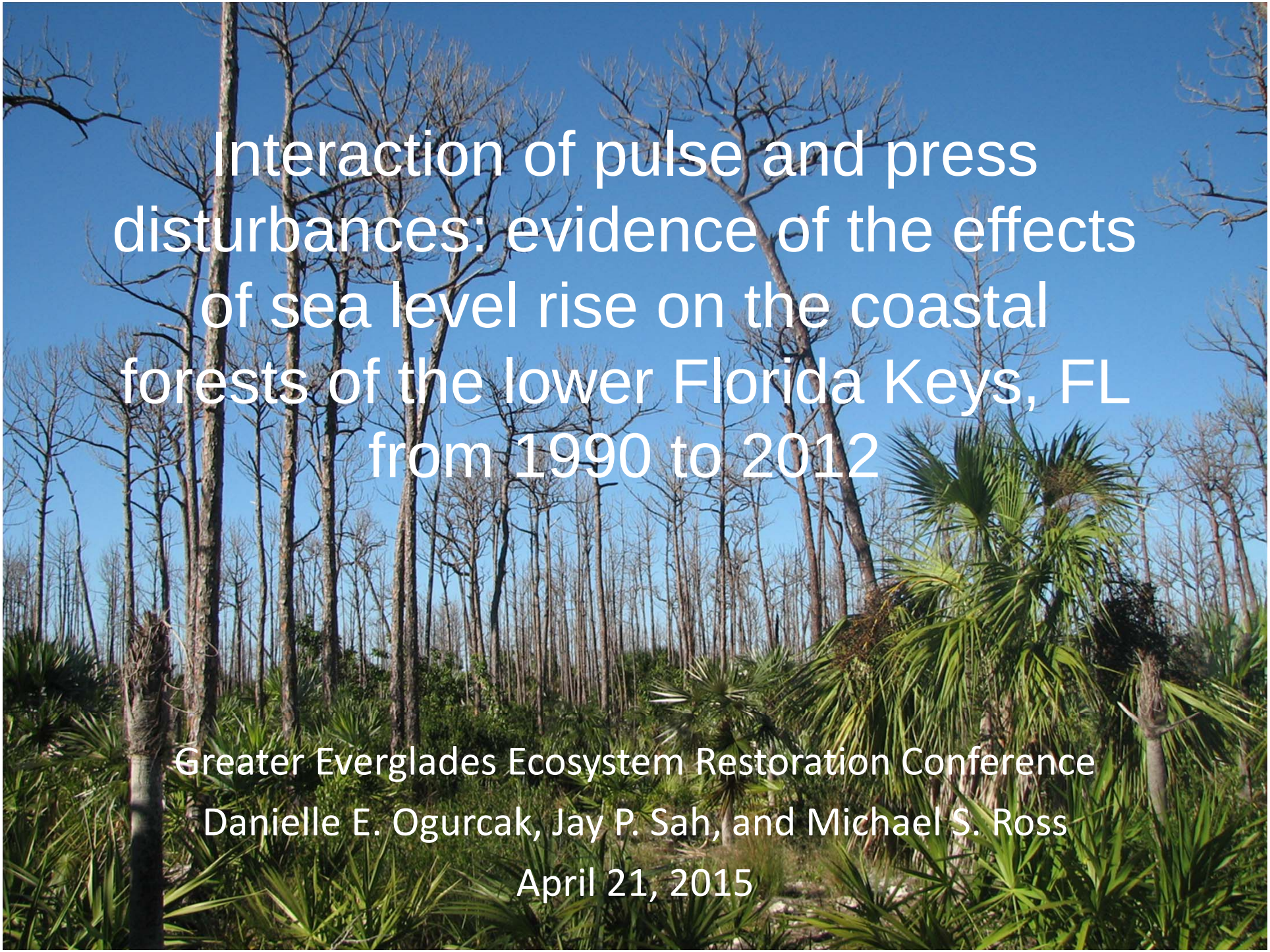


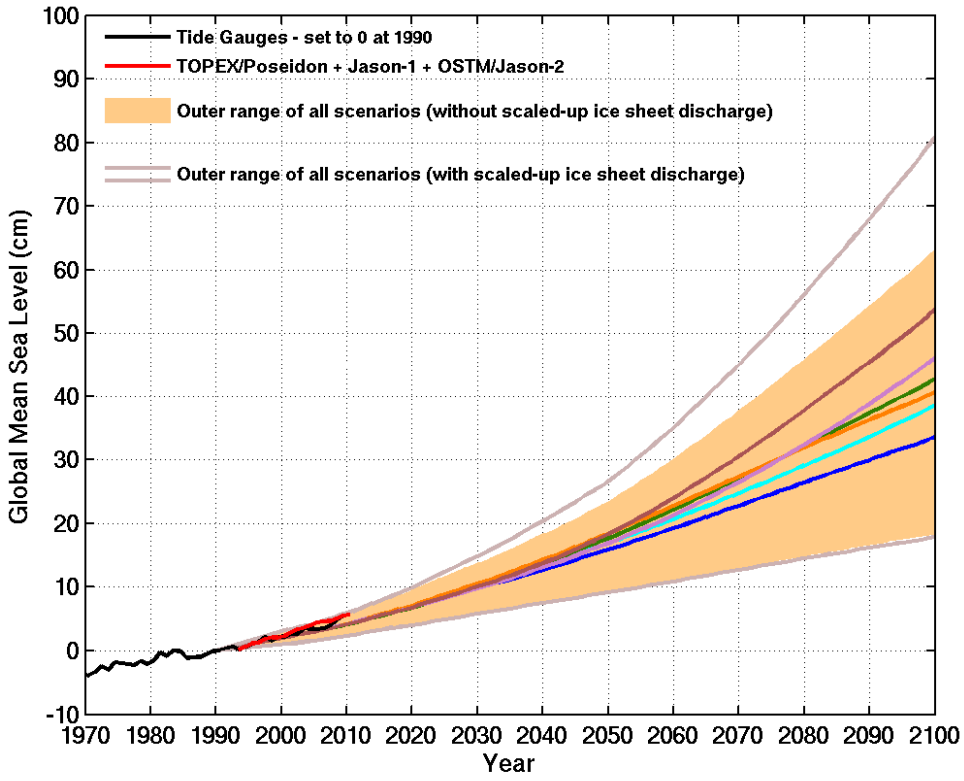
Interaction of pulse and press disturbances: evidence of the effects of sea level rise on the coastal forests of the lower Florida Keys, FL from 1990 to 2012

Greater Everglades Ecosystem Restoration Conference

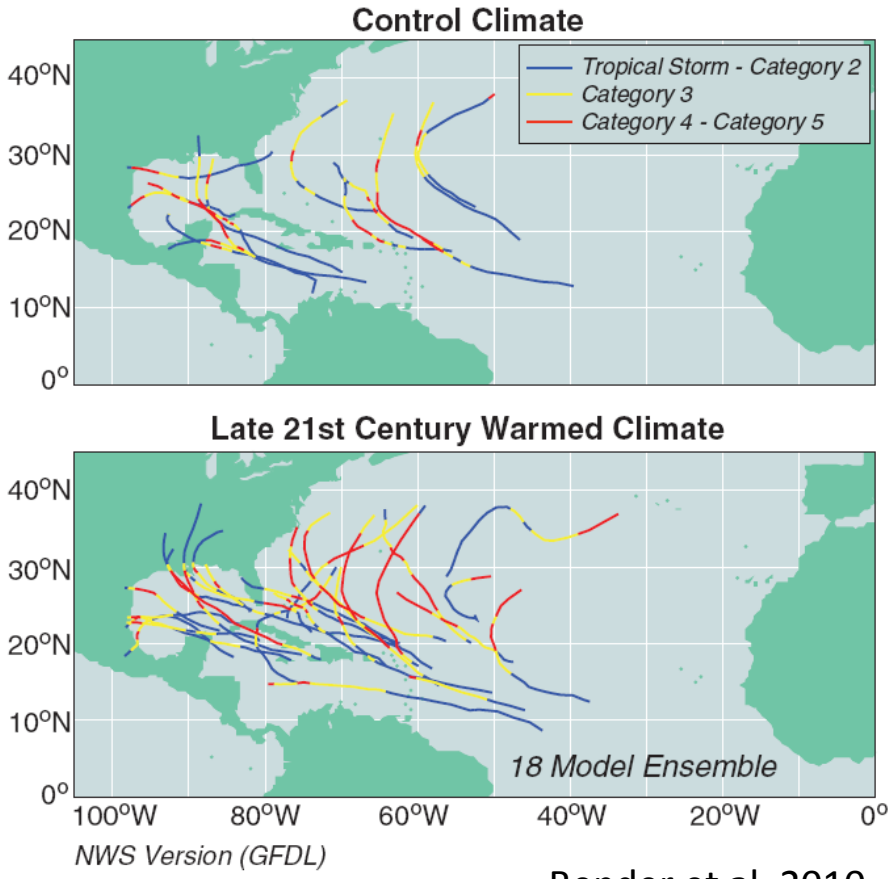
Danielle E. Ogurcak, Jay P. Sah, and Michael S. Ross

April 21, 2015

Press (sea level rise) and pulse (hurricane storm surge) disturbances in south Florida in the 21st century



Church et al. 2011

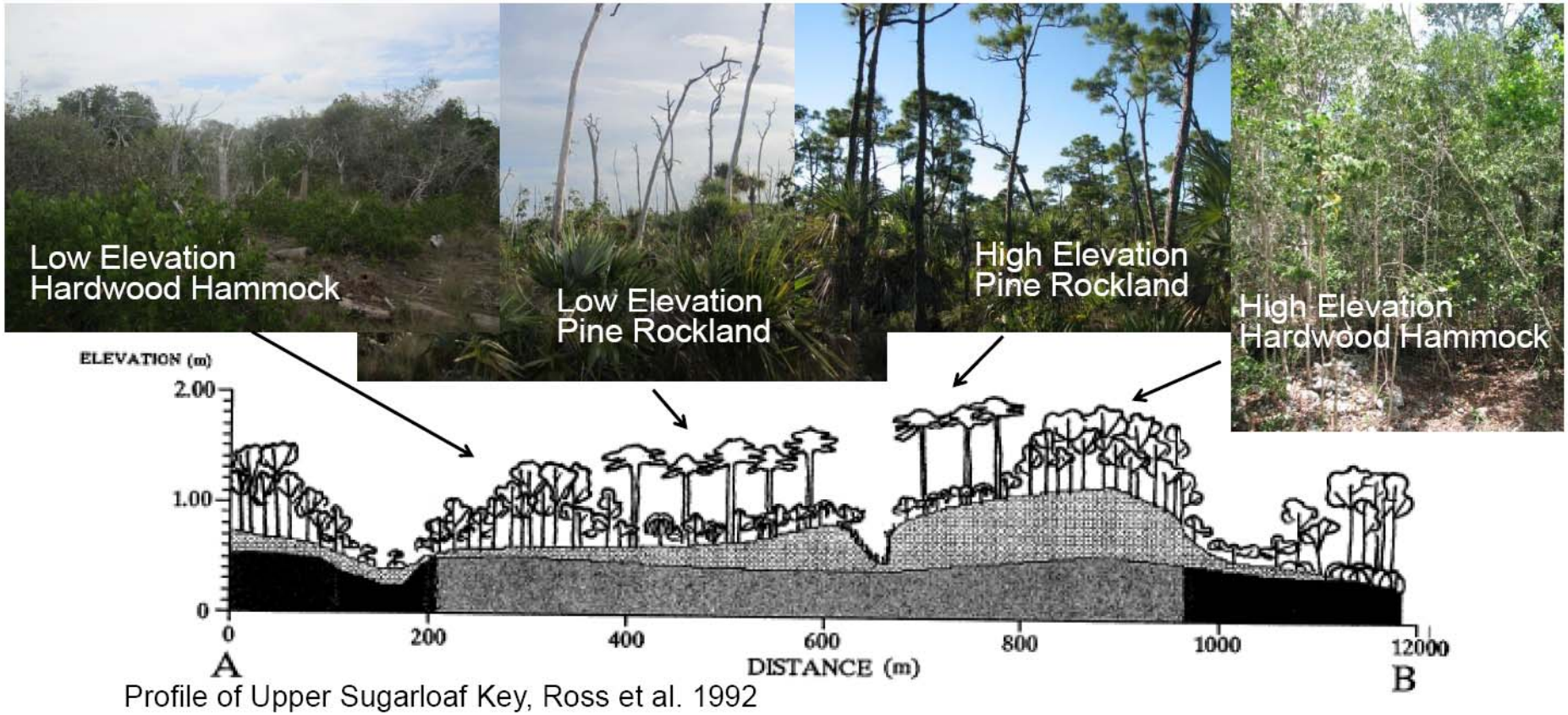


Bender et al. 2010

Press (Ramp) : continual, leading to permanent change in species composition and/or abundance

Pulse : short-term, causing sudden change in species abundance and/or composition which will recover once disturbance ceases

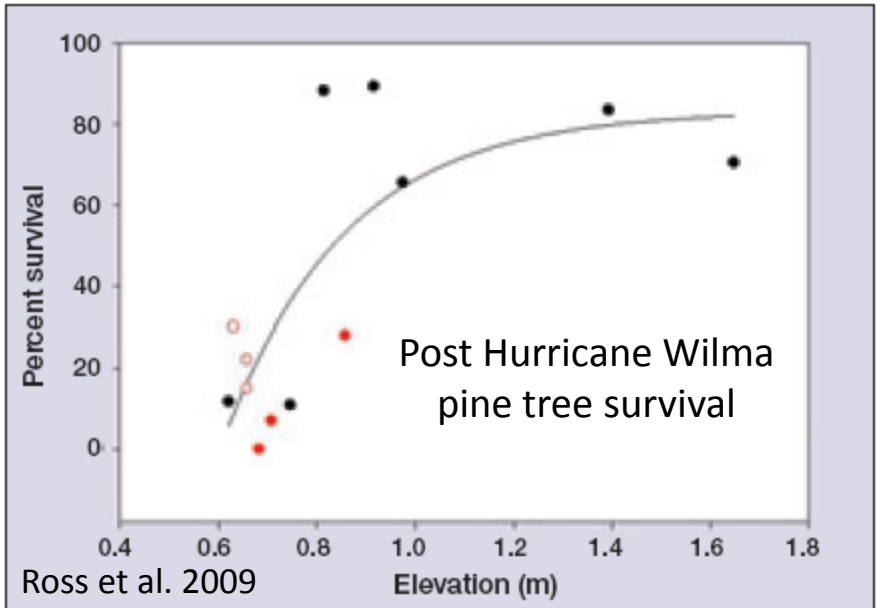
Pine Rockland & Hardwood Hammock Forest Communities of the Lower Florida Keys



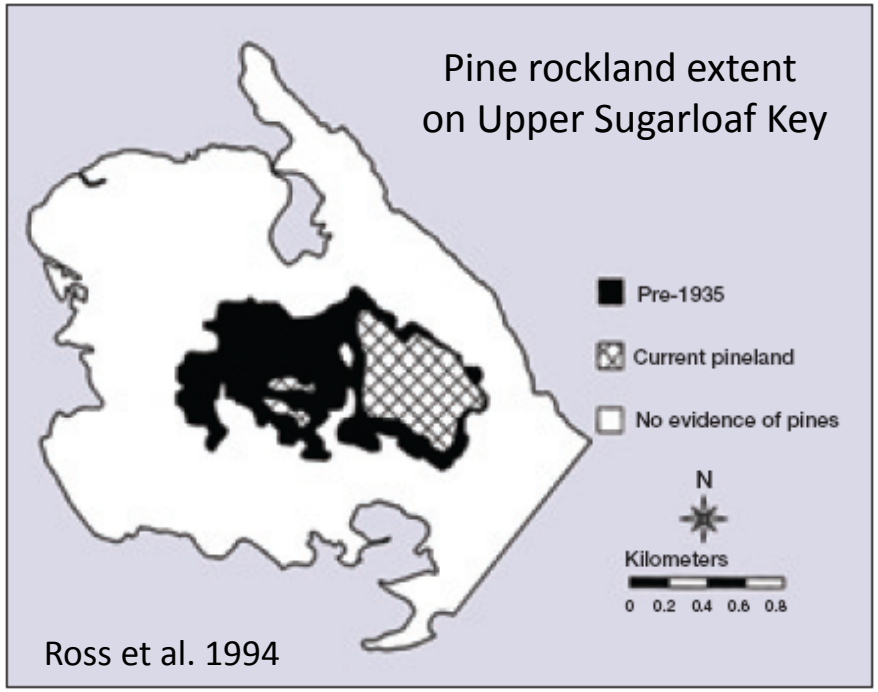
Profile of Upper Sugarloaf Key, Ross et al. 1992

- Elevations range from 0.3 to 2.0 meters above mean sea level
- Provide habitat for many species / high biodiversity
- Disturbance-adapted communities

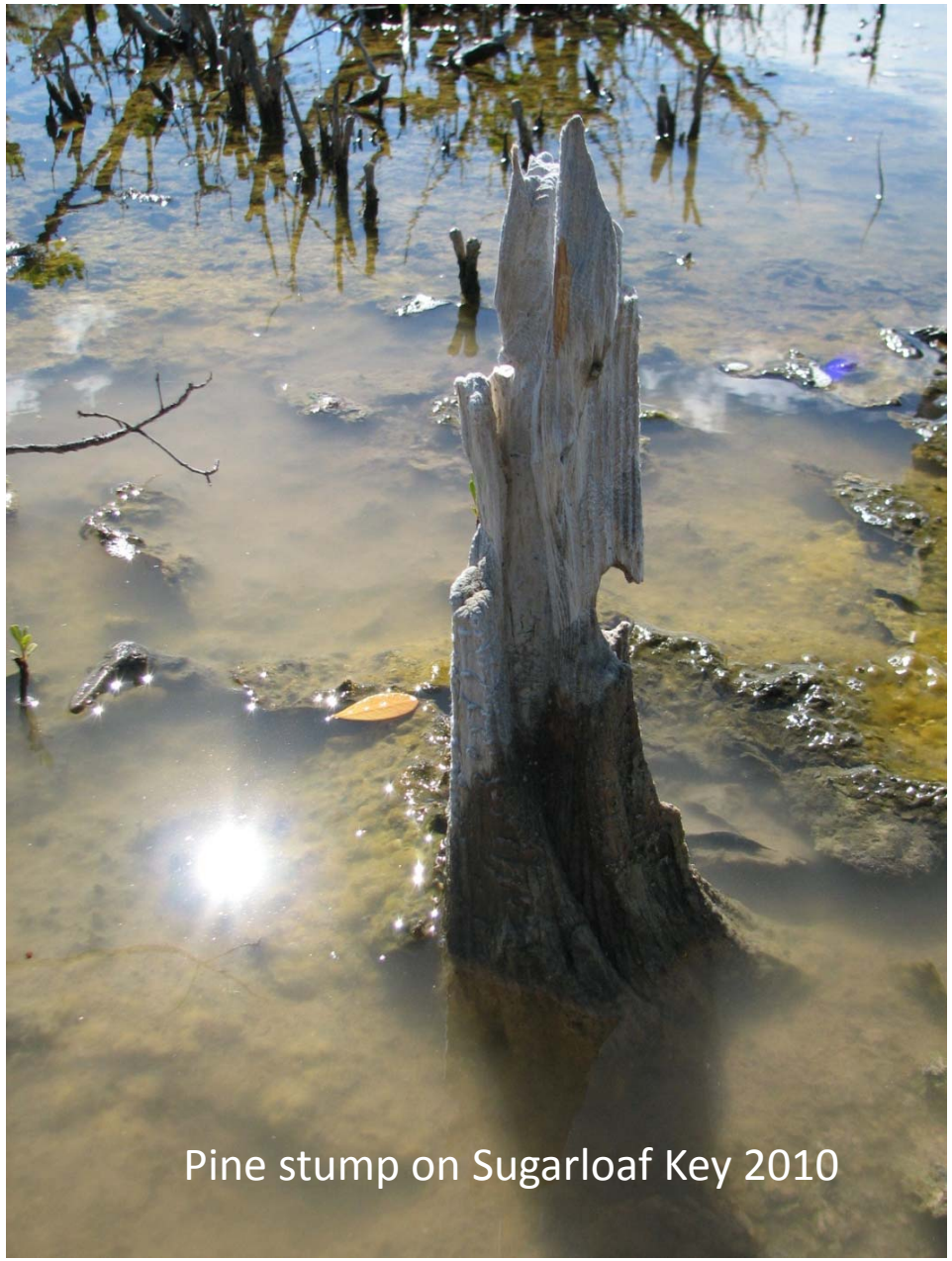
Effects to coastal forests during the 20th Century



Ross et al. 2009



Ross et al. 1994


Pine stump on Sugarloaf Key 2010

Florida Keys: Location and Geology

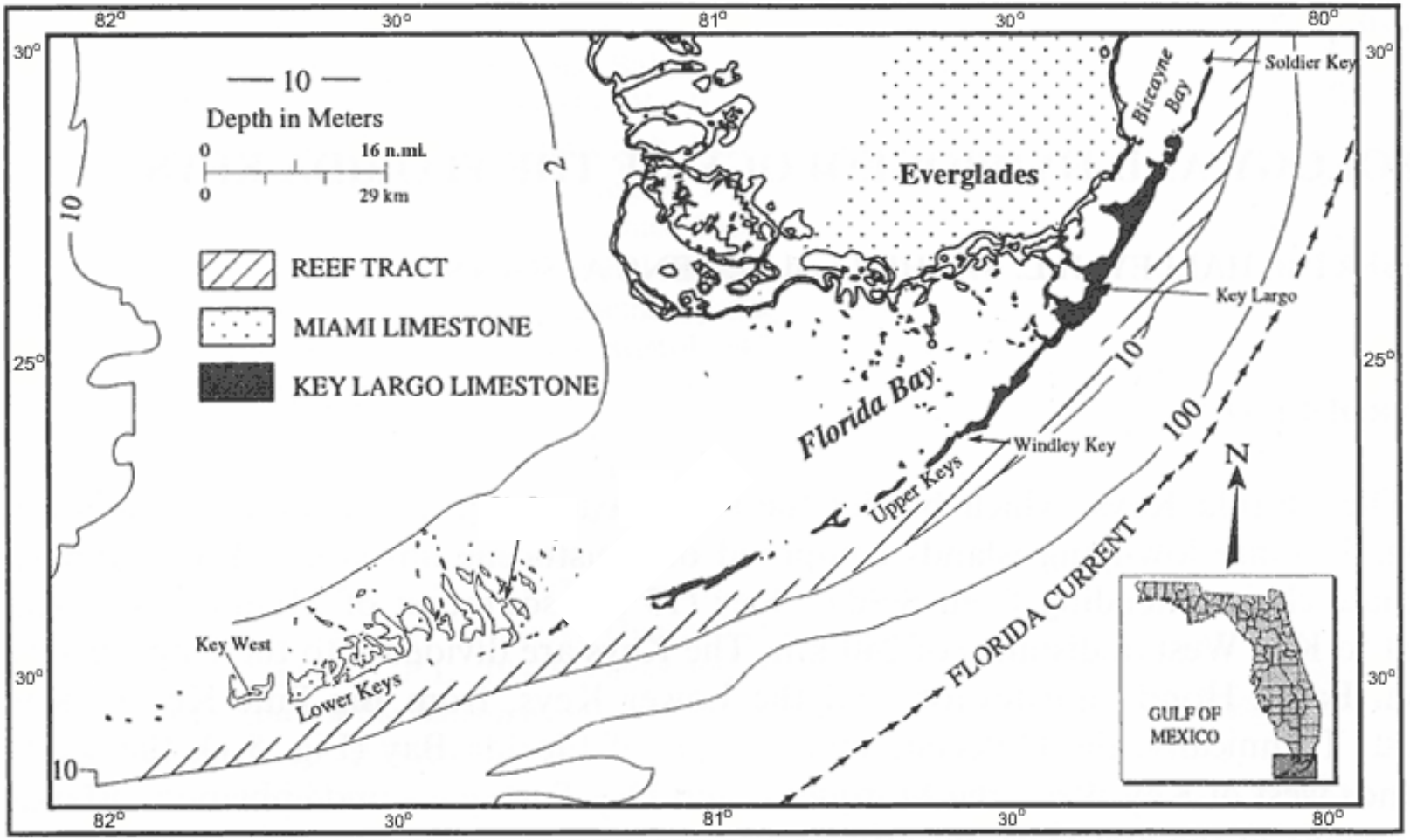
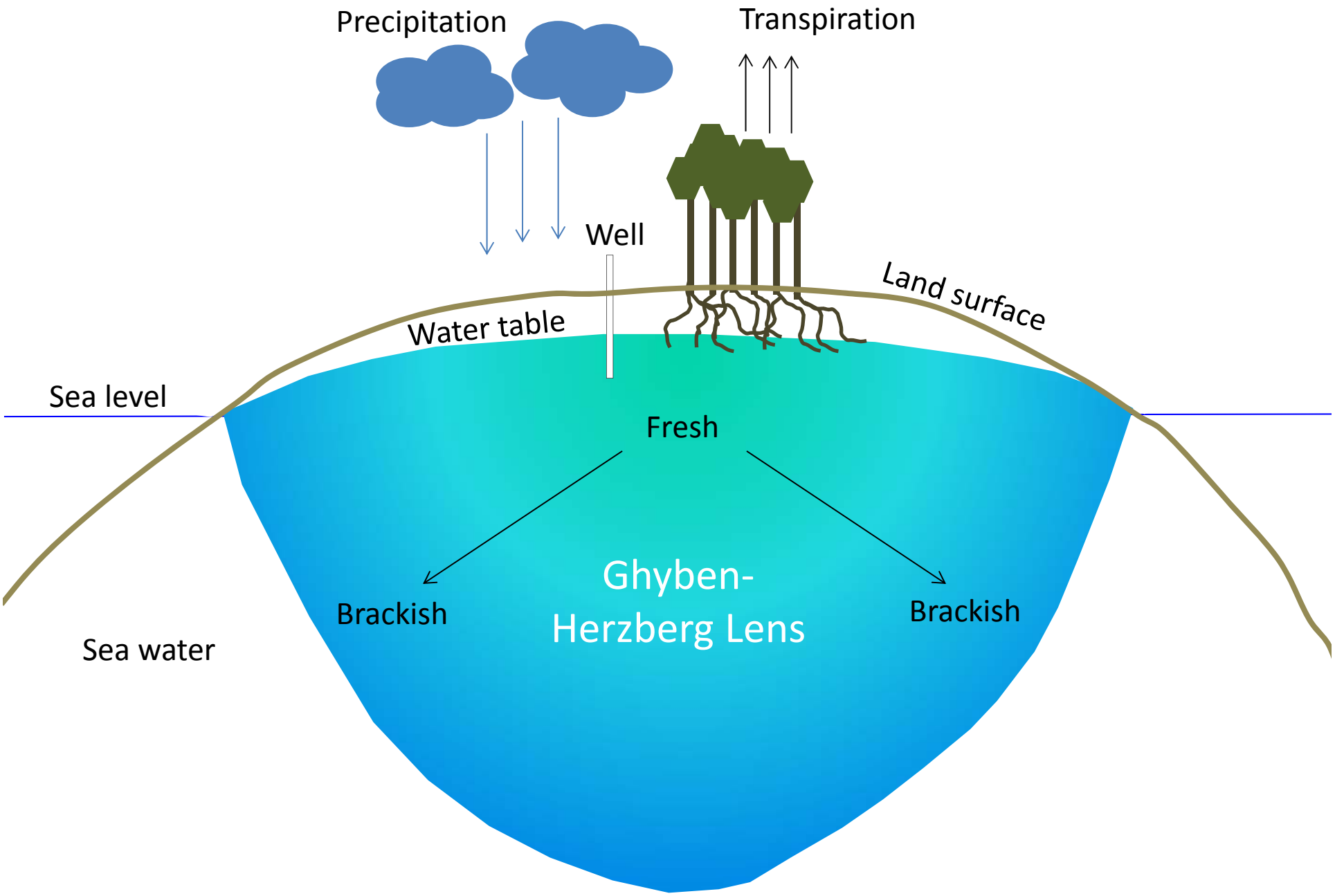
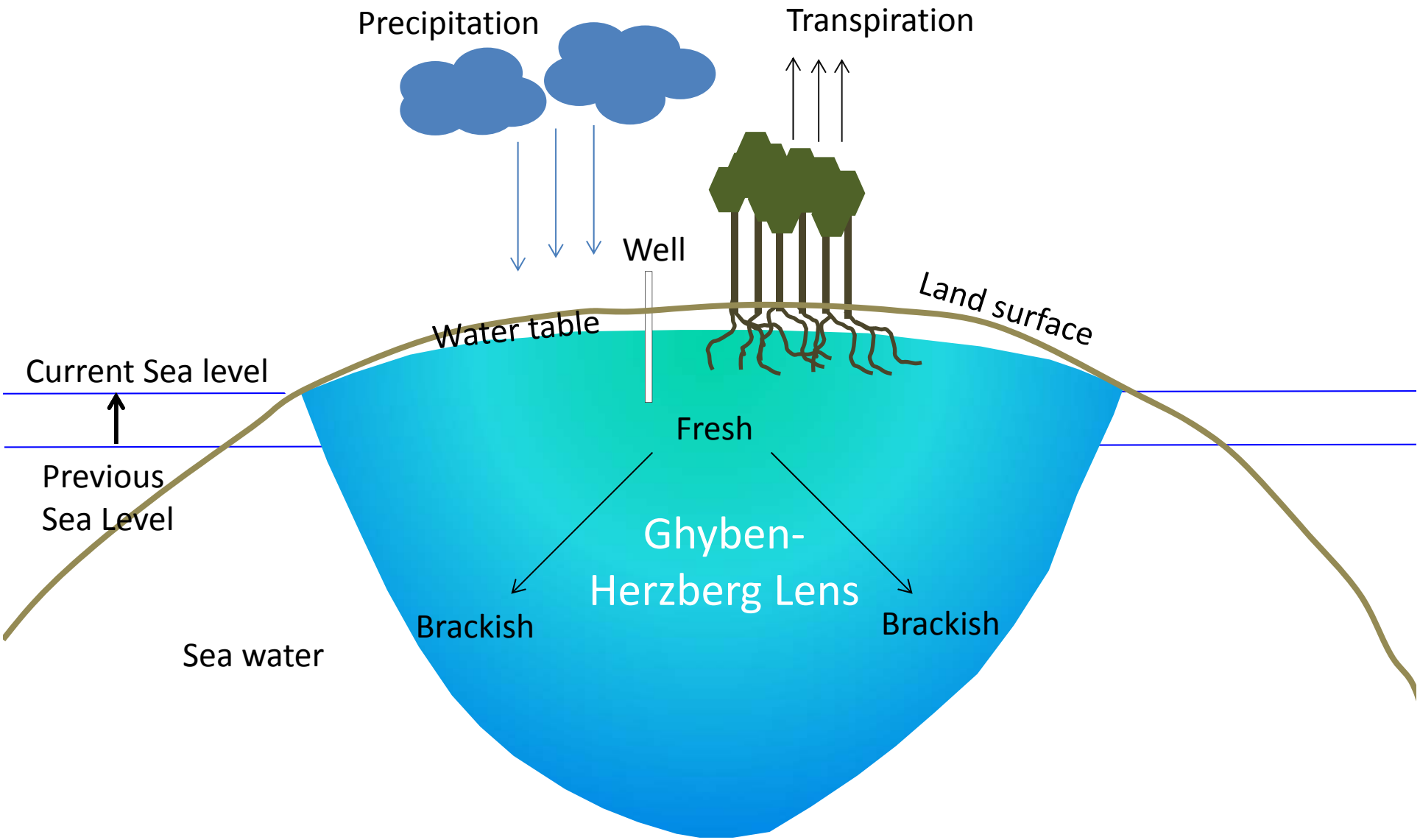


Fig. 5-1. Map showing the Florida Keys, their lithology, and location relative to mainland and reef tract. (Halley et al. 1993)

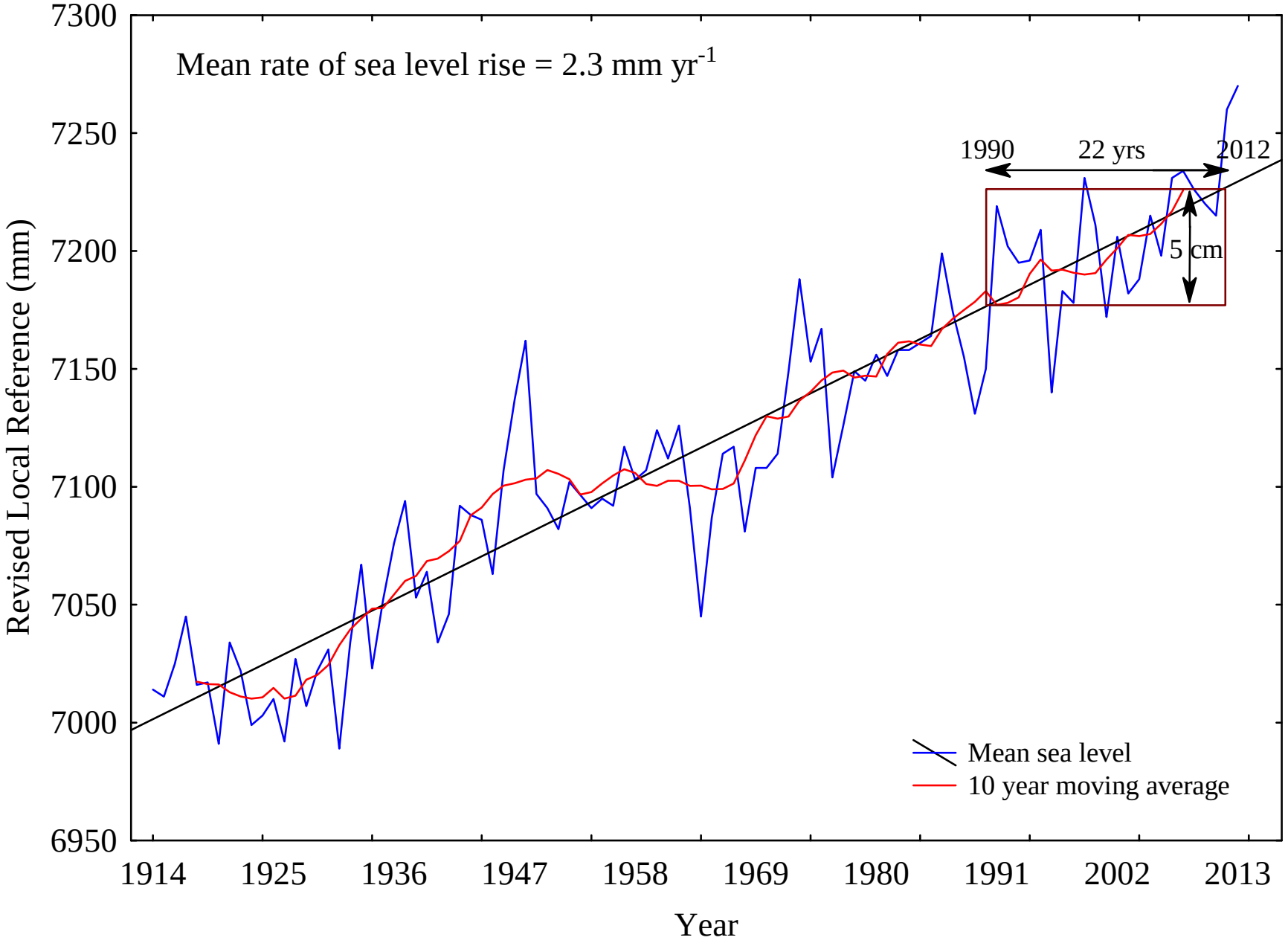
Conceptual Model of Freshwater Lens



Conceptual Model of Freshwater Lens



23cm of SLR at Key West Tide Gauge over 100 years

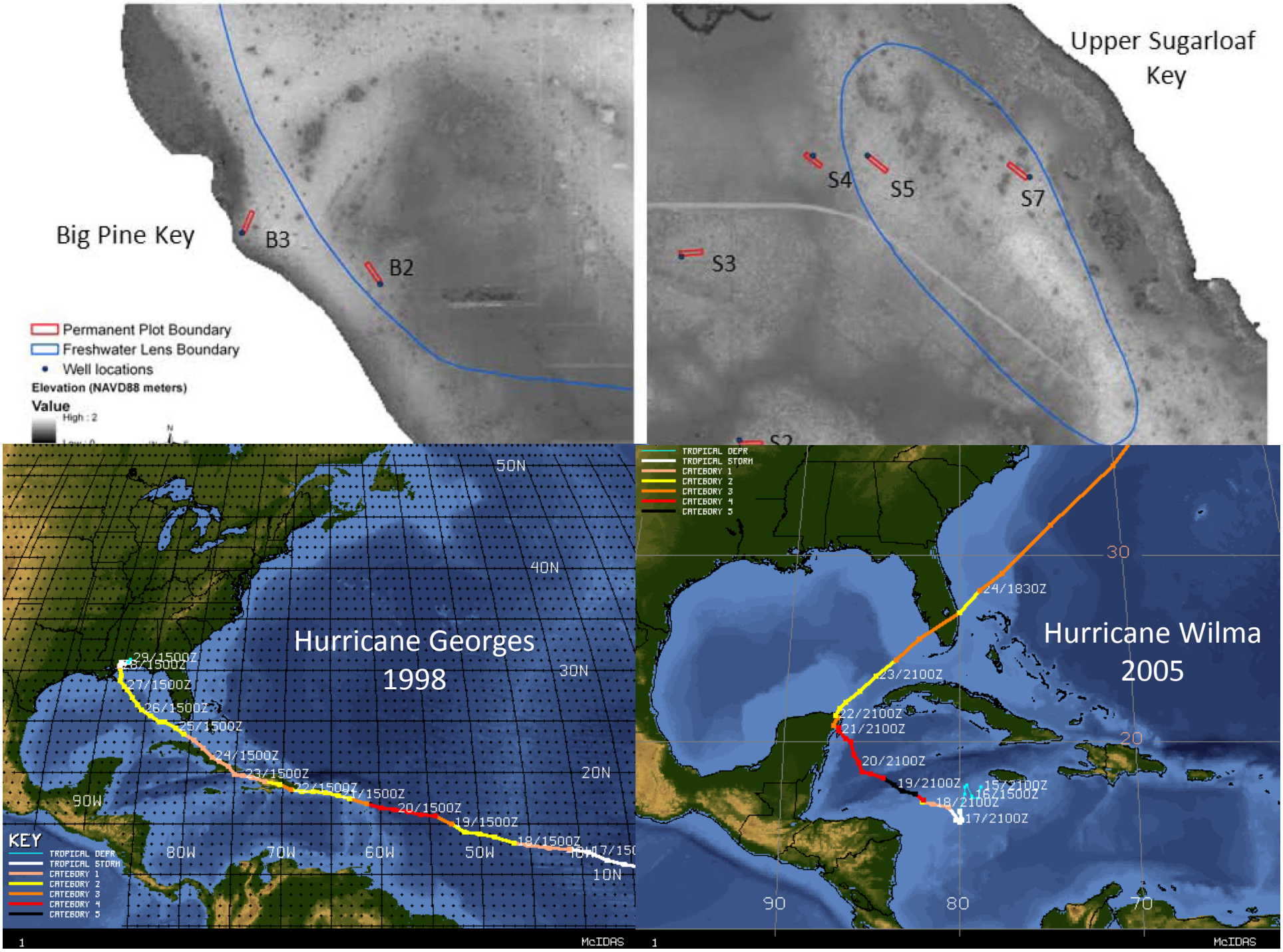


Research Questions

1) Has sea level rise of 5 cm increased groundwater salinity in coastal forests at locations inside and outside the boundaries of the freshwater lens?

2) Are changes in forest structure and species composition associated with the press disturbance (SLR) and/or the pulse disturbance (storm surge)?

3) Are changes in forest structure and composition present in all vegetation strata (canopy, high shrub, low shrub/herb)?


Big Pine Key
B3
B2
Permanent Plot Boundary
Freshwater Lens Boundary
Well locations
Elevation (NAVD88 meters)
Value
High : 2
Upper Sugarloaf Key
S4
S5
S7
S3
Hurricane Georges
1998
50N
40N
30N
20N
90W
80W
70W
60W
50W
10N
29/1500Z
28/1500Z
27/1500Z
26/1500Z
25/1500Z
24/1500Z
23/1500Z
22/1500Z
21/1500Z
20/1500Z
19/1500Z
18/1500Z
KEY
TROPICAL DEPR
TROPICAL STORM
CATEGORY 1
CATEGORY 2
CATEGORY 3
CATEGORY 4
CATEGORY 5
1
McIDAS
Hurricane Wilma
2005
30
20
90
80
70
24/1830Z
23/2100Z
22/2100Z
21/2100Z
20/2100Z
19/2100Z
18/2100Z
17/2100Z
1
McIDAS

Sampling 1990s & 2010s

Groundwater salinity monitoring

- Wells sampled at periodic intervals
  - 1990s (1989 – 1992) bi-monthly and monthly sampling
  - 2010s (2012 - 2013) every two months

Statistical Analyses

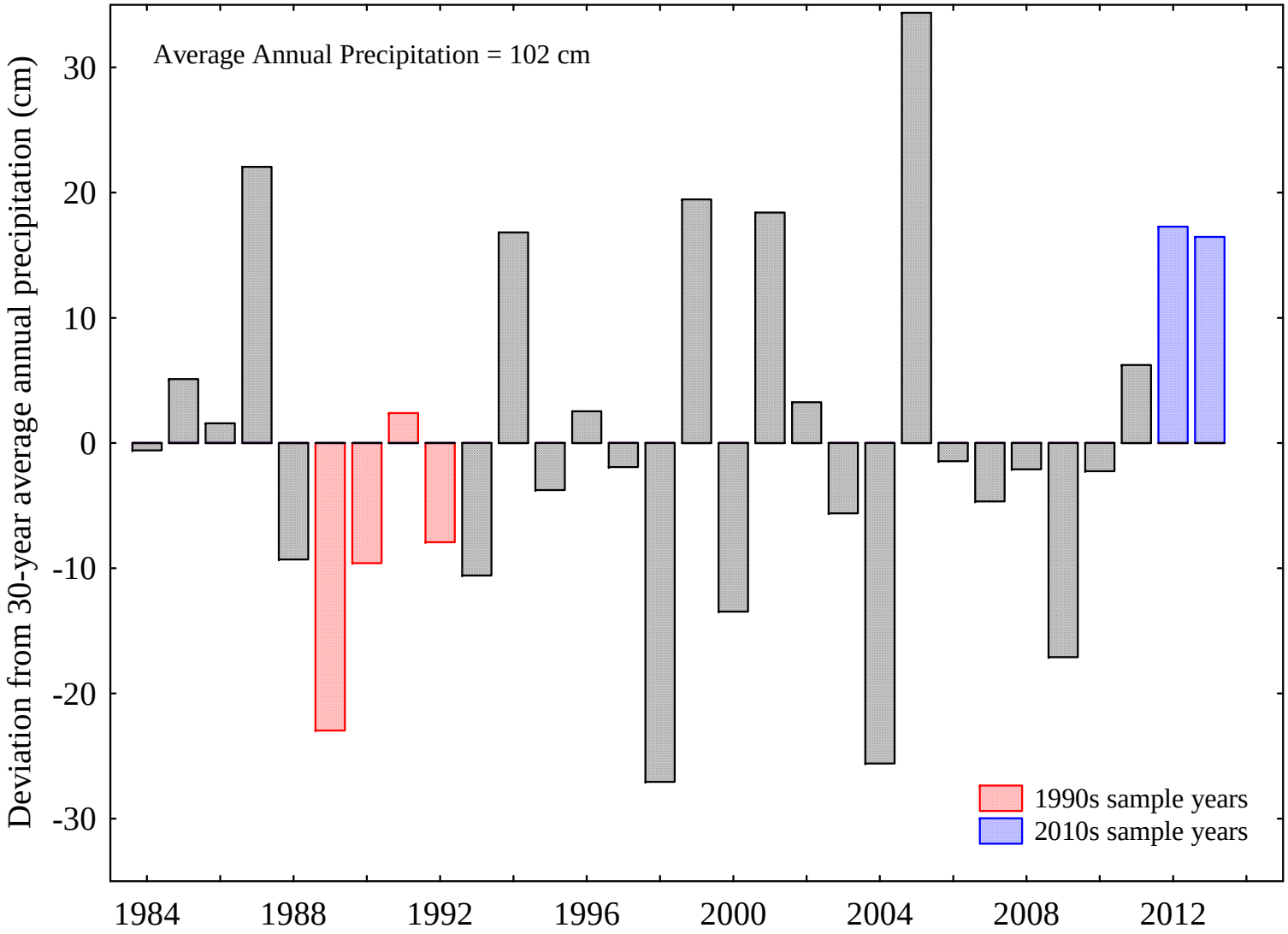
- Mixed Linear Effects Modeling including random effects with post-hoc tests in R v. 3.1.2
- Nonmetric multidimensional scaling (NMDS) ordination and vector fitting to 3 environmental variables in DECODA v. 3.01

Vegetation sampling

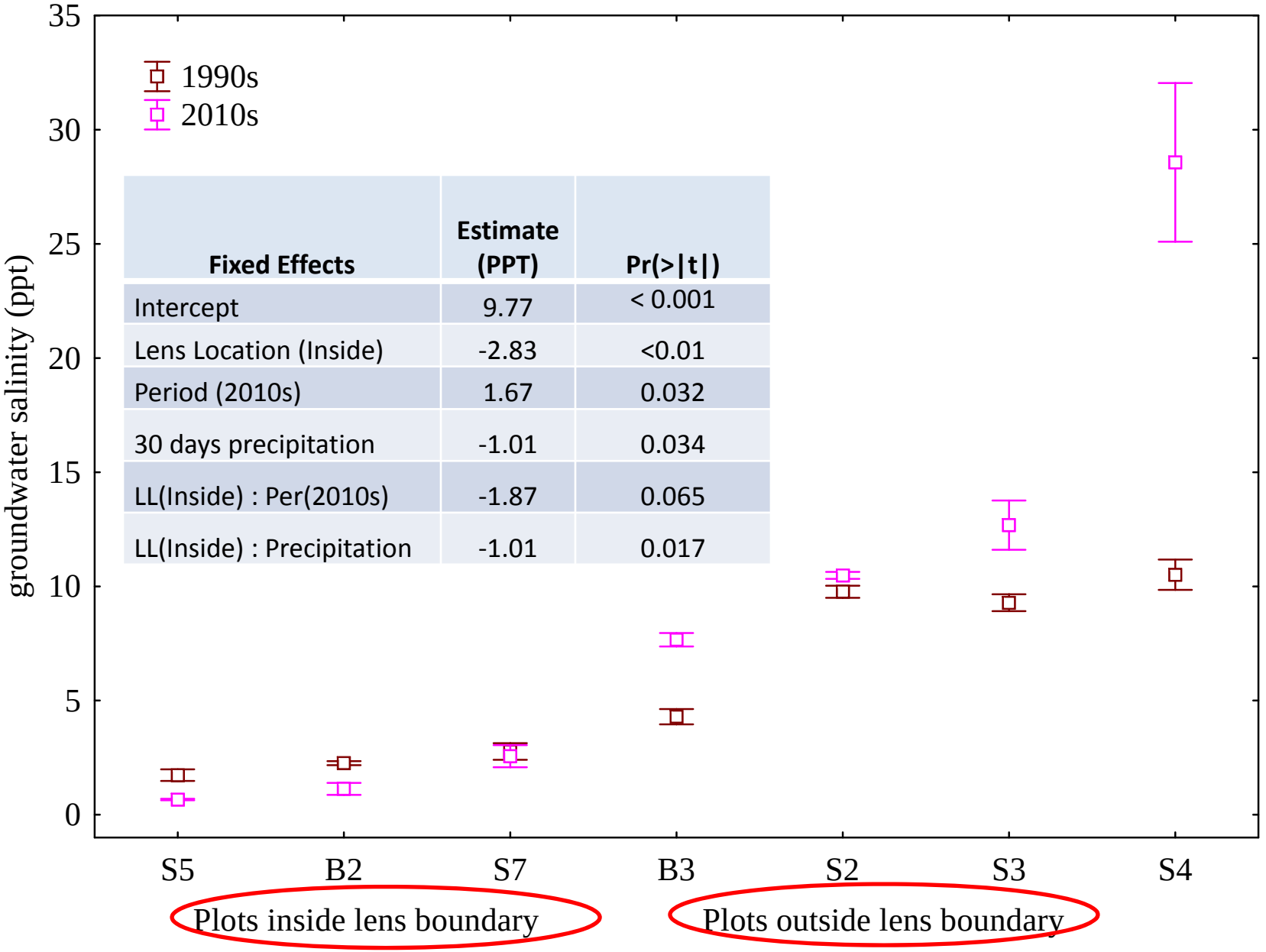
- Basal area calculated for all trees > 3cm dbh
- Percent cover estimated in high and low shrub strata in 5x5 m quadrats

Plot	Island	Habitat	Lens Location	# of sub plots	Area (m^2)	Distance to coast (m)	Ht (m) above LMSL
B2	BPK	PR	Inside	6	600	189	0.69
B3	BPK	HH	Outside	6	600	46	0.91
S2	SLK	HH	Outside	6	600	282	0.66
S3	SLK	PR	Outside	6	600	758	0.59
S4	SLK	HH	Outside	5	500	633	0.52
S5	SLK	PR	Inside	6	600	535	0.91
S7	SLK	HH	Inside	6	600	308	0.88

Deviation from 30-year average annual precipitation received at Key West International Airport (1984 – 2013)

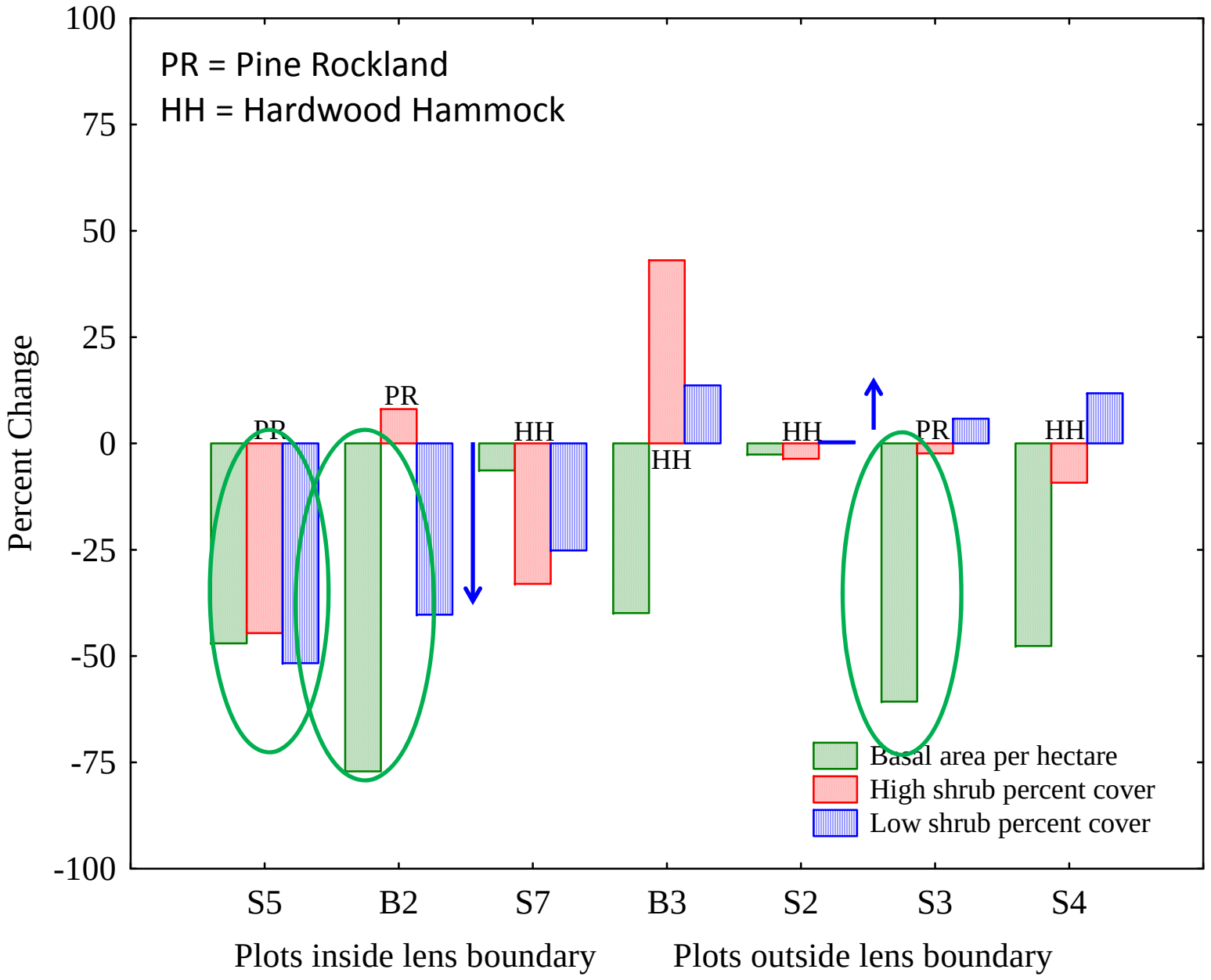


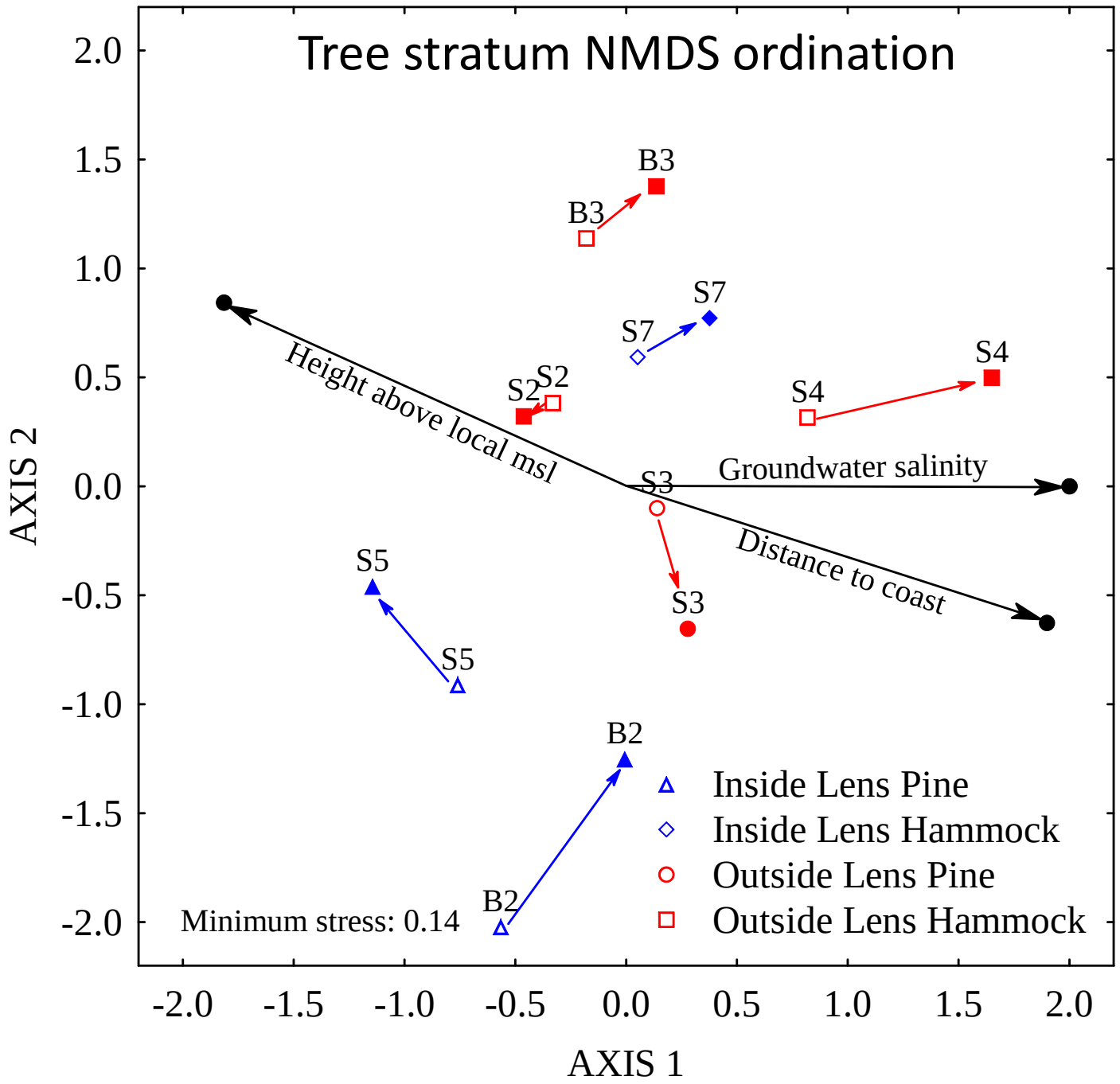
Mean groundwater salinity (PPT) +/- SE in each sampling period

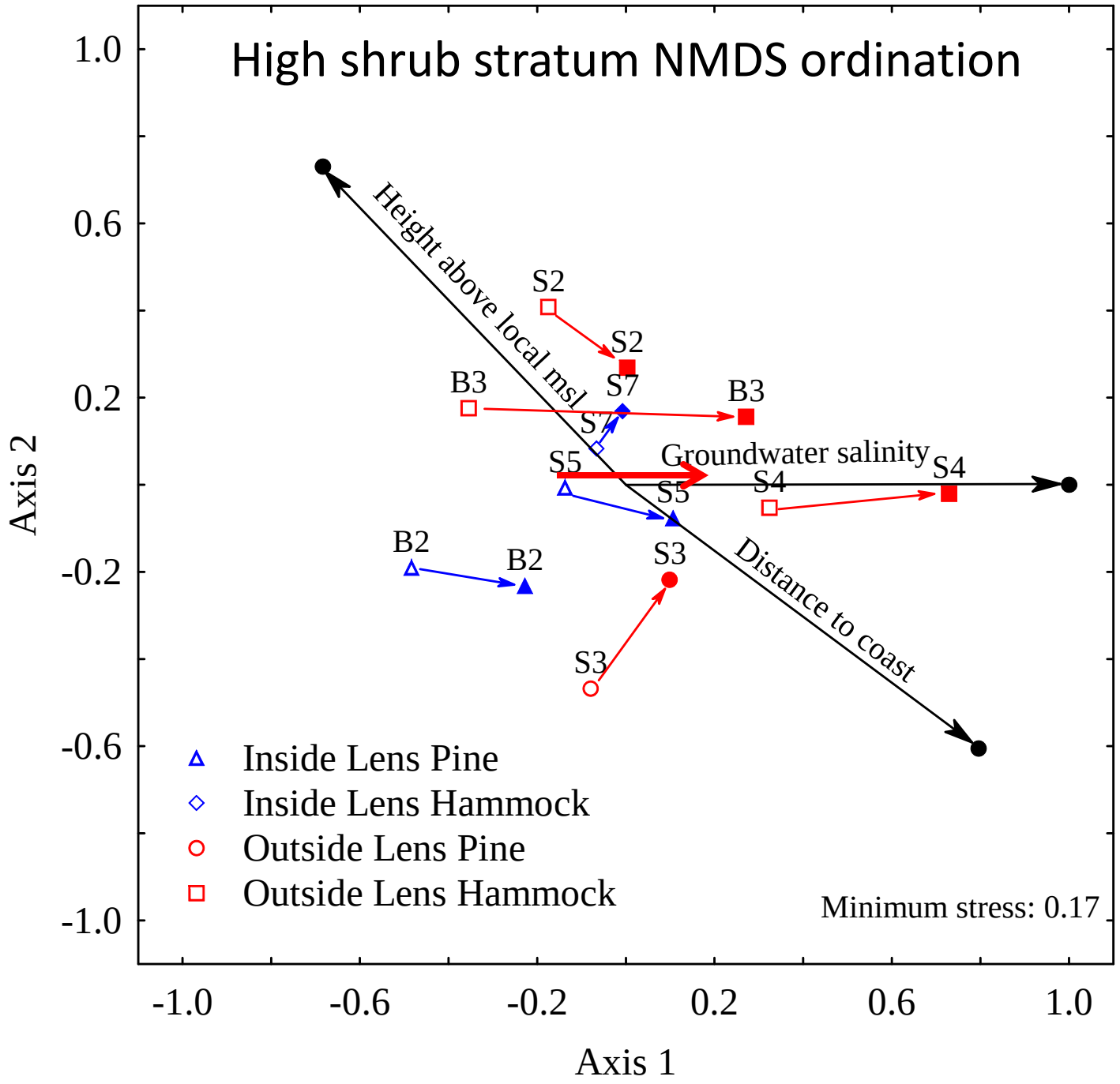


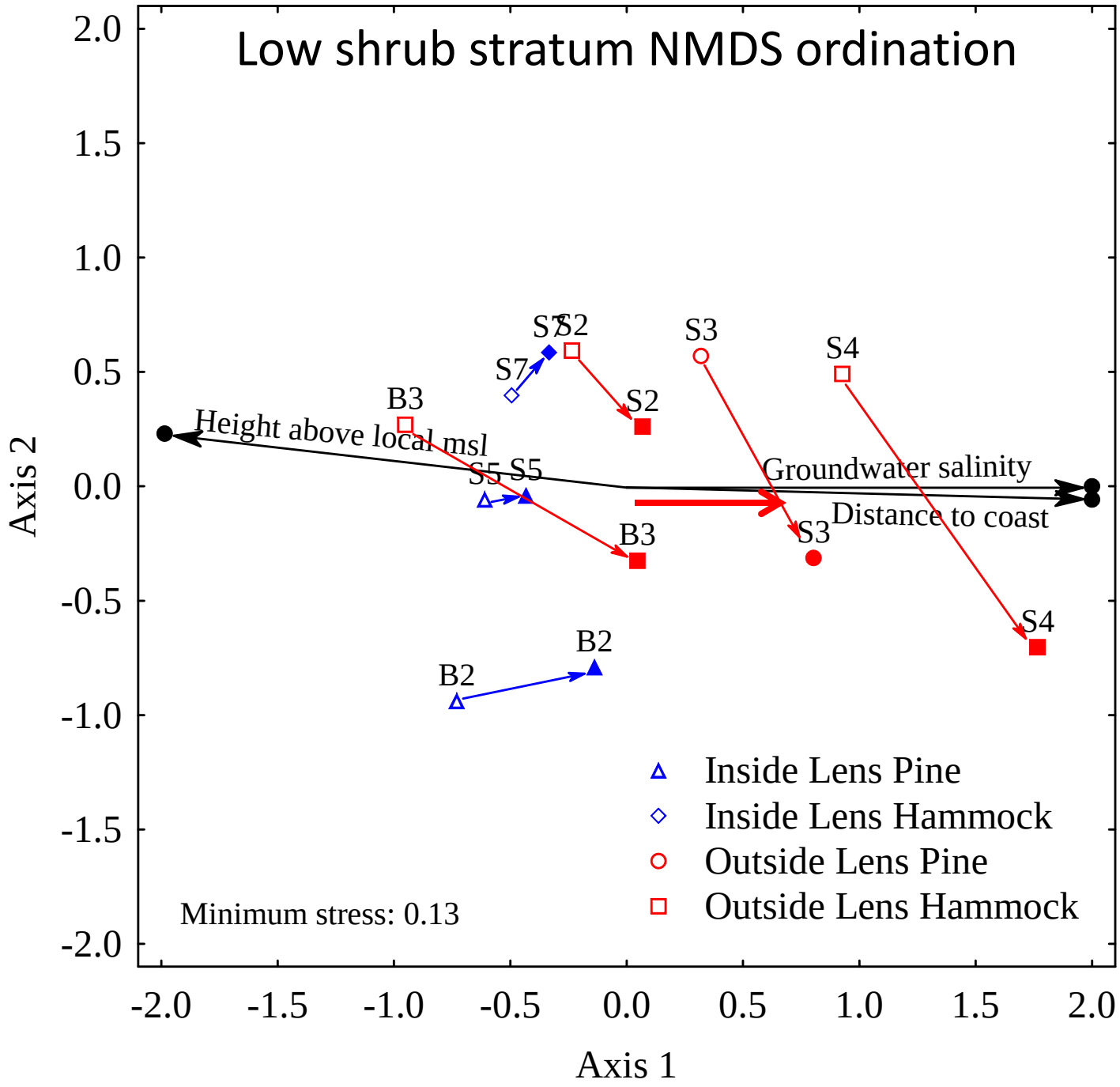
Fixed Effects	Estimate (PPT)	Pr(>|t|)
Intercept	9.77	< 0.001
Lens Location (Inside)	-2.83	<0.01
Period (2010s)	1.67	0.032
30 days precipitation	-1.01	0.034
LL(Inside) : Per(2010s)	-1.87	0.065
LL(Inside) : Precipitation	-1.01	0.017

Percent Change in vegetation abundance in 3 strata

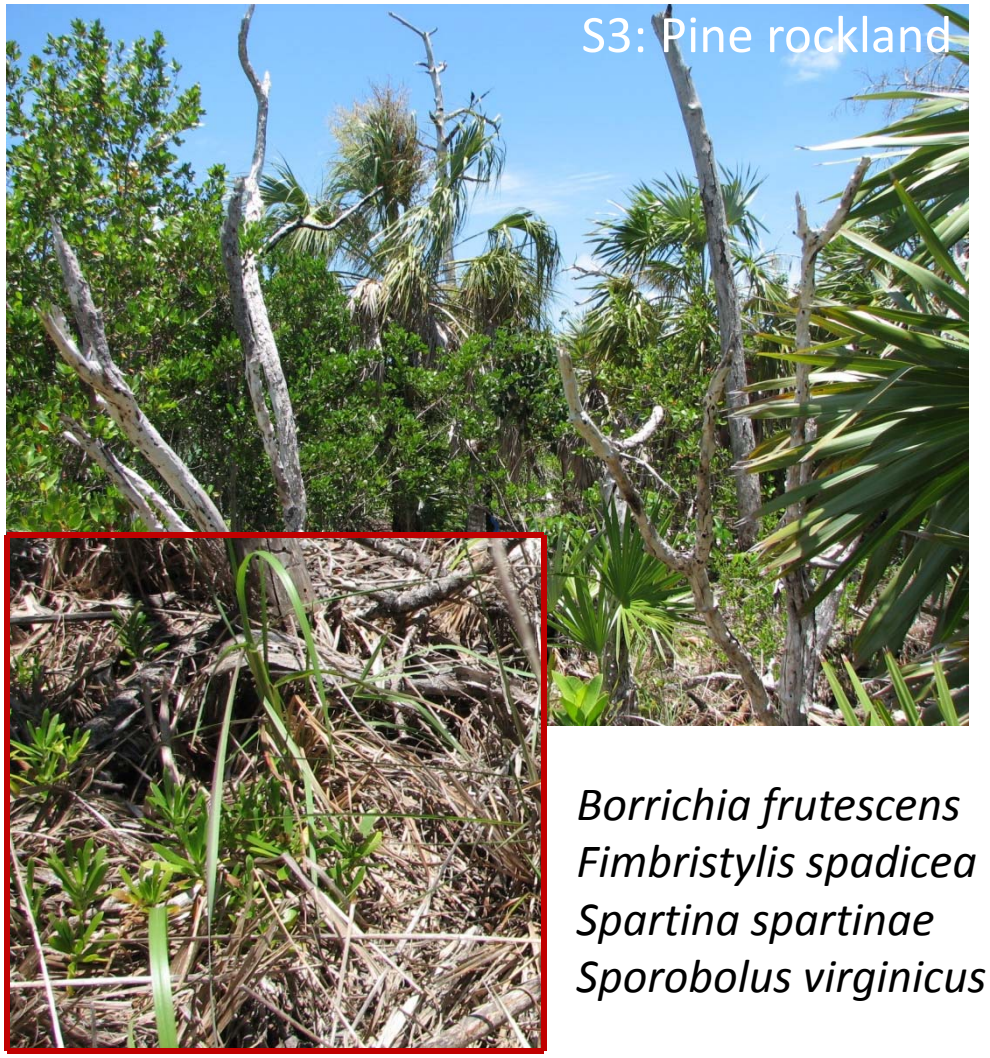



Tree stratum NMDS ordination
AXIS 2
AXIS 1
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
B3
B3
S7
S7
S4
S4
S2
S2
Height above local msl
Groundwater salinity
S3
S3
Distance to coast
S5
S5
B2
B2
Minimum stress: 0.14
Inside Lens Pine
Inside Lens Hammock
Outside Lens Pine
Outside Lens Hammock


High shrub stratum NMDS ordination
Axis 2
Axis 1
1.0
0.6
0.2
-0.2
-0.6
-1.0
-1.0
-0.6
-0.2
0.2
0.6
1.0
Height above local msl
Distance to coast
Groundwater salinity
S2
S2
B3
S7
S7
B3
S5
S5
S4
S4
B2
B2
S3
S3
Inside Lens Pine
Inside Lens Hammock
Outside Lens Pine
Outside Lens Hammock
Minimum stress: 0.17


Low shrub stratum NMDS ordination
Axis 2
Axis 1
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
S7
S2
S3
S4
B3
S2
S7
S5
S5
B3
S3
S4
B2
B2
Height above local msl
Groundwater salinity
Distance to coast
Inside Lens Pine
Inside Lens Hammock
Outside Lens Pine
Outside Lens Hammock
Minimum stress: 0.13

Low shrub layer: Gain in species typical of coastal buttonwood forest



Borrichia frutescens
Fimbristylis spadicea
Spartina spartinae
Sporobolus virginicus

Summary and Conclusions

- SLR increased groundwater salinity only at plots outside the FWL, while groundwater salinity at inside lens locations was dominated by amount of recent precipitation received

- Pulse disturbance (storm surge) was primarily responsible for changes in structure and composition of the **tree stratum**, while press disturbance (SLR) or interaction of the disturbances was observed to change **shrub strata** along a trajectory of increasing groundwater salinity only in coastal forest plots outside the FWL

- Changes in composition of low shrub stratum are an early indicator of effects of sea level rise on fresh water-requiring coastal forests

Thank you!

- Thank you to the U.S. Fish and Wildlife Service National Key Deer Refuge for providing logistical support for permanent plot sampling

- Thank you to Dr. Michael S. Ross, Dr. Jay P. Sah, and Dr. René M. Price for collaboration and guidance on this research

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- Thank you to members of the South Florida Terrestrial Ecosystems Lab for helpful comments