Big-River Monitoring on the Colorado Plateau

Dustin Perkins[1], Mike Scott[2], Greg Auble[2], Mark Wondzell[3], Chris Holmquist-Johnson[2], Eric Wahlig[2], Helen Thomas[1], and Aneth Wight[1]; [1]Northern Colorado Plateau Network, P.O. Box 848, Bldg. 11, Arches National Park, Moab, UT 84532
[2]U.S. Geological Survey, Biological Resources Discipline, FORT Science Center, 2150 Centre Ave., Building C, Fort Collins, CO 80526; [3]National Park Service, Water Resources Division, 1201 Oakridge Dr., Ste. 150, Fort Collins, CO 80525

Introduction

Water has always been in short supply in the western U.S., making it a consistent source of conflict. In the Colorado River drainage, an increasing human population fuels increased demands for water from the river and its tributaries. As a result, streamflow in virtually all of these systems has been altered by reservoirs and other water-development projects. In most cases, reduced flows have significantly altered peak flows and increased base flows that structure floodplain vegetation, stream-channel morphology, and water quality (e.g., temperature, suspended sediment, nutrients). The resulting changes in riverine and riparian habitats—that is, channel narrowing—can be quite complex. Channel narrowing can reduce the diversity and scale of geomorphic surfaces and associated habitats; disconnect floodplain surfaces from the river; and change riparian vegetation and biological diversity, as habitat for vegetation and aquatic organisms is altered and reduced.

In response to concerns expressed by resource managers in multiple National Park Service (NPS) units, the Northern Colorado Plateau Network (NCPN) has implemented a big-rivers monitoring project along the Green and Yampa rivers in Dinosaur National Monument, the Gunnison River at Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, and along the Colorado and Green rivers in Canyonlands National Park. The Yampa River is the longest relatively free-flowing river reach remaining in the Colorado River basin. The Green River is highly regulated by Flaming Gorge Dam but is partially restored below its confluence with the Yampa River. There have been large-scale changes to the Green River since Flaming Gorge Dam was completed in 1962.

Monitoring of these rivers and their riparian vegetation focuses on processes that affect the river channel, active bars, and riparian floodplains. To get a complete picture of river conditions, the NCPN has paired intensive monitoring at sentinel sites with coarse-scale measurements from remote sensing. This monitoring effort would be a large undertaking under any circumstances. With scarce resources, it is made possible only by strong partnerships with the U.S. Geological Survey, NPS Water Resources Division, and staff from the four NPS units where we monitor big rivers.

We hypothesize that streamflow regimes will shift in response to increasing human demands on regional water resources, coupled with anticipated climate change. Expected changes include lower annual flow, more droughts, and more instances of large, infrequent floods caused by extreme precipitation events and extreme winters. These shifts will likely lead to channel narrowing as (1) vegetation indicative of inactive and

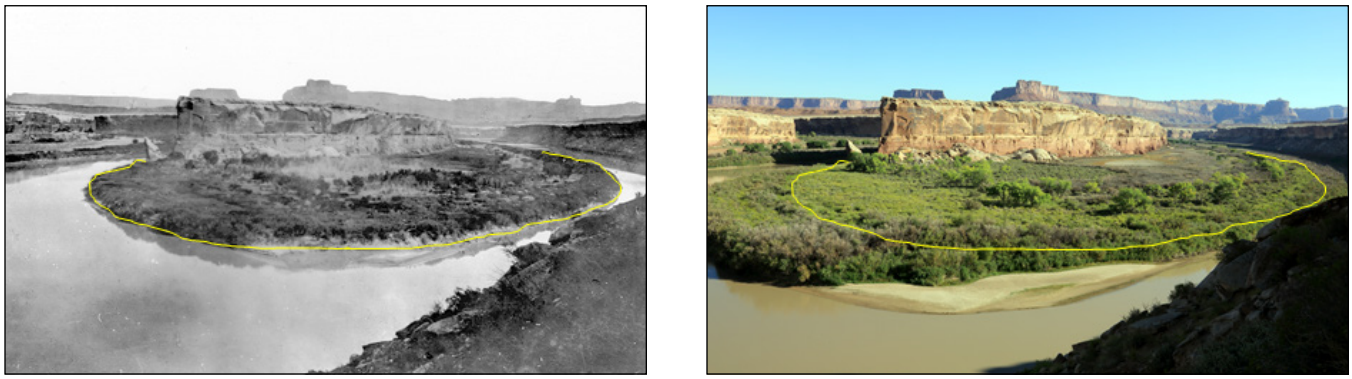


Figure 1. Paired photographs at Bonita Bend on the Green River in Canyonlands National Park by E. O. Beaman in 1871 (L) and M. Miller in 2012 (R). The pictures show extensive river-channel narrowing and vegetation encroachment at this site.

active floodplains encroaches, stabilizing formerly active-channel deposits, and (2) lateral and vertical deposition of alluvial sediments creates new, smaller active channel and active floodplain surfaces (Figure 1).

Early detection and quantification of the channel-narrowing process will allow NPS managers to (1) work cooperatively with water users to identify and possibly mitigate the effects of human-caused depletions on big rivers and related resources, and (2) identify reaches sensitive to narrowing so that management actions may be implemented in an efficient, cost-effective manner. This paper focuses on geomorphic and riparian conditions at two sentinel sites at Dinosaur National Monument (NM). Data from these sites demonstrate the range of information generated by this monitoring project and how it might be used to address relevant management questions.

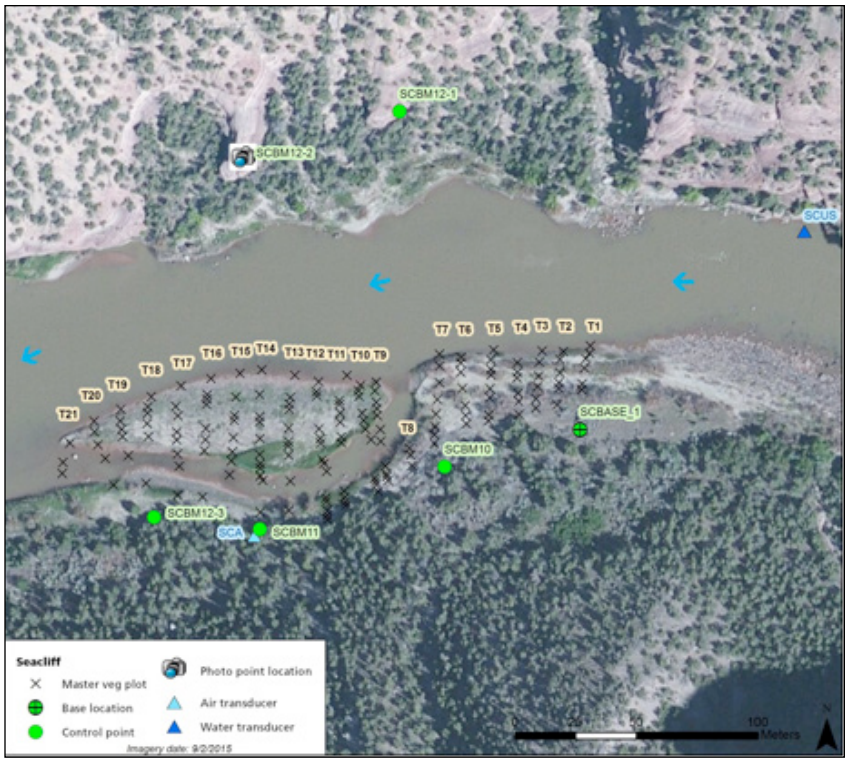


Figure 3. Seacliff sentinel site showing plot locations, benchmarks for surveying (base location and control points), air and water transducers, and photopoint locations. (Note: the downstream water transducer is not shown; it is located 200 meters downstream and depicting the location would have altered the scale.)

Methods

We established nine sentinel monitoring sites on the Green and Yampa rivers in Dinosaur NM. These sites broadly represent all channel types found within the monument, including alluvial and canyon-bound settings. The sites discussed in this paper represent the range of different habitats in the system. Deerlodge, on the Yampa River, is a broad, alluvial, restricted-meander reach. Seacliff, on the Green River below its confluence with the Yampa, is a debris fan-affected canyon site. For more details, see Scott and Perkins (in press).

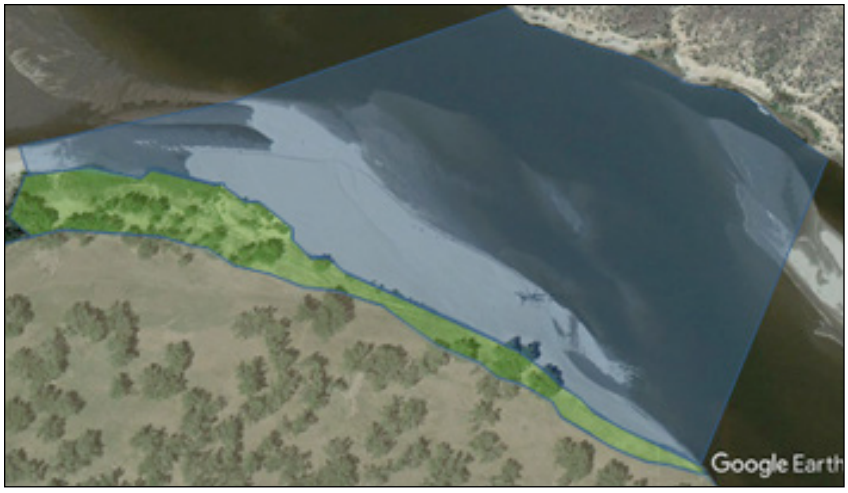


Figure 2. Graphic representation of the active channel (blue), active floodplain (green), and inactive floodplain (brown) at the Deerlodge sentinel site.

We used RTK (real time kinematic) survey equipment to establish permanent, 1-m^2 vegetation quadrats across the active channel, active floodplain, and inactive floodplain of each sentinel site (see Figures 2, 3). Active channels are generally flooded every 1–2 years, and active floodplains every 3–15 years. Inactive floodplains are flooded less than every 15 years. We performed repeated sampling of vegetation cover, by species, to assess changes in overall vegetation cover over time.

At the same time, we placed water-level dataloggers upstream and downstream of each study site to measure water pressure. An air datalogger was placed nearby to measure air pressure. By subtracting the air pressure from the water pressure and figuring in the weight of water, we can calculate the number of days and percent of the growing season when each quadrat is inundated.

We surveyed topographic features (e.g., tops of banks, toes of banks, edge of

water, chutes, sand caps) and created digital elevation models (DEMs; 10-cm resolution) from the topographic surveys. Using geomorphic change-detection software in ArcGIS, we overlaid paired years of DEMs to quantify the spatial distribution and volume of alluvial material eroded and/or deposited across the sentinel site.

Finally, we used photopoints that capture the entire site to document visual evidence of the changes occurring at each site.

In this paper, we compare data collected from 2010 to 2014.

Results and Discussion

In initial results, both sites showed similar levels and trends in total percent vegetation cover on active-floodplain surfaces. Both sites had distinct decreases in vegetative cover following a year with a high-flow event (2011) (Figure 4). Vegetative cover then remained low in the two subsequent, low-flow years (2012 and 2013). In 2014, vegetative cover increased back to near-2010 levels (~27% mean total cover at both sites), after a moderate-to-high peak flow and subsequent moderate-to-high base flows that year.

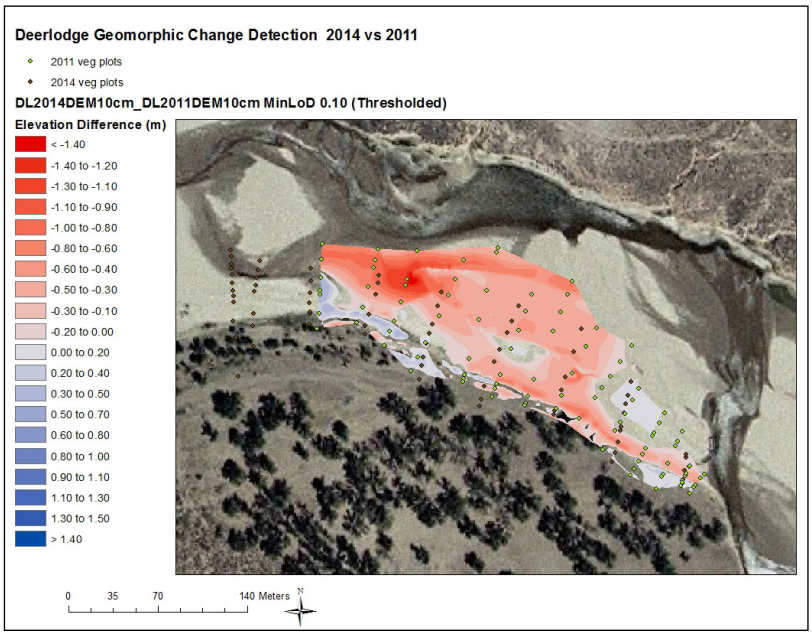


Figure 5. Plan view of the Deerlodge sentinel site depicting spatial areas of erosion (red shading) and deposition (blue shading) between 2011 and 2014. The figure was thresholded to only show differences greater than 10 cm. Figure shows general erosion of the site. Flow is from right to left in the image.

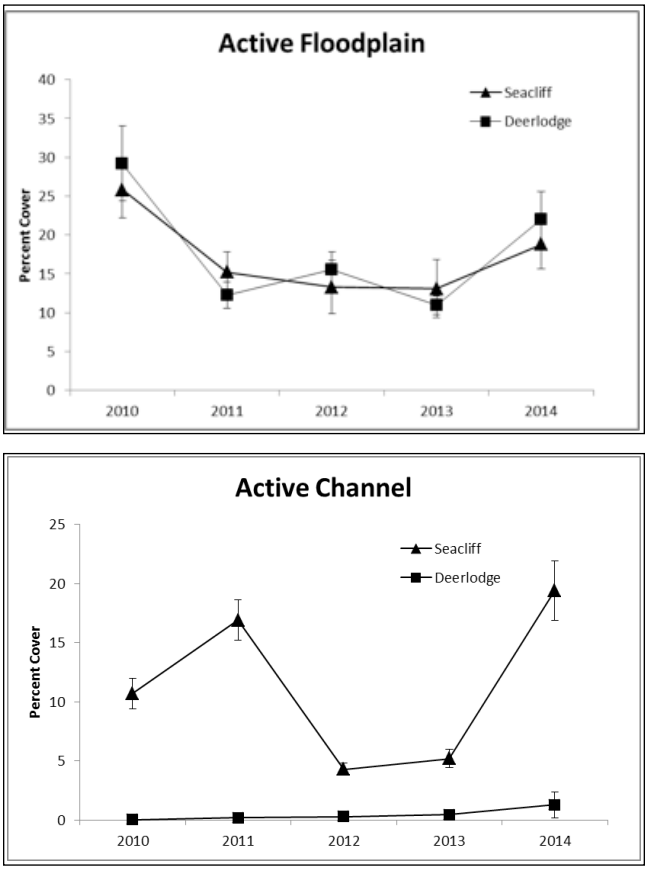


Figure 4. Percent cover of vegetation on active-floodplain and active-channel surfaces for the Seacliff and Deerlodge sentinel sites, as measured in the field for the years 2010–2014. Sampling dates in all years are July–September, post-snowmelt flooding.

On the other hand, the sites showed distinctly different levels and trends in vegetative cover on active-channel surfaces in the same years. In part, this reflects differences in channel setting, geomorphic processes, and flow modification between the sites (Figure 4). In years when peak flows exceeded the two-year average recurrence flow and base flows were elevated, the total average vegetation cover on active-channel surfaces at the Seacliff site approached that observed on active-floodplain surfaces at both sentinel sites. However, cover declined to 4.3 and 5.2% in low-flow years.

In contrast, the lateral bar that forms the active channel at the Deerlodge sentinel site is likely reworked and re-deposited during most peak flows, and thus is largely devoid of vegetation (total % cover was less than 1.5% for all years), except for annuals that establish each year following flow recession. Moreover, because of large stream-stage fluctuations on the relatively unregulated Yampa, the sandy, higher, and less-frequently inundated portions of the bar can become dry during the growing season and are not easily colonized by perennial vegetation.

One interpretation of these differences is that active-channel surface habitats on the Green River began to transition to floodplain surfaces following flow regulation. Growth of plant species generally found on active floodplains may expand into the active channel. In post-dam years when flows equaled or exceeded the average two-year recurrence flow (2010, 2011, and 2014), floodplain and transitional surfaces (characterized by the presence of floodplain and active-channel plant species) were inundated or sub-irrigated, and vegetation growth and cover was enhanced at Seacliff.

Stream-stage measurements collected at sentinel sites allow us to classify their vegetation and geomorphic surfaces (i.e., active channel, active floodplain) in terms of two hydrologic variables: (1) days a quadrat was inundated and (2) the percentage of the growing season a quadrat was inundated. Auble and others (1994; 2005) have demonstrated that the occurrence of riparian plant species is strongly related to the inundation duration of the surfaces on which they grow. This helps us to detect transitions from active-channel to active-floodplain related to channel narrowing. Hydrology measurements from both sites showed that active-channel quadrats were inundated close to 50% of the time, transitional quadrats (plots transitioning between active floodplain and active channel) inundated around 20% of the time, and active floodplain quadrats approximately 5% of the time.

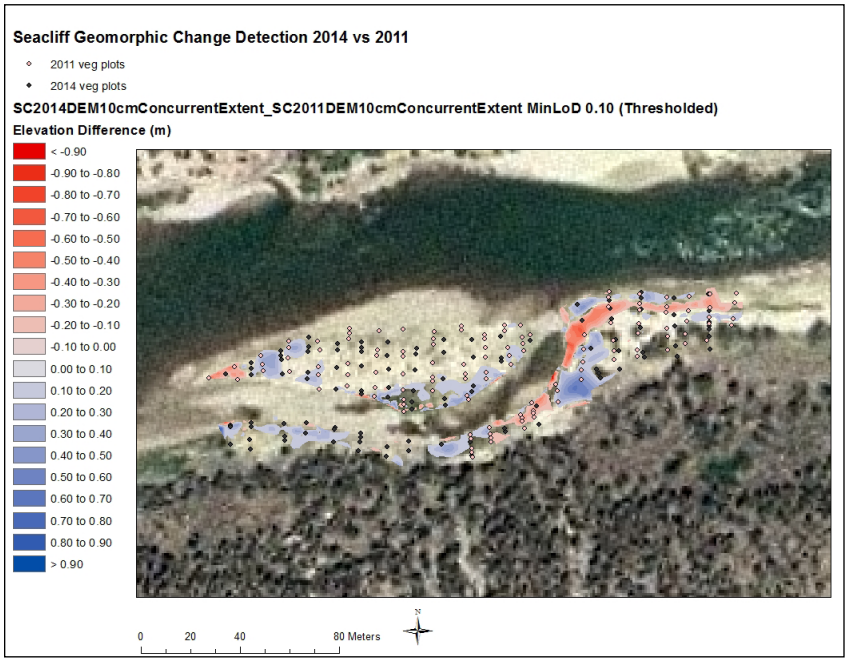


Figure 6. Plan view of the Seacliff sentinel site depicting spatial areas of erosion and deposition between 2011 and 2014. The figure was thresholded to only show differences greater than 10 cm. The figure indicates some deposition on the sand caps in the center of the site and mixed deposition and erosion at the downstream and upstream ends. River flow is from right to left in the image.

Geomorphic change results also illustrated differences between the Deerlodge and Seacliff sites. The expansive, sandy, lateral bar at Deerlodge displayed comparatively large volumetric changes in both erosion and deposition between 2011 and 2014 (Figure 5). Overall, there was net erosion of nearly 8,000 m^3 of material during those years. In contrast, the Seacliff sentinel feature, an expansion cobble bar, showed only modest levels of erosion and deposition over the same period. From 2010 to 2014, there was net deposition of ~100 m^3, primarily on portions of the adjacent floodplain and on a narrow sand cap along the edge of the cobble bar (Figure 6).

Conclusions

Stream-channel narrowing is a widespread response of rivers to natural or human-caused changes in the flow regime—particularly, water withdrawals and reduced peak-flood events associated with dams. The NCPN can combine data from its big-river monitoring with data collected from its other monitoring projects (e.g., invasive plants, water quality, remote sensing) to gain more powerful, comprehensive insight into geological and ecological changes occurring in these systems. For example, our invasive-plant monitoring showed that levels of invasive-plant occurrence were highest on the regulated Green River above the confluence with the Yampa, more moderate on the partially restored Green River below the Yampa confluence, and lowest on the unregulated Yampa River (Perkins et al. 2015). In addition, preliminary analysis of invasive-plant data from Black Canyon of the Gunnison National Park shows that several invasive species have declined over the past 12 years (Perkins and Wight 2016), perhaps due in part to increased environmental flows that more closely mimic natural hydrographs.

Results from these two example sentinel sites over the first few years of monitoring demonstrate measurable, logical, site-specific responses to annual variation in streamflow. By linking hydrologic, vegetation, and geomorphic measurements, we can tie changes in riverine processes affecting specific surfaces to the

amount of water that was on that plot in a given year. We can then connect those water amounts to annual hydrographs. In so doing, we can track the value of natural flows and large floods in the natural stream-habitat resetting process, which is essential to river health. These data will assist managers with myriad questions, such as evaluating the water right and high flows at Black Canyon of the Gunnison National Park; monitoring and evaluating proposed flows from the Aspinall (Gunnison River) and Flaming Gorge (Green River) dams; showing the value, differences, and resources of an unregulated river; and evaluating different invasive-species management options.

Literature Cited

Auble, G. T., J. M. Friedman, and M. L. Scott. 1994. Relating riparian vegetation to present and future streamflows. Ecological Applications 4:544–554.

Auble, G. T., M. L. Scott, and J. M. Friedman. 2005. Use of individualistic streamflow-vegetation relations along the Fremont River, Utah, USA to assess impacts of flow alteration on wetland and riparian areas. Wetlands 25:143–154.

Perkins, D. W., M. L. Scott, and T. Naumann. 2015. Non-native plant invasions differ across three river reaches with varying degrees of river regulation. River Research and Applications 32:1279–1288. DOI:10.1002/rra.2981

Perkins, D., and A. Wight. 2016. Invasive exotic plant monitoring in Black Canyon of the Gunnison National Park and Curecanti National Recreation Area, 2003–2015. Natural Resource Report NPS/NCPN/NRR—2016/1315. National Park Service, Fort Collins, Colorado.

Scott, M. L., and D. W. Perkins. In press. Big rivers monitoring within Dinosaur National Monument: A summary of monitoring results to detect change in channel condition. Northern Colorado Plateau Network, Moab, Utah.