Integrating high-resolution vegetation data and 14 years of topographic surveys to quantify impacts to sandbar campsites, Grand Canyon National Park

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GSA Annual Meeting, 2018
Background

- Glen Canyon Dam constructed in 1963
- Erosion of sandbars due to lack of sediment replenishment
- Vegetation encroachment due to lack of flooding
- Reduction in size and number of sandbar campsites, a vital recreational resource
- Controlled floods primary management strategy to replenish sandbars

Causes of Campsite Loss

- Erosion from daily fluctuations
- Vegetation Encroachment
- Gulllying
The debris-fan eddy complex

- Debris fans form channel constrictions
- Create pools, rapids, and recirculating eddies
- Slower velocities in eddies allow sand deposition
- Separation bars and reattachment bars areas are primary area used as campsites by river runners and hikers
37 Long-Term Monitoring Study Sites

Goals

1. Quantify changes in vegetation at campsites
2. Analyze elevation and slope change due to: controlled floods, daily dam releases, and gullying

- What are the geomorphic and vegetation responses to flow regulation?
- Are controlled floods increasing the size of campsite area long-term?

- Sandbar topography and campsite area measured on a near-annual basis
- 1998-present
- Total-station surveys
- 1-m Digital Elevation Models (DEMs)
- Specific criteria define usable campsite area (smooth sand, < 8 degree slope)
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Non-Critical Reaches = wide sections of canyon, numerous debris-fans

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Critical Reaches = narrow sections of canyon, limited number of campsites

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Methods

A. Campsite surveys (2002-2016)
B. Elevation change calculated from DEMs of difference
C. Slope change based on 8° threshold
D. Vegetation change using canyon-wide maps of vegetation (May 2002 and 2009)
   - 4-Band orthoimagery (RGB + NIR)
   - 0.20 m resolution
   - Normalized Difference Vegetation Index
     \[
     \text{NDVI} = \frac{(\text{NIR} - \text{VIS})}{(\text{NIR} + \text{VIS})}
     \]
E. Gullies detected from flow direction and flow accumulation tools (ArcGIS) using slope rasters

Two Components

1. Determined cause of campsite area changes from 2002-2009 (includes 2004 and 2008 controlled flood)
Results (2002-2009)

- Net decline of campsite area of 2,547m$^2$ (12%), despite two controlled floods
- Erosion and slope change more prevalent in critical reaches (both gains and losses)
- Vegetation expansion more prevalent in non-critical reaches
- Gully ing occurred at 5 sites, accounted for < 1% of overall loss (important locally, but not overall)

Two drivers of campsite change
- Short-term gains and losses associated with controlled floods and flood deposit erosion
- Long-term one directional loss of due to vegetation encroachment
Specific Mechanisms of Topographic Change (2002-2009)

Elevation Change with no slope change

A. Deposition → burial of vegetation/boulders → campsite gain
B. Erosion → exposure of vegetation/boulders → campsite loss
C. Deposition → presence of driftwood/debris → campsite loss
D. Erosion → sandbar smoothing → campsite gain

Elevation Change and slope change

1. Deposition → creates flat area → campsite gain
2. Deposition → creates steep area → campsite loss
3. Erosion → removes flat area → campsite loss
4. Erosion → removes steep area → campsite gain

Lateral Cutbank Retreat

Site 22.1R
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- Controlled floods both create and destroy campsite area
- Not a direct correlation between increases in sandbar size and campsite size
Estimating Cause of Campsite Change (2002-2016)

- Campsite area declined by 37%
- 6 Controlled Floods
- Avg. vegetation expansion rate of 413 $m^2/\text{year}$
- Gains in campsite area from topographic change essentially negligible
- Vegetation expansion basically outpacing the short term gains associated with controlled floods
Conclusions

What are the geomorphic and vegetation responses to flow regulation?
• Native and non-native vegetation continues to expand
• Gains from controlled floods often short-lived due to fluvial mainstem erosion (daily fluctuating dam releases)

Are controlled floods increasing the size of campsite area long-term?
• Despite the use of more frequent floods......not exactly
• Sandbars maintaining or increasing in volume (Grams et al., 2015;2018) , but not direct relationship (Hazel et al., 2008)

Recommendations
• Manual vegetation removal (particularly sites in critical reaches)
• Update vegetation expansion rates with 2013 imagery

South Canyon RM 32.2, looking downstream

USGS Desert Laboratory Repeat Photography Collection
Publications and Contact

  [https://doi.org/10.3133/sir20175096](https://doi.org/10.3133/sir20175096)

- USGS Data Release (2018)
  [https://www.sciencebase.gov/catalog/item/59a5d3dae4b024f204d408b5](https://www.sciencebase.gov/catalog/item/59a5d3dae4b024f204d408b5)

- River Research and Applications article (September 2018)
  *Quantifying geomorphic and vegetation change at sandbar campsites in response to flow regulation and controlled floods, Grand Canyon National Park, Arizona*
  [https://doi.org/10.1002/rra.3349](https://doi.org/10.1002/rra.3349)

Acknowledgements

Funded by Glen Canyon Dam Adaptive Management Program through a cooperative agreement between the USGS Grand Canyon Monitoring and Research Center and NAU. Thanks to Rod Parnell, Joe Hazel, Tom Gushue, Rob Ross, Tim Andrews, and all the NAMS!