Findings from Ecosystem and NSE modeling workshops, March 2010

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Basic approach

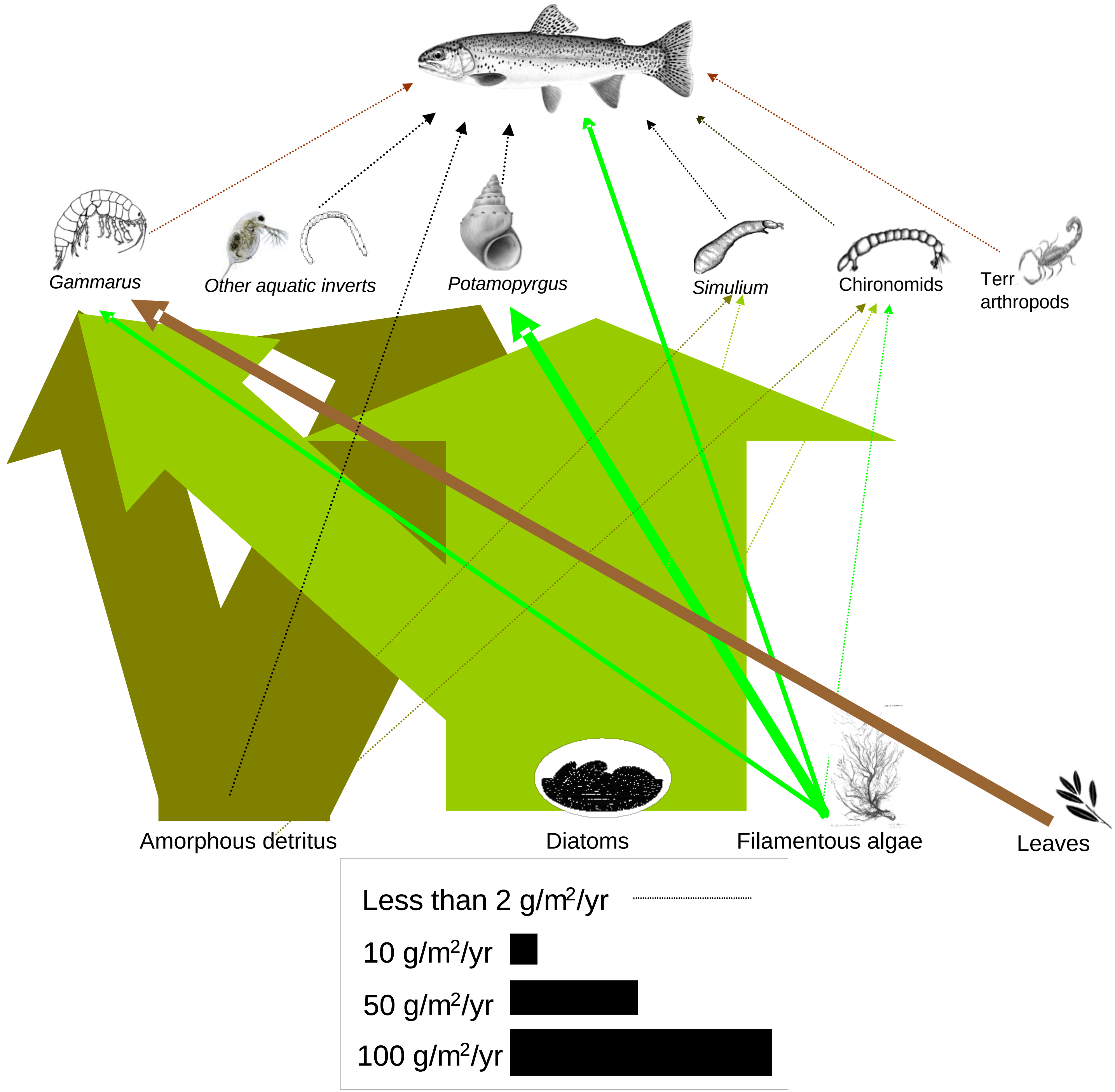
- GCM modeling in 1990s produced a very complex spatial model, difficult to understand and almost impossible to calibrate with field data
- Our approach in the 2010 workshop was to work with much simpler food web models
  - "snapshot" data on biomasses, trophic flows (Ecopath model)
  - Dynamic predictions of biomass responses to changes in flow and exotic fish control (Ecosim model)
- The key aim was to determine whether we can model dynamic interactions well enough to explain observed changes in the aquatic ecosystem above Lees Ferry and near the LCR since 1990.
- Iterative approach: use model prediction "failures" (lack of fit to data) to help identify driving variables

A central aim of the analysis is to help answer some key policy questions

- How do changes in flow (annual, diurnal, HFEs) affect Lees Ferry trout, and trout abundance downstream where native fish may be impacted?
- Should mechanical removal be continued, or stopped to help distinguish between effects of it and river warming on native fish recruitment?
- Can HFEs be combined with other flow treatments to prevent massive rainbow trout recruitment and movement downstream?
- Should the FSF treatment be continued, extended into summer period increase effects, or replaced by an SASF experiment?
- Should some aquatic monitoring programs be cut back in favor of new research initiatives?

We began with snapshot estimates of abundances and biomass flows

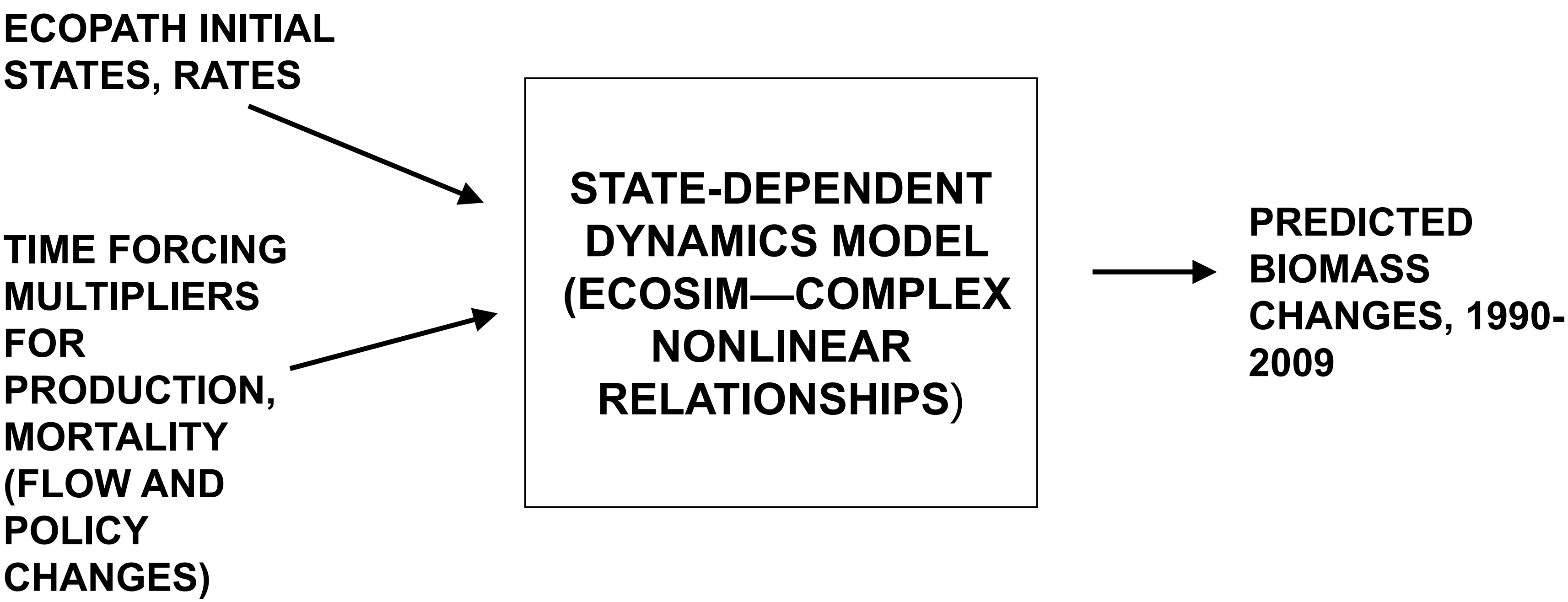
- GCMRC foodbase research group has assembled biomass information for all trophic levels, along with estimates of production and consumption.
- A key result of this analysis is to provide estimates of the proportion of the production of each major type of organism that is utilized as consumption, i.e. moves up the food web.


Gammarus
Other aquatic inverts
Potamopyrgus
Simulium
Chironomids
Terr arthropods
Amorphous detritus
Diatoms
Filamentous algae
Leaves
Less than 2 g/m2/yr
10 g/m2/yr
50 g/m2/yr
100 g/m2/yr

Key findings from the foodweb snapshot studies

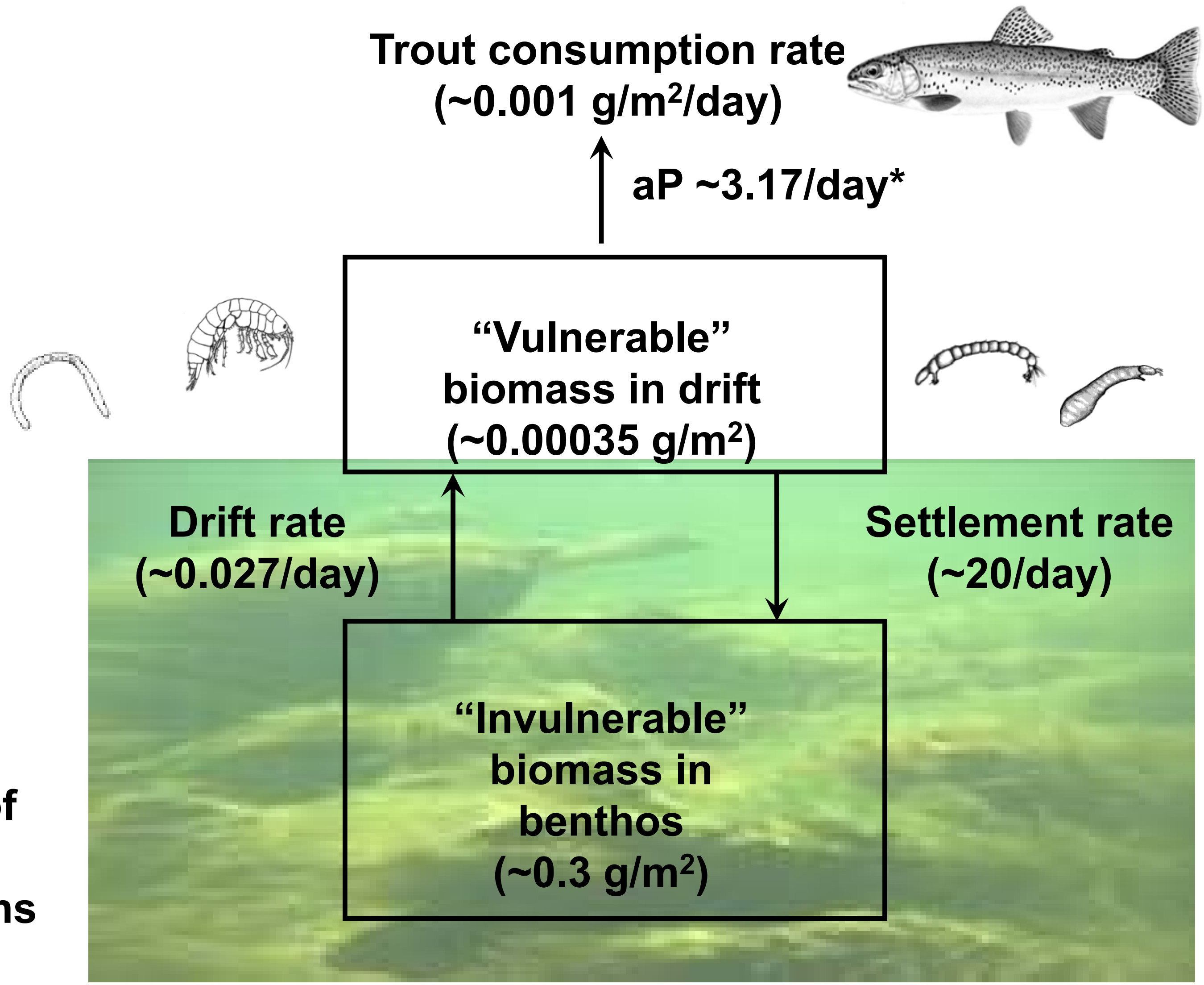
- Very little cladophora production is utilized by consumers
- Invertebrate production is based mainly on consumption of diatoms and “amorphous detritus” from mixed sources
- There is very little contribution of terrestrial production to aquatic consumers
- Major, persistent changes in production and consumption of key invertebrates have followed BHBF flows
- Very high proportions of the production of chironomids and simulids are consumed by fish, i.e. fish come close to “overharvesting” these prey types.
- Invertebrate and fish biomass and production per unit area are roughly five times lower at the LCR confluence than above Lees Ferry, i.e. overall fish abundance is food limited.

Moving from static to dynamic models



ONE OF THE MOST VALUABLE RESULTS OF THIS EXERCISE HAS BEEN SYNTHESIS OF TIME SERIES DATA FOR COMPARISON TO MODEL PREDICTIONS

Vulnerability exchange rates of invertebrates into/from the drift are critical for understanding ecosystem stability and limitation of consumption by fish



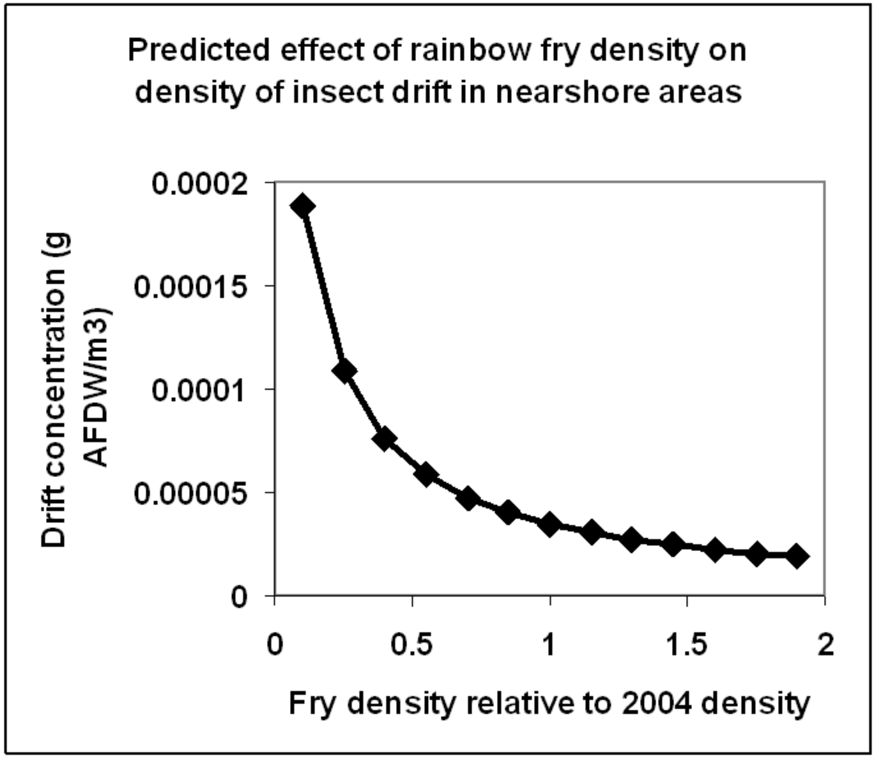
* Implied max reaction distance to prey implied by this rate is 0.49m

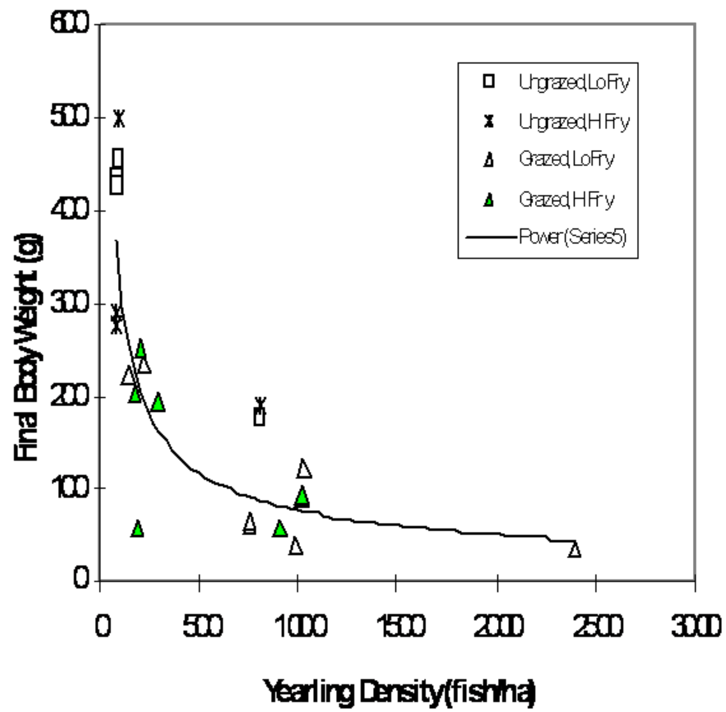
(Details of these calculations are in “vulnerability

Effect of fry density on nearshore drift concentrations and potential growth

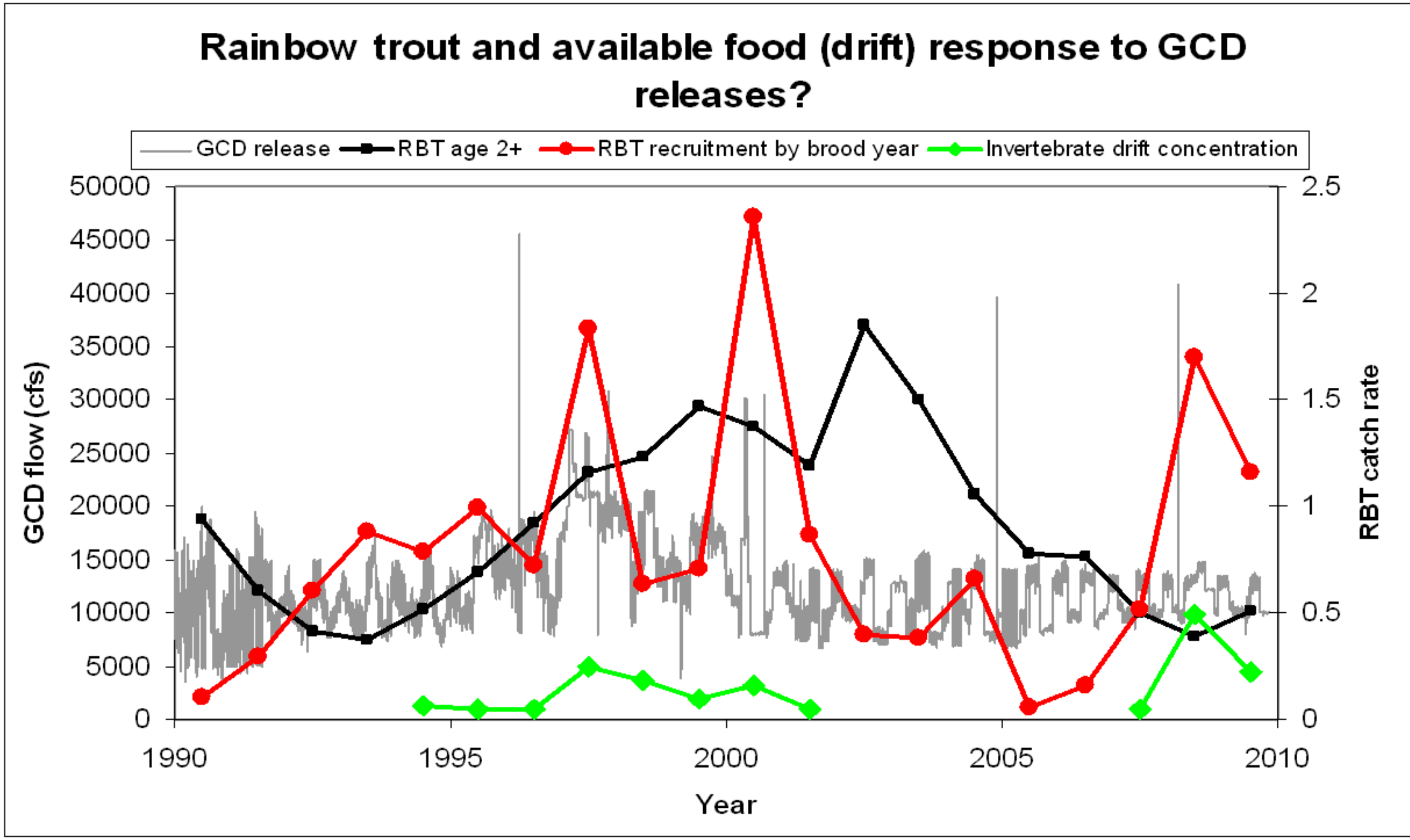
OUR MODEL

BC PONDS, POST AND PARKINSON EXPERIMENT





What has driven changes in Lees Ferry trout?



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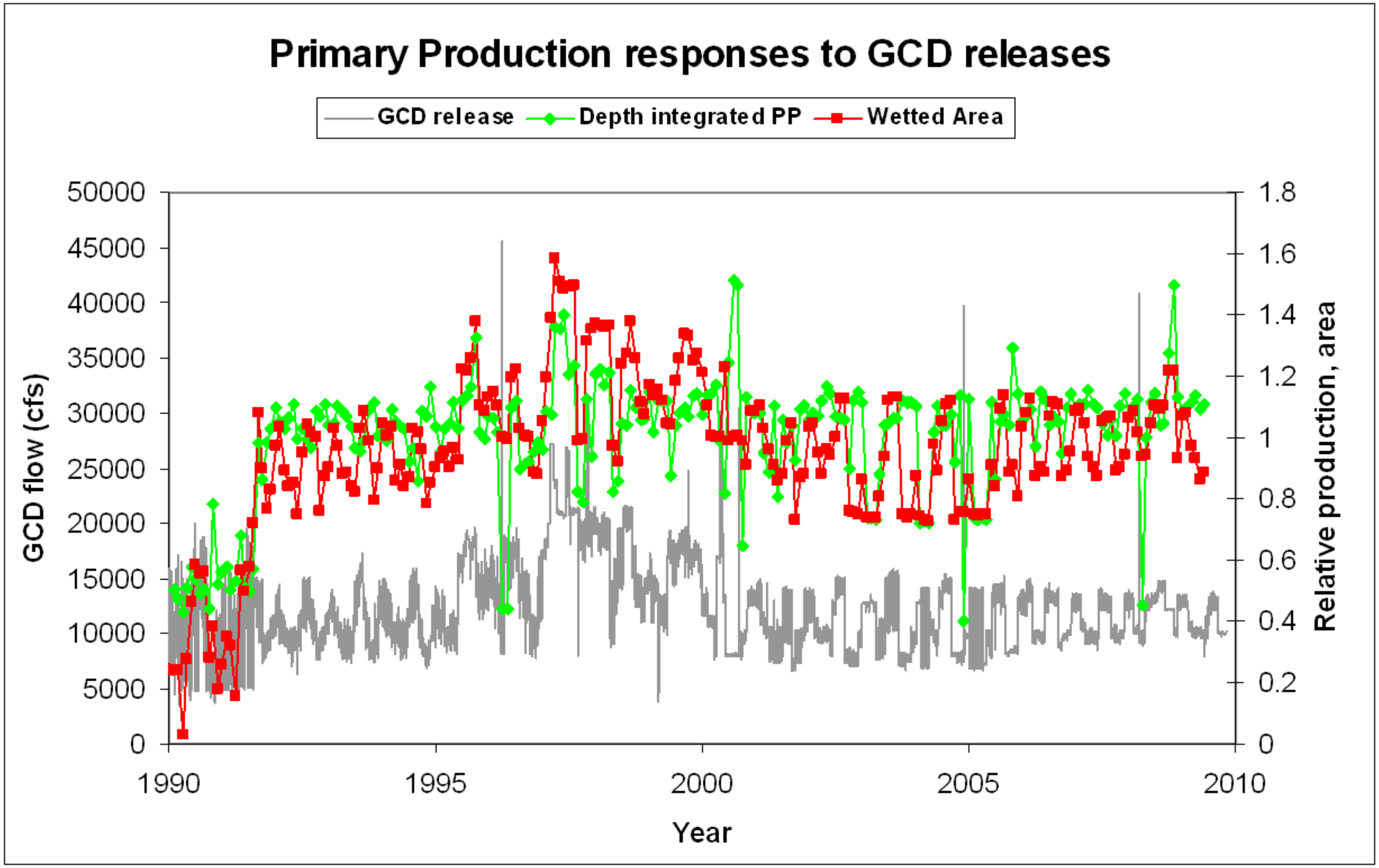
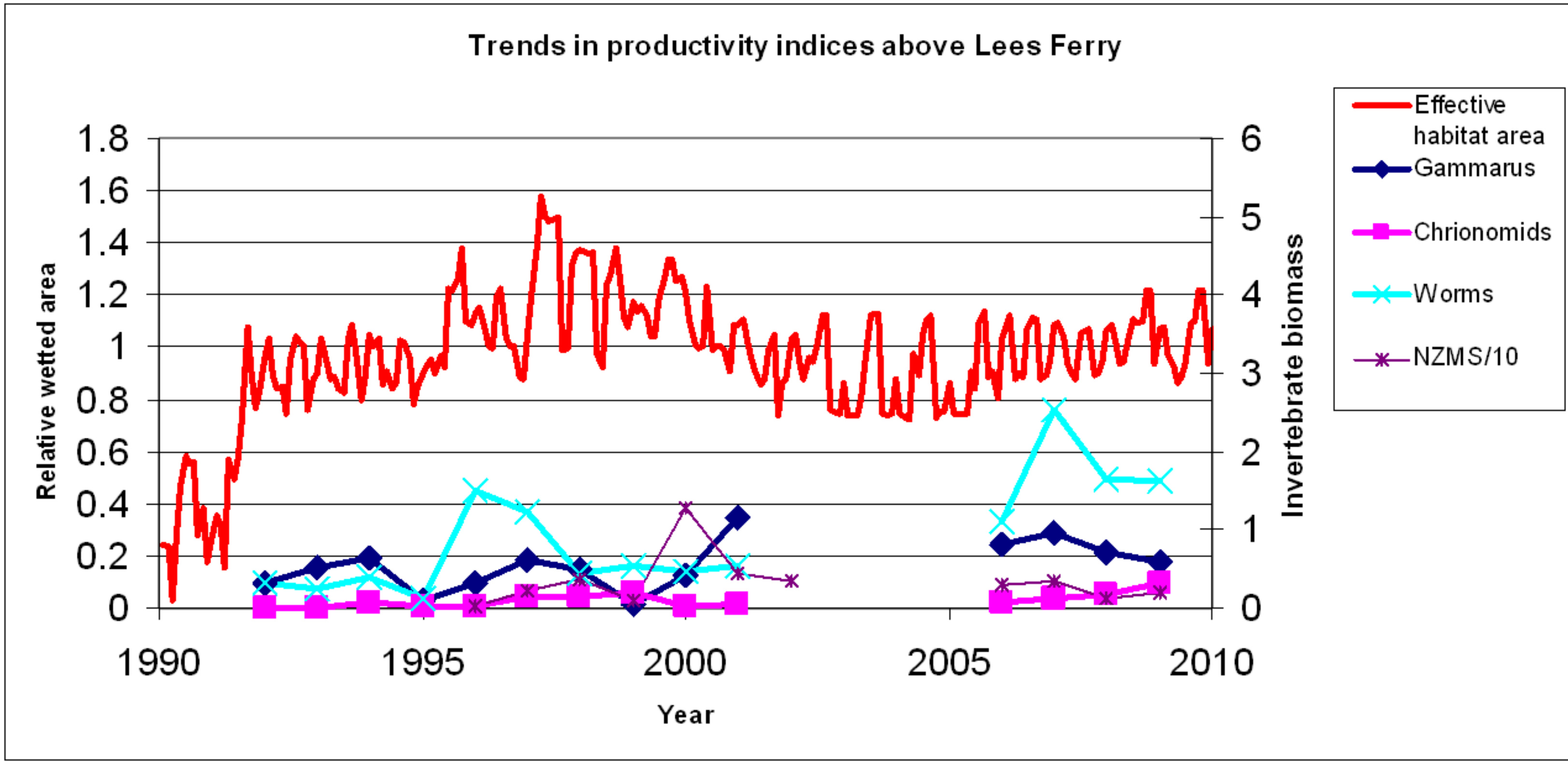
- Low trout recruitments 2002-2006 correlated with poor spawning (deliberate dewatering, poor oxygen in 2005)
- Available food (drift) concentrations may have been low, appear to have been stimulated by BHBFs 1996, 2008

Flow-driven changes in primary production and usable wetted area in the Lees Ferry reach



From lake powell dynamics.xls, LF stage area.xls,lees ferry integrated pp trends.xls

What has driven changes in Lees Ferry trout?



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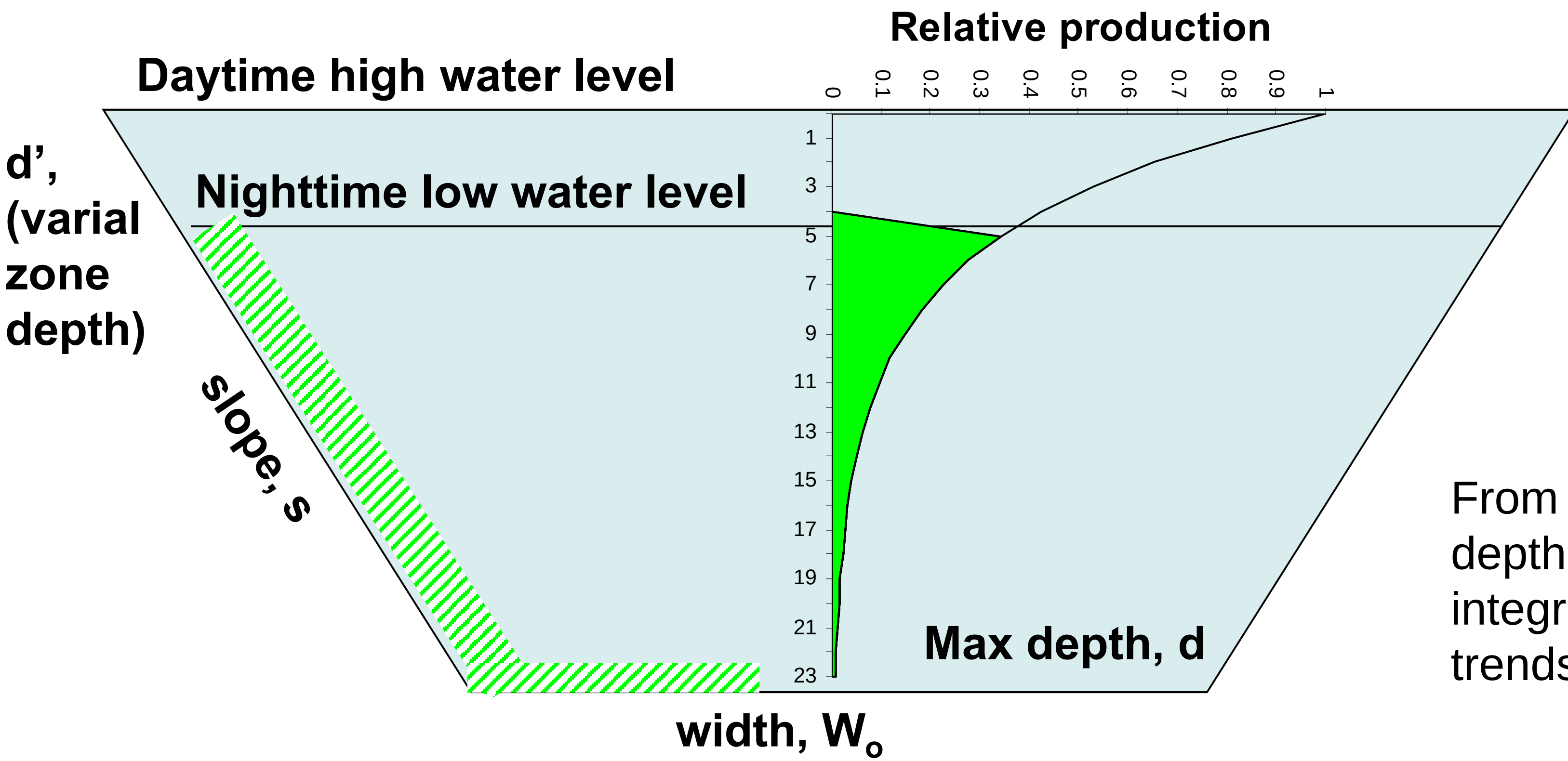
- Trout decline 2000-2006 correlated with decline in habitat area
- Trout trends related to invertebrate biomass pulses after high flow experiments

Estimating effect of stage changes on depth-integrated primary production



From Lees ferry depth integrated PP trends.xls

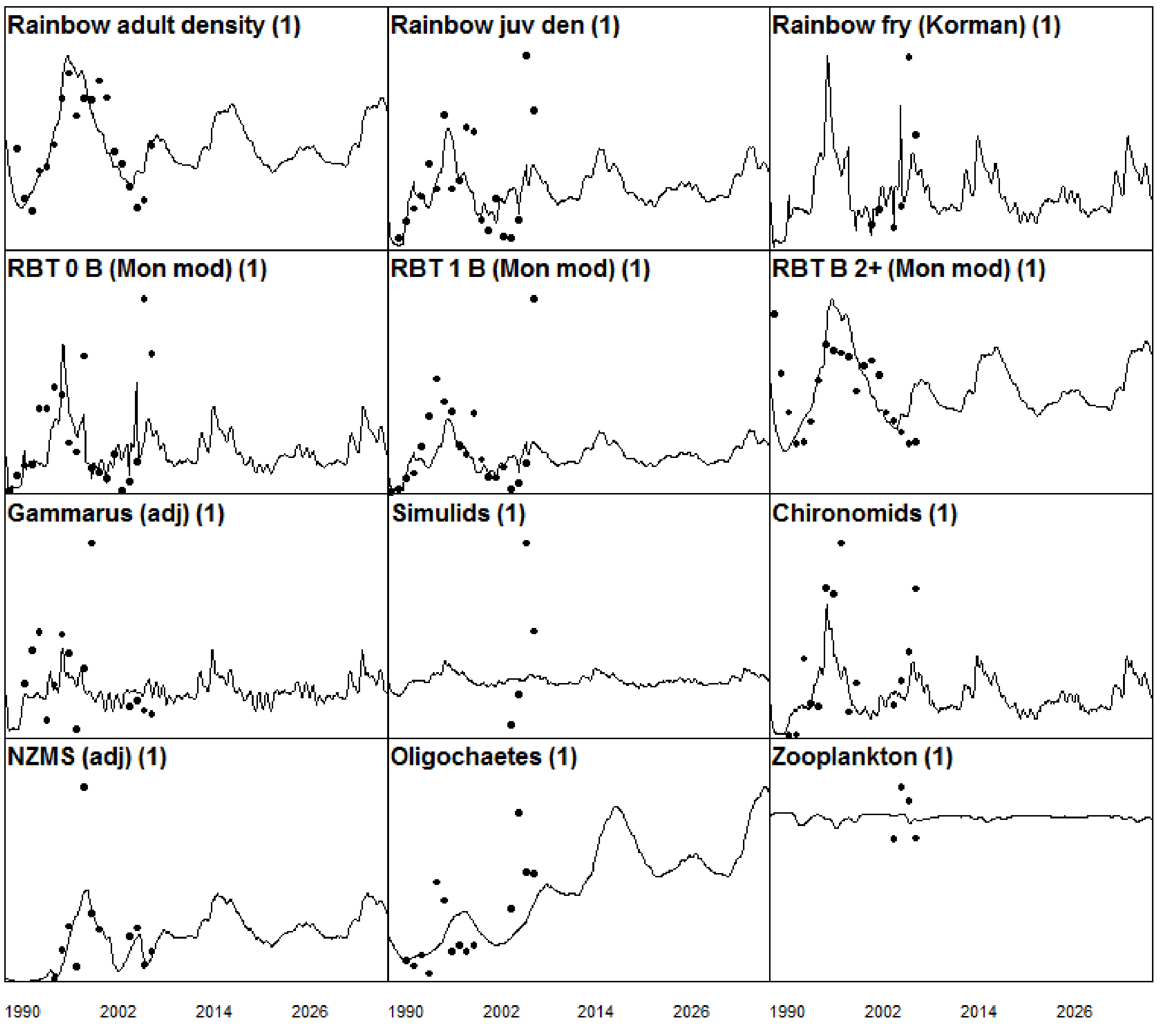
Integrating across the bottom:

Total PP=$W_o e^{-\lambda d} + 2(s/\lambda)[e^{-\lambda d'} - e^{-\lambda d}]$

Main effects of water regulation on rainbow trout recruitment

- Major increase resulted from MLFF
- Major decline resulted from low (drought period) flows and trout suppression (low spring) flows
- Exceptional recruitments resulted from
  - High flow experiments of 1996, 2008
  - Steady summer flows in 2000
- Poor recruitment in 2006 following high temperatures and low oxygen in 2005

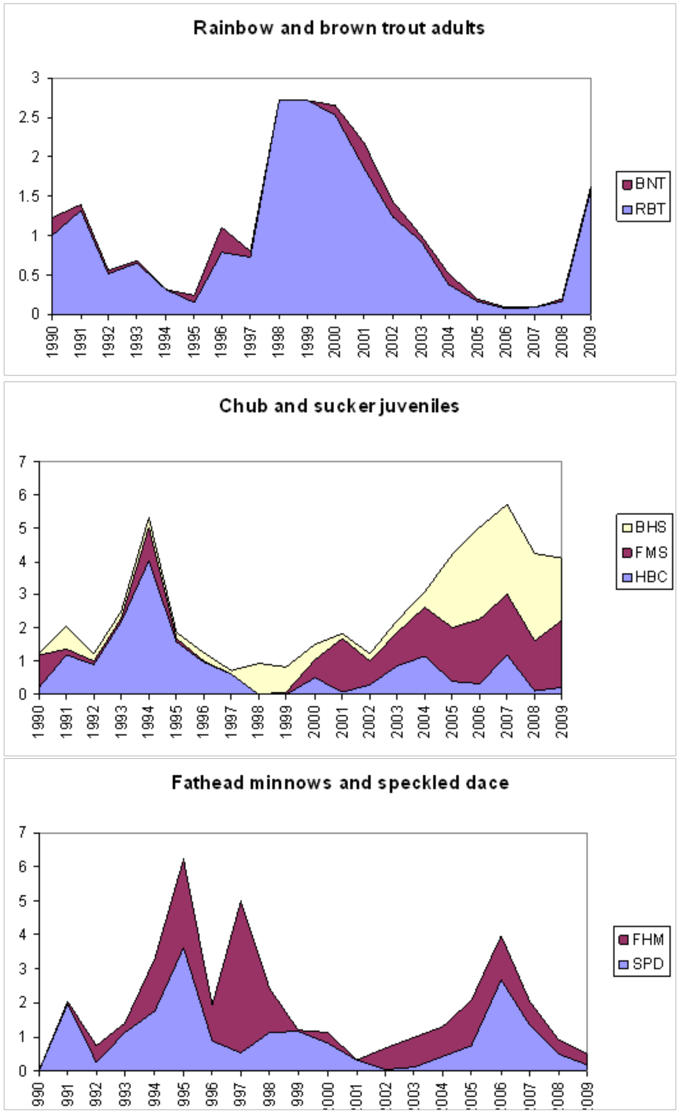
Inconsistent monitoring programs limit our ability to test and calibrate ecosystem models



It would be a grave mistake to discontinue the current foodbase monitoring program (proposed budget cut)

This would even more severely limit our ability to quantify how flow management influences fish populations indirectly through effects on the aquatic foodbase

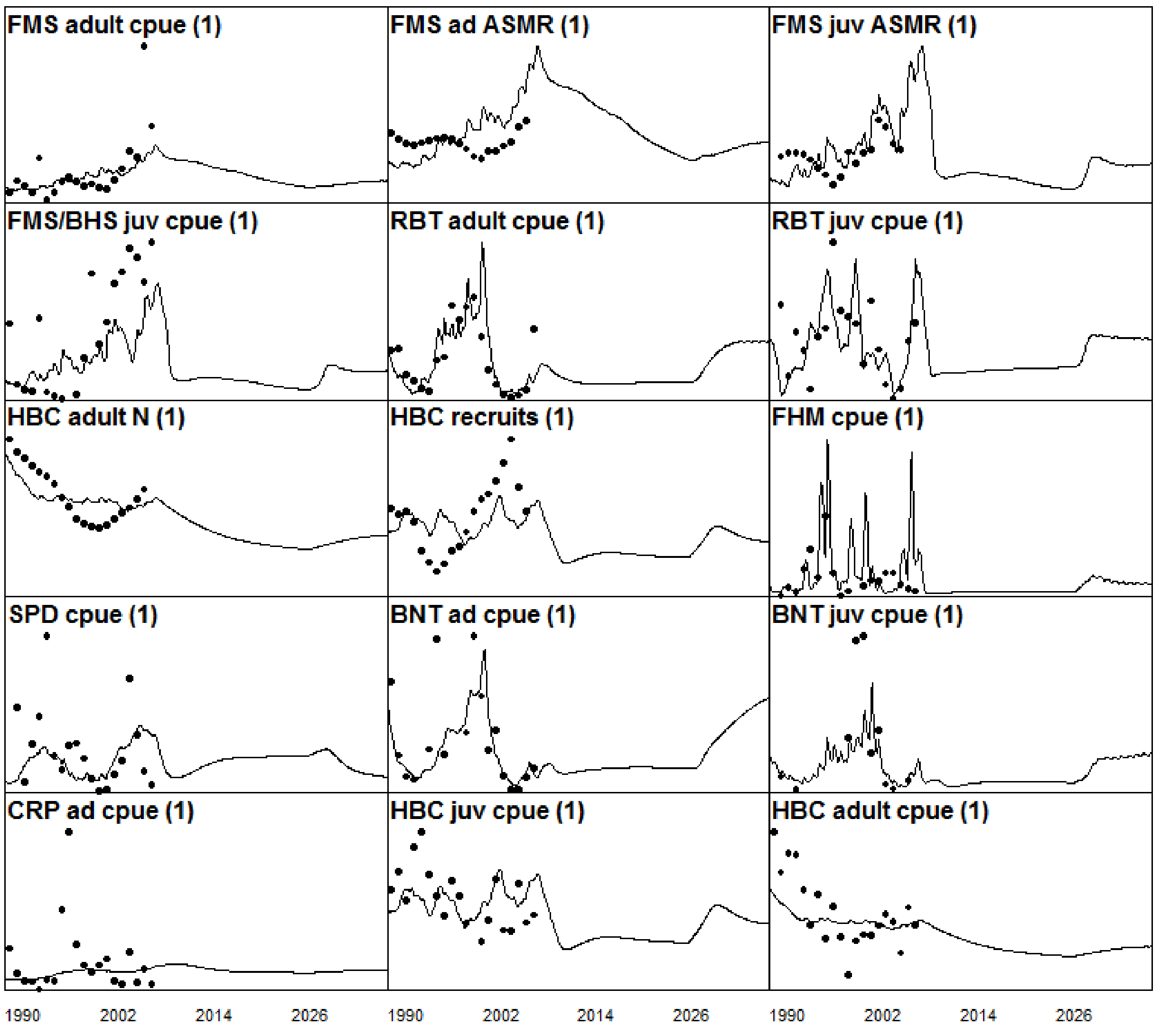
Predation impacts of trout on other fishes near the LCR?



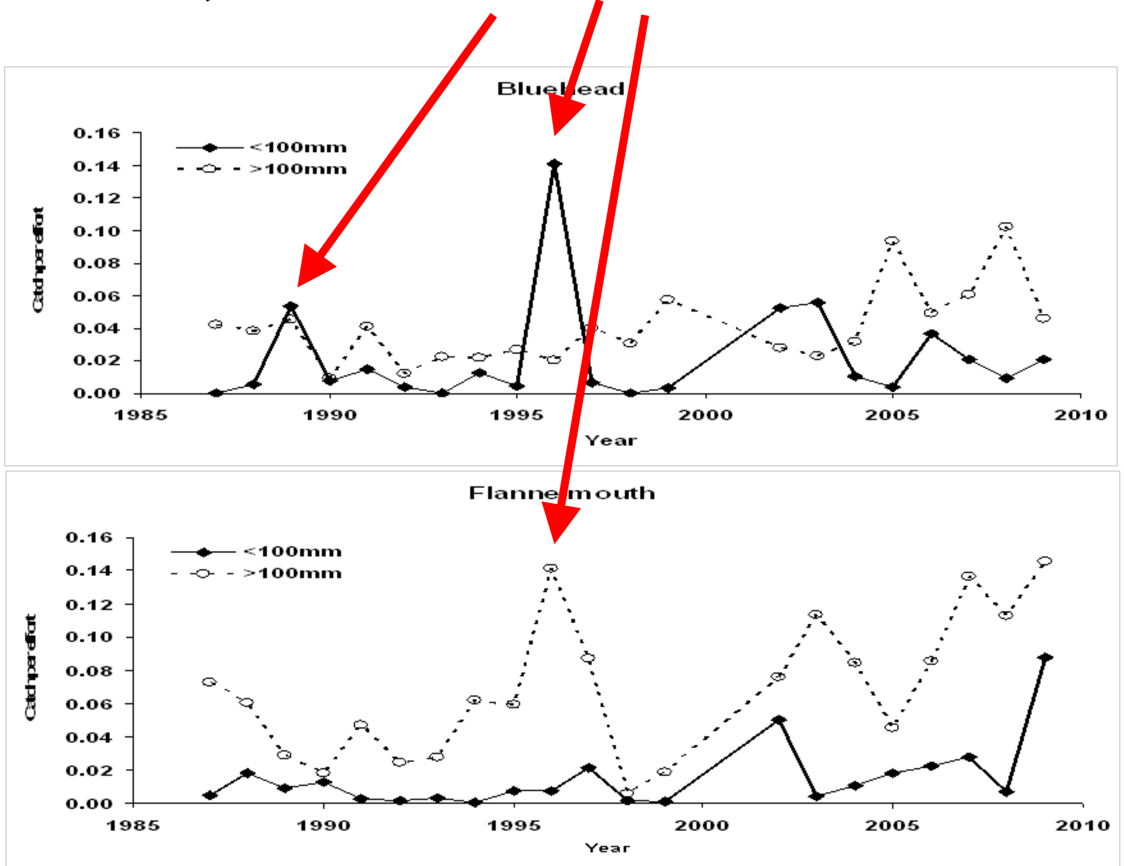
- **Trout declines are correlated with increased abundance of small fishes, native and non-native**
- **Increases after 2000 began before 2003-2005 warm water period and 2003-2006 mechanical removal, but after trout decline began**
- **Abundances remained high after the river cooled, are now dropping as trout recover from mechanical removal**
- **No evidence that peak of native fish juveniles in mid-1990s led to any increases in adult abundance; post-2000 juvenile increases are associated with increases in adult abundance, especially for suckers**

From LCR composite fish trends.xls

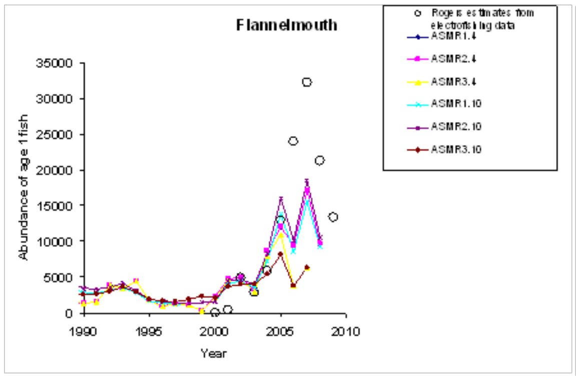
Inconsistent monitoring programs limit our ability to test and calibrate ecosystem models

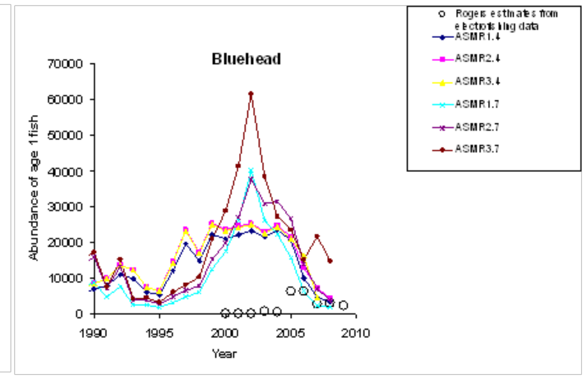


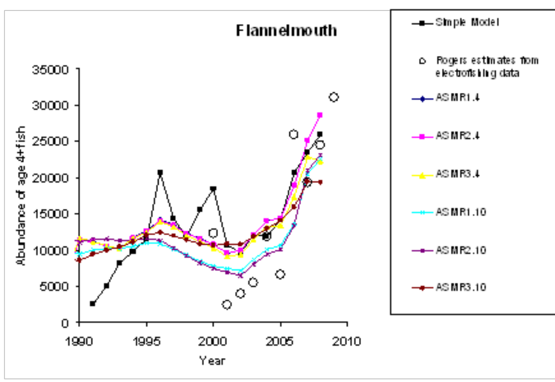
Juvenile sucker densities in the lower LCR suggest that at least two large juvenile cohorts tried to rear in the mainstem before 2003, but were unsuccessful.

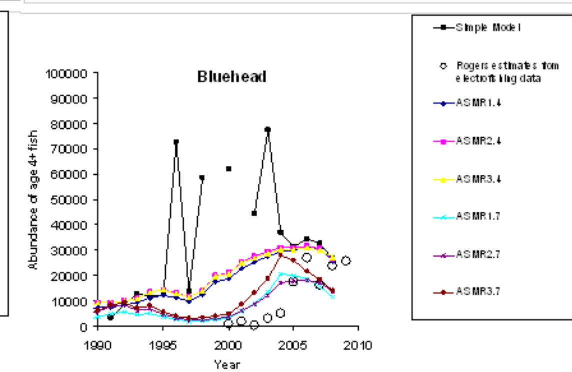


Suckers have increased dramatically since 2000

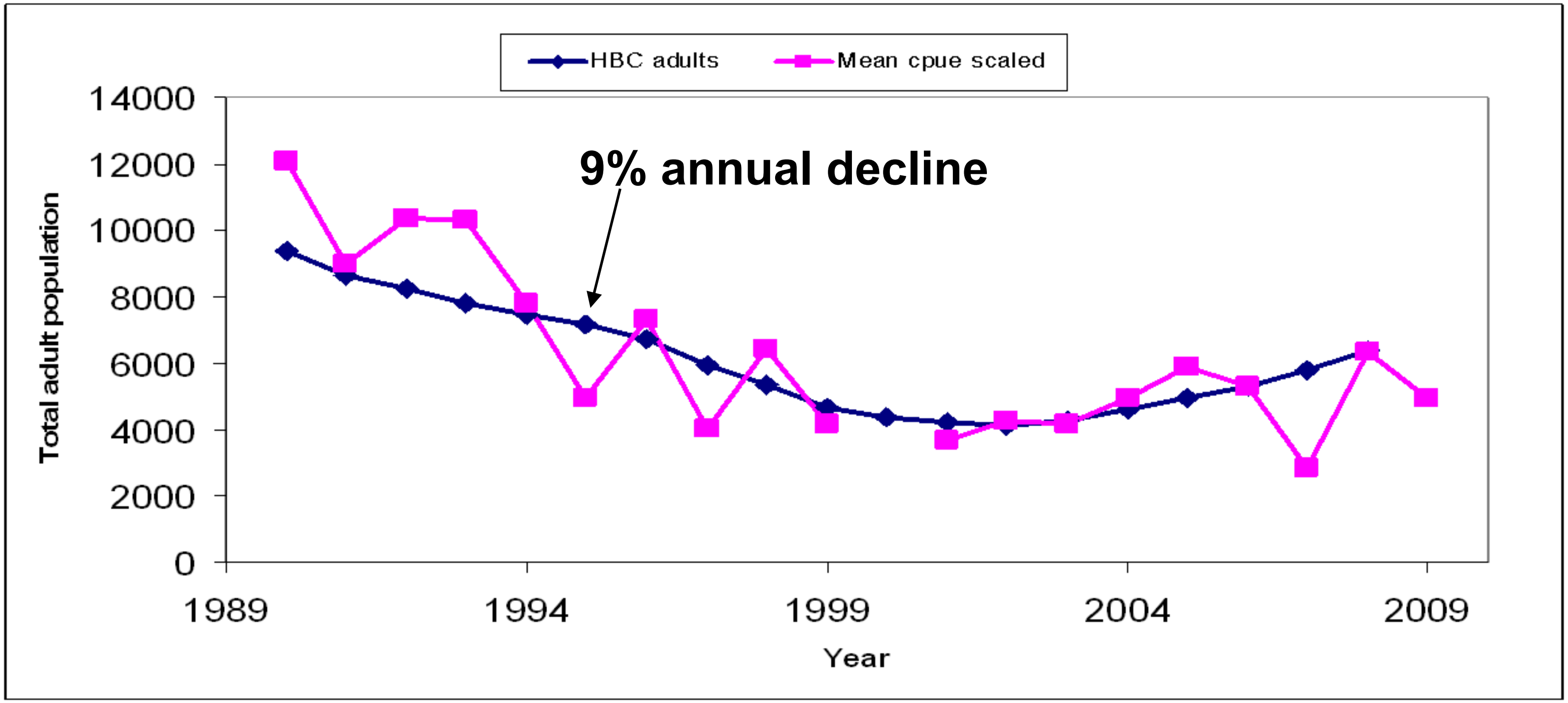








Ecosim does not want to predict the observed decline in humpback chub adult abundance over 1990-1999



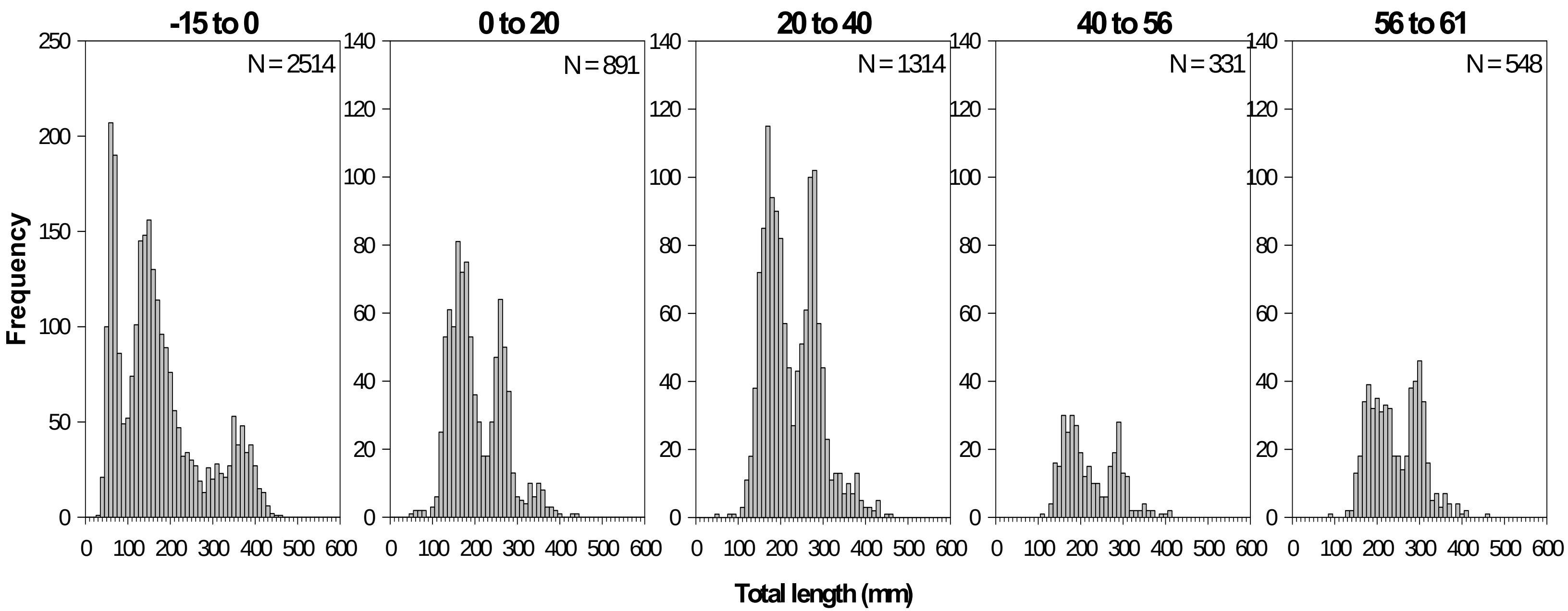
From Lcr composit fish trends.xls

- There was an apparent increase in natural mortality rate of older chub during the mid 1990s, as the rainbow trout population peaked, probably not due directly to predation
- Early tagging data also suggest 5-10% higher annual adult mortality rate during that period (20% vs 13-15%)

Caveats about the trend data

- Sampling has been inconsistent, with missing data for some gears/years, especially in the late 1990s
- Juvenile suckers did not show a clear peak in the mid-1990s when other small fish were numerous
- Peaks in fathead minnows and dace are seen in all gears; however, magnitude of the 1990s peak was much higher that 2000s peak in electrofishing data, but similar in backwater seine data.

It is most likely that rainbow trout in the LCR reach originate mainly from Lees Ferry, i.e. the Lees Ferry population drives recruitment to the LCR population



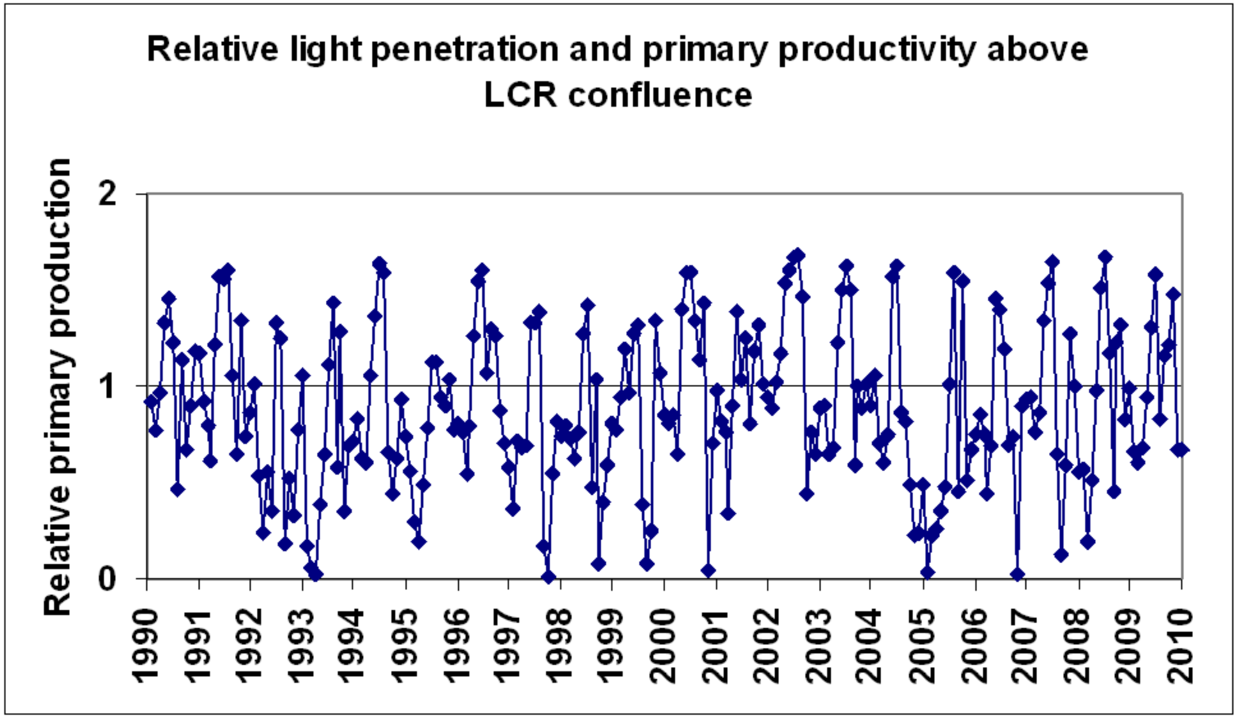
Trout length frequencies in early 2009, moving downstream from Lees Ferry; note absence of age 0 (<100mm) fish below RM 0

From 2000-2009 lf downstream length freq stuff.doc

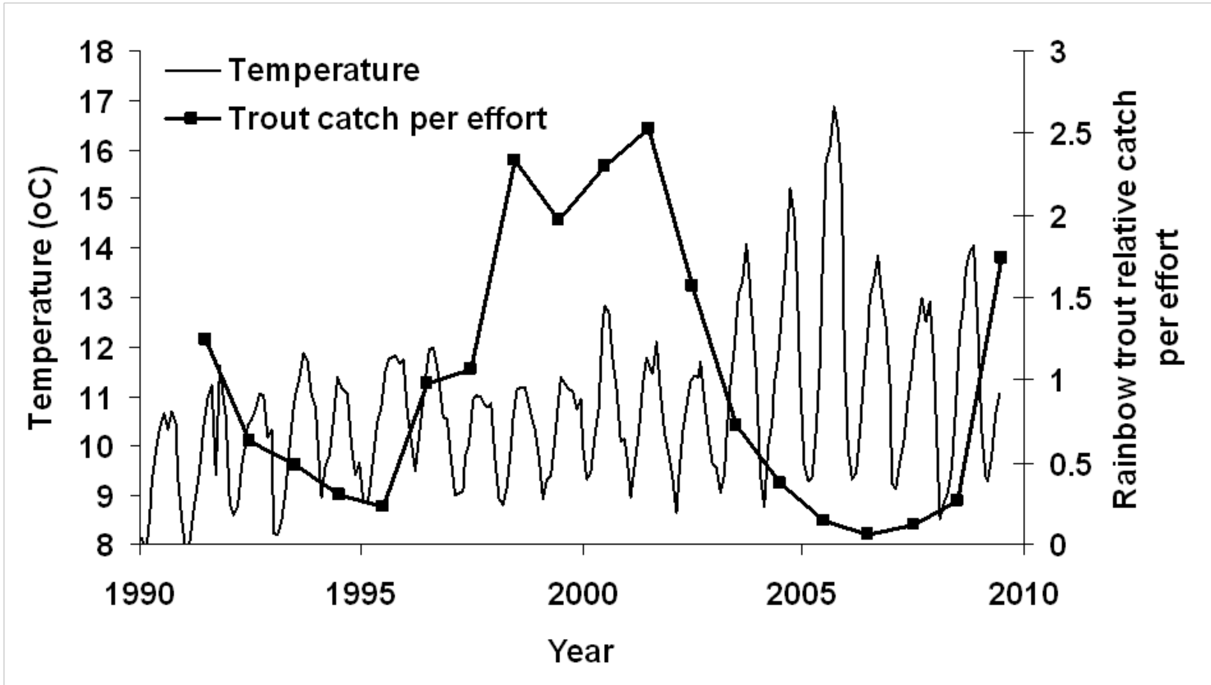
Physical drivers of productivity and predation risk at the LCR confluence have also affected native fish populations

PARIA FLOW → MAINSTEM TURBIDITY → DEPTH-INTEGRATED PRIMARY PRODUCTION

MAINSTEM TURBIDITY → VULNERABILITY TO TROUT



Temperature vs predation?

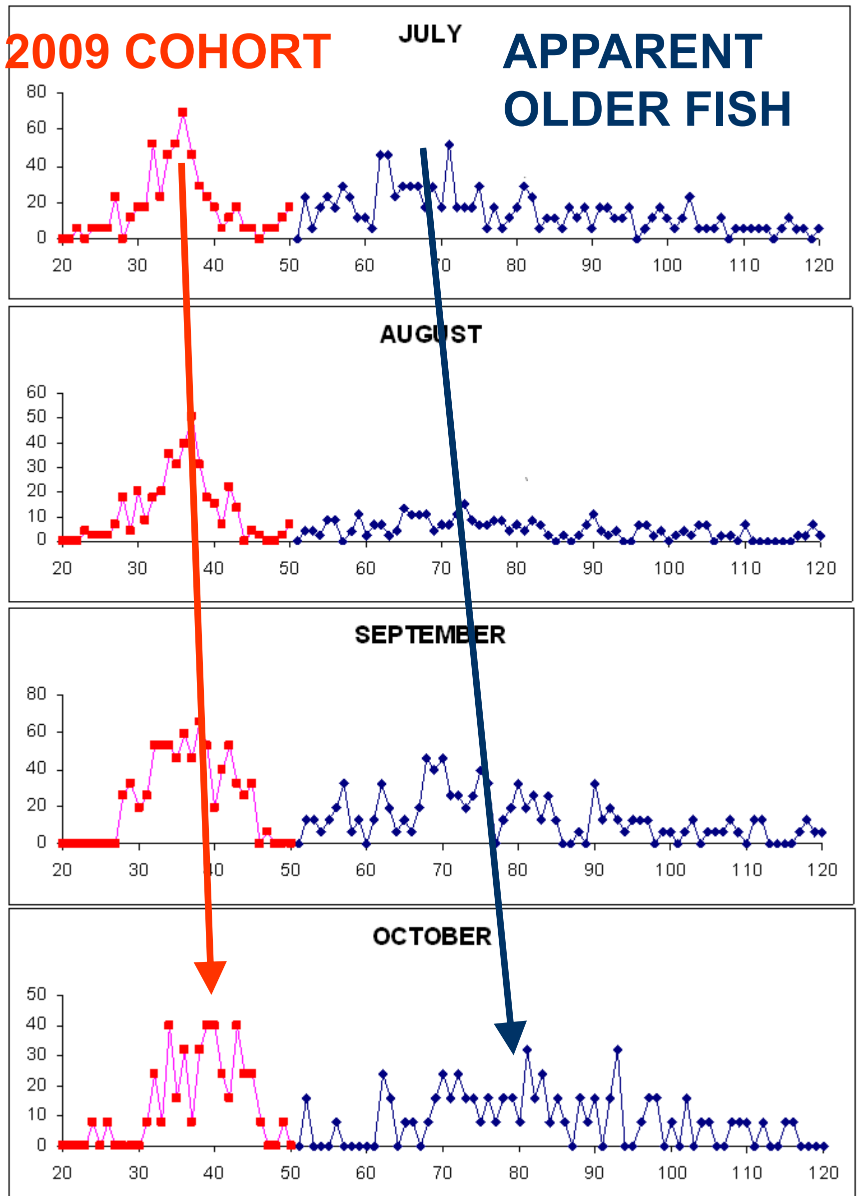


- Temperature increase in 2003 coincided with start of mechanical removal program.
- There have been somewhat elevated temperatures over the whole period of low trout abundance since 2003.
- Mechanical removal in 2009 cut back the trout population before many native fish juveniles had entered the mainstem.

Assessing viability of mainstem rearing

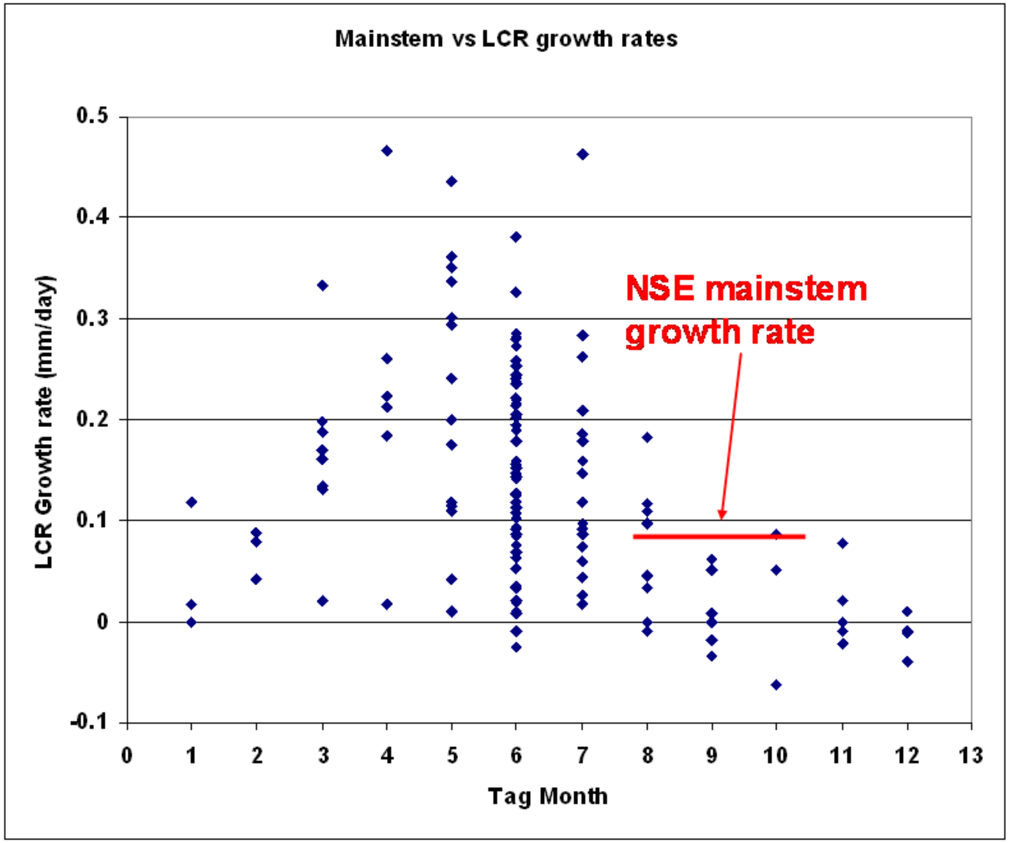
- Juvenile abundance estimates near the main spawning source (LCR) give estimates of potential recruitment contributions, but not cumulative growth/survival of outmigrants
- We need to use methods such as reading early life history changes from otoliths to see what life history "trajectories" actually contribute to the populations of older fish

Juvenile humpback chub in the mainstem, 2009 NSE study

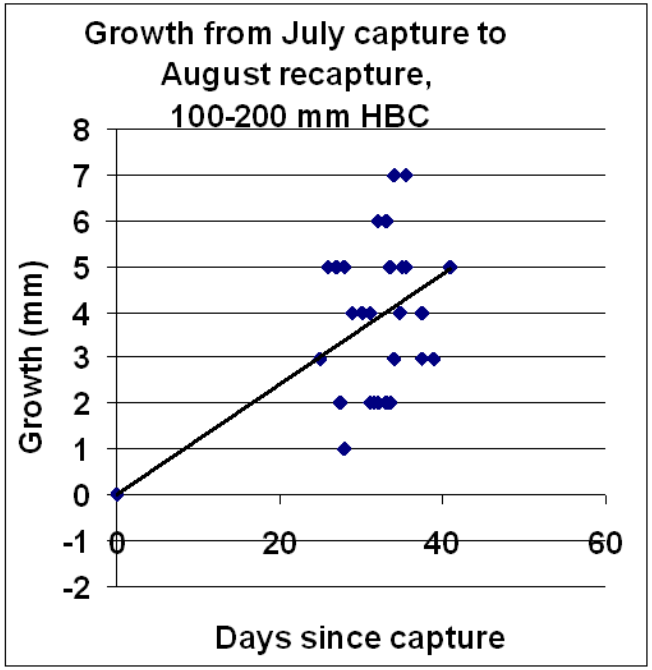


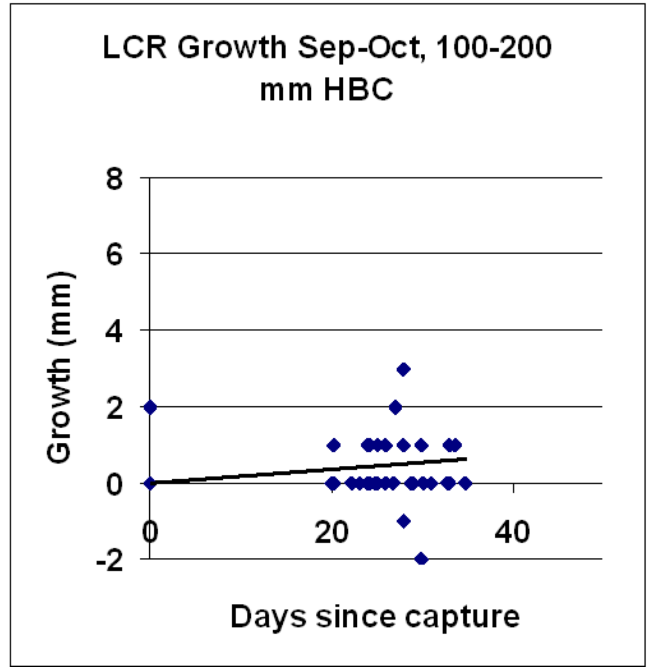
- Good apparent survival of age 0 fry
- "Older" fish are mixture of slow-growing 2008 fish and 2009 migrants
- No obvious effect of steady flows in Sept. and Oct.
- Larger fish rearing in mainstem may grow *faster* than fish rearing in the LCR

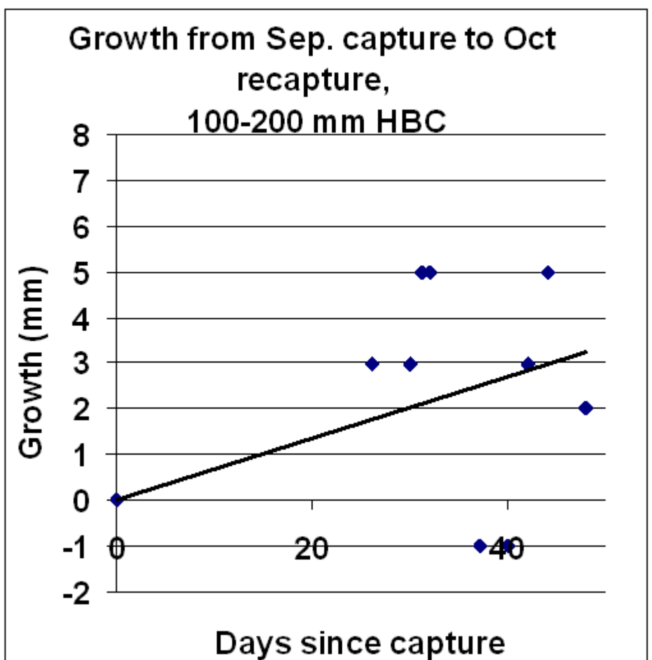
A curious finding from the NSE study: age 1-3 juvenile chubs grow faster in the mainstem in late summer and fall than in the LCR



THIS MEANS THERE IS POTENTIAL FOR IMPROVED GROWTH (AND LATER SURVIVAL) IF CHUBS CAN SURVIVE THE INITIAL SUMMER-FALL PERIOD IN THE MAINSTEM



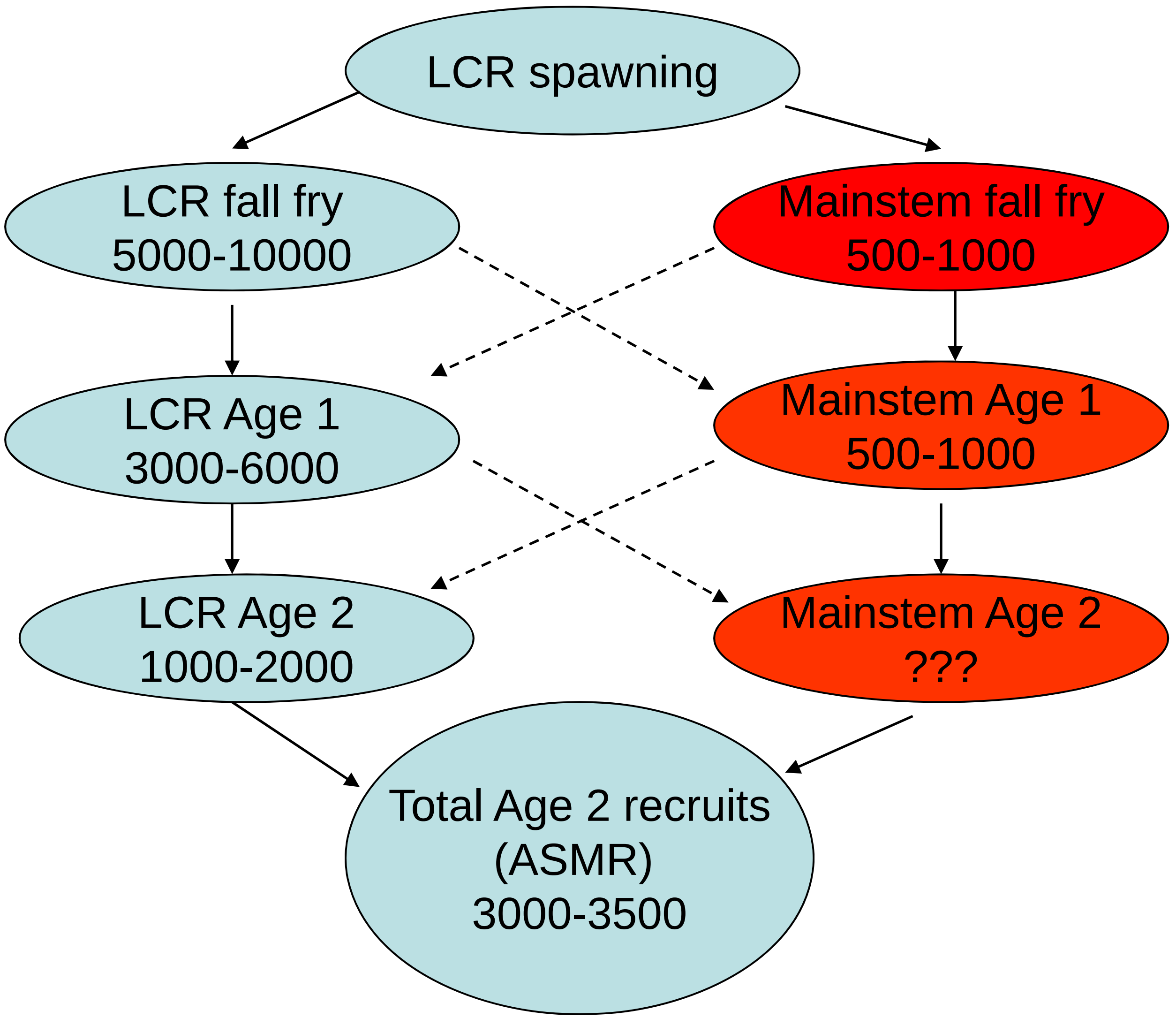




Have fall steady flows improved chub growth and/or survival?

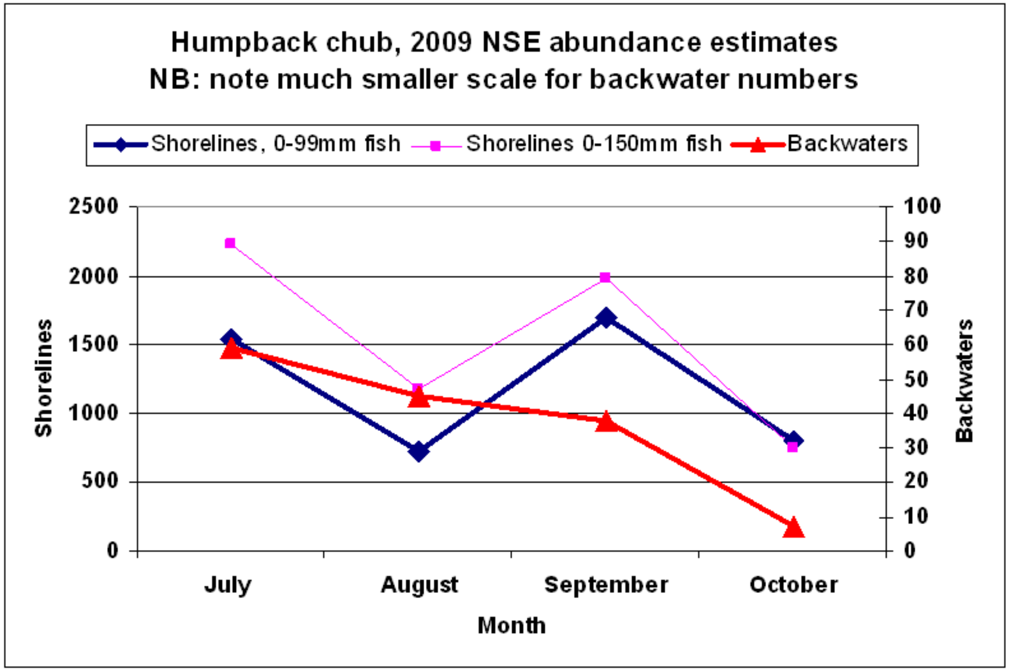
NO!

Combining FWS and NSE estimates of humpback chub recruitment



Backwaters near the LCR: safe havens or death traps?

- There are only a few backwaters in the reach below the LCR used by humpback chub
- Small fish tethered inside and outside backwater in 2008 showed near 100% survival outside for 24 hr, no survival inside during clear water, but 50% survival during turbid water in both habitats (to be repeated in 2010).
- Chub abundances were much lower, and declined much faster, in backwaters in 2009 than outside:



From backwater vs shoreline numbers 2009 NSE.xls

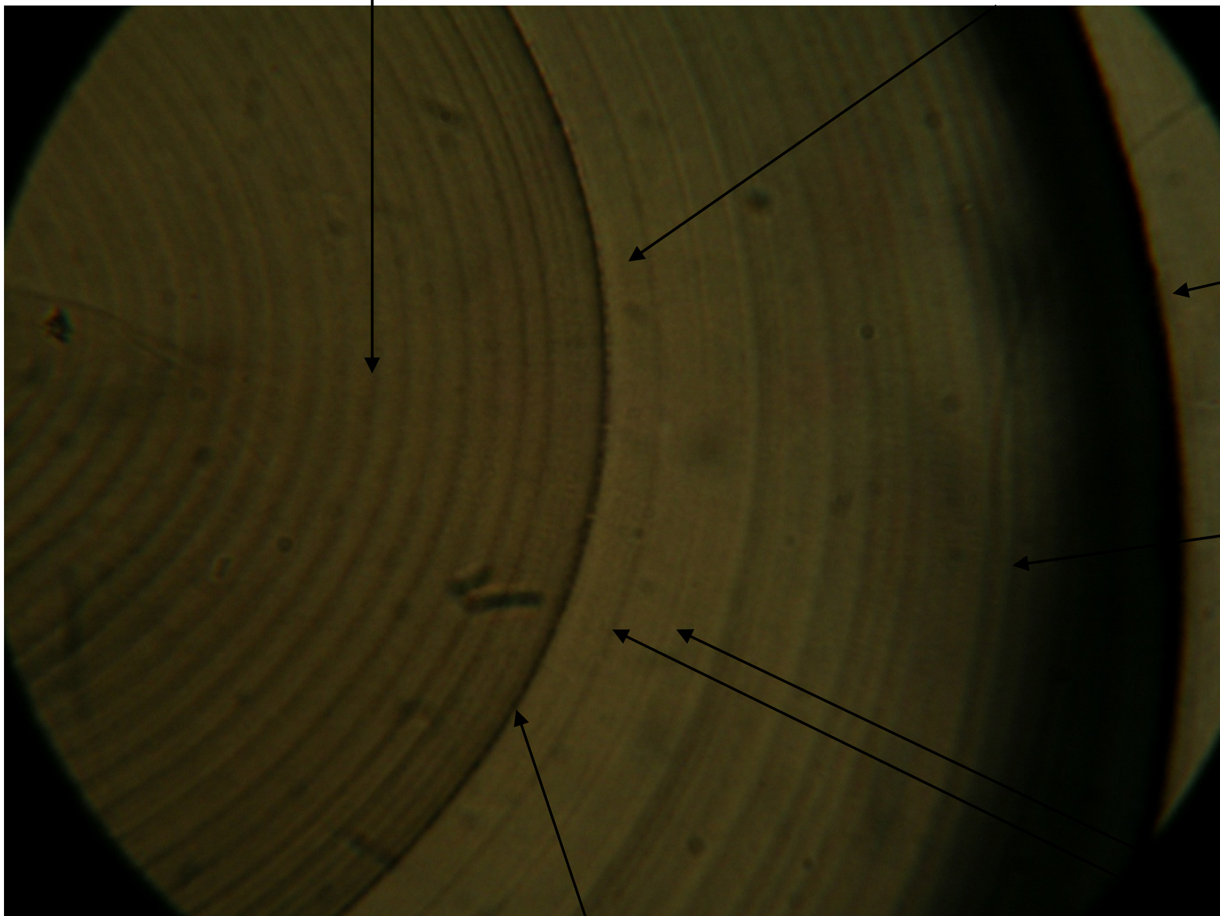
We cannot untangle the chub growth and movement effects without ageing fish, looking at individual growth histories of surviving fish

- Otoliths provide detailed histories, would require killing some (100-200) juveniles
- We may be able to get more information from other hard parts without killing fish, e.g. fin rays and scales. The NSE program will begin sampling these in 2010.

Daily increments- from core to growth check ~35-55 increments (Fast growth in LCR?)

Very, very small increments- slow growth (not visible in image)

~Core



Otolith edge

Faster growth at edge- migration to LCR before collected?

Fish: FMS collected @ Boulder on 6/26/2009, 64mm- Image- 800x

Growth check- transition from warm (fast growth-LCR) to cold (MS)?

Korman’s “life is better on Sunday” pattern(?)

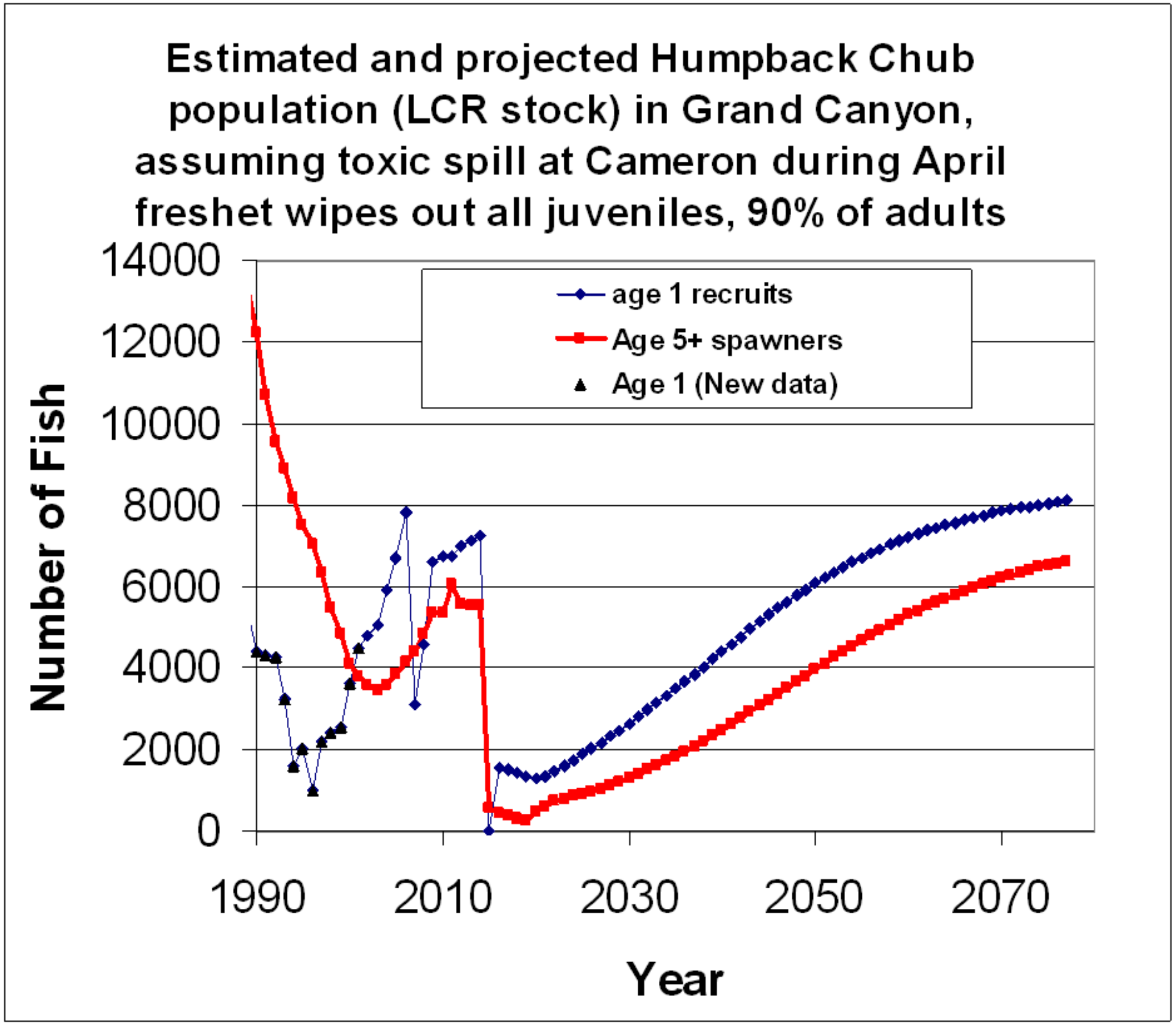
At least some age 0 native fish spawned in the LCR are moving back and forth to/from the mainstem, "testing" its habitat quality!

- If we improve mainstem rearing conditions/survival, there will very likely be increases in recruitment
- Our older experience suggested that such testing by fish less than three months old was largely unsuccessful. But now we are seeing overwinter survival of small humpback chub in the mainstem

What is the main threat to native fishes in Grand Canyon?

- **It is the LCR !**
- The LCR is the main spawning area for native fishes, especially humpback chub
- Sooner or later, while we are busily focused on the mainstem, something very nasty is going to come down the LCR (toxic spill, exotic fish, tapeworm, low flow)

What is the main threat to native fishes in Grand Canyon?



Policy implications of fish trends near LCR

- MLFF and LSSF did not by themselves result in native fish increases
- LSSF had modest effect compared to later changes
- Mechanical removal appears to have a strong effect, whether or not the river is warmer
- Humpback chub recruitment now includes a substantial mainstem rearing component, but mainstem is still not suitable for chub spawning (still too cold)
- Trout abundances in the mainstem near LCR are driven by the Lee’s Ferry rainbow population and brown trout of unknown spawning origin, most likely Bright Angel Creek
- Trout influence native fish both through direct predation and also severe competition for very limited foodbase

Past mistake in AMP aquatic ecosystem monitoring design

- Failure to monitor community production and respiration, LF reach and LF to LCR
- Failure to consistently monitor available foodbase (drift) concentrations
- Failure to consistently monitor native fish population changes, inability to assess recruitment changes from size frequency patterns

If you do not provide consistent funding over time for core monitoring programs

This is what will happen to the Grand Canyon Adaptive Management Program