UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MAINE

MAINE PEOPLE'S ALLIANCE and NATURAL RESOURCES DEFENSE COUNCIL, INC.,	
Plaintiffs,	
v.	Case No. 1:00-cv-00069-JAW
HOLTRACHEM MANUFACTURING COMPANY, LLC and MALLINCKRODT US LLC,	
Defendants.	

PLAINTIFFS' POST-TRIAL BRIEF

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INTRODUCTION

On the opening day of trial, the Court asked three questions: How bad is mercury contamination in the Penobscot estuary? How bad is it likely to be in the future? And what do we do about it? The trial evidence provides the following answers:

Mercury contamination in the Penobscot is severe, posing unacceptable risks to human health and the environment. Sediment mercury is more than ten times greater than background levels on a dry weight basis, and around seven times greater when normalized to carbon. Mercury concentrations in lobsters, black ducks, eels, and rock crabs all exceed the standard for safe human consumption set by the State of Maine. In response to data generated by the Court-ordered study, the Maine Department of Marine Resources (DMR) closed a seven-square mile portion of the lobster and crab fishery in the lower Penobscot—a step it deemed necessary to protect human health. The Maine Department of Inland Fisheries and Wildlife warned pregnant women and young children not to consume any duck from Mendall Marsh, again because of mercury levels discovered during the Court-ordered study. Songbirds in the marsh have blood mercury concentrations surpassing any on record. And fish in the river exceed safe mercury thresholds developed by independent scientists and endorsed by peer reviewers.

This contamination persists more than 40 years after the dominant inputs of mercury from defendant's chlor-alkali plant in Orrington. While portions of the ecosystem are cleansing themselves, the pace is slow. The best estimate, derived from an extensive survey of sediment cores, is that, on average, and in those locations that are recovering, sediment in the main stem of the river will not reach acceptable levels for three decades. In Mendall Marsh, the predicted recovery time is on the order of six decades. In the Orland

River and lower estuary, natural recovery will take more than seven decades. In addition, a substantial portion of the ecosystem is not recovering at all; surface mercury concentrations are constant or increasing in many locations, and mercury appears to be spreading downstream to the heart of the Penobscot lobster fishery. What looks like recovery in some areas is coming at the expense of increasing contamination in others, as mercury is redistributed throughout the estuary.

To address this persistent and dangerous contamination, the Court should order the immediate, intensive pursuit of active remedies to accelerate recovery of the ecosystem. All three members of the Court-appointed Study Panel, plus the project leader hired by the panel, recommend that result. Every other witness who testified to that question at trial, except those retained by Mallinckrodt, agreed. Plaintiffs seek an order empanelling an expert group of mercury scientists and engineers to map out, under the Court's supervision, a feasible suite of remedies, with whatever additional data gathering and pilot testing is necessary to that end. Consistent with the purposes of the Resource Conservation and Recovery Act (RCRA), active remedies will address the continuing human health and environmental dangers the Court-ordered study has uncovered, and will hold Mallinckrodt accountable for having polluted the river in violation of the law. As the First Circuit held earlier in this case, RCRA places "a congressional thumb on the scale in favor of remediation." *Maine People's Alliance v. Mallinckrodt, Inc.*, 471 F.3d 277, 297 (1st Cir. 2006).

BACKGROUND

In 2002, this Court held Mallinckrodt liable for polluting the Penobscot River with mercury. *Maine People's Alliance v. HoltraChem Mfg. Co.*, 211 F. Supp. 2d 237, 251-52 (D. Me. 2002). The First Circuit affirmed. *Maine People's Alliance*, 471 F.3d at 279. While

Mallinckrodt's appeal was pending, this Court issued an order directing a study of mercury contamination in the Penobscot River. JX 2.[1] The purposes of the study were to determine (1) "the extent of existing harm resulting from mercury contamination," (2) "the need for and feasibility of a remediation plan," and (3) "the elements of and timetable for . . . the appropriate remediation plan." *Id*. at 1-2. The implementing order contemplated that the study would assess "whether mercury within the study site presently poses an unacceptable risk to human health and/or the environment." *Id.* at 5. The Court required Mallinckrodt to fund the study. *Id.* at 7.

At Mallinckrodt's request, the study was designed and led by a panel of neutral scientists. JX 2 at 3-4; Tr. 3376-77 (Connolly). Each side to the litigation nominated a member, and together those panelists selected a chair. JX 2 at 3-4. The defendant nominated Dr. Chris Whipple, the plaintiffs nominated Dr. Nick Fisher, and those two nominated Dr. John Rudd. Tr. 23 (Rudd), 464-65, 474 (Whipple), 676 (Fisher); ECF Nos. 166, 167. The three panelists then hired Dr. Drew Bodaly to manage the project. Tr. 23-24 (Rudd); ECF No. 286. Each of the panelists, plus Dr. Bodaly, is a Ph.D. scientist with decades of experience studying mercury and contaminated ecosystems. JX 14; JX 18; JX 25; JX 30.

The Court instructed the Study Panel to conduct sound science. Tr. 18-19 (Rudd). The panel carried out its work independently, and each member perceived his job to be to evaluate the data without bias. Tr. 21-22 (Rudd), 474, 584-85 (Whipple), 680 (Fisher). None considered himself to be working for either of the parties; each felt obligated only to the Court. Tr. 21 (Rudd), 474-75 (Whipple), 680 (Fisher). Over the course of the study, the

[1] In this brief, JX refers to joint exhibits, PX refers to plaintiffs' exhibits, DX refers to defendant's exhibits, and Tr. refers to the trial transcript.

panelists had occasional disagreements about what the data showed, but "the standard for settling those arguments was evidence." Tr. 523 (Whipple).

The Study Panel divided its work into separate phases. Phase I was intended to determine "whether there really was a problem and how bad it was and how widespread it was." Tr. 35 (Rudd). The panel proposed a Phase I study plan to the Court, solicited comments from the parties, and revised the study plan in response to comments before receiving Court approval to proceed. Tr. 35-36 (Rudd).[2] The panel completed Phase I in January 2008 and filed a report with the Court, ECF No. 382, on which the parties commented the next month, ECF Nos. 387, 388. By order dated March 7, 2008, the Court approved the Phase I report and directed the panel to proceed to Phase II. In so doing, the Court held:

> It is now established in the record that mercury (Hg) deposited in the Penobscot River in significant quantities and to substantial negative effect from the HoltraChem site has and is now in the process of methylation posing a danger to the health of the wildlife in the River and risks of a substantial nature to the well-being of human beings who ingest the products of the River. That is the distillation of the factual predicate on which this case is to proceed.

ECF No. 390 at 2.

The Study Panel proceeded to Phase II, with two primary objectives: to estimate the rate of natural recovery, and to understand what controls mercury transport in the ecosystem. Tr. 69 (Rudd). The panel also "got our feet wet a little bit" with remediation options, and did "very preliminary testing" of some ideas. Tr. 69-70 (Rudd). Identifying

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[2] *See* ECF Nos. 235-1 (Phase I study plan), 243 (plaintiffs' comments), 244 (defendant's comments), 259-1 (revised study plan), 264 (plaintiffs' comments on revised study plan), 265 (defendant's comments on revised study plan), 266 (order approving revised Phase I study plan).

specific remedies was not a major objective of Phase II, Tr. 70 (Rudd); that was intended for a subsequent phase. The Study Panel again proposed a study plan to the Court, solicited comments from the parties, and revised the study plan in response to comments before receiving Court approval to proceed. Tr. 37 (Rudd).[3]

To conduct Phase II of the investigation, the Study Panel engaged a group of additional scientists to undertake specific research. Tr. 26-27 (Rudd). The panel sought out "top of the line" people, Tr. 27 (Rudd), and ultimately assembled an "astonishing group" to conduct the study, Tr. 1418 (Wiener). The scientists they retained are "leaders in their field[s]." Tr. 1418 (Wiener).

The panel produced a final Phase II report in April 2013. ECF No. 652. The report addressed the scope and severity of mercury contamination in the estuary and the time it will take for the ecosystem to recover if it is left alone. The Study Panel's principal findings are unanimous:

- From its Orrington plant, Mallinckrodt released six to 12 metric tons of mercury into the Penobscot River between 1967 and 2000. JX 6-1 at 1-6; DX 978 at 121.
- Sediment and key wildlife species in the Upper Estuary (from the old Veazie Dam to the southern tip of Verona Island) are heavily contaminated with mercury. JX 6-22; Tr. 29 (Rudd), 499, 505 (Whipple), 680-81, 694 (Fisher), 995-96 (Bodaly).

[3] *See* ECF Nos. 391 (proposed Phase II study plan), 392 (plaintiffs' comments), 393 (defendant's comments), 402 (order requiring revisions to study plan), 407 (revised study plan), 409 (plaintiffs' comments on revised study plan), 410 (defendant's comments on revised study plan), 413 (order approving revised Phase II study plan).

- Mercury levels in Penobscot lobsters, crabs, eels, and black ducks exceed the state health standard and pose a risk to human consumers, especially to pregnant women. JX 6-1 at 1-30; Tr. 480-81, 488-89, 497, 585 (Whipple), 85-86, 105-06 (Rudd).
- Mercury methylation rates in Mendall Marsh are extraordinarily high. Tr. 112-14, 116-17 (Rudd), 538-39 (Whipple), 693-94 (Fisher).
- Mercury levels in songbirds, predator fish, and prey fish exceed animal toxicity thresholds adopted by the Study Panel on advice from recognized experts who reviewed more than a hundred published studies. JX 6-22 at 22-3; JX 6-2 at 2-18 to 2-19 & Tbl. 2-6; Tr. 262-63 (Rudd), 1872 (Evers).
- The ecosystem is cleaning itself slowly, and will not reach acceptable levels of mercury in sediment or biota for many decades. JX 6-22 at 22-2; JX 6-6 at 6-14 to 6-15; Tr. 140 (Rudd), 574-75 (Whipple), 681-82 (Fisher).
- Some portions of the ecosystem are not yet recovering at all, but instead are getting worse; surface sediment mercury concentrations in a substantial number of locations are well above targets and continue to increase. JX 6-1 at 1-24; JX 6-22 at 22-2; Tr. 577-78 (Whipple).

In light of these findings, the Study Panel, by consensus, recommends active remediation to eliminate the health and environmental risks posed by this legacy pollution. Tr. 30 (Rudd), 475 (Whipple), 682, 751 (Fisher); JX 6-23 at 23-4.

The Study Panel members were not required to reach consensus; any one of them was free to dissent. The fact that the panel's central conclusions are unanimous speaks to the strength of the scientific record that supports each one. The Study Panel's principal findings and recommendations were also endorsed by the panel's project leader, Dr. Bodaly

(Tr. 995-98), its full-time research scientist, Dr. Dianne Kopec (Tr. 2017-19), its peer reviewer, Dr. James Wiener (Tr. 1471-72), and plaintiffs' expert, Dr. Charles Driscoll (Tr. 2085-87). As Dr. Whipple, defendant's nominee to the Study Panel, testified: "I think our principal finding is that left to itself, which I think we would all wish we could have recommended, the system simply is too contaminated and will be too slow to recover and that we need to consider active remediation measures as a result." Tr. 475.

ARGUMENT

I. Mercury Contamination in the Penobscot Estuary Poses Unacceptable Risks to Human Health and the Environment

A. Mercury Is a Persistent and Toxic Pollutant

Mercury is "probably the most toxic metal there is on the periodic table." Tr. 684 (Fisher). It does not degrade or break down over time. Tr. 692 (Fisher). Once mercury enters an ecosystem, it remains "[f]orever," unless it can be buried or transported away. Tr. 692 (Fisher). The primary concern in ecosystems contaminated with mercury is methylmercury, a type of organic mercury formed when inorganic mercury interacts with certain bacteria. JX 6-1 at 1-4; *Maine People's Alliance*, 211 F. Supp. 2d at 244.

When an organism ingests methylmercury, nearly all of the toxin crosses the gut lining and enters the organism's tissues—more, "by far," than any other metal. Tr. 690-91 (Fisher). Once methylmercury enters the lowest prey items in an ecosystem, it "marches up the food chain, amplifying in concentration, through a process known as biomagnification." *Maine People's Alliance,* 211 F. Supp. 2d at 244. As a result, the highest predators in the food web bear the highest methylmercury concentrations, and the longer the predator's lifespan, the more methylmercury it will accumulate. *Id.*; Tr. 691 (Fisher). Even at low concentrations, methylmercury attacks the nervous system and can impair an organism's ability to reproduce, resist disease, and behave normally. *Maine People's Alliance,* 211 F. Supp. 2d at 245.

In human beings, methylmercury harms the central nervous system. *Id*. Methylmercury is a fetal neurotoxicant, well documented to cause adverse effects on brain development to children exposed to low doses in utero. *Id.*; Tr. 480-81 (Whipple), 799 (Grandjean). People are exposed to methylmercury principally by eating contaminated fish. *Maine People's Alliance,* 211 F. Supp. 2d at 245. Once ingested by a pregnant woman, methylmercury is absorbed into the bloodstream and distributed to the developing fetus. *Id*. Methylmercury cannot be excreted from the fetal brain. *Id*.

B. Mercury Concentrations and Mercury Methylation Rates in Penobscot Sediments Far Exceed Those in Reference Areas

Total mercury in sediment is "an important factor in controlling the amount of methylmercury," Tr. 932 (Bodaly), and methylmercury in sediment will "translate to more methylmercury that's biologically available to animals that eat there," Tr. 747 (Fisher). Sediment mercury levels are thus a good indicator of contamination, even though "the primary indicator of concern" is mercury in biota. Tr. 2116 (Driscoll). Mercury concentrations in Upper Estuary sediments are significantly elevated compared to upstream and coastal reference areas. Tr. 241-42, 259, 404 (Rudd), 693-94 (Fisher), 1024-26 (Bodaly). Moreover, methylation rates in Mendall Marsh are among the highest ever recorded, Tr. 1563-64 (Gilmour), presenting particular dangers to wildlife who feed there.

1. Sediment mercury concentrations in the Penobscot are many times greater than in relevant reference areas

The Study Panel compared sediment mercury contamination in the Penobscot with reference sites that show "regional background" mercury concentrations. Tr. 78-80 (Rudd);

JX 6-17 at 17-3. These reference areas reflect only natural sources and atmospheric deposition of mercury. Tr. 78-79 (Rudd), 983 (Bodaly). In such areas that are "away from significant human activity"—including the East Branch of the Penobscot River, the outer reaches of Penobscot Bay, and other Maine estuaries—background mercury levels are about 55 ng/g on a dry weight basis. Tr. 982-88 (Bodaly); JX 6-17 at 17-6 & Fig. 17-2. Samples collected near the upstream boundary of the Upper Estuary averaged about 100 ng/g on a dry weight basis. Tr. 124-25 (Rudd), 988-89 (Bodaly). This shows the ultimate recovery that can be expected in the Upper Estuary and sets a practical limit for the effects of any remediation. Tr. 983 (Bodaly).

To compare Penobscot mercury concentrations to these background levels, the panel looked at both dry weight and carbon-normalized measurements.[4] Mercury levels in surface sediments of the Upper Estuary average about 900 ng/g dry weight, about 18 times higher than regional background levels and about nine times higher than the Upper Estuary's expected ultimate recovery. Tr. 84 (Rudd), 3383-84 (Connolly); JX 6-1 at 1-28 Tbl. 1-1; JX 6-21 at 21-2; PX 61 (JX 6-23 at 23-18 Fig. 23-2). On a carbon-normalized basis, the "numbers are different, but the conclusion is pretty much the same," Tr. 241 (Rudd); river sediments are still elevated about six to seven times compared to background sites. Tr. 1024-25 (Bodaly). In sum, "it doesn't matter what way you look at it," the sediment mercury values show that the Upper Estuary is "very contaminated." Tr. 242, 404 (Rudd);

[4] To calculate levels on a "dry weight" basis, mercury or methylmercury in the sample is measured and expressed as "the total amount of mercury in nanograms per gram dry weight of the . . . dried sediment material." Tr. 50-51 (Rudd). To calculate levels on a "carbon-normalized" basis, the amount of organic carbon in a sediment sample is also measured, and then the mercury concentration is expressed as nanograms of total mercury or methylmercury per gram of organic carbon. Tr. 51 (Rudd).

see also Tr. 499 (Whipple) ("quite elevated"), 693 (Fisher) (contamination "very pronounced"), 1026 (Bodaly) ("significantly contaminated").

The Study Panel's target for the main stem of the Penobscot River is to reduce sediment mercury levels by half—to about 450 ng/g dry weight—based on the reductions needed to protect human and wildlife health. JX 6-21 at 21-2 to 21-3 & Tbl. 21-1; Tr. 154, 157 (Rudd), 989 (Bodaly), 2127-28 (Driscoll). This target is still more than four times higher than the Upper Estuary's expected ultimate recovery and eight times higher than regional background. Tr. 989-90 (Bodaly).

In Mendall Marsh, sediment mercury levels average about 700 to 750 ng/g dry weight on the marsh levees (the slightly raised areas adjacent to water channels), 450 to 490 ng/g dry weight on the marsh platform (the flatter areas where decaying vegetation dilutes mercury concentrations somewhat), and 1,400 ng/g dry weight on intertidal mudflats within the marsh. Tr. 108-10, 230 (Rudd); JX 6-1 at 1-23; JX 6-21 at 21-3 Tbl. 21-1; JX 87 at 36. By contrast, sediment mercury levels in reference marshes average 28 ng/g dry weight in intertidal mudflats and 70 ng/g in marsh platform soils—roughly seven to 50 times lower than in Mendall Marsh. Tr. 229-31 (Rudd); JX 87 at 36. To protect species inhabiting the marsh, the Study Panel set a sediment remediation target of 100 ng/g for the marsh platform, based on the need to reduce biota mercury levels by about 80 percent. Tr. 122-23 (Rudd); JX 6-21 at 21-3 & Tbl. 21-1; JX 6-23 at 23-10.

2. Mercury methylation rates in Mendall Marsh are extraordinarily high

What sets Mendall Marsh apart is not just elevated total mercury levels but the rate of methylmercury production. Dr. Cynthia Gilmour, a Smithsonian Institution biogeochemist, measured mercury methylation rates in Mendall Marsh. JX 6-11. The results she documented were "extremely high." JX 6-11 at 11-89, 11-90 to 11-92 Figs. 11-3.2 to 11-3.4; Tr. 1563-64 (Gilmour). Dr. Gilmour testified that "we went back and redid all of our early analyses because I didn't believe the numbers -- the numbers were that high for methylmercury." Tr. 1572. Whereas methylmercury typically constitutes one or two percent of total mercury in sediments and soils, Mendall Marsh soils average about eight percent methylmercury, and range as high as 18 percent. Tr. 1582-83 (Gilmour); JX 6-11 at 11-47 Fig. 11-2.20, 11-66 Fig. 11-2.33, 11-89 to 11-91 & Fig. 11-3.3. In Mendall Marsh pore water—the water in between particles of sediment, where methylmercury is most bioavailable—methylmercury is up to 80 percent or more of total mercury. JX 6-11 at 11-67, 11-92; Tr. 1574-75 (Gilmour), 1457 (Wiener). One Mallinckrodt witness described Mendall Marsh as a "perfectly efficient methylmercury-producing system." Tr. 2973 (Vlassopoulos).

Dr. Gilmour prepared two figures that illustrate the extreme efficiency of methylmercury production in Mendall Marsh. PX 57 (JX 6-11 at 11-90 Fig. 11-3.2) (sediment soils); PX 58 (JX 6-11 at 11-92 Fig. 11-3.4) (pore water). Red dots high up in the center of the figures reveal that there is as much or more methylmercury in the marsh than in environments with orders of magnitude more total mercury. These results are "striking"; Dr. Rudd called the methylmercury percentages "among the highest I've ever seen." Tr. 112-14, 116-17. Dr. Whipple testified that "these concentrations are . . . really high enough that they are dangerous." Tr. 539. Dr. Fisher was "alarmed at the high rates of methylation." Tr. 693-94. To Dr. Wiener, what the figures depict is "worrisome," Tr. 1457, representing a "worst-case scenario as far as conversion of inorganic mercury to methylmercury," Tr. 1425.

Dr. Whipple referred to the red-dot plot as a "defining figure." Tr. 539. Dr. Fisher, too, said it influenced him to favor active remediation. Tr. 752-53. The dramatic methylation rates in Mendall Marsh suggest that other marshes in the Upper Estuary may merit focused attention as well. For example, the Orland River is another wetland system that has very high total mercury concentrations (over 1,000 ng/g on average, JX 6-1 at 1-28; JX 6-5 at 5-3) and the potential for high methylation rates and biota contamination. Tr. 2115-16, 2132-33 (Driscoll), 182-83 (Rudd). The Study Panel "didn't sample . . . the biota . . . very completely" in the Orland River. Tr. 182 (Rudd). Dr. Rudd testified that "in retrospect, I wish we'd spent a little more effort on the Orland." Tr. 183. Other fringe marshes throughout the Upper Estuary could harbor similar contamination. Tr. 1458-59 (Wiener), 2133 (Driscoll).

3. Mallinckrodt's attempt to minimize the extent of sediment contamination is without basis

At trial, Mallinckrodt's witness Dr. John Connolly claimed the Study Panel exaggerated the severity of mercury contamination in the estuary when it relied on dry weight rather than carbon-normalized concentrations. Tr. 3248-50. But the Study Panel considered both means of measurement, and displayed both in its reports to the Court. JX 6-1 App. 1-2 at 50, 53; JX 6-1 App. 1-3 at 25-30. By either measure, the panel found Upper Estuary sediments to be severely contaminated. Tr. 242-43, 404 (Rudd), 499 (Whipple), 693-94 (Fisher). Dr. Connolly conceded that sediment mercury in the Brewer to Orrington reach of the Penobscot is elevated "about nine times" compared to sediments just above the Veazie Dam and about 18 times compared to the East Branch reach farther upstream. Tr. 3250, 3383-84. The East Branch fits Dr. Connolly's criteria for an appropriate reference site, because it is subject to regional sources of mercury contamination but not to local point sources. Tr. 3381 (Connolly), 985 (Bodaly).

Dr. Connolly argued in his expert report that sediment mercury levels in Mendall Marsh are less than twice as high as those in reference marshes. JX 45 at 14. But his analysis was an "apples-and-oranges" comparison mixing distinct sediment types; Dr. Rudd presented data showing the marsh is elevated seven to 50 times compared to the same sediment types in appropriate reference areas. Tr. 228-31 (Rudd); JX 87 at 36. Moreover, Dr. Connolly ignored the extraordinary methylation rates in Mendall Marsh. On cross-examination, he conceded that if the marsh has twice the total mercury of a background location, and ten times the rate of methylmercury production, then it will have 20 times more methylmercury. Tr. 3389-91.

By any measure, sediment mercury concentrations in the Penobscot study area far exceed background levels, posing grave dangers, detailed below, to both human health and the environment.

C. Mercury in Penobscot Species Consumed by People Poses an Unacceptable Risk to Human Health

To assess human health risk, the Study Panel sampled Penobscot foods consumed by people, including lobsters, rock crabs, black ducks, and eels. The average mercury concentrations in these species at many locations substantially exceed the state safety standard (referred to as the Maine Fish Tissue Action Level), in some cases by an alarmingly large margin. Consumption of these foods would also cause consumers to exceed the U.S. Environmental Protection Agency (EPA) reference dose, the safe ingestion rate set by the federal government. Mercury levels in Penobscot foods therefore pose an unacceptable risk to human health.

1. Governing state and federal mercury limits provide the appropriate safety standard

The Maine action level to protect against developmental harm from fetal exposure to methylmercury is 0.2 ppm, or 200 ng/g. JX 85 at 6. The action level is defined as the concentration "below which there should be negligible risk of toxicity at a consumption rate of one meal a week." JX 85 at 1. When tissue concentrations exceed this level, the state explores regulatory action to protect consumers. JX 85 at 1. The state's 0.2 ppm limit is a level that "pregnant women would be well-advised not to exceed." Tr. 572 (Whipple).

The EPA reference dose establishes a safe intake level and is expressed in terms of a mercury ingestion rate: 0.0001 milligrams of mercury per kilogram of body weight per day (0.0001 mg/kg-day, or 0.1 ug/kg-day). Tr. 487 (Whipple), 802 (Grandjean); PX 122 at 4-87. The reference dose is the "fundamental standard of protection . . . that we think is the guidance we all need to follow." Tr. 485-86 (Whipple). In reliance on the reference dose, EPA published national guidance for safe mercury concentrations in fish at 0.3 ppm, or 300 ng/g. PX 122 at xvi. EPA also encouraged states to set their own thresholds, to account for state-specific information. *Id*. The Maine standard of 0.2 ppm is lower than the federal level because people in Maine eat more fish than the national average. Tr. 484-85 (Whipple).

The Maine safety standard was "based on a sensible method . . . and local data." Tr. 486 (Whipple). The EPA reference dose was established after a lengthy process and rigorous effort, including a comprehensive review by the National Academy of Sciences, commissioned by Congress. PX 122 at 4-12 to 4-88; PX 123. "[T]he amount of work that went into the [reference dose] was -- was really quite enormous." Tr. 487 (Whipple). The Study Panel never seriously considered using any other standard to assess health risk, because "it would be completely insensible for the Study Panel to challenge that body of work and to try to reinvent our own standard." Tr. 487 (Whipple); *see also* Tr. 936 (Bodaly) ("I didn't feel we could have any justification" to deviate from the state action level).

2. Penobscot foods exceed mercury safety limits

More than 90 percent of lobsters sampled north of Fort Point, eels below Veazie Dam, and black ducks in Mendall Marsh exceed the state safety limit for mercury. JX 6-14 at 14-2, 14-13; Tr. 1798-99 (Kopec). Average mercury concentrations in the northern-most sampling stations for rock crabs, south of Fort Point, also exceed the Maine safety standard. JX 6-1 App. 1-3 at 53.[5]

Mercury concentrations in the average lobster in the Upper Estuary are 50 percent higher than the state limit, with the highest levels found in lobsters just south of Verona Island. PX 144; Tr. 807 (Grandjean); JX 6-14 at 14-45. In 2012, the average legal-size lobster captured at South Verona contained mercury concentrations two and a half times the Maine safety standard. Tr. 1804-05 (Kopec); PX 170; PX 170A. Dr. Fisher testified that these lobster mercury concentrations "set off alarm bells" and "definitely got my attention." Tr. 701; *see also* Tr. 497 (Whipple) (there is "too much mercury in lobsters" in the Upper Estuary). In early 2014, after reviewing the Study Panel's data, the state Department of Marine Resources announced an emergency closure of the lobster and crab fishery in the upper Penobscot estuary. PX 83; PX 85 (map of closed area). The state made the closure permanent a few months later, a step it deemed "necessary to protect the public health." PX 84 at 1, 3.

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[5] The Study Panel did not sample crabs in the Upper Estuary, where it found the highest mercury levels in lobsters. JX 6-1 App. 1-3 at 55 (map of sampling locations). Dr. Bodaly testified that "in hindsight, the sampling should have been done further north, as well." Tr. 959.

Of particular concern, mercury contamination appears to be spreading farther south in the estuary, into an important commercial lobster fishery. Tr. 499-500 (Whipple). As the Study Panel reported: "[T]he potential for significant human exposures via lobster consumption may actually be increasing as mercury concentrations south of Fort Point Cove increase." JX 6-22 at 22-2. If the spread of contamination goes unchecked, the consequences for the state's fishery and for consumers of Penobscot lobster could be severe. *See* Tr. 500-01 (Whipple).

Mercury in the average eel in the Upper Estuary is also two and a half times the state limit. JX 6-14 at 14-13; PX 144. Eels in the Old Town to Veazie reach of the river, above the influence of defendant's plant, are also elevated, but their concentrations are significantly lower than in eels downriver. JX 6-14 at 14-14; Tr. 1779, 1786 (Kopec).

Average mercury levels in black ducks in Mendall Marsh are almost four times higher than the state safety standard. Tr. 489-90 (Whipple). These concentrations exceed any that have ever been reported in the scientific literature, Tr. 1971-72 (Kopec), and they alarmed the Study Panel. In 2011, the panel sought the Court's permission to share the black duck data with the state, and the Court approved. Tr. 1972-75 (Kopec), 491 (Whipple); ECF No. 567. In response, the state Department of Inland Fisheries and Wildlife promptly issued a consumption advisory and posted warning signs in Mendall Marsh, instructing children and pregnant and nursing women not to eat any waterfowl from the area. PX 67. This was the first warning anywhere in the State of Maine regarding the consumption of ducks. Tr. 1975 (Kopec).[6]

[6] Mercury concentrations in Mendall Marsh ducks declined during the winter of 2013-14, JX 13 Figs. 2, 3, but average concentrations were still more than twice the state safety standard in duck muscle. The decline was statistically significant in duck blood but not in

The health risk from consuming these Penobscot foods is further illustrated by comparison to the EPA reference dose. Plaintiffs' expert Dr. Philippe Grandjean compared mercury concentrations in the samples collected by the Study Panel to the reference dose of 0.1 micrograms per kilogram of body weight per day, assuming a 60 kilogram woman (about 132 pounds) and a 180 gram meal size (about 6 ounces). Tr. 814-16 (Grandjean); PX 146. According to Dr. Whipple, Dr. Grandjean's analysis has a useful purpose, "which is asking the question of, how often could someone eat such a meal and stay out of trouble." Tr. 623. Based on this comparison, consuming an average meal of lobster from the Upper Estuary equals nine days' worth of acceptable mercury intake. PX 146; Tr. 816 (Grandjean). A meal of the most contaminated lobster equals 33 days' worth of acceptable intake, or more mercury than EPA recommends ingesting from all sources over an entire month. PX 146; Tr. 567 (Whipple). An average meal of eel or black duck equals 15 or 18 days' worth of acceptable intake, respectively. PX 146. During that period, the woman would have to refrain from consuming any additional mercury-containing foods to avoid exceeding the reference dose. Tr. 816 (Grandjean), 567 (Whipple).

This analysis understates the risk because it assumes that the consumer has no other source of methylmercury. Tr. 818-20 (Grandjean). The best available research shows that the average woman in Maine has an existing methylmercury body burden at two-thirds of the reference dose already, and 20 percent of Maine women exceed it. Tr. 818-19 (Grandjean); DX 753 at 225. If this exposure were factored in, the period during which a

edible breast muscle. JX 13 at 6. The most likely explanation for the decline is that an unusually cold winter and resulting ice cover limited duck foraging in the marsh, where the ducks get most of their mercury. Tr. 604 (Whipple), 1981-83 (Kopec); JX 13 at 8-9.

consumer would exceed the reference dose from eating Penobscot foods would be much longer. Tr. 819-20 (Grandjean).

In 2002, this Court credited Dr. Grandjean's testimony that mercury concentrations in Penobscot seafood were so high that "[a] pregnant woman could not eat a single Penobscot fish in the measured range without endangering fetal health." *Maine People's Alliance*, 211 F. Supp. 2d at 245-46. The Study Panel's sampling since then reveals more pervasive contamination, at higher levels than were previously known and in more species than were previously tested. *Compare* ECF No. 123 (Tr. 4-B at 16-19), *with* JX 6-14 at 14-111, 14-116, 14-117, 14-133. These data reinforce the fact that mercury in the Penobscot poses an unacceptable risk to human health.

3. Mallinckrodt's arguments fail to undercut the conclusions of the Study Panel and the State of Maine

Mallinckrodt argues that the Study Panel's methodology for assessing health risk was flawed, that alternative standards developed by the defendant for this litigation should have been applied, and that mercury levels in all sampled Penobscot species are perfectly safe for consumers. Defendant is wrong on all counts.

a. The Study Panel was not required to conduct a "human health risk assessment"

Mallinckrodt's witness Dr. Russell Keenan asserted that the Study Panel was required to conduct a formal "human health risk assessment" to evaluate health risk. JX 55 at 2-5. In particular, Mallinckrodt criticized the Study Panel's decision not to perform one element of a formal human health risk assessment: a species-specific consumption survey among local consumers. JX 55 at 2-3. Mallinckrodt's witness Dr. Michael Bolger waffled on whether the panel was also required to measure blood mercury levels in people who eat

Penobscot seafood, first saying it was "necessary," then saying only that it would be "a nice to-do." Tr. 2393-94.

The Court did not direct the Study Panel to conduct the type of lengthy and invasive assessment Mallinckrodt wants. Tr. 254-55 (Rudd), 478-79 (Whipple). Nor was it necessary to answer the question the Court asked the Study Panel to address. Tr. 253-55 (Rudd), 479-80 (Whipple). Comparing mercury concentrations in food to the Maine safety standard and the EPA reference dose is both appropriate and sufficient to establish an unreasonable risk to human health. Tr. 479-80 (Whipple), 423 (Rudd).

b. The alternative "safety standards" proposed by Mallinckrodt are extreme and unfounded

Mallinckrodt objects to the Study Panel's use of the Maine action level to determine whether mercury in Penobscot foods poses an unacceptable risk. Dr. Keenan argued that the state standard applies only to freshwater fish and cannot be used to evaluate mercury levels in lobsters and black ducks. JX 55 at x; Tr. 2478. However, nothing in the state's action level says it applies only to freshwater fish. Tr. 550-51 (Whipple); JX 85. For purposes of evaluating health risk, the species of contaminated food is irrelevant; what matters is how much mercury it contains. Tr. 552-53 (Whipple). It is therefore appropriate to apply the same level to ducks and lobsters, Tr. 551-52 (Whipple), as the state itself did in taking action to prevent consumption of both species, Tr. 2001-02 (Kopec); PX 84.

To supplant the state action level of 200 ng/g, Dr. Keenan offered substitute mercury limits, much higher than the state standard. Based on a series of assumptions about consumption rates—and by further assuming that the average woman in Maine weighs 20 pounds more than the state assumes—Dr. Keenan came up with his own "safe" mercury targets of 490 ng/g for eels, 510 ng/g for lobsters and rock crabs, and an astronomical 1,500 ng/g for black ducks. Tr. 2595-96, 2598. He then testified that "I certainly think it would have been health-protective" to *triple* these values. Tr. 2597. He is therefore "comfortable" with thresholds of around 1,500 ng/g for eels, lobsters, and rock crabs, and 4,500 ng/g for black ducks. Tr. 2598, 2609. These values are more than seven times and 22 times higher, respectively, than the state standard.

Dr. Whipple testified that the method Dr. Keenan used is "simply wrong." Tr. 546-47. It is based on "one central assumption" that Dr. Whipple finds "completely unrealistic"—that an individual's only source of methylmercury in the diet is from one particular species. In other words, Dr. Keenan assumed that the person who eats Penobscot lobster, duck, crabmeat, or eel never eats any other seafood or gets methylmercury from any other source. Tr. 547 (Whipple). Dr. Keenan claimed that the assumptions he used are "very conservative," Tr. 2488, but Dr. Whipple disagreed, describing Dr. Keenan's methodology as "nonconservative to the point of approaching silliness." Tr. 547.

The additional assumptions underlying Dr. Keenan's new numbers are also dubious. As one example, Dr. Keenan assumes that a person's black duck consumption is averaged across an entire calendar year, rather than concentrated during the three-month hunting season. Tr. 548-49 (Whipple). Just by assuming that the same amount of duck is consumed during the hunting season, instead of spread out across the year, it is easy to identify scenarios in which a pregnant woman "would get way too much mercury." Tr. 549 (Whipple).

Notably, the Food and Drug Administration has issued nationwide "do-not-eat" advisories for pregnant women for four species of fish that average between 0.7 and 1.45 ppm mercury, or 700 to 1450 ng/g. JX 84; PX 97 at 1. According to defendant's witness Dr.

Bolger, "it's just not worth the risk" for pregnant women to eat fish with mercury concentrations that high. Tr. 2373-74, 2424. Yet Dr. Keenan's proposed safe level for black ducks is 1,500 ng/g—higher than the highest average of the four species FDA warns pregnant women never to eat.[7]

c. Mercury diminishes the benefits of eating fish

At trial, defendant's witness Dr. Bolger focused on the health benefits of eating fish generally. Tr. 2289, 2292. Eating fish can be healthy. Tr. 799 (Grandjean), 561 (Whipple). But even Dr. Bolger concedes that methylmercury diminishes the benefits a consumer would otherwise derive from fish. Tr. 2405 (Bolger); *see also* Tr. 800 (Grandjean), 561 (Whipple). The main objective is to get the "benefits of eating fish while consuming as little methylmercury as possible." Tr. 562 (Whipple). At certain mercury concentrations, the only sound advice is "don't eat even a single meal," because the health risks are too high. Tr. 562-63 (Whipple), 2424 (Bolger). The State of Maine followed that approach here, posting the black duck warning and closing a portion of the Penobscot lobster and crab fishery because it was "necessary to protect the public health." PX 84.

Dr. Bolger did precious little to support the opinions he expressed. He agreed to testify for Mallinckrodt without reviewing any materials related to the case. Tr. 2350. He signed his expert report six days after he was retained by defendant. Tr. 2350. He admitted that he never read the Study Panel's report or the underlying study data. Tr. 2350-51. Yet he asserted, based on almost no analysis, that eating high-mercury meals from the

[7] FDA also warns women of childbearing age to strictly limit their consumption of albacore tuna, JX 84, and Dr. Bolger agrees with that advice. Tr. 2423 (Bolger). Mercury levels in northern estuary lobster are essentially the same as levels in albacore tuna. Tr. 2423 (Bolger); PX 144.

Penobscot poses no health risk because it would not cause a meaningful change in blood mercury levels without "weeks of continuous exposure." Tr. 2433-34. According to Dr. Whipple, that "simply is not true." Tr. 570-71.

Dr. Bolger testified that he is "not second-guessing" the state's safety standard, and he is unfamiliar with how that level was derived. Tr. 2440. He said that he does not have an informed opinion about the state's closure of the lobster and crab fishery. Tr. 2421-22. And with respect to the state decision to warn people not to eat black ducks, Dr. Bolger said: "I can't disagree with it." Tr. 2425. Dr. Bolger's testimony therefore offers no basis to reject the conclusions of the state and the Study Panel that mercury contamination in Penobscot foods poses an unreasonable risk to human health.

D. Mercury Contamination Poses Unacceptable Risks to Penobscot Wildlife

There are no applicable regulatory standards that set mercury toxicity thresholds for wildlife. Tr. 937 (Bodaly). In order to assess whether mercury exposure is harming Penobscot wildlife, the panel compared measured Penobscot mercury levels against levels that, according to the scientific literature, cause toxicity. Tr. 934-35 (Bodaly). This use of scientific benchmarks is a "very reasonable" and "common" practice in large ecosystem investigations. Tr. 1449-50 (Wiener); *see also* Tr. 2129-30 (Driscoll).

The Study Panel enlisted "terrific," "highly qualified" scientists "who know th[e] literature very well" to develop appropriate toxicity thresholds. Tr. 2130 (Driscoll). For birds, the panel relied on Dr. David Evers, a wildlife researcher with decades of experience designing, conducting, and publishing studies on the effects of mercury on birds. Tr. 941-45 (Bodaly), 1867-68 (Evers); JX 17. Dr. Evers is a "world-renowned authority on the ecotoxicology of methylmercury in birds," Tr. 1444 (Wiener), and is widely considered "the last word" on avian toxicity, Tr. 703 (Fisher). For fish, the panel relied on a comprehensive literature review by Dr. Mark Sandheinrich, "a very respected researcher in the field of toxicity of methylmercury to fish." Tr. 938 (Wiener); *see also* JX 26; JX 6-2 App. 2-1.

1. Mercury concentrations in birds far exceed toxicity thresholds

Dr. Evers reviewed 162 scientific studies, including 98 about birds, most of which had been subjected to peer review. Tr. 1871-72; JX 6-2 App. 2-2 at 23-39. From these studies, Dr. Evers derived a value called the "effects concentration 20" or "EC_{20}." The EC_{20} is the contaminant concentration that will produce harmful reproductive effects in 20 percent of a population. Tr. 1880-81 (Evers). When 20 percent of the population is jeopardized, the population may no longer be self-sustaining. Tr. 1881-82 (Evers). The EC_{20} is the "best, most relevant standard for protecting a target species at the population level." Tr. 1882 (Evers).

Invertivorous (invertebrate-eating) birds are often at greater risk from mercury exposure than piscivorous (fish-eating) birds. JX 6-2 App. 2-2 at 3, 11 & Fig. 3; Tr. 1876-80, 1900 (Evers), 1034 (Bodaly). This is especially true of wetland-dwelling invertivores, like songbirds in Mendall Marsh, that prey on spiders and other higher trophic level organisms. Tr. 1877-78 (Evers); JX 6-16 at 16-58 to 16-67. Dr. Evers therefore developed different EC_{20} values for Penobscot piscivores and invertivores. For piscivores he proposed, and the Study Panel adopted, an EC_{20} of 2.0 ug/g in blood. JX 6-2 App. 2-2 at 3; Tr. 1882-84 (Evers). For more sensitive invertivores he proposed, and the Study Panel adopted, an EC_{20} of 1.2 ug/g in blood. JX 6-2 at 2-6, App. 2-2 at 3; Tr. 1884 (Evers). Dr. Evers testified that if his goal were to *eliminate* toxic effects to invertivores, he would set the standard even lower—around 0.4 or 0.5 ug/g in blood. Tr. 1907.

The primary basis for the invertivore target is a peer-reviewed 2011 paper by Jackson et al., reporting nest failure in invertivorous Carolina wrens at two mercury-contaminated sites in Virginia. Tr. 1884, 1885 (Evers); JX 64. Dr. Evers designed and oversaw the Carolina wren study, and his co-authors include academics and government researchers. Tr. 1885, 1911-12 (Evers); JX 64 at 759. The results of the study are the best information available to assess the effects of mercury on songbirds' ability to reproduce. Tr. 1908 (Evers), 1032-33 (Bodaly) (describing the Jackson study design as "solid," "about as good as you can do"), 507-08 (Whipple) ("I think none of us believed we could have done a better study than that one."). In addition to the Jackson paper, studies by Drs. Dan Cristol and Gary Heinz support the panel's invertivore target. Tr. 1885-86 (Evers), 1032 (Bodaly).

Many of the birds sampled by the Study Panel exceed the relevant targets, some by an order of magnitude. JX 6-14 at 14-59 Tbl. 14-3; JX 10 App. 2. The greatest ecological threat is to songbirds in Mendall Marsh. The blood mercury levels of Nelson's sparrows sampled in the marsh are "extremely high": ten to 15 times greater than have been found anywhere else in North America. Tr. 1811-15, 1893 (Evers). "Virtually all" Nelson's sparrows sampled in the lower Penobscot exceeded the Study Panel's threshold, compared to just two percent that exceeded the threshold at reference sites. Tr. 1816 (Kopec); *see also* JX 6-14 at 14-58. In red-winged blackbirds, another songbird, blood mercury concentrations at Mendall Marsh are "tremendously high[]"—up to 14 ug/g, more than ten times the Study Panel's target. Tr. 1823 (Kopec); *see also* JX 8 Fig. 16. "[T]hese are the highest concentrations that have ever been reported for red-winged blackbirds." Tr. 1824 (Kopec); *see also* Tr. 1899 (Evers). Other invertivores also exceeded the Study Panel's target, including 77 percent of Virginia rails tested, 65 percent of swamp sparrows, and 20 percent of song sparrows. JX 6-14 at 14-59 Tbl. 14-3.[8]

According to the Jackson study, mercury concentrations of 4.4 ug/g in songbird blood correspond to a 90 percent reduction in nest success, Tr. 1903-04 (Evers)—almost a total inability to produce viable offspring. The mean concentrations detected in Penobscot songbirds at some sampling sites and times exceed even this level. Tr. 1904 (Evers). Indeed, Dr. Evers's research team found very few hatch-year birds when they sampled Mendall Marsh. Tr. 1892-93. He testified that it is "highly likely" that both Nelson's sparrows and red-winged blackbirds are suffering reproductive harm, Tr. 1897-99, 1933, and that he would be "hard-pressed" to find a bird expert who thought otherwise, Tr. 1931; *see also* Tr. 2006 (Kopec) ("[T]oxicity must be occurring in those birds."). Dr. Evers, the Study Panel, and other independent scientists are unanimous that the evidence of harm to Penobscot birds justifies pursuing active remediation now. Tr. 1933 (Evers), 262-63 (Rudd), 585 (Whipple), 722-23, 751 (Fisher), 997-99 (Bodaly), 2006 (Kopec), 1463-64, 1471-72 (Wiener).

To challenge the Study Panel's findings regarding Penobscot birds, Mallinckrodt presented Dr. Betsy Henry. Dr. Henry is not a wildlife biologist, and she has never designed a field or lab study on birds. Tr. 2810-11 (Henry). She proposes a threshold of 3.0 to 4.0 ug/g in blood as an appropriate screening level for harm to invertivorous birds. Tr. 2774. Her screening range does not "reflect the current thinking of expert avian ecotoxicologists

[8] Mercury concentrations in bats (which are mammals) also exceeded the threshold proposed by Dr. Evers and adopted by the Study Panel. JX 6-2 App. 2-2, at 3, 21; JX 6-14 at 14-134; Tr. 1922-23 (Evers). Although there is more uncertainty about whether the data establish harm to bats, there is "no scientific basis" for opining that mercury is having no effect. Tr. 1921, 1928 (Evers).

who work on mercury." Tr. 1919 (Evers). Nor is Dr. Henry's range consistent with the Study Panel's piscivore safety threshold of 2.0 ug/g—despite the fact that Dr. Henry does not challenge the piscivore target. Tr. 2813. Invertivores are more sensitive to mercury than piscivores are, Tr. 1876-80, 1900 (Evers), yet Dr. Henry's invertivore target is higher than the piscivore target she does not contest. Dr. Henry's threshold also exceeds the one Mallinckrodt proposed to the Study Panel in 2010, based in part on an Evers study from 2008. PX 112 at 6, 7; Tr. 2815-17 (Henry). Dr. Henry did not consider that Evers study, Tr. 2817, notwithstanding her client's prior citation to it.

Dr. Henry testified to the importance of using "the best information we have" when assessing toxicity, even when that information is imperfect. Tr. 2799. However, in developing her screening level, Dr. Henry "[c]ompletely disregarded" the Jackson study of Carolina wrens. Tr. 2871. She said she saw problems in the Jackson study design, including a failure to control for all factors that might confound the effects of mercury. Tr. 2789-91. But all field studies contend with confounding factors present in the natural environment: Dr. Henry testified that she knows of *no* study that has controlled for all confounding factors to isolate the differential impact of mercury. Tr. 2874-75.

Dr. Henry also testified that harm to Penobscot songbirds can only be proven through a multi-year field toxicity test. Tr. 2913-15. The Study Panel had vigorous discussions on whether to conduct such a study. Tr. 94-95 (Rudd), 505-06 (Whipple), 709-10 (Fisher). When Dr. Rudd put the question to the Court, Judge Carter instructed the panel not to include field toxicity tests as part of the Phase II study plan. Tr. 96 (Rudd). A year later, Special Master Calkins advised the panel that "there is no order prohibiting further toxicology testing," and that such tests could be proposed if the panel could "tie the need for it to remediation." DX 165. By then the panel had determined that such tests were not worthwhile, and decided "to rely on the experts who really understand this field and are intimately aware [of] the latest developments." Tr. 99 (Rudd).

While Dr. Henry asserted at trial that only a field test will provide proof of harm to the Nelson's sparrow, Tr. 2795-96 (Henry), her expert report was more equivocal. There she wrote that "*[i]deally*" "a properly designed field study *should* be able to address [w]hether or not there are measurable effects on reproduction that would be considered *indicative* of *potential* population-level effects." JX 53 at 19 (emphasis added); Tr. 2904. As to the discrepancy between her trial testimony and her written report, Dr. Henry cautioned against "reading anything into the words" she used in her expert report. Tr. 2905. In fact, as Dr. Henry's own written language suggests, there is little likelihood that a field test would produce conclusive results. Tr. 97 (Rudd), 506 (Whipple), 1450 (Wiener).

Mallinckrodt's principal technical advisor, Dr. Connolly, told the Study Panel that ecological risk need *not* be demonstrated by a field toxicity test, but "can be based . . . on tissue concentrations documented to cause population level impacts at other sites." PX 112 at 3. When Dr. Henry was first confronted with that statement at trial, she disagreed with it, but when she learned it originated with her colleague Dr. Connolly, she changed her mind and agreed. Tr. 2906-07. Dr. Henry further conceded that field toxicity tests are not routinely performed at contaminated sites to inform remediation, Tr. 2798, and that "reasonable scientists" could conclude that a field test is not necessary to proceed to remediation in the Penobscot, Tr. 2911.

Dr. Henry's insistence on toxicity testing is also inconsistent with her client's conduct during the study process. In its comments on the Study Panel's revised Phase I study plan, Mallinckrodt asked the panel to *eliminate* fish and bird toxicity studies, and perhaps perform them in a later phase. PX 149 at 7-2, 7-3. The panel's proposed Phase II work plans did not include toxicity studies for any biota, *see* ECF Nos. 391, 407, but defendant did not object. PX 155; PX 157; Tr. 3507 (Connolly).

Dr. Henry's testimony revealed a stubborn insistence on supporting Mallinckrodt's litigation position. When she was asked whether it was possible for a reasonable scientist to set a toxicity threshold below 3.0 ug/g for songbirds in Mendall Marsh, as Drs. Evers, Sandheinrich, Bodaly, Kopec, and the Study Panel had done, Dr. Henry replied: "Um, hypothetically." Tr. 2841. She was compelled to agree that mercury levels in the blood of Nelson's sparrows and red-winged blackbirds in the marsh exceed her own inflated threshold for adverse reproductive effects, and therefore may cause significant adverse harm at the population level. Tr. 2954; JX 45 at 59 (Dr. Connolly, citing Dr. Henry). Still, she would not concede the possibility that leaving the marsh alone will prolong and expand the potential harm she herself identified. Tr. 2954-56. Dr. Henry's advocacy-oriented testimony for Mallinckrodt fails to rebut the Study Panel's unanimous finding that there is an unreasonable risk to birds in the Penobscot.

2. Mercury concentrations endanger Penobscot fish

To evaluate risk to fish in the Penobscot, the Study Panel set two targets—one for predator fish and one for prey. For predator fish, Dr. Sandheinrich recommended a range of 300 to 700 ng/g on a whole body basis, or approximately 400 to 900 ng/g in muscle. JX 6-2 at 2-5 & App. 2-1 at 31. The panel set the target within this range, at 500 ng/g. JX 6-2 at 2-5 to 2-6. The panel chose a target at the low end of the range, but not the lowest, because it wanted to be protective but reasonable. Tr. 940-41 (Bodaly). Dr. Wiener reviewed the literature supporting this threshold and agreed with the target. Tr. 1441-43 (Wiener).

The panel set a separate target at 50 ng/g for prey fish, the smaller species in the Penobscot that serve as a food source for other animals higher up the food web. JX 6-2 at 2-8 to 2-9. To set the prey fish target, the Study Panel relied largely on a review paper by Depew et al., which incorporates the results from four different studies that looked at reproductive endpoints, and which proposed a threshold of 40 ng/g to protect against reproductive harm. Tr. 947-52 (Bodaly); JX 76 at 7 Tbl. 3. The panel chose a prey fish target of 50 ng/g—slightly higher than the threshold proposed by Depew et al. JX 6-2 at 2-9. Dr. Wiener again agreed that this was a reasonable target based on the published literature. Tr. 1443-44. It is also consistent with the 500 ng/g target for predatory fish that consume these prey, because biomagnification can lead to a tenfold increase in methylmercury concentrations between trophic levels. Tr. 1443-44 (Wiener). The application of dietary screening benchmarks, like those reported by Depew and used by the Study Panel, is a scientifically valid, proven approach for assessing methylmercury risks. JX 99 at 2.

In addition, the scientific literature shows that methylmercury levels believed to be safe for aquatic organisms keep declining. According to Dr. Bodaly, there is "[v]ery definitely" a "quite dramatic" trend that "as new studies come out, the level of methylmercury that has been established to cause toxic effects keeps going down." Tr. 970. Therefore, "we should be thinking conservatively about these limits because almost certainly future studies will lower them even lower than they are now." Tr. 970 (Bodaly).

Methylmercury levels in Penobscot fish exceed the Study Panel's toxicity thresholds. The only predator fish sampled by the panel, eels, exceed the target for fish health. JX 6-1 at

1-30 Tbl. 1-4; JX 6-14 at 14-111 App. 14-1 (mean total mercury exceeds 500 ng/g at most sampling stations in Brewer-Orrington and Orrington-Bucksport reaches in each year from 2007-2010); JX 10 App. 1 (same for 2012). And most mean mercury concentrations in prey fish—tomcod, Fundulus (mummichog), and rainbow smelt—sampled by the Study Panel in the Upper Estuary exceed the 50 ng/g target. JX 6-1 at 1-30 Tbl. 1-4; JX 6-14 at 14-112 to 14-114 (through 2010); JX 10 App. 1 (2012).

In response to these findings, defendant's Dr. Keenan again created his own higher targets, after reevaluating the literature reviewed by the Study Panel. Through his recalculations, Dr. Keenan came up with a range of 1,600 to 6,600 ng/g for predator fish (three to 13 times higher than the Study Panel's target of 500), and 680 to 5,030 ng/g for prey fish (13 to 100 times higher than the Study Panel's target of 50). JX 55 at 4-10, 4-13.

The Study Panel and other independent scientists criticized Dr. Keenan's alternative targets. First, to derive his thresholds, Dr. Keenan combined the much higher mercury levels capable of causing fish mortality and growth impairment with the far lower levels that cause reproductive harm. Tr. 2586 (Keenan), 1480 (Wiener). According to Dr. Wiener, "[i]t makes no sense to combine these." Tr. 1481. As Dr. Wiener explained, "[r]eproduction is the most sensitive endpoint," and "diminished reproductive success is the most significant adverse effect of methylmercury exposure from a population-level perspective." JX 99 at 1. The Court recognized in 2002 that "[m]ethylmercury's effects are largely sublethal: Methylmercury may not kill an animal, but it will impair the animal's ability to reproduce." *Maine People's Alliance*, 211 F. Supp. 2d at 245. By "lump[ing] different end points together," Dr. Keenan produced an estimate with "virtually no value" in terms of assessing harm. Tr. 1480-81 (Wiener). His approach is "not scientifically valid." JX 99 at 1.

Second, Dr. Keenan excluded all studies other than those that found effects on fish survival, growth, and reproduction. Tr. 2541-42 (Keenan). Dr. Fisher testified that the last 30 years of research demonstrate the importance of looking at the additional effects that Dr. Keenan ignored, including biochemical and behavioral changes. Tr. 737-38, 741-42. According to Dr. Kopec, Dr. Keenan's selective reassessment "clearly inflates the concentration of [mercury] harmful to fish by artificially limiting the research papers used." JX 95 at 2.

Third, for the studies he did consider, Dr. Keenan routinely discarded low reported values and included high reported values from the same study. He could not articulate any principled basis for doing so. The obvious effect was to skew his safe targets even higher. He offered but then retracted several different explanations for his choice of numbers to derive his fish targets. Tr. 2543, 2570-71, 2584-85.[9]

Fourth, Dr. Keenan testified that the Study Panel's prey fish target was unreasonably low because it was exceeded by fish throughout the State of Maine. Tr. 2530. In offering this opinion, he compared the prey fish target to mercury levels in *predator* fish, which accumulate much higher mercury concentrations. Other witnesses criticized Dr. Keenan for his misleading approach. Tr. 626 (Whipple), 1015-16 (Bodaly), 1482-83 (Wiener). Moreover, Dr. Keenan is wrong that the target is unrealistic; prey fish are already at or below the mercury target in the lower reaches of the Penobscot estuary, outside the

[9] Specifically, Dr. Keenan testified that he would not rely on a no-observed-adverse-effects-level (NOAEL) from a study without a reported low-observed-adverse-effects-level (LOAEL). Tr. 2541-43, 2571. But he later admitted he did not follow this "basic tenet." Tr. 2543, 2725-26. He testified at deposition that he would include "control value NOAELs" if they were bounded with a LOAEL. Tr. 2569-70. But he subsequently admitted he did not follow this principle either, and that his deposition testimony was inaccurate. Tr. 2569-70, 2571-72.

influence of Mallinckrodt-generated contamination. Tr. 2009-10 (Kopec); JX 6-14 at 14-112 App. 14-2 to 14-114 App. 14-4. The targets are therefore demonstrably achievable.[10]

3. The Study Panel's methodology was scientifically sound

Mallinckrodt insists that the Study Panel should have conducted a formal ecological risk assessment. As presented by Mallinckrodt, an ecological risk assessment follows a formulaic approach with an "eight-step process" pursuant to federal guidance developed under a different statute than the one at issue here. Tr. 2502, 2507(Keenan); DX 759. However, as Mallinckrodt concedes, the Court did not order the panel to conduct an ecological risk assessment. Tr. 2854 (Henry). Instead, Special Master Calkins explicitly left it to the Study Panel to determine an appropriate methodology for assessing harm: "Given that there are no statutory or regulatory criteria or framework that the Study Panel is required to follow, the Study Panel, in the exercise of its scientific expertise and objectivity, should develop and articulate its recommendations and reasons in a manner that, in its opinion, best meets the requirements of the orders of the court in this case." PX 10 at 10. The Study Panel did precisely that, adopting a "data-driven process" rather than Mallinckrodt's proposed "cookbook" plan. Tr. 253-55 (Rudd). The panel's sound process reveals that Penobscot mercury poses unacceptable risks to wildlife.

II. Absent Active Remediation, Mercury Contamination in the Penobscot Estuary Will Persist for Many Decades

A. Natural Recovery, Where It Is Being Observed, Is Occurring Slowly

The Study Panel retained Dr. Kevin Yeager and Dr. Peter Santschi—one of the top sedimentologists in the world, *see* Tr. 129 (Rudd)—to collect and analyze sediment cores

[10] In any event, Dr. Whipple testified that even if the prey fish target is too low, "our overall conclusions and recommendations are completely independent of that number." Tr. 626.

from throughout the Penobscot estuary, in order to identify historical mercury accumulation rates and to calculate a projected rate of recovery. JX 6-5 at 5-2, 5-5; JX 6-6 at 6-2 to 6-3. By analyzing the concentrations of mercury and certain radioactive tracers at various depths in each core, Drs. Yeager and Santschi could recreate the historical record of mercury deposition and attenuation, and project any observed recovery into the future. Tr. 128-29 (Rudd); JX 6-1 at 1-13 to 1-14. The Study Panel's goal was to estimate how long it will take for the Penobscot estuary to recover on its own, in the absence of active remediation. JX 6-1 at 1-10 & 1-29 Tbl. 1-2.

Dr. Yeager led the fieldwork and collected three sediment cores, roughly 90 centimeters deep, at each of 72 different sampling locations. Tr. 1286, 1288 (Yeager); JX 6-5 at 5-5, 5-14. Cores from 58 of the sampling locations were suitable for full analysis. Tr. 1299 (Yeager); JX 6-5 at 5-6 to 5-7. The cores were collected from four principal regions within the study area: the lower Penobscot River (downstream of Veazie Dam, denoted PBR in the report), Mendall Marsh (MM), the Orland River (OR), and Fort Point Cove and the lower estuary (ES). *See* JX 6-5 at 5-2, 5-6 Fig. 5-1 to 5-10 Fig. 5-8 (maps of coring locations).

This was an unusually large and comprehensive data set from which to assess recovery rates. According to Dr. Whipple, "the number and quality of the cores we got is really . . . exceptional." Tr. 516. Dr. Yeager has been involved in only one other project of similar magnitude, as chief scientist collecting sediment cores in the Gulf of Mexico following the BP oil spill. Tr. 1278-79. The value of this "remarkable data set" is that it provides "an extremely comprehensive picture" of the ecosystem. Tr. 2137 (Driscoll). These cores thus provide "our most trusted estimate of recovery rates in the Penobscot system." JX 6-1 at 1-11; *see also* Tr. 137-38 (Rudd) (the sediment cores are the "definitive data" on recovery), 2136 (Driscoll) (the core data "provide the best resource to estimate" recovery times).

Dr. Santschi examined mercury records from the sediment cores and observed a clear pattern across the data set as a whole. Many cores show a dramatic mercury spike that corresponds to the period of major mercury releases from the Mallinckrodt plant. Tr. 1687 (Santschi). After the initial major release, there was a relatively rapid decline from the peak mercury concentrations in sediment. JX 6-6 at 6-14; Tr. 1687 (Santschi). That decline leveled off, however, as mercury concentrations became homogenized and were redistributed across the entire estuary, leading to a "slower system recovery" phase. JX 6-6 at 6-15; Tr. 1688 (Santschi). Dr. Santschi drew a rough dividing line between these two observed phases, and used the historical recovery from the past 21 years to project expected recovery in the future. Tr. 1688 (Santschi), 129 (Rudd). To a certain extent, Dr. Santschi testified, the 21 year period is arbitrary; he could have focused on "20 years or 19 years or 25 years." Tr. 1688, 1694. But the time period he chose matches well with the trend he observed across the cores generally, and is also "sufficiently long so that one has enough mercury data" points for a meaningful analysis. Tr. 1688, 1694-95 (Santschi).

For those cores that indicate recovery, Dr. Santschi determined the rate of decline in mercury concentrations, reported in half times. (A half time is the amount of time it takes for surface sediment mercury concentrations to decrease by half toward a selected asymptote. Tr. 131 (Rudd)). Dr. Santschi derived average recovery half times of 31 years in the main stem of the Penobscot River, 22 years in Mendall Marsh, 77 years in the Orland River, and 78 years in the lower estuary. JX 6-6 at 6-14. As Dr. Santschi noted, however, "[c]alculated apparent half times of several decades do not mean that after that time, sediments have fully recovered." JX 6-6 at 6-15. In many locations, surface mercury concentrations are high enough that it will take several half times to reach the Study Panel's targets. In Mendall Marsh, for example, it will take three or four half times to reach the relevant target, which means a projected recovery time of roughly 66 to 88 years. Tr. 140 (Rudd), 575 (Whipple). To reach 120 percent of background concentrations, the recovery times are longer: 106 years for Mendall Marsh, 147 years for the main stem, 165 years for Fort Point Cove (the lower estuary), and 390 years for the Orland River. JX 6-1 at 1-29 Tbl. 1-2.

Plaintiffs' expert Dr. Driscoll conducted his own review of the Study Panel's sediment core data and corroborated Dr. Santschi's conclusions. JX 48 at 16-20 & Tbl. 1, Figs. 3a-3d; Tr. 2147-49, 2152-56 (Driscoll). Dr. Driscoll agreed that recovery is occurring "on the order of multiple decades. It's a long time to recovery." Tr. 2156. Dr. Yeager endorsed Dr. Santschi's recovery rates as "entirely reasonable," based on an "enormous data set," and "very well-constrained." Tr. 1343.

These projected recovery times are not precise to the year, but the big picture is clear. Tr. 1709-10 (Santschi), 2154-55 (Driscoll). "[I]t will be many decades" before the system recovers. Tr. 1709 (Santschi). Absent intervention, "it will take a lifetime to get back to reasonable levels." Tr. 1685 (Santschi). "[I]t's just obvious that the system has not cleaned up very quickly." Tr. 681-82 (Fisher). Without remediation, there will be "multiple decades of mercury contamination in the Penobscot estuary that exceeds levels the Study Panel has deemed to be safe for human health and the environment." Tr. 140 (Rudd).

The slow projected recovery is no surprise in light of the degree of contamination that persists more than 40 years after the major releases from Mallinckrodt's plant. According to Dr. Fisher: "It's fairly simple, actually. . . . [T]he system is very contaminated, has been contaminated for a long time. If the system was cleaning itself up rapidly, then we would not see the high degree of contamination that we see in the sediment and biota." Tr. 751.

B. In Some Locations, Mercury Contamination Is Increasing

The calculated half times apply only to the locations where mercury contamination appears to be improving. Tr. 1700-01 (Santschi), 2150 (Driscoll). There are a number of areas, however, where "the concentration of total mercury actually is increasing as one moves towards the [sediment] surface . . . in other words, it's getting worse, not better." Tr. 1345 (Yeager); *see also* Tr. 2139 (Driscoll). Dr. Santschi and Dr. Driscoll could not include such locations in their recovery estimates, because the half times there would be "infinity." Tr. 1699 (Santschi), 2150, 2153 (Driscoll); *see also* JX 48 at 19-20 (showing 16 cores in this category, out of the 57 cores Dr. Driscoll analyzed). Their projections are therefore minimum numbers for recovery, because they exclude those areas where recovery is not yet occurring. Tr. 1345 (Yeager). Of the cores that show increasing contamination, many have high surface mercury concentrations. JX 89; Tr. 2246-50 (Driscoll).[11]

This is especially troubling in light of *where* the areas of worsening contamination are located. Dr. Driscoll plotted on a map the cores that show no recovery, and found them

[11] This includes cores MM 11B (surface mercury greater than 1000 ng/g, or ten times the Study Panel target for Mendall Marsh); PBR 13B (greater than 1100 ng/g); PBR 14C (greater than 1300 ng/g); PBR 9A (almost 2000 ng/g); PBR 26A (greater than 1000 ng/g); OR 2B (approximately 1900 ng/g); and ES 18B (nearly 900 ng/g). JX 89.

to be concentrated in a handful of locations: the upper Orland River, the mouth of Mendall Marsh, the reach of the Penobscot River just south of Bangor, and—of most concern—the lower estuary. JX 48 at 21 Fig. 4; *see also* Tr. 249-50 (Rudd), 1331-32 (Yeager). Because "mercury in the upper most sediment levels is still increasing in the southern part of the estuary," the "potential for significant human exposure, via lobster consumption, may actually be increasing as mercury concentrations south of Fort Point Cove increase." JX 6-22 at 22-2. According to Dr. Whipple:

> [W]e've been using the -- the shorthand term recovery time as if things will only get better going forward in the future. . . . [B]ut the data can be interpreted to say that as one goes further south . . . in the estuary, there are areas at which the mercury is still arriving and may still be increasing. And as you head further south, . . . you're heading into the area where there's an important commercial lobster fishery, and . . . if ten years from now, the concentrations in those lobsters are double what they are today, you've got a real mess on your hands.

Tr. 500. The relevant question is thus not only whether natural attenuation is too slow, but "will areas get worse if we do nothing?" Tr. 578 (Whipple).

C. A Large Mobile Sediment Pool and Natural Sediment Trapping Facilitate Slow Redistribution of Mercury and Delay Recovery

The long recovery times calculated by Dr. Santschi and corroborated by Dr. Driscoll are consistent with the hydrodynamics of the estuary—namely, the existence of a large pool of mercury-contaminated sediments that are trapped in the estuary and retarding recovery. JX 6-1 at 1-15 to 1-16.

The Study Panel retained Dr. Rocky Geyer to evaluate hydrodynamics and sediment transport processes in the estuary. *See* JX 6-7. Dr. Geyer is a 30-year veteran of the Woods Hole Oceanographic Institution, with experience characterizing river systems from the Hudson to the Amazon. Tr. 1143-46 (Geyer); JX 19. He assessed transport processes in the

Upper Estuary, particularly the movement of sediment through the water column. Tr. 1147-49 (Geyer); JX 6-7 at 7-4 to 7-9. Dr. Geyer's results show that only a modest amount of sediment enters the estuary from above the former Veazie Dam, Tr. 1150 (Geyer), but there is a great deal of sediment resuspended within the Upper Estuary, Tr. 1185-86 (Geyer). He found that the system is a "very effective trap," with "very little evidence of sediment leaving the system to the south." Tr. 1151. Dr. Geyer identified a number of major "trapping zones" within the Upper Estuary, where sediment within the system tends to focus, including at the entrance to Mendall Marsh, along the south and east sides of Verona Island, and in the Orland River. JX 6-7 at 7-3 Fig. 7-1; Tr. 1183-85, 1267-68.

Sediment trapping is the result of several factors, including a powerful salt front, tidal flow, and associated turbulence. Tr. 1186 (Geyer); JX 6-7 at 7-22 to 7-24, 7-30. Seasonal variations in these factors lead to continual remobilization and redeposition of surface sediments in the estuary, creating a large bed of mobile sediment. Tr. 1153-54 (Geyer); JX 6-7 at 7-1; JX 6-1 at 1-15 to 1-16. Dr. Geyer analyzed surface sediments throughout the estuary, the physical characteristics of which confirmed the existence of a mobile sediment pool. Tr. 1169-76; 1180 (Geyer). This phenomenon occurs in many ecosystems. Tr. 1154-55 (Geyer). The Penobscot's mobile pool is large, and a "crude estimate" puts it at around 400,000 tons. Tr. 1209-10 (Geyer). More critically, the pool is heavily contaminated: Mercury concentrations range between 800 and 1,400 ng/g, "centering around" 1,200 ng/g. Tr. 1177-78 (Geyer).

The mobile pool explains the projected multi-decadal recovery times. Tr. 1270 (Geyer). Although Dr. Geyer set out with the intent to disprove Dr. Santschi's long half times, he testified that his data in fact support them. Tr. 1202-04. Dr. Geyer's observations provide "a conceptual model for what physical processes are responsible" for the rate of recovery, and Dr. Santschi's sediment core analysis provides "the most accurate estimate of system recovery" in the Penobscot. Tr. 1202, 1267-68 (Geyer). The mobile pool thus adds "not just a plausible, but a solid . . . explanation of the physical transport processes and pathways that are leading to the observed half-time, the observed geochemical decay, and the natural attenuation that has been observed." Tr. 1269 (Geyer). This also explains the increasing mercury concentrations in some areas. The mobile pool has "spread out the contamination in the intervening decades" since Mallinckrodt's major releases, and the core data suggest the contamination is continuing to spread. Tr. 2147 (Driscoll).

D. Dr. Connolly's Projected Recovery Times Are Unsupported by the Data and Are Not Credible

In contrast to the Study Panel, Mallinckrodt's Dr. Connolly asserted that recovery is occurring at a faster half time of five to 15 years. His calculations are not credible.

1. Dr. Connolly's analysis of sediment core data is unreliable

Dr. Connolly reviewed the Study Panel's sediment core data to calculate competing recovery rates. To do so, he used just 20 of the 58 sediment cores that Dr. Yeager collected, concluding that the rest were not "useful." Tr. 3435-36, 3431-32 (Connolly). By contrast, Dr. Santschi and Dr. Driscoll each used more than 40 cores, excluding only those that they found showed no recovery. JX 89; JX 48 at 19-20 Figs. 3a-3d. According to Dr. Santschi, it is not valid to "just take a few cores and . . . cherry-pick and come up with either [a] short time or [a] very long time, and that's not the scientific process. So I wanted to use as much of the data which we gathered and evaluate actually for the whole system, not just for a particular location." Tr. 1688, 1711-13. Dr. Connolly then concluded that the entire system has a 15-year recovery half time, based on only seven cores from his subset of 20—those from Mendall Marsh. JX 45 at 37-38; Tr. 3315-16. The other 13 cores for which he calculated recovery half times, which are equally valid even by Dr. Connolly's methodology, show half times as high as 77 years in the main stem of the Penobscot, 39 years in the Orland River, and 73 years in the lower estuary. Tr. 3432-33; JX 45 at 37-38 & Tbl. 5-1. Dr. Connolly admitted that the Mendall Marsh cores he used are not representative of recovery in the Orland River or the estuary and bay downstream. Tr. 3491-93 (Connolly). Yet they are the only cores he cited for his recovery projection.

Even within the cores that Dr. Connolly deemed useful, he considered only a subset of the available data points. Dr. Santschi evaluated a consistent 21-year historical record in each core and let the data speak for themselves. Tr. 1716-18 (Santschi). But Dr. Connolly used varying intervals of the sediment record that ranged from four to 24 years, and that started anywhere from zero to 4.5 centimeters below the sediment surface. JX 45 at 37. By his own admission, Dr. Connolly relied solely on his "professional judgment" to determine "if there was some evidence in my mind" that justified excluding the surface layers of a core from his analysis. Tr. 3298 (Connolly). Then, deeper in the core, he cut off his analysis if he perceived "some break in the [mercury] trend." Tr. 3297-98 (Connolly). These judgments led to inconsistency and bias. As Dr. Santschi put it, "it's a fishing expedition . . . to get shorter . . . half-times." Tr. 1719. Dr. Connolly's use of narrower intervals and fewer data points "increase[s] the variability and decrease[s] the confidence in the projection." Tr. 2157-58 (Driscoll).

Dr. Connolly justified his selective use of data by claiming that, until recently, recovery was slowed by ongoing sources of mercury to the estuary. JX 45 at 34-35. He cited three lines of evidence in support: U.S. Geological Survey (USGS) measurements of mercury entering the Upper Estuary from upstream, ongoing inputs from the Mallinckrodt plant, and concentrations in blue mussels over time. *Id*. None of these lines of evidence holds up.

First, the USGS data are unreliable. Tr. 1485-87 (Wiener), 2175-77 (Driscoll); PX 70 at 21 (Wiener handwritten comments). The data are universally held to be untrustworthy because they were collected prior to the advent of clean sampling techniques, and "there's no tolerance whatsoever for people who show up at a conference with such data in-hand." Tr. 1486-87 (Wiener). At his deposition, Dr. Connolly conceded that the USGS data were "not highly reliable," Tr. 3457, but he continued to use them anyway. On direct examination at trial, he expressed some concern about the data, "because the techniques that were used potentially introduce some bias." Tr. 3325. Nonetheless, he maintained that the data are "indicative of likely higher [mercury] levels back then." Tr. 3325. On cross-examination, he conceded that using the USGS data to measure the magnitude of mercury loadings coming over Veazie Dam "is probably not accurate." Tr. 3442. Pressed further, he said the data crossed the threshold for him to discard, due to their unreliability. Tr. 3450-51. But he continued to cling to the information as "still sort of a suggestion of something." Tr. 3457-58. Finally, he retracted his use of the discredited data. Tr. 3459.[12]

Second, Dr. Connolly cited mercury releases from the Mallinckrodt plant that continued until 1999, but conceded that those releases were "very small" and inconsequential. Tr. 3325, 3471-73. His remaining basis, declining levels in blue mussels, is at odds with the empirical evidence, which he admitted shows no real trend. Tr. 3408-09;

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[12] In his expert report, Dr. Connolly used the same USGS data, without qualification, to argue that upstream sources accounted for much of the mercury in the lower river. JX 45 at 21. Although defendant abandoned its other-source argument at trial, JX 108 at ¶¶1, 2, Dr. Connolly's repeated use of unusable data undercuts his credibility.

JX 6-14 at 14-52. Thus, all three of Dr. Connolly's bases for arguing that ongoing sources slowed recovery until recently are unfounded.

2. Dr. Connolly's reliance on purported biota trends to project a fast recovery is untrustworthy

Dr. Connolly also cited trends in mercury concentrations in selected Penobscot biota to predict ecosystem recovery. He testified that he examined biota trends "as a confirmatory line of evidence," alongside his analysis of core data. Tr. 3335, 3337. However, in his expert report, he did not use the term confirmatory or otherwise qualify his use of biota trends. JX 45 at 30-32.

Dr. Connolly's approach is scientifically invalid. As multiple independent experts testified, the biota sampling record is too short to discern meaningful trends, much less to use such "trends" to predict system recovery. Tr. 733-35 (Fisher), 668-69 (Whipple), 1465 (Wiener) ("[T]here's interannual variation that leads to things bouncing around in the short-term that makes it very hard sometimes to see a trend within a five- or eight-year period. . . . [T]o really get a handle on trends, you have to look at multidecadal data."); JX 6-14 at 14-2 ("[T]he current four to five-year monitoring period is insufficient to determine long-term trends in the region."). Dr. Connolly himself conceded that it is possible to be misled by short-term fluctuations in mercury concentrations in biota. Tr. 3406; *see also* Tr. 1467-69 (Wiener) (short-term trends can mislead, citing data in JX 78 at 31 Fig. 16). Undeterred, he predicted recovery half times of five to 15 years based on what he called trends in the Penobscot biota data. JX 45 at 30.

Dr. Connolly's method for identifying trends is misguided. He eyeballed bar charts, eschewing any statistical analysis, because "it's hard to meet that [statistical significance] bar with this short record." Tr. 3398-3400 (Connolly). This approach conflicts with the views of his Mallinckrodt colleague, Dr. Dimitri Vlassopoulos, who testified in an analogous context that "[i]f it's not statistically significant, we cannot conclude that there was any effect." Tr. 3017; *see also* Tr. 3400-01 (Connolly), 2001 (Kopec) ("[S]tatistics are used to separate science from speculation.").

The Study Panel and outside reviewers rejected Dr. Connolly's methodology and conclusions. Dr. Rudd called it "just wrong," explaining that "everything I've heard in my 35 years of working with biologists is that you can't use short-term changes in any particular species to predict long-term changes in an ecosystem. . . . [N]obody does that." Tr. 246. Dr. Fisher, a trained biologist, re-reviewed the biota data after reading Dr. Connolly's expert report, and "wasn't buying [Dr. Connolly's analysis] at all." Tr. 728-30, 732, 734; *see also* Tr. 1465 (Wiener), 2176-77 (Driscoll); JX 104 at 3.

Dr. Connolly's biota trend analysis also reveals a clear bias. He considered four aquatic species (blue mussels, mummichogs, tomcod, and rainbow smelt) because, he said, they have strong site fidelity and a sufficient number of stations with a long sampling record in the Upper Estuary. Tr. 3336-38. Site fidelity is important to Dr. Connolly because it permits an analysis that reflects local conditions. *See* JX 45 at 31. But of those species, tomcod "certainly" have weaker site fidelity than mussels and mummichog, while rainbow smelt have only "reasonable" site fidelity. Tr. 3403-04 (Connolly). And the other two species have few sampling stations north of Fort Point with a record long enough to meet Dr. Connolly's stated criteria. *See* JX 6-14 at 14-52; JX 45 Fig. 5-4; Tr. 3404-05, 3406-08, 3409-10 (Connolly). At the same time, Dr. Connolly refused to consider winter flounder, which met his stated criteria for site fidelity, sampling location, and sampling frequency. Tr. 3416-17 (Connolly). Winter flounder show no statistically significant declines at any sampling station. JX 8 Fig. 6; *see also* JX 93 (Kopec: "Absolutely deceptive to omit winter flounder from the list of species available for temporal trends."). Dr. Connolly also did not consider mercury trends in birds such as Nelson's sparrows and red-winged blackbirds, which showed statistically significant *increases* in mercury concentrations at specific sites from 2007 to 2012. Tr. 3420, 3422; JX 8 Figs. 14, 16.

In any event, substituting Dr. Connolly's recovery rates for Dr. Santschi's does not change the big picture: Absent intervention, it will take many decades before the Penobscot recovers to acceptable mercury levels. Even if the average half time in Mendall Marsh is 15 years and not 22, as Dr. Connolly says, multiplying by the three to four half times necessary to meet the Study Panel's uncontested sediment target means it will take four to six decades before the marsh reaches its target. In addition, Dr. Connolly's own calculations indicate that recovery times in the Orland River, the main stem of the Penobscot River, and the lower estuary are on the order of four decades or longer. JX 45 at 37 Tbl. 5-1. And this entirely excludes those areas that are not showing any recovery at all. By every analysis, then, absent active remediation, the Penobscot estuary is many decades away from safe mercury concentrations.

III. The Trial Evidence Demonstrates the Need for Active Remedies to Accelerate Restoration of the Penobscot Estuary

The Study Panelists unanimously recommend the pursuit of active remedies to reverse persistent mercury pollution in the Penobscot. Tr. 30 (Rudd), 538 (Whipple), 751 (Fisher). Their recommendation is endorsed by Dr. Bodaly, Dr. Kopec, and outside reviewers. Tr. 997 (Bodaly), 2017-19 (Kopec), 1471 (Wiener), 2087 (Driscoll). It is fully supported by the data collected and analyzed during the nearly nine-year length of the Court-ordered study. Those data compelled the panel to conclude that, "left to itself, . . . the system simply is too contaminated and will be too slow to recover." Tr. 475 (Whipple); *see also* Tr. 192-94 (Rudd), 751 (Fisher). Plaintiffs urge the Court to adopt the Study Panel's recommendation.

A. There Is an Urgent Need for Active Remediation

The scientific data are clear: Legacy mercury concentrations in the mobile sediment pool are "too high." Tr. 194 (Rudd). This keeps mercury levels "in surface sediments too high." Tr. 194 (Rudd). The mercury methylates and enters biota, producing "concentration[s] in the . . . biota [that are] still too high." Tr. 194 (Rudd). The result is that Penobscot foods eaten by people contain mercury levels that exceed by far the state's safety standard. PX 144. Methylmercury concentrations in Mendall Marsh are higher than "almost anywhere" and "high enough that they are dangerous." Tr. 539 (Whipple). Mercury concentrations in birds in Mendall Marsh are at levels "known to cause toxic effects." Tr. 2017 (Kopec). And mercury in predator and prey fish exceed the Study Panel's attainable thresholds. JX 6-1 at 1-30 Tbl. 1-4.

Based on the data collected during the Court-ordered study, the state posted the first-ever warning against eating black ducks and closed a portion of the lobster and crab fishery because it was "necessary to protect the public health." PX 67; PX 84. Moreover, the system has "already been contaminated for 47 years" and "if Mendall Marsh [i]s going to be . . . at high concentrations for another 66 years," that is "just too long." Tr. 192 (Rudd); *see also* Tr. 194-95 (Rudd), 539 (Whipple). Not only is natural attenuation unacceptably slow on average, the mercury contamination is continuing to spread to areas that include the downstream Penobscot Bay lobster fishery. Tr. 577-78, 667 (Whipple). For all these reasons, "there is an urgent need to initiate remediation activities." Tr. 2087 (Driscoll).

At the outset, the Study Panelists hoped they would not have to recommend active remediation. Tr. 21 (Rudd), 475 (Whipple). But the study data led them inescapably to that recommendation. When "[y]ou've documented . . . these high levels of contamination, you've documented this harm, and then you say you're not going to recommend that it be cleaned up? . . . [T]hat's not reasonable." Tr. 999 (Bodaly).

B. The Court Should Order an Independent Search for Active Remedies

1. The remedial process should be open to all options

The exploration of active remedies should be open to all potential options and conducted by unbiased, independent scientists and engineers. The Study Panelists are "primarily mercury scientists," not remediation experts, and their remediation proposals are not definitive. Tr. 2228 (Driscoll); *see also* Tr. 1502-03 (Wiener). In addressing potential remediation, Dr. Rudd testified that their goal was to "point out from a scientific perspective . . . where we think it would be feasible to intervene," but their proposals are "quick preliminary" ideas. Tr. 151-52 (Rudd). Dr. Whipple and Dr. Fisher agreed that their remediation proposals are "a concept rather than a design." Tr. 524-25 (Whipple); *see also* Tr. 752 (Fisher). Determining how best to remediate the Penobscot system is "within the expertise of people we did not have on the Study Panel." Tr. 525 (Whipple).

In light of these limitations, "the best course of action would be to make all options open and evaluated for the most cost-effective approach." Tr. 2087 (Driscoll). There is no reason to "close the box" and constrain the options to only those that were suggested in the Phase II report. Tr. 2164-65 (Driscoll). Mercury remediation is "an area of very active research and study and development," Tr. 1474 (Wiener), and "there's a lot of smart people out there, and there's a lot of very interesting and innovative technologies that are coming online," Tr. 2165 (Driscoll). The Study Panelists and Dr. Wiener all agree with Dr. Driscoll that the process going forward should be unconstrained by the proposals in the Phase II report. Tr. 179-80 (Rudd), 529 (Whipple), 745 (Fisher), 1474 (Wiener). Even Mallinckrodt's witness Mr. Ed Glaza admitted "there is value in allowing a . . . consideration of . . . a range of alternatives" to address the specific risks in the Penobscot. Tr. 3203.

The next phase of work should involve independent, unbiased mercury scientists and remediation engineers. There is an "ongoing need for people who understand the mercury science" to ensure that engineers do not make "significant mistakes," but the main questions to be answered require remediation expertise. Tr. 526 (Whipple). In assessing options, this group should be "independent," "nonpartisan," and answerable to the Court, similar to the way the Court structured the Study Panel. Tr. 462 (Rudd). Such independence is important to ensure that they are "people who would be looking for solutions, rather than problems." Tr. 461-62 (Rudd).

2. There are viable alternatives to pursue

Although the precise appropriate remedy for the Penobscot is not yet clear, there are plenty of viable options to evaluate during a targeted remediation phase. The study data suggest some promising approaches, which can be supplemented with additional ideas from remediation experts.

One avenue worth exploring is the removal of some portion of the contaminated mobile sediments. An engineered sediment trap is one way this might be accomplished. *See* Tr. 285-86 (Rudd), 524-25 (Whipple), 751-52 (Fisher). Another idea is to use targeted hydraulic dredging to remove mobile sediments from natural trapping areas. Tr. 286-87 (Rudd), 1214, 1271 (Geyer). Capping is also a "proven technology" that should be on the table during remediation discussions. Tr. 2168 (Driscoll). Other ideas include oxygenation, food chain manipulation, and confined aquatic disposal of contaminated sediments. JX 47 at 28; Tr. 529-30 (Whipple). These and any other promising options should be evaluated during a remediation phase. Tr. 286-87 (Rudd), 525 (Whipple), 751-52 (Fisher), 1214 (Geyer), 2164-69 (Driscoll).[13]

Another possible remedy, which showed substantial promise in initial field trials, is the application of activated carbon to Mendall Marsh. Tr. 1613-14 (Gilmour). Over the 24-month period that activated carbon was tested in small plots in the marsh, Dr. Gilmour measured "a significant reduction in methylmercury in pore water, which is an indicator of exposure to animals." Tr. 1601 (Gilmour). Although "the efficacy does decline over time," the effect was "significant over the entire course of the study." Tr. 1600 (Gilmour); *see also* JX 6-19 at 19-24 Tbl. 19-7A. In additional laboratory studies, Dr. Gilmour reported that "activated carbon was effective in reducing methylmercury in pore water and methylmercury uptake into the organisms." Tr. 1606-07; JX 69. An evaluation of dozens of studies found that in the overwhelming majority of experiments, more than 80 percent, activated carbon showed no harmful effects on benthic species. Tr. 1612-13 (Gilmour). The next step is to conduct further Penobscot-specific studies to assess whether activated carbon is "efficacious in reducing uptake into organisms" and "how the carbon might affect plant communities." Tr. 1608-09 (Gilmour). This can be done through larger scale testing during the remediation phase. Tr. 1642 (Gilmour), 2172 (Driscoll). Even if an activated

[13] At trial, Mallinckrodt repeatedly raised the specter of bank-to-bank dredging of the entire river, but this is a straw man. No one is contemplating bank-to-bank dredging. Tr. 281 (Rudd). Mallinckrodt also suggested that some remedies could cause more harm than good. Nobody favors an active remedy that would worsen the situation.

carbon remedy turns out to require periodic re-applications for some length of time, that would be no reason to rule it out. As Dr. Gilmour put it: "[S]ay you have some disease and your doctor says, come in for treatment, . . . but you're going to have to get treated again in a few years. You're not going to not do the treatment because you have to get treated again in a few years. If you can fix it, you know, fix it." Tr. 1628-29.

Given the remaining "engineering questions that need to be addressed that [the Study Panel] didn't address," it is too soon to decide which option, or combination of options, will be best. Tr. 287 (Rudd); *see also* Tr. 525 (Whipple), 751-52 (Fisher). Remedial options should be pilot-tested before they are tried more broadly. Tr. 2171-73 (Driscoll). The system must be monitored over the long term to see how it is responding, and to allow for adaptive management. Tr. 2172-74 (Driscoll). It is likely that active remediation will be feasible. Tr. 751 (Fisher). There is a high level of "interest and energy" being devoted to mercury remediation all over the world, and "the time is right to look for innovative approaches." Tr. 2166-67 (Driscoll). On balance, Dr. Driscoll is "very confident that . . . cost-effective remedies could be . . . implemented that would improve the situation -- highly confident." Tr. 2171 (Driscoll).

3. Mallinckrodt did not attempt an open-minded exploration of possible remedies

Mallinckrodt's narrow criticisms of the remediation concepts contained in the Phase II report do not provide meaningful insight into the likelihood that an effective active remedy can be found. Mallinckrodt's witnesses sought only to poke holes in the Study Panel's preliminary ideas.

Mallinckrodt's witness Mr. Glaza focused exclusively on the Study Panel's proposals for sediment trapping. Tr. 3162-63 (Glaza). He "did not attempt to conceptualize or develop alternative approaches." Tr. 3164 (Glaza). He did not evaluate the possibility of collecting mobile sediments from natural trapping areas, though he admitted this approach might be a plausible remediation option. Tr. 3169, 3217 (Glaza). He did not review or develop an opinion on the use of activated carbon in Mendall Marsh. Tr. 3163 (Glaza). He did not conduct the full feasibility study that is typically used to evaluate all possible remedial options at a contaminated site. Tr. 3196-3200 (Glaza). He did not form an opinion about whether there is a need to proceed with active remediation, Tr. 3166 (Glaza), and he did not rule out the possibility of finding an effective active remedy, Tr. 3167 (Glaza). Dr. Rudd concluded that Mr. Glaza's work was "overly negative," focused on problems rather than solutions, and provided further evidence that a remediation phase should be conducted by nonpartisan, independent scientists and engineers. Tr. 461-62.

Nor do Dr. Connolly's remediation assessments offer any insight into the prospects for active remediation in the Penobscot. He too considered only the rough remediation ideas sketched out in the Phase II report. Tr. 3497. Moreover, he admitted that EPA rejected his conclusions (offered on behalf of his client, General Electric) about the need for and effectiveness of dredging at a different contaminated site in the Hudson River. Tr. 3498-99. In that matter, his warnings that dredging would resuspend buried PCBs and cause significant negative impacts have not come to pass; instead, the dredging project is "[i]n large part" meeting its water quality targets. Tr. 3499-3500.

C. Insights from the Study Provide Direction and Focus in Devising Active Remedies

The Study Panel's role thus far has been to identify "where we could intervene in the ecosystem to make a difference"; the next step is to "address the engineering questions that need to be answered." Tr. 287 (Rudd). In tackling those questions, the Study Panel's work provides "very, very high-quality useful information that can be applied to remedial decisions about what to do next." Tr. 1424 (Wiener). Four insights relevant to remediation are discussed briefly below.

1. Reducing concentrations of total mercury should result in proportional reductions of methylmercury

The Study Panel's discovery that total mercury in sediment is a strong driver of methylmercury concentrations in sediment and biota is a "fundamental observation," Tr. 2102 (Driscoll), and a "big break-through" that establishes a clear objective for remediation, Tr. 56-59 (Rudd). Most of the species of concern in the Penobscot feed in a benthic, sediment-based food web, so remedial actions that reduce total mercury in sediments will trigger reductions up the food web as well. Tr. 59 (Rudd), 1098, 1110 (Bodaly), 1994 (Kopec).

In the main stem of the Penobscot River, there is a "very strong" relationship between total mercury and methylmercury in surface sediments, which "means that most of the varian[ce] of . . . the methylmercury concentration was explained by the corresponding total mercury concentration." Tr. 57 (Rudd); *see also* Tr. 534 (Whipple). The correlation coefficient—or R-squared value—for this relationship was 0.86 in near-shore sediments and 0.89 in intertidal sediments, indicating that total mercury concentrations explain 86 to 89 percent of the variance in methylmercury concentrations "all up and down the system." Tr. 57-58 (Rudd), 2103-04, 2106 (Driscoll); PX 117 (JX 4 at 57 Fig. 24); PX 62 (JX 6-23 at 23-24 Fig. 23-7). Such an "astonishingly tight relationship" is "unusual" in environmental data. Tr. 1453-54 (Wiener); *see also* Tr. 58 (Rudd), 533 (Whipple), 2103-04 (Driscoll).

In wetlands throughout the Upper Estuary, the relationship is more variable, but overall the Study Panel found "fairly strong relationships" between total mercury and methylmercury in wetlands as well. Tr. 2102 (Driscoll), 186-87 (Rudd), 1578 (Gilmour). For example, when controlling for elevation, total mercury explained 55 to 92 percent of the variance in methylmercury concentrations across all wetlands that were sampled. Tr. 2104-06 (Driscoll); JX 6-23 at 23-25 Fig. 23-8. In Mendall Marsh specifically, Dr. Gilmour found that total mercury explained, on average, about 30 percent of the variance in methylmercury concentrations, after controlling for variables like soil depth, season, pH, and type of site. Tr. 1578-80; PX 71 at 3 & Tbl. 1. These relationships are "very significant." Tr. 1580 (Gilmour).

Thus, "each section . . . of the Penobscot System, whether it's the marsh or . . . the main stem of the river" has "a very clear relationship between . . . total mercury and methylmercury." Tr. 746 (Fisher); *see also* Tr. 2102-03 (Driscoll). Moreover, the correlations are "one-to-one," meaning that "if you can reduce total mercury, you will reduce methylmercury by a similar percentage." Tr. 533 (Whipple); *see also* Tr. 157 (Rudd) ("[I]f we were to -- to reduce the concentration of total mercury by a factor of two, we'd reduce the concentration of methylmercury by a factor of two."), 1454-55 (Wiener) ("strongly correlated" and "linear"); PX 71 at 4 & Tbl. 2.

Methylmercury production in sediments is the source of methylmercury in most Penobscot biota. Using analyses of stomach contents and stable isotopes of carbon, nitrogen, and sulfur, the Study Panel found that "most of our target species," including marsh birds, eels, tomcod, flounder, Fundulus (mummichog), and lobster all feed in whole or in part in sediment-based, benthic food webs. Tr. 1990-94 (Kopec); *see also* Tr. 1098, 1110 (Bodaly), 100-01 (Rudd); JX 6-16.[14] Average total mercury levels in sediment explained 99 percent of average methylmercury concentrations in lobsters. Tr. 236-39 (Rudd); JX 87 at 39. Similarly, bird blood mercury levels in Mendall Marsh are elevated about nine to ten times above reference marshes, while sediment levels are elevated about seven times, a "very close" correspondence indicating "that total mercury is the main driver of methylmercury in bird blood." Tr. 234-35 (Rudd); JX 87 at 37 Tbl. 3. And marsh food web analyses reveal that birds and their invertebrate prey in Mendall Marsh both have mercury levels about ten times higher than the Scarborough Marsh reference site, which "strongly suggests that if we can bring the mercury concentration in Mendall Marsh down . . . ideally to the level in Scarborough Marsh, we would also see a correlated decline in the blood mercury concentration in the birds." Tr. 1998 (Kopec).

These two insights—a benthic-based food web and sediment methylmercury levels that are driven in large part by total mercury levels—provide a valuable foundation for identifying active remedial measures. Tr. 58-59, 187 (Rudd), 747-48 (Fisher), 1993 (Kopec). "[I]f there's some way we could reduce the total mercury concentration in the entire ecosystem, we could reduce the rate of methylmercury production and the concentration of methylmercury in biota." Tr. 59 (Rudd); *see also* Tr. 932 (Bodaly). Such an effect was demonstrated at the Experimental Lakes Area in Canada, which is "a living example of if we reduce mercury input to a system, we reduce mercury concentrations in fish over the course of just a few years." Tr. 1593 (Gilmour); *see also* Tr. 933 (Bodaly)

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[14] "[N]itrogen stable isotopes give you an indication of what trophic level an organism is feeding at," and "carbon and sulfur isotopes . . . can be used to define the base of the food web." Tr. 1992 (Kopec). Overall, "the stomach content gives you a short-term picture of what a fish is eating, and the stable isotopes give you a long-term view of that." Tr. 1993 (Kopec).

("[W]hen you put more mercury in a system, you get more methylmercury in the food chain and biota. And when you reduce mercury in the system, you get less mercury in the food chain and biota.").

Mallinckrodt's attempts to debunk these insights are based on a selective and incomplete analysis. Its witness Dr. Vlassopoulos asserted that total mercury concentrations are not predictive of methylmercury concentrations in sediment. Tr. 2985-86. But he conceded that he had considered only a small subset of data, from one location, which reported an R-squared of 0.11. Tr. 2987, 3040-41. The data he reviewed showed the weakest connection by far of all the comparisons between total mercury and methylmercury reported by the Study Panel, which showed R-squared values of 0.55, 0.66, 0.81, 0.86, 0.89, and 0.92 for various locations in the river and marshes. *See* JX 6-1 at 1-34 Figs. 1-3a & 1-3b, App. 1-2 at 57 Fig. 24, App. 1-3 at xiii Fig. i; JX 6-23 at 23-24 to 23-25 Figs. 23-7 & 23-8. Dr. Vlassopoulos ignored these other data sets with much higher explanatory power when he formed his opinion that total mercury and methylmercury in sediment are not closely related. Tr. 3040, 3042. In addition, Dr. Vlassopoulos admitted that it "would be a reasonable assumption" that reducing total mercury in marsh *pore water* will reduce methylmercury in pore water. Tr. 3047. This relationship is critical because methylmercury in marsh pore water "is the methylmercury that's most available to organisms" and, therefore, most relevant to bioaccumulation. Tr. 1575, 1644-45 (Gilmour).

The Study Panel's rationale for remediation focusing on total mercury in Penobscot sediments "just seemed obvious" and "really isn't all that complicated." Tr. 186 (Rudd). "[T]here would be no methylmercury in the environment if there wasn't inorganic mercury." Tr. 186 (Rudd). Even in Mendall Marsh, which has more variable mercury methylation rates, reducing delivery of total mercury will reduce methylmercury proportionally. Tr. 1583-84, 1592 (Gilmour). The Study Panel's data, along with "all of the scientific literature on mercury dynamics certainly support[] the supposition that if you could reduce total mercury, which . . . is mostly inorganic mercury, in surface sediments, you would reduce methylmercury in surface sediments, and you would reduce methylmercury in biota." Tr. 932 (Bodaly).

2. The mobile pool and ongoing redistribution of mercury compel consideration of system-wide remedies

Another "really important thing" the Study Panel discovered is the existence of a mobile pool of sediments that "presently holds a lot of the mercury and is retarding the rate of recovery." Tr. 29-30 (Rudd). The presence of this mobile pool mandates that system-wide remedies be considered, in addition to targeted remedies in especially sensitive locations like Mendall Marsh and, perhaps, the Orland River.

The Study Panel's insights about the nature and behavior of the mobile pool inform remediation designs in two major ways. First, the mobile pool provides a focal point for remediation ideas because "interven[ing] somehow in the mobile pool and reduc[ing] its mercury concentration by some sort of active mitigation" would be "a whole ecosystem approach to cleaning up the situation." Tr. 142-43 (Rudd). Second, the mobile sediments are responsible for ongoing lateral redistribution of mercury that may exacerbate contamination in some areas, Tr. 577-78 (Whipple), including the Orland River and the prime lobster fishery in upper Penobscot Bay. This lateral redistribution also feeds mercury into Mendall Marsh. Tr. 1192-93 (Geyer). A system-wide remediation approach that addresses the mobile pool would target the root of the mercury problems in the Penobscot. Tr. 160-61 (Rudd), 577-78 (Whipple), 1425 (Wiener). For these reasons, the

Study Panel "very strongly" recommends that remediation experts look for ways to reduce mercury concentrations in the mobile sediments. Tr. 285-87 (Rudd).

3. Mendall Marsh merits special attention

A third insight is the need to remediate Mendall Marsh. There is a sediment trapping zone where the river feeds the marsh. JX 6-7 at 7-3 Fig. 7-1. Methylation rates within the marsh are extremely high. Tr. 533 (Whipple); PX 57 (JX 6-11 at 11-90 Fig. 11-3.2). These factors create a "perfect storm" of mercury contamination, Tr. 119-20 (Rudd), and explain the unprecedented levels of mercury in black ducks and songbirds that feed in the marsh. Remediation experts should attempt to address this dangerous situation, and determine whether other wetlands within the ecosystem, like those within the Orland River, require targeted remedies in addition to the more systemic measures aimed at the mobile sediment pool.

4. There are no substantial ongoing sources that will foil recovery

The need to focus remediation on legacy mercury in sediments, not ongoing sources, is a fourth key insight from the Study Panel's work. JX 6-23 at 23-2 to 23-4; Tr. 154, 188 (Rudd). Dr. Ralph Turner investigated possible ongoing mercury inputs from the Orrington plant, tributaries, and upstream sources. JX 6-1 at 1-41 Fig. 1-8; JX 6-3 at 3-61 to 3-62 & Fig. 3-35. He concluded that the ongoing mercury releases from the Mallinckrodt plant site are low; he is "not concerned" about such inputs interfering with remediation in the river as long as remedial activities at the site are conducted carefully. DX 955 at 257-59. He did not find any other large, ongoing sources to the Upper Estuary. DX 955 at 180-81; JX 6-1 at 1-7 to 1-8; *see also* Tr. 366 (Rudd), 2242 (Driscoll) ("[L]egacy mercury from past inputs dominate[s] the mercury dynamics in the current system."). The study data show that remediation efforts should focus on legacy mercury in Upper Estuary sediments, not on ongoing sources, which are inconsequential. JX 6-1 at 1-8; JX 6-23 at 23-2 to 23-4.

D. Any Necessary Additional Information Can Be Collected As Part of the Remediation Process

The Phase II report is "extremely comprehensive," Tr. 2085 (Driscoll), and provides a "very clear picture of how [the Penobscot] system works," Tr. 476 (Whipple). With respect to mercury contamination, the Penobscot is now one of the best understood estuaries anywhere. Tr. 152 (Rudd), 476 (Whipple). As in any scientific study, there are still some unknowns, and "further investigation is always a nice thing." Tr. 152 (Rudd), 2067 (Kopec). Left to their own devices, inquisitive scientists "can continue to find interesting questions to pursue . . . until the end of time." Tr. 478 (Whipple). Based on the analysis conducted to date, however, the remediation planning and design process can and should begin now. Tr. 178 (Rudd), 478 (Whipple), 2067 (Kopec), 2174 (Driscoll).

Throughout the trial, various witnesses referred to additional investigations that could be conducted in the Penobscot. Ideas include: (1) a closer examination of mercury concentrations and methylation rates in the Orland River and in other marshes along the Penobscot's main stem, Tr. 182-83 (Rudd), 1458-59 (Wiener), 2115-16, 2132-33 (Driscoll); (2) better quantification of the size of the mobile sediment pool, Tr. 1209-13 (Geyer); (3) investigation of potential erosion of mercury from mudflats, Tr. 251-52 (Rudd), 582-83, 641 (Whipple); and (4) looking for additional hotspots of mercury contamination in coves near the Orrington plant, Tr. 180-81 (Rudd).

While each of these proposed investigations may yield useful information, all further study should focus on and serve remediation needs and be directed by the team coordinating that process. Further data-gathering should not create delay. "[F]rom a scientific or engineering perspective," there is "no reason" not to convene a remediation team to begin evaluating remedial options now. Tr. 178 (Rudd), 2174 (Driscoll). Additional information can be collected concurrently with remedy pilot testing, and can be used to guide the remedy process and ensure that remedial actions are "doing the job." Tr. 2172-73 (Driscoll).

IV. The Equities Compel Pursuit of Active Remedies to Clean Up Mercury Pollution in the Penobscot

"Once liability has been found, equitable relief in RCRA citizen suits is largely in the informed discretion of the trial court." *Maine People's Alliance*, 471 F.3d at 298. Before granting injunctive relief, the Court must consider the balance of relevant harms. *Id*. at 296. The traditional "four-part framework" for injunctions provides "a suitable guide." *Id*.; *see also Francisco Sánchez v. Esso Standard Oil Co.*, 572 F.3d 1, 14 (1st Cir. 2009) (applying traditional equitable factors in review of preliminary injunction in RCRA citizen suit). The First Circuit instructs, however, "that the operation of that framework is inevitably colored by the nature of the case and the purposes of the underlying environmental statute (here, RCRA)." *Maine People's Alliance*, 471 F.3d at 296.

The purpose of RCRA's imminent and substantial endangerment provision is "'to eliminate any risks posed by toxic waste.'" *Id.* at 287 (quoting *United States v. Price*, 688 F.2d 204, 214 (3d Cir. 1982)). As the First Circuit has explained, when Congress amended RCRA in 1984, it affirmed that RCRA's enforcement provisions are "intended to give courts the tools to 'eliminate any risks posed by toxic waste.'" *Id*. (quoting S. Rep. No. 98-284, at 59 (1983)). This Court should exercise its discretion in accordance with Congress's intention "'to invoke the broad and flexible equity powers of the federal courts in instances where hazardous wastes threaten [] human health.'" *Id*. at 297 (quoting *Price*, 688 F.2d at 211).

The First Circuit advises that once an imminent and substantial endangerment has been identified, as is the case here, RCRA places "a congressional thumb on the scale in favor of remediation." *Id*.

Under the traditional four-part test for injunctive relief, plaintiffs must demonstrate (1) irreparable injury; (2) that remedies available at law are inadequate; (3) that the balance of hardships tips in their favor; and (4) that the public interest would not be disserved by a permanent injunction. *Id.* at 296 (citing *eBay Inc. v. MercExchange, L.L.C.*, 547 U.S. 388, 391 (2006)); *Ortiz-Bonilla v. Federación de Ajedrez de Puerto Rico, Inc.*, 734 F.3d 28, 40 (1st Cir. 2013). Plaintiffs meet this test.

A. Plaintiffs Suffer Irreparable Injury

Mallinckrodt released six to 12 metric tons of mercury into the Penobscot River. JX 6-1 at 1-6; DX 978 at 121. More than 40 years later, much of it remains in river sediments, where concentrations exceed background levels by more than ten times on a dry weight basis. JX 6-23 at 23-2, 23-17 to 23-18 & Figs. 23-1 & 23-2. Mercury has entered the food web, causing levels in lobsters, rock crabs, black ducks, and eels to exceed the threshold the State of Maine deems safe for human consumption. JX 6-14 at 14-13 & Tbl. 2, 14-43 to 14-45, 14-94 to 14-95. The Maine DMR has closed a portion of the Penobscot lobster and crab fishery to protect public health. PX 84. The Department of Inland Fisheries and Wildlife has warned women and young children not to consume black ducks from Mendall Marsh. PX 67. Songbirds in the marsh have blood mercury levels higher than any ever recorded. Tr. 1811, 1815, 1824 (Kopec), 1893, 1899 (Evers). Several species of fish exceed the toxicity thresholds set by the Study Panel. JX 6-1 at 1-30 Tbl. 1-4.

In light of these facts, irreparable injury is clear. As the Supreme Court has ruled: "Environmental injury, by its nature, . . . is often permanent or at least of long duration, *i.e.,* irreparable. If such injury is sufficiently likely, therefore, the balance of harms will usually favor the issuance of an injunction to protect the environment." *Amoco Prod. Co. v. Vill. of Gambell*, 480 U.S. 531, 545 (1987). The harm mercury inflicts on human beings is also permanent. Tr. 797 (Grandjean) (developmental "dysfunctions or deficits" in children exposed to methylmercury are "permanent"). In this case, irreparable injury is more than sufficiently likely; it has already occurred, and the harm continues every day.

B. There Are No Adequate Remedies at Law

There are no remedies available at law to redress plaintiffs' injuries. Money damages will not restore the river. Only injunctive relief can accomplish that. RCRA itself recognizes this reality, authorizing courts to "restrain" violations or "take such other action as may be necessary" to abate an "imminent and substantial endangerment to [human] health or the environment." 42 U.S.C. § 6972(a); *see also Francisco Sánchez*, 572 F.3d at 7 (affirming authority of district courts to issue injunctions in RCRA imminent and substantial endangerment suits); *Amoco*, 480 U.S. at 545 (explaining that environmental harm "can seldom be adequately remedied by money damages").

C. The Balance of Hardships Weighs Strongly in Favor of Granting Injunctive Relief

Plaintiffs' harm "outweigh[s] the harm the defendant would suffer from the imposition of an injunction" ordering the pursuit of active remedies. *Ortiz-Bonilla*, 734 F.3d at 40 (internal quotation marks omitted). The harm to plaintiffs is palpable and severe. A great natural resource is thoroughly contaminated with a potent neurotoxin that lives long in the environment, entering and biomagnifying up the food web, harming fish and wildlife and threatening human health. Defendant is a dominant source of that pollution. *Maine People's Alliance*, 211 F. Supp. 2d at 255.

The relative harm to defendant is slight: An active remedy will cost money. But defendant does not assert an inability to pay, even in light of rough cost estimates of $170 million or more for active remedies. PX 147 at ¶ 19; JX 6-21 at 21-6 & Tbl. 21-2. The most recent annual report of defendant's parent company Covidien, which is financially responsible for the cost of any judgment, reveals gross profits of $6.1 billion, and net income of $1.7 billion, for fiscal year 2013. PX 121 at 58. While plaintiffs do not belittle the expenditures remediation may entail, the financial burden on a company so prosperous is small. *See Interfaith Cmty. Org. v. Honeywell Int'l, Inc.*, 263 F. Supp. 2d 796, 874 (D.N.J. 2003) (concluding that "any potential economic harm to [defendant] Honeywell from the issuance of an injunction is not sufficient grounds for this Court to refuse to enter an injunction," given that "Honeywell is a large international corporation with revenues in the billions of dollars" and the economic harm to it "does not outweigh the interests of the public in a prompt cleanup of the Site that is protective of human health and the environment"), *aff'd,* 399 F.3d 248 (3d Cir. 2005).

Moreover, any economic burden on defendant is the result of its own actions, accountability for which it has actively avoided for more than four decades. Mallinckrodt knew in 1970 that the plant was releasing huge amounts of mercury to the River. *Maine People's Alliance*, 211 F. Supp. 2d at 241-42; PX 20 at ¶¶4-5. Later in 1970, EPA and Mallinckrodt each took sediment samples from the Penobscot near the plant outfall. PX 20 at ¶10. The sampling uncovered high sediment concentrations of mercury radiating out from the Orrington site. JX 49 at 2. Mallinckrodt did nothing in response. In 1972, defendant's own consultant told the company to sample mercury downriver. PX 20 at ¶11. The plant manager said he would sample sediment and fish, but he did not do so. PX 20 at ¶12; *see also Maine People's Alliance*, 211 F. Supp. 2d at 242-43.

After the government pressed defendant to clean up the plant site, Mallinckrodt produced Investigation Reports in 1995 and 1998. Despite explicit requests by federal and state authorities that Mallinckrodt "collect data from downriver areas to determine whether mercury was methylating and whether such methylation was having an adverse impact on the river south of the plant," defendant refused. *Maine People's Alliance*, 211 F. Supp. 2d at 244. Mallinckrodt "took very few steps to collect data bearing on the effects of mercury downriver of the plant," and this Court found that Mallinckrodt's failure to do so "appears to have been by design." *Id.* at 244 & n.9.

Delay has consequences: It has prolonged and expanded harm to human health and the environment. Especially viewed in light of Mallinckrodt's dilatory tactics, the harm of *not* pursuing remediation outweighs any possible harm to defendant. *See Interfaith Cmty. Org.*, 263 F. Supp. 2d at 874 ("The Court further concludes that injunctive relief is necessary to prevent irreparable harm to Plaintiffs and the public in light of Honeywell's history of delay in investigating and remediating the Site since it was first directed to do so by the State of New Jersey some twenty years ago."), *aff'd*, 399 F.3d at 265-66; *see also* Tr. 2259-60 (Driscoll) (noting "very high" risks of doing nothing, in light of mercury levels in biota, closure of lobster fishery, and impairment of ecosystem).

D. The Public Interest Supports Restoring an Important Public Resource

The injunction plaintiffs seek would vindicate the public interest. The Penobscot is a precious natural resource. It is the largest estuary in New England, cutting through the heart of Maine. Estuaries are particularly productive natural environments—"really critical resources." Tr. 2091 (Driscoll). The Penobscot estuary has enormous environmental and economic value, sustaining diverse fish and wildlife, and feeding millions of people inside and outside the state.

Over Mallinckrodt's objection, the Court permitted trial testimony from members of the community. Plaintiffs presented four witnesses to demonstrate the human impacts of defendant's actions. Kenneth Wyman lives in Stockton Springs. Tr. 1830. For the last 26 years he has fished the Penobscot River for lobster and crabs. Tr. 1830-32. Until the Maine DMR fishery closure this year, he set up to 150 of the 800 traps his license permits in the area around Verona Island and Fort Point Cove. Tr. 1833-35. He has captured tens of thousands of pounds of lobster and crabs from the river each year. Tr. 1835-36. For more than two decades Mr. Wyman unwittingly sold mercury-contaminated lobsters and crabs to the general public, from mid-May to Christmas, seven days a week. Tr. 1837. He also fed that food to his family, including his children, his pregnant daughter-in-law, and his grandchildren. Tr. 1838-39. He believed the food he was catching, selling, and feeding his family was safe to eat. Tr. 1839-40.

Maine DMR has now closed the productive area where Mr. Wyman used to fish. Tr. 1840; PX 85. When he first learned of the reason for the closure, he "was sickened to the core." Tr. 1841. He will lose income from the State closure, but that is not his prime concern. He said: "I mean, it's -- it's devastating to me to lose the income, but in all reality, I mean -- and anyone can think and say what they want. It's devastating to me -- for me to know that I have processed and put all of this, you know, into -- into the public. It really is." Tr. 1843. Mr. Wyman closed his direct testimony with a plea to clean up the river:

> It needs to be cleaned up. I mean, the closure, as we can see, is from Fort Point to Wilson Point now. . . . This needs to be taken care of before it becomes totally catastrophic. If this continues to leech out of the river in to the rest of the Penobscot Bay and who knows where, I mean, what will happen to our industry?

Tr. 1844.

Mr. Wyman's fellow community members echoed his call for remedial action. Richard Judd, an Orrington resident and nature enthusiast too concerned to swim in or eat food from the river at his doorstep, looked forward to the day when "people that live along it and the people in Bangor" can return to enjoying "a river system that I really feel is a treasure for this area." Tr. 1753-55, 1761-62. Bob Duchesne, a local birding guide and ambassador of the Penobscot River Restoration Trust, explained that "the Penobscot River is a signature river for the area" with "a lot of recreational value potential along it." Tr. 1660, 1668-69. Mercury contamination generated by Mallinckrodt frustrates the otherwise successful efforts of the River Trust to restore historic fish runs and enhance recreational opportunities on the river. Tr. 1668-69 (Duchesne).

Butch Phillips, an Elder of the Penobscot Nation, explained at trial that members of the tribe have lived along the river for thousands of years, through 500 generations. Tr. 1851-53, 1859. His ancestors, whose bones are "buried along the river," gathered from the river and surrounding lands all their necessities—clothing, food, transportation, medicine, weapons, and housing. Tr. 1860, 1853. Mr. Phillips portrayed the intimate connection between his people and the Penobscot: "We [are] part of the river and the river [is] a part of us." Tr. 1853. Mallinckrodt's actions over the last 40 years have diminished the spiritual power of the river in the Penobscot Nation's rituals and traditions. Tr. 1853-54.

The testimony of these four witnesses raises and answers a key question concerning the public interest: To whom does the river belong? As Mr. Wyman concluded:

> It's -- that -- that bay down there don't belong to Ken Wyman. That belongs to the public. That belongs to every resident in the state of Maine. You know. That's -- it's not for me solely. It needs to be cleaned up, if there is a way of cleaning it up. It most certainly does.

Tr. 1844.

E. Plaintiffs Seek an Order Directing the Pursuit of Active Remediation

Plaintiffs seek an order (1) affirming the Study Panel's findings that (a) the Penobscot estuary is heavily contaminated with mercury, and (b) absent active remediation, it will remain contaminated for too long a time, on the order of decades; (2) accepting the Study Panel's recommendation to pursue active remedies to accelerate recovery of the ecosystem; (3) adopting the Study Panel's biota thresholds as remediation targets to eliminate unacceptable risks to human health and wildlife; and (4) directing the creation of a panel of independent engineers and mercury scientists to design and propose to the Court a suite of active remedies to achieve those targets as quickly as possible, along with a long-term monitoring program to chart progress toward specific remediation goals. Plaintiffs also ask the Court to retain control of the process, either on its own or through a Special Master, so that the engineers and scientists involved report not to either party but to the Court.

The trial evidence compels the Court's adoption of the Study Panel's major findings. The Court-ordered study was performed with scientific integrity by an exceptional group of experts. The trial record supports the panel's principal conclusions that the Penobscot estuary is severely contaminated with mercury and will remain contaminated for too long a time to be left alone. As a result, active remediation, if feasible, is required in order to abate substantial dangers to human health and the environment and prevent further harm. The trial record also supports the panel's biota mercury targets, which derive (for human health) from standards prescribed by the State of Maine, or (for biota health) from the advice of leading experts steeped in the relevant scientific literature. These targets represent reasonable remediation goals.

As discussed above, the Study Panel did not address the feasibility of specific remedial measures. Instead, it suggested possible scientific approaches, and did "very preliminary testing" of some options. Tr. 69-70 (Rudd). A focused remediation phase is now required. As a next step, the panel recommends that top engineers and mercury scientists convene, and, in consultation with government regulators, devise a set of active remedies. Every member of the Study Panel agrees with Dr. Driscoll that, if the Court convenes such a group of experts, all available remedial options, including but not limited to those suggested in Chapter 21 of the Phase II report, should be on the table. Tr. 262 (Rudd), 524-25, 649 (Whipple), 744-45 (Fisher), 2164-65 (Driscoll). Plaintiffs recognize the possibility that, after due deliberation, the experts may advise the Court that it is not possible to fix the problem, or that fixing it would be prohibitively expensive, or that trying to fix it presents too great a risk of making things worse. But such a result is unlikely. Remediation of mercury-contaminated sites is an area of "very active research and study and development." Tr. 1474 (Wiener). Dr. Driscoll is "highly confident" that a cost-effective remedy can be devised and implemented. Tr. 2171, 2279.

The Court should retain control over any further remedy proceedings. Judge Carter prescribed a process that protected the independence of the Court's experts. The Study Panel was unaligned with either party; it focused all its attention on sound science and objective results. The excellent study the panel produced reflects the wisdom of the Court's approach. Any future science and engineering work on remedy should aspire to the same standard. The best way to assure that is for the Court to be in charge.

An active remedy phase will take more time, which is another reason to start immediately. Outstanding questions would have to be resolved: Who will be in charge day-to-day? What role, if any, would the existing Study Panel and its contractors play? What process would be established for the parties to weigh in on a proposed remediation plan before the Court decides whether to approve it? Plaintiffs do not propose answers to these questions now, because they do not presume the Court will grant the relief they seek. If the Court does so, then the parties can weigh in immediately on these issues, and any others the Court may raise.

Plaintiffs are sensitive to the time the Court already has expended on this case. If the Court orders a remediation phase, it could appoint a Special Master, either Susan Calkins or a suitable replacement, to oversee the process. That may be an economical way, contemplated by Rule 53, to retain judicial control without unduly burdening the Court.

CONCLUSION

For more than four decades, mercury contamination in the Penobscot has posed unacceptable risks to human health and the environment. Absent remediation, those risks will remain for many decades to come. Plaintiffs urge the Court to initiate an intensive, immediate search for effective active remedies.

Respectfully submitted,

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Dated: August 28, 2014

CERTIFICATE OF SERVICE

I hereby certify that on August 28, 2014, I electronically filed Plaintiffs' Post-trial Brief and Appendix with the Clerk of Court using the CM/ECF system, which will send notification of such filing to all counsel of record in the above-captioned matter.

I hereby certify that on August 28, 2014, I mailed the document by United States Postal Service to the following non-registered participant:

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