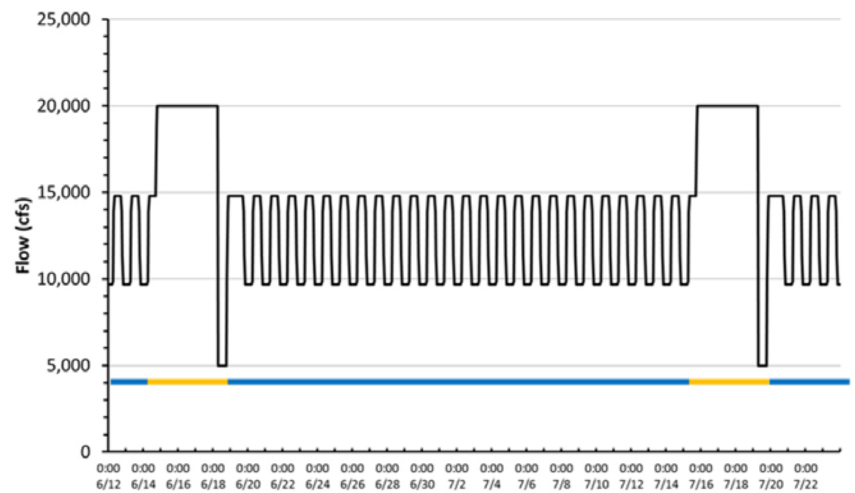
Trout Management Flows:

A Review of Data, Research Results, and Information Needs



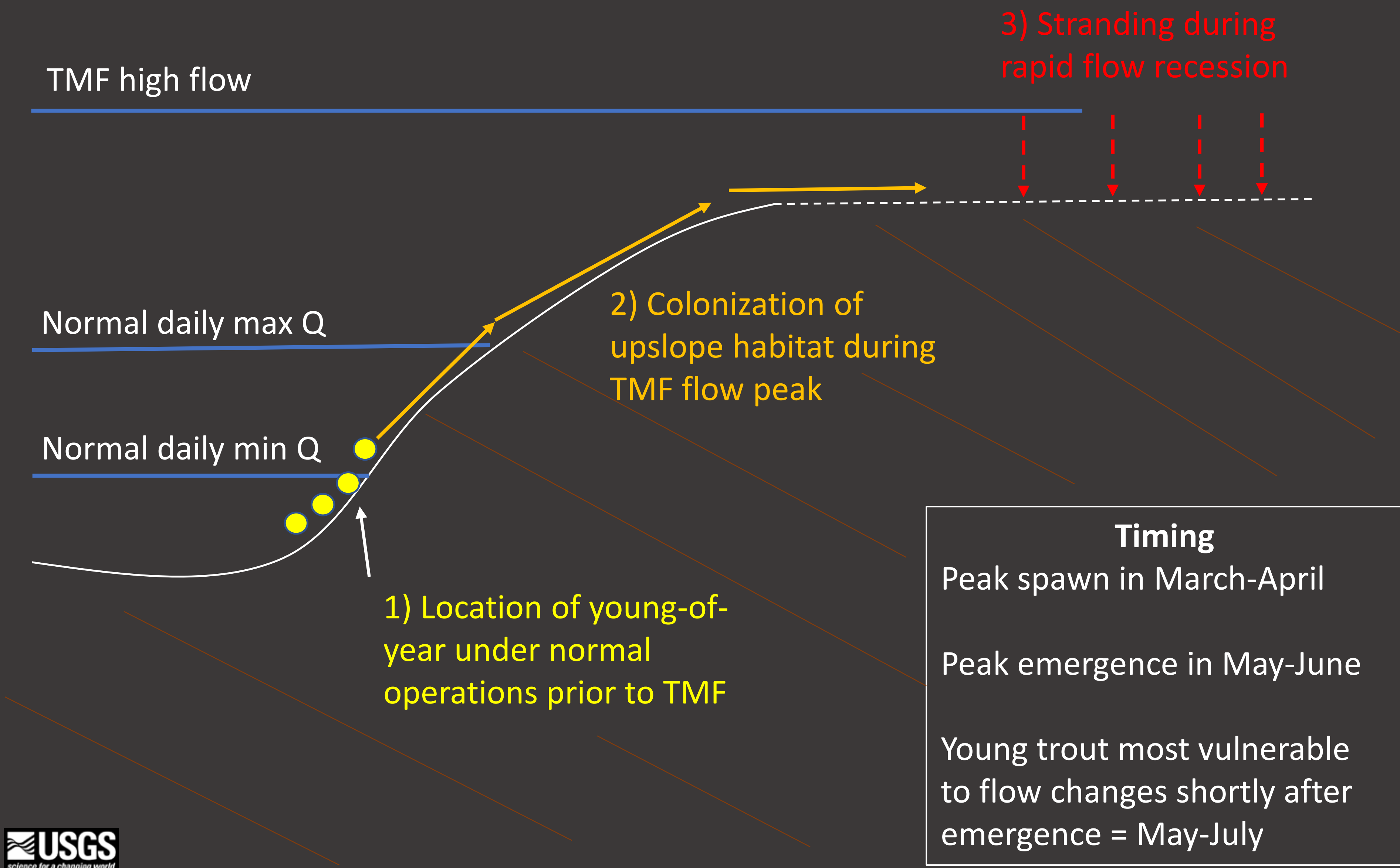
Example implementation of a two-cycle TMF in June and July with resumption of normal fluctuations between cycles and afterward

Adapted from: Glen Canyon Dam Long-Term Experimental and Management Plan December 2015 Draft Environmental Impact Statement http://ltempeis.anl.gov/documents/draft-eis/vol1/Chapter_2-Alternatives.pdf

Michael Yard, USGS, GCMRC

Josh Korman, Ecometric Research

Basic Trout Management Flow (TMF) Concept



Timing

Peak spawn in March-April

Peak emergence in May-June

Young trout most vulnerable to flow changes shortly after emergence = May-July

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Outline for Talk

- Objective and rationale for TMFs as defined in the Glen Canyon Dam Long-Term Experimental and Management Plan
- Potential negative effects of TMFs
- Conceptual model describing factors regulating trout recruitment, abundance, and dispersal
- History of flows that have controlled, or attempted to control, trout recruitment
- Data on trout recruitment in Glen Canyon and dispersal to LCR
- TMF Design (conceptual framework and uncertainties)
- Preliminary Results (Hypsometric Analyses)

Objectives of TMFs in Glen Canyon Dam Long-Term Experimental and Management Plan

Trout Management Flows (TMF) are intended to reduce the probability of large recruitment events of young Rainbow Trout in Glen Canyon.

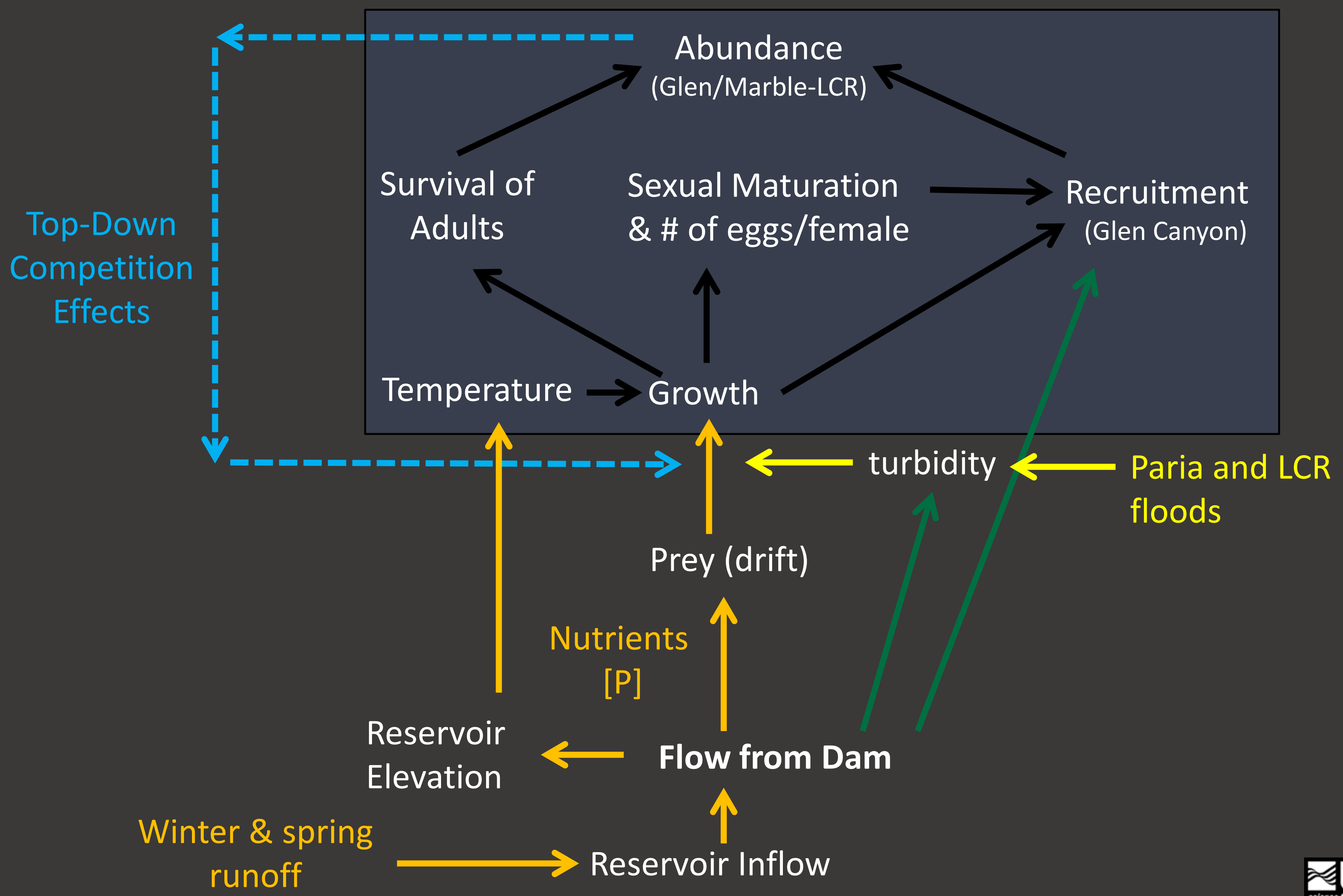
- High levels of recruitment can contribute to poor growth and population collapse which has negative effects on the trout fishery in Glen Canyon (e.g., '05-'06, '14-'15).
- High levels of recruitment in Glen Canyon can increase the number of trout dispersing into Marble Canyon and lead to higher trout abundance at the Little Colorado River and potential negative effects on humpback chub (e.g., '07-'09, '11-'14).

Negative Effects of TMFs

1. Tribal & Angler concerns about intentional killing
2. Costs to hydropower
3. Increased beach erosion
4. Concerns about stranding native fish

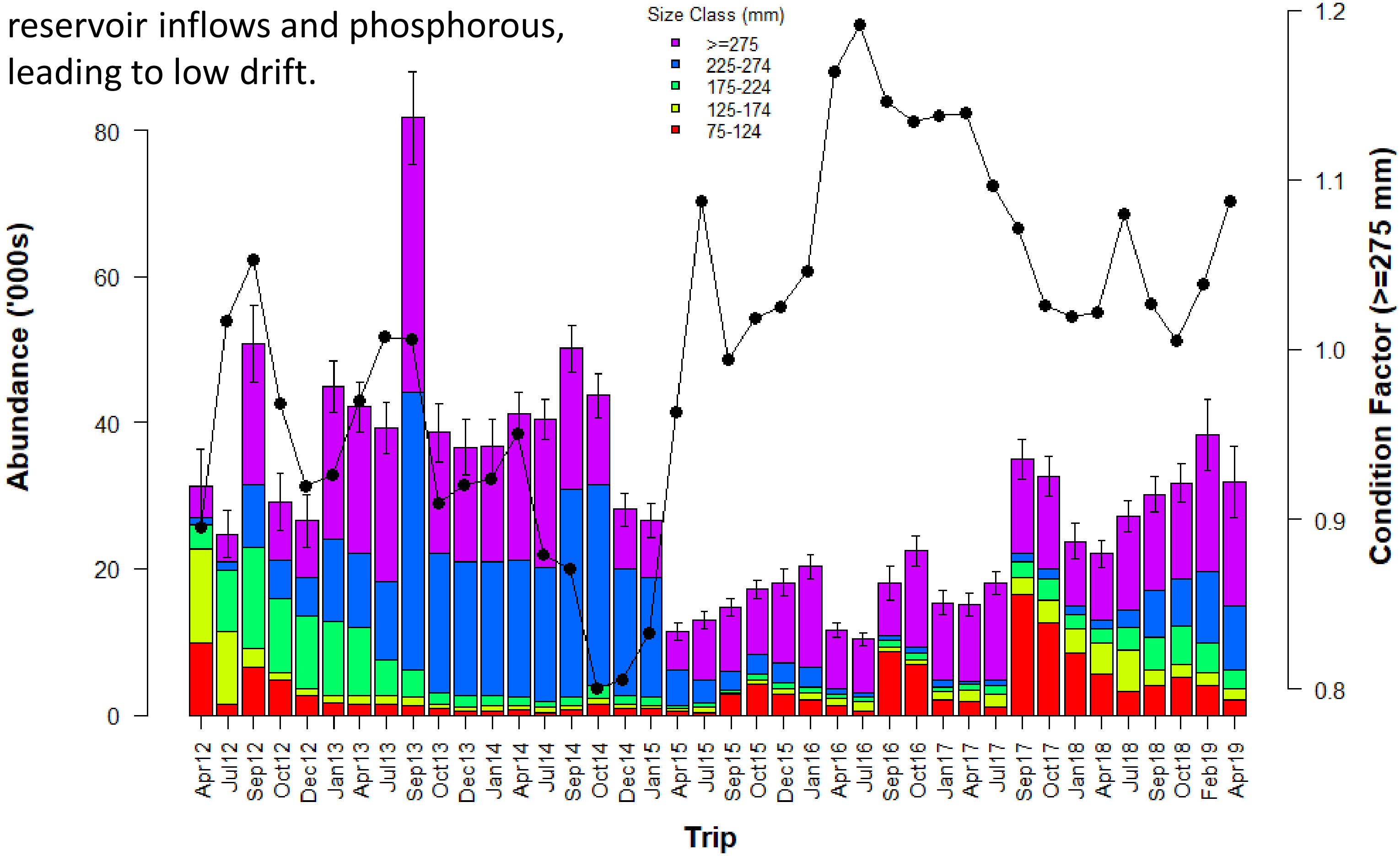
Preliminary data. Do not cite.

Conceptual Model



Trends in Abundance, Recruitment, and Condition

1) 2011 equalization flows led to high recruitment and abundance. Condition factor deteriorates due to low reservoir inflows and phosphorous, leading to low drift.



2) Very low growth, poor condition, die-off

3) Recovery of growth, condition, recruitment, and abundance

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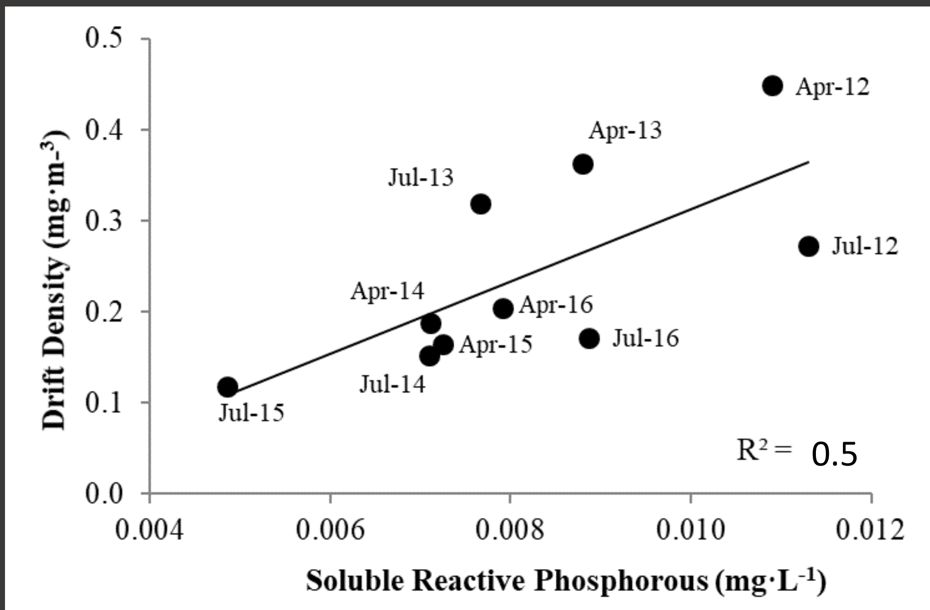
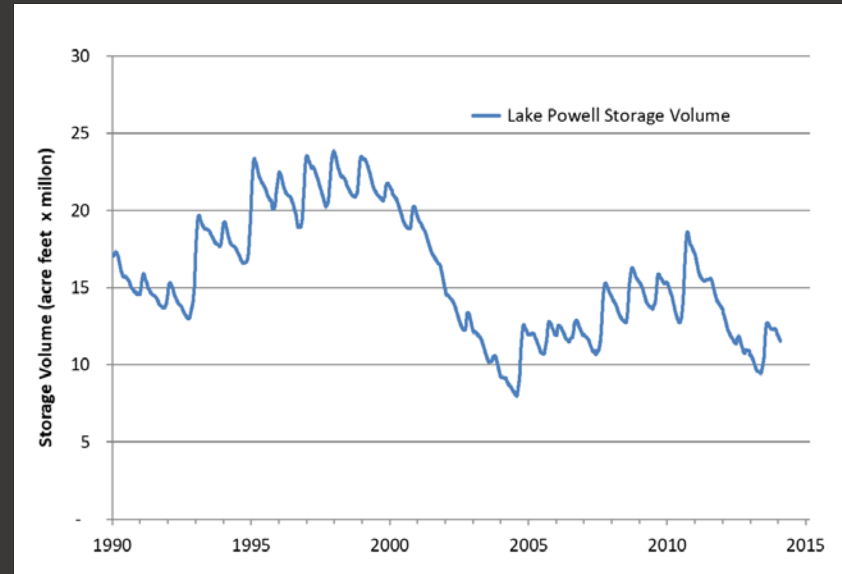
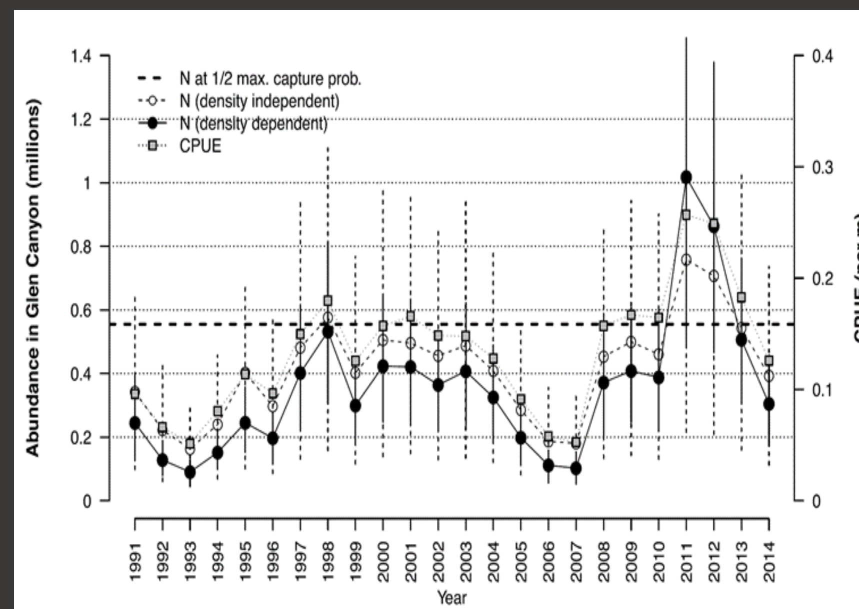
Preliminary data. Do not cite.

Relationship between Lake Powell Reservoir and Abundance of Trout in Glen Canyon

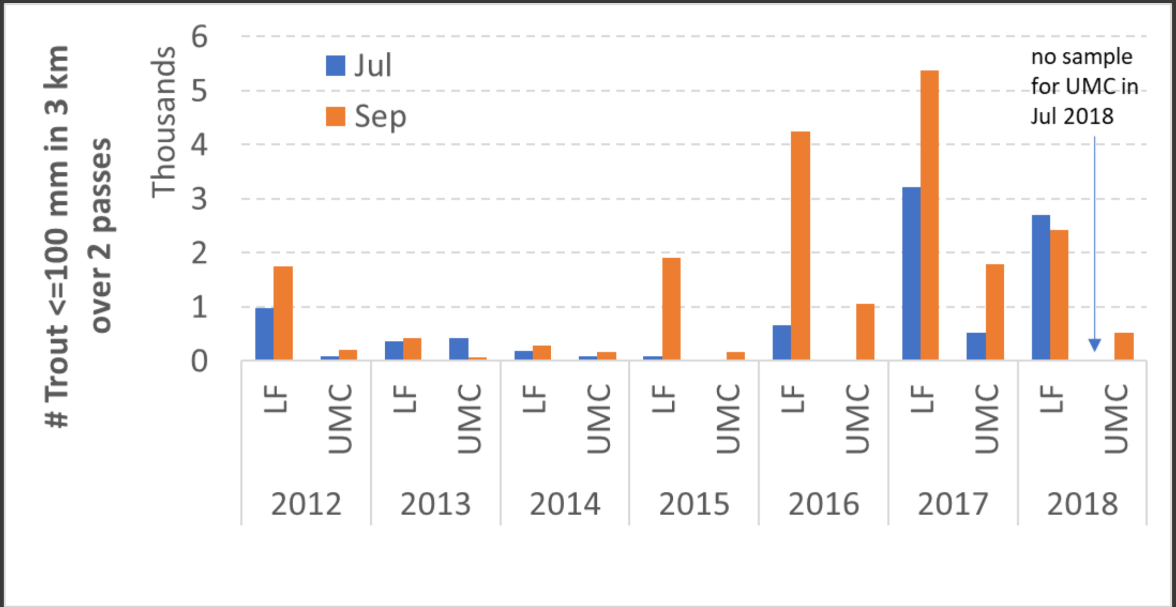






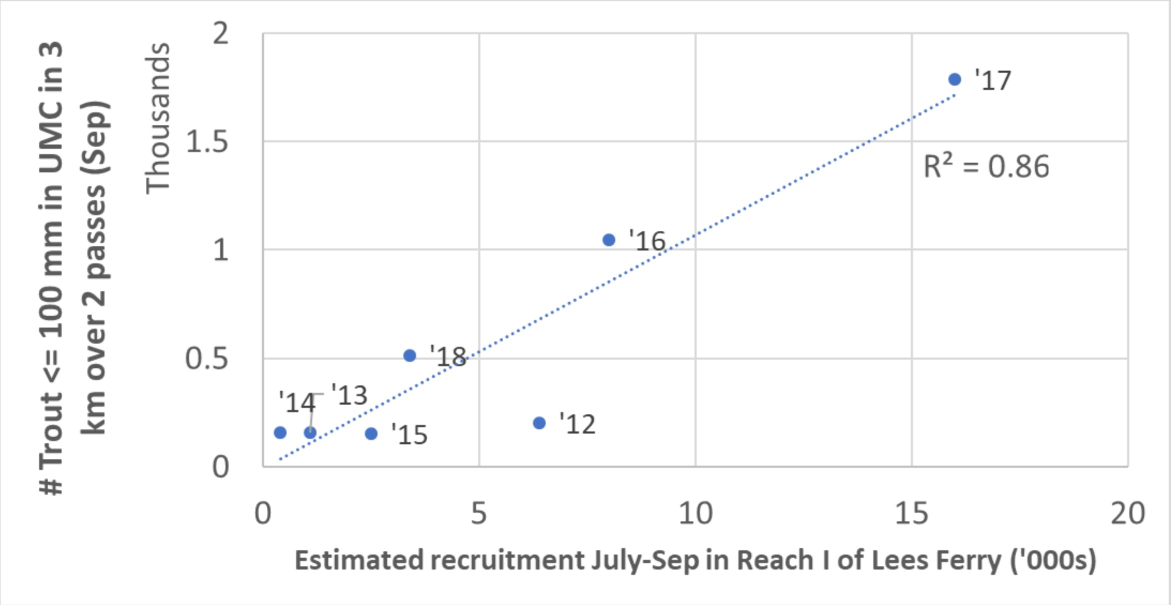
Korman and Yard , 2017
Korman, Yard, Kennedy 2017

Downstream Dispersal of Young of Year (YoY) into Marble Canyon



YoY in Upper Marble Canyon (UMC) very rare in July but can be present In September ('16 and '17).

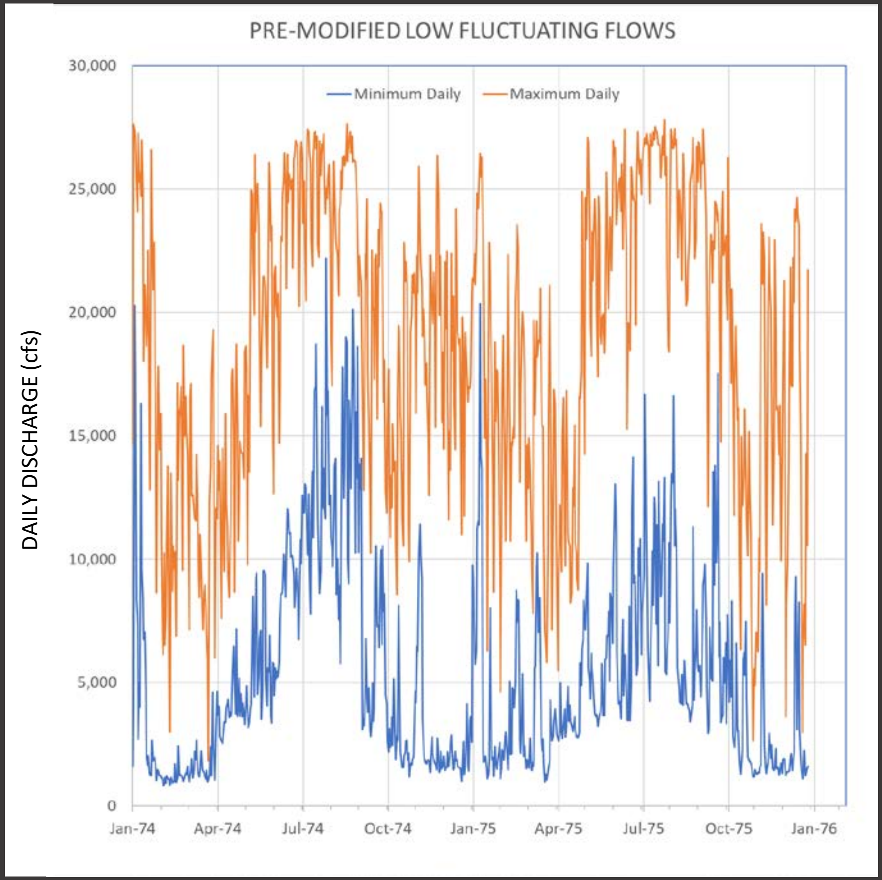
Suggests majority of dispersal from Glen – UMC occurs Jul-Sep.

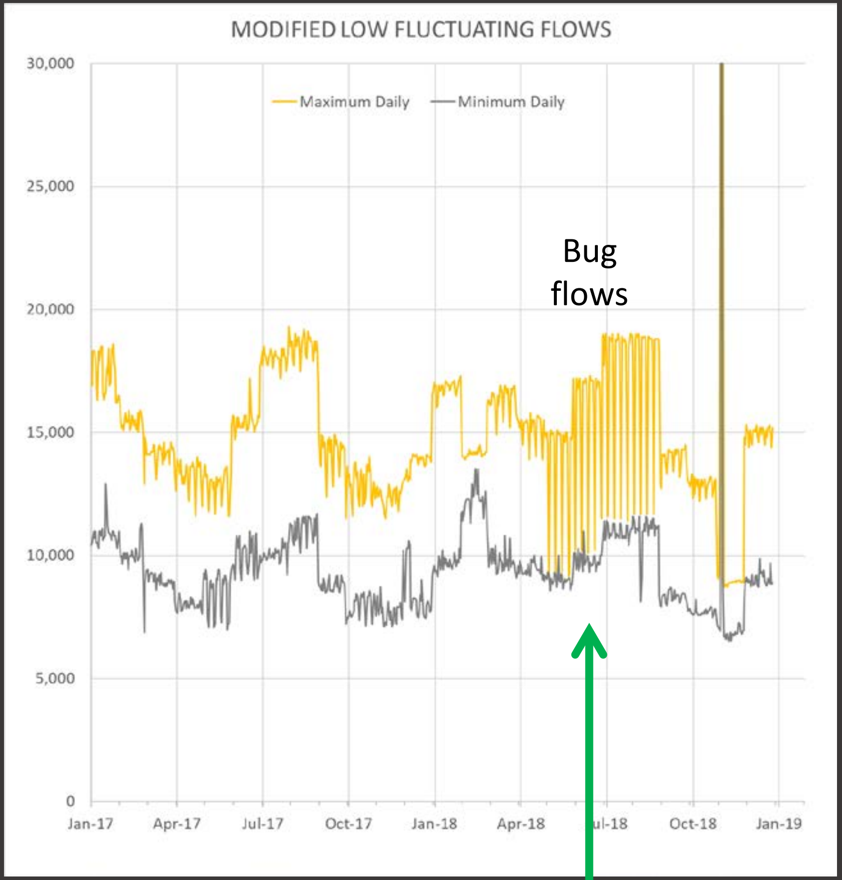


# of YoY in Upper Marble well predicted by recruitment in Lees Ferry in Jul-Sep.

Suggests that reducing recruitment in Glen Canyon can limit downstream dispersal

Trout Management Flows pre-MLFF





the original TMF

the anti-TMF

Preliminary data.
Do not cite.

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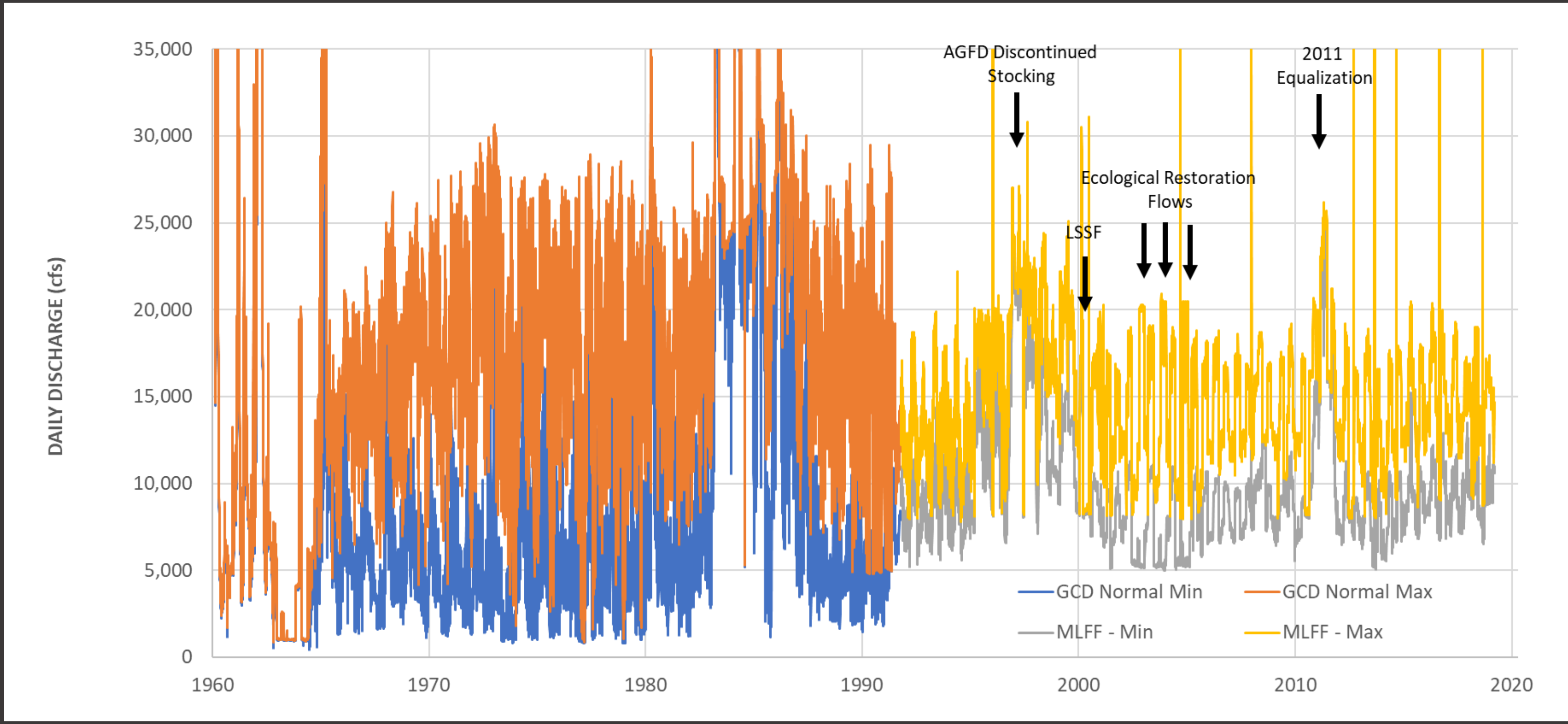
History of Flows Potentially Effecting Trout Recruitment

PRE-MODIFIED LOW FLUCTUATING FLOW (1963 – 1991)

MODIFIED LOW FLUCTUATING FLOW (MLFF : 1992 – P)

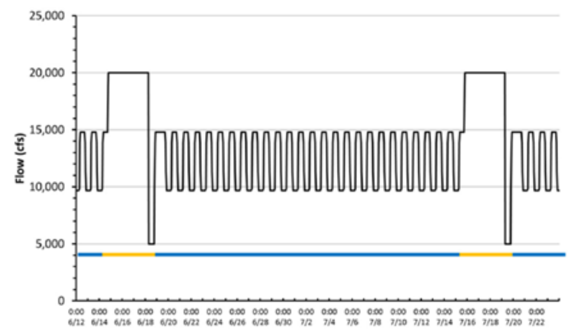


Preliminary data. Do not cite.

TMF Design Uncertainties

- **Recruitment forecasting (Triggering mechanism)**
  - Status of trout population (# of fish old/large enough to potentially spawn)
  - Condition factor (% of population that will spawn and fecundity)
  - Survival of juveniles (flow, phosphorous, drift)

- **Flow Design**
  - Maximum peak discharge of the TMF cycle
  - Time interval between max flow level and beginning flow recession
  - Downward ramp rate of flow recession
  - Minimum discharge at the peak of the TMF cycle
  - Number of TMF cycles per year (1, 2, 3, …….)
  - Triggering Mechanism
  - When to begin implementing TMF cycle



Example implementation of a two-cycle TMF in June and July with resumption of normal fluctuations between cycles and afterward

Adapted from: Glen Canyon Dam Long-Term Experimental and Management Plan December 2015 Draft Environmental Impact Statement http://ltempeis.anl.gov/documents/draft-eis/vol1/Chapter_2-Alternatives.pdf

Preliminary data. Do not cite.

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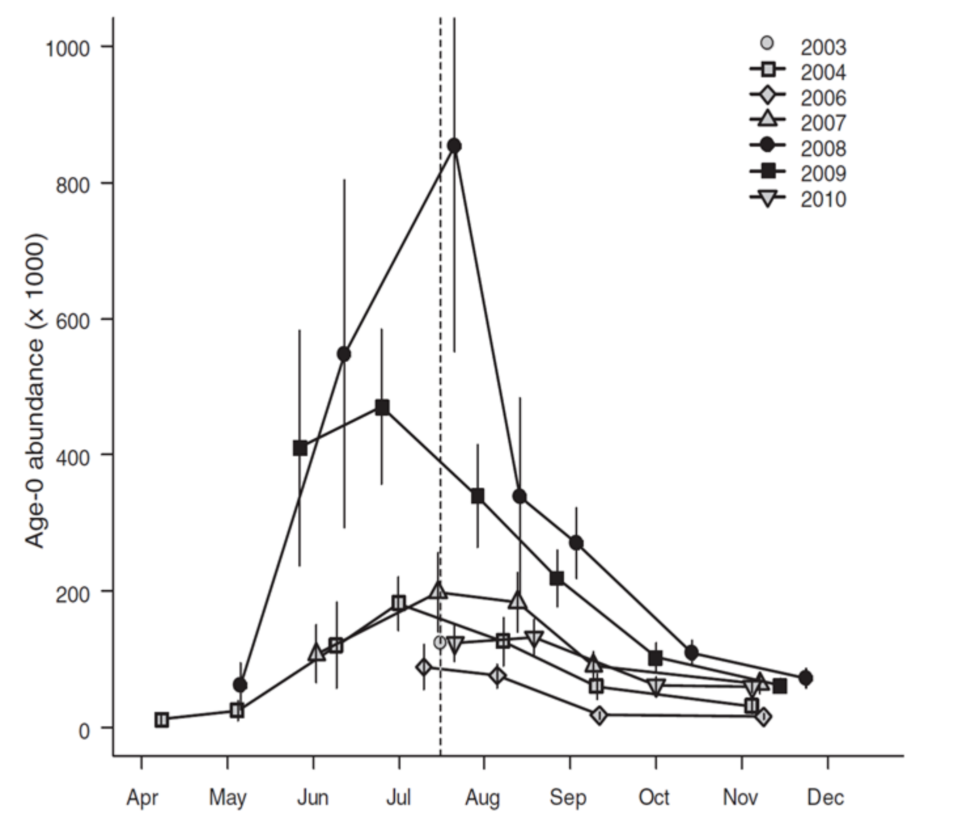
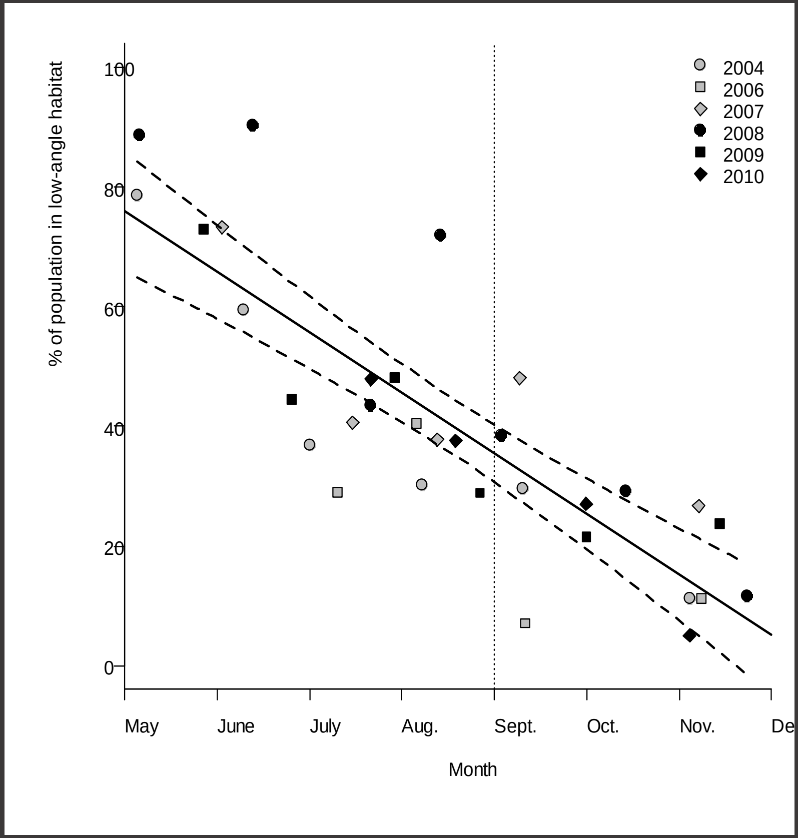
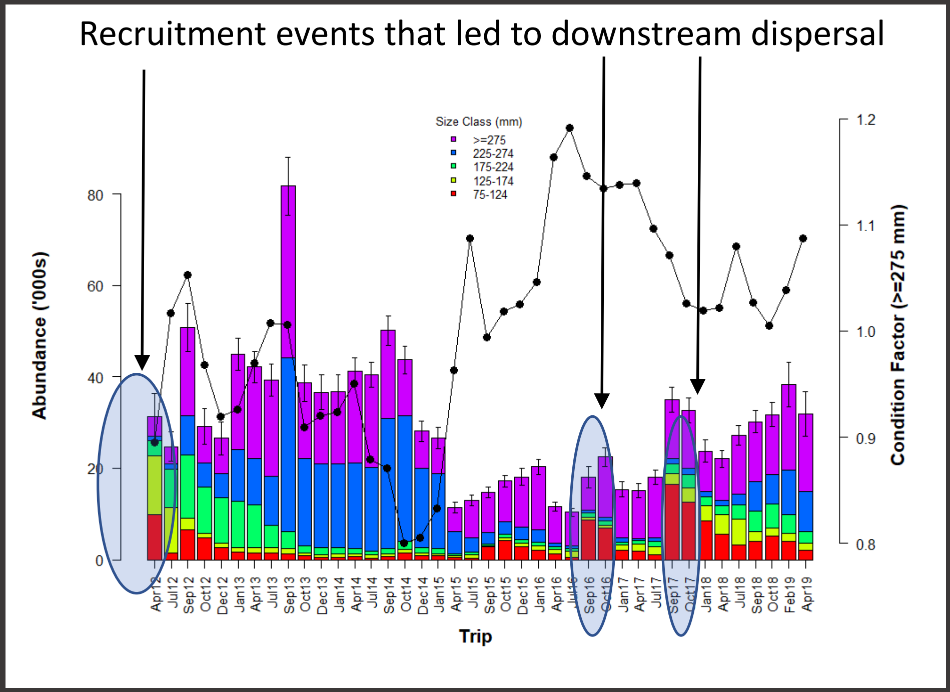
Young of Year Trout are Likely Most Vulnerable to Stranding May-June. Efficacy of TMFs in July and August Uncertain



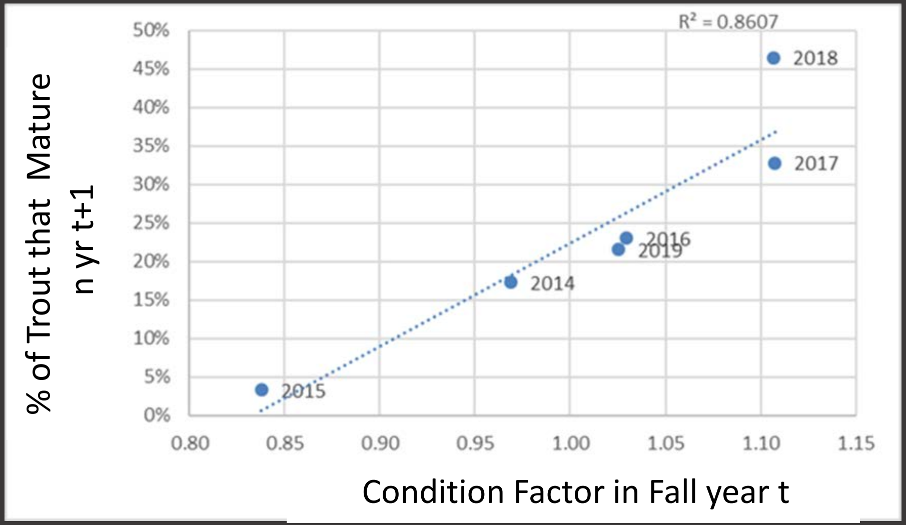


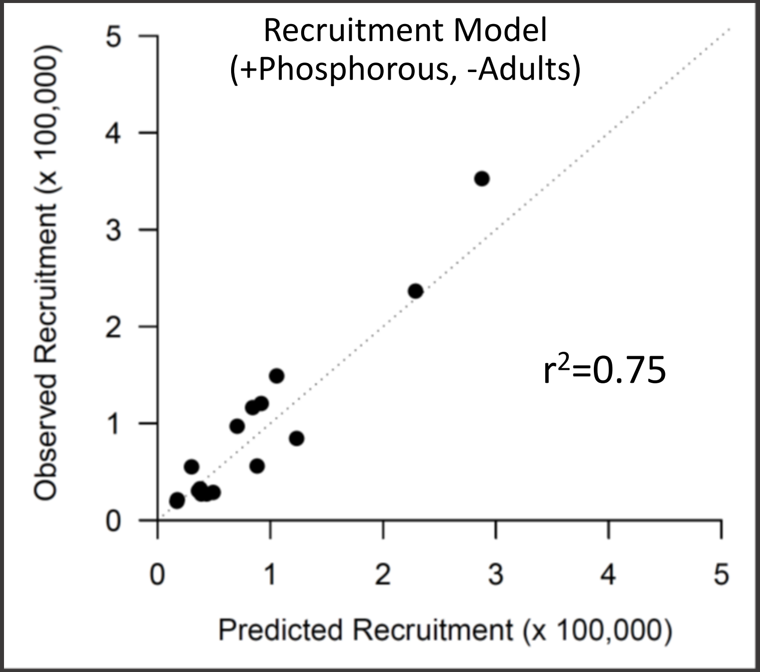
Korman et al. 2011

Recruitment forecasting (Triggering mechanism)



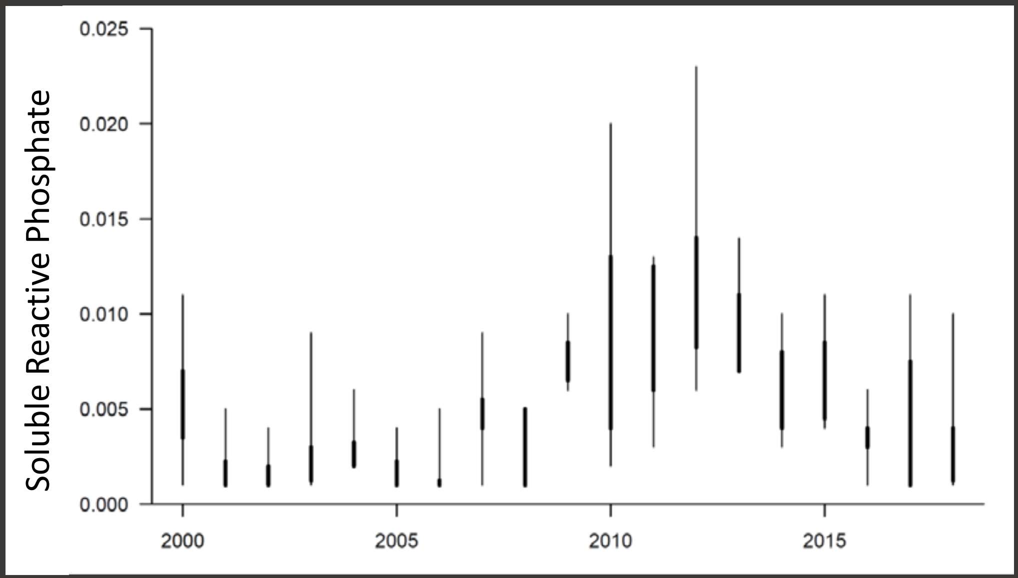
Preliminary data. Do not cite.

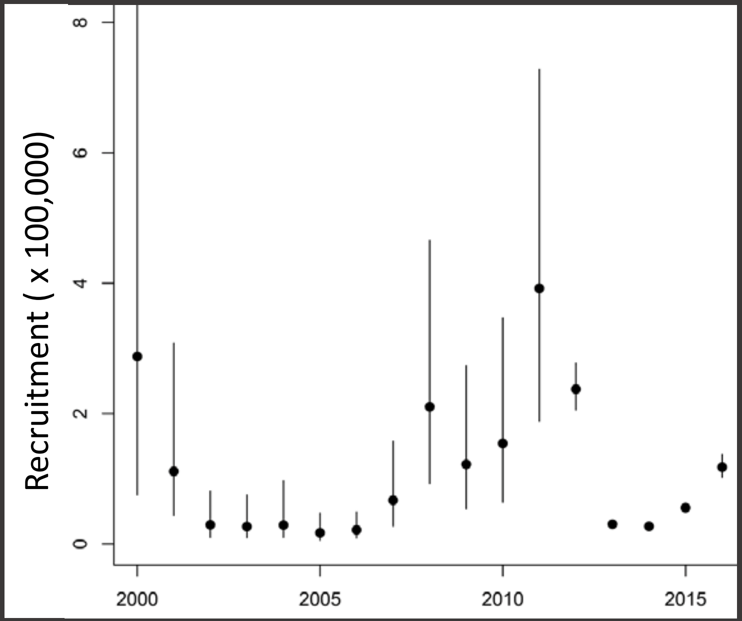




C. Yackulic
Preliminary data.
Do not cite.

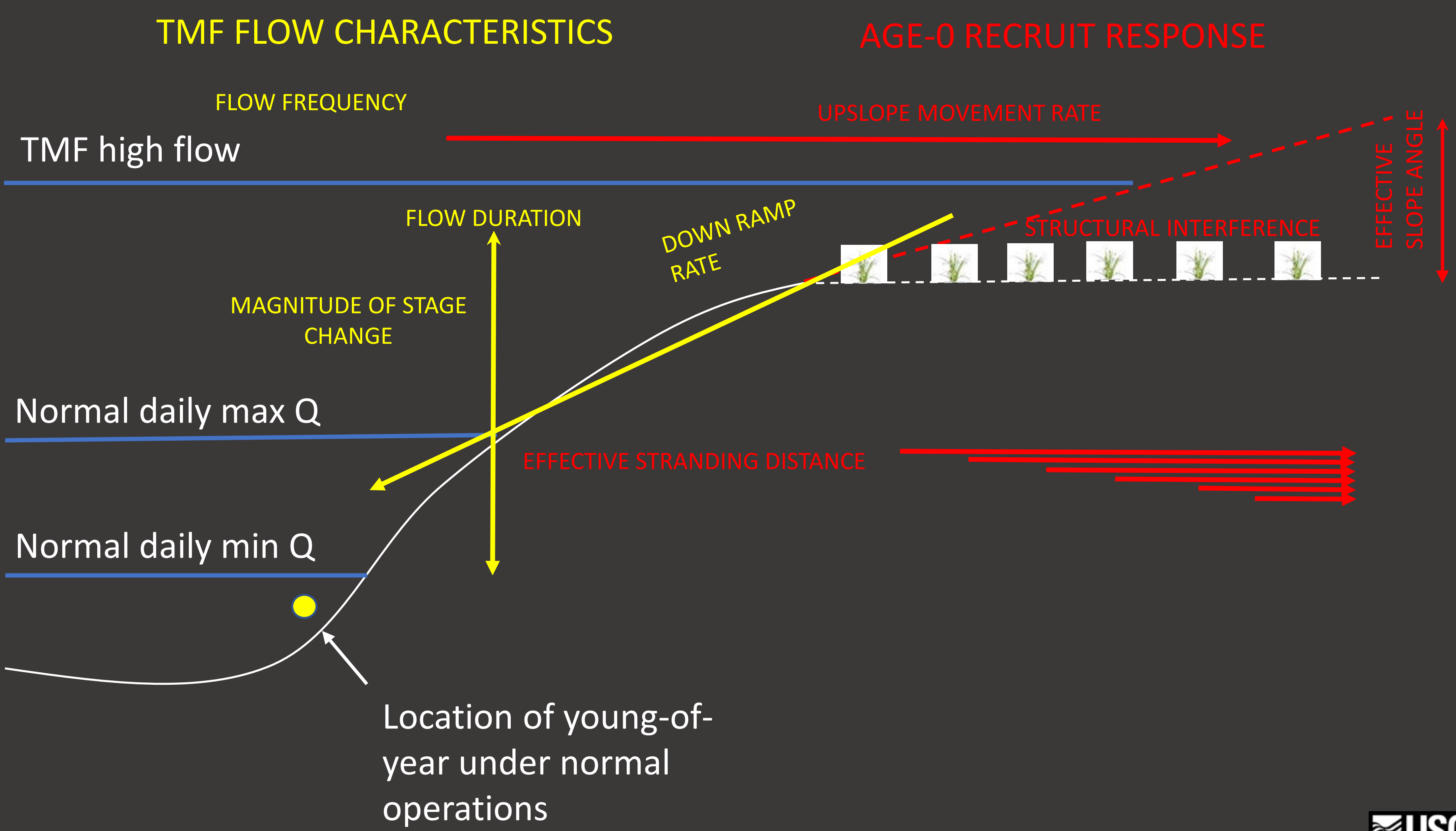
Relationship between Nutrients (SRP) and Trout Recruitment





C. Yackulic, preliminary data. Do not cite.

TMF Design Considerations



AGE-0 RECRUIT RESPONSE – QUESTIONS AND UNCERTAINTIES

FLOW ASCENSION - Dispersal

- Following inundation, what is the dispersal rate (m/da) upslope to the new minimum stage elevation?
- Are upslope movement rates by YOY into low angle habitat, fish size dependent?
- When there are changes in monthly discharge volumes or TMF's or BUG flows, what proportion of young-of-year (YOY) move upslope across this newly wetted habitat?
- Are the YOY density distributions narrowly confined to the newly wetted edge or are fish densities unevenly distributed across the newly inundated zone?
- Are upslope movement rates by YOY into low angle habitat, food dependent?
- Does vegetation impede upslope movement?

FLOW RECESSION - Stranding

- What flow recession rates are effective at stranding?
- When flows recede, are there size-classes that are more or less vulnerable to stranding?
- What effect does night vs day have on YOY vulnerability to stranding?
- What effect does bare substrate vs. vegetation have on YOY vulnerability to stranding?
- What effect does shoreline slope have on YOY vulnerability to stranding?
- When flows recede, what is the minimum distance required to safely return down to the newly wetted edge?

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Current Approach Being Used to Assist in Designing TMF

Optimization approach being used to design and evaluate future flows

- Literature review (stranding studies)
- GIS and Hypsometric Analysis: Slope discharge relationships and other physical spatial attributes: hypsometric analysis to quantify the area of inundation, substrate types, vegetative cover, and velocity
- **Development of TMF model to evaluate alternate flows**
- TRGD study to assess annual recruitment of YOY (< 75 mm FL)

- Mesocosm experiments (model parameters)
- Field assessments (opportunistic sampling across monthly flow changes during summer)

TMF Experiment (Contingency Plans)

- Mark-recapture studies, pre- & post flood response to YOY
- TRGD Study to assess annual recruitment of YOY (inter- and intra-annual comparisons with and w/o TMF)

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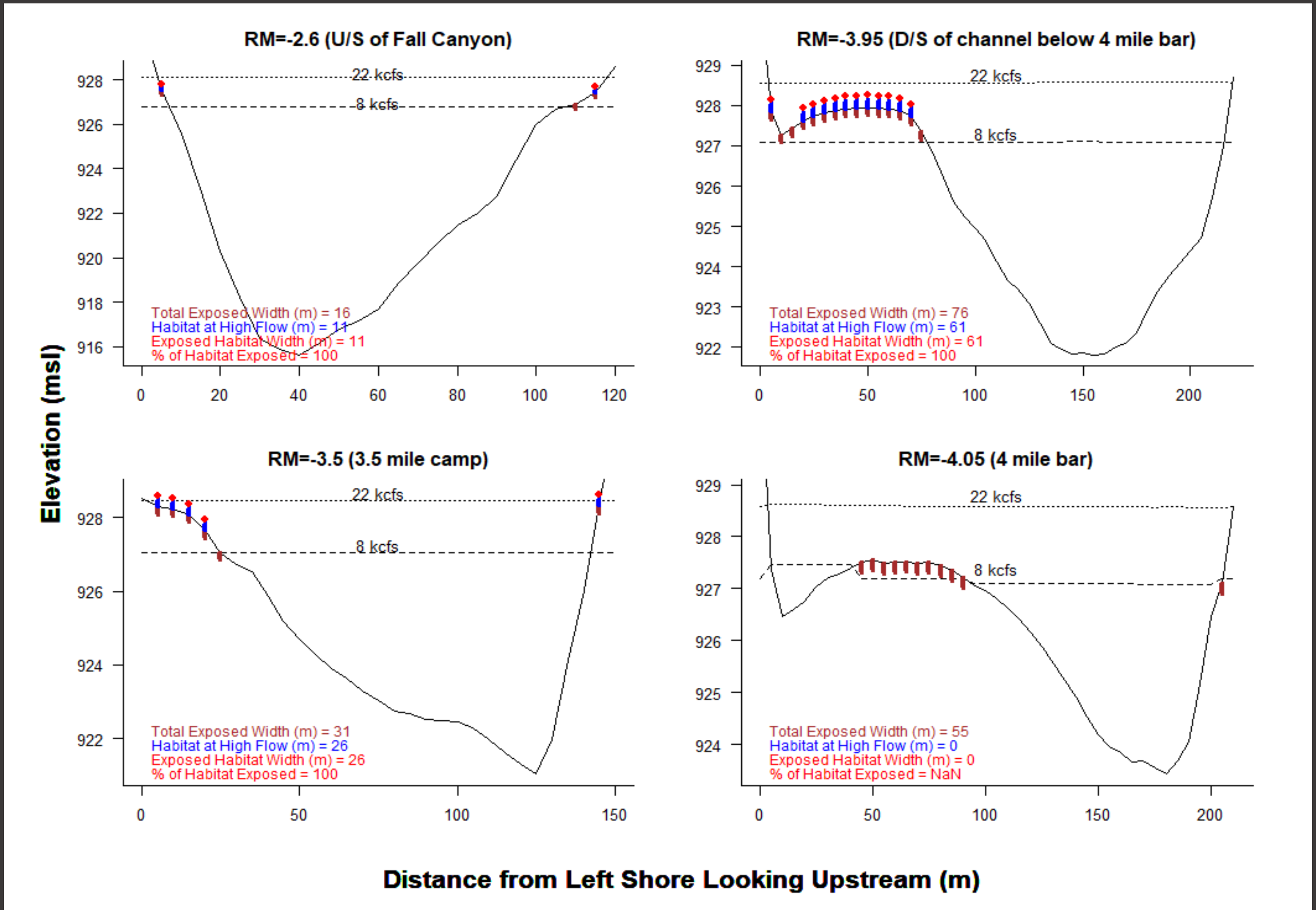
Hypsometric - TMF Model



Preliminary data. Do not cite.

Predicted 22 – 8 kcfs Flow Change Effect

- Useable habitat computation assumes that the high flow habitat is colonized
- Habitat 'loss' computation assumes that all fish in useable exposed habitat are lost (due to stranding or displacement-related mortality), but this might only occur over very flat terrain.
- More complicated dynamics are likely, but observations are lacking.

Preliminary data. Do not cite.

Extent of Potential TMF-Related Loss Depends on Assumed Habitat Preferences of Young of Year Trout

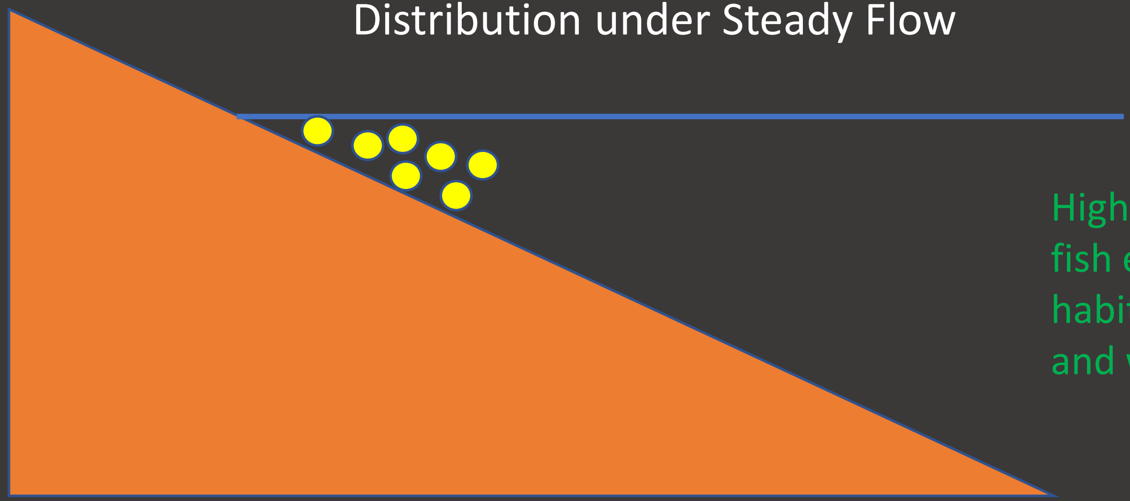
			Habitat Preference Assumption	
			A	**B**
8 kcfs min flow **High Flow**		**Max Depth (m)**	1	2
(kcfs)		**Max Vel (m/s)**	1	0.5
			% Habitat Exposed	
16			91	51
18			97	59
20			99	74
22			100	81
24			100	89

Conclusions

- Sensible implementation strategy for TMFs is to first reduce some uncertainties via mesocosm studies or small-scale field experiments.
- Evaluating population-level effects of TMFs can only be determined by doing them.
- The ideal circumstances for implementing TMFs (population status, condition factor, fecundity, limnology, and hydrology) occurs infrequently (e.g. 2011)
- There are alternate means of addressing over-recruitment problems in Glen Canyon (harvest, bug flows, nutrient additions) and at high trout abundance at the LCR (mechanical removal).
- High trout abundance is not the only factor that limits HBC abundance at the LCR (Yackulic et al. 2018). The LCR HBC population has survived multiple periods of high trout abundance (’98-’01, ’08-’09, ’11-’14, ’17-’19).
- Relatively certain social, recreational, environmental, and hydropower costs may outweigh uncertain benefits of TMFs.
- Direction from TWG is needed to determine whether TMF-related studies are part of 2021-2023 workplan.

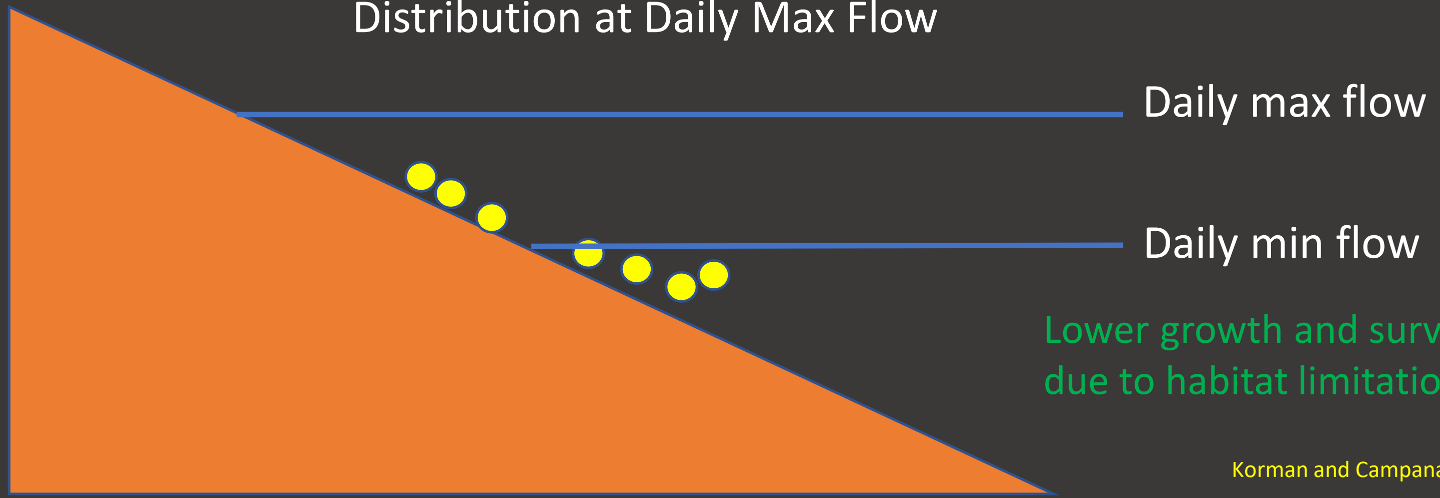
Effects of Daily Variation in Flow on Young of Year Trout during the Summer

Distribution under Steady Flow



Higher growth and survival because fish experience optimal habitat conditions (depth, velocity, and water temperatures)

Distribution at Daily Max Flow



Lower growth and survival due to habitat limitations

Korman and Campana, 2009