Effects of the 2023 Spring HFE and Balancing Flows on Rainbow and Brown Trout in Glen Canyon

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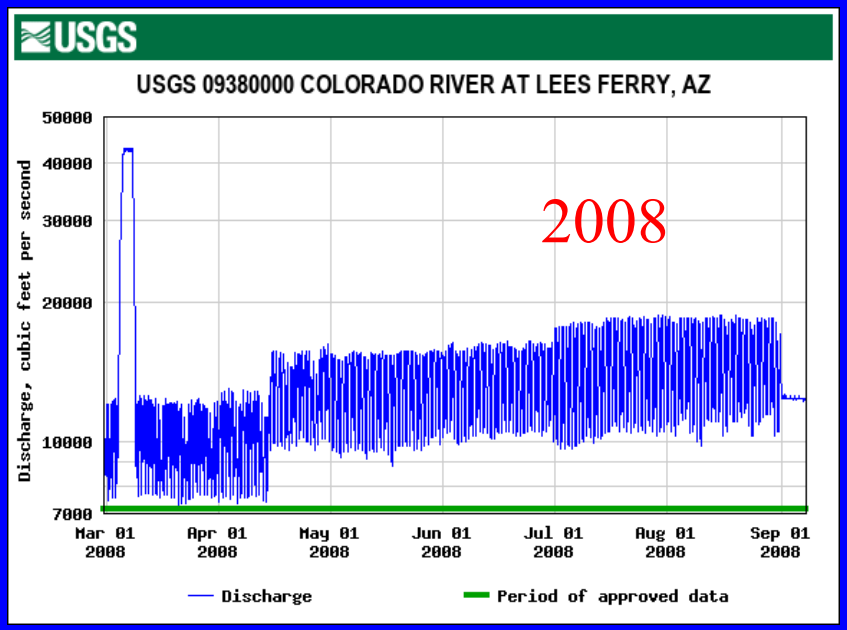
Components of LTEMP EIS based on Glen Canyon Trout Studies

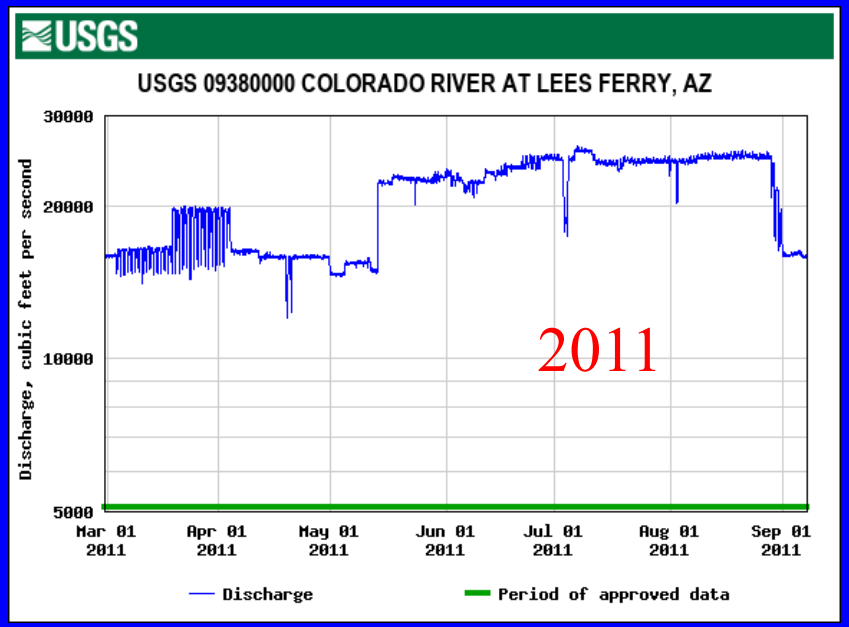
- LTEMP EIS imposed temporary ban on spring HFEs (through 2020) over concern that they could lead to high abundance of rainbow trout in Glen Canyon and ultimately at the LCR inflow reach. Spring 2023 HFE is the first since LTEMP EIS ban.

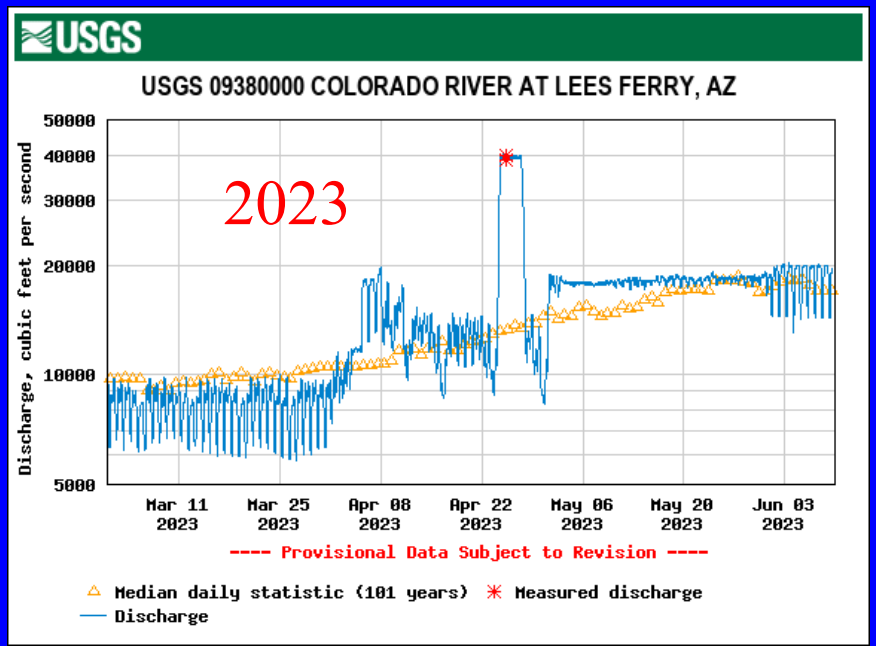
- Adjustments in monthly volumes for reservoir Equalization/Balancing flows defined in the 2007 EIS were not in scope for LTEMP EIS, though effects of 2011 equalization flows on trout were recognized and part of rationale for Trout Management flows (and relevant to upcoming EIS).

- **2023 operations provide a great opportunity to evaluate the flow –trout assumptions behind LTEMP decisions: Do spring HFE's and balancing flows increase survival rates of young rainbow trout as they did in 2008 and 2011?**

Hydrographs

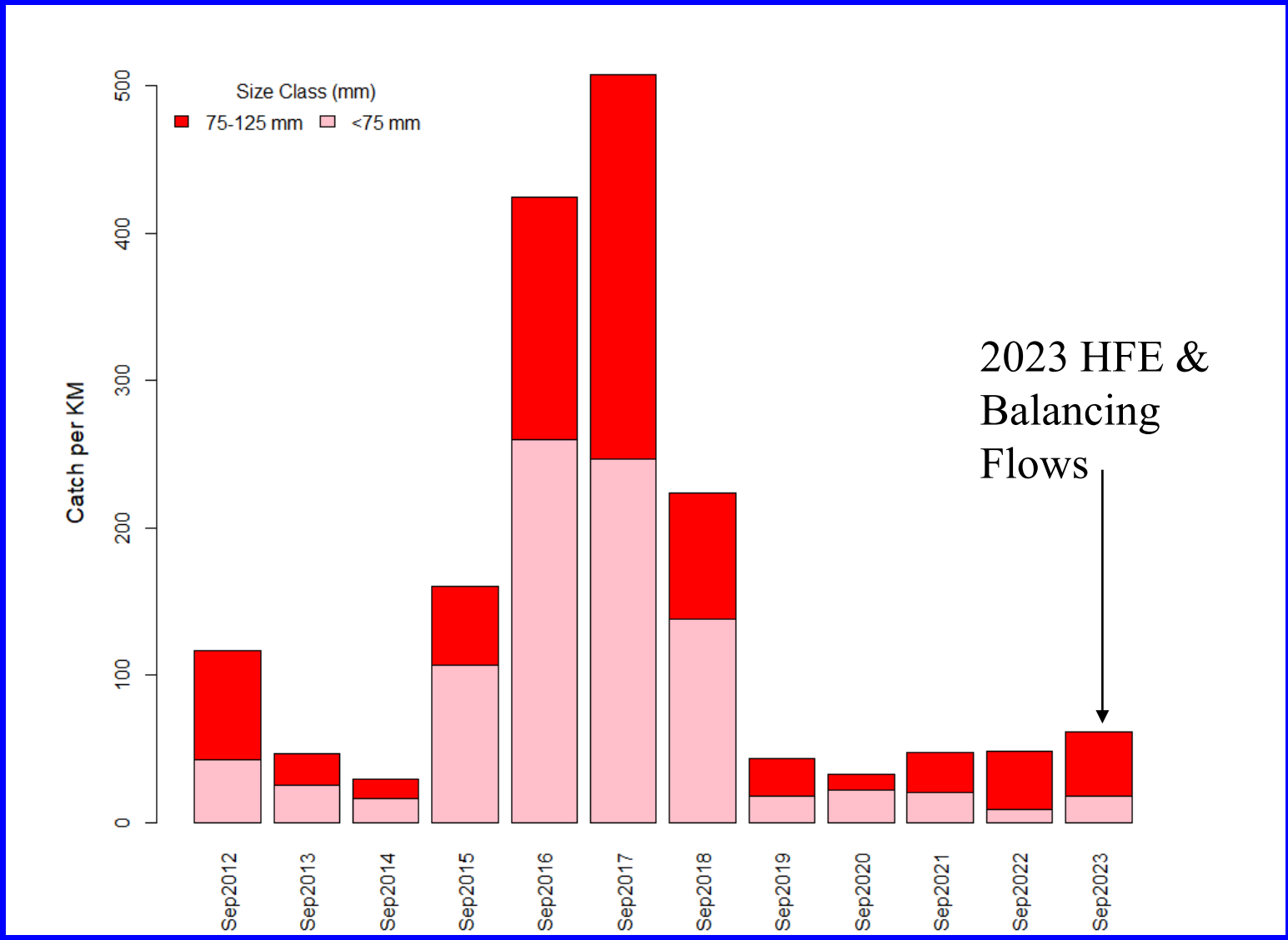




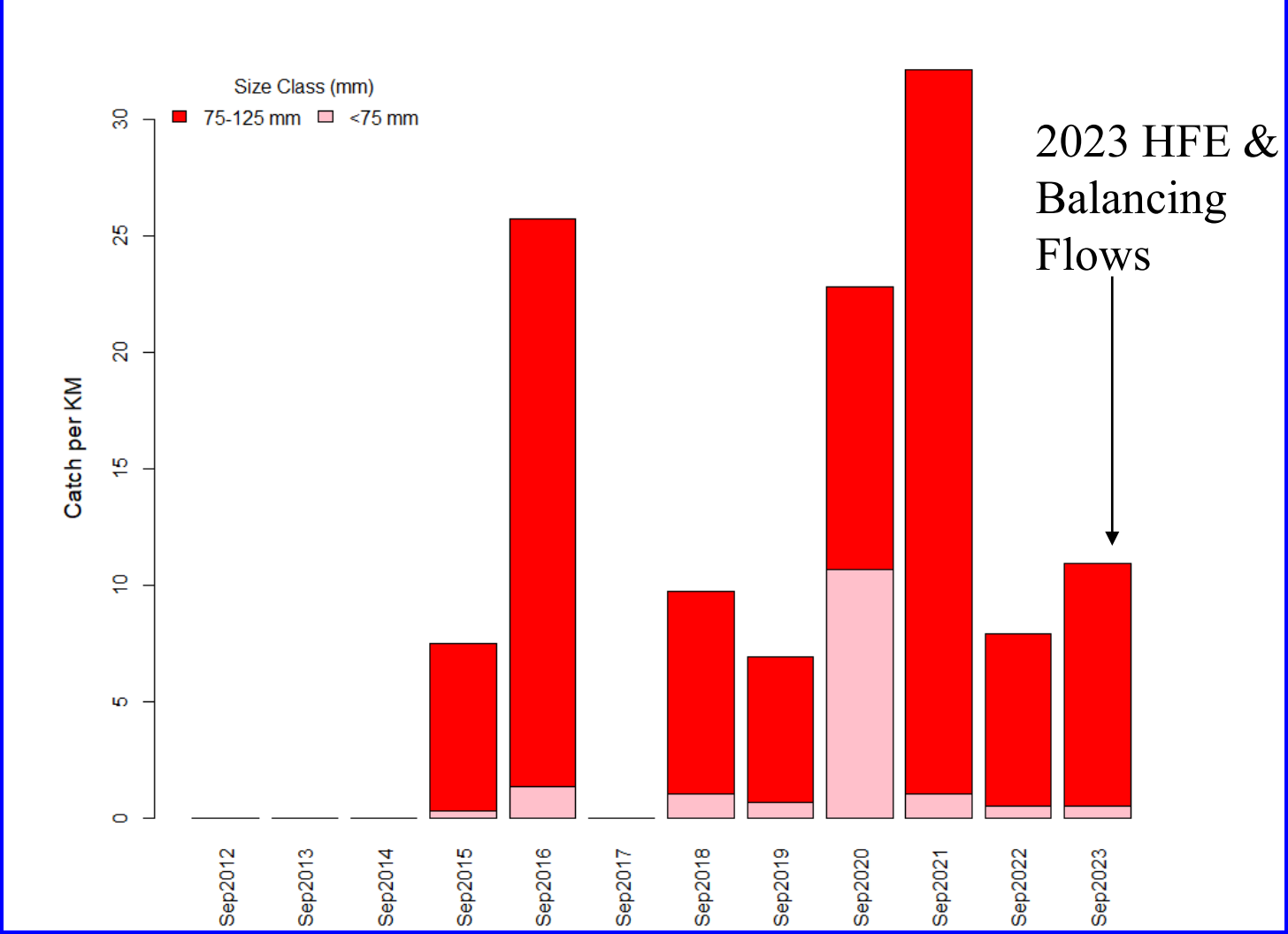


- 2008 ~ ROD operations during summer (~10-18 kcfs)
- 2011 equalization: steady flows ~ 22-25 kcfs
- 2023 balancing: steadier flows of ~ 18 kcfs

Rainbow Trout Young-of-Year Catch Rates in Fall (Reach 1C – 4 mile bar)



Brown Trout Young-of-Year Catch Rates in Fall (Reach 1C – 4 mile bar)



So Why No response of Rainbows to HFE and Balancing Flows in 2023 Compared to 2008/2011?

1. Only one spring HFE since high resolution monitoring began (2008). Other factors could have contributed to higher juvenile rainbow abundance in 2008 (e.g., phosphorous concentration, more spawners).

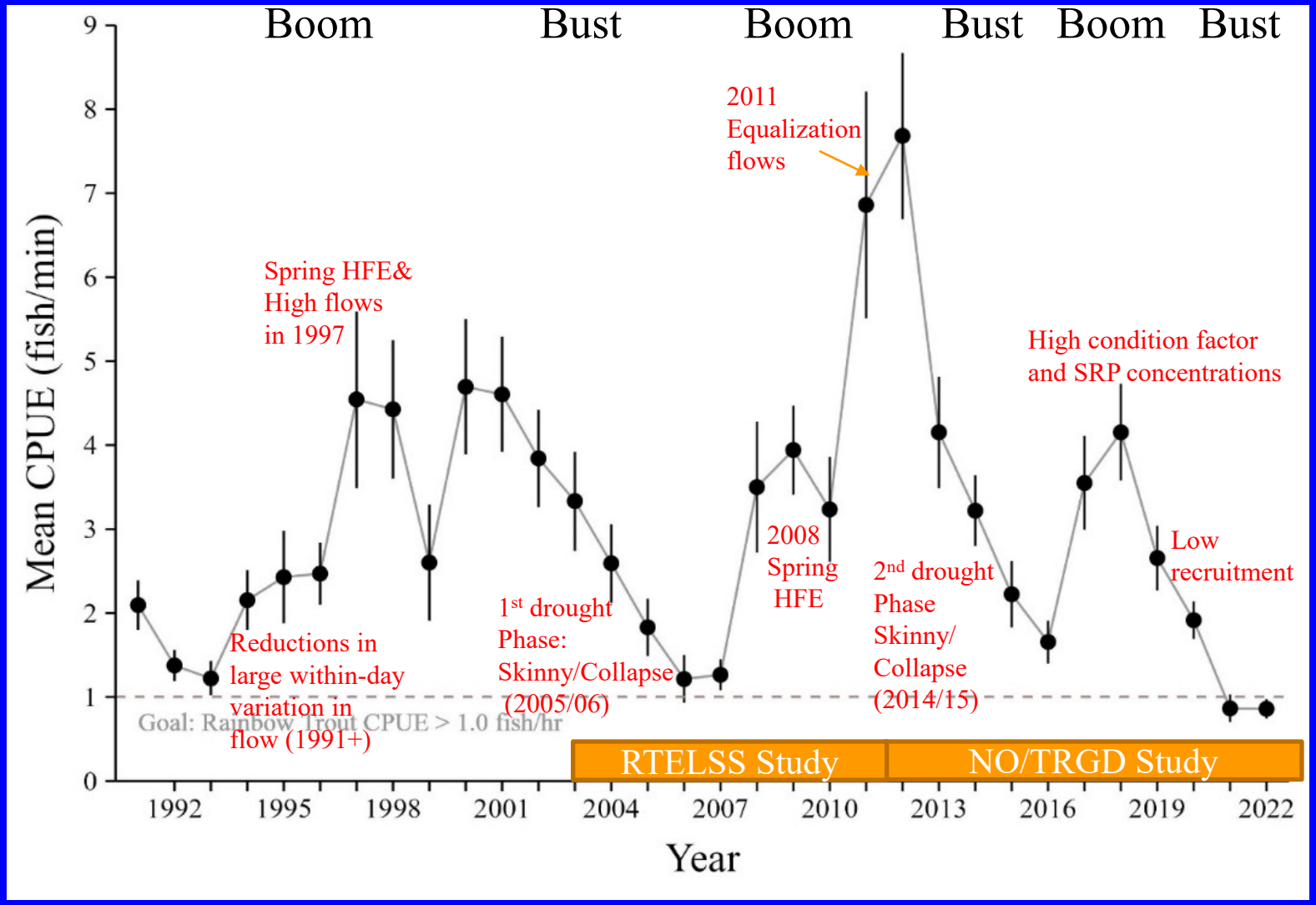
2. 2023 HFE (Apr 24) implemented 1.5 months later than 2008 HFE (Mar 5).
   - Higher proportion of fry would be present during 2023 HFE (flushing effect)
   - Higher proportion of fry would be exposed to low prey conditions (due to bed scour) in the 1-1.5 months following the 2023 HFE compared to 2008 HFE.

3. Conditions in Glen Canyon in 2023 were very different compared to 2008
   - Brown trout are much more abundant (predation/competition)
   - Macrophytes are much more abundant
   - Algal community is much more diverse
   - Higher water temperature and lower dissolved oxygen concentrations(!) in summer of 2023.

- Under current conditions, survival of young trout does not appear to be enhanced by late-timed spring HFEs or balancing flows (preliminary). Stay-tuned for population abundance and growth story at January 2023 ARM.

Extra slides for potential questions

Drivers of Long-Term Trend in Rainbow Trout Abundance in Glen Canyon



Rogowski et al. 2023 (AGF)

Citations Supporting Hypotheses on Factors Driving Rainbow Trout Abundance in Glen Canyon and the LCR Inflow Reach

Effects of 1991+ Steadier Flows and Other Factors on Rainbow Trout Abundance in Glen Canyon

1. McKinney, T., Speas, D.W., Rogers, R.S., and W.R. Persons. 2001. Rainbow trout in a regulated river below Glen Canyon Dam, Arizona, following increased minimum flows and reduced discharge variability. Nor. Am. J. Fish. Manage. 21: 216 222.
2. 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.
3. Korman, J., Deemer, B.R., Yackulic, C.B., Kennedy, T.A., and M. Giardina. 2022. Drought related changes in water quality surpass effects of experimental flows on trout growth downstream of Lake Powell reservoir. Can. J. Fish. Aquat. Sci. 80:424 438.

Effects of Flow and Density on Abundance Trends in Glen Canyon and the LCR Inflow Reach

1. Korman, J., Martell, S.J.D., Walters, C.J., Makinster, A.S., Coggins, L.G., Yard, M.D., and W.R. Persons. 2012. Estimating recruitment dynamics and movement of rainbow trout (Oncorhynchus mykiss) in the Colorado River in Grand Canyon using an integrated assessment model. Can. J. Fish. Aquat. Sci. 69: 1827-1849.
2. 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.
3. Yackulic, C.B., Korman, J., Yard, M.D., and J. Dzul. 2018. Inferring species interactions through joint mark-recapture analysis. Ecology 99(4): 812-821.

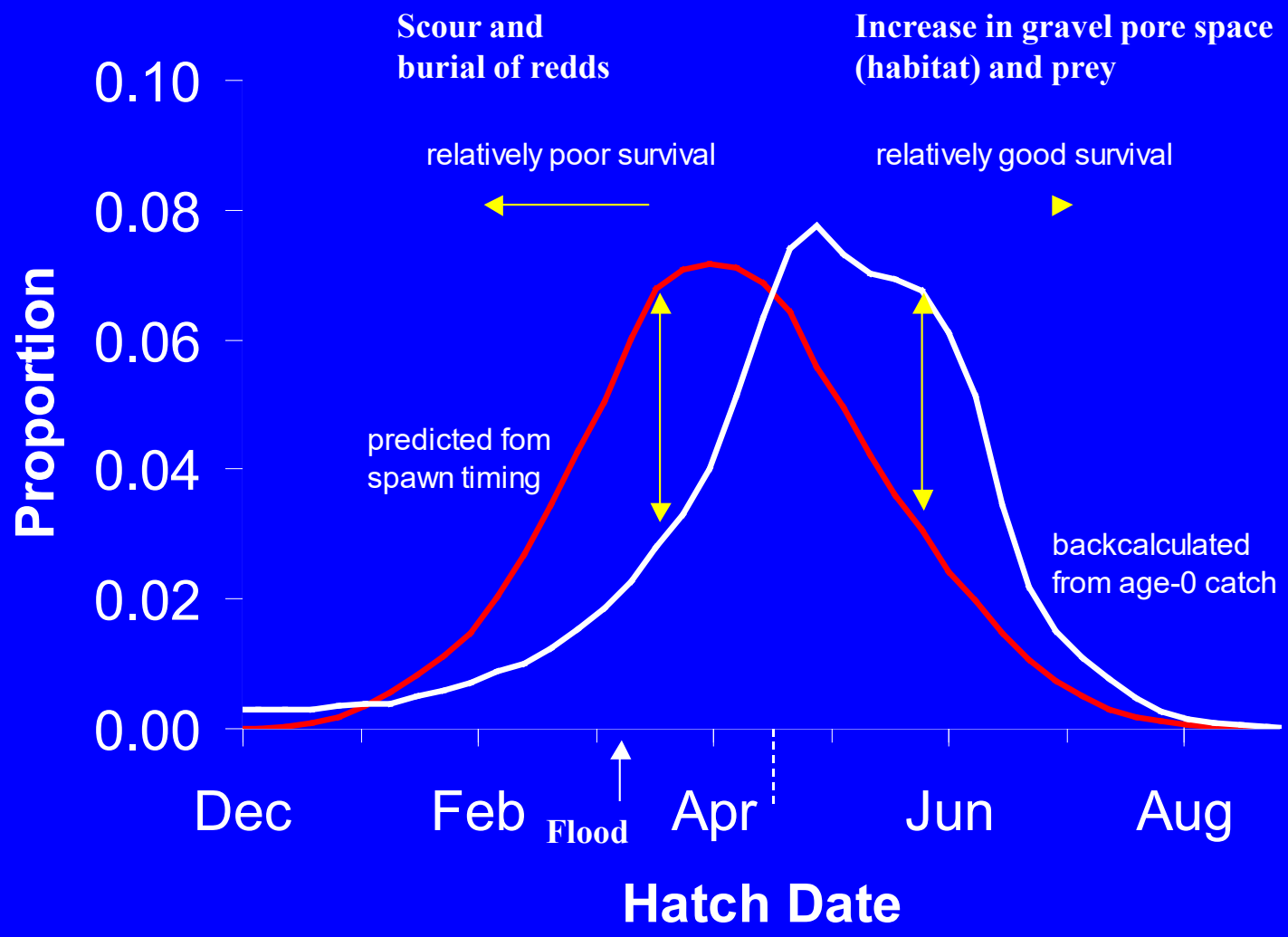
2008 HFE Effect

1. Korman, J. Kaplinski, M. and T.S. Melis. 2011. Effects of Fluctuating Flows and a Controlled Flood on Incubation Success and Early Survival Rates and Growth of Age 0 Rainbow Trout in a Large Regulated River. Transactions of the American Fisheries Society 140: 487 505

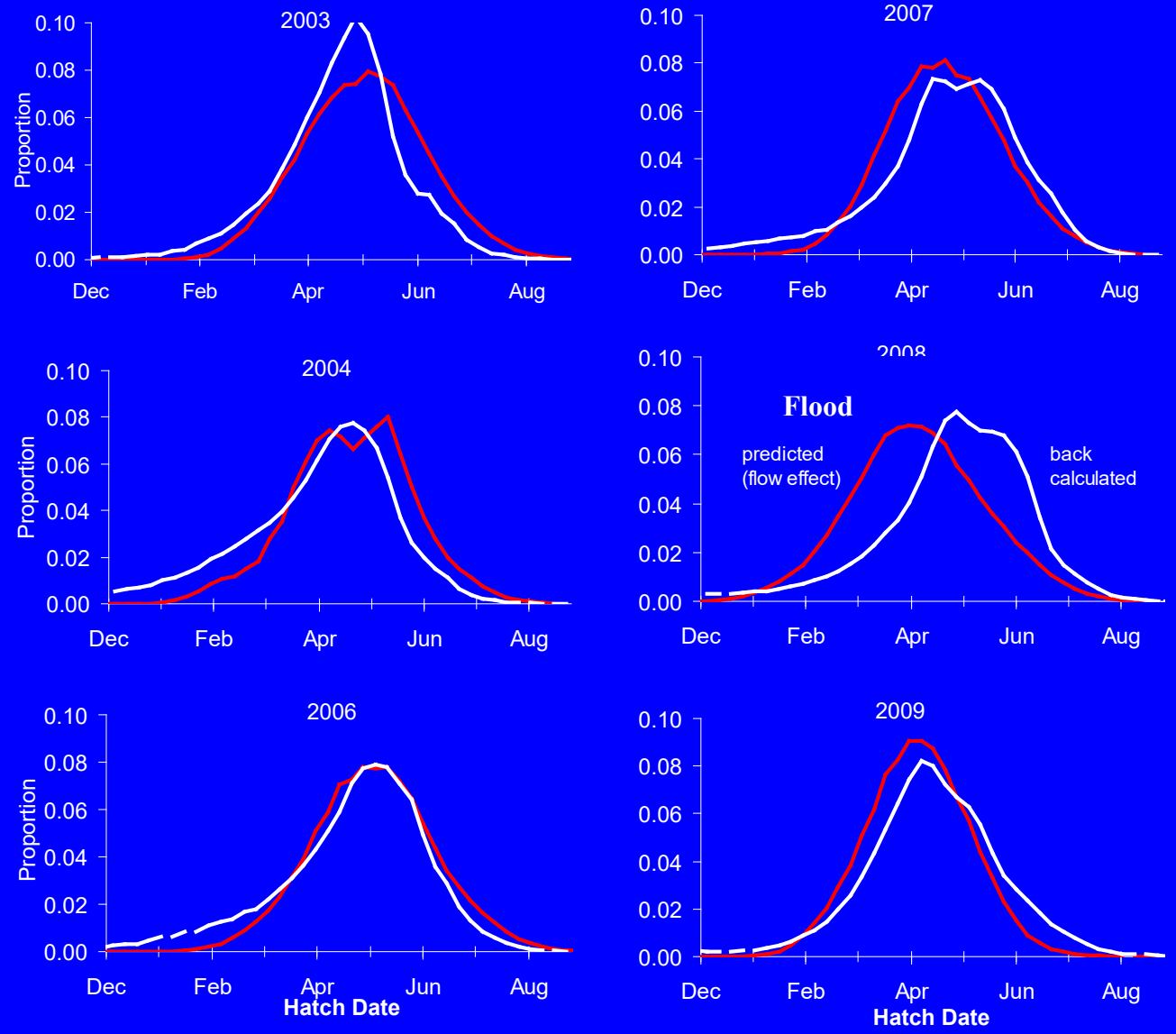
Equalization Flow Effect and Carry-on Effect Leading to RBT Population Collapse in 2014/15

1. Avery L.A., Korman, J., and W.R. Persons. 2015. Effects of increased discharge on spawning and age-0 recruitment of rainbow trout in the Colorado River at Lees Ferry, Arizona. N. Am. J. Fish. Manage. 35:671-680.
2. Korman, J., M.D. Yard, Dzul, M.C., Yackulic, C.B., Dodrill, M.J., Deemer, B.R., and T.A. Kennedy. 2021. Changes in prey, turbidity, and competition reduce somatic growth and cause the collapse of a fish population. Ecol. Monog. 91(1).

Effect of 2008 HFE on Seasonal Variation in Early Survival Rates



Considerable Variation in Early Survival Rates Among Weekly Cohorts in 2008 Only (spring HFE)



Effects of Non-native Fish Suppression Flows and the 2008 spring HFE on Early Survival Rates

All Eggs (from total redds)
Viable eggs (from redds not dewatered)
Viable stock-recruit relationship ('03-'07+'10 only)

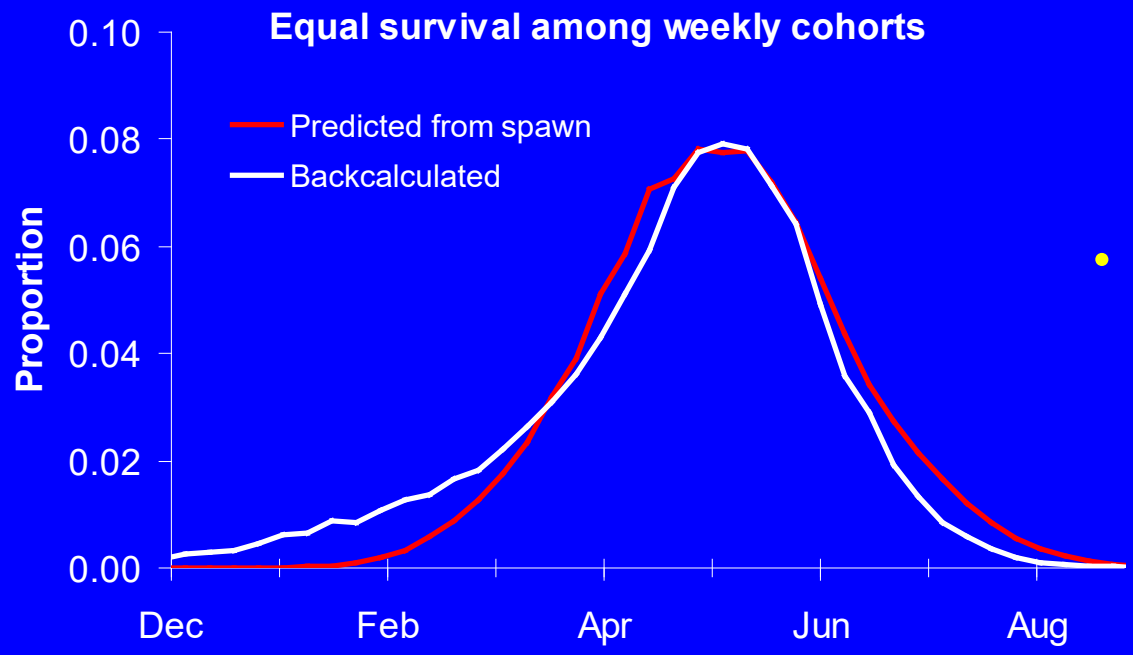
Age-0 Abundance in July (millions)

1.0
0.8
0.6
0.4
0.2
0.0

0 1 2 3 4 5 6 7

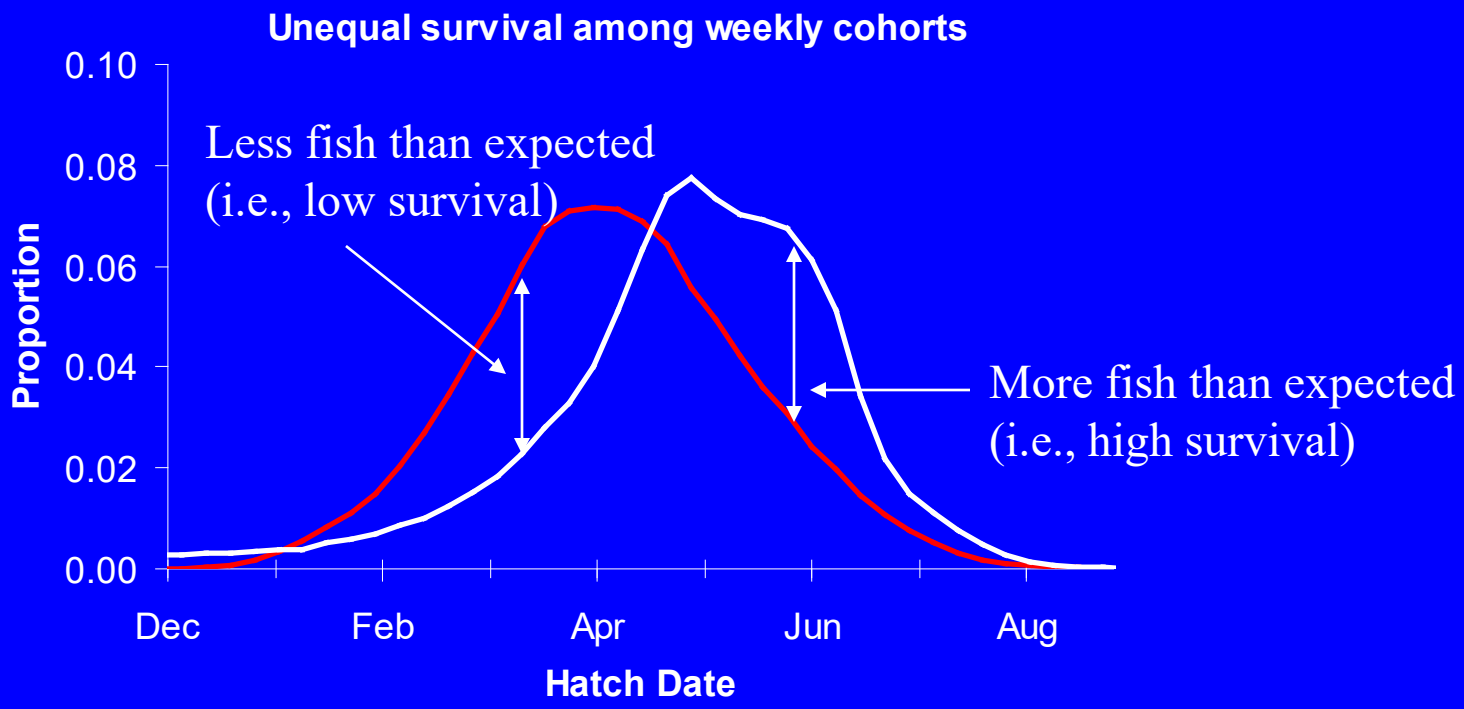
Eggs (millions)

2008
2009
2007
2006
2010
2004
2003



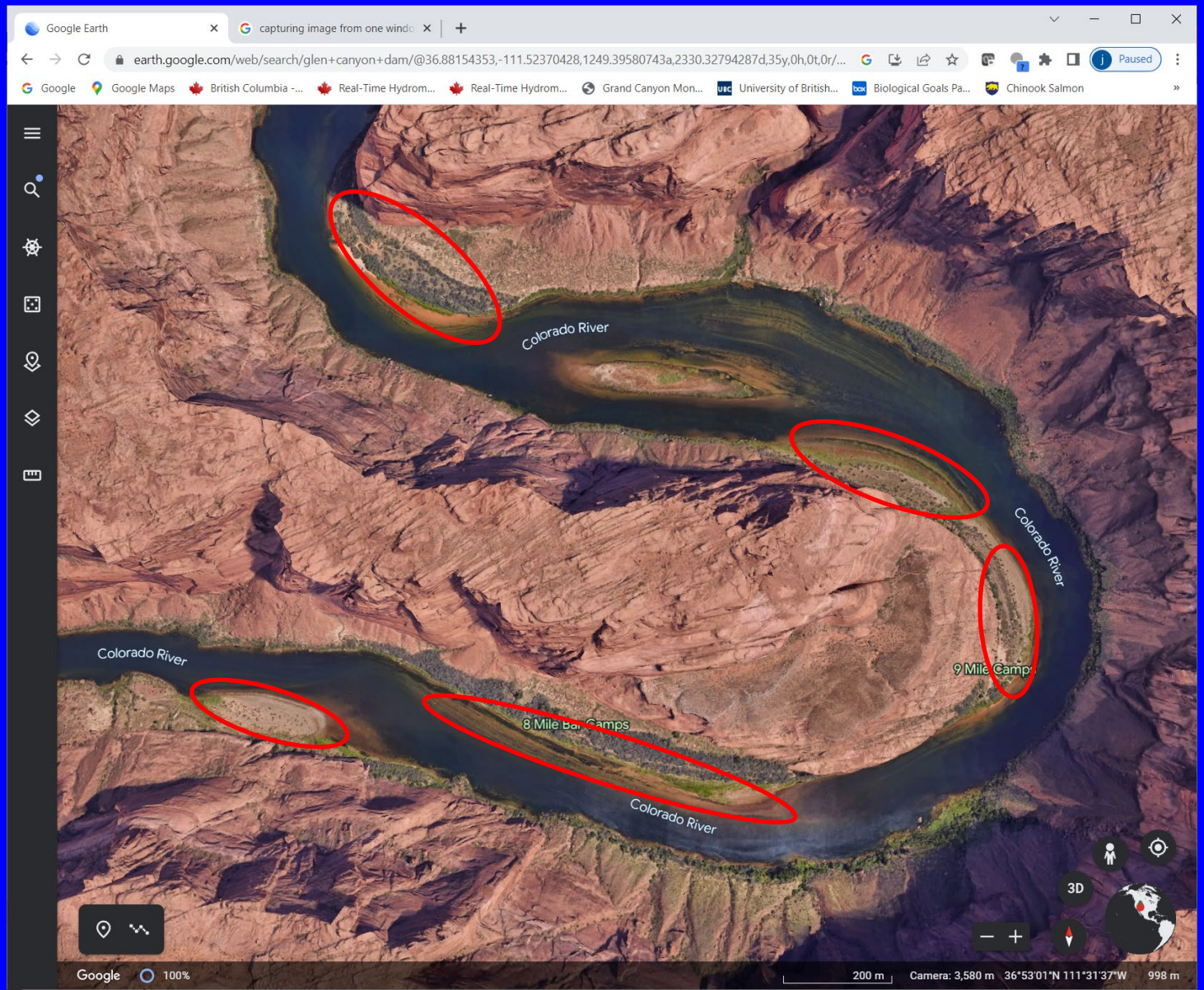
Hatch Date Analysis

- **Objective is to relate variation in early survival rates among weekly cohorts to changes in flow between spawning and capture of age-0 fish**

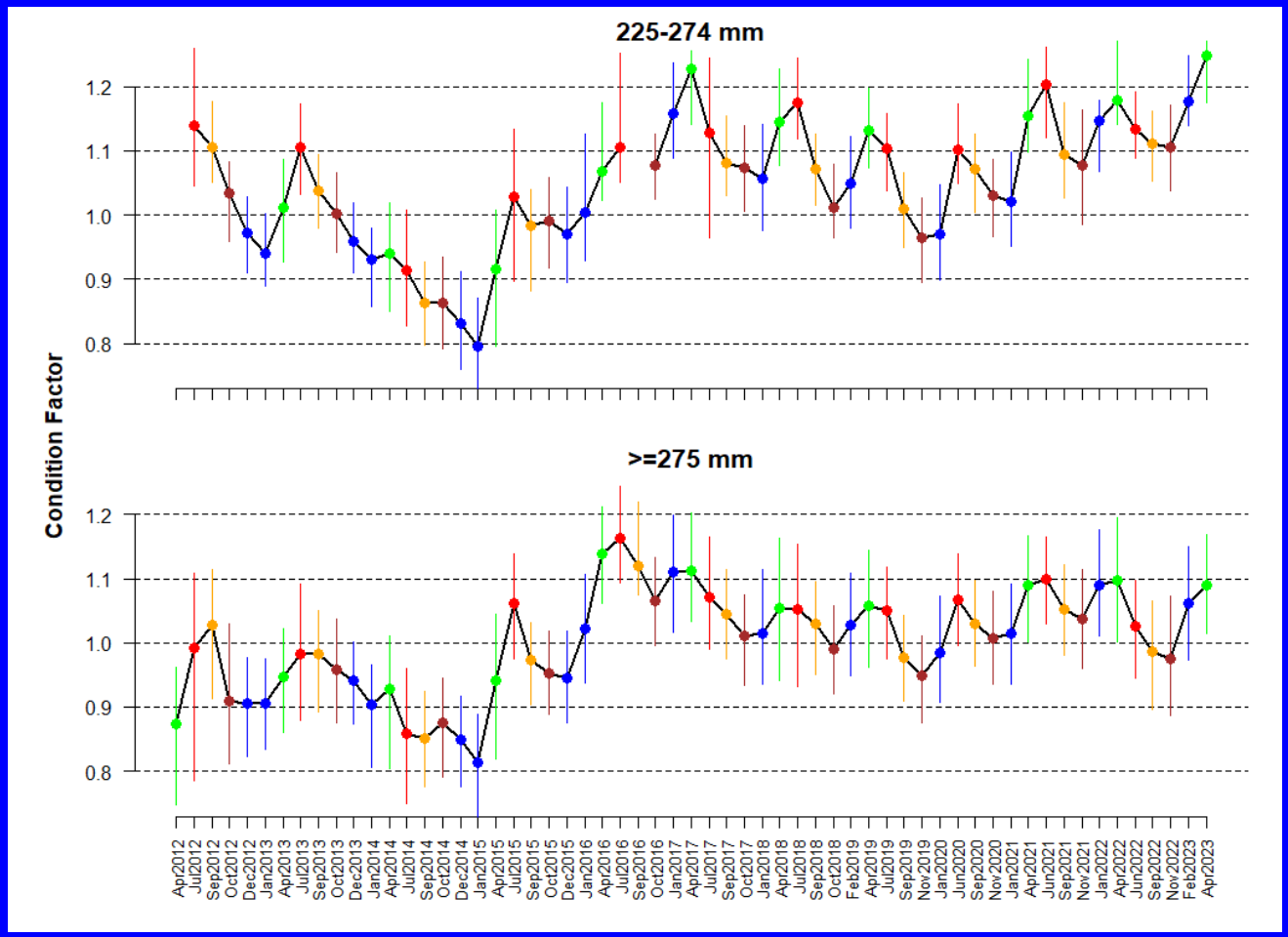


High Flows Inundate Vegetated Areas

Creating ideal habitat for juvenile trout if flows are steady



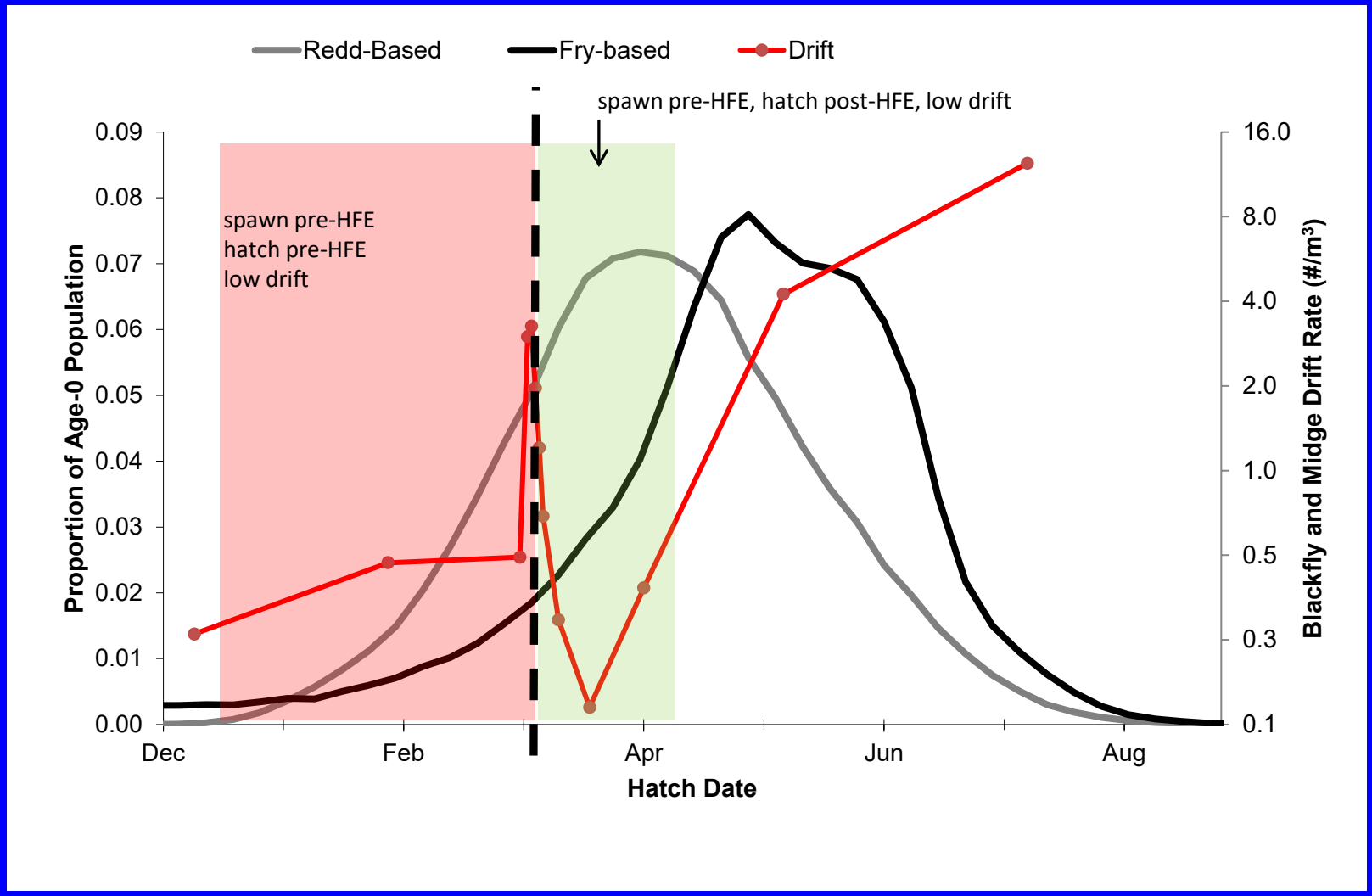
Current State of Rainbow Trout (Condition Factor)



Current condition factor (Apr ‘23) similar to Apr ’16, which resulted in good recruitment in 2017 under normal operations

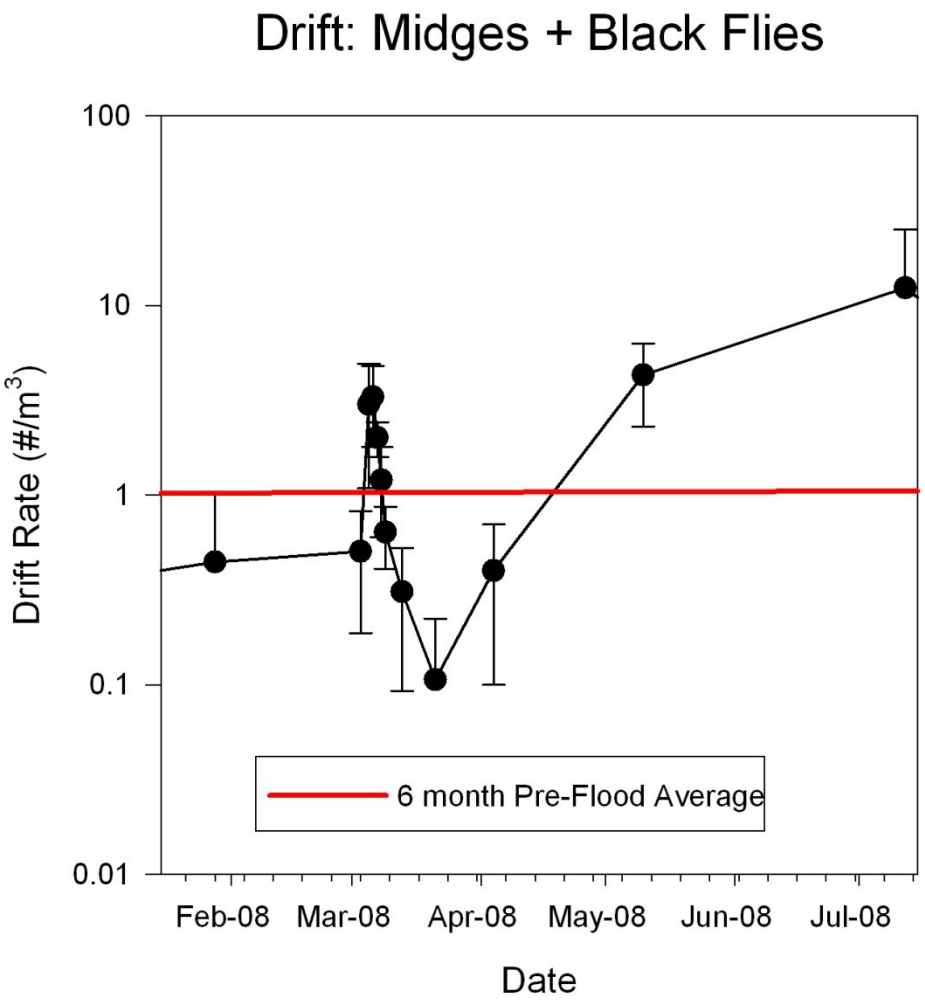
What will happen in 2023 with an HFE and balancing flows?

Effects of 2008 HFE on Food Base for Age-0 Trout



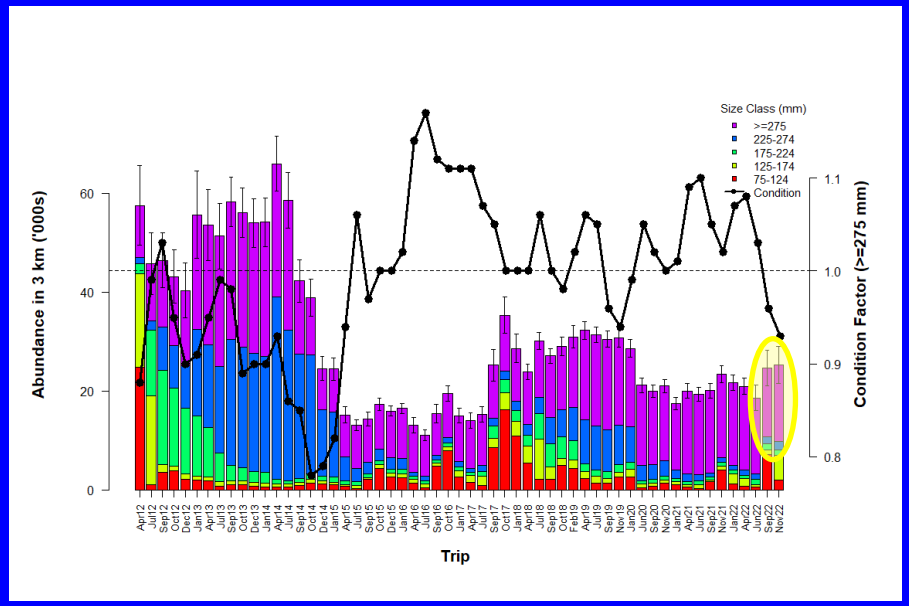
Ted Kennedy, USGS,
Flagstaff, unpublished data

Effects of 2008 HFE on Food Base for Age-0 Trout



Ted Kennedy, USGS, Flagstaff, unpublished data

Current State of Rainbow Trout (Spawning Capability)



% of RBT <150 mm that express gametes when squeezed

Sample				
Year	Size	M+F	M	F
2014	1144	13%	10%	4%
2015	994	2%	2%	1%
2016	687	22%	18%	3%
2017	186	32%	27%	5%
2018	442	44%	33%	11%
2019	2075	17%	12%	5%
2020	2004	9%	6%	2%
2021	2497	20%	16%	4%
2022	1507	33%	26%	7%
2023	1249	40%	30%	10%

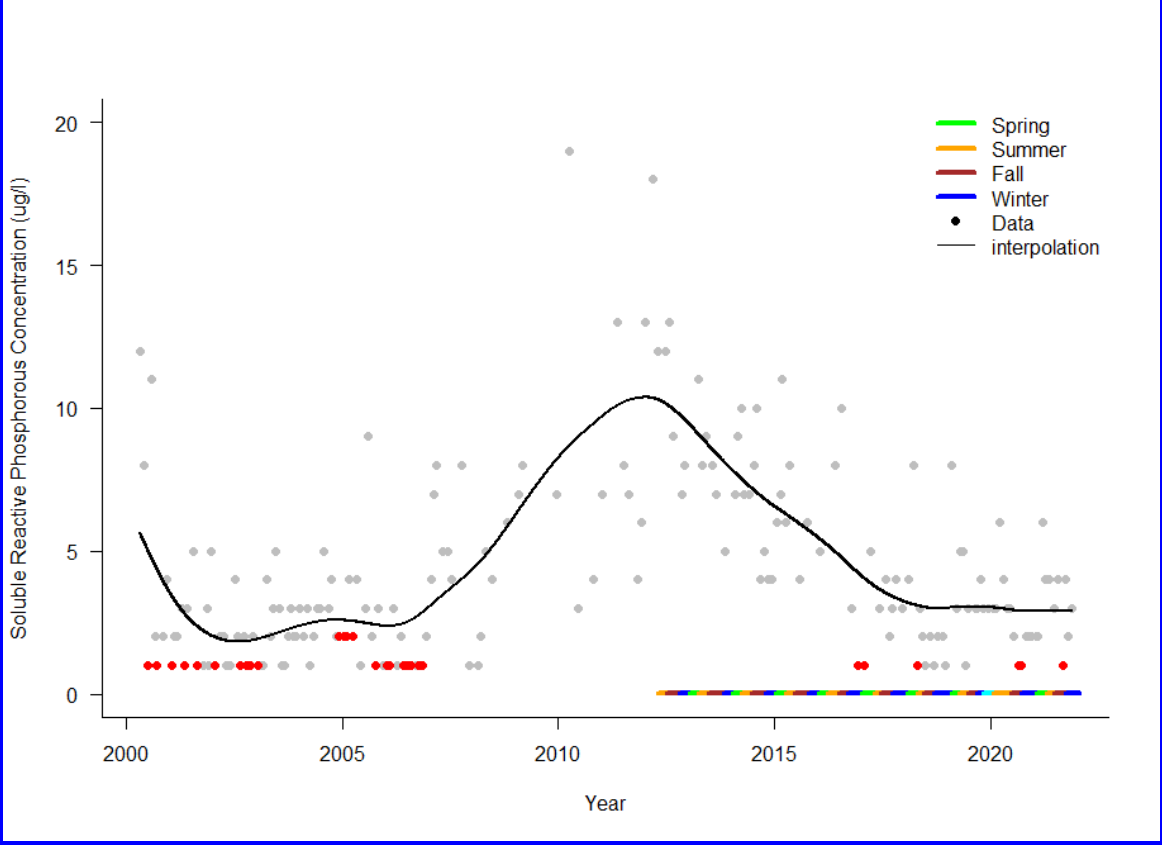
- All observations lead to a prediction of a strong recruitment year for RBT in Glen Canyon in 2023, and thus possibility of increase RBT abundance at the LCR in later years
- Uncertainties: 1) later-timed HFE in 2023; 2) much higher BNT abundance; 3) higher macrophyte abundance; 4) very different algal community

Phosphorous

- **Higher concentrations of soluble reactive phosphorous (SRP) in 2008 and 2011 may have contributed to food base and trout fry response.**

- **SRP is a better/equal predictor of annual rainbow trout recruitment than flow-based metrics (e.g., high flows, fluctuations in flow).**

- **But SRP levels partially confounded with higher flows**



C. Yackulic & B. Deemer, USGS, Flagstaff, unpublished data