

# Project D: Experimental Management of Aeolian-Fluvial Interactions and Riparian Vegetation Feedbacks for Cultural Resources in Grand Canyon

Glen Canyon Dam Adaptive Management Program Annual Reporting Meeting  
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Flagstaff, AZ

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## FY 25-27 TWP Projects: Archaeological and Cultural Resources

- *Triennial Workplan (TWP) projects collectively examine whether and how dam operations and experiments like HFEs, vegetation management, and site management by NPS help to achieve the LTEMP goal of preservation in place:*
- GCMRC TWP
  - **Project D: Dam Operations, Vegetation Management, Archaeological Sites (USGS, Sankey, Fairley)**  
(FY2025/2026/2027: \$415k/\$562k/\$573k)
    - D.1. Monitoring the Effects of Dam Operations on Archaeological Sites
    - D.2. Monitoring Landscape-Scale Ecosystem Change with Repeat Photography
    - D.3. Evaluating Effects of LTEMP Non-Flow Actions and other Experimental Vegetation Management on Archaeological Sites
- Reclamation TWP
  - Project 5.B. Cultural Resources Monitoring – Grand Canyon (NPS, Ellen Brennan, Jennifer Dierker) and Project 5.C. Glen Canyon NRA (NPS, Amy Shott)
  - Project 4.D. Experimental Vegetation Treatment – GRCA and GLCA (NPS, Lonnie Pilkington, Taryn Preston)

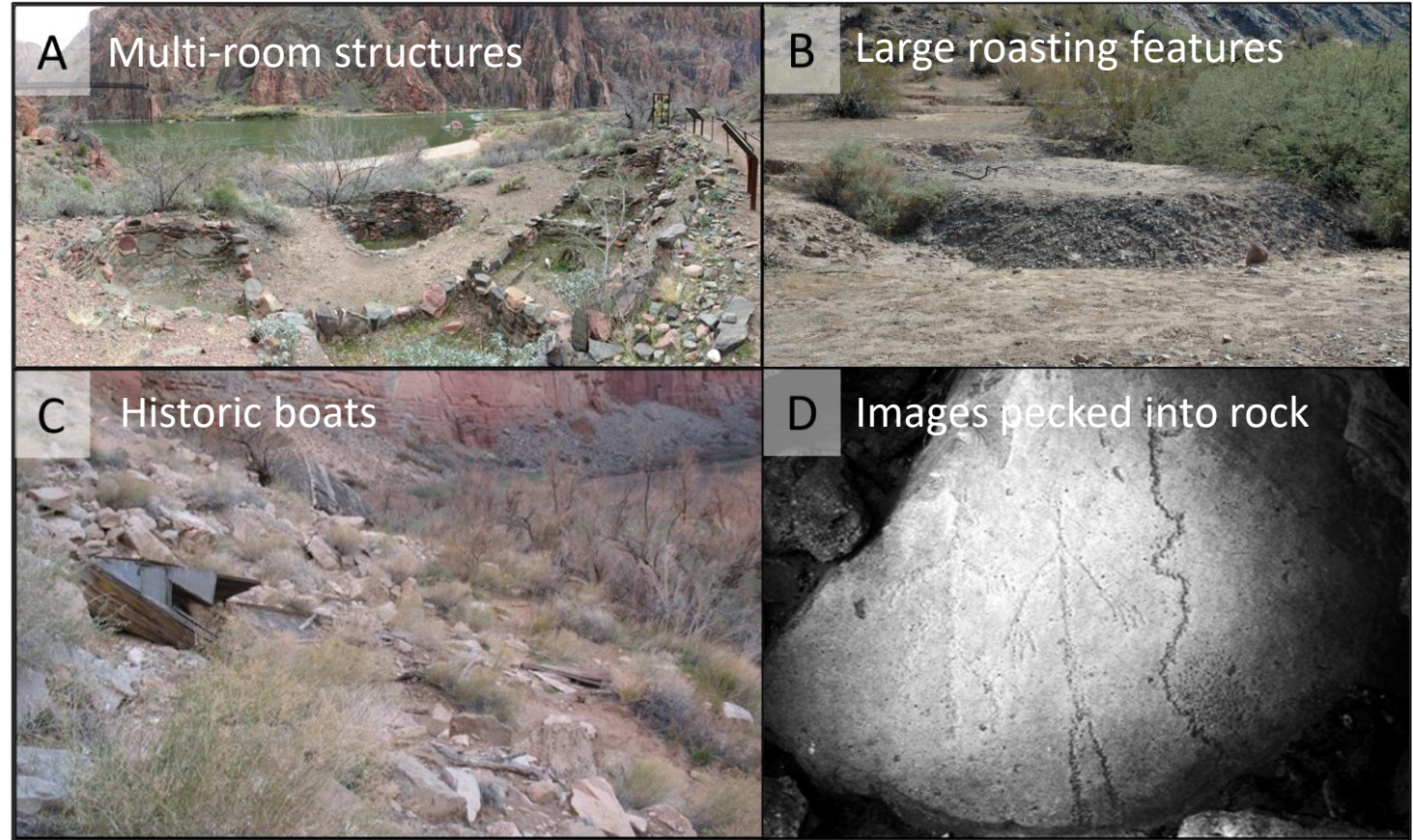


## Project D: Activities During FY2025

- GRCA archaeological site lidar monitoring and repeat photography
  - Project Element D1 and D2: May 2025 River Mission
- Finalized analysis and interpretation of monitoring data acquired in FY2024
  - Project Element D1
    - See Metrics Goal 1 Poster (Fairley)
- Collaboration with GRCA NPS LTEMP Experimental Vegetation Management
  - Project Element D3 in collaboration with 5D and 4B
    - This presentation
- Modeling to support NPS, BOR, Post-2026
  - Not presented at ARM. Funded by BOR and NPS, not GCDAMP. Leverages Project D data and expertise.

# Human Activity and Archaeology Along the Colorado River in Grand Canyon

- Indigenous peoples have inhabited the Canyon region periodically since time immemorial
- Today, evidence of ancestral peoples and recent historic activities is displayed in 100s of archaeological sites along the river in Grand Canyon National Park
- Many sites are deteriorating due to dam operation effects (lack of floods, vegetation encroachment, loss of sediment) and other factors (rainfall run-off, and visitor impacts)



A. Prehistoric hearth in alluvial cutbank

B. Prehistoric bowl exposed by rainfall-runoff

C. Slab structure in gully



D. Fire-altered rock exposed by wind deflation

Photo credits: J. Dierker and other National Park Service staff



Research article

# Archaeological sites in Grand Canyon National Park along the Colorado River are eroding owing to six decades of Glen Canyon Dam operations

Joel B. Sankey <sup>a</sup>  , Amy East <sup>b</sup>, Helen C. Fairley <sup>a</sup>, Joshua Caster <sup>a</sup>, Jennifer Dierker <sup>c</sup>, Ellen Brennan <sup>c</sup>, Lonnie Pilkington <sup>c</sup>, Nathaniel Bransky <sup>a</sup>, Alan Kasprak <sup>a, d</sup>

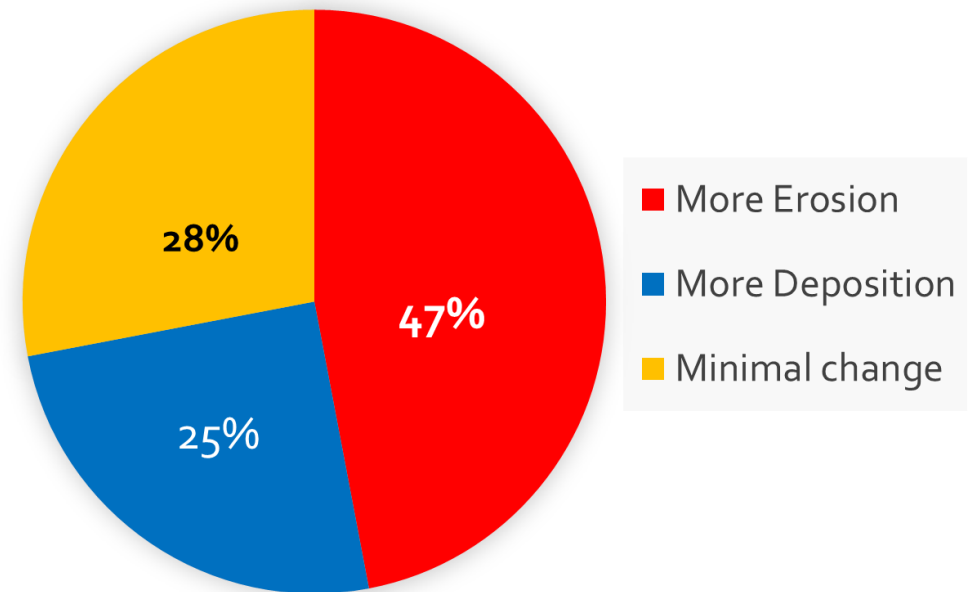
## Highlights

- Integrity of 362 Colorado River archaeological sites assessed 60 years after damming.
- River-sourced aeolian sand decreased since 1973, making most sites more erosion-prone.
- Proportion of sites eroding by gully processes has increased since 2000.
- Erosion limits management goal to maintain or improve site integrity *in situ*.
- Environmental management opportunities: floods, low flows, riparian plant removal.

## Metric Status of Goal 1: Archaeological Sites and Cultural Resources

- Metric #2 Topographic Change
- Amount of measured net deposition or erosion
- Lidar survey measurements of topographic change repeated at sites ~ every 3 years
- See Poster for details
- More sites show more erosion between 2010 and 2024 compared to other categories of change

Percentage of Sample Sites (n=36) with  
Topographic Change by Type

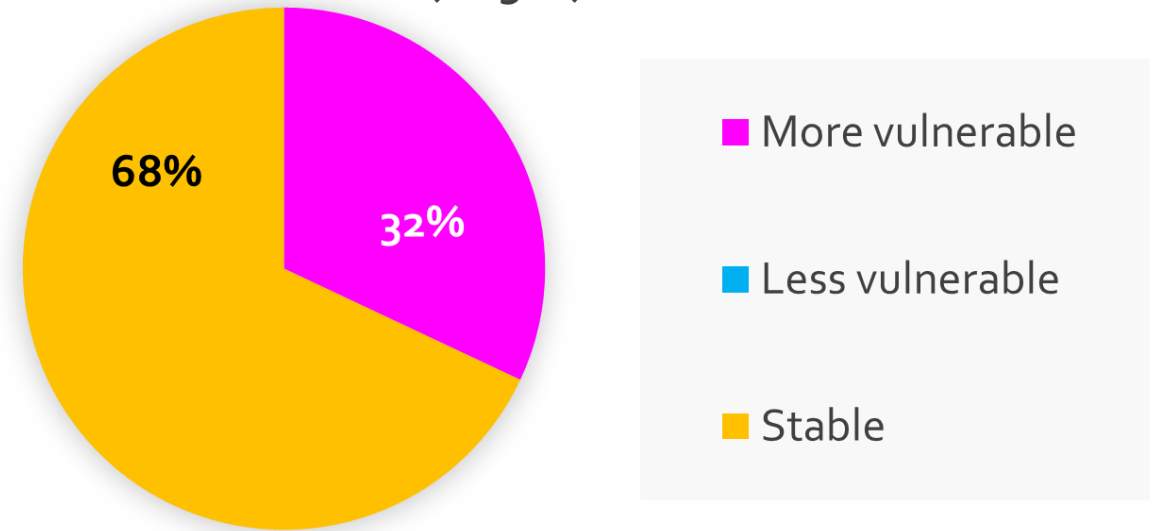


*Summary of normalized volumes of topographic change (deposition or erosion) at the sample of archaeological sites surveyed between 2010 and 2024.*

## Metric Status of Goal 1: Archaeological Sites and Cultural Resources

- Metric #3 Change in Vulnerability to Loss of Integrity
- Characterizes vulnerability of sites to future degradation
- Based on classification of sites evaluated ~ each decade
- See Poster for details
- Many archaeological sites became more vulnerable to future loss of integrity between 2014 and 2021

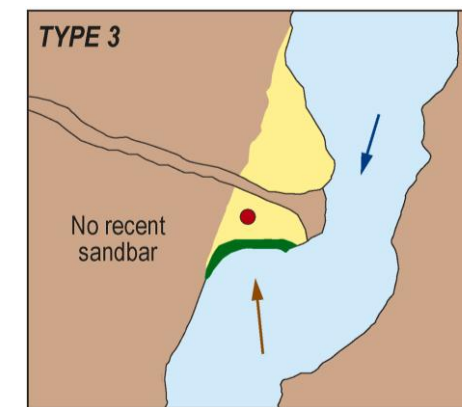
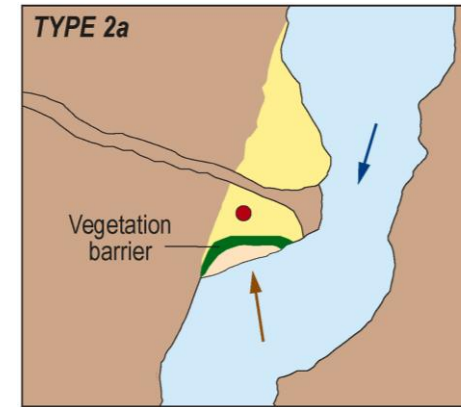
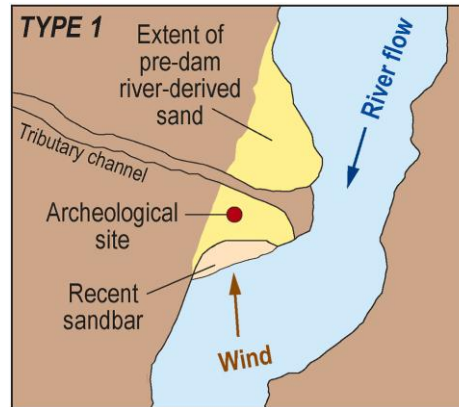
Change in Vulnerability of Total Site Population  
(N=362)



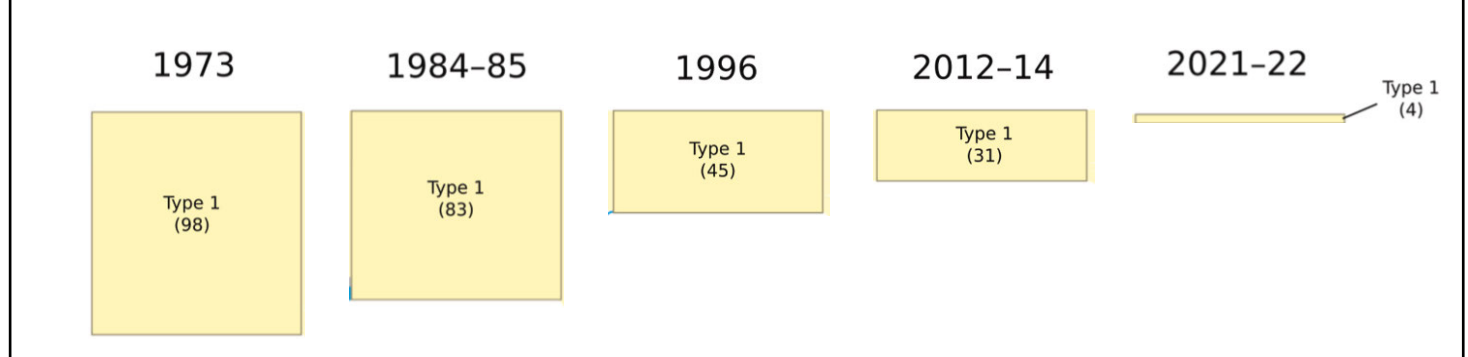
*Summary of change in vulnerability of cultural sites to degradation from 2014 to 2021*

# River management and archaeological site preservation

- Burial of archaeological sites by river-sourced aeolian sand provides a protective cover from erosion
  - Important for site preservation
- Long term reduction in sediment supply and increase in riparian vegetation since closure of dam increase archaeological site erosion and decrease preservation potential



Decadal decrease in TYPE 1 archaeological sites with upwind sediment supply



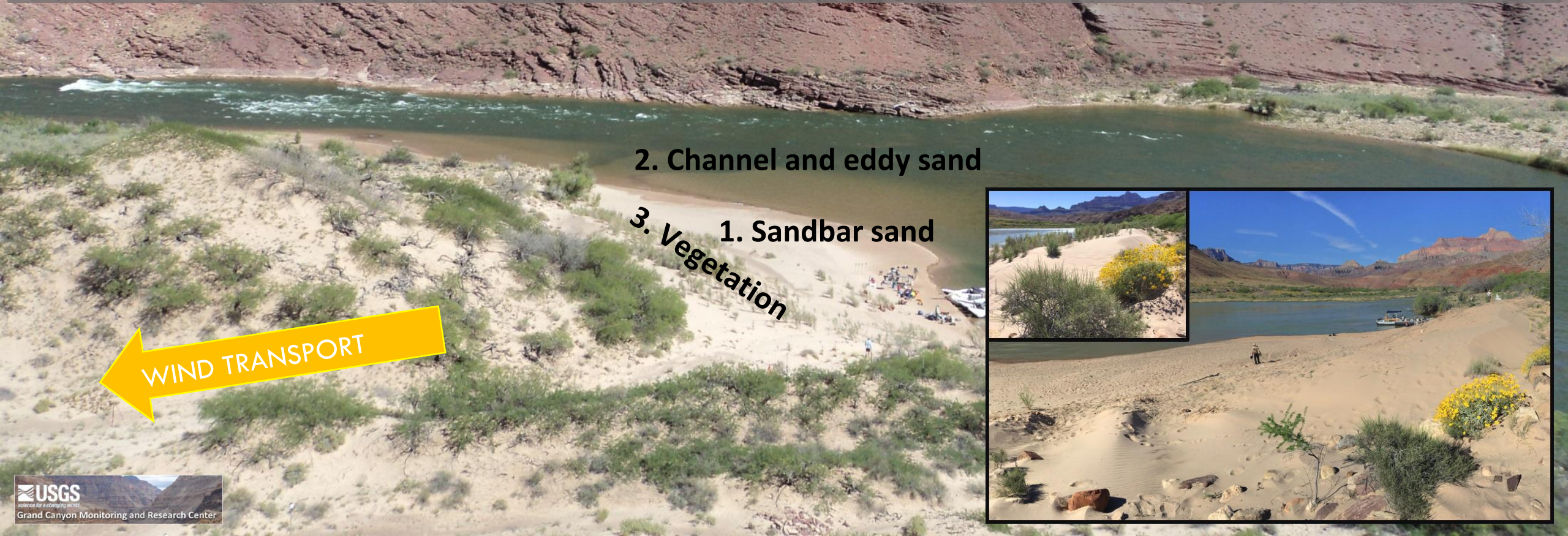
# Experimental management to increase wind transport of river-sourced sand

Increase aeolian sediment supply:

1. High Flow Experiment (HFE) dam releases to rebuild river sandbars (*Sankey and others, 2018, Aeolian Research*)
2. Lowering dam releases to expose sand that is normally underwater in the river channel & eddies (*Sankey and others, 2022, JGR-ES*)

Minimize vegetation blocking aeolian sand transport:

3. Vegetation-management to remove riparian vegetation on sandbars (*Pilkington and others, 2022, Park Science*)



## Vegetation management for aeolian dunefield restoration

- Implemented in coastal dunefields around the world
  - Improve cultural, ecological, recreational resources
- Not common for aeolian dunefields in river environments



a) February 1999

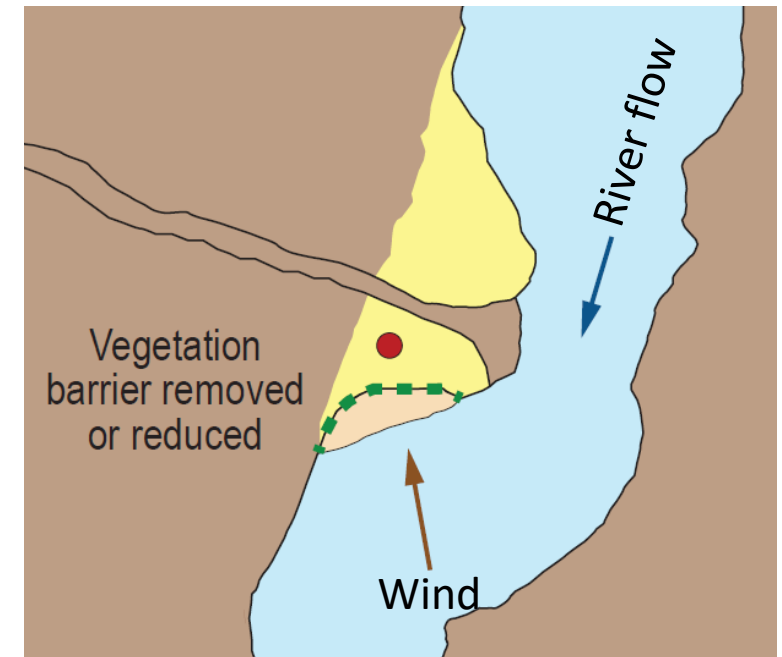


b) June 2013

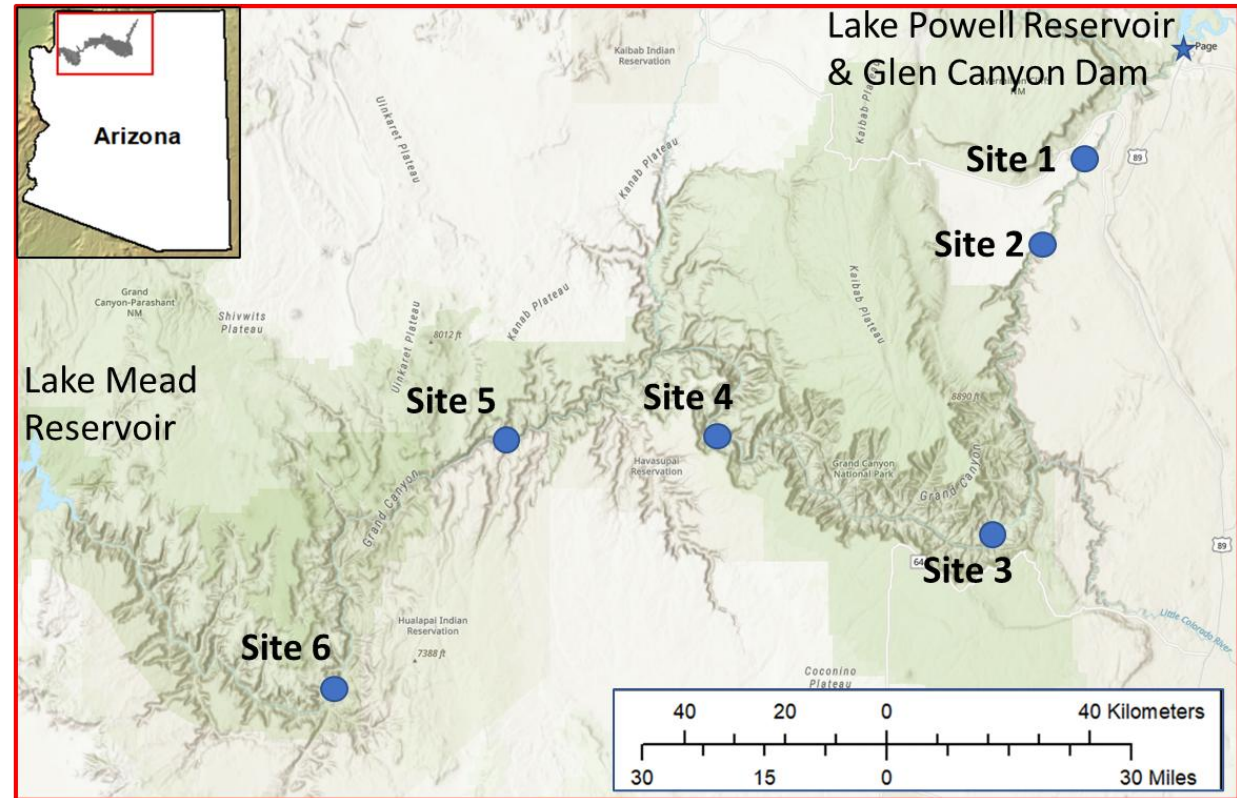
*Photos taken before (top) and after (bottom) removal of invasive vegetation to restore a coastal dunefield at Doughboy Bay, Stewart Island, New Zealand (Konlechner and others, 2014)*

## Experimental management research question

- Does removal of riparian vegetation barriers located between river sandbars and aeolian dunefields increase the resupply of aeolian sediment?



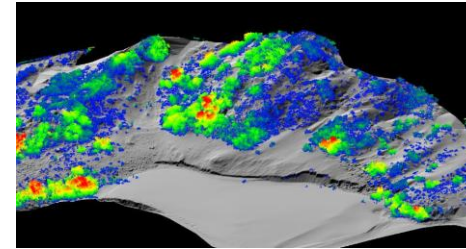
## Colorado River in Grand Canyon National Park



### Study sites

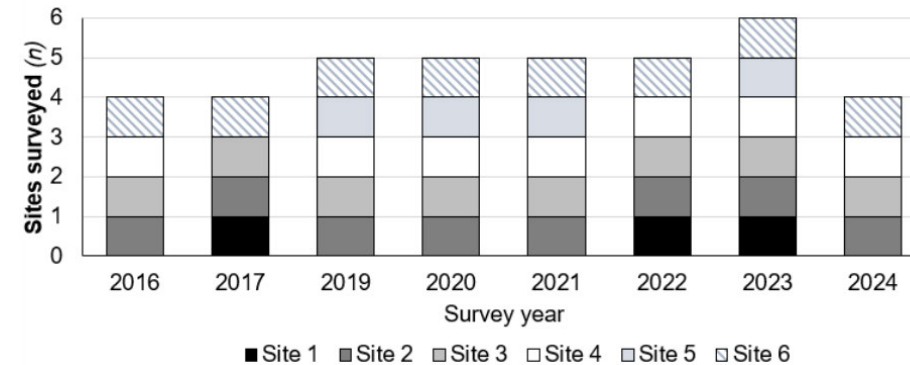
- National Park Service sandbar vegetation removal annually since 2019
- High Flow Experiment (HFE) dam releases in November 2018 and April 2023
- USGS monitoring pre-2019 (baseline) and annually since

# Experimental management methods and hypotheses



Hypotheses – Following sandbar vegetation removal:

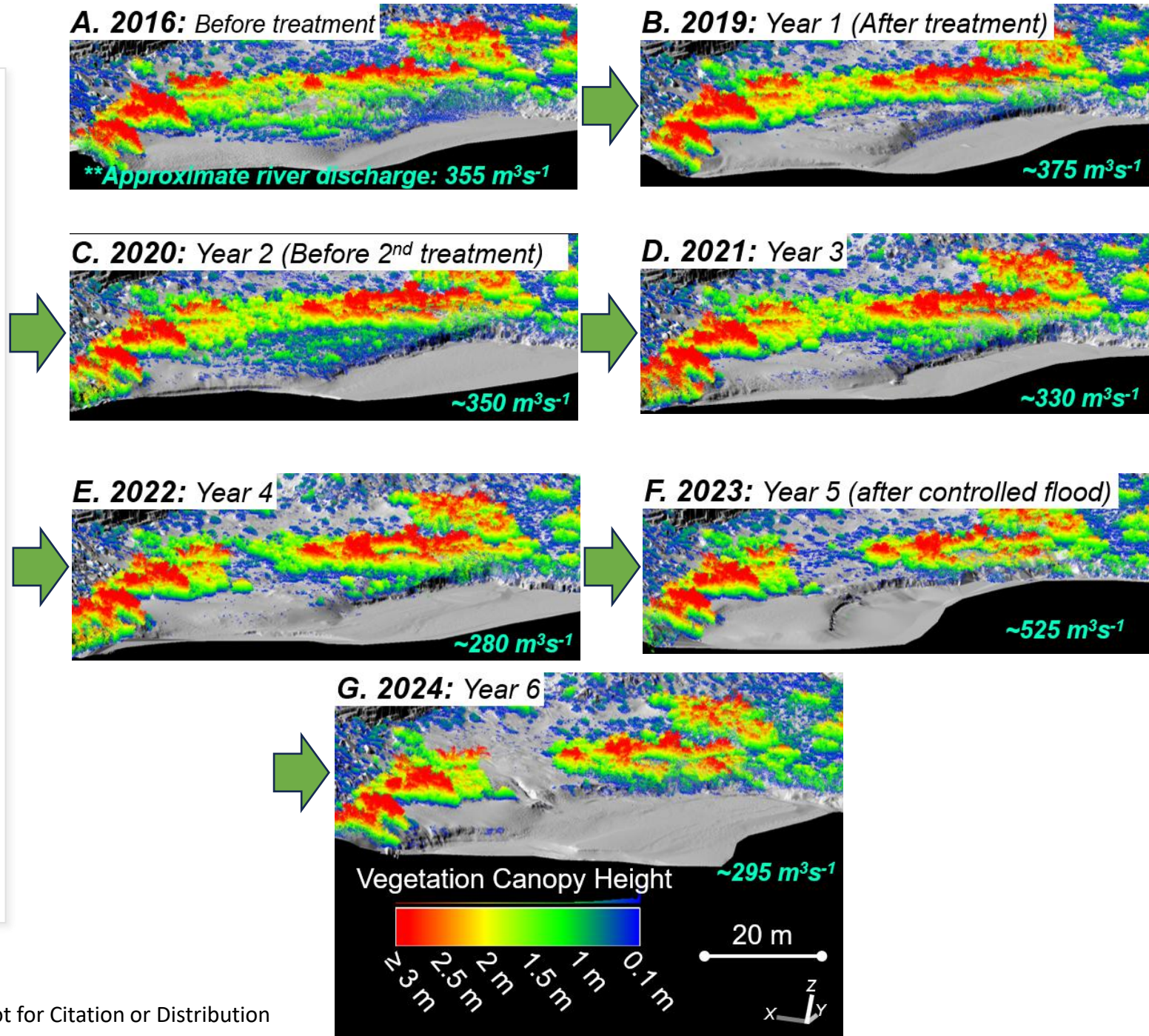
1. Vegetation cover ↓
2. Sediment erodes on sandbars and deposits in downwind dunefields (net topographic changes);
3. Sediment mobility ↑ (total topographic changes);
4. ↓ Cover = ↑ Sediment mobility



Topographic change metric	Description	Calculation
Net change	Change in sediment storage	$\Delta_{\text{deposition}} - \Delta_{\text{erosion}}$
Total change	Surface variability, representative of sediment mobility and transport	$\Delta_{\text{deposition}} + \Delta_{\text{erosion}}$

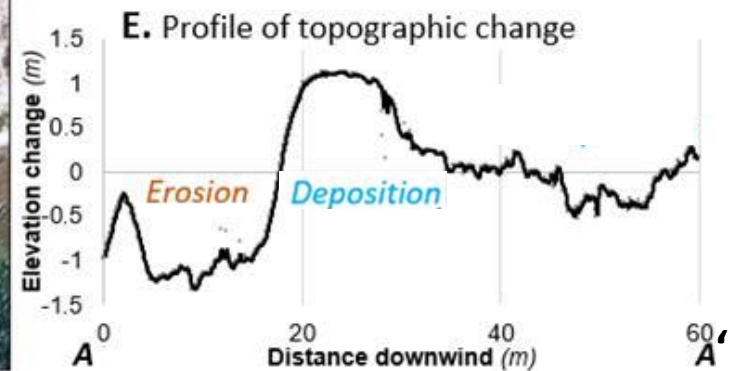
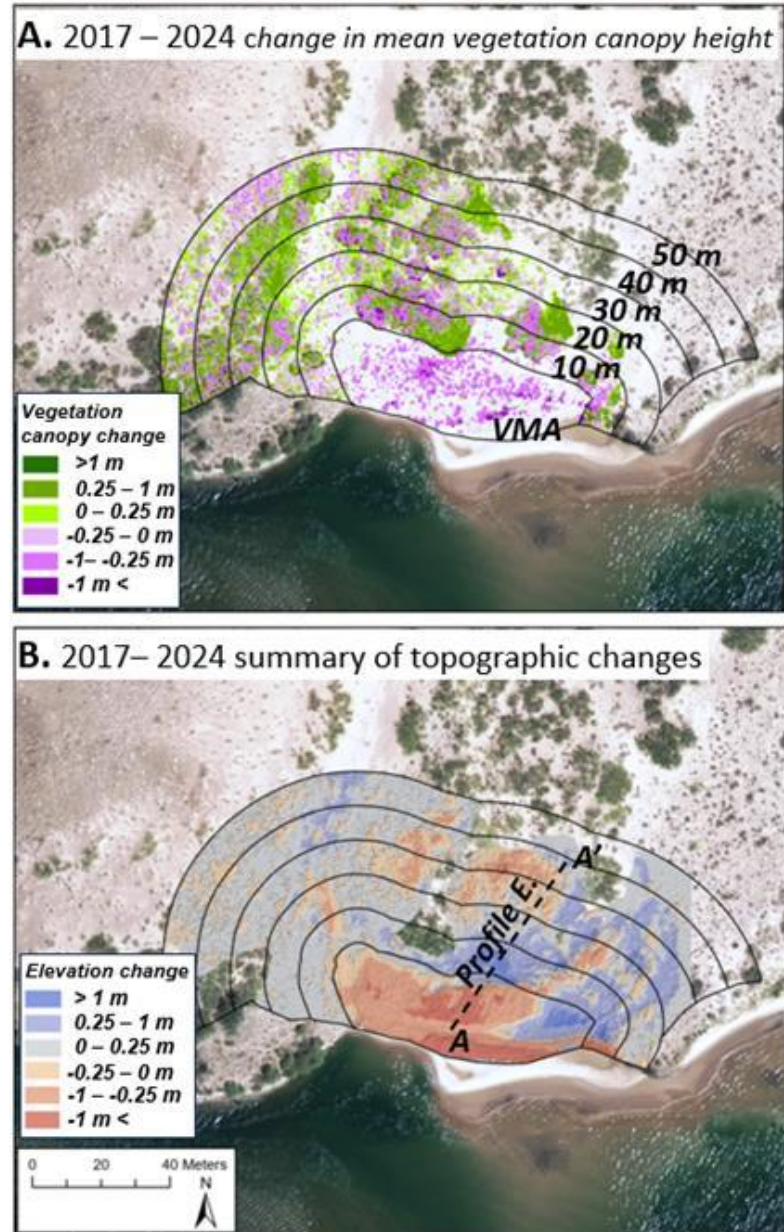
# Results

- Lidar canopy height models illustrate effects of repeated sandbar vegetation removals



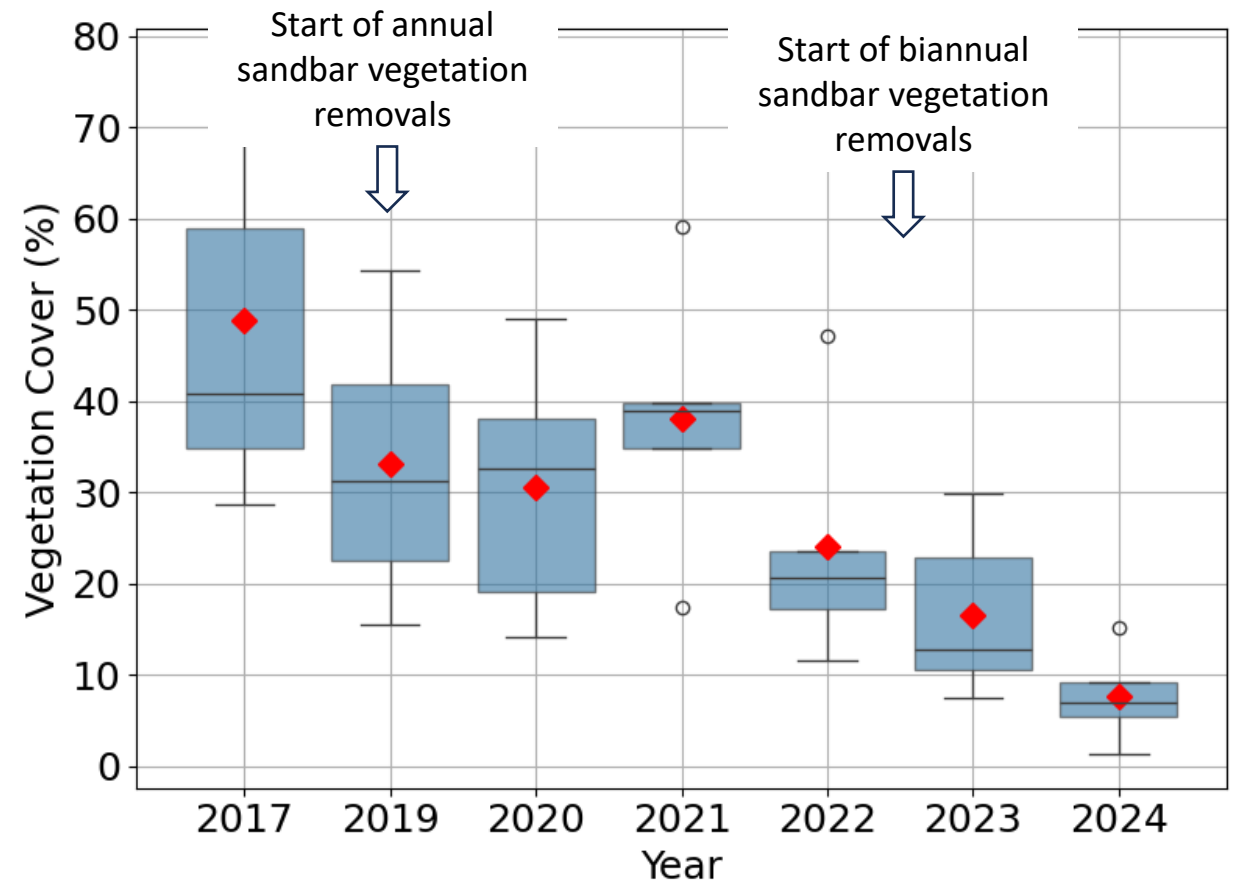
# Results

- Geomorphic change detection of lidar canopy height models (A) and digital elevation models (B) illustrate effects of repeated sandbar vegetation removals on vegetation and coupled sandbar-dunefield morphodynamics



## Results – Hypothesis 1

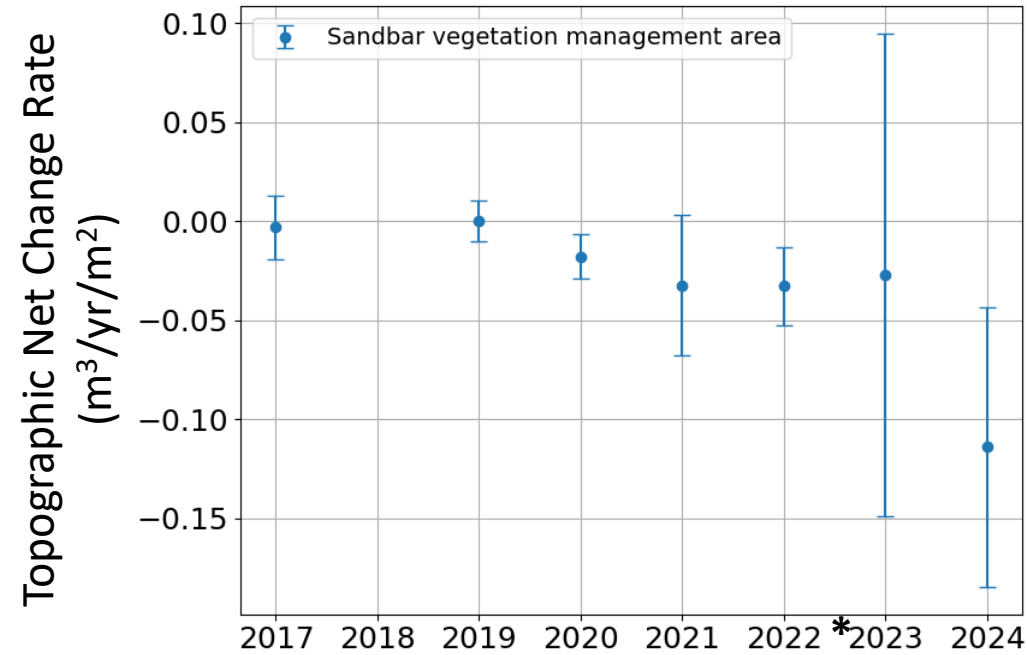
Following sandbar vegetation removal:  
vegetation cover ↓



Regional Kendall:  $S = -64.0$ ;  $Z = -4.93$ ;  $p = 0.0000008$

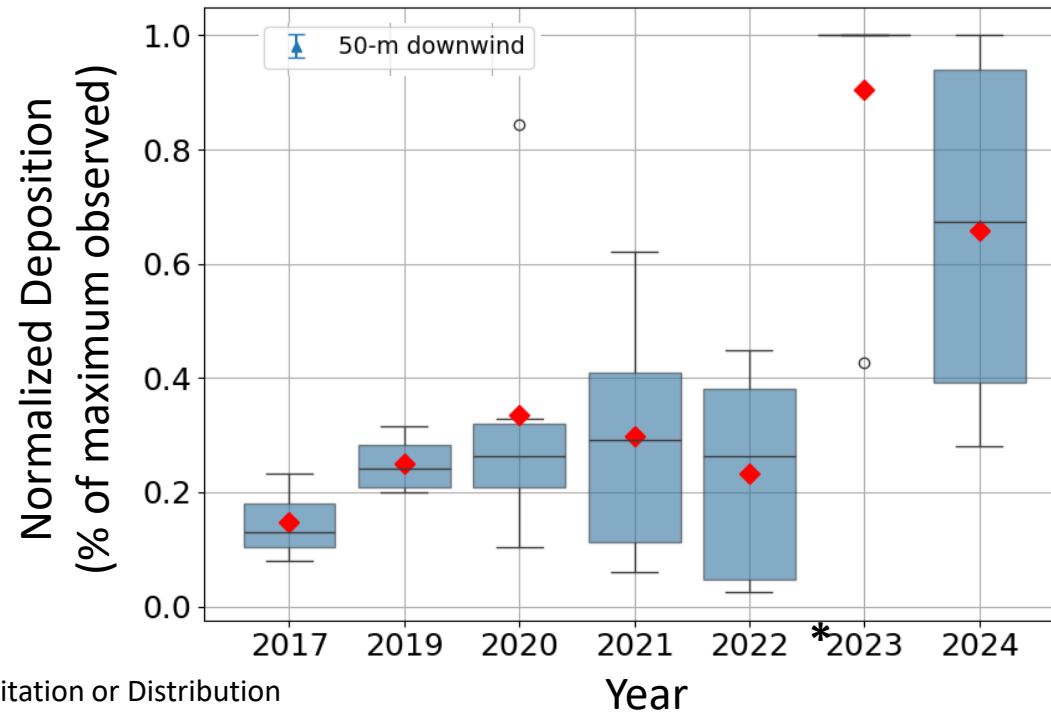
## Results – Hypothesis 2

Following sandbar vegetation removal:  
sediment erodes on sandbars and  
deposits in downwind dunefields



Regional Kendall:  
 $S = -22.0$   
 $Z = -1.69$   
 $p = 0.09$

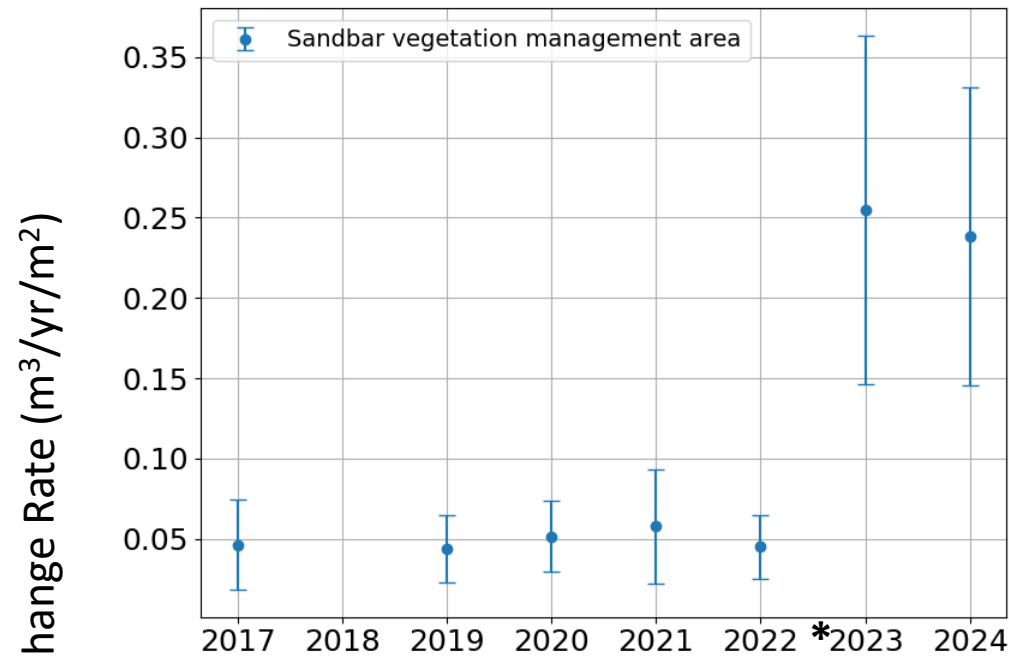
\*Biannual sandbar  
vegetation removals  
and HFE



Regional Kendall:  
 $S = 38.0$   
 $Z = 2.92$   
 $p = 0.003$

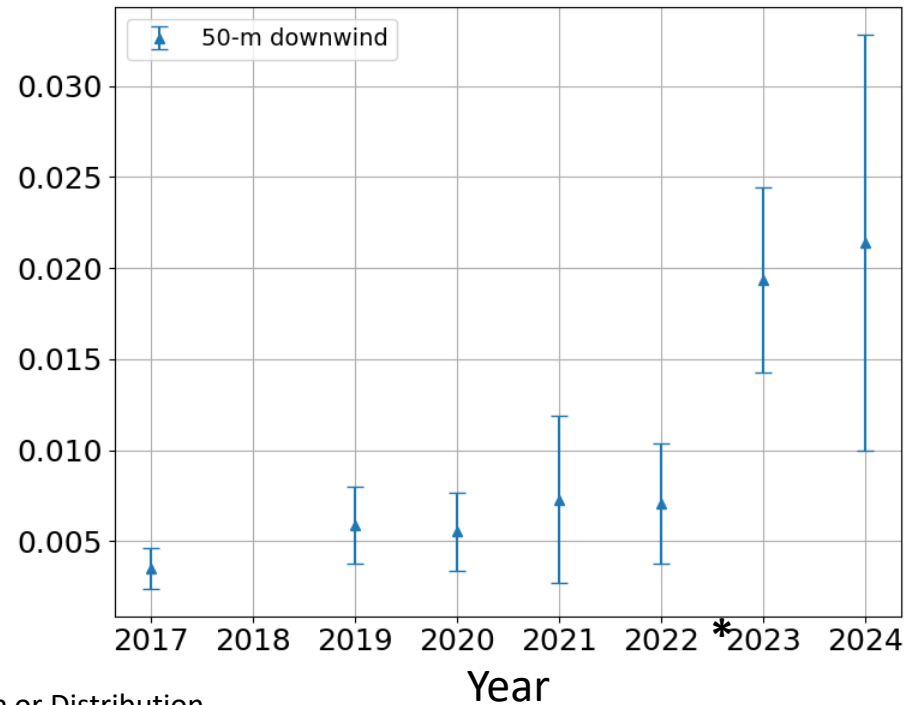
## Results – Hypothesis 3

Following sandbar vegetation removal:  
sediment mobility ↑



Regional Kendall:  
 $S = 40.0$   
 $Z = 3.08$   
 $p = 0.002$

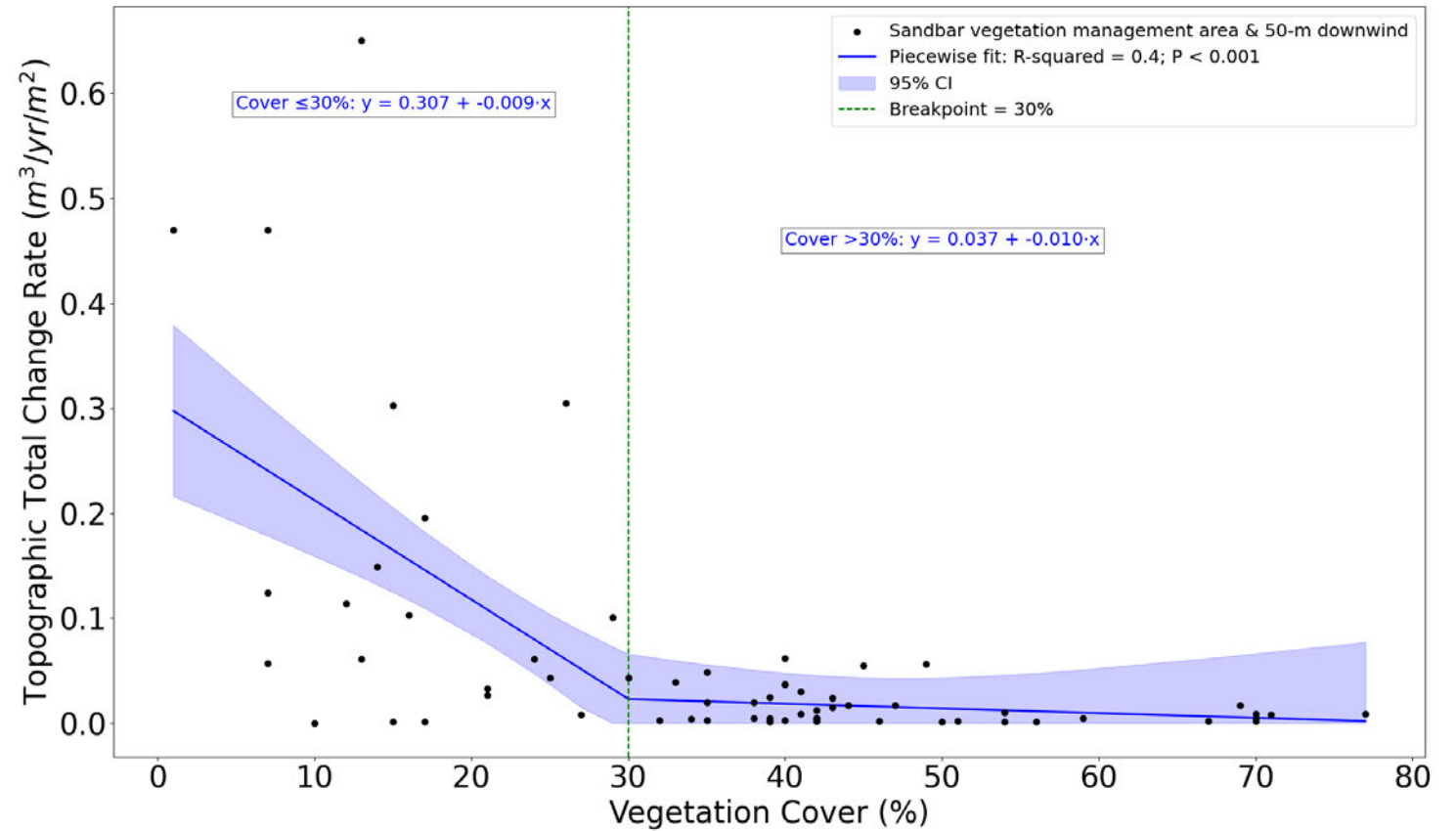
\*Biannual sandbar  
vegetation removals  
and HFE



Regional Kendall:  
 $S = 52.0$   
 $Z = 4.00$   
 $p = 0.00006$

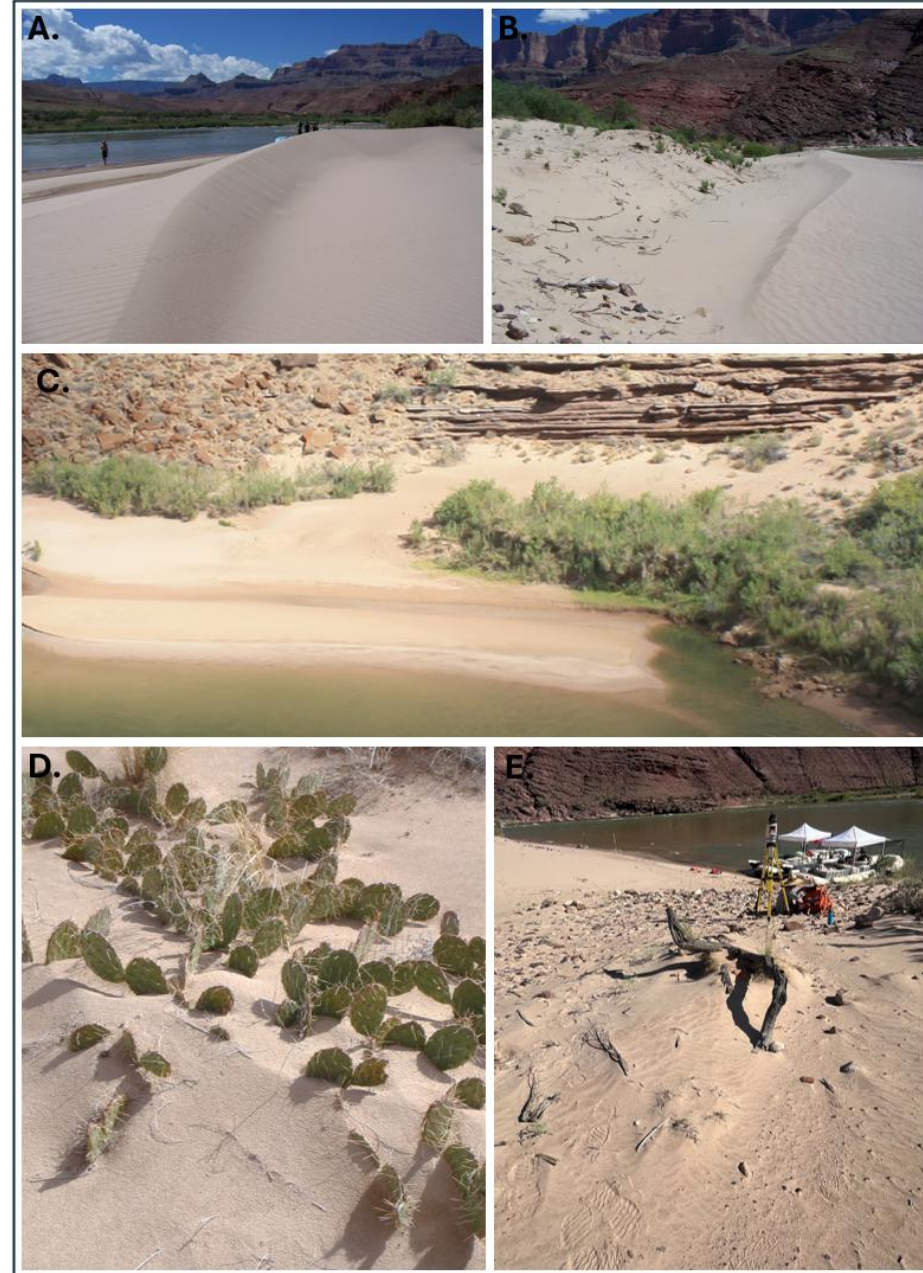
## Results – Hypothesis 4

Following sandbar vegetation removal:  
↓ Cover = ↑ Sediment mobility



## Key Points

- Riparian vegetation removal can increase wind transport of river sand when implemented frequently
- Reducing sandbar plant cover to low level (>0 %, <30 %) allows for wind transport while maintaining vegetation
- Regular implementation of HFEs is needed to resupply river-sourced sand
- Strategic riparian vegetation removal designs can further increase wind transport
- Managing for increased sand deposition in dunefields and archaeological sites may need additional actions



## References Cited

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