2019 Symposium Proceedings

Brook Trout: The Scourge and the Saint. Applying Lessons Learned from Both Eradication and Reintroduction Efforts across the West and East to Better Manage this Char

American Fisheries Society/ The Wildlife Society Joint Annual Meeting

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Symposium Abstract

Depending on one's perspective, brook trout *Salvelinus fontinalis* hold distinction as a scourge, invading trout habitat across the American West, or a saint, serving as a beloved symbol of the long lost wilderness of Eastern North America. As fisheries managers in the West struggle to eradicate the prolific and adaptable brook trout in order to protect vulnerable native cutthroat and bull trout populations, fisheries managers in the East struggle to successfully protect and reintroduce brook trout to their natal watersheds. How can the struggles and experiences of fisheries managers across the West and East shed light on the persistence and vulnerability of brook trout? What are the genetic, biological, demographic, habitat preference and interspecies behavioral characteristics that make brook trout such a menacing invader of coldwater aquatic systems in the West, and such a challenge to reclaim their former niche in the coldwater systems in the East? This symposium hopes to share relevant and perhaps novel information gleaned from the intense interest in this char that now more than ever captivates the attention of coldwater fisheries managers, scientists and advocates dedicated to native aquatic species conservation.

Symposium Summary

In the East, brook trout show high levels of genetic differentiation among populations and major clades. Recent work shows that some eastern populations respond to heat stress in different ways (i.e., patterns of gene expression). This work suggests that some populations may be better equipped than others to deal with stressful temperatures, and that genetic variation may help provide resilience to populations against warming conditions. However, widespread population fragmentation and genetic drift have decreased genetic diversity in wild brook trout populations and will likely continue to threaten the future outlook for many populations. Larger, more interconnected populations found in waters with higher baseflows and without the presence of non-native trout tend to have higher numbers of effective spawners. Despite widespread stocking, generally hatchery brook trout have not successfully interbred with wild brook trout and survived. Brook trout have held their own against rainbow and brown trout in Vermont since the 1950's, and have returned to a number of lakes and ponds with improving pH and alkalinity in New York's Adirondacks, yet less so for that region's rivers and streams. Lab and field research found that brook trout do not compete successfully with brown trout in using coldwater refugia during the summer and maintaining body weight. Removal of brown trout from streams where they overlap with brook trout across different states in the East has resulted in greater survival of young of year brook trout, larger adult brook trout, and greater use of warmer, downstream waters. Brook trout that use main stem habitats tend to grow larger, which may help them coexist with some brown trout populations.

Across the West, brook trout have exerted significant impacts to 10 different subspecies of native trout since their introduction in the 19th century. Eleven states are actively using piscicides to eradicate brook trout, often in concert with construction of or use of existing fish passage barriers, and more than half are experimenting with stocking of YY-male brook trout to reduce brook trout spawning success. Simulations have indicated the use of YY-males in combination with suppression is a viable strategy for eradicating brook trout. Removal of brook trout have corresponded to dramatic increases in cutthroat population abundance at all ages, and to a lesser degree more moderate increases in bull trout abundance. Suppression efforts through electrofishing rarely have achieved desired outcomes as brook trout populations levels return to pre-suppression levels in several years. Genetic monitoring with effective number of breeders can potentially improve the monitoring of brook trout suppression efforts. Yet recreational fishing for brook trout in the West is popular, and education and engagement of the public and stakeholders is key to the success of any project to suppress or eradicate local brook trout.

The brook trout's ability to outcompete other trout in the coldest waters, thrive in headwater habitat, spawn and reproduce successfully in small headwater streams or lake inlets, tolerate acid water chemistry, survive in small populations with low genetic diversity, and colonize upstream habitat successfully (in one case scaling a 9 foot waterfall barrier in a flood event) have equipped them to be a survivor across many headwaters in its Eastern range, as well as to be a exceptional invader of coldwater habitat across most of the West. Research has demonstrated the importance of flood event timing for trout egg survival and young of year recruitment: flooding in February/March is generally bad for brook trout, and flooding in April/May is generally bad for rainbow and cutthroat trout. Changes in flood patterns will likely continue to affect future native and non-native brook trout success. In the East, efforts to restore aquatic connectivity have been strong, but future climate resiliency efforts must simultaneously address the limiting factors of habitat loss, warming waters and competing fish species. Across the West, every state is working to balance the desire to provide sport fishing opportunities for brook trout while also creating, maintaining, and enhancing native trout populations by limiting the brook trout's substantial competition, predation and hybridization impacts.

Presentation Title, Contact, Abstract, Summary Points and Further Reading:

Understanding Local Adaptation in Cold Water Fish to Predict Responses to Climate Change

Mariah Meek, Michigan State University, mhmeek@msu.edu

Abstract:

Brook trout *(Salvelinus fontinalis*) are a sentinel cold-water species and their native populations are being seriously impacted by climate change. Despite the negative effects of climate change on cold-water species, we have a poor understanding of how local adaptation will interact with future environmental conditions to cause differences in population level effects. In this study, we evaluated the differences in response to thermal stress among several populations of brook trout in the lakes of Adirondack Park, NY. We used a common garden and RNA-sequencing experiment to identify genes that are differentially expressed in response to thermal stress. We found individual lakes were not only genetically distinct, but they also had unique responses to heat stress, despite being in close geographic proximity to one another. We are now applying this information to a study of brook trout across the species native range to evaluate which populations may have the ability to adapt to warming temperatures, and which may be most at risk. Understanding population and individual differences in the capacity to tolerate changes in climate will aid in making predictions about which populations are most vulnerable or resistant to the negative effects of climate change.

Summary Points:

- Each brook trout lake population is very genetically distinct, even over small geographic scales.
- Despite genomic differences, there are some molecular responses to thermal stress that are similar across populations. We can take advantage of these similarities to monitor populations for thermal stress.
- There is a link between an individual's genotype and response to thermal stress. We are exploring this link to see if we can identify the genetic diversity that will allow populations to better cope with increasing temperatures in a changing climate.

Further Reading:

https://www.huffpost.com/entry/can-trout-evolve-to-survi_b_9406796?guccounter=1
https://meeklab.com/research/

Comparison of Brook Trout Density and Distribution in Vermont's Streams between the 1950s and the 2000s

Jud Kratzer, Vermont Fish & Wildlife Department, jud.kratzer@vermont.gov

Abstract:

Within their native range, some Brook Trout populations have experienced significant declines. The purpose of this study was to document the current status of wild Brook Trout in Vermont streams and to determine if substantial changes have occurred over the past half century. Brook Trout population densities from 150 survey sites within 138 streams were compared between two time periods, comprised of the "1950s" (1952-1960) and "2000s" (2005-2016), and Brook Trout distribution was mapped using data from 1,062 sites in the 1950s and 2,644 sites in the 2000s. Brook Trout and other salmonids were sampled using single or multiple pass electrofishing. Distribution and abundance of wild Brook Trout in Vermont streams has been stable over this period of five decades. Brook Trout were found in 182 HUC-12 sub-watersheds in the 1950s and in 186 sub-watersheds in the 2000s. While most

population measures were consistent between the two time periods, significantly higher densities of young-of-year Brook Trout were observed in current populations, which may reflect improved environmental protections initiated since the 1950s. A decline in sympatric Brown Trout and Rainbow Trout sites also suggest that non-native trout populations have not appreciably expanded into Brook Trout streams over the past 50 years.

Summary Points:

- From the 1950's to the 2000's Brook Trout abundance increased on average in Vermont's Brook Trout-dominated streams. Specifically, young of the year abundance increased, while abundance of yearling and older Brook Trout was unchanged.
- The presence of non-native Brown and Rainbow Trout in Brook Trout-dominated streams in the 1950's was not related to changes in Brook Trout abundance through time.
- Brook Trout distribution at the HUC-12 watershed scale was the same in the 2000's as in the 1950's.

Further Reading:

Vermont's federal aid report on this project: https://vtfishandwildlife.com/sites/fishandwildlife/files/documents/Learn%20More/Library/REPORTS%20AND%20DOCUMENTS/FISHERIES%20MANAGEMENT/Statewide%20BKT%20Stream%20Eval%202017.pdf

Role of Declining Inorganic Aluminum Concentrations and Exposure Duration in the Recovery of Brook Trout Populations in Acidified Streams of the Adirondack Mountains, New York

Barry Baldigo, US Geological Survey, bbaldigo@usgs.gov

Abstract:

Many acidified lakes and streams in the western Adirondacks have begun to recover following recent declines in acidic deposition. Water chemistry and mortality of caged Brook Trout Salvelinus fontinalis were characterized in six streams during spring 2015-17 and compared with results from 1984-2003 toxicity tests to assess temporal trends in toxicity and inorganic aluminum (Ali), and the role of Ali-exposure duration on survival. The variability, mean, and highest Ali concentrations at Buck Creek, and at five other streams sampled during spring periods, decreased significantly since the late 1980s. Logistic models that define the effects of Ali concentration and exposure duration on Brook Trout mortality, indicate that Ali surpassed acute-mortality thresholds (4 µmol L-1) at Buck Creek for 3-to-4 months annually during 2001-03 and for only 2-to-3 weeks annually during 2015-17. These models provide a means to predict how changes in federal regulations, designed to limit atmospheric emissions of NOx and SOx and achieve target N and S deposition loads, may affect stream ecosystems. While these models illustrate how the 1990 Amendments to the Clean Air Act reduced acidity and Ali toxicity, additional fish surveys from previously sampled streams are needed to assess how biological recovery is progressing in local streams.

Summary Points:

- The 1990 amendment to the Clean Air Act decreased inorganic Aluminum concentrations & the duration of toxic episodes in many Adirondack streams.
- Inorganic Aluminum concentrations still exceeded thresholds and caused high levels of brook trout mortality during spring 2015-17 toxicity tests.

- Though biological recovery is uncertain, chemical recovery from acidification is complicated but clearly underway in many headwater streams of this region.

Further Reading:

https://www.sciencebase.gov/catalog/item/55df5594e4b0518e354e0b06

Growth and Spatial Distribution of Sympatric Stream Salmonids in a Long-Term Individual-Based Study – Clues to Coexistence in a Changing Environment

Keith Nislow, USFS Northern Research Station, knislow@fs.fed.us

Abstract:

Differential responses of sympatric species to environmental change may reveal mechanisms of species coexistence or replacement. Using long-term (> 20 years) individually-based data on spatial distribution and individual growth and size of brook trout, brown trout and Atlantic salmon we found a mix of commonalities and differences. Patterns of stream network use were consistent, with salmon only using the 3rd order mainstem, brown trout largely in the mainstem but also in lower sections of connected tributaries, and brook trout occupying the entire stream network. All three species accomplished a disproportionate amount of growth during the spring interval (~ April-June). For the two resident species individual size and growth rates increased over time, due to density-dependent responses to decreased abundance, with flow and temperature as additional influences. The strength of density-dependent and density-independent factors differed between the two species, and was influenced by spatial location and by age-class. Results support the importance of small tributaries for native brook trout persistence in the presence of non-natives. However, stronger density-dependent growth responses in brown trout, given the role of individual size in competitive and predator-prey interactions and projected high variability in recruitment and abundance, may have negative implications for future coexistence.

Summary Points:

- Substantial annual variation in cohort strength (good vs. bad years) is a general characteristic of stream fish populations including salmonids. In combination with established measure of species overlap (such as habitat use), among-species differences in the pattern of cohort strength variation, and in the response to this variation with respect to key population characteristics (such as individual body size), can help determine the likelihood of species coexistence or replacement.

- In a long-term intensive field study (western MA, USA), three co-occurring species (brook trout (native resident), brown trout (non-native resident) and Atlantic salmon (native migratory) exhibited distinct patterns of habitat use, where brook trout occupied both the mainstem and large and small tributaries, with the other two species confined to mainstem (salmon) or mainstem and large tributaries.

- In contrast to interspecific differences in habitats use, good years and bad years co-varied both between the resident species, and between distinct brook trout populations, suggesting a common response to annual variation in environmental conditions as a driver of variation in cohort strength. Individual body size increased over the course of the study for both species with evidence of density-dependence (fish were larger in weak cohort years). Brown trout maintained a maximum body size advantage over brook trout, but this advantage was reduced for brook trout occupying productive mainstem habitats. Overall, results indicate that differences in habitat use are likely more important than response to cohort variation and foster coexistence for these three Atlantic-basin species. For native brook trout, ability to use small tributaries, while maintaining access to high-growth mainstem habitats may be key to coexistence with non-native brown trout.

Further Reading:

Spatial Hydro-Ecological Decision System (SHEDS) https://ecosheds.org/
SHEDS Brook Trout Occupancy Model: https://ecosheds.org/models/brook-trout-occupancy/latest/

Temperature-Dependent Brown x Brook Trout Interactions: Implications for Management

Than Hitt, US Geological Survey, nhitt@usgs.gov

Abstract:
Although it is widely recognized that climate change and biological invasions may have synergistic effects on native species, most studies treat these effects independently. Here we demonstrate thermally-dependent competition for food between adult brook trout and brown trout in an experimental stream system. We compared fish movement, aggression, spatial evenness, and ventilation rate between allopatric and sympatric populations at 4 temperature levels (14, 17, 20, 23 C) in the presence of a thermal refuge (14-16 C) provided by groundwater upwelling. Replicated trials revealed an important behavioral difference between allopatric and sympatric populations: although all fish congregated in the thermal refuge when ambient temperatures reached 20 C, only brown trout periodically accessed food in warmer sections of the stream when in sympatry with brook trout. In contrast, brook trout exhibited this behavior when isolated from brown trout. Accordingly, management to reduce introduced brown trout numbers may expand the capacity for native brook trout populations to cope with increasing temperatures. We discuss implications for management of introduced brook trout in western North America.

Summary Points:

- We showed that effects of introduced species on brook trout are temperature-dependent.
- Brook trout were able to use warmer water where brown trout were absent vs where they were present in an experimental stream system.
- Managing to limit introduced fishes may promote climate-resiliency for native brook trout in some locations.

Further Reading:

Modeling groundwater influence in Shenandoah National Park streams:
https://chesapeake.usgs.gov/shenandoah_groundwater/
Accounting for thermal resiliency in brook trout thermal habitat forecasts:
https://chesapeake.usgs.gov/fishforecast/
Inferring watershed hydraulics and cold-water habitat persistence using multi-year air and stream temperature signals. [Link]
Accounting for the influence of groundwater on the thermal sensitivity of headwater streams to climate change. [Link]

Distribution and status of trouts and chars in North America. Chapter 7 In: Diversity and Status of Trouts and Chars of the World. 2019. American Fisheries Society, Bethesda, Maryland. [Link]

Managing Brook Trout and Angler Expectations in a Multi-Year Westslope Cutthroat Trout Restoration Project in Western Montana

Jim Brammer, USDA Forest Service, James.Brammer@usda.gov

Abstract:

Many children's first fist day fishing is spent on a mountain-meadow stream, full of brook trout. Increasingly, adult anglers are seeking solitude in small streams away from crowded rivers, catching fish that filled childhood memories. So it is with Montana's Selway Creek. Before the Forest Service's 2007 acquisition of Selway Meadows, this grassy banked, meandering stream, nestled in a beautiful valley with a road along its margins, was off-limits to most people. Public ownership brought new opportunities and growing interest from anglers enjoying a previously unreachable and lightly fished stream. The acquisition also offered resource managers an opportunity to remove brook trout and restore native cutthroat to thirty plus miles of connected habitat; with the added potential of revitalizing a declining western pearlshell mussel population. This scope of restoration opportunity is uncommon in Montana, since most valley bottom streams and their tributary confluences are in private ownership. Public acceptance of restoration opportunities in the Selway watershed depends on managers' ability to minimize loss of angling opportunities between brook trout removal and re-establishment of a catchable cutthroat fishery. Live fish translocations in tributaries, coupled with reintroduction of sterile triploids in the main-stem fishery, are being considered.

Summary Points:

- Public acceptance is needed to use chemicals to remove non-native brook trout and thereby restore native cutthroat trout populations to this 35 mile project.
- Angler concerns about the interruption of recreational fishing, and the loss of fishing opportunities for non-native brook trout populations, are real and must be addressed through public interactions, listening and planning accordingly that includes stocking of sterile triploid Westslope Cutthroat (WCT) for 3 years after rotenone application, and then reintroduction of WCT for up to 8 years.
- Project success was achieved in part because of diverse funding from fisheries and rangeland budgets and external grants.

Further Reading:

Simulating the Use of Sex Ratio Manipulation for the Eradication of Invasive Brook Trout

Casey Day, University of Montana, caseycday@gmail.com

Abstract:

In aquatic ecosystems in the western United States, invasive brook trout have commonly been targeted by management agencies for suppression and eradication toward the restoration of native Salmonids. Recently, programs have been developed to manipulate brook trout sex ratios in the wild through the outplanting of hatchery-raised males possessing two Y chromosomes. The success of such programs may depend upon several factors such as the survival and reproductive fitness of YY males, their dispersal

capacity, and the number and locations of YY males to be released. To explore these factors, we developed a system model of a brook trout population in the Lower Pend Oreille River watershed in eastern Washington State. The model simulates the outplanting of YY males and the subsequent inheritance of individual sex chromosomes in an environment that is both spatially explicit and temporally dynamic. We demonstrate that when concurrent with electrofishing suppression, the outplanting of YY males may result in brook trout eradication through sex ratio manipulation. Further, we demonstrate the sensitivity of model outcomes to YY male fitness, management strategies, and spatial heterogeneity in brook trout abundances. Finally, we discuss the role of simulation modeling in the management of aquatic invasive species.

Summary Points:

- Simulations indicated the use of YY-males in combination with suppression is a viable strategy for eradicating brook trout.
- Factors such as YY-male fitness and dispersal are crucial to eradication success.
- Effects of YY-male releases on native fishes, such as density-dependent mortality, should also be considered

Further Reading:

https://github.com/ComputationalEcologyLab/CDMetaPOP

Brook Trout and Brown Trout Suppression As a Means to Benefit Migratory Bull Trout in a Northwest Montana Stream

Sean Moran, Avista Corporation, sean.moran@avistacorp.com

Abstract:

Avista and stakeholders to the Clark Fork Settlement Agreement developed projects to address non-native fish impacts as part of a native salmonid enhancement strategy, during the relicensing of Avista's Clark Fork River hydroelectric dams. Brook Trout x Bull Trout hybridization and Brown Trout redd superimposition on Bull Trout redds provided the impetus to enact a non-native fish suppression project in the East Fork Bull River (EFBR), an important migratory Bull Trout rearing tributary in northwest Montana. From 2007 through 2009, nearly 5,500 non-native trout (including 1,900 Brook Trout) were removed from the lower EFBR by electrofishing and fish traps, in an attempt to reach a 90% reduction in non-natives. Pre- and post-suppression monitoring electrofishing described reductions in non-native species' biomass that ranged from 61% for Brook Trout to 74% for Brown Trout and a short-lived (two-year) increase in juvenile Bull Trout abundance. Subsequent monitoring depicted that non-native abundance remained depressed from pre-suppression levels; however, due to a host of other ongoing programmatic and environmental factors, the short-lived increase (and a subsequent decrease) in juvenile Bull Trout, was difficult to attribute to any one factor (e.g., relative abundance of non-native salmonids).

Summary Points:

- Brook and brown trout suppression was proposed because lack of permanent barrier, stream size and complexity, hydrograph for trapping, and resource users. Native fish found in highest elevation portion of stream network.
- Brook and brown trout suppression, including electrofishing, trapping, redd excavation, was good: 93% reduction in brook trout and 50+% reduction in brown trout.

- Other external factors appear to be impacting bull trout population response to brook trout suppression work, including climate change driven rain on snow events.

One Fish, Two Fish, 15,000 Fish: Brook Trout Suppression for Bull Trout Recovery in the Upper Malheur

Brandon Haslick, Burns Paiute Tribe, brandon.haslick@burnspaiute-nsn.gov

Abstract:
Non-native brook trout introduced into the headwaters region of the Malheur River have exacerbated recovery efforts for ESA-listed bull trout. Factors that have contributed to bull trout declines include competition for available resources and hybridization. The Burns Paiute Tribe (BPT) coordinates a collaborative multi-agency effort focused on recovering bull trout populations in the upper Malheur. To date, the BPT has conducted brook trout suppression primarily via mechanical removal (gillnetting and electrofishing). Current population estimates do not demonstrate the desired impacts of these mechanical removal efforts. The BPT and collaborators mobilized an alternative strategy several years ago to account for this possibility. Baseline data collection on non-target species and drainage hydrology currently form the emerging foundations for phased chemical piscicide treatments in the upper Malheur. The BPT and partners have initiated education and outreach efforts and the NEPA process, with the target of late summer 2020 for the first phase of treatment. The BPT is exploring the possibility of using environmental DNA to aid in determining treatment success and with collaborators has plans to stock project sites post-treatment with species native to the basin to prevent net loss of angling opportunities. Regulatory and environmental compliance processes are pending.

Summary Points:

- Fisheries managers are best served by planning the next phase or iteration of any project while the current phase is being conducted in order to sustain momentum and make progress more efficient.
- An education and outreach program is essential to any successful fish eradication project. Engaging the public is vital not only to obtain buy-in and an understanding of why the project is necessary, but also to prevent potential litigation or project sabotage. Additionally, it allows for trust through transparency, with questions and concerns addressed.
- Continuous cost-benefit analysis is advised when conducting management projects as new information is received. It is vitally important to not do more harm than good.

Further Reading:

https://www.cbfish.org/Project.mvc/ProjectDocuments/1997-019-00

Spatial Patterns and Environmental Drivers of Effective Number of Breeders in Eastern Brook Trout Populations

Zachary Robinson, University of Montana, zachary.robinson@umconnect.umt.edu

Abstract:
Genetic approaches are increasingly being used in fisheries conservation and estimates of effective number of breeders (Nb) have shown great promise as a monitoring tool. Nb captures population information previously unavailable to resource managers from a single sampling event. Nb is a

population-level parameter reflecting the number of breeders and the variance of their contribution to a single reproductive bout. To date, our research has shown that Nb in brook trout populations is less variable than abundance and interannual variation in estimates appears to be environmentally influenced. Additionally, we find that the beneficial effects of management efforts, such as acid rain remediation, are well-documented with Nb estimates. Although more research is needed, we suggest that Nb in small head-water brook trout populations may be an index of habitat-specific reproductive capacity. We evaluate environmental factors influencing variation in Nb among 51 populations within the Chesapeake Bay drainage. We modeled empirical estimates of Nb as a function of habitat characteristics, exotic species presence, and management actions to identify factors that significantly influence Nb. Moving forward, this model can be used to prioritize and assess the status of existing populations and identify potential native brook trout habitats.

Summary Points:

- Estimates of the effective numbers of breeders (Nb) improve genetic monitoring by providing information about the amount and variance of cohort-specific reproductive success from a single sampling event.
- Our modelling of Nb across the Chesapeake Bay drainage demonstrated that, on average, Nb is higher in larger habitats with lower temperature, higher base flow, and without nonnative salmonids present.
- Genetic monitoring with Nb can support existing prioritization tools by identifying brook trout populations with few successful spawners within the native range and potentially improve the monitoring of suppression outside the native range.

Further Reading:

2017 Keeping things local: Subpopulation N_b and N_e in a stream network with partial barriers to fish migration. https://onlinelibrary.wiley.com/doi/10.1111/eva.12454
Effective number of breeders provides a link between interannual variation in stream flow and individual reproductive contribution in a stream salmonid.
https://onlinelibrary.wiley.com/doi/full/10.1111/mec.13273
Patch-based metrics: A cost effective method for short- and long-term monitoring of EBTJV wild Brook Trout populations? https://link.springer.com/article/10.1007%2Fs10592-018-1116-1
Sampling strategies for estimating brook trout effective population size.
https://link.springer.com/article/10.1007%2Fs10592-011-0313-y

Passing the Impassable: Brook Trout Population Response to Hurricane Irene

Andrew Whiteley, University of Montana, andrew.whiteley@umontana.edu

Abstract:

Extreme events such as severe flooding from hurricanes might lead to population extirpation, especially for small and isolated populations already prone to strong demographic and genetic stochasticity. We examined the demographic and genetic consequences of extreme flooding from Hurricane Irene with a before and after analysis of a set of isolated and connected brook trout populations from three watersheds within the species' native range. Above-waterfall isolated populations had reduced genetic variation compared to downstream interconnected sites before Hurricane Irene. Following Hurricane Irene, none of the above-barrier sites was extirpated. Two of the seven isolated sites, one in each of two watersheds, had increased genetic variation after the hurricane (mean increase in heterozygosity = 16%, mean increase in allelic richness = 15%). This increase in genetic variation in two sites strongly suggests

that gene flow occurred as a result of the flooding. Counter to expectations, this pulse of gene flow during an extreme flooding event might lead to increased persistence probability in the receiving populations (genetic rescue) by reducing inbreeding depression. Periodic pulses of gene flow might provide one piece to the long-standing puzzle of how small genetically depauperate brook trout populations are able to persist in isolation.

Summary Points:

- Extreme flooding from Hurricane Irene had a greater negative effect on genetic variation in brook trout populations in higher order streams, whereas lower order streams appeared to serve as refugia during the flooding.
- In some cases, brook trout were able to ascend what appeared to be impassable waterfalls (3 meters at low flow) during the flooding. Those populations had dramatically increased genetic variation after the Hurricane and should now have increased probabilities of persistence
- These results provide a demonstration of the importance of small headwater habitats, provide an additional explanation for how small salmonid populations persist in isolation, and suggest that populations in the west might spread even more if flooding occurs and brook trout are able to move in a similar manner as we observed.

Brook Trout Population Responses to Climate Variation in Southern Appalachian Streams Yoichiro Kanno, Colorado State University, yoichiro.kanno@colostate.edu

Abstract:
We investigated climate attributes associated with inter-annual variation in brook trout abundance in southern Appalachian Mountain streams, using time-series count data throughout the region (Virginia to the south). There was a high degree of synchrony among sites in patterns of inter-annual variation in summer-time trout abundance, particularly in young-of-the-year fish. This regional synchrony occurred because abundance of young-of-the-year brook trout was negatively associated with high precipitation during winter (December-February), suggesting that winter floods have a disproportionate effect on the early life stage of brook trout due to gravel scour and egg/larval mortality. High abundance of young-of-the-year fish was followed by high abundance of age1+ fish in the subsequent year. Thus, the precipitation effect on young-of-the-year abundance was a driver of population dynamics of this short-lived species. This analysis suggests that precipitation and resulting flow regimes may explain why brook trout populations are robust in some regions, but not in others. We also describe ongoing continental-scale effort to analyze existing brook trout population data in the context of global climate change.

Summary points:

- Seasonal flows, particularly winter high flows that scour river bed, drive young-of-the-year abundance and subsequently brook trout population dynamics.
- Extreme flows is a better predictor of young-of-the-year abundance than mean flows.
- Flow regimes may partly explain why brook trout are successful in invading streams in the intermountain west.

Further Reading:

https://onlinelibrary.wiley.com/doi/10.1111/gcb.12837
https://onlinelibrary.wiley.com/doi/10.1111/fwb.12682
https://onlinelibrary.wiley.com/doi/10.1111/fwb.12906
https://esajournals.onlinelibrary.wiley.com/doi/10.1002/ecs2.2356

https://www.nrcresearchpress.com/doi/full/10.1139/cjfas-2018-0241

Brook Trout, Climate Change, and Appalachian Riverscapes

J. Todd Petty, West Virginia University, todd.petty@mail.wvu.edu

Abstract:
A central question in contemporary brook trout conservation is, can this species survive climate change? We describe multiple lines of research designed to quantify brook trout vulnerability to climate change and identify restoration / conservation measures needed to sustain brook trout populations in the core of their native range. Our results indicate that brook trout vulnerability to climate change is spatially complex at the regional scale (e.g., the scale of the mid-Atlantic Highlands): some areas will be strongly impacted by stream warming while others may actually cool as a result of increased precipitation. We also have found that protected cold water tributaries can serve to mitigate projected warming in larger river main stems. Finally, we present findings from a riverscape scale restoration program that suggests that combining stream channel restoration, acid precipitation remediation, and dispersal barrier removal can be used to effectively restore fluvial brook trout metapopulations. Successful conservation of brook trout in the central Appalachian region will depend on highly coordinated restoration programs that address stream warming, dispersal barriers, and impacts from exotic trout.

Summary Points:

- Brook trout restoration in the eastern US must simultaneously address factors that are currently limiting brook trout populations (e.g., acidification, habitat loss) and build future climate resiliency.
- Addressing current limiting factors and building climate resiliency is most easily accomplished through watershed scale restoration, rather than piecemeal segment scale projects.
- Building climate resiliency for brook trout will require exotic species management.

Further Reading:

Google scholar profile: https://scholar.google.com/citations?user=q6-E97YAAAAJ&hl=en
Conservation planning at the intersection of landscape and climate change: a case study with brook trout in the Chesapeake Bay watershed.
https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.2585
Non-native trout limit native brook trout access to space and thermal refugia in a restored large-river system. https://onlinelibrary.wiley.com/doi/full/10.1111/rec.12925
Stream channel restoration increases climate resiliency in a thermally vulnerable Appalachian river. https://afspubs.onlinelibrary.wiley.com/doi/full/10.1002/nafm.10185

Genetic Structure of Wild Brook Trout and Implications for Adaptability and Persistence

Dave Kazyak, USGS, Leetown Science Center, dkazyak@usgs.gov

Abstract:
We characterized variation at 12 microsatellite DNA loci in 21,998 Brook Trout within and among 836 populations from Georgia to Quebec to the western Great Lakes region. Contemporary population genetic variation showed the signatures of geographic expansion of Brook Trout from Mississippian, mid-Atlantic and Acadian glacial refuges, as well as differentiation at the drainage basin scale. Within-population diversity tended to be lower in the southern Appalachians relative to the mid-Atlantic and

northeastern regions. In contrast, among-population differentiation was more pronounced in the southern Appalachians. Most populations in the southeast were isolated with small effective population sizes, and the hallmark signatures of genetic drift were widespread. As a result, nearly all populations had a unique genetic signature. We discuss the implications of these findings for wild Brook Trout and will identify key research opportunities to use genetics and genomics to support conservation and management.

Summary Points:

- Population structure of brook trout reflects a variety of processes across different spatial and temporal scales. We found deep genetic clusters that seem to correspond to glacial refugia, patterns of hierarchical watershed structure, and evidence of recent isolation and genetic drift.
- Stocking hatchery Brook Trout strains (which originated in the northeast and were subsequently domesticated) has not resulted in widespread hatchery introgression in the eastern US. Most of the diversity we see in Brook Trout across the landscape appears to be endemic, however, there are some populations with strong signatures of introgression.
- Many populations of wild Brook Trout are small and isolated. We found strong evidence of genetic drift, and effective population size estimates indicate that genetic drift continues to happen at a rapid rate in many populations. This is especially prevalent in the southern Appalachians but also occurs at higher latitudes. Science-based management guidelines are needed to address this loss of biodiversity, which will likely be important for adaptation to coming environmental changes.

Further Reading:

https://www.tu.org/blog/scientist-dave-kazyak-discusses-fascinating-brook-trout-genetics-work/

Conservation Lessons and Opportunities: The Eastern Brook Trout Joint Venture's Last Decade
Steve Perry, Eastern Brook Trout Joint Venture, ebtjv.coordinator@gmail.com

Abstract:
The Eastern Brook Trout Joint Venture (EBTJV) formed as the National Fish Habitat Action Plan's first partnership in 2004, bringing together 17 states and numerous federal agencies and non-governmental groups together around the common goal of assessing the status of the Eastern Brook Trout and working to restore fishable populations. Well into its second decade, the EBTJV has achieved significant progress in population assessment at the catchment level, connecting its members through research and common objectives, and implementing aquatic connectivity and habitat conservation projects. Challenges in the future include implementation of population restoration projects to create new wild brook trout patches, conserving existing populations in the face of demographic growth and climate change, and enlisting larger funding support. Lessons learned from this collaborative experiment will be analyzed and shared.

Summary Points:

- The EBTJV’s 2018 Road Map to Conservation identified removing small dams and upgrading culverts, developing strategies to eliminate non-native fish conservation and planting riparian zones as 3 top conservation strategies to protect and restore eastern brook trout in the face of climate change and other future threats.

- EBTJV has had 88 projects funded since 2006. 241 partners. $3.3 million, $17.5 million from partners. Average cost per project of $230k. Socioeconomic impact of these projects estimated to be $317 million.
- Looking ahead the EBTJV will focus on catchment assessments, genetics, identifying thermal refugia that includes incorporating groundwater data.

Further Reading:

Eastern Brook Trout Joint Venture www.easternbrooktrout.org

Western Native Trout Initiative: The Role of Competing Species in the Conservation of Native Trout across the West

Julie Carter, Western Native Trout Initiative, jcarter@azgfd.gov

Abstract:

The Western Native Trout Initiative (WNTI) is a public-private Fish Habitat Partnership that works collaboratively across 12 western states to conserve and protect 21 native trout and char species. The introduction and establishment of nonnative trout is the most significant threat to the majority of WNTI species. Brook Trout (Salvelinus fontinalis) have extensively colonized across the range of at least 10 WNTI species, resulting in competition, predation, and/or introgression with native trout populations, most notably to inland cutthroat trout subspecies and Bull Trout (*S. confluentus*). Fisheries managers use a variety of approaches to reduce or eliminate populations of Brook Trout and other nonnative trout in priority watersheds for native trout including the installation of migration barriers, mechanical or chemical removal, and altering sport fish stocking procedures to eliminate stockings in or adjacent to priority areas. At the same time, Brook Trout populations are also valued by agencies and the public as a sport fish, and recreational populations may also be maintained. Herein lies one of the many challenges to manage native trout populations while balancing the desires of the angling public and the dual mandates of state wildlife agencies to manage for sport fish opportunities and native fish conservation.

Summary Points:

- The Western Native Trout Initiative (WNTI), a National Fish Habitat Partnership and Western Association of Fish and Wildlife agencies initiative, covers 12 western states and 21 species of western native trout. WNTI works collaboratively across the states to conserve, protect, restore and recover these species by raising and directing funds on projects that accomplish these objectives. The type of projects includes fish passage, barrier construction to isolate native trout from nonnative trout, habitat restoration, population assessments, and genetic assessments. While WNTI's charge is to fund native trout conservation projects to benefit the species, we are also cognizant of the dichotomy of managing both for native trout conservation and nonnative trout recreation with species including brook trout.
- Brook trout have colonized across the range of at least 10 native trout species in the West that are recognized as WNTI species. Brook trout interactions can result in competition, predation, or hybridization (in the case of bull trout) with western native trout species. Yet WNTI also recognizes that brook trout are a valuable sport fish in the western U.S. and state agencies must manage for both types of opportunities. State fish and wildlife agencies have dual mandates to conserve the wildlife that are trust species for the public as well as to provide angling opportunities to the public that support agencies through the purchase of fishing licenses and the associated gear and tackle.

- We asked 11 western states a series of questions about managing for native trout conservation and brook trout recreational fishing opportunities. The results indicated that brook trout impact between 1-4 species of native trout in each of the western states in the lower 48. State wildlife agencies manage brook trout populations passively or actively, and similarly among states. The majority of states maintain more brook trout populations for recreational angling than those targeted for reduction or eradication. The majority of states use multiple tools to reduce or eradicate brook trout populations including piscicides, mechanical removal, fishing regulations, and some have begun using the YY Trojan male introduction approach. Ultimately, every state is working to balance the desire to provide sport fishing opportunities for brook trout while also creating, maintaining, and enhancing native trout populations.

Further Reading:

Western Native Trout Initiative: www.wnti.org
Evaluating the role of tiger musky to eradicate brook trout in Idaho high mountain lakes: http://www.tandfonline.com/loi/ujfm20