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1.0 MDMR authority

The Maine Department of Marine Resources (MDMR) is a cabinet level agency of the State of Maine. MDMR was established to regulate, conserve, and develop marine, estuarine, and diadromous fish resources; to conduct and sponsor scientific research; to promote and develop marine coastal industries; to advise and cooperate with state, local, and federal officials concerning activities in coastal waters; and to implement, administer, and enforce the laws and regulations necessary for these purposes. MDMR is the lead state agency in the restoration and management of diadromous (anadromous and catadromous) species of fishes. MDMR's policy is to restore Maine's native diadromous fish to their historical habitat.

2.0 Description of the drainage

The Kennebec River, Maine's second largest river, has a total drainage area of 5,930 square miles (ENSR 2007). Major tributaries, listed from upstream to downstream, include the Moose River, Dead River, Carrabassett River, Sandy River, Sebasticook River, Messalonskee Stream, and Cobbosseecontee Stream. The Kennebec River originates at Moosehead Lake and flows south approximately 233 km (145 mi) where it is joined by the Androscoggin River, Maine's third largest river, to form Merrymeeting Bay. The Kennebec River then travels approximately 30 km (19 mi) before exiting to the ocean at Fort Popham. Major communities located along the mainstem of the Kennebec River include Bingham, Anson, Madison, Norridgewock, Skowhegan, Waterville, Winslow, Augusta, Hallowell, and Gardiner. The upper two-thirds of the basin, generally above Waterville, is hilly and mountainous, being part of the Appalachian Mountain Range. The lower third of the basin, including the Sebasticook River and Cobbosseecontee Stream tributary areas, has a gentler topography representative of the coastal area. The Carrabassett River and Sandy River are major contributors to flooding in the watershed; both tributaries are considered hydrologically flashy and contribute approximately 40% of the peak discharge of the Kennebec River during flood events (ENSR 2007).

2.1 Focus area

This document focuses on the regions of the Kennebec River basin that were historically inhabited by diadromous fishes, specifically the Kennebec River from the Williams Project to the Gulf of Maine and seven tributaries (the Carrabassett River, Sandy River, Sebasticook River, Messalonskee Stream; Seven Mile Stream; and Cobbosseecontee Stream). The focus area is comprised of four major hydrologic zones (Figure 1). The upper Kennebec River from the Williams Project to the Lockwood Project (rkm 181-101) is comprised of impounded river separated by short sections of flowing river. The restored Kennebec River from the Lockwood Dam to the head-of-tide and former location of the Edwards Dam (rkm 101-74) is free-flowing riverine habitat with a defined channel. The upper Kennebec River estuary (rkm 74-45), Merrymeeting Bay (rkm 45-30) and the Androscoggin River estuary (Brunswick Project downstream to former Bay Bridge) are tidal freshwater habitat. The lower Kennebec Estuary (rkm 0-30) is tidal with salinity ranging from 0–32‰ depending on location and freshwater discharge. The temporal scope of the document includes the past, present, and reasonably foreseeable future actions for the next 40-50 years and their effects on migratory fish and the fisheries they support. This document focuses on upstream and downstream diadromous fish movement and access to spawning/rearing habitat in the Kennebec River and its tributaries, including an evaluation of the dams that act as barriers to fish movement in the river. MDMR's restoration efforts in the focus area have been ongoing since 1987 (Table 1).

2.2 Water classifications

Kennebec River, main stem.
From the Route 201A bridge in Anson-Madison to the Fairfield-Skowhegan boundary, including all impoundments - Class B.
From the Fairfield-Skowhegan boundary to the Shawmut Dam - Class C.
From the Shawmut Dam to its confluence with Messalonskee Stream, excluding all impoundments - Class B.
Waters impounded by the Hydro-Kennebec Dam and the Lockwood Dam in Waterville-Winslow - Class C.
From its confluence with Messalonskee Stream to the Sidney-Augusta boundary, including all impoundments - Class B.

Sandy River, main stem.
From the outlet of Sandy River Ponds to the Route 142 bridge in Phillips - Class AA.
From the Route 142 bridge in Phillips to its confluence with the Kennebec River - Class B.
Sandy River, tributaries - Class B unless otherwise specified.
All tributaries entering above the Route 142 bridge in Phillips - Class A.
Wilson Stream, main stem, below the outlet of Wilson Pond - Class C.

Carrabassett River, main stem.
Above a point located 1.0 mile above the dam in Kingfield - Class AA.
From a point located 1.0 mile above the dam in Kingfield to a point located 1.0 mile above the railroad bridge in North Anson - Class A.
From a point located 1.0 mile above the railroad bridge in North Anson to its confluence with the Kennebec River - Class B.
Carrabassett River, tributaries - Class A unless otherwise specified.
South Branch Carrabassett River - Class AA. The Legislature finds, however, that permitted water withdrawal from this river segment provides significant social and economic benefits and that this existing use may be maintained.
All tributaries entering the Carrabassett River below the Wire Bridge in New Portland - Class B.
West Branch Carrabassett River above its confluence with Alder Stream - Class AA

In addition, the mainstem Kennebec between MillStream in Norridgewock andWeston Dam is in Category 4-C for flow regime alternations (MDEP 2016).

2.3 Hydropower in the Kennebec Watershed

Hydropower projects approved by the Federal Energy Regulatory Commission (FERC) operate under the terms of a license or an exemption (MDEP 2007). Licenses are issued under the Federal Power Act for the development or continued operation of non-federal waterpower projects. Licenses are valid for a maximum of 50 years. Under FERC's regulations, a licensee must file to relicense a project no later than 2 years prior to the license expiration date. When a license expires, FERC may deny license renewal, issue a new license to the original licensee or a new licensee, or recommend to Congress that the United States acquire the project. If action has not been taken by the license expiration date, the project will operate on an annual license until relicensing action is taken. Exemptions from the licensing provisions of the Federal Power Act are issued in perpetuity for the development of non-federal waterpower projects having a capacity of 5,000 KW or less and utilizing an existing dam or natural water feature. Exemptions are subject to conditions imposed by fish and wildlife agencies

Currently there are 16 federally licensed hydropower projects (18 dams) within this geographical range (Table 2; Figure 1). Three hydropower projects have been decommissioned and removed on the Lower Kennebec and major tributaries. Edwards Dam, removed in 1999, was the lowermost dam on the Kennebec River. Madison Electric Works, which was the lowermost dam on the Sandy River, was removed in 2006. Fort Halifax, removed in 2008, was the lowermost dam on the Sebasticook River.

2.4 Status of fish passage at hydropower projects

Lockwood Project –The upstream fish passage facility at the Lockwood Project became operational in 2006 pursuant to the 1998 Settlement. It is an interim fish lift that terminates in a trap-and-truck facility. Fish and water are collected in the hopper, lifted, and discharged into a 12-foot diameter sorting tank. River herring (Alewife and Blueback Herring) and American Shad are dip-netted into two ten-foot diameter tanks, Atlantic Salmon are moved into a 250-gallon isolation tank, and other species are sluiced downstream. The river herring, American Shad, and Atlantic Salmon are trucked upstream to spawning habitat by MDMR. An upstream passage facility designed specifically for American Eel (ramp) is installed in the bypass in the spring and removed in the fall. Downstream passage is provided via spill, a downstream bypass in the power canal that releases 350 cfs, or through the turbines. An angled boom in the power canal serves to guide fish to the bypass.

Pursuant to the 1998 Settlement, permanent (swim-through) upstream passage at the Lockwood Project and the Hydro Kennebec Project was to be operational two years after 8,000 American Shad were captured in any single season at the interim facility at Lockwood or a biological assessment trigger was initiated for Atlantic Salmon, Alewife or Blueback Herring. The interim upstream passage facility at Lockwood Project was never converted to a permanent facility, because the trigger number was never met – the greatest number of American Shad passed at Lockwood in a single year has been 830 fish. Ultimately, the listing of Atlantic Salmon and the resulting Interim Species Protection Plan (ISPP) became the trigger for providing permanent upstream passage at the four mainstem dams. The current license requires the Licensee to provide an upstream fish passage to be operational by May 1, 2022. The Licensee has plans, currently at the 90% design phase, to construct a new vertical slot fishway in the Lockwood bypass reach that is intended to provide swim-through passage for all diadromous fish species. The Licensee expects to construct the facility in 2021. The existing fish lift will continue to be operated as a trap-and-transport facility.

Hydro Kennebec–Pursuant to the ISPP and the current license, the permanent upstream fish passage facility at the Hydro Kennebec Project, a fish lift, became operational in the fall of 2017. Fish and water are collected in the hopper, lifted, and discharged into an exit flume that extends 470 feet into the headpond. An upstream passage facility designed specifically for American Eel (ramp) is located on the west side of the spillway; the entrance and exit are installed in the spring and removed in the fall. Downstream passage is provided via spill (although spill is rare), through a gate located in the powerhouse forebay that discharges into a large plunge pool, or through the turbines. An angled boom in the forebay serves to guide fish to the bypass.

Shawmut– Pursuant to the ISPP and the current license, the Licensee is required to provide an upstream fish passage to be operational by May 1, 2022. The Licensee has plans, currently in the 90% design phase, to construct a new fish lift at the upper powerhouse and a fishway channel that extends through a peninsula that separates the upper and lower powerhouses. Permanent upstream eel passage (ramp) was operational on the east side of the spillway until the installation of a rubber dam on the spillway in 2009 that eliminated attraction to the area. Since 2010, a portable eel passage (6-foot long, 1-foot wide ramp with climbing substrate, a collection bucket and attraction water) has been installed annually between the first section of the hinged flashboards and the unit 1 tailrace. Water released at this location to provide additional downstream passage for Atlantic Salmon smolts may interfere with upstream eel passage as evidenced by declines in upstream migrants from 2016 to 2018. In 2019, a second upstream eel passage, similar in design to the other ramp, was installed adjacent to the forebay plunge pool

Downstream passage is provided via the spillway, hinged flashboards, the turbines or a surface weir (sluice) and Tainter gate in the forebay. The 4-feet wide by 22-inch deep sluice is located on the right side of the intake structure by Unit 6. When all stoplogs are removed, the sluice passes 30-35 cfs over the face of the dam and into a 3-feet deep plunge pool. The 7-foot high by 10-foot wide Tainter gate is located to the right of the sluice and can pass up to 600 cfs; it is unclear from the Final License Application if water released from the Tainter gate also passes into the 3-foot deep plunge pool. The sluice and Tainter gate are operated from April 1-June 15 to pass Atlantic Salmon smolts and kelts and from November 1 to December 31 (depending on ice and flow conditions). Four sections of hinged flashboards immediately adjacent to the canal headworks are opened for the smolt migration season and provide approximately 560 cfs of spill.

Downstream passage for American Eel is provided by passing approximately 425 cfs through the Tainter gate and turning off units 7 and 8 for 8 hours for a six-week period between September 15 and November 15. A study conducted by the Licensee in 2008 (Next Era Energy 2009) on the downstream passage of American Eel found that passage via the deep gate increased with higher flow through the gate when Units 7-8 were turned off (58.3% at 207 cfs and 83.5% at 425 cfs), immediate survival increased with the higher flow, and immediate survival of eels passing through Units 1-6 was 90% (9 of 10). Survival of eels not entering the forebay was not described. In 2009, the Licensee in consultation with resource agencies designed and constructed a plunge pool below the outlet of the deep gate. MDMR questions whether passing downstream migrating American Eel via a flow of 425 cfs into a 3-foot deep plunge pool is safe.

Weston– Pursuant to the ISPP and the current license, the Licensee is required to provide an upstream fish passage to be operational by May 1, 2022. The Licensee has plans, currently the

90% design phase, to construct a new fish lift at the powerhouse. An upstream passage facility designed specifically for American Eel (ramp) is located on the west side of the south channel dam. Downstream passage is provided via a surface sluice gate and associated unregulated spill, or through the turbines.

Abenaki and Anson–These two projects, separated by 0.76 river miles, have the same owner and were licensed together. Both projects currently have upstream and downstream passage facilities for American Eel, and both have the same license requirements for upstream and downstream passage for Atlantic Salmon. Briefly,[1] interim downstream passage is to be operational at each project two years after the Licensee receives written notice from MDMR and the U.S. Fish and Wildlife Service (USFWS) that sustained annual stocking of Atlantic Salmon above the projects has begun or will begin within two years. Permanent upstream passage is to be operational at each project within two years after the Licensee receives written certification from the MDMR and USFWS that 226 adult Atlantic Salmon originating from the Kennebec River and obtained from the Lockwood fish lift or another Kennebec River trap and truck facility have been released into the Kennebec River watershed above the Weston dam in any single season. In no event, however, will permanent upstream and permanent downstream passage for Atlantic Salmon be required to be operational prior to May 1, 2020.

2.5 Impoundments

The Weston Project impoundment is 12.4 miles long and is 930 acres. The Shawmut Project impoundment is 12 miles long and is 1310 acres. The Hydro Kennebec Project impoundment is 3 miles long and is 250 acres. The Lockwood Project impoundment is 1.2 miles long and is 81.5 acres.

Impoundments alter flow dynamics of river systems, effectively converting once lentic river reaches into lotic systems, which in turn alters temperatures and sediment transport characteristics relative to the freely flowing condition (Kondolf et al. 2014, Davies et al. 1999). Impoundments contribute to increasing embeddedness of downstream substrate (i.e., channel armoring), alter the distribution and availability of stream substrate size classes, and reduce habitat suitability for native invertebrates and fishes that rely on more lentic systems (Tiffen et al. 2016). Impacts to biological communities can translate to reduced water quality.

The altered hydrological and temperature regimes in impoundments can create habitat that is more favorable for lacustrine species instead of the native stream-dwelling species (Watson et al. 2018). The "artificial" habitat in impoundments has been associated with establishment of populations of non-native species, (introduced either to provide recreational opportunities or accidentally via boat traffic), allowing them to become invasive (Graf 2003). In Maine, some of the piscivorous invasive species that have become established in impoundments include smallmouth bass *Micropterus dolomieu* and largemouth bass *Micropterus salmoides* (Watson et al. 2018).

Impoundments have been associated with migratory delays for downstream migrating diadromous species, including America Eel and salmonids (Raymond 2011, Jepson et al. 2000,

[1] The licenses contain additional details regarding fish passage for Atlantic Salmon.

Mensinger 2020). Migratory delays may be the result of the absence of migratory cues in headponds that are normally associated with lentic systems, as evidenced by documented search behavior within headponds (Brown et al. 2009; Trancart et al. 2020). When coupled with the presence of invasive piscivorous species, migratory delay in impoundments can associated with increased mortality for migrants via predation (Jepson et al. 2000, Raymond 2011).

2.6 Fish passage testing and performance standards

Diadromous fish species require safe, timely, and effective access to high quality habitats at different life stages in order to successfully survive and reproduce. Hydroelectric projects often prevent or delay migrations or cause injury or mortality that contribute to population declines. These adverse impacts can be mitigated by properly designed fishways, however many fishways fail to perform as intended, including fishways developed and operated utilizing USFWS Fish Passage Design Criteria (USFWS 2019). When there are a series of fishways within a migration corridor for diadromous species, such as in the upper Kennebec River, the risks increase that one or more underperforming fishways will result in significant cumulative negative impacts to these fish populations. This potential for cumulative impacts creates the need for highly effective fish passage at each of the dams that meet agency design and performance standards.

To ensure that minimum restoration goals for the Kennebec River are met, the new fish passage facility at the Hydro Kennebec Project and the facilities that have been proposed for the Lockwood, Shawmut, and Weston projects (to be operational by May 1, 2022) will need to be tested for their effectiveness in passing adult and juveniles stages of Atlantic Salmon, American Shad, Blueback Herring, Alewife, Sea Lamprey, and American Eel during their upstream and downstream migrations. In a report that analyzed mitigation (fish passage) at hydropower projects, FERC (2004) acknowledged the impacts of the projects on fish populations and the importance of testing the effectiveness of fish passage facilities and also recognized the use of modeling tools for assessing management actions and fish passage improvements at multiple projects.

Migratory delay comes at energetic costs to further upstream migration and subsequent reproduction, consequently, it is recommended that fish pass performance include not only target numbers or percentage of fish passing, but also metrics for movement rates and time to pass (Castro-Santos et al. 2009; Castro-Santos and Letcher 2010; Castro-Santos and Perry 2012; Castro-Santos et al. 2016; Stich et al. 2019). The overall energetic costs to migration and reproduction imposed by migratory delay will increase with the number of dams encountered and should be factored in when setting passage time performance standards.

In the Environmental Analysis of three recent relicensing proceedings[2], the FERC did not support recommendations made by the resource agencies for effectiveness testing of all new fish passage facilities. One reason FERC did not support effectiveness testing was the lack of specific performance standards by which the effectiveness testing could be evaluated. Therefore, MDMR has developed performance standards for five species, Atlantic Salmon, American Shad, Blueback Herring, Alewife, and Sea Lamprey, which are described and justified in sections 3.5-

[2] American Tissue FERC No. 2809-034; Barker Mills FERC No. 2808; Ellsworth FERC No. 2727-092.

3.9. Effective fish passage is also important for American Eel, which spawns just once and dies (semelparous), but performance standards have not been developed at this time.

3.0 Diadromous fish in the Kennebec River watershed

The Kennebec River, Maine's second largest drainage, historically was inhabited by 11 native diadromous species: Shortnose Sturgeon (*Acipenser brevirostrum*), Atlantic Sturgeon (*Acipenser oxyrinchus*), Rainbow Smelt (*Osmerus mordax*), Atlantic tomcod (*Microgadus tomcod*), Striped Bass (*Morone saxatilis*), Alewife (*Alosa pseudoharengus*). American Shad (*Alosa sapidissima*), Blueback Herring (*Alosa aestivalis*), Atlantic Salmon (*Salmo salar*), Sea Lamprey (*Petromyzon marinus*), and American Eel (*Anguilla rostrata*). These species were once very abundant and supported important commercial fisheries. In 1867, the Governor appointed two Commissioners of Fisheries under a legislative resolve to restore anadromous fish to the rivers and inland waters of the state. The Commissioners surveyed the fisheries in Maine's major river systems and concluded that the decline of anadromous species was caused by impassable dams, overfishing, and pollution of the water (Foster and Atkins 1867).

Foster and Atkins (1868) and Atkins (1887) reported that four species of anadromous fish (Shortnose Sturgeon, Atlantic Sturgeon, Striped Bass, and Rainbow Smelt) historically did not migrate past Taconic Falls where the Lockwood Project is located, while six species historically migrated farther upstream (Table 3). Foster and Atkins (1868) and Atkins (1887) reported that Atlantic Salmon ascended many miles in the Carrabassett River and the Sandy River, and these two rivers probably were the principal spawning grounds; however, the upstream limit of Atlantic Salmon may have been about 12 miles above the Forks (confluence of the Kennebec River and Dead River) and at Grand Falls on the Dead River. Foster and Atkins (1868) and Akins (1887) also reported that Alewife and American Shad ascended as far upstream as Norridgewock Falls, current location of the Abenaki and Anson projects, and into the lower part of the Sandy River. It is likely their close relative, the Blueback Herring, had the same range. The historic upstream limit of American Eel and Sea Lamprey is not known, but American Eel currently are found in the Williams Project impoundment and Sea Lamprey generally occupy large river and tributary habitats with extents similar to Atlantic Salmon.

The restoration of diadromous fish species in the Kennebec River began with a Settlement Agreement that was signed in 1986 by the Kennebec Hydro Developers Group (KHDG) and the State of Maine. Eleven years later, FERC for the first time in its history refused to renew a hydropower license for environmental reasons and ordered the decommissioning and removal of the Edwards Dam on November 25, 1997. The following year a multi-party settlement agreement (1998 Agreement) was signed that included new schedules or triggers for upstream and downstream fish passage at the seven KHDG projects and provided additional funds for restoration efforts. Removal of the Edwards Dam allowed Shortnose Sturgeon, Atlantic Sturgeon and Striped Bass free access to all their historic habitat on the mainstem of the Kennebec River. In addition, the restored Kennebec River supports the greatest abundance and biomass of American Eel between Merrymeeting Bay and the Williams Dam (Yoder et al. 2006). The installation of fish passage facilities at barriers in the Sebasticook River and removal of the Fort Halifax Dam has resulted in the largest run of river herring on the east coast (Wippelhauser 2021).

Restoration of Atlantic Salmon, American Shad, Blueback Herring, Alewife, and Sea Lamprey has lagged on the mainstem Kennebec River, primarily because of the lack of upstream fish passage. This situation is particular critical for the endangered Gulf of Maine (GOM) Distinct Population Segment (DPS) of Atlantic Salmon, one of the most iconic and imperiled species in the United States. All high-quality spawning habitat for Atlantic Salmon lies above four dams (Sandy River) or six dams (Carrabassett River and mainstem Kennebec River) and restoring runs into the Kennebec River in sufficient numbers is essential to meet recovery goals for the entire species statewide (USFWS and NMFS 2019). About 60% of American Shad and Blueback Herring historic spawning habitat is above the Lockwood and Hydro Kennebec projects, and 10% of Alewife historical spawning habitat is above the Shawmut Project. Sea Lamprey habitat above these projects exceeds 90% of presumed historic habitats. Significant underutilized habitat exists for American Eel.

3.1 Atlantic Salmon (*Salmo salar*)

3.1.1 Goals and objectives

Pursuant to the *Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar)* (USFWS and NMFS 2019), the following abundance criteria must be met for downlisting of the Gulf of Maine Distinct Population Segment (GOM DPS) from endangered to threatened and for delisting the species[3]:

> ***Downlisting:*** The DPS has total annual returns of at least 1,500 adults originating from wild origin, or hatchery stocked eggs, fry or parr spawning in the wild, with at least 2 of the 3 SHRUs having a minimum annual escapement of 500 naturally reared adults.
>
> ***Delisting:*** The DPS has a self-sustaining annual escapement of at least 2,000 wild origin adults in each SHRU, for a DPS-wide total of at least 6,000 wild adults.

3.1.2 Biology and ecology

The Atlantic Salmon is a medium-sized, highly migratory, anadromous, iteroparous fish that historically ranged from northeastern Labrador to the Housatonic River in Connecticut (Collette and Klein-MacPhee 2002). In Maine, adult Atlantic Salmon ascend their natal rivers from spring through fall with the peak occurring in June (Meister 1958, Baum 1997). Adults that return to spawn after one year at sea are termed “grilse”, and those that return after two years at sea are termed “two sea winter” or 2SW” fish; occasionally a “3SW” fish will return. Spawning occurs in late October through November, therefore, early returning fish seek out cold water refugia until the fall. Preferred spawning habitat is a gravel substrate with adequate water circulation to keep the buried eggs well oxygenated (Peterson 1978), and spawning sites are often located at the downstream end of riffles where water percolates through the gravel or where upwellings of groundwater occur (Danie et al. 1984). The optimal water temperature during the spawning period ranges from 7.2°C to 10.0°C (Jordan and Beland 1981, Peterson et al. 1977). The female digs a series of nests (redds) in the gravel where the eggs are deposited and are fertilized by one or more males (Jordan and Beland 1981). Female 2SW adults produce an average of 7,500 eggs

[3] The complete list of criteria to accomplish recovery or delisting is in Appendix A.

(Baum and Meister 1971). Currently, few post-spawn salmon (kelts) survive to return as repeat spawners. The eggs hatch in late March or April, and the alevins (sac fry) remain in the redd until mid-May (Gustafson-Greenwood and Moring 1991) when they emerge and begin active feeding. Within days, the fry enter the parr stage, identified by the vertical bars on their sides, and begin to actively defend territories (Allen 1940, Kalleberg 1958, Mills 1964, Danie et al. 1984). Some male parr become sexually mature (precocious parr) and can successfully participate in spawning. In a parr's second or third spring, when it has grown to 12.5 to 15 cm in length, a series of physiological, morphological, and behavioral changes occur (Schaffer and Elson 1975). This smoltification process prepares the fish for migration to the ocean and life in salt water. In Maine, the vast majority of wild/naturally reared parr remain in freshwater for two years (90% or more). Naturally reared smolts in Maine range in size from 13 to 17 cm and most smolts enter the sea during May to begin their ocean migration to feeding areas in the North Atlantic.(USASAC 2004).

Atlantic Salmon are part of a co-evolved diadromous fish community that together shaped Maine's riverine and lacustrine habitats through connectivity with the ocean (Fay et al. 2006, Saunders et al. 2006). As the returns of Atlantic Salmon to Maine's rivers declined, it is likely that some of these ecosystem functions also declined or were lost, including reductions to the primary productivity due to the loss of marine derived nutrients from metabolic waste products, eggs, and carcasses that are incorporated into the local food web in the areas where spawning occurs (Moore et al. 2011, Guyette et al. 2014).

3.1.3 Historical and current distribution

Foster and Atkins (1868) and Atkins (1887) reported that within the Kennebec River Atlantic Salmon ascended many miles in the Carrabassett River and the Sandy River, and these two rivers probably were the principal spawning grounds; however, the upstream limit of Atlantic Salmon may have been about 12 miles above the Forks (confluence of the Kennebec River and Dead River) and at Grand Falls on the Dead River. Currently, MDMR transports all returning Atlantic Salmon that utilize the Lockwood Project fish lift to the Sandy River where they are released.

3.1.4 Relevant fishery and stock status

Historically, hundreds of thousands of adult Atlantic Salmon returned annually to spawn in the rivers of New York and New England and represented a culturally significant species for Maine's tribes and later became an important economic resource both recreationally and commercially. Habitat loss and degradation due to dams and industry, overharvest, and other human impacts brought the Atlantic Salmon to the brink of extinction within its U.S. range (Fay et al. 2006, NAS 2004). Today, the only remaining populations of Atlantic Salmon in the United States, the GOM DPS, exist in several watersheds in Maine.

The GOM DPS of Atlantic Salmon, originally listed as endangered in December 2000 by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), encompassed salmon populations in small river systems along the Maine coast. In 2009, the GOM DPS was expanded (74 FR 29344), and critical habitat was delineated (74 FR 23900) for three Salmon Habitat Recovery Units (SHRUs) within the expanded DPS: the Merrymeeting Bay SHRU, Penobscot Bay SHRU, and Downeast SHRU. The Merrymeeting Bay SHRU includes the Kennebec, Androscoggin, Sheepscot, Pemaquid, Medomak, and St. George watersheds. The total functional, critical habitat units for each SHRU within the GOM DPS are (74 FR 23900, Table 2): Merrymeeting Bay SHRU (40,001), Penobscot Bay SHRU (63,058) and Downeast Coastal (29,111). However, nearly all the high-quality habitat in the Merrymeeting Bay SHRU is in the Kennebec River, specifically in the Sandy River, Carrabassett River, and upper Kennebec River.

As described in section 3.5.1, the minimum spawning escapement required is 500 naturally reared adults in two of the three SHRUs for downlisting and 2,000 in each of the three SHRUs for delisting. However, the current numbers of wild origin Atlantic Salmon that return to Maine rivers are orders of magnitude less than those required to meet ESA recovery standards. A total of just 389 naturally reared adults returned to the GOM DPS in 2020.[4] Data provided by MDMR and restoration partners, represented in the U.S. Atlantic Salmon Assessment Committee (USASAC 2019) reports, indicate severe limitations in freshwater production of "naturally reared" fish that would contribute to meeting recovery goals. Based on the amount of available critical habitat, downlisting and delisting (recovery) of the GOM DPS of Atlantic Salmon will rely on expanding the population being restored in the Kennebec River. Providing safe, timely, and highly effective passage on the Kennebec River is essential to meeting recovery goals.

Because the expanded listing included the Kennebec River, Brookfield Renewable (the indirect parent company of the Licensees of the Lockwood, Hydro Kennebec, Shawmut, and Weston projects) developed Interim Species Protection Plans (ISPPs) that created schedules for constructing upstream fish passage and testing the effectiveness of existing downstream fish passage at the four projects; the ISPPs were incorporated into the project licenses by FERC. Prior to the December 31, 2019 expiration of the ISPPs, Brookfield Renewable consulted with state and federal fishery agencies to develop a Species Protection Plan (SPP) to replace the ISPPs. The SPP was submitted to FERC on December 31, 2020, and was rejected by FERC on July 1, 2020 in response to letters from the resource agencies expressing their lack of support for the SPP. At this time, there is no take permit, no Biological Opinion, and no reasonable and prudent measures to avoid, minimize, and mitigate project impacts on Atlantic Salmon.

3.1.5 Past and current management actions in the Kennebec River

Restoration of the species began in 2003 when MDMR initiated a stocking program in the Sandy River using three life stages of GOM DPS Atlantic Salmon. In addition to adult Atlantic Salmon returns, which are transported from the Lockwood Project fishlift to the Sandy River in trucks and allowed to spawn naturally, MDMR has utilized Penobscot-origin, F2 generation fry and eyed-eggs for supplementation. For five years, eyed-eggs were raised in streamside incubators and released as fry. Since 2004, eyed-eggs have been deposited in man-made redds in the winter, and allowed to develop and emerge naturally (Table 4). Despite these efforts, much of the spawning habitat in the Kennebec River remains underutilized due to poor adults returns and a limited supply of eggs. The USFWS has also transported Penobscot-origin F1 generation parr to the Nashua National Fish Hatchery to stock as smolts into the Kennebec river. The first stocking of 100,000 smolts occurred in the spring of 2020, with planned stocking to continue into the foreseeable future if funding is available.

[4] https://atlanticsalmonrestoration.org/cms/cms-annual-reports-meeting-notes/2021-cms-annual-meeting-reports-notes

3.1.6 Findings of current research

DIA model

Nieland et al. (2013) developed a population viability analysis, the Dam Impacts Assessment (DIA) model, to examine the demographic effects of 15 hydropower dams and actions resulting from the Penobscot River Restoration Project (PRRP)[5] on Atlantic Salmon survival and recovery in the Penobscot Bay SHRU (NMFS 2012). The model incorporated life stage-specific information for Atlantic Salmon to simulate the life cycle of the species in the Penobscot River. Most model inputs were considered to be random variables, and Monte Carlo sampling from probability density functions was used to create multiple estimates of population trajectories over time (50 years, roughly ten generations). Two scenarios were modeled – the base case (existing conditions) and recovery case (freshwater survival was doubled and marine survival was quadrupled). Within each scenario, the impacts of the following actions were analyzed: 1) all dams on; 2) all dams off; 3) mainstem dams off, tributary dams on; 4) tributary dams off, mainstem dams on; and 5) implementation of the PRRP (Veazie, Great Works, and Howland off.) Dams “on” were operating normally, and dams “off” were removed. In addition, hatchery supplementation could be turned off and passage efficiency at dams could be increased.

DIA modelling results indicated:

1. Salmon abundance (median number of 2SW females), salmon distribution to upper reaches of the Penobscot watershed, and the proportion of wild-origin fish in the upper reaches of the watershed increased as mainstem dams were removed. Under the base case, with stocking, and with all dams removed, the number of 2SW females approached recovery (~450).
2. Salmon abundance increased when marine survival and freshwater survival were increased, but increased marine survival resulted in the greatest increase in salmon abundance. Under the recovery scenario, with no stocking, and implementation of the PRRP, the number of female 2SW fish was approximately 2,000.
3. Implementation of the PRRP (2 dams removals and the Howland bypass) coupled with performance standards (downstream passage within 24 hours and 96% passage survival at the Milford, West Enfield, Orono, and Stillwater dams and upstream passage within 48 hours and 95% passage efficiency at the Milford and West Enfield dams) and stocking supplementation would not result in jeopardy.

MDMR model

Because NMFS never created a DIA model for the Kennebec River, MDMR developed a simple deterministic model utilizing the best available data, current research, and knowledge of the watershed to assess the cumulative impacts of multiple dams on Atlantic Salmon recovery. The model was used to develop survival goals for upstream and downstream passage at each hydropower facility. Major assumptions of the model were generally consistent with NOAA Fisheries Dam Impact Models (Nieland et al. 2013; Nieland and Sheehan 2020), utilized in the Penobscot River, and included:

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[5] The PRRP included the purchase of the Veazie, Great Works, and Howland hydropower projects; removal of the two lowermost mainstem dams on the mainstem (Veazie and Great Works); decommissioning of the lowermost dam on the Piscatquis River (Howland) and construction of a bypass around the dam; construction of a new upstream passage facility at the Milford Project; construction of a second powerhouse at the Orono and Stillwater projects to replace the lost power generation; and increased flow through the Stillwater River after the fish passage season.

1. The number of salmon smolts produced by the Sandy River, Carrabassett River, and mainstem Kennebec downstream of the Williams Project was estimated from the following equations (habitat units were modeled in 74 FR 23900):
    a. Low = (habitat units) x (1.0 smolts/unit) (P. Christman, Sheepscot River Monitoring, MDMR).
    b. Intermediate = (habitat units) x (2.0 smolts/unit); and
    c. High number =(habitat unit) x (3 smolts/unit) (Legault 2005, Orciari et al. 1994).
2. Downstream migrating smolts experienced natural in-river mortality of 0.0033%/km (Stevens et al. 2019) from the release point in each spawning area to the first dam, between dams, and downstream to the Augusta.
3. Estuarine mortality was 0.00368/km for smolts that had passed no dams; 0.0087/km for fish that passed 2 dams; .0115/km for fish that passed 4 dams; 0.013 for fish that passed five dams, and 0.0145/km for fish that passed 6 dams (Stevens et al. 2019). The estuary extended from the head-of- tide at Augusta to the outlet of Merrymeeting Bay (The Chops).
4. The estimates for marine survival were:
    a. Low = 0.321% (Penobscot River average 2008-2018, estuarine mortality removed, J. Kocik).
    b. Intermediate=1.08% (Penobscot River maximum 2008-2018, estuarine mortality removed, J. Kocik).
    c. High = 2.72% (Penobscot River maximum 1969-2018, estuarine mortality removed, J. Kocik).

    These values were consistent with those used in the DIA model (Figure 3.9.4; for the base case, 90% of marine survival values for 1969-2008 ranged from 0.00124-0.01782, mean~0.00627, median = 0.00436; std dev~0.00598; marine survival was increased by a factor of 4 for the recovery case).
5. Downstream passage survival at each of the six mainstem dams was set at 97% and upstream passage efficiency at each dam was set at 96% consistent with performance standards proposed by the Licensee and at 99% for upstream and downstream effectiveness as proposed by MDMR. The SPPs for the Penobscot River also include time to pass standards (no more than 24 hours for downstream passage and no more than 48 hours for upstream passage). Neither the DIA nor the MDMR model included an analysis of passage delays; however, studies have demonstrated that the downstream passage timing standard is achievable.

At low marine survival (0.00321), low or high freshwater production (1 or 3 smolts/100m^2), and passage through 6 dams, the estimated number of adult Atlantic Salmon returning to the Kennebec River ranged from 46-176 (Figure 2). At medium marine survival (0.01080), the downlisting target was surpassed only with high freshwater production and 99%/99% passage efficiency (Figure 2). At the highest marine survival (0.02720), high freshwater production, and 99%/99% passage efficiency the reclassification goal of 2,000 adult was not attained. Regardless of the marine survival and freshwater production, the 99%/99% effectiveness scenario resulted in 28-29% more adult returns than the 97/96% scenario.

While this analysis indicates that it may be possible to achieve recovery goals, it is important to acknowledge the issue of passage delays. Smolts that are emigrating downstream need to reach the estuary in a timely manner due to temperature and physiological processes (McCormick et al. 1998). In addition, it is recognized that adult upstream passage delays can have substantial long-term effects. Adult salmon that spend excessive amounts of time in warm mainstem river waters will deplete fat reserves needed for both the upstream spawning migration and for returning to the ocean the following year (Rand and Hinch 1998; Naughton et al. 2005). Passage delays will need to be minimized in order to achieve recovery goals.

Adults salmon return to Maine’s rivers during summer and can be exposed to high temperature events. High temperature both slows and increases the energetic cost of migration at the expense of energy stores necessary for continued upstream movement and reproduction; if thermal stress is severe, it can result in death (Pörtner and Farrell 2008; Jonsson and Jonsson 2009; Elliott and Elliott 2010; Martin et al. 2012). Migratory delays caused by dams can compound the problem, preventing salmon from reaching suitable thermal refuge habitat necessary to withstand high summer temperatures (Hasler et al. 2012; Frechette et al. 2018). In the Kennebec River, suitable cool water habitat for adults exists only upstream of existing dams in headwater tributaries like the Sandy River. Minimizing delays caused by dams is imperative to ensure that salmon reach thermal refuge habitat in order to maximize the survival of fish and available energy stores for reproduction.

Effectiveness studies demonstrate the difficulty of meeting high performance standards for fish passage, although increased flow may improve survival of downstream migrants. Radio telemetry studies conducted at the Weston, Shawmut, Hydro-Kennebec, and Lockwood projects resulted in baseline survival[6] of downstream migrating Atlantic Salmons molts ranging from 89.5–100%, but only 66-94.5% of smolts successfully passed the projects within 24 hours (Table 5). Because the 93.5% baseline survival at the Shawmut Project was less than the 96% proposed in the ISPP, downstream passage flow was increased from 420 to 650 cfs although no additional testing occurred. Radio telemetry studies conducted at four projects in the Penobscot River resulted in adjusted survivals of 84.0-98.0% (Table 5) after spill had been increased between 20% and 50% of river flow at each station from 8 pm to 4 am during the peak two weeks of the outmigration period.

In the Kennebec River, upstream passage effectiveness has only been tested at the Lockwood Project. In 2016, 20 wild adult Atlantic Salmon that were captured in the fish lift were radio tagged and moved downstream. Sixteen of the 18 that returned to the project area were recaptured (89%), and the time from return to the project area to recapture was 0.7-111.2 days (mean = 17 days). When the study was repeated in 2017, 13 of 19 (68%) tagged adult Atlantic Salmon that returned to the project area were recaptured, and time to recapture was 3.3-123 days (mean = 43.5). Due to the poor results, the study was discontinued. As part of a study of energy consumption, adult Atlantic Salmon were captured at the Lockwood fish lift, tagged with thermal radio tags and released downstream of the Project. In 2018, 66.7% of the tagged adults (4 of 6) were recaptured, and the time to recapture was 16-33 days (mean = 21.8). The following year,

[6] The baseline rate does not consider amount of time to pass the project. The adjusted survival is calculated from fish that passed a project within 24 hours.

45.0% of tagged adults (9 of 20) were recaptured, and the time to recapture was 9-30 days (mean = 18.7).

The NMFS (2013) clearly foresaw the need for high performance standards. The Biological Opinion issued for the ISPPs states on page 17: “Data to inform downstream passage survival standards for Atlantic Salmon smolts and kelts in the Kennebec and Androscoggin Rivers are very limited. However, given the best available information, it is anticipated that downstream survival standards that will be incorporated in the final SPP will likely need to be between 96% and 100% at each Project. These standards will be refined using information from passage studies that will be undertaken as part of the ISPP. It is possible that the proposed studies will indicate that the interim downstream passage facilities currently in place are not enough to meet the standard and that significant structural and/or operational changes may be necessary to achieve such a high level of survival. The interim period will be used to determine how best to operate or modify the Projects to achieve sufficiently high survival rates. In addition, over the term of the interim period we and/or the licensee will develop a model for the Androscoggin and Kennebec Rivers to provide data that will be used to inform the development of upstream and downstream performance standards.”

3.2 American Shad (Alosa sapidissima)

3.2.1 Goals and objectives

The goal for American Shad is to achieve and sustain a minimum population of 1,018,000 adults entering the mouth of the Kennebec River annually based on 5,015 hectares of spawning and nursery habitat in the mainstem and identified tributaries.

Objectives are to:

- Achieve and maintain an adult return of a minimum of 203 adults/hectare.
- Achieve and sustain a minimum population of 509,000 adult American Shad above Augusta.
- Pass at least 303,500 adult American Shad at the Lockwood and Hydro Kennebec Project dams.
- Pass at least 260,500 adult American Shad at the Shawmut Project dam.
- Pass at least 156,600 adult American Shad at the Weston Project dam; and
- Pass at least 99,200 adult American Shad at the Benton Falls Project dam.

3.2.2 Biology and ecology

The American Shad is a highly migratory, pelagic, schooling species that ranges along the east coast of North American from Newfoundland to Florida (Colette and Klein-MacPhee 2002; Scott and Crossman 1973). American Shad spend most of their lives in the ocean. As adults they return to their natal rivers to spawn, exhibiting low stray rates (3%,), and are capable of migrating long distances upstream (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). Spawning sites in Virginia were associated with hydrographic parameters (high current velocity, high dissolved oxygen, and shallow depth), physical habitat features (increasing sediment size and woody debris), and the presence of a forested shoreline

(Bilkovec 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). Populations of American Shad that spawn north of Cape Hatteras are iteroparous with the repeat spawners ranging from 63-74% in the Connecticut, Saint John, and Mirimichi rivers (Colette and Klein-MacPhee 2002). Repeat spawners are especially important due to higher lifetime fecundity rates and reduced annual variability of spawning stock size (Harris and Hightower 2012). 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°C (Marcy 1976, Watson 1970). In the Connecticut, which supports the largest American Shad run on the east coast of the United States, year-class strength is determined during the larval emergence stage and is significantly correlated with mean river discharge, water temperature, and total monthly precipitation (Crecco et al 1983; Crecco and Savoy 1984; Crecco and Savoy 1985).

3.6.3 Historical and current distribution

American Shad historically were able to access 2,508 hectares of riverine spawning/rearing habitat above the head-of-tide in Augusta (Table 6). Adults ascended the mainstem Kennebec River as far upstream as Norridgewock Falls, current location of the Abenaki and Anson projects, migrated into lower part of the Sandy River, and ascended to the confluence of the East Branch and West Branch of the Sebasticook River (Foster and Atkins 1868; Akins 1887). Most of the habitat (59.6%) lies above the Lockwood Dam, while 20.9% is between the head-of-tide (site of former Edwards Dam) and the Lockwood Dam, and 19.5% is in the Sebasticook River.

Removal of Edwards Dam was an important step in enhancing the American Shad population, but access to habitat above the Lockwood dam is clearly necessary to reach production and distribution goals. Currently, swim-through fish passage on the Sebasticook River allows adult American Shad to access 489 hectares of habitat. In contrast, 1,495 hectares of spawning/rearing habitat in the Kennebec River above the Lockwood Dam is not freely accessible. MDMR annually transports American Shad that use the fish passage facility at the Lockwood Project, which is not connected to the headpond, to upstream spawning /rearing habitat.

This plan provides reach by reach (dam to dam) minimum production targets for adult American Shad. Minimum production targets are based on accessible and potentially accessible spawning/nursery habitat area and the adult production/unit of habitat area, a method commonly used in other American Shad plans in the Connecticut River (CRASC 2017), Susquehanna River (SRAFRC 2010), and Penobscot River (MDMR and MDIFW 2008). Because of insufficient data for Maine’s rivers, we used the most recent determination of minimum adult production/unit habitat developed for the Connecticut River (203 adults/hectare; CRASC 2017). This value likely underestimates the true production/unit habitat due to upstream and downstream passage inefficiencies that were known to exist when it was calculated (CRASC 2017). MDMR may increase the minimum adult production target values as improvements to habitat quantity and quality and fish passage occur in the future.

3.2.4 Relevant fishery and stock status

American Shad are managed in state waters by the Atlantic States Marine Fisheries Commission (ASMFC). The ASMFC Fishery Management Plan (FMP) for Shad and River Herring was adopted in 1985. Amendment 1, adopted in 1998, required specific American Shad monitoring programs, and established a five-year phase-out of the ocean-intercept fishery for American Shad by January 1, 2005. Amendment 3, approved in 2010, revised American Shad regulatory and monitoring programs, required states and jurisdictions to develop sustainable fishery management plans (SFMPs) in order to maintain commercial and recreational harvest fisheries beyond January 2013, and to submit a habitat plan regardless of whether their fisheries would remain open to harvest. Effective May 19, 1998, the State of Maine closed all state waters to commercial fishing for American Shad, and established a two fish per day recreational limit for American Shad. Gear restrictions limit anglers to a single hook and line while fishing American Shad.

The *Atlantic States Marine Fisheries Commission 2020 American Shad Benchmark Stock Assessment and Peer Review Report* ("benchmark stock assessment") (ASMFC 2020) included fisheries-dependent and fisheries-independent data obtained from member resource agencies. Commercial landings data combined from all rivers and estuaries along the east coast (for the United States and Canada) have declined since the 1950s by more than an order of magnitude, from as high as 11 million pounds in 1957 to less than a quarter of million pounds in 2016. Adult mortality for the coastwide metapopulation is unknown. However, adult mortality was determined to be unsustainable for 3 stocks (Connecticut, Delaware, and Potomac) and sustainable for 5 stocks (Hudson, Rappahannock, York, Albemarle Sound, and Neuse). It is important to note that juvenile and adult mortality must be sustainable for population abundance to be favorable (i.e. not depleted). Abundance status is unknown for most systems, but was determined to be depleted for one system (Hudson) and not depleted for one system (Albemarle Sound). Because abundance status is unknown for most systems due to data limitations, trends in YOY and adult abundance since the 2005 closure of the ocean-intercept fishery were analyzed. MDMR's young-of-year beach seine survey showed no trend for the period 2005-2017.

The benchmark stock assessment utilized a newly developed simulation model based on habitat and life history traits that was applied to most of the systems known to have American Shad to model theoretical effects of fish passage and dams on spawner potential (Stich 2019). This approach allowed the comparison of three broad scale scenarios: 1) historical or "intact" rivers, 2) worst case scenario with current dams and "no passage", and 3) dams with imposed realistic upstream and downstream passage to best reflect the "status quo." Based on this modeling exercise, coastwide production potential was more than 72.8 million spawners per year compared with the no passage scenario of just under 42.8 million spawners, a reduction of 41%. Even with extensive fish passage efforts, dams represented a fixed constraint of about 37% on the fishery potential of American Shad.

3.2.5 Past and current management actions in the Kennebec River

Restoration of American Shad in the Kennebec River began in 1987 with the signing of the first KHDG settlement agreement, which provided funds for restoration in exchange for delays in upstream fish passage. Between 1987 and 1997, MDMR stocked millions of American Shad fry and thousands of fingerlings and adults above the Edwards Dam (Table 7). The removal of

Edwards Dam in 1999 allowed American Shad free access to about 21% of their historic spawning habitat. Pursuant to the 1998 Settlement Agreement, the installation of permanent upstream fish passage (a swim-through fish lift) at the Benton Falls Project and at the Burnham Project in 2006 and the removal of the Fort Halifax Dam in 2008 made all historic American Shad spawning/rearing habitat in the Sebasticook River accessible. Pursuant to the 1998 Settlement Agreement, interim upstream passage became operational at the Lockwood Project in 2006. Since the interim fish lift became operational in 2006, only 1,413 adult American Shad have used it (Table 8). Attempts to determine why so few American Shad use the Lockwood fish lift have failed. In 2015, the Licensee in consultation with the agencies, conducted a sound study, a 2D hydraulic modeling study, and a radio telemetry study. Interestingly, adult American Shad used in the telemetry study were angled by recreational fishermen in the tailrace, but none of the tagged American Shad were detected near the fishway entrance.

3.2.6 Findings of current research

Major conclusion from the benchmark stock assessment were:

- At low levels, stocks are sensitive to both biotic and abiotic perturbations that truncate age structure thereby reducing population resilience.
- Recovery of American Shad stocks will need to address multiple factors (e.g., fish passage, predation, water quality, climate change, etc.) in addition to harvest.
- Habitat quantity is greatly reduced from historic levels, and even with fish passage will continue to be a limiting factor on a coastwide basis.

In the past decade, computer models have been used to explore the potential impacts of dams to American Shad populations with similar results. Harris and Hightower (2017) developed a "density-dependent, deterministic, stage-based matrix model to predict the population-level results of transporting American Shad to suitable spawning habitat upstream of dams on the Roanoke River, North Carolina and Virginia". They reported that predicted population increases were highest when young-of-year survival was improved, and transport benefited the population only if high rates of effective fecundity and juvenile survival could be achieved. Castro-Santos and Letcher (2010) developed a simulation model that synthesized bioenergetics, reproductive biology, and behavior to estimate the effects of migratory distance and delays at dams on spawning success and survival of individual adult migrants that ascended the Connecticut River, spawned, and survived to return to the marine environment. They found that delays to both upstream and downstream movements had dramatic effects on spawning success and the spatial extent of spawning. Most recently, Stich et al. (2019) developed a stochastic, life-history based, simulation model for the Penobscot River and found that the probability of achieving management goals (total spawner abundance, distribution to upstream habitat, and percentage of repeat spawners) was greatest with high downstream passage efficiency, minimal migration delays at dams, and high upstream passage efficiency.

A version of the model developed by Stich (2019) was used in the benchmark stock assessment. Each coastal river system was modeled using the potential spawning habitat available prior to the construction of dams and latitudinal-appropriate life history parameters developed for regional metapopulations (e.g., clines in size-at-age, maturity rates, and iteroparity) and used in the stock assessment. Dr. Stich has made the life history models for the Connecticut, Kennebec (Stich et al. 2020), Merrimack, Mohawk-Hudson, Penobscot, Saco, and Susquehanna river available, and provided MDMR with the results of standard base runs for the Kennebec River. The base runs predicted population abundance over time under varied fish passage efficiencies and distribution of spawning fish in the watershed. MDMR has used these results to develop performance standards for fish passage facilities at hydropower projects on the mainstem Kennebec River.

Haro and Castro-Santos (2012) described the failure of fishways designed to pass American Shad. They found that few designs had incorporated knowledge of the swimming, schooling, and migratory behaviors of American Shad; technical fishways designed for adult salmonids on the Columbia River have never been rigorously evaluated for American Shad; similar but smaller fishway designs on the East Coast frequently had poor performance; and effective downstream passage for juvenile and postspawning adult American Shad has been given little consideration in most passage projects.

There are multiple examples of upstream fish passage facilities at hydropower projects that are not effective for passing American Shad. In the Kennebec River, few adults annually enter the fish lift at the Lockwood Project (0-830) and similarly low numbers utilize the vertical slot fishway on the nearby Androscoggin River (0-1,096) despite the fact that spawning occurs less than a mile downstream. On the Merrimack River, an average of 17% of the American Shad that passed the first barrier successfully also passed the second barrier (Sprankle 2005). On the Susquehanna River, Connecticut River, and Merrimack River, the mean passage efficiencies for American Shad migrating upstream through fishways from the first dam to the spawning grounds were less than 3% (Brown et al 2013). Migration delays caused by fishways or trapping facilities need to be considered because they can limit spawning success and the number of repeat spawning adults (Castro-Santos and Letcher, 2010).

Survival of adult American Shad migrating downstream at hydropower dams is highly variable. In the Penobscot River, survival of adults ranged from 76.6-95.8% and was 51.4% at one project in the Androscoggin River with median time to pass ranging from 8.0 hours to 5.3 days (Table 9).

<u>3.3 Blueback Herring (Alosa aestivalis)</u>

3.3.1 Goals and objectives

The goal for Blueback Herring, is to

- Achieve and sustain a minimum population of 6,000,000 adults entering the mouth of the Kennebec River annually based on 5,015 hectares of spawning and nursery habitat in the mainstem and identified tributaries.
- Achieve and maintain an adult return of a minimum of 1,196 adults/hectare (484/acre).
- Achieve and sustain a minimum population of 3,000,000 adults above Augusta.
- Pass at least 1,788,000 adults at the Lockwood and Hydro Kennebec Project dams.
- Pass at least 1,535,000 adults at the Shawmut Project dam.
- Pass at least 922,400 adults at the Weston Project dam; and
- Pass at least 585,000 adults at the Benton Falls Project dam.

3.3.2 Biology and ecology

The Blueback Herring is an anadromous, highly migratory, pelagic, schooling fish found along the east coast of North America from Cape Breton, Nova Scotia and the Bay of Fundy watershed, New Brunswick, to Florida in the United States (Scott and Crossman 1973; Colette and Klein-MacPhee 2002). Blueback herring and Alewife are collectively referred to as river herring because of their similarity in size and appearance. Blueback herring spend most of their lives in the ocean and as adults they return to their coastal rivers to spawn. In the portions of their range where Blueback Herring and Alewife co-occur, Blueback Herring prefer to spawn over hard substrates in swift current (Loesch and Lund 1977; Johnston and Cheverie 1988). Blueback herring will ascend freshwater far upstream (Massmann 1953; Davis and Cheek 1966; Perlmutter *et al*. 1967; Crecco 1982); their distribution is a function of habitat suitability and hydrological conditions, such as swift flowing water (Loesch and Lund 1977). In tributaries of the Rappahannock River, Virginia, upstream areas were found to be more important for Blueback Herring spawning than downstream areas (O'Connell and Angermeier 1997). Spawning occurs at temperatures ranging from a minimum of 13°C (Hawkins 1979; Rulifson et al. 1982) to a maximum of 27°C (Loesch 1968). Blueback herring are repeat spawners and there appears to be an increase in repeat spawning from south to north (Rulifson et al. 1982). In Nova Scotia, 75% of adults in Nova Scotia had previously spawned (O'Neill 1980). Spawning typically occurs over an extended period, with groups or "waves" of migrants staying 4 to 5 days before rapidly returning to sea (Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Klauda et al. 1991). The majority of spent adult Blueback Herring emigrating from the Connecticut River moved through fish passage facilities between 1700 and 2100 hours (Taylor and Kynard 1984). Initially, Blueback Herring eggs are demersal, but during the water-hardening stage, they are less adhesive and become pelagic (Johnston and Cheverie 1988). In general, Blueback Herring eggs are buoyant in flowing water, but settle along the bottom in still water (Ross and Biagi 1990). Juvenile Blueback Herring spend three to nine months in their natal rivers before migrating to the ocean (Kosa and Mather 2001). In the Kennebec River, female and male Blueback Herring reach a maximum age of 7 years and total length of 289 mm and 277 mm, respectively. Females may produce 30,000-400,000 eggs. Blueback herring return to the Kennebec River to spawn for the first time at age 2 (males) and age 3 (females). Spawning fish are primarily between three and four years old.

3.3.3 Historical and current distribution

Foster and Atkins (1867) and Atkins (1887) did not describe the range of Blueback Herring in the Kennebec River. However, the species likely accessed the same areas as Alewife and American Shad considering their comparable swimming abilities and spawning habitat requirements. Therefore, this plan assumes that adult Blueback Herring ascended the mainstem Kennebec River to Norridgewock Falls, current location of the Abenaki and Anson projects, migrated into lower part of the Sandy River, and ascended to the confluence of the East Branch and West Branch of the Sebasticook River and were able to access 2,508 hectares of spawning and rearing habitat above Augusta (Table 6).

The removal of Edwards Dam in 1999 allowed Blueback Herring free access to about 21% of their historic spawning habitat. Pursuant to the 1998 Settlement Agreement, the installation of permanent upstream fish passage (a swim-through fish lift) at the Benton Falls Project and at the Burnham Project in 2006 and the removal of the Fort Halifax Dam in 2008 made all historic

Blueback Herring spawning/rearing habitat in the Sebasticook River accessible (489 hectares, 19.5% of historic habitat). Returns of adult Blueback Herring to the Benton Falls fish lift ranged from 1.2-1.3 million from 2017-2019 (Table 8).

Pursuant to the 1998 Settlement Agreement, interim upstream passage became operational at the Lockwood Project in 2006. Between 2014 and 2019, an average of 84,925 adult Blueback Herring (range 34,063-164,886) have been lifted at the Lockwood Project fish lift, and transported upstream by the MDMR (Table 8). Because the fish lift is not connected to the headpond, the majority (59.6%) of historic Blueback Herring habitat remains inaccessible.

3.3.4 Relevant fishery and stock status

States manage their river herring fisheries (Blueback Herring and Alewife) collaboratively through the Atlantic States Marine Fisheries Commission (ASMFC), which periodically conducts stock assessments or stock updates on all managed species. According to the most recent stock update for river herring (ASMFC 2017), severe declines in commercial landings of river herring began coastwide in the early 1970s and domestic landings are now a fraction of what they were at their peak (>30 million pounds annually from 1950-1972) and have remained at persistently low levels since the mid-1990s. Beginning in 2002, several states enacted moratoria on their commercial and /or recreational fisheries (Massachusetts, Rhode Island, Connecticut, Virginia for waters flowing into North Carolina, and North Carolina). As of January 1, 2012 states or jurisdictions without an approved sustainable fisheries management plan (SFMP), as required under ASMFC Amendment 2 to the Shad and River Herring FMP, were closed. As a result, prohibitions on harvest (commercial or recreational) were extended to the following states: New Jersey, Delaware, Pennsylvania, Maryland, D.C., Virginia (for all waters), Georgia and Florida.

ASMFC approved Maine's first SFMP to harvest river herring in 2010 and an updated SFMP in 2017. Maine has 38 municipalities with the exclusive right to commercially harvest river herring, and currently 22 municipalities actively harvest river herring. Directed commercial harvest of Alewife or Blueback Herring does not occur in the main stem of nine rivers (Penobscot, Kennebec, Androscoggin, Saco, St. Croix, Presumpscot, Machias, Salmon Falls, and East Machias), but does exist on the tributaries of larger rivers. The primary sustainability threshold is a minimum escapement of 35 fish per surface acre of spawning habitat. Escape numbers are measured through passage counts above commercial fisheries and managed by closed fishing days, season length, gear restrictions or continuous escapement. If the escapement threshold is not met than the commercial fishery will close for conservation. River herring populations in five of Maine's river systems with a commercial harvest (Androscoggin, Kennebec, Sebasticook, Damariscotta, and Union) either showed an increase or no trend in multiple assessment criteria (ASMFC 2017).

Recreational fishermen are allowed to harvest four-days per week throughout the year. The limit is 25 fish per day and gear is restricted to dip net and hook-and-line. Recreational fishermen may not fish in waters, or in waters upstream, of a municipality that owns fishing rights. Recreational fishing for river herring in Maine is limited and landings are low.

3.3.5 Past and current management actions in the Kennebec River

Restoration of Blueback herring has been a combination of active (stocking) and passive (natural expansion into accessible spawning/rearing habitat) actions in the Kennebec River watershed. The removal of Edwards Dam in 1999 allowed Blueback Herring free access to about 21% of their historic spawning habitat. Blueback herring naturally expanded into this habitat as evidenced by the presence of juveniles in the restored Kennebec River. Pursuant to the 1998 Settlement Agreement, interim upstream fish passage (a fish pump) became operational at the Fort Halifax Project in 2000, and MDMR stocked captured adult river herring into upstream habitat. Biological sampling indicates that few of the fish were Blueback Herring (Table 8). Pursuant to the 1998 Settlement Agreement, permanent upstream fish passage (a swim-through fish lift) became operational at the Benton Falls Project and at the Burnham Project in 2006. Following removal of the Fort Halifax Dam in 2008, the number of Blueback Herring migrating into spawning/rearing habitat in the Sebasticook River has increased by 1400% (Table 8). Also pursuant to the 1998 Settlement Agreement, interim upstream passage became operational at the Lockwood Project in 2006. The number of Blueback Herring returning to the mainstem has increased (Table 8), but the population is maintained by MDMR stocking efforts.

3.3.6 Findings of current research

This plan provides reach by reach (dam to dam) production targets for adult Blueback Herring. Production targets are based on accessible and potentially accessible spawning/nursery habitat area and the most recent determination of adult production per unit of habitat area, a method commonly used for American Shad and Alewife. The unit production was estimated from the number of Blueback Herring passed at Benton Falls and the amount of available upstream habitat. The targets were calculated as target number of adult Blueback Herring = (habitat surface hectares) × (1,196 adults/hectare).

The Kennebec River watershed contains approximately 2,508 hectares of Blueback Herring riverine spawning/nursery habitat that was historically accessible (Table 6). The majority of the habitat (59.6%) is above the Lockwood Dam, while 20.9% lies between the head-of-tide (site of former Edwards Dam) and the Lockwood Dam, and 19.5% is in the Sebasticook River (Table 6). Removal of Edwards Dam was an important step in enhancing the Blueback Herring population, which naturally recolonized the reach between Augusta, the Lockwood Dam, and the Fort Halifax Dam. The population rapidly expanded in the Sebasticook River after the removal of Fort Halifax with over one million adults being passed annually at Benton Falls in the past 4 years (Table 8). Blueback herring began using the fish lift at the Lockwood Project soon after it became operational in 2006 (Table 8). However, free access to habitat above the Lockwood dam is clearly necessary to reach production and distribution goals. MDMR estimates that the habitat above the Lockwood Project could produce a minimum of 2 million Blueback Herring.

Dr. Daniel Stich has recently developed a stochastic, life-history based, simulation model for Blueback Herring for the Mohawk River and the Kennebec River; these models are conceptually similar to the American Shad model. Dr. Stich ran 48 scenarios to explore the effects of downstream passage survival (1.00, 0.95, and 0.90) in combination with varying upstream passage efficiency (0.70-1.00) and time-to-pass (1, 3, 7, and 20 days per dams) on Blueback Herring distribution and abundance. The upstream and downstream passage facilities should be operated daily (24 hours/day) to accommodate the migratory movements of river herring (Grote et al. 2014).

MDMR is not aware of any effectiveness testing that has been conducted on Blueback Herring. However, studies of the related Alewife have resulted in downstream passage efficiencies that raged from 90.9-100.0% with median time to pass form 0.9 hours to 3.3 days and upstream passage efficiency from 19.8-65.1% (Table 9).

3.4 Alewife (Alosa pseudoharengus)

3.4.1 Goals and objectives

The goal for **Alewife** is to

1. Achieve and maintain an adult return that exceeds a minimum of 581.5 adults/hectare (235/acre) and is consistent with the Maine State average of 988.4/ha (400/acre).
2. Achieve and sustain a minimum population of 5,785,000 adults above Augusta.
3. Pass at least 608,200, adults at the Lockwood, Hydro Kennebec, and Shawmut project dams.
4. Pass at least 473,500 adults at the Weston Project dam; and
5. Pass at least 4,540,200 adults at the Benton Falls Project dam.

3.4.2 Biology and ecology

The Alewife is an anadromous, highly migratory, euryhaline, pelagic, schooling species that historically ranged from South Carolina to Labrador, Nova Scotia, and northeastern Newfoundland (Berry 1964; Winters et al. 1973; Burgess 1978). Alewife and Blueback Herring are collectively referred to as river herring because of their similarity in size and appearance Although Alewife and Blueback Herring co-occur throughout much of their respective ranges, Alewife are typically more abundant than Blueback Herring in the northern portion of their range (Schmidt et al. 2003). The Alewife spends the majority of its life at sea, returning to freshwater river systems along the Atlantic coast of the United States to spawn. Alewife spawn in lakes and ponds in coastal watersheds (Loesch 1987), in the slow-moving sections of rivers or streams (Jones et al. 1978), in shore-bank eddies or deep pools below the dams (Loesch and Lund 1977). Alewife home to their natal waters to spawn (Ross and Biagi 1990), but can be introduced to new habitat or may stray to new habitat which they will recolonize. Alewife may ascend long distances in freshwater to reach spawning habitat. In the Rappahannock River, upstream areas were found to be more important than downstream areas for spawning Alewife (O'Connell and Angermeier 1997). Spawning typically is initiated at water temperatures ranging from 5-10°C (Loesch 1987), and may last two to three days for each group or "wave" of fish that arrives (Cooper 1961; Kissil 1969; Kissil 1974). Many Alewife are repeat spawners, with some individuals completing seven or eight spawning events in a lifetime (Jessop et al. 1983). In the Kennebec River, female and male Alewife reach a maximum age of 8 and 7 years and total length of 331 mm and 316 mm, respectively. Females may produce 60,000-467,000 eggs. Alewife return to the Kennebec River to spawn for the first time at age 2 (males) and age 3 (females). Spawning fish are primarily between the ages of 4 and 5, with 17-19% being repeat spawners. The spawning habitat of Alewife can range from sand, gravel, or coarse stone substrates, to submerged vegetation or organic detritus (Edsall 1964; Mansueti and Hardy 1967; Jones et al. 1978). Adults migrate downstream soon after spawning. The fertilized eggs remain demersal and adhesive for several hours (Mansueti 1956; Jones et al. 1978), after which they become pelagic. Eggs most often hatch within 80 to 95 hours (Edsall 1970), the yolk-sac is absorbed within 2-5 days of hatching, and the larvae begin feeding exogenously (Cianci 1965; Jones et al. 1978). Outmigration of the juveniles is related to declining water temperature (Pardue 1983; Loesch 1987) and changes in water flow, water levels, precipitation, and light intensity (Cooper 1961; Kissil 1974; Richkus 1975; 1975b; Pardue 1983).

3.4.3 Historical and current distribution

Alewife historically were able to access 9,946 hectares of spawning and rearing habitat above the head-of-tide in Augusta (Table 6). Adults ascended the mainstem Kennebec River as far upstream as Norridgewock Falls, current location of the Abenaki and Anson projects, migrated into lower part of the Sandy River, and ascended to the confluence of the East Branch and West Branch of the Sebasticook River (Foster and Atkins 1868; Akins 1887). Currently, swim-through fish passage allows adult Alewife to access 3,557 hectares of habitat in the Sebasticook River and 999 hectares in Seven Mile Stream. However, 1,047 hectares of spawning/rearing habitat in the Kennebec River is not freely accessible. MDMR annually transports Alewife that use the fish passage facility at the Lockwood Project, which is not connected to the headpond, to upstream spawning/rearing habitat.

This plan provides reach (dam to dam) minimum production targets for adult Alewife. Minimum production targets are based on accessible and potentially accessible spawning/nursery habitat area and the adult production/unit of habitat area, a method commonly used in other American Shad plans and studies in the Connecticut River (CRASC 2017), Susquehanna River (SRAFRC 2010), and Penobscot River (MDMR 2008).

In the past, MDMR has used 235 adults/acre as the unit area production, which was the average minimum production of six harvested populations for the period 1971-1983 when the fishery was closed one day per week. Recent analysis of data for seven harvested runs for the period 2005-2017 (with three closed days per week) and reanalysis of the 1971-1983 data resulted in updating the average unit production to 400 adults/acre. This updated estimate of unit production is an average for harvested populations. The average production in this plan were calculated by the equation: number of adult Alewife = (habitat surface acres) × (400 adults/acre) or in metric units number of adult Alewife = (habitat surface hectares) × *(988.4 adults/hectare). The unit production of non-harvested populations, which would be a more accurate assessment of habitat carrying capacity, has been estimated for Maine and New Brunswick Alewife populations and is used for management of Alewife populations in Canada (Gibson and Myers 2003; Gibson et al. 2017).

3.4.4 Relevant fishery and stock status

States manage their river herring fisheries (Blueback Herring and Alewife) collaboratively through the Atlantic States Marine Fisheries Commission (ASMFC), which periodically conducts stock assessments or stock updates on all managed species. According to the most recent stock update for river herring (ASMFC 2017), severe declines in commercial landings of river herring began coastwide in the early 1970s and domestic landings are now a fraction of what they were at their peak (>30 million pounds annually from 1950-1972) and have remained at persistently low levels since the mid-1990s. Beginning in 2002, several states enacted moratoria on their commercial and /or recreational fisheries (Massachusetts, Rhode Island, Connecticut, Virginia for waters flowing into North Carolina, and North Carolina). As of January 1, 2012 states or jurisdictions without an approved sustainable fisheries management plan (SFMP), as required under ASMFC Amendment 2 to the Shad and River Herring Fisheries Management Plan, were closed. As a result, prohibitions on harvest (commercial or recreational) were extended to the following states: New Jersey, Delaware, Pennsylvania, Maryland, D.C., Virginia (for all waters), Georgia and Florida.

ASMFC approved Maine's first SFMP to harvest river herring in 2010 and an updated SFMP in 2017. Maine has 38 municipalities with the exclusive right to commercially harvest river herring. Currently, 22 municipalities actively harvest river herring. Directed commercial harvest of Alewife or Blueback Herring does not occur in nine of Maine's largest rivers (Penobscot, Kennebec, Androscoggin, Saco, St. Croix, Presumpscot, Machias, Salmon Falls, and East Machias), but commercial fisheries do exist on the tributaries of larger rivers. The primary sustainability threshold is a minimum escapement of 35 fish per surface acre of spawning habitat. Escape numbers are measured through passage counts above commercial fisheries and managed by closed fishing days, season length, gear restrictions or continuous escapement. If the escapement threshold is not met than the commercial fishery will close for conservation. River herring populations in five of Maine's river systems with a commercial harvest (Androscoggin, Kennebec, Sebasticook, Damariscotta, and Union) either showed an increase or no trend in multiple assessment criteria (ASMFC 2017).

Recreational fishermen are allowed to harvest four-days per week throughout the year. The limit is 25 fish per day and gear is restricted to dip net and hook-and-line. Recreational fishermen may not fish in waters, or in waters upstream, of a municipality that owns fishing rights. Recreational fishing for river herring in Maine is limited and landings are low.

3.4.5 Past and current management actions in the Kennebec River

Restoration of Alewife to the Kennebec River began in 1987 with the signing of the first KHDG settlement agreement. With funds from the settlement, MDMR stocked approximately 1.3 million adult Alewife into 9 inaccessible lakes and ponds from 1987 through 2006 (Table 10).

By 2003, the Maine Department of Marine Resources (MDMR) and its partners had provided upstream fish passage at four non-hydropower dams in the Sebasticook River (Guilford Dam, Sebasticook Lake, Stetson Pond, Plymouth Pond), which in turn triggered construction of upstream passage at the Benton Falls Project and the Burnham Project. A fish lift at each of the projects became operational in 2006. After the Fort Halifax Dam was removed, the Alewife population migrating up the Sebasticook River expanded significantly (Table 8; Wippelhauser 2021). Upstream passage into Webber Pond on Seven-Mile Stream also has resulted in a large Alewife population. Alewives returning to the mainstem of the Kennebec River have increased in number, but the population is maintained by stocking.

3.4.6 Findings of current research

Barber et al. (2018) developed a developed a deterministic model to explore the theoretical nutrient dynamics of Alewife migrations at differing spawner abundances. Adult Alewife on their spawning migration importing nitrogen and phosphorus into freshwater habitats, and outmigrating juveniles subsequently transport freshwater-derived nutrients into the ocean.

Productivity level was the major determinant of export, while fisheries mortality had the strongest effect on adult import.

The “Alewife population model”, a web-based application[7] for understanding likely fish passage outcomes for Alewife, was developed by Betsy Barber, Alejandro Molina-Moctezuma, Jamie Gibson, Andrew O’Malley, and Joseph Zydlewski. The basic structure and inputs of the original model have been described in Barber et al. (2018), and the same information and the R code is annotated at the web site.

The Alewife population model was developed to compare theoretical spawner abundance between scenarios with different dam passage rates. Spawner abundance is calculated using a deterministic population model, which defines inputs using averages applied to groups. The model is used to explore general trends and compare the results of scenarios when different average values are used as inputs. The model does not make forecasts or predictions about the exact number of spawners that will be present in the river after a certain number of years**.** In addition, no annual environmental variability was built into the model; inputs were averages; all spawning habitat was considered to be of the same quality; all density-dependent mortality was included in the recruitment curve; and in the absence of dams, fish were distributed throughout the system according to habitat availability. The types of questions that can be answered using the Alewife population model are those that make comparisons between scenarios, such as:

1. How would improving passage at a specific dam increase total Alewife abundance in the river?
2. Where would passage improvements result in the largest increase in spawner abundance?

MDMR used the Alewife population model to compare total theoretical Alewife abundance in the Kennebec River between scenarios with different upstream and downstream fish passage efficiencies given the distribution of spawning habitat relative to the four mainstem dams. In order to achieve a minimum number of spawners (608,200 adult Alewife) to historic habitat in the Kennebec River, upstream passage of adults would need to be at least 90% effective at each of the four dams and downstream passage of adults and juveniles at each of the four dams would need to be at least 95% effective (Figure 3). If dams were removed, required upstream and downstream passage effectiveness of adults and juveniles at remaining projects would decrease. Because adult Alewife have limited energy stores, time to pass at each dam should be minimized. The upstream and downstream passage facilities should be operated daily (24 hours/day) to accommodate the migratory movements of river herring (Grote et al. 2013). These results form the basis of our performance standards.

Several fish passage studies of adult Alewife have been conducted in recent years using small radio telemetry tags. These Studies have resulted in estimated downstream passage efficiencies that ranged from 90.9-100.0% with median time to pass form 0.9 hours to 3.3 days and upstream passage efficiency from 19.8-65.1% (Table 9).

[7] https://umainezlab.shinyapps.io/Alewifepopmodel/

3.5 Sea Lamprey (*Petromyzon marinus*)

3.5.1 Goals and objectives

The goal for Sea Lamprey is to restore access for the species to historic spawning and nursery habitat.

3.5.2 Biology and ecology

The Sea Lamprey is an anadromous, semelparous, species that ranges in the wester Atlantic Ocean from the St. Lawrence River in Canada to the State of Florida in the United States (Scott and Crossman; Colette and Klein-MacPhee 2002). Unlike the other diadromous species native to Maine, there is no evidence that Sea Lamprey home to their natal river system (Hansen et al. 2016). They spawn in gravel-cobble substrate, and the spawning process results in streambed modification and sediment transport (Nislow and Kynard 2009; Sousa et al. 2012; Hogg et al. 2016). Lamprey spawning activities condition the habitat for other species, including Atlantic Salmon, by removing fines and reducing substrate embeddedness (Kircheis 2004). Given the high degree of embeddedness in Maine streams due to past land use practices, the role of lamprey as "ecosystem engineers" is particularly important (Kircheis 2004; Sousa et al. 2012). Sea Lamprey spawning in Maine begins in late May and extends into early summer and peaks at water temperatures of 17-19˚C (Kircheis 2004). Sea Lamprey metamorphize as juveniles and swim downstream to feed in the ocean in the late fall and spring (Kircheis 2004). General movement is thought to occur at nighttime and during high flow events (Kircheis 2004). Given their small size at 100 mm to 200 mm (Kircheis 2004), turbine entrainment is possible without appropriately sized exclusion screening or other measures to bypass outmigrating Sea Lamprey.

Anadromous Sea Lampreys also serve as a conduit of nutrients between marine and freshwater systems. Semelparous adults contribute marine derived nutrients (MDN) to rivers, whereas filter-feeding ammocetes, (the juvenile life stage that spends up to eight years in stream sediments), break down terrestrially derived nutrients in streams, and eventually export nutrients into the marine environment (Beamish 1980, Kircheis 2004; Nislow and Kynard 2009; Weaver et al. 2018). Atlantic coastal streams are generally considered to be phosphorus-limited, although Sedgeunkedunk Stream in Maine was found to be both nitrogen and phosphorus limited (Weaver et al. 2016). Nislow and Kynard (2009) demonstrated that Sea Lamprey contributed phosphorus to a Connecticut River tributary at levels as great as 0.26 gm^{-2}. Sea Lamprey spawning occurs in late spring and early summer, thus pulses of MDN from post-spawn lamprey carcasses occur after canopy formation reduces light penetration to the stream and concurrent with the emergence of macroinvertebrates and Atlantic Salmon fry (Beamish 1980; Nislow and Kynard 2009; Weaver et al. 2015, 2016). Consequently, the influx of nutrients may help support stream food webs during a time when nutrients and energy flow might otherwise be limiting (Weaver et al. 2016). Further, Sea Lamprey are the sole semelparous species among the complex of sea run species that spawn in Maine's rivers. Gametes and metabolic waste from iteroparous species, such as Atlantic Salmon, river herring, and shad do serve as a source of MDN, but carcasses of semelparous species are generally a more important source of nutrients, highlighting the importance of providing lamprey passage into critical habitat areas (Moore et al. 2011; Nislow and Kynard 2009). The species is an important component of the riverine ecosystem in Maine that, like other sea run fish species, has been prevented from reaching much of its historic range by barriers to upstream passage.

3.5.3 Historical and current distribution

The historical distribution of Sea Lamprey in the Kennebec River is not known. However, in watersheds unrestricted by dams, Sea Lamprey are capable of reaching small, high-gradient, headwater streams (Nislow and Kynard 2009).

The removal of Edwards Dam in 1999 allowed Sea Lamprey free access to the mainstem Kennebec River as far upstream as the Lockwood Dam and the Fort Halifax Dam. Between 2006 and 2020, a total of 194 Sea Lamprey have been used the Lockwood Project fish lift (average 13, range 0-15).

3.5.4 Relevant fishery and stock status

Currently there is no commercial harvest of Sea Lamprey in Maine, although Carolina Biological Supply Company harvested as many as 8,000 sea lamprey from the Sheepscot River at Head Tide in the 1970's and 1980's (Kircheis 2004).

In Europe, the Sea Lamprey has declined over the last 25 years from a combination of (1) habitat loss associated with dam construction, (2) degradation of water quality from mining, industrial, and urban development, (3) direct loss of habitat by sand extraction and dredging, (4) overfishing, and (5) changes in water quality (temperature) and quantity (Hansen et al.2016). Dams without fishway that are appropriate for Sea Lamprey or fishways that are not operated at night may have resulted in a similar decline in abundance of Sea Lamprey along the Atlantic coast. Assessment of the status of Sea Lamprey is complicated by the fact that adult sea lampreys do not appear to home to natal streams (Waldman et al. 2008), but rather, select spawning streams through innate attraction using other sensory cues (Vrieze et al. 2010, 2011

3.5.5 Past and current management actions

Sea Lamprey have not been actively managed in the past. Recent research has led to an appreciation of the ecological goods and services provided by the species, and as a result, MDMR has begun efforts to improve upstream and downstream passage adult and juveniles.

3.5.6 Findings of current research

On the Connecticut River, Castro-Santos et al. (2016) reported that 64% of entries into fish passage structures occurred at night (i.e., between sunset and sunrise); in fact, entry rates were as much as 24.4 times greater at night. In a study on the River Mondego, (Portugal), Pereira et al. (2016) found that most detections of Sea Lamprey in a vertical-slot fish pass occurred at night, i.e., between dusk and dawn (88% in 2014 and 75% in 2015). Data from fish passage facilities in Connecticut indicate that in the early part of the upstream migration period, lamprey enter fish passes exclusively at night. As the run progresses, however, lamprey may enter at any time (Steve Gephard, CTDEEP Fisheries, pers. comm. Old Lyme, CT). At the Westfield River fish passage facility in Massachusetts, nearly all lamprey pass at night (Caleb Slater, Massachusetts Division of Fisheries and Wildlife. Pers. Comm. Westborough, MA). In 2020, lamprey passage occurred primary in the evening hours at the Milford fish lift, with some passage occurring in the early morning (e.g. 1am EST) (MDMR, unpublished data). Given the strong propensity for lamprey to exhibit nocturnal movement patterns, fishways, including fish lifts, should be operated at night to allow for lamprey passage.

On the Connecticut River, the combined passage percentage for Sea Lamprey at Turner's Falls was 46.7%, whereas fish pass entry was 64.1% of tagged individuals (Castro-Santos et al. 2016). This is comparable to entry rates for Pacific lamprey at Bonneville (67%) and McNary Dams (61%) on the Columbia River (Johnson et al. 2012; Keefer et al. 2013a; 2013b). At Turner's Falls, failure to pass was predominantly associated with the fish pass entrance, so concerted improving ability for lamprey to enter fish ladders is likely to be a key aspect of ensuring overall passage success (Castro-Santos et al. 2016). Passage efficiency for a vertical-slot fish pass on the River Mondego, (Portugal), was determined to be 33% via PIT telemetry and 31% via radio-telemetry (Pereira et al. 2016). In 2020, 50 radio tagged sea-lamprey passed the Milford fish lift on the Penobscot River at 81% (MDMR, unpublished data).

Detection of a radio-tag from a Sea Lamprey at Brownsville on the Pleasant River (a tributary of the Penobscot River) in August 2020 indicates that two dam removals, installation of a fish lift that is operated day and night, and installation of a nature-like fishway at a decommissioned hydropower project has positive impacts on lamprey migratory range (MDMR, unpublished data).

During the years 2014-2020, the earliest recorded Sea Lamprey was counted at the Milford Dam fish lift (Penobscot River) on May 7; lamprey have been recorded at Milford as late as July 6 (MDMR unpublished data). Lamprey on the Westfield River have been observed as early as April 14 during the years 2005 to 2019 (Caleb Slater, Massachusetts Division of Fisheries and Wildlife. Pers. Comm. Westborough, MA). For the years 1978-2018, lamprey were recorded at the Rainbow Dam fishway on the Farmington River, (a tributary of the Connecticut River) as early as 16 April (mean start date of 29 April) and as late as July 11 (mean end date of 24 June; CT DEEP Fisheries Division, unpublished data, Old Lyme, CT). Given the long distances that Sea Lamprey must travel to reach spawning grounds while temperatures are favorable for spawning, we recommend that a Sea Lamprey passage season should begin no later than May 1 and extend to July 30. As more information becomes available, this season can be adjusted. \

3.6 American Eel (*Anguilla rostrata*)

3.6.1 Goals and objectives

The goal is to provide safe, timely, and effective upstream and downstream passage for American Eel throughout its historically accessible habitat.

3.6.2 Biology and ecology

The American Eel is a highly migratory, semelparous, facultative catadromous species that spends most of its life in freshwater or estuarine environments and spawns in the ocean (Collette and Klein-MacPhee 2000; Shepard 2015). The species ranges over more than 50 degrees of latitude, being found from the southern tip of Greenland, along the entire eastern coast of North America, around the Gulf of Mexico, and through most of the West Indies (Smith 1989). Within that range, it may use the broadest types of habitat of any fish species (Helfman et al. 1987). Spawning occurs in winter and early spring only in a large region of the Sargasso Sea (Kleckner and McCleave 1985; Wippelhauser et al. 1985; McCleave et al. 1987) probably in association with, or delimited by, density fronts meandering east-west in the Sargasso Sea (Kleckner and McCleave 1988). The eggs hatch and release a long-lived larval stage (leptocephalus) which drift and swim in the upper 300 m of the water column for several months, growing slowly to a length of 5-6 cm (Kleckner and McCleave 1985). The oceanic current move the leptocephali to the south and west and into the Gulf Stream, which transports them northward along the east coast of the U.S. Somewhere over the continental shelf, the larvae metamorphose into a miniature transparent eels (glass eels). Glass eels actively migrate toward land and freshwater and ascend rivers during the winter and spring. The migration occurs earlier in the southern portion of the range and later in the northern portion (Helfman et al. 1987; McCleave and Kleckner 1982). Glass eels ascend estuaries by drifting on flooding tides and holding position near bottom on ebb tides (McCleave and Kleckner 1982; Wippelhauser and McCleave 1987) and also by actively swimming along shore in the estuaries and above tidal influence (Sheldon and McCleave 1985 Barbin and Krueger 1994). When the migrating glass eels become pigmented they are termed elvers or yellow eels. Depending on where they cease their upstream migration, some yellow eels reach the extreme upper portions of the rivers while others stay behind in the brackish areas (Hardy 1978, Fahay 1978). The timing and duration of elver/yellow eel upstream migration can occur over a broad period of time from March through October, peaking in May through July. Yellow eel can continue migrating until they reach sexual maturity (Richkus and Whalen 1999). The growth rates of elvers/yellow eels are highly variable, although growth appears to vary with latitude and habitat (slower growth in the north than in the south; slower growth occurs in freshwater than in estuaries). The variable growth rates make length a poor predictor of age (Facey and Van Den Avyle 1987). Eventually yellow eels undergo a final metamorphosis into a silver eel, the adult stage that will migrate to the Sargasso sea to spawn and die. Silver eels may begin their seaward spawning migration in late summer through fall from New England tributaries (Facey and Van Den Avyle 1987). The yellow eel undergoes several physiological changes in becoming a silver eel, including: (1) a color change from yellow/green to metallic, bronze-black sheen; (2) body fattening; (3) skin thickening; (4) enlargement of the eye and change in visual pigment; (5) increased length of capillaries in the rete of the swim bladder; and (6) digestive tract degeneration (Facey and Van Den Avyle 1987).

The timing of the American Eel migrations in Maine’s waters is well-known from commercial harvests and MDMR monitoring. Upstream migrations generally begin earlier in the western part of the state and downstream migrations generally begin earlier in the upper reaches of a watershed. The upstream migration of glass eels is considered to occur from March 15- June 15. The upstream migration season for elvers and yellow eels is June 1-September 30. The downstream migration of silver eels occurs from August 15- October 31. Migration mostly occurs at night although glass eels may occasionally move during the day.

3.6.3 Historical and current distribution

Foster and Atkins (1868) and Atkins (1887) did not describe the historical range of American Eel in the Kennebec River watershed. However, the current range on the mainstem of the river extends as far upstream as Williams Project impoundment.

3.6.4 Relevant fishery and stock status

Like anadromous species, the abundance of American Eel has declined, and the decline has been attributed in part to dams, overfishing, and poor water quality. The species has been considered for listing under the ESA twice, but the USFWS determined in both cases that listing was not warranted at the time.

States manage their American Eel fisheries collaboratively through the Atlantic States Marine Fisheries Commission (ASMFC), which periodically conducts stock assessments or stock updates on all managed species. Currently two states, Maine and South Carolina, commercially harvest glass/elver eels (legally defined as eel <6 inches total length); all 15 states and jurisdictions commercially harvest yellow eels; and New York commercially harvests silver eels. Prior to the glass eel harvest in Maine, which began in the late 1970s, silver eels accounted for the majority of the Maine's commercial eel landings.

In the 2012 benchmark stock assessment, both trend analyses and DB-SRA results indicated the American Eel stock has declined in recent decades and the prevalence of significant downward trends in multiple surveys across the coast was cause for concern. Therefore, the stock status was depleted, and no overfishing determination could be made at that time based solely on the trend analyses performed. In the 2017 stock assessment update, the trend analysis results were similar to the 2012 results with few exceptions. Despite downward trends in the indices, commercial yellow American Eel landings have been stable in the recent decades along the Atlantic coast (U.S. and Canada) although landings still remain much lower than historical landings. Therefore, the stock status is unchanged, it is depleted, and no overfishing determination can be made based on the trend analyses performed.

Since the ASMFC Interstate Fisheries Management Plan for American Eel (FMP) was approved in 1999, it has been modified four times. Addendum I (2006) established a mandatory catch and effort monitoring program for American Eel. Addendum II (2008) made recommendations for improving upstream and downstream passage for American Eels. Addendum III (2013) made changes to the commercial fishery, specifically implementing restrictions on pigmented eels, increasing the yellow eel size limit from 6 to 9 inches, and reducing the recreational creel limit from 50 fish to 25 fish per day. Addendum IV (2014) established a coastwide landings cap of 907,671 pounds of yellow eel, reduced Maine's glass eel quota to 9,688 pounds, and allowed for the continuation of New York's silver eel weir fishery in the Delaware River. Two management triggers for the yellow eel fishery were established: (1) if the coastwide cap is exceeded by more than 10% in a given year, or (2) the coastwide cap is exceeded for two consecutive years regardless of the percent overage. If either one of the triggers were met then states would implement state-specific allocations based on average landings from 1998-2010 with allocation percentages derived from 2011-2013. Addendum V (2018) revised the yellow eel coastwide cap and management triggers based on recent fishery performance and updated landings data, and removing state-by-state quotas for the yellow eel fishery.

3.6.5 Past and current management actions in the Kennebec River

Since 1995, the MDMR has been requesting the installation of upstream and downstream eel at each hydropower facility as part of a settlement agreement or the relicensing process. Pursuant to the 1998 Settlement Agreement, upstream and downstream passage (either permanent or interim) for American Eel has been provided at all of the mainstem dams in the Kennebec River and the Sebasticook River. However, our understanding of the best means of providing downstream passage and the timing of the outmigration of silver eels have evolved in the last 25 years and testing of the existing interim facilities has not been rigorous. Analysis of Maine's silver eel harvest data indicates that the downstream migration of silver eels in the Kennebec River primarily occurs from August 15 to October 31.

3.6.6 Findings of current research

Anguillicoloides crassus, a highly infectious exotic nematode that infects the swimbladder of Anguillid eels, was originally found in 1995 at two separate locations in the U.S., an American eel aquaculture operation in Texas and from a single wild eel captured in Winyah Bay, South Carolina. Collections in 1998 and 1999 found a mean parasite prevalence rate (percent infected) of 52% in the Carolinas, but only 10-29% in Chesapeake Bay and less than 12% in the Hudson River; a study in 2010 found the same decline in parasite prevalence with latitude, but prevalence had increased to 58% in South Carolina, 41% in Chesapeake Bay, and 39% in New York (Shepard 2015). MDMR sampling has documented *A. crassus* in Maine. A major concern is that this parasite, which can damage the swim bladder of the American eel hosts, could potentially reduce the ability of infected adult eels to migrate and spawn successfully in the Sargasso Sea.

4.0 Economic value of the diadromous fishery resource

The Kennebec River supports important recreational fisheries for Striped Bass and American Shad and commercial fisheries for river herring and American Eel and annually exports millions of juvenile and adult sea-run fish to Maine's coastal waters.

Statewide, the Striped Bass fishery supported 3,110 jobs and generated $202-million dollars in revenue in 2016 (Southwick Associates 2019). In 2019, Maine's recreational fishermen landed 92,081 American Shad. The lucrative American Eel (elver) fishery was worth over $20 million dollars in 2018 and 2019. Statewide, the commercial harvest of river herring is a source of income for the municipalities with fishing rights and was valued at $814,240 in 2019 and $586,182 in 2020. Maine's lobster industry, valued at $485.4 million in 2019, became increasingly dependent of river herring as bait since the Atlantic herring stocks plummeted. Sea-run fish are an important part of the riparian and coastal environment, providing forage for eagles, seals, puffins, whales, cod, pollack, and other freshwater and marine species.

<u>4.1 Value of salmon habitat</u>

The Kennebec River once supported a robust Atlantic Salmon population, and habitat in the Kennebec River is critical to the recovery of the species today. In particular, the Sandy River has the greatest biological value for spawning and rearing habitat in the watershed, but it is currently only accessible to adult salmon through a trap and truck program around the four mainstem dams (NMFS 2009). Dams are also the most significant contributing factor to the loss of salmon habitat connectivity within the range of the DPS (Fay et al. 2006) and have been identified as the greatest impediment to self-sustaining Atlantic Salmon populations in Maine (NRC 2004). In the Kennebec River, there are approximately 251,083 units of historically accessible spawning and rearing habitat for Atlantic Salmon, however hydropower dams reduce or impede access to roughly 222,105 units (88.5%) of that habitat (NMFS 2009). Put into perspective, this is a loss of 30% of the historic habitat of Atlantic Salmon within the state of Maine; the only remaining intact population of Atlantic Salmon in the United States.

The Atlantic Salmon Restoration and Conservation Program (ASRCP) was established in 2018. The program is an In-Lieu Fee Program for compensating adverse impacts to Atlantic Salmon within the State of Maine. The ASRCP allows a consistent and defensible mechanism for calculating program credits and debits (fees) based on project impacts to Atlantic Salmon habitat. The scope of impacts includes any adjacent or blocked, spawning or rearing Atlantic Salmon critical habitat. The fee schedule defines a cost per habitat unit for each of the three bioregions and it was developed by incorporating a series of cost models and quantitative habitat measures. For the Merrymeeting Bay Salmon Habitat Recovery Unit (MMB SHRU), the bioregion that includes the Kennebec River, the cost per habitat unit is $4,850.

The four mainstem dams on the Lower Kennebec constitute the single largest impact on historical habitat in the Kennebec River. Lockwood, Hydro-Kennebec, Shawmut, and Weston and their associated impoundments impact both principle constituent elements defined in the Endangered Species Act listing of the species: migratory corridors and spawning and rearing habitat. In addition, the Anson and Abenaki project also impact historical salmon habitat but are not within the current critical habitat listing for Atlantic Salmon. These two projects also are located much further upstream and have a lesser impact on other anadromous species.

For simplicity, the calculations of habitat value (Table 14) are based on blocked habitat and do not include adjacent habitat impacts. The sum of rearing habitat impacted by the six dams is roughly 93,369 units. The quantity of rearing habitat used for this calculation is based on a modeling approach developed by Wright et al. (2008). The sum of measured spawning habitat impacted by the four dams is roughly 2,145 units. Spawning habitat has been identified by habitat surveys, but the majority of habitat in the watershed has not been surveyed and thus the quantity of spawning habitat used in this calculation represents only a portion of actual spawning habitat in the Kennebec watershed. If the fee schedule developed for the Kennebec River is applied to the total habitat impacted by the six dams, the cost to restore, enhance, create, or preserve in order to mitigate for the lost habitat would be approximately $463.8 million for projects below Williams and over $1 billion for all historic salmon habitat. While this approach is appropriate for estimating the monetary value of the impact to habitat in the Kennebec River, the quantity of habitat that is impacted is so great that it is impossible to replace in-kind.

5.0 Climate Change and Atlantic Salmon

The Atlantic Salmon is a cold-water anadromous species that has a narrow temperature tolerance range. As such, this species is susceptible to the effects of climate change during both the freshwater and marine phases of its life cycle (Brett 1956; Pörtner and Farrell 2008; Jonsson and Jonsson 2009; Hare et al. 2016). The negative effects of climate change on salmonids, however, are expected to be worse in systems with habitat that is degraded or is fragmented by dams (Rieman and Isaak, 2010; Williams et al. 2015).

In the northeastern United States, the streams and rivers where Atlantic Salmon occur are predicted to experience warmer summer water temperature combined with overall drier summers, with rainfall predominantly occurring as localized but intense events (Magnuson et al., 1997; Spierre and Wake, 2010; Todd et al. 2011). Winters are predicted to be wetter, with more rain than snow, which have the potential to alter winter baseflow, ice cover, and the timing, frequency, and severity of ice breakup events (Magnuson et al., 1997; Beltaos and Burrell 2003; Spierre and Wake, 2010). Mid-winter ice break-up events can be particularly detrimental to the over-winter survival of Atlantic Salmon and other aquatic life (Cunjak et al. 1998; Turcotte and Morse 2017). Reduced ice cover also has been linked to reduced overwinter survival of juvenile Atlantic Salmon (Hedger et al. 2012).

Salmon metabolism increases with increasing temperature, thus river temperature drives processes like timing of spawning, hatching of eggs and emergence timing, growth rates, size and age at smolt transition, migration patterns, gonad development, and fecundity (Jonsson and Jonsson 2009). At a certain temperature, termed the upper incipient lethal temperature, salmon begin to experience thermal stress; if salmon are unable to find cooler water, then they will die (Jonsson and Jonsson 2009; Elliott and Elliott 2010). For salmonids, the upper incipient lethal temperature is generally between 20 and 28 °C (Jonsson and Jonsson 2009; Elliott and Elliott 2010). Below the upper incipient lethal temperature, but outside the range of optimal temperatures, growth of juvenile salmon and energy stores of over-summering of adult salmon are reduced (Berman and Quinn 1991; Hasler et al. 2012).

Maximizing growth of juvenile salmon, energy stores available for adults, and overall survival, requires that Atlantic Salmon have access to suitable cold-water refuge habitat during summer heat events (Torgersen et al. 1999; 2012). Low flow conditions, road-stream crossings, and dams all can impede access to cooler headwater tributaries and cool refuges (Torgerson et al. 1999; Hasler et al. 2012; Brewitt et al. 2014). The warmer, drier summers expected to occur in Maine under future climate change scenarios make maintaining access to headwater tributaries and thermal refuges even more important (Magnuson et al. 1997; Spierre and Wake 2010; Todd et al. 2011; Dugdale et al. 2016; Frechette et al. 2018).

Headwater habitats have been identified as critically important for salmonid species, including Atlantic Salmon(Colvin et al. 2018). In addition to serving as cool refuges, productivity (in terms of parr density) has been positively associated with cumulative drainage area: i.e., parr density was lower in mainstem reaches (Sweka and Mackey 2010), possibly because of higher temperatures in the larger mainstem habitat. Colder headwater streams could also serve as an invasion shield, protecting native species like salmon from negative interactions with non-native species with higher temperature tolerances (Isaak et al. 2015). Erkinero et al. (2019) found greater life history diversity for Atlantic Salmon in tributaries than in river mainstems. Life history diversity can buffer effects of population fluctuations and help ensure population persistence; a concept referred to as the “portfolio effect” (Schindler et al. 2010). This evidence of the portfolio effect in Atlantic Salmon further supports the need to ensure that salmon have access to a variety of habitat types, particularly headwater tributaries, to maximize life history diversity and population persistence in the face of a changing climate.

In addition to impeding access to critical headwater habitat, dams and associated impoundments also impose other thermal challenges for salmon that can compound the effects of climate change. Impoundments created by dams alter the river temperature regime, both in the impoundment itself and in downstream habitat. Removal of the mainstem dams in the Klamath River (California) is expected to result in a decrease in mainstem river temperature by 2 to 4˚C, which would help buffer the effects of climate change induced temperature increase on salmon and steelhead (Goodman et al. 2011; Perry et al. 2011; Brewitt et al. 2014). On the Snake River, most of the acute thermal stress on radio-tagged salmon and steelhead occurred at dams, with the warmest temperatures experienced in reservoirs or even in the fishways (Caudill et al. 2013; Keefer and Caudill 2016). In fact, when fishway temperatures were warmer, individuals made repeated passage attempts resulting in energetically costly passage delays (Caudill et al. 2013).

The large area of impounded water and significant numbers of dams between the only climate resilient habitat in the Kennebec river, the Sandy River, upper Kennebec, and Carrabassett River, creates an increasing urgency to remove dams in the Kennebec drainage to ensure safe, timely, and effective passage.

6.0 Summary

The Kennebec River is unique among all of Maine's river systems – it is the only one that currently supports populations of all of the State's native diadromous fish species. These fishes were once very abundant, but dams, overfishing and degraded water quality reduced their numbers or resulted in extirpation from historic habitat. Restoration efforts in the last 34 years have included fish stocking, dam removals, installation of fish passage at some dams, reduced commercial and recreational harvest, and water quality standards that have eliminated anoxic "dead zones." In some areas of the watershed, diadromous species have responded with significant increases in abundance. However, the six hydropower dams on the lower Kennebec River and the cumulative deleterious impacts they have on six species of diadromous fishes, one being endangered, represent a system out of balance. This comprehensive fisheries management plan provides a framework that balances restoration of diadromous fishes and the need for sustainable energy production. 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 Licensee commissioned a study, *Energy Enhancements and Lower Kennebec Fish Passage Improvements Study* (Feasibility Study), for stakeholder review and comment on May 20, 2019 FERC Accession #s 20190701-5155 and 20190701-5154). The Feasibility Study considered several fish passage options, one being dam removal, for the Shawmut, Lockwood, and Weston projects. Removal of those projects was determined to be feasible and reasonably practical. Therefore, the recommendation should be given full consideration.

6.1 Species Goals for the Kennebec River

The goal for **Atlantic Salmon** is to provide safe, timely, and effective upstream and downstream passage in order to achieve a minimum annual return of 500 naturally-reared adults to historic spawning/rearing habitat in the Kennebec River for downlisting and a minimum annual return of 2,000 naturally-reared adults to historic spawning/rearing habitat in the Kennebec River for reclassification.

The goal for **American Shad** is to provide safe, timely, and effective upstream and downstream passage in order to achieve a minimum annual return of 1,018,000[8] wild adults to the mouth of the Kennebec River; a minimum annual return of 509,000 adults above Augusta; a minimum of 303,500 adults annually passing upstream at the Lockwood and Hydro Kennebec Project dams; a minimum of 260,500 adults annually passing upstream at the Shawmut Project dam; and a minimum of 156,600 adults annually passing upstream at the Weston Project dam.

[8] Based on 5,015 hectares of spawning/rearing habitat and a minimum return of 203 adults per hectare.

The goal for **Blueback Herring** is to provide safe, timely, and effective upstream and downstream passage in order to achieve a minimum annual return of 6,000,000[9] wild adults to the mouth of the Kennebec River; a minimum annual return of 3,000,000 adults above Augusta; a minimum of 1,788,000 adults annually passing upstream at the Lockwood and Hydro Kennebec Project dams; a minimum of 1,535,000 adults annually passing upstream at the Shawmut Project dam; and a minimum of 922,400 adults passing upstream at the Weston Project dam.

The goal for **Alewife** is to provide safe, timely, and effective upstream and downstream passage in order to achieve a minimum annual return of 5,785,000[10] adults above Augusta; a minimum of 608,200 adults annually passing at the Lockwood, Hydro Kennebec, and Shawmut project dams; and a minimum of 473,500 adults annually passing upstream at the Weston Project dam.

The goal for **Sea Lamprey** and **American Eel** is to provide safe, timely, and effective upstream and downstream passage throughout the historically accessible habitat of these two species.

6.2 Upstream Passage Performance Standards Necessary to Meet Species Goals

While the current proposal cannot meet these goals, should another proposal provide a more realistic proposal to meeting goals, the following would be recommended. DMR would recommend that the Licensee shall be responsible for providing, operating, maintaining, and evaluating volitional upstream fish passage facilities at the Lockwood, Hydro Kennebec, Shawmut, and Weston projects that shall be capable of passing the minimum populations annually in a safe, timely, and effective manner. Each project facility shall be considered to be performing in a safe, timely, and effective manner if:

1. At least 99% of the adult Atlantic Salmon that pass upstream at the next downstream dam (or approach within 200 m of the project powerhouse) pass upstream at the project within 48 hours.
2. At least 70% of the adult American Shad that pass upstream at the next downstream dam (or approach within 200 m of the project powerhouse) pass upstream at the project within 72 hours.
3. At least 90% of the adult Blueback Herring that pass upstream at the next downstream dam (or approach within 200 m of the project powerhouse) pass upstream at the project within 72 hours.
4. At least 90% of the adult Alewife that that pass upstream at the next downstream dam (or approach within 200 m of the project powerhouse) pass upstream at the project within 72 hours; and
5. At least 80% of the adult Sea Lamprey that pass upstream at the next downstream dam (or approach within 200 m of the project powerhouse) pass upstream at the project within 48 hours.

[9] Based on 5,015 hectares of spawning/rearing habitat and a minimum return of 1,196 adults/hectare.
[10] Based on 9,946 hectares of spawning/rearing habitat and a minimum of 581.5 adults/hectare; the Maine State average is 988.4/hectare.

DMR would recommend that the Licensee shall operate the upstream passage daily from May 1 through November 10. The Licensee shall operate the upstream passage 24 hours per day from May 1 through June 30 to accommodate diurnal and nocturnal migrants.

The upstream passage facility shall adhere to the USFWS design criteria (USFWS 2019).

The Licensee shall initiate three consecutive years of upstream passage effectiveness testing using radio telemetry or an equivalent technique for each of the five species (Atlantic Salmon, American Shad, Blueback Herring, Alewife, and Sea Lamprey). The study plans shall be developed in consultation with, and require approval by, the MDMR and the other regulators and resource agencies. Based on the results of the annual reports, the regulators may require adjustments to the study methodology for the next year's evaluation.

Failure to meet effectiveness goals should result in significant modification of the project.

6.3 Downstream Passage Performance Standards Necessary to Meet Species Goals

While the current proposal cannot meet these goals, should another proposal provide a more realistic proposal to meeting goals, the following would be recommended. DMR would recommend that the Licensee shall be responsible for providing, operating, maintaining, and evaluating a volitional downstream fish passage facilities at the Lockwood, Hydro Kennebec, Shawmut, and Weston projects that shall be capable of passing adult and juvenile Atlantic Salmon(kelts and smolts), adult and juvenile American Shad, adult and juvenile Blueback Herring, adult and juvenile Alewife, adult American Eel (silver eel), and juvenile microphthalmia Sea Lamprey in a safe, timely and effective manner. MDMR recommends that each project facility shall be considered to be performing in a safe, timely, and effective manner if:

1. At least 99% of the Atlantic Salmon smolts and kelts that pass downstream at the next upstream hydropower dam (or approach within 200 m of the project spillway) pass the project within 24 hours.
2. At least 95% of the adult and juvenile American Shad that pass downstream at the next upstream hydropower dam (or within 200 m of the project spillway) pass the project within 24 hours.
3. At least 95% of the adult and juvenile Blueback Herring that pass downstream at the next upstream hydropower dam (or within 200 m of the project spillway) must pass the project within 24 hours.
4. At least 95% of the adult and juvenile Alewife that pass downstream at the next upstream hydropower dam (or within 200 m of the project spillway) pass the project within 24 hours.

The downstream passage facility shall adhere to the USFWS design criteria (USFWS 2019).

DMR would recommend the licensee shall pass 600 cfs through the forebay Taintor gate from April 1 to June 15 to provide safe passage for smolts and provide a minimum of 6% of Station Unit Flow (about 400 cfs at maximum generation) through the combined discharge of the forebay Taintor and surface sluice gates from June 16 to December 31 to provide passage for shad, blueback herring, alewife, kelts, and American eel. During the interim period between license issuance and the installation of the new fish guidance boom and turbine screening, the

Licensee shall lower four sections of hinged flashboards to pass 560 cfs via spill from April 1 to June 15 to provide a safe passage route for Atlantic salmon smolts.

The Licensee shall initiate three consecutive years of downstream passage effectiveness testing using radio telemetry or an equivalent technique for adult and juvenile Atlantic Salmon, adult and juvenile American Shad, adult and juvenile Blueback Herring, adult and juvenile Alewife, adult American Eel, and microphthalmia Sea Lamprey. The study plans shall be developed in consultation with, and require approval by, the MDMR and other regulators and resource agencies. Based on the results of the annual reports, the regulators may require adjustments to the study methodology for the next year's evaluation.

Failure to meet effectiveness goals should result in significant modification of the project.

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Table 1. Major events in diadromous fish restoration in the Kennebec River.

Year(s)	Major events
1987	First Kennebec Hydro Developers Group (KHDG) Settlement Agreement
1987-2006	MDMR stocks 1.3 million river herring into historic habitat above Edwards Dam
1987-1997	MDMR stocks American Shad adults (1,849), fry (44.6 million) and fingerlings (197,176) into historic spawning habitat above Edwards Dam
1988-2006	Interim, downstream passage operational at Benton Falls, Fort Halifax, Burnham, Lockwood, Shawmut, and Hydro Kennebec projects
1992	Interim upstream passage (fish pump) installed at Edward Dam
1993	Kennebec River Resource Management Plan
1998	Lower Kennebec River Comprehensive Hydropower Settlement (1998 Settlement)
1999	Removal of Edwards Dam
1999	MDMR completes upstream fish passage at Stetson Pond (Sebasticook River)
1999-2011	Installation of upstream eel passage at seven KHDH Dams
2002	MDMR removes Guilford Dam and completes upstream passage at Plymouth Pond (Sebasticook River)
2003	MDMR completes upstream passage at Sebasticook Lake (Sebasticook River)
2003	MDMR initiates salmon stocking (eggs, fry, returning adults) in Sandy River
2003	Relicensing of Abenaki and Anson project
2006	Fish lifts operational at Benton Falls and Burnham projects (Sebasticook River) and Lockwood Project (Kennebec River)
2006	Fish lift operational at Lockwood Project (Kennebec River)
2006	MDMR ceases stocking Alewife into 6 accessible lakes and ponds
2006	Removal of Madison Electric Works Dam (Sandy River)
2008	Removal of Fort Halifax Dam (Sebasticook River)
2009	MDMR completes upstream passage at Webber Pond Dam (Seven Mile Stream)
2009	Expanded listing of the GOM DPS of Atlantic Salmon including Kennebec River
2012-2013	Interim Species Protection Plans (ISPP) for Atlantic Salmon for Kennebec River and Androscoggin River
2012-2014	Downstream passage effectiveness studies for Atlantic Salmon smolts at Lockwood, Hydro Kennebec, Shaw, and Weston
2016	Fish lift operational at Hydro Kennebec Project
2016-2017	Upstream passage studies of adult Atlantic Salmon at the Lockwood Project
2017	Relicensing of the Williams Project
2017-2020	MDMR and partners remove Masse Dam (2017) and Lombard Dam (2018) and install fish passage at Ladd Dam (2019) and Box Mills Dam (2020) in Outlet Stream (Sebasticook River)
2018	A total of 5,580,111 river herring return to the Sebasticook River, the largest self-sustaining run on the east coast
2019	MDMR and partners complete upstream fish passage at Togus Pond
2020	MDMR develops the Kennebec River Diadromous Fisheries Management Plan

Table 2. Hydropower Projects in the Kennebec River drainage.

FERC Status	FERC number	Project name and development	Total capacity (KW)	Mean GW-hrs (2012-2017)	Expiration date
Licensed	2574	Lockwood	6,550	30.73	10/31/2036
Licensed	2611	Hydro-Kennebec	15,433	73.21	9/30/2036
Licensed	2322	Shawmut	8,650	53.18	1/31/2021
Licensed	2325	Weston	14,750	83.97	10/31/2036
Licensed	2364	Abenaki	19,917		4/30/2054
Licensed	2365	Anson	9,000		4/30/2054
Licensed	2335	Williams	14,500	92.38	12/31/2017
Licensed	5073	Benton Falls	4,468		2/28/2034
Licensed	11472	Burnham	1,000		10/31/2036
Exempt	8736	Pioneer	300		
Exempt	4293	Waverly Avenue	700		
Licensed	2556	Messalonskee	6,200		6/30/2036
Licensed		Union Gas (M5)	1,800		
Licensed		Rice Rips (M3)	1,600		
Licensed		Oakland (M2)	2,800		
Licensed	2555	Automatic (M4)	800		6/30/2036
Licensed	2809	American Tissue	1,000		4/30/2019
Exempt	7473	Gilman Stream	120		
Exempt	8791	Starks	35		
FERC approved	2329	Wyman	78,000	377.9	10/31/2036
FERC approved	2612	Flagstaff	Storage		2/28/2036
FERC approved	2142	Harris	76,600	216.19	10/31/2036
FERC approved	2671	Moosehead Lake	Storage		10/31/2036
FERC approved	2615	Brassua	4,180	30.73	3/31/2012
FERC approved	11132	Eustis	250		11/31/2026
Nonjurisdictional	UL 97-16	Moxie			

Table 3. Historic and current diadromous fish range in the focus area.

Species	Historic range	Current accessible range
Atlantic tomcod	Mainstem to head-of tide	Mainstem to head-of tide
Rainbow Smelt	Mainstem to Lockwood Dam	Mainstem to Lockwood Dam
Shortnose Sturgeon	Mainstem to Lockwood Dam	Mainstem to Lockwood Dam
Atlantic Sturgeon	Mainstem to Lockwood Dam	Mainstem to Lockwood Dam
Striped Bass	Mainstem to Lockwood Dam; Sebasticook to Benton Falls Dam	Mainstem to Lockwood Dam; Sebasticook to Benton Falls Dam
American Shad	Mainstem to Abenaki Dams; Sandy River to Rt 4	Mainstem to Lockwood Dam (truck stocking upstream)
Blueback herring	Mainstem to Lockwood Dam; Sandy River to Rt 4	Mainstem to Lockwood Dam (truck stocking upstream)
Alewife	Mainstem to Abenaki Dam; Sandy River to Rt 4	Mainstem to Lockwood Dam (truck stocking upstream)
Atlantic Salmon	Mainstem to confluence of Kennebec and Dead River; Carrabassett River; Sandy River	Mainstem to Lockwood Dam (truck stocking upstream)
Sea Lamprey	Unknown- similar to salmon	Mainstem to Lockwood Dam
American Eel	Unknown-above Williams Dam	Above Williams Dam

Table 4. Atlantic Salmon stocking and adult returns to the Kennebec River.

Year	Number of fry stocked	Number of eggs stocked	Total number of adult returns	Total naturally reared returns	Proportion naturally reared
2003	39,000				
2004	55,000	12,000			
2005	30,000	18,000			
2006	6,500	41,800	15	5	
2007	15,400	18,000	16	8	0.50
2008		245,500	21	8	0.38
2009		166,494	33	11	0.33
2010		567,920	5	3	0.60
2011		859,893	64	43	0.67
2012		920,888	5	4	0.80
2013		691,857	8	7	0.88
2014		1,159,330	18	16	0.89
2015		274,383	31	29	0.94
2016		619,364	39	39	1.00
2017		447,106	40	40	1.00
2018		1,227,353	11	10	0.91
2019		917,613	60	58	0.97
Total	145,900	8,187,501	306	223	

Table 5. Results of effectiveness testing for Atlantic Salmon smolts in the Kennebec (K) and Penobscot (P) rivers. Baseline survival is estimated from all fish. Adjusted survival (with lower and upper confidence intervals, LCI and UCI) is estimated from fish that successfully passed downstream within 24 hours. To achieve passage standards in the Penobscot, 25-50% of river flow has been spilled for the 2-week peak migration period since 2016.

			Baseline	Adjusted		
River	Project	Year	Survival	Survival	75% LCI	75% UCI
K	Weston	2013	95.70%			
K	Weston	2014	89.50%	87.50%		
K	Weston	2014	99.70%	66.00%		
K	Shawmut	2013	96.30%			
K	Shawmut	2014	93.60%	89.50%		
K	Shawmut	2014	90.60%	83.80%		
K	Hydro Kennebec	2012				
K	Hydro Kennebec	2013	94.10%			
K	Hydro Kennebec	2014	98.00%	90.00%		
K	Lockwood	2013	100.00%			
K	Lockwood	2014	97.70%	94.70%		
K	Lockwood	2014	98.00%	88.80%		
P	West Enfield	2014	95.70%			
P	West Enfield	2015	81.80%	76.70%	66.30%	83.00%
P	West Enfield	2015	82.00%	75.10%	67.20%	78.40%
P	West Enfield	2016	97.00%	96.80%	95.40%	**97.90%**
P	West Enfield	2017	99.70%	94.80%	92.70%	**96.80%**
P	West Enfield	2018	92.30%	91.80%	89.20%	94.70%
P	Milford	2014	92.70%			0.00%
P	Milford	2015	90.40%	84.80%	72.70%	92.40%
P	Milford	2015	84.90%	80.90%	73.20%	84.30%
P	Milford	2016	92.50%	92.80%	87.70%	**97.70%**
P	Milford	2016	93.40%	91.60%	88.20%	**94.70%**
P	Milford	2017	100.00%	98.10%	95.70%	**100.00%**
P	Milford	2017	99.30%	97.60%	**96.00%**	**99.10%**
P	Milford	2018	98.90%	98.80%	95.30%	**100.00%**
P	Milford	2018	98.60%	98.60%	94.70%	**100.00%**
P	Stillwater	2014	98.20%			0.00%
P	Stillwater	2015	75.20%	69.00%	52.90%	82.90%
P	Stillwater	2015	75.50%	69.20%	62.30%	76.20%
P	Stillwater	2016	95.40%	93.30%	90.50%	**96.10%**
P	Stillwater	2016	96.10%	94.30%	91.90%	**96.50%**
P	Stillwater	2017	97.80%	95.20%	93.00%	**97.40%**
P	Stillwater	2017	98.30%	95.30%	93.20%	**97.50%**
P	Stillwater	2018	98.90%	90.30%	87.00%	93.80%
P	Stillwater	2018	98.50%	91.70%	88.70%	94.50%
P	Orono	2014	92.30%			0.00%
P	Orono	2015	87.60%	82.00%	71.00%	90.30%
P	Orono	2015	86.90%	82.80%	79.30%	86.20%
P	Orono	2016	90.80%	89.70%	86.10%	92.90%
P	Orono	2016	87.00%	85.80%	81.90%	89.40%
P	Orono	2017	100.00%	98.60%	**96.80%**	**100.00%**
P	Orono	2017	100.00%	99.70%	**98.30%**	**100.00%**
P	Orono	2018	100.00%	97.80%	95.10%	**100.00%**
P	Orono	2018	100.00%	99.20%	95.80%	**100.00%**

Table 6. American Shad, Blueback Herring, and Alewife habitat and estimated production in the Kennebec River above the head-of-tide.

Habitat description	Surface area (ha)	% of total area	American Shad production	Blueback herring production	Alewife production
Kennebec-ED to LO	524	20.9	106,332	626,461	
Kennebec-LO/HK to SH	212	8.4	42,966	253,135	
Kennebec SH to WE	512	20.4	103,965	612,514	
Kennebec WE to AB	415	16.5	84,215	496,156	
Sandy to Rt 4 bridge	356	14.2	72,345	426,223	
Sebasticook to EB-WB	489	19.5	99,212	584,515	
Sebasticook lakes/ponds	9,946	78.6			7,730,400
Seven Mile lakes/ponds					
Webber Pond					1,065,200
Wesserunsett Lake	568				561,700
Sandy (4 lakes)	479				473,500
Totals			509,035	2,999,004	1,034,819

Table 7. American Shad stocked in the Kennebec River (KE) or the Sebasticook River (SE).

Adults were obtained from the Kennebec River, Narraguagus River (NA), Connecticut River (CO), Saco River, (SA), and Merrimack River (ME).

Year	Source	Adults released	Fry released (KE)	Fry released (SE)	Fingerlings released
1987	KE	16			
1987	NA	183			
1988	CO	616			
1989	NA	174			
1989	CO	444			
1989	KE	1			
1990	NA	36			
1990	CO	568			
1991	CO	639			
1992	CO	994			
1993	CO	880	186,000		16,000
1994	CO	898	51,000		15,600
1995	CO	1,518	388,000		27,841
1996	CO	462	599,990	320,000	3,070
1997	CO	420	1,484,908	474,313	60,261
1997	SA		459,241		
1998	CO		1,348,937	725,420	27,907
1999	CO		2,020,838	839,068	13,141
2000	CO		3,346,727	500,004	27,685
2001	ME		1,489,913	618,879	6,671
2002	ME		5,671,856	1,034,207	
2003	ME		5,989,358	1,857,184	
2004	ME		4,931,174	510,962	
2005	ME		1,105,343		
2006	CO		262,131		
2007	ME		7,937,841	422,518	
	Total	7,849	37,273,257	7,302,555	198,176

Table 8. River herring, American Shad, and Striped Bass at fish passage facilities. Adults returned to the Fort Halifax Project (FH), Benton Falls Project (BF) and Lockwood Project (LO); Alewife and Blueback Herring were estimated from biological sampling.

Site	Year	Total river herring	Alewife	Blueback Herring	American Shad	Striped Bass
FH	2000	137,658	137,658			
FH	2001	142,845	142,155	690		
FH	2002	151,574	150,743	831		
FH	2003	131,633	131,616	17		
FH	2004	143,697	143,663	34		
FH	2005	81,576	81,265	311		
FH	2006	46,960	43,865	3,095		
FH	2007	458,491	457,464	1,027		
FH	2008	401,059	388,692	12,367		
BF	2009	1,327,861	1,263,015	64,846	9	
BF	2010	1,628,187	1,201,559	426,628	3	4
BF	2011	2,751,473	2,537,226	214,247	54	
BF	2012	1,703,520	1,499,216	204,304	163	1
BF	2013	2,272,027	1,964,613	307,414	113	14
BF	2014	2,379,428	1,784,425	595,003	26	22
BF	2015	2,158,419	1,725,165	433,254	48	3
BF	2016	3,128,753	2,131,789	996,964	18	3
BF	2017	3,547,698	2,339,419	1,208,279	65	314
BF	2018	5,579,901	4,201,838	1,378,063	26	3
BF	2019	3,287,701	2,086,545	1,201,156	114	169
LO	2006	3,152				83
LO	2007	4,534			30	
LO	2008	90,940	89,121	1,819		
LO	2009	45,428				10
LO	2010	75,072	59,363	15,709	28	4
LO	2011	31,066				8
LO	2012	156,428				11
LO	2013	95,314				31
LO	2014	108,256	73,883	34,373	1	22
LO	2015	89,496	55,433	34,063	26	33
LO	2016	206,941	88,463	118,478	830	214
LO	2017	238,481	73,595	164,886	201	137
LO	2018	238,953	145,267	93,686	275	109
LO	2019	182,987	118,921	64,066	22	

Table 9. Results of fish passage effectiveness testing at multiple sites.
Studies to determine the effectiveness (survival) of downstream (DS) and upstream (US) passage facilites were conducted on adult fish. The time for 50% of the fish to successfully pass also is provided.

Species	Year	Type	Project	River	Survival estimate	Confidence Interval	Median time
Alewife	2019	DS	Pejepscot	Androscoggin	80.9%	75% CI = 76.3-85.7%	0.9 hr
Alewife	2015	DS	Lockwood	Kennebec	85.0%	75% CI = 69.0-100.0%	10.7 hr
Alewife	2018	DS	Milford	Penobscot	86.1%	75% CI = 82.1-89.7%	0.6 d
Alewife	2018	DS	West Enfield	Penobscot	93.7%	75% CI = 90.9-96.7%	0.7 d
Alewife	2018	DS	Stillwater	Penobscot	94.6%	75% CI = 92.4-97.8%	0.4 d
Alewife	2018	DS	Orono	Penobscot	97.8%	75% CI = 96.0-98.8%	2.1 hr
Alewife	2016	DS	Hydro Kennebec	Kennebec	100.0%	75% CI = 98.4-100.0%	3.3 d
American Shad	2019	DS	Pejepscot	Androscoggin	51.4%	75% CI = 41.6-61.1%	5.3 d
American Shad	2017	DS	Milford	Penobscot	76.6%	75% CI = 71.1-82.2%	1.6 d
American Shad	2018	DS	Milford	Penobscot	86.2%	75% CI = 82.4-89.9%	1.1 d
American Shad	2017	DS	Orono	Penobscot	87.0%	75% CI = 82.4-91.2%	1.6 d
American Shad	2018	DS	West Enfield	Penobscot	88.0%	75% CI = 84.4-91.9%	3.9 d
American Shad	2018	DS	Orono	Penobscot	94.4%		8.1 hr
American Shad	2018	DS	Stillwater	Penobscot	94.7%		0.3 d
American Shad	2017	DS	Stillwater	Penobscot	95.8%	75% CI = 91.7-97.9%	4.7 d
American Shad	2015	DS	Vernon	Connecticut			11.9 hr
American Shad	2016	DS	Vernon	Connecticut			11.6 hr
American Eel	2018	DS	Garvins Falls	Merrimack	70.1%	75% CI = 62.9-76.4%	0.2 hr
American Eel	2017	DS	West Enfield	Penobscot	84.0%		2.0 hr
American Eel	2018	DS	Amoskeag	Merrimack	84.1%	75% CI = 76.0-89.9%	0.6 hr
American Eel	2018	DS	Lowell	Merrimack	84.2%	75% CI = 74.1-90.3%	0.3 hr
American Eel	2019	DS	Garvins Falls	Merrimack	88.3%	75% CI = 82.7-92.3%	1.6 hr
American Eel	2018	DS	Lawrence	Merrimack	88.9%	75% CI = 79.8-94.2%	-
American Eel	2019	DS	Pejepscot	Androscoggin	90.0%	75% CI = 86.0-94.0%	2.1 hr
American Eel	2016	DS	Milford	Penobscot	90.0%		1.2 d
American Eel	2018	DS	Hooksett	Merrimack	90.5%	75% CI = 83.8-94.6%	0.1 hr
American Eel	2019	DS	Hooksett	Merrimack	90.6%	75% CI = 84.8-94.3%	0.2 hr
American Eel	2019	DS	Amoskeag	Merrimack	91.7%	75% CI = 85.8-95.3%	1.5 hr
American Eel	2016	DS	Stillwater	Penobscot	92.0%		1.8 hr
American Eel	2016	DS	Orono	Penobscot	98.0%		1.6 hr
American Eel	2015	DS	Wilder	Connecticut			0.2 hr
American Eel	2015	DS	Bellows Falls	Connecticut			0.2 hr
American Eel	2015	DS	Vernon	Connecticut			0.2 hr
American Shad	2010	US	Conowingo lift	Susquehanna	44.9%	±10.4%	
American Shad	2012	US	Conowingo lift	Susquehanna	25.8%	±10.6%	
American Shad	2015	US	Conowingo lift	Susquehanna	21.6%	±9.5%	
American Shad	2015	US	Lockwood	Kennebec	0.0%		
American Shad	2019	US	Pejepscot	Androscoggin	0.0%		
American Shad	2018	US	Holtwood	Susquehanna	4.2%		
American Shad	2019	US	Holtwood	Susquehanna	6.5%		
Alewife	2019	US	Pejepscot	Androscoggin	19.8%	75% CI = 14.8-24.9%	
Alewife	2019	US	Milford	Penobscot	65.1%	95% CI = 56.9-73.8%	

Table 10 Alewife habitat in the focus area and number of downstream barriers
Accessible lakes and ponds are shown in bold. The number of hydropower dams are shown first, followed by the number of non-hydropower dams in parentheses.

Subwatershed	Water body	Surface hectares	Number of dams
Sandy River	Clearwater Pond	322.0	4 (1)
Sandy River	Norcross Pond	45.6	4 (1)
Sandy River	Parker Pond	41.5	4 (1)
Sandy River	North Pond	70.0	4 (1)
Wesserunsett Stream	Wesserunsett Lake	568.3	3 (2)
Sebasticook River	**Pattee Pond**	288.1	0 (0)
Sebasticook River	China Lake	1,587.2	0 (4)
Sebasticook River	Lovejoy Pond	131.1	1 (1)
Sebasticook River	**Unity Pond**	1,023.0	1 (0)
Sebasticook River	**Pleasant Pond**	310.8	2 (2)
Sebasticook River	**Plymouth Pond**	194.2	2 (1)
Sebasticook River	**Sebasticook Lake**	1,735.3	2 (1)
Sebasticook River	Wassokeag Lake	429.8	4 (4)
Sebasticook River	Big Indian Pond	400.6	4 (3)
Sebasticook River	Douglas Pond	212.5	4 (0)
Sebasticook River	Great Moose Lake	1,450.4	4 (2)
Sebasticook River	Little Indian Pond	57.9	4 (3)
Seven-Mile Stream	**Webber Pond**	506.7	0 (1)
Seven-Mile Stream	**Three-Mile Pond**	435.8	0 (1)
Seven-Mile Stream	**Spectacle Pond**	56.3	0 (1)
Seven-Mile Stream	Three Cornered Pond	78.9	0 (1)
Total		9,946.0	

Table 11. Estimated value of Atlantic Salmon spawning/rearing habitat. Estimates of cost to mitigate for lost value of Atlantic Salmon habitat blocked by dams in the Kennebec River. For more information see Section 5.1. *Spawning habitat has been identified by habitat surveys, but the majority of habitat in the watershed has not been surveyed and thus the quantity of spawning habitat in this table represents only a portion of actual spawning habitat in the Kennebec watershed.

	Y (Occupied) N (Unoccupied) I (Inaccessible)*	Critical Habitat	Blocked Rearing Habitat Units	Blocked Spawning Habitat Units*
Lockwood	Y	Y	93,369	Not surveyed
Hydro-Kennebec	Y	Y	91,284	Not surveyed
Shawmut	Y	Y	87,800	Not surveyed
Weston	Y	Y	74,617	2,145
Anson	N	N	38,954	Not surveyed
Abenaki	N	N	38,954	Not surveyed
Cost to Mitigate Lost Habitat				$ 463,816,081

Figure 1a. Map of the Kennebec River watershed showing location of hydropower dams.

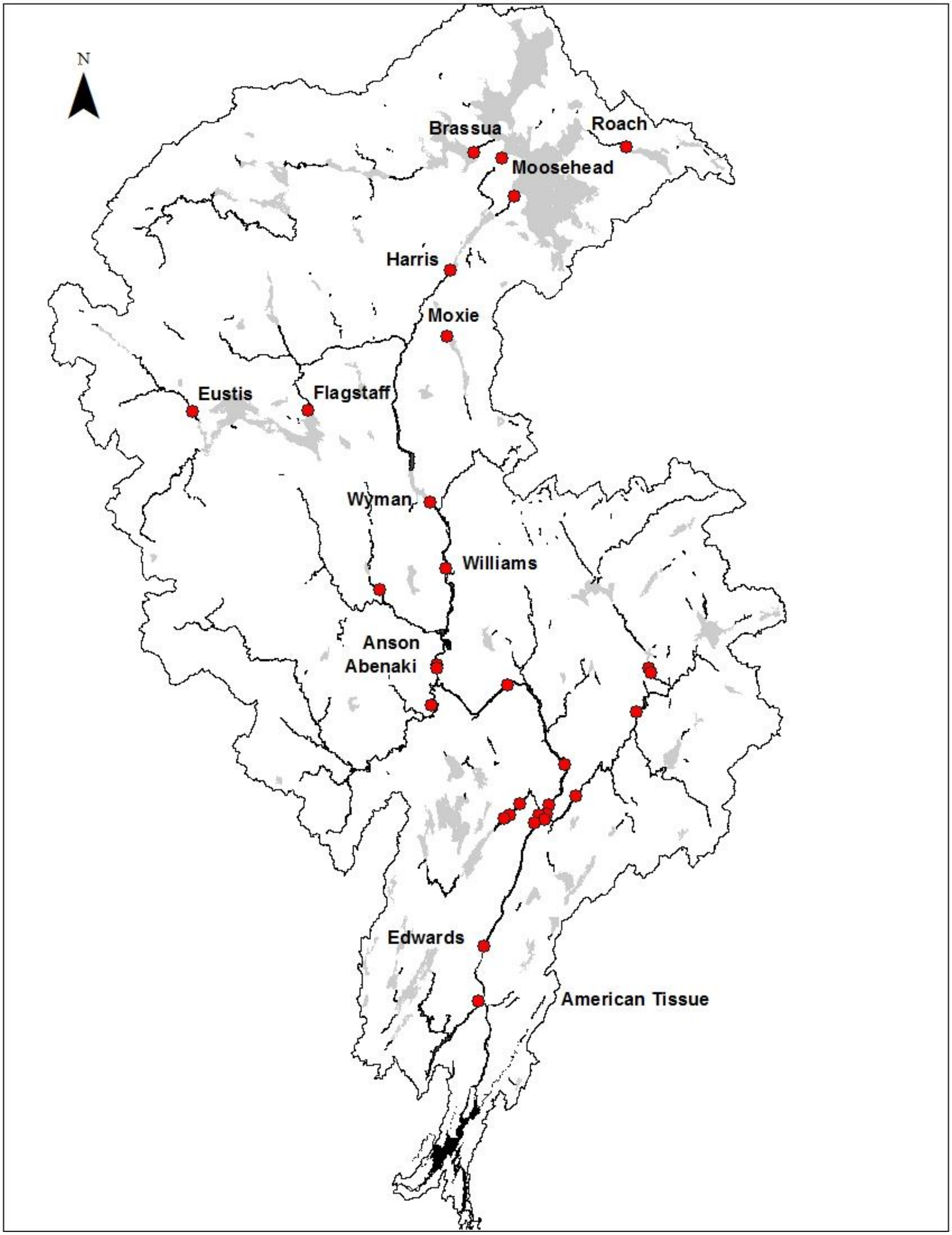


Figure 1b. Map of the upper Kennebec River showing location of hydropower dams.

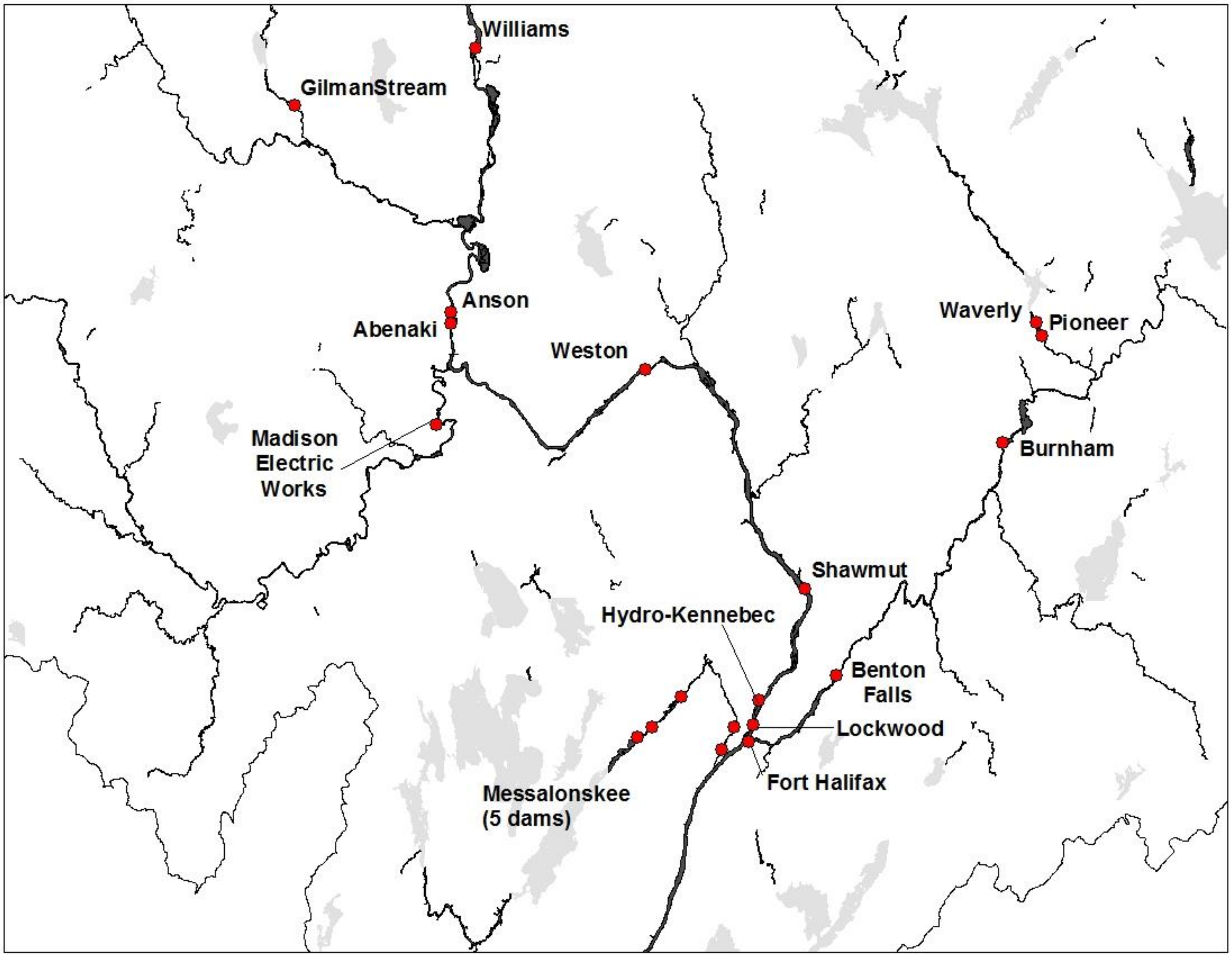


Figure 2. Estimated returns of adult Atlantic Salmon to the Kennebec River with six mainstem dams operating (Lockwood, Hydro-Kennebec, Shawmut, Weston, Abenaki, and Anson). The model was run with low marine (LM=0.00321), medium marine (MM=0.01080), and high marine (HM=0.02720) survival and low freshwater (LF=1 smolt/100m^2) and high freshwater (HF=3 smolts/100m^2) smolt production at downstream/upstream passage efficiencies of 97%/96% or 99%/99% at each dam. The former has been proposed by the Licensee, the latter is proposed by MDMR.

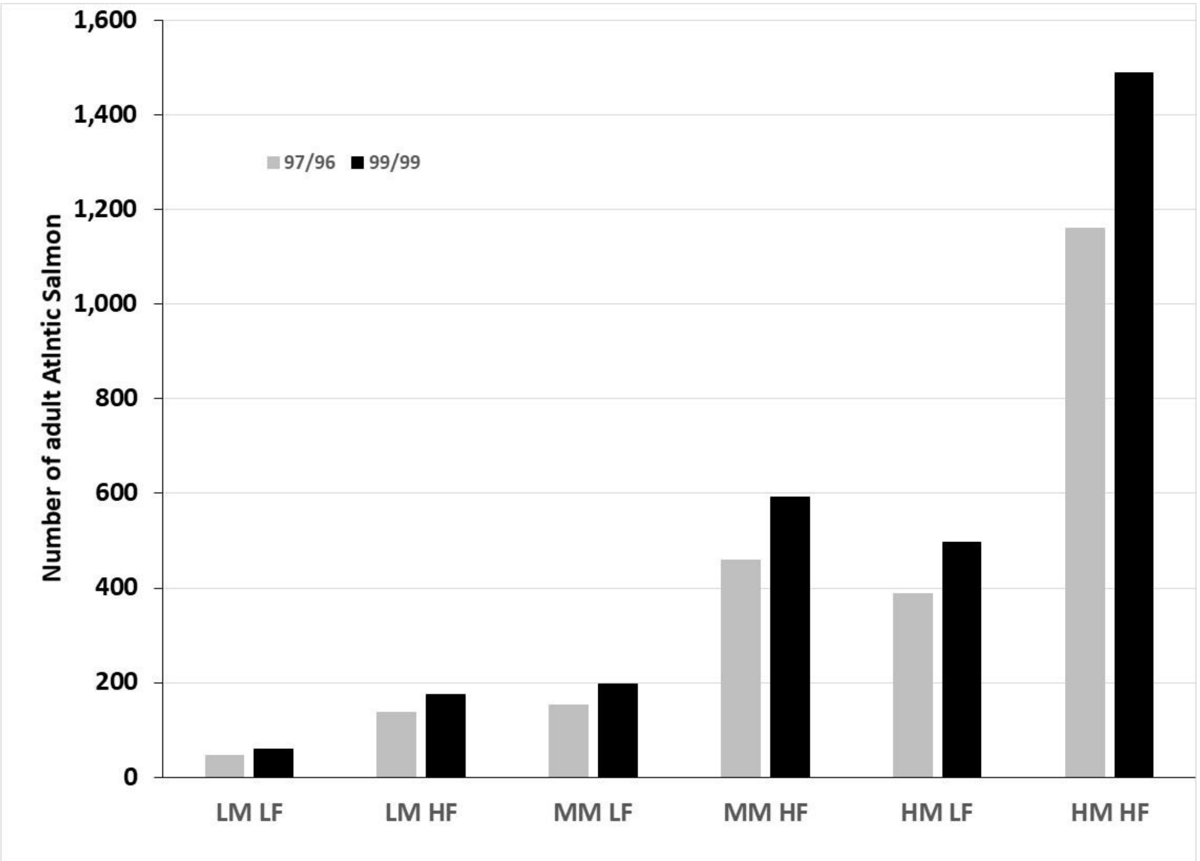
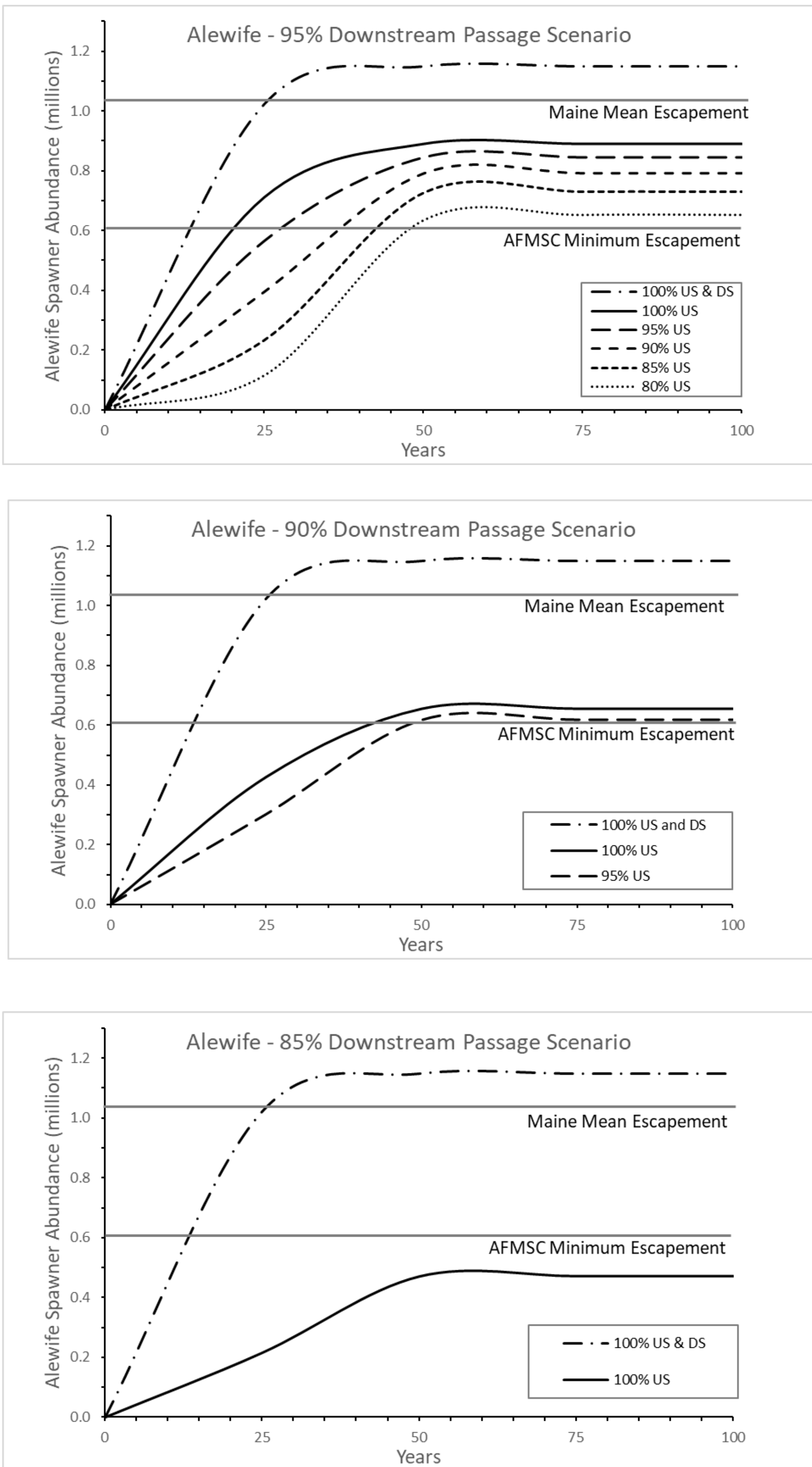


Figure 3. Modeled downstream (DS) passage efficiency (Panel A 95%; B 90%; and C 95%) and upstream passage efficiency needed to produce the minimum number of adult Alewife returns meet Atlantic States Marine Fisheries Commission's threshold (235/acre) and to be consistent with the Maine mean escapement (400/acre).



Appendix A. Recovery goals, objectives and criteria for the GOM DPS of Atlantic Salmon.