Colorado River, Vegetation, and Climate: Five Decades of Spatio-Temporal Dynamics in the Grand Canyon in Response to River Regulation

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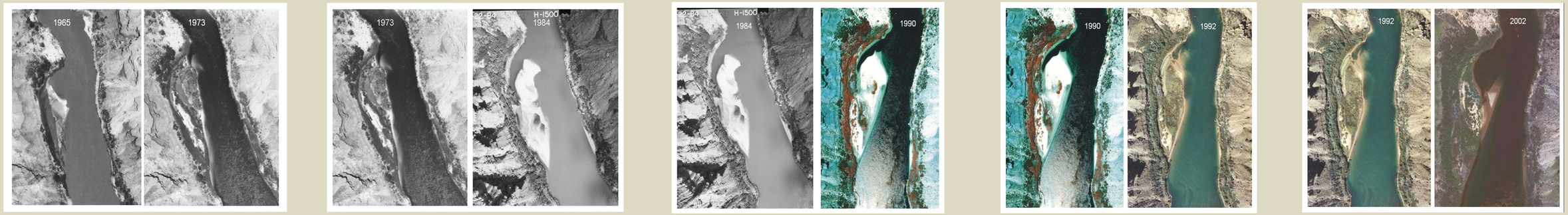


Time series at Kwagunt Marsh (river kilometer 89.5 from Lee's Ferry) from 1965 to 2002, illustrating the expansion of vegetation since regulation and channel narrowing

Overview

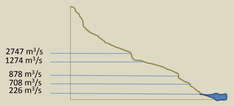
- Multi-decadal analysis of remotely sensed imagery of 400 km of the Colorado River confirms a net increase in vegetated area since the completion of Glen Canyon Dam in 1963.
- The rates and magnitude of vegetation change appear to be river stage-dependent.
- Riparian vegetation expansion on geomorphic surfaces at lower elevations was greater for decades with lower peak and average discharges.
- Vegetation expansion was minimized at stage elevations that discharge equaled or exceeded more than ~ 5 % of time.
- Increased and decreased vegetated area at higher elevations coincided with regionally significant wet and dry periods that included the current early 21st century drought.

A. Photo from 1890 (R. Stanton) near Nankoweap Rapid in Grand Canyon. Sandbars below annual flood line were sparsely vegetated

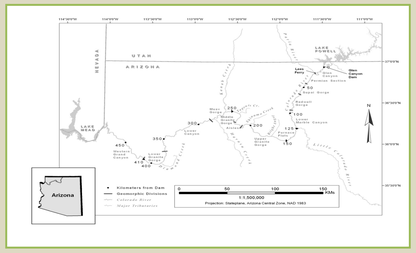
B. Repeat photo from 1991 (USGS), 28 years after Glen Canyon Dam became operational. Riparian vegetation expanded onto previously bare sandbars.

Study Area & Methods

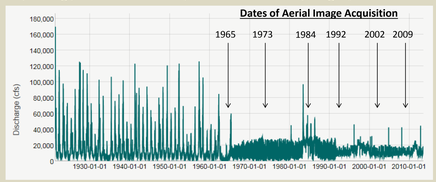
- The Colorado River in Marble and Grand Canyon is 400 km long.
- The operation of Glen Canyon Dam, located 26 km upstream from the mouth of Marble Canyon, has greatly decreased the magnitude and duration of floods.
- We used aerial and digital imagery-based vegetation maps: from 1965, '73, '84, '92, '02, '09; for 4-27 km segments of the river for '65-'92; and the entire corridor for '02, '09
- We quantified total vegetation among 5 river stage-elevation zones
- We used the 20th-21st century regional precipitation record in analyses
- We evaluated % exceedance by stage elevations from 1921-2009



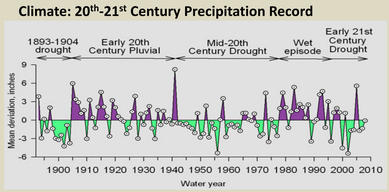
5 stage-elevation zones



Hydrology: 20th-21st Century Colorado River Hydrograph



Climate: 20th-21st Century Precipitation Record

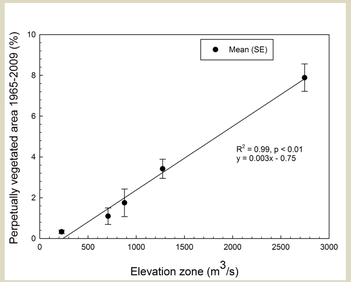


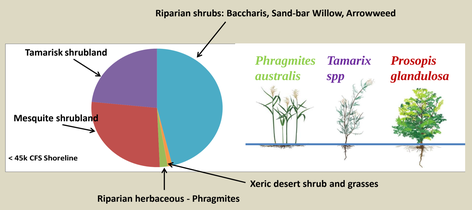
(reproduced from Hereford and others, http://esp.cr.usgs.gov/projects/sw/historical/precip_sw.html)

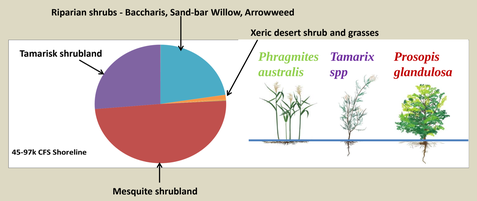
Results and Discussion

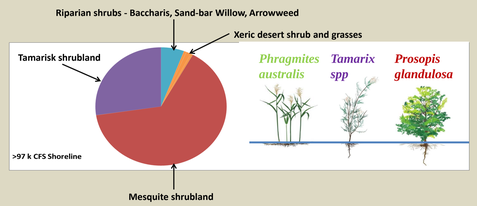
Vegetation longevity by elevation zone

- **Vegetation was less stable at lower elevation zones from 1965 to 2009**

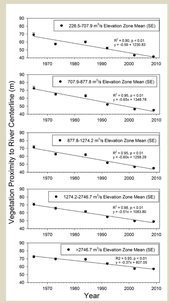








- Tamarisk was an early colonizer following regulation
- Riparian shrubs (Baccharis, Sandbar willow and Arrowweed have expanded the most between 2002 – 2009 below the 1274 m^3/s (45k cfs) stage
- Vegetation has expanded shoreward and often in upstream direction

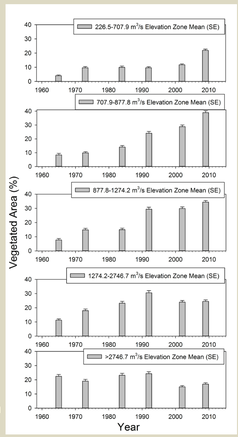


1965-2009

- Long-term vegetation changes are associated with distinct hydrology of elevation zones
- Changes in vegetated area by elevation zone are associated with decadal changes in Glen Canyon Dam operations and/or regional changes in precipitation

Lowest elevation zone - river

Highest elevation zone - xeric



Potentially affected by:

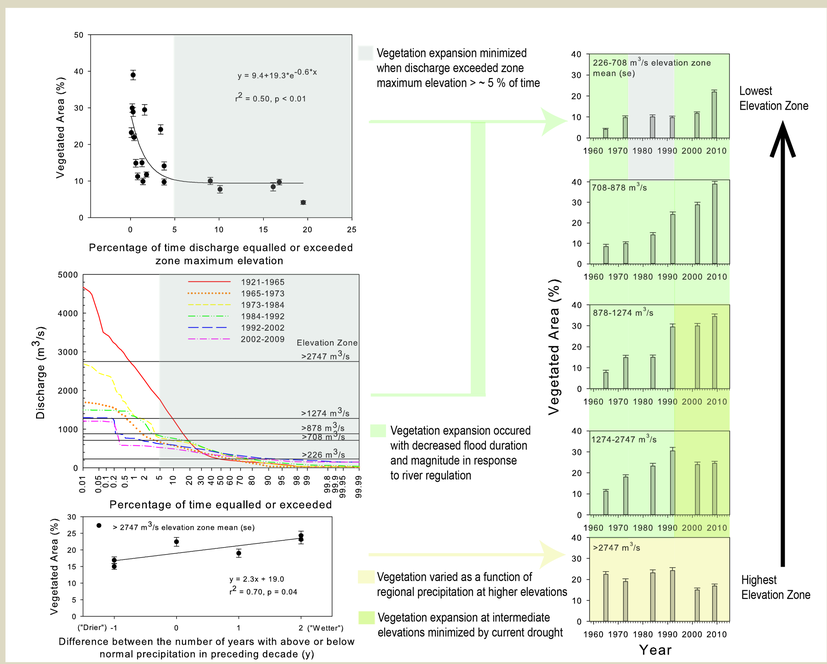
Current Dam Operations **(<708 m^3/s)**

Higher Powerplant Operations **(<878 m^3/s)**

Recent Controlled Floods **(<1274 m^3/s)**

Rare Post-dam Floods **(<2747 m^3/s)**

Never Inundated Post-dam **(>2747 m^3/s)**



- Over time, vegetation expansion has progressively occurred within a smaller number of elevation zones and at increasingly lower elevation zones
- Vegetation expansion is correlated with percent of time stage elevation was exceeded.
- Stage elevations in which discharge equaled or exceeded the maximum zone elevation more than approximately 5% of time had minimized vegetation expansion
- At higher elevations, vegetated area reflected regional precipitation patterns, and coincided with significant wet and dry periods. Intermediate elevation zones analyzed for riparian vegetation appeared to be decoupled from river hydrology in the current, early 21st-century drought.
- Long-term riparian vegetation change is therefore significantly related to river hydrology at lower elevation zones (<1274 m^3/s) and regional climate at higher elevations (>2747 m^3/s), with interacting effects at mid-elevation zones
- Results show promise for improved understanding of the interplay of river regulation and climate effects and riparian vegetation response at a local and river-wide scale in this highly modified river system.

Acknowledgments

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(Preliminary Data from Ralston and Sankey, Do Not Cite)