Annual Reporting Meeting – Day 1 (January 18, 2011)

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5	Update to TWG on Campsite Monitoring and other Recreation Projects (Goal 9)	Helen Fairley
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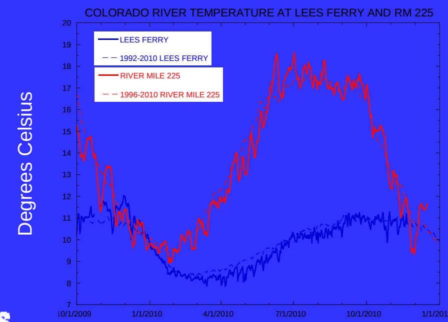
Update on Water Quality and 2010 Sand Input

GCDAMP Annual Reporting Meeting
January 18, 2011

Paul Grams and David Topping

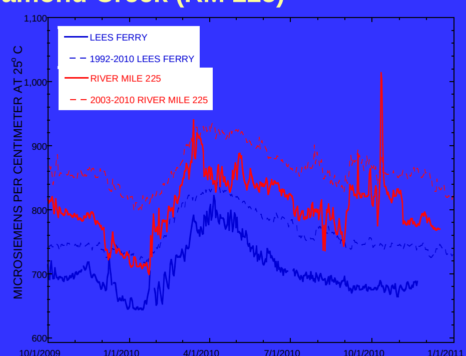
U.S. Department of the Interior
U.S. Geological Survey

2010 Water Temperature at Lees Ferry and Diamond Creek (RM 225)

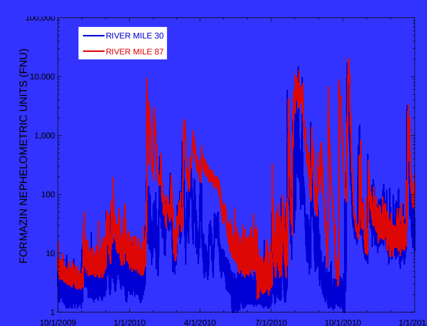


2010 was an average year

2010 Specific Conductance at Lees Ferry and Diamond Creek (RM 225)



Turbidity at RM 30 and RM 87

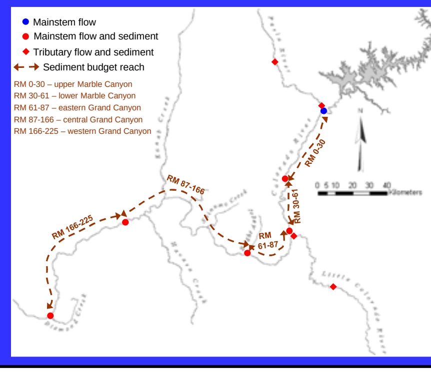


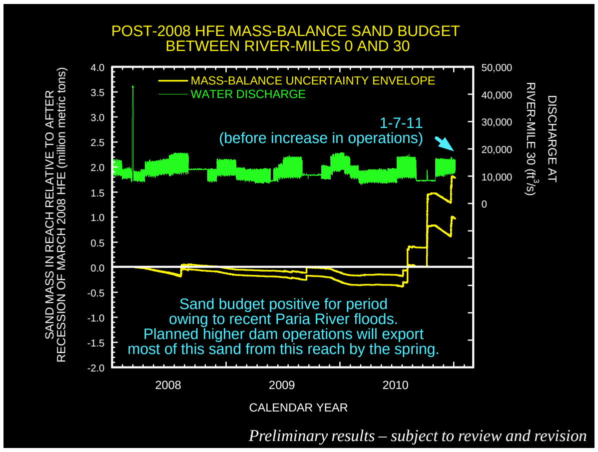
Flux monitoring for managing sediment and sandbars

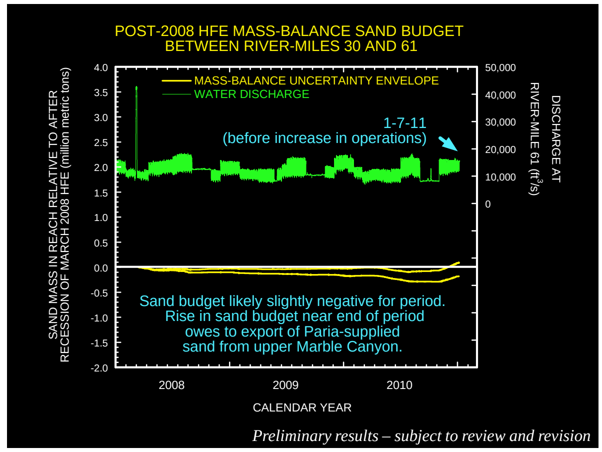
- **Flux monitoring:**
  - **Tracks tributary sediment inputs and mainstem transport at five locations to track status of the sediment "bank account."**
  - **Provides the information needed to time high flows for building sandbars to follow periods of sand accumulation.**

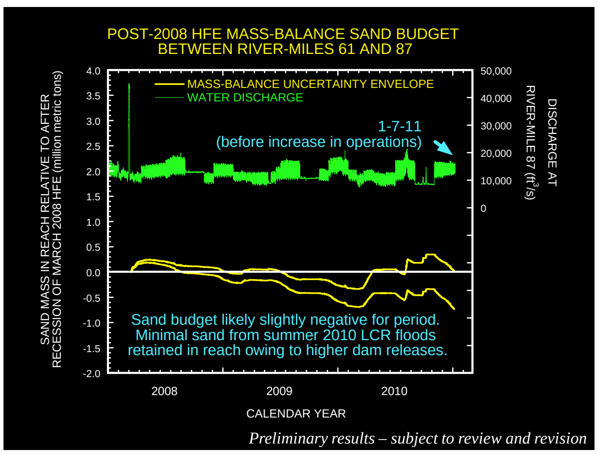
USGS Sediment Flux Monitoring Program in Grand Canyon

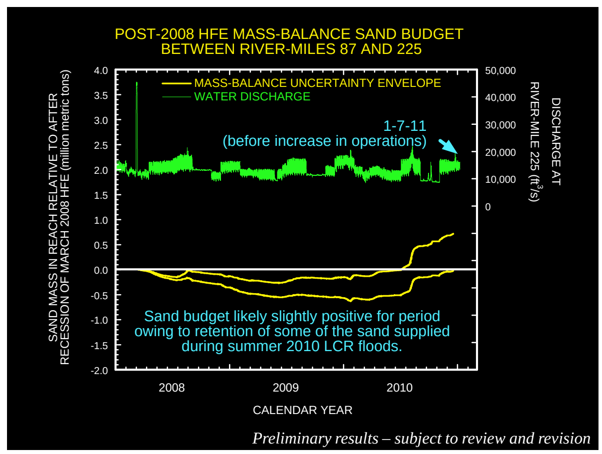
David Topping
Ronald Griffiths
Thomas Sabol
Nicholas Voichick
Karen Vanaman











Sand update: January 7, 2011

- RM 0 to RM 30,
  - Budget is currently positive (Jan. 7, 2011) between 1.0 and 1.8 million metric tons.
  - Does not include recent change in operations
- RM 30 to RM 61
  - Budget is currently slightly negative, between 0 and -0.2 million metric tons.
  - Slight rise at end of period is transfer of fall 2010 inputs from upper to lower Marble Canyon.
- RM 61 to 87
  - Budget is currently slightly negative, between 0 and -0.7 million metric tons.
  - Not much retention of summer 2010 Little Colorado River inputs.
- RM 87 to 225
  - Budget is currently positive (Jan. 7, 2011) between 0 and 0.7 million metric tons.
  - Retention of some of the summer 2010 Little Colorado River floods.

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Preliminary results – subject to review and revision

Summary

- Water temperature at Lees Ferry and Diamond Creek is about average.
- Specific conductance (salinity) is low.
- Turbidity in Marble Canyon has been relatively high.
- There were above average sand inputs in July through October 2010.
- Winter fluctuating flows (currently 13,000 to 20,000 cfs) will export sand.

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Preliminary results – subject to review and revision

Other Goal 7 FY 2010 Accomplishments/Products

- Monitoring
  - Flow, temperature, water quality and sediment data collected processed and reported
  - 9 published papers, including HFE reports (USGS reports, journal articles, and proceedings papers)
  - Through a cost-sharing and savings agreement with Arizona Water Science Center, implemented flow and sediment monitoring on Kanab and Havasu Creeks
- Modeling
  - 4 published papers (USGS reports, journal articles, and proceedings papers)
  - Use of sand routing model in 2011 hydrograph development
  - Knowledge transfer of sand routing model to Reclamation for use in HFE Environmental Assessment
  - Continued efforts towards development of working 3D eddy model

USGS

Goal 7 FY 2011

- Monitoring
  - Continued operation of monitoring stations, reporting of data, and publication of methods and results
  - Work with database and web staff to improve accessibility to data
- Modeling
  - Use of sand routing model (DEPENDING ON INTEREST AND NEED)
  - Sandbar stability experiments still underway at ASU (now with very little GCDAMP support)
  - 3D eddy model development still underway at USGS in Golden, CO (for now, with USGS base funding and very little GCDAMP support)

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Goal 8: Long Term Monitoring for Changes in Sediment Storage "SedTrend"

GCDAMP Annual Reporting Meeting
January 18, 2011
Phoenix AZ

Paul Grams, Matt Kaplinski, and Joe Hazel

U.S. Department of the Interior
U.S. Geological Survey

Purposes of SedTrend Channel Mapping Project

- Provides long-term monitoring for changes in sand storage to evaluate effects of dam operations over periods of several years.
- Provides channel topography for modeling.
- Provides data to evaluate the degree to which sandbar monitoring sites are representative of system-wide changes in sandbars
- Provides channel topography for characterization and evaluation of aquatic habitat.

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Strategic Science Questions that motivate Goal 8 Monitoring

- AMWG Priority 3: What is the best flow regime? (GCDAMP goals 1–11)
  - Is there a "Flow-Only" operation (i.e., a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales?

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Strategic Science Questions that motivate Goal 8 Monitoring

- AMWG Priority 3: What is the best flow regime? (GCDAMP goals 1–11)
  - Is there a "Flow-Only" operation (i.e., a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales?

What have we learned?

- *High flows rebuild sandbars.*
- *We've also learned that the cost can be net erosion from the channel and lower parts of sandbars.*
- *Sandbars erode again following high flows → Need to repeat high flows to maintain bars.*
- *Thus, the part of the question about "maintaining sandbars over decadal timescales?" remains unanswered.*

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Strategic Science Questions that motivate Goal 8 Monitoring

- AMWG Priority 3: What is the best flow regime? (GCDAMP goals 1–11)
  - Is there a "Flow-Only" operation (i.e., a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will restore and maintain sandbar habitats over decadal timescales?

What questions will we want to answer if there are repeated high flows over the next 10 years?

- *Will multiple high flows conducted over a period of several years result in net increases in sandbar area and volume?*
- *With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable?*

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These are the fundamental sediment-related high flow science questions. *How will they be addressed?*

Strategic Science Questions that motivate Goal 8 Monitoring

- *Will multiple high flows conducted over a period of several years result in net increases in sandbar area and volume?*
- Addressed by monitoring sandbars above 8,000 cfs stage.
  - Annual (with high flows) to every-other year (without high flows) monitoring of long-term sandbar monitoring sites (NAU sites).
  - Systemwide monitoring every 4 years by overflights.

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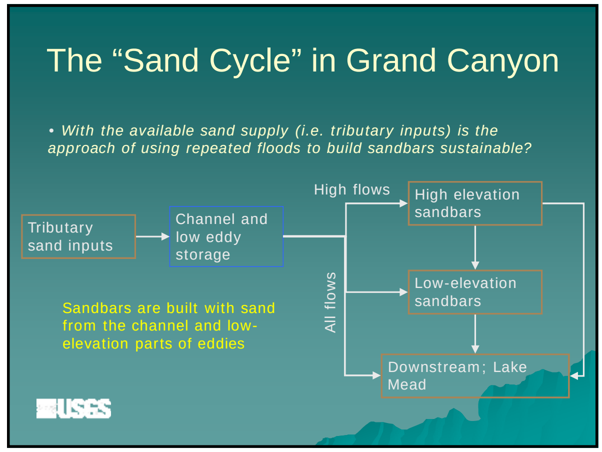
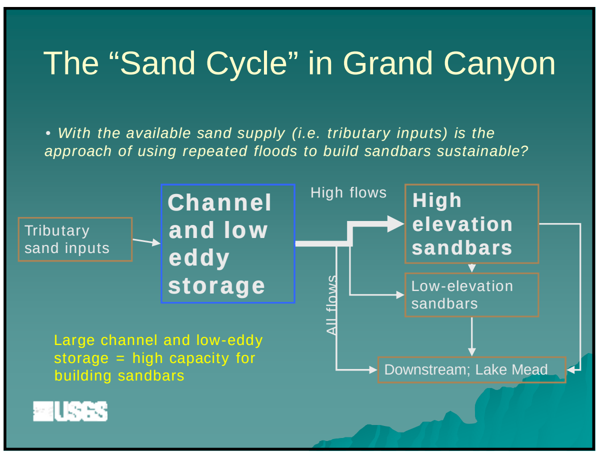
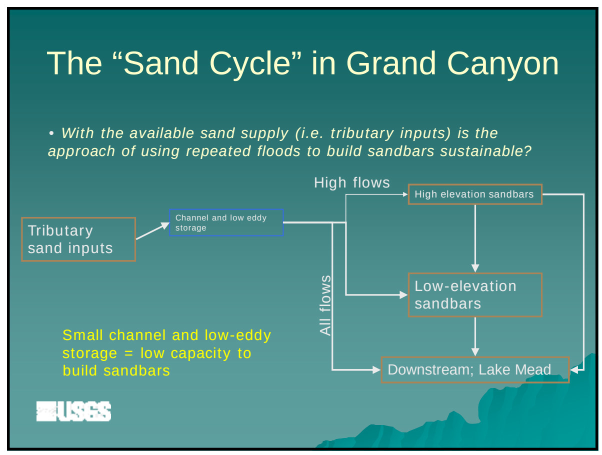
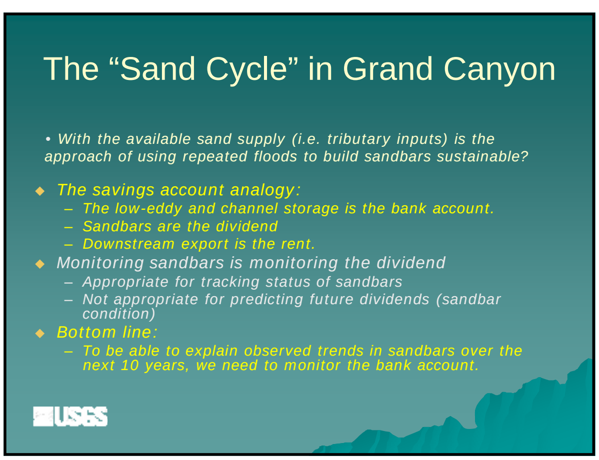
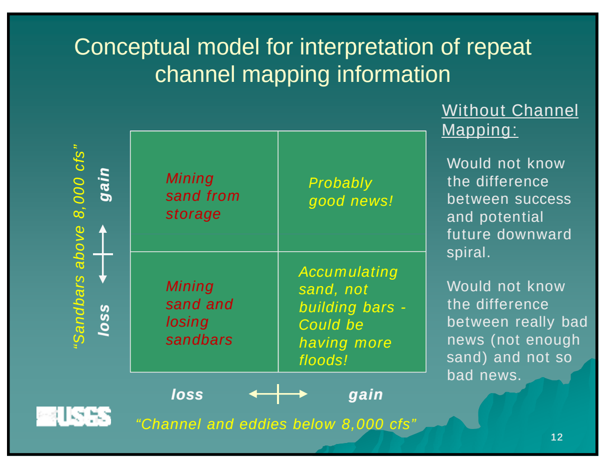
Strategic Science Questions that motivate Goal 8 Monitoring
With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable?
Addressed by repeat channel mapping
USGS

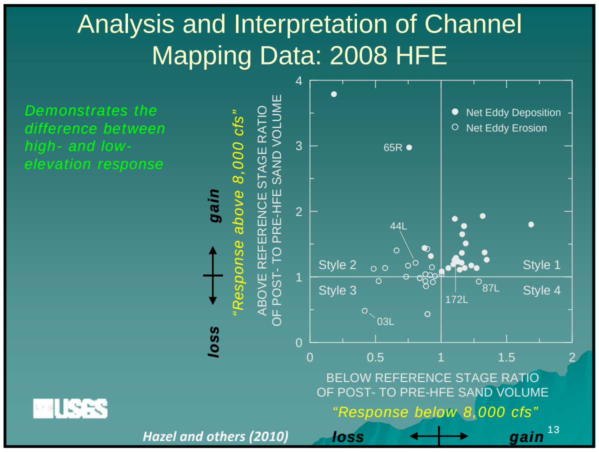

The “Sand Cycle” in Grand Canyon
• With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable?
Tributary sand inputs
Channel and low eddy storage
High flows
High elevation sandbars
All flows
Low-elevation sandbars
Downstream; Lake Mead
Sandbars are built with sand from the channel and low-elevation parts of eddies
USGS

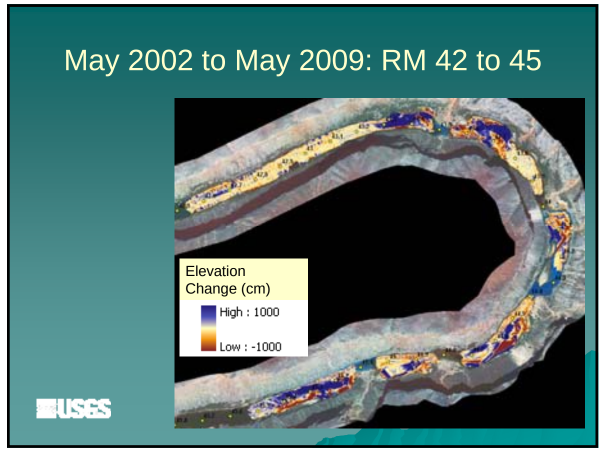

The “Sand Cycle” in Grand Canyon
• With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable?
Tributary sand inputs
Channel and low eddy storage
High flows
High elevation sandbars
All flows
Low-elevation sandbars
Downstream; Lake Mead
Large channel and low-eddy storage = high capacity for building sandbars
USGS

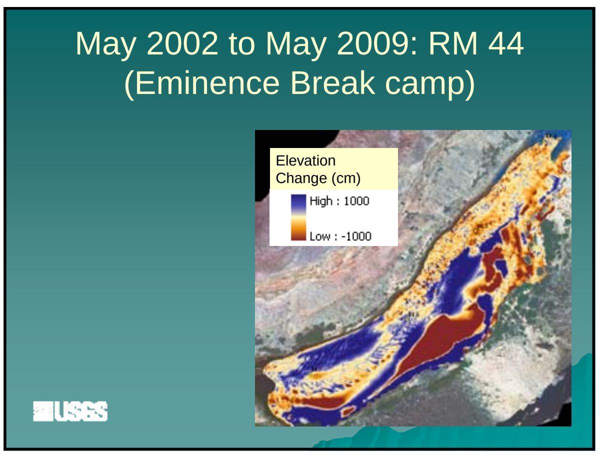

The “Sand Cycle” in Grand Canyon
• With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable?
Tributary sand inputs
Channel and low eddy storage
High flows
High elevation sandbars
All flows
Low-elevation sandbars
Downstream; Lake Mead
Small channel and low-eddy storage = low capacity to build sandbars
USGS

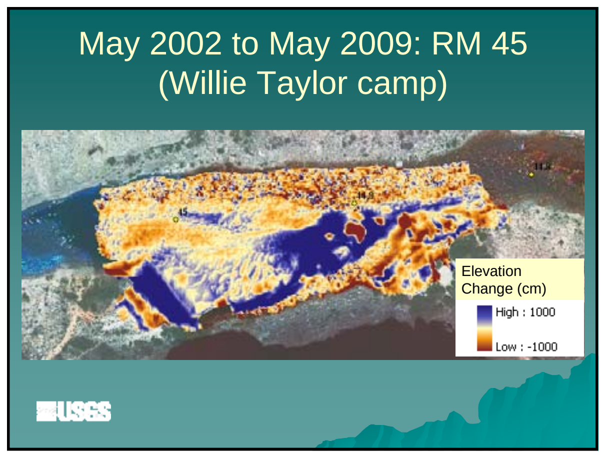

The “Sand Cycle” in Grand Canyon
• With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable?
The savings account analogy:
– The low-eddy and channel storage is the bank account.
– Sandbars are the dividend
– Downstream export is the rent.
Monitoring sandbars is monitoring the dividend
– Appropriate for tracking status of sandbars
– Not appropriate for predicting future dividends (sandbar condition)
Bottom line:
– To be able to explain observed trends in sandbars over the next 10 years, we need to monitor the bank account.
USGS

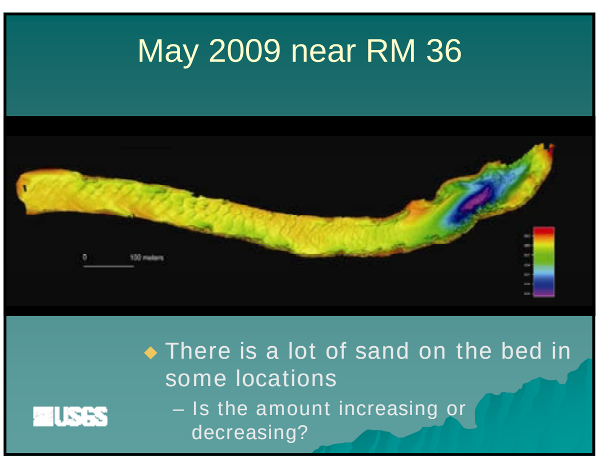

Conceptual model for interpretation of repeat channel mapping information
Without Channel Mapping:
Would not know the difference between success and potential future downward spiral.
Would not know the difference between really bad news (not enough sand) and not so bad news.
"Sandbars above 8,000 cfs"
gain
loss
Mining sand from storage
Probably good news!
Mining sand and losing sandbars
Accumulating sand, not building bars - Could be having more floods!
loss
gain
"Channel and eddies below 8,000 cfs"
USGS
12

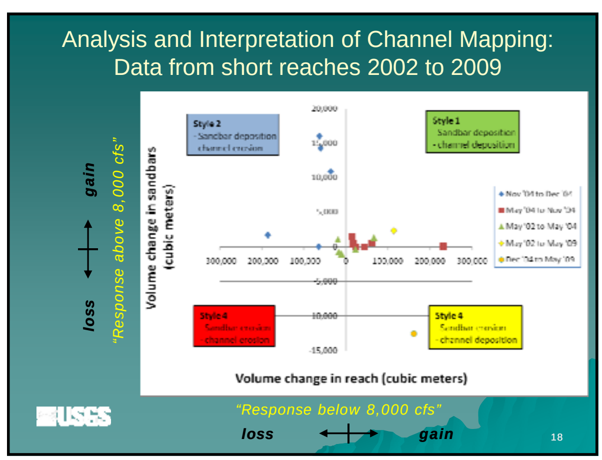

Analysis and Interpretation of Channel Mapping Data: 2008 HFE
Demonstrates the difference between high- and low-elevation response
gain
loss
"Response above 8,000 cfs"
ABOVE REFERENCE STAGE RATIO OF POST- TO PRE-HFE SAND VOLUME
Net Eddy Deposition
Net Eddy Erosion
65R
44L
Style 2
Style 1
Style 3
Style 4
172L
87L
03L
0
0.5
1
1.5
2
3
4
BELOW REFERENCE STAGE RATIO OF POST- TO PRE-HFE SAND VOLUME
"Response below 8,000 cfs"
Hazel and others (2010)
loss
gain
13


May 2002 to May 2009: RM 42 to 45
Elevation Change (cm)
High : 1000
Low : -1000


May 2002 to May 2009: RM 44 (Eminence Break camp)
Elevation Change (cm)
High : 1000
Low : -1000


May 2002 to May 2009: RM 45 (Willie Taylor camp)
Elevation Change (cm)
High : 1000
Low : -1000


May 2009 near RM 36
There is a lot of sand on the bed in some locations
– Is the amount increasing or decreasing?


Analysis and Interpretation of Channel Mapping: Data from short reaches 2002 to 2009
gain
loss
"Response above 8,000 cfs"
Volume change in sandbars (cubic meters)
Style 2
Style 1
Style 4
Style 4
20,000
10,000
-10,000
-15,000
300,000
200,000
100,000
0
Volume change in reach (cubic meters)
"Response below 8,000 cfs"
loss
gain
18

Results from repeat channel mapping of short reaches: 2000 to 2009

- Comparison of responses above and below 8,000 cfs stage
  - High- and low-elevation responses are often opposite, sometimes they are similar
    - Reflects response to HFEs
    - Reflects periods of sand accumulation
    - Reflects periods of sandbar erosion
- Small fraction of changes in sand storage are above 8,000 cfs stage
  - Up to 25% when HFEs build sandbars
  - Usually less than 5% under normal operations
- Short reaches (up to 10 mi) NOT representative of long reaches (~ 30 mi)
- To explain the responses and make interpretations about prospects for sandbar maintenance over long time periods, we need to conduct these analyses over longer reaches.

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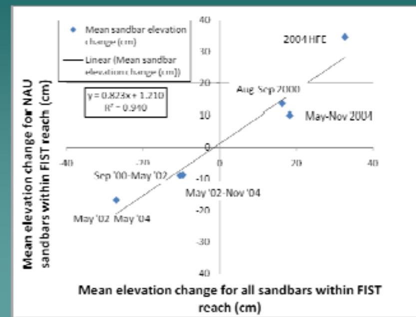
Within short (1.5 to 3 mile) reaches, sandbar monitoring sites (NAU sites) are representative of all sandbar changes above 8,000 cfs stage



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Outstanding questions that continued repeat channel mapping will help answer

- Is the approach of using repeated HFEs to build and maintain sandbars sustainable over long (decadal) periods of time?
- Are the sandbar monitoring sites representative of changes over long (~30 mi) reaches?
- Can we monitor sand storage by subsampling?
  - Once we've done some repeat mapping of long reaches, we may be able to devise an appropriate subsampling scheme.

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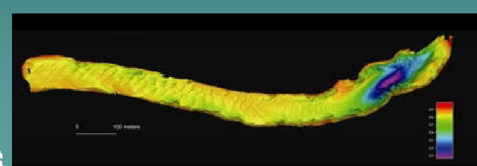
SedTrend Channel Mapping: 2010-2012

- 2011
  - Complete reports that are in progress on the data collected between 2000 and 2009.
  - Map RM 61-87 and process those data.
- 2012
  - Compare 2011 data with previous mapping for the parts of the RM 61-87 reach where data are available and publish report on that comparison.
  - Map either RM 0-30 or RM 166-225.



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FY10: Sandbar and Campsite Monitoring in Colorado River in Marble and Grand Canyons

Joe Hazel, Matt Kaplinski, Rod Parnell, and Nathan Schott

U.S. Department of the Interior
U.S. Geological Survey

Annual Reporting Meeting
January 18, 2011

Strategic Science Questions pertaining to sandbars and campsites

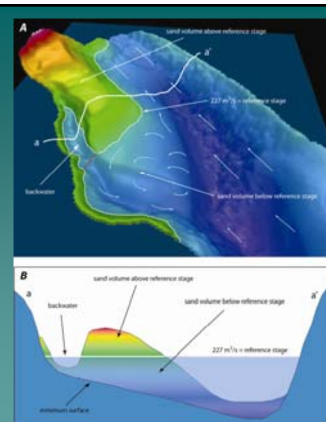
- Is there a "flow-only" operation that will rebuild and maintain sandbar habitats over decadal timescales?
- Will multiple high flows conducted over a period of several years result in net increases in sandbar area and volume?
- Determine and track the effects of ROD operations on the size, quality, and distribution of camping beaches in the Colorado River ecosystem.

Where is the sand?

~50 to 90% of the sand in Marble Canyon is stored in eddies. About 90% of the sand in eddies is stored below the stage elevation reached by a flow of 8,000 ft^3/s (Hazel et al., 2006, J. Geophys. Res., 11).

Study Design

1) Topographic field surveys annually and in some years more frequently between 1990 and 2009 at long-term study sites distributed throughout the river corridor
2) Bathymetric surveys were collected in the 1990s and before and after the 2004 HFE and 2008 HFE

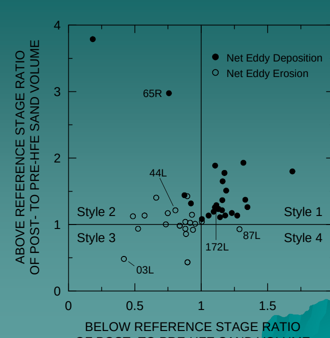


Grams et al., 2010, FISC

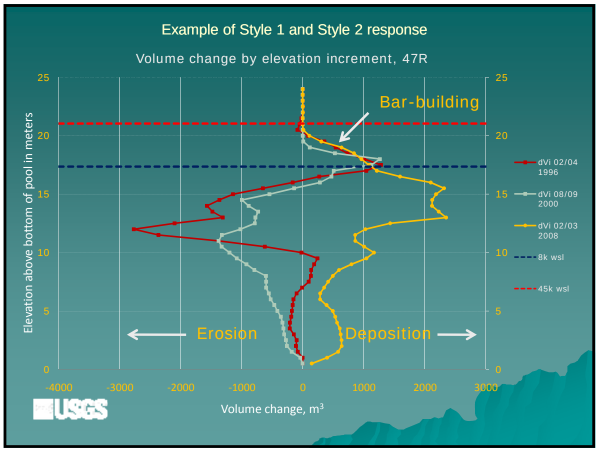
2008 HFE styles of topographic response

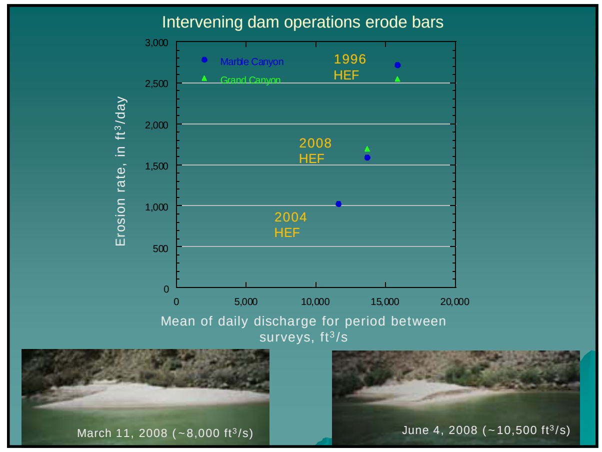
Style 1 was net increase in volume (fill) at all elevations above and below reference stage (45% of the study sites)

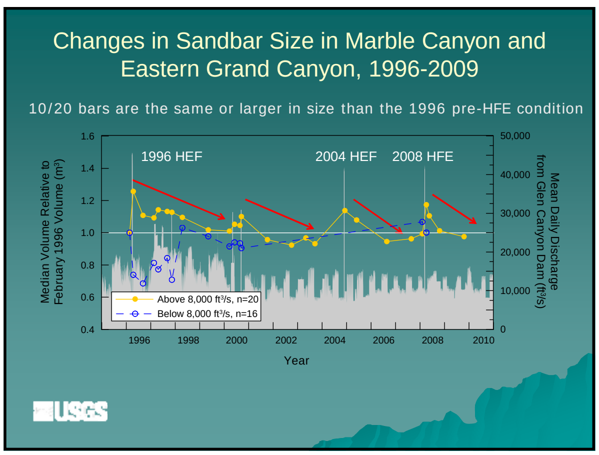
Style 2 was net decrease in volume (scour) in the eddy and channel below reference stage and net fill in the eddy above base flow stage (37% of the sites)

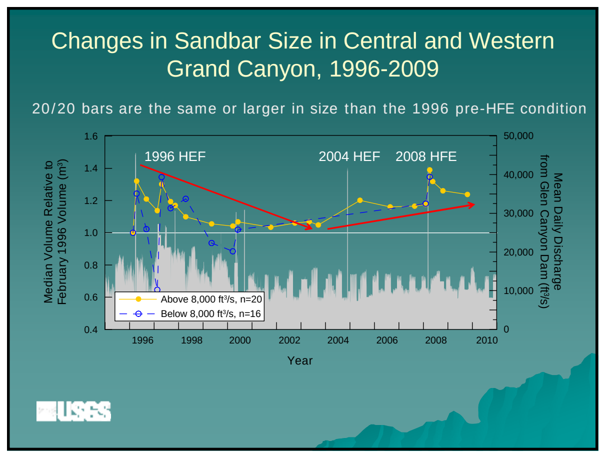


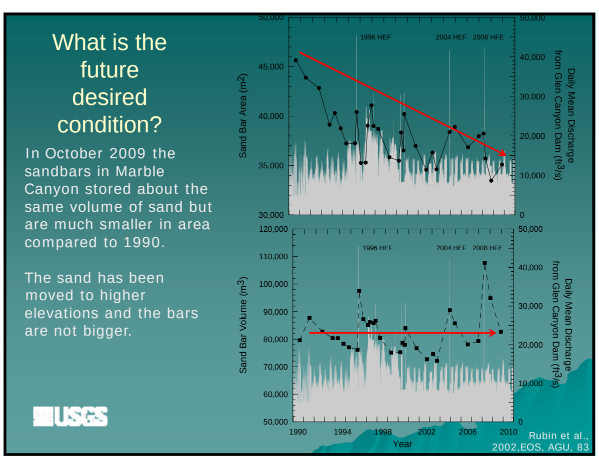
Hazel et al., SIR 2010-5015

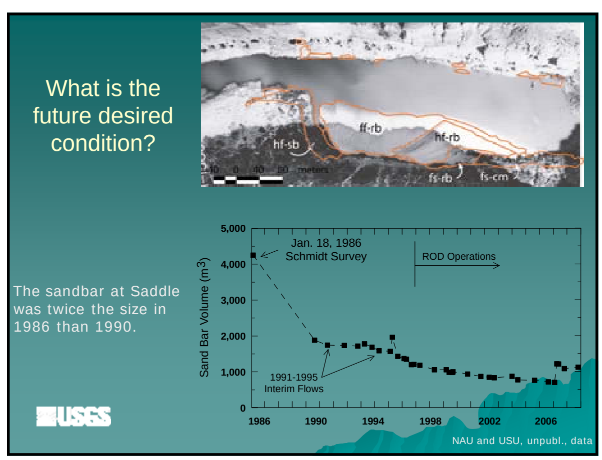

Example of Style 1 and Style 2 response
Volume change by elevation increment, 47R
Bar-building
Elevation above bottom of pool in meters
Erosion
Deposition
dVi 02/04 1996
dVi 08/09 2000
dVi 02/03 2008
8k wsl
45k wsl
Volume change, m³
USGS


Intervening dam operations erode bars
Marble Canyon
Grand Canyon
1996 HEF
2008 HEF
2004 HEF
Erosion rate, in ft³/day
Mean of daily discharge for period between surveys, ft³/s
March 11, 2008 (~8,000 ft³/s)
June 4, 2008 (~10,500 ft³/s)


Changes in Sandbar Size in Marble Canyon and Eastern Grand Canyon, 1996-2009
10/20 bars are the same or larger in size than the 1996 pre-HFE condition
1996 HEF
2004 HEF
2008 HFE
Median Volume Relative to February 1996 Volume (m³)
Mean Daily Discharge from Glen Canyon Dam (ft³/s)
Above 8,000 ft³/s, n=20
Below 8,000 ft³/s, n=16
Year
USGS


Changes in Sandbar Size in Central and Western Grand Canyon, 1996-2009
20/20 bars are the same or larger in size than the 1996 pre-HFE condition
1996 HEF
2004 HEF
2008 HFE
Median Volume Relative to February 1996 Volume (m³)
Mean Daily Discharge from Glen Canyon Dam (ft³/s)
Above 8,000 ft³/s, n=20
Below 8,000 ft³/s, n=16
Year
USGS

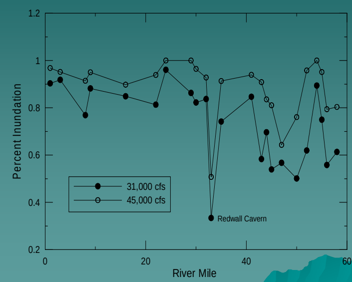

What is the future desired condition?
In October 2009 the sandbars in Marble Canyon stored about the same volume of sand but are much smaller in area compared to 1990.
The sand has been moved to higher elevations and the bars are not bigger.
Sand Bar Area (m²)
Sand Bar Volume (m³)
Daily Mean Discharge from Glen Canyon Dam (ft³/s)
Year
Rubin et al., 2002,EOS, AGU, 83
USGS


What is the future desired condition?
hf-sb
ff-rb
hf-rb
fs-rb
fs-cm
meters
The sandbar at Saddle was twice the size in 1986 than 1990.
Jan. 18, 1986 Schmidt Survey
ROD Operations
1991-1995 Interim Flows
Sand Bar Volume (m³)
NAU and USU, unpubl., data
USGS

The potential role of powerplant capacity flows to build bars?

73% inundated by 31,000 ft³/s
88% inundated by 45,000 ft³/s

31,000 inundation depth=3.2 m
45,000 inundation depth=4.1 m



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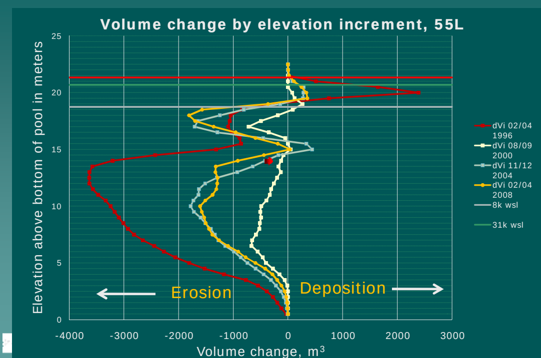
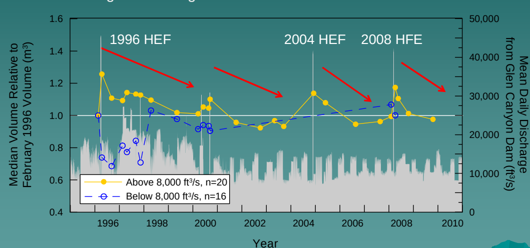
There is a substantial difference in deposit thickness that can result from that difference in inundation depth



Changes in Sandbar Size in Marble Canyon and Eastern Grand Canyon, 1996-2009

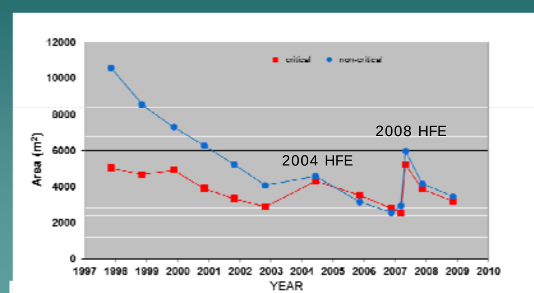
Deposition by the two 31,000 ft³/s in 2000 were not effective in bar building or slowing the erosion rate between 1996 and 2000



USGS

Campsite changes 1999-2009

25% and 55% of the area measured in 1999 remains in noncritical and critical reaches, respectively



Strategic Science Questions pertaining to sandbars and campsites

- Is there a "flow-only" operation that will rebuild and maintain sandbar habitats over decadal timescales?

The results from the 2008 HFE show that floods timed with tributary-supplied sand can build bars. Questions remain whether this is a sustainable approach for Marble Canyon over decadal timescales.

- Will multiple high flows conducted over a period of several years result in net increases in sandbar area and volume?

There are distinct longitudinal differences in sandbar volume that suggest this has occurred in central and western Grand Canyon.

- Determine and track the effects of ROD operations on the size, quality, and distribution of camping beaches in the Colorado River ecosystem.

The 2008 HFE resulted in short-term campsite area gains but campsite area continues to decline in both critical and noncritical reaches.

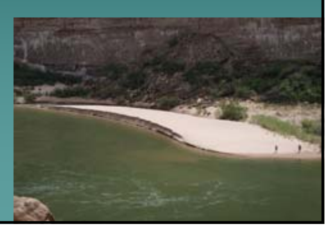
USGS

Anticipated products in FY2011:

Hazel, J.E., Jr., Kaplinski, M., Schott, N., Parnell, R., Grams, P., and Ross, R., in progress, Sand Storage Measured at Selected Sites in Colorado River in Marble and Grand Canyons, Arizona, 1990-2009: U.S. Geological Survey Scientific Investigations Report 20xx-xxxx, xx p.

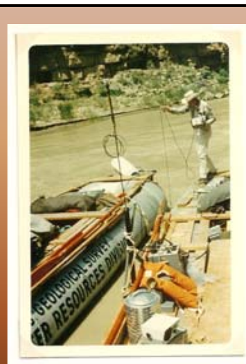
Kaplinski, M., Grams, P., Hazel, J.E., Gushue, T., Tusso, R., Kohl, K., Shott, N., in progress, Monitoring Fine-Sediment Volume in the Colorado River Ecosystem, Arizona: Construction and Analysis of Digital Elevation Models, U.S. Geological Survey Scientific Investigations Report.

Parnell, R., Kaplinski, M., Hazel, J.E., Jr., and Schott, N., in progress, Campsite Area Measurements in Marble and Grand Canyons, 1998-2009: U.S. Geological Survey Data Series Report.



USGS

N OF SEDIMENT FROM THE COLORADO RIVER– 1965 TO 2009

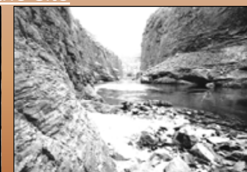


Nina E. Kilham, John C. Schmidt, Joseph M. Wheaton, Paul E. Grams
With a little help from: Alan Howard, Bill Emmett, Tim Randle, and Matt Kaplinski

FY 2010 Project Annual Reporting Meeting for TWG

Below Redwall Cavern RM 33.50L
Downstream view from the site

January 15, 1890; Stanton expedition



January 3, 1992; Robert H. Webb (~daily mean 13,400 ft³/s)

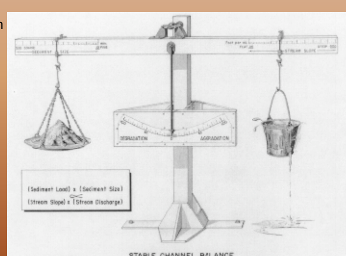
March 30, 1999 (~daily mean 13,600 ft³/s)

April 4, 2009 (~8,000 ft³/s)

Photo compilation M. Majerova (Utah

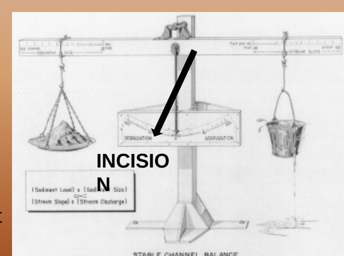
Borland's illustration of Lane's (1955) concept, drawn by Vitaliano

What do first principles tell us?



Balance between the energy of the river provided by flowing water to transport sediment, and the sediment load supplied to the river.

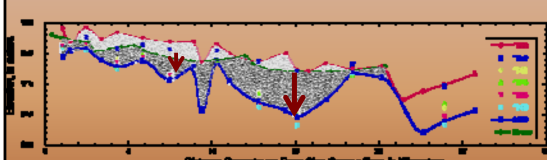
95% of sediment cut-off

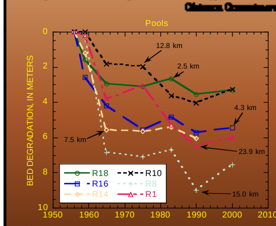


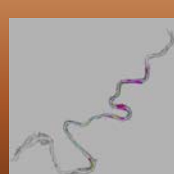
63% reduction in 2-yr flood

Topping et al., 2003

In Glen Canyon, sediment deficit, bed incision occurred ….

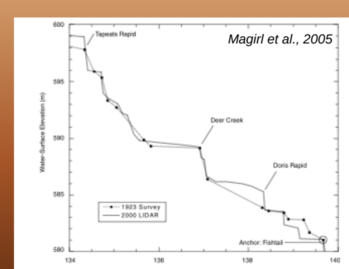






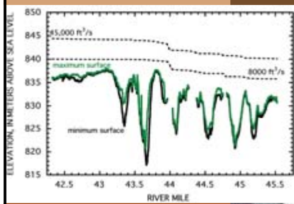
Grams et al., 2007

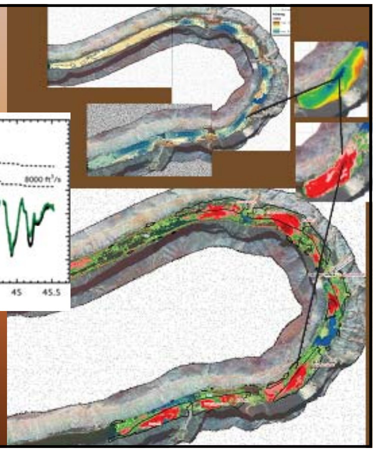
Coarse bouldery rapids prevent bed adjustment in Grand Canyon. With low sediment supply and steep channel slope, mass balance deficit remains and available fine sediment is efficiently removed from system.



RM 42.3-45.5

Minimum Surface





Transient Storage

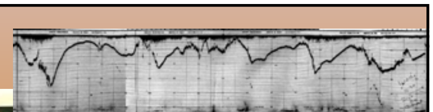
Key Questions

- Is there evidence for a wave of pool evacuation downstream from Glen Canyon Dam?
- How fast did (or is) the Colorado adjusting to sediment trapping behind the dam?

Why do these questions matter?

- We know that the sand for building sandbars (during floods) comes from the channel.
- We know that floods use (by transporting downstream and building sandbars) about as much sand as tributaries supply.
- We do NOT know the long term trend of sand storage in the channel.
  - If negative, the capacity to use high flows to build sandbars will decrease.
    - Must be extremely careful about scheduling of high flows and consider the effect of intervening dam operations.
  - If positive, the capacity to use high flows to build sandbars is great.
    - Opportunity to be more aggressive with high flows and intervening operations.
  - If neutral, the capacity to use high flows to build sandbars is likely adequate.
    - Intermediate approach.

1976



1965

1984

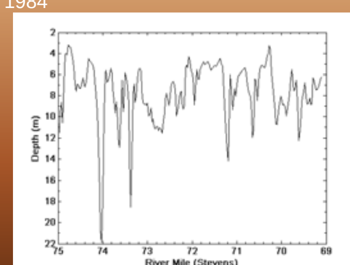


Photo from William Emmett

2000

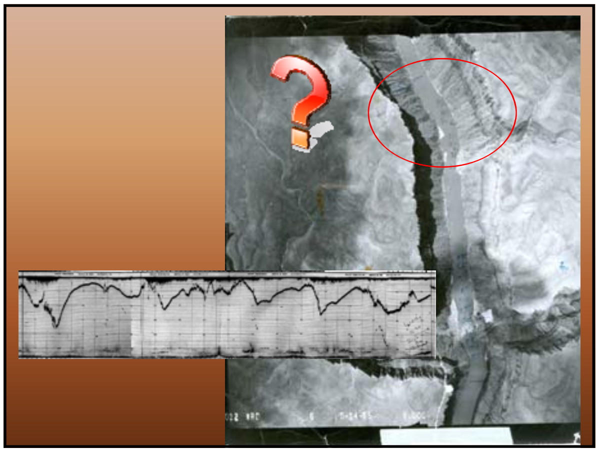
Photo from Matt Kaplinski

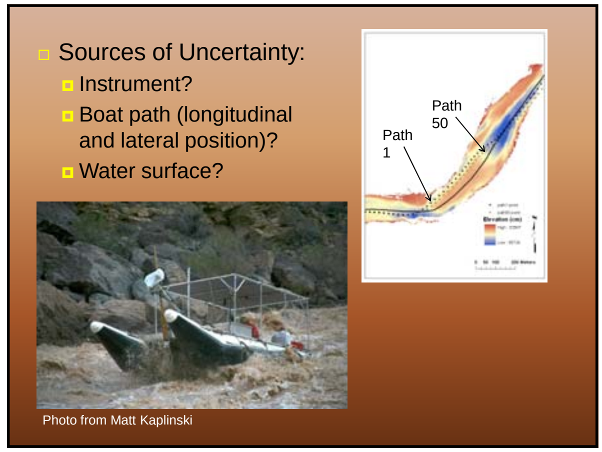
June 20 [camped at Buck Farm]
"After dinner, we stayed up well into the night — at least, those of us who lasted – telling tall tales and partaking of libation. Here comes the famous barracuda story and the infamous pistol shooting. Nine bottle so far — what a crew!"

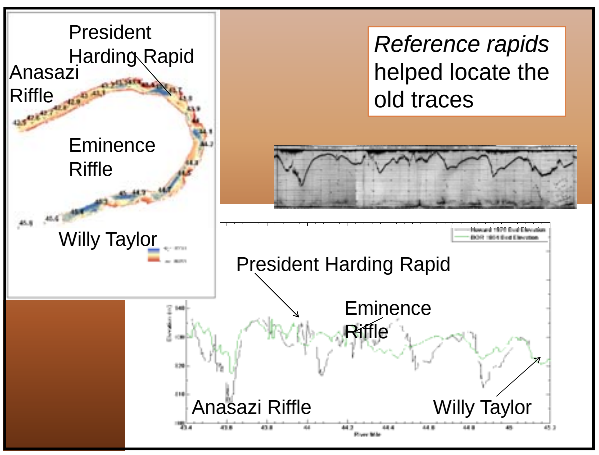
Historic Datasets

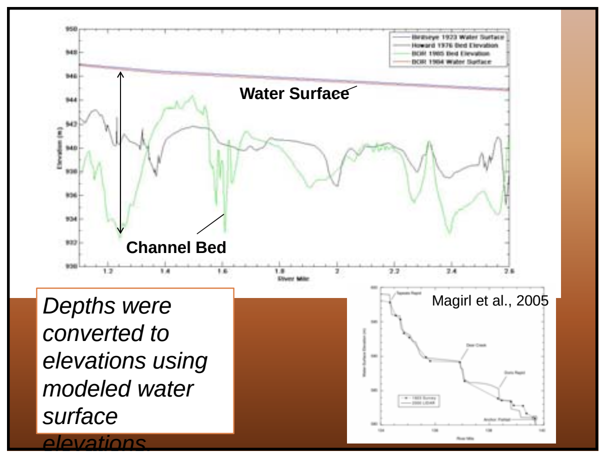
Year	Data Source	Instrument	m	Discharge cms	WSE* m	Path m	Total m
Jun-65	Leopold/Emmett	Heathkit, MI-11A Fishfinder	0.3	1372	1	2.5	**2.7**
Jul-76	Howard/Dolan	reported in Dolan et al., 1978	0.3	578	0.4	2.5	**2.5**
Mar-84	USGS/BOR	reported by Tim Randle as a total error high WSE of .6 low .15	0.15	678-708	0.6	2.5	**2.6**
1992-1995	Graf	sonic-depth sounder	0.39	194-558	0	0	**0.4**
Aug-00	FIST	Reson SeaBat 8124 multibeam-sonar **	0.088	227	0	0	**0.1**
May-02	FIST	Reson SeaBat 8124	0.074	227	0	0	**0.1**
Jun-04	FIST	Reson SeaBat 8124	0.063	227	0	0	**0.1**
Nov-04	FIST	Reson SeaBat 8124	0.048	227	0	0	**0.0**
Dec-04	FIST	Reson SeaBat 8124	0.05	227	0	0	**0.1**
May-09	GCMRC	Garmen GPS Fish Finder	0.15	227	0.32	0	**0.4**

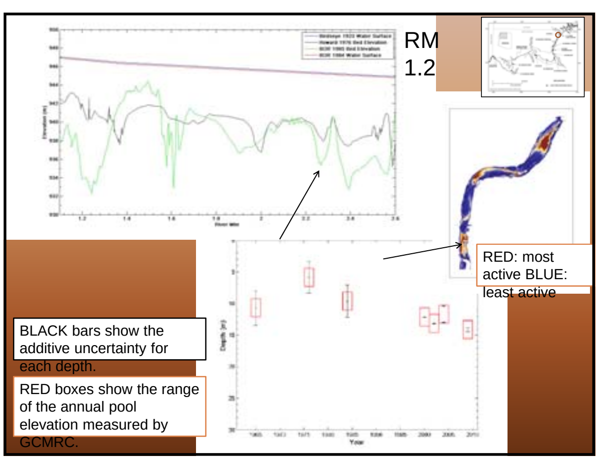
**Reported by MaGirl et al., 2008*
***SDEz Reported in Table 4 of Kaplinski et al., 2009*

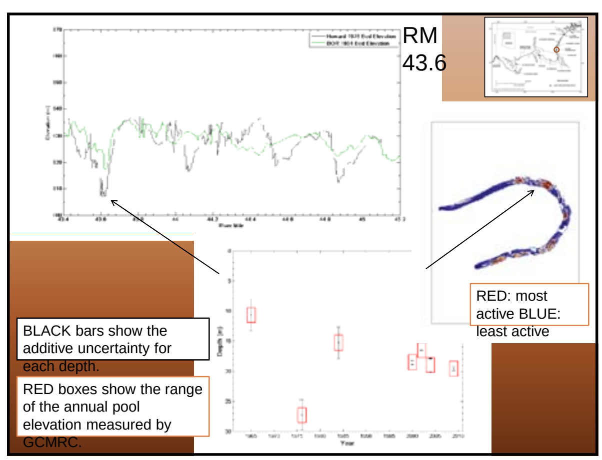


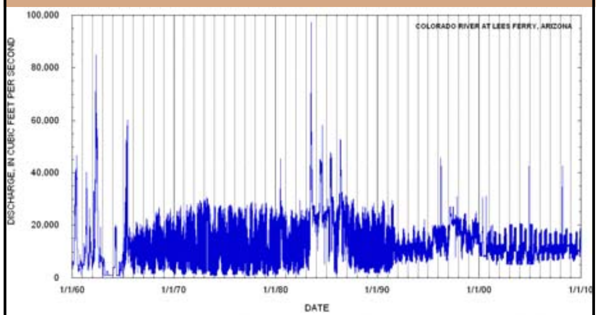

Sources of Uncertainty:
Instrument?
Boat path (longitudinal and lateral position)?
Water surface?
Path 50
Path 1
Photo from Matt Kaplinski

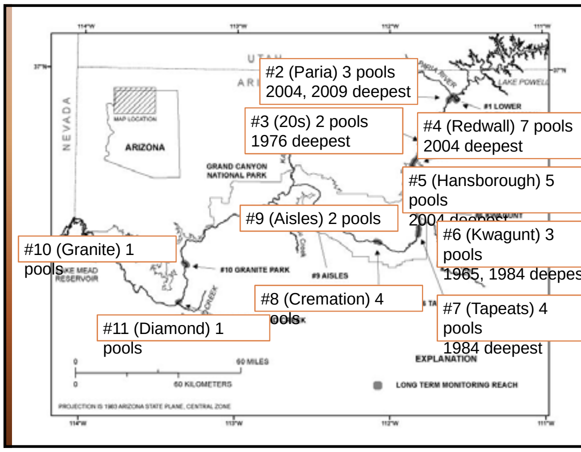

President Harding Rapid
Anasazi Riffle
Eminence Riffle
Willy Taylor
Reference rapids helped locate the old traces
President Harding Rapid
Eminence Riffle
Anasazi Riffle
Willy Taylor


Water Surface
Channel Bed
Depths were converted to elevations using modeled water surface elevations
Magirl et al., 2005


RM 1.2
RED: most active BLUE: least active
BLACK bars show the additive uncertainty for each depth.
RED boxes show the range of the annual pool elevation measured by GCMRC.


RM 43.6
RED: most active BLUE: least active
BLACK bars show the additive uncertainty for each depth.
RED boxes show the range of the annual pool elevation measured by GCMRC.





What this analysis means…

- The first analysis of the amount of sediment stored in pools in the main channel of the Colorado River between Glen Canyon and Hoover Dams from 1965 to 2009.
- This information can be used to assess the location of long-term study sites, and the relationship between the mobilization and storage of sediment in the main channel and the more intensively monitored eddies.
- This information will help understand long-term trends of sand storage and thereby make more informed decisions about dam operations, such as high flows, to restore sandbars.

Update to TWG on Campsite Monitoring and other Recreation Projects (Goal 9)

Helen Fairley
TWG Annual Reporting Workshop, Phoenix, AZ
January 18, 2011

U.S. Department of the Interior
U.S. Geological Survey

FY 2010 Recreation Projects



1. Monitor Changes in Campsite Area & Quality
   - Campsite area measurements (NAU repeat surveys)
   - Evaluate vegetation encroachment at campsites
     - Evaluate change using remotely sensed imagery and repeat photographs (AAB, Bob Webb, Weeden photo matches)
2. Develop GIS-Based Campsite Atlas
3. Recreation Safety in Relation to Flows Study

Evaluating Role of Vegetation Encroachment in Campsite Area Change

- 1998-2007: NAU campsite area/sand bar surveys showed campsite area declining more rapidly than sand bar area and volume
- Kaplinski et al (2005, 2010) hypothesizes that vegetation encroachment explains the difference
- In the 2010-2011 BWP, GCMRC proposed conducting an interdisciplinary remote sensing project involving comparisons of 2002, 2005, and 2009 imagery; one component involves quantifying rate and amount of vegetation encroachment at campsites using imagery
- Processing of 2009 imagery is well underway but not yet completed (see DASA presentation tomorrow)
- Evaluating vegetation encroachment on campsites is on hold until 2009 imagery is available for analysis

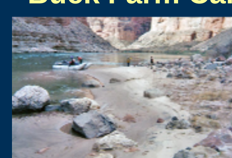
Compile repeat photography to track vegetation encroachment at campsites

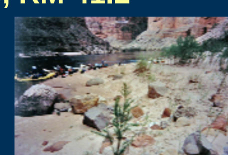
- In addition to analyzing aerial imagery, GCMRC is compiling photo-matches to supplement other sources of information documenting effects of riparian vegetation on campable area in the CRE
  - Adopt-A-Beach photographs
  - Robert H Webb repeat of Stanton photos, 1890 to 1990 and 1990 to 2010
  - Weeden photo matches 1973 to 2007-2010
  - J. Schmidt photo matching project

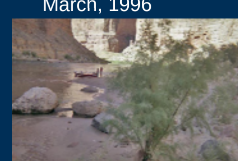
Adopt-A-Beach

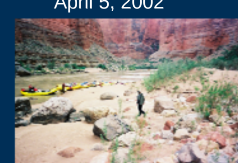
- In 1196, GCRG started this project as an expedient way to monitor effects of 1996 high flow and engage river guides in a “citizen science” initiative
- Project has been continuous since 1996
- In 2010, volunteer river guides adopted 44 beaches; river guides continue to match photos & document observations about change on a written form
- In the fall, GCRG compiles the data, prepares annual report, posts photos on GCRG website
- 2009 report distributed to TWG by Lynn Hamilton July 2010; FY2010 report currently in progress

Buck Farm Camp, RM 41.2


March, 1996


April 5, 2002


July 10, 2004


May 25, 2009

Talking Heads Camp, RM 133.7

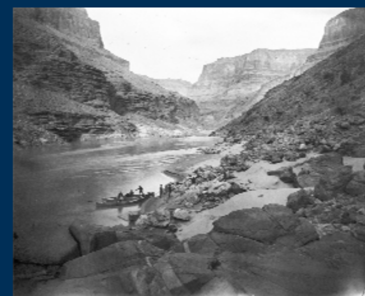

April 17, 1996

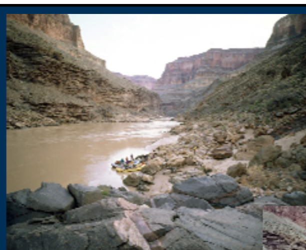

July 15, 1998


Sept 20, 2006


June 8, 2009

Robert H Webb is matching Stanton photos from 1890, 1990-91 and 2010-11





GIS Atlas Project: Revelant SSQs

Atlas will be a data repository & research tool for use in future research & monitoring projects addressing:

- How do varying flows positively or negatively affect campsite attributes?
- How to varying flow regimes positively or negatively affect group encounter rates, campsite competition, and other important social parameters known to be important variables of visitor experience?
- How do dam controlled flows affect visitors' recreation experience, and what are optimal flows for maintaining a high quality recreational experience?

GIS Atlas Project Summary

- USGS (GCMRC) and NPS (GRCA) worked collaboratively in 2007-2009 to develop GIS-based campsite atlas maps and match 1973 Weeden photographs
- Atlas is designed to serve as primary data repository and research tool for future campsite monitoring in the CRE
- 500+ current and historical camps identified; ~ 220 currently actively managed by NPS (NPS primary sites)
- Atlas will be used to track change and archive data from GCD AMP & CRMP monitoring projects
- NPS already using some atlas elements (e.g., maps) to monitor recreation impacts and capacity changes

IN 2010, NPS compiled camp maps and basic data into proto-DVD for river runners

GIS Atlas Shortfalls

- Project is behind schedule – several reasons:
  - GCRMC decided to upgrade GIS software and servers and to redesign website in 2009: this has taken longer than anticipated and delayed installation/testing of pilot atlas in 2010 as planned
  - NPS lost staff in 2008-2009, some positions were not backfilled; NPS GIS technician working on this project was assigned other work priorities

USGS

GIS Atlas 2010 Accomplishments

- Campsite field mapping completed in 2007-2009; mapped data transferred to GIS and has been updated through FY2009
  (Field work accomplished in conjunction with NAU sand bar/campsite monitoring, NPS CRMP monitoring, and GC Youth trips)
- 500+ current and "legacy" campsites identified & input to GIS
- 4400+ photographs of campsites digitized, entered into photo database, linked to GIS data
- 400+ documents about GRCA campsites scanned -- approx. 30 key reports will be made available with the first atlas
- As of December 2010, GCRMC DASA staff installed new version of ArcServer (GIS software). Now are developing and testing a proto-type version of the atlas on internal website

USGS

Project Schedule (2011)

- Enter 2010 NPS data and additional photographs into database – winter/spring 2011
- Finalize customized code to link GIS data, photos, and reports and test on internal web – winter/spring 2011
- Prepare introductory web pages, refine web delivery software, etc . – spring 2011
- Serve first public version of the atlas – summer 2011

USGS

Recreation Safety in Relation to Flows

- Primary SSQ
  - How can safety and navigability be reliably measured in relation to flows?
- Secondary SSQ
  - What are the drivers for recreational experiences in the CRE, and how important are flows relative to other drivers in shaping recreational experience outcomes?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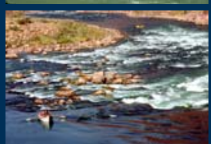
Recreation Safety in Relation to Flows

Project Summary:

- Original plan was to compile and analyze all GCES, NPS, and other relevant data on recreation safety in relation to Colorado River flows
- NPS requested change in scope to focus on literature review, review of other safety monitoring programs, review of options for monitoring safety in relation to flows
- Research is being conducted through coop with Northern Arizona University (2 Yr NAU Masters Thesis)

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Recreation Safety in Relation to Flows: 2010 Accomplishments and Next Steps:

- NAU graduate student (Kelly McGill) started project in summer 2009; data collection mostly completed in 2010; write up in progress now (winter 2011)

  1) Compiled currently available river recreation safety data from Grand Canyon National Park
  2) Researched what other safety-related studies have been conducted in other parts of the US and how other river management agencies across the nation have address safety issues
  3) Identified knowledgeable experts in river recreation safety and conducted interviews with them
  4) Conducted informal, voluntary survey of Grand Canyon river guides

- Draft thesis anticipated late winter-spring 2011
- Final report anticipated summer 2011

USGS

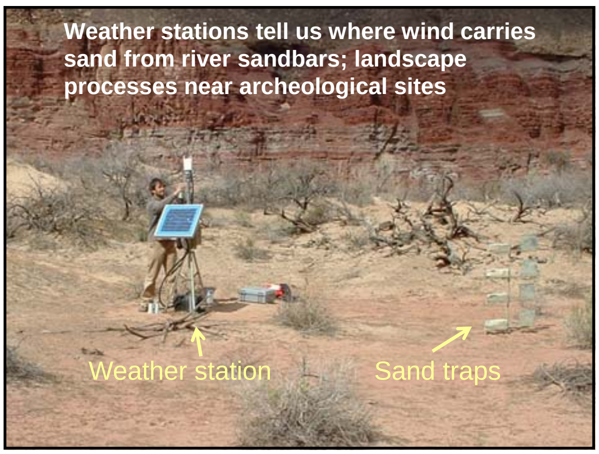
USGS
science for a changing world

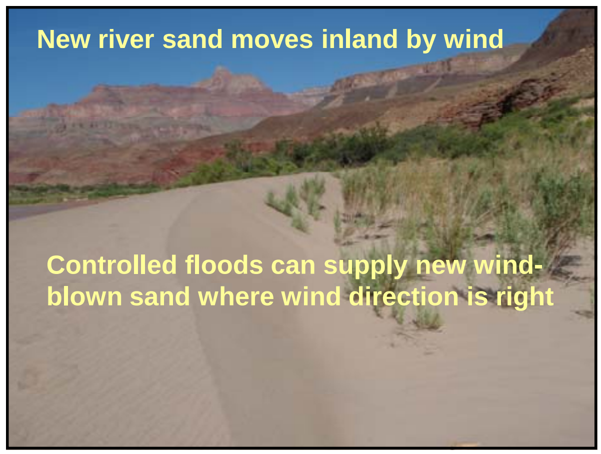
Ground cover and stability of aeolian landscapes

TWG Annual Reporting Meeting
January 18, 2011

Amy Draut
Research Geologist
U.S. Geological Survey, Santa Cruz, CA

U.S. Department of the Interior
U.S. Geological Survey



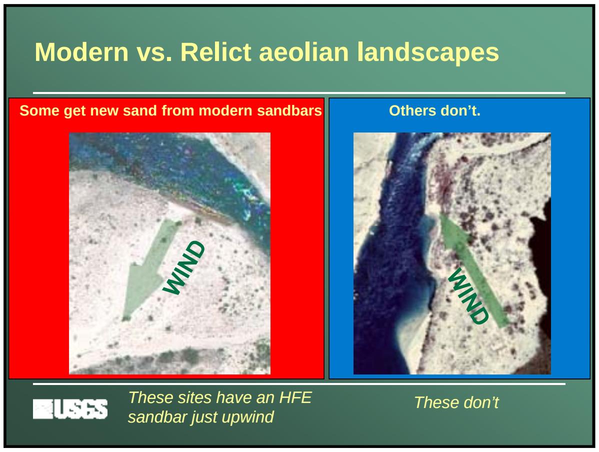


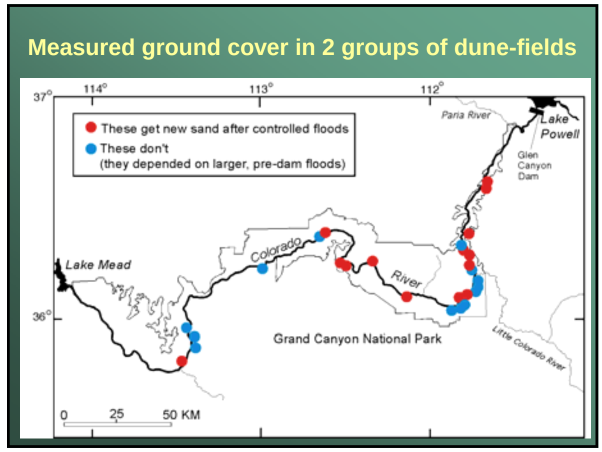
Aeolian landscapes form downwind of river sandbars

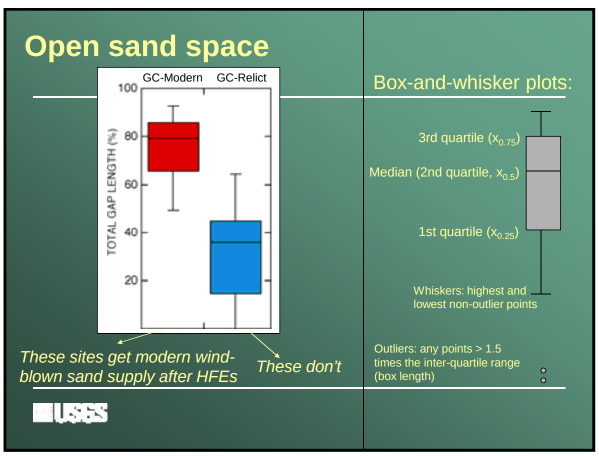
Measure ground cover

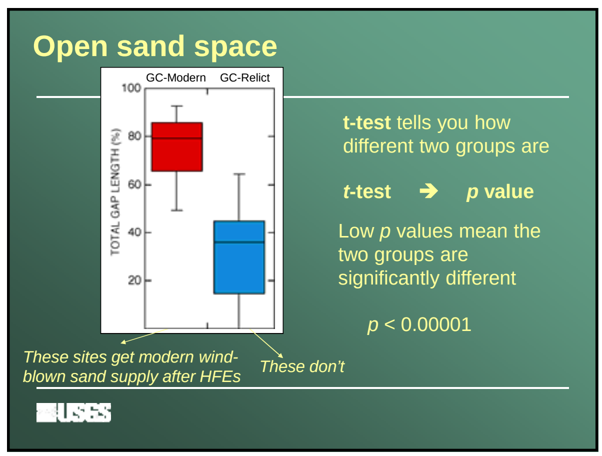
Compare ground cover on aeolian landscapes that get new wind-blown sand (after controlled floods) with those that don't get new sand

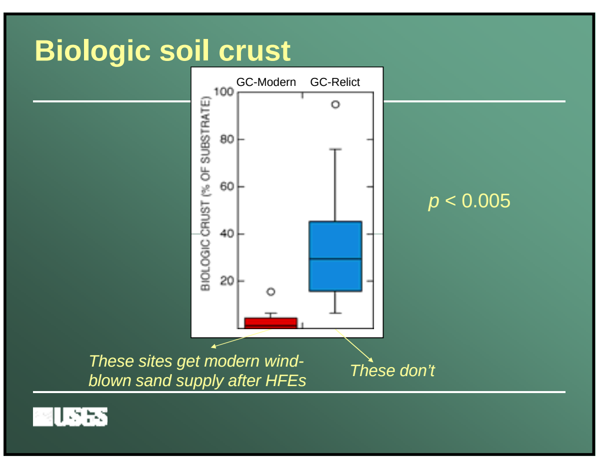
USGS

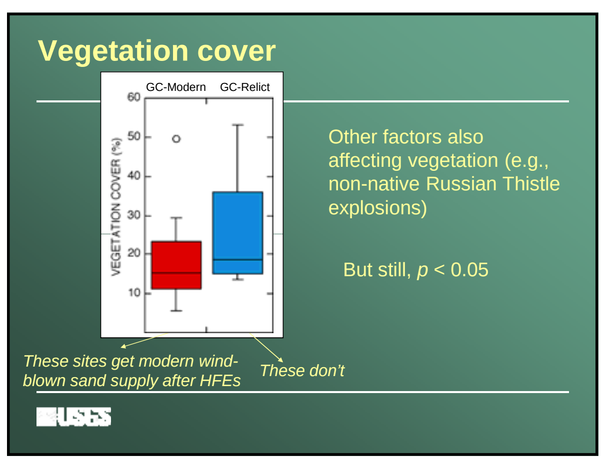

Modern vs. Relict aeolian landscapes
Some get new sand from modern sandbars
Others don't.
WIND
WIND
These sites have an HFE sandbar just upwind
These don't


Measured ground cover in 2 groups of dune-fields
These get new sand after controlled floods
These don't (they depended on larger, pre-dam floods)
114°
113°
112°
37°
36°
Paria River
Lake Powell
Glen Canyon Dam
Lake Mead
Colorado
River
Grand Canyon National Park
Little Colorado River
0 25 50 KM

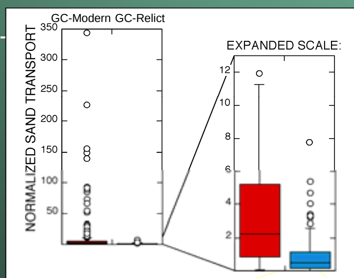

Open sand space
GC-Modern GC-Relict
TOTAL GAP LENGTH (%)
100
80
60
40
20
These sites get modern wind-blown sand supply after HFEs
These don't
Box-and-whisker plots:
3rd quartile ($x_{0.75}$)
Median (2nd quartile, $x_{0.5}$)
1st quartile ($x_{0.25}$)
Whiskers: highest and lowest non-outlier points
Outliers: any points > 1.5 times the inter-quartile range (box length)


Open sand space
GC-Modern GC-Relict
TOTAL GAP LENGTH (%)
100
80
60
40
20
t-test tells you how different two groups are
t-test → p value
Low p values mean the two groups are significantly different
$p < 0.00001$
These sites get modern wind-blown sand supply after HFEs
These don't


Biologic soil crust
GC-Modern GC-Relict
BIOLOGIC CRUST (% OF SUBSTRATE)
100
80
60
40
20
$p < 0.005$
These sites get modern wind-blown sand supply after HFEs
These don't


Vegetation cover
GC-Modern GC-Relict
VEGETATION COVER (%)
60
50
40
30
20
10
Other factors also affecting vegetation (e.g., non-native Russian Thistle explosions)
But still, $p < 0.05$
These sites get modern wind-blown sand supply after HFEs
These don't

Sand transport by wind



$p < 0.00005$

These sites get modern wind-blown sand supply after HFEs

These don't

USGS

Aeolian dunes without modern sand supply:

Have:

More biologic crust

More vegetation

Less open sand

Less sand transport

USGS

… compared with places that still get sand supply

USGS

Relict aeolian landscapes – Implications for archeological site stability

Less sand movement on ground surface = crusts stabilize soil, dunes less mobile.

BUT, too little windblown sand to fill small gullies

Small gullies become large gullies

USGS

Modern aeolian landscapes with sand supply – Implications for archeological site stability

More sand movement on ground surface = dunes shift, migrate

Artifacts covered/uncovered by dunes

Windblown sand can fill small gullies

Gullies can heal

USGS

How "natural" are the GC aeolian dunes with modern sand supply?

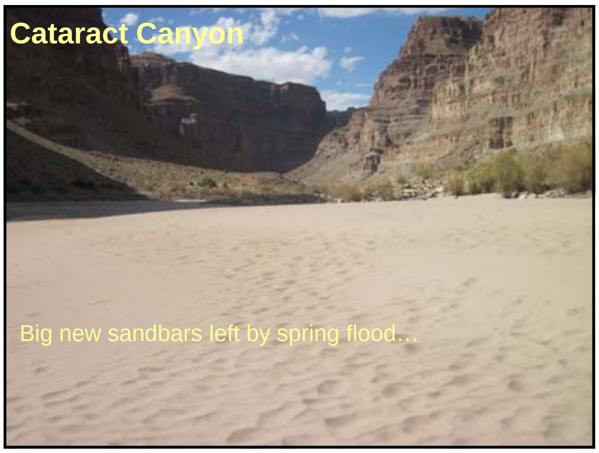
- **Grand Canyon has had 3 controlled floods in past 15 years**
- **How do aeolian landscapes compare in a place that has spring floods making big sandbars EVERY year?**

USGS

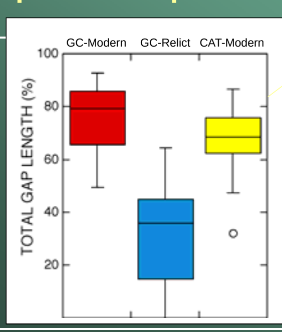
Colorado River, Cataract Canyon, Utah

- 16 river-miles below confluence of Green and Colorado Rivers, above Lake Powell
- Mostly (well, more) natural hydrology and sediment supply
- Canyonlands NP
- No GCMRC support

USGS



Open sand space

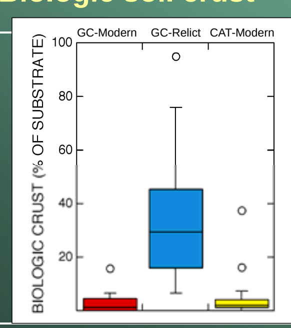


Cataract aeolian landscapes just downwind of annual flood deposits (n=13) very similar to those in Grand Canyon that get sand from occasional HFEs

$p > 0.05$

USGS

Biologic soil crust

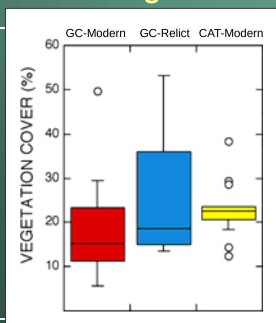


Cataract aeolian landscapes just downwind of annual flood deposits (n=13) very similar to those in Grand Canyon that get sand from occasional HFEs

$p > 0.05$

USGS

Results: Vegetation cover



Inconclusive, but still shows no significant difference between Cataract and Grand Canyon's modern aeolian dune fields

$p > 0.05$

USGS

Grand Canyon's vs. Cataract's aeolian landscapes

- **No significant differences between ground cover on Cataract aeolian dunes that get sand from flood deposits every year and those in Grand Canyon that only get sand occasionally from HFEs**
- **Good news! HFEs are effectively simulating "natural" conditions of ground cover on those aeolian dunes that can get modern sand supply**

USGS

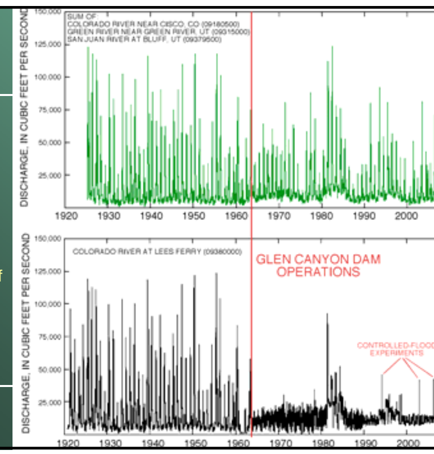
Conclusions

- **Two types of aeolian landscape in Grand Canyon:**
  - **Modern (get new sand supply after HFEs)**
  - **Relict (no modern sand supply = changes in vegetation, soil crust, open sand, transport)**
- **Stability of landscapes and archeological sites controlled by different processes in modern vs. relict aeolian dunes**
- **HFE sand blowing inland effectively reproduces "natural" ground-cover conditions on modern dune-fields (similar to Cataract's aeolian dunes supplied by annual flood sand)**

USGS

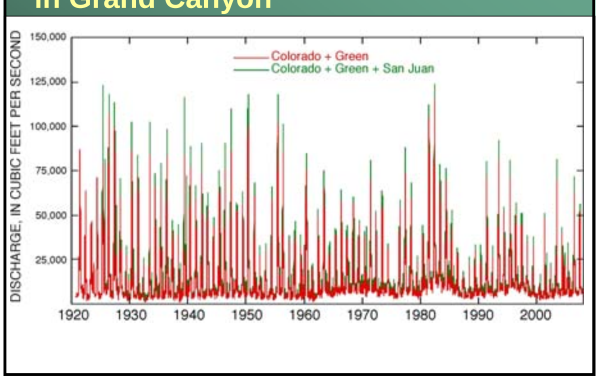
Going in to Lake Powell

Coming out of Lake Powell

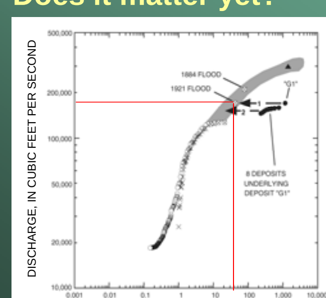


USGS

Flows in Cataract vs. what would be in Grand Canyon



Loss of sand supply to relict dunes: Does it matter yet?



Flood frequency curve by Topping et al., 2003

- **Flood of 170,000 cfs can supply sand to the source areas for the canyon's largest relict dune fields**
- **Last was in 1921**
- **Would have ~40 yr return interval**
- **So, Yes it does matter by now**

USGS

Normalizing sand-transport rates: used local 4-minute wind and rain data

$$\frac{\text{(Mass in sand traps / \# of days to accumulate it) per cm}}{q = 1.8\sqrt{\frac{d}{D}}\frac{\rho}{g}u_*^3} \times 10^7 = \text{Dimensionless \#}$$

Don't have u_* (shear velocity), so substitute u_{2m} (wind velocity) in Bagnold (1941) transport equation

Kawamura (1951)

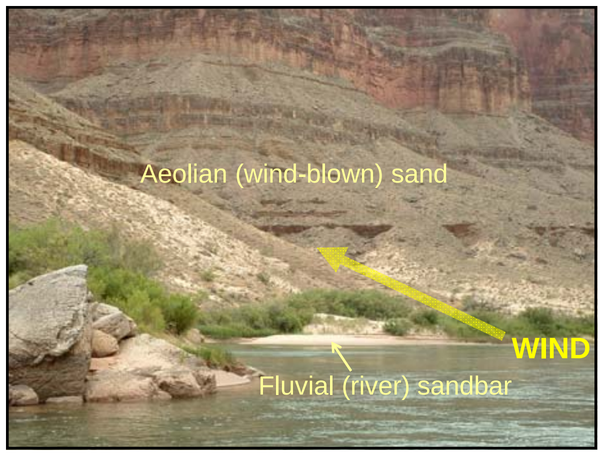
$$q = 2.78\frac{\rho}{g}(u_* - u_{*t})(u_* + u_{*t})^2$$

Zingg (1953)

$$q = 0.83\left(\frac{d}{D}\right)^{0.75}\frac{\rho}{g}u_*^3$$

You can use other transport equations instead, doesn't change results.

USGS



Rainbow Trout Early Life Stage Survival

FY 2010 TWG Report

Josh Korman
Ecometric Research
January 18, 2011

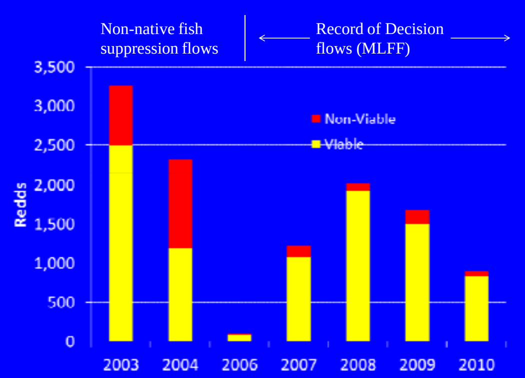
Why Monitor Early Life History Stages of Rainbow Trout in the Lees Ferry Reach?

1. Survival for early life stages of rainbow trout in the Lees Ferry reach ultimately determines the number of juveniles recruiting to the adult population, which over the long term controls the trend in adult abundance.

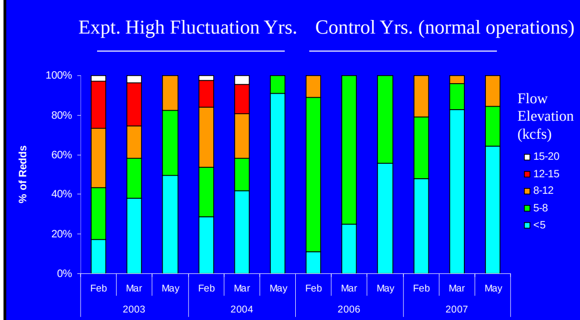
2. Very difficult to evaluate flow effects on population trends without monitoring early life stages.
   - Flow very likely effects more sensitive early life stages
   - Long lag until those stages recruit to adult population typically monitored.
   - Effects of multiple flow regimes often confounded (e.g., HFE-FSF)

3. Adult abundance in the Lees Ferry reach effects the tailwater fishery and possibly native fish abundance

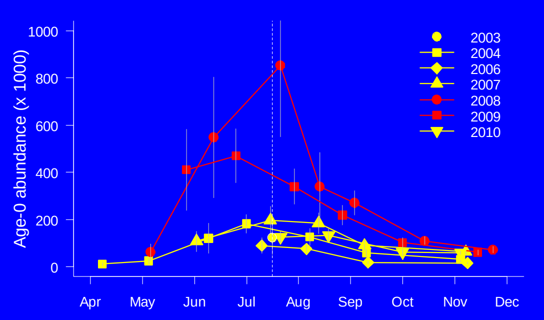
Redd Counts



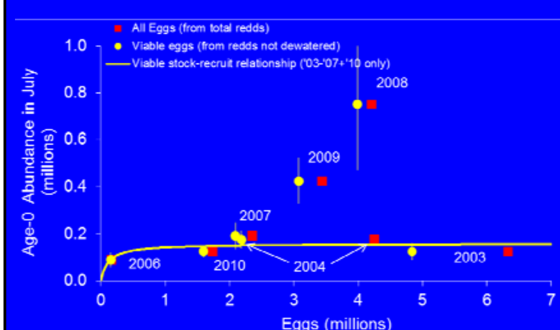
Redd elevations

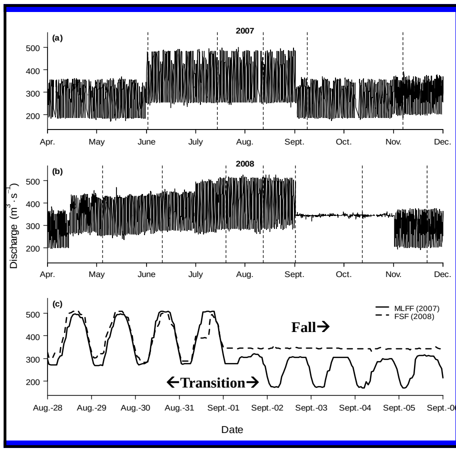


Seasonal Trend in Age-0 Abundance in the Lees Ferry Reach, 2003-2010



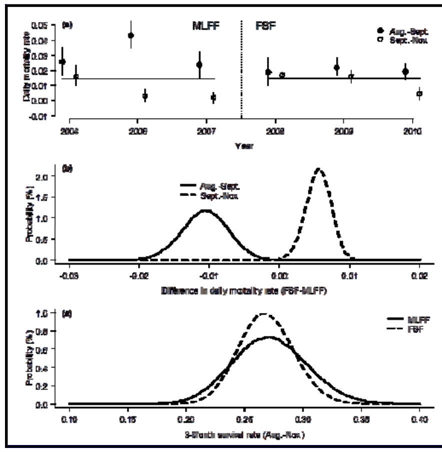
Effects of Non-native Fish Suppression Flows and the 2008 High Flow Experiment on Early Survival





Fall Steady Flow (FSF) Effects

Is age-0 survival higher during transition and fall periods under FSF?

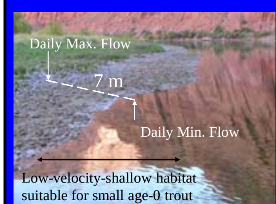


Mortality Rates by Year and Period

Mortality Differences Between Flow Regimes

Net Survival by Flow Regime

Timing of Age-0 Habitat Use Critical to Developing Effective Non-Native Suppression Flows



Low-angle habitat

Preferred by smaller age-0 trout, May-July

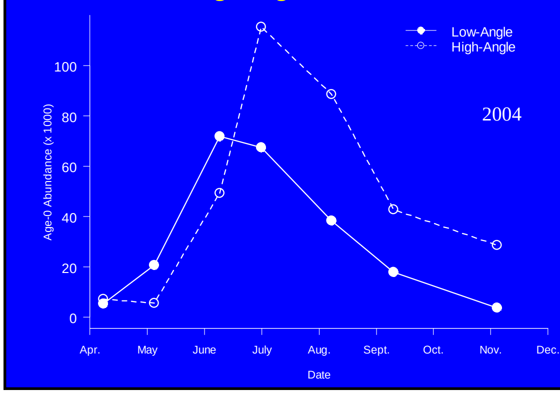
Likely more sensitive to variation in flow

High-angle habitat

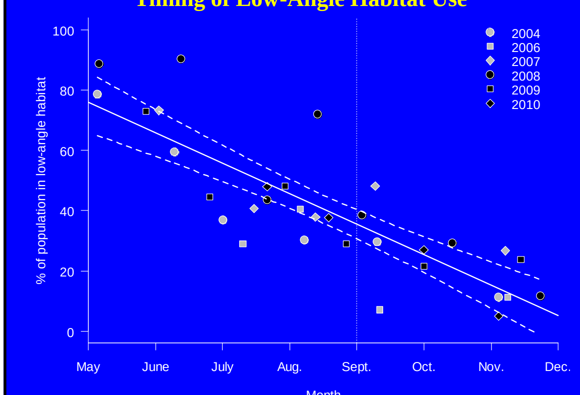
Preferred by larger age-0 trout, July-Winter

Likely less sensitive to variation in flow

Ontogenetic Habitat Shift from Low- to High-Angle Shorelines



Timing of Low-Angle Habitat Use



Conclusions

1. Flow-dependent incubation losses of 25-50% in non-native fish suppression flow years were not large enough to reduce abundance of age-0 trout because of a strong density-dependent survival response following emergence.

2. Stock-recruit curve indicates that as few as 300 redds are required to sustain Lees Ferry population. Perhaps not many redds required near LCR (Nankoweep, mainstem) to sustain a small local population.

3. 2008 High Flow Experiment increased survival rates of recently emerged trout over four-fold in 2008 and over 2-fold in 2009 (no effect by 2010). But n=1 - 1.5, so don't give up on HFEs quite yet!

4. No substantive effect of the Fall Steady Flow Regime on age-0 trout abundance by late fall.

Management Opportunities

1. Trout suppression flows should occur in May-July when fry are still in flow-sensitive low-angle habitat, and when most of density-dependence has probably already occurred.

2. Higher GCD release volumes this year may stimulate trout production:
   - Cleaner substrate in LF and MC
   - Steadier flows during critical juvenile rearing period
   - Increased 'pasture area' due to greater width leading to increased growth/survival

4. High releases provide a unique cost-effective opportunity to test trout suppression flows (egg or juvenile suppression).

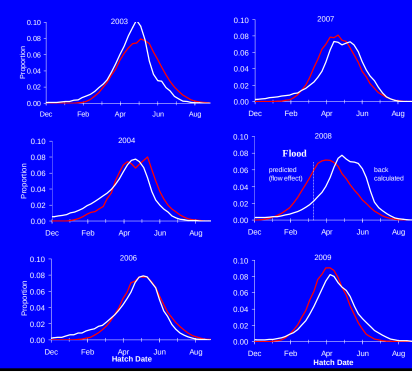
FY 2010 Accomplishments

- GCMRC and AGF completed all sampling planned for 2010 (5 redd surveys and 4 fry surveys, no otoliths analyzed).
- USGS open-file report on 2008 HFE, and Trans. Am. Fish. Soc. And Reg. Rivers papers on HFE and non-native fish suppression flows, published or in press.
- Two manuscripts describing Fall Steady Flow effects and trends in habitat use in 2nd stage of review for Can. J. Fish. Aquat. Sci.
- Information from RTELSS used in ecosystem modelling and non-native fish control structured decision making process.

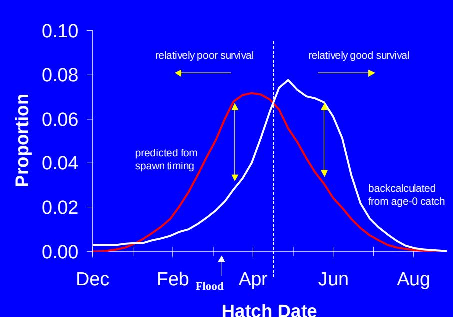
Acknowledgements

- **Funding:** Glen Canyon Dam Adaptive Management Program
- **Logistics and Field Work:** Dave Foster, Matt Kaplinski, Mike Yard, Carol Fritzinger, Arizona Game and Fish, and many others.
- **Data Interpretation:** Ted Melis, Mike Yard, Lew Coggins, Steve Martell, Carl Walters, Eric Parkinson, Mike Bradford
- **Otolith Microstructure:** Steve Campana, Bill Pine

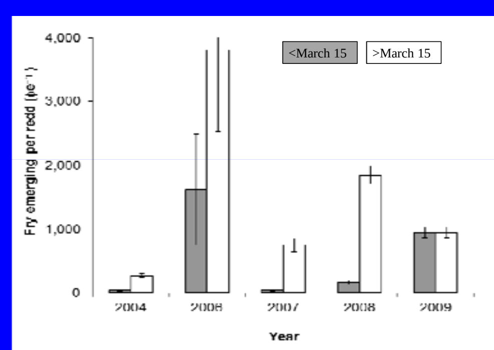
Considerable Variation in Early Survival Rates Among Weekly Cohorts in 2008 Only (flood year)



Effect of 2008 Controlled Flood on Seasonal Variation in Early Survival Rates



Inter-annual Differences in Early Survival Rates Before and After March 15



Linking whole-river carbon cycling to quantitative food webs in the Colorado River

Robert O. Hall, Jr.	University of Wyoming
Emma Rosi-Marshall	Cary Inst. of Ecosystem Studies
Colden Baxter	Idaho State University
Ted Kennedy	GCMRC
Wyatt Cross	Montana State University

Kevin Donner, Holly Wellard, Sarah Zahn, Kate Behn, Amber Ulseth and Dustin Kincaid

Goal 1

Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels.

Overarching Questions

1. To what degree are fishes food limited? Where does the food base come from?

2. How do <u>patterns</u> of carbon flow through the food web affect fishes?

3. How do dam operations affect all of these things?

These questions require an ecosystem approach based upon flows of energy.

To address questions we have…

1. Measured inputs, stocks, outputs, and transport of primary production and terrestrial inputs in the Colorado River.
2. Measured secondary production of components of food web.
3. Identified trophic linkages to estimate what resources support higher trophic levels.
4. Quantified organic matter flow in the Colorado River food web from basal resources to fishes.

Why an ecosystem approach based on energy flows?

1. Animal population dynamics depends on ecosystem properties such as
   a. Amount, source and quality of food
   b. Physical template (flow, turbidity, temperature)
   c. Competition and predation with other animals
   d. Interaction of the above

2. Energy flow allows a common currency from everything from organic matter inputs to fish production

Units:
$\frac{\text{grams organic matter}}{\text{meter}^2 \text{ year}}$ ← Energy is more or less equivalent to organic matter

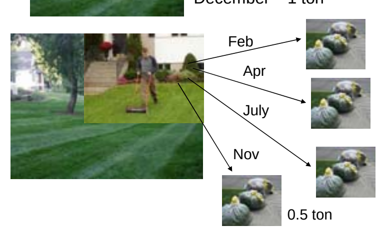
Why is measuring production, and not just biomass, important?

Your neighbor's lawn

January – 1 ton
March – 1 ton
June – 1 ton
September – 1 ton
December – 1 ton

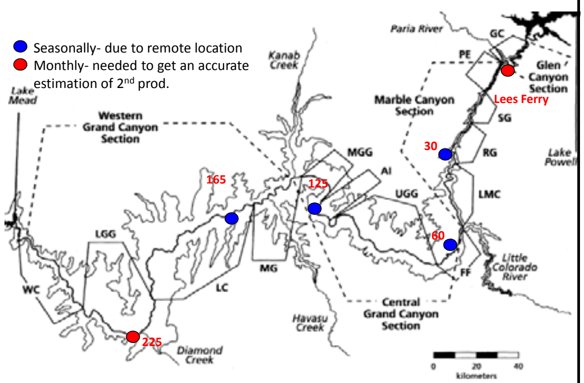
Your Answer

1 ton



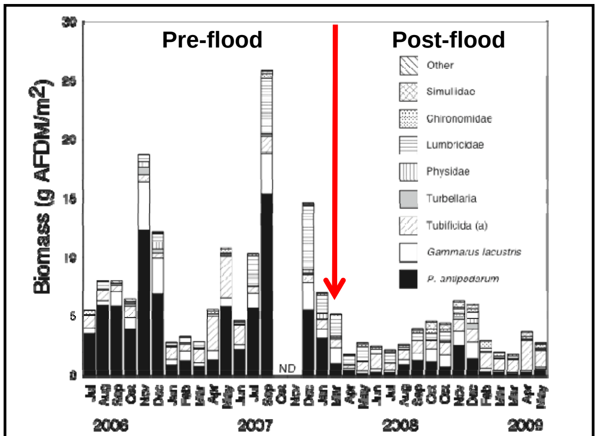
3 tons

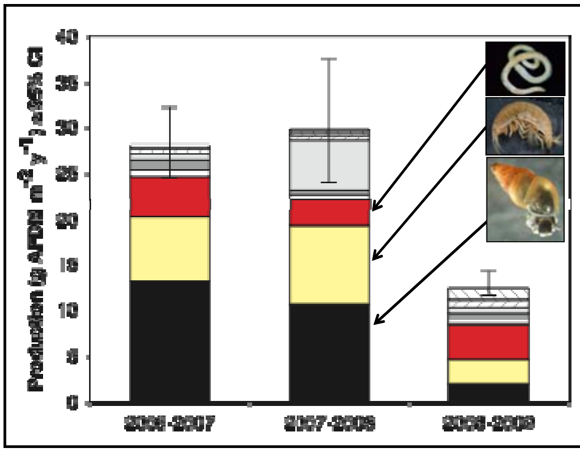
Sampling regime

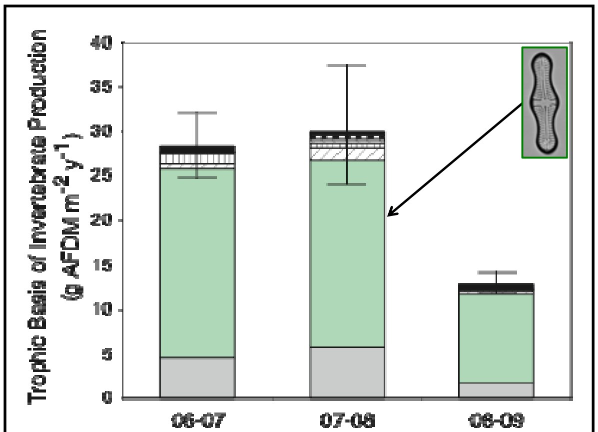


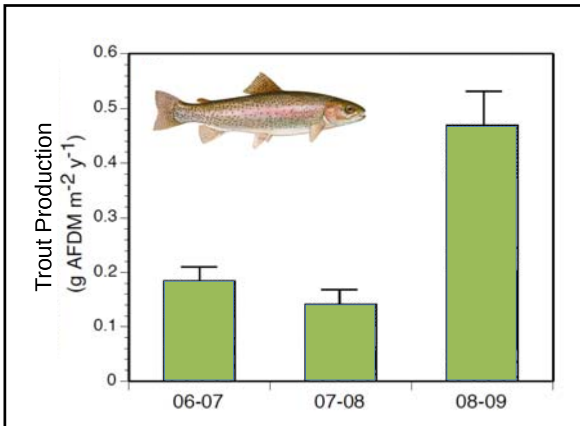
Increased trout production despite reduced total prey production following the 2008 controlled flood

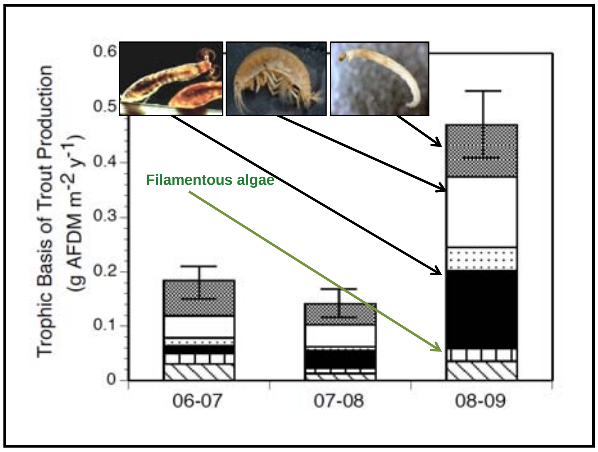
In revision, *Ecological Applications*

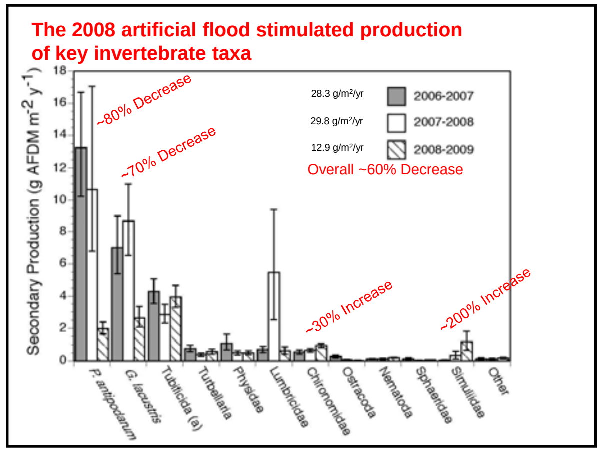


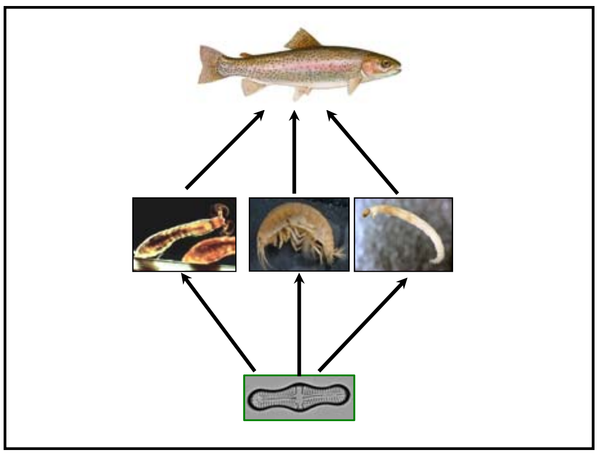


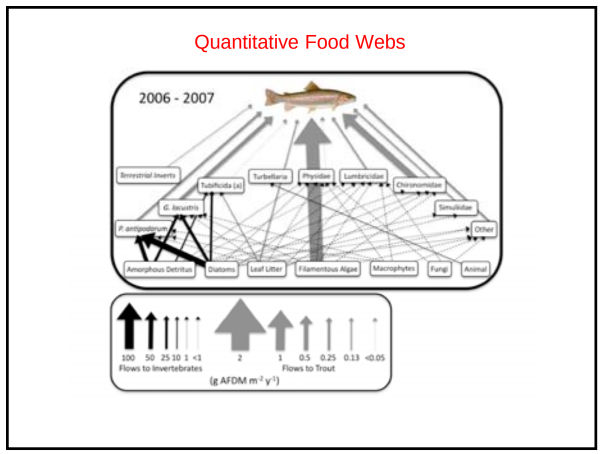


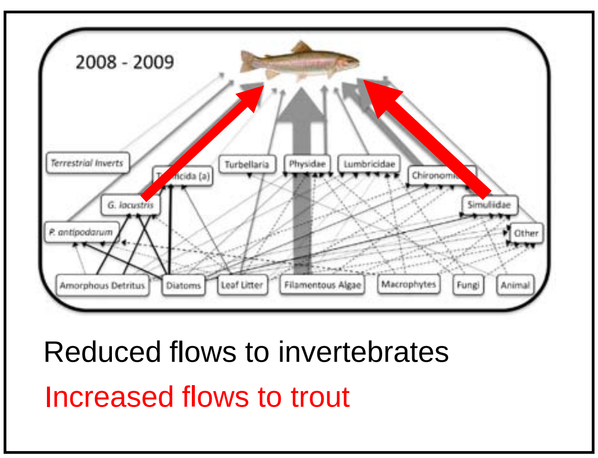


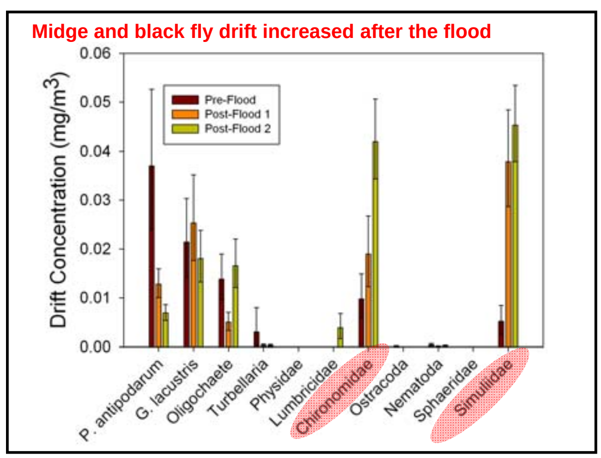

Trophic Basis of Trout Production
(g AFDM m-2 y-1)
0.6
0.5
0.4
0.3
0.2
0.1
0
Filamentous algae
06-07
07-08
08-09


The 2008 artificial flood stimulated production of key invertebrate taxa
Secondary Production (g AFDM m-2 y-1)
~80% Decrease
~70% Decrease
28.3 g/m²/yr
29.8 g/m²/yr
12.9 g/m²/yr
2006-2007
2007-2008
2008-2009
Overall ~60% Decrease
~30% Increase
~200% Increase
P. antipodarum
G. lacustris
Tubificida (a)
Turbellaria
Physidae
Lumbricidae
Chironomidae
Ostracoda
Nematoda
Sphaeridae
Simuliidae
Other




Quantitative Food Webs
2006 - 2007
Flows to Invertebrates
Flows to Trout
(g AFDM m-2 y-1)


2008 - 2009
Terrestrial Inverts
Turbellaria
Physidae
Lumbricidae
G. lacustris
Simuliidae
P. antipodarum
Other
Amorphous Detritus
Diatoms
Leaf Litter
Filamentous Algae
Macrophytes
Fungi
Animal
Reduced flows to invertebrates
Increased flows to trout

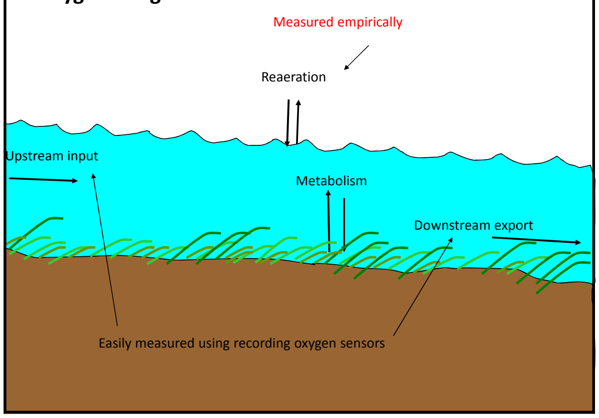

Midge and black fly drift increased after the flood
Drift Concentration (mg/m3)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Pre-Flood
Post-Flood 1
Post-Flood 2
P. antipodarum
G. lacustris
Oligochaete
Turbellaria
Physidae
Lumbricidae
Chironomidae
Ostracoda
Nematoda
Sphaeridae
Simuliidae

Summary

- Increase in trout production despite a decrease in total invertebrate production
- The few taxa that support most trout production increased following the flood (both in production and drift)
- Artificial floods appear to improve resource conditions for non-native rainbow trout

Downstream Food Webs

An oxygen budget for a river reach



Estimating primary production parameters

Estimate metabolism by fitting below model to data.

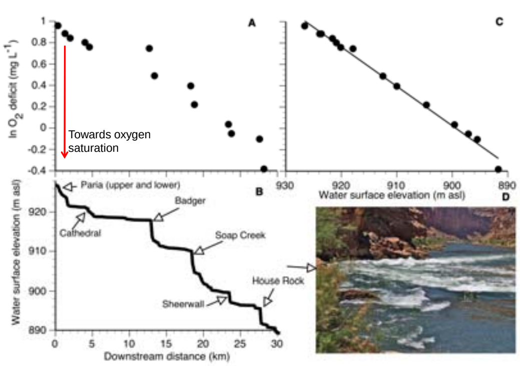
Minimize negative log-likelihood function.

$$C_t = C_o + \frac{GPP}{z_t} \times \frac{PAR_t}{\Sigma PAR} + \frac{CR\Delta t}{z_t} + K(C_s - C_0)\Delta t$$

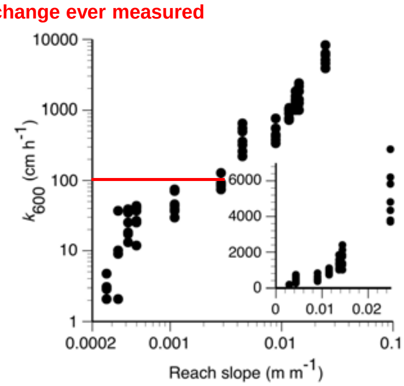
O_2; Fraction of light over interval; Gas exchange rate; O_2 saturation deficit; Time interval

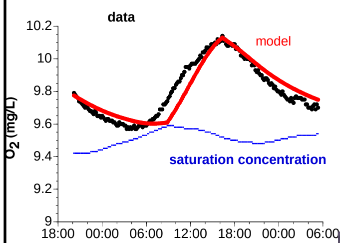
Van de Bogert et al. 2007

Scaling gas exchange across long reaches



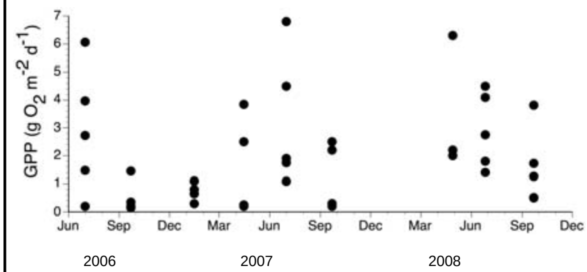
Colorado River has among highest rates of gas exchange ever measured



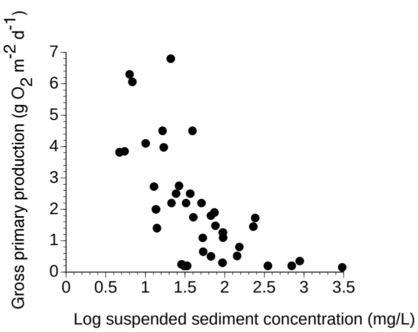


GPP = 2.6 g $O_2 m^{-2} d^{-1}$

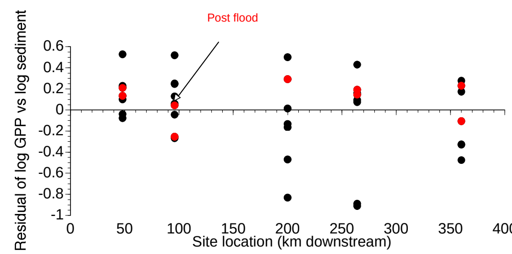
Primary production varies through time



Suspended sediment regulates variation in GPP



Small effect of experimental high flows?



Allochthonous material

During periods of high turbidity, a lot of allochthonous organic matter also enters the river.

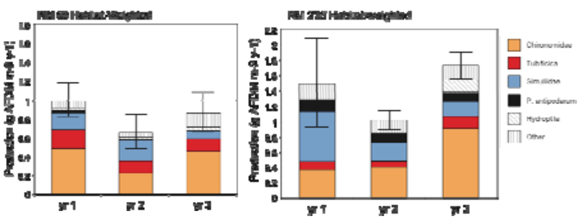
This allochthonous material may be an important food resource.

Organic Matter Inputs to Downstream Ecosystem

Source	Annual Inputs (organic matter metric tons)	Annual Inputs (organic matter g/m²)
Lake Powell & Tailwater POM / DOM	4,400 / 40,000	128 / 1167
Litter Inputs from Riparian Zone	500	14
Algal Production Downstream	2000-5000	60-150
Tributary Allochthonous Inputs	400,000	13,000

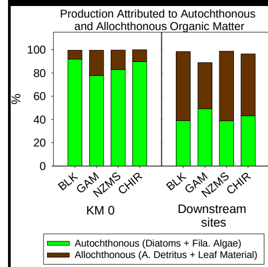
But low primary production relative to trib inputs does not mean low importance to food webs!

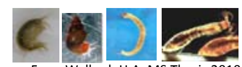
2nd production of invertebrates in downstream reaches



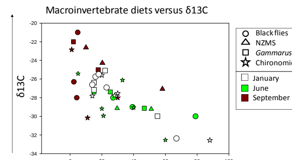
For reference: Lees Ferry production ~27 g AFDMm^{-2}y^{-1}
Lees Ferry post-flood ~ 12 g AFDMm^{-2}y^{-1}

Production attributable to autochthonous and allochthonous resources

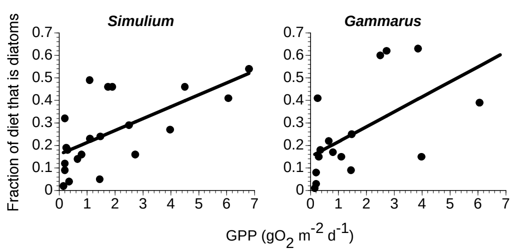




From Wellard, H.A. MS Thesis 2010

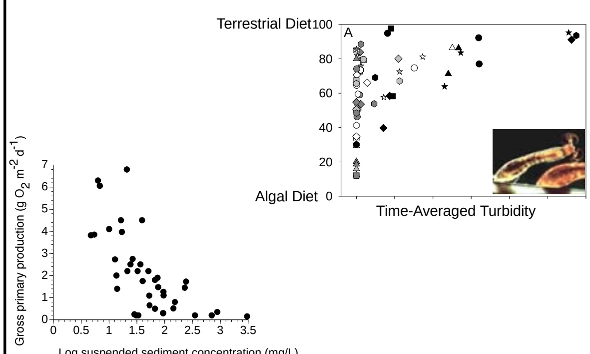


Algae consumption by invertebrates tracks primary production



Holly Wellard, unpublished

Suspended sediments influence GPP and invertebrate diets

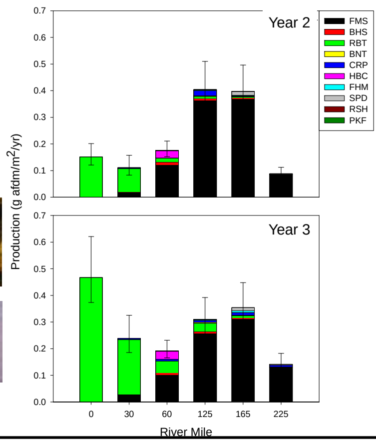


The downstream food web…

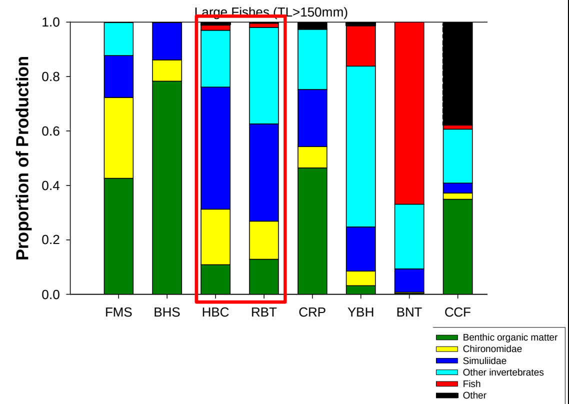
1. Base of food web varies with turbidity
2. Invertebrate production is much lower than Lees Ferry
3. Invertebrate resource consumption tracks primary production
4. Despite huge inputs of tributary-derived allochthonous material, algal production supports ~1/2 of the downstream invertebrate production

Production and food base of downstream fishes

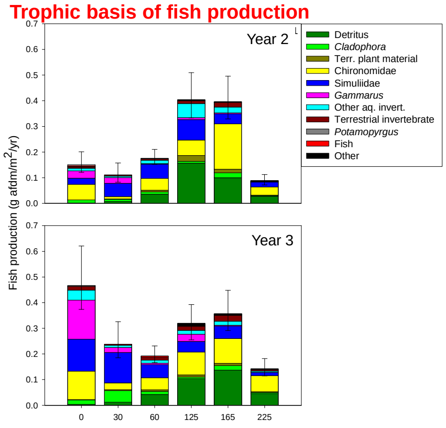
Fish production is comparable across sites



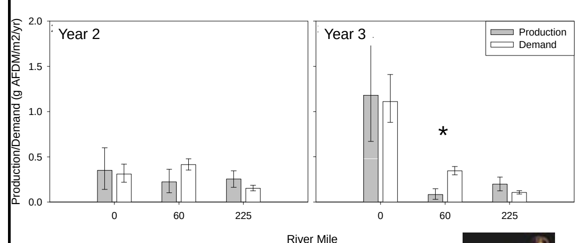
Production attributable to different resources



Trophic basis of fish production

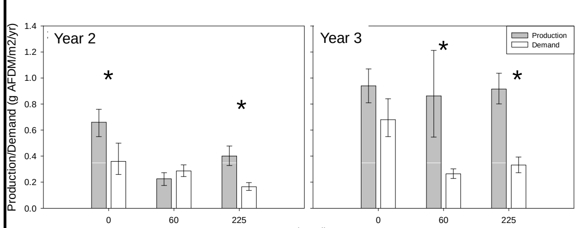


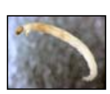
Production / Demand – Blackflies



- Blackfly production = or < demand by fishes
- Resource is tracked by assemblage through space, time

Production / Demand – Midges





- Midge production > or = demand by fishes

Competition—Natives vs. Non-Natives

Schoener's coefficient of competition

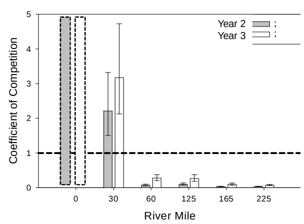
Accounts for…

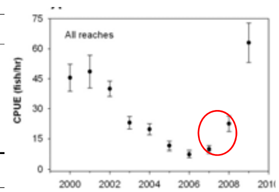
- Diet composition/overlap
- Assimilation efficiencies
- Availability
- Consumption rate

> 1 = competition between groups stronger than within

< 1 = competition within groups stronger than between

Competition—Natives vs Non-natives





- River mile 0 would far exceed all other sites
- Coefficient exceeds 1 at sites with large rainbow trout populations
- Coefficients increased in Year 3 due to RBT increase

Findings

1. To what degree are fishes food limited? Where does the food base come from?

   Evidence for food limitation at all sites including Lees Ferry. In Lees Ferry, algae forms the base of the food web. Downstream, base of food web varies with turbidity.

2. How do patterns of carbon flow through the food web affect fishes?

   Fish production is most likely limited by a few invertebrate species that constitute their preferred prey. Diets of downstream fishes are broader than Lees Ferry. Competition between natives and non-natives likely during especially years of high RBT abundance.

3. How do dam operations affect all of these things?

   The 2008 artificial flood stimulated rainbow trout production. We have not yet seen strong evidence of flood effects on downstream food webs or fish production.

Core Monitoring

CMIN 1.1.1 Determine and track the composition and biomass of primary producers [*primary production*] below Glen Canyon Dam in conjunction with measurements of flow, nutrients, water temperature, and light regime.

CMIN 1.2.1 Determine and track the composition and biomass of benthic invertebrates [*benthic invertebrate production*] below Glen Canyon Dam in conjunction with measurements of flow, nutrients, water temperature, and light regime.

CMIN 1.5.1 Determine and track the composition and bio-mass of drift in the Colorado River in conjunction with measurements of flow, nutrients, water temperature, and light regime.

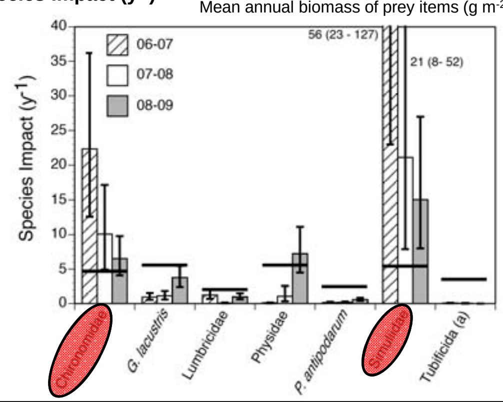
Next Steps…

1. Continuous estimates of primary production from Lees Ferry
2. Carbon budget for Lees Ferry and downstream
3. Analyze stable isotope data to further link animal production with base of food web
4. Synthesize downstream invertebrate production data
5. Settle upon a suite of monitoring protocols
6. Conduct food base PEP
7. Implement core food base monitoring

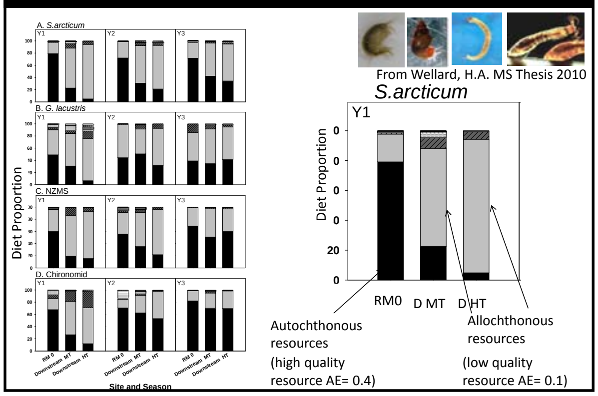
FY2010 Accomplishments

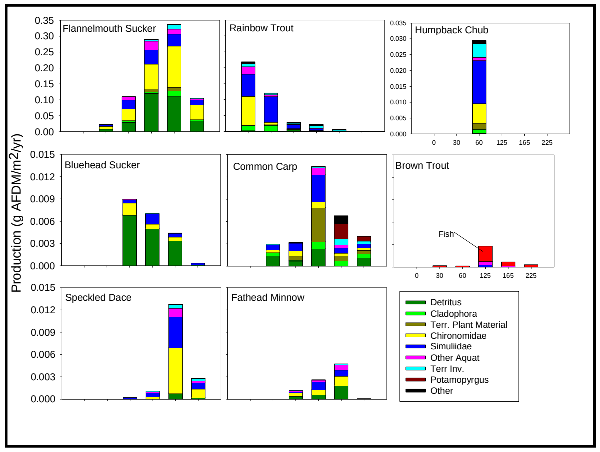
2 Journal articles
3 USGS Reports
2 Masters Theses
5 Presentations to AMP committees
5 Presentations at National Meetings

Species Impact (y^{-1}) $= \dfrac{\text{Annual consumption by trout (g m}^{-2}\text{ y}^{-1})}{\text{Mean annual biomass of prey items (g m}^{-2})}$

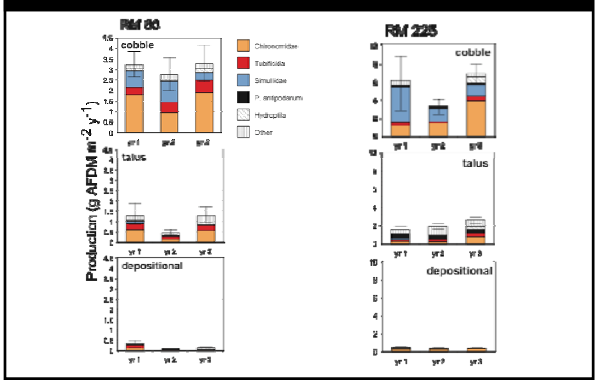


What fuels invertebrate production in downstream reaches?





Production varies by habitat



Modelling Population Dynamics of Rainbow Trout in Lees Ferry and Marble Canyon

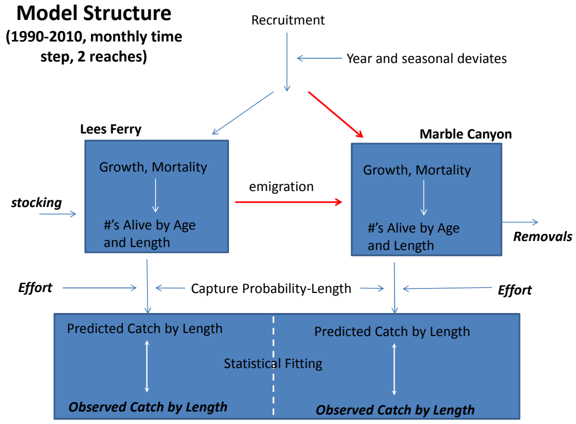
Josh Korman, Carl Walters, Andy Makinster,
Lew Coggins, Bill Persons, Mike Yard

Objectives of Modelling

1. Estimate the inter-annual trend in recruitment of juveniles to the adult populations and relate to dam operations.
2. Estimate how many trout migrate from Lees Ferry to Marble Canyon each year and magnitude of 'local' recruitment in Marble Canyon.
3. Estimate the time of year when outmigration occurs and size of fish that move.
4. Determine how well data and model can distinguish among competing hypotheses about recruitment and outmigration dynamics.

Model Structure

(1990-2010, monthly time step, 2 reaches)



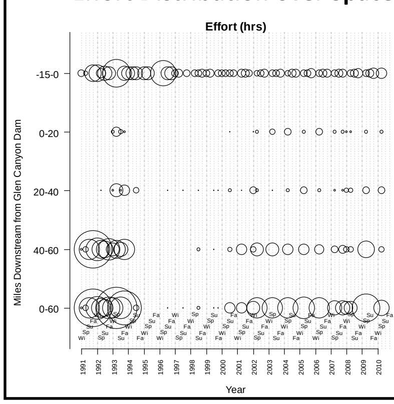
The Data

	Lees Ferry	Marble Canyon	Control Reach	Total
# of Trips	60	51	24	135
# Years with Trips	20 ('91-'10)	17 ('91-'10)	5 ('03-'06, '09)	
Average # Trips per Year	3.00	3.00	4.80	
Average Effort per Trip (Hrs)	5.90	6.27	9.11	6.61
Average Proportion Shoreline Sampled per Trip	0.14	0.04	0.45	0.21
Total Fish Captured Across Trips	59,093	15,699	12,687	87,479

Other Data that can be used in fitting:

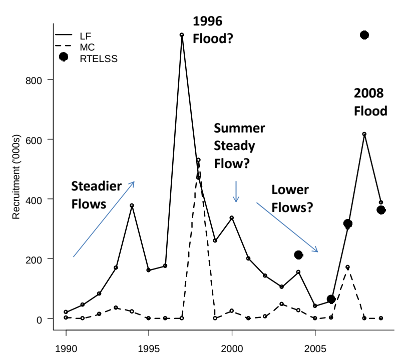
Age-0 abundance in Lees Ferry reach ('04-'09)
Total abundance in control reach ('03-'06)
Size-at-age data from otoliths in Lees Ferry (<100 mm, '04-'09)
Proportion of hatchery fish in population ('91-'96)
Prior on extent of recruitment in MC from spawning surveys

Effort Distribution over Space and Time

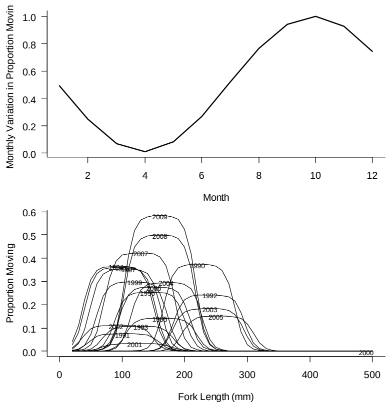


- Lees Ferry has been consistently sampled
- Marble Canyon (MC) much less so, big hole '95-'98. Most effort in lower MC
- Must aggregate MC data and model entire reach as a whole
- Lots of variation in location of sampling in MC can lead to biases in MC abundance trend

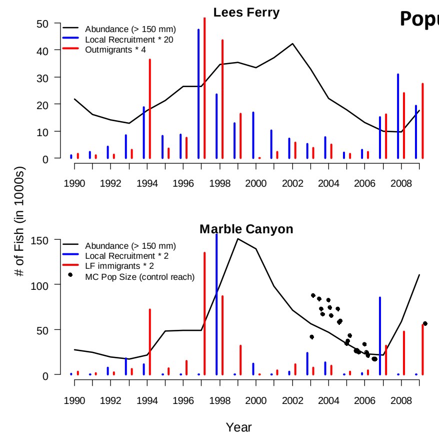
Recruitment Trend from Global Model



Outmigration: Seasonal Timing and Fish Size

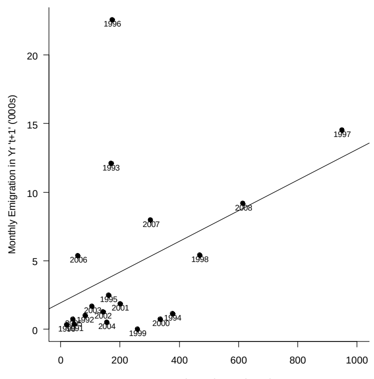


Population Trends

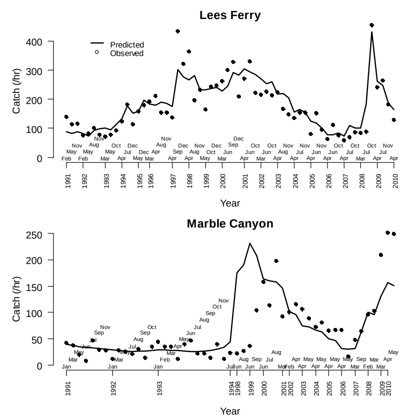


Population growth in Marble Canyon mostly driven by immigration from Lees Ferry, but note some local recruitment

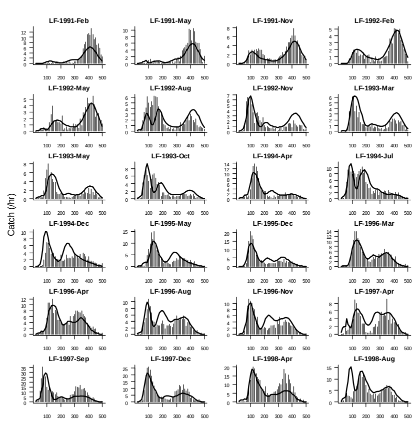
Emigration Rate vs. Recruitment from Global Model



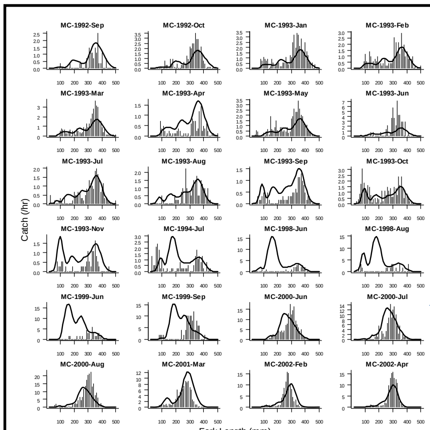
High emigration in some flood and post-flood years



Fit to Aggregated CPE by Reach

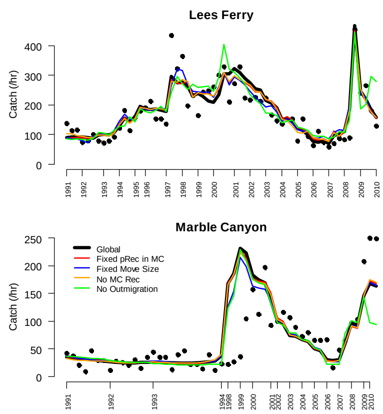


What the Model Actually Fits to: Catch by 10 mm Length Class



Mysterious appearance of large fish in June 2000.

Likely a sampling artefact : <1 hr effort for all samples between 95-99.



Data Not Sufficient to Distinguish Among Competing Models

Main Conclusions from Modelling

- Two major recruitment events over last two decades
  - 1997, 2008. 2008 caused by HFE. Best bet is that 1997 caused by 1996 HFE
  - Magnitude of 1997 event uncertain (limited MC sampling)
  - Surprisingly, little evidence of downstream movement from 2000 recruitment event
- Marble Canyon population could be supported mostly by immigrants from Lees Ferry, but models that allow limited and considerable recruitment in Marble Canyon also fit the data well.
- Data are also not sufficient to distinguish among alternate models that predict differences in seasonal timing and size at outmigration.
- FY2011 work will focus on improving calculations of uncertainty in model predictions to provide reliable comparison of alternate models. Simulation to evaluate future monitoring efforts.
- Large-scale and long-term mark-recapture program, coupled with more extensive sampling in Marble Canyon, required to evaluate these dynamics and efficacy of PBR removal program

Data Limitations

1. Inconsistent sampling in Marble Canyon
   - No or very little sampling in some years
   - Effort distribution among reaches in Marble Canyon very inconsistent
2. No information on size-at-age and how it varies among reaches
   - Makes it difficult to assign recruitment (birth) year for fish of a given size
   - Leads to large uncertainty in assignment of recruitment and outmigration to particular years
   - This in turn makes it difficult to evaluate factors that drive recruitment and outmigration
3. No information on relationship between vulnerability to sampling and fish size, and variation in catchability between Lees Ferry and Marble Canyon

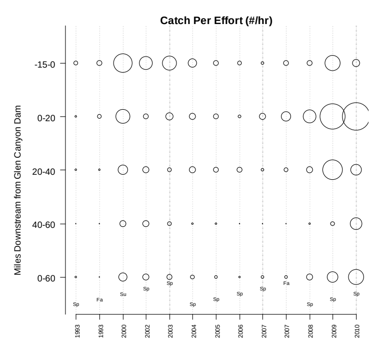
Data Collection Required to Meet Information Needs

1. PIT tag ~ 25% of Lees Ferry age-0 population in Fall each year (~15,000)
2. Recapture pit tags in PBR and in LCR Reach
   - Large cost of recapture in these areas already covered by removal program
3. Recapture pit tags in Marble Canyon between PBR and LCR
   - Dedicate one AGF nonnative trip to Marble Canyon only
   - This effort would be needed even in the absence of tagging to improve estimates from model (consistent sampling in MC)
4. Conduct small-scale mark-recapture experiments in Lees Ferry and Marble Canyon to define size-dependent vulnerability functions.
5. Integrate mark-recapture data with catches of unmarked fish into existing model to derive reliable estimates of key population dynamic parameters

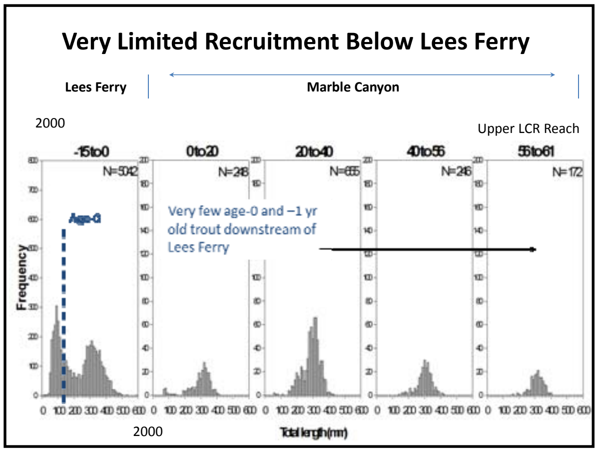
Expected Recaptures from Each Annual Marked Cohort

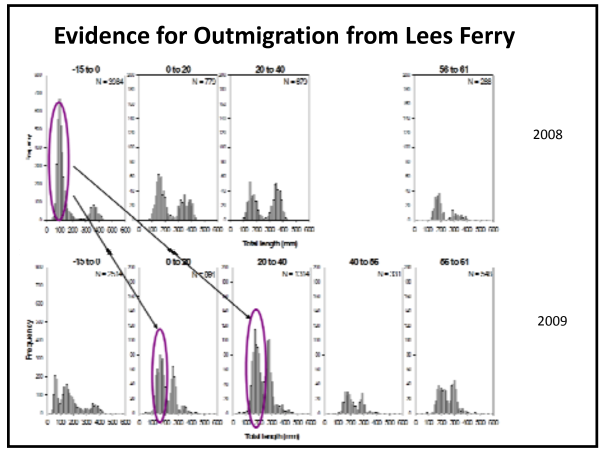
	Proportion emigrating at age 1		
	0.1	0.25	0.5
RTELSS LF Age-0 recaptures	201		
AGF LF Age-1 recaptures	94	79	52
PBR Age-1 recaptures	220	550	1,101
MC recaptures (not including PBR and upper LCR)	16	39	79
LCR recaptures (upper stratum)	102	256	511

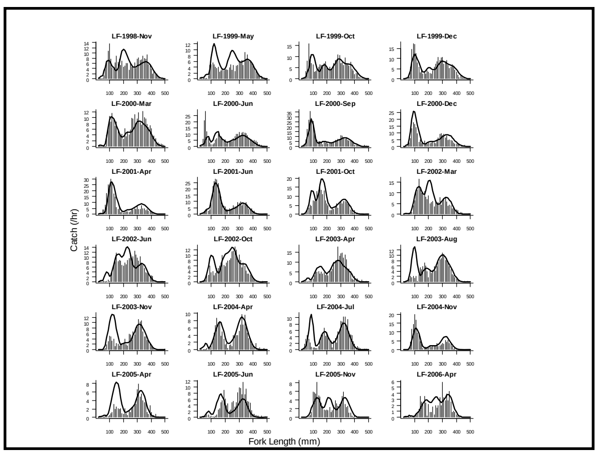
Spatial Gradient in Abundance in Marble Canyon

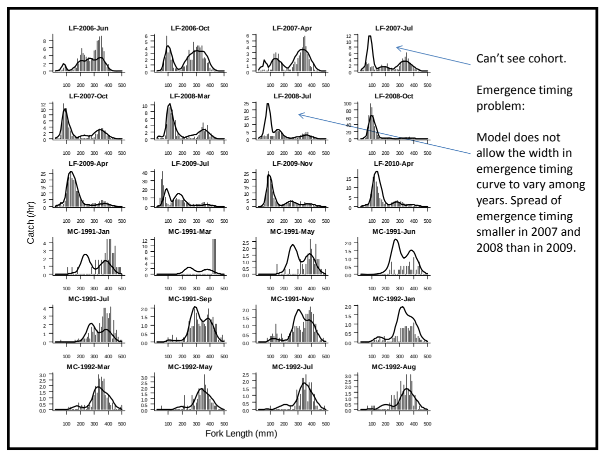


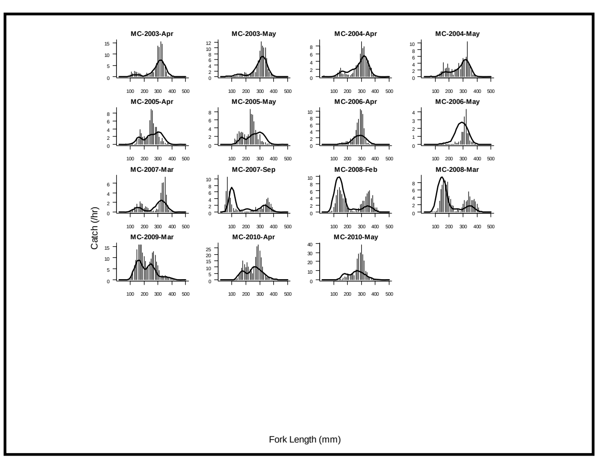
- 2000-2002 and 2008-2010 high abundance periods.
- Upstream-downstream gradient in density apparent.
- Gradient is a bit variable through time, but lower MC always lower density than upper MC.
- Must adjust MC data to account for the temporal variability in location of sampling with respect to density gradient.

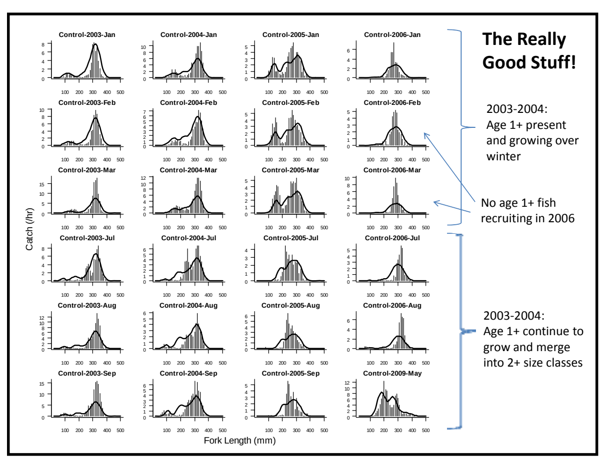

Very Limited Recruitment Below Lees Ferry
Lees Ferry
Marble Canyon
2000
Upper LCR Reach
-15to0
N=542
0to20
N=28
20to40
N=65
40to56
N=26
56to61
N=72
Age-0
Very few age-0 and –1 yr old trout downstream of Lees Ferry
Frequency
2000
Total length(mm)


Evidence for Outmigration from Lees Ferry
-15 to 0
0 to 20
20 to 40
56 to 61
2008
-15 to 0
0 to 20
20 to 40
40 to 56
56 to 61
2009
Frequency
Total length (mm)

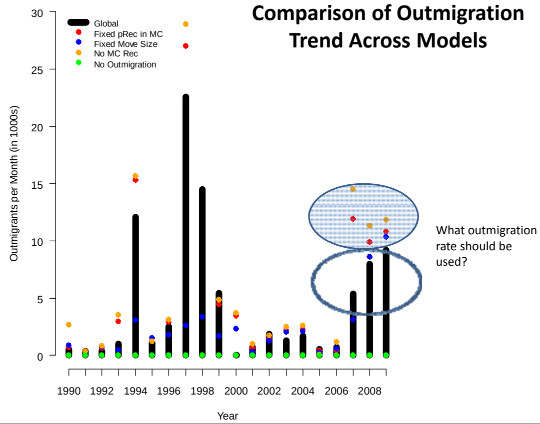

LF-1998-Nov
LF-1999-May
LF-1999-Oct
LF-1999-Dec
LF-2000-Mar
LF-2000-Jun
LF-2000-Sep
LF-2000-Dec
LF-2001-Apr
LF-2001-Jun
LF-2001-Oct
LF-2002-Mar
LF-2002-Jun
LF-2002-Oct
LF-2003-Apr
LF-2003-Aug
LF-2003-Nov
LF-2004-Apr
LF-2004-Jul
LF-2004-Nov
LF-2005-Apr
LF-2005-Jun
LF-2005-Nov
LF-2006-Apr
Catch (/hr)
Fork Length (mm)


LF-2006-Jun
LF-2006-Oct
LF-2007-Apr
LF-2007-Jul
LF-2007-Oct
LF-2008-Mar
LF-2008-Jul
LF-2008-Oct
LF-2009-Apr
LF-2009-Jul
LF-2009-Nov
LF-2010-Apr
MC-1991-Jan
MC-1991-Mar
MC-1991-May
MC-1991-Jun
MC-1991-Jul
MC-1991-Sep
MC-1991-Nov
MC-1992-Jan
MC-1992-Mar
MC-1992-May
MC-1992-Jul
MC-1992-Aug
Catch (/hr)
Fork Length (mm)
Can't see cohort.
Emergence timing problem:
Model does not allow the width in emergence timing curve to vary among years. Spread of emergence timing smaller in 2007 and 2008 than in 2009.


MC-2003-Apr
MC-2003-May
MC-2004-Apr
MC-2004-May
MC-2005-Apr
MC-2005-May
MC-2006-Apr
MC-2006-May
MC-2007-Mar
MC-2007-Sep
MC-2008-Feb
MC-2008-Mar
MC-2009-Mar
MC-2010-Apr
MC-2010-May
Catch (/hr)
Fork Length (mm)


Control-2003-Jan
Control-2004-Jan
Control-2005-Jan
Control-2006-Jan
Control-2003-Feb
Control-2004-Feb
Control-2005-Feb
Control-2006-Feb
Control-2003-Mar
Control-2004-Mar
Control-2005-Mar
Control-2006-Mar
Control-2003-Jul
Control-2004-Jul
Control-2005-Jul
Control-2006-Jul
Control-2003-Aug
Control-2004-Aug
Control-2005-Aug
Control-2006-Aug
Control-2003-Sep
Control-2004-Sep
Control-2005-Sep
Control-2009-May
Catch (/hr)
Fork Length (mm)
The Really Good Stuff!
2003-2004: Age 1+ present and growing over winter
No age 1+ fish recruiting in 2006
2003-2004: Age 1+ continue to grow and merge into 2+ size classes

Comparison of Outmigration Trend Across Models

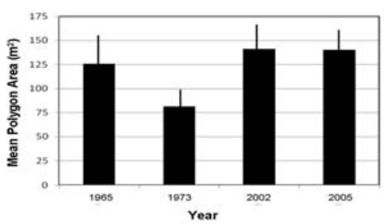


Information Needs to Evaluate Efficacy of PBR and LCR Mechanical Removal Programs and Factors that Drive Outmigration and Abundance at the LCR

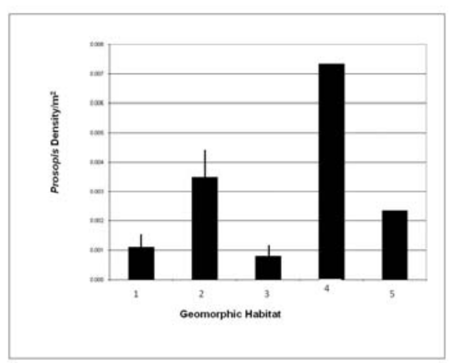
1. Annual number of outmigrants (Lees Ferry Management)
   – What drives outmigration
2. Details on seasonal timing and size of outmigrants, and residence period in PBR
   – Improve efficiency of PBR removal
3. Number of escapees that make it to LCR
   – Effective harvest rate of PBR removal
4. Extent of local recruitment in Marble Canyon (below PBR)

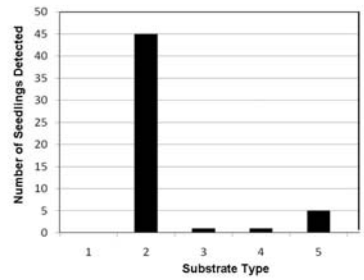
The natural history of Western Honey Mesquite in Grand Canyon, A Changing Ecology

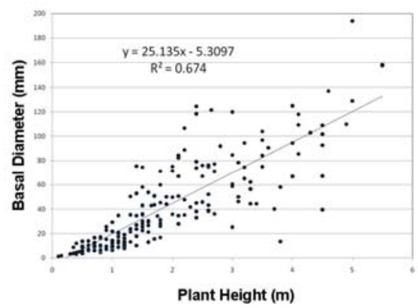
- Gwendolyn Waring, Barbara Ralston, Larry Stevens and Steven Archer



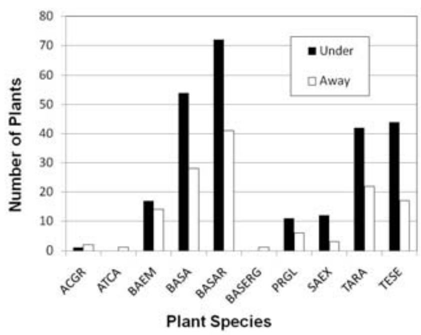
Substrate	Statistic	Mean #/1000 m²	Mean BD (mm)	Mean #/1000 m²	Mean BD (mm)
Sandbar	Mean	2.1	72.1	0.7	24.5
	stdev	1.34	35.31	0.81	15.12
	n	11	6	11	3
	t	1.796	1.943	1.796	2.353
	95% CI	0.7235	28.0116	0.4410	20.5404
Debris Fan	Mean	3.9	31.2	6.6	45.6
	stdev	2.77	31.10	3.67	32.61
	n	16	15	18	14
	t	1.746	1.753	1.734	1.761
	95% CI	1.2101	14.0775	1.5015	15.3501
Channel Margin	Mean	0.1	16.9	1.4	---
	stdev	0.17	18.60	2.81	---
	n	11	11	12	---
	t	1.796	1.796	1.782	---
	95% CI	0.0901	10.0705	1.4453	---
Sandbar Backchannel	Mean	7.3	56.6	---	---
	stdev	0.00	33.52	---	---
	n	1	1	---	---
	t	6.314	6.314	---	---
	95% CI	0.0000	211.6451	---	---
Cobblebar	Mean	2.3	25.8	---	---
	stdev	0.30	37.34	---	---
	n	2	2	---	---
	t	2.920	2.920	---	---
	95% CI	0.6199	77.0982	---	---
Grand Total	Mean	3.5	40.0	5.4	44.6
	stdev	2.82	35.56	4.09	32.28

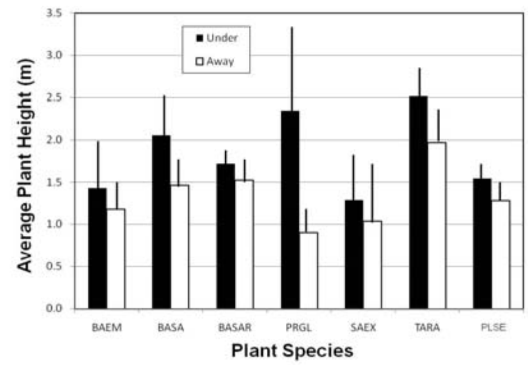






Species	Under	Away	X^2	*P*
Acacia greggii	1	2	0.167	>0.5
Atriplex canescens	0	1	0.500	>0.3
Baccharis emoryi	17	14	0.145	>0.5
Baccharis salicifolia	**54**	**28**	**4.122**	**0.031**
Baccharis sarothroides	**72**	**41**	**4.252**	**0.034**
Baccharis sergiloides	0	1	0.500	>0.3
Prosopis glandulosa	11	6	0.735	>0.3
Salix exigua	**12**	**3**	**5.400**	**0.02**
Tamarix spp.	**42**	**22**	**3.125**	**0.010**
Pluchea sericea	**44**	**17**	**5.975**	**0.021**

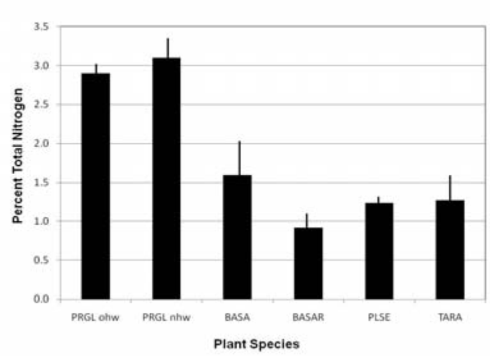




Variable	Depth	Pre-dam terraces		Post-dam terraces		TOTAL	
		Under	away	under	Away	under	away
δN	0-5 cm	3.32±0.55	1.84±1.22	1.92±0.37	1.81±0.27	2.77±0.40	1.83±0.65
	5-10 cm	1.58±0.41	3.28±0.33	1.52±0.56	2.25±0.66	1.56±0.32	2.87±0.35
	pooled	2.45±0.39	2.56±0.64	1.72±0.30	2.01±0.28	2.15±0.27	2.31±0.37
δC	0-5 cm	-22.14±0.85	-12.68±2.9	-12.07±2.20	-7.58±1.78	-18.1±1.6	-10.3±1.8
	5-10 cm	-19.88±1.49	-8.71±2.38	-11.98±2.29	-7.84±2.69	-16.7±1.6	-8.31±1.7
	pooled	-21.00±0.87	-10.69±1.9	-11.54±1.47	-8.01±1.44	-17.04±1.2	-9.40± 1.2
% N	0-5 cm	0.088±0.015	0.009±0.002	0.028±0.009	0.030±0.017	0.064±0.012	0.019±0.008
	5-10 cm	0.100±0.032	0.003±0.003	0.032±0.006	0.013±0.005	0.073±0.021	0.008±0.003
	pooled	0.094±0.017	0.006±0.002	0.029±0.005	0.021±0.008	0.067±0.012	0.013±0.004
% C	0-5 cm	1.043±0.171	0.263±0.092	0.870±0.226	1.297±0.675	0.974±0.133	0.740±0.33
	5-10 cm	1.481±0.422	0.210±0.037	0.952±0.186	1.020±0.309	1.27±0.27	0.584±0.18
	pooled	1.262±0.227	0.236±0.048	0.873±0.134	1.103±0.333	1.10±0.15	0.654±0.18
C:N	0-5 cm	12.33±0.590	48.36±20.44	38.52±6.52	56.08±11.01	22.81±4.24	51.87±11.73
	5-10 cm	16.64±1.69	46.05±10.22	39.79±8.32	76.28±29.88	25.90±4.5	58.14±13.3
	pooled	14.49±1.01	47.20±10.90	40.58±4.85	63.04±12.65	25.43±3.13	54.40±8.25

Variable	(N = 8)		Basar Post-dam		Basa Post-dam		Post-dam		Plse Post-dam	
	Pre-dam (8)	Post-dam (8)	Under (4)	Away (4)	Under (2)	Away (2)	Under (5)	Away (5)	Under (1)	Away (1)
$\delta^{15}N$	0.38±0.81	-1.57±0.88	-1.69±1.03	-2.69±1.93	1.43±1.66	-0.52±1.75	4.45±4.00	6.74±0.34	2.08	1.78
$\delta^{13}C$	-25.8±0.71	-26.5±0.57	-26.8±3.15	-28.9±1.66	-26.2±1.59	-26.1±0.41	-27.1±0.94	-26.6±1.19	-28.4	-26.9
% N	2.91±0.17	3.10±0.23	1.01±0.33	0.82±0.23	1.64±0.41	1.55±1.37	1.09±0.21	1.28±0.63	1.23	1.24
% C	48.11±1.05	47.86±0.49	48.69±1.05	47.72±1.31	46.67±0.96	46.18±0.30	39.96±1.10	40.47±2.32	46.00	47.84
C:N	16.6±0.74	15.5±1.07	50.0±14.54	60.3±18.77	28.8±6.56	31.2±27.74	37.6±7.25	37.3±20.27	37.3	38.6

Foliar	Prgl	Basar	
Comparison	pre- vs. post-dam	under-away	under-away
d15N	**0.003 ***	0.157	0.462
d13C	0.260	0.157	0.527
%N	0.099	1.000	0.527
%C	0.260	0.157	0.462
C:N	**0.04 trend**	1.000	0.527

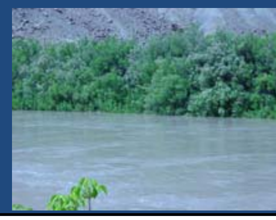


Terrestrial Riparian Vegetation Monitoring on the Colorado River corridor: Glen Canyon Dam to Lake Mead

David J. Cooper & Jennifer R. Jones
Department of Forest, Rangeland and Watershed Stewardship
Colorado State University, Fort Collins, CO 80523
Statisticians: Starcevich, Schweiger, Olsen, Urquhart

Monitoring Objective

This protocol is designed to *assess status* and *detect trends* in terrestrial riparian resources on the main stem of the Colorado River in the Grand Canyon from Glen Canyon Dam to Separation Canyon, river kilometer 0 to 411.3



Specific Core Monitoring Objectives (2008 PEP & 2010 TWG Review)

1. Determine and track the patch number, patch distribution, composition and area of the NHWZ, OHWZ, and sand beach communities as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community. (6.2.1, see USGS 2010)
2. Determine and track the distribution and abundance of non-native species in the Colorado River ecosystem as measured at 5-year or other appropriate intervals based on life cycles of the species and rates of change for the community. (6.5.1)
3. Determine status and trends in species composition and structure of riparian vegetation.

GCMRC Management Objectives

- Maintain
  - marsh, seep, and spring communities
  - NHWZ and OHWZ communities
  - sand-beach communities
  - Southwestern Willow Flycatcher habitats
  - & reduce non-native species
- These objectives will be informed by trends detected by this protocol

Survey Design

- Statistical based survey designs are scientifically defensible and cost effective for large scale monitoring (Olsen et al. 1997)
- This design is based on a framework developed by EPA's EMAP (Environmental Monitoring & Assessment Program) developed by Olsen, Urquhart
- Adopted by the NPS Inventory & Monitoring Program
- Both have mandated the use of probability survey designs (every site has a known statistical probability of being sampled, some more habitats common than others)

Previous Monitoring Program

- Statistical based – but no stratifications other than vertical
- Sample sites not placed in a geomorphic context
- Plot placement based on stage elevations, and plots not fixed, can move as stage/discharge relations change
- Plots small

This Protocol

- Stratifies using large and local-scale geomorphic drivers known to influence vegetation composition and dynamics
- Use larger permanently marked plots
- Increased sampling frequency

Target Population

- All terrestrial riparian resources from river to top of Old High Water Zone
  - Shoreline features such as bars and marshes
- Sample sites must be:
  - Accessible by boat
  - Sampled safely
  - Cause no impacts to sensitive resources, i.e. Cultural
- The sample frame is the spatially explicit portion of the target population from which sample sites are chosen

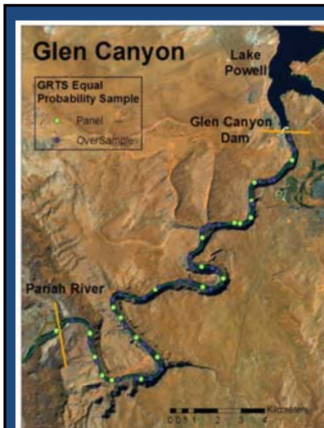
Survey Design

Sites were selected using a generalized random tessellation stratified (GRTS) survey design with sampling directed at three scales

1. Landscape-scale geomorphic reaches (Schmidt and Graf 1990)
2. Local-scale debris fan eddy landforms
3. The elevation/flood frequency, water table depth gradient within each landform

Landscape Scale Strata

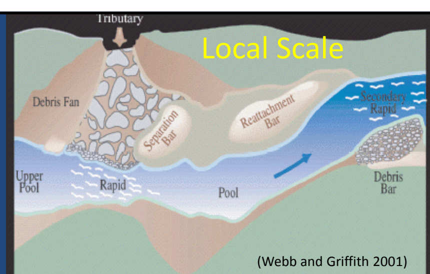
Strata based on geomorphic reaches, influence of major tributaries, and regional vegetation



GLEN CANYON Stratum

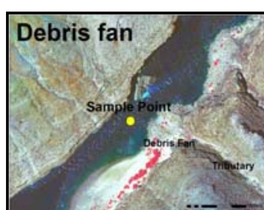
20 sample points (green) and 50 oversample points (blue) in each landscape stratum

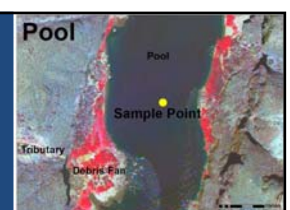
Local Scale

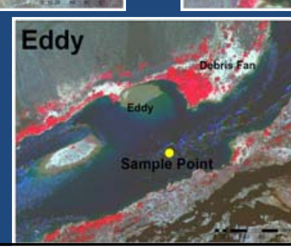


(Webb and Griffith 2001)

- Landforms influence vegetation due to variance in disturbance, sediment texture, erosion, etc.
- Ideally sample sites are selected from a discrete population of all target features
- No complete GIS layers are available for Grand Canyon that delineate ALL local scale features from which sample sites can be selected
- Site to be inspected by GCMRC staff to assess geomorphic setting of each point
- 5 points of each landform type, selected in each stratum







- GRTS provides an ordered list of spatially balanced sites
- Sites evaluated in numbered order until the sample size was reached for each geomorphic feature in each stratum
- Spring 2011 field visit to verify site classification
- Site verification will include all sites in the GRTS ordered list (20+50 in each stratum, 280 sites),
- Allows inclusion probabilities for population estimate of each geomorphic feature to be calculated

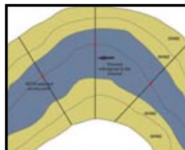
Panel Design

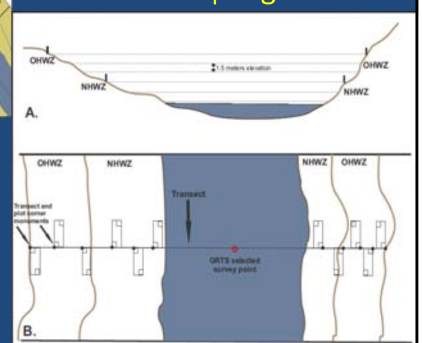
- Pure panel (Fuller 1999)
  - All sites are visited in each sample period
  - Simple method for estimating net change between sample periods
- Sample every other year
- Could miss some inter-annual variability
- No intra-annual sampling
- N of sites limited by work that can be accomplished in one river trip

Response Design

- Focuses on vascular plants
- Measure canopy coverage by species
- Other biota and physical variables can be added
- Detailed SOPs (Standard Operating Procedures) should be developed by GCMRC staff to insure that data collection is standardized
- Example SOPs are in other NPS I&M protocols

Sampling



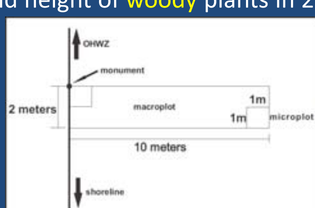


- One transect
- Orthogonal to river
- Permanent marker at top of both OHWZ
- Plots 2x10 m
- 1.5 m elev. drop (survey or laser range finder)

Plot corners with numbered caps

Vegetation Sampling

- Canopy cover of vascular plants in each permanent plot
- 1 m^2 and 20 m^2 plots
- Herbaceous species in 1 m^2 plots
- Cover and height of woody plants in 20 m^2 plots



Suggested Metrics

- Vegetation
  - Species diversity
  - Cover/presence of non-native species
  - National Wetland Indicator Status (NWI)
  - Dominant species
- Abiotic
  - Surface texture
  - Changes in stage elevation

Data Collection, Management

- Field crew training and SOPs are essential for repeatability
- Electronic or manual data collection
- Data management follows protocol of GCMRC
- Each trip sample 80 transects, with 5-20 plots each

Status and Trends

- Summary statistics for status after each sample period
- Population estimates including mean, variance, and standard deviation of each metric
  - Compare vegetation metrics between
  - Strata (4), geomorphic feature (4), elevation zone (3-7)
  - Combinations of above
- Use data to test null hypothesis that no change has occurred in each metric between sample periods
- Vegetation composition compared at all 3 scales using ordination techniques
- Trend analysis should be conducted every two years

Reference Sites

- Suggested by 2008 terrestrial PEP
- Compare GC vegetation with
- Riparian reference sites in Cataract Canyon
- Largest canyon reach above Glen Canyon dam that is relatively intact hydrologically
- Coordinate/collaborate with NPS Upper Colorado River I&M program

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Grand Canyon National Park Vegetation Mapping Project

Mike Kearsley, Mark Nebel – NPS / GRCA S&RM
Kass Green – Kass Green Associates

EXPERIENCE YOUR AMERICA

Overview of Presentation

- Background
- Phase 1 Methods
- Results
- Methods Changes for Phase 2

Background

- Project Motivation
- Project Scope
  - GRCA
  - PARA (LAKE)
- Existing Vegetation Maps
  - Qualities
  - Shortcomings

Background

- FGDC Standards
  - National Map Accuracy Standard
  - National Veg. Classification Standard
  - Metadata Standard
  - Taxonomy Standard
  - Accuracy Assessment Requirements
  - Minimum Mapping Unit

Background

- Procurement
  - FedBizOpps
    - Request for Qualifications
    - Request for Proposals
  - Commercial Fixed-Price Contract
    - Best Value Award
    - Kass Green Associates (Alta Vista)

Project Phases

Phase 1 Methods

- Developing the Classification Key
  - NatureServe.org (NVCS) Classification
    - Phase 1: 89 NVC Associations
    - Overall: 164 Associations
  - KGA Field Key
    - 25 Drafts
    - 27 Map Classes
    - Model to NVC Association

Phase 1 Methods

- Example Key Rules


7.2 Does *Pinus ponderosa* comprise ≥ 50% (relative cover) of the tree and dwarf tree cover, AND does *Abies* spp. plus *Pseudotsuga menziesii* comprise <= 15% of the total segment cover?
If yes, then .... **Southern Rocky Mountain Ponderosa Pine Forest and Woodland Group**

7.2.1 Do shrubs occupy ≥ 3% of the segment and AND cover is > grass/herb cover?
If no, go to 7.2.2. If yes, then .... ***Pinus Ponderosa* Forest and Woodland with Shrub Understory Alliance**

7.2.1.1 Does *Quercus gambelii* occupy ≥2% of the total segment AND *Robinia neomexicana*, *Arctostaphylos patula*, *Populus tremuloides*, or *Purshia stansburiana* cover is at least 2% < *Quercus gambelii* cover?
If yes, then________________ ***Pinus ponderosa* / *Quercus gambelii* Woodland**

7.2.1.2 Does *Robinia neomexicana* occupy ≥ 2% of the total segment AND *Arctostaphylos patula*, *Populus tremuloides*, or *Purshia stansburiana* cover < *Robinia neomexicana* cover?
If yes, ... ***Pinus ponderosa* / *Robinia neomexicana* Woodland**

7.2.1.3 Does *Arctostaphylos patula* occupy ≥ 2% of the total segment coverAND *Purshia stansburiana*, and *Populus tremuloides* and coveris at least 2% < *Arctostaphylos patula* cover?
If yes, ... ***Pinus ponderosa* / *Arctostaphylos patula* Woodland**

7.2.1.4 Is *Purshia stansburiana* in the shrub strata?
If yes, ... ***Pinus ponderosa* / *Purshia stansburiana* Woodland**

7.2.1 Else________________ ***Pinus ponderosa* Forest and Woodland with Mixed Shrub Understory Alliance**

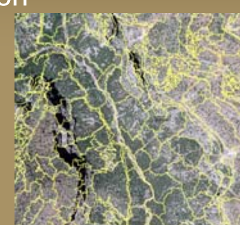
Phase 1 Methods

- Imagery
- ADS40 airborne digitial imagery (Fugro Horizons for NAIP) June 2007
- One meter spatial resolution
- Delivered as 4 band DOQQs
- Deep shadows
- Mosaiced / cut into regions.

ADS40 IR image showing deep shadows in bright Angel Canyon

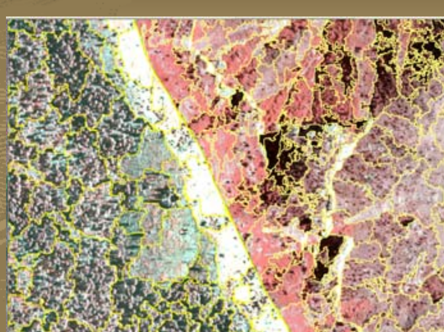
Phase 1 Methods

- Image Segmentation
- Trimble eCognition software
- Separate Algorithms for Rim (Above/ Below) and Shadow
- Reviewed by NPS
- Edited by KGA personnel
- Not perfect, but acceptable considering depth of shadow



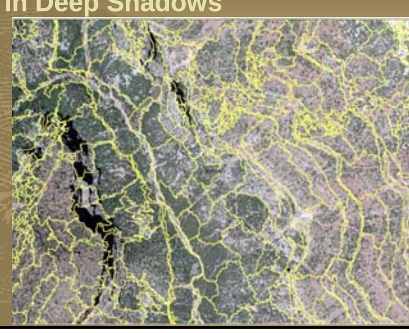
ADS40 IR image showing deep shadows in bright Angel Canyon

Example Segmentation



Spectral Fidelity of the ADS40 Imagery Allowed for Segmentation Even in Deep Shadows

Not perfect, but pretty good considering the depth of the shadows



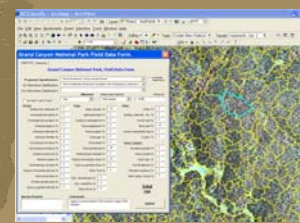
Phase 1 Methods

- Acquire Independent Variables
  - Imagery Variables
    - ADS40 (incl. adaptive texture of IR)
    - Landsat
  - Edaphic Factors
    - DEM-derived
    - Fire History / Intensity
    - Geospatial modeling (SLAP)

Phase 1 Methods

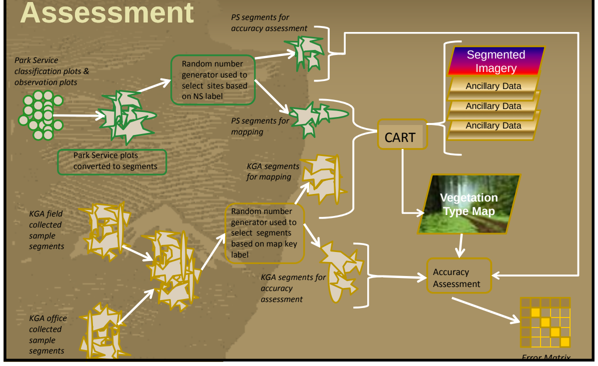
- Calibration Data

- Digital field forms
- 720 NPS points
- 500 KGA Segments
- Subset of points randomly withheld for accuracy assessment



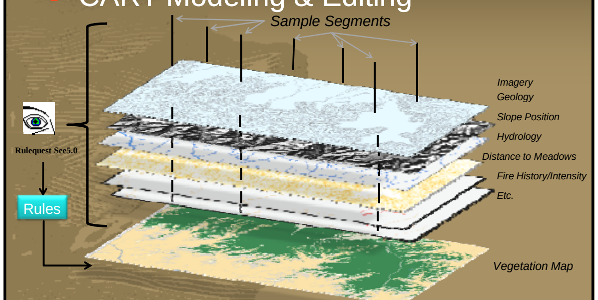
Screen shot of field form running in ArcMap 9.3

Stratifying Samples for Use in CART Verses Accuracy Assessment



Phase 1 Methods

- CART Modeling & Editing



- Rules developed in See5 from samples applied to all segments and exported to ArcGIS to create vegetation map

Phase 1 Methods

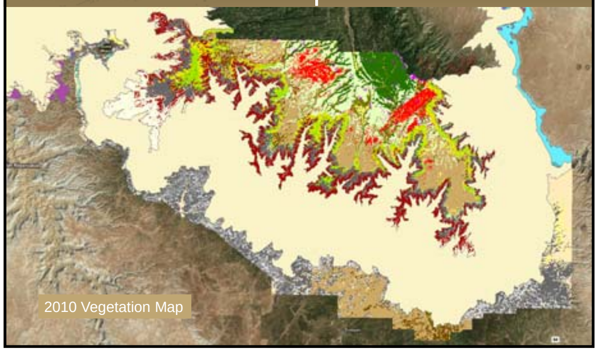
- Preliminary Review
  - KGA Field Trips
    - May and June 2010
    - 226 additional sites visited / edited
  - NPS Validation
    - August 2010, draft map
    - Stratified by map class, randomized
    - 47 sites, South- and North Rims
    - 72% agreement (62% SR; 91% NR)

Phase 1 Results

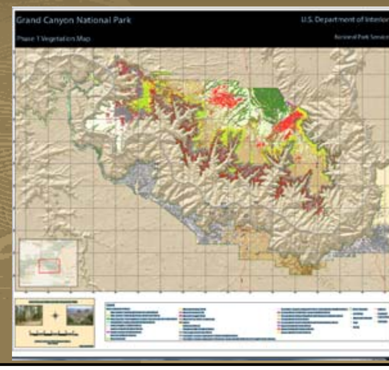
- Maps and data delivered
  - Segments labeled to NVC Association
  - Accuracy Assessment at "Map to" class
    - NVC Alliances and Associations
    - Below-rim to Life Form (to Phase 2)

Phase 1 Results

- 1982 vs. 2010 maps for Phase 1 area

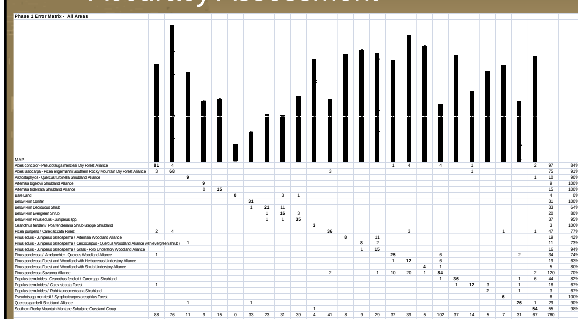


Phase 1 Results



Phase 1 Results

- Accuracy Assessment



Accuracy Assessment Results

- Overall accuracy of 81%
- Largest source of confusion (14% of confusion) is between Pinus ponderosa Savanna Alliance and Pinus ponderosa Forest and Woodland with Herbaceous Understory Alliance which is confusion between two different grass understory species
- Next largest source of confusion (8%) is between Pinus edulis - Juniperus osteosperma / Artemisia Woodland Alliance and Pinus edulis - Juniperus osteosperma / Grass - Forb Understory Woodland Alliance. When shrub cover is sparse, as it is in the canyon, it is very easy to confuse shrub and grass.

Moving to Phase 2

- Changes in Methods / Emphasis
  - ArcGIS 10 Image Processing
  - New Field Equipment (Trimble Yuma)
  - Imagery ('05 film, WorldView2)
  - Sparse vegetation = field emphasis and more landform / solar inputs
  - Classification is complete, Field Key is complete

Thank You

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CRMP Mitigation Program Summary

Since 2007:

- Completed 115 campsite and attraction site assessments (out of 234) along the river corridor
- Installed multiple long-term monitoring photopoints at 36 campsites
- Completed crucial mitigation actions at 39 sites including:
  - ✓ Planting
  - ✓ Pruning
  - ✓ Trail maintenance and re-routing
  - ✓ Social trail obliteration
  - ✓ Campsite delineation and obliteration
  - ✓ Social trail obliteration

For 2011:

- Have 66 site re-assessments scheduled
- Have 50 new site assessments scheduled
- Have 24 crucial mitigation action sites selected and scheduled for work

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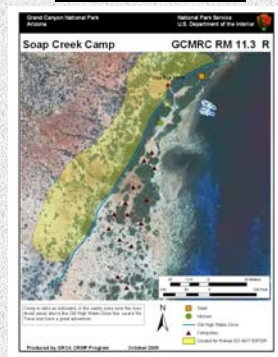
Soap Creek Project



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Soap Creek Project

In 2008, completed Phase I

- Collected native plant cuttings and seed
- Established new campsites near river
- Obliterated vast network of social trails
- Obliterated log constructed staircase

In 2009, completed Phase II

- Began 125 square meter campsite closure with active planting
- Planted 65 native nursery and salvage plants
- Installed 8 experimental ollas
- Began watering experiments between traditional berms and olla irrigation

In 2010, started Phase III

- Planted another 265 native nursery and salvage plants
- Installed 22 new ollas
- Replaced mortality from original planting and continued watering experiments

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National Park Service

November 2008

November 2010

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CRMP Monitoring Program Summary

What are the effects of campsite use on vegetation as a result of implementation of the 2006 CRMP?

- First trip Spring 2007
- To date: Spring and Fall for 4 years
- 66 camps total ~ 39-41 visited each trip

Monitoring Design:

- Series of 7 panels:
  - Panel 1 repeats each time
  - Panels 2-7 rotate every 3 years
- Campsites randomly selected representing:
  - Small, medium, and large campsites
  - Low, moderate, and high use
- New high water zone (35,000 cfs) – 66 transects
- Old high water zone (90,000 cfs) – 31 transects
- 50 meter transects
  - Vegetation cover by species
  - Substrate cover
  - Vegetation structure

Year	Season	1	2	3	4	5	6	7	Total Sites
2007	Spring	15	10				10	10	45
	Fall	15	10	10				10	45
2008	Spring	15	10	10	10				45
	Fall	15		10	10	10			45
2009	Spring	14			8	9	9		40
	Fall	14				9	9	9	41
2010	Spring	14	9				9	9	41
	Fall	14	9	8				9	42
2011	Spring	14	9	8	8				39
	Fall	14		8	8	9			39

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Management Questions

- ❖ Are there any detectable changes in total vegetation cover or structure?
- ❖ Do we see an increase in exotic plant cover?
- ❖ Does species richness remain stable?
- ❖ Is there a loss of microbiotic soils or an increase in bare soil or sand?
- ❖ Is there a change in the number of mature trees?
- ❖ How does any detectable change vary among campsite size and use level?

January 2011
Revisiting protocols and presenting preliminary results along with recommendations for future monitoring and expansion below Diamond Creek and to attraction sites.

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Invasive Plant Species Management Summary

Park managers are directed to give high priority to control and management of **exotic species** that can be **easily managed** and have **substantial impacts** on the Park's resources.

Ravenna grass – *Saccharum ravennae*

- Ongoing control program since early 1990s
- Manual removal of more than 30,000 plants
- Volunteer efforts have been integral to success
- Found huge new population in 2006!

Pampus grass – *Cortaderia selloana*

- Currently manageable, but need to continue working with Glen Canyon to control upriver populations
- Need to work with local nurseries to discontinue stock
- Found first individuals up a side canyon in 2010

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Russian olive – *Elaeagnus angustifolia*

- Only scattered individuals in park
- Working with Glen Canyon to remove all upriver trees (removed 49 in fall 2010)
- Park staff will continue to monitor all sites and remove any new individuals found

Sahara mustard – *Brassica tournefortii*

- Thrives on wind-blown sand deposits & disturbance
- Early flowering – monopolizes resources
- Found at Lees Ferry in 2003
- Removed 239,833 plants
- Coordinating efforts with Glen Canyon staff

Other Species We Focus On:

- Siberian elm (*Ulmus pumila*)
- Camelthorn (*Alhagi maurorum*)
- Russian thistle (*Salsola tragus*)
- Perennial pepperweed (*Lepidium latifolium*)
- African mustard (*Malcolmia africana*)

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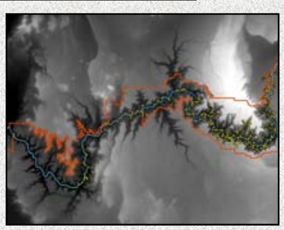
Tamarisk Management Project Summary

- Tamarisk control in side canyons began in 2002
- Tamarisk removed from over 130 project areas using hand tools and herbicide
- 287,281 tamarisk trees removed from side canyons along 217 miles of river
- Over 45,000 volunteer hours ($911,250) donated
- Provided hands-on stewardship opportunities
- Botanists documented 15 new plant species
- Project received international recognition



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Future Project Plans

- Continue cyclic maintenance of 130+ project sites
- Remove tamarisk from additional side canyons using same methodology (compatible with proposed wilderness setting and character)
- Continue monitoring every 3-5 years
- Expand project and partnerships
- Set appropriate goals based on past data analysis (e.g. increasing native species abundance and richness)
- **Pro-actively, aggressively, and comprehensively prepare for tamarisk leaf beetle's spread in Grand Canyon National Park!**

In 2009:
- completed sweep surveys at 277 sites
- found 6 larvae (RM 4.5 and RM 12)
- no adults found
- no surveys below Diamond Creek
- no surveys between Glen Canyon Dam and Lees Ferry

Diorhabda carinulata

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In partnership with USGS-Biological Resources Division with support from Grand Canyon Association, we were able to:

- Design a simple sampling and monitoring system that utilizes a subset of the Colorado River Monitoring Plan sites
- Complete 6 rounds of sampling in the river corridor
- Complete sampling in partnership with Glen Canyon NRA from Lees Ferry to Glen Canyon Dam
- Install temporary instruments to gather microclimate information
- Train rangers, park staff, and volunteers in beetle monitoring
- Compile existing data sets for baseline conditions habitat conditions
- Continue partnership with Grand Canyon Youth

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What Did We Find in 2010?

The beetle moved MUCH faster than anticipated!

- Beetles are found at stock tanks near Tuweep, up side canyons (Stone Creek, Kanab Creek, etc), and non-continuously from Glen Canyon Dam to Diamond Creek.
- Beetles are found in abundance in Glen Canyon NRA.

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By September 2010:

- there were obvious signs of defoliation for the first 30 miles and sporadically from river mile 138-180
- In areas where beetles were present, there was 80-95% defoliation of tamarisk
- Beetles were more/less distributed the length of Kanab Creek
- No sign of beetles yet between Diamond Creek and Lake Mead NRA

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What is GRCA's plan for 2011 and Beyond?

- **Continue to sample for the tamarisk beetle in the river corridor**
  - Work will be completed a minimum of 3 times each summer to capture all of the beetle's life phases
  - Support will be provided by Grand Canyon Youth and NPS river trips
  - Standard monitoring protocols will be followed
  - Data will be provided to the Tamarisk Coalition and will be available to the public
  - Continue partnership with USGS-Biological Resources Division
- **Prepare public outreach information and brochures**
- **Expand partnerships with Lake Mead and Glen Canyon NRAs**
- **Prioritize areas for active restoration with a focus on areas near documented southwestern willow flycatcher nesting sites**
- **Seek funding for post-beetle site restoration**
- **Continue seed collection & plant propagation for active restoration in the Colorado River corridor**

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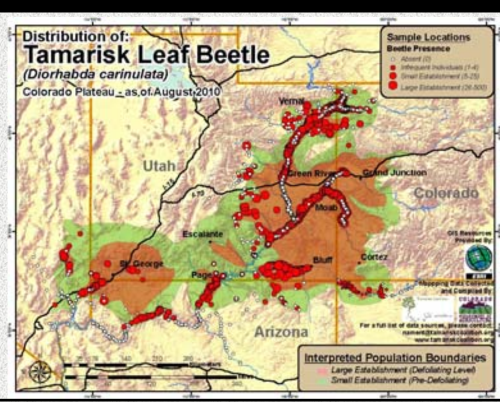

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Tamarisk Leaf Beetle Background

- Identified in 1992 as a potential biological control agent
- Extensive testing completed by USDA Animal and Plant Health Inspection Service (APHIS)
- Highly specialized on tamarisk
- First beetles released in 2001; by 2006 populations were released in 6 states
- **There have been no approved active releases in Arizona and there is a current ban on releases on NPS lands**

Genetic work in 2009 changed the name from *Diorhabda elongata* to ***Diorhabda carinulata*** – the species found in GRCA