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STATUS ASSESSMENT OF COASTAL AND ANADROMOUS BROOK TROUT IN THE UNITED STATES

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Abstract—Brook Trout *Salvelinus fontinalis* in New England coastal streams can exhibit partial anadromy, but the status of Brook Trout and anadromous behavior is unknown for much of the region. We conducted a sub-watershed-scale (~12,000 ha) assessment of coastal and anadromous Brook Trout from Maine to Long Island, New York using data from regional fisheries professionals. Across 185 sub-watersheds, the status of coastal Brook Trout, and the presence of anadromous behavior, is highly variable and uncertain across New England. Brook Trout are thought to be extirpated from 40 sub-watersheds (22%), and the status is unknown in 39 (21%) sub-watersheds. There was low certainty regarding current status in 78 (42%) sub-watersheds, with a majority occurring in Maine. The status of Brook Trout was known with moderate-high certainty in at least some sub-watersheds in all states. The certainty of anadromy was low for 142 (77%) sub-watersheds, and was high for only two sub-watersheds in Massachusetts and four in Maine. This assessment can be used with other local information to initiate a regional anadromous Brook Trout conservation program focused on habitat protection and restoration, and for reducing the uncertainty of the status of coastal and anadromous Brook Trout through further targeted assessments.

INTRODUCTION

The Brook Trout *Salvelinus fontinalis* is a charr native to northeastern North America (Benke 2002). Brook Trout in small streams often have small home ranges, but some populations occupying interconnected habitats can exhibit seasonal movements into larger rivers (Petty et al. 2012). Brook Trout with access to lacustrine habitats can be adfluvial whereby individuals in ponds or lakes migrate into tributaries to spawn; those in Lake Superior that are adfluvial or completely lacustrine are commonly referred to as coaster Brook Trout (Schreiner et al. 2008). Populations with access to sea can exhibit partial (i.e., facultative) anadromy whereby some individuals, often called salters or sea-run Brook Trout, migrate to estuaries (or open ocean) to feed during various times of the year (Ryther 1997).

Anadromy in Brook Trout arises due to the species' propensity to move, over-production of juveniles, a physiological ability to tolerate saline environments, and the persistence of critical habitats (Curry et al. 2010). Individuals with lower food conversion efficiencies are more likely to exhibit anadromy, because prey are larger and more diverse

in saltwater environments (Morinville and Rasmussen 2003; Morinville and Rasmussen 2006), which can lead to higher growth rates (Thériault et al. 2007a). Larger Brook Trout are physiologically more tolerable of saline environments (McCormick and Naiman 1984), and of Brook Trout exhibiting anadromy, faster growing individuals typically migrate first (Morinville and Rasmussen 2003).

Vague historical accounts suggest that anadromous Brook Trout could be found in any suitable habitat to which they could return after spending a few months in salt water. This included streams as far north as Labrador's Atlantic coast and as far south as the Manasquan River, New Jersey (Karas 2002). While there are some historical accounts of specific Brook Trout populations exhibiting anadromy (Smith and Saunders 1958), little is known about historical anadromy for many watersheds within that general historical distribution. Likewise, some extant populations are known to be anadromous (Thériault et al. 2007b), but little information exists for Brook Trout in many watersheds with virtually no information on anadromous behavior.

Despite this uncertainty, anadromous Brook Trout are thought to have declined substantially due to the same factors impacting inland populations: land use, habitat deterioration and fragmentation, and nonnative species interactions (Ryther 1997; Hudy et al. 2008; Stranko et al. 2008). Given the need to move between fresh and salt water, the construction of dams and other impassable structures likely had a disproportionate impact on anadromous Brook Trout. For example, in Maine the access to riverine habitat by river herring (*Alosa pseudoharengus* and *Alosa aestivalis*) is only 20% of historical levels because of dams (Hall et al. 2011), many of which were built on coastal streams also used by anadromous Brook Trout. Competition with and predation by nonnative fishes have also been cited as reasons for declines (Ryther 1997). Last, because anadromous Brook Trout grow large from feeding in marine environs, they have been harvested for both subsistence and sport since European colonization (Smith 1833).

Our goal was to conduct a status assessment of coastal Brook Trout in the United States from Maine to New York at the sub-watershed-scale (~12,000 ha). Based on the status of Brook Trout populations, and the presence of anadromy, we identified opportunities to protect extant Brook Trout populations exhibiting anadromy, identified where anadromous Brook Trout may be restored, and identified additional assessment needs where Brook Trout information was sparse.

METHODS

The status of coastal Brook Trout populations was assessed through data compilation (with a data review) by regional fisheries professionals (see Acknowledgements). Professionals were asked to

identify each coastal stream and river that currently has Brook Trout or was thought to have had Brook Trout historically and attribute it with information on: (1) the current status of Brook Trout, (2) the certainty associated with current status, and (3) the certainty of current anadromy. Current status was classified as Abundant, Frequently Present, Occasionally Present, Extirpated, or Unknown. Certainty of current status was classified as High, High-Moderate, Moderate, Moderate-Low, Low, and Unknown based on the type of data used to classify status (e.g., electrofishing survey, creel survey, angler logs, and anecdotal angler reports). Certainty of anadromy was classified as High, High-Moderate, Moderate, Moderate-Low, Low, and Unknown based on the quality of data used to determine the presence of anadromy (e.g., otolith microchemistry, telemetry, angler reports). The sub-watersheds in the Watershed Boundary Dataset (12-digit Hydrologic Unit Code or HUC 12; www.nrcs.usda.gov) were then attributed accordingly with information on the current status, certainty of current status, and certainty of anadromy using the highest status or certainty level within each sub-watershed.

Next, we identified conservation and assessment strategies for each sub-watershed. The strategies were designed to mirror those defined by the Eastern Brook Trout Joint Venture (www.easternbrooktrout.org), while considering the unique aspects of anadromous Brook Trout. To define strategies, we used information on the current status of Brook Trout, certainty of anadromy, and habitat integrity (from Trout Unlimited's Conservation Success Index; Williams et al. 2007) to identify Protect, Reconnect, Restore, Reintroduce, and Assessment (Anadromous, Population, and General) strategies at the sub-watershed scale (Figure 1; Table 1).

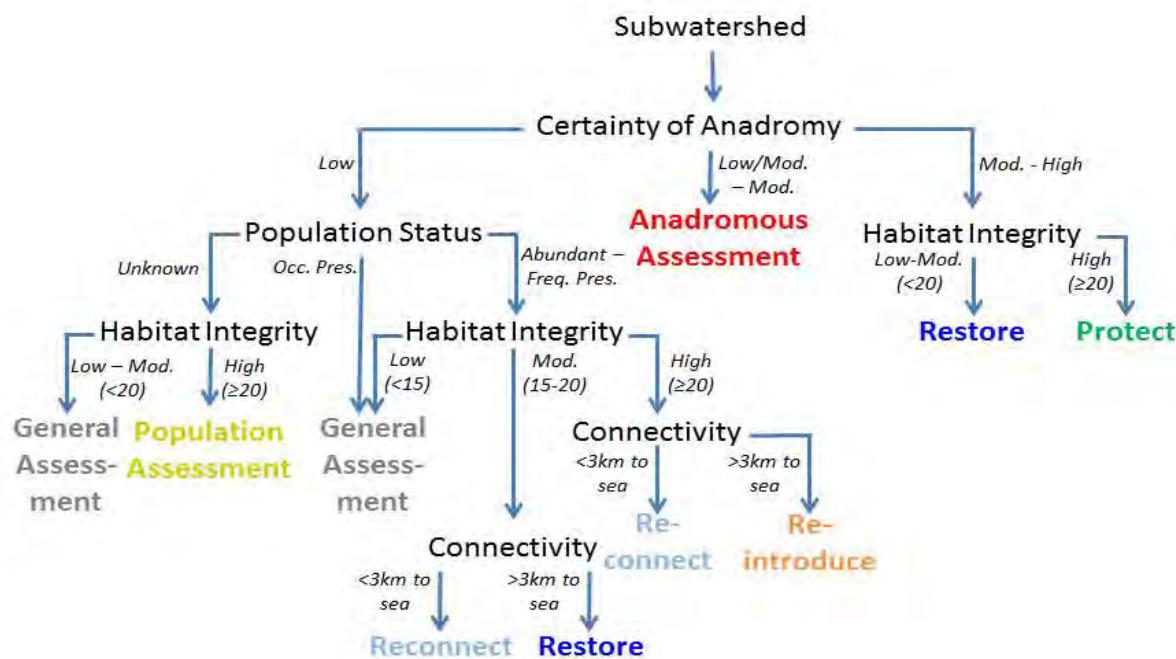


Figure 1. Flow chart used to identify general sub-watershed conservation and assessment strategies for coastal and anadromous brook trout in New England.

Table 1. Conservation and assessment strategies for coastal and anadromous brook trout in New England.

Strategy	Description
Protect	A protect strategy was defined for sub-watersheds with a moderate to high level of certainty of having anadromous Brook Trout that also has high habitat integrity indicating watershed conditions are intact.
Reconnect	A reconnect strategy was defined for sub-watersheds with a low certainty of having anadromous Brook Trout but where Brook Trout are frequently present or abundant, habitat integrity is moderate to high, and the amount of habitat connected to the sea is less than 3-km below the downstream-most dam (if present).
Restore	A restore strategy was defined for sub-watersheds with a moderate-high or high level of certainty of having anadromous Brook Trout and where habitat integrity was low to moderate-high, suggesting that some restoration could be needed to ensure the long-term persistence of anadromous Brook Trout. A restore strategy was also defined where the certainty of anadromy is low but Brook Trout are frequently present or abundant, habitat integrity is moderate-high, and connectivity to the sea was greater than 3-km.
Reintroduce	A reintroduce strategy was defined for sub-watersheds where there was low certainty regarding the presence of anadromy but where Brook Trout are frequently present or abundant and habitat integrity is high.
Anadromous assessment	In sub-watersheds where there is only a moderate level of certainty regarding the presence of anadromy, the streams in these sub-watersheds should be further assessed to confirm the presence of anadromous Brook Trout before a sub-watershed-specific conservation strategy can be identified.
Population assessment	In sub-watersheds where the current status of Brook Trout is unknown but habitat integrity is high, these sub-watersheds should be inventoried to determine both the status of Brook Trout and the presence of anadromy.
General assessment	Sub-watersheds with unknown Brook Trout status and moderate to low habitat integrity, with Brook Trout only occasionally present, or with Brook Trout present but poor habitat integrity, were defined as needing general overall assessment.

RESULTS

Current or historical coastal Brook Trout streams were identified in 185 sub-watersheds from Maine to Long Island, New York. Ninety-four sub-watersheds were in Maine where the current status of Brook Trout was highly variable (and highly uncertain), whereas only five sub-watersheds were in Rhode Island (Table 2; Figure 2, top left panel). Brook Trout are thought to be extirpated from 40 sub-watersheds (22%), and

the status is unknown in 39 (21%) sub-watersheds. There was low certainty of current status in the majority of sub-watersheds (78 or 42%), and only one sub-watershed in New York state had a current status that was highly certain. The largest uncertainty in status was in Maine (Figure 2, top middle panel). Even more uncertain was the status of anadromy. The certainty regarding anadromy was low for 142 (77%) sub-watersheds and was unknown for 13 (7%) sub-watersheds. Only six sub-watersheds contained

Table 2. Number of sub-watersheds by current status, certainty of current status, certainty of anadromy, conservation strategy, and assessment strategy by state.

		State							
		Status	CT	MA	ME	NH	NY	RI	Total
Current population status	Abundant	0	3	3	0	2	0	0	8
	Freq. present	0	7	24	4	1	0	0	36
	Present	0	0	0	0	0	0	0	0
	Occ. present	5	12	40	0	3	2	62	
	Extirpated	27	10	1	1	1	0	0	40
	Unknown	0	2	26	3	5	3	39	
Current status certainty	High	0	0	0	0	1	0	0	1
	High-Mod.	20	20	10	5	5	3	63	
	Moderate	12	4	6	0	4	2	28	
	Mod.-Low	0	3	11	0	1	0	15	
	Low	0	7	64	1	0	0	72	
	Unknown	0	0	3	2	1	0	6	
Anadromous certainty	High	0	2	4	0	0	0	0	6
	High-Mod.	0	0	0	0	0	0	0	0
	Moderate	0	5	10	0	2	0	17	
	Mod.-Low	3	0	0	0	2	2	7	
	Low	29	27	77	6	3	0	142	
	Unknown	0	0	3	2	5	3	13	
Conservation strategy	Protect	0	0	3	0	0	0	0	3
	Reconnect	0	0	1	0	0	0	0	1
	Restore	0	4	4	1	0	0	0	9
	Reintroduce	0	0	6	0	0	0	0	6
Assessment strategy	Population	0	0	12	0	0	0	0	12
	Anadromous	3	5	10	0	2	4	4	24
	General	29	25	58	7	10	1	130	
Total sub-watersheds		32	34	94	8	12	5	185	

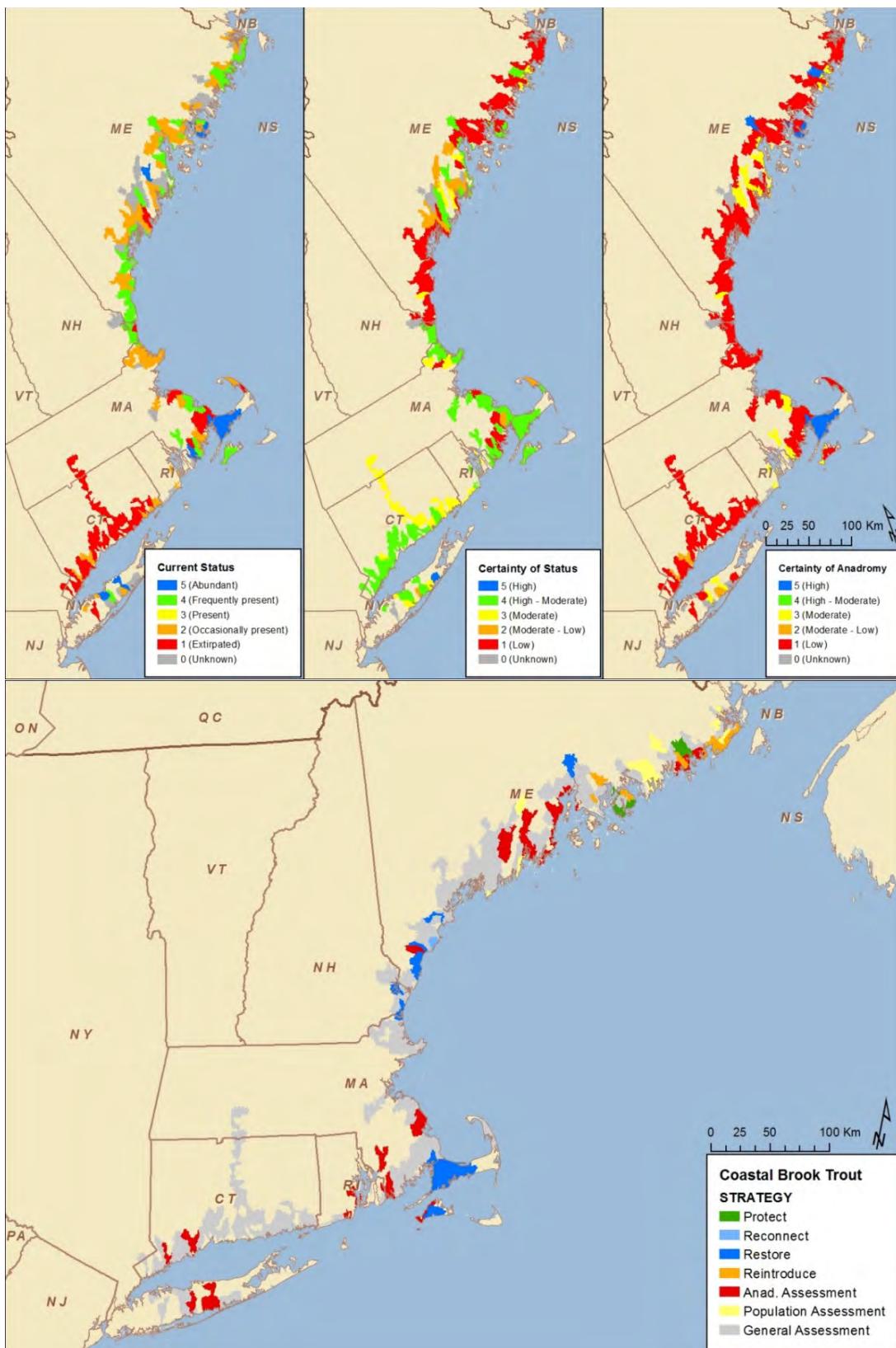


Figure 2. Coastal Brook Trout current status, certainty of current status, certainty of anadromy, and conservation and assessment strategies for coastal streams of New England.

anadromous Brook Trout with a high level of certainty – two in Massachusetts and four in Maine (Figure 2, top right panel). New Hampshire was the only state where the certainty regarding anadromy was low for all sub-watersheds.

Conservation strategies were identified for 19 sub-watersheds in New England, with Restore being the most commonly identified strategy (9 sub-watersheds) and Reintroduce being the next most common strategy (6 sub-watersheds; Table 2). The only protection strategies identified were for sub-watersheds in Maine, including those that already have some level protection (e.g., Acadia National Park; Figure 2 bottom panel). There are many sub-watersheds with further assessment needs based on the uncertainty regarding Brook Trout status and anadromy (Table 2; Figure 2, bottom panel).

DISCUSSION

This assessment represents the first attempt to document the extent of coastal and anadromous Brook Trout at a sub-watershed scale (~12,000 ha) in the United States. The status of coastal Brook Trout in New England streams has declined since pre-colonial times (Ryther 1997), but our assessment data showed there is still a large amount of uncertainty regarding even the current status of populations; over two-thirds of all streams had little or no information on Brook Trout. Likewise, the status of an anadromous life history is thought to have declined faster than resident populations (Ryther 1997), but there is even more uncertainty surrounding the status of anadromy. Clearly there is a need to assess many coastal streams for extant populations and whether they exhibit anadromy. However, identifying anadromy at a regional scale will be difficult and costly unless new, cost efficient techniques are developed.

Despite the uncertainty in status, the conservation strategies we identified can offer some guidance to where watershed protection and restoration efforts could be focused. The strategies identified here focus on protecting abundant Brook Trout, Brook Trout populations exhibiting anadromy, and watersheds with intact habitat – strategies similar to those defined by the Eastern Brook Trout Joint Venture for inland populations. The strategies with the most uncertainty surrounding them are those where Brook Trout are abundant and habitat restoration or reconnection could result in the re-emergence of anadromy. However,

it is not clear if and when anadromy will emerge in populations, as efforts in this area have just begun with the first successful anadromous Brook Trout reintroduction in the Childs River, Massachusetts (Hurley 2011). Genetics data suggest that Brook Trout do not move between systems very often, except between tributaries with a common estuary (Annett et al. 2012). This suggests that re-emergence of anadromy from colonizers or strays from neighboring systems post restoration (or reconnection) is not likely without nearby source populations. While not prescriptive, these strategies are intended to suggest how different assessment information can be parsed to identify the general strategies needed in a particular sub-watershed, and this assessment information represents a starting point – to be used with local data and in coordination with local partners - to develop regional conservation strategies for anadromous Brook Trout (Hudy et al. 2008).

As an example, the Red Brook sub-watershed (Cape Cod, Massachusetts) has a Brook Trout population that is abundant, with a high certainty of anadromous behavior, because of ongoing research and monitoring associated with restoration projects (Snook et al. 2012). The conservation strategy identified for the sub-watershed was Restore because while the Brook Trout are abundant and exhibiting anadromous behavior, there are threats on the landscape to instream habitat and habitat restoration is needed to ensure long-term persistence. In fact, there have been ongoing restoration and land protection efforts in Red Brook for 25 years. This multi-faceted project has focused largely on habitat restoration (e.g., fish passage and cranberry bog restoration), but has also included land protection measures (e.g., establishment of the Red Brook Wildlife Management Area) and research. Other projects focused on restoration of anadromous Brook Trout are occurring throughout New England, ranging from fish passage projects near Acadia National Park in Maine, to restoration projects on two famous Brook Trout rivers on Long Island, New York – the Carmans and Connetquot rivers.

The Native Fish Conservation Area (NFCA) concept has application to the conservation of anadromous Brook Trout in New England. The concept focuses on cooperative management and restoration of watersheds for long-term persistence of native aquatic communities (Williams et al. 2011). Brook Trout are an indicator of watershed health

(Stranko et al. 2008), and managing entire watersheds for anadromous Brook Trout is likely to benefit other native species, especially diadromous fishes. Existing protected areas such as Acadia National Park, Cape Cod National Seashore, and Waquoit Bay National Estuarine Research Reserve already exist to anchor watersheds as NFCAs, including some currently inhabited by anadromous Brook Trout. Other watersheds may need to be cooperatively managed across complex patchworks of public and private lands, and the NFCA concept provides a framework for cooperative watershed management in these complex environs. Anadromous Brook Trout still persist in New England despite four centuries of anthropogenic development. This suggests that a strategic conservation program, potentially using the NFCA concept as a guiding framework and Red Brook as a model watershed, could enhance anadromous Brook Trout conservation across New England.

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