Summary of Passage Delays at State of the Art Fishway at Milford

Studies conducted in the Penobscot River at the Milford Project show significant upstream passage delay of Atlantic Salmon similar to those that would likely occur at Shawmut. Upstream adult Atlantic Salmon studies were conducted by Black Bear Hydro Partners (BBHP; a subsidiary of Brookfield Renewable Energy Group) in 2014 and 2015 and concurrent studies were conducted by University of Maine (UM) in the same years at the Milford Project. In the 2014 BBHP study, delay times at Milford ranged from 1.9 hours to 36.9 days, but results were confounded by the fish lift being shut down for multiple periods during the study (ATS Species Protection Plan 2014 annual report filed with FERC March 24, 2015). In the 2015 BBHP study, 49 fish were tagged and 47 were included in the delay estimate. In 2015, delay times ranged from 2.5 hours to 35 days, with 17% of tagged fish passing within 48 hours and 46% within 1 week (ATS Species Protection Plan 2015 annual report filed with FERC May 31, 2016). In the 2014 UM study, 22 fish were tagged but only 10 were included in the delay estimate. In 2014, delay times at Milford ranged from 1.2 hours to 76 days, with 50% of tagged fish (n=10) passing within 48 hours and 70% of tagged fish passing within 1 week (Izzo 2016). In 2015, the UM study tagged 49 fish and found delay times ranged from 7.4 hours to 26 days, with 34.7% of tagged fish passing within 48 hours and 63.2% passing within 1 week (Izzo 2016). In 2018, Rubenstein (2021 Thesis Defense) found that the average approach time to Milford Dam was 4.0 days and 23 days spent below the dam before passing. In 2019, the approach time to Milford Dam was 4.0 days while delay time was 11 days. This fish lift is considered "state of the art" yet the false attraction and small entrance areas inherent at these large, complex sites, similar to Shawmut, will result in significant delays.

Pre-Spawner Mortality and Loss of Iteroparity from Fish Passage Delays for ESA Listed Salmon

Recent research by the University of Maine at Orono, in collaboration with MDMR, indicates that Atlantic Salmon delayed below both Lockwood Dam and Milford Dam experience substantially greater temperatures than they would if their migration to cold-water holding areas in the vicinity of spawning habitat was unimpeded. Exposure to these high temperatures, which often exceeded thermal stress levels for the species, is associated with increased metabolic costs, depletion of energy stores, and reductions in spawning success, survival, and rates of repeat spawning (Rubenstein 2021 Thesis Defense). The bioenergetic model developed for this project based on Lennox et al. (2018), field validation of the model, and actual Kennebec and Penobscot Atlantic Salmon lipid readings, temperature, run timing, and passage efficiency data suggests that the expected delays at these fishways are significantly reducing the probability of spawning success and iteroparity. This impact of delay is well established for sea-run species in the literature (Glebe and Leggett 1981; Jonsson et. al. 1997; Bowerman et. al. 2007; Martin et al. 2015; Fenkes et al. 2016).

This new information shows that reasonable estimates of delay at four dams based on similar fish lifts at Lockwood and Milford, which MDMR would expect would be similar to the Shawmut project, results in an increase in the number of fish that would run out of energy before spawning, presumably to die unless they abandoned their migration (Rubenstein 2021 Thesis Defense). The model estimated the resulting pre-spawn mortality based on Kennebec specific temperatures was 6.8% for zero dams, 10.7% for one dam, 18.1% for two dams, 26.9% for three dams, and 45.5% for four dams. That translates to a 38.7% increase in pre-spawn mortality for fish traveling up to the Sandy River compared to a no dam scenario, a previously unquantified estimate. This effectively means more than one out of three returning adults would die prior to spawning because of delays caused by the dams. In addition, this research shows that reasonable estimates of delay at four dams result in a 65% decrease in the number of fish that would have the energy to recondition after spawning, which allows fish to return to spawn again in subsequent years, between the zero dam scenario and the four dam scenario. The ability to spawn multiple times is foundational to Atlantic Salmon populations across their range (Fleming 1996; Lawrence et al. 2016; Bordeleau et al. 2020). This estimate does not take into account downstream passage efficiency at hydro projects, which is an additive source of mortality. That added mortality of downstream passage was predicted by NOAA to be 49%-58% in their August 28, 2020 preliminary prescription for the Shawmut project. Combined impacts of upstream delays and poor downstream survival essential eliminate this important life history characteristic, further diminishing the chances of attaining self sustaining populations with four dams between spawning grounds in the Sandy River (Lawrence et al. 2016).

MDMR reran its Atlantic Salmon model using only smolt production in the Sandy River (0-4 dams; 97% downstream passage efficiency; marine survival of 0.0108; and either 96% upstream passage efficiency survival) at each dam or the estimated pre-spawn survivals resulting from passage delays (Rubenstein 2021 Thesis Defense). With all dams in place, the estimated mortality due to delays reduces the number of adult returns by 36% compared to Brookfield’s proposal of 96% at each dam (Table 1). This is a significant loss that would likely preclude recovery prospects for Atlantic salmon just through this mechanism.

Table 1. Comparison of modeled adult Atlantic Salmon returns under Brookfield proposed passage efficiencies (i.e. survival) and with the pre-spawn survival as estimated by Rubenstein (2021). Smolt production is either: Low (1 smolt/100m2) or High (3/100m2).

Scenario	4 dams Low	4 dams High	3 dam Low	3 dam High	2 dams Low	2 dams High	0 dams Low	0 dams High
BREG 96/97 passage	87	262	105	316	125	376	189	918
Pre-Spawn Survival & 96/97	56	168	87	261	11	334	183	891
Decrease (%)	36	36	17	17	11	11	3	3

Dams are thus associated with and causal to increased mortality of post-spawn Atlantic Salmon, as reflected in the rates of repeat spawning in dammed rivers: repeat spawning rates in the Penobscot River (Maine, c.1%) and the St. Johns River (New Brunswick, 1.2%) are much less than in undammed systems (Maynard et al. 2018, Bordeleau et al. 2020). Because most repeat spawning Atlantic Salmon are female (Fleming 1996, Bordeleau et al. 2020), the loss of repeat spawning related to impacts of delays at dams translates into a direct reduction of potential egg production for the river system. Repeat spawners are larger and produce more eggs than maiden spawners; for example, in the Trinité River (Quebec) and Mirimichi River (New Brunswick), repeat spawners were estimated to produce nearly 2000 more eggs then maiden two sea-winter females. Further, repeat spawners can buffer populations against years with high mortality of post-smolts at sea, as repeat spawners represented a greater proportion of the total Atlantic Salmon run in years when returns of maiden spawners were low (Bordeleau et al. 2020). Consequently, these older, larger, repeat spawning females are critical for population resilience (Hixon et al. 2014; Bordeleau et al. 2020) and reducing the persistent, fixed source of mortality for post-spawn Atlantic Salmon associated with delays at dams is imperative for population recovery. Given that delays at Milford and Lockwood dams both significantly exceed the proposed averaged 48-hour passage standard for upstream migrating adults, MDMR considers it highly likely that passage delays at Shawmut will also be long enough to produce biologically significant decreases in survival and the probability of repeat spawning. This new information demonstrates that the cumulative effects of these delays would certainly preclude the ability to recovery Atlantic Salmon in the United States. Lawrence et al (2016) found kelt survival is key to population persistence. Lawrence et al. (2016) found that *"As the number of dams increases from one to four, the probability of negative population growth increases four-fold. Kelt survival rate, number of dams, and smolt dam passage survival were all found to be significant factors in predicting population persistence. The present study suggests two primary conclusions: (i) dams are likely to have a negative influence on Atlantic salmon; and (ii) kelts have considerable and positive influence on population viability."* In addition, in their Augusta 28, 2020 preliminary prescription for the Shawmut project, NOAA predicted that the overall survival of kelts through the four projects cumulatively would be 42% to 51%, an incredibly low number of fish that would preclude the important life history trait of repeat spawning. The losses of smolts and kelts on the magnitude of what is expected, along with other impacts of these projects, make recovery of self-sustaining populations of salmon nearly impossible.

Summary of Existing Information on Sea-Lamprey Passage

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 and early morning hours at the Milford fish lift (31/45 fish or 68.8%), with many of those occurring in the early morning (e.g. 1am EST) (Figure 1; MDMR, unpublished data). In 2021, DMR, USGS, and University of Maine found a similar pattern when tracking movement of 100 tagged fish in the Penobscot River, with data currently going through QA/QC. Given the strong propensity for lamprey to exhibit nocturnal movement patterns and demonstrated motivation to utilize upstream habitat, fishways should be operated at night to allow for lamprey passage. Lampreys do not necessarily hone to their natal streams and therefore we would expect lamprey to behave in a similar way in the Kennebec as we would in the Penobscot or Connecticut where nocturnal fish passage information is documented.

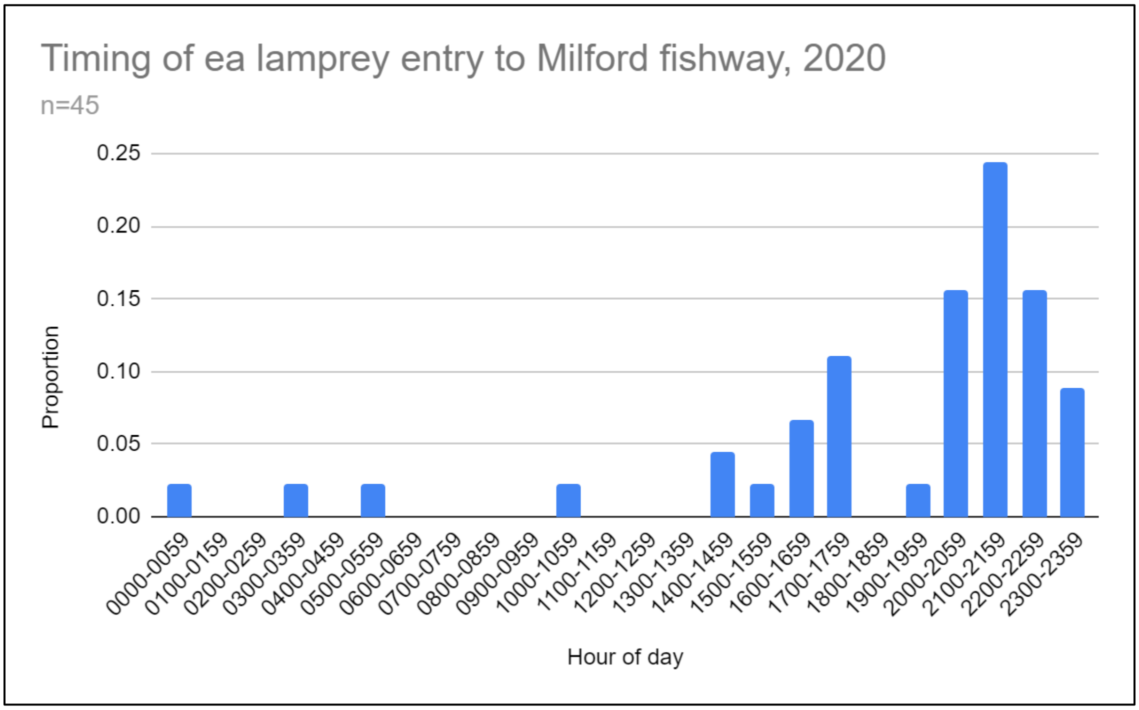

Figure 1. Sea Lamprey timing data from a 2020 Penobscot River tagging study, time of entry to the Milford fish lift.

Studies in the Penobscot demonstrate that lamprey are very well suited for upstream migration studies, where 100% of the tagged fish returned to the dam and 82% passed Milford. This year (2021) 100 lamprey were tagged with a preliminary estimate of 72% upstream efficiency and noted predominate nocturnal movement (QA/QC in progress). The 80% performance standard has been achieved at Milford so this request is reasonable. MDMR would anticipate a more than 80 times increase in lamprey reaching above the Weston project with nighttime operations (Table 10).

Table 10. Theoretical difference in Sea Lamprey returns using assumptions of 1) Milford returns with expansion for efficiency of 7,000 starting population, the 80% standard for upstream passage per project (Nighttime), and a 26.4% efficiency of passage (80% efficiency times 33% entry during daylight hours) with No Nighttime passage based on Penobscot and Connecticut entry timing. Results show a more than 80 times reduction in the number of lampreys above the Weston project using these assumptions.

	Motivated LP	Lockwood	Hydro-Kennebec	Shawmut	Weston
Nighttime	7000	5600	4480	3584	2867
No Nighttime	7000	1848	488	129	34

The Kennebec River below Lockwood has many thousands of Sea Lamprey, as MDMR crews and fishermen observe redd building annually just below Lockwood dam and thousands of redds at Six Mile Falls just upstream of the Sidney, Maine boat launch.

As previously reported, the efficiency of the Milford fishway was used as the benchmark for the performance standard and it is reasonable that fish passage efficiency would increase significantly if the fishways are operated at night, approximately 80 times using the example from Table 10. The obvious difference in counts of Sea Lamprey in the Kennebec (18 counted in 2021) vs Milford (5,776 in 2021) in recent years and predominance of nighttime movement in our 2020 and 2021 studies indicate that 24 hr operations are a major factor in providing for runs of Sea Lamprey into historic habitat. We also hypothesize that the lack of pheromones of lamprey ammocetes above the Lockwood Project reduces motivation (Bjerselius 2000) but that would immediately change if fish are passed upstream and can successfully spawn (e.g. a single spawning event can result in tens of thousands of juveniles).

MDMR's goal is to restore Sea Lamprey to historic spawning and nursery habitat in the Kennebec river drainage upstream of Lockwood Dam, particularly within the Sandy River. For the species to reach spawning habitat in the Sandy River, effective passage at all four dams is essential. Restoring Sea Lamprey to their historic range within the state is beneficial in and of itself and for the restoration and recovery of other sea run fish, particularly endangered salmon (Kircheis 2004). In watershed unrestricted by dams, Sea Lamprey are capable of reaching small, high-gradient, headwater streams (Nislow and Kynard 2009). 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). Sea 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).

Anadromous Sea Lamprey also serve as a conduit of nutrients between marine and freshwater systems. Semelparous adults contribute marine derived nutrients (MDN) to rivers and are important sources of phosphorus in phosphorus-limited systems of New England, like Maine's Sedgeunkedunk Stream (Weaver et al. 2018, Nislow and Kynard et al 2009). 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). Sea Lamprey spawning occurs in late spring and early summer, thus pulses of MDN from post-spawn 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 are otherwise being 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 American 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 Atlantic Salmon (Moore et al. 2011; Nislow and Kynard 2009).

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