## List of Presentations

<table>
<thead>
<tr>
<th>No.</th>
<th>Title of Presentation</th>
<th>Author / Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Update on Water Quality and 2010 Sand Input</td>
<td>Paul Grams, David Topping</td>
</tr>
<tr>
<td>2</td>
<td>Goal 8: Long Term Monitoring for Changes in Sediment Storage “Sed Trend”</td>
<td>Paul Grams, Matt Kaplinski, and Joe Hazel</td>
</tr>
<tr>
<td>3</td>
<td>FY10: Sandbar and Campsite Monitoring in Colorado River in Marble and Grand Canyons</td>
<td>Joe Hazel, Matt Kaplinski, Rod Parnell, and Nathan Schott</td>
</tr>
<tr>
<td>4</td>
<td>Sediment from the Colorado River —1965 to 2009</td>
<td>Nina Kilham, John Schmit, ...</td>
</tr>
<tr>
<td>5</td>
<td>Update to TWG on Campsite Monitoring and other Recreation Projects (Goal 9)</td>
<td>Helen Fairley</td>
</tr>
<tr>
<td>6</td>
<td>Ground Cover and Stability of Aeolian Landscapes</td>
<td>Amy Draut</td>
</tr>
<tr>
<td>7</td>
<td>Rainbow Trout Early Life Stage Survival FY 2010 TWG Report</td>
<td>Josh Korman</td>
</tr>
<tr>
<td>8</td>
<td>Linking whole-river carbon cycling to quantitative food webs in the Colorado River</td>
<td>Kevin Donner, Holly Welland, Sarah Zahn, Kate Behm, ...</td>
</tr>
<tr>
<td>9</td>
<td>Modeling Population Dynamics of Rainbow Trout in Lees Ferry and Marble Canyon</td>
<td>Josh Korman, Carl Walters, Andy Makinster, Lew Coggins, ...</td>
</tr>
<tr>
<td>10</td>
<td>The natural history of Western Honey Mesquite in Grand Canyon, A Changing Ecology</td>
<td>Gwendolyn Waring, Barbara Ralston, Larry Stevens, and Steven Archer</td>
</tr>
<tr>
<td>11</td>
<td>Terrestrial Riparian Vegetation Monitoring on the Colorado River Corridor: Glen Canyon Dam to Lake Mead</td>
<td>David J. Cooper and Jennifer R. Jones</td>
</tr>
<tr>
<td>12</td>
<td>Grand Canyon National Park Vegetation Mapping Project</td>
<td>Mike Kearsley, Mark Nebel, and Kass Green</td>
</tr>
<tr>
<td>13</td>
<td>CRMP Mitigation Program Summary</td>
<td></td>
</tr>
</tbody>
</table>
Update on Water Quality and 2010 Sand Input

GCDAMP Annual Reporting Meeting
January 18, 2011
Paul Grams and David Topping

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

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

Draft data subject to revision. DAY 1 OF 2.
TWG review document, DO NOT CITE, reproduce, or distribute.

Date: 1/19    DRAFT DO NOT CITE.
Sand update: January 7, 2011

- RM 0 to RM 30,
  - Budget is currently positive (Jan. 7, 2011) between 1.0 and 1.6 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 RM 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 RM 225
  - Budget is currently positive (Jan. 7, 2011) between 0 and 0.7 million metric tons.
  - Minimal sand from summer 2010 LCR floods retained in reach owing to higher dam releases.

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.
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

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)
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

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.

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.

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?
- 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.

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?

Strategic Science Questions that motivate Goal 8 Monitoring

AMWG Priority 3: What is the best flow regime? (GCDAMP goals 1–11)
- 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.

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

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.

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.
Analysis and Interpretation of Channel Mapping Data: 2008 HFE

Demonstrates the difference between high- and low-elevation responses.

May 2002 to May 2009: RM 42 to 45

May 2002 to May 2009: RM 44 (Eminence Break camp)

May 2002 to May 2009: RM 45 (Willie Taylor camp)

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

**Response below 8,000 cfs**

**Response above 8,000 cfs**

Date: 1/19   DRAFT DO NOT CITE.  6
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.

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.

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

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.
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 ft³/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

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)
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.

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.

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 larger.

What is the future desired condition?

The sandbar at Saddle was twice the size in 1986 than 1990.
The potential role of powerplant capacity flows to build bars?

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

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.

Anticipated products in FY2011:

Anticipated products in FY2011:
EVACUATION OF FINE 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, 1930, 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)

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.

INCISIO

95% of sediment cut-off

63% reduction in 2-yr flood

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

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.

Date: 1/19    DRAFT DO NOT CITE.
**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.

---

**Historic Datasets**

<table>
<thead>
<tr>
<th>Year</th>
<th>Data Source</th>
<th>Instrument</th>
<th>Discharge</th>
<th>WSE*</th>
<th>Path Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun-65</td>
<td>Leopold/Emmett, Howard/Dolan</td>
<td>Fishfinder</td>
<td>0.3</td>
<td>1372</td>
<td>2.5</td>
</tr>
<tr>
<td>Jul-76</td>
<td>Howard/Dolan reported in Dolan et al., 1978</td>
<td>Fishfinder</td>
<td>0.3</td>
<td>578</td>
<td>0.4</td>
</tr>
<tr>
<td>Mar-84</td>
<td>USGS/BOR</td>
<td>reported by Tim Randle as a total error high WSE of .6 low .15</td>
<td>0.15</td>
<td>678-708</td>
<td>0.6</td>
</tr>
<tr>
<td>1992-1995</td>
<td>Graf</td>
<td>sonic-depth sounder</td>
<td>0.39</td>
<td>194-558</td>
<td>0</td>
</tr>
<tr>
<td>Aug-00</td>
<td>FIST</td>
<td>Reconv Seabat 8124 multi-beam sounder</td>
<td>0.088</td>
<td>227</td>
<td>0</td>
</tr>
<tr>
<td>May-02</td>
<td>FIST</td>
<td>Reconv Seabat 8124</td>
<td>0.074</td>
<td>227</td>
<td>0</td>
</tr>
<tr>
<td>Jun-04</td>
<td>FIST</td>
<td>Reconv Seabat 8124</td>
<td>0.063</td>
<td>227</td>
<td>0</td>
</tr>
<tr>
<td>Nov-04</td>
<td>FIST</td>
<td>Reconv Seabat 8124</td>
<td>0.048</td>
<td>227</td>
<td>0</td>
</tr>
<tr>
<td>Dec-04</td>
<td>FIST</td>
<td>Reconv Seabat 8124</td>
<td>0.05</td>
<td>227</td>
<td>0</td>
</tr>
<tr>
<td>May-09</td>
<td>GMRRC</td>
<td>Garmin GPS Fish Finder</td>
<td>0.15</td>
<td>227</td>
<td>0.32</td>
</tr>
</tbody>
</table>

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

---

*RM 42.3-45.5*

**Minimum Surface**

**Transient Storage**

---

*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!
Sources of Uncertainty:
- Instrument?
- Boat path (longitudinal and lateral position)?
- Water surface?

Reference rapids helped locate the old traces.

 Depths were converted to elevations using modeled water surface elevations.

BLACK bars show the additive uncertainty for each depth.

RED boxes show the range of the annual pool elevation measured by GCMRC.

RED: most active
BLUE: least active
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

Evaluate vegetation encroachment at campsites
Evaluate change using remotely sensed imagery and repeat photographs (AAB, Bob Webb, Weeden photo matches)

1. Monitor Changes in Campsite Area & Quality
   - Campsite area measurements (NAU repeat surveys)
   - Evaluate vegetation encroachment at campsites

2. Develop GIS-Based Campsite Atlas

3. Recreation Safety in Relation to Flows Study

Evaluate 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 1996, 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
Robert H Webb is matching Stanton photos from 1890, 1990-91 and 2010-11

GIS Atlas Project: Relevant 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 do 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

Talking Heads Camp, RM 133.7

April 17, 1996

July 15, 1998

Sept 20, 2006

June 8, 2009
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

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

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

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?

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

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)
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

Wind-blown sand forms aeolian dunes

Weather stations tell us where wind carries sand from river sandbars; landscape processes near archeological sites

New river sand moves inland by wind

Controlled floods can supply new wind-blown sand where wind direction is right

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
Modern vs. Relict aeolian landscapes

Some get new sand from modern sandbars
Others don’t.

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)

Open sand space

Box-and-whisker plots:

3rd quartile (Q₃)
Median (2nd quartile, Q₂)
1st quartile (Q₁)
Outliers: any points > 1.5 times the inter-quartile range
Whiskers: highest and lowest non-outlier points

GC-Modern GC-Relict

These sites get modern wind-blown sand supply after HFEs
These don’t

Open sand space

t-test tells you how different two groups are

\[ t\text{-test} \Rightarrow p\ value \]
Low p values mean the two groups are significantly different
\[ p < 0.00001 \]

Biologic soil crust

GC-Modern GC-Relict

These sites get modern wind-blown sand supply after HFEs
These don’t

p < 0.005

Vegetation cover

GC-Modern GC-Relict

These sites get modern wind-blown sand supply after HFEs
These don’t

Other factors also affecting vegetation (e.g., non-native Russian Thistle explosions)

But still, \( p < 0.05 \)
Sand transport by wind

- **Sand transport by wind**

  - **p < 0.00005**
  - These sites get modern wind-blowing sand supply after HFEs
  - These don’t

Aeolian dunes without modern sand supply:

- **Have:**
  - More biologic crust
  - More vegetation
  - Less open sand
  - Less sand transport

- **Implications for archeological site stability**
  - Less sand movement on ground surface
  - Dunes less mobile
  - Artifacts covered/uncovered by dunes
  - Windblown sand can fill small gullies
  - Small gullies become large gullies

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**

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?**
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

Cataract Canyon

Spring flood in 2010 around 54,000 cfs

Big new sandbars left by spring flood...

... forming aeolian dunes downwind

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

\[ p > 0.05 \]

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

\[ p > 0.05 \]
Results: Vegetation cover

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

\[ p > 0.05 \]

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

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)

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

- Flood of 170,000 cfs can supply sand to 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
Normalizing sand-transport rates:
used local 4-minute wind and rain data

\[ q = \frac{1.8 \sqrt{D \rho g}}{10^7} \]

*Dimensionless #*

Don’t have \( u^* \) (shear velocity), so substitute \( u_2m \)
(wind velocity) in Bagnold (1941) transport equation

Kawamura (1955)

\[ q = \frac{2 \sqrt{D \rho g (u_2m - u_m - u_1) u_2m}}{10^7} \]

Zingg (1953)

\[ q = \frac{a \sqrt{D \rho g u_2m^3}}{10^7} \]

You can use other transport equations instead; doesn’t change results.

---

Date: 1/19  DRAFT DO NOT CITE.
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 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.
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
  - Low-velocity-shallow habitat suitable for small age-0 trout

- **High-angle habitat**: Preferred by larger age-0 trout, July-Winter
  - Likely less sensitive to variation in flow
  - Preferred habitat for larger age-0 trout, July-Winter

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.

Draft data subject to revision. DAY 1 OF 2. TWG review document, DO NOT CITE, reproduce, or distribute.
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).
- 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 Meli, Mike Yard, Lew Caggins, Steve Mantell, 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 patterns 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.
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:
grams organic matter
meter$^2$ year

Energy is more or less equivalent to organic matter

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

Your neighbor’s lawn

Your Answer
1 ton

3 tons

Date: 1/19     DRAFT DO NOT CITE.
Increased trout production despite reduced total prey production following the 2008 controlled flood

Sampling regime
- Seasonally – due to remote location
- Monthly – needed to get an accurate estimation of 2nd prod.

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

In revision, Ecological Applications
The 2008 artificial flood stimulated production of key invertebrate taxa.

Quantitative Food Webs

Midge and black fly drift increased after the flood.

Reduced flows to invertebrates
Increased flows to trout.
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

Measured empirically

Resaturation

Upstream input

Metabolism

Downstream export

Easily measured using recording oxygen sensors

Estimating primary production parameters

Estimate metabolism by fitting below model to data.

Minimize negative log-likelihood function.

\[
C_t = C_o + \frac{GPP}{z} \times \frac{PAR}{\Sigma PAR} + \frac{CR \Delta t}{z} + K(C_t - C_o)\Delta t
\]

Van de Bogart et al. 2007

Scaling gas exchange across long reaches

Colorado River has among highest rates of gas exchange ever measured

**Draft data subject to revision. DAY 1 OF 2.**

TWG review document, DO NOT CITE, reproduce, or distribute.
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**

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

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 AFDM m⁻² yr⁻¹
Lees Ferry post-flood ~12 g AFDM m⁻² yr⁻¹

Algae consumption by invertebrates tracks primary production

Holly Wallard, unpublished

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 attributable to autochthonous and allochthonous resources

Production Attributed to Autochthonous and Allochthonous Organic Matter

% 20 40 60 80 100
Invertebrate diets versus d13C -22 -20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0

Macro invertebrate diets versus δ13C

δ13C

NZMS

KM 0

Downstream sites

Autochthonous (Diatoms + Fila. Algae)
Allochthonous (A. Detritus + Leaf Material)

Time-Averaged Turbidity

Log suspended sediment concentration (mg/L)

The downstream food base of downstream fishes

Production and food base of downstream fishes

Date: 1/19 DRAFT DO NOT CITE.
Fish production is comparable across sites.

Production attributable to different resources

Trophic basis of fish production

Production / Demand — Blackflies

Production / Demand — Midge

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
**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.

**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

---

**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.

---

**FY2010 Accomplishments**

2 Journal articles
3 USGS Reports
2 Masters Theses
5 Presentations to AMP committees
5 Presentations at National Meetings
What fuels invertebrate production in downstream reaches?

Production varies by habitat
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.

The Data

<table>
<thead>
<tr>
<th></th>
<th>Lees Ferry</th>
<th>Marble Canyon</th>
<th>Control Reach</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Trips</td>
<td>60</td>
<td>51</td>
<td>24</td>
<td>135</td>
</tr>
<tr>
<td># Years with Trips</td>
<td>20 (’91–’10)</td>
<td>17 (’91–’10)</td>
<td>5 (’05–’06, ’10)</td>
<td></td>
</tr>
<tr>
<td>Average # Trips per Year</td>
<td>3.00</td>
<td>3.00</td>
<td>4.00</td>
<td></td>
</tr>
<tr>
<td>Average Effort per Trip (hrs)</td>
<td>6.90</td>
<td>6.27</td>
<td>9.11</td>
<td>6.51</td>
</tr>
<tr>
<td>Average Proportion Sampled per Trip</td>
<td>0.14</td>
<td>0.04</td>
<td>0.45</td>
<td>0.21</td>
</tr>
<tr>
<td>Total Fish Captured Across Trips</td>
<td>59,093</td>
<td>15,699</td>
<td>12,687</td>
<td>87,479</td>
</tr>
</tbody>
</table>

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

- Steadier flows in 1996, 2008
- Steady flow in Summer 2008
- Lower flows in 2005
- Floods in 1996 and 2008
Main Conclusions from Modelling

- Two major recruitment events over last two decades
  - 1997, 2006, 2009 caused by HFE. Best bet is that 1997 caused by HFE.
  - Surprisingly, little evidence of downstream movement from 2000 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 seasonally timing and size at outmigration.
- FY2011 work will focus on improving calculations of uncertainty in models 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

Expected Recaptures from Each Annual Marked Cohort

<table>
<thead>
<tr>
<th>Proportion emigrating at age</th>
<th>0.1</th>
<th>0.25</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTE lucky LF Age-0 recaptures</td>
<td>201</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGF LF Age-1 recaptures</td>
<td>94</td>
<td>79</td>
<td>52</td>
</tr>
<tr>
<td>PBR Age-1 recaptures</td>
<td>220</td>
<td>550</td>
<td>1,101</td>
</tr>
<tr>
<td>MC recaptures (not including PBR and LCR)</td>
<td>16</td>
<td>39</td>
<td>79</td>
</tr>
<tr>
<td>LCR recaptures (upper stratum)</td>
<td>102</td>
<td>256</td>
<td>511</td>
</tr>
</tbody>
</table>

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 tag in PBR and in LCR Reach
   - Large cost of recapture in these areas already covered by removal program.
3. Recapture tag in Marble Canyon between PBR and LCR
   - Dedicate one ADF normative 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 in existing model to derive reliable estimates of key population dynamic parameters.
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

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Variable</th>
<th>Mean #/cm²</th>
<th>Mean BD (mm)</th>
<th>Mean #/1000 m²</th>
<th>Mean BD (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandbar</td>
<td>Mean</td>
<td>0.1</td>
<td>0.4</td>
<td>0.7</td>
<td>24.5</td>
</tr>
<tr>
<td></td>
<td>stdev</td>
<td>0.14</td>
<td>0.13</td>
<td>0.81</td>
<td>15.12</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>11</td>
<td>6</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>t</td>
<td>1.796</td>
<td>1.943</td>
<td>1.796</td>
<td>2.353</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>0.7235</td>
<td>28.0116</td>
<td>0.4410</td>
<td>20.5404</td>
</tr>
<tr>
<td>Debris Fan</td>
<td>Mean</td>
<td>0.01</td>
<td>0.013</td>
<td>0.012</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>stdev</td>
<td>0.01</td>
<td>0.0012</td>
<td>0.0012</td>
<td>0.0012</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>1</td>
<td>61</td>
<td>51</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>t</td>
<td>1.746</td>
<td>1.753</td>
<td>1.734</td>
<td>1.761</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>1.2101</td>
<td>14.0775</td>
<td>1.5015</td>
<td>15.3501</td>
</tr>
<tr>
<td>Channel</td>
<td>Mean</td>
<td>0.01</td>
<td>0.017</td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td>stdev</td>
<td>0.01</td>
<td>0.0034</td>
<td>0.0034</td>
<td>0.0034</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>t</td>
<td>1.796</td>
<td>1.796</td>
<td>1.782</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>0.0901</td>
<td>10.0705</td>
<td>1.4453</td>
<td>---</td>
</tr>
<tr>
<td>Sandbar</td>
<td>Mean</td>
<td>0.00</td>
<td>0.00</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>stdev</td>
<td>0.00</td>
<td>0.00</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>1</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>t</td>
<td>6.314</td>
<td>6.314</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>0.0000</td>
<td>211.6451</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Cobblebar</td>
<td>Mean</td>
<td>0.23</td>
<td>0.38</td>
<td>0.24</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>stdev</td>
<td>0.30</td>
<td>0.37</td>
<td>0.28</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>t</td>
<td>2.920</td>
<td>2.920</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>0.6199</td>
<td>77.0982</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Grand Total</td>
<td>Mean</td>
<td>0.3</td>
<td>0.6</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>stdev</td>
<td>0.43</td>
<td>0.49</td>
<td>0.49</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>41</td>
<td>35</td>
<td>41</td>
<td>17</td>
</tr>
</tbody>
</table>

- Draft data subject to revision. DAY 1 OF 2.
**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)


**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

GLEN CANYON Stratum

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

Local Scale

- 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

Debris fan

Eddy

Pool

Sample Point
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)

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

Vegetation Sampling

- Canopy cover of vascular plants in each permanent plot
- 1 m² and 20 m² plots
- Herbaceous species in 1 m² plots
- Cover and height of woody plants in 20 m² plots
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
Grand Canyon National Park Vegetation Mapping Project

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

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

- Example Key Rules

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

- 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

**Example Segmentation**

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

---

Date: 1/19

DRAFT DO NOT CITE.
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

Stratifying Samples for Use in CART Verses Accuracy Assessment

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

Phase 1 Methods

- CART Modeling & Editing
  - Imagery
  - Geology
  - Slope Position
  - Hydrology
  - Distance to Meadows
  - Fire History/Intensity
  - Etc.

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

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
Grand Canyon National Park

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 35 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 54 site re-assessments scheduled
- Have 60 new site assessments scheduled
- Have 66 site re-assessments scheduled

CRMP Mitigation Program Summary

For 2011:
- Have 24 crucial mitigation action sites selected and scheduled for work

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 60 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 260 native nursery and salvage plants
- Installed 22 new ollas
- Replaced mortality from original planting and continued watering experiments

Soap Creek Project

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?

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
  - 65 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) – 94 transects
    - Old high water zone (90,000 cfs) – 31 transects
    - 50 meter transects
    - Vegetation cover by species
    - Substrate cover
    - Vegetation structure

CRMP Monitoring Program Summary

Does species richness remain stable?
- Is there a loss of microbiotic soils or an increase in bare soil or sand?
Grand Canyon National Park

Invasive Plant Species Management Summary

Park managers are directing 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 2009

Pampas 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

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

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!

What Did We Find in 2010?

- 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.

Other Species We Focus On:
- Russian olive – Elaeagnus angustifolia
  - Thorny wind-blown sand deposits & disturbance
  - Early flowering – monopolizes resources
  - Found at Lee’s Ferry in 2002
  - Removed 278,853 plants
- Sahara mustard – Brassica tournefortii
- Russian thistle – Salsola tragus
- Maltepia africana
- African mustard (Malcolmia africana)
- Russian evil – Phacelia angustifolia
  - Hands-on stewardship opportunities
  - Found at Lee’s Ferry in 2003
  - Removed 278,853 plants
  - Coordinating efforts with Glen Canyon staff

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 Lee’s Ferry to Glen Canyon Dam
- Installed 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

What Did We Find in 2010?

- Beetles were 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.
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

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

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
- adult beetles lay eggs on tamarisk
- larvae emerge – live 27 days (3 stages or instars)
- final instar pupates into cocoon
- adults emerge from cocoon
- adults copulate
- genetic work in 2009 changed the name from Diorhabda elongata to Diorhabda carinulata – the species found in GRCA
- adult beetles lay eggs on tamarisk
- larvae emerge – live 27 days (3 stages or instars)
- final instar pupates into cocoon
- adults emerge from cocoon
- adults copulate