Parascalops breweri Hairy-tailed mole

Scalopus aquaticus Eastern mole

Pipistrellus subflavus Eastern pipistrel bat

Tamias striatus Eastern chipmunk

Sciurus niaer Eastern fox squirrel

Sciurus carolinensis Eastern gray squirrel

Tamiasciurus hudsonicus Red squirrel

Glaucomys volans Southern flying squirrel

Marmota monax Woodchuck

Sylvilacais floridanus Eastern cottontail rabbit

Didelphis marsupialis Opossum

Procyon lotor Raccoon

Mephitis mephitis Striped skunk

Mustela sp. Weasel

Mustela visor Mink

Castor canadensis Beaver

Ondatra gibethica Muskrat

Felis domestica House cat

Urocyon cinereoargenteus Gray fox  
Vulpes fulva Red fox  
Canis famlliaris Dog  
Ursus americanus Black bear  
Odocoileus virginianus White-tail deer

Rana palustris Pickerel frog  
Rana catesbeiana Bullfrog  
Rana clamitans Green frog  
Rana sylvatica Wood frog  
Hyla sp. Gray treefrog  
Hyla crucifer Spring peeper  
Pseudacrjs brachyphona Mountain chorus frog  
Bufo americanus American toad  
Bufo fowleri Fowlers toad

Notophthalinus viridescens Red-spotted newt  
Plethodon glutinosus Slimy salamander  
Plethodon cinereus cinereus Red-backed salamander  
Aneides aneus Green salamander  
Eurycea bislineata bislineata Northern two-lined salamander  
Eurvcea longicauda Long-tailed salamander  
Ambystoma maculatum Spotted salamander  
Ambystoma jeffersonianum Jefferson's salamander  
Desmognathus fuscus fuscus Northern dusky salamander  
Desmognathus ochrophaeus Mountain dusky salamander  
Desmognathus guardamaculatus Black-bellied salamander  
Desmognathus monticola Seal salamander  
Gvrinophilus porphyriticus Spring salamander  
Pseudotriton ruber ruber Northern red salamander  
Necturus maculosus Mudpuppy

Diadophis punctatus edwardsi Northern ringneck snake  
Storeia occipitomaculata Red-bellied snake  
Thamnophis sirtalis sirtalis Eastern garter snake  
Opheodrys aestivus Rough green snake  
Lampropeltis triangulum triangulum Eastern milk snake  
Elaphe obsoleta obsoleta Black rat snake  
Coluber constrictor Northern black racer  
Nerodia sipedon sipedon Northern water snake  
Regina septemvittata Queen snake  
Agkistrodon contortrix mokasen Northern copperhead

Eumeces fasciatus Five-lined skink  
Sceloporus undulatus Northern fence lizard

Terrapene carolina carolina Eastern box turtle  
Chrysemys picta x marginata Painted turtle  
Sternotherus odoratus Common musk turtle  
Chelydra serpentina Snapping turtle  
Pseudemys concinna Eastern river cooter  
Graptemvs geographica Common map turtle

## HABITAT USE BY FISHES

1. A total of 4,939 fish representing 32 species was collected with electrofishing gear in 1984 (Table 2). No major differences were observed in species composition between the 3 major sections of the river.
2. Analysis of counts of fish, conducted with the use of SCUBA and snorkeling equipment, indicated that fish densities among the dominant habitats (edge pool, middle pool, riffle, and run), were significantly different. Fish densities in edge pool and riffle habitats were comparable, but densities in edge pool habitat were significantly higher than densities in middle pool and run habitats. Densities of fish in riffles were significantly higher than those in middle pool habitat, but were similar to those in run habitat. Snag and edge riffle habitats supported the highest densities of fish. All sizes of centrarchids found in the New River were seen using snag habitat.
3. Canonical correlation of the fish densities and four habitat variables (depth, velocity, amount of vegetation, and amount of cobble-boulder substrate), showed that velocity and vegetation amount were most strongly correlated with fish densities.
4. Fish species-lifestage composition and densities differed among the habitat types. Five habitat-use guilds (edge-pool, middle-pool,

edge-channel, riffle, and generalists) were described for fishes of the New River and compared to guilds proposed by other researchers. Larger centrarchids preferred slower velocity, deep habitats (deep edge and middle pool, and snags) while the young centrarchids preferred shallower habitat. However, all ages of smallmouth bass were nearly ubiquitous in the habitats of the study area. The cyprinids and percids preferred shallow areas, but preferences for velocity differed among the species-lifestages. Forage species and young of the predator species preferred shallow areas, while large predators preferred deeper habitats. Predation risk and food availability are believed to contribute to the spatial segregation among New River fishes.

5. At nighttime, edge pool habitat had the highest fish densities, and middle pool and riffle areas had similar densities. Habitat-use and activity shifts between daytime and nighttime were found for many species-lifestages.
  
6. The habitats with the greatest number of fish are also the areas most susceptible to the dramatic, daily flow fluctuations associated with hydropower generation. The potential effects of flow fluctuation associated with the proposed conversion of Bluestone Dam to hydro electric operation depend on the magnitude and frequency of flow fluctuations.

7. Measurements of spawning areas and mound nests of the endemic bigmouth chub (Nocomis platvrhynchus) indicate that bigmouth chubs have narrow habitat requirements for spawning. Areas with plenty of small to large gravel (3-64 mm diameter), for mound construction, shallow depths, and moderate velocity are needed. The location of spawning mounds in shallow riffle and run areas near the bank makes these nests especially vulnerable to flow fluctuations.
  
8. Midday underwater observations of 199 bigmouth chubs (>100 mm) were made in September, 1985, and 75 microhabitat utilization measurements were taken. Small (100-150 mm) and large (>150 mm) bigmouth chubs had similar microhabitat use patterns. Bigmouth chubs were only seen using riffle and adjacent run habitat. Within utilized areas, habitat variables (depth, velocity, substrate, and cover) were used in accordance with their availability except for an avoidance of the shallowest available depths.
  
9. Bigmouth chubs occupied positions near the substrate, where velocities were slower than the mean water column velocity. This is probably a feeding strategy that allows the bigmouth chub to minimize energy expenditure and maximize exposure to drifting food items.
  
10. Because of its narrow habitat preferences, the bigmouth chub is potentially susceptible to the impacts of frequent, rapid fluctuations in flow associated with hydroelectric facilities. The potential affects of flow fluctuations from the proposed conversion of Bluestone

Dam on bigmouth chub populations include dewatering spawning mounds' and disruption of food sources. Other cyprinids that also spawn in the mounds built by bigmouth chubs may be affected by flow fluctuations. However, the data obtained were obtained during spring and summer and are difficult to extrapolate to the proposed winter flow fluctuations.

Table 2. Number and percent of total of each species collected with electrofishing equipment at 100 stations (daytime and nighttime) in the New River, West Virginia, between Hinton and Ephraim Creek, July to October, 1984.

SPECIES	COMMON NAME	SECTION 1		SECTION 2		SECTION 3		ALL SECTIONS	
		NUMBER	PERCENT	NUMBER	PERCENT	NUMBER	PERCENT	NUMBER	PERCENT
<i>Notropis volucellus</i>	mimic shiner	33	2.0	915	46.6	117	8.9	1065	21.6
<i>Micropterus dolomieu</i>	smallmouth bass	322	19.4	231	11.8	304	23.1	857	17.4
<i>Ambloplites rupestris</i>	rock bass	341	20.6	110	5.4	68	5.2	519	10.5
<i>Notropis telescopus</i>	telescope shiner	140	8.4	177	9.0	195	14.8	512	10.4
<i>Notropis (Luxilus) spp.</i> <sup>1</sup>	striped and white shiner	193	11.6	128	6.5	110	8.4	431	8.7
<i>Pimephales notatus</i>	bluntnose minnow	104	6.3	108	5.5	102	7.8	314	6.4
<i>Noemius platyrhynchus</i>	bigmouth chub	97	5.8	38	1.9	92	7.0	227	4.6
Unidentified <i>Notropis</i> spp.	shiners	181	10.9	6	0.3	1	0.1	188	3.8
<i>Hypentelium nigricans</i>	northern hog sucker	35	2.1	44	2.2	75	5.7	154	3.1
<i>Notropis spilopterus</i>	spotfin shiner	32	1.9	42	2.1	33	2.5	107	2.2
<i>Camptostoma anostomus</i>	stoneroller	46	2.8	12	0.6	40	3.0	98	2.0
<i>Micropterus punctulatus</i>	spotted bass	12	0.7	29	1.5	23	1.7	64	1.3
<i>Notropis rubellus</i>	rosyface shiner	1	0.1	27	1.4	30	2.3	58	1.2
<i>Lepomis macrochirus</i>	bluegill sunfish	25	1.5	9	0.5	12	0.9	46	0.9
<i>Percina roanoka</i>	Roanoke darter	18	1.1	10	0.5	18	1.4	46	0.9
<i>Pylodictis olivaris</i>	flathead catfish	16	1.0	10	0.5	17	1.3	43	0.9
<i>Etheostoma blennioides</i>	greenside darter	6	0.4	9	0.5	20	1.5	35	0.7
<i>Percina caprodes</i>	logperch	13	0.8	6	0.3	8	0.6	27	0.5
<i>Percina oxyrhyncha</i>	sharpnose darter	3	0.2	7	0.4	17	1.3	27	0.5
<i>Notropis hudsonius</i>	spottail shiner	5	0.3	20	1.0			25	0.5
<i>Etheostoma caeruleum</i>	rainbow darter	9	0.5	6	0.3	3	0.2	18	0.4
<i>Lepomis auritus</i>	redbreast sunfish	8	0.5	4	0.2	1	0.1	13	0.3
<i>Labidesthes sicculus</i>	brook silverside	1	0.1	7	0.4	3	0.2	11	0.2
<i>Lepomis gibbosus</i>	pumpkinseed sunfish	3	0.2			8	0.6	11	0.2
<i>Notropis photogenis</i>	silver shiner	5	0.3	2	0.1	3	0.2	10	0.2
<i>Rhinichthys cataractae</i>	longnose dace	3	0.2			6	0.5	9	0.2
Unidentified darter	darter			3	0.2	2	0.2	5	0.1
<i>Ictalurus punctatus</i>	channel catfish					4	0.3	4	0.1
<i>Pomoxis annularis</i>	white crappie	3	0.2	1	0.1			4	0.1
<i>Cyprinus carpio</i>	common carp	3	0.2					3	0.1
<i>Lepomis megalotis</i>	longear sunfish			3	0.2			3	0.1
<i>Lepomis cyanellus</i>	green sunfish					2	0.2	2	0.0
<i>Morone chrysops</i> X <i>axatilis</i>	hybrid whiteXstriped bass					1	0.1	1	0.0
<i>Micropterus salmoides</i>	largemouth bass	1	0.1					1	0.0
Unidentified <i>Lepomis</i> spp.	sunfish					1	0.1	1	0.0
<b>Totals</b>		<b>1659</b>	<b>100</b>	<b>1964</b>	<b>100</b>	<b>1316</b>	<b>100</b>	<b>4939</b>	<b>100</b>

<sup>1</sup> This subgenus includes striped shiner (*Notropis chryscephalus*) and white shiner (*Notropis albeolus*).

### FRESHWATER MUSSELS

The float survey for freshwater mussels in the NRGNR located dense mussel assemblages throughout most of this river reach, to include 7 living species and valves of an eighth species. No live mussels were found downstream of the large pool at Sewell. The mucket (Actinonaias carinata) was the dominant species within the Park, occurring at all sites with mussels and comprising over 90% of the mussel assemblage. Two other species, the purple wartyback (Cyclonaias tuberculata) and spike (Elliptio dilatata) were present in all major mussel beds and accounted for roughly 4% and 2% of the mussel fauna, respectively. The buckhorn (Tritogonia verrucosa) was relatively common upstream of Sandstone Falls, but was not collected further downstream; it constituted less than 1% of the fauna. The three other species; pocketbook (Lampsilis ovata), wavy-rayed lampmussel (Lampsilis fasciola), and elktoe (Alasmidonta marginata) were collected infrequently and are uncommon throughout the river reach downstream of Bluestone Dam. No live specimens or relic valves of any federally endangered species were collected during this survey.

Mussels reside in all reaches of the NRGNR from Hinton downstream to Sewell. Most large mussel beds occur in the upper third of the Park, and their frequency of occurrence declines dramatically downstream of Glade Creek. Quantification of mussel densities via snorkeling transects indicated that most mussel beds have 2.5 to 13.7 mussels/m<sup>2</sup>. No discernible pattern of mussel densities was observed, although differences in species composition were readily apparent. All beds have substrates

consisting predominantly of gravel and cobble, usually interspersed with small boulders. Mean current velocities over beds range from 0.03 to 0.56 m/s. Higher velocities occur over beds associated with islands, where water is diverted through relatively narrow channels. These channels typically contain dense mussel beds. Many beds are associated with aquatic macrophytes, especially water star-grass (Heteranthera dubia).

Although mussel beds occur throughout much of the Park, most of them occupy the upper third of this river reach and several are of particular value. A small bed, between two islands above Brooks Branch, supports all 7 mussel species and harbors the highest densities of elktoes, wavy-rayed lampmussels, and pocketbooks in the Park. Another mussel bed at the lower end of Brooks Island also contains all 7 species. Three of the largest and most densely populated beds occur below the old railroad trestle at Glade, above the mouth of Piney Creek, and below the Interstate-64 bridge- This latter site was impacted by I-64 construction, primarily from siltation and heavy road-building equipment driven across the river bed. The sheer size and abundance of mussels in these large beds provide strongholds for successive reproduction of all 7 species and an important source of juveniles for downstream colonization. Because of their significance to the overall stability and diversity of the mussel resource in the NRGNR, their protection and monitoring are of particular importance.

For more detailed information about this biological survey of the New River Gorge National River, see Volumes 2, 3, and 4.

## ANNOTATED BIBLIOGRAPHY

### Biota of the New-Kanawha River

Addair, J. 1944. Fishes of the Kanawha River system and some factors which influence their distribution. Ph.D. Dissertation, Ohio State University, Columbus, Ohio. 224 pp.

Between 1933 and 1944, fishes were seined at 166 stations located on tributaries and the main channel of the New River from the Virginia border (RM 190) to the Ohio River. A map and a brief description is presented for each of the 86 species of fish (17 families) identified from the collections. Thirty species representing five families were captured in the New River Gorge: Catostomidae (2 species), Cyprinidae (14), Ictaluridae (2), Percidae (5) and Centrarchidae (7). A brief description of the geology of the New River and its tributaries was included. In addition, artificial keys were constructed for the families as well as genera, species and subspecies of all fishes collected. Almost no collection methodology or collection site descriptions were given, other than general locations on distribution maps. The taxonomy is outdated, and sampling bias (seining only) probably under-represented species inhabiting riffle habitats.

Amrine, J. tf. Jr. 1982. The New River connection to the black fly problem in southern West Virginia I. New River Symposium 1:36-56.

Extensive collections were carried out over a four year period from 1977 to 1981 to determine the distribution, densities, habitat preference, and adult production of the blackfly, *Simulium Jenningsi*. During the study, 11,743 blackflies were captured; all but 21 of which were *S. jenningsi*. The primary breeding area for the blackflies was found to be an 11 km section of the New River from Hinton to Meadow Creek, approximately the upper 20% of the New River Gorge. Calculations based on high densities of pupae found among *Podostemum* beds indicated a daily production of  $5.25 \times 10^5$  blackflies along the 11 km study section, from May through October. The high densities of *S. Jenningsi* were attributed to optimal flows and relatively pristine waters present in the upper Gorge area. Control recommendations centered on application of *Bacillus thuringiensis* S14, a larvicide that affects only nematoceros dipterans (mosquitos, blackflies, and some midges). Three applications of BTS14 at monthly intervals from April to June were recommended at an estimated cost of \$9,000, producing a significant reduction in blackfly densities for 4-5 years.

Bates, J.M. 1979. Mussel Investigations, State of West Virginia. W. Va. Project 3-97-R. 91 pp.

From June 1969 through June 1971, mussels were collected in the Ohio River and tributary streams in West Virginia using numerous collection techniques. Four sites on the Gauley River and two sites on the New River (one below Bluestone Dam, one below Kanawha Falls) were included in the survey. A list of all mussels collected in West Virginia is presented, as well as distributions and pictures (poor quality) of each species (six in New River).

Bryson, W. T., R. T. Lackey, J. Cairns, Jr., and K. L. Dickson. 1975. Restocking after fishkills as a fisheries management strategy. Transactions of the American Fisheries Society 104: 256-263

Research showed stocking the New River near Narrows, Virginia with channel catfish (*Ictalurus punctatus*), following a partial fishkill caused by treated industrial waste, to be unsuccessful and of no measurable benefit to the fishery. Only an estimated 50 of 3,000 catfish stocked were recovered by anglers. Factors contributing to the failure of the restocking program probably included the considerable amount of time between the fishkill and restocking (16 months), and the relatively small size of the stocked fish.

Burt, W.H. , and R.P. Grossenheider. 1976. A field guide to the Mammals of America north of Mexico. Houghton Mifflin Co. , Boston.

Range maps for all mammal species were studied and those species that were listed as potentially present in the Gorge are listed below.

SHREWS: masked *Sorex cinereus*. smoky *S. fumeus*, southeastern *S. longirostris*, longtail *S. dispar*, n. water *S. palustris*. pygmy *Microsorex hoyi*, least *Cryptotis parva*. shorttail *Blarina brevicauda*.

MOLES: starnose *Condylura cristata*, eastern *Scalopus aquaticus*.

BATS: keen myotis *Myotis keeni*, little brown myotis *M. lucifungus*, Indiana myotis *M. sodalis*, small footed myotis *M. subulatus*, silver-haired bat *Lasiurus noctivagus*, eastern pipistrel *Pipistrellus subflavus*, red *Lasiurus borealis*, big brown *Eptesicus fuscus*, hoary *Lasiurus cinereus*, western big-eared *Plecotus townsendii*, eastern big-eared *P. rafinesquii*.

MICE: eastern harvest *Reithrodontomys humulis*, white-footed *Peromyscus leucopus*, deer *P. maniculatus*, golden *P. nuttalli*??, e. woodrat *Neotoma floridana*, rice rat *Oryzomys palustris*??, meadow jumping *Zapus hudsonius*, woodland jumping *Napaeozaous ins ignis*.

LEMMING: s. bog lemming *Synaptomys cooperi*.

VOLES: boreal redback *Clethrionomys gapperi*, meadow *Microtus pennsylvanicus*, yellownose *M. chrotorrhinus*, pine *pitymys pinetorum*.

RABBITS: snowshoe hare *Lepus americanus*. e. cottontail *Sylvilagus floridanus*, New England cottontail *S. transitionalis*.

WOODCHUCK, CHIPMUNK, AND SQUIRRELS: woodchuck *Marmota monax*. e. chipmunk *Tamias striatus*, e. gray *Sciurus carolinensis*, e. fox *S. niger*. red *Tamiasciurus hudsonicus*. n. flying *Glaucomys sabrinus*. s. flying *G. volans*.

FURBEARERS: least weasel *Mustela rixosa*. longtail weasel *M. frenata*, mink *M. vison*. river otter *Lutra canadensis*. beaver *Castor Canadensis*, muskrat *Ondatra zibethica*. spotted skunk *Spilogale pitorius*, striped skunk *Mephitis mephitis*, raccoon *Procyon lotor*. black bear *Ursus americanus*, coyote *Canis latrans*?. red fox *Vulpes fulva*. gray fox *Urocyon cinereoargenteus*. bobcat *Lynx rufus*. whitetail deer *Odocoileus virginianus*.

Cairns, J. Jr. and K. L. Dickson. 1973. The effects of waste discharges from Radford Army Ammunition Plant on the biota of the New River, Virginia. VPI&SU Water Resources Research Center Bull 57: 1-57.

This bulletin outlines the effects of discharges of acid, organic solvents, heat, nitrogenous wastes, and ash from the Radford Army Ammunition Plant (RAAP) on the abundance and taxonomic composition of benthic invertebrates (identified to genus), macrophytes (to species), algae (to genus, some to species), and fishes (to species) in the New River. Waste discharges appeared to have little effect on the invertebrate assemblage, although collection techniques (kick netting) were minimally quantitative. The most severe damage resulted from impacts of nitrogen below a TNT landfill, which resulted in reductions in the number of genera and total number of organisms by 30 and 46%, respectively. Impacts on aquatic macrophytes included decreases in number and biomass near discharge points, and increases in biomass at downstream stations presumably due to nutrient enrichment. Impacts on algal populations were localized, and effluents appeared primarily to reduce the number of fish species present

near discharge points. Overall, RAAP waste discharges had minimal impacts on the flora and fauna of the river as a whole, but apparently toxic effects on biota directly downstream of oleum (fish and macrophytes affected) and ash (algae affected) discharges.

Cherry, D. S. , J. Cairns, Jr. , and R. L. Graney. 1980. Asiatic clam invasion causes and effects. *Water Spectrum*. Fall 1980: 19-24.

The article describes the invasion of the Asiatic clam, *Corbicula fluminea*, and its spread across the United States (range map given). Reference is made to the invasion of the New River by the Asiatic clam and how thermal discharge from the Glen Lyn Power Plant has affected the distribution of this species. Also discussed are economic problems associated with *Corbicula*, as well as difficulties in controlling these problems. Possible uses of *Corbicula* are mentioned including use as a source of protein and calcium, human food and as a biological indicator of pollution.

Cherry, D. S. , R. , C. Hoehn, S. S. Waldo, D. H. Willis, J. Cairns, Jr., and K. L. , Dickson. 1977. Field-laboratory determined avoidances of the spotfin shiner and the bluntnose minnow to chlorinated discharges. *Water Resources Bulletin* 13(5):1047-1055.

The responses of the spotfin shiner (*Notropis spilopterus*) and the bluntnose minnow (*Pimephales notatus*) to intermittent chlorine discharges from the Glen Lyn fossil fuel power plant in the New River were investigated by seine collections in the discharge channel and in a field laboratory. No fish were captured during chlorination periods when Total and Free chlorine residuals were 0.46 and 2.7 mg/l, respectively. The spotfin shiner was less sensitive than the bluntnose minnow. It appears these species have adapted to the discharges by active avoidance behavior.

Clark, A. H. 1982. Survey of the freshwater mussels of the upper Kanawha River (RM91-95), Fayette County, West Virginia, with special reference to *Epioblasma torulosa torulosa* (Rafinesque) and *Lampsilis abrupta* (Say) (*Lampsilis orbiculata* (Hildreth), of authors). Final Report, USFWS 50181-0546-2. 104 pp.

Detailed surveys in September 1982 were carried out from RM 91 to 95 using hand collections, searches of muskrat middens, a crowfoot dredge, and SCUBA gear. Over 1000 specimens of 23 species of unionids were collected, including the endangered *Lampsilis abrupta* (estimated population size 1000). The report includes discussions of the taxonomy, morphology, and distribution of endangered mussels in the area, maps of collecting sites and species distributions, detailed copies of data sheets contain-

ing locations and descriptions of the collecting sites, and a list of live or dead specimens of each species captured at each site.

Clarkson, R.B., O.K. Evans, R. Fortney, W. Grafton and L. Rader. 1981. Rare and endangered vascular plant species in West Virginia. U.S. Govt. Printing Office: 1981-701-547-82. 76 pp.

The authors compiled all reports involving collections of rare flora in West Virginia. Data for each species included common and scientific name, habitat, collection site (county) and abbreviated comments on vulnerability to extirpation, range and abundance. Eighty-eight rare species representing 38 families were identified from the three counties that contain the New River Gorge: 65 in Fayette, 21 in Raleigh and 20 in Summers. No detailed collection records were given.

Conant, R. 1975. A field guide to the reptiles and amphibians of central and eastern North America. Houghton Mifflin Co. , Boston.

The field guide contains general range maps for all of the herbs found in the eastern United States. Those species whose ranges include the New River Gorge, West Virginian are listed below. Those species whose ranges may or may not include the Gorge are followed by question marks

TURTLES: snapping *Chelydra serpentina*, musk *Sternotherus odoratus*, map *Graptemys geographica*??, painted *Chrysemys p. picta* and *p. marginata*, box *Terrapene carolina*, cooter *Chrysemys floridana*, spiny softshell *Trionyx spiniferus*.

LIZARDS: n. fence *Sceloporus undulatus*. five-lined skink *Eumeces fasciatus*, broad-headed skink *E. laticeps*, n. coal skink *E. anthracinus*.

SNAKES: n. water *Natrix sipedon*. queen *N. septemyittata*, e. garter *Thamnophis sirtalis*, e. ribbon *T. sauritus*. n. red-bellied *Storeria occipitomaculata*, n. brown *Storeria dekayi*, e. hognose *Heterodon platyrhinos*, e. worm *Carphophis amoenus*. n. ringneck *Diadophis punctatus*. smooth green *Opheodrys vernalis*?. rough green *O. aestivus*?. n. black racer *Coluber constrictor*, n. pine *Pituophis melanoleucus*?. black rat *Elaphe obsoleta*, corn *E. guttata*?. e. milk *Lampropeltis triangulum*, copperhead *Agkistrodon contortrix*, timber rattler *Crotalus horridus*.

SALAMANDERS: hellbender *Cryptobranchus alleganiensis*, mudpuppy *Necturus maculosus*, red-spotted newt *Notophthalmus viridescens*, Jefferson *Ambystoma jeffersonianum*, spotted *A. maculatum*, marbled *A. opacum*, mountain dusky *Desmognathus ochrophaeus*, n. dusky *D. fuscus*, black-bellied *D. quadramaculatus*, Appalachian seal *D. monticola*, green *Aneides aeneus*, n. spring *Gyrinophilus porphyriticus*, n. red *Pseudotriton ruber*, midland mud *P. montanus*??, slimy *Plethodon glutinosus*<sub>f</sub> ravine *P. richmondi*??, valley and ridge *P. hoffmani*?. Wehrle's *P. wehrlei*. red-backed *P. cinereus*, four-toed *Hemidactylium scutatum* n. two-lined *Eurycea bislineata*, cave *E. lucifuga*, long-tailed *E. longicauda*.

FROGS AND TOADS: a. spadefoot toad *Scaphiopus holbrooki*. American toad *Bufo americanus*. Fowler's toad *B. woodhousei*<sub>f</sub> spring peeper *Hyla crucifer*<sub>f</sub> gray tree *H. versicolor*. upland chorus *Pseudacris triseriata*. mountain chorus *P. brachyphona*. cricket *Acyis crepitans*?. bullfrog *Rana catesbeiana*. green *R. clamitans*, pickerel *R. palustris*. wood *R. sylvatica*.

Dickson, K. L., J. Cairns, Jr., D. S. Cherry, and J. R. Stauffer. 1976. An analysis of the applicability of EPA's draft water-temperature criteria: a site-specific case-history evaluation. Pages 316-326 in G. W. Esch and F. W. McFarlane, eds. , Thermal ecology II, ERDA Symp. Ser. 40 (Conf-750425).

The applicability of the EPA's draft water-temperature criteria in evaluating the impact of thermal discharges from Appalachian Power Company's Glen Lyn Power Plant on the New River in Virginia is analyzed. It was not possible to make a realistic impact assessment using the criteria. Field data on the aquatic community and on fish preference and avoidance temperatures proved more useful in evaluating the impact of the thermal discharge. Impacts of heat discharges on seven species, using the draft water-temperature criteria, are given.

Dillon, R.J. Jr. 1977. Factors in the distributional ecology of upper New River molluscs (Virginia-North Carolina). Honors Thesis, Biol. Dept. , VPI&SU. 59 pp.

Distributional data are presented for six species of unionid mussels, all of which potentially inhabit the New River Gorge: *Tritogonia verrucosa*, *Cyclonaias tuberculata*, *Elliptio dilatata*, *Alasmidonta marginata*, *Lasmigona subviridis*, and *Lampsilis ovata*. Detailed collection records are given, although the downstream station was located just below Claytor Lake on the Little River.

Dillon, R.J. Jr. and E.F. Benfield. 1982. Distribution of pulmonate snails in the New River of Virginia and North Carolina, USA: interaction between alkalinity and stream drainage area. *Freshwater Biol.* 12: 179-186.

The distributions and abundances of 5 species of pulmonate snails are given from collections at 87 sites in the New River during 1976-1979. *Physella hendersoni*, *P. heterostropha pomila*, *Fossaria obrussa*, *Pseudosuccinea columella*, and *Helisoma anceps* were identified from collections, and abundance was positively correlated with alkalinity, drainage area, and the alkalinity-area interaction. Statistical analyses indicated, however, that alkalinity did not limit the distribution of the 5 snail species, although water chemistry may have significantly influenced the distribution of periphyton food, indirectly affecting snail distribution.

Embree, W.N., E.A. Friel, T.A. Ehlke and S.M. Ward. 1982. Water Resources Data, West Virginia, Water Year 1982. U. S. G. S. Water-Data Report WV-82-1.

Two gaging stations in West Virginia on the New River provided data on discharge, water quality and temperature of water entering the Gorge. Detailed records were provided for the station 0.5 km below Bluestone Dam, while only discharge data were presented for the station 2.4 km below the confluence of the Greenbrier River (0.5 km above the Gorge boundary). Detailed data from Glen Lyn, Virginia was also provided, allowing comparisons among the three stations to determine the influences of the Bluestone Dam and Greenbrier River on the flow regime in the Gorge.

Giattina, J. D. , D. S. Cherry, J. Cairns, Jr., and S. R. Larrick. 1981. Comparison of laboratory and field avoidance behavior of fish in heated chlorinated water. *Trans. Am. Fish. Soc.* 110:526-535.

The effects of intermittent chlorination and temperature selection on the movement of fish were studied in an integrated field and laboratory project on the New River at the Glen Lyn Power Plant in Virginia. A decline in fish abundance in the chlorinated, heated discharge was observed within 95% confidence limits. In most cases, laboratory determined avoidance concentrations (determined for 13 species) predicted accurately the total residual chlorine concentrations that would elicit the avoidance behavior of fish under field conditions. (*Notropjs spilopterus*) was the most abundant of the species collected).

Grafton, W.N. 1982. Plants and vegetation of the New River Gorge. *New River Symposium* 1:69-73.

In a condensation of an earlier publication, Grafton briefly describes the common plants that are encountered in the dry, moist, and wet habitats in the Gorge, as well as several special habitats (barren rocks, sandy riverbeds, rock crevices, and deep ravines). In addition, several lists of plant species are presented, including: 1) species normally encountered above 2500 ft elevation that are found in the deep, wet ravines; 2) introduced plants; 3) plants that have migrated downstream along the river; and 4) rare plants. Aquatic macrophytes are not included in the listings.

Grafton, W.N. and E.K.W. Grafton. 1981. Literature review of geology/soils, plant, and animal information pertinent to the New River Gorge National River, West Virginia. U.S. Park Service, Oak Hill, West Virginia. 150 pp.

All published information specific to the New River Gorge from Hinton to Gauley Bridge, West Virginia is summarized. Included in the summary is a description of the geological history and stratigraphy of the gorge, as well as a summary of coal-bearing formations and coal mining operations within the gorge boundaries. Common soil types and their distributions are reviewed, including their suitability for supporting various recreational activities. The paleontology of the area is summarized, including brief descriptions of some of the forest types found in the various geological formations. The summary of floral and faunal surveys includes a history of botanical exploration in the Gorge, a survey of forest and vegetation types, the identification and distributions of plants (with a separate section on rare and endangered plants), and a review of commercial timber resources. Subsequent sections include information on the occurrence and distribution of mammals, birds, fishes (exclusive of Addair 1944), and invertebrates (exclusive of Klarberg 1977). An annotated bibliography of sources used by the authors is included.

Grafton, W.N. and C. McGraw. 1976. The vascular flora of New River Gorge, West Virginia. Center for Extension and Continuing Education, West Virginia University, Beckley, West Virginia. 19 pp.

From collections made in 1967, 1972 and 1973, the authors identified 1067 species (478 genera, 123 families) of vascular plants in the New River Gorge. A complete set of collected specimens was verified and deposited in the West Virginia University herbarium in Morgantown. No detailed collection records were presented. Included in the survey was a brief discussion of the botanical history of the Gorge, previous collections, and unique vegetation types that have become established in the Gorge due to the C&O Railroad, introductions as ornamental species or migration down the New River.

Graney, R. L, D. S. Cherry, J. H. Rodgers, Jr., and J. Cairns, Jr. 1980. The influence of thermal discharge and substrate composition on the population structure and distribution of the Asiatic clam, Corbicula fluminea, in the New River, Virginia. *The Nautilus* 94:130-135.

Six study sites, 3 upstream and 3 downstream of the discharge of thermal effluent from a power plant, were sampled from October, 1976 through December, 1978 to determine the effects of thermal discharge and sediment composition on Corbicula fluminea population structure and distribution. Substrate composition was found to have no effect on these parameters. A substantial increase in clam density occurred in the discharge areas indicating that thermal discharge points may serve to facilitate the northward expansion of Corbicula in the United States.

Green, N.B. 1969. Amphibians and reptiles in West Virginia. Marshall University, Huntington, West Virginia. 47 pp. (mimeo).

The distribution of the amphibians and reptiles of West Virginia on a county by county basis was included in a key to the various taxa, and 32 amphibians and 18 reptiles were reported from Summers, Raleigh and Fayette counties. No information was given on locations or descriptions of location sites, although more detailed collection records were available from published collections or West Virginia Biological Survey records.

Hambrick, P.S., R.E. Jenkins, and J.H. Wilson. 1975. Distribution, habitat, and food of the cyprinid fish Phenacobius teretulus, a New River drainage endemic. *Copeia* 1975:172-176.

Distribution of P. teretulus is given, determined from examination of extensive historic collection records. Most specimens were collected from North Carolina and Virginia, with the exception of one collection in Indian Creek, West Virginia (discharges into Bluestone Reservoir), and one at the upper end of the Greenbrier River. No collections were reported within the Gorge boundaries. The cyprinid inhabits riffles and runs of larger (10-100 m width) softwater streams, feeding nocturnally on Diptera (40-92% by number), Trichoptera (6-50%), and Ephemeroptera (2-10%). Distribution appears to be limited primarily by water chemistry. The Gorge may provide suitable habitat if water hardness is low, but preferred habitats would not be amenable to sampling with seines (e.g., Addair 1944).

Hess, L. 1983. Preliminary analysis of the food habits of some New River fishes with emphasis on blackfly utilization. New River Symposium 2: 15-21.

The dietary importance of the blackfly, *Simulium jenningsi* to New River fishes was investigated by analyses of a total of 351 stomachs from 26 species electroshocked immediately below Bluestone Reservoir. Of the 26 species, 24 contained blackflies, which ranged from 1% (flathead catfish) to 84% (spottail shiner) of the total number of ingested prey items (average 44%). Overall, blackflies occurred in 58% of the stomachs examined (range 0-100% for the 24 species), and species feeding on *Simulium* averaged 10 flies per stomach. Blackflies appeared to be most important in the diet of cyprinids (average 62% of the stomachs with blackflies, averaging 12 per stomach and 41% (by number) of all prey eaten. Of the sportfish sampled, 40% of the spotted bass contained blackflies, averaging 17 per stomach (36% of all prey). Preliminary results indicate that *Simulium* is a significant part of the diet of resident fish populations, and control treatments with *Bacillus thuringiensis* var. *israelensis* could reduce blackfly densities to a point that would adversely affect sportfish feeding and growth.

Hill, B. H. 1981. Distribution and production of *Justica americana* in the New River, Virginia. *Castanea* 46:162-168.

Distribution of *J. americana* was determined from aerial photography of the New River from the Virginia-North Carolina border to Allisonia in 1979. Production was determined from monthly harvests of above and below-ground biomass from June through August 1979. *J. americana* was restricted to the hardwater sections (approx. 50 mg CaCO<sub>3</sub>/L) downstream of the Grayson-Carroll county line. Above and below-ground biomass averaged 448 and 2077 g ash free dry weight (AFDW)/m<sup>2</sup>, respectively, and productivity averaged 23.3 g AFDW/m<sup>2</sup> from 16 June to 4 August, which was 4 to 5 times greater than any other aquatic macrophyte in the New River. *J. americana* contributes 179 of the 1500 metric tons (AFDW) of organic matter provided annually by breakdown of aquatic macrophytes in the study area.

Hill, B.H. and J.R. Webster. 1982a. Periphyton production in an Appalachian River. *Hydrobiologia* 97:275-280.

The production of epilithic algae was measured by carbon-14 uptake on natural substrates at four sites on the New River, Virginia, from June through November, 1980. All sites were located above Claytor Lake, the lower two (hardwater) near Reed Creek and the upper two (softwater) near Elk and Crooked Creeks. Mean algal production ranged from approximately 3.5 to 6.5 mg C/g/h and 0.2 to 2.0 mg C/g/h at the hardwater and softwater sites, respectively. Production was generally 3-5 times greater in the

hardwater areas. Concurrent estimates of other energy sources in the New River indicated that periphyton accounted for 19.5% of the total organic input, and was an important component of the organic matter dynamics due to its high food quality and digestibility.

Hill, B.H. and J.R. Webster. 1982b. Aquatic macrophyte breakdown in an Appalachian river. *Hydrobiologia* 89:53-60.

Breakdown rates of *Podostemum ceratophyllum*, *Elodea canadensis*, *Potamogeton crispus*, *Justica americana* and *Typha latifolia* were quantified during 1979 by determination of ash free dry weight loss in nylon mesh leaf bags placed at four sites (2 hardwater, 2 softwater) in the New River above Claytor Lake. Bags were retrieved after 2 days, one, four, six, and eight weeks. There were no significant differences in breakdown rates between the hardwater and softwater sites. Leaf decomposition rates ranged from 3.7% day (*P. ceratophyllum*) to 0.7% day (*T. latifolia*). Shredder, primarily *Taeniopteryx* sp. (Plecoptera) accounted for 35% of the total number of macroinvertebrates found in the leaf packs, followed by filterers (31.6%, primarily *Hydropsyche* sp. (Trichoptera)), scrapers, gatherers, and predators. Evidence suggests that aquatic macrophytes may provide an important source of energy during the period in late summer after periphyton production has declined, and prior to the input of conditioned allochthonous leaf litter in the autumn.

Hocutt, C. H. 1974. Methodologies developed for the assessment of fish and macroinvertebrate communities in the New River, Virginia. Ph.D. Dissertation, VPI&SU, Blacksburg, VA. 174 pp.

Hocutt sampled fish (rotenone) and invertebrates (artificial substrates) from six locations in the New River near the Celanese Fibers Co. at Pearisburg, Virginia. Forty species of fish were collected at the six sites, as well as 89 taxa of macroinvertebrates. The primary focus of the thesis is on the development of quantitative methodologies for assessing the two biological communities and impacts of discharges from the Celanese plant on community structure (concluded to be minimal). Lists of fish and invertebrates may be useful for comparisons with Gorge collections.

Hocutt, C.H. 1979. Drainage evolution and fish dispersal in the central Appalachians: summary. *Bull. Geol. Soc. Am.* 90:129-130.

This paper summarizes probable dispersal routes of fishes from the Mississippi River east to the Atlantic slope via the Pleiocene-Pleistocene Teays River system (now the New-Kanawha). Hocutt theorizes that the succession of falls, rapids, and cascades in the New River Gorge

may have provided barriers to both upstream and downstream movement', of fishes, based on the depauperate New River fish fauna and several species identified as endemic: *Exoglossum laurae*, *Nocomis platyrhynchus*, *Notropis scabriceps*, *Phenacobius teretulus*, *Etheostoma kanawhae*, *E. osburni*, *Percina oxyrhyncha*, *P. maculata*, and *Cottus carolinae*. Hocutt further hypothesizes that the Gauley River may have provided the primary dispersal route for fishes from the Mississippi drainage to the Atlantic slope, due to past geological formations and drainage locations.

Hocutt, C.H. , R. E. Denoncourt, and J.R. Stauffer, Jr. 1978. Fishes of the Greenbrier River, West Virginia, with drainage history of the central Appalachians. *J. Biogeog.* 5:59-80.

During 1972 and 1974, 32 fish collections were made at 30 locations in the Greenbrier River drainage using seines and an AC/DC electroshocking unit. Brief site descriptions are given for each collection location, one of which was located at Hinton in the New River. A total of 53 species was collected from all sites and an additional 18 were listed as expected. The station in the New River yielded 12 species, with 70% of the number collected belonging to five species of *Notropis*. Six species were not previously reported from the drainage: *Ericymba buccata*, *Notropis telescopus*, *Pimephales promelas*, *Percina maculata*, *P. oxyrhyncha*. and *Cottus carolinae*. Included in the report is an extensive review of the drainage evolution of the central Appalachians, as well as the zoogeography of the Greenbrier River, emphasizing immigration routes for many of the collected fishes.

Hocutt, C. H. , R.F. Denoncourt, and J.R. Stauffer, Jr. 1979. Fishes of the Gauley River, West Virginia. *Brimleyana* 1:47-80.

Fishes were collected from 52 stations located in several watersheds in the Gauley River drainage using seines, electroshockers, rotenone, gill nets, and trot lines. Detailed descriptions of collection sites are provided. A brief summary is provided for each of the 13 watersheds sampled, outlining the habitat provided by the stream and some of the major species encountered. This is followed by an annotated list of the 50 species collected in the drainage, which includes six species not reported previously above Kanawha Falls: *Lampetra aepyptera*, *Moxostoma erythrurum*, *Ictalurus natalis*, *I. Nebulosus*, *Noturus flavus*, and *Percina caprodes*. The report ends with a brief discussion of the zoogeography of the New-Gauley rivers, including possible dispersal routes for fishes encountered in the collections.

Hocutt, C. H. and P. S. Hambrick. 1973. Hybridization between the darters *Percina crassa roanoka* and *Percina oxyrhyncha* (Percidae:

Etheostomatini), with comments on the distribution of *Percina crassa roanoka* in New River. *Am. Midi. Nat.* 90:397-405.

A hybrid darter collected (with rotenone) from the New River below the confluence of the Little River is described. Morphometric and meristic characteristics of the two species and the hybrid are given, as well as a photograph comparing shapes and color patterns of the males. *P. c. roanoka* has recently expanded its range into the New River drainage and occurs in fast water habitats. It has been collected at the mouth of the Greenbrier River, and hybridization with *P. oxvrhyncha* in the New River within the Gorge may yield darters that cannot be identified.

Hocutt, C. H. , P. S. Hambrick, and M. T. Masnik. 1977. Rotenone methods in a large river system. *Arch. Hydrobiol.* 72(2):245-252.

The use of rotenone, block nets, and potassium permanganate proved to be an effective method for sampling fishes in the New River. Six stations, from Ripplemead to Glen Lyn were sampled with this method. Three species were added to the known fauna, nine distributional records of fishes in the main-channel New River were established. Rotenone sampling resulted in higher numbers of species and specimens collected per station than seining.

Hocutt, C.H. , R. L. Kaesler, M. T. Masnik, and J. Cairns, Jr. 1974 Biological assessment of water quality in a large river system: an evaluation of a method for fishes. *Arch. Hydrobiol.* 74(4): 448-462.

Fish were collected (seining and rotenone) during the summers of 1971 and 1972 from the New River in the vicinity of a synthetic fibers plant, Pearisburg, VA. Data were analyzed by two methods and contrasted; the diversity index ( $\bar{d}$ ) of tfilhm and Dorris and the Jaccard similarity coefficient ( $S_j$ ). The Jaccard similarity coefficient was recommended as a procedure for evaluating aquatic biota. A list of fish species and total number collected at each station is included.

Holt, P.C. (ed. ). 1969. The distributional history of the biota of the Southern Appalachians. Part I. Invertebrates. VPI&SU, Res. Div. Monogr. 1. 295 pp.

This volume contains 11 contributed papers on the identification, distribution, and evolutionary ecology of invertebrates found in the Southern Appalachian range. Several of the papers contain distributional data pertinent to the New River Gorge: amphipods (*Gammarus minus*), crayfish (genus *Cambarus*, including key, evolutionary history, and distribution maps; there appear to be seven species in the Gorge area),

ostracods (seven genera in the Gorge area of West Virginia), and terrestrial molluscs (descriptive figures provided, no detailed distributional data).

Jenkins, R. E. , E. A. Lachner, and F. J. Schwartz. 1971. Fishes of the central Appalachian drainage: their distribution and dispersal. Pages 43-117 in P.O. Holt, ed. , The distributional history of the biota of the southern Appalachians, Part III: Vertebrates. VPI&SU Research Division Monographs 4, Blacksburg, VA.

Composition, origin, distribution and dispersal of the freshwater fish faunas of central Appalachian drainages are treated. The New-Kanawha drainage is included. Forty-seven species are listed as inhabiting the New River (above Kanawha Falls). However, the information was obtained primarily from previous literature (e.g., Addair 1944, Ross 1959, and Ross and Perkins 1959).

Jordan, D. S. 1890. Report of the explorations made during 1888 in the Allegheny region of Virginia, North Carolina and Tennessee and in western Indiana, with an account of the fishes found in each river basin of those regions. Bull. U.S. Fish. Comm. 8(1888): 97-173.

Fish were collected from four tributaries of the New River near Pulaski and Wytheville, Virginia. Outdated taxonomy and of limited use.

Kennedy, J.H. 1980. Macroinvertebrate drift in the New River, Virginia. Ph.D. Dissertation, VPI&SU, Blacksburg, VA. 229 pp.

From June, 1976 through September, 1977, drift net samples taken from a bridge (county route 721 near Fries, Virginia) were analyzed to determine diel and seasonal periodicity of macroinvertebrate drift in the New River, as well as the influence of abiotic and biotic factors on diel drift patterns. Temperature, DO, and discharge rates are presented for the study period along with extensive discussions of diel and seasonal drift patterns for Ephemeroptera, Plecoptera, Coleoptera, Trichoptera, Diptera, and total immatures. Results of the study indicated that the drift was dominated by immature insects, discharge and moonlight influenced drift (discharge effects variable depending on taxa, moonlight suppressed drift), drift was influenced by growth and life-history stage (increase at maturity), and drift was stable across years. This dissertation and Klarberg (1977) should provide good species lists of possible aquatic insects in the Gorge.

Kennedy, J. H. and H. B. White III. 1979. Description of the nymph of *Ophiogomphus howei* (Odonata: Gomphidae). Proc. Entomol. Soc. Wash. 81:64-69.

This paper provides an extensive description, of the nymph, its habitat, species associations, food preferences, and emergence patterns. The nymph makes up a significant portion of the benthic fauna of the New River in North Carolina and Virginia, and is recognized by its small size, lack of dorsal hooks, and small or absent lateral spines on abdominal segment 7. Nymphs were found in sand and gravel in swiftly-flowing water feeding on water mites (Acari), mayfly nymphs (Baetidae), and chironomid larvae. Emergence occurred from 30 April through 15 May at water temperatures of 19 C. Other species collected *O. howei* included *Gomphus vastus*, *G. spiniceps*, *Ophiogomphus asperpus*, *Macromia illinoiensis*, and *Neurocordulia yamaskanensis*.

Klarberg, D. P. 1977. Investigations of the macrobenthos and physiochemistry of the upper New River basin. Ph.D. Dissertation, Virginia Tech, Blacksburg, Virginia.

Investigations of the macroinvertebrate community of the New River in West Virginia included collections in 1970 and 1971 at three sites below Bluestone Reservoir; two above the confluence of the Greenbrier River, one in the New River Gorge. Invertebrates were collected with a Surber net and a D-frame kick net. Data analysis included determination of diversity and trophic structure as well as cluster analysis of community composition. A total of 137 taxa was identified from all of the surveys, with 53 insect taxa identified (to genus) from the three sites below Bluestone: Coleoptera (7), Diptera (2), Ephemeroptera (8), Lepidoptera (1), Megaloptera (1), Odonata (3), Plecoptera (4) and Trichoptera (7). The three collection sites below Bluestone generally exhibited lower insect densities than the upstream stations, with dipterans, trichopterans, and ephemeropterans predominate in both years. In decreasing order of importance, the trophic structure of the macroinvertebrate community below Bluestone was made up of collectors, predators, scrapers, and shredders. No physiochemical measurements were taken at the three downstream sites, and appendix tables list only numerical totals of each taxa captured at each site. No analyses of seasonal abundance patterns or production potentials were attempted.

Lachner, E. A. , and R. E. Jenkins. 1971. Systematics, distribution and evolution of the chub genus Nocomis Girard (Pisces: Cyprinidae) of the eastern United States, with description of new species. Smithsonian Contrib. Zool. 85:1-97.

The chub genus Nocomis of North America is characterized, and relationships among three species groups in Nocomis are discussed. Two new

species are described from the central Appalachian region. The ecological requirements of chubs are reviewed and species preferences discussed. The primary ecological distinction among the species is stream size. Associations, interrelationships and frequency of hybridization were compared among four species. A key to the species of Nocomis is provided.

Maciorowski, A.F., E. F. Benfield and A. C. Hendricks. 1977. Species composition, distribution, and abundance of oligochaetes in the Kanawha River, West Virginia. *Hydrobiologia* 54:81-91.

Oligochaetes were captured during July and August 1973 at 14 stations along the Kanawha River between Alloy (RM 89.9) and Scary (RM 42.7) West Virginia. A total of 30 samples was taken at each station using a Ponar grab (0.053 m<sup>2</sup>) in the soft sediments along the shoreline. Three stations (1-3) were located in relatively unpolluted sites, while the remaining samples were collected around industrial effluent pipes. Eighteen taxa were collected (identified primarily to genus), including two species previously unreported from North America. Six taxa were collected from Site 1 (just below the Falls), with a mean density of 401 individuals/m<sup>2</sup>. Tubificids dominated the samples, accounting for 91% of the number of oligochaetes collected. Diversity increased to a maximum of 14 taxa at Site 3 (1102/ra<sup>2</sup>), although tubificids still comprised 92% of the samples by number. Site-specific distribution patterns indicated *Branchiura sowerbyi* (Tubificidae), *Dero obtusa* and *Limnodrilus hoffmeisteri* (Naididae) were potential biological indicators of industrial inputs into the river. *B. sowerbyi* appeared to be restricted to the relatively non-impacted areas, being relatively abundant at Sites 1-3, but almost absent at Sites 4-14. The latter two species exhibited a reversed distribution pattern, occurring at low densities at stations 1-3, but accounting for up to 74% of the oligochaetes captured near effluent pipes at Sites 4-14.

Markham, S. L., C. H. Hocutt, and J. R. Stauffer, Jr. 1980. The crayfish (Decapoda: Astacidae and Cambaridae) and the freshwater mussels (Mollusca: Pelecypoda) of the lower New River, Virginia and West Virginia. *Nat. Hist. Misc.* 208:1-11.

A survey of the New River drainage from Lurick, Virginia to the mouth of the Gauley River produced six species of crayfish and six species of freshwater clams, *Cambarus sciotensis* was the most abundant crayfish species collected. The introduced species *Orconectes virilis*, has increased its distribution in the New River, accounting for three new county records in West Virginia. The introduced freshwater clam, *Corbicula fluminea*, was the most abundant clam species, occurring at 9 of 11 sites. *Cyclonaias tuberculata* was the most abundant unionid species. From stations on the main channel of the NRGNR, only *Orconectes virilis*, *O. spinosus* and *O. sciotensis* were collected. Mussels found in the NRGNR

were *Tritogonia verrucosa*, *Cyclonaias tuberculata*, *Actinonaias carinata carinata*, *Lampsilis ovata ventricosa* and *Corbicula fluminea*.

Masnik, M. T. , J. R. Stauffer Jr., and C. H. Hocutt. 1978. A comparison of fish collection methods after rotenone application in the New River, Virginia. *Virginia Journal of Science*, 29(1): 5-9.

This study was conducted to assess the relative sampling efficiency of the use of a block net versus the use of personnel with dipnets during rotenone application in a large river. Use of the block net resulted in significantly higher numbers of species and specimens collected per locality than by dipnetting alone. Ninety-two percent of all Percidae specimens taken were collected in the block net. The list of the 36 species collected is included.

McLeod, D.M, 1976. Report on Bluestone Reservoir. Va. St. Water Control Board, mimeo, 36 pp.

This report details water quality data collected from April through November, 1974 to determine potential causes of fish kills in Bluestone Reservoir. Data contained in the report includes concentrations of nitrogen, phosphorus, dissolved oxygen, chloride, sulfate, total, suspended, and dissolved solids, chlorophyll a, b, and c, heavy metals, and pesticides, as well as BOD, pH, temperature, conductivity, and turbidity. None of the parameters listed appeared to provide a potential cause for observed fish kills.

Miller, R. R. 1972. Threatened freshwater fishes of the United States. *Transactions American Fisheries Society* 101:239-252.

Threatened, native freshwater fishes are listed for 49 states. In West Virginia, four species found in the NRGNR are listed as depleted. The four species are the tongue-tied minnow (*Exoglossum laurae*), cutlips minnow (*Exoglossum maxjmingua*), New River shiner (*Notropis scabriceps*), and the Kanawha minnow (*Phenacobius teretulus*).

Morris, J. S. and R. W. Taylor. 1978. A survey of the freshwater mussels (*Bivalvia:Unionidae*) of the Kanawha River of West Virginia. *Nautilus* 92:153-155.

During April to September, 1976, mussels were collected (crowfoot dredge) from six stations in the Kanawha River below the confluence of the Gauley River in Fayette, Kanawha, and Putnam counties. Detailed de-

scriptions are given of the collecting sites. Mussels (13 spp.) -were found only at the upper two stations, while stations 3,4, and 6 supported large beds of *Corbicula fluminea*. Industrial wastes, urban runoff, and habitat destruction were cited as the probable causes of the lack of mussels at downstream sites.

Newbern, L. 1978. Detritus transport in the New River. M.S. Thesis VPI&SU, Blacksburg, Va.

See Newbern et al. (1981)

Newbern, L. A. , J. R. Webster, E.F. Benfield and J. H. Kennedy. 1981. Organic matter transport in an Appalachian Mountain river in Virginia, U.S.A. *Hydrobiologia* 83:73-83.

DOM, FPOM, and CPOM were collected monthly from June 1976 to May 1977 using drift nets and grab water samples at two sites in the New River, the upper site (I) near Fries, Virginia, and the lower site 210 km downstream at the head of Bluestone reservoir. DOM ranged from 1-50 and 11-19 mg l<sup>-1</sup> at sites I and II, respectively. Particulate organic matter (CPOM and FPOM) was generally at higher concentrations at the upstream site. The authors suggest two important factors in the New River organic matter dynamics: the trapping and processing of POM by Claytor Lake, and DOM inputs from municipalities located along the river. Flow regimes (flow rates, flushing time, discharge depth) from mainstream impoundments (e.g., Bluestone Reservoir) could have significant impacts on the types of organic material available downstream, and thus the structure and species composition of the aquatic biota that develops.

Paul, R.W., Jr. 1978. Leaf processing and the effects of thermal perturbation on leaf degradation in the New River, Va. Ph.D. Diss. VPI&SU, Blacksburg, Va.

In 1975 and 1976 leaf litter processing was studied in the New River, upstream and downstream from the entrance of heated effluents of the Glen Lyn fossil fuel plant. Leaf processing in the New River proceeds at rates similar to those of small streams. The effect of the thermal perturbation on leaf processing was significant. However, the overall effect on the aquatic system was minor.

Potter, W.A. 1978. Assessment of the effects of impingement and entrainment on the fish community of the New River, Va. M. S. Thesis, VPI&SU, Blacksburg, Va.

During 1976 and 1977 the fishes washed of the vertical travelling screens at the Glen Lyn Power Plant were collected. The alewife (*Alosa pseudoharengus*) accounted for 86.6% of the fish impinged at the station. Most of the fish were dead prior to impingement. It was estimated that 14.5 to 21.7% of the larvae that drifted by the station were entrained. It was concluded that losses to the intake of the station were not significant enough to affect the fish community structure of the New River.

Potter, W.A., K.L. Dickson, and L. A. Nielsen. 1978. Larval sport fish drift in the New River. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 32: 672-679.

Larval fishes were collected from the New River near Glen Lyn, Virginia, from June through August, 1976. Fishes were collected in three replicate 10-min samples taken at the surface during the day, at dawn, or at sunset twice weekly using a 0.6 x 0.9 m rectangular net (0.5 mm mesh) suspended from the route 460E bridge. In order of descending abundance, channel catfish, flathead catfish, spotted bass, rock bass, and smallmouth bass were identified from the larval tows. Total drift estimates for the June to August period ranged from 47,000 (smallmouth bass) to 2,410,000 (channel catfish).

Potter, W.A., K.L. Dickson, J. Cairns, Jr., and J. R. Stauffer, Jr. 1978. Effects of entrainment on the fish community of the New River, Glen Lyn, Virginia, USA. 56th annual meeting of the Virginia Academy of Science, Blacksburg, Virginia. Virginia Journal Science 29(2):93 (Abstract only).

See Potter 1978.

Rodgers, J. H., Jr., D. S. Cherry, J. R. Clark, K. L. Dickson, and J. Cairns, Jr. 1977. The invasion of Asiatic clam, *Corbicula fluminea* in the New River, Virginia. Nautilus 91:43-46.

*Corbicula* was collected in the Kanawha River near Charleston in 1961, but had not been reported further upstream in the New-Kanawha drainage. This report summarizes morphological measurements and regression analyses from 40 specimens collected near Glen Lyn, Virginia, which was apparently invaded by the clam in 1975. Fishermen and waterfowl are cited as the most probable dispersive mechanisms. Probable impacts of *Corbicula* in the river include a decline in other bivalve populations in the river (particularly important, indigenous *Margaritifera*, *Tritogonia*, *Elliptio*, *Sphaerium*, and *Pisidium*) and problems with industrial and municipal water use.

Ross, R. D. 1959. Drainage evolution and distribution problems of the fishes of the New (Upper Kanawha) River System in Virginia IV. Key to the identification of fishes. Va. Agri. Exp. Sta. Tech. Bull. 146. 20 pp.

A key to New River fishes is presented, derived largely from Addair's (1944) collections in West Virginia. The paper includes keys to families (19) and species (127) of New River fishes. Taxonomy is outdated for several species, but the keys are detailed.

Ross, R. D. 1969. Drainage evolution and fish distribution problems in the southern Appalachians of Virginia. Pages 277-292 in P-C. Holt (ed.), The distributional history of the biota of the southern Appalachians. Part I. Invertebrates. VPI&SU Res. Div., Monogr. 1. 295 pp.

This paper deals specifically with the drainage evolution of the New, James, and Roanoke Rivers and its relationship to the fish species found in each drainage. The paper begins with a general review of the geological history of the southern Appalachian region and methodologies employed to study species zoogeography. The remainder of the discussion centers on the evolution of the three rivers through the Pleiocene and Pleistocene periods, and how drainage development affected the distributions of several -fish species. Ross rejects past theories on evolution of the three rivers, and concludes with his hypothesis of past stream movements and stream captures that are consistent with fish distribution patterns.

Ross, R.O. and 3.O. Perkins. 1959. Drainage evolution and distribution problems of the fishes of the New (Upper Kanawha) River System in Virginia III. Records of fishes of the New River. Va. Agri. Exper. Sta. , Tech. Bull 145. 20 pp.

After brief descriptions of the hydrography, physiography, and ecology of the New River drainage, distributional records are presented for fishes collected in the main channel and 18 tributaries in Pulaski, Montgomery, Giles, Grayson, Carroll, Floyd, tfythe, Bland, and Craig counties. No specific site data is presented, or any ecological variables associated with the various fish species.

Seidel, M.E. 1982. The turtle *Pseudemys concinna* (Testudines:Emydidae) in the New River. New River Symposium 1:77-81.

Step-wise discriminate analysis on the cranial structure of cooters from Bluestone Reservoir indicated that the species was not the Florida cooter (*P. floridana*) as previously described, but the river cooter, *P. cognata*. Early collections and examination of turtle bones from an archaeological site near Bluestone support the contention that cooters were present in the New River prior to the construction of Bluestone Dam. In addition to the cooter, the spiny softshell (*Trionyx spiniferus*), stinkpot (*Sternotherus odoratus*), snapping (*Chelydra serpentina*), and painted (*Chrysemys picta*) turtles were cited as the only other species inhabiting the New River. See also Seidel, M. E. 1981. A taxonomic analysis of Pseudemys turtles (Testudines: Emydidae) from the New River, and phenetic relationships in the subgenus Pseudemys. *Brimleyana* 6:25-44 (essentially the same report republished).

Shingleton, M. V. , C. H. Hocutt, and J. R. Stauffer, Jr. 1981. Temperature preference of the New River shiner. *Trans. Am. Fish. Soc.* 110: 660-661.

New River shiners, *Notropis scabriceps*, were collected from the Greenbrier River during the spring of 1980 (ambient temperature 12 C). They were subsequently acclimated to 6, 12, 18, 24, 30, or 33 C and placed in a thermal gradient trough to determine temperature preferences. Shiners acclimated to 6, 12, and 18 C preferred warmer water, while the -reverse was true for fish acclimated to higher temperatures. The final preferred temperature was 19.3 C, and the authors hypothesized that the relatively low temperature preferences exhibited by the shiners may partially explain its distribution, which appears to be restricted to the headwaters of the New River and its tributaries.

Stansbery, D. H. 1980. The naiad mollusks of the Kanawha River below Kanawha Falls with special attention to endangered species (*Bivalvia:Unionoida:Unionidae*). mimeo, 55 pp.

Stansbery collected mussels from the Kanawha river with SCUBA gear and a crowfoot brail during 1979 between RM 88.5 and 92.5. *Cyprogenia stegaria* was found in a muskrat midden at river mile 92.3, possible the first recent record of the species in West Virginia other than the Ohio River. A single live specimen of the endangered *Lampsilus orbiculata orbiculata* was also found at this sampling site. No mussels were collected at RM 91.0 or 88.5. Species lists and collection records are presented for each of the 22 species collected.

Stauffer, J. R., Jr. 1975. The influence of temperature on the distribution, community structure and condition of fish of the New River,

Glen Lyn, Virginia. Ph.D. Dissertation, VPI&SU, Blacksburg, VA. 174 pp.

Stauffer sampled fish (rotenone) from six locations in the New and East Rivers near the Appalachian Power Company's Glen Lyn fossil fuel plant in 1973 and 1974. Forty-eight species of fish were collected. Data was collected on the fish community structure, laboratory temperature preference and avoidance of various species, fish condition factors and catfish feeding behavior. The total effects of the heated discharge on the fish community's structure and function was regarded as minimal. *Campostoma anomalum*, *Notropis rubellus*, *Notropis spilopterus* and *Pimephales notatus* were designated as important forage species based on abundance. The list of fish species may be useful for comparisons with Gorge collections.

Stauffer, J. R. Jr. 1980. Aquatic biological survey of the New River, Virginia and West Virginia. Final Report, Div. Ecol. Serv., USFWS. mimeo, 36 pp.

In 1979, fish crayfish, and mussels were sampled in the New River from Lorick, Virginia to the mouth of the Gauley River, West Virginia. Fish and crayfish were collected with a seine and electroshocking unit, and crayfish were also captured using kick-netting. Mussels were captured by seiling and snorkeling. Collection sites are deJciibed, but descriptions are general and no map is provided. A total of 58 species of fishes was collected, and the number of each species captured at each site is presented (*Labidesthes sicculus* new distributional record, just below Bluestone Dam). The distributions and habitat preferences of four endemic fishes are also discussed. Six species of crayfish were collected, and are listed by collection site. Five species of mussels (plus *Corbigula*) were also captured at 11 sites, and collection records are presented. The report concludes with an evaluation of impacts of hydroelectric development at Bluestone Dam on downstream biota.

Stauffer, J. R. , Jr., J. H. Wilson, and K. L. Dickson. 1976. Comparison of stomach contents and condition of two catfish species living at ambient temperatures and in a heated discharge. *Prog. Fish-Cult.* 38(1):33-35.

Comparison of the stomach contents and condition of young of the year channel catfish (*Ictalurus punctatus*) and flathead catfish (*Pylodictus olivaris*) were made. Fish were collected after application of rotenone at a control station and in the heated discharge from Appalachian Power Company's Glen Lyn, Virginia plant. This paper has little utility in the present study.

Stauffer, J. R. Jr., M. B. Brooks, C. H. Hocutt, and R. E. Jenkins. 1982. Checklist of the fishes of the central and northern Appalachian Mountains. Proc. Biol. Soc. Wash. 95:27-47.

This paper compiles fish collection records dealing with Ohio River and Atlantic slope drainages in an area bounded by New York-Ohio and Alabama-South Carolina. A total of 398 forms are listed, which includes species captured above (87 species) and below (101 species) Kanawha Falls. No collection records are given, and Addair's (1944) collections are not included.

Stauffer, J. R. Jr., R. F. Denoncourt, C. H. Hocutt, and R. E. Jenkins. 1976. A description of the cyprinid fish hybrid, *Notropis chrysocephalus* x *Notropis photogenus*, from the Greenbrier River, West Virginia. Natural History Miscellanea 0(204):1-6.

A survey of the fishes of the Greenbrier River system yielded several specimens of striped shiner (*Notropis chrysocephalus*) x silver shiner (*Notropis photogenus*) hybrids. This paper describes the hybrid based on 13 specimens and compares it to a similar hybrid also from the Greenbrier River.

Stauffer, J. R., Jr., K. L. Dickson, J. Cairns, Jr., and D. S. Cherry. 1976. The potential and realized influences of temperature on the distribution of fishes in the New River, Glen Lyn, Virginia. Wildl. Monogr. 50:40 pp.

This report contains collection data for 47 species of fish collected (rotenone) near the Glen Lyn Power Plant in 1973 and 1974. Each species is discussed regarding its abundance and the water temperatures at the site of capture; Laboratory temperature preference tests were also conducted for five cyprinids, four centrarchids, and one catostomid, and avoidance temperatures are given for each. Results indicated that temperature was an extremely important factor governing the distributions of almost all species. The report is of limited utility except for the species' lists and collection records.

Stauffer, J. R., Jr., C. H. Hocutt, M. T. Masnik, and J. E. Reed, Jr. 1975. The longitudinal distribution of the fishes of the East River, West Virginia-Virginia. Va. J. Sci. 26:121-125.

Rotenone and seines were used to collect fish at 13 stations in the East River system. Over the two-year period, 49 species representing seven families were collected. *Notropis stramineus* was added to the

ichthyofauna of Virginia. Range extensions were established for several species. The list of species is included.

Stauffer, J. R. , Jr., K. L. Dickson, J. Cairns, Jr., W. F. Calhoun, M. T. Masnik, and R.H. Myers. 1975. Summer distribution of fish species in the vicinity of a thermal discharge, New River, Virginia. Arch. Hydrobiol. 76(3):287-301.

Studies were conducted to determine the effect the discharge from Appalachian Power Company's Glen Lyn, Virginia plant. For for some species (*Hypentelium nigricans*, *Ictalurus punctatus*) there was a marked effect of temperature on the spatial and temporal distributional patterns. For other species multivariate techniques were used to screen for the effects of temperature, photoperiod, time since last chlorination period, river flow and gradient on abundance. Three major responses to temperature were found: 1) Avoidance of high temperatures (*Hypentelium nigricans*, *Notropis rubellus* and *Campostoma anomalum*). 2) Attraction to high temperatures (*Ictalurus punctatus*). 3) Indifference to temperature changes within the range observed (*Notropis spilopterus*).

Taylor, R.W. 1983. A survey of the freshwater mussels of the Kanawha River. Prepared for Huntington - District, Corps of Engineers, Huntington, W. V. Contract No. DACW69-82-C-0081. 62 pp.

This report covers a survey of the mussel fauna of the Kanawha river from head to mouth. Twenty-seven species of mussels plus the Asiatic clam *Corbicula fluminea* were recorded in this survey. One of these was a healthy population of the federally endangered *Lampsilis orbiculata*. Mussel populations were most dense and diverse in the area Just below Kanawha Falls, and in the lower 75 miles of river are presumed to be devoid of mussel life except for the Asiatic clam. Photos, current distributions, and status in W. Virginia are given for all species found.

Vaughn, G. L. 1979. Effects of strip mining on fish and diatoms in streams of the New River drainage basin, Tennessee, USA. J. Tenn. Acad. Sci. 54(3): 110-114.

Fish and diatom communities were sampled over a 3 year period from four small watersheds of the New River Drainage basin of East Tennessee, to determine the effects of strip mining. The trend for both fish and diatoms was toward smaller populations and fewer species of less equitable distribution with increased strip mining.

Webster, J. R. , E.F. Benfield, and J. Cairns, Jr. 1972. Model predictions of effects of impoundment on particulate organic matter transport in a river system. Pages 339-364 in J. V. Ward and J.A. Stanford, editors. The ecology of regulated streams, Plenum Press, New York, USA.

Webster et al. in their attempt to develop a general model of POM transport in streams, combined concepts from biological and civil engineering models and placed them on a framework of geomorphological models that describe the physical conditions for biological functions. Where necessary, data from the New River (North Carolina and Virginia) and Claytor Lake was used. However, rather than simulating the effect of Claytor Lake on POM transport in the New River, the model is intended to be a means of summarizing current knowledge of POM dynamics in a river-reservoir ecosystem. The paper has limited utility in the present study.

West Virginia DNR. 1983. New River Basin Plan. Div. Wat. Res., Charleston, West Virginia. 127 pp.

The New River Basin Plan was prepared as mandated by the Clean Water Act of 1972. The plan was designed to identify and provide potential solutions to water quality problems in the New River. Included in the plan are physical/chemical data on New River tributaries within the Gorge. Flow rates and water chemistry (nitrate, sulfate, manganese and iron) data were presented for 14 sampling sites, while temperature, pH, dissolved oxygen and conductivity were given for all sites. In addition, qualitative benthos collections were made at some sites using a kick net, and collected orders were listed for each site.

Wilson, J. H. and K. L. Dickson. 1977. Water quality at five proposed industrial sites on the Roanoke and New Rivers. Virginia Water Resources Research Center. Bull. 84:1-80.

This study involved measurement of 18 physical-chemical parameters and collection of benthic invertebrates (basket and kick samples) that were used to evaluate physical, chemical, and biological water quality at three sites on the New River, with the downstream site located approximately 12 km above Bluestone Reservoir. Collection records for benthic invertebrates are presented by site and month (identified to genus), and data is also given on monthly flow rates, heavy metal concentrations (sediments?, taken from another study), and monthly water quality parameters. The study is of limited utility, due to infrequent sampling, non-quantitative methods, and minimal invertebrate identification.

Wilson, J.H. and A. C. Hendricks. 1974. The effect of Claytor Lake, a pump storage reservoir, on phytoplankton activity in the New River. ASB Bull. 21:91.

Diel variability in dissolved oxygen was measured (carbon 14 method) near Pembroke, Virginia in June, July, and August 1973 to determine photosynthetic affects on oxygen levels in the New River. Diurnal curves indicated large algal populations in the river, particularly during periods of high discharge from Claytor Lake. Data indicate Claytor Lake (and probably Bluestone Reservoir) act as incubation sites, providing large amounts of photosynthetically active algae to downstream sites. This is an abstract only, no discussion of impacts of algal production on downstream biota, particularly as a food source.