Conserving the Eastern Brook Trout:
An Overview of Status, Threats, and Trends

Eastern Brook Trout
JOINT VENTURE

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INTRODUCTION

The brook trout *Salvelinus fontinalis* is a recreationally and culturally important species, regional icon, and indicator of high water quality. Biologists have long known that brook trout populations are declining across their historic eastern range from Maine to Georgia. In recognition of this trend of long-term decline and continued vulnerability, representatives from over 50 state and federal fish and wildlife management agencies, nongovernmental organizations, and academia met in June 2004 to discuss the opportunity for a collaborative approach to the conservation of brook trout in the eastern United States. In addition to identifying threats to brook trout across their historic range, it was the group's consensus that there was an opportunity to form an Eastern Brook Trout Joint Venture (EBTJV). A collaborative approach to brook trout management is justified because (1) brook trout are declining across their entire eastern range; (2) causes for these declines are similar; (3) an integrated collaborative approach would be cost effective; (4) watersheds of concern span state borders and state and federal jurisdictions; and (5) federally managed lands along the Appalachian and Adirondack crest provide strongholds of many viable populations.

At the 2004 meeting, participants agreed that a broad-scale, geographic-based conservation strategy is necessary to stop brook trout declines, improve technology transfer, and effectively prioritize funds and projects to restore this recreationally and culturally important species. Past conservation efforts and applications of new technologies have occurred in a fragmented fashion, often with only localized effectiveness, and without consideration of broader conservation goals. For example, cutting-edge techniques for mitigating the impacts of acid precipitation are used to great effect in parts of West Virginia, new methodologies for eliminating non-native salmonids have been developed in eastern Tennessee, and locally comprehensive research into the adaptive significance of genetic strains has been applied in New York; however, these valuable developments in management technology have not been effectively transferred among agencies.

This document summarizes a recently completed assessment of brook trout populations across the Appalachian range, documents opinions of fisheries managers on perturbations to brook trout in their respective areas, and briefly comments on future trends of Appalachian brook trout. It will provide the basis for a more detailed action plan that will outline proactive, collaborative, range-wide and regional strategies to implement habitat, land use, and management activities to conserve, protect, and restore eastern brook trout populations.

GOAL STATEMENT

The long-term goal of the Eastern Brook Trout Joint Venture is to implement range-wide strategies that sustain healthy, fishable, brook trout populations. This goal can be reached by:

- Enhancing or restoring brook trout populations that have been impacted by habitat modification, invasive species or other disturbances.

- Encouraging partnerships among management agencies and stakeholders to seek solutions to issues such as regional environmental and ecological threats.

- Developing and implementing outreach and educational programs to ensure public awareness of the challenges that face brook trout populations.

- Developing support for implementation of programs that perpetuate and restore brook trout throughout their historic range.

SUMMARY OF RANGE-WIDE ASSESSMENT

Range-Wide Status of Brook Trout Populations

Hudy et al. (2005) recently completed a comprehensive study of the status of brook trout populations throughout the Appalachian region from Maine to Georgia. The study area encompassed approximately 25% of the native range of brook trout in North America and 70% of the native U.S. range. The scale chosen by researchers was 6th level hydrologic unit watersheds (approximately 22,000 acres), hereafter referred to as subwatersheds. Data from 1,374 subwatersheds within the historic range of brook trout were compiled. Within the historical range, subwatersheds were classified into seven categories: (1) absent (brook trout not present or never present); (2) no data; (3) present but qualitative data only; (4) present and intact (>90% of historical habitat contained wild, reproducing brook trout); (5) present but moderate (<90% but > 50% of historical habitat contained wild, reproducing brook trout); (6) present but greatly reduced (<50% of historical habitat contained wild, reproducing brook trout); and (7) extirpated.

The assessment revealed that wild brook trout populations in the eastern United States are impaired. Present and intact brook trout populations were found in only 5% of all subwatersheds assessed over the entire eastern range. Moderately reduced brook trout populations were found in 9% of the assessed watersheds. The most common subwatershed classification in the survey (27%) was for brook trout populations that were considered severely reduced from historic levels. Based on the knowledge of agency biologists, it is estimated that brook trout have been extirpated in 21% of sub-watersheds with suitable habitat. In a small percentage (5%) of watersheds where brook trout were absent, it could not be confirmed whether they were extirpated or never occurred. The majority of historic large riverine brook trout habitats no longer support reproducing populations. Brook trout population status was unknown in 14% of subwatersheds.

Regional Status of Brook Trout Populations

Regionally, Maine possesses the most intact subwatersheds (147) for stream brook trout populations as well as the most subwatersheds (658) where brook trout were present but only qualitative data were available. New Hampshire (195) and New York (106) followed Maine with respect to the number of watersheds where brook trout were present but only qualitative data were available. Within the New England region, Connecticut possessed the highest number of subwatersheds with brook trout present but severely reduced (129) as well as extirpated subwatersheds (29).

Among the North Atlantic states of New York, New Jersey, and Pennsylvania, New York contained the most present brook trout subwatersheds (26). Pennsylvania had the greatest number of subwatersheds with brook trout classified as reduced (118), severely reduced (507), extirpated (449), and unknown (218).

Among the Mid-Atlantic States of West Virginia, Virginia and Maryland, Virginia remains a stronghold for stream-dwelling brook trout populations with 36 subwatersheds classified as brook trout present and intact and 80 subwatersheds classified as present but reduced. West Virginia contained the highest number of subwatersheds with brook trout classified as severely reduced (249) as well as a large percentage of watersheds with insufficient data to determine if brook trout were extirpated or never historically existed. Virginia had the largest number of extirpated subwatersheds (148) in the region.

Among the southeastern states of North Carolina, South Carolina, Tennessee and Georgia, Tennessee was the only state with an intact subwatershed. Tennessee and North Carolina combined had only five subwatersheds where brook trout populations were present but reduced. North Carolina also has the highest number of present but severely reduced subwatersheds (116) and extirpated subwatersheds (95). Brook trout remain in less than 30% of the historical subwatersheds in Georgia.

Intact brook trout populations in lakes are confined exclusively to Maine (185), New Hampshire (3), New York (2), and Vermont (1). In Maine, brook trout lakes in 323 subwatersheds have severely reduced status and 235 subwatersheds have unknown population status. New Hampshire contains the highest number subwatersheds with lakes of unknown status (250), while Vermont and New York contain the most subwatersheds (14) where brook trout populations in lakes have been extirpated.

Though the eastern brook trout is certainly not threatened as a species across its vast range in the eastern United States, the assessment illustrates that both stream and lake populations have endured losses throughout their historical range. Brook trout continue to persist, however, in isolated strongholds and in a large number of fragmented populations.

Agency Threats Rankings

In addition to compiling data on brook trout populations over a 17-state region, Hudy et al. (2005) interviewed regional fishery managers and asked them to rank perturbations and threats for all subwatersheds that historically supported reproducing brook trout populations. Perturbations and threats were separated into three categories of severity: (1) eliminates brook trout life cycle component; (2) reduces brook trout population; and (3) potentially impacts brook trout population. Across the entire study area, the top five perturbations listed as a category 1 or 2 severity for streams were high water temperature, agriculture, riparian condition, one or more non-native fish species, and urbanization.

Similar threats to lake brook trout populations were found in Maine, New York, Vermont, and New Hampshire. Non-native fish species constituted by far the largest threats to lake populations, while acid precipitation, low dissolved oxygen, eutrophication, and forestry were less widespread perturbations.

Current Threats to Eastern Brook Trout

Range-Wide Perturbations

Perturbations that negatively affect brook trout and their habitats may influence the entire range of brook trout or may be evident only at the watershed or stream scale (e.g., sediment loading in a stream caused by highway construction). Two of the most serious perturbations that occur at the range-wide scale are climate change and acidic deposition.

Climate Change

In July 2004 an international group of scientists attended a Workshop on Climate Sensitivity sponsored by the Intergovernmental Panel on Climate Change. Their task was to compare predictions of climate change from computer simulation models and assess levels of uncertainty (Kerr 2004). The predicted outcome from eight models indicated a global average temperature increase of 5.4^{0}F in response to a doubling of carbon dioxide concentrations. Levels of uncertainty among leading scientists have continued to decrease over the past 15 years, which indicates general consensus about future increases in temperature.

A 5.4^{0}F increase in temperature across the eastern U.S. is likely to have enormous consequences on the distribution and abundance of brook trout. Meisner (1990) showed how the southern margin of the brook trout's range was related to ground water temperature, which typically equals mean annual air temperature. Meisner (1990) also presented a coarse-scale map to illustrate estimated losses of brook trout range based on a 6.8^{0}F increase in temperature. Using Meisner's (1990) methodology, Flebbe (1993) predicted that North Carolina and Virginia would lose 89-92% of their brook trout streams. While some uncertainty remains about the exact temperature increase that will result from climate change, it is clear that the present range of brook trout will continue to shrink during this century and the Southern Appalachians are likely to bear the brunt of these losses.

Acidic Deposition

The current threats assessment determined that acidic deposition severely impacted brook trout in several states although it does not constitute a widespread threat across the entire eastern range. West Virginia, Virginia, North Carolina, Pennsylvania and New Hampshire all sustained losses of brook trout population from acid deposition (Hudy et al. 2005). Localized impacts to brook trout and other naturalized trout species from acidification have been staggering. For example, Carline et al. (1992) estimated that more than 2,000 miles of trout streams were adversely influenced by acidification in Pennsylvania. Bulger (2003) estimated that 30% of Virginia's historic trout streams no longer support brook trout (one the most acid tolerant freshwater fish) and that up to 10,000 miles of trout streams in the Southern Appalachian region may have been lost to acidification. Emissions of sulfur dioxide, nitrogen oxide, and ammonia are the primary causes of acidic deposition, which has been most evident in the eastern United States. Acidic deposition has been particularly harmful to brook trout, because they tend to occur in headwater streams and lakes that lack buffering capacity and are especially vulnerable to acidic inputs.

Since passage of the Clean Air Act Amendments in 1990, emissions of compounds that contribute to acidic deposition have been reduced (Stoddard et al. 2003). Water chemistry has improved somewhat in the Northern Appalachian Province of Pennsylvania, New York, and regions farther north. However, there has been no improvement in streams within the Ridge and Valley and Blue Ridge Provinces, which include parts of southern Pennsylvania, Maryland, Virginia, West Virginia, Tennessee, and North Carolina.

Watershed-Scale Perturbations

Poor land and water use practices and the introduction of competing fish species have significantly reduced the distribution of brook trout throughout much of their historic range. Anthropogenic alterations of private lands containing brook trout habitat is an increasing threat. Impacts related to development and agriculture generally result from land disturbing activities and include sedimentation, channelization, removal of riparian vegetation, and other alterations that degrade brook trout habitat.

Fish abundance, as well as species composition, is affected by the quality of aquatic habitat (Hubert and Bergersen 1998). Riparian and aquatic ecosystems are currently being altered or lost at a greater rate than any time in history (National Research Council 1992). Brook trout have long been considered indicators of healthy ecosystems. Optimal brook trout habitat in streams is characterized by a 1:1 pool to riffle ratio, silt-free rocky substrate, clear, cold water with stable flow and temperature regimes, and well vegetated, stable banks, with abundant instream cover (Brasch et al. 1958; MacCrimmon and Campbell 1969; Raleigh 1982). However, the single most important factor affecting brook trout distribution and production is water temperature (Creaser 1930; Mullen 1958; McCormick et al. 1972).

Water Temperature

Brook trout thrive in water temperatures $<65^0$F and tolerate brief periods of up to 72^0F; optimum growth occurs between 55^0F and 65^0F (Raleigh 1982). Exposure to temperatures of 75^0F for only a few hours is usually lethal (Flick 1991). Temperature is an important limiting factor in the growth and distribution of juvenile brook trout (McCormick et al. 1972) and their density is negatively correlated with increased July mean water temperatures (Hinz and Wiley 1997). Land use practices that remove streambank vegetation are often detrimental to brook trout populations because removal of a stream's canopy or excessive clear-cutting within a watershed can result in thermal pollution (Hall and Lantz 1969; Platts and Nelson 1989). Additionally, reducing overhead cover along the stream margin can be a major factor limiting brook trout abundance (Enk 1977). Eliminating inputs of large woody debris into streams also has a negative effect on an important process that creates and maintains brook trout habitat (Hicks et al. 1991). In addition to impacts on stream temperatures and riparian cover, any land use activity that removes vegetative cover, disturbs the soil mantle, reduces infiltration rates, decreases soil moisture storage, or increases overland flow has the potential to negatively affect streams by causing higher peak stream flows and more rapid attainment of peaks (Hibbert 1967). These types of activities can also increase sediment loads (Hall and Lantz 1969; Wesche and Isaak 1999), which are widely regarded as the greatest source of water pollution in the United States (USEPA 1973).

Urbanization

The human population of the United States has increased every decade during the 20^{th} century. Throughout this period of population growth, the northeastern U.S. has remained the most densely populated (Hobbs and Stoops 2002). The nation's population growth has primarily been in suburban metropolitan areas rather than cities. As suburban fringes and rural lands are developed for homes, commerce, and transportation, the natural vegetative cover and soils are replaced with constructed artificial landscapes and impervious surfaces. When such urbanization overlaps brook trout habitat in areas that were once forests and fields, streams may be negatively affected through increased water temperatures, sedimentation, habitat modification and loss of fish populations (USEPA 1997). Brook trout are sensitive to environmental changes and the cumulative effects of urbanization have limited their occurrence and distribution. Because brook trout occur in watersheds that are often a patchwork of public and private lands, urbanization will continue to negatively affect brook trout populations.

Modification of Hydrologic Regime

When high flows accompany large depositions of sediment from side slopes or streambank erosion, they cause significant streambed movement and stream turbidity (James 1956; Burns 1972). An accelerated rate of sediment deposition in streams can adversely affect brook trout by reducing the production of food organisms (Raleigh 1982; Everest et al. 1987), decreasing dissolved oxygen content of sub-gravel waters, smothering eggs and embryos in redds (Raleigh 1982; Everest et al. 1987; Reiser and White 1988), and aggrading pools, causing a loss of overwintering habitat (Fisk et al. 1966; Raleigh 1982; Rabeni and Smale 1995). Also, because brook trout are opportunistic sight feeders (Wiseman 1951; Benson 1953; Reed and Bear 1966) they are particularly susceptible to even moderate turbidity levels because it reduces their ability to locate food (Bachman 1958; Herbert and Merkens 1961; Sweka and Hartman 2001).

Instream Flow

Water use practices that substantially alter streamflow, increase water withdrawals, or reduce stream flow may affect the sustainability of brook trout populations (VDFW 1993). Late summer stream flow, annual stream flow variation, and water velocity are in-stream habitat attributes that are highly correlated to trout density (Binns and Eiserman 1979). Channelization of streams for flood control can also decrease trout abundance (Henegar and Harmon 1971) by reducing available cover, an essential component of brook trout habitat (Giger 1973; Raleigh 1982). In addition, channelization causes water to flow over a wider, shallower streambed, which can cause trout spawning failures (VDFW 1993).

Invasive Species

The introduction and spread of competing fish species has a substantial impact on trout populations (Dunham et al. 2002; Peterson and Fausch 2003; NCWRC 2003; Dunham et al. 2004). Brook trout are extremely vulnerable to the effects of predation and competition from other fishes, particularly in the first years of life (Bonney 2001). The potential impact of stocking hatchery-reared trout on top of self-sustaining brook trout populations include genetic alteration due to interbreeding or altered selection pressures (Hindar et al. 1991; Kruger and May 1991; Allendorf et al. 2001); displacement (Waters 1983; Larson and Moore 1985; Hindar et al. 1991), and introduction of diseases (Goede 1986; Hindar et al. 1991; Kruger and May 1991; Stewart 1991).

Habitat Degradation and Fragmentation

Man-made barriers that obstruct fish passage (Belford and Gould 1989; Gibson et al. 2005) can fragment brook trout populations and prevent migration to suitable spawning habitat (Brasch et al. 1958), to cool water refuges during warm periods during the summer (Powers 1929; Scott and Crossman 1973), and to overwintering habitat (Cunjack and Powers 1986). Land application of pesticides and herbicides can result in residual inputs to adjacent waters (Wong et al. 2000) causing considerable impacts to brook trout populations with the most serious effects occurring for young-of-the-year fish (Warner and Fenderson 1960). The removal of gravel and other streambed material also has a number of detrimental effects on brook trout (Wentworth 1987; White 1987). Optimal substrate for the maintenance of a diverse invertebrate population in streams consists of a mosaic of gravel, cobble, and boulders with cobble being dominant (Raleigh 1982). Stream reaches dominated by rubble and gravel bottoms support the highest brook trout densities (Hoover and Morrill 1939).

Abandoned Mine Lands

A large portion of the native range of the brook trout lies within the Appalachian coal producing states of Virginia, West Virginia, Maryland, and Pennsylvania. Regardless of the specific mining method, the nature of coal mining results in disturbances to the environment. For example, within the Appalachian coal-producing states it has been estimated that since the early 1900s over 10,000 miles of streams have been polluted by acid mine drainage (AMD) from more than 65,000 documented sources of coal mine drainage (USEPA 2001). The United States Geological Survey (USGS) estimates that more than 3,400 miles of streams and associated groundwater have been contaminated in Pennsylvania alone (USEPA 2001). Acid mine drainage can be extremely toxic. For example, water flowing from the Kempton Mine discharge, an abandoned deep mining operation in the headwaters of the Potomac River in Maryland, has a pH of 2-3 and since 1950 has discharged in excess of 91,600 tons of acid and 14,700 tons of iron and aluminum into the river (Garner 2002). Such drainages render receiving streams lifeless. Less toxic discharges often result in much reduced abundances of fish and other aquatic species.

FUTURE TRENDS

There are two key questions that natural resource agencies might pose: “What is the future of the eastern brook trout given current environmental and human population growth trends?” and “Can the negative ecological impacts resulting from these trends be significantly altered through identification, development, adoption, and implementation of effective conservation strategies?”

The consequent outcomes of two forces, climate warming and human population growth will weigh heavily on the future of brook trout. Increased stream temperatures were ranked by biologists as the top threat to Appalachian brook trout, and owing to projected increases in air temperature, we can expect stream temperatures to increase during this century. If measures are not taken to protect streams against temperature increases by protecting riparian areas, improving local hydrology and mitigating stormwater runoff, further losses in brook trout populations are imminent.

As the human population increases, we can expect a wide array of disturbances to the landscape that will negatively affect brook trout populations. Among the 17 states covered in the Hudy et al. (2005) brook trout assessment, human population growth from 2000 to 2004 averaged 3.4%. The five southernmost states (VA, TN, NC, SC, GA) had an average increase in population of 5.5% over this same period, and these are the states where intact brook populations were most reduced. Human population growth likely will lead to additional urbanization, fragmentation of the landscape, and degradation of riparian habitats. Hence, the region with the most vulnerable brook trout populations is likely to experience the greatest impacts from climate warming and human disturbances.

Though the future for eastern brook trout appears bleak, it is certainly not hopeless. In recent years we have seen how restoration projects at the watershed scale have resulted in dramatic improvements in coldwater fisheries. These projects provide ample evidence that existing management tools and technology can effectively address many environmental disturbances. The challenge facing regional fishery managers and non-governmental conservation organizations is that of educating the public about the need for immediate action, securing cooperation among public and private landowners, and garnering needed resources to implement conservation and restoration strategies at multiple scales.

CONCLUSIONS

Wild brook trout populations in the eastern United States declined substantially during the past century and continue to face threats. Impacts from agriculture, grazing, loss of riparian forests, urbanization, and competition with invasive species, global climate change, acid precipitation, and other anthropogenic alterations to the landscape are decreasing the presence and robustness of brook trout populations across their historic range. Creation and perpetuation of effective partnerships among state and federal agencies and others interested in the successful conservation of existing brook trout populations and restoring and reconnecting extirpated populations are the primary goals of the Eastern Brook Trout Joint Venture. Achieving these goals will require comprehensive development of range-wide and regional strategies that focus on a strong public education campaign, increased assessment of brook trout population status and threats, forming creative partnerships to effectively address habitat threats, re-evaluation of hatchery practices, and the judicious identification of restoration opportunities. The forthcoming action plan will outline comprehensive conservation strategies for eastern brook trout, provide guidance on funding opportunities, and outline on-the-ground tactics that can be immediately implemented. Cooperation among state and federal agencies, nongovernmental organizations, academia, and the private sector is crucial to achieving this ambitious goal.

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