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Executive summary

Little question exists that Earth's climate is changing and that human causes are fundamentally important. Climate model projections indicate the climate will continue to warm at rates equal to or faster than rates in recent decades until at least the middle of the twenty-first century. The effects of climate change could be particularly profound for native fishes and aquatic ecosystems of the Rocky Mountains because these systems often lack resilience and are strongly dependent on temperature and stream flow regimes that are already documented to be changing. The vulnerability of fish populations and communities to climate change will vary across the region based on local conditions and the amount of change that occurs. Because management budgets are limited, it will be important to prioritize limited resources based on some understanding of that vulnerability and the range of management alternatives. To consider management in the face of climate change, we have synthesized information on climate change and native fishes, stream habitats, and the observed and anticipated effects of climate change in the Rocky Mountain West. This report is organized around the following questions: *What is changing, what are the implications for native fishes,* and *what can we do about it?*

Important changes for fishes and their habitats will be driven by two factors, air temperature and precipitation, that are the principle components of climate. Air temperatures across the Rocky Mountain West are warming faster than global averages and increased by about 1 ^{0}C over the last century. Changes in precipitation are less consistent, but slightly dryer summers and wetter winters are anticipated in the northern Rocky Mountains while the southern Rockies experience generally drier conditions. The temporal and spatial patterns of change are not likely to be constant or linear, but will vary with local trends and shorter-term, climate cycles such as the Pacific Decadal Oscillation and the El Niño Southern Oscillation. As climate change progresses, however, long-term warming trends and increasing variability will result in more frequent events (e.g., droughts, intense precipitation, periods of unusually warm weather) that were considered extreme during the twentieth century and the magnitude of these events may also exceed recent historical levels. Changes in stream environments will parallel trends in the climate system, with streams becoming warmer, more variable in flow timing and amount, and subject to more frequent extreme events that could be synchronized across broader areas through regional flooding, droughts, and wildfires. Climate change is also likely to influence channel structure and forest and riparian communities through altered patterns and severity or intensity of wildfire, inputs of sediment and large wood, and disturbances such as debris flows. Although stream changes have been and are anticipated to be widespread,

changes will not necessarily occur at the same rates across the Rocky Mountain West. Some stream systems are changing more rapidly than others and some even show trends opposite to general expectations. The characteristics of watersheds and streams that may either aggravate or confer some resistance to the general effects of climate change will be an important question for further research.

The implications of climate change for native fishes are challenging to anticipate because of a general lack of long term monitoring data for Rocky Mountain populations and the complexity of interactions between biological and physical processes that are involved. In general, however, suitable habitats that are defined by temperature, flow and other physical or biotic conditions must shift in location (generally higher elevation or latitude). Some species, populations and communities may be able to track these changes and simply “relocate” but upstream limits of available habitat and barriers to dispersal and migration will limit many others. In other cases, the interaction of climate change, heterogeneous landscape responses, shifting species distributions, and new biotic and physical interactions will create novel environments, trophic cascades, and communities that have no natural precedent. These complex interactions will make prediction and management even more difficult. Natural selection and phenotypic plasticity could help many species and populations adapt to new environments but the speed and capacity for adaptation of most species are not well known and may be outpaced by the rate of climate change.

What we do about climate change will depend on available information, management resources, and policy direction. The basic decision, however, is to either work to conserve existing species, populations, and communities through adaptation strategies or to facilitate their transitions to new conditions that are most desirable and feasible in the future.. Our recommendations to guide management responses fall in five general areas. First, if the goal is adaptation and conservation of existing species or communities, efforts to enhance resistance and resilience of existing populations will be key. Important steps will include efforts to reduce non-climate stresses that may influence survival, growth, and habitat capacities; conserve and expand critical habitats; reconnect streams; and conserve genetic and phenotypic diversity. Second, because the potential threats of climate change and the feasibility of successful adaptation will vary widely across managed landscapes it will be important to prioritize limited resources. Steps to that end include efforts to: clarify goals and values; focus on populations as fundamental units of conservation; consider the relative vulnerability and relative value among populations and habitats; and favor actions robust to uncertainty. The latter step has also been called a “no regrets” strategy where the focus is on actions that will be useful whether the climate changes as anticipated or not. Third, if it is not likely that existing populations or communities can be maintained in the face of climate change, managers may consider efforts to facilitate transitions to new conditions. Facilitation might occur passively through the simple removal of

existing barriers allowing native or non-native species to move into new areas. It might be active through the intentional introduction of species to new environments. The latter option can be particularly controversial and requires clear articulation of the conservation values at stake. Fourth, the effectiveness of any actions associated with the first three recommendations depends on the quality of available information to guide decisions. For that reason it is important to develop local information. Important steps toward that end include efforts to: understand context based on existing climate projections and models of hydrologic, temperature, or biological changes near or encompassing the areas of interest; synthesize existing information for the area of concern such as inventory and monitoring data or local climatic trends that could be used to understand the status, distribution and vulnerability of important species, habitats or watersheds; model to fill gaps where useful data are limited or future projections are needed; and monitor to document trends and validate models. Finally, because the issues associated with climate change will be socially and ecologically complex and because new information and tools are developing quickly, it will be important to coordinate efforts across disciplines, across agencies and jurisdictions, and with the public.

The resources available to managers and biologists dealing with climate change will always be limited. The challenges associated with climate change are substantial, perhaps as important as the habitat losses already imposed on aquatic ecosystems by past human actions. The urgency is confounded by large uncertainties associated with the Earth's future climate trajectory and poor understanding of how broad climate trends will translate to local effects on streams and aquatic communities. Where do we start? Some have argued that public education on aquatic issues and the tradeoffs we make with other values may be the single most important thing aquatic managers and biologists can do for the long term conservation of aquatic ecosystems, biological diversity, fishes, and fisheries. Without a fundamental change in understanding and support of aquatic conservation, not much may change. We believe that local monitoring, with climate change in mind, is one of the most important steps biologists and managers can take in response to climate change. Monitoring data will help test hypotheses relevant to stream system responses to climate change, will provide managers with important insight to the relative utility of management actions, and may also provide a basis for making difficult decisions. Partnerships between research and management, and continued monitoring and education through both local and broader collaborative efforts, could help that process and effective adaptation to a changing climate.