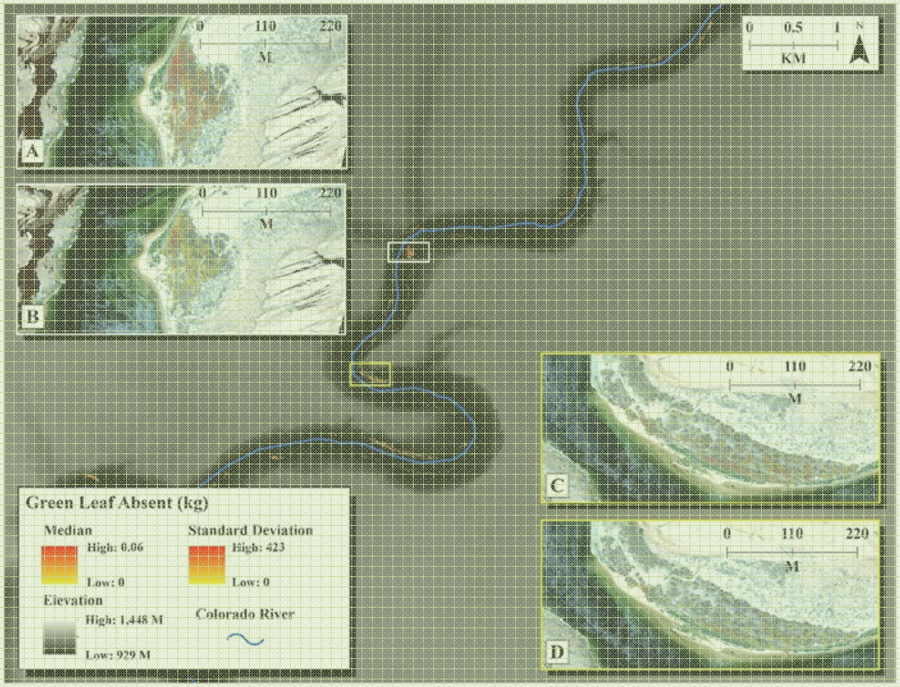
Riparian vegetation monitoring with remote sensing

Annual Reporting Meeting, January 26, 2015

Joel Sankey (USGS) jsankey@usgs.gov,
Laura Cagney (USGS), Temuulen Sankey (NAU), Ashton Bedford (NPS), Rene Horne (NAU),
Phil Davis (USGS), Joshua Caster (USGS), Paul Grams (USGS), Barbara Ralston (USGS)



Talk Outline

- 2013 Overflight image mosaic
- Long-term riparian vegetation changes 1964 to 2013
- Remote sensing of tamarisk changes and tamarisk beetle impacts 2009 to 2013

2013 Overflight Image Mosaic

Timeline:

- Acquisition – Memorial Day weekend 2013
- Image mosaic complete – December 2015
- Image mosaic dataset publication – 2016
- Riparian vegetation mapping and other analyses of data mosaic for Triennial Workplan studies – Fiscal years 2015, 2016, & 2017

2013 Overflight Image Mosaic

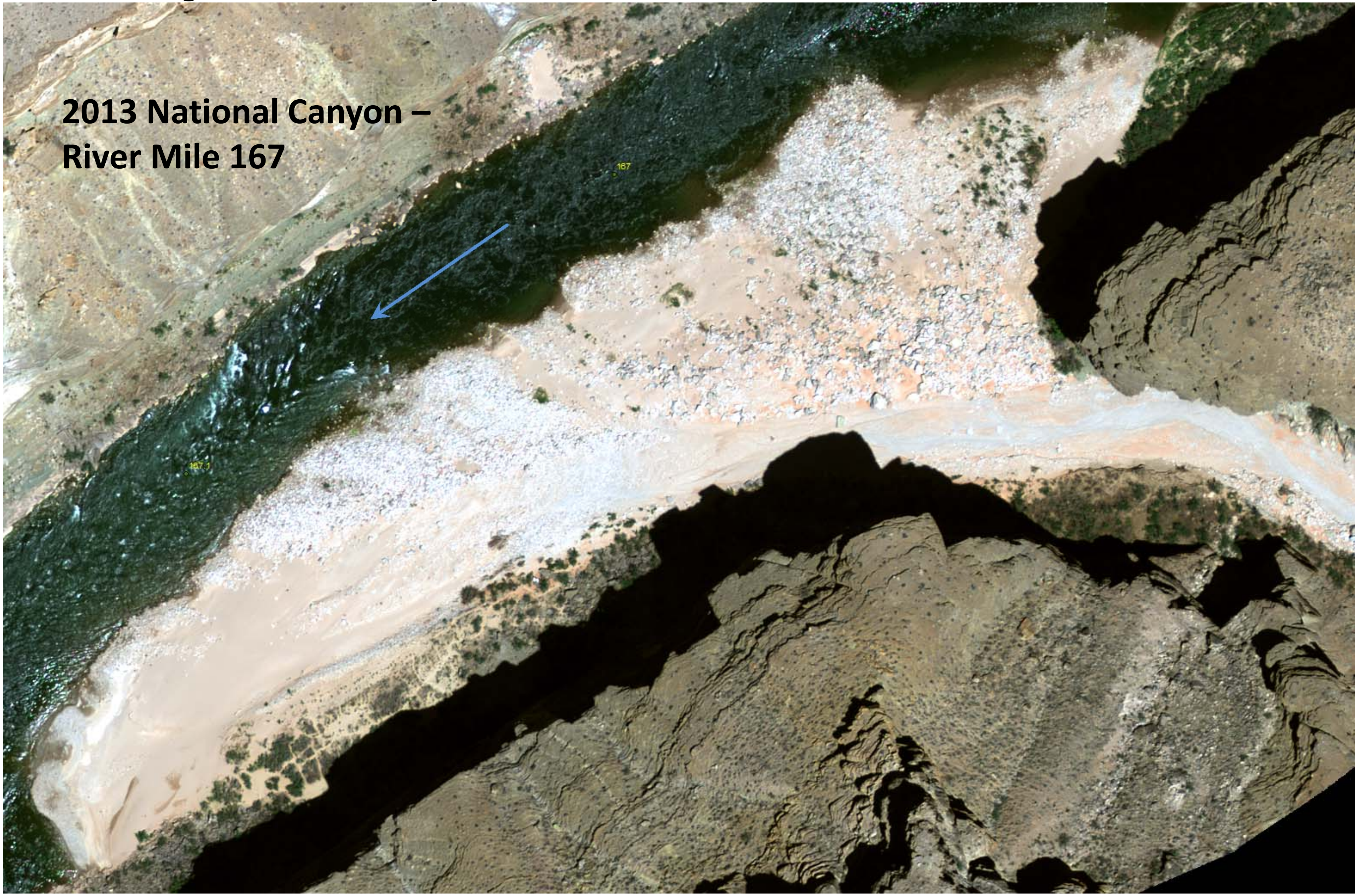
Details:

- 4 Image Bands – Blue, Green, Red, Near Infrared
- Pixel Resolution – 0.20 meters
- 215 GB un-compressed storage size
- 144 Image Scenes cover the Colorado River from Lake Powell (15.8 miles upstream of Lees Ferry) to Lake Mead (281.1 miles downstream of Lees Ferry)
  - 270 river miles and 285.7 km^2 of river/riparian/upland area
- Registered to 2009 overflight image mosaic for change detection
  - Error (horizontal positional accuracy) is < 30 cm

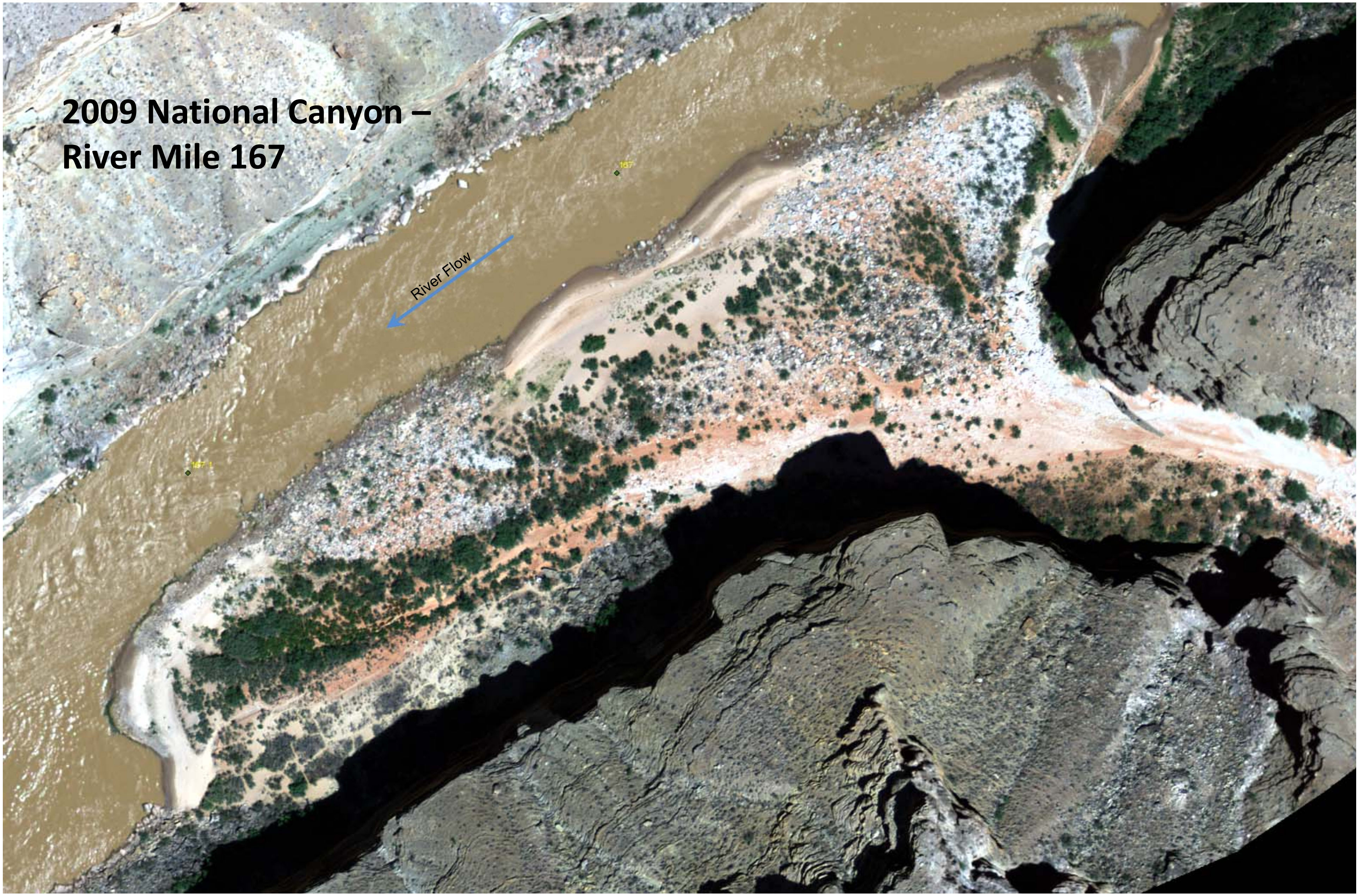
2013 Image Mosaic Examples

2013 Image Mosaic Examples

2013 Image Mosaic Examples



2009



2013 Image Mosaic Examples

2009

2013 Image Mosaic Examples

2009

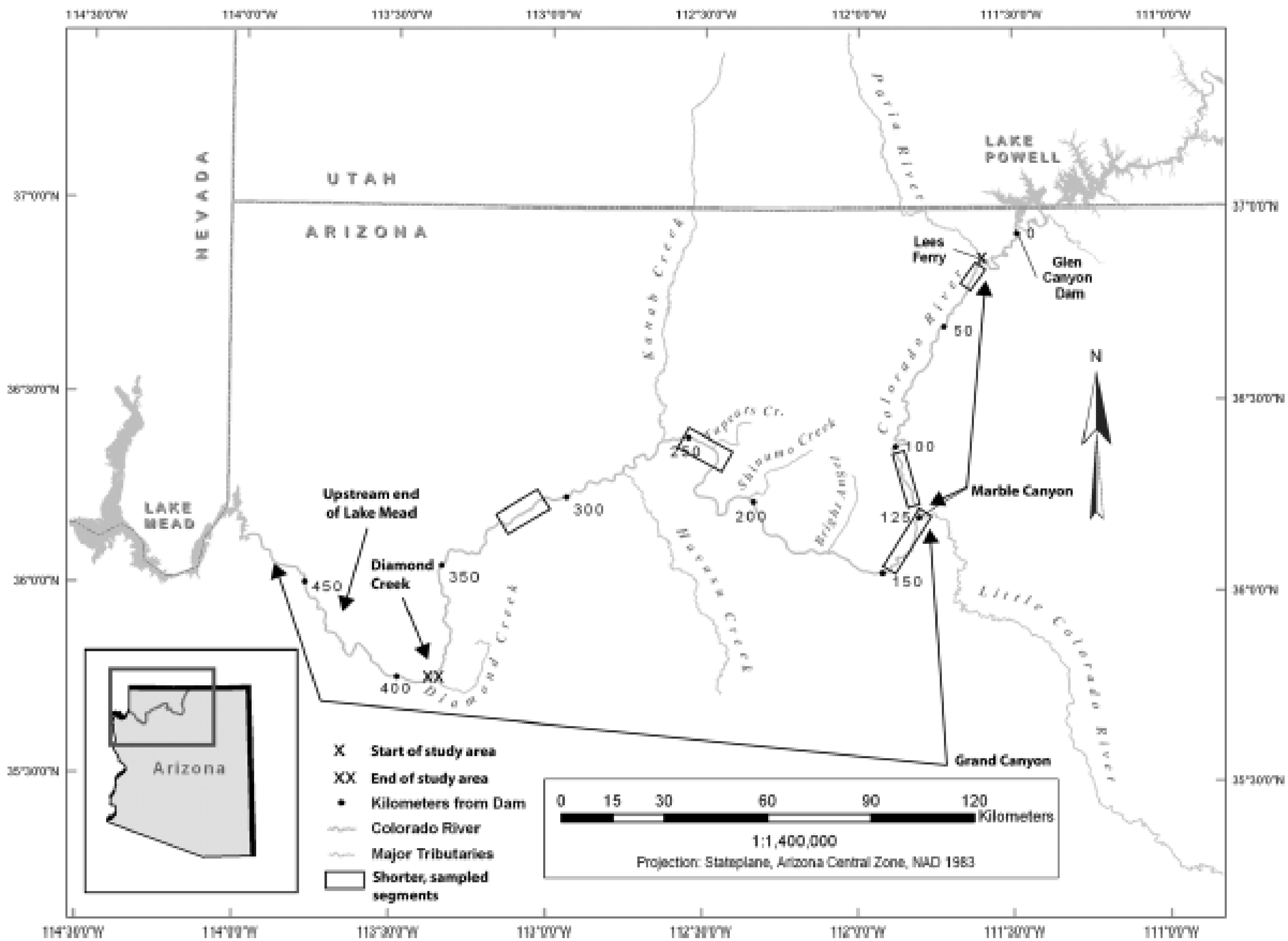
Talk Outline

- 2013 Overflight Image Mosaic
- Long-term riparian vegetation changes 1964 to 2013
- Remote sensing of tamarisk changes and tamarisk beetle impacts 2009 to 2013

Monitoring long-term riparian vegetation changes

- In FY2015 published long-term riparian vegetation changes from analysis of imagery from 1964 to 2009
  - Sankey, J. B., B. E. Ralston, P. E. Grams, J. C. Schmidt, and L. E. Cagney (2015), Riparian vegetation, Colorado River, and climate: Five decades of spatiotemporal dynamics in the Grand Canyon with river regulation, *Journal of Geophysical Reseach Biogeosciences*, 120, 1532–1547, doi:10.1002/2015JG002991.
- In this presentation, I'll extend the analysis of changes from 1964 to 2013

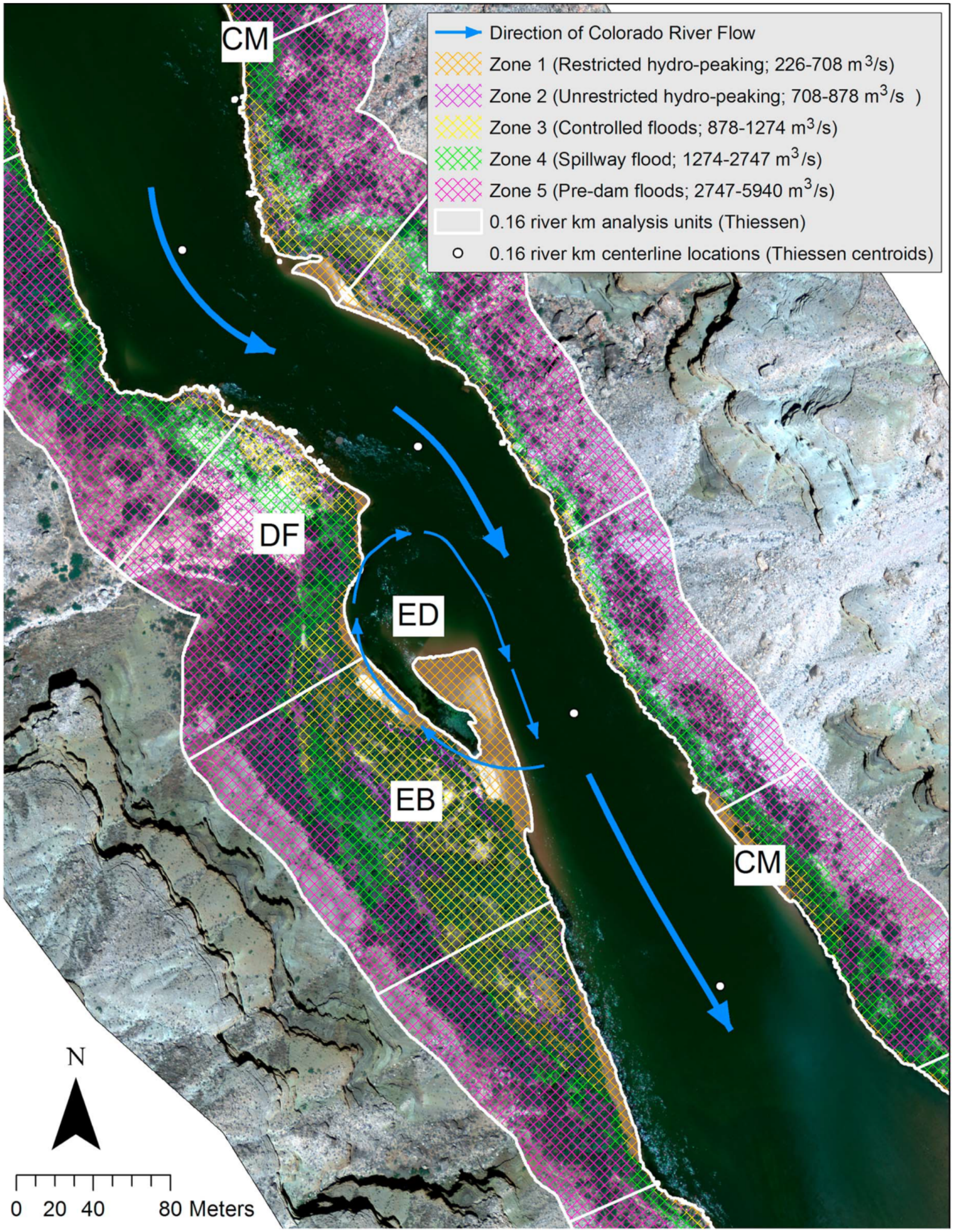
Long-term riparian vegetation changes
- methods

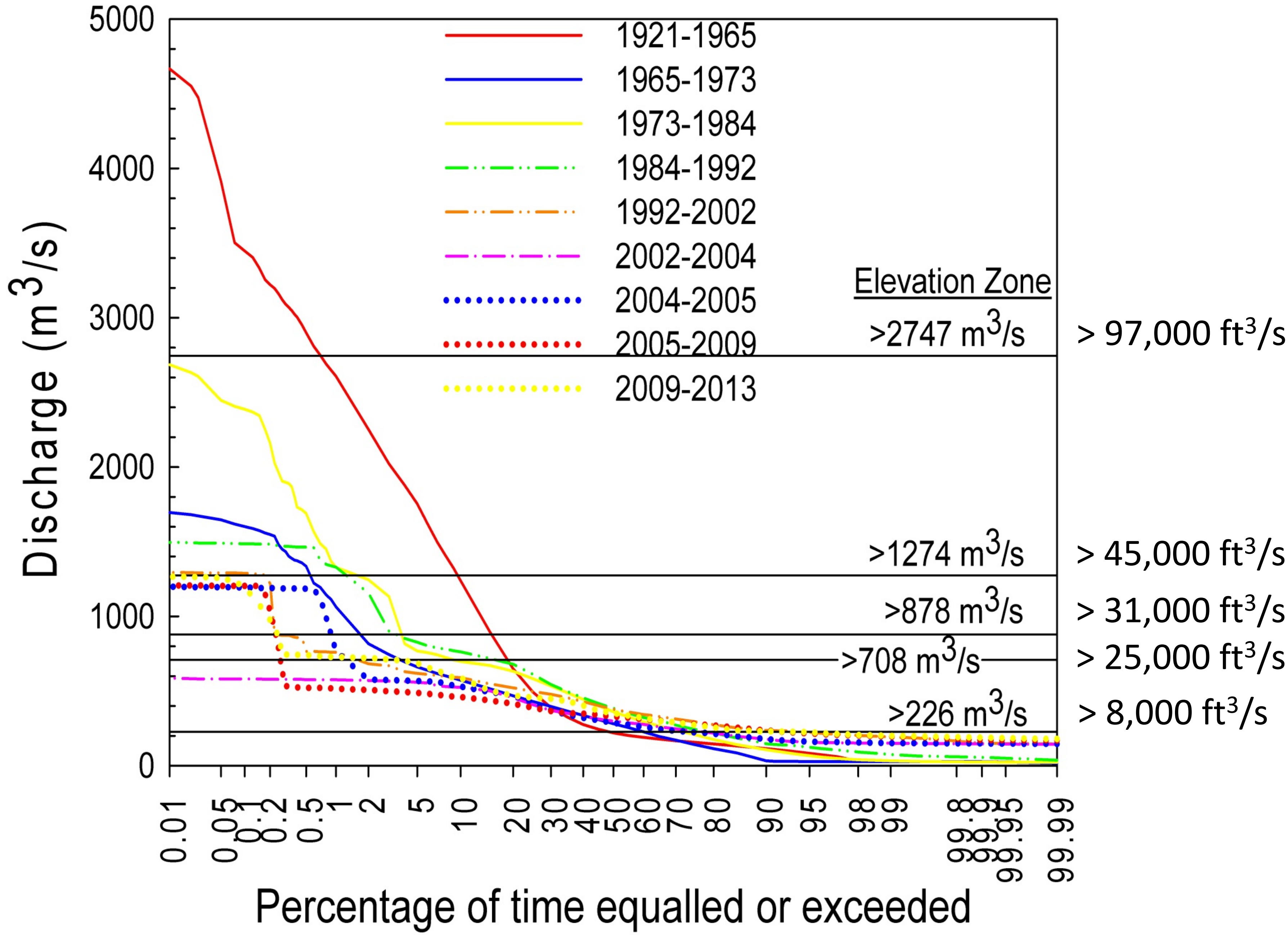


Long-term riparian vegetation changes

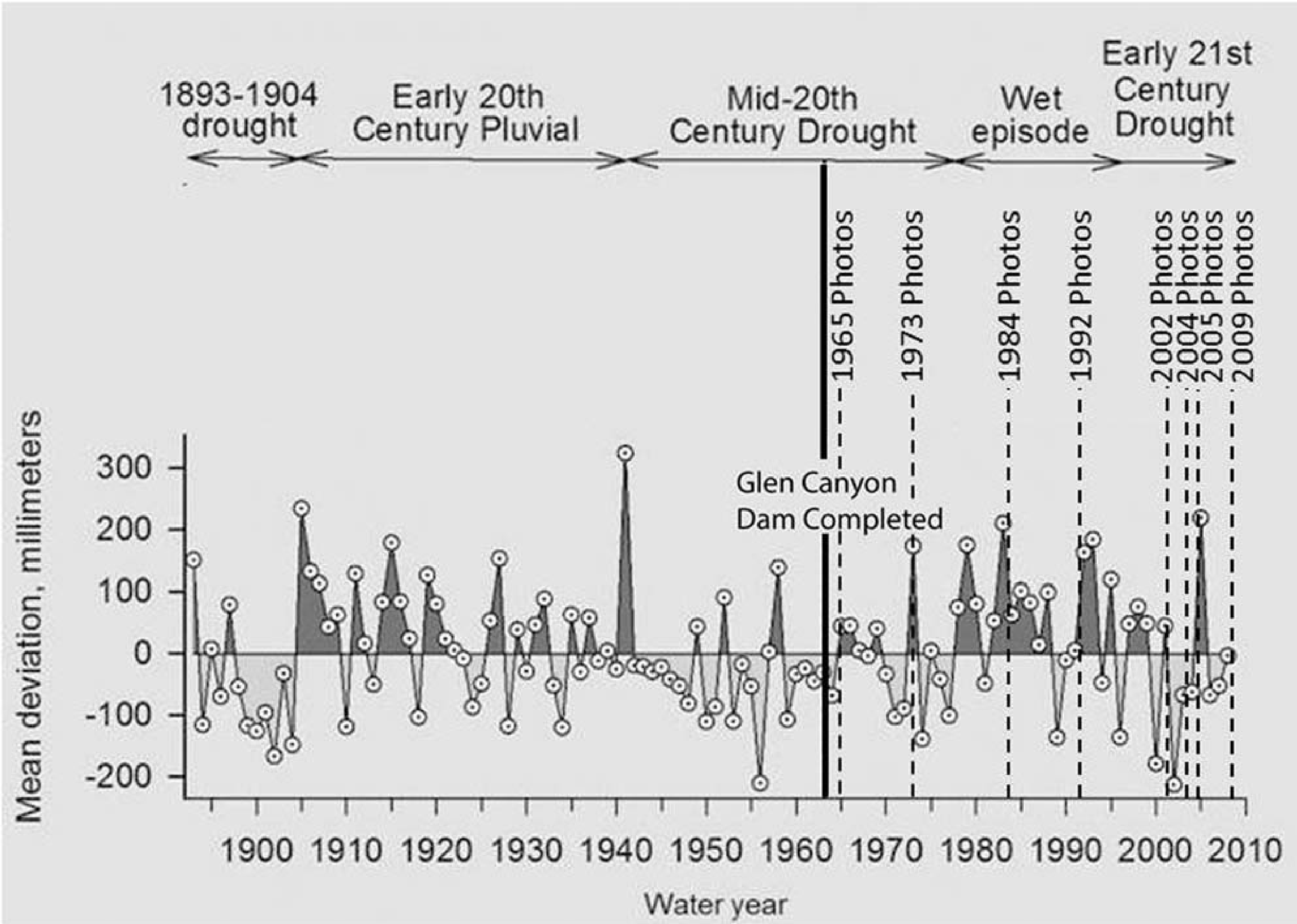
- methods

- Analyze by 5 “zones” of the historical riparian area inundated by discharges:
  - 8,000 to 25,000 ft^3/s
  - 25,000 to 31,000 ft^3/s
  - 31,000 to 45,000 ft^3/s
  - 45,000 to 97,000 ft^3/s
  - 97,000 to 210,000 ft^3/s





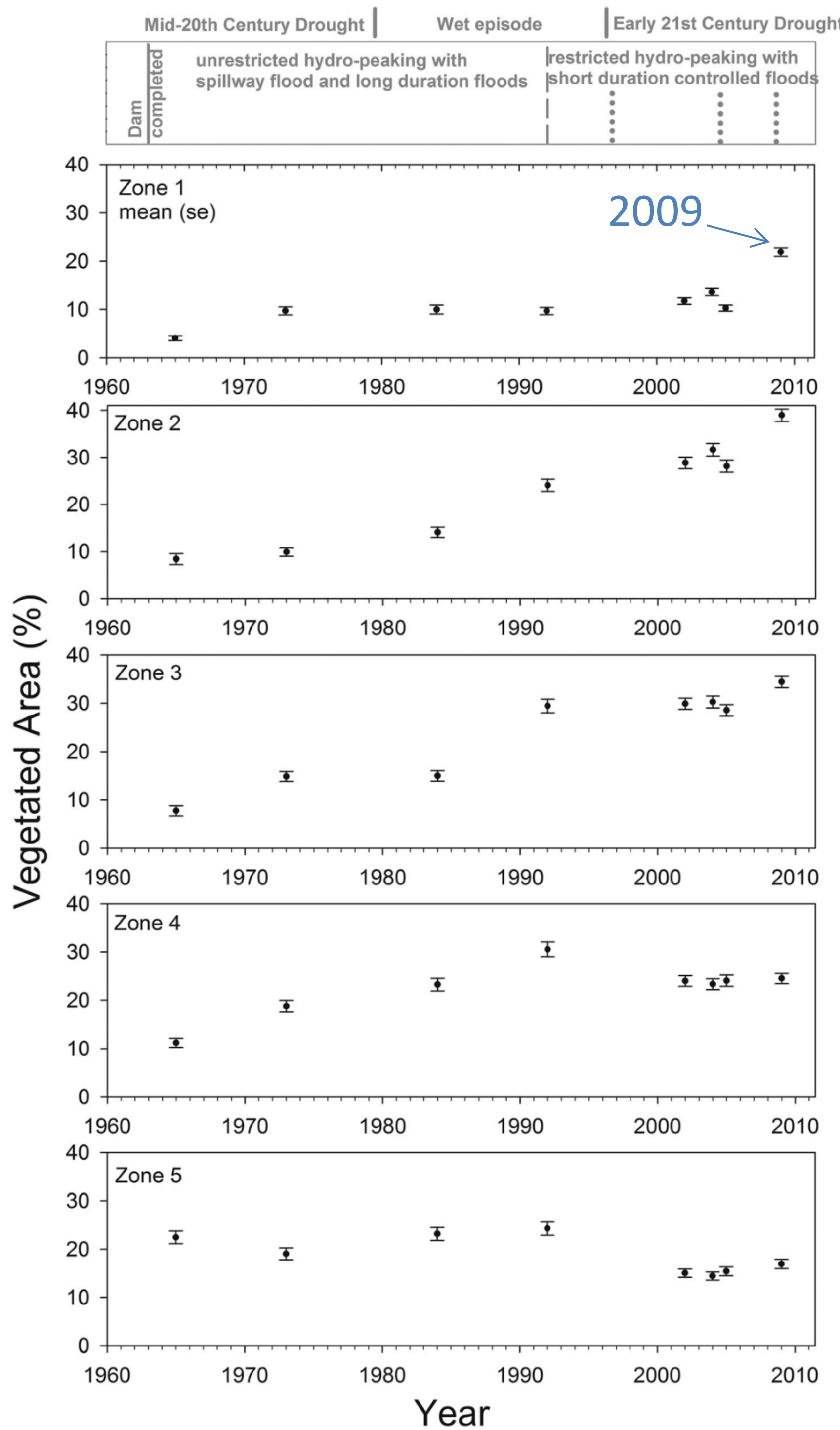
Discharge (m3/s)
Percentage of time equalled or exceeded
1921-1965
1965-1973
1973-1984
1984-1992
1992-2002
2002-2004
2004-2005
2005-2009
2009-2013
Elevation Zone
>2747 m3/s
>1274 m3/s
>878 m3/s
>708 m3/s
>226 m3/s
> 97,000 ft3/s
> 45,000 ft3/s
> 31,000 ft3/s
> 25,000 ft3/s
> 8,000 ft3/s



R. Hereford (USGS)

Long-term riparian vegetation changes 1964 to 2009

Sankey et al., 2015



Zone 1: 8,000 to 25,000 ft^3/s

Zone 2: 25,000 to 31,000 ft^3/s

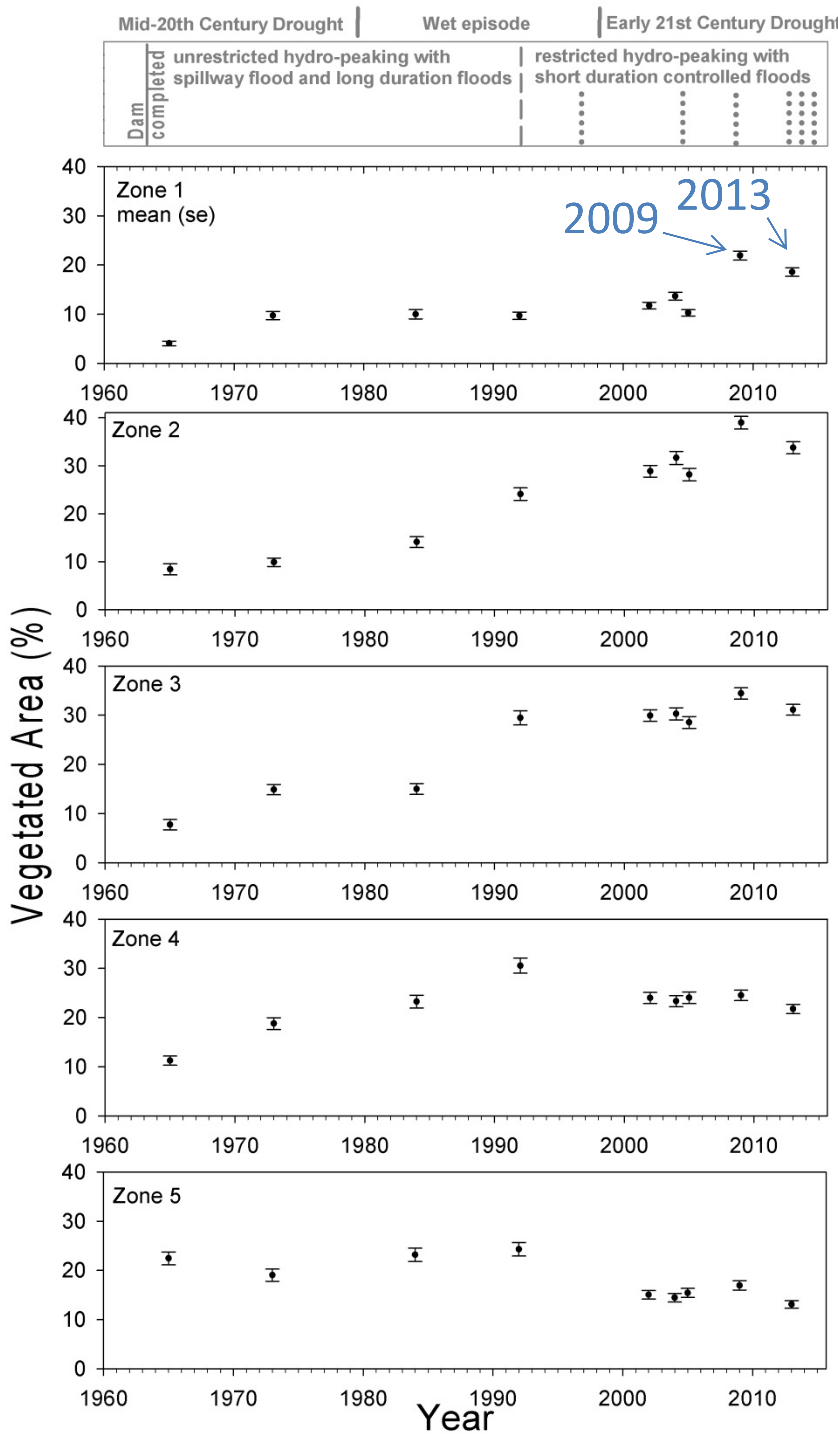
Zone 3: 31,000 to 45,000 ft^3/s

Zone 4: 45,000 to 97,000 ft^3/s

Zone 5: 97,000 to 210,000 ft^3/s

Long-term riparian vegetation changes 1964 to 2013

- results



Zone 1: 8,000 to 25,000 ft^3/s

Zone 2: 25,000 to 31,000 ft^3/s

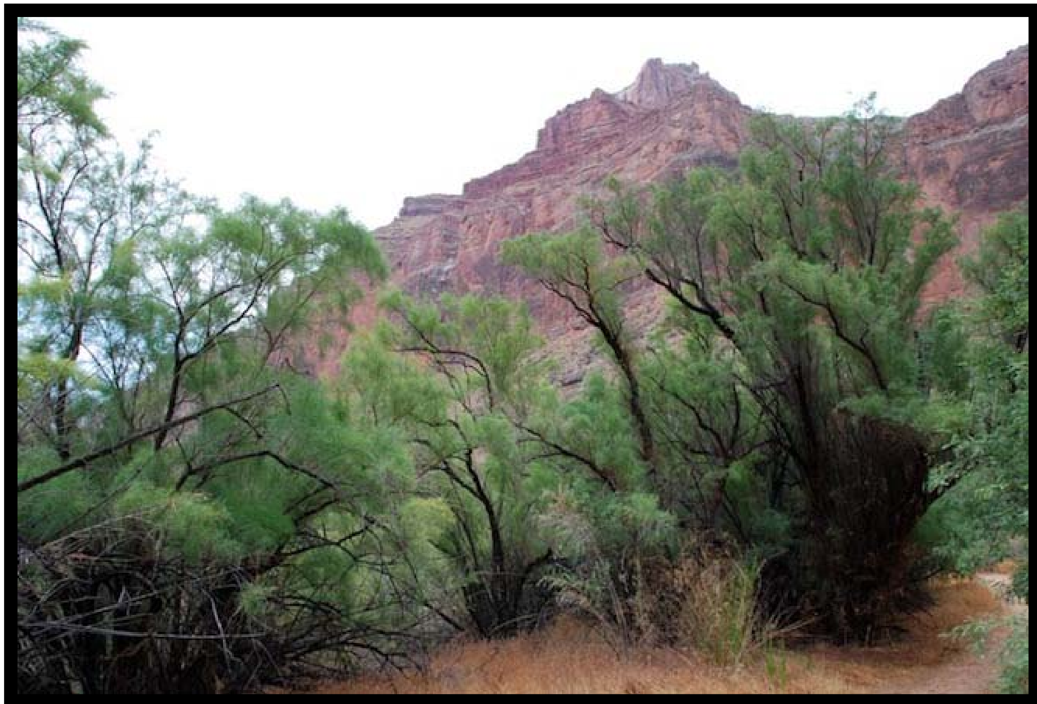
Zone 3: 31,000 to 45,000 ft^3/s

Zone 4: 45,000 to 97,000 ft^3/s

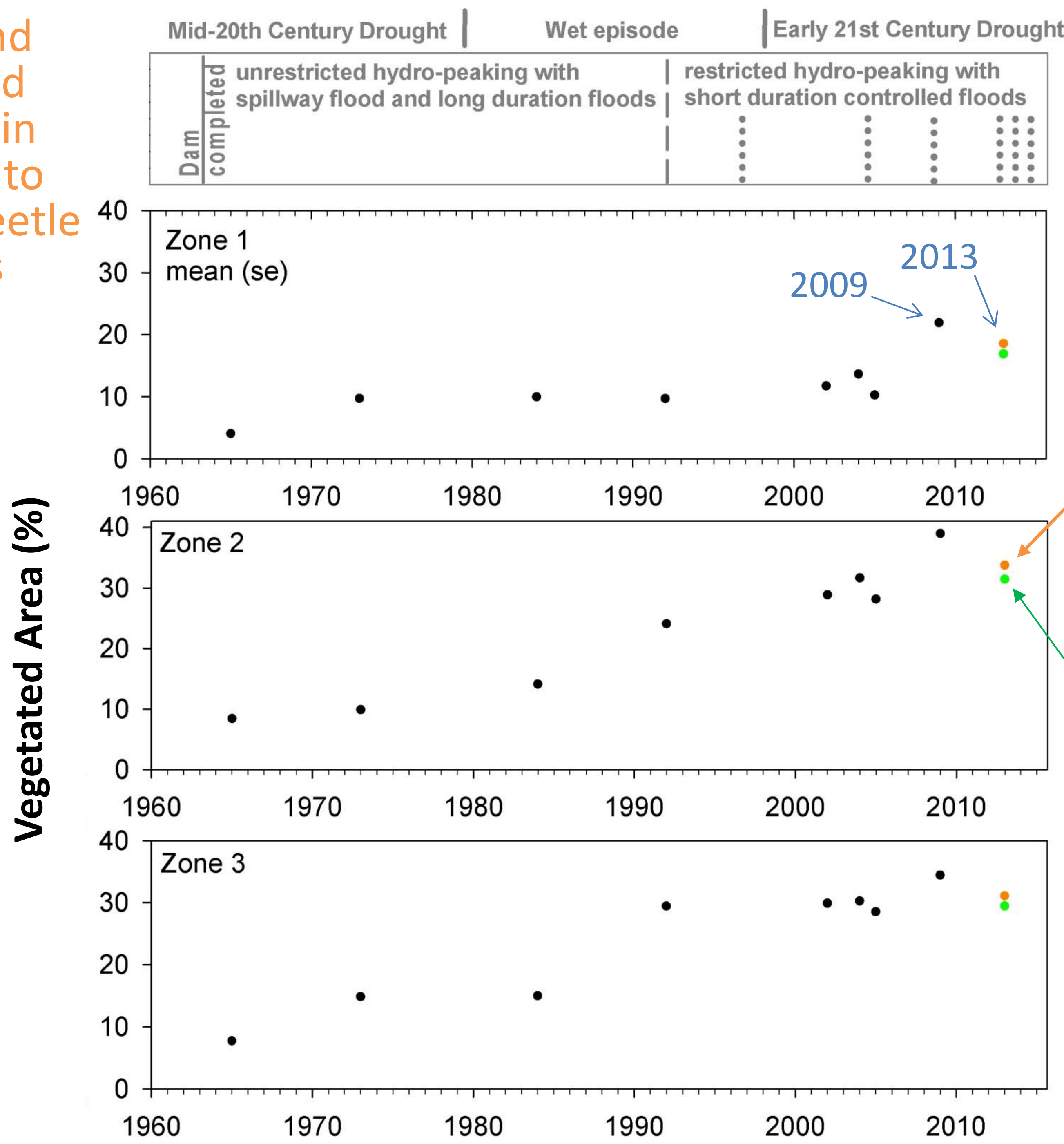
Zone 5: 97,000 to 210,000 ft^3/s

Monitoring long-term riparian vegetation changes - summary

- No change or small decrease in vegetated area in all zones from 2009 to 2013
- However, long-term trend is vegetation increase in zones inundated by discharges less than 45,000 ft^3/s
- 2013 data doesn't alter statistical importance of predictors (Sankey et al., 2015)
  - Vegetation decoupled from river hydrology in zones inundated by discharges > 97,000 and possibly > 45,000 ft^3/s; vegetated area decreases due to rainfall drought
  - Vegetated area increases in zones below 45,000 ft^3/s with (i) elevated baseflows that make more water available to plant roots, and (ii) lower frequency and magnitude of peak flows/floods
- How do we explain the 2009 to 2013 changes in zones below 45,000 CFS? HFE deposition and shoreline changes? Rainfall drought?




Brown and defoliated Tamarisk in 2013 due to Tamarisk Beetle impacts



Defoliated Tamarisk + Total (Green) Vegetation in 2013

Total (Green) Vegetation in 2013

Talk Outline

- 2013 Overflight Image Mosaic
- Long-term riparian vegetation changes 1964 to 2013
- Remote sensing of tamarisk changes and tamarisk beetle impacts 2009 to 2013

Tamarisk
(*Tamarix spp.)*

- History
  - In the US since 1800s
  - Decorative species
  - Invasive species
- Biology
  - Salt cedar
  - Tap-root
- Management
  - Dominant in the Southwest
  - Spread rate: 20 km/year
  - Expensive mechanical control

Tamarisk Beetle (*Diorhabda carinulata*)

- Biology
  - Natural predator of the shrub
  - Eats the leaves
  - Tamarisk defoliation
- History of Introduction
  - Asia
  - Texas- early 2000s
  - Utah- 2005
- Found in Grand Canyon NP and Glen Canyon NRA in 2009

Objectives and Methods

- Map area and biomass of green and defoliated tamarisk – new remote sensing for monitoring tamarisk and beetle impacts
  - Change detection of multispectral imagery
    - What percent of green tamarisk in 2009 was defoliated in 2013?
    - Glen Canyon, Kanab Creek, National Canyon (3 reaches)
    - Ashton Bedford, M.S. Thesis NAU, Defending Spring 2016
  - Fusion of multispectral imagery with lidar data
    - Quantify and map spatial distribution of biomass of total, green-leaf, and defoliated leaf (litter) tamarisk in 2013
    - Glen Canyon (one reach)
    - Sankey, TT, Sankey, JB, Bedford, A, Horne, R, in review, Remote sensing of tamarisk biomass, insect herbivory, and defoliation: novel methods and applications in the Grand Canyon region, Arizona, USA. *Photogrammetric Engineering and Remote Sensing*

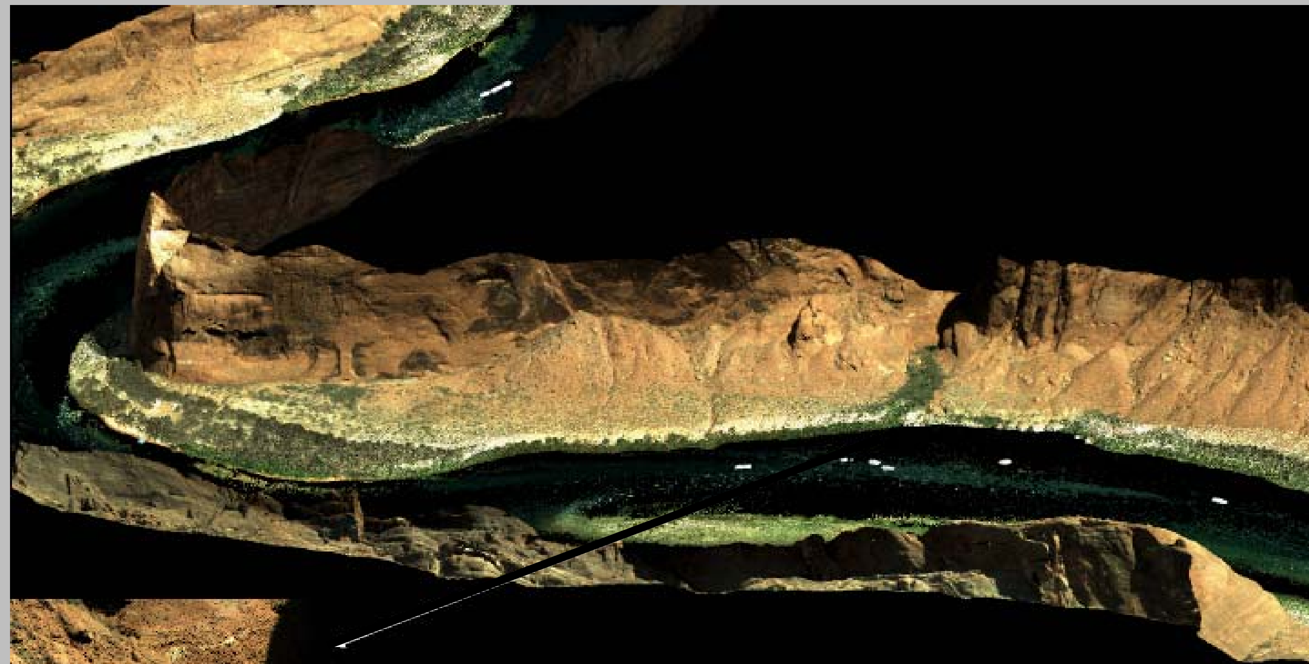
What percent of green tamarisk in 2009 was defoliated in 2013?

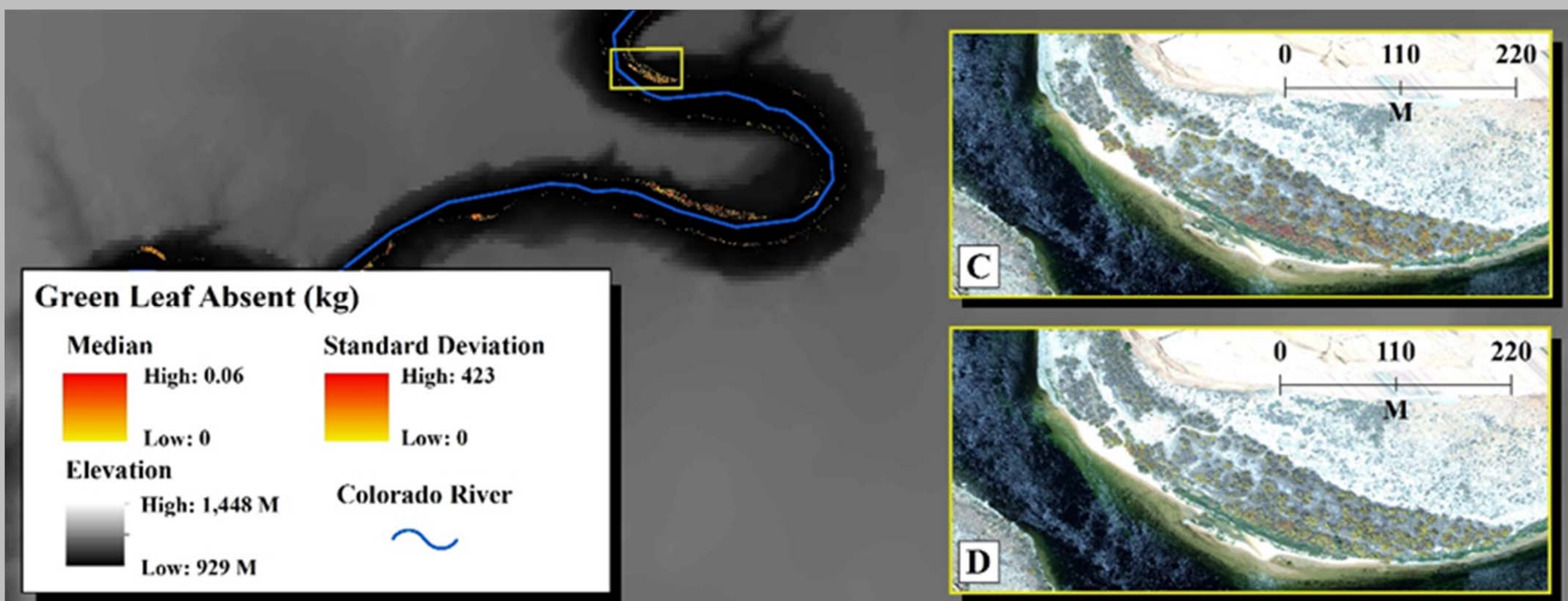
(Bedford, M.S. Thesis)

Reach	Percent of Tamarisk Vegetation	Total Area (m^2)
Glen Canyon (Glen Canyon Dam to Lees Ferry)		
Green	76 %	20,005
Defoliated	24 %	9,053
Kanab (RM 134.6 to 155.7)		
Green	77 %	4,047
Defoliated	23 %	1,095
National (RM 158.6 to 180.5)		
Green	88 %	21,727
Defoliated	12 %	2,893

Spatial distribution of tamarisk biomass

(Sankey et al., manuscript in review)





Remote sensing of tamarisk and defoliation - summary

- Biomass maps in Glen Canyon
  - 8.68 kg/m^2 mean total above ground tamarisk biomass
  - 0.52 kg/m^2 mean total above ground tamarisk “green leaf absent” (i.e., litter) biomass
    - 4,300 kg of tamarisk leaf biomass potentially shed within the riparian area of Glen Canyon
- Practical utility of the maps and data:
  - Future monitoring of defoliation and beetle impacts
  - Planning for vegetation management
    - Identify locations of widespread defoliation for vegetation removal
    - Estimate biomass that would need to be removed mechanically, or consumed (fuel) by prescribed fire
    - Tamarisk and defoliation relative to inundating flows

Thanks for listening!

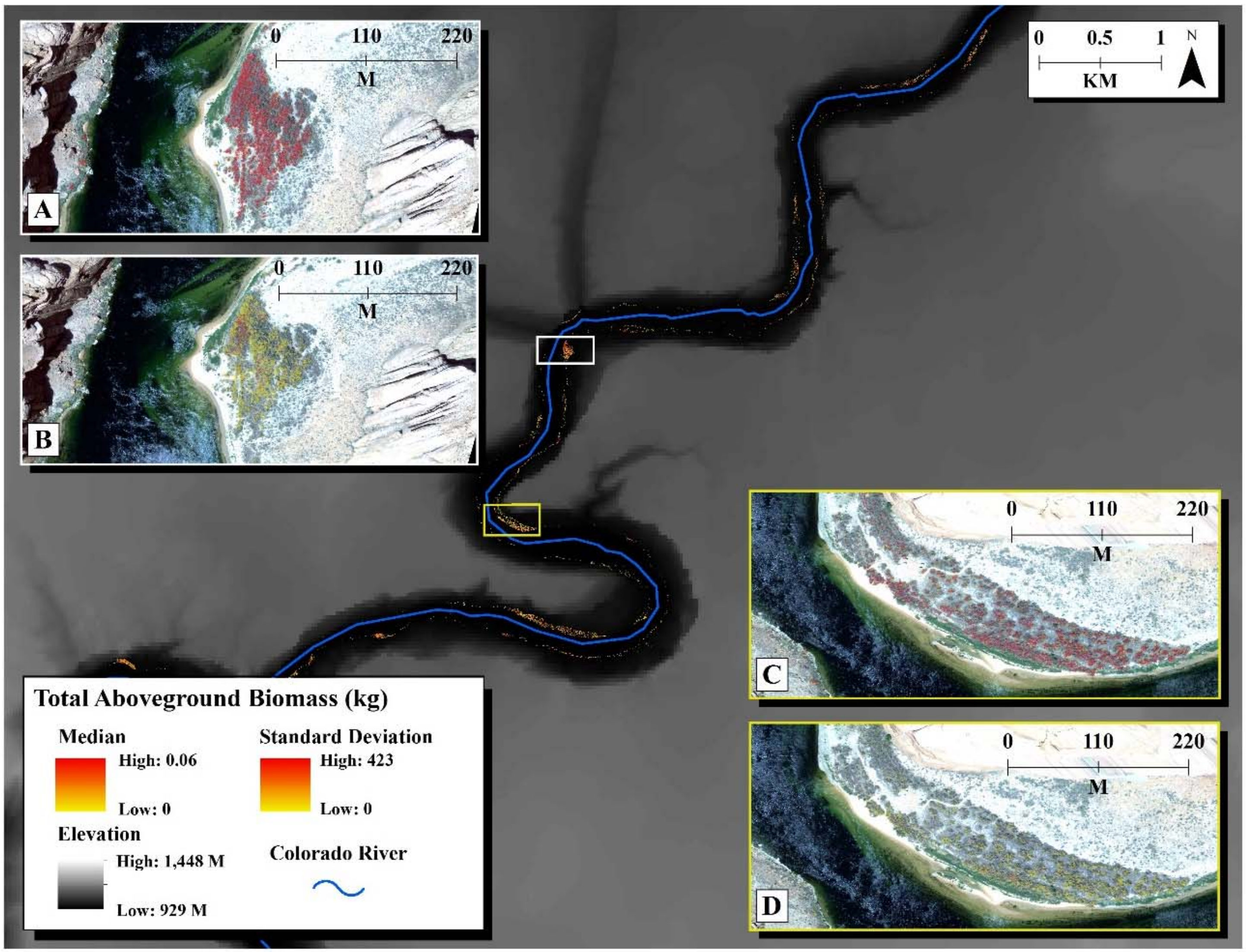
Acknowledgements

Summary

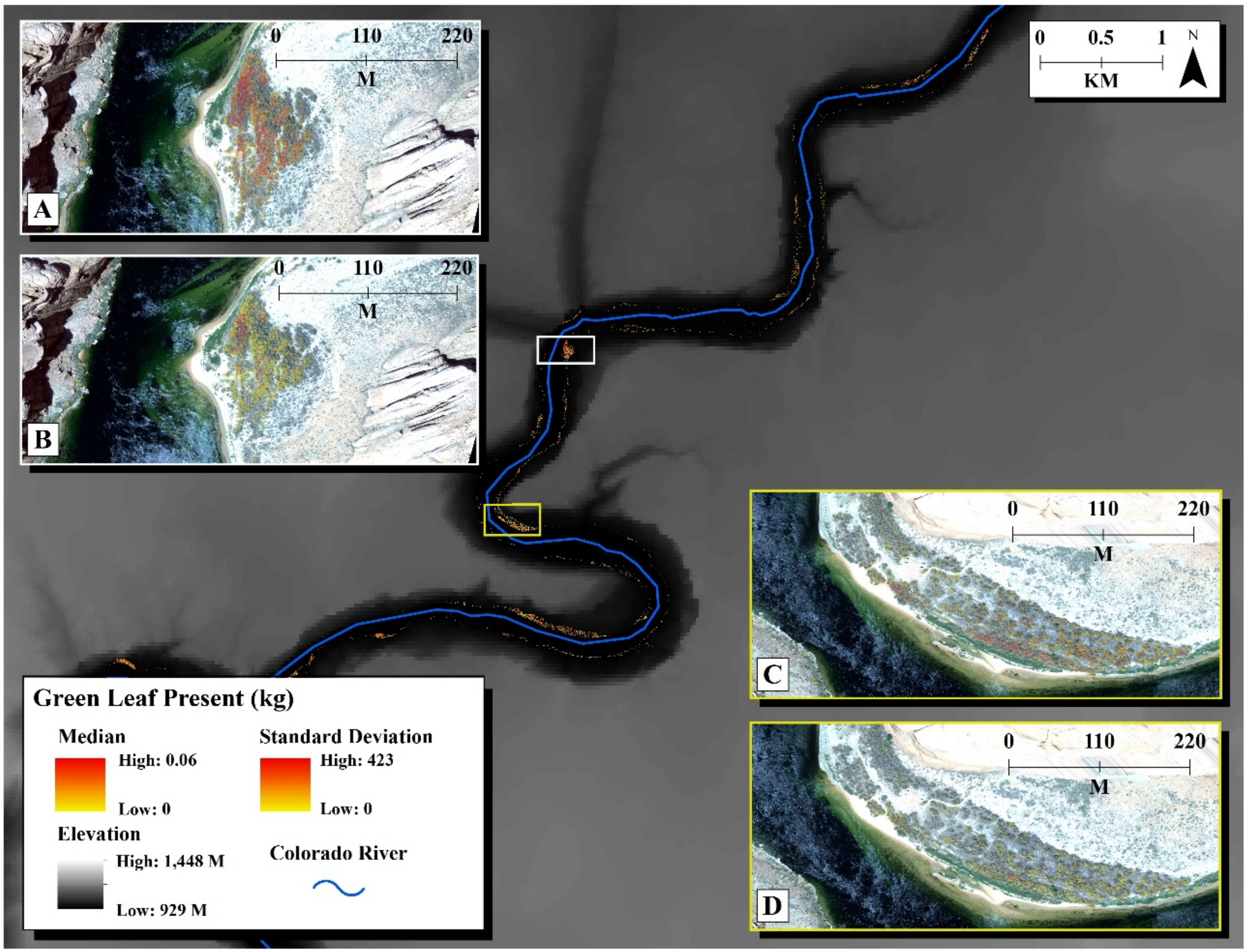
- 8.68 kg/m^2 : mean total above ground tamarisk biomass
- 0.52 kg/m^2 : mean total above ground tamarisk "green leaf absent" (i.e., litter) biomass
  - 4,300 kg : potential tamarisk leaf biomass potentially shed over the riparian zone within Glen Canyon
- Practical utility of the maps and data:
  - Planning for vegetation management
    - Identify locations of high degree of defoliation for vegetation removal treatments
    - Estimate amount of biomass that would need to be removed either mechanically, consumed as fuel in a prescribed fire
    - Identify areas of high degree of defoliation that are within the HFE flood stage

PERS paper intro with methods

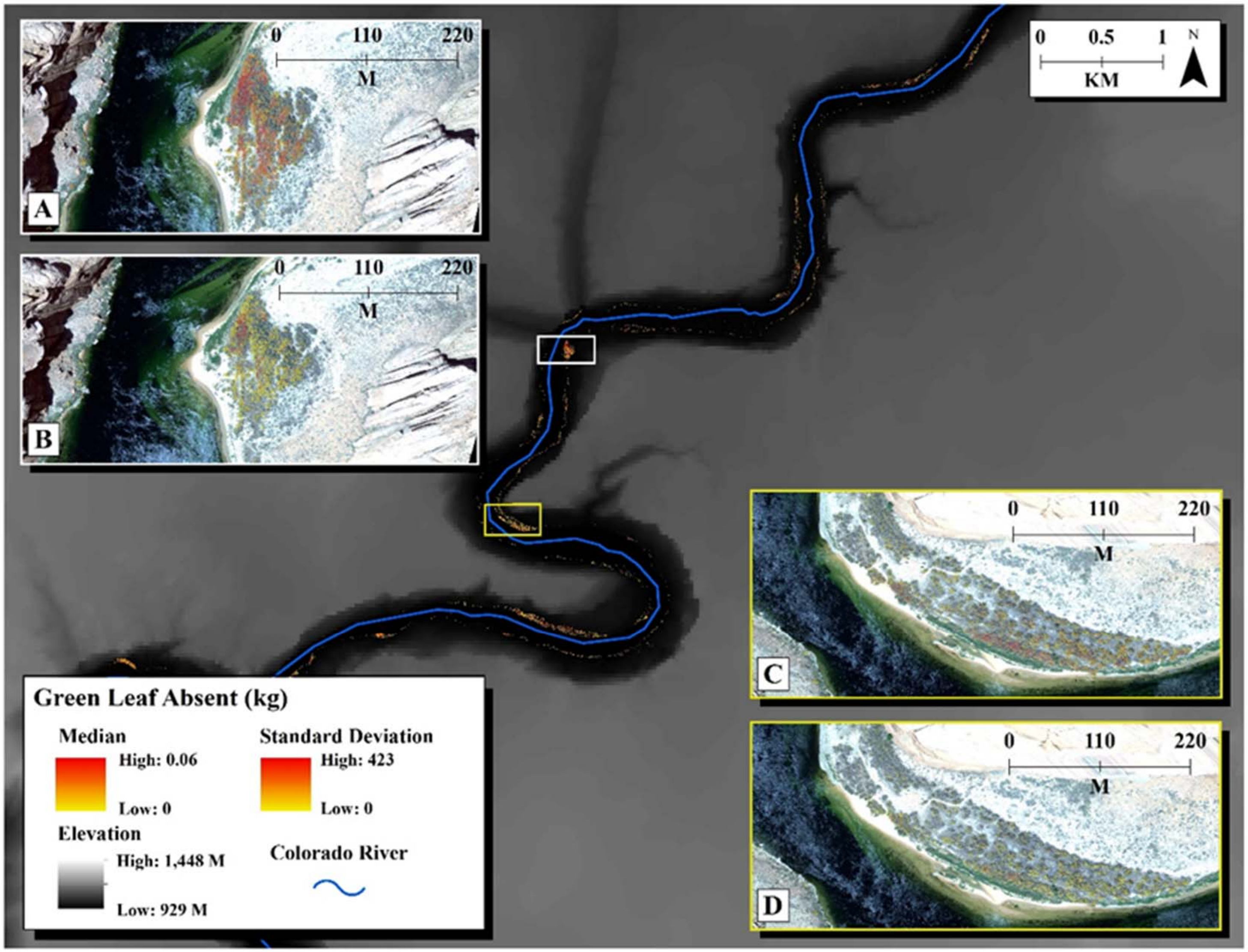
- Research Objectives
  - Develop a remote sensing method to estimate total aboveground tamarisk biomass as well as leaf-only tamarisk biomass using lidar and existing allometric relationships,
  - Demonstrate how the fusion of lidar and multitemporal, mulstispectral imagery can be used to monitor the effects of green leaf biomass defoliation,
  - Quantify the uncertainties associated with the above estimates in a robust manner that accounts for each of the key sources of uncertainty in riparian biomass estimates.
- Paper in review
  - Sankey, TT, Sankey, JB, Bedford, A, Horne, R, in review, Remote sensing of tamarisk biomass, insect herbivory, and defoliation: novel methods and applications in the Grand Canyon region, Arizona, USA. *Photogrammetric Engineering and Remote Sensing*
- Methods
  - Fusion of lidar (2013) and multispectral imagery (2009 and 2013) from overflights: Glen Canyon Dam to ~6 miles upstream of Lees Ferry
  - Use multispectral imagery to map tamarisk
  - Use lidar allometry to estimate tamarisk biomass
  - Use change detection of multispectral imagery with lidar-derived biomass to estimate biomass of total, green-leaf, and defoliated leaf (litter) tamarisk in 2013



A
0
110
220
M
B
0
110
220
M
0
0.5
1
KM
N
C
0
110
220
M
D
0
110
220
M
Total Aboveground Biomass (kg)
Median
High: 0.06
Low: 0
Standard Deviation
High: 423
Low: 0
Elevation
High: 1,448 M
Low: 929 M
Colorado River

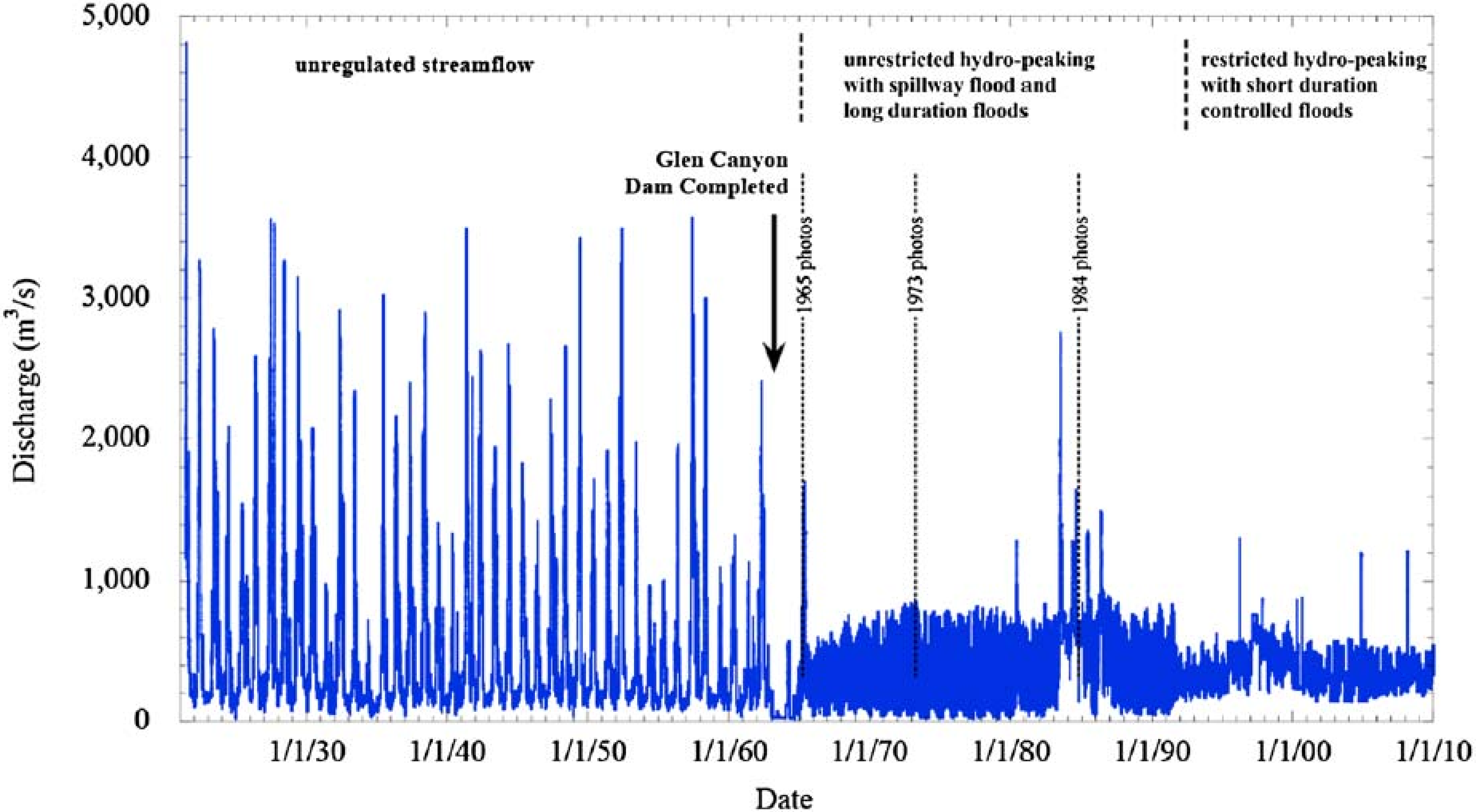


0 110 220
M
A
0 110 220
M
B
0 0.5 1
KM
N
0 110 220
M
C
0 110 220
M
D
Green Leaf Present (kg)
Median
High: 0.06
Low: 0
Standard Deviation
High: 423
Low: 0
Elevation
High: 1,448 M
Low: 929 M
Colorado River

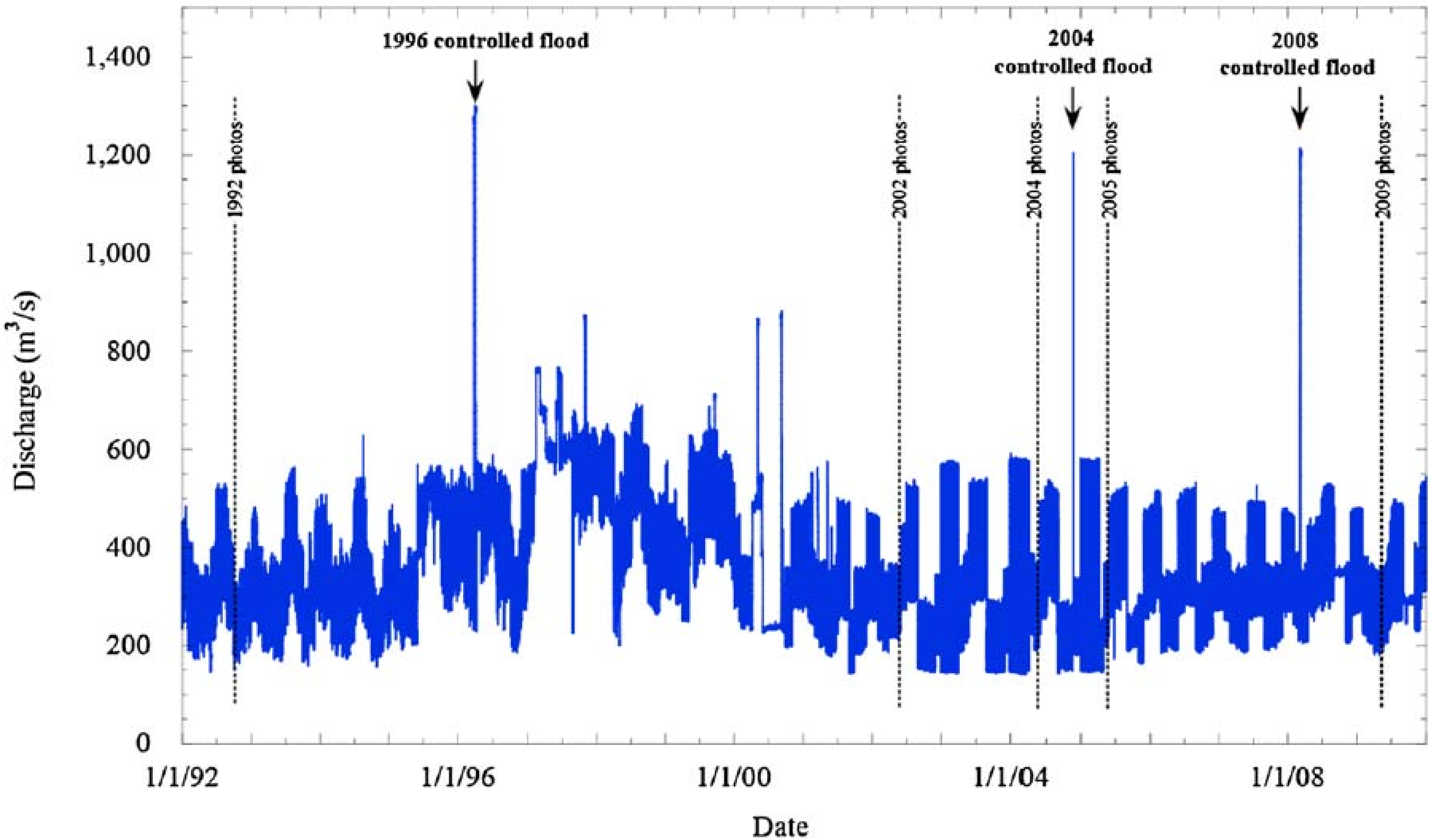


0
110
220
M
A
B
C
D
0
0.5
1
KM
N
Green Leaf Absent (kg)
Median
High: 0.06
Low: 0
Standard Deviation
High: 423
Low: 0
Elevation
High: 1,448 M
Low: 929 M
Colorado River

Summary



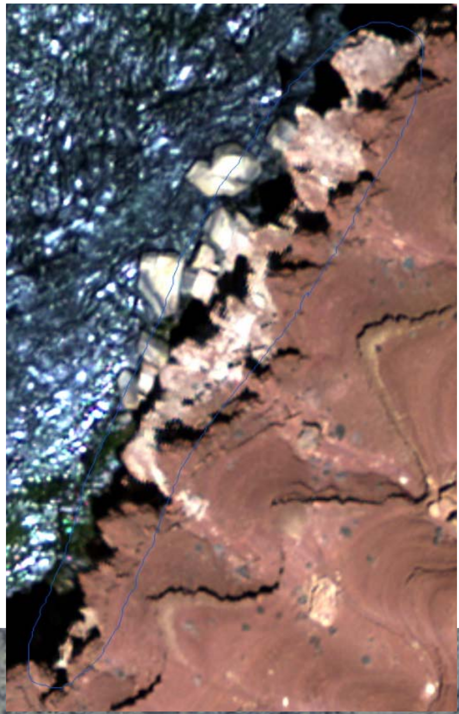
5,000
4,000
3,000
2,000
1,000
0
Discharge (m^3/s)
unregulated streamflow
unrestricted hydro-peaking
with spillway flood and
long duration floods
restricted hydro-peaking
with short duration
controlled floods
Glen Canyon
Dam Completed
1965 photos
1973 photos
1984 photos
1/1/30
1/1/40
1/1/50
1/1/60
1/1/70
1/1/80
1/1/90
1/1/00
1/1/10
Date

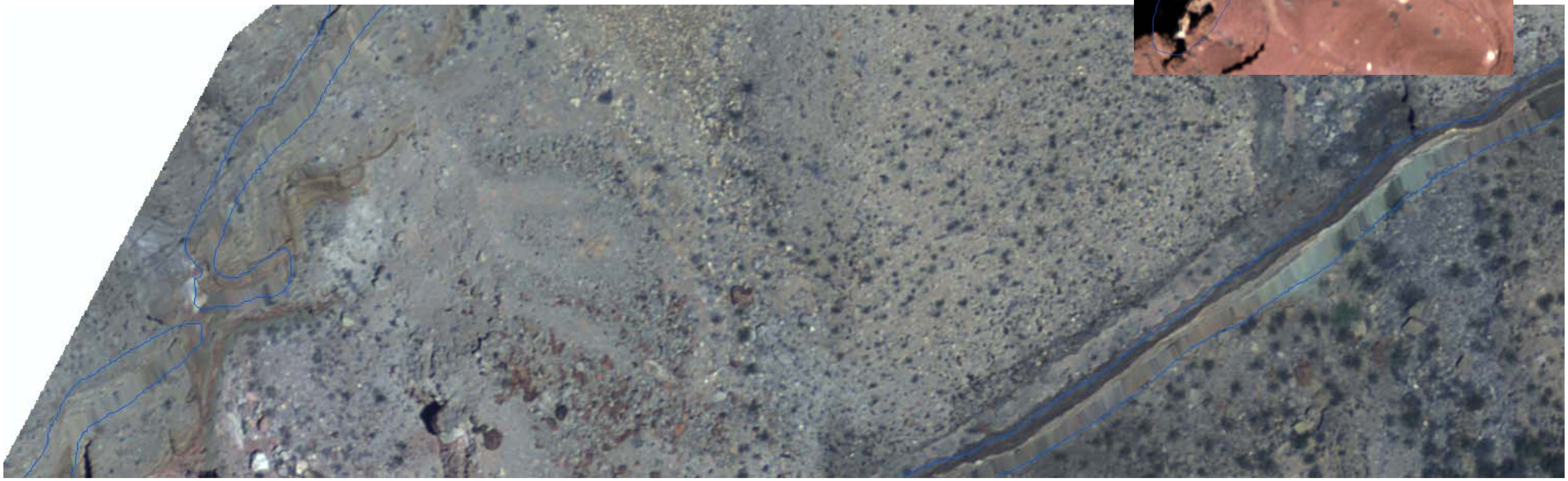

1996 controlled flood
2004 controlled flood
2008 controlled flood
1992 photos
2002 photos
2004 photos
2005 photos
2009 photos
Discharge (m³/s)
1,400
1,200
1,000
800
600
400
200
0
1/1/92
1/1/96
1/1/00
1/1/04
1/1/08
Date

2013 Overflight Image Mosaic

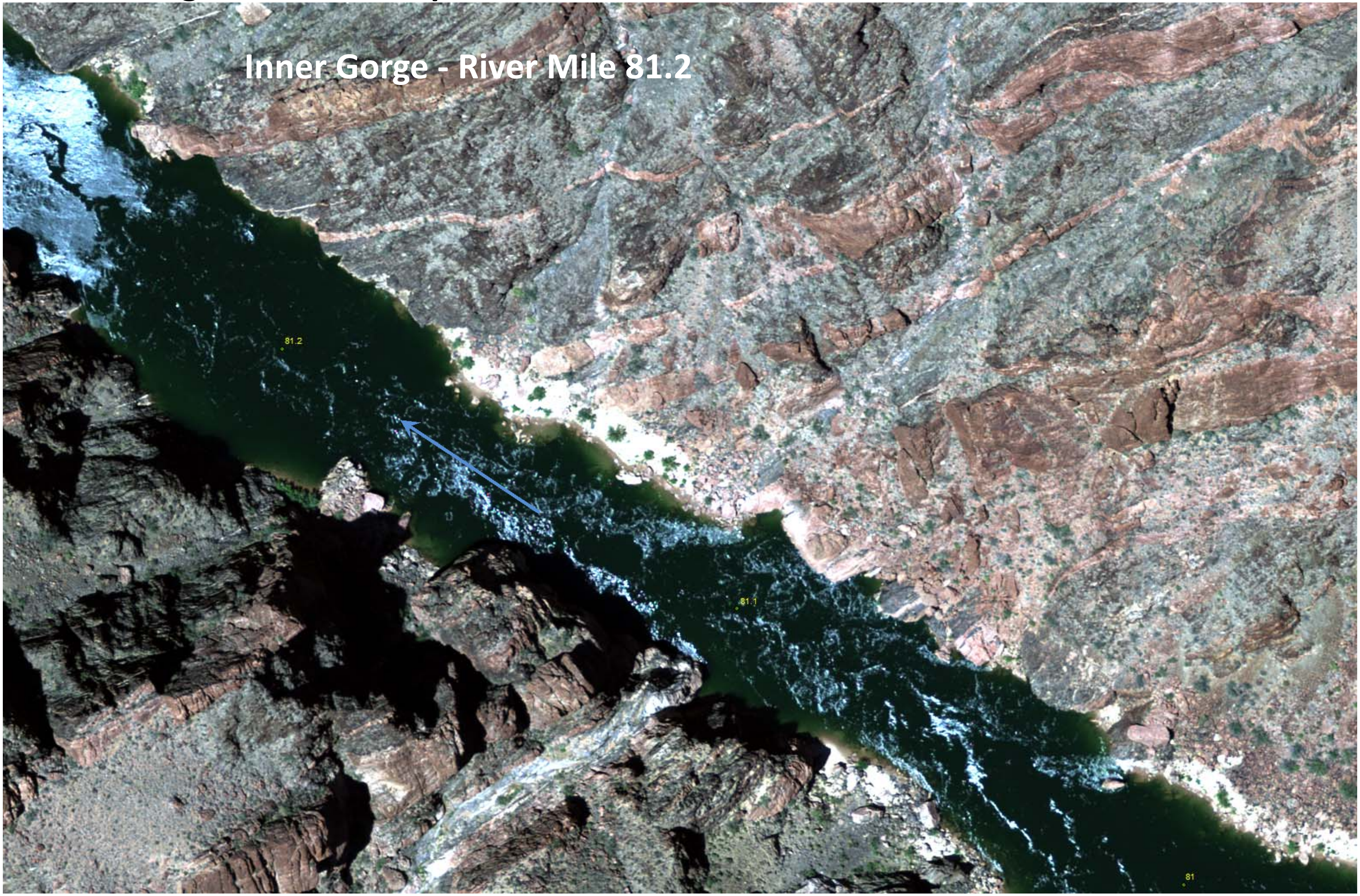
Details:

- During mosaic preparation remove "smear" (mechanical error) from the data.
  - Smear could not be removed in less than $0.24\ km^2$ or 0.09% of the total image area





2013 Image Mosaic Examples



2013 Image Mosaic Examples

Methods

- Overflight Multispectral Image Mosaics
  - 2009: Pre-beetle image
  - 2013: Post-beetle image
  - 2009:2013 (Pre/Post Comparison)
- NDVI (Normalized Difference Vegetation Index)
  - 2009
  - 2013
  - 2009:2013
- 3D Lidar images
  - 2013
  - Vegetation height
  - Canopy volume and biomass density

Methods

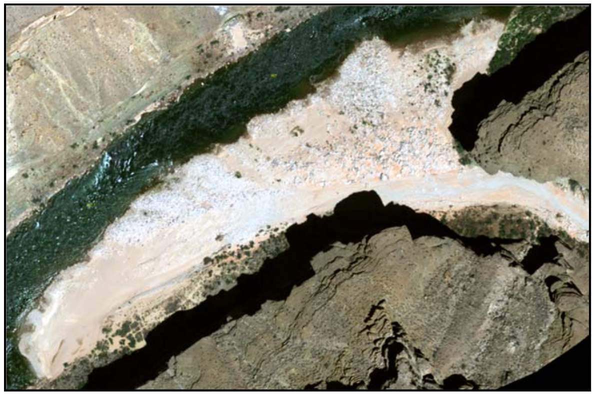
- Overflight Multispectral Image Mosaics
  - 2009: Pre-beetle image
  - 2013: Post-beetle image
  - 2009:2013 (Pre/Post Comparison)
- NDVI (Normalized Difference Vegetation Index)
  - 2009
  - 2013
  - 2009:2013
- 3D Lidar images
  - 2013
  - Vegetation height
  - Canopy volume and biomass density

Remote sensing of tamarisk defoliation

- Research Question
  - What percent of green tamarisk in 2009 was defoliated in 2013?
- M.S. Thesis (Ashton Bedford), Northern Arizona University, defense Spring 2015
- Three reaches
  - Glen Canyon (19.6 miles from Glen Canyon Dam to 3.6 miles downstream of Lees Ferry)
  - Kanab (From 134.6 to 155.7 miles downstream of Lees Ferry)
  - National (From 158.6 to 180.5 miles downstream of Lees Ferry)
- Methods
  - Image classification of tamarisk in 2009
    - Glen Canyon Tamarisk Classification accuracy = 87 %
    - Kanab Tamarisk Classification accuracy = 83 %
    - National Tamarisk Classification accuracy = 72 %
  - Change detection vegetation greenness indices from 2009 to 2013

Remote sensing of tamarisk defoliation

Reach	Percent of Tamarisk Vegetation	Total Area (m^2)
Glen Canyon (Glen Canyon Dam to Lees Ferry)		
Green	76 %	20,005
Defoliated	24 %	9,053
Kanab (RM 134.6 to 155.7)		
Green	77 %	4,047
Defoliated	23 %	1,095
National (RM 158.6 to 180.5)		
Green	88 %	21,727
Defoliated	12 %	2,893



Remote sensing of tamarisk defoliation – Lidar Fusion – Tamarisk Biomass