Impacts of an Invasive Ecosystem Engineer Upon Wetlands and Aquatic Communities Across a Subtropical Agroecosystem

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Outline

1. Introduction
2. Wild Pig Diet
3. Drones and Pig Rooting
4. Impact of Invasive Fauna on Aquatic Communities
5. Indirect Impacts of Wild Pigs on Tadpoles
6. Conclusions

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1. Introduction – Wildlife & Agriculture

Where does wildlife conservation and management occur?

38% of world's land under agriculture

26% is rangeland

In Florida, rangeland is 486,000 ha (12 million ac) or 1/3 of land area

Florida's population may double by 2060
121,400 ha ag, 109,300 ha natural habitat converted

Wildlife conservation and management in agricultural lands is **critical**

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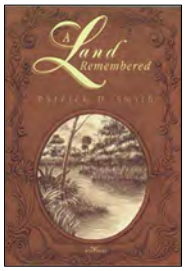
1. Introduction – Ranching in Florida

Long history

- Cattle first introduced by the Spanish in 1521
- Cracker cowmen of the 1800s

Florida home to five of top 10 cow/calf operations

$3 billion industry



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1. Introduction - Wild Pig (*Sus scrofa*)

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1. Introduction – Study Site

Buck Island Ranch
- 4,250 ha (10,500 ac)
- Cow-calf operation, top-20 in Florida
- South-central Florida, Everglades headwaters

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- 2 pasture types – improved and semi-native

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- Oak-palm woodlands
- 600+ seasonal wetlands
- 560 km of ditches

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- 600+ seasonal wetlands
- 560 km of ditches
- 36 study wetlands, 0.4-1.8 ha

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2. Wild Pig Diet

Past studies have used DNA metabarcoding to examine seasonal shifts in diet (Bergmann et al. 2015)

Studies have also examined wild pig diet using this technique (Robeson et al. 2017)

However, none have examined seasonal shifts in diet of wild pigs

Objectives:

1. Inventory diet items
2. Compare diet shifts across an entire year
3. Evaluate impacts on wetland species with an emphasis on amphibians

Collaboration with: Boughton lab (UF), Wisely lab (UF), Boughton lab (Archbold), Piaggio lab (USDA), Robeson lab (UAMS)

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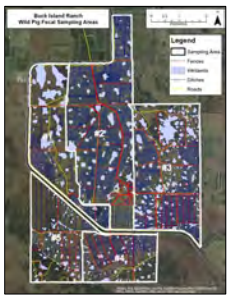
2. Wild Pig Diet

March 2016 – February 2017

Ranch divided into 5 sampling areas

≥ 5 fecal samples every 2 months



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2. Wild Pig Diet

219 total samples

Discarded 23

- 17 non-suid, 6 too old

196 samples retained

QAQC of BLAST Consensus Lineages – previously published primer sets (trnL, CO1, 12S)

1. Each OTU reviewed
2. BLAST results compared to local species inventories and primary literature
3. Identified to lowest taxonomic level
4. Discarded any not identified to Family
5. CO1 & 12S – Pig and human OTUs removed
6. CO1 – certain taxa immediately excluded

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2. Wild Pig Diet

- CO1 primers – 7 taxa undetected by 12S
  - Fish (1), Amphibian (3), Reptile (2), Mammal (1)
- 12S – 6 taxa undetected by CO1
  - Fish (3), Amphibian (2), Mammal (1)

Scientific Name	CO1 Frequency	12S Frequency
Fish		
Amia calva	1	2
Etheostoma fusiforme	1	0
Erimyzon sucetta	0	16
Notropis sp.	0	1
Clarias batrachus	0	1
Amphibian		
Pseudobranchus axanthus	2	0
Siren sp.	4	0
Gastrophryne carolinensis	2	0
Lithobates grylio	0	4
Lithobates sphenocephalus	0	8
Reptile		
Kinosternon steindachneri	2	0
Gopherus polyphemus	4	3
Alligator mississippiensis	1	2
Anolis carolinensis	1	0
Mammal		
Dasypus novemcinctus	0	1
Didelphis virginiana	14	6
Peromyscus gossypinus	59	1
Mus musculus	48	63
Rattus rattus	14	0
Bos taurus/indicus	48	73
Odocoileus virginianus	22	14
Procyon lotor	42	13
Canis latrans	3	1

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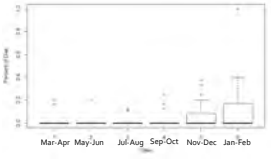
2. Wild Pig Diet

Wetland animal taxa across time
- Percent of diet differs with peak in January-February

5 amphibian taxa consumed
- Eastern narrow-mouthed toad
- Siren (4) and dwarf siren (2)
  - Only in January-February
- Pigs are rooting up and consuming aestivating salamanders



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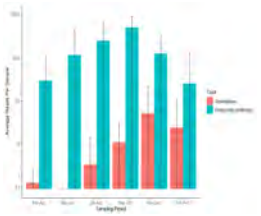
2. Wild Pig Diet

What are they rooting for?

Exotic earthworm (*Pontoscolex corethrurus*) detected in 84% of samples with significant temporal change in hits/sample
- Highest from September to October
- Invasive species, common in agricultural areas and found in circumtropical distribution across 56 countries (González et al. 2006)
- Coincides with frequency of acorn consumption
- No knowledge of on-site worm density, but presumably high
- Possible facilitation of one invasive species by another?

- Earthworms in the fall, wetland-dependent fauna in the winter



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3. Drones and Pig Rooting

Develop rooting analysis protocol

- Obtain UAV-derived imagery for study areas
- Mosaic imagery to create a single georeferenced image
- Perform spatial analyses on mosaicked image to quantify extent of rooted areas
- Fly 36 wetlands and 24 pastures 4 times during dry season for 3 years

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3. Drones and Pig Rooting

Drone – DJI Phantom 4

Map Pilot for DJI App

Open app in field

Input flight parameters

Mission saved and reflown with same parameters for each subsequent flight

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3. Drones and Pig Rooting

- 35-140 images / wetland

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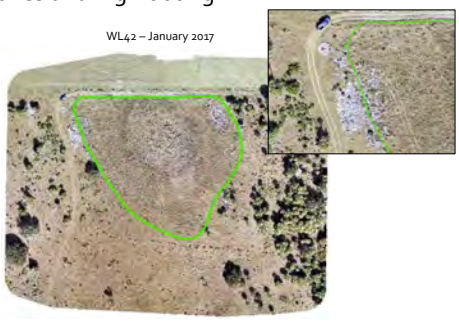
3. Drones and Pig Rooting

WL42 – January 2017



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3. Drones and Pig Rooting

Classify Raster

Train ArcGIS by classifying a subset of pixels

Perform a Maximum Likelihood Classification analysis

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3. Drones and Pig Rooting

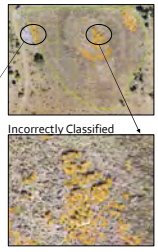
Delete incorrectly-classified polygons

Create fishnet to form grid

Delete incorrectly classified polygons

Correctly Classified

Incorrectly Classified



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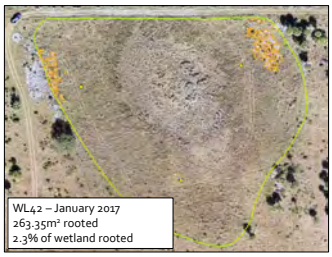
3. Drones and Pig Rooting

Calculate Extent of Rooting Damage



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4. Impact of Invasive Fauna on Aquatic Communities

Salamanders - Sirens and amphiumas

- Two-toed amphiuma (*Amphiuma means*)
- Greater siren (*Siren lacertina*)
- Lesser siren (*Siren intermedia*)



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4. Impact of Invasive Fauna on Aquatic Communities

Does rooting in wetlands impact aquatic salamanders?

Trapped salamanders from 2016-2018
July-November (varied by conditions)

15 crayfish traps randomly placed in each study wetland, checked once a day for 5 days

Salamanders collected and returned to lab
Measured, marked, and released

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4. Impact of Invasive Fauna on Aquatic Communities

84 greater sirens

8 lesser sirens

and 16 two-toed amphiumas captured

Different distributions across ranch

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4. Impact of Invasive Fauna on Aquatic Communities

All taxa, not just salamanders, recorded

Large data set on fish, snakes, turtles, and invertebrates

7 exotic taxa – 6 fish, 1 snail

- African jewelfish, brown hoplo, blue tilapia, walking catfish, black acara, sailfish catfish, Island apple snail

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4. Impact of Invasive Fauna on Aquatic Communities

37 taxa trapped
- 15,523 individuals over 7,311 trap nights
- 6 amphibians, 10 reptiles, 13 fish, 1 mammal, 2 snails, 1 crayfish, 4 insects

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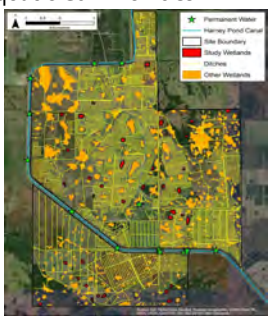
4. Impact of Invasive Fauna on Aquatic Communities

Multivariate community analysis

Environmental variables
- Year
- Pasture type and location
- Wetland area, maximum depth
- Average trap depth
- Distance to nearest ditch
- Distance to nearest wetland and permanent water

Exotic species variables
- Cumulative rooted wetland area
- Relative abundance of island apple snail, jewelfish, brown hoplo, walking catfish, and blue tilapia



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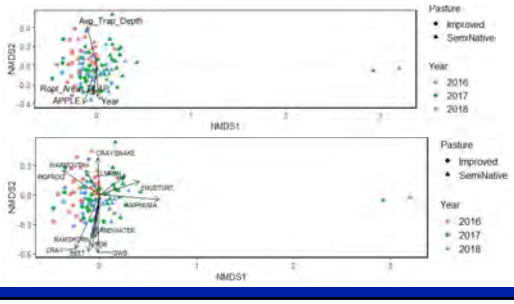
4. Impact of Invasive Fauna on Aquatic Communities

Non-metric multidimensional scaling (NMDS)



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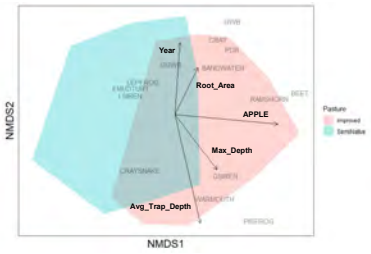
4. Impact of Invasive Fauna on Aquatic Communities

Non-metric multidimensional scaling (NMDS)

- Removed outlier wetland



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4. Impact of Invasive Fauna on Aquatic Communities

Invasive Species Associations - mvabund

Native Species	Invasive Impact	r	p-value
Florida Watersnake	African Jewelfish	0.57	0.004
	Brown Hoplo (South of Canal Only)	0.19	0.03
	Blue Tilapia	0.67	<0.001
Florida Green Watersnake	Brown Hoplo	0.36	<0.001
	Blue Tilapia	0.39	<0.001
Striped Mud Turtle	Brown Hoplo (North of Canal Only)	-0.22	0.03
Florida Mud Turtle	Island Apple Snail (North of Canal Only)	-0.25	0.02
	Pig Rooting (2018 Only)	-0.43	0.007
Golden Topminnow	African Jewelfish (2016 Only)	-0.36	0.02
Warmouth	Brown Hoplo (Improved Pasture Only)	0.27	0.03
	Walking Catfish (Improved Pasture Only)	0.35	0.006
Green Giant Water Bug	African Jewelfish	-0.95	0.01
Water Scavenger Beetle	Island Apple Snail	0.50	<0.001
Ramshorn Snail	Island Apple Snail	0.59	<0.001

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4. Impact of Invasive Fauna on Aquatic Communities

Impacts on native fishes?

- Negative correlation between jewelfish and topminnows
  - Competition? Predation?

Impacts on native herpetofauna?

- Watersnakes benefiting from these exotic fish invasions?
  - Does this have individual or population-level consequences?
- Pig impacts on small semi-aquatic turtles?

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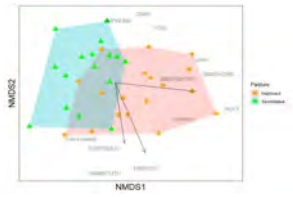
4. Impact of Invasive Fauna on Aquatic Communities

Very dynamic environments

Community structure strongly driven by habitat type and year

No two years with same hydropattern



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5. Indirect Impacts of Wild Pigs on Tadpoles

Frogs
- Important prey
- Consume ***lots*** of insects
- Energy flow from aquatic to upland habitats

Global amphibian declines

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5. Indirect Impacts of Wild Pigs on Tadpoles

Are pigs indirectly affecting species' abundances?
Dip netted 36 wetlands for tadpoles from 2016-2018
For each dip, the number of tadpoles of each species were recorded
For non-rooted wetlands: 25 dips
For rooted wetlands: 50 dips (half in rooted areas)
Dips in 10-40 cm of water

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5. Indirect Impacts of Wild Pigs on Tadpoles

In 2018, all wetlands sampled 3 times
1715 tadpoles in unrooted areas
14/36 wetlands rooted
Additional tadpoles from rooted areas was 254
Total of 1969
Squirrel treefrog (*Hyla squirella*) – 985
Southern cricket frog (*Acris gryllus*) – 354
Eastern narrow-mouthed toad (*Gastrophryne carolinensis*) – 196
Green treefrog (*H. cinerea*) – 175

Some species restricted to one habitat type:
Barking Treefrog (*H. gratiosa*) and Pinewoods Treeforg (*H. femoralis*)

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5. Indirect Impacts of Wild Pigs on Tadpoles

Comparison of captures between non-rooted areas and rooted areas (n = 14)

Species	Non-Rooted Areas (# Captured)	Rooted Areas (# Captured)	Percent Change
Southern Cricket Frog (*Acris gryllus*)	151	50	-66.89
Eastern Narrow-Mouthed Toad (*Gastrophryne carolinensis*)	104	66	-36.54
Green Treefrog (*Hyla cinera*)	64	13	-79.66
Pine Woods Treefrog (*Hyla femoralis*)	20	4	-80.00
Barking Treefrog (*Hyla gratiosa*)	2	0	-100.00
Squirrel Treefrog (*Hyla squirella*)	382	112	-70.68
Pig Frog (*Lithobates grylio*)	1	1	0.00
Southern Leopard Frog (*Lithobates sphenocephalus*)	20	15	-25.00
Little Grass Frog (*Pseudacris ocularis*)	2	2	0.00
All Species	746	263	-64.75%

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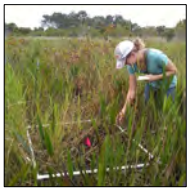
5. Indirect Impacts of Wild Pigs on Tadpoles

Incorporate vegetation data into analysis
- Four 1m² quadrats in rooted and non-rooted areas
- Stem counts, species richness

Incorporate select landscape and trap density estimates



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5. Indirect Impacts of Wild Pigs on Tadpoles

Construct a global model to evaluate difference between rooted and non-rooted areas and dredge for importance weights
- Tadpole ~ Apple Snail + Cattle Density:Pasture Type + Giant Water Bug Abundance + Jewelfish Abundance + Naiad Abundance + Plant Species Richness + Area Rooted + Rooted Status + Stem Count + (1|Wetland ID)

Species	Apple Snail	Cattle:Pasture	Giant Water Bug	Jewelfish	Naiad	Plant Species	Rooted Area	Sampling Area	Stem Count
Southern Cricket Frog	0.31	0.69	0.23	0.47	0.49	0.30	0.28	0.08	**0.99**
Eastern Narrow-Mouthed Toad	0.25	**0.83**	0.73	0.22	0.40	0.39	0.30	0.31	0.28
Green Treefrog	0.61	0.17	0.24	0.23	**0.85**	0.33	0.56	0.49	0.55
Pine Woods Treefrog	**0.87**	0.77	0.86	0.55	0.46	0.46	0.25	0.11	0.27
Squirrel Treefrog	0.20	0.75	0.41	0.24	0.54	0.77	0.20	0.55	**0.84**
All Species	0.24	0.51	0.22	0.22	0.22	0.29	0.23	0.12	**1.00**

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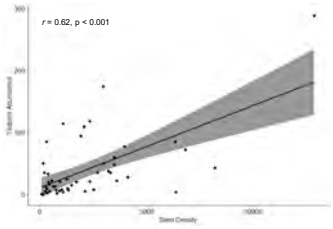
5. Indirect Impacts of Wild Pigs on Tadpoles

Correlation between stem count and cricket frog tadpole abundance



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6. Conclusions

Pig Diet

Eating amphibians, consuming salamanders in winter

Drones & Rooting

Developed efficient method to measure rooting

Impact of Invasive Fauna

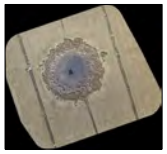
Community structure impacted strongly by habitat and year

Evidence that some invasive species associated with differences in community

Impacts on Tadpoles

Decline from non-rooted to rooted areas; stem density important for most abundant spp.



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