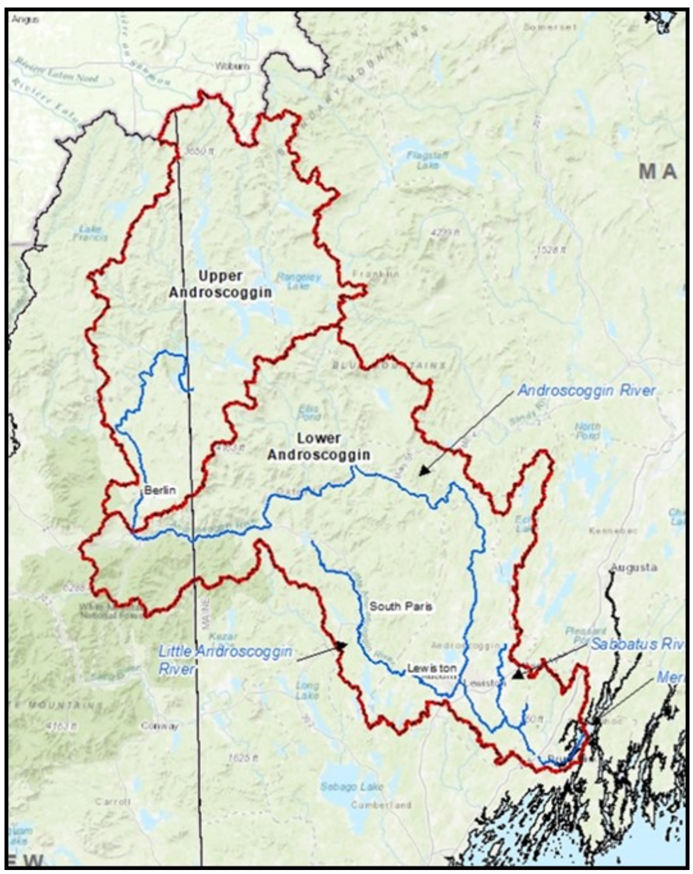
Greater Atlantic Region Policy Series
[20-01]

Androscoggin River Watershed Comprehensive Plan for Diadromous Fishes



NOAA Fisheries
Greater Atlantic Regional Fisheries Office

ABSTRACT

In the next ten years, multiple hydropower projects in the lower Androscoggin River watershed will begin relicensing; several have already started. Licensing actions present a rare opportunity to develop a comprehensive watershed plan prioritizing diadromous fish restoration and conservation efforts. A comprehensive plan outlines a framework that balances restoration of diadromous fishes, the interests of diverse stakeholders, and the need for sustainable energy production. Additionally, Section 10(A) of the Federal Power Act requires consideration of non-power generation uses of a waterway, such that a new or successive license shall, "…be best adapted to a *comprehensive plan* for improving or developing a waterway or waterways…" This includes the protection, mitigation, and enhancement of fish, wildlife, and habitat. The *Androscoggin River Watershed* ***Comprehensive Plan for Diadromous Fishes*** (Androscoggin CP) builds off existing management actions in the *Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar)* and *Draft Androscoggin Fisheries Management Plan* to provide synergistic restoration benefits. The geographic scope of the Androscoggin CP is the Androscoggin River watershed with a restoration focus downstream from Lewiston Falls, the Little Androscoggin River, the Sabattus River, and the Little River. These areas align with critical habitat for Atlantic salmon and represent a practical portion of the historical diadromous fish habitat on which we intend to focus our efforts. The vision for the Androscoggin CP is to support development of terms and conditions in the hydropower licensing process, foster coordination among agencies and stakeholders, and support a collaborative restoration approach.

KEYWORDS

Androscoggin River, energy, fisheries management, hydropower, restoration, watershed planning

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LIST OF ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius
ASMFC	Atlantic States Marine Fisheries Commission
CEG	Crucial Economics Group
CP	Comprehensive Plan
DEEP	Department of Energy and Environmental Protection
DPS	Distinct Population Segment
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
EwE	Ecopath with Ecosim
FERC	Federal Energy Regulatory Commission
FMP	Fishery Management Plan
FR	Federal Register
FRP	Final Recovery Plan
GIS	Geographic information system
GOM	Gulf of Maine
HUC10	10-Digit hydrologic unit code
HUC12	12-Digit hydrologic unit code
ISPP	Interim Species Protection Plan
kW	Kilowatt(s)
MDIFW	Maine Department of Inland Fisheries and Wildlife
MDMR	Maine Department of Marine Resources
MW	Megawatt(s)
MWh	Megawatt hour(s)
NAACC	North Atlantic Aquatic Connectivity Collaborative
NHD-Plus	National Hydrography Dataset Plus
NOAA Fisheries	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PRD	Protected Resources Division
ROR	Run-of-river
SHRU	Salmon Habitat Recovery Unit
SSB	Spawning stock biomass
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

1. NEED FOR A PLAN

Several factors support the need for a Comprehensive Plan (CP) for the Androscoggin River Watershed that focuses and prioritizes diadromous fish conservation efforts in the watershed, including:

1. The lack of aquatic connectivity in the Androscoggin River and impaired water quality currently contribute to the reduced range of diadromous species and low quality of available habitat. Energy companies, non-governmental organizations, state and federal agencies have made progress addressing these two issues in the last 40 years. Additional efforts with greater focus are needed to re-establish connectivity and improve habitat conditions in portions of the Androscoggin River.
2. Licenses on many hydroelectric facilities within the Androscoggin Watershed will expire within the next decade. This presents an opportunity to prioritize restoration activities based on agency goals and emerging opportunities and compile those actions in a plan for reference during licensing proceedings. Such a plan would support any post-licensing amendments or settlement agreements with specific hydroelectric facilities.
3. A comprehensive plan can facilitate coordination with other current management plans; provides guidance for developing future habitat projects and barrier removal projects; promotes effective coordination among state and federal agencies and stakeholders; and examines how the larger goals for the Androscoggin River Watershed will promote the overall public interest.

2. INTRODUCTION

The Androscoggin River flows from the White Mountains in New Hampshire and the Blue Mountains in Western Maine to Merrymeeting Bay in the Gulf of Maine (GOM) (Figure 1). Historically, a diverse array of Atlantic coast diadromous species occupied the river. Those species include, in phylogenetic order: sea lamprey (*Petromyzon marinus*), shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser oxyrhynchus oxyrhynchus*), American eel (*Anguilla rostrata*), blueback herring (*Alosa. aestivalis*), alewife (*A. pseudoharengus*), American shad (*A. sapidissima*), rainbow smelt (*Osmerus mordax*), Atlantic salmon (*Salmo salar*), striped bass (*Morone saxatilis*), and Atlantic tomcod (*Microgadus tomcod*) (Atkins 1887).

2.1 PURPOSE OF THE COMPREHENSIVE PLAN

The purpose of the CP is to establish a framework that balances the restoration of diadromous fishes and the need for sustainable energy production, while defining goals to protect, conserve, and enhance Androscoggin River habitat and resources.

This CP supports our agency's mission and the State of Maine's fish management efforts. NOAA issued a final Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (USFWS and NMFS 2018), and the state has a Draft Androscoggin Fisheries Management Plan. Actions identified in this CP build off management actions in these plans to provide synergistic restoration benefits. We will consult with our state and federal resource agency partners to determine the most effective strategy for managing trust resources to achieve restoration goals.

2.2 SCOPE OF THE COMPREHENSIVE PLAN

This CP evaluates seven diadromous species that have both historical and current presence in the Androscoggin River Watershed:

- American shad
- Blueback herring
- Alewife
- Atlantic salmon
- American eel
- Sea lamprey
- Striped bass

This list of target species was determined based on NOAA Fisheries' goals and objectives, along with the recommendations from the state of Maine's Draft Fisheries Management Plan (MDMR and MDIFW 2017). Atlantic and shortnose sturgeon are in the Androscoggin watershed below the Brunswick Dam; however, goals for their restoration does not include habitat above the Brunswick Dam. Therefore, they are not a target species for this plan. The geographic scope of this comprehensive plan is the Androscoggin River Watershed with a restoration focus on the Androscoggin River downstream from Lewiston Falls, the Little Androscoggin River, the Sabattus River, and the Little River (Figure 2). These areas align with critical habitat for Atlantic salmon and represent a practical portion of the historical habitat for anadromous species to focus restoration efforts. Background information on drainage characteristics and land use (Section 3), and the inland fishery resource (Section 7) are provided for the entirety of the Androscoggin River Watershed. The timeline for this CP encompasses present day through 2030. NOAA Fisheries will update the CP as new information arises or management goals change.

2.3 ROLE OF NOAA FISHERIES

The restoration goals for the Androscoggin River Watershed are to provide access to historical spawning, rearing, and migration habitats necessary for diadromous species to complete their life cycles and to make accessible seasonal habitats necessary to support the enhancement of the stocks. The restoration focus includes habitat downstream from Lewiston Falls, the Little Androscoggin River, the Sabattus River, and the Little River. Structural and operational modifications to barriers and hydroelectric facilities to ensure safe, timely, and effective passage of migrating adult and juvenile fish, including passage necessary for dispersal and seasonal movement, will facilitate this goal.

NOAA Fisheries is responsible for the stewardship of the nation's ocean resources and their habitat. NOAA Fisheries provides vital services for the nation, including productive and sustainable fisheries, safe sources of seafood, the recovery and conservation of protected resources, and healthy ecosystems –all backed by sound science and an ecosystem-based approach to management. U.S. fisheries are among the world's largest and most sustainable. Seafood, harvested from U.S. federally managed fisheries, is inherently sustainable because of the U.S. fishery management process. Using the Magnuson-Stevens Act as the guide, NOAA Fisheries works in partnership with Regional Fishery Management Councils to assess and predict the status of fish stocks, set catch limits, ensure compliance with fisheries regulations, reduce bycatch, and designate essential fish habitat.

The resilience of our marine ecosystems and coastal communities depend on healthy marine species including diadromous species. Under the Federal Power Act, the Fish and Wildlife Coordination Act, Magnuson-Stevens Fishery Conservation and Management Act, the Endangered Species Act, Marine Mammal Protection Act and National Environmental Policy Act, NOAA Fisheries works to conserve and restore public trust resources, and recover protected marine species, while promoting economic and recreational opportunities.

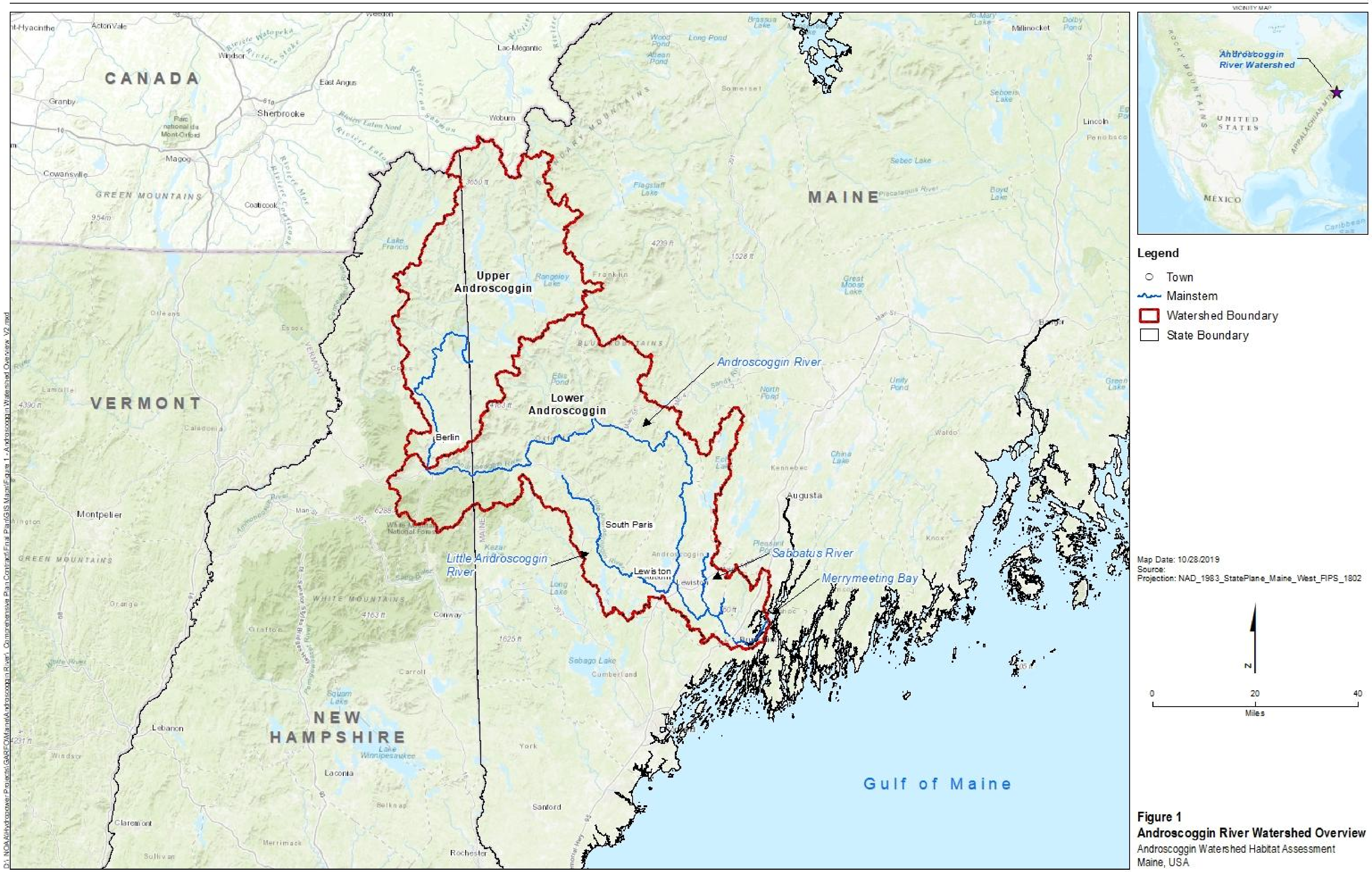


Figure 1
Androscoggin River Watershed Overview
Androscoggin Watershed Habitat Assessment
Maine, USA

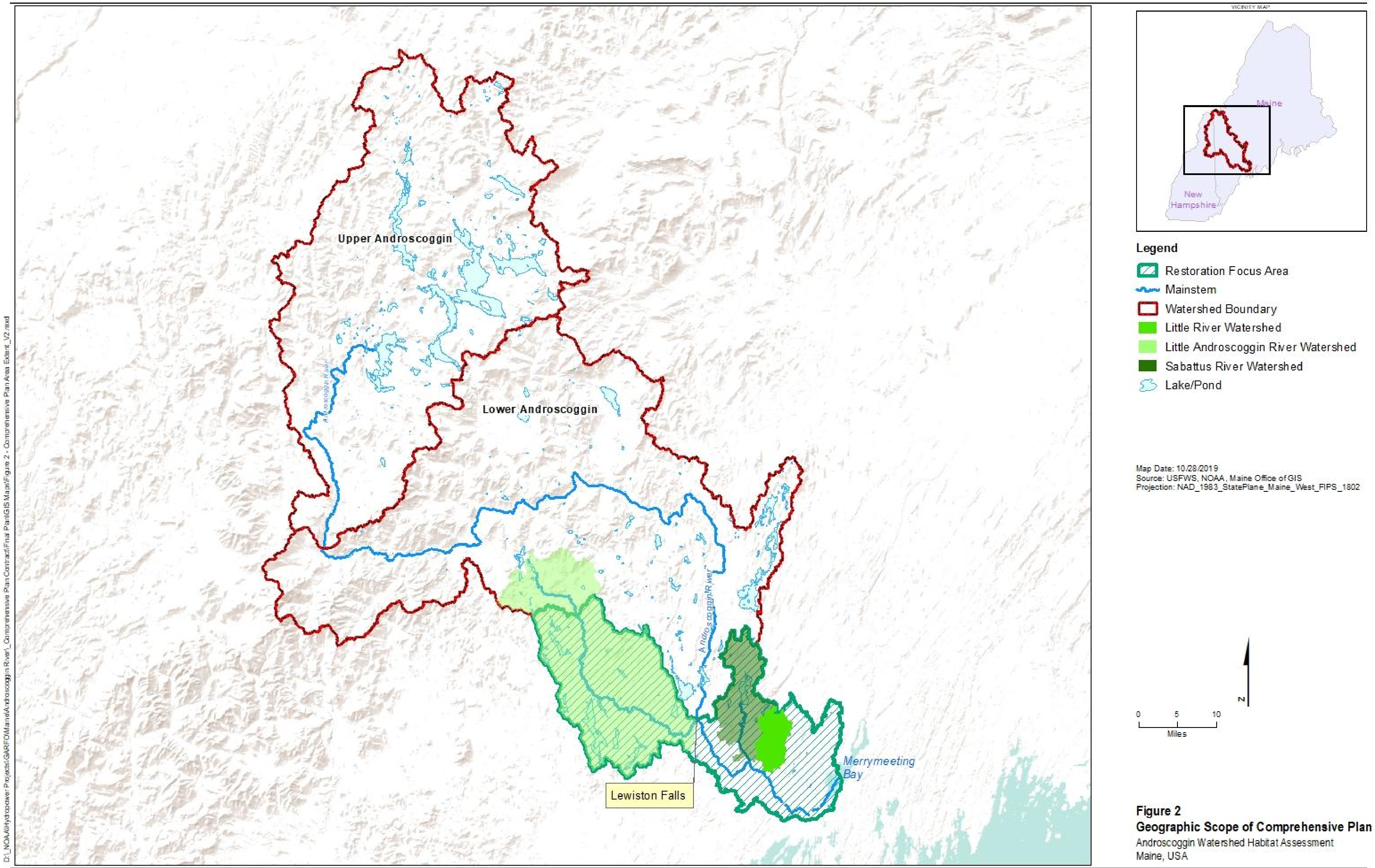


Figure 2
Geographic Scope of Comprehensive Plan
Androscoggin Watershed Habitat Assessment
Maine, USA

2.4 BACKGROUND ON DIADROMOUS FISHES IN THE ANDROSCOGGIN RIVER WATERSHED

Diadromous species, including American shad, blueback herring, alewife, Atlantic salmon, and American eel, were abundant in the Androscoggin River before dam construction began. American shad, blueback herring, and alewife are collectively referred to as alosine, which refers to their subfamily name Alosinae. With construction of a low-head dam in 1807 at the Androscoggin River head-of-tide, diadromous species began to decline. Atlantic salmon could pass over the low-head dam and continue upstream. Construction of higher dams caused the complete extinction of Atlantic salmon above tidal waters in 1844 (MDMR and MDIFW 2017). Severe water pollution virtually eliminated the remaining populations of migratory species in the tidal portion of the river. Alewife and American shad that continued to reproduce in the 6-mile stretch of river below Brunswick supported significant commercial fisheries until the 1920s. By the early 1930s, severe water pollution from upstream industries and municipalities had caused the decline of these commercial fisheries. With the passage of the 1972 Water Quality Act, subsequent improvements were made to the river's water quality in the 1970's (McFarlane 2012). These efforts combined with active fisheries management by MDMR (including an anadromous fish restoration program and stocking of species into historical habitat), have allowed for the existence of recreational fisheries for American shad and striped bass in the Androscoggin River estuary.

The present day abundance of diadromous species is a small percentage of historical abundance. However, restoration efforts during the past 40 years resulting from regulated water quality standards, installation of fish passage facilities, and dam removals on the mainstem and tributaries have resulted in an improvement in these conditions. With the passing of the Clean Water Act, water quality conditions in the Androscoggin River have improved substantially such that aquatic connectivity remains the largest obstacle to a restored diadromous fishery (MDMR and MDIFW 2017). Following installation of fish passage facilities in the 1970s and 1980s, the state of Maine began actively stocking alewife and blueback herring (collectively "river herring") into spawning habitat throughout the watershed. Annual stocking of river herring by the state continues today. While these initial efforts to restore the diadromous fishery have realized some progress, much work remains to restore each species to areas in the watershed where they were historically abundant.

3. DESCRIPTION OF THE ANDROSCOGGIN RIVER WATERSHED

The Androscoggin River is Maine's third largest river and drains 3,530 square miles. The majority (80 percent) of the drainage is located within Maine, while the remainder is in New Hampshire. The Androscoggin River runs 178 miles from the Magalloway River at Umbagog Lake to the Kennebec River at Merrymeeting Bay, which extends another 20 miles before reaching the GOM. The Androscoggin River drops more than 1,500 feet from its origin to tidewater.

3.1 RESTORATION FOCUS AREA

The Androscoggin River Watershed restoration focus area includes three major tributaries: the Little Androscoggin River, the Sabattus River, and the Little River (Table 1). Natural barriers to fish passage exist on the mainstem Androscoggin and Little Androscoggin Rivers (Figure 3), which form boundaries for addressing species-level restoration within the CP focus area. Other natural barriers may exist, which would require site-specific surveys. The following sections describe the watershed parameters for each sub-basin based on best available data.

3.1.1 Little Androscoggin River

The Little Androscoggin River flows from Bryant Pond to its confluence with the Androscoggin River in Auburn, Maine. The Little Androscoggin River Watershed encompasses 354 square miles and has a total length of 586 stream miles. Twelve lakes and ponds are located within the Little Androscoggin River drainage encompassing 16 square miles (Table 1).

3.1.2 Sabattus River

The Sabattus River flows from the Sabattus Pond to its confluence with the Androscoggin River south of Lisbon, Maine. The Sabattus River Watershed and Sabattus Pond encompasses 72 square miles. Five lakes and ponds are located within the Sabattus River drainage encompassing 3.7 square miles.

3.1.3 Little River

The Little River rises near West Bowdoin and flows south to its confluence with the Androscoggin River east of Lisbon Falls, Maine. The Little River is 7.3 miles long and the watershed encompasses 27 square miles. There are no lakes and ponds in the Little River watershed.

3.1.4 Lakes and Ponds within the Androscoggin River Watershed

Numerous lakes and ponds within the Sabattus and Little Androscoggin drainage provide abundant spawning habitat for alewife, rearing habitat for juvenile alewife and eels, and growth habitat for adult eel (Table 2). Within the Sabattus drainage, 2,168 acres of potential spawning habitat exist, while 7,357 acres are present within the Little Androscoggin drainage. Additionally, dam impoundments along the Androscoggin and Little Androscoggin rivers provide lentic habitat for diadromous fishes (Table 2).

Table 1. Androscoggin River watershed parameters

River System	Upper Androscoggin	Lower Androscoggin		
Hydrologic Units	**Androscoggin River**	**Androscoggin River**	**Little Androscoggin River**	**Sabattus River/Little River**
HUC10 Watersheds Count	6	9	1	1
ME	5	9	1	1
NH	5	2	0	0
HUC10 Watersheds (Square Miles)	1,370	1,730	354	73
ME	835	1,542	354	73
NH	536	188	0	0
Stream Miles	1,941	3,407	586	118
ME	1,086	2,942	586	118
NH	855	464	0	0
Lakes/Impounded Waters (Acres)	54,400	21,254	10,246	2,342
ME	48,474	21,158	10,246	2,342
NH	5,920	90	0	0
Estuarine Areas				
ME	0	6.7	0	0
NH	0	0	0	0

NOTES: HUC10 = 10-Digit hydrologic unit codes.
ME = Maine.
NH = New Hampshire.
HUC10 watersheds and lakes/impounded waters overlap political boundaries

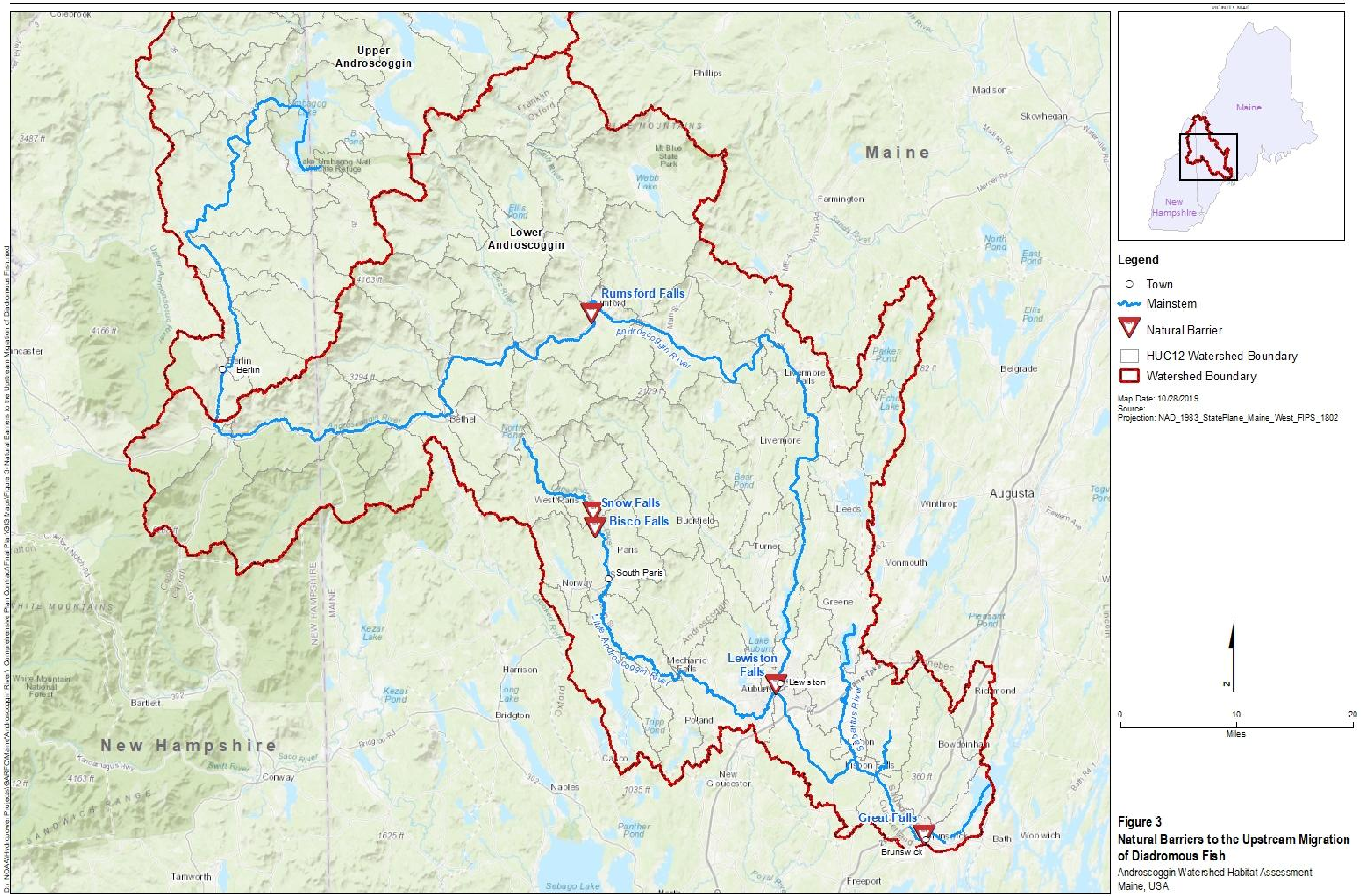


Figure 3
Natural Barriers to the Upstream Migration of Diadromous Fish
Androscoggin Watershed Habitat Assessment
Maine, USA

Table 2. Acreages of lakes and ponds within the Androscoggin River restoration focus area

Drainage/Area	Lake/Pond Surface Acres
Sabattus River	
Little Sabattus Pond	25
Sabattus Pond	1,787
Loon Pond	70
Sutherland Pond	53
No Name Pond	123
Total	**2,168**
Little Androscoggin River	
Taylor Pond	625
Marshall Pond	102
Lower Range Pond	290
Worthley Pond	42
Middle Range Pond	366
Upper Range Pond	391
Hogan Pond	177
Whitney Pond	170
Tripp Pond	768
Thompson Lake	4,426
Total	**7,357**
Impoundments	
Brunswick	313
Pejepscot	213
Worumbo	1,124
Barker's Mill	11
Barker Mill Upper	142
Hackett Mills	93
Marcal/Mechanic Falls	95
Total	**1,992**
Watershed Total	**11,517**
Source: Maine Department of Marine Resources and Marine Department of Inland Fisheries and Wildlife 2017.	

3.2 LAND USE AND DEVELOPMENT

3.2.1 Historical Land Use and Development

Native Americans, mostly from the Abenaki nation, lived near, hunted, and travelled the Androscoggin River. Native Americans established portages and a system of trails throughout the Androscoggin Watershed. The Abenaki were heavily dependent on agriculture highlighted by the largest settlement at Canton Point and fishing at the base of Lewiston and Great Falls. In the 1600s, Europeans began to enter the Lower Androscoggin Watershed through Merrymeeting Bay. The English established a commercial fishing operation at Pejepscot Falls in Brunswick where fishermen caught salmon and sturgeon by the barrels. During the 17^{th} and early 18^{th} century, the traditional way of life for the Abenaki was undergoing drastic change and many moved north to mission villages in Canada. However, after Canada went under British rule in 1763, many English settlers spread up the Androscoggin River valley and the Abenaki returned to their homeland in the Androscoggin Watershed. In the 1760s and 1770s, settlers cleared much of the land that the Abenaki originally occupied and they constructed farmsteads, houses, and mills along the Androscoggin River (BHS 2007).

The Androscoggin River initially served as an exploration route for accessing the interior portions of the watershed (MDMR and MDIFW 2017). When European colonization began in the mid-1700s, sizeable stands of white pines dominated much of the riverbank. The first sawmill was built in 1753 at the Brunswick upper dam. Dam construction in the watershed began in 1770 at Lewiston Falls. In the 1800s, industrial development on the Androscoggin River was substantial (BHS 2007). The river provided power for the lumber mills and timber companies used it for log drives to supply raw material. Primary industry included pulp and paper mills, tanneries, textile factories, and hydropower companies. These entities would cause major impacts on water quality in the 1800s through the 1900s (MDMR and MDIFW 2017).

3.2.2 Current Land Use and Development

Current land use within the Androscoggin River Watershed is predominantly forested (Table 3). Urban land, agricultural land, and wetland areas comprise a small percentage of the land within the Androscoggin River Watershed (Table 3).

Table 3. Land Use (square mile) within the Androscoggin River Watershed

River System	Upper Androscoggin	Lower Androscoggin		
Land Use Type	**Androscoggin River**	**Androscoggin River**	**Little Androscoggin River**	**Sabattus River/Little River**
% Urban Land (ME/NH)	1.1/2.1	5.7/2.3	7.9/0	12.7/0
% Agriculture (ME/NH)	0/0.3	4.6/0.4	6.9/0	13.7/0
% Barren Land (ME/NH)	1.5/2.2	1.7/6.4	0.5/0	0.1/0
% Forested (ME/NH)	82.6/87.2	77.6/89	72.7/0	54.2/0
% Scrub/shrub, grasslands, barren land (ME/NH)	0/0	0.2/0	0/0	0.1/0
% Wetland (ME/NH)	5.3/5.4	6.8/1.1	7.3/0	14.4/0
% Water (ME/NH)	9.4/2.8	3.4/0.7	4.7/0	5/0

NOTES: % = Percent.
ME = Maine.
NH = New Hampshire.

3.2.3 Hydropower in the Androscoggin Watershed

Construction of hydropower dams started in the Androscoggin River Watershed over 200 years ago. The first dam was built at Lewiston Falls in 1770 (MDMR and MDIFW 2017). Great Falls in the town of Brunswick had a series of dams constructed in the 1800s, which caused the extirpation of the diadromous fishery (MDMR and MDIFW 2017). Many hydroelectric projects in the Androscoggin Watershed are located at dams that supported industrial complexes but no longer serve that original purpose. For this reason, much of the ancillary and generation facilities are antiquated, though some project owners have upgraded their facilities over the years. No project developers have constructed new hydroelectric dams in recent history.

The 32 licensed hydroelectric projects throughout the Androscoggin River Watershed combine for a total authorized capacity of nearly 257 megawatts (MW) (Table 4). Eighteen of these projects' licenses will expire before 2030. Eight of the 32 licensed hydroelectric projects are within the restoration focus area of this CP (Figure 4). In Maine, subsidiaries of the Canadian companies Brookfield Renewable Energy Group (BREG), Ontario Power Generation, and Kruger Energy own all the projects except for a few privately owned, micro-hydro facilities. In

New Hampshire, Hull Street Energy and BREG own all but one of the ten licensed projects in the Androscoggin River Watershed.

Table 4. Licensed hydroelectric projects within the Androscoggin River watershed.

Project Name	Waterway	State	License Expiration Date	Authorized Capacity (MW)
Gulf Island-Deer Rips	Androscoggin River	ME	12/31/48	29.34
Brunswick*	Androscoggin River	ME	02/28/29	19
J. Brodie Smith	Androscoggin River	NH	07/31/24	15
Gorham	Androscoggin River	NH	07/31/24	2.15
Shelburne	Androscoggin River	NH	07/31/24	3.72
Lewiston Falls*	Androscoggin River	ME	08/31/26	28.44
Gorham	Androscoggin River	NH	07/31/24	4.8
Cross Power	Androscoggin River	NH	07/31/24	3.22
Cascade	Androscoggin River	NH	07/31/24	7.92
Rumford Falls	Androscoggin River	ME	09/30/24	44.5
Riley-Jay Livermore	Androscoggin River	ME	09/15/48	19.7
Sawmill	Androscoggin River	NH	07/31/24	3.174
Riverside	Androscoggin River	NH	12/31/33	7.9
Barker’s Mill*	Little Androscoggin River	ME	01/31/19	1.5
Pontook	Androscoggin River	NH	09/30/31	9.6
Errol	Umbagog Lake	NH	07/31/23	2.031
Worumbo*	Androscoggin River	ME	11/30/25	19.1
Barker Mill Upper*	Little Androscoggin River	ME	07/31/23	0.95
Aziscohos	Magalloway River	ME	03/31/25	5.311
Kennebago	Kennebago River	ME	exempt	0.9
Pejepscot*	Androscoggin River	ME	08/31/22	15.88
Hackett Mills*	Little Androscoggin River	ME	08/31/24	0.485
Wight Brook	Wight Brook	ME	exempt	0.03
Otis	Androscoggin River	ME	09/15/48	10.35
Stoney Brook	Stoney Brook	ME	exempt	0.035
Abbotts Mill	Concord River	ME	exempt	0.09
Upper Spears Stream	Upper Spears Stream	ME	exempt	0.065
Biscoe Falls	Little Androscoggin River	ME	exempt	0.093
Upper Androscoggin	Androscoggin River	ME	08/31/26	1.695
Marcal*	Little Androscoggin River	ME	06/30/37	1.31
Upper & Middle Dams	Rapid River	ME	11/30/52	0
Corriveau	Swift River	ME	exempt	0.35

*Projects in the CP Restoration Focus Area

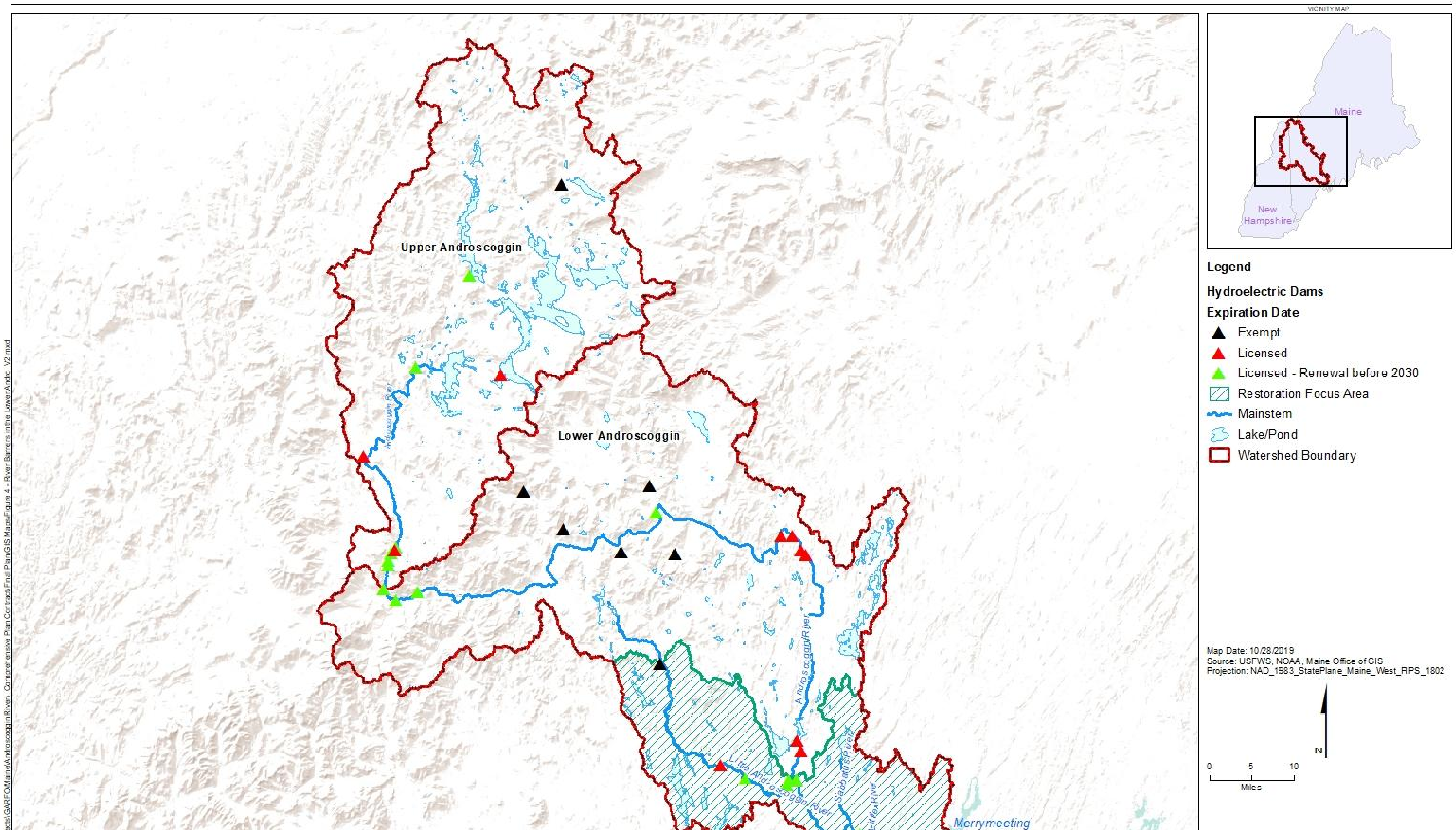


Figure 4
Hydroelectric Dams in the Androscoggin River Watershed
Androscoggin Watershed Habitat Assessment
Maine, USA

3.3 WATER QUALITY IN THE ANDROSCOGGIN RIVER WATERSHED

3.3.1 Historical Water Quality

Paper mills came into operation in the Androscoggin Watershed during the mid to late 1800s. Sulfur from the paper-making process was discharged into the Androscoggin River headwaters at a rate of over 6,000 tons of liquid waste material each week, along with pulp and solid waste (MDMR and MDIFW 2017). Direct discharge of pulp, sulfur, and insoluble factory wastes severely polluted the Androscoggin River. Construction of the Gulf Island Dam just north of Auburn and Lewiston between 1926 and 1927 caused reduced river flows. The finished dam impounded a large river area causing dissolved oxygen levels to drop. In the 1930s and 1940s, several surveys characterized the health of the Androscoggin River. The results of the surveys indicated a severely polluted river. The impacts of pollution included the river not freezing in the winter and health problems for residents and industry workers. Pollution originated from the use of sulfur in paper processing and the direct discharge of liquid waste and insoluble wastes. Public response to these impacts led to the formation of the Maine Sanitary Water Board in 1941 (MDMR and MDIFW 2017). The Board hired a consultant to survey the river. Its findings indicated the paper industry as the primary source of pollution. The state of Maine formed the Androscoggin River Technical Committee in 1942 to rectify the pollution issues in the river. The principal result of the Technical Committee’s work was reduced waste discharge from pulp and paper mills (MDMR and MDIFW 2017). Additional surveys resulted in court ordered reduction of discharges to the river during the 1950s and 1960s. In the 1960s, a new pulp-making process eliminated or greatly reduced the use of sulfur. The last sulfite mill on the Androscoggin River closed in 1966 (MDMR and MDIFW 2017). Since the 1970s, there have been dramatic improvements to water quality within the Androscoggin River due to water pollution control. The passing of the Water Quality Act in 1965 and the Clean Water Act in 1972 led to more pollution abatement efforts. Rumford native, Senator Edmund Muskie championed the legislation that regulated discharges of pollutants into U.S. waters and gave the U.S. Environmental Protection Agency (EPA) the authority to set wastewater standards for industries and implement pollution control programs (BHS 2007).

3.3.2 Current Water Quality

While water quality has improved dramatically since the 1970s, mill discharges, combined sewer overflows, dam impacts, and historical sediment contaminants continue to affect overall water quality (MDEP 2016). Water quality in the Androscoggin River Watershed ranges from AA (best) to C (worst) (MDMR and MDIFW 2017). Most of the surface waters within the historical range of the diadromous species covered in this CP are Class C:

- Androscoggin River (mainstem) – predominately Class B and C.

- Androscoggin River (upper drainage) – near New Hampshire Boundary, largely Class A (but not included within bounds of the CP).
- Androscoggin River (minor tributaries) – Class B.
- Little Androscoggin River (mainstem) – predominantly Class C near its confluence with the Androscoggin River.
- Little Androscoggin River (tributaries) – predominantly Class B.

Point and nonpoint source pollution affect water quality within the Androscoggin River Watershed. Point-source pollution results from wastewater treatment plant discharge and combined sewer overflows. Nonpoint-source pollution originates from the use of fertilizers and pesticides in the watershed. Other nonpoint-source pollution stems from eroded soil, petroleum residues, road salt, and wildlife feces entering the waterbodies (MDEP 2016).

3.4 RECREATION USAGE AND PUBLIC ACCESS

Recreational activities currently occur along the mainstem of the Androscoggin River, Little Androscoggin River, and Sabattus River. Within the mainstem Androscoggin River, a town boat launch at Brunswick provides recreation access to the lower mainstem and Merrymeeting Bay. Several boat launches exist between Brunswick and Lewiston Falls, including launches at Pejepscot and Worumbo dams. A boat launch near the mouth of the Sabattus River provides access to the Worumbo head pond (MDMR and MDIFW 2017).

Most recreational access points in the Little Androscoggin River are located on privately owned land or at informal locations (not municipally operated). Access is also available at state bridge crossings and at a boat launch in Mechanic Falls. In the Sabattus River, a trailered boat launch in Lisbon provides access to the Sabattus and Androscoggin Rivers (MDMR and MDIFW 2017). A public boat launch in Lisbon provides access to the Sabattus River. A restricted access site at Little Sabattus Pond also exists.

Recreational fisheries for diadromous fishes are largely located below Brunswick Dam; anglers frequently target American shad, rainbow smelt, and striped bass (MDMR and MDIFW 2017). A recent fishery for northern pike (*Esox lucius*, an invasive species) has developed in the Gulf Island-Deer Rips impoundments. Recreational fisheries for resident species occur above Brunswick throughout the Androscoggin, Little Androscoggin, Sabattus, and Little Rivers. There are valuable inland fisheries in lakes and ponds (e.g., Thompson Lake, Sabattus Pond, Gulf Island impoundment, Lake Auburn, Webb Lake, etc.). On the Androscoggin River, improved water quality has increased public fishing for warmwater fish including smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*M. salmoides*) (MDMR and MDIFW 2017). Fisheries for stocked and wild salmonids are present in tributaries to the Lower Androscoggin and Little Androscoggin Rivers, in areas below dams, and select free-flowing river sections. Recreational angling for endangered Atlantic salmon is prohibited throughout range of the GOM DPS. However, the potential exists for the incidental capture and misidentification of both juvenile and adult Atlantic salmon. Direct or indirect mortality may result even in fish that are caught and released as a result of injury or stress.

4. THE RESTORATION POTENTIAL FOR THE DIADROMOUS FISHERY

We determined the restoration potential for the target diadromous species within the Androscoggin River Watershed through:

- Evaluation of each species' biological and population characteristics (distribution, habitat requirements, current status).
- Examination of geospatial data related to waterway barrier characteristics, current and historical species ranges, and potential habitat availability upon removal or modification of select barriers.

These analyses inform a potential restoration approach for each of the diadromous species. The restoration potential for each species forms part of this CP framework that will provide state and federal agencies with information necessary to help prioritize management efforts and pro-active restoration opportunities, identify settlement opportunities with stakeholders, and support actions under their regulatory authorities.

The biological analysis consisted of a thorough review of available literature specific to each species for populations located within the watershed, as well as more general literature related to species life history. The geospatial analysis consisted of an evaluation of the barriers present in the watershed and the potential available habitat for each diadromous species resulting from removal or modification of these facilities. The restoration focus area consists of the following HUC-12 watersheds (Figure 5):

- Androscoggin River-Merrymeeting Bay
- Denham Stream
- Cathance River
- Little River
- Newell Brook-Androscoggin River
- Sabattus River
- Sabattus Pond
- Taylor Pond-Little Androscoggin River
- Waterhouse Brook
- Whitney Pond

- Thompson Lake
- Meadow Brook-Little Androscoggin River
- Marshall Pond-Bog Brook
- Stony Brook-Little Androscoggin River
- Pennesseewassee Lake.

4.1 BIOLOGICAL ANALYSIS

We researched the current and historical distribution of each of the selected species within the watershed area and described the key characteristics of each population including habitat requirements, status of the recreational fishery (if applicable), incidental catch rates and other population specific threats, interactions with the inland fishery species, and any historical and current management actions.

We reviewed the literature containing the information previously described for each species. These documents included species-specific management plans (both within and outside the Androscoggin River Watershed), state agency websites, species profiles, peer-reviewed literature, and reference books on Atlantic diadromous species. To the extent practicable, information specific to the species population in the Androscoggin River Watershed was the focus for this exercise. Otherwise, the broader Atlantic population of the species was the basis for information.

4.2 GEOSPATIAL ANALYSIS

Geospatial analyses determined the potential available habitat for diadromous species resulting from removal or modification of selected hydroelectric and non-hydropower barriers along the Androscoggin, Little Androscoggin, and Sabattus Rivers.

We did not perform geospatial analysis for Atlantic salmon and striped bass. The restoration approach outlined in this CP will follow the Final Atlantic Salmon Recovery Plan (USFWS and NMFS 2018) and the state of Maine's restoration plan for striped bass (MDMR and MDIFW 2017). The Atlantic Salmon Recovery Plan (USFWS and NMFS 2018) functions as a standalone comprehensive plan for the species and MDMR's Management Plan outlines a state-specific plan for striped bass. This CP discusses these restoration plans in Sections 6.5.7 and 6.6.5, respectively.

For American shad, blueback herring, alewife, sea lamprey, and American eel, we accessed several online geographic information system (GIS) data sources to gather the information necessary to determine available habitat as described in the following sections.

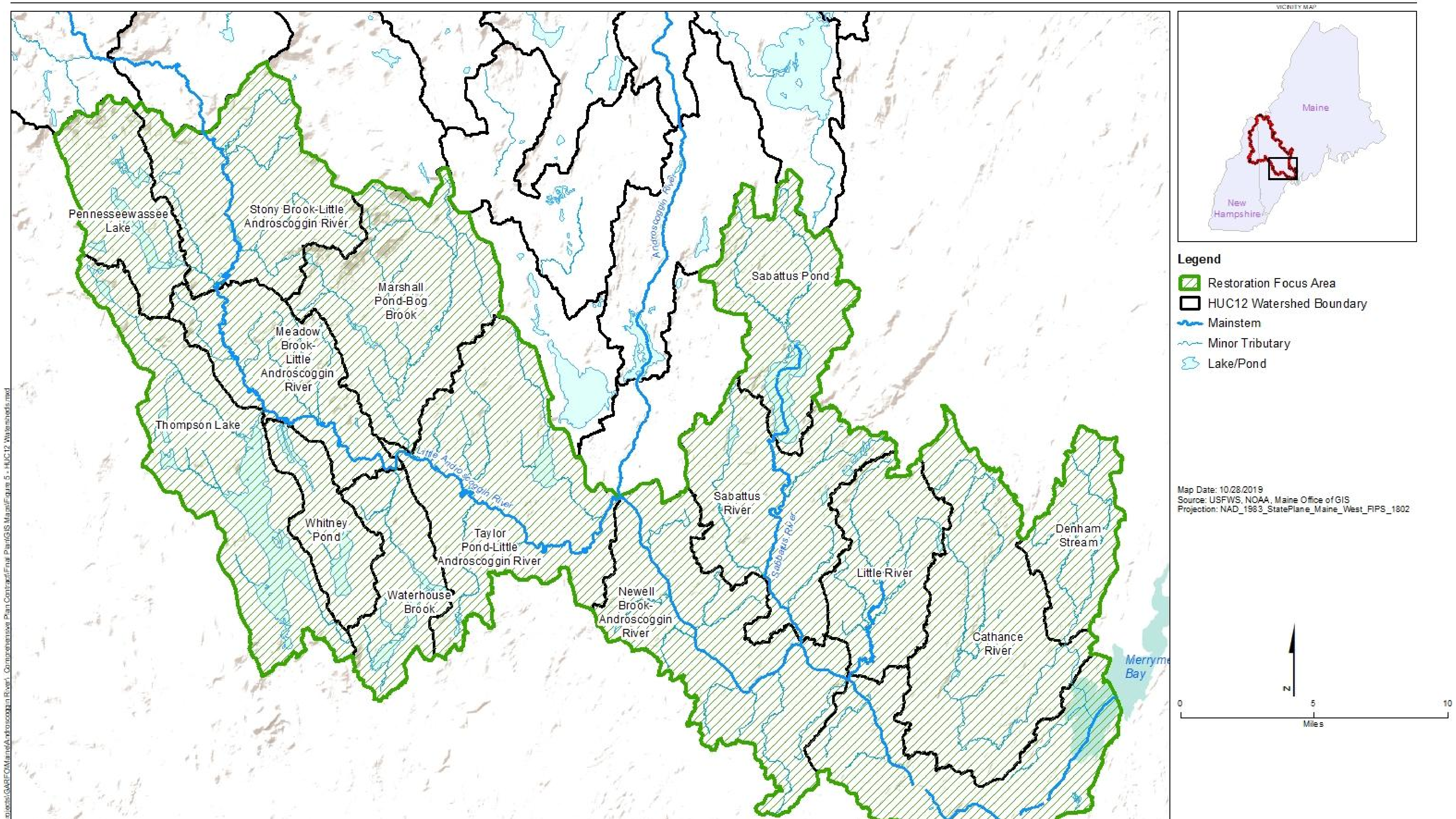


Figure 5
HUC 12 Watersheds in the Restoration Focus Area
Androscoggin Watershed Habitat Assessment
Maine, USA

4.2.1 Maine Stream Habitat Viewer

The Maine Stream Habitat Viewer is an interactive website maintained by the Maine Coastal Program as part of the Maine Stream Connectivity Work Group, which is a partnership of state, federal, industry and non-government organizations working cooperatively to improve Maine's stream restoration efforts (https://webapps2.cgis-solutions.com/MaineStreamViewer/).

Data obtained from the Maine Stream Habitat Viewer included stream barrier types, (crossings, waterfalls, dams, and natural barriers) stream reaches categorized by species (salmon and alewife) and function, watershed boundaries, and towns. The stream barrier type GIS layers provide information about field surveyed dams, crossings, waterfalls, and natural barriers. Both the waterfall and natural barrier datasets are considered incomplete, but represent the best available information by state agency personnel. With the exception of the Sabattus Pond HUC 12 sub-watershed, the entire restoration focus area has been surveyed by trained volunteers organized by the Maine Stream Connectivity Working Group.

The crossings data layer was collected from public road, trail, and railroad crossings and some private crossings where approval from the landowner allowed publication of the data. The survey methods used were developed by the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program and its partners. Each surveyed crossing site was categorized as a barrier, potential barrier, no barrier, or unknown. A crossing barrier has attributes that significantly affect aquatic organism passage. A perched culvert is an example of a crossing barrier. A potential crossing barrier has attributes that likely affect aquatic organism passage. Lack of water depth and excessive velocities are examples of a potential crossing barrier. Both the barrier and potential barrier categories do not necessarily preclude the passage of diadromous fishes, rather the qualitative assessment denotes the need for improvement of aquatic organism passage. The no barriers category represents sites that meet aquatic organism passage standards and unknown barrier sites were unable to be visited by a survey crew.

Other data we exported from this site involved queries of species habitat types (e.g., critical habitat areas, spawning reaches, rearing reaches, etc.). In some cases, the exported data were ArcGIS shapefile layers incorporated into maps. GIS professionals digitized other data, such as rearing habitat stream reaches, from pdf images.

4.2.2 Drainage Area Evaluation

We used GIS data from EPA to determine smaller drainage areas within each HUC12 covered in this CP. Determination of the size of drainage areas is important for evaluating potential habitat usage by selected species, as drainage areas below a certain square mileage may not have the characteristics necessary to provide suitable habitat for spawning. The national hydrography dataset (NHDv2) included the cumulative drainage area for each reach segment in the CP focus area at a scale of 1:100,000 or possibly 1:24,000 resolution.

We queried attribute tables for the Little Androscoggin River and the Androscoggin mainstem to Lewiston Falls (which includes the Little River and Sabattus watersheds) for the appropriate drainage area thresholds for American shad and blueback herring. USGS staff in Maine developed hydraulic geometry regression equations for coastal and central Maine river systems (Dudley 2004). We used the bankfull average depth regression equation to determine the drainage area needed to provide suitable habitat for these species. We concluded that American shad require a drainage area of at least 25 square miles (representing 1.5 foot average bank full depth), and blueback herring require a drainage area of at least 10 square miles (representing 1 foot average bankfull depth). We sorted the data for these cutoffs, and any cumulative drainage area for a reach segment that did not fall within these criteria were not included in the calculation of potential habitat for the specific species.

We did not use thresholds for American eel, sea lamprey or alewives. American eel and sea lamprey are able to utilize minimal stream depths. Alewife spawning is limited to lakes and ponds. Additionally, drainage area calculations were not determined for striped bass or Atlantic salmon, as restoration efforts for these species will follow existing state and federal plans.

5. GEOSPATIAL ANALYSES: BARRIER INVENTORY

As part of the geospatial analysis, we completed a barrier inventory for the Androscoggin River Watershed. The combined biological and geospatial analyses (specific to each diadromous species) determine the restoration potential (Section 6).

This evaluation presents an inventory of hydroelectric dams within the watershed and identifies projects that should receive priority for fish passage and protection measures with the upcoming relicensing requirements. An overarching goal of the Androscoggin River Watershed CP is to establish a framework that balances the restoration of the diadromous fishery and the need for sustainable energy production. The principal mechanism for addressing this goal is to work with licensees of hydroelectric projects that are in relicensing under the Federal Energy Regulatory Commission (FERC) or soon to be in relicensing. In addition, this evaluation presents an inventory of non-hydropower and natural barriers. Section 8 presents a more detailed description and analyses of energy production.

The barrier inventory in this CP focuses on barriers categorized as described in Section 4.2.1. Barriers presented include hydroelectric dams, non-hydropower dams, stream crossings, and natural barriers/falls (Figure 6). All dam sites are categorized as a barrier or potential barrier. Section 5.1 presents the hydroelectric dam inventory, and Section 5.2 presents the inventory of non-hydropower barriers ranked as moderate priority or higher.

5.1 HYDROELECTRIC DAMS

There are 32 licensed hydroelectric projects present throughout the Androscoggin River Watershed; 18 licenses expire before 2030. NOAA Fisheries plans to participate in the licensing process for seven of these facilities (Table 5) to ensure the projects provide safe, timely, and effective fish passage that restores populations of migratory fishes. The hydroelectric projects not up for licensing before 2030 have less priority for restoration efforts at this time (Figure 4).

Mechanic Falls will not undergo licensing within the timeframe of this CP. However, given its location within the historical distribution of diadromous fishes and a fish passage condition in the current license, this project is a priority for restoration activity. Conversely, Biscoe Falls has a license exemption and blocks only a small portion of historical habitat, thus it is not a priority. Many hydroelectric facilities located upstream of Rumford Falls will undergo licensing in the near-term but are not considered high priority for NOAA Fisheries engagement. However, we anticipate that each licensing process will include an environmental flow analysis and consideration of impacts to American eels.

We describe each hydroelectric facility in the following sections in order of occurrence from Merrymeeting Bay upstream through the watershed.

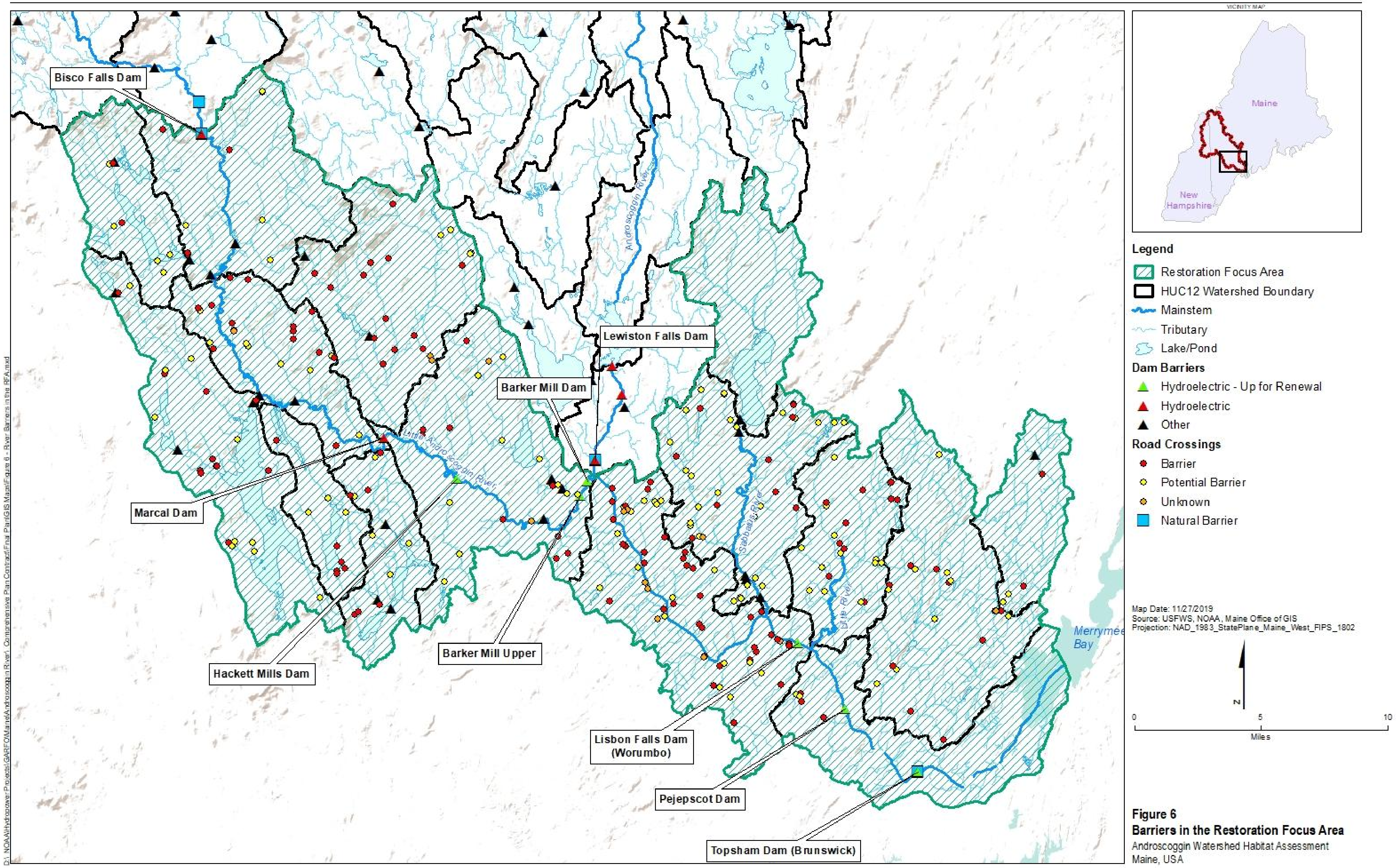


Figure 6
Barriers in the Restoration Focus Area
Androscoggin Watershed Habitat Assessment
Maine, USA

Table 5. Hydroelectric facilities with expiring licenses before 2030 that NOAA Fisheries will actively participate in the licensing process.

Facility Name	FERC Project Number	Facility Owner	River Location	License Expiration
Barker's Mill	P-2808	KEI Maine Power Management, LLC	Little Androscoggin	31 January 2019
Pejepscot	P-4784	Brookfield White Pine Hydro, LLC	Androscoggin	31 August 2022
Barker Mill Upper	P-3562	KEI Maine Power Management, LLC	Little Androscoggin	31 July 2023
Hackett Mills	P-6398	Eagle Creek Renewable Energy	Little Androscoggin	31 August 2024
Worumbo	P-3428	Eagle Creek Renewable Energy	Androscoggin	30 November 2025
Lewiston Falls	P-2302	Brookfield White Pine Hydro, LLC	Androscoggin	31 August 2026
Brunswick	P-2284	Brookfield White Pine Hydro, LLC	Androscoggin	28 February 2029
NOTE: FERC = Federal Energy Regulatory Commission.				

5.1.1 Brunswick Dam

The Brunswick Hydroelectric Project is the first barrier on the Androscoggin River located at a high-gradient river reach that is tidal up to the cities of Brunswick and Topsham. Under the original license issued in 1979, the Licensee was required to build upstream and downstream fish passage facilities; however, these efforts were largely ineffective at passing most alosines and salmon. The upstream fishway consists of an undersized, steep vertical slot with an integrated trap and haul facility located on the southern shore. There are documented issues with fish not locating the fishway entrance amidst competing attraction flow from turbine discharges and spillway and gate flow (Weaver et al. 2019). Some species (most notably American shad) do not pass the fish ladder in a timely manner. Injury and descaling occurs due to the undersized vertical slots. The downstream fishway is a surface weir located between the hydroelectric units that discharges through a pipe to the tailrace. There is no entrainment prevention at the Project. Fish kills during emigration have occurred (Bangor Daily News 2016). Improved fish passage at this barrier is necessary to restore diadromous species throughout the watershed.

In 2013, NOAA's Protected Resources Division (PRD) issued a Biological Opinion on the Licensee's Interim Species Protection Plan (ISPP) for Atlantic salmon. FERC incorporated provisions of the ISPP into the Project's license. As outlined in the ISPP, the Licensee conducted testing of the downstream passage efficiency and survival for juvenile Atlantic salmon in 2014. Test results indicated an average of 13 percent mortality. As a result, Licensee committed to providing additional spill flow during low flow periods to avoid take – defined in the Biological Opinion as a mortality rate of 7 percent or greater. The Licensee's ISPP for the Brunswick

Project expired at the end of 2019. In the spring of 2018, the Licensee performed downstream efficiency studies. The 2018 study demonstrated that modified operations, specifically additional spill flow, resulted in a downstream mortality of 5.2%. At the writing of this plan, the licensee for the Brunswick Project was consulting with us on a new species protection plan.

5.1.2 Pejepscot Dam

The Pejepscot Hydroelectric Project is the second dam on the Androscoggin River, on the border between Cumberland and Sagadahoc counties. The Pejepscot Project operates run-of-river and includes both upstream and downstream fish passage facilities. An automated fish lift during the migration season provides upstream passage. Fish are crowded and lifted daily at least every 2 hours from 8 a.m. to 4 p.m. Two 18-inch-diameter pipes extending from the powerhouse intake to the tailrace provide downstream passage.

Fishway counts at the downstream Brunswick Project and the upstream Worumbo Project indicate the upstream fishway at Pejepscot passes diadromous species though no information on delay is available. There are several studies of fish passage effectiveness at the Pejepscot Project, but the results are tenuous because the flows have been abnormally high or low (MDMR 2016a, MDMR and MDIFW 2017; MDMR 2019). In 2012, PRD issued a Biological Opinion on the Atlantic salmon ISPP for the Pejepscot Project. The ISPP included studies evaluating measures to protect downstream migrating Atlantic salmon. Studies showed an average whole-station mortality of 13.7 percent for downstream migrating salmon smolts. Due to the low numbers of returning adults to the Androscoggin River, a quantitative study of the upstream efficiency of the Pejepscot facility for Atlantic salmon is not feasible at that time. In March 2017, the Licensee submitted an ISPP for a 6-year term (concurrent with expiration of the current license). In 2017, PRD issued a Biological Opinion on the new ISPP. The Biological Opinion included a take exemption of 8 percent mortality of downstream migrating salmon smolts. The Licensee proposed implementing spill flows to achieve the take exemption standard. The Licensee conducted downstream efficiency and survival studies in the spring of 2018, which demonstrated a mortality of 4.7% for downstream migrating salmon smolts at the Pejepscot Project. The project is currently undergoing the integrated licensing process.

5.1.3 Worumbo Dam

The Worumbo Hydroelectric Project is the third dam on the Androscoggin River located at Ten Mile Falls in Lisbon Falls. The Worumbo Project consists of three concrete gravity dam sections, a gated spillway, a two-unit powerhouse, a non-overflow abutment, and a floodwall. The Project is equipped with upstream and downstream fish passage facilities for anadromous species. The upstream fish passage constructed in 1988 is a fish lift with two entrances on either side of the tailrace connected by a gallery and a fish viewing and counting room in the exit flume. Four tailwater pumps and a piping system from the exit flume provide attraction water to the fish lift. The downstream fish passage consists of three overflow weirs located approximately

11 feet above the turbine intakes that discharge into a collection gallery between the entrances. Flow from the collection gallery travels through a 36-inch diameter pipe into a plunge pool before spilling over a weir into the tailrace. In 2017, PRD issued a Biological Opinion on the ISPP for the Worumbo Project. The Biological Opinion included a take exemption of 6.5 percent mortality of downstream-migrating juvenile Atlantic salmon.

5.1.4 Lewiston Falls

The Lewiston Falls Hydroelectric Project is the fourth dam on the Androscoggin River located at a natural waterfall between the cities of Auburn and Lewiston. The primary environmental focus of the original license issued in 1986 was to mitigate effects of the Project on water quality, which at the time was not meeting water quality standards due to low dissolved oxygen and contamination from industrial discharges. The Licensee agreed to minimum flow and dissolved oxygen enhancement measures. Though water quality has improved, there are still instances when water quality in the impoundment does not meet state standards (Brookfield White Pine Hydro LLC 2017). The Project does not include any upstream passage. In 2013, Brookfield Power filed an ISPP for Atlantic salmon with the FERC. However, critical habitat for Atlantic salmon was not designated upstream of Lewiston Falls. The current Atlantic Salmon Recovery Plan does not include restoring salmon above Lewiston Falls. Therefore, the Licensee's ISPP did not include fish passage measures.

5.1.5 Barker's Mill Dam

The Barker's Mill Hydroelectric Project is the first dam on the Little Androscoggin River located in the City of Auburn. The powerhouse is located approximately 1,000 feet from the confluence with the Androscoggin River (downstream of Lewiston Falls and upstream of Worumbo). The dam is located approximately 3,000 feet upstream of the powerhouse, creating a long powerhouse. The Project does not include any upstream passage. Downstream passage protection measures are limited to a single gate opening at the dam. The effectiveness of this downstream passage protection measure is unknown.

The bypass reach is documented Atlantic salmon spawning and rearing habitat with suitable water quality when the dam is spilling. Diadromous fishes have access to the Project through fishways at the hydroelectric projects on the mainstem Androscoggin River. Although habitat and water quality are suitable, passage at the lower three dams will need improvements to support restoration efforts. Alosines and American eel are present at the base of the dam. Atlantic salmon have been observed below the Project. The project is awaiting a new license.

5.1.6 Barker Mill Upper Dam

The Barker Mill Upper Hydroelectric Project is the second dam on the Little Androscoggin River located approximately 3,500 feet upstream from the Barker's Mill Project in the City of Auburn. The Project does not include any upstream passage for diadromous species. The Project has two surface weirs located on either side of the turbine intake that discharge through pipes to the tailrace that function as downstream passage for emigrating fishes. The effectiveness of this downstream passage protection measure is unknown. The project is undergoing the traditional licensing process.

5.1.7 Hackett Mills Dam

The Hackett Mills Hydroelectric Project is the fourth dam on the Little Androscoggin River (the third dam is the breached Littlefield dam). The Project does not include any upstream passage for diadromous species. The Project has an angled bar rack for entrainment prevention and a bypass sluiceway that discharges into the bypass reach. The effectiveness of these downstream measures is unknown.

5.1.8 Mechanic Falls

The Mechanic Falls Hydroelectric Project is the fifth dam on the Little Androscoggin River located approximately 5 miles upstream from the Hackett Mills Dam. The Project does not include any upstream passage for diadromous species. The Project has a bar rack for entrainment prevention and a surface weir discharging into the bypass reach as the downstream passageway. The effectiveness of these downstream measures is unknown. The Project license expires in 2037. The existing license includes an article stipulating the installation of upstream fish passage facilities upon completion of a fisheries management plan.

5.2 NON-HYDROPOWER BARRIERS

We completed an inventory of non-hydropower barriers for the restoration focus area (Figure 6). Select non-hydropower barriers are discussed in the following sections, organized by HUC12 sub-watershed (Figure 5), based on the following criteria: proximity to priority hydroelectric projects with potential for modification or operational changes to improve fish passage; ranking as moderate or higher priority barriers; and timing of restoration actions relative to FERC licensing actions at mainstem barriers. Crossing barriers are numerous throughout the restoration focus area, therefore we focused on the sites that limit passage along the migratory corridor of the target diadromous species. Though all crossing barrier and potential barrier sites limit aquatic organism passage and ecosystem function, we evaluated the crossings from the survey data to estimate the severity of the blockage with respect to the target diadromous species.

5.2.1 Little River Watershed

The Little River watershed spans 27 square miles and discharges into the Androscoggin River upstream of the Pejepscot Dam. There are no dams in the watershed. Nine road crossings are barriers (Figure 6). Of these, four crossing barriers (Purlington Brook, Little Gillespie Brook and two unnamed crossings) appear to need improved passage conditions for diadromous species. As part of the Species Protection Plan process for Atlantic salmon, the Licensee for the Pejepscot Project conducted a Little River Habitat Assessment for Atlantic salmon in the lower 6.7 miles of the river (Topsham Hydro 2012). The study documented a series of riverine habitats suitable for Atlantic salmon, though there was limited spawning habitat. No severe or significant barriers are present with the exception of one large ephemeral log debris dam. A couple of the culverts and a cascade near the confluence with the mainstem present potential barriers for weaker swimming species and life stages.

5.2.2 Sabattus River/Sabattus Pond Watershed

The Sabattus River and Sabattus Pond are a combined 72-square-mile watershed that discharges into the Androscoggin River upstream of the Worumbo Dam. Barriers in this watershed include six dams with no fish passage and ten crossings. Two of the dams are breached and all of the crossing barriers are located in the tributary headwaters outside of the migratory corridor (Figure 6). The Maine Stream Connectivity Work Group has not surveyed the Sabattus Pond HUC 12 watershed.

5.2.3 Taylor Pond-Little Androscoggin River Watershed

The Taylor Pond-Little Androscoggin River Watershed comprises 56 square miles upstream of the confluence with the mainstem of the Androscoggin River. Barriers include three tributary non-hydropower dams, one non-hydropower mainstem dam, and ten crossings (Figure 6). The dams do not include fishways. The breached Littlefield Dam on the Little Androscoggin is a partial barrier. The majority of the road crossing barriers are located on small tributaries with little habitat value. However, there are road crossings on Cool Brook and Morgan Brook that block upstream habitat.

5.2.4 Marshall Pond-Bog Brook Watershed

The Marshall Pond-Bog Brook Watershed comprises 45 square miles that discharge into the Little Androscoggin River upstream of the Hackett Mills Dam. Barriers include two non-hydropower dams with no fish passage and 13 road crossings (Figure 6). Three of the thirteen crossing barriers (two on the Middle Branch of Bog Brook and the other on the West Branch of Bog Brook) are located within the migratory corridor and should be improved, though each crossing barrier does not preclude passage of diadromous species at all river flows.

5.2.5 Meadow Brook-Little Androscoggin River Watershed

The Meadow Brook-Little Androscoggin River Watershed comprises 29 square miles upstream of the Mechanic Falls Dam. Barriers include one mainstem Little Androscoggin River

Dam with no fish passage and thirteen road crossings (Figure 6). None of the road crossing barriers are located within the migratory corridor.

5.2.6 Waterhouse Brook Watershed

The Waterhouse Brook Watershed comprises 19 square miles upstream of the Mechanic Falls Dam. Barriers include three non-hydropower dams with no fish passage and six crossings (Figure 6). Only the dams are located in the migratory corridor.

5.2.7 Whitney Pond Watershed

Hogan Pond and Whitney Pond both drain to a 0.4 mile unnamed stream that is a tributary to the Little Androscoggin River. This unnamed stream has its confluence 0.7 miles upstream of the Welchville Dam and has a watershed area of 15 square miles. Six crossing barriers in the watershed are located in the headwaters outside of the migratory corridor; however, downstream barriers on the mainstem Little Androscoggin River must be addressed to fully support restoration of diadromous species in this watershed.

5.2.8 Thompson Lake Watershed

The Thompson Lake Watershed comprises 47 square miles upstream of the Welchville Dam. Barriers include five non-hydropower dams with no fish passage and eleven crossings that are barriers (Figure 6).

5.2.9 Stonybrook-Little Androscoggin River Watershed

The Stony Brook-Little Androscoggin River Watershed comprises 41 square miles upstream of the Welchville Dam. Barriers include four non-hydropower dams with no fish passage and four crossings (Figure 6). In addition, some natural barriers on both Moody and Cole Brooks may limit fish passage.

6. RESTORATION EVALUATION FOR EACH DIADROMOUS SPECIES

The restoration potential for each of the diadromous species was determined by performing an evaluation of the biological characteristics of each species along with the potential available habitat resulting from removal or modification of current barriers in the Androscoggin River Watershed. We combined this information with the results of the barrier inventory to develop a potential approach for species restoration.

6.1 AMERICAN SHAD

6.1.1 Biological Characteristics of American Shad

American shad is a anadromous, species with a present range extending from the St. Lawrence River in Canada to the St. Johns River in Florida (ASMFC 2009a). American shad spend most of their lives in pelagic, marine waters, and migrate as adults into coastal rivers and tributaries to spawn. Shad exhibit strong homing to their natal river and are capable of migrating long distances (e.g. 204 miles in the Connecticut River) up unimpeded rivers and streams (CRASC 1992; MDMR and MDIFW 2008; SRAFRC 2010). Generally, in river systems with limited barriers, American shad prefer to spawn in upstream and mid-river segments until energy reserves or water temperatures no longer facilitate spawning (Massmann 1952, Bilkovic et al. 2002). American shad are broadcast spawners with semi-buoyant eggs and females will spawn multiple times throughout their annual migration (Hyle et al. 2014, McBride et al. 2016). Northern populations of American shad are iteroparous, meaning they have multiple reproductive cycles over the course of their lifetime (e.g., repeat spawners). Repeat spawners are especially important due to higher lifetime fecundity rates and reduced annual variability of spawning stock size (Harris and Hightower 2012). This narrative will describe the distribution of and habitat requirements for American shad, as well as the fishery status, shad interactions with other aquatic species, and historical and current management and monitoring efforts for the Androscoggin River Watershed.

6.1.2 Historical and Current Distribution

American shad within the Androscoggin River Watershed had a range up to Lewiston Falls on the Androscoggin River and to Biscoe Falls on the Little Androscoggin River (Figure 7). Spawning in the watershed historically occurred from Merrymeeting Bay to Lewiston Falls, and in the Little Androscoggin River spawning occurred from the confluence with the Androscoggin River to Biscoe Falls (MDMR 2014). Dam construction along the Androscoggin River extirpated the shad run (Atkins 1887), isolating shad from previously utilized spawning and nursery habitat on the mainstem Androscoggin. Their present day range ends at Lewiston Falls on the mainstem Androscoggin and the Barker’s Mill Facility on the Little Androscoggin River. Spawning habitat is limited to areas with fish passage on the Androscoggin River (MDMR and MDIFW 2017).

The primary impediment to restoring American shad distribution in the Androscoggin River Watershed is poor passage at the Brunswick Hydroelectric Project. The Brunswick Project is located at the head-of-tide on the Androscoggin River and includes a vertical slot fishway, initially designed to pass 85,000 American shad annually (MDMR and MDIFW 2017). Construction of the fishway was complete in 1983 and was one of the first vertical slot fishways designed to pass American shad on the east coast. However, when FERC issued the 1979 license for the Brunswick Project, the license did not require passage efficiency studies to achieve performance criteria. Since the fishway began operation, the number of American shad passing has been low; cumulatively, only 1,455 fish (through visual observations, underwater video, radio telemetry studies) passed through the fishway from 1985 to 2017. Most shad entering the fishway rarely pass beyond the corner pool (MDMR 2014). This number is incredibly low considering the approximately 8,000 adult shad and over 5 million fry stocked into historical spawning habitat above the Brunswick Project and the thousands of fish that swim in the Project tailrace every year (MDMR and MDIFW 2017). At the Worumbo Hydroelectric Project, American shad have passed the facility during three migration seasons with seven fish counted in 2004 (Miller Hydro Group 2004), 18 in 2015, and 45 in 2016 (MDMR 2016a; MDMR 2017a). Trap counts at the Brunswick facility have been higher but consistently below 100 fish from 1990 to 2015 (MDMR 2017b). In 2016, 1,096 American shad were recorded (MDMR 2017b) and in 2017 only one individual was recorded (MDMR 2018).

Water quality in the Androscoggin River Watershed is another historical factor affecting the distribution of American shad. By the 1930s, severe water pollution from upstream industry almost eliminated the population of shad in the estuary, and what few individuals continued to reproduce below Brunswick supported a small commercial fishery. Water quality initiatives began in the Androscoggin River in the 1970s and dramatically improved the water conditions (MDMR 2014).

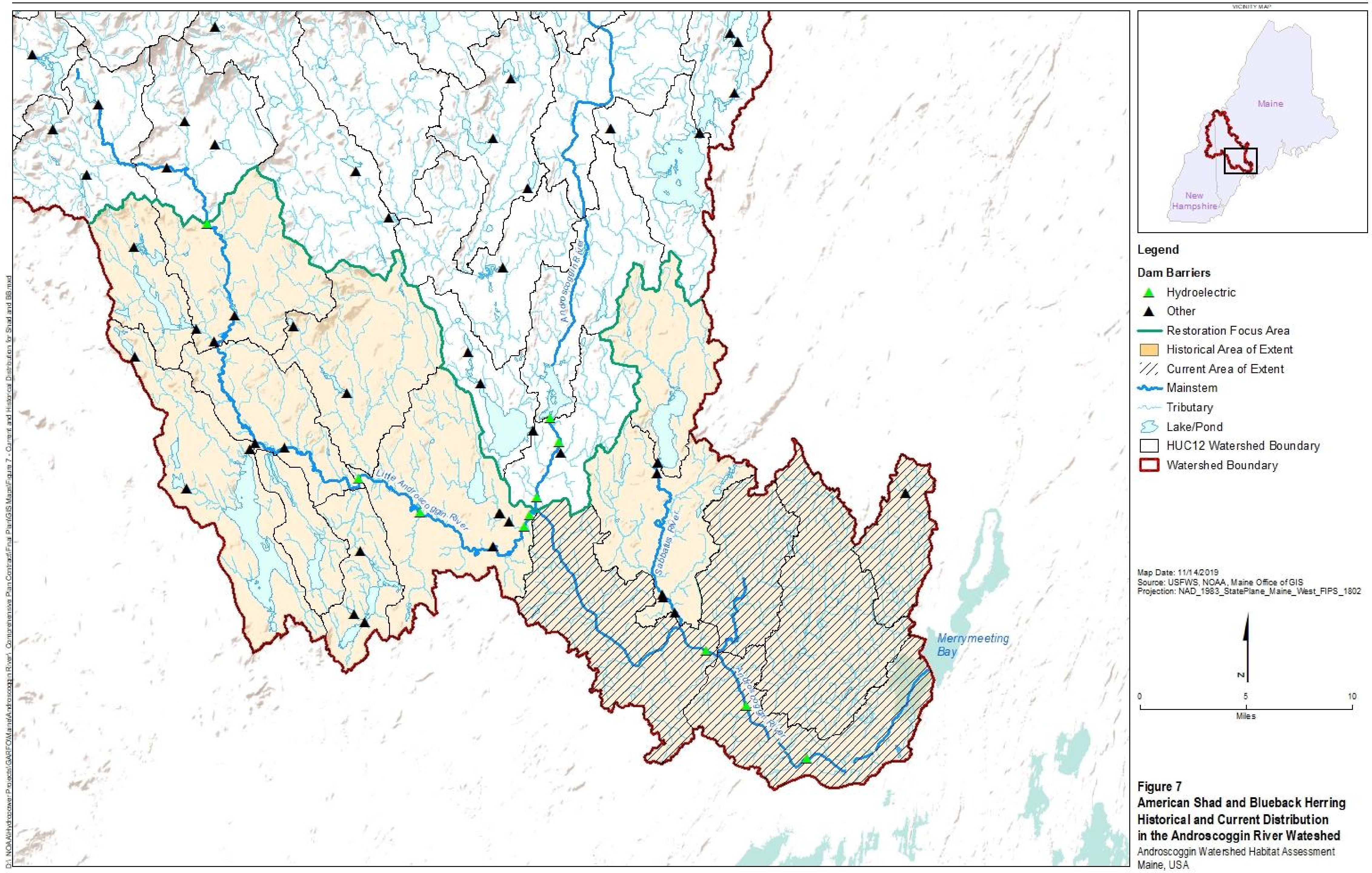


Figure 7
American Shad and Blueback Herring Historical and Current Distribution in the Androscoggin River Wateshed
Androscoggin Watershed Habitat Assessment
Maine, USA

6.1.3 Habitat Requirements

According to the Maine American Shad Habitat Plan, there are over 62 river miles of potential American shad habitat in the Androscoggin River, but only 30 of these miles are currently accessible by shad, due to dam construction (MDMR 2014). American shad require various habitats throughout their life cycle, primarily using the mainstem of the rivers for spawning, larval, and juvenile nursery habitat (ASMFC 2010a). Favorable spawning substrate includes areas with larger substrate such as gravel; however, American shad will spawn in habitat with widely varied substrate size, from silt to large rocks and boulders (Walburg and Nichols 1967, Bilkovic et al. 2002). While depth is not a primary factor for American shad spawning locations, the optimum depth range for spawning American shad (and for all life stages) is between 5 and 19.7 meters (Stier and Crance 1985, Greene et al. 2009).

American shad eggs and larvae are typically found at or just downstream of spawning areas. Favorable habitat for egg development is in areas with extensive woody debris and in deep pools away from the shoreline, as important prey items in these habitats feed larval and juvenile American shad (Chittenden 1969). Survival rates of American shad eggs are also typically highest in these habitats with extensive debris and large substrates (rocks, rubble), as the substrate allows for proper water velocity that prevent finer grained substrates from settling and suffocating the eggs (Walburg and Nichols 1967). Larvae transform into juveniles 3 to 5 weeks after hatching. Juveniles disperse downstream of the spawning areas, generally staying in a lower portion of the same river for the summer (McCormick et al. 1996). Most juveniles in river systems in the northern Atlantic states will begin their seaward migration when water temperatures are between 18 and 26 degrees Celsius (Marcy 1976, Watson 1970).

6.1.4 Recreational Fishery and Stocking

Recreational catch numbers for American shad are largely unknown; available as mostly estimates (ASMFC 2010a). Recreational fishing for American shad is popular in most Atlantic coast states during the spring spawning run, but harvest information is unreliable. The Marine Recreational Fisheries Statistics Survey operates to obtain information on recreational fisheries, but it does not adequately capture data for American shad or other anadromous fishes. The survey design focuses on coastal and estuarine fishing sites rather than inland non-tidal waters where the largest portion of recreational fishing for American shad occurs (ASMFC 2010a).

The last coast wide stock assessment for all Atlantic American shad was completed in 2007, which found that stocks throughout the coastal states are at historic lows and do not appear to be recovering (ASMFC 2007a,b). The main causes for decline are habitat loss from dam construction, overfishing, and poor water quality. Peer review panels for the Atlantic State Marine Fisheries Commission (ASMFC) have recommended that new restoration actions should be identified, which included enhancement of dam passage for American shad (ASMFC 2010b).

Following construction of the Brunswick fishway, MDMR began a restoration program for shad. Pre-spawning individuals were stocked into suitable spawning habitat below Lewiston Falls between 1985 and 2010 (MDMR and MDIFW 2017). Additionally, between 1999 and 2008, they stocked hatchery-reared shad fry in the same waters. Multi-year observations of American shad eggs between the Brunswick Project and a railroad bridge approximately 1 mile downstream, suggest a current spawning population in this area (MDMR and MDIFW 2017). For years following release of the marked shad fry, the state has collected adult American shad from mortalities at various dams, seine surveys, and recreational anglers (MDMR 2014). MDMR is currently working on advanced methods to identify oxytetracycline marked otoliths from stocking efforts. Juvenile abundance of American shad in stocked areas appears to have increased, though the direct success of this stocking effort requires validation.

6.1.5 Competition, Predation, and Interaction with Inland Fishery

American shad have various predators throughout their life cycle. American shad eggs and larvae are potential prey for any larger fish (Greene et al. 2009). Larger predators such as striped bass, Atlantic cod (*Gadus morhua*), and monkfish (*Lophius americanus*) consume juvenile American shad (McDermott et al. 2015). One study in the Connecticut River has noted a connection between the drop in American shad with an increase in striped bass populations (Savoy and Crecco 2004). Once in open pelagic waters, they are a schooling species consumed by numerous piscivorus marine animals. Spawning American shad also serve as a prey base for riverine fishes, birds, and other species as they enter coastal rivers at a time of year when other prey are limited and the nesting and breeding season begins for wildlife (ASMFC 2010a). Information on specific competitor species for American shad is limited; however, it is expected blueback herring or other fish species of a comparable size utilize the same habitats during the same life stage and forage on the same prey sources.

Several invasive species inhabit the Lower Androscoggin River, including white catfish (*Ameiurus catus*), common carp (*Cyprinus carpio*), and northern pike (*Esox lucius*). Populations of these invasive species have increased where American shad are present. The impact of these invasive species on American shad is unknown; however, white catfish prey upon fish eggs of native species. The population increase of this species, and other invasive species, in nursery areas may potentially have a negative impact on shad survival (MDMR 2014).

6.1.6 Previous and Current Management/Monitoring Actions for American Shad

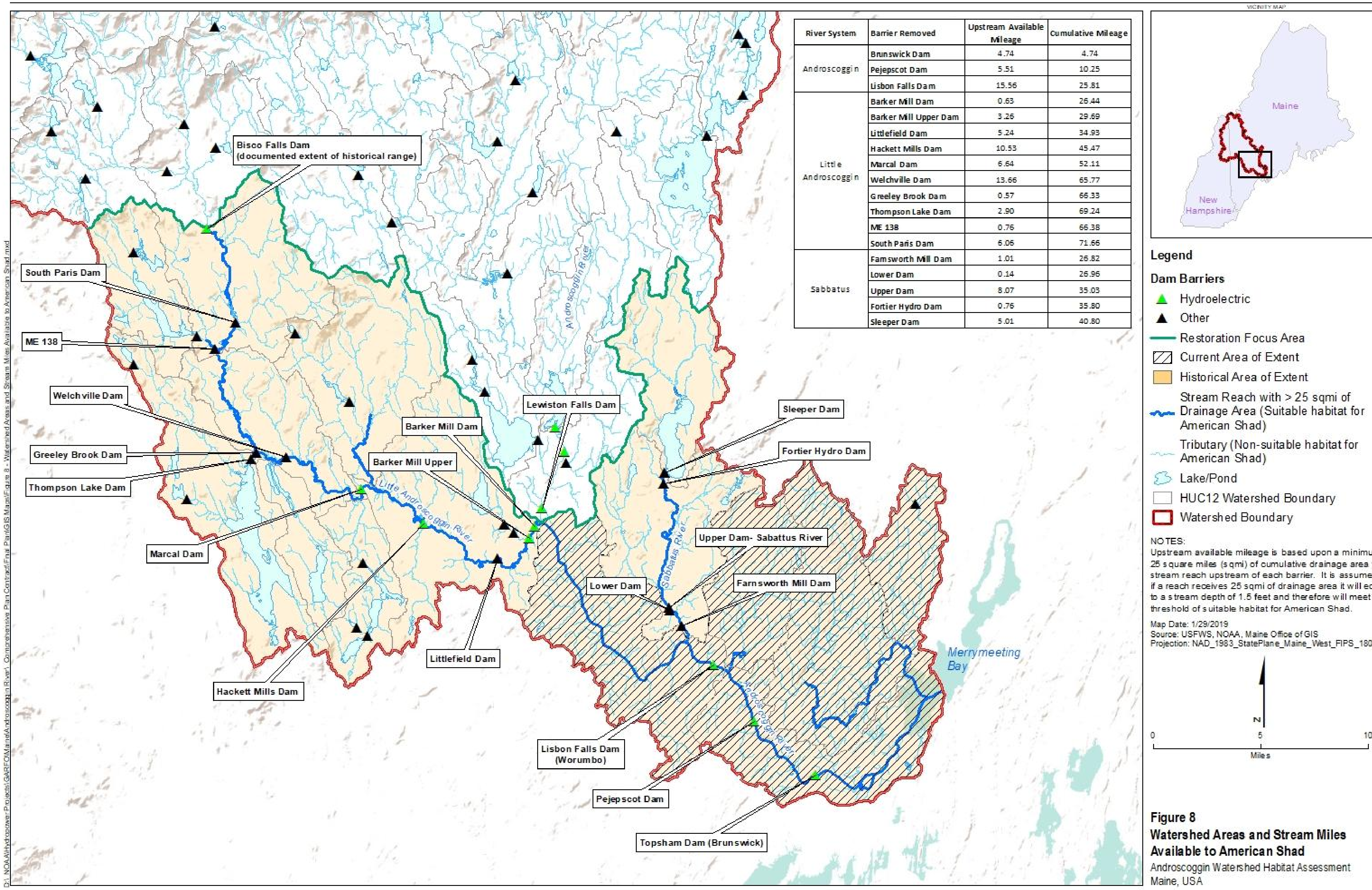
In 1985, ASMFC prepared a cooperative Fishery Management Plan for American Shad and River Herrings (ASMFC 1985). The plan recommended management measures for enhancing stock and implementation of the measures was at the discretion of the individual states. Shad stocks continued to decline in the 1990s and ASMFC issued an amendments in 1999, 2009, and 2010 (ASMFC 1999, 2009b, 2010a). The 2010 addendum stated that previous priority management actions described in the initial version of the plan (e.g., reducing overharvest and enhancing stocking efforts) were likely not the primary causes for decline of shad (ASMFC 2010a). Instead, the most recent addendum suggests that management actions should focus largely on improving fish passage at migration barriers and reducing dam passage mortality and delay (ASMFC 2010a).

In the Androscoggin River Watershed, MDMR works in collaboration with other federal agencies during the FERC relicensing process for many of the hydroelectric projects along the river to advocate for improvements to fish passage that will allow for safe, timely, and effective passage for diadromous fishes, including American shad (MDMR 2014). There are three primary monitoring projects in Maine for American shad: (1) fishway monitoring on the mainstem of major rivers including the Androscoggin River Watershed; (2) juvenile beach seine and in-river trawl surveys; and (3) recreational fishing surveys. Video monitoring at the Brunswick fishway determines the number of individuals approaching and passing the fishway each year. There are currently no efforts to field verify the assumed current American shad spawning habitat and no passage efficiency studies. The current recommended management actions from MDMR for American shad include:

- Remove mainstem hydroelectric dams or modifying facilities to improve or create fish passage.
- Field verify assumed current spawning habitat.
- Conduct population estimates.
- Map young-of-year habitat in the Kennebec River/Merrymeeting Bay estuary.
- Conduct fishway efficiency studies.
- Determine locations beyond those currently monitored where shad passage may also be obstructed by dams or other facilities.
- Monitor water chemistry during the summer at assumed spawning areas (MDMR 2014).

6.1.7 Potential Shad Habitat Availability

American shad have access to Lewiston Falls on the mainstem Androscoggin and the Barker’s Mill Project on the Little Androscoggin River (Figure 7). American shad use stream reaches within drainage areas of at least 25 square miles, as these areas have average bankfull stream depths of 1.5 feet. Geospatial analysis of drainage areas meeting this criterion within the bounds of the CP show that most of the potential habitat for shad is located within the mainstem of the Androscoggin, Little Androscoggin, and Sabattus Rivers (Figure 8). This analysis suggests additional potential habitat when compared to Maine’s American Shad Habitat Plan (MDMR 2014). Our analysis includes tributary habitats not included in the state’s GIS analysis.



River System	Barrier Removed	Upstream Available Mileage	Cumulative Mileage
Androscoggin	Brunswick Dam	4.74	4.74
	Pejepscot Dam	5.51	10.25
	Lisbon Falls Dam	15.56	25.81
Little Androscoggin	Barker Mill Dam	0.63	26.44
	Barker Mill Upper Dam	3.26	29.69
	Littlefield Dam	5.24	34.93
	Hackett Mills Dam	10.53	45.47
	Marcal Dam	6.64	52.11
	Welchville Dam	13.66	65.77
	Greeley Brook Dam	0.57	66.33
	Thompson Lake Dam	2.90	69.24
	ME 138	0.76	66.38
	South Paris Dam	6.06	71.66
Sabbatus	Farnsworth Mill Dam	1.01	26.82
	Lower Dam	0.14	26.96
	Upper Dam	8.07	35.03
	Fortier Hydro Dam	0.76	35.80
	Sleeper Dam	5.01	40.80

Figure 8
Watershed Areas and Stream Miles Available to American Shad
Androscoggin Watershed Habitat Assessment
Maine, USA

6.2 RIVER HERRING

6.2.1 Biological Characteristics of River Herring

River herring, which includes alewife and blueback herring, are anadromous fishes with a range extending from Cape Breton, Nova Scotia, to the St. Johns River in Florida (Greene et al. 2009). River herring are a schooling fish and spend most of their lifespan in the ocean before returning to freshwater streams to spawn (Collette and Klein-MacPhee 2002). Both alewife and blueback herring are iteroparous and return to the same watershed where they spawned in previous years (Fay et al. 1983). While river herring are repeat spawners, adult freshwater mortality rates vary based on location and spawning year. One study found that, on average, 90.7 percent of alewife populations in Love Lake, Maine, do not survive the first spawning migration (Havey 1973). River herring can diversify their population genetics by spawning with multiple subpopulations within a single watershed (Palkovacs et al. 2008, Maryland Sea Grant 2011). Iteroparity provides repeat opportunities to diversify the genetic pool within a watershed population. Alewife also exist as landlocked populations, completing their full life cycle in fresh water (Greene et al. 2009). They are a common prey for many species including popular recreational fishes, birds, and mammals. The following section will describe the distribution of and habitat requirements for river herring, as well as the fishery status, river herring interactions with other aquatic species, and historical and current management and monitoring efforts. The information presented in this section will focus on the specific Androscoggin River Watershed river herring populations, to the extent that data are available.

6.2.2 Historical and Current Distribution

The Androscoggin River Watershed served as historical spawning grounds and migratory corridors for river herring. River herring were historically abundant in the Androscoggin River watershed (Figures 7 and 9). The first anthropogenic barrier on the Androscoggin River mainstem to affect herring was a dam constructed at the head of tide (MDMR and MDIFW 2017). This head of tide dam restricted river herring movement to the tidal portion of the Androscoggin mainstem. River herring spawn within the estuarine portion of the mainstem Androscoggin, but rapidly declined in the 1930s when pollution levels in the river increased (MDMR and MDIFW 2017). By the 1970s and 1980s, increased efforts to improve water quality and fisheries management in the Androscoggin resulted in the construction of fish passage facilities at three major dams on the mainstem, improved water quality, and a resurgence in river herring populations (MDMR and MDIFW 2017). In 2006, a total of 79 dams were reported as present on the Androscoggin River Watershed, though some of these dams have since been breached, removed, or provide fish passage facilities (Hall et al. 2010). The construction of the Brunswick fishway facility in 1981 provided non-volitional access to 53.8 percent of historical lake habitat on the Androscoggin (Brown et al. 2006) through a trap and haul program.

Blueback herring spawning grounds consisted of the Androscoggin River estuary, lower Androscoggin River from Great Falls to Lewiston Falls, and Little Androscoggin River to Biscoe Falls. Alewife historical spawning grounds consisted of the lower Androscoggin River to Lewiston Falls, 10 ponds and lakes on the Little Androscoggin River, and five ponds in the Sabattus River Watershed (MDMR and MDIFW 2017). For the Little Androscoggin River, Biscoe Falls acted as a natural barrier to river herring upstream movement (MDMR and MDIFW 2017). Prior to dam construction on the Little Androscoggin, approximately 30 percent of the blueback herring spawning habitat was in upstream regions (MDMR and MDIFW 2017). Alewife historically used lakes and ponds as spawning habitat in the Little Androscoggin (77%) and Sabattus (23%) watersheds.

Alewife and blueback herring inhabit a smaller range of the Androscoggin River Watershed impeded by dams and stream crossings, though both species continue to use the watershed. The Androscoggin River estuary currently has blueback herring and alewife runs and supports some blueback herring spawning grounds. The main channel of the Androscoggin River is primarily a migratory corridor with limited spawning grounds for alewife. On the mainstem Androscoggin River, blueback herring are limited to upstream migration by Lewiston Falls (MDMR and MDIFW 2017). In recent years, the state has observed blueback herring spawning in the mainstem Androscoggin below the Brunswick Dam. There is no evidence of blueback herring spawning above the Brunswick Dam. Since few blueback herring enter the Brunswick fish ladder, their spawning habitat in the mainstem Androscoggin is considered inaccessible (MDMR and MDIFW 2017). In 2017, MDMR reported 41,923 river herring (mostly alewife) collected in the Brunswick fish trap (MDMR 2018). Fish passage counts occur at the Brunswick and Worumbo Hydroelectric Projects on the mainstem Androscoggin (Figure 10). Passage at Brunswick is highly variable and not meeting the restoration potential for the watershed.

6.2.3 Habitat Requirements

River herring have species-specific spawning habitat needs including varying water flows, substrate types, and water temperatures. There is no observed overlap in natural spawning grounds for the two species of river herring in Maine (ASMFC 2012). Both species can migrate far upstream to reach suitable spawning habitat. River herring return to rivers and streams in the spring and early summer at 4 to 5 years of age to spawn, but fish as young as 3 years have reportedly returned to the rivers to spawn (ASMFC 2012). In river migration typically begins when water temperatures reach 11 ºC (Mullen et al. 1986). Both species cease spawning when water temperatures exceed 27 ºC (Pardue 1983). Spent river herring typically return to the ocean, commonly staying near shore in large schools (Kircheis et al. 2004). Alewife may remain in ponds until sufficient flows flush the waterbody.

Blueback herring prefer to spawn in fast-flowing shallow or deep water with a hard substrate and spawn when water temperatures reach 13.9 °C (Greene et al. 2009). They commonly spawn in mainstem river channels with a tidal influence, but also spawn in inland freshwater streams (ASMFC 2012). Blueback herring in Maine spawn between May and June, depending on water temperatures (ASMFC 2012).

Alewife spawning habitat consists of lakes, ponds, and still waters within rivers and streams (MDMR and MDIFW 2017). Alewife enter rivers in Maine for spawning between May and early June (Kircheis et al. 2004). Alewife typically spawn in littoral zones of lentic ecosystems with a gravel or vegetated substrate (Jones et al. 1978, Greene et al. 2009). Optimal spawning temperature for alewife in Maine ranges from 12.8 to 15.5 ºC (Kircheis et al. 2004, ASMFC 2012). While more successful in natural streams and ponds, alewife may successfully spawn in eddies, pools, and lentic waters created by dams (Greene et al. 2009). Stream flow is a trigger for alewife upstream movement, where the fish generally travel when stream flow is high; however, extreme stream flow can delay upstream movement of alewife (Greene et al. 2009).

River herring eggs are demersal in still water or pelagic in flowing water during the initial release from the female (Loesch and Lund. 1977; Jones et al. 1978; Mullen et al. 1986). After a 24-hour hardening period, the eggs enter the water column (Fay et al. 1983). Time to hatching is temperature dependent, with warmer temperatures resulting in a shorter incubation period (Fay et al. 1983). In Maine, alewife eggs hatch out after 3 days at 22 ºC and 6 days at 15.5 ºC (Kircheis et al. 2004).

River herring larvae develop through two stages – a yolk-sac stage and a larval stage. The yolk-sac stage begins upon larvae hatching from the egg until the yolk-sac is fully absorbed, which only lasts a few days for river herring (Jones et al. 1978). The larval stage is the final stage before transformation into juvenile river herring. Larvae can be found in both calm and flowing waters but tend to avoid habitat with fast-flowing waters, such as the center of a river channel (Walsh et al. 2005).

Juvenile river herring thrive in freshwater streams for the first few months of their life. Vertical diel migration occurs in both species, with fish moving toward the bottom during the day and toward the surface at night (Loesch and Lund 1982). Alewife growth rate is dependent on the quality of food sources available in the nursery habitats, with more productive habitats resulting in faster growing and larger juvenile alewife (ASMFC 2012). There is little information available on the habitat requirements for juvenile blueback herring; however, they tend to stay closer to surface waters for a longer period than alewife (Warinner et al. 1969). Both species migrate toward coastal waters in the fall (Warinner et al. 1969), or in some cases, the following spring (Dovel 1971). In Maine, juvenile alewife typically migrate to the ocean from mid-July through early December (Kircheis et al. 2004). Environmental conditions that encourage juvenile out-migration from nursery habitat include increased rainfall, rapidly declining water temperatures, and increased water levels (Kissil 1974, Richkus 1975).

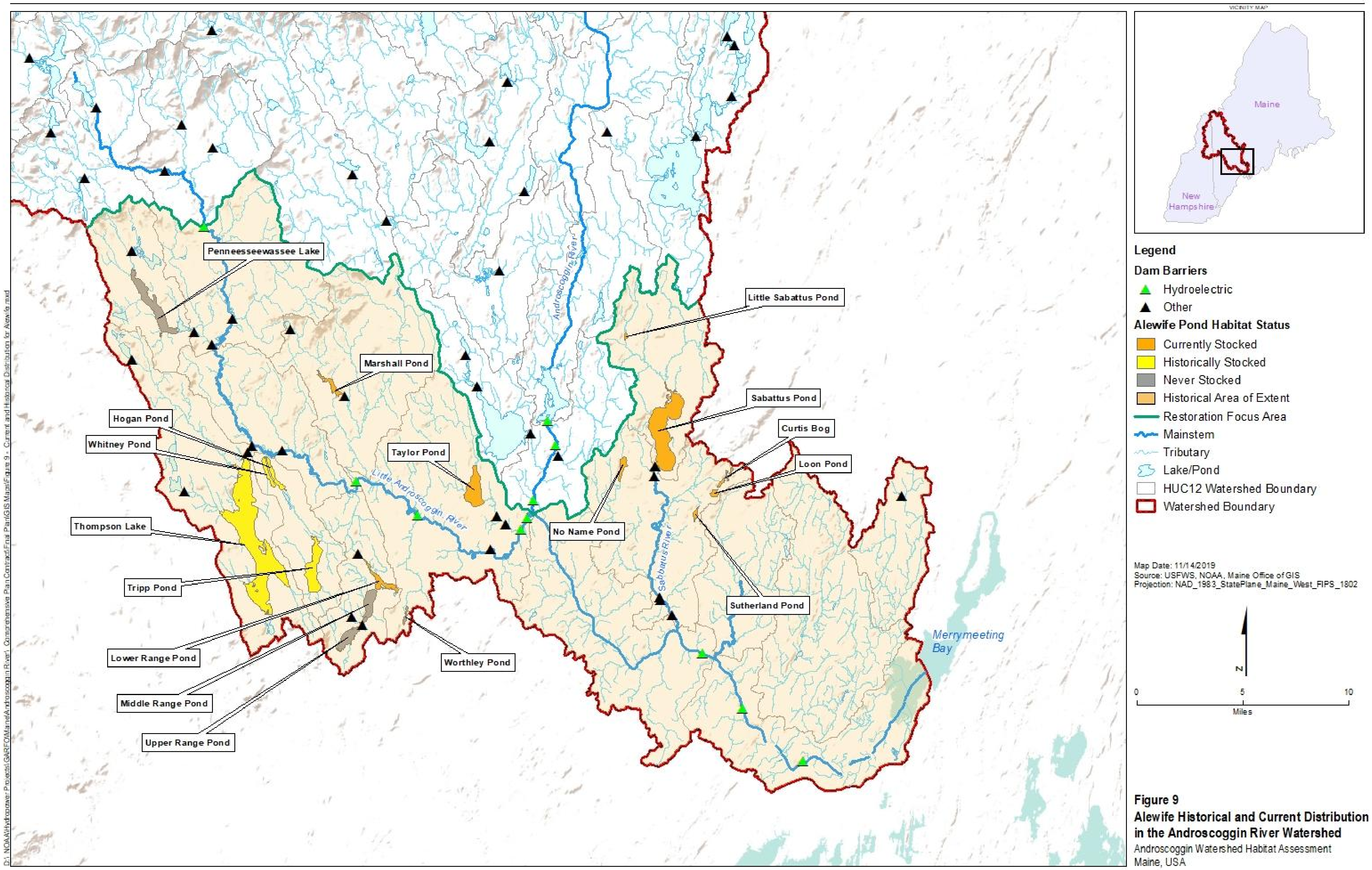


Figure 9
Alewife Historical and Current Distribution in the Androscoggin River Watershed
Androscoggin Watershed Habitat Assessment
Maine, USA

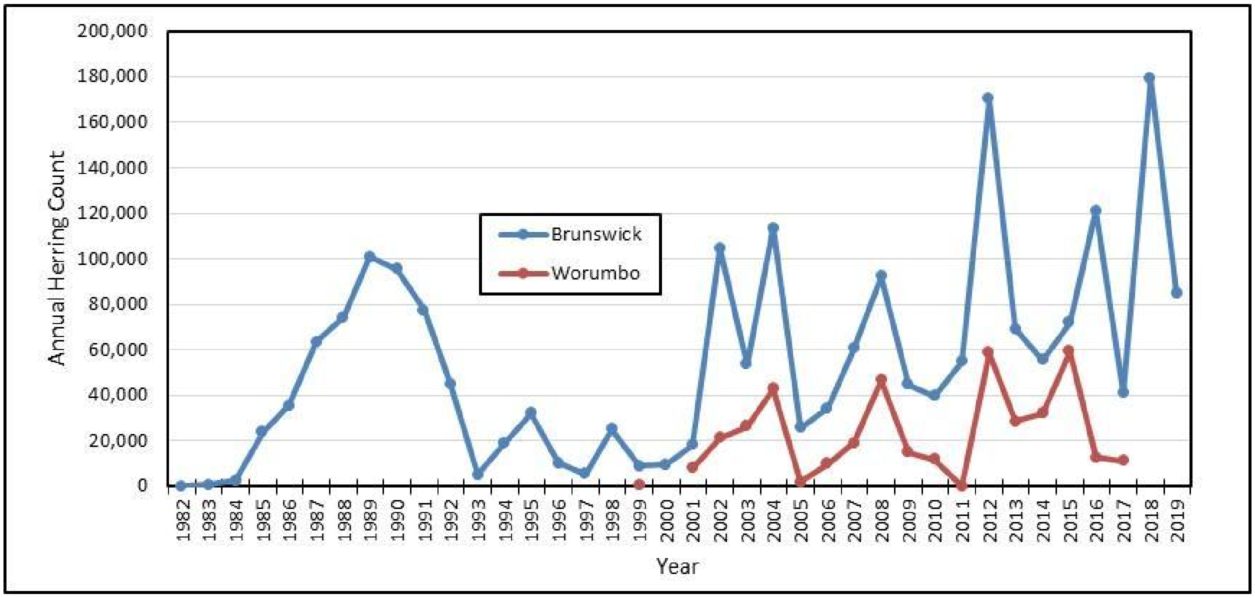


Figure 10. River herring passage counts at the Brunswick and Worumbo Projects.

6.2.4 Recreational Fishery and Stocking

The Maine river herring recreational fishery is active year-round and managed by MDMR. Individuals are limited to taking up to 25 river herring per day via hook and line or dip net and must have an appropriate Maine state fishing license or registration (MDMR 2012). Maine prohibits recreational fishing near fishways. Where municipalities have a lease for commercial harvest, harvest activities cease during a three days per week closure to allow herring migration to spawning habitat. Recreational fishing in municipal-leased waterways must also adhere to the annual harvest plan established by the municipality and approved by MDMR and ASMFC (MDMR 2012). Otherwise, recreational fishing in or upstream of a municipality that owns fishing rights to the waterway is prohibited (ASMFC 2012).

There are currently no hatcheries in Maine rearing juvenile herring (ASMFC 2012); however, the state stocks adult herring from more abundant populations in areas to restore populations with little or no abundance (Tables 6 and 7). To aid in the restoration of alewife in the Androscoggin River, MDMR stocked alewife in the lower mainstem Androscoggin in 1983, after the Brunswick fishway began operation (MDMR and MDIFW 2017). Fish numbers increased to almost 26,000 individuals by 1987. Continued monitoring of alewife in the fishway has reported alewife numbers of up to 170,000 individuals. The state stocks ponds at six fish per acre of pond habitat (Tables 6 and 7); however, this is dependent on the number of fish caught at the Brunswick fishway, which often does not allow stocking at this rate (MDMR and MDIFW 2017).

Table 6. Alewife stocking numbers for the eight water bodies currently stocked.

	Mainstem Androscoggin		Little Androscoggin			Sabattus		
Year	Brunswick Impoundment	Brunswick Tailrace	Taylor Pond	Lower Range Pond	Marshall Pond	No Name Pond	Little Sabattus Pond	Sabattus Pond
1983	243	–	2,202		312	–	–	2,117
1984	–	–	2,672	217	499	–	–	2,067
1985	–	–	2,560	1,505	504	–	–	17,714
1986	3,918	–	3,854	1,529	514	–	–	–
1987	13,674	–	3,908		635	–	–	–
1988	21,798	–	3,674	1,770	523	–	–	–
1989	28,363	–	3,907	1,827	1,920	–	–	–
1990	43,546	100	2,263	2,085	595	–	–	–
1991	10,477	750	4,149	1,727	657	–	–	–
1992	7,987	–	3,209	1,720	600	–	–	–
1993	756	54	1,025	914	617	–	–	–
1994	2,027	–	1,457	1,022	593	–	–	–
1995	19,850	55	1,688	1,670	1,595	–	–	–
1996	1,040	–	3,016	1,193	693	–	–	–
1997	3,954	–	–	–	–	–	–	–
1998	4,322	–	4,343	1,853	1,005	–	–	10,795
1999	–	–	993	–	–	–	–	4,679
2000	3,465	–	–	–	–	–	–	5,963
2001	13,375	42	126	1,318	612	–	344	1,575
2002	103,324	1,726	1,478	–	–	–	–	–
2003	26,074	1,726	4,182	1,033	–	735	137	10,519
2004	86,355	651	3,761	1,854	612	600	172	10,097
2005	7,589	702	–	–	–	–	–	–
2006	8,032	599	3,876	4,000	1,629	605	318	11,797
2007	33,344	60	8,000	3,700	1,500	1,590	1,700	22,558
2008	59,400	957	4,500	2,500	1,500	800	500	–
2009	20,759	–	4,517	1,968	1,150	544	585	11,444
2010	20,564	229	3,232	1,328	1,272	683	721	3,205
2011	25,737	66	4,319	1,493	1,527	555	753	12,263
2012	115,692	100,631	4,318	1,617	1,454	518	888	11,968
2013	38,369	201	4,521	1,552	1,327	558	1,034	12,450
2014	24,977	24,145	3,980	1,506	1,117	555	–	11,784
2015	27,638	547	4,560	2,186	1,500	1,000	1,000	12,746
2016	83,941	–	4,593	3,481	1,500	–	–	10,210
2017	16,035	3	4,500	2,076	979	874	1,100	13,384
2011-17 Total	332,389	125,593	30,791	13,911	9,404	4,060	4,775	84,805
Grand Total	876,625	133,244	109,383	50,644	28,941	9,617	9,252	199,335

Table 7. Alewife stocking numbers for the twelve water bodies not stocked since 2010.

	Mainstem Androscoggin			Little Androscoggin			Sabattus					
Year	**Pejepscot**	**Durham**	**Auburn**	**Taylor Stream**	**Thompson Lake**	**Hogan Pond**	**Sabattus River**	**Sutherland Pond**	**Loon Pond**	**Lisbon**	**Little River**	**Bog Brook**
1983	–	–		–	–	–	–	–	–	46	–	–
1984	–	–	74	–	–	–	–	–	–	–	–	–
1985	–	–	233	–	11,292	511	–	–	–	–	–	509
1986	–	–	519	–	6,033	510	–	–	–	–	–	515
1987	–	–	118	–	–	1,009	–	–	–	123	–	617
1988	21,510	–	–	–	–	1,008	–	–	–	–	–	603
1989	22,078	–	–	–	–	1,344	–	–	–	–	515	–
1990	34,224	–	–	–	–	1,103	–	–	–	–	509	390
1991	–	–	–	–	–	1,162	–	–	–	–	–	696
1992	–	–	–	–	–	1,062	–	–	–	–	–	690
1993	–	–	–	–	–	–	–	–	–	–	–	–
1994	–	–	–	–	–	2,186	1,333	–	–	–	–	500
1995	–	–	858	–	–	–	1,630	–	–	–	–	–
1996	–	736	–	–	–	–	2,359	–	–	–	–	403
1997	–	–	–	–	–	–	847	–	–	–	–	359
1998	–	–	–	–	–	–	1,613	–	505	–	–	789
1999	–	–	–	–	–	–	1,267	–	–	–	–	–
2000	–	–	–	–	–	–	–	–	–	–	–	–
2001	–	13	–	–	–	–	–	–	–	–	–	671
2002	–	–	–	–	–	–	–	516	–	–	–	–
2003	–	–	–	–	–	–	1,953	–	–	–	–	518
2004	200	–	–	–	–	–	3,112	–	–	–	–	690
2005	–	–	–	–	–	–	–	–	–	–	–	–
2006	–	–	–	–	–	–	1,498	–	–	–	–	1,000
2007	–	–	–	100	–	–	4,064	–	–	–	–	908
2008	–	–	–	100	–	–	14,000	–	–	–	–	800
2009	–	–	–	–	–	–	1,853	–	–	–	–	–
2010	–	–	–	–	–	–	1,360	–	–	–	–	–
Total	78,012	749	1,802	200	17,325	9,895	36,889	516	505	169	1,024	10,658

6.2.5 Competition, Predation, and Interaction with Inland Fishery

River herring primarily feed on zooplankton, such as copepods, amphipods, and shrimp during each life stage, though adults migrating to fresh water to spawn reduce their feeding habits (Collette and Klein-MacPhee 2002, Greene et al. 2009). Anadromous alewives exhibit size-selective predation on zooplankton that seasonally affect zooplankton community structure, while landlocked alewives have phenotypic variations that do not produce the same communal zooplankton shifts (Palkovac and Post 2009). Alewives also feed on other fish larvae including eels, other herring, their own young, and fish eggs (Collette and Klein-MacPhee 2002). Larval stage river herring feed on smaller zooplankton species than adults, with the size of their food source increasing as they develop. Both species show some prey selectivity in the larval stage (Pardue 1983).

River herring may compete with resident freshwater species for food and spawning habitat, but the potential for interspecies competition is unknown. Most investigations regarding interspecies competition relate to landlocked populations of alewives. The Maine Division of Inland Fisheries and Wildlife (MDIFW) noted the potential for alewives to compete with rainbow smelt in landlocked situations, which would pose a problem for recreational fishing since smelt are the primary food source for landlocked Atlantic salmon, brown trout (*Salmo trutta*), and lake trout (*Salvelinus namaycush*) (Kircheis et al. 2004). Rainbow smelt diet could also change under the presence of alewife to reduce forage competition (Kircheis et al. 2004). Anecdotal information about interspecies competition arose in the 1990s. Some suggested that reintroduced alewife affected the food availability for popular recreational species such as smallmouth bass. In 1995, the state closed the fishways on the St. Croix River to river herring in response to concerned anglers resulting in an alewife population collapse. One study examined the connection between alewife population growth and smallmouth bass decline in a Maine Lake in the St. Croix River Watershed (Willis 2006). Results of the study suggested the presence of alewife did not slow smallmouth bass growth, and diets between the two species did not overlap (Willis 2006).

River herring are a source of prey for many fish and wildlife, including predatory game fish, mammals, and birds of prey (MDMR 2017c). Striped bass are an important predator of river herring and may influence their population size. In Connecticut, the striped bass population size has increased and that has been attributed to a decline in river herring numbers (Savoy and Crecco 2004), resulting in the closure of the anadromous river herring fishery (CTDEEP 2017). River herring historically contributed to the diets of commercially important fish such as Atlantic cod (Ames 2004, Ames and Lichter 2013). The spring and fall migrations contributed a significant food source to the coastal system (Hall et al. 2012). Restoration of river herring to coastal rivers has the potential to support the sustainability of these fisheries (McDermott et al. 2015).

River herring have a variety of connections to other species in the stream community beyond predation and forage. The alewife floater (*Anodonta implicata*) is a freshwater mussel dependent on alewife for larval transportation (Davenport and Warmuth 1965). Populations of alewife floater have increased in numbers and range due to improved fish passage (Smith 1985). In the absence of river herring, Atlantic salmon smolts are more susceptible to predatory fish such as striped bass, which adversely affects the Atlantic salmon population (Blackwell and Juanes 1998, Grout 2006). Alewife presence may alter water quality in lakes and ponds over a long-term scale since the planktivorous fish consume lake-based nutrients in their food source and export nutrients as they migrate to the ocean (Kircheis et al. 2004, MDMR 2017c). In one lake study, total phosphorus concentrations decreased during the presence of alewives and subsequently rebounded after alewives left the system (Kircheis et al. 2004).

6.2.6 Previous and Current Management/Monitoring Actions for River Herring

The Androscoggin River Watershed historically produced a river herring harvest, but this was not the primary source of commercial harvest in Maine. Other watersheds, including the Penobscot, Sheepscot, Damariscotta, Medomak, and St. George watersheds, were larger stock contributors to the overall state commercial landings of river herring (Hall et al. 2012). Maine river herring harvests have declined since the 1950s associated with declining adult returns (ASMFC 2012). Several factors including stream barriers, habitat reduction, and predation caused the harvest decline (ASMFC 2012).

In 2011, ASMFC approved fisheries management plans for harvesting river herring in Maine administered by MDMR and associated state municipalities (ASMFC 2012). The current harvest plan requires municipalities to close the river herring fishery three days per week to allow herring migration to spawning grounds. Municipalities submit an annual sustainable harvest plan to MDMR with subsequent approval by ASMFC. In 2011, there were 22 municipal permits for river herring harvest in Maine watersheds. Other municipalities closed their waterways to river herring harvest to allow for conservation and to prevent overexploitation (ASMFC 2012). There is currently no commercial fishery within the Androscoggin River Watershed except for occasional gillnetting in the estuary.

Maine’s current management program for river herring focuses on repopulating both species in rivers where their numbers are declining or extirpated. Efforts include creating access to upstream spawning habitat via dam removal or fish passage installation, developing trap and haul programs for streams that do not currently have fish passage, and stocking alewife and blueback herring to supplement wild populations (ASMFC 2012). Restoration and management efforts have taken place in multiple watersheds including the Androscoggin, Kennebec, and Saco Rivers. In 1983, MDMR developed the Androscoggin River anadromous fish restoration program, which focuses on restoring habitat and fish communities, with an initial focus on river herring and American shad (MDMR 2016b). Project goals include:

- Increase the river herring population in historical spawning and nursery grounds.
- Conserve the present native fish community in support of river herring.
- Characterize the river herring migratory pathway in the Androscoggin River Watershed.
- Evaluate river herring reproduction.
- Improve habitat accessibility.
- Increase public awareness of the restoration program.

Maine completes juvenile population surveys in coastal rivers, with three survey stations occurring in the Androscoggin estuary (ASMFC 2012). ASMFC drafted an interstate fishery management plan for shad and river herring that includes management by the state of Maine (ASMFC 2009b). The goal of the plan is to protect, enhance, and restore migratory spawning stocks to sustainable levels.

The National Resources Defense Council petitioned NOAA Fisheries in 2011 to list alewife and blueback herring as endangered species under the Endangered Species Act (ESA) throughout all or part of their range. In 2013, NOAA Fisheries completed a status review and determined that listing alewife and blueback herring under the ESA was not warranted. As part of the determination, the agency would re-evaluate the listing determination within five years. Interim to the re-evaluation, NOAA Fisheries established the River Herring Technical Expert Working Group (TEWG). The TEWG consisted of scientists, industry representatives, conservation groups, tribal leaders, and government officials with expertise in river herring conservation. Members of the TEWG provided information to support the development of the 2015 River Herring Conservation Plan. NOAA Fisheries issued a new listing determination in June 2019 that indicated listing of these species was not warranted at that time. The TEWG continues to act as an information exchange forum in collaboration with the ASFMC.

6.2.7 Potential Blueback Herring Habitat Availability

Blueback herring historically had abundant habitat in the Androscoggin River Watershed (Figure 7). Geospatial analysis of drainage areas meeting the 10 square mile threshold show that the mainstem of the Androscoggin, Little Androscoggin, and Sabattus Rivers and portions of their tributaries are potential blueback herring habitat with 27.94, 71.68, and 25.06 potential stream miles, respectively (Figure 11). With the exception of the mainstem of the Androscoggin River and a short reach of the Little River, this historical habitat is currently unoccupied and inaccessible by blueback herring.

6.2.8 Potential Alewife Habitat Availability

Alewife were historically abundant in the Androscoggin River Watershed. Currently, alewife occupy 12.8 percent of the potential spawning habitat through the stocking program (Figure 9). Alewife do not have volitional access to any spawning habitat except for the Little River, Cathance River, and Denham Stream HUC12 sub-watersheds. The state of Maine will likely continue the restoration approach for alewife with stocking of select ponds until fish passage installation or removal of downstream barriers.

6.3 AMERICAN EEL

6.3.1 Biological Characteristics of American Eel

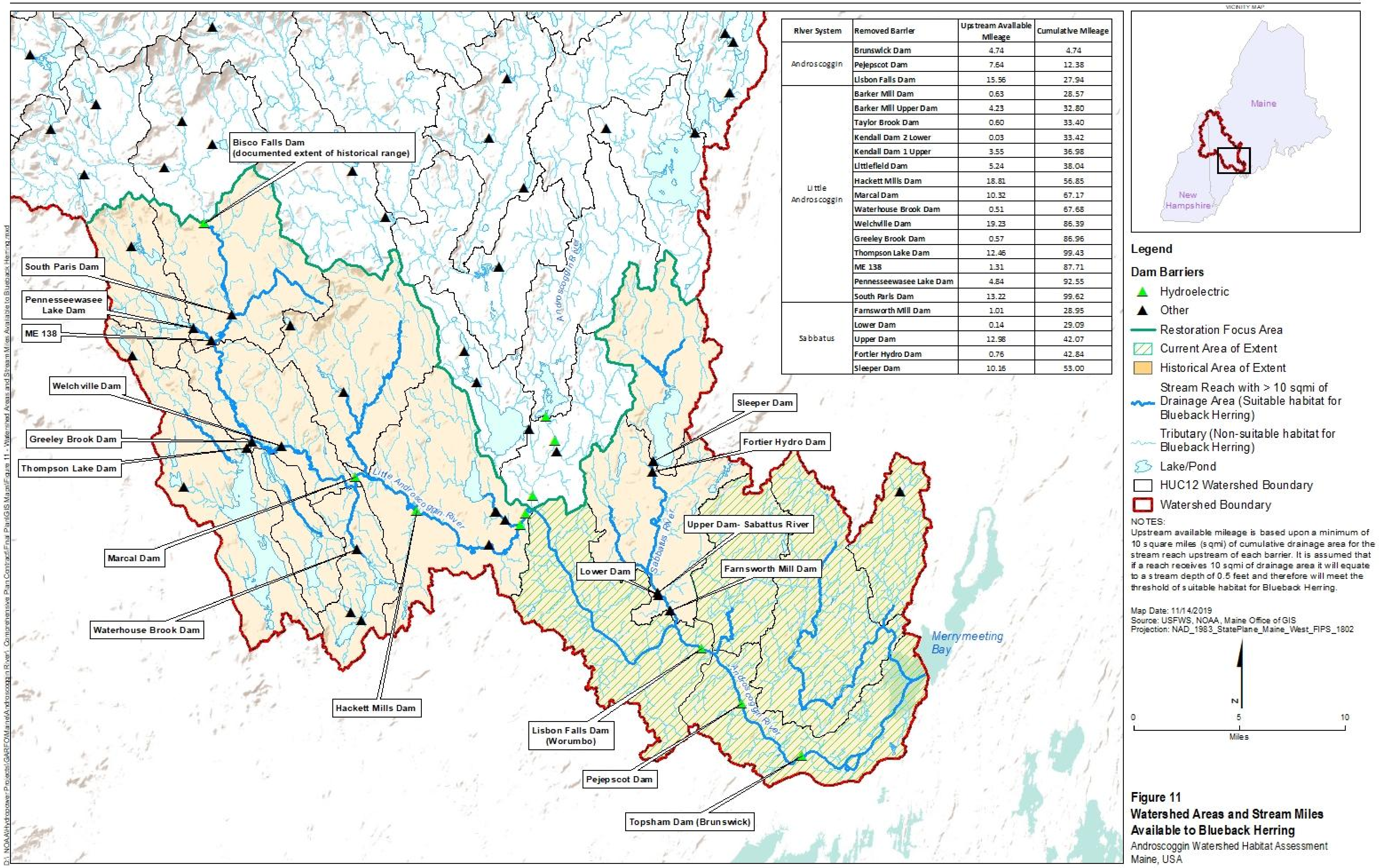
The American eel is a catadromous species that enters coastal rivers as juveniles and matures in freshwater habitat. Juveniles and adult yellow phase eels use estuarine, pond, lake, wetland, and marsh habitats. Eels can live for up to 30 years in Maine waterbodies. American eel exist throughout much of the Androscoggin River Watershed; however, numerous dams impede access. In particular, silver phase emigrating adult eels face a perilous journey past multiple hydroelectric projects before reaching the Merrymeeting Bay.

The following section will describe the distribution of American eel and their habitat requirements, as well as the fishery status, eel interactions with other aquatic species, and historical and current management and monitoring efforts. The information presented in this section will focus on the specific Androscoggin River Watershed American eel populations, to the extent that data are available.

6.3.2 Historical and Current Distribution

American eel were historically present in large numbers in East Coast streams, contributing up to 25 percent of the total fish biomass in many rivers; however, eel abundance has declined largely since the 1970s, with further decline in the 1980s and 1990s. The decline was primarily a result of decreases in habitat accessibility and quality, overfishing, restricted river access, and climate change (Shepard 2015).

Dams that impede or block upstream passage and hydroelectric facilities that cause high mortality during emigration caused the decline of American eel abundance and distribution in the Androscoggin River Watershed. Most facilities do not have designated eel passage; however, eel are present throughout the watershed (Figure 12). In Maine, biologists have been monitoring upstream passage of eel for over a decade. Surveys conducted in the Kennebec and Androscoggin Rivers above Merrymeeting Bay found that the largest density of American eels on the Androscoggin River occurred below the Brunswick Dam (Kennebec Estuary Land Trust 2010). Although there is no specific design provision for upstream eel passage at the head of tide



River System	Removed Barrier	Upstream Available Mileage	Cumulative Mileage
Androscoggin	Brunswick Dam	4.74	4.74
	Pejepscot Dam	7.64	12.38
	Lisbon Falls Dam	15.56	27.94
Little Androscoggin	Barker Mill Dam	0.63	28.57
	Barker Mill Upper Dam	4.23	32.80
	Taylor Brook Dam	0.60	33.40
	Kendall Dam 2 Lower	0.03	33.42
	Kendall Dam 1 Upper	3.55	36.98
	Littlefield Dam	5.24	38.04
	Hackett Mills Dam	18.81	56.85
	Marcal Dam	10.32	67.17
	Waterhouse Brook Dam	0.51	67.68
	Welchville Dam	19.23	86.39
	Greeley Brook Dam	0.57	86.96
	Thompson Lake Dam	12.46	99.43
	ME 138	1.31	87.71
	Pennesseewasee Lake Dam	4.84	92.55
	South Paris Dam	13.22	99.62
Sabbatus	Farnsworth Mill Dam	1.01	28.95
	Lower Dam	0.14	29.09
	Upper Dam	12.98	42.07
	Fortier Hydro Dam	0.76	42.84
	Sleeper Dam	10.16	53.00

Figure 11
Watershed Areas and Stream Miles Available to Blueback Herring
Androscoggin Watershed Habitat Assessment
Maine, USA

Brunswick dam, some limited migration occurs (Yoder et al. 2006). Certain barriers upstream of Brunswick present more of an impediment to eel passage than others do.

Recent surveys observed a limited number of eels above Lewiston with none seen above the Gulf Island Dam (Yoder et al. 2006, as cited in Kennebec Estuary Land Trust 2010). Timing of upstream movement in nearby watersheds typically occurs between mid-May and September, with peak movement in late June and July triggered by water temperature and lower water flows later in the year (Shepard 2015).

6.3.3 Habitat Requirements

American eel exist in freshwater, estuarine, and coastal waters from the southernmost tip of Greenland to Brazil. Eel spawn and eggs hatch in the Sargasso Sea and ocean currents transport the larval eel to the North American coast. From the larval stage, eels transform into glass eels and enter coastal waters to migrate upstream. Glass eels utilize habitats of varying salinity, including fresh, brackish, and marine waters, to grow into yellow eels. Yellow eels can grow up to 30 years, reaching reproductive maturity at the silver eel life stage.

Silver American eels leave continental waters in the late summer and fall to undertake a migration to their Sargasso Sea spawning grounds. The spawning migration occurs in August through October in the northern portions of the range and from October to December in the Mid-Atlantic States and may continue until March in the southern United States. Their extensive geographic dispersal and migration distances make American eel difficult to study (Shepard 2015).

Within the Androscoggin River Watershed, glass and yellow eels likely utilize a variety of productive habitats for growth and development. For glass eels, substrate quality and water flow may be important parameters for habitat selection, as they burrow during the day in between movements upstream at night (ASMFC 2013).

6.3.4 Fishery and Stocking

American eels occupy a significant and unique niche in the Atlantic coastal reaches and tributaries. Their life history and biology affords great flexibility in habitat use and diet. The American eel fishery primarily targets yellow stage eel. Silver eels are caught during their fall migration as well. Eel pots are the most typical gear used; however, fishermen also use weirs, fyke nets, and other fishing methods. Glass eel harvesting is prohibited along the Atlantic coast except in Maine and South Carolina. In recent years, Maine is the only state reporting significant glass eel and elver harvest. Although yellow eels were historically a source of food, today’s fishery sells yellow eels primarily as bait for recreational fisheries. Markets in Asia import glass eels to serve as seed stock for aquaculture facilities.

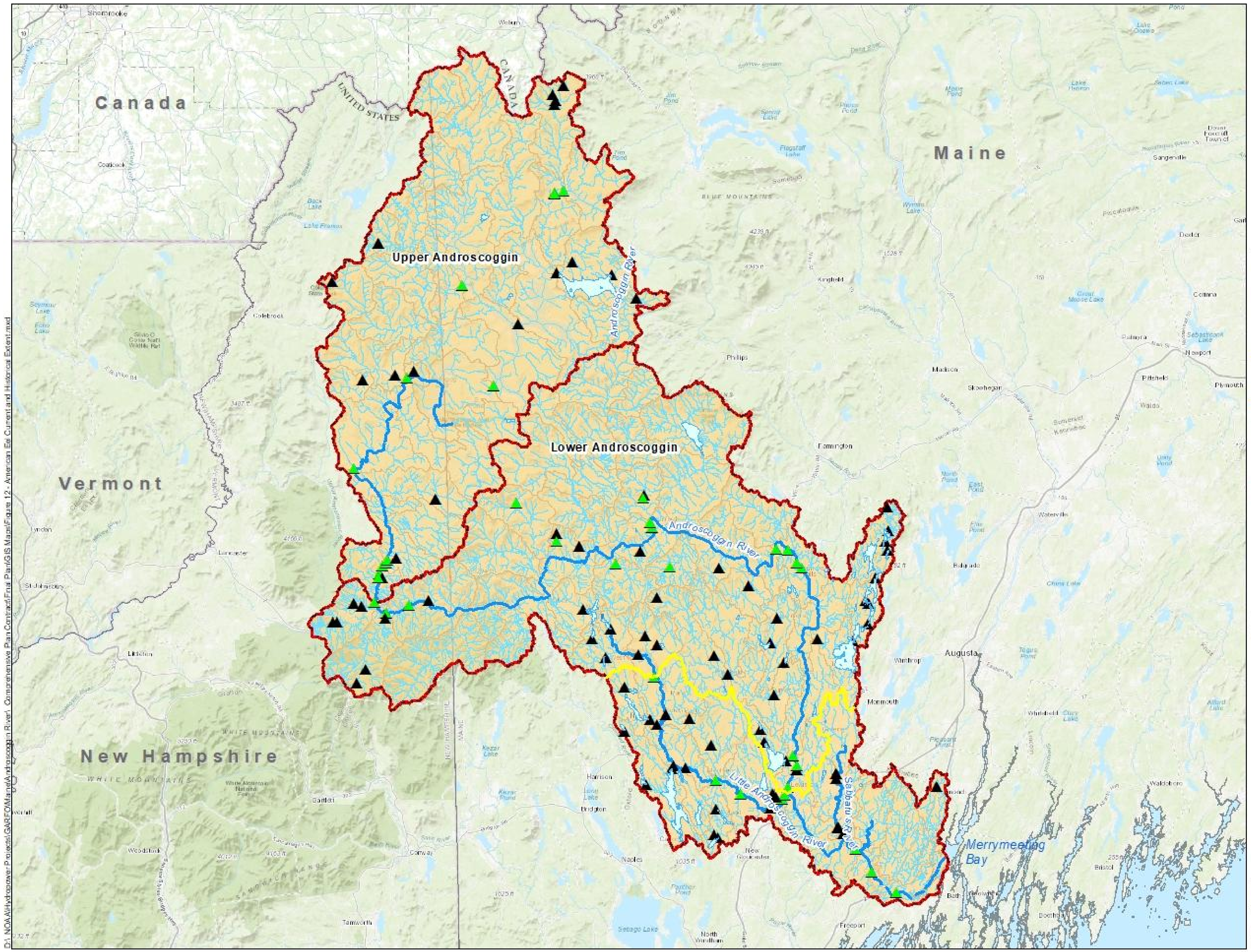
Commercial landings of yellow and silver American eels peaked in the 1970s and 1980s and have since declined. Harvesting of glass eel is currently subject to coastwide harvest moratoria, except in Maine and South Carolina where populations are lower than historically observed, but higher than other coastal states (ASMFC 2000). Due to the population-wide decline of American eel, ASMFC enacted a Fishery Management Plan (FMP) in 1999, with addenda in 2008 and 2013 (ASMFC 2000, 2008, 2013). The commercial eel fishery primarily targets the yellow eel stage. Currently, the glass eel fishery harvest has increased as the market price has risen to $2,000 per pound. Yellow eel harvesters typically use these fish as bait for various recreational fisheries. The average commercial value of eel landings in the United States has varied from less than $100,000 to a peak of over 6 million dollars in the late 1990s, followed by declining value again in the early 2000s (ASMFC 2013). A goal of the most recent FMP addendum is to increase the accuracy of fishery surveys throughout the Atlantic states. To increase accuracy of reporting, states with a commercial yellow eel fishery will be required to implement a trip level reporting system for both dealer and harvester reporting. Dealer and harvester landing catches must submit reports to the state of landing monthly or more frequently, if possible. In addition, states should continue to collect biological data per the specifications in the FMP and continue to report on the estimated percentage of harvest going to food and harvest used as bait (ASMFC 2013).

Most of the recreational harvest of American eel results from incidental take when anglers are targeting other species. There has been a declining trend in the recreational catch of eel since the 1990s. In 2007, NOAA Fisheries estimates a recreational catch of 57,986 American eel coast-wide, with approximately 59 percent released alive by anglers.

The state of Maine does not stock American eel in coastal rivers.

6.3.5 Competition, Predation, and Species Interaction

American eel are an important ecological resource, serving as prey species for many fishes, mammals, and birds. Predation on American eel likely comes from many larger native and non-native fishes in the Androscoggin including bass, carp and northern pike. Information on specific competitor species for American eel is limited; however, American eel may have the potential for competition from other fish species of a comparable size that utilize similar habitats and forage on the same prey sources. The most critical species affecting American eel is a swim bladder nematode, *Anguillicoloides crassus*, an eel parasite (GOM Council 2007). This invasive species,native to Southeast Asia, was released from a Texas aquaculture facility in the mid-1990s, reaching Maine watersheds in 2006. The parasite causes a variety of health problems in American eel and can negatively affect migrating silver eels.



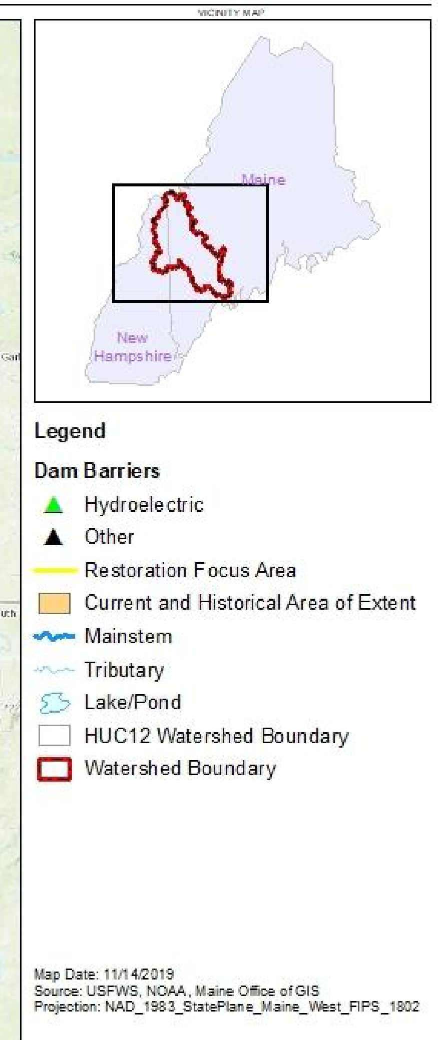


Figure 12
American Eel Current and Historical Distribution in the Androscoggin River Watershed
Androscoggin Watershed Habitat Assessment
Maine, USA

Climate change is another key stressor to the American eel population; climate changes may affect American eel spawning success, larval growth and survival, or the transport of larvae to continental habitats by changing ocean currents (Shepard 2015). Spawning and juvenile growth may be particularly susceptible to climate change since they are dependent on riverine and marine habitats.

6.3.6 Previous and Current Management/Monitoring Actions for American Eel

American eel numbers are substantially less than in the past, largely due to historical overfishing, habitat alteration, food web changes, habitat restriction, and predation. A 2012 Benchmark Stock Assessment concluded that the American eel population in U.S. waters is at historically low levels and near depleted (ASMFC 2013). Eel abundance had declined from historical levels but remained relatively stable until the 1970s. More recently, fishermen, resource managers, and scientists postulated a further decline in abundance based on harvest information and available assessment data. This resulted in the development of the Commission's FMP for American eel (ASMFC 2000), with three subsequent amendments (ASMFC 2008, 2013, 2014). The FMP required that all states maintain increased conservative management measures and implement a 50 fish per day bag limit for the recreational fishery. Although recreational take is low, the 2013 FMP addendum recommended recreational fishery management measures to reduce the chance of excessive recreational harvest. These included a minimum size regulation of 9 inches and a recreational bag limit of 25 fish per day per angler (ASMFC 2013).

The ASMFC Addendum III to the American eel FMP included a range of options for managing the commercial glass, yellow and silver eel fisheries, as well as the recreational fishery (ASMFC 2013). Measures included decreasing the tolerance for harvest in pigmented eels, minimum size and mesh requirements for yellow eel harvest, and seasonal closure restrictions for silver eel. As the second phase of management in response to the 2012 stock assessment, the goal of Addendum IV is to continue to reduce overall mortality and increase overall conservation of American eel stocks with additional regulatory measures (ASMFC 2014). This Addendum addresses the commercial glass, yellow, and silver eel fisheries.

Future efforts such as understanding habitat requirements for American eels, engaging the relevant regulatory agencies to increase or improve upstream and downstream passage, and encouraging habitat restoration will help meet the goal of reducing mortality on all life stages (ASMFC 2014). In addition, monitoring programs would facilitate the collection of data for evaluating the annual health of the eel stock, as well as to provide both statistically valid and scientifically rigorous information for stock assessment analysis (ASMFC 2014).

6.3.7 Potential American Eel Habitat Availability

American eel can occupy and thrive in diverse habitat types. Therefore, increased accessibility throughout the Androscoggin River Watershed will likely lead to higher population abundances.

6.4 SEA LAMPREY

6.4.1 Biological Characteristics of Sea Lamprey

The sea lamprey is an anadromous, migratory species with a present range extending from the St. Lawrence River in Canada to the St. Johns River in Florida on the United States' eastern shoreline (Page and Burr 2011). Sea lamprey spend most of their life cycle in freshwater streams, with young lamprey, or ammocoetes, living for up to 5 years in streams before developing into juvenile lamprey and migrating into the ocean (Werner 2004). Adults return to freshwater streams the following spring to spawn. As a semelparous species, sea lamprey die after spawning is complete. This section will describe the distribution of sea lamprey and their habitat requirements, as well as the fishery status, lamprey interactions with other aquatic species, and historical and current management and monitoring efforts. The information presented in this section will focus on the specific Androscoggin River Watershed sea lamprey populations, to the extent that data are available.

6.4.2 Historical and Current Distribution

Historical information on sea lamprey abundance in the Androscoggin River Watershed and for the state of Maine is minimal (Saunders et al. 2006). The historical distribution of sea lamprey likely extended to Snow Falls in the Little Androscoggin River and to Rumford Falls in the mainstem Androscoggin River (Figure 13). Although sea lamprey have many of the same unique swimming characteristics as American eel and suction of their mouths, as semelparous species that survive on energy reserves during immigration, they do not have the time to immigrate that eel do. Therefore, it is unlikely that immigration past Lewiston Falls occurred with great frequency.

Sea lamprey have been observed entering the Brunswick fishway, but the numbers of individuals entering were low (0–28 individuals per year) until 2012, when numbers started to increase (19–240 individuals per year) (MDMR and MDIFW 2017). Currently, sea lamprey occupy the Androscoggin River up to Lewiston Falls in the mainstem. The extent of distribution among the tributaries of the mainstem is unknown (MDMR and MDIFW 2017).

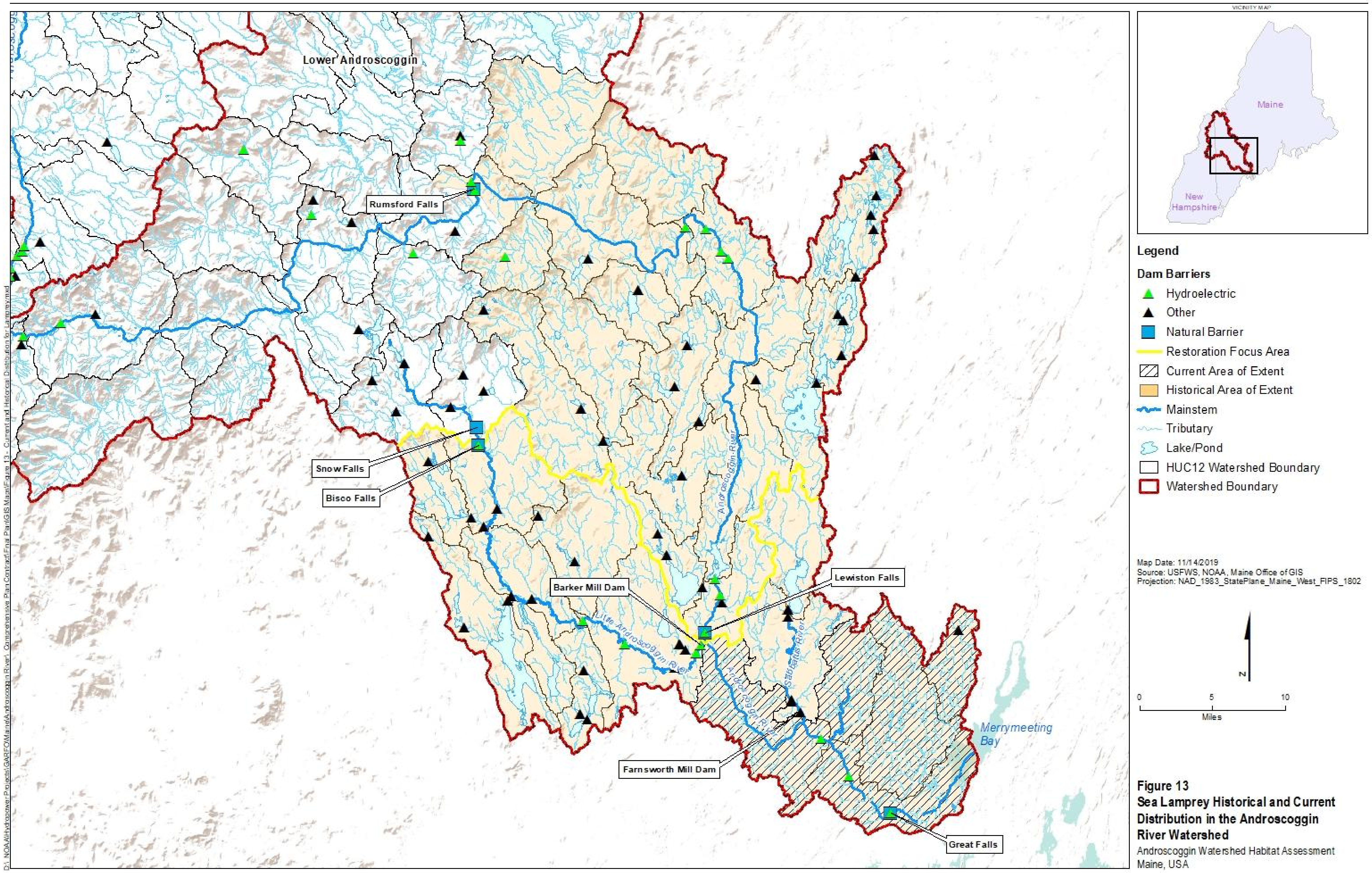


Figure 13
Sea Lamprey Historical and Current Distribution in the Androscoggin River Watershed
Androscoggin Watershed Habitat Assessment
Maine, USA

6.4.3 Habitat Requirements

Sea lampreys require a variety of stream substrates and water flow rates for successful recruitment and survival to adulthood. Adult lamprey need a gravelly bottom substrate in rapidly flowing shallow water for constructing their spawning redds (Collette and Klein-MacPhee 2002, Maitland 2003). Small amounts of sand are also needed in redds for egg adhesion (Applegate 1950). When gravel is not available for redd construction, lamprey can utilize other materials, including shells, lumps of clay, and rubble (Morman et al. 1980, as cited in Maitland 2003). Adequate stream flow over redds is required for successful spawning; however, currents that are too swift can result in disrupted mating and eggs being disbursed downstream. Ammocoetes require a muddy or sandy bottom in still or running water for burrowing and filter feeding (Maitland 2003). Ammocoetes are commonly found in stream velocities averaging from 0.2 to 0.3 meter per second (Thomas 1962, as cited in Maitland 2003), but can also occur in areas away from the main current in very slow or reverse flowing waters (Maitland 2003). Stream velocities exceeding 0.8 meter per second are too fast for ammocoetes to burrow (Thomas 1962, as cited in Maitland 2003). Sea lampreys are present in streams of all sizes (Morman et al. 1980, as cited in Maitland 2003).

Sea lampreys are anadromous, where adults enter freshwater streams for spawning, the young develop in fresh water habitat, and the juveniles migrate to salt water. Migrating adult lampreys can travel upwards of 200 miles to reach spawning grounds (Collette and Klein-MacPhee 2002). Stream barriers, such as dams and waterfalls, are impassable to sea lamprey and can limit the distance and habitat used by lamprey for migratory pathways and spawning. Some low-gradient waterfalls can be passed by lampreys (Collette and Klein-MacPhee 2002), where they cling to the rocky bottom substrate and rest in between upstream movement. The increase of barriers, such as dams, and reduced water quality, resulted in a decline in sea lamprey populations and limitations on access to preferred spawning grounds (Lucas et al. 2009, Lasne et al. 2015).

Juvenile lamprey are not strong swimmers and depend heavily on adequate stream flow to migrate upstream and downstream (Kircheis et al. 2004). Juvenile emigration to the ocean occurs in the fall during rain events since the precipitation increases flow, and thus emigration rates. During droughts, juveniles may delay or halt migration depending on water temperature and other impediments and will resume their movement in the spring (Kircheis et al. 2004). Habitat with fluctuating seasonal streamflow is essential for adult sea lamprey immigration and juvenile emigration.

Sea lamprey require specific water quality parameters for successful spawning, recruitment, and survival, and are typically not tolerant of heavily polluted habitats. Water temperatures needed for successful sea lamprey spawning range from 11 to 25 °C (Maitland 2003). For successful egg hatching, water temperatures in the stream must range between 15 and

25 °C (Maitland 2003). Ammocoetes tolerate low levels of dissolved oxygen, even anoxic conditions for a few hours, when burrowed in the substrate (Hill and Potter 1970, Potter et al. 1970). Both juvenile and adult sea lampreys cannot tolerate significant levels of pollution, which can cause extirpation in stream reaches (Maitland 2003). Pollution barriers can prevent adults from migrating upstream and be detrimental to juvenile migrating downstream. In streams with lower levels of pollution, adults can tolerate downstream low-level pollutants if the upstream waters and spawning area are clean (Maitland 2003).

6.4.4 Recreational Fishery and Stocking

There is little to no recreational fishery for sea lamprey in Maine (Kircheis et al. 2004). They are difficult to catch with traditional fishing methods (Collette and Klein-MacPhee 2002). Commercial harvest of sea lamprey has occurred in Maine for medical and biological research. During the 1970s and 1980s, researchers caught several thousand sea lampreys from the Sheepscot River (Kircheis et al. 2004). Currently, there are three companies that can harvest sea lamprey in Maine, all three of which harvest either ammocoetes or adult lamprey for biological and medical research.

There is no known record of sea lamprey stocking in the Androscoggin River Watershed (MDMR and MDIFW 2017).

6.4.5 Competition, Predation, and Interaction with Inland Fishery

Ammocoetes burrow in the mud and filter feed on algae and plankton (Kircheis et al. 2004). Adult sea lamprey are parasitic, where they acquire their food source from a fish host without usually killing it. Typical interaction between a sea lamprey and host fish involves the lamprey attaching to the fish with its suction-like mouth and consuming fluids and tissue through a buccal funnel with circular lines of sharp teeth. This action will leave the fish with a wound and scar that generally heals if the number of lampreys feeding on a single host is minimal and the host is in good health (Kircheis et al. 2004). Sea lamprey use a variety of host animals for feeding, including alewife, blueback herring, American eel, American shad, sturgeon (*Acipenser* spp.), Atlantic salmon, as well as other lampreys. Juvenile sea lamprey attach and feed on freshwater fish hosts. Juvenile have a brief period of attachment to a host fish, which reduces the chance of host mortality. Adult sea lamprey digestive tracts stop functioning upon returning to freshwater rivers to spawn and do not feed in fresh water (Kircheis et al. 2004).

Sea lampreys are a source of food for both freshwater and marine aquatic species. Lamprey eggs are a prey source for some minnow species (Scott and Crossman 1973), and possibly other fish species including common shiner (*Luxilus cornutus*), fallfish (*Semotilus corporalis*), and American eel (Kircheis et al. 2004). Ammocoetes are a prey item for other fish species and birds (Maitland 2003). Juveniles are a source of prey for many aquatic species including striped bass (Kircheis et al. 2004). Both striped bass and other large predators feed on adult sea lamprey. Freshwater fish known to prey on sea lamprey include brown trout, northern pike, and walleye (*Sander vitreus*) (Kircheis et al. 2004). Birds of prey and some mammals, such as raccoons and otters, will also feed on adult lamprey.

Sea lamprey mating behavior and life history provide beneficial interactions to aquatic species in upstream freshwater habitats. As a semelparous species, sea lamprey play a key role in providing marine-derived nutrients to upstream environments. The deposition of nutrients from dead adult lamprey nourish juveniles of other species, such as the Atlantic salmon, and act as a source to primary production and the trophic structure of the local environment for months (Saunders et al. 2006). Sea lamprey mating behavior involves manipulating the streambed, which can restore and enhance stream substrate and improve water flow through the recently disrupted substrate. Bioturbation by sea lamprey when assembling nests improves stream quality through modification of embeddedness, the presence of microhabitats, find sediment cover, and the benthic macroinvertebrate community (Hogg et al. 2014). Aquatic species such as minnows and salmonids will use lamprey nests after the spawning period is complete (Kircheis et al. 2004).

6.4.6 Previous and Current Management/Monitoring Actions for Sea Lamprey

MDMR and MDIFW have developed management goals for diadromous fishes in the Androscoggin River Watershed (MDMR and MDIFW 2017). The overall goal is to help restore and guide diadromous fish management while maintaining balance with local fisheries. For sea lamprey, fisheries and spawning habitat management will occur in the Androscoggin River estuary, and fisheries management will occur in the Androscoggin River up to Lewiston Falls and in the Little Androscoggin River.

Federal and state agencies in the northeast United States are developing sea lamprey stocking programs, population assessments, and habitat restoration programs in some rivers. Recent efforts by multiple agencies have resulted in the development of a sea lamprey restoration program under the Connecticut River Atlantic Salmon Commission. A recent survey on the Jeremy River in Connecticut, which had a dam removed in 2016 opening 17 miles of habitat to anadromous fish (Marteka 2016), found sea lamprey nests present in the newly accessible habitat (Williams 2017). In 2016, the Fisheries Division of Connecticut Department of Energy and Environmental Protection stocked 45 lamprey in the Pequabuck River and 50 lamprey in the Pequonnock River as part of a lamprey restoration effort (CTDEEP 2016). Restoration of sea lamprey runs occurred in the Naugatuck River in Connecticut by transplanting pre-spawned lamprey into the newly accessible habitat (Williams 2017). Sea lamprey were observed using habitat in the Sedgeunkedunk Stream, a tributary to the Penobscot River in Maine, within days of a dam removal (Hogg et al. 2013).

6.4.7 Potential Sea Lamprey Habitat Availability

Sea lamprey can occupy and thrive in diverse substrates. Therefore, increased accessibility throughout much of the Androscoggin River Watershed will likely lead to higher population abundances. The mainstem of the Androscoggin downstream from Rumford Falls, Little Androscoggin downstream from Snow Falls, Sabattus, and Little Rivers are all potential sea lamprey habitat.

6.5 ATLANTIC SALMON

6.5.1 Biological Characteristics of Atlantic Salmon

Atlantic salmon is an anadromous, migratory species with a present range extending from Labrador to Long Island Sound (NOAA 2015). Atlantic salmon spend most of their lives in pelagic marine waters and only enter coastal tributaries and rivers to spawn. This section will describe the distribution of Atlantic salmon and their habitat requirements, as well as the fishery status, interactions with other aquatic species, and historical and current management and monitoring efforts. The information presented in this section will focus on the specific Androscoggin Watershed Atlantic salmon populations, to the extent that data are available.

6.5.2 Historical and Current Distribution

The Androscoggin River Watershed served as historical spawning grounds and migratory corridors for Atlantic salmon (Foster and Atkins 1867). In the mainstem Androscoggin River, salmon would migrate up to Rumford Falls, a natural barrier to further migration (MDMR and MDIFW 2017). Salmon would also enter the Little Androscoggin, with Snows Falls acting as a natural barrier to further upstream movement. The Sabattus and Little Rivers, both tributaries to the Androscoggin River, also supported a historical population of Atlantic salmon, which used the rivers as migratory pathways (Figure 14). Atlantic salmon spawning habitat included the mainstem Androscoggin, Little River, and Little Androscoggin River. Historical salmon spawning habitat is limited to the Lower Androscoggin River due to natural barriers. By 1844, the construction of impassable dams extirpated Atlantic salmon above tidewater in the Androscoggin River (MDMR and MDIFW 2017).

Currently, Atlantic salmon are present in the Androscoggin River estuary and the Lower Androscoggin River; salmon pass the Brunswick fish ladder in small numbers with some years recording no passage. A radiotelemetry study conducted in 2011 tracked salmon to the Barker's Mill Project bypass reach and various locations in designated critical habitat (MDMR 2012). Salmon use the estuary and Lower Androscoggin River as a migratory pathway, but no observed spawning has recently occurred in the mainstem Androscoggin (MDMR and MDIFW 2017). Salmon migration in the mainstem ends at the Lewiston Falls Hydroelectric Project, limiting spawning habitat to the lower mainstem and accessible tributaries. There is currently no fish

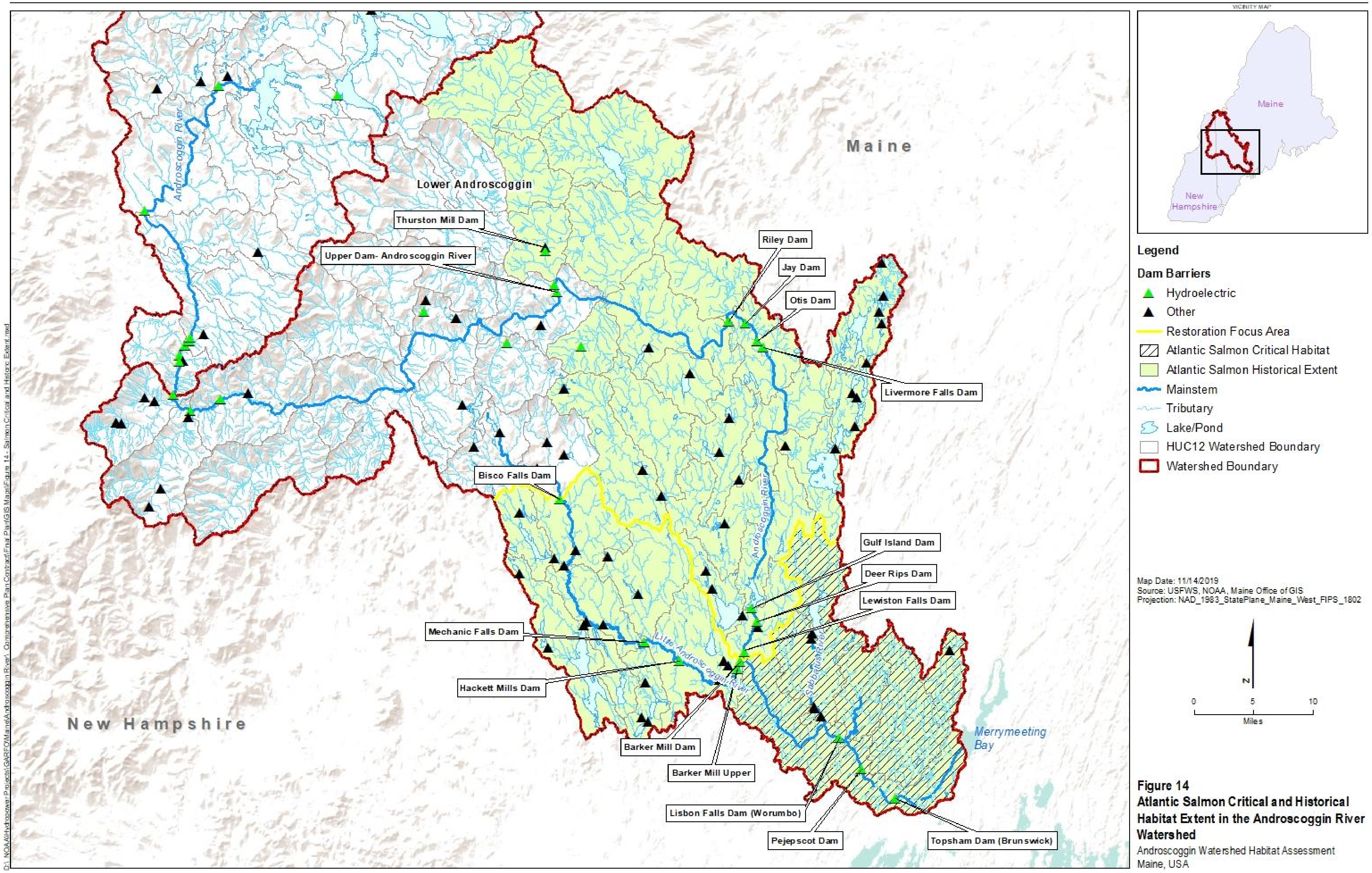


Figure 14
Atlantic Salmon Critical and Historical Habitat Extent in the Androscoggin River Watershed
Androscoggin Watershed Habitat Assessment
Maine, USA

passage at the barriers in the Little Androscoggin, leaving those spawning grounds inaccessible to returning adults (MDMR and MDIFW 2017). The Little River, which is a tributary to the mainstem Androscoggin between the Pejepscot and Worumbo dams, is the primary spawning habitat accessible for migrating Atlantic salmon.

6.5.3 Habitat Requirements

Atlantic salmon are highly migratory anadromous fish, entering the ocean as smolts to grow and mature, and returning to freshwater streams as adults to spawn. Adults can travel up to 200 miles upstream to reach suitable spawning grounds but can also spawn just above the head of tide (Collette and Klein-MacPhee 2002). The spawning period in the GOM is from October to early November. Adult salmon typically return to their natal streams for spawning (NOAA 2015). Substrate preferences include gravelly or sandy streambeds in which females dig redds for depositing eggs (Collette and Klein-MacPhee 2002). Some post-spawned adult salmon (kelts) are often in poor condition and die before returning to the ocean. Kelts that survive will either return to the ocean soon after spawning or remain in larger rivers or ponds during the winter months before emigrating with the spring freshets.

Atlantic salmon develop from eggs to young free-swimming salmon over the course of a few months. Salmon eggs are sedentary and settle into the adult-constructed redds within gravelly streambeds to incubate (Collette and Klein-MacPhee 2002). Hatching occurs from April to early May. Newly hatched larvae possess a yolk sac, which they utilize and deplete in approximately 6 weeks while remaining in the redd (Saunders et al. 2006). Upon complete yolk sac absorption, the free-swimming salmon larvae, called fry, depart the redd and enter the water column and begin actively feeding.

Salmon growth to mature fish requires years of development. Young salmon, called parr, develop from fry after the fry leave the redd (Saunders et al. 2006). The parr live in freshwater streams for up to 3 years, though individuals may stay 6 years in some GOM rivers (Collette and Klein-MacPhee 2002). Substrate preferred by parr include boulders and rubble. Parr utilize various stream habitats based on the presence of predators, the availability of prey items, and on the age and size of the individual (McCormick et al 1998). Salmon can become sexually mature after only 1 year at sea and can return to spawn in fresh water for 2 or 3 years in succession. Some fish may only spawn every other year, while others only spawn once after spending up to 5 years at sea (Collette and Klein-MacPhee 2002).

6.5.4 Recreational Fishery and Stocking

Recreational fishing of Atlantic salmon is currently limited to landlocked salmon populations that share some common genetic ancestry with sea-run fish but do not exhibit anadromy. MDIFW manages fishing for landlocked salmon. Catches are restricted per state regulations. Between mid-August and September, the bag limit for landlocked salmon decreases to one fish per day in streams, rivers, and brooks. Sea-run Atlantic salmon are a federally protected species in Maine and fishing for the species is prohibited (MDMR 2017b).

The state stocked Atlantic salmon, along with other popular recreational freshwater fishes, in the Lower Androscoggin watershed (MDMR and MDIFW 2017). Attempts to establish a stocked fishery in the 1980s and 1990s resulted in failure and led to the shutdown of the program. Stocking of salmon fry in the Androscoggin River commenced in 2001, 18,500 fry have been stocked to date. MDIFW stocks landlocked Atlantic salmon in lakes that meet habitat requirements throughout Maine (MDMR 2017b). In Androscoggin County, the stocked waterbodies include Thompson, Tripp, and Pennesseewassee lakes, which are part of the Little Androscoggin drainage, as well as Auburn Lake, which is part of the mainstem Androscoggin drainage.

6.5.5 Competition, Predation, and Interaction with Inland Fishery

An Atlantic salmon’s diet changes as individuals enter new life stages. Newly hatched salmon fry begin life with a yolk sac, which is consumed after 6 weeks (Saunders et al. 2006). Upon yolk-sac depletion, the fry consume phytoplankton and eventually include small insects in their diet as they develop into parr (NOAA 2015). Salmon parr primarily feed on macroinvertebrates (Porter 1975).

In the ocean, adult salmon are voracious predators and feed on a wide array of fishes and crustaceans. They have been observed eating alewives and blueback herring, along with rainbow smelt, lances (*Ammodytes* spp.), mackerels (Scombridae), and various crustaceans (Collette and Klein-MacPhee 2002). Adult salmon returning to fresh water to spawn tend to reduce or cease feeding when in fresh water.

Juvenile and adult Atlantic salmon are subject to predation in freshwater streams. Larger fish, birds, and mammals prey on salmon smolts (NOAA 2015). Striped bass can predate heavily on downstream-migrating Atlantic salmon smolts (Blackwell and Juanes 1998). Though striped bass similarly feed on smolts in rivers in Maine, it is uncertain that striped bass predation is the primary reason for the decline in smolt numbers (Beland et al. 2001).

Atlantic salmon benefit from prey buffering by other fish species at various salmon life stages. Juvenile American shad and blueback herring may act as a prey buffer for Atlantic salmon fry and parr, where the abundant presence of other species dilutes the predation risk on the salmon (Saunders et al. 2006). In areas where salmon smolts coexisted with adult alewives, prey buffering occurs, protecting smolts from native predators (Mather 1998, USASAC 2004, Saunders et al. 2006). The American shad provides a similar prey buffer for adult Atlantic salmon since both species have similar immigration periods (Saunders et al. 2006).

Atlantic salmon behavior and spawning provide a nutrient exchange between upstream freshwater and marine ecosystems. Adult salmon provide nutrient sources to the freshwater environment through waste secretion, deposition from spawning, and post-spawning mortality (Merz and Moyle 2006). Similarly, when juvenile salmon migrate from the rivers to the ocean, they are transferring freshwater nutrients to the marine environment and providing marine predators with another food source (Saunders et al. 2006).

6.5.6 Previous and Current Management/Monitoring Actions for Atlantic Salmon

Atlantic salmon stocks have been in decline for almost 200 years. Salmon populations in central New England and Long Island Sound rivers no longer exist and attempts to reintroduce the fish to larger watersheds in New England such as the Connecticut and Merrimack have been discontinued (USFWS and NMFS 2018). Causes of salmon population declines include water quality degradation, impediment to movement and access to spawning grounds due to stream barriers, and low marine survival (NOAA 2015). Atlantic salmon were listed as endangered in Maine in 2000, but the listing was restricted to certain small river populations (USFWS and NMFS 2018). In 2009, the GOM Distinct Population Segment (DPS) of Atlantic salmon expanded to include more rivers, including the Androscoggin River (65 Federal Register [FR] 69459 and 74 FR 29344). Critical Habitat has been designated for listed Atlantic salmon pursuant to Section 4 of the ESA (74 FR 29300 and 74 FR 39003). Parts of the Androscoggin River Watershed including the mainstem Androscoggin River below Lewiston Falls, the Sabattus River, and the Little River are included within that designation.

Multiple agencies have developed restoration plans for Atlantic salmon in Maine. After the ESA listing of Maine Atlantic salmon populations, USFWS and NOAA Fisheries developed a recovery plan with a primary objective of removing Maine Atlantic salmon populations from the endangered and threatened species list (USFWS and NMFS 2018). Delisting would require the establishment of long-term sustainable populations of Atlantic salmon, the reduction of current threats and impediments to Atlantic salmon, and the development of management options to ensure long-term salmon survival. MDMR and MDIFW have established a set of management goals for the Androscoggin River Watershed to help maintain and restore diadromous and residential freshwater fish populations. The Androscoggin estuary, the mainstem Androscoggin up to Lewiston Falls, the Sabattus River drainage, the Little River drainage, and the Little Androscoggin drainage are managed migratory pathways (MDMR and MDIFW 2017). Fish passage improvements will be necessary on all reaches with blockages. Effectiveness testing of upstream and downstream fish passage facilities to ensure safe, timely, and effective passage is necessary. Assessment of juvenile Atlantic salmon populations by MDMR in the Little Androscoggin drainage will be conducted after documented presence of adult salmon (MDMR and MDIFW 2017).

The licensees for the Brunswick, Pejepscot, and Worumbo Projects on the mainstem Androscoggin River evaluated smolt survival past each project (MDMR and MDIFW 2017). Average downstream survival of salmon smolts at the Brunswick Project was 87.2 percent between 2013 and 2015. Salmon smolt survival at Pejepscot from 2014 to 2015 averaged at 88.8 percent. Results of the 2018 smolt studies for the Brunswick and Pejepscot Projects will be available soon. Downstream salmon smolt survival at the Worumbo Project averages 86.7 percent for study years 2013 to 2015.

Access to historical salmon spawning grounds within the Androscoggin River Watershed is both ongoing and in the planning phase. In 2009, removal of a 100-year old dam on Little River provided upstream access to Atlantic salmon, American eel, and sea lamprey. The dam removal opened 43 miles of salmon stream habitat and spawning grounds. On the Little Androscoggin, which contains a large portion of historical salmon spawning grounds, the Marcal Project is required to install upstream fish passage for anadromous fishes, including Atlantic salmon, based on resource agency determination (MDMR and MDIFW 2017).

Atlantic salmon are reared in a hatchery and stocked in suitable stream habitats as fry, parr, smolts or adults to supplement the Maine sea-run Atlantic salmon population in some rivers. The Penobscot River, for example, which possesses one of Maine’s largest Atlantic salmon runs, receives hatchery-raised fish from two hatcheries managed by USFWS (NOAA 2015). There are currently no hatchery operations specifically dedicated to stocking salmon in the Androscoggin River Watershed.

6.5.7 Potential Atlantic Salmon Habitat Availability

The Final Recovery Plan (FRP) for the GOM distinct population of Atlantic salmon outlines potential habitat availability for Atlantic salmon in the Androscoggin River Watershed (USFWS and NMFS 2018). USFWS and NOAA Fisheries prepared the recovery plan for the GOM population, which serves as a technical advisory document that makes recommendations to achieve recovery objectives for the population.

6.6 STRIPED BASS

6.6.1 Biological Characteristics of Striped Bass

Striped bass is an anadromous, migratory species that ranges from the St. Lawrence River in Canada to the St. Johns River in Florida (Collette and Klein-MacPhee 2002). They are an important recreational and commercial species for the northeast region of the United States and an important predatory component of the estuarine food web. Spawning occurs in late spring to early summer in either fresh or brackish river waters (Hill et al. 1989). Larval and young striped bass grow in freshwater streams and eventually migrate to estuaries as juveniles. Adults migrate into coastal marine waters to feed and grow returning to brackish and freshwater streams to reproduce as well. Striped bass are currently present in the Androscoggin River Watershed (MDMR and MDIFW 2017). This section will describe the distribution of and habitat requirements for striped bass, as well as the fishery status, bass interactions with other aquatic species, and historical and current management and monitoring efforts. The information presented in this section will focus on the specific Androscoggin River Watershed striped bass populations, to the extent that data are available.

6.6.2 Historical and Current Distribution

Striped bass currently exist in several watersheds throughout Maine and are an important recreational fishery to the area. The Androscoggin River Watershed is historical habitat for striped bass migration, spawning, and forage. The Androscoggin estuary both historically supported and currently supports (on a smaller scale) striped bass migration and growth, and in some areas, striped bass spawning (MDMR and MDIFW 2017). The Lower Androscoggin River up to Lewiston Falls, Little Androscoggin River, and Sabattus River historically functioned as a migratory pathway for striped bass.

The current range of striped bass in the Androscoggin River Watershed includes the mainstem Androscoggin up to Lewiston Falls (MDMR and MDIFW 2017). Striped bass do enter the Brunswick fishway on the Androscoggin, with six individuals observed in 2017 (MDMR 2017b). There are two distinct groups of striped bass in the Androscoggin River Watershed—one comprising larger sea-run bass from populations throughout the United States eastern coastal waters and a second native population of smaller-sized individuals. The larger-sized group tends to remain in the estuary and upstream reaches for foraging, whereas the native population uses the Androscoggin as spawning grounds (MDNR and MDIFW 2017). The larger migratory group of Atlantic striped bass can range from the St. Lawrence River in Canada to the St. Johns River in Florida (ASMFC 2016a).

6.6.3 Habitat Requirements

Spawning striped bass require specific habitat characteristics including certain water quality attributes, velocity, and substrate types. Striped bass can migrate up to 200 miles upstream to suitable spawning grounds (Hill et al. 1989). Spawning habitat typically consists of shallow, turbid regions with good water flow. Striped bass preferentially select habitat with higher stream velocities for spawning (Beasley and Hightower 2000). Striped bass are broadcast spawners, releasing eggs and sperm simultaneously into the water column. Fertilized eggs are semi-buoyant and non-adhesive, needing flowing water to remain suspended in the water column (Hill et al. 1989). Depositional sediment may smother eggs laid in slack or still waters. Hatching success is best in the water column; however, some eggs that settle on coarse substrate successfully hatch (Hill et al. 1989).

Striped bass larvae depend on a variety of stream velocities, water temperatures, and turbulence to develop into juvenile fish. Larvae hatch out from eggs after a period of up to 4 days depending on the water temperature. Warmer waters promote faster development and a shorter hatch-out period for larval striped bass (Hill et al. 1989). Juvenile striped bass have fully functioning swimming capabilities and are similar in overall appearance to adults. Juveniles spend the first 2 years in small groups and eventually begin forming schools by age 2 or 3 (Collette and Klein-MacPhee 2002). Juveniles remain near shore in estuaries until they reach 2 to 4 years of age, at which time they move towards the ocean and begin the coastal migration (ASMFC 2016a).

Adult striped bass are powerful swimmers and tend to form large schools with other adults, particularly during the migration period (Collette and Klein-MacPhee 2002). While they are powerful swimmers, striped bass do not readily use all types of fish passage systems (ASMFC 2010b; Smith and Hightower 2012). After departing the rivers and estuaries, adults migrate along the Atlantic coastline, traveling northward during the summer and south during winter (Greene et al. 2009). While most adults are anadromous, there are smaller contingent populations of striped bass that either remain in freshwater rivers year-round or migrate between freshwater and brackish water.

6.6.4 Recreational Fishery and Stocking

Striped bass make up a vital component of the Maine recreational fishery. They are a popular game fish for both locals and tourists. Current saltwater fishing regulations for striped bass includes Androscoggin River headwaters to the head of tide (MDMR 2017d). The open season in the Androscoggin River Watershed, plus the Kennebec River and Sheepscot River watersheds, is from 1 May to 30 June with special gear restrictions and 1 July to 30 November with no special gear restrictions. The striped bass recreational fishery is open year-round in all other saltwater regions within Maine. Fish take is limited to one fish per person per day, and the total length requirement for take is 28 inches or greater (MDMR 2017d).

Recreational and commercial fishing for striped bass are active industries throughout the United States' Atlantic coastline. There are currently 8 jurisdictions that operate commercial fisheries for striped bass and 14 that operate recreational striped bass fisheries (ASMFC 2016a). Commercial fisheries harvest peaked in 1973 and then began declining through the early 1980s, which marked the striped bass population collapse. Commercial harvest began to grow again after implementation of new fisheries management programs, which limited harvest to 7 million pounds (ASMFC 2016a). Since 1991, recreational fishing dominates the striped bass catch according to the most recent stock report available (ASMFC 2016b).

Historical stocking of striped bass in Maine occurred from 1986 to 1991, with over 35,000 bass placed in the Androscoggin River (Upton 1993). The Kennebec and downeast rivers also received stocked bass during this period. The state does not currently stock striped bass (MDMR and MDIFW 2017).

6.6.5 Competition, Predation, and Interaction with Inland Fishery

Resource competitors to striped bass include other similar sized fish species encountered in estuarine waters. Hybrid striped bass, which are a cross between striped bass and white bass (*Morone chrysops*), compete with striped bass for food sources and may compete with striped bass for habitat and spawning grounds (Patrick and Moser 2001). The hybrid striped bass is considered a game fish and was regularly stocked in lakes in parts of the United States (Fuller 2018) but are not part of the Maine stocking program (MDMR and MDIFW 2017. American shad spatially overlap with striped bass in their spawning and nursery grounds, but the primary spawning ground for each species is distinct (Bilkovic et al. 2002). The separation of spawning grounds may minimize interspecific competition and predation, since American shad and striped bass can prey on one another in different age classes and may compete for food sources in the larval stage.

Striped bass feed on a variety of organisms and their prey type changes as individuals grow from young fish to adults. Young bass are non-selective feeders, primarily eating zooplankton, macroinvertebrates, and fish as food sources become available with seasonal fluctuations (Stevens 1966, Greene et al. 2009). Juveniles and adults will forage on many smaller fish species, including alewife, American eel, blueback herring, American shad, Atlantic menhaden (*Brevoortia tyrannus*), and rainbow smelt (Collette and Klein-MacPhee 2002). Atlantic salmon smolts migrating downriver can also comprise a substantial portion of adult striped bass diet (Blackwell and Juanes 1998). Striped bass predation on salmon smolts has been observed in Maine on the Narraguagus River and estuary; the behavior does not appear to occur in fresh water (Beland et al. 2001). Several invertebrates, including squid, lobster, shrimp, softshell clams, and mussels, also comprise the striped bass diet.

Striped bass are susceptible to predation in the egg, larval, and juvenile life phases; adults have few predators in estuaries and streams. Bluefish (*Pomatomus saltatrix*) may prey on young-of-the-year striped bass to the point where the population size is detrimentally affected (Buckel et al. 1999). Several freshwater and estuarine fish species feed on striped bass larvae and eggs when available.

6.6.6 Previous and Current Management/Monitoring Actions for Striped Bass

MDMR developed management goals for diadromous fishes in the Androscoggin River watershed to help restore and guide diadromous fish management while maintaining balance with local fisheries (MDMR and MDIFW 2017). For striped bass, fisheries and spawning habitat management will occur in the Androscoggin River estuary, and fisheries management will occur in the Androscoggin River up to Lewiston Falls and in the Little Androscoggin River. Currently, striped bass are collected from the Brunswick fishway and returned downstream as the current downstream passages from the Brunswick upstream pond are considered inappropriate for striped bass passage (MDMR and MDIFW 2017). MDMR may support passing striped bass through the Brunswick fishway, as well as other fishways in Maine, contingent on safe downstream passage.

ASMFC assesses and manages the Atlantic striped bass population across the eastern United States under Amendment 6 to the Atlantic Striped Bass FMP (ASMFC and Atlantic Striped Bass Plan Development Team 2003). The overall goal of ASMFC Amendment 6 is to maintain a healthy spawning stock and diverse migratory striped bass population while balancing their conservation with appropriate commercial and recreational fisheries management. The management program also includes a provision to restore and conserve striped bass essential habitat (ASMFC and Atlantic Striped Bass Plan Development Team 2003). ASMFC has stock assessment data on the striped bass ranging back to 1982 (ASMFC 2016b). The Atlantic striped bass stock is currently not overfished. The spawning stock biomass (SSB) is above the SSB threshold determined by ASMFC but has been in decline since 2004 (ASMFC 2016b). Using projection models, ASMFC predicts the SSB has a 20 percent chance of dropping below the SSB threshold in 2018 (ASMFC 2016b). ASMFC continues to modify the striped bass management program based on new stock assessment information and new fish stock goals.

6.6.7 Potential Striped Bass Habitat Availability

Striped bass are present in the Androscoggin River Watershed at least from Merrymeeting Bay to Brunswick; historical range beyond this is unclear, although it is likely that the Lower Androscoggin and Little Androscoggin Rivers served as migratory corridors for striped bass. We did not perform a geospatial evaluation of potential available habitat for striped bass; this CP follows MDMR recommendations for the management and restoration of striped bass within the Androscoggin River Watershed.

7. INLAND FISHERY OF THE ANDROSCOGGIN WATERSHED

7.1 INLAND SPECIES

The Androscoggin River Watershed inland fishery has a similar species composition as neighboring rivers. Electrofishing surveys along the mainstem of the river have identified 27 inland fish species occupying both warmwater and coldwater habitats within the drainage (Yoder et al. 2006).

Sport fishes are of particular interest within the watershed. MDIFW manages recreational fishing with native species being the priority focus. These fishes include native landlocked Atlantic salmon, brook trout (*Salvelinus fontinalis*), landlocked rainbow smelt, lake trout, rainbow trout (*Oncorhynchus mykiss*), brown trout, smallmouth bass, and largemouth bass.

Trout are present throughout the Androscoggin River Watershed (MDIFW 2001b, 2001c, 2002b, 2009). Trout habitat is complex, consisting of high quality riffles and pools, submerged wood, boulders, undercut banks, and aquatic vegetation. The significance of these habitat components increases if the fish are able to swim between connected habitats.

Landlocked Atlantic salmon habitat consists of large, deep, clear waters, which are cool and highly oxygenated. The presence of rainbow smelt is a good indication of salmon habitat. Landlocked salmon are native to lakes in Maine though some introduced populations persist in New Hampshire, Vermont, Massachusetts, and New York (MDIFW 2012).

Along with native brook trout and landlocked salmon, non-native bass are important sportfish within the Androscoggin River (MDIFW 2001c). Smallmouth and largemouth bass thrive in many of Maine’s lakes and ponds, as well as in many larger rivers and streams. Though these fish can coexist within the same water reaches, largemouth bass typically prefer shallow, weedy areas of eutrophic and mesotrophic lakes, and slow-moving rivers and streams. Smallmouth bass are present throughout the watershed. Largemouth bass generally occupy habitat throughout the southern portion of the watershed (MDIFW 2001c).

7.2 PUBLIC USES AND MANAGEMENT ACTIONS FOR THE INLAND FISHERY

Recreational fishing is an important contributor to state and local economies and communities in Maine. To sustain this market, MDIFW developed detailed statewide management plans for all major freshwater sportfishes, which include management goals and objectives. Fish of minor importance such as the black crappie (*Pomoxis nigromaculatus*), brown bullhead (*Ameiurus nebulosus*), common carp, sunfishes, yellow perch (*Perca flavescens*), and white catfish are also in these management plans (MDIFW 2002a).

Sustaining coldwater fisheries within the Androscoggin River Watershed frequently requires active stocking of hatchery-raised trout and salmon. River and stream stocking of trout supports fisheries where angler exploitation exceeds recruitment from wild stocks or where habitat conditions are marginal (MDMR and MDIFW 2017). MDIFW stocks lake and brown trout to maintain populations or to create new fisheries in waters with suitable habitat (MDIFW 2001a, 2001b); however, the state is not creating new populations with their stocking efforts. Brook trout introduction guidelines prevent the stocking of hatchery-reared fish in select heritage waters with native populations and requires review and consent from the Maine Legislature's Fish and Wildlife Committee (MDIFW 2009).

Landlocked salmon, the most highly prized sport fish, is highly catchable, has a long lifespan, has good growth potential, is tolerant of a moderately wide range of habitat conditions, and can be easily cultured in hatcheries. While self-sustaining populations of landlocked salmon exist, MDIFW supplements this highly management-responsive species by regular plantings of hatchery-reared fish in many waters (MDIFW 2012).

Bass are highly important as a popular sportfish because they are excellent fighters and palatable (MDIFW 2001c). Natural reproduction maintains bass populations within the Androscoggin River Watershed. Stocking is unnecessary.

8. ENERGY POTENTIAL IN THE ANDROSCOGGIN RIVER WATERSHED

As codified in Section 10(a)(1) of the Federal Power Act, a hydropower project must serve the public interest, not just the Licensee's interest in power generation. The Androscoggin River produces 257 MW of electrical generation. The associated dams and project operations are a significant contributor to the severe depletion or extirpation of the diadromous fishery to levels unsustainable without the intervention of resource agencies. This lack of balance between energy and fishery resources – a public trust resource - suggests that the development of the Androscoggin River does not meet a comprehensive development standard. We completed an energy analysis to demonstrate the energy potential within the watershed and the potential for maintaining or enhancing energy production while meeting a comprehensive development standard for fishery and other public resources. Understanding the energy potential within the watershed will provide state and federal agencies with information to prioritize management efforts and proactive restoration opportunities, identify settlement opportunities with stakeholders, and support actions under the Federal Power Act that meet a comprehensive development standard. In summary, our analysis indicated a potential for enhanced energy production in the Androscoggin River with new stream-reach development, powering of non-powered dams, or existing facility upgrades. Further information on energy development in the Androscoggin River is available in other government reports (Francfort and Rinehart 1995, DOE 2016).

8.1 ANALYSIS METHODS

The objective of this energy potential evaluation was to determine the existing and theoretical hydroelectric energy available in the Androscoggin River Watershed within the limits of historical anadromy. We inventoried the existing installed capacity and annual generation for each hydroelectric facility. Installed capacity is the actual generation capacity at a facility that may or may not match the authorized capacity in the FERC license. From this information and existing hydrologic information (e.g., USGS stream gauges), we evaluated the feasibility for existing facility upgrades. In addition to evaluation of the hydroelectric projects, we evaluated examples of the potential for electricity generation at a non-powered dam and a new stream-reach development.

8.2 INVENTORY OF INSTALLED CAPACITY

An inventory of installed capacity and annual generation for the hydroelectric facilities located on the Androscoggin and Little Androscoggin Rivers in Maine from the estuary to the New Hampshire state line was conducted. Review of FERC licenses for each facility provided information regarding plant generation capacity and hydraulic head. We compared these data with plant data obtained from other sources such as the U.S. Energy Information Administration (2018). Non-jurisdictional and exempt facilities are not included in this inventory. Within the historical extent of anadromy, 13 facilities are located on the

Androscoggin River (Figure 4) with a total generation capacity of 168.86 MW based on FERC records. Individual units range from 3.125 to 14.22 MW. Generation capacity of the three facilities on the Little Androscoggin River total 3.88 MW based on FERC records with individual units ranging from 0.95 to 1.5 MW. Additional information related to this analysis can be provided upon request.

8.3 THEORETICAL POTENTIAL FOR FACILITY UPGRADES

We evaluated the theoretical potential for upgrades of these facilities to generate additional power. We used the following power equation to calculate hydropower in kilowatts (kW) (Home Power Magazine 2018):

$$kW = H \times Q \times 62.4 \times 0.746 \div 550 \times E$$

where:

H is head, in feet

Q is flow, in cubic feet per second

62.4 pounds is the weight of 1 cubic foot of water

0.746 is kW which equals 1 horsepower

550 foot-pounds per second is 1 horsepower

E is an overall efficiency factor.

We determined flow based on the drainage area ratio at each facility to that of a known USGS gaging station. The equation used to determine the drainage-area ratio estimates, modified from Ries (2006), is:

$$Q_u = (A_u/A_g)^b Q_g$$

where;

Q_u is estimated flow statistic for the ungaged site,

A_u is the drainage area for the ungaged site,

A_g is the drainage area for the stream gage,

Q_g is the flow statistic for the streamgage, and

b is an exponent based on state-specific regression equations. We used one, as Maine does not specify the exponent.

We used StreamStats Version 4 developed by USGS for Maine to identify basin characteristics, including contributing drainage area for each facility (USGS 2018a). USGS gaging stations used for this analysis include Station 01059000 Androscoggin River near Auburn, Maine; Station 01054500 Androscoggin River at Rumford, Maine; and Station 01058500 Little Androscoggin River near Auburn, Maine (Figure 15; USGS 2018b). Figure 15 shows the locations of these gages and the hydroelectric facilities. All facilities have a drainage area ratio between 0.5 and 1.5. We multiplied the daily flow values in cubic feet per second for the reference USGS Station by the drainage area ratio identified for each facility to estimate mean daily flow at the respective facility.

Using these data, we developed flow duration curves showing the probability of a given flow at each facility. We tabulated these curves and the probability distributions to estimate river discharge at each facility.

We used the power equation noted above to calculate the theoretical generation and analyze the potential to upgrade the facilities to generate additional power. We used the gross head value for each facility for “H” with flow based on probability values determined by the flow duration curves. Turbine flow determines the efficiency factor. We assumed turbines reach highest efficiency at 60% design flow. A sharp increase in turbine efficiency occurs between zero and ten percent design flow (Table 8).

Table 8. Representative efficiency factors for a given percent design flow.

% Design Flow	Turbine Efficiency
0	0.00
10	0.75
20	0.77
30	0.88
40	0.905
50	0.915
60	0.92
70	0.915
80	0.91
90	0.90
100	0.88
Source: U.S. Department of the Interior 2012.	

All projects, except the Gulf Island development, operate as run-of-river (ROR) mode. The Gulf Island development is an intermittent peaking facility. When inflows to the Gulf Island impoundment are below the hydraulic capacity of the Gulf Island development, the development operates in its normal peaking mode, in which water is stored and released to maximize energy generation during daily peak electrical loads. This mode of operation causes fluctuation of the Gulf Island impoundment and fluctuations in river flow below the Project. The Deer Rips-Androscoggin Number 3 development operates as a ROR facility in that it uses inflows from the Gulf Island development.

The Gulf Island-Deer Rips Project reregulates the river flow and affects the operation of several downstream hydroelectric projects through a variable daily discharge schedule. The hydroelectric projects downstream from the Gulf Island-Deer Rips Project operate as ROR facilities, using the peaking flows released from the Gulf Island-Deer Rips Project.

All of the ROR projects have minimum flow requirements. However, by operating the projects in a ROR mode, inflow to the project impoundment effectively becomes the environmental flow below the project.

The theoretical power generated for each unit of probability (i.e., 0 to 100 percent) were multiplied by 365 (days per year) and 24 (hours per day) to obtain power generation in kW-hour units for the respective flow value. Annual potential power generation was then calculated as the summation of the difference between power generated for each unit of probability (i.e., conversion of a flow duration curve to a power duration curve). Based on an average wholesale price of $50 per megawatt hours (MWh) of electricity in the New England area as reported by ISO New England (2018) the average annual revenue that could be derived from each facility was also calculated. We assigned all projects in the analysis a 1 percent outage correction.

We downloaded the historical generation data in MWh reported from 2001 to 2016 for each of the licensed facilities from the U.S. Energy Information Administration (2018). An average of the energy produced was then calculated. For years without data, we used the average annual production for all reported years. These data along with the analysis of theoretical generation results estimates the increase in power generation and revenue achievable by potential upgrades at each facility.

We estimated the cost to upgrade generation capacity using an estimated cost of $1,930 per kW (U.S. Energy Information Administration 2018). We calculated a simple payback time in years by dividing the total upgrade cost by the average annual additional revenue 2001 to 2016 data. Year-to-year variability of actual energy production at a given power plant may affect the results.

Based on these calculations for the years and facilities analyzed, an additional 399,050 MWh, a 39 percent increase of power, is theoretically possible by 10 of the 12 facilities located on the Androscoggin River mainstem (Table 9). Theoretical generation calculated for the Lisbon-Worumbo and Gulf Island facilities calculated is less than the 16-year average reported generation for these units. This discrepancy may be due to, but not limited to, flow values or plant turbine efficiency used herein being less than actual. With respect to the difference between installed capacity and potential capacity, the three projects with the largest potential to gain extra capacity are Rumford Falls (31.5 MW), Brunswick (14.4 MW) and Pejepscot (7.0 MW) (Table 9).

Based on an average wholesale price of $50.00 per MWh; additional revenue totaling more than $2.8 million could be generated for two of the three mainstem projects in the restoration focus area and an additional $16.4 million for the mainstem projects outside of restoration focus area as delineated in this CP. The estimated upgrade costs for all the mainstem Androscoggin River facilities totals more than $137.1 million. The calculated simple payback (excluding interest) varies from a minimum of 1.8 years at the Deer Rips and Livermore Projects to 18.8 years at the Pejepscot Project (Table 9).

Our calculations suggest that existing hydroelectric generation at facilities on the Little Androscoggin River have no potential for increase. Average annual generation produced in the Little Androscoggin River is 1.3% of that produced in the mainstem of the Androscoggin River. One or more facility upgrades on the mainstem of the Androscoggin can readily replace any lost generation on the Little Androscoggin River (Table 9).

We based the potential increased generation presented herein on modification of generator capacity only. In order to assess the feasibility of hydroelectric upgrades, Licensees must consider other factors such as powerhouse configuration, available headwater elevation, plant discharge capabilities, and other engineering and design factors, which are beyond the scope of this analysis.

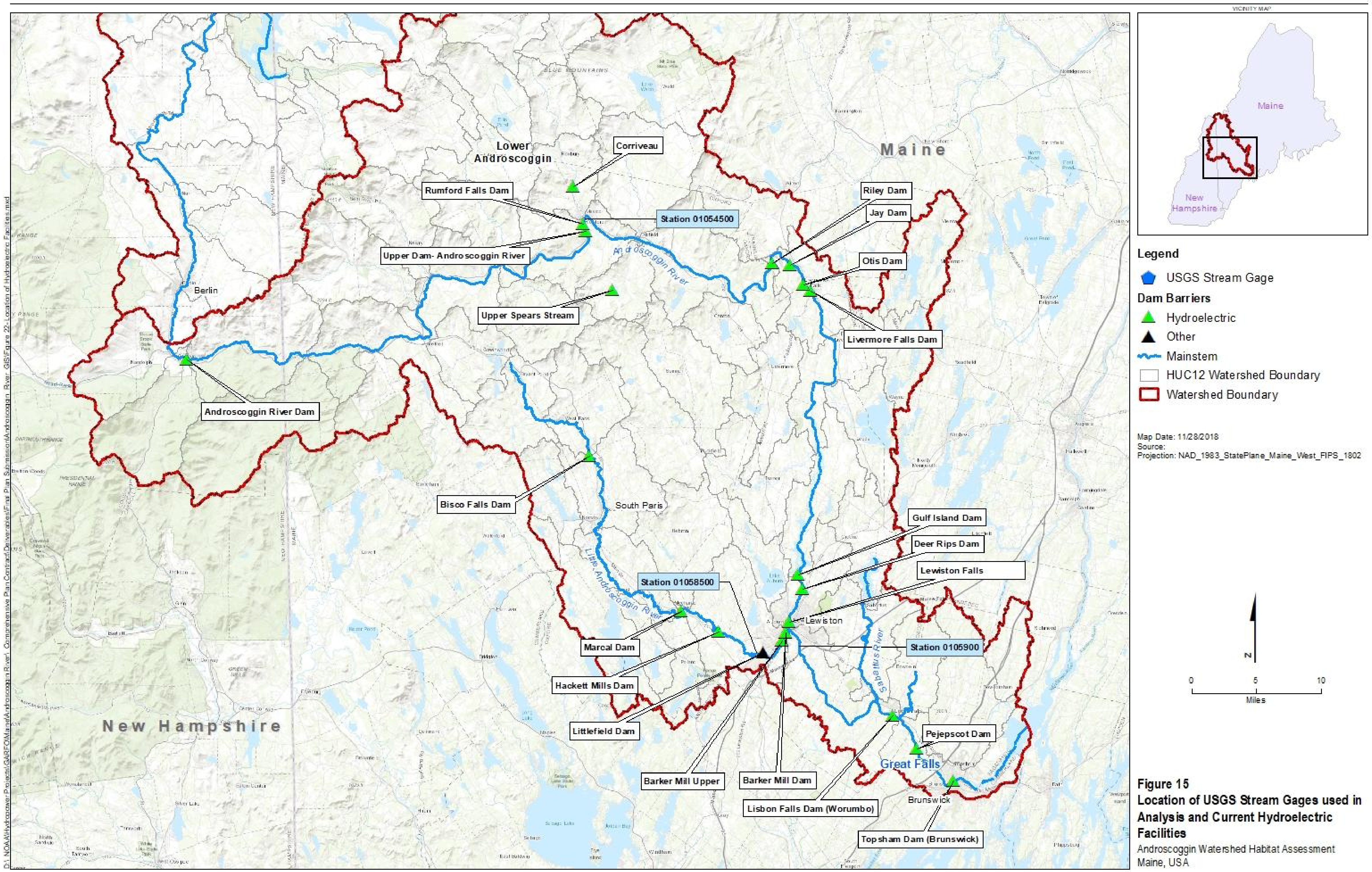


Figure 15
Location of USGS Stream Gages used in Analysis and Current Hydroelectric Facilities
Androscoggin Watershed Habitat Assessment
Maine, USA

Table 9. Summary of current and calculated generation and power plant capacity for hydroelectric facilities

Project	Average Generation (MWh)	Theoretical Generation (MWh)	Potential Increase (MWh)	Additional Yearly Revenue[1]	Installed Capacity (MW)	Theoretical Capacity (MW)	Additional Capacity (MW)	Estimated Upgrade Costs	Simple Payback (yr)
Mainstem Androscoggin River Projects in Restoration Focus Area (RFA)									
Brunswick	97,131	138,864	41,733	$2,087,000	12.0	26.4	14.4	$27,835,000	13.3
Pejepscot	71,870	86,219	14,349	$717,000	10.0	17.0	7.0	$13,489,000	18.8
Lisbon-Worumbo	90,779	85,718	-5,061	-$253,000	14.0	14.1	0.1	$0	0.0
Mainstem Androscoggin River Projects outside of RFA									
Lewiston Falls	138,332	158,658	20,327	$1,016,000	28.4	31.1	2.7	$5,166,000	5.1
Deer Rips	36,726	64,006	27,280	$1,364,000	7.0	8.3	1.3	$2,523,000	1.8
Lewiston Project Upper Andro[2]	26,939	64,251	37,311	$1,866,000	3.6	8.3	4.7	$9,159,000	4.9
Gulf Island	153,411	139,089	-14,321	-$716,000	20.9	20.9	0.0	$0	0.0
Livermore	36,818	87,184	50,367	$2,518,000	12.3	14.6	2.4	$4,578,000	1.8
Otis	56,156	69,789	13,633	$682,000	10.4	11.9	1.5	$2,968,000	4.4
Jay	11,960	38,071	26,111	$1,306,000	3.1	6.4	3.3	$6,323,000	4.8
Riley	26,435	57,388	30,953	$1,548,000	7.8	10.1	2.3	$4,360,000	2.8
Rumford Falls	272,631	409,615	136,984	$6,849,000	39.4	70.8	31.5	$60,736,000	8.9
Little Androscoggin River Projects in RFA									
Barker's Mill	4,912	5,587	675	$34,000	1.5	1.6	0.1	$125,000	3.7
Barker Mill Upper	5,516	6,809	1,293	$65,000	1.0	1.1	0.1	$237,000	3.7
Marcal	2,887	2,343	-544	-$27,000	1.0	1.0	0.0	$17,000	-0.6
Totals by Reaches (# of projects)									
Mainstem in RFA (3)	259,780	310,801	56,082	$2,551,000	36.0	57.5	21.5	$41,324,000	N/A
Mainstem outside RFA (9)	759,408	1,088,051	342,966	$16,432,000	132.9	182.5	49.6	$95,813,000	N/A
Mainstem Androscoggin (12)	1,019,188	1,398,852	399,048	$18,983,000	168.9	240.0	71.1	137,137,000	N/A
Little Androscoggin River (3)	13,315	14,739	1,424	$71,000	3.4	3.6	0.2	$379,000	N/A

8.4 POTENTIAL FOR ELECTRICITY GENERATION AT A NON-POWERED DAM

We evaluated one existing non-powered dam, the Lower Lisbon (D.B. Plant) Dam located on the Sabattus River, for adding hydroelectric generation. We obtained flow duration statistics at this location using USGS StreamStats Version 4 for Maine. The existing hydraulic head for this structure is approximately 20 feet. Using these data, we developed the potential power generation curve and annual generation as described previously. We used plant construction cost of $3,800 per kW capacity of potential developments to determine plant capital cost to add hydropower to existing non-powered dams (Oak Ridge National Laboratory 2015). In addition, we assumed $1M for fish passage facilities. We calculated simple payback time as just under 30 years by dividing total cost by annual revenue.

8.5 POTENTIAL FOR A NEW STREAM-REACH DEVELOPMENT

We selected the breached Littlefield Dam located on the Little Androscoggin River for new stream-reach development analysis of a location where a dam does not exist. We used a plant construction cost, excluding permitting cost, of $4,900 per kW capacity of the planned turbine as reported in the Hydropower Baseline Cost Modeling Report. In addition, we assumed $1M for fish passage facilities. Simple payback time is over 28 years dividing total cost by annual revenue.

9. ECONOMIC ANALYSIS OF THE DIADROMOUS FISHERY

9.1 GOAL OF THE ECONOMIC ANALYSIS

This analysis evaluates the economic benefits that could result from modification or removal of dams in the Lower Androscoggin River Watershed. The pathways of economic benefits that we considered were those resulting from changes in fish habitat and fish abundance. Dams affect fisheries by altering migration pathways and habitat access. Specifically, dams result in the loss and degradation of spawning habitat area for diadromous fish species. They can also affect habitat quality by changing stream hydrodynamics and physical form. Therefore, dam modifications (removal, breach, or fishways) have the potential to influence reproductive success and habitat condition of those species that use the Androscoggin River for any part of their lifecycle. Benefits to these species, in turn, affect other aquatic species that depend on them for forage, reproduction, or other needs. The ecosystem level connections associated with diadromous fishes likely produces increased migratory fish abundance within the Northeast Atlantic system, broadening the scope of fishery and aquatic species effects to include potential benefits to valuable commercial and recreational species.

This evaluation considers three types of value affected by changes in the focus fisheries or linked aquatic species. These three potential sources of value are:

- Commercial use value.
- Recreational use value.
- Nonuse value.

Together these value types are intended to capture the “total economic value” of the potential environmental changes in the Androscoggin River, because they include those using the system (use values) and those who value improvements in the system without using or intending to use the system (nonuse values) (Freeman et al. 2014). Economic values are distinct from expenses. If an angler spends a large sum of money to have a fishing experience (such as on fishing gear, lodging, and travel expenses), it is possible that the trip is just barely worth the cost. It is also possible that the value of the trip to that person (measured in dollar terms) far exceeds the cost. The value that exceeds expenses, or consumer surplus, is recreational use value.

Similarly, commercial use value is not the same as the gross revenue from fisheries landings, although it is frequently a proxy for beneficial changes in fisheries since business costs are private and difficult to quantify. As with recreational benefits, commercial value is the extent to which fishing revenue exceeds expenses. An estimate of gross revenues can capture commercial value if we assume that any changes in operations costs associated with changes in catch are negligible, and therefore the increase in income will directly increase net profit.

The third type, nonuse value, refers to values people have for environmental attributes, without the necessity of direct experience. Survey research has consistently demonstrated this phenomenon (Krutilla 1967, Johnston et al. 2017). This value (also referred to as passive use) has been recognized by the courts as a measure of the public interest in environmental change (e.g., in natural resource damage assessment; see Boyd 2004).

9.2 METHODS DAM MODIFICATION SCENARIO

The analysis was conducted using existing ecosystem models and data to complete three steps: (1) quantify estimates of biomass change relevant to fisheries; (2) estimate commercial fishing use value change; and (3) estimate recreational use value change. We describe, but do not quantify, nonuse values.

For this analysis of economic value, we remove or add fish passage to all dams within the Lower Androscoggin River and tributaries. Changes in available alewife habitat are reflected in the forage fish stock and the associated effects that propagate through the food web. Due to their spawning habitat preferences, alewives are highly vulnerable to river connectivity changes. Therefore, alewife are good indicators for other anadromous species that spawn in the rivers and upper boundaries of estuaries.

We estimate the change in alewife abundance using the total spawning habitat opened up due to dam modification and a measure of fish production per unit of additional habitat. We estimated the total area of spawning habitat above the dams as 36.8 square miles. We used the standard production estimate of 235 alewife per water surface acre. We used this full above-dam habitat area (hereafter Area 1) to estimate effects, which embeds the assumption that 100 percent of fish can traverse the dam. As a sensitivity test, we compared results developed under these assumptions to results using alternative estimates of habitat area and dam passage efficiency. Other researchers estimated spawning habitat above the dams on the Lower Androscoggin as 46 km^2 (Hall et al. 2012, Mattocks et al. 2017) (hereafter Area 2). Further, fish passage efficiency varies by dam type, species, and other factors. Overall efficiency of fish passage at dams has been estimated as ranging from 0 to 100 percent (Bunt et al. 2012). We used values of 50 percent and 100 percent to demonstrate the effect of improved fish passage at barriers.

Because alewife migrate, the commercial and recreational benefits of population increases extend well beyond the Androscoggin River (Figure 16). To make use of the best available data from surveys and models, we estimated fisheries benefits for the entire Northeast Atlantic (GOM, Georges Bank, Southern New England, and Middle Atlantic Bight), which is the full marine range of the alewife.

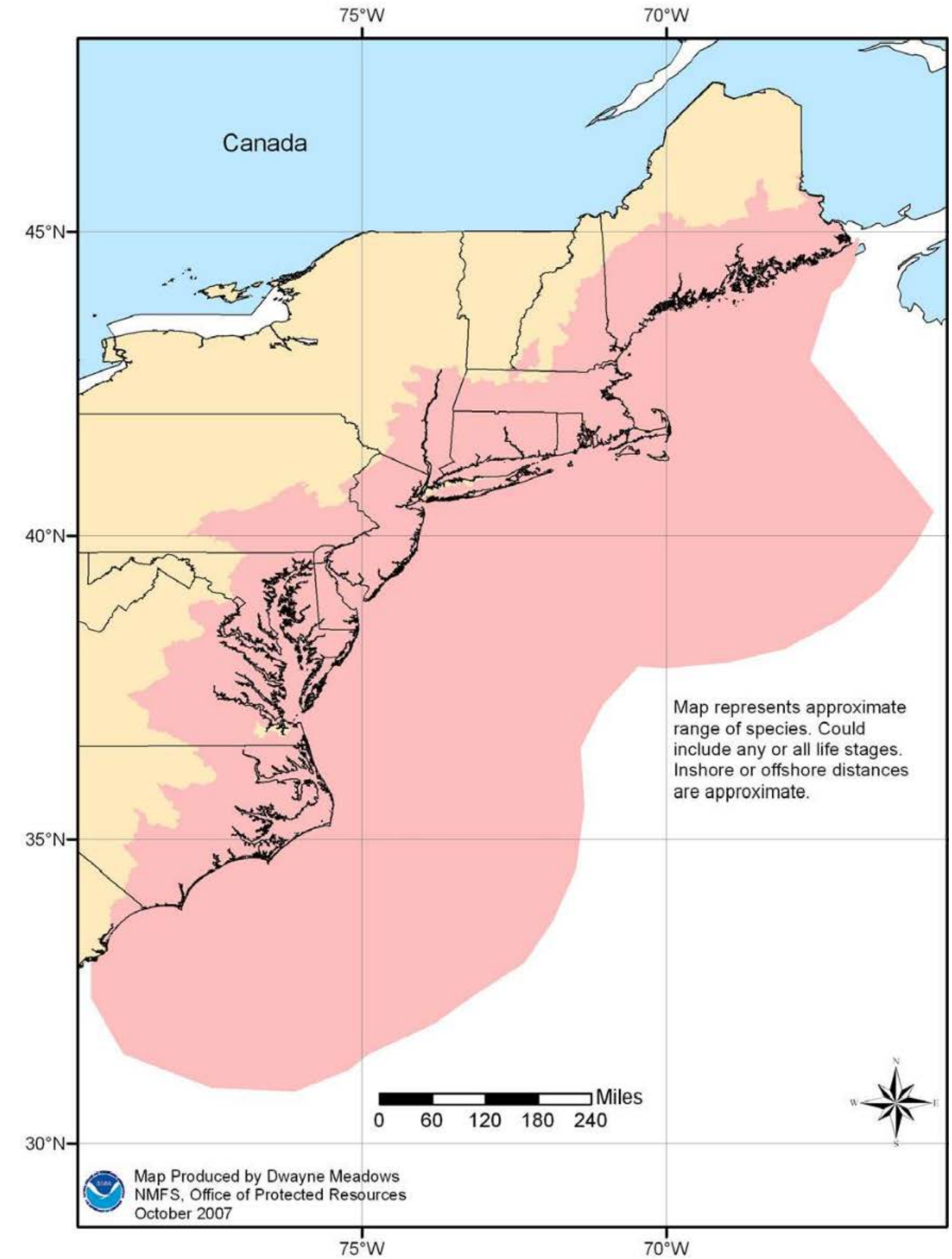


Figure 16. Atlantic coast alewife range.

9.3 QUANTIFYING EFFECTS ON FISHERIES

The direct ecological effect of opening up habitat area is an expected increase in fish abundance within the Androscoggin River for diadromous species. However, due to study limitations, these abundance increase estimates were only available for alewife and not for the other six focus species. Our economic analyses rely on changes in fish abundance; therefore, we sought supplemental information to support our analysis.

We utilized the Ecopath with Ecosim (EwE) model developed at the University of Massachusetts, Amherst, to examine the effects on fishes due to dams in the Northeast Atlantic (Dias and Jordaan, 2016). The EwE approach is a well-supported framework for modeling ecosystem trophic mass balance (Christensen and Walters 2004) and has been used extensively by NOAA Fisheries and others to identify fishery management goals (e.g., Pikitch et al. 2012). The EwE model generates changes in fish populations by modeling changes in food web relationships. Researchers applied the model to the Northeast Atlantic to evaluate increases in alewives and other forage fishes for a scenario of complete dam removal, based on prior research into historical habitat area (Mattocks et al. 2017). The model found substantial changes in numerous aquatic species resulting from dam removals in eight New England watersheds including the Androscoggin. The baseline fish biomass estimates used by Dias and Jordaan (2016) use the same data sources as other NOAA Fisheries ecological network modeling (e.g., Link et al. 2006, Link et al., 2008). Additional information regarding our EwE analysis can be provided upon request.

We scaled the existing EwE model results to the Lower Androscoggin scenario using a simple proportion of area. We estimated the proportion of alewife habitat area in the Lower Androscoggin relative to the full northern New England extent, as previously estimated by Hall et al. (2012) and Mattocks et al. (2017). We compared biomass baseline and predicted biomass changes from the scaled EwE model to estimate changes in economic value, as described in the next sections.

9.3.1 Commercial Use Value

We compared biomass baseline and predicted biomass changes from the scaled EwE model to estimate changes in economic value across multiple commercial fisheries. All the commercial value increase was due to the indirect effect of how increases in alewife biomass affect the food web in the Northeast Atlantic region. We omitted direct effects of dam changes on spawning rates of other forage fish species and exclude any fish population changes (besides alewives) that might result from improved quality of in-stream habitat, due to a lack of data.

We estimated the commercial fishing value increase with three steps to generate gross revenues using available data sources (Table 10). First, we divided the change in fish biomass due to the dam modification scenario by baseline fish biomass to generate a biomass change ratio (unitless proportion) per fish category. Second, we multiplied this ratio by existing catch (pounds) to generate a change in commercial landings. Third, we multiplied the change in landings by a recent price per pound (adjusted to $2017) to estimate the value increase due to the scenario.

Table 10. Steps and data sources used to estimate commercial fisheries value change.

Calculation Step	Formula	Information and Data Sources
1: Biomass change ratio	(biomass change) / (biomass baseline)	EwE results scaled to Androscoggin
2: Change in commercial landings	(biomass change ratio) × (baseline catch)	Step 1 calculation and landings data (NOAA 2018a)
3: Change in commercial value	(change in catch) × (ex-vessel price)	Step 2 calculation and ex-vessel price (NOAA 2018a)

The EwE results use categories of species biomass that either represent individual species (sometimes subdivided into size classes) or groups of similar species (e.g., guilds), referred to as nodes in EwE models. Applying EwE results required matching these EwE categories to legally harvestable fish species for which commercial landings data were available. Thus, we used only a subset of the EwE results for the commercial economic analysis.

Determining which species and size of species would be included in biomass estimates was based on a combination of fishing regulation information and best professional judgment. Fishing regulations vary by location, by season, and may change through time. There can also be quota limits, bycatch limits, temporary moratoriums, or other restrictions. To address this spatial and temporal heterogeneity in restrictions and the uncertainty of future fishing regulations, we matched EwE categories to regulations that were similar in multiple areas, based on review of a subset of state and NOAA regulations.

In selecting the EwE categories to include in the estimate of biomass available for commercial harvest, we made choices that would tend to bias the total biomass estimate low. We used a narrow set of species or size categories, rather than a more expansive set, that might have overestimated the biomass available for harvest. In some cases (e.g., menhaden, bluefish), multiple size categories for a species appeared in the EwE results. In these cases, we calculated an overall percentage increase for that species as a weighted average of biomass across catchable size classes. Through these choices, we intentionally erred on the side of conservative value estimates.

We used a 3-year average (2014–2016) of commercial landings data to calculate average landings/year as well as average total revenue/year (NOAA 2018a). Data from all Atlantic coast states north of North Carolina were included. We omitted North Carolina because the Northeast

Atlantic region defined in Dias and Jordaan (2016) included only a portion of the North Carolina coast (north of Cape Hatteras). This choice to omit North Carolina was conservative since it omitted some relevant commercial landings. However, this choice was viewed as preferable to including changes in fish biomass that were not included in the original model boundaries, which would have effectively added value of fish biomass that was not part of the original EwE model estimates.

Not all EwE categories aligned perfectly with NOAA Fisheries landings categories. For sharks, there were two relevant EwE categories, coastal sharks and pelagic sharks, but one combined NOAA Fisheries category “sharks.” To rectify this difference, we created an average biomass change ratio, weighted by biomass, to represent the two EwE categories. When NOAA Fisheries landing data categories were more detailed than the EwE category, we summed landings across categories (e.g., for hake species).

We used the most recent data year to estimate price for each fish category. Total ex-vessel values (per fishery) for 2016 (NOAA 2018a) were divided by 2016 landings (NOAA 2018a) and adjusted to year 2017 dollars using the Consumer Price Index Inflator. We multiplied the price per species by the landing changes estimated for the dam modification scenario to generate a total value per species to estimate commercial value per species. We summed values across all species to generate the total commercial value of dam modification.

We excluded some well-known, EwE-modeled fisheries from the analysis for various reasons. The most significant shrimp fishery in the region, the northern shrimp (*Pandalus borealis*), was excluded because it is currently under a fishing moratorium. Dogfish and small weakfish are not part of the analysis because only the small size category registered a change in the EwE model, and we had no way to apportion landings biomass across categories (NOAA 2018a). Anchovy landings data are insufficient and did not occur from 2014–2016.

Perhaps most significantly, given their large biomass, we excluded alewife harvest from value estimates. If alewife populations increase, commercial offshore fishing restrictions could be relaxed. However, in keeping with a conservative approach, we chose not to assume that the modeled increase in alewife would lead to an increase in the commercial alewife harvest at sea.

Inland fishing for alewife currently occurs at several locations in Maine. Between 2014 and 2016, Maine harvests were an average of 1,436,000 pounds, and $432,000 of value per year. However, we did not include any inland commercial fisheries in our analysis. In addition, none of the Maine alewife commercial fishing occurs in the Androscoggin River or its tributaries. We do not expect Androscoggin alewife productivity to generate significant increases in fisheries harvest in adjacent rivers since adults have high fidelity to spawning areas.

9.3.2 Recreational Use Value

We applied biomass baseline and predicted biomass changes from the scaled EwE model to estimate changes in economic value across multiple recreational fisheries, using methods comparable to the commercial value estimates. We used the same scenario and modeling scope in recreational fishing methods as in commercial. We estimated an increase in recreational fish biomass resulting from the dam modification scenario and the indirect effects of increases in alewife biomass on the food web in the Northeast Atlantic region. We omitted direct effects of dam changes on spawning of other forage fish species and exclude any fish population changes that might result from improved quality of in-stream habitat due to lack of data. The recreational value methods used three steps to estimate value that differ only slightly from the commercial value methods (Table 11). We divided the change in fish biomass due to the dam modification scenario by baseline fish biomass to generate a biomass change ratio (percent) per fish category. This ratio was multiplied by existing catch (number of fish) to generate a change in recreational catch (kept and released). By multiplying the biomass change ratio to existing catch, we estimated the percentage of new harvested biomass. Finally, we multiplied the change in catch by a (consumer surplus) value per fish ($2017) that represents improvements in angler welfare from the additional fish caught.

Table 11. Steps and data sources used to estimate recreational fisheries value change.

Calculation Step	Formula	Information and Data Sources
1: Biomass change ratio	(biomass change) / (biomass baseline)	EwE results scaled to Androscoggin
2: Change in total fish caught	(baseline total fish caught) × (biomass change ratio)	State-level catch data by selected species (2014−2017) (NOAA 2018b), and Step 1 calculation
3: Change in recreational value	(change in total fish caught) × (value per fish caught)	Step 2 calculation, and EPA (2004) value per additional fish caught

We chose a subset of the EwE results to use in recreational value assessment based on data availability. Recreational catch data were only available for five species matching EwE results, a subset of the fisheries that had commercial landings data. Similar to the commercial harvest, we used catch data from tidal waters of the included states since these were the only readily available data and were consistent across all states. Recreational catch data are available for all states in our study area (NOAA 2018b).

Annual recreational fish caught (includes fish harvested and released), by state and by species was estimated as a 3-year average of the most recent data years (2015–2017) (NOAA

2018b). As with the commercial analysis, we excluded North Carolina. We estimated value per additional fish caught by species using estimates from EPA (2004; Table D4-8). We averaged values for shore and boat fishing modes and adjusted to 2017 dollars using the Consumer Price Index Inflator (Bureau of Labor Statistics 2018).

9.3.3 Nonuse Value

Nonuse values for an environmental change can be larger than use values; thus, they are important to consider despite estimation challenges. An extensive economic literature has demonstrated that nonuse values exist for many types of improvements to ecosystems, habitat, and species populations. However, we did not quantify these values due to data limitations. Instead, we provided qualitative description of these values in results.

Based on the literature, nonuse values for the affected fishes and non-fish species, including seabirds, pinnipeds (e.g., seals), and turtles, are likely but cannot be quantified either because values available in the literature are not relevant or because the EwE estimates of changes are not sufficiently precise to match values to species groups. For example, sea turtles have a known value but are part of a group of large pelagics unassigned to one species. There is also nonuse value literature associated with changes in river ecosystems (i.e., river restoration). These studies cover numerous ecosystem services and report a variety of values associated with changes to streams, aquatic habitat, and riparian systems (See Section 9.4.4).

9.4 RESULTS

9.4.1 Fisheries

The effort to scale the EwE model results from the Northeast Atlantic to the Lower Androscoggin generated a wide range of biomass changes across multiple fish categories. The percentage change in biomass shows a similar pattern across species groups (Figure 17). The largest biomass and percentage changes among fisheries were in the alosines. Many commercial and recreational species showed increases in biomass.

9.4.2 Commercial Use Value

The increase in biomass percentages for commercial species ranged from 0.05 to 8.3 percent for Area 1 (59 km^2) and Area 2 (46 km^2) (Table 12). When applied to annual landing data, we estimated the overall increase in fish landings to range from 5.5 to 14.1 million pounds per year (Table 13). Those increases were valued at $1.7 to $4.4 million (Table 13). Ranges in landings and value resulted from varying input data on the habitat area used and fish passage efficiency. Several species contributed to the commercial fishery increases, topped by summer flounder (Paralichthys dentatus), Atlantic herring (Clupea harengus), and menhaden (Brevoortia tyrannus).

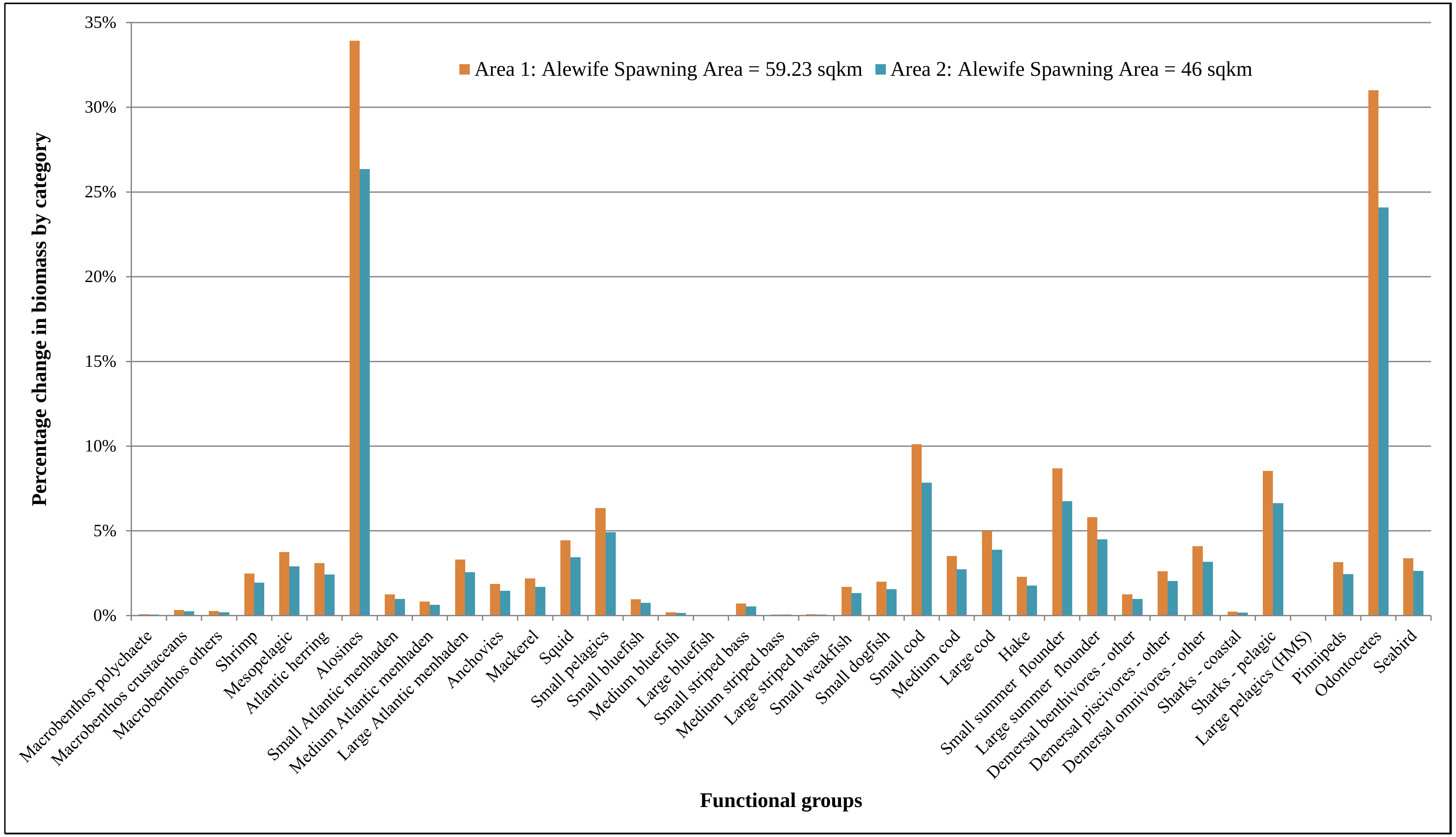


Figure 17. Percentage change in fish biomass by functional group for two scenarios of habitat restoration in the Lower Androscoggin River for 100 percent fish passage efficiency. The 50 percent increase in fish passage efficiency are half as much (not shown).

Table 12. Input data used to value commercial use.

EwE Category[(a)]	NOAA Landings	2014−2016 Average Landings (pounds)	Estimated Price ($/pounds)	Increase in Biomass using Area 1, 100% Fish Passage	Increase in Biomass using Area 2, 100% Fish Passage
Medium Menhaden; Large Menhaden	Menhaden	405,464,316	0.10	1.82%	1.41%
Atlantic Herring	Herring, Atlantic	171,817,483	0.22	3.1%	2.40%
Atlantic Mackerel	Mackerel, Atlantic	12,552,183	0.27	2.19%	1.70%
Large Atlantic Cod	Cod, Atlantic	3,917,804	1.96	4.99%	3.87%
Squid	Squids	1,999	0.96	4.44%	3.45%
Hake	Hake, Atlantic, Red/White, Offshore Silver, Red, Silver; Southern, White	19,439,899	0.90	2.27%	1.77%
Medium Striped Bass	Bass, Striped	5,398,644	4.11	0.06%	0.05%
Small Bluefish; Medium Bluefish; Large Bluefish	Bluefish	2,946,000	0.78	0.72%	0.56%
Large Summer Flounder	Flounder, Summer	7,132,685	4.01	5.80%	4.50%
Coastal Sharks; Pelagic Sharks	Sharks	23,895	0.62	8.31%	6.46%

(a) See text for documentation of omitted fisheries.

Table 13. Commercial use value increase per year and sensitivity analysis.

EwE category[(a)]	100% Fish Passage Landings Increase Area 1 (pound)	100% Fish Passage Landings Increase Area 2 (pound)	100% Fish Passage Value Increase Area 1 ($2017)	100% Fish Passage Value Increase Area 2 ($2017)	50% Fish passage Landings Increase Area 1 (pound)	50% Fish Passage Landings Increase Area 2 (pound)	50% Fish Passage Value Increase Area 1 ($2017)	50% Fish Passage Value Increase Area 2 ($2017)
Medium Menhaden; Large Menhaden	7,381,410	5,732,650	724,507	562,677	3,690,705	2,866,325	362,254	281,338
Atlantic Herring	5,319,605	4,131,383	1,148,438	891,915	2,659,803	2,065,692	574,219	445,958
Atlantic Mackerel	274,661	213,311	74,247	57,663	137,331	106,656	37,123	28,831
Large Atlantic Cod	195,312	151,686	383,447	297,798	97,656	75,843	191,723	148,899
Squid	89	69	85	66	44	34	42	33
Hake	442,065	343,322	399,941	310,607	221,032	171,661	199,970	155,304
Medium Striped Bass	3,153	2,448	12,967	10,071	1,576	1,224	6,484	5,035
Small Bluefish; Medium Bluefish; Large Bluefish	21,334	16,568	16,671	12,947	10,667	8,284	8,336	6,474
Large Summer Flounder	413,735	321,320	1,658,242	1,287,846	206,867	160,660	829,121	643,923
Coastal Sharks; Pelagic Sharks	1,986	1,543	1,233	958	993	771	617	479
TOTAL:	14,053,350	10,914,302	$4,419,779	$3,432,548	7,026,675	5,457,151	$2,209,889	$1,716,274

(a) See text for documentation of omitted fisheries.

9.4.3 Recreational Use Value

The increase in catch for recreational species ranged from 0.05 to 5.8 percent for Areas 1 and 2 (Table 14). When applied to annual recreational catch data, we estimated the overall increase in fish catch to range from approximately 351,000 to 904,000 fish per year (Table 15). Those increases were valued at $4.0 to $10.4 million (Table 15). Ranges in catch and value resulted from varying input data on the habitat area used and fish passage efficiency. Summer flounder dominates the recreational value increase.

Table 14. Input data used to value recreational use.

Species	2015−2017 Average Catch (number of fish)	Catch Increase for Area 1	Catch Increase for Area 2	Estimated Value per Additional Fish Caught ($2017)
Bluefish	6,105,709	0.72%	0.56%	8.54
Striped Bass	11,932,978	0.06%	0.05%	20.84
Summer Flounder	11,560,185	5.80%	4.50%	11.60
Atlantic Mackerel	6,315,301	2.19%	1.70%	8.54[a]
Atlantic Cod	891,817	4.99%	3.87%	20.84[b]

(a) The EPA (2004; Table D4-8) value for bluefish was applied, as the most similar.
(b) The EPA (2004; Table D4-8) value for striped bass was applied, as the most similar.

Table 15. Recreational use value increase per year and sensitivity analysis.

Species	Catch Increase due to Area 1 (# of fish)	Catch Increase due to Area 2 (# of fish)	Value Increase due to Area 1 ($2017)	Value Increase due to Area 2 ($2017)	Catch Increase due to Area 1, 50% Fish Passage (# of fish)	Catch Increase due to Area 2, 50% Fish Passage (# of fish)	Value Increase due to Area 1, 50% Fish Passage ($2017)	Value Increase due to Area 2, 50% Fish Passage ($2017)
Bluefish	44,215	34,339	377,681	293,320	22,107	17,169	188,840	146,660
Striped Bass	6,968	5,412	145,202	112,769	3,484	2,706	72,601	56,385
Summer Flounder	670,554	520,775	7,781,040	6,043,016	335,277	260,387	3,890,520	3,021,508
Atlantic Mackerel	138,189	107,322	1,180,400	916,738	69,094	53,661	590,200	458,369
Atlantic Cod	44,459	34,529	926,430	719,497	22,230	17,264	463,215	359,748
TOTAL	**904,385**	**702,376**	**$10,410,753**	**$8,085,340**	**452,192**	**351,188**	**$5,205,377**	**$4,042,670**

9.4.4 Nonuse Value

Among the seven target species, only Atlantic salmon has been the subject of dedicated nonuse value study to our knowledge. A literature review located three separate studies valuing this salmon species – Kay et al. (1987), Stevens et al. (1991), and Stevens et al. (1997). The studies varied in many respects, such as in the scope of the change in Atlantic salmon considered, in the type of sample analyzed, and analysis methodology. However, in all cases, the authors measured positive willingness to pay for improvement in Atlantic salmon. This analysis was not able to apply directly those values to the Androscoggin Watershed and are not tabulated here.

As with the commercial and recreational value analyses, the EwE modeling greatly expands the scope of species that can be included in the nonuse value analysis. In particular, the EwE categories of seabirds, pinnipeds (e.g., seals), large pelagics (e.g., sea turtles), and odontocetes (e.g., dolphins) stand out as potentially representing nonuse values. Notably, odontocetes have a relatively large estimated modeled change in biomass. Improvements in numbers to these species will likely generate substantial nonuse values. However, an impediment to valuation is that EwE results cannot easily be interpreted as specific quantitative changes to particular species within the groups. Because nonuse values will be sensitive to total change by species, this data gap cannot be overcome. We can infer, however, that changes in dolphins or similar species would likely have substantial values. Studies showing significant values for improved abundance or status for certain marine fishes and mammals include Richardson and Loomis (2009) and Wallmo and Lew (2012).

A species does not necessarily need to be threatened, endangered or rare, or charismatic to give rise to nonuse values. It is entirely possible that other species such as alewife, the important forage fish that this analysis is based on, would also have some nonuse value associated with its increase. Richardson and Loomis (2009) provide examples of studies that demonstrated that people value changes in some non-charismatic aquatic species. However, without evidence of such values in the study region, and species-specific values, it is difficult to infer or estimate value for such changes.

Nonuse values have also been quantified for changes to ecosystems, such as improvements in river ecosystems due to restoration. Two recent reports analyze this large literature: Bergstrom and Loomis (2017) and Brouwer and Sheremet (2017). In general, these authors find increasing value for increasing length of restored river. A variety of ecosystem services are valued in the studies, such as flood regulation, erosion control, water quality regulation, water recreation, landscape aesthetics, and wildlife habitat (Brouwer and Sheremet 2017). The average willingness to pay per household across studies varies from $3 to $220 per year, which translates to $0.25 – $10.18 per mile (Bergstrom and Loomis 2017; all values in 2015 dollars). The reported values in the underlying studies are a mixture of recreational use value and nonuse value, with nonuse value an important fraction of the total. The scope of this analysis did not include the available meta-regression models, such as Brouwer and Sheremet (2017), Johnston et al. (2003), or Johnston et al. (2005), to estimate nonuse values and total economic value for the changes in the Lower Androscoggin Watershed.

9.5 ECONOMIC BENEFIT OF RESTORED FISHERIES

Only a small percentage of the predicted biomass increases for the Lower Androscoggin scenario is included in our estimates of catch by the commercial fisheries. The percentage of biomass landed for all species combined was 7.8 percent. The total biomass per fishery category that was extracted in the harvest ranged from 0.0 (squid) to 34.2 percent (menhaden) (Table 16). The commercial catch percentages averaging 7.8 percent are conservative compared with estimated commercial catch rates for forage fish of 80 percent reported by Pikitch et al. (2012) for forage fish species, overall. This 80 percent figure is from page 69 of Pikitch et al. (2012), based on their discussion of the typical 20 percent minimum biomass threshold.

A similar cross-check was conducted for the recreational catch and similarly found that a low percentage of biomass was caught. The percentage of biomass caught for all species combined was 6.8 percent. However, this calculation is less certain than that for commercial fishes. We used average weight per fish to convert numbers of fish to biomass. Average weight was for harvested recreational catch for each of the fisheries, by state, and by year (NOAA 2018b). Weight data were for harvested fishes only, which excludes caught and released fishes, which are typically a substantial portion of total catch. We expect that using average weight per fish based on harvested fishes will tend to overestimate the recreational biomass, since anglers typically harvest large fish and release small fish. Furthermore, if released fishes are caught more than once, their biomass would be counted more than once. Nevertheless, this calculation confirms that we are not valuing more biomass than the EwE model predicted.

We did not account for increased value directly related to alewife, such as the possibility of increased commercial landings. If alewife abundance increases in the Androscoggin, this would increase the likelihood that in-watershed communities would petition the state of Maine for reestablishment of historical harvest rights, a process continuing into contemporary times with 17 active locations recently tallied (McClenachan et al. 2015). Beyond direct commercial economic value, McClenachan et al. (2015) describe further benefits of recovering historic alewife harvests in Maine, such as community building, recreational opportunities, and increased local tourism.

Table 16. Percentage of predicted increase in biomass that is commercially landed and recreationally caught.

EwE result	Commercial % Biomass Captured	Recreational % Biomass Captured
Medium Menhaden; Large Menhaden	34.2%	Not applicable
Atlantic Herring	5.1%	Not applicable
Atlantic Mackerel	3.0%	0.3%
Large Atlantic Cod	8.5%	10.3%
Squid	0.0%	Not applicable
Hake	4.3%	Not applicable
Medium Striped Bass	2.7%	74.0%
Small Bluefish; Medium Bluefish; Large Bluefish	6.5%	47.9%
Large Summer Flounder	7.5%	12.4%
Coastal Sharks; Pelagic Sharks	0.3%	Not applicable
TOTAL	7.8%	6.8%

We conducted an additional check on our analysis to consider whether there would be significant diminishing returns from additional landings or catch. As commercial fish landings or recreationally caught fishes increase, each additional unit may have less value, particularly if landings or catch is already relatively large. In the case of commercial fisheries, landings are variable year to year. We consider the small percentage increases treated here will not lead to significant diminishing returns, particularly since many fishery stocks are low relative to historical levels. For recreational anglers, we evaluated current catch rates, to get a sense of whether the estimated additional fishes caught are over a large or small number of fishing days. We looked at saltwater recreational days of fishing data for 2011, for striped bass and bluefish, the only single-species data broadly available from Maine to Virginia (USFWS et al. 2011). In these two cases, given millions of total fishing days per year in each case, predicted additional catch per day would average less than 1 percent. Thus, diminishing return is not an issue for the recreational fishing increases either.

9.6 CONCLUSIONS

We expect modifications or removal of all dams in the Lower Androscoggin River to generate substantial commercial and recreational fishing benefits. Using only a subset of all affected fish species and conservative estimates of fisheries effects, the estimated economic values for two different scenarios of habitat area above dams is $5.8 to $14.8 million in total benefits annually. These benefits consist of $1.7 to $4.4 million for commercial fishing benefits and $4.0 to $10.4 million in recreational fishing benefits. These benefits would accrue to fishermen distributed from Maine to Virginia.

The food web model indicated small to large changes up the food chain to larger predators such as pinnipeds (e.g., seals), large pelagics (includes sea turtles), odontocetes (e.g., dolphins), as well as in-stream habitat. Although we did not have sufficient data to quantify values accruing from these changes, the economic evidence suggests that they are likely to generate substantial nonuse values.

10. PREVIOUS FISHERY MANAGEMENT ACCOMPLISHMENTS AND CURRENT MANAGEMENT STATUS

This section details the current management issues for those species included in the CP. It also includes a list of management plans reviewed while developing the CP.

10.1 CURRENT MANAGEMENT ISSUES IN THE ANDROSCOGGIN RIVER WATERSHED

The following management issues in the Androscoggin River Watershed affect the diadromous fishery:

- The lack of effective upstream and downstream fish passage at the Brunswick Project is limiting successful American shad and other diadromous species restoration.
- The lack of upstream fish passage at the seven dams within the mainstem of the Little Androscoggin River and the dams located along its tributaries preclude the restoration of diadromous fishes.
- None of the five dams on the Sabattus River provide upstream fish passage.
- Alewife spawning success is low within the hydropower impoundments on the mainstem of the Androscoggin River. This does not significantly contribute to the returning adult population.
- The only hydropower facility to have dedicated upstream fish passage for the American eel is the Worumbo Project. Fishways designed for anadromous fishes are typically less effective for American eel.
- Some stream-road crossings in the watershed limit aquatic connectivity.
- Impaired water quality.
- Some of the bypass reaches at hydroelectric facilities lack sufficient minimum flows, particularly on the Little Androscoggin River.

10.2 COMPREHENSIVE PLAN CONSIDERATION OF OTHER FISHERY MANAGEMENT PLANS

We considered the following management plan concepts, philosophies, and guidelines during the development of the CP:

- **Species Specific**

  - ASMFC Interstate Fishery Management Plan for Shad and River Herring (River Herring Management) (2009b).
  - ASMFC Interstate Fishery Management Plan for the American Eel (2013).
  - Recovery Plan for the GOM Distinct Population Segment for the Atlantic Salmon (2016).
  - MDMR American Shad Habitat Plan (2014).

- **Watershed Specific**

  - MDMR Draft Fisheries Management Plan for the Lower Androscoggin River, Little Androscoggin River, and Sabattus River (2017).
  - Maine Department of Inland Fisheries and Wildlife Upper Androscoggin River Fishery Management Plan (2014).
  - Biological Opinion for the Lockwood (2574), Shawmut (2322), Weston (2325), Brunswick (2284), and Lewiston Falls (2302) Projects (2013).
  - Biological Opinion for the Pejepscot Project (4784) (2017).
  - Biological Opinion for the Worumbo Project (3428) (2017).

- **Critical Habitat**

  - Endangered and Threatened Species Designation of Critical Habitat for Atlantic Salmon, GOM Distinct Population Segment (2009).
  - Endangered and Threatened Species Designation of Critical Habitat for the GOM, New York Bight, and Chesapeake Bay Distinct Population Segments of Atlantic Sturgeon (2016).

11. SUMMARY OF THE COMPREHENSIVE PLAN ANALYSES

11.1 RESTORATION GOALS FOR THE DIADROMOUS FISHERY

11.1.1 American Shad

The restoration approach for American shad will focus on improving passage on the lower mainstem Androscoggin, Little Androscoggin, and Sabattus Rivers. We will engage in the FERC relicensing and compliance actions at the Brunswick, Pejepscot, and Worumbo Projects on the Lower Androscoggin River mainstem. On the Little Androscoggin River, four hydroelectric projects and three non-hydro barriers on the mainstem need fish passage. The first three hydroelectric projects (Barker's Mill, Barker Mill Upper, and Hackett Mills) will require a new license within ten years. Conditions in those new licenses for upstream and downstream fish passage measures will provide access to the Taylor Pond-Little Androscoggin and the Marshall Pond-Bog Brook sub-watersheds, adding nearly 20 miles of riverine habitat. Once there are observations of diadromy at the fourth hydroelectric project (Marcal), we will work with our partners to exercise our reserved authority to install new fish passage measures at that facility. Two of the three non-hydropower dams on the mainstem (Welchville and Littlefield dams) are breached with the Littlefield Dam being only a partial barrier. The breached dams remain a passage barrier. At the Welchville and Littlefield dams, we will work with our partners to improve fish passage or remove these barriers, adding another 25 miles of habitat. Fish passage installation and barrier removal in the Little Androscoggin River and Sabattus River watersheds will more than triple the habitat available based on our GIS analysis. These actions will also benefit many of the other species migrating in the Little Androscoggin River.

Nearly all of the potential American shad habitat (35 miles) on the Sabattus River will be accessible once the first three non-hydro dams are removed or provide fish passage. Two of those dams are breached with full removal of the Mill Street dam likely to occur in the next few years.

Our goal is to have annual recruitment of adult American shad reach the upper limits of suitable spawning habitat in the Little Androscoggin and Sabattus Rivers. In addition, our goal is to have safe emigration for both adults and juvenile shad to the Gulf of Maine. Once we open up the mainstem and tributary spawning habitat for American shad, we anticipate a minimum of 125,000 adult American shad will return each year to the Androscoggin River.

11.1.2 Blueback Herring

The restoration approach for blueback herring will mirror that of American shad as both species require similar spawning and rearing habitats. Blueback herring will use smaller drainage areas compared to American shad that will require removing or modifying additional barriers further upstream in the sub-watersheds. Once restoration is completed, we anticipate a minimum of one million blueback herring returning to the Androscoggin River each year.

11.1.3 Alewife

Based on our analysis, the Taylor Pond-Little Androscoggin River, Sabattus River, and Sabattus Pond sub-watersheds (Figure 5) are primary focus areas for volitional passage. The Taylor Pond-Little Androscoggin sub-watershed includes the two hydroelectric facilities (Barker's Mill and Barker Mill Upper), which are presently undergoing licensing (Table 5). Upstream fish passage facilities will be part of the new licenses at both facilities as well as improvements to the downstream passage facilities. New fish passage facilities at the Barker's Mill and Barker Mill Upper Projects and potential removal of the partial barrier at Littlefield Dam would provide alewife full volitional access to Worthley Pond. In addition, fish passage or dam removal at the three private dams on Taylor Brook would provide alewife access to spawning habitat in Taylor Pond. These include Kendall Dams 1 and 2, and Taylor Brook Dam.

The Sabattus River sub-watershed has three barriers: Mill Street dam, Lower Lisbon Falls (Farwell) dam, and Upper Lisbon Falls dam. Both the Mill Street and Upper dams are breached suggesting they are prime candidates for full removal. The next upstream dam, the Farwell Mills dam, sits on a large ledge falls and anticipated fish passage will include dam removal and the restoration of passage around the falls. After completion of these fish passage projects, alewife will have volitional access to No Name Pond, Sutherland Pond, Curtis Bog, and Loon Pond in the Sabattus River sub-watershed. Within a mile of the Sabattus Pond outlet, three dams require fish passage or removal before alewife have access to that spawning habitat. The fourth upstream dam is the Fortier dam, a former hydropower site that is now defunct, in deteriorated condition, where dam removal is technically feasible. The fifth upstream dam is the Sabattus dam, a low-head, masonry dam in poor condition where a complete removal has been designed. The sixth upstream dam, the Sleeper dam, is at the outlet of the 1,962 acre Sabattus Pond, which represents most of the alewife habitat in the Sabattus River watershed. The Sleeper dam controls water levels in Sabattus Pond and an anticipated rebuild or repair of the dam will include a fishway. Upon completion of these alewife restoration projects, the alewife production potential will exceed 700,000 returning adults in the Androscoggin River Watershed.

A future second phase of alewife restoration involves addressing barriers in Little Androscoggin River sub-watersheds to allow volitional access to spawning habitat. These sub-watersheds include Marshall Pond-Bog Brook, Waterhouse Brook, Whitney Pond, and Thompson Lake (Figure 5). Three mainstem barriers on the Little Androscoggin River are important factors in the success and sequencing of the second phase of alewife restoration: Hackett Mills, Marcal, and Welchville dams. Both Hackett Mills and Marcal are licensed hydroelectric projects. Fish passage at these projects will occur through conditioning of the new and existing licenses. Welchville dam, owned by the Town of Oxford, is dilapidated. Fish passage through either dam removal or fishway construction will restore connectivity. Marshall Pond, the Range ponds, and Thompson Lake will require fishways to provide access to the spawning habitat, but the spawning habitat in the Whitney Pond sub-watershed will be accessible by addressing the mainstem dams. Any fishway to Thompson Lake will require consultation with Maine Inland Fisheries and Wildlife before installation. Upon completion of the second phase of alewife restoration, the production potential will exceed 2.3 million returning adults in the Androscoggin River Watershed.

Within the geographic scope of this CP, there is additional spawning habitat for alewife that may be addressed in future plans (e.g., the Pennesseewassee Lake sub-watershed). At this time, we do not have plans to address those passage issues as it represents only a small percentage of the historical spawning habitat.

11.1.4 American Eel

The restoration approach for American eel includes installing and maintaining upstream eel ways at hydroelectric facilities within the Androscoggin River Watershed. More importantly, downstream protection measures and bypasses are necessary at hydroelectric facilities, as turbine mortality is a significant threat to pre-spawn silver eels (Shepard 2015, ASFMC 2013). Therefore, we will focus efforts on hydroelectric projects within the restoration focus area of this CP where there is opportunity. At non-hydropower dams, dam removal is the preferred option to facilitate habitat usage by American eel. Where dam removal is infeasible, construction and maintenance of upstream eel ways by owner and/or community-based restoration improve access. With the exception of severe barriers, most culverts in the watershed are not a focus of restoration efforts for American eel. Because of the numerous hydroelectric facilities that may cause significant mortality for silver eels in the Upper Androscoggin River Watershed, we will focus on habitat improvements below Lewiston Falls.

11.1.5 Sea Lamprey

The restoration approach for sea lamprey should follow the same approach as described for American eel, as their spawning habitat requirements span most of the watershed. Our goal is to restore volitional passage for sea lamprey, providing access to their historical habitats within the mainstem Androscoggin River up to Lewiston Falls, and the Little Androscoggin, Sabattus, and Little Rivers. Lewiston Falls is the upper boundary because of the state's focus on freshwater, resident species only and the numerous hydroelectric facilities inhibiting downstream passage of sea lamprey juveniles.

11.1.6 Atlantic Salmon

The approach proposed in this CP to restore the Atlantic salmon in the Androscoggin River Watershed will follow the approach outlined to restore the GOM distinct population of

Atlantic salmon in the FRP (USFWS and NMFS 2018), which serves as a species-specific CP. The recovery plan serves as a technical advisory document that makes recommendations to achieve recovery objectives for the population.

The salmon FRP identifies five broad recovery actions (and corresponding specific actions) to achieve recovery objectives:

1. ***Habitat connectivity.*** Enhance connectivity between the ocean and freshwater habitats important for salmon recovery.

2. ***Genetic Diversity.*** Maintain the genetic diversity of Atlantic salmon populations over time.

3. ***Conservation Hatchery***. Increase adult spawners through the conservation hatchery program.

4. ***Freshwater Conservation***. Increase adult spawners through the freshwater production of smolts.

5. ***Marine and Estuary***. Increase Atlantic salmon survival through increased ecosystem understanding and identification of spatial and temporal constraints to salmon marine productivity.

6. ***Federal/Tribal Coordination***. Consult with all tribes on a government-to-government basis.

7. ***Outreach, Education, and Engagement***. Collaborate with partners and engage interested parties in recovery efforts for the GOM DPS.

The overall goals of this CP align most directly with the FRP Recovery Action Number 1, Habitat Connectivity. The proposed restoration approach for salmon will follow the 13 specific recovery actions listed under the habitat connectivity category. Section 13 presents details on how the final recommendations of this CP align with specific recovery salmon recovery actions, both at the recovery plan level and with the Merrymeeting Bay Salmon Habitat Recovery Unit (SHRU) work plan site-specific recovery actions.

11.1.7 Striped Bass

This CP does not include actions for the restoration of striped bass. Restoration of this species is reliant on the actions of other management programs.

11.2 ENERGY ANALYSES

The current generation capacity of 12 facilities on the Androscoggin River within the historical extent of diadromy totals 168.86 MW based on FERC records with individual units ranging from 3.125 to 14.22 MW. Generation capacity of the four facilities on the Little Androscoggin River total 3.88 MW based on FERC records with individual units ranging from 0.45 to 1.5 MW. We evaluated the theoretical potential for upgrades of these facilities to generate additional power. We determined that many of the facilities on the mainstem have the potential for substantial increases in capacity and annual generation. Based on these calculations, an additional 399,050 MWh, a 39 percent increase, is theoretically possible by 10 of the 12 facilities located on the mainstem Androscoggin River. This number is an average ranging from an estimated low of 13,360 MWh to a high of 136,980 MWh (Table 17). Conversely, on the Little Androscoggin River, these calculations suggest that existing hydroelectric generation has minimal potential for an increase in power. To evaluate the potential of new-stream reach and non-powered dam development, we chose two candidate projects for theoretical generation and revenue that both showed a multiple decade simple pay back. This suggests that additional development beyond existing hydroelectric facility upgrades is uneconomical under current market conditions and incentives.

When we compare total generation for the three projects on the Little Androscoggin River to the total hydroelectricity produced in Maine, the data from 2001 to 2012 indicate that the percentages ranged from 0.3 to 0.4 percent of generation, whereas the 12 projects on the mainstem Androscoggin River ranged from 26 to 28 percent. When we compare these projects to all electricity generated in Maine, the Little Androscoggin River projects represent 0.04 to 0.11 percent of generation, whereas the mainstem Androscoggin River projects represent 4 to 7 percent. This suggests that the mainstem of the Androscoggin River produces a significant portion of the State’s power, whereas the Little Androscoggin produces minimal generation that may be readily replaced with potential upgrades at mainstem facilities or other means of renewable energy.

Table 17. Summary of energy analysis for areas analyzed in this CP.

Summary parameter	Little Androscoggin River watershed projects[1]	Mainstem Androscoggin projects outside RFA	Mainstem Androscoggin projects in RFA
No. of projects analyzed	3	9	3
Rated Capacity (MW)	3.4	132.9	36.0
Ave. Annual Generation (MWh)	13,315	759,408	259,780
Additional Capacity (MW)	0	21.5	49.6
Additional Generation (MWh)	0	342,966	56,082
Estimated current annual revenue[2]	$0.7 million	$38.0 million	$13.0 million
Additional annual revenue from upgrades	$0	$17.1 million	$2.8 million
Total upgrade cost	N/A	$95.8 million	$41.3 million
Estimated payback period (years)[3]	N/A	1.9 – 8.9	13.3-18.8

1. Excludes Hackett Mills
2. Based on $50/MWh
3. Payback period varies from project to project based on several different project configurations and assumptions unique to a given project.

11.3 ECONOMIC BENEFIT

The NOAA Fisheries is an agency within the U.S. Department of Commerce whose mission is to promote job creation, economic growth, sustainable development, and improved standards of living for Americans. The Androscoggin River is an economic engine for the state of Maine and the United States by sustaining commercial and recreational fisheries in balance with industry and energy production. We recommend specific actions in this CP that promote economic benefit. For example, the removal of dams and construction of fishways can create economic opportunity, as can upgrading a powerhouse to generate more electricity. With respect to increasing the population of diadromous fishes identified in the restoration focus area, our analysis indicates substantial economic benefit resulting in this diadromous fishery restoration.

Subsequent to modifications or removal of all dams in the Lower Androscoggin River, we expect substantial commercial and recreational fishing benefits. Using only a subset of all affected fish species and conservative estimates of fisheries effects, we estimated the economic values for two different scenarios of accessible habitat area above dams to range from $5.8 to $14.8 million in total benefits. These benefits consisted of $1.7 to $4.4 million for commercial fishing benefits and $4.0 to $10.4 million in recreational fishing benefits. These benefits would accrue to the fishing industry distributed from Maine to Virginia.

11.4 SYNTHESIS OF ANALYSES

This section incorporates the results of the geospatial, energy, and economic analyses performed in this CP with the management goals presented in the state of Maine's Draft Fisheries Management Plan. NOAA Fisheries' goal is the development of management actions that will improve and restore the diadromous fishery and habitat in the Androscoggin River Watershed while maintaining or improving hydroelectric power production.

Section 10(a) of the Federal Power Act establishes the comprehensive development standard which each project must meet to be licensed. A licensed project shall be:

> *...best adapted to a comprehensive plan for improving or developing a waterway or waterways for the use or benefit of interstate or foreign commerce, for the improvement and utilization of waterpower development, for the adequate protection, mitigation, and enhancement of fish and wildlife (including related spawning grounds and habitat), and for other beneficial public uses, including irrigation, flood control, water supply, and recreational or other purposes...*

Development of the Little Androscoggin River for hydropower generation did not include mitigation of project impacts on diadromous fishes and associated habitat. Millions of alewife that are unable to spawn in the Little Androscoggin River Watershed has decreased direct and indirect economic activity and has limited the amount of prey available for economically valuable predator species such as cod, haddock, striped bass, bluefish, and lobster.

We summarized the existing and theoretical capacity at FERC license projects within the Androscoggin River Watershed (Figure 18) and the adult diadromous restoration potential based on the MDMR's estimates (Figure 19). The lower three mainstem Androscoggin River projects have a combined installed capacity of 36 MW with the potential for 57.5 MW. The Lower Androscoggin River includes suitable habitat to support roughly 388,000 alewife, 731,000 blueback herring, and 84,000 American shad. Safe, timely, and effective upstream and downstream passage at these projects would support this level of restoration. The four licensed projects on the Little Androscoggin River have a combined rated capacity of 3.9 MW with a theoretical increase to 4.1 MW. MDMR (2017b) estimates adult returns of approximately 1,730,000 alewife, 327,000 blueback herring, and 38,000 American shad. This represents a considerable difference between the river reaches concerning energy production and fisheries productivity. Finally, the combined existing capacity for all the FERC licensed projects on the Androscoggin River from Lewiston Falls up to and including Rumford Falls is 129.3 MW with a potential increase of up to 185.5 MW. MDMR did not assess diadromous restoration potential above Lewiston Falls.

The first three projects on the Androscoggin River have the potential to meet a comprehensive development standard for our trust resources based on the annual generation and existing measures to mitigate impacts to fishery resources. The Little Androscoggin River, however, does not meet the comprehensive development standard for our trust resources at this time (see Figures 18 and 19). Greater effort to improve diadromy is required in the Little Androscoggin River to balance the waterway development and protection of fishery resources and habitat. The recommended actions described in Sections 11.1 and 12.0 would greatly facilitate the balancing of development and restoration of fishery resources to meet a comprehensive development standard.

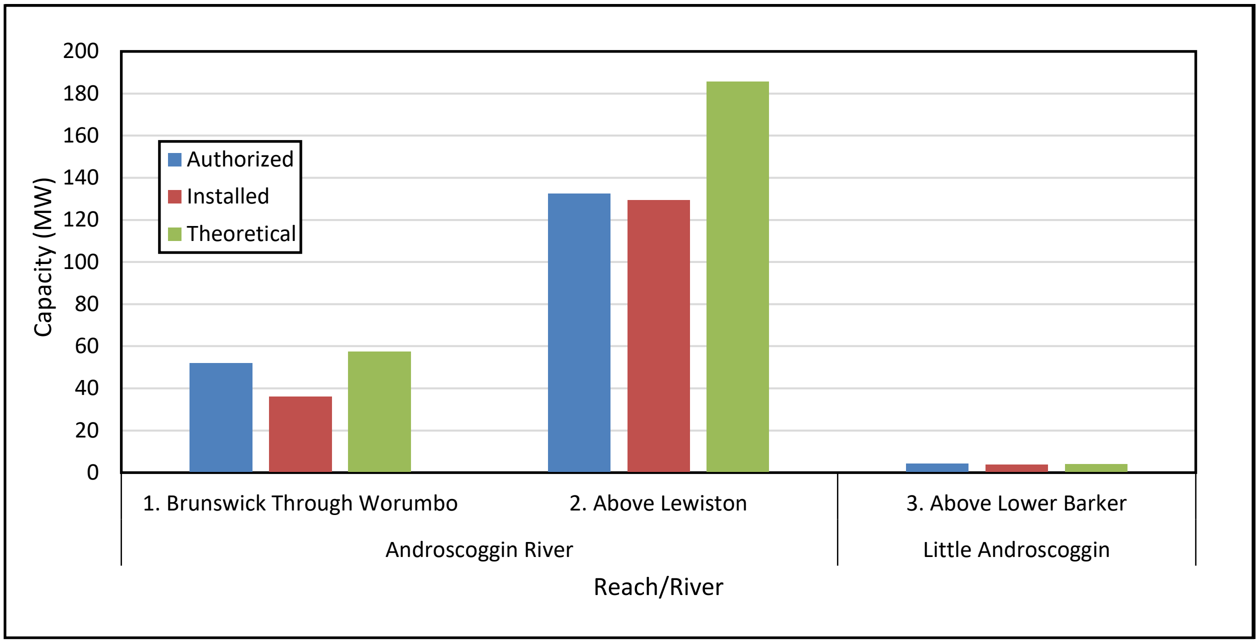


Figure 18.   Summed capacities for FERC licensed project. Authorized represents the capacity of the FERC license. Installed is the capacity that is currently available. Theoretical is based on the methods described in Section 8.

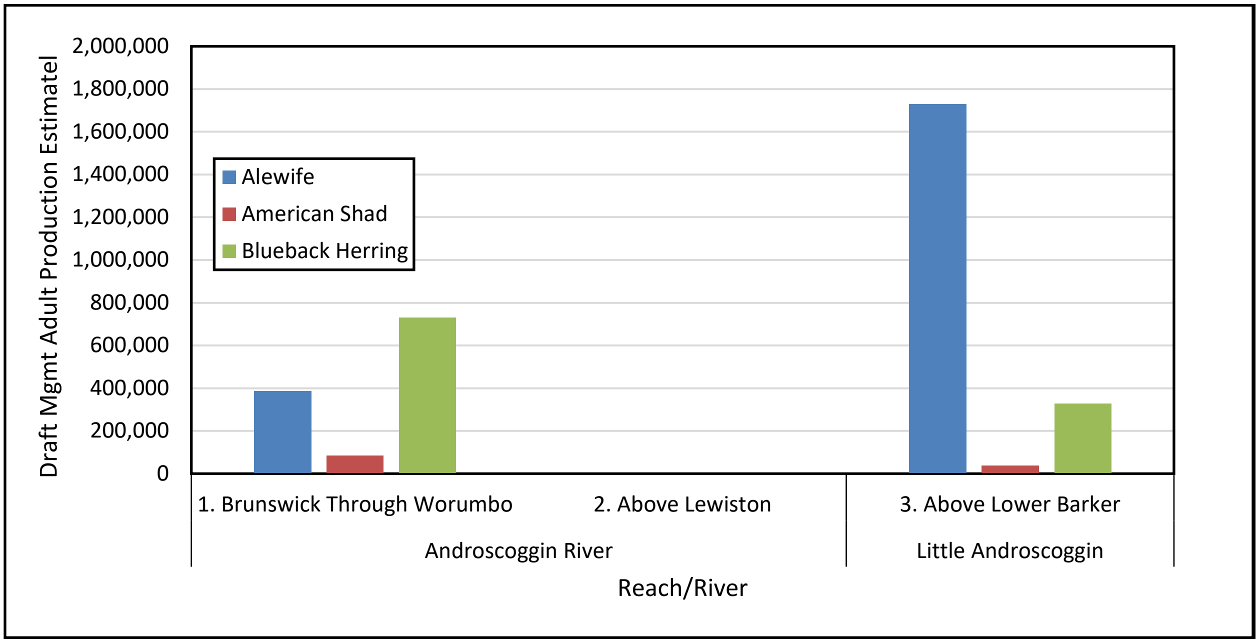


Figure 19. Adult alewife production estimates (data from MDMR 2017b).

12. RECOMMENDATIONS AND PRIORITY ACTIONS

The purpose of the CP is to establish a framework that balances the restoration of the diadromous fishery and the need for sustainable energy production, while defining goals to protect, conserve, and enhance Androscoggin River habitat and resources. This CP supports improving access to habitats in the restoration focus area through dam removal and fishway installation to increase the recreational and commercial fishery while also supporting energy production and facility upgrades. We recommend the following priority actions to achieve our goals for diadromy and meet a comprehensive development standard for the Androscoggin River. Each recommendation requires outreach, feasibility analysis, funding, and other considerations (e.g., assessment of invasive species control). Therefore, actions to implement these recommendations require planning beyond the scope of this CP.

12.1 BARRIER MODIFICATION OR REMOVAL

12.1.1 FERC Licenses

Within the restoration focus area, all but one of the hydroelectric project licenses will expire in the next decade or have recently expired. With each license expiration, there is an opportunity to install new fish passage facilities, improve or replace existing fish passage facilities, or decommission and remove the facility. Our preference is dam removal, where possible, as this action results in the maximum benefit for our trust species. However, we acknowledge and support the need for renewable energy production. Where a new or subsequent license is warranted, we will use our authorities to condition licenses appropriately for safe, timely, and effective fish passage. Where applicable, we will also support facility upgrades to increase power generation that do not pose an additional threat to our trust resources. We also support licensing hydropower decisions based on a watershed approach. Comprehensive license requirements that address the cumulative impacts of hydropower facilities on nonpower resources would prove beneficial to power and nonpower interests versus the standard project by project actions.

12.1.2 FERC Compliance

After license issuance, the Licensee must meet the terms and conditions of that license to continue operating the project. We will work with the FERC's Division of Hydropower Administration and Compliance, our partners, and the Licensee to ensure the Licensee meets license conditions relevant to our trust species. Specific actions include development of site-specific performance standards, regular site visits and inspections of fish passage facilities, additions and corrections in the administrative record, adaptive management of resource goals and objectives, review of fish passage monitoring requirements, and continued consultation to meet facility performance standards. If a Licensee proposes to amend the license to increase energy production, we will support those facility upgrades that do not pose an additional threat to our trust resources.

12.1.3 Non-hydro Barriers

Numerous non-hydro barriers in the restoration focus area require modification or removal to support diadromous fish restoration. These barriers include both road crossings and non-hydro dams. We will work with our partners to prioritize these barriers for removal, modification, or installation of fishways. Specific actions include providing technical advice, funding through competitive grant programs, and permitting assistance.

12.2 RESEARCH

Well-directed research is necessary to support restoration goals in this CP, as well as other management plans. We need a better understanding of the biological, biotic, and abiotic requirements for each target species, as well as the engineering designs for fish passage facilities. Studies with the greatest implication for informing FERC licensing and compliance, as well as direct management activities, will receive highest priority for consideration. We will work across NOAA Fisheries divisions and line offices (e.g., NOAA science centers), as well as federal and state partners, and NGOs to identify specific research needs and funding opportunities. We recommend the following research actions.

12.2.1 Habitat Assessments

The geospatial and biological analyses in this CP represent an initial attempt to quantify the production potential of restored connectivity throughout the historical extent of diadromy. For some species such as alewife and American shad, we have validated areal production estimates that provide an estimate of production potential after delineating increased habitat availability following barrier removal or fishway installation. For other species, such as American eel and sea lamprey, production estimates are lacking. Therefore, we will promote, conduct, and fund research that addresses improving existing production estimates and establishing new production estimates for the full suite of diadromous species in the Androscoggin River Watershed. In addition, not all habitat is equal. We will work with partners to develop better habitat suitability indices that more accurately determine carrying capacity of different habitat types. In conjunction with field surveys and in-depth geospatial analyses, we will refine restoration goals and fish passage performance standards for hydroelectric facilities in the watershed.

12.2.2 Fish Passage Research

The goal of this CP is to better balance energy production and the diadromous fishery. Because removing all the dams in the restoration focus area would not meet this comprehensive development standard, effective fish passage is a necessary component of a sustainable future for the Androscoggin River Watershed. Fish passage is an evolving science (Silva et al. 2017). We will continue to support fish passage research that maximizes the efficacy of installed fishways while minimizing the capital investment and life cycle costs incurred by the fishway owner. Examples of key research directives include developing fishways that pass a multitude of species, minimize migration delay, promote volitional passage, decrease operation and maintenance burdens, and facilitate monitoring.

12.2.3 Socioeconomic Benefits of Restoration

As an agency within the U.S. Department of Commerce, NOAA Fisheries strives to understand the socioeconomic benefits of a restored diadromous fishery. As highlighted by the analyses in this CP, the socioeconomic benefits of a restored fishery extend well beyond the watershed. We will promote, conduct, and fund research that quantifies the direct and indirect benefits of increased fish productivity in both riverine and marine habitats.

12.2.4 Effects of Restored Diadromy on Water Quality

Sea-run fish are an important source of marine-derived nutrients for freshwater systems. Like-wise, outmigrating juveniles are a significant export vector of freshwater-derived nutrients into estuarine and marine habitats. The balance between these two nutrient sources is critical to supporting healthy water quality conditions in freshwater lakes. Escapement, productivity, and carrying capacity all factor into the balancing of this nutrient cycle (Barber et al. 2018). Further, external negative factors to restoration of diadromous fishes (e.g., lawn fertilizer, broken septic systems) need full consideration when evaluating potential contributors to a lake or pond’s water quality status. Therefore, we will work with partners, agencies and researchers to review studies proposed and data collected that address these concern.

12.2.5 Species Interaction in Response to Increased Diadromy

Species interaction remains a debated topic among resource managers. Concerns regarding competition for food and spawning habitat are often cited. Most investigations regarding interspecies competition relate to landlocked populations of alewives. Section 6.2.5 provides more detail regarding the concern and recent history of the issue. We anticipate that a more robust body of science on this topic will bolster our efforts for promoting restoration of sea-run fishes. Therefore, we will work with partners, agencies and researchers to review studies and data collected that address this concern.

12.3 PUBLIC OUTREACH AND STAKEHOLDER ENGAGEMENT

The extirpation and dramatic declines in the diadromous fishery coast-wide have led to a public that has forgotten the benefits of healthy fish populations in rivers and oceans. We will engage the public to educate them about the benefits of fishery restoration, as well as how we work to balance fishery and energy needs. Dozens of restoration projects throughout the Androscoggin River restoration focus area will benefit from having a well-informed and motivated public. With the completion of each project, we hope to build momentum that will ultimately help us realize our goal of a diadromous fish restoration in the Androscoggin River Watershed. Existing restoration projects provide opportunities for an education and engagement effort. The Penobscot River Restoration Project and the Sebasticook River are two very successful basin wide restorations that we can use as examples to educate the public about the benefits when we balance energy production with fisheries.

13. ALIGNMENT OF COMPREHENSION PLAN RECOMMENDATIONS WITH STATE AND NOAA FISHERIES PLANS

The specific recommendations of the CP are consistent with and follow the recovery goals identified in the Atlantic salmon FRP and MDMR management plan for striped bass. Inland fisheries management interests should be given proper consideration as restoration actions are proposed. The recommendations directly and indirectly support the frameworks proposed under each plan, while also benefiting the full suite of diadromous species covered by the CP. Specifically, recommendations considered in this CP directly align with the following habitat connectivity recovery actions listed in the Atlantic salmon FRP:

- Identify and prioritize highest priority fish passage barriers for remediation.
- Perform fish passage barrier assessments throughout the GOM DPS.
- Determine the feasibility of connectivity projects important to Atlantic salmon.
- Conduct engineering studies for potential fish passage improvement projects.
- Permit potential fish passage improvement projects.
- Remove dams according to prioritization guidelines, as feasible.
- Remove or replace culverts according to prioritization guidelines, as feasible.
- Install fishways according to the prioritization guidelines, as feasible.
- Establish fish passage efficiency targets that do not jeopardize the continued existence of the GOM DPS of Atlantic salmon.
- Establish accessible passage criteria for road stream crossings.
- Conduct pre- and post-barrier removal and fish passage improvement monitoring using up-to-date methods.

The recommendations for restoration in this CP are sited in salmon critical habitat and historical salmon range within the Lower Androscoggin River. Implementation of fish passage projects in the restoration focus areas supports completion of the above-listed actions at dams and road crossings of the highest priority for the improvement of the GOM DPS of Atlantic salmon.

Additionally, the recommendations of this CP indirectly support the following FRP broad recovery actions:

- ***Genetic Diversity*** □Once projects are implemented as recommended in this CP, increased access to salmon habitat and improved salmon populations will allow for prioritizing genetic data needs and improved management of data resulting from stocking and genetic evaluation.

- ***Conservation Hatchery and Freshwater Conservation*** □These recovery actions aim to increase adult spawners through hatchery programs and freshwater production of smolts. Once projects are implemented as recommended in this CP, areas of restored salmon habitat (including freshwater and riparian habitats) and increased salmon access to these areas will work to improve populations throughout the Lower Androscoggin Watershed. Increased populations of returning adult salmon would also provide opportunities to increase hatchery broodstock.

- ***Federal/Tribal Coordination and Outreach, Education and Engagement*** □As projects are implemented under the guidance of this CP, project-specific details and work plans would be shared with all appropriate tribal governments for continued shared responsibility and co-management of diadromous species. Additionally, restoration efforts would create opportunities for stakeholder and public outreach platforms including access to web-based information on priority projects and coordination with state and community level programs.

At the SHRU level, the recommendations for diadromous fish restoration presented in this CP are consistent with the following site-specific recovery actions listed in the Merrymeeting Bay Salmon Habitat Recovery Unit Work Plan:

- Develop plans to adjust operations at Brunswick, Pejepscot, and Worumbo Projects on the Androscoggin River to improve upstream and downstream passage for salmon.

- Develop plans to adjust operations at Barker’s Mill Dam on the Little Androscoggin River to increase upstream and downstream passage efficiency improving migration for salmon and other diadromous species.

We acknowledge the potential for conflict in the plan with MDIFW management objectives for inland fisheries management. The state resource agencies (MDMR and MDIFW) are working on a statewide planning tool to identify potential resource areas of concern and the need for resolution. We foresee the need for coordination among state and federal agencies, towns, individuals, and NGOs as actions within in this plan are implemented.

14. IMPLEMENTATION OF THE COMPREHENSIVE PLAN

This CP will guide NOAA Fisheries' activities supporting the restoration of diadromous fishes over the next 10 to 12 years in the Lower Androscoggin River Watershed through recommended management and restoration actions. NOAA Fisheries is responsible for implementing actions proposed in this CP. However, we anticipate the establishment of an implementation team comprised of state and federal resource agencies, hydropower developers, and non-government organizations to guide the implementation of the restoration proposed herein. The team will track progress towards the goals established in the CP, seek solutions to obstacles, and coordinate updates to the CP as necessary.

Team members and their respective agencies are limited to implementing actions within this CP to the extent permitted by law and subject to the availability of resources, in accordance with their respective missions, policies, and regulations. The implementation team will also seek funding opportunities to implement the research and management recommendations identified in the CP. The team will meet regularly (e.g., annually), if practical, with participation from stakeholders and other partners as needed.

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