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Potential effects of climate change on streamflow for seven watersheds in eastern and central Montana

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ABSTRACT

Study region: Eastern and central Montana.
Study focus: Fish in Northern Great Plains streams tolerate extreme conditions including heat, cold, floods, and drought; however changes in streamflow associated with long-term climate change may render some prairie streams uninhabitable for current fish species. To better understand future hydrology of these prairie streams, the Precipitation-Runoff Modeling System model and output from the RegCM3 Regional Climate model were used to simulate streamflow for seven watersheds in eastern and central Montana, for a baseline period (water years 1982–1999) and three future periods: water years 2021–2038 (2030 period), 2046–2063 (2055 period), and 2071–2088 (2080 period).
New hydrological insights for the region: Projected changes in mean annual and mean monthly streamflow vary by the RegCM3 model selected, by watershed, and by future period. Mean annual streamflows for all future periods are projected to increase (11–21%) for two of the four central Montana watersheds: Middle Musselshell River and Cottonwood Creek. Mean annual streamflows for all future periods are projected to decrease (changes of −24 to −75%) for Redwater River watershed in eastern Montana. Mean annual streamflows are projected to increase slightly (2–15%) for the 2030 period and decrease (changes of −16 to −44%) for the 2080 period for the four remaining watersheds.

1. Introduction

1.1. Purpose and scope

Streams and riparian areas in the Northern Great Plains provide critical habitat for aquatic and terrestrial wildlife. State, federal, and university biologists sampled more than 1500 sites on Montana prairies between 1999 and 2007, and found 32 native fish species (Bramblett, 2014). These fish tolerate extreme conditions including heat, cold, floods, and drought. However, changes in streamflow associated with long-term climate change may transform some prairie streams from essential refuges to habitats no longer capable of supporting some or all of the current fish species. Management of the current fish

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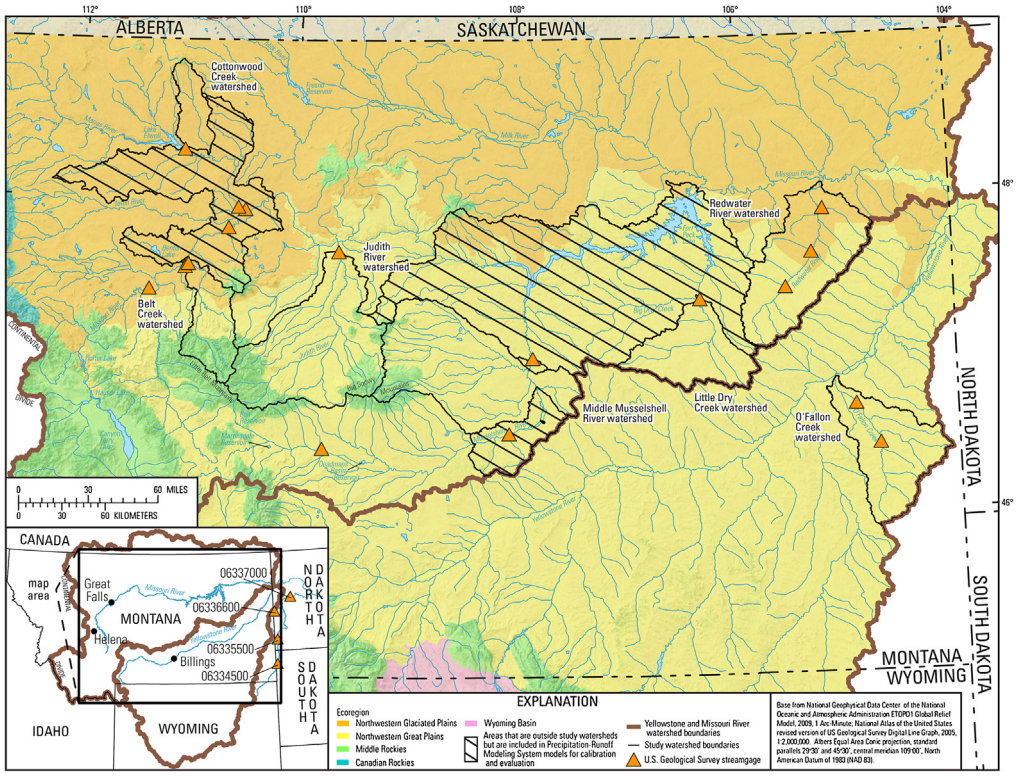

Fig. 1. Location of the study area, watersheds included in the Precipitation-Runoff Modeling System Models, and selected USGS streamgages in eastern and central Montana.

communities and their aquatic habitat requires more information regarding the future of lower order streams in smaller watersheds in eastern and central Montana.

Studies have examined climate change effects on larger river watersheds across the United States, including the Missouri River watershed within Montana (Stone et al., 2001; U.S. Bureau of Reclamation, 2011; U.S. Bureau of Reclamation, 2012). In addition, historic and future streamflows were simulated for streams in several western United States watersheds, including the upper Missouri River and tributaries, but no calibration or evaluation data for the models are available for the upper Missouri simulations (Littell et al., 2011; U.S. Forest Service, 2014). Consequently more information is needed on future streamflows in smaller watersheds (<7000 square kilometers) in eastern and central Montana.

To investigate potential effects of climate change on streamflow in smaller watersheds in eastern and central Montana, streamflow characteristics (mean monthly and mean annual streamflows) were estimated for a baseline period [water years (WY) 1982–1999] and for three future time periods: WY 2021–2038, WY 2046–2063, and WY 2071–2088. (Water year refers to the 12-month period October 1 through September 30; it is designated by the calendar year in which it ends.) Streamflow for these periods was simulated using the Precipitation-Runoff Modeling System (PRMS) forced with baseline climate data from Daymet (1-km resolution; Thornton et al., 2012) and future climate model output data derived from the RegCM3 regional climate model (15-km resolution; Hostetler et al., 2011). The streamflow information will be used by fisheries biologists to estimate effects of climate change on fisheries in the northern Great Plains. The Supplementary information provided with this paper contains details regarding the PRMS models. Simulated mean monthly streamflows and ranges of PRMS input parameter values are available in Chase et al. (2016).

1.2. Description of study area

Seven watersheds in eastern and central Montana were chosen where at least 7 years of streamflow data for calibration and evaluation were available; and where streamflows were not substantially affected by operation of reservoirs (the largest reservoirs in the study area had storage capacities less than 12,330,000 cubic meters). The three watersheds in eastern Montana were O'Fallon Creek, Redwater River, and Little Dry Creek. The four watersheds in central Montana were Middle Musselshell River, Judith River, Cottonwood Creek, and Belt Creek. Areas outside Middle Musselshell River, Cottonwood Creek and Belt Creek watersheds were included in the PRMS simulations in order to include data from U.S. Geological Survey (USGS) streamgages downstream from major reservoirs as inflows to the PRMS models, for model calibration and evaluation (Fig. 1).