MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

University of Marylan
CENTER FOR ENVIRONMENTAL SCIENC
APPALACHIAN LABORATORY

Adoption Statement
Maryland Brook Trout Management Plan
2006

We, the undersigned, adopt the Maryland Brook Trout Fishery Management Plan as a guide to managing brook trout in Maryland waters. The Maryland Brook Trout Fishery Management Plan provides a framework for restoring and maintaining brook trout populations while allowing social and economic benefits from the resource. The plan adopts management strategies that address population issues such as genetic concerns, fragmentation, exploitation and monitoring and analysis needs. The plan also recommends habitat strategies, recognizing that urbanization and its effect on aquatic habitat is currently the most serious threat to brook trout. The development of this plan was a joint effort among Fisheries Service, Resource Assessment Service and the University of Maryland Center for Environmental Studies Appalachian Laboratory. We recognize that it will take a coordinated effort within the Department of Natural Resources to implement the plan.

The Maryland Department of Natural Resources and partners will periodically review and update the plan and report on progress made in achieving the management plan's goals and objectives.

DATE **December 19, 2006**

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2006
Maryland Brook Trout
Fisheries Management Plan

Photo by Matt Kline

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EXECUTIVE SUMMARY

Brook trout are Maryland's only native freshwater trout species and have been a popular recreational angling resource since European colonization of North America. Brook trout require relatively pristine conditions for survival and typically cannot survive when water temperatures exceed 68^{0}F. Anthropogenic alterations to Maryland's environment over the last several centuries including clear cutting of forests, establishing large agricultural areas, and urbanization have resulted in the extirpation of brook trout from 62% of their historic habitat in Maryland. Of the remaining 151 streams where brook trout populations are found, over half are in westernmost Garrett County, the least developed area of Maryland. The vast majority (82%) of the remaining populations are classified as "greatly reduced", meaning that within the subwatersheds where they occur they occupy only 1% to 10% of the area that was historically inhabited. A major difficulty in managing the brook trout resource is that only 11% of all brook trout streams and stream miles are fully within state lands, the vast majority of habitat is on private land and a mix of private/public lands. Of the more immediate threats to brook trout populations in Maryland, urbanization is the most serious. In watersheds where human land use exceeds 18% brook trout populations cannot survive. If impervious surface area is greater than 0.5% in a watershed brook trout will typically be extirpated. There are also long-term threats to brook trout populations such as global warming. Current predictions indicate that warming water temperatures over the next 100 years could eliminate brook trout populations statewide except for western Maryland (Garrett County) by approximately 2100.

The Maryland DNR has listed brook trout as a "Species of Greatest Need of Conservation" in its federally mandated Wildlife Diversity Conservation Plan. Concern for the status of the brook trout resource prompted the Maryland Department of Natural Resources (MD DNR) Inland Fisheries Management Division, which is responsible for management of statewide freshwater sport fish species, to develop a brook trout Fisheries Management Plan (FMP). Partners in this effort include researchers from the University of Maryland Center for Environmental Studies Appalachian Laboratory (UMCES-AL), MD DNR Fisheries Service, and the MD DNR Biological Stream Survey (MBSS).

Brook trout in Maryland are valuable for aesthetic, recreational, economic, and biological reasons. Because of their habitat and life history requirements brook trout are typically found in the more pristine, aesthetically pleasant areas of Maryland. While there is no commercial fishery for brook trout, recreational angling has been occurring for centuries. There is increasing local and national recognition of the uniqueness and quality of fishing for native brook trout. This recognition is highlighted by the creation of the multi-state Eastern Brook Trout Joint Venture (EBTJV) and the formation of the Maryland Brook Trout Alliance, a citizen-based Maryland brook trout advocacy group. While no economic valuation of the recreational fishery has been done in Maryland, findings from Pennsylvania, which has a similar wild brook trout fishery, has shown significant economic impact from the resource. Wild trout anglers in Pennsylvania contribute more than $2 million annually to local economies. Brook trout are considered a biological indicator species because they represent a whole suite of unique aquatic and terrestrial organisms that occupy and share the same habitat. Loss of brook trout from a system indicates negative changes to the habitat and overall system.

The goal of the Brook Trout FMP is to *"restore and maintain healthy brook trout populations in Maryland's freshwater streams and provide long-term social and economic benefits from a recreational fishery"*. Management objectives were developed to support the goal based on a thorough review and analysis of the problems affecting the status and survival of the brook trout resource in Maryland. The management framework to meet the objectives, including the work necessary to implement the plan is provided in the Management Recommendations and Research Needs sections of the FMP. Implementation will require a committed work plan that extends over many years in order to be successful.

GOAL AND OBJECTIVES

The goal of the Maryland Brook Trout Fishery Management Plan is to *restore and maintain healthy brook trout populations in Maryland's freshwater streams and provide long-term social and economic benefits from a recreational fishery.*

Achieving this goal will require meeting the following objectives:

1) Collect and organize available brook trout data and information from the array of sources where they currently reside.

2) Gather and utilize the latest genetic information to formulate recommendations that maintain appropriate genetic integrity of distinct stocks.

3) Evaluate current and future freshwater fishery management policies and practices to assure that they support healthy brook trout populations.

4) Determine stakeholder preferences for managing wild brook trout.

5) Determine best methods to maintain, protect and restore populations. The primary emphasis is to maintain and protect existing populations and then move toward restoration of extirpated populations where possible.

6) Educate State and County agencies on the importance of preserving the limited number of habitats that support brook trout. Work cooperatively with agency staff to promote an ecosystem-based approach to protecting/restoring brook trout, with particular emphasis on DNR public lands.

7) Determine habitat requirements and anthropogenic stressors for brook trout. Work with State and County agencies, institutions, community watershed groups, private organizations and landowners to maintain or restore cold water habitat for brook trout through best management practices, restoration of stream buffers, mitigation of stream blockages, land planning, and initiatives to reduce the impact of development in watersheds that contain brook trout populations or have streams with habitat conditions that are suitable for restoring brook trout populations.

8) Provide information to State and County agencies, institutions, community watershed groups, private organizations and landowners to ensure that brook trout populations are preserved, protected or enhanced in restoration and protection efforts.

9) Coordinate stream monitoring programs within DNR and develop a comprehensive strategy that will ensure continued tracking of long-term stock status.

INTRODUCTION

Brook trout *Salvelinus fontinalis* are Maryland's only native salmonid species and are members of a group known as charr, not trout as their common name implies. The term charr is the English name historically given to all members of the genus *Salvelinus*, including *Salvelinus* species such as lake trout *S. namaycush* and bull trout *S. confluentus,* also incorrectly referred to as trout. Species such as the commonly recognized brown *Salmo trutta* and rainbow *Oncorhyncus mykiss* trout and the Atlantic salmon *Salmo salar* and various Pacific salmon *Oncorhyncus spp*. are all considered members of the trout group. In physical appearance brook trout are distinguished from trout and other charrs by three principal characteristics, the absence of vomerine teeth (characteristic of all charrs), light body spots on a dark background (reversed on trouts), and the worm-like vermiculations on the back of the fish (unique to brook trout).

From a geological perspective paleoichthyologists have suggested that during the latter part of the Oligocene Epoch (33.7 to 23.8 million years ago) of the Mesozoic era there was a division of the salmon-like fishes into the *Salvelinus* (charrs) and the *Salmo* and *Oncorhyncus* (trout and salmon) branches. Brook trout are first recognized as a specific species that evolved during the Pliocene Epoch (5.3 to 1.8 million years ago). Over the last million years in North America there have been at least 4 ice ages, the last of which occurred approximately 70,000 years ago, that shaped the historical distribution of brook trout populations in Maryland until European colonization. At this point, brook trout were found in river basins in all three of Maryland's geographic classification areas: the Appalachian Plateau (western Maryland), the Piedmont (Central Maryland.), and in a few tributaries of the Coastal Plain along the Coastal Plain/Piedmont Fall line (Figure 1).

Since English colonization of America, the brook trout resource has been almost exclusively recreational. Commercial fisheries for brook trout existed in the Long Island area of New York in the late 1700's and minor commercial fishing, usually seasonal or incidental, was reported to have existed in the New England states up until the early 1800's. From this point in time, recreational angling for brook trout became the primary source of exploitation with no commercial harvest allowed in the United States and Canada. From Maryland records the earliest recorded information on brook trout after English colonization comes from the writings of Meshack Browning, a well-known western Maryland outdoorsman who recorded the details of many of his hunting and fishing adventures in the late 1700's and early 1800's. He described catching brook trout up to 20 inches in length by the dozens in "little meadows", streams within the Youghiogheny River drainage in western Maryland (Browning 1859). Management of wild brook trout populations began in Maryland in 1876 when the first regulation to establish an open season was instituted.

LIFE HISTORY

Habitat

Brook trout habitat in Maryland is typically headwater streams (first, second, and third order) but includes a small number of moderately sized tailwaters having average widths up to approximately 40 meters. Silt free, spring-fed, riffle-run areas that contain mixed gravels, cobble, and sand, generally characterize the habitat. Other features include a pool-riffle ratio of approximately 1:1 with areas of slow, deep water. Generally, stream flow and water temperatures tend to be relatively stable. Stream banks are well vegetated and secure. This ensures the formation and protection of in-stream conditions that provide the necessary pools for resting, riffles for feeding, and escape cover that is normally found along undercut banks and under woody debris or large rock ledges. Seasonally intermittent streams that maintain permanent pools or flow are considered viable brook trout habitats.

A synopsis of pertinent data on brook trout habitat characteristics from published literature follows. Habitat type varies with the size of stream. Cover takes many forms; however, it is one of the most essential features that directly influence the number and weight of trout in a lotic environment. In-stream cover may include the following: depth, rocky substrate (gravel to boulders), water surface turbulence, undercut banks, over-hanging vegetation, submerged vegetation, roots, logs and miscellaneous debris jams. Minimum seasonal stream flow (typically late fall) often determines trout capacity in freestone streams. Cover for adult brook trout should be located in areas with water depths ≥ 15 cm and velocities of < 15 cm/second. Spawning substrate gravel should average between 0.3 – 8 cm diameter with an optimal diameter of 3 – 6 cm. Escape cover for juveniles and fry during winter and after emergence requires a substrate that is resistant to shifting and ranges in size from medium to large sized gravel, to small cobble.

Salmonids occupy different habitats in winter than in summer. Winter water temperatures between 4 - 8ºC trigger hiding behavior that protects trout from physical damage from ice and conserves metabolic energy. Bjornn (1971) observed trout and salmon in many Idaho streams enter the substrate when stream temperatures declined to 4 - 6ºC.

Stream flow is a critical habitat parameter that determines quality of trout habitat. Lowest flows typically occur during late summer and winter. A base flow ≥ 55% of the average annual daily flow is considered excellent, 25 – 50% is fair, and < 25% is poor for maintenance of quality trout habitat (Binns and Eiserman 1979). Brook trout often inhabit streams that receive ground water discharge (Threinen and Poff 1963) which helps to maintain suitable water temperatures throughout the summer.

Tagging data suggests that brook trout habitat in one of two southern Ontario streams shifted upstream as water temperatures in downstream areas increased during spring and summer (Meisner 1990). This study also reported that the brook trout's range in a stream was related to ground water temperature which typically equals mean annual air temperature. Elevated air temperature, increased solar exposure and related reductions in ground water and base flow, will greatly reduce available brook trout habitat, particularly in first order, headwater reaches. Brook trout in Maryland have been restricted to small headwater locations (Ray Morgan, personal communication). Maryland brook trout populations have been impacted by the presence of non-native brown trout which have further isolated them into the headwater reaches of streams (Ray Morgan, personal communication).

Water Quality

Brook trout appear to be more tolerant of low pH than other trout species. The optimal pH range for brook trout is 6.5 – 8.0 with a tolerance range of 4.0 – 9.5 (Creaser 1930; Raleigh 1982). The lower limit of survival, especially for embryos and hatchlings, was reported to be pH 4.5 (Power 1980). The pH observed in a survey of Virginia trout streams during 1975 – 1978 ranged from 6.8 - 8.5 (Mohn and Bugas 1980). Menendez (1976) demonstrated that continued exposure to a pH below 6.5 resulted in decreased hatching and growth in brook trout.

Brook trout are sight feeders and feeding can be impaired by high or persistent water turbidity. Optimum turbidity values for brook trout growth are approximately 0 - 30 Jackson Turbidity Units (Raleigh 1982). Generally brook trout habitat in good to excellent condition is not expected to experience significant or limiting levels of turbidity.

Temperature Tolerance

Temperature plays a very important role in fish growth. Water temperature that is too high or too low will decrease growth due to metabolic demands. Temperature is directly related to respiration ratewhich affects metabolic rate. Fish only grow when energy is available; therefore, growth is poor if metabolism is low. Higher water temperature causes higher metabolic costs which require longer foraging times and more consumption. Indirect influence of water temperature on fish affects growth rate by limiting food abundance, altering toxicity of water borne pollutants, and changing oxygen concentration and biochemical oxygen demand.

There is general agreement from field and laboratory studies that water temperature is the single most important factor limiting the geographic distribution of brook trout. Brook trout may be found in waters with a temperature range between 0 - 24º C. Summer stream temperature is the most important single factor influencing brook trout distribution and production (Creaser 1930; MacCrimmon and Campbell 1969). Upper and lower temperature limits for adult brook trout vary according to acclimation differences that result from seasonal temperature cycles. The literature suggests that very brief exposure to water temperatures up to 22^0C may be tolerated. However, populations are more stable and productive when water temperatures don't exceed 19^0C. Currently, the Maryland state water quality maximum temperature standard for wild reproducing trout stream designations (Maryland Department of the Environment, Use III, Natural Trout Water) is established at 20ºC.

Mohn and Bugas (1980) reported that brook trout frequently occur in Virginia streams where summer water temperatures never exceed 20^{0}C, noting that cooler night temperatures were essential to population maintenance. Barton et al. (1985) confirmed that temperature was the most significant factor determining the presence or absence of resident trout in small southern Ontario streams. They found that control of temperature and to a lesser extent turbidity and stability of discharge, can be achieved through establishment or maintenance of forested riparian buffer strips. Water temperatures in streams flowing through clear-cut areas were found to increase linearly with distance from buffered areas. Stream sections with no forested riparian buffer could increase in temperature by more than 7^{0}C at sites over 6 km downstream from buffered riparian areas (Barton et al. 1985)

The optimal water temperature range for growth and survival is from 11 - 16^{0}C (Baldwin 1951; Raleigh 1982; Drake and Taylor 1996). Baldwin (1951) identified 14^{0}C as an optimal water temperature for brook trout; with temperatures outside the range of 11 - 16^{0}C as tolerable, although growth and activity were compromised. For reproductive needs, a mean temperature of 9^{0}C is required for optimal developmental and hatching success. The upper lethal water temperature limit for hatchlings is 20^{0}C and approximately 25^{0}C for juveniles and adults, while the reported maximum temperature for growth of juvenile brook trout was 14.4^{0}C (MacCrimmon and Campbell 1969). Grande and Andersen (1991) experimentally determined an LT50 (temperature at which 50% of the population survives) in controlled studies for brook, brown and rainbow trout to be 25.2º C, 26.2º C, and 26.6º C, respectively. Tolerance limits for critical life stages should be less than 50% (TL50).

Longevity, Growth, and Food habits

Fast growing fish usually mature earlier and die sooner than slow growing fish, however, Jonasson (1991) demonstrated that longevity increased with trout body size. It is advantageous for trout to acquire a large size but only with a slow growth rate. Longevity significantly decreases with warmer water, although growth is faster. Baldwin (1957) observed that brook trout ate 50% of their own weight (in minnows) weekly at 13^{0}C; ate less at 9^{0}C and 17^{0}C; and at 21^{0}C food consumption was only 6% of body weight per week.

Review of historical data sets shows that since consistent sampling was initiated in the 1960's, Maryland brook trout populations rarely have individuals that reach or exceed 305mm in length (MD DNR data; MD MBSS data). Brook trout in Maryland are presumed to be short lived because they typically inhabit small, coldwater streams. Growth characteristics from 1,402 brook trout collected in the central portion of Maryland (Howard, Carroll, Baltimore, Harford and Cecil Counties) from 1987 - 2004 by the Maryland Fisheries Service supports this assumption (Figure 2). Brook trout growth in this portion of MD exceeded that observed (MD DNR data, 1988 – 2003) from a population of brook trout collected from western Maryland (Catoctin Mountain region, Frederick county) with higher gradient and colder streams (Figure 3, N = 2,433). Brook trout rarely exceeded 150 mm (fork length) from the Catoctin Mountain area, whereas, brook trout from the central region regularly exceed 150mm and commonly attained lengths up to 220mm. Brook trout growth in Virginia was reported to be excellent when compared to adjacent states (Mohn and Bugas 1980). Population analyses of 26 Virginia streams found brook trout with mean lengths of 146mm and 321mm total length for age 1 and age 4 fish, respectively; age 3 (254mm) was the maximum age detected in most streams (Mohn and Bugas 1980).

Behnke (1980) described two forms of longevity in brook trout he studied; a smaller, shorter-lived form (3-4 years) and a larger, longer-lived (8-10 years) form located in the northern portion of its native range. Age at maturation can vary from one or two years in southern populations to three or four years in northern populations. Longevity is three to four years in southern populations and often six to seven years in northern populations.

Brook trout are described as being opportunistic in their feeding habits. Large brook trout can be carnivorous and have been found to feed on a wide range of organisms. Scott and Crossman (1973) observed large brook trout in northern waters eating small mammals during the summer, such as field mice, voles, and shrews. Small to medium sized brook trout rely heavily upon aquatic insect larvae and terrestrial invertebrates; the literature indicates that the brook trout will consume any prey it encounters as long as it fits into its mouth. Ricker (1932) compiled a very extensive list of organisms fed upon by brook trout in a study conducted in Ontario and brook trout in Maryland would be expected to prey upon a similarly wide variety of aquatic and terrestrial insects. Common insects consumed include species of stoneflies, mayflies, caddisflies, midges and chironomids. Other food items include leeches, worms, spiders, ants, mollusks, clams, snails, cladocerans, amphipods, decapods, diatoms and any number of associated stream fishes, including juvenile brook trout and those of non-native trout.

Reproduction

Spawning begins by mid-October and is usually over by December 1 in most areas of the United States. Brook trout begin to migrate upstream in late summer, seeking gravel-bottomed areas in cold, spring-fed tributaries, and spawn in late October and early November. Populations inhabiting lakes or ponds will migrate into inflowing tributaries to spawn at this same time of year. Hokanson (1973) observed that water temperature had little influence on time of spawning, but had a major influence on spawning activity and egg viability. He found functionally mature, male brook trout with motile spermatozoa at 19^0C. Although age at sexual maturity varies among populations, males usually mature before females and size at first maturity depends upon growth rate and the productivity of their habitat.

Raleigh (1982) described suitable spawning substrate for brook trout as gravel 3 - 8 cm in diameter and ≤ 5% fines. The introduction of sediments, especially fines, may entomb embryos and reduce intergravel water flows, slow removal of embryonic wastes, and decrease intergravel dissolved-oxygen supply to embryos (Harshbarger 1975; Waters 1995). Sand concentrations greater than 15% in spawning gravel were found to reduce the numbers of emerging brook trout fry (Hausle 1973). Chapman (1988) reported that a higher percentage of fine sediment in brook trout redds was generally detrimental to the survival of fish embryos. Consequently, reproductive success of brook trout and brown trout decreases with increasing amounts of fine-grained sediment in spawning areas (Harshbarger 1975; Waters 1995). The selection of spawning substrate is determined in part by the size of the spawning female. Larger brook trout will select larger gravel substrate on which to spawn.

Redd (nest) building is done by the female and the redd is defended for a time by both the male and the female. The female remains at the redd a short time after her eggs are fertilized and the male has left. During the egg laying process, the female brook trout brushes the eggs into interstitial spaces in the gravel after each egg release and fertilization by the male, and then reworks another egg pit immediately upstream of the previously constructed pit. Females may spawn with different males. Egg deposition in Virginia was observed between October and November (Mohn and Bugas 1980). In streams, brook trout nearly always construct their redds in gravel; however, sandy bottoms with upwelling water are sometimes used. Maryland DNR Fisheries Service personnel have observed brook trout spawning over predominantly sandy substrate in Jabez Branch, an Anne Arundel County coastal plain brook trout population (C. Gougeon, personal communication).

Brook trout eggs incubate and hatch beneath the gravel substrate, and the fry absorb the yolk sac before exiting the substrate. Eggs are large, 3.5 - 5.0 mm in diameter, and fecundity is related to the size of the female. Scott and Crossman (1973) reported female brook trout having from 100 eggs for fish 144 mm in length (FL) to as many as 5,000 eggs for a female 565mm in length (FL). Oxygen tension and water temperature influence the time until hatching. Hatching times have been reported as 100 days at 5^0C, 75 days at 6.1^0C and 50 days at 10^0C (Scott and Crossman 1973). The upper lethal water temperature for developing eggs has been reported as 11.7^0C (Scott and Crossman 1973). Davis (1961) found the incubation time from fertilization to hatching varied between 7 and 13 weeks within the temperature range considered suitable for incubation (4.5 – 11.5º C). Power (1980) determined the incubation period varies with temperature, averaging 129 days at 3^0C and 60 days at 8^0C. Brook trout eggs failed to develop at temperatures above 13^0C with a suggested safe upper limit of 11.5^0C (Embody 1934; Hokanson et al. 1973). Embody (1934) also observed that a minimum water temperature of 4.5^0C was necessary during incubation to the eyed stage; however, egg development could be completed at water temperatures as low as 1.7^0C with higher mortality and less robust fry. MacCrimmon and Campbell (1969) reported a temperature range of 4.5^0C - 11.5^0C as optimal for brook trout egg development.

Diseases

Another important threat to native brook trout populations throughout its range is the introduction of non-native diseases. The most likely method of introduction is expected to originate from bait shops and fish hatchery operations. Currently, data confirming adverse impacts to wild brook trout and associated fish populations from introduced diseases has not been determined, and there isn't a state program in effect to identify and track such impacts.

Whirling disease is an introduced disease that is caused by the presence of the parasite *Myxobolus cerebralis.* To date, it has only been isolated in one watershed in Maryland. While rainbow trout are the only species in the watershed found to harbor the parasite, all fish species in the river can be carriers (fish that are infected with the parasite but have not shown any clinical disease signs). This can change as stressors in the watershed change and impact the immune systems of resident species. Other disease agents, including *Flexibacter columnaris* (peduncle disease), *Flavobacterium spp*. (bacterial gill disease) and another parasite *Ichthyophithirius multifilis* (also know as Ich or white spot disease) have been confirmed at several of Maryland's cold water hatcheries during 2000 – 2005 (S. Rivers, personal communication).

The introduction of these diseases into wild brook trout populations can be minimized by adherence to Maryland's Cold Water Policy (Figure 4) that recommends not stocking waters of the state that contain wild trout populations. To further protect native populations, Code of Maryland Regulations (COMAR) 08.02.11.04K restricts introductions and transfers of fish species in Maryland waters without written permission of Fisheries Service in order to prevent the introduction and spread of exotic diseases. Work during the 1990's resulted in a document entitled "Aquatic Animal Health Policy and Implementation Plan" that was signed as a Memorandum of Understanding between the Secretaries of the Maryland Department of Agriculture and Natural Resources. This document provides a guide to aquaculture in the state and should prevent the introduction of pathogens and disease agents (S. Rivers, personal communication). Care must also be exercised not to stock into interconnected watersheds with access to known populations of wild brook trout. Brook trout in the wild have been reported to suffer from any number of parasites that include a long list of trematodes, cestodes, acanthocephalans, and nematodes.

CURRENT STATUS OF MARYLAND'S BROOK TROUT RESOURCE

DNR Inland Fisheries Management division monitors the status of brook trout populations in Maryland. DNR's Maryland Biological Stream Survey (MBSS) program collects additional information on brook trout population status as supplemental information to their statewide stream monitoring program, and academic institutions also collect data during their specific monitoring and research efforts. Brook trout population monitoring efforts by the Inland Fisheries Management division are performed annually as part of Federal Aid in Fish Sport Restoration grants received from the United States

Fish and Wildlife Service. Historically, brook trout population sampling frequency and methodology have been determined by the Inland Fisheries Management Regional fisheries managers, with the intent of sampling all populations at least once every five years; an objective that has not been met due to shortages of staff, funding, and time.

The resource assessment completed for this management plan was based on reviewing the most comprehensive and recent Inland Fisheries five-year Federal Aid Report listing of brook trout streams (H. Stinefelt, personal communication) and comparing the list with the data from more recent Inland Fisheries Division surveys, the MBSS statewide database, and the University of Maryland Appalachian Laboratory historic database. Population status was accorded when multiple year classes were present with multiple individuals per year class. Streams where only one to several individuals were collected are not listed as supporting populations. The length of stream where brook trout populations occurred was estimated from USGS quad maps and verified by regional fisheries biologists. In many cases, stream length varied seasonally or downstream limits to brook trout populations were not documented, thus stream length inhabited was estimated by the biologists based on their extensive understanding of the stream acquired over decades of experience. Additional brook trout resource information was garnered from Hudy's et. al manuscript (2005) on the status of brook trout populations in the eastern United States.

As of fall 2005, there were 151 streams (including unnamed tributaries) in Maryland supporting brook trout populations,109 for which brook trout were the only trout species present. For the other 42 streams, 33 supported a mixed population of brook and brown trout, 6 supported a mixed population of brook, brown, and rainbow trout, and 3 supported a mixed population of brook and rainbow trout (Tables 1 - 2). The amount of stream length supporting brook trout populations was estimated at 607.4 km (379.6 miles) statewide; 397.4 km (248.4 miles) for which brook trout were the only salmonid species present (Tables 1 - 2). Estimated stream length of combined mixed brook and other trout species totaled 210.0 km (131.3 miles); 137.6 km (86 miles) brook and brown trout streams; 68.4 km (42.8 miles) brook, brown, and rainbow trout streams; and 4.0 km (2.5 miles) brook and rainbow trout streams (Tables 1 - 2).

Land ownership along Maryland streams supporting brook trout populations was broken into three categories: 1) streams on public land, 2) streams on public and private land, and 3) streams on private land only. Only 17 streams (11.3%) were fully on public land, 72 (47.7%) were on public and private land, and 62 (41.0%) were fully on private land (Table 2). For stream length (km), only 71.7 km (44.8 miles) (11.7%) were fully within public lands, 319.5 km (199.7 miles) (52.6%) were within public and private lands, and 216.7 km (135.4 miles) (35.7%) were fully on private lands (Tables 1 - 2). Based on these calculations, an estimated 11% of brook trout streams and stream miles are fully on state owned land, while an estimated 35.7% of brook trout stream kilometers (62 of 151 streams) are fully within private ownership.

Geographically, Maryland is divided into five provinces: the Appalachian Plateau, the Piedmont, the Coastal Plain, the Blue Ridge, and the Ridge and Valley (Figure 1).

Historically, brook trout populations were mainly in the Appalachian Plateau, Ridge and Valley, Blue Ridge, and Piedmont areas with a few populations extending downstream from Piedmont populations into the Coastal Plain. At a finer scale, these five areas are broken down into eighteen river basins of which brook trout now occur in eight. The two westernmost basins, the North Branch Potomac and the Youghiogheny combined, have over half (52.3%) of all statewide brook trout streams and account for 42% of all brook trout stream length statewide (256.6 km). The Gunpowder basin supports the next highest number of brook trout stream populations (31, 25.2%) followed by the Middle Potomac (16, 10.6%), Susquehanna (8, 5.3%), Patapsco (7, 4.6%), Upper Potomac (2, 1.3%), and the West Chesapeake (1, <1.0%). Brook trout only populations are most prevalent (75.9%) in the two westernmost river basins (North Branch, 42 of 48 populations or 87.5%); Youghiogheny, (19 of 31 populations or 61.3%) as compared to the Gunpowder basin where almost half (18 of 38 populations or 47.3%) of all brook trout populations occur with brown trout populations.

Population densities for brook trout are dependent on habitat variables (natural) and anthropogenic impacts. In the most pristine habitats, numbers of adult (age 1+) brook trout can range as high as 2,874 adult fish per kilometer (Little Savage River, 2004). Table 3 lists population densities (number of adults (age1+) brook trout per stream km) for populations that have been sampled in the last ten years by DNR Fisheries and MBSS programs.

Population fragmentation is common among brook trout populations in Maryland’s river basins. In all basins, the vast majority of streams are reproductively isolated from historic connections through anthropogenic alterations to habitat, barriers, and exotic introductions. The North Branch basin supports the only fully interconnected brook trout system, the headwaters and tributaries of the upper Savage River above the Savage River reservoir, most of which are contained in the Savage River State Forest. This system consists of 12 named streams comprising 94.3 km of fully interconnected brook trout populations with no physical or chemical barriers to movement. Including the brook trout streams that flow into the reservoir and may have some connectivity to each other and the upper Savage (if the trout are able to migrate successfully through the reservoir), these numbers increase to 18 named streams and 145.1 km (Figure 5) or approximately 24% of all brook trout stream kilometers in the state. Throughout the rest of the state no other system approaches this level of connectivity. For example, in the Gunpowder basin (in central Maryland) with the second highest number of brook trout streams, the vast majority of brook trout populations are confined to headwater portions of streams with no connectivity to other populations because of physical (blockages, high water temperatures, etc.), chemical (pH), and biological (brown trout competition) barriers (Figure 6). In the mainstem North Branch Potomac River above the Jennings Randolph Reservoir, brook trout tributary populations are isolated by chemical, physical (AMD inputs, high summer water temperatures, disrupted hydrology) and biological blockages (smallmouth bass presence) that prevent movement between systems.

Hudy et. al (2005) conducted a survey and analysis of brook trout population status for the entire range of the eastern brook trout. Biologists from DNR Inland

Fisheries and researchers from the UMCES-AL collaborated on this project and provided information on brook trout population status, both historic and current, and projected environmental and anthropogenic stressors. Watershed evaluations were done at a 6^{th} level hydrologic unit (HU) scale (mean size 8,279 ha, USGS 2002), referred to by Hudy et. al (2005) as subwatersheds. This unit was selected because the size is similar to that of the commonly used USGS topographic quadrangle maps and also because it was the smallest unit in which whole streams were typically contained.

As a result of the cooperative study, the following parameters were summarized. Maryland is divided into 320 subwatersheds, of which 187 (59%) historically were outside the native range of brook trout. Of the 133 subwatersheds that were within the native range in Maryland, brook trout have been extirpated from 83 (62%) and remain in 50 (38%) (Figure 7). Delving further into these statistics makes the current status of Maryland brook trout populations clearer. Hudy et. al (2005) rated the status of a population according to three categories based on information provided by state biologists: 1) *Intact*, > 50% of all native habitat in the subwatersheds supports self-sustaining brook trout populations; 2) *Reduced*, 10% to 50% of native habitat in the subwatersheds supports self-sustaining brook trout populations; and 3) *Greatly reduced*, 1% to 10% of native habitat in the subwatersheds supports self-sustaining brook trout populations. Only 3 (6%) subwatersheds in Maryland met the *intact* criteria, 5 (10%) were in the *reduced* category, and 42 subwatersheds (84%) were in the *greatly reduced* category. All 3 of the *intact* subwatersheds are located in western Maryland (Garrett and Allegany counties). In summary, of the remaining 38% of subwatersheds in Maryland that have self-sustaining brook trout populations, only 3 are *intact* with the majority (84%) being *greatly reduced*, i.e. only 1 - 10% of native habitat is occupied.

Hudy et. al (2005) also looked at land use practices in the watershed compared to brook trout population status. Within the Mid-Atlantic region (MD, PA, WV, VA, NJ) they found that when human land use (any human-caused change from the pre-settlement habitat type) exceeded 18% within a subwatershed, brook trout extirpation was likely. *Intact* populations were most likely to be found in subwatersheds where human land use was less than 10%. In Maryland, the top five reasons cited by state biologists and UMD researchers for loss and degradation of brook trout populations statewide were: 1) high water temperatures, 2) agriculture, 3) urbanization, 4) exotics (brown trout), and 5) poor riparian habitat.

FISHERY CHARACTERISTICS

History of Brook trout management in Maryland

State directed management of fish stocks was first initiated in Maryland in 1874 when the state legislature established a Commissioner of Fisheries position, a response to complaints of deteriorating fish stocks (Powell 1967). The commissioner was charged with establishing a system to replenish fish populations through aquaculture and controlled management of the waterways of the state. The initial effort at brook trout management arose from the recognition that severely degraded brook trout habitat in the eastern portion of Maryland had reduced populations leading the commission to authorize the propagation of brook trout in hatcheries. Brook trout eggs were obtained from Maine and Rhode Island (Powell 1967) in 1877 and 50,480 yearling brook trout were distributed to the public for stocking. The popularity of this program grew steadily and brook trout were cultured statewide until the early 1970's when their production was phased out and replaced primarily with rainbow trout. Sources of brook trout for culture were from a variety of other state sources up until 1949, when trout from New Jersey were used to establish a brood stock. An 1897 recommendation by the Commissioner of Fisheries stated that eggs should be obtained from Maryland fish only but the recommendation was not heeded, From 1877 through-1948, eggs were purchased from a variety of states. In 1949, trout from New Jersey were used to establish a brood stock. Popularity of the propagation program grew steadily and brook trout were cultured statewide until the early 1970's, when production of brook trout was phased out and replaced primarily with rainbow trout. The management of brook trout in Maryland up until the 1980's was primarily hatchery oriented for stocking purposes.

The MD DNR Inland Fisheries Management Division's Coldwater Management Policy (Figure 4) has had the most significant influence over brook trout management and regulation in Maryland. Adopted January 3, 1986, the policy established criteria for regulations and stocking protocols for the management of trout resources in Maryland. Specific topics covered in the policy include: habitat, research, natural trout populations, laws and regulations, hatchery trout, cooperative trout production projects, put and take trout fishery, private water trout stocking, public access to trout fishing waters, and public information and education.

Based on the Coldwater Management Policy, Maryland fishery managers have attempted to minimize or eliminate the stocking of hatchery trout where wild trout populations occur to achieve "*no appreciable impact upon the natural trout resource*". In Glade Run (Garrett County), Owens Creek (Frederick County) and Fishing Creek (Frederick County), put and take trout management was eliminated in streams where wild brook trout or naturalized brown trout were present and/or potentially limited by the presence of hatchery trout and the associated increase in fishing pressure. In each of these instances, when stocking was eliminated, wild brook trout standing crops increased (J. Mullican, personal communication). In areas like the Savage River (upstream of the Savage Reservoir) and the North Branch (upstream of Jennings Randolph Lake), where strong native brook trout populations occur, stocking put and take areas or delayed harvest for trout fishing areas, has been limited to rainbow trout in order to minimize the potential for stocked trout to establish reproducing populations.

Special Management areas where brook trout are present

Maryland DNR does not have a management program specifically directed toward brook trout populations. However, there are several areas where the management program is geared towards a multi-species wild trout fishery that includes brook trout.

Savage River

The lower Savage River below the Savage Reservoir is located in Western Maryland, Garrett County, and is approximately 4 miles in length. For at least 50 years prior to 1987 the Savage River and later the Savage River tailwater area were regulated as a put and take trout fishery. Fisheries Service staff documented a wild brook trout population downstream of the Savage River Dam in 1982 (C. Gougeon, personal communication). A "Trophy Trout Fishing Area" was established in 1987 to enhance wild trout populations from the dam one mile downstream to the derelict Piedmont Dam, with the initial intent of developing a “world class tailwater brook trout fishery” (personal communication, R. Bachman). The regulation eliminated the use of bait, established a 12" minimum size and a five trout per day creel limit. A 9" minimum size limit for brook trout was established downstream of the Piedmont Dam at the same time. The regulation was further modified to extend the Trophy Trout Fishing Area to include the area from the Savage River Dam downstream to the Allegany suspension bridge. Put and take trout management was continued in the remainder of the Savage River tailwater. Due to the success of the regulations in developing a fishery for brook trout and an unexpected brown trout fishery, fishery regulations regarding the special area were further modified. New regulations became effective in 1991 and included the entire Savage River tailwater from the Savage River Dam to the North Branch Potomac River. The modified regulations established a fly- fishing only area from the Savage River dam to the Allegany suspension bridge, a distance of approximately 1.25 miles, and excluded all other types of fishing. The remaining tailwater area was restricted to the use of artificial flies or lures, including those equipped with treble hooks. Minimum size limits were 12" for brook trout and 18" for brown trout with a 2 trout daily creel limit. The stocking of hatchery trout was completely discontinued throughout the Savage River tailwater after 1990. Effective January 1, 2004, regulations were further modified to require the use of a single hook point on artificial lures and flies in the Savage River tailwater, specifically intended to reduce the hooking mortality of wild brook trout caught on artificial lures. Initially, the standing crop of brook trout increased once stocking ceased, but the unexpected establishment of brown trout at the same time steadily reduced the brook trout population. Standing crop data illustrate this inverse relationship; as adult (age 1+) brown trout numbers and biomass have increased, there has been a corresponding decrease in brook trout numbers and biomass from 1987 to 2003 (Figure 8).

North Branch Potomac River

The coldwater fishery section of the North Branch Potomac River is located in Western Maryland, Garrett and Allegany counties, and is approximately 63 miles in length with 33 miles above Jennings Randolph Reservoir and 30 miles downstream of the dam. The construction of Jennings Randolph Reservoir by the U. S. Army Corps of Engineers, completed in 1982, resulted in improved water quality downstream in a watershed characterized by acid mine drainage (AMD) pollution and degraded water quality. Native brook trout, as well as naturalized brown trout, were successfully reproducing in the Jennings Randolph Dam (JRD) tailwater area by 1990 (A. Klotz, personal communication). By 1994, AMD remediation efforts in the watershed improved water quality in the North Branch upstream of the JRD further enhancing water quality in the tailwater area. At this time, special regulations were implemented on two stream sections in the tailwater to enhance wild trout populations. A catch and release trout fishing area 0.8 miles in length was established 0.4 miles downstream of the JRD. A second catch and release trout fishing area, approximately four miles in length, was located about 2.5 miles downstream of the JRD. Both areas are limited to artificial flies or artificial lures and adult hatchery trout are not stocked in either area. Put and take trout management has continued on the 1.25 mile stream segment between the catch and release areas. Native brook trout, most likely augmented by seasonal migrations from tributary populations, comprise only a small segment of the overall wild trout population in the North Branch (A. Klotz, personal communication).

Youghiogheny River

The Youghiogheny River flows north through Garrett county in Western Maryland before entering Pennsylvania and is part of the Mississippi River drainage system. The river and its tributaries are in the historic native brook trout range and likely supported native brook trout populations throughout the watersheds. Early accounts (late 1700's) of the first English settlers, in what is now Garrett County, mention brook trout ascending Sang Run from the mainstem Youghiogheny during mid-summer, possibly in response to elevated water temperatures. Garrett County was extensively logged over a relatively short period of time around the turn of the 19th century. Agricultural development and coal mining (both surface and deep mine) increased rapidly at about the same time as the logging occurred. All of these activities would have most likely resulted in a significantly higher water temperature regime within the mainstem river.

Albert Powell, an early pioneer in Maryland fisheries management, reported that the Youghiogheny was well known for its high quality smallmouth bass fishery in the 1920's. Smallmouth bass are native to the basin and probably increased their upstream distribution as water temperatures increased. It is likely that wild brook trout were already restricted to tributary streams due to temperature constraints by the time that smallmouth bass became common in the mainstem. However, some trout were present and Powell (1967) reported that rainbow and brown trout were introduced into the river during the late 1800's. A good trout fishery for these species existed until September 1929, when a sudden low pH spike related to activities at the Crellin Mine, wiped out virtually all fish life in the downstream section of the river in a single day. Poor water quality continued for several decades until the Crellin Mine ceased operations around 1950.

Water quality gradually recovered in the Youghiogheny. Further improvements in water quality were realized from modern anti-pollution requirements for coal mining, reclamation efforts on old abandoned mine sites, and improved forest management practices. Currently, agricultural activities dominate the watershed. As a result, forest cover in the watershed is only a fraction of the total forest canopy that existed when settlers first reached the area. While summer water temperature regimes will not support brook trout survival in the mainstem river, virtually every tributary characterized by perennial flow, good water quality, and suitable water temperatures does support viable brook trout populations. Seasonal movements of trout into the river are likely, and anglers occasionally catch brook trout in the mainstem. Fisheries management in the river is geared towards put-and-take fishing and a special regulation catch-and-release area downstream of the Deep Creek Lake power plant water release. A viable smallmouth bass population exists throughout the river's mainstem.

Big Hunting Creek

Big Hunting Creek is located in the Catoctin Mountains region, Frederick County, Maryland, in the central portion of the state and flows through Cunningham Falls State Park and Catoctin National Park. Historically, the headwater area of Big Hunting Creek and several tributary streams supported native brook trout populations prior to modern fishery management efforts. A portion of Big Hunting Creek within Catoctin National Park was designated as a fly fishing only area as early as 1938 (J. Voight, personal communication), although harvest was permitted. Catch and release, fly fishing only regulations were adopted for Big Hunting Creek within the boundaries of Catoctin Mountain Park in 1965. After the completion of Cunningham Falls Lake in 1972, catch and release, fly fishing only for trout was extended upstream to the reservoir and the area of Big Hunting Creek upstream of the reservoir. After 1974, trout stocking upstream of the reservoir was curtailed to protect and enhance the wild trout population, presumably only native brook trout. However, at least 3000 adult brown trout were stocked above Cunningham Falls Lake in 1974 and may account for the wild brown trout population that exists there today. Also in 1974, the catch and release regulation was modified to permit the harvest of one trout per day over 15". The regulation was again modified in 1983 to permit catch and release trout fishing only using artificial flies which eliminated all harvest of trout. In 1983, the National Park Service (NPS) determined that Catoctin Mountain Park was within NPS jurisdiction and began enforcing fishing regulations. In 1993, the NPS and DNR approved a Fishery Management Plan for Big Hunting Creek which endorsed the continuation of catch and return, fly fishing only for the stream and its tributaries.

Currently, native brook trout occur in Big Hunting Creek upstream of Cunningham Falls Reservoir and in Hauver Branch, a tributary stream that enters the reservoir. They also occur in the tributaries downstream of the reservoir, Distillery Run and Ike Smith Creek. The wild trout population in the mainstem of Big Hunting Creek downstream of the reservoir is primarily composed of brown trout.

Little Hunting Creek

Little Hunting Creek is located in the Catoctin Mountains region, Frederick County, Maryland, in the central portion of the state and flows primarily through private property (through Cunningham Falls State Park) and into Big Hunting Creek (downstream of Cunningham Falls Reservoir). Put and take trout management was eliminated in Little Hunting Creek in 1994 in order to promulgate wild trout management under catch and release fishing only and limited to artificial lures or flies. The catch and release area was extended further downstream in 2000. Originally intended to enhance the existing wild brown trout resource, the management change has also resulted in a smaller but consistent wild brook trout component in Little Hunting Creek (J. Mullican, personal communication). Wild brook trout were not collected in sampling efforts in Little Hunting Creek prior to 1994 and apparently recolonized the area after put and take trout management was eliminated.

Gunpowder Falls

The Gunpowder Falls special trout management area is located in Baltimore County, Maryland, from the base of Prettyboy Reservoir to the head of Loch Raven Reservoir. Coldwater management in the river encompasses three different regulatory areas;, a catch and release section, a wild trout section (general statewide regulation), and a put and take section. Historic summer water temperature regimes in the river have been marginal for brook trout survival (C. Gougeon, personal communication). Brook trout are occasionally captured, most likely, as seasonal migrants from native populations in several tributaries. The few brook trout encountered are considered transients from tributaries and do not represent a significant mainstem population.

RECREATIONAL FISHERY STATUS

Little information on historical or current recreational use and economic value of Maryland’s brook trout fishery resources is available. To date, no effort has been made to quantify angling pressure and harvest on Maryland’s brook trout streams. However, the Pennsylvania Fish and Boat Commission recently conducted an angler creel survey on wild trout waters (wild trout defined as any self sustaining population of brook, brown, and rainbow trout) in Pennsylvania (T. Green, personal communication). While not specifically directed towards brook trout, the study determined catch and harvest rates by species and divided the streams into two size groups: width > 6m and width < 6m. Similar to Maryland, the majority of brook trout streams in Pennsylvania are less than 6m in width. A number of the findings from this study may be similar to what is occurring in Maryland, based on the similarity in brook trout stream sizes and geographic region. Angler effort was greater on weekends than weekdays and overall effort was low, ranging from 12 - 15 angler hours/kilometer. Catch rates of brook trout were high (1.76 trout/hour) but harvest was low.. Approximately 92% of all trout caught were released.

Anglers harvested 12.7 brook trout per kilometer of stream, a very low number when compared to typical population densities in Maryland's stable brook trout populations of 200 - 300 adult trout/kilometer. In comparison with a stocked put-and-take trout stream in Maryland, the angler effort in Big Elk Creek during the 1998 opening weekend was estimated at 880 angler hours/kilometer (A. Heft, personal communication). This area does not have a wild brook trout population,. The economic impact of wild trout fishing in Pennsylvania was estimated at $45.00 per day on average when angling for brook trout. Overall, it was estimated that direct and in-direct expenses contributed more than $2 million annually to local economies.

Maryland Inland Fisheries Management Division conducted a voluntary web survey in 2004 focused on brook trout. There were 156 responses and the results suggested that use and exploitation of the brook trout resource in Maryland was similar to the Pennsylvania results. Angler response regarding harvest of brook trout was reported as never (62%), seldom (23%) and occasional (13%). The majority of anglers (87%) used artificial baits (flies 71%, lures 16%) while only 9% used live bait. Angler motivation for pursuing brook trout was primarily to enjoy the natural surroundings with the opportunity to fish for a native species (65%). Other responses included the angling challenge (8%), the aesthetic conditions (wilderness, undeveloped, etc.) associated with a brook trout stream (8%), and a combination of these responses (15%).

REGULATORY HISTORY AND STATUS

Regulatory authority for brook trout management in Maryland is the responsibility of the Maryland Department of Natural Resources, Fisheries Service, Inland Fisheries Management Division. The Department has the authority to promulgate regulations in relation to fishing seasons, creel limits, methods, and related aspects of the fishery as needed. Presently, managers propose regulation changes on a two- year schedule with a public comment period and public informational meetings to allow discussion and input.

Fishing regulations protecting brook trout were more conservative in Maryland during the latter part of the 19th century and early into the 20th century, particularly with regard to seasonal fishing restrictions. For example, an 1878 regulation in Baltimore County prohibited the harvest of brook trout for a period of three years. In Maryland, there are currently no specific regulations for brook trout populations, although there are a number of specially regulated trout fishing areas to protect and enhance wild trout populations. At present, the vast majority of brook trout populations are not under special management regulations and are regulated under the generic statewide trout regulation: no closed season, no minimum size, and a daily and possession limit of two.

A review of the history of trout regulations in Maryland demonstrates that in the late 1800's and early to mid-1900's there was directed management of brook trout (Table 4). In the late 1960s, a statewide regulation of no closed season, no minimum size, and a creel limit of seven was enacted. In 1975, this regulation was modified to a 5 fish creel limit west of Frederick County and a 3 fish creel limit east of Frederick County. The modification provided additional protection to wild trout populations in the eastern part of the state. In 1983, this protection was eliminated from the regulation and the statewide creel limit became 5 trout per day with no minimum size or closed season. Finally, in 1987, the regulation affecting brook trout populations was changed to its current form which includes a reduced daily creel limit of 2 fish and no closed season or minimum size.

ANTHROPOGENIC IMPACTS

Urbanization

Urbanization is the process by which the proportion of a population living in and around a city increases, resulting in increased development, increased density of infrastructure (roads, schools, shopping malls, office space, etc.) and loss of undeveloped areas (forests, fields, vegetated riparian zones, etc.). The impacts of urbanization on brook trout streams are numerous and affect most aspects of the healthy functioning of a stream system. Some examples of direct impacts include increased impervious surface, loss of riparian buffer, loss of stream shading, change in surface and sub-surface hydrological regimes, increased sedimentation, reduced flow, increased high flow events, changes in channel morphology, and changes in physical makeup of streambed composition.

Maryland's geographic location on the Eastern seaboard and its close proximity to large cities and the nation's capital has helped to create a burgeoning human population. Since 1990, the state's population has increased 15.7% (from 4.7 million to 5.5 million in 2004) and is predicted to reach 6.4 million by 2030, an additional 12% increase (Maryland Department of Planning statistics). Most of the increase has occurred in counties east of the Catoctin Mountains, in areas where surviving brook trout populations are already fragmented and at risk. Examples of this include: Frederick County's Antietam creek watershed, where urban land use has increased from 9.4 % in 1973 to 22.7% in 2000; Deer Creek in Harford and Baltimore counties, where urban land use has increased from 4.0% in 1973 to 12.4% in 2000; and Little Gunpowder falls in Baltimore county, where urban land use has increased from 12.3% in 1973 to 24.0% in 2000 (Maryland Department of Planning statistics).

Using Hudy's et al. (2005) summary of stressors affecting brook trout populations in Maryland, state biologists and University of Maryland researchers identified urbanization as a high or medium impact in 100 of 145 subwatersheds where brook trout historically occurred. Increased water temperature is a major impact of urbanization on a watershed, and water temperature is a critical component of brook trout life history. Maryland's analysis mirrors the finding from Hudy et al. (2005) that 79.3% (106 of 145 subwatersheds) of Maryland's historic and current brook trout streams are impacted by high water temperatures. Hudy et al. (2005) also predict that when human land use (development, homes, agriculture, etc.) within a subwatershed exceeds 18%, brook trout habitat is impacted and populations will not survive. In Maryland, this has already been demonstrated in the last decade by the loss of brook trout populations in Baltimore county watersheds (Gunpowder basin) and the Antietam creek watershed (Stranko et al. 2006).

The mitigation of impacts from urbanization is both a challenge and a necessity in order to preserve, protect and enhance the brook trout resources of the state. Brook trout populations are extremely sensitive to the cumulative impacts that occur with increasing urbanization. Empirical data and historical brook trout extirpations support the understanding that there are critical thresholds for brook trout survival in Maryland.

Impervious surfaces

Urbanization promotes a chain of events that are strongly correlated with increasing imperviousness. Impervious surfaces associated with urban areas include roads, rooftops and parking lots. Imperviousness promotes rapid runoff to aquatic habitats and disrupts the natural hydrology of flowing waters. Frequent, short duration runoff events with higher magnitude peak discharges result in large-scale physical alterations to streams. Point and non-point discharges originating from wastewater treatment facilities and storm water management facilities can combine in an urban area to compound impacts to water quality and hydrology. High watershed imperviousness is responsible for decreasing stream discharge during low flow periods; reducing in-stream physical habitat; and, increasing stream temperature, embeddedness, erosion and sediment transport. High imperviousness can significantly reduce ground water recharge that can impact ground water influx to headwater streams. The response to high impervious cover and high magnitude, frequent discharge is for the stream channel to increase in cross-sectional area by down cutting, channel widening, or both. Urban areas typically have higher pollutant and nutrient loads. All such impairments degrade and threaten existing brook trout habitats and their biological community structure. Maryland DNR's MBSS program (Southerland 2005) found that brook trout populations were eliminated in watersheds with impervious surface exceeding 4%, and substantial reductions in populations are apparent with as little as 0.5% imperviousness (Figure 9).

Acidification- Atmospheric, Acid Mine Drainage (AMD)

The burning of fossil fuels has promoted acid deposition across the native range of the brook trout. Acid deposition results from the release of nitrogen oxide, sulfur dioxide and ammonia into the atmosphere. Prevailing weather patterns are generally the transporting mechanism for acid deposition that often originates miles from the source. The Maryland MBSS program reports that acidic deposition from atmospheric input is the most common source of stream acidification in Maryland. Impacts on brook trout populations in Maryland are primarily from the Catoctin Mountains and westward, where the acid neutralizing capacity (ANC) is poor due to the geology and land use within the watersheds.

Acid mine drainage (AMD) is the other main source of acidification impacting brook trout streams in Maryland. A large portion of the native range of brook trout lies within the Appalachian coal producing states, including Georgia, Tennessee, North

Carolina, Virginia, West Virginia, Maryland, and Pennsylvania (Figure 10). Coal production from these states was approximately 35% of the national total in 2003 (U.S. Dept. of Energy, Energy Information Administration). Regardless of the specific mining method, the nature of coal mining results in disturbances to the environment. For example, within the Appalachian coal states it has been estimated that since the early 1900's over 17,000 km of streams have been polluted by acid mine drainage (AMD) from more than 65,000 documented sources of coal mine drainage (U.S. Environmental Protection Agency, Mid-Atlantic Integrated Assessment 2001). In Pennsylvania alone, the United States Geological Survey (USGS) estimates that more than 5,500 km of streams and associated groundwaters have been contaminated (U.S. Environmental Protection Agency, Mid-Atlantic Integrated Assessment 2001). In Maryland, water flowing from the Kempton Mine discharge, an abandoned deep mining operation in the headwaters of the North Branch Potomac River, has a pH of 2-3. Since 1950, it has discharged in excess of 91,600 tons of acid and 14,700 tons of iron and aluminum into the river (M. Garner, personal communication).

Federal recognition of the environmental impacts of coal mining resulted in passage of the Surface Mining and Reclamation Act (SMCRA) of 1977 (Public law 95-87). Specifically mentioned in the Findings Section (SEC 101, c) was the impact on fish: "many surface mining operations result in disturbances of surface areas …destroying fish and wildlife habitats…" This legislation initiated environmental mining impact standards that provided some minimum protection for brook trout populations and also enabled state governments to begin the process of reclaiming abandoned mine sites and restoration of water quality. However, a legacy of enormous environmental problems remains including reclamation of abandoned sites and the development of controversial new mining practices, such as mountaintop removal.

Currently, brook trout populations in Maryland are primarily affected by coal mining in two ways: impacts from abandoned mine sites (typically AMD) and ongoing mining operations and reclaimed sites. Abandoned mine sites are prevalent throughout the Appalachian region of the brook trout range, and Maryland is no exception (Figure 11). These sites affect brook trout populations by altering water quality through contaminated groundwater and runoff. The chemistry of coal and surrounding rock layers in the Appalachian region (high pyrite levels) is such that once exposed to water and air the water becomes highly acidic, hence the origin of the term acid mine drainage. This high acidity also allows the release of naturally occurring metals (i.e. iron, aluminum, and manganese) in the rock, coal layers, and spoils that are toxic to aquatic organisms. Ongoing mining affects are due to the very nature of surface and deep mining, where practices such as overburden removal, storage of waste materials, creation of wash ponds, hydrological disruptions, and subsidence, all create environmental impacts which are unavoidable. Table 5 provides a list of many of the documented impacts of both surface coal mining and deep coal mining. These impacts are detrimental to the health and survival of brook trout populations and other aquatic biota, even if they are later reduced or eliminated upon reclamation.

The stream miles in Maryland impacted by AMD and mining are in a portion of the state (Garrett and Allegany counties) where the environmental conditions and low potential for urbanization otherwise create favorable conditions for long term survival of brook trout populations (Figure 10). Reclamation and restoration of impacted streams in this area of the state will provide the best opportunities to create and maintain brook trout populations, and will reconnect and reduce fragmentation of already existing populations.

Agriculture

Agriculture was listed by Hudy et al. (2005) as having the second most important negative impact on brook trout populations in Maryland. Much of the impact is historical, with the loss occurring decades and even centuries ago. Historical conversion of forested land to agricultural use created a suite of negative environmental impacts similar to what occurs in urbanization: higher water temperatures, increased sedimentation, hydrology changes, stream bank erosion, and the loss of riparian cover along the streams. The addition of livestock exacerbates these problems by damage to stream banks and substrate and the addition of nutrients (manure).

Over the last several decades recognition among the agricultural community, resource managers, and state and federal regulatory agencies of the importance of protecting our streams from the negative impacts of agriculture has resulted in the creation of numerous incentive and conservation programs to protect these lands and associated waters. Federal and state programs such as the Conservation Reserve Enhancement Program (CREP), Wildlife Habitat Initiative Program (WHIP), and others provide cost-share and reimbursement incentives to farmers to protect stream banks, plant cover crops, fence livestock out of streams, and a variety of other best management agricultural practices. The greatest opportunity to protect the brook trout resource lies in utilizing these programs to assist farmers in protecting stream habitats where brook trout populations persist. Few opportunities to restore extirpated brook trout populations exist in agricultural areas where the habitat changes are already too severe. The rapid urbanization and population growth occurring in Maryland's rural agricultural communities further reduces the potential for restoration.

Barriers

Fish barriers that impact brook trout populations in Maryland range from physical structures (i.e. dams, impounded water upstream of a dam) to water conditions (acid inputs, thermal barriers) to biological barriers (exotics such as brown trout). Most brook trout populations in Maryland are restricted to the upper portions of streams so physical blockages are not typically a problem. In some cases, blockages protect populations by preventing the spread of brown trout from downstream populations.

A more common problem in Maryland is the barriers caused by physical (water temperature, impounded water) and chemical (acidity) impacts. Fragmentation (lack of interconnectivity with other populations) of brook trout populations due to these impacts occurs to some extent in virtually all of Maryland, even in the most intact watersheds such as the Savage River. Examples include: high summer water temperatures that exceed brook trout tolerance; acid inputs that isolate populations to specific portions of a stream year round; and impounded waters that isolate stream populations.

Fragmentation of populations is detrimental to the long term genetic stability and survival of a population, as discussed in the genetics section of this management plan. In addition, physical and chemical barriers (either seasonal or permanent) can limit or eliminate the ability of a population to recolonize suitable habitat after natural events such as a drought, or an anthropogenic event causing population extinction (water regime disruption, chemical spill, etc.). Reconnecting isolated brook trout populations within subwatersheds, at a minimum, will be vital to the long term survival of brook trout in Maryland.

Exotic species

The impacts of exotic fish species on brook trout populations have been well documented throughout the native eastern brook trout range. Exotic species include smallmouth bass *Micropterus dolomieui* and muskellunge *Esox masquinongy* in the New England states and rainbow and brown trout throughout the entire range. In Maryland, brown trout are currently the only exotic that has been documented to have had a significant negative impact on brook trout populations. The literature is extensive on the negative impacts that brown trout, both wild and stocked, can have on native brook trout populations (Fausch and White 1981; Waters 1983; Fausch 1988). There are several mechanisms by which brown trout negatively impact brook trout, primarily from competition for similar resources between two species that share similar ecological and physiological requirements. Field and laboratory studies have demonstrated the specific competitive interactions that lead to brown trout dominance. These include: competition for spawning sites and inter-specific competition among males for females (Grant et al. 2002); competition for food, feeding trials with wild and hatchery brook and brown trout showed that brown trout outperformed and out-competed the brook trout (Dewald and Wilzbach 1992); niche replacement, where the two species have occurred together the removal of brown trout led to significant increases in brook trout populations (Waters 1983; Ault and White 1994); differential mortality rates due to predation and angling, brown trout are less susceptible to angling pressure and predation (Cooper 1953; Alexander 1977); food habits, larger brown trout are highly piscivorous and have been shown to routinely prey on brook trout (Alexander 1977); differential growth rates and life history traits, brown trout have shown higher growth rates when sympatric with brook trout (Dewald and Wilzbach 1992); and brown trout exhibit higher aggressiveness and territoriality (Kalleberg 1958; Fausch 1984; Dewald and Wilzbach 1992).

Brown trout impacts on brook trout populations in Maryland have been extensive, particularly in the Gunpowder River system. The mainstem Gunpowder supports a high density wild brown trout population (C. Gougeon, personal communication) and an extremely popular wild trout fishery. The distribution of brook trout in this system is limited to the headwaters of tributary streams (Figure 6). Even though year-round water temperatures in the mainstem Gunpowder River (tailwater) are more than adequate for brook trout, there is not a self-sustaining population. Fragmentation of the brook trout population in this system, maintained by the presence of an abundant wild brown trout population, puts the brook trout resource at risk of genetic extinction and extirpation due to stochastic events since natural recolonization is not possible. Long term population monitoring in the Savage River tailwater has shown a steady decline in the native brook trout population and is strongly correlated to the increase in the wild brown trout population (Figure 8). There are no records in Maryland where brook trout have out- competed brown trout.

The brown trout is a vital component of recreational fisheries management in Maryland, but recognition of the detrimental impact this species has on brook trout populations is vital to conserving the native brook trout. Conservation and restoration efforts will have to take into account the presence of brown trout within a system, and restoration of some brook trout populations may have to include removal of brown trout populations. Where habitat conditions are suitable, restoring certain streams that support both wild brown trout and brook trout to brook trout only populations presents the greatest opportunity in Maryland to increase the number and miles of brook trout streams and to reduce the level of fragmentation within subwatersheds.

Global Warming

With climate warming there is potential that stenothermal fishes, those with narrow thermal ranges and generally intolerant of habitat perturbations, may be replaced by eurythermal fishes, those with wide thermal ranges and generally tolerant of habitat perturbations. Changes in fish assemblages due to climate warming may be gradual but the replacement of species assemblages may be relatively rapid due to the loss of connectivity and the time frame for climate change. Predicted changes in ground water temperatures (Figure 12) and the impact on summer stream water temperatures will alter the thermal regimes of what are currently brook trout streams in Maryland over the next 100 years (Meisner 1990). Meisner (1990) predicts a mean increase in groundwater temperatures of 2 - 4^{0}C by 2100 (Figure 12). This will increase summer stream water temperature above the critical threshold for brook trout and result in the extirpation of brook trout throughout most of the species historic range in Maryland (Figure 13). Brook trout populations will be restricted to the Youghiogheny and upper North Branch Potomac River drainages in Garrett and western Allegany counties.

GENETIC CONSIDERATIONS

Introduction

Traditional fishery management activities have been directed towards biological and physical (habitat and water quality) parameters and population/stock assessments. The goal of fisheries management has been to maximize yield by balancing harvest and recruitment. For commercial fisheries this translates into what can be brought to market; for recreational fisheries harvest and angling experiences (numbers and/or size) are important. While generally accepted and considered successful, the traditional management approach is driven by data that are collected and analyzed in the short term. This results in a perspective that fails to consider the long term effects of harvest and catch on the genetic composition of the population and the ecosystem as a whole. Over the last several decades, the development and refinement of electrophoretic techniques has made it possible to add a genetic component to the process of brook trout fisheries management. Brook trout genetic work has been in progress since the 1980's, focusing on identifying and examining populations in relationship to their physical location.

Throughout their geographic range, brook trout have been a historically important fish species for indigenous North American peoples and as a popular angling and recreational resource for settlers and their descendants. The physical requirements needed to support brook trout survival make them sensitive to habitat and water quality changes, and populations have been suffering declines throughout their native range since colonial times. It is estimated that prior to settlement there were more than 3,000,000 brook trout in Maryland streams; in 1999, it was estimated that there were only 300,000 fish (Boward et al. 1999).

Genetic considerations are a vital component of developing a comprehensive, long- term fishery management plan for brook trout because of their distribution, and in some cases isolation, in Maryland streams,. Incorporating a genetics component in any long term plan is valuable for a variety of reasons. Survival of a species is dependent upon its ability to respond to changing environmental conditions. Protecting genetic diversity, therefore, is vital from an evolutionary standpoint. Likewise, over time, populations in different watersheds and even stream reaches may be locally adapted to the conditions in those waters. Disruptions to these systems could negatively impact the survival of these populations.

Mechanisms of loss of genetic diversity

Recognizing the importance of preserving genetic diversity in a comprehensive management strategy for brook trout leads to a need to understand the mechanisms of how diversity can be lost. Four main factors related to population size are recognized as potential causes of diversity loss: founder effects, demographic bottlenecks, genetic drift, and inbreeding. *Founder effects* refer to the establishment of a new population by a small number of individuals, where genetic diversity is limited to the founders. An example of this would be the reintroduction of brook trout into an unpopulated stream where the parental stock is low in number and all come from the same population. If the new population is reproductively isolated from other populations, initial genetic diversity will be low and will likely decrease over time. *Demographic bottlenecking* is a situation where a population experiences a one time severe reduction with the few surviving individuals repopulating the stream, similar to a founder effect. An example would be a reproductively isolated stream that experiences a fish kill due to a warm water event, drought, or a poor water quality event (spill, acidity, etc.). The severity of genetic loss is directly proportional to the number of repopulating adults. *Genetic drift* is a loss of rare alleles from a population and can occur as a result of a prolonged bottleneck event. Rare alleles provide elasticity in the genetic makeup. They are important for providing adaptation responses to evolutionary challenges, such as a new parasite or change in temperature regimes. An example would be an isolated brook trout population experiencing a 3 or 4 year summer drought that results in a chronic bottleneck. *Inbreeding* occurs when closely related individuals mate, reducing diversity over time. It is a major problem in small populations. Inbreeding depression can occur when the fitness of individuals is affected, such as reduced fecundity, growth, survivorship, etc. Inbreeding is more likely if it occurs in a short period of time, such as the impacts of a repeated drought. Small, stable populations are not as susceptible to inbreeding as larger populations that suffer a severe decline caused by external factors. The result of the loss of genetic diversity from any of these factors is especially important in small populations that are relatively or completely isolated from other populations. Meffe and Carroll (1994) provide an illustration of the importance of population size on loss of diversity. For isolated populations, loss of diversity from a population of 1000 is 0.05% and from a population of 50 the loss is 1%. Over a 20 generation period, the loss from a population of 1000 is <1%, while the loss from a population of 50 is 18%!

Genetically effective population (GEP) sizes

The genetically effective population size (N_e) is the size of a population that would have the same amount of inbreeding or of random gene frequency drift as the population being studied (Kimura and Crow 1963) or the size of a population necessary to maintain a genetically functional population. N_e is typically less than the actual population size (N_{census}), the degree of which is highly variable by species. N_e is useful for predicting when a population, based on census monitoring, would reach a point where reduced genetic variation would threaten the survival of the population.

Importance of genetic component in a management plan

Incorporating a genetic component into a fishery management plan is essential for the long term fitness of a population(s). Meffe and Carroll (1994) provide guidelines for the process of developing a long-term management plan for a particular species. A review of these guidelines suggests that the genetic conservation of brook trout populations in Maryland is currently being compromised. Additionally, considering the genetic component(s) of a population has become increasingly more important in fish conservation plans involving hatcheries, taxonomic studies, and captive breeding programs (Meffe and Carroll 1994). The qualitative guidelines for genetically based conservation principles developed by Meffe and Carroll (1994) are as follows (italics indicate specific guidelines of concern for Maryland):

1. Large genetically effective population sizes are better than small ones because they will lose genetic diversity more slowly.

2. *The negative effects of genetic drift and inbreeding are inversely proportional to population size. Thus avoid managing for unnaturally small populations.*

3. Management of wild populations should be consistent with the history of their genetic patterns and processes. For example, historically isolated populations should remain isolated unless other concerns dictate that gene flow must occur. *Gene flow among historically connected populations should continue at historical rates, even if that calls for assisted movement of individuals.*

4. Low genetic diversity per se is not cause for alarm because some species historically have low diversity. However, sudden and large losses of diversity in natural or captive populations are cause for concern.

5. Avoid artificial selection in captivity. This is best done by keeping breeding populations in captivity for as few generations as possible and by simulating wild conditions as nearly as possible.

6. After a population crash, encourage rapid population growth to avoid a prolonged bottleneck.

7. *Avoid possible outbreeding depression caused by breeding distantly related populations if other choices are available.*

8. *Avoid inadvertent introductions of exotic alleles into wild or captive populations.*

9. *Harvest of wild stocks (hunting, fishing) can select for genetic changes which can affect the future evolution of the population or species. For example, culling the largest individuals can select for earlier maturity and smaller body sizes. Avoid selection in harvesting wild stocks.*

10. Maintenance of genetic diversity in captive stocks is no substitute for genetic diversity in the wild.

Genetic status of Maryland brook trout populations

Behnke (1980) posed the question of whether there were distinct northern and southern groups of brook trout or a single homogenous stock established after the last glacial retreat during the Pleistocene. Subsequently, several authors surveyed genetic relationships of brook trout populations throughout their native range as tests of competing biogeographic hypotheses. Stoneking et al. (1981) surveyed populations from Tennessee and North Carolina and compared them with fish from New York and Pennsylvania using allozyme techniques.. Their results indicated the presence of separate northern and southern phylogenetic lineages suggesting sub-specific status. Quattro et al. (1990) and Morgan and Baker (1991) surveyed western Maryland populations of brook trout using mitochondrial DNA restriction fragment length polymorphisms (mtDNA RFLP) and allozymes respectively, and found significant genetic divergence between populations from the Chesapeake Bay and Ohio River drainages.

Additional allozyme evidence for phylogeographic structure was found among brook trout populations from the Great Smoky Mountains (McCracken et al. 1993; Kriegler et al. 1996), where significant genetic differentiation among native brook trout populations was detected. Hayes et al. (1996) examined 11 native populations of brook trout from the southern Appalachian Mountains for mtDNA haplotypic diversity and found sequence divergence of up to 0.8 % between populations. A study from the southern edge of the glaciated region of eastern North America determined that there was a high degree of genetic variation in populations of brook trout from Pennsylvania and New York (Perkins et al. 1993). Most of this genetic diversity was partitioned among four major river basins (St. Lawrence, Delaware-Hudson, Susquehanna, and Allegheny). In recent studies, northern populations of brook trout, defined as those from recently glaciated (i.e., Wisconsin glacial episode) regions in Canada and Great Lakes drainages in the United States, have been extensively characterized based on allozyme surveys and mtDNA RFLP (Danzmann and Ihssen 1995; Jones 1995; Jones et al. 1996; Jones et al. 1997; Danzmann et al. 1991, 1998). A single mtDNA haplotype assemblage dominated most northern brook trout populations, indicating recolonization from a single Atlantic refugium (Danzmann et al. 1998). Notable exceptions were several western Great Lakes populations that contained divergent mtDNA assemblages believed to have recolonized from a Mississippi River refugium and divergent haplotypes in the Canadian Maritime Provinces thought to have reentered from an Acadian (northeastern coastal) refugium.

Besides demonstrating the evidence for refugial origin of populations throughout the native range of brook trout, the study by Danzmann et al. (1998) delineated six major brook trout clade assemblages (hereafter designated as assemblages A-F). Assemblage A haplotypes were distributed throughout the mid-range of the species from New York south to Virginia and west to the Great Lakes drainages. Assemblage B was the most widespread grouping found in abundance throughout the native range with the exception of the southern reaches (Tennessee). Assemblage C was located in the Ohio River drainage in West Virginia and those of the eastern Great Lakes. Assemblage D brook trout were only found in the Mississippi drainage of western Maryland while assemblage E, the most distant genetically, was found only in the Mississippi drainage of Tennessee, the most southern population examined. Assemblage F fish only appeared in the Ohio River drainage of West Virginia. One assemblage (B) dominated populations from the northern range, while more assemblage diversity was evident in mid-Atlantic regions.

Only one population from the southern range was tested (Indian Camp Creek in Tennessee), and while it was defined as containing the most genetically divergent assemblage (E), the lack of additional information from southern populations precluded assessment of assemblage diversity in this region. However, studies of brook trout populations from the southern reaches of the native range indicate relatively high genetic diversities (McCracken et al. 1993; Kriegler et al. 1996; Hayes et al. 1996). These findings suggest that mid-Atlantic populations of brook trout may define a transitional zone between genetically diverse southern populations and relatively homogenous northern populations.

Assemblage B haplotypes dominated the eastern portions of (this) which one?? drainage, including the Gunpowder River, Principio Creek, and Patapsco River drainages in Maryland as well as Dry Run in Virginia. These haplotypes were most closely related to the Edray Hatchery haplotype, and prior evidence indicated that this assemblage dominates most of the northeastern range of brook trout (Jones 1995; Danzmann and Ihssen 1995; Jones et al. 1996; Danzmann et al. 1998). Assemblage A haplotypes were found mostly in the western drainages of the Chesapeake watershed including the Monocacy River, Savage River, and North Branch Potomac River. The Kellogg Creek population (all assemblage A haplotypes) in the Susquehanna River drainage is a notable exception to this east-west Chesapeake division. Assemblage D haplotypes were confined to the Youghiogheny River drainage in western Maryland. Exceptions to this grouping were assemblage A haplotypes 78 and 79 found in Black Run and haplotype 75 (assemblage B) found in Puzzley Run. Big Piney Branch contained assemblage A and B haplotypes only. Assemblages C, E, and F were mostly from Ohio River drainage populations in West Virginia and Tennessee (lone assemblage E haplotype; Danzmann et al. 1998) and were most closely related to the ancestral haplotype.

Morgan and Danzmann (1997; 2001) and Hall et al. (2002) suggested high mtDNA RFLP diversity among brook trout populations in the mid-Atlantic when compared to northern populations (Jones et al. 1997; Danzmann et al. 1998). These prior studies revealed low mtDNA assemblage diversity in recently glaciated regions in Canada and northeastern USA. The majority of haplotypes in these studies were from assemblage B with a small number from assemblage A. In contrast, brook trout from the mid-Atlantic belong to five of the six established mtDNA assemblages (Morgan and Danzmann 1997, 2001; and Hall et al. 2002).

Most studies of populations from the southern Appalachians have produced evidence that genetic diversity is relatively high in the southern portion of the brook trout's native range (McCracken et al. 1993; Hayes et al. 1996; Kriegler et al. 1996). The only population included from the southern range was Indian Camp Creek in the Tennessee River drainage (Danzmann et al. 1998). The single haplotype found in this population was the only haplotype making up the most divergent assemblage from that study. This information, coupled with the high mtDNA sequence divergences (as high as 0.8 %) found between southern populations (Hayes et al. 1996) suggested that regions south of the putative mid-Atlantic possess higher mtDNA haplotypic diversity. However, based on these comparisons, mid-Atlantic populations emerge as transitional in an ascending continuum of haplotypic diversity from north to south. Future research should focus on this region.

The question arises in this discussion as to whether past stocking events, followed by naturalization of stocked fish or their hybridization with wild fish, could account for these assemblage transfers between major drainages. One problem in examining the genetic structure of Maryland brook trout populations is the rather large-scale introductions of brook trout eggs, fingerlings, and adults throughout the state in the early 1900s. Stocking fish was an action in response to angler concerns about the lack of trout, and other game species (Elser 1961; Powell 1967). At that time, agriculture, timber harvesting and mining had severely affected Maryland trout streams.   However, only headwater streams (especially the upper reaches) were sampled in Maryland (Morgan and Danzmann 1997, 2001; Hall et al. 2002). These headwater streams were generally not stocked due to early, primitive road systems that prevented access by stocking trucks (R. Morgan, personal observation). Initially, the stocking emphasis was on fingerlings but later was switched to stocking larger fish for put-and-take fisheries (Powell 1967). Fingerling survival appeared to be poor and angling pressure in the put-and-take areas quickly removed the larger brook trout (Powell 1967). Some brook trout from federal hatcheries were also stocked, but these were larger fish placed into put-and-take zones. Danzmann and Ihssen (1995) found little evidence for the post-stocking success of hatchery stocked brook trout in the Algonquin Park region of Ontario based upon the survival of putative hatchery mtDNA haplotypes. These factors combine to enforce the assertion that stream captures are a more likely explanation for multiple assemblages in the brook trout populations sampled. One exception is the Panther Branch sample from the Gunpowder River drainage in eastern Maryland. Stream capture is unlikely to account for the delivery of assemblage D trout to this stream due to its geographic distance from the putative source of assemblage D haplotypes (Youghiogheny River drainage in western Maryland).

Currently, genetic work focuses on analyses of microsatellite loci in brook trout. The work has demonstrated the power of this bioanalytical technique in understanding the population structure of native brook trout throughout its range. For Maryland brook trout populations (Figure 14), this technique expands the number of discrete brook trout complexes to five, one more than reported by Hall et al. (2002). Basically, results obtained from microsatellite work show a complex of six streams (top of Figure 14) associated with the Catoctin Mountains (Blue Ridge ecoregion), three streams from the Gunpowder and Patapsco drainages   (Northern Piedmont), two streams from the Youghiogheny drainage (Central Appalachians), four streams from the upper North Branch drainage (Central Appalachians), and one from the Susquehanna drainage (Northern Piedmont). These groupings are genetically distinct with the length of each arm representing isolation distance from adjoining populations (Figure 14).

Mid-Atlantic brook trout are under increasing pressure from urbanization and pollution such as acid mine drainage (Boward et al. 1999; Warren et al. 2000). In addition, brook trout may disappear from low altitude regions, like the Piedmont of the mid-Atlantic, because of climatic warming (Meisner 1990). Population models indicate that multiple anthropogenic stresses have the potential to cause serious population declines (Marschall and Crowder 1996). Though the brook trout is currently considered stable throughout most of its native range (Warren et al. 2000), certain populations may become increasingly rare in the future, especially those near urban areas. For instance, when sampling tributaries near urban areas in the Patapsco and Susquehanna rivers, considerably more time was spent collecting adequate samples sizes of brook trout than in streams located in rural areas or state park land.

Management based on genetic differentiation among populations has become a widely utilized and successful conservation strategy (Meffe and Carroll 1994; Waples 1995). Knowledge of the genetic structure of a fish population is critical to effective management. In particular, it is crucial to understand subdivision structure within a population and to understand structure within a species or species complex. Although probably not a major problem in brook trout, it is also important to identify whether or not there is a possibility for differential harvesting among or within populations – this may be needed to understand population dynamics, especially in fishes with low fecundity such as the brook trout.

The transitional status of mid-Atlantic populations of brook trout provides an opportunity to conserve a significant amount of genetic diversity within a relatively small area. The natural history (i.e., stream capture, historical isolation, etc.) of the streams sampled from this region is likely to have made a greater contribution to extant assemblage structure than anthropomorphic actions (i.e., stocking). Therefore, management of brook trout in the mid-Atlantic should be based on major hydrological divisions that separate major lineages except where evidence exists for assemblage mixing by natural means. In these drainages, more subtle management divisions are warranted.

MANAGEMENT RECOMMENDATIONS

The ultimate goal of Maryland's Brook Trout FMP is to "*restore and maintain healthy brook trout populations in Maryland's freshwater streams and provide long-term social and economic benefits from a recreational fishery.*" The objectives of the plan (listed on page 8) provide the general framework for supporting this challenging goal. The following management and research recommendations identify specific actions to accomplish the objectives and implement the plan (Table 6).

General Management Recommendations

1 Collect sufficient brook trout life history and angler exploitation information for management needs.

Policy, regulatory, and management decisions rely on biological and socio-economic data to make appropriate decisions. While some life history and angler exploitation data is available for Maryland brook trout populations there is a need for more information. Of particular importance is information relating to life history characteristics of brook trout populations statewide (population densities, mortality, longevity, growth rates, etc.) and angler exploitation of these populations (harvest rates, angler effort, etc.).

Strategy 1.1 Investigate the life history characteristics, i.e. mortality, longevity, fecundity, growth rate, of Maryland brook trout populations statewide.

Action 1.1.1 Identify and pursue additional funding sources to accomplish the needed work.

Strategy 1.2 Investigate angler use and exploitation on Maryland brook trout populations statewide through creel surveys, and relate harvest and incidental angling mortality to brook trout length frequency structure and maximum fish size.

Action 1.2.1 Identify and pursue additional funding sources to accomplish the needed work.

2. Establish a statewide brook trout Genetic Effective Population (GEP) index.

The majority of Maryland's brook trout populations are fragmented within their historic range within watersheds, and connectivity between these fragmented populations is minimal to non-existent due to chemical, physical, and biological (exotics) barriers. Isolation of a population can lead to genetic problems and loss of viability. Anthropogenic stressors on brook trout in Maryland, particularly east of Allegany County, are increasing on the most vulnerable and fragmented populations. Determining which populations are most at risk and which populations have the best chance of long term viability is vital to directing brook trout conservation efforts. A key component of this effort is developing GEP size index for the state.

Strategy 2.1 Develop a GEP index for brook trout populations in the state of Maryland.

Action 2.1.1 Submit a proposal for funding a GEP index research project to the Maryland DNR State Wildlife Grant program for FY07.

Strategy 2.2 Utilize the index to categorize the status of brook trout populations in Maryland and create a priority list of those most at risk, and those for which conservation efforts would have long term potential for long term restoration.

3. Develop a plan to identify and preserve brook trout populations that are at risk of imminent extirpation.

Identifying and protecting at risk brook trout populations is critical for the short term survival of the species. The risk of extinction has increased because of the fragmentation and isolation of brook trout populations throughout the state. Extirpation of individual populations is a permanent loss of a genetic resource and also has negative social and economic impacts through the loss of an angling resource, aesthetic value (property value, etc.), and the regulatory and social protection afforded a unique, native resource.

Strategy 3.1 Identify and protect at risk brook trout populations.

Action 3.1.1 Determine at risk populations by statewide fisheries region using current data, and then by using GEP index information once it becomes available.

Action 3.1.2 Develop a priority list of populations to be protected, incorporating the GEP index value, land ownership (private versus public), upstream watershed size and land use, public resource access, connectivity to other brook trout populations, and recreational value.

4. Develop a comprehensive brook trout management plan for the Upper Savage River watershed, the only large area with intact, connected populations.

The upper Savage River watershed, upstream of the Savage River dam and including all reservoir tributaries, is Maryland's only unfragmented brook trout resource. It consists of 16 named streams and numerous unnamed tributaries, comprising over 100 miles of interconnected streams. This system accounts for 25% of all brook trout stream miles statewide, supports the highest densities statewide, and is located in the mountainous portion of Maryland that is predicted to be least affected by global warming. The majority of stream lengths are on public land (Savage River State Forest), however, the critical headwater portions of most of these streams are on private lands. Even though public lands provide some protection to aquatic habitat, many threats have been identified to the long-term viability of the brook trout resource. Along the headwater streams on private land, agriculture and timbering are prevalent. In addition, stream channelization has occurred and there is increasing housing and farmette development. Associated impacts with these activities include: sedimentation, temperature and flow regime alterations, groundwater disturbance and loss of flow, etc. Also, numerous impoundments occur along the Upper Savage section adversely affecting summer water temperatures. Heft (personal communication, 2005) recorded high summer water temperatures in the Savage headwaters in three different tributaries, the reverse of what would occur in an unimpacted system. A specific management plan to conserve and restore brook trout is needed because of the unique nature and status of the geographic area. There are increasing (and accumulating) pressures on the watershed that impact brook trout (particularly the headwater streams).

Strategy 4.1 Develop a brook trout management plan for the Savage River watershed upstream of the Savage River dam. This plan will be used as blueprint for developing plans in other brook trout watersheds.

Action 4.1.1 Develop a comprehensive Geographic Information System (GIS) database detailing land ownership and usage within the upper Savage River watershed, incorporating summer water temperatures and brook trout population abundance from the Maryland DNR’s Inland Fisheries and MBSS databases.

Action 4.1.2 Utilizing the GIS analysis, identify areas within the Savage River watershed that are negatively impacting brook trout populations and water quality and develop a priority list of restoration/conservation activities.

Action 4.1.3 Identify areas within the Savage River that need additional conservation.

Strategy 4.2 Present the information and recommendations in the BTFMP to the MD DNR Western Regional Team to solicit input and support.

Strategy 4.3 Develop a watershed-wide strategy for protecting habitat, especially buffer protection and restoration in impacted headwater streams. Incorporate existing land preservation and buffer strip restoration programs at the State and Federal government level.

Strategy 4.4 Identify adverse summer water temperature impact areas (impoundments, etc.) and develop strategies to alleviate the impacts.

Strategy 4.5 Designate the upper Savage River watershed a fisheries “Habitat Area of Particular Concern” (HAPC). This designation will allow the development of regulations and monitoring programs to protect the resource on a watershed specific basis. It will also help to develop and foster the public and resource users’ support for the management actions that need to occur; it will focus efforts to accomplish necessary research; and it will demonstrate Maryland’s commitment to protecting and conserving this unique resource.

Action 4.5.1 Institute angling regulations to provide for maximum protection of brook trout while still ensuring angler use of the resource, i.e. no closed season, no harvest, single hook barbless lures only, no bait.

Strategy 4.6 Promote and encourage the development of a citizens-based Savage River watershed advocacy organization. MD DNR will provide technical support as needed..

5. Encourage riparian buffer habitat preservation and restoration.

The loss of riparian habitat contributes to Impaired water quality and flows, increasing sedimentation, warming water temperatures, increased scour and flood events, and other negative impacts as described in this plan. The USDA and the Maryland DNR have a joint habitat protection incentive program (CREP) designed to provide financial incentives and compensation to farmers to actively protect the vital stream corridors and associated habitats found on their lands. This program pays farmers to restore and protect the vital riparian and wetland habitats associated with streams on their properties, through fencing and planting activities. Other programs such as the environmental quality incentives program (EQIP) and the wildlife habitat incentives program (WHIP) offered through the Natural Resource Conservation Service (NRCS) are also available. Often improvements on property not eligible for CREP will qualify for EQIP or WHIP funds.

Action 5.1.1 Develop a list of target watersheds in Maryland that could benefit from the CREP program, rank each system based on brook trout population status (best to worst), headwater agricultural impact, and size and connectedness of the system.

Action 5.1.1 Using the list generated from Action 5.1.1, actively recruit and enroll farmers from the targeted watersheds into the CREP program.

Action 5.1.2 Create a list of the Federal, state, and NGO conservation and restoration programs that are available to landowners; inform Regional Fisheries managers and biologists of these programs so they can work with private landowners to improve land use and water quality.

6. Convey impact(s) of human activities on brook trout populations to local and state government agencies and the general public.

Loss and alteration of habitat is the biggest threat to brook trout resources. In many situations, developers, county regulatory agencies and state agencies have inadequate knowledge and understanding of how development and other anthropogenic activities impact brook trout populations.

Strategy 6.1 The information that is needed by regulators and developers to appropriately consider and plan activities so they do not adversely impact brook trout populations is available. Developing an outreach strategy to convey this information twill provide key agencies and developers with the understanding necessary to make appropriate decisions.

Action 6.1.1 Develop a series of PowerPoint presentations that illustrate the life history needs of brook trout and the adverse impacts that can occur from anthropogenic activities. Provide an ecosystem perspective by including a description of how brook trout serve as indicators of overall stream health; and what a healthy brook trout population means to the health of a watershed and the lives of those who reside there.

Action 6.1.2 Meet with county and local government officials/agencies and commercial developers to present the information and to establish a dialog on the issues relating to the conservation and value of Maryland's native brook trout.

Action 6.1.3 Make presentations available to the general public through appropriate pathways, i.e. website, libraries, etc.

Action 6.1.4 Work cooperatively with other state agencies to insure adherence to state water quality standards.

7. Develop guidelines for restoring extirpated brook trout populations.

Restoration of extirpated brook trout populations should follow a set of guidelines to protect genetic integrity and include a monitoring component to determine success.

Strategy 7.1 Develop statewide restoration guidelines for restoring extirpated brook trout populations.

Action 7.1.1 Adopt and modify the guidelines developed for brook trout restoration by the American Fisheries Society's Southern Division Trout Committee.

Action 7.1.2 Incorporate a genetic component into the guidelines to direct brood fish selection location.

8. Complete genetic inventory of discrete brook trout populations.

Brook trout have discrete genetic populations by drainage area and even by river system. Long term management strategies need to incorporate an understanding of the genetic makeup of the population(s) being managed to insure genetic diversity and preservation of stocks and prevent deleterious effects from reduced genetic diversity. Efforts on a regional basis have been encouraged by the Eastern Brook Trout Joint Venture (EBTJV); approximately half the brook trout populations in Maryland have been sampled and their genetic structure determined. Completing a genetic inventory of the remaining brook trout populations is vital to the conservation and restoration of the resource. Cooperation with Pennsylvania and West Virginia has already been established for streams that cross state boundaries.

Action 8.1 Secure funding (an estimated $10,000) to complete the statewide brook trout genetic inventory. The USFWS State Wildlife Grant Program and EBTJV are two possible funding sources for completing this work.

9. Foster interaction with anglers and resource user groups about the management of brook trout in Maryland.

Historically, brook trout management in Maryland has been secondary to other coldwater trout species (rainbow, brown) management. No creel census surveys have been directed at determining brook trout resource use, harvest, and angler opinion. There have been no public discussions to solicit public opinion and desires about the conservation of the resource. The opinions and suggestions of stakeholders and the public are necessary to insure that the plan has the support necessary to be successful.

Strategy 9.1 Establish pathways to inform the general public about brook trout conservation and protection.

Action 9.1.1 Utilize the Maryland Sportfish Advisory Commission (SFAC), DNR Regional Teams, and other appropriate state agencies to solicit input on brook trout conservation measures.

Action 9.1.2 Post the BTFMP on the DNR Fisheries Service webpage and request on-line comments on conservation measures as part of the regular review of the BTFMP.

Action 9.1.3 Conduct informational meetings as appropriate on new issues and conservation actions.

10. Support grass roots advocacy groups dedicated to conservation of brook trout in Maryland.

One of the most effective conservation tools is the development of citizen-organized and operated watershed advocacy and restoration groups. These organizations are typically community based and allied with other NGO's (non-governmental organizations). They are typically well received by individuals within the watershed and local government personnel. In more rural areas, there can be a fear of government regulation and intervention. Citizen-based advocacy groups can help to allay these fears and/or remove the specter of government. As volunteer based organizations, participating members usually have a high level of energy and purposefulness. They are there because of intrinsic values associated with natural resources.

Strategy 10.1 Encourage public participation in fishery management through informational and regulatory meetings and the development of organized watershed advocacy groups. Current Federal efforts are directed at assisting the formation of advocacy groups by funding startup and operational costs.

Action 10.1 Develop a list of watershed advocacy organizations in Maryland with current contact information. Evaluate the need for additional groups. Create a list of Federal agency contacts that can assist in with citizen advocacy groups.

Agency-specific Recommendations

11. Develop statewide coordinated monitoring schedule.

Currently, Inland Fisheries does not have a schedule for monitoring brook trout population status. Of the 151 streams identified as having viable populations, only a small number are monitored annually. Current regional efforts include a goal to sample each brook trout population within the region at least once during the five year Federal Aid grant period (C. Gougeon, A. Klotz, personal communications). Lack of staff and available time has prevented this goal from being accomplished.

Strategy 11.1 Develop a consistent, coordinated monitoring program to: 1) assess and track population abundance and viability; 2) monitor and detect environmental changes from anthropogenic (acidification, sedimentation, development/urbanization, AMD, etc.) and natural causes (floods, drought); 3) monitor and detect exotic species encroachment and impacts; and 4) monitor/detect water flow and temperature changes.

Action 11.1.1 Develop a monitoring schedule to insure that all brook trout populations statewide are sampled at least once every 3 years.

Action 11.1.2 Coordinate brook trout sampling efforts between Inland Fisheries and the MBSS to maximize efficiency. Where possible, reduce the number of sites Inland Fisheries needs to monitor. Fisheries should focus on monitoring streams for recreational fisheries, MBSS on sampling headwater, privately owned streams.

12. Develop a statewide standardized brook trout population sampling protocol.

Current sampling efforts for assessing brook trout populations utilize electrofishing to collect fish. Population assessment is typically done one of two ways: 1) a three pass depletion is conducted and trout per kilometer and hectare, and kilograms per kilometer are calculated along with individual length and weight data; or 2) a one pass shocking episode is performed and the number of brook trout observed is noted or recorded; basically confirming presence or absence of a population. Regional sampling efforts are independent of one another and vary within the regions themselves, making statewide data analysis and comparisons difficult or impossible. Also, most sampling efforts are limited to collecting fish data only. No water quality or habitat data is collected, thereby missing information that is vital for effective long-term management. The MD DNR MBSS program collects data on freshwater fish, water, and habitat conditions in streams throughout the state utilizing standardized methods. Combining some of these methods with Inland Fisheries sampling methods would improve monitoring information, particularly for monitoring habitat and water quality conditions and changes over time. Currently, there are no data on what has occurred from a water quality/habitat standpoint in most of Maryland's brook trout streams.

Strategy 12.1 Develop a standardized sampling protocol for monitoring brook trout populations that includes: MBSS water quality and habitat data collection components; establishment of permanent sampling stations; number of stations per stream length; and fish collection methodology.

Action 12.1.1 Create a sampling standardization committee with members from Inland Fisheries and MBSS to develop the sampling methodology.

Action 12.1.2 Conduct training with Inland Fisheries staff to implement the standardized methodology.

Action 12.1.3 Collect summer water temperatures with in-stream temperature recorders as part of brook trout monitoring.

<u>13. Create a centralized statewide brook trout data depository</u>.

Inland Fisheries brook trout data is not stored in one format or location, but is regionally maintained. Analysis of statewide brook trout population trends or comparisons of systems is difficult, time consuming, and impractical because of data storage and availability issues. In addition, the MBSS and the University of Maryland Appalachian Laboratory have large data collections, current and historic, that are not readily accessible to Inland personnel.

Strategy 13.1 Develop a database that incorporates, and where possible, standardizes, the historic and current statewide brook trout information available from the Inland Fisheries, the MBSS, and the University of Maryland monitoring programs.

Action 13.1.1 Establish a data management group that includes a representative from each of the major groups (DNR, UM, and MBSS) to standardize the data collection format and create a statewide database of brook trout information.

Action 13.1.2 Identify other sources of brook trout data, such as MD Bureau of Mines, additional academic institutions, and Federal agencies, and incorporate the data into the statewide format.

Action 13.1.3 Develop a GIS database describing brook trout population boundaries, population information, habitat variable information, and water temperature data, as discussed in Action 4.1.1 of the *General Recommendations* section.

RESEARCH RECOMMENDATIONS

Research on brook trout in Maryland has been limited to some genetic and mercury contamination investigations, and a population distribution and density project (Western Maryland, 1988-1990). Basic life history information, angler use and harvest, and land use impacts on brook trout populations have not been investigated. Long term management of Maryland's brook trout resource requires more information than is currently available. Making appropriate management decisions is difficult because of this lack of information. Described below are research needs that would provide the needed information for long term management of Maryland's brook trout populations.

1. Determine brook trout life history parameters

Investigate major life history parameters of Maryland brook trout populations, including: longevity, mortality rate, growth rate, population structure, and age at sexual maturity.

2. Determine angler use, harvest, and economic benefit of the brook trout resource.

Investigate angler use and harvest of the brook trout resource, including: creel surveys, angler questionnaires, and economic benefits.

3. Investigate brook trout movement patterns.

Investigate brook trout movement patterns within watersheds/subwatersheds/ impoundments, where populations are separated by seasonal or permanent impediments to movement (i.e. high summer water temperatures, reservoirs, exotic trout population barriers, etc.).

4. Investigate the impact of non-native trout and other exotic freshwater fish species on brook trout populations.

Investigate the impact of non-native fish (i.e. brown and rainbow trout) on brook trout populations, including: establishment of self-sustaining exotic trout populations; stocking of put-and-take trout on wild brook trout populations; and the effect of removal of established exotic trout populations on brook trout.

5. Investigate the effectiveness and impact of current statewide brook trout regulations.

Investigate value and impact of current management regulations on brook trout populations statewide; determine if regulations are adequately protecting the resource.

6. Determine the extent of streams impacted by acid rain and acid mine drainage.

Determine the number of streams/stream miles affected by acid rain and acid mine drainage that have brook trout or could potentially support brook trout; develop a priority list of streams where water quality could be restored to support brook trout populations.

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Table 1. Geographic coordinates and stream length inhabited for Maryland's self sustaining brook trout populations as of 2005.

Key: River Basin - YG=Youghiogheny, NBP=North Branch Potomac, UP=Upper Potomac, MP=Middle Potomac, WC=West Chesapeake, PA=Patapsco, GU=Gunpowder, SU=Susquehanna; County - GA=Garrett, AL=Allegany, FR=Frederick, AA=Anne Arundel, BA=Baltimore, CA=Carroll, HO=Howard, HA=Harford; UT=Unnamed tributary

	River Basin	Watershed	Cty.	Stream Name	Geographic coordinates (estimated from center of inhabited stream)	Estimated Stream miles inhabited
1	YG	Casselman	GA	Piney Creek	N 39 42.865 W 78 56.945	0.5
2	YG	Casselman	GA	Two Mile Run	N 39 41.659 W 79 02.784	3.0
3	YG	Casselman	GA	North Branch, UT	N 39 39.006 W 79 12.261	1.0
4	YG	Casselman	GA	Big Shade Run	N 39 42.824 W 79 10.049	2.0
5	YG	Casselman	GA	North Branch, UT	N 39 34.462 W 79 14.935	1.0
6	YG	Casselman	GA	South Branch	N 39 36.665 W 79 11.535	10.0
7	YG	White's Creek (PA)	GA	Puzzley Run	N 39 42.470 W 79 13.855	2.0
8	YG	White's Creek (PA)	GA	Buck's Run	N 39 42.748 W 79 14.743	1.5
9	YG	Mill Run	GA	Mill Run	N 39 42.883 W 79 19.188	7.7
10	YG	Mill Run	GA	Mill Run , UT	N 39 43.117 W 79 16.939	1.0
11	YG	Bear Creek	GA	Bear Creek, below hatchery	N 39 39.309 W 79 20.045	8.0
12	YG	Bear Creek	GA	Bear Creek, above hatchery	N 39 37.640 W 79 16.713	6.0
13	YG	Bear Creek	GA	Little Bear Creek, unnamed tributary	N 39 39.957 W79 16.608	1.6
14	YG	Bear Creek	GA	Little Bear Creek	N 39 39.276 W 79.15.860	3.6
15	YG	Bear Creek	GA	Fikes Run	N 39 40.312 W 79 20.052	2.0
16	YG	Bear Creek	GA	Cove Run	N 39 40.399 W 79 18.204	2.0
17	YG	Buffalo Run	GA	Buffalo Run	N 39 39.497 W 79 26.980	3.0
18	YG	Deep Creek L.	GA	Smith Run	N 39 29.500 W 79 21.878	1.0
19	YG	Deep Creek L.	GA	Meadow Mt. Run	N 39 31.400 W 79 15.977	2.7
20	YG	L. Youghiogheny	GA	Little Youghiogheny	N 39 25.38 W 79 17.35	1.0
21	YG	Cherry Creek	GA	Unnamed tributary	N 39 18.769 W 79 25.977	1.5
22	YG	Youghiogheny	GA	Weimers Run	N 39 28.284 W 79 24.635	0.5
23	YG	Laurel Run	GA	Laurel Run	N 39 37.611 W 79 27.503	2.5
24	YG	Roaring Run	GA	Roaring Run	N 39 27.348 W 79 25.838	1.0
25	YG	Gap Run	GA	Gap Run	N 39 35.505 W 79 23.406	3.0
26	YG	Ginseng Run	GA	Ginseng Run	N 39 34.618 W 79 23.230	3.5
27	YG	Hoyes Run	GA	Hoyes Run	N 39 32.848 W 79 23.552	2.9
28	YG	Hoyes Run	GA	Fork Run	N 39 32.107 W 79 32.298	1.9
29	YG	Black Run	GA	Black Run	N 39 24.018 W 79 18.656	1.9
30	YG	Youghiogheny	GA	Unnamed tributary	N 39 15.899 W 79 28.172	1.0
31	YG	Cherry Creek	GA	Unnamed tributary	N 39 20.219 W 79 24.360	1.2
32	NBP	Shields Run	GA	McMillan Fork	N 39 17.044 W 79 24.682	2.8
33	NBP	Shields Run	GA	Shields Run	N 39 16.940 W 79 23.562	4.3
34	NBP	Shields Run	GA	Aronhalt Fork	N 39 17.599 W 69 23.405	2.8

Table 1. Continued (page 2 of 4)						
	River Basin	Watershed	Cty.	Stream Name	Geographic coordinates (estimated from center of inhabited stream)	Estimated Stream miles inhabited
35	NBP	Glade Run	GA	Glade Run	N 39 18.883 W 79 29.088	3.6
36	NBP	Steyer Run	GA	Steyer Run	N 39 19.039 W 79 18.294	1.9
37	NBP	Laurel Run	GA	Laurel Run	N 39 20.878 W 79 17.104	5.0
38	NBP	Laurel Run	GA	Trout Run	N 39 21.208 W 79 19.145	3.0
39	NBP	Laurel Run	GA	Riley Spring Run	N 39 20.464 W 79 17.774	1.0
40	NBP	Lostland Run	GA	South Prong Lostland	N 39 22.804 W 79 16.476	2.7
41	NBP	Lostland Run	GA	Lostland Run	N 39 21.988 W 79 14.815	1.5
42	NBP	Lostland Run	GA	North Prong Lostland	N 39 23.515 W 79 15.399	3.0
43	NBP	Short Run	GA	Short Run	N 39 21.502 W 79 15.999	1.5
44	NBP	Wolfden Run	GA	Wolfden Run	N 39 23.722 W 79 12.608	5.0
45	NBP	Elklick Run	GA	Elklick Run	N 39 26.454 W 79 09.216	3.8
46	NBP	Folly Run	GA	Folly Run	N 39 27.123 W 79 08.325	4.4
47	NBP	Laurel Run	GA	Laurel Run	N 39 28.685 W 79 07.089	2.6
48	NBP	Savage River	GA	Savage River, mainstem below dam	N 39 29.812 W 79 06.302	4.5
49	NBP	Savage River	GA	Unnamed tributary	N 39 30.662 W 79 06.504	0.5
50	NBP	Savage River	GA	Crabtree Creek	N 39 28.095 W 79 12.011	13.0
51	NBP	Savage River	GA	Middlefork Creek	N 39 31.304 W 79 10.325	6.5
52	NBP	Middlefork Creek	GA	Tom's Spring Run	N 39 30.880 W 79 11.041	1.5
53	NBP	Savage River	GA	Dry Run	N 39 31.651 W 79 09.155	1.7
54	NBP	Savage River	GA	Monroe Run	N 39 33.317 W 79 10.235	3.1
55	NBP	Savage River	GA	Big Run	N 39 39.167 W 79 09.418	5.5
56	NBP	Big Run	GA	Unnamed tributary, Whiskey Hollow	N 39 34.791 W 79 10.930	1.5
57	NBP	Savage River	GA	Pine Swamp Run	N 39 32.380 W 79 06.792	4.0
58	NBP	Savage River	GA	Bear Pen Run	N 39 43.670 W 79 07.444	2.0
59	NBP	Savage River	GA	Poplar Lick	N 39 36.006 W 79 07.287	6.3
60	NBP	Savage River	GA	Savage R. above reservoir	N 39 36.509 W 79 02.851	15.9
61	NBP	Savage River	GA	Elk Lick Run	N 39 36.405 W 79 05.892	2.7
62	NBP	Savage River	GA	Black Lick Run	N 39 37.012 W 79 05.215	2.5
63	NBP	Savage River	GA	West Branch Blue Lick Run	N 39 38.157 W 79 04.607	2.1
64	NBP	Savage River	GA	Blue Lick Run	N 39 37.966 W 79 03.504	5.3
65	NBP	Savage River	GA	Christley Run	N 39 39.614 W 79 02.559	1.7
66	NBP	Savage River	GA	Mudlick Run	N 39 39.944 W 79 01.725	3.1
67	NBP	Savage River	GA	Unnamed tributary	N 39 39.944 W 79 00.306	0.5
68	NBP	Savage River	GA	Little Savage River	N 39 36.821 W 79 01.635	3.4
69	NBP	Georges Creek	AL	Mill Run	N 39 32.697 W 79 03.662	3.3
70	NBP	Georges Creek	AL	Laurel Run	N 39 34.361 W 79 00.850	3.2
71	NBP	Georges Creek	AL	Koontz Run	N 39 35.524 W 79 00.136	3.6
72	NBP	Georges Creek	AL	Elk Lick Run	N 39 34.119 W 78 55.798	0.7
73	NBP	Georges Creek	AL	Neff Run	N 39 36.032 W 78 55.764	0.5
74	NBP	Georges Creek	AL	Matthews Run	N 39 35.694 W 78 54.953	2.0

Table 1. Continued (page 3 of 4)						
	River Basin	Watershed	Cty.	Stream Name	Geographic coordinates (estimated from center of inhabited stream)	Estimated Stream miles inhabited
75	NBP	Georges Creek	AL	Sand Spring Run	N 39 40.163 W 78 56.518	0.5
76	NBP	Braddock Run	AL	Braddock Run	N 39 38.282 W 78 49.622	6.5
77	NBP	Braddock Run	AL	Cash Valley Run	N 39 39.375 W 78 48.983	0.5
78	NBP	Mill Run	AL	Mill Run	N 39 32.192 W 78 54.765	1.5
79	NBP	Evitts Creek	AL	Hazen Run	N 39 43.156 W 78 40.525	1.0
80	UP	Antietam Creek	WA	Little Antietam Creek	N 39 39.729 W 77 31.471	4.3
81	UP	Antietam Creek	WA	Unnamed tributary	N 39 39.417 W 77 32.366	3.0
82	MP	Monacacy	FR	Bear Branch	N 39 16.738 W 77 24.107	3.0
83	MP	L.Tuscarora Ck.	FR	Little Tuscarora Creek	N 39 28.368 W 77 28.512	3.0
84	MP	L.Tuscarora Ck.	FR	Unnamed tributary	N 39 28.074 W 77 28.540	2.0
85	MP	L.Tuscarora Ck.	FR	Clifford Branch	N 39 30.715 W 77 28.679	5.0
86	MP	L.Tuscarora Ck.	FR	Unnamed tributary	N 39 29.423 W 77 29.174	1.8
87	MP	Fishing Creek	FR	Oxys Hollow	N 39 31.135 W 77 28.510	2.0
88	MP	Fishing Creek	FR	Fishing Creek	N 39 32.939 W 77 28.881	5.0
89	MP	Fishing Creek	FR	Little Fishing Creek	N 39 32.644 W 77 27.823	5.0
90	MP	L. Hunting Creek	FR	Buzzard Branch	N 39 35.224 W 77 29.375	3.5
91	MP	L. Hunting Creek	FR	Little Hunting Creek	N 39 35.376 W 77 28.052	5.0
92	MP	Hunting Creek	FR	High Run	N 39 36.645 W 77 26.704	1.8
93	MP	Hunting Creek	FR	Left Fork	N 39 36.857 W 77 28.454	2.0
94	MP	Hunting Creek	FR	Right Fork	N 39 37.962 W 77 28.564	2.6
95	MP	Owens Creek	FR	Owens Creek	N 39 39.753 W 77 28.880	2.5
96	MP	Catoctin Creek	FR	Spruce Run	N 39 35.320 W 77 31.374	5.0
97	MP	Catoctin Creek	FR	Middle Creek	N 39 37.415 W 77 31.560	4.0
98	WC	Severn River	AA	Jabez Branch	N 39 04.152 W 76 39.129	1.0
99	PA	Jones Falls	BA	Dipping Pond Run	N 39 25.877 W 76 41.498	0.5
100	PA	N.Br. Patapsco	BA	Snowden Run	N 39 24.811 W 76 55.489	1.0
101	PA	N.Br. Patapsco	CA	Stillwater Creek	N 39 24.079 W76 55.342	0.5
102	PA	N.Br. Patapsco	CA	Cooks Run	N 39 26.099 W 76 51.155	1.5
103	PA	N.Br. Patapsco	BA	Timber Run	N 39 26.663 W 76 51.548	1.0
104	PA	N.Br. Patapsco	BA	Norris Run	N 39 27.717 W 76 51.860	1.0
105	PA	S.Br. Patapsco	BA	Unnamed tributary	N 39 20.474 W 76 54.334	0.5
106	GU	L. Gunpowder Falls	HO	Laurel Brook Run	N 39 30.496 W 76 25.625	0.5
107	GU	L. Gunpowder Falls	HA	Overshot Branch	N 39 30.894 W 76 26.560	0.5
108	GU	L. Gunpowder Falls	HA	Thornton Branch	N 39 36.021 W 76 32.118	1.5
109	GU	L. Gunpowder Falls	HA	Sawmill Branch	N 39 31.542 W 76 31.729	2.0
110	GU	Gunpowder Falls	BA	Greene Branch	N 39 30.550 W 76 35.783	1.0
111	GU	Gunpowder Falls	BA	Unnamed tributary	N 39 30.929 W 76 38.209	1.1
112	GU	Gunpowder Falls	BA	Piney Creek	N 39 34.269 W 76 40.313	1.7
113	GU	Gunpowder Falls	BA	Buffalo Creek	N 39 33.853 W 76 41.843	2.9
114	GU	Gunpowder Falls	BA	Unnamed tributary	N 39 34.359 W 76 38.157	2.4
115	GU	Gunpowder Falls	BA	Charles Run	N 39 34.994 W 76 35.660	0.5

Table 1. Continued (page 4 of 4)						
	River Basin	Watershed	Cty.	Stream Name	Geographic coordinates (estimated from center of inhabited stream)	Estimated Stream miles inhabited
116	GU	Gunpowder Falls	BA	Panther Branch	N 39 36.091 W 76 38.952	1.1
117	GU	Gunpowder Falls	BA	Bush Cabin Run	N 39 36.165 W 76 41.840	2.5
118	GU	Gunpowder Falls	BA	Unnamed tributary	N 39 36.911 W 76 42.257	0.5
119	GU	Western Run	BA	Beaver Dam Run	N 39 38.167 W 76 43.157	1.0
120	GU	Western Run	BA	Oregon Branch	N 39 29.697 W 76 41.316	1.5
121	GU	Western Run	BA	Baisman Run	N 39 28.826 W 76 41.538	1.5
122	GU	Western Run	BA	BlackRock Run	N 39 35.011 W 76 46.525	1.0
123	GU	Western Run	BA	Indian Run	N 39 33.927 W 76 46.221	0.5
124	GU	Western Run	BA	Deadman Run	N 39 29.650 W 76 44.241	0.5
125	GU	Little Falls	BA	Unnamed tributary	N 39 36.360 W 76 36.187	1.6
126	GU	Little Falls	BA	Unnamed tributary	N 39 36.750 W 76 36.300	1.6
127	GU	Little Falls	BA	First Mine Branch	N 39 37.817 W 76 34.532	2.0
128	GU	Little Falls	BA	Third Mine Branch	N 39 39.508 W 76 36.806	2.0
129	GU	Little Falls	BA	Fourth Mine Branch	N 39 39.560 W 76 38.429	2.6
130	GU	Little Falls	BA	Owl Branch	N 39 38.693 W 76 39.837	0.8
131	GU	Gunpowder Falls	BA	Unnamed tributary	N 39 37.574 W 76 42.461	0.5
132	GU	Gunpowder Falls	BA	Frog Hollow Run	N 39 39.144 W 76 42.811	1.0
133	GU	Gunpowder Falls	BA	Unnamed tributary	N 39 39.662 W 76 43.825	1.1
134	GU	Gunpowder Falls	BA	Indian Run	N 39 39.626 W 76 49.120	1.5
135	GU	Gunpowder Falls	BA	Compass Run	N 39 38.263 W 76 46.866	1.0
136	GU	Gunpowder Falls	BA	Poplar Run	N 39 39.999 W 76 47.542	2.7
137	GU	Gunpowder Falls	BA	Unnamed tributary	N 39 40.844 W 76 45.356	1.0
138	GU	Gunpowder Falls	BA	Unnamed tributary	N 39 40.979 W 76 46.697	1.0
139	GU	S.Br. Gunpowder Falls	BA	Silver Run	N 39 41.464 W 76 45.821	1.6
140	GU	S.Br. Gunpowder Falls	BA	Walker Run	N 39 42.006 W 76 46.341	2.5
141	GU	S.Br. Gunpowder Falls	CA	Muddy Creek	N 39 42.413 W 76 48.102	2.0
142	GU	S.Br. Gunpowder Falls	CA	Unnamed tributary	N 39 40.959 W 76 49.992	2.7
143	GU	Grave Run	CA	Unnamed tributary	N 39 40.129 W 76 51.445	1.1
144	SU	Deer Creek	CA	South Stirrup Run	N 39 35.770 W 76 24.447	3.0
145	SU	Deer Creek	HA	Kellogg Branch	N 39 37.787 W 76 25.421	2.3
146	SU	Deer Creek	HA	Gladden Branch	N 39 38.325 W 76 24.658	1.1
147	SU	Deer Creek	HA	Rock Hollow Branch	N 39 38.885 W 76 26.721	2.5
148	SU	Deer Creek	HA	Wet Stone Branch	N 39 38.493 W 76 26.442	1.6
149	SU	Little Deer Creek	HA	Unnamed tributary	N 39 39.270 W 76 30.764	1.0
150	SU	Little Deer Creek	HA	Spooners Creek	N 39 38.513 W 76 28.722	2.0
151	SU	Deer Creek	HA	Unnamed tributary	N 39 37.821 W 76 18.146	1.0

Table 2. Land ownership along the stream, population composition (brook trout only or existing with other trout species), and put and take stocking status for Maryland's self sustaining brook trout populations as of 2005.

Key: River Basin - YG=Youghiogheny, NBP=North Branch Potomac, UP=Upper Potomac, MP=Middle Potomac, WC=West Chesapeake, PA=Patapsco, GU=Gunpowder, SU=Susquehanna; County - GA=Garrett, AL=Allegany, FR=Frederick, AA=Anne Arundel, BA=Baltimore, CA=Carroll, HO=Howard, HA=Harford; Land ownership – P=Public, V=Private, PV=Public and private Trout species – BK=Brook trout, BR=Brown trout, RB=Rainbow trout; UT=Unnamed tributary

	River Basin	Watershed	County	Stream Name	Public (P) Private (V) Mixed (PV)	BK	BK/ BR	BK/ RB	BK/ BR/ RB	Stocked, put and take
1	YG	Casselman	GA	Piney Creek	PV	X				
2	YG	Casselman	GA	Two Mile Run	V	X				
3	YG	Casselman	GA	North Branch, UT	V	X				
4	YG	Casselman	GA	Big Shade Run	PV	X				
5	YG	Casselman	GA	North Branch, UT	PV	X				
6	YG	Casselman	GA	South Branch	PV				X	
7	YG	White's Creek (PA)	GA	Puzzley Run	P	X				
8	YG	White's Creek (PA)	GA	Buck's Run	P	X				
9	YG	Mill Run	GA	Mill Run	V			X		X
10	YG	Mill Run	GA	Mill Run , UT	V	X				
11	YG	Bear Creek	GA	Bear Creek, below hatchery	V				X	X
12	YG	Bear Creek	GA	Bear Creek, above hatchery	PV		X			
13	YG	Bear Creek	GA	L. Bear Creek, unnamed tributary	P	X				
14	YG	Bear Creek	GA	Little Bear Creek	PV		X			
15	YG	Bear Creek	GA	Fikes Run	V		X			
16	YG	Bear Creek	GA	Cove Run	V		X			
17	YG	Buffalo Run	GA	Buffalo Run	V		X			
18	YG	Deep Creek L.	GA	Smith Run	V	X				
19	YG	Deep Creek L.	GA	Meadow Mt. Run	PV	X				
20	YG	L. Youghiogheny	GA	Little Youghiogheny	V	X				
21	YG	Cherry Creek	GA	Unnamed tributary	V	X				
22	YG	Youghiogheny	GA	Weimers Run	V	X				
23	YG	Laurel Run	GA	Laurel Run	V		X			
24	YG	Roaring Run	GA	Roaring Run	V	X				
25	YG	Gap Run	GA	Gap Run	V		X			
26	YG	Ginseng Run	GA	Ginseng Run	V				X	
27	YG	Hoyes Run	GA	Hoyes Run	V				X	
28	YG	Hoyes Run	GA	Fork Run	V	X				
29	YG	Black Run	GA	Black Run	V	X				
30	YG	Youghiogheny	GA	Unnamed tributary	V	X				
31	YG	Cherry Creek	GA	Unnamed tributary	V	X				
32	NBP	Shields Run	GA	McMillan Fork	V	X				
33	NBP	Shields Run	GA	Shields Run	V	X				

Table 2. Continued (page 2 of 4)										
	River Basin	Watershed	County	Stream Name	Public (P) Private (V) Mixed (PV)	BK	BK/ BR	BK/ RB	BK/ BR/ RB	Stocked, put and take
34	NBP	Shields Run	GA	Aronhalt Fork	V	X				
35	NBP	Glade Run	GA	Glade Run	V	X				
36	NBP	Steyer Run	GA	Steyer Run	V	X				
37	NBP	Laurel Run	GA	Laurel Run	PV		X			
38	NBP	Laurel Run	GA	Trout Run	PV	X				
39	NBP	Laurel Run	GA	Riley Spring Run	PV	X				
40	NBP	Lostland Run	GA	South Prong Lostland	PV	X				
41	NBP	Lostland Run	GA	Lostland Run	V			X		
42	NBP	Lostland Run	GA	North Prong Lostland	PV	X				
43	NBP	Short Run	GA	Short Run	V	X				
44	NBP	Wolfden Run	GA	Wolfden Run	V	X				
45	NBP	Elklick Run	GA	Elklick Run	PV	X				
46	NBP	Folly Run	GA	Folly Run	PV	X				
47	NBP	Laurel Run	GA	Laurel Run	PV	X				
48	NBP	Savage River	GA	Savage River below dam	PV				X	
49	NBP	Savage River	GA	Unnamed tributary	P	X				
50	NBP	Savage River	GA	Crabtree Creek	PV		X			
51	NBP	Savage River	GA	Middlefork Creek	PV	X				
52	NBP	Middlefork Creek	GA	Tom's Spring Run	PV	X				
53	NBP	Savage River	GA	Dry Run	PV	X				
54	NBP	Savage River	GA	Monroe Run	P	X				
55	NBP	Savage River	GA	Big Run	PV	X				
56	NBP	Big Run	GA	Unnamed tributary	P	X				
57	NBP	Savage River	GA	Pine Swamp Run	PV	X				
58	NBP	Savage River	GA	Bear Pen Run	P	X				
59	NBP	Savage River	GA	Poplar Lick	P	X				
60	NBP	Savage River	GA	Savage R. above reservoir	PV				X	X
61	NBP	Savage River	GA	Elk Lick Run	PV	X				
62	NBP	Savage River	GA	Black Lick Run	PV	X				
63	NBP	Savage River	GA	West Branch Blue Lick Run	PV	X				
64	NBP	Savage River	GA	Blue Lick Run	PV	X				
65	NBP	Savage River	GA	Christley Run	PV	X				
66	NBP	Savage River	GA	Mudlick Run	PV	X				
67	NBP	Savage River	GA	Unnamed tributary	V	X				
68	NBP	Savage River	GA	Little Savage River	PV	X				
69	NBP	Georges Creek	AL	Mill Run	PV	X				
70	NBP	Georges Creek	AL	Laurel Run	PV	X				
71	NBP	Georges Creek	AL	Koontz Run	V	X				
72	NBP	Georges Creek	AL	Elk Lick Run	V	X				

Table 2. Continued (page 3 of 4)

	River Basin	Watershed	County	Stream Name	Public (P) Private (V) Mixed (PV)	BK	BK/ BR	BK/ RB	BK/ BR/ RB	Stocked, put and take
73	NBP	Georges Creek	AL	Neff Run	V	X				
74	NBP	Georges Creek	AL	Matthews Run	V	X				
75	NBP	Georges Creek	AL	Sand Spring Run	V	X				
76	NBP	Braddock Run	AL	Braddock Run	V	X				
77	NBP	Braddock Run	AL	Cash Valley Run	V	X				
78	NBP	Mill Run	AL	Mill Run	P	X				
79	NBP	Evitts Creek	AL	Hazen Run	V			X		
80	UP	Antietam Creek	WA	Little Antietam Creek	PV	X				
81	UP	Antietam Creek	WA	Unnamed tributary	PV	X				
82	MP	Monacacy	FR	Bear Branch	V	X				
83	MP	L.Tuscarora Ck.	FR	Little Tuscarora Ck.	V	X				
84	MP	L.Tuscarora Ck.	FR	Unnamed tributary	V	X				
85	MP	L.Tuscarora Ck.	FR	Clifford Branch	P	X				
86	MP	L.Tuscarora Ck.	FR	Unnamed tributary	P	X				
87	MP	Fishing Creek	FR	Oxys Hollow	V	X				
88	MP	Fishing Creek	FR	Fishing Creek	P		X			
89	MP	Fishing Creek	FR	Little Fishing Creek	P	X				
90	MP	L. Hunting Creek	FR	Buzzard Branch	V		X			
91	MP	L. Hunting Creek	FR	Little Hunting Creek	PV		X			
92	MP	Hunting Creek	FR	High Run	P	X				
93	MP	Hunting Creek	FR	Left Fork	PV	X				
94	MP	Hunting Creek	FR	Right Fork	P		X			
95	MP	Owens Creek	FR	Owens Creek	P		X			
96	MP	Catoctin Creek	FR	Spruce Run	V	X				
97	MP	Catoctin Creek	FR	Middle Creek	V	X				
98	WC	Severn River	AA	Jabez Branch	PV	X				
99	PA	Jones Falls	BA	Dipping Pond Run	V		X			
100	PA	N.Br. Patapsco	CA	Snowden Run	V	X				
101	PA	N.Br. Patapsco	CA	Stillwater Creek	PV	X				
102	PA	N.Br. Patapsco	BA	Cooks Run	PV	X				
103	PA	N.Br. Patapsco	BA	Timber Run	PV	X				
104	PA	N.Br. Patapsco	BA	Norris Run	V	X				
105	PA	S.Br. Patapsco	BA	Unnamed tributary	PV	X				
106	GU	L. Gunpowder Falls	HO	Laurel Brook Run	PV	X				
107	GU	L. Gunpowder Falls	HA	Overshot Branch	PV	X				
108	GU	L. Gunpowder Falls	HA	Thornton Branch	V	X				
109	GU	L. Gunpowder Falls	HA	Sawmill Branch	V	X				
110	GU	Gunpowder Falls	BA	Greene Branch	V	X				
111	GU	Gunpowder Falls	BA	Unnamed tributary	PV		X			
112	GU	Gunpowder Falls	BA	Piney Creek	V		X			
113	GU	Gunpowder Falls	BA	Buffalo Creek	PV		X			

Table 2. Continued (page 4 of 4)										
	River Basin	Watershed	County	Stream Name	Public (P) Private (V) Mixed (PV)	BK	BK/ BR	BK/ RB	BK/ BR/ RB	Stocked, put and take
114	GU	Gunpowder Falls	BA	Unnamed tributary	V		X			
115	GU	Gunpowder Falls	BA	Charles Run	V		X			
116	GU	Gunpowder Falls	BA	Panther Branch	PV		X			
117	GU	Gunpowder Falls	BA	Bush Cabin Run	PV	X				
118	GU	Gunpowder Falls	BA	Unnamed tributary	PV	X				
119	GU	Western Run	BA	Beaver Dam Run	V		X			
120	GU	Western Run	BA	Oregon Branch	PV		X			
121	GU	Western Run	BA	Baisman Run	PV		X			
122	GU	Western Run	BA	BlackRock Run	V		X			
123	GU	Western Run	BA	Indian Run	V		X			
124	GU	Western Run	BA	Deadman Run	V		X			
125	GU	Little Falls	BA	Unnamed tributary	V		X			
126	GU	Little Falls	BA	Unnamed tributary	V		X			
127	GU	Little Falls	BA	First Mine Branch	V		X			
128	GU	Little Falls	BA	Third Mine Branch	V		X			
129	GU	Little Falls	BA	Fourth Mine Branch	V		X			
130	GU	Little Falls	BA	Owl Branch	V		X			
131	GU	Gunpowder Falls	BA	Unnamed tributary	P	X				
132	GU	Gunpowder Falls	BA	Frog Hollow Run	PV	X				
133	GU	Gunpowder Falls	BA	Unnamed tributary	PV	X				
134	GU	Gunpowder Falls	BA	Indian Run	V	X				
135	GU	Gunpowder Falls	BA	Compass Run	PV	X				
136	GU	Gunpowder Falls	BA	Poplar Run	PV	X				
137	GU	Gunpowder Falls	BA	Unnamed tributary	PV	X				
138	GU	Gunpowder Falls	BA	Unnamed tributary	PV	X				
139	GU	S.Br. Gunpowder Falls	BA	Silver Run	PV	X				
140	GU	S.Br. Gunpowder Falls	BA	Walker Run	V	X				
141	GU	S.Br. Gunpowder Falls	CA	Muddy Creek	V	X				
142	GU	S.Br. Gunpowder Falls	CA	Unnamed tributary	V	X				
143	GU	Grave Run	CA	Unnamed tributary	V	X				
144	SU	Deer Creek	CA	South Stirrup Run	V	X				
145	SU	Deer Creek	HA	Kellogg Branch	PV	X				
146	SU	Deer Creek	HA	Gladden Branch	V	X				
147	SU	Deer Creek	HA	Rock Hollow Branch	V	X				
148	SU	Deer Creek	HA	Wet Stone Branch	V	X				
149	SU	Little Deer Creek	HA	Unnamed tributary	V	X				
150	SU	Little Deer Creek	HA	Spooners Creek	V	X				
151	SU	Deer Creek	HA	Unnamed tributary	V	X				

Table 3. List of self-sustaining brook trout populations in Maryland as of 2005, including date of most recent survey and population density statistics where applicable.

Key: River Basin - YG=Youghiogheny, NBP=North Branch Potomac, UP=Upper Potomac, MP=Middle Potomac, WC=West Chesapeake, PA=Patapsco, GU=Gunpowder, SU=Susquehanna;
County - GA=Garrett, AL=Allegany, FR=Frederick, AA=Anne Arundel, BA=Baltimore, CA=Carroll, HO=Howard, HA=Harford; UT=Unnamed tributary;
Survey/Agency - MBSS = Maryland Biological Stream Survey, FS=Fisheries Service

	River Basin	Watershed	County	Stream Name	Most recent survey/Agency	# adult trout per km	# adult trout/ha
1	YG	Casselman	GA	Piney Creek	1995/MBSS		
2	YG	Casselman	GA	Two Mile Run	2000/MBSS		
3	YG	Casselman	GA	North Branch, UT	1997/MBSS		
4	YG	Casselman	GA	Big Shade Run	1995/MBSS		
5	YG	Casselman	GA	North Branch, UT	1997/MBSS		
6	YG	Casselman	GA	South Branch	1995/MBSS		
7	YG	White's Creek (PA)	GA	Puzzley Run	1990/FS	220+/-21	628+/-25
8	YG	White's Creek (PA)	GA	Buck's Run	2000/FS		
9	YG	Mill Run	GA	Mill Run	2002/FS	153 to 244	
10	YG	Mill Run	GA	Mill Run , UT	2001/MBSS		
11	YG	Bear Creek	GA	Bear Creek, below hatchery	2001/MBSS		
12	YG	Bear Creek	GA	Bear Creek, above hatchery	2001/MBSS		
13	YG	Bear Creek	GA	L. Bear Creek, unnamed tributary	2001/MBSS		
14	YG	Bear Creek	GA	Little Bear Creek	2001/MBSS		
15	YG	Bear Creek	GA	Fikes Run	2000/FS		
16	YG	Bear Creek	GA	Cove Run	2000/FS	604+/-96	106+/-17
17	YG	Buffalo Run	GA	Buffalo Run	2000/FS		
18	YG	Deep Creek Lake	GA	Smith Run	1992/FS		
19	YG	Deep Creek Lake	GA	Meadow Mt. Run	1992/FS		
20	YG	Little Youghiogheny	GA	Little Youghiogheny	2004 /MBSS		
21	YG	Cherry Creek	GA	Unnamed tributary	1995/MBSS		
22	YG	Youghiogheny	GA	Weimers Run	2004/FS		
23	YG	Laurel Run	GA	Laurel Run	2000/FS		
24	YG	Roaring Run	GA	Roaring Run	1997/FS		
25	YG	Gap Run	GA	Gap Run	1987/FS		
26	YG	Ginseng Run	GA	Ginseng Run	2000/FS		
27	YG	Hoyes Run	GA	Hoyes Run	2000/FS	47+/-28	
28	YG	Hoyes Run	GA	Fork Run	2000/FS	410+/-74	
29	YG	Black Run	GA	Black Run	2000/FS		
30	YG	Youghiogheny	GA	Unnamed tributary	2000/FS		
31	YG	Cherry Creek	GA	Unnamed tributary	1994/MBSS		
32	NBP	Shields Run	GA	McMillan Fork	2000/FS		
33	NBP	Shields Run	GA	Shields Run	1998/FS	194+/-24	
34	NBP	Shields Run	GA	Aronhalt Fork	2000/FS		
35	NBP	Glade Run	GA	Glade Run	1994/FS	154	
36	NBP	Steyer Run	GA	Steyer Run	1992/FS	102	

Table 3. Continued (page 2 of 4)							
	River Basin	Watershed	County	Stream Name	Most recent survey/Agency	#adult trout per km	#adult trout/ha
37	NBP	Laurel Run	GA	Laurel Run	2003/FS	100	
38	NBP	Laurel Run	GA	Trout Run	1992/FS	277	
39	NBP	Laurel Run	GA	Riley Spring Run	2003/FS	22	
40	NBP	Lostland Run	GA	South Prong Lostland	2000/FS	194	
41	NBP	Lostland Run	GA	Lostland Run	2000/FS	167	
42	NBP	Lostland Run	GA	North Prong Lostland	2000/FS		
43	NBP	Short Run	GA	Short Run	2003/FS	176	
44	NBP	Wolfden Run	GA	Wolfden Run	2003/FS	113 - 220	
45	NBP	Elklick Run	GA	Elklick Run	1996/FS		
46	NBP	Folly Run	GA	Folly Run	2000/FS	1442	
47	NBP	Laurel Run	GA	Laurel Run	2000/FS	137 - 216	
48	NBP	Savage River	GA	Savage River, mainstem below dam	2005/FS	44 - 593	
49	NBP	Savage River	GA	Unnamed tributary	2000/FS		
50	NBP	Savage River	GA	Crabtree Creek	2000/FS;2005/ MBSS	565 - 641	
51	NBP	Savage River	GA	Middlefork Creek	2000/FS;2005/ MBSS	375	
52	NBP	Middlefork Creek	GA	Tom's Spring Run	2002/MBSS		
53	NBP	Savage River	GA	Dry Run	2003/MBSS; 2000/FS	776	
54	NBP	Savage River	GA	Monroe Run	2003/MBSS; 2000/FS	637	
55	NBP	Savage River	GA	Big Run	00 (FS)	846	
56	NBP	Big Run	GA	Unnamed tributary, Whiskey Hollow	2002/MBSS		
57	NBP	Savage River	GA	Pine Swamp Run	2000/FS	1206	
58	NBP	Savage River	GA	Bear Pen Run	2000/FS	2757	
59	NBP	Savage River	GA	Poplar Lick	2005/FS	226	
60	NBP	Savage River	GA	Savage River, mainstem above reservoir	2005/FS	8 - 246	
61	NBP	Savage River	GA	Elk Lick Run	2000/FS	1361	
62	NBP	Savage River	GA	Black Lick Run	2002/ MBSS		
63	NBP	Savage River	GA	West Branch Blue Lick Run	2002/MBSS		
64	NBP	Savage River	GA	Blue Lick Run	2002/MBSS	1694	
65	NBP	Savage River	GA	Christley Run	2002/MBSS		
66	NBP	Savage River	GA	Mudlick Run	2002/MBSS		
67	NBP	Savage River	GA	Unnamed tributary	2005/FS		
68	NBP	Savage River	GA	Little Savage River	2005/FS	2874	
69	NBP	Georges Creek	AL	Mill Run	1998/FS		
70	NBP	Georges Creek	AL	Laurel Run	1999/FS	981	
71	NBP	Georges Creek	AL	Koontz Run	1999/FS	951	
72	NBP	Georges Creek	AL	Elk Lick Run	2002/MBSS; 1999/FS	878	
73	NBP	Georges Creek	AL	Neff Run	2001/FS		

Table 3. Continued (page 3 of 4)							
	River Basin	Watershed	County	Stream Name	Most recent survey/Agency	#adult trout per km	#adult trout/ha
74	NBP	Georges Creek	AL	Matthews Run	2001/FS	698	
75	NBP	Georges Creek	AL	Sand Spring Run	2002/FS		
76	NBP	Braddock Run	AL	Braddock Run	2003/FS; 2002/MBSS	248-1339	
77	NBP	Braddock Run	AL	Cash Valley Run	2003/FS	435	
78	NBP	Mill Run	AL	Mill Run	2002/MBSS		
79	NBP	Evitts Creek	AL	Hazen Run	2002/MBSS		
80	UP	Antietam Creek	WA	Little Antietam Creek	2004/FS	472+/-21	81+/-4
81	UP	Antietam Creek	WA	Unnamed tributary	2004/FS	70	16
82	MP	Monacacy	FR	Bear Branch	2001/FS	present	
83	MP	Little Tuscarora Creek	FR	Little Tuscarora Creek	2001/FS	present	
84	MP	L.Tuscarora Ck.	FR	Unnamed tributary	1995(FS)		
85	MP	L.Tuscarora Ck.	FR	Clifford Branch	2003/FS	155 - 213	35 – 53
86	MP	Little Tuscarora Creek	FR	Unnamed tributary to Clifford Branch	2003/FS	abundant	
87	MP	Fishing Creek	FR	Oxys Hollow	1994/FS		
88	MP	Fishing Creek	FR	Fishing Creek	2003/FS	485 - 875	21 – 59
89	MP	Fishing Creek	FR	Little Fishing Ck.	2003/FS	409 - 868	39 – 82
90	MP	Litt. Hunting Ck.	FR	Buzzard Branch	2005/MBSS		
91	MP	Litt. Hunting Ck.	FR	Litt. Hunting Creek	2004/FS	33 - 86	2 – 10
92	MP	Hunting Creek	FR	High Run	2003/FS	abundant	
93	MP	Hunting Creek	FR	Left Fork	2000/FS	abundant	
94	MP	Hunting Creek	FR	Right Fork	2001/FS	178+/-0.9	23+/-0.1
95	MP	Owens Creek	FR	Owens Creek	2005/FS	179 - 1247	32 – 131
96	MP	Catoctin Creek	FR	Spruce Run	1990/FS		
97	MP	Catoctin Creek	FR	Middle Creek	1992/FS		
98	WC	Severn River	AA	Jabez Branch	2005/FS		
99	PA	Jones Falls	BA	Dipping Pond Run	1996/FS	11	1
100	PA	N.Br Patapsco	BA	Snowden Run	1994/FS		
101	PA	N.Br. Patapsco	CA	Stillwater Creek	2005/FS	118	30
102	PA	N.Br. Patapsco	CA	Cooks Run	1999/FS	present	
103	PA	N.Br. Patapsco	BA	Timber Run	2003/FS	40	10
104	PA	N.Br. Patapsco	BA	Norris Run	2003/FS	present	
105	PA	S.Br. Patapsco	BA	Unnamed tributary	2003/FS	36	41
106	GU	Little Gunpowder Falls	HO	Laurel Brook Run	2003/FS	present	
107	GU	Little Gunpowder Falls	HA	Overshot Branch	2003/FS	5	1
108	GU	Little Gunpowder Falls	HA	Thornton Branch	2003/FS	23	10
109	GU	Little Gunpowder Falls	HA	Sawmill Branch	2005/FS	present	
110	GU	Gunpowder Falls	BA	Greene Branch	2003/FS	14	9
111	GU	Gunpowder Falls	BA	Unnamed tributary	2000/FS	27	3
112	GU	Gunpowder Falls	BA	Piney Creek	2000/FS	149	13
113	GU	Gunpowder Falls	BA	Buffalo Creek	2000/FS	22	5
114	GU	Gunpowder Falls	BA	Unnamed tributary	2000/FS	18	3

Table 3. Continued (page 4 of 4)							
	River Basin	Watershed	County	Stream Name	Most recent survey/Agency	#adult trout per km	#adult trout/ha
115	GU	Gunpowder Falls	BA	Charles Run	2003/FS	13	3
116	GU	Gunpowder Falls	BA	Panther Branch	2000/FS	31	8
117	GU	Gunpowder Falls	BA	Bush Cabin Run	2005/FS	47	18
118	GU	Gunpowder Falls	BA	Unnamed tributary	2005/FS	brown trout	
119	GU	Western Run	BA	Beaver Dam Run	2000/FS	27	6
120	GU	Western Run	BA	Oregon Branch	2005/FS	present	
121	GU	Western Run	BA	Baisman Run	2005/FS	present	
122	GU	Western Run	BA	BlackRock Run	2000/FS	brown trout	
123	GU	Western Run	BA	Indian Run	2000/FS	28	7
124	GU	Western Run	BA	Deadman Run	2000/FS	brown trout	
125	GU	Little Falls	BA	Unnamed tributary	2000/FS	15	1
126	GU	Little Falls	BA	Unnamed tributary	2000/FS	5	1
127	GU	Little Falls	BA	First Mine Branch	2000/FS	6 - 10	0 - 3
128	GU	Little Falls	BA	Third Mine Branch	1997/FS	present	
129	GU	Little Falls	BA	Fourth Mine Branch	2000/FS	18	5
130	GU	Little Falls	BA	Owl Branch	2000/FS	76	21
131	GU	Gunpowder Falls	BA	Unnamed tributary	2000/FS	18	12
132	GU	Gunpowder Falls	BA	Frog Hollow Run	2004/FS	14	3
133	GU	Gunpowder Falls	BA	Unnamed tributary	2000/FS	149	14
134	GU	Gunpowder Falls	BA	Indian Run	2000/FS	28	7
135	GU	Gunpowder Falls	BA	Compass Run	2001/FS	27	8
136	GU	Gunpowder Falls	BA	Poplar Run	2002/FS	27	2
137	GU	Gunpowder Falls	BA	Unnamed tributary	2000/FS	96	16
138	GU	Gunpowder Falls	BA	Unnamed tributary	2001/FS	139	36
139	GU	South Branch Gunpowder Falls	BA	Silver Run	2003/FS	217	56
140	GU	South Br. Gunpowder Falls	BA	Walker Run	2004/FS	78	25
141	GU	South Branch Gunpowder Falls	CA	Muddy Creek	1997/FS	6	2
142	GU	South Br. Gunpowder Falls	CA	Unnamed tributary	2000/FS	66	33
143	GU	Grave Run	CA	Unnamed tributary	2001/MBSS		
144	SU	Deer Creek	CA	South Stirrup Run	2001/FS	10	2
145	SU	Deer Creek	HA	Kellogg Branch	2003/FS	23	8
146	SU	Deer Creek	HA	Gladden Branch	2003/FS	34	27
147	SU	Deer Creek	HA	Rock Hollow Branch	2004/FS	22	8
148	SU	Deer Creek	HA	Wet Stone Branch	2001/MBSS		
149	SU	Little Deer Creek	HA	Unnamed tributary	2001/MBSS		
150	SU	Little Deer Creek	HA	Spooners Creek	2004/MBSS		
151	SU	Deer Creek	HA	Unnamed tributary	2004/MBSS		

Table 4. Historical Maryland freshwater fishing regulations relating to brook trout.

Date	Regulation Summary
1874	"…Persons controlling artificial ponds may sell brook trout"
1876	"…unlawful to have in possession any speckled trout (sic brook trout) or speckled river trout except during May, June, and July"
1878	"…unlawful to catch or kill any speckled trout in any manner…for a space of three years in Baltimore County"
1880	"…unlawful to take speckled trout or speckled river trout except during April, May, June, and July, and none caught on Sundays"
1890	"…Protect trout in Frederick, Cecil, and Washington counties December through June"
1900	"…prevents destruction of trout in Casselman river by use of floating sawdust"
1910	"…legal size for brook trout is 6 inches"
1914	Frederick county season for brook trout March 31 through July 1, creel limit 40 per day, minimum size 6 inches.
1914	[Garrett County]" …unlawful for any person to take any brook trout or any trout from any stream in Garrett County which has been stocked by State hatchery for a period of two years from 1914"
1935	"…stocking Garrett streams with fish, brook trout to be stocked at 8 to 10 inches, whereupon stream would be closed [sic to angling] for a one year period"
1964	Trout stamp requirement enacted, anglers fishing for and possessing trout must have a trout stamp.
19XX	Trout, all species, no minimum size, creel limit 7 per day.
1975	Trout, all species, no minimum size, creel limit 5 per day in designated waters. Creel limit 3 in all other waters of the state east of Frederick county and not listed as a designated water.
1983	Trout, all species, no minimum size, creel limit 5 per day statewide.
1987	Trout, all species, no minimum size. Creel limit 2 per day statewide, except in designated put and take trout fishing areas, 5 per day

Table 5. Generalized impacts from surface and deep coal mining that are detrimental to brook trout populations.

Impact	Effects
Acid mine drainage	Low pH Toxic metal release Iron precipitation “Slugs” of poor water quality released from precipitation events
Hydrological changes	Reduced/increased groundwater flows Altered absorption and runoff patterns Water temperature increases Flood events Creation of impoundments
Erosion	Sedimentation Increased turbidity Stream character changes Increased roads/ATV access
Physical habitat	Dewatering/burying/sedimentation of stream miles Increased scour Loss of interstitial spaces/invertebrate production Alteration/loss of spawning/nursery areas Concretion of stream bed gravel/rock Loss of woody debris/nutrient input Fish passage blockages/impediments Loss of riparian buffers

Table 6. Maryland Brook Trout Fishery Management Plan (BTFMP) recommended management or research actions and the plan objectives these actions support. The goal and objectives of the BTFMP are listed on page 8 of the plan. Recommendations along with strategies and actions to carry them out are listed on page 38-47 of the plan.

Management Recommendation	**Brook Trout Management Plan Objective**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. Develop sufficient life history & exploitation information	■						■	■	
2. Establish statewide GEP index		■	■		■				
3. Develop plan to ID and preserve at risk populations			■		■				
4. Develop comprehensive management plan for Savage River					■				
5. Encourage riparian buffer preservation/restoration						■	■	■	
6. Convey impact of human activities to agencies & public						■	■	■	
7. Develop guidelines for restoring extirpated populations					■			■	
8. Complete genetic inventory of discrete populations			■						
9. Foster interaction with user groups				■			■		■
10. Support advocacy groups						■	■	■	■
11. Develop coordinated statewide monitoring schedule	■				■				■
12. Develop statewide standardized sampling protocol	■				■				■
13. Create centralized statewide brook trout data depository	■				■				
Research Recommendation									
1. Determine life history parameters	■		■		■		■		
2. Determine angler use, harvest, economic benefit of resource			■	■	■				
3. Investigate brook trout movement patterns		■	■		■				
4. Investigate impact of non-native fish species on brook trout			■		■		■		
5. Investigate effectiveness and impact of current regulations			■		■				
6. Determine extent of streams impacted by acid rain/drainage					■	■	■	■	

Figure 1. Map of Maryland's physiographic provinces (USGS 2001). Historical native brook trout range is considered to be west of the fall line (Piedmont province and west).

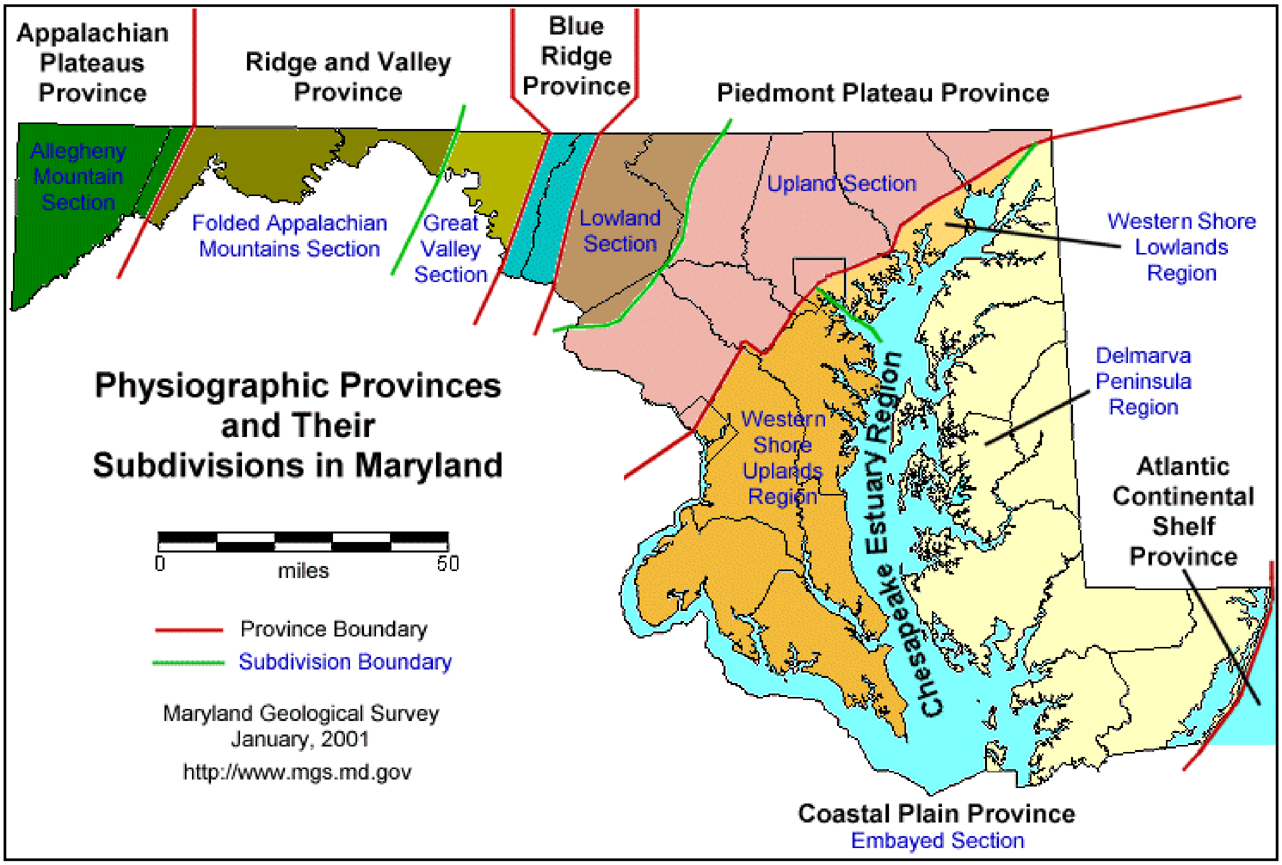


Figure 2. Brook trout length-frequency from selected streams in the Central Region of Maryland, 1987-2004 (MD DNR Fisheries Service data).

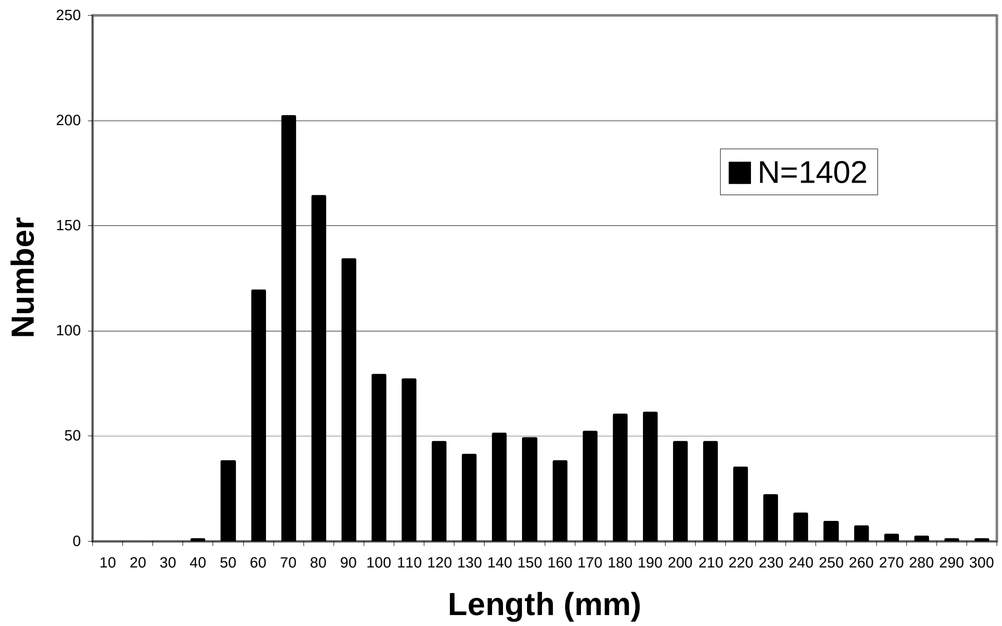


Figure 3. Brook trout length-frequency for the left and right forks of Fishing Creek, Frederick County, Maryland, 1988-2003 (MD DNR Fisheries Service data).

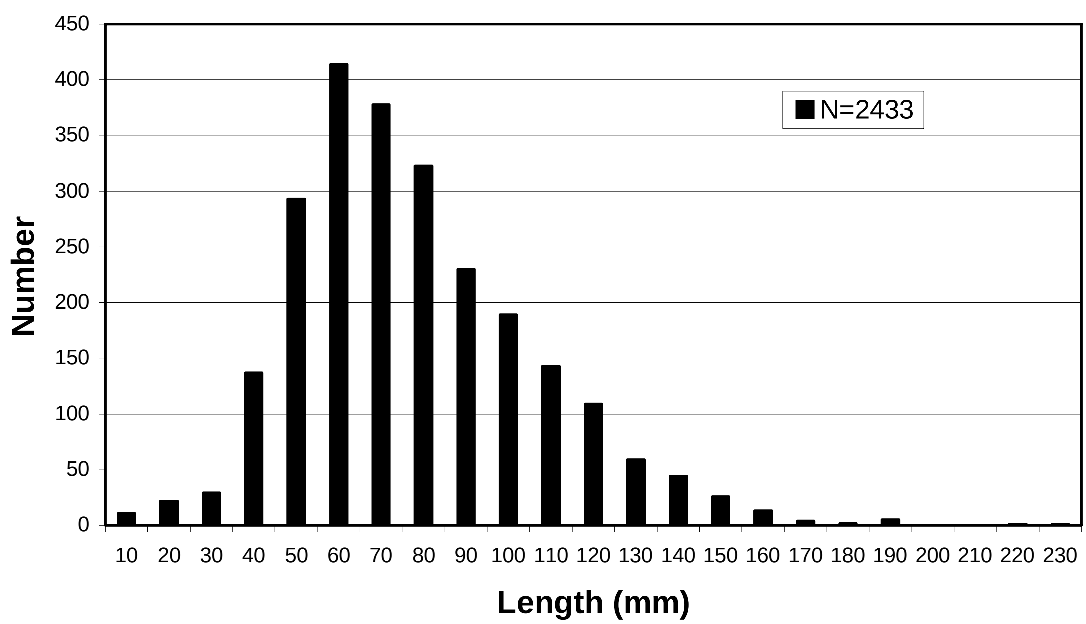


Figure 4. Maryland Department of Natural Resources' Coldwater Fisheries Management Policy.

MARYLAND DEPARTMENT OF NATURAL RESOURCES
MANAGEMENT OF MARYLAND'S COLD WATER FISHERIES RESOURCE,
ADOPTED JANUARY 3, 1986.

COLD WATER FISHERIES MANAGEMENT POLICIES
To assist the Cold Water Fisheries Program in the performance of its work, the Department of Natural Resources has adopted the following Policies to serve as guidelines for the management of Maryland's Cold Water Fisheries Resource. Adopted January 3, 1986.

HABITAT POLICY
Suitable habitat is basic to successful cold water fisheries management. ***Therefore:*** it is the policy of the Department of Natural Resources to protect, maintain, improve, restore, and expand cold water fisheries habitat.

RESEARCH POLICY
Accurate and up to date knowledge of the cold water fisheries resource is fundamental to its proper management. ***Therefore:*** it is the policy of the Department of Natural Resources to establish and maintain a current data base on the quality and quantity of the cold water fisheries resource and to evaluate the implication of these data as they relate to this resource and the recreational opportunities associated with the resource.

NATURAL TROUT POPULATIONS POLICY
Naturally reproducing trout populations are a valuable natural resource. ***Therefore:*** it is the policy of the Department of Natural Resources to protect, conserve, and enhance existing natural trout populations and to establish additional populations wherever feasible.

LAWS AND REGULATIONS POLICY
Laws and regulations are necessary to protect and properly manage the cold water fisheries resource of the State. ***Therefore:*** it is the policy of the Department of Natural Resources to recommend and implement laws and regulations based upon a careful evaluation of pertinent biological, social, and economic considerations which will result in adequate protection and conservation of the resource.

HATCHERY TROUT POLICY
The use of hatchery reared trout to provide recreational trout fishing is a valuable and necessary fishery management tool. Without hatchery trout, the opportunity to "fish for trout" would cease to exist for many anglers within the State. In addition, selected stocks of trout produced in hatcheries can be utilized to expand the cold water fisheries resource or assist in its restoration. ***Therefore:*** it is the policy of the Department of Natural Resources to utilize hatchery produced trout in a manner which will provide maximum benefit to the angler and the cold water fisheries resource *with no appreciable negative impact upon the natural trout resource* (italics added).

COOPERATIVE TROUT PRODUCTION PROJECTS POLICY
Additional trout for "special management" and/or "put and take" stocking are desirable since State trout production facilities are operating at their maximum capacity and trout are no longer being made available to the State from federal facilities. ***Therefore:*** it is the policy of the Department to assist and advise, within existing economic limitations and consistent with the Department's trout stocking guidelines, all individuals and groups which are capable of and offer to produce trout for stocking into the waters of the State to provide public recreational trout fishing.

PUT AND TAKE TROUT STOCKING POLICY
Cold water fisheries habitat is a limited resource within Maryland. ***Therefore:*** it is the policy of the Department to stock trout for put and take fishing into the most suitable waters which are open to public fishing within a given geographical area.

PRIVATE WATERS TROUT STOCKING POLICY
Cold water fisheries habitat is a limited resource within Maryland. ***Therefore:*** it is the policy of the Department to stock trout into privately owned waters only when such stocking is determined to be in the best interest of the natural resource and is consistent with an approved cold water management plan.

PUBLIC ACCESS TO TROUT FISHING WATERS POLICY
Adequate access to trout fishing waters is fundamental to public recreational trout fishing. ***Therefore:*** it is the policy of the Department to obtain and public access maintain to trout fishing waters for recreational trout fishing.

PUBLIC INFORMATION AND EDUCATION POLICY
Meaningful communication is the key to successful management of the State's cold water fisheries resource. ***Therefore:*** it is the policy of the Department to maintain active lines of communication with trout anglers as well as other citizens who are interested in the coldwater fisheries resource through public hearings, formal and informal meetings.

Figure 5. Map of the Savage River Watershed within Maryland. The area within the red oval is the Upper Savage River system, emphasizing the number of streams and their inter-connectedness (R. Morgan, personal communication 2005).

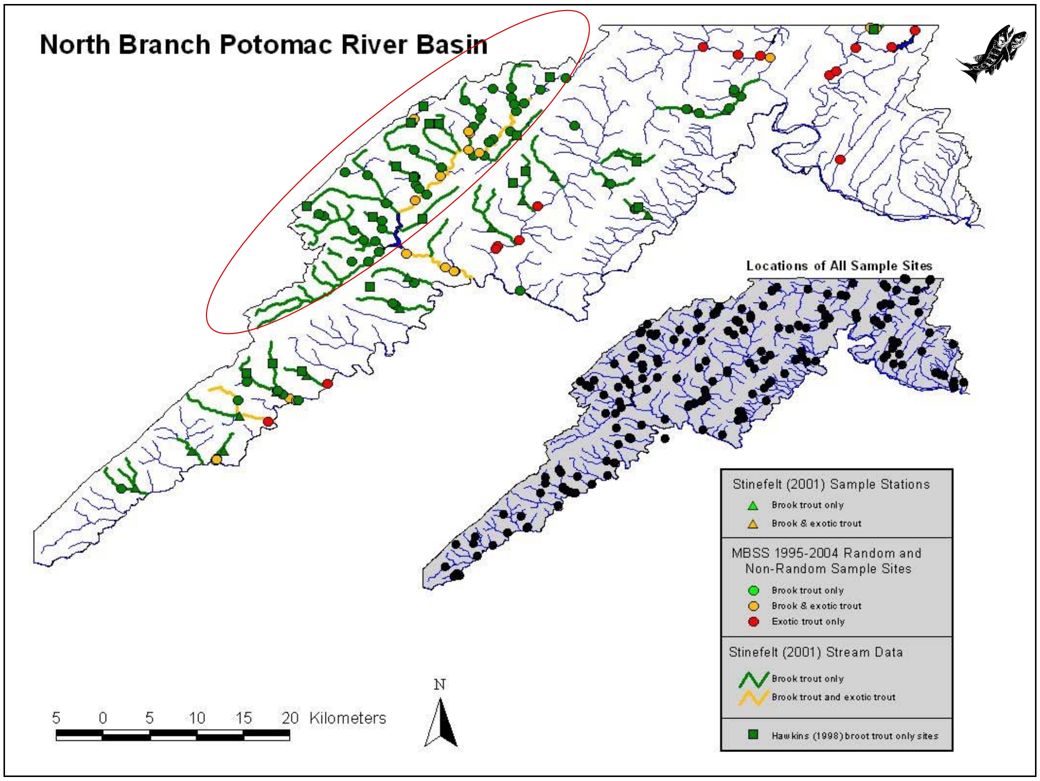


Figure 6. Brook trout populations in Maryland's Gunpowder River basin, emphasizing the isolation and disconnect between individual populations (R. Morgan, personal communication).

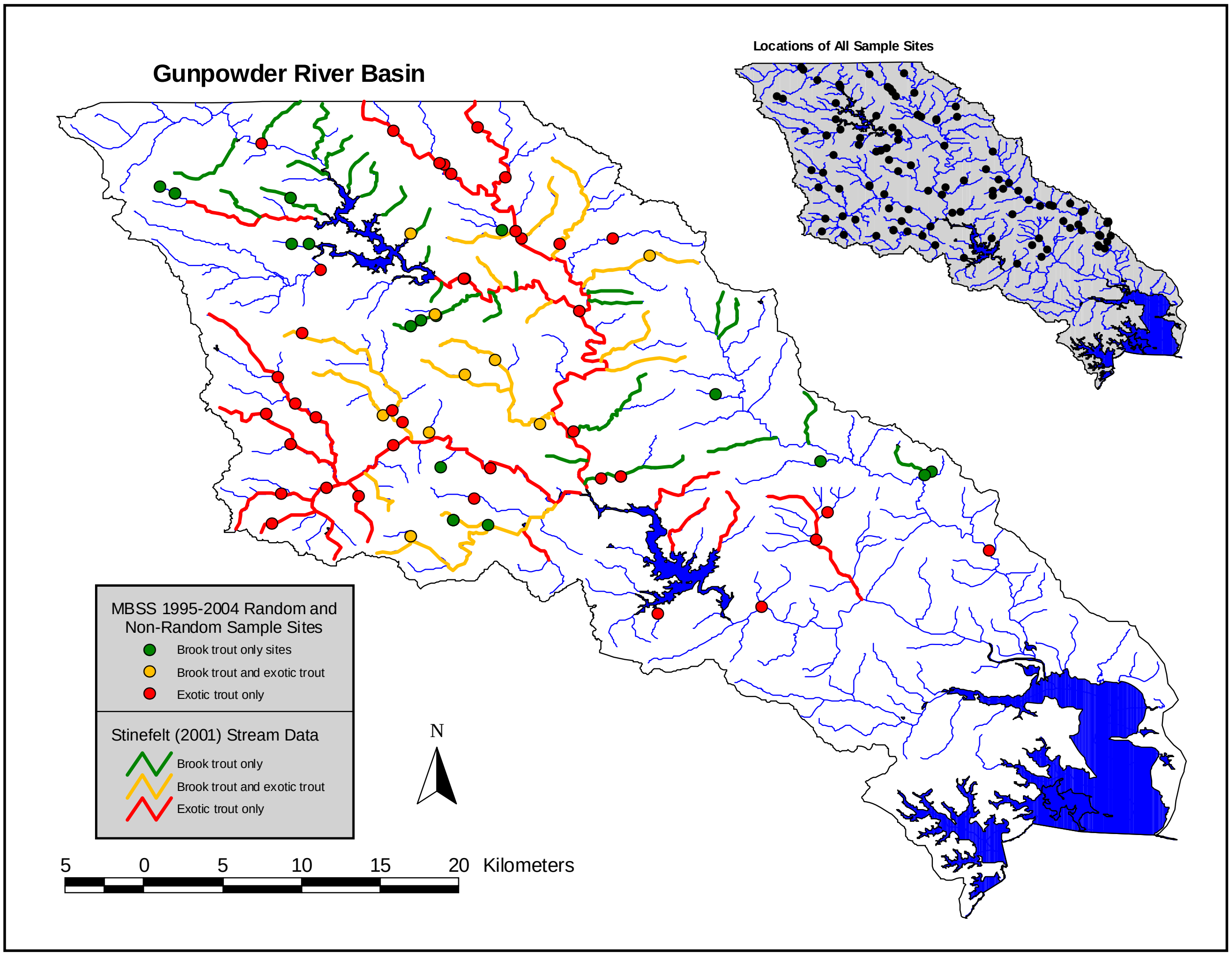


Figure 7. Status of Maryland brook trout populations by Subwatershed (Hudy et al. 2005).

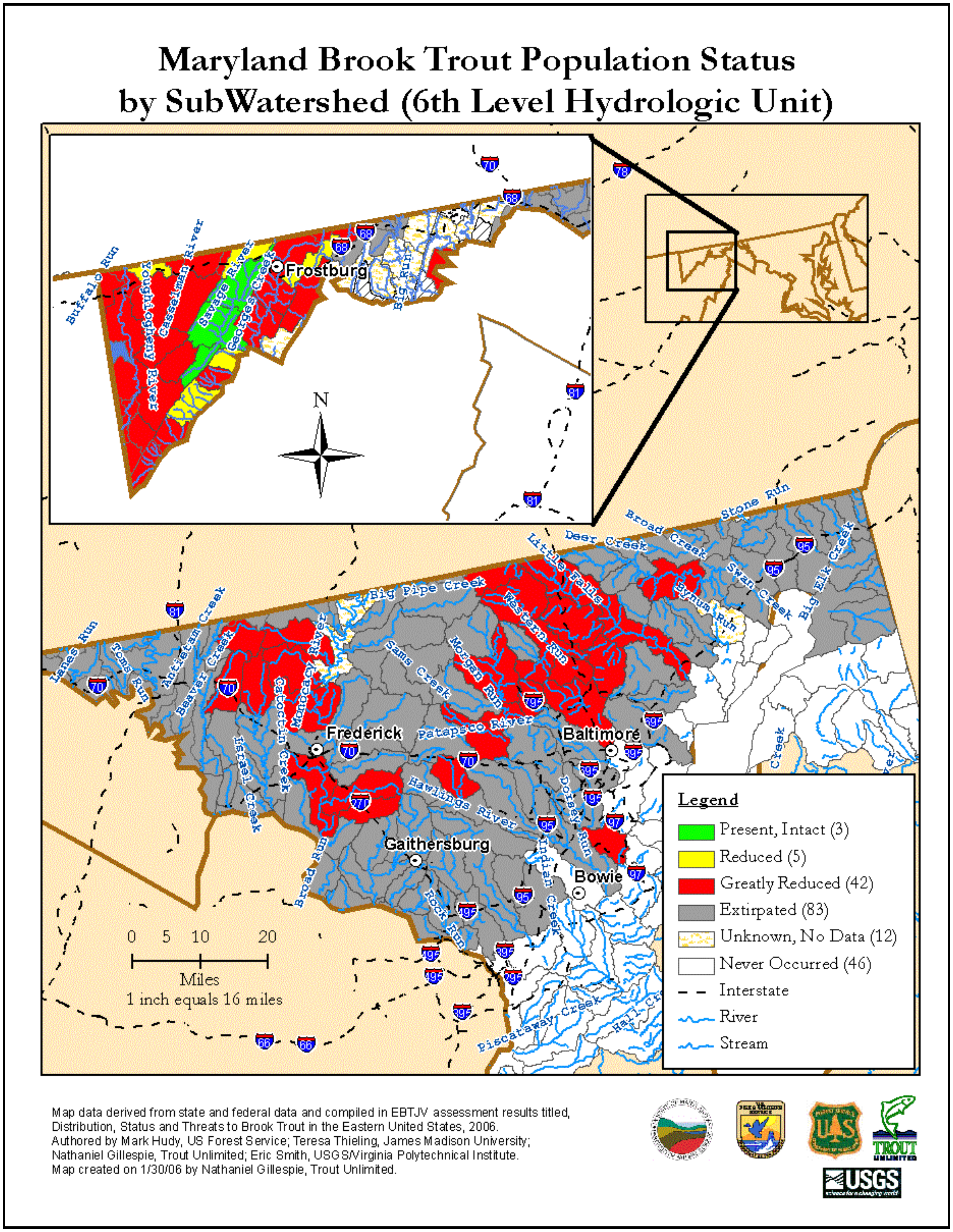


Figure 8. Mean standing crop (kg/ha) of Maryland's Savage River brook and brown trout populations. Pooled data from three long term depletion estimate sampling locations, 1988 – 2003.

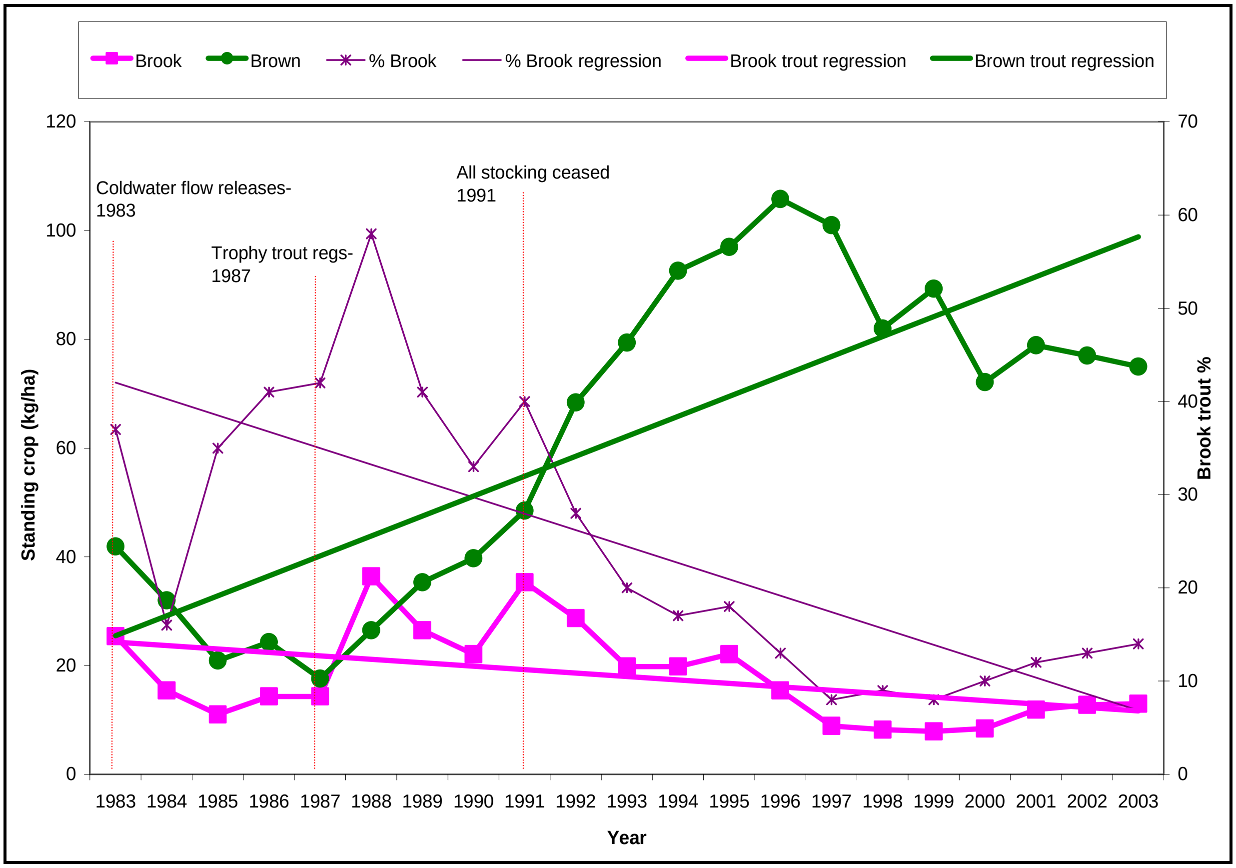


Figure 9. Number of brook trout (number per MBSS sample site) versus percent impervious surface, statewide pooled samples (R. Morgan, personal communication).

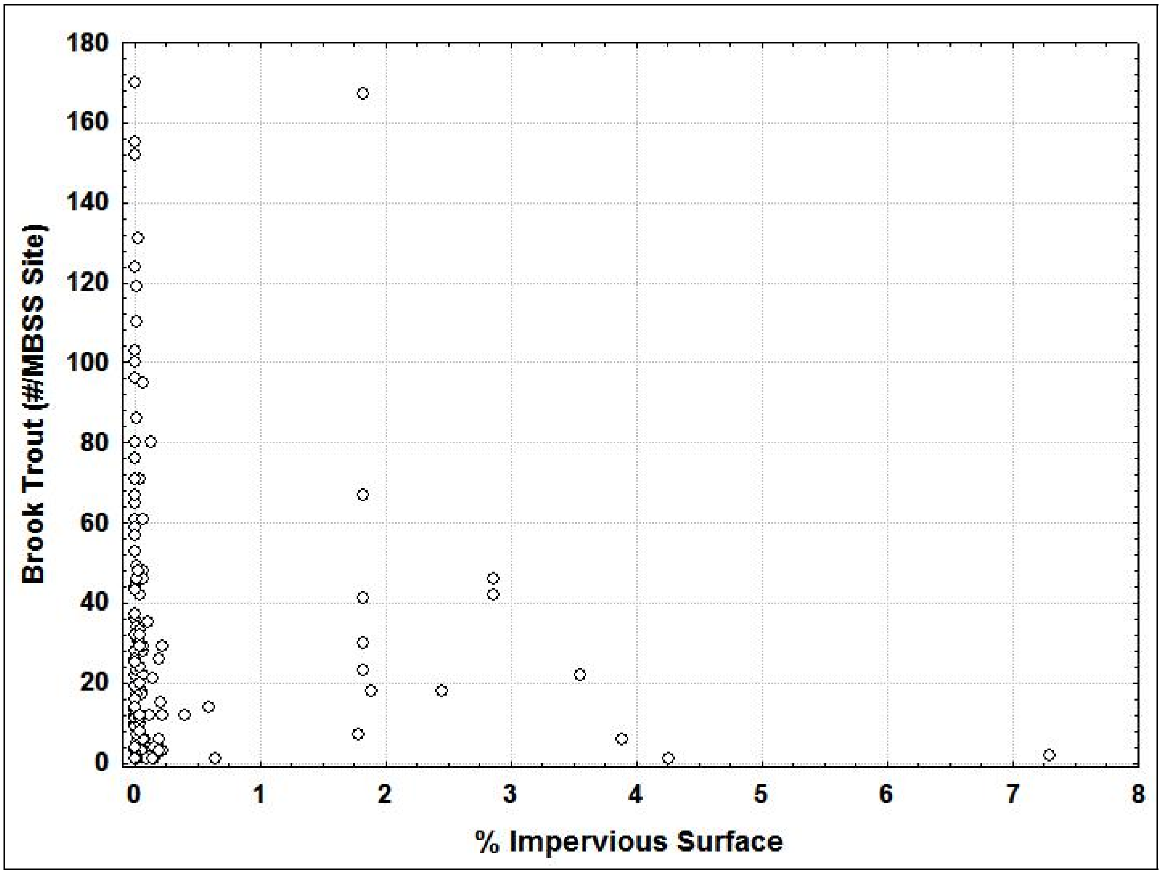


Figure 10. Map of the Appalachian coal producing states in relation to the native range of the Eastern brook trout (U.S. Dept. of Energy 2003).

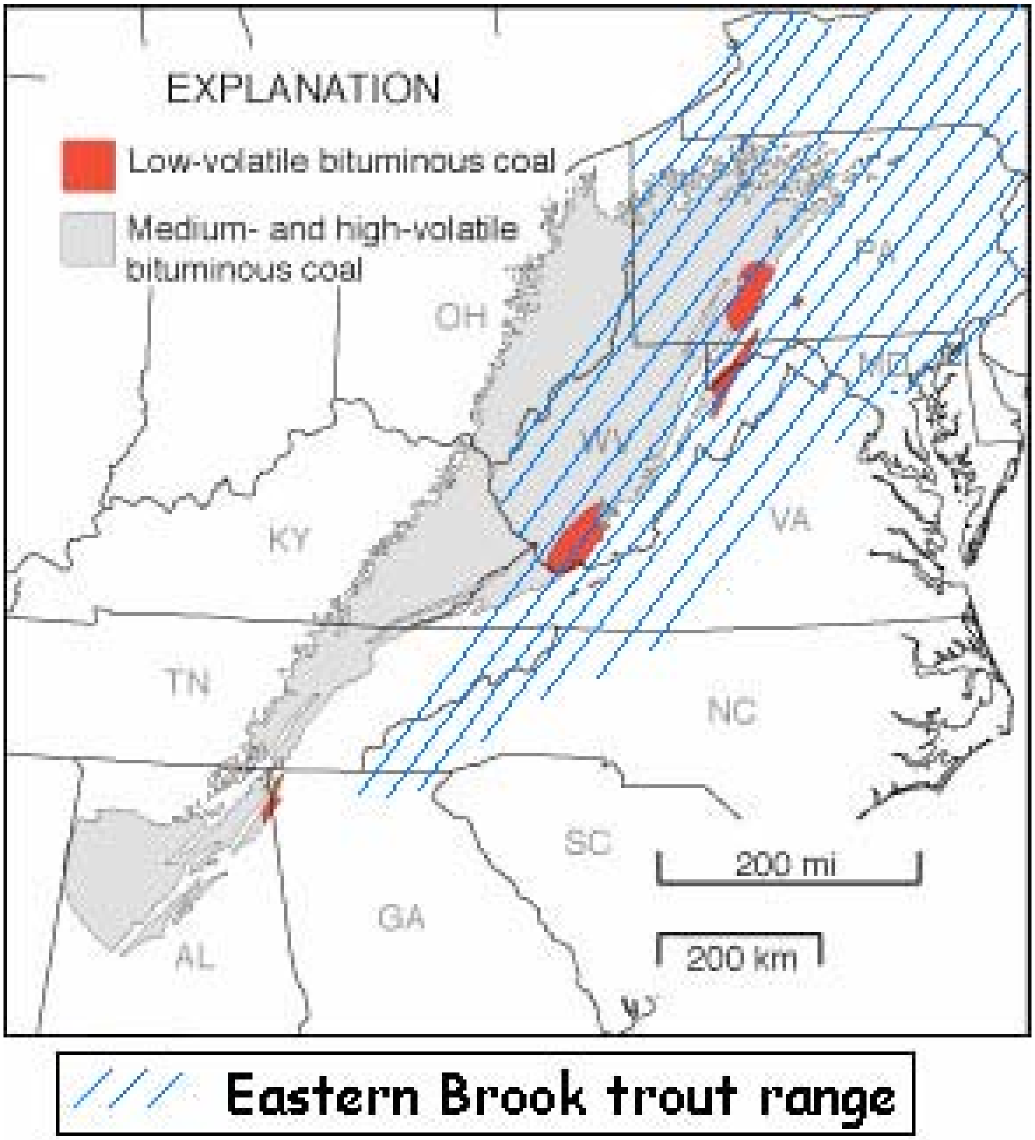


Figure 11. Abandoned mine sites (shown as red triangles) in Maryland (USEPA 1995).

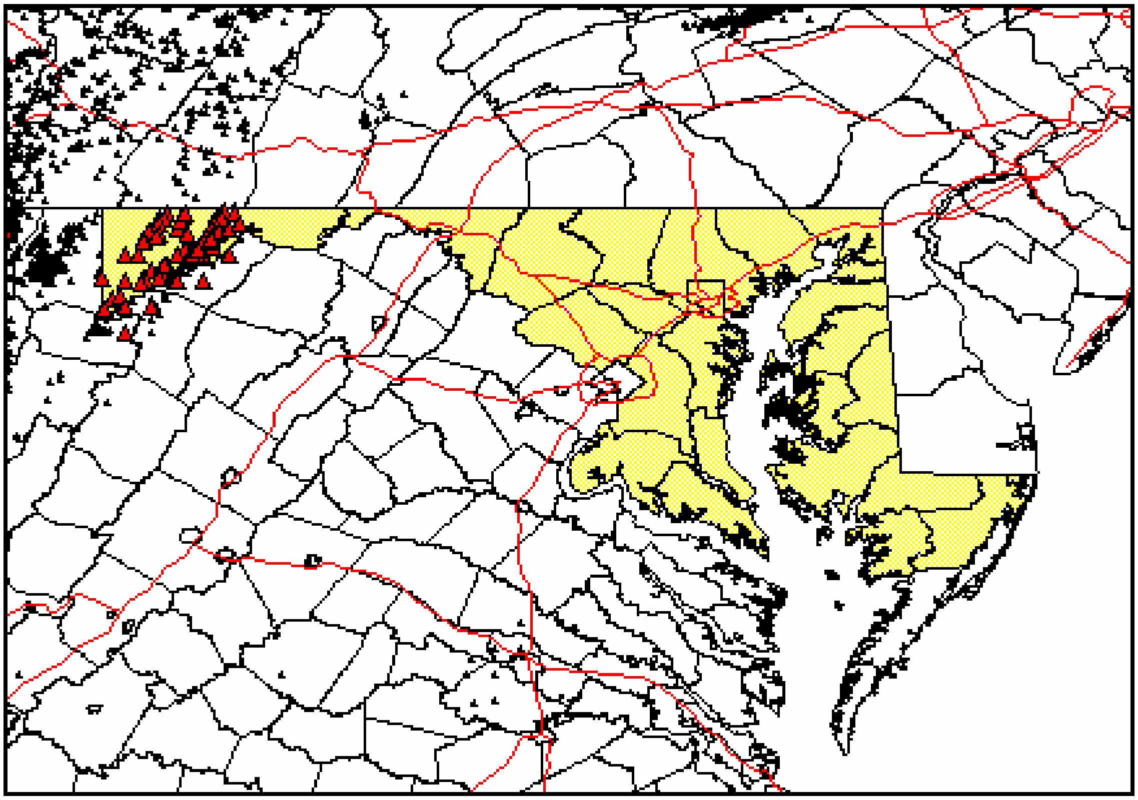


Figure 12. Map of Maryland brook trout range showing portion of range (light green area) where groundwater temperatures are predicted to increase by 2 - 4^0C by 2100 (R. Morgan, personal communication).

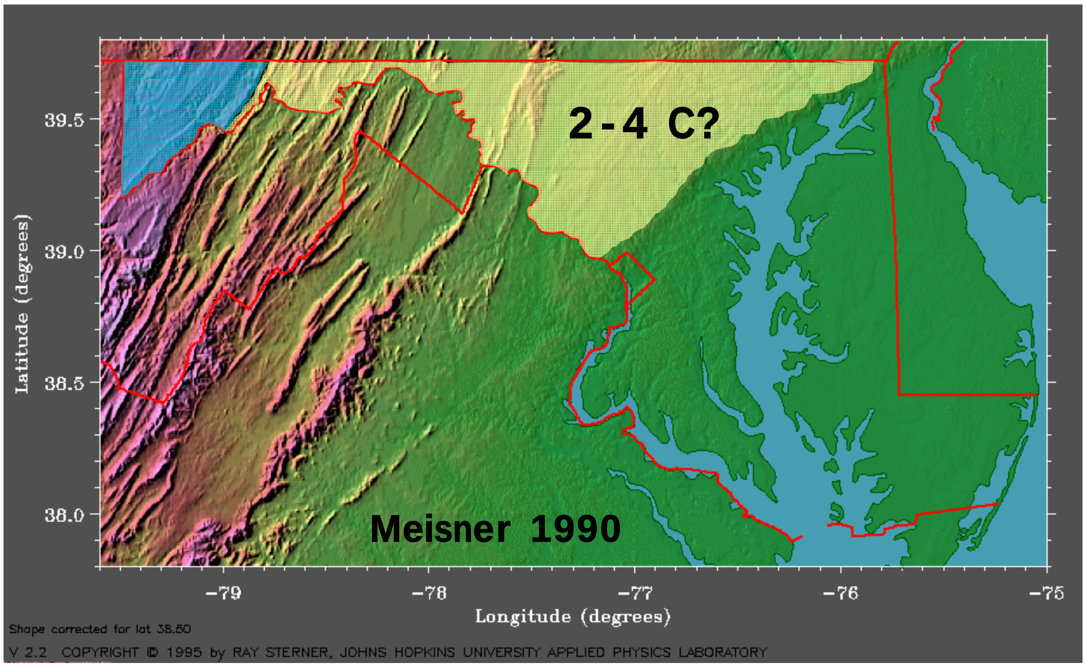


Figure 13. Predicted brook trout range in the Eastern United States by the year 2100. Darkened area shows predicted range and shaded area shows where brook trout have been extirpated due to increasing water temperatures resulting from climatic warming. Note that brook trout are predicted to be extirpated everywhere in Maryland except Garrett and Allegany counties (Meisner 1990).

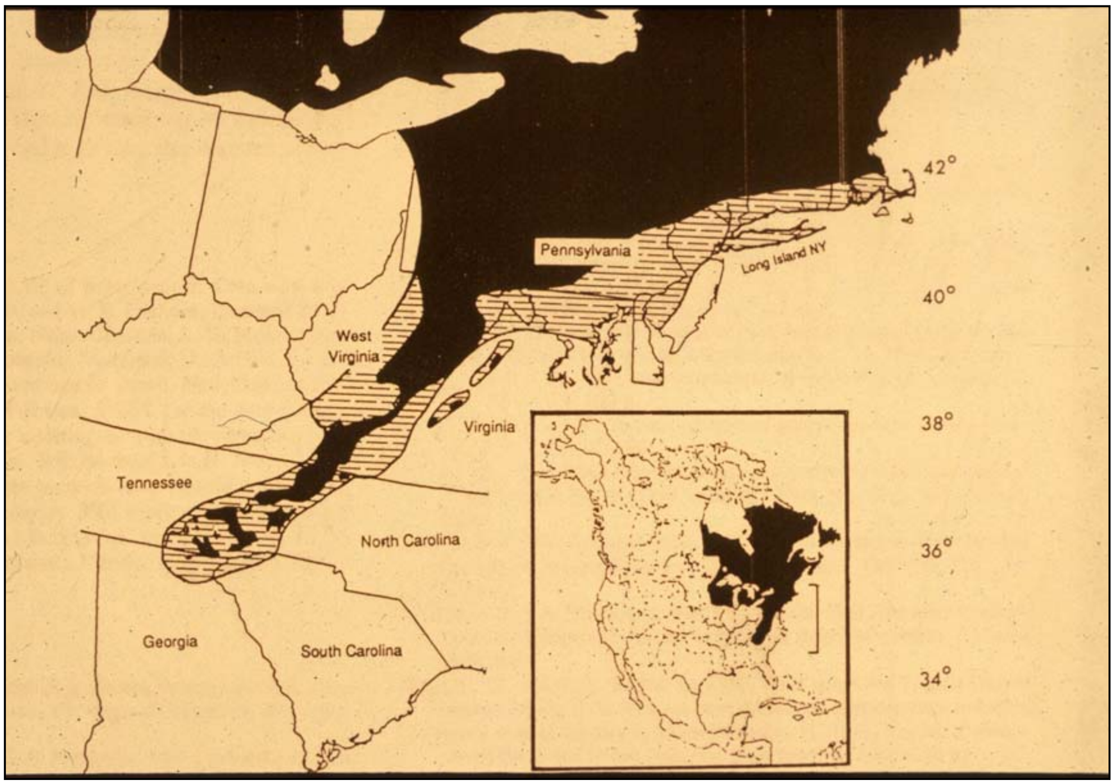
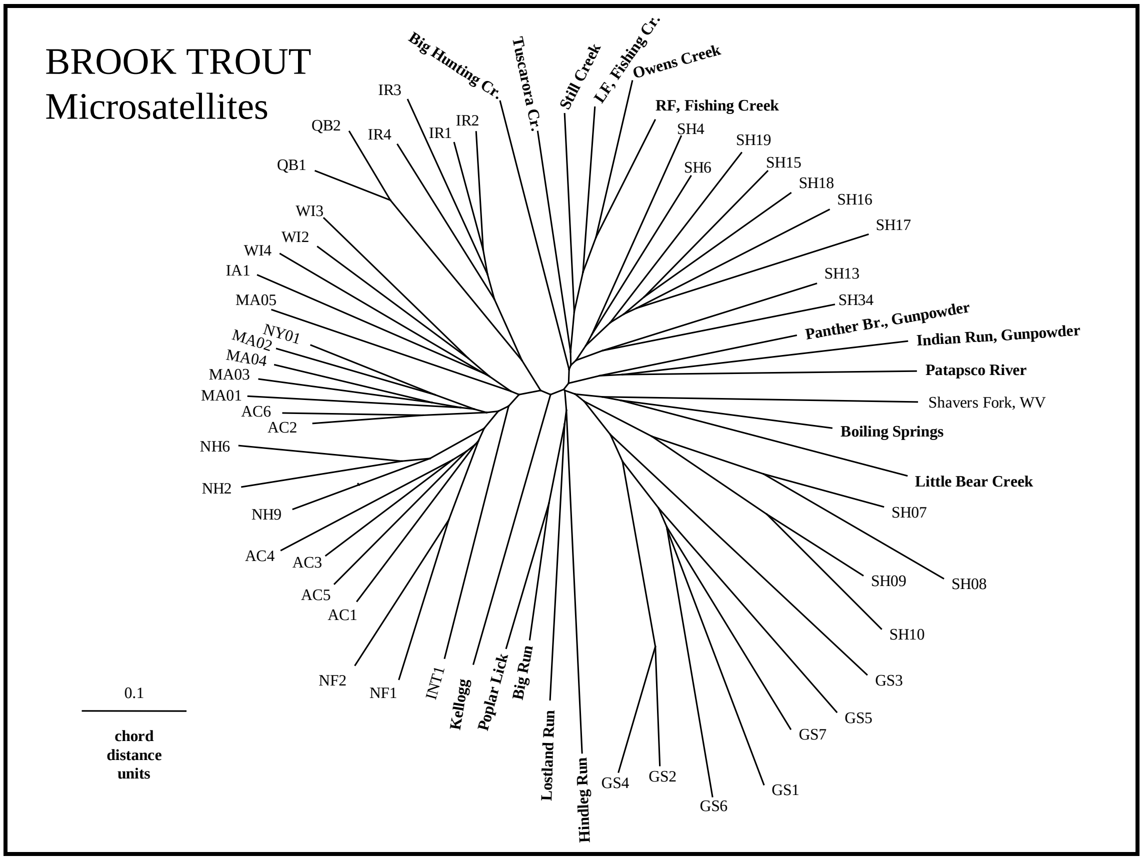


Figure 14. Map of the genetic makeup (by microsatellites) of brook trout populations in Maryland (King and Morgan, unpublished data).



Appendix A

Listing and Description of State Coldwater/Brook Trout Management Plans.

Brook trout management plans from other states and management agencies were solicited and collected for inclusion in this document. Requests for brook trout management plans were sent to 20 states and agencies. Most states and agencies contacted did not have specific brook trout management plans, but did have coldwater management plans (Table A1). North Carolina was the only state contacted that had a brook trout management plan. The Southern Division of the American Fisheries Society-Trout Committee has produced a Position Statement on Managing Southern Appalachian Brook Trout. The Great Lakes Fishery Commission published a *Brook Trout Rehabilitation Plan for Lake Superior*.

The search for plans and management strategies focused on surrounding states with similar ecosystems and concerns in the hope that reviewing these plans could provide a framework and concepts for Maryland's brook trout Fishery Management Plan. Pennsylvania has a trout management plan with a wild trout section (Pennsylvania Fish and Boat Commission 1997). West Virginia does not have a document although they do avoid stocking hatchery trout into brook trout streams (Mike Shingleton, personal communication). Virginia does not have a published plan (Scott Smith, personal communication)

The Pennsylvania wild trout management plan has different management strategies for streams based upon the biomass of wild trout the stream supports. Class "A" brook trout streams: support 30 kg/ha or more of brook trout, biomass of brook trout less than 15 cm total length of at least 0.1 kg/ha, and brook trout must comprise at least 75% of the total trout biomass. These streams have a no stocking policy and are noted as priorities for protection of water quality and habitat. Anglers are allowed to harvest 8 fish/day with a 7 inch minimum length from mid-April to Labor Day; thereafter the limit is 3 fish/day. There are no gear or tackle restrictions. Class "B" and lower wild trout streams can be stocked with hatchery trout if it is recreationally desirable. Pennsylvania Fish Commission is reviewing the plan and consideration is being given to managing some populations on a drainage basin scale with some harvest regulation changes (Tom Greene, personal communication)

New Jersey published a draft coldwater fisheries management plan that includes a wild trout section (Hamilton and Barno 2004). The plan mentions the opportunity to develop and implement a brook trout management plan. Strategies for managing wild trout in NJ include: resource inventory, brook trout genetics study, restricting harvest on wild trout streams, habitat concerns, education/communication. The wild trout management policy focuses on habitat restoration and protection; no stocking on wild trout streams, and brook trout will be the preferred species in establishing or re-establishing wild populations.

The North Carolina Wildlife Resources Commission has produced a draft brook trout management plan as a supplement to its trout management plan (North Carolina Wildlife Resources Commission 1989; 2003). The plan identifies brook trout as a special resource with the goal of identifying, protecting and enhancing brook trout in North Carolina. The genetically distinct southern Appalachian brook trout are the native trout in North Carolina and the focus of the plan. Main sections of the plan are: habitat protection and enhancement, regulations, distribution, population enhancement, and education. The habitat section focuses on regulatory strategies to protect water quality in brook trout streams from the impact of construction and acid precipitation. The angling regulations in place appear to protect populations from overharvest. The distribution section outlines steps to create a database on brook trout distribution and genetics. The population enhancement section develops strategies to protect brook trout populations from stocking hatchery trout and restoration and enhancement of historic brook trout streams with genetically appropriate stocks of brook trout. Education would focus on conveying information about brook trout management to the public through various media. The North Carolina plan also includes an appendix with protocols for restoration of brook trout to unpopulated streams and reclamation of brook trout streams with sympatric populations of brown and rainbow trout.

The Southern Division American Fisheries Society-Trout Committee has written a position statement on the management of southern Appalachian brook trout (Habera and Moore 2004). The document focuses on the unique genetics and habitat of the brook trout found in the Appalachians south of the New River. The SDAFS position statement and North Carolina's brook trout plan are built around the same core issues and concerns. The National Park Service and U.S. Fish and Wildlife Service were among the partners in developing the document. The position statement contains a brief definition and purpose section then outlines a history and status of southern Appalachian brook trout. The document identifies 8 issues of concern: habitat protection, genetic inventories, taxonomic status, hatchery brook trout stocking, restoration and enhancement, angling regulations, monitoring, and planning. Each issue is expanded upon in the document.

The Great Lakes Fishery Commission produced *A Brook Trout Management Plan for Lake Superior* (Newman et al. 2003). The plan addresses the issues surrounding restoration of populations of migratory lake dwelling brook trout native to the Lake Superior basin. The actions suggested to restore the population include: restoration of tributary habitat, regulation of harvest, and introduction of genetically appropriate strains of brook trout. Wisconsin has attempted restoration of brook trout streams by removing brown trout with some success (Avery 2002.).

New England states have a distinct set of concerns regarding brook trout. No management plans were received from these states (except Connecticut) but reading their websites indicates special concern for lacustrine populations and the impacts of acid precipitation. The Connecticut trout management plan indicates a strong reliance on hatchery trout (Hyatt et al. 1999.) Wild trout, including brook trout, were mentioned in the plan but there was little emphasis on managing their populations.

Missouri and Arkansas have similar trout management plans (Kruse 2003; Bowman and Jones 2004). Each state has very few wild trout populations and no native trout populations. Missouri has a few spring creeks that support trout populations but most of the trout in both states are found in tailwaters. Management in both states is focused on hatchery trout stocking strategies.

California has a trout management plan (Hopelain 2003.). The plan advocates an ecosystem based (watershed) approach to managing its trout resource. The two themes are habitat and native species protection/management and recreational angling. The protection of coldwater ecosystems and developing plans for watershed management units is emphasized.

The three brook trout management plans reviewed (North Carolinas, the Southern Division of the American Fisheries Societies', and the Lake Superior) addressed similar issues. Coldwater habitat restoration and protection was a major goal in each plan. The maintenance of locally adapted genetically pure brook trout populations was a priority issue in each plan. Other common themes were restoration of brook trout populations, limiting exposure of wild trout to hatchery trout, review of angling regulations, and educating the public about brook trout. The Lake Superior plan viewed angler harvest as a limiting factor because anglers depleted migratory stocks of brook trout in the past and significant harvest is still an issue. The North Carolina and SDAFS plans did not view angler harvest as a limiting factor for brook trout in the southern Appalachian region.

Coldwater ecosystems and habitat were a major concern in the trout management plans reviewed. The value of wild trout was recognized and native species of trout are favored in some plans. Brook trout are viewed as a species of special concern in most of their native range. Most states acknowledge that non-native and hatchery trout satisfy the recreational needs of most anglers.

Table A1. Trout and brook trout management plan status by state, water body or organization.

State/Agency	Brook Trout Plan	Trout Plan
Pennsylvania	---	X
Virginia	---	---
West Virginia	---	---
New Jersey	---	X
North Carolina	X	X
Tennessee	?	?
Georgia	?	?
New York	?	?
Connecticut	---	X
Massachusetts	?	?
Maine	?	?
New Hampshire	?	?
Arizona	---	X
Missouri	---	X
Wisconsin	?	?
Lake Superior	X	---
Southern Division American Fisheries Society	X	---
California	---	X

Key: **--** None
X Plan in place
? Unknown

Appendix B

Coldwater Tailwater Fisheries in Maryland with a Brook Trout Component or the Potential to Support a Brook Trout Population.

Despite its relatively small geographic size Maryland boasts a significant number of important tailwater trout fisheries. Other than the Youghiogheny River, where the dam which serves as the source of cold water is located on a tributary stream, all of Maryland's tailwater fisheries rely on a consistent, year-round discharge of cold water from an impoundment constructed on the mainstem of the stream.

A variety of project functions that may include water supply, flood control, flow augmentation, and water quality control, can constrain the maintenance of suitable habitat for trout downstream. Even in cases where recreation is one of the stated purposes of a project, the interests of trout downstream must often compete with those of other recreational users such as recreational whitewater boaters. In all cases in Maryland tailwater fisheries trout management downstream is a benefit that is secondary to the primary functions of each project.

Of the tailwater trout fisheries in Maryland only the Savage River supports a significant wild brook trout component. The regulatory history of trout management in the Savage River tailwater has previously been described in the History of Brook Trout Management section in the FMP. Wild brown trout are the dominant trout species in the Big Hunting Creek tailwater fishery and in the Gunpowder Falls tailwater. Brown trout and rainbow trout (introduced as fingerlings) dominate the Youghiogheny River Catch and Release Trout Fishing Area, maintained through regular releases from the Deep Creek Lake Power Plant into the Youghiogheny River at Hoyes. The North Branch Potomac River tailwater area supports a small component of wild brook trout among the more common brown trout and rainbow trout. A small number of cutthroat trout, stocked as fingerlings, also occur in the North Branch tailwater. Site specific descriptions of release protocols, management issues, and limiting factors at each of Maryland's important tailwater trout fisheries are described in the following paragraphs.

Savage River

The primary function of the Savage River Reservoir is to provide water quality enhancement in the North Branch Potomac downstream. The dam was constructed and is operated and maintained by the U.S. Army Corps of Engineers (ACOE); control and domestic water supply are incidental to the primary function (Stan Brua, personal communication). The construction of Jennings Randolph Reservoir on the North Branch Potomac River in 1982 allowed for considerably more flexibility in managing flows from the Savage Dam. Fisheries Service staff working in cooperation with a multi-agency In stream Flow Committee, developed reservoir and flow management protocols for the Savage to enhance coldwater habitat downstream of the dam by controlling water temperature and flow regimes within a range that would support wild trout on a year-round basis. The initial intent of fishery management efforts was to develop “a world class tailwater brook trout fishery” (R. Bachman, personal communication). The measures included minimum flow maintenance, temperature enhancement, reservoir surface elevation management, and recommendations for managing recreational boating releases. Protocols for managing whitewater boating activities included seasonal exclusions to protect trout reproduction, and flow ramping recommendations to minimize abrupt flow volume and water temperature changes, and trout stranding. Flow management, in concert with regulations and fishery management, has resulted in a high quality coldwater trout fishery (dominated by brown trout) of which native brook trout are an important component. Future issues that will likely affect the operation of the Savage River Dam are Total Daily Maximum Loading criteria for the North Branch downstream (which will require diluting flows of high quality Savage River water to achieve), and heightened interest in whitewater boating, including scheduled whitewater releases in summer. Historically this section of the Savage River was within the native range of Maryland brook trout. Summer water temperatures never exceed the tolerance levels for brook trout survival and growth.

Jennings Randolph Reservoir

Jennings Randolph Reservoir on the North Branch of the Potomac River was completed and filled in 1982. The dam was constructed and is maintained and operated by the U.S. ACOE. Water quality in the watershed was poor due to extensive acidification caused by acid mine drainage (AMD) pollution from abandoned coal mines. Jennings Randolph Lake was not expected to support fish life. The tailwater area was expected to be severely impacted as well. However, water quality downstream was much better than expected initially and further improved following AMD mitigation efforts on the watershed. Coldwater management potential downstream was evident by the late 1980's and efforts to develop a trout fishery in the tailwater were initiated by Fisheries Service. Wild brook trout were documented in the North Branch tailwater by 1990.

Jennings Randolph Dam has four primary project purposes, each mandated by federal legislation. They include, in order of priority; flood control, water quality control downstream, flow augmentation, and recreation. The ACOE, operators of the dam, generally attempt to accommodate Fisheries Service recommendations designed to enhance coldwater management downstream. The recommendations include water temperature maintenance in the outflow of about 12°C seasonally, a minimum flow of at least 120 cfs, and a maximum flow of 2000 cfs. Flows in excess of 2000 cfs produce elevated total gas saturation levels as a result of the design of the outlet structure. Maximum gas supersaturation (about 130% of atmospheric) is reached at discharge volumes of 4500 cfs or greater. The effects range from sub-lethal, with physical damage and displacement of fish and macroinvertebrates, to lethal, producing significant mortalities to fish and macroinvertebrates. The effects are most pronounced in the first 4 km downstream of Jennings Randolph Dam, where total gas pressure ranges between 130% and 115% at discharge volumes greater than 4500 cfs. Although the Army COE has investigated the problem, including contracting an independent consultant to identify solutions, no action has been undertaken to date to address the causes of gas supersaturation in the outflow of Jennings Randolph Dam. The elimination of gas supersaturation would significantly benefit wild trout management downstream. Despite the continuing adverse water quality impacts associated with gas supersaturation, the North Branch tailwater supports a quality fishery that includes wild brook trout (A. Klotz, personal communication). Historically this section of the North Branch Potomac River was within the native range of Maryland brook trout. Summer water temperatures never exceed the tolerance levels for brook trout survival and growth.

<u>Youghiogheny River</u>

The Youghiogheny River tailwater fishery results from the release of coldwater from the 3900 acre Deep Creek lake via a small, privately owned hydroelectric company, Deep Creek Lake Power Plant (DCLPP) located downstream of the lake. The release is sufficient to create temperature and flow conditions in the river capable of supporting trout survival for several miles downstream. The first four miles downstream of the DCLPP are managed as a catch and return trout fishing area using artificial lures or flies only. The Youghiogheny is also unique in that the owners of the power plant have operated within a license permit containing specific requirements, developed by Fisheries Service, to enhance coldwater habitat downstream. The requirements include: maintenance of at least 40 cfs in the Youghiogheny River downstream between June 15 and September 1, water temperature control to less than 25°C in the Youghiogheny River as measured four miles downstream (achieved by initiating generating flows from the DCLPP), and enhancement of dissolved oxygen levels in the DCLPP discharge to state standards of 6.0 ppm (achieved by routing the discharge over a weir in the tailrace of the DCLPP). The result has been an improvement of about 50% in mean trout standing crop downstream since the permit conditions were mandated in 1995. Although brook trout occur seasonably in low numbers in the catch and release area of the Youghiogheny River, likely as migrants from tributaries, the summer temperature regime is currently inadequate to support brook trout on a year-round basis.

<u>Big Hunting Creek</u>

Cunningham Falls Lake was constructed on the mainstem of Big Hunting Creek in the early 1970's by the Maryland State Park Service as a recreational resource. The Big Hunting Creek tailwater fishery depends on minimum flow releases from the dam during seasonal low flow periods. During the early 1980's the fisheries service in conjunction with the Park Service developed guidelines for the management and operation of the dam outflow to protect and enhance the downstream trout fishery (H. Stinefelt, personal communication). The primary intent of this management was to re-establish the native brook trout population (H. Stinefelt, personal communication). To date this goal has not been met, although a high quality wild brown trout population has become established. Suspected reasons for the failure of the native brook trout to re-establish include the relatively small volume of the lake (surface area 35 acres) that limits minimum summer flow to 1.5 cfs (J. Mullican, personal communication). Because Cunningham Falls lake is a recreational area, with bathing beaches, maintaining surface elevation in summer to meet recreational demands is a priority for park managers, further limiting water availability. The existing lake discharge permit requires that the park must meet minimum discharge, even if dry summer conditions draw the lake down below full pool and the swimming area is lost. Maintaining a relatively high recreational pool elevation in the lake during summer also increases the likelihood of flow over the spillway during sudden precipitation events, and resulting thermal impacts downstream. Park managers attempt to temper spillover by adjusting flow from the bottom of Cunningham Falls Lake. However, the timing of precipitation events and limited staffing may hinder the ability of park staff to make gate adjustments and temper spillovers in a timely way in every case, creating potential for thermal shock to trout downstream. Historically this section of the Big Hunting Creek was within the native range of Maryland brook trout. Summer water temperatures never exceed the tolerance levels for brook trout survival and growth

Gunpowder Falls

The Gunpowder Falls tailwater trout fishery originates at the outflow of Prettyboy Reservoir dam on the mainstem Gunpowder Falls River and extends downstream to the head of Loch Raven Reservoir. Both dams and reservoirs are owned and operated by the City of Baltimore as water supply reservoirs. In general, water release protocols for Prettyboy Dam specify an absolute minimum flow of 11.5 cfs. In typical water years, the minimum flow is usually maintained at 30 to 50 cfs. During low recharge periods, when reservoir surface elevation is reduced over a short time, reservoir managers may reduce flow as needed to conserve water, resulting in minimum flow maintenance greater than 11.5 cfs but less than 30 cfs. If the downstream Loch Raven Reservoir falls below a targeted surface elevation, reservoir managers may make large scale releases from Prettyboy Dam to restore Loch Raven Reservoir to the desired level. All releases are incrementally increased to avoid adverse thermal impacts. Since November 1986, when the minimum flow was agreed upon through 2003, all releases have been withdrawn from the 55 foot level in Prettyboy Reservoir. At full pool, water is permitted to exit over the spillway in winter or spring when water temperatures are acceptably cool. No warm spillover is permitted. However, if it occurs, the warmer spillway flow is tempered by a larger volume release of cold water from the 55 foot level.

Beginning in spring, 2004, releases will be initiated from the 10 foot level gate with the objective of warming the Gunpowder Falls tailwater earlier in the season to promote more favorable growth conditions for trout and provide additional forage for rainbow trout in the form of large zooplankton. The new release strategy will only be possible when surface temperatures are acceptably cold and water level in the reservoir exceeds the 10 foot intake. As the season progresses, the next gate adjustment will blend the 10 and 55 foot gates using one of two wet wells. One wet well is currently out of service due to leaks but will be repaired, facilitating combined flow from the 10 and 55 foot gates.

Future discharge from Prettyboy Dam during hot summer months and low flow periods will likely revert to the 55 foot level or 100 foot level to ensure that the tailwater remains within the desired temperature range for trout. In addition, mixing of outflow from multiple gates will only be a viable option if discharge is in excess of 50 cfs because the large cone valves cannot finely calibrate gate flows at lesser flow volumes. Ambient air temperature and season will be considered in managing temperature at discharges of less than 50 cfs. Other protocols include the avoidance of high volume discharges at or prior to spawning in order to prevent spawning trout from constructing redds in areas subject to dewatering at normal fall flow levels.

Fishery management efforts in the 28.2 km of river length downstream of the dam to the next reservoir are divided into three strategies: a catch and release section (11.6 km), a wild trout section (6.8km), and a put and take section (9.8km), from upstream to downstream respectively. Temperature regimes, the complicated water release agreement and complications, and historical stocking and management have not allowed for brook trout to be a component of the coldwater fishery to date. On occasion brook trout are collected in the mainstem river likely as seasonal migrants from the few surviving native populations in several tributary streams. Historically this section of the Gunpowder river was within the native range of Maryland brook trout. Summer water temperatures typically do not exceed the tolerance levels for brook trout survival and growth (C. Gougeon, personal communication).

Appendix C

History of Brook Trout Propagation and Stocking in Maryland

Hatchery and Rearing Facilities

A Commissioner of Fisheries was established by the Maryland legislature in 1874 in response to the deterioration of fish stocks. This position was charged with establishing a system to replenish fish populations through aquaculture and controlled management of the waterways of the State.

The first recognized hatchery in Maryland was built in Druid Hill Park in Baltimore City. Buildings were constructed in the park near existing springs to house hatching and grow-out facilities. The first fish in the facilities were salmon, but by 1877 brook trout were being hatched at Druid Hill. The source of these eggs was not specifically described, but personal communication with Albert Powell indicated that the brook trout eggs probably came from Rhode Island and Maine (A. Powell, personal communication). Attempts were also made to strip eggs from native Maryland brook trout. The Maryland Annual Report from 1897 reported that although lack of appropriations necessitated the purchase of eggs from Rhode Island, the Commissioners were not in favor of this practice, and preferred that the eggs be taken from Maryland fish (Powell 1967).

In the early years of trout culture in Maryland, funding was limited. There was no provision made by legislature to fund the stocking of fish from Druid Hill Park, so the public applied for fish and picked them up for transport. In 1877, the Maryland Annual Report stated that 50,480 brook trout were distributed to the public (Powell 1967). The trout program was quite popular and by 1878 applications for trout exceeded supply. Maryland culturists responded by procuring more eggs and in 1879, 104 applicants received 234,000 brook trout. By 1899, 2,212,600 brook trout fingerlings were being distributed from Druid Hill across the State (Powell 1967). There are no records as to where the trout were stocked, but it is assumed that they were stocked in and around Baltimore County. Transport in those early years was by horse and wagon, early motor vehicles and train. The trout were transported as fingerlings in whatever waterproof container the applicant provided. With variations in transport vessels and distance from source, it is not certain how many of these trout could have survived to the intended stocking site.

The Commissioners of Fisheries authorized the propagation and stocking of other salmonid species in the early 1900's. With the introduction of rainbow trout and Pacific and Atlantic salmon, the demand for brook trout began to diminish. The Commissioners recognized that severely reduced brook trout habitat would limit the effectiveness of any restoration stocking. However, the restoration of the species was important, so the Commissioners reserved the remaining 40,000 – 70,000 brook trout at Druid Hill for carefully planned and supervised restoration projects in the Baltimore area. They also began to look into culture facilities in the western counties where suitable habitat and demand still existed for brook trout.

Problems developed at Druid Hill Park in the early 1900's. Increased demand for public water, lack of interest in expansion on the part of Baltimore City, and transport problems to western Maryland all led to the demise of the facility and it was closed in 1915. In the 1940's there was a brief attempt to resurrect the facility, but expenses were too great and Druid Hill was permanently abandoned. To solve problems of transport, the Commissioners sought to establish hatching and rearing facilities in western Maryland to place trout closer to suitable stocking areas. Several attempts were made to establish hatcheries in Garrett County in the area now inundated by Deep Creek Lake. Facilities were attempted at Deep Creek (the Delawder site) in 1884, but severe fungal problems forced immediate stocking of fingerlings into Deep Creek. The Lake Brown facility operated from 1897 through 1905, with no records of success. A facility at Meadow Mountain Run operated from 1906 to 1912, but constant problems with flooding caused its closure. The area was flooded to form Deep Creek Lake in the 1920's.

In 1917, a facility was established at Lewistown in Frederick County and it functioned as a hatchery and rearing station until 1948. Since 1948, the facility has been used sporadically for trout production. Problems at this facility included freezing, low pH and flow problems. In 1922, a facility was established at Cherry Creek in Garrett County. Production was good until severe drought and temperature problems dictated the stocking of fingerling brook trout into area streams. The facility was abandoned totally in 1928 and its equipment was eventually transferred to Bear Creek Rearing Station. A facility at White Rock was leased and managed by the Izaak Walton League of Frederick County in the early 1920's as a cooperative project with the State. The operators were given brook trout from the Maryland Conservation Department. In 1925, the cost of fish food became too great and the State assumed operations of White Rock and continued until 1946. This became the first facility where adults were stocked out at eight to ten inches total length. To this point all other facilities had stocked advanced fingerlings or smaller. The facility was eventually closed due to high costs. In 1928, work began on two facilities – Bear Creek in Garrett County and Cushwa in Washington County. The Izaak Walton League of Washington County was instrumental in beginning construction of dirt bottom raceways at Cushwa. The Works Progress Administration under Franklin Delano Roosevelt's works initiatives through the federal government converted the dirt bottom ponds to concrete raceways in 1939. The facility was used full-time until 1946, when it converted to a part-time operation.

Bear Creek Rearing Station began in 1928 on a plot of ground adjacent to Bear Creek. Workers used old, silted-in stream channels as the sites for raceways. Bear Creek was dammed to divert water into the old channels and brook and rainbow trout were transferred in from Lewistown later that year. Eventually, the channels were converted to concrete raceways and the facility received upgrades and new raceways as the years progressed. This site proved to be successful during the summer months, but problematic during the winter when freezing temperatures and ice problems prevailed. This led State officials to look for a spring-fed source for a hatchery.

A high-yield spring was identified in Washington County on Beaver Creek. This area had been recommended since 1926, but was not purchased until 1946 when attempts at other sites failed. In 1948 construction began at Beaver Creek with dirt bottom ponds, a hatching building and storage buildings. The yield of the spring at an average 3000 gallons per minute (gpm) and constant temperature of 54ºF proved to be effective and the Beaver Creek facility became the main trout hatchery in Maryland. The facility went through various improvements and expansions to improve survival and production capabilities, and in the 1960's was renamed the Albert M. Powell Trout Hatchery. The Beaver Creek Hatchery was the site of experimentation and the development of a disease recent strain of brook trout.

Little Hunting Creek in Frederick County served as a site for a trout rearing facility from 1928 to 1946. The facility belonged to Lawrence Richey, Secretary to President Herbert Hoover and was operated as a cooperative effort with both the Maryland Conservation Department and the United State Bureau of Fisheries. The trout raised at this facility were divided between Maryland and the Bureau of Fisheries in an 80:20 split. The facility eventually moved into a lease agreement, but the number of fish supplied was more expensive than other facilities, so the agreement terminated in 1946.

Brook trout facilities still in use today for trout include Bear Creek Rearing Station, Albert Powell (Beaver Creek), and Cushwa Rearing Station. Flow problems at Lewistown Work Center have reduced the facility to a temporary holding area for trout. There are other trout rearing and hatching facilities in Maryland today, but these have not been used for the hatching and propagation of brook trout.

Hatchery design/equipment

Trout production in the late 1800's began with very primitive equipment. Culture began at Druid Hill Park with several wooden troughs and 140 hatching (Ferguson) jars contained in a hatching building. (In later years, the troughs were made of aluminum and later fiberglass.) Each trough was lined with wire mesh trays to hold the eggs in the water column. Eggs were also place in the hatching jars with adequate water flow through each jar. These hatching devices could accommodate up to one million eggs. Trout were stocked as swim-up fry or small fingerlings, so minimal feeding occurred at this facility. (This small size at stocking may have contributed to poor success of the stocked fish.)

A hatching house was established on Deep Creek in Garrett County and supplied other facilities nearby. However, repeated problems with fungal attack on the eggs led to the eventual closing of this site. The Lake Brown Hatching Station was never completed and was abandoned. The Meadow Mountain Run facility received fry from other sources and placed them in excavated nursery ponds lined with oak planking. This site raised the trout to fingerling size. Flooding eventually forced the closure of this facility.

Lewistown Hatchery began as a hatching building that contained numerous hatching troughs. As the need for adult trout grew, an outside concrete raceway was constructed and trout were raised to four to six-inch size before being stocked. The 1925 Maryland Annual Report referred to ice and other adverse conditions as being deterrents at the Lewistown facility (Powell 1967). As a result, twelve troughs from Lewistown were taken to Cherry Creek in Garrett County to attempt to establish a new hatchery. Flow and temperature problems forced transfer of the troughs from Cherry Creek to Bear Creek Rearing Station.

All of the remaining facilities began as dirt bottom raceway or pond facilities. Fish health problems abounded and Bear Creek, Beaver Creek, Cushwa and the Little Hunting Creek facilities all eventually converted to concrete raceways.

Trout production by age

Eggs

In the early years of trout production in Maryland, limited resources and experience dictated that eggs were either purchased for or donated to the State. Culture in the late 1880's found that hatch rate was low, probably due to lack of knowledge on the part of the culturists. Success improved with improved technique and new equipment. As larger facilities were developed, culturists began to hold brood fish and stripped their own eggs, and began to feed trout to gain larger stocking size.

Although no written record exists as to specific procedures used in Maryland, it is assumed that the culturists were using standard practice for egg procurement and rearing. Purchased or donated eggs arrived in the resistant eyed-stage and were acclimated to ambient water temperature in the incubation units. For State egg production, the procedure was more complicated. Culturists maintained brood trout in hatcheries and knew, by observation, when the fish were ready to be spawned. Ripe females would be taken from the water and wiped dry on the abdomen to prevent water from falling into the dry spawning container. Eggs were stripped by pressing along the abdomen toward the urogenital pore to force them out. The first few eggs were checked to insure that they were ripe and ready for fertilization. Next, sperm-containing milt was stripped from males into the container to be followed shortly by the addition of water. Water added to the motility of the sperm, but fertilization had to occur quickly since water caused the outer layers of the egg to swell and close to penetration (called water hardening). In later years, water hardening was followed quickly by the application of an iodophor to reduce fungal contamination.

Once the eggs were fertilized they were placed on trays in gently flowing water in a dark location. During the first few days following fertilization, the "green" eggs were very sensitive and had to be protected from light and physical shock in order to allow cell divisions to occur to thicken and protect the embryonic layers. Culturists used the appearance of the "eye" in the egg as an indicator that the sensitive period has passed. Eggs were then moved to other trays or hatching jars for incubation. In the early 1970's, stack tray incubators allowed the incubation of many eggs in a limited space in a more efficient manner. Workers were careful to pick out the eggs that turned white or became opaque, since these were either unfertilized or dead and possible sites for fungal attack. The incubation period for eggs varied with water temperature.

Fry

When the eggs began to hatch, the fry with attached yolk sacs were moved to troughs supplied with enough water flow to provide enough oxygen, yet not impale the fry against end screens. Workers cleaned the fry tanks with feathers from large birds because they would not damage the delicate tissues of the developing fish. At Druid Hill the minute the yolk sac was absorbed, and the fry began to "swim-up" to fill the swim bladder, they were stocked. The delicate nature of these trout contributed to poor success rates of these stocking efforts. Later, fry were fed ground, hard egg yolks or beef liver to increase their hardiness prior to stocking.

Fingerlings

As facilities expanded, trout were held longer prior to stocking. Fingerlings were often protected in screened or covered tanks to protect them from excessive sun and predators. Feeding was done with high protein meat and egg diets in the early years, to be replaced by commercial pellet diets later. As nutrition improved, so did the success of the fingerlings. Researchers found that fish raised in high-density situations did not thrive on natural diets, but grew well on the commercial pellets (Stickney 1991).

Adults

It was the late 1930's before State operations routinely provided adult trout, although the adult size at that time was six inches or greater. With improved and larger facilities and better nutrition, trout sizes for adults increased from eight-to-ten to the more common ten-to-twelve inch lengths found today. Adult production required additional care as environmental conditions such as oxygen levels and dirt accumulation could significantly impact the fish. The trout had to be graded (separated by size) to keep growth rates more uniform per raceway and to prevent excessive aggression. Diets had to be adjusted as age required. Culturists had to be familiar with their fish and keep an eye out for evidence of health problems. Dirt bottom ponds were abandoned when researchers realized that disease vectors could survive in the accumulated sediments and cleaning these structures proved to be difficult if not impossible.

Maryland Brook Trout Brood

In 1928, trout in Maryland experienced a bacterial disease outbreak not previously observed. Researchers later identified the disease as furunculosis (causative agent *Aeromonas salmonicida*). This disease proved to be particularly hard on brook trout in State hatcheries and in those facilities using dirt bottom raceways and ponds. In later years, the Eastern Fish Culture Disease Laboratory at Leetown researched the disease and found sulfamerazine to be an effective control for the disease (Powell 1967). The furunculosis problems that began in 1928 were attributed to imported eggs. This gave a renewed push for the State to develop its own egg program and this started the rearing of brood fish and harvest of eggs from brook trout in Maryland. To start the effort, Maryland procured adult brook trout from the Conservation Department of New Jersey. While many of these trout died, 430 fish survived.

Albert Powell decided to attempt a novel treatment by treating the remaining brook trout with sulfamerazine and telamicean (terramycin?) every fifteen days until spawning in November of 1948. Attempts to spawn the females that year yielded no eggs. A necropsy of several female brook trout found that the eggs were poorly formed and clumped together in a congealed mass. The remaining brook trout from this apparent failure were released into a controlled stream reach within the hatchery with no further treatment, with the expectation that they would probably die. To the surprise of all, the following year most of these fish were still alive and by fall the females were ready to spawn with viable eggs. These brook trout and their offspring proved to now be resistant to furunculosis. Studies by personnel at Leetown Fish Health Center in West Virginia verified this fact. All State brook trout from 1949 on were from this group of fish.

In some respects, Mr. Powell was very lucky with this experiment; today's wisdom councils against frequent treatment with antibiotics and chemicals. In fact, law strictly regulates the administration of these chemicals. Also, where sulfamerazine was once the treatment of choice for furunculosis and several other diseases, today it has been rendered useless by over-use. Many bacterial strains have become resistant to sulfamerazine to the point that, even though it is permitted for use in trout by the United States Food and Drug Administration, drug manufacturers find little or no market for its use and have ceased its production. (Noga 1996)

Future years found decreasing production of brook trout due to the fact that rainbow trout were more economical to grow to adult size. However, the Maryland disease resistant brook trout strain commanded a lot of respect on the east coast of the United States. In a file memo dated June 12, 1967, Maryland Department of Game and Inland Fish personnel made a request to the Chief of Inland Fish Management to procure brook trout eggs from Pisgah Forest, North Carolina because these were offspring from Maryland's disease resistant brood stock. Other memos indicate that this brood stock was supplied to federal hatcheries. Keeping this in mind, it is possible that some of the brook trout provided to Maryland by federal hatcheries were from Maryland disease resistant strain.

As conversion to rainbow and brown trout occurred, the number of brook trout brood kept at Beaver Creek (Powell) hatchery decreased. By the early 1970's the last of the brook trout was removed from State facilities.

Nutrition and Feeding

In the early years, limited feeding occurred. If trout could not be transported at swim-up fry stage, the young trout were fed hard-boiled egg yolks that were chilled and then ground to a fine ground pepper size. Later, a similar procedure was used with cooked beef liver, which proved to be very successful with small fingerlings.

Early feeding conflicted with the budget, so culturists tried mixtures of pork and sheep organs, fresh and canned fish in addition to other meats cast off at local farms or butcher shops. Sometimes the ingredients were cooked but many times they were raw, creating contamination and disease problems. Even when some meats were cooked and cut or ground, they contributed too many bacterial problems, either by dirt build up in ponds or raceways or by stress created by poor nutrition. There were other diets around, but they contained many grains, salt and milk and were more expensive diets. Eventually, the all-meat diets were modified to include grain meal to improve nutrition.

Diets fed to fish during World War I and II were particularly bad. Meat was rationed, but slaughterhouses knew that fish culturists needed meat, so they passed off questionable meat by-products, diseased animals and wastes to aquaculture. Fortunately, fish was not rationed, so culturists were able to obtain fish for using in food. A positive outcome of WWII was the availability of surplus military freezers that were procured for fish rearing facilities in Maryland. This allowed storage and better hygiene for fish food. (Stickney 1991)

Maryland began using some pelleted feed in 1942. It was used sporadically through 1956, but expense and varying quality caused problems. By the 1960's, diets had become more standardized and funding allowed conversion to an all-pellet diet. The advantage to the commercial pellet diet was in the varied sizes and content of the feed. As trout grow their nutritional needs change and pellet size and content were formulated to meet those needs.

Historical brook trout production records

The production records for the hatcheries are contained within the stocking records. Record keeping was inconsistent from year to year and some of the production by weight numbers are lacking. No detailed records exist prior to 1948.

The early brook trout production was carried primarily by Bear Creek and Albert Powell (Beaver Creek) Hatchery. Brood trout were maintained at Powell and each year eggs from these fish were hatched to provide stock for Bear Creek and satellite facilities. Most of these brood trout were of the "disease resistant strain" developed by culturist Albert Powell and these were provided to the federal government for their hatchery production as well.

The State began to supplement stocking with brook trout from the federal hatcheries in the late 1950's. Trout were received from Leetown and Bowden Hatcheries in West Virginia, Paint Bank in Virginia, and Reynoldsdale in Pennsylvania.

Through the years, many aquaculturists found that rainbow trout were easier to rear in hatcheries and more economical, with fewer disease problems being encountered. The late 1960's saw fewer brook trout from State hatcheries and more from federal hatcheries. State production of brook trout ended in 1976. The federal facilities also began to reduce their numbers of brook trout into the early 1980's. Federal budget cuts forced the closing, sale and privatization of many federal hatcheries in the 1980's and trout supplied to Maryland ended in 1987.

Table C1 contains production and stocking information for State facilities. Table C2 contains federal and commercial hatchery information.

Historical brook trout stocking records

The brook trout stocking records for the State cover the period from 1948 through 1988. No records were found prior to 1948, although Maryland Annual Reports refer to the stocking of brook trout. These references were short and contained little detail. Much of the information prior to 1948 was anecdotal and could not be confirmed. The brook trout stocking information was derived from records found at Bear Creek Rearing Station and Albert Powell Trout Hatchery (Beaver Creek). For federally allotted trout, these stocking records were checked against file memos from the federal to state authorities.

Sizes at stocking varied widely according to age of the trout and the year they were stocked. In the 1800's, brook trout were stocked as swim-up fry or young fingerlings. As technology and food preparations advanced, the time in a hatchery or rearing station increased and larger sizes were achieved. Fry or young fingerlings were usually stocked at a total length of three inches or less. In the 1940's and beyond, stocked fingerlings were between three and five inches. The biggest changes were noticed in the adults and brood trout stocked. Adults progressed from a small size of six to eight inches and ten fish to the pound to stock in the late '70's and '80's where trout ten to twelve inches at roughly two fish to the pound were released.

A summary of trout sizes and numbers stocked found in records is contained in Table C3. While numbers were present in all cases, many records did not include size at stocking, so estimates of stocked weights are calculated using only those records presenting length and weight information.

In 1969 tragedy struck at Bear Creek. Gas exploration by a gas and oil exploration company in the watershed produced a sediment blowout into Bear Creek, and the rearing station was inundated with sediment and polluted water. The fish production for that year was essentially lost and the exploration company was cited for environmental damage. Trout to replace the Bear Creek production were purchased from

Kriss Pines Hatchery, a commercial supplier, in Pennsylvania while rearing station was cleaned and put back into service.

Information regarding the general stocking of each area in Maryland with brook trout is contained in Table C4. Detailed information by facility is contained in Tables C5 through C10.

Brood stock of native brook trout came from Maryland streams, New Jersey, and federal hatcheries. Information on these fish came from a variety of sources, including memos on file from the federal government to the State. Maryland maintained its own brook trout brood fish from the late 1940's until the early 1970's. Maryland brook trout brood stock was abandoned in favor of rainbow trout. The remaining brood brook trout were stocked out of Albert Powell in 1971.

In the late 1980's the Maryland State Trout Biologist Howard Stinefelt stripped eggs from brook trout and raised them to fingerling size in a private spring. These trout were used in an experimental stocking for Locust Run in Baltimore County. No record of the number of eggs exists, but the effort yielded 1000 brook trout for Locust Run.

Table C1. Brook trout stocked into Maryland waters from State facilities, 1948-1976.
(An additional 1000 brook trout were produced by field biologists)

Year	Bear Creek				Albert Powell Hatchery			Cushwa
	fry	**fingerling**	**adult**	**brood**	**fingerling**	**adult**	**brood**	**adult**
1948		200	10085			6500		
1949			12262			3700		
1950			3200			7300		
1951	25000	28000	1		7500	1450		
1952		1500	6353			2675		
1953			2844			933		
1954		40000	3781			5006		
1955		4000	4750			2415		
1956		21000	8425			1500		
1957		400	4250			6741		
1958			7350			21246	6	
1959		1400	9580	40	6041	13163	9	
1960		2500	1650	1	16250	21502	15	
1961			5825		7010	41817	5	
1962			4819	4		33145	51	
1963		16000	6300			38250	16	
1964			14750	4	10000	22950	35	
1965		43600	10025		16200	32950	35	
1966			100			12275	24	
1967		29120	4550			31845	23	
1968			1280		3000	23450	36	
1969			5280			18086		
1970			825			10840		250
1971			3655			19250	418	
1972			9000			5000		10000
1973			7740			5750		
1976					9000			
Totals	**25000**	**187720**	**148680**	**49**	**75001**	**389739**	**673**	**10250**

Table C2. Brook trout stocked into Maryland waters from federal and commercial facilities 1958-1988.

Year	FEDERAL															COMMERCIAL		
	Federal – Unknown			**Paint Bank, VA**			**Bowden, WV**			**Leetown, WV**			**Reynoldsdale, PA**			**Kriss Pines, PA**		
	Fing.	**Adult**	**Brood**	**Fing.**	**Adult**	**Brood**	**Fing.**	**Adult**	**Brood**	**Fing.**	**Adult**	**Brood**	**Fing.**	**Adult**	**Brood**	**Fing.**	**Adult**	**Brood**
1958											1000							
1959											1500	6						
1961											357							
1962								19950			600							
1963							40000	10000										
1964							1000											
1967					13366													
1968					7160	10												
1969					5650	730												
1970		7900			13025												17668	
1971		6600			10425													
1972		14000	14		18000													
1973		500		12000	15500													
1976											24100							
1977		1800			2000					???	800							
1978											26100							
1979					21500													
1980					3000			35250										
1981		2000			28750													
1982					25000			500										
1983					15000													
1987													26000					
1988																		
Totals		**32800**	**14**	**12000**	**178376**	**740**	**41000**	**65700**		**???**	**54457**	**6**	**26000**				**17668**	

Key: ???=Stocking occurred but number is unknown.

Table C3. Brook trout production statistics in Maryland, by facility, 1948-1988 (data presented is only for facilities which could provide data for both numbers and weight).

Facility	Number of trout	Weight	Trout per pound (range)
Bear Creek	63704	15370	4.71 (0.5 to 64.3)
Albert Powell	168145	58886	6.2 (0.3 to 125)
Cushwa	10250	3973	2.5 (2.2 to 2.8)
Federal – not specified	27264	9187	2.5 (2.2 to 2.9)
Bowden – federal	93700	15817	21.6 (2.9 to 495)
Leetown – federal	35957	5146	5.9 (0.3 to 36.8)
Paint Bank – federal	117116	36521	3.0 (0.3 to 9.7)
Reynoldsdale – federal	26000	65	400 (400)
Kriss Pines – commercial	17668	9098	1.9 (1.4 to 2.5)

Table C4. Number of brook trout stocked in Maryland waters by county and area, 1948-1988.

Area	Brook trout stocked
ANNE ARUNDEL COUNTY	
Lake Waterford	8300
Patuxent Ponds	2750
Severn Run	18204
ALLEGANY COUNTY	
Battie Mixon Pond	2300
Colliers Run	1000
Evitts Creek	66305
Evitts Creek Ponds	4100
Fifteenmile Creek	3750
Flintstone Creek	22082
Jennings Run	3140
Laurel Run Moscow	4665
Matthew Run	1410
Mill Run	11785
Millstone Run	3000
Neff Run	300
North Branch Potomac River	1090
Rocky Gap Creek	1150
Staub Run	1400
Wills Creek	4750
Winebrenner Run	1505
Wright's Run	175
BALTIMORE COUNTY	
Avalon Pond	2250
Beetree Run	16710
Gunpowder Falls	42170
Gwynnbrook Pond	2500
Jones Falls	13450
Little Falls	29357
Little Gunpowder Falls	256
Locust Run	1000* (Stinefelt production)
CARROLL COUNTY	
Beaver Run	13679
Bennett Cerf Pond	250
Farm Museum Pond	500
Homestead Pond	500
Middle Run	1000
Piney Run	13825
Westminster Pond	4523
CECIL COUNTY	
Basin Run	13575
Principio Creek	12832
Stone Run	2000

Table C4. Continued (page 2 of 4)	
Area	Brook trout stocked
CHARLES COUNTY	
Cedarville Lake	62
FREDERICK COUNTY	
Bear Branch	2000
Big Hunting Creek	33506
Camp David Pond	1002
Catoctin Creek	1000
Cunningham Falls Lake	4000
Fishing Creek	33062
Frank Bentz Pond	2850
Friends Creek	23720 + fingerlings (no numbers)
Lewistown Work Center	500
Little Hunting Creek	9525
Middle Creek	20088
Owens Creek	15225
Talbot Run	3000
Toms Creek	6000
Tuscarora Creek	2000
Urbana Lake	5000
GARRETT COUNTY	
Bear Creek	49820
Big Run	16773
Blue Hole North Branch Potomac River	19
Blue Lick Run	200
Broadford Lake	5000
Buffalo Run	6755
Casselman River	9706
Cherry Creek	9655
Crabtree Run	9502
Deep Creek Lake	46422
Dung Hill Run	400
Glade Run	8480
Glotfelty Property	20
Helbig Stream Deer Park	20
Herrington Manor Lake	1000
Laurel Run Kenton	1000
Laurel Run Schell	500
Laurel Run White Rock	5300
Little Bear Creek	2500
Little Youghiogheny River	3220
Meadow Mountain Run	11775
Middle Fork Creek	350
Mill Run	8070
Miller’s Run	700
Monroe Run	16824
Moon Run	400
Muddy Creek	5121

Table C4. Continued (page 3 of 4)	
Area	Brook trout stocked
New Germany Lake	23222
Pawn Run	500
Piney Creek	2475
Piney Reservoir	10850
Poplar Lick Run	8168
Puzzley Run	2190
Salt Block Run	2990
Sand Run	100
Savage Property Friendsville	20
Savage Reservoir	43500
Savage River unspecified	5251
Savage River below reservoir	125
Savage River above reservoir	98506
Schaeffer Property Oakland	20
Smouse Dam Oakland	20
South Branch Bear Creek	4550
White Rock Run	4170
White Thorn Lake	400
Wolfden Run	460
Wolfe Run	100
Youghiogheny River	60832
Youghiogheny Watershed	16000
HARFORD COUNTY	
Bynum Run	4750
Arnold Branch	1200
Deer Creek	16238
Deer Creek Special Area	500
Falling Branch	5484
Holly Rock	1200
James Run	6250
Kellogg Branch	1200
Sulphur Branch	1200
Thomas Run	1200
HOWARD COUNTY	
Middle Patuxent River	500
Patuxent River	20156
MONTGOMERY COUNTY	
Izaak Walton Pond	500
Lake Needwood	3000
Little Seneca Creek	28860
Northwest Branch	12750
Rock Creek	24308
PRINCE GEORGE’S COUNTY	
Allen’s Pond	2750
Cosca Lake	750
Melwood Pond	3588
Pine Lake	500

Table C4. Continued (page 4 of 4)	
Area	Brook trout stocked
Tucker Pond	500
WASHINGTON COUNTY	
Beaver Creek	45217
Blair's Valley Lake	11500
Elks Picnic Area	200
Indian Springs Pond	750
Licking Creek	1000
Little Antietam Creek north	3000 + fingerlings (no numbers)
Little Antietam Creek south	11335
Little Conococheague Creek	2500
Little Tonoloway Creek	8733
Marsh Run	6608
Semples Run	752
Sharpsburg Run	0 + fingerlings (no numbers)
Sidling Hill Creek	20250
St James Run	7150
Tonoloway Creek	2405
Washington County	5000
WICOMICO COUNTY	
Salisbury Pond	3030
TOTAL BROOK TROUT STOCKED	**1,266,873**

Table C5. Number of brook trout produced at Bear Creek Hatchery by life stage and county/area into which they were stocked, 1948 through 1988.

Area	fry	fingerling	adult	brood
ALLEGANY				
Battie Mixon Pond			1200	
Colliers Run	1000			
Evitts Creek			9985	
Evitts Creek Ponds			1550	
Flintstone Creek			1050	
Jennings Run			600	
Laurel Run Moscow			225	
Matthew Run			105	
Mill Run			895	
Millstone Run			3000	
Neff Run			300	
North Branch Potomac River (Garrett/Allegany)			1090	
Rocky Gap Creek			1000	
Staub Run			540	
Wills Creek			750	
Winebrenner Run			150	
Wright's Run			155	
CARROLL				
Piney Run			200	
CECIL				
Basin Run			75	
Principio Creek			75	
GARRETT				
Bear Creek		3000	23341	4
Big Run		16773		
Blue Hole North Branch Potomac River			19	
Blue Lick Run			200	
Buffalo Run			1655	
Casselman River		9706		
Cherry Creek	8000	1000	655	
Crabtree Run	8000	100	977	
Deep Creek Lake		21000	4522	
Dung Hill Run			400	
Glade Run	8000		235	
Glotfelty Property			20	
Helbig Stream Deer Park			20	
Laurel Run Kenton			1000	
Laurel Run Schell			500	
Laurel Run White Rock		2500	2800	
Little Bear Creek		1000		
Little Youghiogheny River			1063	
Meadow Mountain Run		11500	275	
Middle Fork Creek		150	200	
Mill Run		2800	740	
Miller's Run			700	
Monroe Run		16373	451	
Moon Run			400	

Table C5. Continued (page 2 of 2)				
Area	**fry**	**fingerling**	**adult**	**brood**
Muddy Creek			3265	
New Germany Lake		1400	10890	
Pawn Run		500		
Piney Creek			2100	
Piney Reservoir			4600	
Poplar Lick Run		6768	1400	
Puzzley Run			1875	40
Salt Block Run			1920	
Sand Run			100	
Savage Property Friendsville			20	
Savage River unspecified			4250	1
Savage River below reservoir			125	
Savage River above reservoir		34950	38937	
Schaeffer Property Oakland			20	
Smouse Dam Oakland			20	
South Branch Bear Creek		3800		
White Rock Run			170	
White Thorn Lake		400		
Wolfden Run			460	
Wolfe Run			100	
WASHINGTON				
Beaver Creek			4000	
Marsh Run			1700	
Sidling Hill Creek			4350	
St James Run			3000	
Youghiogheny River		54000	2260	
BEAR CREEK TOTAL	**25000**	**187720**	**148680**	**45**

Table C6. Number of brook trout produced at Albert Powell Hatchery (Beaver Creek) by life stage and county/area into which they were stocked, 1948 through 1988.

Area	fingerling	adult	brood
ALLEGANY			
Evitts Creek		34679	26
Evitts Creek Ponds		250	
Flintstone Creek		10951	3
Jennings Run	40	1200	
Laurel Run Moscow	2500	1490	
Matthew Run		1205	
Mill Run		7440	
Rocky Gap Creek		150	
Staub Run		700	
Winebrenner Run		1210	
Wright's Run		20	
ANNE ARUNDEL			
Lake Waterford		1000	
Severn Run		10950	154
BALTIMORE			
Avalon Pond		1500	
Beetree Run	1500	11700	10
Gunpowder Falls		20670	
Gwynnbrook Pond		500	
Jones Falls		13450	
Little Falls		23443	14
Little Gunpowder Falls		256	
CARROLL			
Beaver Run		7875	4
Middle Run	1000		
Piney Run	750	4875	
Westminster Pond		750	23
CECIL			
Basin Run		11000	
Principio Creek		8550	
Stone Run		2000	
CHARLES			
Cedarville Lake – Charles			65
FREDERICK			
Bear Branch	2000		
Big Hunting Creek	4200	20656	
Camp David Pond	1000	2	
Catoctin Creek	1000		
Fishing Creek	5001	22261	
Frank Bentz Pond		100	
Friends Creek	9500	9216	4
Little Hunting Creek	4000	4275	
Middle Creek	5000	10588	
Owens Creek	3000	3625	
Talbot Run	3000		
Toms Creek	6000		
Tuscarora Creek	2000		
Urbana Lake		500	

Table C6. Continued (page 2 of 2)			
Area	**fingerling**	**adult**	**brood**
GARRETT			
Bear Creek	3080		5
Buffalo Run	1000		
Crabtree Run	425		
Little Bear Creek	1500		
Mill Run	400		
New Germany Lake		1000	
Piney Reservoir		500	
Salt Block Run	500		
South Branch Bear Creek	750		
White Rock Run	2000	2000	
Wolfden Run			
Wolfe Run			
Youghiogheny River	355		
HARFORD			
Arnold Branch	1200		
Bynum Run		4750	
Deer Creek		12760	64
Deer Creek Special Area		500	
Falling Branch	1500	3984	
Holly Rock	1200		
James Run		6250	
Kellogg Branch	1200		
Sulphur Branch	1200		
Thomas Run	1200		
HOWARD			
Middle Patuxent River		500	
Patuxent River		10955	61
MONTGOMERY			
Little Seneca Creek		11345	15
Rock Creek		24308	
PRINCE GEORGE'S			
Melwood Pond			88
WASHINGTON			
Beaver Creek		29100	27
Blair's Valley Lake		2000	
Elks Picnic Area		200	
Indian Springs Pond		750	
Little Antietam Creek north	3000		
Little Antietam Creek south	3000	6800	35
Little Conococheague Creek		2500	
Little Tonoloway Creek		7550	33
Marsh Run		4400	8
Semples Run		750	2
Sidling Hill Creek		1000	
St James Run		3100	
Tonoloway Creek		2200	5
WICOMICO			
Salisbury Pond		1500	30
ALBERT POWELL TOTAL	**75001**	**389739**	**676**

Table C7. Number of brook trout produced by Cushwa Rearing Station (MD) and Federal facilities (no specific source identified) by life stage and county/area into which they were stocked, 1948 through 1988.

Area	Cushwa	Federal (general)	
	adult	adult	brood
ANNE ARUNDEL			
Lake Waterford	1000		
Severn Run	1000		
BALTIMORE			
Gunpowder Falls		1500	
CECIL			
Basin Run	1000		
Principio Creek	1000	750	
CARROLL			
Beaver Run		1300	
Westminster Pond		500	
FREDERICK			
Big Hunting Creek	1500	3600	
Fishing Creek	1500	1000	
Frank Bentz Pond	500		
Friends Creek		500	
Little Hunting Creek	500	250	
Middle Creek		1000	
Owens Creek		1000	
Urbana Lake		500	
GARRETT			
Buffalo Run		1000	
Mill Run		800	
Piney Reservoir	250		
Piney Run		2000	
HARFORD			
Deer Creek		3000	14
HOWARD			
Patuxent River	2000	1500	
MONTGOMERY			
Little Seneca Creek		5500	
PRINCE GEORGE'S			
Melwood Pond		500	
WASHINGTON			
Beaver Creek		3000	
Blairs Valley Lake		2000	
Sidling Hill Creek		1000	
Little Tonoloway Creek		100	
WICOMICO			
Salisbury Pond		500	
CUSHWA TOTAL	**10250**		
FEDERAL GENERAL TOTAL		**32800**	**14**

Table C8. Number of brook trout produced at Paint Bank and Bowden Federal hatcheries by life stage and county/area into which they were stocked, 1948 through 1988.

Area	Paint Bank			Bowden	
	fingerling	**adult**	**brood**	**fingerling**	**adult**
ALLEGANY					
Battie Mixon Pond		1000			
Evitts Creek		12575			6000
Evitts Creek Ponds		2300			
Fifteenmile Creek		3750			
Flintstone Creek		7930			500
Jennings Run		1100			200
Laurel Run Moscow		250			200
Matthew Run					100
Mill Run		1150			2300
Staub Run		60			100
Wills Creek		3000			
Winebrenner Run		45			100
ANNE ARUNDEL					
Lake Waterford		5000			1000
Patuxent Ponds		2750			
Severn Run		2500			2000
BALTIMORE					
Avalon Pond		750			
Beetree Run		2000			
Gunpowder Falls		2000			
Gwynnbrook Pond		2000			
Little Falls		2000			
CARROLL					
Beaver Run		4500			
Bennett Cerf Pond		250			
Farm Museum Pond		500			
Homestead Pond		500			
Piney Run		6000			
Westminster Pond		3250			
FREDERICK					
Big Hunting Creek		250			2000
Cunningham Falls Lake		2000			2000
Frank Bentz Pond		750			1500
Friends Creek		500			2000
Lewistown Work Center					500
Little Hunting Creek		500			
Middle Creek		2000			1000
Owens Creek		1000			4500
Urbana Lake		1000			1000
GARRETT					
Bear Creek		13860	330	4000	
Broadford Lake		1500			1500
Buffalo Run		2100			
Deep Creek Lake	12000	3900			
Glade Run		245			
Herrington Manor Lake		1000			

Table C8. Continued (page 2 of 2)					
Area	**Paint Bank**			**Bowden**	
	fingerling	**adult**	**brood**	**fingerling**	**adult**
Little Youghiogheny River	500	1057			600
Mill Run		1030			1500
Muddy Creek		1056			800
New Germany Lake		4928			4000
Piney Creek		275	100		
Piney Reservoir		3800			1000
Puzzley Run		225	50		
Salt Block Run		320			250
Savage Reservoir		3500			20000
Savage River unspecified		1000			
Savage River above reservoir		16153	260		5000
Youghiogheny River		2917			1300
HOWARD					
Patuxent River		5500			
MONTGOMERY					
Izaak Walton Pond		500			
Lake Needwood					3000
Little Seneca Creek					1500
Northwest Branch		10000			2750
Pine Lake		500			
PRINCE GEORGE'S					
Allen's Pond		2000			750
Cosca Lake		750			
Melwood Pond		3000			
Tucker Pond		500			
WASHINGTON					
Beaver Creek		2500			1400
Blair's Valley Lake		3000			2500
Licking Creek		500			500
Little Antietam Creek south					1500
Little Tonoloway Creek					1050
Marsh Run					500
Sidling Hill Creek		8900			2250
St James Run					1050
Tonoloway Creek		200			
Washington County		5000			
WICOMICO					
Salisbury Pond		1000			
PAINT BANK TOTAL	12500	177876	740		
BOWDEN TOTAL				4000	81700

Table C9. Number of brook trout produced at Leetown and Reynoldsdale hatcheries by life stage and county/area into which they were stocked, 1949 through 1988.

Area	Leetown			Reynoldsdale
	fingerling	adult	brood	fingerling
ALLEGANY				
Battie Mixon Pond		100		
Evitts Creek		2500		
Flintstone Creek		1000		
Wills Creek		1000		
BALTIMORE				
Beetree Run		1500		
Gunpowder Falls		2000		16000
Little Falls		2100		
CECIL				
Basin Run		1500		
Principio Creek		2457		
FREDERICK				
Fishing Creek		2000		
Friends Creek	0 +++	2000		
Owens Creek		1600		
Urbana Lake				
GARRETT				
Bear Creek		1000		
Broadford Lake		2000		
Buffalo Run		1000		
Mill Run		800		
New Germany Lake		1000		
Savage Reservoir		20000		
Savage River above reservoir		1000	6	
MONTGOMERY				
Little Seneca Creek				10000
WASHINGTON				
Beaver Creek		2300		
Blair's Valley Lake		2000		
Little Antietam Creek north	0 +++			
Sharpsburg Run	0 +++			
Sidling Hill Creek		1600		
LEETOWN TOTAL	0 +++*	52457	6	
REYNOLDSDALE TOTAL				26000

* no numbers reported for fingerling stocking

Table C10. Number of adult brook trout produced at Kriss Pines Hatchery (commercial hatchery) in 1970 and the Maryland county/area into which they were stocked.

Area	Number adult brook trout
ALLEGANY	
Evitts Creek	540
Flintstone Creek	648
ANNE ARUNDEL	
Lake Waterford	300
Severn Run	1600
BALTIMORE COUNTY	
Little Falls	1800
FREDERICK COUNTY	
Big Hunting Creek	1300
Fishing Creek	1300
Middle Creek	500
Owens Creek	500
GARRETT COUNTY	
Bear Creek	1200
Piney Reservoir	700
Savage River above reservoir	2200
HARFORD COUNTY	
Deer Creek	400
HOWARD COUNTY	
Patuxent River	140
MONTGOMERY COUNTY	
Little Seneca Creek	500
WASHINGTON COUNTY	
Beaver Creek	2890
Sidling Hill Creek	1150
TOTAL	17668

Appendix D

Status of Brook Trout Populations in Tributaries of the North Branch Potomac River (NBPR), the Mainstem NBPR above Jennings Randolph Reservoir, and the Mainstem below Jennings Randolph Reservoir

(Savage River watershed not included, previously discussed in main body of BTFMP)

History

The North Branch Potomac River Watershed encompasses about 499 square miles in Garrett and Allegany Counties, Maryland and 844 square miles in West Virginia. The major land uses in the North Branch Potomac River watershed consists of forestland (76 %), agriculture (14%), and urban areas (10%), with barren lands and wetlands comprising less than 1% of the watershed area (Rodney et al. 2000). By the early 1900's the North Branch Potomac River and many of its major tributaries were severely degraded by coal mining and deforestation, resulting in decimated brook trout and associated coldwater stream fish species populations. Until recently acid mine drainage (AMD) has affected the water quality of the river to a point where fish were uncommon (Pavol 1987). Since the early 1990's many abandoned mine lands have been reclaimed and several of the major acid mine drainage sources are being treated by the Maryland Department of the Environment's Bureau of Mines (MDE BOM). The forest has re-grown to form a dense overhead canopy consisting of 80 – 100 year old red oak, white oak, chestnut oak, hickory, black cherry, eastern hemlock, and beech trees (Metz 2003). Brook trout have now re-colonized many streams in the North Branch Potomac River Watershed (NBPRW); however these populations are still subject to various environmental stressors.

Water Quality and Stream Habitat Characterization

Water quality studies conducted by the Maryland Biological Stream Survey (MBSS) during 1996 showed dissolved oxygen levels suitable for brook trout survival in all the North Branch Potomac River 1st through 3rd order streams that were sampled (Rodney et al. 2000). However many of these streams were affected by acid deposition or AMD, which limited brook trout abundance. The study showed that 14% of the stream miles were chronically acidified by having acid neutralizing capacities (ANC) less than 0 ueq/L. Additionally about 50% of the stream miles were subject to periodic acidification due to acid deposition during early spring run-off events. The remaining stream miles were well buffered from the acid deposition.

The MBSS study also rated physical habitat in the watershed's stream miles. Stream habitat was rated as Poor or Very Poor in about one-third of the basins' stream miles. The identified problems that contributed to poor habitat included lack of forested buffer zones, lack of large woody debris, channelization, and sedimentation. These conditions all negatively affect brook trout abundance and distribution in the watershed.

Specific descriptions of the mainstem NBPR and tributaries

North Branch Potomac River (Kempton to Jennings Randolph Lake)

The Maryland Department of the Environment's Bureau of Mines initiated an acid mine drainage (AMD) treatment program beginning in 1993 to improve water quality in the North Branch Potomac River. The Maryland Department of Natural Resources' (MD DNR) Fisheries Service began trout management in the river utilizing adult hatchery trout in 1994 (Pavol and Klotz 2000). Fish population surveys by MD DNR studies conducted from 1993 through 2000 found low numbers of brook trout in the mainstem North Branch Potomac River. Water temperatures limit year round brook trout survival in the North Branch Potomac River upstream of Jennings Randolph Lake (Pavol and Klotz 2000).

Laurel Run (Kempton)

Watershed includes Chestnut Ridge Run and Red Oak Run. Anecdotal information for Laurel run indicates a historical brook trout population prior to coal mining in all streams within the watershed; however the stream is currently fishless due to severe AMD. The MDE BOM is treating the AMD in Laurel Run. A fish population survey by MD DNR in 1990 in Red Oak Run showed brook trout were absent from this stream, but creek chubs and blacknose dace were present.

Sand Run

Watershed includes the North and South Forks. Sand Run receives treated mine drainage from the Mettiki Coal Corporation. The stream is stocked with 1,000 adult rainbow trout annually as part of the put and take program. Brook trout were not present in this sub-basin in a 1989 survey, and it was noted that high embeddedness in the stream substrate might be a limiting factor for brook trout populations.

Shields Run

Watershed includes McMillan Fork and Aronhalt. Brook trout are present in the Shields Run watershed (Table D1), however low stream flows associated with underground mining are a limiting factor of abundance in the McMillan Fork (Morgan 2002).

Unnamed 2nd order tributary upstream of Bayard, WV

No data.

Nydeggar Run

No brook trout present in 1994, however white sucker, creek chub, mottled sculpin, fantail darter, and blacknose dace were collected. Agricultural practices along the stream likely limit brook trout populations.

Glade Run

Former Put and Take trout stream, removed from list due to presence of brook trout in 1989. By 1994 a viable population was documented in the lower mainstem, but not in the upper watershed. Agriculture land use elevating stream temperatures in the upper portion of the watershed may be a limiting factor for brook trout populations.

Steyer Run

A brook trout population was documented in 1986; however it was threatened by coal strip-mining activities (Jenson 1988). Fisheries Service advocated re-designing a proposed strip mine to protect the stream and the trout population. After the strip-mining commenced, a low-density population of adults was documented in 1992 and 2000 (Table D1).

Bradshaw Hollow Run

This small stream is located within the Potomac State Forest and is protected by the Water Influence Zone of the Potomac/Garrett State Forest's 10-year Management Plan. Brook trout are present in low numbers near the mouth (Table D1); however a stream blockage at a culvert crossing on PSF road limits upstream habitation.

Laurel Run, Potomac State Forest, including Trout Run and Riley Spring Run

No trout were present in Laurel Run or Trout Run in 1973 as AMD affected the watershed (Davis 1988). After AMD reclamation projects were completed, brook trout re-colonized the stream system from unaffected unnamed tributary streams (Hughes et al.1980). A small population of brown trout exists in Laurel Run, the result of fingerling brown trout stockings by the Nemacolin Chapter of Trout Unlimited during the late 1980's. A 2003 survey showed that brook trout populations are found in Laurel Run and its two tributaries, Trout Run and Riley Spring Run (Table D1).

Crooked Run, Potomac State Forest

No data.

Lostland Run, including North and South Prong, Potomac State Forest

The Lostland Run watershed was polluted by AMD and devoid of trout and other associated coldwater fish species as recently as 1979 (Pavol 1988). Pavol (1988) reported that by 1983 brook trout re-colonized the North and South Prongs of Lostland Run. The MDE BOM has operated a limestone doser on the South Prong of Lostland Run since 1992 to treat AMD in the watershed. Viable brook trout populations are now found in all three stream reaches (Table D1).

Short Run

Reproducing population of brook trout documented in 1982 and in 1995, however no population estimate made. We conducted a survey in 2003 and brook trout are still present (Table D1). This stream has a very high gradient, and brook trout were found throughout the high gradient areas.

Wolfden Run

Wolfden Run has been affected by past coal mining activities. A survey conducted in 1989 by the Fisheries Service showed that Wolfden Run was fishless at stations upstream and downstream of the Kitzmiller Water Supply Impoundment. By 2003, however, a fisheries survey conducted by the MD DNR Fisheries Service at the stations upstream and downstream of the impoundment showed viable reproducing brook trout populations (Table D1). No other fish species were collected. It was observed that a large culvert at the mouth near the North Branch Potomac River created an impassible fish barrier. Also the water supply impoundment creates an impassible barrier for upstream fish movement. It is reasonable to assume that the brook trout re-colonized the stream from an extreme headwater population.

Three Forks Run including Left Prong, Right Prong, and Jennings Run

Three Forks Run is severely degraded by AMD which is being treated by a MDE BOM doser. MBSS data indicates that Three Forks Run is fishless.

Stoney Hollow Run

This small stream lies within the US ACOE Property and is a direct tributary to Jennings Randolph Lake. No fish data exists.

Elklick Run

A tributary to Jennings Randolph Lake, portions of the watershed are on US ACOE Property. A baseline biological study was conducted in 1996 to document stream conditions as part of an AMD restoration plan (Pavol et al.1997). Brook trout were present in low numbers near the mouth upstream to a natural fish blockage. The four upstream stations were fishless due to the effects of AMD.

North Branch Potomac River downstream of Jennings Randolph Lake

The completion of the Jennings Randolph Lake Dam enabled suitable temperature regimes for trout populations, and the AMD treatment by the MDE BOM on the upper NBPR starting in 1993 made water quality improvements for conditions even more favorable for trout. Several trout management regulation schemes are applied to the NBPR from the JRL Dam downstream to Pinto, MD. Brook trout have been documented in each of these management areas, however abundance is low. Spawning areas and competition with other trout species may be a limiting factor.

Folly Run

A high-density brook trout population exists throughout the stream (Table D1). The lower portion of the stream is within the MD DNR Fisheries Management Area property.

Laurel Run (downstream of Jennings Randolph Lake)

A MD DNR Fisheries Service survey conducted in 2001 documented a brook trout population with a high YOY density (Table D1). Hatchery-origin brown and rainbow trout were present in the stream from NBPR stockings during 2001.

<u>Georges Creek Watershed sub-basin</u>

The Georges Creek basin, located in eastern Garrett County and Western Allegany County, drains about seventy square miles and contains approximately ninety miles of stream miles in the mainstem and tributaries. Georges Creek Watershed is impacted by mining and improper residential development resulting in poor stream stability. Acid mine drainage is a major source of water pollution in the Georges Creek Watershed, about one-third of the watershed stream miles are affected by AMD (McGann 2000) which limits brook trout distribution and abundance. Other pollution sources include combined sewer overflows (CSO's) and sediment from strip mine operations. However the watershed does maintain some high quality stream reaches where brook trout still exist. Under the Maryland Clean Water Action Plan the Georges Creek watershed is a Category I and Selected Category 3 Priority Restoration Watershed. Many governmental, private, and public groups have formed partnerships to improve the aquatic ecosystem in the watershed (Klotz and Belasco 2001). Streams within the Georges Creek watershed have been degraded by various pollution sources including acid mine drainage (AMD), organic pollution, high sediment loads, and non-point sources (Pegg 1989; Johnson 2000). The Georges Creek Watershed Association (GCWA) was formed in 1999 to address water quality and stream degradation in the watershed by creating partnerships with governmental and conservation agencies to achieve the goal of environmental restoration in the watershed. The Georges Creek watershed also is one of Maryland's first watersheds to participate in the Maryland Department of Natural

Resources Watershed Restoration Action Strategy (WRAS) plan. The WRAS incentive provides for funding and technical assistance in identifying and correcting problem areas.

As part of the restoration efforts in the watershed, the MDNR Fisheries Service Restoration and Enhancement Division conducted a comprehensive fish population and stream habitat survey in the Georges Creek watershed during 1999 (Johnson 2000). This report documented several stream portions within the watershed that were not degraded due to the presence of viable brook trout populations as well as the presence of other coldwater-community fish species populations. The report also documented the loss of these fish populations due to water quality and stream habitat degradation. Since the 1999 survey, the MD DNR Fisheries Service has worked as a partner with the GCWA and the Maryland Department of Environment's Bureau of Mines (MDE BOM) to conduct further biological and water quality monitoring on streams where AMD treatment is being conducted (Belasco 2001; Belasco and Klotz 2002).

A comprehensive fish population survey was conducted in the Georges Creek basin in 1999 (Johnson 2000) and the following streams were documented to have naturally reproducing brook trout populations.

Mill Run

Mill Run supports a reproducing brook trout population (Table D1) upstream of the major AMD source known as the Church seep. Mill Run has been the focus of a major water quality improvement project that employs the use of state of the art AMD treatment technology (Belasco and Klotz 2002).

Laurel Run (Moscow)

Laurel Run had the highest density of adult brook trout in the Georges Creek watershed study during 1999 (Table D1). However this stream is managed under special Put and Take Trout management that is limited to anglers over 65 and under 16 years of age. The stream is stocked with about 500 adult rainbow trout annually.

Koontz run

Koontz Run supports a brook trout population; however no YOY brook trout were collected during the 1999 survey (Table D1). Small AMD seeps in the Koontz Run watershed were observed during the survey.

Elklick run

Elklick Run upstream of the Midland-Gilmore Reservoir contained a brook trout population containing the highest density of YOY brook trout during the 1999 survey in the Georges Creek watershed (Table D1).

Matthew Run, Neff Run

Neff Run has been a stream that has undergone a major restoration project in recent years from impacts of severe AMD and sediment loads (Johnson 2000). This stream has been identified as a stream in need of restoration by several agencies including the Nemacolin Chapter of Trout Unlimited, the MDE BOM, MD DNR, GCWA, the Natural Resource Conservation Service (NRCS), and the Allegany Soil Conservation District. The MD DNR Chesapeake and Coastal Watershed Services Watershed Restoration Division conducted a Stream Corridor Assessment Method (SCAM) survey of Neff Run. This survey identified problem areas such as bank erosion, AMD, pipe outfalls, fish barriers, trash dumping and other unusual conditions along Neff Run. As a result of this survey several stream restoration projects have be completed or are planned in the near future. For example, the NRCS has just completed Phase I of a major in-stream habitat restoration project where 43 in-stream rock vanes were constructed in order to reduce down cutting, improve bank stabilization, and improve physical in-stream fish habitat (C. Hartsock, personal communication). The Nemacolin Chapter of TU along with many other organizations conducted a riparian zone tree-planting project, and the MDE BOM eliminated one source of AMD into the stream during 2001. The MDE BOM is planning to conduct AMD abatement measures in the Neff Run watershed by utilizing limestone fines stream dumping and the construction of five limestone leach beds in 2003 (J. Mills, personnel communication).

An electrofishing survey of Neff Run upstream of the AMD-impacted Matthew Run tributary was conducted in 1987 (Davis 1987) and a small population of brook trout was present in the stream. Blacknose dace, creek chubs, and mottled sculpins were also found in low abundance. Pegg (1989) found similar fish species composition in Neff Run upstream of Matthews Run, and showed that the AMD-impacted Matthew Run reduced fish and benthic macroinvertebrate populations in Neff Run. A survey conducted by the MD DNR Fisheries Service during 1994 in Neff Run upstream of Matthews Run showed that the brook trout population was reduced due to a new source of AMD. The brook trout population of Neff Run was restricted to the short headwater area, and probably consisted of only a few individual fish. We noted that AMD, high embeddedness, and partial canopy coverage were limiting factors for fish populations in Neff Run (Johnson 2000). This source of AMD has since been eliminated, and brook trout have re-colonized this section of the stream. Stream habitat improvements in Neff Run were completed in 2002, and should reduce high bedloads and sedimentation in the stream. Portions of Neff Run's riparian zone have been planted in trees, and should eventually improve coldwater temperature regimes.

Matthew Run upstream of the AMD source in the lower portion of this stream supports viable brook trout and mottled sculpin populations (Johnson 2000). AMD remediation projects in Neff Run and Matthews Run are planned to start construction in 2003. Matthews Run can serve as a source of coldwater fish species to re-colonize Neff Run as water quality improves.

Sand Spring run

Headwaters upstream of the Town of Frostburg support a small population of brook trout.

<u>Braddock run sub-basin</u>

Braddock Run (includes Cash Valley Run, Ashley Run, Porters Run, and Helmans Run)

The Braddock Run watershed encompasses 17.5 square miles (11,174 acres) and contains about 75 mainstem and tributary stream miles. The watershed lies within the Ridge and Valley province in western Allegany County, MD, and flows through the town of LaVale. Braddock run is a tributary of Wills Creek and is within the North Branch Potomac River Watershed. The watershed is predominately woodland (68.7%), with urban and residential land uses accounting for 22.9% of the watershed area. Reclaimed mined land, mostly within the upper portion of the watershed accounts for 5.3% of the land, and hay and pasture make up the remaining 3.1%.

Braddock Run is unique because most of the stream flow in the mainstem originates from an abandoned deep coal mine known as the Hoffman Tunnel. The Hoffman Tunnel drainage flows at an average rate of 25 cubic feet per second and temperatures are isothermal, approximately 55^{0}F year round. Water quality measured during the 1930's showed the pH of the drainage was between 3.0 and 3.5. However since the 1960's to the present the pH has remained at approximately 6.5, with net alkaline discharge of 100 ppm CaCo3 and 0 acidity. Iron levels are high enough to produce the characteristic "yellow boy" color associated with streams affected by AMD.

A comprehensive fish and aquatic macroinvertebrate population survey was conducted by the MD DNR Fisheries Service during 2003 as part of the Braddock Run Watershed Environmental Assessment Plan prepared by the United States Department of Agriculture (2003). Brook trout and several other fish species are reproducing in the mainstem Braddock Run (Table D1). Cash Valley Run, a tributary to Braddock Run in the lower portion of the watershed, contained the highest adult and YOY trout densities of the sample stations (Table D1). Brook trout were present in Helman's Run and Porter's Run, however the population was limited to a few individuals. Limiting factors such as stream blockages and urban development were identified as limits to brook trout populations in these streams.

The USDA conducted a Stream Corridor Assessment survey with the assistance of several other governmental agencies in 2001 to develop a comprehensive watershed management plan (USDA 2002). The survey identified and described 303 environmental problems that adversely affected water quality, fish and wildlife habitat, and human use of the stream corridor. The survey report provides a basis for resource managers to establish restoration priorities and to develop comprehensive plans for future restoration work.

Table D1. Status of brook trout populations in the North Branch Potomac River Watershed (excluding the Savage River basin).

Stream name	Stream miles	Year sampled	Adult trout (#/mile)	YOY (#/mile)
North Branch Potomac, Upstream of J. R. reservoir	28.6	2001	Present only seasonally	Present only seasonally
Laurel Run (includes Red Oak & Chestnut Runs)	10.9	2003	Extirpated (AMD)	Extirpated (AMD)
Sand Run (North & South Forks)	4.2	1989	Extirpated (AMD)	Extirpated (AMD)
Shields Run (Mcmillan & Aronholt Forks)	11.0	1998	194	45
Unnamed tributary (near Bayard)	?		?	?
Nydegger Run	10.1	1994	Extirpated (ag. damage)	Extirpated (ag. damage)
Glade Run	18.5	1994	154	No YOY
Steyer Run	4.1	1992	102	No YOY
Bradshaw Run	?	?	Present in low numbers	
Laurel Run (Potomac State Forest)	13.6	2003	100	17
Trout Run	-	2003	277	17
Riley spring Run	-	2003	22	327
Crooked Run	2.0	?	Unknown	
Lostland Run	9.1	1994	167	37
South Prong	-	1994	194	70
North Prong	-	1994	535	69
Short Run	4.4	2003	176	158
Wolfden Run	5.0	2003	113 – 220	203 – 271
Three Forks Run	14.2	1997	Extirpated (AMD)	

Table D1. Continued				
Stream name	**Stream miles**	**Year sampled**	**Adult trout (#/mile)**	**YOY (#/mile)**
Left Prong	-	1997	Extirpated (AMD	
Right Prong	-	1997	Extirpated (AMD	
Jennings Run	-	1997	Extirpated (AMD	
Stony Hollow Run	0.7	?	Unknown	
Elklick Run	3.4	1996	Present, limited by AMD	
NBPR, downstream to Pinto	12	2003	Present in very low numbers	
Folly Run	4.4	1996	1442	56
Laurel Run	7.1	2001	137 - 216	1343 – 1817
Mill Run		1998	Present in low numbers, AMD	
Laurel Run		1999	530	39
Koontz Run		1999	514	0
Elklick Run		1999	475	311
Matthew Run		2001	377	154
Neff Run		2001	Present in low numbers, AMD	
Sand Spring Run		2002	Present in low numbers	
Braddock Run		2003	134 - 723	12 – 62
Cash Valley Run		2003	235	1076
Ashley Run		2003	0	293
Porters Run		2003	Present in low numbers	
Helmans Run		2003	Present in low numbers	