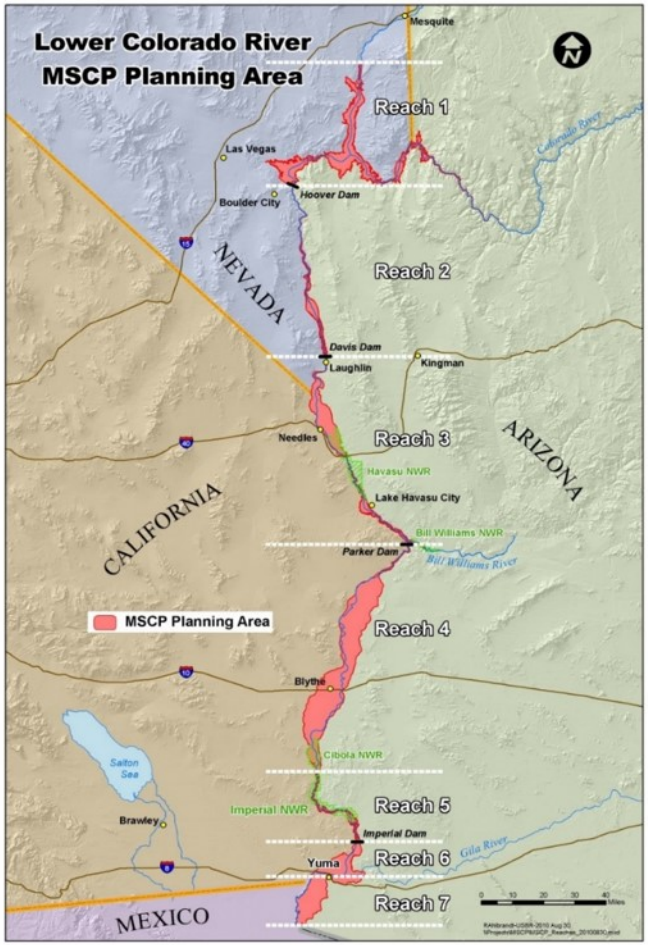
Deriving ground-based and airborne LiDAR metrics for habitat restoration on the Lower Colorado River

Jimmy Knowles, US Bureau of Reclamation
Lucas P Spaete, Boise State University
Bob Unnasch, Sound Science LLC
Sonja Kokos, US Bureau of Reclamation
Nancy F Glenn, Boise State University

Lower Colorado River Multi-Species Conservation Program

- 50-year mitigation program
- Balance water use with conservation
- Contribute to recovery of endangered species and reduce the likelihood of additional listings
- Program Area includes the Colorado River from Lake Mead to the Mexican Border



Lower Colorado River MSCP Mitigation

- Create and manage over 8,100 acres of habitat:
  - 12 Birds
  - 4 Mammals
  - 3 Fish
  - 1 insect

- Southwestern willow flycatcher (SWFL), yellow-billed cuckoo, and other riparian obligate species occupy riparian forests with varying structure and density.

Habitat Creation Challenges

- What is Appropriate Habitat for Each Species?
  - (Minimum) patch size?
  - Canopy height?
  - Canopy closure?
  - Canopy distribution, Leaf Area Index, etc.?

MSCP: Conceptual Models

- SWFL most influential habitat elements:
  - **Soil Moisture**
    - Seasonality & Duration
  - **Patch Size**
  - **Forest Structure**
    - Canopy Height
    - Canopy Closure
    - Intermediate & Understory structure
    - Gap Size and Distribution

Lower Colorado River
Multi-Species Conservation Program

Balancing Resource Use and Conservation

Southwestern Willow Flycatcher
(*Empidonax traillii extimus*) (SWFL)
Basic Conceptual Ecological Model

Life Stages, Critical Biological Activities and Processes, Habitat Elements, and Controlling Factors

Photos courtesy of the Bureau of Reclamation.

March 2015

Ground-based Monitoring for Habitat Elements

- Based on:
  - MacArthur and Horn. 1969. Foliage Profile by Vertical Measurements
  - Radtke and Bolstad. 2001. Laser point-quadrat sampling for estimating foliage-height profiles in broad-leaved forests
- Challenges:
  - Time / resource intensive
  - Difficult to assess over multiple scales
  - Unable to assess the variance of foliar height diversity (FHD) with change in scale
  - Observer bias

Questions

- What physiognomic structure constitutes the range of SWFL habitat that can be managed?
- What qualitative and quantitative measures can be used to assess habitat elements?
  - What metrics can assess similarity between sites with a low and high density of SWFL?
  - Is airborne lidar (ALS) sufficient to be used as a quantitative measure, or is ground-based lidar (TLS) detail needed at local level?

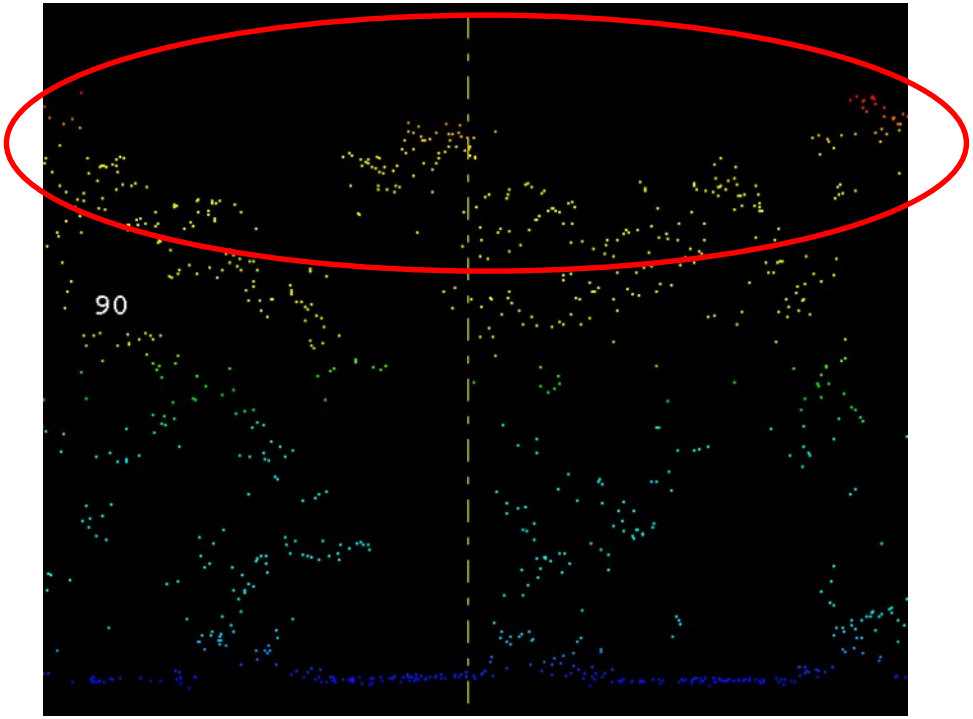
ALS and TLS Data

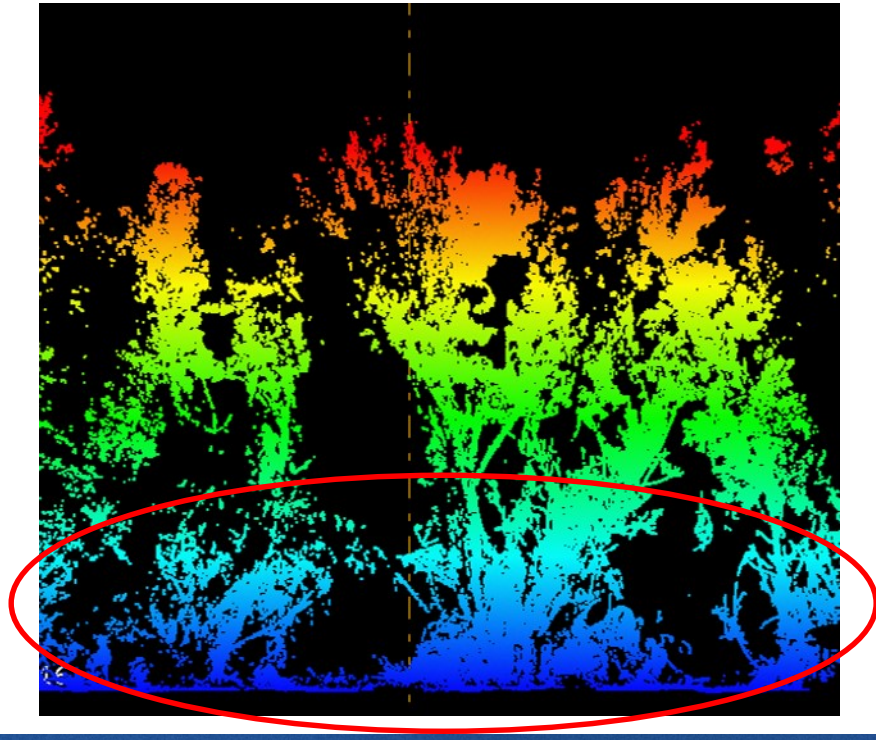
Airborne Laser Scanning (ALS, aka lidar)

- Complete coverage of study
- Canopy detection

Terrestrial Laser Scanning (TLS)

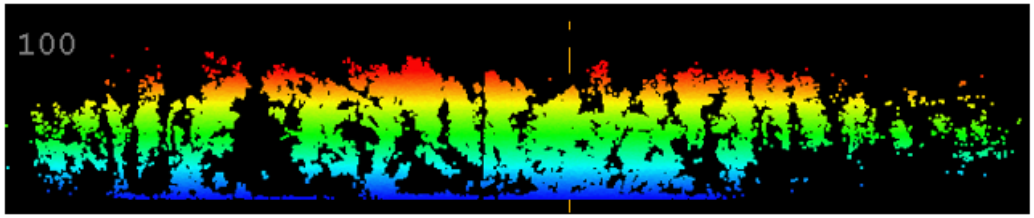
- Very high detail (point density)
- Understory detection

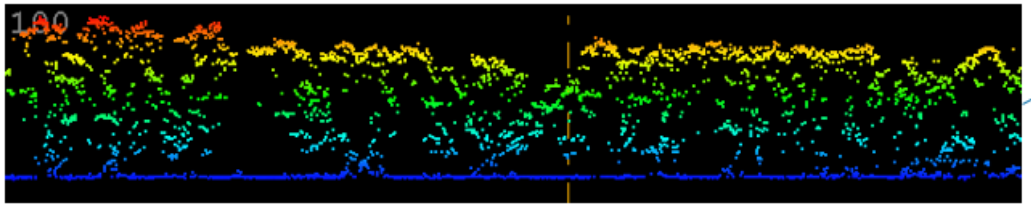




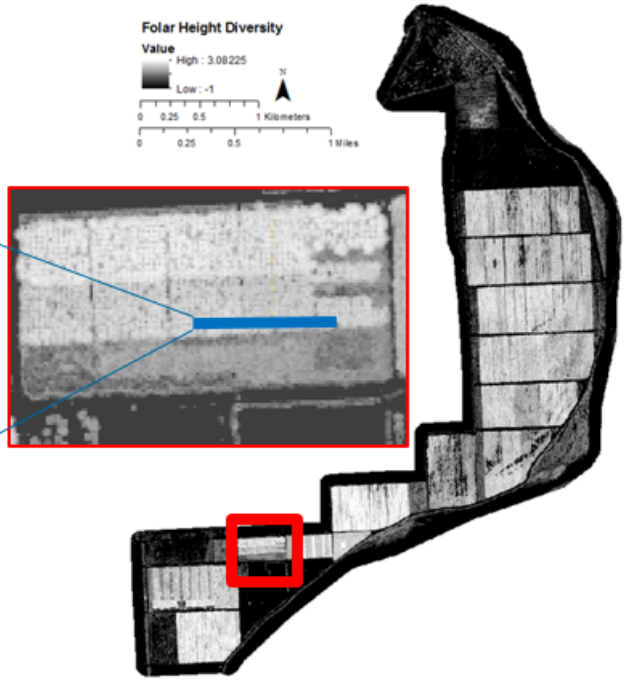
ALS and TLS Data

TLS



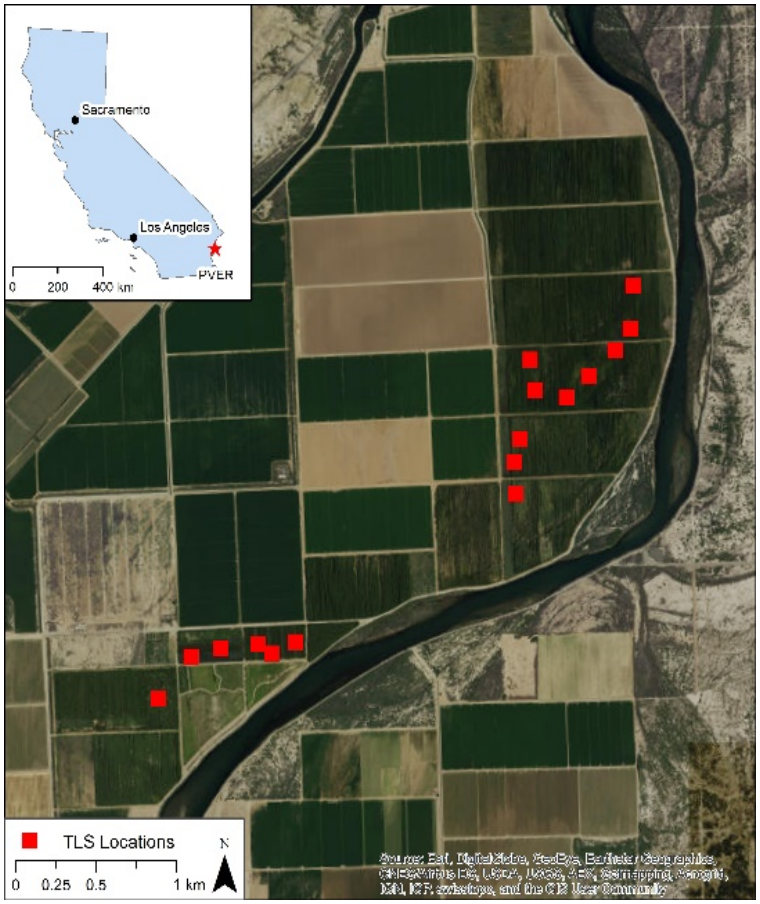


ALS



Palo Verde Ecological Reserve, CA

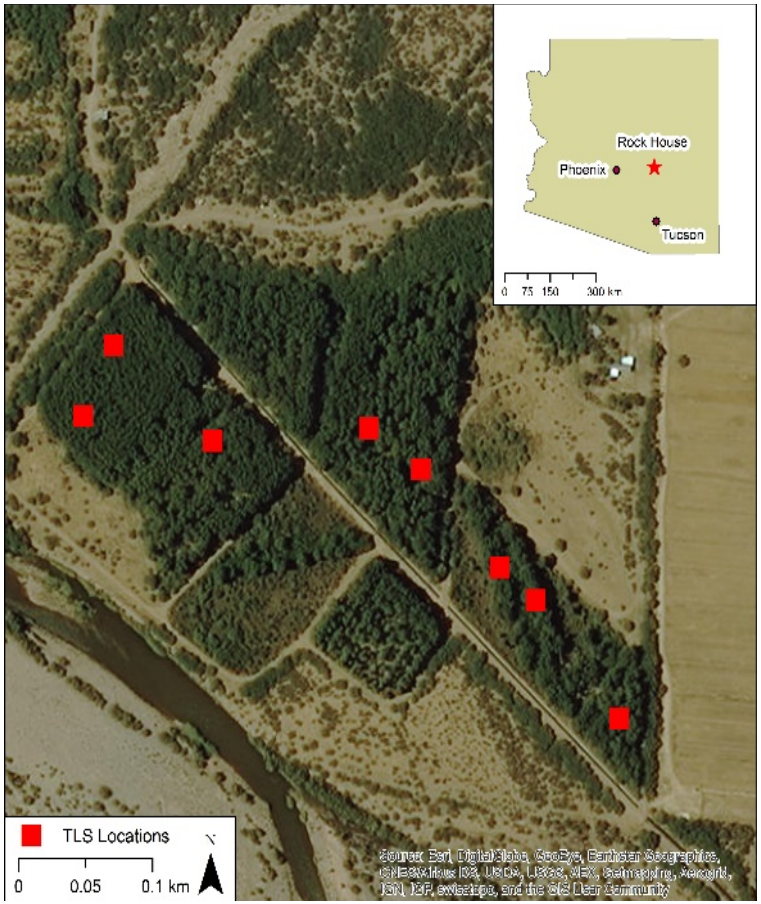
- Cottonwood and Goodding's & coyote willow
- Sandy-loam soils, with variable saturation
- 2 SWFL recorded between 2009-2016



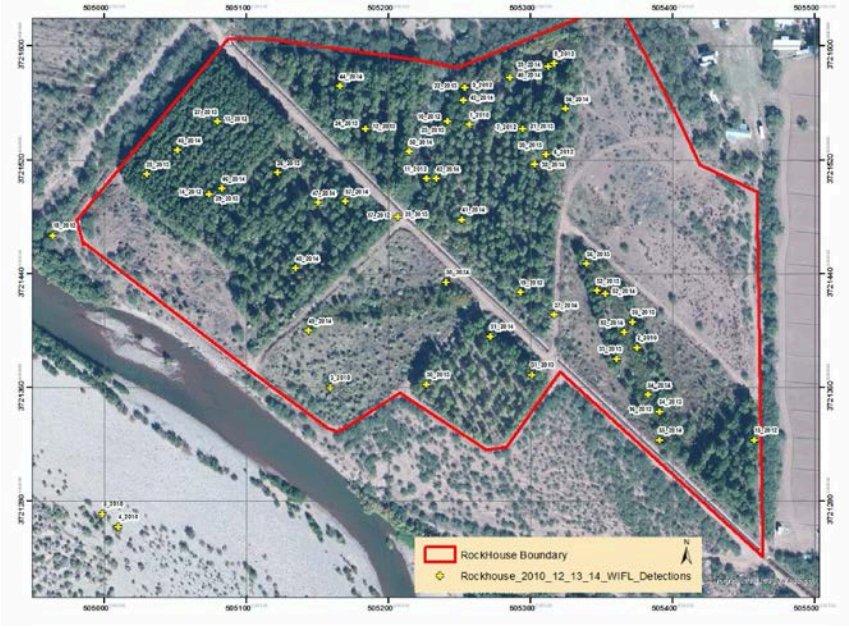
Palo Verde Ecological Reserve, CA

Rockhouse Riparian Restoration Site, AZ

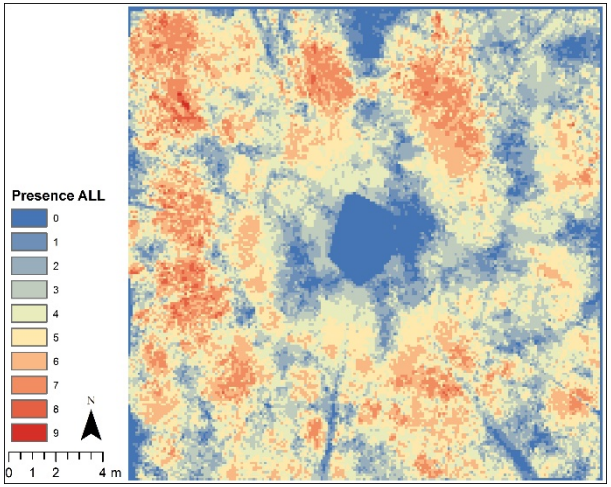
- Cottonwood, mesquite, Goodding's willow
- Sandy-loam and silty-loam soils with variable saturation
- 46 SWFL detected 2010-2014

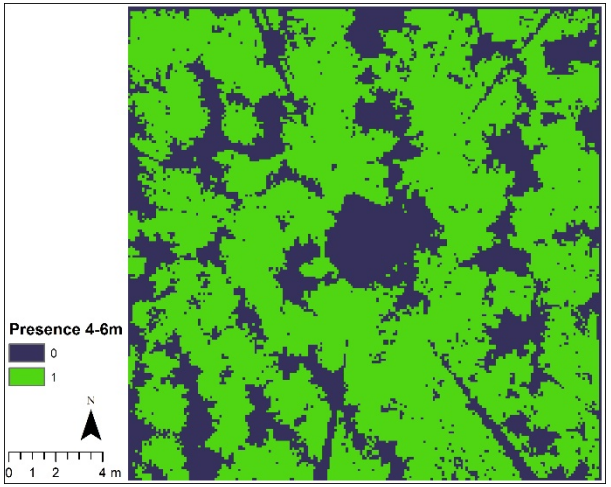


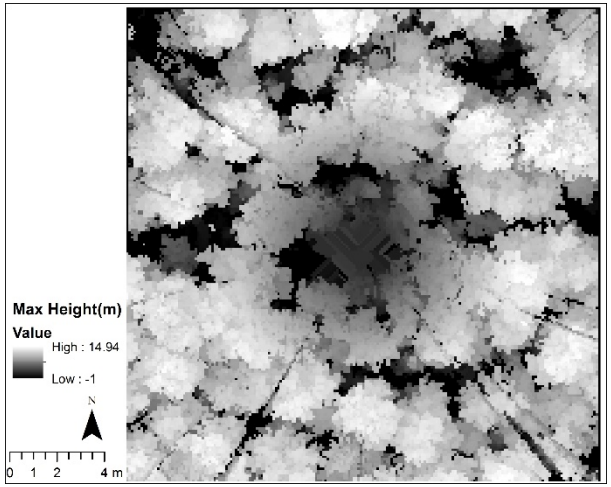
Rockhouse Riparian Restoration Site, AZ



Example TLS Products



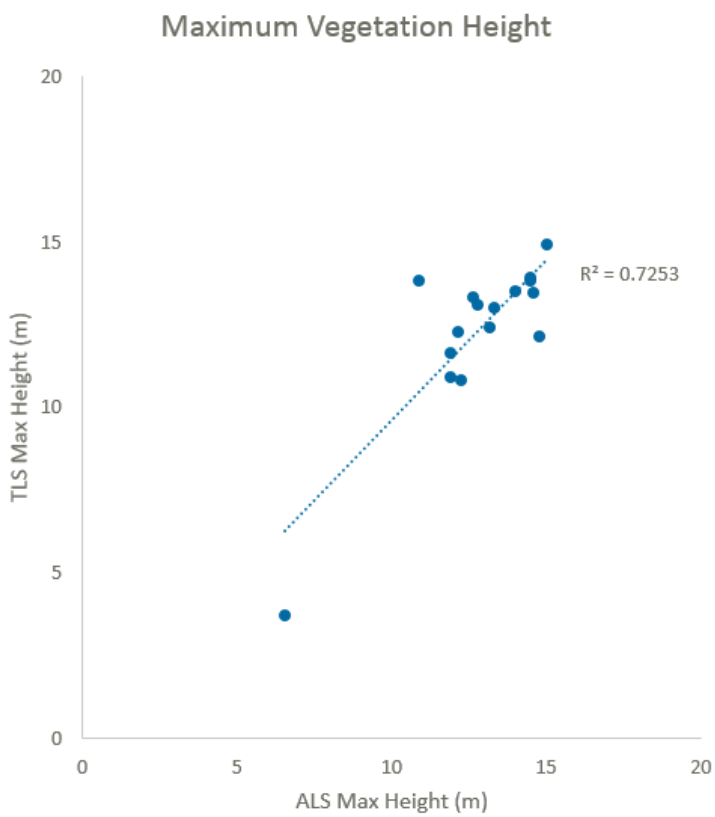


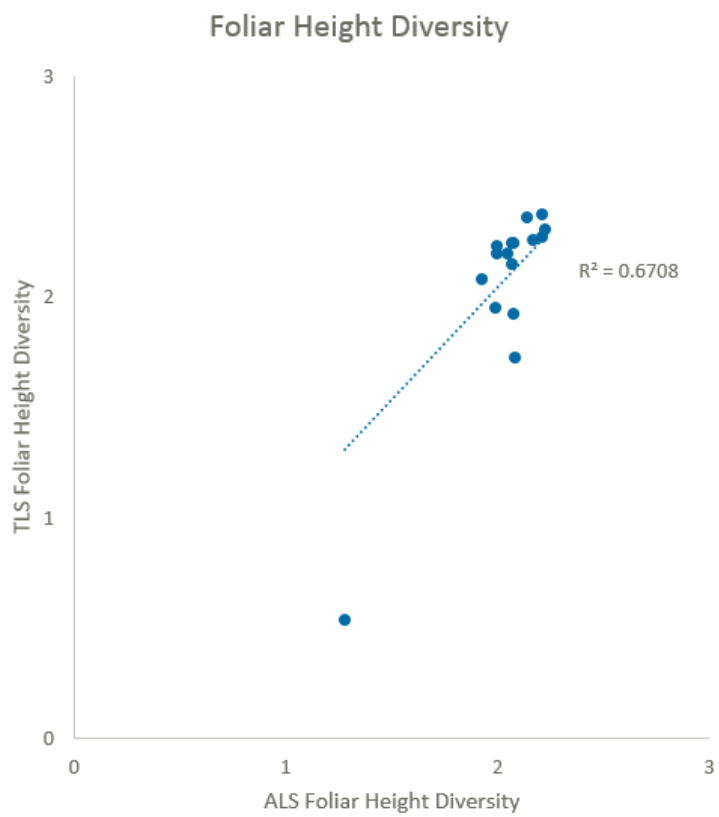


Presence all & via stratum, pver14

Height, pver11

Example TLS – ALS Comparison

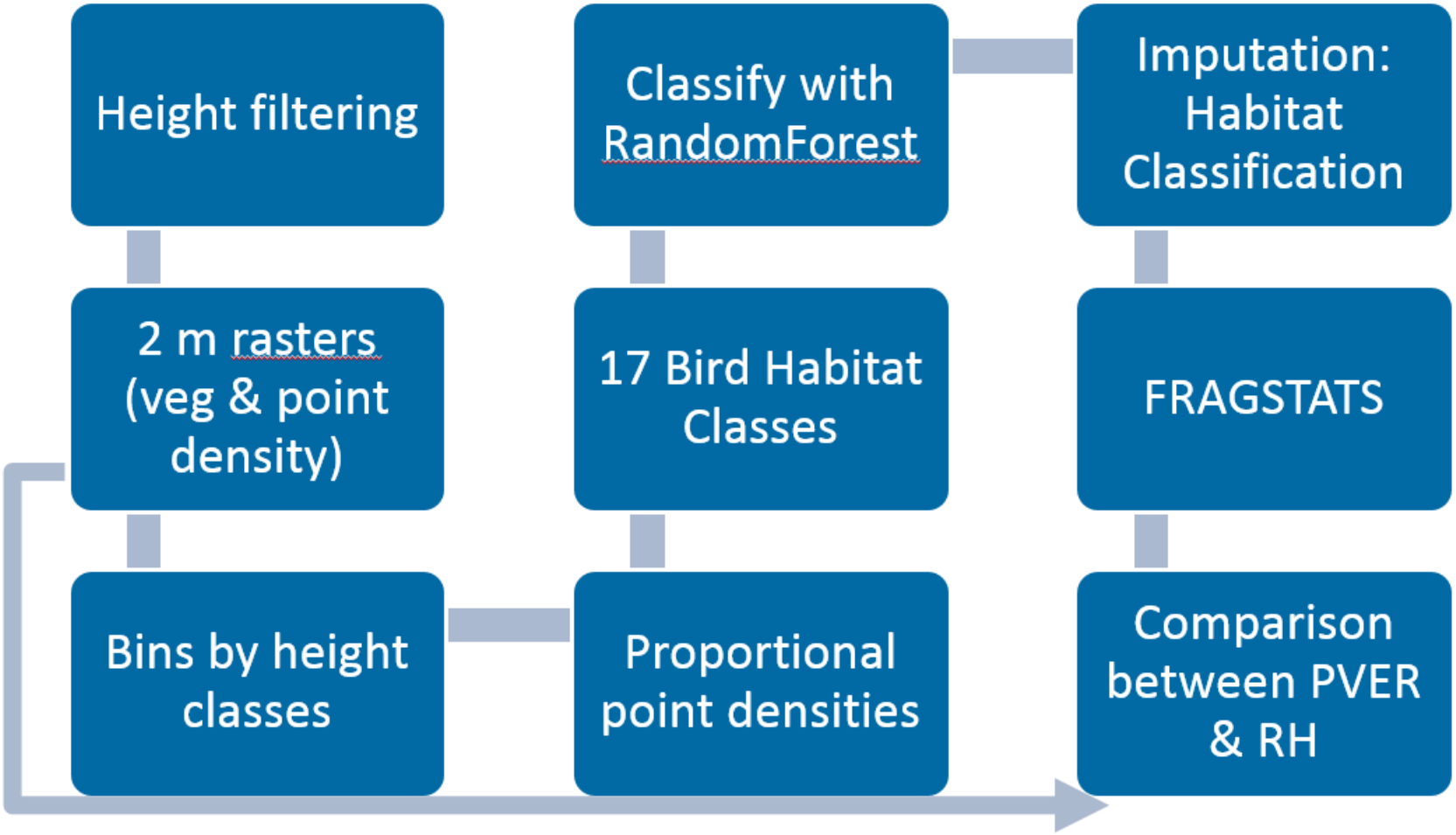




TLS

- TLS challenges similar to traditional field monitoring
  - unable to address multi-scale
  - upper canopy not well defined in some areas
  - precise positioning difficult due to closed canopy
  - biased sampling approach
  - fine-scale repeat monitoring

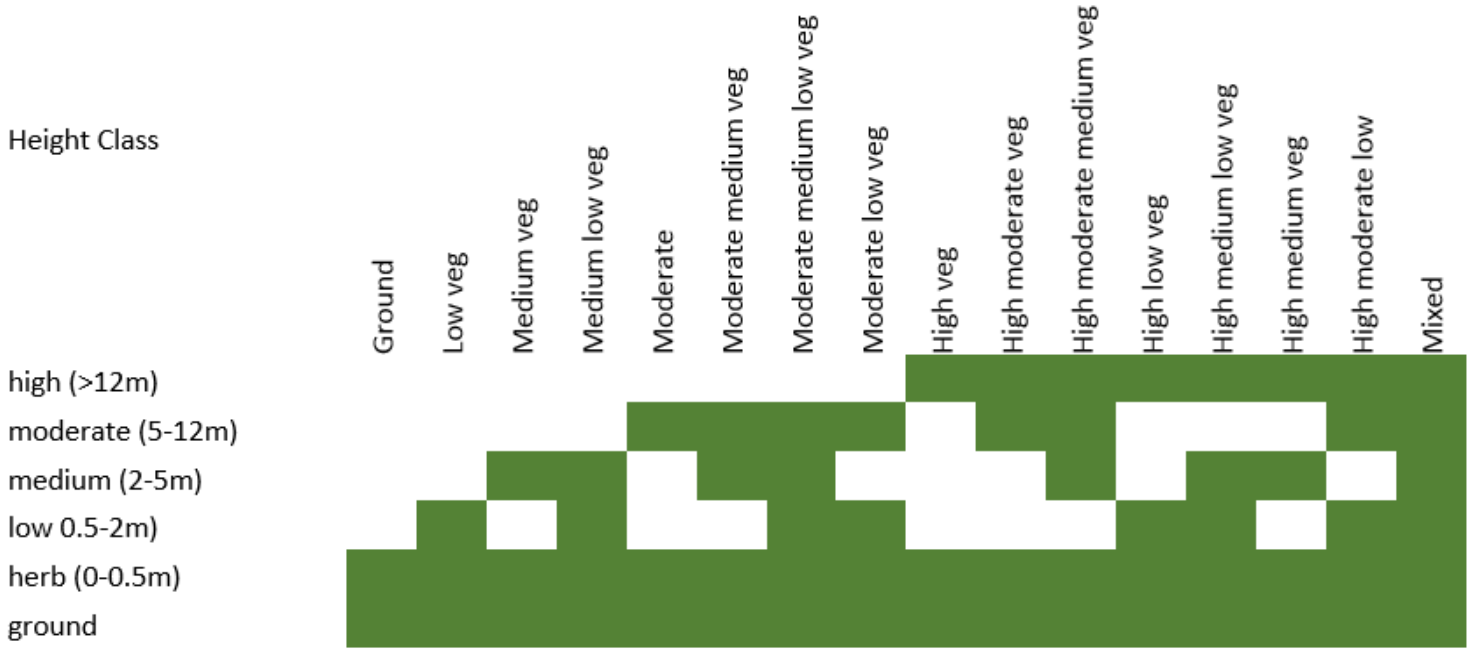
ALS Workflow



Bird Habitat Classes

Ground	0-50cm	50cm – 2m	2m – 5m	5m – 12m	>12m	Class	Code
0	0	0	0	0	0	NoData	1
= 1		0	0	0	0	Ground	2
>0	>0	>.25	0	0	0	Low veg	3
>0	>0	0	>.25	0	0	Medium veg	4
>0	>0	>0	>.25	0	0	Medium low veg	5
>0	>0	0	0	>.25	0	Moderate	6
>0	>0	0	>0	>.25	0	Moderate medium veg	7
>0	>0	>0	>0	>.25	0	Moderate medium low veg	8
>0	>0	>0	0	>.25	0	Moderate low veg	9
>0	>0	0	0	0	>0	High veg	10
>0	>0	0	0	> 0	>0	High moderate veg	11
>0	>0	0	>0	>0	>0	High moderate medium veg	12
>0	>0	>0	0	0	>0	High low veg	13
>0	>0	>0	>0	0	>0	High medium low veg	14
>0	>0	0	>0	0	>0	High medium veg	15
>0	>0	>0	0	>0	>0	High moderate low	16
>0	>0	>0	>0	>0	>0	Mixed	17

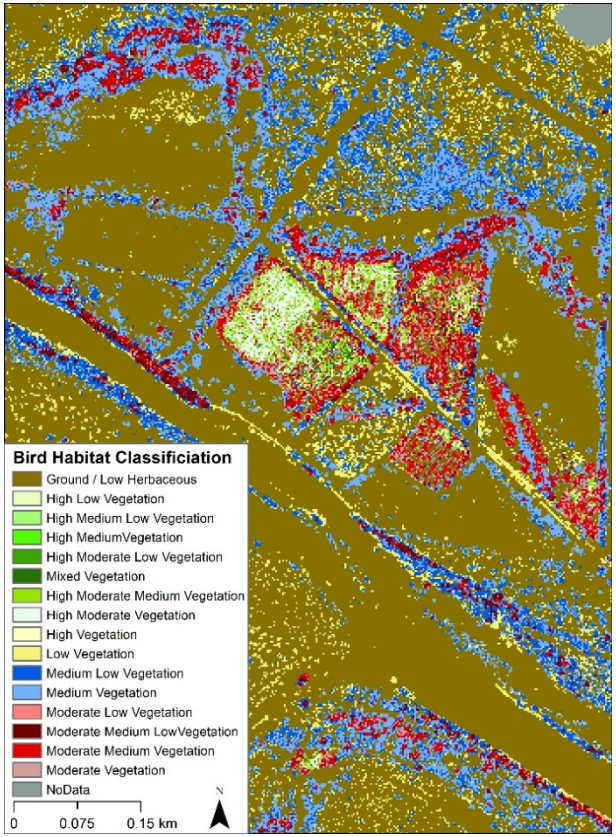
Bird Habitat Classes



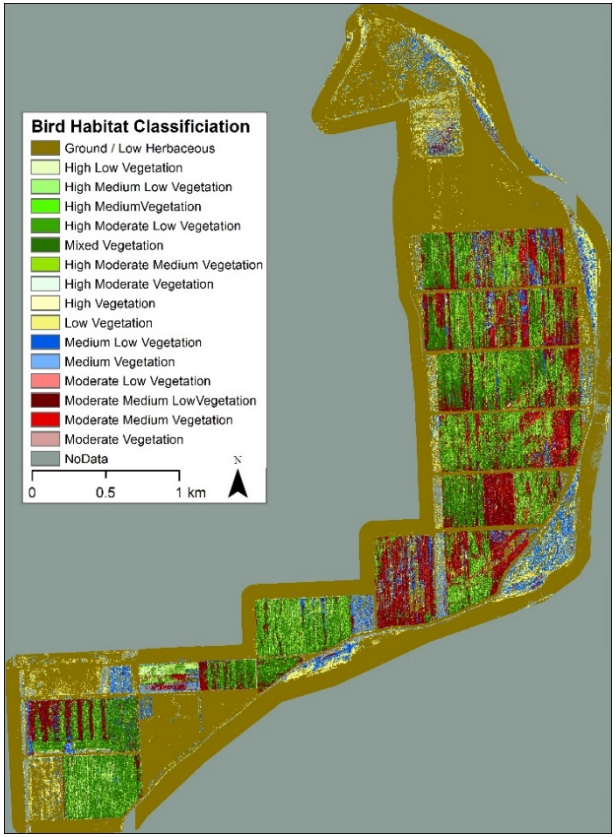
ALS Habitat Classification

based on distribution of point densities of height classes

Rockhouse



Palo Verde Ecological Reserve



Example ALS Vegetation Metrics

RH

Height			
Min	Max	Mean	Std Dev
0.00	8.95	3.36	3.44
Veg Cover			
40%			
FHD (1 m bin)			
1.28			

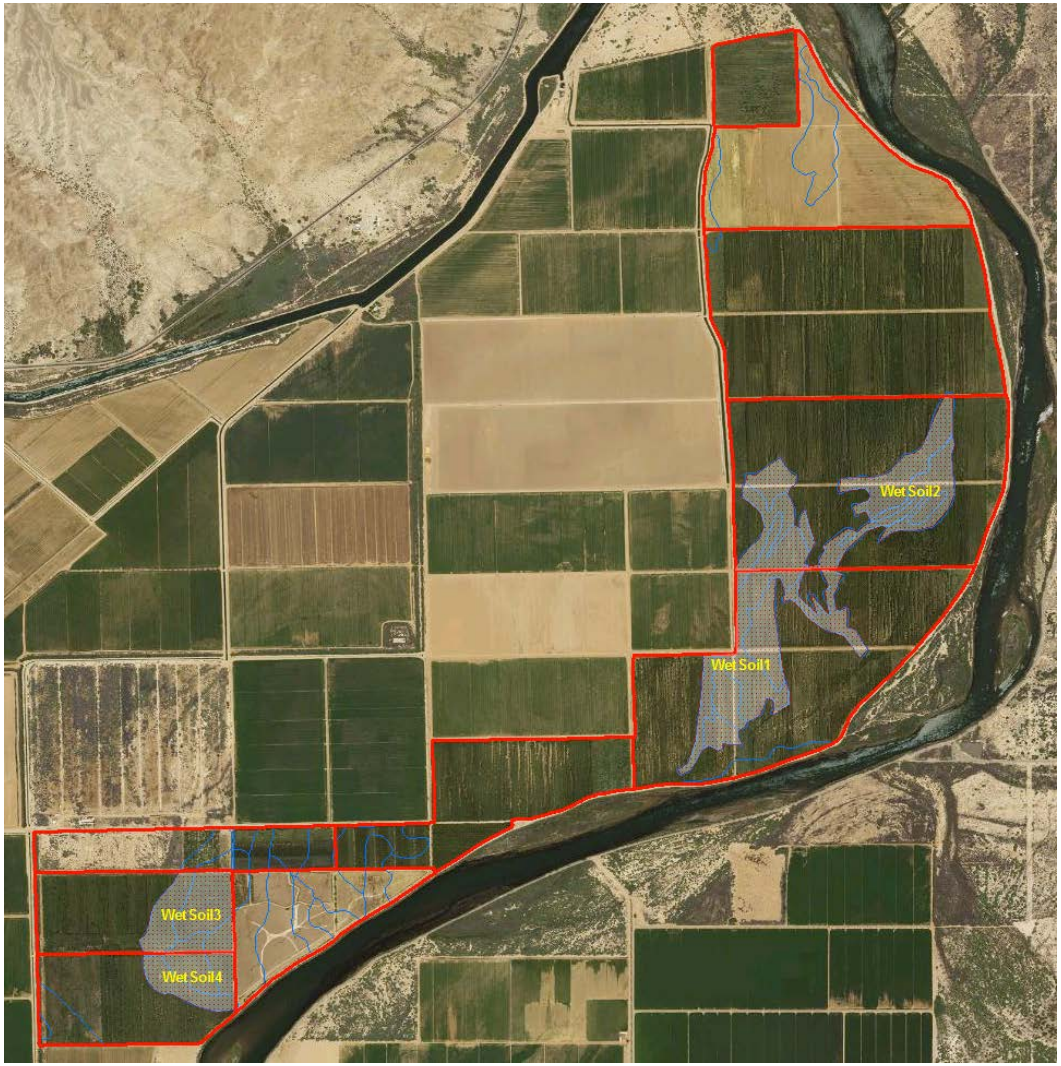
PVER

Height			
Min	Max	Mean	Std Dev
0.08	13.37	6.11	4.83
Veg Cover			
65%			
FHD (1 m bin)			
2.04			

Percent of Stand in Bird Habitat Classes

Restoration Phase														
Stand ID	RHAll	PVER11 Phase 1	PVER12 Phase 2	PVER13 Phase 3	PVER08 Phase 4	PVER09 Phase 4	PVER10 Phase 4	PVER05 Phase 5	PVER06 Phase 5	PVER07 Phase 5	PVER03 Phase 6	PVER04 Phase 6	PVER01 Phase 7	PVER02 Phase 7
High veg	0%	2%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
High medium veg	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
High medium low veg	0%	0%	1%	3%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
High moderate veg	14%	13%	4%	14%	12%	2%	3%	4%	3%	0%	3%	3%	1%	1%
High moderate medium veg	12%	19%	29%	51%	57%	52%	29%	25%	15%	2%	34%	29%	21%	18%
High moderate low	1%	2%	3%	7%	5%	2%	3%	1%	1%	0%	1%	1%	1%	0%
High low veg	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
mixed	2%	19%	4%	11%	7%	6%	6%	27%	25%	6%	12%	23%	24%	31%
moderate	11%	2%	1%	0%	0%	0%	0%	2%	1%	1%	1%	1%	1%	1%
Moderate medium veg	22%	8%	8%	0%	1%	3%	7%	12%	12%	19%	10%	13%	12%	11%
Moderate medium low veg	4%	16%	32%	4%	8%	35%	49%	17%	25%	21%	34%	25%	23%	25%
Moderate low veg	2%	1%	0%	0%	0%	0%	0%	1%	1%	1%	0%	1%	0%	0%
Medium veg	7%	5%	2%	0%	0%	0%	0%	1%	1%	4%	0%	1%	2%	1%
Medium low veg	2%	4%	11%	2%	5%	0%	2%	3%	3%	15%	3%	2%	8%	5%
Low veg	2%	0%	1%	0%	1%	0%	0%	1%	2%	5%	1%	0%	1%	1%
Ground	21%	2%	1%	0%	2%	0%	0%	5%	11%	23%	1%	0%	5%	4%

Percent of Stand in Bird Habitat Classes



Percent of Stand in Bird Habitat Classes

Stand ID	RHAll	Wetsoil3 phase 2	wetsoil4 phase 3	Wetsoil1 phase 5	Wetsoil2 phase 6
High veg	0%	0%	3%	0%	0%
High medium veg	0%	1%	1%	0%	0%
High medium low veg	0%	3%	3%	0%	0%
High moderate veg	14%	3%	12%	1%	3%
High moderate medium veg	12%	26%	48%	5%	24%
High moderate low	1%	3%	5%	0%	1%
High low veg	0%	0%	2%	0%	0%
mixed	2%	2%	3%	6%	29%
moderate	11%	1%	1%	1%	1%
Moderate medium veg	22%	4%	1%	11%	9%
Moderate medium low veg	4%	25%	10%	17%	20%
Moderate low veg	2%	0%	0%	1%	1%
Medium veg	7%	3%	0%	4%	0%
Medium low veg	2%	10%	3%	9%	2%
Low veg	2%	3%	0%	8%	1%
Ground	21%	13%	7%	27%	8%

BHC Patch Sizes

Patch Class	Patch Size
1	4-16 m^2
2	16-64 m^2
3	64-256 m^2
4	256-1,024 m^2
5	1,024-4,096 m^2
6	4,096-16,384 m^2
7	> 16,384 m^2

FRAGSTATS Results

patch statistics Rock House

		Number of Patches							Percent of BHC area in Patch class						
Patch Size Class	Percent of Stand	1	2	3	4	5	6	7	1	2	3	4	5	6	7
High veg	0%	9	1	0	0	0	0	0	82%	18%	0%	0%	0%	0%	0%
High medium veg	0%	4	0	0	0	0	0	0	100%	0%	0%	0%	0%	0%	0%
High medium low veg	0%	0	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%	0%
High moderate veg	14%	81	58	24	4	0	1	0	7%	13%	15%	14%	0%	51%	0%
High moderate medium veg	12%	102	75	49	11	0	0	0	10%	20%	40%	31%	0%	0%	0%
High moderate low	1%	69	6	1	0	0	0	0	75%	20%	5%	0%	0%	0%	0%
High low veg	0%	1	0	0	0	0	0	0	100%	0%	0%	0%	0%	0%	0%
mixed	2%	97	34	2	0	0	0	0	50%	44%	6%	0%	0%	0%	0%
moderate	11%	239	165	34	1	0	0	0	25%	47%	26%	3%	0%	0%	0%
Moderate medium veg	22%	145	93	53	18	4	0	0	8%	13%	25%	27%	27%	0%	0%
Moderate medium low veg	4%	144	64	7	0	0	0	0	40%	45%	14%	0%	0%	0%	0%
Moderate low veg	2%	79	23	0	0	0	0	0	61%	39%	0%	0%	0%	0%	0%
Medium veg	7%	144	57	13	2	1	0	0	24%	25%	14%	10%	27%	0%	0%
Medium low veg	2%	61	20	5	0	0	0	0	43%	33%	24%	0%	0%	0%	0%
Low veg	2%	66	28	9	0	0	0	0	34%	33%	33%	0%	0%	0%	0%
Ground	21%	101	60	44	11	1	2	0	6%	9%	20%	21%	11%	34%	0%

FRAGSTATS Results

patch statistics PVER (wetsoil1 Phase5)

		Number of Patches							Percent of BHC area in Patch class						
Patch Size Class	Percent of Stand	1	2	3	4	5	6	7	1	2	3	4	5	6	7
High veg	0%	1	0	0	0	0	0	0	100%	0%	0%	0%	0%	0%	0%
High medium veg	0%	1	0	0	0	0	0	0	100%	0%	0%	0%	0%	0%	0%
High medium low veg	0%	2	0	0	0	0	0	0	100%	0%	0%	0%	0%	0%	0%
High moderate veg	1%	194	41	0	0	0	0	0	68%	32%	0%	0%	0%	0%	0%
High moderate medium veg	5%	550	309	102	11	0	0	0	23%	32%	32%	12%	0%	0%	0%
High moderate low	0%	121	8	0	0	0	0	0	88%	12%	0%	0%	0%	0%	0%
High low veg	0%	1	0	0	0	0	0	0	100%	0%	0%	0%	0%	0%	0%
mixed	6%	87	83	46	22	3	2	0	3%	8%	12%	23%	13%	41%	0%
moderate	1%	315	66	7	0	0	0	0	63%	30%	7%	0%	0%	0%	0%
Moderate medium veg	11%	938	573	205	29	1	0	0	19%	30%	33%	16%	2%	0%	0%
Moderate medium low veg	17%	290	237	129	38	14	2	1	4%	8%	13%	15%	20%	15%	24%
Moderate low veg	1%	250	32	0	0	0	0	0	78%	22%	0%	0%	0%	0%	0%
Medium veg	4%	565	261	57	1	0	0	0	33%	39%	25%	2%	0%	0%	0%
Medium low veg	9%	581	339	139	20	4	1	0	14%	23%	28%	12%	9%	14%	0%
Low veg	8%	470	289	115	36	3	0	0	13%	20%	25%	31%	12%	0%	0%
Ground	27%	411	244	126	37	10	4	2	3%	5%	8%	9%	9%	17%	48%

Conclusions

Pending analysis of additional SWFL-occupied habitat

- Example treatments to PVER could include:
  - Thinning to remove some understory and create more structural diversity in upper canopy
    - Simultaneously reduce canopy cover
  - Reduce patch sizes and increase number of patches to create mosaics
  - Patches include structural variability in mid to upper canopy (5- 12m+)

QUESTIONS????

Jimmy Knowles

Email jknowles@usbr.gov

https://www.lcrmscp.gov

THANK YOU