Agenda Item 5.2
For Information

**Council**

**CNL(15)44**

***Measures to Improve Fish Passage in the North-Eastern United States Including Development of Performance (Survival) Standards for Fish Passage at Hydroelectric Dams***

***(Tabled by the US)***

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### Introduction

The iconic Atlantic salmon was once abundant in nearly every major river in New England. Today, the State of Maine supports the last remnant populations of anadromous Atlantic salmon (*Salmo salar*) in the United States. In 2000, a suite of populations of Atlantic salmon were recognized as endangered under the Federal Endangered Species Act (ESA); the initial ESA-listing was revised in 2009 to include a wider geographic area (over half the state of Maine) and a greater number of populations. These populations are referred to as the Gulf of Maine Distinct Population Segment (GOM DPS) of Atlantic salmon. The primary objective for the management of Atlantic salmon in the United States is to rebuild the GOM DPS of Atlantic salmon (and the ecosystems upon which they depend) to a point where the protections of the Endangered Species Act are no longer required. The primary threats to endangered Atlantic salmon are low marine survival and dams (NRC, 2004; USOFR, 2009). Given that dams represent a primary threat to the species in the United States, an enhanced strategy to restore connectivity within the freshwater range of the GOM DPS is now well under way.

While removing dams and other barriers results in the greatest restoration of access to habitat (Pess *et al*., 2014), there are situations in which dams cannot be removed. In these situations, two federal agencies, NOAA's National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service (USFWS) work with the dam owners to ensure that the fish passage devices are effective at passing fish. In the United States, several federal statutes relate to the governance of fish and wildlife resources and hydropower dams. Of particular note, Section 18 of the Federal Power Act provides NMFS and USFWS with the authority to require fishways at hydroelectric dams. Further, the ESA requires that any federal agency of the United States must ensure that any action it authorizes, funds, or undertakes does not prevent the survival and recovery of any endangered species.

The Federal Energy Regulatory Commission (FERC) is the lead federal agency that regulates energy generation from hydroelectric projects and would be obliged to comply with the terms of the ESA and the Federal Power Act. Before issuing or revising permits for hydropower dams and operations, FERC must consult with NMFS and USFWS to ensure that dam operations do not negatively impact the survival and recovery of ESA-listed species.

No new main-stem dams have been constructed in Maine since 1989. Since licenses of existing dams typically expire every 30 years, the dam owners must consult with FERC (and consequently NMFS and USFWS) to obtain a new license. These events are opportunities to improve fish passage in most instances. In the past, NMFS and USFWS provided dam owners with design criteria for the construction of fishways. If the fishways ultimately proved to be ineffective at passing fish, there was little recourse available to the agencies.

Recently, NMFS has moved away from designing fish passage devices and instead, has focused on performance criteria that must be achieved to ensure the survival and recovery of the species. This novel approach includes the development of performance (survival) standards at each hydroelectric dam within the freshwater range of the GOM DPS. NMFS also requires that the dam owners monitor whether they are attaining the necessary survival standards, and if the rates are not achieved, to take action to improve passage performance and to ensure that the standards are met. Further, the dam owners must demonstrate, through quantitative monitoring, that they are meeting or exceeding the performance standard for at least three consecutive years in order to continue to operate the dam.

In developing this strategy, we surveyed other examples where recovery programs for endangered or threatened fish were successful in areas where hydroelectric dams were present. After a comprehensive review, we identified a system in use in the Columbia River basin on the Pacific coast of the United States, in which survival performance standards at dams are in use. The approach has been applied there with great effect for a variety of Pacific salmon species (http://www.salmonrecovery.gov/Hydro.aspx) including the critically endangered Snake River Sockeye salmon, which must pass four dams in the Snake River and four dams in the Columbia River. Naturally, the models developed on the west coast were specific to Pacific salmon, and we needed a model that incorporates population dynamics, habitat production, and recovery goals specific to Atlantic salmon. Our model would provide the information that we needed to identify a target survival passage standard for each hydroelectric project that is sufficient to ensure the survival and recovery of Atlantic salmon.

**Dam Impact Analysis Model for Atlantic salmon**

In 2013, NMFS' Northeast Fisheries Science Center published the Dam Impact Analysis (DIA) Model (Nieland *et al.*, 2013) and a recent publication in the ICES Journal of Marine Science details an early application in the Penobscot River (Nieland *et al.*, 2015). The DIA Model is a population viability analysis that uses life-history characteristics and estimated passage and survival rates at dams to better understand the impacts of dams on the production potential of Atlantic salmon. In particular, we developed the DIA Model to evaluate upstream and downstream survival standards at hydroelectric dams and ensure that recovery of Atlantic salmon can be achieved. The DIA Model is also flexible enough to conduct several 'optimization' schemes. To date, the optimization analyses have not been used in a management context, but we expect to do so in the very near future. In its simplest application, it can be used to assess the demographic effects of various survival rates and determine the relative effects on recovery prospects over time.

The first application of the DIA model was in the Penobscot River (Figure 1). In 2011, we received a Species Protection Plan from the owners of the four dams (Milford, Stillwater, Orono, and West Enfield) on the lower Penobscot River. The Species Protection Plan proposed to continue to operate the dams with several stringent conservation measures that should result in high levels of downstream smolt survival (96% within 24 hours) and high levels of upstream passage for adults (95% within 48 hours). Given the various conservation measures outlined in the Species Protection Plan, we determined that the continued operations of these four dams would not preclude recovery of Atlantic salmon as long as certain mitigating activities were undertaken. These activities included:

- the removal of Veazie and Great Works Dams (the two lowermost main-stem dams on the river);
- immediate decommissioning of Howland Dam and the installation of a bypass structure around the dam;
- immediate attainment of downstream survival levels of 96% at the remaining four main-stem dams and immediate attainment of upstream passage rates of 95% at Milford and West Enfield dams;

- sustained improvements in freshwater and marine survival; and
- continued supplementation by Green Lake National Fish Hatchery (NMFS, 2012; Figure 2).

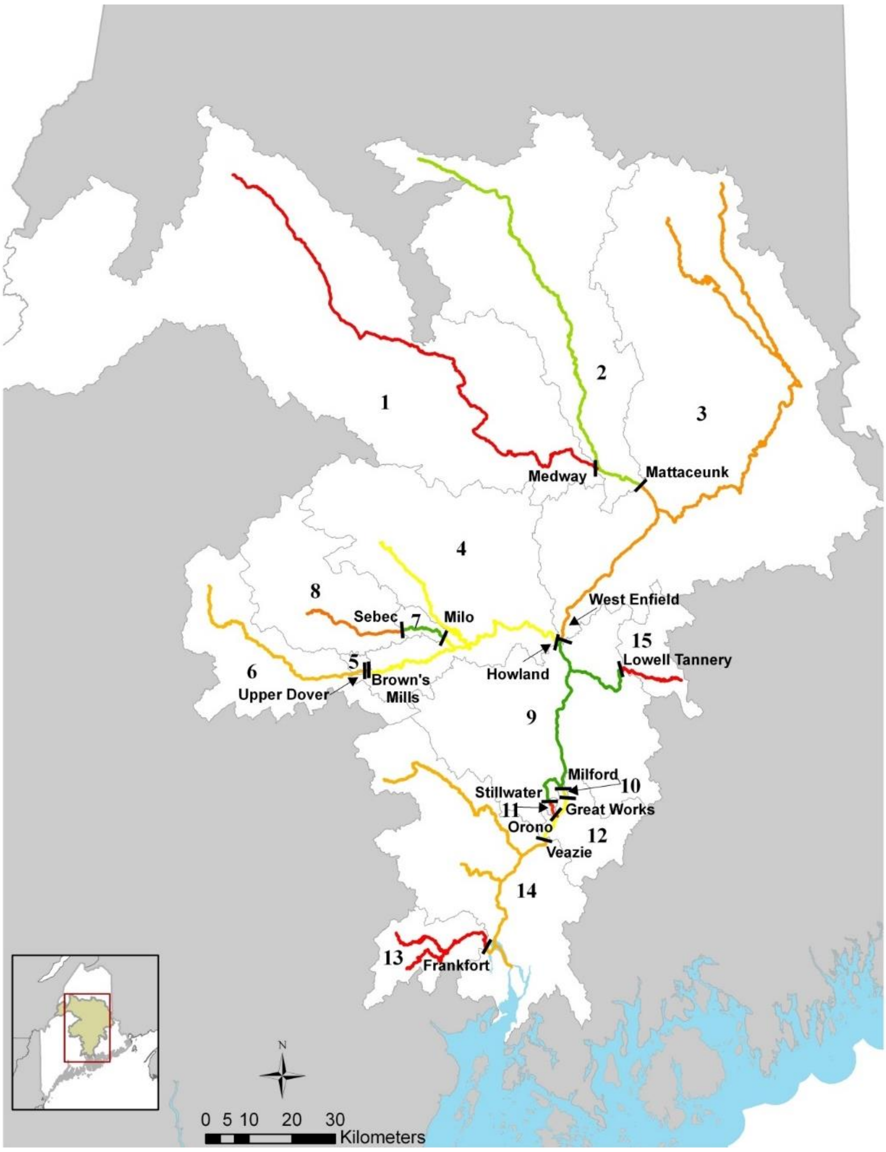


***Figure 1.*** *The Penobscot River, Maine, USA. Freshwater production units are delimited by dams (black bars).*

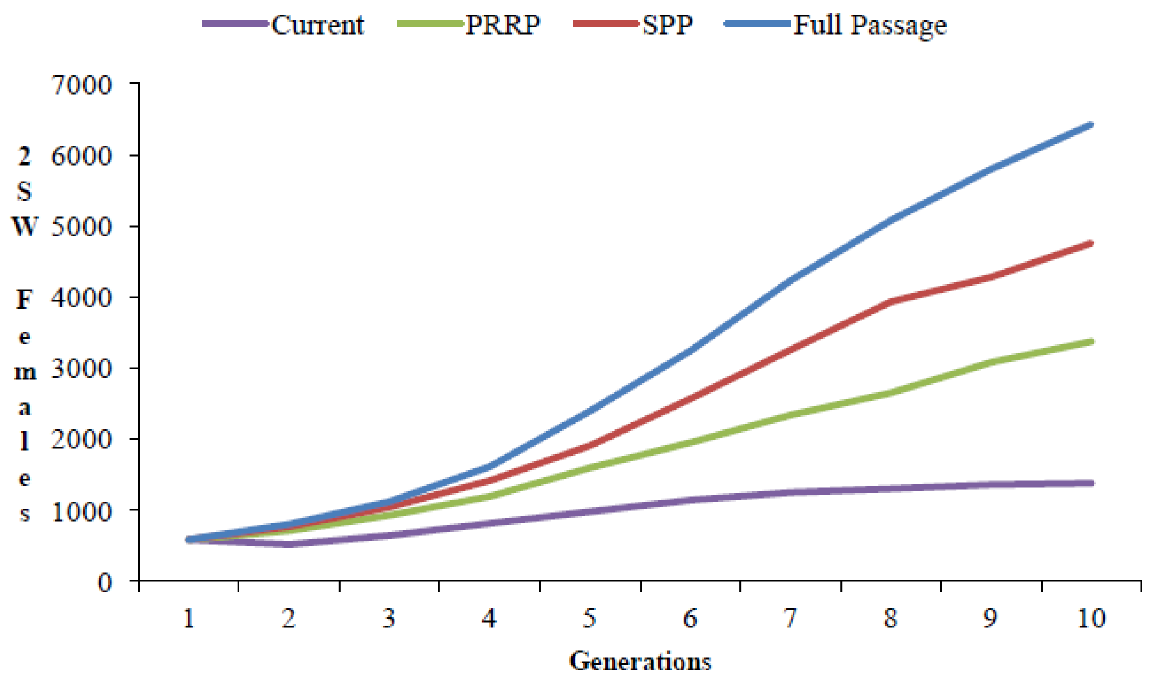


***Figure 2.*** *Projected abundance levels of Atlantic salmon in the Penobscot River with no changes in management ('Current' in purple), implementation of the PRRP ('PRRP' in green), implementation of the PRRP and the provisions of the SPP ('SPP' in red) , and complete dam removal ('Full Passage' in blue). 'Current' passage estimates are derived from a variety of empirical studies and modeled survival levels as described by Amaral et al. (2012). These projections assume favorable marine and freshwater survival levels in the future.*

In the analysis, we refer to the removal of Veazie and Great Works Dams and the decommissioning of Howland Dam as part of the Penobscot River Restoration Project (PRRP) and to the suite of actions that the dam owner must complete as the Species Protection Plan, which is additive to the PRRP. Our assumptions about the decommissioning of the Howland Dam and the installation of the bypass structure around the dam involve immediate attainment of complete upstream fish passage (100% survival); this is an optimistic assumption which will be rigorously tested as few fishways achieve 100% passage. We believe that this assumption is reasonable, however, because the bypass structure around the dam will provide a mechanism for the safe passage of all life stages of most fish species around the dam (unlike most technical fishways).

The modeling approach incorporates life stage-specific information, river flow information, and dam mortality impacts to simulate the life cycle of Atlantic salmon in the Penobscot River including:

- fecundity;
- egg to smolt mortality;
- freshwater mortality;
- downstream direct and indirect mortality estimates at dams;
- marine mortality;
- upstream direct and indirect mortality estimates at dams;
- within-river homing and straying rates; and
- hatchery supplementation.

The model is flexible, allowing for changes in all the input variables including the number of dams, upstream and downstream dam passage rates, and other variables. The life-history modeling approach enables incorporation of a wide array of life-history types to accommodate other diadromous species. The model is also being applied to other river systems (e.g. the Kennebec River) to develop performance standards at hydroelectric dams in these systems.

Most model inputs were considered to be random variables, and Monte Carlo sampling from probability density functions was used to create multiple realisations of population trajectories over time. All DIA Model iterations were run for 50 years, roughly ten generations, and 5,000 iterations were run for each simulation. The DIA Model was built in Microsoft Excel with the @Risk add-on.

The DIA Model can be used to compare alternative scenarios of environmental and dam conditions to identify critical parameters and information needs for recovery efforts. The predicted abundance and distribution of adults and number and proportion of smolts killed due to the effects of dams were reported for several modeling scenarios. The DIA Model simulations are not meant to predict absolute abundance, distribution, or mortality, but rather are meant to project the relative changes under different modeling scenarios. The DIA Model revealed that recovery potential of Atlantic salmon is most sensitive to marine and downstream dam passage survival rates.

The DIA Model predicts that the implementation of these survival standards will lead to an improvement in the numbers, reproduction and distribution of Atlantic salmon under similar environmental conditions. This is the case because:

- the proposed performance standards result in an increase in the abundance of pre-spawn adult Atlantic salmon returning to the Penobscot River; and
- the increase in the number of returning Atlantic salmon, due to the improved downstream survival and upstream passage rates at the dams, will lead to increased distribution of Atlantic salmon in the upper Penobscot watershed (i.e. where abundant spawning and rearing habitat exists).

**Implementing Performance Standards**

When analyzing the impacts of a hydroelectric dam on ESA listed Atlantic salmon, we must consider the effects to the species' abundance, distribution, and reproduction. If the dam appreciably reduces the species' chances for survival and recovery, we are required to develop an alternative (e.g. new fishway, turbine shutdowns and spillage, downstream diversion) that would improve the abundance, distribution, or reproduction of Atlantic salmon in the geographic area impacted by the dam. By requiring the dam owners to meet certain and explicit upstream and downstream survival standards, we have a clear assurance that the project will have minimal impacts on the survival and recovery of Atlantic salmon. These assurances can only truly be delivered when accompanied by a rigorous monitoring and review process. In short, this process uses the adaptive management paradigm to articulate a goal (the performance standard), quantitatively monitor whether or not the goal is attained, review results, and adjust as necessary. An example of an explicit decision process for downstream passage is described in Annex 1.

Unfortunately, 2014 was a very challenging year with adult salmon returns among the lowest on record. Mechanical breakdowns occurred at the lift for the lowest dam on the Penobscot River (at Milford Dam) for a period of approximately two weeks in 2014. This, among other challenges led us to conclude that the dam owners did not achieve its performance standard for upstream passage in 2014. Further, monitoring of downstream passage rates of smolts is as yet inconclusive in terms of documenting whether the performance standards are being achieved. We have advised the dam owners that they did not attain the required performance standard and that further modifications to their operations and monitoring of progress towards attainment of the performance standard are required. As such, we have had extensive discussion with the dam owners and other relevant authorities (e.g. the Maine Department of Marine Resources) in order to assist the dam owners in achieving the performance standards as quickly as possible. To that end, we have recently developed, and are currently implementing, a comprehensive fishway operations and maintenance plan and refinements of study methodologies. We fully expect fish passage evaluations and operations (particularly at Milford Dam) to be greatly improved in 2015 as a result.

**Other Protective Measures**

It is also important to ensure that once access to important freshwater habitats is restored, that the habitats are capable of supporting all life stages of Atlantic salmon. Thus, the US has several mechanisms to protect, conserve, and enhance habitats for the species. This is primarily achieved under the Magnuson Stevens Fishery and Conservation Act and the ESA. Under the Magnuson Act, habitat necessary for each life stage of Atlantic salmon to complete their life cycle is identified and protected. Under the ESA, critical habitat has been designated for Atlantic salmon that ensures that the habitats that are necessary for the survival and recovery of the species are protected. These designations indicate areas important to Atlantic salmon and inform the public of the need to protect these important areas. The US approach to habitat protection and restoration is consistent with the NASCO Plan of Action for the Application of the Precautionary Approach to the Protection and Restoration of Atlantic Salmon Habitat (see CNL(14)75).

Recognizing that habitat protection is only one part of the equation, the United States equally embraces the need to restore the productive capacity of Atlantic salmon habitat which has been adversely impacted through reduced connectivity caused by dams and improperly designed road crossings. This is accomplished partly through incentive-based programs which provide federal, state and private funds to support dam removal and other fish passage improvements such as the construction of fishways. However, it is important to note that these projects can only be accomplished through partnerships with many jurisdictions and interested parties. Conservation organizations are key partners in salmon protection and recovery in the United States, including working with local governments to put together proposals to seek funding to implement community-based restoration projects. The Penobscot River Restoration Project is the best known of these, but there are many others (recent highlights are summarized in CNL(14)75, CNL(14)33 and CNL(15)32). In addition, representatives from a variety of industries and industry organizations are excellent partners to seek the adoption of protective measures into their business rules and also to implement restoration and recovery projects on their lands, frequently using their equipment and staff (http://sfimaine.org/fin-meetings/).

**Future Work Implementing Performance Standards**

The Penobscot, Kennebec, and Androscoggin Rivers contain a significant amount of valuable habitat for Atlantic salmon in Maine as well as a number of hydroelectric dams. Going forward, we will expand the DIA Model to identify survival standards at all dams in the GOM DPS necessary to protect and recover Atlantic salmon. We are also actively seeking ways to advance adaptive management of fish passage restoration for other sea-run species (e.g., American shad, *Alosa sapidissima*) by applying the DIA Model in Maine and elsewhere. In addition, we are seeking ways to more explicitly link performance standards to measurable recovery criteria for Atlantic salmon in future modeling and regulatory actions. In conclusion, the recent application of a rigorous adaptive management paradigm including the development and implementation of performance standards substantially advances prospects of recovery for endangered Atlantic salmon in the United States.

**Acknowledgements**

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Annex 1. Example of decision process for implementing the downstream performance standard described in the species protection plan for the Penobscot River.