WORKSHOP ON BIOINDICATORS AND CLIMATE CHANGE

Potomac Yard Complex
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CONTRIBUTORS

Numerous people contributed to the conception, development, and successful implementation of this workshop. Contributors included

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1 INTRODUCTION

The goals of this workshop were twofold:) to provide state and tribal biocriteria managers with updated information on how climate change may affect their monitoring and assessment programs for protecting and restoring their water resources; and 2) to obtain inputs and perspectives from the state and tribal biologists and managers on potential sensitive indicators, trends in biomonitoring results, conflicts already perceived among bioassessment objectives, thoughts regarding future directions for existing biomonitoring programs to address climate change, and concerns regarding resources or other potential implementation issues related to climate change adaptations. While the first workshop focused primarily on stream and river systems, as these are generally the most advanced in the development of bioassessment and biocriteria programs, this meeting also brought lake systems into perspective in relation to climate change. These systems provided an historical view from which to analyze climate change effects on program components and results and to evaluate alternatives. This workshop is part of an ongoing process to assess program vulnerabilities and to define an approach for adapting management of all aquatic ecosystems. Inputs from the participating state and tribal bioassessment/biocriteria managers, summarized in Section 5 (below) helped to identify existing concerns and focus further analyses on the most vulnerable aspects of bioassessment and monitoring programs across the country.

2 PARTICIPANTS

Overall there were approximately 74 participants attending this workshop, including representation by 26 states, 4 tribes/tribal organizations, 4 U.S. Environmental Protection Agency (USEPA) representatives from the Office of Research and Development (ORD), 6 staff members from the Office of Water (OW), 1 staff member from the U.S. Geological Survey, 1 speaker from National Center for Atmospheric Research (NCAR), 2 staff members from the American Rivers (Washington, DC-based NGO), and 6 academic researchers. All workshop participants are listed with contact information in Appendix A.

3 WORKSHOP STRUCTURE

Keynote presentations set the foundation for the workshop, progressing from an overview of global climate change effects on aquatic ecosystems to research on specific temperature tolerances and biological responses to climate change. During the breakout sessions, technical,

implementation and strategic issues were discussed, along with strategies for integrating the climate change paradigm into existing state and tribal water quality programs. Case studies were presented to aid in understanding the technical ramifications of adapting existing biocriteria programs. A brief synopsis of each presentation is given below; the PowerPoint presentations associated with each talk were printed and distributed to each workshop participant, and are available online at: http://www.epa.gov/ncea/workshop/.

4 SUMMARY OF PRESENTATIONS

4.1 Climate Change Effects on Aquatic Ecosystems

Dr. LeRoy Poff of Colorado State University presented an overview of major aspects of climate change effects expected on aquatic ecosystems. He connected global climate change back to local ecological responses with both a conceptual model and causal links. Dr. Poff showed that from an individual (e.g., body size) all the way to an ecosystem level (e.g. productivity) climate change is affecting ecological responses. He went on to use an example of ice melt in lakes and projections for warming based on reduced ice cover. That warming would in turn influence shifts in natural fish habitat and allow for many different invasive species to potentially populate new territory. Dr. Poff also indicated that climate change is not occurring in a vacuum. Other stressors, such as land use change, are affecting the natural environment and may overwhelm the climate change signal in any given area. He indicated the usefulness of certain applications (e.g., CADDIS) to assist in the determination of what stressors may be strongest in any one system. Finally, Dr. Poff stressed looking at species traits along environmental gradients to aid in knowing which traits should vary "mechanistically" with climate change.

4.2 Historical Climate Reconstructions Using Lake Indicators

Dr. Sherilyn Fritz, University of Nebraska – Lincoln, Department of Geosciences, presented long-term perspectives on climate change impacts on lake ecosystems. She began by giving everyone a brief background on paleolimnology and some of the tools (sediment cores, diatoms) used to measure the history and indicators of lake age. Dr. Fritz explained how it is possible to interpret changes in lake levels, possibly due to climate change, through sectioning and carbon dating lake sediment cores. She went on to explain how diatoms can also be used to show shifts in lake levels, and to interpret changes in species composition and food webs. Dr.

Fritz maintained that both climate and lake ecosystems show considerable variation that must be considered when evaluating recent trends. For example, major periods of drought in the historic record are a potential confounding factor to which flora and fauna (e.g., diatoms), as well as lake geochemistry may not respond in a linear fashion.

4.3 Climate Change Observations, Models, and Tools

Dr. David Yates from the National Center for Atmospheric Research (NCAR) explained how global climate models reproduce the climate system and what we learn from them. He gave an overview of how climate models have become increasingly more detailed and therefore better representations of actual climate patterns (e.g., more reasonably representing climate around mountains and other topographic features), and also summarized major model uncertainties. Dr. Yates indicated that while Global Circulation Models (GCMs–climate models) are not intended to detect anthropogenic climate changes, they shed light on attributions of major sources of changes. He described specific examples of using regionally refined or statistically downscaled climate modeling to assist water utilities understand and plan for future impacts of climate change on their ability to provide a reliable water supply, stressing that these utilities are more concerned about the security of supply than climate change. Dr. Yates described how the generic flow models are being adapted to include climate change forecasts. He then summarized this process in an example watershed.

4.4 Climate Change Effects on Streams, Rivers Focusing on State Programs

Dr. David Allan of the University of Michigan focused on how to define climate change in the context of aquatic assessments. Is climate change a new stressor, does it interact with other stressors, or is it both? He emphasized that certain physical impacts to aquatic ecosystems can have the same outcomes as climate change. Dr. Allan also discussed vulnerabilities to climate change effects, especially in ecological transition zones. He discussed adaptation, and for managers, "managing the unavoidable". There is a need to find ways to adapt to new climate, since the climate is changing. One way would be to cautiously update bioassessment tools; deciding when and how to factor climate change into decision making is essential when building or updating infrastructure or making long-term decisions for a bioassessment program. Dr. Allan concluded with some expectations of climate change (e.g., longer growing season) and specific actions (e.g., establish sentinel sites) we could take moving forward.

4.5 Long Term Studies Using Indicators to Detect Climate Change

Dr. Piet Verdonschot of the Netherlands Center for Ecosystem Studies presented the European view of climate change and a model of how to respond to the interaction between climate and other changes (i.e., land use, nutrient loading, acid deposition) in the best interest of conservation and finally to communicate this to the community, stakeholders, and decision makers. He talked about the indicators of climate change, including glacier retreat and ice break-up, and about changes in land use, sinuosity, discharge, and climate that have led to a decline in macroinvertebrates over the past 30 years. Dr. Verdonschot followed-up with a discussion of warming, and the various effects on rivers and biological indicators, such as brown trout and spring algal blooms. He also described the climate signal in European lakes as well as persistence and stability in Swedish streams using various statistical measures. Dr. Verdonschot concluded that among many things, variation in precipitation and discharge alter the composition and function of stream ecosystems and that current assessments may have "overlooked" climate signals.

4.6 Research on Temperature Tolerances

Dr. Lester Yuan of the US EPA Office of Research and Development (ORD) National Center for Environmental Assessment (NCEA) asked how climate variability influences invertebrate assemblage structure and biological assessment metrics. He used a case study of the Upper Grande Ronde River in Oregon to test the average summer air and water temperatures and ensuing macroinvertebrate assemblage composition. Dr. Yuan found that while general richness metrics are associated with many environmental factors, including climate, temperature-specific metrics may provide a more predictable response. He followed-up by explaining that different taxa require different environmental conditions (i.e., temperature) to survive. Regional data were used to develop inference models to predict long-term temperature histories at the study sites. While biologically-inferred temperatures increased over the study period, the relationship between temperature inferences and direct measurements was not strong. Dr. Yuan suggested that refinement of taxon-environment models to include more variables may yield more precise predictions.

4.7 State Data Sets and Climate Change Effects

Chris Yoder of the Center for Applied Biodiversity and Biocriteria, Midwest Biodiversity Institute (CABB/MBI) presented data from Maine and Ohio with initial climate change observations. Maine's fish sampling and assessment program was reviewed with preliminary remarks: 1) Maine's rivers are "isolated" coastal drainages which may increase their vulnerability; 2) Physical stressors are readily apparent (hydrologic, habitat, thermal); and 3) These stressors could be exacerbated by climate change. The Ohio dataset was discussed in a stress/response format, with typical chemical stressors addressed, as well as temperature tolerance. Mr. Yoder concluded that expanded assessments are necessary with experiments to design field-derived stress/response analyses.

4.8 Climate Change, Aquatic Ecosystems, and Biological Indicators

Dr. Britta Bierwagen of the US EPA Global Change Research Program (GCRP) in NCEA/ORD, gave an overview of the current thinking of consequences of climate change on aquatic ecosystems, the effects on biological indicators, and the current and on-going research within EPA, States, and Tribes. She mentioned the effects that warming of the atmosphere would have on water temperature, quantity, quality, and flow; and also how these effects would have management consequences, on bioassessment programs and other water resource programs. As Dr. Bierwagen talked about State biocriteria program goals, she mentioned that comparison to reference conditions was fundamental to defining targets of desired condition, but that climate change effects on both reference and non-reference sites creates a moving baseline, presenting challenges in both the short and long term. She discussed how current indicators may be confounded by climate change and measures may respond differently than expected based on climate. Accordingly, she presented a framework of categorizing indicators based on their sensitivity to various climate change effects through consideration of species traits as well as observed responses, and as an approach for developing climate sensitive and insensitive indices. Dr. Bierwagen went on to define climate sensitive and insensitive indicators. She referenced the important but potentially difficult objective of inserting climate change wording into biocriteria program management goals. She discussed particular needs for more information, as well as next steps to be taken, to begin to adapt bioassessment programs in response to climate change effects.

4.9 Case Study: Comparing Hydrologic Response to Fluctuating Climate with Land Use Effects

Dr. Michael Paul of Tetra Tech, Inc., Center for Ecological Sciences, presented results of a case study that compared the effects of land use and climate on aquatic systems. He began with a background on hydrology, explaining why flow is important to stream organisms. Dr. Paul went on to explain flow in the context of climate changes, in various parts of the country. He expanded this explanation to urban growth, specifically to the "Baltington" (Baltimore-Washington) region, and described how years of historic flow data were partitioned into a group of average annual flows delivered by an average number of storms, and a group of average annual flows delivered in significantly fewer than the average number of storms to mimic possible future climate change. Comparing flow rates from urban and forested areas, he found that during high flow events, future climate effects were not important relative to land use changes; however, during low flow events, future climate effects were important relative to land use changes. Dr. Paul summarized that due to this difference, the effects of climate change will be felt to differing degrees – relative to land use change.

4.10 Pilot Study: Evidence of Climate Change in State Bioassessment Data Sets

Ms. Anna Hamilton of Tetra Tech, Inc., Center for Ecological Sciences, presented preliminary results of a pilot study examining state bioassessment data from four states: Maine, North and South Carolina, and Utah. The Maine data focused on a specific site, which was rated to be in reference condition "AA", but not pristine according to the Maine bioassessment program protocols. The site has been sampled for 23 years. Ms. Hamilton looked at various stressors in a community ordination analysis, including year, temperature, stream bed components (gravel, pebble, sand), flow, and conductivity. Year was the strongest factor associated with observed differences in community compositions. Ms. Hamilton reported on evaluation of taxa traits to predict and test responses of potential climate change indicators, and on associated development of a traits data base. She discussed the potential importance of level of taxonomy in consideration of temperature preferences and tolerances, using *Baetis* and *Rhyacophila* as specific examples. Multiple benthos inferred temperatures were also plotted from 1984-2006, with the inferred temperatures rising at the Maine sample site about 1°C or a bit more, though inferred temperatures and measured temperatures were not significantly correlated. The actual summer temperatures have also risen from a long-term gauge northeast of this site almost 3°C since 1970.

4.11 Approaches for Maintaining Reference Conditions and BCG in the Face of Climate Change

Mr. Evan Hornig of EPA's Office of Water, Office of Science and Technology (OST) presented background information about the Clean Water Act, in reference to climate change and reference conditions. His discussion included information about determining aquatic life uses using reference sites, and how the original definitions for biological integrity or biological condition gradient may need to be updated to take into account climate change effects. Some of Mr. Hornig's suggestions included protecting reference sites influenced by climate, adding sentinel sites to a sampling regime, include emphasis on bioindicators that indicate urban stress (sediment, metals, PAHs), as well as collecting antecedent flow and temperature data on a regular basis to develop a baseline.

4.12 State Perspectives on Climate Change and Bioassessment

Utah – Jeff Ostermiller

Mr. Jeff Ostermiller of the Utah Department of Environmental Quality/Department of Water Quality (DEQ/DWQ) offered his view on how climate change may impact bioassessment programs in various states. He impressed upon the audience that not only is the global climate changing, but in order to respond to that change as a scientific community, a change in the paradigm will require fundamental changes at all management levels. Water quality management decisions (e.g., impairment rating, water quality standards) are made at short time scales, and/or at the scale of sites or watersheds. These are not necessarily large or timely enough to take climate change into account. Moreover, if climate change is viewed as a confounding variable to more traditional stressors, then researchers need to find a way to remove change associated with climate when evaluating sites with current regulations. For example, Mr. Ostermiller wondered what a TMDL for climate change would look like. He continued that the best measures currently used to detect traditional human-caused disturbances may not be the best measures to detect climate effects, as shown using O/E at 13 reference sites in Utah. Mr. Ostermiller suggests an eventual reallocation of resources to answer the question of climate change, possibly including: measuring climate effects with phenology, deployment of extra temperature recorders, creating a network of re-sampled reference sites, and/or examining climate change effects on water chemistry. If biological responses to climate are proven to be stronger when they are associated with chemical contamination, the ability to assign causal effect of climate on biota may be affected. Using current nutrient regulations as an example, Mr. Ostermiller surmised that difficulties in association could make applying current water quality concepts to standards and regulations challenging. He underscored the fact that current standards may not be sufficiently protective under future climate scenarios. Mr. Ostermiller sees need for long-term data sets across large spatial scales to help in examining the climate change phenomena. He believes states can provide data to help fill the gaps, but with a need to address issues in comparability to make the data meaningful. Mr. Ostermiller concluded by offering that much like other stressors, climate change issues transcend political boundaries, and that solutions will require coordination among numerous state, national, and international agencies.

North Carolina – Trish MacPherson

Ms. MacPherson from the NC Division of Water Quality presented the current severe drought status in the state as an over-riding issue. One third of the state has been in

"exceptional" drought for over a year, with the remainder of the state also suffering from moderate to severe drought conditions. The NOAA/NCEP national drought forecasters are not predicting improvement in the southeast region in the crucial period of January – March. These drought conditions have had immediate impacts on their bioassessment program - there simply is not water to study in many basins. Reference conditions also have been adversely affected. The recent severity of drought, while potentially related to climate change, may also be overshadowing the other effects of climate. Ms. MacPherson mentioned the potential for targeting sampling of areas as they recover from drought as a natural experiment to understand drought-related species responses, information which could be applied to long-term understanding of climate change effects.

California – David Herbst

Dr. David Herbst of the University of California, Mammoth Lakes Sierra Nevada Research Lab discussed the problem of climate change in the Sierra Nevadas. One focus in this region is projecting a loss of snow-pack at certain elevations, an issue that is different in the short-term than much of the country which is dealing with drought conditions. Dr. Herbst also discussed that they are trying to find a way to account for climate "drift" of reference condition, and posed the question of re-calibrating reference sites to a moving target. However, this could be complicated, as climate change effects could compound responses at some sites but not at others, and so accounting for climate change would likely not be simple linear corrections. Dr. Herbst suggested possible reference station arrays that could be used for detecting climate change effects. At this point, there is no global climate change (GCC) stream assessment plan for USFS or NPS federal lands in the Sierra Nevadas.

5 SUMMARY OF BREAKOUT SESSIONS

5.1 First day, group discussion

At the end of the first day, there was a large group discussion using the expert presentations as a backdrop. Several summary points emerged. Many people, including permit requesters, are starting to see climate change as a "scapegoat" for other (regulated) environmental stressors. There was discussion as to the extent to which programs can use comparison between reference and impaired sites to determine why impairment is happening, and account for contribution due to climate change compared to other stressors. CADDIS was

mentioned as a valuable tool for continued use in stressor identification, especially if expanded to include temperature and/or other climate sensitivity information. Chronic vs. acute stressors also were discussed, as were the implications of the fact that climate will not affect all sites equally.

Another key discussion on the first day was that if climate change imposes a "moving target" paradigm, does there have to be a new approach to setting standards? Should standards set based on existing (or historic) reference conditions be maintained as climate alters reference conditions over time, or should standards be re-calibrated to reflect altered baseline (reference) conditions in response to the new climate change paradigm? There was some input that standards and uses are "sacred"; that in some states, standards established 20-30 years ago have withstood the test of time. On the other hand, the question was raised as to whether such standards could be met in the future.

Times scales for detecting/defining climate change effects in relation to other stressors were discussed. Some states were concerned that their constituents expect to see improvements in waterbodies that reflect the large amounts of money spent to "fix" them, with outcomes measured based on comparison to existing reference conditions. However, climate change is a long-term issue, and it may take time to figure out how to assess biological condition over the next 50 years. The issue may also include how to effectively communicate these alternatives to constituents.

5.2 Second Day, First Breakout Session – Technical Issues

On the second day, the workshop attendees were randomly divided into four groups of about 20 each to participate in breakout session discussions focusing on technical aspects of monitoring program components in relation to climate change influences. The primary and supplementary questions framed to structure this session were:

Primary Questions:

- What aspects of biomonitoring might be important to assure good indicator trends? Methods, sentinel sites, trends analyses? Differences between lakes and streams?
- What can we do about vulnerable reference locations? (vulnerability due to climate change vs. other changes like land use). Does this issue change the way we monitor our population of reference sites or waterbodies? What do we do about reference site drift?

Supplementary Questions:

- What are the effects of climate change relative to land use impacts? Interference/exaggeration/indifference between land use and climate change? How does this affect monitoring for system responses?
- How important is temperature compared to hydrologic changes?
- What indicators are temperature sensitive, insensitive?
- What indicators might be most reflective of hydrology? Drought compared to flood? Winter vs summer?
- How important is taxonomy to detecting/tracking climate change? How variable, in terms of sensitivity to climate change variables, are species within a genus, genera within a family?
- Will various diversity metrics (e.g., number of EPT taxa) be useful measures of climate change? What other existing metrics may be useful?

  Index periods (e.g., will most vulnerable/representative sampling period change)?

5.2.1 Sampling Approach, including References and Sentinel Sites

Each of the four groups discussed reference site needs and problems, as well as the concept and potential benefits of sentinel sites that are believed to be responsive to climate change are established, including which was more appropriate with regard to accounting for climate change effects. Decisions need to be considered regarding fixed location sampling versus sampling a population of references within a watershed or other system designation. It was noted that at present, some states have had to drop some long-term reference monitoring sites to incorporate probabilistic sampling into their monitoring programs. Other considerations include number of reference/sentinel sites needed; and what to do when adequate reference locations can not be found or are lost due to budget cuts, climate change, or land use changes. There was discussion that probabilistic sampling alone may not be sufficient to capture signals from climate change, relevant to both reference and sentinel sties. A regional monitoring perspective, including regional placement and monitoring of reference and/or sentinel sites, should be considered.

5.2.2 Sampling Site Vulnerability

Overall there was agreement that ecoregional (e.g., level 3) classifications were not particularly meaningful with regard to defining risk or vulnerability to climate change, and do not contribute to detecting or partitioning climate change effects. Nevertheless, the value of

regional monitoring on the one hand, and possibilities for sub-classifying regions to improve ability to detect change on the other were discussed. The natural hydrologic regime of streams/rivers was widely discussed as substantially affecting vulnerability and responses to climate change, especially considering the effects of groundwater and snowmelt on temperature and flow. It would be useful to develop a typology to describe different hydrologic regimes that contribute to making some sites more vulnerable to climate change than others. This may help define sites or areas that need to be monitored and help guide selection of sentinel (or reference) sites to monitor, especially if this type of sampling does not conflict with current sampling needs, but rather fits in with it. Estimates of natural variability among sites are valuable and need to be built into assessment models; including consideration of different approaches for estimating variability (e.g., sampling the same sites consistently, visiting a site or stream reach periodically). Sites should be sampled and compared at a regional level.

In a related concept, it was suggested that regional climate change risks be defined, potentially using the existing regional statistical downscaling of climate change predictions developed by the National Center for Atmospheric Research (NCAR) and available on their website. This would support a risk-based approach of defining regional expectations of the "most likely" climate change effects, with some indication of degree of confidence, which in turn was discussed as a reasonable approach for developing and evaluating regional recommendations for biological assessment program adaptations.

5.2.3 Methods Comparability

The consistency and comparability of methods was a concern, especially with regard to ability to conduct trend as well as regional spatial analyses. Although there was substantial discussion of and interest in cross-jurisdictional data sharing and analysis, there was recognition of limitations due to methods differences which in many cases respond to specific state program needs, and may be difficult to rectify. Also mentioned was the value of having a common 'data dictionary' that is not state-specific but rather can be used across states. EPA's STORET and its replacement WQX were considered in this regard. In a related issue, there was discussion about whether there is sufficient data archiving, how archiving should best be managed and at what scale (e.g., perhaps regionally rather than state by state). If data are archived at a larger scale, who should pay for this effort?

5.2.4 Indicators

On a large scale, wetlands were suggested as potentially good indicators of climate change. Shifts due to climate change may be more easily observed in these landscapes due to the large number of impacts and speciation. Wetlands with low anthropogenic disturbance would be preferable. In lake ecosystems, it was generally agreed that there is at present insufficient information on the best parameters to measure and indicators to use. The possibility of using some paleolimnological measures was mentioned. On a smaller scale, many groups discussed examining changes in water chemistry and/or temperature for detection of climate change effects in stream/river systems, especially in the shorter term. Deploying temperature loggers in streams and rivers would provide a wealth of data. There is some concern about the management and analysis of such large quantities of data once collected. The possible value of bed stability measures was discussed.

There was substantial discussion of the importance of hydrologic parameters as indicators of climate change and drivers of biological responses, but also a general consensus that the particular parameters that would be best to measure and how to measure them need to be defined. Nevertheless, the value of existing USGS gauges was made clear, with discussion of the increasing imperative to maintain these gauges, and possibly for increasing the active USGS gauging network. Existing approaches mentioned for analyzing historic USGS gauge data include Indicators of Hydrologic Alteration (IHA, software by the Nature Conservancy), Streamstats (USGS) and GISHydro (University of Maryland Department of Civil and Environmental Engineering and the Maryland State Highway Administration).

Increase in invasive species was discussed as a response expected due to climate change, and therefore as a possible indicator. It was mentioned that climate change may expand and/or shift suitable habitat for invasive species, and that invasions may reflect (and so be predicted by) a habitat matching model.

Also discussed were various aspects of the reliability of biological indicators, in particular with regard to level of taxonomy. Differences in taxonomic levels between labs, or different sampling methods between states can impact comparability and analysis results. The concept was discussed of using species traits and functional roles instead of only taxonomic designations (species, genera, or operational taxonomic units (OTUs)) as a basis for analyzing

temporal trends and spatial patterns. There was widely acknowledged importance in gathering more information on species traits in order to identify climate change indicator taxa; the attributes database currently being compiled was seen as providing a valuable product in this regard. Species replacements were considered a related issue, where again, the possibility of adapting metrics to include "sensitive" taxa instead of total taxa richness within target groups (e.g., mayflies) was discussed. This kind of adaptation could help account for temperature tolerant organisms moving north. The importance of evaluating long-term, legacy data sets for identifying good climate change indicators was emphasized.

5.2.5 Taxonomic Issues

It was considered important to understand what level of taxonomic resolution is essential to support detection of climate change effects and separation of these from other stressors. For example, do rare taxa provide significant information to the assessment of climate change effects? Other components of this issue include whether needed taxonomic resolution is the same for all assemblage types, and what the costs and benefits are of different levels of taxonomic information. The potential value of standardization across programs for common assemblages was discussed.

5.2.6 Analyses

It is critical to understand how climate change affects rank (in terms of magnitude) relative to other sources. In addition, there is much evidence that other stressors interact with climate change; and even some evidence that these interactions may represent a greater magnitude of effect than climate change alone. It is important within the framework of bioassessment analyses and associated research goals to tease out climate signals and define sources of effects.

Many analyses currently undertaken involve correlation, including the development of temperature tolerances; and correlation does not imply causation. Some of these issues can be addressed by expanding analyses to include covariables. In addition, laboratory studies of tolerances/optima, and physiological requirements can be useful. However experience, including some European studies, suggests that laboratory and field study results do not always agree.

There were questions regarding a sufficient frequency for re-sampling reference (and perhaps impaired) locations to support analyses for detection of trends. This was considered an important number to know to define biomonitoring needs and adaptation recommendations. There also was discussion about whether community or species level responses were most fruitful to evaluate.

5.2.7 Index Period

There was discussion about how climate change will impact sampling during index periods. Some areas have become more flashy or flood-prone during the existing sampling index period, necessitating the rescheduling of the regular biomonitoring sampling efforts. Climate change can alter the timing of occurrence of typical seasonal environmental patterns and associated biological responses (e.g., warming spring temperatures may occur earlier in the year). California has had some success basing their sampling period on degree days; they have calibrated their index period on air temperature data and sample accordingly. There was discussion about whether index periods may need to be altered, expanded, and/or made consistent among states within a region; an index period adequate for use attainment studies or to evaluate specific stressors may not be appropriate to tease out climate change effects.

5.3 Second Day, Second Breakout Session – Strategic Issues

The groups were convened again later to tackle more "strategic" questions, as follows:

Primary Questions:

- What aspects of a state or tribe's monitoring program are most important to consider in the context of climate change?
- What degree of modifications in program design could states and/or tribes implement?
- How do we deal with climate change from an impairment listing (303d) point of view?
- What could states do right now
    - Evaluate potential vulnerabilities of high quality waters
    - Establish sentinel sites or water bodies
    - Consider the need to refine or maintain programs at level needed to ascribe cause (Critical Elements Review)
    - Evaluate repeat sampling of reference sites (especially in high quality waters) (e.g., 25% on an annual basis, etc.).

Supplementary Questions:

- What changes may be needed in sampling protocols? Probabilistic vs fixed station (repeat) sampling – competition for resources vs data needs for different types of questions? Adoption of sentinel sites?
- Are there significant differences in management issues between lakes and streams/rivers that may affect incorporation of climate change considerations?
- What kind of technical assistance may be desired from EPA?

5.3.1 Cross-Jurisdictional Climate Monitoring Network

Consistent with discussions during the morning breakout sessions, there was substantial interest for increasing collaboration among states, tribes, academia, citizens, etc. However, states and tribes need to be convinced of the benefits before taking resources away from existing programs, at least in part based on clear technical inputs and incentives from EPA. Attributes of successful cross-jurisdictional efforts were discussed, including bottom-up organization and clear cause-driven goals. It will be tough to monitor the effectiveness of climate change research, just as it is currently tough to demonstrate the effectiveness of BMPs.

5.3.2 Reference/Sentinel Sites

A central theme through all the discussion groups was support for a regional (or even larger scale) collaboration in which sentinel sites that are believed to be responsive to climate change are established, and indicators identified and tracked. Continued sampling of reference sites is also important. Sentinel sites and criteria for their selection need to be more precisely defined before climate change monitoring can be effectively integrated into the existing framework. There are good monitoring networks out there to serve as examples or templates for the establishment of sentinel sites (i.e. acid rain monitoring). There also are some states with an existing sentinel site network that can serve as templates for the establishment of other state or regional networks. In order to obtain funding for this type of network and for it to succeed, it will be essential that the relevance of the data to current water quality programs is effectively communicated to management.

5.3.3 Monitoring Programs

First, it can not be taken for granted that every state organization has a biomonitoring program; several do not. There is often a lack of resources and manpower to fuel a yearly program. Within ongoing biomonitoring programs, there was concern about whether and how

climate change monitoring could effectively be integrated into the existing framework. Incentive from EPA for states to start climate change monitoring programs would help. Working with the states and tribes to create programs that work in different parts of the country instead of supplying a "cookie-cutter" program that everyone must use would be easier to present to management and state biologists. We may need to go back and re-visit some of the questions we asked when initially setting up biomonitoring programs.

5.3.4 Communication and Cooperation among Agencies and Stakeholders

There were general comments that the time for meaningful climate change communication is now, addressing the public as well as state, federal, and tribal organizations. Communicating assessment results to the public without too much detail but without watering down results was considered central. Types of results that were seen as meaningful to communicate climate change results to the public and stimulate public involvement included Lester Yuan's method of inferring long-term temperature changes from changes in biological communities, and results on the loss of fish.

Everyone is limited by resources, so collaboration is key. Working smarter, perhaps on a regional basis (large rivers, larger watersheds), but not overlapping efforts may allow managers to see the larger climate change picture. Coordination among large-scale, long-term programs (LTER, NEON, USFS) would be valuable.

5.4 Recommendations for EPA's Next Steps

- Develop list of things that states would currently be able to do to start monitoring climate change effects.
- Evaluate and develop immediate and long-term program needs and goals.
- Enhance communication among different agencies and coordination of efforts to monitor for climate change.
- Define what should be done relative to bioassessment programs to improve their technical quality and focus on appropriate objectives outside of consideration of climate change, and evaluate whether and how adding climate change into the mix might change these recommendations.
- Regional climate and watershed models may be explored further.
- Possibly develop a typology to describe different hydrological regimes that influence vulnerability of sites to climate change, to support a risk-based regional classification and associated reference station criteria.

- At future meetings, update workshop participants and other interested state and tribal managers on the results from the pilot projects.

5.5 Summary of Things to Do Now and In the Future

Now

- Evaluate potential vulnerabilities of high quality waters.
- Establish sentinel sites or water bodies.
- Develop bioassessment program capabilities to a level needed to assess cause (Critical Elements review).
- Evaluate repeat sampling of reference sites (especially in high quality waters; e.g., 25% on an annual basis).

Future

- Incorporate non-steady state paradigm into standards.
- Create specific approaches for detecting and accounting for climate change.
- Communicate among organizations and with the public.

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