Glen Canyon Dam Adaptive Management Work Group
Agenda Item Information
February 22-23, 2012

Agenda Item
Grand Canyon Monitoring and Research Center (GCMRC) Updates

Action Requested
✓ This is an information item.

Presenter
Jack Schmidt, Chief, Grand Canyon Monitoring and Research Center, USGS

Previous Action Taken
N/A

Relevant Science
✓ See below.

Background Information

2011-2012 Knowledge Assessment Workshops
Workshops were held in late October and late January. These workshops focused on providing synthetic overviews of current understanding in aquatic ecology, including fisheries, and in sediment transport and geomorphology. In both cases, workshops were structured to include summaries of relevant scientific background, summaries of work conducted during the past 5 years, and summaries of key uncertainties remaining in the subject areas. The workshops included summaries of the specific information requests that have been made in the past by stakeholders, and specifically by the Tribes. Talks and other information presented during these workshops are being posted at the GCMRC website. The data and findings presented in these workshops are being used in development of the new work plans of the GCMRC.

Sediment and Water Quality Update
Tributary sediment inputs have been minimal since recession of the 2008 HFE – during the period between spring 2008 and January 1, 2012. During this period, more sand was evacuated from Marble Canyon than was delivered from the Paria River and minor tributaries. Between 1.8 and 4.0 million metric tons (mmt) were eroded from Marble and eastern Grand Canyons during this period. More sand was eroded from upper Marble Canyon (1.4 ± 0.4 mmt) than from lower Marble Canyon (0.3 ± 0.4 mmt). Erosion in eastern Grand Canyon, the 26 river miles between the Little Colorado River and the gaging station near Bright Angel Creek, was 1.2 ± 1.0 mmt. Some of the sand that has been eroded in these river segments has been deposited in the central and western Grand Canyon, and the rest of this sand has been transported to Lake Mead. The rate at which sand was eroded from Marble and eastern Grand Canyons increased in summer 2011 when high volume releases from Lake Powell reservoir began.

The unprecedented combination of high upper Colorado River basin runoff, low storage levels in Lake Powell, and high Glen Canyon Dam release volumes have also affected downstream water temperature. Mid-July release temperature was about 12º C and increasing. These were the warmest releases by one degree or more than have occurred since 2005, when the release temperature was about 14º C. Predictions for water temperature of releases in 2012 indicate a return to cooler temperatures, although release temperatures are likely to remain elevated relative to periods when Lake Powell has been full.

Priorities for Next Cycle of Research and Monitoring

Monitoring and research priorities for the new funding cycle of FY 2013/2014 will be presented. These priorities reflect GCMRC's recommendations for how to resolve significant science-based management uncertainties, the need to monitor key resource components, and the commitments made to support agency needs related to the Non-native Fish Control and High Flow Protocol Environmental Assessments, the recent Biological Opinion regarding humpback chub, and other related agency actions.

Insights about the Colorado River Ecosystem

Grand Canyon Monitoring and Research Center, sister agencies, and cooperators

The Big Questions

What is an appropriate rehabilitation goal for the physical habitat of the Colorado River – for the available sediment supply and the large-scale flow regime?

How can a non-native trout sport fishery in Glen Canyon coexist with an endangered humpback chub population in Marble and Grand Canyons?

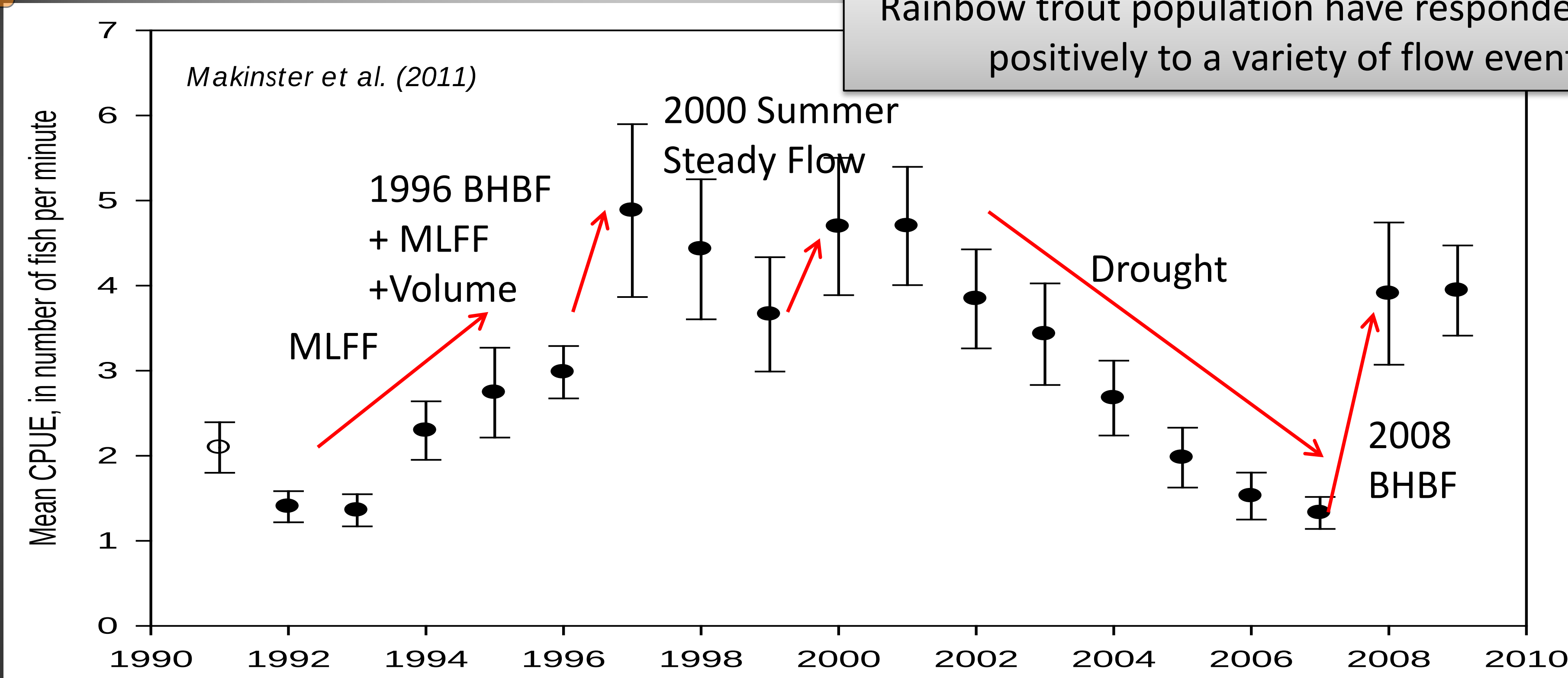
Do trout have substantial population-level effects on humpback chub? *At what density* of rainbow trout do these effects become important, *what ages of humpback chub* are most impacted, and by what mechanisms?

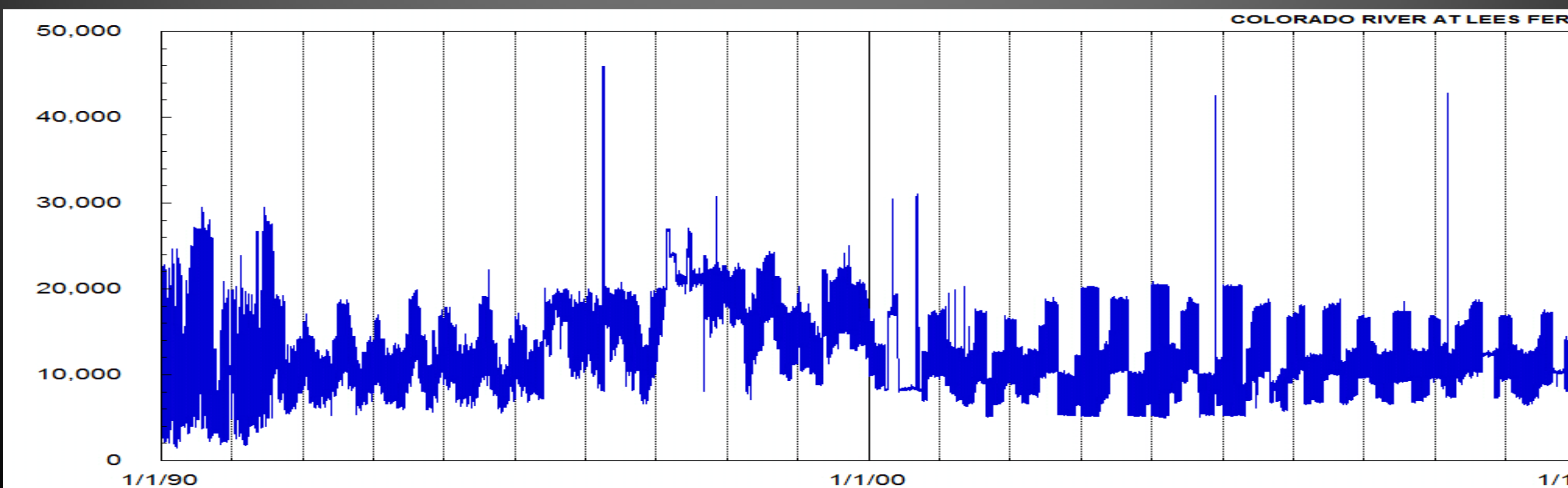
- Predation (mainly juv.)
- Competition – habitat/food (both adult and juv.)

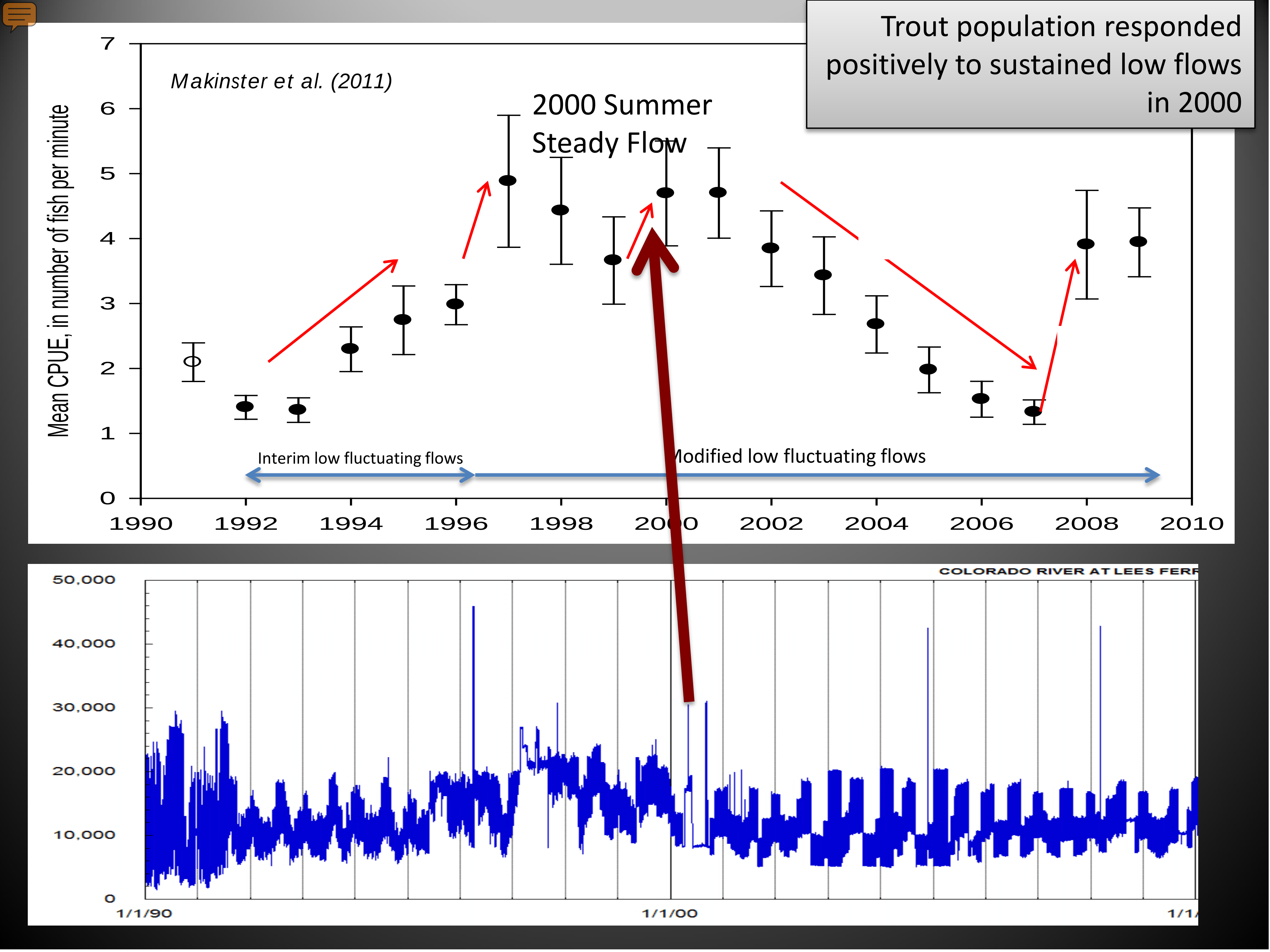
Will warmer mainstem temperatures alone allow for increased survival of humpback chub?

USGS

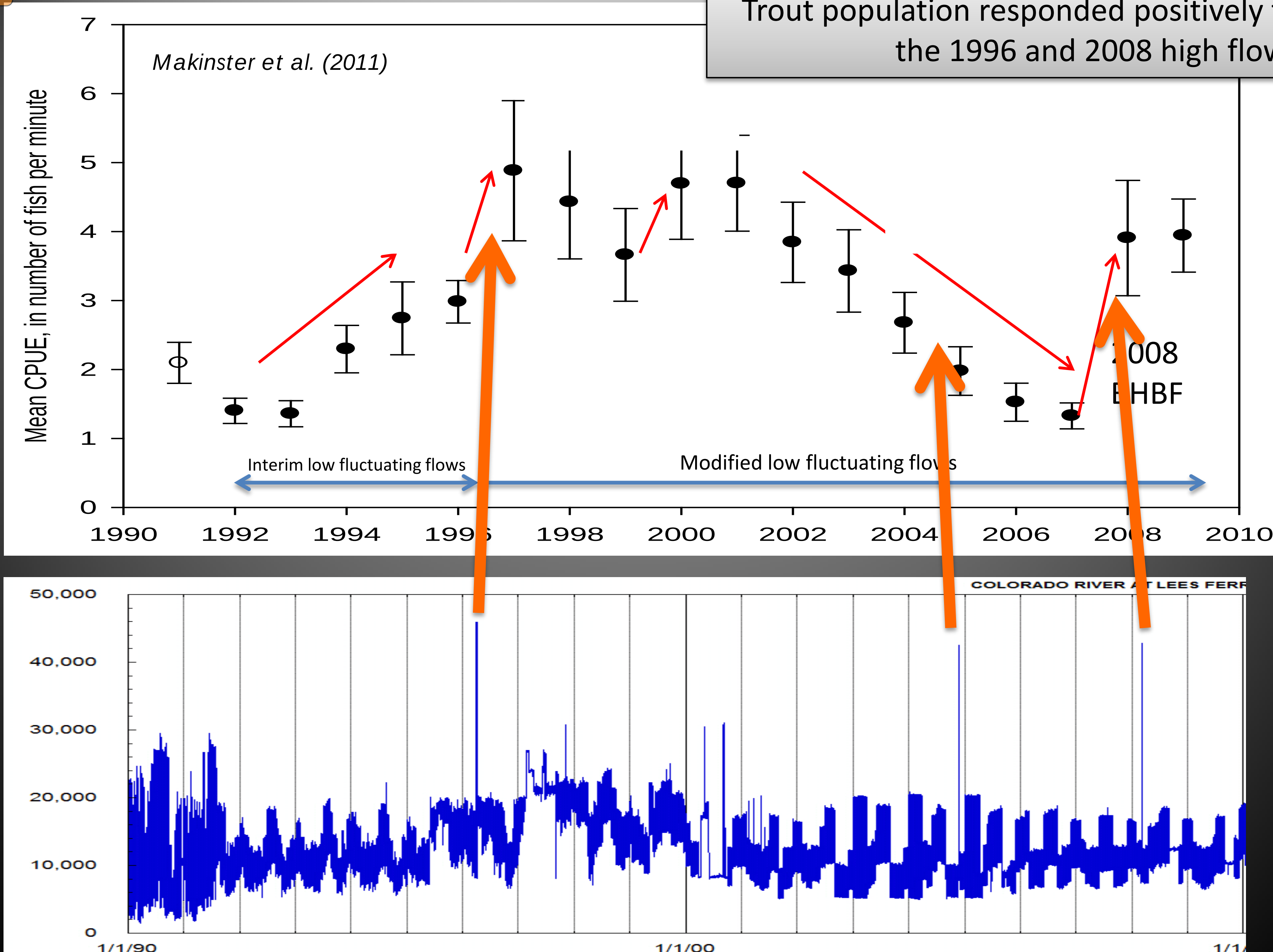
Rainbow trout population have responded positively to a variety of flow events





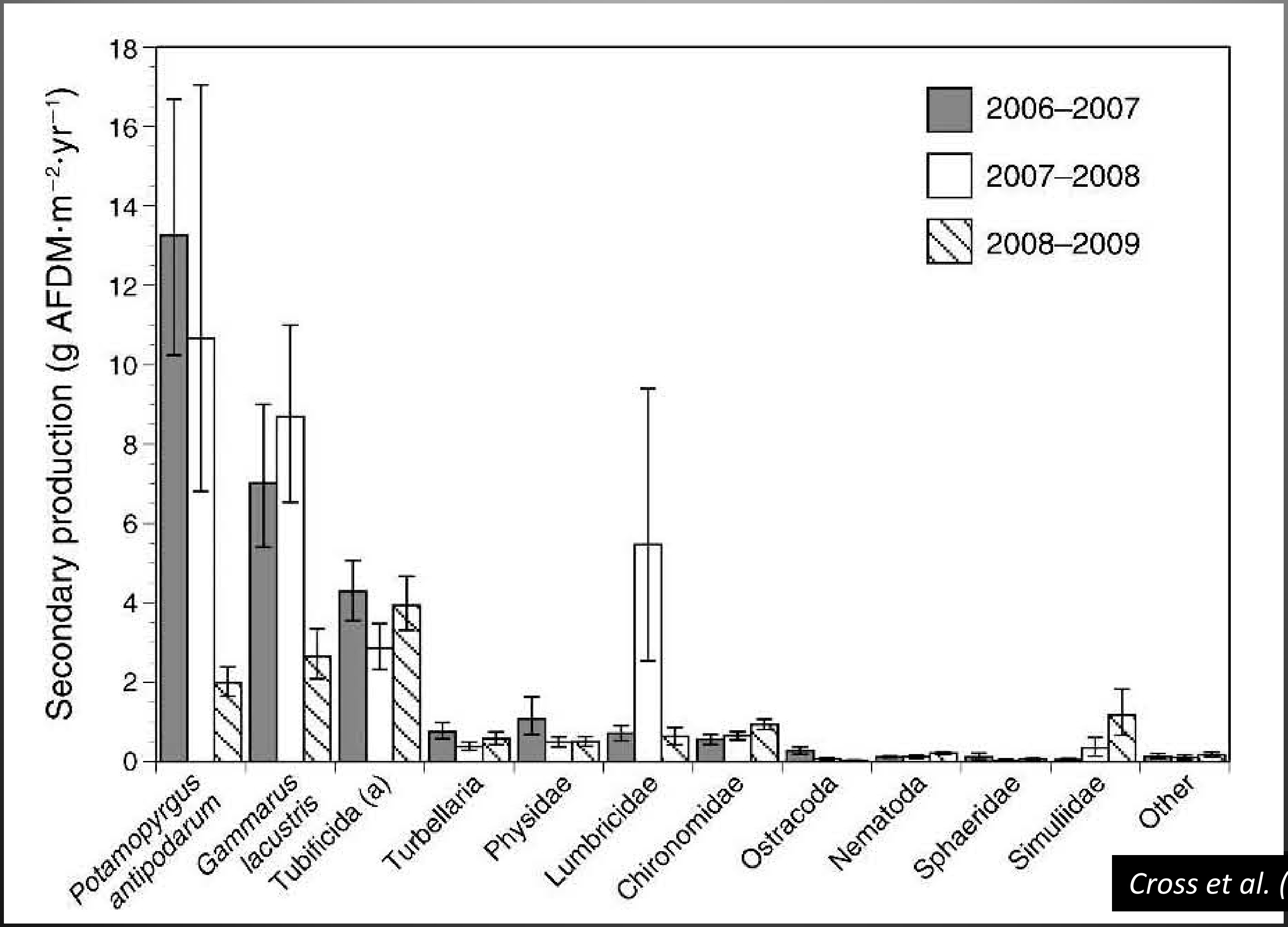

Trout population responded positively to sustained low flows in 2000
Makinster et al. (2011)
2000 Summer Steady Flow
Mean CPUE, in number of fish per minute
0
1
2
3
4
5
6
7
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Interim low fluctuating flows
Modified low fluctuating flows
COLORADO RIVER AT LEES FERR
50,000
40,000
30,000
20,000
10,000
0
1/1/90
1/1/00

Trout population responded positively to the 1996 and 2008 high flows



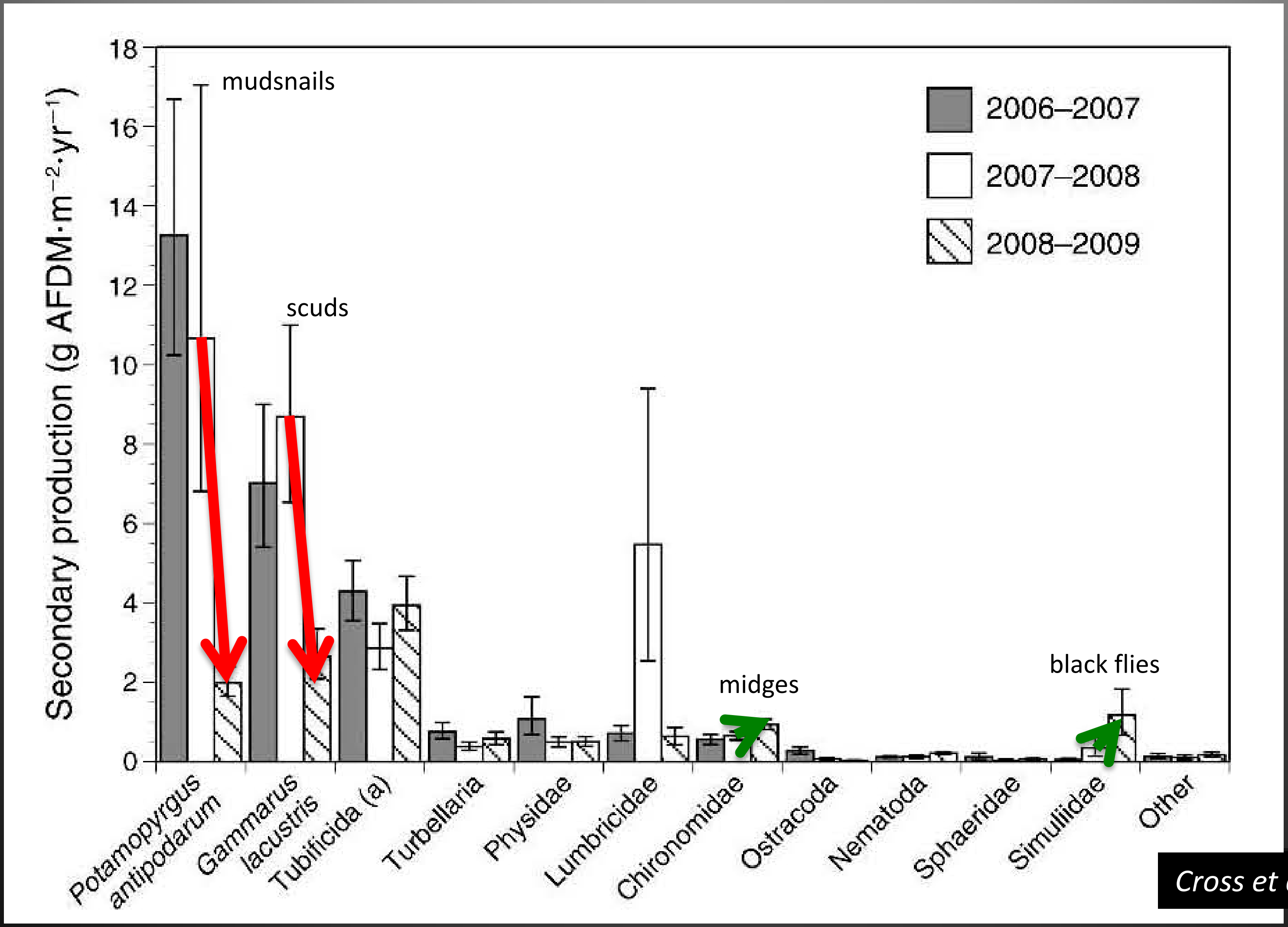
Why a positive response to high flows?

High flow events can exert a strong control on invertebrate assemblages and secondary production in the tailwater reach



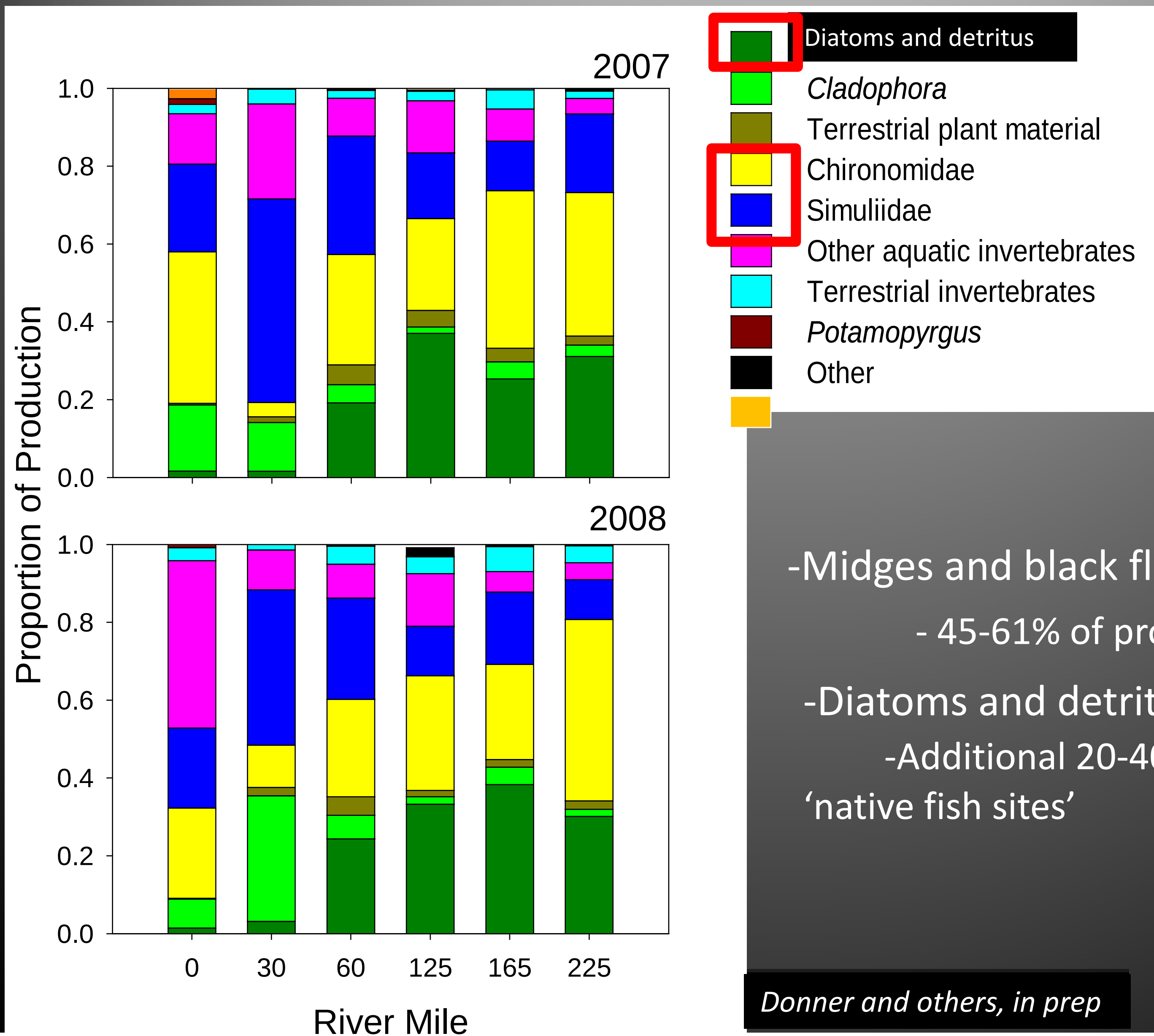
Cross et al. (2011)

After the 2008 HFE, there was a decrease in the two major taxa and significant increases in two desirable taxa



Cross et al. (2011)

The two desirable taxa fuel the production of native and non-native fishes



Trophic basis of fish production. These data account for the "digestability" of different food items

-Midges and black flies

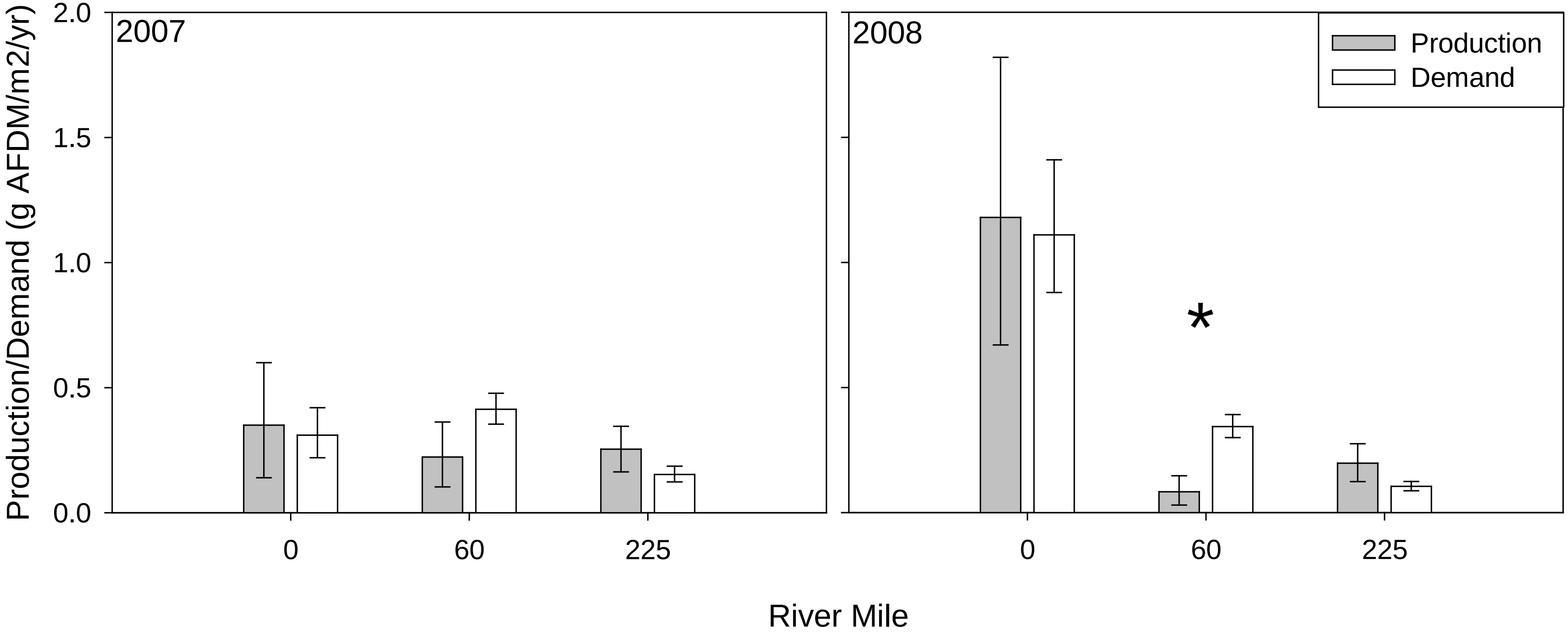
- 45-61% of production

-Diatoms and detritus

-Additional 20-40% of production at 'native fish sites'

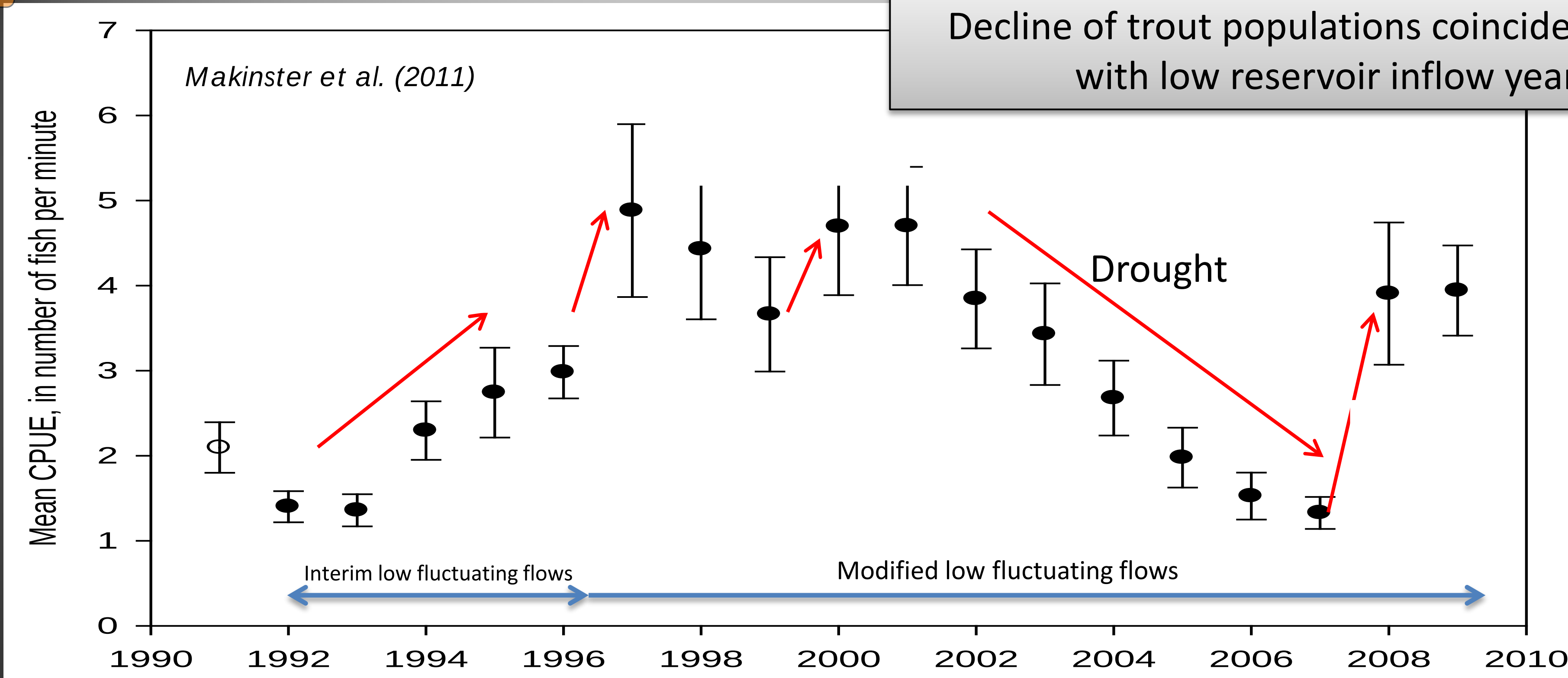
Donner and others, in prep

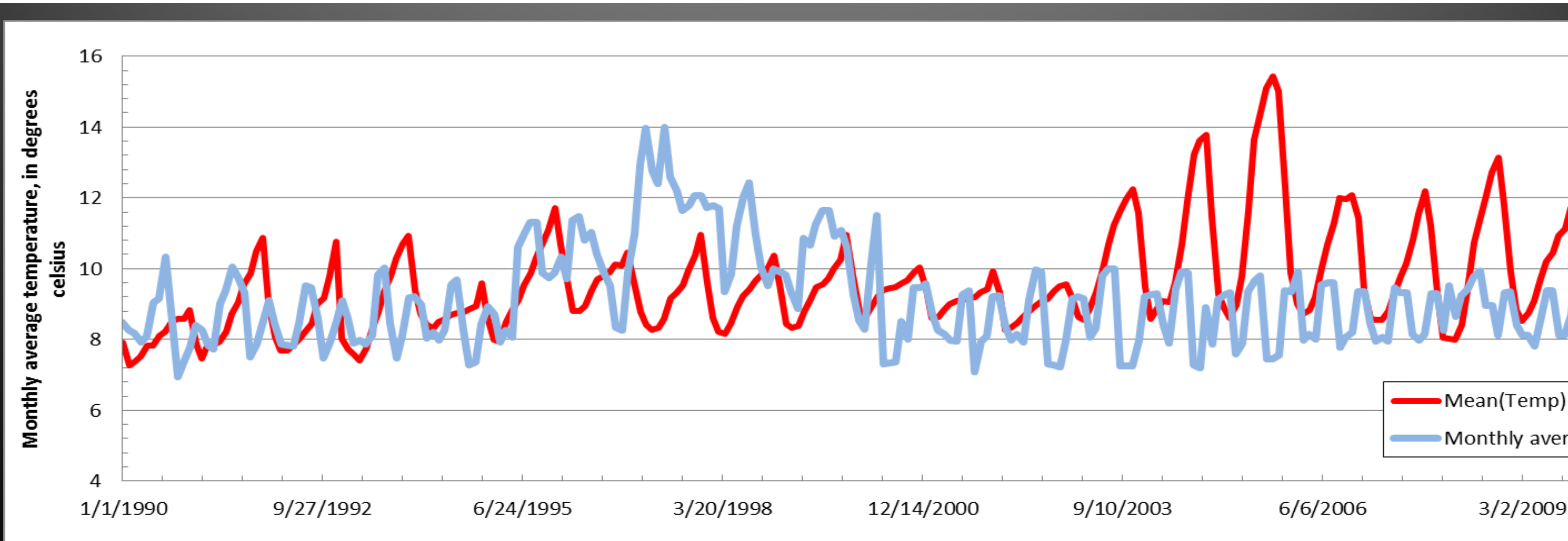
Fish production throughout the river appears limited by the availability of high quality food

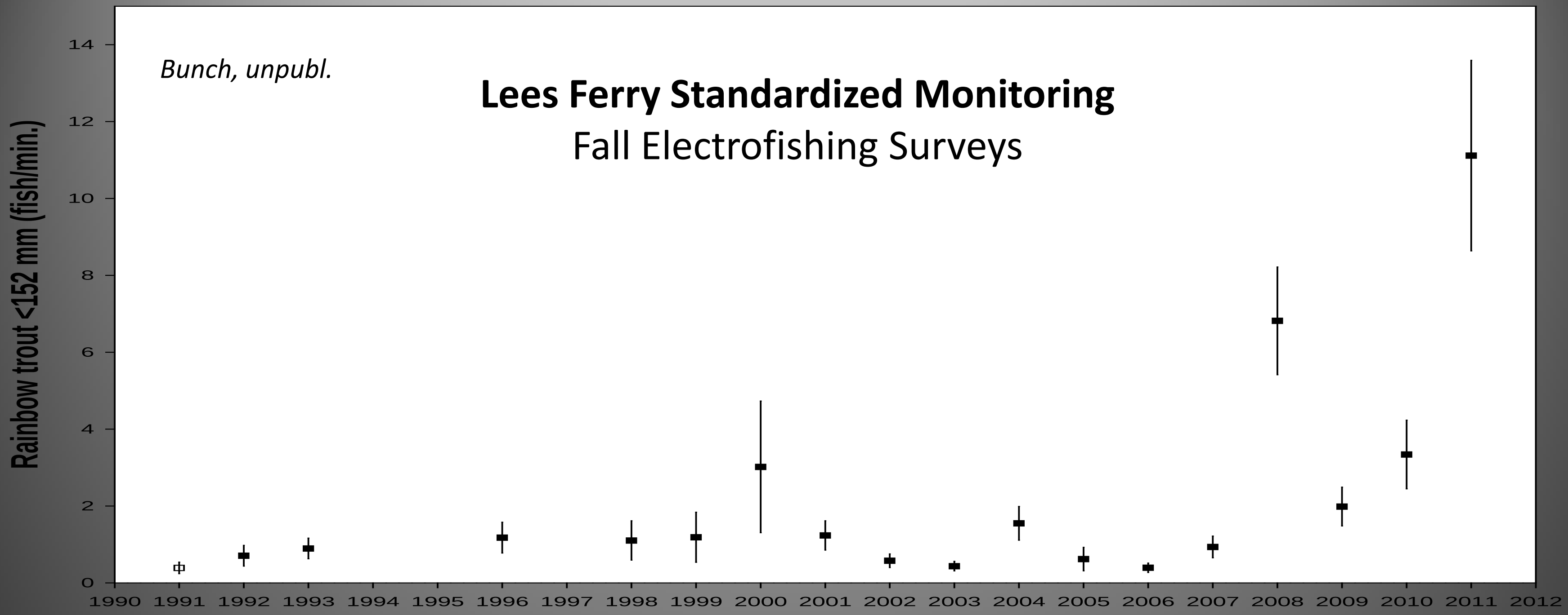


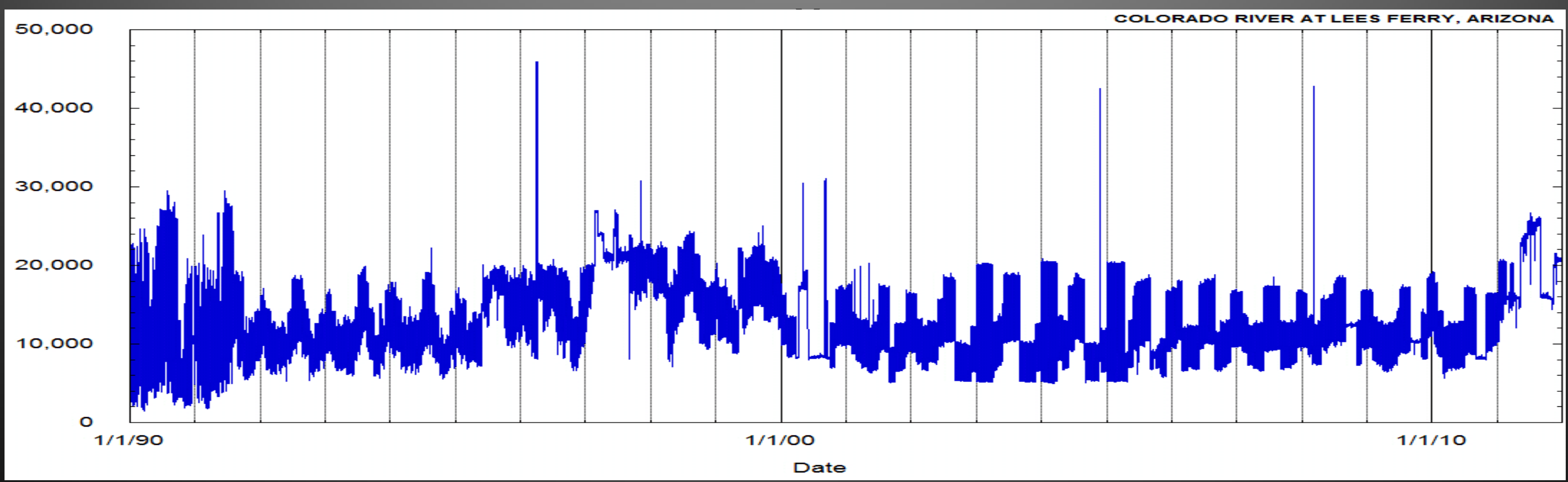
- Black fly (and midge, not shown) production ≈ or < demand by fish

Decline of trout populations coincided with low reservoir inflow years









Present trout abundance in Glen Canyon is unprecedented

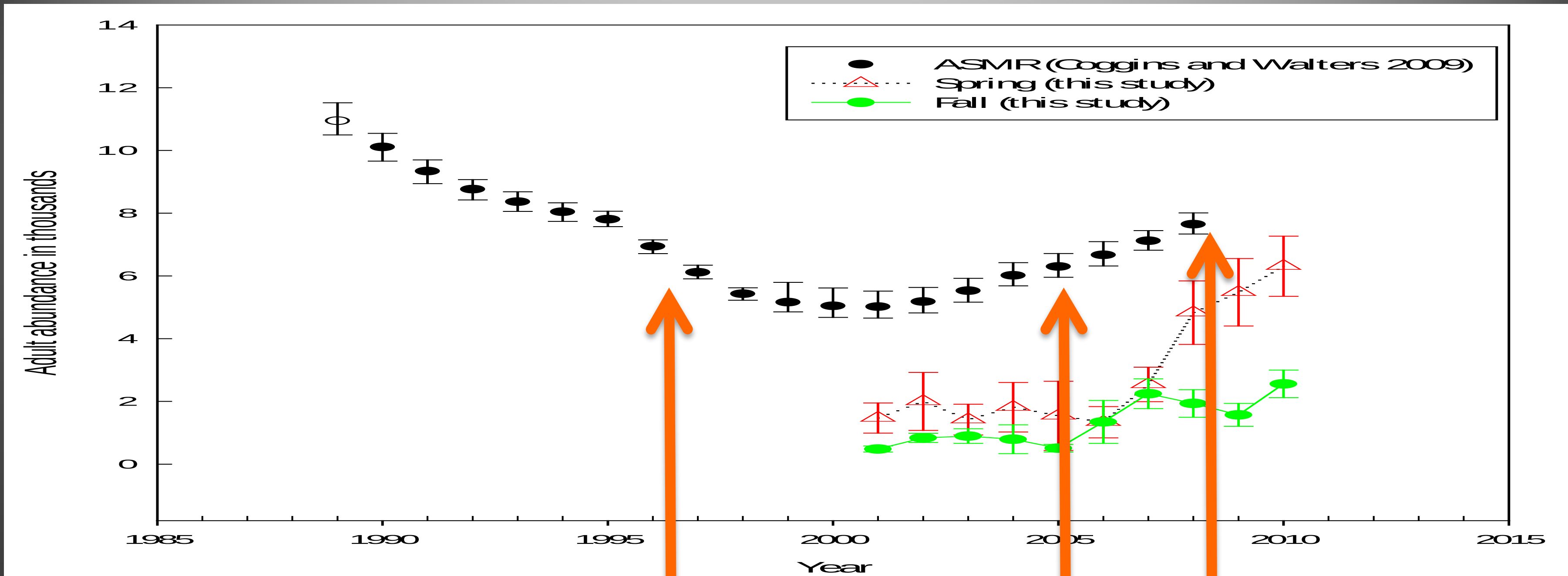
Juvenile humpback chub survival in the mainstem is relatively high near the LCR confluence (NSE reach). Survival rates elsewhere are unknown.

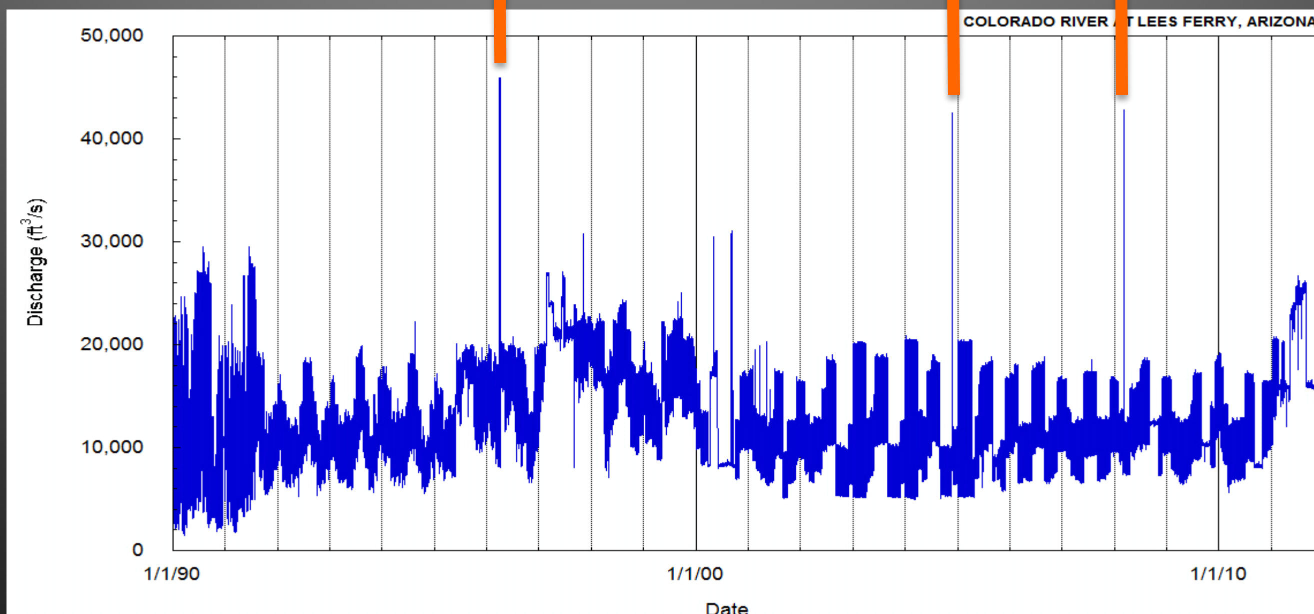
Near Shore Ecology Sampling Humpback Chub Inter-annual Survival

		Jul 09 – Oct 09	Oct 09 – Jul 10	Jul 10 – Oct 10	Oct 10 – Jul 11
HBC 40-99 mm TL	Monthly Survival Rates	0.98	0.93	0.94	0.90
	Annual Survival Rates	0.47		0.32	
HBC 100-199 mm TL	Monthly Survival Rates	0.87	0.99	0.80	0.99
	Annual Survival Rates	0.57		0.49	

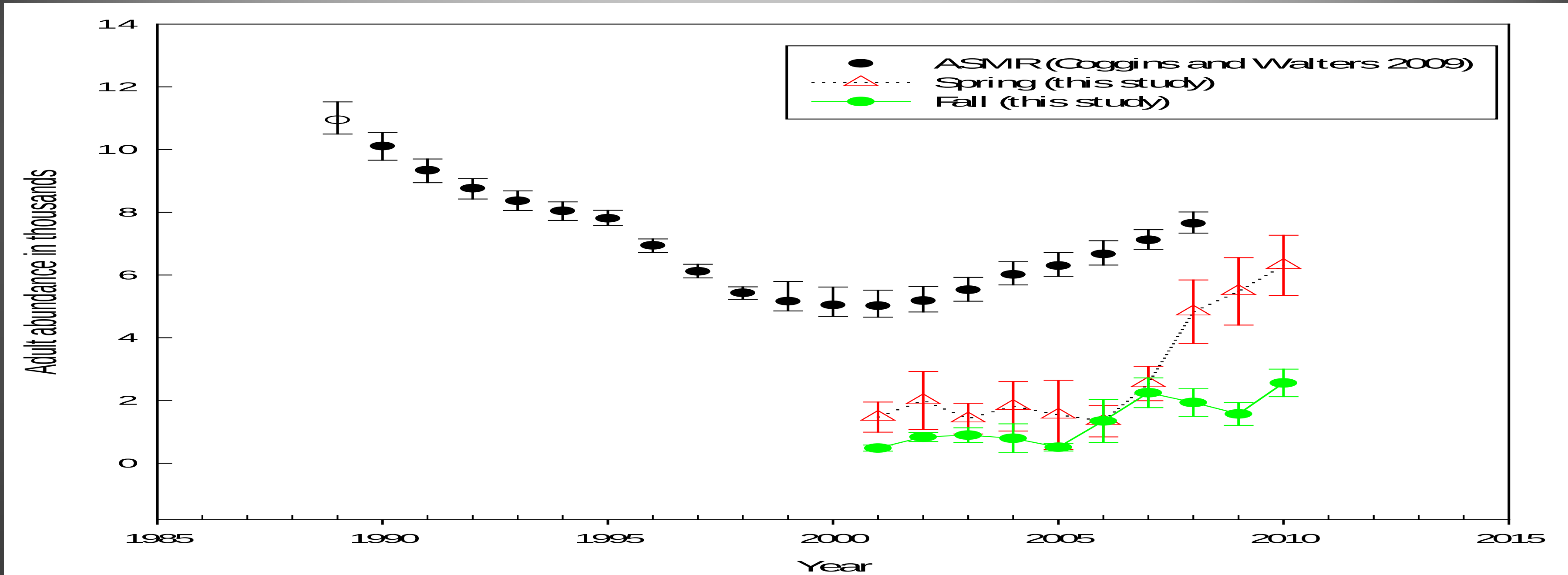
There were no obvious differences in survival rates during the fall periods of experimental steady flows in 2009 and 2010.

(Pine et al. unpubl.)

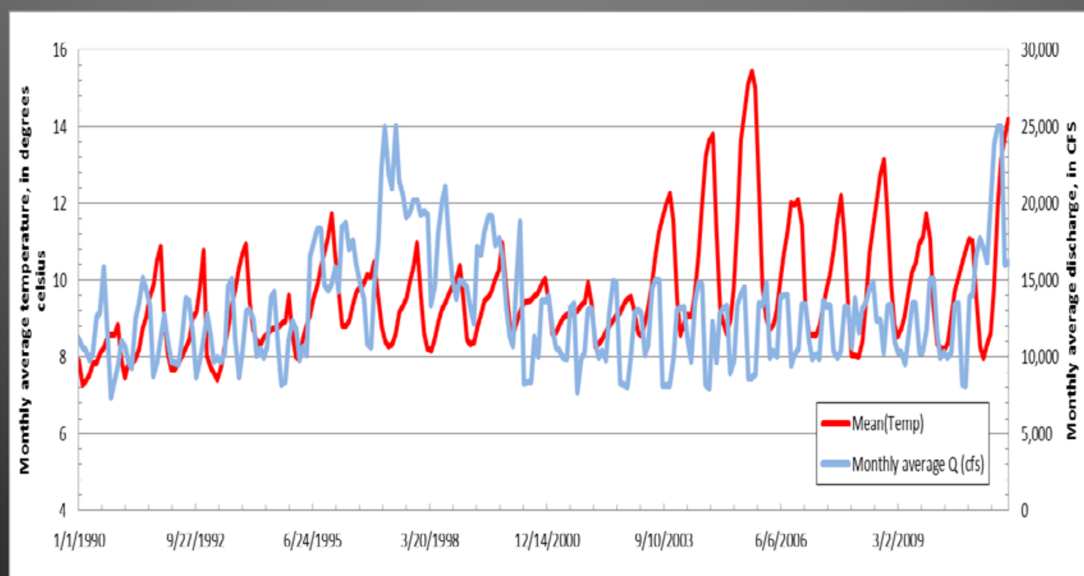


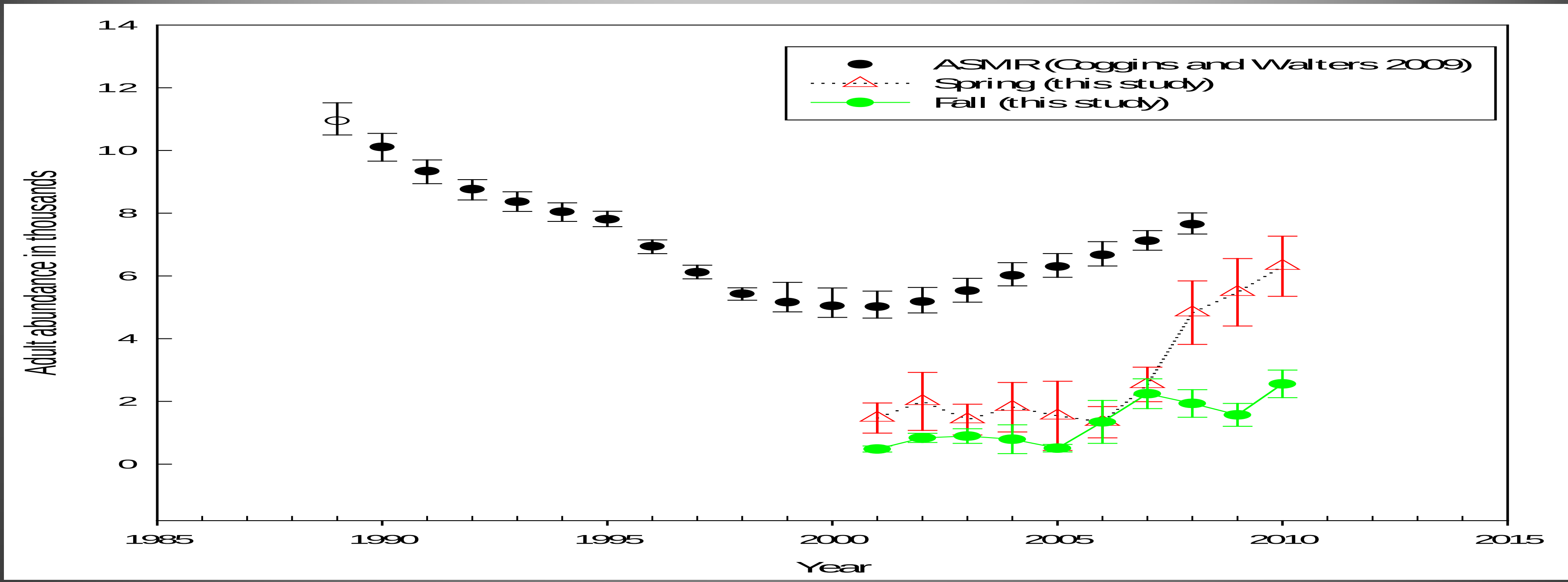


ASMR model and field sampling indicate a decade-long increase in HBC population



Population increase partly associated with increasing mainstem temperatures





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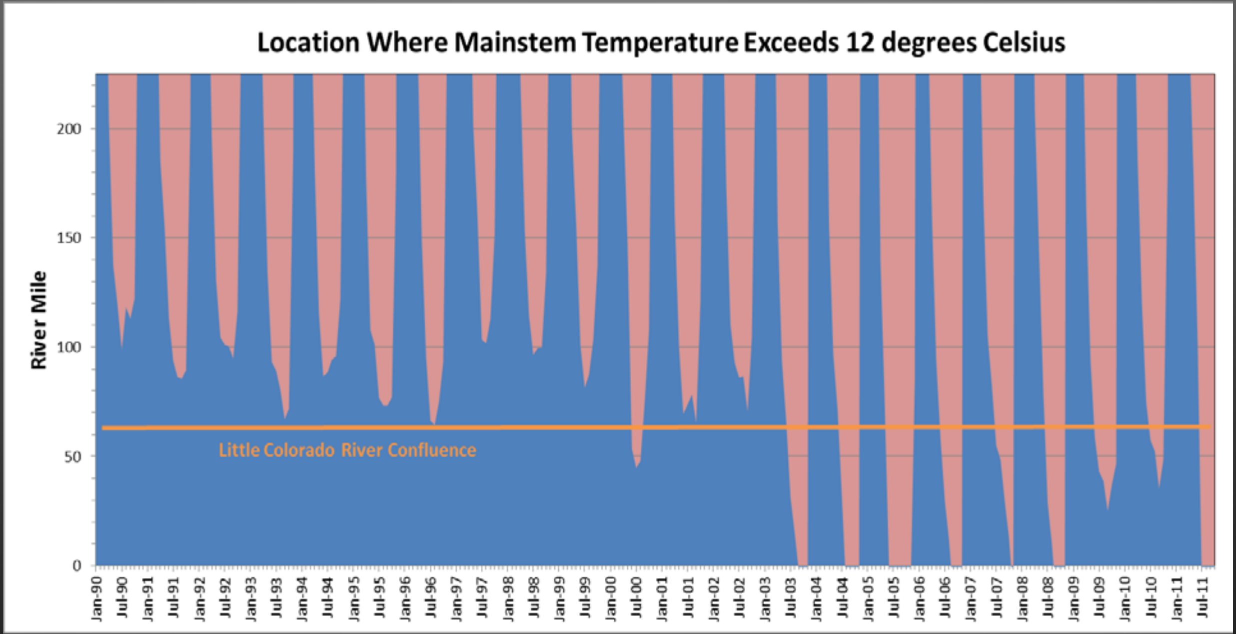
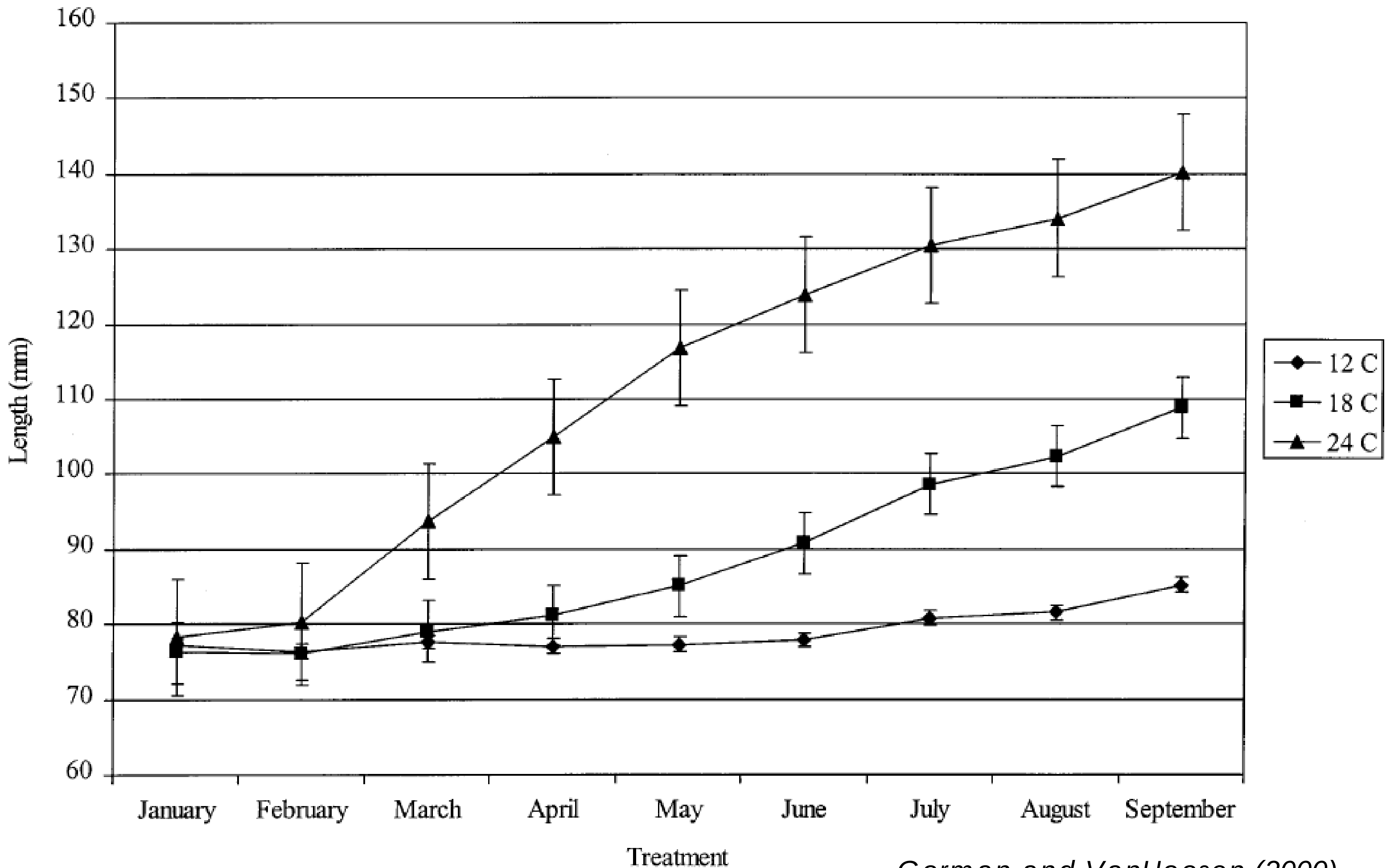


Warming increases the growth rate of humpback chub

Growth rate of humpback chub at three temperatures



Gorman and VanHoosen (2000)

Humpback chub growth rate declined during experimental fall steady flow period in relation to the summer fluctuating flow period

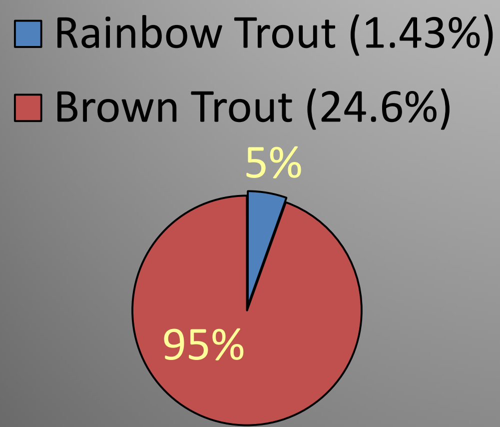
- <u>Counterintuitive Result</u>
  - Colorado River, dL/dt 0.13 → 0.08 mm/d

The fact that declines were also measured in the Little Colorado River at the same time suggests that there were other controls than simply mainstem stage changes controlling growth rates, i.e. available light decreased in fall, possible leading to reduced food availability

- Counterintuitive Result
  - Colorado River, dL/dt 0.13 → 0.08 mm/d
  - Little Colorado River, 0.21 → 0.02 mm/d
- Water temps did not change over this period (light did…, what about food?)

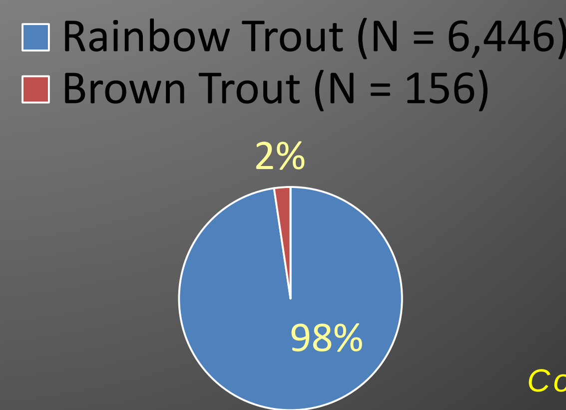
There is no simple relation between flow regime and humpback chub growth rate

Relative Incidence of Piscivory



Yard et al (2011)

Relative Trout Abundance



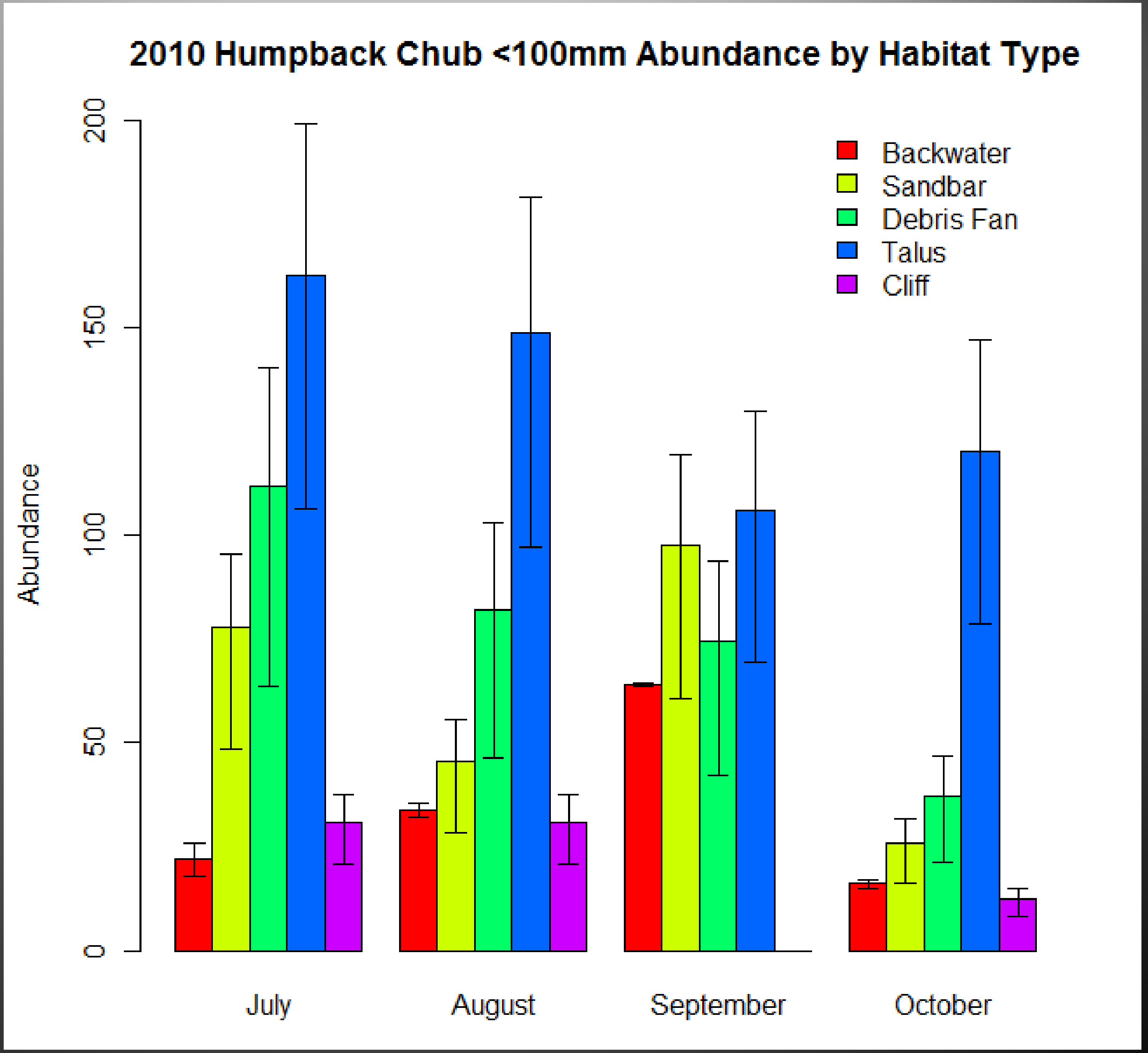
Coggins et al (2011); Coggins (2008)

Brown trout are potentially a significant source of predation on humpback chub. Brown trout densities are highest near Bright Angel Creek, but brown trout occur in low numbers elsewhere, including near the LCR

Aquatic habitat is partly formed by the geomorphic architecture of the river corridor

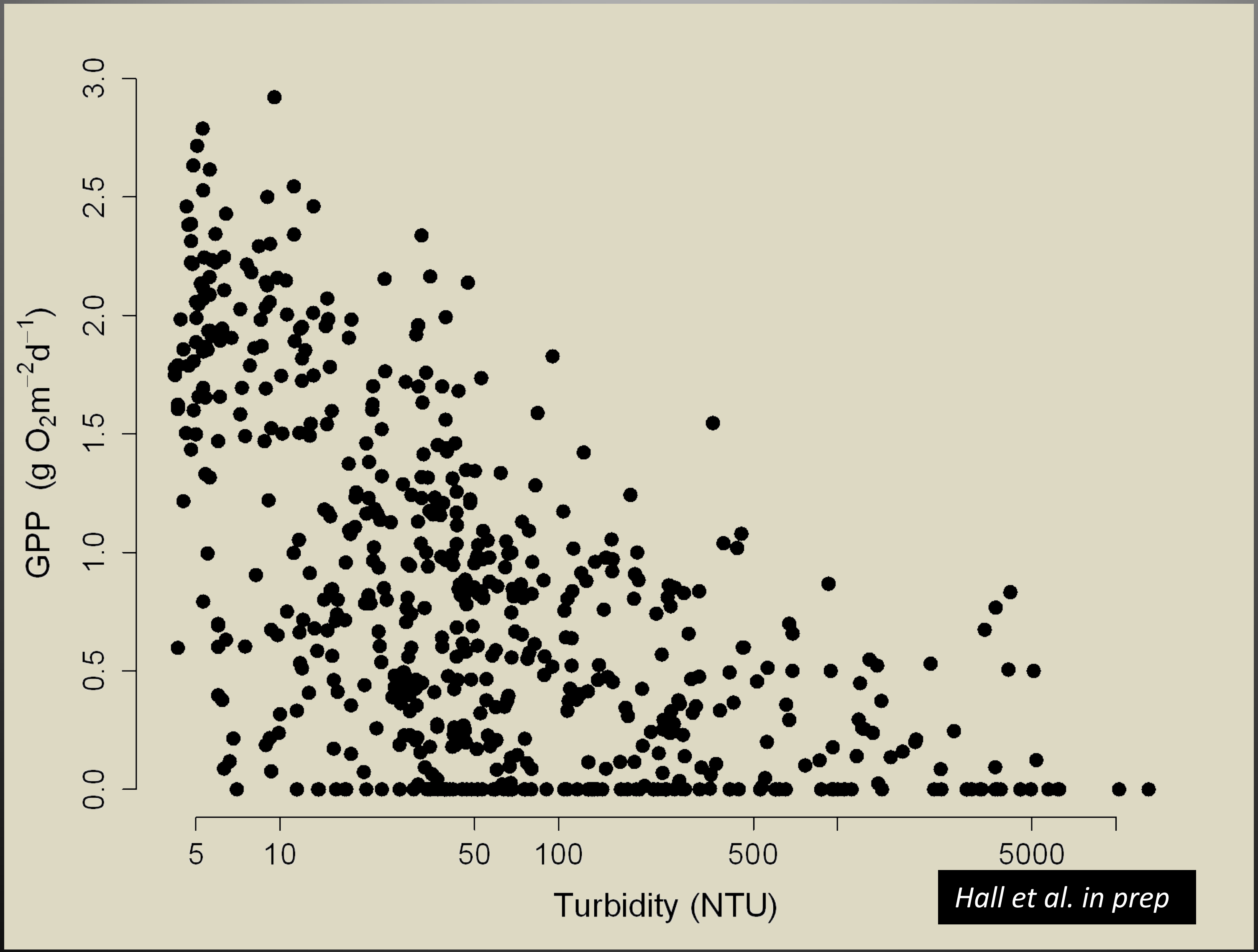
Juveniles use a variety of habitats generally in proportion to their availability

Backwaters, however, were disproportionally selected for when available. But, backwaters made up only a small portion(1-2%) of available habitats in the NSE study area. Juvenile HBC survived when backwaters were unavailable.

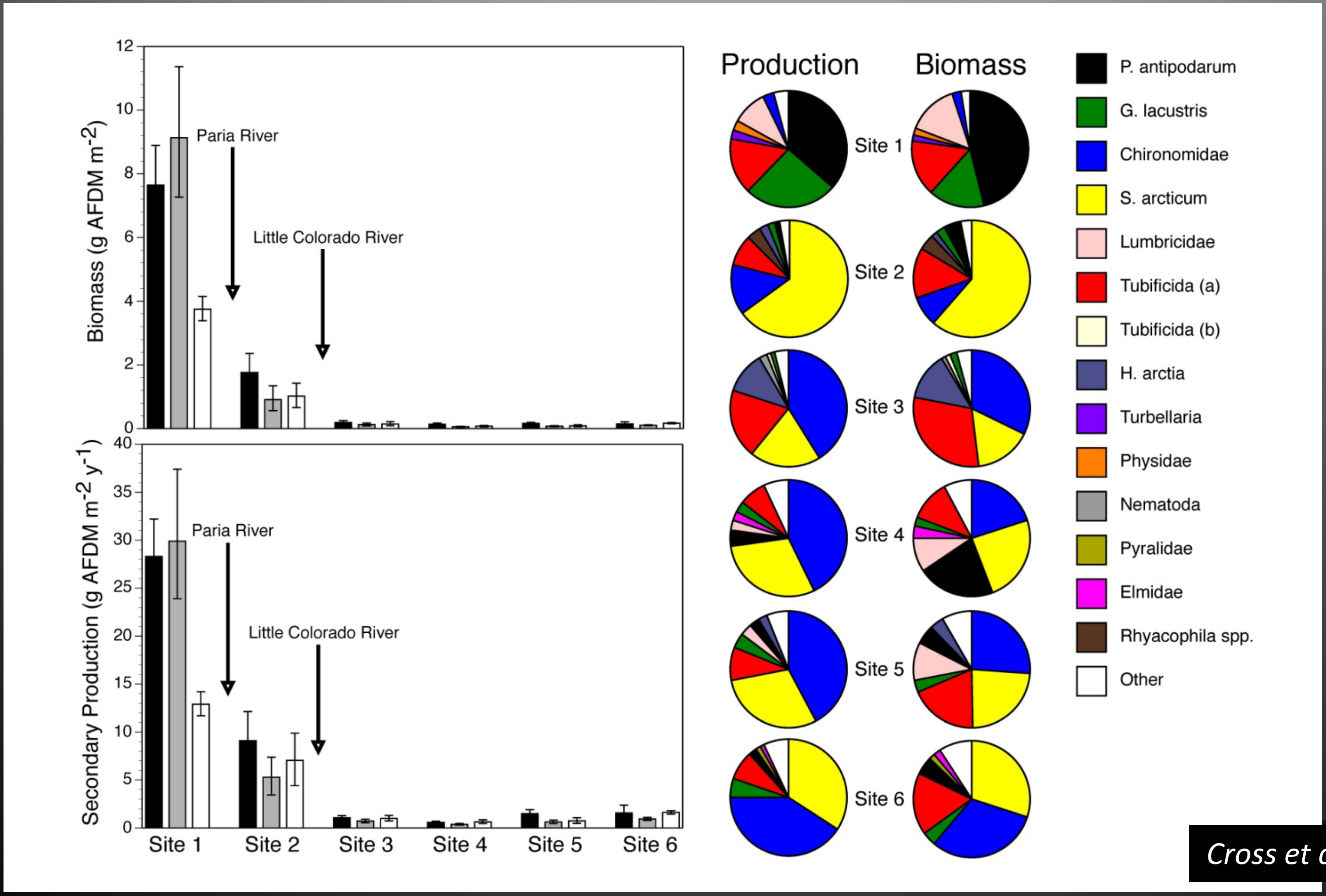


(Pine et al. unpubl.)

Turbidity strongly controls algae production in Grand Canyon



Invertebrate production exhibits stepped declines below the Paria and LCR, and production below the LCR is extremely low relative to other streams and rivers

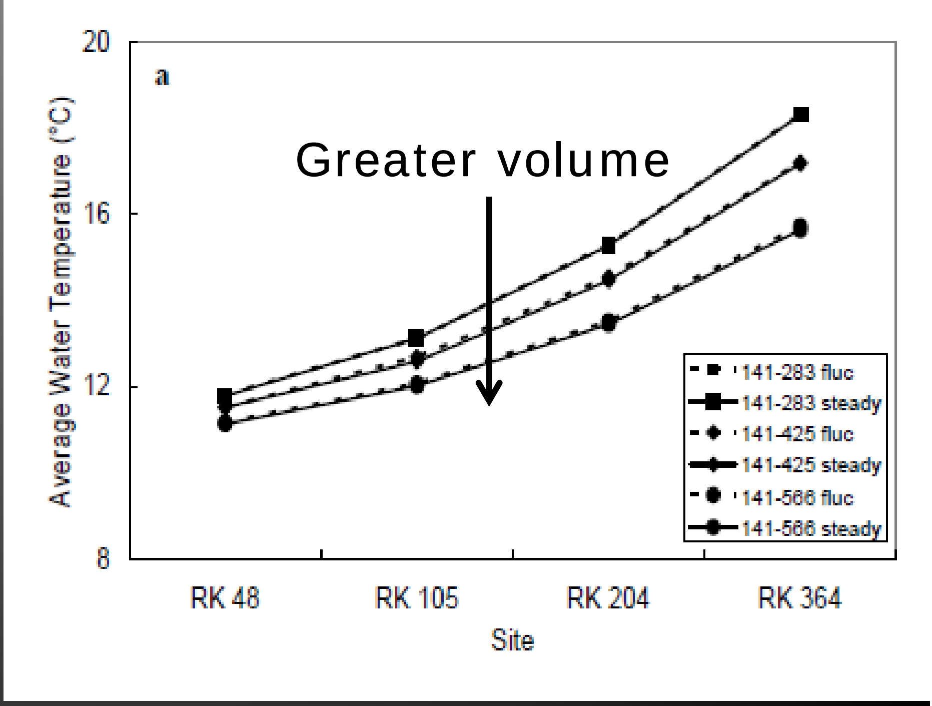


Cross et al. in prep

Volume of flow is the greatest determinant of the rate of downstream warming of stream flow – higher volumes of flow decrease the rate of warming

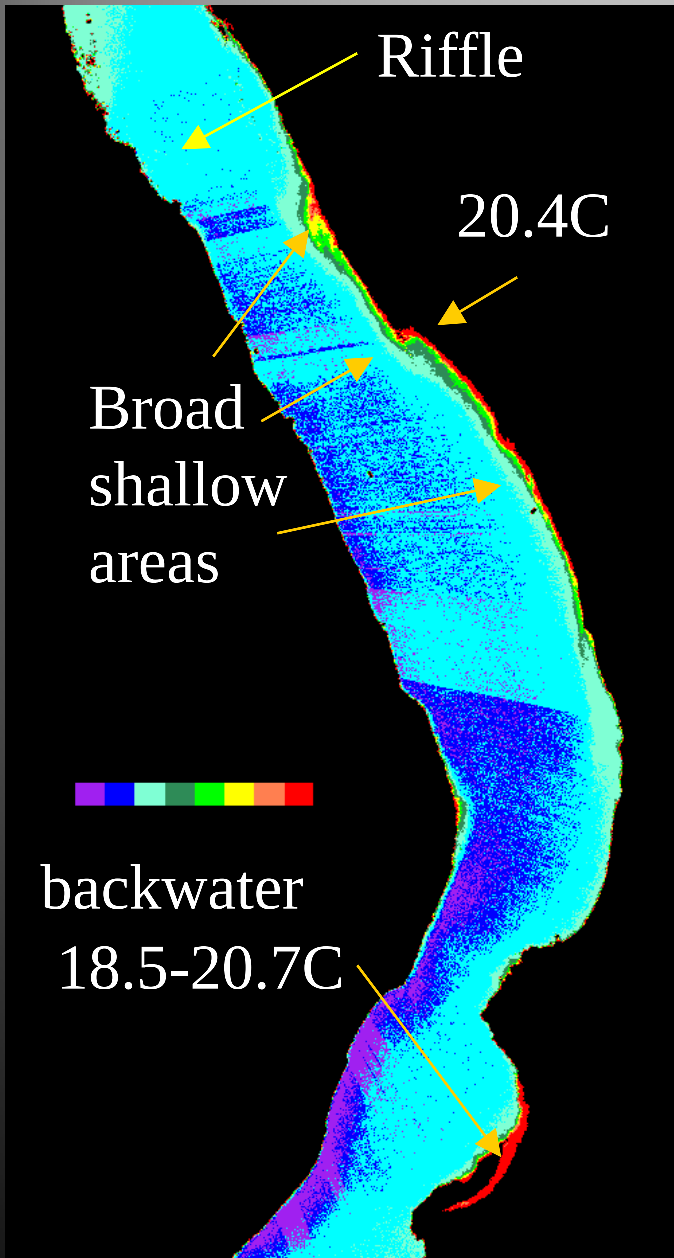
- No significant difference between steady and fluctuating flows
- **Flow volume not release pattern controls warming**

  - Unsteady temperature model
    - Predicts mainstem temperature for steady and fluctuating flows by distance downstream

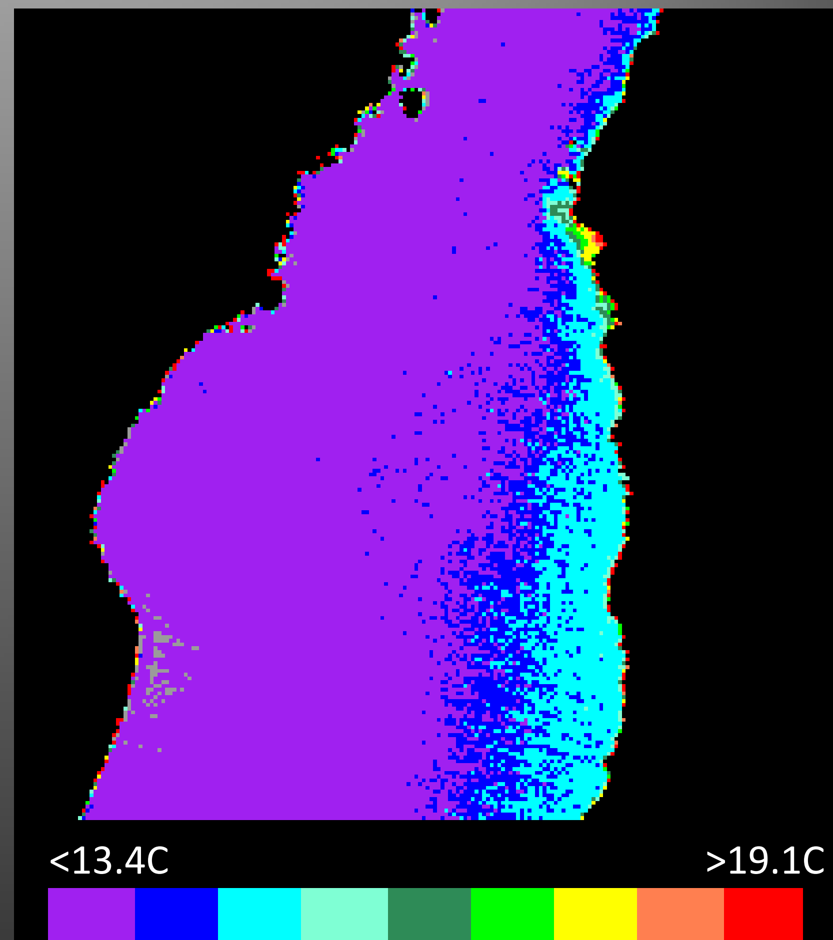


Anderson and Wright, 2007

Refugia areas along the shore warm to a greater extent during steady flows

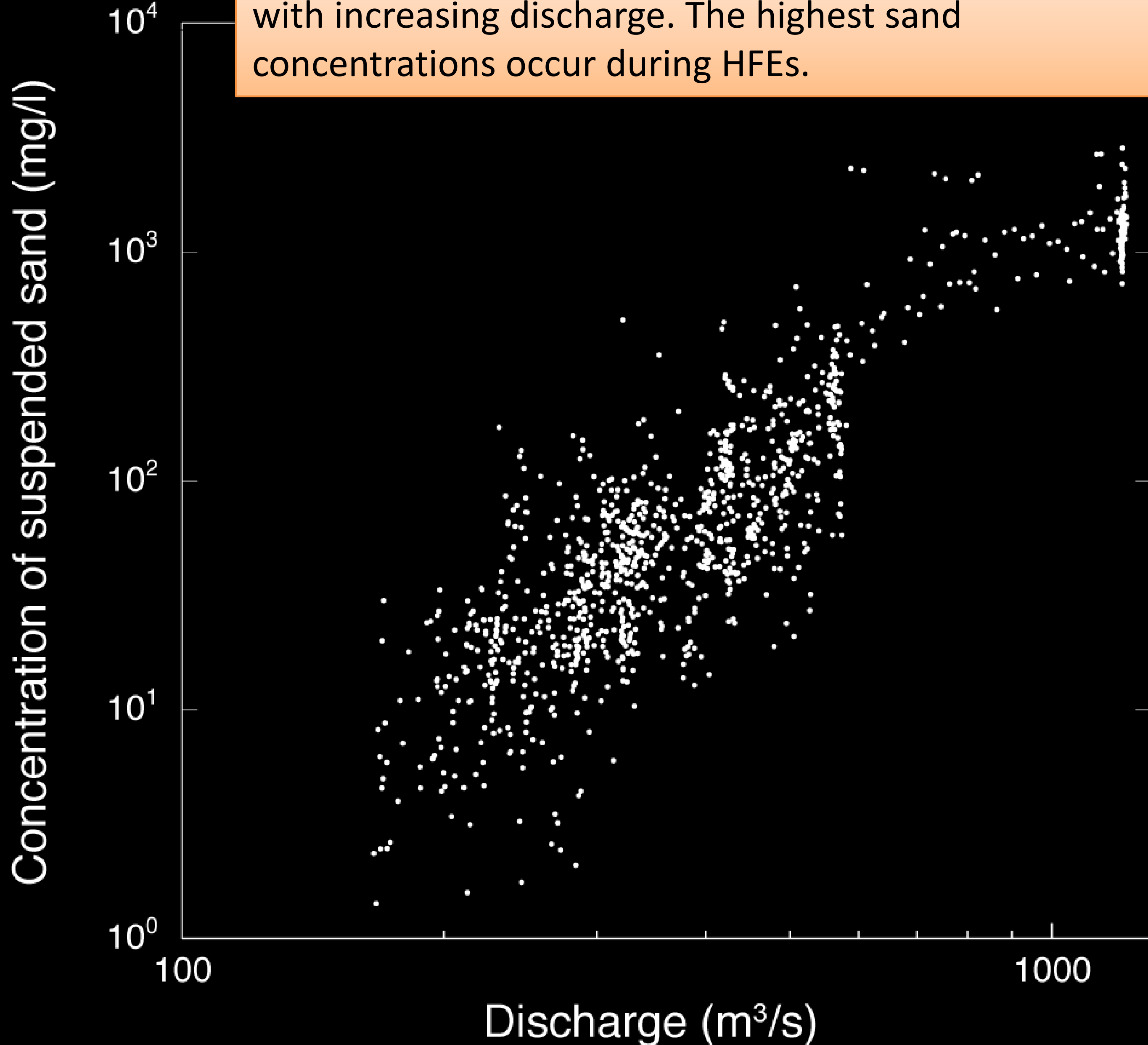


RM 68 Thermal infared image 7/25/00

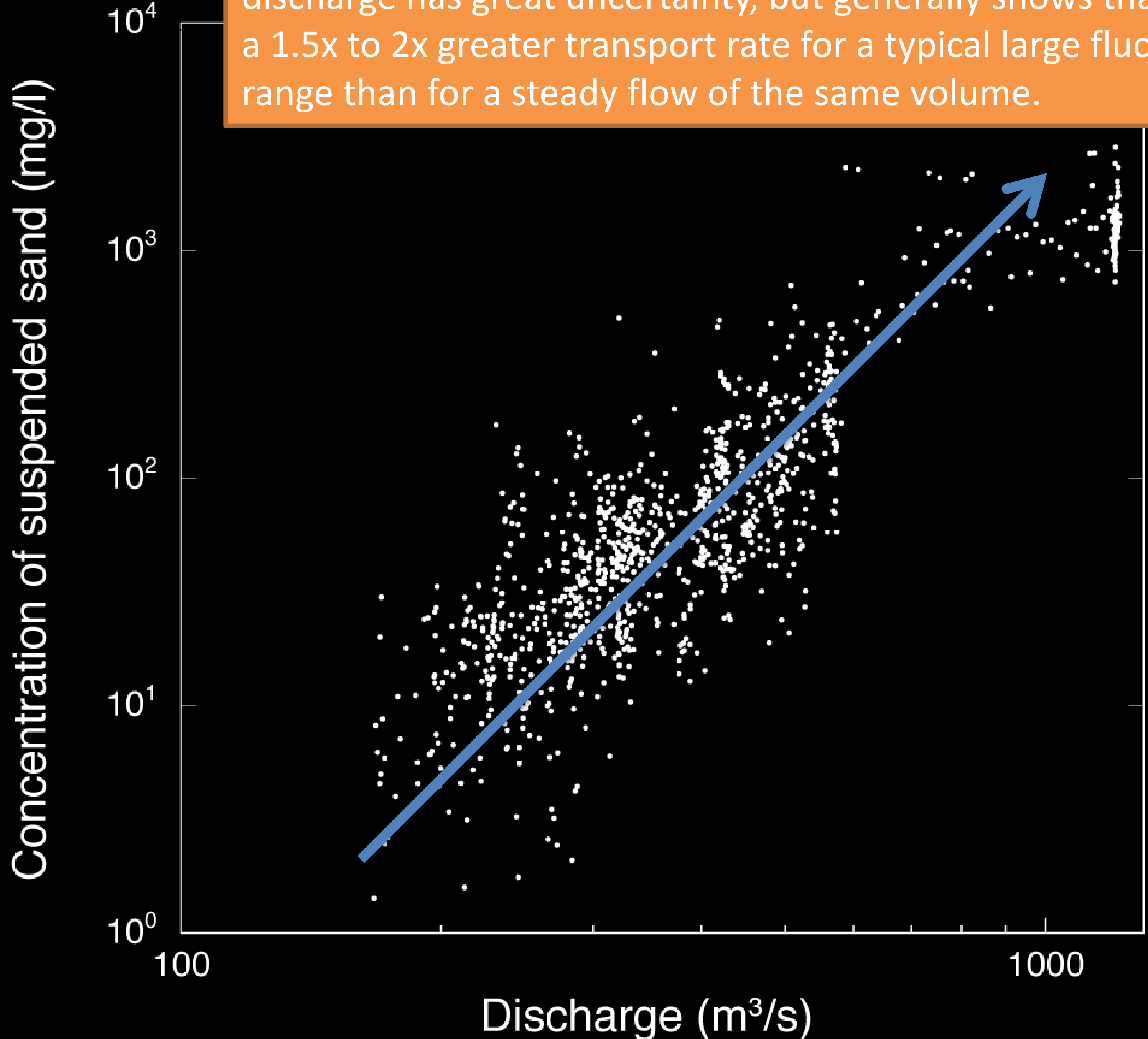


RM 64.6LThermal Infared Imagery 7/25/00

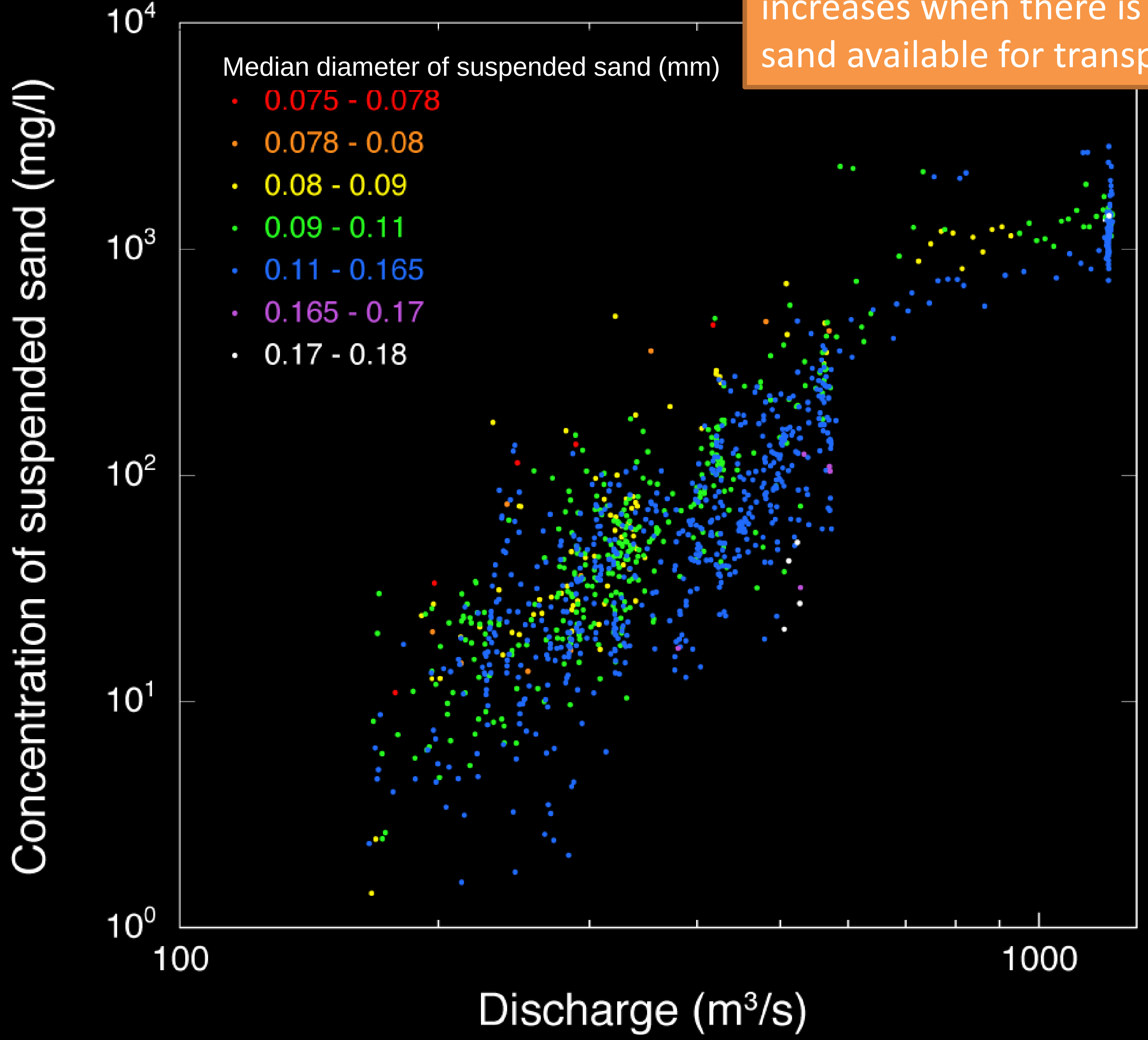
Concentration of suspended sand increases exponentially with increasing discharge. The highest sand concentrations occur during HFEs.

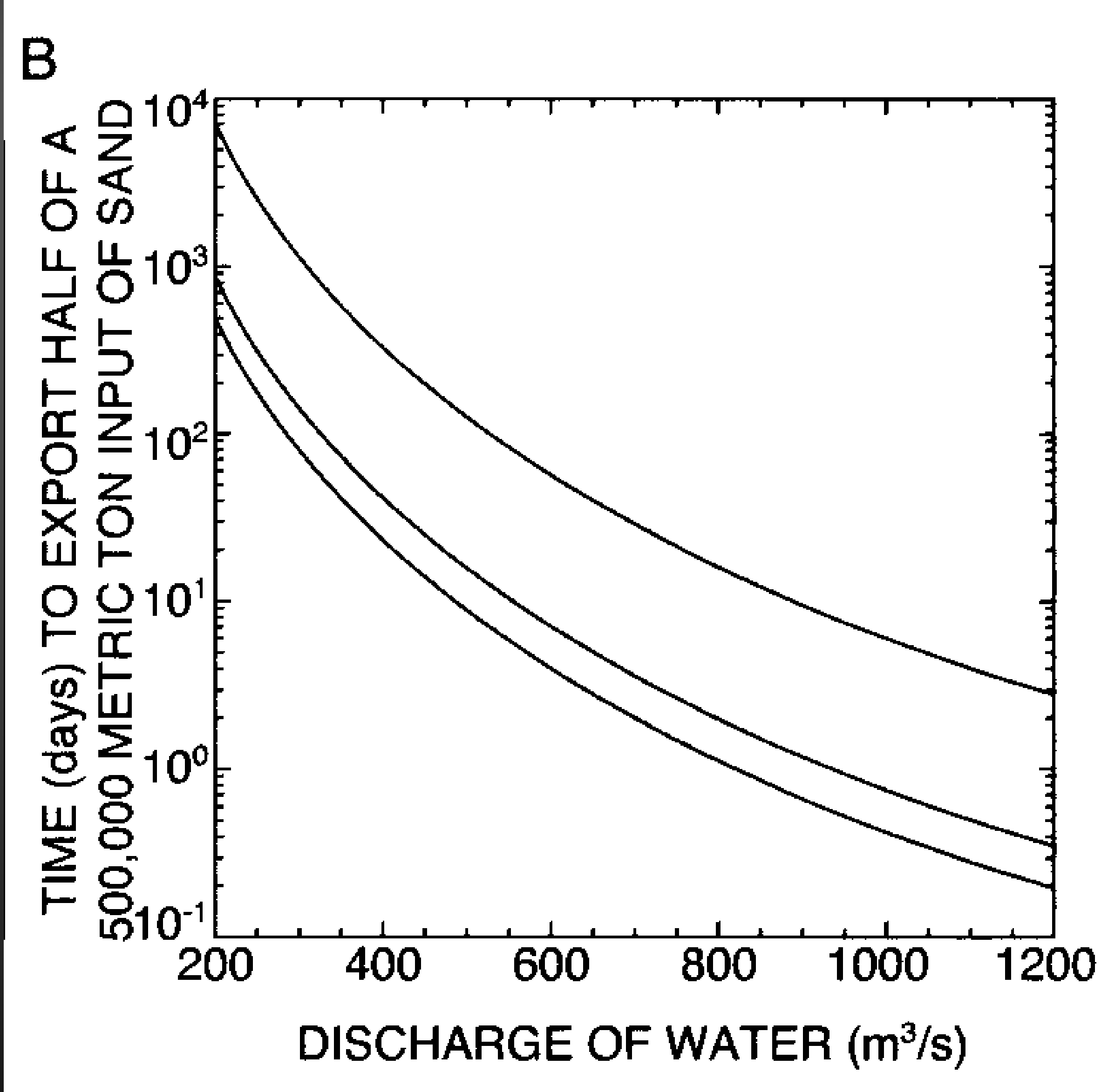


Predicting the amount of sand transport for any specific discharge has great uncertainty, but generally shows that there is a 1.5x to 2x greater transport rate for a typical large fluctuation range than for a steady flow of the same volume.



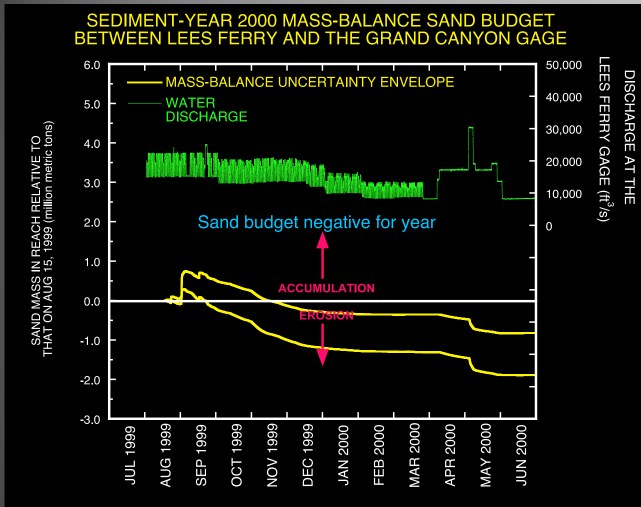
Mainstem transport rate greatly increases when there is very fine sand available for transport.





Implication – immediately after an infusion of very fine sand from a tributary, the mainstem exports that sand quickly.

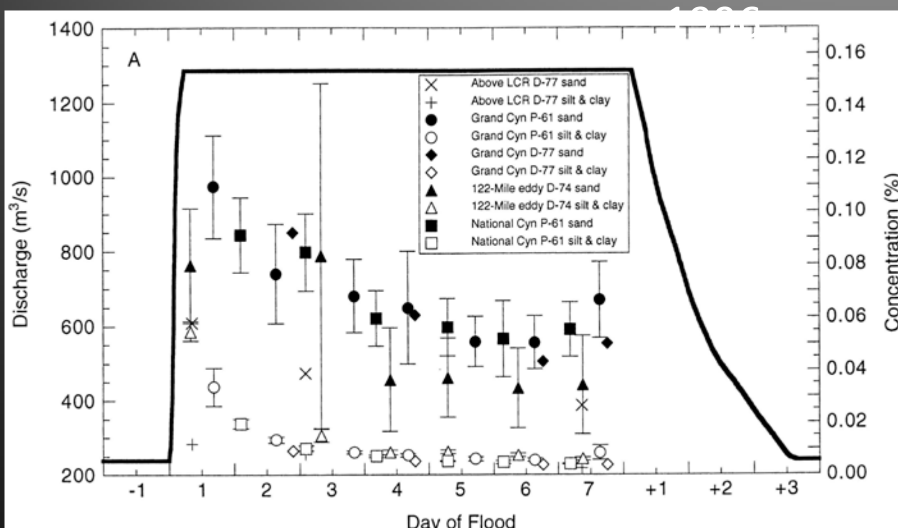
Rubin et al. (2002) estimated a few weeks to a few months to export half a hypothetical 500,000 ton supply.



Maintaining positive mass balance is very hard.

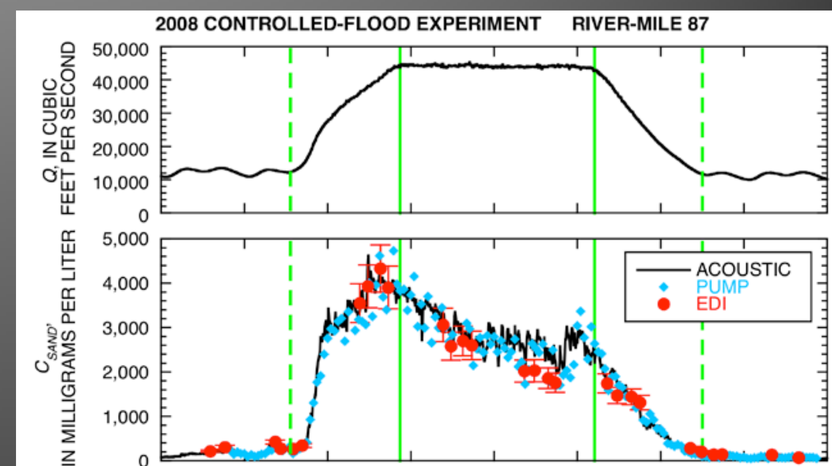
Topping, written commun.

The available supply is quickly depleted. There is significant transport even during typical base flows.



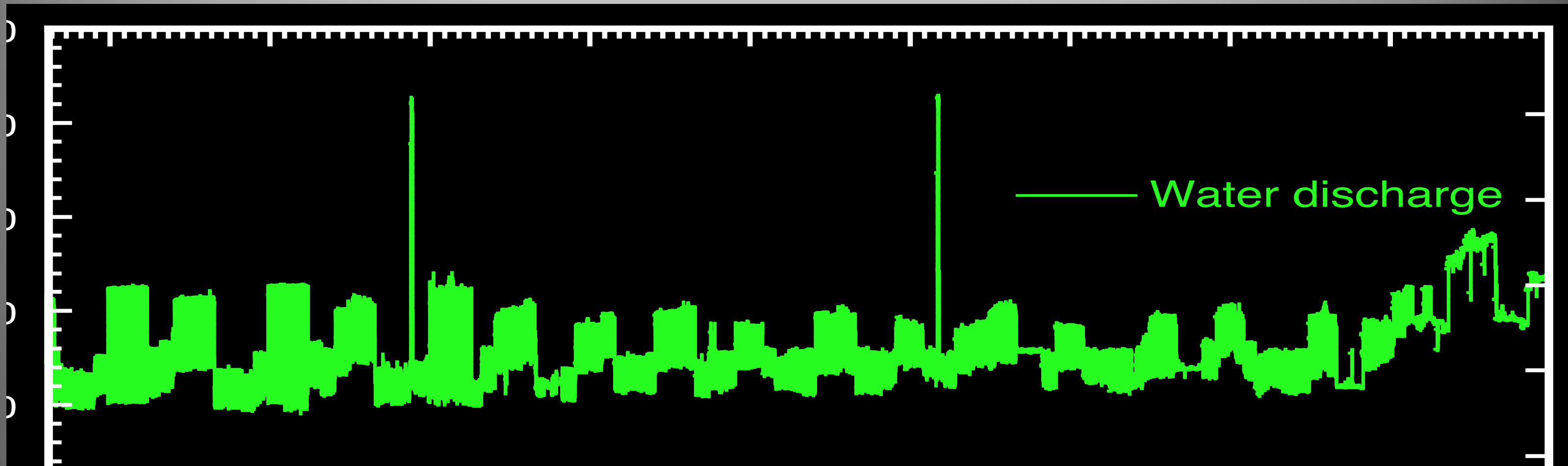
Change in suspended sediment concentration with time during two large dam releases

Topping, Rubin, various papers

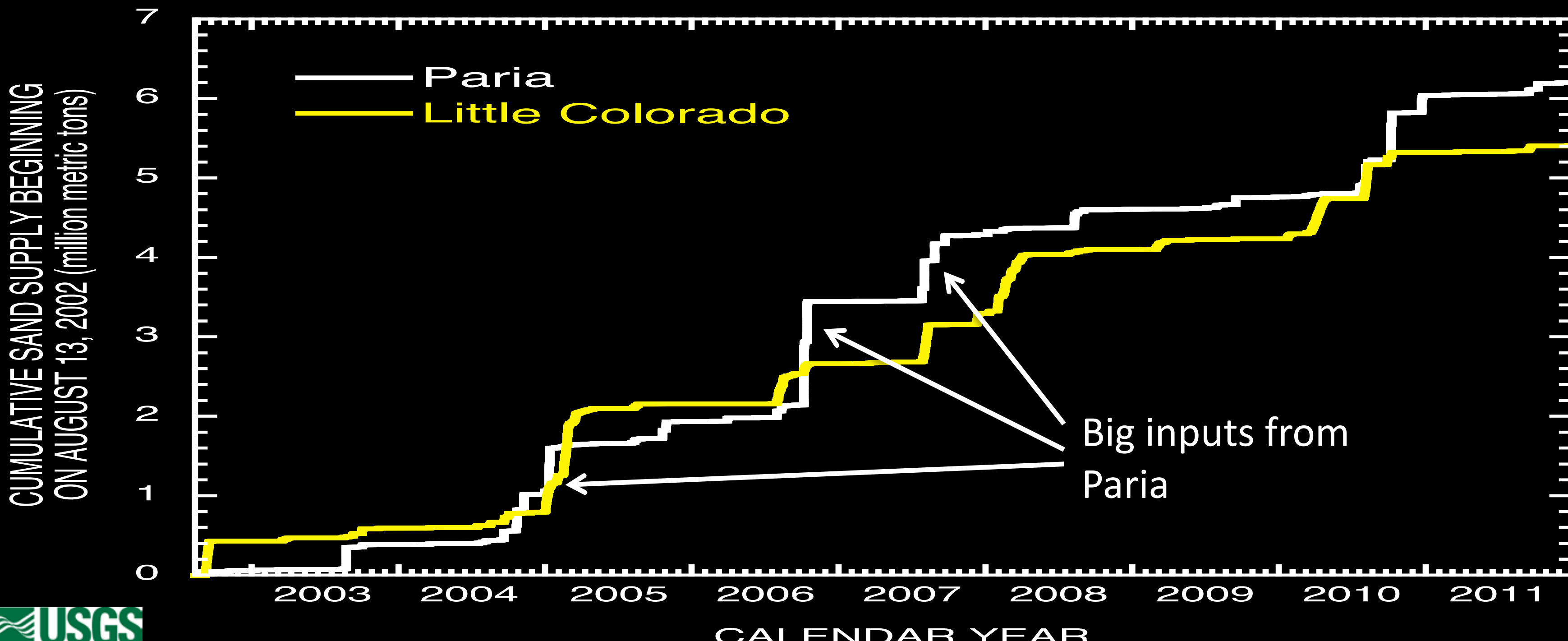


2008

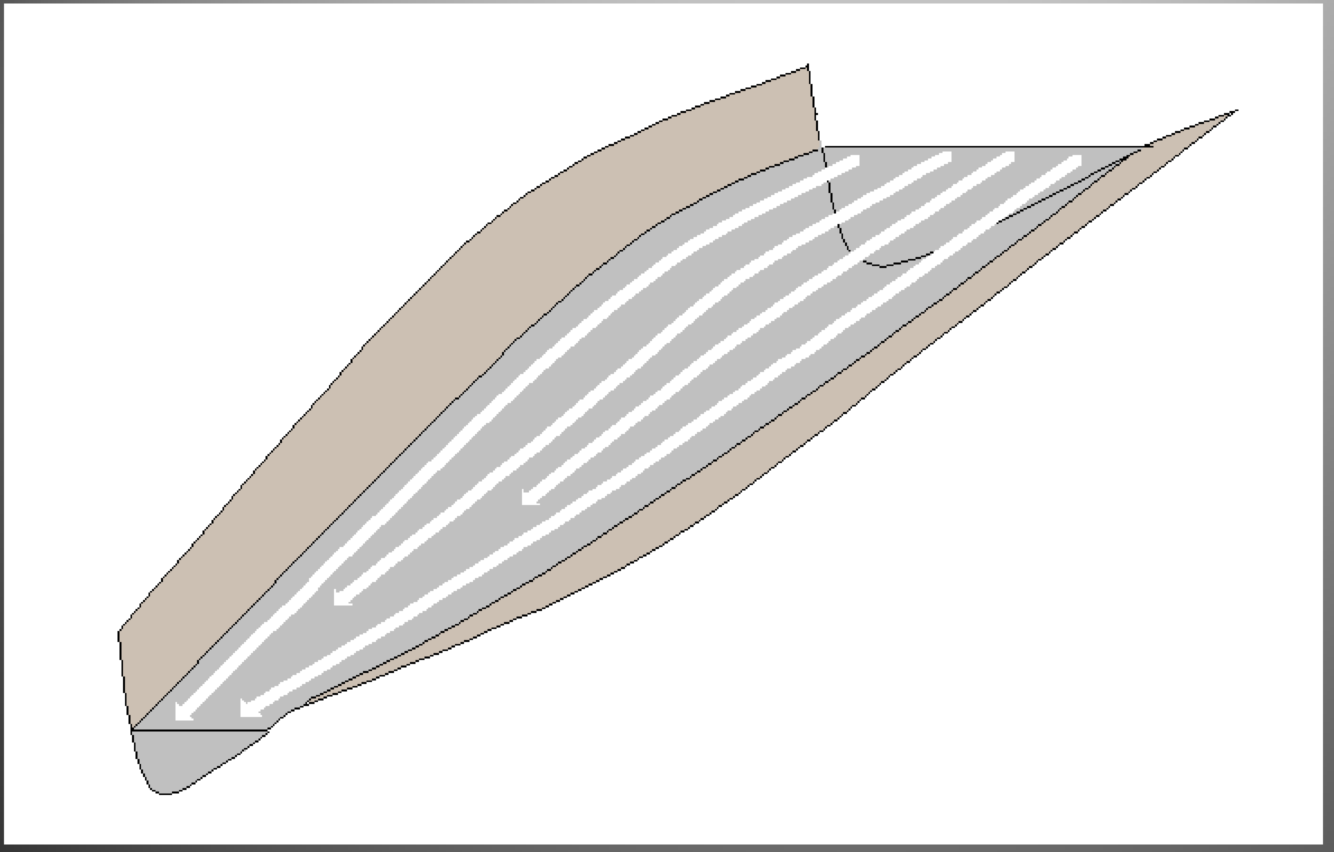
Topping et al., 2010



SAND SUPPLY FROM THE PARIA AND LITTLE COLORADO RIVERS

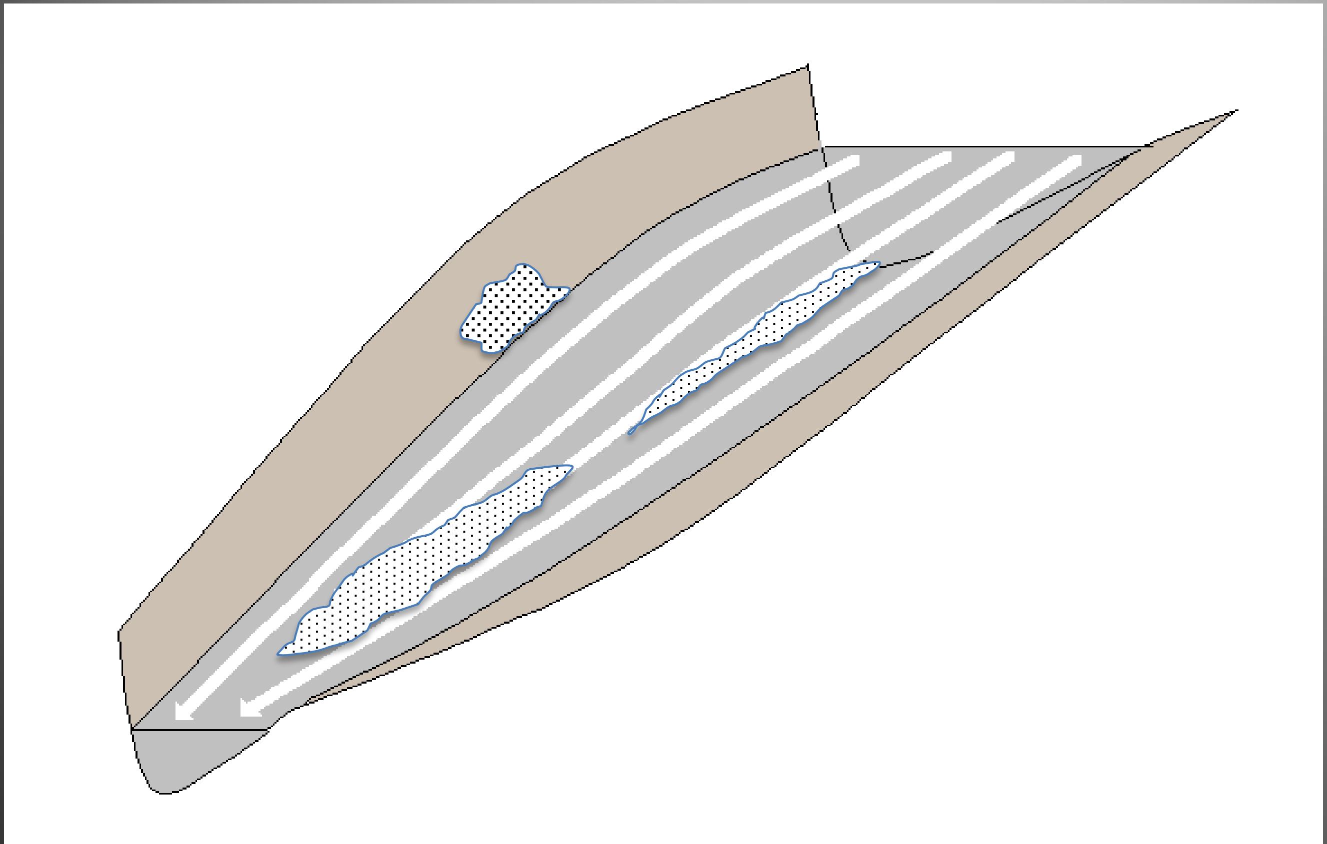


USGS
science for a changing world

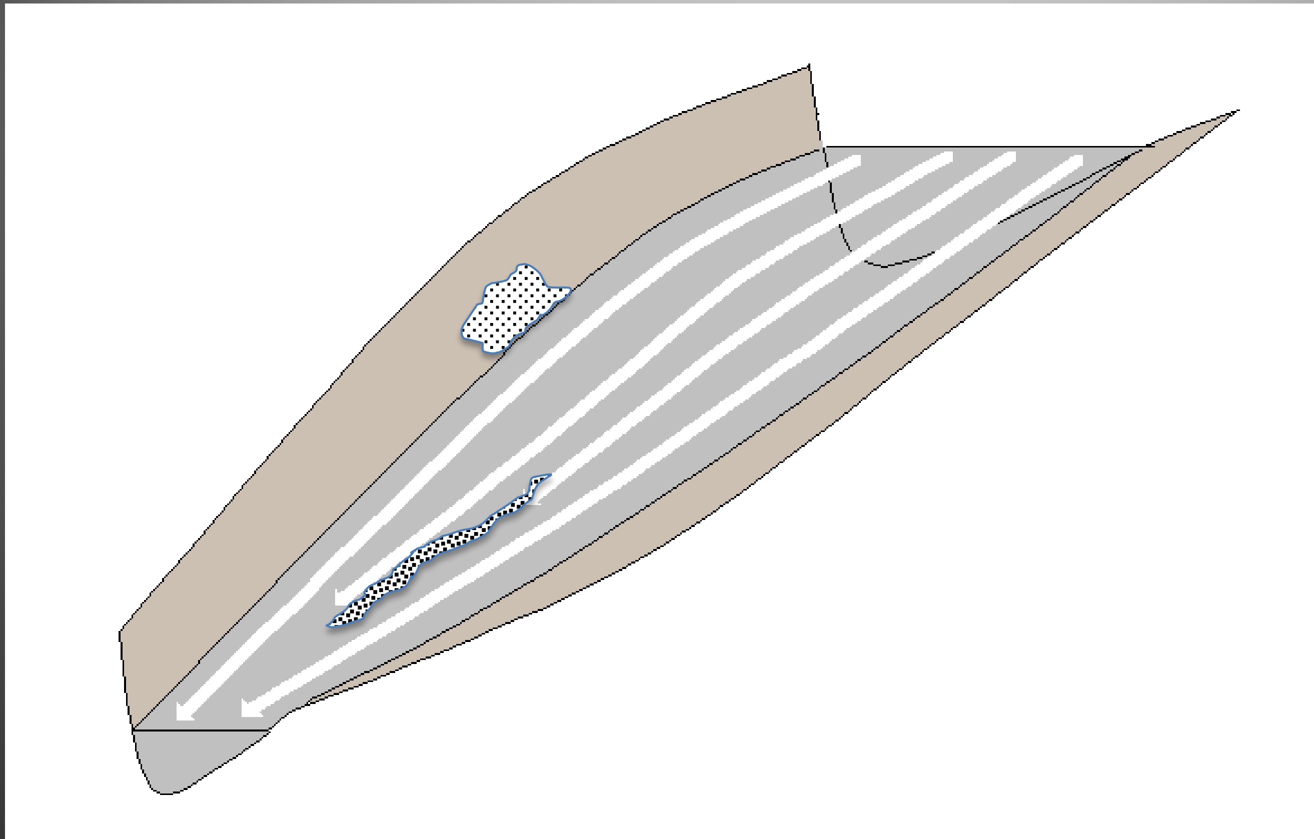


How the physical system works

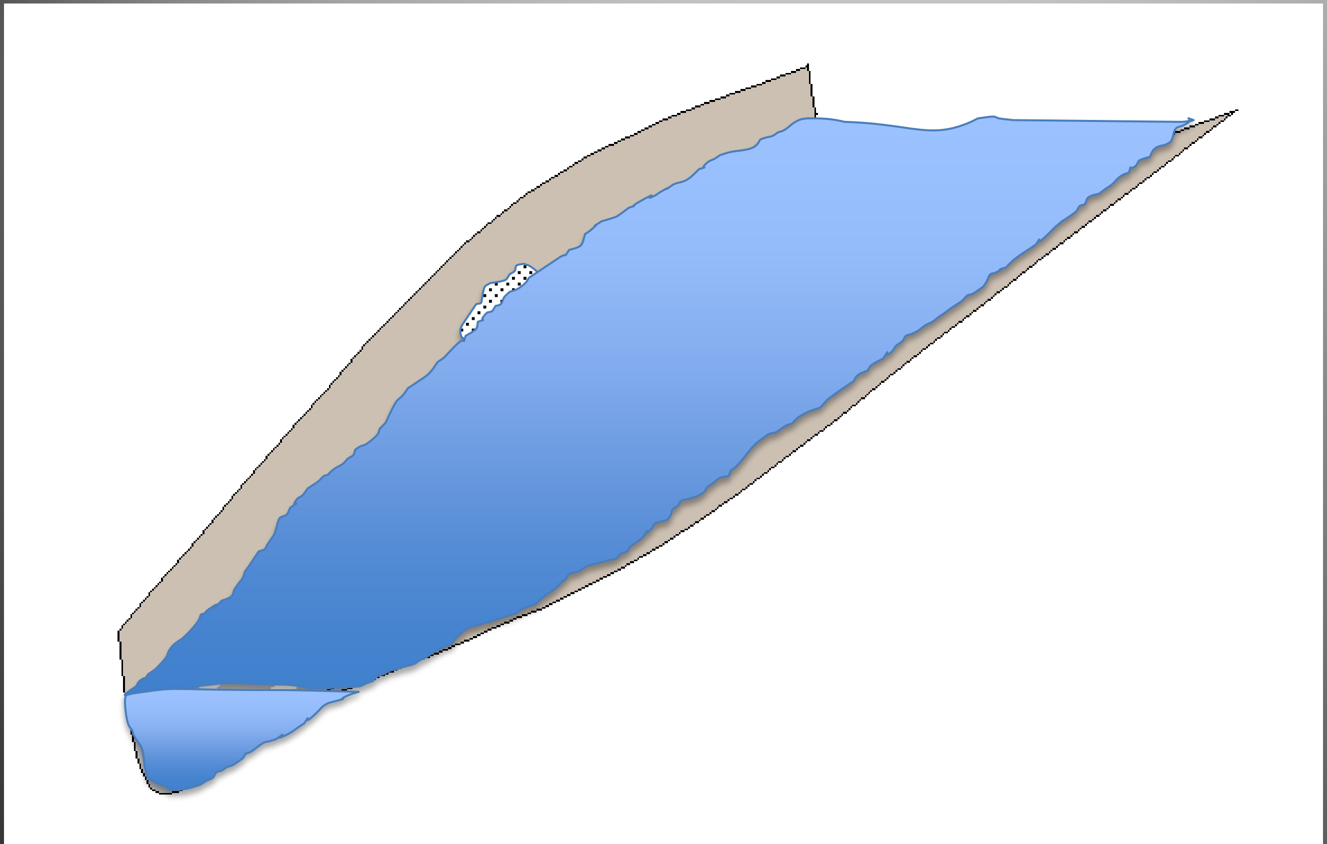
Colorado River in Grand Canyon behaves like a pipe – a pipe with a very rough boundary



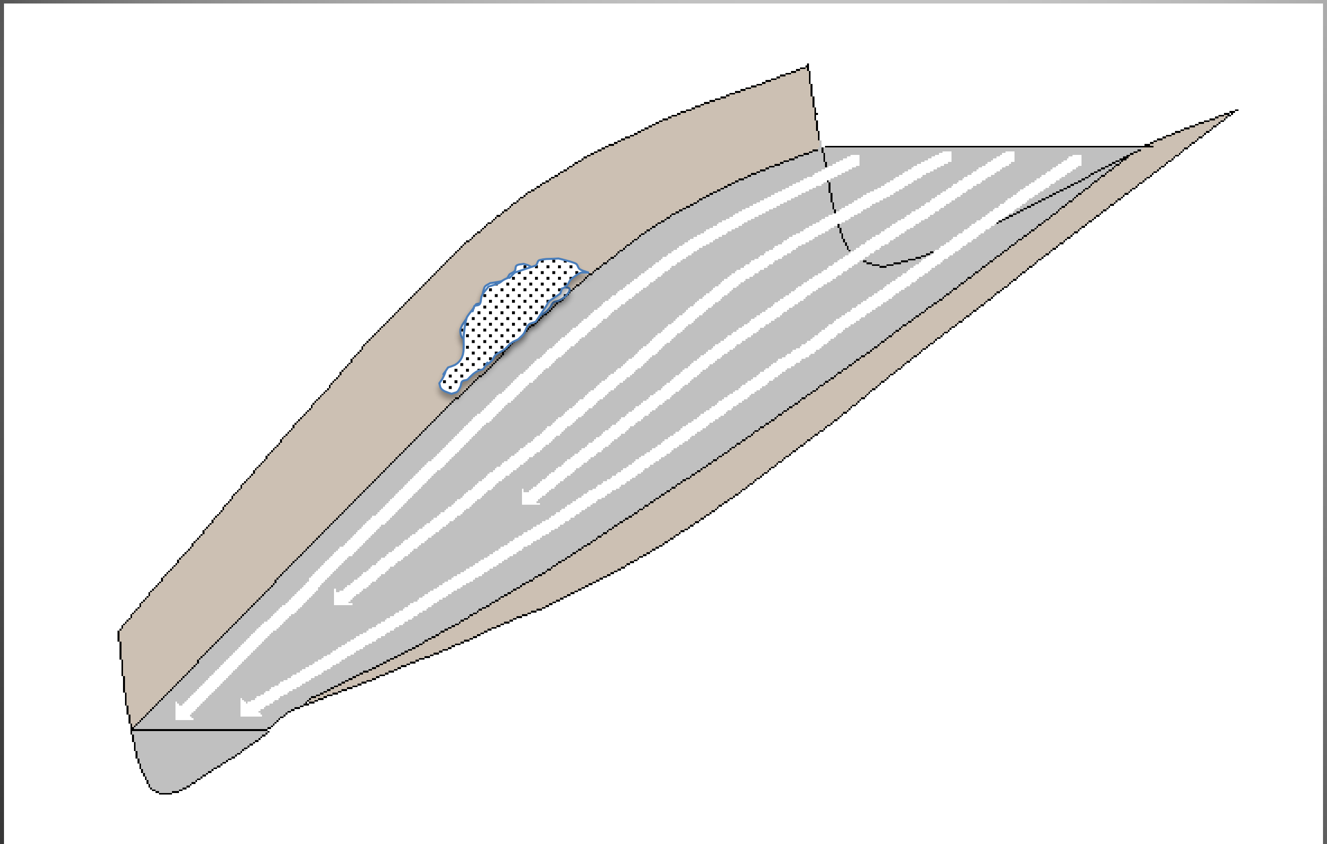
When fine sediment enters the river from tributaries (primarily the Paria River) …



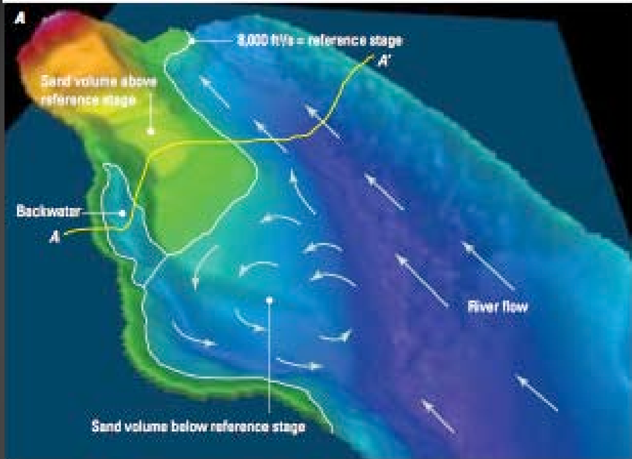
This sand and mud is quickly transported downstream. The mud is transported most quickly and the sand that remains on the bed becomes coarser.

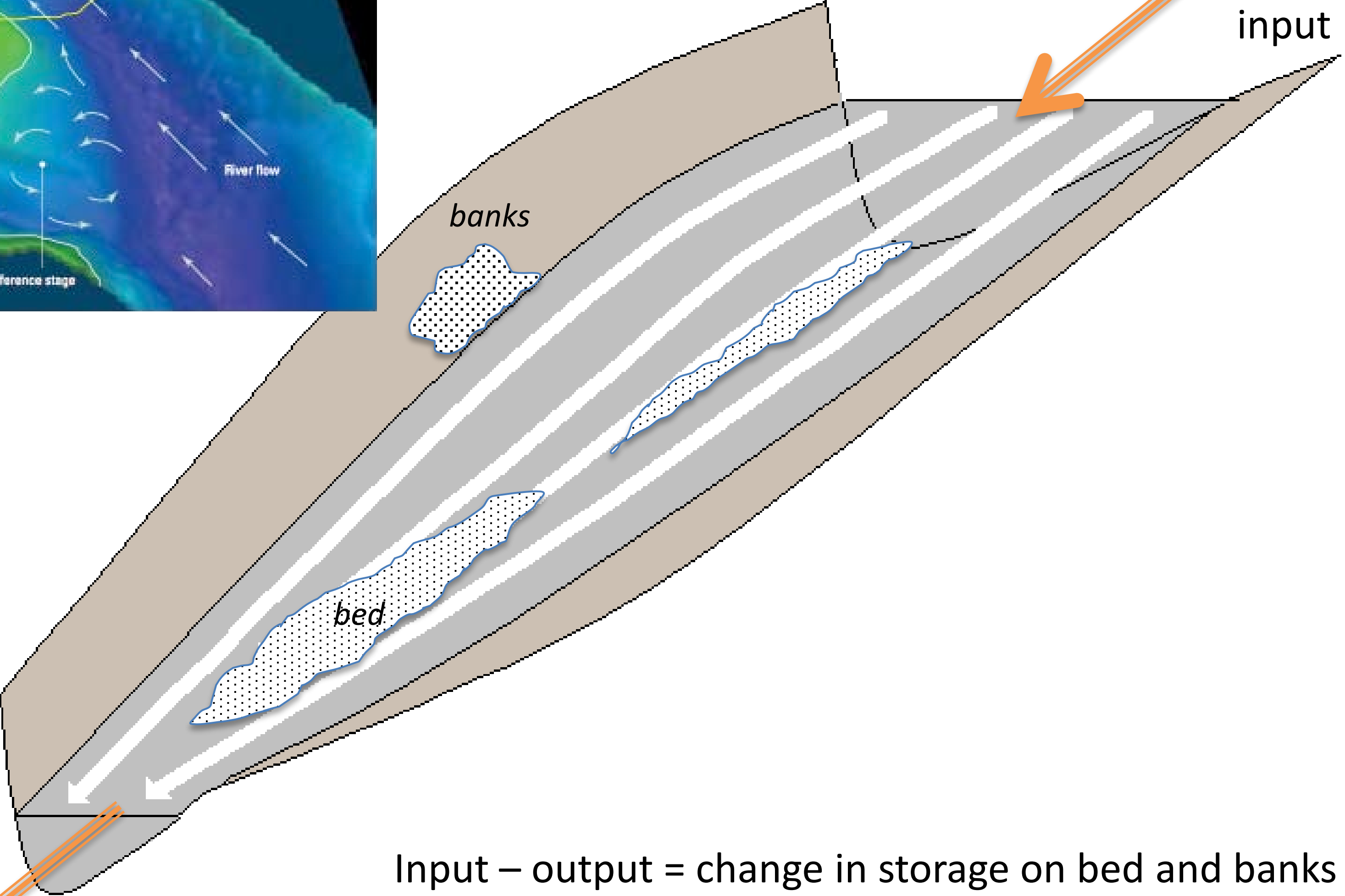


Unless there are floods that mobilize the sand on the bed, thereby transporting some sand towards Lake Mead and depositing a small proportion of sand in eddies and long the channel margin



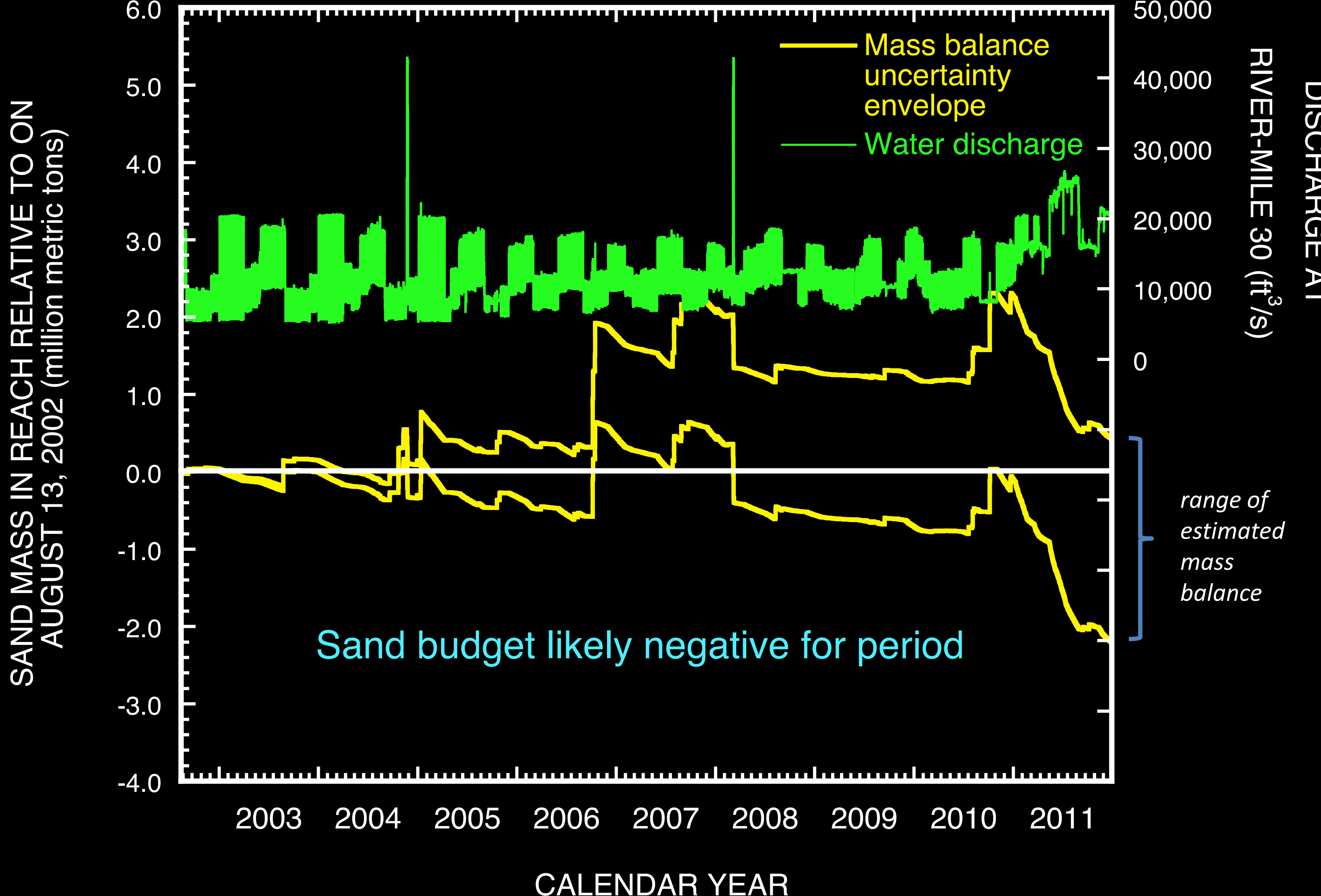
Upon recession of the flood, the sand deposits along the margin of the river are typically *larger*, and the amount of sand on the channel bed is much smaller

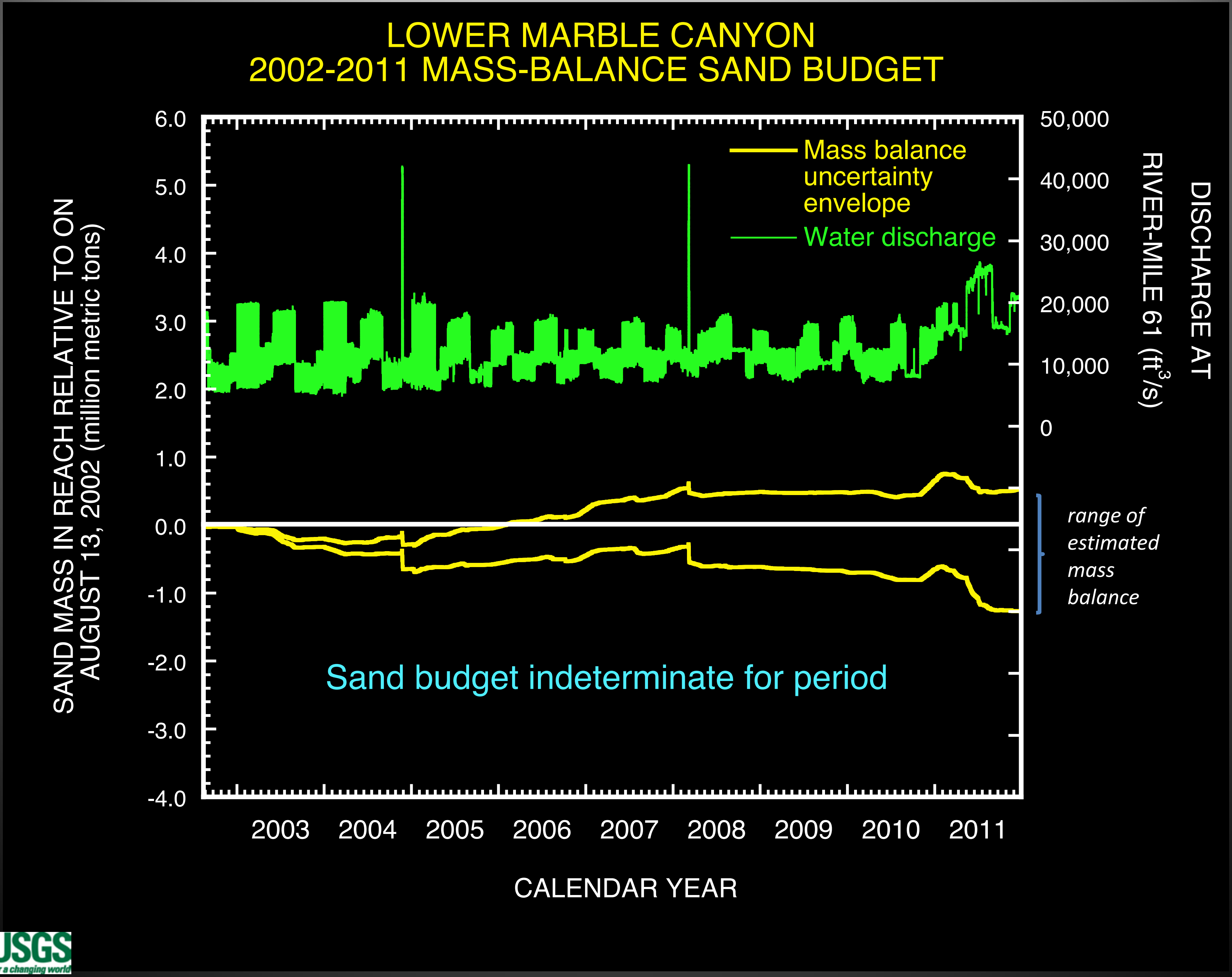




Input – output = change in storage on bed and banks

UPPER MARBLE CANYON
2002-2011 MASS-BALANCE SAND BUDGET




LOWER MARBLE CANYON
2002-2011 MASS-BALANCE SAND BUDGET
Mass balance uncertainty envelope
Water discharge
SAND MASS IN REACH RELATIVE TO ON AUGUST 13, 2002 (million metric tons)
DISCHARGE AT RIVER-MILE 61 (ft3/s)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
50,000
40,000
30,000
20,000
10,000
0
range of estimated mass balance
Sand budget indeterminate for period
2003
2004
2005
2006
2007
2008
2009
2010
2011
CALENDAR YEAR

What are the implications of a negative sediment mass balance?

1952, photo by Kent Frost.

1995, photo by USGS.

Not every sand bar has eroded to the same degree

Grapevine, RM 81.76L

Late afternoon, August 7, 1976 (~daily mean 9,000 ft^3/s)

1300 August 7, 1985 (~21,300 ft^3/s)

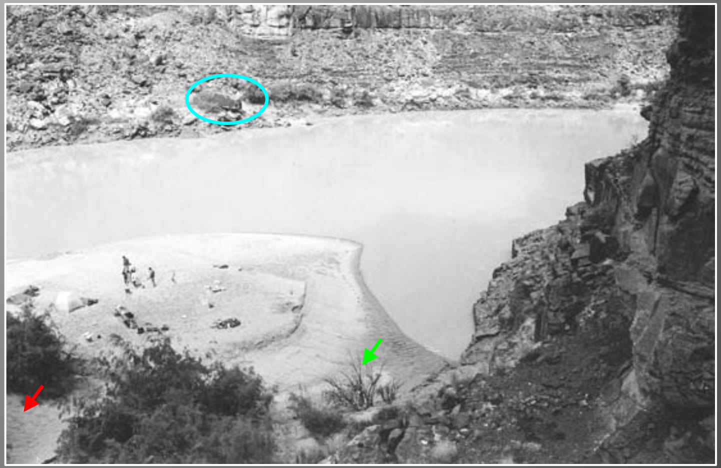
1645 January 24, 1989 (~13,600 ft^3/s)

0945 April 6, 2008 (~10,400 ft^3/s)

Changes in sand bar area result from geomorphic processes. Changes in campsite area result from geomorphic and biological processes.

19 Mile Canyon (RM 19.41L)

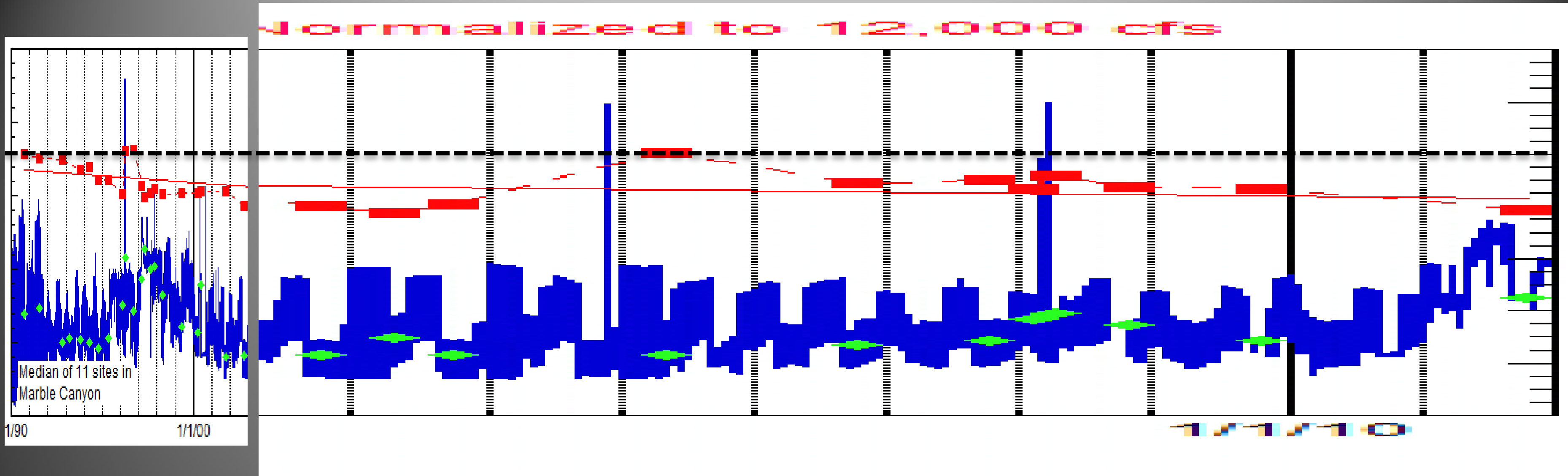
1973



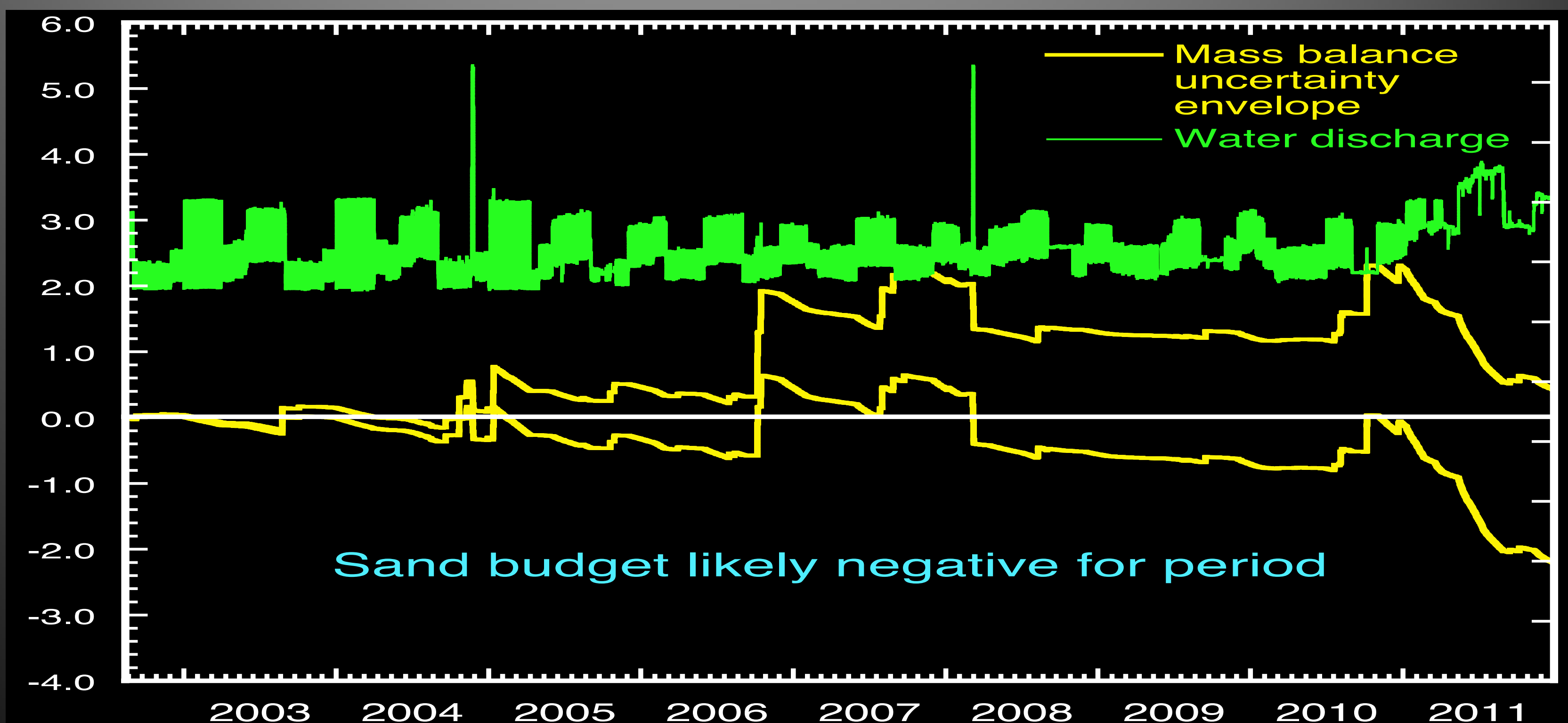
1115 October 10, 1985 (~4,100 ft^3/s)

1100 March 30, 2008 (~7,700 ft^3/s)

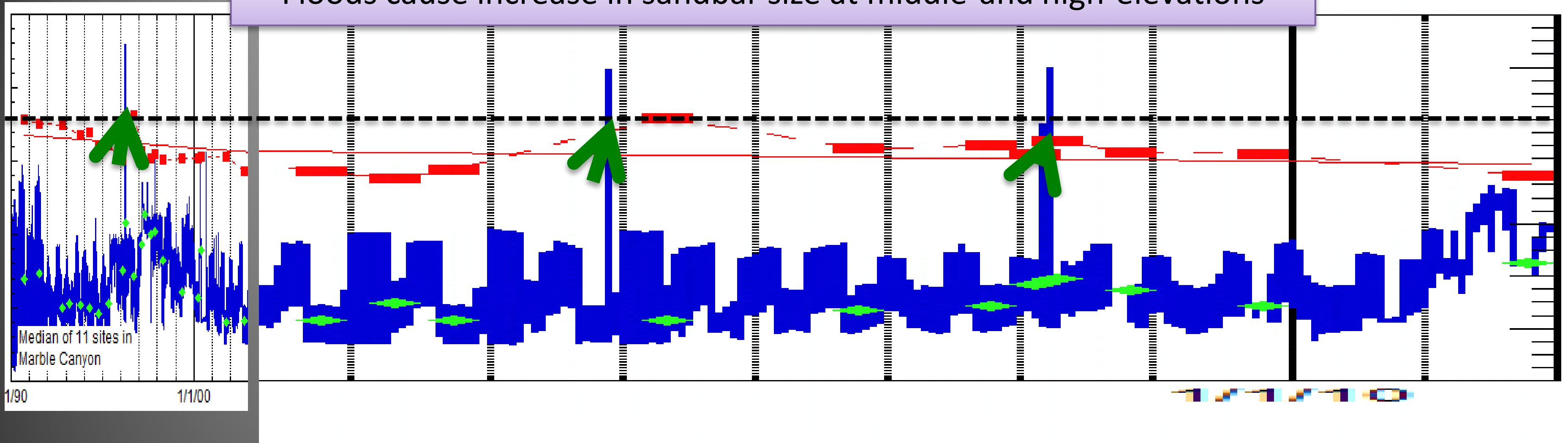
0900 April 10, 2009 (~7,500 ft^3/s)



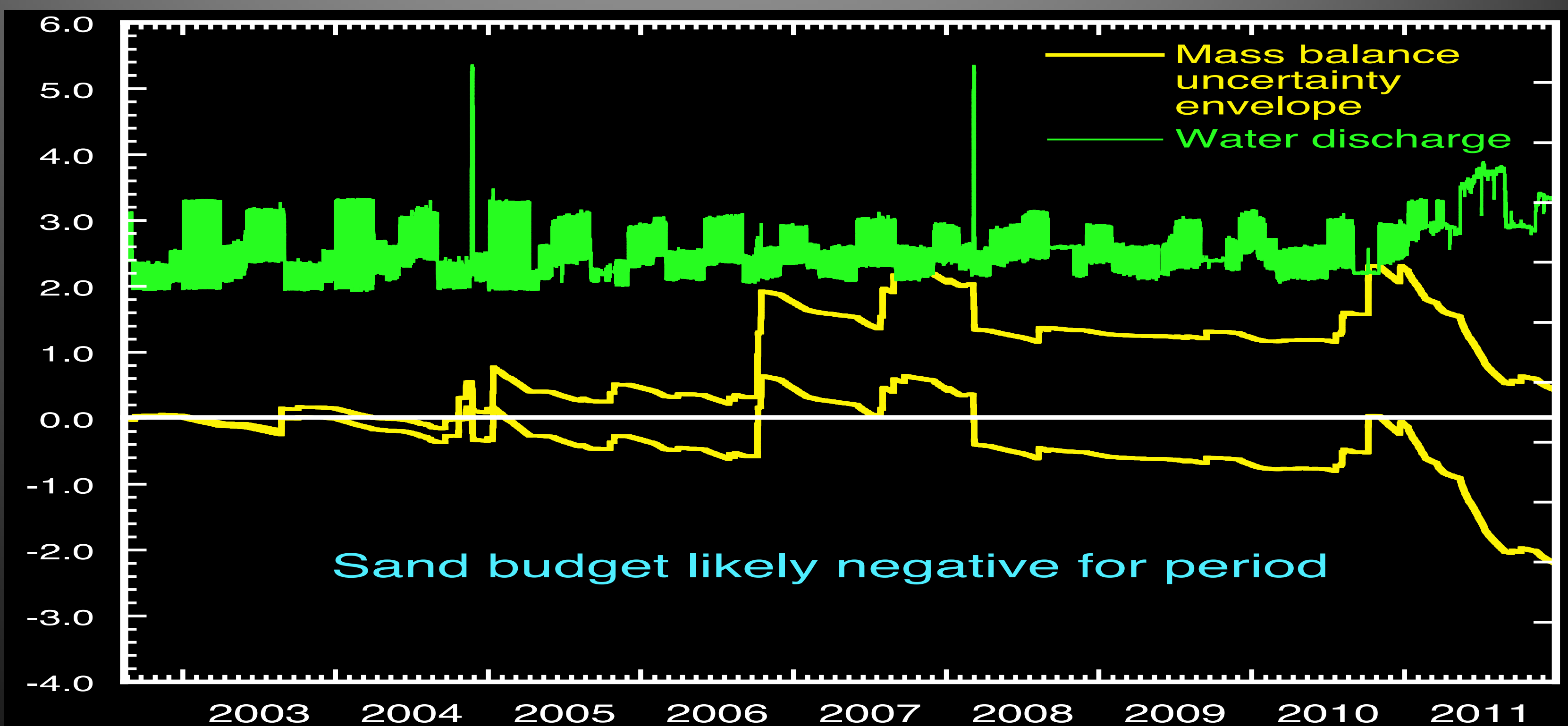
Grams, KA workshop, 2012



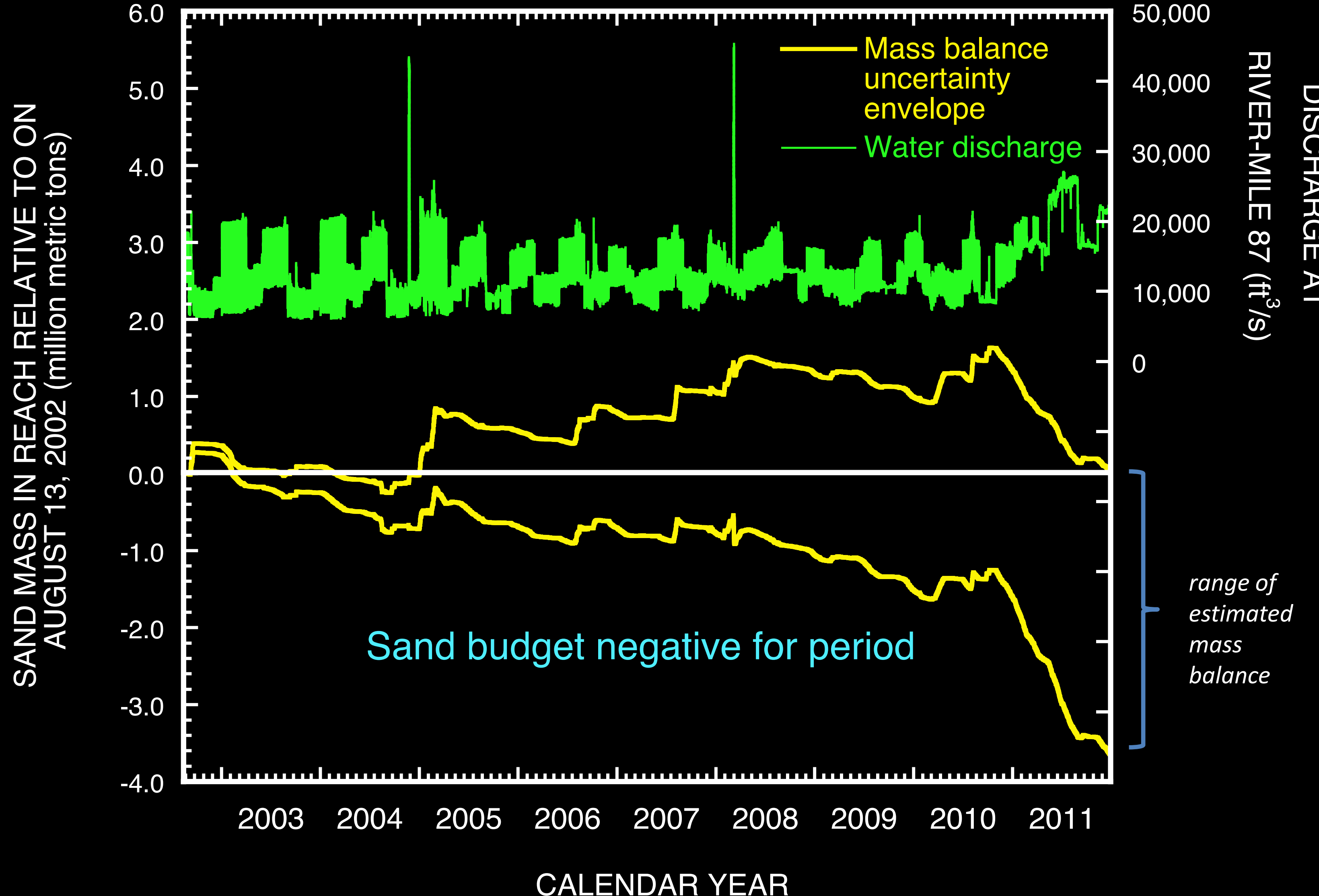
Floods cause increase in sandbar size at middle-and high-elevations



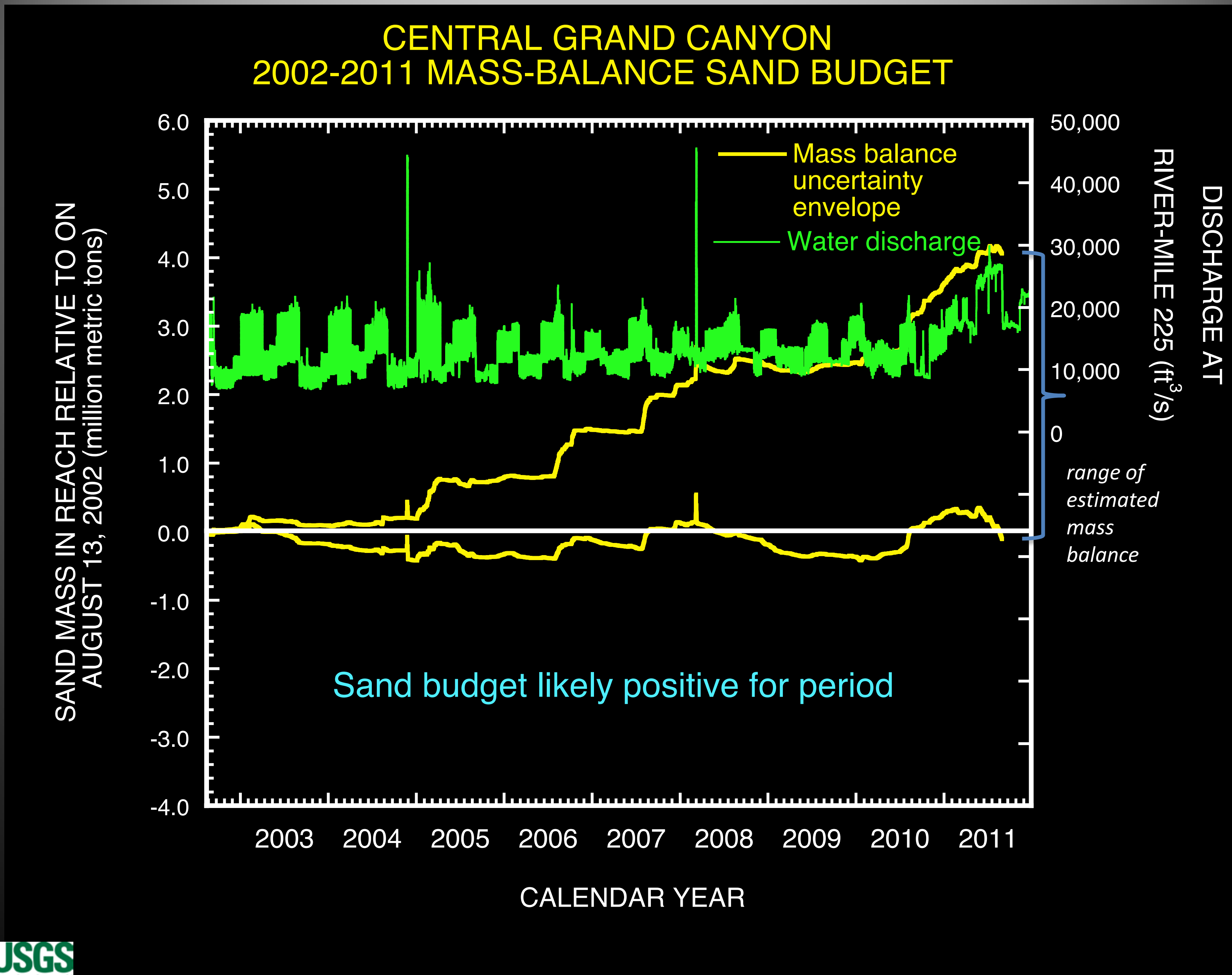
Grams, KA workshop, 2012



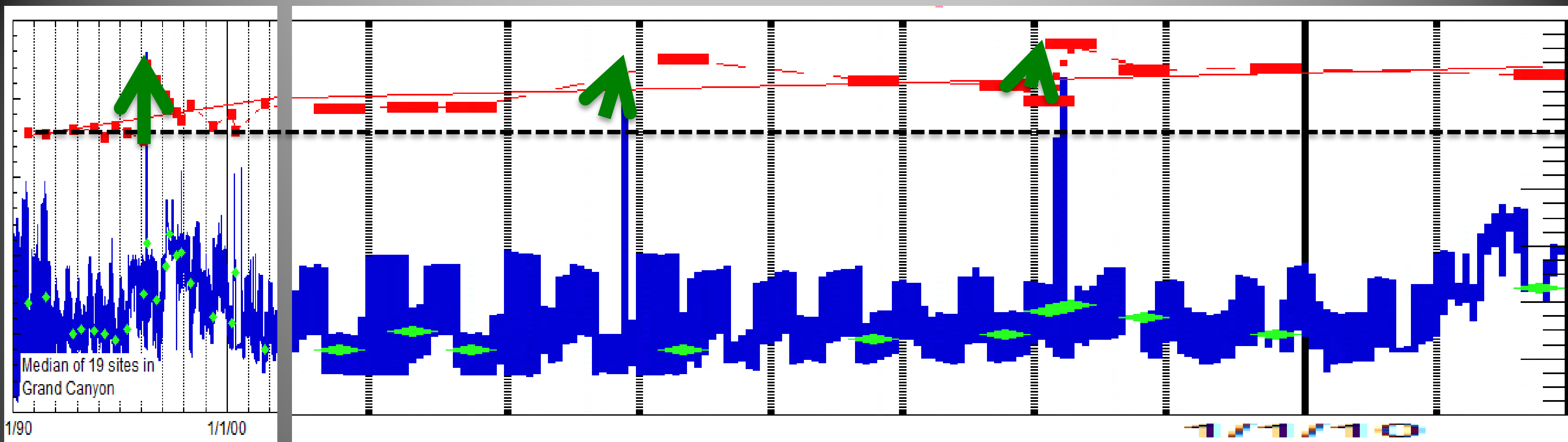
EASTERN GRAND CANYON
2002-2011 MASS-BALANCE SAND BUDGET



USGS science for a changing world

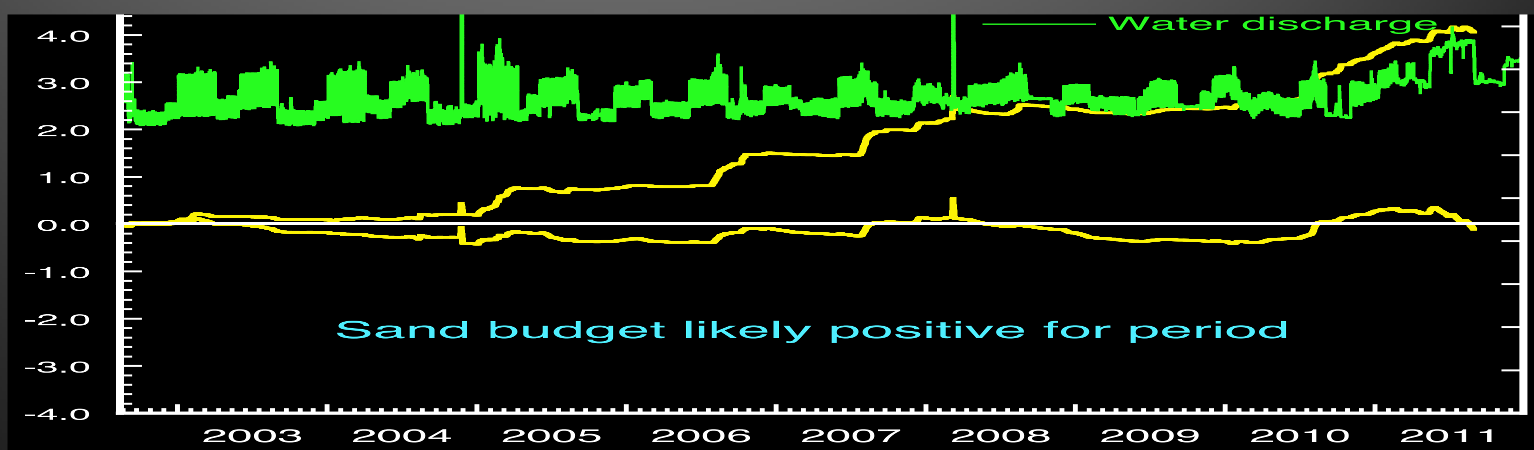


CENTRAL GRAND CANYON
2002-2011 MASS-BALANCE SAND BUDGET
SAND MASS IN REACH RELATIVE TO ON AUGUST 13, 2002 (million metric tons)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Mass balance uncertainty envelope
Water discharge
50,000
40,000
30,000
20,000
10,000
0
DISCHARGE AT RIVER-MILE 225 (ft3/s)
range of estimated mass balance
Sand budget likely positive for period
2003
2004
2005
2006
2007
2008
2009
2010
2011
CALENDAR YEAR
USGS
science for a changing world



eastern Grand Canyon (RM 61-87)

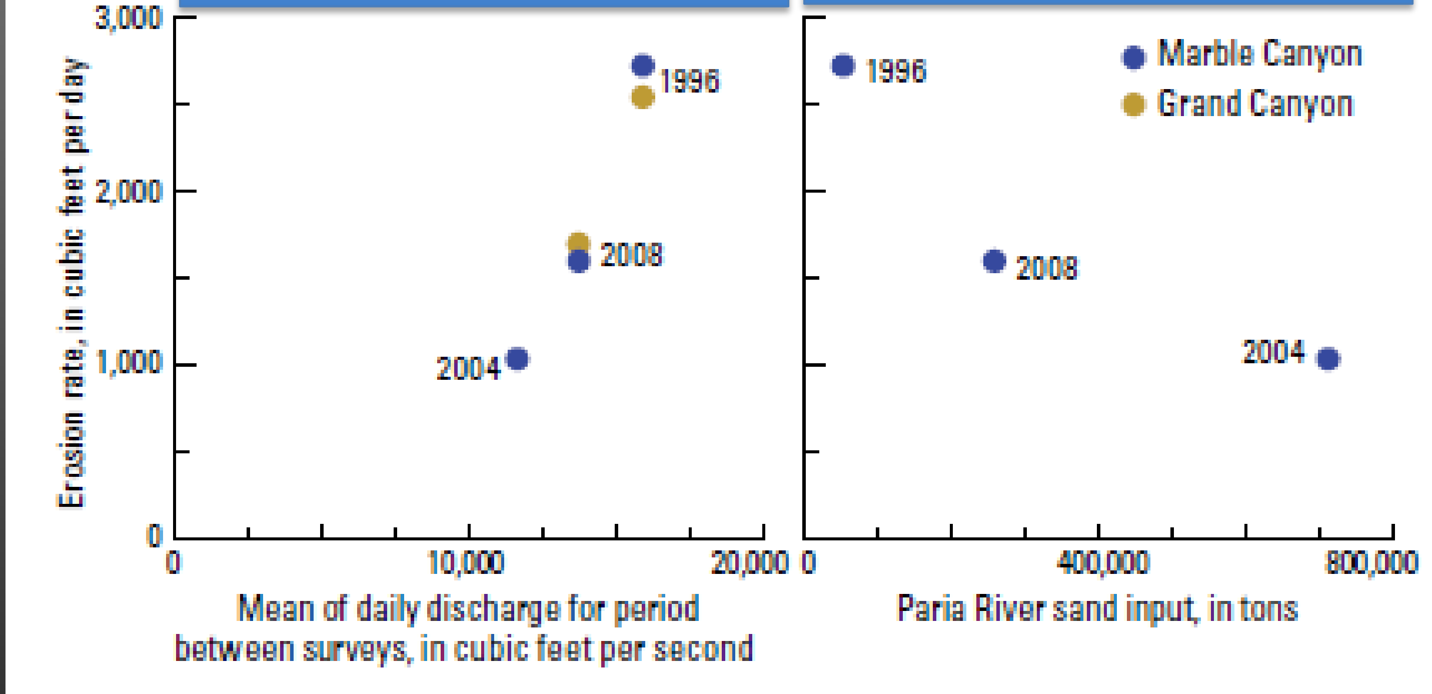
central and western Grand Canyon (RM 61-87)



Rate of sandbar erosion following floods is positively correlated with flow volume and negatively correlated with tributary sediment inputs

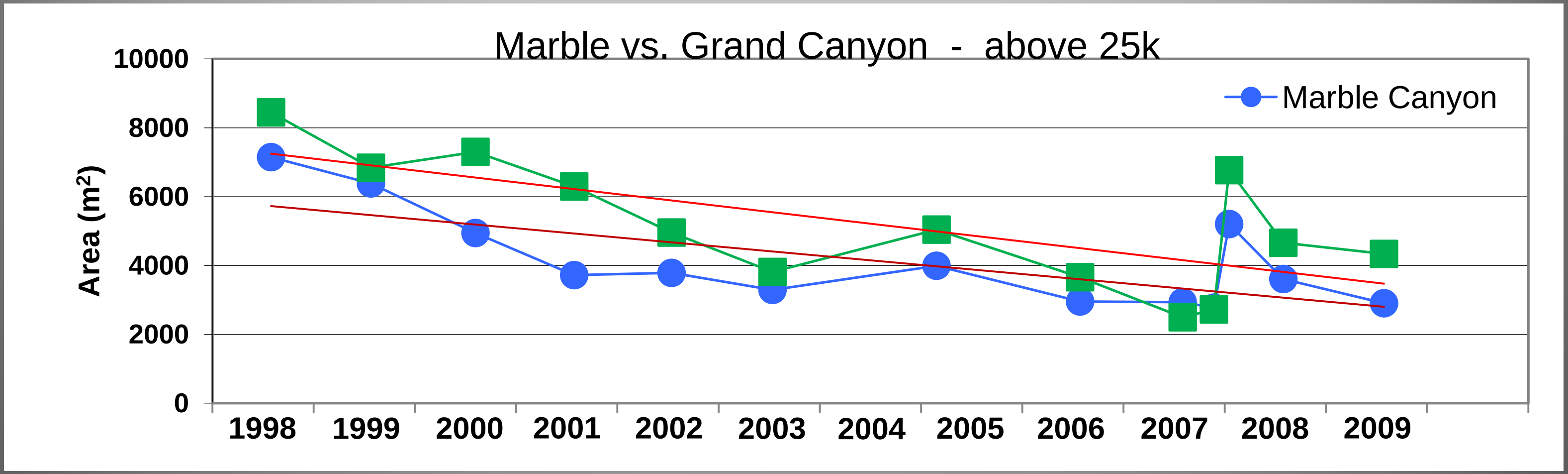
Higher flows → higher erosion rates

Tributary resupply → lower erosion rates

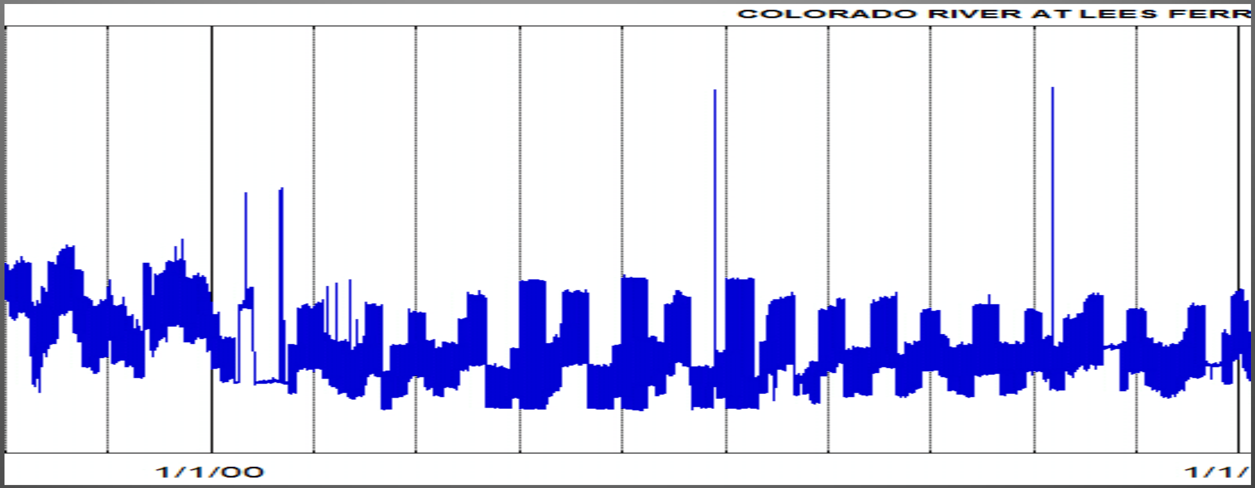


Grams and others (2010); Schmidt and Grams (2011)

Ramping rates do not significantly affect rate of sandbar mass failure (Alvarez and Schmeeckle, in prep.)



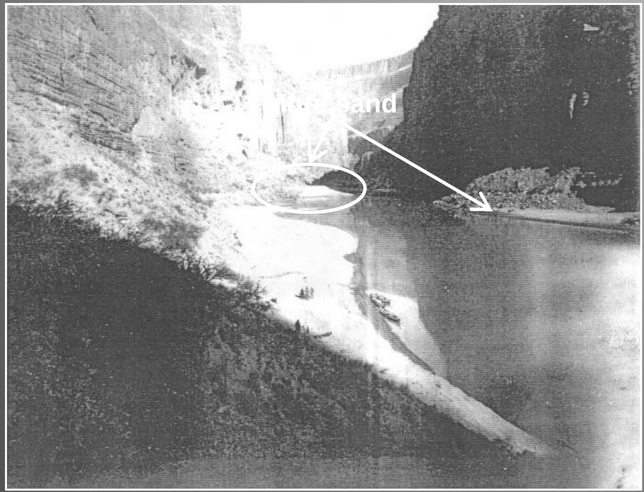
(Kaplinski et al, unpubl)



Total amount of campsite area has declined

Campable area (a.k.a. campsite capacity) is declining faster/more steadily than sand bar area - vegetation encroachment appears to be a primary (but not the only) cause of this difference

RM 41.50R:



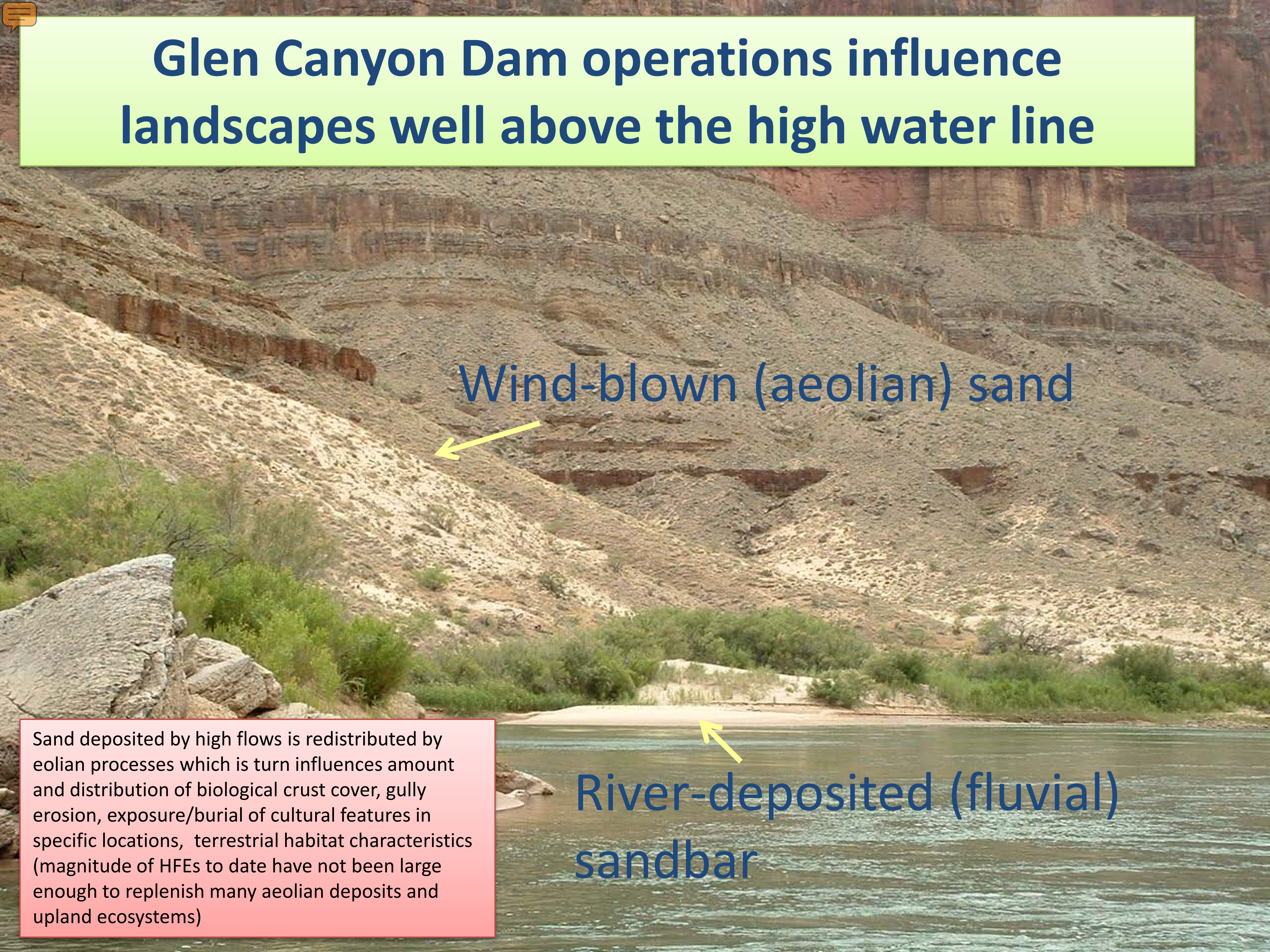
January 16, 1890 (Stanton's collection)

→

September 10, 1994 (~daily max 12,600 ft^3/s, min 8,100 ft^3/s, mean 10,000 ft^3/s; Robert H. Webb collection)

1155 March 31, 2008 (~10,000 ft^3/s) → 1255 May 14, 2008 (~11,300 ft^3/s)

Glen Canyon Dam operations influence landscapes well above the high water line



Sand deposited by high flows is redistributed by eolian processes which is turn influences amount and distribution of biological crust cover, gully erosion, exposure/burial of cultural features in specific locations, terrestrial habitat characteristics (magnitude of HFEs to date have not been large enough to replenish many aeolian deposits and upland ecosystems)

Questions ahead

- Aquatic ecosystem
  - Aquatic food base (mainstem and tribs)
  - Native fish population dynamics
  - Non-native fish population dynamics
  - Efficacy of translocations and of trout control
- Terrestrial ecosystem
  - Riparian ecosystem dynamics
  - Efficacy of control options
- Physical processes
  - Better characterization of average, large-scale changes in sand storage, sand bars, and campsites
  - Improvements in modeling capability
- Cultural resources
  - Appropriate detailed for site monitoring
  - Detailed vs. large-scale
- Socio-economic resources