

Species-level evaluation of riparian vegetation dynamics using remotely sensed imagery from aerial overflights

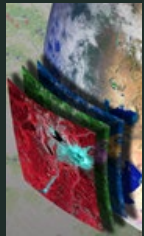
Glen Canyon Dam Adaptive Management Program Annual Reporting Meeting,
January 14, 2020, Phoenix, AZ

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US Geological Survey, Grand Canyon Monitoring and Research Center

Species-level evaluation of riparian vegetation dynamics using remotely sensed imagery from aerial overflights

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REMOTE SENSING AND
GEOINFORMATICS LAB
NORTHERN ARIZONA UNIVERSITY



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Grand Canyon Monitoring and Research Center



- Project C.2 Imagery-based riparian vegetation monitoring at the landscape scale
- LTEMP Resource and Goal
 - Riparian Vegetation
 - Maintain native vegetation and wildlife habitat, in various stages of maturity, such that they are diverse, healthy, productive, self-sustaining, and ecologically appropriate.

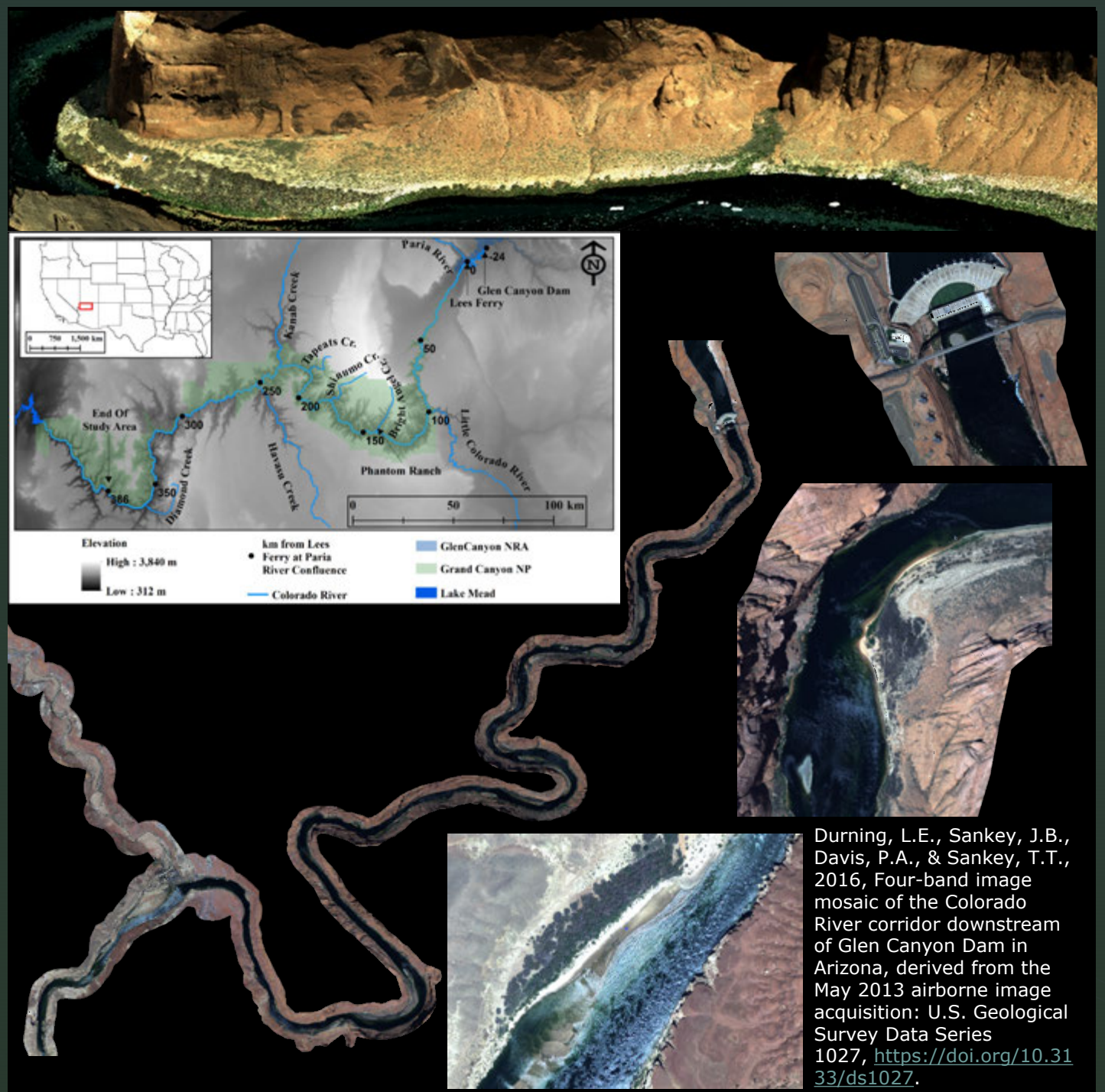


▸ Presentation Outline

- Remote sensing overflights
- Species-level evaluation of riparian vegetation dynamics from remote sensing overflight imagery
- Closing thoughts

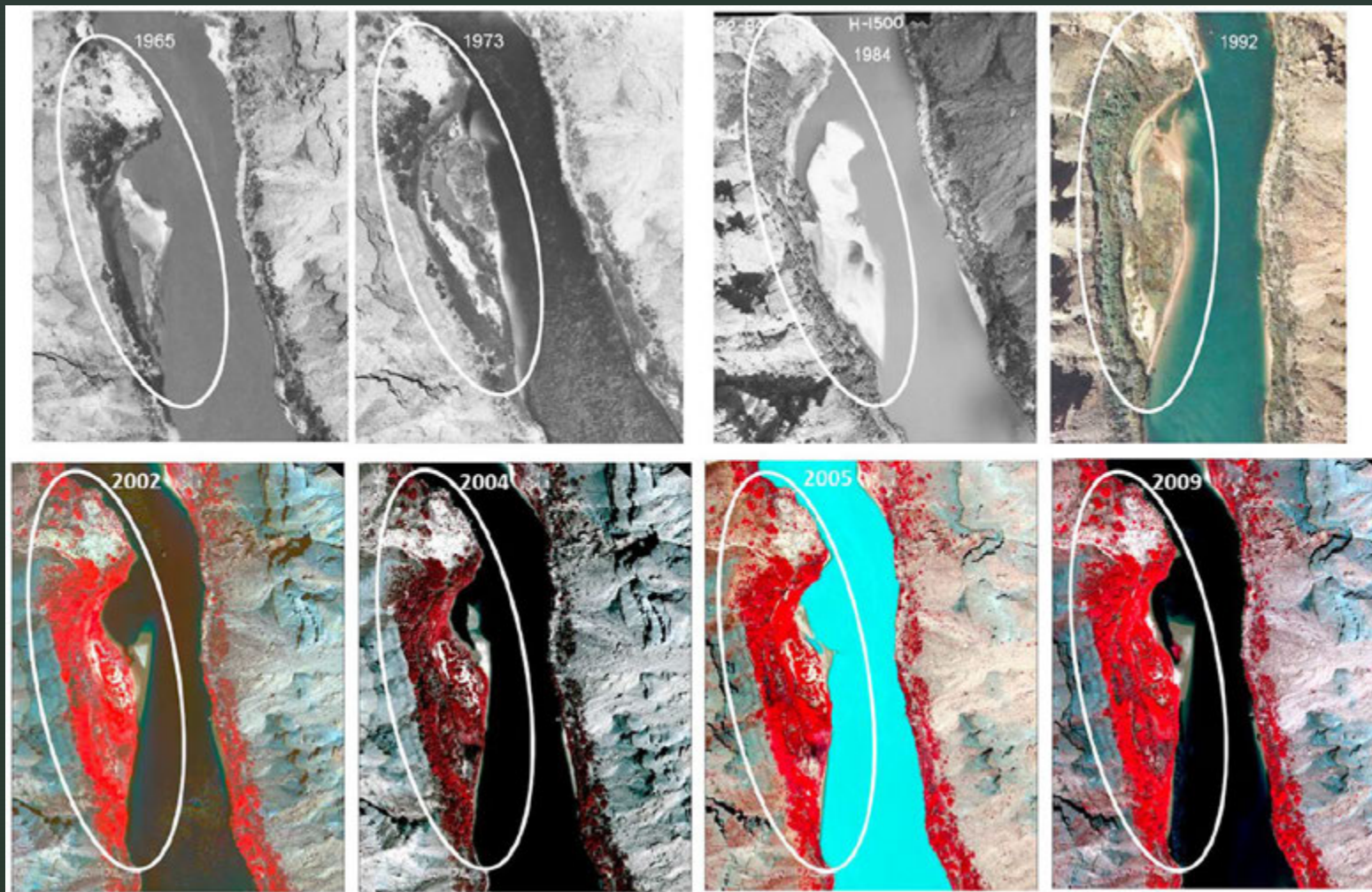
Remote Sensing Overflights

- "Historical" overflights
 - Analog air photos since the 1960s (and even earlier)
- "Modern" overflights
 - Multispectral digital image mosaics
 - 2002, 2004, 2005, 2009, 2013, **2021**



Durning, L.E., Sankey, J.B., Davis, P.A., & Sankey, T.T., 2016, Four-band image mosaic of the Colorado River corridor downstream of Glen Canyon Dam in Arizona, derived from the May 2013 airborne image acquisition: U.S. Geological Survey Data Series 1027, <https://doi.org/10.3133/ds1027>.

Air Photos and Multispectral Imagery from Overflights of the Colorado River in Grand Canyon



Sankey, J.B., Ralston, B., Grams, P.E., Schmidt, J.C., and Cagney, L.E., 2015, Riparian vegetation, Colorado River, and climate: five decades of spatiotemporal dynamics in the Grand Canyon with river regulation: *Journal of Geophysical Research*, v. (online), doi: 10.1002/2015JG002991.

Products from Modern Overflights

Multispectral imagery

Digital topography

Website content and virtual online maps.

Cartographic products
- River map books
- Publication maps

Colorado River Centerline and River Mile System

Flowlines
- Extracted from low-flow water's edge (~8,000 CFS) in overflight imagery
- Modelled from overflight topography and water surface elevation data(Magirl, 2008)

Land cover classification
- water, sand, vegetation

Vegetation species classification

Campsite delineation
- Campsite atlas

Topography data
- Topographic change detection
- Hydrologic flow modeling.

Modern Overflight Products

- Imagery and datasets available through GCMRC website
 - Online maps
 - Data applications
 - Data releases

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GCMRC Data and Tools

Online Maps

GCMRC's Geospatial Science and Technology project builds and maintains a variety of online maps related to active science projects and general information about the Colorado River and larger Grand Canyon region.

[Go to Online Maps](#)

Data Applications

GCMRC also develops web-based, database-driven applications for specific long-term monitoring projects. These applications range from tools that explore water and sediment data of the Colorado River to rapid photographic data sets that span decades.

[Go to Data Apps](#)

Data Releases

Data releases made available by GCMRC can be found here as they are published via the USGS Fundamental Science Practices (FSPs). Individual science product links will have icons to the USGS ScienceBase website for each entry.

[Go to Data Releases](#)

Home | Data and Tools

The Grand Canyon Monitoring and Research Center offers a collection of data resources and online tools – including web maps, applications, and other content – that convey scientific information related to ongoing monitoring of the Colorado River. Some applications are a culmination of long-term monitoring work, while others are developed around more a specific set of information usually derived and published separately from a larger project database.

Status - Active

Explore More Science

- GCMRC
- Colorado River
- Grand Canyon
- Templeton Conservation and Restoration
- Grand Canyon Trust Adaptive Management Program (GCMAMP)
- USGS

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Layers:

- NPFS Composite Polygons
- Show Map Features
- NPFS Composite Polygons
 - Day View Only
 - LEGACY DEM
 - Primary Camp
- Show Map Features
 - Cities
 - City
 - Town
- River Miles
- Colorado River
- Tributaries

GCMRC 2003-2010 Imagery

Map 2010 Imagery

- Red Band_1
- Green Band_2
- Blue Band_3

Identify

- Print
- Clear
- Measurement
- Print
- Editor

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GCMRC Data Applications

Below are data applications associated with the Grand Canyon Monitoring and Research Center's efforts to monitor and study the Colorado River System of the Grand Canyon Basin. New data applications will be added as they become available.

New Data 0

Clear Type | Clear Layer | Select Location | Select Year | Select Date | [Go Home](#) | [Help](#)

Time published: 2008-02-01

GCMRC NEEP Services Page

The National Earth System Information Architecture (NESA) system has been implemented by the Grand Canyon Monitoring and Research Center. This system provides a central location for all GCMRC data and information. The system is designed to be user-friendly and accessible to a wide range of users. For more information, please visit the GCMRC NEEP Services Page.

Time published: 2008-02-01

Sandbar Monitoring Sites - Remote Camera Photographs Application

GCMRC and Southern Science University have engaged in long-term monitoring of 10 sandbar sites along the Colorado River in Grand Canyon. Remote camera data have been used to monitor sandbar changes in response to various flow rates over time. This application provides users with a gallery of high-resolution photographs of 10 sandbar sites.

Time published: 2008-02-01

APPLICATION - Discharge, Sediment, and Water Quality Monitoring Application

This site provides the Grand Canyon Monitoring and Research Center's discharge, sediment and water quality monitoring application. The application provides users with a gallery of high-resolution photographs of 10 sandbar sites.

Time published: 2008-02-01

APPLICATION - Grand Canyon Sandbar Monitoring

This site provides the Grand Canyon Monitoring and Research Center's long-term sandbar monitoring program. The application provides users with a gallery of high-resolution photographs of 10 sandbar sites.

Time published: 2008-02-01

APPLICATION - Grand Canyon Citizen Science Story Map

This site provides the Grand Canyon Monitoring and Research Center's citizen science story map. The application provides users with a gallery of high-resolution photographs of 10 sandbar sites.

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GCMRC Data Releases

This page provides links to data releases related to the Grand Canyon Monitoring and Research Center's efforts to monitor effects of river operations on the downstream ecosystem of the Colorado River in Marble and Grand Canyons, Arizona.

New Data 0

Clear Type | Clear Layer | Select Location | Select Year | Select Date | [Go Home](#) | [Help](#)

Time published: 2010-01-01

Colorado River Web System - Grand Canyon, Arizona

This site provides the Grand Canyon Monitoring and Research Center's web system. The application provides users with a gallery of high-resolution photographs of 10 sandbar sites.

Time published: 2010-01-01

Riparian vegetation classification data for the Colorado River within Grand Canyon (derived from 2010)

This site provides the Grand Canyon Monitoring and Research Center's riparian vegetation classification data. The application provides users with a gallery of high-resolution photographs of 10 sandbar sites.

Time published: 2010-01-01

Bank classifications along the Colorado River in Grand Canyon derived from 2002, 2008, and 2010 high-resolution topographic information (PHOTO)

This site provides the Grand Canyon Monitoring and Research Center's bank classifications. The application provides users with a gallery of high-resolution photographs of 10 sandbar sites.

Time published: 2010-01-01

Catalog of Photographs Showing Change in Riparian Vegetation in the Grand Canyon, 1988-2010

This site provides the Grand Canyon Monitoring and Research Center's catalog of photographs. The application provides users with a gallery of high-resolution photographs of 10 sandbar sites.

Time published: 2010-01-01

Riparian Vegetation 2010 Data and Pattern Code

This site provides the Grand Canyon Monitoring and Research Center's riparian vegetation data. The application provides users with a gallery of high-resolution photographs of 10 sandbar sites.

Modern Overflight Products

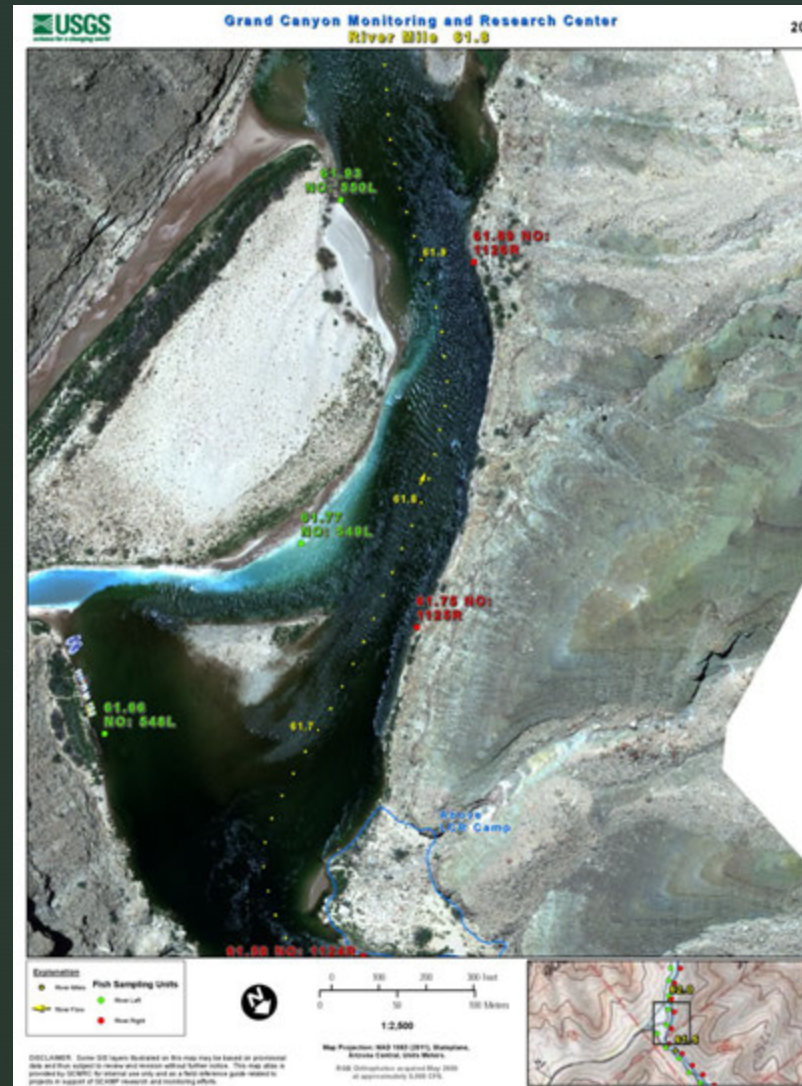
Mapbooks

- All projects use these!
- Critical to field data collection
- River navigation
- Citizen science



Modern Overflight Products

- Fish sampling unit system
 - Based on shorelines derived from imagery
 - Used for all fish monitoring and research
- LCR humpback monitoring depends on imagery too



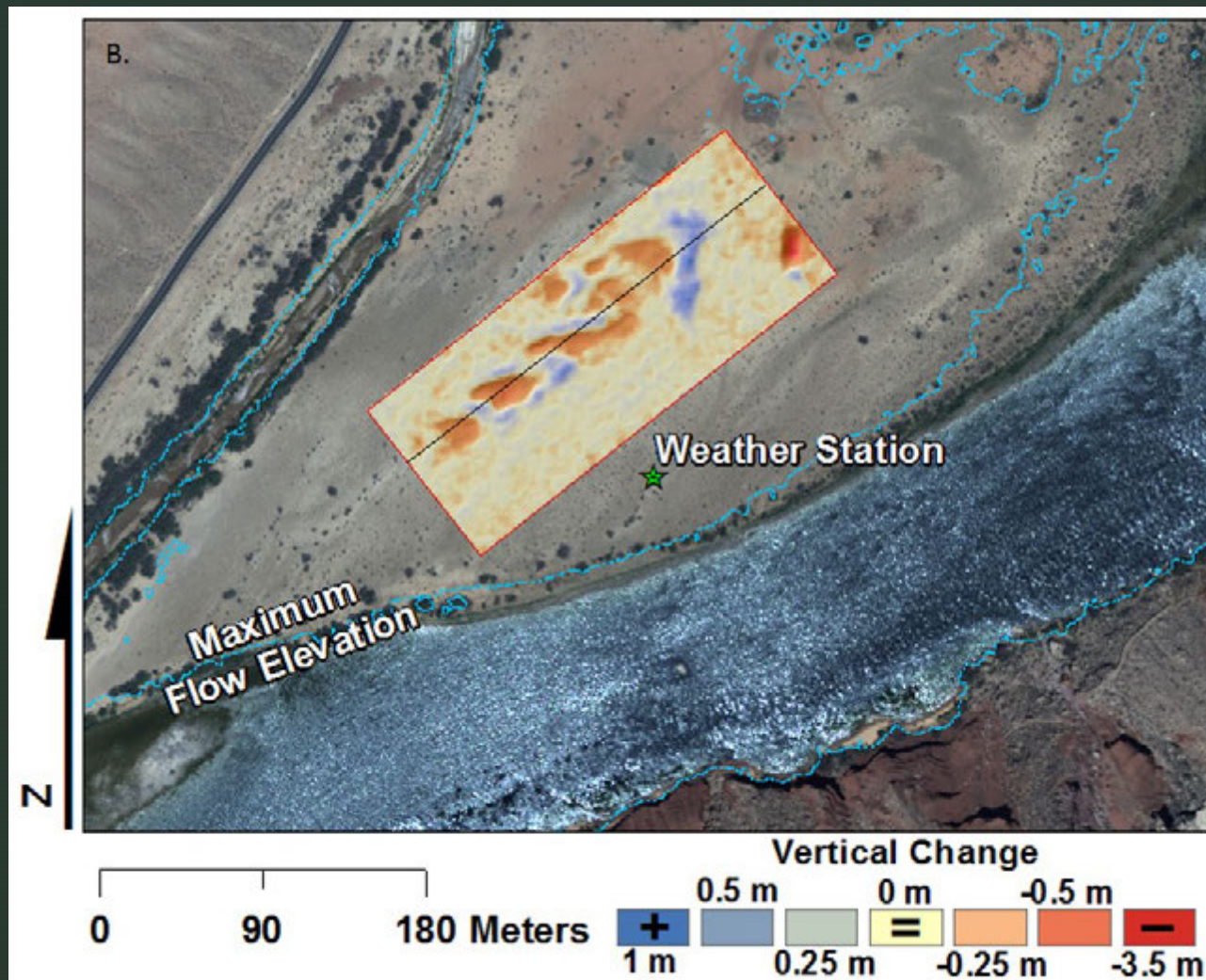
Modern Overflight Products

Remote sensing topographic change detection 2002-2013

Digital Surface & Elevation Models (DSM & DEM)

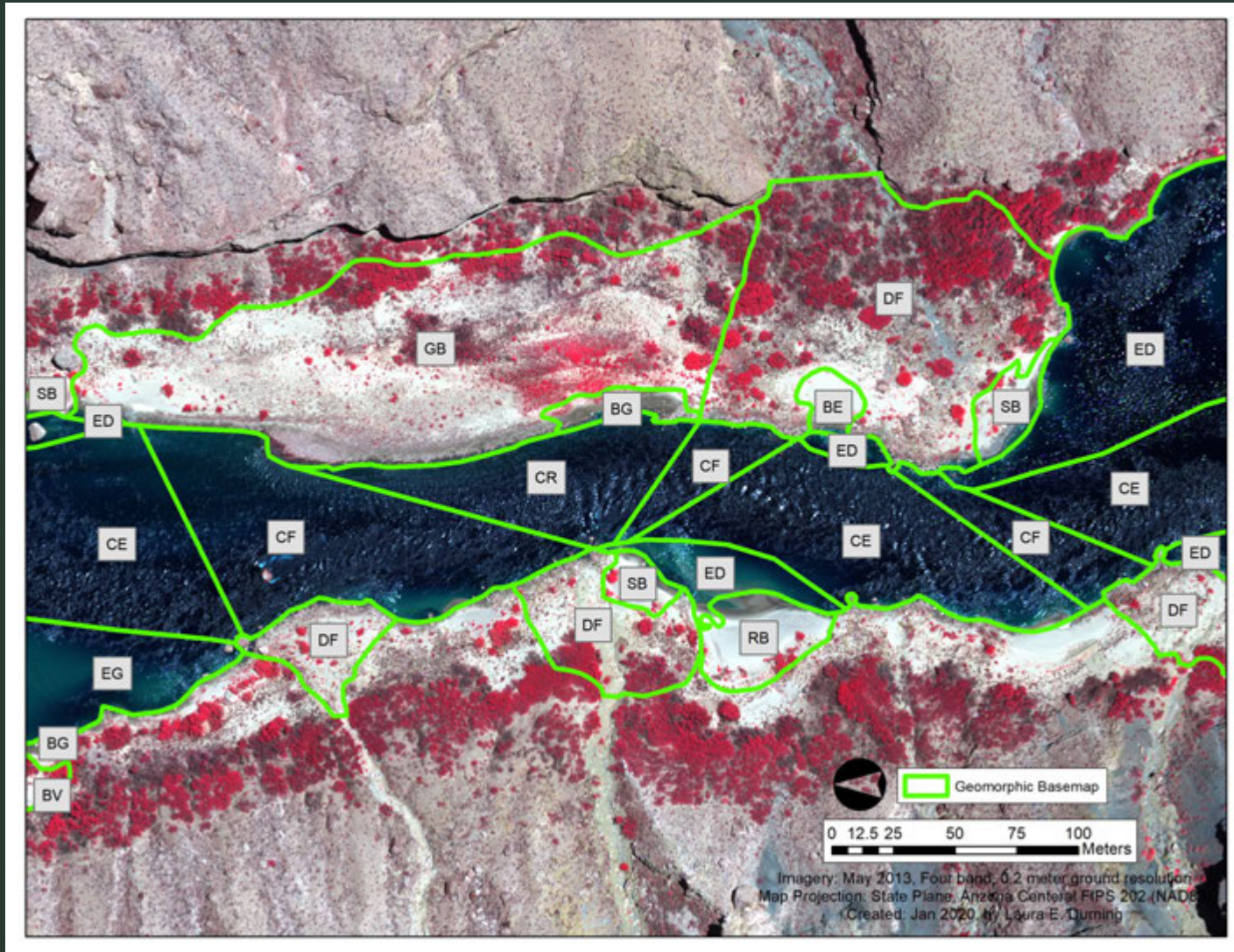
- DEM topographic change detection
- e.g., sand dunes

Sankey, J.B., Kasprak, A., Caster, J., East, A.E. and Fairley, H.C., 2018. The response of source-bordering aeolian dunefields to sediment-supply changes 1: effects of wind variability and river-valley morphodynamics. *Aeolian research*, 32, pp.228-245.



Modern Overflight Products

- Geomorphic basemap



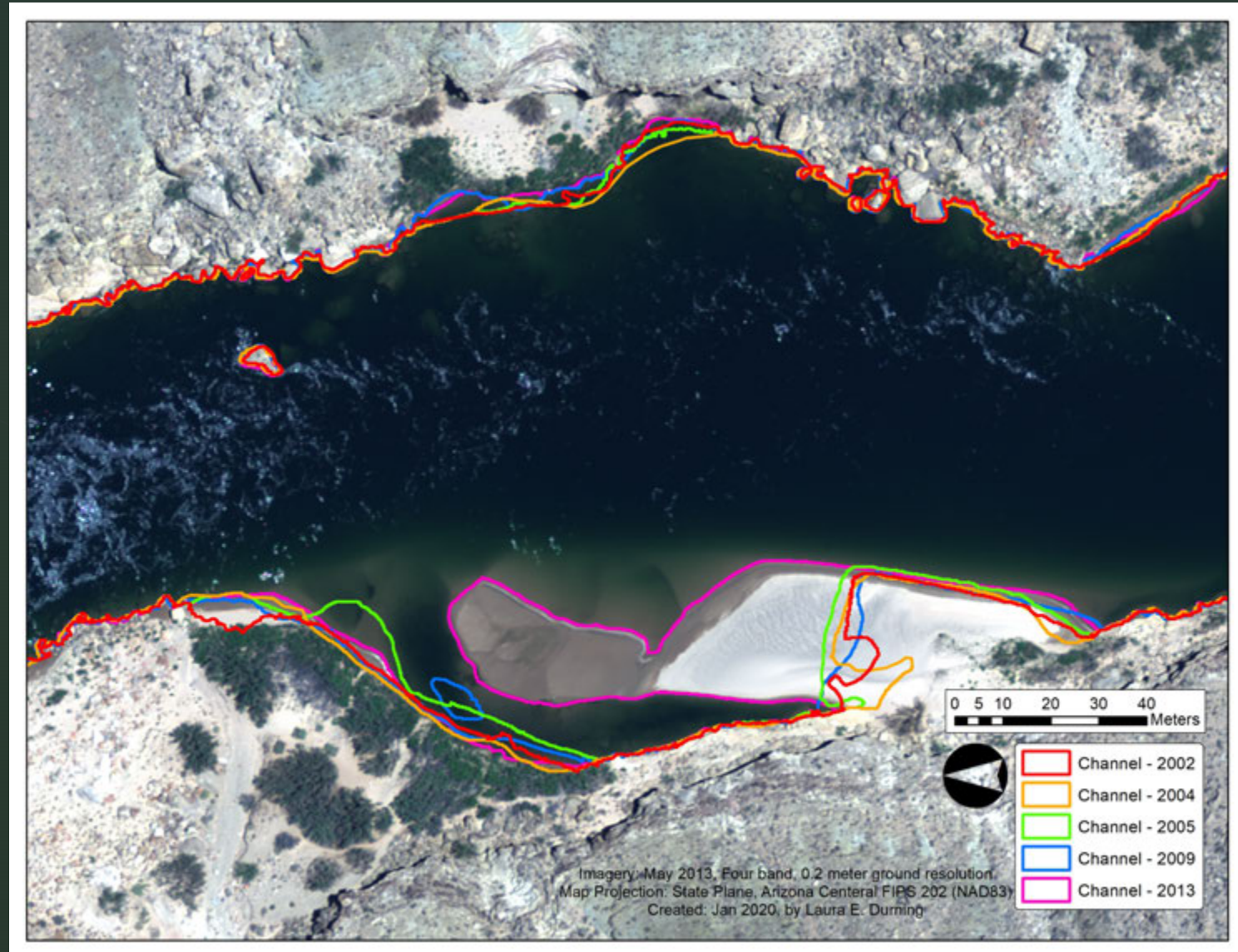
Unpublished data, do not cite

Modern Overflight Products

River channel changes

- Flowlines depicting low-flow water's edge (~8,000 CFS) in overflight imagery
- 2002, 2004, 2005, 2009, & 2013

- Sankey, et al., 2015
- Durning, L.E., Sankey, J.B., Chain, G.R., and Sankey, T.T., 2017, Water classification of the Colorado River Corridor, Grand Canyon, Arizona, 2013—Data: U.S. Geological Survey data release, <https://doi.org/10.5066/F7PZ5799>.

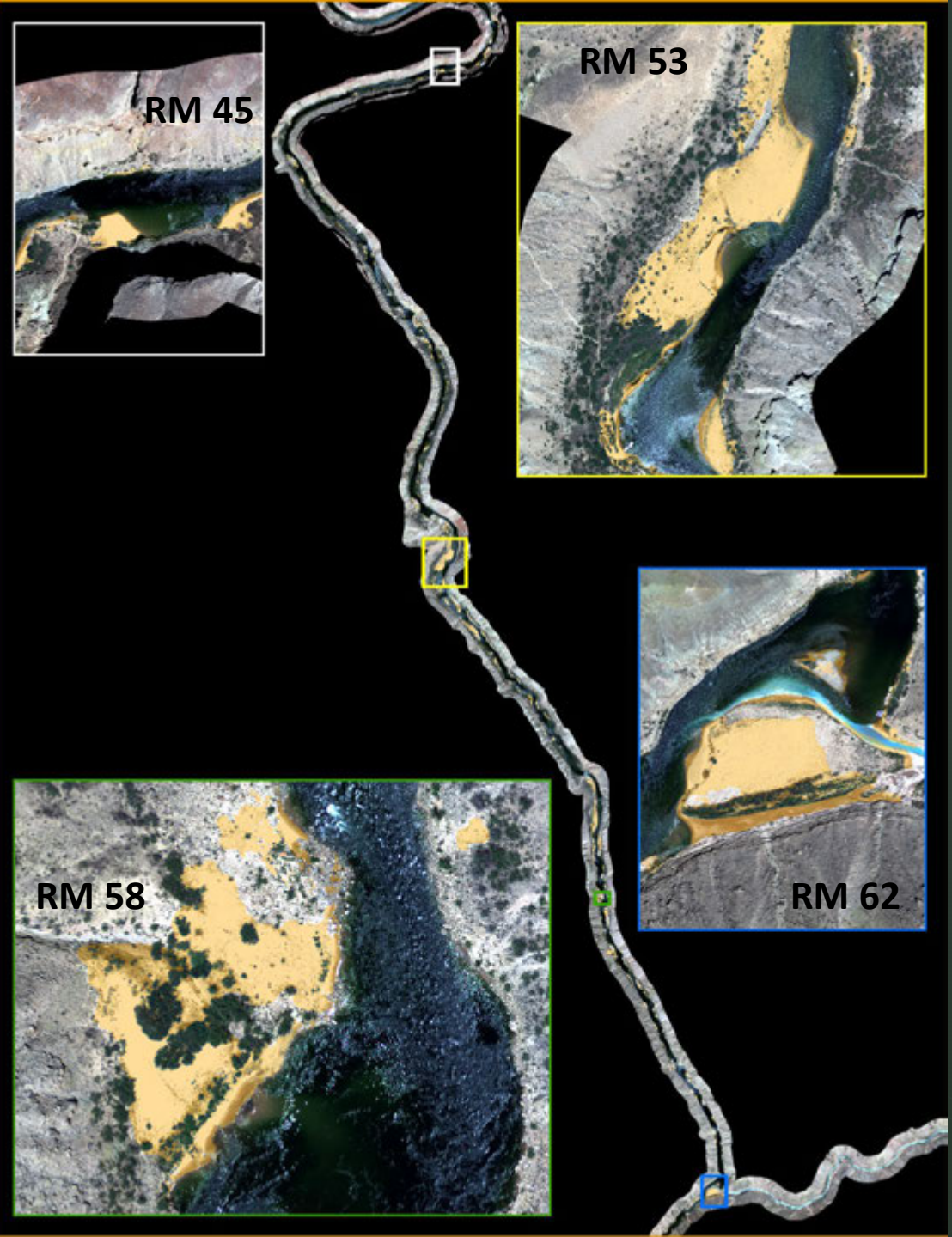


Modern Overflight Products

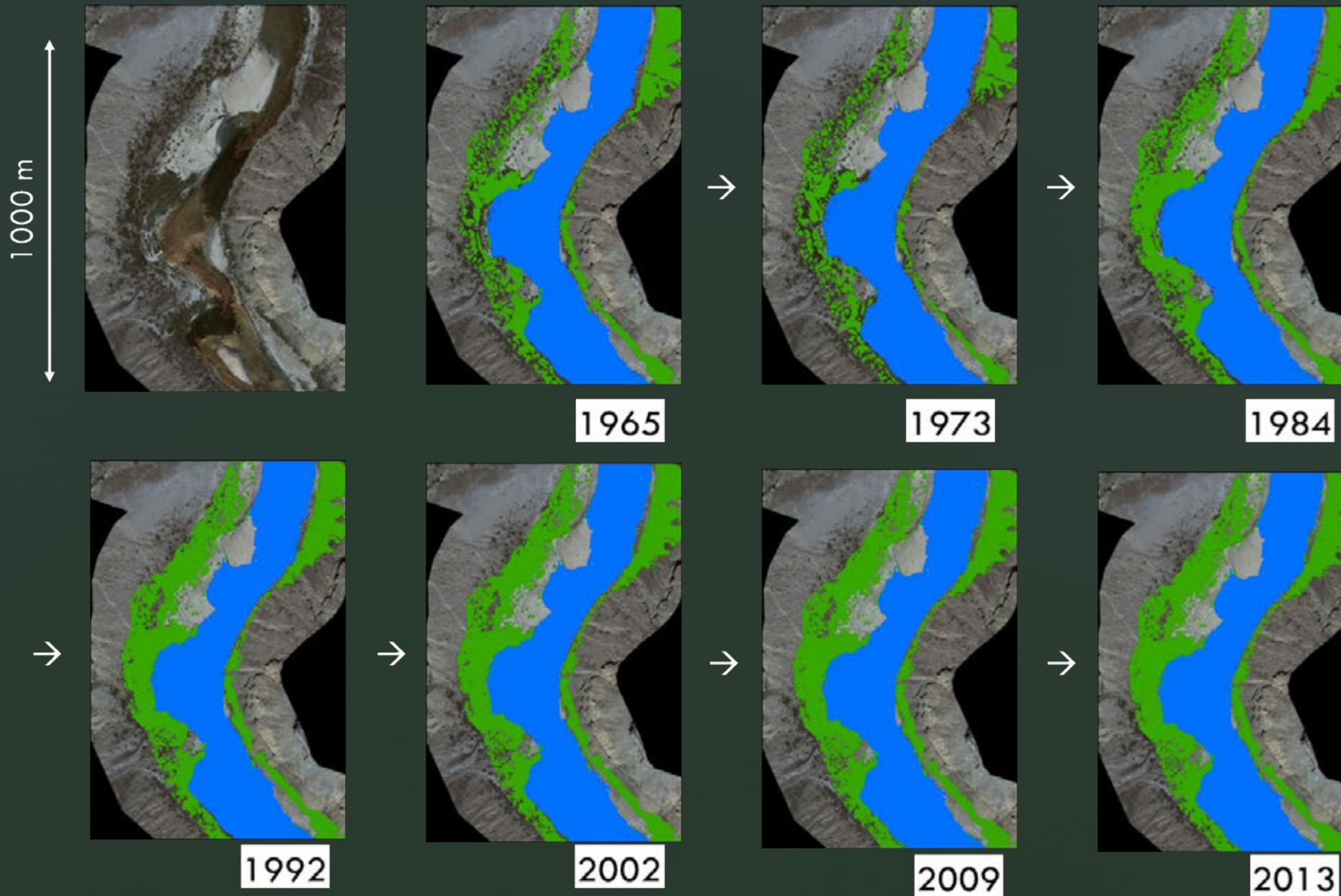
Landcover changes

- Image classifications of bare unvegetated sand
- 2002, 2009, 2013

Sankey, J.B., Chain, G.R., Solazzo, D., Durning, L.E., Bedford, A., Grams, P.E., and Ross, R.P., 2018, Sand classifications along the Colorado River in Grand Canyon derived from 2002, 2009, and 2013 high-resolution multispectral airborne imagery: U.S. Geological Survey data release, <https://doi.org/10.5066/P99TN424>.



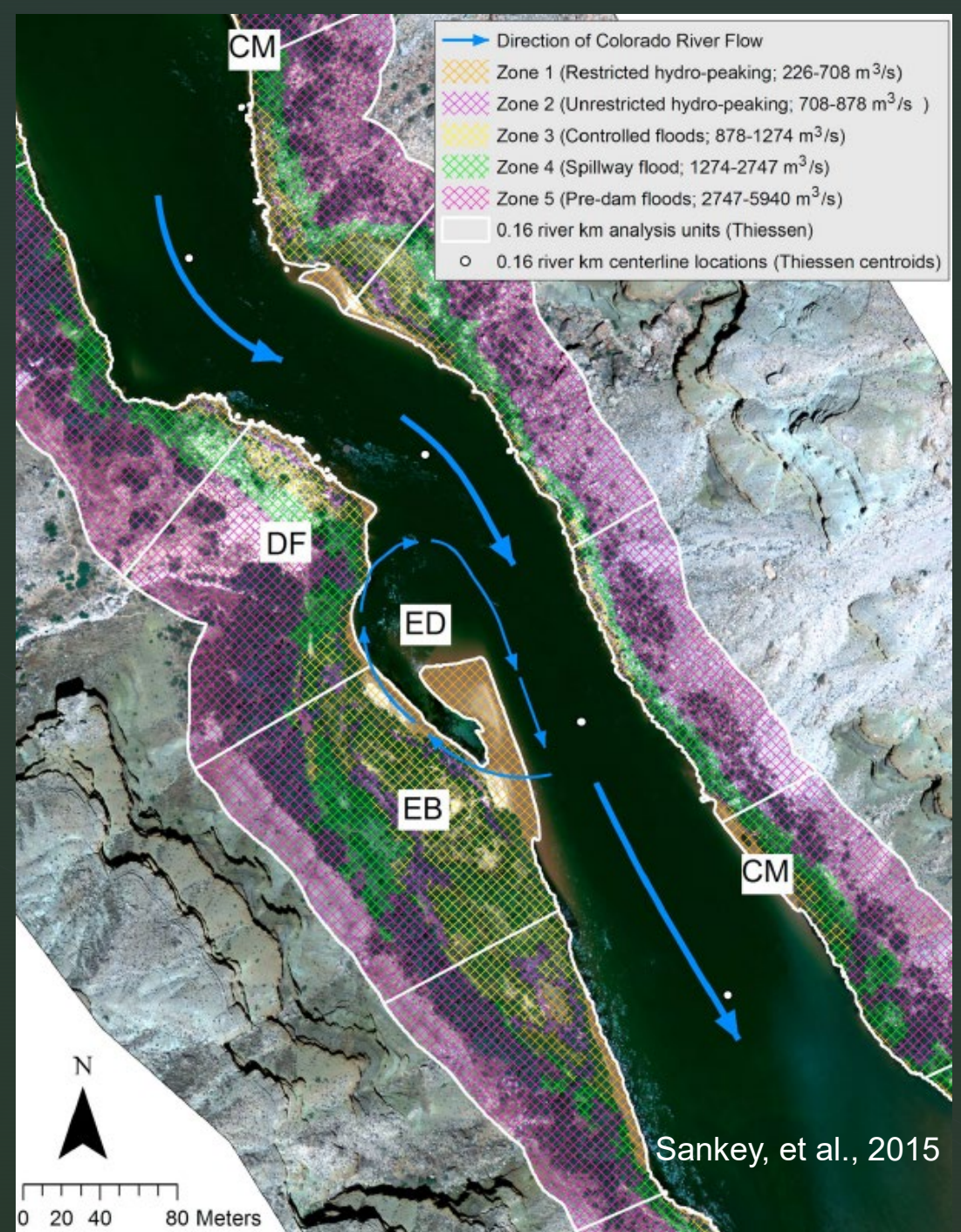
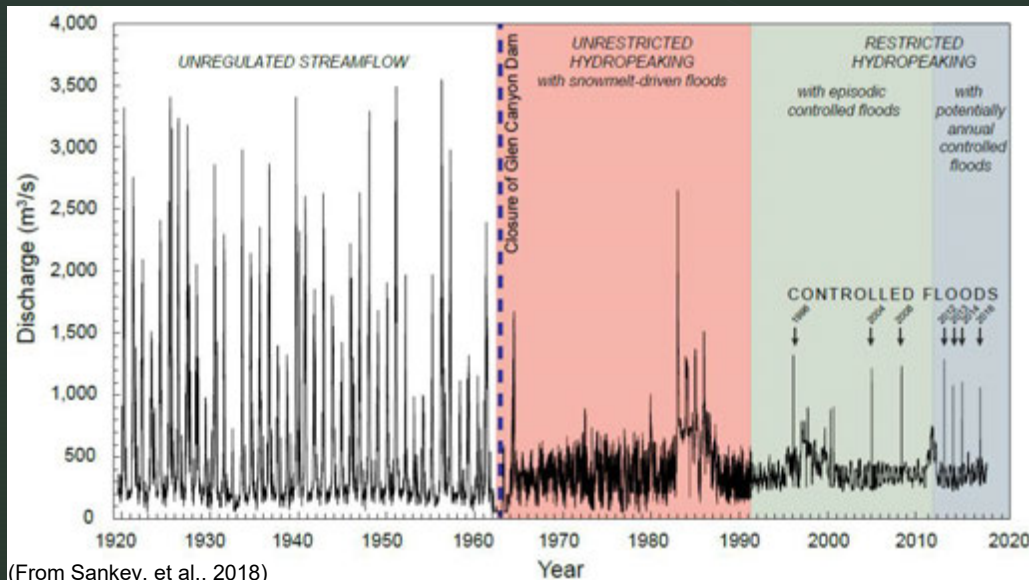
Modern Overflight Products



Kasprak, A., Sankey, J.B., Buscombe, D., Caster, J., East, A.E. and Grams, P.E., 2018. Quantifying and forecasting changes in the areal extent of river valley sediment in response to altered hydrology and land cover. *Progress in Physical Geography: Earth and Environment*, 42(6), pp.739-764.

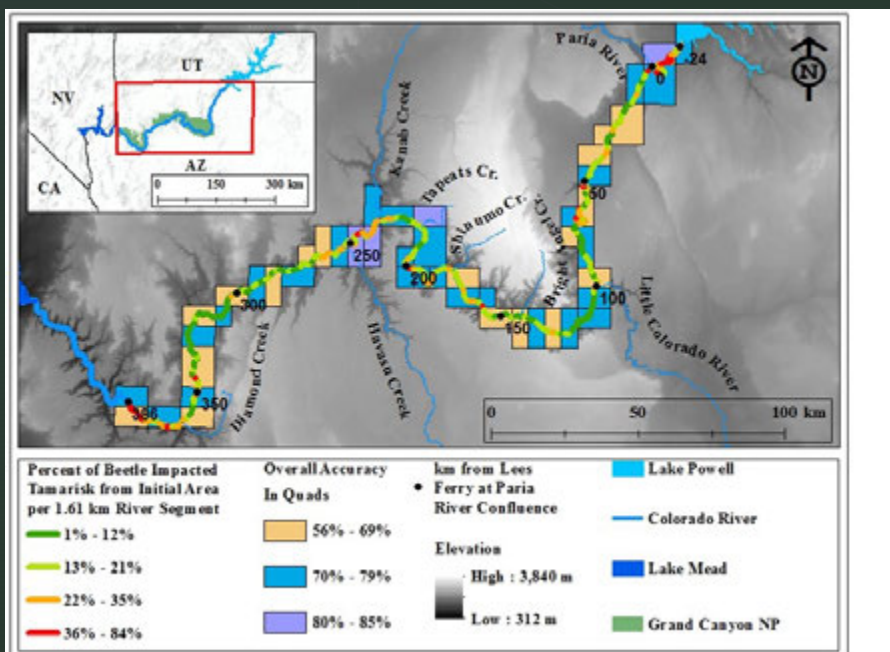
Modern Overflight Products

- Landcover changes and Glen Canyon Dam and Colorado River hydrology
 - Modelled Shorelines
 - Geomorphic basemap
 - River center-line and river-mile system
 - Landcover changes



Modern Overflight Products

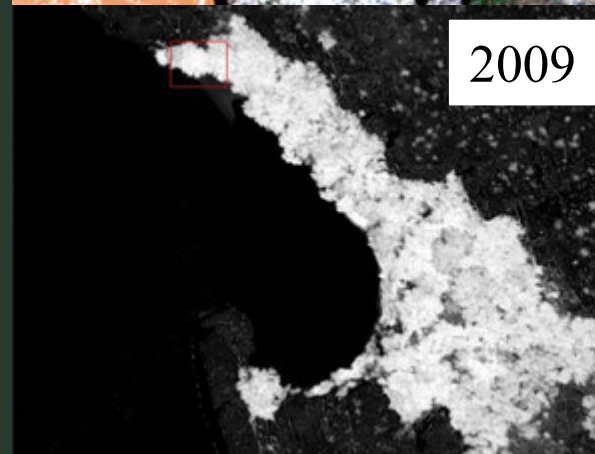
Tamarisk and Tamarisk Beetle Impacts



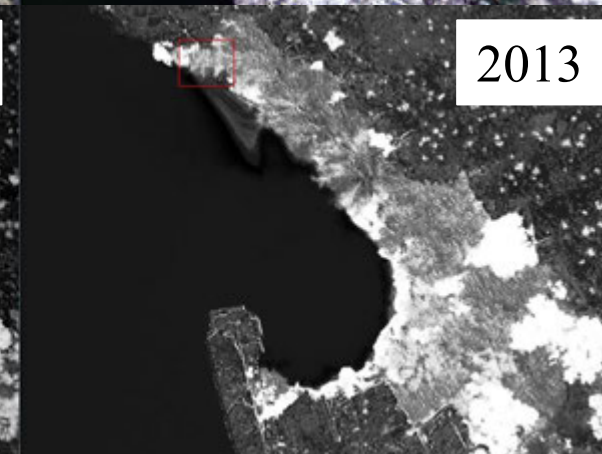
2009



2013



2009



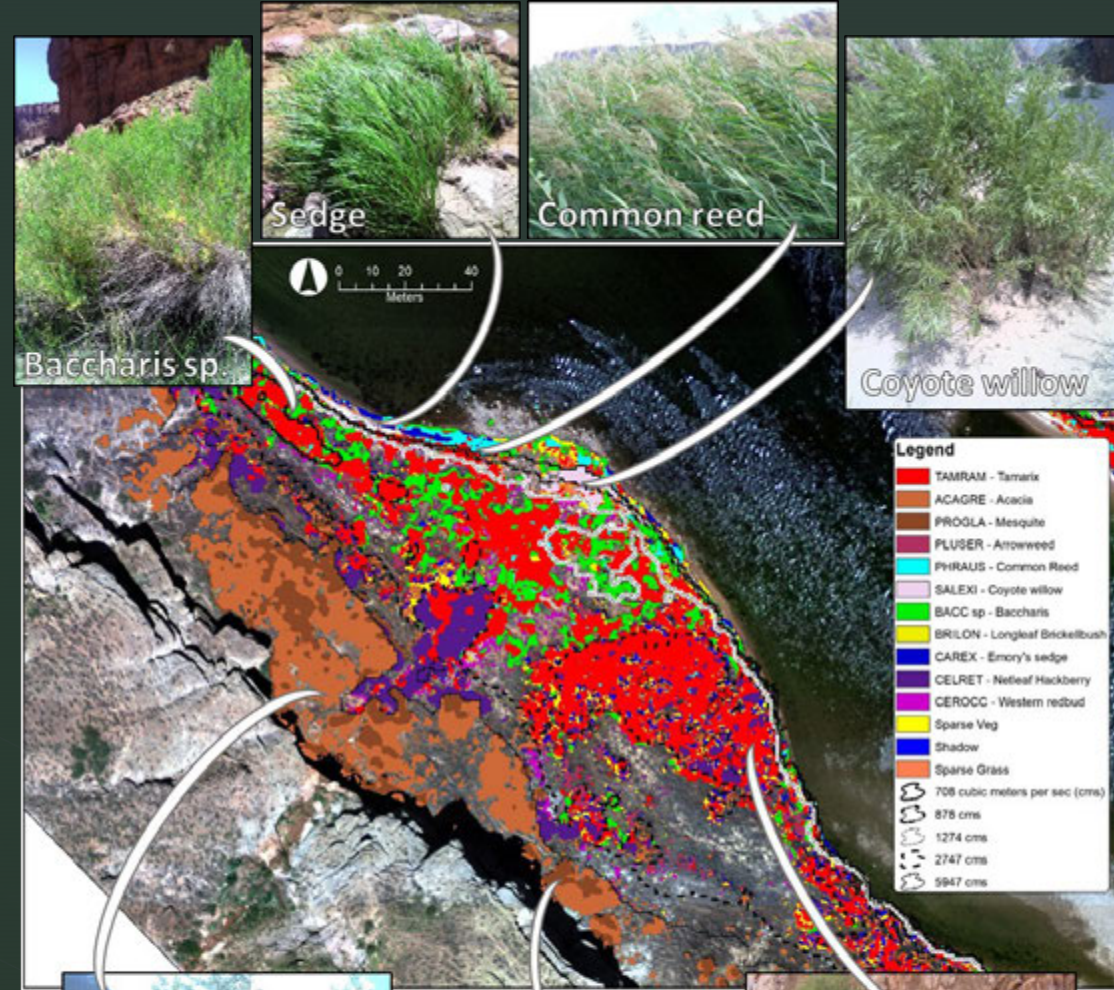
2013

Bedford, A., Sankey, T.T., Sankey, J.B., Durning, L.E., and Ralston, B.E., 2018, Remote sensing of tamarisk beetle (*Diorhabda carinulata*) impacts along 412 km of the Colorado River in the Grand Canyon, Arizona, USA: *Ecological Indicators*, v. 89, p. 365-375, <https://doi.org/10.1016/j.ecolind.2018.02.026>.

Modern Overflight Products

Vegetation Species Classification

- Map covers from Glen Canyon Dam to Pearce Ferry
- 26 species and 7 additional generalized vegetation classes
- Overall accuracy 71%



Durning, L.E., Sankey, J.B., Bedford, A., and Sankey, T.T., 2018, Riparian species vegetation classification data for the Colorado River within Grand Canyon derived from 2013 airborne imagery: U.S. Geological Survey data release, <https://doi.org/10.5066/P9OUB1RS>.

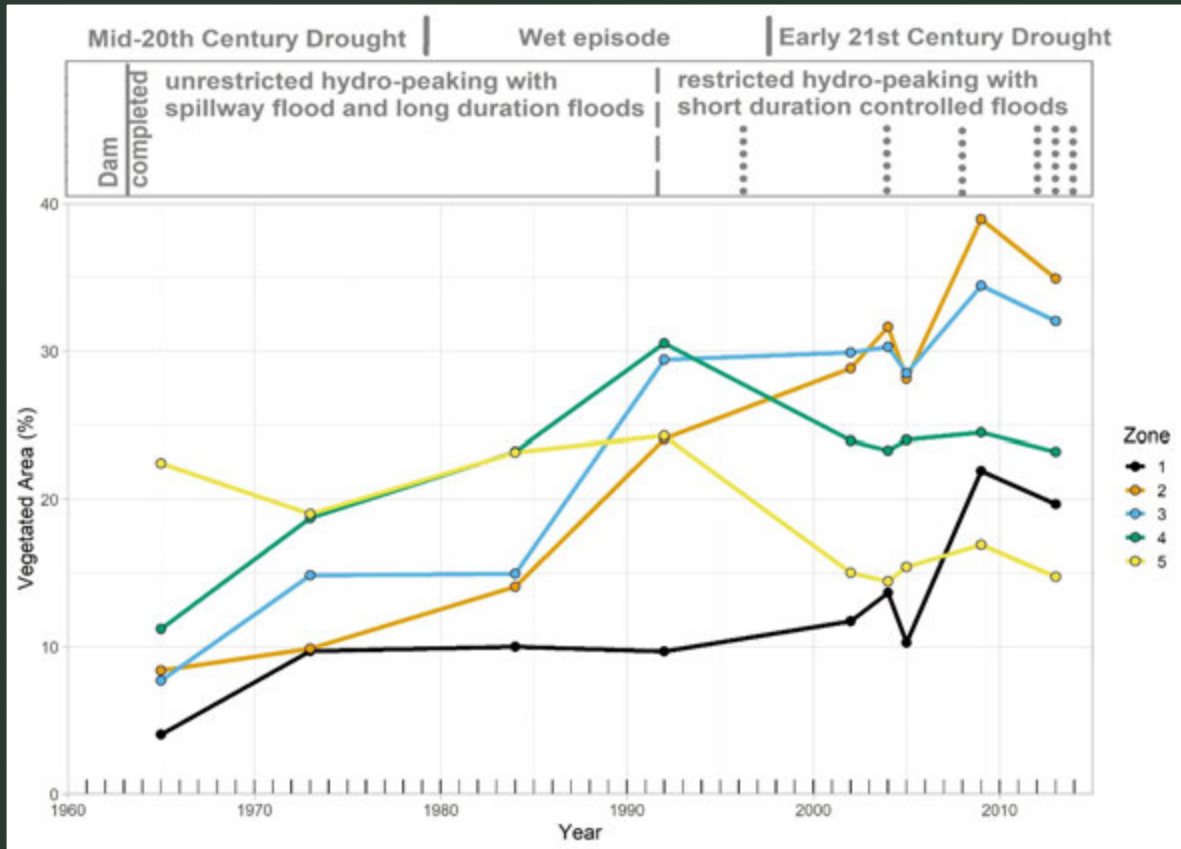
Overflight – 2021

- General timeframe
 - 2021-2024 Work plan
 - 2021 - 1 year for managing contract and acquiring data
 - Mission scheduled for May 2021
 - 2022 - 1 year for building image mosaic & serving it online
 - 2023 - Image analysis and product generation begin
- Approximately \$0.6 million to contract the acquisition
- GCMRC staff support and funding required
 - to plan and manage the acquisition
 - to process, serve, and analyze the data

Species-level evaluation of riparian vegetation dynamics: analysis of overflight imagery from 2002, 2009, and 2013



Long-term changes in riparian vegetation quantified with historic and modern overflight imagery (1965 - 2013)



Sankey et al., 2015

Changes in riparian vegetation and vegetation-sand dynamics quantified with modern overflight imagery (2002-2009-2013)

- Types of riparian vegetation encroachment onto sand
 - "Sustained" – sand in 2002 and vegetated in 2009 & 2013
 - "Recent" – sand in 2002 & 2009 but vegetated in 2013
 - "Burial and emergence" – vegetated in 2002 & 2013, but sand present in 2009.



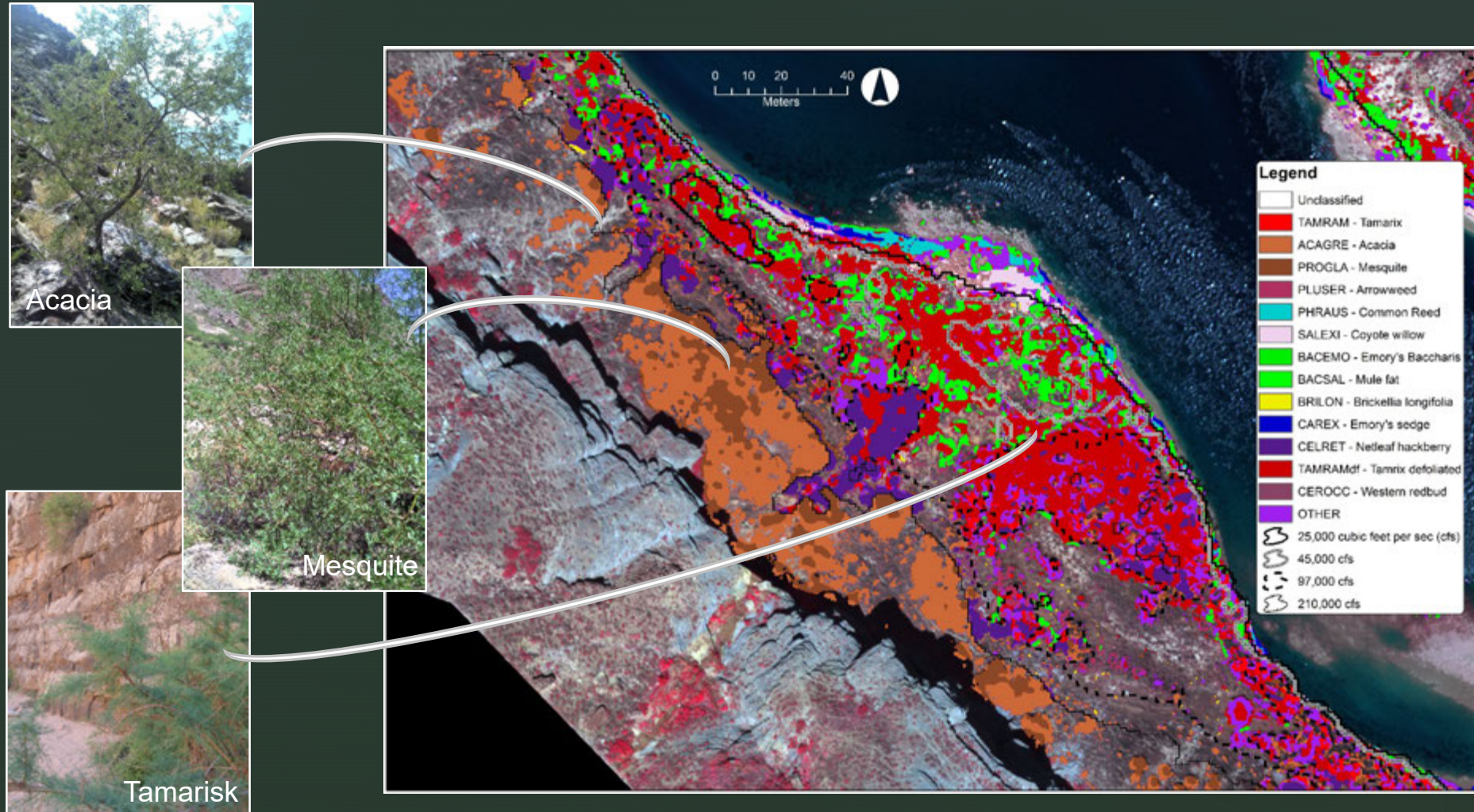
Changes in riparian vegetation and vegetation-sand dynamics quantified with modern overflight imagery (2002-2009-2013)

Research Questions:

How do the spatial distributions of vegetation species vary by inundation frequency and geomorphic surface?

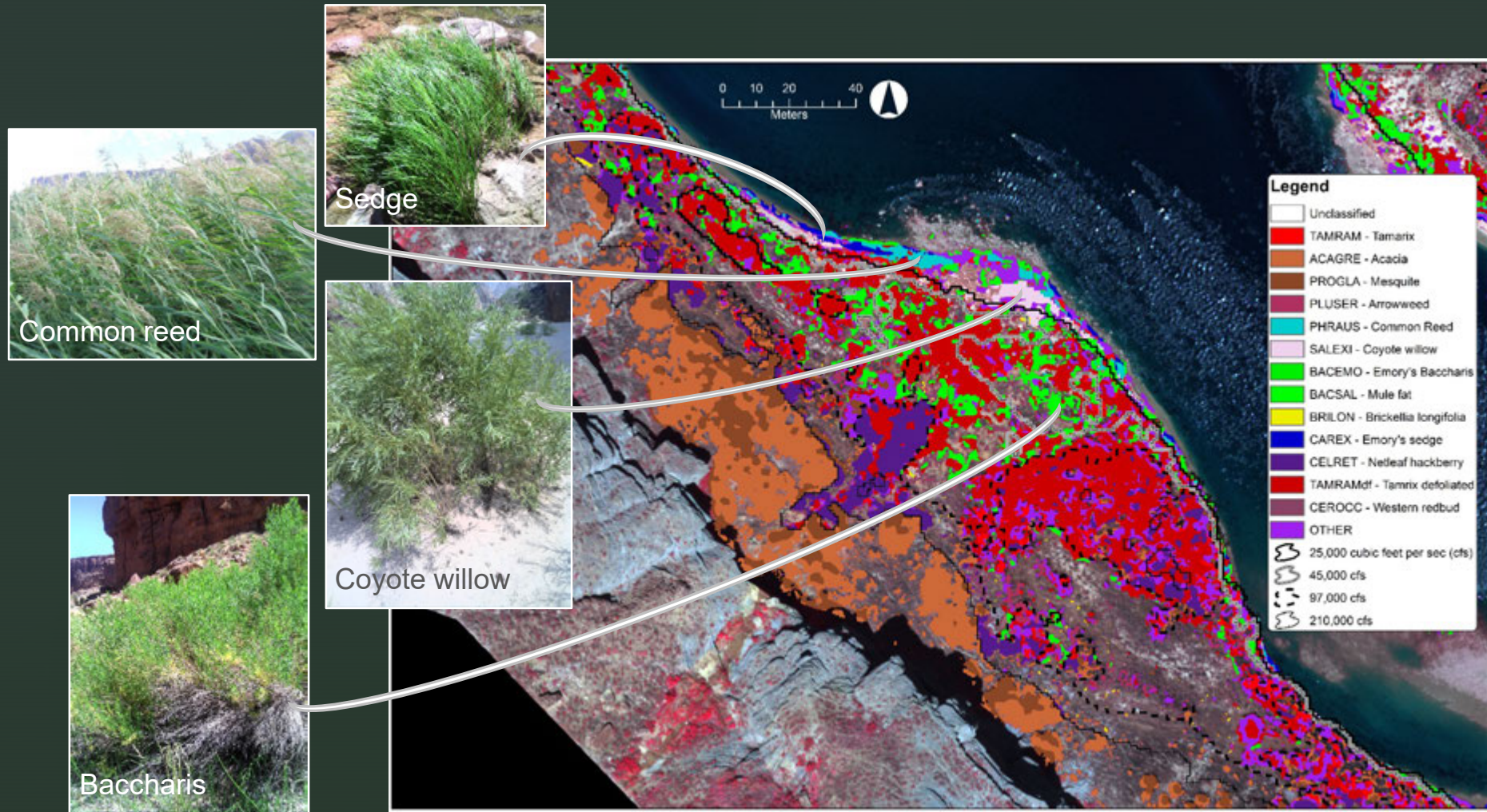
How does vegetation encroachment onto bare sand vary by species, inundation frequency and geomorphic surface?

Methods – Species-level Classification of Riparian Vegetation



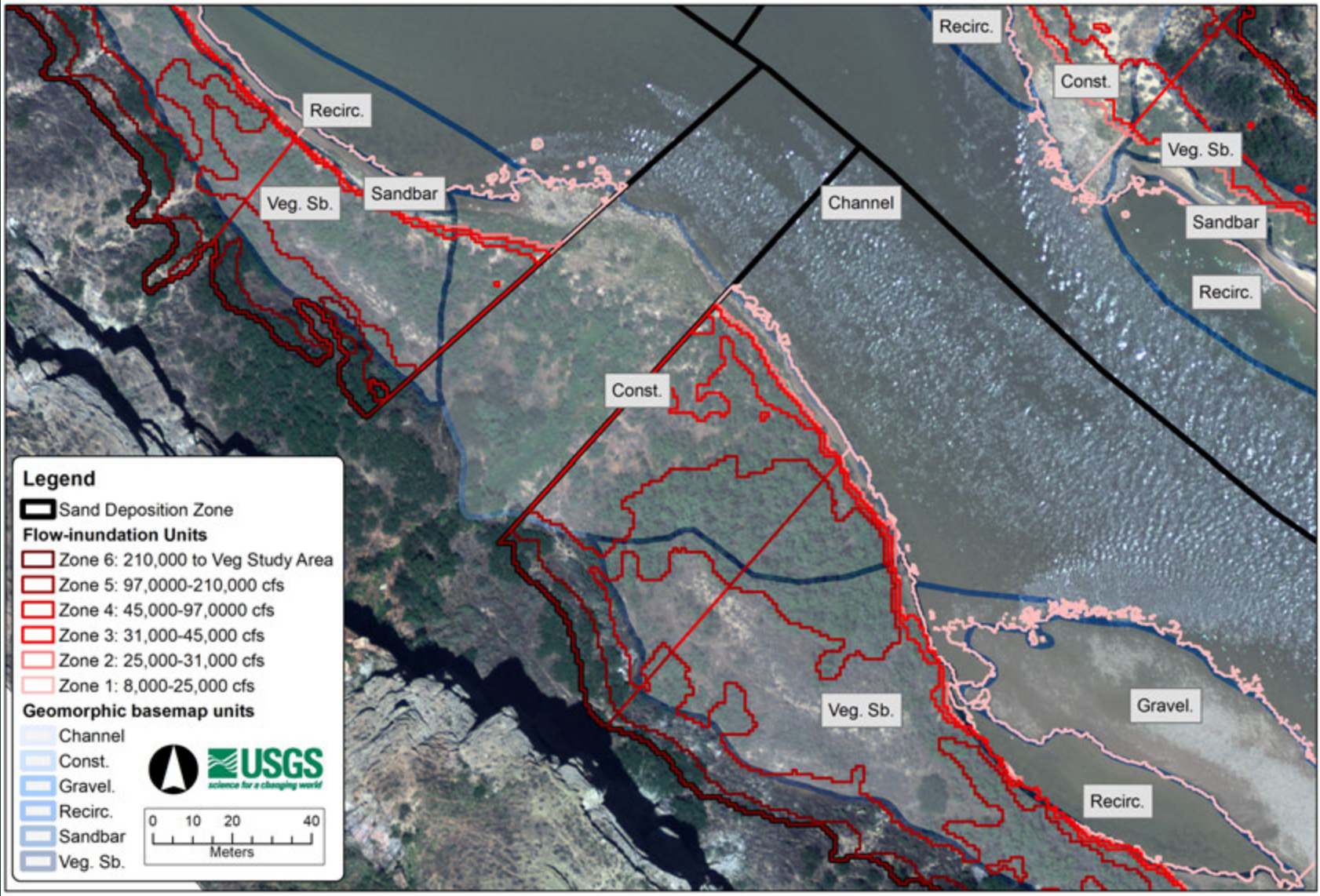
Durning et al., 2018.

Methods – Species-level Classification of Riparian Vegetation



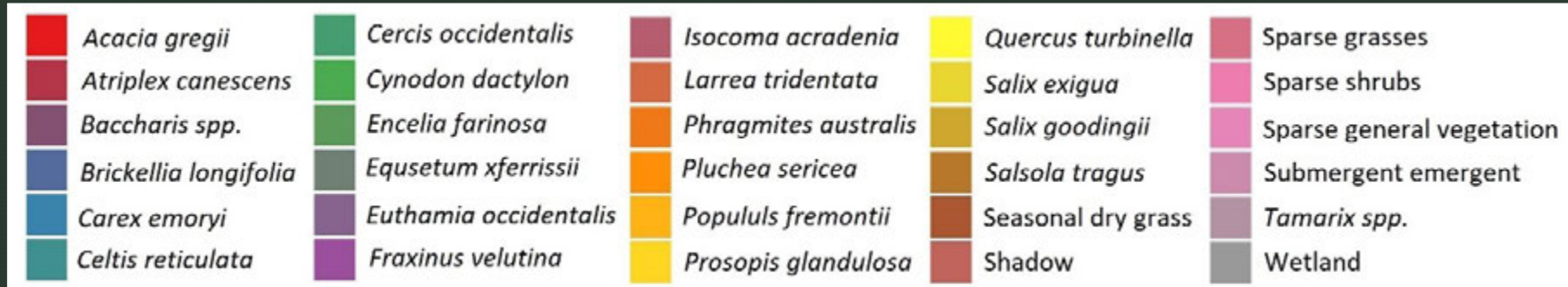
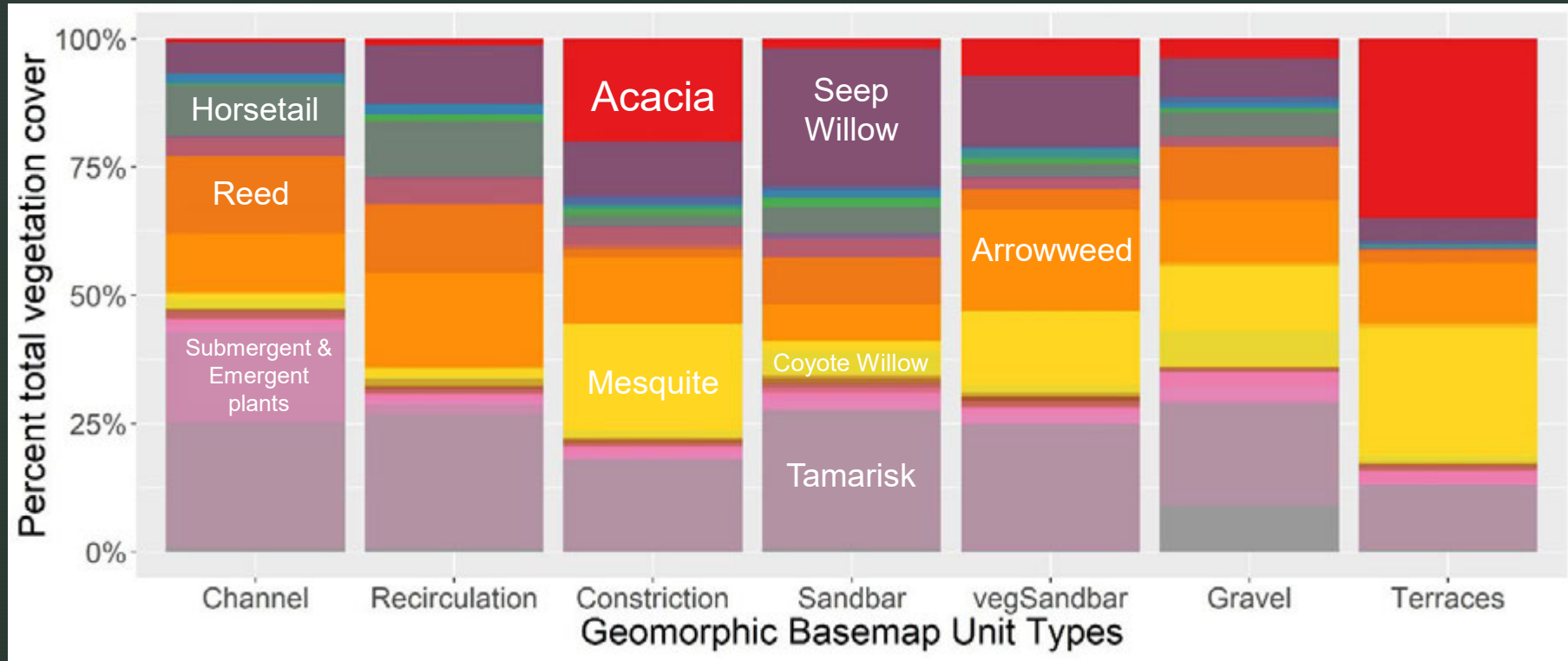
Durning et al., 2018.

Methods – Geomorphic basemap and inundation zones



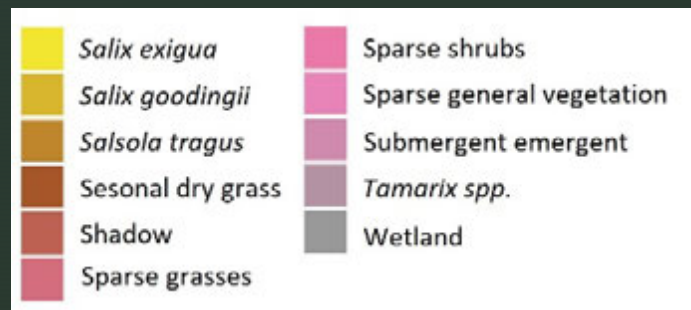
Unpublished results, do not cite

Results - Species cover on geomorphic landforms

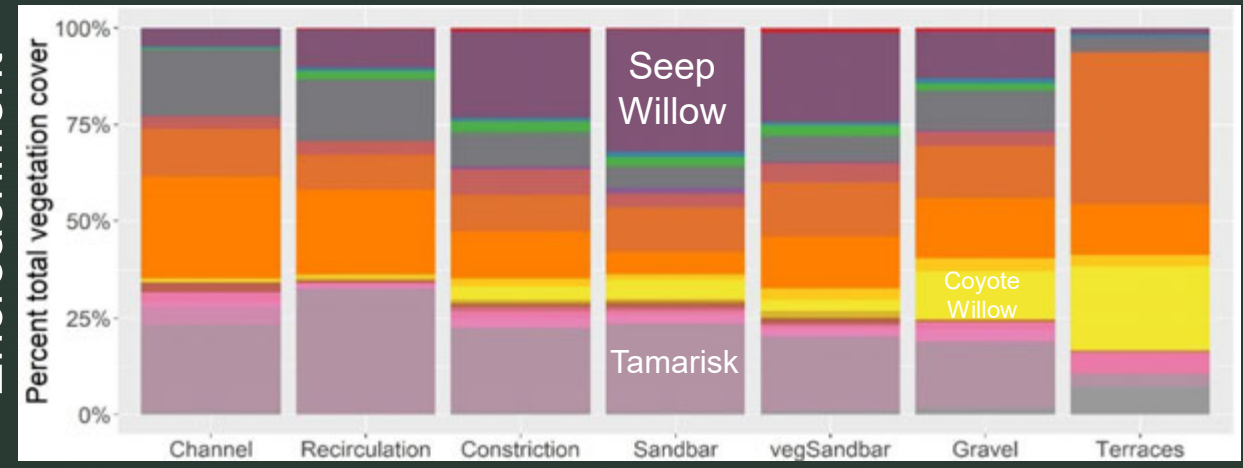


Unpublished results, do not cite

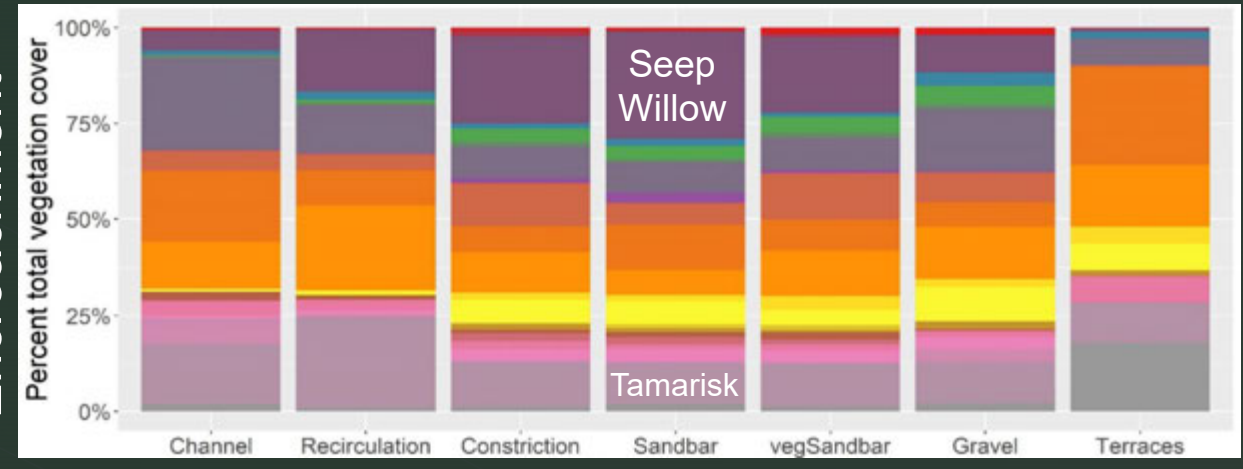
Results - Encroachment on geomorphic landforms



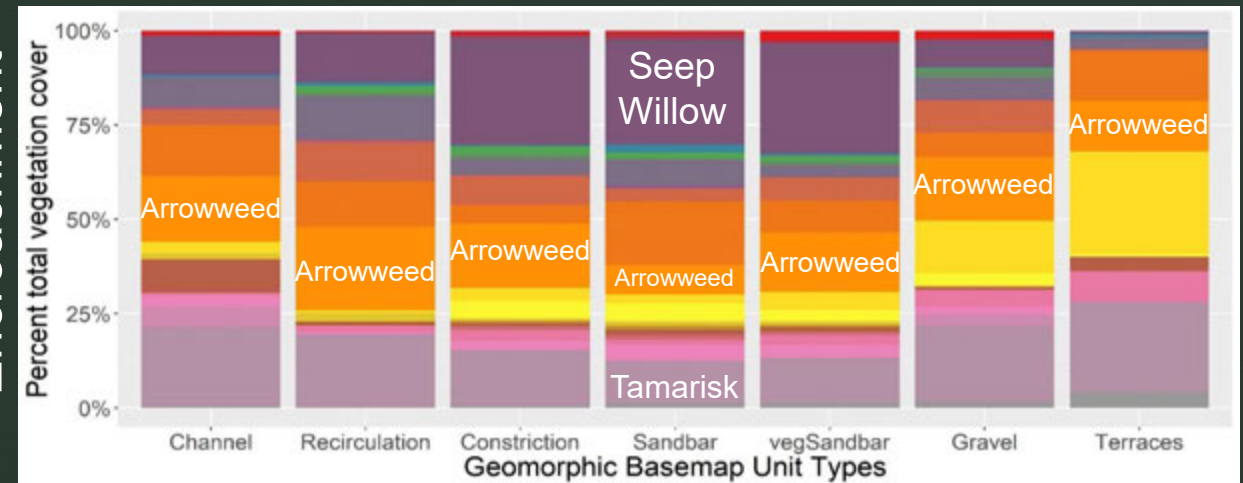
Sustained
Encroachment



Recent
Encroachment



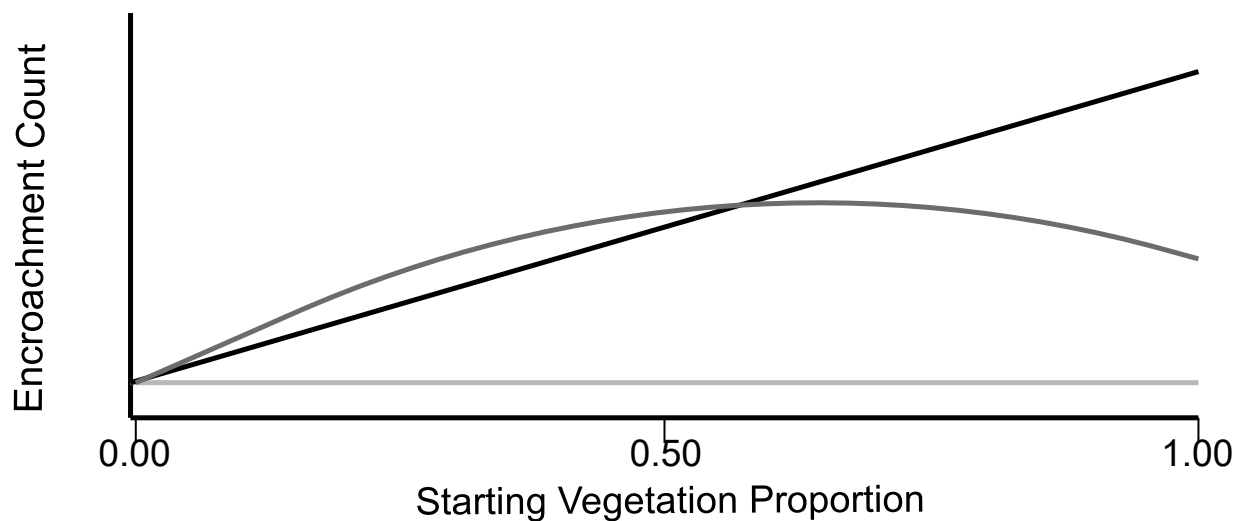
Burial and
Encroachment



Unpublished results, do not cite

Methods - Modeling encroachment behavior

- Focused on the 7 most common encroachment species
encroachment: Tamarisk, seep willow, arrowweed, coyote willow, alkali goldenbush, phragmites, & horsetail.
- Evaluated encroachment rates relative to species cover using 210 generalized linear models

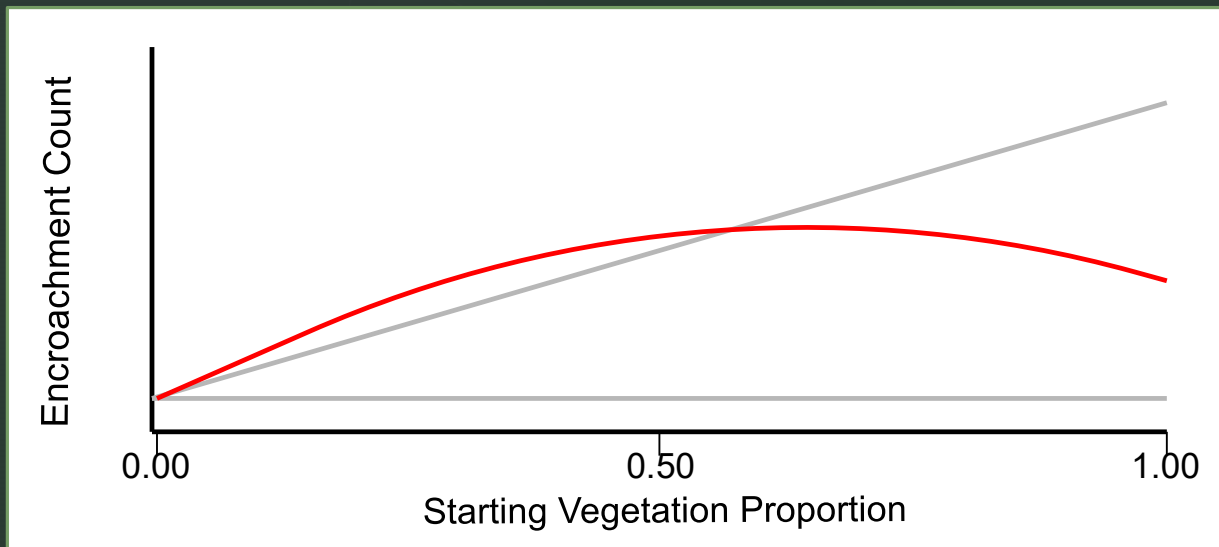


Alternative Models

- rates of encroachment increase linearly with species cover
- encroachment rates "slow" at higher cover
- encroachment rates don't change as cover increases

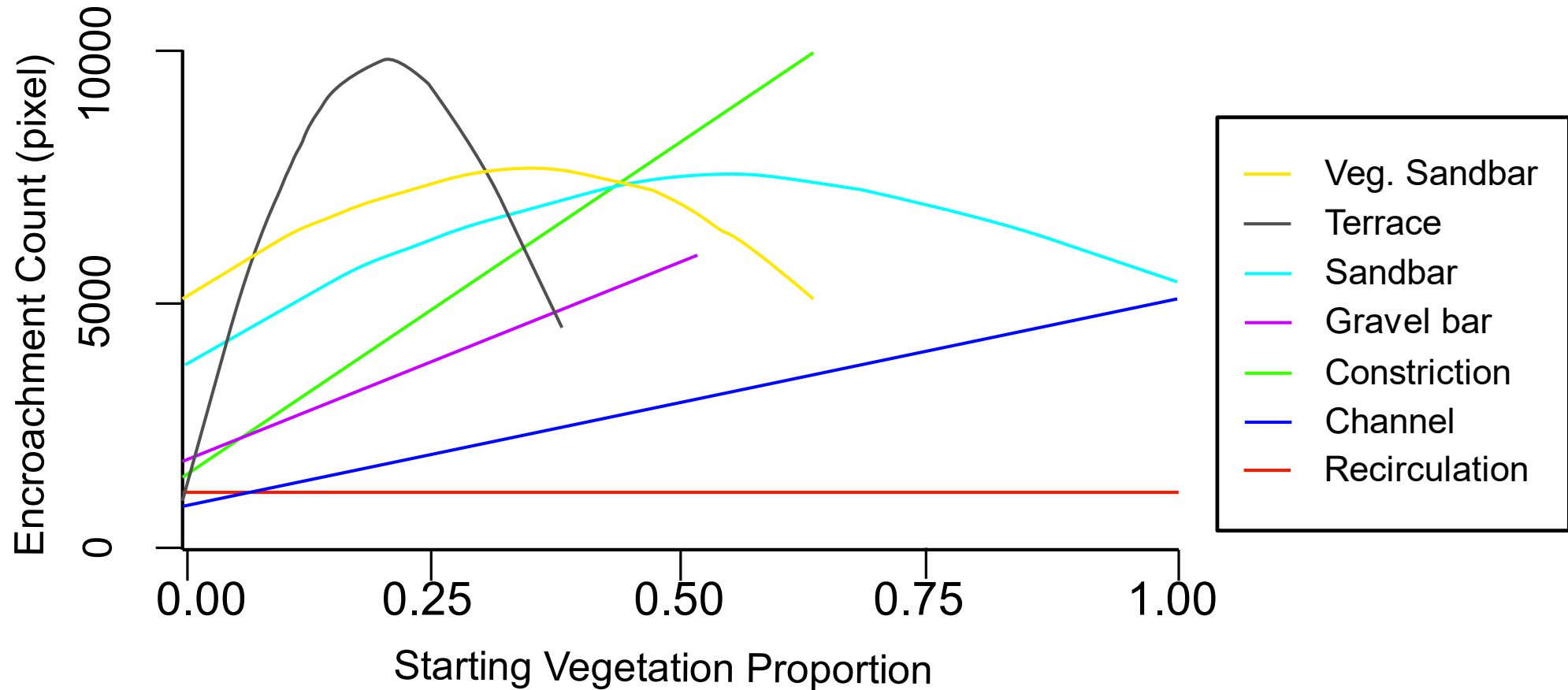
Results - Modeling encroachment behavior

- All species in all inundation zones showed a quadratic trend.



- Implies that encroachment rates slow down as vegetation cover increases to high amounts;
- for example, plants might run out of available space for encroachment at high cover,
- or, might reflect successional changes among species as encroachment and cover increase

Results - Modeling encroachment behavior



Results - Modeling encroachment behavior

Geomorphic Landforms	Intercept	Linear	Quadratic	no selection
Sandbar		1	6	
Veg. Sandbar		1	6	
Constriction		2	5	
Terrace	1	1	4	1
Gravelbar	1	3	3	
Recirculation	1	3	2	1
Channel		6	1	

- When evaluating encroachment within geomorphic landforms see that species behave differently on the different landforms
- For example:
 - Sandbars: quadratic relationships for nearly all species
 - Channel: linear relationships for nearly all species

Key Points - Changes in riparian vegetation and vegetation-sand dynamics quantified with modern overflight imagery (2002-2009-2013)



- The occurrence and expansion of riparian vegetation from 2002 to 2013 varied by species for different hydrologic zones and geomorphic landforms.
- On all geomorphic landforms and within all hydrologic zones common drivers of encroachment were seep willow, tamarisk, and arrowweed.
- Sandbars inundated and resupplied from HFE(s) indicate that several of the most common riparian species, most notably seep willow, are resilient to burial by sand.

Closing Thoughts

- Remote sensing provides a powerful way to evaluate environmental changes synoptically throughout the entire river corridor
- Overflight data are used universally in the GCDAMP
 - all projects, scientists, managers, and stakeholders
- Overflight 2021!!!

