



Competition versus Facilitation: Testing Multiple Stress Gradient Effects on Salt Marsh and Mangrove Interactions

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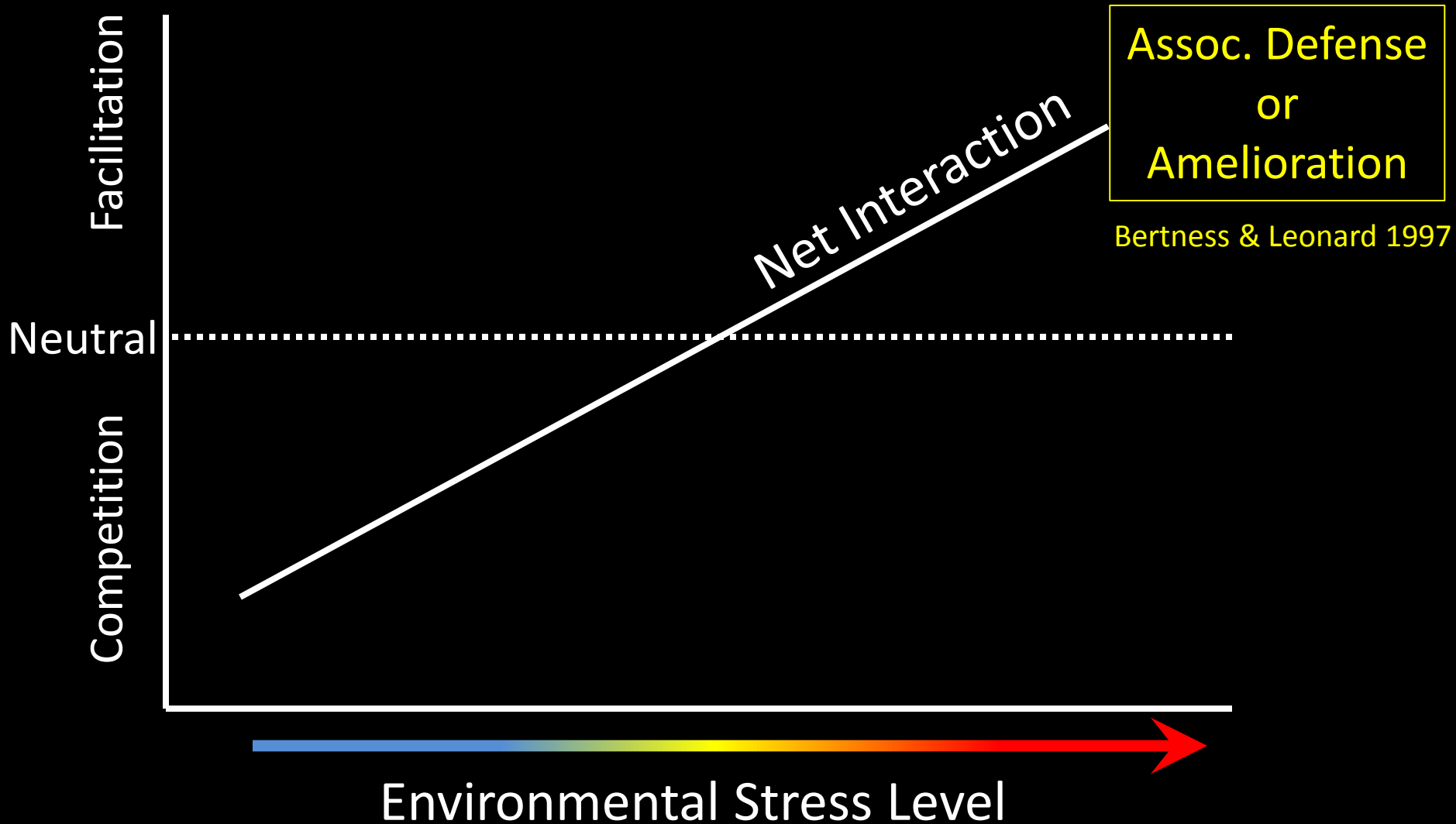
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Do Stressors alter Salt Marsh Effect on Mangroves?

- Study 1
 - Primary Stressor: Water Depth
- Study 2
 - Multiple Stressors:
 - Latitude
 - Salinity
 - Canopy Coverage
 - Herbivory
 - Nutrients

Stress Gradient Hypothesis

Bertness and Callaway 1994



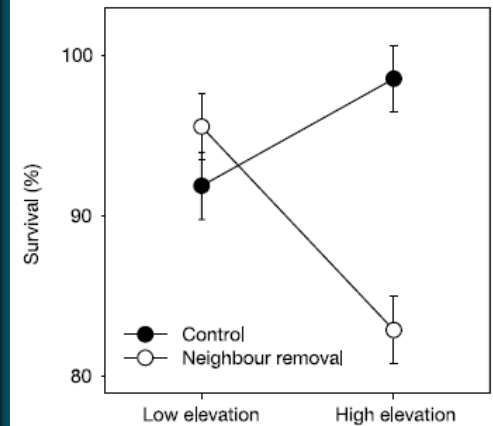
Global Alpine Experiment

Callaway et al. 2002

Relative Neighbor Effect (Inverse RNE)

Positive = Facilitation

Negative = Competition

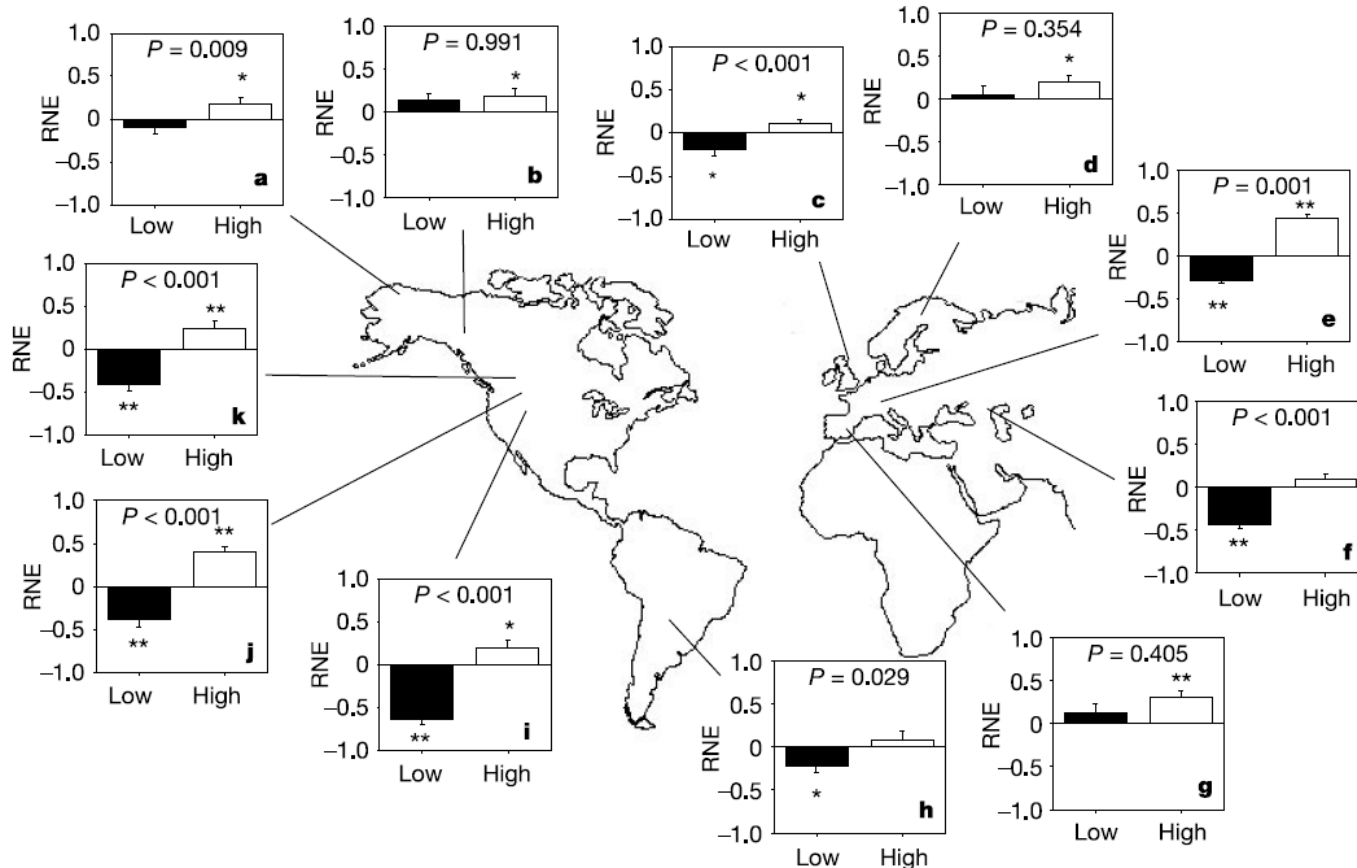


Low High

Stress

Competition

Facilitation



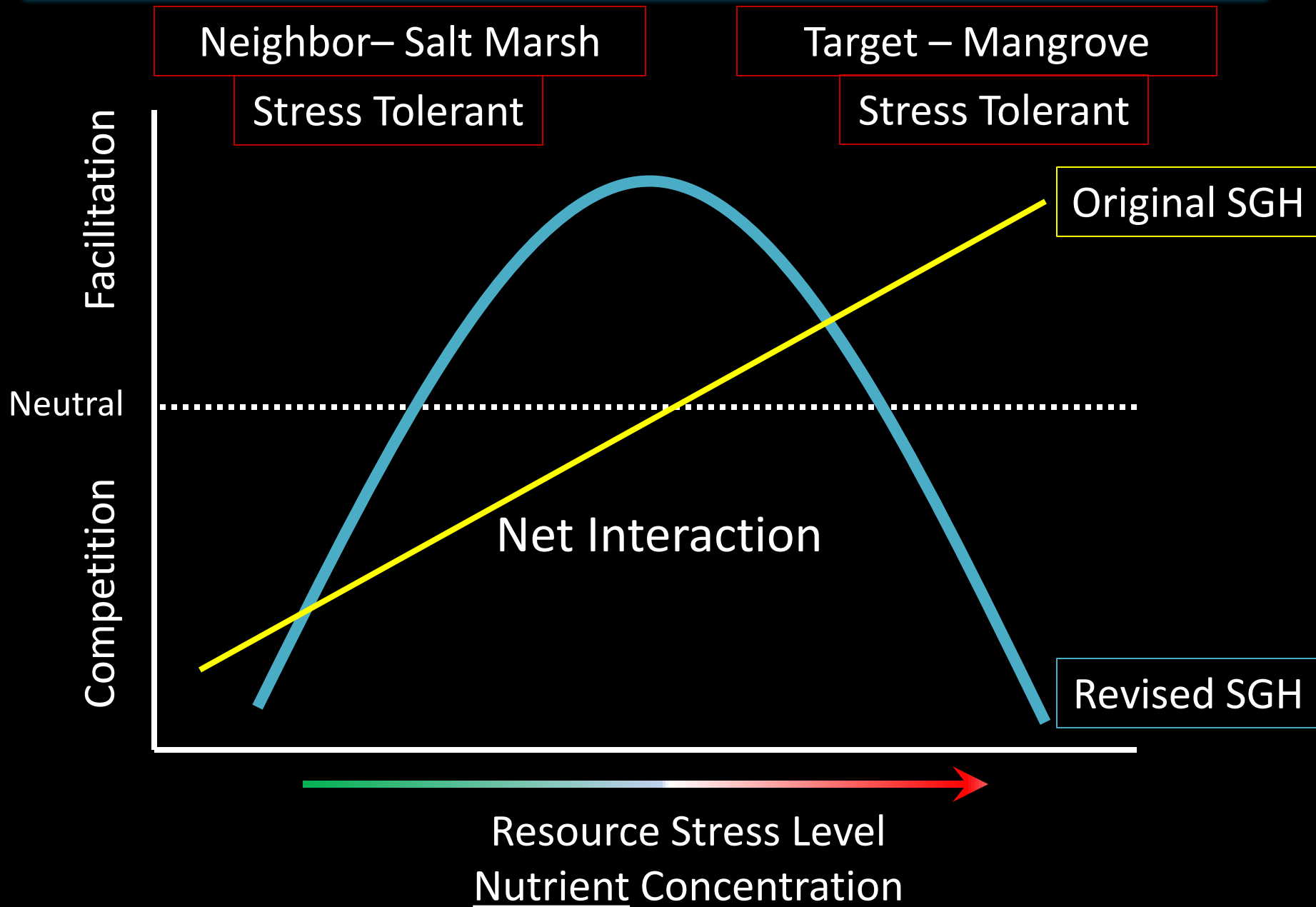
Revised Stress Gradient Hypothesis

(Revised SGH)

Maestre et al. 2009

- Life History of Interacting Species
 - Competitive
 - Stress Tolerant
- Stress Gradient Type
 - Resource (e.g., Nutrients)
 - Non-Resource (e.g., Freeze frequency)

Revised SGH Example



Study 1

Primary Stressor: Water Depth

Experimental Design at Restored Site

4 Herbaceous Salt Marsh Species

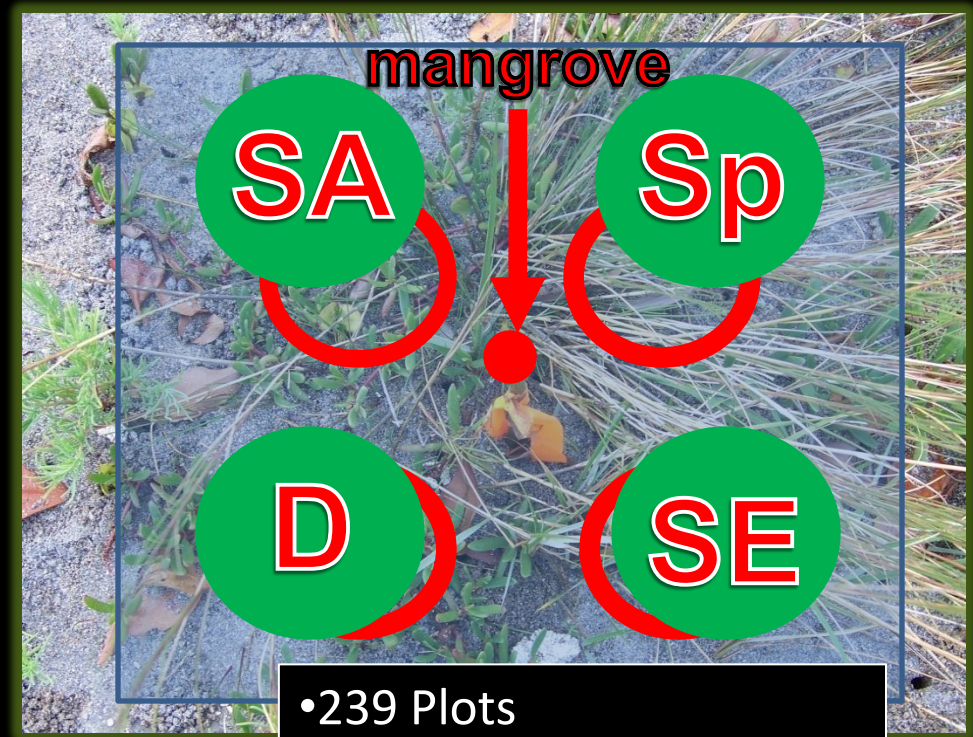
- *Spartina alterniflora*
- *Spartina patens*
- *Distichlis spicata*
- *Sesuvium portulacastrum*

Combinations

Salt Marsh Treatments

- Species Richness
 - 0 (Bare)
 - 1 (All singles)
 - 2 (All Pairs)
 - 3
 - 4 (All Possible)

1 *R. mangle* per plot



- 239 Plots
- 36 cm Elevation Gradient

Experimental Design

Mangroves

Growth:

Height

No. of leaves

Sampling Period:

6, 11, 18 months



Stress Gradient

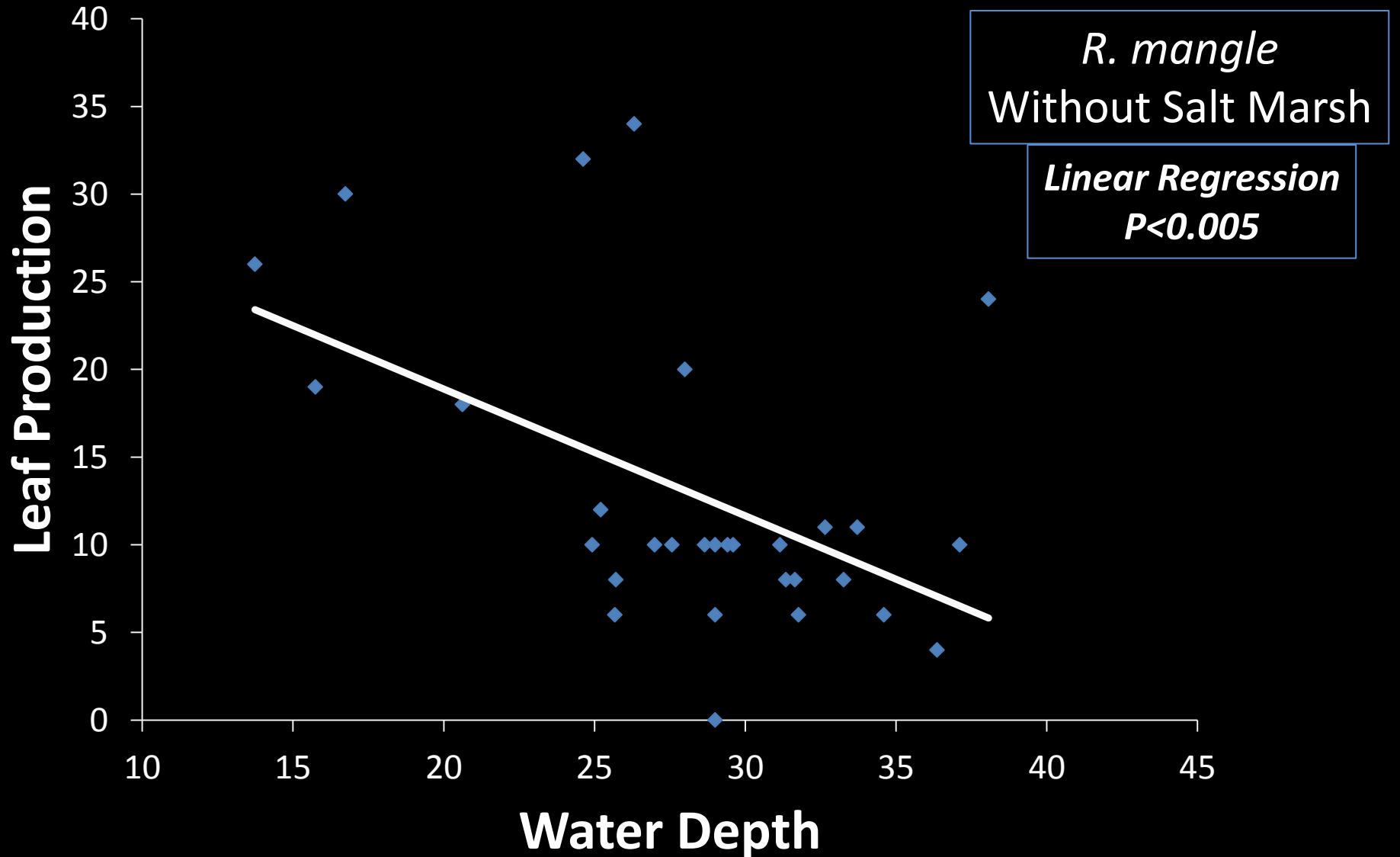
Water Depth

Shallow (low stress) (1-20cm)

Medium (med. stress) (20-30cm)

Deep (high stress) (30-40cm)

Indication of Stress



Relative Interaction Intensity (RII)

Index of relative dominance of facilitative or competitive effects of neighbor plant on target plant

- Positive values = Facilitative
- Negative values = Competitive

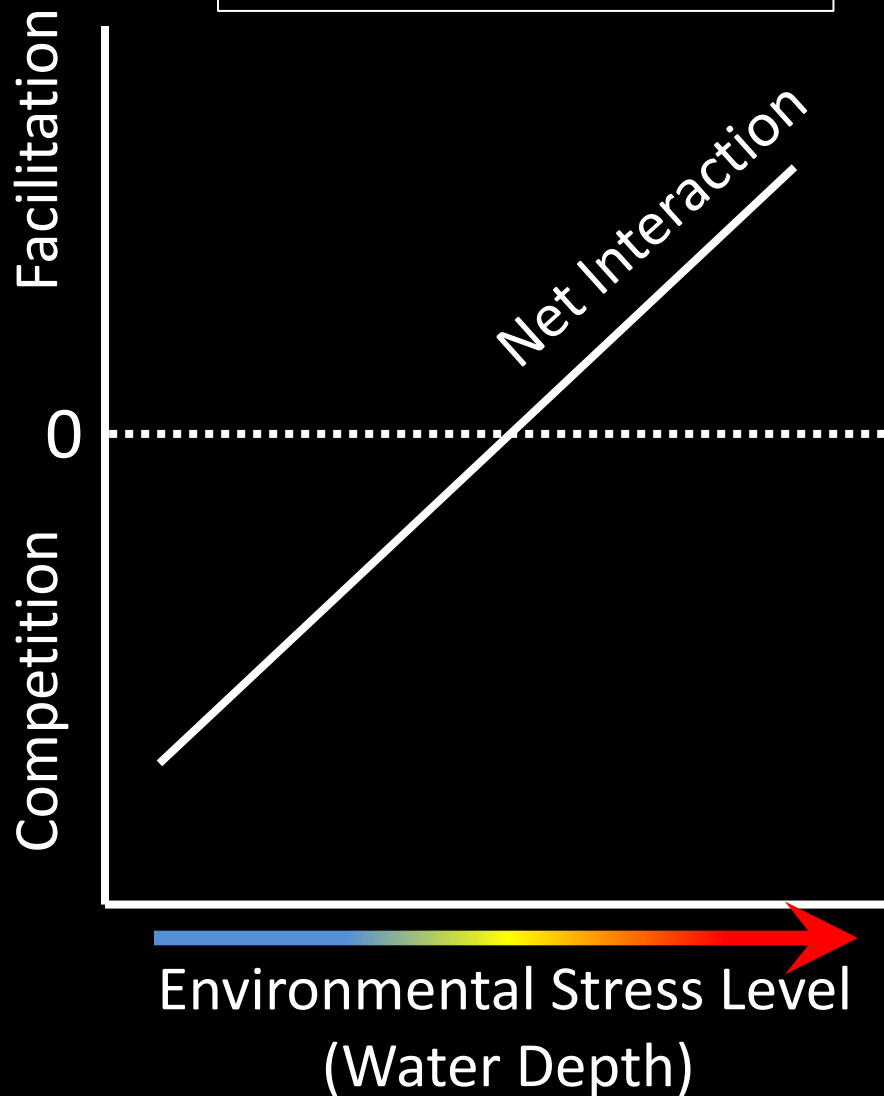
$$RII = (T_w - T_o) / (T_w + T_o)$$

T_w = Growth of target plant with neighbor present

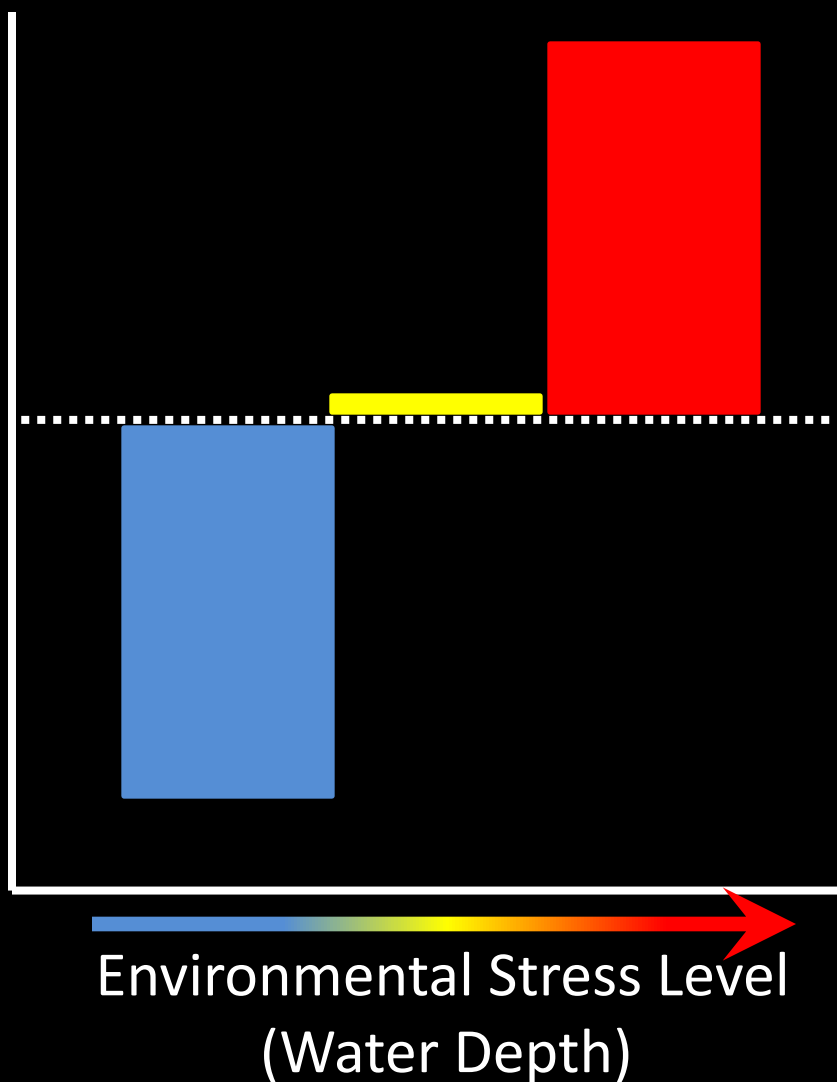
T_o = Growth of target plant without neighbor present

Stress Gradient Hypothesis

Theoretical Prediction



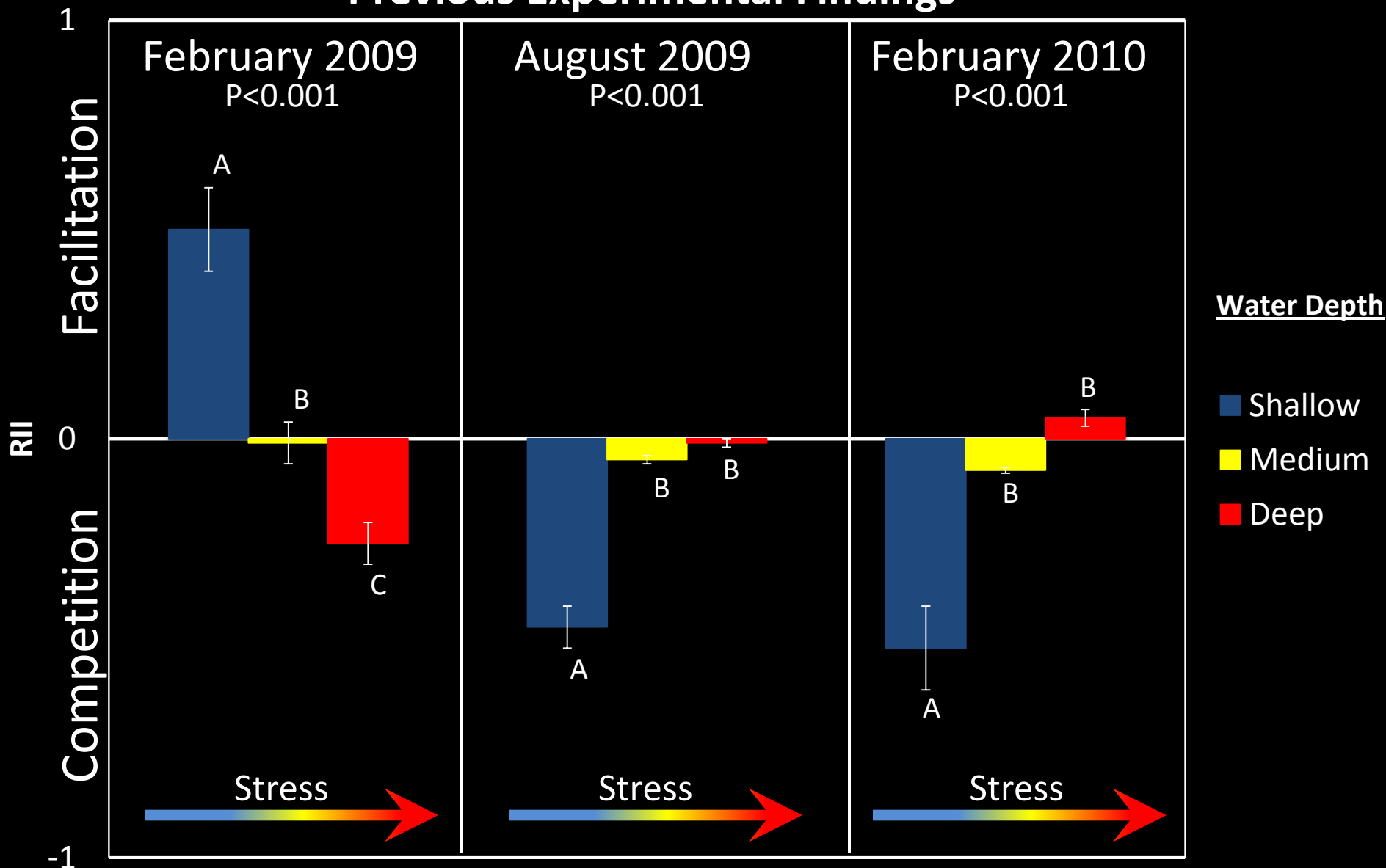
Supporting RII results



Salt Marsh effect on *R. mangle* Leaf Production

G. Coldren, C.E. Proffitt, D. Devlin, K. Tiling

Previous Experimental Findings



Proposed: Multiple Stress Gradient Hypothesis

Neighbor – Salt Marsh

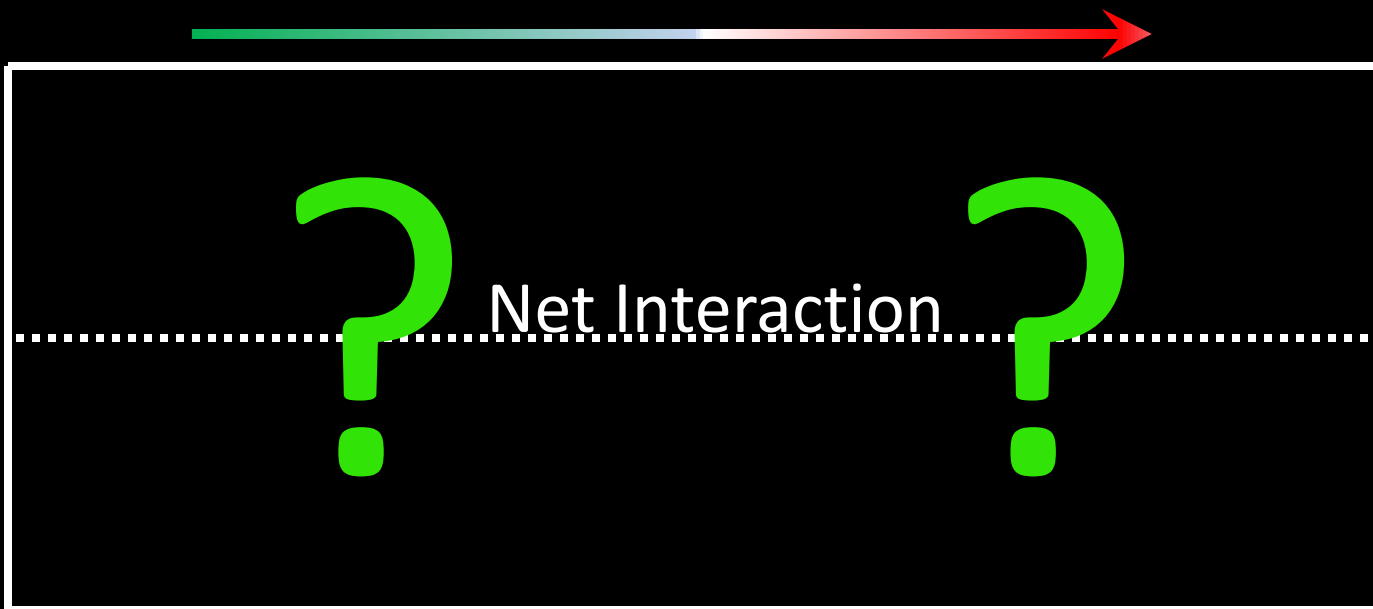
Stress Tolerant

Target – Mangrove

Stress Tolerant

Non-Resource Stress Level
Freeze Intensity

Facilitation
Neutral
Competition



Resource Stress Level
Nutrient Concentration


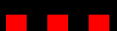
Study 2
Multiple Stressors

Sampling Sites (10 Current Sites)



29° 50' Latitude

Species Distribution Overlap

Mangrove Species

-  Dominant
-  Patchy

Salt Marsh Species

-  Dominant
-  Patchy

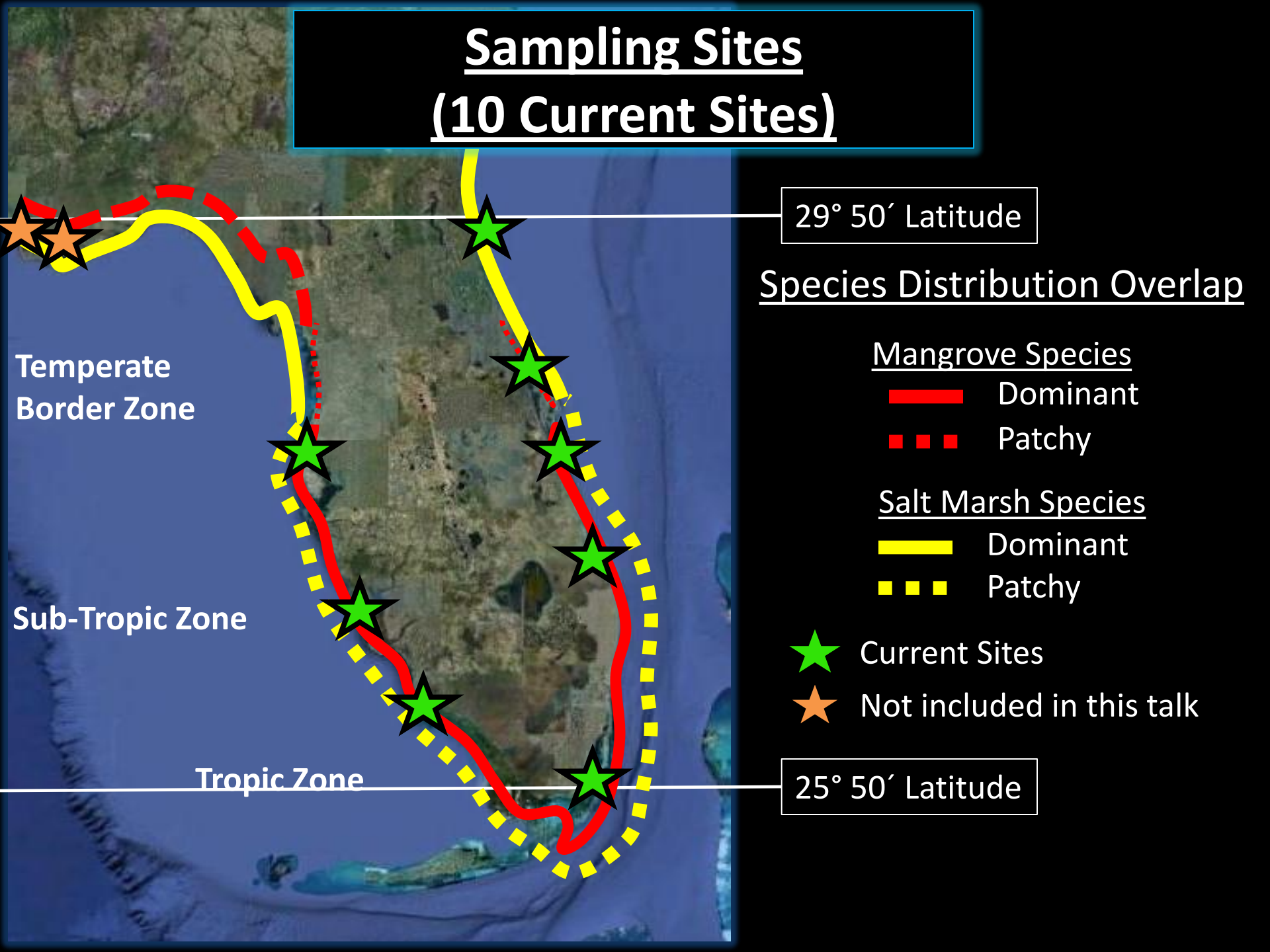
-  Current Sites
-  Not included in this talk

25° 50' Latitude

Temperate
Border Zone

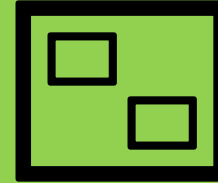
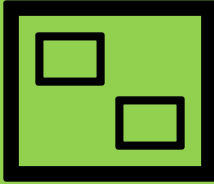
Sub-Tropic Zone

Tropic Zone

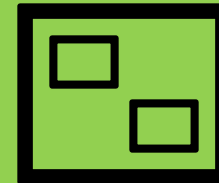
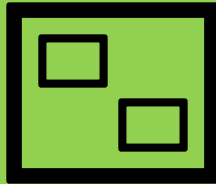
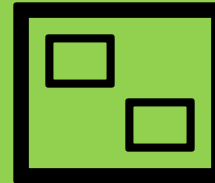
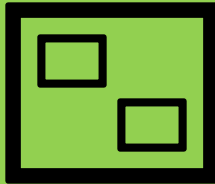


Open Water

Average tidal depth



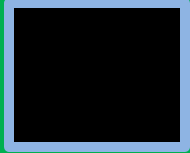
3x3m
Quadrat



Terrestrial

3x3m - Stress & Adult Mangroves

Saltmarsh
& Seedling



0.5x0.5m

Seedling



0.5x0.5m

3x3meter Quadrat

6 per site

0.5x0.5 Quadrat

12 per site

Salt marsh Present/Absent plots

Experimental test of
Salt Marsh effect

Methods

3x3meter Quadrat

- Stress Conditions
 - Soil Salinity
 - % organic Soil
 - Canopy Cover
 - Water Depth
 - Soil Firmness
 - Herbivory
 - Latitude
- Adult Mangroves (By Species)
 - Density
 - Height
 - D.B.H.
 - Canopy size
 - Leaf/Scar ratio
 - Health Rank

0.5x0.5meter Quadrat

- Seedling Mangroves • 2 Quadrats
 - (By Species)
 - Density
 - Height
 - Canopy Size
 - Leaf production
 - Leaf/Scar ratio
 - Health Rank
 - 1 Salt Marsh Aboveground Clipped (Biomass)
 - 1 Intact

Study 2 Multiple Stressors

- Part A: Observational
 - Sampled: Fall 2012
 - Measured all variables in 3x3m and 0.5x0.5m
- Part B: Experimental
 - Salt Marsh: Absence vs. Presence
 - Paired plots created in Fall 2012
 - Sampled: Spring 2012
 - ~7 months
 - Measured tagged seedlings
 - Compared against stressor baseline created in Part A

Salt Marsh Dampens Effects of Stressors

Multiple Regression

Salt Marsh Absent

Model $P < 0.014$ ($R^2 = 0.342$)

Avicennia Height = (Standardized Coefficients)	Constant	Non-Resource		Resource	
		Salinity	Herbivory	Canopy Openness	% Organic
	20.539	-1.075	-0.839	+0.678	+0.945
Total Stress Effect				-0.291	

Salt Marsh Present

Model $P = 0.117$ ($R^2 = 0.143$)

Avicennia Height = (Standardized Coefficients)	Constant	Non-Resource		Resource	
		Salinity	Herbivory	Canopy Openness	% Organic
No Significant Effect of Stressors					
Total Stress Effect				0	



Salt Marsh

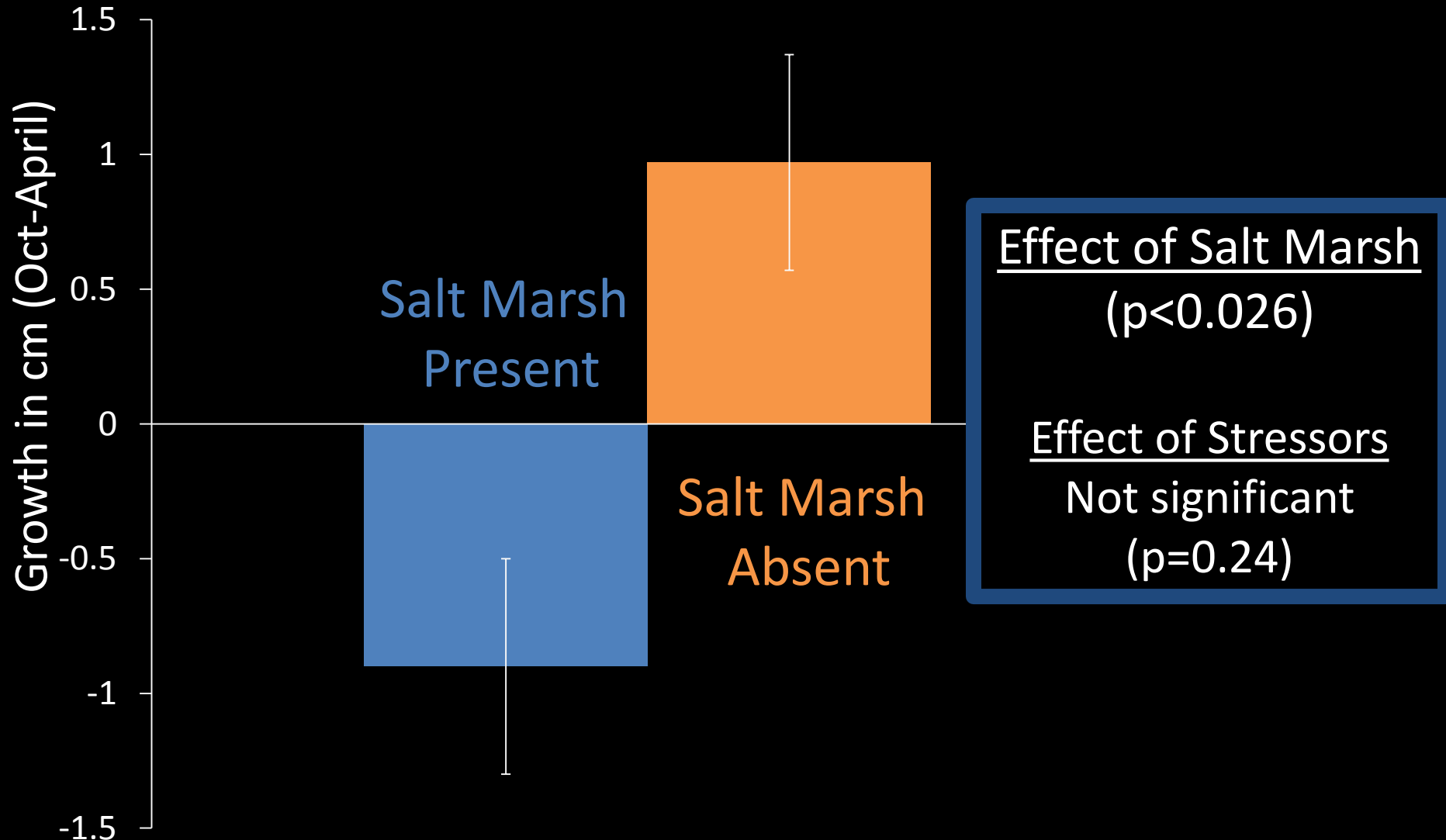
Facilitative effect
+0.291



Study 2 Multiple Stressors

- Part A: Observational
 - Sampled: Fall 2012
 - Measured all variables in 3x3m and 0.5x0.5m
- Part B: Experimental
 - Salt Marsh: Absence vs. Presence
 - Paired plots created in Fall 2012
 - Sampled: Spring 2012
 - ~7 months
 - Measured tagged seedlings
 - Compared against stressor baseline created in Part A

Growth in Height *Avicennia germinans*



Avicennia germinans Survival (Oct-April)

Logistic Regression

Salt Marsh Absent

Model P=0.0005

Non-resource

Resource

Non-resource

Avicennia
Survival=
(Standardized
Coefficients)

Constant

Salinity

Herbivory

Adult Man.
Can.
Openness

% Organic

Soil
Softness

Latitude

NS

NS

+1.094

NS

-0.729

NS

Salt Marsh Present

Model P=0.149

Non-resource

Resource

Non-resource

Avicennia
Survival=
(Standardized
Coefficients)

Constant

Salinity

Herbivory

Adult
Man. Can.
Openness

% Organic

Soil
Softness

Latitude

No Significant Effect of Stressors

Health Rank Classification

- 0 = Dead
- 1 = only 1 pair of green leaves remaining
- 2 = at least $\frac{1}{2}$ branches have no leaves or severely damaged/yellow leaves
- 3 = most branches have at least 2-3 green leaf pairs and live growing tips
- 4 = all branches have at least 2-3 green leaf pairs and live growing tips

Avicennia germinans Health Rank Change

Multiple Regression

Total Salt Marsh Effect +0.447

Salt Marsh Absent

Model P=0.0005

Non-resource

Resource

Non-resource

Avicennia
Health Rank
Change =
(Standardized
Coefficients)

Constant

Salinity

Herbivory

Adult
Mang. Can.
Openness

% Organic

Soil Softness

Latitude

-15.683

NS

-0.307

+0.373

NS

NS

+0.421

R²= 0.574

Total Stress Effect

-0.259

Salt Marsh Present

Model P=0.0005

Non-resource

Resource

Non-resource

Avicennia
Health Rank
Change =
(Standardized
Coefficients)

Constant

Salinity

Herbivory

Adult
Mang.
Can Open

% Organic

Soil
Softness

Latitude

-23.778

NS

NS

NS

NS

NS

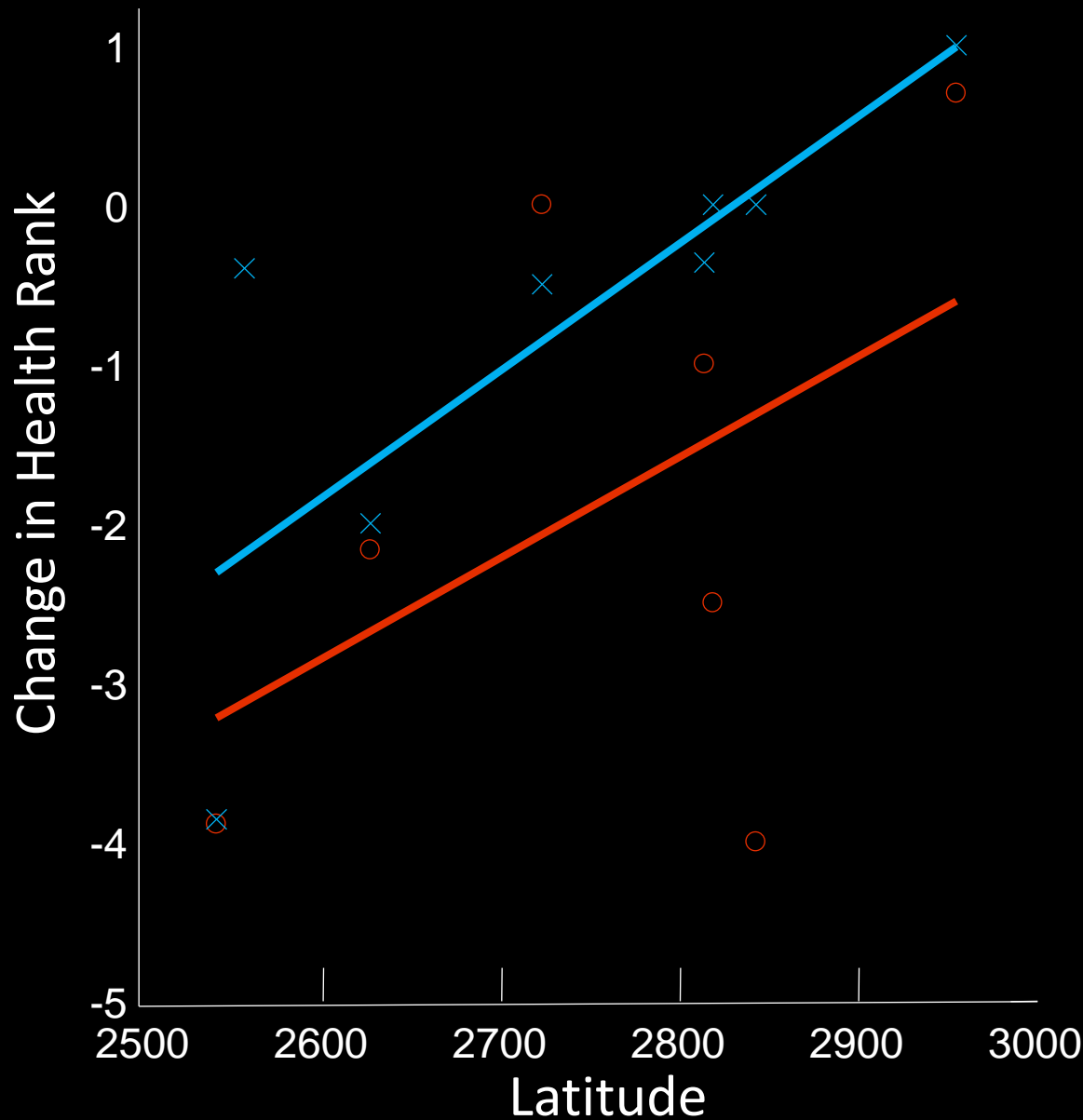
+0.706

R²= 0.574

Total Stress Effect

+0.706

Latitude effect on *Avicennia germinans* change in Health Rank (Oct-May)



Effect of Salt Marsh
All positive
regardless of stress

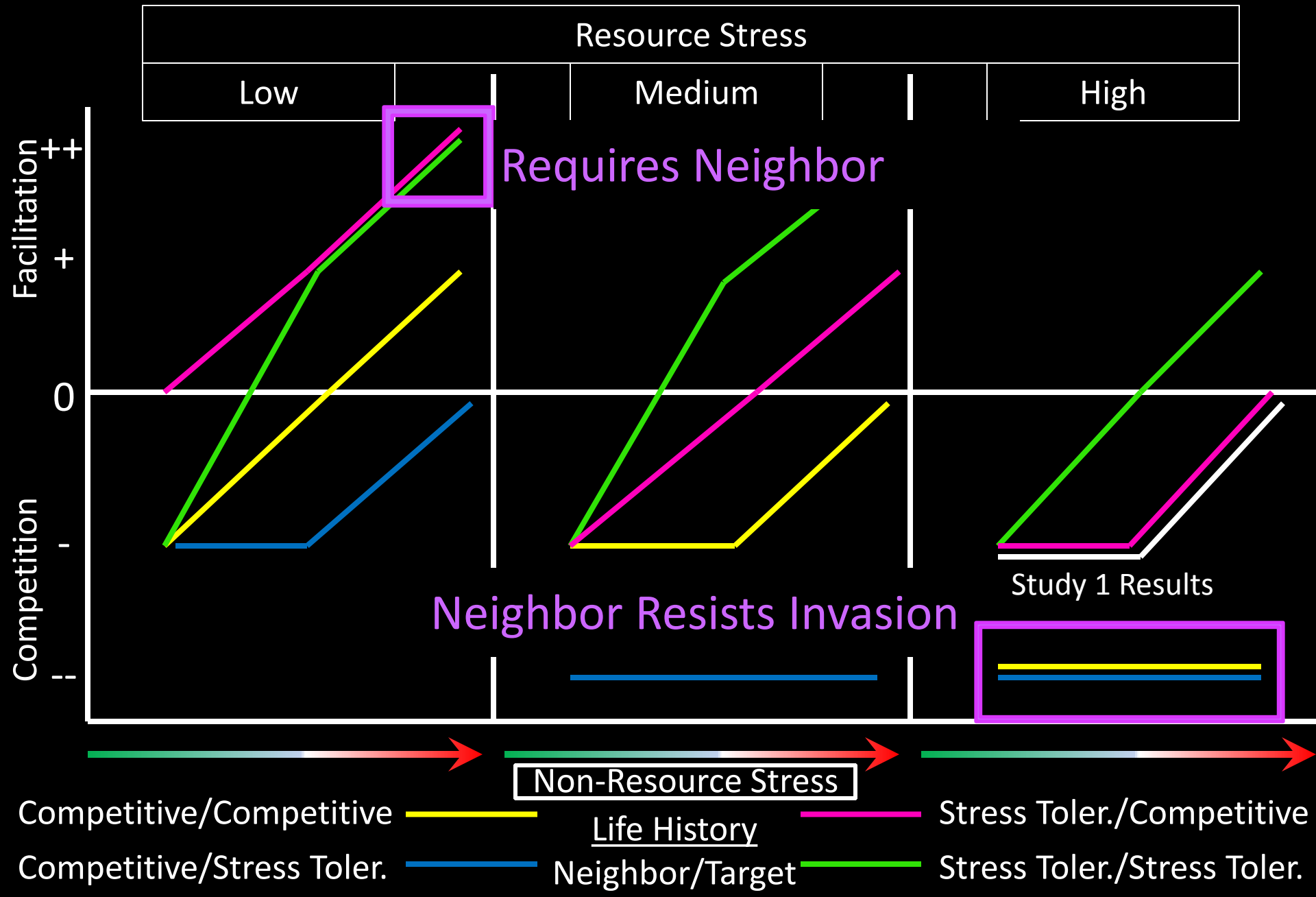
Salt Marsh
— Present
— Removed

Conclusions

Effects of salt marsh on mangroves

- Study 1
 - *Rhizophora mangle* only
 - Varied over time
 - Varied by water depth
 - Not consistent with SGH
- Study 2
 - *Avicennia germinans* only
 - Observational
 - Seedling Size (Height)
 - » Salt Marsh: Positive Effect - Dampens effect of stressors
 - Experimental
 - Seedling Growth (Change in Height)
 - » Salt Marsh: Small Negative Effect - Unaffected by stressors
 - Seedling Survival and Health
 - » Salt Marsh: Positive Effect - Dampens effect of stressors
- Stress Gradient Hypothesis: Results only rarely conformed to SGH
 - Multiple Stress Gradient Hypothesis

Multiple Stress Gradient Hypothesis Predictions



Acknowledgements

- My Committee

- C. Edward Proffitt
- Donna Devlin
- Ilka “Candy” Feller
- Margaret Koch
- Erik Noonburg
- Uta Berger

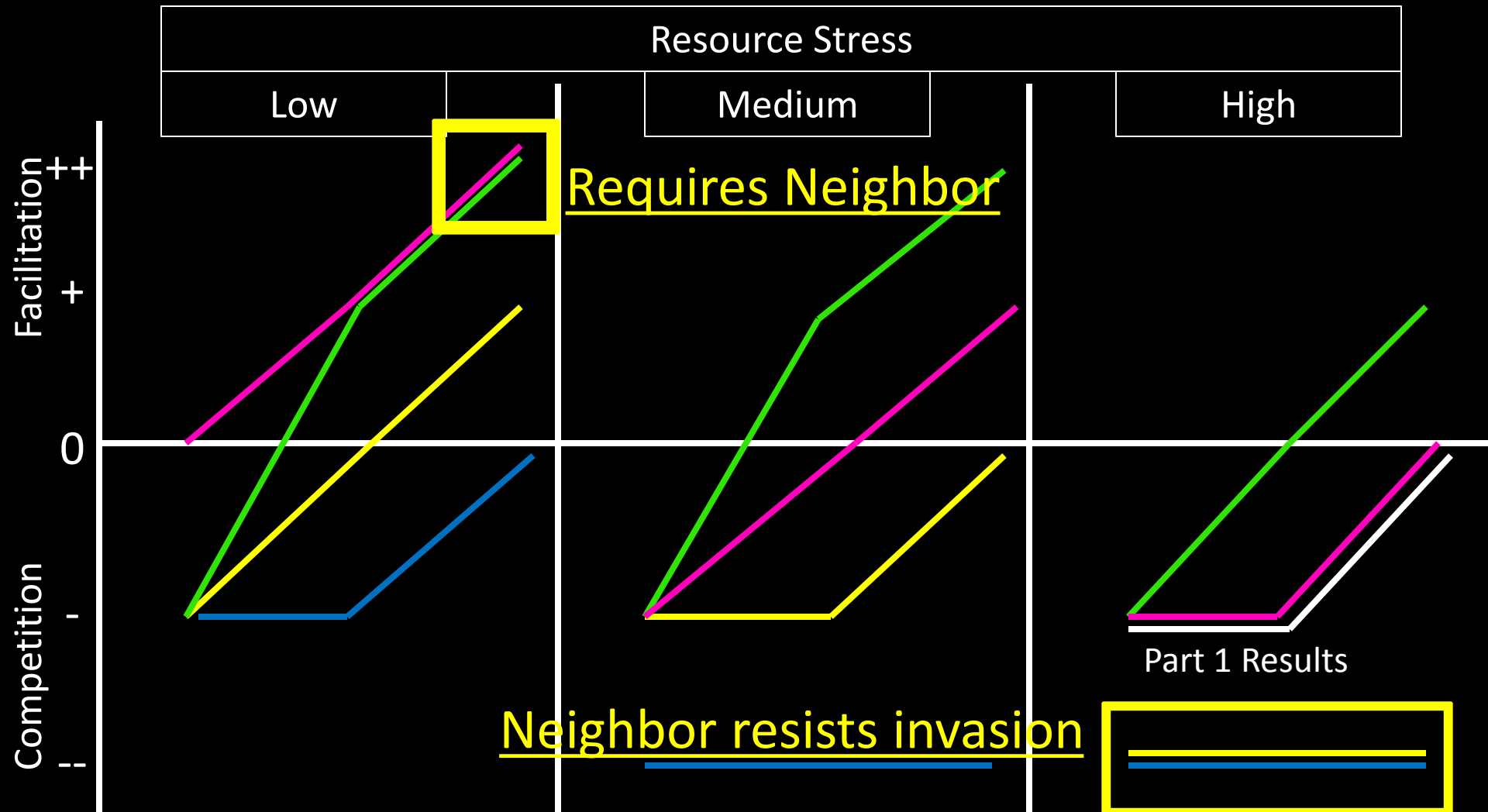


- Field and Lab Assistance

- Kathryn Tiling
- Dana Smith
- Pedro Lara
- Benjamin Sollins



Multiple Stress Gradient Hypothesis Predictions



Requires Neighbor

Neighbor resists invasion

Part 1 Results

Non-Resource Stress

Competitive/Competitive

—

Life History

—

Stress Toler./Competitive

Competitive/Stress Toler.

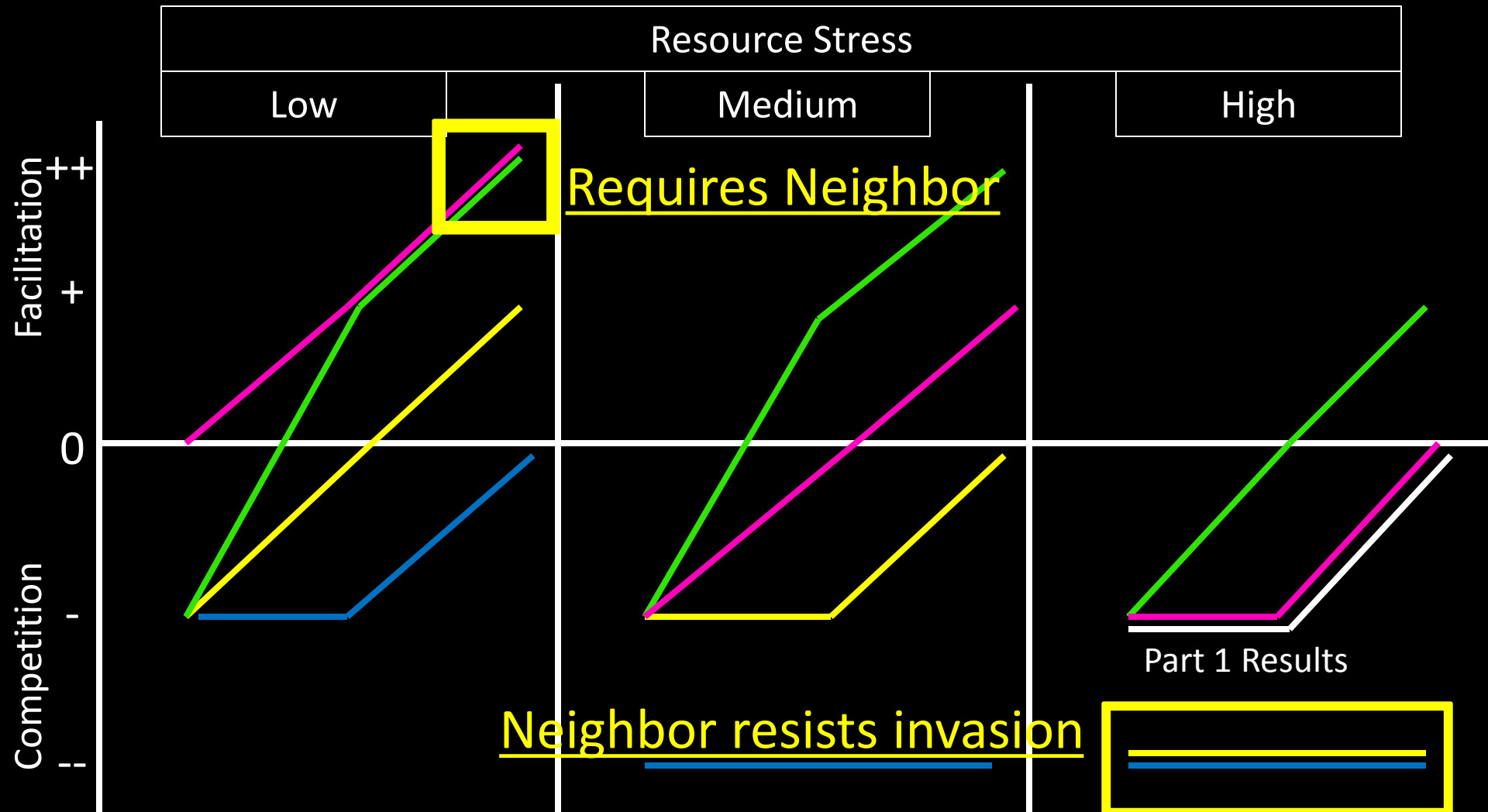
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Neighbor/Target

—

Stress Toler./Stress Toler.

Multiple Stress Gradient Hypothesis Predictions



Requires Neighbor

Neighbor resists invasion

Non-Resource Stress

Part 1 Results

Competitive/Competitive

—

Life History

—

Stress Toler./Competitive

Competitive/Stress Toler.

—

Neighbor/Target

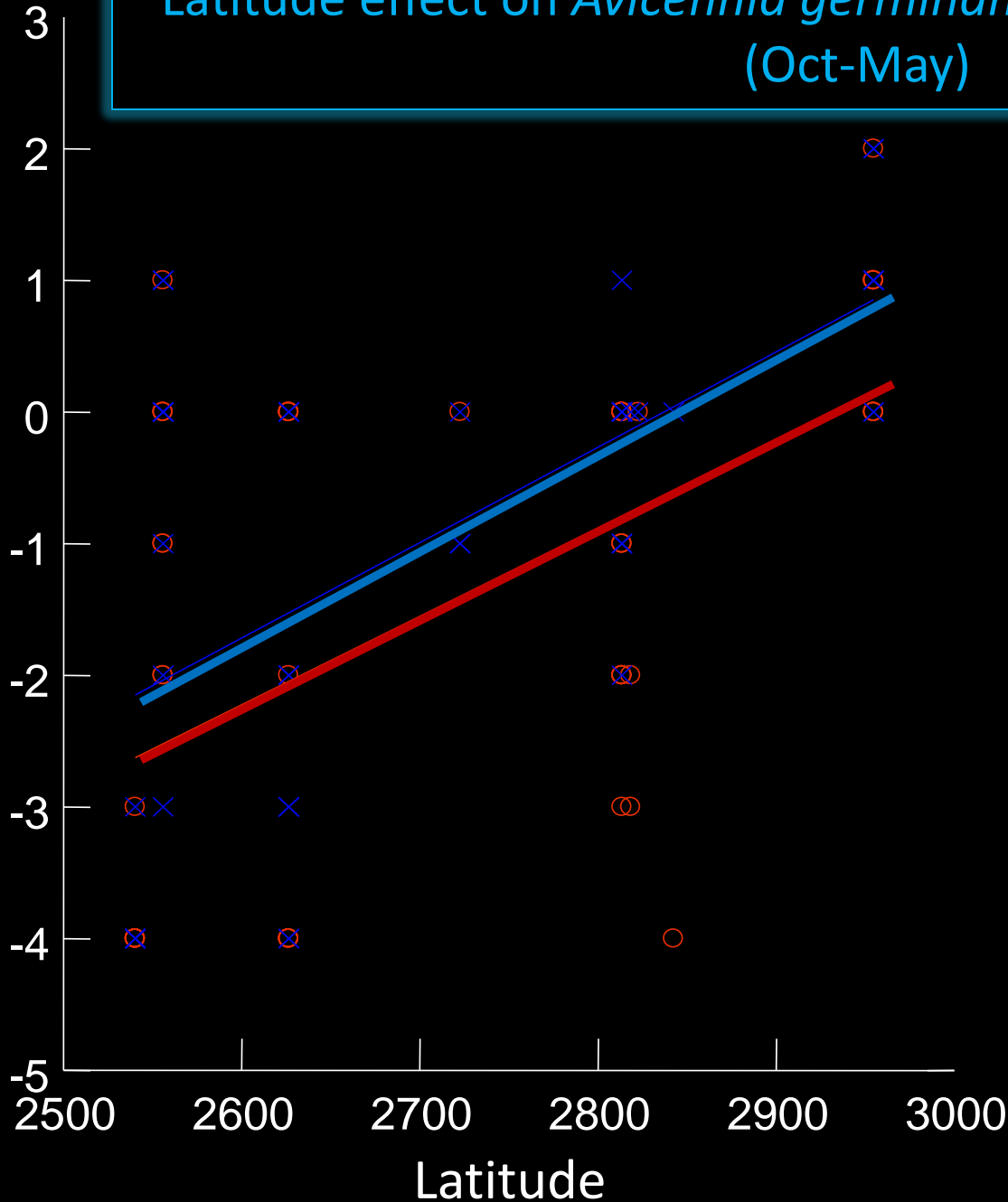
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Stress Toler./Stress Toler.

Latitude effect on *Avicennia germinans* change in Health Rank
(Oct-May)

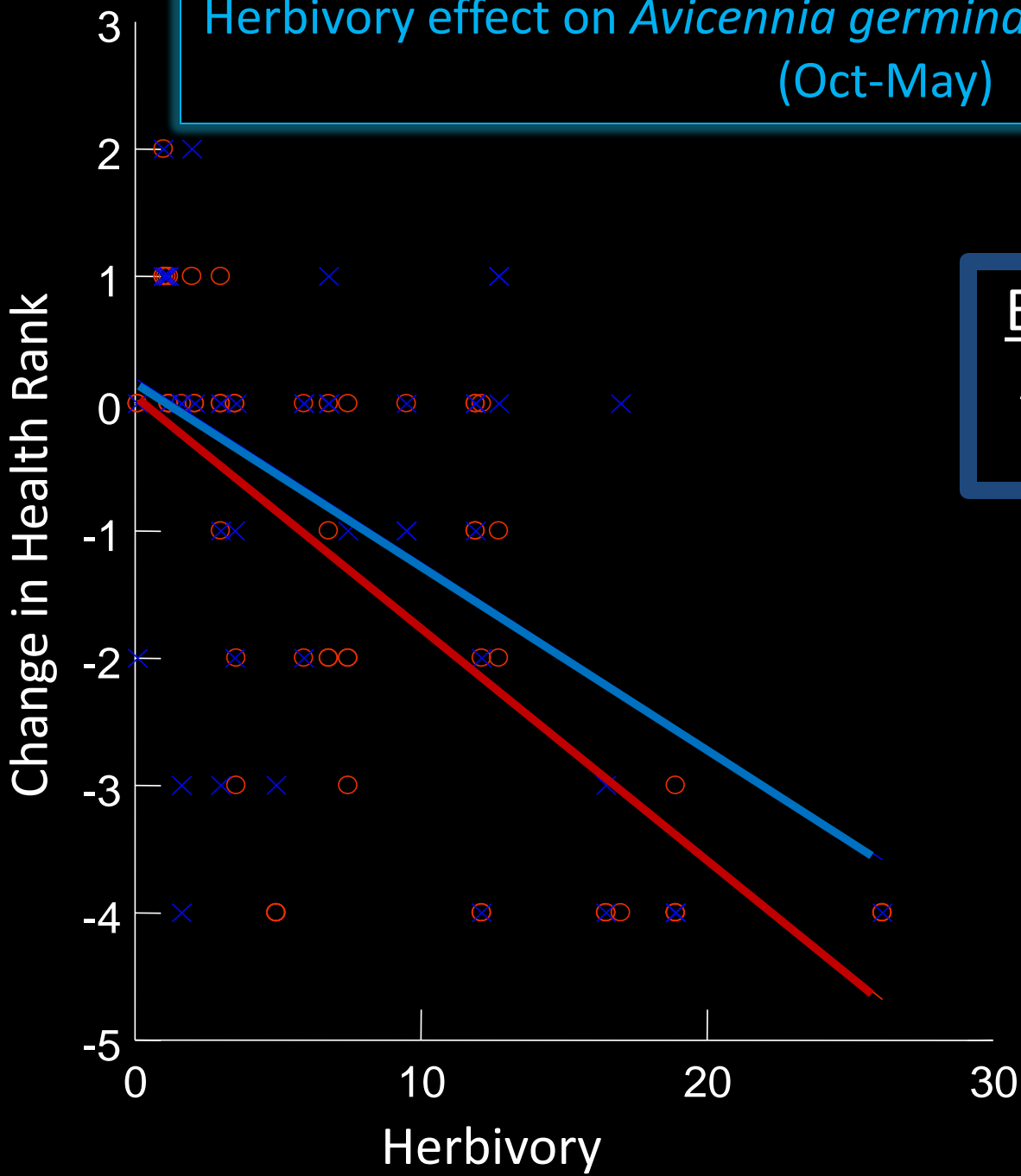
Change in Health Rank

Effect of Salt Marsh
All positive
regardless of stress



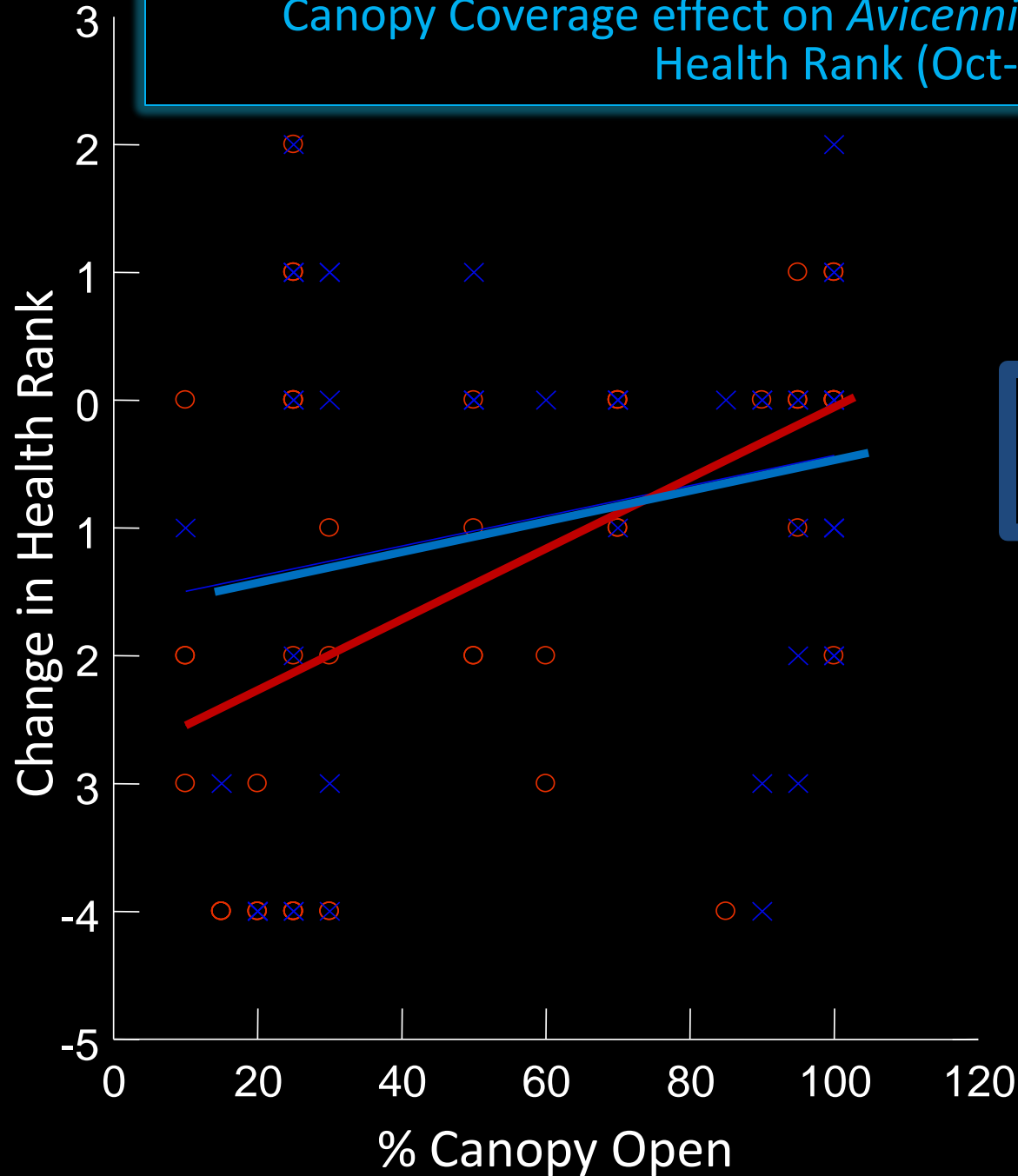
Salt Marsh
— Present
— Removed

Herbivory effect on *Avicennia germinans* change in Health Rank (Oct-May)



Effect of Salt Marsh
All small to moderate positive

Canopy Coverage effect on *Avicennia germinans* change in Health Rank (Oct-May)

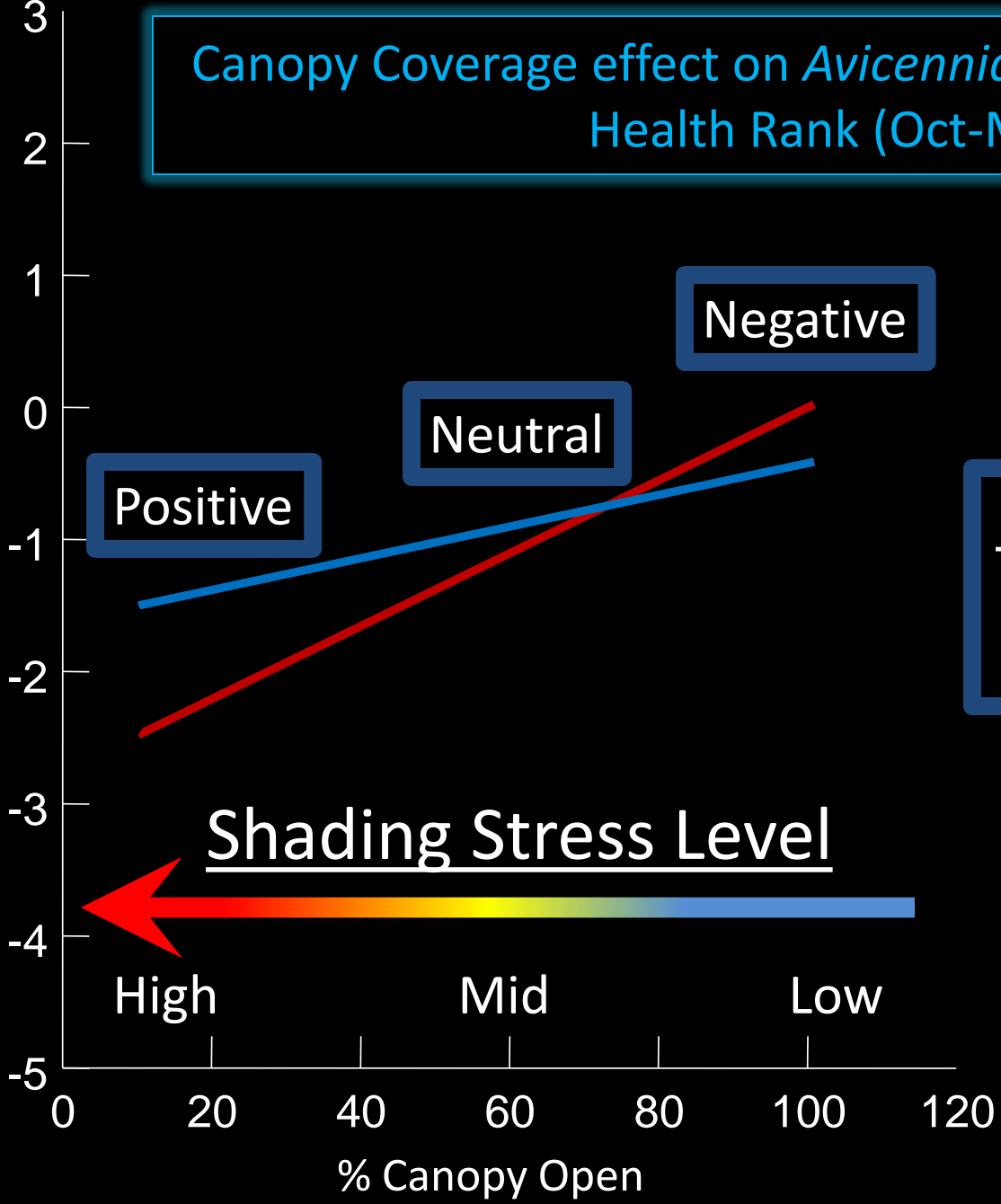


Effect of Salt Marsh
Varied by stress level

Salt Marsh
— Present
— Removed

Canopy Coverage effect on *Avicennia germinans* change in Health Rank (Oct-May)

Change in Health Rank



Negative

Neutral

Positive

Effect of Salt Marsh
Only result to match
SGH predictions

Shading Stress Level

High

Mid

Low

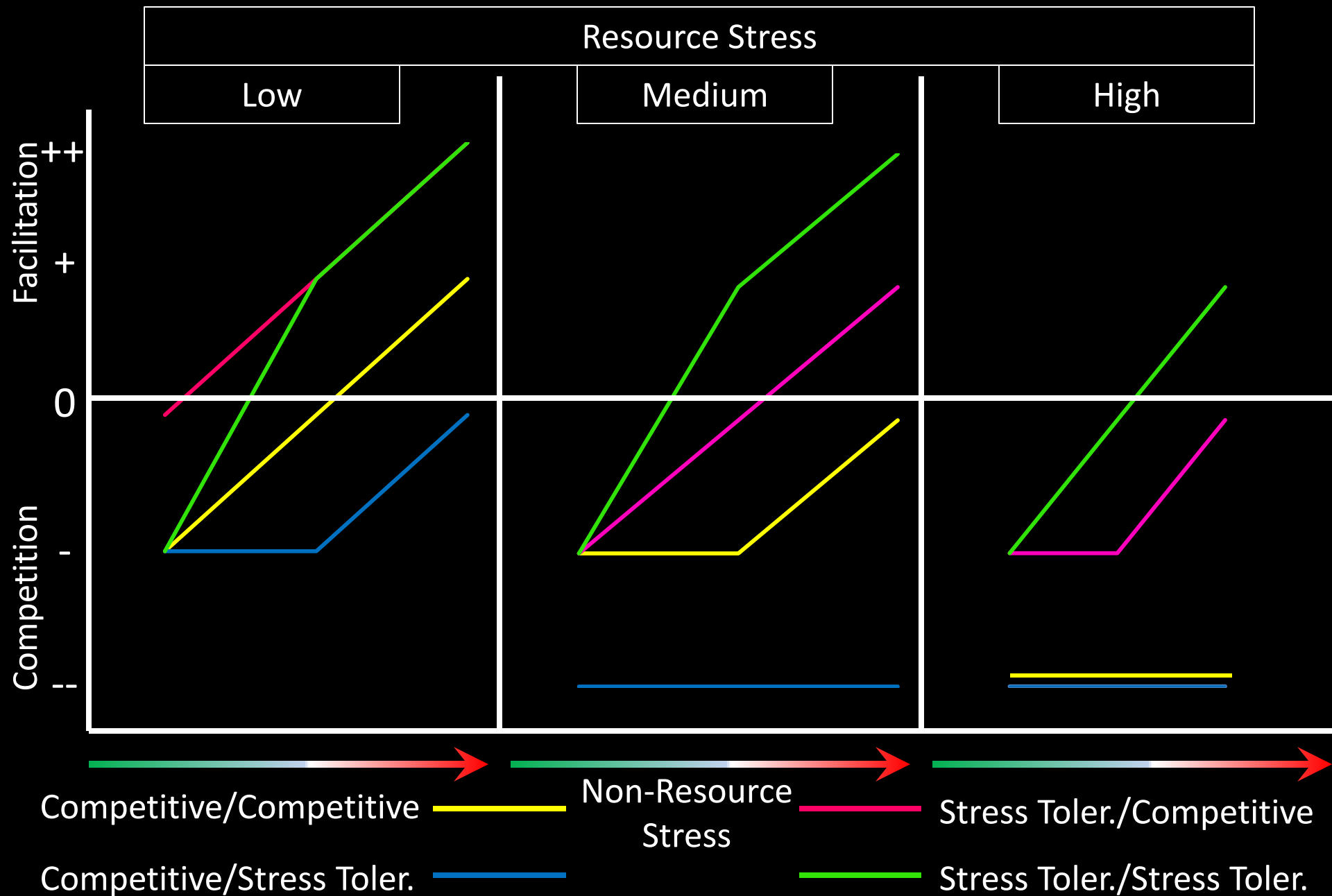
Salt Marsh

Present

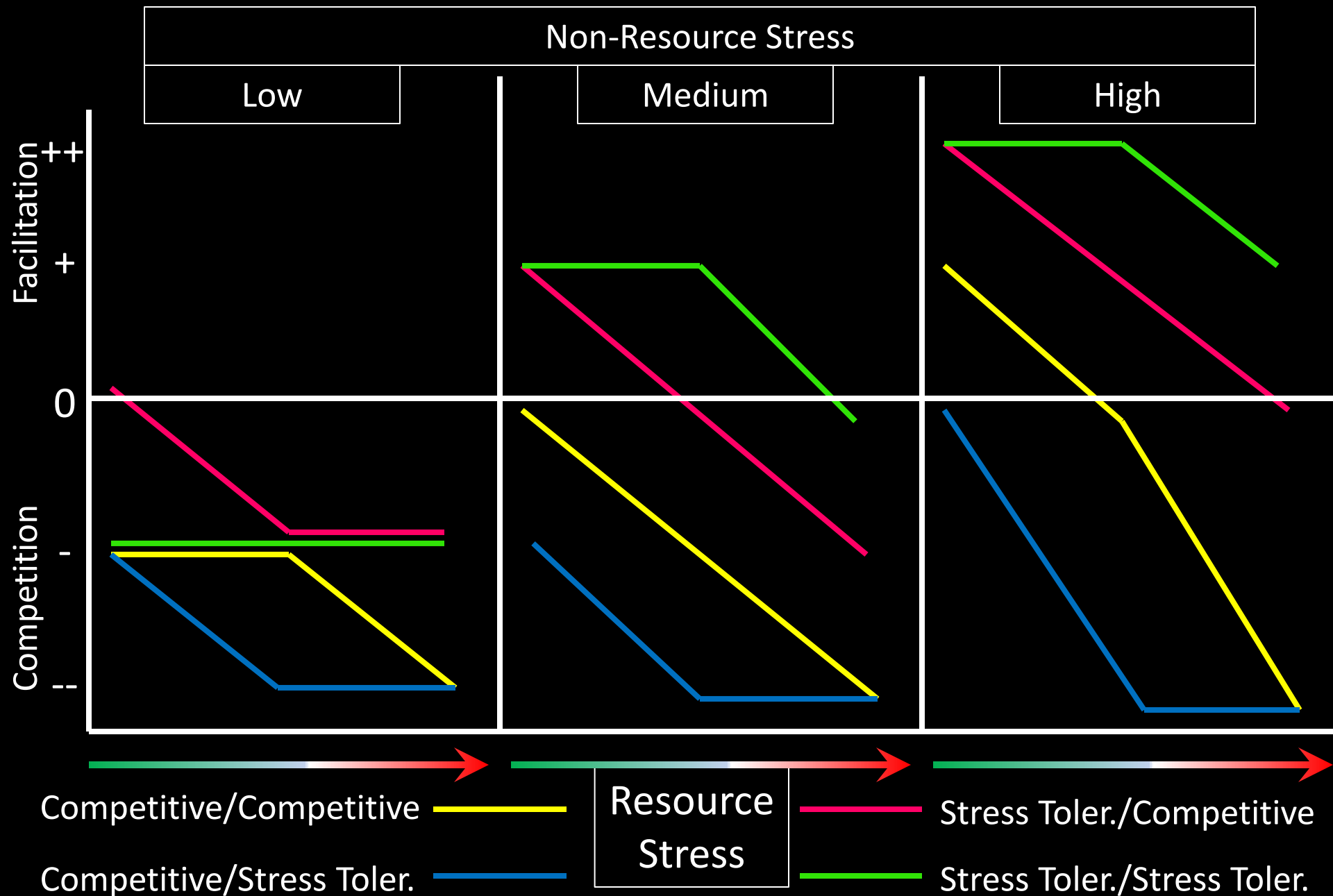
Removed

% Canopy Open

Multiple Stress Gradient Hypothesis Predictions



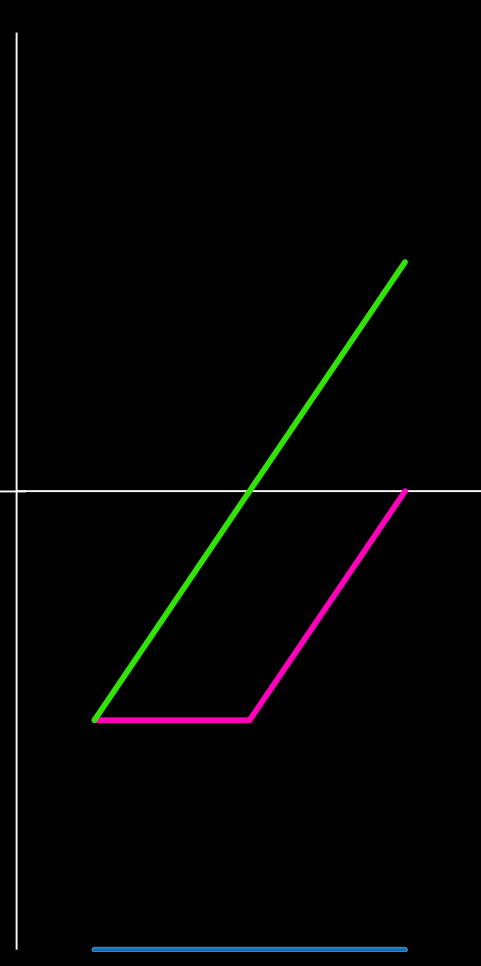
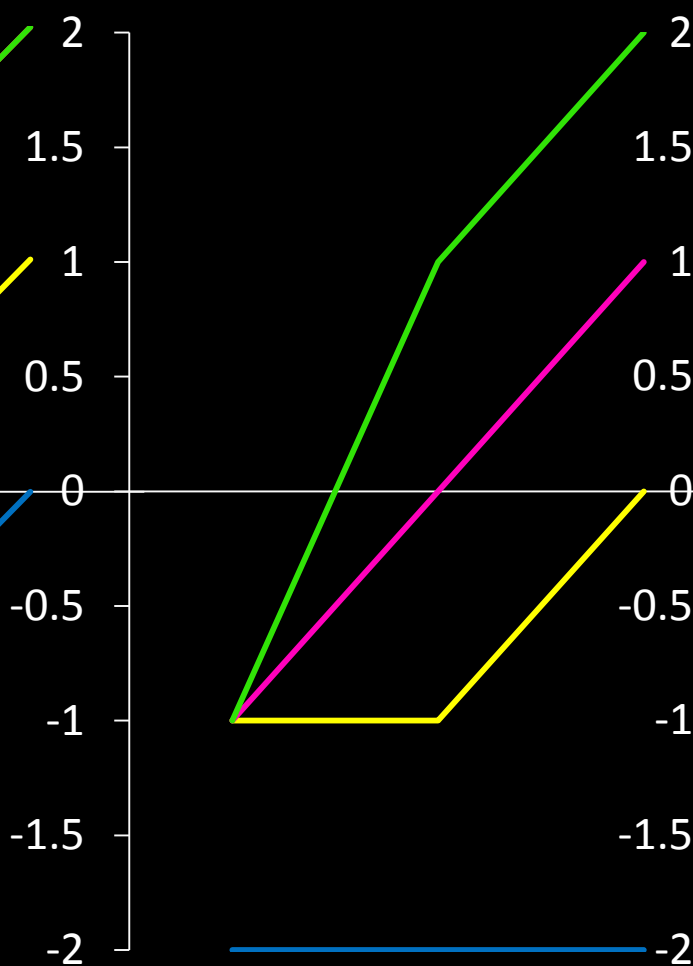
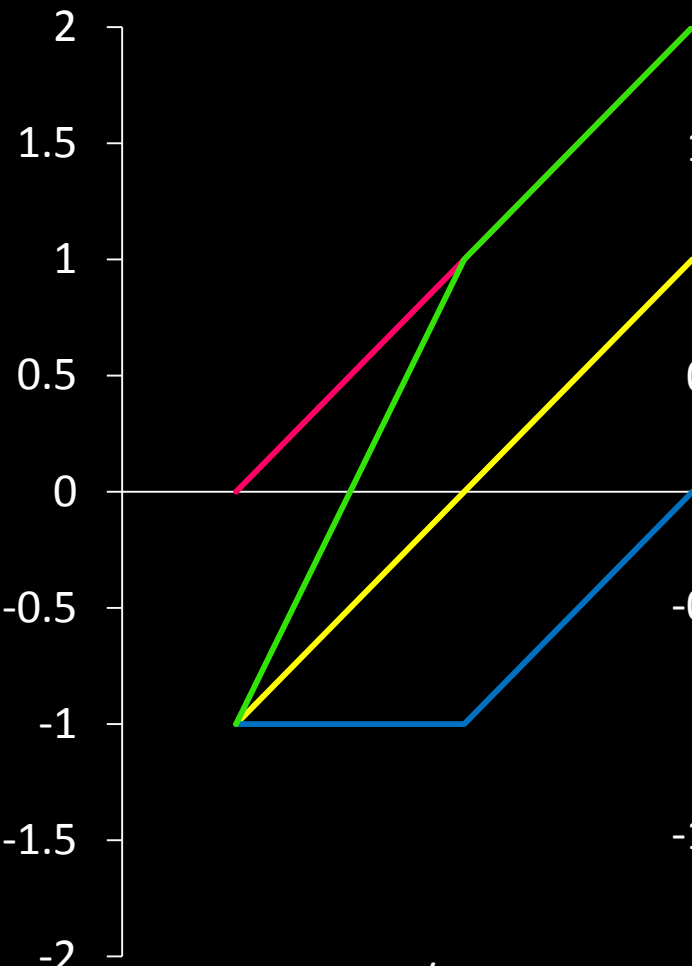
Multiple Stress Gradient Hypothesis Predictions



Low Resource Stress

Med Resource Stress

High Resource Stress

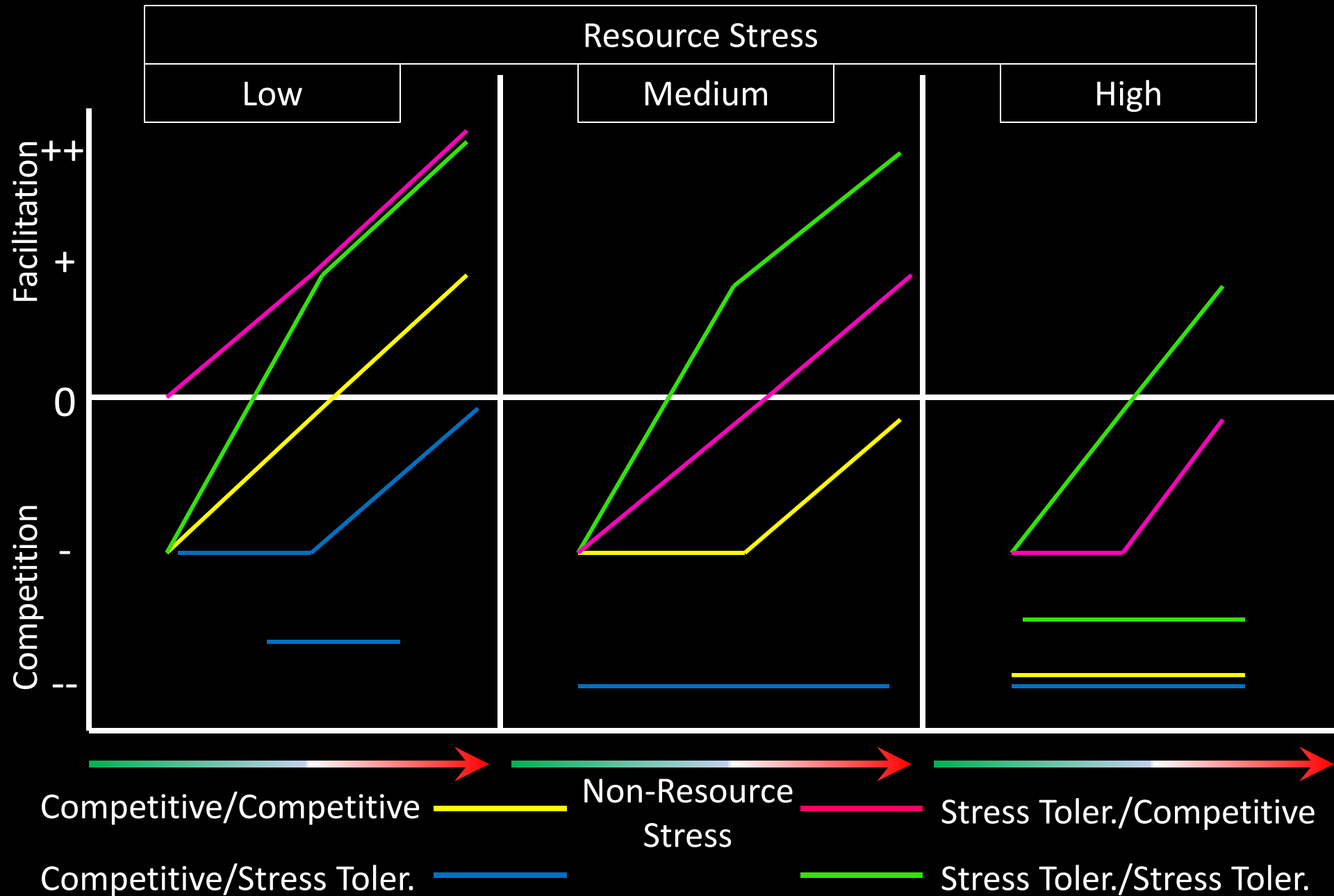


— Competitive/Competitive
— Competitive/Stress Toler.
— Stress Toler./Competitive
— Stress Toler./Stress Toler.

— Competitive/Competitive
— Competitive/Stress Toler.
— Stress Toler./Competitive
— Stress Toler./Stress Toler.

— Competitive/Competitive
— Competitive/Stress Toler.
— Stress Toler./Competitive
— Stress Toler./Stress Toler.

Multiple Stress Gradient Hypothesis Predictions



Growth Height and Canopy Volume

- No effect of salt marsh or stress gradients on Height or Canopy Growth in survivors
- Correlation: Height and Canopy Volume
 - Time 1 = 0.441
 - Time 2 = 0.604

Results if you only consider latitude Logistic Regression

Salt Marsh	Present	Removed
Avicennia Survival= (Standardized Coefficients)		
	1.020	1.007
	P=0005	P=0005

Future Work

- Expand the study over additional sites
 - Increase replication for more complex models
- Test multiple stressor effects in experimental setting
- Scale up to adult species composition using Individual Based Modeling

OBJECTIVES

- Previous study
 - Effects of salt marsh on mangroves
 - Small scale (0.25m²)
 - Short term ~1.5 year
 - *Rhizophora mangle* only
- This study
 - Effects of salt marsh on mangroves
 - Over broad scale
 - *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa*
 - Multiple stress gradients