Effects of HFEs on Growth and Population Dynamics of Rainbow Trout in Glen Canyon and Marble Canyon

Natal Origins mark-recapture project (2012-2017)

Trout
Recruitment
Growth
Dynamics

(2018-2020 Glen Canyon Only)

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Michael D. Yard, USGS, GCMRC, Flagstaff, AZ

Scott A. Wright, USGS, California Water Science Center, Sacramento, CA

AMWG Reporting Meeting, March 2018

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- **Sampling design and modelling:** Charles Yackulic and Carl Walters
- **Supporting data:** Ted Kennedy et al., Dave Topping et al., Bridget Deemer
- **Field work: Thanks to the boatmen, biologists, and technicians!**

Primary Publications from Natal Origins Mark-Recapture Project or Data (2012-2017)

Rainbow Trout Growth and Population Dynamics (6) – Natal Origins Sampling Trips

- Korman, J., M.D. Yard, and T.A. Kennedy. 2017. Trends in rainbow trout recruitment, abundance, survival, and growth during a boom-and-bust cycle in a tailwater fishery. Trans. Am. Fish. Soc. 146:1043-1057.
- Korman, J., and M.D. Yard. 2017. Effects of environmental covariates and density on the catchability of fish populations and the interpretation of catch per unit effort trends. Fish. Res. 189:18-34.
- Dzul, M.C., Yackulic, C.B., and J. Korman. 2017. Estimating disperser abundance using open population models that incorporate data from continuous detection PIT arrays. Can. J. Fish. Aquat. Sci. e-first article.
- Yard, M.D., Korman, J., Walters, C.J., and T.A. Kennedy. 2016. Seasonal and spatial patters of growth of rainbow trout in the Colorado River in Grand Canyon Arizona. Can. J. Fish. Aquat. Sci. 73:125-139.
- Korman, J, Yard, M.D., and C.B. Yackulic. 2016. Factors controlling the abundance of rainbow trout in the Colorado River in Grand Canyon in a reach utilized by endangered humpback chub. Can. J. Fish. Aquat. Sci. 73:105-124.
- Dodrill, M.D., Yackulic, C.B., Yard, M.D. and J.W. Hayes. 2016. Prey size and availability limits maximum size of rainbow trout in a large tailwater: insights from a drift-foraging bioenergetics model. Can. J. Fish. Aquat. Sci. 73: 759-772.

Humpback Chub (4) – Juvenile Chub Monitoring conducted during Natal Origins Sampling Trips

- Yackulic, C.B, Yard, M.D., Korman, J. and D.R. Haverbeke. 2014. A quantitative life history of endangerd humpback chub that spawn in the Little Colorado River: variation in movement, growth, and survival. Ecol. Evol. 4: 1006-100.
- Yackulic, C.B., Korman, J., Yard, M.D., and J. Dzul.. 2018. Inferring species interactions through joint mark-recapture analysis. Ecology. Early view article.
- Dzul, M.C., Yackulic, C.B., Korman, J., Yard, M.D., and J.D. Muehlbauer. 2016. Incorporating temporal heterogeneity in environmental conditions into a somatic growth model. Can. J. Fish. Aquat. Sci. 74:316-326.
- Finch, C., W. E. Pine, C. B. Yackulic, M. J. Dodrill, M. Yard, B. S. Gerig, L. G. Coggins, and J. Korman. 2016. Assessing Juvenile Native Fish Demographic Responses to a Steady Flow Experiment in a Large Regulated River. River Research and Applications 32:763-775

Outline

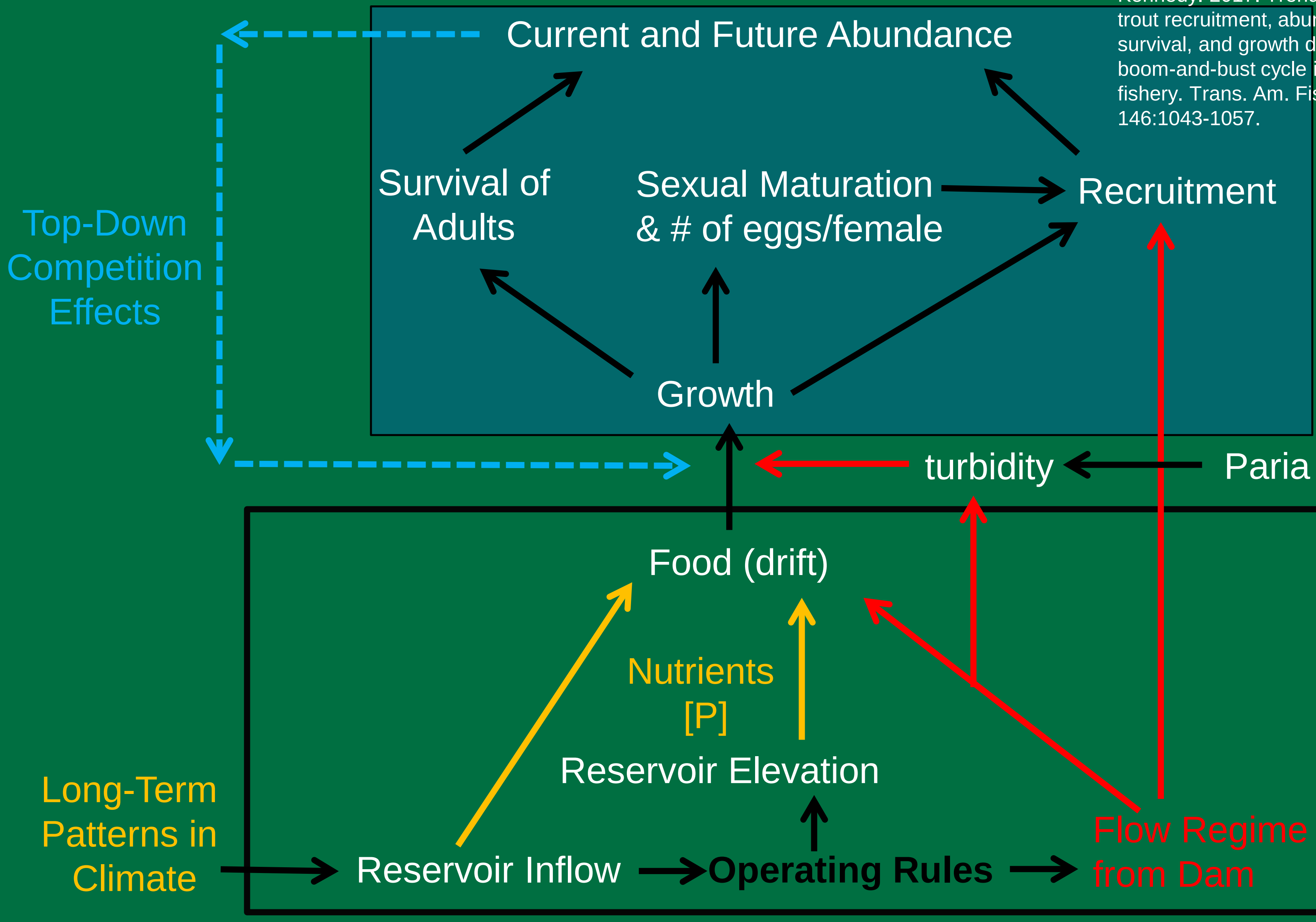
1. Conceptual model describing factors that control rainbow trout growth and abundance.

2. Effect of HFEs on rainbow trout growth in Glen Canyon

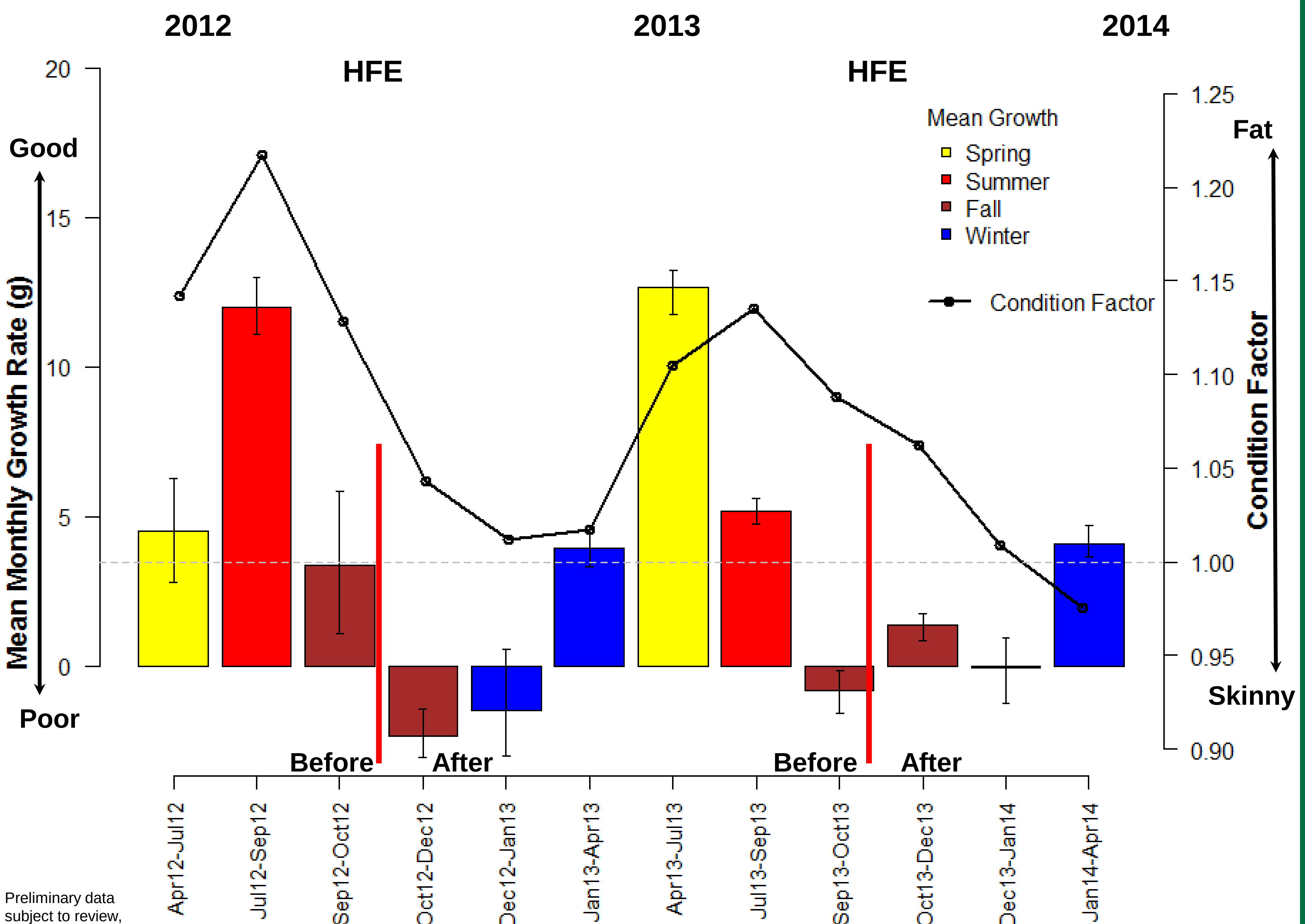
3. Effects of HFEs on rainbow trout growth and abundance in Marble Canyon

Conceptual Model for Rainbow Trout in Glen Canyon and Marble Canyon

Korman, J., M.D. Yard, and T.A. Kennedy. 2017. Trends in rainbow trout recruitment, abundance, survival, and growth during a boom-and-bust cycle in a tailwater fishery. Trans. Am. Fish. Soc. 146:1043-1057.

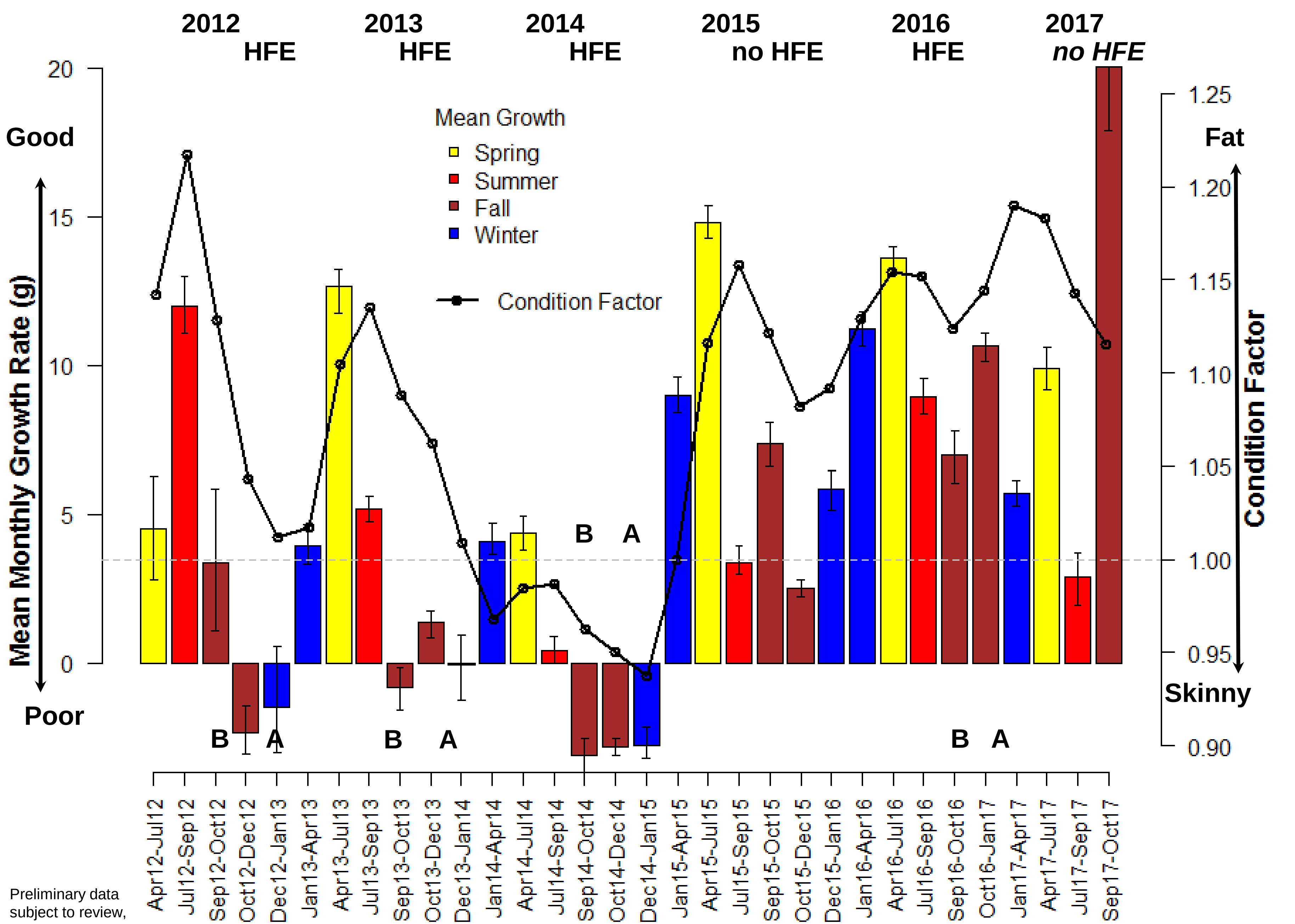


Trends in Growth and Condition (200 mm trout)



Preliminary data subject to review, do not cite

Trends in Growth and Condition (200 mm trout)



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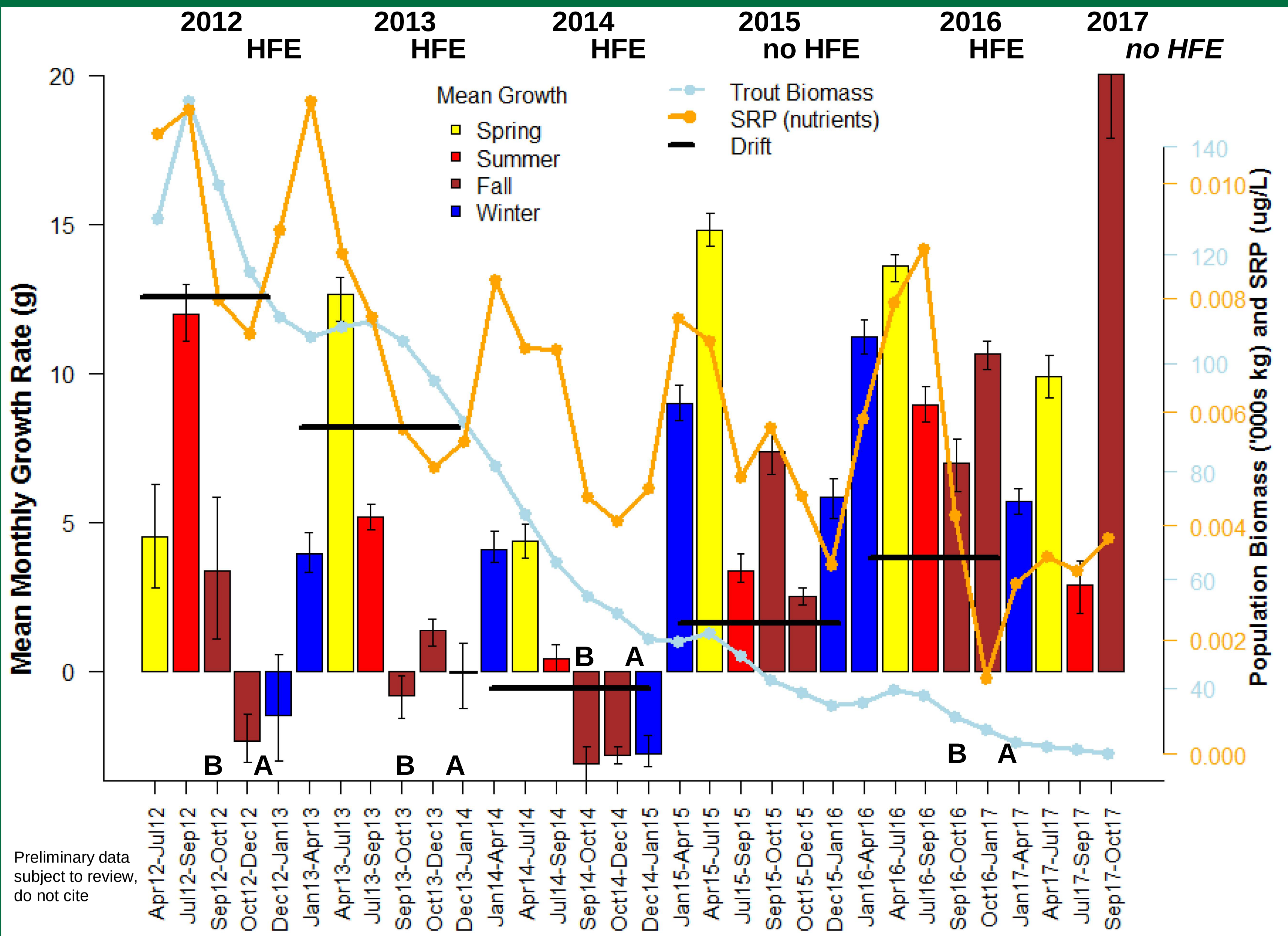
Effect of Nutrients and Biomass on Growth



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Summary of HFE Effects on Rainbow Trout Growth in Glen Canyon

Fall-Winter Growth	HFE Years	Non-HFE Years
Poor	’12 ’13 ‘14	
Good	‘16	’15
% Good Years	1 of 4 = 25%	1 of 1 = 100%

- Fall HFEs appear to reduce trout growth in fall and winter in Glen Canyon when assessed based on differences among years.

- **BUT** many limitations to this annual assessment:
  - Only 1 non-HFE year (no replication)
  - Poor growth immediately before HFEs occurred in 2 of 3 poor growth years (‘13, ‘14)
  - Confounding of HFE effect with nutrients and competition

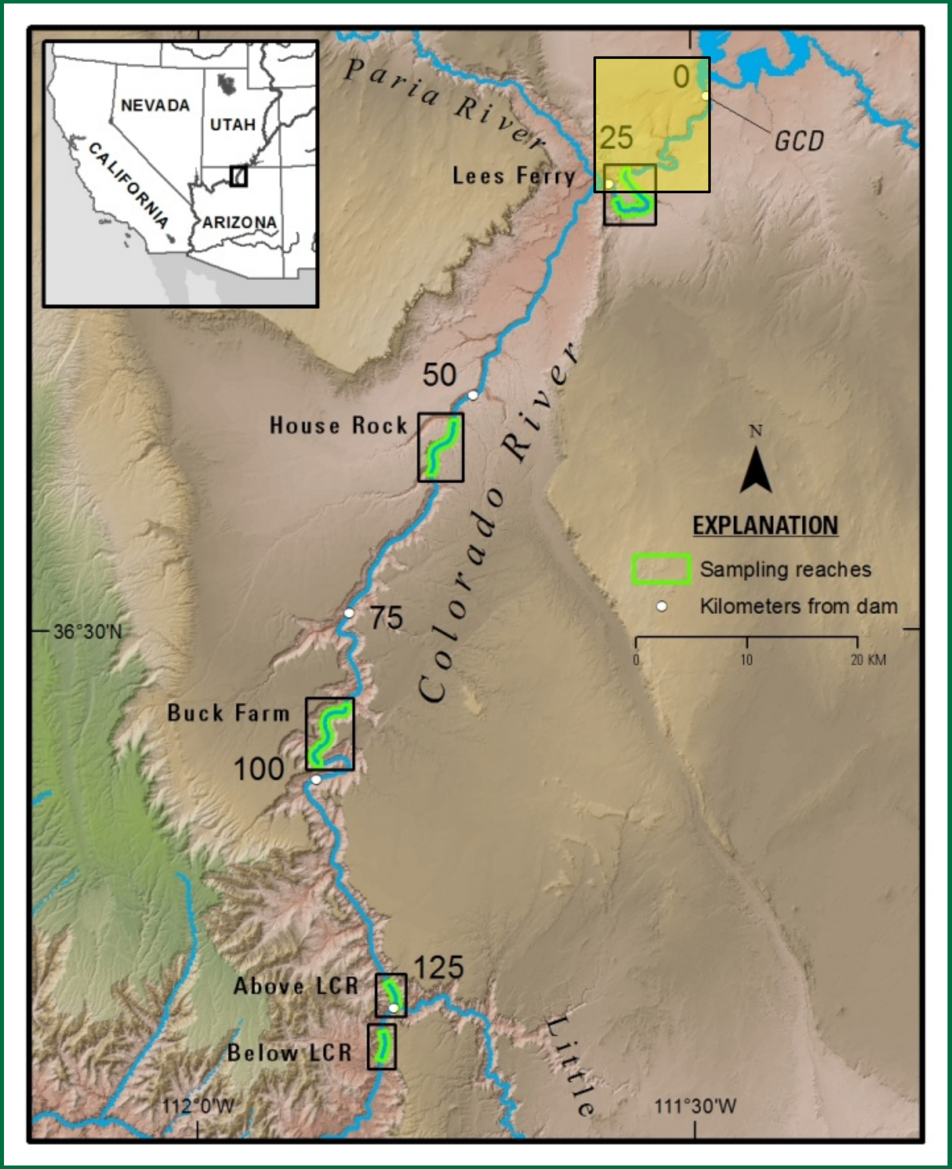
- Nutrients released from GCD and trout competition appear to have a bigger effect on growth than fall HFEs

- More years of mark-recapture data will allow us to quantify the likely modest effect of HFEs on trout growth.

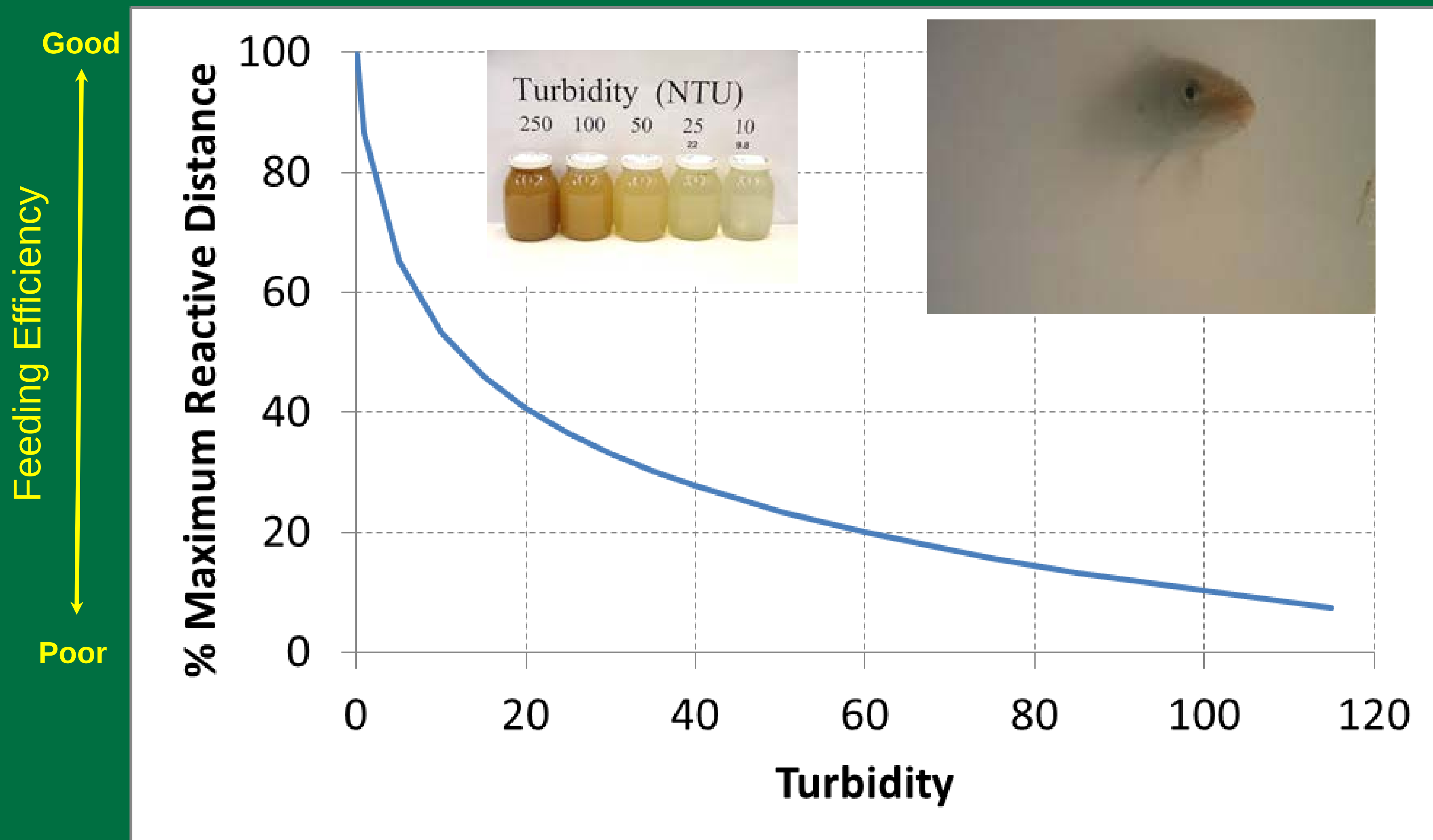
- Effects of HFEs on expanding macrophyte community in Glen Canyon and subsequent effect on food base and trout growth requires a much longer time period to evaluate.

Modelling Rainbow Trout Growth and Effects of HFEs in Marble Canyon

- Predict growth as a function of dam-influenced covariates based on a linear regression model fit to more than 10,000 growth observations
- Data available from 18 trip intervals (Apr ’12 - Sep ’16) in 5 reaches
- Covariates:
  - Discharge
  - Water temperature (metabolism)
  - Turbidity – Feeding efficiency
  - Light
  - Competition (trout abundance)
  - Drift (food)
- Most covariates influenced by GCD operations directly or through secondary effects



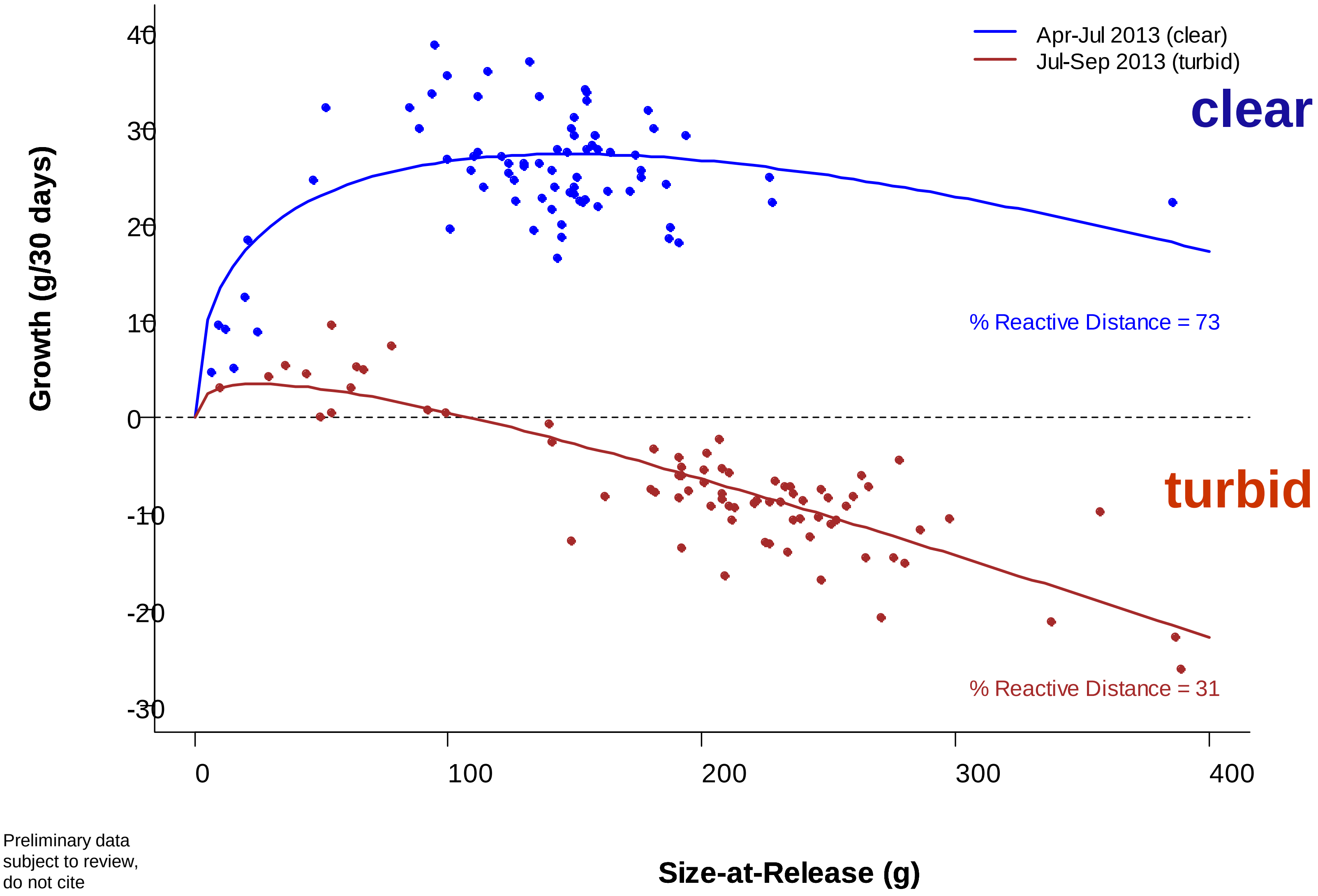
Very Modest Increases in Turbidity Substantially Reduce Trout Feeding Efficiency



Rosenfeld and Taylor, 2003

Effect of Turbidity-Feeding Efficiency on Growth

(1% of available data used to fit model)



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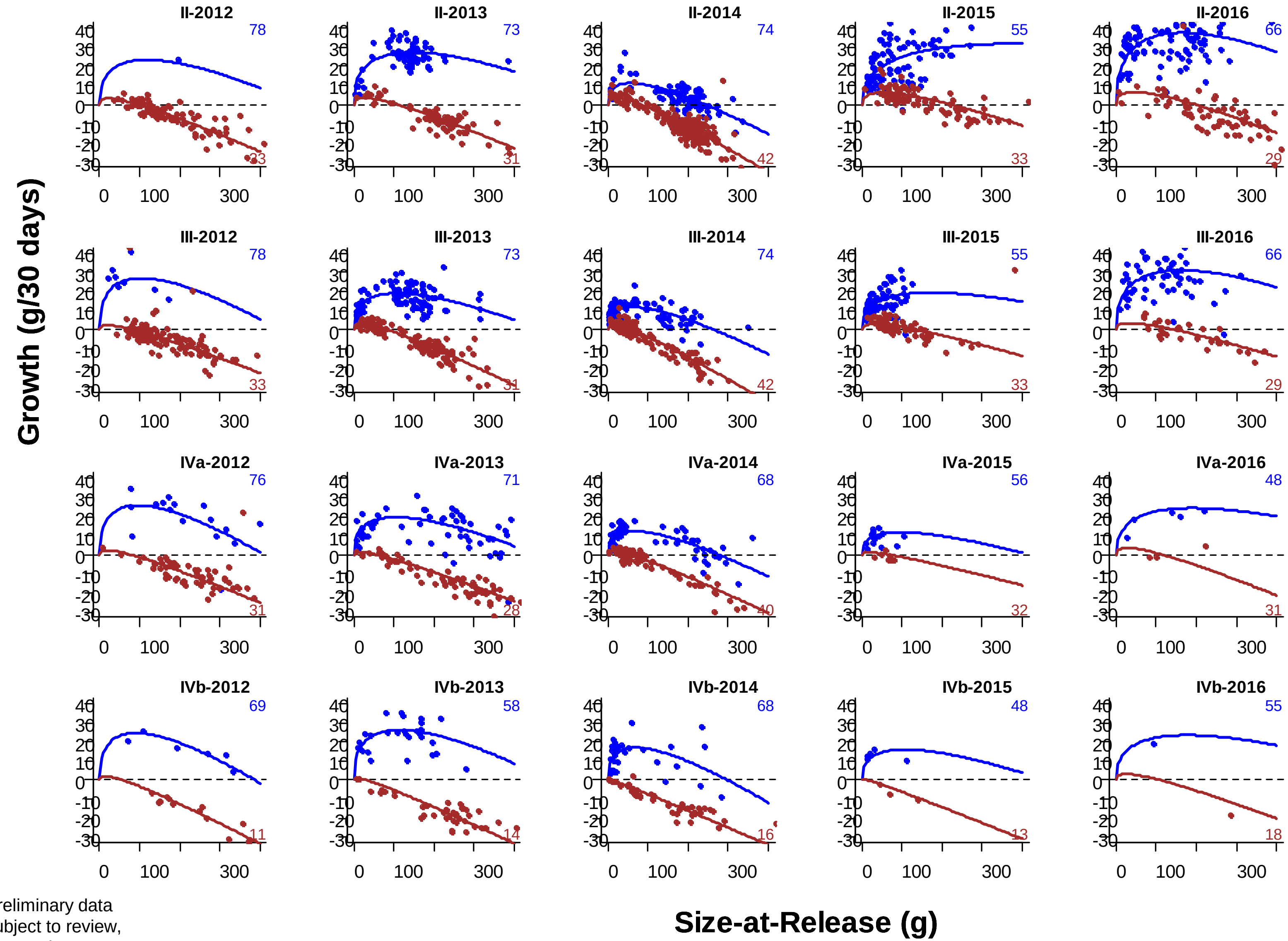
Turbidity-Feeding Efficiency on Growth Observed in all Reaches Downstream of Paria in all Years



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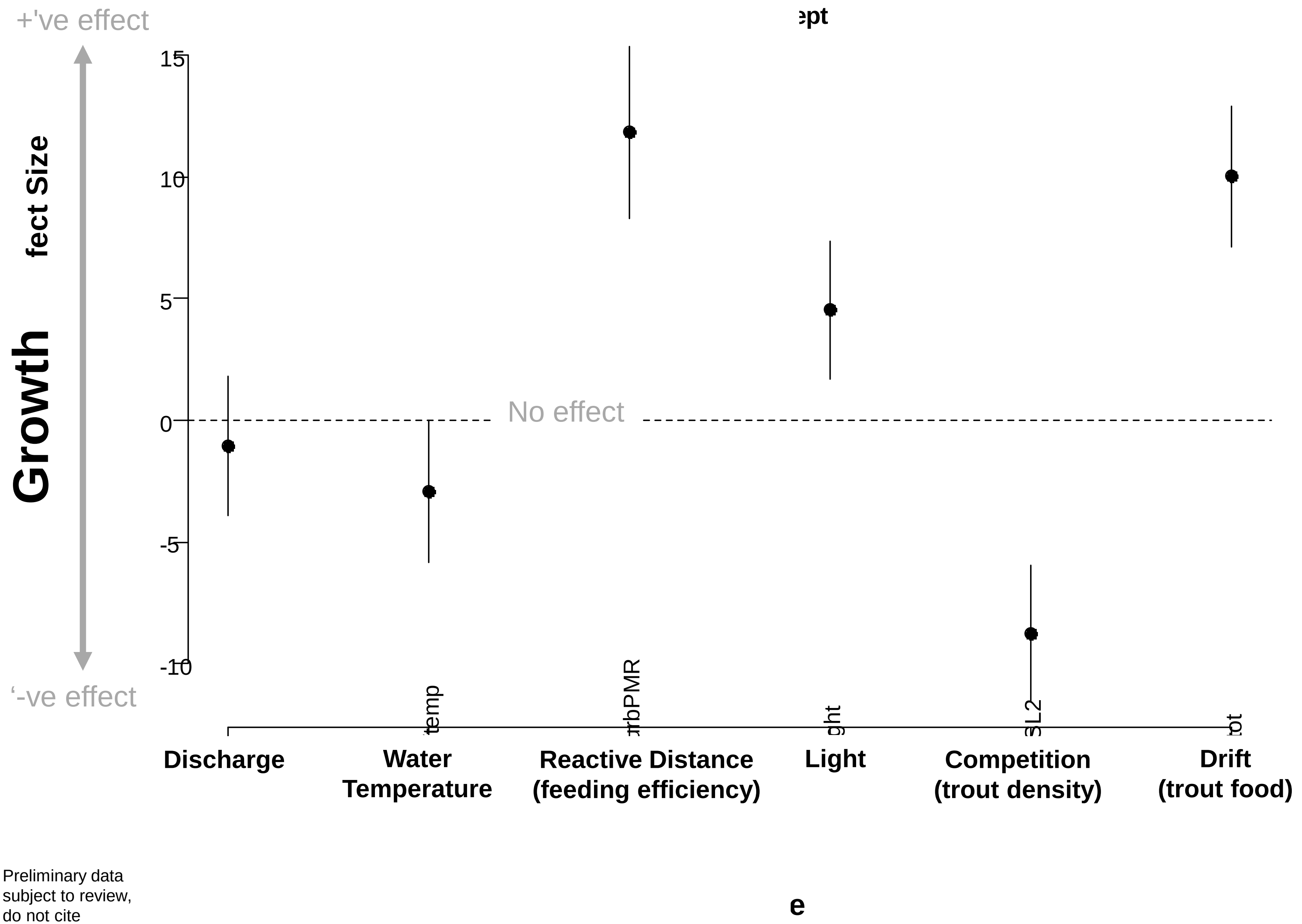
Predictors of Growth in Weight



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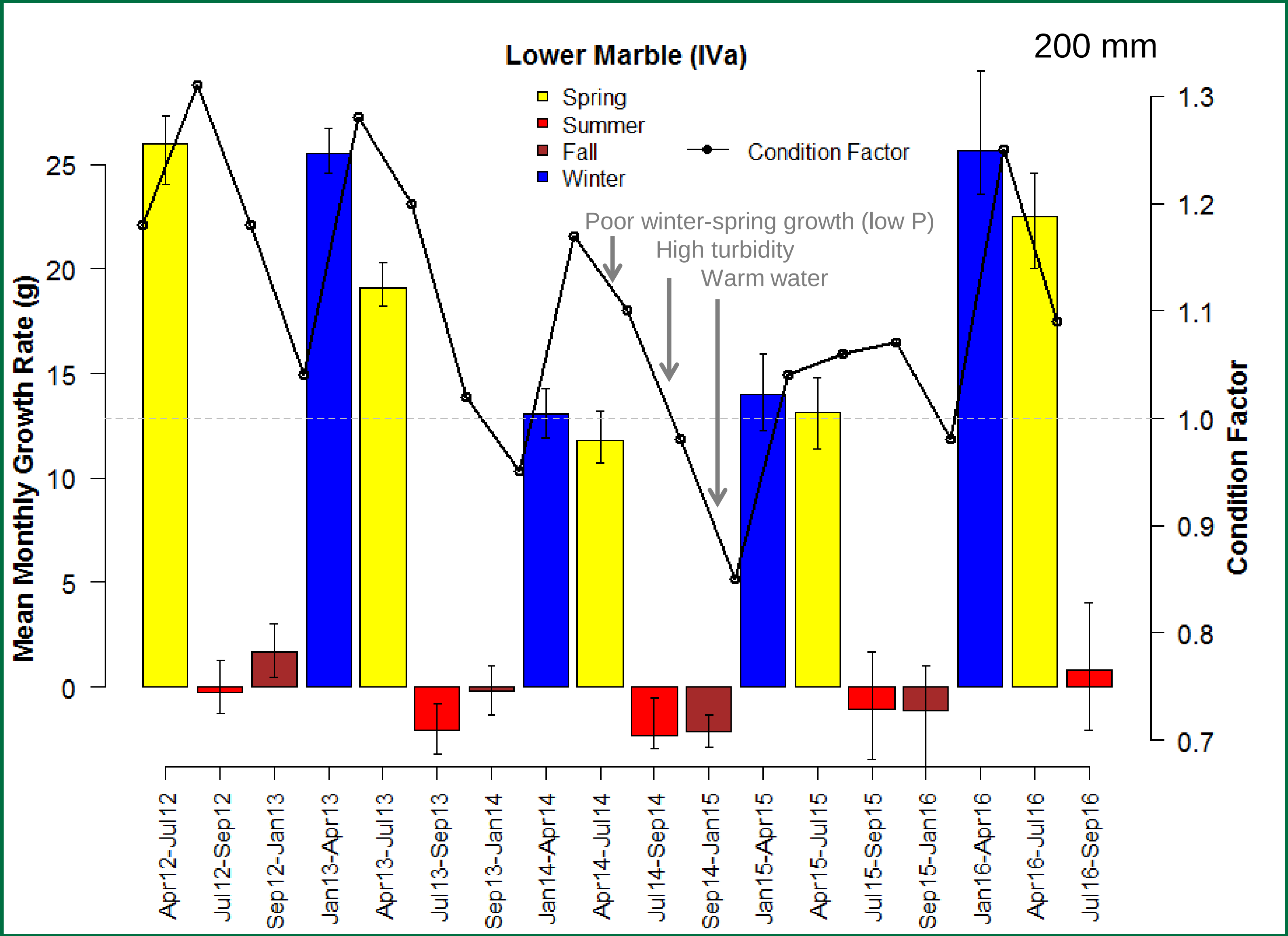
Limiting Rainbow Trout Growth in Marble Canyon in Winter and Spring will Reduce Condition and Abundance



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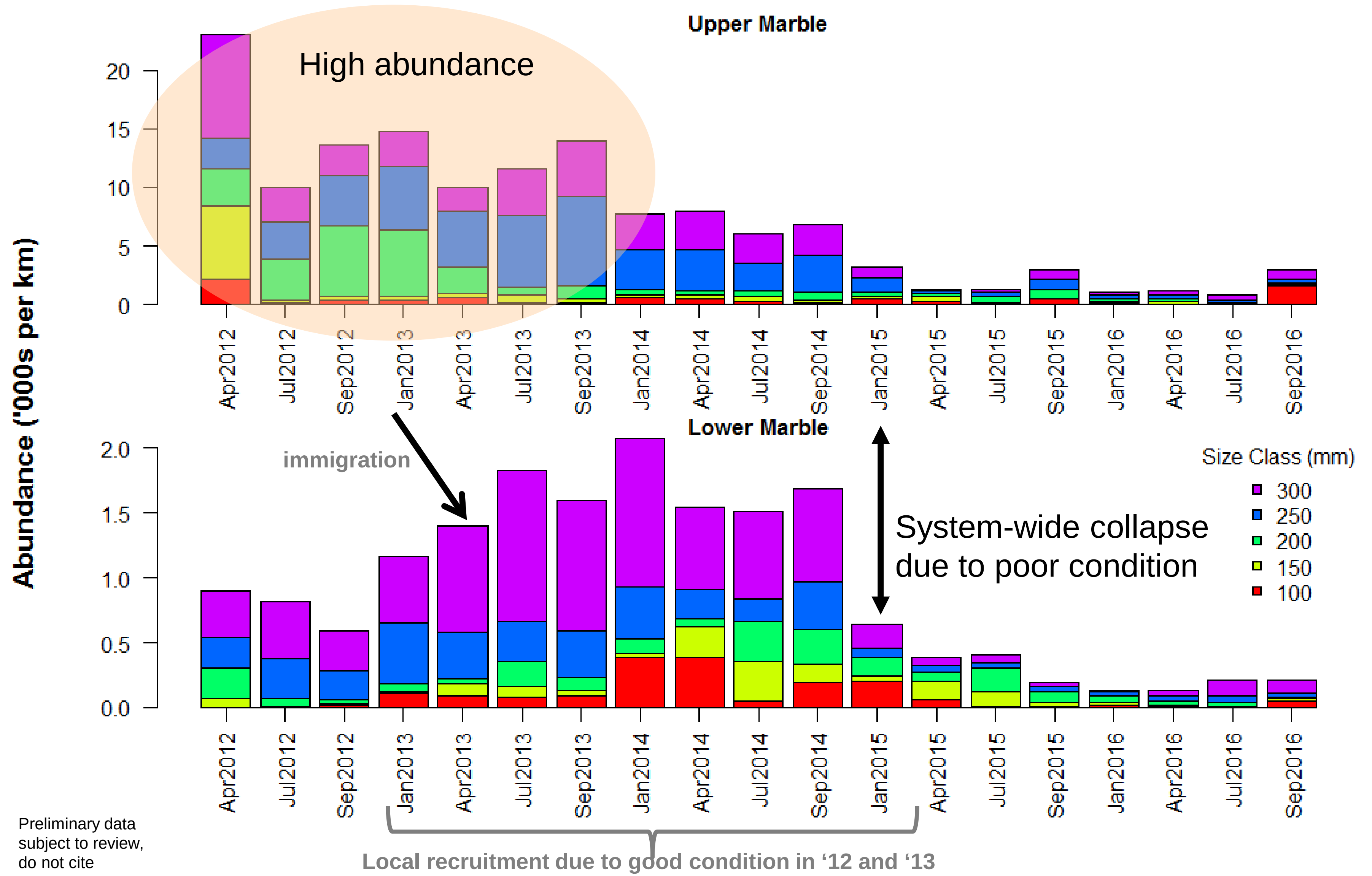
Trout Population Collapsed Due to Very Low Condition Factor in Fall 2014



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Rapid Reduction in Rainbow and Brown Trout Abundance in Marble Canyon due to elevated Turbidity and Temperature and Low Phosphorous 2003-2006 mechanical removal study

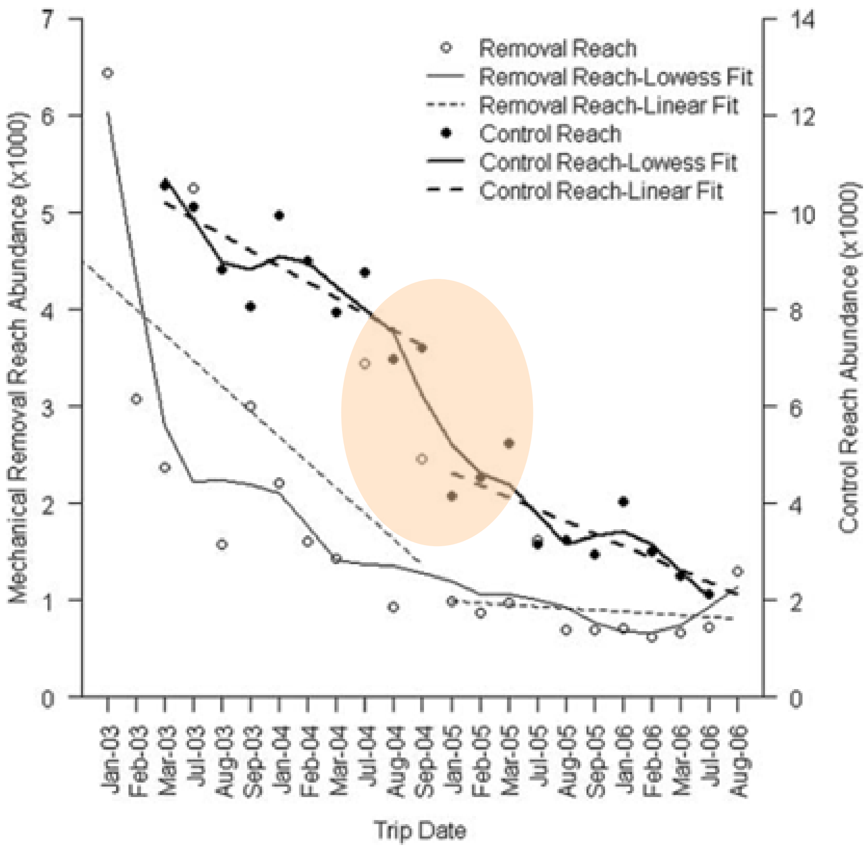


FIGURE 7. Estimated rainbow trout abundance in the mechanical removal and control reaches of the Colorado River at the beginning of each trip during 2003–2006. The solid lines represent locally weighted polynomial regressions (lowess) fitted to each time series. The dashed lines represent linear regressions fitted separately to the 2003–2004 and 2005–2006 portions of the time series.

Coggins et al. 2011. Nonnative Fish Control in the Colorado River in Grand Canyon, Arizona: An Effective Program or Serendipitous Timing?

Simulation of Turbidity Before and After 2013 HFE

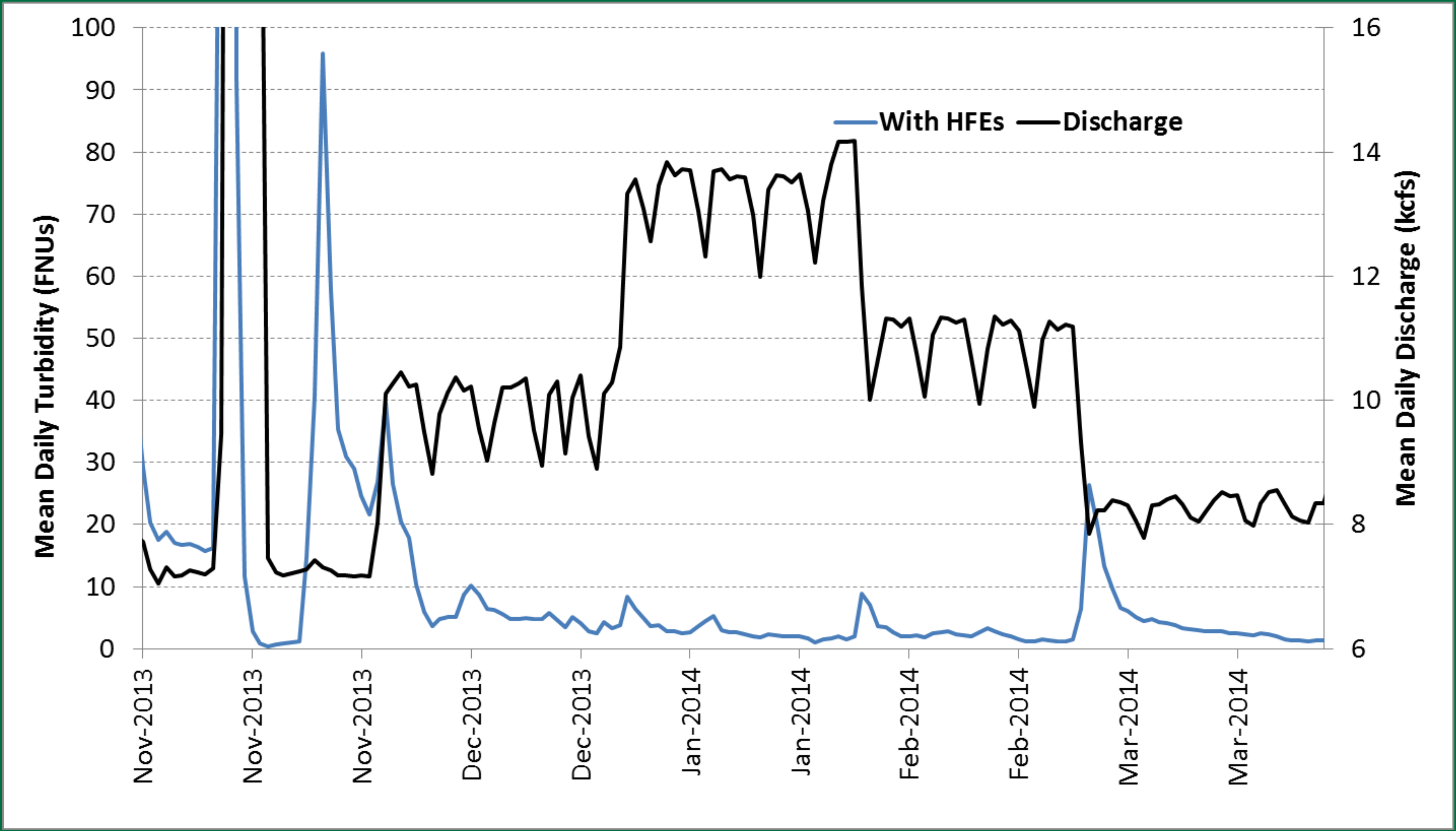
2013 HFE

Paria input

December volume

January volume

Paria input



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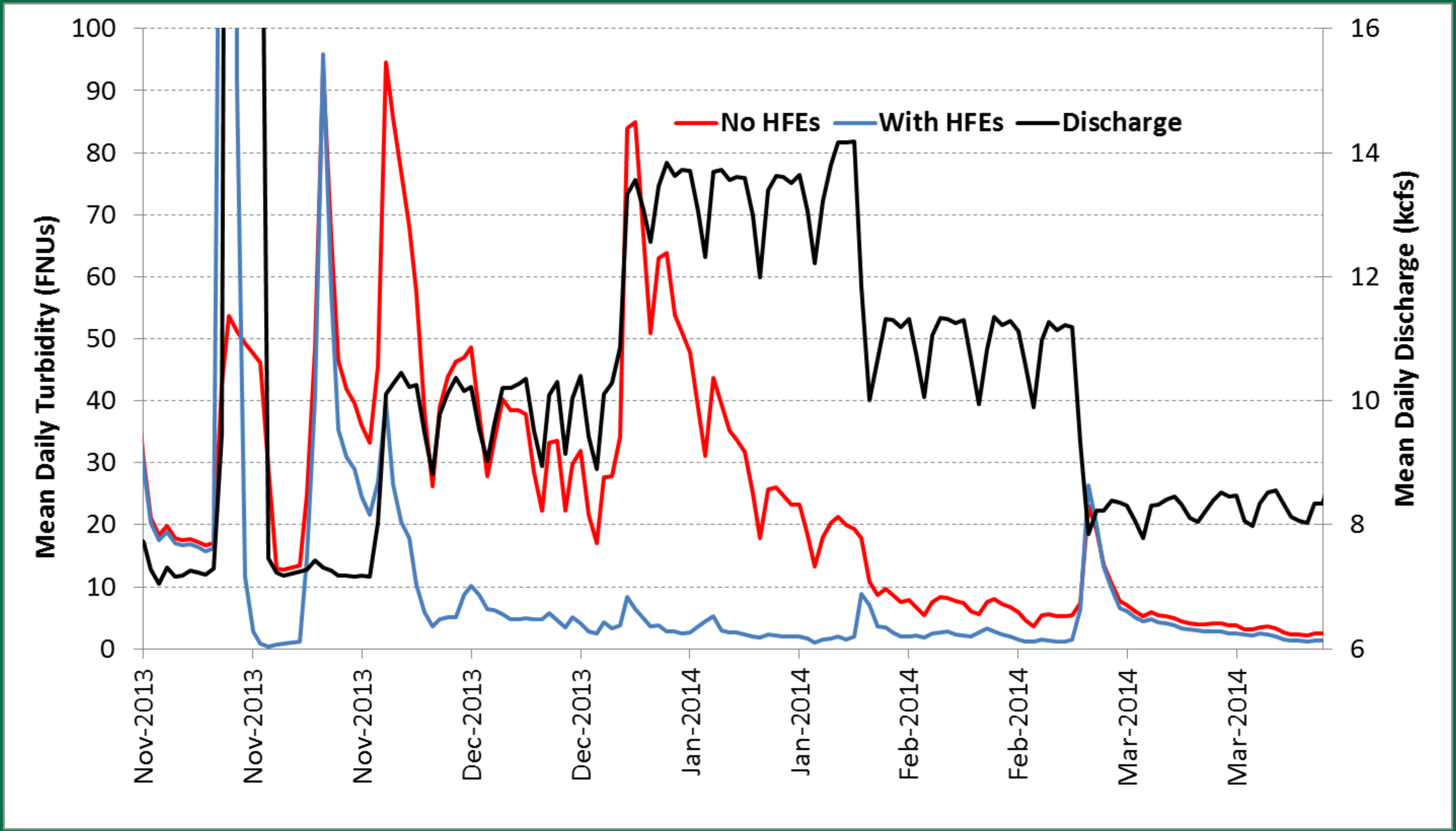
HFEs Reduce Turbidity after the High Flow

2013 HFE | Paria input | December volume | January volume | Paria input



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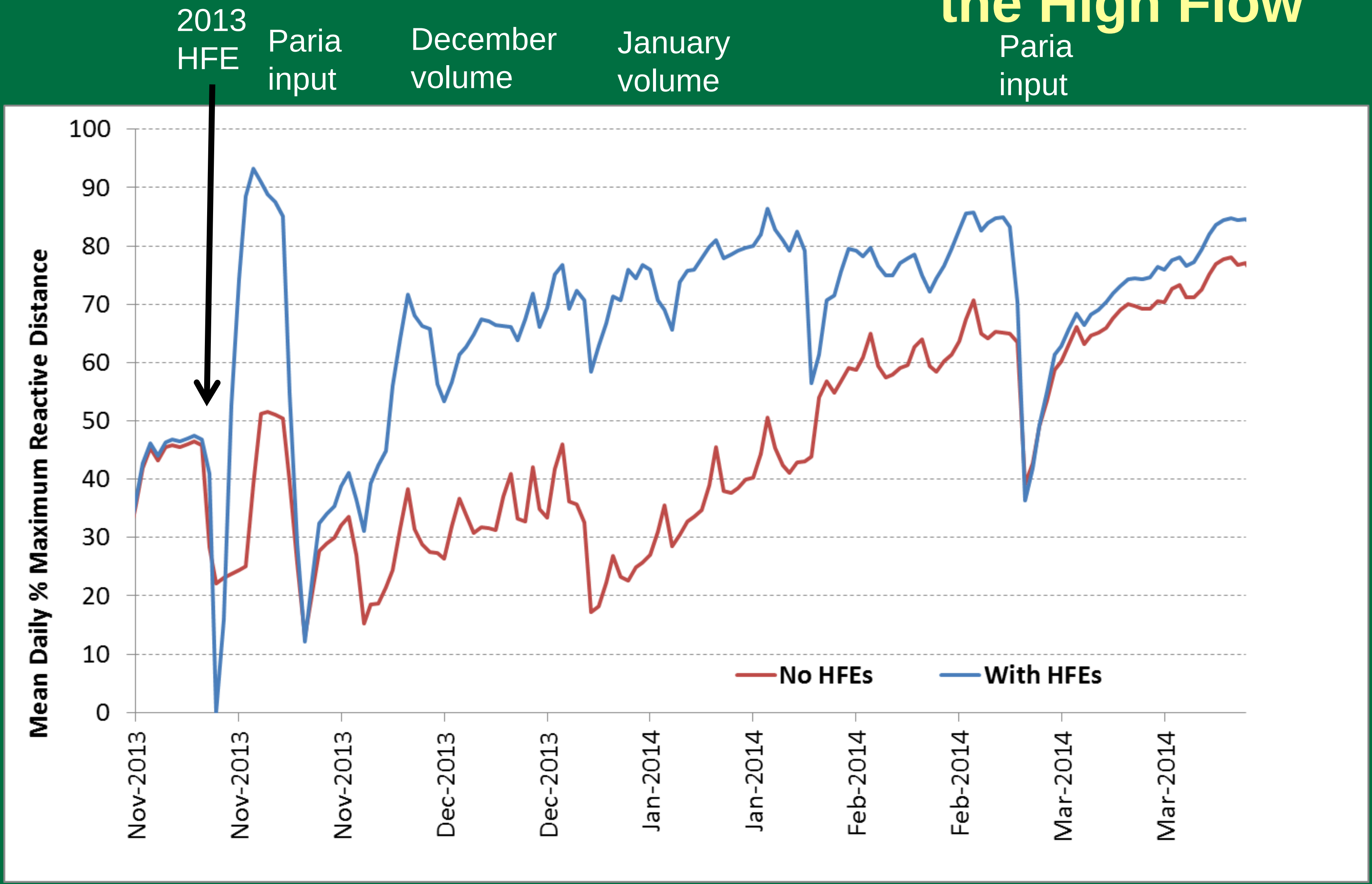
HFEs Improve Trout Feeding Efficiency After the High Flow



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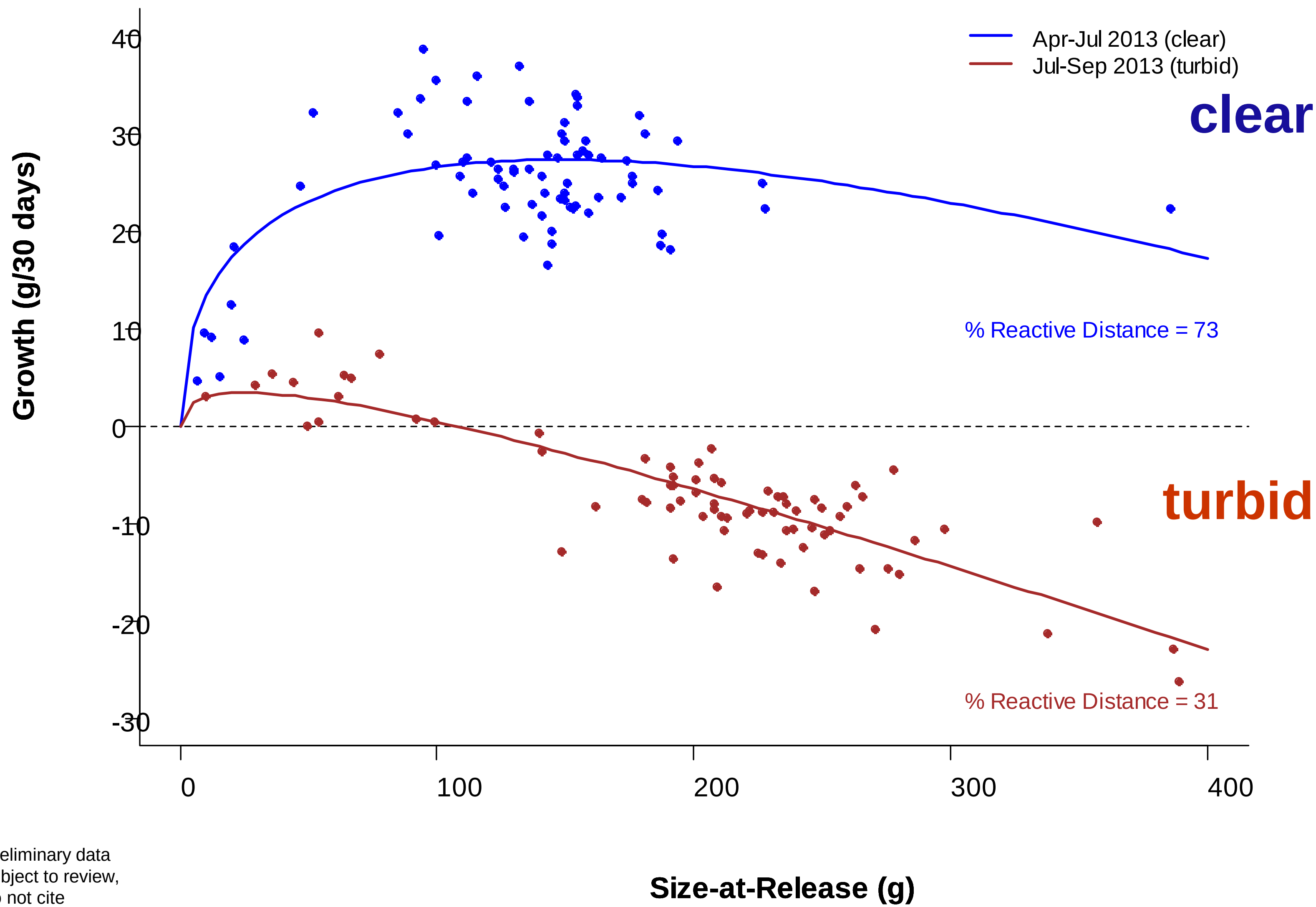
Magnitude of Feeding Efficiency Change with and without HFEs similar to Pre- and Post-Monsoon Differences



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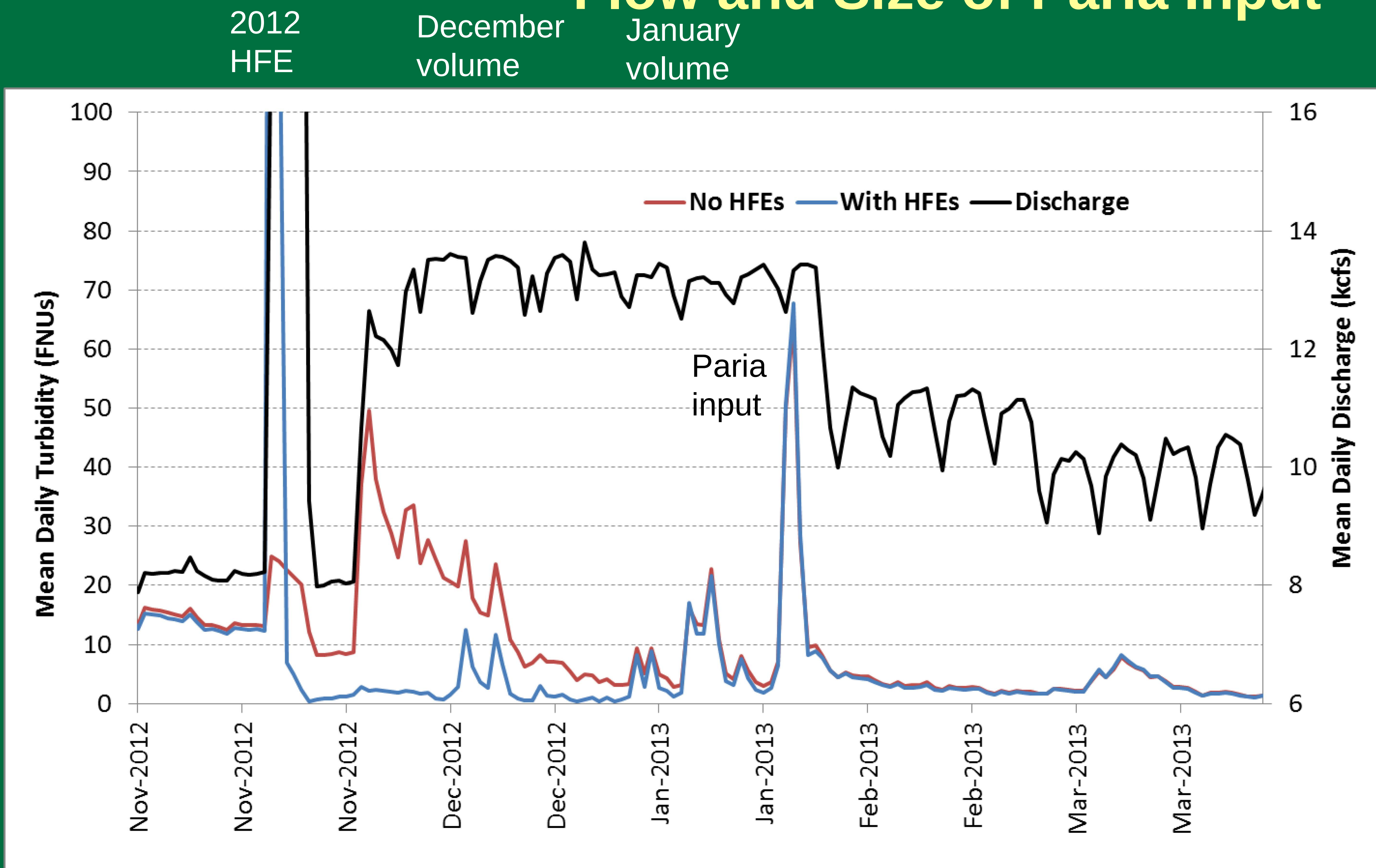
Period of Clear Water after HFE Depends on Flow and Size of Paria Input



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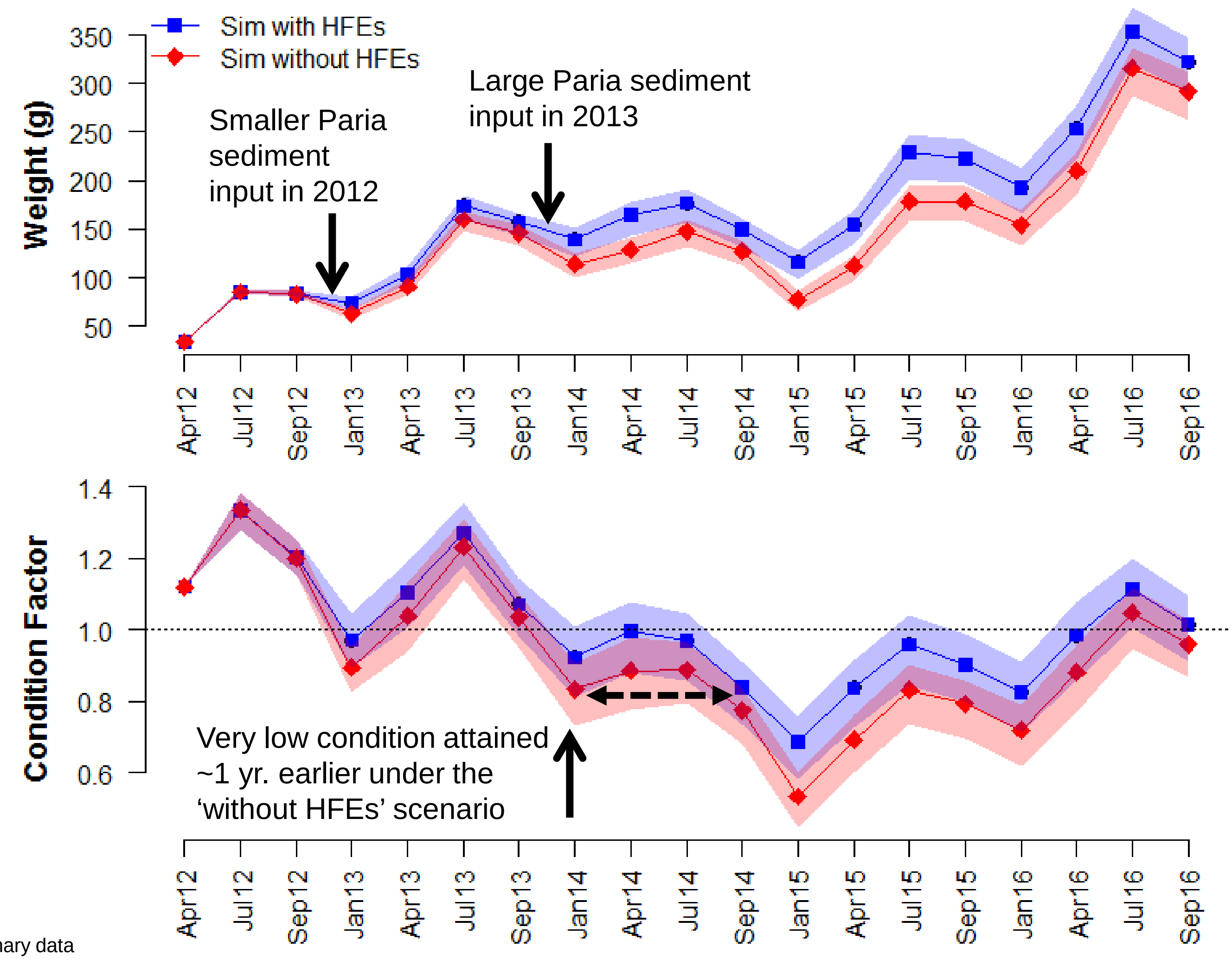
Predicted Effect of HFEs on Trout Growth in Marble Canyon



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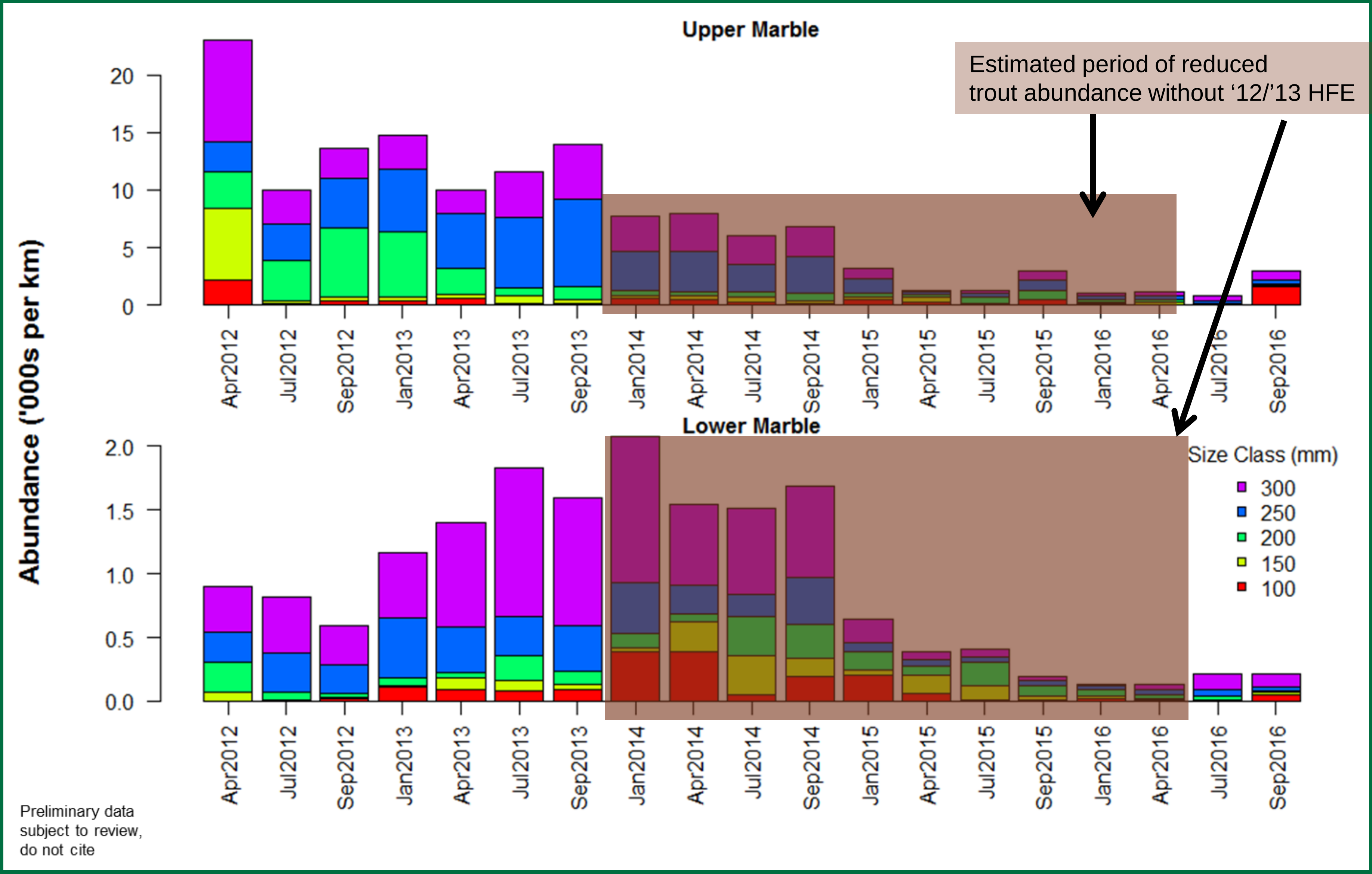
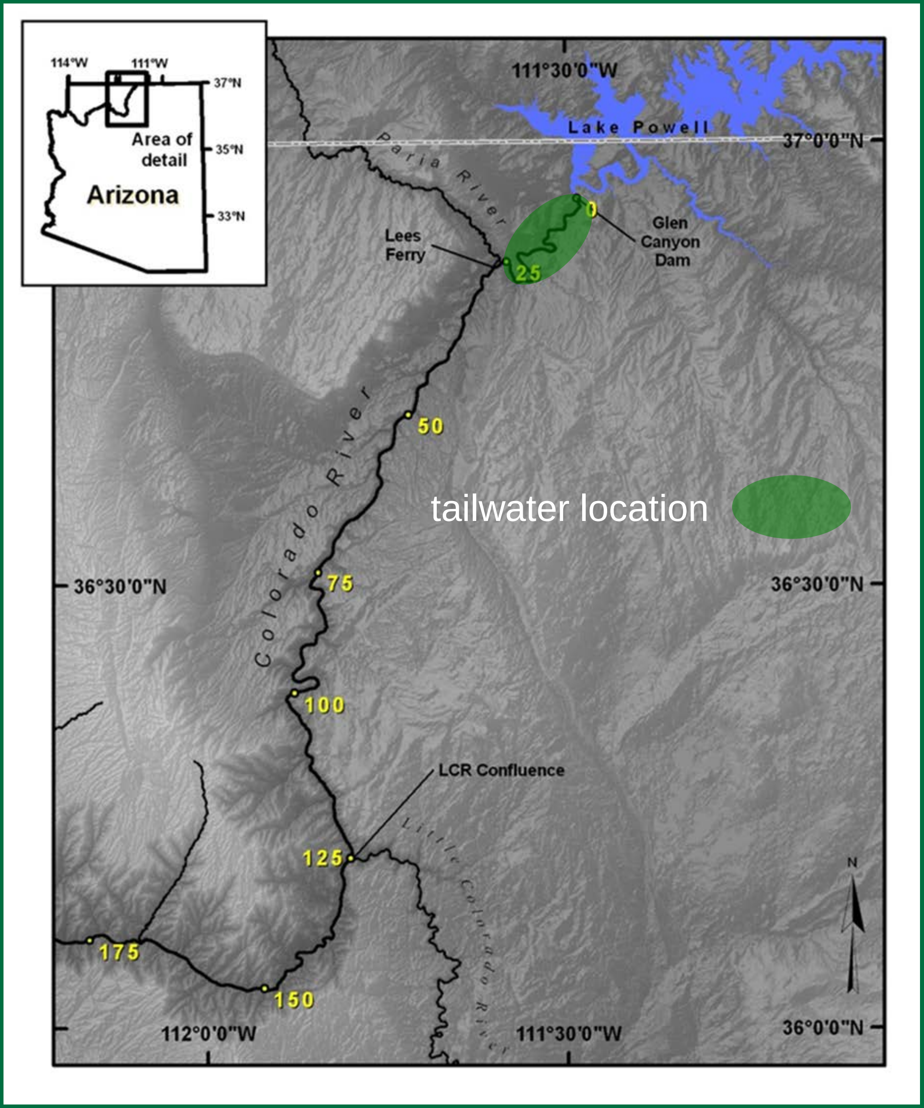
Estimated Change in Trout Abundance in Marble Canyon & below LCR without HFEs in '12 and '13

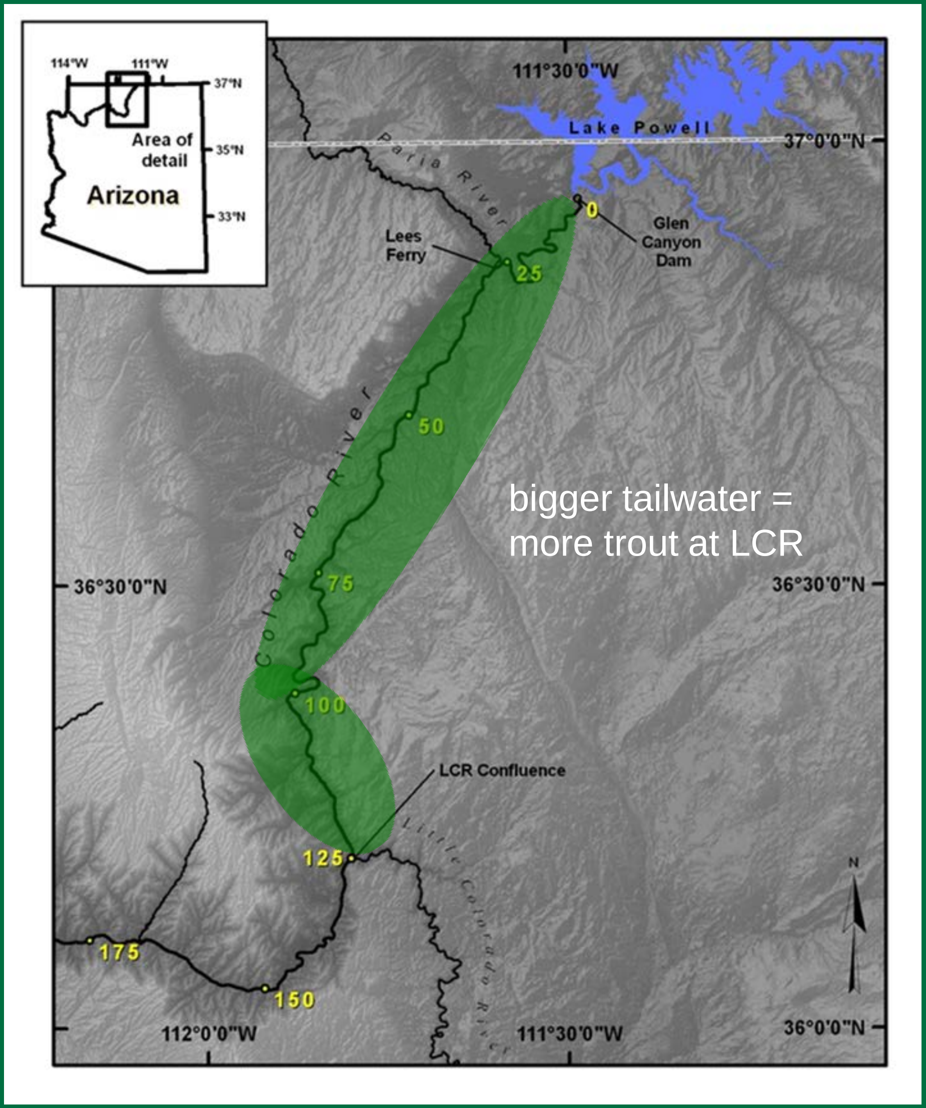


HFEs or TEFs (Tailwater Extension Flows)?
Paria Sediment. Use it for Beaches or Trout Control?

With fewer HFEs



With frequent HFEs



Conclusions

- Frequent HFEs clean the bed in Marble Canyon→ reduce turbidity → promote trout growth → help sustain high levels of trout abundance.

- The idea that turbidity has a strong influence on trout distribution in Grand Canyon, and that it can be used for trout control, is not new!

  - Valdez and Ryel 1995; Melis et al. 2015; Yard et al. 2016; Korman et al. 2016.
  - Turbidity curtain identified as best option for trout control in non-native EA (Runge et al. 2011)

- This study provides two new pieces of information (>10,000 growth observations and updated sediment model) that allows us to predict how GCD flow effect turbidity and trout in Marble Canyon.

HISTORY OF GCDAMP's ASSESSMENT OF "CRe TURBIDITY MANAGEMENT" TO CONSERVE NATIVE FISH

- **Spring 2002 – *HBC "911" Emergency Response* – fish biologists report declining trend in adult HBC, the finding results in *AMWG's humpback chub ad hoc committee* and consideration of a dozen experimental "management strategies" intended to arrest the decline and conserve humpback chub - one of which is to determine feasibility of importing "fine-sediment" from Lake Powell source areas to the CRe, near the Paria River confluence w/ the Colorado River = turbidity cover for native fish when Paria does not contribute enough fines to meet a "200 FNU" condition in the main channel of Marble / Eastern Grand Canyons.**

- **2004-5 – *Mechanical Removal* project reports *abrupt* decline in rainbow trout throughout Marble and Grand Canyons at start of Year-3 MR treatment, and this step-change (shown in Coggins et al, 2011, Fig 7, p. 468) coincides with long string of Paria and**
- **LCR floods / sediment inputs that occurred from mid-September 2004 through January 2005; including the largest winter Paria River flood in January 2005, since December 1966.**

- **2007 – *Sediment Augmentation* - Randle et al. (2007) deliver final technical feasibility report to AMWG, which declares that sources of fine sediment from the delta of Navajo Creek within Lake Powell could, in fact, be transported around Glen Canyon Dam & delivered to the CRe to manage turbidity of Marble and eastern Grand Canyons, but at a cost ranging from $150 (silt/clay only) – 400 (silt/clay/sand) million w/ annual maintenance of ~$9 million if an extra 1 Tg of sand were also to be augmented for sandbars as well. (estimated costs provide a means to *value* Paria River sediment provided as "ecosystem service" compliments of *Mother Nature*.**

- **Fall 2010 – *Non-Native Trout Control EA / SDM Workshop* – fish experts identify 19 options for controlling trout below Lees Ferry, with concept of "turbidity curtain" being rated the most effective long-term strategy (see Runge et al., 2011, p. 29, Table 3, hybrid option E [Sediment curtain (single strategies: 3b, 5e, 6, 13): #13 is long-term strategy to emigration; #5 is the short-term strategy to emigration while infrastructure is being built; #3 is needed in short-term to reduce extant RBT population. Assumptions: RBT and BNT limit HBC recovery, Lees Ferry is the source of RBT, removal @ PBR or sediment curtain])**

Implications for Management

- **Triggering criteria for a fall HFE could include trout abundance in Marble Canyon.** If abundance is high and Paria sediment input is large, not conducting an HFE has the following benefits:
  - Result in a system-wide (Paria-LCR and probably beyond) reduction in trout by partially restoring natural turbidity regime.
  - Reduce hydropower losses.
  - Reduce reliance on mechanical removal and other lethal approaches to trout control like Trout Management Flows (+ for tribes, fisherman, cost).
  - Increase probability for spring-timed HFEs
    - modify sediment accounting period.
    - May be beneficial for trout and food base in Glen Canyon
    - Create beaches just prior to main boating season.
- We have already implemented such a “Do No Harm” approach for fall HFEs (green sunfish in 2015).

Future Work

- Improve calibration of shifting rating curve sediment transport model (Wright).

- Quantify effect of turbidity on drift in Marble Canyon.
  - Current estimate of trout growth reduction without HFEs is likely too low because it assumes higher turbidity does not reduce invertebrate biomass (Yackulic/Deemer/Kennedy).

- Model net effect of reduced trout abundance and higher turbidity on Humpback Chub at the LCR (Dzul/Yackulic).

- Need to improve trout monitoring in Marble Canyon if managers decide to use trout abundance as one of the HFE triggers