Evaluating Trout Stream Restoration Benefits: A Case Study at Pine Creek, Wisconsin

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ABSTRACT: In 2007-2011, the Wisconsin Department of Natural Resources and the Kiap-TU-Wish Chapter of Trout Unlimited conducted an extensive stream restoration project at Pine Creek, a native brook trout stream in the Driftless Area of Wisconsin. Primary project objectives were to remedy severe stream bank erosion and increase brook trout abundance by 40-50%. The project restored 2.11 stream miles at a cost of $270,000. In 2009, the Pine Creek Restoration Project was recognized by the National Fish Habitat Action Plan as one of 10 national "Waters to Watch". Key elements of a monitoring program to evaluate project success included physical and biological attributes measured pre- and post-restoration. Physical attributes included stream temperature and habitat (stream width, water depth, water velocity, canopy cover, stream bank height and cover, and stream bed substrate). Biological attributes included macrophytes, macroinvertebrates, and trout. Beneficial project outcomes included: a decrease in stream temperature, a reduction in stream width, greatly reduced stream bank heights and erosion potential, and increases in water depth, stream bank cover, presence of coarse stream bed substrate, and macrophyte presence. Unanticipated project outcomes included: no change in canopy cover, a decrease in water velocity, no significant improvement in macroinvertebrate metrics, and a significant increase in brown trout abundance and decrease in brook trout abundance. Within eight years post-restoration, numbers of brook trout per mile decreased by 70% (3,800 to 1,200), while numbers of brown trout per mile increased by 3,150% (175 to 5,600). A continuation of this trend may lead to the loss of the brook trout fishery. With brook trout being the only native trout species in the Driftless Area, this project highlights the need for appropriate restoration techniques that can protect and enhance brook trout in streams that could be subject to brown trout co-habitation.

INTRODUCTION

Pine Creek is a third-order, cold-water stream located in Maiden Rock Township, Pierce County, Wisconsin, at the northwestern end of the Upper Midwest's Driftless Area (Figure 1). Pine Creek emanates from a series of large springs and flows westerly into the Mississippi River at Lake Pepin. Consisting primarily of heavily forested coulees and upland agricultural areas, the Pine Creek watershed is part of the karst landscape of the Driftless Area ecoregion, which is characterized by thin loess soils underlain by fractured limestone. The Wisconsin Department of Natural Resources (WDNR) lists Pine Creek as a Class I trout stream that has historically sustained a naturally-reproducing population of brook trout. Approximately 1.8 miles of Pine Creek and 1.1 miles of classified tributaries are protected in the Pine Creek Fishery Area. The lower two miles of Pine Creek are separated from the headwaters by approximately 0.5 mile of subterranean flow (WDNR 2017).

As is characteristic of many streams in the Driftless Area, Pine Creek has good water quality but has suffered from severe stream bank erosion. In the early 20th century, poor agricultural practices and runoff from the watershed mobilized the thin loess soils at the tops of the surrounding bluffs and deposited them in the valley floor. Before a stream restoration project began in 2007, Pine Creek was still moving these deposits, resulting in steeply eroded and raw stream banks with massive deposition of fine sediment in the streambed. Overgrazing on adjoining pasture lands compounded the erosion and sedimentation problem, which severely limited habitat and brook trout reproduction in Pine Creek.

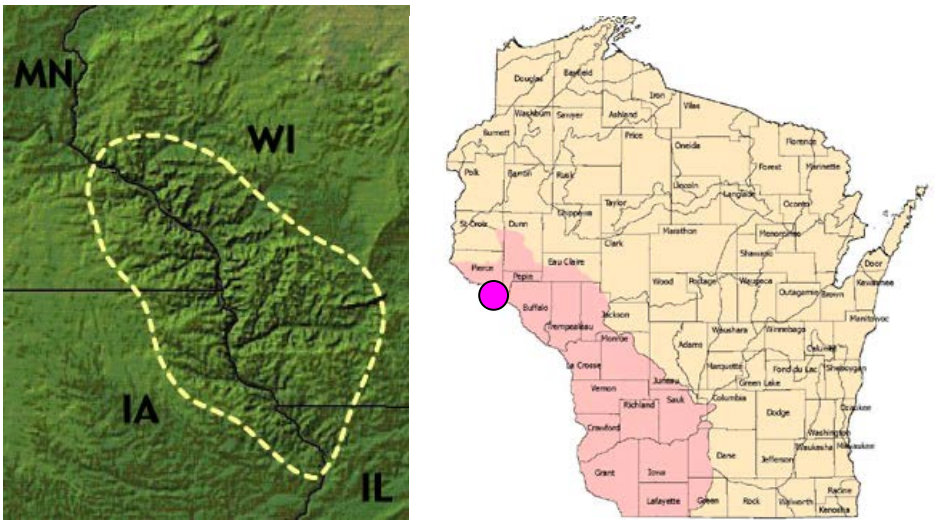

Figure 1. Location of Pine Creek in the Upper Midwest's Driftless Area

In 2002 and 2003, the West Wisconsin Land Trust (WWLT) purchased two agricultural properties (220 acres) that encompass the majority of the Pine Creek Fishery Area, thus conserving these properties forever. With much of the stream corridor in WWLT ownership and open to the public, WWLT, three Trout Unlimited (TU) chapters, and WDNR began planning a stream restoration project in 2006. The goal of the Pine Creek Restoration Project was to enhance and conserve the native brook trout population in Pine Creek by stabilizing severely eroding banks, providing in-stream cover, and improving aquatic habitat in the stream. Measurable project objectives included:

1. Improve the stream temperature regime and armor the stream for climate change.
2. Reduce stream bank erosion to 10% of pre-existing conditions.
3. Increase coarse stream bottom substrate by 50%.
4. Increase aquatic macrophyte growth by 25%.
5. Increase numbers of brook trout by 40-50%.
6. Increase numbers of brook trout 10 inches and larger by 50-100%.

During the 2007-2011 period, 2.1 miles of Pine Creek and two major spring tributaries were restored by WDNR, in partnership with TU (Kiap-TU-Wish, Clear Waters, and Twin Cities Chapters), WWLT, Fairmount Santrol, the National Fish Habitat Action Plan (NFHAP), the U.S. Fish and Wildlife Service, the Trout and Salmon Foundation, and Patagonia (Sours 2011). The total cost of the Pine Creek Restoration Project was $270,000 ($24 per lineal foot of stream). In 2009, the success of the project was recognized by the NFHAP, which listed Pine Creek as one of 10 national "Waters to Watch".

Stream restoration is an integral part of trout stream management in Wisconsin, with the restoration work generally targeting Class I or Class II trout streams. Although stream restoration may take different forms, it generally involves the re-establishment of aquatic functions and related biological, chemical, and physical characteristics of streams that would have occurred prior to disturbance. Trout anglers fishing inland waters in Wisconsin are required to purchase a trout stamp, from which the proceeds are directed toward stream habitat restoration work. Hunt (1988) and Avery (2004) have documented a half century (1953-2000) of evaluations of trout stream habitat restoration projects in Wisconsin, and have shown how restoration has been successful at improving trout populations in terms of trout number and size (Mitro et al. 2011).

The Pine Creek Restoration Project was accomplished using techniques developed by WDNR fisheries managers across the Driftless Area (White and Brynildson 1967; Hunt 1993). Steep eroding banks were sloped back (typically at a 3:1 slope) to open the stream channel to the flood plain, thereby dissipating flood energy. As a result, stream bank erosion and sedimentation are greatly diminished, water can infiltrate in the riparian area, and water pollutants can be removed and processed. Where suitable, "LUNKER" structures were added to provide trout cover from predators and refuge during floodwaters (Vetrano 1988). These structures were covered with rock and soil and then reseeded to stabilize the stream banks. Boulder clusters and root wads were installed to enhance midstream cover. In addition, plunge pools were excavated to create deep water and over-wintering habitat. The installation of bank cover narrows the stream, which results in bottom scouring that exposes gravel substrate favorable for aquatic insects and successful trout reproduction. Bank stabilization results in a decrease in suspended sediment during runoff events, thus improving water quality in the stream. An improvement in the temperature regime of the stream may also occur, due to a narrower, deeper channel, increased current velocity, and bank shading.

With degraded cold-water streams present throughout the Driftless Area, and with global climate change posing an increasing threat to these sensitive systems (Mitro et al. 2011), stream restoration is a critical tool for enhancing and protecting aquatic ecology, and upland restoration is an effective means of improving water quality and sequestering carbon. With limited resources available, it is imperative that restoration practices produce the best long-term outcomes with the most efficient use of funding, for ecological and public benefits.

METHODS

Because of the cost and visibility of the Pine Creek Restoration Project, it was very important to document the achievement of the project objectives, as presented above. This was accomplished by measuring pre- and post-restoration temperature and habitat conditions, trout densities and size distribution, and macrophyte and macroinvertebrate community health. Evaluation of the project objectives was conducted jointly by local WDNR fisheries staff and Trout Unlimited (Kiap-TU-Wish Chapter) volunteers, via collection of pre- and post-restoration temperature, habitat, and biotic data.

Temperature, Habitat, Macrophyte, and Macroinvertebrate Monitoring:

The methods used for pre- and post-restoration monitoring of Pine Creek air and stream temperatures, habitat conditions, macrophyte presence, and macroinvertebrate communities are described in Hastings, et al. (2011) and Johnson (2017).

Trout Surveys:

Hunt (1971) has emphasized the critical need to document quantitative changes in trout populations and their environment as a result of stream restoration. At Pine Creek, WDNR fisheries staff have been conducting trout surveys at two sites within the restoration project area (Figure 2), using WDNR monitoring protocols for coldwater wadeable streams (Lyons et al. 1996; WDNR 2007). To conduct the survey work, WDNR staff use a stream barge electrofishing unit with 3 electrodes. The generator runs DC at 100-200V and 4A. The survey crew consists of the three electrode handlers/netters and a boat operator/puller. The survey station length is 35 times the mean stream width, which was calculated pre-restoration and continues to be used post-restoration. Surveys are conducted on a catch per unit effort basis, using one pass in an upstream direction. Effort time is recorded but trout numbers are generally compared by distance (number per mile). Air and water temperatures and weather conditions are also recorded on the day of the survey. Any extenuating circumstances (flooding, turbidity, excessive plant

growth, etc.) which may have an effect on the catch rate are also noted. All trout surveys are conducted between June 15 and September 15, to allow capture of young-of-year fish.

Figure 2. WDNR's Pine Creek trout survey sites

Trout surveys in the upper part of the restoration area (Station 2A) were conducted in 2000, then annually during the 2005-2017 period. Pre-restoration survey years at Station 2A include 2000 and 2005-2008. Post-restoration survey years at Station 2A include 2009-2017. The stream length surveyed at Station 2A was 200 meters. Trout surveys in the lower part of the restoration area (Station 2B) were conducted during the 2005-2010 period. Pre-restoration survey years at Station 2B include 2005-2007, while post-restoration survey years at Station 2B include 2008-2010. The stream length surveyed at Station 2B was 172 meters. Survey data included brook and brown trout numbers and lengths. Based on the stream distance surveyed at each station, numbers of brook and brown trout per mile were estimated for young-of-year fish, adult fish in multiple size categories (typically one- two-inch length increments), and all size categories combined (total trout per mile). The WDNR trout survey data were used to determine whether Project Objectives 5 and 6 were met.

RESULTS

Temperature, Habitat, Macrophyte, and Macroinvertebrate Monitoring:

The results of pre- and post-restoration monitoring of Pine Creek stream temperatures, habitat conditions, macrophyte presence, and macroinvertebrate communities are presented in Johnson (2017).

Trout Surveys:

Improvement of the native brook trout fishery was a primary focus of the Pine Creek Restoration Project, as noted in Project Objectives 5 and 6. Since WDNR Station 2A in the upper part of the restoration area

(Figure 2) has the best record of annual trout survey data, this station can be used to compare the pre- and post restoration trout populations. A caveat of the survey data at Station 2A is the assumption that this station is representative of trout abundance and size in the remainder of the restoration reach.

A comparison of the pre- and post-restoration abundance of brook trout in Pine Creek (expressed as total trout/mile) is shown in Figure 3. The pre-restoration abundance of brook trout in Pine Creek was already robust, ranging from 1,905-5,609 trout/mile and averaging 3,817 trout/mile during the five-year pre-restoration survey period. The brook trout population immediately benefited from the restoration work, with post-restoration abundance increasing dramatically to 7,787-7,964 trout/mile in 2009-2010. In subsequent years, however, brook trout abundance in Pine Creek has experienced a steep decline, reaching a minimum of 1,213 trout/mile in 2016. As of 2016, brook trout abundance has decreased by 68%, compared to mean pre-restoration abundance. Project Objective 5 targeted a 40-50% increase in brook trout numbers.

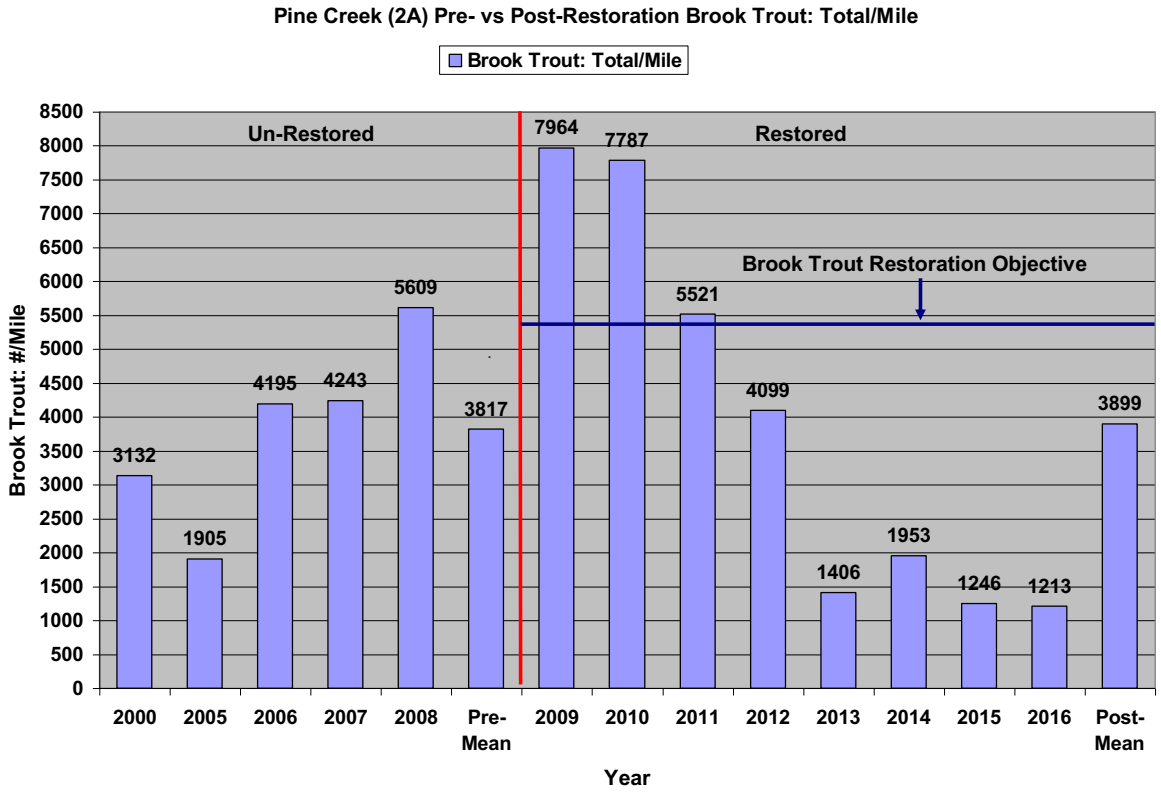

Figure 3. Pre- and post-restoration abundance of brook trout in Pine Creek

A comparison of the pre- and post-restoration abundance of 10-inch plus brook trout in Pine Creek (Figure 4) shows a similar trend. Annual pre-restoration abundance of these larger brook trout varied widely, ranging from 0-72 trout/mile and averaging 31 trout/mile during the five-year pre-restoration survey period. After a rapid post-restoration increase that peaked at 104 trout/mile in 2011, the abundance of 10-inch plus brook trout has declined dramatically, reaching a minimum of 0 trout/mile in 2015. As of 2016, the abundance of 10-inch plus brook trout in Pine Creek has decreased by 74%, compared to mean pre-restoration abundance. Project Objective 6 targeted a 50-100% increase in 10-inch plus brook trout numbers.

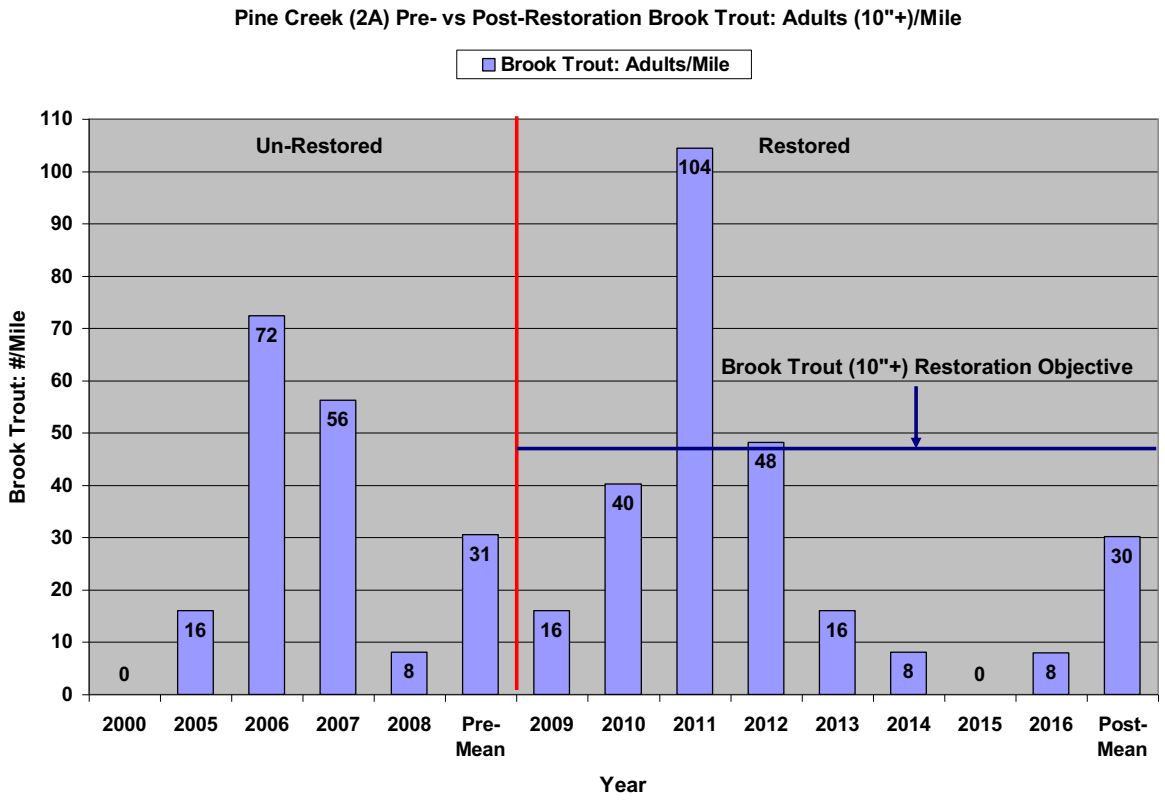

Figure 4. Pre- and post-restoration abundance of 10-inch plus brook trout in Pine Creek

While the post-restoration abundance of brook trout in Pine Creek has been rapidly decreasing, the post-restoration abundance of brown trout has increased markedly (Figure 5). Small numbers of brown trout were present in annual pre-restoration surveys at Station 2A, but the brown trout proportion of total trout abundance never exceeded 7%, with the stream dominated by brook trout. The post-restoration abundance of brown trout in 2009-2010 remained similar to the pre-restoration abundance. However, a steep increase in brown trout abundance began in 2011, with the greatest increase occurring between 2013 and 2014. In 2016, brown trout abundance in Pine Creek reached 5,633 trout/mile, representing a 3,137% increase, compared to mean pre-restoration abundance. On average, pre-restoration trout abundance in Pine Creek was 3,991 trout/mile, with brook and brown trout present in a 96%:4% proportion. In comparison, post-restoration trout abundance has averaged 6,299 trout/mile, with brook and brown trout present in a 62%:38% proportion. However, with rapidly-increasing numbers of brown trout in Pine Creek since 2011, the proportion of brook trout has decreased to 18% in 2016.

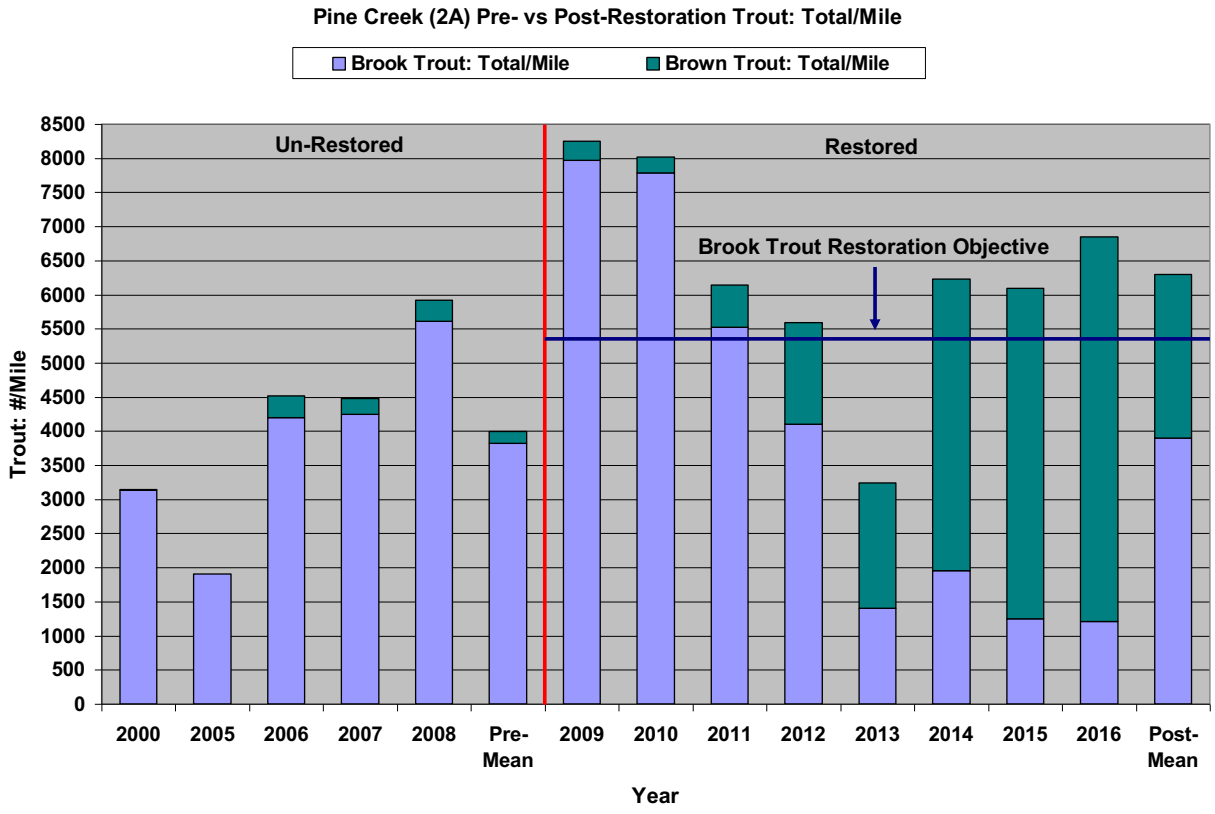

Figure 5. Pre- and post-restoration abundance of brook trout and brown trout in Pine Creek

DISCUSSION

Pre- and post-restoration monitoring of stream temperature, habitat, and biota was an integral part of the Pine Creek Restoration Project, providing a wealth of information on project outcomes, including benefits, unintended consequences, and opportunities for improvement. Monitoring also enabled a determination of whether the six key project objectives were met (Johnson 2017). A discussion of project benefits for improving the Pine Creek temperature regime, greatly reducing erosion potential, and re-connecting the stream to the floodplain can also be found in Johnson (2017).

Changes in Trout Dynamics:

The main impetus for the Pine Creek Restoration Project and the primary project goal was to enhance and conserve the native brook trout population in Pine Creek. However, within five years post-restoration, Pine Creek had become dominated by brown trout (Figure 5), a significant unanticipated consequence of the restoration project. By 2013, brook trout abundance in Pine Creek was lower than that during any of the five pre-restoration years surveyed, and abundance has continued to decline through 2016. This outcome represents a dramatic reversal of brook trout presence in Pine Creek, falling far short of Project Objective 5, a 40-50% increase in brook trout numbers.

Brown trout were already present in Pine Creek before the restoration project began (Engel, personal communication, 2017). However, brown trout abundance was very low, ranging from 233-321 trout/mile during the pre-restoration period of 2006-2008 (Figure 5). In comparison, brook trout abundance ranged

from 4,195-5,609 trout/mile during the same period, with brook trout comprising 94% of the Pine Creek trout population.

Although the pre-restoration abundance of brown trout in Pine Creek was very low (6%), WDNR was concerned about their presence in a Class I, naturally-reproducing brook trout stream. As a result, WDNR trout survey crews attempted to purge Pine Creek of brown trout via electrofishing and removal in 2007 and 2008. However, trout surveys in 2009 and 2010 (Figure 5) showed that this effort was unsuccessful, and brown trout removal was no longer a viable management option as post-restoration brown trout abundance increased rapidly (Engel, personal communication, 2017).

The Pine Creek Restoration Project resulted in a major expansion of the Pine Creek trout population, with mean post-restoration trout abundance (6,299 trout/mile) representing a 58% increase over mean pre-restoration trout abundance (3,991 trout/mile) (Figure 5). Brook trout experienced an immediate but short-lived benefit of the restoration project, with abundance peaking at 7,787-7,964 trout/mile in 2009-2010. Since 2011, however, brown trout abundance has increased rapidly at the expense of brook trout abundance, which reached a low point in 2016 (1,213 trout/mile and 18% of the total trout population). Although the mean post-restoration abundance of brook trout in Pine Creek has increased by 2%, compared to mean pre-restoration abundance, brook trout abundance had decreased by 68% as of 2016. Hence, the 58% increase in mean post-restoration trout abundance is due to the substantial expansion of brown trout presence in Pine Creek.

Engel (personal communication, 2017) notes that the post-restoration success of brown trout in Pine Creek may be due in part to their ability to out-compete brook trout for occupation of the best available habitat, which the restoration project created via installation of LUNKER structures, boulder clusters, and root wads. Fausch and White (1981) note that brown trout exclude brook trout from preferred resting positions, a critical and scarce resource. The combined effects of such interspecific competition, an increased susceptibility of brook trout to angling, differential response to environmental factors, and brown trout predation on juvenile brook trout may account for declines of brook trout populations while brown trout populations expand in many streams where the two species co-exist. Hitt et al. (2017) note that the distribution of native brook trout in eastern North America is often limited by brown trout, in part via interference competition for access to thermal refugia and forage habitats.

The post-restoration increase in overhead cover and shade provided by LUNKER structures and root wads may also favor the presence of brown trout in Pine Creek. Cover is recognized as one of the basic and essential components of trout streams, as noted by Boussu (1954), Lewis (1969), and Raleigh (1982). In a study to determine the amount of shade utilized by brook, rainbow, and brown trout, Butler and Hawthorne (1968) reported that rainbow trout showed the lowest preference for shade produced by artificial surface cover. Brown trout showed the highest use of shade, while brook trout were intermediate between brown and rainbow trout.

Engel (personal communication, 2017) believes that habitat restoration in brook trout streams will result in improved brook trout populations and size structure. However, if brown trout have access to these streams, brown trout will prevail but not totally eliminate brook trout. The dramatic post-restoration change in Pine Creek trout dynamics suggests that trout stream restoration in the Driftless Area should not be a “one size fits all” exercise. An exceptionally cold temperature regime in Pine Creek did not provide a competitive advantage for brook trout, and brown trout removal was unsuccessful, even when abundance was low.

Resource managers hoping to protect and enhance native brook trout streams, especially those vulnerable to brown trout co-habitation, should consider an adaptive management approach that creates habitat favorable for brook trout. This consideration will become even more critical as climate change creates

stream temperature regimes that are more suitable for brown trout, at the expense of brook trout (Mitro et al. 2011; Cunningham, et al. 2014).

ACKNOWLEDGMENTS

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