GEOMORPHOLOGIC AND VEGETATION ANALYSIS AT COLORADO RIVER CAMPSITES, MARBLE AND GRAND CANYONS, AZ

HADLEY, Daniel R.[1], GRAMS, Paul E.[2], PARNELL, Roderic A.[1]

[1] Geology Program, School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff, AZ 86001, drh232@nau.edu; roderic.parnell@nau.edu

[2] U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, AZ 86001, pgrams@usgs.gov

Introduction | Purpose

Since 1963, Glen Canyon Dam has interrupted the flow of the Colorado River through Marble and Grand Canyons (Fig. 1), changing the natural flow regime and blocking the upstream supply of fine-grained sediment. This has 1) Caused widespread erosion of sandbars used as campsites due to the decrease in sand availability (Kearsley et al., 1994), 2) Caused vegetation encroachment on sandbars due to lack of flooding (Fig. 2) (Turner and Karpiscak, 1980), and 3) Decreased the number and size of campsites (Kaplinski et al., 2005, 2010).

NAU's Sandbar Monitoring Lab has surveyed 37 campsites throughout the CRE since 1998, but current campsite monitoring is limited to detecting changes in campsite area only. Factors such as slope, amount of vegetation, and presence of gullying determine the amount of usable camp area, but these factors have not been quantified (Kaplinski et al., 2010). The goals of this project are to 1) Analyze the elevation and slope changes within usable camp areas, 2) Quantify the amount of vegetation change at campsites, and 3) Determine the primary cause of usable camp area change in the context of management activities (HFE's and daily/seasonal dam operations).

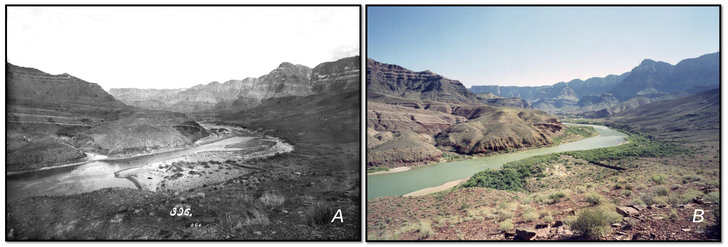

Figure 2. Upstream view from Cardenas Hilltop near river mile 71.3 showing the dramatic increase in vegetation and decrease in sandbar area. A) Photograph taken by Robert B. Stanton on January 23rd, 1890. B) Matched photograph taken on September 20th, 2010 by Bill Lemke. Photographs courtesy of the U.S. Geological Survey, Desert Laboratory Repeat Photography Collection.

Background

NAU campsite monitoring data has shown an overall decline in usable area above the 25,000 ft^3/s stage elevation, with large fluctuations in usable area between the 15,000 -25,000 ft^3/s stage elevation (Fig. 3). Usable camp area is defined by Kearsley et al. (1999) as a smooth substrate with little to no vegetation, less than eight degrees of slope, and that is suitable for use as a kitchen/common area or sleeping surface.

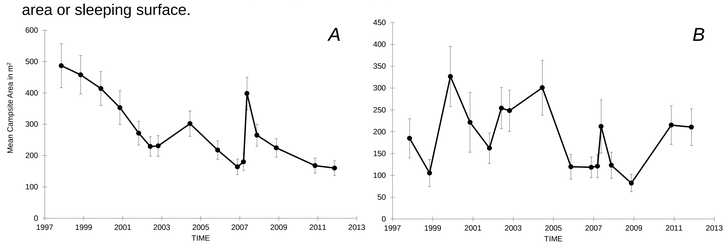

Figure 3. Time series plots of mean usable camp area for 37 sites, with standard error of the mean as error bars. (A) Mean campsite area in the high stage elevation zone (Above 25,000 ft^3/s) and (B) Mean campsite area in the low stage elevation zone (15,000 to 25,000 ft^3/s). Figure modified from Kaplinski et al., 2014 *in review*

References

Kaplinski, M., Hadley, D., Grams, P., Parnell, R., Hazel, J.E., 2014, Colorado River Campsite Monitoring, 1009-2012, Grand Canyon National Park, Arizona: U.S. Geological Survey Data Series Report, *in review*

Kaplinski, M., Behan, J., Hazel, J.E., Parnell, R., and Fairley, H.C., 2005, Recreational values and campsites in the Colorado River ecosystem, *in* Gloss, S., Lovich, J.E, and Melis, T.S., eds., The state of the Colorado River ecosystem in Grand Canyon: U.S. Geological Survey Circular 1282, p.193-205.

Kaplinski, M., Hazel, J.E., Jr., and Parnell, R., 2010, Colorado River Campsite Monitoring, 1998 – 2006, Grand Canyon National Park, Arizona, *in* Melis, T.S., Hamill, J.F., Coggins, L.C., Jr., Grams, P.E., Kennedy, T.A., Kubly, D.M., and Ralston, B.E., eds., Proceedings of the Colorado River Basin Science and Resource Management Symposium, November 18-20, 2009, Scottsdale, AZ: U.S. Geological Survey Scientific Investigations Report 2010–5135, p. 275-284.

Kearsley, L.H., Schmidt, J.C., and Warren, K.D., 1994, Effects of Glen Canyon Dam on Colorado River sand deposits used as campsites in Grand Canyon National Park, USA: Regulated Rivers—Research & Management, v. 9, no. 3, p. 137–149

Kearsley, L.H., Quartoroli, R., and Kearsley, M.J.C., 1999, Changes in the number and size of campsites as determined by inventories and measurement, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The controlled flood in Grand Canyon: Washington D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p 147-159.

Schmidt, J.C., and Grams, P.E., 2011, Understanding Physical Processes of the Colorado River, *in* Melis, T.S., ed., Effects of three high-flow experiments on the Colorado River ecosystem downstream from Glen Canyon Dam, Arizona: U.S. Geological Survey Circular 1366, p. 17-51.

Turner, R.M, and Karpiscak, M.M., 1980, Recent vegetation changes along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona: U.S. Geological Survey Professional Paper 1132, 125p.

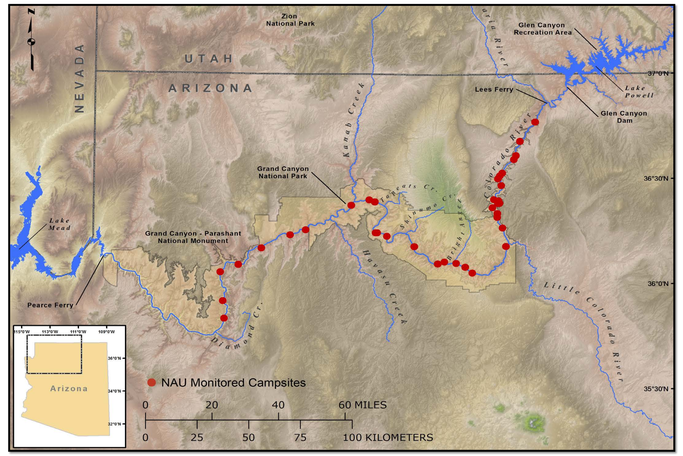

Figure 1. Location of campsites surveyed by NAU's Sandbar Monitoring Lab. River mileages are used to describe distances along the Colorado River through Grand Canyon. Lees Ferry is designated as river mile 0 (RM 0), Diamond Creek is at river mile 225 (RM 225).

Vegetation Methods | Results

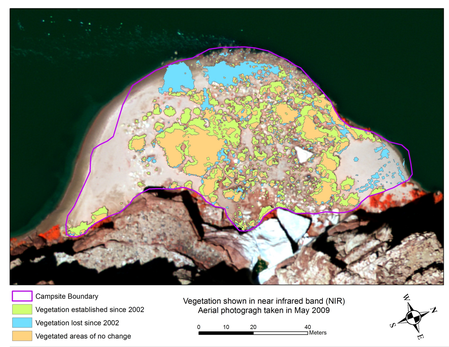

Figure 4. Four-band aerial imagery from 2002 and 2009 were used to quantify vegetation change within 504 campsite boundaries and within the total extent of usable camp area mapped by NAU from 1998-2009. Example shown is vegetation change within the campsite boundary at Hot Na Na camp at RM 16.6L. Data was summarized by critical and non-critical recreation reaches. Critical reaches are defined as areas with few campsites and where competition for sites is high (Kearsley and Warren, 1993).

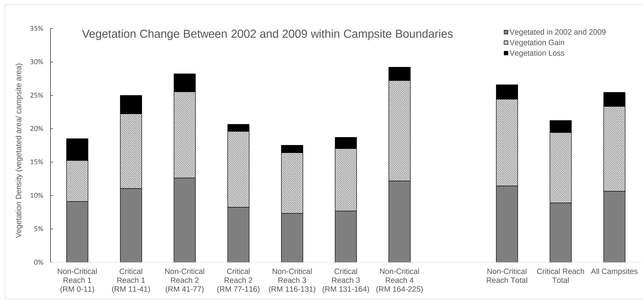

Figure 5. Vegetation change between 2002 and 2009 within campsite boundaries summarized by individual recreational reaches. Note that the All Campsites summary includes campsites in the Glen Canyon reach and past Diamond Creek (RM 225).

Geomorphology Methods | Results

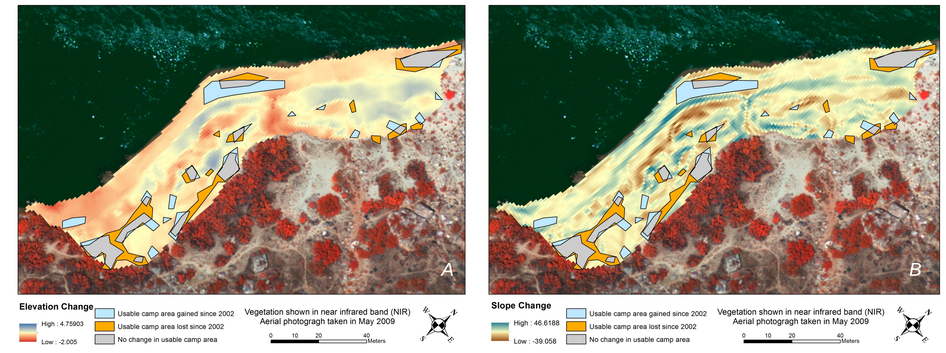

Figure 6. Digital elevation models (DEMs) of sandbars generated from total station survey data were used to create elevation (A) and slope (B) difference rasters. Difference rasters represent the change between 2002 and 2009. Example shown is of Eminence camp at RM 44.5L. Elevation difference rasters were categorized into areas of deposition (> 4 cm of change), erosion (< -4 cm of change), and no significant elevation change (+/- 4 cm). Slope difference rasters were categorized into areas based on the 8º slope threshold for usable camp area where flat areas are < 8º and steep areas are > 8º. These areas are 1) Slope change from flat to steep, 2) Slope change from steep to flat, 3) Flat areas of no change, and 4) Steep areas of no change. Categorized difference rasters were intersected with usable camp change areas as measured by NAU in 2002 and 2009. Elevation, slope, and vegetation changes within campsite change areas were calculated and summarized by critical and non-critical recreation reaches.

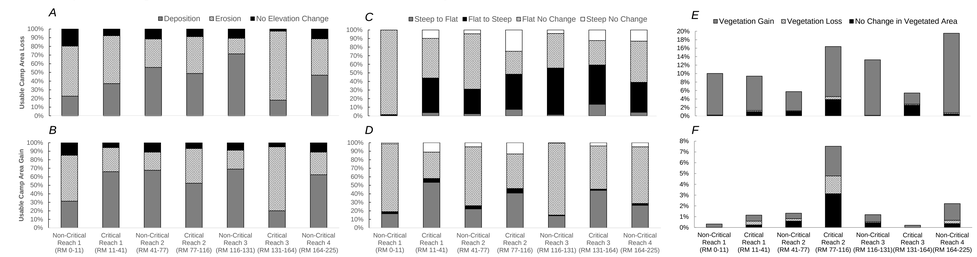

Figure 7. Elevation, slope, and vegetation change within campsite change areas between 2002 and 2009 summarized by recreational reach. (A) Elevation change within camp loss areas, (B) Elevation change within camp gain area, (C) Slope change within camp loss area, and (D) Slope change within camp gain areas, (E) Vegetation change within camp loss areas, and (F) Vegetation change within camp gain areas. Note that a different scale was used for vegetation change as the values were much smaller.

Conclusions

Vegetation change within campsite boundaries varied greatly by site, with some campsites having over 40% of its area vegetated between 2002 and 2009 (Kwagunt Marsh Camp, RM 55.9R), and some having no increase in vegetation (Sand Pile Camp, RM 30.7R). Vegetation increased within campsite boundaries for every reach between 2002 and 2009, with non-critical and critical reaches having a similar net vegetation gain (11% and 9%, respectively)

First order changes in elevation and slope within usable camp area show that 1) Camp gain areas had more deposition than erosion occurring in both critical and non-critical reaches, 2) Camp loss areas had more erosion than deposition occurring in both critical and non-critical reaches, and 3) Campsite gain areas in critical reaches had more area of decreasing slope (to under 8º) than campsite gains in non-critical reaches.

Preliminary analysis suggests that changes in sandbar elevation (erosion and deposition) and slope of bar (areas flattening out or becoming steeper) due to HFE's and daily/seasonal dam operation plays a greater role in usable camp area change than does vegetation expansion. However, elevation, slope, and vegetation change are not mutually exclusive, requiring further analysis to determine the primary agent of campsite change. Analysis of these changes between different stage elevation zones is also required to fit these in the context of dam management activities.

Acknowledgments

This project is supported by the Glen Canyon Dam Adaptive Management Program through a cooperative agreement between the U.S. Geological Survey Grand Canyon Monitoring and Research Center and Northern Arizona University. Thanks to Matt Kaplinski and Joe Hazel (NAU's Sandbar Monitoring Lab), and Tom Gushue and Rob Ross (GCMRC).