APPENDIX A – WITNESS SUMMARIES

At the Court's request, in the following Appendix plaintiffs summarize the testimony of each trial witness. Witnesses who testified by deposition are identified as such beneath the witness's name in the text.

Dr. Drew Bodaly

Dr. Bodaly is a biologist with more than 30 years of experience investigating the impacts of mercury on ecosystems. Tr. 928-29; *see generally* JX 14. He served as project leader of the Penobscot River Mercury Study. Tr. 927-28; ECF No. 286. Dr. Bodaly concurs in the panel's major findings and recommendations. Tr. 996-97.

Dr. Bodaly testified there is "[no] question the Penobscot is significantly contaminated" compared to regional background, whether surface sediment mercury concentrations are expressed on a dry weight or carbon-normalized basis. Tr. 1025-26. The Study Panel observed "that there was usually a strong relationship" between total mercury and methylmercury in sediments. Tr. 932. This is consistent with the scientific literature, which establishes that "when you put more mercury in a system, you get more methylmercury in the food chain and biota." Tr. 933. Conversely, "when you reduce mercury in the system, you get less mercury in the food chain and biota." Tr. 933.

Dr. Bodaly played a lead role in developing the Study Panel's remediation targets for biota and sediment. Tr. 930-31. The Study Panel relied on the State of Maine action level to determine whether mercury concentrations in lobsters, crabs, eels, and black duck meat pose unreasonable risks to human health. Tr. 936. There are no applicable government thresholds designed to protect the health of wildlife itself. Tr. 937. Dr. Bodaly and the Study Panel instead turned to experienced wildlife researchers Dr. Mark Sandheinrich and Dr. David Evers to develop appropriate targets. Tr. 937-38, 941-42, 953-54. The Study Panel chose a fish tissue target in the range recommended by Dr. Sandheinrich. Tr. 940-41. The panel followed Dr. Evers's advice in setting bird targets. Tr. 943-44. The Study Panel also set a target for prey fish, based in part on a recent peer-reviewed publication by Depew et al. Tr. 947-48, 952.

Mercury concentrations in lobsters need to be reduced by up to 50 percent in order to meet the Study Panel's targets; eels, black ducks, and songbirds all need to be reduced by 50 percent or more. JX 6-2 at 2-18 to 2-19. The panel determined that reducing surface sediment concentrations by about 50 percent in the main stem of the river and 75 percent in Mendall Marsh will bring wildlife and human exposure down to safe levels. Tr. 989, 998. Dr. Bodaly concurs with the Study Panel that, because of the large reduction in sediment mercury needed to meet biota safety targets, the river ecosystem will take multiple decades to recover. Tr. 997-98. Given this slow recovery timeframe, pursuing active remediation is "the obvious answer." Tr. 998-99.

Dr. Bodaly's testimony supports the conclusions that mercury contamination in the Penobscot poses unreasonable risks to human health and the environment, that the contamination will persist at unsafe levels for many decades if nothing is done, and that the Court should order the pursuit of active remediation as a result.

Dr. Michael Bolger

Dr. Bolger testified for Mallinckrodt regarding the health risks from mercury in Penobscot foods. Dr. Bolger 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 the defendant. Tr. 2350. He never read the Study Panel's report. Tr. 2350-51.

Dr. Bolger testified that eating high mercury meals from the Penobscot poses no health risk because it would not cause a meaningful change in blood mercury levels without "weeks of continuous exposure." Tr. 2434. According to Dr. Whipple, that "simply is not true." Tr. 570-71. Dr. Bolger did not perform any calculations to support his conclusion. Tr. 571.

Dr. Bolger also testified that eating fish provides health benefits generally. Tr. 2289, 2292. He conceded, however, that methylmercury diminishes those benefits. Tr. 2405.

Dr. Bolger affirmed that he is "not second-guessing" the State of Maine human health safety standard for mercury concentrations in fish, and he is unfamiliar with how it was derived. Tr. 2440. He did not express, and does not have, an opinion concerning the state's closure of the lobster and crab fishery. Tr. 2421-22. With respect to the state's decision to warn people not to eat black ducks, Dr. Bolger said, "I can't disagree with it." Tr. 2425.

Dr. Bolger's opinions do not undermine the Study Panel's conclusion that mercury concentrations in Penobscot foods pose unreasonable human health risks.

Dr. Todd Bridges
[Testifying by deposition]

Dr. Bridges is the senior research scientist for environmental matters at the U.S. Army Corps of Engineers. JX 33 (Bridges Dep. Tr.) at 5; *see generally* JX 15. For the past 20 years, a "major focus" of his work has been contaminated sediment. JX 33 at 6. He is the director of the Center for Contaminated Sediments, a clearinghouse of sediment management expertise within the Corps. *Id.* at 17-18. At the Study Panel's invitation, Dr. Bridges attended a two-day workshop on Penobscot remediation options in 2009. *Id.* at 50-51. During that workshop, Dr. Bridges toured the river and participated in informal brainstorming discussions. *Id.*

Dr. Bridges testified that, if the Court orders pursuit of active remediation, the "next seemingly logical step" is to perform a feasibility study that would lay out in technical detail possible alternatives. *Id.* at 200-01. In addition to fleshing out the ideas mentioned in the Phase II report, Dr. Bridges recommends "engaging parties that have broader experience in risk management for sediments and the engineering and the science related to that undertaking," and asking, "'What have we left out? Are there alternatives that we have not considered? Are there options or technologies that we should be considering that we have yet to consider?' to make sure that you don't leave a good idea behind simply because you didn't have the right people." *Id.* at 201.

One alternative "that is worthy of evaluation and consideration" is the use of sediment traps to capture contaminated particles: the Penobscot River would "certainly not [be] the first . . . project that considers how a sediment trap might be used to address the challenges associated with . . . mobile contaminants." *Id.* at 177, 199. Confined aquatic disposal to store contaminated sediments could also prove feasible, as it has in other locations. *Id.* at 150, 169. And activated carbon can be "an effective tool." *Id.* at 184. But these are just a few ideas: "[F]or projects like the Penobscot . . . you would be well-suited and well-advised to consider a broad range of options." *Id.* at 185-86.

Dr. Bridges's testimony supports the Study Panelists' testimony that any search for active remedies should include but not be limited to the conceptual ideas the panel described in the Phase II report.

Dr. Aram Calhoun
[Testifying by deposition]

Dr. Calhoun is a professor of wetland ecology at the University of Maine. JX 34 (Calhoun Dep. Tr.) at 5; *see generally* JX 16. At the Study Panel's request, Dr. Calhoun performed a visual assessment of plant cover at the soil amendment test plots established by Dr. Gilmour in Mendall Marsh. JX 34 at 15. Dr. Calhoun has performed numerous similar visual assessments in other ecosystems. *Id.* at 47-49.

Although Dr. Calhoun took several trips to the study area, she performed only one plant cover assessment at each of the test plots. *Id.* at 43-44, 84, 88-89. She made her assessments *after* amendments had been added to the plots. *Id.* at 43-44. The information she collected therefore cannot and does not show whether soil amendments (including activated carbon) had any effect on vegetation at the test plots; such an inference is possible only by comparing an assessment like Dr. Calhoun's against a pre-treatment baseline survey. *Id.* at 17-19, 61-63, 69. Without a pre-treatment baseline, the fact that some types of vegetation were absent at some treatment plots Dr. Calhoun surveyed is meaningless, especially given that plant cover in the marsh is highly heterogeneous. *Id.* at 18, 82.

Dr. John Connolly

Dr. Connolly has served as Mallinckrodt's principal technical advisor in this litigation since 2000. Tr. 3222, 3377. He offered opinions about the severity of mercury contamination in the estuary, the rate at which the ecosystem is recovering, and what further work the Court should order. Tr. 3243-45.

Dr. Connolly claimed that the Study Panel exaggerated the severity of mercury contamination in the estuary when it relied on dry weight rather than carbon-normalized concentrations. Tr. 3248-58. 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 Study Panel found Upper Estuary sediments to be highly contaminated. Tr. 242-43, 404 (Rudd); *see also* Tr. 499 (Whipple), 693-94 (Fisher).

Dr. Connolly also argued 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-to-oranges" comparison mixing distinct sediment types; sediments in the marsh are elevated seven to 50 times compared to corresponding types of sediment at appropriate reference sites. Tr. 228-31 (Rudd); JX 87 at 36. And in comparing Mendall Marsh sediment mercury concentrations with those in reference areas, Dr. Connolly omitted consideration of the extraordinary methylation rates in the marsh. Tr. 3389-91.

To derive a recovery half time projection of 15 years, Dr. Connolly relied on just seven of the Study Panel's 58 sediment cores. Tr. 3315-16, 3431-32; JX 45 at 38. In addition, he analyzed varying depth intervals within those cores, claiming that faster ecosystem recovery in recent years justified his method. JX 45 at 34-35, 37; Tr. 3304-05, 3440-41. But of the three lines of evidence he offered for the existence of a period of faster recovery—U.S. Geological Survey data, mussel data, and HoltraChem discharge data—he conceded that none is strong evidence individually, and he has since retracted or acknowledged each as unreliable or inconsequential. *See* JX 45 at 34-35; Tr. 3304-05, 3326, 3441, 3408-09, 3459, 3471-73. Dr. Connolly also claimed that trends in mercury concentrations in selected Penobscot biota supported his recovery prediction. Tr. 3335, 3337. But as multiple independent experts testified, the biota sampling record is too short to reveal meaningful trends, much less to guide predictions for system recovery. Tr. 733-35 (Fisher), 668-69 (Whipple), 1465-66 (Wiener); *see also* JX 6-14 at 14-2. In purporting to discern trends, Dr. Connolly did not employ statistical analysis. Tr. 3398.

Dr. Connolly argued that, other than ongoing monitoring, no further remedial steps should be taken before conducting a toxicity test on songbirds in Mendall Marsh. Tr. 3370-72; JX 45 at 59. However, during the study process, Mallinckrodt asked the panel to *eliminate* fish and bird toxicity studies from an early phase, and did not object to their non-inclusion in Phase II work plans. PX 149 at 7-2, 7-3; PX 155; PX 157; Tr. 3507.

Dr. Connolly's testimony does not credibly undercut (1) the Study Panel's conclusions that (a) the Upper Estuary is severely contaminated with mercury and (b) natural recovery will take multiple decades to achieve, or (2) the panel's recommendation to pursue active remediation now.

Dr. Charles Driscoll

Dr. Driscoll is a Distinguished Professor of Environmental Systems Engineering at Syracuse University. Tr. 2073; *see generally* PX 124. He researches "the effects of disturbance on ecosystems and remediation of ecosystems"; has studied mercury in aquatic, terrestrial, wetland, and marine ecosystems since the mid-1980s; and has worked at other mercury-contaminated sites. Tr. 2074, 2075, 2078-80. At plaintiffs' request, Dr. Driscoll reviewed the Study Panel's Phase I and Phase II reports, the underlying data, and other data sources. Tr. 2081-82. He concluded that the Study Panel's work is "extremely comprehensive" and "scientifically sound." Tr. 2084-85; JX 47 at 2-3; *see generally* Tr. 2084-87, 2179.

Dr. Driscoll found that Penobscot sediment and biota tissue mercury levels are high relative to samples from elsewhere in the Gulf of Maine. Tr. 2101-02, 2117-19; JX 47 at 9, 10 & Tbl. 1, 11 & Tbl. 2, 12 & Fig. 2, 16, 17 & Fig. 5, 18 & Fig. 6, 19. He also verified the Study Panel's "fundamental observation" that there is a "very strong relationship" between total mercury and methylmercury in Penobscot sediments—particularly in the main stem of the river, but also in wetland areas. Tr. 2102-03; *see also* JX 47 at 12, 13, 14 & Fig. 4, 15. He testified that "the most logical assumption" is that a decrease in total mercury concentrations in sediment will lead to a decrease in methylmercury concentrations. Tr. 2108-09; *see also* Tr. 2243-44; JX 47 at 15.

Dr. Driscoll independently calculated recovery times for the Penobscot estuary and emphasized the importance of using "all the [sediment] cores together" to understand the dynamics of the system. Tr. 2138; *see also* Tr. 2139, 2278. He found that, overall, the system is recovering "on the order of multiple decades." JX 47 at 22-24; *see also* JX 48 at 16, 17 & Tbl. 1, 18, 19 & Figs. 3a-b, 20 & Figs. 3c-d. Sediment cores in some areas, including the upper Orland River, the mouth of Mendall Marsh, and the lower estuary, show no recovery at all. JX 48 at 21.

Dr. Driscoll concluded there is "an urgent need for active remediation," given that "clearly there is substantial contamination in the fisheries and wildlife," "[t]he contamination in sediments has remained high over an extended period," and "[t]here is some evidence of recovery, but the rate of recovery is extremely slow." Tr. 2179. He recommended that a group of engineering and mercury science experts convene to consider possible active remedial measures, unconstrained by the Study Panel's specific conceptual proposals. Tr. 2164; JX 47 at 25-32. Dr. Driscoll testified that "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. As a result, he is "very confident that . . . cost-effective remedies could be . . . implemented that would improve the situation." Tr. 2171. He agreed that such a remediation program can begin now, concurrently with any efforts to gather additional data that "might be helpful to guide a remediation effort." Tr. 2172, 2174. Dr. Driscoll also recommended further investigation of the Orland River and other smaller fringe marshes to look for mercury problems similar to those in Mendall Marsh. Tr. 2115-16, 2132-34.

Dr. Driscoll's testimony supports the Study Panel's principal findings, as well as its recommendation to pursue active remedies to accelerate recovery of the ecosystem.

Mr. Bob Duchesne

Mr. Duchesne, of Hudson, is a birding guide and outdoors enthusiast. Tr. 1659-60. He shared with the Court the impact that mercury contamination in the Penobscot ecosystem has had on his birding business and on his efforts to promote tourism in Maine.

Mr. Duchesne owns his own bird touring company and regularly leads tours through different parts of Maine. Tr. 1659-61. In the past, Mr. Duchesne took tours to Mendall Marsh—one of the few places in the state that is home to the Nelson's sparrow, a small, buff-colored songbird with a distinctive raspy call. Tr. 1662-63. However, the last time he took a group to Mendall Marsh, he was "aghast" to find a notice posted by the state and warning against consumption of mercury-contaminated black ducks. Tr. 1664-65; PX 67. Mr. Duchesne no longer guides tours in the marsh, explaining that "[w]hen you come across warning posters saying don't eat the water fowl, that's not something I want to show tourists from away," especially given that "the environmental pristineness of Maine" is "one of our selling points." Tr. 1664-65.

Mr. Duchesne served on the Governor's task force to promote "nature-based tourism" in Maine. Tr. 1671. He has also served as one of the public faces of the Penobscot River Restoration Trust, a local effort to restore fishing runs and increase recreational opportunities on the river. Tr. 1668-69. It is "personally saddening" for Mr. Duchesne that the efforts he has expended "trying to build ecotourism and build a rural economy in the state" have been "taken away or at least damaged" by ongoing mercury pollution in the river. Tr. 1671-72. As Mr. Duchesne explained, "to sully a portion of the river when you're trying to build tourism on it is a little bit detrimental to what you're trying to establish in the first place." Tr. 1671.

Mr. Duchesne supports exploration of remedial actions that could hasten recovery of the ecosystem. Tr. 1672.

Dr. David Evers

Dr. Evers is a wildlife researcher with decades of experience designing, conducting, and publishing peer-reviewed studies on the effects of mercury on birds. *See generally* JX 17. The United States government tapped him to lead the 80-person team investigating harm to birds in the wake of the BP oil spill in the Gulf of Mexico. *Id.* at 2; Tr. 1866.

To advise the Study Panel on appropriate toxicity thresholds, Dr. Evers reviewed 98 articles on mercury's effect on birds, nearly all from the peer-reviewed scientific literature. Tr. 1871-72; JX 6-2 App. 2-2 at 23-39. He developed an "effects concentration 20" or "EC_{20}" for both piscivorous and invertivorous birds. JX 6-2 App. 2-2 at 3. This EC_{20} is the concentration of mercury in animal tissue that may impair reproduction in 20 percent of a particular population. Tr. 1881. When mercury levels in wildlife exceed the EC_{20}, the population may no longer be self-sustaining. Tr. 1881-82. The EC_{20} is the "best, most relevant standard for protecting a target species at the population level." Tr. 1882

Dr. Evers's EC_{20} for piscivores is 2.0 ug/g in blood, based in part on studies of common loons that show a 40 percent reduction in reproductive success at around 3.0 ug/g. Tr. 1882-84; JX 6-2 App. 2-2 at 3, 15-17. Invertivores are often at greater risk from mercury than piscivores. JX 6-2 App. 2 at 3, 11 & Fig. 3. This is especially true for wetland invertivores, like songbirds in Mendall Marsh, that eat higher trophic level prey like spiders. Tr. 1877-78. Dr. Evers derived an EC_{20} of 1.2 ug/g for mercury in invertivore blood, based primarily on a peer-reviewed 2011 study of mercury's effects on Carolina wrens by Jackson et al., which reported the results of a field experiment that Dr. Evers designed and oversaw. Tr. 1884, 1885; JX 6-2 App. 2-2 at 3, 17-18.

Dr. Evers rejected the invertivore target of 3.0-4.0 ug/g devised by Mallinckrodt's witness, Dr. Betsy Henry. Her target is equivalent to mercury concentrations that would diminish reproduction by 40-50 percent in the more mercury-tolerant loon. Tr. 1918. Dr. Henry's target does not reflect the current thinking of expert avian ecotoxicologists. Tr. 1919.

Mercury levels in Nelson's sparrows in Mendall Marsh exceed Dr. Evers's EC_{20} by up to eight times. *See* JX 8 at Fig. 14. They are among the highest levels catalogued in Dr. Evers's database of more than 8,000 songbird samples. Tr. 1893. Average mercury levels in Penobscot red-winged blackbirds are up to ten times higher than the EC_{20}. *See* JX 8 at Fig. 16. Dr. Evers has never seen higher mercury levels. Tr. 1899. Dr. Evers testified that he would be "hard-pressed" to find a bird expert who did not see reproductive harm to these species based on the reported results. Tr. 1931. While Dr. Evers testified that a field toxicity study could be useful, Tr. 1942, he sees "that the Nelson's sparrows fall in the realm of having significant reproductive harm," Tr. 1932-33. He concluded that the levels of mercury in Penobscot songbirds justify a hard look at means to reduce blood mercury as swiftly as possible. Tr. 1933.

Dr. Evers's testimony supports the Study Panel's finding of grave risk to songbird populations in Mendall Marsh.

Dr. Nick Fisher

Dr. Fisher is a Distinguished Professor at the State University of New York at Stony Brook. Tr. 677. He is an expert in marine biogeochemistry, particularly the cycling of metals, including mercury. Tr. 678; *see generally* JX 18. He is a member of the Court-appointed Study Panel, nominated by plaintiffs. Tr. 676; PX 1 at 1.

Dr. Fisher described mercury as "probably the most toxic metal . . . on the periodic table." Tr. 684. There is no known use for mercury in aquatic organisms. Tr. 706. Over the last 30 years, "increasingly we're finding [methylmercury] levels that were previously thought to be tolerable to be not so tolerable" Tr. 737. Once it is released to the environment, mercury is there "forever"; it does not break down, it just moves around. Tr. 692.

He testified that the Penobscot estuary "is very contaminated, has been contaminated for a long time," and is not cleaning itself rapidly: "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. Comparing the Penobscot to both contaminated and uncontaminated sites, he underscored that mercury contamination in the estuary is "very pronounced." Tr. 693-94, 727. Given the association between Maine and lobsters, he testified that seeing "lobster at levels that might be dangerous for human consumption . . . set off alarm bells to me, and . . . definitely got my attention." Tr. 701. He is also "particularly alarmed at the high rates of methylation in Mendall Marsh." Tr. 693-94.

During the Court-ordered study, Dr. Fisher proposed field toxicity studies to document adverse effects on Penobscot biota from mercury contamination, and felt strongly that they should be carried out. Tr. 708. But he acknowledged that they are "extremely tricky experiments to do," that the wrong (*i.e.*, an insensitive) species might be selected for study, that the Jackson et al. 2011 paper on Carolina wrens—a "pretty carefully done study"—nonetheless "was subject to criticism" by Mallinckrodt, and that "in the end, we may know not much more than we know now." Tr. 710, 713, 725-26, 771. He believes it was scientifically legitimate for the Study Panel to decline to conduct a field toxicity study, and instead to infer harm from literature values. Tr. 722-23. He has "come to accept and even endorse the approach" the Study Panel took to determine toxicity. Tr. 740.

Dr. Fisher expects a proportional drop in methylmercury in sediments and benthic-feeding biota if total mercury in sediments is reduced. Tr. 747-48.

Dr. Fisher joins in the Study Panel's principal findings, and in its recommendation to pursue active remediation. Tr. 680, 682.

Dr. Rocky Geyer

Dr. Geyer is a senior scientist at Woods Hole Oceanographic Institution. Tr. 1143-44; *see generally* JX 19. His primary area of expertise is in estuarine dynamics, or "the forces that affect the movement of water in an estuary . . . and associated effects of those processes on sediment transport." Tr. 1146. He has investigated river systems on multiple continents. Tr. 1144-45. The Study Panel retained Dr. Geyer to evaluate the movement of sediment through the Upper Estuary. *See* JX 6-7 at 7-3.

Dr. Geyer surveyed the Penobscot from Winterport to Fort Point, assessing transport processes. Tr. 1147-49; JX 6-7 at 7-4 to 7-9. He concluded that the estuary is a "very effective trap," with "very little evidence of sediment leaving the system to the south." Tr. 1151. This sediment trapping is the result of several factors, including a powerful salt front, tidal flow, and associated turbulence. Tr. 1186; 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; JX 6-1 at 1-15 to 1-16; JX 6-17 at 7-1; *see also* Tr. 1169-80. This mobile pool is large, around 400,000 tons. Tr. 1209-10. It is also heavily contaminated: Mercury concentrations range between 800 and 1,400 ng/g, "centering around" 1,200 ng/g. Tr. 1177-78.

The existence of the mobile pool explains the multidecadal recovery half times calculated by Dr. Santschi. Tr. 1270. Although Dr. Geyer set out with the intent to disprove Dr. Santschi's half times, he testified that his data support them, by providing a conceptual model for the physical processes responsible for the slow rate of recovery. Tr. 1202-04. The mobile pool is "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.

Dr. Geyer's work has potential ramifications for remediation strategies. He identified a handful of major "trapping zones" within the Upper Estuary, where mobile sediments tend to accumulate. JX 6-7 at 7-3; Tr. 1183-85. He believes it is "worth exploring" the feasibility of targeted sediment removal at these locations. Tr. 1214. In Dr. Geyer's view, removing mercury-contaminated sediment from one or more trapping zones would accelerate ecosystem recovery. Tr. 1214-15. Moreover, removing mercury-contaminated sediment is "inherently valuable": "mercury is causing harm . . . so if we can remove it from the system, each mercury molecule that gets removed is not going to cause harm in this environment." Tr. 1215.

Dr. Geyer's testimony supports the Study Panel's finding that natural recovery will take many decades.

Dr. Gary Gill
[Testifying by deposition]

The Study Panel asked Dr. Gill, a mercury chemist at the Pacific Northwest National Laboratory, to provide an independent peer review of some chapters of the Phase II report. JX 35 (Gill Dep. Tr.) at 6; JX 20 at 1. Dr. Gill has been involved in multiple major interdisciplinary studies of mercury-contaminated ecosystems. JX 35 at 11-14, 28-29, 144; *see generally* JX 20.

Dr. Gill has worked with or knows by reputation some of the Study Panel members and their expert contractors. JX 35 at 113-20. They are, in his view, "a very talented group of people." *Id.* at 118-19. According to Dr. Gill, the study they conducted is "as good or better than any of the other programs out there"; it contains "really high-quality scientific information," and is "absolutely" worthy of publication in the scientific literature. *Id.* at 144-45.

Dr. Gill testified that the Study Panel's report "[c]learly" demonstrates a relationship between total and methylmercury. *Id.* at 44; *see generally id*. at 42-46. That finding is "significant," *id.* at 34, because a robust relationship between total and methylmercury provides "a means by which to begin to understand how to clean up the system," *id.* at 36.

Dr. Cynthia Gilmour

Dr. Gilmour is a Smithsonian Institution biogeochemist with decades of experience studying mercury methylation. Tr. 1561; *see generally* JX 21. The Study Panel retained Dr. Gilmour to perform two tasks: (a) evaluate methylation rates in Mendall Marsh and the factors that influence methylation, and (b) conduct a field trial of surface amendments that could be applied to the marsh as part of a remedy. *See* JX 6-11; JX 6-19.

Dr. Gilmour found that methylation rates in Penobscot tidal marshes are "exceptional," among the highest that have ever been documented. Tr. 1564; JX 6-11 at 11-89. Dr. Gilmour compared methylmercury concentrations in sediment and pore water from Penobscot marshes to those she has measured in a range of other ecosystems over the past few decades. JX 6-11 at 11-90 & Fig. 11-3.2, 11-91, 11-92 & Fig. 11-3.4. The concentrations in the Penobscot "stand out" compared to concentrations in other systems, including others that are more heavily contaminated with total mercury. Tr. 1572-73; *see* JX 6-11 at 11-90 & Fig. 11-3.2 (PX 57), 11-91, 11-92 & Fig. 11-3.4 (PX 58). Dr. Gilmour also found that there is a statistically significant relationship between mercury and methylmercury in Mendall Marsh. Tr. 1576-77; PX 71 at 1-4. The slope of that relationship is very close to one-to-one, which means that doubling mercury will double methylmercury. Tr. 1581-82; PX 71 at 4.

Separately, Dr. Gilmour conducted a field trial in Mendall Marsh to evaluate the efficacy of *in situ* amendments, including activated carbon. JX 6-19 at 19-4. The objective was to see if applications "to the surface of the marsh could be effective in reducing methylmercury risk to organisms." Tr. 1594. Over a two-year period, Dr. Gilmour found that activated carbon amendments resulted in "significant reductions" in pore water mercury and methylmercury at test sites in the marsh. JX 6-19 at 19-23. Methylmercury in pore water is the form that is most bioavailable, and can be used as a proxy for the rate of uptake by organisms. Tr. 1575-76. Although the efficacy of activated carbon does "decline over time," the positive effect she measured was "significant over the entire course of the study." Tr. 1600; *see also* JX 6-19 at 19-24 Tbl. 19-7A. In additional laboratory studies, Dr. Gilmour found that "activated carbon was effective in reducing methylmercury in pore water and methylmercury uptake into the organisms." Tr. 1606-07; *see also* JX 69. In addition, Dr. Gilmour cited an evaluation of dozens of studies that found that in more than 80 percent of experiments, there were no harmful effects from application of activated carbon. Tr. 1612.

Dr. Gilmour identified two issues that should be addressed before pursuing activated carbon further: ensuring that it effectively reduces methylmercury uptake into organisms in the Penobscot, and evaluating any potential impact on plant communities. Tr. 1608-09. But according to Dr. Gilmour, activated carbon holds promise for reducing methylmercury in contaminated Penobscot marshes in particular, because of the specific chemistry of the system. Tr. 1614. And she concluded that, based on study data, it is worth seeing what can be done to diminish methylmercury concentrations in Mendall Marsh; she believes there are promising options available to do that. Tr. 1629.

Dr. Gilmour's testimony supports the Study Panel's recommendation to pursue active remediation in Mendall Marsh.

Mr. Ed Glaza

Mr. Glaza is a professional engineer. Tr. 3063. He was retained by Mallinckrodt to evaluate the Study Panel's sediment trapping recommendations. Tr. 3069. He "did not attempt to conceptualize or develop alternative approaches" other than sediment trapping, and he did not evaluate any remedial options in Mendall Marsh, such as the use of activated carbon. Tr. 3162-64.

Mr. Glaza concluded that the panel's sediment trapping proposals should not be pursued further because they would not be effective, would present implementation challenges, and would present risks from potential releases of mercury contamination. Tr. 3070-71, 3136-37, 3139-40. His ultimate conclusion is based on problems he sees with the sediment traps themselves, not other elements of the proposals like confined aquatic disposal, sediment storage, or clean sediment dispersal. Tr. 3176, 3190.

In assessing the sediment trap concepts, Mr. Glaza relied on calculations that did not account for natural sediment trapping in the river, and he conceded there is not enough information to rule out the possibility of collecting mobile sediments from natural trapping areas. Tr. 3190, 3217. He made no quantitative assessment of how much contaminated sediment currently is mobilized in the estuary, or how that would change if elements of an active remedy were implemented. Tr. 3169, 3176-77. And in suggesting that active remedies might raise community and regulatory concerns, he never solicited input from any regulators or local community representatives. Tr. 3183-85, 3191-95.

Mr. Glaza expressed concern that ongoing sources, including remobilized sediments, might recontaminate the estuary after a remedy is implemented. Tr. 3122-23. However, he does not know whether ongoing sources would interfere with an active remedy or be sufficient to recontaminate the system. Tr. 3195-96. He did not evaluate that issue in a quantitative or detailed way. Tr. 3195-96.

Mr. Glaza asserted that the existing risks in the Penobscot from mercury contamination are not yet adequately characterized. Tr. 3091-92, 3140, 3200-01. However, he testified that he was "not in a position to . . . make a judgment on the degree of risk presented," and that such an opinion was beyond "the task that I was charged with and . . . the determination that I would be qualified to make." Tr. 3165-66. He did not conduct his own assessment of existing risks, and was relying instead on the opinions expressed by other defense witnesses. Tr. 3165-66, 3201.

Mr. Glaza agreed that, if the risks from mercury contamination are adequately understood, the next step would be to convene a multidisciplinary team of mercury scientists and engineers to consider "a range of alternatives to address those . . . focused risks." Tr. 3200-03. He has no opinion about whether there is a need to proceed with active remediation, and testified that "I certainly have not" ruled out the possibility that there might be an effective remedy in the Penobscot. Tr. 3166-67.

Dr. Philippe Grandjean

On behalf of plaintiffs, physician and epidemiologist Dr. Philippe Grandjean testified to the risk that mercury concentrations in Penobscot lobsters, eels, and black ducks pose to human consumers. Tr. 792-93. Dr. Grandjean has studied the adverse health effects of mercury exposure for 30 years. Tr. 793; *see generally* JX 51 App. A. He has published hundreds of articles in scientific journals. JX 51 App. A. He conducted the Faroe Islands study, a seminal investigation linking in utero exposure to mercury via a pregnant woman's diet to permanent neurological harm. Tr. 796-97. The U.S. EPA relied on the Faroe Islands study when it set its safe methylmercury exposure standard, or "reference dose," of 0.1 micrograms per kilogram of body weight per day. Tr. 800-02; PX 123 at 5-9.

There is an international consensus that "developmental neurotoxicity, that is adverse effects on brain development, is a critical effect of methylmercury exposure." Tr. 799. Because studies show that developmental impairment "begins to happen at exposure levels that are close to the reference dose," pregnant women's exposure should be kept "clearly below" that level. Tr. 799, 884-85. Even short-term exceedances can cause adverse effects during sensitive periods in a pregnancy. Tr. 804.

Dr. Grandjean compared mercury concentrations in Penobscot species against the EPA reference dose. He found that mercury concentrations in an average Penobscot lobster would put a 60 kilogram woman at the EPA reference dose for nine consecutive days, assuming she had a blood mercury level of zero before eating the lobster. Tr. 815-16; PX 146. An average eel or black duck would put that same woman at the limit for 15 and 18 days, respectively. Tr. 815, 817; 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). Given that the average Maine woman's background blood mercury is two-thirds of the reference dose, a Penobscot meal would cause her to exceed the reference dose for even longer than Dr. Grandjean's calculations show. Tr. 818-20; DX 753 at 225.

In light of these facts, Dr. Grandjean concluded that the Penobscot foods he evaluated are unsafe for human consumption. PX 146 at 4-5, 21; Tr. 824-25. He agreed with the state's actions to close a portion of the Penobscot lobster fishery, which the state determined was "necessary to protect public health," and to warn pregnant women and children not to eat black ducks in Mendall Marsh. Tr. 825-26; PX 84; PX 67.

Dr. Grandjean did not believe it was necessary to conduct a formal human exposure study in this case. Tr. 821-22. Such studies are expensive and take "many, many years." Tr. 822. The "wealth of information" the Study Panel collected about mercury levels in the three species he analyzed, the EPA's reference dose, and the existing body of epidemiology studies are more than sufficient to conclude that consumption of Penobscot food species poses unreasonable risks to human health. Tr. 821-22.

Mr. Reed Harris
[Testifying by deposition]

Mr. Harris was contracted to develop a detailed hydrodynamic model of the Penobscot that could show the movement of mercury through the ecosystem. JX 36 (Harris Dep. Tr. I) at 19-20; *see generally* JX 22. However, that effort did not "yield[] the results that were needed fast enough," and the Study Panel discontinued work on the project in 2012. JX 36 at 33; JX 37 (Harris Dep. Tr. II) at 250-52. Following abandonment of the detailed model, Mr. Harris developed a "simple," "coarse" "single-box" model. *See* JX 36 at 40-41.

When Mr. Harris plugged field data into his model, he could not confirm the Study Panel's hypothesis that the mobile pool is controlling recovery in the estuary. *Id.* at 51-52. This result does not mean that the mobile pool is not controlling recovery, but simply that "the field numbers that we currently have for the size of the mobile pool and the rate at which particles go through that mobile pool are not consistent with that hypothesis." *Id.* at 202. Dr. Geyer, who collected the field data, said that current estimates of the mobile pool's size are "crude." Tr. 1207-10. And Mr. Harris acknowledged that "there is no model that is ideally suited" for simulating the mobile pool the Study Panel discovered in the estuary. JX 36 at 40-43.

Mr. Harris's model is not intended to predict the rate of recovery of sediment mercury concentrations in the estuary. JX 37 at 300-01; *see also* JX 36 at 59; JX 6-18 at 18-5 ("The modeling was not intended to predict the rate of recovery of sediment [mercury] concentrations."). Dr. Geyer agreed that the model "doesn't have much . . . predictive value in terms of assigning a timescale" and should not be used to calculate a numerical recovery rate. Tr. 1268-69. Instead, the core data collected from the field is "the best estimate . . . of mercury recovery." JX 36 at 29.

Dr. Betsy Henry

Dr. Betsy Henry was retained by Mallinckrodt to opine on the risk of harm to birds and mammals. Tr. 2746. Dr. Henry is not a wildlife biologist. Tr. 2811. She has never designed or conducted a field or laboratory study on birds, or published on the subject. Tr. 2810-11.

Dr. Henry set a screening level for harm in invertivorous birds at 3.0-4.0 ug/g. Tr. 2774. This level is three times higher than the Study Panel's invertivore target. Tr. 2813-14. The upper end of her range is higher than the threshold previously suggested by her colleague Dr. Connolly, Mallinckrodt's chief technical advisor. Tr. 2813.

In developing her screening level, Dr. Henry failed to consider studies of more tolerant piscivores that find impacts at or below her proposed invertivore screening level. Tr. 2816-19, 2825, 2833-37. She "[c]ompletely disregarded" a recently published peer-reviewed study of mercury's effects on invertivorous Carolina wrens. Tr. 2871. Dr. Henry claimed she saw problems in the study's design. Tr. 2789-90. But the study's design has withstood peer review and been blessed by federal and state government agencies, as well as industrial polluters responsible for remediating the contaminated site the study characterizes. Tr. 1911-12 (Evers). Moreover, similar criticisms could be leveled against other studies on which Dr. Henry did rely. Tr. 2879-81.

The blood mercury concentrations of Nelson's sparrows and red-winged blackbirds in Mendall Marsh are more than double Dr. Henry's screening level, for certain years and locations. *See* JX 6-14 at 14-56, 14-72. Dr. Henry nevertheless resisted agreeing even with her own colleague Dr. Connolly's statement that current mercury levels "may cause significant adverse harm" to those species. Tr. 2953-55. She maintained that no remedial action should be taken or even explored pending a two to three year field toxicity test. Tr. 2913-15. The Court did not require the Study Panel to perform a field toxicity test. Tr. 96, 98 (Rudd). Nor are such tests routinely performed at contaminated sites. Tr. 2798 (Henry). Dr. Henry conceded that reasonable scientists can disagree as to whether field toxicity tests are a prerequisite to remediation in the Penobscot, and ultimately agreed that ecological risk "can be based on tissue concentrations documented to cause population-level impacts at other sites." Tr. 2906-07, 2911.

Dr. Henry claimed at trial that a field study would show whether harm to Penobscot songbirds actually exists. *E.g.,* Tr. 2795-96. But she wrote in her expert report only that "[*i*]*deally*, results of 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); *see also* Tr. 2904. When asked at trial about her earlier equivocation, she "caution[ed]" against "reading anything into the words that I've chosen here." Tr. 2905. Dr. Henry refused to acknowledge that delaying remedial action will prolong and expand any present harm to birds. Tr. 2954-56.

Dr. Richard Judd

Richard Judd is a member of plaintiff organizations MPA and NRDC. Tr. 1758. He moved to Maine to teach at the University of Maine. Tr. 1754 (Judd). He has lived on the banks of the Penobscot River, about a quarter mile from the Mallinckrodt plant, for nearly 30 years. Tr. 1753-54.

Being near water has been important to Dr. Judd throughout his life. Growing up in northern Michigan, he "basically lived in the water." Tr. 1754-55. When he moved to Maine, he chose a home on the Penobscot's banks in the hope that his family would have a similar experience to what he had while growing up. Tr. 1755-57. However, mercury pollution in the Penobscot has deprived him and his family of that opportunity. Dr. Judd is afraid to wade, swim, or snorkel in the river, or to allow his daughter to do the same. Tr. 1757. Nor do he and his family eat Penobscot fish or shellfish. Tr. 1757. Although he is an avid kayaker and canoer, he fears coming in contact with the water in the Upper Estuary. Tr. 1758. His "sense . . . that the river is a degraded ecosystem" permeates the time he does spend on the river, and diminishes his enjoyment of the experience. Tr. 1758.

Dr. Judd testified at the liability trial in this case more than a decade ago. Tr. 1761. He returned to testify in this trial, to express his desire to "speed the process" this Court commenced when it ordered a study of the river. Tr. 1761. As Dr. Judd said, the Penobscot River "is a treasure for this area." Tr. 1761. "[T]he quicker we can get it cleaned up and quicker we can make it a healthy ecosystem . . . the more the people . . . that live along it and the people in Bangor will -- will enjoy it." Tr. 1762.

Dr. Judd's testimony supports a finding that the public interest favors injunctive relief to remediate persistent mercury pollution in the Penobscot.

Dr. Russell Keenan

Dr. Keenan is a private consultant retained by Mallinckrodt. Tr. 2445. He testified that mercury concentrations in Penobscot foods are safe for people to eat. Tr. 2593. He also testified that mercury concentrations in Penobscot fish do not pose any harm to the fish themselves. Tr. 2528.

Dr. Keenan has never published an article on health risk from mercury exposure. Tr. 2592-93. To assess human health risk here, Dr. Keenan invented his own proposed safety standards to supplant the fish tissue action level prescribed by the State of Maine. JX 55 at 3-6 to 3-7; Tr. 2595. In place of the state standard of 200 ng/g, Dr. Keenan offered mercury safety targets of 490 ng/g for eels, 510 ng/g for lobsters and rock crabs, and 1,500 ng/g for black ducks. JX 55 at 3-6 to 3-7. He then testified that "I certainly think it would have been health-protective" to triple these values, to around 1,500 ng/g for eels, lobsters, and rock crabs, and 4,500 ng/g for black ducks. Tr. 2597-98, 2609. That makes his threshold for black ducks 22.5 times the state standard. Dr. Whipple testified that Dr. Keenan's method is "simply wrong," "completely unrealistic," and "nonconservative to the point of approaching silliness." Tr. 547.

Next, Dr. Keenan created his own safety thresholds to evaluate harm to fish in the Penobscot; these too are many times higher than the Study Panel's targets. JX 55 at 4-6. 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; JX 55 App. D at Tbl. D-2, App. E at Tbl. E-2. According to Dr. Wiener, the Study Panel's peer reviewer, "[i]t makes no sense to combine these." Tr. 1481. Dr. Keenan also ignored entirely studies showing biochemical and behavioral changes in fish, JX 55 at 4-9, 4-12 to 4-13; *see also* Tr. 736-38, 741-42 (Fisher), which, according to Dr. Kopec, "clearly inflates the concentration of [mercury] harmful to fish by artificially limiting the research papers used," JX 95 at 2. Dr. Keenan claimed that the Study Panel's safe target for small prey fish was unrealistic, Tr. 2530, but he ignored the fact that prey fish currently meet that target in uncontaminated regions in the Penobscot estuary, JX 6-14 at 14-112 to 14-114. Instead, he compared the target for small prey fish in the Penobscot to levels in large predator fish in Maine lakes, a highly misleading exercise. Tr. 1482-83 (Wiener).

Dr. Keenan's unsupported opinions fail to rebut the Study Panel's conclusions that mercury in the Penobscot poses unacceptable risks to human and ecological health.

Dr. Carol Kelly
[Testifying by deposition]

Dr. Kelly is a microbiologist and biogeochemist with more than three decades of experience conducting interdisciplinary ecosystem research. JX 39 (Kelly Dep. Tr.) at 6; *see generally* JX 23. At the Study Panel's request, she verified that the various laboratories analyzing mercury concentrations in water, sediment, and biota samples collected by the panel employed proper quality assurance and control measures. JX 39 at 12, 17-18. She prepared a series of reports reviewing the work of the laboratories the panel retained, which included inter-laboratory comparisons and quality control/quality assurance data and analysis. JX 6-1 App. 1-1. Overall, Dr. Kelly was "quite happy" with the performance of the laboratories participating in the Court-ordered study. JX 39 at 106.

Dr. Dianne Kopec

Dr. Kopec is a research biologist with experience designing, conducting, and interpreting data derived from field studies of wildlife exposed to toxic contaminants. Tr. 1766-67. Dr. Kopec is the principal author of the Phase II report chapters and subsequent monitoring reports discussing biota sampling results and food web analysis. Tr. 1764-65; JX 6-14; JX 6-16; JX 13; *see also* JX 6-9; JX 6-10; JX 6-13. Dr. Kopec agrees with the Study Panel's principal findings, as well as its recommendation to pursue active remediation. Tr. 2017.

Dr. Kopec worked with Dr. Bodaly to propose the biota targets the Study Panel ultimately adopted. Tr. 2049. She refuted Mallinckrodt witness Dr. Keenan's criticism of the Study Panel's decision to apply the Maine state action level as the human health protection target for lobsters, crabs, eels, and black ducks, noting that applying the action level to species other than freshwater fish, and using the action level as an indicator of danger, are consistent with the state's own practices. Tr. 2001-02. She also contradicted Mallinckrodt witnesses' claims that the Study Panel's prey fish target is unachievable, noting that several species sampled at reference sites and in the outer reaches of the Penobscot, away from Mallinckrodt's pollution, already meet the target. Tr. 2009-10. Regarding the panel's invertivorous bird target, Dr. Kopec explained that it is supported by multiple papers in the scientific literature, beyond the Jackson et al. study co-authored by Dr. Evers. Tr. 2007-09.

Dr. Kopec testified that mercury concentrations in lobsters, eels, and black ducks exceed the Maine state action level. Tr. 1780-81, 1798-1800, 1970-71; *see also* JX 6-1 at 1-30 Tbl. 1-4. Ninety percent of the lobsters sampled at Fort Point between 2008 and 2010 exceeded the action level. Tr. 1798-99. Significantly higher mercury concentrations have been found every year the panel sampled at South Verona Island, up through 2012. Tr. 1796-97, 1804-05. "Virtually all" eels sampled below Veazie Dam in the most recent sampling year exceeded the state threshold. Tr. 1786. Black duck tissue mercury levels are higher than any in the scientific literature—so high that Dr. Kopec urged the panel to seek the Court's permission to share the data with the state. Tr. 1971-73. The Court granted permission, and the Maine Department of Inland Fisheries and Wildlife subsequently warned pregnant women and children not to eat any waterfowl from Mendall Marsh. Tr. 1974-75; PX 67.

Mercury concentrations in eels, songbirds, shorebirds, and black ducks exceed the panel's target for protection of the organisms themselves. JX 6-1 at 1-30 Tbl. 1-4. Mercury levels in Nelson's sparrows and red-winged blackbirds in Mendall Marsh are the highest recorded for the species at any site in North America. Tr. 1815, 1824; *see also* 1816-23. Dr. Kopec did not "see . . . the logic" in Dr. Henry's recommendation to put remediation on hold while conducting a field test of songbirds in Mendall Marsh, given that "toxicity must be occurring in those birds." Tr. 2005-06.

Dr. Kopec's testimony supports the Study Panel's principal findings and recommendations to the Court.

Mr. Butch Phillips

Mr. Phillips, an Elder of the Penobscot Indian Nation, testified to the impact that mercury pollution in the estuary has had on the Nation's cultural life, and expressed his support for exploration of active remedies to accelerate the river's recovery.

As Mr. Phillips explained, the Penobscot Nation has lived on the river for "thousands of years." Tr. 1852-53. His ancestors gathered all their necessities from the river and surrounding land. Tr. 1853. From that tradition grew the belief that "we were part of the river and the river was a part of us." Tr. 1853.

About 500 people still live on the Nation's reserved lands, the islands in the river north of Old Town. Tr. 1851. Mercury pollution in the river ecosystem has disrupted the Nation's ability to follow the traditions of its ancestors. For example, as an Elder, Mr. Phillips performs religious and cultural ceremonies, many of which traditionally take place on the river. Tr. 1852, 1854. Mercury pollution has tarnished the river's spiritual power. Tr. 1854, 1858.

Mr. Phillips has also worked with the Penobscot River Restoration Trust to decommission dams and restore historic fish runs from Penobscot Bay to the Nation's reserved lands. Tr. 1857-58. Restoration of those fish runs would be "a cause for celebration" for the Nation. Tr. 1858. But in order to reach tribal waters, the fish would need to swim through the mercury-contaminated Upper Estuary. Tr. 1858. Exposure to that pollution would diminish the value of reestablishing the fish runs. Tr. 1858.

Mr. Phillips wants to see mercury concentrations in the river reduced. Tr. 1856. He believes that "any improvement . . . in the river is working towards that goal that I always hoped for," which is "that my children, my great -- my grandchildren, and -- and the -- the unborn . . . could see the Penobscot River as my ancestors did generations ago." Tr. 1857.

Mr. Phillips's testimony supports the conclusion that remediation of mercury pollution in the Penobscot is in the public interest.

Dr. John Rudd

Dr. Rudd is Chair of the Court-appointed Study Panel. Tr. 18, 19. He is a Ph.D. microbiologist, specializing in "the production of methylmercury and . . . the transport of methylmercury through ecosystems." Tr. 11, 16. He has worked on whole ecosystems and mercury-contaminated sites since the early 1980s. Tr. 11-16.

Dr. Rudd testified that the Study Panel was committed to an independent investigation built on sound science. Tr. 18-19, 21-22, 261. To conduct the necessary field work and analyses, the panel hired "highly respected," "internationally renowned" scientists. Tr. 26-27. The panelists and scientists working with them "discussed things as much as [they] could," and shared ideas that were later refined or discarded. Tr. 28. Their most refined thinking is reflected in their filed reports and trial testimony. Tr. 456-57. The panel reached consensus on all its major findings and recommendations. Tr. 28-30, 153, 262-63.

Dr. Rudd testified that the Penobscot system is "heavily contaminated" with mercury. Tr. 29. Sediment mercury levels in the Upper Estuary are "much higher" than upstream or downstream on both a dry weight and carbon-normalized basis. Tr. 49, 53-54, 259. Biota are also contaminated, including human food species like black ducks, eels, and lobsters, which were "two or three" and "up to seven or eight times above" the State of Maine human consumption guidelines. Tr. 29, 86-89. In Mendall Marsh, the combination of trapped fine sediments and efficient methylmercury production create a "perfect storm," such that mercury levels in species like Nelson's sparrows, red-winged blackbirds, and black ducks are many times higher than in non-contaminated reference sites. Tr. 119-22.

The study data show that the Penobscot ecosystem has been contaminated for over four decades and will remain at high mercury concentrations for "six or seven more decades," which is "just too long" and justifies looking for active remediation options. Tr. 192, 194-95. Any lingering uncertainty about the exact recovery half time in the system is a "scientific debate" but it "doesn't affect the final bottom-line recommendations [to pursue active remedies] . . . at all." Tr. 445.

With respect to remediation, Dr. Rudd explained that finding a very strong relationship between total mercury and methylmercury was the Study Panel's "first big break-through," because it showed that reducing total mercury in the entire ecosystem would reduce methylmercury production and the concentration of methylmercury in biota. Tr. 29-30, 57-59. In addition, the panel discovered that the concentration of total mercury in surface sediments "is controlled by the concentration of mercury in the mobile pool," so reducing mercury in the mobile pool would get at "the root of the problem." Tr. 166, 160-61. Dr. Rudd endorsed an "open and impartial analysis" of "[a]ll options" for remediation, grounded in these scientific insights. Tr. 262. The group evaluating remediation should be "independent," "nonpartisan," and focused on "looking for solutions, rather than problems." Tr. 461-62. "There's no reason" a remediation group's pursuit of viable options cannot begin immediately. Tr. 178.

Dr. Mark Sandheinrich
[Testifying by deposition]

Dr. Sandheinrich is Chair of the Biology Department at the University of Wisconsin-La Crosse. JX 40 (Sandheinrich Dep. Tr.) at 6; *see generally* JX 26. His primary area of expertise is the bioaccumulation of mercury and its effects on fish. JX 40 at 10. The Study Panel commissioned a literature review from Dr. Sandheinrich on the effects of methylmercury on fish and wildlife. *Id.* at 13; *see* JX 6-2 App. 2-1. His review is the basis for the panel's fish health target. Tr. 939-41 (Bodaly).

Dr. Sandheinrich advised the panel that adverse effects in fish are known to occur when mercury concentrations in the whole body range from 300 to 700 ng/g. JX 6-2 App. 2-1 at 31; *see also* JX 40 at 77-78. He concluded that the threshold for toxic effects is likely lower. JX 6-2 App. 2-1 at 31. The Study Panel converted Dr. Sandheinrich's effects range to 400 to 900 ng/g in axial muscle alone, and set a target within that range, at 500 ng/g. JX 6-2 at 2-5 to 2-6. Dr. Sandheinrich agrees this threshold is reasonable. JX 40 at 92-93. The higher threshold that Dr. Connolly proposed in a memo to the Study Panel, on the other hand, is not. As Dr. Sandheinrich explained, Dr. Connolly's suggested range of 700–900 ng/g whole body represents the lowest concentration range that produced toxic effects in one study, but the study did not test for effects at lower concentrations. *Id.* at 120; PX 111 at 1-2.

Dr. Sandheinrich's literature review also supported the Study Panel's development of a target to protect fish predator health, *see* JX 6-2 App. 2-1 at 2-8 to 2-9, and he is a co-author of the Depew et al. paper on which the Study Panel based that target. JX 40 at 96. Dr. Sandheinrich believes the Study Panel's target is a "reasonable" interpretation of Depew et al. *Id.* at 101-02.

Dr. Sandheinrich also reviewed the scientific literature on mercury's effects on birds. JX 6-2 App. 2-1 at 17-18. Dr. Sandheinrich's review pre-dated publication of the Jackson et al. (2011) study, which is the primary basis for the panel's target of 1.2 ug/g in invertivore blood. *See id.* at 1 (dating review to 2010). His findings are nonetheless consistent with that target. Dr. Sandheinrich concluded that the threshold for toxic effects should be lower than 3.0 ug/g, based on the literature available at the time of his review. *See id.* at 17; JX 40 at 60-65; PX 111 at 1-2, 4. And he acknowledged that some of the studies he considered were of piscivorous birds that may be "substantially" more tolerant to mercury than invertivorous songbirds. JX 6-2 App. 2-1 at 17-18; *see also* JX 40 at 68-71.

Dr. Sandheinrich endorsed the Study Panel's approach to assessing ecological harm by relying on the scientific literature rather than site-specific toxicity tests. Reliance on the scientific literature to assess toxicity is not only "legitimate" but is the "best means" of determining what exposure levels are dangerous. JX 40 at 48-49.

Dr. Peter Santschi

Dr. Santschi is an environmental radiochemist and one of the top sedimentologists in the world. Tr. 1681-82 (Santschi), 129 (Rudd); *see generally* JX 27. At the Study Panel's request, he analyzed sediment core data to calculate recovery rates for mercury contamination in various regions of the Penobscot study area. JX 6-6 at 6-1.

Dr. Santschi projected recovery rates using observed patterns in sediment core mercury concentrations from the past 21 years. JX 6-6 at 6-3. He noted that mercury concentrations in the Penobscot spiked sharply after the major releases from the Mallinckrodt plant in the late 1960s, and then declined rapidly in the first decade or two thereafter. Tr. 1687; JX 6-6 at 6-15. That decline slowed down, 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. In Dr. Santschi's view, the past 21 years of historical sediment core data reflect that slow recovery phase and provide sufficient information to project the observed rate of recovery into the future. Tr. 1688, 1694-95; JX 6-6 at 6-3.

For those cores that show declining mercury concentrations over time, Dr. Santschi calculated average recovery half times of 33 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. A half time is the amount of time it takes for surface sediment mercury concentrations to decrease by half toward an assumed asymptote. *See* Tr. 1686-87; JX 6-6 at 6-3. Dr. Santschi noted that "[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. Tr. 1688; JX 6-6 at 6-15.

Dr. Santschi's calculated half times apply only to the locations where mercury contamination appears to be improving. Tr. 1700-01. In a number of areas, mercury concentrations are either staying the same or increasing. Tr. 1685, 1699-1700. Dr. Santschi could not include these locations in his recovery rate projections, because the recovery half time they provide is "infinity." Tr. 1699.

Although his numbers are not exact to the year, Dr. Santschi is confident it will take many decades for natural recovery to occur. Tr. 1709-10. "[I]t will take a lifetime to get back to reasonable levels" of mercury contamination. Tr. 1685. Dr. Santschi criticized the competing recovery rate analysis conducted by Mallinckrodt's witness Dr. Connolly, which Dr. Santschi called "a fishing expedition . . . to get shorter . . . half-times." Tr. 1719.

Dr. Santschi's testimony confirms that active remediation is necessary because of the slow natural attenuation of mercury contamination in the Penobscot estuary.

Mr. Jack Siegrist
[Testifying by deposition]

As a research assistant at Applied Biomathematics, Mr. Siegrist served "as sort of a help desk" to the Study Panel, providing technical assistance to Dr. Kopec on the software package the panel used to conduct statistical analyses of the data it collected. JX 41 (Siegrist Dep. Tr.) at 15-16, 109; *see generally* JX 28. He also helped the panel set up the specific analyses it used to determine how much statistical power its sample sizes provided. JX 41 at 34, 109. According to Mr. Siegrist, the statistical analyses the Study Panel employed are standard and "fairly simple." *Id.* at 114-15, 117-18. Mr. Siegrist has not reviewed the Phase II report or any draft of it. *Id.* at 12, 21-22, 38. He has reached no conclusion regarding the study's use of statistics. *Id.* at 29. Based on his interactions with Dr. Kopec, Mr. Siegrist has no reason to believe that the panel performed any statistical analyses improperly. *Id.* at 112-13.

Dr. Ralph Turner
[Testifying by deposition]

Dr. Turner is a mercury geochemist who has worked on mercury-contaminated sites, including chlor-alkali sites, since 1975. DX 955 (Turner Dep. Tr. I) at 7-10. Dr. Turner investigated possible ongoing mercury inputs to the estuary from upstream sources, tributaries, and the Mallinckrodt plant. JX 6-1 at 1-41; JX 6-3 at 3-61 to 3-62 & Fig. 3-35.

The amount of mercury entering the estuary from above the former Veazie Dam is "very small compared to the large quantity of legacy total [mercury] stored in the sediments and wetlands of the upper estuary and Fort Point Cove." JX 6-1 at 1-8. Ongoing contributions from the plant site and tributaries below the Veazie Dam are even smaller. *Id.* at 1-7 to 1-8; DX 955 at 257-59. Dr. Turner did not find any large, ongoing mercury sources in the Upper Estuary. DX 955 at 180-82; JX 6-1 at 1-41 Fig. 1-8; *see also* Tr. 366 (Rudd). There is some lingering uncertainty regarding the exact quantification of mercury coming from various current sources, but Dr. Turner believes that "we did enough measurements to be pretty confident of what the total loading in the river . . . above HoltraChem is." DX 978 at 40.

Dr. Turner's results support the Study Panel's finding that the contribution of ongoing sources to mercury contamination in the Upper Estuary is inconsequential, and that remediation efforts should focus on legacy mercury in sediments. JX 6-1 at 1-7 to 1-8; *see also* JX 6-23 at 23-2 to 23-4.

Dr. Dimitri Vlassopoulos

Dr. Vlassopoulos is a private consultant retained by Mallinckrodt. Tr. 2962-63. He works for the same firm that employs Mallinckrodt witnesses Dr. Connolly and Dr. Henry. *See* Tr. 2962; JX 53 at 1; JX 45 at 1. He commented on Dr. Gilmour's analyses regarding methylation rates in Mendall Marsh and the effectiveness of sorbent amendments as a possible remediation tool. Tr. 2965.

Dr. Vlassopoulos agreed with Dr. Gilmour that Mendall Marsh is uniquely effective at generating methylmercury. *Compare* Tr. 2973, 3038, *with* Tr. 1564 (Gilmour), *and* JX 6-11 at 11-89. He described Mendall Marsh as a "perfectly efficient methylmercury-producing system." Tr. 2973.

Dr. Vlassopoulos asserted that total mercury concentrations are not predictive of methylmercury concentrations in sediment, based on what he perceived to be a low R-squared value of 0.11 between one particular set of methylmercury and total mercury samples from Mendall Marsh. Tr. 2985-86, 2987-88. (The R-squared value is a measure of how strongly one variable explains another; the highest possible R-squared value is 1. Tr. 533-34 (Whipple).) Dr. Vlassopoulos conceded that he considered only a subset of the data, from one location, in reaching his conclusion. Tr. 2986-87, 3040-42. The limited 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, b, App. 1-2 at 57 Fig. 24, App. 1-3 at xiii Figs. i(A), (B); JX 6-23 at 23-24 Fig. 23-7 to 23-25 Fig. 23-8.

Dr. Vlassopoulos also reviewed Dr. Gilmour's field tests of *in situ* sorbent amendments in Mendall Marsh. Tr. 3013-15. He argued that activated carbon was effective at reducing methylmercury concentrations in pore water for roughly one year. Tr. 3023. Dr. Gilmour again disagreed; her analysis shows that it was effective through the entire two-year duration of the study. Tr. 1600-01; JX 6-19 at 19-1 to 19-2. Dr. Vlassopoulos did not evaluate any other remedial option. Tr. 3057.

Dr. Vlassopoulos's review of a small subset of the data collected by the Study Panel offers no basis to rule out the prospect of viable active remedies.

Dr. Chris Whipple

Dr. Whipple is a risk assessment expert employed by Environ International Corporation, a worldwide environmental consulting firm. Tr. 465-66, 586. Since the 1980s, he has worked on various projects related to the risks of mercury exposure. Tr. 467-70. He is a member of the Court-appointed Study Panel, nominated by Mallinckrodt. Tr. 464-65.

According to Dr. Whipple, mercury contamination in the Penobscot poses a "significant danger" to human health: "animals that people frequently eat . . . have mercury concentrations that are too high according to guidance from the state health department." Tr. 585, 503. Eels south of Veazie Dam and lobsters at South Verona Island exceed the state mercury consumption action level by two and a half times. Tr. 488-89. Black duck mercury levels are even higher. Tr. 489. According to Dr. Whipple, Mallinckrodt witness Dr. Bolger's assertion that it would take weeks of continuous exposure to create a health risk "simply is not true." Tr. 570-71.

The Study Panel did not seriously consider using a standard other than the state action level to assess human health risk. Tr. 487. It would have been "completely insensible for the Study Panel to challenge that body of work and to try to reinvent our own standard." Tr. 487. Nor did Dr. Whipple, a risk assessment expert, deem it necessary for the panel to conduct a formal human health risk assessment to determine that people who eat high-mercury Penobscot foods are at risk. Tr. 478-79, 586.

Mercury contamination in the Penobscot also poses a "significant danger" to ecological health. Tr. 585. Mercury concentrations in songbirds are "some of the highest ever observed in those species" and exceed "toxicity reference points" from the scientific literature. Tr. 505. Conducting a toxicity test on those birds is neither necessary nor advisable. Tr. 505-10.

Even after 40 years, methylmercury concentrations in the Penobscot are "higher . . . than we've seen almost anywhere," "really high enough that they are dangerous." Tr. 539; *see also* PX 57. And according to the "exceptional" collection of sediment cores gathered by the panel, Tr. 516, mercury contamination appears to be getting worse, not better, in at least one critical area: the productive lobster fishery in the southern estuary. Tr. 499-500. As Dr. Whipple explained, "we'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." Tr. 500; *see also* JX 6-22 at 22-2 ("[T]he potential for significant human exposures via lobster consumption may actually be increasing as mercury concentrations south of Fort Point Cove increase.").

Dr. Whipple joins his fellow Study Panelists in calling for active remediation. Tr. 585. "[T]his system is simply too contaminated for too long to believe it's going to clean itself effectively in any reasonable time." Tr. 539. The investigation of remedial alternatives should not be limited to the ideas suggested in the Phase II report. Tr. 529.

Dr. James Wiener

Dr. Wiener, a Distinguished Professor at the University of Wisconsin-La Crosse, has worked on large, interdisciplinary studies of mercury-contaminated ecosystems for more than 30 years. Tr. 1407-08, 1410, 1411; *see generally* JX 31. He served as an outside peer reviewer of the Penobscot River Mercury Study. Tr. 1412-13. In Dr. Wiener's view, the Penobscot River Mercury Study is "an extraordinarily well-done study by a group of people who are very capable and brought the best mix of skills, knowledge, and analytical tools to the table." Tr. 1424. It "is as good a project as [he has] ever seen and far better than most." Tr. 1426.

Dr. Wiener concurs in the Study Panel's major conclusions and recommendations. Legacy mercury stored in the estuary is the source of the Penobscot's ecological problems. Tr. 1472. The Study Panel's data reveal an "astonishingly tight" relationship between the inorganic mercury trapped in the system and highly toxic, bioavailable methylmercury. Tr. 1453-54, 1457-58. The rate at which methylmercury is produced from this legacy mercury is "extremely high" and may present a "worst-case scenario." Tr. 1425.

Dr. Wiener deems the Study Panel's mercury safety thresholds for biota to be reasonable and well-supported. Tr. 1441-44. In developing targets, the Study Panel correctly focused on the much lower mercury concentrations that influence a species' ability to reproduce, rather than the higher doses needed to kill an organism. Tr. 1428-30, 1479-80. As Dr. Wiener explained, by the time mercury concentrations are high enough to kill lower trophic level animals, upper trophic level consumers—including humans—will already be suffering toxic effects. Tr. 1430. Dr. Wiener believes that in the future, science will find that adverse effects from mercury occur at even lower concentrations than those presently acknowledged. Tr. 1439-41.

When compared to the panel's thresholds, biota mercury levels documented in the Penobscot "demonstrate[] conclusively that methylmercury is accumulating to concentrations that pose significant risks to multiple species of predatory fish, birds, and mammals, including humans." Tr. 1463-64. The panel's decision to assess risk by comparing exposure levels to thresholds from the literature is "very reasonable and defensible," and a common scientific practice. Tr. 1449-50. Field toxicity testing was unnecessary and "might have produced more questions than answers." Tr. 1449-50.

Dr. Wiener agrees with the Study Panel's recommendation to pursue active remedial options. Tr. 1471. Because mercury remediation "is an area of very active research and study and development," such an investigation should consider all potentially effective remedies, not just those mentioned in the Phase II report. Tr. 1474.

Dr. Wiener's testimony confirms the scientific quality of the Court-ordered study and supports the Study Panel's principal findings and recommendations.

Mr. Ken Wyman

A long-time resident of Stockton Springs, Mr. Wyman testified to the impact that mercury contamination in the Penobscot has had on him and his family. Tr. 1830.

For the last 26 years, Mr. Wyman has fished the Penobscot River for lobster and crabs. Tr. 1830-31. Until the Maine Department of Marine Resources closed the fishery, Tr. 1840, 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 more than 10,000 pounds each of lobster and crab per year from the river. Tr. 1835-36. For almost 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 them to his family, including his children, his pregnant daughter-in-law, and his grandchildren. Tr. 1838-39. He believed the fish he was catching, selling, and feeding his family were safe to eat. Tr. 1839-40.

Maine DMR has closed the 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 supports the state's decision to close the fishery. Tr. 1843. At trial, he testified: "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 asked the Court to order active remediation of the Penobscot, for the good of the lobster and crab fishing community, and for the entire state:

> 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 know where, I mean, what will happen to our industry? 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.

Mr. Wyman's testimony puts a human face on the harm Mallinckrodt has caused and supports a finding that an order compelling remediation is in the public interest.

Dr. Kevin Yeager

Dr. Yeager is a sedimentary geologist and environmental radiochemist; he is a tenured associate professor at the University of Kentucky. Tr. 1273. He led the fieldwork and analysis for the Study Panel's sediment core collection effort in the Penobscot. *See* Tr. 1279-80; JX 6-5. Dr. Yeager quantified total mercury inventory in Penobscot sediments, calculated rates of sediment accumulation across the study area, and determined contemporary mercury flux. JX 6-5 at 5-5; Tr. 1282-84.

Dr. Yeager's team collected three sediment cores, roughly 90 centimeters deep, at each of 72 sampling locations. Tr. 1283, 1289-90. Cores from 58 of the locations were suitable for full analysis. Tr. 1299-1300. The cores were collected from four regions: the lower Penobscot River (denoted PBR), 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 to 5-10 (maps of coring locations). The sediment cores were then divided into thin sections and analyzed for mercury and various radioisotopic tracers, like Cesium-137, which serve as rough historical markers. Tr. 1274-75, 1294-96, 1299-1302, 1366. This required approximately 28,000 total measurements. Tr. 1301-02.

Extrapolating from the sediment core data, Dr. Yeager estimated a total inventory of more than nine metric tons of mercury stored in Penobscot sediments. Tr. 1284-85, 1303-16; JX 6-5 at 5-14 to 5-19. He also measured the rates of sediment accumulation at each of the locations analyzed. Tr. 1283; JX 6-5 at 5-19 to 5-24. These sediment accumulation rates were used by Dr. Santschi in a subsequent analysis to calculate projected recovery rates. JX 6-6 at 6-5. In addition, Dr. Yeager determined the contemporary mercury flux, or the rates of current (as opposed to historic) delivery of mercury to surface sediments. Tr. 1282, 1285. His analyses "clearly show that total [mercury] is being redistributed throughout the system." JX 6-5 at 5-31.

Dr. Yeager corroborated Dr. Santschi's recovery rate projections derived from the sediment cores, testifying that they are "entirely reasonable," based on an "enormous data set," and "very well-constrained." Tr. 1343. He also noted that mercury concentrations are increasing, not decreasing, towards the surface at a number of locations. Tr. 1345. In other words, "it's getting worse, not better." Tr. 1345. According to Dr. Yeager, Dr. Santschi's projections should therefore be considered minimum numbers for recovery, because they ignore those areas where recovery is not yet occurring. Tr. 1345.

Dr. Yeager's testimony confirms that there is a significant amount of mercury remaining in the Upper Estuary; observed recovery is happening slowly; mercury is being redistributed throughout the ecosystem; and the contamination in some locations is still getting worse.