Changes in Habitat Connectivity Affect Habitat Use of Fish in DECOMP Physical Model (DPM)

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Objectives:

1. Determine which vegetation communities are preferred by Largemouth Bass, Bowfin, and Florida Gar.

2. Determine if hydrological factors, environmental factors, or factors associated with DECOMP Physical Model affect habitat preference of these species.

Background: Habitat Use

- Animals move across the landscape to fulfill basic biological needs

- Areas with attributes that contribute to survival are *habitats*

Do animals spend their time in some areas more than others?

- Habitat preference- when more time is spent in a habitat than predicted by its relative abundance in the landscape

Background: Habitat Use

- Insight into the biological requirements of species
- Ecological factors that contribute to their persistence
- Project the effects of habitat alteration on species

How will Everglades restoration affect fish communities?

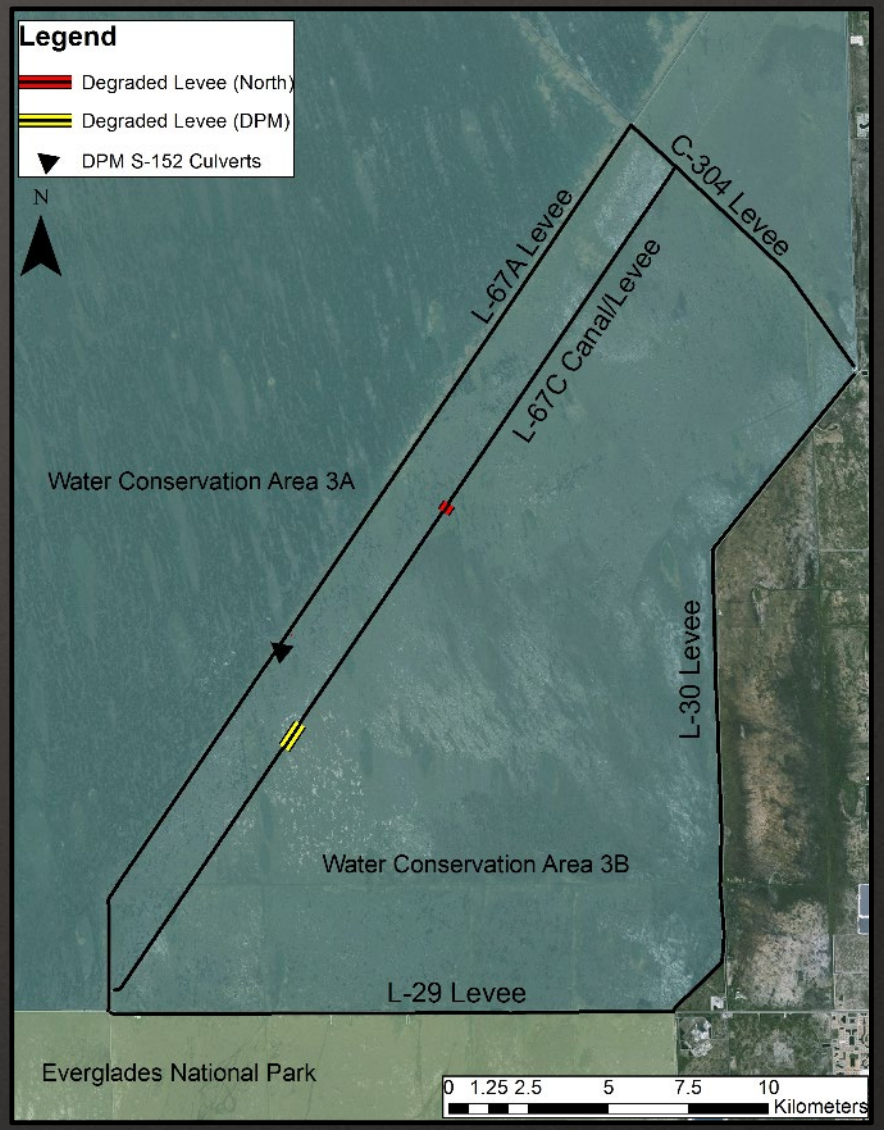
Model Setting: The Florida Everglades

- Dynamic landscape
  - Annual wet/dry cycle
- Mosaic of freshwater vegetation communities
- Topography of vegetation communities and seasonal variation in rainfall influence water availability within habitats
  - Influences population dynamics and behavior of aquatic organisms (Chick et al. 2004, Parkos et al. 2011)

How will restoration affect Everglades ecology?

- DECOMP Physical Model (DPM)
  - Field-scale test to restore hydrological connectivity between WCA-3A and 3B by removing barriers (decompartmentalization)
    - Levee removal
    - Canal backfill treatments
    - Controlled water deliveries

How will these changes affect large-bodied fish?

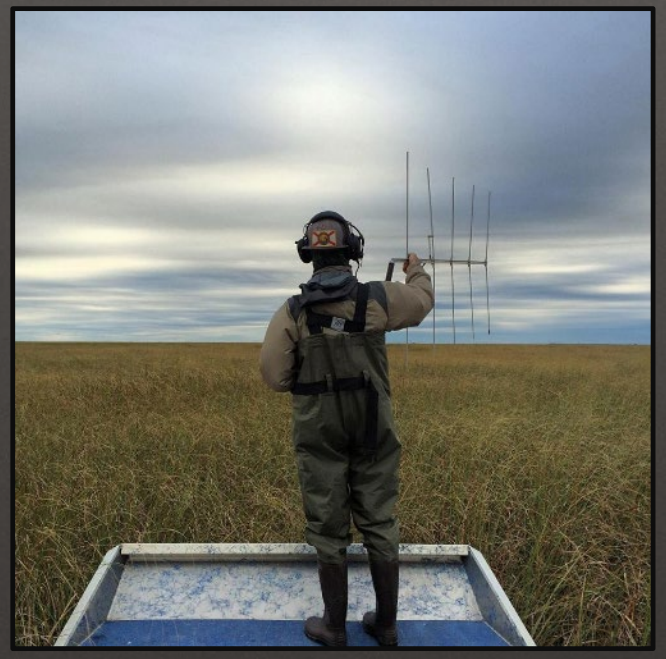


Methods: Fish Tagging

- Largemouth Bass (*Micropterus salmoides*), Bowfin (*Amia calva*), and Florida Gar (*Lepisosteus platyrhincus*)
- LMB and Bowfin in May 2011, Florida Gar November 2015
- Collected using airboat electrofishing
- Surgically implanted radio-transmitters (12 month battery life)
- 140 LMB, 100 Bowfin, 40 Florida Gar

Methods: Fish Tracking

- Locate fish weekly using an airboat
- Used fixed-wing aircraft in remote locations
- Mean accuracy of 1.88 m from airboat, 98.47 m from aircraft



Methods: Habitat Mapping

- Vegetation mapping
  - WorldView-2 satellite data
  - 2 m spatial resolution
    - Floating broadleaf plants, graminoid marsh (sparse and regular), sawgrass marsh (sparse, regular, dense), cattail marsh, sawgrass/cattail marsh (50-75% cattails), herbaceous marsh, shrub/herbaceous marsh, shrubs/trees, and canal
- Dynamic mapping
  - Water surface models and digital elevation models from EDEN to estimate water depth

Over 300 maps of study area that displayed habitat class and median water depth at 2 m resolution

Methods: Defining Use and Availability

- Fish locations assigned to habitat class based on field observations
- Habitat availability defined separately for each location
  - Species-specific availability radius (99th percentile of step-lengths)
  - Least-cost raster to avoid estimates that traversed emergent landscape features
- **Pixels with depth values <20 cm deemed unavailable**

Availability radii and dynamic mapping allowed for determination of volumetric habitat proportions available for each relocation

Methods: Habitat Preference

Objective 1: Identify which habitats are preferred by focal species

- Population-level selection ratios (Manly et al. 2002)

$$\hat{w}_i = \frac{u_{i+}}{\sum_{i=1}^{n} \left(\pi_{ij} u_{+j}\right)}$$

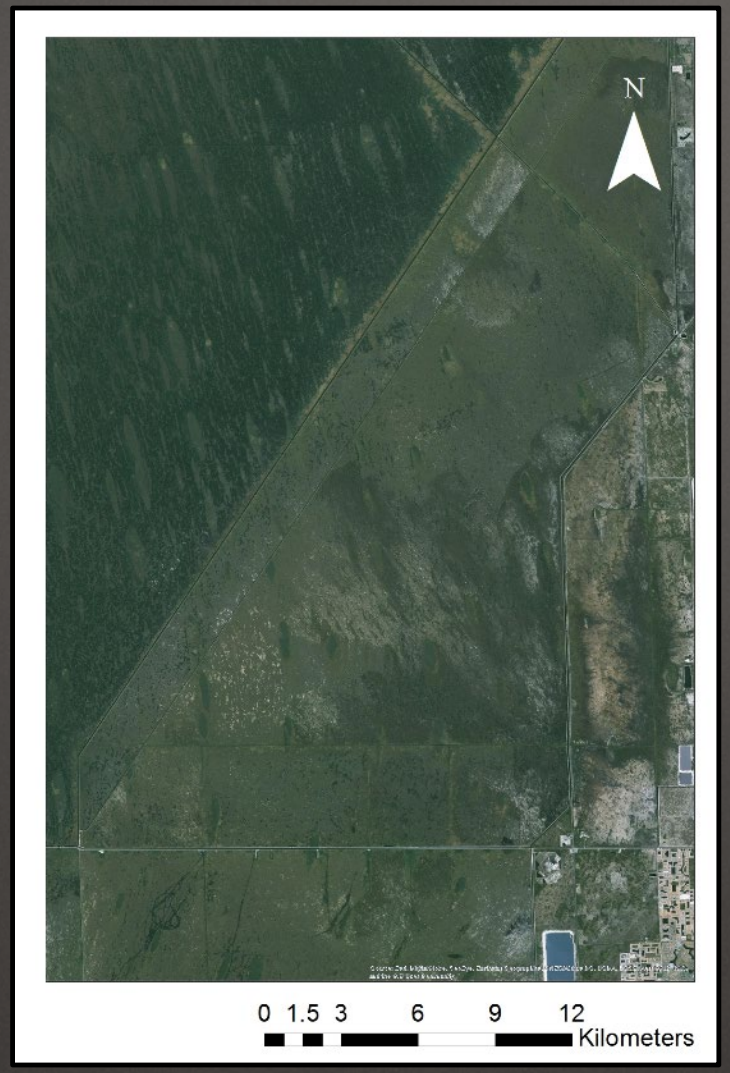
- 95% confidence intervals
- If $\hat{w}_i > 1$ preferred, if $\hat{w}_i < 1$ avoided, $\hat{w}_i = 1$ random use

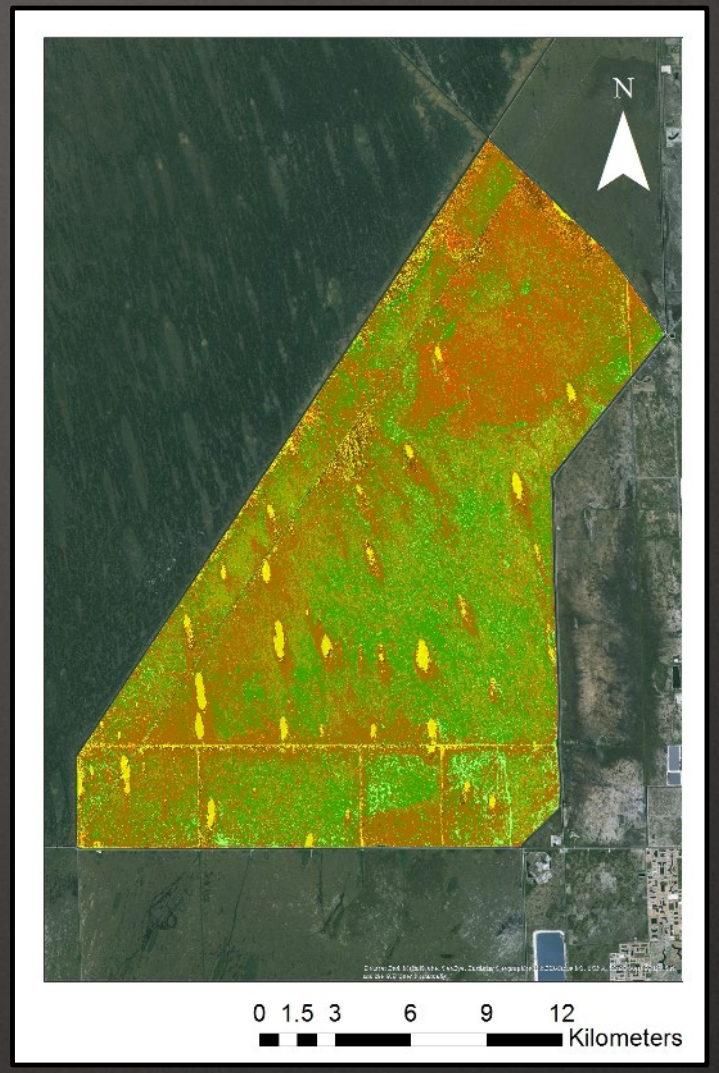
Methods: Habitat Preference

Objective 2: Identify factors that influence habitat preference of focal species

- Canal selection ratios
- Generalized linear mixed-effects models and multi-model selection
  - Environmental: Mean daily maximum air temperature, mean daily photoperiod
  - Hydrological: Mean daily marsh depth, change in daily marsh depth
  - **Management: S-152 culvert condition, DPM implementation**
  - Trend, mean fish length, AR-1 (auto-regression)

Results: Vegetation Classification

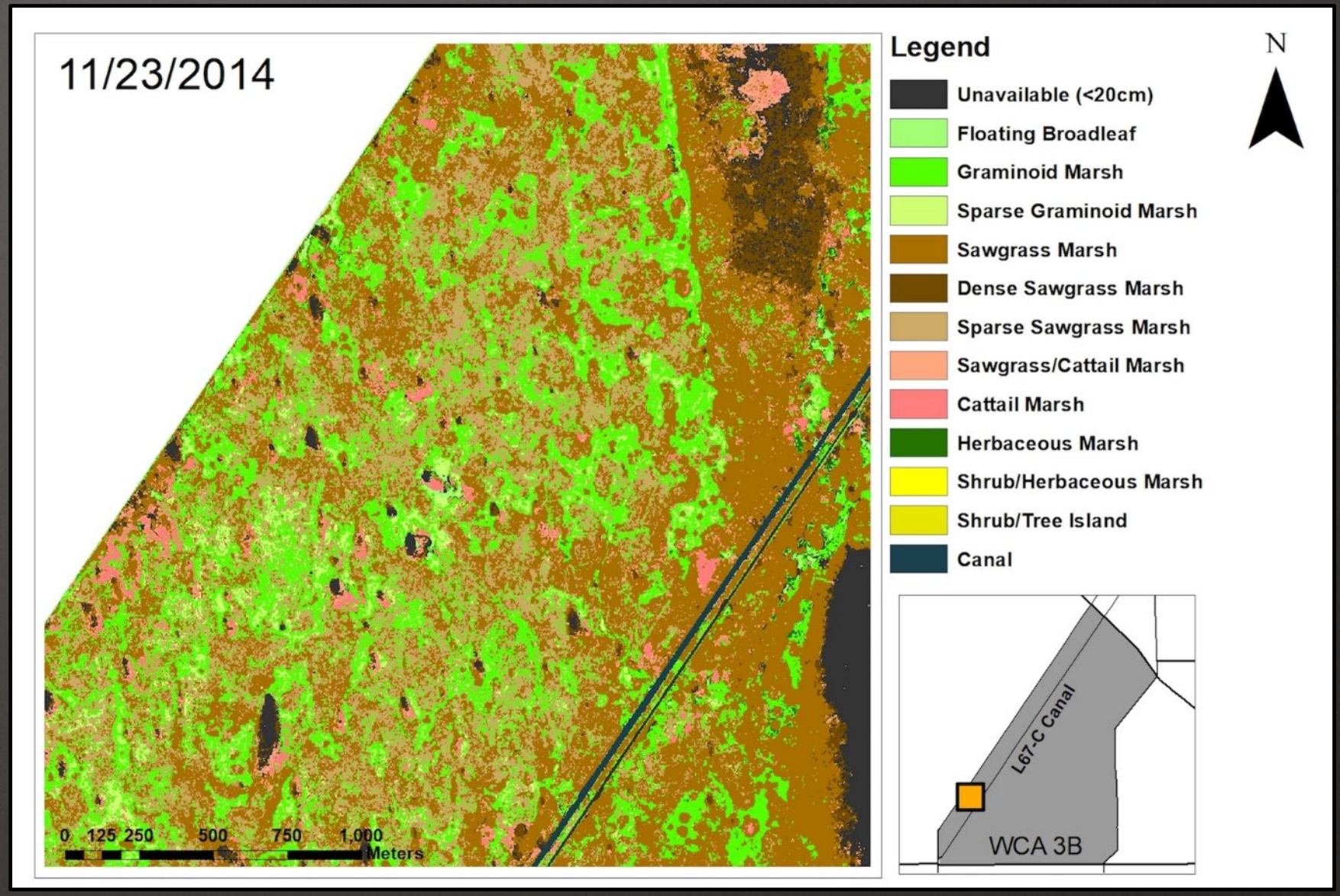




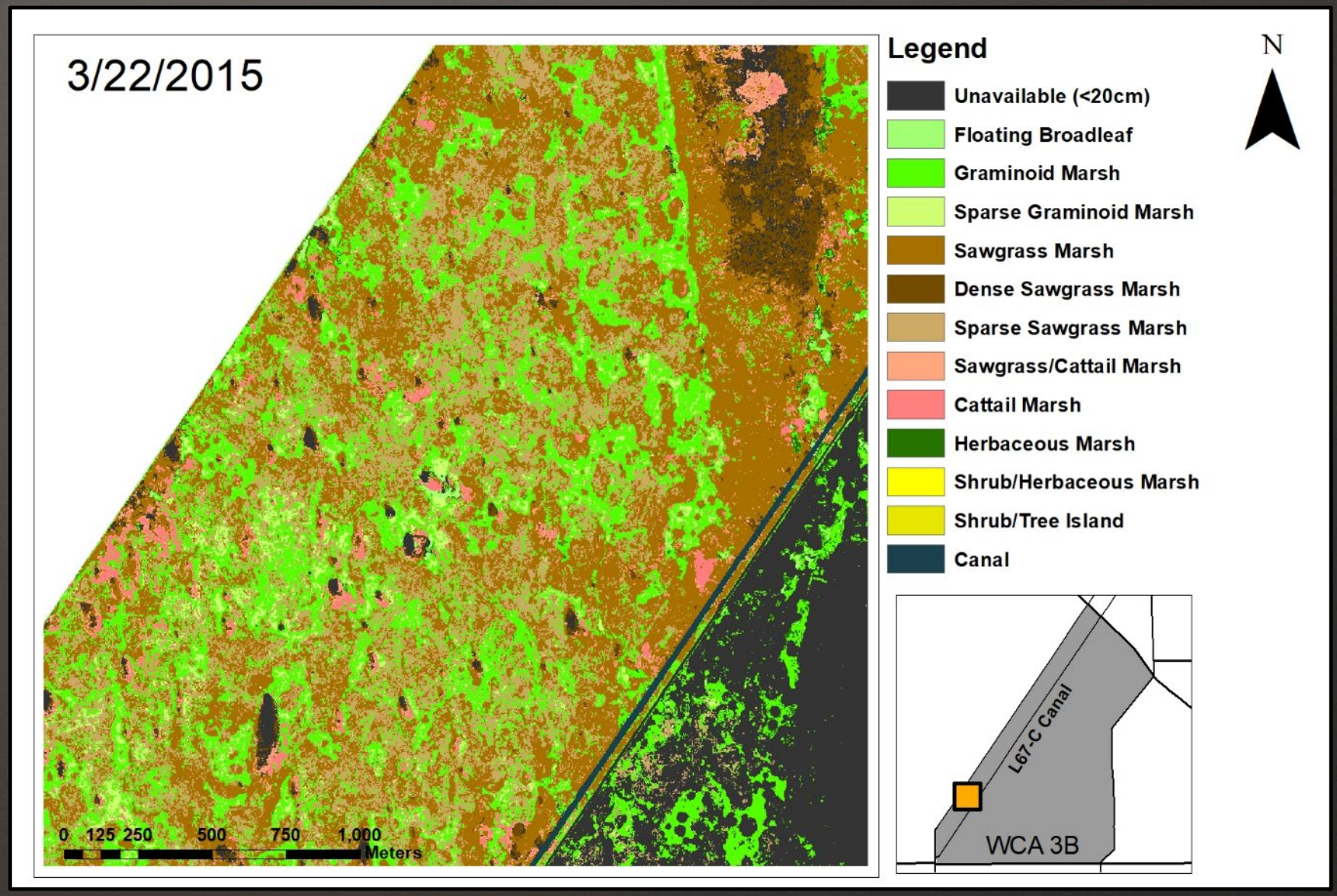
Legend

- Floating Broadleaf
- Graminoid Marsh
- Sparse Graminoid Marsh
- Sawgrass Marsh
- Dense Sawgrass Marsh
- Sparse Sawgrass Marsh
- Sawgrass/Cattail Marsh
- Cattail Marsh
- Herbaceous Marsh
- Shrub/Herbaceous Marsh
- Shrub/Tree Island
- Canal

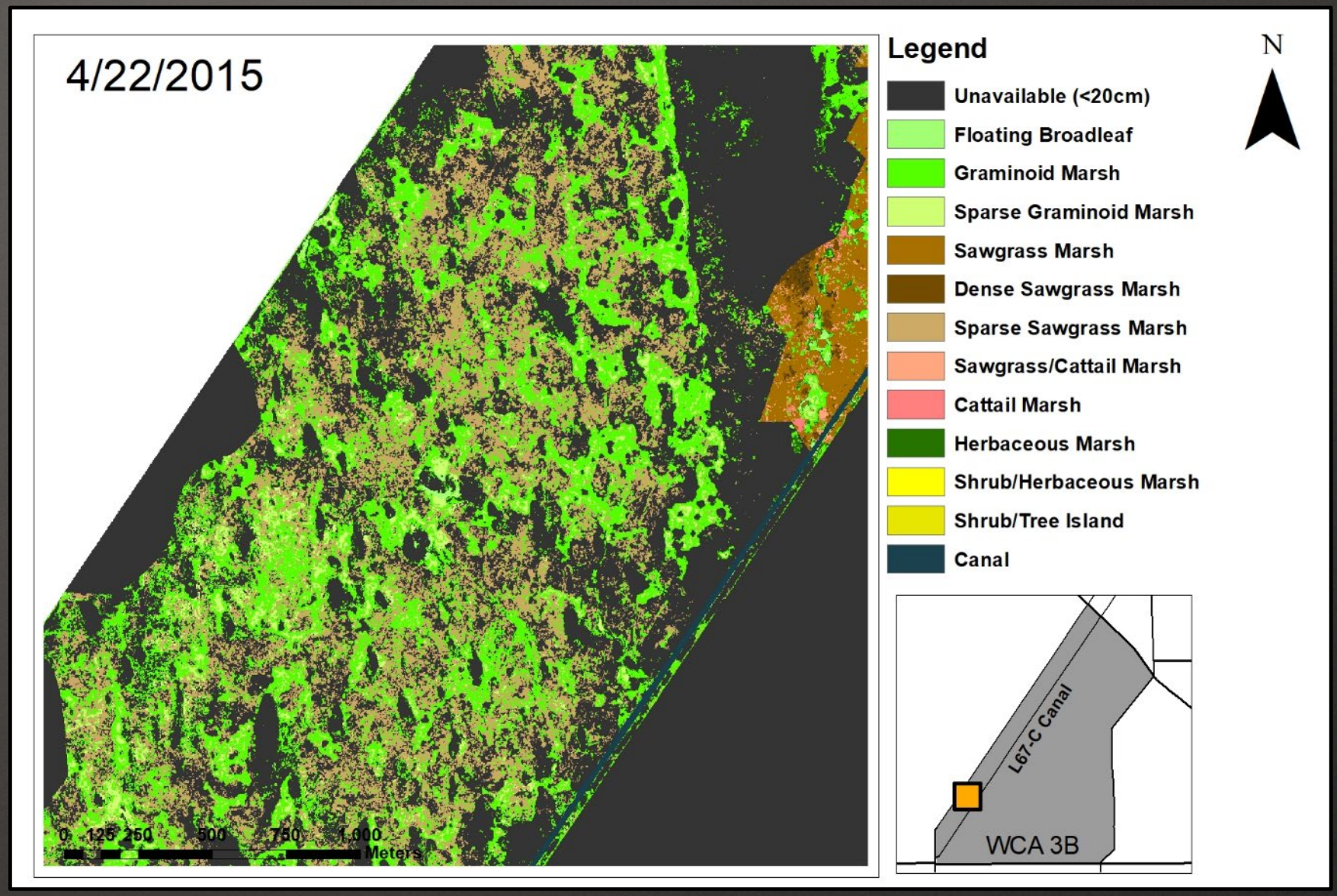
Results: Dynamic Mapping



Results: Dynamic Mapping



Results: Dynamic Mapping



Results: Weekly Habitat Preference

Objective 1: Determine which vegetation communities preferred by Largemouth Bass, Bowfin, and Florida Gar.

	LMB	Bowfin	Florida Gar
Floating Broadleaf	0	1.9%	0
Graminoid Marsh	0	0	0
Sparse Graminoid Marsh	0.4%	0.6%	0
Sawgrass Marsh	0	0	0
Dense Sawgrass Marsh	0	0	0
Sparse Sawgrass Marsh	6.5%	0.6%	0
Sawgrass/Cattail Marsh	0	0	0
Cattail Marsh	0	0	0
Herbaceous Marsh	0	0	0
Canal	50.2%	27.9%	26.5%

Results: Weekly Habitat Preference

Objective 2: Determine if hydrological factors, environmental factors, or factors associated with DPM affect habitat preference of focal species.

Model	-2 Log Psuedo Likelihood	Psuedo-AICc	ΔAICc	w_i
LMB				
Trend + Length + Temp + Photo + DPM	400.55	404.60	-	0.83087
Trend + Length + Temp + Photo + DPM + S-152	403.84	407.90	3.30	0.15957
Trend + Length + Temp + Photo + DPM + Mean Depth	409.86	413.91	9.31	0.00790
Trend + Length + Temp + Photo + DPM + S-152 + Mean Depth	413.02	417.08	12.48	0.00162
Trend + Length + Temp + Photo + DPM + S-152 + Mean Depth + Δ Depth	420.78	424.83	20.23	0.00003
Length + Temp + Photo	431.68	435.74	31.14	0.00000
Trend + Length + Temp + Photo	442.11	446.16	41.56	0.00000

Results: Weekly Habitat Preference

	Estimate ± SE	Kenward-Rogers df	*F-value*	*P-value*
LMB Model: Trend + Length + Temp + Photo + DPM				
Trend	0.0008 ± 0.00	1, 222.5	0.85	0.3579
Length	0.1671 ± 0.03	1, 221.5	37.26	<0.0001
Temp	0.0648 ± 0.02	1, 208.7	13.84	0.0003
Photo	-0.1751 ± 0.05	1, 201.0	13.85	0.0003
DPM	0.8667 ± 0.12	1, 222.8	54.63	<0.0001

Canal selection ratios increase post-DPM!

Results: Weekly Habitat Preference

Objective 2: Determine if hydrological factors, environmental factors, or factors associated with DPM affect habitat preference of focal species.

Model	-2 Log Psuedo Likelihood	Psuedo-AICc	ΔAICc	w_i
Bowfin				
Trend + Temp + Photo + DPM	381.65	385.73	-	0.60592
Trend + Temp + Photo + DPM + S-152	382.78	386.87	1.14	0.34266
Trend + Temp + Photo + DPM + Mean Depth	387.35	391.43	5.7	0.03505
Trend + Temp + Photo + DPM + S-152 + Mean Depth	388.93	393.01	7.28	0.01591
Trend + Temp + Photo + DPM + S-152 + Mean Depth + Δ Depth	396	400.09	14.36	0.00046
Trend + Temp + Photo	404.42	408.51	22.78	0.00001
Temp + Photo	424.87	428.95	42.08	0.00000

Results: Weekly Habitat Preference

	Estimate ± SE	Kenward-Rogers df	*F-value*	*P-value*
Bowfin				
Model: Trend + Length + Temp + Photo + DPM				
Trend	0.0067 ± 0.00	1, 144.0	7.37	0.0074
Length	0.1093 ± 0.04	1, 143.4	7.92	0.0056
Temp	-0.0307 ± 0.03	1, 143.6	0.85	0.3568
Photo	-0.0943 ± 0.10	1, 137.4	0.97	0.3262
DPM	0.9291 ± 0.17	1, 134.5	28.38	<.0001
Model: Trend + Length + Temp + Photo + DPM + S-152				
Trend	0.0068 ± 0.00	1, 142.9	7.51	0.0069
Length	0.1062 ± 0.04	1, 141.8	7.32	0.0077
Temp	-0.0269 ± 0.03	1, 144.5	0.63	0.4297
Photo	-0.1211 ± 0.11	1, 144.7	1.23	0.2684
DPM	0.9508 ± 0.18	1, 135.6	28.17	<.0001
S-152	0.0926 ± 0.18	1, 124.5	0.26	0.6108

Canal selection ratios increase post-DPM!

Results: Weekly Habitat Preference

Objective 2: Determine if hydrological factors, environmental factors, or factors associated with DPM affect habitat preference of focal species.

Model	-2 Log Psuedo Likelihood	Psuedo-AICc	ΔAICc	w_i
Florida Gar				
Trend + Temp + Photo	133.91	138.11	-	0.66395
Trend + Temp + Photo + S-152	135.46	139.66	1.55	0.30589
Trend + Temp + Photo + S-152 + Δ Depth	140.93	145.14	7.03	0.01975
Trend + Temp + Photo + Mean Depth	142.34	146.55	8.44	0.00976
Trend + Temp + Photo + S-152 + Δ Depth + Mean Depth	147.76	151.97	13.86	0.00065

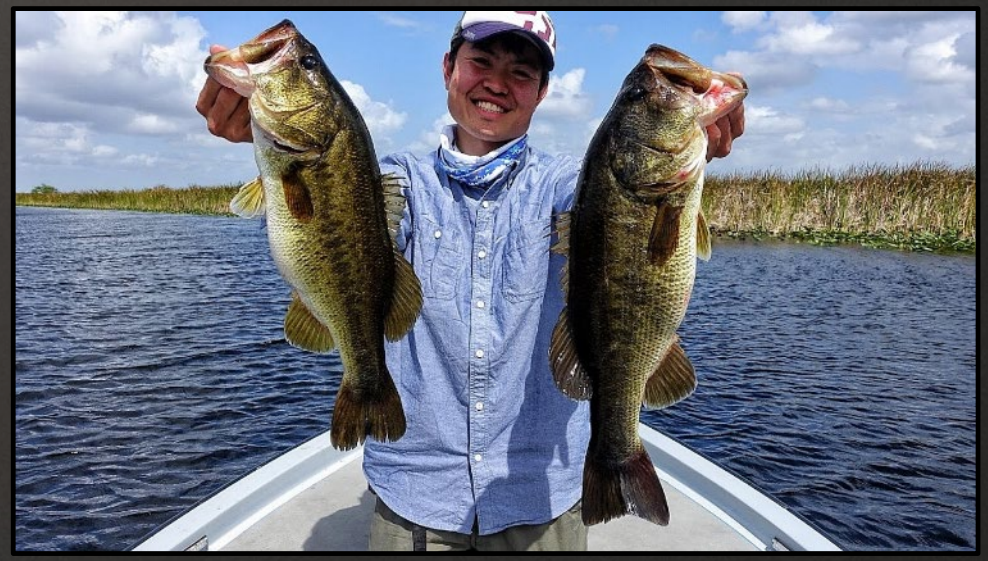
Results: Weekly Habitat Preference

	Estimate ± SE	Kenward-Rogers df	*F-value*	*P-value*
Florida Gar				
Model: Trend + Temp + Photo				
Trend	-0.0114 ± 0.00	1, 62.39	-3.41	0.0011
Temp	-0.0174 ± 0.04	1, 41.69	-0.44	0.6601
Photo	-0.2020 ± 0.10	1, 62.86	-1.95	0.0559
Model: Trend + Temp + Photo + S-152				
Trend	-0.0106 ± 0.00	1, 61.53	9.14	0.0036
Temp	-0.0270 ± 0.04	1, 39.44	0.4	0.5308
Photo	-0.1452 ± 0.13	1, 61.92	1.26	0.2664
S-152	-0.1415 ± 0.19	1, 61.11	0.58	0.4477

Canal selection ratios decrease during study, but effects of DPM are unclear

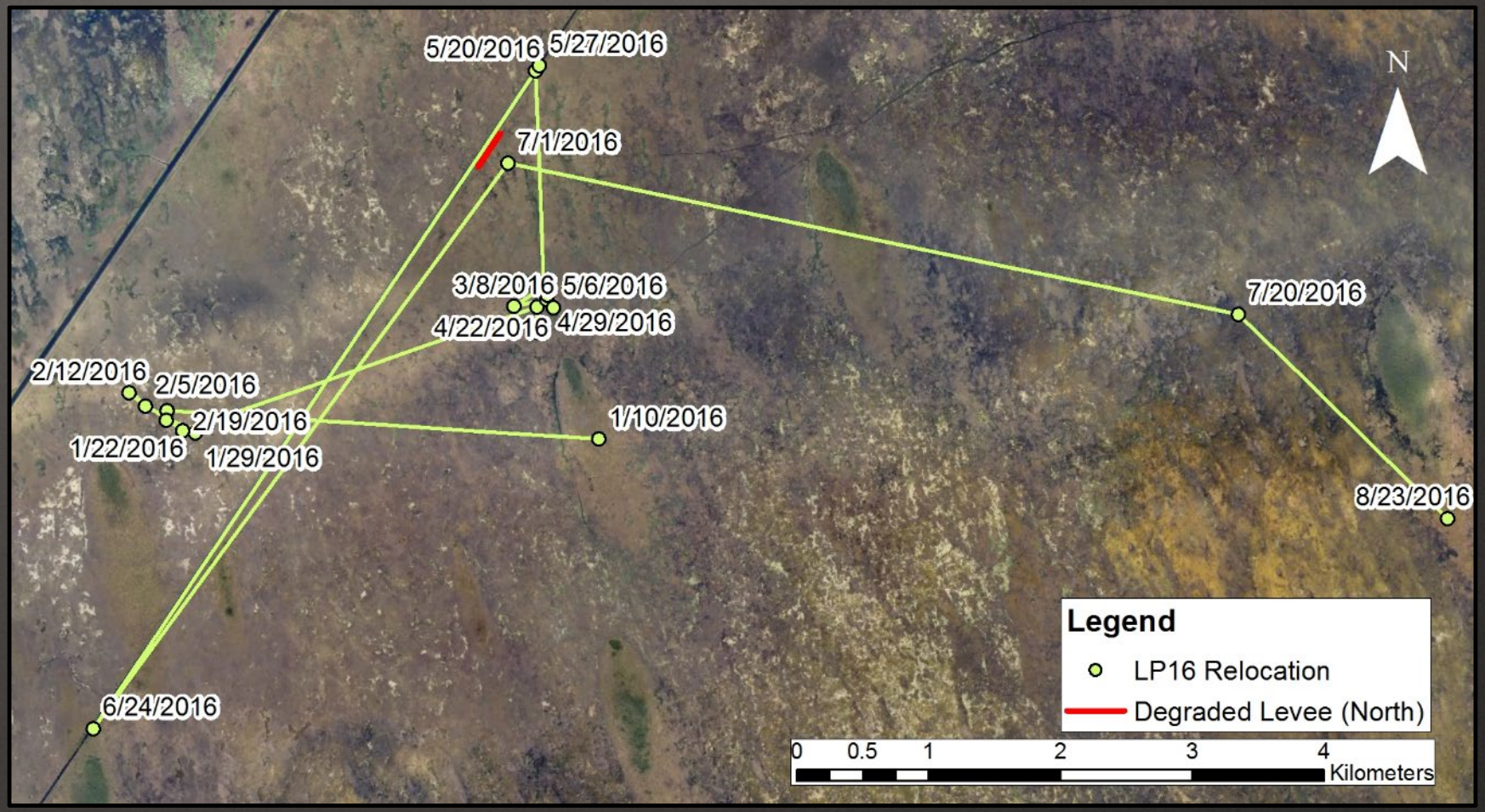
Discussion

- All three species demonstrate preference for canal habitat
  - Preference for sparse sawgrass, dense sawgrass, floating broadleaf, and sparse graminoid marsh
- Water management practices affect habitat use of study species
  - DPM implementation
  - S-152 culvert releases uncertain
- Canal backfilling may increase canal use
  - Modification of >7,300 m^2 L-67C canal
  - High-quality fish habitat
  - Increased prey density (Bush 2017)



Discussion

- Levee removal created corridor used by 17% of LMB, 11% Bowfin, and 32% Florida Gar



Acknowledgements

- Trexler Lab technicians
- Daniel Gann and Brittany Harris (FIU GIS Center)
- Mike Bush (FIU)
- Gary Roam (aviation support)
- Funded by the US Geological Survey for the DECOMP Physical Model (Cooperative Agreement G10AC00409)