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Potential implications of a warmer future for the Colorado River ecosystem

Kimberly L. Dibble

Annual Reporting Meeting
Phoenix, AZ
January 13, 2020

U.S. Department of the Interior
U.S. Geological Survey

Presentation Outline

- **Drivers of water temperature in the CRe**
  - ***What drives water temperatures in Grand Canyon and across the CRe?***
- **Present and future river temperatures**
  - ***How will climate change, drought, and reservoir storage decisions influence future river temperatures?***
- **Implications of warmer temperatures on fish**
  - ***How has river temperature shaped post-dam aquatic communities, and how may they change in the future?***

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FY18-20 Project Elements, Study Objectives, and LTEMP Resource Goals

- **Project Element E1**: Temperature and nutrients in the CRe – patterns, drivers, and improved predictions
  - *Study Objective*: Modify previous models for predicting CRe temperatures to reflect exponential (rather than linear) warming.
- LTEMP Resource Goals: Identify processes that drive spatial and temporal variation in nutrients and temperature within the CRe and establish quantitative and mechanistic links among these ecosystem drivers, primary production, and higher trophic levels.
  - Natural Processes (#3), Humpback Chub (#1), Other Native Fish (#1), Rainbow Trout Fishery (#2)
- *Builds off data collected during Project Element H.4 (FY13-14) and Project Element 9.8 (FY15-17 Workplan)*

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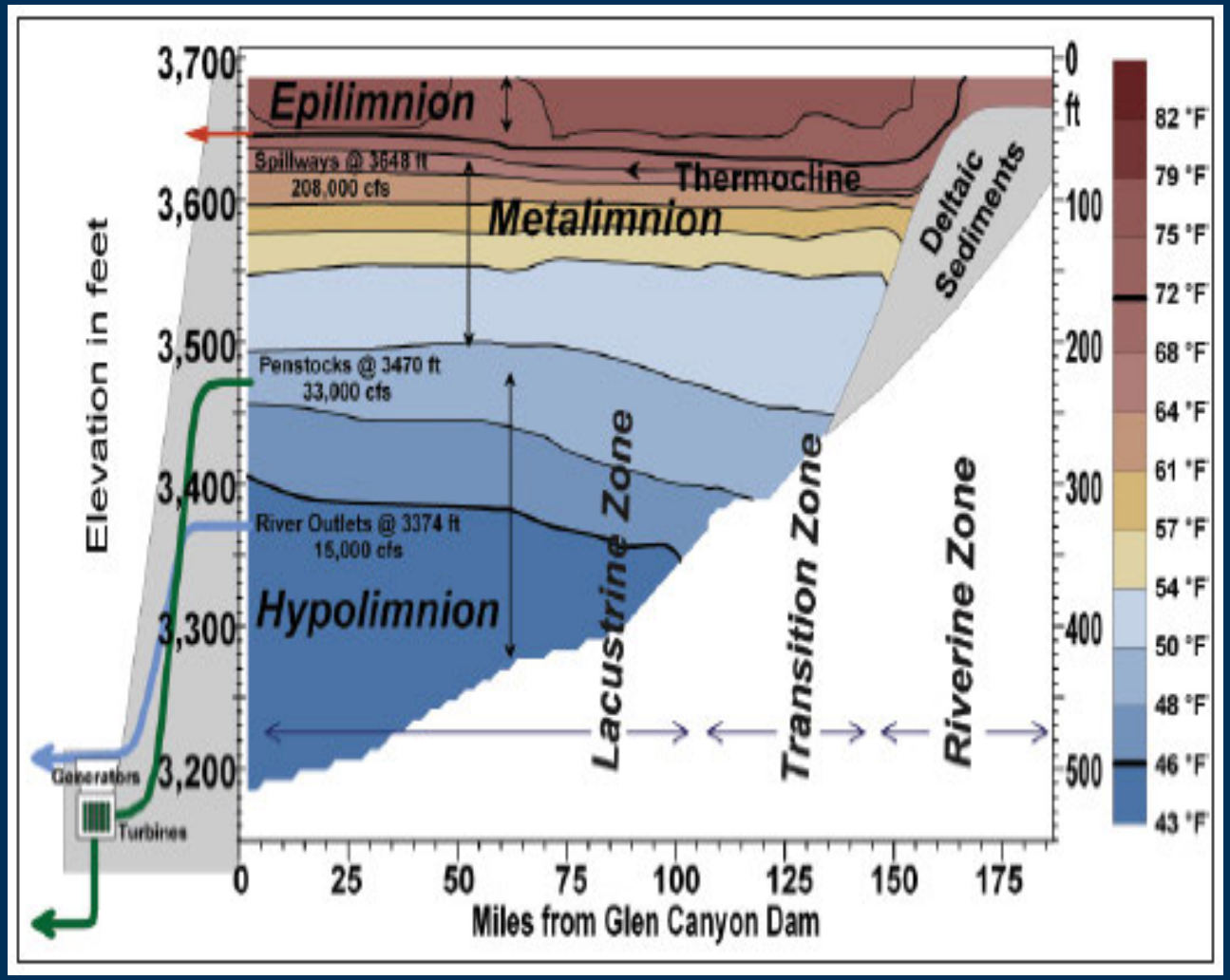
Lake Powell thermal stratification



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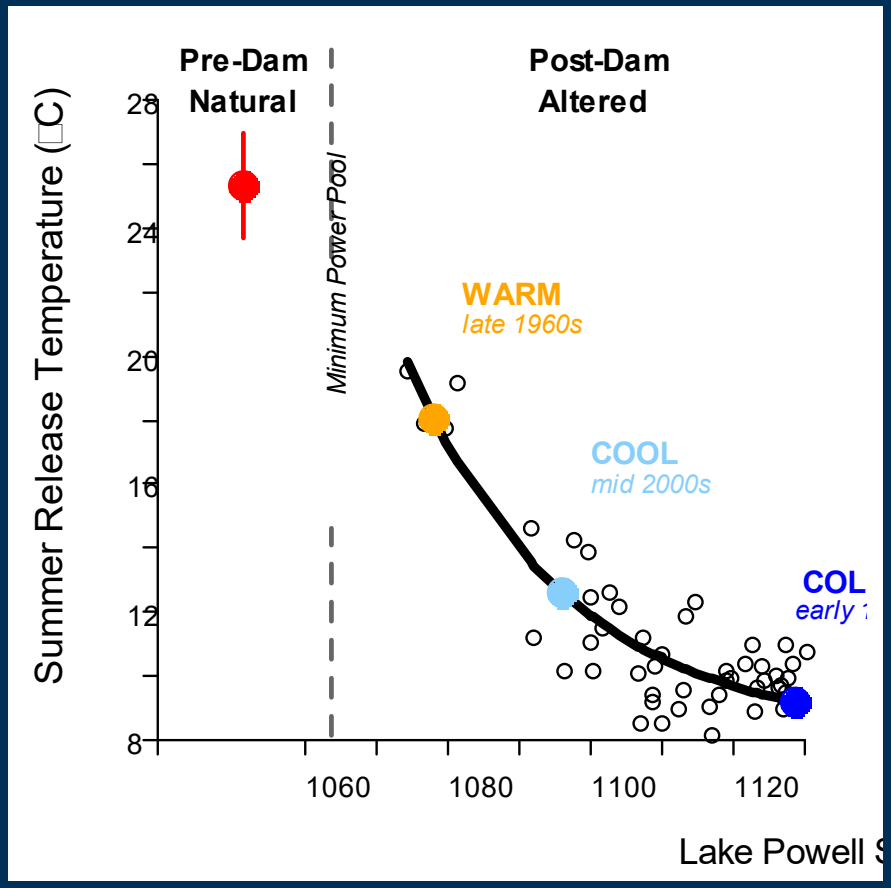
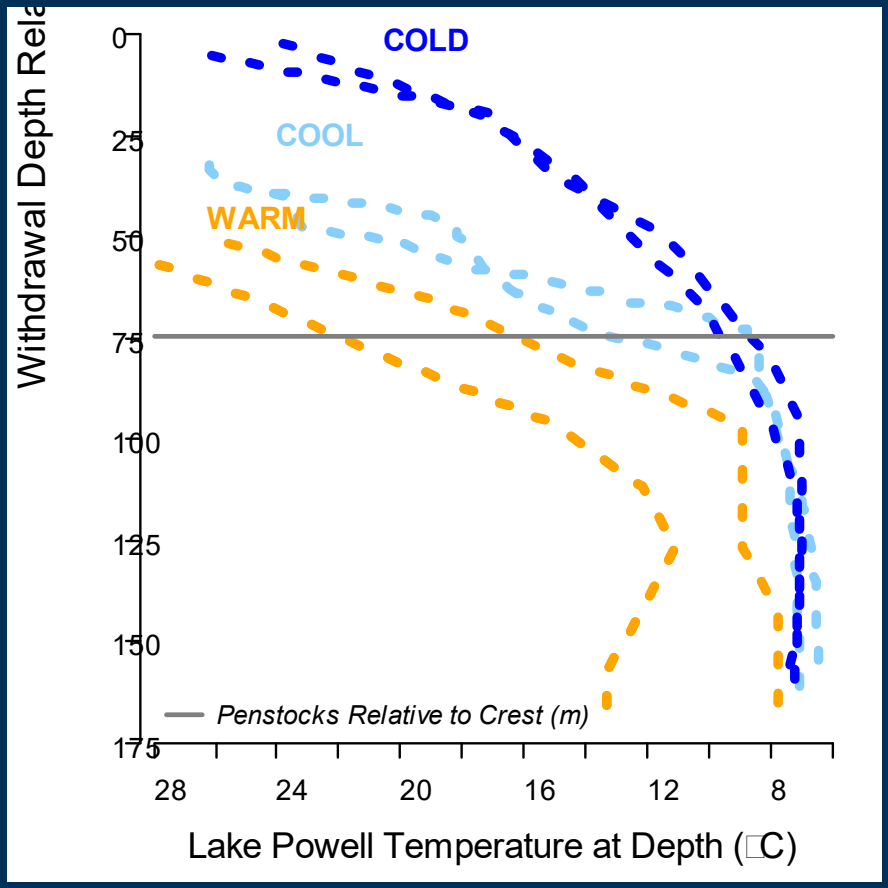
Vernieu et al. 2005

Lake Powell elevation as a driver of temperature



Dibble et al., In Review, Ecol Apps



Dibble et al., In Review, Ecol Apps

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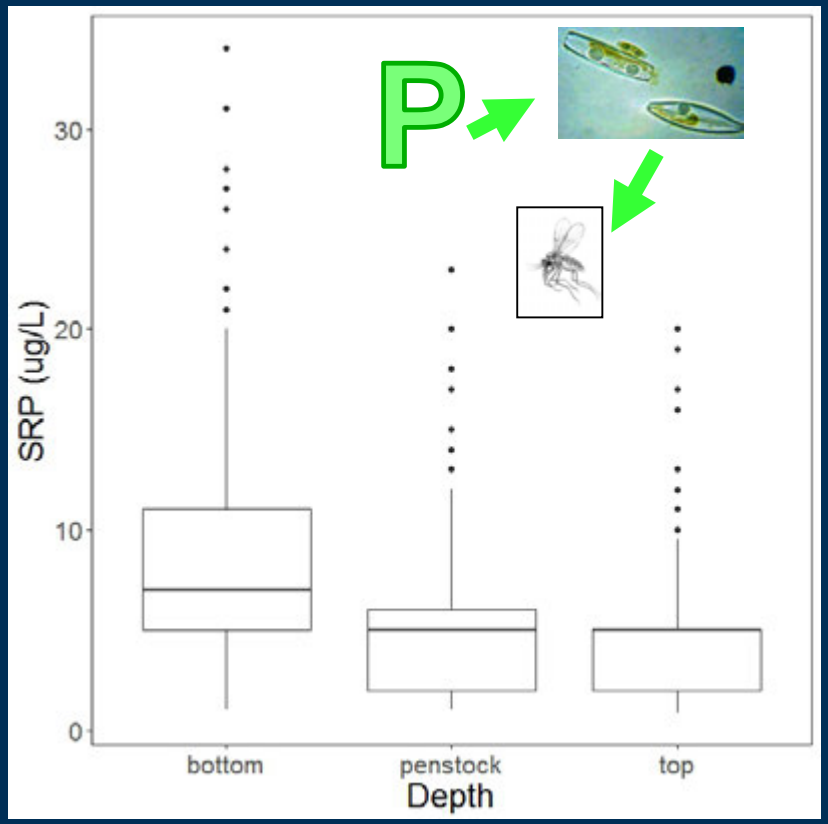
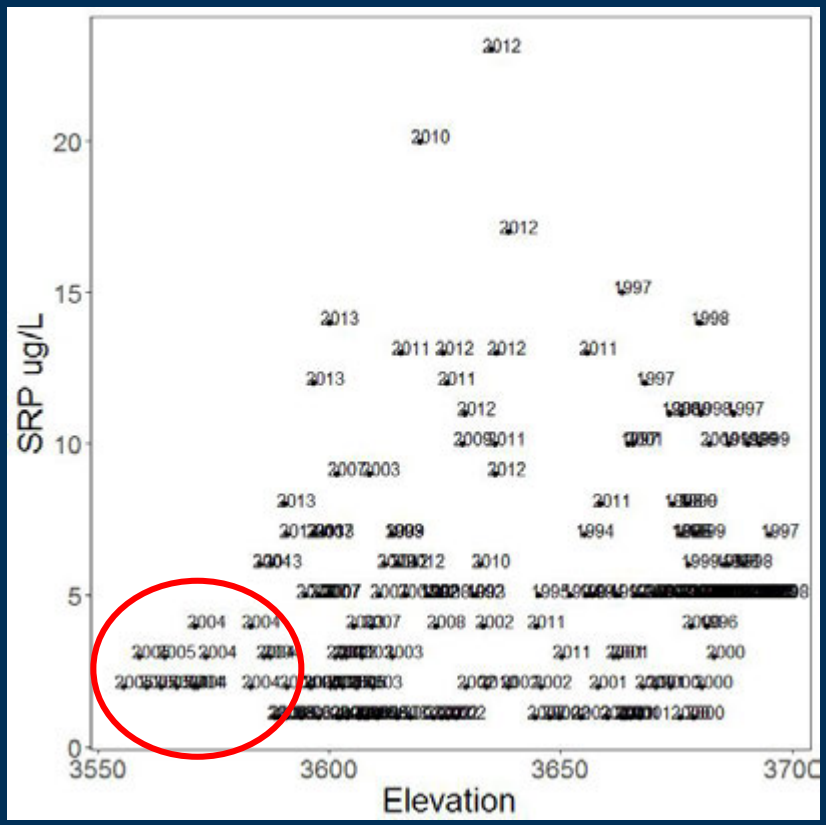
Lake Powell storage strongly influences river temperature downstream from Glen Canyon Dam

Preliminary Data – Do Not Cite

Warmer reservoir releases contain less nutrients



Deemer and Yackulic, Unpub. Data



Deemer and Yackulic, Unpub. Data

Phosphorus concentrations are elevated in bottom water

Warmer withdrawals may decrease nutrient availability → fish

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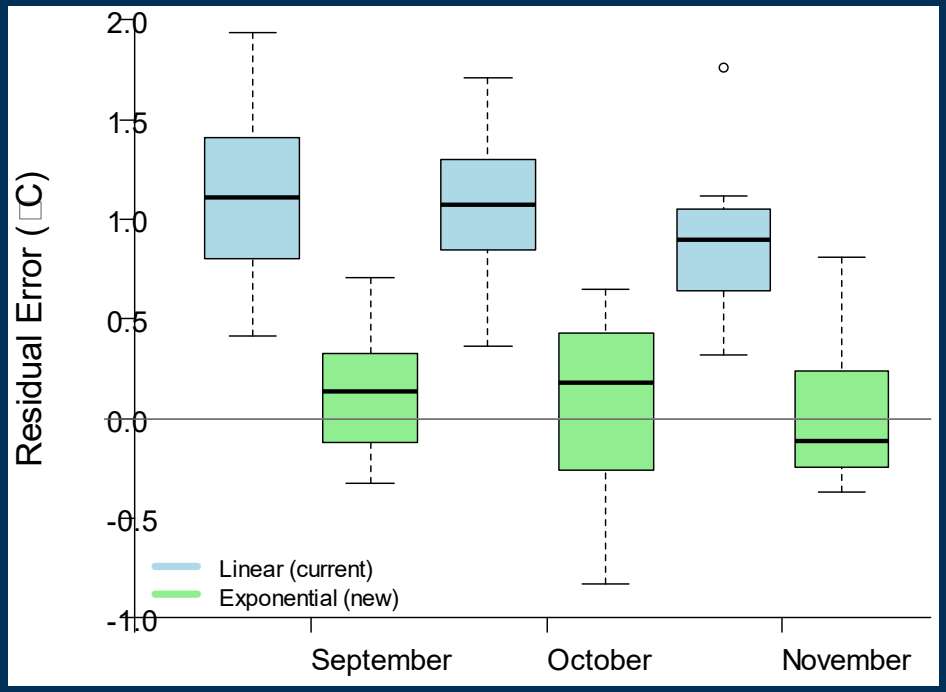
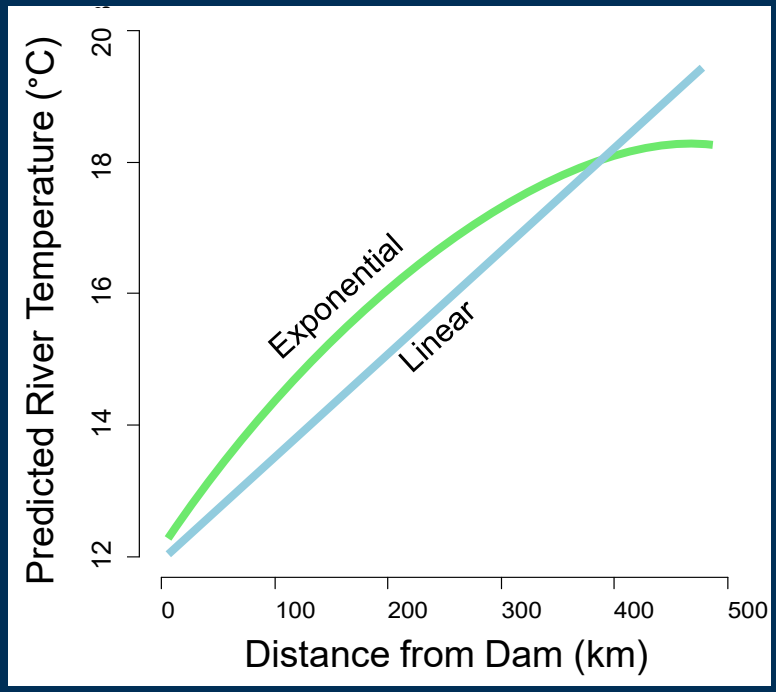
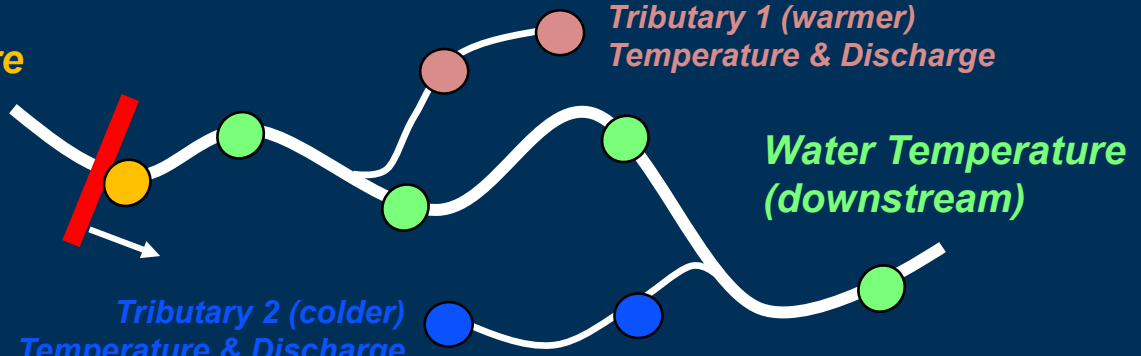
Preliminary Data – Do Not Cite

To model future river temperatures, we modified the current CR temperature model





Release Temperature
Air Temperature
Discharge at dam



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Preliminary Data – Do Not Cite

Ecological Applications, 25(8), 2015, pp. 2168–2179

FY13-14; Project Element H.4

Flow management and fish density regulate salmonid recruitment and adult size in tailwaters across western North America

KIMBERLY L. DIBBLE,[1,3] CHARLES B. YACKULIC,[1] THEODORE A. KENNEDY,[1] AND PHAEDRA BUDY[2]

[1]*U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona 86001 USA*
[2]*U.S. Geological Survey, Utah Cooperative Fish and Wildlife Research Unit, Department of Watershed Sciences and the Ecology Center, Utah State University, Logan, Utah 84322 USA*

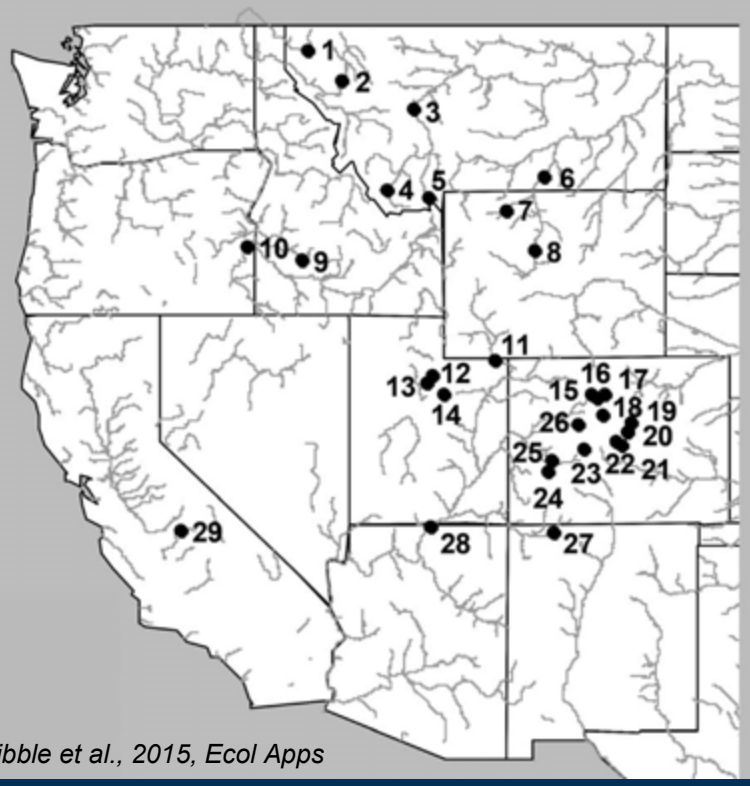
Warm water temperatures and shifts in seasonality increase trout recruitment but only moderately decrease adult size in western North American tailwaters

Kimberly L. Dibble · Charles B. Yackulic · Theodore A. Kennedy

FY15-17; Project Element 9.8

Dibble et al. 2018, EBF

Western North American dams included in synthesis



Dibble et al., 2015, Ecol Apps

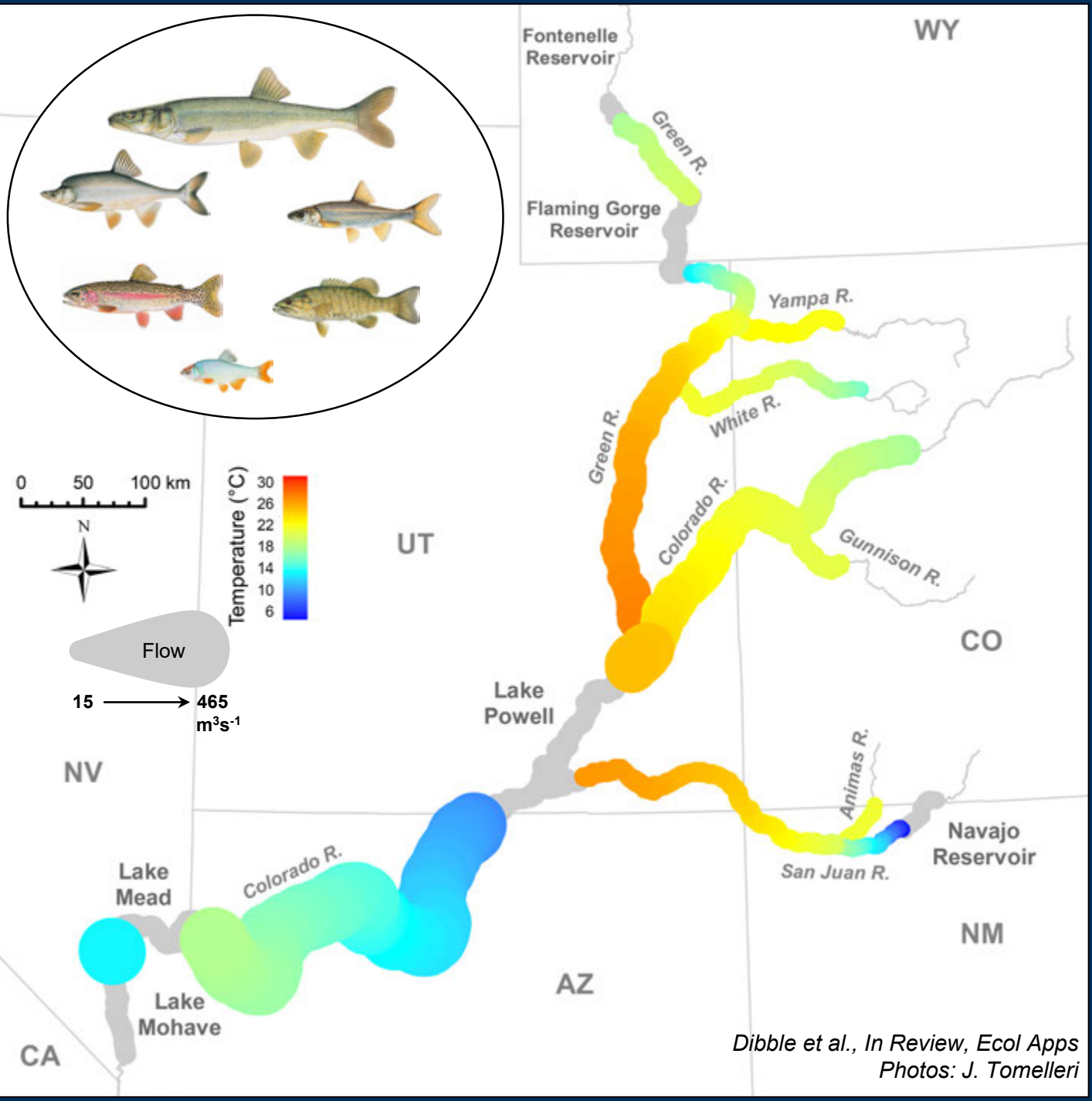
FY 2013-14 & FY 2015-17 Workplans = Data on Hand + USGS WaterSmart Funding

Wikimedia Commons, Creative Commons Copyright, Author: Shannon1; https://commons.wikimedia.org/wiki/File:Coloradorivermapnew1.jpg

Current thermal regime

Upper Basin
- Short tailwaters
- Warm summer thermal regime

Lower Basin
- Long tailwaters
- Cold summer thermal regime



Dibble et al., In Review, Ecol Apps
Photos: J. Tomelleri

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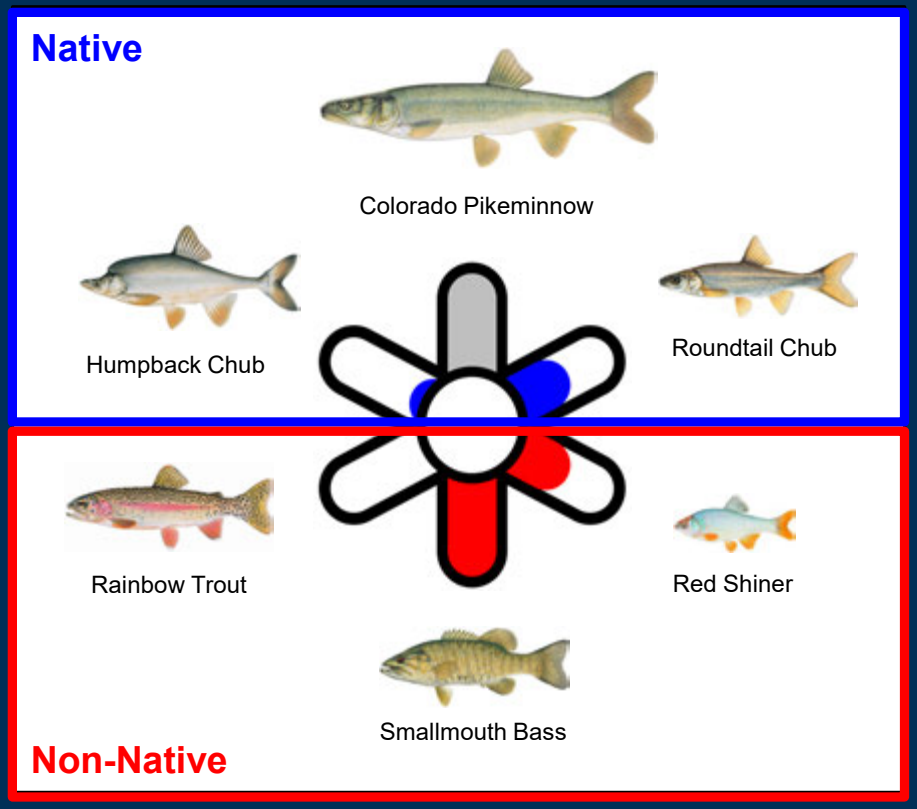
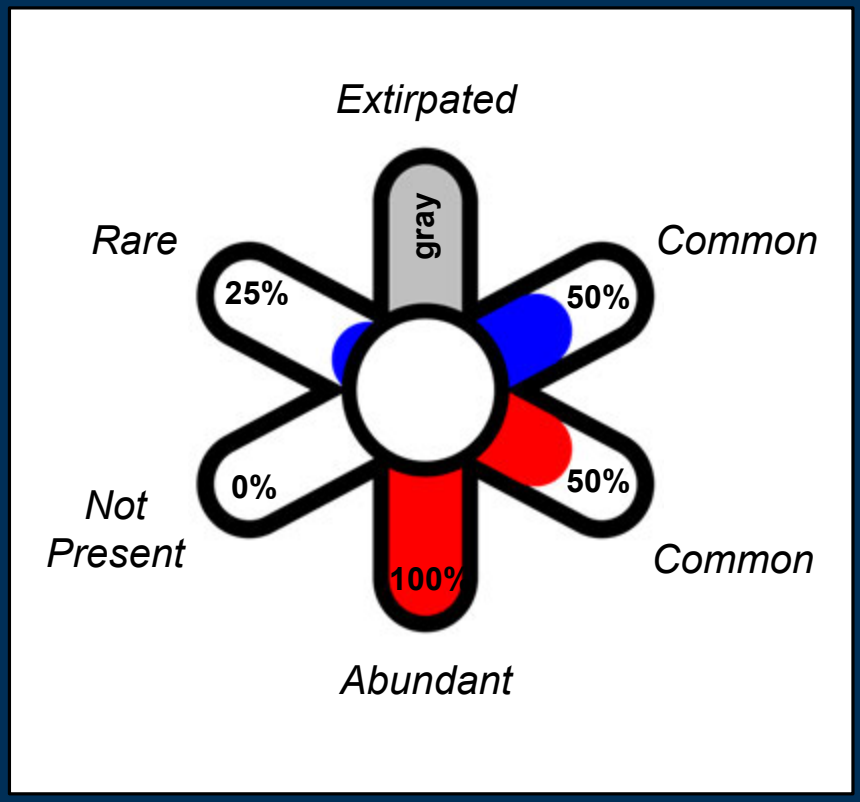
Preliminary Data – Do Not Cite

Fish community distribution and abundance

1. Species-Level Information



2. Relative Abundance



Photos: J. Tomelleri

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Preliminary Data – Do Not Cite

Fish community dynamics relative to current thermal regime

Cold-water non-native salmonids common to abundant in tailwaters

Warm-water non-native fish common to abundant in Upper Basin

Warm-water native fish rare or extirpated in basin

Humpback chub abundant in Grand Canyon despite cold water temperatures

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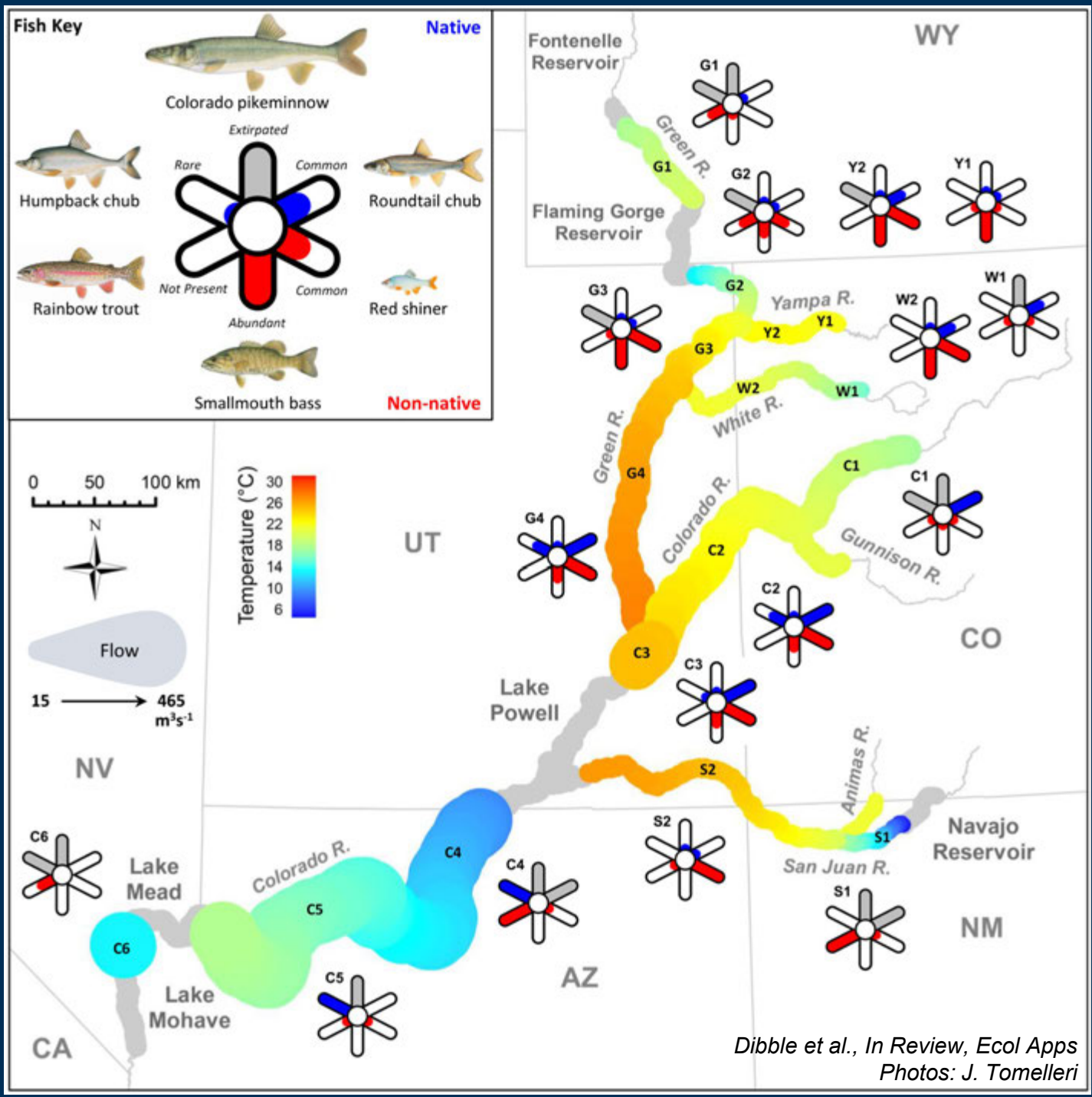
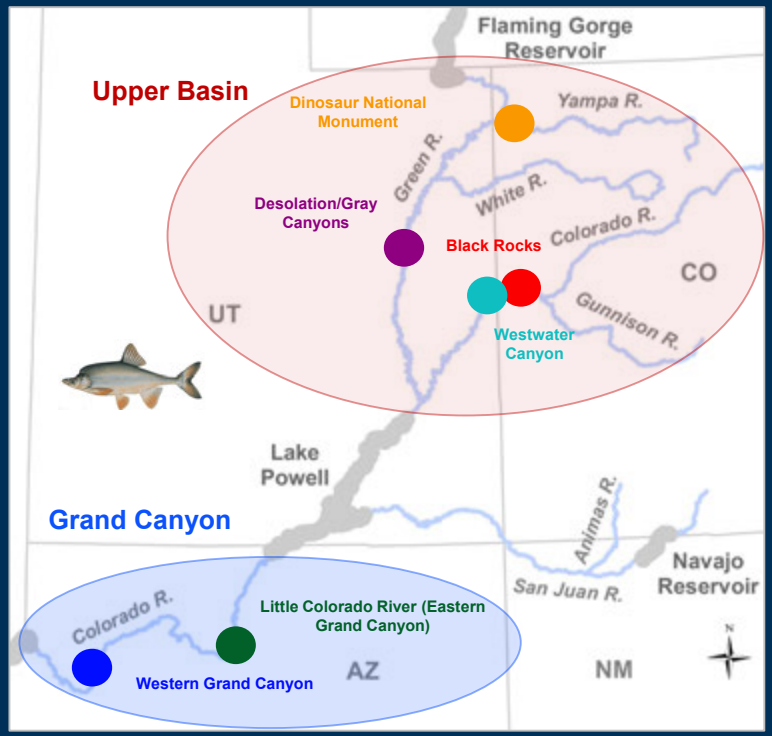
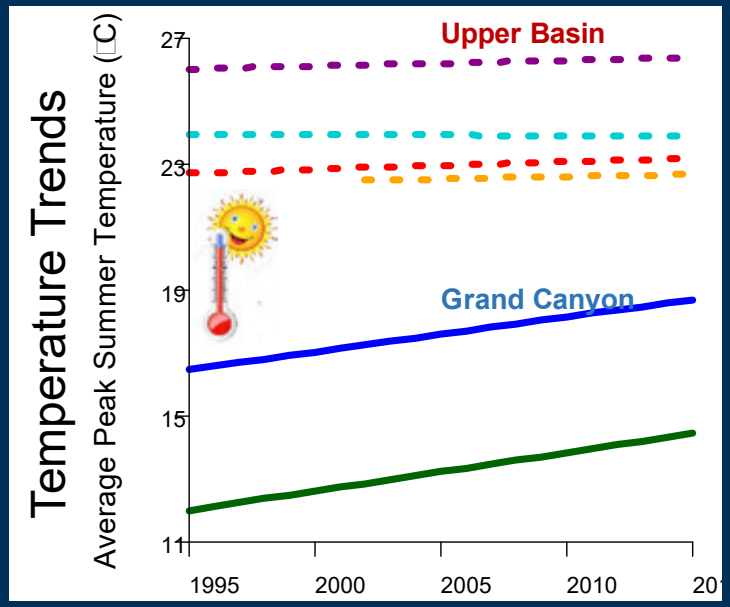
Preliminary Data – Do Not Cite

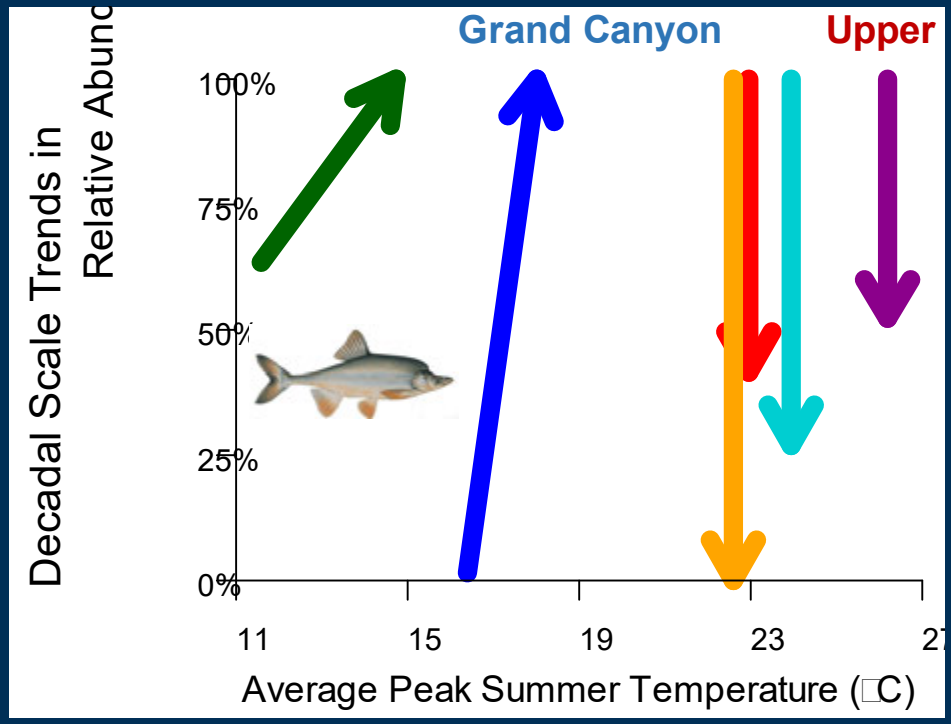


Dibble et al., In Review, Ecol Apps
Photos: J. Tomelleri

Humpback Chub decadal scale trends in abundance relative to temperature



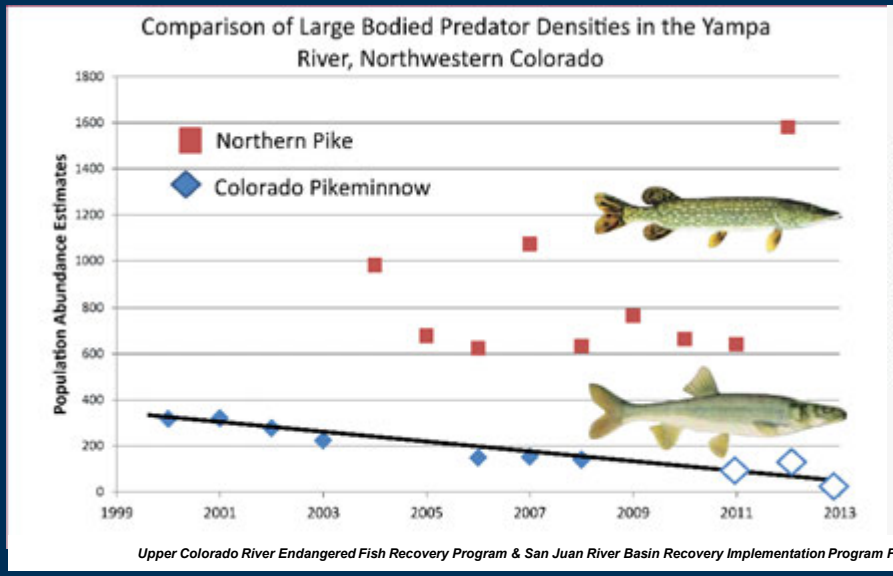


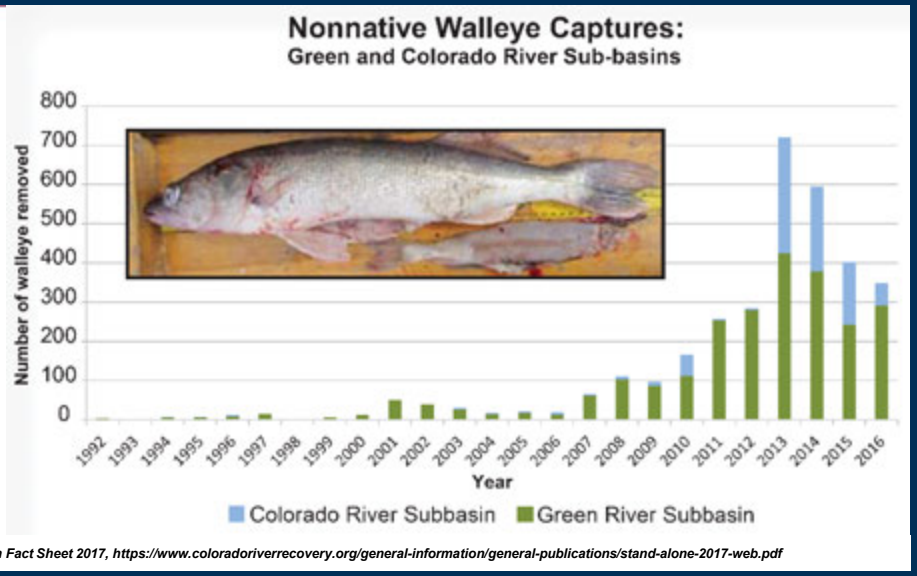


Dibble et al., In Review, Ecol Apps
Photos: J. Tomelleri

Preliminary Data – Do Not Cite

Warm-water non-native fish in Upper Basin

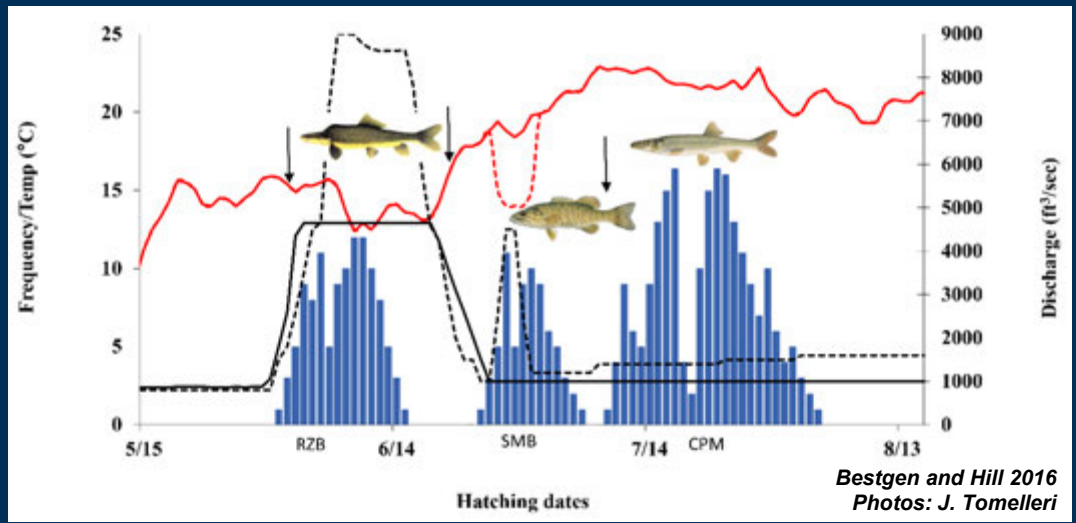




Upper Colorado River Endangered Fish Recovery Program & San Juan River Basin Recovery Implementation Program Fact Sheet 2017, https://www.coloradoriverrecovery.org/general-information/general-publications/stand-alone-2017-web.pdf

UCREFRP & SJRBRIP Fact Sheet 2017

UCREFRP & SJRBRIP Fact Sheet 2017



Bestgen and Hill 2016
Photos: J. Tomelleri

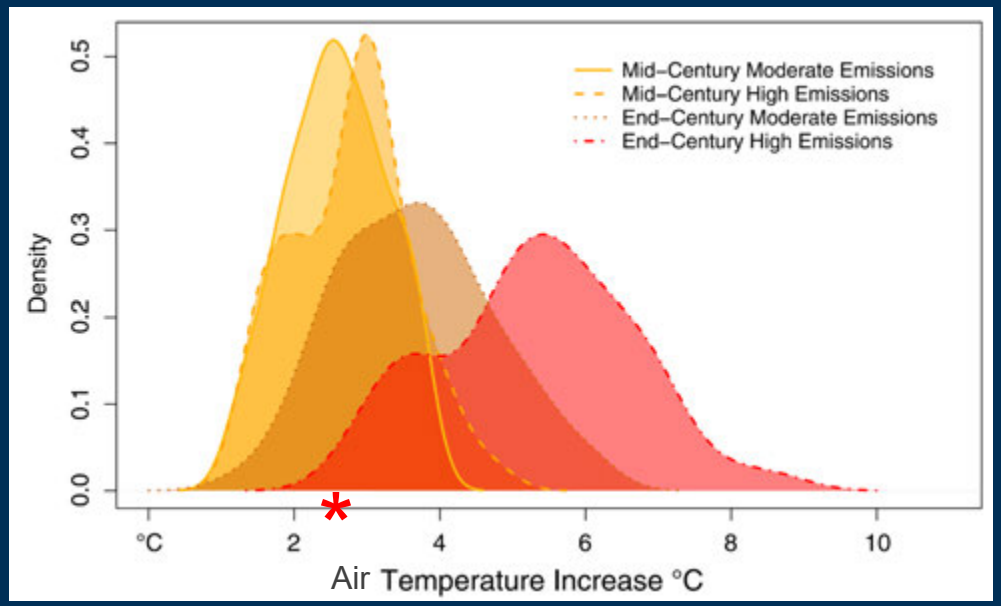
Humpback Chub

Bonytail

Colorado Pikeminnow

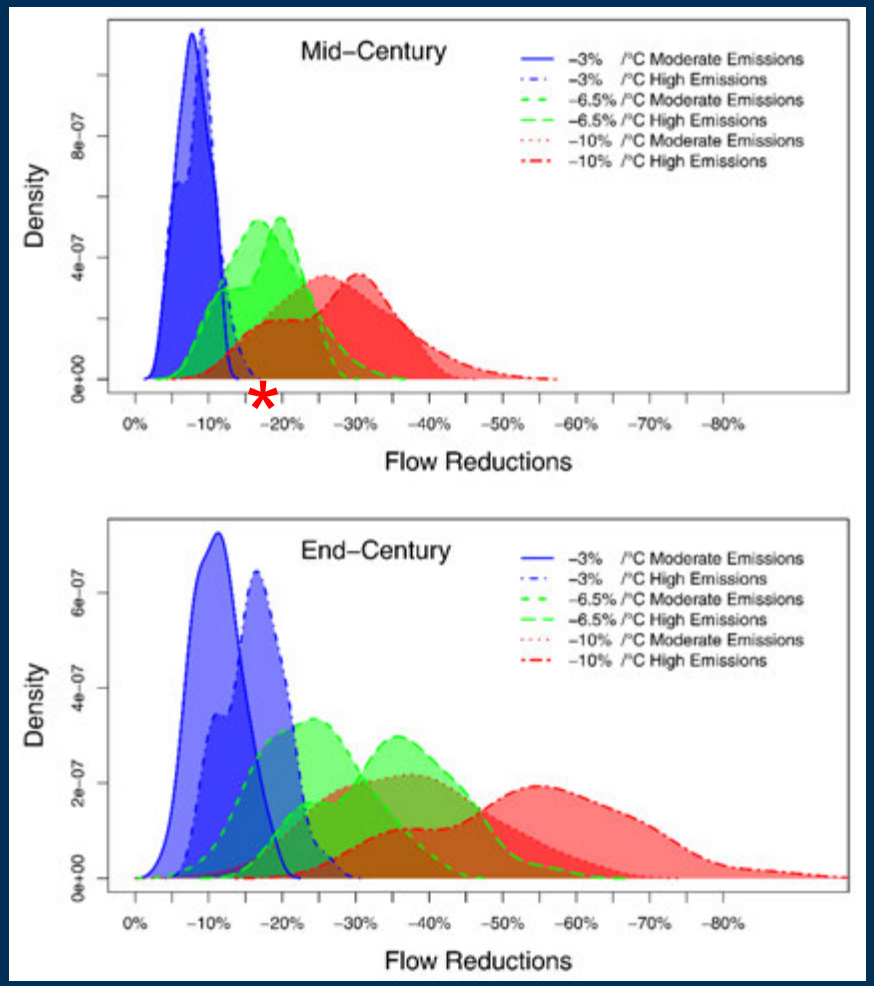
Razorback Sucker

What are basin-wide expectations for the future?



Increased air temperature (2.6ºC)

Decreased flow (17%)



Udall and Overpeck 2017 **

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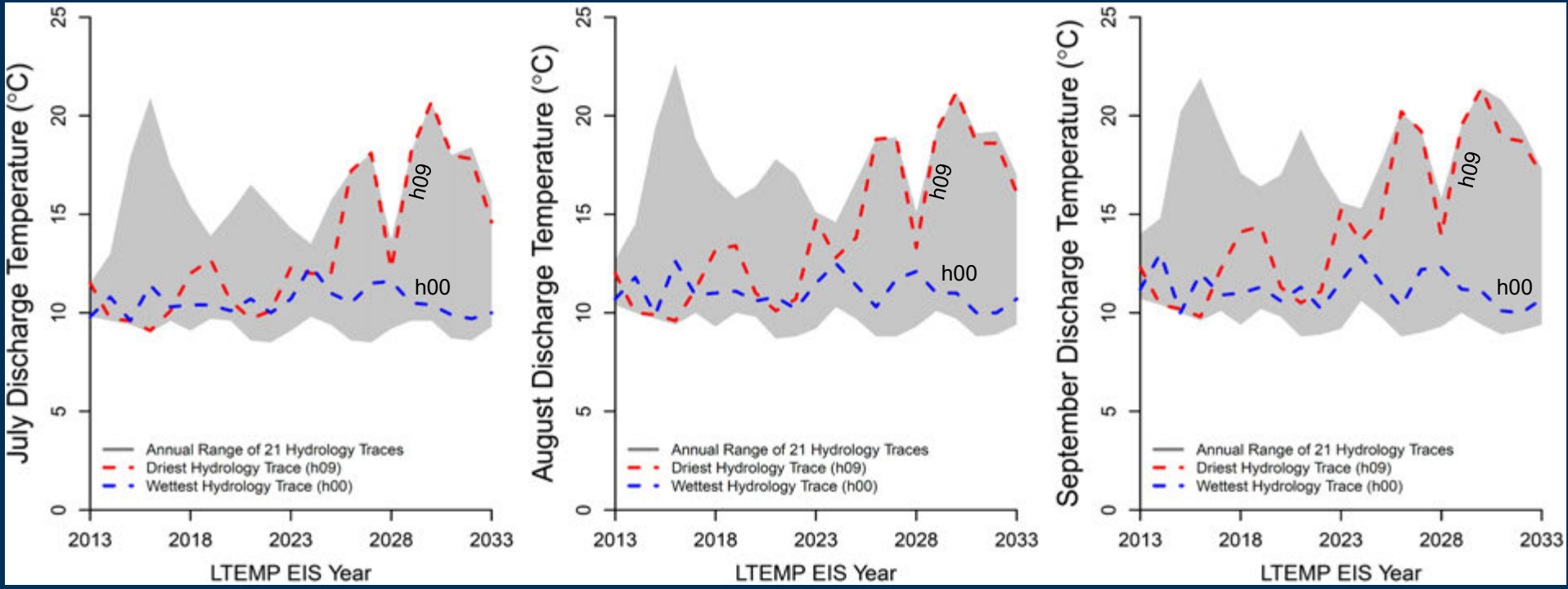
** *High emissions: business-as-usual, SRES A2 and RCP8.5; Moderate emissions: somewhat reduced by mitigation, SRES A1B and RCP4.5*

Potential future Lake Powell release temperatures (LTEMP EIS)



Dibble et al., In Review, Ecol Apps

Drier hydrology traces based on mean annual inflows indicate release temperatures in summer have the potential to reach ~20 °C

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Preliminary Data – Do Not Cite

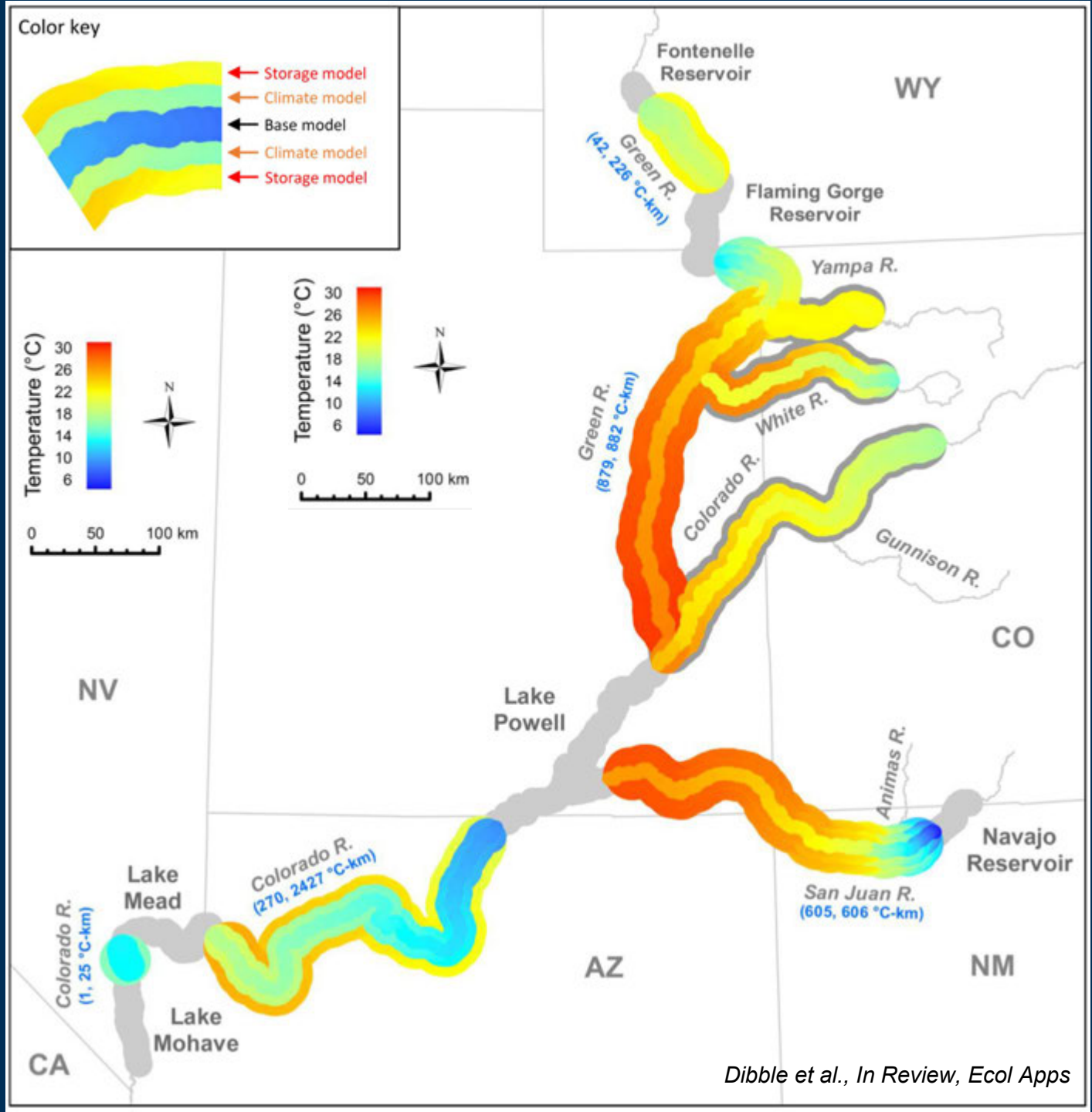
To what degree will changes in air temperature, discharge, and storage drive future river temperatures?

Increased air temperature (2.6ºC)

Decreased Colorado River flow (17%)

Decreased reservoir storage

Future thermal regime



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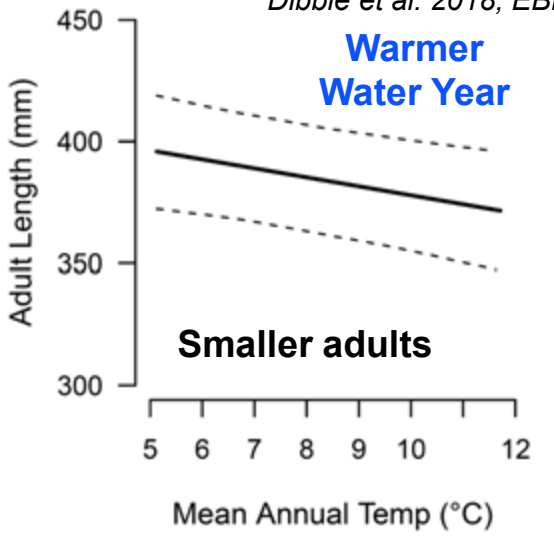
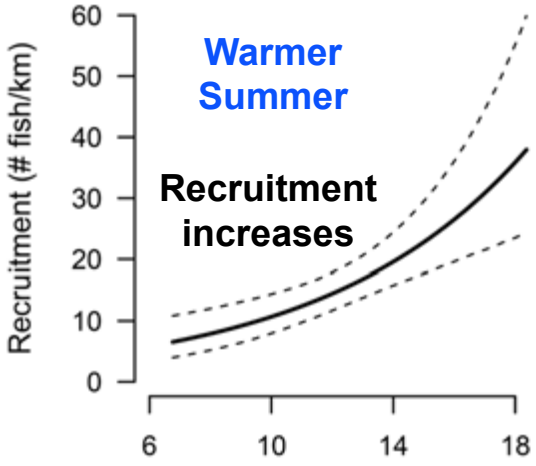
Dibble et al., In Review, Ecol Apps

Effects of warmer water on rainbow trout

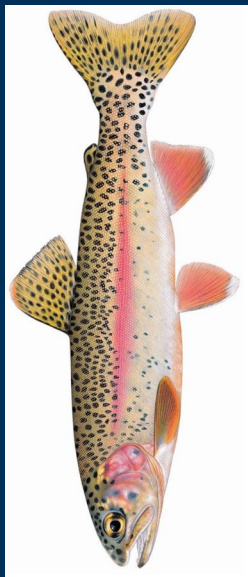
Dibble et al. 2018, EBF



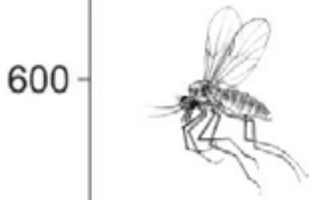
FY15-17; Project Element 9.8



Dibble et al. 2018, EBF



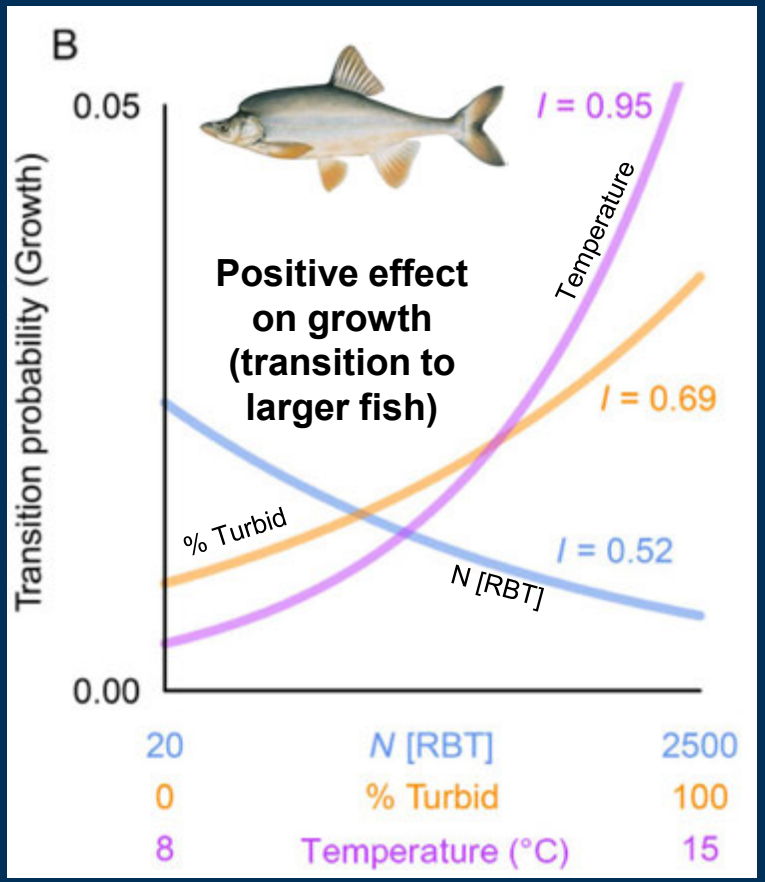
Dodrill et al. 2016, CJFAS, with modifications



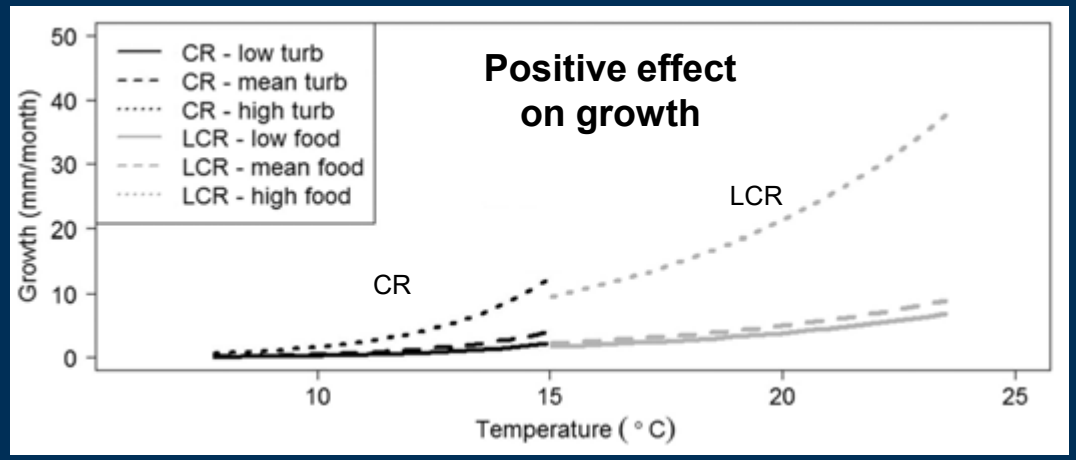
Warmer temperatures = smaller adult trout with current foodbase

Preliminary Data – Do Not Cite

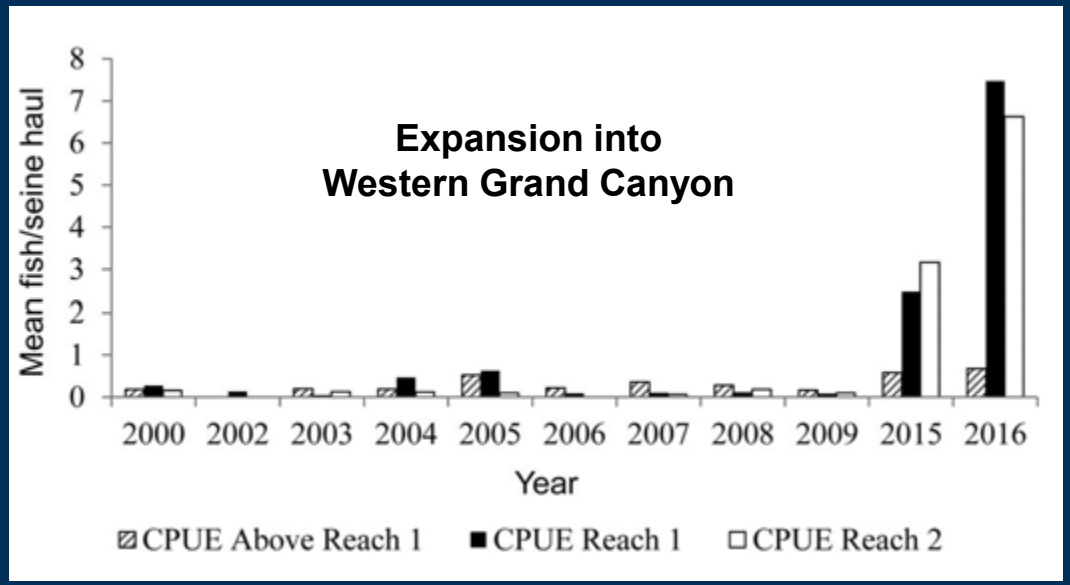
Effects of warmer water on humpback chub



Yackulic et al. 2018, Ecology



Dzul et al. 2016, CJFAS



VanHaverbeke et al. 2018, Southwestern Naturalist

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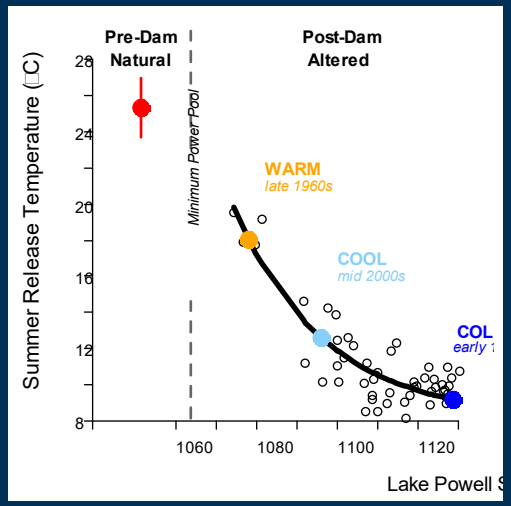
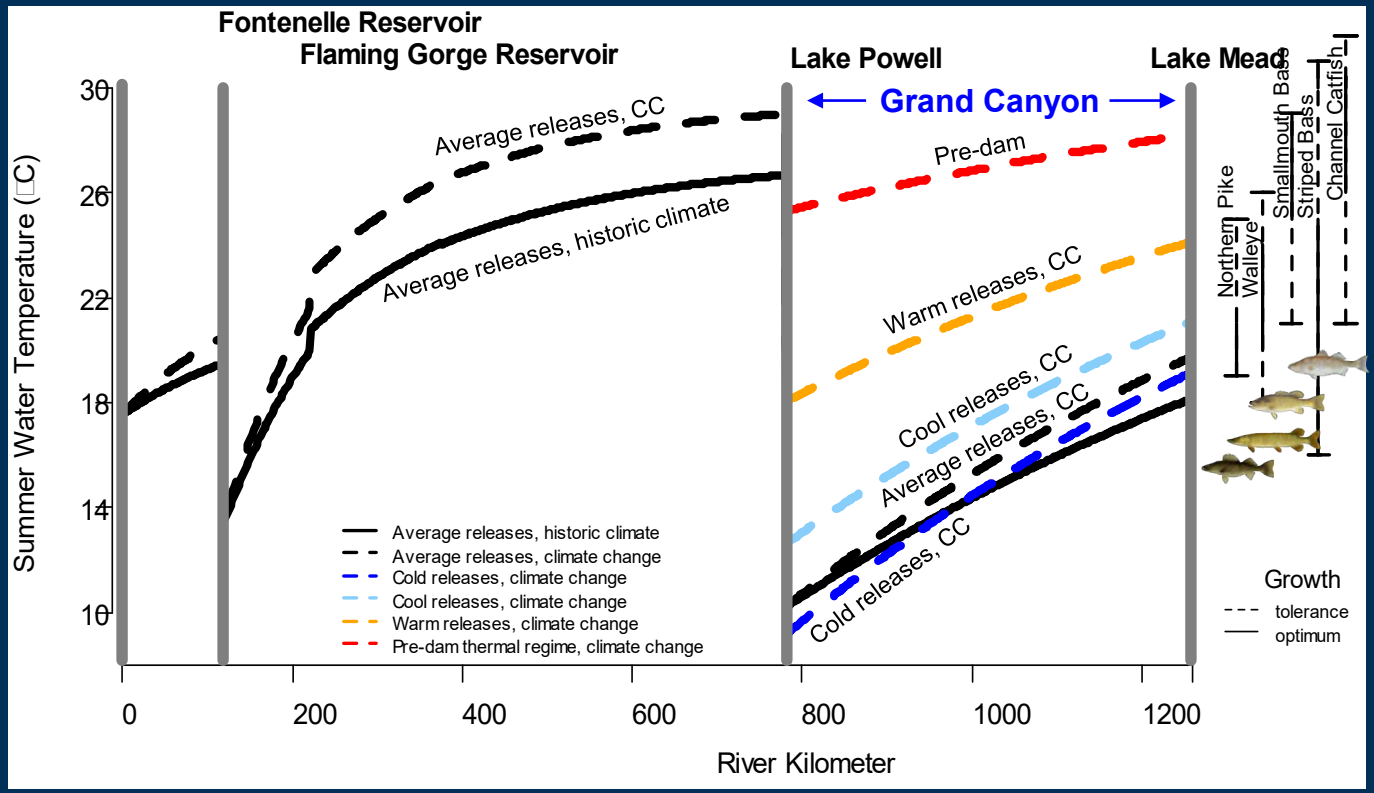
Warm-water non-native fish invasion into GC?



Dibble et al., In Review, Ecol Apps



Dibble et al., Unpub. Data

USGS

Preliminary Data – Do Not Cite

Potential ecological outcomes of a warmer CRe

Potential mainstem spawning and higher growth of native fish

Humpback Chub

Razorback Sucker

Potential boost in invertebrate taxa; better food base

Caddisflies

Midges

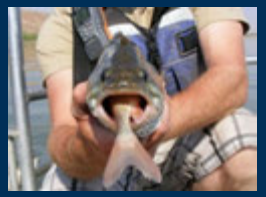
Potential nutrient decline (warmer, epilimnetic), implications for food base

P

Diatoms

Midges

Potential rainbow trout decline, replacement by piscivorous non-native fish



Smallmouth Bass

Northern Pike

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Preliminary Data – Do Not Cite

Acknowledgements

Funding

- USBR Glen Canyon Dam Adaptive Management Program
- USGS WaterSMART Program

Coauthors

- Charles Yackulic, USGS
- Jack Schmidt, Utah State University
- Ted Kennedy, USGS
- Kevin Bestgen, Colorado State University

Data

- Colorado Division of Water Resources
- U.S. Army Corps of Engineers
- U.S. Bureau of Reclamation, Hydromet
- USDA NRCS National Water and Climate Center
- Upper Colorado River Endangered Fish Recovery Program
- USFWS San Juan River Basin Recovery Implementation Program
- USGS BioData and WaterWatch
- Tom Gushue, USGS, GIS Support

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