Health Consultation

Review of Anadromous Fish: Penobscot River

PENOBSCOT INDIAN NATION

INDIAN ISLAND, MAINE

MAY 19, 2021

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Office of Community Health and Hazard Assessment
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

HEALTH CONSULTATION

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Prepared by the
U.S. Department of Health and Human Services
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Summary

Introduction

In May 2004, the Chief of the Penobscot Indian Nation (PIN) asked ATSDR to evaluate the public health effects of exposure to contaminants discharged by the Lincoln Pulp and Paper Mill at Lincoln, Maine [ATSDR 2006]. In 2006, ATSDR published a health consultation that reviewed available fish sampling data and calculated fish consumption limits. The main contaminants of concern were dioxins, chlorinated dibenzofurans (furans), polychlorinated biphenyls (PCBs), and methylmercury. ATSDR reviewed fish tissue data from 1988 through 2003. Fish species examined in that review included smallmouth bass (*Micropterus dolomieu*) and white sucker (*Catostomus commersonii*) from the Penobscot River. Other data for that review included studies conducted on behalf of the PIN and the U.S. Geological Survey. The sampling data included data for chlorinated dibenzo-p-dioxins such as 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), chlorinated-dibenzofurans such as 2,3,7,8-tetrachloro-dibenzofuran (TCDF), PCBs, and methylmercury [ATSDR 2006].

In 2014, ATSDR reviewed contaminants in fish tissue and other edible aquatic species and plants. That assessment was part of a multi-agency effort between the U.S. Environmental Protection Agency (EPA), U.S. Geological Survey, ATSDR, PIN, and U.S. Fish and Wildlife Service. That combined effort was identified as an EPA New England Indian Program, Regional Applied Research Effort [ATSDR 2014]. ATSDR calculated contaminant exposure doses for fish, wood duck (*Aix sponsa*), snapping turtle (*Chelydra serpentine*), fiddlehead fern (*Matteuccia struthiopteris*), and medicinal roots. The fish species included chain pickerel (*Esox niger*), white perch (*Morone americana*), yellow perch (*Perca flavescens*) (perch species depended on which were available), smallmouth bass (*Micropterus dolomieu*), brown bullhead *(Ameiurus nebulosus*), and American eel (*Anguilla rostrata*). Those edible species were analyzed for methylmercury, PCBs, dioxins, and chlorinated dibenzofurans. ATSDR determined that PIN members who ate fish and turtles were exposed to contaminants at levels of health concern. ATSDR found that PCBs, dioxin, and methylmercury in fish and snapping turtle were at levels that could cause a health hazard, including an increased excess lifetime cancer risk. ATSDR presented those findings to the Penobscot Indian Nation. ATSDR recommended that the general population of PIN members reduce their fish intake and limit the amount of turtle they eat. ATSDR also recommended that children younger than age 8 years, women who are breastfeeding, and women who are pregnant or who might become pregnant eat no Penobscot River fish.

This health consultation reviews the health implications of contaminants detected in several anadromous fish species as they return to Penobscot Reservation waters in the Penobscot

River. Anadromous fish spend most of their time in the ocean and typically only return to freshwater to spawn. The species collected and analyzed include alewife (*Alosa pseudoharengus*), American shad fillets and roe (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*), rainbow smelt (*Osmerus mordax*), sea lamprey (*Petromyzon marinus*), and striped bass (*Morone saxatilis*). Tissue samples from the portions of fish used by tribal members were analyzed for contaminants, including dioxin, furans, per- and polyfluoroalkyl substances (PFAS), PCBs, polybrominated diphenyl ethers (PBDEs), and total mercury. ATSDR's review of those data will be provided to Penobscot Tribal members as they engage in subsistence fishing and their traditional cultural practices. The findings and recommendations of this health consultation will assist the PIN in reducing tribal member exposure to toxic contaminants and provide information to assess the sustainability of a traditional Penobscot subsistence diet.

ATSDR evaluated cancer and non-cancer effects that could result from eating contaminated fish. The potential that exposure could contribute to cancer was evaluated. That is a theoretical estimate of cancer risk and not an actual number of cancer cases in the community. ATSDR uses this estimate as a tool for deciding whether public health actions are needed to protect health.

The implications of our findings are of concern to PIN members who seek to follow traditions of eating anadromous fish species. ATSDR developed several conclusions for review by the PIN members. Those conclusions—along with recommendations—are listed below.

Please note: the fish species evaluated in this health consultation have levels of dioxin that represent a health hazard for PIN members of all age groups. Contaminant-specific recommendations are provided for comparative purposes only. Those recommendations would only apply if the contaminant presented was the only contaminant in the fish tissue.

The remainder of this health consultation is a thorough evaluation of the fish tissue data and their public health implications. These anadromous fish have not been available to eat in the past because river dams have kept these species from returning to the Penobscot River. The PIN Department of Natural Resources has provided fish consumption advisories to PIN members for these fish species and will work with ATSDR to educate PIN members on the recommendations in this health consultation. The goal of this health consultation is to provide consumption guidance to PIN members.

This evaluation included three fish intake rates: 1) Wabanaki Traditional Lifeways Scenario Diet (286 grams per day for an adult; 143 grams per day for a child), 2) 40 grams per day, and 3) 10 grams per day. The Wabanaki intake rates equal 5 ounces daily for children and 10 ounces daily for adults. The other intake rates equal 10 ounces weekly (40 grams per day) and 10 ounces monthly (10 grams per day). Children were assumed to have a body weight of 35 pounds (16 kilograms) and their ages ranged from 1 to 6 years. Adults were assumed to be ages 21 years or older and have a body weight of 176 pounds (80 kilograms).

The focus of this health consultation was on public health implications of eating some anadromous fish species. These anadromous fish species represent a group of fish that spend most of their life in the ocean and return to fresh waters, such as the Penobscot River, to spawn. Freshwater fish—which are not the subject of the evaluation—are species that spend some or all their lives in fresh water, such as rivers and lakes.

ATSDR would also like to direct the reader to information from the Food and Drug Administration about eating fish. The information is available from: https://www.fda.gov/media/129959/download. That website includes a special emphasis on women who are or might become pregnant, breastfeeding mothers, and young children. The resources contain strategies to make informed choices when it comes to fish that are nutritious and safe to eat. The website features a chart that makes it easy to choose dozens of healthy and safer options and includes information about the nutritional value of fish. A questions and answers section has more information on how to use the chart and additional tips for eating fish.

Conclusions

Please note: the fish species evaluated in this health consultation have levels of dioxin that represent a health hazard for PIN members of all age groups. Contaminant-specific recommendations are provided for comparative purposes only. Those recommendations would only apply if the contaminant presented was the only contaminant in the fish tissue.

1. PIN members who eat fish for a year or more at the three intake rates considered could be exposed to harmful levels of dioxins, chlorinated dibenzofurans, and dioxin-like PCBs.

   Basis for conclusion

   ATSDR estimated cancer risk in children based on 6 years of exposure and cancer risk in adults based on 30 years of exposure. The exposure durations were used in the health consultation based on the previous public health assessment [ATSDR 2014] where those values were implemented. The following rates were used:

   - 5 ounces (143 grams) daily (child) or 10 ounces (286 grams) daily (adult)
   - 10 ounces (40 grams per day) weekly
   - 10 ounces (10 grams per day) monthly

   If PIN members (children and adults) eat anadromous fish discussed in the report at the three rates described previously, the dioxins, chlorinated dibenzofurans, and dioxin-like PCBs in those fish could produce harmful effects, including a significantly increased risk for liver cancer. Boys who eat anadromous fish could experience reproductive problems later in life. Pregnant women could expose their developing fetus to dioxins that could result in developmental problems in newborns and young infants. Pregnant women also might experience complications during their pregnancy. These effects are described in more detail in the section of the report that covers dioxins, furans, and dioxin-like PCBs.

2. PIN members (children and adults) who eat fish for a year or more might be exposed to harmful levels of PCBs in some anadromous fish species.

   Basis for conclusion

   If PIN members eat some types of anadromous fish described in this health consultation at the highest intake rate of 5 to 10 ounces daily, the PCBs in those fish could cause harmful non-cancer health effects and might result in an elevated cancer risk. At the intake rate of 10 ounces weekly, eating only striped bass is a concern for harmful effects in children and adults. At the intake rate of 10 ounces monthly, eating only striped bass is a concern for harmful effects in children but not adults. The highest levels of PCBs were detected in striped bass; therefore, reducing the intake of striped bass might reduce the risk for harmful effects. PIN members might experience adverse immune effects, such as a decreased antibody response, from PCB exposure. Studies also have shown exposure-associated damage to glands associated with the eyes and changes in toenails and fingernails.

3. Certain anadromous fish have mercury levels that are a health concern for children. One species (sea lamprey) is a health concern for adult women who are or might become pregnant.

   Basis for conclusion
   Methylmercury is most harmful to children and developing fetuses and could interfere with a child's ability to learn and process information. Therefore, it is especially important for pregnant and breastfeeding women, women who might become pregnant, and children to limit their consumption of certain anadromous fish. PIN members should restrict their consumption of fish as follows:
   - Children should not eat more than 5 ounces per day of rainbow smelt, striped bass, or sea lamprey
   - Children should not eat more than 10 ounces per week of sea lamprey
   - Pregnant women or women planning to become pregnant should not eat more than 10 ounces daily of sea lamprey

   Following these recommendations will decrease the risk for neurological damage from mercury exposure.

4. One type of PFAS (per- and polyfluoroalkyl substances), known as perfluorooctane sulfonic acid (PFOS), was detected in four species of fish at levels that might pose an increased risk for non-cancer harmful health effects. Those species include American shad roe, blueback herring, striped bass, and sea lamprey. PIN members (children and adults) who eat those PFOS-containing anadromous fish at the three intake rates described might experience adverse health effects.

   Studies in humans and animals provide suggestive evidence that PFOS might contribute to cancer. Estimating a numeric cancer risk is challenging, and the potential effect of PFOS exposure on the risk for developing cancer remains unclear.

Basis for conclusion
Studies in mice have shown that PFOS exposure can adversely affect the immune system, specifically through reduced antibody response. A lowered immune response might hurt the ability of PIN members to fight off infections. Studies in rats have shown that PFOS exposure might be associated with decreases in body weight and changes in glucose metabolism (increased serum glucose) as the young rats grow.

We do not know if the immune and developmental effects seen in rodents exposed to PFAS would occur in humans. Humans and rodents differ to some extent in how they excrete PFAS. Humans and animals react differently to PFAS, and not all effects seen in animals will occur in humans. In addition, long-term exposure studies in rodents have not been conducted.

This health consultation evaluates PFAS exposure from only one source—eating anadromous fish. It does not and cannot account for PFAS exposure from other sources. These points add uncertainty to the conclusions about whether harmful effects might be possible in people who eat these fish.

5. PIN members (children and adults) who eat any fish species at the highest intake rates for a year or more might be exposed to harmful levels of polybrominated diphenyl ethers (PBDEs).

   Basis for conclusion
   Adult rats that ate small amounts of PBDEs for 8 weeks showed damage to their reproductive systems, specifically reduced serum testosterone levels. Testosterone plays an important role in adults and in male and female children. Testosterone in males is important for development during puberty, sperm creation, and muscle and bone strength. Testosterone in females is important for maintaining other hormone levels, fertility, and making new blood cells. PIN members should follow these fish consumption guidelines:
   - Children should not eat any fish species at 1 ounce/day (or more)
   - Adults should not eat any fish species at 10 ounces/day (or more) and should not eat striped bass at 1 ounces/day (or more).

Recommendations

ATSDR recommends the following:

1. PIN members should not eat any of the anadromous fish described in this health consultation because dioxin levels might cause harmful effects, including a significantly increased risk for liver cancer.

2. Children should not eat any striped bass because of PCBs and PBDEs. Adults should not eat striped bass daily or at 10 ounces per week because of PCBs and PBDEs.

3. PIN members should avoid certain anadromous fish species because of mercury levels in the fish.

    - Pregnant women or women planning to become pregnant should not eat any sea lamprey because of elevated mercury levels in this species.
    - Children should not eat any rainbow smelt, striped bass, or sea lamprey daily because of mercury levels.
    - Children should not eat sea lamprey at 10 ounces per week because of mercury.

Next Step

- ATSDR remains available to provide, on request, input on public health questions related to possible site-related exposure.

Abbreviations used in this health consultation

ACOG	American Congress of Obstetricians-Gynecologists	oz	ounce
ATSDR	Agency for Toxic Substances and Disease Registry	PBDEs	polybrominated diphenyl ethers
bw	body weight	PFAS	per- and polyfluoroalkyl substances
C	concentration	PFBA	perfluorobutanoic acid
CDC	Centers for Disease Control and Prevention	PFDA	perfluorodecanoic acid
ED	exposure duration	PFDoA	perfluorododecanoic acid
EF	exposure frequency	PFOS	perfluorooctane sulfonic acid
EPA	United States Environmental Protection Agency	PFOSA	perfluorooctane sulfonamide
FDA	Food and Drug Administration	PFUnA	perfluoroundecanoic acid
g	gram	pg	picogram
g/day	grams per day	pg/g	picogram per gram
HQ	hazard quotient	PIN	Penobscot Indian Nation
IR	ingestion rate	RfD	reference dose
kg	kilogram	TCDD	tetrachlorodibenzo-p-dioxin
max	maximum	TEF	toxic equivalency factor
mg	milligram	TEQ	toxic equivalent
mg/kg	milligram per kilogram	UCL	upper confidence limit
mg/kg/day	milligram per kilogram per day	µg	microgram
mo	month	µg/kg	microgram per kilogram
MRL	minimal risk level	µg/kg/day	microgram per kilogram per day
n/a	not available	wk	week

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Background and statement of Issues

The Penobscot Indian Nation (PIN) reservation is in central Maine. It comprises all the islands and riverbeds in the Penobscot River and its branches (see Figures A-1 through A-3 in Appendix A). Indian Island, as shown in Figure A-4, (in Appendix A) is the PIN primary residence and the seat of tribal government.

Past investigations

In May 2004, the Chief of the PIN asked ATSDR to evaluate the public health effects of exposure to contaminants discharged by the Lincoln Pulp and Paper Mill in Lincoln, Maine. In June 2006, ATSDR published a health consultation on the Penobscot River Basin, located near Lincoln, Maine [ATSDR 2006]. That health consultation reviewed available fish sampling data from 1988 to 2003 and calculated fish consumption limits. The main contaminants of concern were dioxins, chlorinated dibenzofurans (furans), polychlorinated biphenyls (PCBs), and methylmercury. At that time, ATSDR recommended that anyone eating fish from the Penobscot River follow the Penobscot Indian Nation Department of Natural Resources fish consumption advisories.

In May 2008, a joint effort between the U.S. Environmental Protection Agency (EPA), U.S. Geological Survey, ATSDR, PIN, and U.S. Fish and Wildlife Service finalized the Quality Assurance Project Plan for the EPA New England Indian Program, Regional Applied Research Effort [ATSDR 2014; EPA 2008]. That project addressed a regional research need to determine the level of contaminant exposure faced by PIN members who wanted to continue to fish, hunt, trap, and gather according to their culture and traditions [EPA 2008].

Finalized in July 2009, the Wabanaki Traditional Cultural Lifeways Exposure Scenario was a coordinated effort between EPA and five federally recognized Tribal Nations in Maine, including the PIN [Harper and Ranco 2009]. The five Tribal Nations include the Aroostook Band of Micmacs, the Holton Band of Maliseet Indians, the Passamaquoddy Tribe of Indian Township, the Passamaquoddy Tribe at Pleasant Point, and the Penobscot Indian Nation. The scenario "provides a quantitative estimate of the environmental contact, diet, and exposure pathways of the traditional lifestyles in Maine" [Harper and Ranco 2009]. The Wabanaki scenario's dietary consumption rates might not represent the PIN members' current patterns. Still, if members use natural resources in a traditional manner, the Wabanaki consumption rates are realistic. ATSDR used the Wabanaki scenario to estimate amounts of fish PIN members might eat fish within certain amounts of time (ingestion rates) [EPA 2008].

This evaluation included three fish intake rates:

1) Wabanaki Traditional Lifeways Scenario Diet (286 grams per day for an adult; 143 grams per day for a child),
2) 40 grams per day, and
3) 10 grams per day.

The Wabanaki intake rates equal 5 ounces daily for children and 10 ounces daily for adults. The other intake rates equal 10 ounces weekly (40 grams per day) and 10 ounces monthly (10 grams per day).

Current investigation

Anadromous fish were important components of the traditional subsistence diet of the Penobscot people but have been largely absent from the diet because they have not been available. These fish spend most of their time in the ocean but breed in freshwater, they are referred to as anadromous fish. When dams were built on rivers in Maine, these fish were not able to return to their historical breeding locations. A restoration project was started in 2012 and 2013 to restore access to the traditional fish species. This project is known as the Penobscot River Restoration Project and included several activities including dam removals [Natural Resources Council of Maine 2020]. Since the dam removal project started in 2012 and 2013, these species of fish are returning to the Penobscot River and could become part of the traditional diet again. The removal of the dams provides an opportunity for traditional diets to include those species.

Anadromous fish generally avoid feeding while spawning. As a result, the body burden of contaminants is likely to differ from fish species that spend their lives in the freshwater riverways. Information on the public health implications of contaminant concentrations within fish tissue may be useful to assist tribal members' seafood choice decision.

Fish species and analysis

The fish collection and analysis protocol included the collection of 75 composite samples (comprised of five to six samples of each of the six types of anadromous fish species). Fish collection occurred in 2017 and 2018. Those 2 years of data are combined in this health consultation. The species collected and analyzed include alewife (*Alosa pseudoharengus*), American shad fillets and roe (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*), rainbow smelt (*Osmerus mordax*), sea lamprey (*Petromyzon marinus*), and striped bass (*Morone saxatilis*). These species were collected from the Penobscot River when they returned to spawn in late April to late July, except for rainbow smelt, which spawns from winter to early spring. The edible tissues of each of the fish types were analyzed for dioxin, furans, and 13 PFAS. In addition to those mentioned, tissue was analyzed for perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorobutanesulfonic acid (PFBS), perfluorohexanesulfonic acid (PFHxS), perfluoropentanoic acid (PFPeA), perfluorohexanoic acid (PFHxA), and perfluoroheptanoic acid (PFHpA). All those seven PFAS were below detectable levels. Only 60 of the 75 composite samples were analyzed for PFAS, PCBs, polybrominated diphenyl ethers (PBDEs), and total mercury. Results were reported as wet weight because exposure estimates were based on how many grams or ounces of fish people ate. Fish were collected using the methods described in the Quality Assurance Project Plan for the EPA Indian Program's Regional Applied Research Effort [ATSDR 2014; EPA 2008].

Discussion

This section gives an overview of the process ATSDR used to evaluate the public health implications of exposure to contaminated fish tissue. The discussion is then divided into sections for each contaminant (methylmercury, PCBs, polybrominated diphenyl ethers, dioxins, chlorinated dibenzofurans, dioxin-like PCBs, and per- and polyfluoroalkyl substances). These sections summarize the key findings. Appendix B gives more details on the evaluation process and detailed public health implications.

Estimating exposures

For each fish species and contaminant concentration, ATSDR first determined a conservative exposure point concentration (which is also known as an exposure concentration) [ATSDR 2019b]. ATSDR then used the exposure point concentration values to calculate exposure doses for each contaminant and each fish species. Exposure doses were calculated for children and adults because doses vary with how much people eat and how much people weigh. Children were assumed to weigh 35 pounds (16 kilograms) and their ages ranged from 1 to 6 years. Adults were assumed to weigh 176 pounds (80 kilograms) and be more than 20 years old.

ATSDR calculated the amount of chemical that PIN members might be exposed to after eating contaminated fish tissue. This value is called the exposure dose and is typically reported as milligram of chemicals ingested per kilogram of body weight each day (mg/kg/day). The exposure doses were calculated for each fish species and contaminant detected. ATSDR-calculated exposure doses were based on three consumption rates:

1) the consumption rates included in the Wabanaki Lifeways Traditional scenario of 286 grams per day for adults and 143 grams per day for children;
2) one meal per week (40 grams per day) for adults and children; and
3) one meal per month (10 grams per day) for adults and children.

The PIN-developed fish advisory rates [Penobscot Indian Nation 2020] were used by ATSDR.

Table 1 depicts the fish tissue intake rates using ounces and grams for ease of understanding. That table includes the conversion between ounces and grams for each of the three intake rates and for children and adults.

Table 1. Depiction of fish tissue intake in ounces per day and grams per day for children and adults for three intake rates.

Age group	Traditional Wabanaki diet oz per day	Traditional Wabanaki diet gm per day	One fish meal every week oz per day	One fish meal every week gm per day	One fish meal every month oz per day	One fish meal every month gm per day
Children	5	143	1.4	40	0.35	10
Adults	10	286	1.4	40	0.35	10

Abbreviations: oz = ounces; g = grams.

Non-cancer evaluation approach

ATSDR compares the exposure doses to an EPA reference dose (RfD) or an ATSDR minimal risk level (MRL). These are both used to evaluate non-cancer concerns. MRLs and RfDs are estimates of the daily human exposure to a hazardous substance that is likely to be without appreciable risk for adverse non-cancer health effects over a specified period of exposure. The evaluation process includes estimating the exposure dose from eating fish and then dividing that dose by the corresponding RfD or MRL to derive the hazard quotient (HQ). If the HQ is below 1, the estimated dose is below the chronic MRL or RfD and non-cancerous harmful effects are not expected. When the HQ is more than 1, then the estimated dose exceeds the chronic MRL or RfD and requires further evaluation to determine if PIN members are at risk for non-cancerous harmful effects. Whether someone is at risk for harmful effects depends on how close their exposure dose is to effect levels identified in human and animal studies. ATSDR used three fish consumption rates so that PIN members can judge for themselves the degree of risk members might have from eating anadromous fish. Reference doses are used for estimating chronic exposures. ATSDR selects an MRL or an RfD based on exposure and other toxicological considerations.

An MRL is an estimate of the amount of a chemical a person can eat, drink, or breathe each day without a detectable risk to health for non-cancer health effects. MRLs are used as a screening tool to help identify exposures that could be potentially hazardous to human health. MRLs help public health professionals determine areas and populations potentially at risk for health effects from exposure to a chemical. ATSDR has developed more than 400 human health MRLs.

Exposure above an MRL does not mean that health problems will occur. Instead, it indicates that health assessors should look more closely at a site where exposures may be identified. MRLs do not define regulatory or action levels for ATSDR.

The way the MRL is calculated can change depending on the type and quality of data available. MRLs can be set for three different lengths of time people are exposed to the substance:

- Acute—1–14 days
- Intermediate—15–365 days
- Chronic—more than 365 days

Cancer evaluation approach

Some chemicals (PCBs and dioxins) reviewed in this document might increase the risk for developing cancer. The cancer risk is estimated using EPA-developed oral cancer slope factors. Cancer risk estimates are presented as the number of extra cancer cases in a group of similarly exposed people. For example, an estimated cancer risk might be one extra cancer case for every 10,000 people who eat 10 ounces of anadromous fish weekly. This risk can also be written as 1×10^{-4}. ATSDR estimates a theoretical cancer risk as a tool to decide whether public health actions are needed to protect health. The estimated risk is not an actual number of cancer cases expected in a community.

The next sections discuss ATSDR's findings based on each contaminant detected in the anadromous fish species. Tables A-2 through A-7 show the cancer and non-cancer risk estimates.

Non-cancer evaluations details

Methylmercury

All fish species sampled contained total mercury, which is to be expected because most marine and freshwater fish contain some level of mercury. The form of mercury in fish tissue most commonly is methylmercury (about 85%), the more toxic form [Jones and Slotten 1996]. Therefore, to be conservative, ATSDR assumed that all the mercury detected in fish is methylmercury. Some of the estimated doses from eating anadromous fish were above the ATSDR MRL, thus requiring further evaluation to determine if PIN members would be at risk for harmful effects. Table 2 summarizes the exposure dose evaluations for methylmercury. Levels of non-cancer concern and below a concern are represented.

The major findings are summarized below:

- At 5 to 10 ounces (143 grams to 286 grams) daily intake rate
    - Mercury levels in American shad, rainbow smelt, striped bass, and sea lamprey are a health concern for young children.
    - Methylmercury levels in sea lamprey are a health concern for female adults who are pregnant or who might become pregnant. They might be exposing their developing fetus to methylmercury that could interfere with a child's ability to learn and process information.

- At 10 ounces (40 grams per day) weekly intake rate
    - Mercury levels in sea lamprey are a health concern for young children. Methylmercury exposure could interfere with a child's ability to learn and process information.

- At 10 ounces (10 grams per day) monthly intake rate
    - No health concerns.

Table 2. Fish species containing mercury above a level of non-cancer concern for children or adults (indicated by HC) or below a level of concern (depicted by a minus "–"symbol) based on three consumption rates.

Fish species		**Child intake rates**	
	143 g/day (5 oz/day)*	**40 g/day (1.4 oz/day)**	**10 g/day (0.35 oz/day)**
Alewife	–	–	–
American shad fillet	–	–	–
American shad roe	–	–	–
Blueback herring	–	–	–
Rainbow smelt	HC	–	–
Striped bass	HC	–	–
Sea lamprey	HC	HC	–
		Adult intake rates	
	286 g/day (10 oz/day)†	**40 g/day (1.4 oz/day)**	**10 g/day (0.35 oz/day)**
Alewife	–	–	–
American shad fillet	–	–	–
American shad roe	–	–	–
Blueback herring	–	–	–
Rainbow smelt	–	–	–
Striped bass	–	–	–
Sea lamprey	HC	–	–

Abbreviations: g = grams; oz = ounces.

*The Wabanaki scenario intake rate for children is 143 g per day, half the adult rate of 286 g per day.

†The Wabanaki scenario intake rate for adults is 286 grams per day.

Table 3 shows an example of estimated doses in children and adults from eating anadromous fish and whether those doses exceed ATSDR's chronic MRL for methylmercury (0.3 µg/kg/day). The table also shows the hazard quotient, indicating whether the estimated dose exceeds the MRL (HQs greater than 1) or is below the MRL (HQs less than 1). When the HQ is less than 1, then non-cancerous effects are not likely. When the HQ is greater than 1, further evaluation is needed to determine whether harmful effects might be possible.

The HQs from eating alewife are 3.1 for children and 1.2 for adults. The estimated dose for adults who eat alewife every day just barely exceeds the chronic MRL. The adult dose is still far below effects levels, thus harmful effects are not likely in adults from eating alewife. The estimated dose in children who eat alewife every day is 0.9 µg/kg/day, which is below the no effect level established by a human study conducted in the Seychelles, a group of islands off the east coast of central Africa [ATSDR 1999]. About half the Seychellois meals involve eating fish. This well-designed human study established a no effect level of 1.3 µg methylmercury/kg/day.

It seems unlikely that children who eat alewife daily would be at risk for harmful effects based on this comparison to the Seychelles study.

Table 3. Site-specific exposure doses for chronic exposure to methylmercury from eating alewife with 0.104 milligram per kilogram methylmercury along with non-cancer hazard quotients.*

PUBLIC HEALTH ASSESSMENT SITE TOOL PHAST **Exposure group**	**Dose (µg/kg/day)**	**ATSDR MRL for methylmercury (µg/kg/day)**	**Exceeds ATSDR MRL for methylmercury**	**Non-cancer hazard quotient**
Child 5 oz/day	0.93	0.3	Yes	3.1†
Adult 10 oz/day	0.37	0.3	Yes	1.2†
Child 10 oz/wk	0.26	0.3	No	0.87
Adult 10 oz/wk	0.052	0.3	No	0.17
Child 10 oz/mo	0.065	0.3	No	0.22
Adult 10 oz/mo	0.013	0.3	No	0.043

Abbreviations: µg/kg/day = microgram per kilogram body weight per day; kg = kilogram; mg/kg = milligram chemical per kilogram food; mo = month; MRL = minimal risk level; oz = ounce; wk = week.

* The calculations in this table were generated using ATSDR's PHAST v1.6.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.3 µg/kg/day.

† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

However, some of the estimated methylmercury doses from eating certain fish species are a health concern. Children who eat rainbow smelt and striped bass daily have doses near levels that could affect their nervous systems. Adults and children who eat sea lamprey daily and children who eat sea lamprey weekly also have methylmercury exposure that could harm their health. Children should avoid eating sea lamprey because of the high mercury levels. PIN members should not eat sea lamprey on a regular basis.

Because people might eat a variety of fish included in the PIN survey, ATSDR calculated the average mercury level in the fish species sampled. Sea lamprey was excluded because of the high mercury level. The average mercury level in the remaining fish from the PIN survey (excluding sea lamprey) is 0.11 mg/kg. PIN residents who eat a variety of these seafood weekly or monthly will have mercury exposure that is below the chronic MRL. People who eat these fish daily will exceed the MRL, but the dose is still below the no effect level identified in the Seychelles study [ATSDR 1999].

Eating seafood has many health benefits for adults and children and for the developing fetus. ATSDR encourages PIN members to follow Food and Drug Administration (FDA) guidelines for choosing commercial fish with low mercury levels. More information about FDA's guidelines are available from https://www.fda.gov/food/consumers/advice-about-eating-fish.

PCBs, dioxins, chlorinated dibenzofurans, and dioxin-like PCBs

All fish species were analyzed for total PCB congeners (related substances), dioxins, chlorinated dibenzofurans, and dioxin-like PCBs. The doses for dioxins and chlorinated dibenzofurans, which includes dioxin-like PCBs, were elevated for all fish species analyzed and all intake rates. For simplicity, this health consultation will use the phrase dioxins or dioxin TEQs (toxic equivalents) when referring to dioxins, furans, and dioxin-like PCBs.

Table 4 shows the fish species sampled and whether eating PCB-contaminated fish is a non-cancer health concern. If estimated doses exceeded the chronic MRL, ATSDR evaluated the doses further to determine whether PIN members would be at risk for non-cancerous health effects.

The major findings are summarized below:

- At intake rates of 5 to 10 ounces daily (286 grams per day), the PCB levels in most of the anadromous fish species represented a potential health concern for children and adults.
- At the intake rate of 10 ounces weekly (40 grams per day), only PCB levels in striped bass are a health concern for children and adults.
- At the intake rate of 10 ounces monthly (10 grams per day), only PCB levels in striped bass are a health concern for children but not for adults.

Table 4. Fish species containing polychlorinated biphenyls above a level of concern for children or adults (indicated by HC) and below a level of non-cancer concern (depicted by a minus "–" symbol) based on three consumption rates.

Fish species	**Child intake rates**		
	143 g/day (5 oz/day)*	**40 g/day (1.4 oz/day)**	**10 g/day (0.35 oz/day)**
Alewife	HC	–	–
American shad fillet	HC	–	–
American shad roe	HC	–	–
Blueback herring	HC	–	–
Rainbow smelt	HC	–	–
Striped bass	HC	HC	HC
Sea lamprey	HC	–	–
	Adult intake rates		
	286 g/day (10 oz/day)†	**40 g/day (1.4 oz/day)**	**10 g/day (0.35 oz/day)**
Alewife	HC	–	–
American shad fillet	HC	–	–
American shad roe	HC	–	–
Blueback herring	HC	–	–
Rainbow smelt	HC	–	–
Striped bass	HC	HC	–
Sea lamprey	HC	–	–

Abbreviations: g = grams; oz = ounces.

*The Wabanaki scenario intake rate for children is 143 g per day, half the adult rate of 286 g per day.

†The Wabanaki scenario intake rate for adults is 286 grams per day.

If adults and children eat anadromous fish species that are of health concern, they might experience a decrease in their immune system from PCB exposure. Studies in monkeys [ATSDR 2000] have shown a decreased antibody response. Monkey studies also have shown damage to glands associated with the eyes and changes in toenails and fingernails.

Table 5 shows the fish species sampled and whether eating those fish with dioxins, chlorinated dibenzofurans, and dioxin-like PCBs represent a non-cancer health concern. The dioxin TEQ levels in all fish species analyzed represented a health concern for children and adults at all intake rates.

Table 5. Fish species containing dioxins, chlorinated dibenzofurans, and dioxin-like PCBs (evaluated at the upper confidence limit of the mean or maximum) above a level of non-cancer concern for children or adults (indicated by HC) based on three consumption rates.

Fish species	Child intake rates		
	143 g/day (5 oz/day)*	**40 g/day (1.4 oz/day)**	**10 g/day (0.35 oz/day)**
Alewife	HC	HC	HC
American shad fillet	HC	HC	HC
American shad roe	HC	HC	HC
Blueback herring	HC	HC	HC
Rainbow smelt	HC	HC	HC
Striped bass	HC	HC	HC
Sea lamprey	HC	HC	HC
	Adult intake rates		
	286 g/day (10 oz/day)†	**40 g/day (1.4 oz/day)**	**10 g/day (0.35 oz/day)**
Alewife	HC	HC	HC
American shad fillet	HC	HC	HC
American shad roe	HC	HC	HC
Blueback herring	HC	HC	HC
Rainbow smelt	HC	HC	HC
Striped bass	HC	HC	HC
Sea lamprey	HC	HC	HC

Abbreviations: g = grams; oz = ounces.

*The Wabanaki scenario intake rate for children is 143 g per day, half the adult rate of 286 g per day.

†The Wabanaki scenario intake rate for adults is 286 grams per day.

Table 6 shows how ATSDR evaluated dioxin TEQs in anadromous fish, using alewife as an example. Table 6 shows the estimated dose in children and adults and whether that dose exceeds EPA's health guideline (RfD) (7×10^{-10} mg/kg/day). The table also shows the hazard quotient, indicating how far above the dose in children and adults is to the RfD. The doses in children and adult approach and sometimes exceed effects levels identified in human and animal studies.

EPA's reference dose for dioxin is based on a study that showed decreased sperm count and motility in men who were exposed as boys to dioxins at 2×10^{-8} mg/kg/day. The estimated dioxin TEQs in male PIN members who eat fish contaminated with dioxins approaches and sometimes exceeds the effect level for sperm damage. Similarly, women who eat anadromous fish from the Penobscot River also have exposures that could damage a fetus. If exposed to dioxins while pregnant, women might have children with memory and attention problems later in life. These problems result because 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) exposure during fetal development can decrease thyroid hormones that are essential for brain development in the newborn and young infants.

Another study [ATSDR 1998], in monkeys, identified behavioral effects from dioxin exposure. This study showed altered play behavior, such as an increased tendency for initiating rough and tumble play and a lower tendency to retreat when challenged compared with control monkeys. Monkey studies also suggest that women who eat anadromous fish could experience an increase in pregnancy complications. Studies in monkeys showed increased abortions, fewer births, and endometriosis. The higher the HQ in Table 6, the greater the risk for adverse effects.

The concentration of dioxin TEQs in alewife is 61 picograms dioxin TEQs per gram of fish (pg/g). Other fish in the PIN survey had similar levels, which ranged from 44 pg/g to 160 pg/g dioxin TEQs. The average dioxin TEQ levels in the PIN survey was 71 pg/g. Therefore, even if PIN members ate a variety of fish from the survey, PIN members would be at risk for these effects.

Table 6. Site-specific exposure doses for chronic exposure to dioxin toxic equivalents (TEQs) in alewife at 6.1×10^{-5} milligram per kilogram (61 picograms/gram) along with non-cancer hazard quotients.*

PHAST Public Health Assessment Site Tool Exposure group	Dose (mg/kg/day)	Exceeds EPA's reference dose for dioxins	Non-cancer hazard quotient
Child 5 oz/day	5.5×10^{-7}	Yes	780†
Adult 10 oz/day	2.2×10^{-7}	Yes	310†
Child 10 oz/wk	1.5×10^{-7}	Yes	220†
Adult 10 oz/wk	3.1×10^{-8}	Yes	44†
Child 10 oz/mo	3.8×10^{-8}	Yes	54†
Adult 10 oz/mo	7.6×10^{-9}	Yes	11†

Abbreviations: mg/kg/day = milligram per kilogram body weight per day; kg = kilogram; mg/kg = milligram chemical per kilogram food; mo = month; oz = ounce; wk = week.

* The calculations in this table were generated using ATSDR's PHAST v1.6.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year).

† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

The dioxin TEQ levels in the PIN survey were much higher than what would be expected in marine fish. Although data are limited, background levels of dioxin TEQs in marine fish are probably around 1 pg/g [Blanco et al. 2013]. With concentrations ranging from 44 pg/g (blueback herring) to 160 pg/g (striped bass), PIN survey fish have much higher dioxin TEQs.

The following PBDEs were reviewed in this health consultation. These are also known as lower-brominated diphenyl ethers. Table 7 shows the complete listing.

Table 7. Listing of polybrominated diphenyl ethers (PBDEs) reviewed in this health consultation, including the chemical name, abbreviation, and Chemical Abstract Registry Number (CASRN).

Chemical name	**Abbreviation**	**CASRN**
2,4-Dibromodiphenyl ether	BDE7	171977-44-9
4,4'-Dibromodiphenyl ether	BDE15	2050-47-7
2,2',4'-Tribromodiphenyl ether	BDE17	147217-75-2
2,4,4'-Tribromodiphenyl ether	BDE28	41318-75-6
2,2',4,4'-Tetrabromodiphenyl ether	BDE47	5436-43-1
2,2',4,5'-Tetrabromodiphenyl ether	BDE49	243982-82-3
2,3',4,4'-Tetrabromodiphenyl ether	BDE66	189084-61-5
2,3',4',6-Tetrabromodiphenyl ether	BDE71	189084-62-6
3,3',4,4'-Tetrabromodiphenyl ether	BDE77	93703-48-1
2,2',3,4,4'-Pentabromodiphenyl ether	BDE85	182346-21-0
2,2',4,4',5-Pentabromodiphenyl ether	BDE99	60348-60-9
2,2',4,4',6-Pentabromodiphenyl ether	BDE100	189084-64-8
2,3',4,4',6-Pentabromodiphenyl ether	BDE119	189084-66-0
3,3',4,4',5-Pentabromodiphenyl ether	BDE126	366791-32-4
2,2',3,4,4',5'-Hexabromodiphenyl ether	BDE138	182677-30-1
2,2',4,4',5,5'-Hexabromodiphenyl ether	BDE153	68631-49-2
2,2',4,4',5,6'-Hexabromodiphenyl ether	BDE154	207122-15-4
2,3,3',4,4',5-Hexabromodiphenyl ether	BDE156	405237-85-6
2,2',3,4,4',5',6-Heptabromodiphenyl ether	BDE183	207122-16-5
2,2',3,4,4',6,6'-Heptabromodiphenyl ether	BDE184	207122-16-5
2,3,3',4,4',5',6-Heptabromodiphenyl ether	BDE191	446255-30-7
2,2',3,3',4,4',5,6'-Octabromodiphenyl ether	BDE196	446255-39-6
2,2',3,3',4,4',6,6'-Octabromodiphenyl ether	BDE197	117964-21-3
2,2',3,3',4,4',5,5',6-Nonabromodiphenyl ether	BDE206	63387-28-0
2,2',3,3',4,4',5,6,6'-Nonabromodiphenyl ether	BDE207	437701-79-6

Polybrominated diphenyl ethers (PBDEs)
All fish species sampled contained PBDEs. Because ATSDR lacks a chronic MRL for PBDEs, this health consultation used the intermediate (15–364 days) MRL for comparison. Some of the estimated doses from eating anadromous fish were above the ATSDR intermediate MRL, thus requiring further evaluation to determine if PIN members would be at risk for harmful effects. Table 8 summarizes the exposure dose evaluations for PBDEs.

The major findings concerning PBDEs include the following:

- At 5 to 10 ounces (143 grams to 286 grams) daily intake rate, PBDEs levels in all species are a health concern for young children and adults.

- At 10 ounces (40 grams per day) weekly intake rate, PBDEs levels in all species are a health concern for young children, and only a health concern for adults eating striped bass.
- At 10 ounces (10 grams per day) monthly intake rate, PBDEs levels in only one species—striped bass—are a health concern for young children and not a health concern for adults eating any species.

Table 8. Fish species containing PBDEs above a level of non-cancer concern for children or adults (indicated by HC) or below a level of concern (depicted by a minus "–"symbol) based on three consumption rates.

Fish species		**Child intake rates**	
	143 g/day (5 oz/day)*	**40 g/day (1.4 oz/day)**	**10 g/day (0.35 oz/day)**
Alewife	HC	HC	–
American shad fillet	HC	HC	–
American shad roe	HC	HC	–
Blueback herring	HC	HC	–
Rainbow smelt	HC	HC	–
Striped bass	HC	HC	HC
Sea lamprey	HC	HC	–
		Adult intake rates	
	286 g/day (10 oz/day)†	**40 g/day (1.4 oz/day)**	**10 g/day (0.35 oz/day)**
Alewife	HC	–	–
American shad fillet	HC	–	–
American shad roe	HC	–	–
Blueback herring	HC	–	–
Rainbow smelt	HC	–	–
Striped bass	HC	HC	–
Sea lamprey	HC	–	–

Abbreviations: g = gram; oz = ounces.
*The Wabanaki scenario intake rate for children is 143 g per day, half the adult rate of 286 g per day.
†The Wabanaki scenario intake rate for adults is 286 grams per day.

Table 9 shows the estimated dose in children and adults from eating anadromous fish and whether those doses exceed ATSDR's intermediate MRL for PBDEs (3×10^{-6} mg/kg/day [lower-brominated diphenyl ethers]).

The HQ from eating striped bass is 20 for children (5 ounces/day) and 7.8 for adults (10 ounces/day). For adults who eat striped bass every day, the dose is 2.3×10^{-5} mg/kg/day, which is about 40 times below the lowest observed adverse effect level established in animal studies. The estimated dose in children who eat striped bass every day is 5.9×10^{-5} mg/kg/day, which is

17 times below the lowest observed adverse effect level established in animal studies (Appendix C provides more details).

Table 9. Site-specific exposure doses and non-cancer hazard quotients for chronic exposure to PBDEs from eating striped bass with 6.6×10^{-3} milligram per kilogram PBDEs.*

Exposure group	Dose (mg/kg/day)	ATSDR MRL for PBDEs (µg/kg/day)	Exceeds ATSDR intermediate MRL for PBDEs	Non-cancer hazard quotient
Child 5 oz/day	5.9×10^{-5}	3×10^{-6}	Yes	20*
Adult 10 oz/day	2.3×10^{-5}	3×10^{-6}	Yes	7.8*
Child 10 oz/wk	1.6×10^{-5}	3×10^{-6}	Yes	5.5*
Adult 10 oz/wk	3.3×10^{-6}	3×10^{-6}	Yes	1.1*
Child 10 oz/mo	4.1×10^{-6}	3×10^{-6}	Yes	1.4*
Adult 10 oz/mo	8.2×10^{-7}	3×10^{-6}	No	0.27

Abbreviations: µg/kg/day = microgram per kilogram body weight per day; kg = kilogram; mg/kg = milligram chemical per kilogram food; mo = month; MRL = minimal risk level; oz = ounce; wk = week.
The non-cancer hazard quotients were calculated using the intermediate (less than 1 year) minimal risk level of 3×10^{-6} mg/kg/day.
* A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

PFAS (per- and polyfluoroalkyl substances)

All fish species (except rainbow smelt) were analyzed for 13 different PFAS. These detected PFAS included

- PFBA (perfluorobutanoic acid),
- PFDA (perfluorodecanoic acid),
- PFDoA (perfluorododecanoic acid),
- PFOS (perfluorooctane sulfonic acid),
- PFOSA (perfluorooctane sulfonamide), and
- PFUnA (perfluoroundecanoic acid).

Table 10 lists the minimum, maximum, and average concentrations measured in the fish tissue. Those values were provided for a relative overview of the variability of the data. Perfluorooctanoic acid (PFOA) is another PFAS that is commonly found in environmental samples. It was analyzed for but not detected in these fish samples. ATSDR used the maximum values to determine the risk for harmful effects (see Appendix B for more details).

Table 10. Listing of detected per- and polyfluoroalkyl substances (PFAS), including minimum, maximum, and average concentrations, in milligrams of chemical per kilogram of fish sampled.

PFAS	Maximum (mg/kg)	Minimum (mg/kg)	Average (mg/kg)
PFOS	2.0×10^{-2}	1.7×10^{-3}	4.9×10^{-3}
PFBA	1.1×10^{-2}	1.3×10^{-3}	4.1×10^{-3}
PFDA	4.8×10^{-3}	1.1×10^{-3}	2.4×10^{-3}
PFDoA	3.1×10^{-3}	1.1×10^{-3}	1.8×10^{-3}
PFOSA	9.8×10^{-3}	1.0×10^{-3}	4.0×10^{-3}
PFUnA	1.4×10^{-2}	1.9×10^{-3}	5.8×10^{-3}

Abbreviations: mg = milligram; kg = kilogram; PFBA = perfluorobutanoic acid; PFDA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFOS = perfluorooctane sulfonic acid; PFOSA = perfluorooctane sulfonamide; PFUnA = perfluoroundecanoic acid.

Table 11 depicts the fish sampled and whether eating those fish with PFOS at the three consumption rates represents a potential for non-cancer health effects. The PFOS levels in four fish species analyzed represented a potential health concern for children and adults at the highest intake of 10 ounces weekly. The four species with elevated levels of PFOS include American shad roe, blueback herring, striped bass, and sea lamprey. At the lowest intake rates of 10 ounces monthly, the levels of PFOS from the four species remain a potential non-cancer health concern for children. Adults who eat fish at the lowest intake rates would be potentially exposed to levels of PFOS above a non-caner concern only for the sea lamprey.

Table 11. Fish species containing perfluorooctane sulfonic acid (PFOS) (evaluated at the maximum concentration) above a level of non-cancer concern for children or adults (indicated by HC), and below a level of concern (depicted by a minus "–"symbol) based on three consumption rates.

Fish species		**Child intake rates**	
	143 g/day (5 ounces/day)*	**40 g/day (1.4 ounces/day)**	**10 g/day (0.35 ounces/day)**
Alewife	Not detected	Not detected	Not detected
American shad fillet	Not detected	Not detected	Not detected
American shad roe	HC	HC	HC
Blueback herring	HC	HC	HC
Rainbow smelt	Not detected	Not detected	Not detected
Striped bass	HC	HC	HC
Sea lamprey	HC	HC	HC
		Adult intake rates	
	286 g/day (10 ounces/day)†	**40 g/day (1.4 ounces/day)**	**10 g/day (0.35 ounces/day)**
Alewife	Not detected	Not detected	Not detected
American shad fillet	Not detected	Not detected	Not detected
American shad roe	HC	HC	–
Blueback herring	HC	HC	–
Rainbow smelt	Not detected	Not detected	Not detected
Striped bass	HC	HC	–
Sea lamprey	HC	HC	HC

*The Wabanaki scenario intake rate for children is 143 g per day, half the adult rate of 286 g per day.

†The Wabanaki scenario intake rate for adults is 286 grams per day.

Table 12 uses striped bass as an example to show how ATSDR evaluated PFOS in anadromous fish. Table 12 shows the estimated PFOS dose in children and adults and whether that dose exceeds ATSDR's PFOS health guideline (MRL) (2×10^{-6} mg/kg/day).

The doses in children and adults approach effects levels identified in animal studies. ATSDR's MRL of 2×10^{-6} mg/kg/day is based on a rat study [ATSDR 2018] that identified delayed eye opening and a temporary decrease in body weight in the offspring of rats after two generations of exposure. Other studies identified other harmful effects at similar doses.

Table 12. Site-specific exposure doses for chronic exposure to perfluorooctane sulfonic acid (PFOS) in striped bass at 0.0061 mg/kg , and non-cancer hazard quotients.

PUBLIC HEALTH ASSESSMENT SITE TOOL PHAST **Exposure group**	**Dose (mg/kg/day)**	**Exceeds ATSDR's MRL for PFOS**	**Non-cancer hazard quotient**
Child 5 oz/day	5.5×10^{-5}	Yes	27 †
Adult 10 oz/day	2.2×10^{-5}	Yes	11 †
Child 10 oz/wk	1.5×10^{-5}	Yes	7.6 †
Adult 10 oz/wk	3.1×10^{-6}	Yes	1.5 †
Child 10 oz/mo	3.8×10^{-6}	Yes	1.9 †
Adult 10 oz/mo	7.6×10^{-7}	No	0.38

Abbreviations: mg/kg/day = milligram per kilogram body weight per day; kg = kilogram; mg/kg = milligram chemical per kilogram food; mo = month; oz = ounce; PFOS = perfluorooctane sulfonic acid; wk = week.

* The calculations in this table were generated using ATSDR's PHAST v1.6.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year).

† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

The following harmful effects, designated in Table 12 as a health concern (HC), might be expected in children:

- Studies in mice have shown that PFOS exposure adversely affects the immune system, specifically through reduced antibody response. A lowered immune response might hurt the ability of PIN members to fight off infections.
- Studies in rats have shown that PFOS exposure results in a decrease in body weight and changes in sugar metabolism (increased serum glucose) as the young rats grow. Similar effects might be expected in some newborns and young PIN children.

We do not know if the immune and developmental effects seen in rodents would occur in humans. Rodents and humans differ in some ways in how they excrete PFAS. Humans and animals react differently to PFAS, and not all effects seen in animals will occur in humans. In addition, long-term exposure studies in rodents have not been conducted. This health consultation evaluates PFAS exposure from only one source—eating anadromous fish. It does not account for PFAS exposure from other sources. These points add uncertainty to the conclusions about whether harmful effects might be possible in people.

- Insufficient information is available about the potential harmful effects of other PFAS detected in anadromous fish. In addition, we do not know whether the mixture of PFAS in anadromous fish might result in greater harm than being exposed to PFOS alone. This lack of knowledge increases the uncertainty when evaluating PFAS in anadromous fish.

What we know about PFAS studies in humans

Many studies have examined PFAS levels in blood and adverse health effects in people. However, not all studies involved the same groups of people, the same type of exposure, or the same PFAS, resulting in a variety of observed health outcomes. Research in humans suggests that high levels of certain PFAS in the blood may lead to various health concerns:

- increased cholesterol levels
- changes in liver enzymes
- decreased vaccine response in children
- increased risk for high blood pressure or pre-eclampsia in pregnant women
- increased risk for kidney or testicular cancer
- small decreases in infant birth weight [ATSDR 2018a]

However, at this time, we do not know the amount of PFAS exposure (the dose) in humans that is associated with the adverse effects. For this reason, ATSDR relies on the doses from animal studies.

Cancer risks

Dioxins, furans, and dioxin-like PCBs

Table 13 lists the fish species containing dioxins, furans, and dioxin-like PCBs above a level of concern for cancer. Tables A-2 through A-4 in Appendix A show the cancer risks based on eating each fish species. These tables also show the minimum and maximum concentrations, the concentrations used to calculate the dose, and calculated exposure doses. See Appendix B for more details on the ATSDR evaluation process used in this health consultation.

Table 13. Fish species containing dioxins, chlorinated dibenzofurans, or dioxin-like PCBs (evaluated at the 95th upper concentration of the mean or maximum concentration) representing an excess of 1 in 10,000 risk for developing cancer for children or adults similarly exposed (indicated by HC), based on three consumption rates.

Fish species		**Child intake rates**	
	143 g/day (5 ounces/day)*	**40 g/day (1.4 ounces/day)**	**10 g/day (0.35 ounces/day)**
Alewife	HC	HC	HC
American shad fillet	HC	HC	HC
American shad roe	HC	HC	HC
Blueback herring	HC	HC	HC
Rainbow smelt	HC	HC	HC
Striped bass	HC	HC	HC
Sea lamprey	HC	HC	HC
		Adult intake rates	
	286 g/day (10 ounces/day)†	**40 g/day (1.4 ounces/day)**	**10 g/day (0.35 ounces/day)**
Alewife	HC	HC	HC
American shad fillet	HC	HC	HC
American shad roe	HC	HC	HC
Blueback herring	HC	HC	HC
Rainbow smelt	HC	HC	HC
Striped bass	HC	HC	HC
Sea lamprey	HC	HC	HC

*The Wabanaki scenario intake rate for children is half the adult rate of 286 grams per day.

†The adult intake rate is based on the Wabanaki scenario of 286 grams per day.

If children eat fish for 6 years and if adults eat fish for 30 years, the dioxins, chlorinated dibenzofurans, and dioxin-like PCBs in those fish could contribute to an increased risk for liver cancer later in life. Table 14 shows a sample of the calculated cancer risk. Children and adults might have cancer risks that exceed six extra cases of cancer for every 1,000 persons who eat 5 or 10 ounces of alewife daily. For children and adults who eat 10 oz alewife weekly, their cancer risk exceeds 1 extra case per 1,000 persons. For children and adults who eat 10 ounces monthly, their cancer risk is about four extra cases per 10,000 persons.

The concentration of dioxin TEQs in alewife is 61 pg/g. Other fish in the PIN survey had similar levels, which ranged from 44 to 160 pg/g. The average dioxin TEQ levels in the PIN survey was 71 pg/g. Therefore, even if PIN members ate a variety of fish from the survey, their cancer risks would be similar to the ones shown in Table 14.

The dioxin TEQs levels in the PIN survey were much higher than what would be expected in marine fish. Although data are limited, background levels of dioxin TEQs in marine fish are probably around 1 pg/g [Blanco et al. 2013]. With concentrations ranging from 44 pg/g (blueback herring) to 160 pg/g (striped bass), PIN survey fish had much higher dioxin TEQs. Table 10 shows the dioxin TEQ cancer risk estimations for chronic exposures for children and adults at the three intake levels.

Table 14. Site-specific cancer risk estimations for chronic exposure to dioxin toxic equivalents (TEQs) in alewife 0.000062 mg/kg (62 picograms per gram).

Exposure group	Exposure duration for cancer (years)	Dioxin TEQ concentration in alewife pg/g	Cancer risk from eating alewife with 62 pg/g	Cancer risk from eating alewife with 1 pg/g
Child 5 oz/day	6	61	6×10^{-3} †,‡	9×10^{-5}
Adult 10 oz/day	30	61	1×10^{-2} ‡	2×10^{-4}
Child 10 oz/wk	6	61	2×10^{-3} ‡	3×10^{-5}
Adult 10 oz/wk	30	61	25×10^{-3} ‡	3×10^{-5}
Child 10 oz/mo	6	61	4×10^{-4} ‡	6×10^{-6}
Adult 10 oz/mo	30	61	4×10^{-4} ‡	6×10^{-6}

Abbreviations: mg/kg = milligram chemical per kilogram food; kg = kilogram; mo = month; oz = ounce; pg = picogram; pg/g = picogram per gram; TEQs = toxic equivalents; wk = week; yrs = years.

* The calculations in this table were generated using ATSDR's PHAST v1.6.1.0.

† A shaded cell indicates the estimated cancer risk is above 1×10^{-4}.

PBDEs

The only evidence for carcinogenicity of PBDEs in human studies is one small case-control study reporting possible associations between adipose PBDE concentrations and risk for pancreatic cancer. Evidence of carcinogenicity in animals is limited [ATSDR 2017]. Because of that, ATSDR was unable to determine the carcinogenic risk for PBDEs exposure in contaminated fish tissue.

Methylmercury and PFOS

Currently, we cannot evaluate the possibility that consumption of PFOS in fish might contribute to increased cancer risk. Some animal studies have shown a link between methylmercury and cancer. Studies do not clearly show whether PFAS contribute to cancer in people. EPA has concluded that there is suggestive evidence that PFOS might increase cancer risk. People exposed to high levels might have increased risk for kidney cancer or testicular cancer. However, these studies are not consistent and might not have looked at other associated factors, such as smoking. Studies in animals have shown PFOA and PFOS exposure to be associated with cancer in the liver, testes, pancreas, and thyroid. However, some scientists believe that humans might not develop the same cancers as animals (ATSDR 2018). Currently, there are no EPA-derived cancer slope factors to quantitatively estimate the carcinogenic risks from exposure to methylmercury or PFOS (see Appendix B for more details).

PCBs

The next section discusses the potential cancer concern for PCBs that are not classified as dioxin-like. Table 15 depicts the fish sampled and whether eating those fish that have PCBs represents a potential cancer health concern. For children, only striped bass represented an increased cancer risk if eaten at the highest (5 to 10 ounces daily) and moderate (10 ounces weekly) intake rates.

For adults, all species (except American shad roe) represent an increased cancer risk if consumed at 5 to 10 ounces daily. Striped bass are also a potential cancer concern at an intake rate of 10 ounces weekly. Adults and children who eat 10 ounces of fish monthly would not be at a potential cancer health concern.

Table 15. Fish species containing PCBs (evaluated at the 95th upper concentration of the mean or maximum concentration) representing an excess of greater than 1 in 10,000 risk for developing cancer for children or adults similarly exposed (indicated by HC [health concern]), and below a level of concern (depicted by a minus "–"symbol) based on three consumption rates.

Fish species	**Child intake rates**		
	143 g/day (5 oz/day)*	**40 g/day (1.4 oz/day)**	**10 g/day (0.35 oz/day)**
Alewife	–	–	–
American shad fillet	–	–	–
American shad roe	–	–	–
Blueback herring	–	–	–
Rainbow smelt	–	–	–
Striped bass	HC	HC	–
Sea lamprey	–	–	–
	Adult intake rates		
	286 g/day (10 ounces/day)†	**40 g/day (1.4 ounces/day)**	**10 g/day (0.35 ounces/day)**
Alewife	HC	–	–
American shad fillet	HC	–	–
American shad roe	–	–	–
Blueback herring	HC	–	–
Rainbow smelt	HC	–	–
Striped bass	HC	HC	–
Sea lamprey	HC	–	–

Abbreviations: g = grams; oz = ounces.

*The Wabanaki scenario intake rate for children is 143 g per day, half the adult rate of 286 g per day.

†The Wabanaki scenario intake rate for adults is 286 g per day.

Conclusions

The fish species evaluated in this health consultation have levels of dioxin that represent a health hazard for PIN members of all age groups. The presentation of contaminant-specific recommendations has been provided for comparison only. Those recommendations would only apply if the contaminant presented was the only contaminant in the fish tissue.

1. PIN members who eat fish for a year or more at three intake rates considered might be exposed to harmful levels of dioxins, chlorinated dibenzofurans, and dioxin-like PCBs.

   Basis for conclusion
   ATSDR estimated cancer risk in children based on 6 years of exposure from eating fish and cancer risk in adults based on 30 years of exposure. Those are the same durations used in the previous public health assessment [ATSDR 2014]. For those estimates , ATSDR used the following rates of eating fish:
   - 5 ounces (143 grams) daily (child) or 10 ounces (286 grams) daily (adult)
   - 10 ounces (40 grams per day) weekly
   - 10 ounces (10 grams per day) monthly

   If PIN members (children and adults) eat anadromous fish at the three rates described, the dioxins, chlorinated dibenzofurans, and dioxin-like PCBs in those fish could produce harmful effects, including a significantly increased risk for liver cancer. Boys who eat anadromous fish could experience reproductive problems later in life. Pregnant women could expose their developing fetus to dioxins that could result in developmental problems in newborns and infants. Pregnant women also might experience complications during their pregnancy. These effects are described in more detail in the section of the report that covers dioxins, furans, and dioxin-like PCBs.

2. PIN members (children and adults) who eat fish for a year or more might be exposed to harmful levels of PCBs in some anadromous fish species.

   Basis for conclusion
   If PIN members eat some anadromous fish described in this health consultation at the highest intake rate of 5 to 10 ounces daily, the PCBs in those fish could cause harmful non-cancer health effects and might result in an elevated cancer risk. The highest levels of PCBs were detected in striped bass. At the intake rate of 10 ounces weekly, eating only striped bass is a concern for harmful effects in children and adults. At the intake rate of 10 ounces monthly, eating only striped bass is a concern for harmful effects in children but not adults. Reducing the intake of striped bass might reduce the risk for harmful effects. The health effects that PIN members might experience from PCB exposure include adverse immune effects, such as a decreased antibody response. Studies also have shown damage to glands associated with the eyes and changes in toenails and fingernails.

3. Certain anadromous fish have mercury levels that are a health concern for children. One species (sea lamprey) is a health concern for adult women who are or might become pregnant.

   Basis for conclusion
   Methylmercury is most harmful to children and developing fetuses and could interfere with a child's ability to learn and process information. Therefore, it is especially important for pregnant and breastfeeding women, women who might become pregnant, and children to limit their consumption of certain anadromous fish. PIN members should limit the amounts of certain fish they eat:
   - Children should not eat more than 5 ounces per day of rainbow smelt, striped bass, or sea lamprey.
   - Children should not eat more than 10 ounces per week of sea lamprey.
   - Pregnant women or women planning to become pregnant should not eat more than 10 ounces daily of sea lamprey. Following these recommendations will decrease the risk for neurological damage from mercury exposure.

4. Levels of perfluorooctane sulfonic acid (PFOS), one type of PFAS (per- and polyfluoroalkyl substances), were detected in four species of anadromous fish at levels that might pose an increased risk for non-cancer harmful health effects. PIN members (children and adults) who eat those fish (American shad roe, blueback herring, striped bass, and sea lamprey) at the three intake rates described might experience these adverse health effects.

   Studies in humans and animals provide suggestive evidence that PFOS might contribute to cancer. As it is challenging to estimate a numeric cancer risk, the potential effect of PFOS exposure on the risk for developing cancer remains unclear.

   Basis for conclusion
   Studies in mice have shown that PFOS exposure might adversely affect the immune system, specifically through reduced antibody response. A lowered immune response might hurt the ability of PIN members to fight off infections. Studies in rats have shown that PFOS exposure might be associated with decreases in body weight and changes in glucose metabolism (increased serum glucose) as the young rats grow.

   People might or might not have the same the immune and developmental effects seen in mice and rats. Humans and rodents differ somewhat in how they ride their bodies of PFAS. The pharmacokinetic difference likely make rodents less sensitive (the PFAS leave their bodies more quickly). Other differences, such as the expression of PPARalpha, a liver metabolism regulator, might make rodents more sensitive. Humans and animals react differently to PFAS, and not all effects seen in animals occur in humans. In addition, long-term exposure studies in rodents have not been conducted. This health consultation evaluates PFAS exposure from only one source — eating anadromous fish. It does not and cannot account for PFAS exposure from other sources. These points add uncertainty to the conclusions about whether harmful effects might be possible in people.

5. PIN members (children and adults) who eat any fish species at the highest intake rates for a year or more might be exposed to harmful levels of polybrominated diphenyl ethers (PBDEs).

   Basis for conclusion
   Adult rats that ate small amounts of PBDEs for 8 weeks showed damage to their reproductive systems, specifically reduced serum testosterone levels. Testosterone plays an important role in adults, and in male and female children. Testosterone in males is important for development during puberty, sperm creation, and muscle and bone strength. Testosterone in females is important for maintaining other hormone levels, fertility, and making new blood cells. PIN members should follow these fish consumption guidelines:

   - Children should not eat any fish species at 1 ounce/day (or more)

   Adults should not eat any fish species at 10 ounces/day (or more) and should not eat striped bass at 1 ounce/day (or more).

Recommendations

1. PIN members should not eat any of the anadromous fish described in this health consultation because dioxin levels might cause harmful effects, including a significantly increased risk for liver cancer.

2. Children should not eat any striped bass because of PCBs and PBDEs. Adults should not eat striped bass daily or at 10 ounces per week because of PCBs and PBDEs

3. PIN members should avoid certain anadromous fish species because of mercury levels in the fish.
   - Pregnant women or women planning to become pregnant should not eat any sea lamprey because of elevated mercury levels in this species.
   - Children should not eat any rainbow smelt, striped bass, or sea lamprey daily because of mercury levels.
   - Children should not eat sea lamprey at 10 ounces per week because of mercury.

Next step

- ATSDR remains available to provide, on request, input on public health questions related to possible site-related exposures.

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Appendix A: Figures and tables

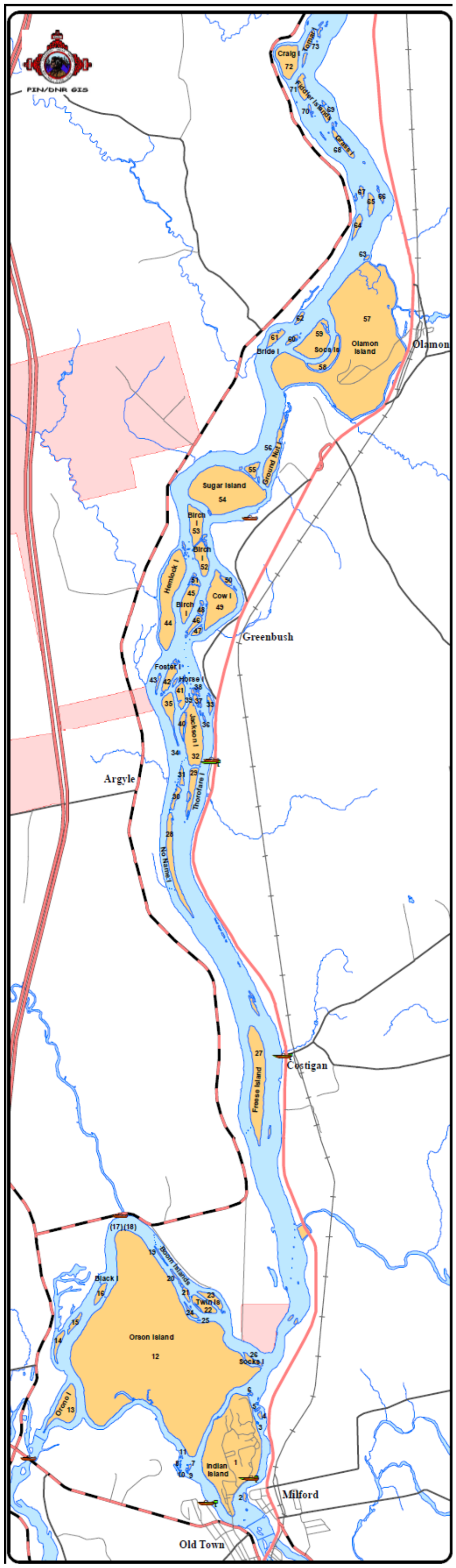

Figure A-1. Penobscot Indian Nation Reservation Islands (1 of 3). Source: https://www.penobscotnation.org/images/natural-resources/GIS/PDFs/RezIslands/rez_ild_8x11_2018.pdf.

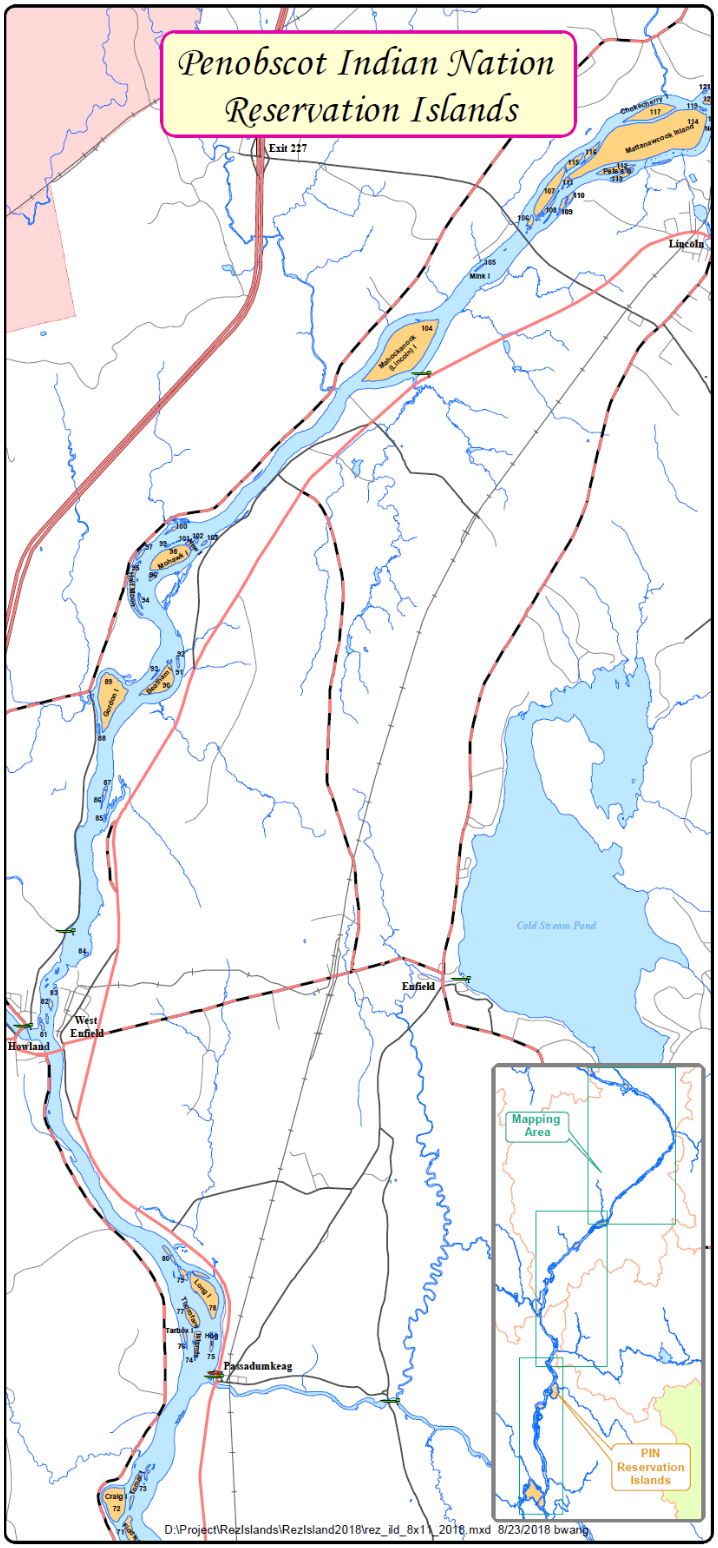

Figure A-2. Penobscot Indian Nation Reservation Islands (2 of 3). Source: https://www.penobscotnation.org/images/natural-resources/GIS/PDFs/RezIslands/rez_ild_8x11_2018.pdf.

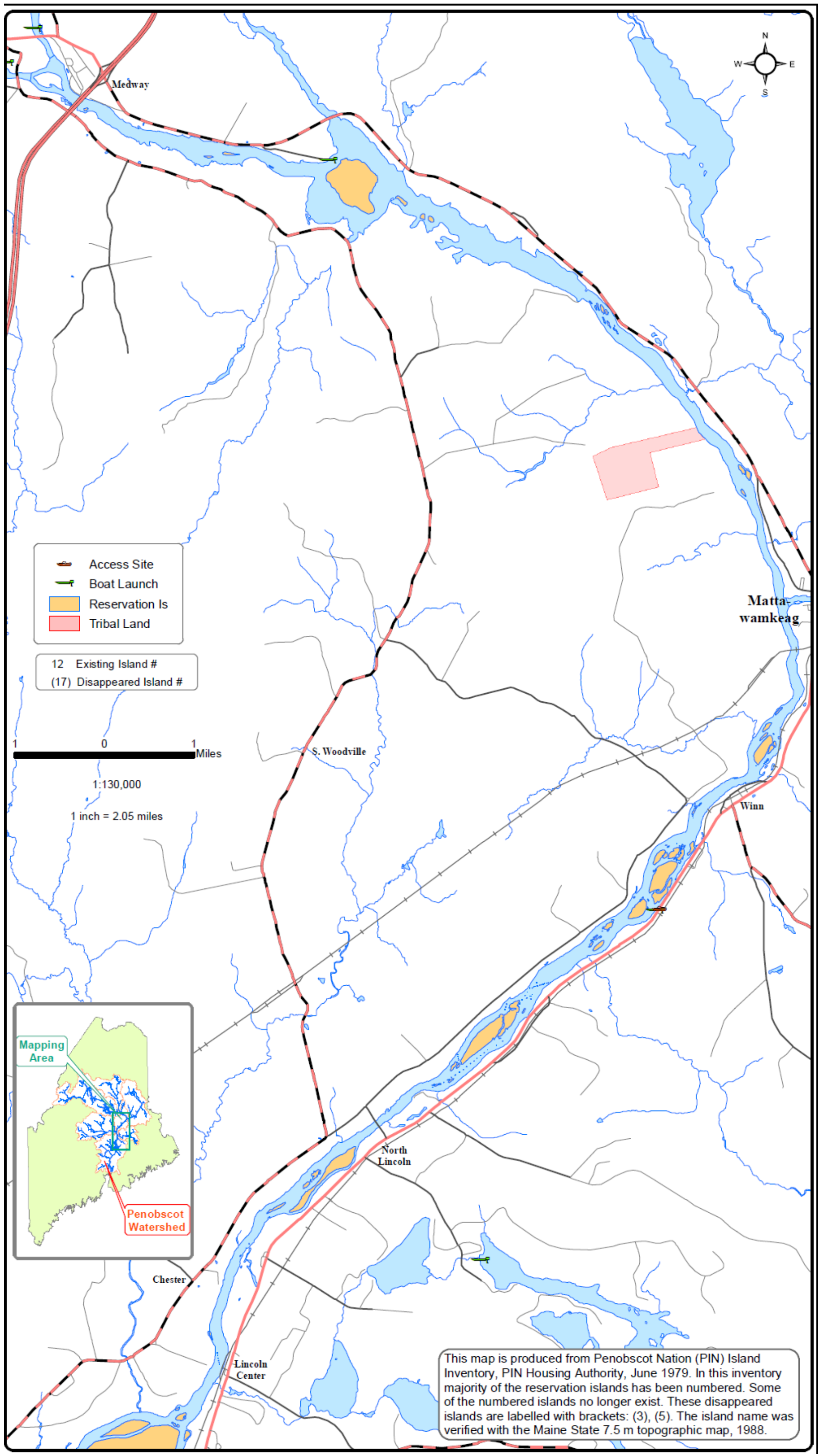

Figure A-3. Penobscot Indian Nation Reservation Islands (3 of 3). Source: https://www.penobscotnation.org/images/natural-resources/GIS/PDFs/RezIslands/rez_ild_8x11_2018.pdf.

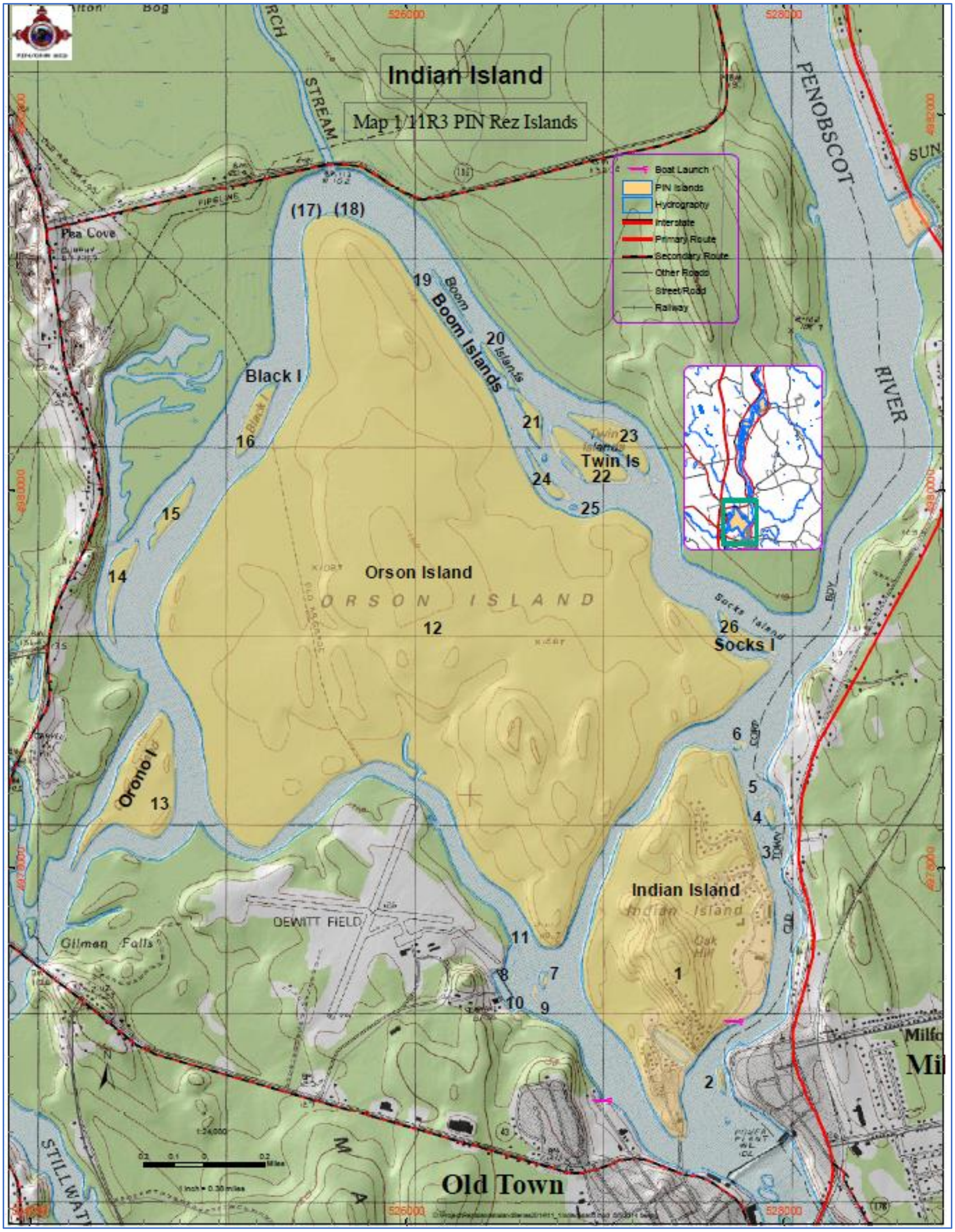

Figure A-4. Map of Indian Island, Penobscot Indian Nation. Source: https://www.penobscotnation.org/images/natural-resources/GIS/PDFs/RezIslands/11_1IndianIsland.pdf.

Table A-1. PFAS and possible effects on organ systems.

Specific PFAS	Cardiovascular	Developmental	Endocrine	Liver	Immune	Reproductive	Serum lipid
PFBA	No	Yes	Yes	Yes	No	No	No
PFDA	No	No	No	No	No	No	No
PFDoA	No	Yes	Yes	Yes	Yes	No	No
PFOS	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PFOSA	No	No	No	No	No	No	No
PFUnA	No	No	No	No	No	No	No

Notes: YES = Indicates possible effects on this target organ system. NO = Indicates no effects/insufficient information.

Abbreviation	Definition	Citation for effects (if applicable)
PFBA	perfluorobutanoic acid	[MDH] Minnesota Department of Health 2017
PFDA	perfluorodecanoic acid	No effects or insufficient information on target organ systems
PFDoA	perfluorododecanoic acid	ATSDR 2018
PFOS	perfluorooctane sulfonic acid	ATSDR 2018
PFOSA	perfluorooctane sulfonamide	No effects or insufficient information on target organ systems
PFUnA	perfluoroundecanoic acid	No effects or insufficient information on target organ systems

Table A-2. Fish species, chemical concentration, dose, and cancer risks using intake of 286 grams per day for adults and 143 grams per day for children.

Species	Chemical	Minimum concentration*	Maximum concentration *	Concentration for dose†	Child dose	Adult dose	Child cancer risk	Adult cancer risk
Alewife	Mercury	8.00E-02	1.10E-01	1.04E-01§	9.3E-04	3.7E-04	n/a	n/a
	PCBs	6.60E-03	1.90E-02	1.6E-029§	1.4E-04	5.7E-05	2E-05	4E-05
	PFBA	4.50E-03	1.10E-02	Max	1.0E-04	4.04E-05	n/a	n/a
	Dioxin‡	7.50E-06	6.10E-05	Max (UCL>max)	5.5E-07	2.04E-07	6E-03	1E-02
American shad fillet	Mercury	5.60E-02	9.60E-02	8.44E-02¶	7.5E-04	3.0E-04	n/a	n/a
	PCBs	7.90E-03	3.40E-02	2.50E-02**	2.2E-04	8.9E-05	3E-05	7E-05
	PFBA	1.40E-03	9.10E-03	Max	8.1E-05	3.2E-05	n/a	n/a
	Dioxin‡	9.90E-06	7.20E-05	5.7E-5¶	5.1E-07	2.0E-07	5E-03	1E-02
American shad roe	Mercury	3.90E-03	2.50E-02	1.90E-02**	1.7E-04	6.8E-05	n/a	n/a
	PCBs	2.10E-03	1.60E-02	1.29E-02¶	1.2E-04	4.6E-05	2E-05	4E-05
	PFBA	1.90E-03	7.60E-03	Max	6.8E-05	2.7E-05	n/a	n/a
	PFOS	2.90E-03	6.90E-03	Max	6.1E-05	2.5E-05	n/a	n/a
	Dioxin‡	2.90E-03	6.90E-03	6.2E-5**	5.5E-07	2.2E-07	6E-03	1E-02
Blueback herring	Mercury	4.30E-06	9.30E-05	Max (UCL>max)	6.0E-04	2.4E-04	n/a	n/a
	PCBs	3.60E-02	6.70E-02	2.42E-02§	2.2E-04	8.7E-05	3E-05	7E-05
	PFBA	1.30E-03	6.20E-03	Max	5.5E-05	2.2E-05	n/a	n/a
	PFOS	3.20E-03	5.40E-03	Max	4.8E-05	1.9E-05	n/a	n/a
	Dioxin‡	1.30E-03	6.20E-03	4.4e-5§	3.9E-07	1.6E-07	4E-03	8E-03
Rainbow smelt LG	Mercury	1.30E-01	1.50E-01	Max	1.3E-03	5.3E-04	n/a	n/a
Rainbow smelt SM	Mercury	9.10E-02	1.40E-01	Max	1.2E-03	5.0E-04	n/a	n/a
Rainbow smelt LG+SM	PCBs	2.60E-03	4.20E-02	2.63E-02**	2.4E-04	9.4E-05	4E-05	7E-05
	PFAS	Not analyzed						
	Dioxin‡	1.30E-05	7.20E-05	6.8E-5§	6.1E-07	2.4E-07	6E-03	1E-02
Striped bass	Mercury	1.30E-01	2.60E-01	2.1E-01**	1.9E-03	7.4E-04	n/a	n/a
	PCBs	2.60E-02	2.50E-01	1.6E-01**	1.4E-03	5.7E-04	2E-04	4E-04
	PFBA	1.50E-03	4.00E-03	Max	3.5E-05	1.4E-05	n/a	n/a
	PFDA	1.10E-03	1.10E-03	Max	1.0E-05	4.0E-06	n/a	n/a
	PFOS	1.70E-03	6.10E-03	Max	5.5E-05	2.2E-05	n/a	n/a
	PFOSA	1.00E-03	2.10E-03	Max	1.9E-05	7.4E-06	n/a	n/a
	Dioxin‡	2.14E-05	2.05E-04	1.6E-4§	1.4E-06	5.7E-07	1E-02	3E-02
Sea lamprey	Mercury	2.90E-01	1.10E+00	7.8E-01¶	7.0E-03	2.8E-03	n/a	n/a
	PCBs	4.36E-03	4.35E-02	2.7E-02§	2.4E-04	9.5E-05	4E-05	7E-05
	PFDA	1.10E-03	4.80E-03	Max	4.3E-05	1.7E-05	n/a	n/a
	PFDoA	1.10E-03	3.10E-03	Max	2.7E-05	1.1E-05	n/a	n/a
	PFOS	2.00E-03	2.00E-02	Max	1.8E-04	7.3E-05	n/a	n/a
	PFOSA	2.30E-03	9.80E-03	Max	8.8E-05	3.5E-05	n/a	n/a
	PFUnA	1.90E-03	1.40E-02	Max	1.3E-04	5.1E-05	n/a	n/a
	Dioxin‡	4.20E-06	7.10E-05	4.6E-5§	4.1E-07	1.6E-07	4E-03	8E-03

Note: Doses are in milligram per kilogram per day. Shaded values exceed 1 in 10,000 increased risk for developing cancer. All calculations were conducted using PHAST v1.6.1.0.

Abbreviations: LG = large mouth; max = maximum; n/a = not analyzed - there is insufficient information available to calculate this value; PCBs = polychlorinated biphenyls; PFBA = perfluorobutanoic acid; PFDA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFOS = perfluorooctane sulfonic acid; PFOSA = perfluorooctane sulfonamide; PFUnA = perfluoroundecanoic acid; SM = small mouth; UCL = upper confidence limit.

*milligram per kilogram. †Maximum was used when there were fewer than eight samples. ‡Includes dioxin, furan, and dioxin-like PCBs. §log normal 95 UCL. ¶normal 95 UCL. **gamma 95 UCL.

Table A-3. Fish species, chemical concentrations, dose, and cancer risks using 10 ounces per week (40 grams per day) intake.

Species	Chemical	Minimum concentration*	Maximum concentration *	Concentration for dose†	Child dose	Adult dose	Child cancer risk	Adult cancer risk
Alewife	Mercury	8.00E-02	1.10E-01	1.04E-01§	2.60E-04	5.20E-05	n/a	n/a
	PCBs	6.60E-03	1.90E-02	1.6E-029§	4.00E-05	8.00E-06	6.E-06	6.E-06
	PFBA	4.50E-03	1.10E-02	Max	2.80E-05	5.70E-06	n/a	n/a
	Dioxin‡	7.50E-06	6.10E-05	Max (UCL>max)	1.50E-07	3.10E-08	2.E-03	2.E-03
American shad fillet	Mercury	5.60E-02	9.60E-02	8.44E-02¶	2.10E-04	4.20E-05	n/a	n/a
	PCBs	7.90E-03	3.40E-02	2.50E-02**	6.30E-05	1.30E-05	1.E-05	1.E-05
	PFBA	1.40E-03	9.10E-03	Max	2.30E-05	4.50E-06	n/a	n/a
	Dioxin‡	9.90E-06	7.20E-05	5.7E-5¶	1.40E-07	2.90E-08	1.E-03	1.E-03
American shad roe	Mercury	3.90E-03	2.50E-02	1.90E-02**	4.80E-05	9.50E-06	n/a	n/a
	PCBs	2.10E-03	1.60E-02	1.29E-02¶	3.20E-05	6.50E-06	5.E-06	5.E-06
	PFBA	1.90E-03	7.60E-03	Max	1.90E-05	3.80E-06	n/a	n/a
	PFOS	2.90E-03	6.90E-03	Max	1.70E-05	3.40E-06	n/a	n/a
	Dioxin‡	2.90E-03	6.90E-03	6.2E-5**	1.50E-07	3.10E-08	2.E-03	2.E-03
Blueback herring	Mercury	4.30E-06	9.30E-05	Max (UCL>max)	1.70E-04	3.40E-05	n/a	n/a
	PCBs	3.60E-02	6.70E-02	2.42E-02§	6.10E-05	1.20E-05	9.E-06	9.E-06
	PFBA	1.30E-03	6.20E-03	Max	1.50E-05	3.10E-06	n/a	n/a
	PFOS	3.20E-03	5.40E-03	Max	1.30E-05	2.70E-06	n/a	n/a
	Dioxin‡	1.30E-03	6.20E-03	4.4E-5§	1.10E-07	2.20E-08	1.E-03	1.E-03
Rainbow smelt LG	Mercury	1.30E-01	1.50E-01	Max	3.70E-04	7.40E-05	n/a	n/a
Rainbow smelt SM	Mercury	9.10E-02	1.40E-01	Max	3.50E-04	6.90E-05	n/a	n/a
Rainbow smelt LG+SM	PCBs	2.60E-03	4.20E-02	2.63E-02**	6.60E-05	1.30E-05	1.E-05	1.E-05
	PFAS	Not analyzed						
	Dioxin‡	1.30E-05	7.20E-05	6.8E-5§	1.70E-07	3.40E-08	2.E-03	2.E-03
Striped bass	Mercury	1.30E-01	2.60E-01	2.1E-01**	5.20E-04	1.00E-04	n/a	n/a
	PCBs	2.60E-02	2.50E-01	1.6E-01**	4.00E-04	8.00E-05	6.E-05	6.E-05
	PFBA	1.50E-03	4.00E-03	Max	9.90E-06	2.00E-06	n/a	n/a
	PFDA	1.10E-03	1.10E-03	Max	2.80E-06	5.60E-07	n/a	n/a
	PFOS	1.70E-03	6.10E-03	Max	1.50E-05	3.10E-06	n/a	n/a
	PFOSA	1.00E-03	2.10E-03	Max	5.20E-06	1.00E-06	n/a	n/a
	Dioxin‡	2.14E-05	2.05E-04	1.6E-4§	4.00E-07	8.00E-08	4.E-03	4.E-03
Sea lamprey	Mercury	2.90E-01	1.10E+00	7.8E-01¶	2.00E-03	3.90E-04	n/a	n/a
	PCBs	4.36E-03	4.35E-02	2.7E-02§	6.60E-05	1.30E-05	1.E-05	1.E-05
	PFDA	1.10E-03	4.80E-03	Max	1.20E-05	2.40E-06	n/a	n/a
	PFDoA	1.10E-03	3.10E-03	Max	7.70E-06	1.50E-06	n/a	n/a
	PFOS	2.00E-03	2.00E-02	Max	5.10E-05	1.00E-05	n/a	n/a
	PFOSA	2.30E-03	9.80E-03	Max	2.50E-05	4.90E-06	n/a	n/a
	PFUnA	1.90E-03	1.40E-02	Max	3.60E-05	7.20E-06	n/a	n/a
	Dioxin‡	4.20E-06	7.10E-05	4.6E-5§	1.10E-07	2.30E-08	1.E-03	1.E-03

Note: Doses are in milligram per kilogram per day. Shaded values exceed 1 in 10,000 increased risk for developing cancer All calculations were conducted using PHAST v1.6.1.0.

Abbreviations: LG = large mouth; max = maximum; n/a = not analyzed - there is insufficient information available to calculate this value; PCBs = polychlorinated biphenyls; PFBA = perfluorobutanoic acid; PFDA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFOS = perfluorooctane sulfonic acid; PFOSA = perfluorooctane sulfonamide; PFUnA = perfluoroundecanoic acid; SM = small mouth; UCL = upper confidence limit.

*milligram per kilogram. †Maximum was used when there were fewer than eight samples. ‡Includes dioxin, furan, and dioxin-like PCBs. §log normal 95 UCL. ¶normal 95 UCL. **gamma 95 UCL.

Table A-4. Fish species, chemical concentrations, dose, and cancer risks using 10 ounces per month (10 grams per day) intake.

Species	Chemical	Minimum concentration*	Maximum concentration *	Concentration for dose†	Child Dose	Adult Dose	Child cancer risk	Adult cancer risk
Alewife	Mercury	8.00E-02	1.10E-01	1.04E-01§	6.5E-05	1.3E-05	n/a	n/a
	PCBs	6.60E-03	1.90E-02	1.6E-029§	9.9E-06	2.0E-06	2E-06	2E-06
	PFBA	4.50E-03	1.10E-02	Max	7.1E-06	1.4E-06	n/a	n/a
	Dioxin‡	7.50E-06	6.10E-05	Max (UCL>max)	3.9E-08	7.7E-09	4E-04	4E-04
American shad fillet	Mercury	5.60E-02	9.60E-02	8.44E-02¶	5.3E-05	1.1E-05	n/a	n/a
	PCBs	7.90E-03	3.40E-02	2.50E-02**	1.6E-05	3.1E-06	2E-06	2E-06
	PFBA	1.40E-03	9.10E-03	Max	5.7E-06	1.1E-06	n/a	n/a
	Dioxin‡	9.90E-06	7.20E-05	5.7E-5¶	3.6E-08	7.1E-09	4E-04	4E-04
American shad roe	Mercury	3.90E-03	2.50E-02	1.90E-02**	1.2E-05	2.4E-06	n/a	n/a
	PCBs	2.10E-03	1.60E-02	1.29E-02¶	8.1E-06	1.6E-06	1E-06	1E-06
	PFBA	1.90E-03	7.60E-03	Max	4.8E-06	9.5E-07	n/a	n/a
	PFOS	2.90E-03	6.90E-03	Max	4.3E-06	8.6E-07	n/a	n/a
	Dioxin‡	2.90E-03	6.90E-03	6.2E-5**	3.9E-08	n/a	4E-04	4E-04
Blueback herring	Mercury	4.30E-06	9.30E-05	Max (UCL>max)	4.2E-05	7.7E-09	n/a	n/a
	PCBs	3.60E-02	6.70E-02	2.42E-02§	1.5E-05	8.4E-06	2E-06	2E-06
	PFBA	1.30E-03	6.20E-03	Max	3.9E-06	3.0E-06	n/a	n/a
	PFOS	3.20E-03	5.40E-03	Max	3.4E-06	7.7E-07	n/a	n/a
	Dioxin‡	1.30E-03	6.20E-03	4.4E-5§	2.7E-08	6.7E-07	3E-04	3E-04
Rainbow smelt LG	Mercury	1.30E-01	1.50E-01	Max	9.3E-05	n/a 5.5E-09	n/a	n/a
Rainbow smelt SM	Mercury	9.10E-02	1.40E-01	Max	8.7E-05	1.9E-05	n/a	n/a
Rainbow smelt LG+SM	PCBs	2.60E-03	4.20E-02	2.63E-02**	1.6E-05	1.7E-05	3E-06	3E-06
	PFAS	Not analyzed						
	Dioxin‡	1.30E-05	7.20E-05	6.8E-5§	4.2E-08	3.3E-06	4E-04	4E-04
Striped bass	Mercury	1.30E-01	2.60E-01	2.1E-01**	1.3E-04		n/a	n/a
	PCBs	2.60E-02	2.50E-01	1.6E-01**	1.0E-04	8.5E-09	2E-05	2E-05
	PFBA	1.50E-03	4.00E-03	Max	2.5E-06	2.6E-05	n/a	n/a
	PFDA	1.10E-03	1.10E-03	Max	7.0E-07	2.0E-05	n/a	n/a
	PFOS	1.70E-03	6.10E-03	Max	3.8E-06	5.0E-07	n/a	n/a
	PFOSA	1.00E-03	2.10E-03	Max	1.3E-06	1.4E-07	n/a	n/a
	Dioxin‡	2.14E-05	2.05E-04	1.6E-4§	1.0E-07	7.6E-07	1E-03	1E-03
Sea lamprey	Mercury	2.90E-01	1.10E+00	7.8E-01¶	4.9E-04	2.6E-07	n/a	n/a
	PCBs	4.36E-03	4.35E-02	2.7E-02§	1.7E-05	2.0E-08	3E-06	3E-06
	PFDA	1.10E-03	4.80E-03	Max	3.0E-06	9.8E-05	n/a	n/a
	PFDoA	1.10E-03	3.10E-03	Max	1.9E-06	3.3E-06	n/a	n/a
	PFOS	2.00E-03	2.00E-02	Max	1.3E-05	6.0E-07	n/a	n/a
	PFOSA	2.30E-03	9.80E-03	Max	6.1E-06	3.8E-07	n/a	n/a
	PFUnA	1.90E-03	1.40E-02	Max	9.0E-06	2.6E-06	n/a	n/a
	Dioxin‡	4.20E-06	7.10E-05	4.6E-5§	2.9E-08	1.2E-06	3E-04	3E-04

Note: Doses are in milligram per kilogram per day. Shaded values exceed 1 in 10,000 increased risk for developing cancer All calculations were conducted using PHAST v1.6.1.0.

Abbreviations: LG = large mouth; max = maximum; n/a = not analyzed - there is insufficient information available to calculate this value; PCBs = polychlorinated biphenyls; PFBA = perfluorobutanoic acid; PFDA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFOS = perfluorooctane sulfonic acid; PFOSA = perfluorooctane sulfonamide; PFUnA = perfluoroundecanoic acid; SM = small mouth; UCL = upper confidence limit.

*milligram per kilogram. †Maximum was used when there were fewer than eight samples. ‡Includes dioxin, furan, and dioxin-like PCBs. §log normal 95 UCL. ¶normal 95 UCL. **gamma 95 UCL.

Table A-5. Fish species, chemical concentrations, dose, and hazard quotient (HQ) using intake of 10 ounces daily or 286 grams per day for adults (5 ounces daily or 143 grams per day for children).

Species	Chemical	Minimum concentration*	Maximum concentration *	Concentration for dose†	Child dose	Adult dose	Child HQ	Adult HQ
Alewife	Mercury	8.00E-02	1.10E-01	1.04E-01§	9.3E-04	3.7E-04	3.1	1.2
	PCBs	6.60E-03	1.90E-02	1.6E-029§	1.4E-04	5.7E-05	7.1	2.8
	PFBA	4.50E-03	1.10E-02	Max	1.0E-04	4.04E-05	n/a	n/a
	Dioxin‡	7.50E-06	6.10E-05	Max (UCL>max)	5.5E-07	2.04E-07	780	310
American shad fillet	Mercury	5.60E-02	9.60E-02	8.44E-02¶	7.5E-04	3.0E-04	2.5	1.0
	PCBs	7.90E-03	3.40E-02	2.50E-02**	2.2E-04	8.9E-05	11	4.5
	PFBA	1.40E-03	9.10E-03	Max	8.1E-05	3.2E-05	n/a	n/a
	Dioxin‡	9.90E-06	7.20E-05	5.7E-5¶	5.1E-07	2.0E-07	730	290
American shad roe	Mercury	3.90E-03	2.50E-02	1.90E-02**	1.7E-04	6.8E-05	0.6	0.2
	PCBs	2.10E-03	1.60E-02	1.29E-02¶	1.2E-04	4.6E-05	5.8	2.3
	PFBA	1.90E-03	7.60E-03	Max	6.8E-05	2.7E-05	n/a	n/a
	PFOS	2.90E-03	6.90E-03	Max	6.1E-05	2.5E-05	31	12
	Dioxin‡	2.90E-03	6.90E-03	6.2E-5**	5.5E-07	2.2E-07	790	320
Blueback herring	Mercury	4.30E-06	9.30E-05	Max (UCL>max)	6.0E-04	2.4E-04	2.0	0.8
	PCBs	3.60E-02	6.70E-02	2.42E-02§	2.2E-04	8.7E-05	11	4.3
	PFBA	1.30E-03	6.20E-03	Max	5.5E-05	2.2E-05	n/a	n/a
	PFOS	3.20E-03	5.40E-03	Max	4.8E-05	1.9E-05	24	9.6
	Dioxin‡	1.30E-03	6.20E-03	4.4E-5§	3.9E-07	1.6E-07	560	220
Rainbow smelt LG	Mercury	1.30E-01	1.50E-01	Max	1.3E-03	5.3E-04	4.5	1.8
Rainbow smelt SM	Mercury	9.10E-02	1.40E-01	Max	1.2E-03	5.0E-04	4.2	1.7
Rainbow smelt LG+SM	PCBs	2.60E-03	4.20E-02	2.63E-02**	2.4E-04	9.4E-05	12	4.7
	PFAS	Not analyzed						
	Dioxin‡	1.30E-05	7.20E-05	6.8E-5§	6.1E-07	2.4E-07	860	350
Striped bass	Mercury	1.30E-01	2.60E-01	2.1E-01**	1.9E-03	7.4E-04	6.2	2.5
	PCBs	2.60E-02	2.50E-01	1.6E-01**	1.4E-03	5.7E-04	72	29
	PFBA	1.50E-03	4.00E-03	Max	3.5E-05	1.4E-05	n/a	n/a
	PFDA	1.10E-03	1.10E-03	Max	1.0E-05	4.0E-06	n/a	n/a
	PFOS	1.70E-03	6.10E-03	Max	5.5E-05	2.2E-05	27	11
	PFOSA	1.00E-03	2.10E-03	Max	1.9E-05	7.4E-06	n/a	n/a
	Dioxin‡	2.14E-05	2.05E-04	1.6E-4§	1.4E-06	5.7E-07	2,000	820
Sea lamprey	Mercury	2.90E-01	1.10E+00	7.8E-01¶	7.0E-03	2.8E-03	23	9.3
	PCBs	4.36E-03	4.35E-02	2.7E-02§	2.4E-04	9.5E-05	12	4.7
	PFDA	1.10E-03	4.80E-03	Max	4.3E-05	1.7E-05	n/a	n/a
	PFDoA	1.10E-03	3.10E-03	Max	2.7E-05	1.1E-05	n/a	n/a
	PFOS	2.00E-03	2.00E-02	Max	1.8E-04	7.3E-05	92	37
	PFOSA	2.30E-03	9.80E-03	Max	8.8E-05	3.5E-05	n/a	n/a
	PFUnA	1.90E-03	1.40E-02	Max	1.3E-04	5.1E-05	n/a	n/a
	Dioxin‡	4.20E-06	7.10E-05	4.6E-5§	4.1E-07	1.6E-07	580	230

Note: Doses are in milligram per kilogram per day. Shaded values represent a hazard quotient above 1. All calculations were conducted using PHAST v1.6.1.0.

Abbreviations: LG = large mouth; max = maximum; n/a = not analyzed - there is insufficient information available to calculate this value; PCBs = polychlorinated biphenyls; PFBA = perfluorobutanoic acid; PFDA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFOS = perfluorooctane sulfonic acid; PFOSA = perfluorooctane sulfonamide; PFUnA = perfluoroundecanoic acid; SM = small mouth; UCL = upper confidence limit.

*milligram per kilogram. †Maximum was used when there were fewer than eight samples. ‡Includes dioxin, furan, and dioxin-like PCBs. §log normal 95 UCL. ¶normal 95 UCL. **gamma 95 UCL.

Table A-6. Fish species, chemical concentrations, dose, and hazard quotient using 10 ounces weekly (40 grams per day) intake.

Species	Chemical	Minimum concentration*	Maximum concentration *	Concentration for dose†	Child Dose	Adult Dose	Child HQ	Adult HQ
Alewife	Mercury	8.00E-02	1.10E-01	1.04E-01§	2.6E-04	5.2E-05	0.9	0.2
	PCBs	6.60E-03	1.90E-02	1.6E-029§	4.0E-05	8.0E-06	2.0	0.4
	PFBA	4.50E-03	1.10E-02	Max	2.8E-05	5.7E-06	n/a	n/a
	Dioxin‡	7.50E-06	6.10E-05	Max (UCL>max)	1.5E-07	3.1E-08	220	44
American shad fillet	Mercury	5.60E-02	9.60E-02	8.44E-02¶	2.1E-04	4.2E-05	0.7	0.1
	PCBs	7.90E-03	3.40E-02	2.50E-02**	6.3E-05	1.3E-05	3.1	0.6
	PFBA	1.40E-03	9.10E-03	Max	2.3E-05	4.5E-06	n/a	n/a
	Dioxin‡	9.90E-06	7.20E-05	5.7E-5¶	1.4E-07	2.9E-08	200	41
American shad roe	Mercury	3.90E-03	2.50E-02	1.90E-02**	4.8E-05	9.5E-06	0.2	0.03
	PCBs	2.10E-03	1.60E-02	1.29E-02¶	3.2E-05	6.5E-06	1.6	0.3
	PFBA	1.90E-03	7.60E-03	Max	1.9E-05	3.8E-06	n/a	n/a
	PFOS	2.90E-03	6.90E-03	Max	1.7E-05	3.4E-06	8.6	1.7
	Dioxin‡	2.90E-03	6.90E-03	6.2E-5**	1.5E-07	3.1E-08	220	44
Blueback herring	Mercury	4.30E-06	9.30E-05	Max (UCL>max)	1.7E-04	3.4E-05	0.6	0.1
	PCBs	3.60E-02	6.70E-02	2.42E-02§	6.1E-05	1.2E-05	3.0	0.6
	PFBA	1.30E-03	6.20E-03	Max	1.5E-05	3.1E-06	n/a	n/a
	PFOS	3.20E-03	5.40E-03	Max	1.3E-05	2.7E-06	6.7	1.3
	Dioxin‡	1.30E-03	6.20E-03	4.4E-5§	1.1E-07	2.2E-08	160	31
Rainbow smelt LG	Mercury	1.30E-01	1.50E-01	Max	3.7E-04	7.4E-05	1.3	0.3
Rainbow smelt SM	Mercury	9.10E-02	1.40E-01	Max	3.5E-04	6.9E-05	1.2	0.2
Rainbow smelt LG+SM	PCBs	2.60E-03	4.20E-02	2.63E-02**	6.6E-05	1.3E-05	3.3	0.7
	PFAS	Not analyzed						
	Dioxin‡	1.30E-05	7.20E-05	6.8E-5§	1.7E-07	3.4E-08	240	48
Striped bass	Mercury	1.30E-01	2.60E-01	2.1E-01**	5.2E-04	1.0E-04	1.7	0.4
	PCBs	2.60E-02	2.50E-01	1.6E-01**	4.0E-04	8.0E-05	20	4.0
	PFBA	1.50E-03	4.00E-03	Max	9.9E-06	2.0E-06	n/a	n/a
	PFDA	1.10E-03	1.10E-03	Max	2.8E-06	5.6E-07	n/a	n/a
	PFOS	1.70E-03	6.10E-03	Max	1.5E-05	3.1E-06	7.6	1.5
	PFOSA	1.00E-03	2.10E-03	Max	5.2E-06	1.0E-06	n/a	n/a
	Dioxin‡	2.14E-05	2.05E-04	1.6E-4§	4.0E-07	8.0E-08	570	110
Sea lamprey	Mercury	2.90E-01	1.10E+00	7.8E-01¶	2.0E-03	3.9E-04	6.5	1.3
	PCBs	4.36E-03	4.35E-02	2.7E-02§	6.6E-05	1.3E-05	3.3	0.7
	PFDA	1.10E-03	4.80E-03	Max	1.2E-05	2.4E-06	n/a	n/a
	PFDoA	1.10E-03	3.10E-03	Max	7.7E-06	1.5E-06	n/a	n/a
	PFOS	2.00E-03	2.00E-02	Max	5.1E-05	1.0E-05	2.6	5.1
	PFOSA	2.30E-03	9.80E-03	Max	2.5E-05	4.9E-06	n/a	n/a
	PFUnA	1.90E-03	1.40E-02	Max	3.6E-05	7.2E-06	n/a	n/a
	Dioxin‡	4.20E-06	7.10E-05	4.6E-5§	1.1E-07	2.3E-08	160	33

Note: Doses are in milligram per kilogram per day. Shaded values represent a hazard quotient above 1. All calculations were conducted using PHAST v1.6.1.0.

Abbreviations: LG = large mouth; max = maximum; n/a = not analyzed - there is insufficient information available to calculate this value; PCBs = polychlorinated biphenyls; PFBA = perfluorobutanoic acid; PFDA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFOS = perfluorooctane sulfonic acid; PFOSA = perfluorooctane sulfonamide; PFUnA = perfluoroundecanoic acid; SM = small mouth; UCL = upper confidence limit.

*milligram per kilogram. †Maximum was used when there were fewer than eight samples. ‡Includes dioxin, furan, and dioxin-like PCBs. §log normal 95 UCL. ¶normal 95 UCL. **gamma 95 UCL.

Table A-7. Fish species, chemical concentrations, dose, and hazard quotient using 10 ounces monthly (10 grams per day) intake.

Species	Chemical	Minimum concentration*	Maximum concentration *	Concentration for dose†	Child dose	Adult dose	Child HQ	Adult HQ
Alewife	Mercury	8.00E-02	1.10E-01	1.04E-01§	6.5E-05	1.3E-05	0.2	0.04
	PCBs	6.60E-03	1.90E-02	1.6E-029§	9.9E-06	2.0E-06	0.5	0.099
	PFBA	4.50E-03	1.10E-02	Max	7.1E-06	1.4E-06	n/a	n/a
	Dioxin‡	7.50E-06	6.10E-05	Max (UCL>max)	3.9E-08	7.7E-09	55	11
American shad fillet	Mercury	5.60E-02	9.60E-02	8.44E-02¶	5.3E-05	1.1E-05	0.2	0.04
	PCBs	7.90E-03	3.40E-02	2.50E-02**	1.6E-05	3.1E-06	0.78	0.16
	PFBA	1.40E-03	9.10E-03	Max	5.7E-06	1.1E-06	n/a	n/a
	Dioxin‡	9.90E-06	7.20E-05	5.7E-5¶	3.6E-08	7.1E-09	51	10
American shad roe	Mercury	3.90E-03	2.50E-02	1.90E-02**	1.2E-05	2.4E-06	0.04	0.01
	PCBs	2.10E-03	1.60E-02	1.29E-02¶	8.1E-06	1.6E-06	0.4	0.081
	PFBA	1.90E-03	7.60E-03	Max	4.8E-06	9.5E-07	n/a	n/a
	PFOS	2.90E-03	6.90E-03	Max	4.3E-06	8.6E-07	2.2	0.4
	Dioxin‡	2.90E-03	6.90E-03	6.2E-5**	3.9E-08	7.7E-09	55	11
Blueback herring	Mercury	4.30E-06	9.30E-05	Max (UCL>max)	4.2E-05	8.4E-06	0.1	0.03
	PCBs	3.60E-02	6.70E-02	2.42E-02§	1.5E-05	3.0E-06	0.76	0.15
	PFBA	1.30E-03	6.20E-03	Max	3.9E-06	7.7E-07	n/a	n/a
	PFOS	3.20E-03	5.40E-03	Max	3.4E-06	6.7E-07	1.7	0.34
	Dioxin‡	1.30E-03	6.20E-03	4.4E-5§	2.7E-08	5.5E-09	39	7.8
Rainbow smelt LG	Mercury	1.30E-01	1.50E-01	Max	9.3E-05	1.9E-05	0.3	0.06
Rainbow smelt SM	Mercury	9.10E-02	1.40E-01	Max	8.7E-05	1.7E-05	0.3	0.06
Rainbow smelt LG+SM	PCBs	2.60E-03	4.20E-02	2.63E-02**	1.6E-05	3.3E-06	0.82	0.16
	PFAS	Not analyzed						
	Dioxin‡	1.30E-05	7.20E-05	6.8E-5§	4.2E-08	8.5E-09	60	12
Striped bass	Mercury	1.30E-01	2.60E-01	2.1E-01**	1.3E-04	2.6E-05	0.4	0.09
	PCBs	2.60E-02	2.50E-01	1.6E-01**	1.0E-04	2.0E-05	5.0	1.0
	PFBA	1.50E-03	4.00E-03	Max	2.5E-06	5.0E-07	n/a	n/a
	PFDA	1.10E-03	1.10E-03	Max	7.0E-07	1.4E-07	n/a	n/a
	PFOS	1.70E-03	6.10E-03	Max	3.8E-06	7.6E-07	1.9	0.38
	PFOSA	1.00E-03	2.10E-03	Max	1.3E-06	2.6E-07	n/a	n/a
	Dioxin‡	2.14E-05	2.05E-04	1.6E-4§	1.0E-07	2.0E-08	140	29
Sea lamprey	Mercury	2.90E-01	1.10E+00	7.8E-01¶	4.9E-04	9.8E-05	1.6	0.3
	PCBs	4.36E-03	4.35E-02	2.7E-02§	1.7E-05	3.3E-06	0.83	0.17
	PFDA	1.10E-03	4.80E-03	Max	3.0E-06	6.0E-07	n/a	n/a
	PFDoA	1.10E-03	3.10E-03	Max	1.9E-06	3.8E-07	n/a	n/a
	PFOS	2.00E-03	2.00E-02	Max	1.3E-05	2.6E-06	6.4	1.3
	PFOSA	2.30E-03	9.80E-03	Max	6.1E-06	1.2E-06	n/a	n/a
	PFUnA	1.90E-03	1.40E-02	Max	9.0E-06	1.8E-06	n/a	n/a
	Dioxin‡	4.20E-06	7.10E-05	4.6E-5§	2.9E-08	5.7E-09	41	8.1

Note: Doses are in milligram per kilogram per day. Shaded values represent a hazard quotient above 1. All calculations were conducted using PHAST v1.6.1.0.

Abbreviations: LG = large mouth; max = maximum; n/a = not analyzed - there is insufficient information available to calculate this value; PCBs = polychlorinated biphenyls; PFBA = perfluorobutanoic acid; PFDA = perfluorodecanoic acid; PFDoA = perfluorododecanoic acid; PFOS = perfluorooctane sulfonic acid; PFOSA = perfluorooctane sulfonamide; PFUnA = perfluoroundecanoic acid; SM = small mouth; UCL = upper confidence limit.

*milligram per kilogram. †Maximum was used when there were fewer than eight samples. ‡Includes dioxin, furan, and dioxin-like PCBs. §log normal 95 UCL. ¶normal 95 UCL. **gamma 95 UCL.

Appendix B. ATSDR's Methodology for Evaluating Potential Public Health Effects

Evaluation methods

This section presents details of ATSDR's methodology for evaluating the public health implications of eating fish with contaminants detected in anadromous fish collected from the Penobscot River. This section also provides some question and answers to aid the reader who might have similar concerns.

What is meant by exposure?

ATSDR's public health evaluations focus on exposure to, or contact with, environmental contaminants. Contaminants released into the environment have the potential to produce harmful health effects if exposures are high enough. Nevertheless, a release does not always result in exposure. People are only exposed to a contaminant if they contact that contaminant—if they breathe, eat, drink, or come into skin contact with a substance containing the contaminant. If no one contacts a contaminant, then no exposure occurs, and thus no health effects could occur. Often the general public does not have access to the source area of contamination or areas where contaminants are moving through the environment. This lack of access to these areas becomes important in determining whether people could contact the contaminants.

An exposure pathway has five elements: 1) a source of contamination, 2) an environmental media, 3) a point of exposure, 4) a route of human exposure, and 5) a receptor population. The source is the place where the chemical was released. The environmental media (such as groundwater, soil, surface water, or air) transport the contaminants. The point of exposure is the place where people contact the contaminated media. The route of exposure (for example, swallowing, breathing in, or skin contact) is the way the contaminant enters the body. The people exposed are the receptor population.

The route of a contaminant's movement is the pathway. ATSDR identifies and evaluates exposure pathways by considering how people might contact a contaminant. An exposure pathway could involve air, surface water, groundwater, soil, dust, or even plants and animals. Exposure can occur by breathing, eating, drinking, or by skin contact with a substance containing the chemical contaminant.

The exposure route evaluated in this health consultation is eating (ingestion of) fish. Specifically, ATSDR evaluated the public health implications of exposure to the following anadromous fish species from the Penobscot River: alewife, American Shad (fillet and roe), blueback herring, rainbow smelt, striped bass, and sea lamprey.

How does ATSDR determine which exposure situations to evaluate?
ATSDR scientists evaluate site conditions to determine if people could have been exposed to site-related contaminants in the past, are currently being exposed, or could be exposed in the future. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, sediment, water, air, or fish) has occurred, is occurring, or will occur through ingestion, skin contact, or inhalation. The exposure situations ATSDR evaluated focused on eating anadromous fish from the Penobscot River.

If someone is exposed, will they get sick?
Exposure does not always result in harmful health effects. The type and severity of health effects a person can experience because of contact with a contaminant depend on the exposure concentration (how much), the frequency (how often) and duration of exposure (how long). It also depends on the route or pathway of exposure (breathing, eating, drinking, or skin contact) and the multiplicity of exposure (combination of contaminants). After exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed person influence how that person's body absorbs, distributes, metabolizes, and gets rid of the contaminant. Together, these factors and characteristics determine the health effects occur.

ATSDR evaluates chemicals by comparing exposure levels, usually in the form of a dose, to health guidelines. Site-specific doses are derived by estimating the amount of intake (from eating fish) divided by someone's body weight. The dose is reported as milligrams of chemicals per kilogram body weight per day (or mg/kg/day). Doses are commonly estimated for children and adults. These estimated doses are compared with health guidelines, also in mg/kg/day, which were developed from available scientific studies about exposure and health effects. Health guidelines, such as ATSDR's minimal risk levels (MRLs) or the U.S. Environmental Protections Agency's (EPA's) reference dose (RfD), reflect a contaminant dose that will not cause (non-cancerous) adverse health effects for a given chemical. To be conservative and protective of public health, health guidelines are set at doses that are many times lower than effect levels identified in animals or human studies. When a health guideline is exceeded, ATSDR conducts a more detailed review to determine if harmful effects might be possible.

When a health guideline is exceeded, ATSDR scientists compare site-specific doses from eating fish to doses from animal and human doses that are known not to and known to produce harmful effects. In general, when site-specific doses approach or exceed effect levels, ATSDR concludes that harmful effects might be possible in people. We then describe the harmful effects that might be possible.

ATSDR estimated site-specific doses using three fish intake rates. These rates represent eating certain amounts of fish daily, weekly, and monthly so that PIN members could gauge the effect of eating local fish. The estimated exposure doses were calculated based on contaminant concentrations in the tissue of anadromous fish identified by PIN members are being part of their traditional diet.

Methodology

Exposure dose concentrations were determined using the following approach. If there were fewer than eight fish samples, then the maximum concentration in fish was used to estimate doses. Otherwise, the data were evaluated using ATSDR guidance to determine appropriate statistical methods [ATSD 2019b]. These methods typically used a 95 upper confidence limit (UCL) of the arithmetic mean. The 95 UCL is a value that provides realistic concentrations that are at least as high as the average. It takes into consideration some of the variation within the data. These data were evaluated to determine which type of distribution the data follow (normal, lognormal, gamma). The statistical program ProUCL Version 5.1 [EPA 2020] was used for determining the 95 UCL calculations. PHAST version 1.5.0.0 was used to calculate the dose and cancer risk estimations [ATSDR 2019b].

The contaminant concentration, quantity of fish eaten, and other parameters, including body weight and exposure frequency and duration, determine a person's exposure dose from fish. ATSDR used the traditional Wabanaki Lifeways exposure consumption rates (10 ounces per day for adults and 5 ounces per day for children) [Harper and Ranco 2009], along with one meal per week (10 ounces per week or 40 grams per day) and one meal per month (10 ounces per month or 10 grams per day). These ingestion rates (10 ounces per week and 10 ounces per month) were from the State of Maine and Penobscot Indian Nation (PIN) fish advisories [Maine 2020, Penobscot Indian Nation 2020]. Those ingestion rates were then used to calculate exposure doses from eating fish (see Appendix A for results of the calculations).

ATSDR evaluated the potential risk for harmful effects based on the calculated exposure dose that exceeded ATSDR's MRL or EPA's RfD [ATSDR 2005; EPA 1993]. If the MRL or RfD was exceeded, ATSDR scientists compared the dose with human and animal studies to decide whether PIN members might be at risk for harmful effects. Additionally, for cancer-causing chemicals, we also calculated the cancer risk should someone eat fish for long periods. This approach is used because ATSDR does not have any fish-specific health-based comparison values for screening contaminants. ATSDR calculated exposure doses for children and adults for each species and each intake rate. This estimation is a theoretical estimate of cancer risk used by ATSDR as a tool for deciding whether public health actions are needed to protect health. It is not an actual number of cancer cases in a community because each cancer risk is based on one set of parameters and eating habits.

ATSDR compared estimated exposure doses to the non-cancer health guidelines (MRLs or RfDs) used as screening levels. The comparison was made by dividing the exposure dose by the MRL (or RfD). If that ratio is greater than 1.0, further evaluation is needed to determine if PIN members are at risk for non-cancerous harmful effects. That ratio is also known as the hazard quotient. Estimated doses that are below non-cancer health guidelines (MRL or RfD) are not expected to cause non-cancerous adverse health effects.

A cancer slope factor (CSF), also known as an oral slope factor, is an EPA-derived estimate of the increased cancer risk from oral exposure to a dose of 1 milligram per kilogram per day (mg/kg-day) for a lifetime. The CSF is used to estimate cancer risks and as a screening tool.

The way MRLs are calculated can change depending on the type and quality of data available. MRLs can be set for three different lengths of time people are exposed to a substance:

- Acute — less than 15 days
- Intermediate — from 15 to 364 days
- Chronic — more than 364 days

The EPA RfDs are only calculated for chronic (lifetime) exposures. ATSDR MRLs are also calculated for different exposure routes, such as inhalation and ingestion. MRLs are developed for non-cancer health effects—ATSDR uses available EPA oral cancer slope factors and other information to evaluate cancer effects.

When multiple chemicals in the same chemical class have sufficiently similar toxicological properties, toxic equivalents (TEQs) can be used to express the overall toxicity of the numerous chemicals as a single value. This health consultation followed 2019 ATSDR guidance for calculating TEQs for dioxin and dioxin-like compounds [ATSDR 2019a]. TEQs provide a means for reducing measurements of numerous different related chemicals (congeners) analyzed from one environmental sample to a single value that can be used for health assessment purposes. They are calculated to represent the overall toxicity of complex mixtures. In the case of dioxin, the toxicity of each congener is weighted against that of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD, or TCDD), historically considered the most toxic member of these chemical classes [ATSDR 2019a].

ATSDR used the following equation (Equation B-1)to estimate PIN ingestion of methylmercury, dioxins, chlorinated dibenzofurans, PFAS, and PCBs in fish. Where possible, ATSDR used site-specific information about the frequency and duration of exposures. When site-specific information was not available, ATSDR used several conservative assumptions to estimate exposures.

Equation B-1. Estimated exposure dose calculation—including assumptions of intake rates, body weight, and exposure duration.

Estimated exposure dose = $(C \times IR \times EF \times ED) / (BW \times AT)$

where:

C = Concentration of chemical in biota (milligram per kilogram);

IR = Ingestion rate varies (see Appendix A for tables with the intake rates);

EF = Exposure frequency (365 days per year);

ED = Exposure duration (30 years for an adult, 6 for a child);

BW = Body weight (adult = 80 kilograms and child = 16 kilograms, which are standard body weights for an average adult and children 1 through 6 years old [ATSDR 2005]);

AT = Averaging time, or the period over which cumulative exposures are averaged

AT = ED × 365 days per year.

Public Health Implications

Methylmercury

Mercury contamination of fish and wildlife can result from burning coal and medical and other waste, alkali and metal processing, and mining of gold and mercury. Mercury is a naturally occurring chemical element found in rock in the earth's crust, including in deposits of coal [EPA 2019]. However, the main source of mercury over most of the landscape is the air. When it gets in the atmosphere, mercury spreads over a wide area and can circulate for years, accounting for its widespread distribution. Some natural sources of atmospheric mercury include volcanoes, geologic deposits of mercury, and ocean spray and gases. All rocks, sediments, water, and soils naturally contain small but varying amounts of mercury. In some areas, scientists have found local mineral occurrences and thermal springs that are naturally high in mercury. When coal is burned, mercury is released into the environment. Coal-burning power plants are the largest human-caused source of mercury emissions to the air in the United States, accounting for more than half of all domestic human-caused mercury emissions [EPA 2005].

Mercury occurs in several different forms: metallic mercury (also known as elemental mercury), inorganic mercury, and organic mercury. Metallic mercury is the pure form of mercury. Inorganic mercury is formed when metallic mercury combines with elements such as chlorine, sulfur, or oxygen. Microorganisms (bacteria and fungi) and natural processes can change mercury from one form to another. The most common organic mercury compound resulting from these processes is methylmercury, which is the form commonly found in fish [ATSDR 1999]. The different forms of mercury are absorbed and distributed differently in the body.

When small amounts of metallic mercury are ingested, only about 0.01% of the mercury will enter the body through the stomach or intestines [Sue 1994, Wright et al. 1980 as cited in ATSDR 1999]. Someone who has a gastrointestinal tract disease might absorb even more metallic mercury. The small amount of metallic mercury that enters the body will accumulate in the kidneys and the brain, where it is readily turned into inorganic mercury. It can stay in the body for weeks or months, but most metallic mercury is eventually excreted through urine, feces, and exhaled breath.

Typically, less than 10% of inorganic mercury is absorbed through the stomach and intestines, but up to 40% can be absorbed in the intestinal tract [Clarkson 1971, Morcillo and Santamaria 1995, Nielson and Anderson, 1990, 1992, Piotrowski et al. 1992]. In the body, a small amount of the inorganic mercury can be converted into metallic mercury, which will be excreted or stored. Inorganic mercury enters the bloodstream and moves to many different tissues, but it will mostly accumulate in the kidneys. Inorganic mercury does not easily enter the brain. It can remain in the body for several weeks or months and is excreted through urine, feces, and exhaled breath.

Methylmercury is the most studied organic mercury compound. It is readily absorbed in the gastrointestinal tract (about 95% absorbed) and can easily enter the bloodstream [Aberg et al. 1969; Al-Shahristani et al. 1976; Miettinen 1973]. It moves rapidly to various tissues and the brain, where methylmercury can be turned into inorganic mercury, which can remain in the brain for long periods. Slowly, over months, methylmercury will leave the body, mostly as inorganic mercury in the feces.

The organic form of mercury (methylmercury) is much more harmful than the metallic and inorganic forms. In fish tissue, mercury is present predominantly as methylmercury (usually more than 85%), the more toxic form [Jones and Slotten 1996]. Therefore, to be conservative, ATSDR assumed that all the mercury detected in fish and shellfish was methylmercury.

The oral health guideline for methylmercury is based on the Seychelles Child Development Study in which people who were exposed to 1.3×10^{-3} mg/kg/day of methylmercury in their food did not experience any adverse health effects [Davidson et al. 1998]. More than 700 mother–infant pairs were followed and tested from birth through age 66 months of the child. The Seychellois live on a group of islands off the east coast of central Africa. They regularly eat a large quantity and variety of ocean fish, with 12 fish meals per week representing a typical exposure.

ATSDR's MRL is based on the Seychelles study. The selection of the critical study for the methylmercury MRL was based on several factors, including the overall quality of the studies, exposure regimen, freedom from confounding and influencing factors, and relevance to U.S. exposures.

EPA has classified methylmercury as a possible human carcinogen (based on inadequate data in humans and limited evidence of carcinogenicity in animals) [EPA 1995]. However, scientific methods for quantitatively determining the excess lifetime cancer risk from exposure to methylmercury are not available. EPA has not developed an oral cancer slope factor for methylmercury. Therefore, we cannot make those cancer risk calculations.

ATSDR derived an MRL of 3.0×10^{-4} mg/kg/day for chronic oral exposure to methylmercury. ATSDR used the MRL health guidelines for methylmercury in this health assessment because, in fish tissue, mercury is present predominantly as methylmercury, the more toxic form, and because the Seychelle study is a more robust study [Bloom 1992; Grieb et al. 1990; Jones and Slotten 1996, ATSDR 1999].

All anadromous fish species sampled during the PIN survey had methylmercury. The doses based on the highest intake rates were above the ATSDR MRL for children eating rainbow smelt, striped bass, or sea lamprey (see Tables A-2 through A-7 in Appendix A for details on the dose calculations and non-cancer estimations). To put these intake rates in perspective, a 3-ounce can of fish has about 85 grams of fish. Total mercury in fish is comprised mostly of methylmercury [ATSDR 1999; EPA 2001].

A study of Faroe Islands children exposed before birth by mothers who were chronically exposed to methylmercury through eating fish and pilot whale meat found a slight increase in neuropsychological impairments in infants. Maternal daily dietary intake levels were used as the dose for the observed developmental effects in the children exposed before birth. The daily dietary intake levels were calculated from blood concentrations measured in the mothers, with additional values obtained from hair samples [EPA 2001]. A major difference in the studies is that the Faroe Islanders ate fish and whale, while the Seychelles Islanders ate primarily fish. Much of the mercury exposure in the Faroe Island study came from eating whale meat, which had much higher mercury levels that most fish. For this reason, we would consider that the Seychelles population is a useful comparison group for PIN. Moreover, the Seychelles study was the basis for the chronic MRL.

Fish consumption advisories

The Maine Centers for Disease Control issues a health advisory an ongoing fish consumption advisory and warning about eating freshwater fish. Maine's Department of Inland Fisheries and Wildlife posts the health advisory in their fishing regulation handbook. The methylmercury-specific advisory states the following:

- Pregnant and nursing women, women who might get pregnant, and children under age 8 years should not eat any freshwater fish from Maine's inland waters. However, brook trout and landlocked salmon can be safely eaten at one meal per month.

- All other adults and children older than 8 years can eat two freshwater fish meals per month. For brook trout and landlocked salmon, the limit is one meal per week [Maine 2020].
- This advisory is applicable for the fish taken from the Penobscot River.

The Penobscot Nation Department of Natural Resources-issued guidelines for eating fish from Penobscot Territory Waters describes the current advisory.

- All children under 8 years and women who are nursing, pregnant, or could become pregnant, should eat NO FISH from Penobscot Nation Territory waters and other Maine inland waters (for methylmercury, PCBs, and dioxin).
- On the Penobscot River below Mattaseunk Dam (Mattawamkeag), eat NO more than one meal per month (for methylmercury).
- Anywhere else, for brook trout, landlocked salmon; eat NO more than one meal per week. Any other fish eat NO more than two meals per month (for methylmercury) [Penobscot Indian Nation 2020].
  (NOTE: Those guidelines are not protective based on the findings in this health consultation. The recommendations in this health consultation are suggested for further guidance).
- Maine Centers for Disease Control's consumption advisory for striped bass is available from https://www.maine.gov/dhhs/mecdc/environmental-health/eohp/fish/saltwater.htm. These are also included in material from the Maine Department of Marine Resources (the department responsible for saltwater fisheries).

It is especially important that children, women who are pregnant or who might become pregnant, and for breastfeeding mothers to follow fish consumption advisories. ATSDR recognizes that members of the PIN are a subsistence community and many community members seek to re-instate their traditional practices. However, mercury levels in the environment and in freshwater and marine fish have risen globally and regionally. Fish caught in New England have mercury levels similar to those found in oceans worldwide and reported in the U.S. Food and Drug Administration’s market basket survey (https://www.fda.gov/food/metals-and-your-food/mercury-levels-commercial-fish-and-shellfish-1990-2012). Sea lamprey fish contained the highest levels of mercury. In addition to the Penobscot advisory, no PIN member should eat any sea lamprey fish because of the mercury levels and potential public health concerns of those avoidable exposures.

Table B-1 shows the non-cancer risk for methylmercury for the fish species analyzed. The table shows the three intake rates with the range of hazard quotients for those species. The highest intake rates for children and adults (Wabanaki scenario) represent the highest potential risk for health concern, represented by the highest hazard quotients. PIN members should not eat fish from the Penobscot River at 10 ounces per day (adults) or 5 ounces per day (children).

The estimated exposure doses for adults and children eating certain fish from the Penobscot River are near levels that might harm a person's health. Therefore, ATSDR cautions that eating certain fish from the Penobscot River at the consumption rates suggested in the scenario could contribute to harmful non-cancer health effects (see Table B-1).

Children should not eat lamprey at the rate of one meal per week. The lowest intake rate (10 grams per day) did not represent a potential health concern for children or adults.

Table B-1. Intake scenarios and resultant hazard quotient ranges for all fish species analyzed, based on the 95 upper confidence limit of the mean or maximum concentrations* detected for mercury.

Intake rate	Hazard quotient range for children	Hazard quotient range for adults	Health concern
Wabanaki scenario (10 ounces/day {286 grams/day} for adults and 5 ounces}/day {143 grams/day} for children)	0.6 to 23	0.2 to 9.3	Yes, for children eating rainbow smelt, striped bass, and sea Lamprey; yes, for women who are pregnant or planning to become pregnant eating sea lamprey
One meal per week (10 ounces/week or 40 grams per day)	0.2 to 1.3	0.03 to 1.3	Yes, but only for children eating sea lamprey.
One meal per month (10 ounces/month or 10 grams per day)	0.04 to 1.6	0.01 to 0.3	No concern

*The concentrations used to calculate the hazard quotients differed for each species. The concentration used ranged from the maximum to a 95 upper confidence limit of the mean.

Polybrominated diphenyl ethers

Polybrominated diphenyl ethers (PBDEs) are flame-retardant chemicals that were added to a variety of consumer products to make them difficult to burn. These substances are not single-chemical compounds, but rather mixtures of several brominated substances. The entire family of PBDEs consists of 209 possible substances that are referred to as congeners [ATSDR 2017].

Nothing definite is known about the health effects of PBDEs in people. Most information regarding the toxicity of PBDEs and their breakdown products (metabolites) is from animal studies. However, several recent studies have evaluated associations between PBDE concentrations in human tissues (blood, breast milk) and various health effects [ATSDR 2017].

Adult rats that ingested small amounts of PBDEs for 8 weeks showed damage to their reproductive systems, specifically reduced serum testosterone levels. Testosterone plays an important role in adults and in male and female children. Testosterone in males is important for development during puberty, sperm creation, and muscle and bone strength. Testosterone in females is important for maintaining other hormone levels, fertility, and making new blood cells. [ATSDR 2017].

PBDEs can stay in our bodies for a long time. Because PBDEs are a recently recognized contaminant of concern, human health effects from eating fish with PBDEs are not well understood but eating fish with elevated levels of PBDEs could be a concern.

PCBs and dioxin

Polychlorinated biphenyls (PCBs) are a group of synthetic organic chemicals that can contribute to several different harmful effects. The name PCB defines the chemical makeup as having many (poly) chlorines (chlorinated) on a double benzene ring (biphenyl). There are no known natural sources of PCBs in the environment. Because they don't burn easily and are good insulating materials, PCBs were used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment. The manufacture of PCBs in the United States ended in August 1977 because evidence showed that PCBs build up in the environment and might cause harmful health effects [ATSDR 2000].

ATSDR and EPA derived the same value for chronic oral exposure to one type of PCB referred to as Aroclor 1254 (2.0×10^{-5} mg/kg/day). ATSDR derived an MRL of 1.0×10^{-9} mg/kg/day for chronic oral exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). EPA recently calculated an RfD of 7.0×10^{-10} for chronic oral exposure to 2,3,7,8-TCDD. Current scientific evidence indicates that 2,3,7,8-TCDD is the most toxic of the dioxins. Therefore, using its RfD and MRL for all dioxins, chlorinated dibenzofurans, and dioxin-like PCBs is most protective of human health. EPA's RfD for 2,3,7,8-TCDD was used when calculating hazard quotients for the exposure dose comparison.

All fish species were analyzed for dioxins, chlorinated dibenzofurans, dioxin-like PCBs, and total PCB congeners. Children and adults eating these species from the Penobscot River would be exposed to doses above the MRL or RfD (at the average and highest detected levels in the fish tissue). These estimates are intended to serve as screening levels to identify contaminants for additional evaluation. ATSDR considers dioxins, chlorinated dibenzofurans, and dioxin-like PCBs in Penobscot River fish to be a non-cancer health hazard. Striped bass contained the highest levels of dioxins, chlorinated dibenzofurans, and dioxin-like PCBs.

ATSDR reviewed the scientific literature for noncarcinogenic effects from exposure to PCBs. The estimated PCB doses from eating any of the anadromous fish species daily is a health concern for children. The estimated PCB doses also are a concern for adults eating fish daily, except for alewife and American shad roe. When eating 10 ounces weekly, the estimated PCB doses is a health concern for children and adult only from eating striped bass. When eating 10 ounces monthly, the estimated PCB doses are only a concern for children. What follows is an example showing how we arrived at these decisions.

Using one meal per week and the PCB concentration in striped bass (0.16 mg/kg or 160 µg/kg), the estimated doses for children (0.4 µg/kg/day) and adults (0.08 µg/kg/day) were above ATSDR's MRL, These doses approached immunological health effects (specifically, decreased antibody response and eyelid and toenail and fingernail changes) in female Rhesus monkeys chronically exposed to 5 µg/kg/day of Aroclor 1254 [Tryphonas et al. 1989; Tryphonas et al. 1991]. The monkey study dose is the lowest-observed-adverse-effect-level identified in the scientific literature for chronic exposure to PCB mixtures. Neurobehavioral effects were observed in infant monkeys exposed to 0.0075 µg/kg/day [Rice 1996, 1997, 1998, 1999; Rice and Hayward 1997, 1999]. Therefore, ATSDR concluded that children and adults would have some risk for harmful effects from eating striped bass weekly.

Table B-2 shows non-cancer risks for PCBs in the anadromous fish species. The three intake rates are depicted along with the range of hazard quotients for those species. The PCB levels in all fish species analyzed represented a potential health concern for children and adults at the highest intake rates. The 40 grams per day intake also represented a potential health concern for children for all fish species analyzed. The levels of PCBs in striped bass represents a potential health concern for all age groups, even at the lowest intake rate of 10 grams per day.

Table B-2. Intake scenarios and resultant hazard quotient ranges for all fish species analyzed, based on the 95 upper confidence limit (UCL) of the mean concentrations* detected for PCBs

Intake rate	Hazard quotient range for children	Hazard quotient range for adults	Health concern
Wabanaki scenario intake rates (286 grams per day)	5.8 to 72	2.3 to 29	Yes, for children and adults eating anadromous fish
One meal per week rates (40 grams per day)	1.6 to 20	0.32 to 4	Yes, but only for children and adults eating striped bass
One meal per month rates (10 grams per day)	0.4 to 5	0.081 to 1	Yes, but only for children eating striped bass

*The concentrations used to calculate the hazard quotients differed for each species. The concentration used were the 95 upper confidence limit of the mean (including: log normal 95 UCL, normal 95 UCL, and gamma 95 UCL).

Studies of workers provide evidence that exposure to PCBs is associated with certain types of cancer in humans, such as cancer of the liver and biliary tract. Rats fed commercial PCB mixtures throughout their lives developed liver cancer. Based on the evidence for cancer in animals, the U.S. Department of Health and Human Services has stated that PCBs may reasonably be anticipated to be carcinogens. EPA and the International Agency for Research on Cancer have determined that PCBs are probably carcinogenic to humans [EPA 1996].

The maximum estimated lifetime dose (1×10^{-4} mg/kg/day) from eating PCB-contaminated fish from the Penobscot River exceeds two additional cancer cases in 100,000 (2×10^{-5}). As such, excess cancers from PCB exposure could occur from eating contaminated fish. The cancer risk range for all fish species analyzed ranged from 1.2×10^{-6} to 4.4×10^{-4}.

Dioxins, chlorinated dibenzofurans, and dioxin-like PCBs

Dioxins are a family of 75 different compounds that have varying harmful effects. They are divided into eight groups, based on the number of chlorine atoms they have, which can be attached to the dioxins and chlorinated dibenzofurans molecule at any one of eight positions. The name of each dioxin or furan indicates the number and the positions of the chlorine atoms. For example, the dioxin with four chlorine atoms at positions 2, 3, 7, and 8 on the molecule is called 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD, or TCDD) [EPA 2012], which is one of the most toxic of the dioxins to mammals and has received the most attention [ATSDR 1998].

The most common way for dioxins to enter the body is through eating food contaminated with dioxins. In general, absorption of dioxins is congener-specific—about 87% of TCDD was absorbed in one human volunteer who ingested a single dose [Poiger and Schlatter 1986]. Dioxins are lipophilic, meaning that they are attracted to lipids (fats) and tend to accumulate in body parts that have more fat, such as the liver. They can also concentrate in breast milk. The body can store dioxins in the liver and body fat for many years before eliminating them.

A toxic equivalency factor (TEF) approach to evaluating health hazards for cancer and non-cancer effect levels has been developed for dioxins (see ATSDR 1998 for more details and ATSDR 2019a). The TEF approach compares the relative potency of individual dioxins and furans with that of TCDD, the best-studied member of this chemical class. The concentration of each dioxin and furan is multiplied by its TEF to arrive at a toxic equivalent (TEQ), and the TEQs are added to give the total toxic equivalency. The total toxic equivalency is then used to estimate the risk for cancer and non-cancer effects.

Twelve PCB congeners fall into a category of dioxin-like PCBs. Because of their structure and mechanism of action, they exhibit toxic behavior like that of chlorinated dibenzo-p-dioxins. However, their toxicity is 0.00001 to 0.1 times lower than that of TCDD, the most toxic dioxin.

All exposure doses calculated with the TEQ approach yielded results above a potential non-cancer health concern for dioxin. The maximum and average levels for dioxins, chlorinated dibenzofurans, and dioxin-like PCBs for fish exceeded the dioxin MRL and RfD and represent a potential non-cancer health concern.

The estimated doses (using one meal per month) for children (1×10^{-7} mg/kg/day) and adults (2×10^{-8} mg/kg/day) exposed to a representative value of the maximum dioxin levels (1.6×10^{-4} mg/kg) in fish were above ATSDR's MRL, and slightly lower than doses in which animals had health effects. The oral health guideline for the most toxic dioxin, TCDD, is based on a study in which health effects occurred in female Rhesus monkeys fed a diet containing 1.2×10^{-7} mg/kg/day of TCDD [Schantz et al. 1992]. The estimated exposure doses from fish are slightly lower than this health effects level. Dioxins are a well-studied family of compounds, and this dose is the lowest health effects level reported in the 33 chronic-duration studies on TCDD. Therefore, ATSDR is concerned that eating fish with the detected levels of dioxin would contribute to harmful non-cancer health effects.

ATSDR should carefully review the toxicology literature to evaluate potential cancer effects:

- The U.S. Department of Health and Human Services has determined that it is reasonable to expect that TCDD could contribute to cancer.
- The International Agency for Research on Cancer has determined that TCDD can contribute to cancer in people, but that it is not possible to classify other dioxins as to their carcinogenicity to humans.
- The National Toxicology Program has determined that TCDD is a human carcinogen [NTP 2016].

The cancer risk levels for the maximum and average levels of dioxin (dioxins, chlorinated dibenzofurans, and dioxin-like PCBs) found in fish were above 1×10^{-4}. Cancer risk levels above 1×10^{-4} are of concern. Therefore, ATSDR cautions that eating fish at the rates listed in the scenario report over a lifetime could contribute to an elevated cancer risk.

Table B-3 shows the non-cancer risks for dioxins, chlorinated dibenzofurans, and dioxin-like PCBs for all fish species. The three intake rates and the range of hazard quotients are shown for all fish species analyzed.

Table B-3. Intake scenarios and resultant hazard quotient ranges for all fish species analyzed, based on the 95 upper confidence limit (UCL) of the mean or maximum concentrations* detected for dioxins, chlorinated dibenzofurans, and dioxin-like PCBs

Intake rate	Hazard quotient range for children	Hazard quotient range for adults	Health concern
Wabanaki scenario (286 grams per day)	560 to 2,000	220 to 820	Yes, for children and adults
One meal per week (40 grams per day)	160 to 570	31 to 110	Yes, for children and adults
One meal per month (10 grams per day)	39 to 140	7.8 to 29	Yes, for children and adults

*The concentrations used to calculate the hazard quotients differed for each fish species analyzed. The concentration used ranged from the maximum to a 95 UCL of the mean (including log normal 95 UCL, normal 95 UCL, and gamma 95 UCL).

PFAS

PFAS are a class of manufactured chemicals not currently regulated in public drinking water supplies. PFAS have been used since the 1950s to make products resistant to heat, oil, stains, grease, and water. They are found in some fire-fighting foams and consumer products such as nonstick cookware, stain-resistant carpets, fabric coatings, food packaging, cosmetics, and personal care products [EPA 2017]. People can be exposed to PFAS in the air, indoor dust, food, water, and consumer products. Because of their extensive use, PFAS are a common exposure for the general U.S. population [ATSDR 2020; CDC 2018; EPA 2016; NIEHS 2016].

PFAS persist in the environment. They are water soluble and may be detected in the soil, sediment, water, or biota. Studies indicate that some PFAS move through the soil and easily enter groundwater, in which they might travel long distances [MDH 2017].

The six anadromous fish species were analyzed for six different PFAS: perfluorobutanoic acid (PFBA), perfluorodecanoic acid (PFDA), perfluorododecanoic acid (PFDoA), perfluorooctane sulfonic acid (PFOS), perfluorooctane sulfonamide (PFOSA), and perfluoroundecanoic acid (PFUnA). The maximum detected PFAS was PFOS (0.02 mg/kg).

ATSDR has developed a provisional intermediate MRL only for one of the detected PFAS (namely, PFOS). We selected the maximum concentration to estimate doses from eating anadromous fish. Four fish species contained levels of PFOS that yielded doses above the provisional intermediate MRL for all intake rates for children. Adults eating fish at the highest and moderate intake rates (286 grams per day) were above the provisional intermediate MRL. Adults eating fish at the moderate and low intake rate (one meal per week or one meal per month) have estimated doses that exceed the MRL and approach immune effects. Eating sea lamprey also exceeds the MRL and approaches effects levels for adults. The exposure doses in children who eat anadromous fish at any of the three fish intake levels exceed the MRL and approaches effect levels for immune and developmental effects. Therefore, ATSDR considers PFOS in Penobscot River fish a potential non-cancer health hazard.

For example, the estimated PFOS doses (using one meal per weekly) for children (1.5×10^{-5} mg/kg/day) and adults (3.1×10^{-6} mg/kg/day) eating striped bass exceeded ATSDR's provisional intermediate MRL of 2×10^{-6}, thus requiring further toxicological evaluation The doses in children were about 2 times below immune effect levels, which puts children at risk for harmful effects to their immune system from PFOS exposure. The estimated dose in adults, however, just barely exceeds the MRL and is about 10 times below immune effect levels; thus, adults are not at risk for harmful effects from eating striped bass monthly. Based on the current scientific literature, ATSDR believes that the immune effect levels from PFOS exposures lies somewhere between the lowest observed adverse effect level for two studies (4.1×10^{-4} mg/kg/day [Dong et al. 2011] and 3.1×10^{-5} mg/kg/day [Guruge et al. 2009]). Site-specific exposure doses from eating anadromous fish that approach or exceed the effect levels identified by the two studies would be considered potentially harmful. The most likely health effect from exposure to PFOS is a decreased response for the immune system. If women eat anadromous fish daily during pregnancy, newborn children might have a decreased birth weight and increased serum glucose.

Table B-4 presents the non-cancer risks for PFOS for all fish species analyzed. The three intake rates and range of hazard quotients are shown for those species. The PFOS levels in all fish species analyzed represented a potential health concern for children and adults at the highest consumption rate and a risk for children at 10 ounces per week (40 grams per day) and 10 ounces per month (10 grams per day). Sea lamprey contained the highest PFOS levels of all fish analyzed and represent the greatest risk from eating anadromous fish.

Table B-4. Intake scenarios and resultant hazard quotient ranges for all fish species analyzed, based on the maximum concentrations detected for PFOS.

Intake rate	Hazard quotient ranges for children	Hazard quotient ranges for adults	Health concern
Wabanaki scenario (286 grams per day)	24 to 92	9.6 to 37	Yes, for children and adults
One meal per week (40 grams per day)	6.7 to 26	1.3 to 5.1	Yes, for children and adults
One meal per month (10 grams per day	1.7 to 6.4	0.34 to 1.3	Yes, children only

Table A-1 (in Appendix A) depicts PFAS detected and what is known about the general toxic effects of the individual PFAS. Endpoint toxicity of PFBA, PFOS, and PFDoA might be similar. The remaining PFAS detected are not well studied and their potential adverse effects are unclear. The data presented in Table A-1 are included to give some perspective on the current knowledge on PFAS and might not be definitive or comprehensive. It is uncertain whether harmful effects might occur from eating anadromous fish with these other PFAS chemical because of the lack of toxicity information.

This health consultation provides the limited information on what is known about health effects of some of these PFAS. For example, long-chained PFAS, which have eight or more carbon atoms, are generally considered to be more toxic than short-chained PFAS [EPA 2018]. There are several limitations and uncertainties of human health risks from PFAS exposures. These include 1) inadequate methods to assess public health implications and 2) limited animal and human data. Although methods are available to evaluate the public health implications of exposure to PFOS and a few other PFAS (which have ATSDR-derived provisional MRLs), none is available to evaluate exposure to a mixture of various PFAS (known as a mixture).

Cancer risks—PFOS

There currently are no scientific methods to evaluate the potential for PFOS to contribute to the development of cancer in humans. There are no EPA oral slope factors that allow estimating a numerical cancer risk. Consequently, ATSDR did not evaluate the potential for PFOS exposure from eating anadromous fish tissue to the development of cancer.

Cancer risks—PCBs

PCB levels in nearly all fish species analyzed represented a cancer health concern for adults at the highest intake rates of 5 or 10 ounces daily. Striped bass represented a cancer health concern for children and adults at the highest intake rate, and at 40 grams per day. The lowest intake rate (10 grams per day) did not represent a cancer health concern for any age group for any species. Table B-5 presents these findings.

Table B-5. Intake scenarios and resultant cancer risk estimations for all fish species analyzed, based on the 95 upper confidence limit of the mean detected for PCBs.

Intake rate	Cancer risk estimations ranges
Wabanaki scenario (286 grams per day)	9 in 100,000 to 1 in 1,000
One meal per week (40 grams per day)	2 in 10,000 to 1 in 100,000
One meal per month (10 grams per day)	4 in 100,000 to 3 in 1,000,000

Cancer risks—dioxin and dioxin-like PCBs

ATSDR's evaluation of potential cancer risks are theoretical estimates of cancer risk typically used by ATSDR as a tool for deciding whether public health actions are needed to protect health. The estimates do not represent the actual number of cancer cases in a community.

Although cancer risk is calculated similarly to exposure dose, for an adult, the calculation applied here used 30 years. Multiplying the exposure dose by the EPA slope factor gives the possible cancer risk. Of importance here is that even exposure to low levels of dioxin is believed to increase a person's cancer risk.

Studies of workers show that exposure to PCBs is associated with certain types of cancer in humans, such as cancer of the liver and biliary tract. Rats fed commercial PCB mixtures throughout their lives developed liver cancer. Based on the evidence for cancer in animals, the U.S. Department of Health and Human Services has stated that PCBs may reasonably be anticipated to be carcinogens. EPA and the International Agency for Research on Cancer have determined that PCBs are probably carcinogenic to humans [EPA 1996]. The maximum estimated lifetime dose (1.4×10^{-4} mg/kg/day) from eating PCB-contaminated fish from the Penobscot River exceeds four additional cancer cases for every 10,000 (4×10^{-4}) people who eat anadromous fish. As such, excess cancers from PCB exposure could be expected from eating anadromous fish for 30 years. Table B-6 presents these findings.

Table B-6. Intake scenarios and resultant cancer risk estimations for all fish species analyzed, based on the 95 upper confidence limit of the mean or maximum concentrations detected for dioxins, chlorinated dibenzofurans, and dioxin-like PCBs.

Intake rate	**Cancer risk estimation ranges**
Wabanaki scenario (286 grams per day)	2 in 100 to 7 in 100
One meal per week (40 grams per day)	3 in 1,000 to 1 in 100
One meal per month (10 grams per day)	7 in 10,000 to 3 in 1,000

One excess cancer case in 1,000 represents a high increased risk, and one excess cancer case in 10,000 represents a moderate increased risk. EPA uses a range of 1 in 10,000 (1×10^{-4}) to 1 in 1,000,000 (1×10^{-6}) to make risk management decisions at Superfund environmental hazards sites. This is a theoretical estimate of cancer risk used by ATSDR as a tool for deciding whether public health actions are needed to protect health; it is not an actual estimate of the number of cancer cases in a community.

According to the American Cancer Society, the overall probability that U.S. residents will develop some type of cancer during their lifetime is 44% (almost 1 in 2) for men and 38% (just over 1 in 3) for women [ACS 2008].

The shaded cells in Tables A-2 through A-4 in Appendix A show those values above 1 in 10,000 or 1×10^{-4} cancer risk levels. The levels of dioxins, furans, and dioxin-like PCBs were elevated in all fish species sampled. Thus, PIN members should consider excluding these from their diet, particularly if they want to decrease their cancer risk from dioxins, furans, and dioxin-like PCBs.

Epidemiologic investigation evaluating cancer in PIN members

Several epidemiological studies have assessed cancer rates among the PIN. But the PIN population is small, which makes comparison with other populations very difficult. In 1994, at the request of the PIN governor, the Centers for Disease Control and Prevention (CDC) analyzed cancer rates among PIN members to try to determine whether 1) the Indian Island population had a higher incidence of cancer than would be predicted, and whether 2) those malignancies that were detected were of the type generally associated with dioxin exposure [Miller and Drabant 1996]. Miller and Drabant used national and Maine estimates to compare the observed number of cancer cases among the PIN with the expected number.

CDC found no evidence to suggest higher rates of cancers specifically associated with dioxin exposure (soft tissue sarcomas, Hodgkin's and non-Hodgkin's lymphoma, stomach, liver and nasal cancers) [Miller 1994]. But, to find an elevation in those cancer cases specifically associated with dioxin exposure would be very difficult. In a population the size of the PIN, the expected cancer rates for those types of cancer are very low. Nevertheless, available cancer study results are presented here in response to community concern over cancer incidence among the tribe. Note, however, these results do not provide comprehensive information on a person's cancer risk.

Another study found a statistically significant excess of lung cancer occurrence, but much of that excess was likely attributable to smoking [Miller 1994; Zahner et al. 1994]. In addition to lung cancer, researchers found high rates of cervical cancer among the PIN [Kusnierz D (Water Resources Program Manager, Penobscot Indian Nation - Department of Natural Resources), email to Gary Perlman (ATSDR), 2020 August 7. Includes an attachment entitled: Penobscot Nation health department cancer registry report 1980–1994. by Valcarcel H. 1994; Miller 1994]. Cervical cancer is preventable through early detection through the Pap test and early administration of the human papillomavirus vaccine. Prudent public health practice would work to prevent smoking initiation and to encourage smoking cessation. Prudent public health practice would also encourage regular Pap tests for PIN adult women and human papillomavirus vaccinations for PIN young girls. The American Congress of Obstetricians and Gynecologists (ACOG) currently recommends that women aged 21 years and older have a Pap test every 2 years. ACOG also recommends that girls and women, ages 9 to 26 years, have a human papilloma virus vaccination, ideally at age 11 to 12 years [ACOG 2010]. The Advisory Committee on Immunization Practices also recommends that boys and men up to age 21 years be vaccinated against human papilloma virus.

Contaminant distribution in the human body after exposures

Mercury, dioxins, furans, PFAS, or PCBs can enter your body if you eat fish contaminated with these chemicals. Inside your body, dioxins, furans, and PCBs tend to accumulate in lipid-rich tissues, such as the liver, fat, skin, and breast milk [ATSDR 2000]. Methylmercury accumulates primarily in muscles and might enter the brain, where it might harm the nervous system [ATSDR 1999]. Some PFAS remain in the body for a long time. The amount of time it takes for half of the substance to be metabolized or eliminated from the body for one specific PFAS PFOS) is 3.3 to 27 years [ATSDR 2018].

Appendix C: Polybrominated Diphenyl Ethers (PBDEs) Dose and Hazard Quotient Tables

Table C-1. Fish species, polybrominated diphenyl ethers (PBDEs) concentrations, dose and hazard quotient (HQ) using 10 ounces daily or 286 grams per day for adults (5 ounces daily or 143 grams per day for children).

Species	Minimum concentration*	Maximum concentration*	Concentration for dose	Child dose	Adult dose	Child HQ	Adult HQ
Alewife	1.4×10^{-3}	2.7×10^{-3}	$2.2 \times 10^{-3\dagger}$	2.0×10^{-5}	7.9×10^{-6}	6.6	2.6
American shad fillet	1.9×10^{-3}	3.8×10^{-3}	$2.9 \times 10^{-3\dagger}$	2.6×10^{-5}	1.0×10^{-5}	8.6	3.4
American shad roe	6×10^{-4}	2.8×10^{-3}	$1.6 \times 10^{-3\dagger}$	1.4×10^{-5}	5.6×10^{-6}	4.6	1.9
Blueback herring	1.9×10^{-3}	3.2×10^{-3}	$2.5 \times 10^{-3\dagger}$	2.2×10^{-5}	8.8×10^{-6}	7.4	2.9
Rainbow smelt	2.2×10^{-5}	3.5×10^{-3}	$3.5 \times 10^{-3\ddagger}$	3.1×10^{-5}	1.3×10^{-5}	10	4.2
Striped bass	3.9×10^{-3}	8.1×10^{-3}	$6.6 \times 10^{-3\S}$	5.9×10^{-5}	2.3×10^{-5}	20	7.8
Sea lamprey	6.7×10^{-4}	3.7×10^{-3}	$2.3 \times 10^{-3\dagger}$	2.0×10^{-5}	8.0×10^{-6}	6.7	2.7

Note: Doses are in milligram per kilogram per day. Shaded values represent a hazard quotient above 1.
*milligram per kilogram. †log normal 95 UCL. ‡Max (UCL>MAX). §gamma 95 UCL.

Table C-2. Fish species, polybrominated diphenyl ethers (PBDEs) concentrations, dose, and hazard quotient (HQ) using 10 ounces weekly (40 grams per day)

Species	Minimum concentration*	Maximum concentration*	Concentration for dose	Child dose	Adult dose	Child HQ	Adult HQ
Alewife	1.4×10^{-3}	2.7×10^{-3}	$2.2 \times 10^{-3\dagger}$	5.6×10^{-6}	1.1×10^{-6}	1.9	0.37
American shad fillet	1.9×10^{-3}	3.8×10^{-3}	$2.9 \times 10^{-3\dagger}$	7.2×10^{-6}	1.4×10^{-6}	2.4	0.48
American shad roe	6×10^{-4}	2.8×10^{-3}	$1.6 \times 10^{-3\dagger}$	3.9×10^{-6}	7.8×10^{-7}	1.3	0.26
Blueback herring	1.9×10^{-3}	3.2×10^{-3}	$2.5 \times 10^{-3\dagger}$	6.2×10^{-6}	1.2×10^{-6}	2.1	0.41
Rainbow smelt	2.2×10^{-5}	3.5×10^{-3}	$3.5 \times 10^{-3\ddagger}$	8.8×10^{-6}	1.8×10^{-6}	2.9	0.59
Striped bass	3.9×10^{-3}	8.1×10^{-3}	$6.6 \times 10^{-3\S}$	1.6×10^{-5}	3.3×10^{-6}	5.5	1.1
Sea lamprey	6.7×10^{-4}	3.7×10^{-3}	$2.3 \times 10^{-3\dagger}$	5.6×10^{-6}	1.1×10^{-6}	1.9	0.38

Note: Doses are in milligram per kilogram per day. Shaded values represent a hazard quotient above 1.
*milligram per kilogram. †log normal 95 UCL. ‡Max (UCL>MAX). §gamma 95 UCL.

Table C-3. Fish species, polybrominated diphenyl ethers (PBDEs) concentrations, dose, and hazard quotient (HQ) using 10 ounces monthly (10 grams per day)

Species	Minimum concentration*	Maximum concentration*	Concentration for dose	Child dose	Adult dose	Child HQ	Adult HQ
Alewife	1.4×10^{-3}	2.7×10^{-3}	$2.2 \times 10^{-3\dagger}$	1.4×10^{-6}	2.8×10^{-7}	0.46	0.093
American shad fillet	1.9×10^{-3}	3.8×10^{-3}	$2.9 \times 10^{-3\dagger}$	1.8×10^{-6}	3.6×10^{-7}	0.6	0.12
American shad roe	6×10^{-4}	2.8×10^{-3}	$1.6 \times 10^{-3\dagger}$	9.8×10^{-7}	2.0×10^{-7}	0.33	0.065
Blueback herring	1.9×10^{-3}	3.2×10^{-3}	$2.5 \times 10^{-3\dagger}$	1.5×10^{-6}	3.1×10^{-7}	0.51	0.1
Rainbow smelt	2.2×10^{-5}	3.5×10^{-3}	$3.5 \times 10^{-3\ddagger}$	2.2×10^{-6}	4.4×10^{-7}	0.73	0.15
Striped bass	3.9×10^{-3}	8.1×10^{-3}	$6.6 \times 10^{-3\S}$	4.1×10^{-6}	8.2×10^{-7}	1.4	0.27
Sea lamprey	6.7×10^{-4}	3.7×10^{-3}	$2.3 \times 10^{-3\dagger}$	1.4×10^{-6}	2.8×10^{-7}	0.47	0.094

Note: Doses are in milligram per kilogram per day. Shaded values represent a hazard quotient above 1.
*milligram per kilogram. †log normal 95 UCL. ‡Max (UCL>MAX). §gamma 95 UCL.
L.

Appendix D Public comments and ATSDR responses

Page	Public Comment	ATSDR response
Commenter A		
iii	The fish tissue was analyzed for total mercury - not methylmercury.	updated text
iii	Change "This evaluation included three fish intake rates: 1) Wabanaki Traditional Lifeways Scenario Diet (286 grams per day for an adult; 143 grams per day for a child), 40 grams per day, and 10 grams per day." to "This evaluation included three fish intake rates: 1) Wabanaki Traditional Lifeways Scenario Diet (286 grams per day for an adult; 143 grams per day for a child), 2) 40 grams per day, and 3) 10 grams per day."	updated text
vi	Change " This report evaluates PFAS exposure from only one source—eating anadromous fish—and dose not and cannot account for PFAS exposure from other sources." to "This report evaluates PFAS exposure from only one source—eating anadromous fish—and does not and cannot account for PFAS exposure from other sources."	updated text
vii	Change "Adult should not eat striped bass daily or at 10 ounces per week because of PCBs." to "Adults should not eat striped bass daily or at 10 ounces per week because of PCBs."	updated text
vii	Change "This Health Consultation will be available for 60 days for written comments to be provided to ATSDR." to "This Health Consultation will be available for 30 days for written comments to be provided to ATSDR."	updated text
2	Change "This evaluation included three fish intake rates: 1) Wabanaki Traditional Lifeways Scenario Diet (286 grams per day for an adult; 143 grams per day for a child), 40 grams per day, and 10 grams per day." to "This evaluation included three fish intake rates: 1) Wabanaki Traditional Lifeways Scenario Diet (286 grams per day for an adult; 143 grams per day for a child), 2) 40 grams per day, and 3) 10 grams per day."	updated text
2	Change "The fish collection and analysis protocol included the collection of 76 composite samples" to "The fish collection and analysis protocol included the collection of 75 composite samples"	updated text
3	13 PFAS were analyzed in the fish. In addition to those mentioned, tissue was analyzed for PFOA, PFNA, PFBS, PFHxS, PFPeA, PFHxA, and PFHpA - all of which were below detectable levels.	updated text

Page	Public Comment	ATSDR response
3	Only 60 of the 75 composite samples were analyzed for PFAS.	updated text
3	total mercury was measured - not methylmercury	updated text
3	Change "Exposure doses were calculated for children and adults because doses vary depending upon how much people eat and how much people weigh Children were..." to "Exposure doses were calculated for children and adults because doses vary depending upon how much people eat and how much people weigh. Children were..."	updated text
4	Change "That table includes the conversion between ounces and grams foreach of the three intake rates as well as for children and adults." to "That table includes the conversion between ounces and grams for each of the three intake rates as well as for children and adults."	updated text
5	Change "All fish species sampled contained methylmercury, which is to be expected because most marine and freshwater fish contain some level methylmercury." to "All fish species sampled contained mercury, which is to be expected because most marine and freshwater fish contain some level mercury."	updated text
6	As methylmercury was not measured, it would probably be more accurate to use Mercury here and the next bullet.	updated text
6	Again, it may be more accurate to use "Mercury" here.	updated text
6	mercury may also be more appropriate here	updated text
7	This is inaccurate as methylmercury was not measured in the anadromous fish.	updated text
8	Did you calculate average mercury levels? Did you estimate methylmercury from the results?	In fish tissue, mercury is present predominantly as methyl mercury (about 85%), the more toxic form (Jones and Slotten 1996). Therefore, to be conservative, ATSDR assumed that all the mercury detected in fish is methylmercury.
12	All fish species were not available for PFAS analysis, so rainbow smelt is not included.	updated text
12	Change "The edible tissues of each of the fish types were analyzed for dioxin, furans, six different PFAS..." to "The edible tissues of each of the fish types were analyzed for dioxin, furans, 13 different PFAS..."	updated text

Page	Public Comment	ATSDR response
13	Change "Perfluorooctanoic acid (PFOA) is another PFAS that is commonly found in environmental samples, but it was not analyzed for in these fish samples. Not knowing the PFOA concentration in fish tissue adds uncertainty to the conclusions." to "It was analyzed for but not detected."	updated text
13	We know the concentration was BDL.	see previous response
14	In general change methylmercury to mercury	updated text
14	Global change shard to shad	updated text
16	Where's Table 10?	adjusted tables
17	Table 10. Site-specific cancer risk estimations for chronic exposure to dioxin toxic equivalents (TEQs) in alewife 0.000061 mg/kg (62 picogram per gram)	updated text
17	Why is this a 1 and not a 2?	updated text
17	Maybe this should be 61?	updated text
17	Cancer risk from eating alewife with 61 pg/g	updated text
17	This differs from the table title.	updated text
19	Change "Adults and children who may consume fish at 10 ounces weekly would not be at a potential cancer health concern." to "Adults and children who may consume fish at 10 ounces monthly would not be at a potential cancer health concern."	updated text
24	Change "This Health Consultation will be available for 60 days for written comments to be provided to ATSDR." to "This Health Consultation will be available for 30 days for written comments to be provided to ATSDR."	updated text
b-14	Shouldn't table A-10 come before A-11?	adjusted tables
Commenter B		
iii	add polybrominated diphenyl ethers (PBDEs)	updated text
iii	change "Penobscot Tribal Leadership" to "Penobscot Nation Department of Natural Resources"	updated text
3	there does not appear to be any mention of PBDE analyses or results. Did ATSDR review these data? If not, there should be an explanation as to why	PBDEs are included in this update

Page	Public Comment	ATSDR response
5	Might be helpful to add a statement that total mercury was analyzed but the literature indicates most of mercury found in fish is methyl mercury	updated text
8	Some of the fish in this table from FDA are the same species (striped bass, smelt, shad) that we sampled. How do the levels found in these fish choices compare to those found in this study of anadromous fish? Have they been tested for the same toxic contaminants? Is there any assurance that stripers, shad purchased at store would be any different than those caught locally? Culturally and economically, locally caught fish would be much more important to tribal members than those purchased from the store. This could be very confusing to people.	table deleted
11	change "alewife fish" to "alewife"	updated text
12	The lab analyzed 13 PFAS compounds. Only 6 were detected. Suggest a list of those analyzed (from QAPP), and then those detected.	updated text
B-8	Maine CDC issues the health advisory. Maine DIFW posts this in their fishing regulation handbook.	updated text
B-8	Might be useful to include Maine CDC's consumption advisory for striped bass. This can be found at https://www.maine.gov/dhhs/mecdc/environmental-health/eohp/fish/saltwater.htm. These are also included in Maine DMR's materials (Maine DMR is the Department responsible for saltwater fisheries.	updated text