

Columbia River Estuary Science-Policy Exchange
September 10-11, 2009
Astoria, Oregon
Meeting Summary

On September 10-11, 2009, the Northwest Power and Conservation Council hosted a science-policy exchange in Astoria, Oregon. The Council supports strategies that protect, enhance, and restore critical habitat in the estuary and lower Columbia River, and the purpose of the exchange was to hear about research and discuss scientific evidence that suggests improvements in the estuary have the potential to increase survival for anadromous fish.

The sessions were well attended, with over 100 participants. Over the course of two days, participants heard from 20 speakers and had the opportunity to query and comment on the information presented. Most members of the region's Independent Science Advisory Board (ISAB) and the Independent Scientific Review Panel (ISRP) attended the exchange.

The following summary focuses on the questions and discussion that followed the presentations. Abstracts of the research and slides of each presentation are available on the Council's website at <http://www.nwcouncil.org/fw/program/2009spe/Default.asp>. An attendance list appended to this summary includes affiliations and contact information for the speakers.

Day 1, Morning Session: Review of Ongoing Status and Trend Monitoring Efforts

Oregon Council member Joan Dukes welcomed participants to Astoria and the mouth of the Columbia River. She acknowledged the efforts of Council staff in organizing the exchange and made opening remarks.

Each of you understands the estuary is an important place for Columbia River fish and wildlife, and it is a vital part of the economy in this area in terms of fishing, recreation, navigation, and other activities. It is an important component of the Council's fish and wildlife program, too, and in that regard, its importance is growing. Policymakers are getting a clearer picture of the processes and opportunities the estuary offers for salmon recovery. The value of these conferences is that non-scientists, like me, get to listen and participate: the best policy is informed by the best available science.

Washington Council member Dick Wallace echoed the thanks to staff and introduced facilitator Donna Silverberg. In opening remarks, he talked about the interaction between policy and science.

A fundamental principal of our fish and wildlife program is adaptive management. We learn from our actions and move forward. A key to the relationship between science and policy is mutual respect. I think of science on a spectrum from research and pure science to applied science, where you

apply theory and research to on the ground challenges. Then you have policy arena. There's a healthy tension between science and policy, and it's important to make them work together.

Speaker 1: John Ferguson, NOAA Fisheries. Current State of Knowledge on How Juvenile Salmon Use the Columbia River Estuary and Plume Habitats.

Ferguson set the stage for the policy exchange with a presentation on the state of the estuary science. He reviewed themes from the 2007 science policy exchange, identified current uncertainties, and offered a look at the future and where estuary science needs to focus. Ferguson pointed out that in 2007, the science exchange presentations made clear that fish from throughout the Columbia Basin use estuary habitat in different ways and for varying amounts of time.

NOAA's sampling found that fish can be in the estuarine habitat for a whole year, and that they use all kinds of estuary habitats, Ferguson reported. He also noted that salmon behavior isn't easy to predict: "When you try to put salmon in box, they jump out."

Ferguson pointed out uncertainties with regard to estuary habitat and key questions that need more research. Among the issues, we need to learn more about what stocks are using the upper reaches of the lower Columbia River estuary, how different stocks use different habitats, and we need to do more research in the tidal-freshwater areas, he said.

Ferguson went on to list other areas of needed inquiry, including: contaminants, cormorant predation, data from the POST tracking arrays; adult fish straying from the Young's Bay net pen rearing program; the variation in smolt-to-adult returns (SARs) and ocean-entry timing; what conditions in the plume lead to improved salmon survival; needed improvements in run forecasting; the overall effect of pinnipeds on salmon throughout the lower river; and adult survival from the mouth of the river to Bonneville Dam.

Speaker 2: David Jay, Portland State University. An Oceanographic Point of View.

Jay presented field observations, remote sensing, and modeling results to provide an overview of the physical processes in the lower Columbia River, estuary and coastal ocean. It is difficult to put together the pieces for salmon recovery in a system as large and complex as the Columbia basin, which encompasses parts of seven states and two Canadian provinces, he said.

Jay pointed out numerous changes that have occurred in the estuary and coastal ocean and the difficulty in resolving whether they are caused by human intervention or climate change. For example, the spring freshet has gotten earlier by 15 days over time, and it has gotten less consistent, with peak spring flows now less than 60 percent of historic peak flows, he said. Jay explained the changes dredging and development of the hydro system have brought about, as well as lowered water levels, increased salinity intrusion in the estuary and the effect of increasingly larger tides.

The Columbia River plume is vital to the coastal ecosystem and salmonids in ways that are poorly understood, Jay said. In summary, he said the tidal river, estuary, and plume are vital to juvenile salmon, and we need to understand the pieces and how they interact.

Questions/Discussion: I have heard people say the plume used to extend to San Francisco, Dukes commented. Can we study what that change means for habitat and fish? she asked. The river is putting out less water now in spring than it did historically; it is correct that there is less fresh water out there, Jay responded. It is difficult to study; it takes lots of inference and modeling, he added. Jay also pointed to opportunities or lack thereof for study, saying “we can’t tell the hydropower system we want to recreate conditions in 1961.” It takes an iterative process to develop models and then we run them and “hold our breath,” he said.

We’ve been trying to relate the size of the plume to salmon productivity, Ferguson said. There is data that infers benefits from a larger plume, he added.

Did you say that water temperatures were measurably higher during operation of the Hanford weapons facilities? Tom Karier asked. Yes, it was a noticeable effect, a one-half degree difference in temperatures at Bonneville Dam, Jay responded.

Rob Walton and Bill Booth asked about the changes in tidal range. There has been a long term change, Jay responded, adding that tides throughout the northeast Pacific Ocean have changed. The amplitude of the daily cycle is increasing, he added. Jay noted that tides on the West Coast vary drastically “from block to block.” We looked at tidal records from Chile to the Aleutians to the Hawaiian Islands, and it seems there is a lot of harbor-to-harbor variation, he said.

Wallace asked about the effect of dike removal in improving estuary conditions. Jay responded that research results for dike removal were quite different in various areas of the estuary. Each reach is different, and the different reaches behave differently, he said.

Speaker 3: Mark Sytsma, Portland State University. Invasive Species: Implications for Habitat Restoration and Effects on Salmonids.

Sytsma explained the process by which invasive species are introduced from the source to the host region, and he described the types of species that have entered the Columbia River. There are non-native species that are not considered invasive; invasive species are those that cause economic impacts. Sytsma said invasive species enter a region by various pathways; the most prominent for the Columbia River is ballast water from ships.

Sytsma pointed out that introduced organisms have greatly changed the river environment. Surveys show 82 non-native species in the lower river and 17 species in the middle river, and the pace of introduction is increasing. Invasive species have direct effects, such as predation on salmonids, and indirect effects, such as hybridization; they also alter the food web.

Juvenile and adult salmon typically encounter between twenty to forty non-native fish during their migration. Most important are smallmouth bass, largemouth bass, and channel catfish.

A number of species, including zebra/quagga mussels and hydrilla weed, are major concerns in the Columbia/Snake river system. Sytsma described the need for early

detection and prevention programs, noting that early detection locates populations when they are small and can be eradicated. He called for more vulnerability assessments at federal hydro and fish passage facilities, research on species management and eradication, and preparation of rapid response plans, including resolving related permitting issues to facilitate control programs for invasive species.

Questions/Discussion: We can discover invasive species when they inhabit small areas, but “we are hamstrung” in getting permits to prevent their spread, Booth commented. We probably need help from various federal agencies with this; everyone is concerned about the use of chemicals, but we have to protect the hydrosystem, he said.

We’re presently encouraging agencies to be as concerned and involved with invasive species as we are, Karier stated. Has testing ballast water been successful in detecting invasive species? he asked. Last week, the federal government (Coast Guard) released standards for ballast water, Sytsma responded. He noted that mid-ocean exchanges of ballast water, the current practice, are not consistently effective. The newer practice is ballast water treatment. However, the largest threat with zebra/quagga mussels is from overland transport of species on recreational boats, Sytsma said.

Wallace asked about the non-native predators of salmon fry. Smallmouth bass and catfish are major species in terms of salmon predation, Sytsma responded. Wallace also asked if cost is a factor in obtaining a specialized camera system that Sytsma said would help with detecting invasive mussels. They cost \$55,000 each, Sytsma replied. Our current problem is processing samples, which take three hours each – we need a faster turnaround, he said. One solution is a technology that’s a ways off, but would allow us to put a dipstick into the water and see if the mussels are present, Sytsma explained.

Bill Maslen asked how much invasive species are skewing the food web. There has not been a lot of work done to determine that. Sytsma responded.

Speaker 4: Amy Borde, Pacific Northwest National Laboratory. Review of Wetland Habitat Characteristics in the Lower Columbia River and Estuary.

Borde described the goal of her research as identifying ecosystem processes and functions and evaluating status and trends to inform the design of salmon restoration. Research has focused on a narrow range of undiked floodplain and shallow water habitats and has included sites in various geomorphic settings and habitat types.

Borde explained the role of submerged aquatic vegetation and described research on the controlling factors of eelgrass, which provides nursery habitat for juveniles of many species. Emergent wetlands are also an area of study, as well as shrub-scrub and forested wetlands, both of which are limited in distribution. Connectivity of these wetlands to the mainstem and their capacity to support salmon are important issues in the research.

Borde cited a number of data gaps, including primary productivity; water temperature in wetland habitats; vegetation and prey associations; and fish use. She concluded that due to a loss of historical habitat, there is a need to restore a diversity of habitats to support a diversity of salmonid life histories and the ecosystems they need.

Questions/Discussion: Karier asked if the researchers encountered purple loosestrife and whether it is a competitor with eelgrass. Borde responded that loosestrife is found in the higher elevation, but that there is competition among plant species. We distinguish between native and introduced species in all of our data collection, and we are looking at issues of competition, she added.

Is the shrub-scrub habitat a product of a disturbance event? Jay asked. Borde acknowledged that the researchers don't really know. We are trying to get a better idea as to whether the systems are accreting, she said.

Sytsma noted that a disease that is moving west poses a threat to Oregon ash. What would be the consequence to wetlands? he asked. Oregon ash is subdominant to cottonwood in the shrub-scrub habitat, Borde said, adding that if Oregon ash disappears, there could be another species taking over. It would definitely leave a hole in the riparian systems, she stated.

Speaker 5: Geoffrey McMichael, Pacific Northwest National Laboratory (PNNL). Survival and Behavior of Juvenile Chinook Salmon in the Lower Columbia River, Estuary, and Plume.

McMichael described the Juvenile Salmon Acoustic Telemetry System (JSATS) used to estimate juvenile salmon survival between Bonneville Dam and the Pacific Ocean. He reported on 2005-2009 data, which puts average travel time for yearling Chinook from Bonneville Dam to East Sand Island at less than four days. According to JSATS data, the fish pick up speed as they leave Bonneville Dam and slow down as they enter the estuary. Once they commit, they move quickly to ocean. Results for 2005 and 2006 show higher than expected losses (up to 50 percent), particularly in the lower 50 km of the river.

Data has shown juvenile spring Chinook salmon used both main channel and off-channel habitats during their migration through the estuary. However, larger proportions of the subyearling Chinook salmon (36%) were detected in off-channel areas in comparison to their yearling counterparts (29%).

Preliminary estimates of survival for yearling Chinook salmon in 2009 showed approximately 90% survival from Bonneville Dam to Harrington Point at river km 50, with sharp declines to the next two arrays at Astoria Bridge (river km 22; 84% survival) and East Sand Island (river km 8; 76% survival). However, estimates of avian predation account for only a small percentage (about 10%) of the estimated loss of JSATS-tagged spring migrants.

Subyearling Chinook salmon survival was also lowest in the final 50 km of the river in 2008, though they survived at a higher rate than the yearling fish, with an estimated 89% surviving to East Sand Island (river km 8). Later (after the first week in July) migrating subyearling Chinook however, had very low apparent survival in most years (30-45%).

McMichael said future work will integrate plume tests with Biological Opinion performance standards, and research will focus on salmon behavior in the lower 50 km of the river. In 2010, researchers will assess route-specific mortality past the dams.

McMichael called development of the JSATS technology a great success story, enabling researchers to collect data that was previously unattainable.

Questions/Discussion: Wallace asked if researchers have an idea about the cause of the mortality, other than predation, that occurs in the lower river and estuary. McMichael said they did not, but some of the mobile tracking work may tell us. He indicated that more tags are found on the bottom of the river in some areas, but it's unclear why the fish died. Wallace asked if the same pattern that is seen with Chinook has been observed with steelhead, sockeye and coho. Some of these species haven't been tagged yet, but we have some data for steelhead that indicates they get past the birds at a higher rate, McMichael said.

Dukes asked about losses from implanting tags and how many of the lower river losses could be attributed to fish that have not yet left the estuary for the ocean or overwintered?

McMichael acknowledged that tagging has an effect; it requires surgery on the fish and there is the burden of having the tag, which is why we only tag larger juveniles. When we compared the proportion of fish with both acoustic and PIT tags, we don't find a greater number on the bird islands, he added. And the time period for travel with the tagged fish is well within normal limits, McMichael said. A large investment is being made to find out what the tagging effects are, he said. The drastic decline in the numbers in the lower river is some combination of fish that are dying and fish that are alive but are staying longer in the estuary, McMichael said.

Guy Norman asked if there is follow-up research planned to learn more about extended rearing that occurs in the estuary. That's a very good idea, McMichael responded. We put out fixed lines for tracking, and we don't know what fish that show up later on were doing, he said.

When do fish prefer to leave the estuary? Jay asked. McMichael said 90 percent leave on an ebb tide. He also said early transported fish take much longer to move through the lower river and estuary than fish transported later.

Panel Comments and Session Wrap Up

There is a lot we don't know and a lot of research that remains to be done, Dukes commented. There are so many data gaps, she added. As projects are completed, the information should be used to further more discoveries, Dukes said.

Many speakers spoke to the value of collaboration; there is a lot of information, but it is not always integrated, Maslen commented. We could leverage a lot of what we've learned by integrating it more holistically, he said.

Wallace said there is enough known in many areas, for example, zebra/quagga mussels and other invasives, to ramp up action now. We've had a lot of focus on avian predators, and we also should look at other predators, like smallmouth bass, he said. And we've heard a lot about the diversity in fish uses of the habitat – we don't need to wait for additional information to make habitat improvements, like dike removal, Wallace stated.

We have a lot more to learn, but there is a lot to work on while we find out more, he concluded.

I agree there is a lot being done, but there are data gaps, Booth stated. A “top-level outcome” of this summit could be a collaborative effort that would bring groups together to put the pieces together, he said. We know we’ve lost a lot of historical habitat, and one question is whether, given recovery goals, we have enough good habitat, Booth said. How much additional rearing habitat, for example, is needed to meet recovery goals? he asked.

I keep coming back to the policy implications of this information in terms of projects we are funding, Karier stated. We need to link the research to what it means for salmon, he urged. If fish are dying in the lower 50 km, we have to ask why and what we can do about it, Karier said. If we need to know this, why are we doing habitat work in the upper river instead? he asked.

To get to recovery, you need to start with the adults and work backwards, Ferguson replied. We need complex habitat types because there are many different fish that use it, he said. Juvenile survival is *a* measure, but not *the* measure, Ferguson continued. He said that while the mortality in the lower river might suggest the emphasis should be there, the upper reaches of the lower Columbia River need attention as well.

Jay cautioned against looking too narrowly at only survival. We need to ask questions about why the juvenile fish are not surviving and where that fits into the ecosystem problem, he said. It’s an ecosystem problem, Jay stated. He went on to point out that the Northwest is “a hotbed” of ocean observing systems, and we need to find out how to work with them and make connections.

As a policymaker, it’s fascinating to listen to these presentations, but because of the way research is done, we end up with discrete pieces of information and it is hard to see larger ramifications, Melinda Eden commented. We need to know how to take the discrete pieces of information to make sense of a bigger view of what we should be doing, she indicated. I see a couple of “tipping points” related to water quality and the food web, Eden said. Food web and water quality issues override other issues about habitat, and if we don’t pay attention to them, “we are wasting our time,” she stated.

Norman asked if there are prospects for seeing more information related to jack returns. The numbers are so much greater than we’ve seen historically, he commented.

Ferguson indicated that sampling later in the year may help. We sample Chinook in May and June, and there is some thinking that we sample too early, he explained. There is promise to sampling later in the year; if we can measure hormones early in the fall or winter, we may be able to segregate those smolts into those which will actually jack, Ferguson said.

Isn’t there bigger question about why this is happening? Karier asked. Yes, there is another huge question out there, and we need to get at it, Ferguson acknowledged.

Afternoon Session: Review of Research to Reduce Restoration

Speakers 6, 7, and 8: Jennifer Morace, USGS; Lyndal Johnson, NOAA Fisheries; Elena Nilsen, USGS. Toxic Contaminants and Their Effects on Resident Fish and Salmonids.

Morace listed four “takeaway themes” from the research on toxic contaminants: they are present in the Columbia River Basin; resident and anadromous fish are exposed to them and their health is compromised as a result; urban and industrial areas in the lower Columbia River show the greatest concentrations; and we need more information about how to deal with them. She explained that many of the contaminants reside in fatty tissues of organisms, and sampling for the contaminants involves putting “fat bags” in the river and analyzing the effects.

Nilsen described the results of monitoring for contaminants in fish, citing the effects of endocrine disrupting compounds, primarily from wastewater. Other pharmaceuticals have also been detected at high levels. She also described a food web study to assess the presence and effects of toxic contaminants in the food web. Nilsen said results indicate contaminants are present in water, sediments, and food webs in the Columbia River, with the signature stronger in urbanized areas. With regard specifically to resident fish, she reported that contaminants are present; in suckers, contaminants were found in all organs analyzed.

Johnson reported on contaminants found in juvenile salmon. DDT is found in fish throughout the system, and researchers found PAHs, PCBs, and PBDEs in juvenile salmon. Contaminants can suppress disease resistance, lead to low lipid levels and poor growth, and affect the cardiac and neurological systems of fish; overall, they compromise the likelihood of survival. Johnson also described the effects of currently used pesticides, noting that some disrupt the sense of smell in salmon; there is the potential that some combinations of pesticides can kill salmon outright. Copper, which occurs where there is a lot of vehicular traffic, may also be causing problems.

The researchers said more information is needed on the pathways of contaminant exposure, which could include the aquatic and terrestrial salmonid prey. They emphasized their research has implications for habitat restoration; contaminants should be considered and monitored when selecting sites to restore.

Questions/Discussion: This is the most complete presentation I’ve seen on this topic, Karier commented. He pointed out that contamination from PCBs and DDT is not a new issue. Why don’t we have more information about sources? Karier asked.

We may know about the original sources of such contaminants as DDT, but it is now in the food web, Morace responded. As for PCBs, we are finding they are still being used; it isn’t just a legacy contaminant, there are current sources, she said. Some of the wastewater compounds like pharmaceuticals are so widespread, and PBDEs are also very prevalent – it’s hard to know just what the source is, Morace stated.

I'm trying to relate what Geoff McMichael told us, that fish just disappear in the lower river, with your information, Eden commented. Is there a connection? Is this attributable to contaminants upstream? And could there be a study to figure that out? she asked.

It could be contributing, Johnson responded. One of the things our data shows is very low lipid levels; we are seeing older fish that are ready to go out to the ocean, that have lower lipid levels than fish in the upper freshwater areas, she said. Contaminants could potentially be playing a role in some of the mortality, but it is hard to know for sure, Johnson acknowledged.

With the ConHab study, we are trying to hone in on those things by looking at the organs in fish, Nilsen added. We are hoping to have more specific answers for these questions, she said, noting that it is easier to do the analysis on resident fish that spend most of their time in a single area.

Eden asked if pharmaceuticals could play a role in causing earlier jacks. It's possible; some pharmaceuticals, like synthetic and natural estrogens, could contribute, Nilsen responded. But it isn't clear that the concentrations are high enough to contribute to that phenomenon, she added. There has been a study that exposed fish to estrogen, but when the exposure was taken away, the fish developed normally, she said. A transitory exposure may not contribute to the occurrence, but we don't really know, Nilsen said.

Booth asked about the increased levels of contaminant concentrations in salmonids passing through the Portland area. How do you explain that? he inquired.

We are seeing more evidence that fish are not just passing through the area, Johnson responded. There are some wild fish from the local area that feed and rear in some of these sites, she said. As for the lower level of contaminants in estuary fish, as the fish move and are no longer feeding on the contaminated food web, the concentrations decrease; also some of the fish sampled are local to the estuary and are coming in without any exposure to an urban/industrial area, Johnson added.

You are dealing in the realm of the Clean Water Act and food safety issues that are under the FDA, Booth commented. Are you seeing things that violate the Clean Water Act and pose a danger to humans? he asked.

We don't have water quality criteria for some of these compounds, Morace responded. Sometimes it is difficult to get permit information from sources like wastewater treatment plants, she added.

Are the contaminants moving? Dukes asked. The Columbia River is a large water body and it does a good job of diluting pollutants, Morace responded. When we saw the sediment data, it was surprising because we weren't seeing those contaminants in the water, she said. There are biological accumulators like fish and other species, and sediment is an accumulator, Morace explained. It also depends on the compound; some are more easily diluted, Nilsen added.

**Speakers 9 and 10: Nichole Sather, PNNL, and Ed Casillas, NOAA Fisheries.
Ecological Role of Tidal-Freshwater and Tidal-Saltwater Habitats for Salmonid.**

Sather provided an overview of research to address critical uncertainties regarding tidal freshwater habitats and the early life history of salmon. The study was conducted on the Sandy River delta, which was chosen because it is in the tidal-freshwater area and provides a diversity of habitats. The area is slated for restoration and study data could offer information about how salmon would respond to restoration. Sather said researchers found salmon in all habitats sampled, along with other fish. Researchers looked at the composition of the salmon diet and habitat conditions. She stated there are large seasonal changes in hydrology, and a big issue in the delta is fish access and habitat connectivity.

Researchers gathered samples to study whether the Sandy delta is representative of other areas of tidal freshwater habitats. The study is attempting to link salmon density and fish communities to habitat attributes. Sather said data developed in the study will be applied to restoration activities.

Casillas organized his presentation in terms of “myths” associated with the estuary and saltwater tidal habitat. Among the myths, he listed and responded to the following:

- Juvenile salmon use the estuary for a short period of time as individuals and as populations. In fact, juvenile salmon are present in the estuary year-round.
- Salmon populations predominantly use the subyearling and yearling strategy to succeed. In fact, all ESUs use a variety of juvenile life history strategies.
- Juveniles only use the estuary to transit to the ocean. In fact, juveniles enter the estuary over a wide range of sizes, and residence time varies.
- Juvenile salmon feed primarily on benthic aquatic organisms. In fact, juveniles feed dominantly on terrestrially derived insects.
- Only subyearlings from lower river stocks use wetland habitats. In fact, subyearlings and yearlings from interior basin stocks also use wetland habitats.
- Estuary restoration does not affect adult returns. In fact, recovering a diversity of life-histories contributes to adult returns; restoration is useful and has benefits.

Casillas concluded that the estuary provides habitat for smaller juvenile salmon to grow, and that preservation and restoration of shallow, low velocity, and low salinity environments are important to the recovery of salmon.

Questions/Discussion: Wallace asked about the factors in maintaining diversity and the role of the estuary and the impact of competition between hatchery and wild fish.

Casillas noted that all salmonid ESUs use all of the estuary habitat strategies to some degree, which spreads the risk. He said researchers are trying to get at the question of whether there is enough habitat or needs to be more. The estuary alone will not solve diversity; you have to get the populations through the system and get them healthy in order to produce diversity. As to competition, we do not have good answers to that question, Casillas said. But we know when you put hatchery fish into the ocean when conditions are bad, hatchery fish compete with wild fish in that environment, he said. But we don't know the answer from the estuary perspective, Casillas acknowledged.

Maslen noted that with lower river fall Chinook using a high proportion of the estuary, one could argue there may not be enough habitats – you may need more for upriver stocks. Casillas responded that researchers in the Skagit River came up with a number for how many fish (4,400) could be supported per acre of habitat. We looked at our numbers in the Columbia River estuary, and so far, we're seeing about 1,100 per acre. We haven't seen saturation with the data we have, but it could happen, he stated.

In your presentation, you said a lot of Chinook migrate into the estuary at the fry stage, Norman commented. Do you have information about other migrants? he asked. Casillas said that a study on the Sixes River showed the dominant strategy to be subyearling; but there were also fry and fingerlings present.

Speaker 11: Mary Ramirez, University of Washington. Development of an Ecosystem Classification System for the Columbia River Estuary.

Ramirez explained the classification system that is being developed for the Columbia River estuary. There was no “off-the-shelf estuarine classification scheme” that effectively addresses tidal-freshwater regions, a major gap in existing classification schemes. She explained the approach to developing the system and the tools used.

The Columbia River classification framework is developed at six hierarchical levels, and Ramirez described each level and its characteristics. The classification system can be applied to managing the estuarine resource, as well as facilitating research, monitoring, and evaluation (RME), and planning and guiding restoration and preservation activities. Ramirez reported that the classification framework will be complete by summer of 2011.

Questions/Discussion: Maslen asked how is empirical data derived on what salmonids consume? Ramirez responded that it is gathered in intensive studies of 30 hours in length. We catch fish and process their stomach contents to determine their diet, she said.

Speaker 12: Tracy Yerxa, Bonneville Power Administration (BPA). Implementing the 2008 FCRPS Biological Opinion Using Emerging Scientific Tools and Restoration Strategies.

Yerxa laid out funding levels for Biological Opinion-related actions in the estuary, including a significant recent increase for RME. An agreement with the State of Washington is expected to add some funds, as will appropriations the Corps of Engineers is seeking from Congress. Yerxa described the Reasonable and Prudent Alternatives (RPAs) that pertain to estuary habitat and RME. BPA is funding work on the habitat classification system, as well as a demonstration restoration project in Reach F, which includes the confluence of the Willamette and Columbia rivers and Portland. She reported that BPA has many partners in the project, including agencies, tribes, and watershed councils.

Questions/Discussion: That was a good overview of where the BPA dollars are going, Karier commented. We are opening up more habitat, taking out dikes, and increasing access to wetlands, he said. We've also heard today about issues of quality, including water quality, non-native species, and vegetation. Is BPA thinking about quality issues, as much as quantity? Karier asked.

We will use the new habitat classification system to consider quality as well, Yerxa replied. In response to a question from Colin Levings, she said land use boundaries would be overlaid onto other features in the classification scheme.

Speakers 13 and 14: Cathy Tortorici, NOAA Fisheries, and Phil Trask, PT&A. Review of Estuary Actions for Salmon and Steelhead Contained in the Columbia River Estuary ESA Recovery Plan Module of NOAA's 2008 Biological Opinion and the Council's Fish and Wildlife Program.

Tortorici gave an overview of the evolution of estuary actions since the 2000 Biological Opinion, as well as related actions identified in the Council's 2009 Fish and Wildlife Program. The current Estuary Module in the 2008 Biological Opinion is a plan to help improve estuary survival for salmon and steelhead listed under the Endangered Species Act. The Action Agencies are looking for projects that will restore estuary habitat and provide survival benefits for anadromous fish.

Tortorici said the module is about salmon and the ecosystem as a whole and is the basis for looking at projects and focusing on those that will make a difference for salmon survival. There are also issues related to monitoring in the estuary and plume, and she pointed out that RME results will be used to shape future actions. Tortorici described an important issue for the estuary as the impact of flow regulation and connection between the lower and upper river, and she called collaboration key to estuary restoration.

Trask described the recovery plan module for the estuary. The first draft was completed in October 2005 and has since gone through revision. The ISAB reviewed the plan and issued a report in 2008. Trask listed the module elements – limiting factors, threats, management actions, cost, schedule, and monitoring and said there are 23 comprehensive actions in the plan, which are supported by projects. He reported that a proposed draft of the module was submitted to NMFS and a final draft will be available in October 2009.

Questions/Discussion: Dukes asked how the “expert panel” that is part of the RPA fits with the Council's process. I would like to think they are integral to your process and what you are trying to accomplish, Tortorici responded. I think we need to bring the two together to make that happen, she said, adding that the RPA process has just begun.

We are wasting our time if we review lots of projects and don't have a collaborative effort, Dukes replied. Plus, you're using a recovery module that didn't fare well with the ISAB in its review, she stated.

Panel Comments and Session Wrap Up

Walton said he was impressed with the information presented. He said he was particularly interested in McMichael's finding about juvenile salmon losses in the lower 50 km of the river. When will we find out enough information about these losses to be confident we are spending our money in the right place? he asked.

We have four to five years of survival data, and we see a consistent pattern with the level of survival, Ferguson responded. Each year when the lower reach is divided, we see most of the mortality is farther downriver, he said. The fundamental question is whether

what's being reported is a true representation of the lower river or an artifact of something else, like the way fish are being tagged and detected, Ferguson explained, noting a discrepancy between acoustic and PIT tag results. There is a challenge before us to resolve this issue, but we don't know how long it will take, he said. I don't think there are a lot of predators in the lower river, but there is difference between what the two tools, acoustic tags and PIT tags, tell us and we have to reconcile that, Ferguson said.

I have a high level of confidence in our data, McMichael stated. As someone pointed out to me earlier in the day, we have never been able to measure this before – the mortality may be higher than we expected, but it may not be abnormal, he said. These fish are going through a large physiological change in the estuary to adapt to saltwater, and this mortality may have been going on forever, McMichael suggested.

That lower river zone is part of the smoltification process, and it has to be a big stressor, Wallace commented. It's a zone where you might naturally see mortality, he said.

Levings suggested it would be interesting to be able to observe the fish when they enter the saltwater wedge to see if it is a stressful zone. Ferguson said he would be surprised to see the salmon “take a 25 percent hit” when they enter the ocean environment. They are physiologically ready to enter the ocean, and it would be difficult to track them – they are moving very fast. It would be interesting to see what they are doing, Ferguson added.

Earl Dawley pointed out that fish losses detected in mobile tracking and with tracking arrays are similar. The two methods track different things, McMichael said. The mobile tracking is focused on a much smaller number of fish; we are not getting a survival estimate with that tracking, he said, adding there is a lot of data that isn't yet fully analyzed. McMichael said that where the two tracking mechanisms have been correlated, however, the data is almost a perfect match.

Karier pointed out a potential discrepancy between theory and practice. One is in outcome, he said. We think of outcome in terms of numbers, but we've also heard we want diversity of habitats and life histories, Karier said. The other discrepancy is with the actions; in practice, we are focused on quantity, i.e., number of dikes and acres, but in theory, it's more complicated, he said. We need to think about the quality, but that's not where the dollars are going, Karier stated.

We've come a long ways since 2000, Ferguson replied. We have to think beyond just survival numbers and consider the benefits we are getting from various activities, he said. We are setting the stage to work on quality issues, Ferguson said, adding that the Action Agencies “should feel good about where we are – it's only been about 10 years.”

Tortorici pointed out that the agencies are dealing with quality issues, “but not necessarily in this forum.” She referred to a joint Corps/EPA sediment manual that was developed, calling it is an example of how water quality is being addressed. One of the drivers from Day One was consideration of life history and diversity, Tortorici continued. Because we are talking about survival, don't think life history and diversity aren't built into it – they absolutely are, she stated.

We've heard a wealth of information today that guides us in the near term and has implications for the long term, Norman stated. In terms of quantity and quality of habitat in the estuary, I can't help but think there is a relationship between tributary and estuary habitat in terms of rearing and survival, he said.

In the Grays River, we are taking a detailed look at survival, Ferguson responded. This area is far from the main estuary, but when restoration actions were taken, juvenile salmon, chum and coho, moved in right away. Tributary actions are important, too, he said. Ferguson said intensively monitored watersheds are needed to prove up on concepts – it's absolutely the way to go.

Habitat quality is important, and the Action Agencies are committed to taking actions to protect and enhance habitat to benefit various species, Maslen said. We're looking at all kinds of issues with regard to enhanced ecosystem function, he added. We are focusing on "the right attributes" as best we understand them and adjusting as we learn more, Maslen stated.

We have \$30 million to invest in the estuary, but our money comes with requirements too, Laura Hicks stated. She emphasized the important role of adaptive management in carrying out the actions: "if it isn't working, we adapt it."

Booth asked why researchers aren't tagging sockeye. We probably should be – it could and should be done, Ferguson responded. They are a different animal; they feed at a different level and they descale more readily, he added. We should try it, and if we did, we could study the survival from Bonneville Dam to the ocean, Ferguson indicated.

No one has asked me to tag sockeye, McMichael added. The mid-Columbia PUDs have done some work with sockeye and some of my colleagues at PNNL have done research on implanting acoustic tags into sockeye, he said. The sockeye handled it very well "to the surprise of the researchers," McMichael said.

We set out 15 years ago to recover coastal coho, according to Bruce McIntosh. We went right for the numbers; we had lots of monitoring, but found we were not focusing on the right things, he said. We made changes in upland habitats, which helped, but it was the lowland habitats that needed attention, McIntosh said. Now we are focusing on the overwintering habitats, he said. Unless you are monitoring and can learn these things, it's hard to make the right changes, McIntosh added.

Morace pointed out the importance of "holistic environmental considerations." Do you want to get fish back if they are returning to an old superfund site? she asked.

Water quality is an important overlay, Maslen agreed. And "water connects all of the pieces," Jay added. We know the climate is changing, and as we focus on how to improve survival in the current environment, are we thinking about climate change in the future? he asked.

We are, Wallace replied. That is the most recent new part of the Council's Fish and Wildlife Program, he said. We don't know exactly how to address it given the complexities, but it's embedded in the program, Wallace stated.

Many federal agencies, including NOAA Fisheries with the Biological Opinion, are including climate change in their work, Walton stated. As the modeling evolves on climate change, it will be incorporated, he added. The Council's draft Sixth Power Plan absolutely addresses climate change, Eden agreed.

Nathan Reynolds of the Cowlitz Tribe noted that he had not heard anyone mention smelt or lamprey. I would urge the Council to consider that long before any species come off the ESA list, more species will go on, he said. You need to work to integrate the new challenges, Reynolds said.

That's a great comment, Wallace responded. We have talked about high-level indicators for our fish and wildlife program, and from the broader standpoint, the Council takes a holistic approach to the ecosystem, he said.

Ferguson pointed out that green sturgeon are also on tap to be listed. We don't understand their ecology very well, but they use the estuary and are out there as a species to consider, he said.

Day 2, Morning Session: Case Studies of Various Habitat Restoration Actions, Adaptive Management, and Action Effectiveness Monitoring.

Speakers 15 and 16: Catherine Corbett, Lower Columbia River Estuary Partnership (LCREP), and Ian Sinks, Columbia Land Trust. Overview and Approaches to Ecosystem Restoration in the Lower Columbia River.

Corbett described changes in the estuary habitat, including the loss of complexity, and addressed the need to restore historic diversity. She laid out the restoration goals, 16,000 acres by 2010, and 19,000 acres by 2014. She cited 160 restoration projects in the lower river, where over 500 acres of historic flood plain have been reconnected. Restoration projects include passage improvements, floodplain reconnection, and habitat enhancements.

Corbett labeled the approach to restoration so far as "opportunity-driven" and acknowledged that efforts have been fragmented and not integrated with upstream projects, and without links to water quality or food webs. She explained efforts to improve the program, moving to a strategic approach and increasing coordination. Corbett described the various tools LCREP is designing to inform restoration and said the goal is to have a "report card" for each restoration project and for the program as a whole.

Sinks said a strategic approach will enhance estuary restoration activities. Most restoration is focusing on processes and structure that leads to quality habitat and functional benefits. He described the ways to restore controlling processes in the estuary. The easier, lower-cost options include planting and weed control; tidal reconnections and multiyear projects are more difficult and costly. Securing land is a major challenge and involves a lot of time and effort; flood control is another big issue with landowners.

Sinks reported that permitting has gotten easier for restoration projects, but timing and bringing together funding is complex and involved. Many projects require follow-up and maintenance, which is something sponsors needs to address.

Questions/Discussion: I'm particularly interested in the strategic approach, Wallace said. Are you setting priorities for different parts of the estuary? Are you targeting habitat types? Is there a lull as you transition? he asked.

We have built the science to go with a strategic approach, but we haven't worked out all of the issues yet, Corbett responded. Our target at this time is to restore the estuary's natural historic diversity, she said.

Maslen raised the issue of providing feedback to projects about how they perform and how well the project criteria ensured performance. We want to collect data for effectiveness monitoring and gain that important feedback, Corbett said. We meet on a regular basis and have a feedback loop, she said. The monitoring has helped us explain and assuage concerns in the community, Sink added.

Where are we on protection? McIntosh asked, adding that the rate of degradation still exceeds the rate of restoration. Columbia Land Trust would agree with that statement, Sink responded. Protecting the best is still an important element of fish recovery, he said.

Corbett pointed to an "unintended consequence" of the Biological Opinion, which give the agencies a legal mandate to implement projects with survival benefits. This could exclude funding for land acquisitions since there might not be direct survival benefits in some acquisitions. You would have to show the land would have been developed unless it is required, she said.

Maslen agreed the Action Agencies need projects with survival benefits. But I look at this less on a single year basis and more over time, he said. As you transition to a more strategic approach, we can move down that continuum from less optimal to more optimal suites of projects that lead to more ecosystem benefits, Maslen said.

Speaker 17: Blaine Ebberts, Corps of Engineers. Adaptive Management for the Ecosystem Restoration Program in the Lower Columbia River and Estuary

Ebberts described the Corps' adaptive management plan for ESA-listed salmon and said one of the Corps' ecosystem goals is to improve the performance of these fish. Adaptive management requires a goal, a plan, an evaluation framework, and research that reduces uncertainty; it also requires collaboration among participants. In the end, he said policymakers need to synthesize all the information to make strategic decisions.

Ebberts pointed out that multiple entities are working on restoration, with millions of dollars being spent. He acknowledged that progress with adaptive management has been slow, but positive; we are moving in the right direction. Ebberts said research informs decisions and a synthesis of research allows a look at cumulative effects estuary wide.

He listed challenges for implementation of adaptive management. Ebberts said the region has the basis for an adaptive management program for ecosystem restoration in the estuary. Increased funding to organize, synthesize and disseminate the data is needed.

Questions/Discussion: The Corps is a large agency with a lot of mandates. Are adaptive management and ecosystem approaches being built into other Corps mandates, such as dredging and flood control? Wallace asked. Adaptive management might be a tool to get to an interagency, interdisciplinary approach to restoration, he commented.

After Hurricane Katrina, Ebberts said the Corps identified actions for change. One of those actions was using adaptive management throughout the agency, he stated. A lot of pieces of what we do are interconnected – as someone said earlier, the water connects it all, Ebberts added.

We were pretty successful in adding adaptive management for our dredging program, added Hicks. We reviewed the Biological Opinion and looked at where we are dredging, she said. We look at this information quarterly and consider how what we're doing affects salinity, temperature, and other water conditions. This is a program that has been going on for years; the Corps has an adaptive management platform that is up, running, and working, Hicks stated.

**Speaker 18: Micah Russell, Columbia River Estuary Study Taskforce (CREST).
Project-level Effectiveness Monitoring in the Estuary and Response in Fish
Communities.**

Russell described the work of a partnership of organizations at four sites that represent diverse habitats and species in the lower river and estuary. The sites include Mirror Lake, Fort Clatsop, Scappoose Bottomlands emerging wetland, and the Sandy River delta. He reported on the active effectiveness monitoring program that is going on and listed the protocols and parameters that are used to assure the monitoring is useful to others and the data is comparable across sites.

Russell outlined the projects, with a focus on Fort Clatsop's South Slough, which he called typical of lower rivers that have been extensively diked. The project was a culvert replacement that reconnected 50 acres of historical off-channel rearing habitat; it returned the area to a "functioning wetland." The response from salmonids was immediate; researchers have seen chum, coho, subyearling and yearling Chinook, steelhead, and cutthroat. Russell provided a description of the fish, saying they are by and large unmarked wild fish and also hatchery fish. We need to better understand which stocks of fish are utilizing restored habitat.

Researchers are working on a "meta-analysis" of monitoring and evaluation data for the lower river and estuary, using data from four parameters at the sites: inundation, water temperature, sediment, and salmon presence. Salmon were present after the project work in all but one of the sites, the Vera Slough. Russell said long-term monitoring data (at least 10 years worth) on at least a minimum set of metrics is invaluable.

Questions/Discussion: Wallace asked if the researchers can determine where the fish are coming from. We have taken fin clips and are analyzing them genetically, but we don't have that information yet, Russell responded. We speculate there is some local spawning going on and that some of the fish are products of net pens, he said. These fish could also be coming through the hydropower system since the sites are not that far off the migration path; we would really like to look at this further, Russell stated.

Norman asked about the implications of the monitoring for adaptive management. Are there discoveries that would lead us in the right direction? he asked. We're just getting started with that, Ebberts responded.

What is the measure of success? Walton asked. Are the projects encouraging productivity, diversity, and spatial distribution? he asked. We trying to get at basic metrics, Russell replied. We're thinking about those things, but now we're trying to keep the monitoring effort going long term, he said, adding that he would like to see some intensively monitored watersheds where such information could be gathered.

McIntosh noted that ODFW is monitoring in Young's Bay. The status of coho is very weak, he said, and there are lots of challenges in that area, which is inundated with hatchery fish; net pens pose an additional challenge.

Speaker 19: Ron Thom, PNNL. Evaluating Cumulative Ecosystem Response of the Columbia River Estuary Ecosystem to Past and Current Restoration Efforts.

Thom described efforts to develop a cumulative effects analysis for the Columbia River estuary, defining it as "the net sum of all changes in selected habitat metrics of all restoration projects occurring over time *or* the net change in ecosystem metrics." He said no one is doing cumulative effects analyses on an ecosystem like the Columbia River estuary, and Thom and his fellow researchers developed a "levels of evidence" approach. The research hypothesis is that restoration will have a cumulative benefit for salmon.

Thom described the sites and indicators of effectiveness being monitored and explained how cumulative effects will be analyzed. For each site, we know the stressors; if you restore the sites, you can calculate the net benefit of restoring the entire system. He also cited studies that link estuarine habitat to juvenile salmon survival benefits. Thom listed findings and products from the analysis so far and offered recommendations, among them the need for more concentrated and coordinated monitoring.

Conference Summary

Colin Levings, a member of both the ISAB and ISRP, offered a summary of take-away messages and insights from the two days. He said the presentations show an impressive array of science projects that are contributing to RME. The following are highlights:

- The ongoing monitoring has produced "excellent information" on salmon use of the estuary and plume; there are questions about the ESUs missing from the estuary and a deficit of sampling in the upper estuary. We heard a re-emphasis on life history diversity; there are salmon in the estuary all year, as we heard in the 2007 presentations. Out past the Columbia River bar, we are seeing mortality; is it linked to the estuary?

- In the systems overview, boundary conditions are important on both the sea and landward sides; the estuary has been squeezed at both ends, with hydro effects from the landward side and the natural tidal cycle from the seaward side.
- Invasive species pose a very valid concern; habitat alteration gives these species a foothold in some cases. The early detection system is slow to respond.
- For the wetland characteristics, eelgrass is being sought as a high-quality habitat. Emergent wetland shows inter-annual variability; data on the shrub-scrub wetlands are needed at all trophic levels.
- Plume survival is being tracked with the JSATS technology; researchers found survival is good to the last 50 km of the river, then decreases, and decreases even further toward Astoria. We need to know why and whether it is real. Is there a relationship with fish that overwinter in the estuary?
- Contaminants present a risk to restoration success and should be a factor in project site selection. Contaminant research shows 20 percent of the wild fish have lipid loss, which could affect health, survival, and production.
- For tidal freshwater habitats, the Sandy River delta research confirms their importance. Validation of whether the research sites are representative is a good thing to do. There are a number of myths versus reality for tidal salt-water habitats; fry is a dominant life history strategy for fish entering the estuary.
- Ecosystem classification tools are very important and will provide an agreed-upon currency for research. The pilot study in Reach F will help focus the work and lead to buy-in. Further integration of various agency efforts is needed.
- With regard to the case studies, we heard the need for a central coordinating body to get all research under one umbrella. Long-term maintenance is important for many projects; adaptive management is key to the success of projects.
- Project-level effectiveness monitoring is producing very important basic data; choosing index locations for monitoring is a very good approach.
- A cumulative effects analysis will be very important to see what happens in the long run with all of the projects that are under way.
- There is concern about the habitat quality in terms of contaminants, the quantity of food available, and whether there is a difference in the types of food salmon eat that contributes to their development.
- There is no silver bullet. The river needs to be viewed as a continuum, from the watershed to the mainstem to the estuary to the ocean; events outside the estuary can override the estuary benefits. An experimental approach, such as an intensively monitored watershed, would be valuable.
- A goal or vision for the estuary that is a crossover between legal, science, and economics would be valuable and would help focus efforts.

Wrap Up Panel Discussion

We've heard consistently about the need for collaboration, Dukes said. I'm hoping we can come away from here with a starting place for collaboration, she added. I'd like to see the research reports and science on the estuary in one central location, Dukes said.

We all have differing roles, Maslen said, suggesting a longer session at the next policy exchange to explore and synthesize them. BPA's role is primarily mitigation, Maslen

said: has it worked? Are we soliciting projects that best meet our goal? We need to see how work interconnects efforts across multiple years, he added. By 2010 we should have a report on what work has been done and what we've learned. It would be interesting to check in one year as to how we have done on collaboration, Maslen concluded.

Hicks said she would like to see groups hone in on where we need to focus along the 160-mile river corridor and identify more habitat restoration sites sooner where things are needed. Habitat restoration should include consideration of water quality.

We face great challenges about how we translate research and monitoring information into restoring ecosystems, McIntosh said. He pointed to the human dimension of restoration, noting there are thousands of landowners trying to implement projects. McIntosh said people need to see a restored watershed. We need to look at watersheds where there is the social will to do restoration and focus on them, building demonstration projects, possibly intensively managed watersheds, he suggested. How do we put "the proof in the pudding" so humans can see what we know about the watersheds, McIntosh said. We may need to invest in figuring out how to work with people more effectively to change attitudes and provide incentives, McIntosh added. We need more work on the human side of the equation.

That's a great point, Walton responded. Let's hone that into a more specific "to do," he agreed. We need to better understand and identify the barriers and incentives landowners and practitioners face in ecosystem restoration, he said. I've observed a sea change in terms of environmental groups and rural interests, Walton said. More people are seeing that a well-managed forest or rangeland is a better neighbor than a housing division or mall, he indicated. We should take advantage of this more productive and cooperative atmosphere, Walton said.

Nancy Huntly, ISAB chair, praised the science exchange, noting the opportunity to hear about things we otherwise don't know about. She said the collaboration theme is "an old theme" and pointed to enormous progress represented by the combinations of groups that are coordinating efforts, conducting the research and presenting the talks. In terms of possible future action, an extensive monitoring program (with many probabilistically selected sites at each of which low-cost, low-intensity attributes were monitored) could complement the IMW network to give a basin-wide evaluation of status and trends, Huntly said.

Eric Loudenslager, ISRP chair, said the presentations reflected "reasonable progress" on ways to assess salmon populations in the estuary. I see three key uncertainties in the estuary. First would be changes in river flow due to storage and regulation, he said. The hydrograph has changed enormously with the hydro system and dredging; they set boundaries and a different configuration that will constrain what fish can do in the environment, Loudenslager said. A second uncertainty is invasive species, some of which we may have to live with, he said. The estuary may have changed in terms of its capacity for salmon – it has to be different than it used to be given the number of non-native species that are now there, Loudenslager added.

The third uncertainty is toxic contaminants and their effects on salmon and habitat restoration sites, he continued. When we see low lipid levels in fish, it has to raise concerns about their ability to transition into salt water, Loudenslager said. “Their physiological changes are quite astounding and remarkable,” and having different chemicals present that they haven’t evolved with could influence their internal functioning, he said. Loudenslager said some ISRP members have suggested having an intensively monitored watershed associated with an estuary restoration project(s) to demonstrate and measure what happens as a result of that work. Adaptive management should include simulation modeling, with defined interventions that occur followed by monitoring to see what happens, he advised.

Booth pointed out that statutorily, the Council’s obligation is to develop a fish and wildlife program to mitigate the development of the Federal Columbia River Power System. There is an issue for the Council in terms of our role with some of these issues, like contaminants, he said. We need to think about what our role should be, other than being informed and advocates, as we move forward with the emerging issues, Booth said.

When I look back in recent history, the various federal, state, and tribal entities say they base their decisions on science, Norman commented. But it’s not the same science, he pointed out. What I’ve seen at the exchange is a real example of the interconnectedness of various studies, Norman stated. It’s a good example of what we could do more of to coordinate our respective policy decisions in relation to science, he stated.

Eden applauded the opportunity to hear the issues presented by speakers, as opposed to reading thick reports. She said she is already working on water quality issues – I want to get the regional water quality agencies to talk to us about what we can do to work on these issues. Eden acknowledged that for the Council, the issues “have to be hydrosystem connected.” We have the underpinnings of that connection, but “we can’t do and shouldn’t do the work of the water quality agencies,” she added.

But we can do discrete scientific studies – if we don’t supply clean water for the fish “we are swimming upstream,” Eden stated. She said it would be helpful to translate the scientific information into what we do next. We are assuming there will be a benefit to salmon, but I want to know how many fish we are going to affect, Eden said. “That’s how we translate science into policy,” she added. Eden also suggested the region should look at the cooperative model being used in the Walla Walla watershed and try to apply it elsewhere.

This exchange has been extremely valuable; it has met and exceeded my expectations – it is science and policy at its best, Wallace wrapped up.

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