PENOBSCOT RIVER RISK ASSESSMENT AND PRELIMINARY REMEDIATION GOAL DEVELOPMENT

Penobscot River Phase III Engineering Study

Penobscot River Estuary, Maine

Prepared for:

United States District Court
District of Maine

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ACRONYMS AND ABBREVIATIONS

Amec Foster Wheeler	Amec Foster Wheeler Environment & Infrastructure, Inc.
BAF	biota-biota accumulation factor
BSAF	biota-sediment accumulation factor
BERA	Baseline Ecological Risk Assessment
BO	Brewer to Orrington
BTV	background threshold value
bw/day	body weight per day
CDI	chronic daily intake
cm	centimeters
Court	United States District Court for the District of Maine
COPC	constituent of potential concern
dw	dry weight
EPA	(US) Environmental Protection Agency
EPC	exposure point concentration
ES	Estuary
Estuary	Penobscot River Estuary
g/day	grams per day
HHRA	Human Health Risk Assessment
HoltraChem	HoltraChem Manufacturing Company, LLC
HQ	hazard quotient
kg	kilograms
kg/day	kilograms per day
LOAEL	lowest observed adverse effect level
MeCDC	Maine Center for Disease Control and Prevention
MEDEP	Maine Department of Environmental Protection
mg/kg	milligrams per kilogram
mg/kg/day	milligrams per kilogram per day
MMSE	Mendall Marsh Southeast
MMSW	Mendall Marsh Southwest
ng/g	nanograms per gram
ng/L	nanograms per liter

NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
OB	Orrington to Bucksport
OV	Orono to Veazie
Phase III Engineering Study	Penobscot River Phase III Engineering Study
PRG	preliminary remediation goal
PRMS	Penobscot River Mercury Study
PRMSP	Penobscot River Mercury Study panel
RfD	reference dose
site	Penobscot River
TRV	toxicity reference value
UCL	upper confidence limit
UPL	upper prediction limit
UTL	upper tolerance limit
ww	wet weight
W	wetland/marsh platform

EXECUTIVE SUMMARY

In January 2016, the United States District Court for the District of Maine (the Court) selected Amec Foster Wheeler Environment & Infrastructure, Inc. to conduct the Penobscot River Phase III Engineering Study (Phase III Engineering Study), to identify and evaluate feasible, effective, and cost-effective measures to remediate mercury in the Penobscot River Estuary. The project area is shown on **Figure I.1-1**. The geographic area to be addressed within the Phase III Engineering Study is described by the Court as follows: *"The evaluation will focus in particular on the region from the site of the former Veazie Dam south to Upper Penobscot Bay, including Mendall Marsh and the Orland River."*

This Penobscot River Risk Assessment and Preliminary Remediation Goal Development is part of the Phase III Engineering Study. It presents the Human Health Risk Assessment (HHRA) and Baseline Ecological Risk Assessment (BERA), evaluating current conditions for the Estuary (site). Baseline risk assessments evaluate the potential threats to human health and the environment, aid in determining whether remedial action is needed, and serve as the basis for the evaluation of the effectiveness of any subsequent remedial action. The HHRA and BERA will be used to identify areas of remedial focus and assist with decision making in future phases of the project. The HHRA and BERA will be used as the baseline for the quantification of risk reduction for the Estuary. This report also includes the development of risk-based mercury sediment preliminary remedial goals (PRGs) for human health and ecological receptors.

The Penobscot River in northern Maine is the second-largest river in New England, with an estuary of 90 square kilometers. A chlor-alkali plant located in Orrington, Maine, released mercury into the Penobscot River starting in 1967. The amount of mercury released annually decreased between 1970 and 1982, and decreased further when the plant was closed in 2000. Elevated levels of methyl mercury measured in sediments and biota led to legal action by the Maine People's Alliance in 2000. This group joined with the Natural Resources Defense Council to bring a lawsuit, pursuant to the imminent and substantial endangerment provision of the Resource Conservation and Recovery Act, against HoltraChem Manufacturing Company, LLC and Mallinckrodt, Inc. A baseline HHRA and BERA, as well as the development of PRGs, were undertaken as part of an engineering study to identify and evaluate feasible, effective, and cost-effective measures to remediate mercury present in the Estuary.

ES.1 OVERVIEW

The purpose of this report is to document risk assessments for human health and ecological receptors that would then be used to develop a sediment remediation goal for mercury. Implementation of a remedy to attain the remediation goal would result in biota tissue concentrations such that humans and ecological receptors can safely consume biota, irrespective of trophic level, without experiencing adverse health effects. Mercury (including methyl mercury) concentrations in the Estuary are driven by sediment mercury concentrations. By connecting biota mercury concentrations with sediment mercury concentrations, sediment remediation goals can be developed and remediation alternatives can be evaluated.

The ecological risk assessment completed in this document is not a Natural Resource Damage Assessment and Restoration (NRDAR) program evaluation. A NRDAR evaluation focuses on effects on an individual level and attempts to quantify the number of individual animals affected in multiple biota classes in order to seek restitution from the responsible party. Instead, this report includes an ecological risk assessment that is used to evaluate population level risks to support development of remediation goals where needed to be protective of ecological receptors. The risk assessment approach used here is consistent with the approach used in the development of sediment remediation goals at other large sediment sites with mercury contamination across the United States, including Berry's Creek, South River, Lower Duwamish Waterway, Pompton Lakes Works, Passaic River, Riegelwood, Portland Harbor, and an oxbow lake adjacent to the Tombigbee River.

While this project is not under CERCLA rules and requirements, the human health risk assessment was completed in general accordance with the Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (RAGS) (EPA, 1989) along with several of its associated parts and supplemental guidance documents.

As part of the human health risk assessment, acceptable concentrations for the ingestion of biota were identified in two different ways: 1) using the CERCLA risk assessment guidance and calculating acceptable concentrations based on ingestion rates and toxicity factors, or 2) using published governmental criteria designed to identify safe consumption levels (e.g., the MeCDC freshwater fish tissue action level of 200 ng/g for methyl mercury).

The Maine Center for Disease Control and Prevention (MeCDC) developed fish tissue action levels as a guide to determine the need for developing fish consumption advisories (MeCDC 2001). In conversations with MeCDC, the agency indicated that the fish tissue action level was only meant to apply to sport fishing, and was not developed with lobster, shellfish, and duck consumption in mind. However, the Maine Department of Marine Resources, working with the MeCDC, used the MeCDC fish tissue methyl mercury action level when designating the lobster and crab fishing closure areas.

Sediment cleanup goals have been developed in this report for both the CERCLA risk assessment method and for the MeCDC methyl mercury fish tissue action level. While both methods are valid, the US District Court adopted the MeCDC 200 ng/g value as a general benchmark as noted in the Order on Remediation Plan (September 2, 2015): "*The expert's differing viewpoints as to the appropriate standards by which to measure remediation are irreducibly complex. The Study Panel Report itself devoted a full chapter consisting of 123 pages to its discussion of the appropriate remediation targets. Phase II, Chapter 2 at 1-123. At this point, it is not necessary to wade into this earnest and highly-technical debate among the eminent scientists concerning the appropriate standards by which success is cleansing the River must be measured. The short answer is that the debate will remain theoretical until the engineers have opined on feasibility and cost and have expressed expert opinions about the likely effectiveness of the remedy. For example, if the lower limits are readily and inexpensively attainable, the Court suspects that*

Mallinckrodt and its experts would have no objections to attaining them. However, if the lower limits are simply unattainable or attainable only with extraordinary expenditure and considerable delay, the Court suspects the Plaintiffs will be satisfied with more cost-effective and efficient, but imperfect, remedy. Nevertheless, to the extent the parties require a general benchmark, the Court adopts the state of Maine standard of 200 nanograms per gram, not the more relaxed benchmark Mallinckrodt's experts proposed."

The ecological risk assessment also followed the general approach for CERCLA style ecological risk assessments, including a risk assessment focused on population-level effects on biota. The risk assessment generally followed the Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (ERAGs) (Interim Final Document Number EPA 540-R-97-006/OSWER 9285.7-25/PB97-963211) dated June 1997 (EPA, 1997) and, as such, the risk assessment quantifies for chronic effects which will induce population-level effects in biota, as discussed in ERAGs Section 7.3.1 "Threshold of Effects on Assessment Endpoints". This section states "The lower bound of the threshold would be based on consistent conservative assumptions and NOAEL toxicity values. The upper bound would be based on observed impacts or predictions that ecological impacts could occur. This upper bound would be developed using consistent assumptions, site-specific data, LOAEL toxicity values, or an impact evaluation" (Page 7-4 of EPA, 1997). Thus, NOAELs and LOAELs were used in the risk assessment for the development of remediation goals under the CERCLA style assessment used for the Estuary. Some effects concentrations or doses that effect as little as 20 percent of the population, which is generally used as a conservative default threshold level for population-level effects, were also considered in the toxicity assessment for completeness.

The ecological toxicity assessment considered toxicity reference values (TRVs) used at multiple large sediment sites with mercury contamination across the United States. These similar sites also underwent multiple levels of review by federal and state agencies together with study groups/panels for agreement on the use of these TRVs. The values and the logic behind their use were considered in the selection of the final TRV values for risk quantification for the Estuary. Some of these TRVs were used directly from the other assessment sites. For others, TRVs were developed from a compilation of appropriate and relevant studies to calculate a geometric mean value. The use of geometric mean TRVs considers the potential for a population-level effect. A TRV for a single toxicity study may be too specialized or focused on one sensitive or insensitive species, exposure route, or dosing regime and, thus, may not be strictly applicable on a population-level basis. The geometric mean of a group of TRVs allows for the TRV to be informed by multiple studies, and accounts for the variability in toxicity across numerous toxicity studies without allowing one study to bias remediation goal development.

The risk and exposure methodology focused on parameters that could be used to estimate a remediation goal in sediment, which is the primary reservoir for mercury in the Estuary. Although the risk assessment provides quantification of risk to human and ecological receptors, the ultimate goal for the document is to identify appropriate exposure and toxicity input parameters for the back calculation of remediation goals for the Estuary that are based on acceptable potential risk levels. The remediation goal for sediment has been estimated through the use of trophic level-specific surrogate species through the use of site-specific BSAFs and BAFs developed to represent other trophic level species. This approach addresses potential data gaps for individual species lacking bioaccumulation factors.

BSAFs and BAFs address potential data gaps in the sampling of trophic levels because the concentrations in the biota and sediment (or other biota) are compared using a ratio of the concentration in tissue with the concentration in either prey tissue or sediment. Bioaccumulation can be calculated between each trophic level or as a combination of trophic levels, where necessary. For example, a BSAF for mummichog relates mercury concentrations in sediment to mercury concentrations in mummichog, accounting for the pathways by which mercury moves from sediment to mummichog. If mummichog consume zooplankton and invertebrates, then the mercury tissue concentrations in mummichog are the integration of mercury from both these prey items in relation to the sediment concentrations within the home range of the mummichog. Thus, the BSAF accounts for bioaccumulation through the prey items (zooplankton and invertebrates) in the BSAF ratio.

In developing sediment remediation goals, it is necessary to identify which trophic level requires the highest level of reduction in sediment concentration. By doing so, the sediment remediation goals identified can achieve mercury exposure levels for biological resources that are predicted to prevent adverse effects. For example, human receptors may ingest a wide variety of fish and shellfish that are exposed to mercury from the sediment, resulting in accumulation of varying concentrations within the tissues. While it may be possible for risk quantification to include combinations of fish and shellfish types with varying mercury concentrations, recent data representative of current conditions within the system are not available for a large number of fish and shellfish types. To address this data gap, data from representative surrogate receptors based on biota type and trophic level were used (e.g., tomcod for trophic level 3 and eel for trophic level 4 species [e.g., predatory fish]).

Through the use of surrogate/representative receptors, the risk quantified for the eel was assumed to be representative of risk for other trophic level 4 fish species. The eel is a reasonable surrogate for other trophic level 4 species, that are present in the Estuary, and may be consumed by people. Species listed as being recreationally harvested from the Estuary include the striped bass, bluefish, Atlantic mackerel, Atlantic cod, haddock, and pollock; however, site-specific data are either lacking or non-existent for these other marine trophic level 4 species in the Estuary. Using data collected for eel allows for estimation of remediation goals for trophic level 4 fish species. Similar remediation goal estimation was performed for trophic level 3 species using data collected for tomcod. This surrogate receptor approach was used throughout the estimation of sediment remediation goals for fish, shellfish, mammals, and birds.

Quantifying exposure through ingestion of a mixture of fish and shellfish species requires many assumptions with attending uncertainties that may be less conservative than the exposure estimated for the ingestion of individual trophic levels of fish that was performed in this assessment. Quantification of exposure through ingestion of a mixture of fish and shellfish species may underestimate the sediment remediation goal. Thus, risk quantification in this assessment was performed on a trophic level basis.

In regards to the tissue-based remediation goals, sediment and biota mercury concentrations can be connected a number of different ways, two of which are used in the risk assessment and sediment preliminary remediation goal (PRG) development. The two ways to connect sediment and biota concentrations are: 1) calculate a biota to sediment ratio, also known as BSAF and 2) calculate the bioaccumulation of mercury through ingestion of prey and sediment via a dietary model. For either of these methods, a number of inputs are necessary:

- Co-located sediment and biota tissue mercury concentrations,
- Toxicity values based on body burden (i.e., tissue concentrations) or ingestion, and
- Measured prey concentrations or
- BAFs to predict predator concentrations from prey concentrations or
- BSAFs to predict prey concentrations from sediment concentrations.

Sediment and prey item concentrations were used in the dietary model to estimate the daily dietary intake or exposure for a receptor. These dietary intakes were compared to dietary toxicity values from literature to determine whether biota are potentially at risk from bioaccumulation of mercury. Biota tissue concentrations collected at the site were also compared to body burden toxicity values from literature to determine whether biota are potentially at risk from bioaccumulation of mercury. Once the potential for risk has been estimated, a sediment PRG was calculated to guide the risk management decision process for the selection of an appropriate remedial alternative. The sediment PRG was back-calculated based on the receptor-specific BSAFs and prey item-specific BAFs developed for the site.

After sediment PRGs have been calculated for each biota tissue and ingestion scenario for both humans and biota, riverine and marsh sediment PRGs were selected to guide and evaluate remediation alternatives. Coupled with these remedial alternatives are recommendations for implementing a long-term (or post-remediation) monitoring (LTM) program. The LTM program can be implemented to collect data that will supplement the current dataset, creating a more robust dataset for statistical analysis. Throughout the LTM program, co-located biota and sediment samples can be collected to periodically update and strengthen the BSAF and BAF relationships and to verify that the sediment PRGs adopted initially remain appropriate to achieve target tissue concentrations. The new data can be used to verify if biota tissue concentrations are decreasing as projected or whether additional work should be conducted through adaptive management. Under the adaptive management framework, the PRGs can be revisited with the more robust dataset with increased statistical power to further evaluate sediment PRGs and their ability to achieve target tissue concentrations. If a reduction in sediment concentrations via remediation does not result in a concurrent reduction in biota tissue concentrations, then potential remedial alternatives can be revisited. Subsequently, the adaptive management framework can be used to collect additional data to support the design of additional remedial actions.

Uncertainties were inherent in the risk assessment process and in the development of PRGs. The primary uncertainty was associated with the amount of data collected (i.e., has enough data been collected to support the conclusions?). Sufficient data is necessary in order to accurately estimate the potential for food chain bioaccumulation into higher trophic level organisms and to select appropriate toxicity values for the evaluation of exposure and risk. Because of these uncertainties, future identified data gaps can be addressed through LTM and the adaptive management framework, which would include the collection of additional collocated sediment and biota samples. Also, given the uncertainty in the selection of toxicity values, an avian reproduction study could be conducted after sediment remediation is completed with appropriate surrogate species that would serve to verify that the selected sediment PRGs are appropriate and are providing long-term protection of avian receptors. These types of careful collections could document the achievement of goals for human consumption through biota tissue collection and the achievement of ecological goals through toxicity testing. This process is typical of large sediment projects around the country and is consistent with the typical remedial investigation, feasibility study, remedial action, and long-term monitoring process utilized for environmental remediation projects under the direction of numerous state and federal agencies.

ES.2 HUMAN HEALTH RISK ASSESSMENT

Results of the HHRA will support risk managers by providing a point of reference for evaluation of the current risks and for quantification of risk reduction that can be achieved by each remedial alternative considered in the Alternatives Evaluation Report. The HHRA was completed using methodologies developed by the United States Environmental Protection Agency (EPA) and the Maine Department of Environmental Protection (MEDEP).

Released inorganic mercury adsorbs to sediment, is methylated by natural environmental processes, and bioaccumulates within the biotic food chain. As a result, the majority of mercury measured in biota is methyl mercury. Consistent with EPA and Maine Department of Environmental Protection risk assessment guidance, exposures to inorganic mercury and methyl mercury, the constituents of potential concern for the Penobscot River Phase III Engineering Study, were quantified to characterize risk from the consumption of local biota by adult and younger child local consumer. Local consumers are defined as those individuals who consume locally-caught shellfish, finfish, and duck as part of their diet. Note that risk was characterized for both methyl mercury and inorganic mercury as part of the overall evaluation of total mercury exposure via consumption of local biota. While inorganic mercury is not likely to be at levels of concern, risk from exposure to inorganic mercury should be quantified.

Human exposure to the two constituents of potential concern is associated with neurobehavioral effects of developmental exposure and may be a risk factor for autoimmune effects. Exposure to inorganic mercury and methyl mercury are not associated with carcinogenic health effects. Noncancer hazard quotients for systemic effects were estimated for both receptor groups for the consumption of the following representative species: American lobster (trophic level 3), blue mussels and soft-shell clams (trophic level 2), rainbow smelt and Atlantic tomcod (trophic level 3), American eel (trophic level 4) and American black duck (trophic level 3).

The results of the quantitative human health risk assessment indicated the following:

- For the local consumer, the noncarcinogenic hazard from exposure for both inorganic mercury and methyl mercury in tissue did not exceed acceptable hazard levels for ingestion of the American lobster, blue mussels, soft-shell clams, rainbow smelt, Atlantic tomcod, and American black duck.
- For the local consumer, the noncarcinogenic hazard from exposure to methyl mercury in the American eel tissue exceeded a target (hazard quotient) (HQ) of 1. However, the noncarcinogenic hazard from ingestion of inorganic mercury in the American eel tissue did not exceed acceptable hazard levels.
- When evaluated by species and sample location, risk from exposure decreases from north to south, from samples taken near the former chlor-alkali plant to those samples in Penobscot Bay.

Based on the above results, it can be concluded that noncarcinogenic hazard to human health from methyl mercury in the Estuary under both current and future use scenarios exceeds an acceptable noncarcinogenic hazard for consumption of American eel. However, noncarcinogenic hazard from inorganic mercury does not exceed acceptable noncarcinogenic HQs for consumption of multiple species of biota.

As part of the development of remedial options, tissue PRGs were developed on a receptor- and biota-specific basis. Tissue PRGs were developed for the local consumer. The fish tissue action level for methyl mercury of 200 nanograms per gram (ng/g) set by the Maine Center for Disease Control and Prevention (MeCDC) was also used for tissue PRGs. The results of the tissue PRG development indicated the following:

- The tissue PRGs for the MeCDC fish tissue action level are lower than tissue PRGs for the local consumer.
- When calculated biota-specific tissue PRGs are compared to background levels, it was observed that, for the American eel, background levels in eel tissues should be considered when evaluating cleanup levels.
- Reported biota concentrations of total mercury in the Estuary are generally less than the risk-based tissue concentrations for local consumer receptors, with the exception of some reported concentrations in American eel tissue.

ES.3 BASELINE ECOLOGICAL RISK ASSESSMENT

Ecological risk assessment addresses the likelihood that adverse effects on the environment, and to specific ecological receptors, may occur or are occurring as a result of exposure to one or more stressors. The purpose of the BERA was to assess potential mercury-related risks within the Estuary on local ecological receptor populations. Results of the BERA will support risk managers by providing a point of reference for evaluation of current risks and for quantification of risk reduction that can be achieved by each remedial alternative to be considered in the Alternatives Evaluation Report. Site-specific data, primarily collected between 2016 and early 2018, were used in the BERA to represent current/baseline conditions at the site, which will be used in the quantification of risk reduction for the Estuary. Risk was characterized for the following assessment endpoints:

1. Survival, growth, and reproduction of aquatic invertebrates;
2. Survival, growth, and reproduction of forage and predatory fish;
3. Survival, growth, and reproduction of wetland-dependent birds;
4. Survival, growth, and reproduction of piscivorous birds; and
5. Survival, growth, and reproduction of piscivorous mammals.

Multiple lines of evidence were used in the BERA to assess potential risk for representative receptors. Mercury concentrations in surface water, sediment, prey tissue, and receptor tissue accumulated through exposure were evaluated to characterize risk using toxicity reference values for mercury associated with direct contact with surface water, food web exposure, and body burden (i.e., tissue accumulation). The results of the BERA are as follows:

- ***Assessment Endpoint 1*** (survival, growth, and reproduction of aquatic invertebrates) risk estimates were performed for total mercury in surface water and tissue residues of blue mussels and tissues residues of American lobster in the Estuary. There is no unacceptable risk based on blue mussel surface water exposure. There is the potential for unacceptable risk to blue mussels based on total mercury tissue NOAEL- and LOAEL-based HQs at or above 1.0. There is no unacceptable risk for the American lobster based on tissue body burdens.
- ***Assessment Endpoint 2*** (survival, growth, and reproduction of forage and predatory fish) risk estimates were performed for mercury in tissue residues and food web modelling for forage fish (mummichog and rainbow smelt) and predatory fish (Atlantic tomcod and American eel). There is no unacceptable risk to forage fish based on tissue body burdens or dietary exposure of total mercury or methyl mercury in the Estuary. Unacceptable risk is possible for predatory fish based on tissue total mercury and methyl mercury NOAEL HQs, but unlikely based on tissue LOAEL HQs below 1.0 which are based on tissue mercury body burdens using a population-level EC20 for reproduction and survival as the LOAEL TRV. There is no unacceptable risk to predatory fish based on dietary exposure to mercury in the Estuary.
- ***Assessment Endpoint 3*** (survival, growth, and reproduction of wetland-dependent birds) risk estimates were performed for mercury in tissue residues and food web modeling for marsh songbirds (represented by the Nelson's sparrow and red-winged blackbird) and aquatic birds (represented by the American black duck) at the Estuary. Blood NOAEL- and LOAEL-based HQs for total mercury and methyl mercury were above 1.0 for marsh songbirds, indicating potential for adverse effects. There is also the potential for unacceptable risk from dietary exposure to mercury for Nelson's sparrow and red-winged

blackbirds based on total mercury and methyl mercury NOAEL HQs equal to or above 1.0, but LOAEL-based HQs were below 1.0. There is the potential for unacceptable risk to aquatic birds based on blood total mercury and methyl mercury NOAEL HQs above 1.0, as well as from dietary exposure to mercury based on a total mercury NOAEL HQ above 1.0, but LOAEL-based HQs were below 1.0.

- ***Assessment Endpoint 4*** (survival, growth, and reproduction of piscivorous birds) risk estimates were performed for mercury in tissue residues and food web modeling for piscivorous birds (represented by the belted kingfisher and the bald eagle) at the Estuary. There is no unacceptable risk to piscivorous birds based on dietary exposure to mercury in the Estuary. Although blood mercury data for piscivorous birds indicates exceedances of the blood LOAEL TRV and elevated egg mercury data, these data are between 6 and 12 years old and might not be considered representative of current site conditions in the Estuary.
- ***Assessment Endpoint 5*** (survival, growth, and reproduction of piscivorous mammals) risk estimates were performed for mercury using food web modeling for piscivorous mammals (represented by the mink). There is no unacceptable risk to mink based on dietary exposure to mercury in the Estuary.

Based on the results of the BERA, there is the potential for unacceptable risk to several receptors because body burdens (i.e., blood concentrations) and/or dietary exposure NOAEL HQs are above 1.0. However, the only receptors with LOAEL HQs above 1.0 are the Nelson's sparrow and red-winged blackbird. When the NOAEL HQs are ≥ 1.0, but the LOAEL HQs are < 1.0, ecologically significant adverse effects to that receptor are possible as the threshold for effects is assumed to be between the NOAEL and LOAEL. There is uncertainty associated with defining the true toxicity threshold, so adverse effects are considered possible. A LOAEL-based HQ ≥ 1.0 indicates potential for adverse effects. There is potential for risk to marsh songbirds due to mercury exposure in the Estuary based on NOAEL and LOAEL HQs > 1.0.

ES.4 SEDIMENT PRELIMINARY REMEDIATION GOALS

For the purposes of developing long-term remedial options, risk-based sediment PRGs for mercury were developed. The PRGs were based on food web modeling and bioaccumulation modeling using target tissue levels for both human and ecological receptors. PRGs were calculated using a weight of evidence approach, involving multiple lines of evidence. Sediment PRGs were calculated using three different approaches:

- Food web modeling tissue-based approach
- Biota-sediment accumulation factor (BSAF) tissue-based approach
- Food web modeling dietary-based approach

Sediment PRGs were calculated for human health using food web modeling and BSAF tissue-based approaches. Human health-based sediment PRGs were also calculated for two different scenarios: the local consumer and the MeCDC fish tissue action level for finfish consumption.

Sediment PRGs were calculated for ecological receptors using food web modeling and BSAF tissue-based approaches, as well as the dietary-based approach. The sediment PRGs were developed for total mercury and methyl mercury, using site-specific and species-specific BSAFs and biota-biota (i.e., predator-prey) accumulation factors (BAFs). BSAFs/BAFs provide insight into conditions driving bioaccumulation within a system and can be used to gauge the potential success of a remedy. BSAFs/BAFs were developed using data primarily collected between 2016 and winter 2018.

ES.4.1 Background Concentrations of Mercury in Sediment

In order to evaluate and select sediment PRGs that are based on current site conditions and protective of human health and the environment, concentrations of sediment representative of background or reference locations were compiled. Sediment samples collected in upstream areas were designated as representative of background conditions in the Estuary. Using this data set, statistical parameters including upper tolerance limits, upper prediction limits, and percentiles were calculated using EPA's ProUCL software (EPA 2016). The resulting statistical background threshold values ranged from 82 ng/g to 180 ng/g for total mercury and 1.43 to. 4.71 for methyl mercury. Sediment background threshold values of 115 ng/g for total mercury and 3.51 for methyl mercury were calculated for the Estuary. Both the total and methyl mercury background values were based on a 95 percent upper tolerance limit. Proposed PRGs should not be established at or below background concentrations because these values would be technically impractical to achieve, given the likelihood of sediment migration and redistribution.

ES.4.2 Sediment Preliminary Remediation Goal Development

Both ecological and human health sediment PRGs were developed. Human health sediment PRGs were developed for two scenarios: the local consumer and the fish tissue action level set by MeCDC. The bioactive zone in estuarine and freshwater tidal environments, like the Penobscot system, is typically 10 to 15 cm (4 to 6 inches); while marine environments tend to have a shallower bioactive zone (5 to 10 cm) (EPA 2015). The proposed sediment PRGs are applicable to sediments within the bioactive zone for estuarine environments.

ES.4.2.1.1 Ecological Preliminary Remediation Goals

Methods

Tables IV.4-1 and **IV.4-2** and **Figures IV.4-1** and **IV.4-2** present the ecological sediment PRGs by receptor and approach for total mercury and methyl mercury, respectively. With the exception of the rainbow smelt, the dietary-based method used to derive sediment total and methyl mercury PRGs resulted in uniformly higher PRG values for the common receptors. For this reason, the dietary-based method was removed from consideration for the final ecological PRGs.

The total mercury and methyl mercury BSAF and food web PRGs were consistent and within a factor of two of each other. The total and methyl mercury BSAF PRGs were lower for Nelson's sparrow, lobster, and Atlantic tomcod, and higher for American black duck by a factor of almost two. Given the difference in the methods, which includes species-specific and area-specific bioaccumulation data, it is reasonable to combine the two methods for consideration of the final PRGs. As such, the following discussion of PRGs is based on the geometric mean of the two tissue-based approaches.

Location-Specific Ecological Sediment Preliminary Remediation Goals

Exposure and hazards were noted to differ by location. To address the habitat and exposure differences, habitat-specific PRGs were calculated for the marsh and intertidal zones (ecological receptors including Nelson's sparrow, red-winged blackbird, and American black duck) and subtidal zones (ecological receptors including finfish and aquatic invertebrates or shellfish). Although finfish and shellfish are also exposed to intertidal sediments, sediment exposure for these receptors are quantified under subtidal sediments, but final PRG selection accounts for sediment exposures from intertidal and subtidal zones.

Marsh and Intertidal Zones: The total and methyl mercury sediment PRGs for marshes and intertidal zones were calculated for marsh songbirds and the American black duck. Sediment total mercury PRGs range between 411 ng/g and 2,693 ng/g with a geomean for marsh and intertidal receptors of 788 ng/g. Sediment methyl mercury PRGs range between 9.1 and 62.7 ng/g with a geomean for marsh and intertidal receptors of 18.1 ng/g (**Table IV.4-3**).

Subtidal Ecological Sediment Zones:

The total and methyl mercury sediment PRGs for subtidal zones were calculated for finfish and shellfish. Subtidal sediment total mercury PRGs range between 731 ng/g and 4,750 ng/g, and subtidal sediment methyl mercury PRGs range between 21.2 and 101 ng/g (**Table IV.4-3**).

ES4.2.1.2 Human Health Preliminary Remediation Goals

Methods

Tables IV.4-1 and **IV.4-2** and **Figures IV.4-3** through **IV.4-6** present the human health sediment PRGs by receptor and approach for total mercury and methyl mercury, respectively. The total and methyl mercury tissue concentrations (ng/g) used as the target levels for the receptors are provided in **Tables IV.2-1** and **IV.2-2**. These values are the tissue concentrations of total and methyl mercury equal to the HQ of 1 or equal to the MeCDC fish tissue action level. The highest to the lowest health-based tissue concentrations are for the local consumer followed by the MeCDC fish tissue action level. The corresponding wide range of sediment PRGs are the result of the approach (food web or BSAF), as well as the consumption assumptions used for each scenario (local consumer and MeCDC fish tissue action level) and age of receptor (child or adult).

The total and methyl mercury sediment PRGs are consistent with each other and within a factor of approximately 2.5 for total mercury and within a factor of approximately 3.1 for methylmercury across the varying exposure scenarios using the food web and BSAF methods. The higher sediment PRGs for total mercury varied by receptor between the two approaches; whereas, the food web sediment PRGs for methyl mercury were consistently higher than the BSAF sediment PRGs for methyl mercury. Given the difference in the methods, which includes species-specific and area-specific bioaccumulation data, it is reasonable to combine the two methods for consideration of the final PRGs. As such, the following discussion of PRGs is based on the geometric mean of the two tissue-based approaches. In addition, the more stringent age of receptor (i.e., child exposure PRGs) were considered for the final PRGs and are discussed below.

Local Consumer Sediment PRGs

The sediment PRGs based on the local consumer are summarized in **Tables IV.4-1** through **IV.4-3** and **Figures IV.4-3** through **IV.4-6**. Similar to the ecological PRGs, habitat-specific human health PRGs were calculated to address the habitat and exposure differences. Marsh and intertidal zone PRGs are based on the ingestion of American black duck, and subtidal zones PRGs are based on ingestion of finfish and shellfish. Although finfish and shellfish are also exposed to intertidal sediments, sediment exposure for these receptors are quantified under subtidal sediments, but final PRG selection accounts for sediment exposures from intertidal and subtidal zones.

Marsh and Intertidal Human Health Sediment PRGs: Because of the habitat characteristics of the marsh, the American black duck was the only human health receptor applicable to marsh sediments. The marsh and intertidal sediment total mercury PRG is 596 ng/g and the methyl mercury PRG is 16.5 ng/g for the black duck based on exposure to the local consumer (**Table IV.4-3**).

Subtidal Human Health Sediment PRGs: The total and methyl mercury sediment PRGs for subtidal zones were calculated for finfish and shellfish. Subtidal sediment total mercury PRGs range between 612 ng/g and 9,189 ng/g, and subtidal sediment methyl mercury PRGs range between 8.22 and 172 ng/g based on exposure to the local consumer (**Table IV.4-3**).

MeCDC Fish Tissue Action Level Sediment PRGs

The sediment PRGs calculated based on the MeCDC fish tissue action level are summarized in **Tables IV.4-1** through **IV.4-3** and **Figures IV.4-3** through **IV.4-6**. It should be noted that sediment PRGs calculated for lobster, blue mussels, and American black duck use the MeCDC fish tissue action level for freshwater finfish of 200 ng/g. However, the action level was only meant to apply to sport fishing and was not developed with lobster, blue mussel, and American black duck tissue consumption in mind. The adult finfish consumption rate utilized for the MeCDC fish tissue action level is based on a consumption rate of one 8-ounce fish meal per week (52 meals per year or 32.4 grams/day) (MeCDC 2001), which is above the local consumer consumption rates for lobster (6-7 meals per year or 1.7 grams/day) (Cooper et al. 1991), blue mussel 1-2 meals per year or 0.272 grams/day) (Cooper et al. 1991), and duck (24 meals per year or 14.9 grams/day) (MDIFW, 2017a), indicating that the use of sediment PRGs based on the MeCDC fish tissue action level for freshwater finfish potentially overestimates the consumption of non-finfish species.

Marsh and Intertidal MeCDC Fish Tissue Action Level-Based Sediment PRGs: The sediment total mercury PRG is 283 ng/g and the methyl mercury PRG is 7.87 ng/g for marsh and intertidal sediments based on the consumption of American black duck using the MeCDC fish tissue action level (**Table IV.4-3**).

Subtidal MeCDC Action Level-Based Sediment PRGs:

The MeCDC fish tissue action level-based sediment PRGs for subtidal zones range between 410 ng/g and 3,580 ng/g for total mercury and between 9.29 and 118 ng/g for methyl mercury based on the consumption of finfish and shellfish (**Table IV.4-3**).

ES4.3 Proposed Sediment PRG Summary

The total and methyl mercury sediment PRGs must be protective of the array of human and ecological receptors identified in this report for the Estuary. Proposed PRGs should not be established at or below background concentrations, which have been calculated as 115 ng/g for total mercury and 3.51 ng/g for methyl mercury, because these values would be technically impractical to achieve given the likelihood of sediment migration and redistribution. In addition, while some portion of the sediment in estuaries is in either periodic or continuous motion, much of the sediment in estuaries is deposited on the sediment bed or (if present) within adjoining marshes, either within marsh channels or on marsh platforms. Overall, with respect to sediment mobility in estuaries, sediment resuspension and mixing occur on the time scale of days (i.e., flood versus ebb tides), weeks (i.e., spring versus neap tides) and seasons (i.e., movement of the salt wedge as the result of seasonal variation in the magnitude of freshwater discharge), as well as in response to storm events that can increase erosive forces in both the subaerial and subaqueous parts of an estuary. This combination of forces - on different time scales and with different magnitudes of impact - suggests that material available for resuspension and transport: (1) is bedded through at least a portion of these different cycles; and (2) originates in both the subtidal (i.e., continuously submerged) and intertidal (alternately submerged and subaerially exposed) portions of the system. When marsh platforms are inundated, this mixed and resuspended material can be transported onto marsh platforms and deposited. Based on this understanding of the conceptual site model for the Estuary, in order for marsh and intertidal sediments to achieve the sediment remediation goal, the same sediment remediation goal should also be applicable to subtidal sediments.

Sediment PRGs based on the most sensitive human and ecological receptors are presented in **Figures IV.4-7** and **IV.4-8** and are summarized in the table below. Because these PRGs are based on the most sensitive receptors for human and ecological health, the proposed ecological- and human health-based total and methyl mercury sediment PRGs would also be protective of other important ecological receptors, including the belted kingfisher, bald eagle, and mink (**Table IV.3-1**).

Receptor and Calculated PRG Basis	Total Hg (ng/g)	MeHg (ng/g)
Most sensitive ecological receptor for marsh/intertidal zone:		
- Marsh songbirds	411 – 442	9.1 – 10.4
Most sensitive ecological receptor for subtidal zone:		
- Blue mussels	731	55.9
Most sensitive human health receptors for marsh/intertidal zone:		
- Local Consumer – black duck	596	16.5
- MeCDC Action Level – black duck	283	7.87
Most sensitive human health receptors for subtidal zone:		
- Trophic Level 3 Shellfish - Lobster (MeCDC Action Level)	518	9.29
- Trophic Level 4 Finfish – American eel (MeCDC Action Level)	410	9.41
Geomean of combined human health and ecological receptors:	511	13
- Local Consumer PRGs – black duck	596	16.5
- MeCDC Action Level PRGs – black duck	283	7.87
- Ecological PRGs – black duck and marsh songbirds	788	18.1

Based on the above evaluation, the following range of PRGs (rounded based on the above values) are proposed for evaluation in the Alternatives Evaluation Report based on scenario. These PRGs are protective of both ecological and human (local consumer and MeCDC fish tissue action level) receptors:

- Total Mercury: 300 to 500 ng/g for the marsh platform, intertidal, and subtidal sediments, and
- Methyl mercury: 8 to 10 ng/g for the marsh platform, intertidal, and subtidal sediments.

The proposed sediment PRGs are applicable to all sediments within the bioactive zone for estuarine environments. The lower end of the PRG ranges represent PRGs to meet the MeCDC fish tissue action level, while the upper end of the ranges represent PRGs protective of ecological risk and the local consumer. These PRGs are proposed for the Estuary as a means to measure remedy effectiveness and risk reduction in the Phase III Alternatives Evaluation Report. The Alternatives Evaluation Report and the Phase III Engineering Study Report will provide information on the feasibility and cost of potential remedies. After review of this information, it is assumed that the Court will make risk management decisions relative to the final PRGs to be used in the cleanup of the Estuary mercury, and as to the remedies to be implemented.

PART I

INTRODUCTION

1.0 INTRODUCTION

In January 2016, the United States District Court for the District of Maine (the Court) selected Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) to conduct the Penobscot River Phase III Engineering Study (Phase III Engineering Study), to identify and evaluate feasible, effective, and cost-effective measures to remediate mercury in the Penobscot River Estuary (the Estuary). The project area is shown on **Figure I.1-1**. The geographic area to be addressed within the Phase III Engineering Study is described by the Court as follows: *"The evaluation will focus in particular on the region from the site of the former Veazie Dam south to Upper Penobscot Bay, including Mendall Marsh and the Orland River."*

This Penobscot River Risk Assessment and Preliminary Remediation Goal Development is part of the Phase III Engineering Study. It presents the Baseline Human Health Risk Assessment (HHRA) and Baseline Ecological Risk Assessment (BERA) evaluating current conditions for the Penobscot River (the site). Baseline risk assessments evaluate the potential threats to human health and the environment, aid in determining whether remedial action is needed, and serve as the basis for the evaluation of the effectiveness of any subsequent remedial action. The HHRA and BERA will be used to identify areas of remedial focus and assist with decision making in future phases of the project. The HHRA and BERA will serve as the baseline in the quantification of risk reduction for the Penobscot River. This report also includes the development of risk-based mercury preliminary remediation goals (PRGs) protective of both human health and ecological receptors.

The Penobscot River in northern Maine is the second-largest river in New England. The Estuary has a surface area of approximately 90 square kilometers (35 square miles) and extends 35 kilometers (22 miles) southward from Bangor, Maine to about Searsport, Maine, with Penobscot Bay extending farther south (**Figure I.1-1**). A chlor-alkali plant located in Orrington, Maine released mercury into the Penobscot River starting in 1967. The amount of mercury released annually decreased between 1970 and 1982, and decreased further when the plant was closed in 2000.

Elevated concentrations of methyl mercury measured in sediments and biota led to legal action by the Maine People's Alliance in 2000. This group joined with the Natural Resources Defense Council (NRDC) to bring a lawsuit, pursuant to the imminent and substantial endangerment provision of the Resource Conservation and Recovery Act, against HoltraChem Manufacturing Company, LLC (HoltraChem) and Mallinckrodt, Inc. The Court ordered an independent scientific study in July 2002, later named the Penobscot River Mercury Study (PRMS), and the Penobscot River Mercury Study Panel PRMSP]) to complete the PRMS. The PRMSP monitored mercury levels in sediment, surface water, and various biota between 2006 and 2012 (PRMSP 2013a). In addition, hydrodynamics, sediment deposition and recovery rates, mercury and sediment transport and mass balances, and food webs were among the topics evaluated by the PRMSP. In particular, the PRMSP commissioned extensive literature reviews to establish toxicity thresholds for species of concern in the Estuary. The Phase II report concluded that there was a potential for elevated levels for risk for some bird species living in Mendall Marsh and other contaminated marshes in the Estuary as well as to humans that consume lobster, ducks, and eels from the upper Estuary.

Based on the results of the PRMS, the court ruled that "the mercury contamination of the Penobscot River estuary caused by Mallinckrodt continues to 'present an immediate and substantial endangerment to health and to the environment,'" and that "the Penobscot River estuary continues to suffer irreparable injury from ongoing mercury contamination caused by Mallinckrodt." Furthermore, the Court concluded that "it is essential for an engineering firm to investigate the current status of mercury contamination in the Penobscot River and to propose potential solutions to mitigate the current harm to the people, biota, and environment of the Penobscot River estuary." Based on the Court's order, the Phase III Engineering Study was initiated in January 2016.

Under the Phase III Engineering Study, Amec Foster Wheeler conducted monthly surface water monitoring in 2016, co-located sediment data collection in 2016 and 2017, and biota monitoring in 2016 and 2017. In addition, a thin interval core sampling program, biota-sediment accumulation factor evaluation, hydrodynamic simulation study, leachability bench-scale testing study, toxicological study, dewatering study, sediment bed erosion study, and marsh platform amendment plot re-sampling study were all undertaken as part of the Phase III Engineering Study. The 2016 and 2017 biota monitoring events continued the monitoring conducted primarily between 2006 and 2012 in the PRMS. The HHRA, BERA, and PRG development incorporate abiotic and biotic media primarily collected in the Estuary and selected reference areas between 2016 and early 2018 (Amec Foster Wheeler 2017a, 2017b, 2018a, 2018b, 2018c).

PART II

BASELINE HUMAN HEALTH RISK ASESSMENT

1.0 INTRODUCTION

This HHRA addresses the likelihood of adverse effects to human health due to the consumption of locally harvested seafood and waterfowl by local consumers. The purpose of this HHRA is to assess potential mercury-related risks within the Estuary on the local human population. Results of the HHRA will support risk managers by providing a point of reference for evaluation of the no-action alternative, through development of protective tissue PRGs, and for quantification of risk reduction that can be achieved by each remedial alternative considered in the Phase III Engineering Study.

The risk management decision in question is for the selection of biota concentrations that would allow for the safe consumption of each biological resource. The risk management decision question could be answered in two ways: 1) meeting PRGs for tissue based on risk assessment guidance or 2) meeting the Maine Center for Disease Control and Protection (MeCDC) freshwater fish tissue action level of 200 ng/g. In Part IV, tissue PRGs derived during the HHRA are used to quantify sediment PRGs for both these potential risk management decision points.

In developing fish advisories, the MeCDC has derived fish tissue action levels for the consumption of finfish only (MeCDC 2001). In conversations with MeCDC, MeCDC indicated that the fish tissue action level was only meant to apply to sport fishing, and was not developed with lobster, shellfish, and duck consumption in mind. However, the Maine Department of Marine Resources applied the MeCDC fish tissue action level when designating the lobster closure areas in the southern portion of the Estuary. Nonetheless, the mass of tissue ingested by humans varies by the type of species, and the application of the MeCDC fish tissue action level is used in the risk assessment with this consideration in mind.

While this project is not under CERCLA rules and requirements, the HHRA methodology follows the United States Environmental Protection Agency (EPA) Risk Assessment Guidance for Superfund Parts A, B, and D (EPA 1989, 1991, and 2001) and other relevant EPA guidance, including the EPA Exposure Factors Handbook (EPA 2011). A screening step to determine constituents of potential concern (COPCs) was not performed as a component of the risk assessment, as mercury and methyl mercury were previously identified as the COPCs for the Estuary (PRMSP, 2013a).

2.0 DATA EVALUATION

For the human health risk assessment, biota data include the two most recent years of data collected as part of the on-going monitoring plan. The years of collection are species-dependent and are as follows:

- Lobster (tail tissue) – 2016 and 2017
- Blue Mussel (whole body) – 2016 and 2017
- Soft-Shell Clam (whole body) – 2008 and 2009
- Rainbow Smelt (whole body) – 2016 and 2017
- Atlantic Tomcod (fillet) – 2016 and 2017
- American Eel (fillet) – 2016 and 2017
- American Black Duck (muscle) – 2014 and 2017-2018

Each species was selected based on available data and to be representative of a class of consumable biota (i.e., lobster, shellfish, finfish, and duck). These biota species are meant to be representative of classes of species based on species type and trophic level, and not as an individual biota type. Data are available for total mercury, which includes both organic and inorganic mercury, for each of the above receptors. Furthermore, samples for each species were taken within areas that have been identified as impacted and as likely sources for local seafood and waterfowl. For shellfish and finfish, methyl mercury concentrations were derived using site-specific, historical methyl mercury to total mercury percentages taken from the Biota-Sediment Accumulation Factor Technical Memorandum (Amec Foster Wheeler 2017c). For lobster, a percent methyl mercury to total mercury of 92 percent was calculated using historic data collected in 2006, 2008, 2009, and 2010 for lobster tail meat only, as opposed to the value of 78 percent presented in the site-specific Biota-Sediment Accumulation Factor Technical Memorandum (Amec Foster Wheeler 2017c), which incorporated tomalley, claw, and whole lobster data. A percent methyl mercury to total mercury of 98 percent was calculated for duck tissue based on samples collected in 2010, 2011, and 2013 the years for which both total and methyl mercury were analyzed for in collected tissue samples.

In addition, the Biota-Sediment Accumulation Factor Technical Memorandum (Amec Foster Wheeler 2017c) indicated that there was a strong correlation between concentrations of total mercury in duck blood and duck muscle tissue. The correlation equation is:

$$\text{muscle mercury (ng/g)} = 0.7956 * \text{blood mercury (ng/g)} + 25.0515$$

Duck blood mercury concentrations are an indication of recent exposure to mercury whereas tissue muscle mercury concentrations represent bioaccumulation of mercury. Because ducks migrate, tissue mercury concentrations are more indicative of a longer time period of exposure including time on the breeding grounds prior to wintering in the Estuary. As such, for the characterization of risk, concentrations of total mercury in duck blood collected during the 2017 and 2018 sampling events were converted to tissue concentrations using the above regression equation. Duck blood and tissue samples were collected in January and/or February of 2017 and 2018 after the ducks had been in the Estuary for several months, reflecting a probable time of higher concentration in the duck tissues, which is a conservative approach.

Inorganic mercury concentrations were derived using the same site-specific historical methyl mercury to total mercury percentages by assuming that any mercury that does not exist in the form of methyl mercury exists as inorganic mercury. However, methyl mercury analytical data was available for soft-shell clams for the years 2008 and 2009, and as such for soft-shell clams both the inorganic and methyl mercury concentrations are based on measured concentrations. For the purposes of assessing baseline risk, total mercury was evaluated as both percentages of inorganic mercury and methyl mercury to total mercury. A summary of the biota data is presented in **Table II.2-1**. Direct contact exposure to inorganic mercury and methyl mercury in surface water and sediment was not evaluated as part of this risk assessment as risk from direct contact so surface water and sediment would be expected to be de minimis.

2.1 Exposure Point Concentrations

For the purposes of this human health risk assessment, the conservative 95 percent upper confidence limit (UCL) on the arithmetic mean for each biota-specific data set was selected as the most appropriate exposure point concentration (EPC). The ProUCL 5.1 software developed by EPA (EPA 2016a) includes statistical methods to address data sets both with and without non-detects, and computes the UCL for a given data set by a variety of alternative statistical approaches (including several approaches that do not require the assumption of normality or log-normality). ProUCL 5.1 then recommends specific UCL values as being the most appropriate for that particular data set. In general, the 95 percent UCL is selected as the EPC for each analyte; however, if the calculated UCL exceeds the maximum detected concentration, then the maximum concentration is substituted as the EPC. For EPCs based on calculated UCLs, the distribution type and specific UCL type selected by the ProUCL software is indicated in the ProUCL output files. Other assumptions made in the calculations of UCLs are as follows:

- Only data deemed usable based on the data validation process were included.
- Only primary samples (no duplicates) were used to calculate EPCs as duplicate samples were analyzed for quality assurance purposes only and are not appropriate for use in the calculation of UCLs.
- In order to be conservative, in cases where more than one UCL was calculated by ProUCL, the greater of the two values was assigned based on best professional judgment. This is a conservative approach and consistent with EPA guidance (EPA, 2016a).

- For datasets with less than five samples, the maximum detected concentration was used as the EPC. This is a conservative approach, consistent with the ProUCL user's guide.

The ProUCL input and output files for each media are presented in **Appendix A** and summarized in **Table II.2-2**.

3.0 EXPOSURE ASSESSMENT

This section identifies the potentially exposed populations (receptors) and possible exposure pathways under current and hypothetical future conditions. Exposed receptors refer to groups of individuals who may be exposed to a chemical or physical agent released into the environment. Potential exposure pathways are those mechanisms by which an exposed receptor could come in contact with impacted environmental media at or originating from the Estuary.

3.1 EXPOSURE SCENARIOS

Potential receptors, exposure pathways, and qualitative/quantitative evaluation methodologies were documented in the conceptual site model in **Figure II.3-1**. As indicated in **Figure II.3-1**, a single receptor population is considered in the HHRA: local consumers of fish and other biota tissue. In addition to the local consumer, there is potential for greater exposure assuming subsistence consumers are present in the population. The subsistence consumer would be an individual who would rely on locally caught finfish, shellfish, and waterfowl as a major component of their diet. However, discussions with the Maine Centers for Disease Control (MeCDC) have indicated that the State of Maine does not consider a non-indigenous subsistence consumer in the development of the fish tissue action level. Furthermore, MeCDC considers that the developed fish tissue action level is protective of sensitive subpopulations, and as such the evaluation of a non-indigenous subsistence consumer is not necessary. Therefore, the calculation of risk from the consumption of locally caught finfish and shellfish was evaluated for local consumers in this BHHRA.

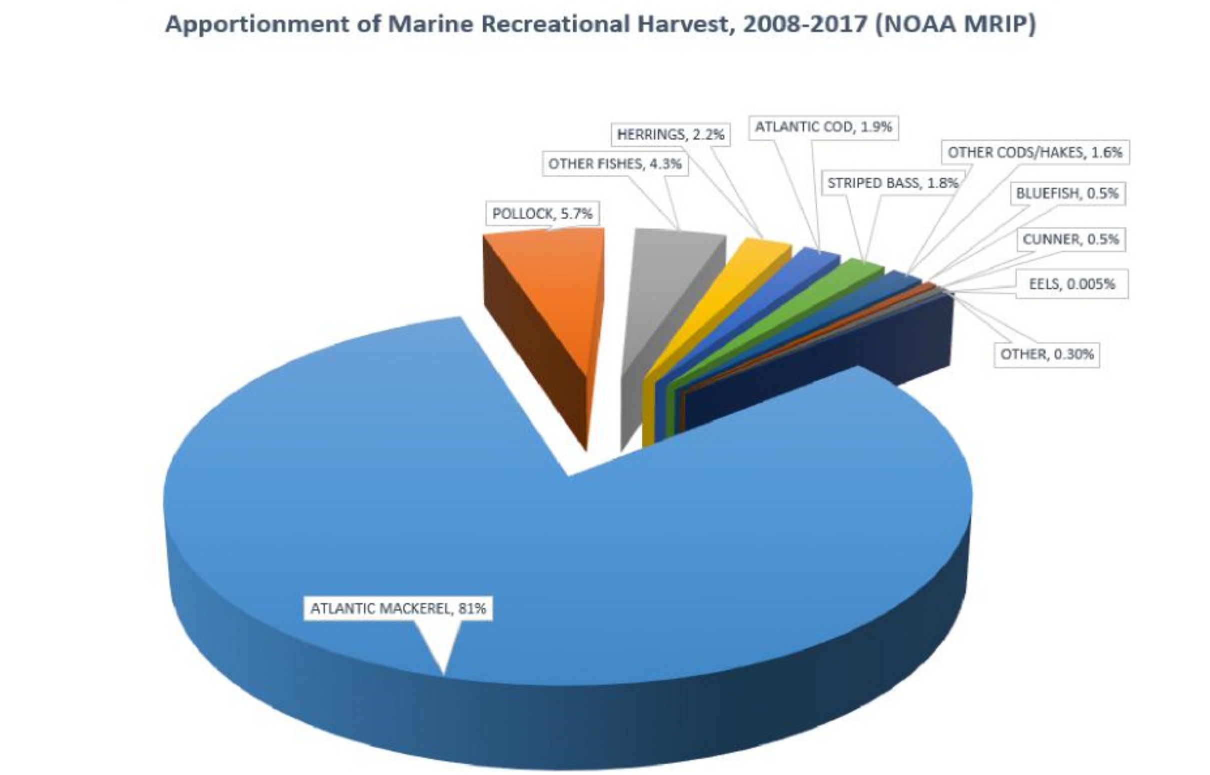
The biota consumption scenarios by local residents assume the ingestion of finfish (catadromous[1] and anadromous[2] fish) from various trophic levels, lobster, shellfish (e.g., clams and mussels), and duck. For each biota type/trophic level, representative species were chosen based on what species could be readily sampled and for some trophic levels multiple species were readily available for sampling in the system. The representative consumable biota species are as follows:

- Lobster (Trophic Level 3)
  – American Lobster
- Shellfish (Trophic Level 2)
  – Blue Mussels
  – Soft-Shell Clams
- Finfish (Trophic Level 3)
  – Rainbow Smelt
  – Atlantic Tomcod

[1] Catadromous fish migrate from freshwater to the sea to spawn (American eel)
[2] Anadromous fish migrate upriver from the sea to spawn (tomcod and rainbow smelt)

- Finfish (Trophic Level 4)
  – American Eel
- Duck (Trophic Level 3)
  – American Black Duck

Note that, while it is unlikely that the American eel would be a large proportion of overall seafood consumption, it is a good representative of an upper-level trophic species. According to the Maine Department of Marine Resources, some of the most popular species landed for recreational consumption include striped bass, bluefish, Atlantic mackerel, Atlantic cod, haddock, and pollock, with American eel being a small (0.025 percent) proportion of the overall marine recreational harvest.[6] With the use of surrogate/representative receptors, risk quantified for the eel is for all



trophic level 4 fish species like striped bass, bluefish, Atlantic mackerel, Atlantic cod, haddock[3], and pollock, which are noted to be a portion of the overall marine recreational harvested fish in Maine. These fish species are at least seasonally present in the Estuary.

Furthermore, the American eel is present and subject to exposure year round, while other upper trophic level species may be seasonally present. Both sea winter flounder and American eel have

[3] Haddock falls under the category of other cods/hakes

been sampled in the Estuary frequently since 2006. The concentrations of total mercury and methyl mercury in both upper trophic level fish are presented in the table below.

Comparison of Concentrations of Total and Methyl Mercury in Trophic Level 4 Fish Tissue

Species	Chemical	Number of Species	Detected Concentration (ng/g)			
			Minimum	Maximum	Average	Median
American Eel	Total Mercury	770	53.3	2,110	491	450
	Methyl Mercury	209	76.7	1,470	470	417
Winter Flounder	Total Mercury	736	9.0	326	57.3	46.3
	Methyl Mercury	86	8.0	113	38.2	35.3

As seen in the table above, the concentrations of total mercury and methyl mercury in winter flounder is roughly an order of magnitude lower than the concentrations reported for the American eel. This is likely due to the fact that American eel is catadromous and spends a portion of its life upstream in fresh water, while the winter flounder lives its entire life in salt water. As such, while the American eel is not commonly consumed, it is an appropriate surrogate for trophic level 4 fish in that it is present year round and is exposed to the entire Estuary, which might be similar to, for example, the striped bass, which should be present except during the winter months.

All of these species contribute to the diet of a local consumers, particularly recreational and commercial anglers. Biota consumption was evaluated separately for adult and child receptors. Age-specific consumption rates were derived for adults and younger children (1–7 years of age) by using the Maine Department of Environment and Protection (MEDEP) assumption (MEDEP 2011) that younger child consumption rates are equal to 30 percent of the adult consumption rates. Children of less than one year of age (i.e., infants) were not evaluated as they were unlikely to consume the evaluated biota as part of their normal infant diet. Note that consumption rates are presented in units of mg/day. The overall consumption of each tissue type, based on a number of meals per year and is averaged over the entire year to develop a daily intake which is then used to derive a daily average dose, as is consistent with EPA guidance (EPA 1989). The overall consumption of each tissue type, based on a number of meals per year and is averaged over the entire year to develop a daily intake which is then used to derive a daily average dose, as is consistent with EPA guidance (EPA 1989). These consumption rates were then applied to representative sampled species that are likely to be consumed by local residents and/or represent a class of biota that is likely to be consumed by local residents.

For the local consumer exposure scenario, the default exposure assumptions taken from the MEDEP risk assessment guidance (MEDEP 2011) for adult body weight (70 kilograms [kg]), child exposure duration (6 years), adult exposure duration (24 years), and exposure frequency (365 days/year) were utilized in the characterization of exposure and development of PRGs. The child body weight of 18.8 kg was derived using the weighted average of the age-specific body weights taken from the EPA Exposure Factors Handbook (EPA 2011). The receptor-specific biota consumption rates are discussed below and summarized in **Table II.3-1**.

3.2 CONSUMPTION RATES

Local seafood consumers are assumed to rely heavily on locally caught seafood as part of their diet. For local consumers, adult finfish tissue consumption rate of 21 grams per day (g/day) was based on estimation of fish intake rates of anglers in Maine (see Table 10-72 of the EPA Exposure Factors Handbook [EPA 2011]). Based on this, the calculated child local consumer finfish consumption rate (30 percent of the adult consumption rate) is 6.3 g/day.

The local consumer consumption rates for lobster and shellfish were taken from the results of a dietary survey taken for the Quincy Bay Superfund site in Massachusetts (Cooper et al. 1991). The results of this survey indicated that adult "Local Consumers" (i.e., the average household) would ingest 1.7 g/day of lobster tissue (trophic level 3) (about 6-7 meals/year), which results in a calculated younger child consumption rate of 0.51 g/day. As a separate shellfish (e.g., clam and mussels – trophic level 2) consumption rate was not available for local consumers, a value was derived by taking the ratio of the clam consumption rate to the lobster consumption rates for the maximally exposed individual receptor of the study, and multiplying that value by the local consumer lobster consumption rate to derive an adult consumption rate of 0.91 g/day and child consumption rate of 0.27 g/day for trophic level 2 shellfish.

Because the 1 g/day finfish ingestion rate for adult local consumers from the Cooper et al. (1991) survey is lower than the 21 g/day Penobscot finfish consumption rate, a mixed diet consumption rate was not evaluated in this HHRA. A mixed diet that aggregates ingestion exposures for lobster, shellfish and finfish would essentially double count exposures and risk for local consumers and is not an appropriate method for the development of biota-specific PRGs.

The consumption of wild-caught duck by local hunters was evaluated using State waterfowl consumption advisories for the lower Estuary. For an adult, the Maine Department of Inland Fisheries & Wildlife recommends a safe eating guideline of no more than two waterfowl meals per month for waterfowl taken from the lower Estuary (MDIFW 2017a). Per the same recommendations, children under the age of eight and pregnant or nursing women should not eat any waterfowl taken from the area.

One 8-ounce duck breast is considered to be one meal, which is equivalent to an adult consumption rate of 14.9 g/day. While the consumption advisory recommends that children under the age of eight not eat any waterfowl meat from the lower Estuary, for the purposes of characterizing risk and the development of PRGs, a younger child consumption rate of 4.5 g/day was derived based on the assumption that a younger child consumption rate is 30 percent of the adult consumption rate.

3.3 ESTIMATED DAILY INTAKE

For the consumption pathways, the estimated human exposure, or intake, is calculated as a chronic daily intake (CDI), which is expressed in terms of mass of the COPC taken into the body per unit of body weight per unit of time (expressed in units of milligrams per kilogram per day [mg/kg/day]). The CDI for each receptor and exposure pathway is a function of the EPC, consumption rate, exposure frequency and duration, body weight, and time. The chronic daily intake for tissue consumption exposure scenarios was calculated using the default equation found in the EPA Risk Assessment Guidance for Superfund Part A (EPA 1989). The equation used to calculate intake of mercury and methyl mercury from the consumption of fish tissue is as follows:

$$CDI\ (\frac{mg}{kg-day}) = \frac{EPC\ \left(\frac{mg}{kg}\right) x\ EF\ \left(\frac{days}{year}\right) x\ ED\ (years) x\ IR\ \left(\frac{mg}{day}\right) x\ 0.000001\ (\frac{kg}{mg})}{BW\ (kg) x\ AT\ (years) x\ 365\ (\frac{days}{year})}$$

Where:

- AT – averaging time (years)
- CDI – chronic daily intake (mg/kg/day)
- EPC – exposure point concentration in biota tissue (milligrams per kilogram [mg/kg])
- BW – body weight (kg)
- ED – exposure duration (years)
- EF – exposure frequency (days/year)
- IR – biota ingestion rate (mg/day)

the CDI is compared to toxicity values for oral exposures (detailed in Section II.4.0) in order to evaluate hazards for each receptor group.

4.0 TOXICITY ASSESSMENT

A toxicity assessment identifies chemical-specific criteria that reflect the intrinsic toxicity of mercury and methyl mercury to humans. These toxicity criteria are used, along with estimates of exposure, to estimate potential cancer risks and non-cancer hazards for receptors identified above. As neither mercury or methyl mercury are considered to be carcinogenic, only non-carcinogenic hazard was evaluated. Only oral toxicity factors are used in the risk assessment because dermal and inhalation exposure pathways are not complete.

For non-cancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular contaminant with the highest level of exposure that is considered protective, that is, its reference dose (RfD). The RfD is an estimate of average daily dose to an individual that is likely to be without appreciable risk of harmful effects during a lifetime. The RfD is expressed in units of mg/kg/day. Oral RfDs for both inorganic mercury and methyl mercury (0.0003 and 0.0001 mg/kg/day, respectively) were taken from the EPA Integrated Risk Information System database (EPA 1995 and 2012, respectively). The oral RfDs, uncertainty and modifying factors, and target organs for both inorganic mercury (mercuric chloride) and methyl mercury are presented in **Table II.4-1**.

5.0 RISK CHARACTERIZATION

The results of the exposure assessment and toxicity assessment were combined to calculate non-cancer health hazards for each receptor population. Non-cancer hazard was developed separately for inorganic mercury and methyl mercury based on the assumption that the total mercury is composed of a predicted percent concentration of methyl mercury based on available site data, with the remaining portion of total mercury being composed of inorganic mercury.

The potential for non-cancer health hazards were calculated using the following equation:

$$HQ\ (unitless) = \frac{CDI\ (\frac{mg}{kg - day})}{RfD\ (\frac{mg}{kg - day})}$$

Where:

- HQ – Hazard quotient (unitless)
- CDI – Chronic daily intake averaged over the exposure duration (mg/kg/day)
- RfD – Oral RfD (mg/kg/day)

The ratio of exposure to toxicity is referred to as the hazard quotient (HQ). An RfD defines a dose below which it is unlikely for even sensitive populations to experience adverse health effects. Thus, if a HQ exceeds the EPA target HQ of 1 (EPA 1989), the potential for non-cancer effects exists. As the purposes of this risk assessment is to characterize baseline risk from the consumption of tissue by local residents, hazards were not summarized across species as risk from exposure to each biota species was evaluated on an individual basis. Furthermore, as the target organs for methyl mercury (developmental and nervous system) and inorganic mercury (immunological and urinary) differ from one another, a cumulative hazard index for both species of mercury was not calculated.

Potential non-cancer hazards for local consumers were calculated using this methodology. The results of the calculations are presented in **Tables II.5-1**.

5.1 LOBSTER CONSUMPTION

For the local consumer, the calculated inorganic mercury and methyl mercury HQs for the consumption of lobster tissue (trophic level 3) are below the target HQ of 1 for both adult and child receptors, indicating that adverse health effects are unlikely from exposure to inorganic mercury or methyl mercury in lobster tissue for local consumers.

5.2 SHELLFISH CONSUMPTION

For the local consumer that ingests blue mussels and soft-shell crabs (trophic level 2), the calculated inorganic mercury and methyl mercury HQs for the consumption of shellfish tissues are below the target HQ of 1 for both adult and child receptors, indicating that adverse health effects are unlikely from exposure to inorganic mercury or methyl mercury in shellfish tissue for local consumers.

5.3 FINFISH CONSUMPTION

5.3.1 Rainbow Smelt

For the local consumer, the calculated inorganic mercury and methyl mercury HQs for the consumption of rainbow smelt (trophic level 3) are below the target HQ of 1 for both adult and child receptors, indicating that adverse health effects are unlikely from exposure to inorganic mercury or methyl mercury in rainbow smelt tissue for local consumers.

5.3.2 Atlantic Tomcod

For the local consumer, the calculated inorganic mercury and methyl mercury HQs for the consumption of Atlantic tomcod (trophic level 3) are below the target HQ of 1 for both adult and child receptors, indicating that adverse health effects are unlikely from exposure to inorganic mercury or methyl mercury in Atlantic tomcod tissue for local consumers.

5.3.3 American Eel

For the local consumer, the calculated inorganic mercury HQs for the consumption of American eel (trophic level 4) are below the target HQ of 1 for both adult and child receptors, indicating that there is no unacceptable hazard from exposure to inorganic mercury in American eel tissue for local consumers. However, the calculated methyl mercury HQs for American eel ingestion by local consumers are 1 for the adult receptor, which is at the target HQ of 1, and 2 for the child receptor, which is above the target HQ of 1, indicating that concentrations of methyl mercury in American eel and other trophic level 4 finfish tissue may be of a concern to child local consumers.

5.4 DUCK CONSUMPTION

For the local consumer, the calculated inorganic mercury and methyl mercury HQs for the consumption of American black duck are at or below the target HQ of 1 for both adult and child receptors, indicating that adverse health effects are unlikely from exposure to inorganic mercury or methyl mercury in American black duck tissue for local consumers.

5.5 RISK DISCUSSION

Based on the results on the risk evaluation, there are elevated local consumer methyl mercury HQs for trophic level 4 finfish when using American eel as the surrogate. However, inorganic HQs are equal to or below the target HQ of 1 for both adult and child receptors for local consumers of all tissue types, indicating that adverse health effects are unlikely from inorganic mercury.

In order to assess a more complete overall understanding of risks to local consumers, risk from exposure to methyl mercury was characterized for individual sampling locations along the

Estuary. In order to do this, EPCs were derived for each sampling location (see **Appendix A**) and used to characterize location-specific risk in a manner consistent with the methodology outlined above. The results of this analysis are presented in **Table II.5-2** and demonstrate that non-cancer HQs generally decrease or remain the same from the higher values taken near the former HoltraChem facility to lower values at sample locations closer to the mouth of the Estuary. The biota concentrations trends for 2016–2017 are presented in **Table II.5-2**.

6.0 PRELIMINARY REMEDIATION GOAL DEVELOPMENT

As part of this evaluation, methyl mercury tissue PRGs were developed for all of the biota types above regardless of the potential risk associated with consumption for each biota type. Combined with the results of the risk evaluation, the tissue PRGs provide a target for focused remediation. Inorganic mercury tissue PRGs were not derived because the calculated inorganic mercury HQs for each biota and receptor were below the target HQ of 1, indicating that inorganic mercury is not of a human health concern and requires no further evaluation. However tissue PRGs for total mercury were extrapolated from the methyl mercury PRGs. In turn, total mercury concentrations of each biota sample are compared to calculated biota-specific benchmark threshold values (BTVs) based on concentrations from reference locations. This comparison was done for the American lobster, rainbow smelt, Atlantic tomcod, American eel, and American black duck (Section 6.3) to ensure that tissue PRGs developed in Section 6 are not more conservative in concentration that naturally occurring background concentrations.

6.1 PRG CALCULATION AND SUMMARY

For each biota class, methyl mercury tissue PRGs were derived using the exposure factors outline in Section II.3.0 with the following equation taken from the EPA RSL User's Guide (EPA 2018a) assuming a target HQ of 1:

$$PRG\left(\frac{ng}{g}\right) = \frac{THQ\ x\ AT\ (365\frac{day}{year}\ x\ ED\ (years))x\ BW\ (kg)}{EF\left(\frac{days}{year}\right)x\ ED\ (years)\ x\ \frac{1}{RfD\left(\frac{mg}{kg-day}\right)}x\ IR\left(\frac{mg}{day}\right)x\ 0.000001\left(\frac{kg}{mg}\right)} x1000000\left(\frac{ng}{mg}\right)x\ 0.001\ (\frac{kg}{g})$$

Where:

- PRG – preliminary remediation goal (nanograms per gram [ng/g])
- THQ – target hazard quotient (unitless)
- AT – averaging time (days)
- BW – body weight (kg)
- ED – exposure duration (years)
- EF – exposure frequency (days/year)
- RfD – oral RfD (mg/kg/day)
- IR – biota ingestion rate (mg/day)

The calculated tissue methyl mercury PRGs are presented in **Table II.6-1** and fall within the following range from lowest tissue PRG (child local consumer) to highest tissue PRG (adult local consumer):

- Lobster (Trophic Level 3): 3,690 to 4,120 ng/g
- Finfish (Trophic Levels 3 and 4): 298 to 333 ng/g

- Duck (Trophic Level 3): 421 to 470 ng/g

In addition, total mercury species-specific tissue PRGs were developed based on the use of species-specific percent contribution of methyl mercury to total mercury. The calculated species-specific total mercury tissue PRGs, assuming the derived species-specific percentage methyl mercury to total mercury described above, are presented in **Table II.6-1** and fall within the following range:

- American Lobster (Trophic Level 3): 3,990 to 4,460 ng/g
- Atlantic Tomcod (Trophic Level 3): 373 to 417 ng/g
- American Eel (Trophic Level 4): 339 to 379 ng/g
- American Black Duck (Trophic Level 3): 430 to 481 ng/g

6.2 MAINE HEALTH ACTION LEVELS

In addition to the above calculated tissue PRGs, the Maine Center for Disease Control and Prevention (MeCDC) has derived fish tissue action levels for the consumption of finfish (MeCDC 2001) for the development of fish advisories. The methyl mercury fish tissue action level was applied to blue mussels, lobsters, and black duck based on the US District Court Order on Remediation Plan (United States District Court, District of Maine 2015) which states that "*The expert's differing viewpoints as to the appropriate standards by which to measure remediation are irreducibly complex. The Study Panel Report itself devoted a full chapter consisting of 123 pages to its discussion of the appropriate remediation targets. Phase II, Chapter 2 at 1-123. At this point, it is not necessary to wade into this earnest and highly-technical debate among the eminent scientists concerning the appropriate standards by which success is cleansing the River must be measured. The short answer is that the debate will remain theoretical until the engineers have opined on feasibility and cost and have expressed expert opinions about the likely effectiveness of the remedy. For example, if the lower limits are readily and inexpensively attainable, the Court suspects that Mallinckrodt and its experts would have no objections to attaining them. However, if the lower limits are simply unattainable or attainable only with extraordinary expenditure and considerable delay, the Court suspects the Plaintiffs will be satisfied with more cost-effective and efficient, but imperfect, remedy. Nevertheless, to the extent the parties require a general benchmark, the Court adopts the state of Maine standard of 200 nanograms per gram, not the more relaxed benchmark Mallinckrodt's experts proposed."* giving additional weight to use of the MeCDC fish tissue action level. The application of fish tissue action levels to lobster, black duck, and blue mussels may be inappropriate, as the MeCDC fish tissue action levels were derived based on a finfish consumption rate of one 8-ounce fish meal per week (52 meals per year, 32.4 g/day) (MeCDC 2001), which is greater than the local consumer consumption rates for lobster (2.1 g/day) (Cooper et al. 1991), shellfish (1.12 g/day) (Cooper et al. 1991), and duck (14.9 g/day) (MDIFW 2017a), and may overestimate actual consumption of lobster, blue mussels, and black duck. Furthermore, in conversations with MeCDC it was indicated that the fish tissue action level was only meant to apply to sport fishing and was not developed with lobster, shellfish, and duck consumption in mind. However, the Maine Department of Marine Resources used the MeCDC fish tissue action level when designating the lobster closure areas. Regardless of the uncertainty associated with the use of the MeCDC fish tissue action level in terms of lobster, shellfish, and duck consumption the MeCDC action level was used in developed of target tissue levels.

The MeCDC derived the methyl mercury fish tissue action level for non-commercial finfish using the following equation:

$$AL\ (\frac{mg}{kg}) = \frac{RfD\ \left(\frac{mg}{kg-day}\right) x\ BW\ (kg)}{FC\ (\frac{kg}{day})}$$

Where:

- AL – action level (mg/kg)
- BW – body weight (kg)
- RfD – oral RfD (mg/kg/day)
- FC– fish consumption rate (kg/day)

For the purposes of deriving fish tissue action levels, a body weight of 60 kg (representing a pregnant woman) and fish consumption rate of 0.0342 kg/day were utilized. In addition, the same RfD for methyl mercury applied in the tissue PRG calculation (0.0001 mg/kg/day) was utilized. Note that the resulting action level for methyl mercury calculated by the MeCDC was 200 ng/g, falls below the range of the calculated lobster and duck tissue PRGs. Note that the MeCDC fish tissue action level was not developed with lobster and duck tissue consumption in mind because it was based on a recreational finfish consumption rate. Note that the MeCDC has not calculated an action level for total mercury at this time; nor have they calculated separate action levels for lobster, shellfish, or duck.

6.3 Comparison to Background

As part of PRG development, a background evaluation was undertaken using samples taken from reference areas (e.g., Frenchmen's Bay). Using the reference samples, background threshold values (BTVs) were calculated using EPA ProUCL 5.1 (EPA 2016a). The ProUCL program generates multiple BTV values based on the distribution for each data set. In general, the 95 percent upper tolerance limit (UTL) with 95 percent coverage was used as the primary BTV (EPA 2009 and 2016a). A 95 percent UTL with 95 percent coverage is based on an established background data set and represents an upper limit such that 95 percent of the sampled data will be less than or equal to the UTL. In cases where the 95 percent UTL with 95 percent coverage is above the maximum detected background value, the maximum detected background value as utilized as the BTV. Other assumptions made in the calculations of BTVs are as follows:

- Only data deemed usable based on the data validation process were included.
- Only primary samples were used to calculate BTVs.
- A statistical outlier test was run and identified high outliers were removed from the BTV calculation.[4]
- In cases were more than one BTV was calculated by ProUCL, the BTV matching the best fitting curve (i.e., normal, gamma, lognormal, or non-parametric) using a goodness-of-fit test and highest R value. was selected. When no curve passed the goodness-of-fit test, the non-parametric BTV was used.

Background data was available for the lobster, Atlantic tomcod, American eel, and the American Black Duck. However, it should be noted for the Atlantic tomcod, only one background sample was available, which does not allow for the calculation of a BTV. Furthermore, the calculated UTLs for the American eel and American black duck were above their maximum detected concentration. For the lobster, American eel, and American black duck, the maximum detected background concentration were 57.5 ng/g, 320 ng/g, and 93.6 ng/g, respectively, and were utilized as the BTVs. When compared to the calculated PRGs, the calculated BTVs for the lobster, Atlantic tomcod, American eel, and American black duck are below their respective PRGs.

The BTV calculations for each media are presented in **Appendix B** and summarized in **Table II.6-2**.

6.4 Comparison to Analytical Results

The total mercury concentrations of each biota sample was compared to both the developed tissue PRGs and the calculated biota-specific BTVs. This comparison was done for the American lobster, Atlantic tomcod, American eel, and American black duck. Blue mussels, soft-shell clams, and rainbow smelt were not evaluated as the overall risk for receptors were below the target HQ of 1 and concentrations did not exceed the action level of 200 ng/g, indicating that they are not an ingestion pathway concern for consumers. This comparison is presented in **Table II.6-3** and indicates the following:

- Concentrations of total mercury for each species are above their background values outside the reference areas, with the exception of some of the reported concentrations in American eel at sample locations BO4 and OB5, some reported concentrations in American lobster at Harborside, and reported concentrations in Atlantic tomcod at sample location ES-13.

[4] Outliers at defined at the 1 percent significance level

- Concentrations of total mercury for each species are generally below their respective local consumer tissue PRGs, with the exception of a number of exceedances in American eel tissue from sample locations BO4 and OB5 and four samples of Atlantic tomcod tissue from sample locations OB5 and OB1.
- Overall, the results of this sample-specific analysis are consistent with the calculated hazard by sample location.

In addition, calculated concentrations of methyl mercury were compared to the MeCDC action level for mercury of 200 ng/g. The results of this comparison are as follows:

- Estimated concentrations of methyl mercury in lobster tissue are above the MeCDC action level of 200 ng/g at a number of locations (16 exceedances at Odom Ledge, 30 exceedances at South Verona, 12 exceedances at Cape Jellison, 9 exceedances at Turner Point, and 1 exceedance at Harborside).
- Estimated concentrations of methyl mercury in Atlantic Tomcod tissue are above the MeCDC action level of 200 ng/g at a number of locations (three exceedances in BO4, five exceedances at OB5, and seven exceedances at OB1).
- The large majority of the calculated concentrations of methyl mercury in American eel tissue for the sampling areas are above the MeCDC action level of 200 ng/g.
- Estimated concentrations of methyl mercury in black duck tissue are above the MeCDC action level of 200 ng/g in several samples (five exceedances at Mendall Marsh and four exceedances at ES-13).

7.0 UNCERTAINTY

A number of assumptions need to be made during the quantitative assessment of risk. The risk assessment process provides conditional estimates that manage uncertainty by using conservative assumptions about exposure and toxicity. For the scenarios provided in the HHRA, upper bound estimates of exposure and conservative site-specific judgments were used per EPA and MEDEP guidance. These assumptions lead to uncertainties in the results of the assessment, and it is important to identify the assumptions and uncertainties inherent in the risk assessment to aid risk management decisions. A summary of the various uncertainties and their potential impact on risk characterization is presented in **Table II.7-1.** This section discusses uncertainties associated with:

- Data Evaluation
- Sampled Tissue Type
- Exposure Assessment
- Toxicological Assessment
- Alternative Health Guidelines

7.1 DATA EVALUATION

Environmental sampling uncertainties are introduced by the field sampling program. The locations of samples collected, as well as the sampling methodology, can bias the estimation of EPCs. If the sampling program targets areas of high concentration, then the overall exposure of the population in the Estuary may be overestimated.

The number of samples can also introduce significant certainty in the risk assessment. For certain exposure points (methyl mercury data for soft-shell clams) and sample locations, a limited number of samples were collected. Due to the small data set, the maximum detected concentration was used as the EPC or the BTV. A larger data set collected from these areas and/or reference area would allow for a more robust calculation of the EPCs for these exposure points and could result in either greater or less risk for receptors exposed to these areas based on the results of the additional sampling. Additional rounds of on-site data monitoring may decrease the uncertainty associated with sampling.

Finally, the use of the maximum detected concentration when less than five detected concentrations were reported is a conservative assumption that has the potential to overestimate exposure and risk.

7.2 SAMPLED TISSUE TYPE

In addition to the standard uncertainty associated with site data, there is an additional level of uncertainty when it comes to reported concentrations of total mercury in lobster tissue. For this risk assessment, risk was characterized for lobster samples collected during 2016 and 2017. Those samples were based on tail tissue only, and did not include claw tissue samples. Per Chapter 14 of the Penobscot River Mercury Study Panel report (PRMSP 2013b), concentrations of total mercury in tail tissue was 2.3 times what is found in claw tissue for each year in which both tail and claw tissue were collected between 2006 and 2010. This correlation is consistent with the tail tissue to claw tissue correlation of 2.3 reported for samples collected in 2015. As such, the EPC for lobster based on tail tissues may overestimate overall concentrations in edible lobster tissue. Using the 2015 data set, it was determined that on average claw tissue is 34 percent of the total edible tissue weight (i.e., the sum of tail and claw tissue sample weights). Based on the assumption that claw tissue concentrations are 2.3 times less than tail tissue concentrations, any calculated weighted total edible tissue concentration would be 20 percent less than the concentration reported in tail tissue alone. Therefore, the reported noncarcinogenic hazard for lobster consumption by all receptors is likely overestimated by up to 20 percent. Furthermore, when evaluating only claw tissue, the percentage methyl mercury to total mercury is 85 percent, which is lower than the tail tissue percent methyl mercury of 92 percent. When considering both potential claw tissue concentrations, as well as, differences in percent methyl mercury to total mercury the evaluation or risk from the consumption of lobster using only tail data has the potential to overestimate risk by up to 26 percent. However, this does not include the consumption of tomalley, or the lobster hepatopancreas, which would have concentrations of mercury elevated above that reported in tail tissue. Thus, there is a potential to underestimate risk when excluding the consumption of tomalley.

7.3 EXPOSURE ASSESSMENT

In risk assessments, a variety of assumptions must be made to estimate the potential human exposure to mercury and methyl mercury through ingestion of biota. The calculations of CDI involve parameters such as consumption rates, which are not necessarily constant values that apply to the populations located within the exposure domain. In order to conservatively estimate potential risks, the EPA recommends conducting risk assessments using reasonable maximum exposure variables for most parameters. There are no EPA Maine-specific default consumption rates for the representative species evaluated in this assessment. Instead, receptor type-specific consumption rates were estimated based on available studies from the EPA and State of Maine. Thus, the consumption rates used may not reflect actual local consumption of each individual biota species.

While the Exposure Factors Handbook (EPA 2011) does not provide species-specific consumption rates for New England coastal receptors, it does provide mean consumption rates for US receptors on a species-specific basis that indicate mean consumption of seafood for the US population are 0.00037 g/day for rainbow smelt, 0.16 g/day for lobster, 0.0026 g/day for eel, 1.0 g/day for clams, and 0.052 g/day for mussels. These national rates range from one to five orders of magnitude lower than the assumed local consumer consumption rates for lobster, finfish, and shellfish, indicating the estimated exposure to seafood may be considerably lower than what was used in this evaluation. The use of assumed local consumption rates may potentially overestimate risk. However, as the sampled species are meant to be representative of different trophic levels and not individual species the use of the generic ingestion rates is acceptable.

Risk from exposure to surface water and sediment via direct contact was not characterized as it is expected to be de minimis. This could potentially result in a minor underestimation of risk.

7.4 TOXICOLOGICAL ASSESSMENT

Uncertainty and/or modifying factors are routinely applied to toxicity values to account for interspecies variation, protection of susceptible populations, and other differences between the underlying toxicity study and the target use of the toxicity value. The uncertainty factors applied to the toxicity factors used in this HHRA range from 10 (methyl mercury) to 1,000 (mercuric chloride). These uncertainties in the toxicological values can lead to over- or under-estimation of risk.

7.5 ALTERNATIVE HEALTH GUIDELINES

As part of a public health campaign, both EPA and the U.S. Food and Drug Administration (FDA) issued advice for the consumption of finfish and shellfish by women who are pregnant or may become pregnant (EPA, 2017a). The document recommends that children and women of childbearing age (about 16-49 years old) eat a variety of fish, including two to three servings (serving size of 4 oz wet weight (ww)) of “best choices” fish (e.g., clam, cod, crab, flounder, lobster, salmon, smelt, etc.) or one serving of “good choice “ fish (e.g., tuna, carp, halibut, eel, snapper, etc.) while avoiding fish with elevated mercury levels (e.g., shark, marlin, mackerel, tuna, etc.). The consumption of fish has a number of health benefits that benefit children’s growth and development during pregnancy and childhood. Based on this, it is recommended that women have anywhere from one to three serving of lower trophic level fish per week while avoiding higher trophic level fish. These recommendations are based on estimated levels of methyl mercury in fish tissue and assume an ingestion rate of 32.4 g/day, the same value used in the MeCDC fish tissue action level., as well as a body weight of 75 kg, resulting in a fish tissue screening level of 230 ng/g for “best choice” fish and 460 ng/g for “good choice” fish. Furthermore, average methyl mercury concentrations were developed on a species-specific basis. Concentrations of methyl mercury for each fish group are as follows:

- Avoid – 490 to 1,450 ng/g
- Best Choice – 10 to 150 ng/g
- Good Choice – 70 to 450 ng/g

Based on this data, the majority concentrations of methyl mercury reported in lobster, finfish, and shellfish tissue would fall within the “best choice” and “good choice” fish tissue methyl mercury levels, indicating that the lobster, shellfish, and finfish in the study area are generally safe to eat and would result in additional health benefits. Furthermore, it was observed the average concentration of methyl mercury in canned tuna is 350 ng/g, which is above the proposed fish tissue methyl mercury PRGs, indicating that the proposed PRGs are conservative and have the potential to be overly protective of local consumers.

8.0 SUMMARY AND CONCLUSIONS

A baseline HHRA has been completed in accordance with the approved work plan and relevant EPA and MEDEP guidance. The baseline HHRA included the following tasks:

- Evaluation of potentially exposed populations based on the potential for biota ingestion;
- Estimation of biota-specific EPCs and human intake of tissue containing mercury and methyl mercury that are based on conservative assumptions about exposure;
- Presentation of a hazard evaluation for both mercury and methyl mercury for each potential receptor/biota combination for the entire site and by individual sample areas to serve as a baseline estimate of current risk;
- Development of biota and receptor-specific tissue PRGs;
- Evaluation of background levels on a species-specific basis.

A summary of non-cancer hazards is presented in **Table II.5-1**. These hazard calculations indicate the following:

- For the local consumer, the noncarcinogenic hazard from ingestion of biota for both inorganic mercury and methyl mercury do not exceed acceptable hazard levels for trophic level 2 species (i.e., blue mussels and soft-shell clams) and trophic level 3 species (i.e., the American lobster, rainbow smelt, Atlantic tomcod, and American black duck).
- For the local consumer, the noncarcinogenic hazard from ingestion of biota to methyl mercury in the trophic level 4 species (i.e., American eel) exceed a target HQ of 1 for a child receptor. However, the noncarcinogenic hazard from exposure to inorganic mercury in the American eel does not exceed acceptable hazard levels.
- When evaluated by sample locations, risk from biota consumption generally decreases or are consistent from those samples taken near the former HoltraChem facility moving towards those samples in the Penobscot Bay.
- When calculated tissue PRGs are compared to background levels, it was observed that, for trophic level 4 finfish species (i.e., American eel), background levels should be considered when evaluating cleanup levels.
- Overall, a majority of trophic level 4 finfish species (i.e., American eel) samples exceed local consumer tissue PRGs.
- Estimated concentrations of methyl mercury in trophic level 3 finfish species (i.e., rainbow smelt and Atlantic tomcod) tissue generally are below the MeCDC methyl mercury fish tissue action level of 200 ng/g. However, estimated concentrations of

methyl mercury in trophic level 4 finfish species (i.e., American eel) tissue generally exceed the MeCDC methyl mercury action level.

Based on the results for the American eel, it can be concluded that noncarcinogenic hazard to human health from methyl mercury in the Estuary under both current and future use scenarios have the potential to exceed an acceptable noncarcinogenic hazard for consumption of trophic level 4 finfish species.

PART III

BASELINE ECOLOGICAL RISK ASSESSMENT

1.0 INTRODUCTION

Ecological risk assessment addresses the likelihood that adverse effects on the environment, and to specific ecological receptor populations, may occur or are occurring as a result of exposure to one or more stressors (EPA 1997a). The purpose of this BERA is to assess potential mercury-related risks within the Estuary on the sustainability of local receptor populations. Results of the BERA will support recommendations made in the Phase III Engineering Report risk managers by providing a point of reference for evaluation of current conditions and for quantification of risk reduction that can be achieved by each remedial alternative to be considered in the Alternatives Evaluation Report.

This BERA follows the process outlined in the EPA Superfund Guidance for Ecological Risk Assessment (EPA 1997a). Based on the investigations conducted by the PRMSP between 2006 and 2012, the first two steps in EPA's eight-step process (Step 1 - Screening Level Problem Formulation and Effects Evaluation and Step 2 - Preliminary Exposure Estimates and Risk Calculations) were not redone, since mercury and methyl mercury were previously identified as the COPCs for the Estuary.

Because the ecological risk assessment follows the general approach for CERCLA-style ecological risk assessments, the risk assessment quantifies for chronic exposure that would induce population-level effects in biota, as discussed in ERAGs Section 7.3.1 "Threshold of Effects on Assessment Endpoints". This section states "The lower bound of the threshold would be based on consistent conservative assumptions and NOAEL toxicity values. The upper bound would be based on observed impacts or predictions that ecological impacts could occur. This upper bound would be developed using consistent assumptions, site-specific data, LOAEL toxicity values, or an impact evaluation" (Page 7-4 of EPA, 1997). Thus, NOAELs and LOAELs were used in the risk assessment for the development of remediation goals under the CERCLA style risk assessment used for the Estuary. Some effects concentrations or doses that affect as little as 20 percent of the population, which is generally used as a conservative default threshold level for population-level effects, were also considered in the toxicity assessment for completeness.

The ecological toxicity assessment considered toxicity reference values (TRVs) used at other large sediment sites with mercury contamination across the Unites States, including Berry's Creek, South River, Lower Duwamish Waterway, Pompton Lakes Works, Passaic River, Riegelwood, Portland Harbor, and an oxbow lake adjacent to the Tombigbee River. These similar sites also underwent multiple levels of review by federal and state agencies together with study groups/panels and public comment for agreement on the use of these TRVs. The values and the logic behind their use were considered in the selection of the final values for quantification in the risk assessment. Some of these TRVs were used directly from the other assessment sites and, for others, TRVs were developed from a compilation of studies to calculate a geometric mean of TRVs from appropriate, relevant, and similar studies. The use of geometric mean TRVs considers the potential for a population-level effect. A TRV for a single toxicity study may be too specialized or focused on one sensitive or insensitive species, exposure route, or dosing regime and, thus, not strictly applicable on a population-level basis. The geometric mean of a group of TRVs allows for the TRV to be informed by multiple studies, and accounts for the variability in toxicity across a large number of toxicity studies without allowing one study to bias remediation goal development.

The risk and exposure methodology focused on parameters that could be used to estimate a remediation goal in sediment, which is the primary reservoir for mercury in the Estuary. Although the risk assessment provides quantification of risk to ecological receptors, the ultimate goal for the document is to identify appropriate exposure and toxicity input parameters for the back-calculation of sediment remediation goals for the Estuary that are based on acceptable potential risk levels.

This document is not a Natural Resource Damage Assessment and Restoration (NRDAR) program evaluation. A NRDAR evaluation focuses on effects on an individual level and attempts to quantify the number of individual animals affected in multiple biota classes in order to seek restitution from the responsible party. Instead, this is a risk assessment that is used to evaluate population level risks to support development of sediment remediation goals, where needed, to be protective of ecological receptors. The risk assessment approach used here is consistent with the approach used in the development of sediment remediation goals at other large sediment sites with mercury contamination across the United States.

1.1 BERA DATA SETS

This BERA incorporates abiotic and biotic media collected in the Estuary and selected reference areas primarily between 2016 and early 2018 to assess current conditions (Amec Foster Wheeler 2017a, 2017b, 2018a, 2018b, and 2018c). Data collected prior to these years that were included in the BERA datasets were minimal, and only selected for use in the BERA where a data gap was identified. Recent data collected include sediment samples collected from 0 to 0.5 foot in depth, surface water samples, and biota tissue samples. The 0 to 0.5-foot depth interval for surface sediment is an appropriate sample interval for ecological receptor exposure in the BERA. The bioactive zone in estuarine and freshwater tidal environments, like the Penobscot system, is typically 4 to 6 inches; while marine environments tend to have a shallower bioactive zone (2 to 4 inches) (EPA 2015).

Mercury and methyl mercury were previously identified as the COPCs for the Estuary, and as such, no other chemicals were assessed in this BERA. The data sets for the Estuary used in the BERA to represent current conditions and characterize potential risk consist of:

- Surface water collected in 2016
- Sediment collected in 2016 and 2017
- Biota tissue:

- Terrestrial insects (whole body) – 2016 and 2017
- Spiders (whole body) – 2016 and 2017
- Polychaetes (whole body) – 2016 and 2017
- Blue mussels (whole body) – 2016 and 2017
- Lobster (tail tissue) – 2016 and 2017
- Forage fish (rainbow smelt and mummichog whole body) – 2016 and 2017
- Predatory fish (Atlantic tomcod and American eel fillet[1]) – 2016 and 2017
- American black duck (blood) – 2014, 2017
- Nelson's sparrow (blood) – 2016 and 2017
- Red-winged blackbird (blood) – 2016 and 2017
- Shrimp (whole body) – 2009

The following datasets were also incorporated into the BERA lines of evidence:

- American black duck (blood) – 2011, 2012
- American black duck (breast muscle tissue) – 2011, 2012, 2014, 2017, and 2018
- Belted kingfisher (blood) – 2007
- Black guillemot (blood, egg) – 2007
- Double-crested cormorant (blood – 2006-2010 and egg – 2006-2012)
- Bald eagle (blood) – 2007
- Osprey (blood) – 2007

The 2009 shrimp data were included in the BERA due to an identified data gap for multiple receptor diets. **Table III.1-1** summarizes the data used in the BERA. **Figure III.1-1** presents the surface water sampling locations used in the BERA for blue mussels. **Figures III.1-2** through **III.1-4** presents the sediment sampling locations used in the BERA for wetland-dependent birds (i.e., marsh songbirds and the American black duck). **Figures III.1-5 through III.1-7** present the sediment sampling locations used in the BERA for belted kingfishers, bald eagles, and mink, respectively. **Figure III.1-8** presents the biota sampling locations used in the BERA. Detailed figures showing the biota sampling locations for each individual species are presented in **Appendix C** for 2016 to 2018 sample collections. For the Estuary, total mercury and methyl mercury data are available for sediment, surface water, terrestrial insects, spiders, polychaetes, and shrimp. Methyl mercury concentrations were derived for the remaining receptors using site-specific, historical methyl mercury to total mercury percentages. **Appendix A** presents the datasets used in the BERA.

The data sets for the reference areas used in the BERA consist of:

- Sediment collected in 2016 and 2017

[1] Fillet samples are only available for Atlantic tomcod and American eel. Use of fillet data to represent whole body exposure is a conservative approach. Mercury analysis of fish tissue types indicates that increases in mercury concentrations from whole fish to fillets can be as high as 60 to 100 percent (Goldstein and Brigham 1995; Wente 1997).

- Biota tissue:
  - Terrestrial insects (whole body) – 2016 and 2017 from Pleasant River
  - Spiders (whole body) – 2016 and 2017 from Pleasant River
  - Nelson’s sparrow (blood) – 2016 and 2017 from Pleasant River
  - Polychaetes (whole body) – 2016 and 2017 from Frenchman Bay
  - Forage fish (rainbow smelt and mummichog whole body) – 2016 and 2017 from Frenchman Bay
  - Predatory fish (Atlantic tomcod fillet[1]) – 2016 and 2017 from Frenchman Bay
  - American black duck (blood) – 2017 and 2018 from Frenchman Bay
  - Blue mussels (whole body) – 2017 from Frenchman Bay
  - Lobster (tail tissue) – 2017 from Frenchman Bay
  - Predatory fish (American eel whole body) – 2016 and 2017 from the Orono to Veazie (OV) reach of Estuary, at location OV-4

The following datasets were also incorporated into the BERA lines of evidence:

- American black duck (blood) – 2011 and 2012 from Frenchman Bay
- American black duck (breast muscle tissue) –2014 and 2017 from Frenchman Bay
- Belted kingfisher (blood) – 2007 upstream of study boundary
- Bald eagle (blood) – 2007 upstream of study boundary

Figure III.1-9 presents the 2016–2017 sediment and biota sampling locations used in the BERA for the reference areas. For the reference areas, total mercury and methyl mercury data are available for sediment, surface water, terrestrial insects, spiders, and polychaetes. Methyl mercury concentrations were derived for the remaining receptors using the site-specific, historical methyl mercury to total mercury percentages due to the lack of available methyl mercury data for those tissues from the references areas. **Appendix A** presents the reference datasets used in the BERA. Discussion of data collection and results of the data quality evaluations are presented in Amec Foster Wheeler (2017a, 2017b, 2018a, 2018b, and 2018c).

2.0 PROBLEM FORMULATION

Problem formulation defines the goals and establishes the scope and focus of an ecological risk assessment. The problem formulation for this BERA includes an overview of the site background and ecological setting, the ecological conceptual exposure model, the selection of assessment endpoints, and the identification of representative receptors. Each of these are discussed in this section.

2.1 Ecological Setting

The ecological setting for the site is based on digitized National Wetlands Inventory maps (developed by the United States Fish and Wildlife Service in 1998) and field observations of habitat and biota made by Amec Foster Wheeler personnel during biota collection events in 2016 and 2017. However, no specific or formal habitat characterization has been performed at the site. The focus of this BERA is the wetlands, river, and bay of the Estuary.

The Penobscot River is the largest river in Maine, with a watershed area of over 8,500 square miles. Twelve diadromous fish species (species that live portions of their life in both fresh and salt water) are found in the Penobscot watershed, including three species listed under the Endangered Species Act (Atlantic salmon [*Salmo salar*], Atlantic sturgeon, [*Acipenser oxyrinchus oxyrinchus*] and shortnose sturgeon [*Acipenser brevirostrum*]) and three species recognized by the National Oceanic and Atmospheric Administration (NOAA) as Species of Concern (alewife [*Alosa pseudoharengus*], blueback herring [*Alosa aestivalis*], and rainbow smelt [*Osmerus mordax*]) (NOAA 2016).

The habitat considered within the focus of this BERA is primarily freshwater tidal marsh and estuary. Each of the general habitat types within the study area is described below.

<u>Upper Estuary (River System)</u> – This area of the Penobscot River, upstream from Verona, contains areas with rocky shores and ledges, interspersed with mud flats, that provide habitat for a wide range of aquatic species. All of this portion of river is tidally influenced, although the tides are less pronounced in the upper sections. Harbor seals (*Phoca vitulina*) frequent the lower reaches of this section. The upper portions of this section, south of Bangor, include some freshwater species.

<u>Mendall Marsh (Tidal Marsh)</u> – Mendall Marsh is located just south of Winterport on the western side of the Penobscot River. It is the largest contiguous area of marsh in the Penobscot system. Mendall Marsh is an important breeding habitat for wetland birds and likely provides recruitment for other wetlands (PRMSP 2013c). Numerous birds and ducks use the marsh, and bald eagles (*Haliaeetus leucocephalus*) are known to nest in the area. The federally-protected red knot (*Calidris canutus*) and roseate tern (*Sterna dougallii*) are known to occur in Hancock County, but are not known to be in the project area (USFWS 2017b).

Lower Estuary (Bay System) – The study area south of Verona and around Fort Point transitions from a confined estuary river to have more open water or bay characteristics. The area experiences large tidal swings, with a 12-foot difference between high and low tides. The bay habitats consist of large mudflats with coastal marsh grasses, interspersed with areas of rocky shores. These varying substrates provide suitable habitat for a wide range of marine species.

2.2 POTENTIAL EXPOSURE PATHWAYS

Exposure pathway identification is necessary for completion of a conceptual exposure model (EPA 1997a). An exposure pathway is the mechanism by which receptors may come into contact with a COPC. A pathway has four sequential components:

1. A source and mechanism of chemical release;
2. A retention or transport medium (or media);
3. A receptor in contact with the final impacted medium (referred to as an "exposure point"); and
4. An exposure route (e.g., ingestion) for the final impacted medium.

Receptor exposure to a COPC in soil, sediment, or surface water varies depending on the species, because of diverse life cycle characteristics. Ecological receptors may be exposed via incidental ingestion, direct contact, and/or the food web. Mercury biomagnifies in the food web, resulting in greater exposure to higher trophic level organisms. Potential ecological exposure pathways are summarized in **Figure III.2-1** and **Figure III.2-2**. **Figure III.2-1** presents the conceptual exposure model, which includes aquatic, wetland-dependent, and piscivorous receptors at the site. The food web model presented in **Figure III.2-2** illustrates the various trophic levels at the site.

2.3 REPRESENTATIVE ECOLOGICAL RECEPTORS

Twelve species, including four finfish, two aquatic invertebrates, five birds, and one mammal were selected as surrogates for ecological receptors that are present at the site. These species were selected based on current and future potential exposure to mercury in the Estuary, and to represent surrogate species for the assessment endpoints selected for this BERA. The rationale for the representative species selection is provided below.

Blue mussel – Blue mussels are present throughout the Lower Estuary. Blue mussels are filter feeders and represent a potential food source for many higher trophic level ecological receptors at the site.

American lobster – Lobsters are present throughout the Lower Estuary. Two lobster closure areas exist within the site due to mercury concerns.

Mummichog – Mummichog represent one species of forage fish at the site and are present in the Upper Estuary and Mendall Marsh. Based on the results of the Phase II food web study (Kopec and Bodaly 2013), mummichog feed from the terrestrial and benthic food webs.

Rainbow Smelt – Smelt represent one species of forage fish at the site with a mixed diet of benthic and pelagic organisms. Rainbow smelt are present in the Upper and Lower Estuary.

Atlantic Tomcod – Tomcod are a benthic-feeding (i.e., fish that consume organisms associated with the sediment) predatory fish at the site. Size ranges of tomcod by age are as follows: young of year are approximately 90 millimeters (mm) by September; Year I fish are approximately 100-250 mm; Year II fish are approximately 200-320 mm; and Year III fish are approximately 280+ mm (NOAA 2000; Stewart and Auster, 1987)). Even as young of year and juveniles, tomcod prey on copepods and amphipods. After reaching 80-90 mm in size, tomcod shift their diet to larger amphipods (e.g., scuds [*Gammarus lawrencianus*]), mysids (i.e., shrimp [*Crangon* spp.]), polychaetes, mollusks, squids and fishes (e.g., smelt, sticklebacks, striped bass, alewives, shed, herring and sculpins) (Stewart and Auster, 1987; Cohen et al. 1990). Atlantic tomcod are present in the Upper and Lower Estuary. Atlantic tomcod analyzed in the BERA had already undergone the diet shift and are sized as predatory juveniles and adults. Tomcod collected for analysis in 2016 and 2017 ranged from 94 to 291 mm with an average of approximately 161 mm. Only three tomcod out of 115 were under 100 mm.

American Eel – Eel is a species with habitats spanning both fresh and salt water, as well as representing the upper trophic level of the fish species as a predatory fish species. Eels are born in the ocean, mature in freshwater, and return to the ocean to spawn. While some American eels swim up freshwater streams to mature, others remain and mature in both estuarine and marine waters. Eels feed in the benthic food web in the Estuary.

Nelson's Sparrow – Nelson's sparrows are migratory species and eat invertebrate prey. This species nests and forages in wetland habitats. Nelson's sparrows are present at the site for breeding, with anticipated arrival in late May and departure as late as October (Shriver et al. 2011).

Red-Winged Blackbird – Red-winged blackbirds are migratory species and eat invertebrate prey, similar to the Nelson's sparrow. This species nests and forages in wetland habitats. Red-winged blackbirds are present at the site for breeding with anticipated arrival in late February and departure as late as August (Bird and Smith 1964).

American Black Duck – American black ducks are omnivorous aquatic birds. Black ducks migrate south from Canada, typically arrive at the site in September/October, and winter through approximately March each year.

Belted Kingfisher – Belted kingfishers are migratory species that predominately eat forage fish. Belted kingfishers have been documented as the most sensitive piscivorous aquatic bird species due to their high metabolic and ingestion rate, low body weight, and the fact that this species ingests up to half of its body weight in fish each day (EPA 1997b). Belted kingfishers are present in Maine during breeding season (Kelly et al., 2009), which occurs from mid-April to late October (EPA, 1993). This is consistent with the observation by Bodaly et. al. (2009) of arrival time of the belted kingfisher at the site.

Bald Eagle – Bald eagles in Maine are primarily fish eaters at inland settings on the lakes and rivers; in coastal estuaries, bald eagles eat a more varied diet adding seabirds and waterfowl (MDIFW 2018). Bald eagles represent piscivorous birds at the site consuming both forage and predatory fish species. Although some bald eagles leave Maine in the winter, many bald eagles remain through the winter (MDIFW 2018). It was assumed that bald eagles are present at the site year-round.

Mink – Mink will prey on small mammals and birds, but almost exclusively feed on fish and other aquatic biota. Mink have been documented as a highly sensitive species to methyl mercury (EPA 1997b) and represent piscivorous mammals at the site consuming forage fish.

2.4 ASSESSMENT AND MEASUREMENT ENDPOINTS

Assessment endpoints identify the ecological values in need of protection (EPA 1997a). The assessment endpoints are intended to encompass the ecological receptors most likely to be exposed to and impacted by COPCs in the Estuary (**Table III.2-1**). The specific assessment endpoints are:

1. Survival, growth, and reproduction of aquatic invertebrates.
2. Survival, growth, and reproduction of forage and predatory fish.
3. Survival, growth, and reproduction of wetland-dependent birds.
4. Survival, growth, and reproduction of piscivorous birds.
5. Survival, growth, and reproduction of piscivorous mammals.

The receptors used to represent surrogate species for Assessment Endpoint 1 are the blue mussel and the American lobster. The receptors used to represent surrogate species for Assessment Endpoint 2 are the mummichog and rainbow smelt for forage fish and the Atlantic tomcod and American eel for predatory fish. The receptors used to represent surrogate species for Assessment Endpoint 3 are the Nelson's sparrow, red-winged blackbird, and American black duck. The receptors used to represent surrogate species for Assessment Endpoint 4 are the belted kingfisher and bald eagle. The receptor used to represent surrogate species for Assessment Endpoint 5 is the mink.

Table III.2-1 identifies the measures of both exposure and effect selected for each assessment endpoint. Measures of exposure include mercury concentrations in the following media:

- Surface water;
- Sediment;

- Prey tissue that ecological receptors are exposed to; and
- Ecological receptor tissue concentrations accumulated through exposure.

Measures of effect include toxicological data (i.e., toxicity reference values [TRVs]) for mercury associated with:

- Direct contact with surface water;
- Food web exposure; and
- Body burden (i.e., tissue accumulation) from food web exposure.

3.0 ECOLOGICAL EXPOSURE ASSESSMENT

The exposure assessment evaluates the potential for exposure to mercury by ecological receptors. This exposure assessment includes the exposure areas evaluated, exposure assumptions, and development of EPCs for abiotic and biotic media.

3.1 EXPOSURE AREAS

Ecological exposure was evaluated using multiple lines of evidence: comparison of tissue concentrations to tissue-residue based TRVs, comparison of abiotic media concentrations to media-specific TRVs, and/or comparison of calculated dietary doses to dietary TRVs (i.e., food web modeling). Exposure areas evaluated for each receptor varied depending on the line of evidence. Direct comparison of abiotic or tissue concentrations was performed for each generalized sampling area in 2016 and 2017 to identify potential areas of concern. In addition, lobsters were evaluated based on the 2014 and 2016 closure areas (**Figure III.1-8**). Exposure areas used for the food web modeling were based on home ranges of the ecological receptor. In addition, for the piscivorous receptors (i.e., belted kingfisher, bald eagle, and mink), the exposure areas were also selected based on collection locations for prey fish. The exposure areas used in the food web modeling are as follows:

Receptor	Exposure Areas for Food Web Modeling
Atlantic tomcod, American eel, and Rainbow smelt	Estuary, Reference
Mummichog and American black duck	Estuary, Mendall Marsh, Reference
Nelson's sparrow and Red-winged blackbird	W-17-N, MMSE, MMSW, Reference
Belted kingfisher, Bald eagle, and Mink	BO-04, OB-05, OB-04, OB-01, Mendall Marsh, South Verona, Fort Point

3.2 EXPOSURE ASSUMPTIONS

Exposure assumptions used in the food web modeling for the surrogate species are summarized in **Tables III.3-1 through III.3-10**. The site foraging factor was assumed to be 1. Body weights are based on the average of the species-specific body weight site data collected in 2016 and 2017, when available. Dietary composition for birds and mink were obtained from scientific literature, including EPA's Wildlife Exposure Factors Handbook (EPA 1993). These dietary compositions for birds and mink were then adjusted for site-specific evaluation based on food items collected at the site. Fish dietary compositions were based on stomach content diet analyses conducted on species-specific fish caught in the Estuary (Kopec and Bodaly 2013). Food ingestion rates for fish were obtained from various scientific literature available. Food and sediment ingestion rates for birds and mink were taken from the fresh matter intake equations provided in either Food Requirements of Wild Animals: Predictive Equations For Free-Living Mammals, Reptiles, And Birds (Nagy 2001) or EPA's Wildlife Exposure Factors Handbook (EPA

1993). Food ingestion rates were on a ww basis, which is more reflective of natural feeding conditions by ecological receptors. Sediment ingestion rates were on a dry weight basis.

Exposure frequencies were site-specific based on the receptor. Site-specific exposure frequency was calculated for migratory bird species to reduce overestimating exposure at the site. Nelson's sparrows migrate to the site for breeding season with anticipated arrivals dates in late May and departure dates as late as October (Shriver et al. 2011). An exposure frequency of 0.50 was assumed for the sparrow based on their anticipated presence of up to six months at the site. Red-winged blackbirds are present at the site for breeding with anticipated arrivals in late February and departures as late as August (Bird and Smith 1964). An exposure frequency of 0.58 was assumed for the blackbird based on their anticipated presence of up to seven months at the site. The black duck arrives at the site around October and winters through approximately March each year. An exposure frequency of 0.50 was assumed for the black duck based on their presence of up to six months at the site. Belted kingfishers are present at the site for breeding, with anticipated arrival in mid-April and departure as late as October (Kelly et al. 2009, EPA 1993, Bodaly et al. 2009). An exposure frequency of 0.50 was assumed for the belted kingfisher based on their presence of up to six months at the site. Although some bald eagles leave Maine, many bald eagles remain through the winter (MDIFW 2018). Bald eagles were assumed to be present at the site year round and an exposure frequency of 1.0 was assumed.

For piscivorous receptors, prey fish size varied depending upon the receptor, as follows:

- Belted kingfisher: fish up to 17.8 centimeters (cm) in length based on ranges cited in EPA (1993) from 2.5 to 17.8 cm in a Michigan study (Salyer and Lagler 1946) and 4 to 14 cm in an Ohio stream study (Davis 1982)
- Bald eagle: fish more than 15 cm in length based on the distribution of fish size recorded for breeding bald eagles in a central Arizona study (Grubb 1995), which was similar to that recorded by Haywood and Ohmart (1986). Of 1,000 estimated fish prey sizes in the Grubb (1995) study, 13 percent were < 15 cm; 56 percent were 15-30 cm; 26 percent were 31-45 cm; and 4 percent were > 45 cm.
- Mink: fish up to 25 cm in length (Alexander 1977).

The forage fish and predatory fish EPCs for the piscivorous receptors accounted for these prey fish sizes, to provide a reasonable estimate of exposure.

3.3 EXPOSURE POINT CONCENTRATIONS

Site-specific data discussed in Section III.1.0 were used to generate the EPCs for each measure of exposure. The UCL of the arithmetic mean concentration calculated using ProUCL 5.1.002 software (EPA 2016) was used as the EPC when enough samples were available to perform statistical analysis. The ProUCL 5.1.002 software developed by EPA (EPA 2016) includes statistical methods to address data sets both with and without non-detects, and computes the UCL for a given data set by a variety of alternative statistical approaches (including several approaches that do not require the assumption of normality or log-normality). ProUCL 5.1.002

then recommends specific UCL values as being the most appropriate for that particular data set. In general, the 95 percent UCL is selected as the EPC for each analyte; however, if the calculated UCL exceeds the maximum detected concentration, then the maximum concentration is substituted as the EPC. For EPCs based on calculated UCL, the distribution type and specific UCL type selected by the ProUCL software is indicated in the ProUCL output files. Other assumptions made in the calculations of UCLs are as follows:

- Only data deemed usable based on the data validation process were included.
- Only primary samples (no duplicates) were used to calculate EPCs as duplicate samples were analyzed for quality assurance purposes only and are not appropriate for use in the calculation of UCLs.
- In order to be conservative, in cases where more than one UCL was calculated by ProUCL, the greater of the two values was assigned based on best professional judgment. This is a conservative approach and consistent with EPA guidance (EPA, 2016a).
- For datasets with less than five samples, the maximum detected concentration was used as the EPC. This is a conservative approach consistent with the ProUCL user's guide in the ProUCL software provides error messages for samples sets of less than five.

Table III.3-11 presents the surface water total mercury EPCs. **Tables III.3-12a and III.3-12b** present the tissue EPCs (ww basis) for total mercury and methyl mercury, respectively. **Tables III.3-13a and III.3-13b** present the sediment EPCs (dry weight basis) and dietary EPCs (ww basis) used in the food web modeling for total mercury and methyl mercury, respectively. Data sets used to generate the EPCs were receptor-specific, accounting for the home range of the biota, as well as habitat type and potential exposure of the receptor and its prey. Marsh songbird sediments included wetland sediments designated as high, mid, and low, and intertidal as the marsh songbird prey items would be exposed to these sediments. Black duck sediments also included wetland sediments designated as high, mid, low, and intertidal. Subtidal sediments were not included in duck exposure. The black duck is a dabbling duck (i.e., a type of duck that feeds primarily along the surface of the water or by tipping headfirst into the water to graze on aquatic plants, vegetation and insects) and exposure to subtidal sediment would be limited. Furthermore, as concentrations of mercury are lower in subtidal sediment versus wetland and intertidal sediment, the exclusion of subtidal sediment is a conservative representation of sediment exposure. For piscivorous receptors, sediments included intertidal sediments for each exposure area due to potential receptor exposure, except for Mendall Marsh where wetland sediments (designated as high, mid, and low), intertidal, and subtidal sediments were included due to tidal influence in the marsh. **Appendix A** includes the ProUCL inputs and outputs for each data set by receptor.

4.0 ECOLOGICAL EFFECTS EVALUATION

The ecological effects evaluation includes identification and development of TRVs representing conservative threshold concentrations or doses for adverse effects to ecological receptors that are used as benchmarks to compare site-specific COPC concentrations. This effects evaluation identifies mercury TRVs for aquatic invertebrate, fish, and avian species.

TRVs were developed following a review of the available scientific literature, online databases (including two EPA databases: the Toxicity Residue Database [EPA 1999a] and the ECOTOXicology Knowledgebase System [EPA 2017b]), and previously published BERAs. In addition, meta-analyses by Depew et al. (2012), Dillon et al. (2010), and Fuchsman et al. (2016a) were reviewed for fish and Fuchsman et al. (2016b) for birds. TRVs based on no observed adverse effects levels (NOAELs) and lowest observed adverse effects levels (LOAELs) were compiled and reviewed. The NOAEL is generally the highest concentration by experiment or observation, which causes no detectable adverse change in the target organism based on a lack of significant difference from the control. The LOAEL is the lowest concentration by experiment or observation, which causes an adverse change measured in the target organism that is significantly different from the control. The true toxicity threshold lies somewhere between the NOAEL and LOAEL. Controlled laboratory studies historically have been the basis for developing effects thresholds in risk assessments. However, application of laboratory observations to wild populations is limited by the uncertainty of how the study organism responds to contaminant dosing in captivity without external stressors, which may play an important part in species responses to the contaminant exposure. TRVs based on point estimates defined as NOAELs or LOAELs estimate potential ecological effects on individual organisms and do not evaluate potential population-level risks. Effects may occur on individual organisms in the studies, but have minimal potential population- or community-level effects. In addition, because LOAELs indicate the "lowest observable adverse effect", LOAELs may not capture the magnitude of risk from contaminant exposure. For these reasons, the calculated potential risks based on NOAELs and LOAELs may overestimate the true population- or community-level effects. Therefore, the use of laboratory- and field-based studies as the basis for developing effects thresholds is becoming more widely accepted in risk assessment.

In addition, use of the point estimate approach is evolving to an effects concentration approach using point estimate toxicity data. This approach is based on effects doses (EDs) for dietary exposure or effects concentrations (ECs) for tissue body burdens, which calculates parametric estimates of the effects doses or concentrations. An ED_{20} or EC_{20} is generally used as conservative default threshold level based on a specific endpoint that could result in 20 percent fewer individuals within a local breeding population. This approach is used in risk assessments as it provides the likelihood and severity of potential effects on local receptor populations. The approach also reduces the uncertainty in the risk characterization and can be used to better inform site management decisions. As such, where available, LOAEL TRVs were based on ED_{20} or EC_{20} values. Where ED_{20} or EC_{20} values were not available, NOAEL and LOAEL TRVs were selected from the compiled toxicity data. EPA (1997a) dictates adoption of the following hierarchy, in terms of decreasing preference, to be followed in assessing selection of endpoints and duration of exposure of ecological receptors:

- Chronic NOAEL,
- Subchronic NOAEL,
- Chronic LOAEL,
- Subchronic LOAEL,
- Acute (less than 15 days) median lethality point estimates, and
- Single dose toxicity values.

For TRV development, each available study was evaluated for applicability, as recommended by EPA (1997a). Studies based on marine, brackish, and freshwater species were reviewed, and studies based on relevant Estuary target species were preferred over other species. Ecologically relevant study endpoints of reproduction, growth, and survival were the focus of TRV selection based on their relevance to the assessment endpoints for the sustainability of wildlife populations. Physiological (e.g., endocrine effects), behavioral, or other sublethal endpoints were not included in the development of TRVs because population-level effects and dose-dependent effects are not as well understood. Chronic studies are preferred to subchronic studies, which are preferred to acute studies (EPA 1999b). Because the BERA focuses on assessing the potential for long-term effects on wildlife, the toxicity values should be chronic values. If chronic values are not specifically reported, acute values can be converted to chronic values by multiplying by 0.01 (EPA 1999b). In addition, a chronic LOAEL can be multiplied by 0.1 for conversion to a chronic NOAEL (EPA 1999b). Available total mercury and methyl mercury TRVs were evaluated for applicability.

In addition, no effect and lowest observed effect toxicity data were used to calculate geometric mean (i.e., geomean) NOAEL and/or LOAEL TRVs when a number of toxicity data were available. The use of a geometric mean TRV provides a weight of evidence approach that considers the potential for population-level effects. While the simple use of the lowest effects value available could be used for quantification of risks on an individual-level basis, it might not be appropriate for use on a population-level basis. When a number of toxicity data are available, the geometric mean of effects concentrations allows for the TRV to be informed by multiple studies, accounting for the variability in toxicity across a large number of available toxicity studies.

This section discusses the TRVs selected for the representative ecological receptors identified in Section III.2.3. Tissue and dietary TRVs are presented on a ww basis. The following TRVs were developed:

- Surface water TRVs protective of mollusks;
- Tissue TRVs protective of aquatic invertebrates, fish, and birds; and
- Dietary TRVs protective of fish and birds.

4.1 AQUATIC INVERTEBRATE TRVS

4.1.1 Blue Mussel

4.1.1.1 Surface Water

Four studies were available in the literature describing effects of mollusks exposed to mercury in surface water **(Table III.4-1**). Thain (1984) dosed common slipper shells with mercuric chloride in water for 16 weeks and saw reduced fecundity and growth at a range of concentrations. As cited in EPA (1999a), the lowest LOAEL of 420 nanograms per liter (ng/L) for reproduction with a bounded NOAEL of 250 ng/L based on Thain (1984) were selected as the surface water TRVs protective of mollusks. Thain (1984) also reported a LOAEL of 1,000 ng/L and a NOAEL of 420 ng/L for growth. The chronic saltwater National Ambient Water Quality Criterion protective of aquatic life is 940 ng/L for dissolved mercury (EPA, 2018b; **Table III.4-1**). This value is derived from data for inorganic mercury, but is applied to total mercury and is based on saltwater exposure to the mysid (EPA 1985). The criterion document (EPA 1985) identifies the blue mussel as the third most sensitive species based on genus mean acute values with the first being the mysid.

4.1.1.2 Tissue

Three studies were available in the literature documenting tissue mercury concentrations in mollusks (**Table III.4-2**). Thain (1984) dosed common slipper shells with mercuric chloride in water for 16 weeks and saw reduced fecundity and growth at a range of concentrations. As cited in EPA (1999a), the lowest LOAEL reported was 10,000 ng/g for reproduction with the highest bounded NOAEL of 8,000 ng/g. Due to the apparent low sensitivity of mollusks to mercury, a study based on copepod exposure was selected for the tissue TRVs protective of benthic invertebrates. Hook and Fisher (2002) measured tissue concentrations of copepods (*Acartia tonsa* and *A. hudsonica*) following a 4-hour exposure to mercury-contaminated phytoplankton. The tissue residues associated with a 50 percent reduction in the number of eggs produced was selected as the LOAEL TRV. Due to the sensitivity of the study endpoint (egg depression) and the presumed sensitivity of zooplankton to mercury, no extrapolation factors were used. The NOAEL and LOAEL TRVs for benthic invertebrate tissue are 48 and 95 ng/g ww.

4.1.2 American Lobster

4.1.2.1 Tissue

Two studies were available in the literature for decapods documenting tissue mercury concentrations and associated effects from mercury exposure (Table III.4-3). Bianchini and Gilles (1996) dosed three crab species with inorganic mercury (i.e., mercuric chloride) in saltwater for varying durations to determine the effect on survival. Canli and Furness (1995) dosed Norway lobster with mercuric chloride and methyl mercuric chloride in water and diet to study the effects on survival. Toxicity data based on exposure to methyl mercury is preferred due to the site-specific calculation of 92 percent of lobster tail tissue being attributable to methyl mercury (Refer to Table

IV.1-2). The methyl mercury NOAEL TRV of 1,820 ng/g ww derived from Canli and Furness (1995) assuming an 80 percent moisture content, as cited in EPA's Toxicity Residue Database (EPA 1999a), was selected as the NOAEL TRV for lobster tissue for total mercury and methyl mercury. A LOAEL TRV based on methylmercury in lobster tissue was not available.

4.2 FISH TRVS

4.2.1 Forage Fish

4.2.1.1 Tissue

Multiple studies available in scientific literature present tissue body burdens in forage fish related to effects from exposure to mercury (**Table III.4-4**). Fish tissue effects thresholds are available for population level effects (i.e., survival, growth, and reproduction) as well as biochemical (including the concentrations of blood plasma components and of enzymes indicative of oxidative stress), behavioral, and histological (cell structure) effects. The focus of fish tissue TRVs for the BERA were effects on survival, growth, and/or reproduction as the population significance of biochemical effects is less clear than those that directly affect parameters, such as growth and spawning behavior.

The lowest bounded LOAEL of 440 ng/g from Matta et al. (2001) based on reduced male survival was selected as the tissue LOAEL TRV for forage fish. Matta et al. (2001) is a multi-generational mummichog study. Mummichog is one of the forage fish receptors for the BERA. The test species for the remainder of the studies available were freshwater fish. Matta et al. (2001) conducted a multi-generational mummichog study in which each treatment group was fed with food for at least six weeks dosed with methylmercuric chloride. Only adult F_0 (parent) fish received the mercury-spiked diet. Exposure to subsequent generations was limited to maternal transfer. Statistically significant effects were observed for mortality of male F_0 fish, altered sex ratios and reduced fertilization success of F_1 fish (offspring of F_0 generation). The LOAEL of 440 ng/g is the concentration in mummichog tissue at which male mummichog survival was reduced, but there was no effect on female survival. A NOAEL of 440 ng/g was selected as the tissue NOAEL TRV, based on no effect on female survival in the study.

There is some uncertainty associated with these TRVs, as observed mortality may have been related to the increased aggressive behavior, as noted in Depew et al. (2012a) and Fuchsman et al (2016). Fuchsman states although mortality is an adverse effect regardless of whether it is a behavioral effect or a chemical-induced effect, extrapolation of a laboratory behavioral effect to the field presents uncertainty. Thus, use of the study should be qualified that female survival was unaffected, and male abundance is less important to fish productivity than female abundance (Fuchsman et al. 2016). However, this LOAEL was within the same order of magnitude of other methyl mercury LOAELs available and was an order of magnitude below the LOAEL TRVs based on mercuric chloride.

Support for the Matta et al. (2001) effects levels is provided by the Webber and Haines (2003), Sandheinrich and Wiener (2011), and Sandheinrich et al. (2011) studies. Webber and Haines (2003) examined the effects of dietary methyl mercury exposure on the growth and survival of golden shiners. There was altered predator avoidance in the high mercury diet that may potentially reduce survival. However, no statistically significant difference was observed on growth and survival was unaffected, resulting in a NOAEL of 520 ng/g ww for growth and survival. Sandheinrich and Wiener (2011) reviewed multiple laboratory and field studies based on exposure to methyl mercury via diet and/or water. Effects concentrations of methyl mercury in fish muscle tissue ranged between 500 and 1,200 ng/g ww and 300 and 700 ng/g ww on a whole body basis. The threshold concentration for toxic effects of 300 ng/g ww on a whole body basis identified by Sandheinrich and Wiener (2011) and Sandheinrich et al. (2011) was based on modeling performed in Dillon et al. (2010). Based on Sandheinrich and Wiener (2011) and Sandheinrich et al. (2011), the Phase II Study report suggested an effect level of 500 ng/g ww in fish tissue is a reasonable target to avoid toxic effects in fish. Another meta-analysis by Beckvar et al. (2005) calculated a tissue threshold effects level (TEL – the threshold value below which biological effects are predicted to rarely occur; CCME 1995 and MacDonald et al. 1996) of 200 ng/g based on growth, reproduction, development, behavior). In addition, a tissue TEL and a probable effects level (PEL - the lower limit of the range of contaminant concentrations that are usually or always associated with biological effects; CCME 1995 and MacDonald et al. 1996) were calculated for use as fish tissue TRVs in the Berry's Creek Study Area BERA (Berry's Creek Study Area Cooperating PRP Group 2017) to account for variability in toxicity across the large number of available toxicity studies. A methyl mercury TEL of 940 ng/g ww and PEL of 3,900 ng/g ww were calculated from ten studies based on growth, survival, and reproduction endpoints. Based on these studies, use of the Matta et al. (2001) study for the TRVs is consistent with the low end of the effects range and is considered conservative and protective of forage fish.

4.2.1.2 Diet

Dietary effects studies for fish exposed to mercury are limited. As such, dietary TRVs for forage fish were also selected from the Matta et al. (2001) study based on the mummichog (**Table III.4-5**). A daily dietary dose LOAEL of 51.8 ng/g body weight per day (bw/day) ww was calculated from the dietary concentration of 1,900 ng/g food dry weight, resulting in reduced survival of males.

Depew et al. (2012) estimated sensitivity for various biological effects in fish and concluded that fish are most sensitive for reproductive effects, then biochemical, behavioral and growth effects. Depew et al. (2012) provided effects levels based on dietary dose concentrations causing adverse effects in fish. The effects levels are not daily dietary doses for fish. That said, for biochemical effects, Depew et al. (2012) found that the highest dietary no effects level for fish was 60 ng/g with a dietary TEL of 180 ng/g and the lowest LOAEL of 140 ng/g. The LOAEL is the lowest concentration at which effects have been observed. The TEL is calculated from the LOAEL and NOAEL as the square root of the product of the 50th percentile of the NOAEL and the 15th percentile of the LOAEL. For reproductive effects, Depew et al. (2012) found the highest dietary no effects level was 40 ng/g with the lowest LOAEL of 50 ng/g. The 40 ng/g value, based on the highest NOAEL, was taken from Friedmann et al. (1996) on the gonadosomatic index for juvenile walleye exposed to dietary methyl mercuric chloride. The 50 ng/g value, based on the lowest LOAEL, was taken from Alverez et al. (2006) on the altered larval behavior for adult Atlantic croaker exposed to dietary naturally-occurring mercury. Based on these data, the Phase II Study report suggested a reasonable level to protect predator fish health was 50 ng/g ww in fish. However, it is difficult to translate sublethal effects in individuals, such as altered neurochemistry, to population level effects. In addition, an expert report of Dr. Keenan (2014) developed a dietary TEL of 680 ng/g for forage fish derived from 42 NOAEL and 21 LOAEL values from 26 studies, which included the study by Matta et al. (2001). However, these effects levels are not daily dietary doses for fish. Based on the available studies, the Matta et al. (2001) study was selected for the dietary TRV basis because the mummichog is one of the forage fish receptors for the BERA and the effects level of 51.8 ng/g bw/day is consistent with the dietary effects level presented by Depew et al. (2012). The dietary concentration of 51.8 ng/g bw/day ww was also selected as the NOAEL TRV due to no effect on female survival.

4.2.2 Predatory Fish TRVs

4.2.2.1 Tissue

As noted in Section 4.2.1.1, fish tissue effect thresholds for methyl mercury have been developed by Beckvar et al. (2005), Depew et al. (2012), Dillon et al. (2010), and Sandheinrich and Wiener (2011). Fuchsman et al. (2016a) re-assessed the effects levels presented by these studies. Ten studies available in the literature presented tissue body burdens applicable to predatory fish related to effects from exposure to mercury (**Table III.4-4**). Toxicity data were primarily available for freshwater and brackish species. One study was available for saltwater species, the European eel, with a LOAEL of 15,300 ng/g based on reduced survival. A LOAEL of 770 ng/g was selected from Dillon et al. (2010) for the predatory fish tissue LOAEL TRV. This LOAEL is the 20 percent effects concentration, termed the EC_{20}, calculated from the multispecies dose–response curve based on effects on reproduction and survival (including early life stage survival) of six freshwater species and one brackish/coastal species (i.e., the mummichog) and includes forage and predatory fish species. Fuchsman et al. (2016a) concluded that, although the EC_{20} concentration of 770 ng/g based on laboratory toxicity data appears to be a more appropriate effects threshold for fish reproduction than the Beckvar et al. (2005) value of 200 ng/g, the value may overestimate adverse effects on fish based on field studies with fish tissue mercury concentrations higher than the EC_{20} with no evidence of adverse impacts to fish populations (e.g., South River and Onondaga Lake). In addition to these studies, a methyl mercury TEL of 940 ng/g ww and PEL of 3,900 ng/g ww were calculated from ten studies based on growth, survival, and reproduction endpoints and used as fish tissue TRVs in the Berry's Creek Study Area BERA (Berry's Creek Study Area Cooperating PRP Group 2017). An expert report of Dr. Keenan (2014) developed a tissue TEL of 1,600 ng/g and PEL of 6,600 ng/g for predatory fish derived from 17 NOAEL and 15 LOAEL values from 10 studies based on growth, survival and reproduction.

Based on the available studies, a LOAEL of 770 ng/g is used for predatory fish such as the tomcod because the eel LOAEL TRV is two orders of magnitude higher. In addition, the American eel tissue being evaluated in the BERA was collected during the yellow phase as a freshwater species. This LOAEL is within the range of values evaluated, including the Phase II Study report suggested effect level of 500 ng/g ww based on Sandheinrich and Wiener (2011) and Sandheinrich et al. (2011) as the lower bound and the eel LOAEL of 15,300 ng/g as the upper bound. An effects concentration in prey species is used to protect the health of predators. As such, the forage fish tissue effects concentration is lower than the predatory fish tissue effects concentration. The LOAEL of 770 ng/g for predatory fish is considered appropriate based on the LOAEL of 440 ng/g used for forage fish. No NOAEL was reported for predatory fish tissue. A NOAEL was calculated from the LOAEL by multiplying by 0.1, representative of a 10x uncertainty factor (EPA 1999b). The resulting NOAEL of 77 ng/g was used as the predatory fish tissue NOAEL TRV.

4.2.2.2 Diet

As noted in Section 4.2.1.2, dietary effects studies for fish exposed to mercury are limited. As such, dietary TRVs for predatory fish were selected from the Gharaei et al. (2008) study based on the Beluga sturgeon (**Table III.4-5**). Beluga sturgeon used for toxicity testing by Gharaei et al. (2008) are anadromous fish like the predatory fish receptors in this BERA, and thus, provide a better representation of potential effects from mercury on predatory fish. Gharaei et al. (2008) exposed beluga sturgeon by feeding each treatment group for 35 days with food dosed with methyl mercuric chloride and evaluated growth and mortality endpoints. The growth endpoint was selected for the basis of the TRVs as growth is a more sensitive endpoint than mortality. A daily dietary dose LOAEL of 139 ng/g bw/day ww was calculated from the dietary concentration of 7,880 ng/g food dry weight that resulted in reduced growth. The expert report of Dr. Keenan (2014) developed a dietary TEL of 680 ng/g and a PEL of 5,030 ng/g for predatory fish, which included the study by Gharaei et al. (2008). However, these effects levels are not daily dietary doses for fish. Similar to tissue exposure, an effects concentration in prey species is used to protect the health of predators. The dietary forage fish effects concentration is lower than the dietary predatory fish effects concentration. The LOAEL of 139 ng/g for predatory fish is considered appropriate based on the LOAEL of 51.8 ng/g used for forage fish. The dietary concentration of 13.4 ng/g bw/day ww was calculated for the NOAEL and selected as the NOAEL TRV.

4.3 BIRD TRVS

4.3.1 Marsh Songbirds

4.3.1.1 Tissue (Blood)

Numerous laboratory and field studies providing blood mercury concentrations related to avian toxicity are available in the literature (**Table III.4-6**). Fuchsman et al. (2016b) reviewed the available studies on methyl mercury effects on avian reproduction and categorized effects levels by relative size of the bird (i.e., small, medium, and large). Effects concentrations differ by size, and the Fuchsman et al. (2016b) meta-analysis provided a range of possible toxicity values based on size as the analysis concluded that body size is the best predictor of mercury sensitivity. Smaller avian receptors, such as songbirds, have higher mass-specific metabolic rates and food ingestion rates in comparison with larger piscivorous birds and waterfowl. Fuchsman et al. (2016b) presents a bird blood effects level range of 2,100 to 4,200 ng/g for small to medium-sized birds representative of marsh songbirds. The low end of this effects range, 2,100 ng/g for the Carolina wren (Jackson et al. 2011), is based on a significant difference in nest success.

The Phase II Study Report presented a bird blood EC_{20}, a blood effects concentration of methyl mercury at which a 20 percent reduction in fledging success would be expected, for insectivorous birds of approximately 1,200 ng/g ww, as presented in Evers (2012) based on the Jackson et al. (2011) study. Jackson et al. (2011) developed a model of nest survival as a function of female blood mercury concentrations based on field studies conducted in two river systems in Virginia (the North Fork Holston River and the South River). Dose–response relationships were derived estimating nest success as a function of blood Hg concentrations. The model predicted a 20 percent reduction in nest success in adult female Carolina wrens with blood concentrations of 1,200 ng/g ww (Jackson et al. 2011). Jackson et al (2011) reported no significant difference observed between the study areas and the upstream reference areas in the number of fledglings produced per nest, but a significant difference was observed in nest success in 2010. However, Fuchsman et al. (2016b) observed that there are multiple confounding factors and limitations to the dose-response relationship developed from the dataset, including small sample sizes, nest success predictions were more accurate in the study area versus reference area resulting in the slope of the dose-response curve to be exaggerated, and baseline blood concentrations set to zero versus observed reference blood concentrations (200 to 500 ng/g ww). The model also did not adequately address inter-annual variability in key reproductive success parameters or the probability of re-nesting of individuals in failed nests. The model also did not consider the potential for causative factors other than mercury potentially resulting in the lower nest success rate in the study area, such as habitat quality, nest type (artificial versus natural), and higher predation rates observed in study area versus reference area (of which were only recorded in the last year of the study). The study also did not determine effects due to predation versus those due to nest abandonment. Thus, the dose-response estimates may not accurately represent mercury exposure and nest success at the study sites. In light of these limitations, a mean blood Hg concentration of 2,130 ng/g ww from the observed 2010 study area dataset can be considered a LOAEL blood concentration based on nest success.

Two additional songbird studies provide support for a blood effects level higher than 1,200 ng/g ww. A tree swallow study (Hallinger and Cristol 2011) reported an effects level of 3,000 ng/g associated with an approximate 20 percent reduction in the number of fledglings. This effects level has a higher confidence than the Carolina wren study and is supported by another high confidence tree swallow study with high confidence that reported a no effect level of 3,000 ng/g for hatching and fledgling success (Longcore et al. 2007).

Based on the evaluation, the bird blood LOAEL of 2,100 ng/g based on reproduction (Jackson et al. 2011; Fuchsman et al. 2016b) was selected for use in the BERA. A NOAEL was calculated from the LOAEL by multiplying by 0.1, representative of a 10x uncertainty factor (EPA 1999b). The resulting NOAEL of 210 ng/g was used as the blood mercury NOAEL TRV for marsh songbirds based on reproduction.

4.3.1.2 Diet

Effects of mercury on avian reproduction through dietary exposure is also reviewed in Fuchsman et al. (2016b) and categorized by relative size of the bird (i.e., small, medium, and large) (**Table III.4-7**). Similar to tissue, effects concentrations differ by size, and the study provided a range of possible toxicity values based on size. Five studies used small birds representative of the marsh bird receptor species for the Estuary, including the zebra finch (Varian-Ramos et al. 2014), Carolina wren (Jackson et al. 2011; Jackson and Evers 2011), and tree swallow (Brasso and Cristol 2008; Hallinger and Cristol 2011). The American kestrel study (Albers et al. 2007) was not included because the kestrel eats other birds and is not appropriately representative of avian receptors for the site; chicks were exposed only by maternal transfer and not diet. A geomean dietary concentration was calculated using the LOAEL TRVs from these studies with life history traits similar to the avian receptors for the Estuary. The use of a geometric mean TRV provides a weight of evidence approach that considers the potential for population-level effects. While the simple use of the lowest study value available could be used for quantification of risks on an individual-level basis, it might not be appropriate for use on a population-level basis. When a number of toxicity data are available, the geometric mean of effects concentrations allows for the TRV to be informed by multiple studies, accounting for the variability in toxicity across a large number of available toxicity studies. A geomean of 260 ng/g bw/day was calculated as the dietary mercury LOAEL TRV for marsh songbirds based on reproduction effects concentrations of 140, 240, and 500 ng/g bw/day for the Carolina wren (Jackson et al. 2011; Jackson and Evers 2011), the zebra finch (Varian-Ramos et al. 2014), and the tree swallow (Brasso and Cristol 2008; Hallinger and Cristol 2011), respectively. This LOAEL is similar to the LOAEL of 268 ng/g bw/day calculated based on Varian-Ramos et al. (2014). The LOAEL of 260 ng/g bw/day is within the range of effects concentrations reported by Fuchsman et al. (2016b) for small-medium sized birds of 50 ng/g bw/day (based on the American kestrel) to 500 ng/g bw/day (based on the Carolina wren). Unbounded NOAELs based on field studies ranges between 20 ng/g bw/day to 1,400 ng/g bw/day for reproduction endpoints (Henny et al., 2005; Longcore et al. 2007; Custer et al. 2007). These unbounded NOAELs are within the effects range observed. Therefore, a NOAEL was calculated from the LOAEL by multiplying by 0.1, representative of a 10x uncertainty factor (EPA 1999b). The resulting NOAEL of 26 ng/g bw/day was used as the dietary NOAEL TRV for marsh songbirds based on reproduction.

4.3.2 American Black Duck

4.3.2.1 Tissue (Blood)

Similar to the marsh songbirds, numerous laboratory and field studies providing blood mercury concentrations related to avian toxicity on larger birds are available in the literature (**Table III.4-6**). Fuchsman et al. (2016b) reviewed the available studies on methyl mercury effects on avian reproduction and categorized effects levels by relative size of the bird (i.e., small, medium, and large). Effects concentrations differ by size, and the study provided a range of possible toxicity values based on size. Studies based on dabbling ducks (mallards) would be most similar to the black duck as the receptor for the Estuary. Studies based on the common loon and the bald eagle were also evaluated. The lowest LOAEL mercury concentration was selected from these two studies.

LOAELs of 5,200 ng/g (Heinz 1974, 1976a, 1976b, and 1979) and 17,000 ng/g (Heinz et al. 2010a, 2010b, and 2010c) were derived by Fuchsman et al. (2016) as mallard EC_{20} blood concentrations based on surviving ducklings per egg. Fuchsman et al. (2016) and Heinz et al. (2009) conclude that mallards are less sensitive to mercury than other larger birds. The evaluation also indicated adverse impacts to black ducks exposed to dietary and egg doses lower than or equal to the effect thresholds for mallards. These results suggest that black ducks may be more sensitive to mercury than mallards. A reproductive LOAEL TRV of 2,000 ng/g was developed for adult piscivorous birds in Evers et al. (2018) based on the EC_{20} presented in Burgess and Meyer (2008) and Evers et al. (2008). The Burgess and Meyer study measured quantile regression measured effects relative maximum productivity (i.e., number of chicks per breading couple), with a 50 percent decrease in productivity approximates a threshold for consistent effects. The maximum observed loon productivity was reduced by 50 percent when female blood methyl mercury levels were 4,300 ng/g. The Evers et al. (2008) study measured adverse effects to reproduction in loons based on exposure to anthropogenic methyl mercury and characterized a significant decrease in productivity at 3,000 ng/g methyl mercury in adult female blood (identified as an EC40 in Evers et al. 2018). The EC_{20} of 2,000 ng/g is consistent with the marsh songbird blood LOAEL of 2,100 ng/g. As such, the marsh songbird blood LOAEL of 2,100 based on reproduction (Jackson et al. 2011; Fuchsman et al. 2016b) was also selected for use in the BERA for the black duck and is applied to all wetland-dependent and aquatic avian species. The adjusted NOAEL of 210 ng/g was used as the blood mercury NOAEL TRV for black ducks based on reproduction.

4.3.2.2 Diet

Effects of mercury on avian reproduction for larger birds through dietary exposure is presented on **Table III.4-7**. One study was available using the black duck as a test species. Finley and Stendell (1978) exposed black ducks to methyl mercury dicyandiamide at a dietary concentration of 3 ppm dw for a period of 28 weeks during two consecutive breeding seasons from which Fuchsman et al. (2016b) calculated an $ED_{80\text{-}90}$ of 410 ng/g bw/day ww based on surviving ducklings per egg. This effect level is similar to the EC_{20} effects level for the mallard according to Fuchsman et al. (2016b), suggesting that black ducks may be more sensitive than mallards as mallard ED_{20s} for the same endpoint ranged between 400 and 1,500 ng/g bw/day based on Heinz studies (**Table III.4-7**). Based on this finding, an ED_{20} of 95 ng/g bw/day ww based on surviving ducklings per mating pair was derived for the black duck using the Finley and Stendell (1978) study data available (refer to **Appendix E** for supporting data). However, this ED_{20} for the black duck appears similar to the findings from the Heinz studies (1974, 1975, 1976a, 1976b, and 1979) that exposed mallards to methyl mercury dicyandiamide at a dietary concentration of 500 ng/g dw for three generations. A 30 percent reduction in 1-week survival rates was observed in the second generation. Using the 500 ng/g dw dietary treatment converted to 470 ng/g ww based on Heinz (1975), a LOAEL of 75 ng/g bw/day ww was estimated from the study (Table III.4-7). This LOAEL supports the black duck ED_{20} calculated, suggesting that inferences of black ducks possibly being more sensitive than mallards are inconclusive. The ED_{20} of 95 ng/g bw/day ww was selected for the dietary TRV for the black duck based on reproduction as it is a target receptor and is supported by the Heinz LOAEL findings. A NOAEL value was not available. A NOAEL was calculated from the LOAEL by multiplying by 0.1, representative of a 10x uncertainty factor (EPA 1999b). The resulting NOAEL of 9.5 ng/g bw/day was used as the black duck dietary NOAEL TRV based on reproduction.

4.3.3 Piscivorous Birds

Effects of mercury on avian reproduction through dietary exposure for piscivorous birds are reviewed in Fuchsman et al. (2016b) and Depew et al. (2012b) along with several other studies identified in scientific literature (**Table III.4-8**). The studies primarily provide either unbounded NOAELs or LOAELs with a NOAEL range of 6 ng/g bw/day to 290 ng/g bw/day and a LOAEL range of 32 ng/g bw/day to 90 ng/g bw/day. A geomean dietary concentration was calculated for the NOAEL and LOAEL TRVs from available studies on Table III.4-8. The use of a geometric mean TRV provides a weight of evidence approach that considers the potential for population-level effects. While the simple use of the lowest study value available could be used for quantification of risks on an individual-level basis, it might not be appropriate for use on a population-level basis. When a number of toxicity data are available, the geometric mean of effects concentrations allows for the TRV to be informed by multiple studies, accounting for the variability in toxicity across a large number of available toxicity studies. Geomeans of 40 ng/g bw/day and 59 ng/g bw/day were calculated as the dietary methyl mercury NOAEL and LOAEL TRVs, respectively, for piscivorous birds based on reproduction effects. These TRVs were used for the belted kingfisher and the bald eagle.

4.4 Piscivorous Mammal TRVs

A multi-generational mink study was selected for the piscivorous mammal dietary TRVs (**Table III.4-9**). Female mink were fed diets containing 0.1, 0.5 and 1.0 mg/kg total mercury (Dansereau et al. 1999). Piscivorous and nonpiscivorous fish naturally contaminated with organic mercury were used to prepare the experimental diets. No negative control was used in this study due to the inability to find a freshwater fish diet uncontaminated by mercury. First generation females (G1) were exposed to the diets for approximately 400 days, and their female offspring (G2) were exposed to the diets for approximately 300 days. All females were mated to males that were fed the diet containing 0.1 mg/kg mercury for 60 days prior to the mating season. Mercury exposure did not affect length of gestation period, number of kits, survival or growth of neonatal kits. There was an inverse relationship between whelping proportion and exposure concentration, but this was not statistically significant. High mortality was observed in G1 females (60 percent) and G2 females (86 percent) fed the 1.0 mg/kg mercury diet. The doses were converted to daily dietary doses using the mink ingestion rate of 0.114 kilograms per day (kg/day) and a body weight of 0.85 kg used in the BERA for the mink. A LOAEL of 121 ng/g bw/day and a NOAEL of 75 ng/g bw/day were calculated for reduced adult survival and used as the dietary mink TRVs in the BERA.

4.5 SELECTED TRVS

A summary of the TRVs selected for surface water exposure for aquatic invertebrates represented by the blue mussel is presented in **Table III.4-10**. A summary of the tissue residue and blood TRVs selected for receptor exposure is presented in **Table III.4-11**. A summary of the dietary TRVs selected for receptor exposure in the food web modeling is presented in **Table III.4-12**.

5.0 ECOLOGICAL RISK CHARACTERIZATION

Risk characterization integrates the results of the ecological effects evaluation and exposure estimation to determine the potential risk to ecological receptors from exposure to mercury in the Estuary. Consistent with EPA guidance (EPA 1997a, 1998, 1999b), the risk characterization for this BERA is based on a multiple lines of evidence approach, including tissue exposure, food web exposure, and a comparison to reference area exposure. The relative strengths and weaknesses and associated uncertainties for each line of evidence are considered in formulating conclusions.

The first part of the risk characterization is the risk description provided in this section, which provides the quantitative results of the risk estimates for the multiple lines of evidence for each of the representative receptors for the site. The risk characterization was performed using the HQ method that compares estimated exposure levels (i.e., surface water or biotic tissue concentrations and/or dietary doses) to analyte-specific TRVs (i.e., NOAELs and LOAELs). A qualitative evaluation is also provided for piscivorous avian receptors based on historical data. The second part is the uncertainty analysis (Section III.6.0), which discusses the specific uncertainties associated with each line of evidence. The resulting BERA conclusions (Section III.7.0) provide an overall interpretation of risk (i.e., the potential for adverse effects) for each assessment endpoint based on interpretation of the strengths and weaknesses of each line of evidence.

This section describes the results of the quantitative risk estimates or HQs for each line of evidence for the assessment endpoints. HQs are the unitless ratios calculated by dividing the exposure estimate for a receptor by the receptor-specific TRV as shown in Equation 1:

Equation 1: $$HQ = \frac{Exposure}{TRV}$$

where:

HQ = Hazard Quotient

Exposure = Abiotic concentration (ng/L), biotic tissue concentration (ng/g), or potential average daily dose (ng/g bw/d)

TRV = Surface water TRV (ng/L), tissue TRV (ng/g), or dietary TRV (ng/g per day)

In interpreting HQ results, NOAEL-based HQs < 1.0 are considered to indicate no unacceptable risk. This determination is based on the compounded conservative assumptions used in the exposure model and the conservative nature of the NOAEL TRVs. Specifically, the NOAEL is a level at which no adverse effects have been observed in toxicity studies. Thus, when HQs based on NOAELs are < 1.0, the likelihood of adverse effects occurring at these concentrations is considered *de minimis* (negligible), and no unacceptable risk is expected. When the NOAEL HQs are ≥ 1.0, but the LOAEL HQs are < 1.0, ecologically significant adverse effects to that receptor are possible. Per EPA's ERAGS (1997), "The threshold for effects is assumed to be between the NOAEL and the LOAEL of a toxicity test". However, uncertainty is associated with defining the true toxicity threshold. Thus, while adverse effects are considered possible in this case, the results are reviewed also in the context of other lines of evidence and supporting information. A LOAEL-based HQ ≥ 1.0 indicates potential for adverse effects.

The following subsections discuss the results of the risk characterization by assessment endpoint and receptor. Dietary composition, exposure parameters, and mercury EPCs are described in Section III.3.0 and summarized in **Tables III.3-1 through III.3-13**. Selected NOAEL- and LOAEL-based TRVs are described in Section III.4.0 and summarized in **Tables III.4-1 through III.4-12**. **Tables III.5-1 through III.5-12** present the NOAEL and LOAEL risk calculations for the ecological receptors. **Table III.5-2c** presents a summary of the tissue HQs. **Table III.5-13** presents a summary of the dietary HQs. **Table III.5-14** presents a summary of the reference area HQs.

As an additional line of evidence in the risk characterization, a background evaluation was undertaken using samples taken from reference areas (e.g., Frenchmen's Bay). Using the reference samples, a BTV was calculated using EPA ProUCL 5.1.002. The ProUCL program generates multiple BTV values based on the distribution for each data set. In general, the 95 percent UTL with 95 percent coverage is the most appropriate BTV as it is the EPA's preferred background statistic. A 95 percent UTL with 95 percent coverage is based on an established background data set that represents an upper limit, such that 95 percent of the sampled data will be less or equal to the UTL. However, if the UTL is above the maximum detected background value, than the maximum detected background value was utilized. Other assumptions made in the calculations of BTVs are as follows:

- Only data deemed usable based on the data validation process were included.
- Only primary samples were used to calculate BTVs.
- A statistical outlier test was run, and any identified high outliers were removed from the BTV calculation[2]
- In cases were more than one BTV was calculated by ProUCL, the BTV matching the best fitting curve (i.e., normal, gamma, lognormal, or non-parametric) using a goodness-of-fit test and highest R value was utilized). When no curve passed the goodness-of-fit test, the non-parametric BTV was used.

Reference data for total mercury were available for the lobster, blue mussel, mummichog, rainbow smelt, Atlantic tomcod, American eel, Nelson's sparrow and the American black duck (blood). However, it should be noted for the Atlantic tomcod, only one background sample was available, which does not allow for the calculation of a BTV. Furthermore, the calculated UTLs for the American eel, blue mussel, rainbow smelt, Nelson's sparrow, and American black duck blood were above their maximum detected concentrations. As concentrations in tissue approach background levels, it indicates that potential remedial activities may not be able to reduce the overall exposure and uptake to mercury in the environment by various biota. Note that there is

[2] Outliers are defined at the 1 percent significance level

a potential for concentrations in tissue that would result in elevated levels of risk would be below their biota-specific BTV, indicating that potential levels of elevated risk for specific receptors could be contributed to background levels. The BTV calculations for each media are presented in **Appendix B**. **Table III.5-15** compares total mercury tissue concentrations to the BTVs for the reference areas.

5.1 AQUATIC INVERTEBRATES

5.1.1 Blue Mussel

5.1.1.1 Measurement Endpoint 1: Comparison of Surface Water Concentrations to Surface Water TRVs Protective of Mollusks

Surface water NOAEL- and LOAEL-based HQs for total mercury were below 1.0 for the protection of mollusks at the exposure areas evaluated (**Table III.5-1**). There is no unacceptable risk to mussels based on surface water exposure.

5.1.1.2 Measurement Endpoint 2: Comparison of Blue Mussel Tissue to Reference Area Concentrations

Blue mussel total mercury tissue concentrations are above the BTV of 13.0 ng/g (**Table III.5-15**).

5.1.1.3 Measurement Endpoint 3: Comparison of Blue Mussel Tissue to Mussel Tissue TRVs

The total mercury tissue NOAEL-based HQs for the blue mussel were above 1.0 at the exposure areas evaluated, indicating the potential for unacceptable risk based on total mercury tissue body burdens (**Table III.5-2a and III.5-2c**). Tissue LOAEL-based HQs were at or below 1.0. The reference area NOAEL- and LOAEL-based HQs were below 1.0 for total mercury. The methyl mercury tissue NOAEL- and LOAEL-based HQs for the blue mussel were below 1.0 at the exposure areas evaluated and the reference location, indicating no unacceptable risk based on methyl mercury tissue body burdens (**Tables III.5-2b** and **III.5-2c**).

5.1.2 American Lobster

5.1.2.1 Measurement Endpoint 1: Comparison of Lobster Tissue to Reference Area Concentrations

American lobster total mercury tissue concentrations are above the BTV of 57.5 ng/g, except for four (out of 40) lobster samples collected from Harborside (**Table III.5-15**).

5.1.2.2 Measurement Endpoint 2: Comparison of Lobster Tissue to Decapod Tissue TRVs

As shown in **Tables III.5-2a through III.5-2c,** tissue NOAEL-based HQs for American lobster were below 1.0 the seven exposure areas evaluated, indicating no unacceptable risk based on tissue body burdens.

5.2 FISH

5.2.1 Forage Fish

5.2.1.1 Measurement Endpoint 1: Comparison of Forage Fish Tissue to Reference Area Concentrations

All of the mummichog and rainbow smelt total mercury tissue concentrations are above the BTVs of 10.7 ng/g and 26.2 ng/g, respectively (**Table III.5-15**).

5.2.1.2 Measurement Endpoint 2: Comparison of Forage Fish Tissue to Forage Fish Tissue TRVs

Forage fish tissue NOAEL- and LOAEL-based HQs for mummichog and rainbow smelt were below 1.0 for total mercury and methyl mercury at the exposure areas evaluated and the reference location (**Tables III.5-2a** through **III.5-2c**), indicating no unacceptable risk to forage fish based on tissue body burdens.

5.2.1.3 Measurement Endpoint 3: Comparison of Calculated Dietary Dose to Forage Fish Dietary TRVs

Mummichog

Mummichog dietary NOAEL- and LOAEL-based HQs were below 1.0 for total mercury and methyl mercury at the exposure areas evaluated and the reference location (**Tables III.5-3a** and **III.5-3b**), indicating no unacceptable risk to mummichog based on dietary exposure to mercury.

Rainbow Smelt

Rainbow smelt dietary NOAEL- and LOAEL-based HQs were below 1.0 for total mercury and methyl mercury at the Estuary and the reference location (**Tables III.5-4a** and **III.5-4b**), indicating no unacceptable risk to rainbow smelt based on dietary exposure to mercury.

5.2.2 Predatory Fish

5.2.2.1 Measurement Endpoint 1: Comparison of Predatory Fish Tissue to Reference Area Concentrations

Atlantic tomcod total mercury tissue concentrations are above the BTV of 36.5 ng/g, except for two samples collected from ES-13 (20/22 samples above background) (**Table III.5-15**). American eel total mercury tissue concentrations are above the BTV of 320 ng/g, except for one sample collected from BO4 (20/21 samples above background) and 14 samples collected from OB5 (11/25 samples above background) (**Table III.5-15**).

5.2.2.2 Measurement Endpoint 2: Comparison of Predatory Fish Tissue to Predatory Fish Tissue TRVs

Atlantic tomcod

The tissue NOAEL-based HQs for the Atlantic tomcod and American eel were above 1.0 for both total mercury (with HQs ranging from 1.8 to 3.1) and methyl mercury (with HQs ranging from 1.4 to 2.5) at four out of five exposure areas (**Tables III.5-2a** through **III.5-2c**). However, tissue LOAEL-based HQs for total mercury and methyl mercury were below 1.0 at those four exposure areas evaluated. The reference area NOAEL- and LOAEL-based HQs were below 1.0 for both total mercury and methyl mercury. Unacceptable risk is possible because NOAEL HQs are > 1.0, but the LOAEL HQs are < 1.0. However, unacceptable risk to Atlantic tomcod is considered unlikely based on tissue mercury body burdens using a population-level EC_{20} for reproduction and survival as the LOAEL TRV.

American Eel

The tissue NOAEL-based HQs for the American eel were above 1.0 for both total mercury (with HQs ranging from 5.1 to 9.1) and methyl mercury (with HQs ranging from 4.3 to 7.9) at the exposure areas evaluated (**Tables III.5-2a** through **III.5-2c**). The NOAEL-based HQs were also above 1.0 at the reference location (HQs of 4.2 for total mercury and 3.6 for methyl mercury). However, tissue LOAEL-based HQs for total mercury and methyl mercury were below 1.0 at the exposure areas evaluated and at the reference location. Unacceptable risk is possible because NOAEL HQs are > 1.0, but the LOAEL HQs are < 1.0. However, unacceptable risk to the American eel is considered unlikely based on tissue mercury body burdens using a population-level EC_{20} for reproduction and survival as the LOAEL TRV.

5.2.2.3 Measurement Endpoint 3: Comparison of Calculated Dietary Dose to Predatory Fish Dietary TRVs

Atlantic Tomcod

The total mercury and methyl mercury dietary NOAEL- and LOAEL-based HQs for the Atlantic tomcod were below 1.0 for both the Estuary and the reference location, indicating no unacceptable risk based on dietary exposure to mercury (**Tables III.5-5a** and **III.5-5b**).

American Eel

The total mercury and methyl mercury dietary NOAEL- and LOAEL-based HQs for the American eel were below 1.0 for both the Estuary and the reference location, indicating no unacceptable risk based on dietary exposure to mercury (**Tables III.5-6a** and **III.5-6b**).

5.3 WETLAND-DEPENDENT BIRDS

5.3.1 Nelson's Sparrow

5.3.1.1 Measurement Endpoint 1: Comparison of Sparrow Blood to Reference Area Concentrations

Nelson's sparrow total mercury blood concentrations are above the BTV of 740 ng/g, except for one sample (out of 27) collected from wetland/marsh platform (W) location W-17-N (**Table III.5-15**).

5.3.1.2 Measurement Endpoint 2: Comparison of Sparrow Blood to Avian Blood TRVs

The blood NOAEL- and LOAEL-based HQs for the Nelson's sparrow for both total mercury and methyl mercury (with NOAEL-based HQs of approximately 20 and LOAEL-based HQs of approximately 2) were above 1.0 for all marsh platform exposure areas evaluated (W-17-N, MMSW, and MMSW) (**Tables III.5-2a through III.5-2c**). The NOAEL-based HQs were also above 1.0 at the reference location (HQs of approximately 2), while the LOAEL-based HQs were below 1.0 (**Tables III.5-2a** through **III.5-2c**). An HQ above 1.0 indicates potential for adverse effects; thus, there is the potential for adverse effects to Nelson's sparrows based on blood mercury levels.

5.3.1.3 Measurement Endpoint 3: Comparison of Calculated Dietary Dose to Avian Dietary TRVs

As shown in **Tables III.5-7a** and **III.5-7b,** the dietary NOAEL-based HQs for the Nelson's sparrow for both total mercury (with HQs ranging from 2.2 to 6.3) and methyl mercury (with HQs ranging from 1.3 to 2.6) were above 1.0 for all marsh platform exposure areas evaluated (W-17-N, MMSE, and MMSW). However, the dietary LOAEL-based HQs for the Nelson's sparrow for both total mercury and methyl mercury were below 1.0 for all exposure areas evaluated. The NOAEL- and

LOAEL-based HQs were below 1.0 for the reference location. Unacceptable risk is possible because NOAEL HQs are > 1.0, but the LOAEL HQs are < 1.0. There is the potential for adverse effects to Nelson's sparrows based on dietary exposure.

The magnitude of these HQs are mainly attributed to the ingestion of terrestrial insects, which accounts for 85 percent of the Nelson's sparrow diet. The dietary mercury dose from terrestrial insects is the largest contributor to total dose across the exposure areas (35 to 75 percent for total mercury and 35 to 69 percent for methyl mercury).

5.3.2 Red-winged Blackbird

5.3.2.1 Measurement Endpoint 1: Comparison of Blackbird Blood to Avian Blood TRVs

The blood NOAEL- and LOAEL-based HQs for the red-winged blackbird for both total mercury (with NOAEL-based HQs ranging from 20 to 36 and LOAEL-based HQs ranging from 2.0 to 3.6) and methyl mercury (with NOAEL-based HQs ranging from 19 to 34 and LOAEL-based HQs ranging from 1.3 to 2.4) were above 1.0 for all marsh platform exposure areas (W-17-N, MMSW, and MMSW) (**Tables III.5-2a** through **III.5-2c**). Reference location data were not available for red-winged blackbirds. An HQ above 1.0 indicates potential for adverse effects; thus, there is the potential for adverse effects to red-winged blackbirds based on blood mercury levels.

5.3.2.2 Measurement Endpoint 2: Comparison of Calculated Blackbird Dietary Dose to Avian Dietary TRVs

As shown in **Tables III.5-8a** and **III.5-8b,** the dietary NOAEL-based HQs for the red-winged blackbird for total mercury (with HQs ranging from 1.0 to 4.2) were at or above 1.0 at the three marsh platform exposure areas evaluated (W-17-N, MMSE, and MMSW) and methyl mercury NOAEL-based HQs (with HQs ranging from 0.76 to 1.7) were above 1.0 for two of the three marsh platform exposure areas (W-17-N and MMSE). However, the dietary LOAEL-based HQs for the red-winged blackbird for both total mercury and methyl mercury were below 1.0 for all exposure areas evaluated. NOAEL- and LOAEL-based HQs were below 1.0 for the reference location. Unacceptable risk is possible because NOAEL HQs are > 1.0, but the LOAEL HQs are < 1.0. There is the potential for adverse effects to red-winged blackbirds based on dietary exposure.

The magnitude of these HQs are mainly attributed to the ingestion of terrestrial insects, which accounts for 90 percent of the red-winged blackbirds diet. Although dietary total mercury and methyl mercury EPCs are generally lower in insects than in spiders and sediment, the dietary mercury dose from terrestrial insects is the largest contributor to total dose across the exposure areas (61 to 85 percent for total mercury and 45 to 78 percent for methyl mercury).

5.3.3 American Black Duck

5.3.3.1 Measurement Endpoint 1: Comparison of Duck Blood to Reference Area Concentrations

American black duck total mercury blood concentrations are above the BTV of 124 ng/g, except for 21 out of 51 samples collected from ES-13 (South Verona) and 2 out of 38 samples collected from Mendall Marsh (**Table III.5-15**).

5.3.3.2 Measurement Endpoint 2: Comparison of Duck Blood to Avian Blood TRVs

The blood NOAEL-based HQs for the American black duck for total mercury (with HQs ranging from 1.4 to 2.2) and methyl mercury (with HQs ranging from 1.1 to 1.7) were above 1.0 at the two exposure areas evaluated (**Tables III.5-2a through III.5-2c**). However, American black duck blood LOAEL-based HQs for total mercury and methyl mercury were below 1.0. NOAEL- and LOAEL-based HQs were below 1.0 for the reference location. Unacceptable risk is possible because NOAEL HQs are > 1.0, but the LOAEL HQs are < 1.0. There is the potential for adverse effects to the American black duck based on blood mercury levels.

A temporal comparison of American black duck blood collected at Mendall Marsh, South Verona, and Frenchman Bay (reference area) between 2011 and 2018 is presented in **Figure III.5-1a.** American black duck blood concentrations from each year sampled were below the bird blood LOAEL of 2,100 ng/g based on reproduction (Jackson et al. 2011; Fuchsman et al. 2016b) at each exposure area. The significant, positive duck blood and muscle tissue correlation (Spearman's rho of 0.94; $p < 0.001$) presented in the Biota Monitoring Report (Amec Foster Wheeler 2017a) was used to calculate estimated duck blood concentrations from duck breast muscle tissue for ducks that were not sampled for blood (i.e., ducks with only breast muscle tissue sampled). Mendall Marsh was the only sampling location where ducks were sampled for muscle, but not blood. Ducks sampled for breast muscle at South Verona and Frenchman Bay were also sampled for blood and were used in the development of the duck blood:muscle correlation. Estimated duck blood concentrations in Mendall Marsh (data from 2011, 2012, and 2014) were statistically compared (Mann-Whitney U test) with actual duck blood concentrations sampled during the same winter in Mendall Marsh (**Figure III.5-1b**). Estimated and actual duck blood concentrations were also compared, pooling the three years of data. Estimated and actual blood concentrations did not differ statistically when all years were combined ($p = 0.10$). Estimated and actual blood concentrations did not differ statistically in 2011 ($p = 0.23$), 2012 ($p = 0.12$), or 2014 ($p = 0.10$). Given that estimated and actual duck blood concentrations were not significantly different provides additional evidence that the blood:muscle correlation can be used in the future for sampling duck blood as a surrogate for muscle tissue. In future LTM events when blood concentrations suggest that duck breast muscle tissues should be below the toxicity value for human health, then duck muscle tissue and blood from the same duck should be sampled.

Mean blood mercury concentrations were significantly different across one or more years at South Verona (Kruskal-Wallis test; $p < 0.001$) and Mendall Marsh (Kruskal-Wallis test; $p = 0.005$) (**Appendix E**). Mercury concentrations in black duck blood were greater at Mendall Marsh than at South Verona and Frenchman Bay (reference area), both within and across years. The mean total mercury concentration in 2018 blood samples in Mendall Marsh ducks was 292 ng/g ww, in South Verona ducks was 180 ng/g ww, and in Frenchman Bay ducks was 54.9 ng/g ww. No significant declines in blood mercury concentrations over time were observed for Mendall Marsh (**Appendix E**). Mercury concentrations at South Verona were largely consistent, with elevated average concentrations reported in 2011 and 2017. There was a decrease in blood mercury concentrations in black ducks across years at Frenchman Bay with an elevated average concentration in 2012.

5.3.3.3 Measurement Endpoint 3: Comparison of Calculated Duck Dietary Dose to Avian Dietary TRVs

The total mercury and methyl mercury dietary NOAEL-based HQs for the American black duck were below 1.0 for the exposure areas evaluated except for total mercury in Mendall Marsh (HQ of 1.5) (**Tables III.5-9a** and **III.5-9b**). The dietary LOAEL-based HQs for both total mercury and methyl mercury were below 1.0 for all exposure areas evaluated. NOAEL- and LOAEL-based HQs were below 1.0 for the reference location. Unacceptable dietary risk is possible in Mendall Marsh because the NOAEL HQ is > 1.0, but the LOAEL HQ is < 1.0. There is the potential for adverse effects to American black ducks based on dietary exposure.

5.3.3.4 Measurement Endpoint 4: American Black Duck Muscle Tissue Evaluation

A temporal comparison of American black duck muscle tissue collected at Mendall Marsh, South Verona, and Frenchman Bay (reference area) between 2011 and 2017 is presented in **Figure III.5-1c**. Mendall Marsh, South Verona, and Frenchman Bay (reference area) between 2011 and 2017 American black duck muscle tissue concentrations from each year were above the Maine Center for Disease Control and Prevention (MeCDC) Fish Tissue Action Level of 200 ng/g ww (2001). Tissue concentrations at Frenchman Bay were consistently below MeCDC Fish Tissue Action Level. **Figure III.5-1d** presents a combined dataset of American black duck muscle tissue collected at each location, as well as modeled tissue concentrations calculated using the duck blood and muscle tissue correlation developed for the site (Amec Foster Wheeler, 2017a). Mean muscle tissue mercury concentrations were significantly different across one or more years at Mendall Marsh and South Verona ($p < 0.001$) (**Appendix E**). Using the combined actual and estimated tissue concentrations, Mendall Marsh tissue concentrations for each year were above the MeCDC Fish Tissue Action Level of 200 ng/g ww (**Figure III.5-1d**). Combined actual and estimated tissue concentrations at South Verona fluctuated above and below the MeCDC Fish Tissue Action Level with 2018 estimated concentrations being typically below 200 ng/g (**Figure III.5-1d**). Combined actual and estimated tissue concentrations at Frenchman Bay were consistently below the MeCDC Fish Tissue Action Level.

Mercury concentrations in black duck tissue were significantly different among Mendall Marsh, South Verona, and Frenchman Bay (reference area), both within and across years. The mean total mercury concentration in modeled 2018 tissue samples in Mendall Marsh ducks was 258 ng/g ww, in South Verona ducks was 168 ng/g ww, and in Frenchman Bay ducks was 68.8 ng/g ww. The average concentration of mercury at Mendall Marsh decreased 66 percent from 2011 to 2018 although a statistically significant decline in tissue mercury concentrations over time could not be ascertained (Amec Foster Wheeler 2018a). Duck tissue concentrations in 2018 were significantly lower than 2011 and 2012 duck tissue data, reflecting a decrease in mercury concentrations at Mendall Marsh from 2011 to 2018 (**Appendix E**). This differs from the initial interpretation of black duck tissue concentrations collected from 2011 to 2014 in Mendall Marsh (Figures 4 and 5 in Sullivan and Kopec 2018), which suggested that black duck tissue concentrations were not changing. While concentrations of mercury at South Verona showed a statistical difference between sample years, the average mean concentration fluctuated from high concentrations in 2011 and 2017 to lower concentrations in 2012, 2014, and 2018. Black ducks at Frenchman Bay showed minimal change in tissue mercury concentrations across years although there were statistical differences between sampling years.

5.4 PISCIVOROUS BIRDS

5.4.1 Belted Kingfisher

5.4.1.1 Measurement Endpoint 1: Comparison of Calculated Dietary Dose to Piscivorous Bird Dietary TRVs

As shown in **Tables III.5-10a** and **III.5-10b,** the dietary NOAEL- and LOAEL-based HQs for the belted kingfisher for both total mercury and methyl mercury were below 1.0 for the exposure areas evaluated and the reference location. No unacceptable risk is anticipated for the belted kingfisher based on dietary exposure to mercury.

5.4.2 Bald Eagle

5.4.2.1 Measurement Endpoint 1: Comparison of Calculated Dietary Dose to Piscivorous Bird Dietary TRVs

As shown in **Tables III.5-11a** and **III.5-11b,** the dietary NOAEL- and LOAEL-based HQs for the bald eagle for both total mercury and methyl mercury were below 1.0 for the exposure areas evaluated and the reference location. No unacceptable risk is anticipated for the bald eagle based on dietary exposure to mercury.

5.4.3 Qualitative Evaluation of Piscivorous Bird Data

Because only historical (2006 to 2010) blood and egg data were available for piscivorous birds, a qualitative assessment is included in the BERA. **Table III.5-16a** presents a summary of the piscivorous bird total mercury blood data collected between 2006 and 2010 for the belted kingfisher, black guillemot, double-crested cormorant, bald eagle, and osprey. Where historical data were provided for age, data were separated for adult and juvenile birds. The data were also evaluated for three different exposure areas based on the historical sample collection locations – upstream of the study boundary, within the study boundary, and downstream of the study boundary (**Figures III.5-2a and III.5-2b**). These blood data were compared to the adult avian blood LOAEL TRV of 2,100 ng/g (Jackson et al. 2011; Fuchsman et al. 2016b) which was used for aquatic birds. Exposure area 95 percent UCLs were below the blood LOAEL for every species and exposure area. The following summarizes the species and exposure areas with individual blood samples greater than the LOAEL of 2,100 ng/g:

- Belted kingfisher – 3.3 percent upstream of the study boundary and 3.8 percent within the study boundary
- Double-crested cormorant – 22 percent within the study boundary and 2.4 percent downstream of the study boundary
- Osprey – 17 percent within the study boundary (adult only) and 25 percent downstream of the study boundary (adult only)

In addition, the following summarizes the species with individual blood samples less than the LOAEL of 2,100 ng/g:

- Black guillemot – total mercury range of 143 to 1,799 ng/g percent downstream of the study boundary
- Eagle – total mercury range of 305 to 1,000 ng/g upstream of the study boundary, 101 to 288 ng/g downstream of the study boundary, and 129 to 413 ng/g within the study boundary
- Osprey – total mercury range of 23.2 to 51.3 ng/g downstream of the study boundary (juvenile only) and 45.7 to 131 ng/g within the study boundary (juvenile only)

Table **III.5-16b** presents a summary of the piscivorous bird egg total mercury and methyl mercury data collected between 2006 and 2012 for the black guillemot, double-crested cormorant, and osprey. Available data were evaluated for two different exposure areas based on the historical sample collection locations –within the study boundary and downstream of the study boundary (**Figure III.5-2b**). The following summarizes the species and exposure area egg data:

- Black guillemot – total mercury range of 482 to 1,182 ng/g downstream of study boundary
- Double-crested cormorant – total mercury range of 109 to 986 ng/g within the study boundary and 38 to 684 ng/g downstream of the study boundary; methyl mercury range of 137 to 955 ng/g within the study boundary and 83 to 394 downstream of the study boundary
- Osprey – total mercury range of 116 to 414 ng/g within the study boundary and 78 to 136 ng/g downstream of the study boundary; methyl mercury concentration of 141 ng/g downstream of the study boundary.

Although blood mercury data for piscivorous birds indicates exceedances of the blood LOAEL TRV and elevated egg mercury data, these data are between 6 and 12 years old and would not likely be considered representative of current site conditions in the Estuary as the data were collected several years ago. The data are presented herein for informational purposes.

5.5 PISCIVOROUS MAMMALS – MINK

5.5.1 Measurement Endpoint 1: Comparison of Calculated Dietary Dose to Mammalian Dietary TRVs

The total mercury and methyl mercury dietary NOAEL- and LOAEL-based HQs for the mink were below 1.0 for the exposure areas evaluated and the reference location, indicating no unacceptable risk to the mink based on dietary exposure to mercury (**Tables III.5-12a** and **III.5-12b**).

5.6 RISK SUMMARY

The lines of evidence in the BERA indicate the following risk conclusions:

- Total mercury tissue concentrations for the ecological receptors are above background tissue concentrations.
- Blue Mussels: There is no unacceptable risk based on surface water exposure. There is the potential for unacceptable risk to blue mussels based on total mercury tissue NOAEL- and LOAEL-based HQs at or above 1.0.
- American Lobster: There is no unacceptable risk based on tail tissue body burdens.
- Forage Fish: There is no unacceptable risk for forage fish based on tissue body burdens or dietary exposure to mercury in the Estuary.
- Predatory Fish: There is the potential for unacceptable risk to Atlantic tomcod and American eel based on tissue total mercury and methyl mercury NOAEL HQs. However, unacceptable risk is unlikely because LOAEL HQs are below 1.0, which are based on tissue mercury body burdens using a population-level EC_{20} for reproduction and survival as the LOAEL TRV. There is no unacceptable risk to predatory fish based on dietary exposure to mercury in the Estuary.
- Nelson's Sparrows and Red-Winged Blackbirds: There is the potential for unacceptable risk to marsh songbirds based on blood total mercury and methyl mercury NOAEL and LOAEL HQs above 1.0 at the three marsh platform exposure areas evaluated, as well as from dietary exposure to mercury based on total mercury and methyl mercury NOAEL HQs equal to or above 1.0. However, the dietary LOAEL HQs for the three locations for both Nelson's sparrow and red-winged blackbird are below 1.0 for both total and methyl mercury.
- American Black Duck: There is the potential for unacceptable risk to the American black duck based on blood total mercury and methyl mercury NOAEL HQs above 1.0, as well as from dietary exposure to mercury based on a total mercury NOAEL HQ above 1.0. However, the LOAEL tissue and dietary HQs for both locations are below 1.0 for both total and methyl mercury.
- Piscivorous Birds: There is no unacceptable risk to piscivorous birds based on dietary exposure to mercury in the Estuary. Although blood mercury data for piscivorous birds

indicates exceedances of the blood LOAEL TRV and egg mercury concentrations are elevated, these data are between 6 and 12 years old and might not be considered representative of current site conditions in the Estuary for making remedial decisions.
- Mink: There is no unacceptable risk to the mink based on dietary exposure to mercury in the Estuary.

Thus, there is the potential for unacceptable risk to several receptors because body burdens (i.e., blood concentrations) and/or dietary exposure NOAEL HQs are above 1.0. However, the only receptors with LOAEL HQs above 1.0 are the Nelson's sparrow and red-winged blackbird. When the NOAEL HQs are ≥ 1.0, but the LOAEL HQs are < 1.0, ecologically significant adverse effects to that receptor are possible as the threshold for effects is assumed to be between the NOAEL and LOAEL. There is uncertainty associated with defining the true toxicity threshold, so adverse effects are considered possible. A LOAEL-based HQ ≥ 1.0 indicates potential for adverse effects. There is potential for risk to marsh songbirds due to mercury exposure in the Estuary based on NOAEL and LOAEL HQs > 1.0.

6.0 UNCERTAINTIES IN THE RISK ASSESSMENT

Uncertainty is inherent in many aspects of the risk assessment process. The use of assumptions and professional judgment are a necessary part of risk assessments, and models are sometimes used in lieu of data. These factors may contribute to the uncertainty associated with the final risk estimates and may result in overestimation or underestimation of risks. Although a BERA generally uses the most realistic site-specific information available, a degree of uncertainty is associated with exposure modeling and risk calculations. As direct measurements are not available for all of the components on which risk estimates depend, conservative assumptions and methodologies are employed to minimize the possibility of underestimating risk.

Consideration of the uncertainty associated with the components of the risk assessment process allows a more meaningful interpretation of the results and a better understanding of the potential for adverse effects on ecological populations, communities, and receptors. The specific sources of uncertainty associated with the each of the elements of the Penobscot BERA and the effects of these uncertainties on the risk estimates are discussed in Sections III.6.1 through III.6.5. A summary of the various uncertainties and their potential impact on risk characterization is presented in **Table II.7-1.**

6.1 DATA USE

The uncertainties associated with the data used in the BERA are as follows:

- The BERA incorporates abiotic and biotic media collected primarily between 2016 and early 2018 to assess current conditions. Data collected prior to these years were minimal and only selected for use in the BERA where data were lacking. The 2009 shrimp data were included in the BERA due to a data gap being identified for multiple receptor diets composed of crustaceans/zooplankton. The shrimp data were used in the dietary risk quantification for the following receptors: rainbow smelt, Atlantic tomcod, American eel, and mummichog. The most recent year of shrimp data was 2009 and data were only collected within the OB reach of the river. Use of the 2009 shrimp data from only one portion of the river may overestimate or underestimate current exposure for ecological receptors consuming shrimp.

- Exposure point concentrations for marsh songbirds were calculated using data from July 2016 and June 2017. The 2017 Biota Monitoring Report acknowledges that songbird blood mercury levels increase with the duration of exposure on the marsh, and songbirds have been historically sampled predominately in July. The blending of data from differing months could have the potential to result in an underestimation of exposure.

- The sediment EPCs for red-winged blackbirds used in the food web modeling are based on a limited dataset due to a smaller home range than the Nelson's sparrow, which may overestimate risk for the red-winged blackbird. The number of sediment samples ranged between 9 and 45 samples for the Nelson's sparrow versus 3 to 6 sediment samples for the red-winged blackbird. The Nelson's sparrow sediment EPCs were lower for each exposure area evaluated on the marsh platform. In addition, the number of blood samples ranged between 26 and 30 samples for the Nelson's sparrow versus 6 to 8 samples for the red-winged blackbird, which might affect the blood EPCs evaluated in the BERA. Reference data were not available for red-winged blackbirds, which may result in an overestimation of potential risk due to site-related impacts because the contribution to risk from background concentrations could not be assessed.

- Fillet samples are only available for Atlantic tomcod and American eel. Use of fillet data to represent whole body exposure is a conservative approach. Mercury analysis of fish tissue types indicates that increases in mercury concentrations from whole fish to fillets can be as high as 60 to 100 percent (Goldstein and Brigham 1995; Wente 1997). Use of fillet data instead of whole body data overestimates dietary exposure to piscivorous receptors and fish tissue whole body burdens in the tissue-based risk characterization.

- Because only historical (2006 to 2012) blood and egg data were available for piscivorous birds, a qualitative assessment is included in the BERA. Piscivorous mammal data were available for mink and otter, but only from one year (2006). These mammal data were not included in this BERA due to only one year of data collection and because the data are 12 years old and not representative of current conditions in the Estuary. The piscivorous bird data are between 6 and 12 years old and are also not considered representative of current site conditions in the Estuary and are included for informational purposes only.

- When developing methyl mercury concentrations in forage fish and predatory fish for food web modeling, concentrations of methyl mercury were calculated by multiplying the total mercury concentrations by a percent methyl mercury to total mercury concentration based on the average of the mummichog and rainbow smelt percent methyl mercury for forage fish and the average of the tomcod and American eel percent methyl mercury for predatory fish. Use of the average does not substantially affect the percent methyl mercury as the percentages are relatively consistent for the species (i.e., 86 percent for mummichog and 79 percent for rainbow smelt and 80 percent Atlantic tomcod and 88 percent for American eel). This would not result in a substantial difference in methyl mercury exposure or potential risks for piscivorous receptors.

- Methyl mercury concentrations for receptors other than sediment, surface water, terrestrial insects, spiders, polychaetes, and shrimp were derived using site-specific, historical average methyl mercury to total mercury percentages, which is not expected to substantially affect the resultant methyl mercury EPCs for the receptors.

6.2 PROBLEM FORMULATION

The uncertainties associated with problem formulation for the BERA are as follows:

- The BERA did not evaluate the surface water exposure pathway for fish or birds. Although not evaluating surface water ingestion may underestimate risk for these species, it is not anticipated to affect overall risk characterization, as surface water exposure is likely to contribute *de minimis* to the risk for these species.

- The BERA did not evaluate the sediment exposure pathway for fish. Although not evaluating the incidental ingestion of sediment may underestimate risk for fish, it is not anticipated to affect overall risk characterization, as incidental ingestion of sediment is typically considered to be minimal (i.e., less than 1 percent) and is likely to contribute *de minimis* to the risk for fish species.

6.3 EXPOSURE EVALUATION

There are uncertainties associated with several parameters in the exposure evaluation, including EPCs, dietary compositions, and exposure assumptions used in the BERA:

- As noted in Section III.3.0, the data sets used to generate the sediment and dietary EPCs for food web modeling accounted for the home range of the receptor, as well as the potential exposure of its prey items. For piscivorous receptors, EPCs were generated for forage fish by collection location based on fish length (≤17.8 cm, ≤25 cm, and ≥ 15 cm for belted kingfisher, mink, and bald eagle, respectively) and included mummichog and smelt data for each location. Note that for the bald eagle, no forage fish greater than 15 cm in length were reported for areas BO-O4 and Mendall Marsh. Instead, forage fish from 3.8 cm to 15 cm in length were used as surrogates. The range of forage fish total mercury EPCs range from 51.6 ng/g to 151 ng/g for the belted kingfisher, 50.9 ng/g to 151 ng/g for the mink, and 38.4 ng/g to 201 ng/g for the bald eagle (**Table III.3-13a**). In contrast, the site-wide EPC for rainbow smelt (presented in **Table II.2-2**) is 71.2 ng/g for all fish with no length exclusions, which falls within the range of the above described EPCs. As such, the use of a site-wide EPC for forage fish would have the potential to over- and/or underestimate risk based on location. Predatory fish EPCs were generated for the bald eagle, including Atlantic tomcod and American eel, by collection location for fish ≥ 15 cm. Locations OV-04 and Mendall Marsh lack predatory fish data, so data from OB-05 and OB-01 were used, respectively. The predatory fish EPCs ranged from 74.3 ng/g to 668 ng/g. The EPCs for Atlantic tomcod (170 ng/g) and American eel (313 ng/g) presented in **Table II.2-2** for all fish with no length exclusions fall within the range of values for fish ≥ 15 cm. As such, the use of a site-wide EPC for predatory fish would have the potential to over- and/or underestimate risk based on location.

- The use of the maximum detected concentration as an EPC instead of a 95 percent UCL concentration when less than five detected concentrations were reported is a conservative assumption that has the potential to overestimate exposure, and therefore potential risk.

- Exposure of lobsters was evaluated by comparing tail tissue mercury concentrations to tissue residue-based TRVs for decapods. Food web modeling for lobsters was not evaluated in the BERA, which may underestimate potential risk to lobsters.

- Sediment EPCs were generated using interval participation weighted concentrations calculated for the 0- to 0.5-foot depth interval for surficial sediment. The 0 to 0.5-foot depth interval for surface sediment is an appropriate sample interval for ecological receptor exposure in the BERA. The bioactive zone in estuarine and freshwater tidal environments, like the Penobscot system, is typically 4 to 6 inches; while marine environments tend to have a shallower bioactive zone (2 to 4 inches) (EPA 2015). Use of interval participation weighted concentrations to calculate the sediment EPCs for the 0 to 0.5-foot depth interval is considered representative of the depth interval and is not anticipated to under- or overestimate risks.

- Exposure parameters for the food web modeling were based on site-specific information, where available, to reduce the uncertainty in the food web modeling. Site-specific information included average body weights for the receptors collected in 2016 and 2017, dietary composition for fish, and exposure frequencies for birds. Exposure parameters obtained from scientific literature include body weights for piscivorous birds and mammals, home ranges, incidental sediment ingestion rates, and food ingestion rates. Parameters based on scientific literature may over- or underestimate exposure. For example, the food ingestion rate for the rainbow smelt was derived from a study on juvenile smelt (Plourde et al. 2012). Juvenile receptors typically have higher relative ingestion rates compared to adults. Thus, exposure for this sensitive life stage may overestimate exposure for adult smelt.

- The dietary assumptions for the belted kingfishers and mink do not include a component for predatory fish despite the mink and belted kingfisher may eat fish sized up to 17.8 cm and 25 cm, respectively. As tomcod length collected in 2016 and 2017 ranged from 9.4 to 29.1 cm, there is a potential for both the mink and belted kingfisher to consume smaller tomcod. However, as tomcod is a representative species for larger predatory fish, it was considered more appropriate to use mummichog and rainbow smelt as the representative fish diet for both the mink and belted kingfisher. This may underestimate potential risk to the belted kingfisher and mink.

- Dietary compositions for birds, fish, and mink were based on stomach content analyses and migration studies, and were adjusted for site-specific evaluation based primarily on recent food items collected at the site. Use of food item surrogates, such as those used for the black duck and mink, based on data recently collected may over- or underestimate exposure since dietary percentages were modified based on available recent data.

  In addition, use of dietary compositions, particularly those estimated from site-specific stomach content analyses collected during one event, may overestimate or underestimate dietary exposure at the site. For example, Kopec and Bodaly (2013) stated that mummichog feed from both the terrestrial and benthic food webs. This is in agreement with published reports of mummichog moving onto the marsh platform during spring tides and grazing along the flooded marsh surface, making mummichog a key link to subtidal food webs (Weisberg and Lotrich 1982; Abraham 1985). However, these results may not represent the overall and longer term diet, as Weisberg and Lotrich (1982) estimated that up to 75 percent of the mummichog diet came from subtidal areas.

- It is not accurate to assume 100 percent exposure frequencies for migratory bird species. Exposure during migration is inherently assessed in the BERA because it is not feasible to assume background mercury exposure is zero when not residing in the Penobscot Estuary. Therefore, the exposure assessment assumes that 100 percent of mercury exposure is site-related and that no additional mercury exposure occurs during the portion of the year when the birds are not residing in the Penobscot Estuary. This likely overestimates site-related risk in that levels of background risk from exposure to mercury are combined with site-related risks. Reference area mercury exposure is assessed in the BERA to provide insight into potential mercury exposure that is not site-related, and this exposure can be compared with site-related exposure. However, for the purposes of risk evaluation, it is not feasible to determine mercury exposures during the migratory season as it is unknown what levels of exposure exist when birds are not resident in the Penobscot Estuary.

- Use of songbird and black duck exposure frequencies of 0.50 and 0.58, respectively, are based on migratory behavior of these species. Although these exposure frequencies reflect migratory behavior, songbirds are most likely to be present in the Penobscot Estuary during their breeding season, which has the potential to result in greater levels of mercury exposure as it is a sensitive point in their lifecycle. As there is no feasible way to determine if mercury uptake is greater or less during breeding season, this uncertainty cannot be realistically addressed. However, increasing the exposure frequencies to 1 for songbirds and the black duck would double the risk estimates for these species.

- Blood mercury concentrations are an indication of recent exposure to mercury whereas tissue muscle mercury concentrations shows bioaccumulation of mercury. It is possible that ducks have detectable concentrations of mercury in muscle tissue and not in blood. Because ducks migrate, tissue mercury concentrations (more indicative of a longer time period of exposure including time from the migration area for ducks and time spent at the Penobscot) may be elevated relative to blood concentrations (more indicative of a shorter time period of exposure) due to prior exposure in the area from which the individual ducks migrated. For this reason, both duck tissue and duck blood was included in the BERA.

- Exposure assessments assume 100 percent bioavailability of mercury at the estimated EPCs. This may result in an overestimation of risk under some exposure scenarios, because a fraction of the mercury is bound to sediments and organic carbon and not available for uptake.

- The possibility that organisms may become tolerant, acclimated, or adapted to the characteristics of their environment was not considered. Thus, risks associated with mercury exposure may be overestimated.

- Use of surrogate data for prey items not available may under or overestimate exposure at the site or the reference areas. Surrogate data were used as follows:

    – Blue mussel and shrimp sample locations are limited to the Estuary. Estuary data for mussels and shrimp were used as a surrogate for Mendall Marsh exposure for ducks and fish species, respectively. In addition, polychate data were used as a surrogate for shrimp reference area (Frenchman Bay) exposure.

  - Reference area data from both Frenchman Bay and Pleasant River were used, as needed, for the dietary item EPCs in the reference area risk calculations. For example, terrestrial insects were not sampled from Frenchman Bay reference area; therefore, the Pleasant River reference area EPCs were used as surrogates. Terrestrial insects, polychaetes, and forage fish were not sampled from OV-04 reference area for the American eel; therefore, Frenchman Bay or Pleasant River reference area EPCs were used as surrogates for the American eel reference location of OV-04.

  - For the piscivorous receptors, prey fish EPCs were calculated based on prey fish size assumptions and by fish collection locations. Fish EPC surrogates were used when either no fish met the size criteria or when no forage or predatory fish were collected at that particular collection location. For example, no forage fish met the size criteria of ≥ 17.8 cm for the bald eagle at BO-04, Mendall Marsh, ES-FP, and the reference location. Therefore, forage fish between 3.8 cm and 15 cm in length were to calculate the forage fish EPCs. Additionally, no predatory fish were collected from Mendall Marsh; predatory fish data from OB-01 were used as surrogate for the Mendall Marsh exposure area. No predatory fish data were collected at location OB-04; predatory fish data from OB-05 were used as surrogate.

- Methyl mercury was non-detect for the polychaete EPCs used for the Atlantic tomcod, American eel, and black duck reference area risk calculations. One-half the maximum detection limit was used as the EPC in these cases. This is not expected to substantially affect exposure in the reference areas.

- The total mercury EPCs for terrestrial insects at MMSE and MMSW that are consumed by songbirds differ by a factor of six (325 ng/g at MMSE versus 56.2 ng/g at MMSW). It appears the difference between the two sites may be attributed to multiple factors. In the 2016 terrestrial insect dataset, there appears to be two levels of mercury concentrations with one level between 20 and 60 ng/g and a second level between 200 and 360 ng/g. The difference in concentration could be associated with the order of the insects within the composite samples. A number of composite samples collected in 2016 included greenhead flies (*Tabanus nigrovittatus*), a species of biting horse-fly typically found in coastal marshes. Deer flies and horse flies tend to have elevated concentrations of mercury relative to other terrestrial insects collected in 2016 and 2017. Another factor could be due to the small number of insect samples at each site (10 samples per site) or possibly the different insect sampling methods employed in 2016 and 2017. These factors may over- or underestimate exposure in the marsh areas.

- The potential variability in climate-change induced increases or decreases in methylmercury generation in the Estuary environment, as well as increases or decreases the bioavailability of methylmercury in the terrestrial and aquatic foodwebs of the Estuary.

6.4 EFFECTS EVALUATION

The uncertainties associated with the effects evaluation are based on the toxicity data used to derive the TRVs, as follows:

- The TRVs are not site-specific; therefore, the over- or underestimation of risk in the assessment is directly related to the conservatism and uncertainty of the TRVs.

- One of the largest uncertainties associated with the point estimate approach (i.e., NOAELs or LOAELs derived from laboratory or field studies) is the lack of information quantified between the NOAEL and LOAEL. When HQs based on NOAELs are < 1.0, the likelihood of adverse effects occurring at these concentrations is considered *de minimis* (negligible), and no unacceptable risk is expected. However, when the NOAEL HQs are ≥ 1.0, but the LOAEL HQs are < 1.0, ecologically significant adverse effects to that receptor are possible. Per EPA's ERAGS (1997), "The threshold for effects is assumed to be between the NOAEL and the LOAEL of a toxicity test". There is uncertainty associated with defining the true toxicity threshold, so adverse effects are considered possible in this case, and the results are reviewed in the context of other lines of evidence and supporting information. A reduction of this uncertainty can be obtained by using the effects concentration approach (ECs or EDs).

- TRVs based on the point estimate approach (i.e., NOAELs or LOAELs derived from laboratory or field studies) estimate potential ecological effects on individual organisms and do not evaluate potential population-level risks. Effects may occur on individual organisms, but have minimal potential population- or community-level effects. LOAELs do not account for the magnitude of risk from contaminant exposure. In addition, application of laboratory observations to wild populations in the point estimate approach is limited by the uncertainty of how the study organism responds to contaminant dosing in captivity without external stressors, which may play an important part in species responses to the contaminant exposure. In addition, LOAEL and NOAEL concentrations have the potential to vary among individuals within a species, between species, size/sex/age, environmental conditions (e.g., temperature) or biological conditions (e.g., nutritional status of organism). These factors can contribute considerably to the variability and uncertainty associated with extrapolating LOAELs and NOAELs. Therefore, the calculated potential risks based on NOAELs and LOAELs may overestimate the true population- or community-level effects. Where available, LOAEL TRVs were based on ED_{20}s or EC_{20}s, which have been modeled to estimate effects levels which 20 percent of the population is expected to be affected. This approach is often used in risk assessments as it provides the likelihood and severity of potential effects on local receptor populations. In addition, the approach can be used to reduce the uncertainty in the risk characterization and to better inform site management decisions.

- Geomean NOAEL and/or LOAEL TRVs were calculated for marsh songbird and piscivorous bird dietary TRVs as multiple studies were available. The use of a geometric mean TRV provides a weight of evidence approach that considers the potential for population-level effects. While the simple use of the lowest effects value available could be used for quantification of risks on an individual-level basis, it might not be appropriate for use on a population-level basis. When a number of toxicity data are available, the geometric mean of effects concentrations allows for the TRV to be informed by multiple studies, accounting for the variability in toxicity across a large number of available toxicity studies.

- Where point estimate NOAELs and LOAELs were used, the lowest LOAEL with a bounded NOAEL was selected when available or appropriate. If a bounded NOAEL was not available, then the NOAEL was calculated from the LOAEL by multiplying by 0.1, representative of a 10x uncertainty factor (EPA 1999b). Use of this uncertainty factor to extrapolate a NOAEL may over-or underestimate risk. Overall, risks are more likely to be overestimated than underestimated due to the use of conservative TRVs.

- Toxicity data from controlled laboratory studies and applicable field studies were used. Potential risks may likely be overestimated when TRVs are based on controlled experiment toxicity data, because the laboratory studies attempt to minimize the variability in contaminant exposure and often use more bioavailable forms of mercury in the test concentrations or prepared diets compared to what a receptor might be exposed to naturally.

- Toxicity data are typically based on test animals under controlled, laboratory conditions and extrapolated to wildlife species. Laboratory conditions are unlikely to be encountered in natural environments. Thus, extrapolation to field conditions results in uncertainty.

- Differential forms and the bioavailability of the mercury in dietary sources can affect the toxicity to receptors, resulting in uncertainty in the effects concentrations. For avian toxicity, controlled experiment toxicity data were based on methyl mercury because this form of mercury is environmentally relevant in food web modeling and is more toxic and bioaccumulative than inorganic mercury. The form of mercury administered in the controlled experiment toxicity studies varied, and included methyl mercuric chloride, methyl mercury dicyandiamine, and methyl mercury cysteine. Depew et al. (2012b) states in relation to methyl mercuric chloride and methyl mercury cysteine that there is insufficient evidence to determine whether one form of dietary methyl mercury is more or less toxic than the other. In the field studies, the form of mercury in the diet varies depending upon the prey items consumed. Therefore, avian field studies were considered to be total mercury exposures, which accounts for methyl mercury exposure.

- Metabolic differences between the receptor species and the study species of controlled experiments or field studies may add a significant level of uncertainty to the quantification of risk.

- Interspecies extrapolation assumes that species have similar absorption, metabolism, distribution, and excretion of mercury. However, for the TRV, it is assumed that receptors of similar size have similar cellular and physiological interactions with mercury and methylmercury. This may overestimate or underestimate risk.

- Bird sensitivity to methyl mercury varies depending on the species, chemical formulation, and route of administration. Heinz et al. (2009) categorized the American kestrel (*Falco sparverius*), osprey (*Pandion haliaetus*), white ibis (*Eudocimus albus*), and snowy egret (*Egretta thula*) as high sensitivity species based on methyl mercury injections into eggs. Medium sensitivity species included the ring-necked pheasant (*Phasianus colchicus*), chicken (*Gallus gallus*), common grackle (*Quiscalus quiscula*), tree swallow (*Tachycineta bicolor*), common tern (*Sterna hirundo*), and great egret (*Ardea alba*), Mallards (*Anas platyrhynchos*) and the double-crested cormorant (*Phalacrocorax auritus*) were among those species categorized as low sensitivity to injected methyl mercury. The study also concluded that the injected mercury was more toxic than the same amount of mercury deposited naturally by the mother by comparing the study results to toxicity data in scientific literature where methylmercury was fed to breeding adults and was deposited into the egg by the mother.

Dietary TRVs for piscivorous birds were calculated as the geomean of available studies to account for varying sensitives of bird species to methyl mercury exposure. Studies included high sensitivity (white ibis, snowy egret, and osprey) and medium sensitivity species (great egret). Therefore, the dietary TRVs for piscivorous birds are considered representative of varying sensitivities and are not expected to underestimate potential risk to piscivorous avian receptors.

- Limited studies were available for dietary mercury exposure of fish. Multiple assumptions (noted in **Table III.4-5**) were used to calculate daily dietary doses for forage fish and predatory fish from the concentrations used in the studies reviewed. These assumptions may under- or overestimate risk to fish based on dietary exposure.

- NOAELs for predatory fish tissue, marsh songbirds, the American black duck, and piscivorous birds were calculated from the LOAELs by multiplying by 0.1, representative of a 10x uncertainty factor (EPA 1999b). Use of this uncertainty factor to extrapolate a NOAEL may over-or underestimate risk.

- Only a tissue NOAEL TRV was available for methyl mercury exposure for the American lobster. NOAEL HQs for the American lobster were below 1.0. Therefore, there is high confidence in the finding of no unacceptable risk for the lobster.

- Because mollusks appear to be less sensitive to mercury toxicity compared to other aquatic invertebrates, copepod toxicity data were used as the basis for the mollusk tissue TRVs due to the sensitivity of the study endpoint (egg depression) and the presumed sensitivity of zooplankton to mercury. Although use of these data are considered protective of aquatic invertebrates collectively as an assessment endpoint, use of these data overestimate potential risk of mollusks from mercury exposure.

- Toxicity studies based on aqueous mercury exposures may underestimate potential toxic responses. Metal speciation in water (and sediment) can greatly influence the bioavailability of that metal. Hook and Fisher (2001) indicated the effects of ingested metals can exceed the effects of metals acquired from the aqueous phase due to different sites of deposition in the animal following different uptake pathways.

6.5 Risk Characterization

The uncertainties associated with the data used in the BERA are as follows:

- The NOAEL toxicity value was used initially when the HQ calculations were performed. This is expected to overestimate risk. However, when NOAEL-based calculated HQs were above 1.0, the LOAEL toxicity values were used to perform the HQ calculation.

- The NOAEL-based and LOAEL-based HQ calculations for the representative species are meant to characterize risk for specific groups of ecological receptors at the site. The conservative assumptions for the representative species may under- or overestimate risk for other species that fall within a given group as an ecological receptor.

- HQs were calculated for total mercury and methyl mercury. Hazard indices (i.e., summation of HQs assuming a cumulative effect) were not calculated for each receptor because summation of total mercury and methyl mercury risk HQs would result in double-counting the risk for methyl mercury and would overestimate risk.

- Reference location NOAEL-based tissue HQs were above 1.0 for the American eel and Nelson's sparrow. These reference area HQs above 1.0 indicate the NOAEL risk estimates for these receptors at the site are elevated, partially due to background conditions. There are inherent uncertainties associated with conservative assumptions used in the ecological risk estimations that may contribute to the potential for elevated risks observed for site receptors. The contribution to risk from background concentrations should be considered in any risk management decision.

7.0 BERA CONCLUSIONS

This BERA was conducted to assess potential mercury-related risks within the Estuary to the viability of local receptor populations. Results of the BERA will support the Phase III Engineering Study by providing a point of reference for evaluation of current conditions and for quantification of risk reduction that can be achieved by each remedial alternative to be considered in the Alternatives Evaluation Report. Site-specific data, primarily collected between 2016 through early 2018, were used in the BERA to represent current/baseline conditions at the site, which will be used in the quantification of risk reduction for the Estuary.

Assessment Endpoint 1 was for the protection of survival, growth, and reproduction of aquatic invertebrate populations. Risk estimates were performed for total mercury in surface water and tissue residues of blue mussels and for tissue residues of American lobster from the Estuary. There is no unacceptable risk based on blue mussel surface water exposure. There is the potential for unacceptable risk to blue mussels based on total mercury tissue NOAEL- and LOAEL-based HQs at or above 1.0. There is no unacceptable risk for the American lobster based on tissue body burdens.

Assessment Endpoint 2 was for the protection of survival, growth, and reproduction of fish populations. Risk estimates were performed for mercury in tissue residues and food web modeling for forage fish (represented by the mummichog and rainbow smelt) and predatory fish (represented by the Atlantic tomcod and American eel) from the Estuary. There is no unacceptable risk to forage fish based on tissue body burdens or dietary exposure of total mercury or methyl mercury in the Estuary. Unacceptable risk is possible for predatory fish based on tissue total mercury and methyl mercury NOAEL HQs, but unlikely, since tissue LOAEL HQs were below 1.0 which are based on tissue mercury body burdens using a population-level EC_{20} for reproduction and survival as the LOAEL TRV. There is no unacceptable risk to predatory fish based on dietary exposure to mercury in the Estuary.

Assessment Endpoint 3 was for the protection of survival, growth, and reproduction of wetland-dependent bird populations. Risk estimates were performed for mercury in tissue residues and food web modeling for marsh songbirds (represented by the Nelson's sparrow and red-winged blackbird) and aquatic birds (represented by the American black duck) from the Estuary. Blood NOAEL- and LOAEL-based HQs for total mercury and methyl mercury were above 1.0 for marsh songbirds, indicating potential for adverse effects. There is the potential for unacceptable risk from dietary exposure to mercury for Nelson's sparrow and red-winged blackbirds based on total mercury and methyl mercury NOAEL HQs equal to or above 1.0, but LOAEL-based HQs were below 1.0. There is the potential for unacceptable risk to aquatic birds based on blood total mercury and methyl mercury NOAEL HQs above 1.0, as well as from dietary exposure to mercury based on a total mercury NOAEL HQ above 1.0, but LOAEL-based HQs were below 1.0.

Assessment Endpoint 4 was for the protection of survival, growth, and reproduction of piscivorous bird populations. Risk estimates were performed for mercury using tissue residues and food web modeling for piscivorous birds (represented by the belted kingfisher and the bald eagle). There is no unacceptable risk to piscivorous birds based on dietary exposure to mercury in the Estuary. Although blood mercury data for piscivorous birds indicates exceedances of the blood LOAEL TRV and elevated egg mercury data, these data are between 6 and 12 years old and might not be considered representative of current site conditions in the Estuary.

Assessment Endpoint 5 was for the protection of survival, growth, and reproduction of piscivorous mammal populations. Risk estimates were performed for mercury using food web modeling for piscivorous mammals (represented by the mink). There is no unacceptable risk to the mink based on dietary exposure to mercury in the Estuary.

Based on the results of the BERA, there is the potential for unacceptable risk to several receptors because body burdens (i.e., blood concentrations) and/or dietary exposure NOAEL HQs are above 1.0. However, the only receptors with LOAEL HQs above 1.0 are the Nelson's sparrow and red-winged blackbird. When the NOAEL HQs are ≥ 1.0, but the LOAEL HQs are < 1.0, ecologically significant adverse effects to that receptor are possible as the threshold for effects is assumed to be between the NOAEL and LOAEL. There is uncertainty associated with defining the true toxicity threshold, so adverse effects are considered possible. A LOAEL-based HQ ≥ 1.0 indicates potential for adverse effects. There is potential for risk to marsh songbirds due to mercury exposure in the Estuary based on NOAEL and LOAEL HQs > 1.0.

PART IV

DEVELOPMENT OF SEDIMENT PRELIMINARY REMEDIATION GOALS

1.0 INTRODUCTION

1.1 Overview

The purpose of this report is to document risk assessments for human health and ecological receptors that would then be used to develop a sediment remediation goal for mercury. Implementation of a remedy to attain the remediation goal would result in biota tissue concentrations such that humans and ecological receptors can safely consume biota, irrespective of trophic level, without experiencing adverse health effects. Mercury (including methyl mercury) concentrations in the Estuary are driven by sediment mercury concentrations. By connecting biota mercury concentrations with sediment mercury concentrations, sediment remediation goals can be developed and remediation alternatives can be evaluated.

The ecological risk assessment completed in this document is not a Natural Resource Damage Assessment and Restoration (NRDAR) program evaluation. A NRDAR evaluation focuses on effects on an individual level and attempts to quantify the number of individual animals affected in multiple biota classes in order to seek restitution from the responsible party. Instead, this is a risk assessment that is used to evaluate population level risks to support development of sediment remediation goals, where needed, to be protective of ecological receptors. The risk assessment approach used here is consistent with the approach used in the development of sediment remediation goals at other large sediment sites with mercury contamination across the United States, including Berry's Creek, South River, Lower Duwamish Waterway, Pompton Lakes Works, Passaic River, Riegelwood, Portland Harbor, and an oxbow lake adjacent to the Tombigbee River.

While this project is not under CERCLA rules and requirements, the human health risk assessment was completed in general accordance with the Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (RAGS) (EPA, 1989) along with several of its associated parts and supplemental guidance documents.

As part of the human health risk assessment, acceptable concentrations for the ingestion of biota were identified in two different ways: 1) using the CERCLA risk assessment guidance and calculating acceptable concentrations based on ingestion rates and toxicity factors, or 2) using published governmental criteria designed to identify safe consumption levels (e.g., the MeCDC freshwater fish tissue action level of 200 ng/g for methyl mercury).

The Maine Center for Disease Control and Prevention (MeCDC) developed fish tissue action levels as a guide to determine the need for developing fish consumption advisories (MeCDC 2001). In conversations with MeCDC, the agency indicated that the fish tissue action level was only meant to apply to sport fishing, and was not developed with lobster, shellfish, and duck consumption in mind. However, the Maine Department of Marine Resources, working with the MeCDC, used the MeCDC fish tissue methyl mercury action level when designating the lobster and crab fishing closure areas.

Sediment cleanup goals have been developed in this report for both the CERCLA risk assessment method and for the MeCDC methyl mercury fish tissue action level. While both methods are valid, the US District Court noted in the Order on Remediation Plan (September 2, 2015) that "*The expert's differing viewpoints as to the appropriate standards by which to measure remediation are irreducibly complex. The Study Panel Report itself devoted a full chapter consisting of 123 pages to its discussion of the appropriate remediation targets. Phase II, Chapter 2 at 1-123. At this point, it is not necessary to wade into this earnest and highly-technical debate among the eminent scientists concerning the appropriate standards by which success is cleansing the River must be measured. The short answer is that the debate will remain theoretical until the engineers have opined on feasibility and cost and have expressed expert opinions about the likely effectiveness of the remedy. For example, if the lower limits are readily and inexpensively attainable, the Court suspects that Mallinckrodt and its experts would have no objections to attaining them. However, if the lower limits are simply unattainable or attainable only with extraordinary expenditure and considerable delay, the Court suspects the Plaintiffs will be satisfied with more cost-effective and efficient, but imperfect, remedy. Nevertheless, to the extent the parties require a general benchmark, the Court adopts the state of Maine standard of 200 nanograms per gram, not the more relaxed benchmark Mallinckrodt's experts proposed.*".

The ecological risk assessment also followed the general approach for CERCLA style ecological risk assessments, including a risk assessment focused on population-level effects on biota. The risk assessment generally followed the Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (ERAGs) (Interim Final Document Number EPA 540-R-97-006/OSWER 9285.7-25/PB97-963211) dated June 1997 (EPA, 1997) and, as such, the risk assessment quantifies for chronic effects which will induce population-level effects in biota, as discussed in ERAGs Section 7.3.1 "Threshold of Effects on Assessment Endpoints". This section states "The lower bound of the threshold would be based on consistent conservative assumptions and NOAEL toxicity values. The upper bound would be based on observed impacts or predictions that ecological impacts could occur. This upper bound would be developed using consistent assumptions, site-specific data, LOAEL toxicity values, or an impact evaluation" (Page 7-4 of EPA, 1997). Thus, NOAELs and LOAELs were used in the risk assessment for the development of remediation goals under the CERCLA style assessment used for the Estuary. Some effects concentrations or doses that effect as little as 20 percent of the population (EC20s or ED20s) were also considered in the toxicity assessment for completeness.

The ecological toxicity assessment considered toxicity reference values (TRVs) used at multiple large sediment sites with mercury contamination across the United States. These similar sites also underwent multiple levels of review by federal and state agencies together with study groups/panels for agreement on the use of these TRVs. The values and the logic behind their use were considered in the selection of the final TRV values for risk quantification for the Estuary. Some of these TRVs were used directly from the other assessment sites. For others, TRVs were developed from a compilation of appropriate and relevant studies to calculate a geometric mean value. The use of geometric mean TRVs considers the potential for a population-level effect. A TRV for a single toxicity study may be too specialized or focused on one sensitive or insensitive species, exposure route, or dosing regime and, thus, may not be strictly applicable on a population-level basis. The geometric mean of a group of TRVs allows for the TRV to be informed by multiple studies, and accounts for the variability in toxicity across numerous toxicity studies without allowing one study to bias remediation goal development.

The risk and exposure methodology focused on parameters that could be used to estimate a remediation goal in sediment, which is the primary reservoir for mercury in the Estuary. Although the risk assessment provides quantification of risk to human and ecological receptors, the ultimate goal for the document is to identify appropriate exposure and toxicity input parameters for the back calculation of remediation goals for the Estuary that are based on acceptable potential risk levels. The remediation goal for sediment has been estimated through the use of trophic level-specific surrogate species through the use of site-specific BSAFs and BAFs developed to represent the trophic level species present in the Estuary. This approach addresses potential data gaps for individual species in the Estuary lacking bioaccumulation factors.

BSAFs and BAFs address potential data gaps in the sampling of trophic levels because the concentrations in the biota and sediment (or other biota) are compared using a ratio of the concentration in tissue with the concentration in either prey tissue or sediment. Bioaccumulation can be calculated between each trophic level or as a combination of trophic levels, where necessary. For example, a BSAF for mummichog relates mercury concentrations in sediment to mercury concentrations in mummichog, accounting for the pathways by which mercury moves from sediment to mummichog. If mummichog consume zooplankton and invertebrates, then the mercury tissue concentrations in mummichog are the integration of mercury from both these prey items in relation to the sediment concentrations within the home range of the mummichog. Thus, the BSAF accounts for bioaccumulation through the prey items (zooplankton and invertebrates) in the BSAF ratio.

In developing sediment remediation goals, it is necessary to identify which trophic level requires the highest level of reduction in sediment concentration. By doing so, the sediment remediation goals identified can achieve mercury exposure levels for biological resources that are predicted to prevent adverse effects. For example, human receptors may ingest a wide variety of fish and shellfish that are exposed to mercury from the sediment, resulting in accumulation of varying concentrations within the tissues. While it may be possible for risk quantification to include combinations of fish and shellfish types with varying mercury concentrations, recent data representative of current conditions within the system are not available for a large number of fish and shellfish types. To address this data gap, data from representative surrogate receptors based on biota type and trophic level were used (e.g., tomcod for trophic level 3 and eel for trophic level 4 species [e.g., predatory fish]).

Through the use of surrogate/representative receptors, the risk quantified for the eel was assumed to be representative of risk for other trophic level 4 fish species. The eel is a reasonable surrogate for other trophic level 4 species, that are present in the Estuary, and may be consumed by people. Species listed as being recreationally harvested from the Estuary include the striped bass, bluefish, Atlantic mackerel, Atlantic cod, haddock, and pollock; however, site-specific data are either lacking or non-existent for these other marine trophic level 4 species in the Estuary. Using data collected for eel allows for estimation of remediation goals for trophic level 4 fish species. Similar remediation goal estimation was performed for trophic level 3 species using data collected for tomcod. This surrogate receptor approach was used throughout the estimation of sediment remediation goals for fish, shellfish, mammals, and birds.

Quantifying exposure through ingestion of a mixture of fish and shellfish species requires many assumptions with attending uncertainties that may be less conservative than the exposure estimated for the ingestion of individual trophic levels of fish that was performed in this assessment. Quantification of exposure through ingestion of a mixture of fish and shellfish species may underestimate the sediment remediation goal. Thus, risk quantification in this assessment was performed on a trophic level basis.

In regards to the tissue-based remediation goals, sediment and biota mercury concentrations can be connected a number of different ways, two of which are used in the risk assessment and sediment preliminary remediation goal (PRG) development. The two ways to connect sediment and biota concentrations are: 1) calculate a biota to sediment ratio, also known as BSAF and 2) calculate the bioaccumulation of mercury through ingestion of prey and sediment via a dietary model. For either of these methods, a number of inputs are necessary:

- Co-located sediment and biota tissue mercury concentrations,
- Toxicity values based on body burden (i.e., tissue concentrations) or ingestion, and
- Measured prey concentrations or
- BAFs to predict predator concentrations from prey concentrations or
- BSAFs to predict prey concentrations from sediment concentrations.

Sediment and prey item concentrations were used in the dietary model to estimate the daily dietary intake or exposure for a receptor. These dietary intakes were compared to dietary toxicity values from literature to determine whether biota are potentially at risk from bioaccumulation of mercury. Biota tissue concentrations collected at the site were also compared to body burden toxicity values from literature to determine whether biota are potentially at risk from bioaccumulation of mercury. Once the potential for risk has been estimated, a sediment PRG was calculated to guide the risk management decision process for the selection of an appropriate remedial alternative. The sediment PRG was back-calculated based on the receptor-specific BSAFs and prey item-specific BAFs developed for the site.

After sediment PRGs have been calculated for each biota tissue and ingestion scenario for both humans and biota, riverine and marsh sediment PRGs were selected to guide and evaluate remediation alternatives. Coupled with these remedial alternatives are recommendations for implementing a long-term (or post-remediation) monitoring (LTM) program. The LTM program can be implemented to collect data that will supplement the current dataset, creating a more robust dataset for statistical analysis. Throughout the LTM program, co-located biota and sediment samples can be collected to periodically update and strengthen the BSAF and BAF relationships and to verify that the sediment PRGs adopted initially remain appropriate to achieve target tissue concentrations. The new data can be used to verify if biota tissue concentrations are decreasing as projected or whether additional work should be conducted through adaptive management. Under the adaptive management framework, the PRGs can be revisited with the more robust dataset with increased statistical power to further evaluate sediment PRGs and their ability to achieve target tissue concentrations. If a reduction in sediment concentrations via remediation does not result in a concurrent reduction in biota tissue concentrations, then potential remedial alternatives can be revisited. Subsequently, the adaptive management framework can be used to collect additional data to support the design of additional remedial actions.

Uncertainties were inherent in the risk assessment process and in the development of PRGs. The primary uncertainty was associated with the amount of data collected (i.e., has enough data been collected to support the conclusions?). Sufficient data is necessary in order to accurately estimate the potential for food chain bioaccumulation into higher trophic level organisms and to select appropriate toxicity values for the evaluation of exposure and risk. Because of these uncertainties, future identified data gaps can be addressed through LTM and the adaptive management framework, which would include the collection of additional collocated sediment and biota samples. Also, given the uncertainty in the selection of toxicity values, an avian reproduction study could be conducted after sediment remediation is completed with appropriate surrogate species that would serve to verify that the selected sediment PRGs are appropriate and are providing long-term protection of avian receptors. These types of careful collections could document the achievement of goals for human consumption through biota tissue collection and the achievement of ecological goals through toxicity testing. This process is typical of large sediment projects around the country and is consistent with the typical remedial investigation, feasibility study, remedial action, and long-term monitoring process utilized for environmental remediation projects under the direction of numerous state and federal agencies.

1.2 SEDIMENT PRG DEVELOPMENT

For the purposes of developing long-term remediation options, risk-based sediment PRGs for mercury were developed. The PRGs were based on food web modeling and bioaccumulation modeling, using target tissue levels for both human and ecological receptors. Sediment PRGs were calculated using multiple lines of evidence. Sediment PRGs were calculated using three different approaches:

- Food web modeling tissue-based approach;
- Biota-sediment accumulation factor (BSAF) tissue-based approach; and
- Food web modeling dietary-based approach.

Sediment PRGs were calculated for human health using food web modeling and BSAF tissue-based approaches. Human health-based sediment PRGs were also calculated for two different scenarios—the local consumer and the MeCDC fish tissue action level for finfish consumption. Sediment PRGs were calculated for ecological receptors using food web modeling and BSAF tissue-based approaches, as well as the dietary-based approach. The sediment PRGs were developed for total mercury and methyl mercury using site-specific and species-specific BSAFs (i.e., ratio of biota tissue to sediment mercury concentrations) and biota-biota (i.e., ratio of prey to predator mercury concentrations) accumulation factors (BAFs). The BSAF is a parameter describing the bioaccumulation of sediment-associated compounds into tissues of ecological receptors. In contrast, the BAF describes the bioaccumulation of a compound in prey tissue to predator tissue via dietary exposure. In addition, sediment PRGs were developed for all of the biota types evaluated in the human health and ecological risk assessments in order to provide a range of potential sediment PRGs that would be protective of human health and ecological receptors. This section discusses development of the BSAFs and BAFs used in the PRG calculations, as well as the computational approach for development of the sediment PRGs. Sections IV.2.0 and IV.3.0 discuss the human health and ecological sediment PRGs, respectively. The bioactive zone in estuarine and freshwater tidal environments, like the Penobscot system, is typically 10 to 15 cm (4 to 6 inches); while marine environments tend to have a shallower bioactive zone (5 to 10 cm) (EPA 2015). The proposed sediment PRGs are applicable to sediments within the bioactive zone for estuarine environments.

1.3 DEVELOPMENT OF BSAFS AND BAFS

Relationships between mercury concentrations observed in sediment and mercury concentrations observed in biota living and foraging in the Estuary were developed by calculating BSAFs and BAFs for mercury and methyl mercury. BSAFs/BAFs provide insight into conditions driving bioaccumulation within a system, and can be used to gauge the potential success of a remedy. BSAFs/BAFs are one of the controlling factors in the development of sediment PRGs. As sediment concentrations change in the system through active remediation or through natural recovery, mercury concentrations within biota tissue is also expected to change, and this change can be estimated by the BSAF/BAF. The BSAF/BAF also can be used to estimate reduction in risk resulting from decreased sediment mercury concentrations. These changes are not uniform for all receptors, because mercury bioaccumulates/biomagnifies in the food web at differing rates for different species. Thus, BSAFs/BAFs were evaluated for different trophic levels within the food web. BSAFs/BAFs were also evaluated at various locations within the Penobscot system to spatially assess bioaccumulation throughout the system.

1.3.1 Data Used

BSAFs/BAFs were developed using data that were primarily collected between 2016 and early 2018. Ideally, BSAFs/BAFs should be developed from spatially and temporally coordinated biota and sediment samples under similar system conditions. Sediment and biota data were utilized to calculate BSAFs for biota by location for total mercury and methyl mercury. A portion of the sediments collected in 2016 and 2017 were directly co-located with biota sample locations. Additional sediment samples were also used in development of the BSAFs as explained below. Sediment samples collected from 0 to 6 inches in depth were used. The bioactive zone in estuarine and freshwater tidal environments, like the Penobscot system, is typically 10 to 15 cm (4 to 6 inches); while marine environments tend to have a shallower bioactive zone (5 to 10 cm) (EPA 2015). The sediments used for BSAFs were determined by the home range of the biota, as well as accounting for habitat type and potential exposure of the receptor and its prey. That is, for each biota collection location, the sediments used in the BSAF at that particular location included sediments within the radius of the biota's home range (**Table IV.1-1**). For example, lobster have a home range of approximately 1.9 miles. Therefore, for a sediment-to-lobster BSAF collected at location "x", the sediments within a 1.9 mile-radius of location "x" were used in the BSAF calculation. For the BAFs, predator-prey data were paired based on the predator's home range size (**Table IV.1-1**).

Total mercury was analyzed for each sediment sample. The majority of the sediment samples were also analyzed for methyl mercury. Non-detect sediment samples were excluded from the analysis because there has to be a detectable concentration for both the biota and the sediment in order to develop a numerical ratio for the BSAF. Total mercury was analyzed for each of the biota; however, methyl mercury was only analyzed for the lowest trophic level biota (i.e., polychaetes, terrestrial insects, and spiders). For the remaining biota, methyl mercury values were calculated by converting the total mercury result to a methyl mercury value, based on the percentage of methyl mercury to total mercury in historical biota samples (**Table IV.1-2**). Historical methyl mercury data were not available for the red-winged blackbird. Therefore, the Nelson's sparrow percentage was used as an estimate for the red-winged blackbird. For fish and shellfish, similar sizes of species were collected for analysis to reduce variability in tissue concentrations due to varying sizes or ages. Non-detect biota samples were also excluded from analysis because there has to be a detectable concentration for both the biota and the sediment in order to develop a numerical ratio for the BSAF. Non-detect biota were only observed in the 2016 polychaete data.

Sediment data used in the BSAFs were on a dry weight basis. Tissue data used in the BSAFs and BAFs were on a ww basis.

1.3.2 Data Assumptions for the Development of the BSAFs and BAFs

BSAF/BAF development included the following deviations from the methodology discussed above:

- The most recent data available for the rock crab were collected in 2015 and for shrimp were collected in 2009. Data pairings for rock crab and sediment and shrimp and sediment included samples collected within eight months of each other, in an effort to evaluate biota samples temporally associated with sediment samples under similar system conditions, while providing a robust data set for evaluation. The same collection year were used for data pairings of rock crab and lobster (2015), rainbow smelt and shrimp (2009), Atlantic tomcod and shrimp (2009), and American eel and shrimp (2009).

- For the BSAF pairings, some of the mummichog, polychaete, and blue mussel samples did not have sediment locations within the home range radius of the collection locations for BSAF pairings. However, sediment samples were collected adjacent to some of these biota locations that were intended to be co-located samples for BSAF pairings. Biota locations were recorded near the center of the collection area (e.g., center of the shoreline area that was sampled). As a result of the small home ranges of these species, the co-located sediments that were collected in the same area that was sampled for biota did not typically fall within the biota radius that was based on the center point of the shoreline. However, because the samples were collected within the same sampling area, the biota and sediment samples were assumed to be co-located and utilized as BSAF pairings.

- Similarly, the BAF pairings had predator biota samples that did not have prey biota sample locations that fell within the home range radius of the predator. BAF pairings were as follows:

  – For a shrimp to lobster BAF, there were no data pairs of lobster and shrimp to calculate a BAF. However, statistical analysis of 2009 rainbow smelt and 2009 shrimp data indicated no significant difference in mercury concentrations ($p < 0.001$) for samples collected from the former facility to OB-01. Since the smelt and shrimp concentrations had no significant difference, rainbow smelt were used as a surrogate for shrimp in the shrimp to lobster BAF. Essentially, it is assumed that the smelt to lobster BAF is approximately equivalent to the shrimp to lobster BAF, and is utilized as surrogate in the PRG calculations.

  – The mummichog samples (2009) did not have any shrimp samples (2009) within the home range radius. Because the shrimp samples were collected within the same sampling area as the mummichog samples, the samples were considered co-located predator and prey samples given the mobility of shrimp, and were utilized as BAF pairings.

  – The 2017 mummichog samples collected at Mendall Marsh did not have any insect samples within the home range radius. This is due to the small predator radius, as the insect samples only ranged from approximately 1.4 to 2.1 home ranges away from the mummichog samples. Nonetheless, because the samples were collected within the same sampling area, they were utilized for the BAF pairings.

- The 2017 American eel samples did not have smelt, insect, or polychaete samples within the home range radius. Given the importance and need for these BAFs for the PRG calculations, the closest prey items were used in the BAF pairings.

- Similar to 2017, the 2016 eel samples did not have smelt, mummichog, insect, or polychaete samples within the home range radius. However, both mummichog and polychaetes had samples collected within the same sampling area, but outside the home range radius, which were used for the BAFs. As was done with the 2017 pairings, the closest smelt location was used for BAFs. For insects, because the American eel location was relatively equidistant from Mendall Marsh and W-17, the median concentrations among the insect locations were used for the BAF.

- For a forage fish to lobster BAF, smelt were used to represent the forage fish portion of the lobster diet. Though lobster would eat mummichog if given the opportunity, it is not likely that the two species would often occupy the same habitat. Mummichog are a marsh and tidal creek species, are not likely to descend to a depth of more than 12 feet, and are generally found at a depth less than 6 feet. Smelt are an inshore species, but are generally at greater depths from 0–145 meters. Lobster are most commonly found at depths of 0–50 meters, with the smaller post larvae settling in the shallow depths. As a result, the collected adult lobsters likely either do not overlap with the mummichog habitat, or the overlap is limited. For these reasons, smelt was used for the forage fish portion of the lobster diet.

- BSAFs for forage fish and predatory fish were calculated by taking the median of the selected BSAFs: the median of the rainbow smelt and mummichog BSAFs for forage fish, and the median of the American eel and Atlantic tomcod BSAFs for predatory fish. Utilizing regression estimates in these pairings would bias the BSAFs, as there are differences in sample locations and variations in the number of locations among both the forage fishes and the predatory fishes. It should be noted the BSAF for each individual forage fish and predatory fish species were similar and within the same order of magnitude (see **Table IV.1-3**).

1.3.3 BSAF/BAF Development

The 2016 and 2017 biota and sediment samples or predator and prey samples paired using the home range of the biota were spatially mapped to sort data by study location (e.g., Mendall Marsh Southeast [MMSE], Mendall Marsh Southwest [MMSW], Odom Ledge). BSAFs were calculated using the median biota concentrations and the median sediment concentrations for each study location individually. BAFs were calculated using the median predator concentrations and the median prey concentrations for each study location. BSAFs and BAFs were developed for total mercury and methyl mercury. A median Estuary study area BSAF/BAF was then calculated, using the BSAFs/BAFs from each study location. The use of the median rather than the mean reduces the influence of a single high or low concentration on the overall BSAF calculation. The median was used to provide a better estimate of central tendency of bioaccumulation that is influenced by differences in the biogeochemical processes of the Estuary.

BSAFs/BAFs were developed by year (2016 and 2017). BSAFs were previously developed based on the 2016/winter 2017 sediment and biota data and presented in the Summary of Biota-Sediment Accumulation Factor Evaluation Technical Memorandum (Amec Foster Wheeler 2017c). These BSAFs are referred to as the 2016 BSAFs herein. BSAFs were then developed based on the 2017 spring/fall sediment and biota data plus the winter 2018 black duck data, in accordance with the methods outlined in that memorandum (Amec Foster Wheeler 2017c). The BSAFs are presented in **Appendix C** and referred to as the 2017 BSAFs. BAFs were developed for 2016 and 2017 using a similar methodology as the BSAFs, and also are presented in **Appendix C**. **Appendix C** also presents the calculated standard error for the 2016 and 2017 BSAFs/BAFs. Note that the equation used to calculate standard error is based on larger normal data sets and may not be applicable to smaller and/or non-normal data sets. However, as there is no well-accepted formula for non-normal median standard error calculation, the calculated standard error using the standard equation was used as an approximation of standard error for the data sets.

The BSAFs were spatially mapped for each receptor by study location for 2016 and 2017. **Appendix C** presents the 2016 and 2017 BSAF figures. The median BSAFs for 2016 and 2017 are presented in **Table IV.1-3** for total mercury and methyl mercury. The median BAFs for 2016 and 2017 are presented in **Table IV.1-4** for total mercury and methyl mercury.

Statistical analyses were also performed on the combined 2016 and 2017 data sets used to develop the BSAFs and BAFs. The statistical evaluations of biota and sediment BSAF data, as well as biota and biota (i.e., predator-prey) BAF data, were conducted using the statistical software package “R”, version 3.4.2 (R Core Team 2017). The statistical evaluations included both site data and reference data. The purpose of combining the data sets from 2016 and 2017 was to compile a larger overall data set and account for interannual variability.

Outlier testing was performed for the biota data sets prior to running the regression estimates to check for potential measurement errors, which interfere with statistical calculations and skew regression analyses. Medians for each biota type were generated by location and year, and then compared to determine whether a location:year combination was an “extreme” value, analogous to an outlier. Two visual methods were used to identify an extreme value: 1) Q-Q plots and 2) box-and-whisker plots. A Q-Q plot is a probability plot of data quantiles and theoretical quantiles. A data set that fits a normal distribution should fall near or on a line. If one or more points do not fall on or near a line, the values are likely extreme values. Box-and-whisker plots show the range of data with the box representing the interquartile range (first quartile to third quartile) and the whiskers representing either the extent of the median plus 1.5 times the interquartile range or the maximum or minimum of the data (if less than the median plus 1.5 times the interquartile range). Any extreme values outside the whiskers are shown as points. The median values were used because when the dataset is not skewed the arithmetic mean and the median are very similar values, but in a strongly skewed data set the median and geometric mean may be better indicators of central tendency.

These methods were conducted on each set of mercury and methyl mercury medians for each species prior to calculating BSAFs or BAFs. Visual inspection of the figures was conducted to identify potential extreme values. In order for a location:year combination to be flagged as an extreme value, both methods for mercury and methyl mercury must indicate that the median is outside the expected range of data. Medians (including the samples that compose that median) that are flagged as being an extreme value were not used in the generation of BAFs and BSAFs. The results of the outlier testing are provided in **Appendix C**.

A Wilcoxon signed rank test was performed on biota:biota pairings by exposure area (represented by sampling location) for total mercury and methyl mercury concentrations. A Wilcoxon signed rank test also was performed on biota:sediment pairings by exposure area for total mercury and methyl mercury concentrations. The Wilcoxon signed rank test is a non-parametric statistical test to evaluate the null hypothesis that the median is not different from zero. Paired biota:biota or biota:sediment median concentrations by exposure area that were significantly different from zero are represented with 95 percent confidence intervals on the scatterplots (**Appendix C)**.

A linear regression through the origin (i.e., intercept set to zero) was performed on median biota tissue or blood total mercury and methyl mercury concentrations as a response variable where: 1) paired prey median concentrations were used as predictor variables for BAFs; and 2) paired sediment median concentrations were used as predictor variables for BSAFs. The reasoning for this is based on the assumption that tissue concentrations in biota are due to exposure to site sediments. Hence, with no exposure to mercury from site sediment, via direct exposure and/or indirect exposure via the food web, the concentration of mercury in biota tissue would be zero. Least squares linear regression lines were fitted to the data, including forcing the equation through the (0,0) point. This satisfies the theoretical assumption that there would be no mercury in the biota if there were no mercury in the sediment.

The statistical code and the output are presented in **Appendix C**. An alpha value of 0.05 was used to determine statistical significance where $p < 0.05$ indicates a rejection of the null hypothesis. The plots and the summaries of BSAF and BAF linear regression model results are presented in **Appendix C**.

The BSAFs and BAFs developed for total mercury and for methyl mercury based on the results of the regression analyses are also presented in **Tables IV.1-3 and IV.1-4,** respectively, for comparison with the 2016 and 2017 median BSAFs/BAFs. For the regression analysis, the 2016 and 2017 similar data sets were combined to maximize the number of data points, which would result in the most statistically robust regressions. In addition, site data and reference data were included in the analysis. The 2016 median and 2017 median BSAFs/BAFs were calculated using site data and reference data separately to compare bioaccumulation at the site versus the reference area. **Tables IV.1-3 and IV.1-4** present only the 2016 median and 2017 median BSAFs/BAFs. It is appropriate to include site and reference data in the regression analysis because the reference areas provide information on uptake at lower concentrations of environmental mercury at ecologically similar locations to the site. The assumption being that because of the similar ecology the rate of uptake would be similar to the site, but with lower concentrations of environmental mercury. As such, the inclusion of the reference areas provides a larger data set for a more robust statistical evaluation. The BSAFs and BAFs developed based on the results of the regression analyses were selected for use in the PRG development. If the regression analysis for a specific BSAF or BAF pairing was either statistically significant (p-value < 0.05) or approaching significance (0.10 > p-value ≥ 0.05), then the slope of the regression equation was used as the BSAF or BAF for PRG development. If the regression analysis was not statistically different from zero (p-value > 0.10), then the median BSAF or BAF from the 2016 and 2017 data combined was selected for use in the PRG development.

For the majority of biota types, the BSAFs based on the regressions using the combined 2016 and 2017 similar datasets (**Table IV.1-3**) fall within the range of the 2016 median and 2017 median Site BSAFs. However, for a number of biota types (i.e., total mercury BSAFs for American eel, terrestrial insect, spider, and polychaetes, and methylmercury BSAFs for terrestrial insects, spiders, mummichog, and American lobster), the selected BSAF based on a regression of the combined 2016 and 2017 datasets fall below both the 2016 median and 2017 median Site BSAFs (**Appendix C-1 and C-3**). The limited number of data points in the 2016 and 2017 data sets individually results in higher median BSAFs for these biota. Whereas, the regression based on the combined (larger) data set resulted in a regression value that is lower, but more statistically robust than using the median BSAFs for the individual years.

1.4 SEDIMENT PRG COMPUTATION APPROACH

The sediment PRGs were developed for total mercury and methyl mercury using the food web modeling and BSAF tissue-based approaches, as well as the dietary-based approach. The sediment PRGs were calculated using the site-specific and species-specific BSAFs and/or BAFs. The equations used to calculate the PRGs are consistent with the methodology used in the forward risk calculation approach in the BERA per EPA (1997a) and vary by receptor based on dietary composition. The three approaches were taken in order to provide multiple lines of evidence for PRG development and provide comparison points between the different approaches. The relative strengths and weaknesses and associated uncertainties for each PRG type are considered in formulating conclusions. The food web model in **Figure IV.1-1** shows how the BSAFs and BAFs were incorporated into the sediment PRG development for the receptors.

1.4.1 Food Web Tissue-Based Sediment PRGs

The tissue-based sediment PRGs for aquatic species (i.e., represented by lobsters, forage fish, and predatory fish) were calculated using the target tissue level (termed PRG_{TIS} in equation below) and estimated exposure using the following equation:

$$PRG_{SED}(\frac{ng}{g}) = \frac{PRG_{TIS}\,(\frac{ng}{g})}{\sum_{p}^{n=p} BSAF_p \times \left(BAF_p \times DC_p\right)}$$

Where:

- PRG_{SED} = Sediment PRG (ng/g, dry weight [dw])
- PRG_{TIS} = Tissue PRG (ng/g)
- $BSAF_P$ = Species-specific BSAF (unitless) of a prey item
- BAF_P = Species-specific BAF (unitless) of a prey item
- DC_P = Dietary Composition (% as a decimal number) of a prey item

The tissue-based sediment PRGs for wetland-dependent birds (i.e., represented by the American black duck) were calculated using the target tissue level (termed PRG_{TIS} in equation below) and estimated exposure using the following equation:

$$PRG_{SED}(\frac{ng}{g}) = \frac{PRG_{TIS}\,(\frac{ng}{g})}{\sum_{P}^{n=P} BSAF_P \times (BAF_P \times DC_P)}$$

Where:

- PRG_{SED} = Sediment PRG (ng/g, dw)
- PRG_{TIS} = Tissue PRG (ng/g) (blood or tissue)
- $BSAF_P$ = Specific-specific BSAF (unitless) of a prey item
- BAF_P = Species-specific BAF (unitless) of a prey item
- DC_P = Dietary Composition (% as a decimal number) of a prey item

The tissue-based sediment PRGs for marsh songbirds (i.e., represented by the Nelson's sparrow and red-winged blackbird) were calculated using the target tissue level (termed PRG_{TIS} in equation below) and estimated exposure using the following equation:

$$PRG_{SED}(\frac{ng}{g}) = \frac{PRG_{TIS}\,(\frac{ng}{g})}{(BSAF_i \times BAF_{b-i} \times DC_i) + \left((BSAF_i \times BAF_{s-i}) \times (BAF_{b-s} \times DC_s)\right)}$$

Where:

- PRG_{SED} = Sediment PRG (ng/g, dw)
- PRG_{TIS} = Tissue PRG (ng/g) (blood)
- $BSAF_i$ = Insect BSAF (unitless)
- BAF_{b-i} = Insect-to-bird BAF (unitless)
- BAF_{s-i} = Spider-to-insect BAF (unitless)
- BAF_{b-s} = Spider-to-bird BAF (unitless)

- DC_i = Insect dietary composition (% as a decimal number)
- DC_s = Spider dietary composition (% as a decimal number)

The dietary compositions for each receptor used in the sediment PRG calculations are presented in **Table IV.1-5**. Dietary exposure for lobsters was not evaluated in the BERA, as lobsters are typically evaluated for tissue body burdens versus dietary exposure in risk assessments. In order to develop a tissue-based sediment PRG for lobster, the dietary composition of lobsters was evaluated. **Figure IV.1-2** presents the typical diet for lobsters of various size, taken from Hanson et al. (2009), from which the dietary composition used in the sediment PRG calculations (and presented in **Table IV.1-5**) was derived with adjustment for site-specific evaluation based on food items collected. In addition, it was assumed that 100 percent of the spider diet is terrestrial insects based on professional judgment and potential food items collected at the site. The target tissue levels are presented in **Table II.6-1** (Part II) for human health and **Table III.4-11** (Part III) for ecological receptors. The selected BSAFs and BAFs for PRG development are presented in **Tables IV.1-3 and IV.1-4,** respectively.

1.4.2 BSAF Tissue-Based Sediment PRGs

In addition to developing tissue-based sediment PRGs for biota based on food web modeling, tissue-based PRGs based on the biota-specific BSAFs were also calculated using the target tissue level (termed PRG_{TIS} in equation below) and estimated exposure using the following equation:

$$PRG_{SED}\left(\frac{ng}{g}\right) = \frac{PRG_{TIS}\left(\frac{ng}{g}\right)}{BSAF}$$

Where:

- PRG_{SED} = Sediment PRG (ng/g, dw)
- PRG_{TIS} = Tissue PRG (ng/g)
- $BSAF_P$ = Species-specific BSAF (unitless)

The target tissue levels are presented in **Table II.6-1** (Part II) for human health and **Table III.4-11** (Part III) for ecological receptors. The selected BSAFs and BAFs for PRG development are presented in **Tables IV.1-3 and IV.1-4,** respectively.

1.4.3 Dietary-based Sediment PRGs

The dietary-based sediment PRGs for aquatic species (i.e., represented by forage and predatory fish) were calculated using the following food chain model equation:

$$PRG_{SED}\left(\frac{ng}{g}\right) = \frac{TRV}{SFF \times IR_F \times EF \times \left(\frac{1}{BW}\right) \times \sum_{P}^{n=P} BSAF_P \times DC_P}$$

Where:

- PRG_{SED} = Sediment PRG (ng/g, dw)
- TRV = Toxicity Reference Value (ng/g bw/day)
- SFF = Site Foraging Frequency (unitless)
- EF = Exposure Frequency (unitless)
- IR_F = Daily food intake rate (kg/day, ww)
- BW = Body Weight (kg)
- $BSAF_P$ = Specific-specific BSAF (unitless) of a prey item
- DC_P = Dietary Composition (% as a decimal number) of a prey item

Note that for aquatic species direct intake of sediment was not considered as part of the PRG calculation. Receptor-specific exposure factors are presented in **Tables III.3-1 through III.3-4** and the dietary TRVs are presented in **Table III.4-12** in the BERA (Part III).

The dietary-based sediment PRGs for the American black duck, Nelson's sparrow, red-winged blackbird, belted kingfisher, bald eagle, and mink were calculated using the following food chain model equation:

$$PRG_{SED}\left(\frac{ng}{g}\right) = \frac{TRV}{SFF \times IR_F \times EF \times \left(\frac{1}{BW}\right) \times \left((IR_{SED} \times P_{SED}) + \sum_{P}^{n=P} BSAF_p \times DC_p\right)}$$

Where:

- PRG_{SED} = Sediment PRG (ng/g, dw)
- TRV = Toxicity Reference Value (ng/g bw/day)
- SFF = Site Foraging Frequency (unitless)
- EF = Exposure Frequency (unitless)
- IR_F = Daily food intake rate (kg/day, ww)
- BW = Body Weight (kg)
- IR_{SED} = Sediment ingestion rate (kg/day, dw)
- P_{SED} = Proportion of diet comprised of sediment (unitless)
- $BSAF_P$ = Specific-specific BSAF (unitless) of a prey item
- DC_P = Dietary Composition (% as a decimal number) of a prey item

Receptor-specific exposure factors are presented in **Tables III.3-5 through III.3-10** and the dietary TRVs are presented in **Table III.4-12** in the BERA (Part III). The selected BSAFs and BAFs for PRG development are presented in **Tables IV.1-3 and IV.1-4,** respectively.

2.0 HUMAN HEALTH PRGS

For human health, sediment PRGs were calculated using the tissue-based approach for two different tissue scenarios, using tissue PRGs developed in the HHRA as follows:

- Local consumer tissue PRGs;
- The MeCDC fish tissue action level for methyl mercury based on adult finfish consumption.

The results of each sediment PRG calculation are discussed below.

2.1 RISK-BASED SEDIMENT PRGS FOR HUMAN RECEPTORS

Using the tissue-based sediment PRG equations shown in Sections IV.1.3.1 and IV.1.3.2, sediment PRGs were calculated from the tissue target levels presented in **Table II.6-1** in Part II for local consumers for American lobster, Atlantic tomcod, American eel, and American black duck using both the food web approach and a BSAF-based approach. Total and methyl mercury sediment PRGs were developed using the species-specific BSAFs, BAFs, and dietary compositions, and are presented in **Appendix D**. The calculated risk-based sediment PRGs are presented in **Table IV.2-1** for total mercury and **Table IV.2-2** for methyl mercury.

2.2 HEALTH ACTION LEVEL-BASED SEDIMENT PRGS FOR HUMAN RECEPTORS

In addition to the above risk-based sediment PRGs, additional sediment PRGs were calculated based on the MeCDC action level of 200 ng/g methyl mercury in finfish tissue, using both a food web approach and BSAF approach. Total mercury and methyl mercury sediment PRGs were developed using the species-specific BSAFs, BAFs, and dietary compositions and are presented in **Appendix D**. In addition, for total mercury, the methyl mercury MeCDC fish tissue action level of 200 ng/g was converted to a total mercury target level by dividing 200 ng/g by the species-specific percent methyl mercury to total mercury percentages presented in **Table IV.1-2**. Note that in conversations with MeCDC it was indicated that the fish tissue action level was only meant to apply to sport fishing and was not developed with lobster and duck consumption in mind. However, the Maine Department of Marine Resources used the MeCDC fish tissue action level when designating the lobster closure areas.

The adult finfish consumption rate utilized for the MeCDC fish tissue action level is based on a consumption rate of one 8-ounce fish meal per week (52 meals per year, 32.4 g/day) (MeCDC 2001), which is above the local consumer consumption rates for lobster (1.7 g/day) (Cooper et al. 1991), shellfish (0.91 g/day) (Cooper et al. 1991), and duck (14.9 g/day) (MDIFW 2017a), indicating that the use of sediment PRGs based on the MeCDC fish tissue action level is not appropriate to apply to non-finfish species, as it overestimates the consumption of non-finfish species. The calculated sediment PRGs are presented in **Table IV.2-1** for total mercury and **Table IV.2-2** for methyl mercury.

3.0 ECOLOGICAL PRGS

For ecological receptors, sediment PRGs were calculated using (1) the tissue-based approaches (food web and BSAF approaches) and tissue TRVs identified in the BERA, and (2) the dietary-based approach using food chain modeling. The results of each sediment PRG calculation are discussed below.

3.1 TISSUE-BASED SEDIMENT PRGS

Using the food web tissue-based sediment PRG equations shown in Section IV.1.3.1 and the BSAF tissue-based equation shown in Section IV.1.3.2, sediment PRGs were calculated using the tissue residue LOAEL TRVs presented in **Table III.4-11** in Part III for the American lobster, blue mussel, mummichog, rainbow smelt, Atlantic tomcod, American eel, Nelson's sparrow, red-winged blackbird, and American black duck. The LOAEL tissue TRVs used in the BERA were selected for use as the tissue PRGs in sediment PRG development, because the LOAEL TRV represents a tissue concentration below which ecologically significant adverse effects to that receptor are unlikely to occur (because concentrations have not reached the threshold at which effects have been observed). Total and methyl mercury sediment PRGs were developed using the species-specific BSAFs, BAFs, and dietary compositions, and are presented in **Appendix D**. The calculated tissue-based sediment PRGs are presented in **Table IV.3-1** for both total mercury and methyl mercury.

3.2 DIETARY-BASED SEDIMENT PRGS

Dietary-based sediment PRGs were calculated for the mummichog, rainbow smelt, Atlantic tomcod, American eel, Nelson's sparrow, red-winged blackbird, American black duck, belted kingfisher, bald eagle, and the mink using the food chain modeling approach. Total and methyl mercury sediment PRGs were developed using the equations presented in Section IV.1.3.3 and the species-specific BSAFs, BAFs, and dietary compositions, and are presented in **Appendix D**. The calculated dietary-based sediment PRGs are presented in **Table IV.3-1** for both total mercury and methyl mercury.

4.0 SEDIMENT BACKGROUND VALUES

In order to evaluate and select sediment PRGs that are based on current site conditions and protective of human health and the environment, concentrations of sediment representative of background or reference locations were assembled. These data were tested statistically to identify the range of background sediment background concentrations for the Estuary that, in turn, can be used to assess potential sediment PRGs and avoid the selection of PRGs that are lower than background concentrations.

Previous investigations looked at a small data set of sediments that were collected in 2009 from depths of 0 cm to 3 cm. Per Chapter 17 of the Phase II Penobscot River Mercury Study, this specific data set showed a range of total mercury concentrations of 30 to 150 ng/g and this range was used in the Phase II report as representative of regional background. Location-specific background ranges included the following:

- Old Town – Veazie (OV) reach of the Penobscot: 78 to 145 ng/g
- Narraguagus and St. George estuaries and the East Branch of the Penobscot River: 28 to 51 ng/g

Furthermore, the Phase II Report indicated the concentrations of mercury entering the system from upstream were 240 ng/g, based on Q-weighted average of filtered particulates in surface water above Veazie Dam. However, this value is elevated above expected background concentrations and is likely due to release of mercury to pore water from recently deposited sediment via microbial processes, resulting in elevated concentrations of mercury in filtered particulates. In addition, the Phase II report indicating that the average percent concentration of background methyl mercury were approximately 1 percent of the total mercury.

For this current evaluation, sediment background data were assembled from multiple sampling events:

- 2006/2007,
- 2009,
- 2016, and
- 2017.

Areas sampled included the East Branch of the Penobscot River, the Sheepscot, St. George, and Narraguagus estuaries; the Addison River; and the Veazie Area. Seventy-three sediment samples were collected from depths ranging 0 to 30.5 cm (0 to 1 foot) (**Appendix B)**. This interval was selected because it includes the bioactive zone for aquatic organisms plus a minimal number of samples from a slightly deeper interval in background areas. Most of the sediments were from the upper 0–15 cm depth interval (70 of 73 sediment samples). Note that for the purposes of developing background values, non-detected results were excluded due to elevated levels.

4.1 TOTAL MERCURY SEDIMENT BACKGROUND

The ProUCL Version 5.1.002 software developed by the EPA was used to assess the range and distribution of the sediment concentrations. The ProUCL software is commonly used to calculate background concentrations and to develop EPCs used in risk assessments. The distribution of the data were assessed by first graphing the data (both a histogram and Q-Q plot [**Appendix B**]). The data set appears to follow a lognormal distribution, with most concentrations shifted to the left side of the histogram. From these plots of the data, one total mercury data point, OV-4 sampled in 2006/2007, was identified as a clear outlier, with a concentration of 252.2 ng/g. Prior to the calculation of background statistics, this data point was removed from the background data set.

The selected background data set had concentrations ranging from 6.8 ng/g to 158 ng/g. The mean and median values for the data set equaled 44.5 ng/g and 35.3 ng/g, respectively. The ProUCL software tests goodness of fit and calculates background statistics for normal, lognormal, gamma, and non-parametric distributions. The generated goodness of fit statistics supported the initial visual observation based on the graphs that the data follow a lognormal distribution. However, use of non-parametric statistics is also supportable by statistical literature (EPA 2009; 2016). Therefore, both lognormal and non-parametric parameters were included in the potential range of background values:

- 95 percent UTL with 95 percent coverage,
- 90th Percentile,
- 95th Percentile, and
- 99th Percentile

The resulting range of background values is 113 ng/g to 180 ng/g, with the 95 percent WH Approx. Gamma UTL with 95 percent coverage percentile representing by the lowest value and the non-parametric 95 percent Chebyshev UPL representing the highest value. The range of valid background parameters does exceed the maximum detected background value (minus the outlier point of 252 ng/g). In this case, the UTL is intended to include all new and additional background data points collected in the future. Thus, acceptance and use of the 95 percent HW Approximate Gamma UTL of 115 ng/g as the upper background limit is intended to avoid the assumption that a data point represents contamination (i.e., a false positive), when it is actually within the interval of anthropogenic and naturally occurring background for the Estuary. The use of the UTL is also intended to prevent selection of a risk-based sediment PRG that falls within the background interval. A sediment background concentration of 115 ng/g for total mercury was selected for the Estuary. Note that this value is consistent with the total mercury regional sediment background value of 55 ng/g, with a range of 30 to 150 ng/g per the Phase II PRMS, which also indicated that 90 ng/g is the minimum concentration below which any targets would be impractical.

4.2 METHYL MERCURY SEDIMENT BACKGROUND

ProUCL Version 5.1.002 was used to assess the range and distribution of the sediment concentrations for methyl mercury. The distribution of the data were assessed by first graphing the data (both a histogram and Q-Q plot [**Appendix B**]). The data set appears to follow a lognormal distribution, with most concentrations shifted to the left side of the histogram. From these plots of the data, it appears that elevated detection limits are outliers to the data set. The highest detected data point, 4.1 ng/g, is not potential outlier at the 1 percent significance level

The selected background data set had concentrations ranging from 0.02 ng/g to 4.1 ng/g. The mean, standard deviation, and median values for the data set were 0.624 ng/g, 0.777 ng/g, and 0.23 ng/g, respectively. The ProUCL-generated goodness of fit statistics supported the initial visual observation based on the graphs that the data follow a lognormal distribution. As for total mercury, non-parametric statistics are also considered applicable, and both lognormal and non-parametric parameters were included in the potential range of background values:

- 95 percent UTL with 95 percent coverage,
- 90th Percentile,
- 95th Percentile, and
- 99th Percentile

The resulting range of background values is 1.43 ng/g to 4.71 ng/g methyl mercury. with the lognormal 90th percentile representing by the lowest value and the lognormal 99th percentile representing the highest value. The range of valid background parameters does exceed the maximum detected background value of 4.1 ng/kg. In order to be consistent with the background value selected for total mercury, the lognormal 95 percent UTL with 95 percent coverage value of 3.51 ng/kg was selected as the background value. This UTL is intended to include all new and additional background data points collected in the future. Thus, acceptance and use of the lognormal 95 percent UTL with 95 percent coverage of 3.51 ng/g as the upper background limit is intended to avoid the assumption that a data point represents contamination (i.e., a false positive), when it is actually within the interval of anthropogenic and naturally occurring background for the Estuary. The use of the UTL is also intended to prevent selection of a risk-based sediment PRG that falls within the background interval. A sediment background concentration of 3.51 ng/g for methyl mercury was selected for the Estuary. The ProUCL input and output files for each sediment background are presented in **Appendix B**.

5.0 UNCERTAINTY ASSOCIATED WITH PRG DEVELOPMENT

Uncertainty is inherent in many aspects in the development of PRGs. The uncertainty associated with the majority of the assumptions in terms of exposure and toxicity factors are identical to those discussed in Part II Section 7.0 and Part III Section 6.0. A summary of the various uncertainties and their potential impact on the calculation of PRGs are presented in **Table II.7-1.** These factors contribute to the uncertainty associated with the development of PRGs and may result in higher or lower PRGs.

Another key contributor to the uncertainties associated with sediment PRG development are the BSAFs and BAFs used in the calculations. The sources of uncertainty associated with the development of site- and receptor-specific BSAFs/BAFs are as follows:

- For the development of site-specific BSAFs, there is a limited amount (<10) of collocated samples for a number of biota. As such, the developed regression equations, along with the calculated BSAFs/BAFs, are not statistically robust and have the potential to either over- or under-estimate uptake from sediment to biota or from prey to predator. Additional sampling would allow for increased statistical certainty in the development of the regression.

  The limited number of data points in the 2016 and 2017 datasets resulted in higher median BSAFs and BAFs for some biota. For the majority of biota types, the BSAFs based on the regressions using the combined 2016 and 2017 datasets (**Table IV.1-3**) fall within the range of the 2016 median and 2017 median Site BSAFs. However, for a number of biota types (i.e., total mercury BSAFs for American eel, terrestrial insect, spider, and polychaetes, and methylmercury BSAFs for terrestrial insects, spiders, mummichog, and American lobster), the selected BSAF based on a regression of the combined 2016 and 2017 datasets fall below both the 2016 median and 2017 median Site BSAFs (**Appendix C-1 and C-3**). Therefore, the regression analysis was performed to combine the datasets and provide a more statistically robust dataset than using the median Site BSAFs for individual years. The regression estimate BSAFs/BAFs in some cases resulted in a lower value, which would result in higher sediment PRGs.

- In the 2016 and 2017 BSAF/BAF analyses, the median values were used because when the dataset is not skewed the arithmetic mean and median are very similar values, but in a strongly skewed data set the median and geometric mean are better indicators of central tendency. The use of the median is anticipated to reduce the uncertainty and provide a better estimate of bioaccumulation.

- The standard error for the 2016 and 2017 median BSAFs/BAFs were calculated to show the potential range of values. Note that the equation used to calculate standard error is based on larger normal data sets and may not be applicable to smaller and/or non-normal data sets. However, as there is no well-accepted formula for non-normal median standard error calculation, the calculated standard error using the standard equation was used as a rough approximate of standard error for all data sets. This approach may under- or overestimate the potential range of values.

- A potentially important issue associated with bioaccumulation and bioavailability of mercury is the composition of mercury in the sediments at the site. The speciation of mercury present (whether in the form of organic or inorganic mercury) affects the site-specific and species-specific BSAFs/BAFs. The BSAF is directly dependent on the geochemical composition of the sediment and this would influence the trophic transfer of mercury to the benthic predators (e.g., fish, birds), which feed on deposit-feeders. Furthermore, mercury speciation in sediment can greatly influence bioavailability, which in turn could affect uptake by various prey species.

6.0 SEDIMENT PRG SUMMARY

6.1 ECOLOGICAL PRG METHODS

Tables IV.4-1 and **IV.4-2** and **Figures IV.4-1** and **IV.4-2** present the ecological sediment PRGs by receptor and approach for total mercury and methyl mercury, respectively. With the exception of the rainbow smelt, the dietary-based method used to derive sediment total and methyl mercury PRGs resulted in uniformly higher PRG values for the common receptors. For this reason, the dietary-based method was removed from consideration for the final ecological PRGs.

The total mercury and methyl mercury BSAF and food web PRGs were consistent and within a factor of two of each other. The total and methyl mercury BSAF PRGs were lower for Nelson's sparrow, lobster, and Atlantic tomcod, and higher for American black duck by a factor of almost two. Given the difference in the methods, which includes species-specific and area-specific bioaccumulation data, it is reasonable to combine the two methods for consideration of the final PRGs. As such, the following discussion of PRGs is based on the geomean of the two tissue-based approaches.

Location-Specific Ecological Sediment PRGs

Exposure and hazards were noted to differ by location. To address the habitat and exposure differences, habitat-specific PRGs were calculated for the marsh and intertidal zones (ecological receptors including Nelson's sparrow, red-winged blackbird, and American black duck) and subtidal zones (ecological receptors including finfish and aquatic invertebrates or shellfish). Although finfish and shellfish are also exposed to intertidal sediments, sediment exposure for these receptors are quantified under subtidal sediments, but final PRG selection accounts for sediment exposures from intertidal and subtidal zones.

Marsh and Intertidal PRGs: The total and methyl mercury sediment PRGs for marshes and intertidal zones were calculated for marsh songbirds and the American black duck. Sediment total mercury PRGs range between 411 ng/g and 2,693 ng/g with a geomean for marsh and intertidal receptors of 788 ng/g. Sediment methyl mercury PRGs range between 9.1 and 62.7 ng/g with a geomean for marsh and intertidal receptors of 18.1 ng/g (**Table IV.4-3**).

Subtidal Ecological Sediment PRGs: The total and methyl mercury sediment PRGs for subtidal zones were calculated for finfish and shellfish. Sediment total mercury PRGs range between 731 ng/g and 4,750 ng/g, and sediment methyl mercury PRGs range between 21.2 and 101 ng/g (**Table IV.4-3**).

6.2 HUMAN HEALTH PRG METHODS

Tables IV.4-1 and **IV.4-2** and **Figures IV.4-3** through **IV.4-6** present the human health sediment PRGs by receptor and approach for total mercury and methyl mercury, respectively. The total and methyl mercury tissue concentrations (ng/g) used as the target levels for the receptors are provided in **Tables IV.2-1** and **IV.2-2**. These values are the tissue concentrations of total and methyl mercury equal to the HQ of 1 or equal to the MeCDC fish tissue action level. The highest to the lowest health-based tissue concentrations are for the local consumer followed by the MeCDC fish tissue action level. The corresponding wide range of sediment PRGs are the result of the approach (food web or BSAF), as well as the consumption assumptions used for each scenario (local consumer and MeCDC fish tissue action level) and age of receptor (child or adult).

The total and methyl mercury sediment PRGs are consistent with each other and within a factor of approximately 2.5 for total mercury and within a factor of approximately 3.1 for methylmercury across the varying exposure scenarios using the food web and BSAF methods. The higher sediment PRGs for total mercury varied by receptor between the two approaches; whereas, the food web sediment PRGs for methyl mercury were consistently higher than the BSAF sediment PRGs for methyl mercury. Given the difference in the methods, which includes species-specific and area-specific bioaccumulation data, it is reasonable to combine the two methods for consideration of the final PRGs. As such, the following discussion of PRGs is based on the geomean of the two tissue-based approaches. In addition, the more stringent age of receptor (i.e., child exposure PRGs) were considered for the final PRGs and are discussed below.

6.2.1 Local Consumer Sediment PRGs

The sediment PRGs based on the local consumer are summarized in **Tables IV.4-1** through **IV.4-3** and **Figures IV.4-3** through **IV.4-6**. Similar to the ecological PRGs, habitat-specific human health PRGs were calculated to address the habitat and exposure differences. Marsh and intertidal zone PRGs are based on the American black duck, and subtidal zones PRGs are based on finfish and shellfish. Although finfish and shellfish are also exposed to intertidal sediments, sediment exposure for these receptors are quantified under subtidal sediments, but final PRG selection accounts for exposures from intertidal and subtidal zones.

Marsh and Intertidal Human Health Sediment PRGs: Because of the habitat characteristics of the marsh, the American black duck was the only human health receptor applicable to marsh sediments. The sediment total mercury PRG is 596 ng/g and the methyl mercury PRG is 16.5 ng/g for the black duck based on the local consumer (**Table IV.4-3**).

Subtidal Human Health Sediment PRGs: The total and methyl mercury sediment PRGs for subtidal zones were calculated for finfish and shellfish. Sediment total mercury PRGs range between 612 ng/g and 9,189 ng/g, and sediment methyl mercury PRGs range between 8.22 and 172 ng/g based on the local consumer (**Table IV.4-3**).

6.2.2 MeCDC Fish Tissue Action Level Sediment PRGs

The sediment PRGs calculated based on the MeCDC fish tissue action level are summarized in **Tables IV.4-1** through **IV.4-3** and **Figures IV.4-3** through **IV.4-6**. It should be noted that sediment

PRGs calculated for lobster, blue mussels, and American black duck use the MeCDC fish tissue action level for freshwater finfish of 200 ng/g. However, the action level was only meant to apply to sport fishing and was not developed with lobster, blue mussel, and American black duck tissue consumption in mind. The adult finfish consumption rate utilized for the MeCDC fish tissue action level is based on a consumption rate of one 8-ounce fish meal per week (52 meals per year or 32.4 grams/day) (MeCDC 2001), which is above the local consumer consumption rates for lobster (6-7 meals per year or 1.7 grams/day) (Cooper et al. 1991), blue mussel 1-2 meals per year or 0.272 grams/day) (Cooper et al. 1991), and duck (24 meals per year or 14.9 grams/day) (MDIFW, 2017a), indicating that the use of sediment PRGs based on the MeCDC fish tissue action level for freshwater finfish potentially overestimates the consumption of non-finfish species.

Marsh and Intertidal MeCDC Action Level-Based Sediment PRGs: The sediment total mercury PRG is 283 ng/g and the methyl mercury PRG is 7.87 ng/g for marsh sediments based on the consumption of American black duck using the MeCDC fish tissue action level (**Table IV.4-3**).

Subtidal MeCDC Action Level-Based Sediment PRGs: The MeCDC fish tissue action level-based sediment PRGs for subtidal zones range between 410 ng/g and 3,580 ng/g for total mercury and between 9.29 and 118 ng/g for methyl mercury based on finfish and shellfish (**Table IV.4-3**).

6.3 PROPOSED SEDIMENT PRG SUMMARY

The total and methyl mercury sediment PRGs must be protective of the array of human and ecological receptors identified in this report for the Estuary. Proposed PRGs should not be established at or below background concentrations, which have been calculated as 115 ng/g for total mercury and 3.51 ng/g for methyl mercury, because these values would be technically impractical to achieve given the likelihood of sediment migration and redistribution. In addition, while some portion of the sediment in estuaries is in either periodic or continuous motion, much of the sediment in estuaries is deposited on the sediment bed or (if present) within adjoining marshes, either within marsh channels or on marsh platforms. Overall, with respect to sediment mobility in estuaries, sediment resuspension and mixing occur on the time scale of days (i.e., flood versus ebb tides), weeks (i.e., spring versus neap tides) and seasons (i.e., movement of the salt wedge as the result of seasonal variation in the magnitude of freshwater discharge), as well as in response to storm events that can increase erosive forces in both the subaerial and subaqueous parts of an estuary. This combination of forces - on different time scales and with different magnitudes of impact - suggests that material available for resuspension and transport: (1) is bedded through at least a portion of these different cycles; and (2) originates in both the subtidal (i.e., continuously submerged) and intertidal (alternately submerged and subaerially exposed) portions of the system. When marsh platforms are inundated, this mixed and resuspended material can be transported onto marsh platforms and deposited. Based on this understanding of the conceptual site model for the Estuary, in order for marsh and intertidal sediments to achieve the sediment remediation goal, the same sediment remediation goal should also be applicable to subtidal sediments.

Sediment PRGs based on the most sensitive human and ecological receptors are presented in **Figures IV.4-7** and **IV.4-8** and are summarized in the table below. Because these PRGs are based on the most sensitive receptors for human and ecological health, the proposed ecological- and human health-based total and methyl mercury sediment PRGs would also be protective of other important ecological receptors, including the belted kingfisher, bald eagle, and mink (**Table IV.3-1**).

Receptor and Calculated PRG Basis	Total Hg (ng/g)	MeHg (ng/g)
Most sensitive ecological receptor for marsh/intertidal zone:		
- Marsh songbirds	411 – 442	9.1 – 10.4
Most sensitive ecological receptor for subtidal zones:		
- Blue mussels	731	55.9
Most sensitive human health receptors for marsh/intertidal zone:		
- Local Consumer – black duck	596	16.5
- MeCDC Action Level – black duck	283	7.87
Most sensitive human health receptors for subtidal zones:		
- Trophic Level 3 Shellfish - Lobster (MeCDC Action Level)	518	9.29
- Trophic Level 4 Finfish – American eel (MeCDC Action Level)	410	9.41
Geomean of combined human health and ecological receptors:	511	13
- Local Consumer PRGs – black duck	596	16.5
- MeCDC Action Level PRGs – black duck	283	7.87
- Ecological PRGs – black duck and marsh songbirds	788	18.1

Based on the above evaluation, the following range of PRGs (rounded based on the above values) are proposed for evaluation in the Alternatives Evaluation Report. These PRGs are protective of both ecological and human (local consumer and MeCDC fish tissue action level) receptors:

- Total Mercury: 300 to 500 ng/g for the marsh platform, intertidal, and subtidal sediments, and
- Methyl mercury: 8 to 10 ng/g for the marsh platform, intertidal, and subtidal sediments.

The proposed sediment PRGs are applicable to all sediments within the bioactive zone for estuarine environments. The lower end of the PRG ranges represent PRGs to meet the MeCDC fish tissue action level, while the upper end of the ranges represent PRGs protective of ecological risk and the local consumer. These PRGs are proposed for the Estuary as a means to measure remedy effectiveness and risk reduction in the Phase III Alternatives Evaluation Report. The

Alternatives Evaluation Report and the Phase III Engineering Study Report will provide information on the feasibility and cost of potential remedies. After review of this information, it is assumed that the Court will make risk management decisions relative to the final PRGs to be used in the cleanup of the Estuary mercury, and as to the remedies to be implemented.

PART V

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TABLES

TABLE II.2-1

DATA SUMMARY
HUMAN HEALTH RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

CAS No.	Analyte	Unit	Representative Species	Representative Species Type	Media	Percentage of Total Mercury[1]	No. of Samples	Frequency of Detection	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Median Concentration
Trophic Level 3 Shellfish[1]												
22967-92-6	Methyl Mercury	mg/kg	American Lobster	Marine Crustacean	Tail tissue	92%	200	100%	0.0411	1.60	0.233	0.177
7439-97-6	Mercury (inorganic)	mg/kg	American Lobster	Marine Crustacean	Tail tissue	8%	200	100%	0.00334	0.130	0.0189	0.0144
7439-97-6	Total Mercury	mg/kg	American Lobster	Marine Crustacean	Tail tissue	NA	200	100%	0.0444	1.73	0.252	0.191
Trophic Level 2 Shellfish												
22967-92-6	Methyl Mercury	mg/kg	Blue Mussel	Marine Bivalve Mollusks	Whole body tissue	43%	151	100%	0.0167	0.0884	0.0335	0.0311
7439-97-6	Mercury (inorganic)	mg/kg	Blue Mussel	Marine Bivalve Mollusks	Whole body tissue	57%	151	100%	0.0224	0.119	0.0449	0.0417
7439-97-6	Total Mercury	mg/kg	Blue Mussel	Marine Bivalve Mollusks	Whole body tissue	NA	151	100%	0.0391	0.207	0.0784	0.0728
22967-92-6	Methyl Mercury	mg/kg	Soft-Shell Clam	Marine Bivalve Mollusks	Whole body tissue	NA[3]	6	100%	0.0136	0.358	0.0469	0.0222
7439-97-6	Mercury (inorganic)	mg/kg	Soft-Shell Clam	Marine Bivalve Mollusks	Whole body tissue	NA	29	100%	0.0244	0.467	0.101	0.0289
Trophic Level 3 Finfish												
22967-92-6	Methyl Mercury	mg/kg	Rainbow Smelt	Anadromous Finfish	Whole body tissue	79%	107	100%	0.0209	0.164	0.0515	0.03934
7439-97-6	Mercury (inorganic)	mg/kg	Rainbow Smelt	Anadromous Finfish	Whole body tissue	21%	107	100%	0.00555	0.0435	0.0137	0.01046
7439-97-6	Total Mercury	mg/kg	Rainbow Smelt	Anadromous Finfish	Whole body tissue	NA	107	100%	0.0264	0.207	0.0652	0.0498
22967-92-6	Methyl Mercury	mg/kg	Atlantic Tomcod	Anadromous Finfish	Muscle tissue	80%	114	100%	0.0260	0.329	0.125	0.118
7439-97-6	Mercury (inorganic)	mg/kg	Atlantic Tomcod	Anadromous Finfish	Muscle tissue	20%	114	100%	0.00669	0.0845	0.0321	0.0304
7439-97-6	Total Mercury	mg/kg	Atlantic Tomcod	Anadromous Finfish	Muscle tissue	NA	114	100%	0.0327	0.413	0.157	0.149
Trophic Level 4 Finfish												
22967-92-6	Methyl Mercury	mg/kg	American Eel	Catadromous Finfish	Muscle tissue	88%	47	100%	0.0701	1.20	0.388	0.370
7439-97-6	Mercury (inorganic)	mg/kg	American Eel	Catadromous Finfish	Muscle tissue	12%	47	100%	0.00989	0.169	0.0547	0.0522
7439-97-6	Total Mercury	mg/kg	American Eel	Catadromous Finfish	Muscle tissue	NA	47	100%	0.0800	1.37	0.442	0.422
Trophic Level 3 Waterfowl[4]												
22967-92-6	Methyl Mercury	mg/kg	American Black Duck	Waterfowl	Muscle tissue	98%	43	100%	0.06382	0.835	0.264	0.212
7439-97-6	Mercury (inorganic)	mg/kg	American Black Duck	Waterfowl	Muscle tissue	2%	43	100%	0.00149	0.019	0.0061	0.0049
7439-97-6	Total Mercury	mg/kg	American Black Duck	Waterfowl	Muscle tissue	NA	43	100%	0.0653	0.854	0.270	0.217

Notes:
1. Methyl mercury percentage of total mercury taken from the Summary of Biota-Sediment Accumulation Factor Evaluation Technical Memorandum Amec Foster Wheeler 2017c) or calculated using current or historic data.
Inorganic mercury percentage of total mercury is based on 100 minus the percentage methyl mercury to total mercury and uses the average value.
2. Lobster data based on tail tissue samples.
3. Methyl mercury percentage of total mercury not available for the Soft-Shell Clam. Instead directly measured concentrations of methyl mercury and mercury were utilized.
4. Duck data based on breast tissue samples and blood concentrations converted to tissue concentrations using a regression equation

Abbreviations:
CAS = Chemical Abstracts Service
mg/kg = milligrams per kilograms
NA = not applicable

PREPARED BY/DATE: IMR 08/03/18
CHECKED BY/DATE: LMS 08/10/18

TABLE II.2-2

EXPOSURE POINT CONCENTRATION
HUMAN HEALTH RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

CAS No.	Analyte	Unit	Representative Species	Minimum Detected Concentration	Maximum Detected Concentration	95th Percentile Upper Confidence Limit[1]	Exposure Point Concentration[2]	Statistic
Trophic Level 3 Shellfish[3]								
22967-92-6	Methyl Mercury	mg/kg	American Lobster	0.0411	1.60	0.290	0.290	Estimated from the Total Hg UCL
7439-97-6	Mercury (inorganic)	mg/kg	American Lobster	0.00334	0.130	0.0236	0.0236	Estimated from the Total Hg UCL
7439-97-6	Total Mercury	mg/kg	American Lobster	0.0444	1.73	0.314	0.314	95% Chebyshev (Mean, Sd) UCL [4]
Trophic Level 2 Shellfish								
22967-92-6	Methyl Mercury	mg/kg	Blue Mussel	0.0167	0.0884	0.0351	0.0302	Estimated from the Total Hg UCL
7439-97-6	Mercury (inorganic)	mg/kg	Blue Mussel	0.0224	0.119	0.0471	0.0471	Estimated from the Total Hg UCL
7439-97-6	Total Mercury	mg/kg	Blue Mussel	0.0391	0.207	0.0822	0.0822	95% Student's-t UCL
22967-92-6	Methyl Mercury	mg/kg	Soft-Shell Clam	0.0136	0.358	0.0999	0.0999	95% Chebyshev (Mean, Sd) UCL
7439-97-6	Mercury (inorganic)	mg/kg	Soft-Shell Clam	0.0244	0.467	0.558	0.467	Maximum Detected Concentration[5]
Trophic Level 3 Finfish								
22967-92-6	Methyl Mercury	mg/kg	Rainbow Smelt	0.0209	0.164	0.0562	0.0646	Estimated from the Total Hg UCL
7439-97-6	Mercury (inorganic)	mg/kg	Rainbow Smelt	0.00555	0.0435	0.0150	0.0150	Estimated from the Total Hg UCL
7439-97-6	Total Mercury	mg/kg	Rainbow Smelt	0.0264	0.207	0.0712	0.0712	95% Student's-t UCL
22967-92-6	Methyl Mercury	mg/kg	Atlantic Tomcod	0.0260	0.329	0.136	0.141	Estimated from the Total Hg UCL
7439-97-6	Mercury (inorganic)	mg/kg	Atlantic Tomcod	0.00669	0.0845	0.0348	0.0348	Estimated from the Total Hg UCL
7439-97-6	Total Mercury	mg/kg	Atlantic Tomcod	0.0327	0.413	0.170	0.170	95% Student's-t UCL
Trophic Level 4 Finfish								
22967-92-6	Methyl Mercury	mg/kg	American Eel	0.0701	1.20	0.449	0.451	Estimated from the Total Hg UCL
7439-97-6	Mercury (inorganic)	mg/kg	American Eel	0.00989	0.169	0.0633	0.0633	Estimated from the Total Hg UCL
7439-97-6	Total Mercury	mg/kg	American Eel	0.0800	1.37	0.512	0.512	95% Adjusted Gamma UCL
Trophic Level 3 Waterfowl[6]								
22967-92-6	Methyl Mercury	mg/kg	American Black Duck	0.06382	0.835	0.495	0.495	Estimated from the Total Hg UCL
7439-97-6	Mercury (inorganic)	mg/kg	American Black Duck	0.00149	0.019	0.012	0.012	Estimated from the Total Hg UCL
7439-97-6	Total Mercury	mg/kg	American Black Duck	0.0653	0.854	0.506	0.313	95% Adjusted Gamma UCL

Notes:
1. Values calculated using ProUCL version 5.1
2. Selected exposure point concentration is the lower of the highest recommended 95% UCL and the maximum detected concentration.
3. Lobster data based on tail tissue samples.
4. 95% H-UCL (0.392) was the suggested UCL to use; however, ProUCL also recommends avoiding the use of H-statistic based 95% UCLs. Instead, the 95% Chebyshev (Mean, Sd) UCL was selected, as the data set is a lognormal distribution.
5. The maximum detected concentration was selected as the EPC, as the calculated UCL was greater than the maximum detected concentration.
6. Duck data based on breast tissue samples.

Abbreviations:
CAS = Chemical Abstracts Service
EPC = exposure point concentration
Hg = mercury
H-UCL = Hull Statistics Upper Confidence Limit
mg/kg = milligrams per kilograms
Sd = standard deviation
UCL = upper confidence limit

PREPARED BY/DATE: IMR 08/03/18
CHECKED BY/DATE: LMS 08/10/18

TABLE II.3-1

EXPOSURE FACTORS
HUMAN HEALTH RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Factor	Symbol	Value	Unit	Reference[1]
Local Consumer				
Averaging Time , non-Carcinogenic Adult	$AT_{nc\text{-}a}$	24	years	MDEP, 2011
Averaging Time , non-Carcinogenic Younger Child	$AT_{nc\text{-}c}$	6	years	MDEP, 2011
Body Weight - Adult	BW_a	70	kg	MDEP, 2011
Body Weight -Younger Child (1-7)	BW_c	18.8	kg	EPA, 2011. Average value for ages 1–7. See note 2.
Exposure Duration - Adult	ED_a	24	years	MDEP, 2011
Exposure Duration -Younger Child (1-7)	ED_c	6	years	MDEP, 2011
Exposure Frequency - Local Consumer	EF_L	365	days/year	MDEP, 2011
Lobster Local Consumption Rate - Adult	$IR_{L\text{-}A}$	1,700	mg/day	Cooper et al., 1991. Based on an assumption of 6-7 meals/year and does not include tomalley.
Lobster Local Consumption Rate -Younger Child (1-7)	$IR_{L\text{-}C}$	510	mg/day	MDEP Assumption of 30% of adult ingestion rate (MDEP, 2011)
Shellfish Local Consumption Rate - Adult	$IR_{S\text{-}A}$	907	mg/day	Derived from Cooper et al., 1991, based on the clam consumption rate to the lobster consumption rates for the subsistence fisherman, an equivalent of 1.5 meals/year. Does not include lobster.
Shellfish Local Consumption Rate -Younger Child (1-7)	$IR_{S\text{-}C}$	272	mg/day	MDEP Assumption of 30% of adult ingestion rate (MDEP, 2011)
Finfish Local Consumption Rate - Adult	$IR_{F\text{-}A}$	21,000	mg/day	Ebert et al., 1993. Based on the 95th percentile consumption rate for all anglers for all waters. Summarized in Table 10-72 of the Exposure Factors Handbook (EPA, 2011).
Finfish Local Consumption Rate -Younger Child (1-7)	$IR_{F\text{-}C}$	6,300	mg/day	MDEP Assumption of 30% of adult ingestion rate (MDEP, 2011).
Duck Local Consumption Rate - Adult	$IR_{D\text{-}A}$	14,900	mg/day	MDIFW 2017a. Based on a Maine consumption rate of 2 duck meals per month (duck meal size of 8 ounces).
Duck Local Consumption Rate -Younger Child (1-7)	$IR_{D\text{-}C}$	4,470	mg/day	MDEP Assumption of 30% of adult ingestion rate (MDEP, 2011).

Notes:
1. See Part V for full references.
2. Younger Child Body Weight Derivation

Age Range (years)	Number of Years	Body Weight (kg)
1 to <2	1	11.4
2 to <3	1	13.8
3 to <6	3	18.6
6 to <7	1	31.8
	Average Body Weight	18.8

Age-specific body weights taken from the EPA Exposure Factors Handbook (EPA, 2011)

Abbreviations:
EPA = Environmental Protection Agency
kg = kilograms
MDEP = Maine Department of Environment and Protection
MDIFW = Maine Department of Inland Fisheries and Wildlife
mg/day = milligrams per day

PREPARED BY/DATE: IMR 01/31/2018
CHECKED BY/DATE: LMS 1/31/2018

TABLE II.4-1

TOXICITY FACTORS
HUMAN HEALTH RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

CAS No.	COPC	Oral Reference Dose (mg/kg/day)	Source	Uncertainy/ Modifying Factors	Target Organ
22967-92-6	Methyl Mercury[1]	1.0E-04	IRIS	10	Developmental/Nervous System
7439-97-6	Inorganic Mercury[2]	3.0E-04	IRIS	1000	Immunological/Urinary

Notes:
1. Oral RfD for methyl mercury taken from the EPA IRIS toxicological profile for methyl mercury at: https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=73 on July 27, 2001.
2. Oral RfD for mercury (inorganic) taken from the EPA IRIS toxicological profile for Mercuric Chloride at: https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=692 on May 1, 1995.

Abbreviations:
CAS = Chemical Abstracts Service
COPC = constituent of potential concern
IRIS = Integrated Risk Information System
RfD = reference dose

PREPARED BY/DATE: IMR 09/12/17
CHECKED BY/DATE: LMS 9/13/17

TABLE II.5-1

RISK CHARACTERIZATION - LOCAL CONSUMER
HUMAN HEALTH RISK ASSESSMENT[1, 2]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

CAS No.	Analyte	Exposure Point Concentration (mg/kg)	Oral Reference Dose (mg/kg/day)	Adult Local Consumer Chronic Daily Intake[2] (mg/kg/day)	Adult Local Consumer HQ[3]	Younger Child Local Consumer Chronic Daily Intake[2] (mg/kg/day)	Younger Child Local Consumer HQ[3]
Trophic Level 3 Shellfish							
American Lobster							
22967-92-6	Methyl Mercury	0.290	1.0E-04	7.0E-06	0.07	7.9E-06	0.08
7439-97-6	Mercury (Inorganic)	0.0236	3.0E-04	5.7E-07	0.002	6.4E-07	0.002
Trophic Level 2 Shellfish							
Blue Mussels							
22967-92-6	Methyl Mercury	0.0302	1.0E-04	3.9E-07	0.004	4.4E-07	0.004
7439-97-6	Mercury (Inorganic)	0.0471	3.0E-04	6.1E-07	0.002	6.8E-07	0.002
Soft-Shell Clams							
22967-92-6	Methyl Mercury	0.0999	1.0E-04	1.3E-06	0.01	1.4E-06	0.01
7439-97-6	Mercury (Inorganic)	0.467	3.0E-04	6.1E-06	0.02	6.8E-06	0.02
Trophic Level 3 Finfish							
Rainbow Smelt							
22967-92-6	Methyl Mercury	0.0646	1.0E-04	1.9E-05	0.2	2.2E-05	0.2
7439-97-6	Mercury (Inorganic)	0.0150	3.0E-04	4.5E-06	0.01	5.0E-06	0.02
Atlantic Tomcod							
22967-92-6	Methyl Mercury	0.141	1.0E-04	4.2E-05	0.4	4.7E-05	0.5
7439-97-6	Mercury (Inorganic)	0.0348	3.0E-04	1.0E-05	0.03	1.2E-05	0.04
Trophic Level 4 Finfish							
American Eel							
22967-92-6	Methyl Mercury	0.451	1.0E-04	1.4E-04	1	1.5E-04	**2**
7439-97-6	Mercury (Inorganic)	0.0633	3.0E-04	1.9E-05	0.06	2.1E-05	0.07
Trophic Level 3 Waterfowl							
American Black Duck							
22967-92-6	Methyl Mercury	0.495	1.0E-04	1.1E-04	1	1.2E-04	1
7439-97-6	Mercury (Inorganic)	0.012	3.0E-04	2.5E-06	0.008	2.7E-06	0.009

TABLE II.5-1

RISK CHARACTERIZATION - LOCAL CONSUMER
HUMAN HEALTH RISK ASSESSMENT[1, 2]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Notes:
1. Yellow highlighting and bold text signifies that the reported HQ is above than the target HQ of 1.0
2. The chronic daily intake was calculated using the following equation:

$$CDI\ (\frac{mg}{kg-day}) = \frac{EPC\ \left(\frac{mg}{kg}\right) x\ EF\ \left(\frac{days}{year}\right) x\ ED\ (years) x\ IR\ \left(\frac{mg}{day}\right) x\ 0.000001\ (\frac{kg}{mg})}{BW\ (kg) x\ AT\ (years) x\ 365\ (\frac{days}{year})}$$

3. The hazard quotient was calculated using the following equation:

$$HQ\ (unitless) = \frac{CDI\ (\frac{mg}{kg-day})}{RfD\ (\frac{mg}{kg-day})}$$

Abbreviations:
CAS = Chemical Abstracts Service
CDI - chronic daily intake (mg/kg/day)
HQ = hazard quotient
mg/kg = milligrams per kilogram
mg/kg/day = milligrams per kilogram per day

PREPARED BY/DATE: IMR 10/24/2017
CHECKED BY/DATE: LMS 10/17/17

TABLE II.5-2

METHYL MERCURY RISKS BY SAMPLING LOCATION
HUMAN HEALTH RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Area	Number of Samples	Minimum Detected Concentration of Total Mercury (ng/g)	Maximum Detected Concentration of Total Mercury (ng/g)	Total Mercury EPC (ng/g)	Statistic	% Contribution Methyl Mercury to Total Mercury	Methyl Mercury EPC (ng/g)	Adult Local Consumer Methyl Mercury HQ	Younger Child Local Consumer Methyl Mercury HQ	Maximum Detected Concentration of Methy Mercury (ng/g)	Exceedance of MeCDC Fish Tissue Action Level of 200 ng/g for Methyl Mercury
Trophic Level 3 Shellfish											
American Lobster											
Frenchman Bay - Reference	20	26.8	64.8	44.0	95% Student's-t UCL	92%	40.7	0.01	0.01	59.9	No
2014 Closure	80	128	1,730	472	95% Chebyshev (Mean, Sd) UCL a	92%	436	0.1	0.1	1600	**Yes**
2016 Closure	80	65.6	925	253	95% Student's-t UCL	92%	234	0.06	0.06	855	**Yes**
Odom Ledge	40	128	1,730	521	95% Chebyshev (Mean, Sd) UCL	92%	481	0.1	0.1	1600	**Yes**
South Verona	40	165	1,320	431	95% Adjusted Gamma UCL	92%	398	0.1	0.1	1221	**Yes**
Cape Jellison	40	98.8	925	284	95% Student's-t UCL	92%	263	0.06	0.07	855	**Yes**
Turner Point	40	65.6	591	242	95% Adjusted Gamma UCL	92%	224	0.05	0.06	547	**Yes**
Harborside	40	44.4	264	113	95% Student's-t UCL	92%	104	0.03	0.03	244	**Yes**
Trophic Level 2 Shellfish											
Blue Mussel											
Frenchman Bay - Reference	20	5.46	13.0	9.10	95% Student's-t UCL	43%	3.91	0.0008	0.0008	5.59	No
ES15	32	44.8	97.6	68.9	95% Student's-t UCL	43%	29.6	0.006	0.006	42.0	No
ES13	40	48.4	144	83.5	95% Adjusted Gamma UCL	43%	35.9	0.007	0.008	61.9	No
ES03	39	51.0	207	99.1	95% Adjusted Gamma UCL	43%	42.6	0.008	0.009	89.0	No
Fort Point	40	39.1	181	87.8	95% Adjusted Gamma UCL	43%	37.8	0.007	0.008	77.8	No
Trophic Level 3 Finfish											
Rainbow Smelt											
Frenchman Bay - Reference	40	5.07	26.2	11.4	95% Student's-t UCL	79%	9.03	0.03	0.03	20.7	No
OB5	6	64.4	201	177	95% Adjusted Gamma UCL	79%	140	0.4	0.5	159	No
OB4	5	44.5	81.9	71.0	95% Student's-t UCL	79%	56.1	0.2	0.2	64.7	No
OB1	35	31.8	146	73.5	95% Student's-t UCL	79%	58.1	0.2	0.2	115	No
ES13	21	26.4	87.8	50.9	95% Student's-t UCL	79%	40.2	0.1	0.1	69.4	No
Fort Point	40	27.1	207	84.6	95% Adjusted Gamma UCL	79%	66.8	0.2	0.2	164	No
Atlantic Tomcod											
Frenchman Bay - Reference	1	36.5	36.5	36.5	Maximum	80%	29.2	0.09	0.1	29.2	No
BO4	12	104	315	239	95% Student's-t UCL	80%	191	0.6	0.6	252	**Yes**
OB5	38	70.7	379	181	95% Adjusted Gamma UCL	80%	145	0.4	0.5	303	**Yes**
OB1	39	49.7	413	207	95% Adjusted Gamma UCL	80%	166	0.5	0.6	330	**Yes**
ES13	22	32.7	239	135	95% Student's-t UCL	80%	108	0.3	0.4	191	No
Fort Point	3	37.2	74.3	74.3	Maximum	80%	59.4	0.2	0.2	59.4	No
Trophic Level 4 Finfish											
American Eel											
OV4 - Reference	6	142	320	320	Maximum	88%	282	0.8	0.9	282	**Yes**
BO4	21	294	1,370	697	95% Adjusted Gamma UCL	88%	613	**2**	**2**	1206	**Yes**
OB5	25	80.0	706	376	95% Student's-t UCL	88%	331	1	1	621	**Yes**
OB1	1	394	394	394	Maximum	88%	347	1	1	347	**Yes**
Trophic Level 3 Waterfowl											
American Black Duck											
Frenchman Bay - Reference	21	10.1	93.6	69.8	95% Student's-t UCL	98%	68.2	0.1	0.2	91.4	No
Mendall Marsh	23	121	854	351	95% Student's-t UCL	98%	343	0.7	0.8	835	**Yes**
ES-13	20	65	717	317	95% Adjusted Gamma UCL	98%	310	0.7	0.7	701	**Yes**

Notes
1. Yellow highlighting and bold text signifies that the reported HQ is above than the target HQ of 1.0

Abbreviations:
-- = Hazard quotients were not developed for this receptor
EPC = exposure point concentration
HQ = hazard quotient
UCL = upper confidence limit
ng/g = nanograms per gram

PREPARED BY/DATE: IMR 08/03/18
CHECKED BY/DATE: LMS 08/10/18

TABLE II.6-1

PRELIMINARY REMEDIATION GOALS - TISSUE
HUMAN HEALTH RISK ASSESSMENT[1]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

CAS No.	Analyte	Local Consumer[1] (ng/g)	
		Adult	Younger Child
Trophic Level 3 Shellfish			
22967-92-6	Methyl Mercury	4,120	3,690
7439-97-6	Total Mercury (American Lobster)[2]	4,460	3,990
Trophic Level 3 Finfish			
22967-92-6	Methyl Mercury	333	298
7439-97-6	Total Mercury (Atlantic Tomcod)[2]	417	373
Trophic Level 4 Finfish			
22967-92-6	Methyl Mercury	333	298
7439-97-6	Total Mercury (American Eel)[2]	379	339
Trophic Level 3 Waterfowl			
22967-92-6	Methyl Mercury	470	421
7439-97-6	Total Mercury (American Black Duck)[2]	481	430

Notes:
1. The preliminary remediation goals were calculated using the following equation:

$$PRG\left(\frac{ng}{g}\right) = \frac{THQ\ x\ AT\ (365\frac{day}{year}\ x\ ED\ (years))x\ BW\ (kg)}{EF\left(\frac{days}{year}\right)x\ ED\ (years)\ x\ \frac{1}{RfD\left(\frac{mg}{kg-day}\right)}x\ IR\left(\frac{mg}{day}\right)x\ 0.000001\left(\frac{kg}{mg}\right)} x1000000\left(\frac{ng}{mg}\right)x\ 0.001\ \left(\frac{kg}{g}\right)$$

2. Total mercury PRGs were derived by dividing the methyl mercury PRG by the species-specific percent contribution of meth
found in Table II.2-1. Assumes a target hazard quotient of 1.0.

Abbreviations:
CAS = Chemical Abstracts Service
ng/g - nanograms per gram

PREPARED BY/DATE: IMR 01/31/18
CHECKED BY/DATE: LMS 1/31/2018

TABLE II.6-2

BACKGROUND SUMMARY
HUMAN HEALTH RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Number of Background Samples	Minimum Total Mercury Background (ng/g)	Maximum Total Mercury Background (ng/g)	Total Mercury Background Value (ng/g)	Methyl Mercury Background Value[1] (ng/g)	Background Statistic
Trophic Level 3 Shellfish - American Lobster					
20	26.8	57.5	57.5	44.9	Max
Trophic Level 3 Finfish - Atlantic Tomcod[3]					
1	36.5	36.5	36.5	29.2	Max
Trophic Level 4 Finfish - American Eel					
6	142	320	320	282	Max
Trophic Level 3 Waterfowl - American Black Duck					
21	10.1	93.6	93.6	91.4	Max

Notes:
1. Calculated percentage of methyl mercury to total mercury as presented in Table II.2-1.
2. Maximum detect refers to the value selected when the most appropriate BTV is greater than the maximum detected concentration
3. Tomcod background is based on a single sample.

Abbreviations:
NA = not applicable
ng/g - nanograms per gram
UPL = upper prediction limit
UTL = upper tolerance limit

PREPARED BY/DATE: IMR 08/03/18
CHECKED BY/DATE: LMS 08/10/18

TABLE II.6-3

EXCEEDANCES BY LOCATION
HUMAN HEALTH RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Sample Location	Total Mercury Background Threshold Value (ng/g)	Local Consumer Total Mercury PRG[1] (ng/g)	Adjusted MeCDC Fish Tissue Action Level[2]	Number of MeCDC Fish Tissue Action Level Exceedances	Number of Total Mercury Background Exceedances	Number of Local Consumer Total Mercury PRG Exceedances
Trophic Level 3 Shellfish - American Lobster						
Frenchman Bay - Reference	57.5	3,990	216	0/20	1/20	0/20
2014 Closure				46/80	80/80	0/80
2016 Closure				21/80	80/80	0/80
Odom Ledge				16/40	40/40	0/40
South Verona				30/40	40/40	0/40
Cape Jellison				12/40	40/40	0/40
Turner Point				9/40	40/40	0/40
Harborside				1/40	36/40	0/40
Trophic Level 3 Finfish - Atlantic Tomcod[3]						
Frenchman Bay - Reference	36.5	373	251	0/1	0/1	0/1
BO4				3/12	12/12	0/12
OB5				5/38	38/38	1/38
OB1				7/39	39/39	3/39
ES13				0/22	20/22	0/22
Fort Point				0/3	3/3	0/3
Trophic Level 4 Finfish - American Eel						
OV4 - Reference	320	339	228	2/6	0/6	0/6
BO4				21/21	20/21	20/21
OB5				17/25	11/25	10/25
OB1				1/1	1/1	1/1
Trophic Level 3 Waterfowl - American Black Duck						
Frenchman Bay - Reference	93.6	430	205	0/21	0/21	0/21
Mendall Marsh				17/23	23/23	2/23
ES-13				9/20	18/20	3/20

Notes:
1. Lower of the adult and child PRGs.
2. MeCDC Fish Tissue Action Level for methyl mercury is 200 ng/g which is adjusted based on the percentage methyl mercury to total mercury presented in Table II.2-1.
3. Tomcod background based on a single sample.

Abbreviations:
MeCDC = Maine Center for Disease Control and Prevention
ng/g = nanograms per gram
PRG = preliminary remediation goals

PREPARED BY/DATE: IMR 08/03/18
CHECKED BY/DATE: LMS 08/10/18

TABLE II.7-1

UNCERTAINTY SUMMARY FOR BASELINE HUMAN HEALTH / ECOLOGICAL RISK ASSESSMENTS AND PRG DEVELOPMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Area of Uncertainty	Description of Approach or Assumption	Potential Effect on Risk/PRG Development: Decreased Risks/Higher PRGs	Increased Risks/Lower PRGs	De minimis Effect on Risks/PRGs
Conceptual Exposure Model	Assessment endpoint receptors are representative of risks across all species within a receptor group	X	X	--
	Sediment exposure was not evaluated for fish	--	--	X
	Surface water and sediment exposure not evaluated for human health	X	--	--
	Surface water exposure not evaluated for fish or birds	--	--	X
Data & Sampling	Sampled prey items are representative of COPC levels in prey actually consumed at site	X	X	--
	Use of historic shrimp data; shrimp data from only one reach of the river	X	X	--
	Use of small sediment sample dataset due to small home range for red-winged blackbird	--	X	--
	Use of fillet samples for Atlantic tomcod and American eel in tissue-based risk quantification using a whole body tissue TRV and in dietary exposure to piscivorous receptors	--	X	--
	Lack of current piscivorous mammal and avian tissue data (latest year available is 2012)	X	X	--
	EPCs for some exposure units/media are based on small sample sizes	X	X	--
	Use of average site-specific percent methyl mercury to total mercury concentration to derive methyl mercury concentrations in biota tissue when actual measured data were not available	--	--	X
	Lack of reference data for red-winged blackbird	--	X	--
	Use of marsh songbird blood data from different summer months	X	--	--
Exposure	The use of the maximum detected concentration as an EPC instead of a 95% UCL for some cases	--	X	--
	Use of one-half the maximum detection limit for non-detect EPCs in the reference areas	--	--	X
	Food web modeling for lobsters not evaluated in the BERA; tissue-based risk characterization only	X	--	--
	Use of interval participation weighted concentrations to calculate the sediment EPCs	--	--	X
	Assumption of 100% bioavailability for mercury	--	X	--
	Assumption that 100% of mercury exposure is site related for migratory bird species	--	X	--
	Exposure parameters based on both site-specific data (where available) and scientific literature	X	X	--
	Lack of predatory fish dietary component for mink and belted kingfisher	X	--	--
	Difference in total mercury EPCs for terrestrial insects at MMSE and MMSW	X	X	--
	Potential variability in climate-change can affect methylmercury generation and bioavailability of methylmercury in the food webs	X	X	--
	Potential for mercury acclimation of receptors	X	--	--
	Use of sample location-specific EPCs for forage/predatory fish instead of site-wide forage/predatory fish EPCs	X	X	--
	Use of food item surrogates when data were not available	X	X	--
	Dietary compositions based on both site-specific data (where available) and scientific literature	X	X	--
	Use of songbird and black duck exposure frequencies of 0.50 and 0.58, respectively, based on observed migratory behavior	X	--	--
	Use of 100% Diet for each biota type as opposed to a mixed diet	--	X	--
Toxicity	Population-level effects inferred by effects in individual organisms	X	X	--
	TRVs are not site-specific	X	X	--
	Differential forms and the bioavailability of the mercury in dietary sources	X	X	--
	Copepod toxicity data used as the basis for blue mussel tissue TRVs due to the sensitivity of the study endpoint (egg depression) and the presumed sensitivity of zooplankton to mercury	--	X	--
	Species-specific sensitivity to mercury	X	X	--
	Extrapolation from test animals in laboratory conditions to wildlife in natural environments	--	X	--
	Interspecies extrapolation assumes species have similar absorption, metabolism, distribution, and excretion of mercury	X	X	--
	LOAEL and NOAEL values vary among individuals within a species, between species, size/sex/age, environmental conditions	X	X	--
	Limited studies were available for dietary mercury exposure of fish	X	X	--
	Only a tissue NOAEL TRV was available for the American lobster	--	X	--
	Toxicity data from controlled laboratory studies - use more bioavailable forms of mercury in the test concentrations/prepared diets compared natural exposure	--	X	--
	TRVs based on the point estimate approach - defining the true toxicity threshold between the NOAEL and LOAEL	--	X	--
	Development of the chronic reference dose for human health	X	X	--
	Where point estimate NOAELs and LOAELs used, lowest LOAEL with a bounded NOAEL selected when available or appropriate	--	X	--
	Uncertainty factor of 0.1 used to estimate NOAEL TRV from unbounded LOAEL TRV	X	X	--
Risk	Availability of Alternate Health Guidelines in the HHRA	--	X	--
	Use of NOAEL TRVs	--	X	--
	Elevated reference area HQs above 1.0 in BERA	--	X	--
BSAFs/BAFs	Limited amount (<10) of collocated samples some biota used in development of BSAFs/BAFs	X	X	--
	For some biota samples that did not have sediment locations within the home range radius of the collection locations, sediment samples from the general sampling area were used	X	X	--
	For some predator biota samples that did not have prey biota sample locations within the home range radius of the predator, surrogate species were used or prey samples from the general sampling area were used	X	X	--
	Mercury speciation affects bioaccumulation and bioavailability of mercury	X	X	--
	Standard errors were calculated for median BSAFs/BAFs using the standard equation as a rough approximate of standard error for all data sets	X	X	--
	Sediment organic matter composition and grain size affects bioaccumulation and bioavailability of mercury	X	X	--

Abbreviations:
HHRA = human health risk assessment
BERA = baseline ecological risk assessment
BSAFs = biota-to-sediment accumulation factors
BAFs = biota-to-biota accumulation factors
UCL = upper confidence limit
EPC = exposure point concentration
LOAEL = lowest observed adverse effects level
NOAEL = no observed adverse effects level
TRV = toxicity reference value
% = percent

Prepared: IMR 08/16/18
Checked: NSR 08/16/18

TABLE III.1-1

DATA SUMMARY
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

CAS No.	Analyte	Unit	Representative Species	Media	Percentage of Total Mercury[1]	No. of Samples	Frequency of Detection	Minimum Detected Concentration	Maximum Detected Concentration	Mean Concentration	Median Concentration
Crustaceans											
22967-92-6	Methyl Mercury	ng/g	American Lobster	Tail tissue	92%	200	100%	41	1,600	233	177
7439-97-6	Total Mercury	ng/g	American Lobster	Tail tissue	NA	200	100%	44	1,730	252	191
22967-92-6	Methyl Mercury	ng/g	Shrimp	Whole body tissue	NA	34	100%	25	85	51	49
7439-97-6	Total Mercury	ng/g	Shrimp	Whole body tissue	NA	35	100%	17	96	72	74
Mollusks											
22967-92-6	Methyl Mercury	ng/g	Blue Mussel	Whole body tissue	43%	151	100%	17	88	33	31
7439-97-6	Total Mercury	ng/g	Blue Mussel	Whole body tissue	NA	151	100%	39	207	78	73
Forage Fish											
22967-92-6	Methyl Mercury	ng/g	Rainbow Smelt	Whole body tissue	79%	107	100%	21	164	52	39
7439-97-6	Total Mercury	ng/g	Rainbow Smelt	Whole body tissue	NA	107	100%	26	207	65	50
22967-92-6	Methyl Mercury	ng/g	Mummichog	Whole body tissue	86%	100	100%	32	221	90	76
7439-97-6	Total Mercury	ng/g	Mummichog	Whole body tissue	NA	100	100%	37	256	104	88
Predatory Fish											
22967-92-6	Methyl Mercury	ng/g	Atlantic Tomcod	Muscle tissue	80%	114	100%	26	332	126	119
7439-97-6	Total Mercury	ng/g	Atlantic Tomcod	Muscle tissue	NA	114	100%	33	413	157	149
22967-92-6	Methyl Mercury	ng/g	American Eel	Muscle tissue	88%	47	100%	70	1,201	388	370
7439-97-6	Total Mercury	ng/g	American Eel	Muscle tissue	NA	47	100%	80	1,370	442	422
Waterfowl											
22967-92-6	Methyl Mercury	ng/g	American Black Duck	Blood	79%	89	100%	40	1,102	225	187
7439-97-6	Total Mercury	ng/g	American Black Duck	Blood	NA	89	100%	51	1,400	285	238
22967-92-6	Methyl Mercury	ng/g	American Black Duck	Muscle tissue	98%	13	100%	118	835	392	380
7439-97-6	Total Mercury	ng/g	American Black Duck	Muscle tissue	NA	13	100%	121	854	402	389
Marsh Songbird											
22967-92-6	Methyl Mercury	ng/g	Nelson's Sparrow	Blood	96%	83	100%	701	9,840	3,305	3,913
7439-97-6	Total Mercury	ng/g	Nelson's Sparrow	Blood	NA	83	100%	734	10,300	3,460	4,096
22967-92-6	Methyl Mercury	ng/g	Red-winged Blackbird	Blood	96%	20	100%	95	8,082	4,480	3,811
7439-97-6	Total Mercury	ng/g	Red-winged Blackbird	Blood	NA	20	100%	99	8,460	4,690	3,990
Terrestrial Invertebrates											
22967-92-6	Methyl Mercury	ng/g	Terrestrial Insects	Whole body tissue	NA	30	100%	2.1	241	41	28
7439-97-6	Total Mercury	ng/g	Terrestrial Insects	Whole body tissue	NA	30	100%	3.0	354	67	35
22967-92-6	Methyl Mercury	ng/g	Spiders	Whole body tissue	NA	30	100%	51	748	325	292
7439-97-6	Total Mercury	ng/g	Spiders	Whole body tissue	NA	30	100%	166	771	336	298
Aquatic Invertebrates											
22967-92-6	Methyl Mercury	ng/g	Polychaetes	Whole body tissue	NA	55	96%	1.1	18	8.6	8.7
7439-97-6	Total Mercury	ng/g	Polychaetes	Whole body tissue	NA	80	100%	8.9	321	62	30
Environmental Media											
22967-92-6	Methyl Mercury	ng/L	Surface Water		NA	12	42%	0.035	0.35	0.043	0.13
7439-97-6	Total Mercury	ng/L	Surface Water		NA	12	83%	1.4	21	1.8	4.7
22967-92-6	Methyl Mercury	ng/g	Sediment		NA	168	100%	0.034	87	9.7	6.1
7439-97-6	Total Mercury	ng/g	Sediment		NA	255	100%	7.5	2,238	644	691

Notes:
1. Methyl mercury percentage of total mercury taken from the Summary of Biota-Sediment Accumulation Factor Evaluation Technical Memorandum Amec Foster Wheeler 2017c) or calculated using current or historic data.
   Inorganic mercury percentage of total mercury is based on 100 minus the percentage methyl mercury to total mercury and uses the average value.
2. Lobster data based on tail tissue samples.
3. Methyl mercury percentage of total mercury not available for the Soft-Shell Clam. Instead directly measured concentrations of methyl mercury and mercury were utilized.
4. Duck data based on breast tissue samples

Abbreviations:
CAS = Chemical Abstracts Service
ng/g = nanograms per gram
NA = not applicable

Revised by: LO 08/09/18
Checked by: IMR 08/10/18

TABLE III.2-1

SUMMARY OF ASSESSMENT ENDPOINTS AND LINES OF EVIDENCE IN BERA
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Receptor Category	Assessment Endpoint	Representative Receptor	Line of Evidence: Measure of Exposure	Line of Evidence: Measure of Effect	Method of Evaluation
Aquatic Invertebrates	Survival, growth, and reproduction of aquatic invertebrate populations	American lobster	Mercury concentrations in lobster tail tissue	Tissue-residue TRVs based on survival, growth, and reproduction	Compare mercury concentrations measured in lobsters to reference area concentrations and tissue-residue-based TRVs for decapods
		Blue mussel	Mercury concentrations in blue mussel whole-body tissue	Tissue-residue TRVs based on survival, growth, and reproduction	Compare mercury concentrations measured in blue mussels to reference area concentrations and tissue-residue-based TRVs for molluscs
			Mercury concentrations in surface water	Surface water TRVs based on survival, growth, and reproduction	Compare mercury concentrations measured in surface water to surface water TRVs for molluscs
Fish	Survival, growth, and reproduction of lower trophic level (i.e., forgae) fish populations	Rainbow Smelt Mummichog	Mercury concentrations in rainbow smelt and mummichog whole-body tissue	Tissue-residue TRVs based on survival, growth, and reproduction	Compare mercury concentrations measured in rainbow smelt and mummichog to reference area concentrations and tissue-residue-based TRVs for fish
			Mercury concentrations in prey and surface sediment	Dietary TRVs based on survival, growth, and reproduction of fish	Compare calculated dietary dose for forage fish to fish dietary TRVs
	Survival, growth, and reproduction of upper trophic level (i.e., predatory) fish populations	American eel Atlantic tomcod	Mercury concentrations in eel and tomcod whole-body tissue	Tissue-residue TRVs based on survival, growth, and reproduction	Compare mercury concentrations measured in eel and tomcod to reference area concentrations and tissue-residue-based TRVs for fish
			Mercury concentrations in prey and surface sediment	Dietary TRVs based on survival, growth, and reproduction of fish	Compare calculated dietary dose for predatory fish to fish dietary TRVs
Wetland-dependent Birds	Survival, growth, and reproduction of omnivorous aquatic bird populations	American black duck	Mercury concentrations in black duck blood	Blood TRVs based on survival, growth, and reproduction	Compare mercury concentrations in black duck blood to reference area concentrations and tissue residue-based avian TRVs
			Mercury concentrations in black duck breast muscle tissue	--	Compare mercury concentrations in black duck tissue to reference area concentrations
			Mercury concentrations in prey and surface sediment	Dietary TRVs based on survival, growth, and reproduction of birds	Compare calculated dietary dose to avian dietary TRVs
	Survival, growth, and reproduction of insectivorous marsh bird populations	Nelson's sparrow	Mercury concentrations in sparrow blood	Blood TRVs based on survival, growth, and reproduction	Compare mercury concentrations in sparrow blood to reference area concentrations and avian blood TRVs
			Mercury concentrations in prey and surface sediment	Dietary TRVs based on survival, growth, and reproduction of birds	Compare calculated dietary dose to avian dietary TRVs
		Red-winged blackbird	Mercury concentrations in blackbird blood	Blood TRVs based on survival, growth, and reproduction	Compare mercury concentrations in blackbird blood to avian blood TRVs
			Mercury concentrations in prey and surface sediment	Dietary TRVs based on survival, growth, and reproduction of birds	Compare calculated dietary dose to avian dietary TRVs
Piscivorous Birds	Survival, growth, and reproduction of piscivorous bird populations	Belted kingfisher	Mercury concentrations in prey and surface sediment	Dietary TRVs based on survival, growth, and reproduction of piscivorous birds	Compare calculated dietary dose to piscivorous avian dietary TRVs
		Bald eagle	Mercury concentrations in prey and surface sediment	Dietary TRVs based on survival, growth, and reproduction of piscivorous birds	Compare calculated dietary dose to piscivorous avian dietary TRVs
		Belted kingfisher, black guillemot, double-crested cormorant, eagle, and osprey	Mercury concentrations in belted kingfisher, black guillemot, double-crested cormorant, eagle, and osprey blood	Blood TRVs based on survival, growth, and reproduction	Compare mercury concentrations in piscivorous blood to avian blood TRVs
		Black guillemot, double-crested cormorant, and osprey	Mercury concentrations in black guillemot, double-crested cormorant, and osprey eggs	--	Evaluate mercury concentrations in piscivorous bird eggs
Piscivorous Mammals	Survival, growth, and reproduction of piscivorous mammal populations	Mink	Mercury concentrations in prey and surface sediment	Dietary TRVs based on survival, growth, and reproduction of piscivorous mammals	Compare calculated dietary dose to piscivorous mammal dietary TRVs

Abbreviations:
TRVs = toxicity reference values

Prepared by: LO 04/13/18
Checked by: NSR 08/01/18

TABLE III.3-1

EXPOSURE PARAMETERS FOR MUMMICHOG BASELINE ECOLOGICAL RISK ASSESSMENT Penobscot River Phase III Engineering Study Penobscot River Estuary, Maine

Exposure Parameter[1]	Description	Values Selected for Exposure/Risk Calculation
Mummichog (*Fundulus heteroclitus*) Body Weight: 0.002–0.012 kg (collected at site in 2016–2017)	Average of males and females collected at site	0.0050 kg
Dietary makeup based on stomach content diet analyses conducted on mummichog caught in the lower Penobscot River[1]: Insects – 90% Amphipods – 7% Decapods (shrimp) – 3%	Dietary composition adjusted for site-specific evaluation based on food items collected	Insects – 90% Shrimp – 10%
Ingestion Rate for Food (kg/day wet weight)	Assumed 7.2% of body weight[2]	0.000360 kg/day
Home Range	Mummichog home range of adults and large young of year of approximately 15 hecarte (700 feet) at high tide in New Jersey salt marsh.[3]	Used in exposure estimates
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range, not to exceed a maximum value of 1.0. The site is considered representative of the mummichog's range.	1.0
Exposure Frequency (unitless)	Mummichog present year-round.	1.0

Sources:
1. Kopec, A.D. and R.A. Bodaly. 2013. Penobscot River Mercury Study Chapter 16: Analysis of aquatic and wetland food webs in the Penobscot estuary. Submitted to Judge John Woodcock United States District Court (District of Maine). April.
2. Weisberg, S.B. and V.A. Lotrich. 1982. The importance of an infrequently flooded intertidal marsh surface as an energy source for the mummichog *Fundulus heteroclitus*: an experimental approach. *Marine Biology*. 66:307-310.
3. Teo, S.L.H. and K.W. Able. 2003. Habitat Use and Movement of the Mummichog (*Fundulus heteroclitus*) in a Restored Salt Marsh. *Estuaries*. June. 26 (3): 720–730.

Abbreviations:
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 11/22/17
Checked by: LSV 11/29/17

TABLE III.3-2

EXPOSURE PARAMETERS FOR RAINBOW SMELT
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Parameter[1]	Description	Values Selected for Exposure/Risk Calculation
Rainbow smelt (*Osmerus mordax*) Body Weight: 0.0034 – 0.072 kg (collected at site in 2016-2017)	Average of males and females collected at site	0.012 kg
Dietary makeup based on average stomach content diet analyses conducted on rainbow smelt caught in the lower Penobscot River and upper Penobscot Bay[1]: Crustaceans/Zooplankton – 62% Fish – 38% Plants – 0.2 %	Dietary composition adjusted for site-specific evaluation based on food items collected	Shrimp – 62% Forage fish (Mummichog) – 38%
Ingestion Rate for Food (kg/day wet weight)	Assumed 11% of body weight[2]	0.00132 kg/day
Home Range	In spring, smelt spawn at head of tide in streams and rivers. In summer, the YOY are in estuaries and adults in coastal waters. In fall, smelt move towards shore and into bays and mouths of rivers, and winter in sheltered bays and large tidal rivers. Current range in Penobscot River is smaller than historical because of dams and other impediments to movement. Historically, did not migrate beyond Milford Dam.	Used in exposure estimates
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range, not to exceed a maximum value of 1.0. The site is considered representative of the smelt's range.	1.0
Exposure Frequency (unitless)	Rainbow smelt present year-round.	1.0

Sources:
1. Kopec, A.D. and R.A. Bodaly. 2013. Penobscot River Mercury Study Chapter 16: Analysis of aquatic and wetland food webs in the Penobscot estuary. Submitted to Judge John Woodcock United States District Court (District of Maine). April.
2. Plourde, Jérôme, Pascal Sirois, and Marc Trudel. 2012. Quantifying zooplankton consumption by larval and juvenile rainbow smelt using a mercury mass balance model. A Multi-State Collaborative to Develop & Implement a Conservation Program for Three Anadromous Finfish Species of Concern in the Gulf of Maine. Award #NA06NMF4720249 (DMR #1350).

Abbreviations:
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 11/22/17
Checked by: LSV 11/29/17

TABLE III.3-3

EXPOSURE PARAMETERS FOR ATLANTIC TOMCOD
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Parameter[1]	Description	Values Selected for Exposure/Risk Calculation
Atlantic tomcod (*Microgadus tomcod*) Body Weight: 0.0003 – 0.13 kg (collected at site in 2016 and 2017)	Average of males and females collected at site	0.035 kg
Dietary makeup based on average stomach content diet analyses conducted on tomcod caught in the lower Penobscot River and upper Penobscot Bay[1]: Crustaceans/Zooplankton – 83% Worms – 1.6% Fish – 10% Plants – 4.8% Animal – 0.73%	Dietary composition adjusted for site-specific evaluation based on food items collected	Shrimp – 88% Forage fish (smelt and mummichog) – 10% Polychaetes – 2%
Ingestion Rate for Food (kg/day wet weight)	Assumed 2.8% of body weight[2]	0.000980 kg/day
Home Range	Tomcod may migrate up to 150 miles between coastal non-spawning waters and riverine spawning habitat. Migrate into the lower reaches of the Penobscot and other Maine rivers during the late fall to feed and then spawn near the head of the tide in mid-winter. By spring migrate back to estuarine and marine areas to grow.	Used in exposure estimates
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range, not to exceed a maximum value of 1.0. The site is considered representative of the tomcod's range.	1.0
Exposure Frequency (unitless)	Tomcod present year-round.	1.0

Sources:
1. Kopec, A.D. and R.A. Bodaly. 2013. Penobscot River Mercury Study Chapter 16: Analysis of aquatic and wetland food webs in the Penobscot estuary. Submitted to Judge John Woodcock United States District Court (District of Maine). April.
2. Lambert, Y. J-D. Dutil, and J. Munro. 1994. Effects of Intermediate and Low Salinity Conditions on Growth Rate and Food Conversion of Atlantic Cod (*Gadus morhua*). *Can. J. Fish. Aquat. Sci.,* 51(7): 1569-1576.

Abbreviations:
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 11/22/17
Checked by: LSV 11/29/17

TABLE III.3-4

EXPOSURE PARAMETERS FOR AMERICAN EEL
BASELINE ECOLOGICAL RISK ASSESSMENT

Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Parameter	Description	Values Selected for Exposure/Risk Calculation
American eel (*Anguilla rostrate*) Body Weight: 0.030 to 0.150 kg (collected at site in 2016-2017)	Average of males and females collected at site	0.0694 kg
Dietary makeup based on average stomach content diet analyses conducted on eel caught in the lower Penobscot River and upper Penobscot Bay[1]: Crustaceans/Zooplankton – 42% Worms – 36% Fish – 0.5% Insects – 15% Molluscs – 2.9% Plants – 0.19 % Animals – 3.1%	Dietary composition adjusted for site-specific evaluation based on food items collected	Shrimp – 48% Polychaetes – 36% Insects – 15% Forage fish (smelt and mummichog) – 1%
Ingestion Rate for Food (kg/day wet weight)	Assumed 10% of body weight based on immature adults[2, 3]	0.00694 kg/day
Home Range	Eels are born in the ocean, mature in freshwater, and return to the ocean to spawn. While some American eels swim up freshwater streams to mature, others remain and mature in both estuarine and marine waters.	Used in exposure estimates
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range, not to exceed a maximum value of 1.0. The site is considered representative of the eel's range.	1.0
Exposure Frequency (unitless)	Eel present year-round.	1.0

Sources:
1. Kopec, A.D. and R.A. Bodaly. 2013. Penobscot River Mercury Study Chapter 16: Analysis of aquatic and wetland food webs in the Penobscot estuary. Submitted to Judge John Woodcock United States District Court (District of Maine). April.
2. Matsui, Isao. 1993. *Theory and Practice of Eel Culture*. CRC Press.
3. Arai, Shigeru.1987. Eel Culture in Greece. Development of Marine and Inland Aquaculture in Greece FI:DP/GRE/85/002. Field Document 1.

Abbreviations:
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 11/22/17
Checked by: LSV 11/29/17

TABLE III.3-5

EXPOSURE PARAMETERS FOR NELSON'S SPARROW
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Parameter	Description	Values Selected for Exposure/Risk Calculation
Nelson's sparrow (*Ammodramus nelsoni*) Body Weight: 0.014 – 0.020 kg (males and females collected from Mendall Marsh in 2016 and 2017)	Average of males and females collected at site	0.017 kg
Dietary makeup varies with season and opportunities (*i.e.,* habitat). This dietary composition is based on breeding *A. n. subvirgatus* (marsh subspecies)[1]: Insects – 83% Spiders – 15% Seeds – 2%	Dietary composition adjusted for site-specific evaluation based on food items collected. As a ground forager, assumed incidental sediment ingestion similar to that of song sparrows (17%)[2]	Insects – 85% Spiders – 15% Sediments – 17%
Ingestion Rate for Food (kg/day wet weight) Ingestion Rate for Sediment (kg/day dry weight)	Estimated using the Nagy [3] fresh matter intake and dry matter intake equations for passerine birds: Fresh Matter Intake: y(grams)=2.438 (body weight in grams)$^{0.607}$ Dry Matter Intake: y(grams)=0.630 (body weight in grams)$^{0.683}$	0.014 kg/day wet weight 0.00436 kg/day dry weight
Home Range	Estimation of home range from tidal marsh in southern Gulf of Maine is approximately 119.68±19.43 hectares for males and 43.58±13.10 hectares for females[4].	Used in exposure estimates
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range, not to exceed a maximum value of 1.0. The site is considered representative of the Nelson's sparrow range.	1.0
Exposure Frequency (unitless)	Nelson's sparrow present at site for breeding with anticipated arrival in late May and departure as late as October[1]. Assumed up to 6 months present at the site.	0.50

Sources:
1. Shriver, W.G., T.P. Hodgman, and A.R. Hanson. 2011. Nelson's Sparrow (*Ammodramus nelsoni*). The Birds of North America Online, 29829151(719). Accessed at: https://doi.org/10.2173/.
2. Hansen, J.A., D. Audet, B.L. Spears, K.A. Healy, R.E. Brazzle, D.J. Hoffman, A. Dailey, A. and W.N. Beyer. 2011. Lead exposure and poisoning of songbirds using the Coeur d'Alene River Basin, Idaho, USA. *Integr Environ Assess Manag,* 7: 587–595.
3. Nagy, K.A. 2001. Food requirements of wild animals: predictive equations for free-living mammals, reptiles, and birds. *Nutrition Abstracts and Reviews*, Series B 71, 21R-31R.
4. Shriver, W.G., T.P. Hodgman and P. Vickery. 2010. Home Range Sizes and Habitat Use of Nelson's and Saltmarsh Sparrows. *The Wilson Journal of Ornithology*, 122(2), 340-345.

Abbreviations:
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 11/22/17
Checked by: LSV 11/29/17

TABLE III.3-6

EXPOSURE PARAMETERS FOR RED-WINGED BLACKBIRD
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Parameter	Description	Values Selected for Exposure/Risk Calculation
Red-winged Blackbird (*Agelaius phoeniceus*) Body Weight: 0.030–0.072 kg (males and females collected from Mendall Marsh in 2016 and 2017)	Average of males and females collected at site	0.047 kg
Dietary makeup varies with season and opportunities (*i.e.,* habitat). This dietary composition is based on the breeding diet in a marsh area of Canada[1] and a breeding diet in Washington[2]: Insects – 94% and 90% Spiders – 1% and 7% Other Items – 5% and 3% Mineral Grit – 0.5%	Dietary composition adjusted for site-specific evaluation based on food items collected Although a ground forager, the red-winged blackbrid does not spend as much time on ground as a song sparrow, so incidental soil ingestion should be lower. Used study from Canada, 0.5%[1].	Insects – 90% Spiders – 10% Sediments – 0.5%
Ingestion Rate for Food (kg/day wet weight) Ingestion Rate for Sediment (kg/day dry weight)	Estimated using the Nagy[3] fresh matter intake and dry matter intake equations for passerine birds: Fresh Matter Intake: y(grams)=2.438 $(\text{body weight in grams})^{0.607}$ Dry Matter Intake: y(grams)=0.63 $(\text{body weight in grams})^{0.683}$	0.0252 kg/day (wet weight) 0.00874 kg/day (dry weight)
Home Range	Estimation of home range is 153 square meters (in marshes) -29,235 square meters (in uplands); males tend to control territory of 2,000 square meters, several females will occupy territory of single male[4]	Used in exposure estimates
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range, not to exceed a maximum value of 1.0. The site is considered representative of the red-winged blackbird range.	1.0
Exposure Frequency (unitless)	Red-winged blackbird present at site for breeding with anticipated arrival in late February and departure as late as August[1]. Assumed up to 7 months present at the site.	0.58

Sources:
1. Bird, R.D., and L.B. Smith. 1964. The food habits of the red-winged blackbird, Agelaius phoeniceus, in Manitoba. *Can. Field-Nat*. 78:179-186.
2. Orians, G.H., and H.S. Horn. 1969. Overlap in foods and foraging of four species of blackbirds in the Potholes of central Washington. *Ecology* 50:930-938.
3. Nagy, K.A. 2001. Food requirements of wild animals: predictive equations for free-living mammals, reptiles, and birds. *Nutrition Abstracts and Reviews*, Series B 71, 21R-31R.
4. Rosenthal, A. 2004. Agelaius phoeniceus. Animal Diversity Web. Accessed April 5, 2017, at: http://animaldiversity.org/accounts/Agelaius_phoeniceus/.

Abbreviations:
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 11/22/17
Checked by: LSV 11/29/17

TABLE III.3-7

EXPOSURE PARAMETERS FOR AMERICAN BLACK DUCK
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Parameter	Description	Values Selected for Exposure/Risk Calculation
American black duck (*Anas rubripes*) Body Weight: 1.15 – 1.66 kg (males and females collected at site in 2017 and 2018)	Average of males and females collected at site	1.36 kg
Dietary makeup varies with season and opportunities (*i.e.,* habitat). This dietary composition is based on fall migration and wintering study[1]: Crustaceans (snail, crab, clam) – 39% Mussels – 22% Amphipods/Isopods – 28% Polychaete – 6% Vegetation – 4%	Dietary composition adjusted for site-specific evaluation based on food items collected Blue mussels used as a surrogate for clams, amphipods, snails, etc. Assumed incidental sediment ingestion similar to that of mallard (< 2%)[2]	Polychaetes – 80% Mussels – 20% Sediments – 2%
Ingestion Rate for Food (kg/day wet weight) Ingestion Rate for Sediment (kg/day dry weight)	Estimated using the Nagy[3] fresh matter intake and dry matter intake equations for omnivorous birds: Fresh matter intake: y(grams)=2.094 (body weight in grams)$^{0.627}$ Dry matter intake: y(grams)=0.67 (body weight in grams)$^{0.627}$	0.193 kg/day (wet weight) 0.0618 kg/day (dry weight)
Home Range	Estimation of home range for post-fledgling juveniles in Moosehom National Wildlife Refuge in eastern Maine averaged 4,987 hectares (range 54 – 28 070 hectares), and maximum distances moved from the roost averaged 9.9 kilometers (range 0.9–42.8 kilometers)[4]	Used in exposure estimates
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range, not to exceed a maximum value of 1.0. The site is considered representative of the black duck's range.	1.0
Exposure Frequency (unitless)	The black duck arrives at the site around October and winters through approximately March each year.	0.5

Sources:
1. Longcore, J.R., D.G. McAuley, G.R. Hepp, and J.M. Rhymer. 2000. American Black Duck (*Anas rubripes*), *The Birds of North America* (P.G. Rodewald, Ed.). Ithaca: Cornell Lab of Ornithology. Accessed at: https://birdsna.org/Species-Account/bna/species/ambduc.
2. United States Environmental Protection Agency. 1993. Wildlife Exposure Factors Handbook. EPA/600/R-93/187 December.
3. Nagy, K.A. 2001. Food requirements of wild animals: predictive equations for free-living mammals, reptiles, and birds. *Nutrition Abstracts and Reviews*, Series B 71, 21R-31R.
4. Frazer, C, J.R. Longcore, and D.G. McAuley. 1990. Home range and movements of post-fledging American black ducks in eastern Maine. *Canadian Journal of Zoology*, 68:1288-1291.

Abbreviations:
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 11/22/17
Checked by: LSV 11/29/17

TABLE III.3-8

EXPOSURE PARAMETERS FOR BELTED KINGFISHER
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Parameter[1]	Description	Values Selected for Exposure/Risk Calculation
Belted kingfisher (*Ceryle alcyon)* Body Weight	Average of males and females[1]	0.15 kg
Dietary makeup varies with season and opportunities (*i.e.,* habitat). Diet made up primarily of small fish (averaging less than 10 cm in length but ranging up to 17.8 cm in length) is preferred, especially stickelbacks or mummichogs, though a wide range of prey is possible, including molluscs, crustaceans, insects, amphibians, young birds and small mammals[1, 2] Prey fish size based on ranges cited in USEPA (1993) from 2.5 to 17.8 cm in a Michigan study (Salyer and Lagler 1946) and 4 to 14 cm in an Ohio stream study (Davis 1982)	Dietary composition adjusted for site-specific evaluation based on food items collected. Assumed incidental sediment ingestion similar of 1% considered conservative because hunting involves flighted strategies so rarely contact sediment[1].	Forage fish – 100% Sediment – 1%
Ingestion Rate for Food (kg/day wet weight) Ingestion Rate for Sediment (kg/day dry weight)	The average body weight of 0.15 kg is used to calculate the Ingestion Rate for Food using 0.50 g food/g body weight/day[1]: Ingestion Rate for Food: (0.50 g food/g body weight/day x 150 g body weight) = 75 g/day Ingestion Rate for Sediment of belted kingfisher estimated using the Nagy[3] dry matter intake equations for carnivorous birds: Dry Matter Intake: y(grams)=0.849 (body weight in grams)$^{0.663}$	0.075 kg/day (wet weight) 0.024 kg/day (dry weight)

Exposure Parameter[1]	Description	Values Selected for Exposure/Risk Calculation
Home Range	Throughout the spring and summer, both male and female will defend a territory that includes their nest site and their foraging area. Territory size averages an approximately 1.6-kilometer shoreline with 3 kilometers as a conservative (upper limit) estimate of the possible distance that they will move to feed[1, 2]	Used in exposure estimates
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range, not to exceed a maximum value of 1.0. The site is considered representative of the belted kingfisher's range.	1.0
Exposure Frequency (unitless)	Belted kingfishers present at site for breeding with anticipated arrival in mid-April and departure as late as October[1,2],[4]. Assumed present at the site for up to 6 months.	0.5

Sources:
1. United States Environmental Protection Agency. 1993. Wildlife Exposure Factors Handbook. EPA/600/R-93/187 December.
2. Bodaly, R.A., A.D. Kopec, J.W.M. Rudd, N.S. Fisher, and C.G. Whipple. 2009. Penobscot River Mercury Study: Update to the Phase I Report. Prepared for Judge John Woodcock, U.S. District Court, Bangor, Maine. May. Accessed: December 18, 2017 at: http://www.maine.gov/dep/spills/holtrachem/.
3. Nagy, K.A. 2001. Food requirements of wild animals: predictive equations for free-living mammals, reptiles, and birds. *Nutrition Abstracts and Reviews*, Series B 71, 21R-31R.
4. Kelly, J. F., E. S. Bridge, and M. J. Hamas (2009). Belted Kingfisher (*Megaceryle alcyon*), version 2.0. In The Birds of North America (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bna.84.

Abbreviations:
cm = centimeters
g = grams
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 08/08/18
Checked by: IMR 08/08/18

TABLE III.3-9

EXPOSURE PARAMETERS FOR BALD EAGLE BASELINE ECOLOGICAL RISK ASSESSMENT Penobscot River Phase III Engineering Study Penobscot River Estuary, Maine

Exposure Parameter[1]	Description	Values Selected for Exposure/Risk Calculation
Bald eagle (*Haliaeetus leucocephalus)* Body Weight	Average of males and females[1]	4.6 kg
Bald eagles are primarily carrion feeders, eating dead or dying fish, but also will catch live fish swimming near the surface or fish in shallow waters. They are opportunistic feeders taking advantage of whatever is plentiful and easy to scavenge or capture, including birds and mammals.[2] Bald eagles in Maine are primarily fish eaters at inland settings on the lakes and rivers[3]. In coastal estuaries and (especially) offshore, they eat a more varied diet, adding seabirds and waterfowl.[3] Scavenging carrion becomes more prevalent as ice cover greatly limits food availability.[3] Prey fish size of more than 17.8 cm in length (assumed lower bound is anything higher than the upper bound of belted kingfisher prey size) based on the distribution of fish size recorded for breeding bald eagles in a central Arizona study (Grubb 1995)[5], which was similar to that recorded by Haywood and Ohmart (1986)[6]. Of 1,000 estimated fish prey sizes in the study, 13 percent were <15 cm; 56 percent were 15-30 cm; 26 percent were 31-45 cm; and 4 percent were >45 cm (Grubb 1995).	Dietary composition adjusted for site-specific evaluation based on food items collected and based on dietary assumptions used in EPA sources[1, 4] Assumed incidental sediment ingestion of 1%.	Forage fish – 80% Predatory fish – 20% Sediment – 1%
Ingestion Rate for Food (kg/day wet weight) Ingestion Rate for Sediment (kg/day dry weight)	The average body weight of 4.6 kg is used to calculate the Ingestion Rate for Food using 0.12 g food/g body weight/day[1] Ingestion Rate for Food: (0.12 g food/g body weight /day x 4,600 g body weight) = 552 g/day Ingestion Rate for Sediment of bald eagle estimated using the Nagy[7] dry matter intake equations for carnivorous birds:	0.552 kg/day (wet weight) 0.228 kg/day (dry weight)

Exposure Parameter[1]	Description	Values Selected for Exposure/Risk Calculation
	Dry Matter Intake: y(grams)=0.849 (body weight in grams)$^{0.663}$	
Home Range	The foraging distance for riverine habitat in Connecticut ranges between 1.9 to 4.3 miles with an average of 3.1 miles[1]	Used in exposure estimates
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range is not to exceed a maximum value of 1.0. The site is considered representative of the bald eagle's range.	1.0
Exposure Frequency (unitless)	Although some bald eagles leave Maine, many bald eagles remain through the winter[3]. Assumed to be present at the site year-round.	1.0

Sources:
1. United States Environmental Protection Agency. 1995. Great Lakes Water Quality Initiative Technical Support Document for Wildlife Criteria. EPA-820-B-95-009. March.
2. United States Environmental Protection Agency. 1993. Wildlife Exposure Factors Handbook. EPA/600/R-93/187 December.
3. Maine Department of Inland Fisheries and Wildlife. 2018. Bald Eagles. Accessed January 10 at: http://www.maine.gov/ifw/fish-wildlife/wildlife/species-information/birds/bald-eagles.html.
4. 40 CFR Appendix D to Part 132, Great Lakes Water Quality Initiative Methodology for the Development of Wildlife Criteria. Accessed at: https://www.law.cornell.edu/cfr/text/40/appendix-D_to_part_132.
5. Grubb, T.G. 1995. Food Habits of Bald Eagles Breeding in the Arizona Desert. Wilson Bull., 107(2): 258-274.
6. Haywood, D.D. and R. D. Ohmart. 1986. Utilization of benthic-feeding fish by inland breeding Bald Eagles. Condor 88:35-42.
7. Nagy, K.A. 2001. Food requirements of wild animals: predictive equations for free-living mammals, reptiles, and birds. *Nutrition Abstracts and Reviews*, Series B 71, 21R-31R.

Abbreviations:
cm = centimeters
EPA = Environmental Protection Agency
g = grams
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 08/08/18
Checked by: IMR 08/08/18

TABLE III.3-10

EXPOSURE PARAMETERS FOR MINK
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Parameter[1]	Description	Values Selected for Exposure/Risk Calculation
Mink (*Neovison vison)* Body Weight	Average of males and females[1]	0.85 kg
Dietary makeup varies with season, habitat and opportunity. Dietary makeup for mink can consist of aquatic prey such as fish, frogs, and crustaceans, as well as birds and small mammals.[1] A mink food consumption study in Michigan indicated that fish represent approximately 85 percent of the mink diet during the spring, winter, and fall.[1, 2] Dominant fish size ranged between 5 and 18 cm in length.[2] EPA sources assume 90% forage fish and 10% birds and small mammals.[3, 4]	Dietary composition adjusted for site-specific evaluation based on food items collected. Assumed incidental sediment ingestion of 2%.	Forage fish – 100% Sediment – 2%
Ingestion Rate for Food (kg/day wet weight) Ingestion Rate for Sediment (kg/day dry weight)	Ingestion Rate for Food of mink estimated using the Nagy[5] fresh matter intake equation for Carnivora: Fresh Matter Intake: y(grams)=0.348 (body weight in grams)$^{0.859}$ Ingestion Rate for Sediment of mink estimated using the Nagy[5] dry matter intake equation for Carnivora: Dry Matter Intake: y(grams)=0.102 (body weight in grams)$^{0.864}$	0.114 kg/day (wet weight) 0.035 kg/day (dry weight)
Home Range	The home range of mink includes their foraging areas around waterways and their dens. Riverine home ranges are linear and depend on food abundance. The home range of adult male mink range from 1.8 km to 5.0 kilometers with an average of 2.63 kilometers (Sweden, stream); whereas female home range tends to be less and averages 1.85 kilometers (Sweden, stream)[1]. Average of males and females is 2.24 kilometers or 1.4 miles.	Used in exposure estimates

Exposure Parameter[1]	Description	Values Selected for Exposure/Risk Calculation
Site Foraging Frequency (unitless)	Site Foraging Frequency is the ratio of the site area to home range is not to exceed a maximum value of 1.0. The site is considered representative of the mink's range.	1.0
Exposure Frequency (unitless)	Mink are present year-round at the site.	1.0

Sources:

1. United States Environmental Protection Agency. 1993. Wildlife Exposure Factors Handbook. EPA/600/R-93/187 December.
2. Alexander, G. 1977. Food of vertebrate predators on trout waters in north central lower Michigan. *Michigan Academician* 10: 181-195
3. United States Environmental Protection Agency. 1995. Great Lakes Water Quality Initiative Technical Support Document for Wildlife Criteria. EPA-820-B-95-009. March.
4. 40 CFR Appendix D to Part 132, Great Lakes Water Quality Initiative Methodology for the Development of Wildlife Criteria. Accessed at: https://www.law.cornell.edu/cfr/text/40/appendix-D_to_part_132.
5. Nagy, K.A. 2001. Food requirements of wild animals: predictive equations for free-living mammals, reptiles, and birds. *Nutrition Abstracts and Reviews*, Series B 71, 21R-31R.

Abbreviations:
cm = centimeters
EPA = Environmental Protection Agency
g = grams
kg = kilograms
kg/day = kilograms per day

Prepared by: NSR 08/08/18
Checked by: IMR 08/08/18

TABLE III.3-11

SUMMARY OF SURFACE WATER EPCs FOR BLUE MUSSELS[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Exposure Area	Parameter[2]	No. of Samples	Frequency of Detection	Minimum Concentration (ng/L)	Maximum Concentration (ng/L)	Mean Concentration (ng/L)	Median Concentration (ng/L)	BERA EPC (ng/L)	Statistic Used
ES-15	Mercury	6	83%	1.7	21	7.8	6.1	13	95% KM (t) UCL
	Methyl Mercury	6	50%	0.043	0.35	0.20	0.21	0.24	95% KM (t) UCL
WQ-FPT	Mercury	6	83%	1.4	1.9	1.7	1.6	1.8	95% KM (t) UCL
	Methyl Mercury	6	33%	0.035	0.040	0.038	0.038	0.040	Maximum[3]

Notes:
1. Surface water samples collected in May through October 2016.
2. Total metal concentration.
3. Recommended UCL exceeds the maximum observation.

Abbreviations:
BERA = baseline ecological risk assessment
EPC = exposure point concentration
KM = Kaplan-Meier
ng/L = nanograms per liter
t = Student's t-distribution critical value
UCL = upper confidence level

Prepared by: LO 09/19/17
Checked by: IMR 11/15/17

TABLE III.3-12a

SUMMARY OF TISSUE & BLOOD TOTAL MERCURY EPCs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Receptor (Sample Year)	Exposure Area	Media	No. of Samples	Frequency of Detection	Minimum Concentration (ng Hg/g, ww)	Maximum Concentration (ng Hg/g, ww)	Mean Concentration (ng Hg/g, ww)	Median Concentration (ng Hg/g, ww)	BERA EPC (ng Hg/g, ww)	Statistic Used
American lobster (2016 - 2017)	Odom Ledge (OL-01)	Tail tissue	40	100%	128	1,730	324	225	521	95% Chebyshev (Mean, Sd) UCL
	South Verona (SVE-01)	Tail tissue	40	100%	165	1,320	375	306	431	95% Adjusted Gamma UCL
	Cape Jellison (CPJL)	Tail tissue	40	100%	98.8	925	244	190	284	95% Student's-t UCL
	Turner Point (L9-45)	Tail tissue	40	100%	65.6	591	212	185	242	95% Adjusted Gamma UCL
	Harborside (HB-01)	Tail tissue	40	100%	44.4	264	102	100	113	95% Student's-t UCL
	2014 Closure (OL-01 & SVE-01)	Tail tissue	80	100%	128	1,730	350	278	472	95% Chebyshev (Mean, Sd) UCL
	2016 Closure (CPJL&L9-45)	Tail tissue	80	100%	65.6	925	228	189	253	95% Student's-t UCL
	Frenchman Bay_{REF}	Tail tissue	20	100%	26.8	64.8	40.6	38.7	44.0	95% Student's-t UCL
Blue mussel (2016 - 2017)	ES-15	Whole body tissue	32	100%	44.8	97.6	64.9	64.9	68.9	95% Student's-t UCL
	ES-13	Whole body tissue	40	100%	48.4	144	76.9	72.6	83.5	95% Adjusted Gamma UCL
	ES-03	Whole body tissue	39	100%	51.0	207	91.0	81.9	99.1	95% Adjusted Gamma UCL
	Fort Point	Whole body tissue	40	100%	39.1	181	78.5	72.7	87.8	95% Adjusted Gamma UCL
	Frenchman Bay_{REF}	Whole body tissue	20	100%	5.46	13.0	8.26	7.56	9.10	95% Student's-t UCL
Mummichog (2016 - 2017)	BO-04	Whole body tissue	21	100%	52.4	234	94.1	67.3	115	95% Student's-t UCL
	OB-05	Whole body tissue	40	100%	48.9	150	86.7	81.1	92.6	95% Adjusted Gamma UCL
	OB-01	Whole body tissue	16	100%	37.4	242	120	110	144	95% Student's-t UCL
	Mendall Marsh	Whole body tissue	23	100%	51.4	256	132	121	151	95% Student's-t UCL
	Frenchman Bay_{REF}	Whole body tissue	40	100%	4.44	13.5	7.22	6.98	7.70	95% Student's-t UCL
Rainbow smelt (2016 - 2017)	OB-01	Whole body tissue	35	100%	31.8	146	65.0	49.6	73.5	95% Student's-t UCL
	OB-04	Whole body tissue	5	100%	44.5	81.9	56.9	54.9	71.0	95% Student's-t UCL
	OB-05	Whole body tissue	6	100%	64.4	201	100	83.7	177	95% Adjusted Gamma UCL
	ES-13	Whole body tissue	21	100%	26.4	87.8	44.3	38.1	50.9	95% Student's-t UCL
	Fort Point	Whole body tissue	40	100%	27.1	207	72.3	58.3	84.6	95% Adjusted Gamma UCL
	Frenchman Bay_{REF}	Whole body tissue	40	100%	5.07	26.2	10.0	7.49	11.4	95% Student's-t UCL
Atlantic tomcod (2016 - 2017)	BO-04	Fillet tissue	12	100%	104	315	201	184	239	95% Student's-t UCL
	OB-05	Fillet tissue	38	100%	70.7	379	160	144	181	95% Adjusted Gamma UCL
	OB-01	Fillet tissue	39	100%	49.7	413	176	174	207	95% Adjusted Gamma UCL
	ES-13	Fillet tissue	22	100%	32.7	239	111	91.7	135	95% Student's-t UCL
	Fort Point	Fillet tissue	3	100%	37.2	74.3	55.7	55.5	74.3	Maximum
	Frenchman Bay_{REF}	Fillet tissue	1	100%	36.5	36.5	--	--	36.5	Maximum
American eel (2016 - 2017)	BO-04	Fillet tissue	21	100%	294	1,370	590	493	697	95% Adjusted Gamma UCL
	OB-05	Fillet tissue	25	100%	80.0	706	320	303	376	95% Student's-t UCL
	OB-01	Fillet tissue	1	100%	394	394	--	--	394	Maximum
	OV-04_{REF}	Fillet tissue	6	100%	142	320	210	169	320	Maximum
American black duck (2014, 2017, 2018)	Mendall Marsh	Blood	38	100%	105	1,400	390	317	460	95% Adjusted Gamme UCL
	ES-13	Blood	51	100%	50.6	700	207	150	300	95% Chebyshev (Mean, Sd) UCL
	Frenchman Bay_{REF}	Blood	52	100%	11.3	370	66.9	55.3	77.1	95% Approximate Gamma UCL

TABLE III.3-12a

SUMMARY OF TISSUE & BLOOD TOTAL MERCURY EPCs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Receptor (Sample Year)	Exposure Area	Media	No. of Samples	Frequency of Detection	Minimum Concentration (ng Hg/g, ww)	Maximum Concentration (ng Hg/g, ww)	Mean Concentration (ng Hg/g, ww)	Median Concentration (ng Hg/g, ww)	BERA EPC (ng Hg/g, ww)	Statistic Used
American black duck	Mendall Marsh	Breast Muscle Tissue	23	100%	121	854	296	260	351	95% Student's-t UCL
(2014, 2017, 2018)[2]	ES-13	Breast Muscle Tissue	20	100%	65	717	240	187	317	95% Adjusted Gamma UCL
	Frenchman Bay$_{REF}$	Breast Muscle Tissue	21	100%	21	94	62	67	70	95% Student's-t UCL
Nelson's sparrow	W-17-N	Blood	27	100%	734	10,300	3,835	2,920	4,829	95% Adjusted Gamma UCL
(2016 - 2017)	MMSE	Blood	30	100%	1,290	9,240	4,212	3,565	5,105	95% Adjusted Gamma UCL
	MMSW	Blood	26	100%	1,410	7,790	4,233	4,195	4,848	95% Student's-t UCL
	Pleasant River$_{REF}$	Blood	26	100%	219	740	422	380	466	95% Student's-t UCL
Red-winged blackbird	W-17-N	Blood	8	100%	99.4	5,850	2,781	2,475	4,213	95% Student's-t UCL
(2016 - 2017)	MMSE	Blood	6	100%	1,090	7,210	4,093	4,425	6,373	95% Student's-t UCL
	MMSW	Blood	6	100%	1,030	8,460	5,498	5,880	7,540	95% Student's-t UCL

Notes:
1. Total mercury concentrations based on results of laboratory analyses.
2. Breast muscle tissue concentrations estimated from a significant, positive correlation between blood and muscle tissue mercury concentrations that was developed for black duck in the 2016 Biota Monitoring Report (Amec Foster Wheeler 2017a).

Abbreviations:
BERA = baseline ecological risk assessment
EPC = exposure point concentration
ng Hg/g, ww = nanograms mercury per gram, wet weight
UCL = upper confidence limit

Prepared by: LO 08/07/18
Checked by: IMR 08/08/2018

TABLE III.3-12b

SUMMARY OF TISSUE & BLOOD METHYL MERCURY EPCs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Receptor (Sample Year)	Exposure Area	Media	No. of Samples	Frequency of Detection	Minimum Concentration (ng MeHg/g, ww)	Maximum Concentration (ng MeHg/g, ww)	Mean Concentration (ng MeHg/g, ww)	Median Concentration (ng MeHg/g, ww)	BERA EPC (ng MeHg/g, ww)	Statistic Used
American lobster (2016 - 2017)	Odom Ledge (OL-01)	Tail tissue	40	100%	118	1,592	298	207	479	95% Chebyshev (Mean, Sd) UCL
	South Verona (SVE-01)	Tail tissue	40	100%	152	1,214	345	281	396	95% Adjusted Gamma UCL
	Cape Jellison (CPJL)	Tail tissue	40	100%	90.9	851	224	174	261	95% Student's-t UCL
	Turner Point (L9-45)	Tail tissue	40	100%	60.4	544	195	170	223	95% Adjusted Gamma UCL
	Harborside (HB-01)	Tail tissue	40	100%	40.8	243	93.7	91.6	104	95% Student's-t UCL
	2014 Closure (OL-01 & SVE-01)	Tail tissue	80	100%	118	1,592	322	255	434	95% Chebyshev (Mean, Sd) UCL
	2016 Closure (CPJL&L9-45)	Tail tissue	80	100%	60.4	851	210	173	232	95% Student's-t UCL
	Frenchman Bay$_{REF}$	Tail tissue	20	100%	24.7	59.6	37.4	35.6	40.5	95% Student's-t UCL
Blue mussel (2016 - 2017)	ES-15	Whole body tissue	32	100%	19.1	41.7	27.7	27.7	29.4	95% Student's-t UCL
	ES-13	Whole body tissue	40	100%	20.7	61.5	32.8	31.0	35.7	95% Adjusted Gamma UCL
	ES-03	Whole body tissue	39	100%	21.8	88.4	38.9	35.0	42.3	95% Adjusted Gamma UCL
	Fort Point	Whole body tissue	40	100%	16.7	77.3	33.5	31.0	37.5	95% Adjusted Gamma UCL
	Frenchman Bay$_{REF}$	Whole body tissue	20	100%	2.33	5.5	3.53	3.23	3.88	95% Student's-t UCL
Mummichog (2016 - 2017)	BO-04	Whole body tissue	21	100%	45.2	202	81.2	58.1	99.2	95% Student's-t UCL
	OB-05	Whole body tissue	40	100%	42.2	129	74.8	69.9	79.9	95% Adjusted Gamma UCL
	OB-01	Whole body tissue	16	100%	32.3	209	104	94.5	124	95% Student's-t UCL
	Mendall Marsh	Whole body tissue	23	100%	44.3	221	114	104	130	95% Student's-t UCL
	Frenchman Bay$_{REF}$	Whole body tissue	40	100%	3.83	11.6	6.23	6.02	6.64	95% Student's-t UCL
Rainbow smelt (2016 - 2017)	OB-01	Whole body tissue	35	100%	25.1	115	51.3	39.2	58.1	95% Student's-t UCL
	OB-04	Whole body tissue	5	100%	35.2	64.7	44.9	43.4	56.1	95% Student's-t UCL
	OB-05	Whole body tissue	6	100%	50.9	159	79.1	66.1	140	95% Adjusted Gamma UCL
	ES-13	Whole body tissue	21	100%	20.9	69.4	35.0	30.1	40.2	95% Student's-t UCL
	Fort Point	Whole body tissue	40	100%	21.4	164	57.1	46.0	66.8	95% Adjusted Gamma UCL
	Frenchman Bay$_{REF}$	Whole body tissue	40	100%	4.00	20.7	7.90	5.92	9.03	95% Student's-t UCL
Atlantic tomcod (2016 - 2017)	BO-04	Fillet tissue	12	100%	82.7	251	160	146	190	95% Student's-t UCL
	OB-05	Fillet tissue	38	100%	56.2	301	127	115	144	95% Adjusted Gamma UCL
	OB-01	Fillet tissue	39	100%	39.5	329	140	138	165	95% Adjusted Gamma UCL
	ES-13	Fillet tissue	22	100%	26.0	190	88.1	72.9	108	95% Student's-t UCL
	Fort Point	Fillet tissue	3	100%	29.6	59.1	44.3	44.2	59.1	Maximum
	Frenchman Bay$_{REF}$	Fillet tissue	1	100%	29.0	29.0	--	--	29.0	Maximum
American eel (2016 - 2017)	BO-04	Fillet tissue	21	100%	258	1,201	517	432	611	95% Adjusted Gamma UCL
	OB-05	Fillet tissue	25	100%	70.1	619	281	266	330	95% Student's-t UCL
	OB-01	Fillet tissue	1	100%	345	345	--	--	345	Maximum
	OV-04$_{REF}$	Fillet tissue	6	100%	124	280	184	148	280	Maximum
American black duck (2014, 2017, 2018)	Mendall Marsh	Blood	38	100%	82.3	1,102	307	249	362	95% Adjusted Gamme UCL
	ES-13	Blood	51	100%	39.8	551	163	118	236	95% Chebyshev (Mean, Sd) UCL
	Frenchman Bay$_{REF}$	Blood	52	100%	8.90	292	52.6	43.5	60.7	95% Approximate Gamma UCL

TABLE III.3-12b

SUMMARY OF TISSUE & BLOOD METHYL MERCURY EPCs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Receptor (Sample Year)	Exposure Area	Media	No. of Samples	Frequency of Detection	Minimum Concentration (ng MeHg/g, ww)	Maximum Concentration (ng MeHg/g, ww)	Mean Concentration (ng MeHg/g, ww)	Median Concentration (ng MeHg/g, ww)	BERA EPC (ng MeHg/g, ww)	Statistic Used
American black duck (2014, 2017, 2018)[2]	Mendall Marsh	Tissue	23	100%	119	837	290	255	344	95% Student's-t UCL
	ES-13	Tissue	20	100%	64	703	235	183	311	95% Adjusted Gamma UCL
	Frenchman Bay$_{REF}$	Tissue	21	100%	21	92	61	66	68	95% Student's-t UCL
Nelson's sparrow (2016 - 2017)	W-17-N	Blood	27	100%	701	9,840	3,664	2,789	4,613	95% Adjusted Gamma UCL
	MMSE	Blood	30	100%	1,232	8,827	4,024	3,406	4,877	95% Adjusted Gamma UCL
	MMSW	Blood	26	100%	1,347	7,442	4,044	4,007	4,631	95% Student's-t UCL
	Pleasant River$_{REF}$	Blood	26	100%	209	707	404	363	445	95% Student's-t UCL
Red-winged blackbird (2016 - 2017)	W-17-N	Blood	8	100%	95.0	5,588	2,657	2,364	4,025	95% Student's-t UCL
	MMSE	Blood	6	100%	1,041	6,888	3,910	4,227	6,088	95% Student's-t UCL
	MMSW	Blood	6	100%	984	8,082	5,252	5,617	7,203	95% Student's-t UCL

Notes:
1. Methyl mercury percentage of total mercury taken from Tabel IV.1-2
2. Breast muscle tissue concentrations estimated from a significant, positive correlation between blood and muscle tissue mercury concentrations developed for black duck in 2016 Biota Monitoring Report (Amec Foster Wheeler 2017a).

Methyl Mercury as % of Total Mercury	
American lobster	92%
Blue mussel	43%
Mummichog	86%
Rainbow smelt	79%
Atlantic tomcod	80%
American eel	88%
American black duck (blood)	79%
American black duck (tissue)	98%
Nelson's sparrow	96%
Red-winged blackbird*	96%

* historic samples unavailable, assumed equal to the value for Nelson's sparrows

Abbreviations:
BERA = baseline ecological risk assessment
EPC = exposure point concentration
ng MeHg/g, ww = nanograms methyl mercury per gram, wet weight
UCL = upper confidence limit

Prepared by: LO 08/07/18
Checked by: IMR 08/08/2018

TABLE III.3-13a

SUMMARY OF TOTAL MERCURY EPCs USED IN THE FOOD WEB MODELING[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Dietary Component (Sample Year)	Endpoint Receptor	Exposure Area	No. of Samples	Frequency of Detection	Minimum Concentration (ng Hg/g)	Maximum Concentration (ng Hg/g)	Mean Concentration (ng Hg/g)	Median Concentration (ng Hg/g)	BERA EPC (ng Hg/g)	Statistic Used
Sediment (dw)[4] (2016-2017)	Nelson's sparrow	W-17-N	9	100%	403	1,269	818	705	1,041	95% Student's-t UCL
		MMSE	29	100%	32.6	1,851	556	398	774	95% Adjusted Gamma UCL
		MMSW	45	100%	32.6	1,413	569	575	784	95% Chebyshev (Mean, Sd) UCL
		Pleasant River$_{REF}$	4	100%	23.9	35.7	30.5	31.1	35.7	Maximum[2]
	Red-winged blackbird	W-17-N	3	100%	403	1,267	950	1,179	1,267	Maximum[2]
		MMSE	6	100%	161	1,851	521	295	1,686	95% Chebyshev (Mean, Sd) UCL
		MMSW	6	100%	265	965	711	846	949	95% Student's-t UCL
		Pleasant River$_{REF}$[14]	4	100%	23.9	35.7	30.5	31.1	35.7	Maximum[2]
	American black duck	Mendall Marsh	117	100%	32.6	2,238	660	637	721	95% Student's-t UCL
		Estuary	31	100%	92.2	1,483	613	675	714	95% Student's-t UCL
		Frenchman Bay$_{REF}$	2	100%	7.53	27.4	17.5	17.5	27.4	Maximum
	Belted kingfisher	BO-04	2	100%	78.8	1,793	936	936	1,793	Maximum
		OB-05	9	100%	626	1,613	1,009	981	1,204	95% Student's-t UCL
		OB-04	4	100%	110	586	347	347	586	Maximum[2]
		OB-01	16	100%	152	1,851	794	761	1,009	95% Student's-t UCL
		Mendall Marsh	81	100%	32.5	1,851	602	617	675	95% Student's-t UCL
		ES-13	13	100%	166	1,163	613	593	757	95% Student's-t UCL
		ES-FP	2	100%	12.3	31.0	21.7	21.7	31.0	Maximum
		Pleasant River$_{REF}$	4	100%	23.9	35.7	30.5	31.1	35.7	Maximum[2]
	Bald eagle	BO-04	5	100%	78.8	1,793	805	786	1,418	95% Student's-t UCL
		OB-05	16	100%	110	1,613	789	783	962	95% Student's-t UCL
		OB-04	14	100%	110	1,613	809	789	1,004	95% Student's-t UCL
		OB-01	128	100%	32.5	1,851	620	622	674	95% Student's-t UCL
		Mendall Marsh	139	100%	32.5	1,851	614	623	665	95% Student's-t UCL
		ES-13	46	100%	92	1,670	765	757	955	95% Chebyshev (Mean, Sd) UCL
		ES-FP	14	100%	12.3	1,163	462	473	633	95% Student's-t UCL
		Pleasant River$_{REF}$	4	100%	23.9	35.7	30.5	31.1	35.7	Maximum[2]
	Mink	BO-04	2	100%	78.8	1,793	936	936	1,793	Maximum
		OB-05	11	100%	626	1,613	981	931	1,140	95% Student's-t UCL
		OB-04	4	100%	110	586	347	347	586	Maximum[2]
		OB-01	55	100%	32.5	1,851	613	554	716	95% Adjusted Gamma UCL
		Mendall Marsh	86	100%	32.5	1,851	594	572	655	95% Student's-t UCL
		ES-13	16	100%	92	1,163	607	622	742	95% Student's-t UCL
		ES-FP	3	100%	12.3	31.0	18.6	12.3	31.0	Maximum[2]
		Pleasant River$_{REF}$	4	100%	23.9	35.7	30.5	31.1	35.7	Maximum[2]
Terrestrial Insects (ww)[5] (2016-2017)	Mummichog	Mendall Marsh	20	100%	2.95	354	76.1	39.7	129	95% Adjusted Gamma UCL
		Estuary	10	100%	5.19	254	49.3	29.8	123	95% Adjusted Gamma UCL
		Frenchman Bay$_{REF}$[9]	10	100%	1.54	63.2	22.8	14.2	35.2	95% Student's-t UCL
	Nelson's sparrow & Red-winged blackbird	W-17-N	10	100%	5.19	254	49.3	29.8	123	95% Adjusted Gamma UCL
		MMSE	10	100%	2.95	354	111	40.5	325	95% Adjusted Gamma UCL
		MMSW	10	100%	3.75	93.7	41.6	39.7	56.2	95% Student's-t UCL
		Pleasant River$_{REF}$	10	100%	1.54	63.2	22.8	14.2	35.2	95% Student's-t UCL
	American eel	Estuary	30	100%	2.95	354	67.2	35.0	141	95% Chebyshev (Mean, Sd) UCL[3]
		OV-04$_{REF}$[10]	10	100%	1.54	63.2	22.8	14.2	35.2	95% Student's-t UCL

TABLE III.3-13a

SUMMARY OF TOTAL MERCURY EPCs USED IN THE FOOD WEB MODELING[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Dietary Component (Sample Year)	Endpoint Receptor	Exposure Area	No. of Samples	Frequency of Detection	Minimum Concentration (ng Hg/g)	Maximum Concentration (ng Hg/g)	Mean Concentration (ng Hg/g)	Median Concentration (ng Hg/g)	BERA EPC (ng Hg/g)	Statistic Used
Spiders (ww)[6] (2016-2017)	Nelson's sparrow & Red-winged blackbird	W-17-N	10	100%	197	431	319	309	366	95% Student's-t UCL
		MMSE	10	100%	198	771	415	402	542	95% Student's-t UCL
		MMSW	10	100%	166	403	274	275	314	95% Student's-t UCL
		Pleasant River$_{REF}$	10	100%	25.9	67.5	45.1	44.2	52.7	95% Student's-t UCL
Polychaetes (ww) (2016-2017)	American black duck	Mendall Marsh	10	100%	37.4	321	121	64.6	219	95% Adjusted Gamma UCL
		Estuary	70	100%	8.94	311	53.3	27.9	89.1	95% Chebyshev(Mean, Sd) UCL
		Frenchman Bay$_{REF}$	10	60%	3.18	8.82	7.06	7.53	6.74	95% KM (t) UCL
	Atlantic tomcod & American eel	Estuary	80	100%	8.94	321	61.7	30.2	98.7	95% Chebyshev(Mean, Sd) UCL
		Frenchman Bay$_{REF}$	10	60%	3.18	8.82	7.06	7.53	6.74	95% KM (t) UCL
		OV-04$_{REF}$ [10] (eel only)	10	60%	3.18	8.82	7.06	7.53	6.74	95% KM (t) UCL
Blue Mussel (ww)[7] (2016 - 2017)	American black duck	Mendall Marsh	151	100%	39.1	207	78.4	72.8	82.2	95% Student's-t UCL
		Estuary	151	100%	39.1	207	78.42	72.8	82.2	95% Student's-t UCL
		Frenchman Bay$_{REF}$	20	100%	5.46	13.0	8.26	7.56	9.10	95% Student's-t UCL
Shrimp (ww)[8] (2009)	Mummichog	Mendall Marsh	35	100%	17.4	96.1	71.7	73.7	76.3	95% Student's-t UCL
		Estuary	35	100%	17.4	96.1	71.7	73.7	76.3	95% Student's-t UCL
	Rainbow smelt, Atlantic tomcod, & American eel	Estuary	35	100%	17.4	96.1	71.7	73.7	76.3	95% Student's-t UCL
		Frenchman Bay$_{REF}$	10	60%	3.18	8.82	7.06	7.53	6.74	95% KM (t) UCL
Forage Fish (ww) (Mummichog & Smelt) [2016 - 2017]	Atlantic tomcod & American eel	Estuary	207	100%	26.4	256	84.0	76.0	89.1	95% Approximate Gamma UCL
		Frenchman Bay$_{REF}$	80	100%	4.44	26.2	8.61	7.32	9.39	95% Student's-t UCL
		OV-04$_{REF}$ [10]	80	100%	4.44	26.2	8.61	7.32	9.39	95% Student's-t UCL
	Belted kingfisher (prey length ≤ 17.8 cm)	BO-04	20	100%	52.4	234	95.6	71.2	118	95% Student's-t UCL
		OB-05	42	100%	48.9	150	85.9	79.2	91.3	95% Student's-t UCL
		OB-04	2	100%	47.5	54.9	51.2	51.2	54.9	Maximum
		OB-01	39	100%	33.6	242	78.9	58.2	114	95% Chebyshev (Mean, Sd) UCL
		Mendall Marsh	23	100%	51.4	256	132	121	151	95% Student's-t UCL
		ES-13	20	100%	26.4	87.8	44.6	37.8	51.6	95% Student's-t UCL
		ES-FP	40	100%	27.1	207	72.3	58.3	84.6	95% Adjusted Gamma UCL
		Frenchman Bay$_{REF}$	80	100%	4.44	26.2	8.61	7.32	9.39	95% Student's-t UCL
	Bald eagle (prey length ≥ 15 cm)	BO-04[11]	21	100%	52.4	234	94.1	67.3	115	95% Student's-t UCL
		OB-05	1	100%	201	201	201	201	201	Maximum
		OB-04	4	100%	44.5	81.9	59.2	55.3	81.9	Maximum[2]
		OB-01	14	100%	31.8	146	86.7	92.7	104	95% Student's-t UCL
		Mendall Marsh[11]	23	100%	51.4	256	132	121	151	95% Student's-t UCL
		ES-13	1	100%	38.4	38.4	38.4	38.4	38.4	Maximum
		ES-FP	1	100%	54.7	54.7	54.7	54.7	54.7	Maximum
		Frenchman Bay$_{REF}$ [11]	80	100%	4.44	26.2	8.61	7.32	9.39	95% Student's-t UCL
	Mink (fish length ≤ 25 cm)	BO-04	20	100%	52.4	234	95.6	71.2	118	95% Student's-t UCL
		OB-05	43	100%	48.9	201	88.5	80.8	95.5	95% Student's-t UCL
		OB-04	5	100%	44.5	81.9	56.9	54.9	71.0	95% Student's-t UCL
		OB-01	51	100%	31.8	242	82.3	77.4	111	95% Chebyshev (Mean, Sd) UCL
		Mendall Marsh	23	100%	51.4	256	132	121	151	95% Student's-t UCL
		ES-13	21	100%	26.4	87.8	44.3	38.1	50.9	95% Student's-t UCL
		ES-FP	40	100%	0.27	207	72.3	58.3	84.6	95% Adjusted Gamma UCL
		Frenchman Bay$_{REF}$	80	100%	4.44	26.2	8.61	7.32	9.39	95% Student's-t UCL

TABLE III.3-13a

SUMMARY OF TOTAL MERCURY EPCs USED IN THE FOOD WEB MODELING[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Dietary Component (Sample Year)	Endpoint Receptor	Exposure Area	No. of Samples	Frequency of Detection	Minimum Concentration (ng Hg/g)	Maximum Concentration (ng Hg/g)	Mean Concentration (ng Hg/g)	Median Concentration (ng Hg/g)	BERA EPC (ng Hg/g)	Statistic Used
Forage Fish (ww)	Rainbow smelt	Estuary	100	100%	37.4	256	104	88.2	112	95% Student's-t UCL
(Mummichog)		Frenchman Bay$_{REF}$	40	100%	4.44	13.5	7.22	7.0	7.7	95% Student's-t UCL
[2016 - 2017]										
Predatory Fish (ww)	Bald eagle (prey length ≥ 15 cm)	BO-04	23	100%	199	1370	561	489	668	95% Adjusted Gamma UCL
(Tomcod & Eel)		OB-05	39	100%	80.0	706	282	249	321	95% Student's-t UCL
[2016 - 2017]		OB-04[12]	39	100%	80.0	706	282	249	321	95% Student's-t UCL
		OB-01	30	100%	69.0	413	212	201	242	95% Student's-t UCL
		Mendall Marsh[13]	30	100%	69.0	413	212	201	242	95% Student's-t UCL
		ES-13	11	100%	103	239	166	164	193	95% Student's-t UCL
		ES-FP	2	100%	55.5	74.3	64.9	64.9	74.3	Maximum
		OV-04$_{REF}$	7	100%	37	320	185	161	257	95% Student's-t UCL

Notes:
1. Total mercury concentrations based on results of laboratory analyses.
2. Recommended UCL exceeds the maximum observation
3. ProUCL recommneds to avoid the use of the H-statistic based 95% UCLs; use of nonparametric methods are preferred for skewed data sets which do not follow a gamma distribution
4. Sediment types used for EPC determination are receptor-specific and home range dependent (see below):

Receptor	Sediment type
Marsh songbirds	Wetland and intertidal
Duck	Wetland and intertidal
Belted kingfisher	Intertidal, except Mendall Marsh exposure area includes intertidal, wetland, and subtidal
Bald eagle	Intertidal, except Mendall Marsh exposure area includes intertidal, wetland, and subtidal
Mink	Intertidal, except Mendall Marsh exposure area includes intertidal, wetland, and subtidal

5. Terrestrial insects include: grasshoppers (order: Orthoptera), damselflies (order: Odonata), dragonflies (order: Odonata), greenhead flies (order: Diptera), leafhoppers (order: Hemiptera), flies (order: Diptera), and mosquitoes (order: Diptera).
6. Spiders include: wolf spider (family: *Lycosidae*), jumping spider (family: *Salticidae*), and crab spider (family: *Thomisidae*).
7. Blue mussel sample locations are limited to Estuary. Estuary data used as a surrogate for Mendall Marsh exposure.
8. Shrimp sample locations are limited to Estuary. Polychaete data used as a surrogate for shrimp in Frenchman Bay.
9. Terrestrial insects were not sampled from Frenchman Bay reference area; Pleasant River reference area EPC used as surrogate.
10. Terrestrial insects, polychaetes, and forage fish were not sampled from OV-04 reference area; Frenchman Bay or Pleasant River reference area EPC used as surrogate as available.
11. No forage fish within size criteria of ≥ 15 cm identified; used forgage fish 3.8 cm to 15 cm in length.
12. No predatory fish data available at location OB-04; predatory fish data from OB-05 used as surrogate.
13. No predatory fish data available at location Mendall Marsh; predatory fish data from OB-01 used as surrogate.
14. No blackbird-paired sediment data available at location Pleasant River; sparrow-paired sediment data from Pleasant River used as surrogate.

Abbreviations:
BERA = baseline ecological risk assessment
EPC = exposure point concentration
ng Hg/g, ww = nanograms mercury per gram, wet weight
UCL = upper confidence limit

Prepared by: LO 08/07/18
Checked by: IMR 08/08/2018

TABLE III.3-13b

SUMMARY OF METHYL MERCURY EPCs USED IN THE FOOD WEB MODELING
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Dietary Component (Sample Year)	Endpoint Receptor	Exposure Area	No. of Samples	Frequency of Detection	Minimum Concentration (ng MeHg/g)	Maximum Concentration (ng MeHg/g)	Mean Concentration (ng MeHg/g)	Median Concentration (ng MeHg/g)	BERA EPC (ng MeHg/g)	Statistic Used
Sediment (dw)[2] (2016-2017)	Nelson's sparrow	W-17-N	9	100%	4.88	86.8	22.8	9.10	58.0	95% Adjusted Gamma UCL
		MMSE	17	100%	2.77	17.9	9.58	9.02	11.7	95% Student's-t UCL
		MMSW	32	100%	1.22	27.0	8.46	4.61	13.7	95% Chebyshev (Mean, Sd) UCL
		Pleasant River$_{REF}$	4	100%	1.19	4.42	2.95	3.10	4.42	Maximum [1]
	Red-winged blackbird	W-17-N	3	100%	5.15	38.0	16.6	6.67	38.0	Maximum [1]
		MMSE	6	100%	4.63	17.9	12.5	13.5	16.1	95% Student's-t UCL
		MMSW	4	100%	3.90	17.4	13.2	15.7	17.4	Maximum [1]
		Pleasant River$_{REF}$[3]	4	100%	1.19	4.42	2.95	3.10	4.42	Maximum [1]
	American black duck	Mendall Marsh	68	100%	0.354	37.3	9.61	6.72	11.4	95% Approximate Gamma UCL
		Estuary	23	100%	0.717	38.0	13.3	9.57	17.2	95% Student's-t UCL
		Frenchman Bay$_{REF}$	2	50%	1.60	1.60	--	--	1.60	Maximum
	Belted kingfisher	BO-04	2	100%	2.50	7.86	5.18	5.18	7.86	Maximum
		OB-05	7	100%	4.77	32.9	13.4	11.2	20.4	95% Student's-t UCL
		OB-04	3	100%	3.73	11.93	6.66	4.30	11.93	Maximum [1]
		OB-01	7	100%	1.93	30.1	14.2	13.1	20.8	95% Student's-t UCL
		Mendall Marsh	50	100%	0.034	30.1	8.09	5.27	10.4	95% Adjusted Gamma UCL
		ES-13	10	100%	3.93	24.6	11.2	7.13	15.5	95% Student's-t UCL
		ES-FP	2	100%	0.900	1.00	0.950	0.950	1.00	Maximum
		Pleasant River$_{REF}$	4	100%	0.693	4.42	2.40	2.25	4.42	Maximum
	Bald eagle	BO-04	2	100%	2.50	7.86	5.18	5.18	7.86	Maximum
		OB-05	10	100%	3.73	32.9	11.4	10.7	19.2	95% Adjusted Gamma UCL
		OB-04	11	100%	3.73	32.9	11.3	10.6	17.9	95% Adjusted Gamma UCL
		OB-01	82	100%	0.034	50.7	8.41	5.13	10.3	95% Approximate Gamma UCL
		Mendall Marsh	92	100%	0.034	50.7	8.15	5.13	9.85	95% Approximate Gamma UCL
		ES-13	26	100%	2.27	24.6	9.95	8.17	11.8	95% Student's-t UCL
		ES-FP	12	100%	0.244	18.8	7.50	6.05	15.2	95% Adjusted Gamma UCL
		Pleasant River$_{REF}$	4	100%	0.693	4.42	2.40	2.25	4.42	Maximum
	Mink	BO-04	2	100%	2.50	7.86	5.18	5.18	7.86	Maximum
		OB-05	7	100%	4.77	32.9	13.4	11.2	20.4	95% Student's-t UCL
		OB-04	3	100%	3.73	11.9	6.66	4.30	11.9	Maximum [1]
		OB-01	33	100%	0.034	30.1	8.09	5.67	11.5	95% Adjusted Gamma UCL
		Mendall Marsh	55	100%	0.034	30.1	7.56	4.33	9.63	95% Approximate Gamma UCL
		ES-13	12	100%	2.27	24.6	10.7	7.13	14.4	95% Student's-t UCL
		ES-FP	3	100%	0.900	1.00	0.967	1.00	1.00	Maximum [1]
		Pleasant River$_{REF}$	4	100%	0.693	4.42	2.40	2.25	4.42	Maximum
Terrestrial Insects (ww)[4] (2016-2017)	Mummichog	Mendall Marsh	20	100%	2.10	241	42.8	27.0	69.7	95% Adjusted Gamma UCL
		Estuary	10	100%	2.40	118	38.0	33.6	58.6	95% Student's-t UCL
		Frenchman Bay$_{REF}$[8]	10	100%	1.30	31.2	15.8	15.7	22.6	95% Student's-t UCL
	Nelson's sparrow & Red-winged blackbird	W-17-N	10	100%	2.40	118	38.0	33.6	58.6	95% Student's-t UCL
		MMSE	10	100%	2.10	241	61.9	40.9	104	95% Student's-t UCL
		MMSW	10	100%	2.90	49.5	23.6	27.0	31.4	95% Student's-t UCL
		Pleasant River$_{REF}$	10	100%	1.30	31.2	15.8	15.7	22.6	95% Student's-t UCL
	American eel	Estuary	30	100%	2.10	241	41.2	27.6	59.7	95% Adjusted Gamma UCL
		OV-04$_{REF}$[9]	10	100%	1.30	31.2	15.8	15.7	22.6	95% Student's-t UCL

TABLE III.3-13b

SUMMARY OF METHYL MERCURY EPCs USED IN THE FOOD WEB MODELING
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Dietary Component (Sample Year)	Endpoint Receptor	Exposure Area	No. of Samples	Frequency of Detection	Minimum Concentration (ng MeHg/g)	Maximum Concentration (ng MeHg/g)	Mean Concentration (ng MeHg/g)	Median Concentration (ng MeHg/g)	BERA EPC (ng MeHg/g)	Statistic Used
Spiders (ww)[5] (2016-2017)	Nelson's sparrow & Red-winged blackbird	W-17-N	10	100%	210	642	342	305	415	95% Student's-t UCL
		MMSE	10	100%	136	748	356	270	482	95% Student's-t UCL
		MMSW	10	100%	50.8	495	276	302	348	95% Student's-t UCL
		Pleasant River$_{REF}$	10	100%	14.6	73.2	44.3	53.6	56.4	95% Student's-t UCL
Polychaetes (ww) (2016-2017)	American black duck	Mendall Marsh	10	100%	1.40	11.3	7.30	7.60	9.11	95% Student's-t UCL
		Estuary	45	96%	1.10	17.7	9.28	9.50	9.98	95% KM (t) UCL
		Frenchman Bay$_{REF}$	5	0%	--	--	--	--	1.00	0% FOD; 1/2 max DL as surrogate
	Atlantic tomcod & American eel	Estuary	55	96%	1.10	17.7	8.91	9.20	9.54	95% KM (t) UCL
		Frenchman Bay$_{REF}$	5	0%	--	--	--	--	1.00	0% FOD; 1/2 max DL as surrogate
		OV-04$_{REF}$ [9] (eel only)	5	0%	--	--	--	--	1.00	0% FOD; 1/2 max DL as surrogate
Blue Mussel (ww) [6,10] (2016 - 2017)	American black duck	Mendall Marsh	151	100%	16.7	88.4	33.5	31.1	35.1	95% Student's-t UCL
		Estuary	151	100%	16.7	88.4	33.5	31.1	35.1	95% Student's-t UCL
		Frenchman Bay$_{REF}$	20	100%	2.33	5.55	3.53	3.23	3.88	95% Student's-t UCL
Shrimp (ww)[7] (2009)	Mummichog	Mendall Marsh	34	100%	25.4	84.6	50.7	49.3	54.5	95% Student's-t UCL
		Estuary	34	100%	25.4	84.6	50.7	49.3	54.5	95% Student's-t UCL
	Rainbow smelt, Atlantic tomcod, & American eel	Estuary	34	100%	25.4	84.6	50.7	49.3	54.5	95% Student's-t UCL
		Frenchman Bay$_{REF}$	5	0%	--	--	--	--	1.00	0% FOD; 1/2 max DL as surrogate
Forage Fish (ww) [10] (Mummichog & Smelt) [2016 - 2017]	Atlantic tomcod & American eel	Estuary	207	100%	21.8	212	69.4	62.8	73.6	95% Approximate Gamma UCL
		Frenchman Bay$_{REF}$	80	100%	3.67	21.7	7.11	6.05	7.76	95% Student's-t UCL
		OV-04$_{REF}$ [9]	80	100%	3.67	21.7	7.11	6.05	7.76	95% Student's-t UCL
	Belted kingfisher (prey length ≤ 17.8 cm)	BO-04	20	100%	43.3	193	79.0	58.8	97.1	95% Student's-t UCL
		OB-05	42	100%	40.4	124	71.0	65.4	75.4	95% Student's-t UCL
		OB-04	2	100%	39.3	45.4	42.3	42.3	45.4	Maximum
		OB-01	39	100%	27.8	200	65.2	48.1	93.8	95% Chebyshev (Mean, Sd) UCL
		Mendall Marsh	23	100%	42.5	212	109	100	124	95% Student's-t UCL
		ES-13	20	100%	21.8	72.6	36.8	31.2	42.6	95% Student's-t UCL
		ES-FP	40	100%	22.4	171	59.7	48.1	69.9	95% Adjusted Gamma UCL
		Frenchman Bay$_{REF}$	80	100%	3.67	21.7	7.11	6.05	7.76	95% Student's-t UCL
	Bald eagle (prey length ≥ 15 cm)	BO-04[11]	21	100%	43.3	193	77.7	55.6	95.0	95% Student's-t UCL
		OB-05	1	100%	166	166	166	166	166	Maximum
		OB-04	4	100%	36.8	67.7	48.9	45.7	67.7	Maximum[1]
		OB-01	14	100%	26.3	121	71.6	76.6	85.5	95% Student's-t UCL
		Mendall Marsh[11]	23	100%	42.5	212	109	100	124	95% Student's-t UCL
		ES-13	1	100%	31.7	31.7	31.7	31.7	31.7	Maximum
		ES-FP	1	100%	45.2	45	45.2	45.2	45.2	Maximum
		Frenchman Bay$_{REF}$ [11]	80	100%	3.67	21.7	7.11	6.05	7.76	95% Student's-t UCL
	Mink (fish length ≤ 25 cm)	BO-04	20	100%	43.3	193	79.0	58.8	97.1	95% Student's-t UCL
		OB-05	43	100%	40.4	166	73.2	66.8	78.9	95% Student's-t UCL
		OB-04	5	100%	36.8	67.7	47.0	45.4	58.6	95% Student's-t UCL
		OB-01	51	100%	26.3	200	68.0	64.0	91.4	95% Chebyshev (Mean, Sd) UCL
		Mendall Marsh	23	100%	42.5	212	109	100	124	95% Student's-t UCL
		ES-13	21	100%	21.8	72.6	36.6	31.5	42.1	95% Student's-t UCL
		ES-FP	40	100%	0.224	171	59.7	48.1	69.9	95% Adjusted Gamma UCL
		Frenchman Bay$_{REF}$	80	100%	3.67	21.7	7.11	6.05	7.76	95% Student's-t UCL

TABLE III.3-13b

SUMMARY OF METHYL MERCURY EPCs USED IN THE FOOD WEB MODELING
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Dietary Component (Sample Year)	Endpoint Receptor	Exposure Area	No. of Samples	Frequency of Detection	Minimum Concentration (ng MeHg/g)	Maximum Concentration (ng MeHg/g)	Mean Concentration (ng MeHg/g)	Median Concentration (ng MeHg/g)	BERA EPC (ng MeHg/g)	Statistic Used
Forage Fish (ww) [10] (Mummichog) [2016 - 2017]	Rainbow smelt	Estuary	100	100%	32.3	221	89.7	76.1	96.5	95% Student's-t UCL
		Frenchman Bay$_{REF}$	40	100%	3.83	11.6	6.23	6.02	6.64	95% Student's-t UCL
Predatory Fish (ww) (Tomcod & Eel) [2016 - 2017]	Bald eagle (prey length ≥ 15 cm)	BO-04	23	100%	166	1145	469	409	559	95% Adjusted Gamma UCL
		OB-05	39	100%	66.9	590	236	208	269	95% Student's-t UCL
		OB-04[12]	39	100%	66.9	590	236	208	269	95% Student's-t UCL
		OB-01	30	100%	57.7	345	177	168	202	95% Student's-t UCL
		Mendall Marsh[13]	30	100%	57.7	345	177	168	202	95% Student's-t UCL
		ES-13	11	100%	86.1	200	138	137	161	95% Student's-t UCL
		ES-FP	2	100%	46.4	62.1	54.3	54.3	62.1	Maximum
		OV-04$_{REF}$	7	100%	31	268	155	135	215	Maximum[1]

Prepared by: LO 08/07/18
Checked by: IMR 08/08/2018

Notes:
1. Recommended UCL exceeds the maximum observation
2. Sediment types used for EPC determination are receptor-specific (see below):

Receptor	Sediment type
Marsh songbirds	Wetland (high, mid, low)
Duck	Wetland and intertidal
Belted kingfisher	Intertidal, except Mendall Marsh exposure area includes intertidal, wetland, and subtidal
Bald eagle	Intertidal, except Mendall Marsh exposure area includes intertidal, wetland, and subtidal
Mink	Intertidal, except Mendall Marsh exposure area includes intertidal, wetland, and subtidal

3. No blackbird-paired sediment data available at location Pleasant River; sparrow-paired sediment data from Pleasant River used as surrogate.
4. Terrestrial insects include: grasshoppers (order: Orthoptera), damselflies (order: Odonata), dragonflies (order: Odonata), greenhead flies (order: Diptera), leafhoppers (order: Hemiptera), flies (order: Diptera), and mosquitoes (order: Diptera).
5. Spiders include: wolf spider (family: *Lycosidae*), jumping spider (family: *Salticidae*), and crab spider (family: *Thomisidae*).
6. Blue mussel sample locations are limited to Estuary. Estuary data used as a surrogate for Mendall Marsh exposure.
7. Shrimp sample locations are limited to Estuary. Polychaete data used as a surrogate for shrimp in Frenchman Bay.
8. Terrestrial insects were not sampled from Frenchman Bay reference area; Pleasant River reference area EPC used as surrogate.
9. Terrestrial insects, polychaetes, and forage fish were not sampled from OV-04 reference area; Frenchman Bay or Pleasant River reference area EPC used as surrogate as available.
10. Methyl mercury percentage of total mercury taken from Table IV.1-2
11. No forage fish within size criteria of ≥ 17.8 cm identified; used forgage fish 3.8 cm to 15 cm in length.
12. No predatory fish data available at location OB-04; predatory fish data from OB-05 used as surrogate.
13. No predatory fish data available at location Mendall Marsh (MM); predatory fish data from OB-01 used as surrogate.

Methyl Mercury as % of Total Mercury		
Blue mussel	42.7%	
Mummichog	86.3%	
Rainbow smelt	79.0%	
Forage Fish*	82.6%	(assumes 50-50 contribution)
Tomcod	79.5%	
Eel	87.6%	
Predatory Fish**	83.6%	(assumes 50-50 contribution)

*Mummichog & Smelt
**Tomcod & Eel

TABLE III.4-1

MOLLUSK TOXICITY STUDIES FOR THE SELECTION OF SURFACE WATER TRVs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Chemical	Chemical Form	Test Species	NOAEL (ng/L)	LOAEL (ng/L)	Exposure Route and Duration	Endpoint	Effect	Source[2]
Mercury	mercury	Blue mussel	--	20,000	water for 21 days	mortality	2% mortality[3]	Geret et al. 2002
Mercury	mercury	Blue mussel	20,000	--	water for 4 days	mortality	0% mortality[3]	Geret et al. 2002
Mercury	mercury	Oyster	20,000	--	water for 21 days	mortality	0% mortality[3]	Geret et al. 2002
Mercury	chloromethylmercury	Mediterranean mussel	48	--	water for 77 days	mortality	0% mortality	Cattani et al. 1998
Mercury	mercury chloride	Mediterranean mussel	6,750	--	water for 77 days	mortality	0% mortality	Cattani et al. 1999
Mercury	mercury chloride	Estuarine bivalve clam	1,890	18,500	water for 4 days, D-shaped larvae need 5 days to complete that stage of development	embryogenesis, growth, mortality	dosing regime	Wang et al. 2009
Mercury	mercury chloride	Estuarine bivalve clam	--	5,400	water for 4 days	embryogenesis	EC50	Wang et al. 2009
Mercury	mercury chloride	Estuarine bivalve clam	--	13,300	water for 4 days, D-shaped larvae need 5 days to complete that stage of development	growth	EC50	Wang et al. 2009
Mercury	mercury chloride	Estuarine bivalve clam	--	14,000	water for 4 days	mortality	96 h LC50	Wang et al. 2009
Mercury	mercury chloride	Estuarine bivalve clam	18,500	187,000	water for 4 days	metamorphosis	dosing regime	Wang et al. 2009
Mercury	mercury chloride	Estuarine bivalve clam	--	235	water for 4 days	metamorphosis	EC50	Wang et al. 2009
Mercury	mercuric chloride	Common slipper shell	**250**	**420**	water for 16 weeks	reproduction	reduced fecundity	Thain 1984
Mercury	mercuric chloride	Common slipper shell	420	1,000	water for 16 weeks	growth	growth reduced	Thain 1984
Mercury	mercuric chloride	Mysid (opposum shrimp)[6]	--	940 (d)	water for 36 days	reproduction	chronic value based on 96 h LC50	

Notes:
1. **Bolded** values selected as TRVs.
2. See Part V for full references.
3. Accumulation study in gills and digestive glands - reported % mortality after 4 or 21 days in solution
4. US EPA National Recommended Water Quality Criteria - Aquatic Life Criteria (saltwater chronic concentration). Aquatic life criteria for toxic chemicals are the highest concentration of specific pollutants or parameters in water that are not expected to pose a significant risk to the majority of species in a given environment or a narrative description of the desired conditions of a water body being "free from" certain negative conditions.
5. As cited in the US EPA (1985) Ambient Water Quality Criteria for Mercury - 1984 publication.
6. Per USEPA (1985), the blue mussel is the third most sensitive species based on Genus Mean Acute Values (with the first being the Mysid).

Abbreviations:
-- not available
(d) - dissolved
EC50 = 50% effect concentration
LC50 = 50% lethal concentration
LOAEL = lowest observed adverse effects level
ng/L = nanograms per liter
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: LO 04/13/18
Checked by: NSR 08/01/18

TABLE III.4-2

MOLLUSK TOXICITY STUDIES FOR THE SELECTION OF MOLLUSK TISSUE-RESIDUE TRVs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Chemical	Chemical Form	Test Species	NOAEL (ng/g ww)	LOAEL (ng/g ww)	Exposure Route and Duration	Endpoint	Effect	Source[2]
Mercury	phenylmercuric acetate	Eastern oyster	--	23,000	water for 19 days	survival	reduced survival	Kopfler 1974
Mercury	mercuric chloride	Eastern oyster	60,000	--	water for 42 days	survival	no effect on survival	Kopfler 1974
Mercury	methylmercuric chloride	Eastern oyster	--	33,000	water for 19 days	survival	reduced survival	Kopfler 1974
Mercury	mercuric chloride	Copepods (*Acartia tonsa* and *A. hudsonica)*	**48**	**95**	ingestion of phytoplankton for 4 hours	reproduction	egg depression[3]	Hook and Fisher 2002
Mercury		Gulf wedge clam	--	20,000	96 hours	survival	LD50	Dillon 1977
Mercury		Gulf wedge clam	--	73,100	96 hours	survival	lethal body burden	Dillon 1977
Mercury	mercuric chloride	Common slipper shell	4,000-8,000	10,000-17,000	water for 16 weeks	reproduction	reduced fecundity	Thain 1984
Mercury	mercuric chloride	Common slipper shell	10,000-17,000	22,000-48,000	water for 16 weeks	growth	growth reduced	Thain 1984

Notes:
1. **Bolded** values selected as TRVs.
2. See Part V for full references.
3. LOAEL based on reported tissue concentration of copepods resulting in a 50 reduction in eggs produced - 2.37 nmol/g dw converted using 200.59 ng Hg/nmol x 2.37 nmol/g = 475 ng/g dw; NOAEL value estimated from Figure 1 (no egg depression at tissue concentrations µp to 1.2 nmol/g dw). LOAEL/NOAEL converted to ww assuming 80% water in copepods.

Abbreviations:
LD50 = 50% lethal dose
LOAEL = lowest observed adverse effects level
ng/g ww = nanograms per gram wet weight
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: IMR 08/13/1980
Checked by: NSR 08/13/18

TABLE III.4-3

DECAPOD TOXICITY STUDIES FOR THE SELECTION OF LOBSTER TISSUE-RESIDUE TRVS[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Chemical Form	Test Species	Tissue Type	NOAEL (ng/g ww)	LOAEL (ng/g ww)	Exposure Route and Duration	Endpoint	Effect	Source[2]
Mercuric chloride	Norway lobster	tail	340	--	water for 30 days	survival	no effect on survival[3]	Canli and Furness (1995)
Mercuric chloride	Norway lobster	tail	230	--	diet for 50 days	survival	no effect on survival[3]	Canli and Furness (1995)
Methyl mercuric chloride	Norway lobster	tail	**1,820**	--	water for 30 days	survival	no effect on survival[3]	Canli and Furness (1995)
Mercuric chloride	Chinese mitten crab	muscle	--	1,000	saltwater for 32 hours	survival	reduction in survival	Bianchini and Gilles (1996)
Mercuric chloride	shore crab	muscle	--	1,000–1,300	saltwater for 48 hours	survival	reduction in survival	Bianchini and Gilles (1996)
Mercuric chloride	brown crab	muscle	--	2,500–3,400	saltwater for 28 hours	survival	reduction in survival	Bianchini and Gilles (1996)

Notes:
1. **Bolded** values selected as TRVs.
2. See Part V for full references.
3. NOAELs converted to wet weight assuming 80% moisture content.

Abbreviations:
LOAEL = lowest observed adverse effects level
ng/g ww = nanograms per gram wet weight
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: LO 04/13/18
Checked by: NSR 08/01/18

TABLE III.4-4

WHOLE-BODY FISH TOXICITY STUDIES FOR THE SELECTION OF FISH TISSUE-RESIDUE TRVs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Chemical Form	Test Species	NOAEL (ng/g ww)	LOAEL (ng/g ww)	Exposure Route and Duration	Effect	Source[2]
Forage Fish						
Mercuric chloride	guppy (adult)	200	--	sediment and water for 20 days	no effect on survival	Kudo and Mortimer (1979)
Methylmercuric chloride	mummichog (multi-generational)	**440**	**440**	diet for at least 6 weeks; multiple generations	no effect on female survival; reduced survival for males only	Matta et al. (2001)
Methylmercuric chloride	golden shiner (freshwater)	230	520	diet for 90 days	altered predator avoidance (potential for reduced survival)	Webber and Haines (2003)
Methylmercuric chloride	golden shiner (freshwater)	520	--	diet for 90 days	growth and survival	Webber and Haines (2003)
Methyl mercury	multiple species	--	500 (300-700 whole body) (500-1,200 axial muscle)	lifetime water exposure	biochemical processes, damage to cells and tissue, and reduced reproduction	Phase II Study TRV based on Sandheinrich and Wiener (2011); Sandheinrich et al. (2011)
Methyl mercury	mutiple species	--	940 (TEL) 3,900 (PEL)	Various	Calculated TEL/PEL based on 10 studies on growth, survival, and reproduction endpoints	Berry's Creek Study Area Cooperating PRP Group (2017)
Mercuric chloride	fathead minnow (larvae-adult)	800	1,310	water for 60 days	reduced growth	Snarski and Olson (1982)
Mercuric chloride	fathead minnow (larvae-adult)	2,750	4,180	water for 60 days	reduced survival	Snarski and Olson (1982)
Mercuric chloride	fathead minnow (larvae-adult)	2,840	4,470	water for 287 days	reduced spawning	Snarski and Olson (1982)
Methylmercuric chloride	fathead minnow (larvae-adult)	10,900	--	water for 336 days	no effect on growth or survival	Olson et al. (1975)
Mercuric chloride	goldfish	--	5,600	water for 2 days	reduced survival	Heisinger et al. (1979)
Methylmercuric chloride	fathead minnow	--	143	diet for at least 21 days	reduced spawning success	Sandheinrich and Miller (2006)
Methylmercuric chloride	fathead minnow (multi-generational)	--	700	diet in multiple generations	reduced spawning success	Hammerschmidt et al. (2002)
Mercuric chloride	creek chub	--	3,720	water for 48 hours	reduced survival	Kim et al. (1977)
Predatory Fish						
Methyl mercury	multiple species	--	500 (300-700 whole body) (500-1,200 axial muscle)	lifetime water exposure	biochemical processes, damage to cells and tissue, and reduced reproduction	Phase II Study TRV based on Sandheinrich and Wiener (2011); Sandheinrich et al. (2011)
Methyl mercury	multiple species	--	1,600 (TEL) 6,600 (PEL)	Various	Calculated TEL/PEL	Expert report Dr. Keenan (2014)
Methyl mercury	mutiple species	--	940 (TEL) 3,900 (PEL)	Various	Calculated TEL/PEL based on 10 studies on growth, survival, and reproduction endpoints	Berry's Creek Study Area Cooperating PRP Group (2017)
Methylmercuric chloride	brook trout	2,700	3,400	water for 756 days	reduced number of viable eggs	McKim et al. (1976)
Methylmercuric chloride	brook trout (embryo-adult)	3,400	9,400	water for 756 days	reduced survival, growth, reproduction	McKim et al. (1976)
Methylmercury	rainbow trout (juvenile)	5,000	--	diet for 84 days	no effect on growth or survival	Lock (1975)
Methylmercuric chloride	rainbow trout (juvenile)	10,400	--	water for 84 days	no effect on growth or survival	Lock (1975)
Methylmercuric chloride	rainbow trout (fingerling)	8,630	--	water for 24 days	no effect on growth	Phillips and Buhler (1978)
Methylmercuric chloride	rainbow trout (subadult)	--	11,200	water for 12 to 33 days	reduced survival	Niimi and Kissoon (1994)
Methylmercuric chloride	rainbow trout (subadult)	12,000	--	water for 75 days	no effect on growth or survival	Niimi and Lowe- Jinde (1984)
Methylmercury	rainbow trout (fingerling)	<100	8,000	diet for 84 days	effect on growth	Rodgers and Beamish (1982)
Methylmercury	walleye (juvenile)	137		diet for 6 mos	juvenile growth and gonad development	Friedmann et al. (1996)
Methylmercury	brook trout, rainbow trout, walleye, fathead minnow, killifish, medaka, grayling	**77**[3]	**770**	EC_{20} calculated from multispecies dose–response curve	effects on reproduction and survival	Dillon et al. 2010
Mercuric chloride	European eel	1,530*	15,300	water for 32 days	reduced survival (25%)	Noel-Lambot and Bouquegneau (1977)
Methylmercuric chloride	bluegill (juvenile)	--	6,500	water for 12.5 days	reduced survival	Cember et al. (1978)

Notes:
1. **Bolded** values selected as TRVs.
2. See Part V for full references.
3. LOAEL converted to NOAEL.

Prepared by: LO 04/13/18
Checked by: NSR 08/01/18

Abbreviations:
LOAEL = lowest observed adverse effects level
ng/g ww = nanograms per gram wet weight
NOAEL = no observed adverse effects level
TRV = toxicity reference value

TABLE III.4-5

WHOLE-BODY FISH TOXICITY STUDIES FOR THE SELECTION OF FISH DIETARY TRVS[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Chemical Form	Test Species	NOAEL (ng/g bw/day ww)	LOAEL (ng/g bw/day ww)	Exposure Route and Duration	Effect	Source[2]
Forage Fish						
Methylmercuric chloride	mummichog	**51.8**	**51.8**	diet for at least 6 weeks	reduced male survival, no effect on females[3]	Matta et al. (2001)
Predatory Fish						
Methylmercuric chloride	Beluga sturgeon	139	285	diet for 35 days	mortality[4]	Gharaei et al. (2008)
Methylmercuric chloride	**Beluga sturgeon**	**13.4**	**139**	**diet for 35 days**	**growth[5]**	**Gharaei et al. (2008)**

Notes:
1. **Bolded** values selected as TRVs.
2. See Part V for full references.
3.TRV calculated using dose of 1,900 ng/g food dw, IRf of 0.36 g food/day, body weight of 11.9 grams from the study (57.5 ng/g bw/day dw); Then converted to wet weight assuming 10% moisture content in fish food per Depew et al. 2012.
Equation = (1,900 ng/g food dw x 0.36 g food/day) / 11.9 g bw = 57.5 ng/g-BW-day dw * 0.90 solids factor = 51.8 ng/g-bw-day ww
4.TRV calculated using dose of 7,880 or 16,220 ng/g food dw, IRf of 1.54 g food/day and body weight of 86 grams from the study (141 or 290 ng/g bw/day); Then converted to wet weight assuming 2% moisture content in food per study; using same approach as in note 3.

5.TRV calculated using dose of 760 or 7,880 ng/g food dw, IRf of 1.54 g food/day and body weight of 86 grams from the study (13.6 or 141 ng/g bw/day dw); Then converted to wet weight assuming 2% moisture content in food per study; using same approach as in note 3.

Abbreviations:
LOAEL = lowest observed adverse effects level
ng/g ww = nanograms per gram wet weight
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: LO 04/13/18
Checked by: NSR 08/01/18

TABLE III.4-6

AVIAN TOXICITY STUDIES FOR THE SELECTION OF AVIAN BLOOD TRVS[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Bird Size	Chemical Form	Test Species	Site	NOAEL (ng/g ww)	LOAEL (ng/g ww)	Exposure Duration	Effect	Source[2]	Comments[2]
Controlled Experiments									
Small birds	Methyl mercury cysteine	Zebra finch	--	--	10,000	2 generations	EC20 - Average number of offspring	Fuchsman et al. 2017; derived from Varian-Ramos et al. 2014	
Medium birds	Methyl Mercury Chloride	American Kestrel	--	--	2,500	circa 60 days	EC20 - Expected number of fledglings.	Fuchsman et al. 2017; derived from Albers et al. 2007 and French et al. 2010	Blood mercuryg estimated from diet-blood regression (French et al. 2010).
	Methyl mercury chloride	Japanese Quail	--	--	15,000	16 weeks	EC80 - Surviving chicks per egg laid.	Fuchsman et al. 2017; derived from El-Begearmi et al. 1982	Male blood only
Large birds	Methyl mercury dicyandiamide	Mallard	--	--	5,200	2 breeding seasons	EC20 - Surviving ducklings per egg.	Fuchsman et al. 2017; derived from Heinz 1974, 1976a, 1976b, 1979, 2010c	Chick mortality associated with neurological signs of mercury toxicity. Blood mercury estimated from egg–blood regression from Heinz et al. 2010.
	Methyl mercury chloride	Mallard	--	--	17,000	71 days	EC20 - Surviving ducklings per egg.	Fuchsman et al. 2017; derived from Heinz et al. 2010a, 2010b, and 2010c	Blood mercury estimated from egg–blood regression.
Field Studies									
Small birds	Mercury (Assume 100% methyl mercury)	Tree Swallow	South River, Virginia	--	3,560	--	Effect on proportion eggs survived and number of fledglings	Brasso and Cristol 2008	
	Mercury (Assume 100% methyl mercury)	Tree Swallow	South River, Virginia	--	3,000	--	10% reduced fledgling success and percent eggs hatched, and ~20% reduction in fledgling per nest	Hallinger and Cristol 2011; Fuchsman et al. 2017	
	Mercury (Assume 100% methyl mercury)	Carolina Wren	South River and North Fork Holston River, Virginia	--	1,200	--	20% reduced nest success	Jackson et al. 2011	Nest success was affected by both increased predation and nest abandonment. Small sample size. Multiple confounding study issues.
	Mercury (Assume 100% methyl mercury)	Carolina Wren	South River and North Fork Holston River, Virginia	--	2,130	--	Nest success (production of ≥1 fledgling)	Fuchsman et al. 2017; Jackson et al. 2011	Nest success was affected by both increased predation and nest abandonment. Small sample size. Multiple confounding study issues.
	Mercury (Assume 100% methyl mercury)	Tree Swallow	6 sites, Maine and Massachusetts	3,000	--	--	Hatching and fledging success	Fuchsman et al. 2017; derived from Longcore et al. 2007	
Medium birds	Mercury (Assume 100% methyl mercury)	American avocet	San Francisco Bay, California	1,470	--	--	Hatching success and chick mortality	Fuchsman et al. 2017; derived from Ackerman et al. 2014 & Ackerman et al. 2008	
	Mercury (Assume 100% methyl mercury)	Black-necked stilts	San Francisco Bay, California	1,500	2,600	--	Mortality of newly hatched chicks	Fuchsman et al. 2017; derived from Ackerman et al. 2014 & Ackerman et al. 2008	
	Mercury (Assume 100% methyl mercury)	Forster's tern	San Francisco Bay, California	3,100	4,200	--	Hatching success	Fuchsman et al. 2017; derived from Ackerman et al. 2014	
	Mercury (Assume 100% methyl	Forster's tern	Lavaca Bay, Texas	700	--	--	Young per nest.	Fuchsman et al. 2017; derived from King et al. 1991	
Large birds	Mercury (Assume 100% methyl mercury)	Common Loon	120 lakes in Wisconsin and Canada	--	4,300	--	Threshold - Maximum productivity of 5–6-week old chicks per pair.	Fuchsman et al. 2017; derived from Burgess and Meyer 2008	Measured effects relative to maximum productivity; 50% decrease from maximum approximates a threshold for consistent effects.
	Mercury (Assume 100% methyl mercury)	Bald eagle	Pinchi Lake, British Columbia, Canada	6,700	--	--	Chicks per territory.	Fuchsman et al. 2017; derived from Weech et al. 2006	Small sample size.

TABLE III.4-6

AVIAN TOXICITY STUDIES FOR THE SELECTION OF AVIAN BLOOD TRVS[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Bird Size	Chemical Form	Test Species	Site	NOAEL (ng/g ww)	LOAEL (ng/g ww)	Exposure Duration	Effect	Source[2]	Comments[2]
Summary									
Small-Medium birds	Mercury (Assume 100% methyl mercury)	Summary	--	--	2,100 – 4,200	--	Typical range of reproduction effects	Fuchsman et al. 2017	
Large birds	Mercury (Assume 100% methyl mercury)	Summary	--	--	4,300 – >6,700	--	Typical range of reproduction effects	Fuchsman et al. 2017	
All Wetland-Dependent and Aquatic Birds	Mercury (Assume 100% methyl mercury)	Summary	--	**210** [3]	**2,100**	--	Low end of reproduction effects range	Fuchsman et al. 2017; derived from Jackson et al. 2011 and Jackson and Evers 2011	

Notes:
1. **Bolded** values selected as TRVs.
2. See Part V for full references.
3. LOAEL converted to NOAEL using uncertainty factor of 0.1.

Abbreviations:
EC20 = 20% effect concentration
EC80 = 80% effect concentration
LOAEL = lowest observed adverse effects level
ng/g ww = nanograms per gram wet weight
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: IMR 08/01/18
Checked by: NSR 08/01/18

TABLE III.4-7

AVIAN TOXICITY STUDIES FOR THE SELECTION OF AVIAN DIETARY TRVs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Bird Size	Chemical Form	Test Species	Site	NOAEL (ng/g bw/day ww)	LOAEL (ng/g bw/day ww)	Exposure Duration	Effect	No-Effect Conc.	Effect Conc. (ng/g ww)	Source[2]	Comments[2]
Controlled Experiments											
Small birds	Methyl mercury chloride	American kestrel	--	--	50	circa 60 days	ED20 - Expected number of fledglings	--	160	Fuchsman et al. 2017; derived from Albers et al. 2007	Exposure to mercury through incubation only. Chicks were exposed only via maternal transfer and not via diet.
	Methyl mercury cysteine	Zebra finch	--	--	240	2 generations	ED20 - Average number of offspring	--	750	Fuchsman et al. 2017; derived from Varian-Ramos et al. 2014	Fledging success was more sensitive than other endpoints
Medium birds	Methyl mercury cysteine	Zebra finch			268		ED16 - reduced number of offspring	--	300	Varian-Ramos et al. 2014	Effect oncentration of 350 ng/g dw converted to ww using 13.9% moisture as cited in Berry's Creek Study Area Cooperating PRP Group (2017). Used average body weight of 0.013 kg from Soderstrom and Johnson (2001) and the Nagy (2001) fresh weight equation for passerines for the food ingestion rate of 0.0116 kg/d to yield LOAEL.
	Mercuric chloride	Japanese quail	--	450	900	1 year	Fertility and hatchability	4,000	8,000	Sample et al. 1996; derived from Hill and Schaffner, 1976	Egg production increased with increasing mercury dose, but fertility and hatchability decreased.
	Methyl mercury chloride	Japanese Quail	--	--	400	2 generations	ED20 - Surviving chicks/egg laid.	--	3,300	Fuchsman et al. 2017; derived from Eskeland and Nafstad 1978	
	Methyl mercury chloride	Japanese Quail	--	--	1,200	16 weeks	ED80- Surviving chicks/egg laid.	--	10,000	Fuchsman et al. 2017; derived from El-Begearmi et al. 1982	Chicks not fed mercury diet; mortality was the result of maternal transfer only.
Large birds	Methyl mercury dicyandiamide	Ring-necked pheasant	--	--	60	12 weeks	ED20 - Reproduction	--	920	Fuchsman et al. 2017; derived from Fimreite 1971	No significant effects on chick mortality. Eggs incubated artificially; does not account for any effects related to incubation behavior.
	Methyl mercury dicyandiamide	Black duck	--	--	410	2 breeding seasons	ED80-ED90 - Surviving ducklings per egg	--	2,600	Fuchsman et al. 2017; derived from Finley and Stendell, 1978	Reduced clutch size, egg production, hatchability and duckling survival.
	Methyl mercury dicyandiamide	Black duck	--	--	95	2 breeding seasons	ED20 - Surviving ducklings per egg	--	670	Derived from Finley and Stendell, 1978	The calculated exposure concentration which affected 20% of the population is 0.74 parts per million mercury (ppm) dose level in dry weight for duckling survival. This concentration was used to derive a daily dietary LOAEL TRV. The 0.74 ppm dry weight concentration was converted from ppm to g/g followed by a dry weight to wet conversion assuming 10% water content in dry feed. This value was then converted to ng/g in wet weight. Used average site specific body weight of 1.36 kg and a food ingestion rate for omnivorous birds of 0.193 kg fw/kg BW/day (Nagy 2001) to calculate daily dietary dose. LOAEL-NOAEL uncertainty factor of 0.1
	Methyl mercury dicyandiamide	Mallard	--	--	400	2 breeding seasons	ED20 - Surviving ducklings per pair	--	2,500	Fuchsman et al. 2017; derived from Heinz 1974, 1976a, 1976b, 1979	Chick mortality associated with neurological signs of mercury toxicity.
	Methyl mercury chloride	Mallard	--	--	1,500	71 days	ED20 - Surviving ducklings per egg	--	9,300	Fuchsman et al. 2017; derived from Heinz et al. 2010a and 2010b	Eggs incubated artificially; does not account for any effects related to incubation behavior.
	Methyl mercury dicyandiamide	Chicken	--	--	270	54 days	ED70 - Hatching success.	--	4,600	Fuchsman et al. 2017; derived from Tejning 1967	
	Methyl mercury dicyandiamide	Mallard	--	6.4	64	3 generations	Fewer eggs and ducklings	--	500	Sample et al. 1996; derived from Heinz et al. 1979	Significant effects (fewer eggs and ducklings were produced) were observed at the 0.5 parts per million mercury dose level; LOAEL-NOAEL uncertainty factor of 0.1
	Methyl mercury dicyandiamide	Mallard	--	--	75	3 generations	Fewer eggs and ducklings	--	470	Heinz 1974, 1975, 1976a, 1976b, 1979	Significant effects (fewer eggs and ducklings produced) were observed at the 0.5 parts per million mercury dose level in dry weight; Converted dose to wet weight per Heinz (1975) using 7% water content in dry mash. Used average body weight of 1 kg (Heinz et al. 1989) and food ingestion rate for omnivorous birds of 0.159 kg fw/kg BW/day (Nagy 2001). LOAEL-NOAEL uncertainty factor of 0.1
Field Studies											
Small birds	Mercury (57% methyl mercury)	American dipper	Upper Willamette River watershed, Oregon, USA	20	--	--	Young per territory.	40	--	Fuchsman et al. 2017; derived from Henny et al. 2005	Invertebrate prey mercury was 57% methyl mercury; Unbounded NOAEL below range of effects for all species; limits utility for TRV derivation.
	Mercury (<50% methyl mercury)	Carolina Wren	South River and North Fork Holston River, Virginia	--	140	--	Nest success (production of ≥1 fledgling)	--	210	Fuchsman et al. 2017; derived from Jackson et al. 2011 & Jackson and Evers 2011	Methyl mercury was 41% of total mercury in diet; nest success was affected by both increased predation and nest abandonment. Small sample size. Multiple confounding study issues.
	Mercury (Assume 100% methyl mercury)	Tree Swallow	Carson River, Nevada	1,400			No effect on hatching success	807		Custer et al. 2007	No effect oncentration of 1,170 ng/g dw converted to ww using 31% moisture (Sample et al. 1998) for tree swallow's primary food item of insects per the study. Used average body weight of 0.0202 kg and fresh weight food ingestion rate of 0.035 kg/day from Nagy (2001) for tree swallow to yield a NOAEL.
	Mercury (Assume 100% methyl	Tree Swallow	6 sites, Maine and Massachusetts	400	--	--	No effect on hatching and fledging success	290	--	Fuchsman et al. 2017; derived from Longcore et al. 2007	
	Mercury (Assume 100% methyl mercury)	Tree Swallow	South River, Virginia	--	500	--	ED20 - Fledglings per nest	--	340	Fuchsman et al. 2017; derived from Hallinger and Cristol 2011 & Brasso and Cristol 2008	
Medium birds	Mercury (90% methyl mercury)	Snowy egret	Carson River, Nevada	--	90	--	Young per nest.	--	460	Fuchsman et al. 2017; derived from Henny et al. 2002 & Hill et al. 2008	90% methyl mercury in diet
Large birds	Mercury (Assume 100% methyl mercury)	Western/Clarks's grebe	Clear Lake, California, USA	30	--	--	Young per nest.	90	--	Fuchsman et al. 2017; derived from Anderson et al. 2008	Diet mercury from Suchanek et al. 2008. Unbounded NOAEL below range of effects for all species; limits utility for TRV derivation.
	Mercury (Assume 100% methyl mercury)	Common loon	120 lakes in Wisconsin and Canada	--	50	--	Threshold - Maximum productivity of 5–6-week old chicks per pair.		210	Fuchsman et al. 2017; derived from Burgess and Meyer 2008	Measured effects relative to maximum productivity; 50% decrease from maximum approximates a threshold for consistent effects.
	Mercury (98% methyl mercury)	Black-crowned night-heron	Carson River, Nevada	80	--	--	Young per nest.	450	--	Fuchsman et al. 2017; derived from Henny et al. 2002 & Hill et al. 2008	98% methyl mercury in diet
	Mercury (90-95% methyl mercury)	Osprey	Northern Quebec, Canada	290	--	--	Fledglings per nest.	1,400	--	Fuchsman et al. 2017; derived from DesGranges et al. 1998 & DesGranges et al. 1999	90–95% methyl mercury in diet

TABLE III.4-7

AVIAN TOXICITY STUDIES FOR THE SELECTION OF AVIAN DIETARY TRVs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Bird Size	Chemical Form	Test Species	Site	NOAEL (ng/g bw/day ww)	LOAEL (ng/g bw/day ww)	Exposure Duration	Effect	No-Effect Conc.	Effect Conc. (ng/g ww)	Source[2]	Comments[2]
Summary											
Small-Medium birds	Mercury (Assume 100% methyl mercury)	summary	--	**26 [3]**	**260**	--	Reproduction geomean calculated	--	--	--	Representative species for site - zebra finch (Varian-Ramos et al., 2014), tree swallow (Brasso and Cristol, 2008; Hallinger and Cristol, 2011), and Carolina wren (Jackson et al., 2011; Jackson and Evers, 2011)
	Mercury (Assume 100% methyl mercury)	summary	--	--	50-500	--	Typical range of reproduction effects	--	160 -750	Fuchsman et al. 2017	
Large birds	Methyl mercury	summary	--	**9.5 [3]**	**95**	--	Reproduction (Fewer ducklings)	--	--	Derived from Finley and Stendell, 1978	ED20 derived

Notes:
1. **Bolded** values selected as TRVs.
2. See Part V for full references.
3. LOAEL converted to NOAEL.

Abbreviations:
Conc. = concentration
ED20 = 20% effect dose
ED70 = 70% effect dose
ED80 = 80% effect dose
ED90 = 90% effect dose
LOAEL = lowest observed adverse effects level
ng/g bw/day ww = nanograms per gram body weight per day wet weight
ng/g ww = nanograms per gram wet weight
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: IMR 08/01/18
Checked by: NSR 08/01/18

TABLE III.4-8

AVIAN TOXICITY STUDIES FOR THE SELECTION OF PISCIVOROUS BIRD DIETARY TRVs[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Bird Size[2]	Chemical Form	Test Species	Site	NOAEL (ng/g bw/day ww)	LOAEL (ng/g bw/day ww)	Exposure Duration	Effect	No-Effect Conc. (ng/g)	Effect Conc. (ng/g ww)	Source[3]	Comments[3]
Controlled Experiments											
Large birds	Methyl mercury	White ibis	--	94	--	Dosed from 90 days of age to 3 years	Fledging success, survival	300	--	Frederick andJayasena (2010); Frederick et al.(2011)	No effect dose due to the lack of a dose-response relationship in reproductive study endpoints and because there was no statistically significant reduction in fledging success. Used body weight of 0.9 kg (Cornell Lab of Ornithology) and fresh weight food ingestion rate of 0.28 kg/day from Nagy (2001) for carnivorous birds to yield a NOAEL.
	Methylmercury chloride	Great egret	--	--	85	diet for 14 weeks	Reductions in appetite and growth in juvenile great egrets	--	500	Spalding et al. 2000	Converted to LOAEL using midpoint of range reported by the study for the ingestion rate (0.17 kg diet/kg bw/day)
Field Studies											
Medium birds	Mercury (90% Methyl mercury)	Snowy egret	Carson River, Nevada	--	90	--	Young per nest	--	460	Fuchsman et al. 2017; derived from Henny et al. 2002 & Hill et al. 2008	90% methyl mercury in diet
Large birds	Mercury (Assume 100% methyl mercury)	Great blue heron	4 sites in British Columbia	7.5	--		Fledging success, nest success, clutch size	33		Elliott et al. 1989	No effect mean dose of 33 ng/g ww. Used average body weight of 2.23 kg (Quinney 1982) and fresh weight food ingestion rate of 0.51 kg/day from Nagy (2001) for carnivorous birds to yield a NOAEL.
	Mercury (Assume 100% methyl mercury)	Western/Clarks's grebe	Clear Lake, California, USA	30	--	--	Young per nest	90	--	Fuchsman et al. 2017; derived from Anderson et al. 2008	Diet mercury from Suchanek et al. 2008. Unbounded NOAEL below range of effects for all species; limits utility for TRV derivation.
	Mercury (Assume 100% methyl mercury)	Common loon	120 lakes in Wisconsin and Canada	--	50	--	Threshold - Maximum productivity of 5–6-week-old chicks per pair.		210	Fuchsman et al. 2017; derived from Burgess and Meyer 2008	Measured effects relative to maximum productivity; 50% decrease from maximum approximates a threshold for consistent effects.
	Mercury (98% Methyl mercury)	Black-crowned night-heron	Carson River, Nevada	80		--	Young per nest	450	--	Fuchsman et al. 2017; derived from Henny et al. 2002 & Hill et al. 2008	98% methyl mercury in diet
	Mercury (Assume 100% methyl mercury)	Bald eagle	Michigan	60	--		Egg lethality	500	--	Giesy et al. 1995	derived from Mallard study (Heinz, 1979); converted using bald eagle body weight of 4.6 kg and ingestion rate of 0.552 kg per day from BERA
	Mercury (Assume 100% methyl	Common loon	Northwest Ontario	6.0	34		Reproduction productivity (adult)	30	170	Depew et al. 2012	Measured prey fish; converted using common loon body weight of 4 kg and ingestion rate of 0.8 kg per day from EPA (1997b)
	Mercury (Assume 100% methyl		New Hampshire/Maine	6.0	32		Reproduction productivity (adult)	30	160		Measured prey fish; converted using common loon body weight of 4 kg and ingestion rate of 0.8 kg per day from EPA (1997b)
	Mercury (Assume 100% methyl mercury)		Wisconsin	6.0	36		Hatch success (egg)	30	180		Egg injection (methylmercuric chloride); converted using common loon body weight of 4 kg and ingestion rate of 0.8 kg per day from EPA (1997b)
	Mercury (Assume 100% methyl mercury)		--	--	--	--	Screening benchmark threshold - Significant reproductive impairment	--	180		Geometric mean of productivity LOAEL and ED50, hatch success ED50
	Mercury (Assume 100% methyl mercury)		--	--	--	--	Screening benchmark threshold - reproductive failure	--	400		Productivity reduced to zero
	Mercury (90-95% methyl mercury)	Osprey	Northern Quebec, Canada	290	--	--	Fledglings per nest	1,400	--	Fuchsman et al. 2017; derived from DesGranges et al. 1998 & DesGranges et al. 1999	90–95% methyl mercury in diet
Summary											
Large birds	Methyl mercury	summary	--	**40**	**59**	--	Reproduction	--	--	geomean calculated	Using available studies for medium and large birds; the most conservative values from Depew et al. 2012 used in geomean calculations

Notes:
1. **Bolded** values selected as TRVs.
2. Bird size ranges are based on average adult female body weight as small = 12–54 grams, medium = 120–423 grams, and large = 794–5,500 grams.
3. See Part V for full references.
4. LOAEL converted to NOAEL.

Abbreviations:
BERA = baseline ecological risk assessment
Conc. = concentration
ED50 = 50% effect dose
EPA = Environmental Protection Agency
kg = kilograms
LOAEL = lowest observed adverse effects level
mg/kg/day = milligrams per kilogram per day
ng/g = nanograms per gram
ng/g bw/day ww = nanograms per gram body weight per day wet weight
ng/g ww = nanograms per gram wet weight
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: NSR 1/11/18
Checked by: LG 01/17/18

TABLE III.4-9

MAMMALIAN TOXICITY STUDIES FOR THE SELECTION OF MINK DIETARY TRVS[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Chemical Form	Test Species	NOAEL (ng/g bw/day ww)	LOAEL (ng/g bw/day ww)	Exposure Route and Duration	No-effect concentration (mg/kg)	Effect Concentration (mg/kg)	Body Weight (kg)	Ingestion Rate (kg per day)	Effect	Source[2]
Methyl mercury	mink	**75**	**121**	diet; two generation study	0.56	0.9	0.85	0.114	reduced adult survival	Dansereau et al. 1999

Notes:
1. **Bolded** values selected as TRVs.
2. See Part V for full references.

Abbreviations:
LOAEL = lowest observed adverse effects level
kg = kilograms
mg/kg = milligrams per kilogam
ng/g bw/day ww = nanograms per gram body weight per day wet weight
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: NSR 1/11/18
Checked by: LG 01/17/18

TABLE III.4-10

SUMMARY OF SELECTED SURFACE WATER MERCURY NOAEL AND LOAEL TRVs
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Receptor	Study Chemical Form	Endpoint	TRVs (ng/L)		Reference
			NOAEL	LOAEL	
Blue Mussel	Mercuric Chloride	Reproduction	250	420	Table III.4-1

Abbreviations:
LOAEL = lowest observed adverse effects level
ng/L = nanograms per liter
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: LO 10/02/17
Checked by: NSR 11/06/17

TABLE III.4-11

SUMMARY OF SELECTED TISSUE RESIDUE/BLOOD MERCURY NOAEL AND LOAEL TRVs
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Receptor Tissue	Study Chemical Form	Endpoint	TRVs (ng/g ww)		Reference
			NOAEL	LOAEL	
Blue Mussel	Mercuric Chloride	Reproduction	48	95	Table III.4-2
Lobster	Methyl mercuric chloride	Survival	1,820	--	Table III.4-3
Forage Fish	Methyl mercuric chloride	Survival	440	440	Table III.4-4
Predatory Fish	Methyl mercury	Reproduction and survival	77	770	Table III.4-4
Marsh Avian Blood	Methylmercury	Reproduction	210	2,100	Table III.4-6
Aquatic Avian Blood	Methylmercury	Reproduction	210	2,100	Table III.4-6

Abbreviations:
LOAEL = lowest observed adverse effects level
ng/g ww = nanograms per gram wet weight
NOAEL = no observed adverse effects level
TRV = toxicity reference value

Prepared by: IMR 08/13/18
Checked by: NSR 08/13/18

TABLE III.4-12

SUMMARY OF SELECTED MERCURY DIETARY NOAEL AND LOAEL TRVs
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Receptor Diet	Study Chemical Form	Endpoint	TRVs (ng/g bw/day, ww) NOAEL	LOAEL	Reference
Forage Fish (Mummichog and Smelt)	Methylmercuric chloride	Survival	51.8	51.8	Table III.4-5
Predatory Fish (Eel and Tomcod)	Methylmercuric chloride	Growth and mortality	13.4	139	Table III.4-5
Marsh Avian (Blackbird and Nelson's Sparrow)	Methyl mercury	Reproduction	26.0	260	Table III.4-7
Aquatic Avian (American Black Duck)	Methyl mercury dicyandiamide	Reproduction	9.5	95.0	Table III.4-7
Piscivorous Small Bird (Belted Kingfisher)	Methyl mercury	Reproduction	40.0	59.0	Table III.4-8
Piscivorous Large Bird (Bald Eagle)	Methyl mercury	Reproduction	40.0	59.0	Table III.4-8
Piscivorous Mammal (Mink)	Methyl mercury	Mortaility	75.1	121	Table III.4-9

Abbreviations:
LOAEL = lowest observed adverse effects level
ng/g bw/day, ww = nanograms per gram body weight per day, wet weight
NOAEL = no observed adverse effects level
TRVs = toxicity reference values

Prepared by: IMR 08/13/18
Checked by: NSR 08/01/18

TABLE III.5-1

COMPARISON OF SURFACE WATER CONCENTRATIONS TO SURFACE WATER TOXICITY VALUES PROTECTIVE OF MOLLUSKS
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Exposure Area	Media	Parameter	Surface Water BERA EPC (ng/L)	TRV (ng/L)		HQ	
				NOAEL	LOAEL	NOAEL	LOAEL
ES-15	Surface Water	Mercury	13	250	420	0.052	0.031
WQ-FPT	Surface Water	Mercury	1.8	250	420	0.0071	0.0042

Abbreviations:
BERA = baseline ecological risk assessment
EPC = exposure point concentration
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
ng/L = nanograms per liter
NOAEL = no observed adverse effect level
TRV = toxicity reference value

Prepared by: LO 09/19/17
Checked by: NSR 12/11/17

TABLE III.5-2a

COMPARISON OF MERCURY TISSUE CONCENTRATIONS TO TISSUE TOXICITY VALUES PROTECTIVE BY RECEPTOR[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Estuary Phase III Engineering Study
Estuary Estuary, Maine

Receptor	Media (Date Range)	Exposure Area	Tissue BERA EPC (ng Hg/g, ww)	TRV (ng Hg/g, ww)		HQ	
				NOAEL	LOAEL	NOAEL	LOAEL
American lobster	Tail tissue (2016 - 2017)	Odom Ledge	521	1,820	--	0.29	--
		South Verona	431	1,820	--	0.24	--
		Cape Jellison	284	1,820	--	0.16	--
		Turner Point	242	1,820	--	0.13	--
		Harborside	113	1,820	--	0.062	--
		2014 Closure	472	1,820	--	0.26	--
		2016 Closure	253	1,820	--	0.14	--
		Frenchman Bay$_{REF}$	44	1,820	--	0.024	--
Blue mussel	Whole body tissue (2016 - 2017)	ES-15	69	48	95	**1.4**	0.73
		ES-13	84	48	95	**1.7**	0.88
		ES03	99	48	95	**2.1**	**1.0**
		Fort Point	88	48	95	**1.8**	0.92
		Frenchman Bay$_{REF}$	9.1	48	95	0.19	0.096
Mummichog	Whole body tissue (2016 - 2017)	BO4	115	440	440	0.26	0.26
		OB5	93	440	440	0.21	0.21
		OB1	144	440	440	0.33	0.33
		Mendall Marsh	151	440	440	0.34	0.34
		Frenchman Bay$_{REF}$	8	440	440	0.017	0.017
Rainbow smelt	Whole body tissue (2016 - 2017)	OB-01	74	440	440	0.17	0.17
		OB-04	71	440	440	0.16	0.16
		OB-05	177	440	440	0.40	0.40
		ES-13	51	440	440	0.12	0.12
		Fort Point	85	440	440	0.19	0.19
		Frenchman Bay$_{REF}$	11	440	440	0.026	0.026
Atlantic tomcod	Fillet tissue (2016 - 2017)	BO4	239	77	770	**3.1**	0.31
		OB5	181	77	770	**2.4**	0.24
		OB1	207	77	770	**2.7**	0.27
		ES13	135	77	770	**1.8**	0.18
		Fort Point	74	77	770	0.96	0.10
		Frenchman Bay$_{REF}$	37	77	770	0.47	0.047
American eel	Fillet tissue (2016 - 2017)	BO-04	697	77	770	**9.1**	0.91
		OB-05	376	77	770	**4.9**	0.49
		OB-01	394	77	770	**5.1**	0.51
		OV-04$_{REF}$	320	77	770	**4.2**	0.42
American black duck	Blood (2014, 2017, 2018)	Mendall Marsh	460	210	2,100	**2.2**	0.22
		ES-13	300	210	2,100	**1.4**	0.14
		Frenchman Bay$_{REF}$	77	210	2,100	0.37	0.037
Nelson's sparrow	Blood (2016 - 2017)	W-17-N	4,829	210	2,100	**23**	**2.3**
		MMSE	5,105	210	2,100	**24**	**2.4**
		MMSW	4,848	210	2,100	**23**	**2.3**
		Pleasant River$_{REF}$	466	210	2,100	**2.2**	0.22
Red-winged blackbird	Blood (2016 - 2017)	W-17-N	4,213	210	2,100	**20**	**2.0**
		MMSE	6,373	210	2,100	**30**	**3.0**
		MMSW	7,540	210	2,100	**36**	**3.6**

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0

Abbreviations:
BERA = baseline ecological risk assessment
EPC = exposure point concentration
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
ng Hg/g, ww = nanograms mercury per gram, wet weight
NOAEL = no observed adverse effect level
TRV = toxicity reference value

Prepared by: IMR 08/13/18
Checked by: LO 08/14/18

TABLE III.5-2b

COMPARISON OF METHYL MERCURY TISSUE CONCENTRATIONS TO TISSUE TOXICITY VALUES PROTECTIVE BY RECEPTOR[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Receptor	Media (Date Range)	Exposure Area	Tissue BERA EPC (ng MeHg/g, ww)	TRV (ng Hg/g, ww)		HQ	
				NOAEL	LOAEL	NOAEL	LOAEL
American lobster	Tail tissue (2016 - 2017)	Odom Ledge	479	1,820	--	0.26	--
		South Verona	396	1,820	--	0.22	--
		Cape Jellison	261	1,820	--	0.14	--
		Turner Point	223	1,820	--	0.12	--
		Harborside	103.7	1,820	--	0.057	--
		2014 Closure	434	1,820	--	0.24	--
		2016 Closure	232	1,820	--	0.13	--
		$Frenchman\ Bay_{REF}$	40.5	1,820	--	0.022	--
Blue mussel	Whole body tissue (2016 - 2017)	ES-15	29.4	48	95	0.61	0.31
		ES-13	35.7	48	95	0.74	0.38
		ES03	42.3	48	95	0.88	0.45
		Fort Point	37.5	48	95	0.78	0.39
		$Frenchman\ Bay_{REF}$	3.88	48	95	0.081	0.041
Mummichog	Whole body tissue (2016 - 2017)	BO4	99.2	440	440	0.23	0.23
		OB5	79.9	440	440	0.18	0.18
		OB1	124	440	440	0.28	0.28
		Mendall Marsh	130	440	440	0.30	0.30
		$Frenchman\ Bay_{REF}$	6.64	440	440	0.015	0.015
Rainbow smelt	Whole body tissue (2016 - 2017)	OB-01	58.1	440	440	0.13	0.13
		OB-04	56.1	440	440	0.13	0.13
		OB-05	140	440	440	0.32	0.32
		ES-13	40.2	440	440	0.091	0.091
		Fort Point	66.8	440	440	0.15	0.15
		$Frenchman\ Bay_{REF}$	9.03	440	440	0.021	0.021
Atlantic tomcod	Fillet tissue (2016 - 2017)	BO4	190	77	770	**2.5**	0.25
		OB5	144	77	770	**1.9**	0.19
		OB1	165	77	770	**2.1**	0.21
		ES13	108	77	770	**1.4**	0.14
		Fort Point	59.1	77	770	0.77	0.077
		$Frenchman\ Bay_{REF}$	29.0	77	770	0.38	0.038
American eel	Fillet tissue (2016 - 2017)	BO-04	611	77	770	**7.9**	0.79
		OB-05	330	77	770	**4.3**	0.43
		OB-01	345	77	770	**4.5**	0.45
		$OV\text{-}04_{REF}$	280	77	770	**3.6**	0.36
American black duck	Blood (2014, 2017, 2018)	Mendall Marsh	362	210	2,100	**1.7**	0.17
		ES-13	236	210	2,100	**1.1**	0.11
		$Frenchman\ Bay_{REF}$	60.7	210	2,100	0.29	0.029
Nelson's sparrow	Blood (2016 - 2017)	W-17-N	4,613	210	2,100	**22**	**2.2**
		MMSE	4,877	210	2,100	**23**	**2.3**
		MMSW	4,631	210	2,100	**22**	**2.2**
		$Pleasant\ River_{REF}$	445	210	2,100	**2.1**	0.21
Red-winged blackbird	Blood (2016 - 2017)	W-17-N	4,025	210	2,100	**19**	**1.9**
		MMSE	6,088	210	2,100	**29**	**2.9**
		MMSW	7,203	210	2,100	**34**	**3.4**

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0

Abbreviations:
BERA = baseline ecological risk assessment
EPC = exposure point concentration
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
ng Hg/g, ww = nanograms mercury per gram, wet weight
NOAEL = no observed adverse effect level
TRV = toxicity reference value

Prepared by: IMR 08/13/18
Checked by: LO 08/14/18

TABLE III.5-2c

SUMMARY OF TISSUE HAZARD QUOTIENTS
BASELINE ECOLOGICAL RISK ASSESSMENT[1]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Receptor	Media (Date Range)	Exposure Area	Tissue Hazard Quotients: Mercury NOAEL	Mercury LOAEL	Methyl Mercury NOAEL	Methyl Mercury LOAEL
American lobster	Tail tissue (2016 - 2017)	Odom Ledge	0.29	--	0.26	--
		South Verona	0.24	--	0.22	--
		Cape Jellison	0.16	--	0.14	--
		Turner Point	0.13	--	0.12	--
		Harborside	0.062	--	0.057	--
		2014 Closure	0.26	--	0.24	--
		2016 Closure	0.14	--	0.13	--
		Frenchman Bay_{REF}	0.024	--	0.022	--
Blue mussel	Whole body tissue (2016 - 2017)	ES-15	**1.4**	0.73	0.61	0.31
		ES-13	**1.7**	0.88	0.74	0.38
		ES03	**2.1**	**1.0**	0.88	0.45
		Fort Point	**1.8**	0.92	0.78	0.39
		Frenchman Bay_{REF}	0.19	0.096	0.081	0.041
Mummichog	Whole body tissue (2016 - 2017)	BO4	0.26	0.26	0.23	0.23
		OB5	0.21	0.21	0.18	0.18
		OB1	0.33	0.33	0.28	0.28
		Mendall Marsh	0.34	0.34	0.30	0.30
		Frenchman Bay_{REF}	0.017	0.017	0.015	0.015
Rainbow smelt	Whole body tissue (2016 - 2017)	OB-01	0.17	0.17	0.13	0.13
		OB-04	0.16	0.16	0.13	0.13
		OB-05	0.40	0.40	0.32	0.32
		ES-13	0.12	0.12	0.091	0.091
		Fort Point	0.19	0.19	0.15	0.15
		Frenchman Bay_{REF}	0.026	0.026	0.021	0.021
Atlantic tomcod	Fillet tissue (2016 - 2017)	BO4	**3.1**	0.31	**2.5**	0.25
		OB5	**2.4**	0.24	**1.9**	0.19
		OB1	**2.7**	0.27	**2.1**	0.21
		ES13	**1.8**	0.18	**1.4**	0.14
		Fort Point	0.96	0.096	0.77	0.077
		Frenchman Bay_{REF}	0.47	0.047	0.38	0.038
American eel	Fillet tissue (2016 - 2017)	BO-04	**9.1**	0.91	**7.9**	0.79
		OB-05	**4.9**	0.49	**4.3**	0.43
		OB-01	**5.1**	0.51	**4.5**	0.45
		$OV\text{-}04_{REF}$	**4.2**	0.42	**3.6**	0.36
American black duck	Blood (2014, 2017, 2018)	Mendall Marsh	**2.2**	0.22	**1.7**	0.17
		ES-13	**1.4**	0.14	**1.1**	0.11
		Frenchman Bay_{REF}	0.37	0.037	0.29	0.029
Nelson's sparrow	Blood (2016 - 2017)	W-17-N	**23**	**2.3**	**22**	**2.2**
		MMSE	**24**	**2.4**	**23**	**2.3**
		MMSW	**23**	**2.3**	**22**	**2.2**
		Pleasant $River_{REF}$	**2.2**	0.22	**2.1**	0.21
Red-winged blackbird	Blood (2016 - 2017)	W-17-N	**20**	**2.0**	**19**	**1.9**
		MMSE	**30**	**3.0**	**29**	**2.9**
		MMSW	**36**	**3.6**	**34**	**3.4**

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0

Abbreviations:
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level

Prepared by: IMR 08/13/18
Checked by: LO 08/14/18

TABLE III.5-3a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR MUMMICHOG
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Parameter		Units	Mendall Marsh	Estuary	Frenchman Bay_{REF}	Reference
EPCs	Shrimp	ng Hg/g, ww	76.3	76.3	76.3	Table III.3-13a
	Insects	ng Hg/g, ww	129	123	35.2	Table III.3-13a
Dietary Fractions	DF Shrimp	unitless	0.10	0.10	0.10	Table III.3-1
	DF Insects	unitless	0.90	0.90	0.90	Table III.3-1
Exposure Factors	SFF	unitless	1.00	1.00	1.00	Table III.3-1
	EF	unitless	1.00	1.00	1.00	Table III.3-1
	BW	kg	0.00500	0.00500	0.00500	Table III.3-1
	IR food	kg/day, ww	0.000360	0.000360	0.000360	Table III.3-1
Doses[1]	Dose from Shrimp	ng Hg/g bw/d, ww	0.55	0.5	0.55	calculated
	Dose from Insects	ng Hg/g bw/d, ww	8.4	8.0	2.28	calculated
	Total Dose	ng Hg/g bw/d, ww	8.9	8.5	2.8	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	51.8	51.8	51.8	Table III.4-12
	LOAEL TRV	ng/g bw/d	51.8	51.8	51.8	Table III.4-12
HQs[2]	NOAEL HQ	unitless	0.17	0.16	0.055	calculated
	LOAEL HQ	unitless	0.17	0.16	0.055	calculated

Notes:
1. Doses were calculated as follows:

$$\text{Dose} = \sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1} \times EF \times SFF$$

Where:
Dose = Potential average daily dose (mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$\text{HQ} = \left[{}^{Dose}/_{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d, ww = nanograms mercury per gram body weight per day, wet weight
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-3b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR MUMMICHOG
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	Mendall Marsh	Estuary	Frenchman Bay_{REF}	Reference
EPCs	Shrimp	ng MeHg/g, ww	54.5	54.5	54.5	Table III.3-13b
	Insects	ng MeHg/g, ww	69.7	58.6	22.6	Table III.3-13b
Dietary Fractions	DF Shrimp	unitless	0.100	0.100	0.100	Table III.3-1
	DF Insects	unitless	0.900	0.900	0.900	Table III.3-1
Exposure Factors	SFF	unitless	1.00	1.00	1.00	Table III.3-1
	EF	unitless	1.00	1.00	1.00	Table III.3-1
	BW	kg	0.00500	0.00500	0.00500	Table III.3-1
	IR food	kg/day, ww	0.000360	0.000360	0.000360	Table III.3-1
Doses[1]	Dose from Shrimp	ng MeHg/g bw/d, ww	0.392	0.392	0.392	calculated
	Dose from Insects	ng MeHg/g bw/d, ww	4.52	3.80	1.47	calculated
	Total Dose	ng MeHg/g bw/d, ww	4.91	4.19	1.86	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	51.8	51.8	51.8	Table III.4-12
	LOAEL TRV	ng/g bw/d	51.8	51.8	51.8	Table III.4-12
HQs[2]	NOAEL HQ	unitless	0.095	0.081	0.036	calculated
	LOAEL HQ	unitless	0.095	0.081	0.036	calculated

Notes:
1. Doses were calculated as follows:

$$\text{Dose} = \sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1} \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$\text{HQ} = \left[{}^{Dose}/_{TRV} \right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g = nanograms methyl mercury per gram
ng MeHg/g bw/d, ww = nanograms methyl mercury per gram body weight per day, wet weight
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-4a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR RAINBOW SMELT
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	Estuary	Frenchman Bay_{REF}	Reference
EPCs	Forage fish (Mummichog)	ng Hg/g, ww	112	7.70	Table III.3-13a
	Shrimp	ng Hg/g, ww	76.3	6.7	Table III.3-13a
Dietary Fractions	DF Forage fish (Mummichog)	unitless	0.380	0.380	Table III.3-2
	DF Shrimp	unitless	0.620	0.620	Table III.3-2
Exposure Factors	SFF	unitless	1.00	1.00	Table III.3-2
	EF	unitless	1.00	1.00	Table III.3-2
	BW	kg	0.0120	0.0120	Table III.3-2
	IR food	kg/day, ww	0.00132	0.00132	Table III.3-2
Dose [1]	Dose from Forage fish (Mummichog)	ng Hg/g bw/d, ww	4.67	0.322	calculated
	Dose from Shrimp	ng Hg/g bw/d, ww	5.20	0.46	calculated
	Total Dose	ng Hg/g bw/d, ww	9.88	0.78	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	51.8	51.8	Table III.4-12
	LOAEL TRV	ng/g bw/d	51.8	51.8	Table III.4-12
HQs [2]	NOAEL HQ	unitless	0.19	0.02	calculated
	LOAEL HQ	unitless	0.19	0.02	calculated

Notes:
1. Doses were calculated as follows:

$$\text{Dose} = \sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1} \times EF \times SFF$$

Where:
Dose = Potential average daily dose (mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$HQ = [{}^{Dose}/_{TRV}]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d, ww = nanograms mercury per gram body weight per day, wet weight
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-4b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR RAINBOW SMELT
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	Estuary	Frenchman Bay_{REF}	Reference
EPCs	Forage fish (Mummichog)	ng MeHg/g, ww	96.5	6.64	Table III.3-13b
	Shrimp	ng MeHg/g, ww	54.5	1.0	Table III.3-13b
Dietary Fractions	DF Forage fish (Mummichog)	unitless	0.380	0.380	Table III.3-2
	DF Shrimp	unitless	0.620	0.620	Table III.3-2
Exposure Factors	SFF	unitless	1.00	1.00	Table III.3-2
	EF	unitless	1.00	1.00	Table III.3-2
	BW	kg	0.0120	0.0120	Table III.3-2
	IR food	kg/day, ww	0.00132	0.00132	Table III.3-2
Dose [1]	Dose from Forage fish (Mummichog)	ng MeHg/g bw/d, ww	4.03	0.278	calculated
	Dose from Shrimp	ng MeHg/g bw/d, ww	3.72	0.07	calculated
	Total Dose	ng MeHg/g bw/d, ww	7.75	0.35	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	51.8	51.8	Table III.4-12
	LOAEL TRV	ng/g bw/d	51.8	51.8	Table III.4-12
HQs [2]	NOAEL HQ	unitless	0.15	0.007	calculated
	LOAEL HQ	unitless	0.15	0.007	calculated

Notes:
1. Doses were calculated as follows:

$$\text{Dose} = \sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1} \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$\text{HQ} = \left[{}^{Dose}/_{TRV} \right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g = nanograms methyl mercury per gram
ng MeHg/g bw/d, ww = nanograms methyl mercury per gram body weight per day, wet weight
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-5a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR ATLANTIC TOMCOD
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	Estuary	Frenchman Bay_{REF}	Reference
EPCs	Shrimp	ng Hg/g, ww	76.3	6.7	Table III.3-13a
	Forage fish (smelt & mummichog)	ng Hg/g, ww	89.1	9.39	Table III.3-13a
	Polychaetes	ng Hg/g, ww	98.7	6.74	Table III.3-13a
Dietary Fractions	DF Shrimp	unitless	0.880	0.880	Table III.3-3
	DF Forage fish (smelt & mummichog)	unitless	0.100	0.100	Table III.3-3
	DF Polychaetes	unitless	0.0200	0.0200	Table III.3-3
Exposure Factors	SFF	unitless	1.00	1.00	Table III.3-3
	EF	unitless	1.00	1.00	Table III.3-3
	BW	kg	0.0350	0.0350	Table III.3-3
	IR food	kg/day, ww	0.000980	0.000980	Table III.3-3
Doses [1]	Dose from Shrimp	ng Hg/g bw/d, ww	1.88	0.17	calculated
	Dose from Forage fish (smelt & mummichog)	ng Hg/g bw/d, ww	0.249	0.0263	calculated
	Dose from Polychaetes	ng Hg/g bw/d, ww	0.0553	0.00377	calculated
	Total Dose	ng Hg/g bw/d, ww	2.18	0.20	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	13	13	Table III.4-12
	LOAEL TRV	ng/g bw/d	139	139	Table III.4-12
HQs [2]	NOAEL HQ	unitless	0.163	0.015	calculated
	LOAEL HQ	unitless	0.016	0.001	calculated

Notes:
1. Doses were calculated as follows:

$$\text{Dose} = \sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1} \times EF \times SFF$$

Where:
Dose = Potential average daily dose (mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$HQ = \left[{Dose}/{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d, ww = nanograms mercury per gram body weight per day, wet weight
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-5b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR ATLANTIC TOMCOD
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Parameter		Units	Estuary	Frenchman Bay$_{REF}$	Reference
EPCs	Shrimp	ng MeHg/g, ww	54.5	1.0	Table III.3-13b
	Forage fish (smelt & mummichog)	ng MeHg/g, ww	73.6	7.76	Table III.3-13b
	Polychaetes	ng MeHg/g, ww	9.54	1.00	Table III.3-13b
Dietary Fractions	DF Shrimp	unitless	0.880	0.880	Table III.3-3
	DF Forage fish (smelt & mummichog)	unitless	0.100	0.100	Table III.3-3
	DF Polychaetes	unitless	0.0200	0.0200	Table III.3-3
Exposure Factors	SFF	unitless	1.00	1.00	Table III.3-3
	EF	unitless	1.00	1.00	Table III.3-3
	BW	kg	0.0350	0.0350	Table III.3-3
	IR food	kg/day, ww	0.000980	0.000980	Table III.3-3
Doses [1]	Dose from Shrimp	ng MeHg/g bw/d, ww	1.34	0.02	calculated
	Dose from Forage fish (smelt & mummichog)	ng MeHg/g bw/d, ww	0.206	0.0217	calculated
	Dose from Polychaetes	ng MeHg/g bw/d, ww	0.0053	0.00	calculated
	Total Dose	ng MeHg/g bw/d, ww	1.55	0.05	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	13	13	Table III.4-12
	LOAEL TRV	ng/g bw/d	139	139	Table III.4-12
HQs [2]	NOAEL HQ	unitless	0.116	0.0035	calculated
	LOAEL HQ	unitless	0.011	0.0003	calculated

Notes:
1. Doses were calculated as follows:

$$\text{Dose} = \sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1} \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$\text{HQ} = [Dose/_{TRV}]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g = nanograms methyl mercury per gram
ng MeHg/g bw/d, ww = nanograms methyl mercury per gram body weight per day, wet weight
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-6a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR AMERICAN EEL
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Parameter		Units	Estuary	$OV\text{-}04_{REF}$	Reference
EPCs	Shrimp	ng Hg/g, ww	76.3	6.7	Table III.3-13a
	Polychaetes	ng Hg/g, ww	98.7	6.74	Table III.3-13a
	Insects	ng Hg/g, ww	141	35.2	Table III.3-13a
	Forage fish (smelt and mummichog)	ng Hg/g, ww	89.1	9.39	Table III.3-13a
Dietary Fractions	DF Shrimp	unitless	0.480	0.480	Table III.3-4
	DF Polychaetes	unitless	0.360	0.360	Table III.3-4
	DF Insects	unitless	0.150	0.150	Table III.3-4
	DF Forage fish (smelt and mummichog)	unitless	0.0100	0.0100	Table III.3-4
Exposure Factors	SFF	unitless	1.00	1.00	Table III.3-4
	EF	unitless	1.00	1.00	Table III.3-4
	BW	kg	0.0694	0.0694	Table III.3-4
	IR food	kg/day, ww	0.00694	0.00694	Table III.3-4
Doses [1]	Dose from Shrimp	ng Hg/g bw/d, ww	3.66	0.32	calculated
	Dose from Polychaetes	ng Hg/g bw/d, ww	3.55	0.242	calculated
	Dose from Insects	ng Hg/g bw/d, ww	2.12	0.529	calculated
	Dose from Forage fish (smelt and mummichog)	ng Hg/g bw/d, ww	0.0891	0.00939	calculated
	Total Dose	ng Hg/g bw/d, ww	9.42	1.10	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	13	13	Table III.4-12
	LOAEL TRV	ng/g bw/d	139	139	Table III.4-12
HQs [2]	NOAEL HQ	unitless	0.703	0.082	calculated
	LOAEL HQ	unitless	0.068	0.008	calculated

Notes:
1. Doses were calculated as follows:

$$\text{Dose} = \sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1} \times EF \times SFF$$

Where:
Dose = Potential average daily dose (mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$HQ = \left[{}^{Dose}/_{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d, ww = nanograms mercury per gram body weight per day, wet weight
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-6b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR AMERICAN EEL
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	Estuary	$OV\text{-}04_{REF}$	Reference
EPCs	Shrimp	ng MeHg/g, ww	54.5	1.0	Table III.3-13b
	Polychaetes	ng MeHg/g, ww	9.54	1.00	Table III.3-13b
	Insects	ng MeHg/g, ww	59.7	22.6	Table III.3-13b
	Forage fish (smelt and mummichog)	ng MeHg/g, ww	73.6	7.76	Table III.3-13b
Dietary Fractions	DF Shrimp	unitless	0.480	0.480	Table III.3-4
	DF Polychaetes	unitless	0.360	0.360	Table III.3-4
	DF Insects	unitless	0.150	0.150	Table III.3-4
	DF Forage fish (smelt and mummichog)	unitless	0.0100	0.0100	Table III.3-4
Exposure Factors	SFF	unitless	1.00	1.00	Table III.3-4
	EF	unitless	1.00	1.00	Table III.3-4
	BW	kg	0.0694	0.0694	Table III.3-4
	IR food	kg/day, ww	0.00694	0.00694	Table III.3-4
Doses [1]	Dose from Shrimp	ng MeHg/g bw/d, ww	2.62	0.05	calculated
	Dose from Polychaetes	ng MeHg/g bw/d, ww	0.34	0.036	calculated
	Dose from Insects	ng MeHg/g bw/d, ww	0.896	0.339	calculated
	Dose from Forage fish (smelt and mummichog)	ng MeHg/g bw/d, ww	0.0736	0.00776	calculated
	Total Dose	ng MeHg/g bw/d, ww	3.93	0.43	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	13	13	Table III.4-12
	LOAEL TRV	ng/g bw/d	139	139	Table III.4-12
HQs [2]	NOAEL HQ	unitless	0.293	0.032	calculated
	LOAEL HQ	unitless	0.028	0.003	calculated

Notes:
1. Doses were calculated as follows:

$$\text{Dose} = \sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1} \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$\text{HQ} = [Dose/_{TRV}]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g = nanograms methyl mercury per gram
ng MeHg/g bw/d, ww = nanograms methyl mercury per gram body weight per day, wet weight
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-7a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR NELSON'S SPARROW[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	W-17-N	MMSE	MMSW	Pleasant $River_{REF}$	Reference
EPCs	Insect	ng Hg/g, ww	123	325	56.2	35.2	Table III.3-13a
	Spider	ng Hg/g, ww	366	542	314	52.7	Table III.3-13a
	Sediment	ng Hg/g, dw	1,041	774	784	35.7	Table III.3-13a
Dietary Fractions	DF Insect	unitless	0.850	0.850	0.850	0.850	Table III.3-5
	DF Spider	unitless	0.150	0.150	0.150	0.150	Table III.3-5
	DF Sediment	unitless	0.170	0.170	0.170	0.170	Table III.3-5
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	Table III.3-5
	EF	unitless	0.500	0.500	0.500	0.500	Table III.3-5
	BW	kg	0.0170	0.0170	0.0170	0.0170	Table III.3-5
	IR food	kg/day, ww	0.0140	0.0140	0.0140	0.0140	Table III.3-5
	IR sediment	kg/day, dw	0.00436	0.00436	0.00436	0.00436	Table III.3-5
Doses [2]	Dose from Insect	ng Hg/g bw/d	43.1	114	19.7	12.3	calculated
	Dose from Spider	ng Hg/g bw/d	22.6	33.4	19.4	3.25	calculated
	Dose from Sediment	ng Hg/g bw/d	22.7	16.9	17.1	0.779	calculated
	Total Dose	ng Hg/g bw/d	88.4	164	56.2	16.4	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	26	26	26	26	Table III.4-12
	LOAEL TRV	ng/g bw/d	260	260	260	260	Table III.4-12
HQs [3]	NOAEL HQ	unitless	**3.4**	**6.3**	**2.2**	0.63	calculated
	LOAEL HQ	unitless	0.34	0.63	0.22	0.063	calculated

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0
2. Doses were calculated as follows:

$$\text{Dose} = \left[\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{SED} \times BW^{-1}\right]\right] \times EF \times SFF$$

Where:
Dose = Potential average daily dose (mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

3. HQs were calculated as follows:

$$\text{HQ} = \left[{Dose}/{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d = nanograms mercury per gram body weight per day
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-7b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR NELSON'S SPARROW[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	W-17-N	MMSE	MMSW	Pleasant $River_{REF}$	Reference
EPCs	Insect	ng MeHg/g, ww	58.6	104	31.4	22.6	Table III.3-13b
	Spider	ng MeHg/g, ww	415	482	348	56.4	Table III.3-13b
	Sediment	ng MeHg/g, dw	58.0	11.7	13.7	4.42	Table III.3-13b
Dietary Fractions	DF Insect	unitless	0.850	0.850	0.850	0.850	Table III.3-5
	DF Spider	unitless	0.150	0.150	0.150	0.150	Table III.3-5
	DF Sediment	unitless	0.170	0.170	0.170	0.170	Table III.3-5
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	Table III.3-5
	EF	unitless	0.500	0.500	0.500	0.500	Table III.3-5
	BW	kg	0.0170	0.0170	0.0170	0.0170	Table III.3-5
	IR food	kg/day, ww	0.0140	0.0140	0.0140	0.0140	Table III.3-5
	IR sediment	kg/day, dw	0.00436	0.00436	0.00436	0.00436	Table III.3-5
Doses [2]	Dose from Insect	ng MeHg/g bw/d	20.5	36.4	11.0	7.92	calculated
	Dose from Spider	ng MeHg/g bw/d	25.7	29.8	21.5	3.48	calculated
	Dose from Sediment	ng MeHg/g bw/d	1.26	0.255	0.299	0.0963	calculated
	Total Dose	ng MeHg/g bw/d	47.4	66.4	32.8	11.5	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	26	26	26	26	Table III.4-12
	LOAEL TRV	ng/g bw/d	260	260	260	260	Table III.4-12
HQs [3]	NOAEL HQ	unitless	**1.8**	**2.6**	**1.3**	0.44	calculated
	LOAEL HQ	unitless	0.18	0.26	0.13	0.044	calculated

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0
2. Doses were calculated as follows:

$$\text{Dose} = \left[\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{SED} \times BW^{-1}\right]\right] \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

3. HQs were calculated as follows:

$$HQ = \left[{Dose}/{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g bw/d = nanograms methyl mercury per gram body weight per day
ng MeHg/g = nanograms methyl mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-8a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR RED-WINGED BLACKBIRD[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	W-17	MMSE	MMSW	Pleasant $River_{REF}$	Reference
EPCs	Insect	ng Hg/g, ww	123	325	56.2	35.2	Table III.3-13a
	Spider	ng Hg/g, ww	366	542	314	52.7	Table III.3-13a
	Sediment	ng Hg/g, dw	1,267	1,686	949	35.7	Table III.3-13a
Dietary Fractions	DF Insect	unitless	0.900	0.900	0.900	0.900	Table III.3-6
	DF Spider	unitless	0.100	0.100	0.100	0.100	Table III.3-6
	DF Sediment	unitless	0.00500	0.00500	0.00500	0.00500	Table III.3-6
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	Table III.3-6
	EF	unitless	0.580	0.580	0.580	0.580	Table III.3-6
	BW	kg	0.0470	0.0470	0.0470	0.0470	Table III.3-6
	IR food	kg/day, ww	0.0252	0.0252	0.0252	0.0252	Table III.3-6
	IR sediment	kg/day, dw	0.00874	0.00874	0.00874	0.00874	Table III.3-6
Doses [2]	Dose from Insect	ng Hg/g bw/d	34.5	91.2	15.8	9.88	calculated
	Dose from Spider	ng Hg/g bw/d	11.4	16.9	9.77	1.64	calculated
	Dose from Sediment	ng Hg/g bw/d	0.683	0.909	0.511	0.0192	calculated
	Total Dose	ng Hg/g bw/d	46.6	109.0	26.0	11.5	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	26.0	26.0	26.0	26.0	Table III.4-12
	LOAEL TRV	ng/g bw/d	260	260	260	260	Table III.4-12
HQs [3]	NOAEL HQ	unitless	**1.8**	**4.2**	**1.0**	0.44	calculated
	LOAEL HQ	unitless	0.18	0.42	0.10	0.044	calculated

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0
2. Doses were calculated as follows:

$$\text{Dose} = \left|\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{SED} \times BW^{-1}\right]\right| \times EF \times SFF$$

Where:
Dose = Potential average daily dose (mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

3. HQs were calculated as follows:

$$HQ = \left[{Dose}/{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d = nanograms mercury per gram body weight per day
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-8b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR RED-WINGED BLACKBIRD[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	W-17	MMSE	MMSW	Pleasant $River_{REF}$	Reference
EPCs	Insect	ng MeHg/g, ww	58.6	104	31.4	22.6	Table III.3-13b
	Spider	ng MeHg/g, ww	415	482	348	56.4	Table III.3-13b
	Sediment	ng MeHg/g, dw	38.0	16.1	17.4	4.42	Table III.3-13b
Dietary Fractions	DF Insect	unitless	0.900	0.900	0.900	0.900	Table III.3-6
	DF Spider	unitless	0.100	0.100	0.100	0.100	Table III.3-6
	DF Sediment	unitless	0.00500	0.00500	0.00500	0.00500	Table III.3-6
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	Table III.3-6
	EF	unitless	0.580	0.580	0.580	0.580	Table III.3-6
	BW	kg	0.0470	0.0470	0.0470	0.0470	Table III.3-6
	IR food	kg/day, ww	0.0252	0.0252	0.0252	0.0252	Table III.3-6
	IR sediment	kg/day, dw	0.00874	0.00874	0.00874	0.00874	Table III.3-6
Doses [2]	Dose from Insect	ng MeHg/g bw-d	16.4	29.1	8.80	6.34	calculated
	Dose from Spider	ng MeHg/g bw-d	12.9	15.0	10.8	1.76	calculated
	Dose from Sediment	ng MeHg/g bw-d	0.0205	0.00869	0.00938	0.00238	calculated
	Total Dose	ng MeHg/g bw-d	29.4	44.2	19.7	8.1	calculated
Dietary TRVs	NOAEL TRV	ng/g bw-d	26.0	26.0	26.0	26.0	Table III.4-12
	LOAEL TRV	ng/g bw-d	260	260	260	260	Table III.4-12
HQs [3]	NOAEL HQ	unitless	**1.1**	**1.7**	0.76	0.31	calculated
	LOAEL HQ	unitless	0.11	0.17	0.076	0.031	calculated

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0
2. Doses were calculated as follows:

$$\text{Dose} = \left[\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{SED} \times BW^{-1}\right]\right] \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

3. HQs were calculated as follows:

$$\text{HQ} = \left[{Dose}/{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g bw/d = nanograms methyl mercury per gram body weight per day
ng MeHg/g = nanograms methyl mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-9a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR AMERICAN BLACK DUCK
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	Mendall Marsh	Estuary	Frenchman Bay_{REF}	Reference
EPCs	Polychaetes	ng Hg/g, ww	219	89.1	6.74	Table III.3-13a
	Mussels	ng Hg/g, ww	82.2	82.2	9.10	Table III.3-13a
	Sediment	ng Hg/g, dw	721	714	27.40	Table III.3-13a
Dietary Fractions	DF Polychaetes	unitless	0.800	0.800	0.800	Table III.3-7
	DF Mussels	unitless	0.200	0.200	0.200	Table III.3-7
	DF Sediment	unitless	0.0200	0.0200	0.0200	Table III.3-7
Exposure Factors	SFF	unitless	1.00	1.00	1.00	Table III.3-7
	EF	unitless	0.500	0.500	0.500	Table III.3-7
	BW	kg	1.36	1.36	1.36	Table III.3-7
	IR food	kg/day, ww	0.193	0.193	0.193	Table III.3-7
	IR sediment	kg/day, dw	0.0618	0.0618	0.0618	Table III.3-7
Doses [1]	Dose from Polychaetes	ng Hg/g bw/d	12.4	5.06	0.382	calculated
	Dose from Mussels	ng Hg/g bw/d	1.17	1.17	0.129	calculated
	Dose from Sediment	ng Hg/g bw/d	0.327	0.324	0.01245	calculated
	Total Dose	ng Hg/g bw/d	13.9	6.55	0.524	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	9.5	9.5	9.5	Table III.4-12
	LOAEL TRV	ng/g bw/d	95	95	95	Table III.4-12
HQs [2]	NOAEL HQ	unitless	**1.5**	0.69	0.055	calculated
	LOAEL HQ	unitless	0.15	0.069	0.0055	calculated

Notes:

1. Doses were calculated as follows:

$$\text{Dose} = \left[\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{food} \times BW^{-1}\right]\right] \times EF \times SFF$$

Where:
Dose = Potential average daily dose (mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$\text{HQ} = \left[{Dose}/{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d = nanograms mercury per gram body weight per day
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-9b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR AMERICAN BLACK DUCK
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	Mendall Marsh	Estuary	Frenchman Bay_{REF}	Reference
EPCs	Polychaetes	ng MeHg/g, ww	9.11	10.0	1.00	Table III.3-13b
	Mussels	ng MeHg/g, ww	35.1	35.1	3.88	Table III.3-13b
	Sediment	ng MeHg/g, dw	11	17	1.60	Table III.3-13b
Dietary Fractions	DF Polychaetes	unitless	0.800	0.800	0.800	Table III.3-7
	DF Mussels	unitless	0.200	0.200	0.200	Table III.3-7
	DF Sediment	unitless	0.0200	0.0200	0.0200	Table III.3-7
Exposure Factors	SFF	unitless	1.00	1.00	1.00	Table III.3-7
	EF	unitless	0.500	0.500	0.500	Table III.3-7
	BW	kg	1.36	1.36	1.36	Table III.3-7
	IR food	kg/day, ww	0.193	0.193	0.193	Table III.3-7
	IR sediment	kg/day, dw	0.0618	0.0618	0.0618	Table III.3-7
Doses [1]	Dose from Polychaetes	ng MeHg/g bw/d	0.517	0.566	0.057	calculated
	Dose from Mussels	ng MeHg/g bw/d	0.498	0.498	0.0551	calculated
	Dose from Sediment	ng MeHg/g bw/d	0.005	0.008	0.00073	calculated
	Total Dose	ng MeHg/g bw/d	1.02	1.07	0.113	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	9.5	9.5	9.5	Table III.4-12
	LOAEL TRV	ng/g bw/d	95	95	95	Table III.4-12
HQs [2]	NOAEL HQ	unitless	0.11	0.11	0.012	calculated
	LOAEL HQ	unitless	0.011	0.011	0.0012	calculated

Notes:

1. Doses were calculated as follows:

$$\text{Dose} = \left[\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{food} \times BW^{-1}\right]\right] \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$\text{HQ} = \left[{Dose}/{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g bw/d = nanograms methyl mercury per gram body weight per day
ng MeHg/g = nanograms methyl mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-10a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR BELTED KINGFISHER[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	BO-04	OB-05	OB-04	OB-01	Mendall Marsh	ES-13	ES-FP	Frenchman Bay_{REF}	Reference
EPCs	Forage Fish	ng Hg/g, ww	118	91.3	54.9	114	151	51.6	84.6	9.39	Table III.3-13a
	Sediment	ng Hg/g, dw	1,793	1,204	586	1,009	675	757	31.0	35.7	Table III.3-13a
Dietary Fractions	DF Forage Fish	unitless	1.000	1.00	1.00	1.00	1.00	1.00	1.00	1.000	Table III.3-8
	DF Sediment	unitless	0.0100	0.010	0.010	0.010	0.010	0.010	0.010	0.0100	Table III.3-8
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-8
	EF	unitless	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	Table III.3-8
	BW	kg	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	Table III.3-8
	IR food	kg/day, ww	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	Table III.3-8
	IR sediment	kg/day, dw	0.0240	0.0240	0.0240	0.0240	0.0240	0.0240	0.0240	0.0240	Table III.3-8
Doses[2]	Dose from Forage Fish	ng Hg/g bw/d	29.4	22.8	13.7	28.4	37.7	12.9	21.1	2.35	calculated
	Dose from Sediment	ng Hg/g bw/d	1.43	0.963	0.469	0.81	0.540	0.606	0.0248	0.0286	calculated
	Total Dose	ng Hg/g bw/d	30.8	23.8	14.2	29.2	38.2	13.5	21.2	2.38	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	40	40	40	40	40	40	40	40	Table III.4-12
	LOAEL TRV	ng/g bw/d	59	59	59	59	59	59	59	59	Table III.4-12
HQs[3]	NOAEL HQ	unitless	0.77	0.59	0.35	0.73	0.95	0.34	0.53	0.06	calculated
	LOAEL HQ	unitless	0.52	0.40	0.24	0.49	0.65	0.23	0.36	0.040	calculated

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0
2. Doses were calculated as follows:

$$Dose = \left[\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{food} \times BW^{-1}\right]\right] \times EF \times SFF$$

Where:
Dose = Potential average daily dose (mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

3. HQs were calculated as follows:

$$HQ = \left[{}^{Dose}/_{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d = nanograms mercury per gram body weight per day
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-10b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR BELTED KINGFISHER[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	BO-04	OB-05	OB-04	OB-01	Mendall Marsh	ES-13	ES-FP	Frenchman Bay$_{REF}$	Reference
EPCs	Forage Fish	ng MeHg/g, ww	97.1	75.4	45.4	93.8	124	42.6	69.9	7.76	Table III.3-13b
	Sediment	ng MeHg/g, dw	7.86	20.4	11.93	20.8	10.4	15.5	1.00	4.42	Table III.3-13b
Dietary Fractions	DF Forage Fish	unitless	1.000	1.00	1.00	1.00	1.00	1.00	1.00	1.000	Table III.3-8
	DF Sediment	unitless	0.0100	0.010	0.010	0.010	0.010	0.010	0.010	0.0100	Table III.3-8
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-8
	EF	unitless	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	Table III.3-8
	BW	kg	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	Table III.3-8
	IR food	kg/day, ww	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	Table III.3-8
	IR sediment	kg/day, dw	0.0240	0.0240	0.0240	0.0240	0.0240	0.0240	0.0240	0.0240	Table III.3-8
Doses [2]	Dose from Forage Fish	ng MeHg/g bw/d	24.3	18.9	11.3	23.4	31.1	10.6	17.5	1.94	calculated
	Dose from Sediment	ng MeHg/g bw/d	0.00629	0.0163	0.00954	0.0166	0.00834	0.0124	0.000800	0.00353	calculated
	Total Dose	ng MeHg/g bw/d	24.3	18.9	11.4	23.5	31.1	10.7	17.5	1.94	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	40	40	40	40	40	40	40	40	Table III.4-12
	LOAEL TRV	ng/g bw/d	59	59	59	59	59	59	59	59	Table III.4-12
HQs [3]	NOAEL HQ	unitless	0.607	0.47	0.28	0.59	0.78	0.27	0.44	0.05	calculated
	LOAEL HQ	unitless	0.41	0.32	0.19	0.40	0.53	0.18	0.30	0.033	calculated

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0
2. Doses were calculated as follows:

$$\text{Dose} = \left|\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{food} \times BW^{-1}\right]\right| \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

3. HQs were calculated as follows:

$$\text{HQ} = \left[{Dose}/{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g bw/d = nanograms methyl mercury per gram body weight per day
ng MeHg/g = nanograms methyl mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-11a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR BALD EAGLE[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	BO-04	OB-05	OB-04	OB-01	Mendall Marsh	ES-13	ES-FP	Frenchman Bay_{REF}	Reference
EPCs	Forage Fish	ng Hg/g, ww	115	201	81.9	104	151	38.4	54.7	9.39	Table III.3-13a
	Predatory Fish	ng Hg/g, ww	668	321	321	242	242	193	74.3	257	Table III.3-13a
	Sediment	ng Hg/g, dw	1,418	962	1,004	674	665	955	633	35.7	Table III.3-13a
Dietary Fractions	DF Forage Fish	unitless	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	Table III.3-9
	DF Predatory Fish	unitless	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	Table III.3-9
	DF Sediment	unitless	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	Table III.3-9
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-9
	EF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-9
	BW	kg	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	Table III.3-9
	IR food	kg/day, ww	0.552	0.552	0.552	0.552	0.552	0.552	0.552	0.552	Table III.3-9
	IR sediment	kg/day, dw	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	Table III.3-9
Doses [2]	Dose from Forage Fish	ng Hg/g bw/d	11.0	19.3	7.86	9.9	14.5	3.69	5.25	0.902	calculated
	Dose from Predatory Fish	ng Hg/g bw/d	16.0	7.71	7.71	5.80	5.80	4.62	1.78	6.18	calculated
	Dose from Sediment	ng Hg/g bw/d	0.703	0.477	0.498	0.334	0.330	0.473	0.314	0.0177	calculated
	Total Dose	ng Hg/g bw/d	27.8	27.5	16.1	16.1	20.6	8.78	7.3	7.10	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	Table III.4-12
	LOAEL TRV	ng/g bw/d	59.0	59	59	59	59	59	59	59	Table III.4-12
HQs [3]	NOAEL HQ	unitless	0.694	0.687	0.402	0.402	0.515	0.220	0.184	0.177	calculated
	LOAEL HQ	unitless	0.47	0.47	0.27	0.27	0.35	0.15	0.12	0.12	calculated

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0
2. Doses were calculated as follows:

$$\text{Dose} = \left[\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{food} \times BW^{-1}\right]\right] \times EF \times SFF$$

Where:
Dose = Potential average daily dose (mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

3. HQs were calculated as follows:

$$\text{HQ} = \left[{}^{Dose}/_{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d = nanograms mercury per gram body weight per day
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-11b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR BALD EAGLE[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	BO-04	OB-05	OB-04	OB-01	Mendall Marsh	ES-13	ES-FP	Frenchman Bay_{REF}	Reference
EPCs	Forage Fish	ng MeHg/g, ww	95.0	166	67.7	85.5	124	31.7	45.2	7.76	Table III.3-13b
	Predatory Fish	ng MeHg/g, ww	559	269	269	202	202	161	62.1	215	Table III.3-13b
	Sediment	ng MeHg/g, dw	7.86	19.2	17.9	10.3	9.85	11.8	15.2	4.42	Table III.3-13b
Dietary Fractions	DF Forage Fish	unitless	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	Table III.3-9
	DF Predatory Fish	unitless	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	Table III.3-9
	DF Sediment	unitless	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	Table III.3-9
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-9
	EF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-9
	BW	kg	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	Table III.3-9
	IR food	kg/day, ww	0.552	0.552	0.552	0.552	0.552	0.552	0.552	0.552	Table III.3-9
	IR sediment	kg/day, dw	0.228	0.228	0.228	0.228	0.228	0.228	0.228	0.228	Table III.3-9
Doses [2]	Dose from Forage Fish	ng MeHg/g bw/d	9.12	15.9	6.50	8.21	11.9	3.05	4.34	0.745	calculated
	Dose from Predatory Fish	ng MeHg/g bw/d	13.4	6.45	6.45	4.85	4.85	3.86	1.49	5.16	calculated
	Dose from Sediment	ng MeHg/g bw/d	0.00779	0.0190	0.0177	0.0102	0.00976	0.0117	0.0151	0.00438	calculated
	Total Dose	ng MeHg/g bw/d	22.5	22.4	13.0	13.1	16.8	6.92	5.85	5.91	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	40	40	40	40	40	40	40	40	Table III.4-12
	LOAEL TRV	ng/g bw/d	59	59	59	59	59	59	59	59	Table III.4-12
HQs [3]	NOAEL HQ	unitless	0.563	0.560	0.324	0.327	0.420	0.17	0.15	0.15	calculated
	LOAEL HQ	unitless	0.38	0.38	0.22	0.22	0.28	0.12	0.10	0.10	calculated

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0
2. Doses were calculated as follows:

$$\text{Dose} = \left[\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{food} \times BW^{-1}\right]\right] \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

3. HQs were calculated as follows:

$$HQ = \left[{Dose}/{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g bw/d = nanograms methyl mercury per gram body weight per day
ng MeHg/g = nanograms methyl mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-12a

DIETARY TOTAL MERCURY RISK CALCULATIONS FOR MINK
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	BO-04	OB-05	OB-04	OB-01	Mendall Marsh	ES-13	ES-FP	Frenchman Bay$_{REF}$	Reference
EPCs	Forage Fish	ng Hg/g, ww	118	95.5	71.0	111	151	50.9	84.6	9.39	Table III.3-13a
	Sediment	ng Hg/g, dw	1,793	1,140	586	716	655	742	31.0	35.7	Table III.3-13a
Dietary Fractions	DF Forage Fish	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-10
	DF Sediment	unitless	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	Table III.3-10
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-10
	EF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-10
	BW	kg	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	Table III.3-10
	IR food	kg/day, ww	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	Table III.3-10
	IR sediment	kg/day, dw	0.0350	0.0350	0.0350	0.0350	0.0350	0.0350	0.0350	0.0350	Table III.3-10
Doses 1	Dose from Forage Fish	ng Hg/g bw/d	15.8	12.8	9.52	14.8	20.2	6.83	11.3	1.26	calculated
	Dose from Sediment	ng Hg/g bw/d	1.48	0.939	0.483	0.589	0.540	0.611	0.0256	0.0294	calculated
	Total Dose	ng Hg/g bw/d	17.2	13.7	10.00	15.4	20.7	7.44	11.4	1.29	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	75	75	75	75	75	75	75	75	Table III.4-12
	LOAEL TRV	ng/g bw/d	121	121	121	121	121	121	121	121	Table III.4-12
HQs 2	NOAEL HQ	unitless	0.23	0.18	0.13	0.21	0.28	0.10	0.15	0.017	calculated
	LOAEL HQ	unitless	0.14	0.11	0.083	0.13	0.17	0.062	0.094	0.011	calculated

Notes:

1. Doses were calculated as follows:

$$\text{Dose} = \left|\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{food} \times BW^{-1}\right]\right| \times EF \times SFF$$

Where:
- Dose = Potential average daily dose (mercury ng/g bw/d)
- C_k = EPC for the kth food type (ng/g, ww)
- DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
- IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
- C_{SED} = EPC for sediment/soil (ng/g, dw)
- IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
- DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
- BW = Body weight (kg)
- EF = Exposure frequency (range 0 to 1.0)
- SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$HQ = \left[{Dose}/_{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:

BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng Hg/g bw/d = nanograms mercury per gram body weight per day
ng Hg/g = nanograms mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-12b

DIETARY METHYL MERCURY RISK CALCULATIONS FOR MINK
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Parameter	Units	BO-04	OB-05	OB-04	OB-01	Mendall Marsh	ES-13	ES-FP	Frenchman Bay_{REF}	Reference
EPCs	Forage Fish	ng MeHg/g, ww	97.1	78.9	58.6	91.4	124	42.1	69.9	7.76	Table III.3-13b
	Sediment	ng MeHg/g, dw	7.86	20.4	11.93	11.5	9.63	14.4	1.00	4.42	Table III.3-13b
Dietary Fractions	DF Forage Fish	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-10
	DF Sediment	unitless	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	Table III.3-10
Exposure Factors	SFF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-10
	EF	unitless	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Table III.3-10
	BW	kg	0.85	0.850	0.850	0.850	0.850	0.850	0.850	0.850	Table III.3-10
	IR food	kg/day, ww	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	Table III.3-10
	IR sediment	kg/day, dw	0.035	0.0350	0.0350	0.0350	0.0350	0.0350	0.0350	0.0350	Table III.3-10
Doses [1]	Dose from Forage Fish	ng MeHg/g bw/d	13.0	10.6	7.86	12.3	16.7	5.64	9.37	1.04	calculated
	Dose from Sediment	ng MeHg/g bw/d	0.00647	0.01681	0.00982	0.00950	0.00793	0.01187	0.000824	0.00364	calculated
	Total Dose	ng MeHg/g bw/d	13.0	10.6	7.87	12.3	16.7	5.66	9.37	1.04	calculated
Dietary TRVs	NOAEL TRV	ng/g bw/d	75	75	75	75	75	75	75	75	Table III.4-12
	LOAEL TRV	ng/g bw/d	121	121	121	121	121	121	121	121	Table III.4-12
HQs [2]	NOAEL HQ	unitless	0.17	0.14	0.10	0.16	0.22	0.075	0.12	0.014	calculated
	LOAEL HQ	unitless	0.11	0.088	0.065	0.10	0.14	0.047	0.078	0.0087	calculated

Notes:
1. Doses were calculated as follows:

$$\text{Dose} = \left|\left[\sum_{k=1}^{n} C_k \times DF_k \times IR_{food} \times BW^{-1}\right] + \left[C_{SED} \times DF_{SED} \times IR_{food} \times BW^{-1}\right]\right| \times EF \times SFF$$

Where:
Dose = Potential average daily dose (methyl mercury ng/g bw/d)
C_k = EPC for the kth food type (ng/g, ww)
DF_k = Dietary fraction of intake of the kth food type (range 0 to 1.0)
IR_{food} = Ingestion rate of the kth food type (ww of food type ingested per day, kg/d)
C_{SED} = EPC for sediment/soil (ng/g, dw)
IR_{SED} = Ingestion rate of the sediment (dw of food type ingested per day, kg, dw/kg/d)
DF_{SED} = Sediment/soil ingestion rate as proportion of diet (range 0 to 1.0)
BW = Body weight (kg)
EF = Exposure frequency (range 0 to 1.0)
SFF = Site Foraging Frequency (range 0 to 1.0)

2. HQs were calculated as follows:

$$HQ = \left[{}^{Dose}/_{TRV}\right]$$

Where: HQ = Hazard Quotient
Dose = Potential average daily dose (ng Hg/g bw/d)
TRV = dietary TRV (ng Hg/g bw/d)

Abbreviations:
BW = body weight
DF = dietary fraction
dw = dry weight
EF = exposure freqency
EPC = exposure point concentration
HQ = hazard quotient
IR = ingestion rate
kg = kilograms
kg/d = kilograms per day
LOAEL = lowest observed adverse effect level
ng MeHg/g bw/d = nanograms methyl mercury per gram body weight per day
ng MeHg/g = nanograms methyl mercury per gram
ng/g bw/d = nanograms per gram body weight per day
NOAEL = no observed adverse effect level
SFF = Site Foraging Frequency
TRV = toxicity reference value
ww = wet weight

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-13

SUMMARY OF DIETARY HAZARD QUOTIENTS
BASELINE ECOLOGICAL RISK ASSESSMENT[1]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Endpoint Receptor	Exposure Area	Dietary Hazard Quotients			
		Mercury		Methyl Mercury	
		NOAEL	LOAEL	NOAEL	LOAEL
Mummichog	Mendall Marsh	0.17	0.17	0.095	0.095
	Estuary	0.16	0.16	0.081	0.081
	Reference	0.055	0.055	0.036	0.036
Rainbow smelt	Estuary	0.19	0.19	0.15	0.15
	Reference	0.02	0.02	0.007	0.007
Atlantic tomcod	Estuary	0.163	0.016	0.116	0.011
	Reference	0.015	0.001	0.0035	0.0003
American eel	Estuary	0.70	0.068	0.29	0.028
	$OV\text{-}04_{REF}$	0.08	0.008	0.03	0.003
Nelson's sparrow	W-17-N	**3.4**	0.34	**1.8**	0.18
	MMSE	**6.3**	0.63	**2.6**	0.26
	MMSW	**2.2**	0.22	**1.3**	0.13
	Pleasant $River_{REF}$	0.63	0.063	0.44	0.044
Red-winged blackbird	W-17-N	**1.8**	0.18	**1.1**	0.11
	MMSE	**4.2**	0.42	**1.7**	0.17
	MMSW	**1.0**	0.10	0.76	0.076
	Pleasant $River_{REF}$	0.44	0.044	0.31	0.031
American black duck	Mendall Marsh	**1.5**	0.15	0.11	0.011
	Estuary	0.69	0.069	0.11	0.011
	Frenchman Bay_{REF}	0.055	0.0055	0.012	0.0012
Belted Kingfisher	BO-04	0.77	0.52	0.61	0.41
	OB-05	0.59	0.40	0.47	0.32
	OB-04	0.35	0.24	0.28	0.19
	OB-01	0.73	0.49	0.59	0.40
	MM	0.95	0.65	0.78	0.53
	ES-13	0.34	0.23	0.27	0.18
	ES-FP	0.53	0.36	0.44	0.30
	Frenchman Bay_{REF}	0.059	0.040	0.049	0.033
Bald Eagle	BO-04	0.69	0.47	0.56	0.38
	OB-05	0.69	0.47	0.56	0.38
	OB-04	0.40	0.27	0.32	0.22
	OB-01	0.40	0.27	0.33	0.22
	MM	0.51	0.35	0.42	0.28
	ES-13	0.22	0.15	0.17	0.12
	ES-FP	0.18	0.12	0.15	0.10
	Frenchman Bay_{REF}	0.18	0.12	0.15	0.10
Mink	BO-04	0.23	0.14	0.17	0.11
	OB-05	0.18	0.11	0.14	0.088
	OB-04	0.13	0.083	0.10	0.065
	OB-01	0.21	0.13	0.16	0.10
	MM	0.28	0.17	0.22	0.14
	ES-13	0.10	0.062	0.075	0.047
	ES-FP	0.15	0.094	0.12	0.078
	Frenchman Bay_{REF}	0.017	0.011	0.014	0.0087

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0

Abbreviations:
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-14

SUMMARY OF REFERENCE AREA HAZARD QUOTIENTS[1]
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Endpoint Receptor	Exposure Area	Mercury		Methyl Mercury	
		NOAEL	LOAEL	NOAEL	LOAEL
Dietary Hazard Quotients					
Mummichog	Reference	0.055	0.055	0.036	0.036
Rainbow smelt	Reference	0.02	0.02	0.007	0.007
Atlantic tomcod	Reference	0.01	0.001	0.00	0.0003
American eel	OV-04$_{REF}$	0.082	0.008	0.032	0.003
Nelson's sparrow	Pleasant River$_{REF}$	0.63	0.063	0.44	0.044
Red-winged blackbird	Reference	0.44	0.044	0.31	0.031
American black duck	Frenchman Bay$_{REF}$	0.055	0.0055	0.012	0.0012
Belted Kingfisher	Frenchman Bay$_{REF}$	0.06	0.040	0.05	0.033
Bald Eagle	Frenchman Bay$_{REF}$	0.2	0.120	0.1	0.10
Mink	Frenchman Bay$_{REF}$	0.017	0.011	0.014	0.0087
Tissue Hazard Quotients					
Blue mussel	Frenchman Bay$_{REF}$	0.1896	0.09579	0.08093	0.04089
American lobster	Frenchman Bay$_{REF}$	0.02	--	0.02	--
Mummichog	Frenchman Bay$_{REF}$	0.017	0.017	0.015	0.015
Rainbow smelt	Frenchman Bay$_{REF}$	0.026	0.026	0.021	0.021
Atlantic tomcod	Frenchman Bay$_{REF}$	0.47	0.047	0.38	0.038
American eel	OV-04$_{REF}$	**4.2**	0.42	**3.6**	0.36
Nelson's sparrow (blood)	Pleasant River$_{REF}$	**2.2**	0.22	**2.1**	0.21
American black duck (blood)	Frenchman Bay$_{REF}$	0.37	0.037	0.29	0.029

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0

Abbreviations:
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

TABLE III.5-15

COMPARISON OF TISSUE CONCENTRATIONS TO BACKGROUND CONCENTRATIONS
BASELINE ECOLOGICAL RISK ASSESSMENT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Sample Location	Total Mercury Background Threshold Value (ng/g)	Statistic	Number of Total Mercury Background Exceedances	Total Mercury BERA EPC[5] (ng/g)
Lobster – Tissue				
Frenchman Bay - Reference	57.5	Max Detect[2]	1/20	44.0
2014 Closure			80/80	**472**
2016 Closure			80/80	**253**
Odom Ledge			40/40	**521**
South Verona			40/40	**431**
Cape Jellison			40/40	**284**
Turner Point			40/40	**242**
Harborside			36/40	**113**
Blue Mussel – Tissue				
Frenchman Bay - Reference	13.0	Max Detect[2]	0/20	9.10
ES-15			32/32	**68.9**
ES-13			40/40	**83.5**
ES-03			39/39	**99.1**
Fort Point			40/40	**87.8**
Rainbow Smelt – Tissue				
Frenchman Bay - Reference	26.2	Max Detect[3]	0/40	11.4
OB5			6/6	**177**
OB4			5/5	**71.0**
OB1			35/35	**73.5**
ES13			21/21	**50.9**
Fort Point			40/40	**84.6**
Mummichog – Tissue				
Frenchman Bay - Reference	10.7	95% HW Approx. Gamma UTL with 95% Coverage[6]	2/40	7.70
BO4			21/21	**115**
OB5			40/40	**92.6**
OB1			16/16	**144**
Mendall Marsh			23/23	**151**
Atlantic Tomcod – Tissue				
Frenchman Bay - Reference	36.5	Max Detect[1]	0/1	36.5
BO4			12/12	**239**
OB5			38/38	**181**
OB1			39/39	**207**
ES13			20/22	**135**
Fort Point			3/3	**74.3**
American Eel – Tissue				
OV4 - Reference	320	Max Detect[2]	0/6	320
BO4			20/21	**697**
OB5			11/25	**376**
OB1			1/1	**394**
Black Duck – Blood				
Frenchman Bay - Reference	124	Max Detect[4]	3/52	77.1
Mendall Marsh			36/38	**460**
ES-13			30/51	**300**
Nelson's Sparrow – Blood				
Frenchman Bay - Reference	740	Max Detect[2]	0/26	466
W-17-N			26/27	**4829**
MMSE			30/30	**5105**
MMSW			26/26	**4848**

Notes:
1. Tomcod background based on a single sample
2. Maximum detect refers was selected as it wthe value was the lower of the maximum detected concentration and the calculated BTV
3. Maximum detect refers to the value selected at the nonparametric UTL
4. Maximum detect refers to the highest detected concentration that was not determined to be an outlier.
5. Exposure point concentrations (EPCs) exceeding respective background threshold values are shown in **bold**.
6. Most appropriate BTV value available that is not above the maximum detect concentration

Abbreviations:
ng/g = nanograms per gram
UPL = upper prediction limit
UTL = upper tolerance limit

Prepared by: LO 04/13/18
Checked by: IMR 08/08/18

TABLE III.5-16a

SUMMARY OF AVIAN PISCIVORE BLOOD TOTAL MERCURY DATA
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Species	Year	MEDIA	AGE	Exposure Area	Parameter	No. of Samples	Frequency of Detection	Units (wet weight)	Minimum Concentration	Maximum Concentration	Median Concentration	Mean Concentration	UCL Concentration	UCL Basis	Blood LOAEL TRV	% of Samples > LOAEL
Belted Kingfisher	2007	BL	NA	UP-SB	Mercury	30	100%	NG/G	68.2	**4,708**	145	356	1,028	95% Chebyshev (Mean, Sd) UCL	2,100	3.3%
Belted Kingfisher	2007	BL	NA	SB	Mercury	26	100%	NG/G	24.0	**2,420**	118	363	738	95% Chebyshev (Mean, Sd) UCL[4]	2,100	3.8%
Black Guillemot	2007	BL	ADULT	D-SB	Mercury	16	100%	NG/G	894	1,799	1,319	1,331	1,437	95% Student's-t UCL	2,100	0%
Black Guillemot	2007	BL	JUVENILE	D-SB	Mercury	13	100%	NG/G	143	373	248	258	290	95% Student's-t UCL	2,100	0%
Double-crested Cormorant	2010	BL	NA	SB	Mercury	18	100%	NG/G	483	**3,200**	1,720	1,630	1,964	95% Student's-t UCL	2,100	22%
Double-crested Cormorant	2006-2010	BL	NA	D-SB	Mercury	42	100%	NG/G	94.4	**2,339**	190	525	903	95% Chebyshev (Mean, Sd) UCL	2,100	2.4%
Eagle	2007	BL	NA	UP-SB	Mercury	13	100%	NG/G	305	1,000	491	528	622	95% Student's-t UCL	2,100	0%
Eagle	2007	BL	NA	SB	Mercury	7	100%	NG/G	129	413	250	283	355	95% Student's-t UCL	2,100	0%
Eagle	2007	BL	NA	D-SB	Mercury	3	100%	NG/G	101	288	186	192	288	Maximum[5]	2,100	0%
Osprey	2007	BL	ADULT	SB	Mercury	6	100%	NG/G	888	**2,430**	1,158	1,337	1,813	95% Student's-t UCL	2,100	17%
Osprey	2007	BL	JUVENILE	SB	Mercury	19	100%	NG/G	45.7	131	85.0	87.6	97.6	95% Student's-t UCL	2,100	0%
Osprey	2007	BL	ADULT	D-SB	Mercury	4	100%	NG/G	189	**2,211**	805	1,002	2,067	95% Student's-t UCL	2,100	25%
Osprey	2007	BL	JUVENILE	D-SB	Mercury	7	100%	NG/G	23.2	51.3	33.8	37.1	44.8	95% Student's-t UCL	2,100	0%

Notes:
1. Samples without coordinate data not included evaluation.
2. Samples collected in the vicinity of Southwestern Maine not included in evaluation
3. **Bold values** > LOAEL TRV
4. H-UCL suggested by ProUCL for historical purposes only
5. Not enough samples for UCL calculation

Prepared by/Date: LO 08/02/18
Checked by/Date: IMR 08/02/18

Abbreviations:

NA - not available		U-SB	Upstream of Study Boundary
BL - blood		SB	Study Boundary
NG/G - nanograms per gram		D-SB	Downstream of Study Boundary

US District Court – District of Maine
Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

TABLE III.5-16b

SUMMARY OF AVIAN PISCIVORE EGG TOTAL MERCURY AND METHYL MERCURY DATA
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Species	Year	MEDIA	Exposure Area	Parameter	No. of Samples	Frequency of Detection	Units (wet weight)	Minimum Concentration	Maximum Concentration	Median Concentration	Mean Concentration
Black Guillemot	2007	EGG	D-SB	Mercury	10	100%	NG/G	482	1,182	836	808
Double-crested Cormorant	2006-2012	EGG	SB	Mercury	148	100%	NG/G	109	986	306	358
Double-crested Cormorant	2006-2009	EGG	SB	Methyl mercury	25	100%	NG/G	137	955	276	310
Double-crested Cormorant	2006-2012	EGG	D-SB	Mercury	162	100%	NG/G	37.9	684	271	279
Double-crested Cormorant	2006-2009	EGG	D-SB	Methyl mercury	22	100%	NG/G	83.0	394	216	219
Osprey	2007	EGG	SB	Mercury	4	100%	NG/G	116	414	146	205
Osprey	2007	EGG	D-SB	Mercury	2	100%	NG/G	77.6	136	107	107
Osprey	2007	EGG	D-SB	Methyl mercury	1	100%	NG/G	141	141	141	141

Notes:
1. Samples without coordinate data not included evaluation.
2. Samples collected in the vicinity of Southwestern Maine not included in evaluation

Prepared by/Date: LO 08/02/2018
Checked by/Date: IMR 08/08/18

Abbreviations:

NA - not available
NG/G - nanograms per gram
SB Study Boundary
D-SB Downstream of Study Boundary

TABLE IV.1-1
BIOTA HOME RANGES
Penobscot River Phase III Engineering Study

Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Species	Group	Home Range (Text)	Maximum Home Range [Numeric (km)] ***	Maximum Home Range [Numeric (ha)] ***	Convert Home Range in ha to ft^2	Home Range Radius	Home Range Radius Recommended	Notes	Source
Red-winged blackbird	bird	153 (in marshes) -29,235 (in uplands) m^2; males tend to control territory of 2,000 m^2, several females will occupy territory of single male	NA	3	314,683	316 ft	300 ft	--	http://animaldiversity.org/accounts/Agelaius_phoeniceus/
Nelson's sparrow	bird	male: 119.68±19.43 ha; female: 43.58±13.10 ha	NA	139	14,973,661	2,183 ft	0.4 mi	source study took place in tidal marsh in southern Gulf of Maine	http://www.jstor.org/stable/40600425?seq=1#page_scan_tab_contents
Black duck (wintering individuals	bird	Overall home range sizes averaged 4987 ha (range 54 – 28 070 ha), and maximum distances moved from the roost averaged 9.9 km (range 0.9–42.8 km)	NA	4,987	536,795,693	13,072 ft	2.5 mi	source study used postfledgling juveniles in Moosehom National Wildlife Refuge in eastern Maine	http://www.nrcresearchpress.com/doi/abs/10.1139/z90-192?journalCode=cjz#.VzSb2vkrJhE
Blue mussel	aquatic invertebrate	sessile adults; larvae dispersal dependent on abiotic and ambient factors like tides. In one study, larval dispersal was typically ~30 km, at least 64 km in some cases	64	NA	NA	104,987 ft	50 ft	note that source study took place off the coast of England (different currents than coastal Maine); adults are sessile so used 50 ft radius rather than larger radius based on glochidia dispersal; 50 ft radius allows for sediment pairing in BSAF developmen	http://marine.rutgers.edu/~wilkin/wip/mfish/GilgHilbish_BlueMussels_Ecology2003.pdf
Polychaetes	aquatic invertebrate	Burrow depth is related tc size, although most worms inhabit the upper 5 cm. Emergence distance 2.55 + 0.13 cm.	0.00005	NA	NA	0.082 ft	50 ft	50 ft radius allows for sediment pairing in BSAF developmen	http://www.macn.secyt.gov.ar/investigacion/descargas/ecologia/articulos/palomo/2000_palomo-iribarne.pdf http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3796461/#pone.0077431.s005
American eel	aquatic vertebrate	Max 4.2 to 4.7 km (river). In Hudson River, 70% of individuals ranged less than 1 km from original tagging area over 2 to 12 months	1	NA	NA	1,640 ft	0.3 mi	spawn in saltwater, return to freshwater to live	http://www.asmfc.org/uploads/file/Chp7_American_Eel_Final.pdf; references section has several home range studies that might be usefu
Atlantic tomcod	aquatic vertebrate	May migrate up to 150 miles between coastal nonspawning waters and riverine spawning habitat; they are an inshore species (generally <10m) during non-spawning, then range upstream of the head of the tide during spawning, which represents approximately 35 miles in the Penobscot River.	241	NA	NA	35 mi	35 mi	migrate into the lower reaches of the Penobscot and other Maine rivers during the late fall to feed and then spawn near the head of the tide in mid-winter, hence the nickname"frostfish." By spring migrate back to estuarine and marine areas to grow. Historically, did not migrate beyond Milford Dam.	http://www.penobscotriver.org/content/4027/anadromous-fish http://maine.gov/dmr/searunfish/reports/Penobscot_Operational_Plan_final_2009.pdf Bergeron et al 1998 http://explorer.natureserve.org/servlet/NatureServe?searchName=Microgadus+tomcod
Rainbow smelt	aquatic vertebrate	Historically, did not migrate beyond Milford Dam (river mile 33.25)	54	NA	NA	16.6 mi	16.6 mi	general cycle - in spring they spawn at head of tide in streams and rivers, in summer the YOY are in estuaries and adults in coastal waters, in fall fish move towards shore and into bays and mouths of rivers, winter in sheltered bays and large tidal rivers. current range in penobscot is smaller than historical because of dams and other impediments to movement. Historically, did not migrate beyond Milford Dam.	https://www1.maine.gov/dmr/smelt/documents/range.pdf; http://maine.gov/dmr/searunfish/reports/Penobscot_Operational_Plan_final_2009.pdf http://lowimpacthydro.org/lihi-certificate-113-milford-hydroelectric-project-on-the-penobscot-river-me/
Mummichog	aquatic vertebrate	home range of adults and large YOY (20–100 mm SL) to be 15 ha at high tide	NA	15	1,614,585	717 ft	700 ft	study took place in New Jersey salt marsh	https://marine.rutgers.edu/pubs/private/156%20(2).pd
Lobster	aquatic invertebrate	mesocosm study - mean home range size = 760.1 ± 132.0 m^2; average core area = 74 ± 10.9 m^2; Campbell & Stasko noted 6-14 km, up to 51 km; UNH info said adolescents moving < 300 m and mature lobsters ~32 km	6	0.089	9,602	1.9 mi	1.9 mi	study notes that lobsters change core areas and home ranges daily; Campbell & Stasko present different range	https://www.researchgate.net/publication/233226147_Home_range_dynamics_of_the_American_lobster_Homarus_americanus Campbell & Stasko 1986 Lobsters.unh.edu/offshore_fishery/faq/faq.htm
Rock Crab	aquatic invertebrate	resident male crabs tend to occupy an area within a 1.6km radius of orginal capture (excluding winter migrations), though in New England and Canada, rock crabs largely remain year-round in inshore waters <20m.	--	--	--	1.0 mi.	1.0 mi.	source used acoustic tags to track resident and transplanted crabs near Prince Edward Island	http://www.fao.org/docrep/017/ap925e/ap925e.pdf, http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2109.2011.02856.x/abstract
Terrestrial insects	terrestrial invertebrate	distance covered during foraging may range from 5 (springtail) to 400 m (darkling beetle). Study of honeybees - individuals recovered from 45 to 5,983 m from apiary of origin. Study of ant colony foraging showed mean total foraging area maxing out at around 30 m^2	6.0	NA	NA	9,815 ft	500 ft	various studies	http://www.nri.org/projects/publications/ecological_methods/h_chapter8_en.pdf; http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3281370/; https://web.stanford.edu/~dmgordon/old2/Gordon1995.pd
Spiders	terrestrial invertebrate	mark-recapture study showed the spiders moved very little over the temporal and spatial scale used: 0–54% per day chance of moving to the adjacent 1-m^2 plot around the pond and 0–2% per day chance of moving to the adjacent 1-m^2 plot to and from the ponc	NA	0.09	9,688	56 ft	200 ft	study used wolf spiders in virginia; study states finding is in contrast to other studies that have shown wolf spiders to completely exit a 900-m2 quadrant within several days - possible causes of this low mobility and its implications for wolf spider distribution and abundance at the pond edge discussed in study 200 ft radius allows for wetland sediment pairing in BSAF developmen	http://www.bioone.org/doi/abs/10.1636/05-85.1?mobileUi=0&journalCode=arac might be able to infer something from this study too: http://www.americanarachnology.org/JoA_free/JoA_v25_n1/JoA_v25_p1.pdf

Notes:
*** See Notes column for details
ft^2 = square feet
ft = feet
mi = mile
ha = hectare
km = kilometer
m^2 = square meter
cm = centimeter
YOY = young of year
mm SL = millimeter standard length

Prepared by: SEB 5/12/16
Checked by: IMR 08/10/18

TABLE IV.1-2

BIOTA METHYL MERCURY PERCENTAGES OF TOTAL MERCURY
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Biota	Historical Value (mean)	2016 Value (mean)	2017 Value (mean)	Combined 2016/2017 Value (mean)
American Black Duck (Blood)	79%	--	--	--
American Black Duck (Tissue)	98%	--	--	--
Terrestrial Insects	63%	62%	80%	71%
Mummichog	86%	--	--	--
American Eel	88%	--	--	--
Blue Mussel	43%	--	--	--
American Lobster (Tail tissue)	92%	--	--	--
Nelson's Sparrow	96%	--	--	--
Polychaete	36%	8.6%	35%	24%
Rainbow Smelt	79%	--	--	--
Spiders	80%	79%	92%	86%
Atlantic Tomcod	80%	--	--	--
Rock crab	91%[1]	--	--	--
Red-Winged Blackbird	96%[2]	--	--	--

Notes:
1. Mean percentage from Phase I Update Report from July 2009.
2. Mean percentage value for Nelson's sparrow.

Abbreviations:
-- not available

Prepared by: IMR 08/03/18
Checked by: NSR 08/03/18

TABLE IV.1-3

COMPARISON OF 2016 AND 2017 BSAFs WITH BSAF REGRESSION SLOPES
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Biota		Mercury					Methyl Mercury				
		2016 Median Site BSAF[2]	2017 Median Site BSAF[3]	BSAF Regression Estimate[4]	BSAF Regression *p*-value[5]	Selected BSAF[6]	2016 Median Site BSAF[2]	2017 Median Site BSAF[3]	BSAF Regression Estimate[4]	BSAF Regression *p*-value[5]	Selected BSAF[6]
Terrestrial Insects[7]	Tissue	0.090	0.028	0.035	0.020	0.035	4.0	2.3	1.3	0.011	1.3
Spiders	Tissue	0.35	1.3	0.48	0.010	0.48	18	56	7.2	0.057	7.2
Nelsons Sparrow[8]	Blood	9.5	4.7	6.0	0.0080	6.0	649	259	307	0.0059	307
Red-Winged Blackbird[8]	Blood	2.0	8.5	4.4	0.10	4.4	111	359	233	0.050	233
Polychaetes	Tissue	0.28	0.06	0.13	0.00085	0.13	0.66	2.3	0.25	0.065	0.25
Rock Crab[9,10]	Tissue	0.30	--	--	--	0.30	19	--	--	--	19
Shrimp[10,11]	Tissue	0.11	--	--	--	0.11	2.9	--	--	--	2.9
American Black Duck[8]	Blood	0.80	0.32	0.45	0.0056	0.45	55	23	29	0.023	29
American Black Duck[8]	Tissue	0.55	0.29	0.38	7.6E-04	0.38	30	21	27	3.3E-04	27
American Lobster[8]	Tissue	0.36	0.50	0.45	4.0E-07	0.45	27	35	24	5.7E-06	24
Mummichog[8]	Tissue	0.39	0.13	0.14	0.0025	0.14	4.0	13	3.8	0.068	3.8
Rainbow Smelt[7,8]	Tissue	0.10	0.08	0.092	0.000012	0.092	7.9	6.6	7.1	0.000032	7.1
Forage Fish[8,12]	Tissue	0.25	0.11	--	--	0.12	5.9	10	--	--	5.5
American Eel[7,8,13]	Tissue	0.76	0.76	0.49	0.044	0.49	62	61	30	0.15	62
Atlantic Tomcod[8]	Tissue	0.28	0.19	0.22	0.033	0.22	21	16	18	0.089	18
Predatory Fish [14]	Tissue	0.52	0.48	--	--	0.36	41	38	--	--	40
Blue Mussel[8]	Tissue	0.26	0.81	0.13	0.014	0.13	5.2	21	1.7	0.089	1.7

Prepared by: IMR 08/03/18
Checked by: LO 08/17/18

Notes:
1. BSAFs presented on wet weight tissue and dry weight sediment basis.
2. BSAF data were derived from sample collection in 2016/early 2017; Only site BSAFs shown in this table.
3. BSAF data were derived from sample collection in summer/fall 2017; Only site BSAFs shown in this table.
4. BSAF regression estimate derived from 2016 and 2017 data combined, including site and reference data to evaluate the relationship.
5. Color coding denotes:

p-value < 0.05; statistically significant	0.049
0.10 ≥ p-value ≥ 0.05; approaching significance	0.081
p-value > 0.10; not statistically different from zero	0.35

6. Selected BSAF is the BSAF regression estimate for those statistically signficant (p-value < 0.05) or approaching signficance (0.10 ≥ p-value ≥ 0.05). For BSAF regression estimates not statistically signficant (p-values > 0.10), the median BSAF from all site locations (excluding reference) from both years was selected as the BSAF.
7. Extreme value(s) removed from biota dataset for regression analysis. Refer to outlier testing results in Appendic C.
8. Methyl mercury BSAFs based on conversion of total mercury to methyl mercury in tissue based on historical site-specific data.
9. BSAF data were derived from sample collection in 2015. Median BSAF based on Site-wide tissue and sediment data.
10. Historical data pairings use Site-wide median tissue and sediment; regression analysis could not be performed.
11. BSAF data were derived from sample collection in 2009.
12. Sediment to forage fish BSAF is based on the median of selected BSAFs for mummichog and smelt.
13. The selected methyl mercury BSAF represents the median value among 2016 and 2017 data, excluding extreme values.
14. Sediment to predatory fish BSAF is based on the median of selected BSAFs for tomcod and eel.

TABLE IV.1-4

COMPARISON OF 2016 AND 2017 BAFs WITH BAF REGRESSION SLOPES
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Biota				Mercury					Methyl Mercury				
Predator		Prey		2016 Median Site BAF[2]	2017 Median Site BAF[3]	BAF Regression Estimate[4]	BAF Regression *p*-value[5]	Selected BAF[6]	2016 Median Site BAF[2]	2017 Median Site BAF[3]	BAF Regression Estimate[4]	BAF Regression *p*-value[5]	Selected BAF[6]
American Black Duck[7]	Blood	Blue Mussel[7]	Tissue	6.4	2.1	3.6	0.13	4.2	12	3.8	6.7	0.13	7.8
		Polychaetes		9.0	7.2	3.1	0.014	3.1	82	21	30	0.069	30
	Tissue	Blue Mussel[7]	Tissue	7.4	2.0	4.0	0.17	4.7	14	3.7	7.4	0.17	8.8
		Polychaetes		9.4	6.6	1.5	0.23	6.6	81	19	19	0.19	20
Rainbow Smelt[7]	Tissue	Mummichog[7,8]	Tissue	0.75	0.62	0.65	0.0000047	0.65	0.68	0.57	0.60	0.0000047	0.60
		Shrimp[9]		--	0.84	--	--	0.84	--	1.0	--	--	1
Nelsons Sparrow[7]	Blood	Terrestrial Insects[8]	Tissue	123	97	114	0.00055	114	84	105	102	0.0030	102
		Spiders		27	7.8	10	0.015	10	26	7.3	9.6	0.017	9.6
Spider	Tissue	Terrestrial Insects[8]	Tissue	4.6	17	7.8	0.012	7.8	5.0	19	7.6	0.020	7.6
Atlantic Tomcod[7]	Tissue	Polychaetes	Tissue	1.1	5.5	1.2	0.35	3.3	15	12	13	0.080	13
		Forage Fish[8,10]		2.0	1.8	1.9	0.0067	1.9	1.9	1.8	1.8	0.0066	1.8
		Shrimp[9]		--	1.5	--	--	1.5	--	1.8	--	--	1.8
American Lobster[7]	Tissue	Blue Mussel[7]	Tissue	4.8	3.7	4.6	0.00097	4.6	8.8	6.7	8.5	0.00097	8.5
		Polychaetes		12	12	12	0.00040	12	93	21	26	0.092	26
		Rainbow Smelt[7,14] (surrogate for Shrimp)		4.9	6.3	4.4	0.0027	4.4	4.9	6.3	4.4	0.0027	4.4
		Rock Crab[7,11]		--	1.1	--	--	1.1	--	0.94	--	--	0.94
Red-Winged Blackbird[7]	Blood	Terrestrial Insects	Tissue	--	174	139	0.31	174	--	175	123	0.36	175
		Spiders		--	22	--	--	22	--	17	--	--	17
American Eel[7]	Tissue	Mummichog[7,8]	Tissue	5.2	5.2	3.9	0.026	3.9	5.3	5.3	4.0	0.026	4.0
		Rainbow Smelt[7,8]		4.3	3.2	3.9	0.017	3.9	4.8	3.5	4.3	0.017	4.3
		Forage Fish[8,10,12]		--	--	4.2	0.0047	4.2	--	--	4.5	0.0046	4.5
		Polychaetes		2.1	8.6	2.4	0.043	2.4	35	22	29	0.0033	29
		Terrestrial Insects[8,13]		7.9	40	11	0.16	33	10	47	16	0.14	39
		Shrimp[9]		--	6.6	6.6	0.0058	6.6	--	7.7	7.6	0.0076	7.6
Mummichog[7]	Tissue	Terrestrial Insects[8]	Tissue	0.66	4.8	--	--	4.8	1.4	4.4	--	--	4.4
		Shrimp[9]		--	3.2	3.0	0.12	3.2	--	3.5	3.4	0.085	3.4

Notes:

Prepared by: IMR 08/03/18
Checked by: NSR 08/03/18

1. BAFs presented on a wet weight tissue and dry weight sediment basis.
2. BSAF data were derived from sample collection in 2016/early 2017; Only site BSAFs shown in this table.
3. BSAF data were derived from sample collection in summer/fall 2017; Only site BSAFs shown in this table.
4. BSAF regression estimate derived from 2016 and 2017 data combined, including site and reference data to evaluate the relationship.
5. Color coding denotes:

p-value < 0.05; statistically significant	0.049
0.10 ≥ p-value ≥ 0.05; approaching significance	0.081
p-value > 0.10; not statistically different from zero	0.35

6. Selected BAF is the BAF regression estimate for those statistically signficant (p-value < 0.05) or approaching signficance (0.10≥ p-value ≥ 0.05). For BAF regression estimates not statistically signficant (p-values > 0.10), the median BAF from all Site locations (excluding reference) from both years was selected as the BAF.
7. Methyl mercury BAFs based on conversion of total mercury to methyl mercury in tissue based on historical site-specific data
8. Extreme value(s) removed from biota dataset for regression analysis. Refer to outlier testing results in Appendic C.
9. BAF data were derived from both biota samples collected in 2009.
10. Forage Fish = Rainbow Smelt + Mummichog
11. BAF data were derived from both biota samples collected in 2015.
12. Eel to forage fish BAF is median of mummichog and smelt BAFs due to numeric and geographical inconsistencies among the predator-prey pairings.
13. The selected BAFs represent the median value among 2016 and 2017 data, excluding extreme values.
14. Paired lobster and shrimp data unavailable, rainbow smelt used as surrogate for shrimp. Evaluation of rainbow smelt and shrimp data (collected in 2009) indicated no significant difference in mercury concentrations from the former facility to

TABLE IV.1-5

SUMMARY OF RECEPTOR DIETARY COMPOSITIONS
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Receptor	Insects	Spiders	Sediments	Mussels	Polychaetes	Forage Fish	Predatory Fish	Shrimp	Rock Crab	Lobsters
Nelson's sparrow	85%	15%	17%	--	--	--	--	--	--	--
Red-Winged blackbird	90%	10%	0.5%	--	--	--	--	--	--	--
American black duck	--	--	2%	20%	80%	--	--	--	--	--
Belted Kingfisher	--	--	1%	--	--	100%	--	--	--	--
Bald Eagle	--	--	1%	--	--	80%	20%	--	--	--
Mink	--	--	2%	--	--	100%	--	--	--	--
Mummichog	90%	--	--	--	--	--	--	10%	--	--
Rainbow smelt	--	--	--	--	--	38%	--	62%	--	--
American eel	15%	--	--	--	36%	1%	--	48%	--	--
Atlantic tomcod	--	--	--	--	2%	10%	--	88%	--	--
American lobster				3.5%	2%	4.5%	--	3%	73%	14%

Note:
-- not applicable

Prepared by: JAW 12/18/17
Checked by: NSR 01/04/18

TABLE IV.2-1

TOTAL MERCURY HUMAN HEALTH SEDIMENT PRELIMINARY REMEDIATION GOALS
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Species	Area	Total Mercury Tissue PRG[1] (ng/g)		Food Web Tissue-Based Total Mercury Sediment PRG (ng/g)		BSAF Tissue-Based Total Mercury Sediment PRG (ng/g)	
		Adult	Younger Child	Adult	Younger Child	Adult	Younger Child
Local Consumer							
Trophic Level 3 - Shellfish							
American Lobster	Site-Wide	4,460	3,990	11,500	10,300	9,911	8,867
Trophic Level 3 - Freshwater Finfish							
Atlantic Tomcod	Site-Wide	417	373	2,340	2,090	1,850	1,660
Trophic Level 4 - Freshwater Finfish							
American Eel	Site-Wide	379	339	602	539	776	694
Trophic Level 3 - Waterfowl							
American Black Duck	Site-Wide	481	430	424	380	1,050	936
MeCDC Fish Tissue Action Level[2]							
Trophic Level 3 - Shellfish							
American Lobster	Site-Wide	216	216	558	558	481	481
Trophic Level 3 - Freshwater Finfish							
Atlantic Tomcod	Site-Wide	250	250	1,400	1,400	1,110	1,110
Trophic Level 4 - Freshwater Finfish							
American Eel	Site-Wide	227	227	361	361	465	465
Trophic Level 3 - Waterfowl							
American Black Duck	Site-Wide	205	205	181	181	445	445

Notes:

1. Assumes a target Hazard Quotient of 1.0.
2. MeCDC Fish Tissue Action Level for total mercury was calculated by dividing the value for methyl mercury (200 ng/g) by the percent methyl mercury to total mercury value found in Table II.2-1.

Abbreviations:

<BKG = Below calculated sediment background level of 115 ng/g for the Penobscot River (Appendix B)
BSAF = biota-sediment accumulation factor
MeCDC = Maine Center for Disease Control and Prevention
ng/g = nanograms per gram
PRG = preliminary remedial goal

Prepared by: IMR 01/31/18
Checked by: NSR 02/01/18

TABLE IV.2-2

METHYL MERCURY HUMAN HEALTH SEDIMENT PRELIMINARY REMEDIATION GOALS
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Species	Area	Methyl Mercury Tissue PRG[1] (ng/g)		Food Web Tissue-Based Methyl Mercury Sediment PRG (ng/g)		BSAF Tissue-Based Methyl Mercury Sediment PRG (ng/g)	
		Adult	Younger Child	Adult	Younger Child	Adult	Younger Child
Local Consumer							
Trophic Level 3 - Shellfish							
American Lobster	Site-Wide	4,120	3,690	217	194	169	152
Trophic Level 3 - Freshwater Finfish							
Atlantic Tomcod	Site-Wide	333	298	58.3	52.2	18.8	16.8
Trophic Level 4 - Freshwater Finfish							
American Eel	Site-Wide	333	298	15.7	14.0	5.38	4.81
Trophic Level 3 - Waterfowl							
American Black Duck	Site-Wide	470	421	22.5	20.2	15.2	13.6
MeCDC Fish Tissue Action Level							
Trophic Level 3 - Shellfish							
American Lobster	Site-Wide	200	200	10.5	10.5	8.22	8.22
Trophic Level 3 - Freshwater Finfish							
Atlantic Tomcod	Site-Wide	200	200	35.0	35.0	11.3	11.3
Trophic Level 4 - Freshwater Finfish							
American Eel	Site-Wide	200	200	9.41	9.41	3.23 (<BKG)	3.23 (<BKG)
Trophic Level 3 - Waterfowl							
American Black Duck	Site-Wide	200	200	9.59	9.59	6.45	6.45

Notes:

1. Assumes a target Hazard Quotient of 1.0.

Abbreviations:

<BKG = Below calculated sediment background level of 3.51 ng/g for the Penobscot River (Appendix B)
BSAF = biota-sediment accumulation factor
MeCDC = Maine Center for Disease Control and Prevention
ng/g = nanograms per gram
PRG = preliminary remedial goal

Prepared by: IMR 01/31/2018
Checked by: NSR 02/01/18

TABLE IV.3-1

ECOLOGICAL SEDIMENT PRELIMINARY REMEDIATION GOALS
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Food Web Tissue-Based Sediment PRGs (ng/g)									
COPC	**Nelson's Sparrow**	**Red-Winged Blackbird**	**American Black Duck**	**American Lobster**	**Blue Mussel**	**Mummichog**	**Rainbow Smelt**	**Atlantic Tomcod**	**American Eel**
Mercury	559	350	1,970	4,690	--	2,390	4,740	4,380	1,220
Methyl Mercury	15.9	9.1	103	95.9	--	69.5	164	136	36.1

BSAF Tissue-Based Sediment PRGs (ng/g)									
COPC	**Nelson's Sparrow**	**Red-Winged Blackbird**	**American Black Duck**	**American Lobster**	**Blue Mussel**	**Mummichog**	**Rainbow Smelt**	**Atlantic Tomcod**	**American Eel**
Mercury	349	482	3,680	4,040	731	3,060	4,770	3,430	1,580
Methyl Mercury	6.84	9.0	38.2	74.8	55.9	114	61.8	43.4	12.4

Dietary-Based Sediment PRGs (ng/g)												
COPC	**Nelson's Sparrow**	**Red-Winged Blackbird**	**American Black Duck**	**American Lobster**	**Blue Mussel**	**Mummichog**	**Rainbow Smelt**	**Atlantic Tomcod**	**American Eel**	**Belted Kingfisher**	**Bald Eagle**	**Mink**
Mercury	6,190	10,500	10,500	--	--	17,100	3,850	44,900	13,400	2,000	2,920	7,590
Methyl Mercury	283	432	2,470	--	--	478	144	1,600	799	43.0	39.7	164

Abbreviations:
-- = not calculated
COPC = constituent of potential concern
ng/g = nanograms per gram
PRGs = preliminary remedial goals

Prepared by: IMR 08/13/18
Checked by: LO 08/14/18

TABLE IV.4-1

TOTAL MERCURY SEDIMENT PRELIMINARY REMEDIATION GOALS[1]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Species	Local Consumer – Human Health				MeCDC Fish Tissue Action Level – Human Health		Ecolgical Receptors		
	Food Web Tissue-Based Total Mercury Sediment PRG (ng/g)		BSAF Tissue-Based Total Mercury Sediment PRG (ng/g)		Food Web Tissue-Based Total Mercury Sediment PRG (ng/g)	BSAF Tissue-Based Total Mercury Sediment PRG (ng/g)	Food Web Tissue-Based Total Mercury Sediment PRG (ng/g)	BSAF Tissue-Based Total Mercury Sediment PRG (ng/g)	Dietary-Based Sediment PRGs (ng/g)
	Adult	Younger Child	Adult	Younger Child	Adult and Child				
American Lobster	11,500	10,300	9,910	8,870	558	481	4,690	4,040	--
Blue Mussel	--	--	138,000	124,000	--	3,580	--	731	--
Mummichog	--	--	--	--	--	--	2,390	3,060	17,100
Rainbow Smelt	4,550	4,080	4,580	4,100	2,730	2,750	4,740	4,770	3,850
Atlantic Tomcod	2,340	2,090	1,850	1,660	1,400	1,110	4,380	3,430	44,900
American Eel	602	539	776	694	361	465	1,220	1,580	13,400
Nelson's Sparrow	--	--	--	--	--	--	559	349	6,190
Red-Winged Blackbird	--	--	--	--	--	--	350	482	10,500
American Black Duck	424	380	1,050	936	181	445	1,970	3,680	10,500
Belted Kingfisher	--	--	--	--	--	--	--	--	2,000
Bald Eagle	--	--	--	--	--	--	--	--	2,920
Mink	--	--	--	--	--	--	--	--	7,590

Notes:

1. Assumes a target Hazard Quotient of 1.0.

Abbreviations:

-- = PRG not calculated for receptor/method
BSAF = biota-sediment accumulation factor
MeCDC = Maine Center for Disease Control and Prevention
ng/g = nanograms per gram
PRG = preliminary remediation goal

Prepared by: IMR 08/13/18
Checked by: LO 08/14/18

TABLE IV.4-2

METHYL MERCURY SEDIMENT PRELIMINARY REMEDIATION GOALS[1]
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Species	Local Consumer				MeCDC Fish Tissue Action Level		Ecolgical Receptors		
	Food Web Tissue-Based Methyl Mercury Sediment PRG (ng/g)		BSAF Tissue-Based Methyl Mercury Sediment PRG (ng/g)		Food Web Tissue-Based Methyl Mercury Sediment PRG (ng/g)	BSAF Tissue-Based Methyl Mercury Sediment PRG (ng/g)	Food Web Tissue-Based Methyl Mercury Sediment PRG (ng/g)	BSAF Tissue-Based Methyl Mercury Sediment PRG (ng/g)	Dietary-Based Sediment PRGs (ng/g)
	Adult	Younger Child	Adult	Younger Child	Adult and Child				
American Lobster	217	194	169	152	10.5	8.22	95.9	74.8	--
Blue Mussel	--	--	4,540	4,060	--	118	--	55.9	--
Mummichog	--	--	--	--	--	--	69.5	114	478
Rainbow Smelt	125	112	46.8	41.9	75.0	28.1	164	61.8	144
Atlantic Tomcod	58.3	52.2	18.8	16.8	35.0	11.3	136	43.4	1,600
American Eel	15.7	14.0	5.38	4.81	9.41	3.23 (<BKG)	36.1	12.4	799
Nelson's Sparrow	--	--	--	--	--	--	15.9	6.84	283
Red-Winged Blackbird	--	--	--	--	--	--	9.1	9.0	432
American Black Duck	22.5	20.2	15.2	13.6	9.59	6.45	103	38.2	2,470
Belted Kingfisher	--	--	--	--	--	--	--	--	43.0
Bald Eagle	--	--	--	--	--	--	--	--	39.7
Mink	--	--	--	--	--	--	--	--	164

Notes:

1. Assumes a target Hazard Quotient of 1.0.

Abbreviations:

-- = PRG not calculated for receptor/method
<BKG = Below calculated sediment background level of 3.51 ng/g for the Penobscot River (Appendix B)
BSAF = biota-sediment accumulation factor
MeCDC = Maine Center for Disease Control and Prevention
ng/g = nanograms per gram
PRG = preliminary remediation goal

Prepared by: IMR 08/13/18
Checked by: LO 08/14/18

TABLE IV.4-3

PROPOSED SEDIMENT PRELIMINARY REMEDIATION GOALS
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Species	Total Mercury PRGs				Methyl Mercury PRGs			
	Local Consumer – Human Health	MeCDC Fish Tissue Action Level – Human Health			Local Consumer – Human Health	MeCDC Fish Tissue Action Level – Human Health		
	Younger Child	Adult and Child	Ecological Receptors	Combined Human Health and Ecological Receptors	Younger Child	Adult and Child	Ecological Receptors	Combined Human Health and Ecological Receptors
Marsh and Intertidal Sediment PRGs (ng/g)[1]								
Nelson's Sparrow	--	--	442	--	--	--	10.4	--
Red-Winged Blackbird	--	--	411	--	--	--	9.1	--
American Black Duck	596	283	2,693	--	16.5	7.87	62.7	--
Geomean Sediment PRG[2]	596	283	788	511	16.5	7.87	18.1	13.3
Subtidal Sediment PRGs (ng/g)[1,3]								
American Lobster (Trophic Level 3 Shellfish)	9,189	518	4,350	--	172	9.29	84.7	--
Blue Mussel (Trophic Level 2 Shellfish)	--	3,580	731	--	--	118	55.9	--
Mummichog (Trophic Level 3 Finfish)	--	--	2,700	--	--	--	89.1	--
Rainbow Smelt (Trophic Level 3 Finfish)	4,090	2,740	4,750	--	68.4	45.9	101	--
Atlantic Tomcod (Trophic Level 3 Finfish)	1,860	1,250	3,880	--	29.6	19.9	76.9	--
American Eel (Trophic Level 4 Finfish)	612	410	1,390	--	8.22	9.41	21.2	--
Marsh Platform, Intertidal, and Subtidal Sediment PRGs (ng/g)								
Proposed total mercury sediment PRG range protective of ecological and human (local consumer and MeCDC fish tissue action level) receptors:			**300 - 500**		**Proposed methyl mercury sediment PRG range protective of ecological and human (local consumer and MeCDC fish tissue action level) receptors:**		**8 - 10**	

Notes:
1. Based on the geometric mean of the food web and BSAF Sediment PRGs
2. Based on the geomean of sediment PRGs for all applicable receptors
3. Although finfish and shellfish are also exposed to intertidal sediments, sediment exposure for these receptors are quantified under subtidal sediments, but final PRG selection accounts for intertidal and subtidal exposures.

Prepared by: IMR 08/13/18
Checked by: LO 08/14/18

Abbreviations:
-- = PRG not calculated for receptor/method or was excluded from consideration
BSAF = biota-sediment accumulation factor
MeCDC = Maine Center for Disease Control and Prevention
ng/g = nanograms per gram
PRG = preliminary remediation goal

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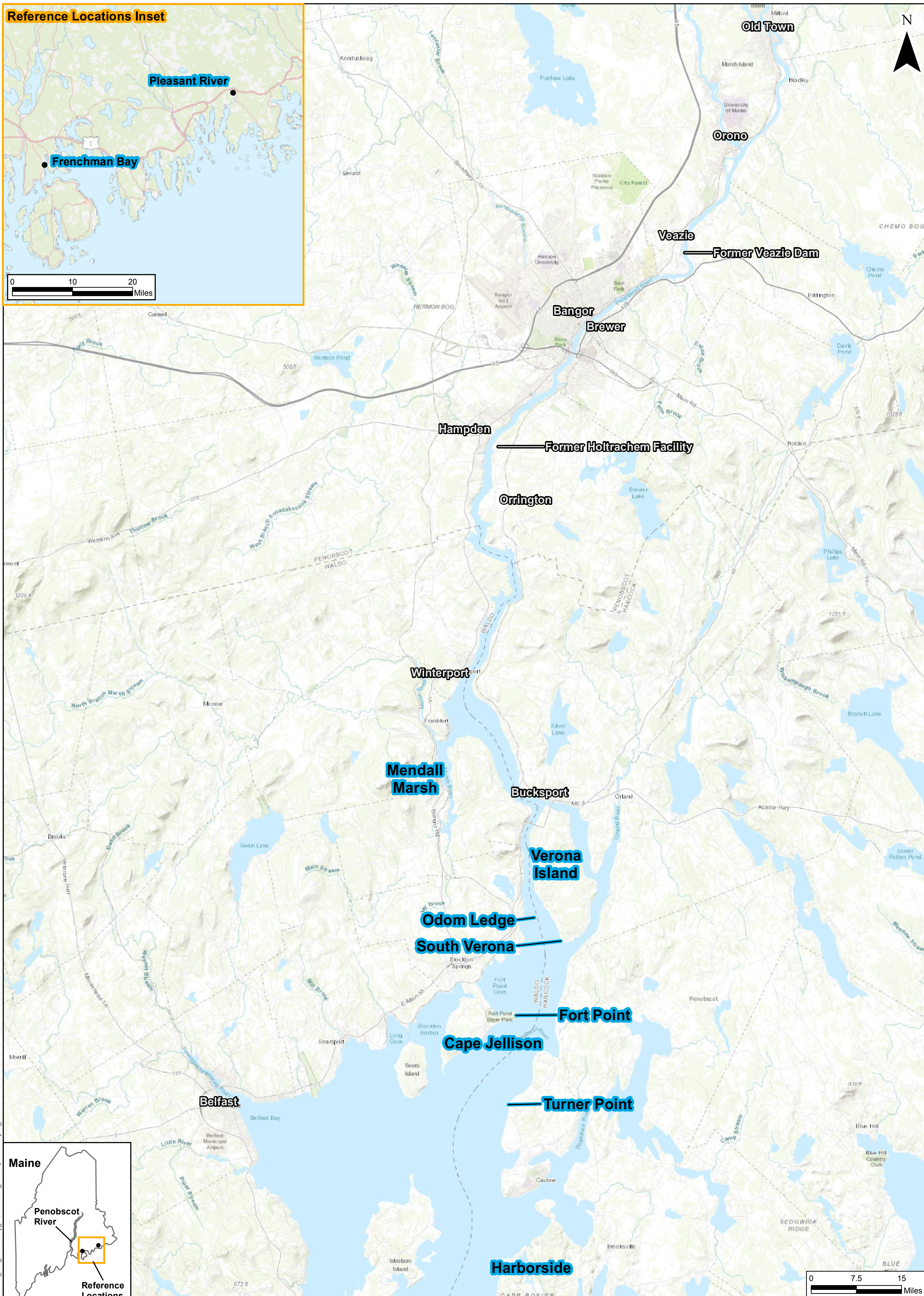
FIGURES



Legend

Mendall Marsh — Geographic Area Label

Figure I.1-1
Site Location

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Penobscot River Risk Assessment and
Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 1/5/2018	Checked/Date: LSV 1/5/2018

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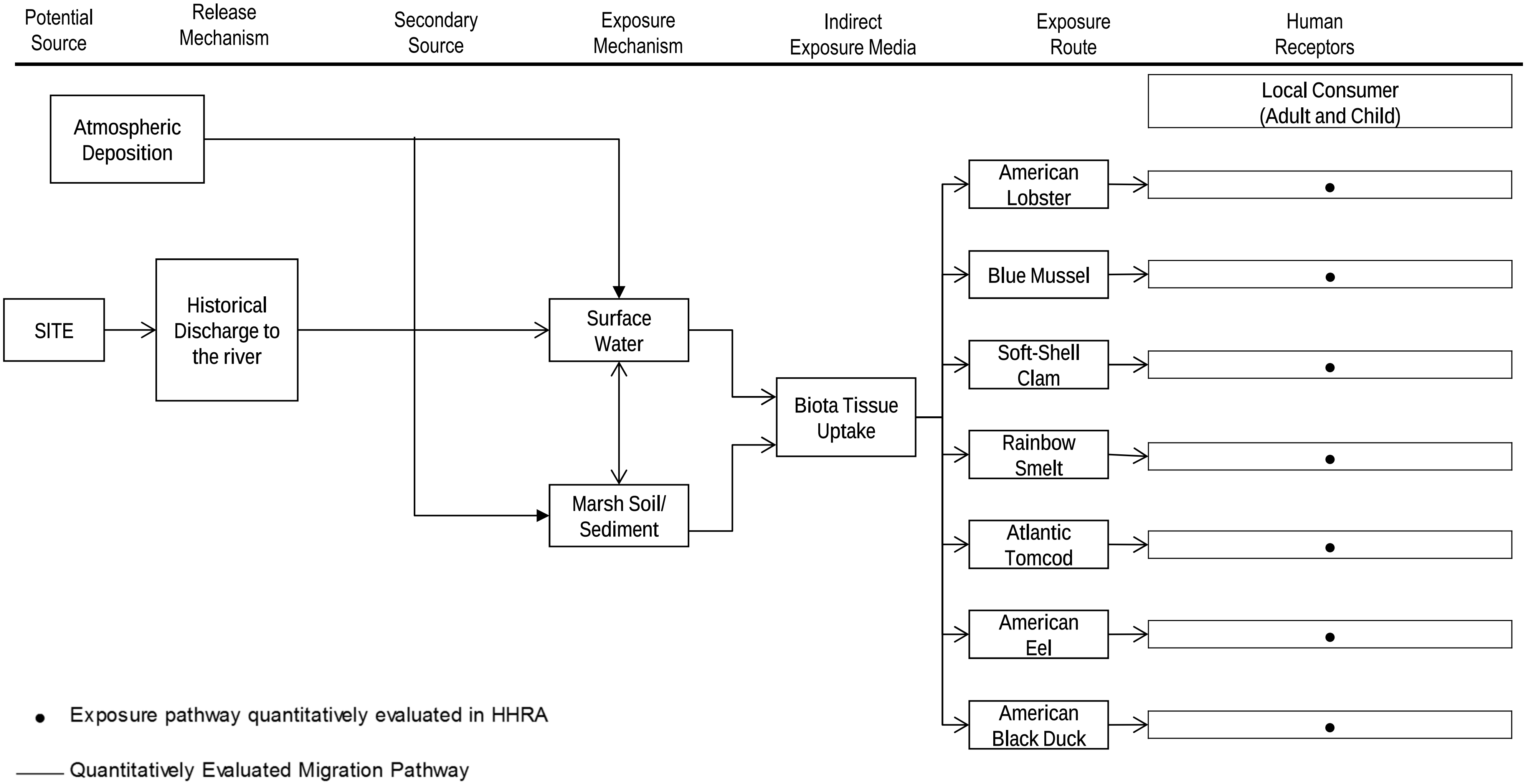
Figure II.3-1
Conceptual Exposure Model – Human Receptors

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study



Prepared by: IMR 07/23/18
Checked by: LMS 08/17/18

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Legend

- River Mile Marker
- Biota Sampling Location
- Blue Mussel Sample
- Surface Water Sample
- **Mendall Marsh** Geographic Area Label

Figure III.1-1
2016 Penobscot River Surface Water Sampling Locations Used in the BERA for Mussels

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 2/1/2018	Checked/Date: NSR 2/1/2018

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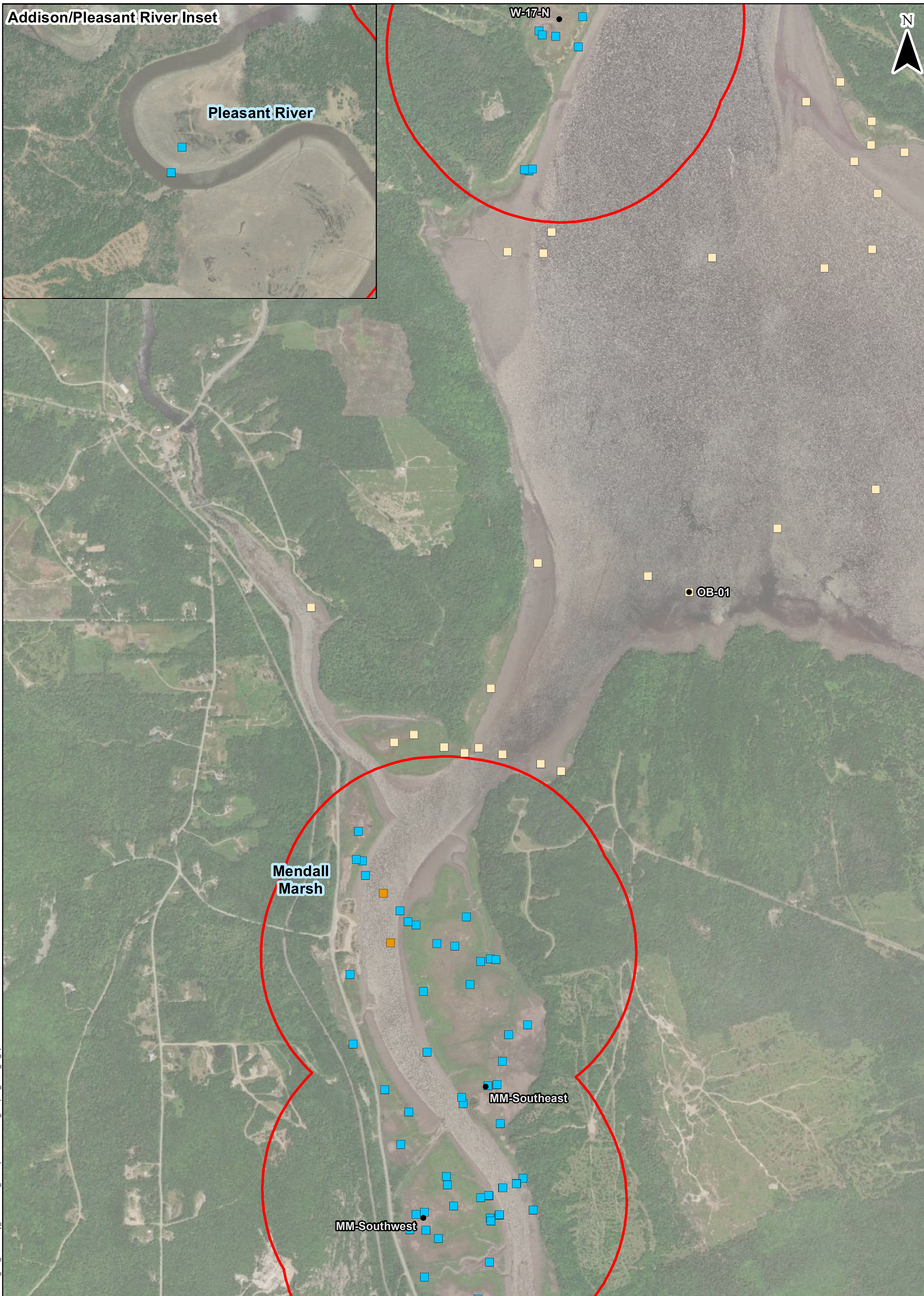

Note:
Home range radius surrounding receptor sampling locations

Mendall Marsh Geographic Area Label

Legend
- Biota Sampling Location
- Sediment Sample Used for Nelson's Sparrow
- Subtidal Sediment Sample Not Used for Nelson's Sparrow
- Sediment Sample Outside of Radius
- Nelson's Sparrow Home Range Radius - 0.4mi

Figure III.1-2
2016-2017 Penobscot River Sediment Sampling Locations Used in the BERA for Nelson's Sparrow

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

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Project: 3616166052	Prepared/Date: RD 8/9/2018	Checked/Date: NSR 8/9/2018

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Note:
Home range radius surrounding receptor sampling locations

Legend
- Biota Sampling Location
- Sediment Sample Used for Red-winged Blackbird
- Sediment Sample Outside of Radius
- Red-winged Blackbird Home Range Radius - 300ft

Mendall Marsh Geographic Area Label

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Figure III.1-3
2016-2017 Penobscot River Sediment Sampling Locations Used in the BERA for Red-winged Blackbird

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

Project: 3616166052 | Prepared/Date: RD 8/9/2018 | Checked/Date: NSR 8/9/2018

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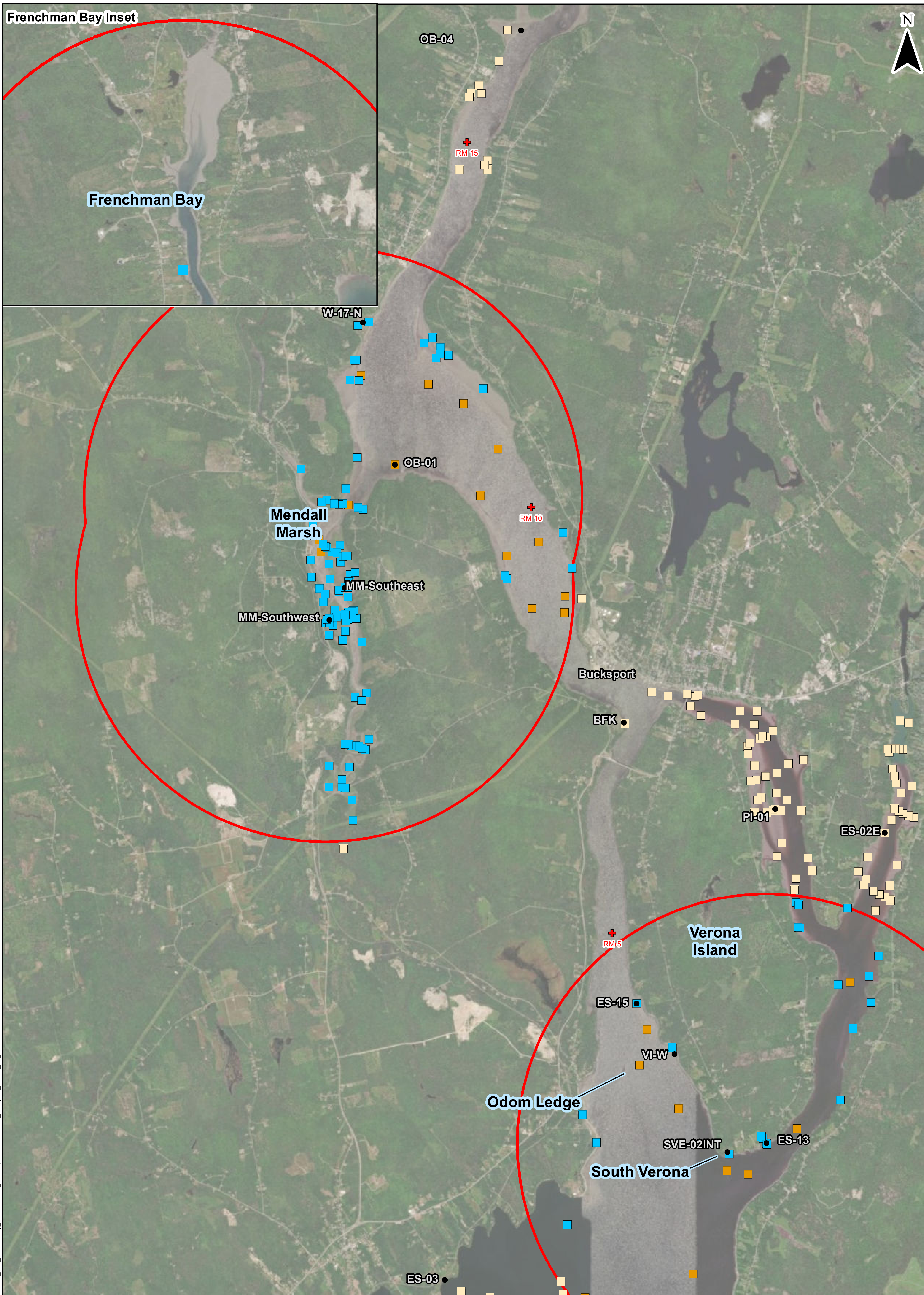

Note:
Home range radius surrounding receptor sampling locations

Mendall Marsh Geographic Area Label

Legend

- River Mile Marker
- Biota Sampling Location
- Sediment Sample Used for Black Duck
- Subtidal Sediment Sample Not Used for Black Duck
- Sediment Sample Outside of Radius
- Black Duck Home Range Radius - 2.5mi

Figure III.1-4
2016-2017 Penobscot River Sediment Sampling Locations Used in the BERA for American Black Duck

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 8/9/2018	Checked/Date: NSR 8/9/2018

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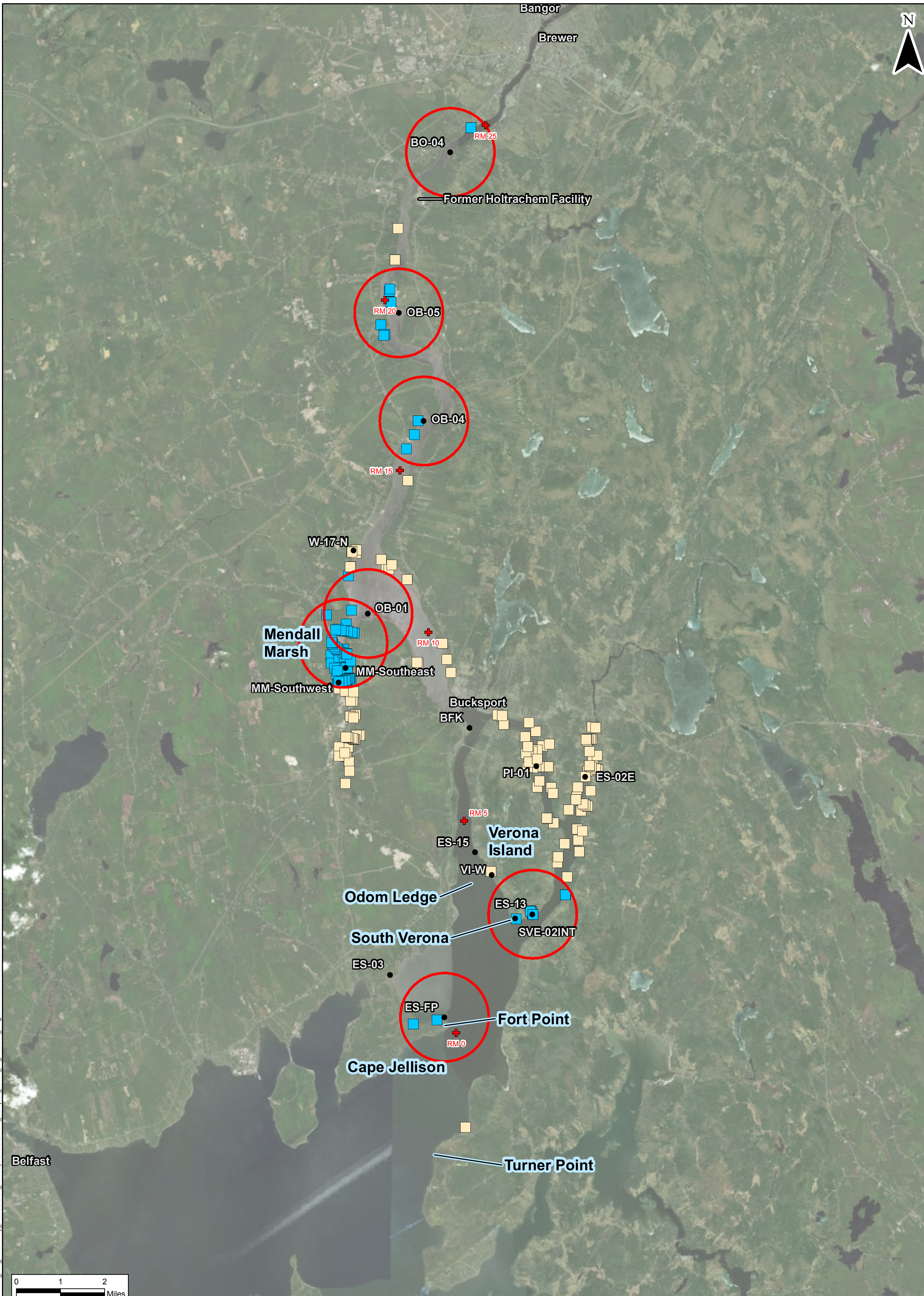

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Note:
Home range radius surrounding receptor's prey item sampling location.

South Verona Geographic Area Label

Legend

- Biota Sampling Location
- River Mile Marker
- Sediment Sample Used for Belted Kingfisher
- Sediment Sample Outside of Radius
- Belted Kingfisher Home Range Radius - 1.0 mile

Figure III.1-5
2016-2017 Sediment Sampling Locations Used in the BERA for Belted Kingfishers

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 2/1/2018	Checked/Date: NSR 2/1/2018

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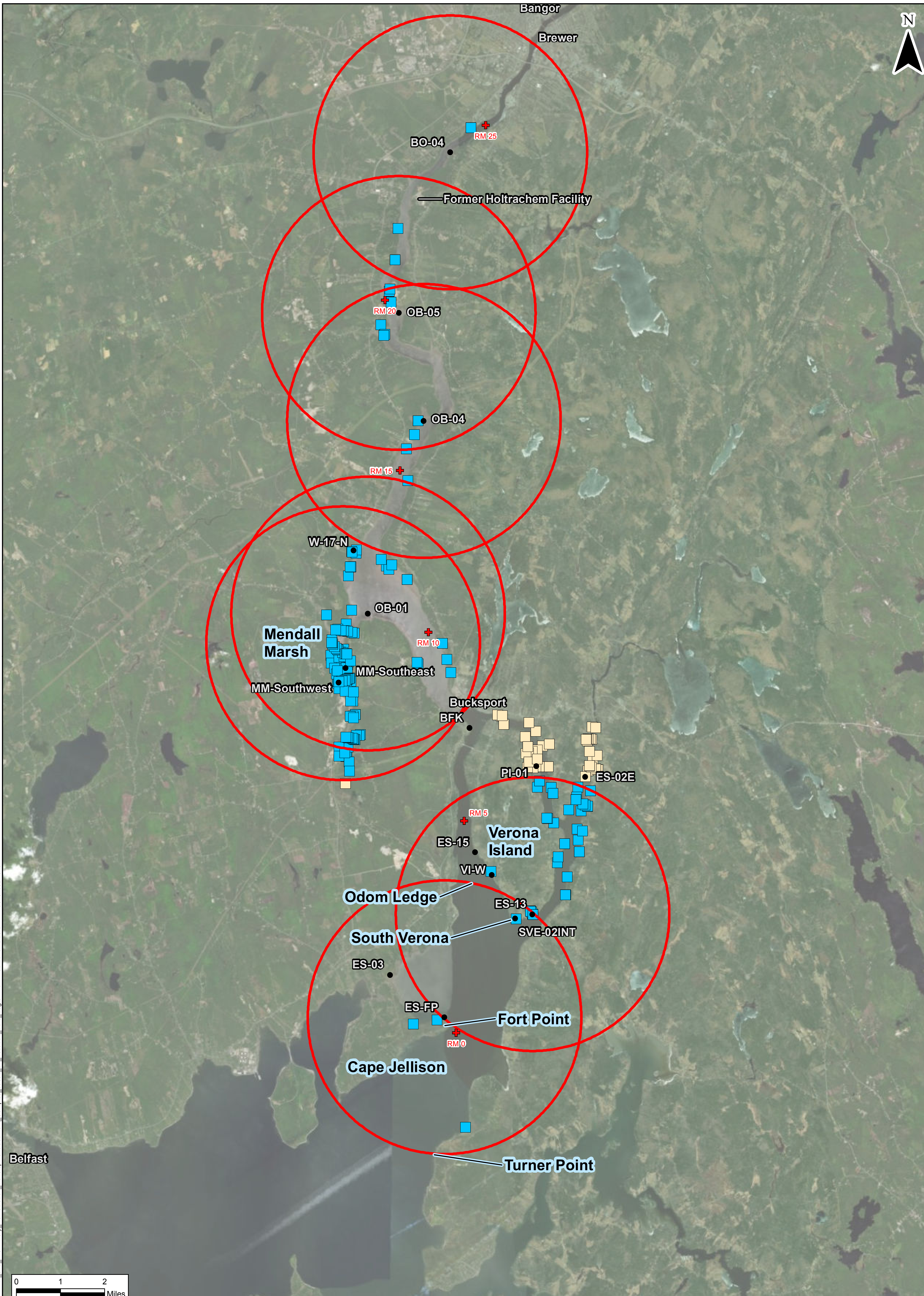

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Note:
Home range radius surrounding receptor's prey item sampling location.

Legend

- River Mile Marker
- Biota Sampling Location
- Sediment Sample Used for Bald Eagle
- Sediment Sample Outside of Radius
- Bald Eagle Home Range Radius - 3.1 miles

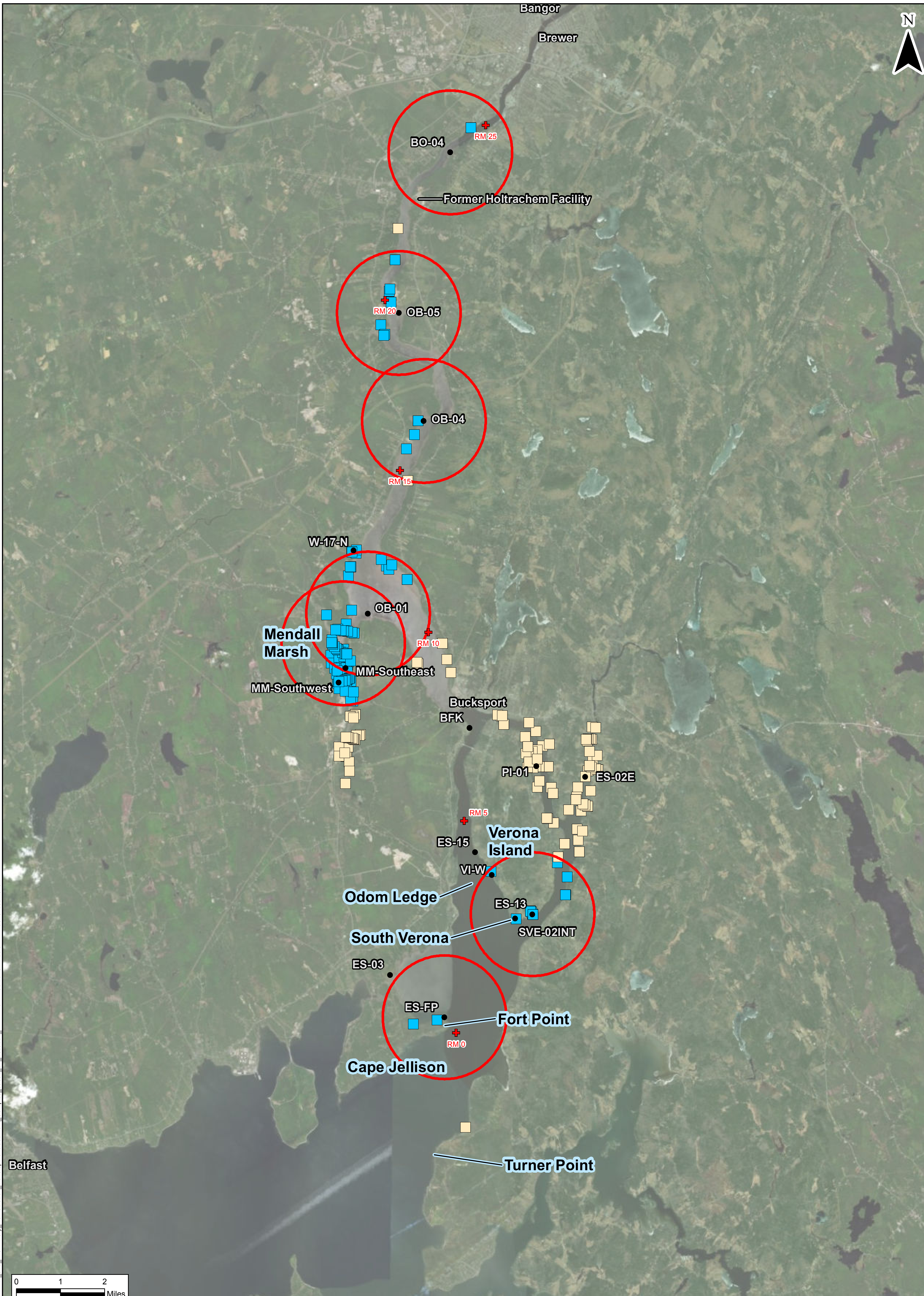
South Verona — Geographic Area Label

Figure III.1-6
2016-2017 Sediment Sampling Locations Used in the BERA for Bald Eagles

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 2/1/2018	Checked/Date: NSR 2/1/2018

Document:G:\Penobscot River\mxds\Report_Figures_2017\RA_and_Preliminary_Remediation_Development\Sediment_Samples_based_on_Location_Bald_Eagle.mxd 1/30/2018 10:59:31 AM rachel.desmond



Note:
Home range radius surrounding receptor's prey item sampling location.

Legend

- River Mile Marker
- Biota Sampling Location
- Sediment Sample Used for Mink
- Sediment Sample Outside of Radius
- Mink Home Range Radius - 1.4 miles
- **South Verona** Geographic Area Label

Figure III.1-7
2016-2017 Sediment Sampling Locations
Used in the BERA for Mink

Penobscot River Risk Assessment and
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Penobscot River Phase III Engineering Study

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Project: 3616166052	Prepared/Date: RD 2/1/2018	Checked/Date: NSR 2/1/2018

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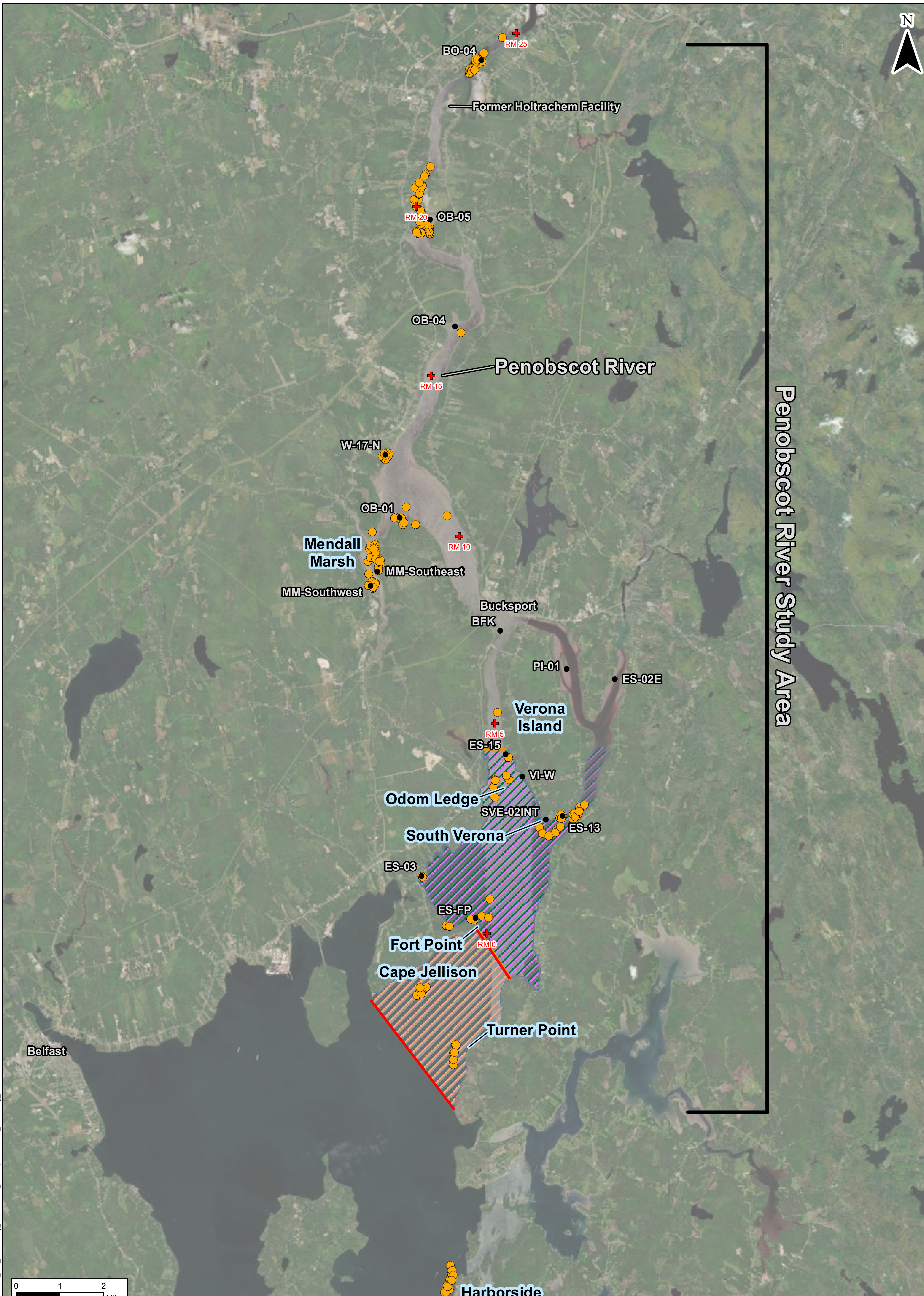

Note:
Biota sample locations do not include spiders, terrestrial insects, or polychaete samples

Legend

- River Mile Marker
- Biota Sampling Location
- Biota Sample
- 2014 Closure Line
- 2016 Closure Line
- 2014 Closure
- 2016 Closure
- **Mendall Marsh** Geographic Area Label

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Figure III.1-8
2016-2017 Penobscot River
Biota Samples

Penobscot River Risk Assessment and
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Penobscot River Phase III Engineering Study

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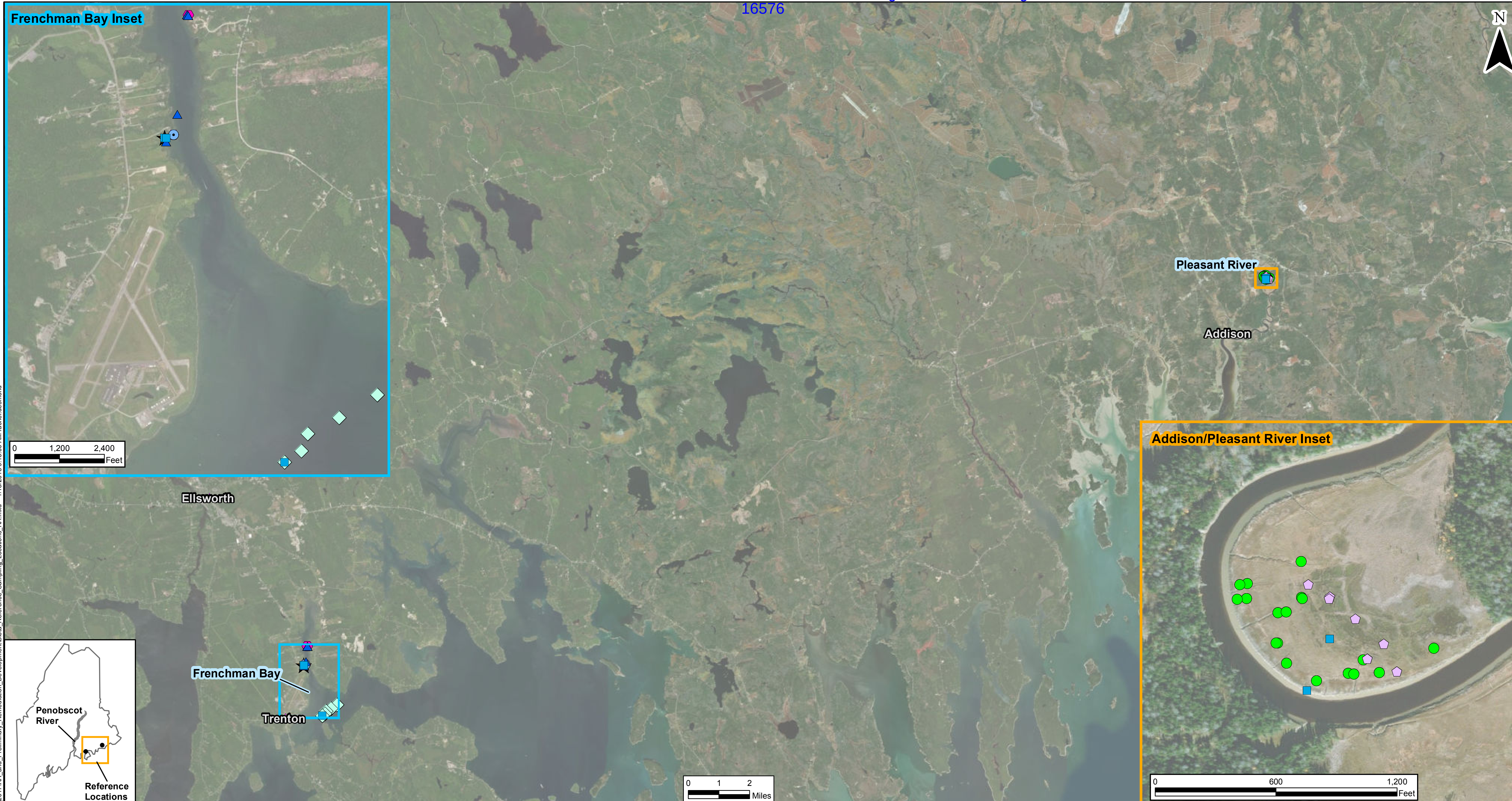

Legend

- Sediment Sample
- Blue Mussel Sample
- Lobster Sample
- Fish Sample (Mummichog, Rainbow Smelt, and Tomcod)
- American Black Duck Sample
- Nelson's Sparrow Sample
- Polychaete Sample
- Spider and Terrestrial Insect Sample
- **Pleasant River** Geographic Area Label

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Figure III.1-9
2016-2017 Biota and Sediment Reference Sampling Locations

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

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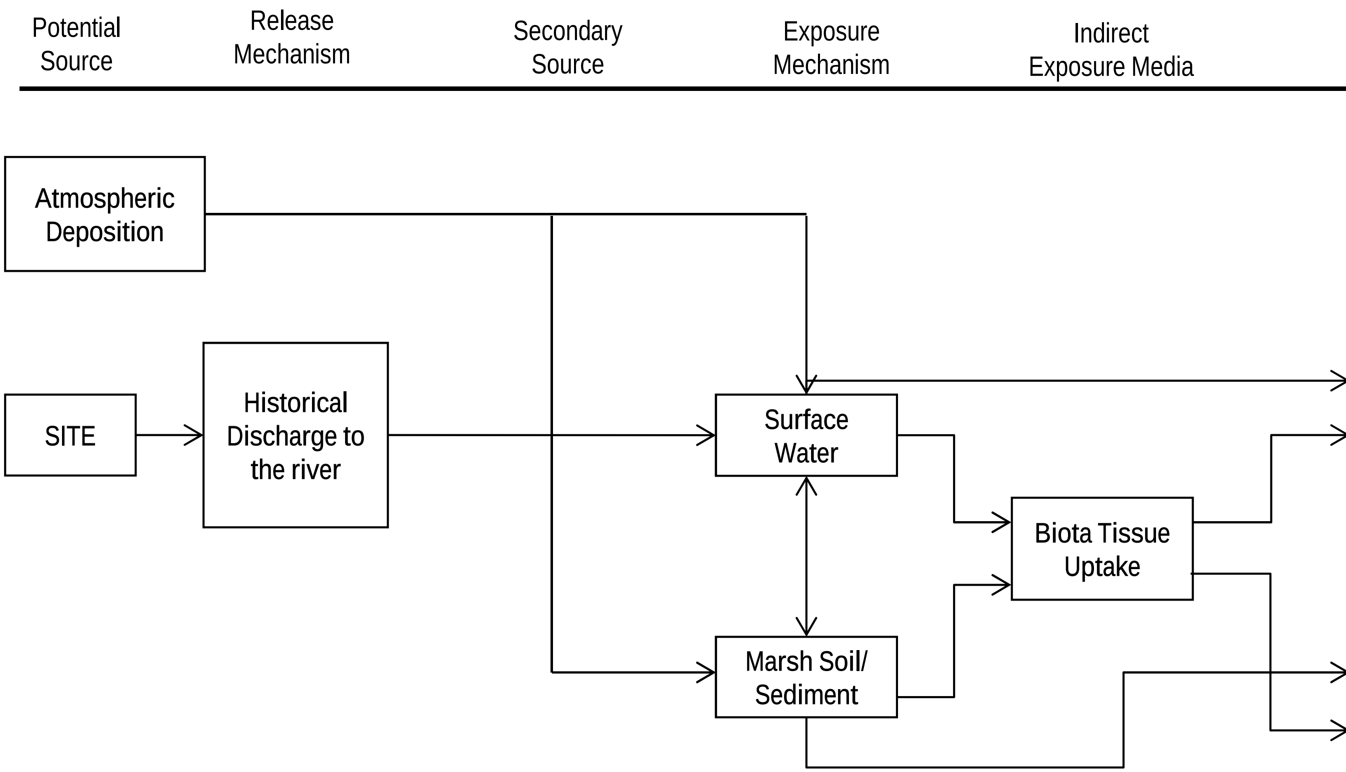
Document: G:\Penobscot River\mxds\Report_Figures_2017\RA_and_Preliminary_Remediation_Development\Biota_Reference_Sampling_Locations_RA.mxd 1/18/2018 9:18:00 AM rachel.desmond

Figure III.2-1
Conceptual Exposure Model – Ecological Receptors

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study



Surface Water exposure routes:

Exposure Route	Lobster	Mussel	Forage Fish	Predatory Fish	Aquatic Bird	Marsh Songbird	Belted Kingfisher	Bald Eagle	Mink
Direct Contact	○	●	○	○	(A)	(A)	(A)	(A)	(A)
Ingestion			○	○	○	○	○	○	○
Food Chain	(B)	(B)	●	●	●	●	●	●	●

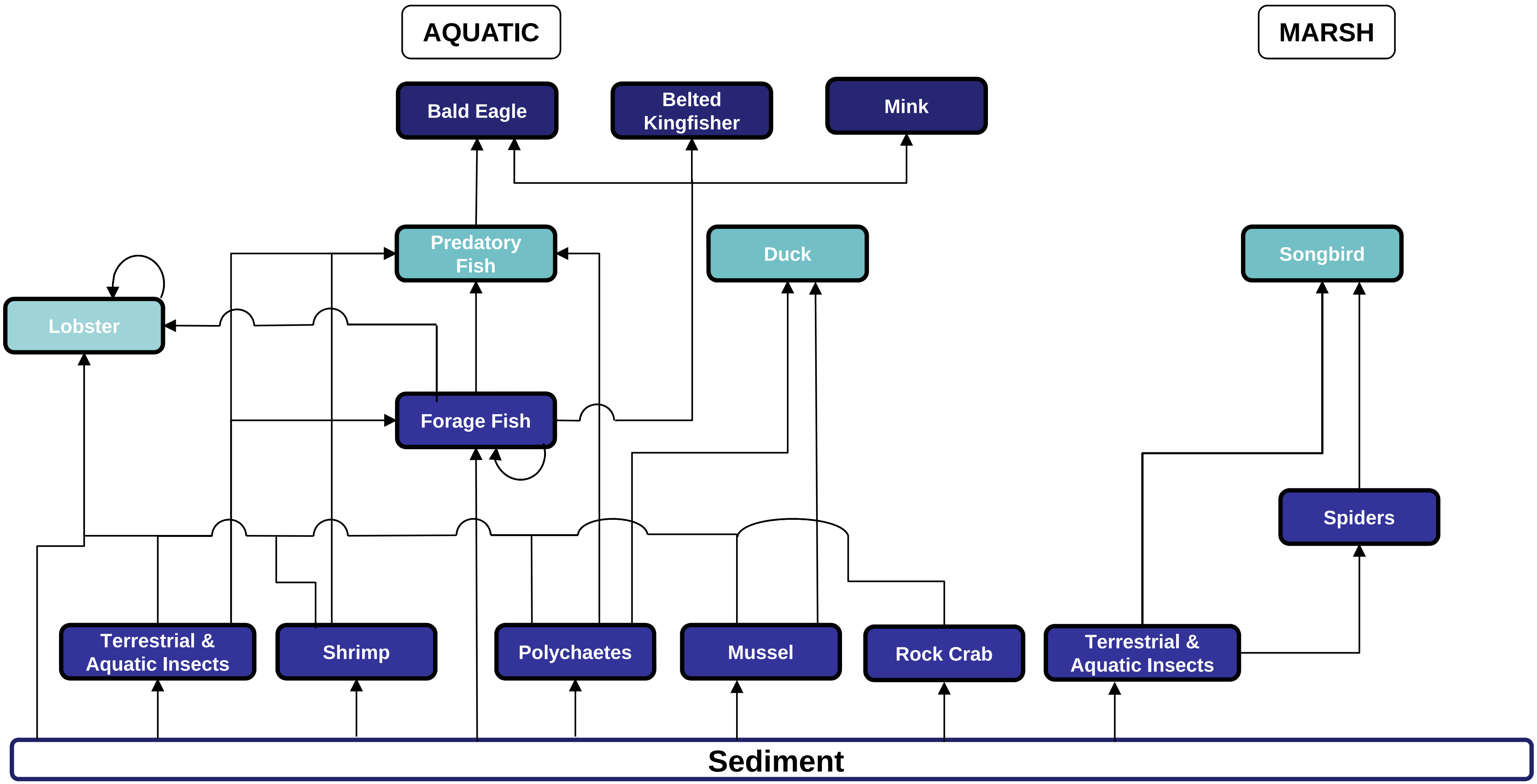
Marsh Soil/Sediment exposure routes:

Exposure Route	Lobster	Mussel	Forage Fish	Predatory Fish	Aquatic Bird	Marsh Songbird	Belted Kingfisher	Bald Eagle	Mink
Direct Contact	○	○	(A)	(A)	(A)	(A)	(A)	(A)	(A)
Ingestion					●	●	●	●	●
Food Chain	(B)	(B)	●	●	●	●	●	●	●

- ● Exposure pathway quantitatively evaluated in BERA
- ○ Exposure pathway potential occurs but not quantitatively evaluated in BERA
- (A) Direct contact with media not traditionally assessed in BERA
- (B) Tissue Uptake quantitatively evaluated in BERA
- —— Quantitatively Evaluated Migration Pathway

Prepared by: IMR 01/16/18
Checked by: NSR 01/16/18

DRAFT

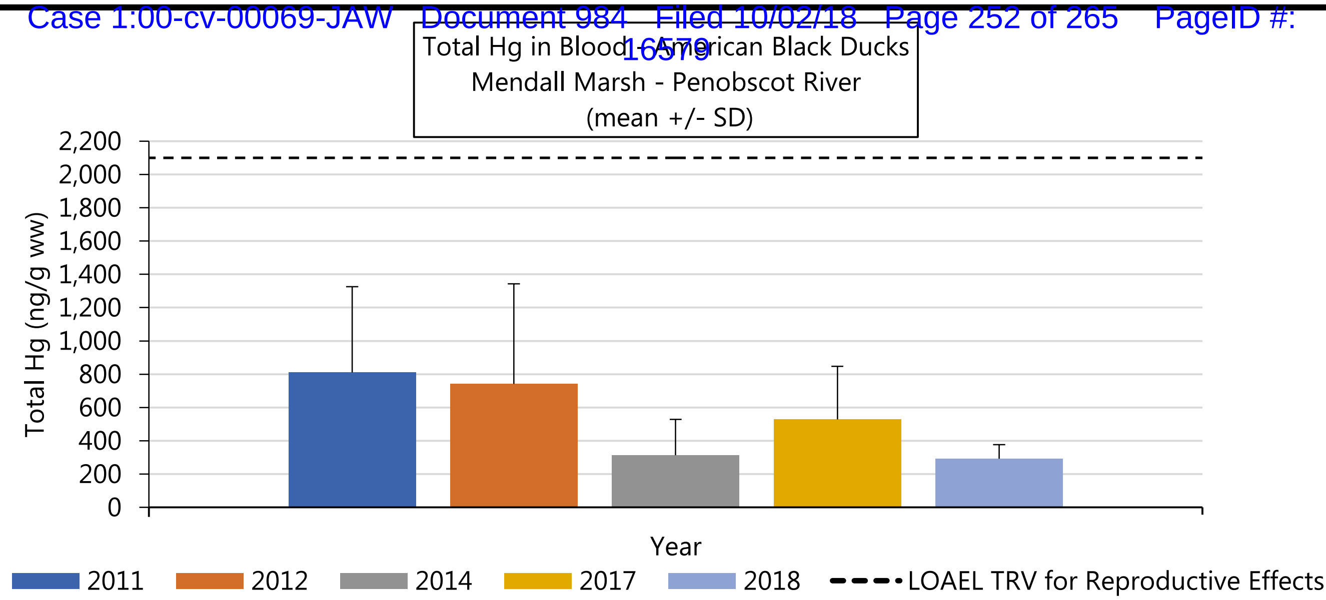


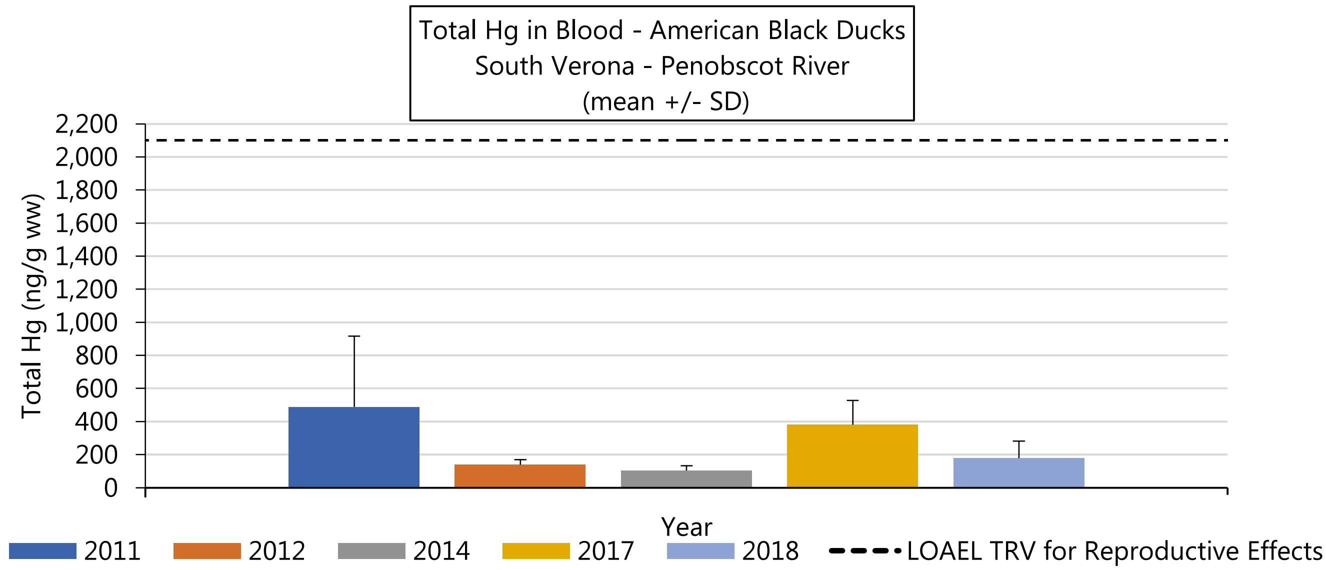
Penobscot River Risk Assessment and Preliminary Remediation Goal Development

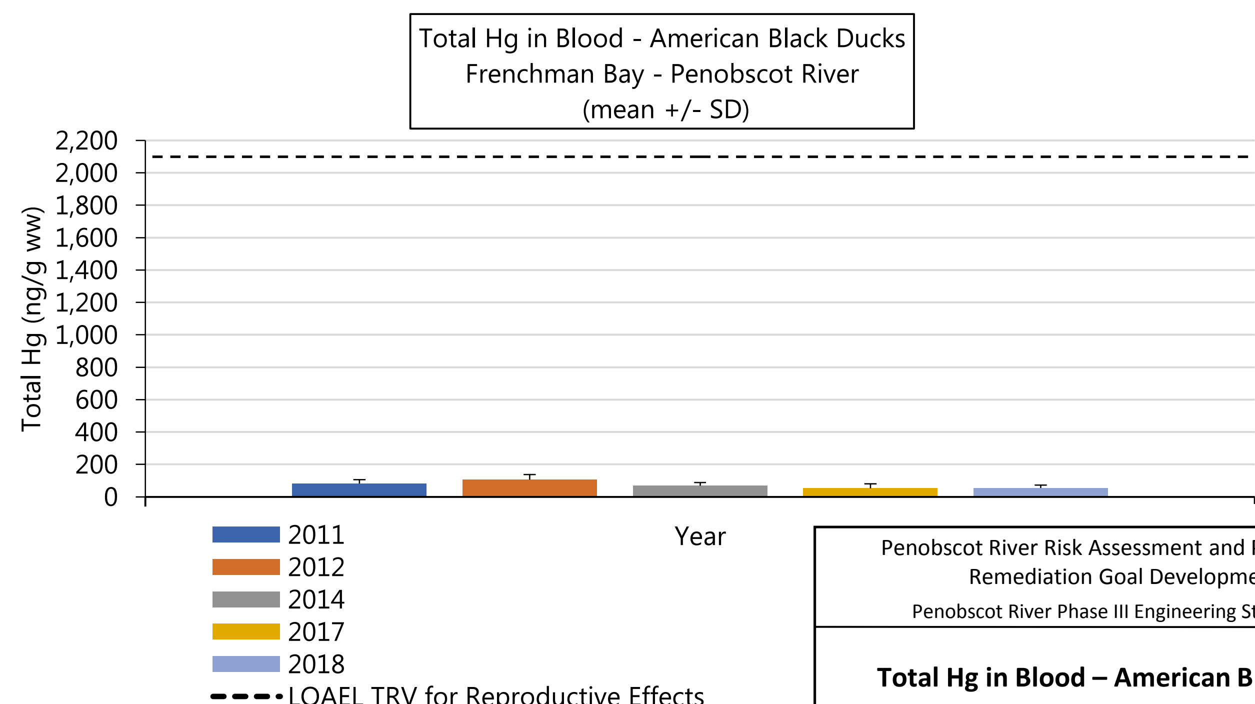
Penobscot River Phase III Engineering Study

Food Web Model for BERA

Prepared by/Date: LO 04/11/18	amec foster wheeler	FIGURE III.2-2
Checked by/Date: NSR 08/09/18		
Project Number: 3616166052		







Penobscot River Risk Assessment and Preliminary Remediation Goal Development

Penobscot River Phase III Engineering Study

Total Hg in Blood – American Black Ducks

Prepared by/Date: RRP 08/02/18

Checked by/Date: LO 08/10/18

Project Number: 3616166052

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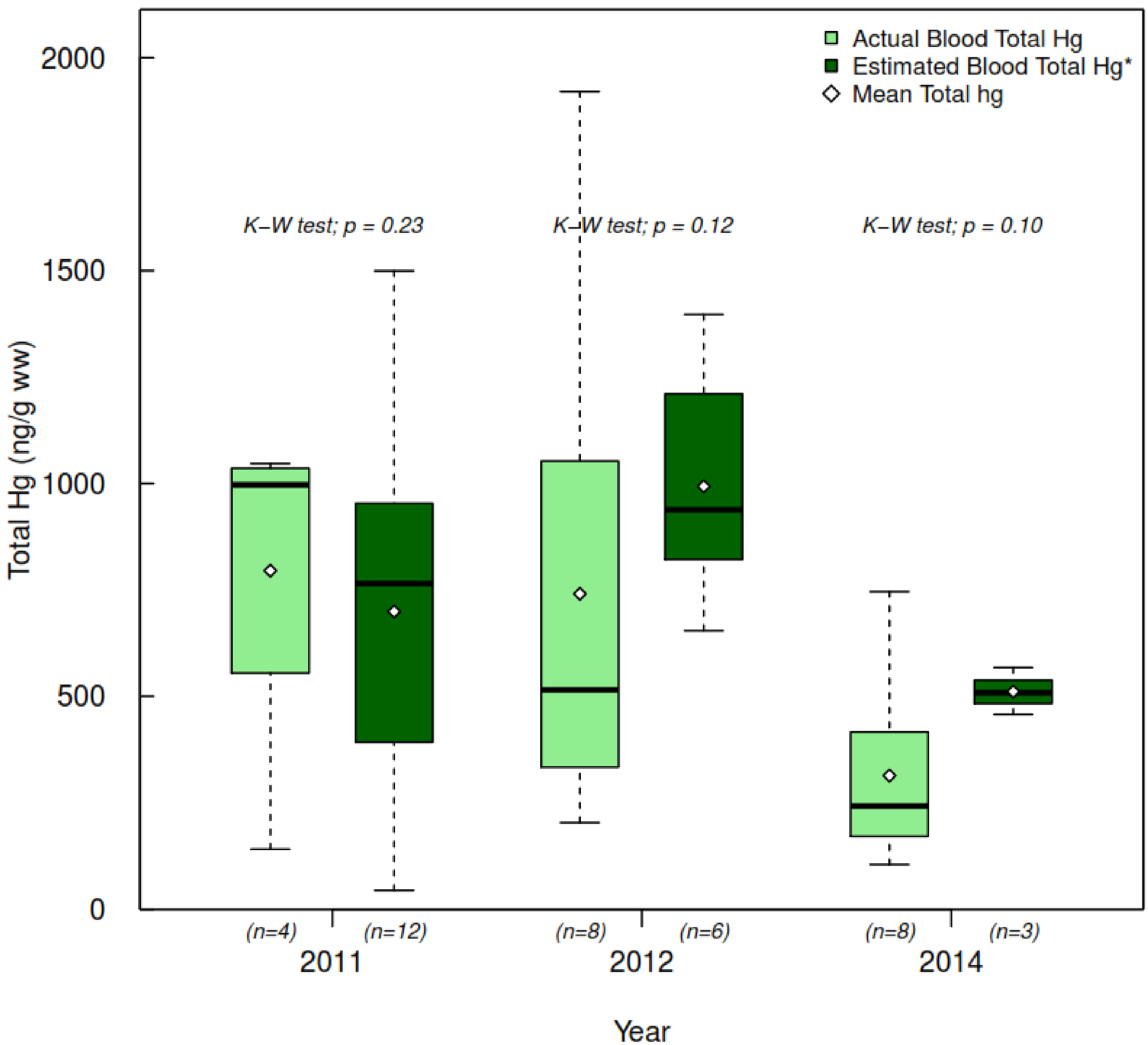
FIGURE

III.5-1a

Comparison of Actual to Estimated Total Hg in Duck Blood at Mendall Marsh**

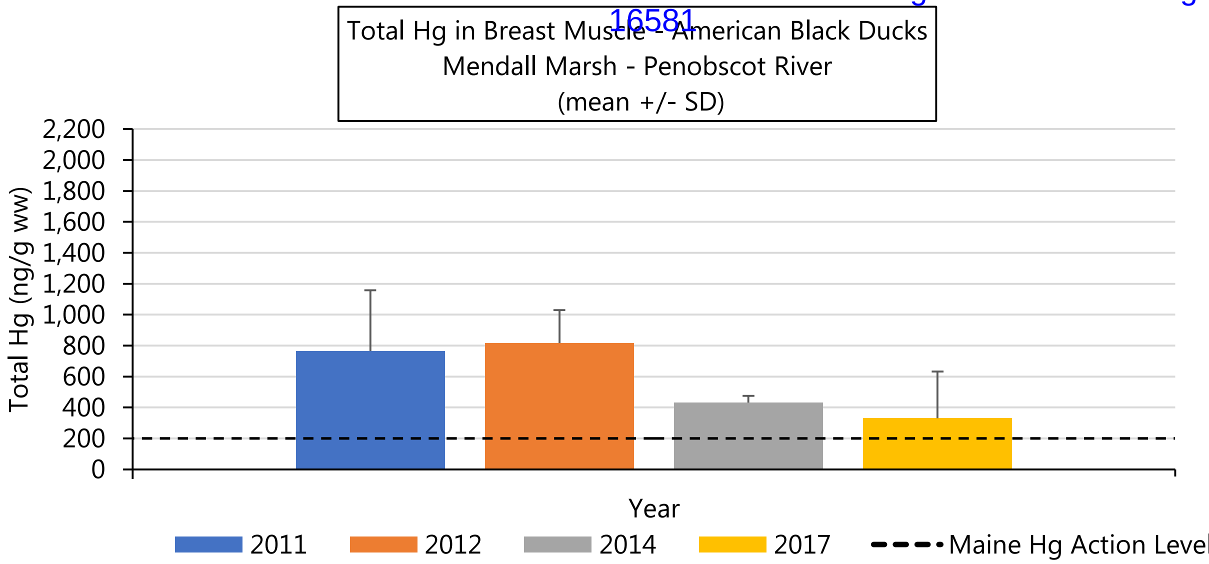


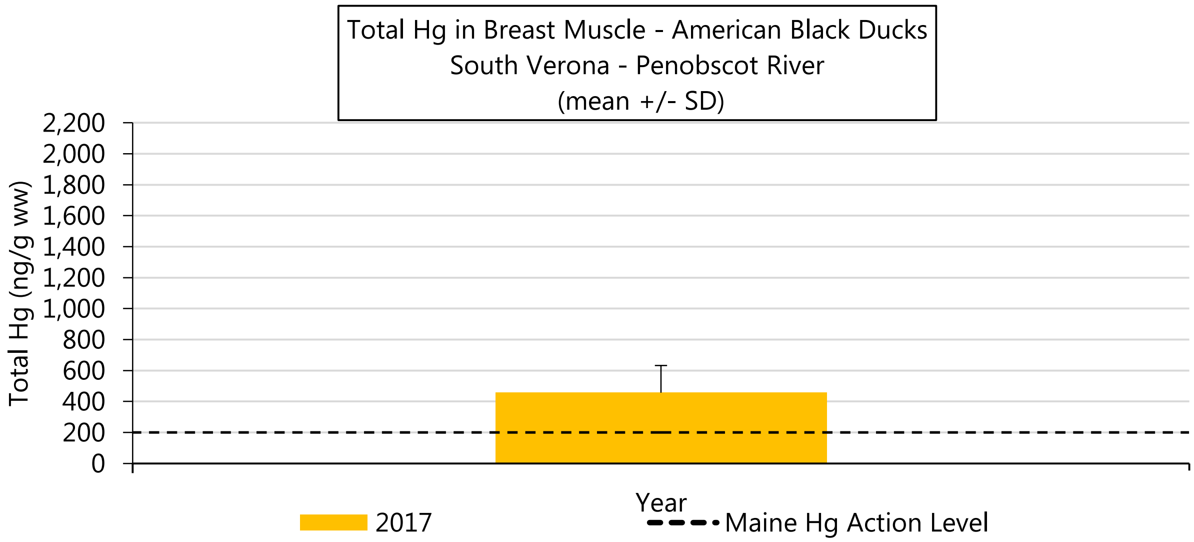
*Blood concentrations estimated from a significant, positive correlation between blood and muscle tissue mercury concentrations that was developed for black duck in the 2016 Biota Monitoring Report (Amec Foster Wheeler 2017a)

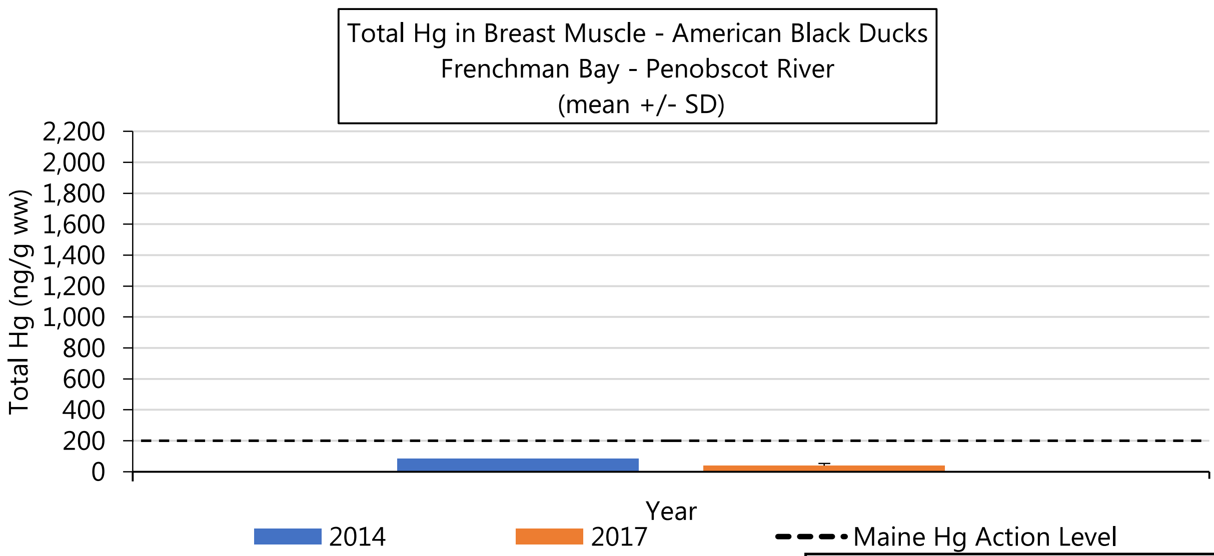
**Only samples with non-paired blood and muscle results included in evaluation

K-W test: Kruskall-Wallis Rank Sum Test

Penobscot River Risk Assessment and Preliminary Remediation Goal Development Penobscot River Phase III Engineering Study	
Comparison of Actual to Estimated Total Hg in Duck Blood at Mendall Marsh	
Prepared by/Date: LO 08/16/18 Checked by/Date: LSV 08/16/18 Project Number: 3616166052	amec foster wheeler FIGURE **III.5-1b**







Penobscot River Risk Assessment and Preliminary Remediation Goal Development

Penobscot River Phase III Engineering Study

Total Hg in Breast Muscle – American Black Ducks

Prepared by/Date: RRP 08/02/18

Checked by/Date: LO 08/10/18

Project Number: 3616166052

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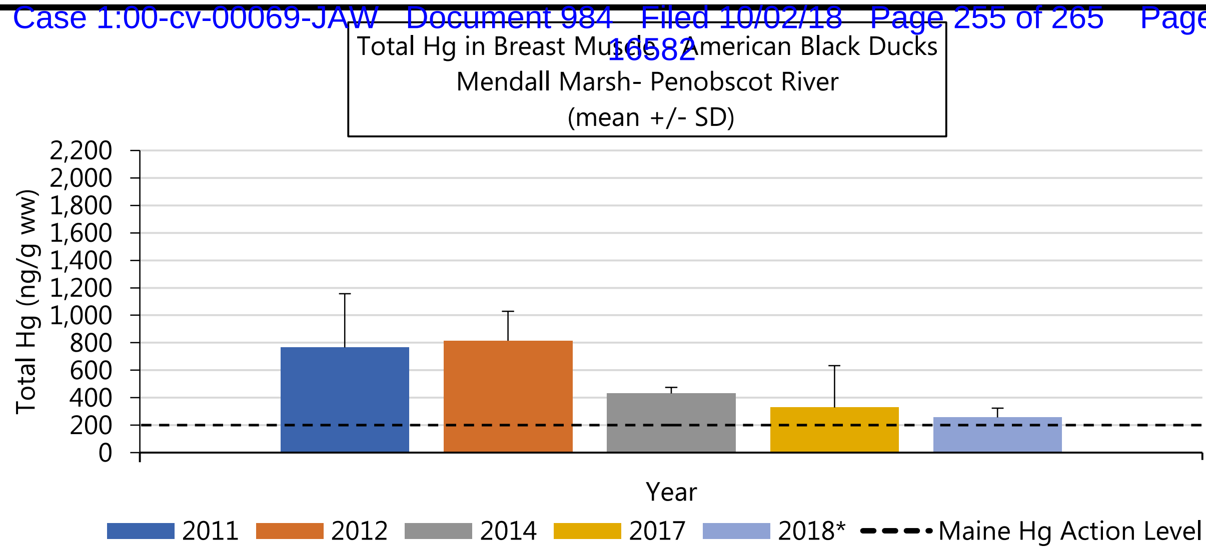
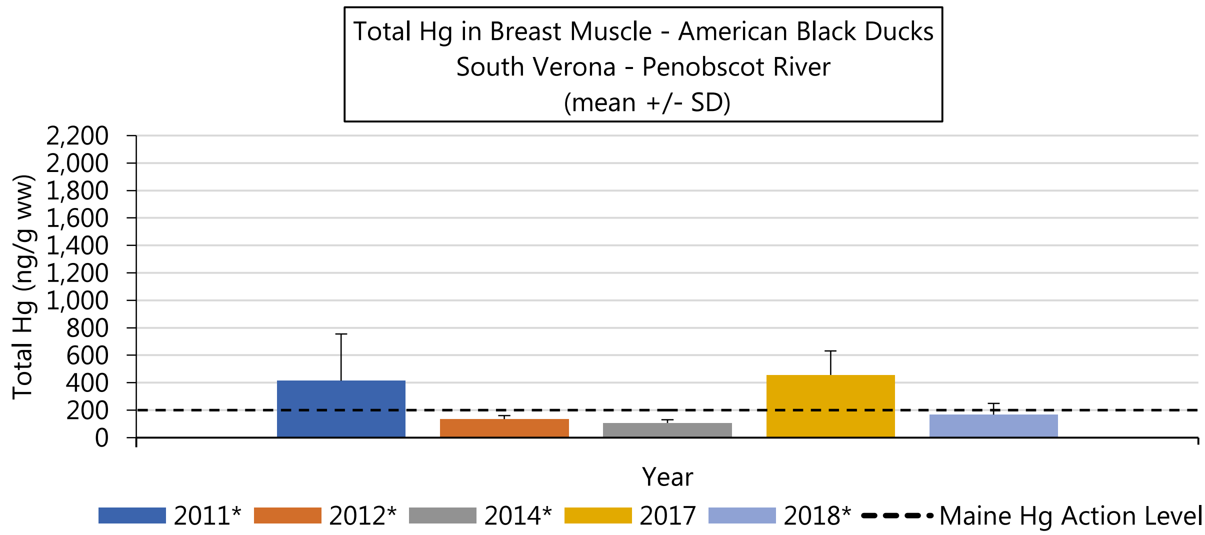
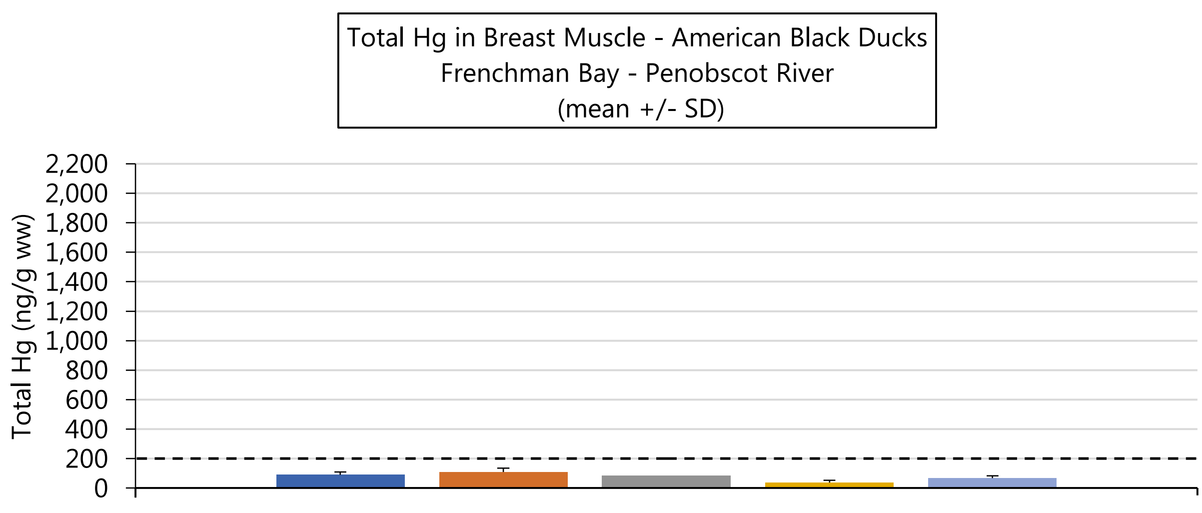
FIGURE

III.5-1c







*Breast muscle tissue concentrations estimated from a significant, positive correlation between blood and muscle tissue mercury concentrations that was developed for black duck in the 2016 Biota Monitoring Report (Amec Foster Wheeler 2017a)

Penobscot River Risk Assessment and Preliminary Remediation Goal Development

Penobscot River Phase III Engineering Study

Total Hg in Breast Muscle – American Black Ducks (with estimated tissue concentrations from blood)

Prepared by/Date: RRP 08/02/18
Checked by/Date: LO 08/10/18
Project Number: 3616166052

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FIGURE
III.5-1d

Legend

- River Mile Marker
- Biota Sampling Location

Sample Type

- Blood Sample Location
- Egg Sample Location

Piscivorous Avian Receptors

- Belted Kingfisher Sample
- Black Guillemot Sample
- Double-crested Cormorant Sample
- Eagle Sample
- Osprey Sample

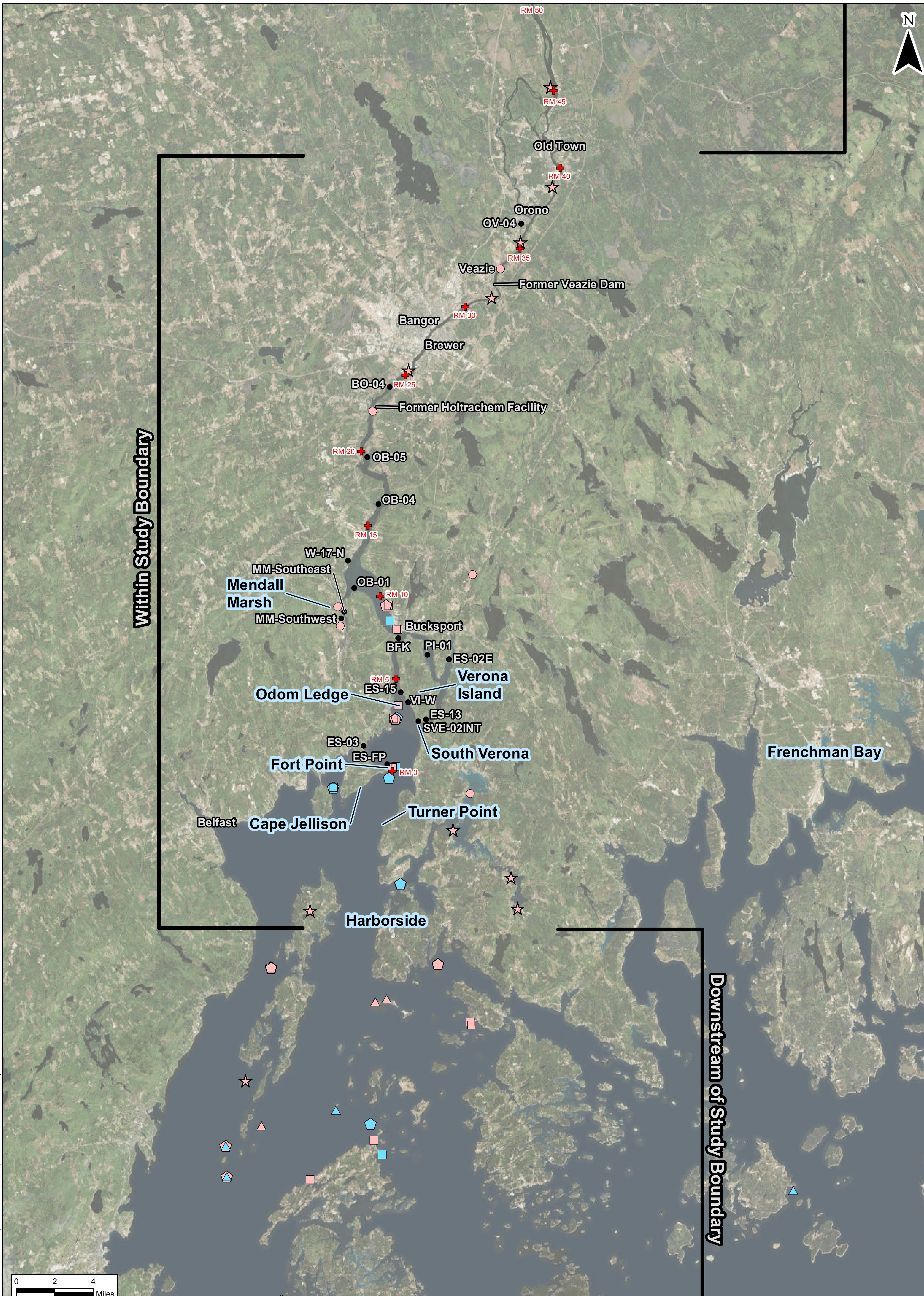
South Verona Geographic Area Label

amec foster wheeler

Figure III.5-2a
Historical Piscivorous Avian Receptors
Used in the BERA - Upstream of Study Boundary

Penobscot River Risk Assessment and
Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 8/17/2018	Checked/Date: NSR 8/17/2018



Legend

River Mile Marker	**Piscivorous Avian Receptors**	
Biota Sampling Location	Belted Kingfisher Sample	
Sample Type	Black Guillemot Sample	
Blood Sample Location	Double-crested Cormorant Sample	
Egg Sample Location	Eagle Sample	South Verona — Geographic Area Label
	Osprey Sample	

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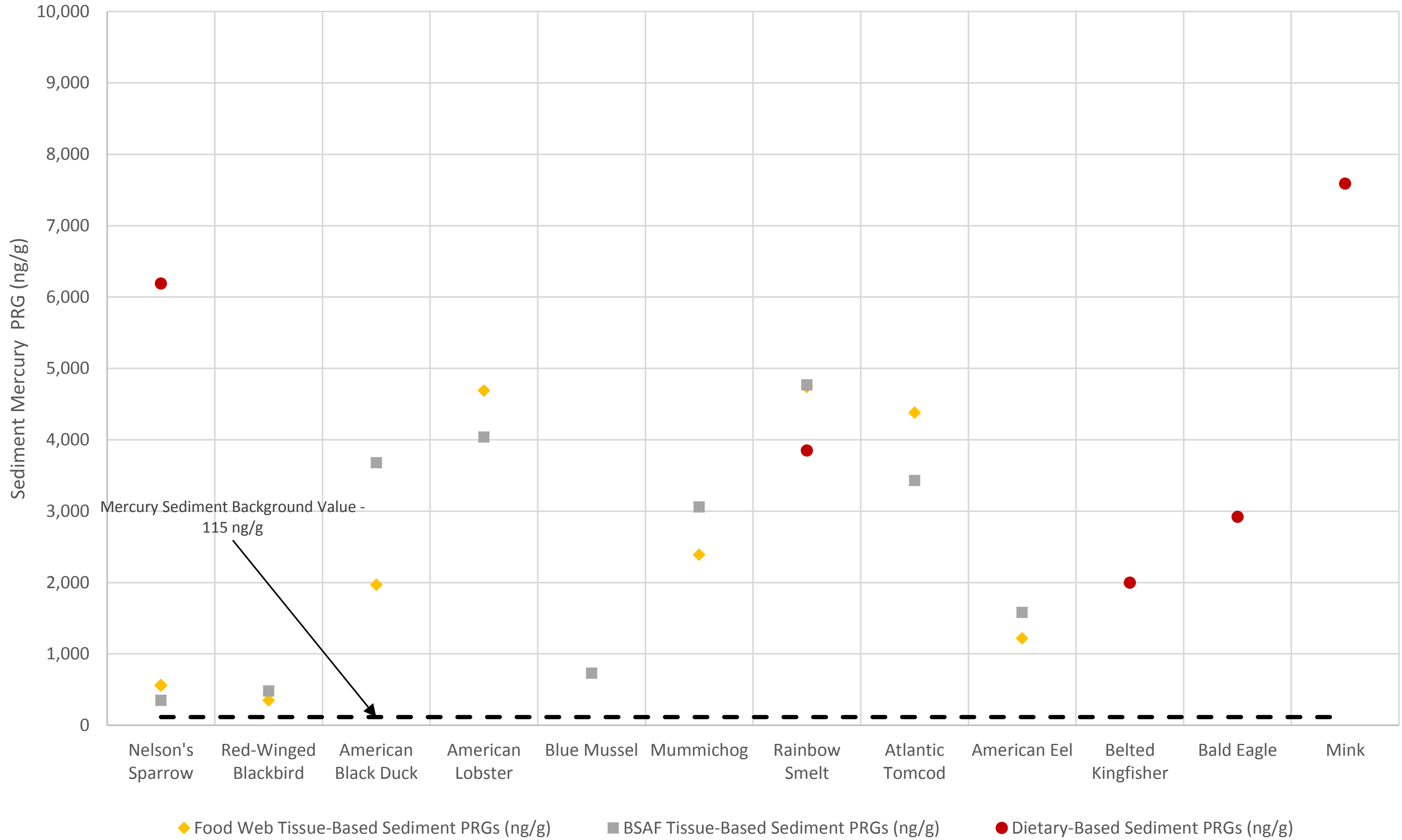
Figure III.5-2b
Historical Piscivorous Avian Receptors Used in the BERA - Within and Downstream of Study Boundary

Penobscot River Risk Assessment and Preliminary Remediation Goal Development
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 8/17/2018	Checked/Date: NSR 8/17/2018

Document:G:\Penobscot River\mxds\Report_Figures_2017\RA_and_Preliminary_Remediation_Development\Piscivorous_Avian_Receptors_for_BERA_south.mxd 8/17/2018 1:47:30 PM rachel.desmond

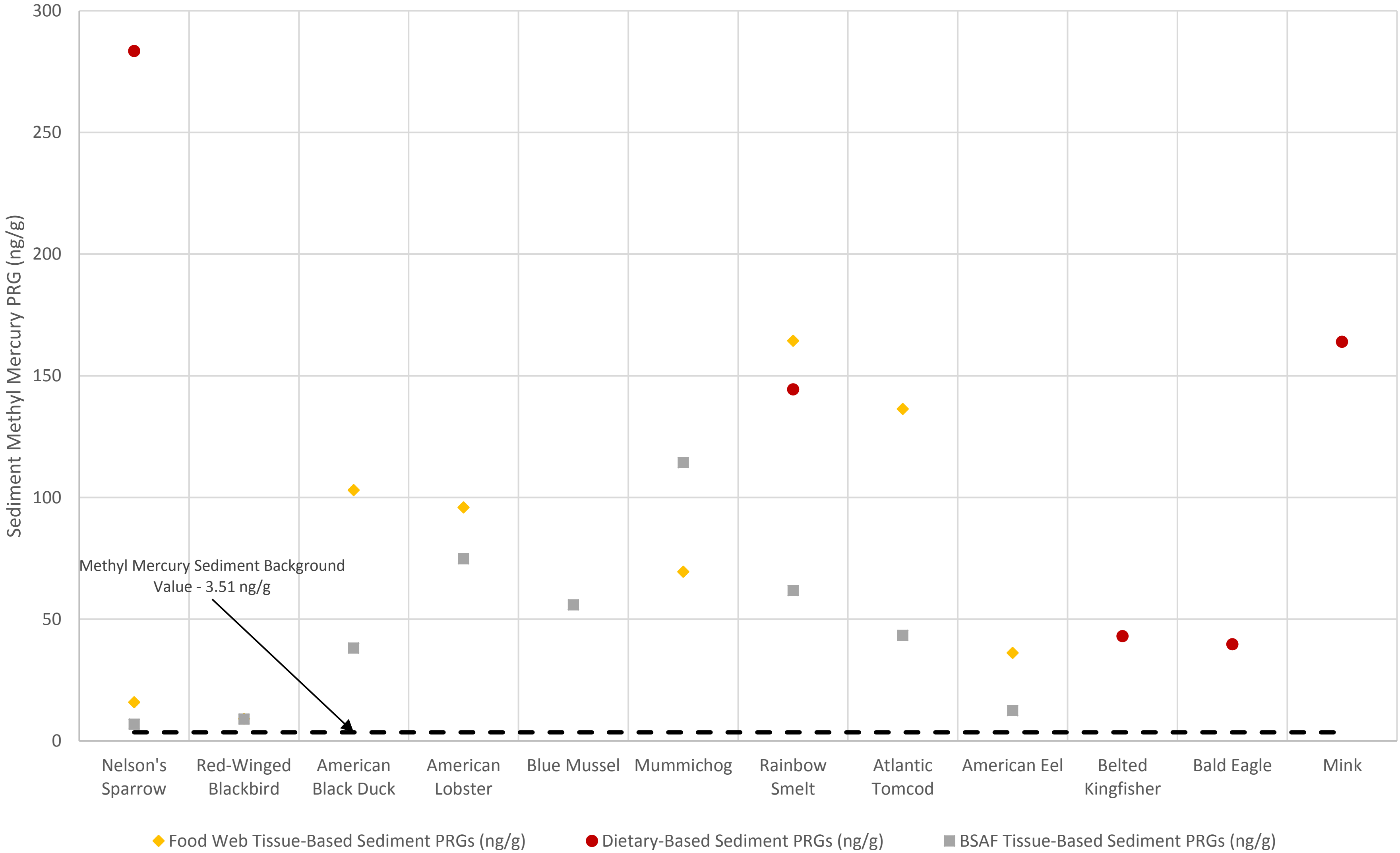
FIGURE IV.4-1
RANGE OF ECOLOGICAL SEDIMENT PRGs BY SPECIES - TOTAL MERCURY
Penobscot River Phase III Engineerring Study
Penobscot River Estuary, Maine



Note: PRG values above 10,000 ng/g for mercury were not included in this chart for purposes of resolution.

Prepared by: IMR 08/15/18
Checked by: LO 08/15/18

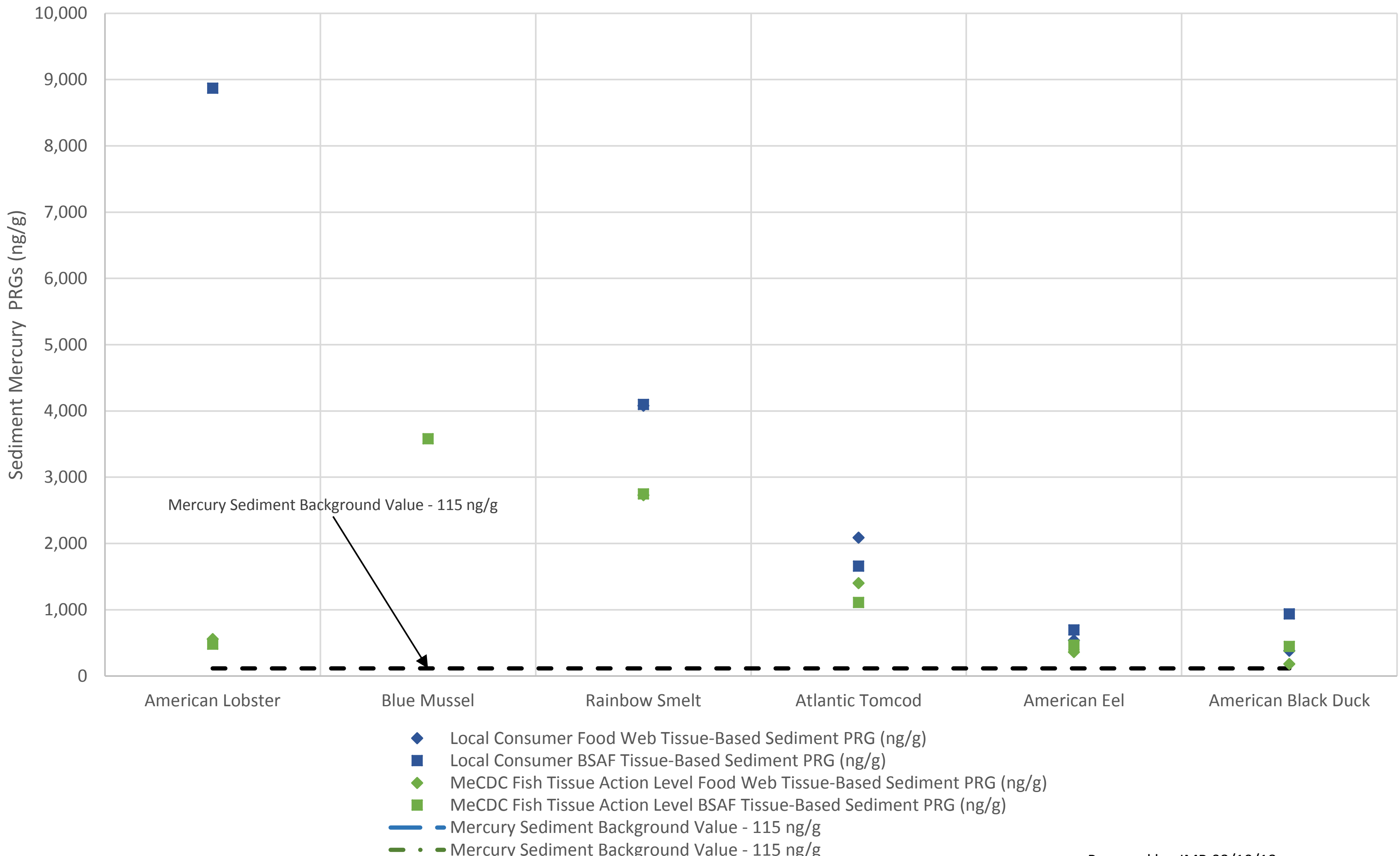
FIGURE IV.4-2
RANGE OF ECOLOGICAL SEDIMENT PRGs BY SPECIES - METHYL MERCURY
Penobscot River Phase III Engineerring Study
Penobscot River Estuary, Maine



Prepared by: IMR 08/15/18
Checked by: LO 08/15/18

Note: PRG values above 300 ng/g for methyl mercury were not included in this chart for purposes of resolution.

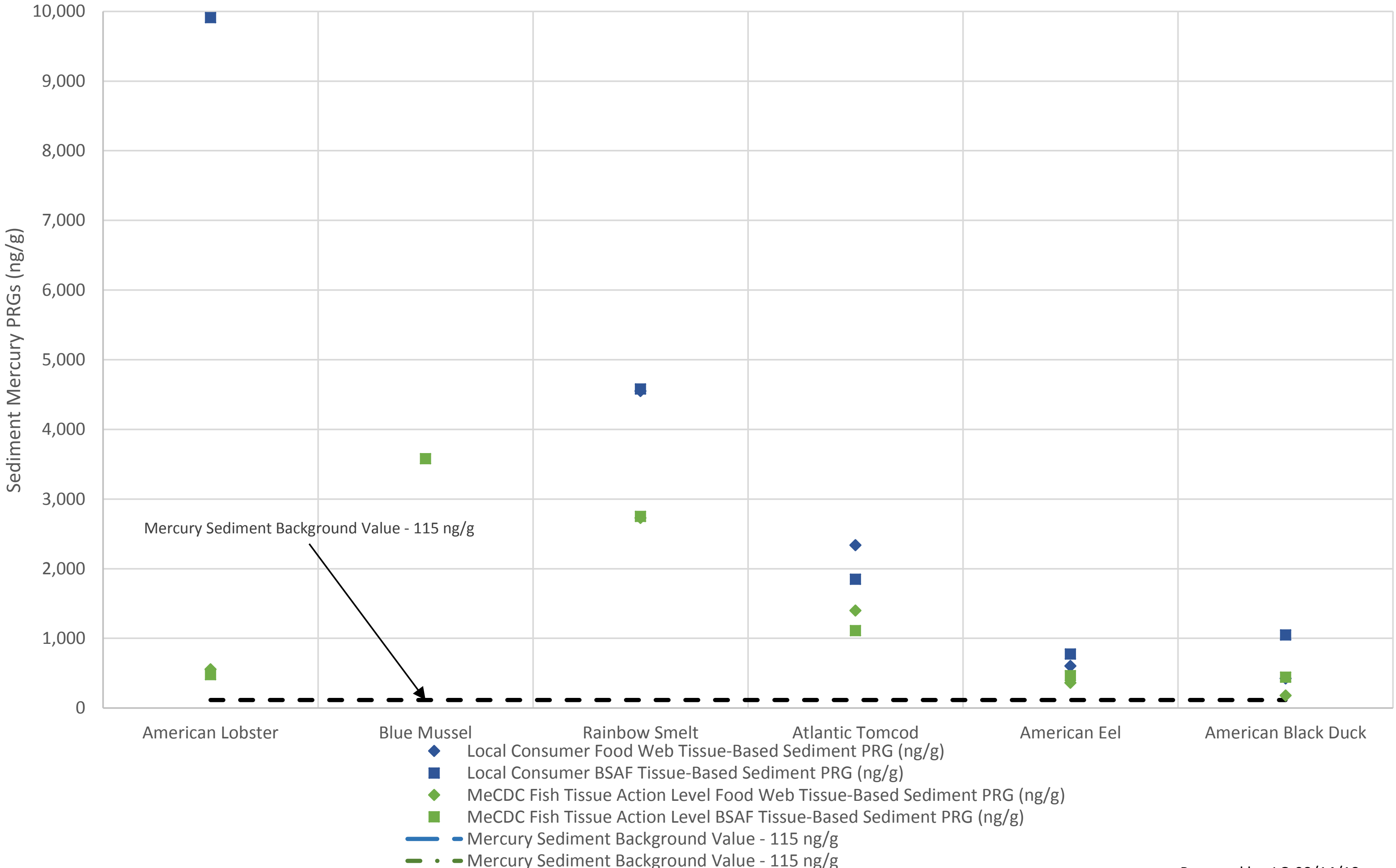
FIGURE IV.4-3
RANGE OF HUMAN HEALTH SEDIMENT PRGs BY SPECIES - TOTAL MERCURY, CHILD RECEPTOR
Penobscot River Phase III Engineerring Study
Penobscot River Estuary, Maine



Note: PRG values above 10,000 ng/g for mercury were not included in this chart for purposes of resolution.

Prepared by: IMR 08/10/18
Checked by: LMS 08/10/18

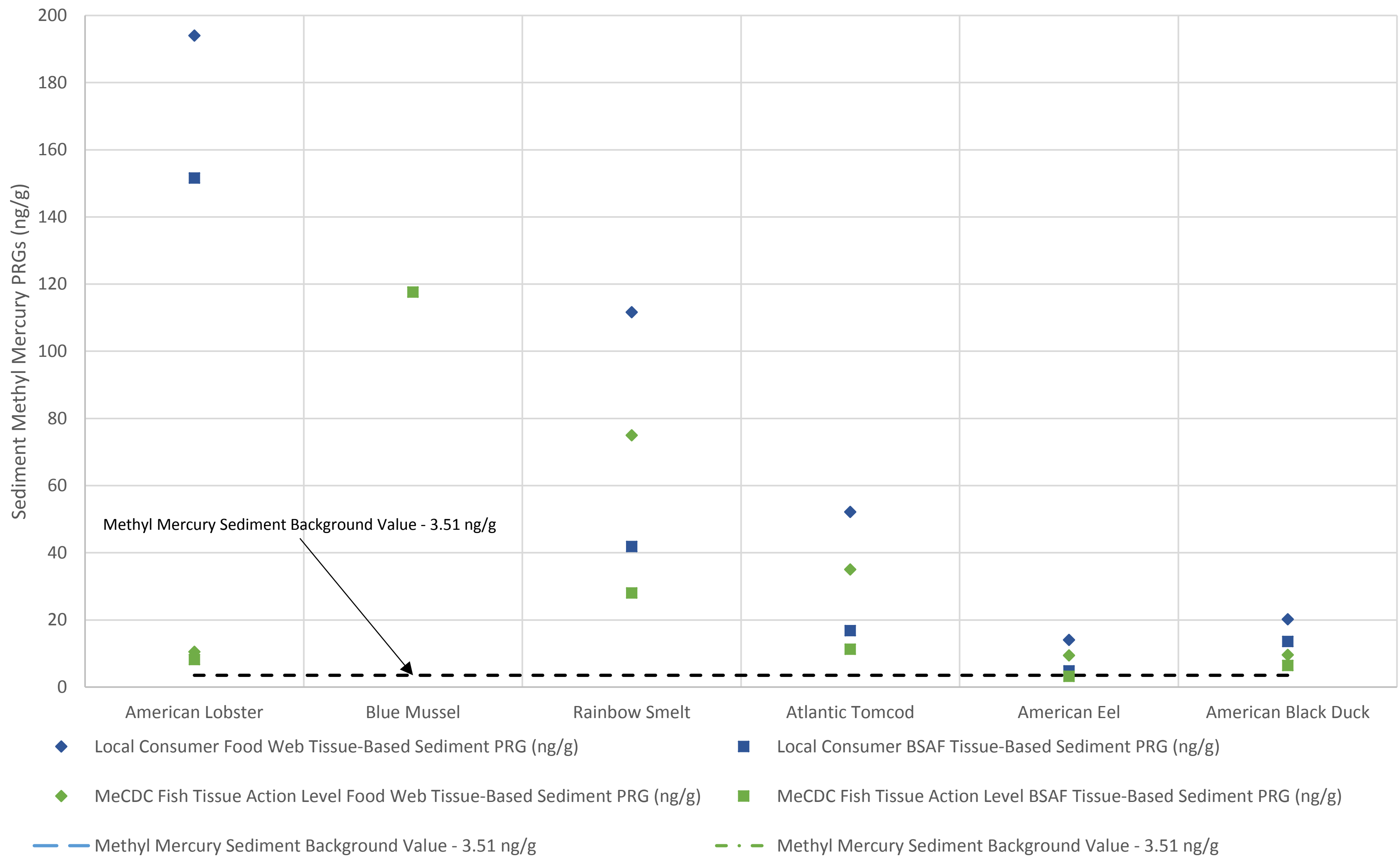
FIGURE IV.4-4
RANGE OF HUMAN HEALTH SEDIMENT PRGs BY SPECIES - TOTAL MERCURY, ADULT RECEPTOR
Penobscot River Phase III Engineerring Study
Penobscot River Estuary, Maine



Note: PRG values above 10,000 ng/g for mercury were not included in this chart for purposes of resolution.

Prepared by: LO 08/14/18
Checked by: IMR 08/15/18

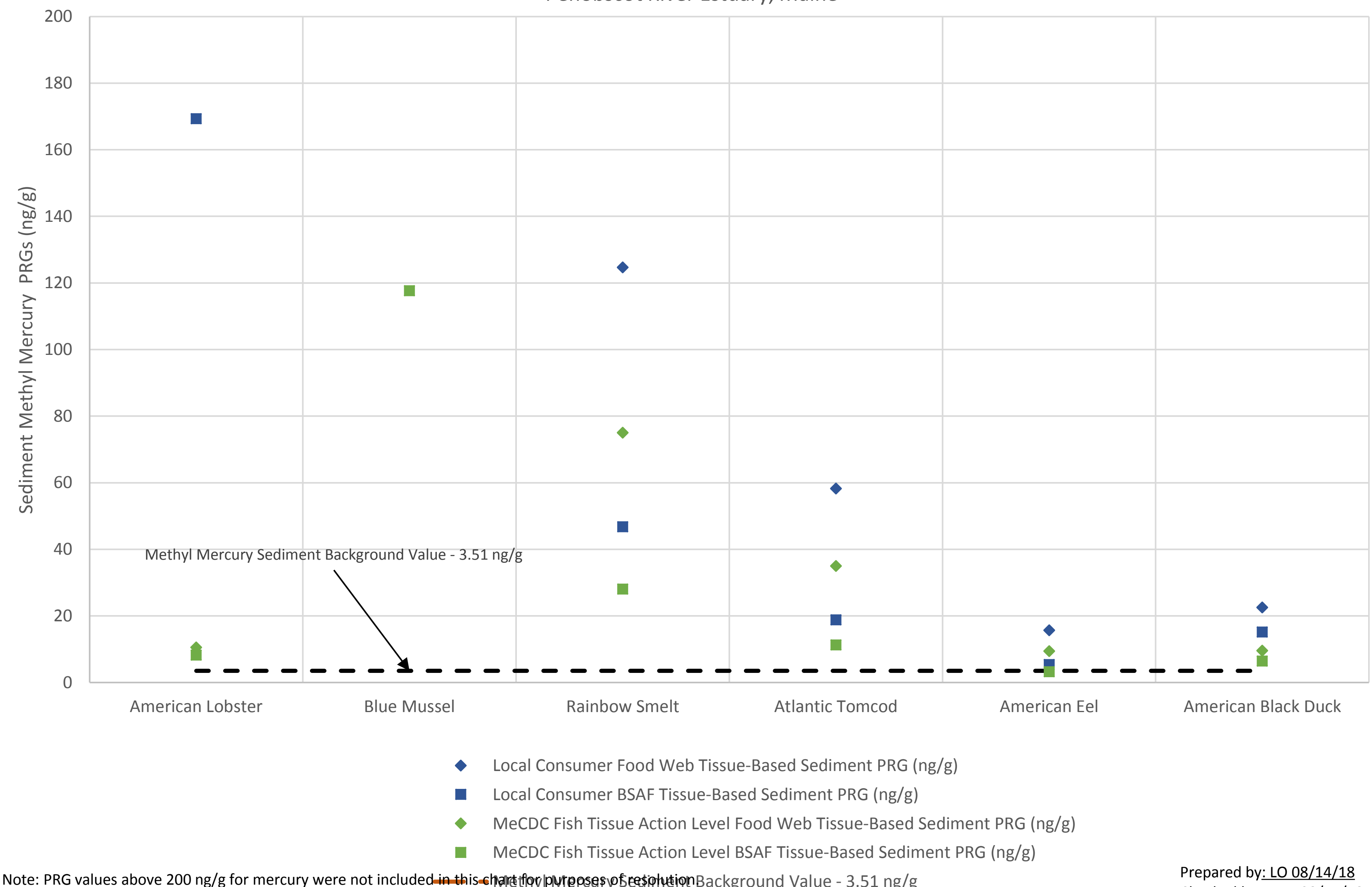
FIGURE IV.4-5
RANGE OF HUMAN HEALTH SEDIMENT PRGs BY SPECIES - METHYL MERCURY, CHILD RECEPTOR
Penobscot River Phase III Engineerring Study
Penobscot River Estuary, Maine



Note: PRG values above 200 ng/g for mercury were not included in this chart for purposes of resolution.

Prepared by: LO 08/14/18
Checked by: IMR 08/15/18

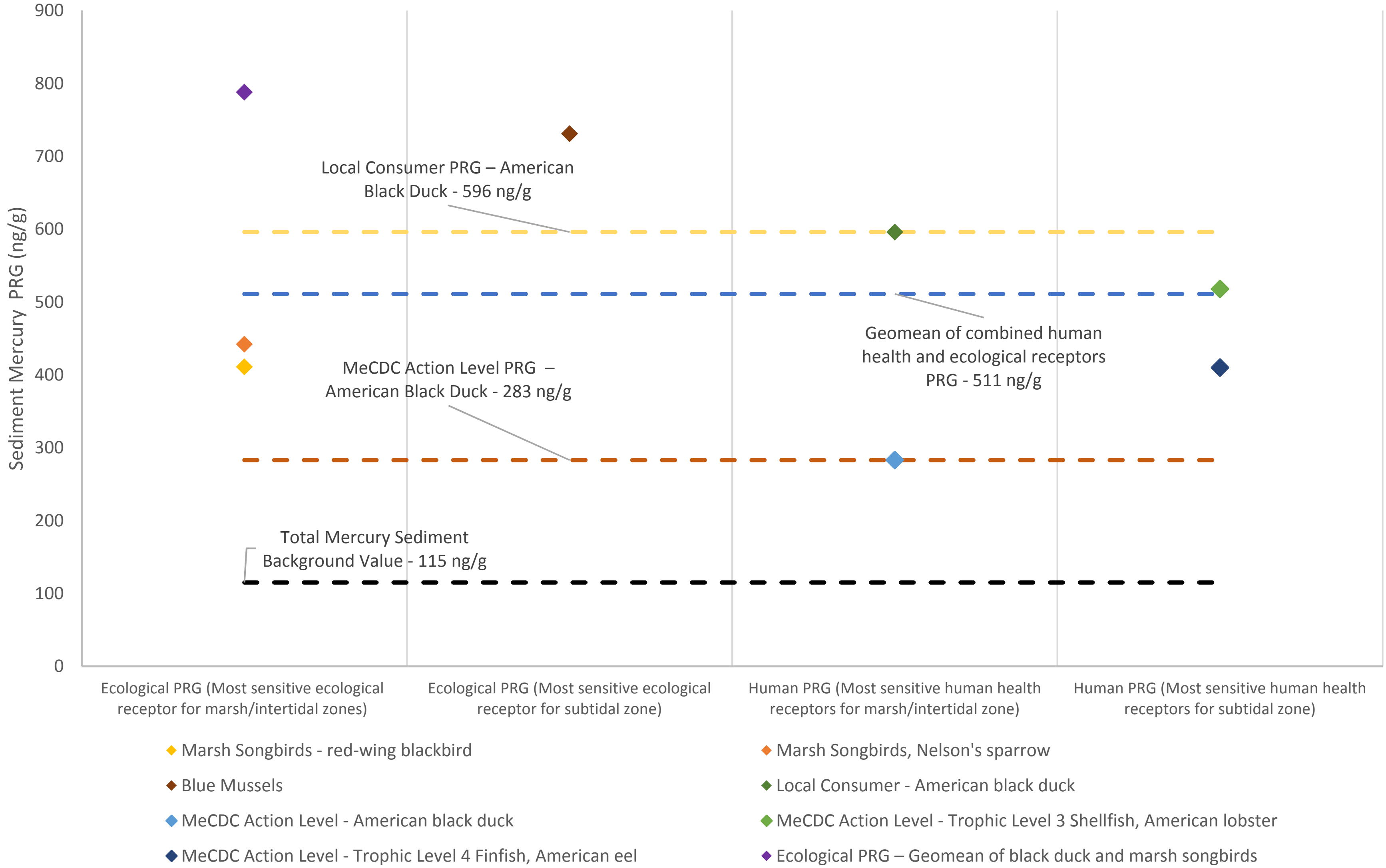
FIGURE IV.4-6
RANGE OF HUMAN HEALTH SEDIMENT PRGs BY SPECIES - METHYL MERCURY, ADULT RECEPTOR
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine



Note: PRG values above 200 ng/g for mercury were not included in this chart for purposes of resolution.

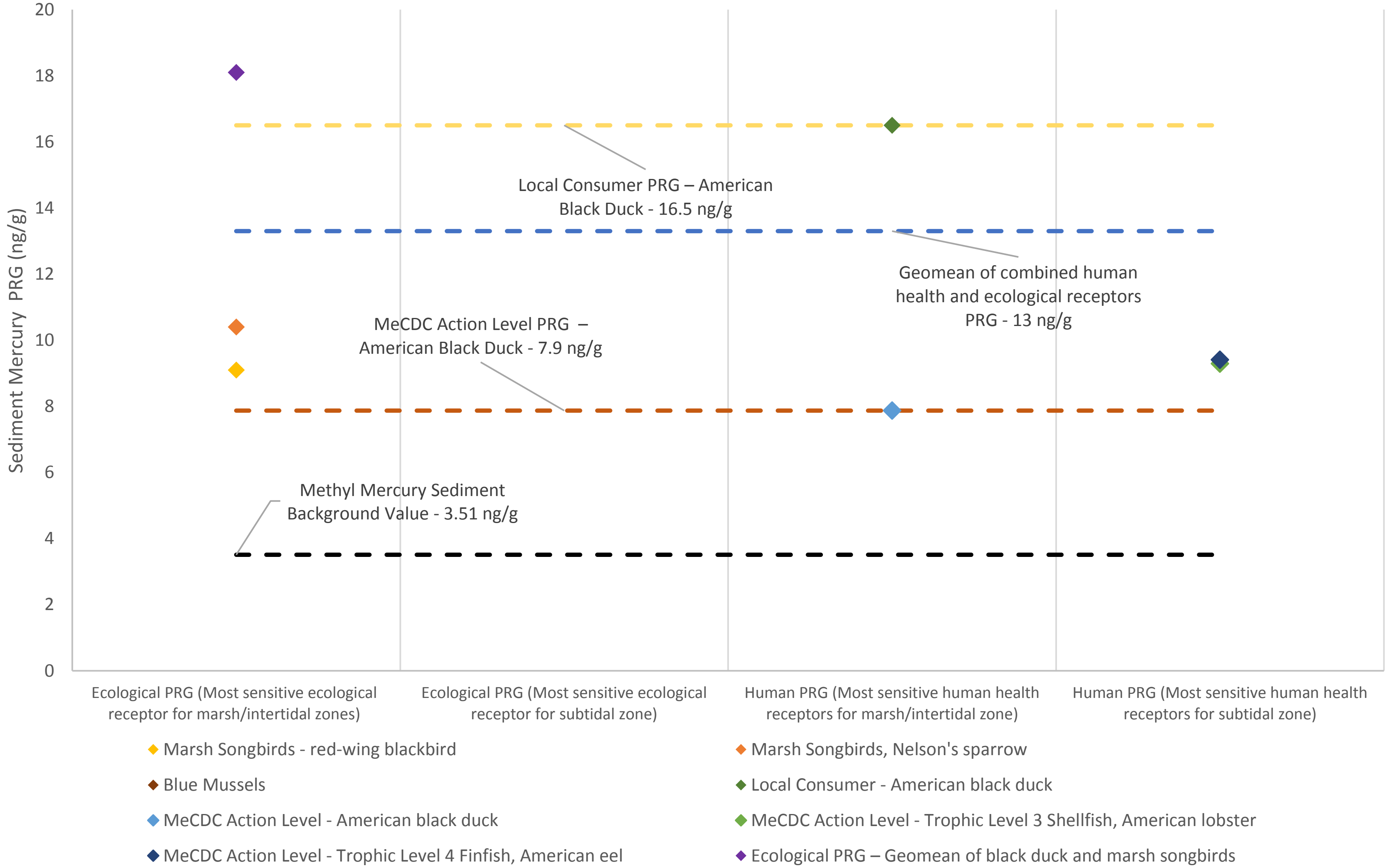
Prepared by: LO 08/14/18
Checked by: IMR 08/14/18

FIGURE IV.4-7
SUMMARY OF TOTAL MERCURY SEDIMENT PRGS
Penobscot River Phase III Engineerring Study
Penobscot River Estuary, Maine



Prepared by: IMR 08/15/18
Checked by: LO 08/15/18

FIGURE IV.4-8
SUMMARY OF METHYL MERCURY SEDIMENT PRGS
Penobscot River Phase III Engineerring Study
Penobscot River Estuary, Maine



Note: PRG values above 20 ng/g for methyl mercury were not included in this chart for purposes of resolution.

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Checked by: LO 08/15/18