INTRODUCTORY WORKSHOP ON CLIMATE CHANGE EFFECTS ON BIOLOGICAL INDICATORS

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CONTRIBUTORS

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

EPA/ORD/GCRP
Dr. Britta Bierwagen
Mr. Joel Sheraga
Ms. Susan Julius
Ms. Jordan West
Dr. Tom Johnson
Dr. Chris Weaver

EPA/OST
Mr. William Swietlik
Ms. Susan Jackson
Mr. Evan Hornig
Ms. Heidi Bell

Academia/NGOs
Dr. David Allen
Dr. Diane McKnight
Dr. David Yates
Dr. Connie Woodhouse
Dr. Lara Kueppers
Dr. Lara Hansen

Tetra Tech, Inc. Center for Ecological Sciences
Dr. Michael Barbour
Dr. Jeroen Gerritsen
Dr. Michael Paul
Ms. Anna Hamilton
Dr. Lei Zheng
Mr. David Bressler
Mr. Bill Mills
Ms. Gia Grier
Ms. Kristen Pavlik
Ms. Carolina Gallardo
Ms. Yukiko Ichishima

1 INTRODUCTION

The goal of this workshop was to provide state and tribal biocriteria managers with information on how climate change may affect their monitoring and assessment programs for protecting and restoring their water resources. This workshop focused primarily on stream and river systems, as these are generally the most advanced in the development of bioassessment and biocriteria programs. These systems thus provided the most developed base from which to analyze climate change effects on program components and results and to evaluate alternatives. This workshop is the beginning of a process to assess program vulnerabilities and to define an approach for adapting management of streams and rivers, as well as other aquatic ecosystems). Inputs from the participating state and tribal bioassessment/biocriteria managers will help identify existing concerns and observations of sensitive indicators and help focus further analyses on the most vulnerable aspects of bioassessment and monitoring programs in different regions of the country.

2 PARTICIPANTS

Overall there were approximately 50 participants attending this workshop, including representation by 25 states, 3 tribes/tribal organizations, 1 territory, 5 U.S. Environmental Protection Agency (USEPA) representatives from the Office of Research and Development (ORD), 4 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), 1 speaker from the World Wildlife Fund (WWF), 2 staff members from the Environmental Law Institute (Washington, DC-based NGO), and 5 academic researchers. All workshop participants are listed with contact information in Appendix A.

3 WORKSHOP STRUCTURE

Keynote presentations progressing from an overview of global climate change effects to regional applications of climate change models and biological responses to climate change set the foundation for the workshop. Breakout sessions focused on biological indicators and drivers of environmental condition, vulnerability of biocriteria programs in WQ agencies, and adaptations of program elements to recognize effects of climate change. 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.

4 SUMMARY OF KEYNOTE AND CASE STUDY PRESENTATIONS

4.1 Climate Change Effects on Aquatic Ecosystems

Dr. Diane McKnight of the University of Colorado, Department of Civil, Environmental and Architectural Engineering, presented an overview of major aspects of climate change effects expected on aquatic ecosystems. She familiarized the workshop participants with a range of studies (e.g., a 1995-97 joint ASLO/NABS synthesis study) and extant evidence that represents the current basis of thinking about aquatic ecosystem effects considered likely in response to projected future climate change. Dr. McKnight summarized issues including changes in the global water cycle and impacts on fresh water supplies, nutrient cycles and water quality; changes in stream hydrographs that could have trophic consequences in stream ecosystems; and potential interactions between changes in stream hydrodynamics with other stressors. Her presentation effectively illustrated the numerous, complex, and important interactions that must be considered with regard to aquatic ecosystems (for example, the changes in timing of nutrient pulsing and metals retention in snow-pack dominated streams with projected changes in amount of snow pack and timing of melting). Dr. McKnight also emphasized the need for but lack of detailed, real-time environmental data (e.g., from *in situ* sensors), and for better development and use of ecological models that can be linked with detailed (regional) climate change models.

4.2 Climate Change: A Perspective from Paleoclimatology and Observations

Dr. Connie Woodhouse of the University of Arizona, Department of Geography and Regional Development, established a background for understanding the "long-term" range of natural variability in climate as a basis for understanding probable components of current and future change resulting from anthropogenic sources. Types of paleoclimatic and observational data relied on for such evidence range from ice cores and ocean sediments which provide records with the longest time frame (hundreds of thousand years) but with coarse resolution (100-500 years); to lake and dune sediment of intermediate duration (~10,000 years); to tree rings and corals which provide shorter duration records (centuries) but with annual or sub-annual resolution. Overall, evaluation of the paleorecords supports a trend of increasing temperatures

over the last 100 years and shows that global temperatures of the decades are the warmest of the past 4 or more centuries. However, there are no clear trends (i.e., high variability) in precipitation, and recent periods of drought still fall within historic ranges. Dr. Woodhouse showed that analysis of tree ring records is able to support detailed and long-term evaluation of drought conditions for different regions, providing highly useful comparisons to present and projected future trends as well as a basis for evaluating expected ecological changes associated with variable drought conditions. Dr. Woodhouse provided an interesting example of the value of using long-term paleorecords in managing water resource issues, showing that allocation of Colorado River Basin water (compact signed in 1922) was actually based on estimates of water availability during an extremely wet period when compared to a 500-year period of record defined from tree ring analysis.

4.3 Modeling the Climate and Projections of Future Climate Change

Dr. David Yates (NCAR) explained how global climate models reproduce the climate system and what we learn from them. He gave a good 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 then summarized the major evidences for anthropogenic contributions to climate change, as well as the major global climate change projections.

4.4 Regional Climate Change and Ecological Impacts

Dr. Lara Kueppers of the University of California at Merced, School of Natural Sciences, discussed regional aspects of climate change modeling. She summarized various scales (e.g., continents versus oceans, high versus low latitudes and/or elevations within continents) of regional differences in climate change projections, and presented information on regional "hotspots" of vulnerability to climate change around the globe. On a scale particularly relevant to workshop participants, Dr. Kueppers' explained the limitations of GCMs in projecting trends for an individual region or watershed, and made particular note of the difficulties in modeling precipitation. She compared two main approaches used to develop refined regional predictions–

statistical "downscaling" and high-resolution Regional Climate Models (RCMs), and provided illustrations of how refinements in scale of RCMs improves projections of precipitation patterns. Dr. Kueppers then showed how important such refinements are to understanding and accurately projecting ecological responses to climate change, using range shifts of the California blue oak as an example. During the discussion after her talk, Dr. Kueppers explained that many academic institutions have regional models that could be useful in establishing partnerships and that the North American Regional Climate Change Assessment Program is developing a Web site which would be a central location for regional data.

4.5 A Framework for Incorporating Climate Information into Impacts Management

Dr. Chris Weaver, an AAAS Science and Technology Policy Fellow at the USEPA National Center for Environmental Assessment (NCEA), Global Change Research Program (GCRP) discussed a systematic strategy for incorporating climate change information into the decision-making process used by biocriteria managers, essentially how to bridge the gap between climate science and biological management endpoints. In addition to the value of codifying an approach for incorporating such new and intrinsically different information into an existing management structure, some of Dr. Weaver's main points were that climate modeling has a separate research agenda and generally produces information at a coarser scale than that needed by the impact assessment community. In addition, bioassessment managers often need different metrics as outputs from climate modeling than are typically produced, specifically related to ecological drivers in the systems which are being managed. Sensitivity analysis of response endpoints to the range of probable driver changes is a key step in focusing on the most relevant data. He suggested that managers shift the overall way they think about climate change from a prediction paradigm to a vulnerability paradigm.

4.6 Watershed-Scale Modeling of the Hydrologic and Water Quality Effects of Climate Change: The Monocacy River Basin Example

Dr. Thomas Johnson of the USEPA, NCEA, GCRP expanded on the framework introduced by Dr. Weaver using a specific watershed-scale modeling study of climate change effects on hydrology and water quality in the Monocacy River Basin as an example. Dr. Johnson's study team is using the BASINS-CAT model to simulate watershed-scale physical, chemical and biological processes that link regional projections of future climate changes in

temperature and precipitation to hydrologic and water quality endpoints that are important to water resource managers. It turns out that watershed hydrology and pollutant loadings are very sensitive to climate change, highlighting the importance of considering climate-associated changes in biological responses to these factors within the context of bioassessment and biocriteria programs.

4.7 Climate Change Effects on Rivers and Streams

Dr. David Allan of the University of Michigan outlined the key mechanisms by which climate change may affect river and stream ecosystems, relating these to major stream ecological processes, as a foundation for understanding the range of biological responses that may be expected. Dr. Allan presented temperature and flow as the primary environmental drivers through which climate changes will impact stream ecological processes. He highlighted numerous factors to be considered in predicting effects, including daily, seasonal, and interannual variability; stream size and longitudinal position; and elevation, topography, and geology; as well as indirect and interactive effects. Dr. Allan summarized evidence for changes in temperature regime influencing dissolved oxygen and water quality, biological productivity, bioclimatic envelopes (species adaptations/requirements for particular temperature regimes), phenology, life cycle events, and others. He gave several examples of various expected changes in flow characteristics (magnitude, timing of peaks, flashiness, frequency of drought, frequency of floods) that may in turn influence channel shape, in-stream habitat, export of organic matter, sediments, nutrients, and others. Biological responses may be seen in shifts in distributions; changes in abundance and composition that reflect different feeding types and tolerance ranges; changes in productivity; changes in riparian vegetation; redistribution of invasive species; and others. Dr. Allan summarized several points relevant to bioassessment programs: 1) changes in species composition, richness, and relative abundance can be expected; 2) changes are at least initially disruptive, and most systems are already stressed; and 3) restructuring of biological assemblages may extend over long time periods (centuries). These changes will require managers to adjust assessment tools (e.g., metrics, indices), probably on an ongoing basis. Other management responses may need to include adjustment of targets and expectations, specific habitat management for species of interest, and management of dispersal corridors.

4.8 A Framework for Categorizing Biological Indicators According to their Sensitivity to Climate Change

Dr. Britta Bierwagen of the USEPA, NCEA, GCRP, presented a preliminary categorization framework in response to the evidence that biological indicators will be affected by climate change, that climate change effects will confound interpretation of biological indicators, and that unaccounted for the shifting ecological baseline will make it difficult to meet biocriteria program goals. Dr. Bierwagen summarized the hallmarks of climate change effects as an additional stressor on ecosystems and one that effects both reference and non-reference sites. The framework concept is that categorization of indicators according to their climate sensitivity would serve as one step in controlling for or detecting climate change effects. Dr. Bierwagen defined the critical characteristics of potential climate sensitive and insensitive indicators as being: 1) temperature sensitive (narrow tolerances, temperature used to cue life history events) or insensitive (broadly tolerant, temperature not an important ecological cue); 2) hydrologically sensitive (intolerant of particular flow conditions) or insensitive (tolerant of a wide range of hydrologic conditions). She summarized classes of indicators that could be considered as including phenology, number of reproductive periods, vulnerable life stages, thermal tolerance, and hydrologic tolerance. Application of this framework will require understanding of how existing indicators used in bioassessment programs respond to climate change, and evaluation of novel indicators to detect climate change. Dr. Bierwagen highlighted the need to also understand how climate-sensitive indicators affect the Biological Condition Gradient and how it affects biocriteria in standards. This concept of indicator classification by climate sensitivity ultimately will be integrated with adaptations of monitoring and analysis approaches (see 4.9 and 4.10) to account for climate change in order to meet bioassessment goals.

4.9 Case Study 1: What Can We Detect and When: Program Implications

Dr. Michael Paul of Tetra Tech, Inc., Center for Ecological Sciences, presented results of a preliminary case study analysis to evaluate the ability of a typical existing bioassessment program to detect climate change, with specific questions focusing a power analysis approach on how long to have a fixed probability of detecting a change at a reference site population, and how long to detect a change at a particular site. He used native taxa richness as a representative bioassessment metric and calculated variances in this metric using the Maryland Biological Stream Survey (MBSS) data. The basis for modeling climate-driven taxa changes were published projections for changes in climate (temperature) and literature information on taxa richness responses to temperature changes. An example result, Dr. Paul showed a difference of

4.5 benthic taxa was needed to be able to detect this change with high power and confidence (power =95% and confidence= 95%). Assuming the higher available estimates for rates of temperature increase and taxa loss, this effect size would be reached in about 15 years. Dr. Paul similarly evaluated and summarized how program ability to detect this climate change-driven effect would change if replication was increased, by assuming samples could be evaluated cumulatively over a period of years, by reducing the level of confidence applied to the detection of difference, and by assuming higher and lower rates of climate change and biological response. He reported the comparable results for fish sampling data. Some of Dr. Paul's main conclusions were that: 1) site-specific estimates of variance in metrics, as well as regionally specific projections of rates of climate change and rates of biological responses should be used for program evaluation whenever possible; 2) choices between targeted and probabilistic sampling designs need to be based on both implications for the questions being asked and on implications for ability to account for climate change within the sampling design; 3) ongoing sampling as well as protection of reference sites is important to biomonitoring program ability to account for climate change.

4.10 Case Study 2: Consequences of Climate Change for Biocriteria

Dr. Jeroen Gerritsen of Tetra Tech, Inc., Center for Ecological Sciences, presented results of a second case study examining the vulnerabilities of existing bioassessment programs to climate change effects, with specific regard to 1) detection of reduced biological condition, and 2) the ability to assign cause to impaired condition. Dr. Gerritsen used proxy estimates of climate changes expected to be influential in stream ecosystems, including temperature, drought, flooding, and flashiness of flow. Stressors evaluated because of their expected vulnerability to or interactions with climate change effects included several measures of habitat condition, impervious surface, nutrients, and conductivity. Both fish and benthic IBIs (indices of biotic integrity), fish taxa richness and benthic EPT (mayflies, stoneflies and caddisflies) taxa richness were selected as response variables. Dr. Gerritsen presented evidence for climate change effects on biological indicators, for example, indicator variability increased markedly in reference sites in dry and wet years compared to average conditions, and there were slight reductions in median indicator values. Greater variability during "non-normal" conditions (wet or dry years as surrogates for climate change) and declines in reference values reduced ability to detect impairment. Changes in some stress-response relationships would affect ability to attribute

cause. Overall, Dr. Gerritsen characterized these climate effects as not devastating to the viability of biomonitoring programs, but requiring adaptation. For instance, further development of analytical methods accounting for climate change over time; of indicators, and of stressor identification approaches is needed.

4.11 Adapting Management to Climate Change

Dr. Lara Hansen, Chief Scientist at the WWF Climate Change Program, summarized the available information for considering climate change from the perspective of adapting management actions. She provided examples of a variety of potential interactions with climate change that will impact toxicity regulation, management of ocean resources, and interpretation of a range of lake and stream chemical and physical conditions. Dr. Hansen outlined the WWF approach for management adaptation to climate changes, which includes: 1) protection of adequate and appropriate space; 2) limitation of non-climate stresses; 3) use of active adaptive management strategies; and 4) reduction of greenhouse gas emissions, and provided specific examples. Of particular interest to state/tribal stream and river managers was the discussion of management approaches that would include consideration of: refugia; latitudinal and elevational gradients; heterogeneity of habitats; and possibilities for connectivity and gene flow. Considerations for adaptation of monitoring approaches, such as assuring that sampling sites and times account for regional change and variability, is also important. Dr. Hansen wrapped up her talk by discussing the WWF's "Climate Camp" initiative as an example of how 15 innovative management projects have been developed and funded by a wide variety of stakeholders, including NGOs, foundations, private businesses, and government agencies. Dr. Hansen's take-home message was that failure to address climate change might make all other environmental management efforts meaningless.

4.12 Linking Science to Policy

Dr. Joel Scheraga, National Program Director of the USEPA, ORD, GCRP gave a final presentation on translating existing scientific knowledge around climate change into sound policy decisions. Dr. Scheraga encouraged managers to take on this issue by describing USEPA's commitment to help stakeholders incorporate climate change information through the GCRP's research and activities. He described GCRP initiatives in the Everglades and the Sacramento River as examples. Dr. Scheraga also described plans for developing a strategic

plan with the Office of Water, including the beginning of a National Water Program Climate Change Workgroup. Dr. Scheraga stated that while the science is still incomplete, it is good enough to move forward in the policy arena.

5 SUMMARY OF BREAKOUT SESSIONS

5.1 Regionally Important Climate Change Drivers, Region-Specific Sensitive Indicators (First Day Breakouts)

The main and subsidiary questions focusing this set of breakout sessions were:

- How will anticipated regional climate change affect drivers of biological community condition and expected community responses? Can we identify regionally specific sensitive biological indicators?
- In each region, what are the most important/influential changes to environmental drivers (note: hydrology, temperature, physical habitat, etc.) from climate change, and what components of the biological system will they affect?
- On a regional basis, what are the key biological attributes that are likely to be sensitive and insensitive to climate change?
- Which common indicators are likely to be sensitive or insensitive?

Participants were divided into regional groups with concentration on particular stream types, to establish groups with common points of reference from which to consider these questions.

The four regional groups were:

- Midwest/Mid-Atlantic Warm-water;
- Subtropical/Southern Warm-water;
- Western/Northwestern Cold-water; and
- Northern Cold-water

Inputs from the four regional breakout groups are summarized in Table 5-1. The general importance of hydrologic and temperature regimes to stream and river ecology lead to some fundamental similarities in results among regional groups. But there also were some notable differences between regions in environmental changes that were of most concern and in species and other biological attributes that were perceived as most sensitive.

5.1.1 Influential Changes to Environmental Drivers

Drought was an aspect of hydrologic regime widely considered important, including its severity, frequency, and/or duration (Mid-West/Mid-Atlantic, North, and Pacific Islands). Also of concern were the related questions of the duration of low summer flows (West/Northwest), and the change of streams from perennial to intermittent flow (West/Northwest and Mid-west/Mid-Atlantic).

Changing patterns of precipitation were emphasized in the north and the southeast, including larger storms with more precipitation contributing to flashiness, both of which would have substantial effects on habitat, erosion, pollutant runoff, and other related processes. Changes in timing of already variable precipitation was mentioned for the Pacific Islands. Increased hydrologic variability and winter precipitation changing from snow to rain was a concern in the west/northwest and in the northern regions, while sea level rise expanding tidal influence in fresh waters and salt water intrusion was specified in the Mid-Atlantic and southeast.

Temperature was considered especially important in the west/northwest region, citing its importance in defining macroinvertebrate distributions and community transitions. Temperature increases and dissolved oxygen reductions were listed as influential in the Southeast, while temperature effects on the timing of ice melt and freeze was considered significant by the northern regional group.

5.1.2 Key Biological Attributes/Indicators

Several regional groups listed at least a few species or taxonomic groups they thought would be sensitive to particular aspects of climate change (see Table 5-1). For example, EPT taxa were specifically mentioned in both the Mid-west/Mid-Atlantic and the Southern/subtropical regional groups; trout were listed in the Subtropic/southern, Mid-Atlantic and the Northern regional groups. The biological attributes discussed were of particular interest. Transitional faunas and taxa at the edges of their ranges were expected to be sensitive indicators (mentioned in the mid-west/mid-Atlantic and the west/northwest). The other most common potential indicators listed were diatoms, phenology, P/R ratios, life history traits, voltinism, and invasive species.

5.1.3 Insights

Numerous participants from different regions perceived common issues associated with the question of accounting for climate change within bioassessment programs (Table 5-1). One widespread concept is that responses to climate change will vary with ecoregion, and that sensitivities will similarly vary with ecoregion. There is a related question that the sensitivity of particular metrics needs to be further evaluated, as many participants recognized that there are too many unknowns to predict with certainty which indicators are likely to be most sensitive. Questions related to interactions between climate change and other stressors, especially land use change, was recognized as an issue that will be difficult to tease apart. An interesting related question was whether the approach is intended to document climate change or tease out the climate change signal.

5.2 Program Vulnerability (Second Day Morning Breakouts)

The overarching question for the second set of breakout groups was:

How are our bioassessment and biocriteria programs vulnerable to climate change effects with regard to interpretation of data?

Subsidiary questions were used to focus the discussions and organize participant inputs.

5.2.1 How are our bioassessment programs currently equipped to deal with climate change?

Some existing bioassessment/biomonitoring programs have long data sets, which are needed to analyze temporal trends and define climate change-associated effects. The problem is, some programs do not. In addition, some states do not conduct repeat sampling (year to year) at fixed reference locations so that evaluating time trends and possibly detecting climate change effects are not well supported.

5.2.2 How do we assess cause, interpret condition in the context of climate change?

State programs attribute probable causes to observed biological effects through the Stressor Identification (SI) process. At this time, however, this process is not put in the context of climate change. There is no accepted process in place to tie sampling/monitoring approach, data analysis, and interpretation of results for determination of cause that specifically accounts for contributions from and interactions with climate change.

5.2.3 What aspects of our assessment process are vulnerable because of climate change?

Two major components of state biomonitoring programs were identified by participants as vulnerable to climate change. **Reference stations** were perceived as vulnerable to degrading habitat conditions with climate change. This would lead to loss of key species and changes in community composition over time. In addition, the **index period** for sampling was seen as shifting over time. That is, ongoing climate change is likely to shift the timing of sampling, as well as impact logistics. There will be a need to recalibrate or adjust the index sampling period.

5.3 Modifications, Needs, and Recommendations to Incorporate Climate Change into Monitoring Programs (Second Day Afternoon Breakouts)

Recommendations from states/tribes were categorized based on technical assistance needed by various USEPA offices. Needs were categorized as either being resource needs or technical needs. These recommendations and needs are meant to serve as a starting point for next steps. Ways of modifying impairment decisions were also discussed.

5.3.1. Modifications: How do we modify impairment decisions under climate change?

There was much discussion around the possible alternatives of treating climate change as an adjustment to the thresholds for other stressors, or treating climate change as a stressor itself. There was overall agreement that treatment of climate change as a stressor is important for assessments. This should be approached by tracking any changes in reference sites from expected condition.

5.3.2 Needs: What are major information needs for states and tribes to adapt their programs to climate change?

Two categories of needs, resource needs and technical needs, were outlined by the workshop participants. Resource needs were limitations recognized by the states as limits to implementing new and/or additional efforts related to revising and adapting their existing programs to account for climate change. These mainly included:

- Funding Support;
- Lack of adequate Personnel;
- Priority setting for Management actions; and
- Sharing resources among agencies to expand capacity.

Technical needs were focused on information needed to better understand the interactions between expected effects of climate change and biomonitoring program endpoints, additional technological support, and general policy support. Participants specifically listed the need for:

- Additional research on hydrologic indicators;
- Filling gaps between regional, hydrologic, and ecological models;
- Technology transfer for use of equipment, including incorporation of processes, guidance;
- Inclusion of language in EPA grants, policies, etc. on climate change as a stressor for monitoring and assessment programs; and
- Incorporation of traditional ecological knowledge as well as non-traditional, such as citizen monitoring and phenological knowledge, in adapting bioassessment programs.

5.3.3 Recommendations: How might we adapt our programs to deal with climate change? What are recommendations to EPA for providing more specific guidelines and approaches?

5.3.3.1 Feasible adaptations with support and technical assistance from EPA (general).

- Conduct regular and repeat reference site sampling; consider strategies for maintenance/protection of reference sites and areas, identifying waterbodies in the best condition;
- Evaluate the need to shift the sampling index period and/or expand sampling seasons;
- Establish sentinel sites for trend monitoring;
- Improve hydrological and temperature data collection;
- Mine historical data records to establish a basis for evaluating climate change;
- Incorporate traditional ecological knowledge, citizen monitoring, phenological knowledge in assessment of biomonitoring data;
- Continue the refinement of biocriteria programs to incorporate the Tiered Aquatic Life Use (TALU) strategy;
- Accept moving target paradigm versus steady state model and adapt accordingly;
- Perform critical elements reviews of individual programs to identify relevant refinements; and
- Engage in collaborative data and resource sharing to maximize limited resources.

5.3.3.2 Recommendations falling within the purview of EPA/ORD

- Conduct research to determine the best hydrologic and biological response indicators, to define biologically sensitive measures to hydrologic changes, and to identify species traits responsive to climate change (temperature, flow, sediment);
- Conduct research to fill gaps between regional, hydrologic, and ecological models;
- Investigate how taxa replacement will affect biological indices used in state programs. Will there be little or no change in biological indices if specific metrics change?
- Provide technical support for data management tools (e.g., R code) to manage temperature logger data and reduce it to useable metrics; and
- Develop tools to make climate data available to other models (e.g., CADDIS).

5.3.3.3 Recommendations falling within the purview of EPA/OW

- Provide assistance to state bioassessment and resource management programs to integrate the concept of climate change as a significant issue that must be accounted for in assessing the condition of aquatic resources;
- Incorporate language referencing climate change in grants, policy, and regulations; and bring climate change into the monitoring strategy and listing guidance;
- Evaluate WQS to be protective in the face of a changing condition paradigm;
- Provide funding support for state/tribal WQ programs to assist in adaptations to existing programs;
- Partner with ORD and other federal agencies on a comprehensive climate change strategy to address mandates of CWA; and
- Provide a summary of this meeting to EPA top management for information and support for making informed decision-making..

Table 5-1. Summary of inputs from the four regional breakout groups during the first breakout session.

	Midwest/Mid-Atlantic Warm-water	Subtropical/Southern Warm-water	Western/Northwestern Cold-water	Northern Cold-water
Influential Changes to Environmental Drivers	Hydrology is key: severe drought; flashiness; sea level rise resulting in tidal fresh expansion; streams changing from perennial to intermittent. Interaction between climate change and water drawdown. Character (intensity, frequency, duration) of change may be most important early warning.	Southeast: More overall rain, but fewer events (flashy precip). Increased coastal salinity intrusions. Increased pollutant runoff, especially sediment. Altered estuarine blooms due to flow timing. DO reductions. Temperature increases Variable energy source changes – GPP increases, reduced inputs. Flashiness – altered channel dimensions, reduced organic matter. Pacific Islands: Trade winds may stop – increased drought. Flashiness a natural condition – timing may change. Increased sediment loads, landslides. Organic matter generally low in streams.	Hydrology Flashiness Low summer flows/duration of summer dry period (and increase in intermittent streams) Increased winter flooding (and erosion, sedimentation) More rain/less snow in winter More hydrologic variability (or regime shift) Temperature Strong correlation with bug assemblages in Montana. Also day of year, elevation. Oregon considering temp IBI. Transition zone important in NM. Insensitive/uncertain: Moisture variation dominated by natural variation Habitat/substrate (may or may not be insensitive) Flow-normalized ion concentrations(may or may not be insensitive) Tough! (almost none)	Hydrology: Bigger storms, more frequent droughts. Increased stream power: erosion, scouring, habitat effects. Similar to effects of urbanization. Temperature Timing of freeze and ice melt (affects hydrology, temperature) More rain replacing snow (affects hydrology)
Key Biological Attributes / Indicators	Species at the extremes of their ranges will be most affected Mixed fauna (cold & warm) in transitional areas EPT – stoneflies will decrease;	Current Indicators *Southeast* Sensitive – EPT (and certain families), mussel taxa, trout, darters, Insensitive – odonates, Some	Consideration of species traits/sensitivities will be important Temperature sensitivity/species on edge of range Most stress indicators	All attributes affected by hydrologic changes will be sensitive Similar to effects of urbanization

	caddis will increase Reduced lithophilic species Frequency of fish DELT Invasive species Periphyton relationship to hydrology	EPT families, midges and worms, tolerants, invasives (red shiner), carp, *Hawaii* Sensitive – odonates, neridids, atyid shrimp, 2 native fish taxa, trout, Insensitive – 3 native fish taxa, tolerants, invasives. <u>Novel Indicators</u> Novel but unrealistic Reptile sex ratios, emergence, life history indicators, voltinism, size-frequencies, Novel and realistic Amphibian indicators, disease/parasitism, mussel mortality	P/R (food/trophic) may be useful Life cycle/voltinism Diatoms Phenology	Temperature sensitive Brook trout, slimy sculpin, Am. Brook lamprey Blephariceridae Warmwater invaders: dusky darter, hydropsychids? Amphibians
Insights	• Need reliable hydrological indicators. • Characterization and monitoring of reference conditions is important to detect climate change. • Collaborate with LTERs. • Use temperature monitors to obtain "minimum" data records. • Most programs will NOT likely change; however, awareness will be heightened.	• What will happen to plant pests and riparian forests? • Southeast is a small dot region – relatively smaller climate change effects? • Southeast has diverse ecoregions – affects will vary by ecoregion • How will optima and tolerance along land cover gradients change? • What will happen to invasive species? Hawaii has a few… • Interactions between stressors and climate are difficult to evaluate • Will western water law come east?	• Almost no inverts not climate sensitive • Most "climate insensitive" species are the "weedy" species (broadly tolerant, etc) • Maybe construct a climate-insensitive IBI • Not enough specific info on conventional metrics to specifically classify sensitivity • Warm-water fish are sensitive to climate change (habitat loss due to lower flows)	• Difficulty in separating climate from other stressors (esp. land use change) – Some stream types, ecoregions different sensitivity than others: • Groundwater systems vs. hard rock watersheds – Many changes subtle, slow; some not: severe drought • Indicators used now are stable, and sensitive to hydrologic and WQ changes • No protocol for managing uncertainty – Not always as bad as

		• Limitations – LA does not have bioindicators, HI does not know what healthy is. • Signal to noise ratios – which will climate affect more? • Are we documenting climate change or teasing climate signals out? • What water quality standard are we protecting?		it's made out to be

Appendix A: Participant and Presenter List

J. David Allan, PhD (P)
Professor
School of Natural Resources and Environment
University of Michigan
440 Church Street
Ann Arbor, MI 48109
E-mail: dallan@umich.edu

Michael T. Barbour, PhD (W)
Director, Center for Ecological Sciences
Tetra Tech, Inc.
400 Red Brook Blvd., Suite 200
Owings Mills, MD 21117
Phone: (410) 356-8993
E-mail: Michael.Barbour@tetratech.com

Alex Barron
Virginia Department of Environmental Quality
629 East Main St.
Richmond, VA 23218
E-mail: ambarron@deq.virginia.gov

Heidi Bell
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Mail Code: 4304T
Washington, DC 20460
Phone: (202) 566-1089
E-mail: bell.heidi@epa.gov

Britta G. Bierwagen, PhD (P)
Physical Scientist
U.S. Environmental Protection Agency
ORD/Global Change Research Program
1200 Pennsylvania Ave. NW
Mail Code: 8601-D
Washington, DC 20460
Phone: (202) 564-3388
E-mail: bierwagen.britta@epa.gov

Edna Buchan
American Samoa Environmental Protection Agency
P.O. Box PPA
Pago Pago, American Samoa
Phone: (684) 633 2304
Fax: (684) 633 5801
E-mail: ebuchan3@yahoo.com

Bob Bukantis
Montana Dept Environmental Quality
P.O. Box 200901
Helena, MT 59602
Phone: (406) 444-5320
Fax: (406) 444-6836
E-mail: bbukantis@mt.gov.

Dr. Lilian Busse
San Diego Regional Water Quality Control Board
9174 Sky Park Court
San Diego, CA 92123
Phone: (858) 467-2791
Fax: (858) 571-6972
E-mail: lbusse@waterboards.ca.gov

Kimberly Cornelison
Louisiana Department of Environmental Quality
P. O. Box 4314
Baton Rouge, LA 70821
Phone: (225) 219-3598
E-mail: Kimberly.cornelison@la.gov

Lee Currey
Maryland Department of the Environment
Science Services Administraton
TMDL Technical Development Program
Watershed and Nontidal Modeling Division
E-mail: lcurrey@mde.state.md.us

Katie DeGoosh
New England Interstate Water Pollution Control Commission
Rhode Island Department of Environmental Management
235 Promenade St.
Providence, RI 02908
Phone: (401) 222-4700 x 7211
Fax: (401) 222-3564
E-mail: katie.degoosh@dem.ri.gov

Jeff DeShon
Ohio Environmental Protection Agency
Division of Surface Water
Ecological Assessment Section
4675 Homer Ohio Lane
Groveport, OH 43125
Phone: (614) 836-8780
Fax: (614) 836-8795
E-mail: jeff.deshon@epa.state.oh.us

Ellen Dickey
Delaware Department of Natural Resources and Environmental Control
Division of Water Resources
89 Kings Hwy.
Dover, DE 19901
Phone: (302) 739-9942
Fax: (302) 739-3491
E-mail: ellen.dickey@state.de.us

Richard Eskin
Director
Maryland Department of the Environment
Science Services Administration
E-mail: reskin@mde.state.md.us

John Fiorentino
Massachusetts Department of Environmental Protection
Division of Watershed Management
627 Main St., Second Floor
Worcester, MA 01608
Phone: (508) 767-2862
Fax: (508) 791-4131
E-mail: john.fiorentino@state.ma.us

Steve Fiske
Vermont Department of Environmental Conservation
Water Quality Division: Biomonitoring Section
103 So. Main St.
Waterbury, VT 05671
Phone: (802) 241-1378
Fax: (802) 241-3008
E-mail: Steve.Fiske@state.vt.us

Carolina Gallardo
Center for Ecological Sciences
Tetra Tech, Inc.
400 Red Brook Blvd., Suite 200
Owings Mills, MD 21117
Phone: (410) 356-8993
E-mail: Carolina.Gallardo@tetratech.com

Jeroen Gerritsen, PhD (P/W)
Principal Scientist, Center for Ecological Sciences
Tetra Tech, Inc.
400 Red Brook Blvd., Suite 200
Owings Mills, MD 21117
Phone: (410) 356-8993
E-mail: Jeroen.Gerritsen@tetratech.com

James B. Glover, PhD
The South Carolina Department of Health and Environmental Control
Aquatic Biology Section
2600 Bull St.
Columbia, SC 29201
Phone: (803) 898-4081
Fax: (803) 898-4200
E-mail: GloverJB@dhec.sc.gov

Gia Grier
Center for Water Resources/Center for Ecological Sciences
400 Red Brook Blvd., Suite 200
Owings Mills, MD 21117
Phone: (410) 356-8993
E-mail: gia.grier@tetratech-ffx.com

Anna Hamilton (W)
Aquatic Ecologist, Center for Ecological Sciences
Tetra Tech, Inc.
502 W. Cordova Rd., Suite C
Santa Fe, NM 87505
Phone: (505) 982-0573
Fax: (505) 982-0584
E-mail: Anna.Hamilton@tetratech.com

Lara J. Hansen, PhD (P)
Chief Scientist, Climate Change Program
World Wildlife Fund
1250 24th St. NW
Washington, DC 20037
Phone: (202) 778-9619
E-mail: lara.hansen@wwfus.org

Evan Hornig
U.S. Environmental Protection Agency
1200 Pennsylvania Ave., NW
Mail Code: 4304T
Washington, DC 20460
Phone: (202) 566-1099
E-mail: hornig.evan@epa.gov

Yukiko Ichishima
Center for Water Resources
Tetra Tech, Inc.
10306 Eaton Place, Suite 340
Fairfax, VA 22030
Phone: (703) 385-6000
E-mail: Yukiko.Ichishima@tetratech-ffx.com

Thomas E. Johnson, PhD (P)
Physical Scientist
U.S. Environmental Protection Agency
ORD/Global Change Research Program
1200 Pennsylvania Ave. NW
Mailcode 8601-D
Washington, DC 20460
Phone: (202) 564-3406
E-mail: Johnson.thomas@epa.gov

Susan Jackson
U.S. Environmental Protection Agency
1200 Pennsylvania Ave., NW
Mail Code: 4304T
Washington, DC 20460
Phone: (202) 566-1112
E-mail: jackson.susank@epa.gov

Susan Julius
Global Change Research Program
U.S. Environmental Protection Agency
1200 Pennsylvania Ave, NW
Washington, DC 20460
Phone: (202) 564-3394
Fax: (202) 565-0061
E-mail: Julius.Susan@epa.gov

Austin Kane
Environmental Law Institute
2000 L St. NW, Suite 620
Washington, DC 20036
Phone: (202) 939-3243
Fax: (202) 939-3868
E-mail: kane@eli.org

Rodney Kime
Pennsylvania Department of Environmental Protection, Assessment Section Chief
Rachel Carson State Office Building
P.O. Box 8467
Harrisburg, PA 17105
E-mail: rkime@state.pa.us

Ronald Klauda
Resource Assessment Service
Maryland Department of Natural Resources
580 Taylor Ave., C-2
Annapolis, MD 21401
Phone: (410) 260-8615
Fax: (410) 260-8620
E-mail: rklauda@dnr.state.md.us

Linda Koch
Hawaii State Department of Health
Environmental Planning Office
919 Ala Moana Blvd., Rm. 312
Honolulu, Hawaii 96814
Phone: (808) 586-4349
Fax: (808) 586-4370
E-mail: linda.koch@doh.hawaii.gov

Lara M. Kueppers, PhD (P)
Assistant Professor, School of Natural Sciences,
University of California, Merced
P.O. Box 2039
Merced, CA 95344
Phone: (209) 228-4054
E-mail: lkueppers@ucmerced.edu

Lewis Linker
U.S. Environmental Protection Agency
Chesapeake Bay Program Office
410 Severn Ave.
Annapolis, MD 21403
Phone: (410) 267-5741
Fax: (410) 267-5777
E-mail: linker.lewis@epa.gov

Trish MacPherson
North Carolina Division of Water Quality
1621 Mail Service Center
Raleigh, NC 27699-1621
Phone: (919) 733-6946
Fax: (919) 733-9959
E-mail: trish.macpherson@ncmail.net

Diane McKnight, PhD (P)
Department of Civil, Environmental and Architectural Engineering
University of Colorado
Boulder, CO 80309
Phone: (303) 492-4687
Fax: (303) 492-6388
E-mail: diane.mcknight@colorado.edu

Gerard McMahon
U.S. Geological Survey
3916 Sunset Ridge Rd.
Raleigh, NC 27607
Phone: (919) 571-4068
Fax: (919) 571-4041
E-mail: gmcmahon@usgs.gov

Glenn Merritt
Environmental Assessment Program
Washington Department of Ecology
P.O. Box 47710
Olympia, WA 98504-7710
Phone: (360) 407-6777
Fax: (360) 407-6884
E-mail: gmer461@ecy.wa.gov

Michael A. Miller
Wisconsin Department of Natural Resources
P.O. Box 7921
Madison, WI 53707-7921
Phone: (608) 267-2753
Fax: (608) 266-2244
E-mail: millema@dnr.state.wi.us

Bill Mills
Research and Development
Tetra Tech, Inc
3746 Mt. Diablo Blvd., Suite 300
Lafayette, CA 94507
Phone: (925) 283-3771
Fax: (925) 283-0780
E-mail: Bill.Mills@tetratech.com.

Mistia Mullins
Washoe Tribe of Nevada and California
919 U.S. Hwy. 395 South
Gardnerville, NV 89410
Phone: (775) 265-8680 x 1245
Fax: (775) 265-3111
E-mail: mistia.mullins@washoetribe.us

Jeffrey Ostermiller
Monitoring Section Manager
Utah Division of Water Quality
288 North 1460 West
Salt Lake City, UT 84114-4870
Phone: (801) 538-6370
E-mail: JOSTERMILLER@utah.gov

Michael J. Paul, PhD (P/W)
Senior Scientist
Center for Ecological Sciences
Tetra Tech, Inc.
400 Red Brook Blvd., Suite 200
Owings Mills, MD 21117
Phone: (410) 356-8993
E-mail: Michael.Paul@tetratech.com

Kristen Pavlik
Center for Ecological Sciences
Tetra Tech, Inc.
400 Red Brook Blvd., Suite 200
Owings Mills, MD 21117
Phone: (410) 356-8993
E-mail: Kristen.pavlik@tetratech.com

Amy Phillips
Biological Monitoring Unit, Environmental Analysis and Outcomes Division
Minnesota Pollution Control Agency
520 Lafayette Rd.
Saint Paul, MN 55155
Phone: (651) 297-2956
Fax: (651) 297-8324
E-mail: amy.phillips@pca.state.mn.us

Ernest Pizzuto
Connecticut Department of Environmental Protection
Bureau of Water Protection and Land Re-use
79 Elm St.
Hartford, CT 06106
Phone: (860) 424-3715
Fax: (860) 424-4055
E-mail: ernest.pizzuto@po.state.ct.us

Daniel Rinella
Environment and Natural Resources Institute
University of Alaska Anchorage
707 A St.
Anchorage, AK 99501
Phone: (907) 257-2734
Fax: (907) 257-2707
E-mail: rinella@uaa.alaska.edu

Joel Scheraga (P)
National Program Director
U.S. Environmental Protection Agency
ORD/Global Change Research Program
1200 Pennsylvania Ave., NW
Mail Code: 8601N
Washington, DC 20460
Phone: (202) 564-3385
E-mail: scheraga.joel@epa.gov

Stacey Sobat
Indiana Department of Environmental Management (IDEM)
Office of Water Quality (OWQ)
Assessment Branch, Biological Studies Section
2525 N. Shadeland Ave. Suite 100
Indianapolis, IN 46219
Phone: (317) 308-3191
Fax: (317) 308-3219
E-mail: ssobat@idem.IN.gov

Shann Stringer
New Mexico Environment Department
Surface Water Quality Bureau
Harold Runnels Bldg., N2106
P.O. Box 26110
Santa Fe, NM 87502
Phone: (505) 827-2921
Fax: (505) 827-0160
E-mail: shann.stringer@state.nm.us

Scott Sufficool, **Esq.**
(Quinault Indian Nation)-Policy Adviser
EPA National Tribal Operations Committee
National Tribal Caucus
5414 152nd St. SW
Edmonds, WA 98026
Cell Phone: (206) 992-4373

William Swietlik (P)
U.S. Environmental Protection Agency
OST/HECD
1200 Pennsylvania Ave., NW
Mail Code: 4304T
Washington, DC 20460
Phone: (202) 566-1129
E-mail: swietlik.william@epa.gov

Roxanne Thomas
Environmental Law Institute
2000 L St. NW, Suite 620
Washington, DC 20036
Phone: (202) 939-3827
Fax: (202) 939-3868
E-mail: thomas@eli.org

Charles M. Thompson
Mississippi Department of Environmental Quality
1542 Old Whitfield Rd.
Pearl, MS 39208
Phone: (601) 664-3900
Fax: (601) 664-3938
E-mail: Charles_Thompson@deq.state.ms.us

Chris Weaver, PhD (P)
AAAS Science and Technology Policy Fellow,
Global Change Research Program
U.S. Environmental Protection Agency
2nd affiliation: Assistant Research Professor
Department of Environmental Sciences
Rutgers University
1200 Pennsylvania Ave.
Mail Code: 8601-N
Washington, DC 20460
Phone: (202) 564-0900
Fax: (202) 564-2018
E-mail: weaver.chris@epa.gov

Jordan West
U.S. Environmental Protection Agency
ORD/Global Change Research Program
1200 Pennsylvania Ave.
Mail Code: 8601D
Washington, DC 20460
Phone: (202) 564-3384
E-mail: west.jordan@epa.gov

Sandra White Eagle
Fort Peck Assiniboine-Sioux Tribes
Office of Environmental Protection
Water Quality Division
603 Court Ave.
P.O. Box 1027
Poplar, MT 59255
Phone: (406) 768-5155
Fax: (406) 768-5606
E-mail: 2paints@nemontel.net

Connie Woodhouse, (P)
Associate Professor
Department of Geography and Regional Development
University of Arizona
409 Harvill Building
Tucson, AZ 85721
Phone: (520) 626-0235
E-mail: conniew1@email.arizona.edu

David Yates, PhD (P)
National Center for Atmospheric Research
3450 Mitchell Lane
Boulder, CO 80301
Phone: (303) 497-8394
Fax: (303) 497-8401
E-mail: Yates@ucar.edu

Rick Ziegler
U.S. Environmental Protection Agency
1200 Pennsylvania Ave., NW
Mail Code: 8623N
Washington, DC 20460
Phone: (202) 564-2257
E-mail: Ziegler.rick@epa.gov