UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
55 Great Republic Drive
Gloucester, MA 01930

April 15, 2022

Bruce Van Note, Commissioner
Maine Department of Transportation
16 State House Station
Augusta, ME 04333-0016

Todd Jorgensen, Administrator
Federal Highways Administration, Maine Division
Edmund S. Muskie Federal Building
40 Western Avenue, Room 614
Augusta, ME 04330

Dear Mr. Van Note and Mr. Jorgensen:

This responds to a March 21, 2022, letter from the Maine Department of Transportation (ME DOT) (attachment 1) that included several questions in relation to the Machias Dyke bridge replacement project located on the Middle River along Route 1 in Machias, Maine. Staff from ME DOT, NOAA's National Marine Fisheries Service (NMFS), and the Federal Highway Administration (FHWA) discussed these questions in a March 31, 2022, meeting. At that meeting, ME DOT requested that we also provide written responses.

As noted in previous correspondence, the project is located within the range of the endangered Gulf of Maine distinct population segment (GOM DPS) of Atlantic salmon. Additionally, the project is located within critical habitat designated for the GOM DPS of Atlantic salmon. Consultation pursuant to section 7 of the Endangered Species Act (ESA) will be required to consider effects of the proposed action on the GOM DPS of Atlantic salmon and its critical habitat. Here, we address the questions raised in the letter from March 21.

> *"1. Your technical assistance letter stated concerns with the culvert alternative providing safe, timely, and effective fish passage. MaineDOT shares these concerns (as noted above). If the understood fish passage standard (95% of all approaching fish pass within a 48-hour period) required for safe, timely, and efficient passage can't be met or committed to, is that likely to result in a jeopardy or an adverse modification determination?"*

In a number of ESA consultations considering effects of hydroelectric dams, we have determined that an action that includes a fishway that ensures that 95 percent of all salmon pass upstream within 48 hours is not likely to jeopardize the continued existence of the GOM DPS of Atlantic salmon or result in the destruction or adverse modification of designated critical habitat. That said, it is important to note that "95 percent in 48 hours" is not a jeopardy standard, and the conclusions reached in those consultations were based on the specifics of those proposed actions and the passage rate was only one factor among many considered in the analysis. During our

ESA section 7 consultation process, we consider whether the effects of the proposed action reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the listed species in the wild by reducing the reproduction, numbers, or distribution of the GOM DPS of Atlantic salmon. The purpose of this analysis is to determine whether the proposed action, in the context established by the status of the species, environmental baseline, and cumulative effects, would jeopardize the continued existence of the GOM DPS of Atlantic salmon. In addition, the analysis will determine whether the proposed action will adversely modify designated critical habitat for Atlantic salmon.

> *"2. The technical assistance process was clear that future monitoring of fish passage efficacy would be required for a culvert alternative. MaineDOT would like to understand how NOAA will use the monitoring results and what happens if the results do not meet passage standards."*

If, in the context of an ESA consultation, we determine that a proposed action is likely to result in the "incidental take" of ESA listed species (e.g., injury, mortality, harm, harassment), and that take is not likely to jeopardize the continued existence of the species, an Incidental Take Statement (ITS) would be included with our Biological Opinion. An ITS serves two functions: (1) It provides an exemption from the section 9 prohibitions for any taking incidental to the proposed action that is in compliance with the terms and conditions; and (2) it provides the means to insure the action as it is carried out as proposed and is not jeopardizing the continued existence of any ESA species by monitoring and reporting the progress of the action and its impact on the species such that consultation can be reinitiated if any of the criteria in 50 CFR 402.16 are met (e.g., if the amount or extent of take is exceeded). If take is anticipated, monitoring to document that take would be required. It is important to note that both short-term and long-term monitoring can be conditions of an ITS, depending on the extent and duration of take anticipated.

Considering the proposed Machias Dyke replacement project, we anticipate that the extent and duration of incidental take, and the associated monitoring requirements, would be significantly different depending on which alternative is selected. If a channel-spanning bridge is chosen as the preferred alternative, we anticipate that some monitoring would be required during construction. However, if consistent with our expectations, the bridge does not impact the passage of Atlantic salmon, long-term monitoring of fish passage would not be required.

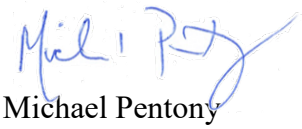
If culverts and/or tide gates are chosen as the preferred alternative, we anticipate that long-term monitoring to evaluate the efficiency of fish passage through the structure would be needed to document the amount or extent of take of Atlantic salmon resulting from passage delays and/or disruptions. We expect that an ESA consultation that considered a culvert/tide gate alternative would anticipate ongoing effects to Atlantic salmon to result from at least the following mechanisms: (1) False attraction for adult Atlantic salmon attempting to enter the Machias River; (2) low upstream passage efficiency for adult Atlantic salmon attempting to enter the Middle River; (3) low downstream passage efficiency for smolts emigrating from the Middle River; (4) injury and mortality incurred by emigrating smolts given very high velocities at some flows; and (5) increased predation on adult Atlantic salmon by seals resulting from delayed passaged attempts and false attraction. It is important to note that the amount or extent of take over the life

of the culvert and/or tide gates would likely be very difficult to estimate and any analysis would need to address significant uncertainty because this type of flow conveyance is largely untested in regards to passage efficiency for Atlantic salmon and other diadromous fish in Maine. As such, fish passage monitoring to document the effects of the structure on Atlantic salmon would be an extensive undertaking (see attachment 2). As noted above, monitoring would be required to document the amount and extent of take over the life of the structure. If monitoring indicates that the amount of take exempted by the ITS is exceeded, ESA section 7 consultation would need to be reinitiated. This could result in new analyses or additional measures to reduce the amount or extent of take. Predicting the outcome of the monitoring and any future measures to reduce take levels (if the extent of take identified in the ITS is exceeded) is not possible at this time.

Ensuring the long-term viability of Atlantic salmon is a high priority for NMFS and improving fish passage is a critical effort to improving the likelihood of the survival and recovery of this species, particularly within designated critical habitat. Given this, we encourage FHWA and ME DOT to select the alternative that would maximize fish passage and opportunities for recovery of Atlantic salmon and the ecosystem on which they depend. If you have any further questions about the ESA, please contact Julie Crocker in our Protected Resources Division (Julie.Crocker@noaa.gov).

Please note that in addition to the requirements to carry out ESA section 7 consultation, an Essential Fish Habitat (EFH) assessment for the proposed project will be required to initiate an EFH consultation. Characterizing and quantifying the habitats affected by the proposed project alternatives, both during construction and over the operational life of the project, will be necessary. Because this proposed project has implications related to climate change, we will require a climate assessment of future effects to habitats from a range of climate factors, including projected sea level rise, higher temperatures, and changes in precipitation patterns. The assessment should also include information for the project alternatives on implications for potential carbon sequestration gains and losses in salt marsh habitats within the Middle River over the life of the project. Questions regarding the EFH assessment should be directed to Chris Boelke in our Habitat and Ecosystem Services Division (Christopher.Boelke@noaa.gov).

Sincerely,



Michael Pentony
Regional Administrator

ec: Bean, Saunders, Johnson – GAR
Ham, Taylor – ME DOT

Attachment 1. March 21, 2022 ME DOT letter
Attachment 2. November 22, 2021 NMFS letter

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

Janet T. Mills
GOVERNOR

Bruce A. Van Note
COMMISSIONER

March 21, 2022

Ms. Jennifer Anderson
Assistant Regional Administrator for Protected Resources
National Marine Fisheries Service
Greater Atlantic Regional Fisheries Office
55 Great Republic Drive
Gloucester, MA 01930

Dear Ms. Anderson:

Thank you for the technical assistance letter, dated November 22, 2021, regarding MaineDOT's Machias Dike Bridge project. National Marine Fisheries Service (NMFS) assistance over the past year has been valuable in understanding the requirements of Endangered Atlantic salmon and NMFS concerns. The MaineDOT Commissioner, Bruce Van Note, has requested that I follow-up with you regarding the technical assistance.

MaineDOT has put significant effort into understanding the available fish passage conditions for the culvert alternative (4M). MaineDOT has modelled various culvert sizes, arrangements, invert elevations, and gate combinations (including no tide gates) to ensure the culvert alternative carried forward represent optimized fish passage.

Alternative 4M consists of three box culverts (10 ft span x 5 ft rise) with tide gates on two of the culverts that would allow seaward flow but would not allow landward flow. The third box culvert would have no flow control so water can flow both directions. The invert of the open box culvert would be installed 2 feet below the existing inverts. As modeled, Alternative 4M would promote fish passage during periods of landward flow (approximately 50% of a 24-hour period).

The model showed that water velocities for the culvert alternatives effectively offer no fish passage during seaward flow for weak and moderate swimming fish. Comparing fish swimming capabilities to expected velocities during normal tides show that fish passage for weak and moderate swimming fish species is available for ~12 hours a day. Strong swimming fish may have available passage window of up to ~15 hours a day. As noted in your letter, the behavioral issues with the passage opportunities provided by Alternative 4M make the prediction of passage efficacy challenging.

NMFS has clearly stated a preference for the bridge alternatives and MaineDOT has noted and fully understands the preference. MaineDOT continues to seek guidance on the regulatory requirements of the Endangered Species Act as they would apply to the culvert alternatives to inform a legally defensible decision on a preferred alternative. Specifically, we need to understand the following items:

1. Your technical assistance letter stated concerns with the culvert alternative providing safe, timely, and effective fish passage. MaineDOT shares these concerns (as noted above). If the understood fish passage standard (95% of all approaching fish pass within a 48-hour period) required for safe, timely,

and efficient passage can't be met or committed to, is that likely to result in a jeopardy or an adverse modification determination?

2. The technical assistance process was clear that future monitoring of fish passage efficacy would be required for a culvert alternative. MaineDOT would like to understand how NOAA will use the monitoring results and what happens if the results do not meet passage standards.

The MaineDOT project team and the Federal Highway Administration would like to meet with you and your staff to discuss these items. The answers you provide are crucial as we continue to assess the potential impacts of culvert and bridge alternatives on natural resource, cultural, and social impacts of the alternatives.

Sincerely,

Joyce Noel Taylor

Joyce Taylor, Chief Engineer

cc: Todd Jorgenson, Administrator, FHWA Maine Division
Eva Birk, FHWA Maine Division
Patrick Keliher, Commissioner, Maine Department of Marine Resources

UNITED STATES DEPARTMENT OF COMMERCE
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November 22, 2021

Bruce Van Note, Commissioner
Maine Department of Transportation
16 State House Station
Augusta, ME 04333-0016

Todd Jorgensen, Administrator
Federal Highways Administration, Maine Division
Edmund S. Muskie Federal Building
40 Western Avenue, Room 614
Augusta, ME 04330

Dear Mr. Van Note and Mr. Jorgensen:

This letter provides the technical assistance requested by the Maine Department of Transportation (DOT) regarding the proposed construction design plan for the Machias Dyke bridge replacement project located on the Middle River along Route 1 in Machias, Maine. Our agency's staff have continued to coordinate and meet virtually throughout 2021; we appreciate your staff's willingness to discuss and explore design alternatives while balancing the many challenging issues your agencies face with this project.

As we have previously noted, the project site is within or near areas that support a number of NOAA trust resources, including designated critical habitat for the endangered Gulf of Maine Distinct Population Segment (GOM DPS) of Atlantic salmon, Essential Fish Habitat (EFH), and habitat for a number of diadromous fish species. We have also previously expressed the importance of developing a design alternative that provides safe, timely, and effective fish passage that will fully restore the function of these habitats and trust resources that occur in the Middle River watershed upstream of the existing Machias Dyke Bridge.

Technical Assistance
On September 21, 2021, DOT provided us information to gain a better understanding of the alternatives being considered and how these may affect our trust resources. As described, DOT is considering two preliminary design alternatives: A pile supported single span bridge (Alternative 10) or a solid-fill dyke bridge with a series of culverts and tide gates (Alternative 4M). Our preferred alternative here is one that will: minimize effects to diadromous fish, including endangered Atlantic salmon; maximize passage opportunities; maximize opportunities for tidal habitat restoration; and minimize negative effects on critical habitat designated for the Gulf of Maine DPS of Atlantic salmon. Alternative 10 appears to provide a better opportunity to meet these goals than Alternative 4M.

Safe, Timely, and Effective Fish Passage
One of our primary considerations in evaluating the different alternatives is the potential for it to provide safe, timely, and effective passage for fish species. Our goals are always to minimize the potential for migratory delay or deterrence for endangered species, including Atlantic salmon. For a project such as this one, we would expect designs to allow for passage of all diadromous species at least 95% of the time (between the 5% and 95% exceedance flows) during the entire migratory window.

While the Machias Dyke Bridge is not a nature-like fishway (NLF), passage criteria for depth, width, and velocity referenced in the *Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes* (Turek 2016) is relevant and should be fully considered here. Based on body length, depth, and swim speeds for Atlantic salmon, the guidelines recommend a minimum depth of passage of 2.25 feet, a minimum width of passage of 6.25 feet, and a maximum velocity of 13.75 feet per second (fps). Given the high swim speed of adult salmon, we expect that they might attempt passage at velocities that would deter other species. The NLF guidelines indicate that if passage for other diadromous fish is to be achieved most of the time, channel widths and depths should be greater than for Atlantic salmon, and velocities should be lower. For example, striped bass have a wider minimum width requirement (9.25 feet) and deeper minimum depth requirement (3.25 feet) than Atlantic salmon (note that if Atlantic sturgeon are to be afforded passage, the minimum depth should be 4.50 feet). Similarly, volitional passage of species with slower swimming speeds requires maximum velocities as low as 0.75 fps (Rainbow smelt, Atlantic tomcod, river herring and American eel ≤ 15 cm).

Alternative 4M
Alternative 4M includes three, 10-foot by 10-foot culverts with flap-gates on two of the culverts and bidirectional flow in the third culvert. According to the information presented by DOT on August 17, 2021, the use of culverts would substantially alter the flow regime and decrease the volitional passage opportunities for diadromous fish entering and exiting the Middle River to approximately 50% of the daily tidal cycle. As such, we remain concerned that this altered flow regime and constricted area with increased velocities through the culverts and tide gates would likely limit volitional passage opportunities to a much smaller percentage of time, mostly occurring around ebb and flood slack tides.

In addition, placing a structure such as a tide gate within a boxed culvert could have significant implications to fish passage. As documented by Rillahan (2021) and Alcotte et al. (2021), tide gates at the Herring River in Massachusetts have had a deleterious effect on fish behavior including unsuccessful passage and delay, injury and mortality and increased exposure to predators like striped bass. Any tide gate, whether fully open or partially open, is likely to provide an attraction flow that fish may try to use for passage. Additionally, partially open or fully open tide gates can create high velocities that sweep fish through narrow openings. When velocities exceed the burst speeds of fish, they cannot make evasive maneuvers away from predators and obstacles in the water, like debris, increasing the risk of injury and mortality. In particular, high velocity flow through the narrow openings of flap gates promotes collisions with the gate structure itself, including the gate and frame. Furthermore, the use of submerged orifices for fish passage can create high velocities that exceed the burst speeds of diadromous fish. The proposed culverts for a replacement dyke structure would be similar to the existing

length of the tide gate culverts (reportedly 110 feet), likely exceeding the distance that most fish could sustain burst speeds.

Submerged passage also limits natural light in the flow conveyance which can adversely affect fish behavior. That is, even if velocities were manageable, many sea-run fish would be reluctant to enter these confined dark spaces volitionally. Deeply submerged passages can also introduce delay by requiring fish to sound or search for a narrow opening, making repeated attempts at entry. Therefore, given the potential to adversely change fish behavior during migration, or even cause injury or mortality, we recommend that no tide gates be used in the Machias Dyke Bridge replacement.

The uncertain performance of culverts, including tide gates, in passing diadromous species in Maine, especially endangered Atlantic salmon, would require more baseline information and long-term monitoring to better understand the potential effects from extensive operation using a type of flow conveyance that has largely been untested in regards to passage efficiency for diadromous fish within the GOM DPS. As such, we anticipate that should you pursue this alternative, we would recommend fish passage monitoring to document the effects of the structure on Atlantic salmon, their critical habitat, and the other diadromous fish in the project area.

Sea Level Rise

The effects of future sea level rise on the operation of the tide gates and fish passage is uncertain at this time. Under normal operation, the two flap gates would presumably stay in an open position and allow flow from the Middle River to Machias River when the water elevation on the Middle River side of the dyke bridge is higher than the Machias River (approximately 50% of the daily tidal cycle). The flap gates would be closed when water elevations are equal on both sides of the dyke bridge or higher in the Machias River. The only tidal exchange when the flap gates are closed would be through the single open box culvert. However, higher sea levels projected for the Gulf of Maine can impact flows in tidal structures such as tide gates and culverts. It will be critical to assess the effectiveness of fish passage over the full range of the normal tide cycle and during predicted storm water elevations from sea level rise. The assessment should evaluate the predicted water velocity through the tide gates and the open box culvert, and the estimated duration of gate closure during normal tide cycles with higher mean sea levels. At a minimum, sea level rise projections should be consistent with the Maine Climate Council's "commit to manage" recommendation of 1.5 feet of relative sea level rise by 2050, relative to the year 2000, and 3.9 feet of sea level rise by the year 2100. The assessment should also include the Maine Climate Council's "prepare to manage" recommended sea level rise projection of 3.0 feet of relative sea level rise by 2050, and 8.8 feet of sea level rise by the year 2100 (Maine Climate Council. 2020). In addition, the National Climate Assessment projects more extreme precipitation events in the Northeast U.S. and parts of New England with corresponding higher air temperature (Easterling et al. 2017). In an assessment of four unregulated rivers in Maine, Hodgkins and Dudley (2013) reported increases in maximum peak river flows based on projected higher temperature and precipitation rates by the end of the century. More extreme precipitation and river flows will also affect the operation of the dyke bridge tide gates, and hence flow rates and patterns for fish passage.

If you continue to pursue this alternative, a climate change assessment should be conducted to evaluate future sea level rise and increases in extreme precipitation and peak flows on the solid-fill dyke bridge with tide gates and box culverts, and its effects on fish passage.

Tidal Habitat Restoration

According to an October 2021 updated analysis conducted by Stantec and provided to us, this project has the potential to restore over 400 acres of tidal habitats, including salt marsh wetlands, intertidal mudflats, tidal streams, and other resources that provide important ecosystem services. Salt marsh wetlands not only serve as important nursery habitat for federally-managed species and their prey, but they provide the capacity to sequester atmospheric CO_2 (18–1,713 g of carbon per meter per year, according to Mcleod et al. 2011).

The DOT has indicated up to 100 acres of tidal habitat is currently available due to the existing state of the Machias dyke allowing some tidal flow into the Middle river during a flood tide. Furthermore, according to the updated Stantec analysis, design alternative 4M may re-establish approximately 116 acres of unvegetated intertidal/subtidal, low, and high marsh habitats in the Middle River compared to the no action alternative. This estimate includes approximately 60 acres and 13 acres of re-established low and high marsh habitats, respectively, and assumes the salinity range within the Middle River will be equivalent to the Machias River. However, this condition may not exist given the limitation of tidal flow through one, 10-foot by 10-foot culvert and the depressed tidal regime in the Middle River (i.e., -2.7 to +2.0 feet NAVD88) compared to tidal transparency (i.e., -6.7 to +7.4 feet NAVD88). We recommend that in light of this new information, the effects of Alternative 4M on the tidal regime and salinity, and the subsequent potential for salt marsh restoration in the Middle River be re-evaluated.

Preference for Alternative 10

According to recent information presented by DOT, Alternative 10 would provide unrestricted tidal flow between the Machias River and the Middle River (i.e. tidal transparency), which in turn would afford more time for fish to enter the Middle River estuary during daily tides. As in freshwater rivers, inverts should be set at the natural grades of riverbeds to allow fish passage even during low flow and low tide conditions. Since the channel velocity will largely be determined by the differential between water levels upstream and downstream of the Machias Dyke Bridge, the best way to minimize velocities over a range of flows and tide levels is for the structure to provide tidal transparency, as would be provided by a single span bridge. Specifically, tidally-influenced water levels upstream and downstream of the bridge structure should track closely in amplitude and period. According to hydraulic modeling results provided by DOT, tidal transparency would furthermore appear to maintain minimum depth and width requirements for diadromous fish per the guidelines. We also expect this alternative would provide the most effective fish passage conditions, and therefore reduce the potential need for additional fish passage monitoring.

A comparative climate change assessment, including sea level rise projections and changes in extreme precipitation and peak flows, should also be conducted for this alternative as it applies to the effectiveness of fish passage.

With regards to tidal habitat restoration, the Stantec analysis indicated the potential to re-establish approximately 403 acres of unvegetated intertidal/subtidal, low, and high marsh

habitats in the Middle River for design Alternative 10. This amount of tidal habitat re-establishment is approximately three times the projected amount calculated for Alternative 4M. Salt marsh wetlands have a higher capacity to sequester carbon compared to terrestrial vegetation and soils, and have the capacity to migrate inland as sea levels rise (Chmura et al. 2003). In addition, coastal marshes have been shown to reduce wave heights, attenuate storm surge and higher sea levels, and reduce property damage compared to unvegetated or hardened shorelines (Gedan et al. 2011; Shepard et al. 2011; Arkema et al. 2013; Temmerman et al. 2013; Narayan et al. 2016). Therefore, this alternative appears to provide the best approach to restoring the habitat and stream function of the Middle River, as well as increasing the capacity for carbon sequestration by tidal marsh vegetation. This alternative also appears to be most consistent with two primary strategies in the Maine Climate Action Plan: protecting and promoting natural climate solutions that increase carbon sequestration and investing in climate-ready infrastructure (Maine Climate Council 2020).

Next Steps

In our view, Alternative 10 is the preferred opportunity for achieving an ecologically sound and climate resilient approach to the replacement of the Machias Dyke Bridge. We encourage you to pursue this alternative to provide safe, timely and effective fish passage while at the same time allowing for restoration of tidal wetland habitats. We recognize the complexity of this project and the need to consider multiple factors as you move this project forward. We look forward to continuing to provide assistance to you and your staff. Should you have any questions regarding the Endangered Species consultation process for this project should be referred to David Bean (David.Bean@noaa.gov), while questions regarding the EFH consultation process should be referred to Mike Johnson (mike.r.johnson@noaa.gov).

Sincerely,

Jennifer Anderson

Jennifer Anderson
Assistant Regional Administrator
for Protected Resources

cc. Eva Birk (FHWA)
Joyce Noel Taylor (MDOT)
Patrick Keliher (MDMR)

References

Alcott DJ, Goerig E, Rillahan C, He P, Castro-Santos T. 2021. Tide gates form physical and ecological obstacles to river herring (*Alosa* spp.) spawning migrations. Canadian Journal of Fisheries and Aquatic Sciences 78: 869–80. dx.doi.org/10.1139/cjfas-2020-0347.

Arkema KK, Guannel G, Verutes G, Wood SA, Guerry A, Ruckelshaus M, Kareiva P, Lacayo M, Silver JM. 2013. Coastal habitats shield people and property from sea-level rise and storms. Nature Climate Change 3(10):913-8.

Chmura GL, Anisfeld SC, Cahoon DR, Lynch JC. 2003. Global carbon sequestration in tidal, saline wetland soils. Global Biogeochemical Cycles 17(4):1-12.

Easterling DR, Kunkel KE, Arnold JR, Knutson T, LeGrande AN, Leung LR, Vose RS, Waliser DE, F. WM. 2017. Precipitation change in the United States. Climate Science Special Report: Fourth National Climate Assessment. [Wuebbles DJ, Fahey DW, Hibbard KA, Dokken DJ, Stewart BC, Maycock TK (eds)]. U.S. Global Change Research Program. p. 207-30.

Gedan KB, Kirwan ML, Wolanski E, Barbier EB, Silliman BR. 2011. The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm. Climatic Change 106(1):7-29.

Hodgkins GA, Dudley RW. 2013. Modeled future peak streamflows in four coastal Maine rivers. U.S. Department of the Interior, U.S. Geological Survey. U.S. Geological Survey Scientific Investigations Report 2013-5080. p. 1-18.

Maine Climate Council. 2020. Maine Won't Wait: A Four-year Plan for Climate Action. Maine Climate Council, December 2020.

Mcleod E, Chmura GL, Bouillon S, Salm R, Björk M, Duarte CM, Lovelock CE, Schlesinger WH, Silliman BR. 2011. A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment 9(10):552-60.

Narayan S, Beck MW, Reguero BG, Losada IJ, van Wesenbeeck B, Pontee N, Sanchirico JN, Ingram JC, Lange G-M, Burks-Copes KA. 2016. The effectiveness, costs and coastal protection benefits of natural and nature-based defences. PLoS One 11(5):e0154735.

Rillahan CB, Alcott D, Castro-Santos T, He P. 2021. Activity patterns of anadromous fish below a tide gate: observations from high-resolution imaging sonar. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 13:200–12. 10.1002/mcf2.10149

Shepard CC, Crain CM, Beck MW. 2011. The protective role of coastal marshes: a systematic review and meta-analysis. PLoS One 6(11):e27374.

Temmerman S, Meire P, Bouma TJ, Herman PMJ, Ysebaert T, De Vriend HJ. 2013. Ecosystem-based coastal defence in the face of global change. Nature 504(7478):79-83.

Turek, J., Haro A, Towler B. 2016. Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes. Interagency Technical Memorandum. 47 pp.