Evaluating Living Shorelines
to Inform Regulatory Decision-Making in South Carolina

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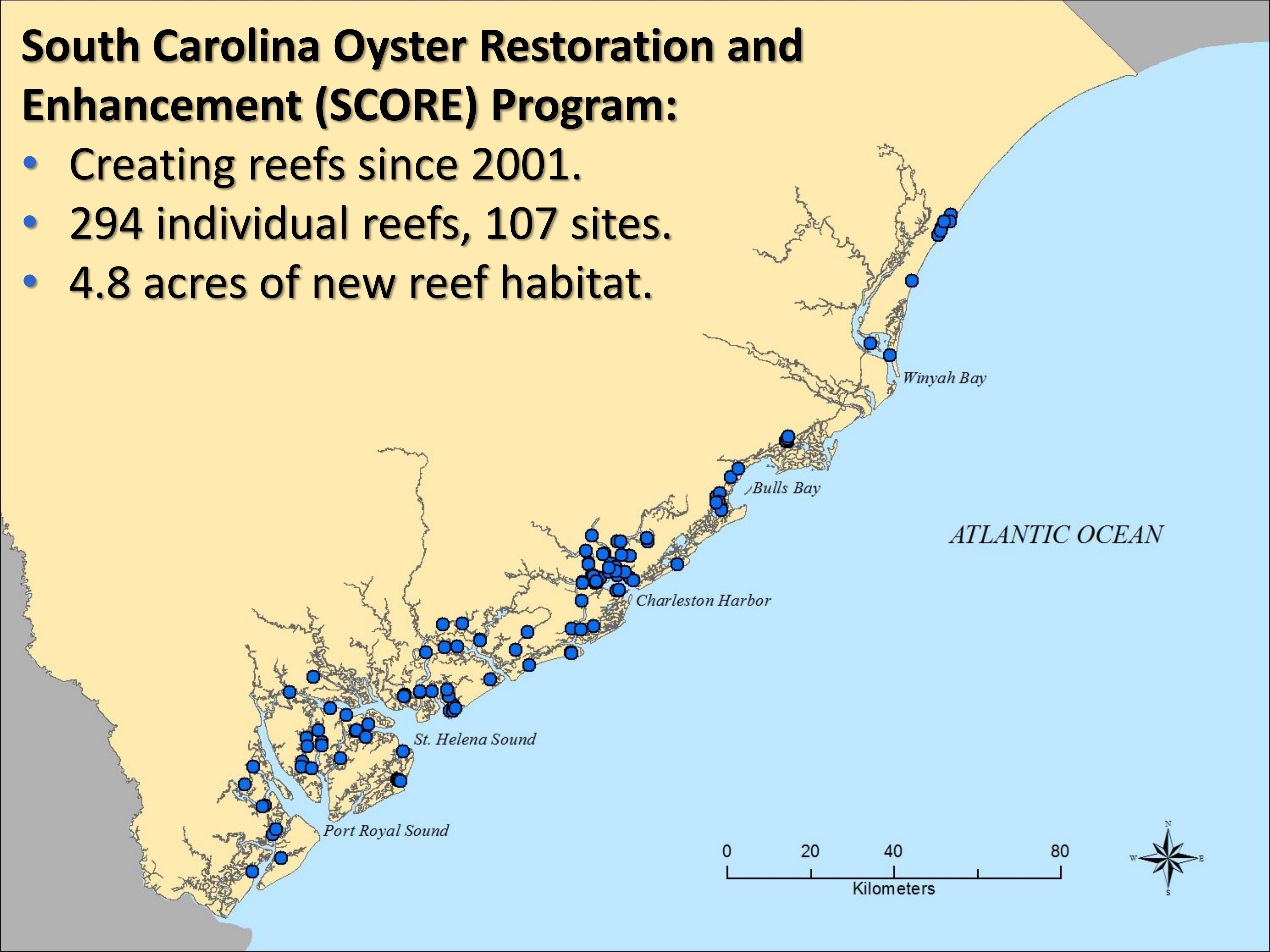
South Carolina Oyster Restoration and Enhancement (SCORE) Program:

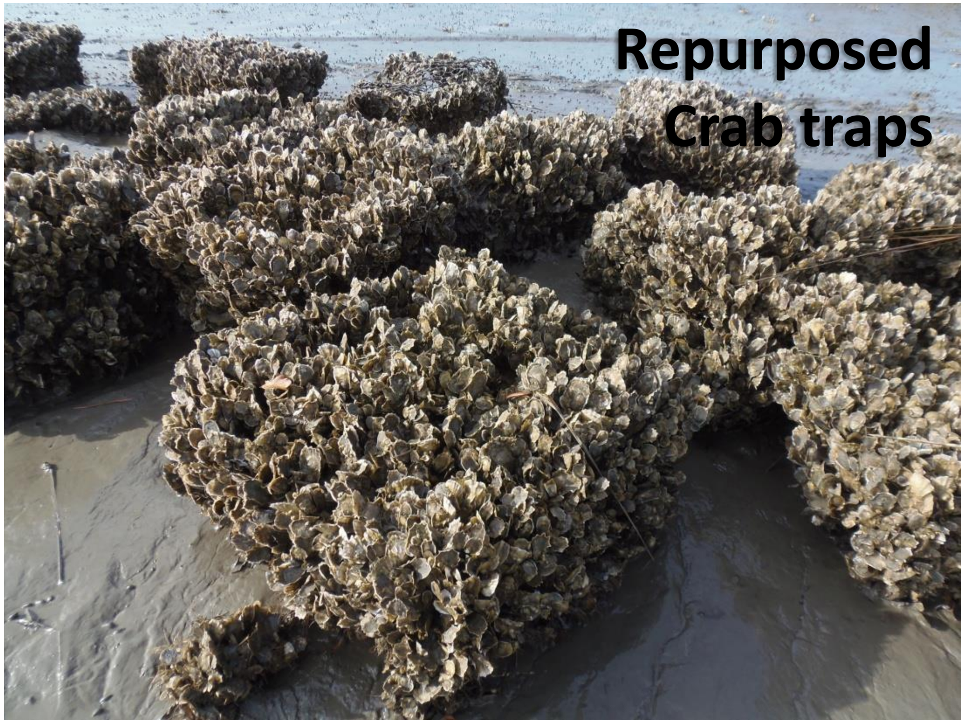
- Creating reefs since 2001.
- 294 individual reefs, 107 sites.
- 4.8 acres of new reef habitat.

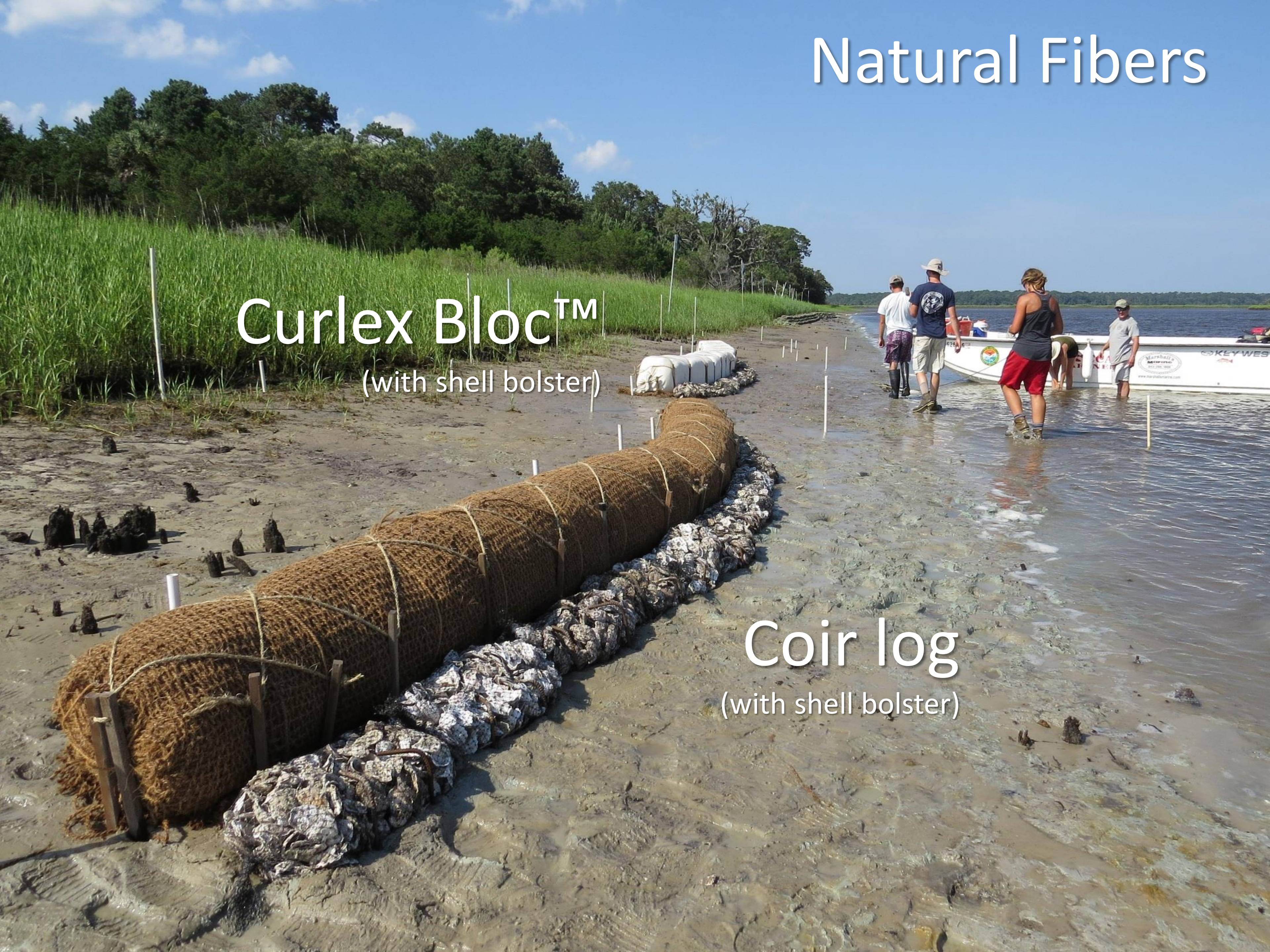



Loose oyster shell


Bagged oyster shell


Oyster castles


Repurposed
Crab traps


Natural Fibers
Curlex Bloc™
(with shell bolster)
Coir log
(with shell bolster)

Wire mesh reefs

Repurposed crab trap (RCT)

Manufactured wire reef (MWR)

Project Components:

- Create and monitor new experimental sites

  -New materials, new location types

- Monitor existing reef sites

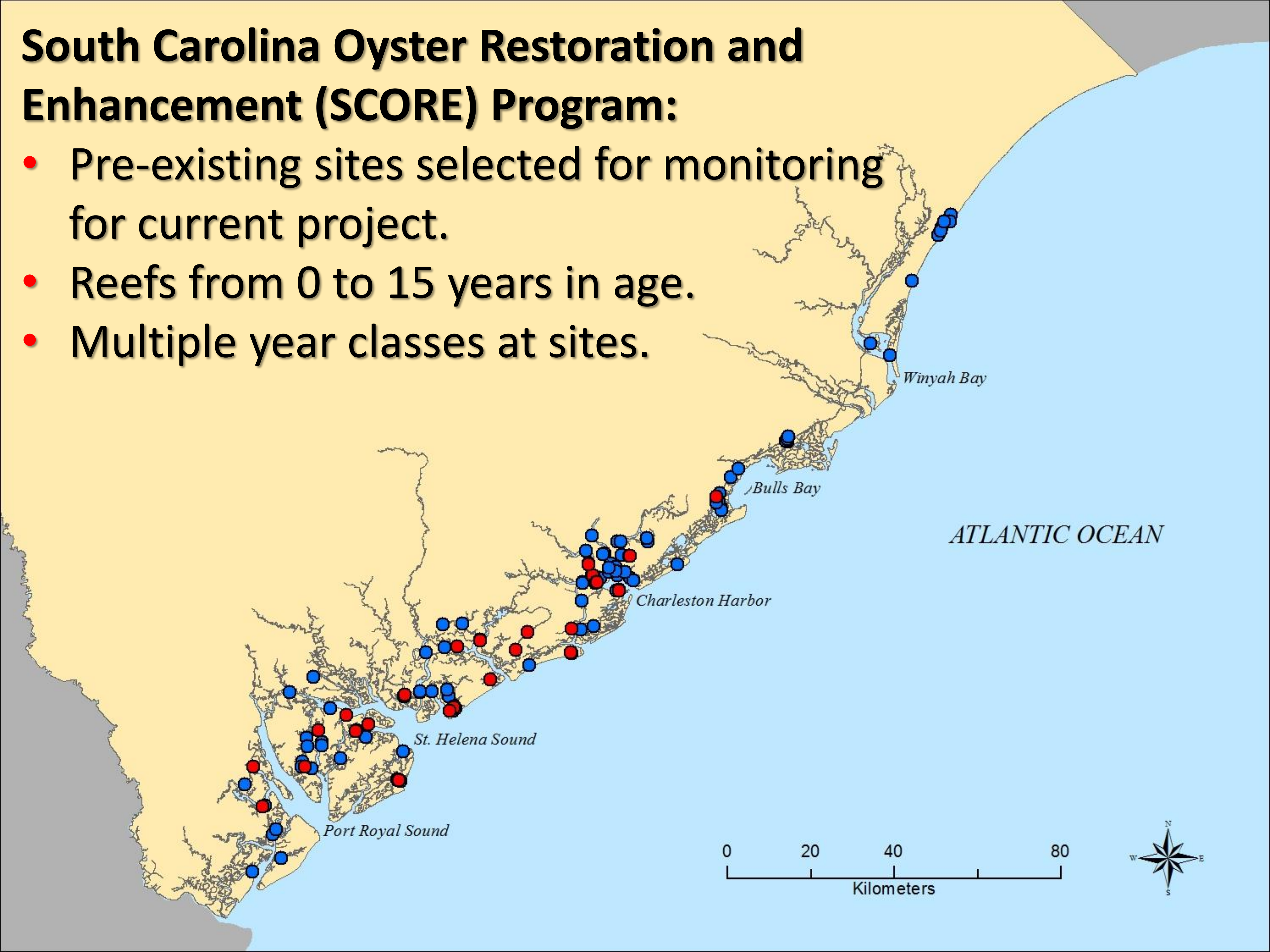
  -Longer time trajectory

- Comprehensive data synthesis and analysis

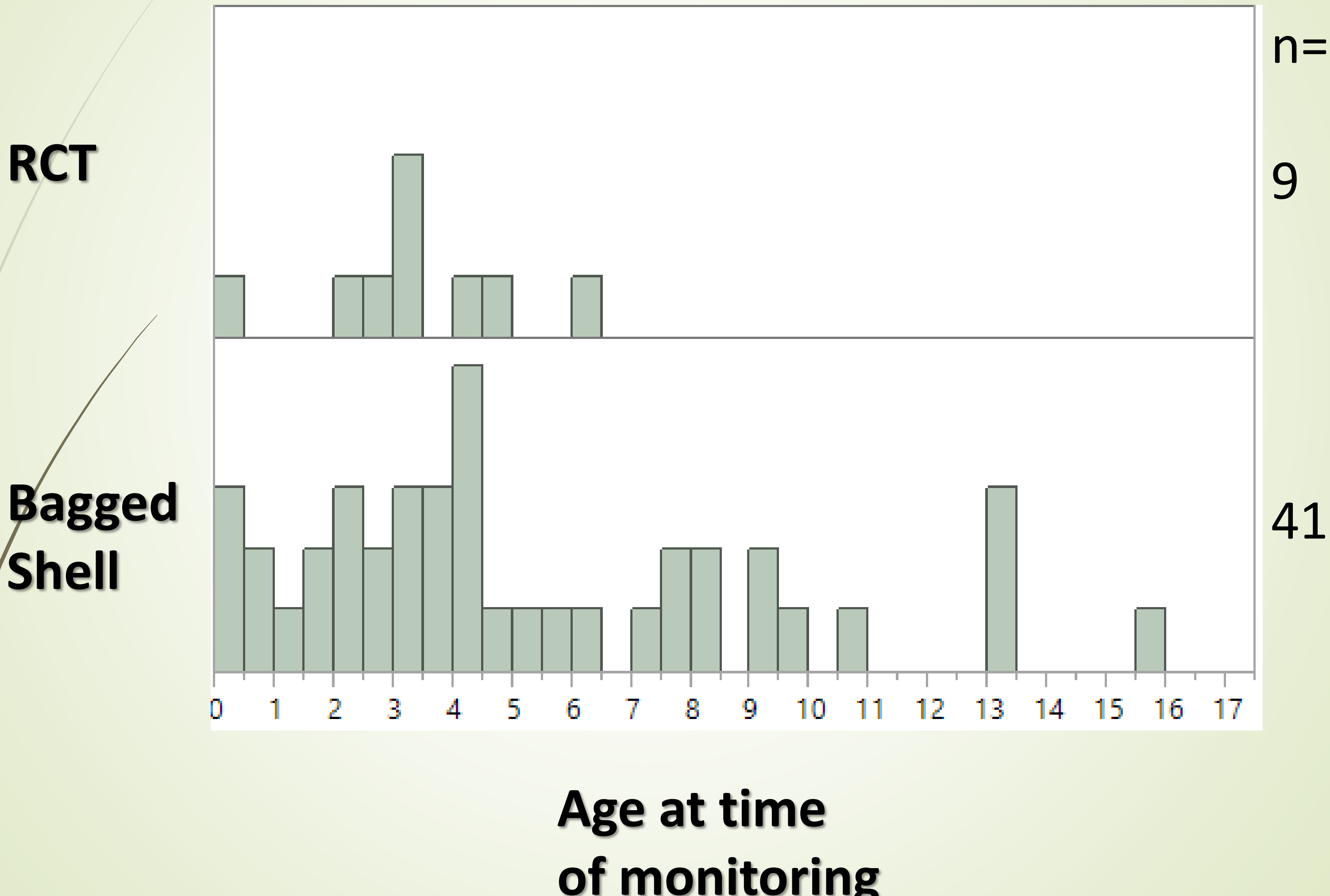
- Compile guidance document

South Carolina Oyster Restoration and Enhancement (SCORE) Program:

- Pre-existing sites selected for monitoring for current project.
- Reefs from 0 to 15 years in age.
- Multiple year classes at sites.



Monitoring of existing reefs

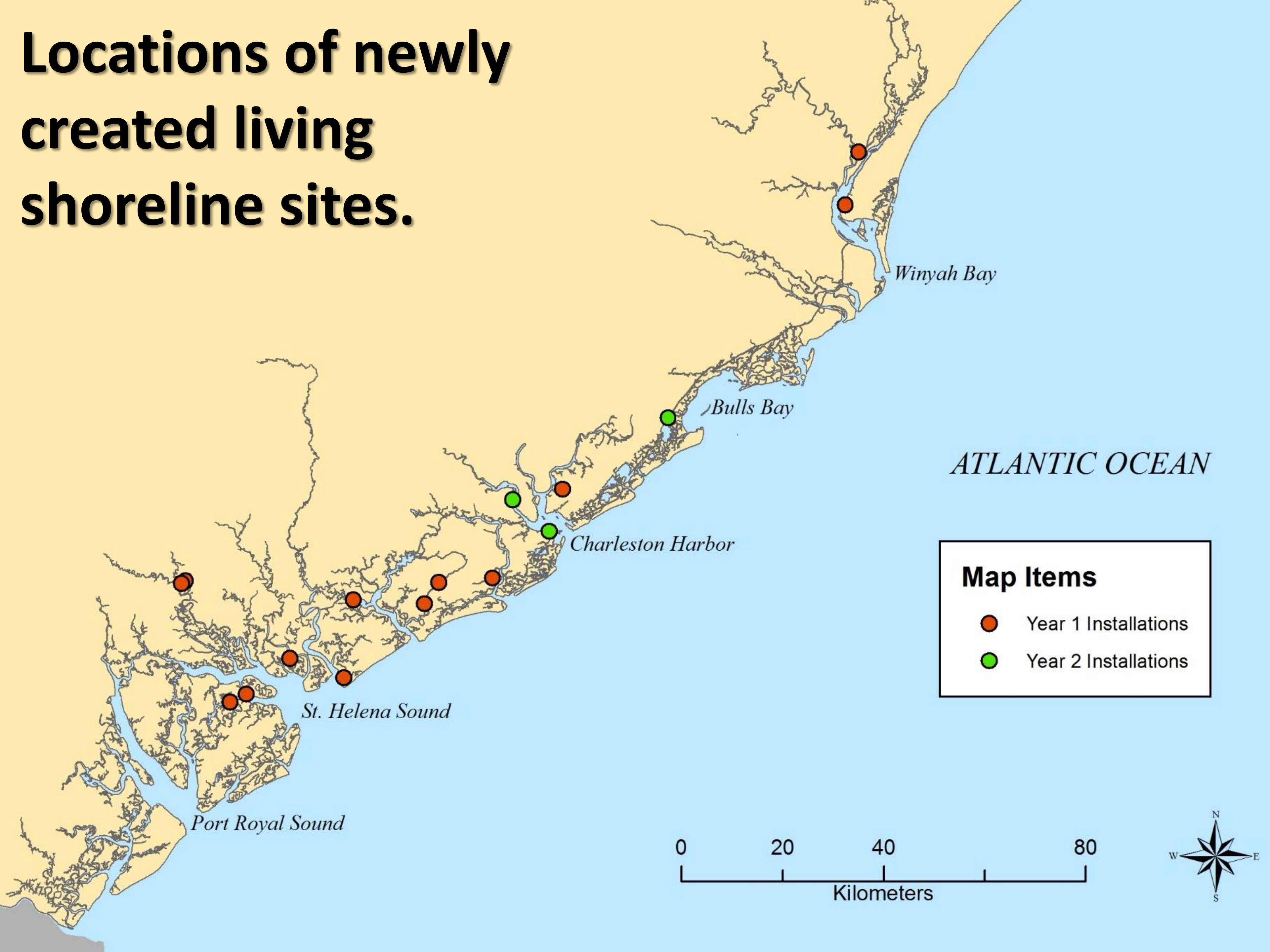


Morphology	Dredged	Inside	Outside	Outside-straight	Straight	ICW: no	ICW: yes
Bagged Shell	4	6	14	6	11	28	13
RCTs	1	3	3		2	7	2

Generally high energy areas

Also open bays, not included for existing reefs

Locations of newly created living shoreline sites.



Site Type Categories

Type A

- Successful bagged shell reef (SCORE) sites.
- Relatively gentle slope.
- Relatively firm sediment.

Type B

- Environment supports oysters, but previous SCORE reefs were not successful.
- Steep slope or soft sediment.

Type C

- Physical environment not conducive to oyster-based strategies (e.g., salinity too low, variable)
- Focus is on natural fiber-based approaches.

Installation of new reefs

Sites		LIVING SHORELINE TREATMENTS							Year
Type	Location	Shell Bags	Bags + pallets	MWR v1	MWR v2	Curlex	Coir -single	Coir -double	
A	Coosaw Cut	1				1	3		2016
	Dataw Is.	1				2	5		2016
	Boy Scout	1				1	3		2016
B	Hobcaw		1	1		1			2016
	Morgan Is.		1	1		1	1		2016
	Bohicket		1	1		1	1		2016
	Dawho		1	1			2		2016
	Abbapoola		1	1			1		2016
	Big Bay		1	1			2		2016
	Awendaw		2	1	1			2	2017
	Orangegrove		2	1	1			2	2017
	Ft Johnson		1	1	1			1	2017
C	Combahee 2					2	4		2016
	Combahee 3					2	4		2016
	Whitehouse					2	4		2017
	Little Dock					1	3		2017

Assessing Site Characteristics

- Substrate characterization
  - Sediment % silt/clay
  - Sink depth (pluffiness). Ease of measurement.
- Bank slope and bank width
- Water body width (fetch)
- Salinity
- Escarpment height
- Erosion rate (DSAS)
- Geomorphology (outside bend, inside…etc.)
- Vertical placement relative to:
  - Tide frame
  - Marsh edge

Assessing Treatment Performance

- Did treatment fail?
- Did treatment lose some integrity?

  -Sliding downslope, dislodged, partial sediment smothering

- How well did it perform?

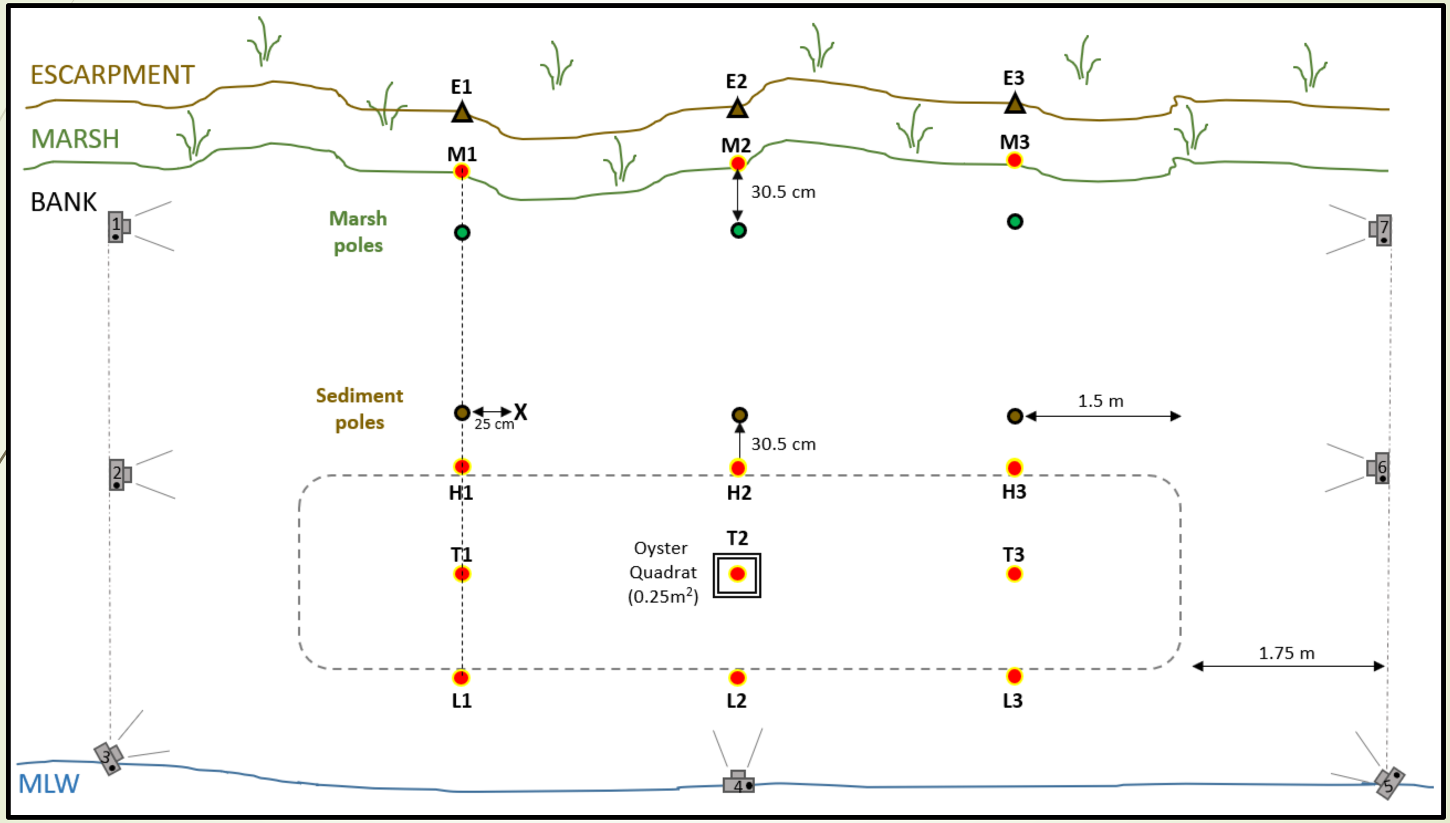
  -Sediment type change

  -Vertical change (sediment build up)

  -Lateral change (marsh expansion or erosion prevention)

  -Oyster coverage

Monitoring design schematic



Immediately after installation.

Big Bay Creek, July 26th 2016


3 months after installation
And Hurricane Matthew.
Big Bay Creek, October 14th 2016

Coir logs, 32 mo. post-install (after 2 hurricanes)
Note natural marsh expansion
Big Bay Creek, May 3rd, 2019

3 months after installation & Hurricane Matthew

Big Bay Creek, October 14th 2016

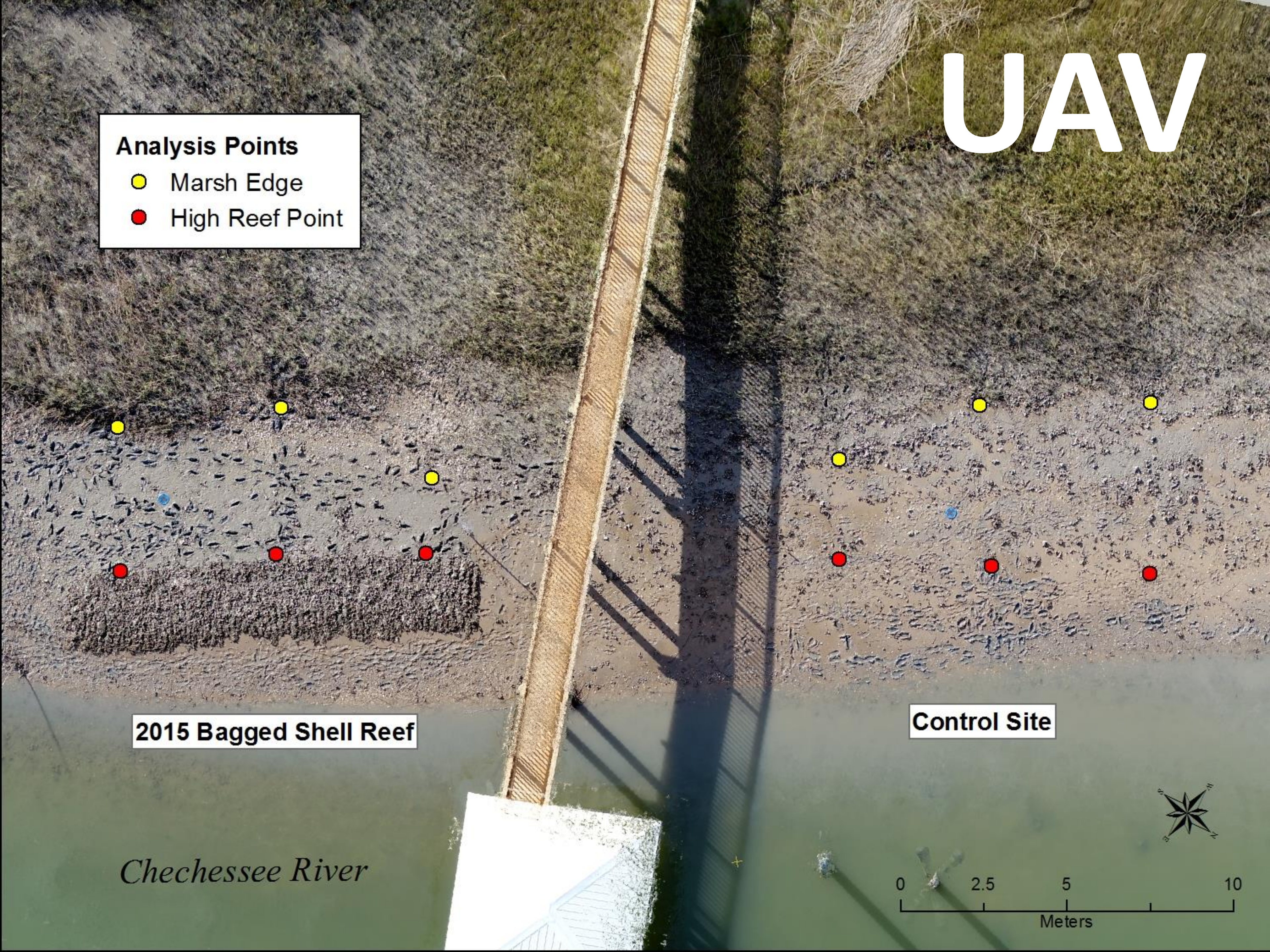
MWR, 32 months after installation

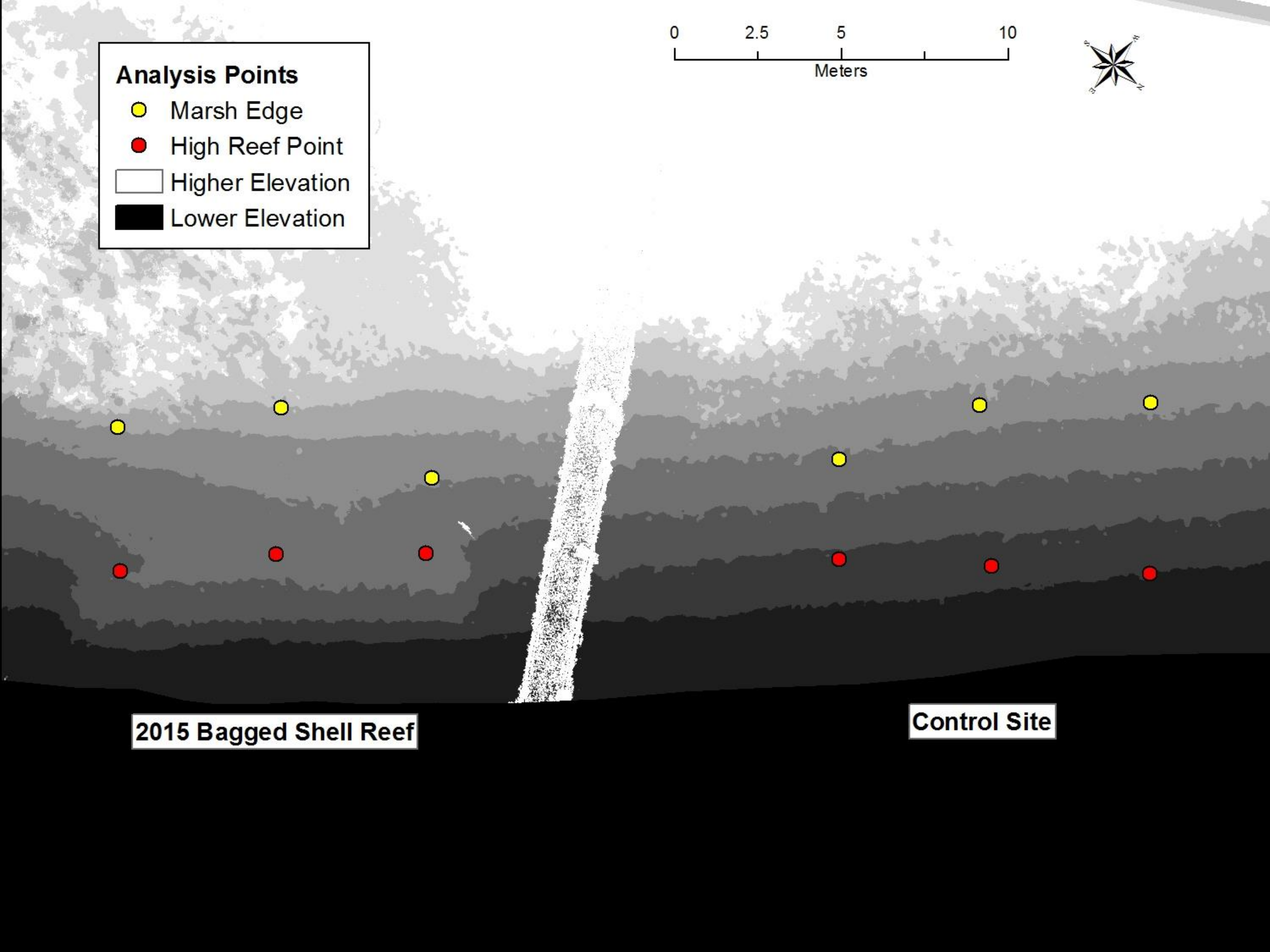
Big Bay Creek, May 3rd, 2019


Curlex Bloc
Coosaw Cut on June 23rd, 2016


August 16, 2016


October 17, 2016


UAV
Analysis Points
Marsh Edge
High Reef Point
2015 Bagged Shell Reef
Control Site
Chechessee River
0
2.5
5
10
Meters

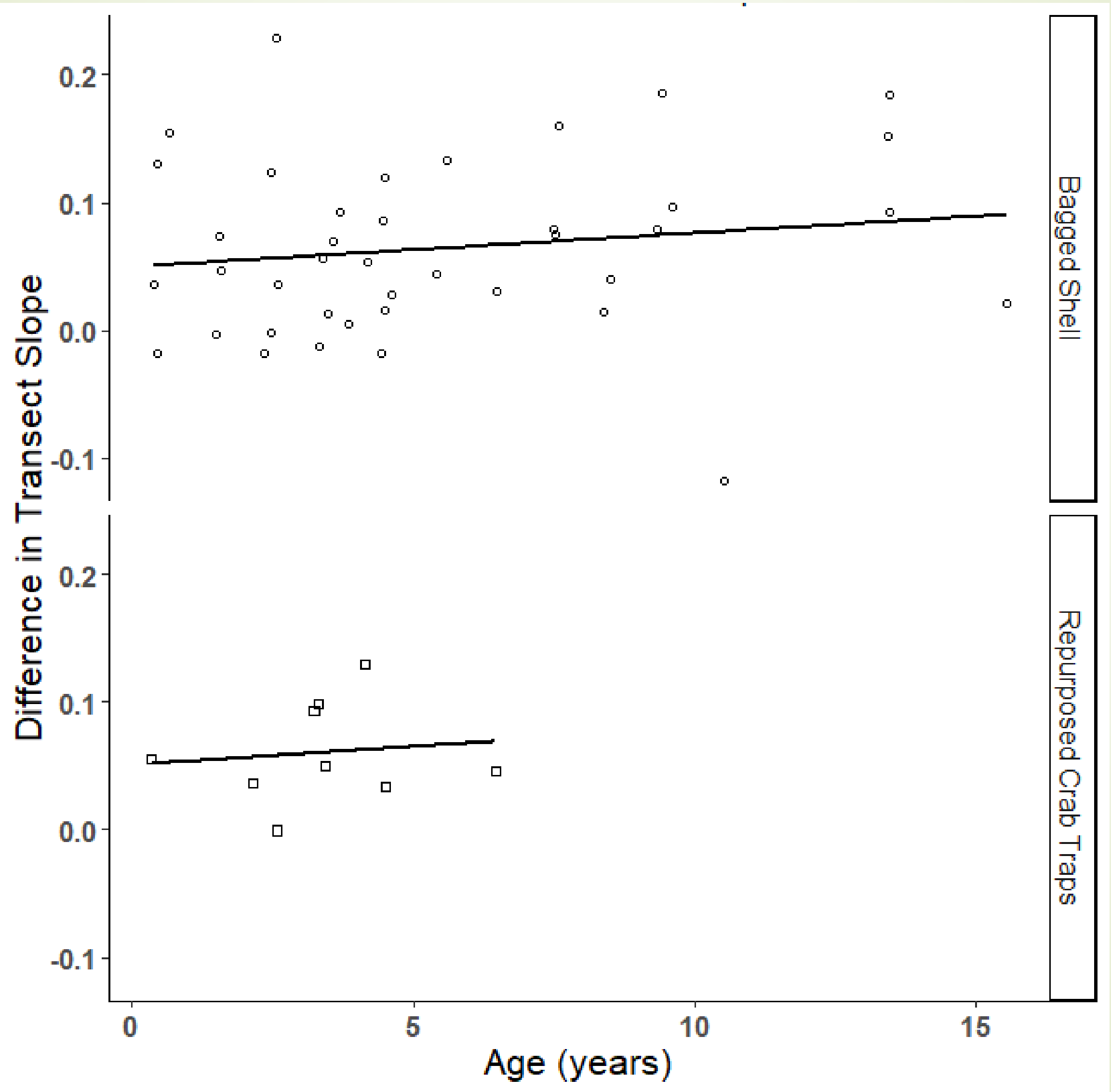


Analysis Points
Marsh Edge
High Reef Point
Higher Elevation
Lower Elevation
0
2.5
5
10
Meters
2015 Bagged Shell Reef
Control Site

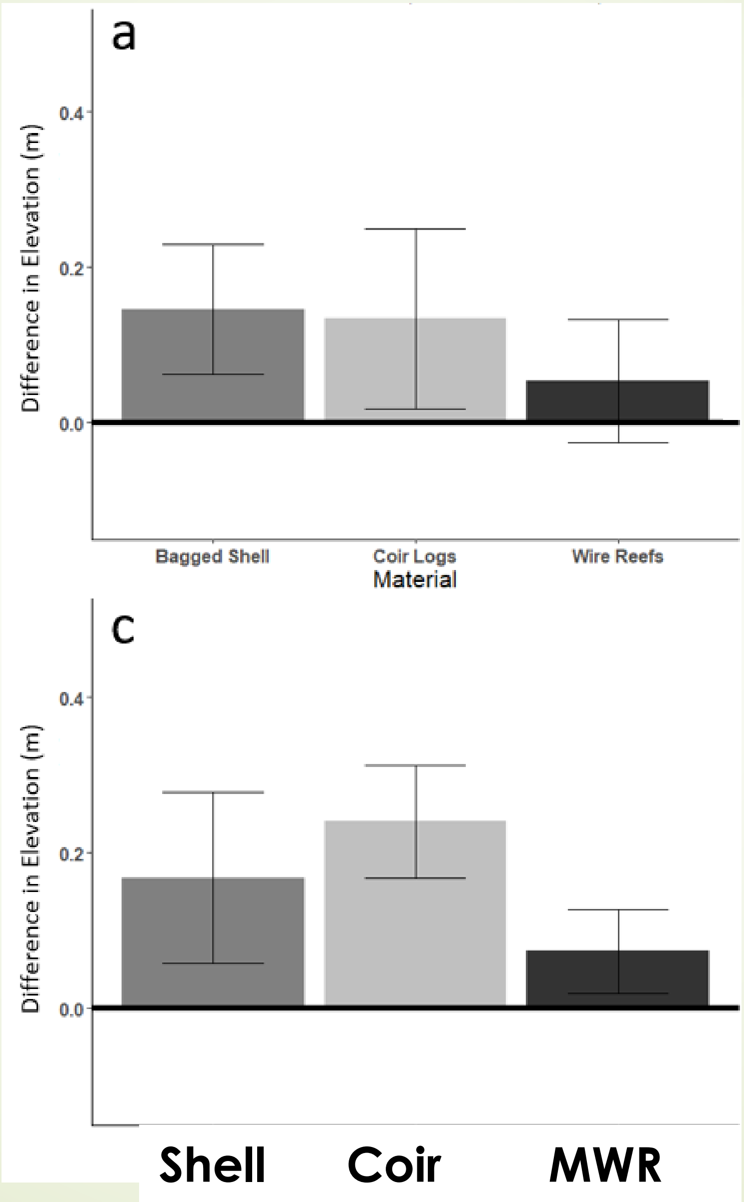
Data analysis

- Regression, ANOVA
  - Treatments over time, treatment comparison
- Stepwise multiple regression
  - Isolate site characteristics associated with performance metrics
- PRIMER
  - Look for trends and patterns between sites
- Combined results with existing knowledge base to develop **decision tree** and **tables**

Results: difference in slope
Existing



Results: difference in accretion New builds



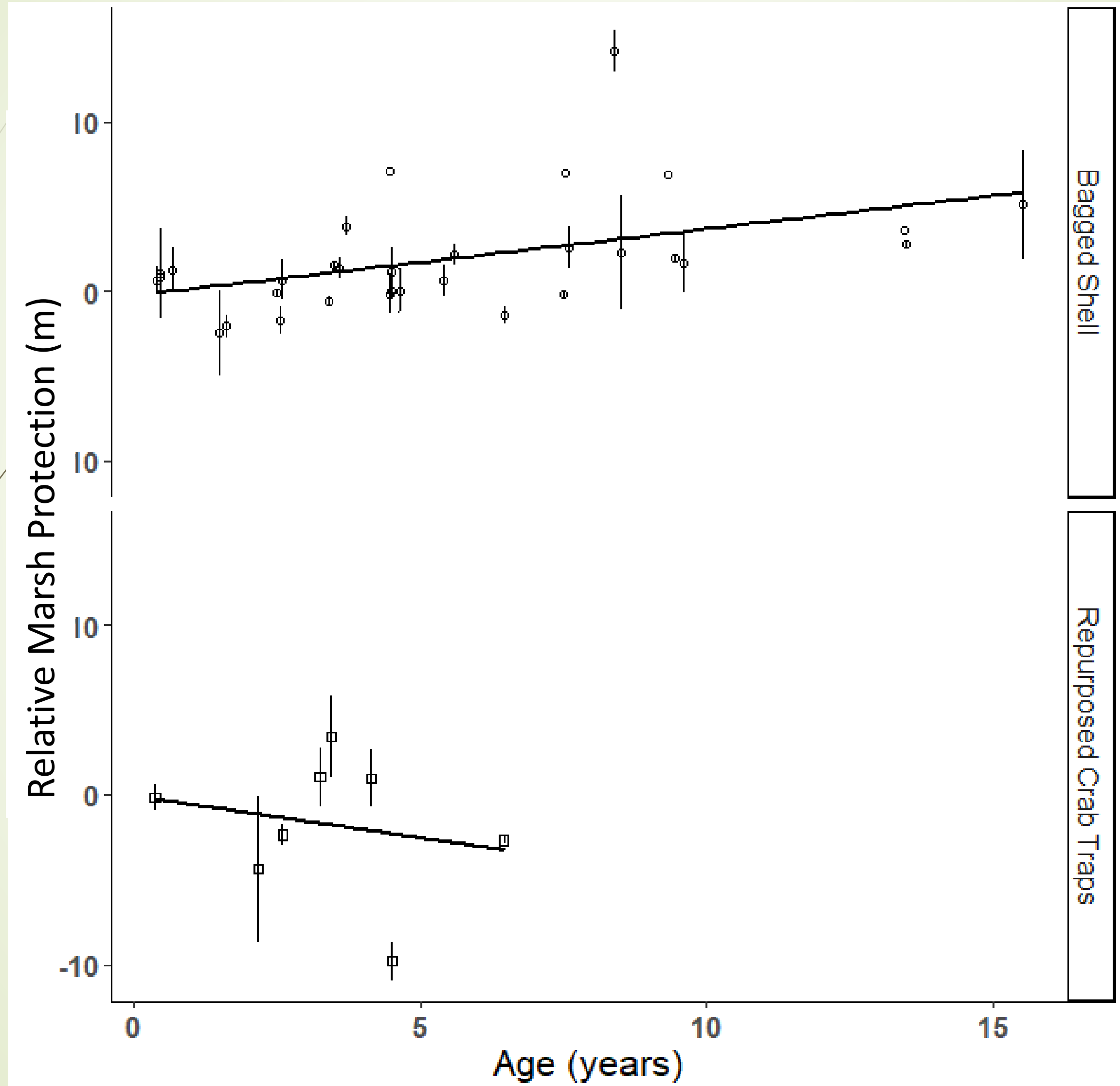
One Year

1 yr: BS=CL>MWR

2 yr: CL>MWR

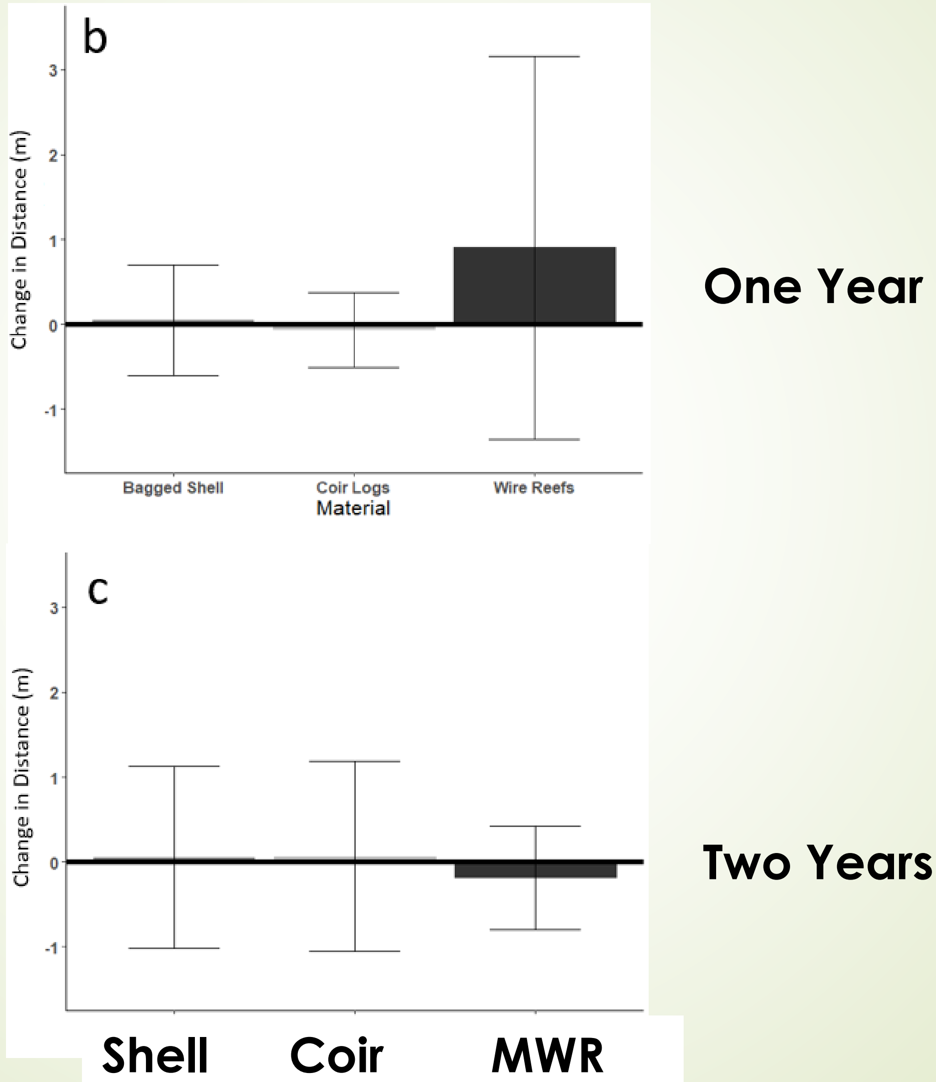
Two Years

Results: difference in marsh edge
Existing

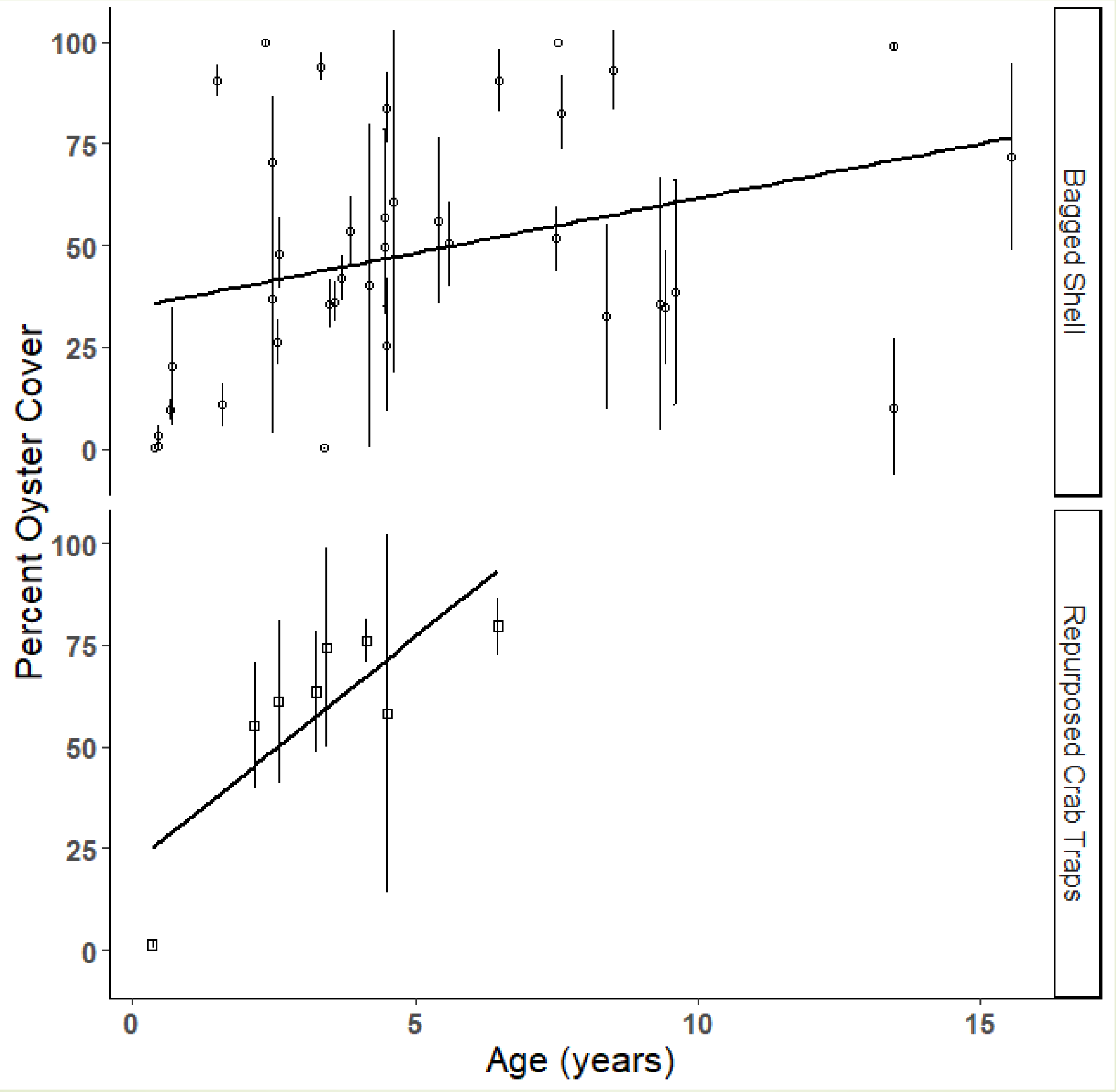


p = 0.004
Slope = 40 cm/yr

Results: difference in marsh edge
New builds



Results: difference in oyster cover Existing

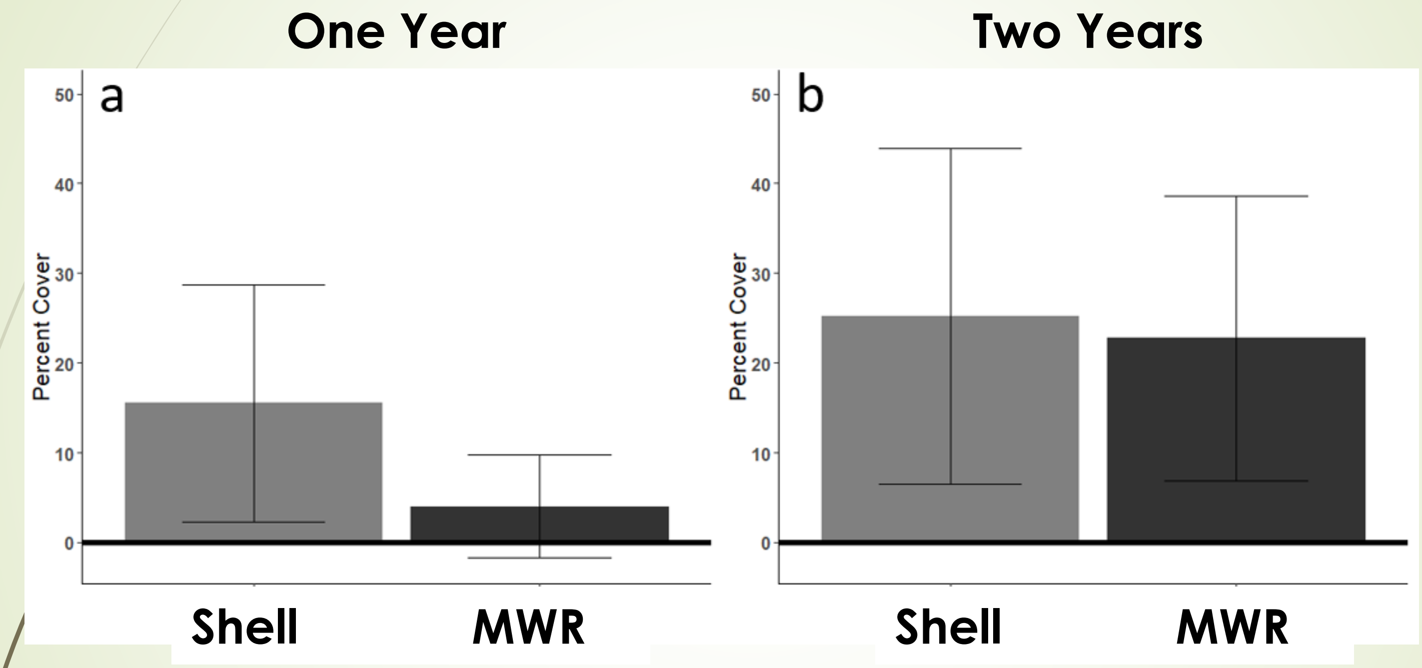


p = 0.02
Slope = 3%/yr

p = 0.01
Slope = 11%/yr

But lack of older data likely biases rate

Results: difference in oyster cover
New builds



1 yr: BS>MWR

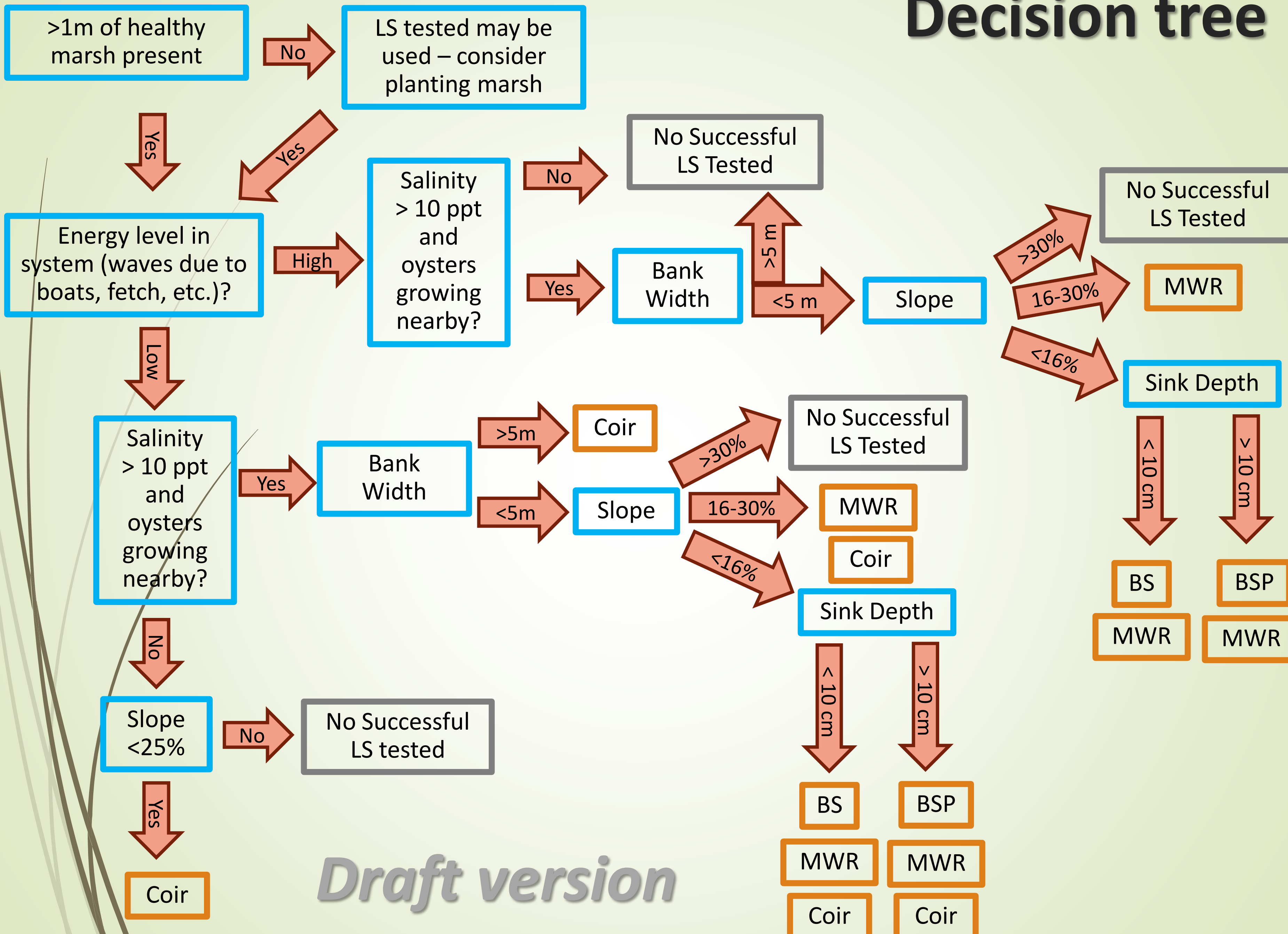
2 yr: BS=MWR

Draft version

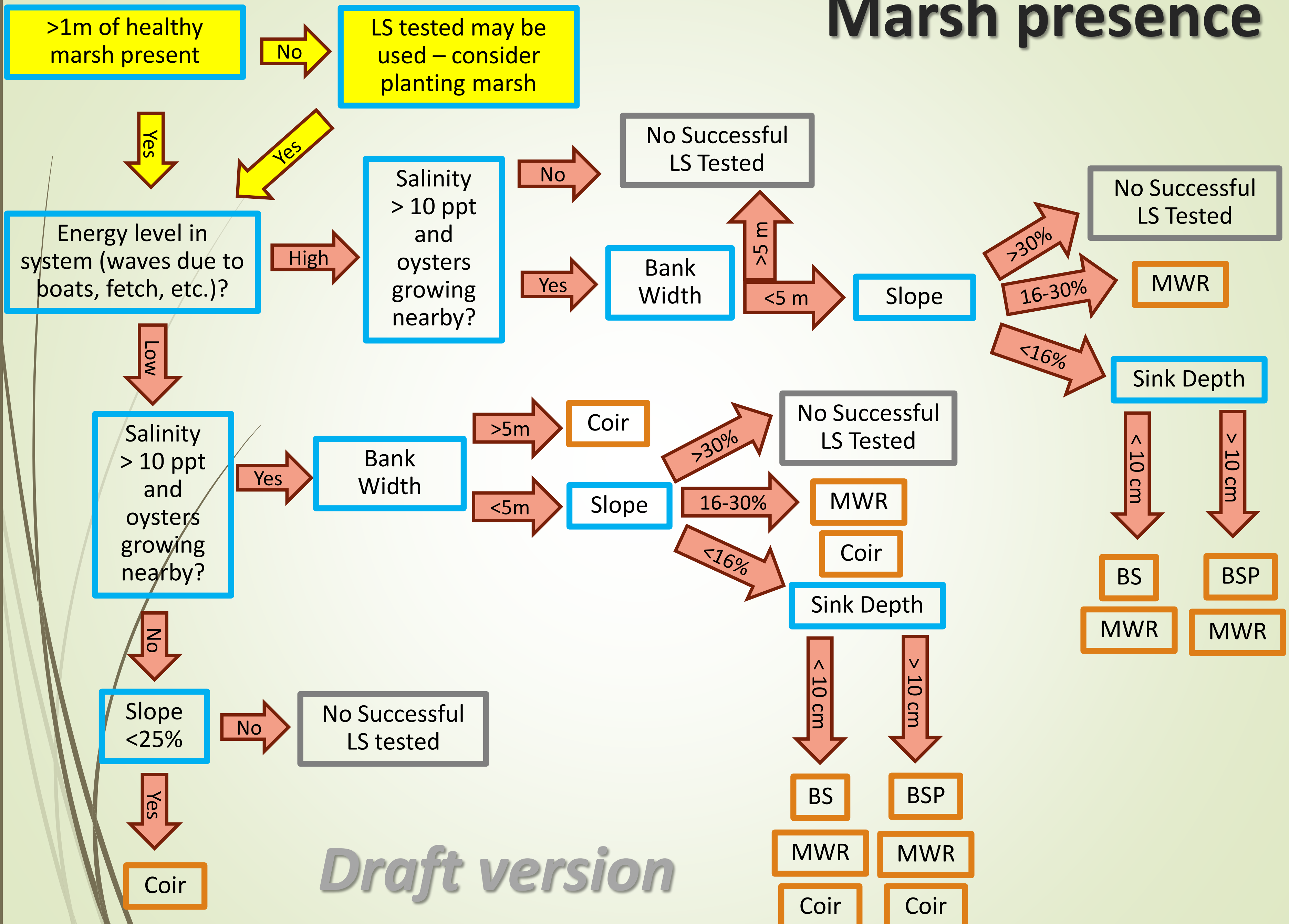
Decision table

Site Conditions		Bagged shell	MWR	Coir log
Energy	**ICW/dredged**	Successful during study. Recommend using extra stakes and checking placement as material may move. Reduced sediment accretion compared to non-ICW.	Successful during study. Recommend using extra stakes and checking placement as material may move. Reduced sediment accretion compared to non-ICW.	Not successful during study. Material moved or degraded quickly.
	Open bay/exposed (wide water width)	Successful during study. Recommend using extra stakes and checking placement as material may move.	Successful during study. Recommend using extra stakes and checking placement as material may move.	Not successful during study. Material moved or degraded quickly.
	Outside bend	Successful during study.	Successful during study.	Successful during study. Lower success rate on outside bend in larger tidal creek or river systems.
	Straight shoreline	Successful during study.	Successful during study.	Successful during study. If low-energy system.
	Inside bend	Successful during study. High sediment accretion potential.	Successful during study. High sediment accretion potential.	Successful during study. High sediment accretion potential.
Salinity	**High salinity (>10 ppt) or oysters naturally occur nearby**	Successful during study.	Successful during study.	Successful during study.
	Low salinity (<10 ppt) or oysters do not naturally occur nearby	Not successful during study.	Not successful during study.	Successful during study. Only choice tested for non-oyster/low salinity areas.
Sediment Firmness/Composition	**High sinkability (>10 cm)**	Successful during study. Recommend using pallets. High potential for sediment accretion.	Successful during study. Recommend using deep stakes or extra stakes. High potential for sediment accretion.	Successful during study. Recommend using extra stakes ot prevent the log from sliding downslope. High potential for sediment accretion.
	Low sinkability (<10 cm)	Successful during study.	Successful during study.	Successful during study.
	Muddy substrate - pluffy (silt/clay >60-70%)	Successful during study. Recommend using pallets and extra stakes. Increased sediment accretion potential.	Successful during study. Good potential for sediment accretion, but may exhibit reduced oyster growth.	Successful during study.
	Sandy substrate - pluffy (silt/clay <60-70%)	Successful during study.	Successful during study.	Successful during study.
Bank Slope and Width	**High slope (>30%)**	Not successful during study.	Not successful during study.	Not successful during study.
	Moderate slope (16%-30%)	Not successful during study.	Successful during study. Tested up to 28%.	Successful during study. Avoid in areas >25%.
	Low slope (<16%)	Successful during study. May exhibit greater sediment accretion at slopes >10%.	Successful during study. Well-suited for high slope (tested up to 28%). High accretion potential at higher slopes (>10%).	Successful during study.
	Bank width (marsh to waterline distance)	Successful during study. Performs best at widths <15 ft (5 m).	Successful during study. Performs best at widths <15 ft (5 m).	Successful during study. For range of bank widths, including banks >15 ft (5 m).
High escarpment		Successful during study. More likely to exhibit marsh protection up to 60 cm. Higher than 60 cm uncertain or ineffective.	Successful during study.	Successful during study. Moderate escarpment heights (20-40 cm) associated with increased sediment accretion.

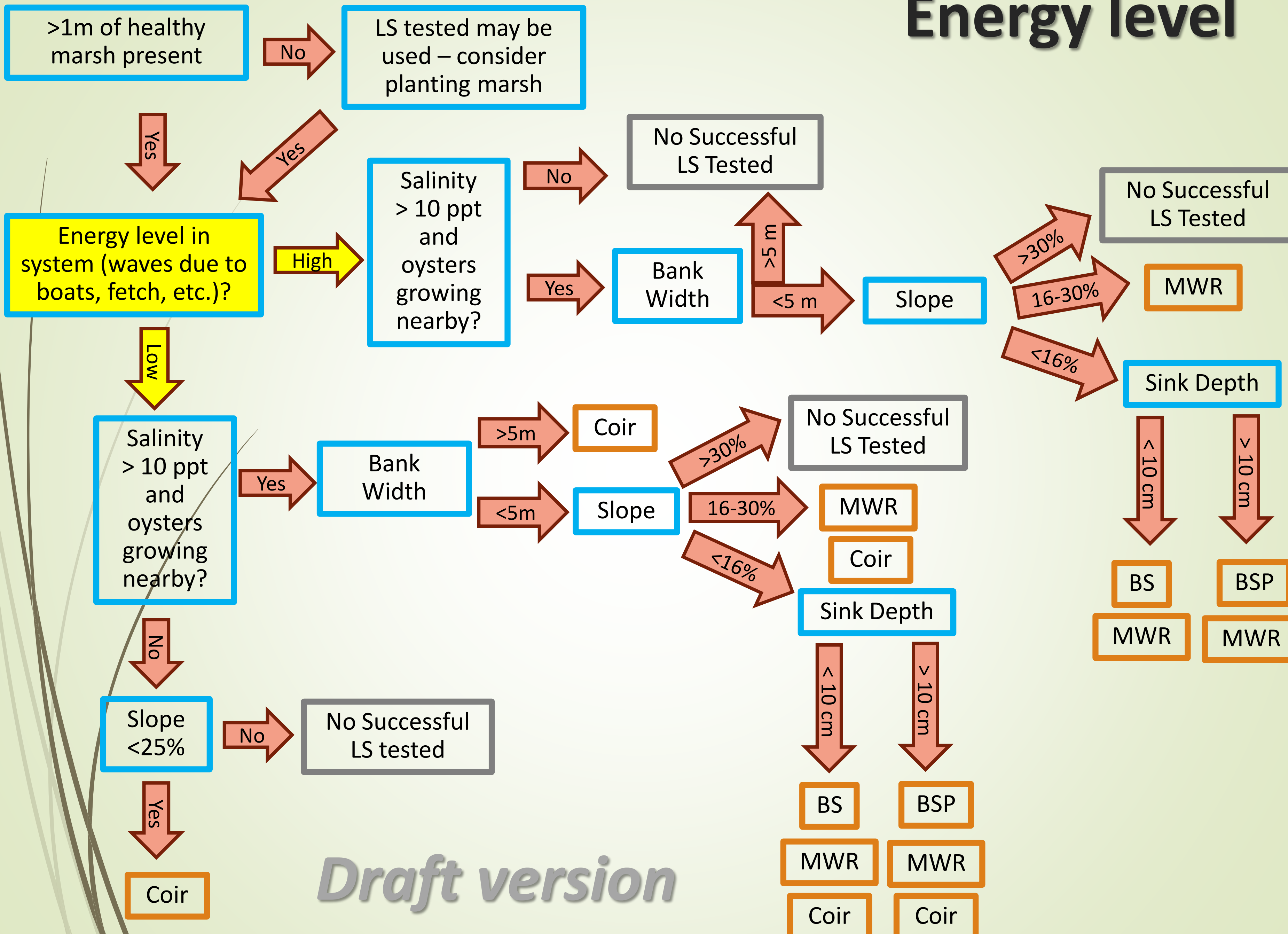
Decision tree



Marsh presence



Energy level



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Energy level

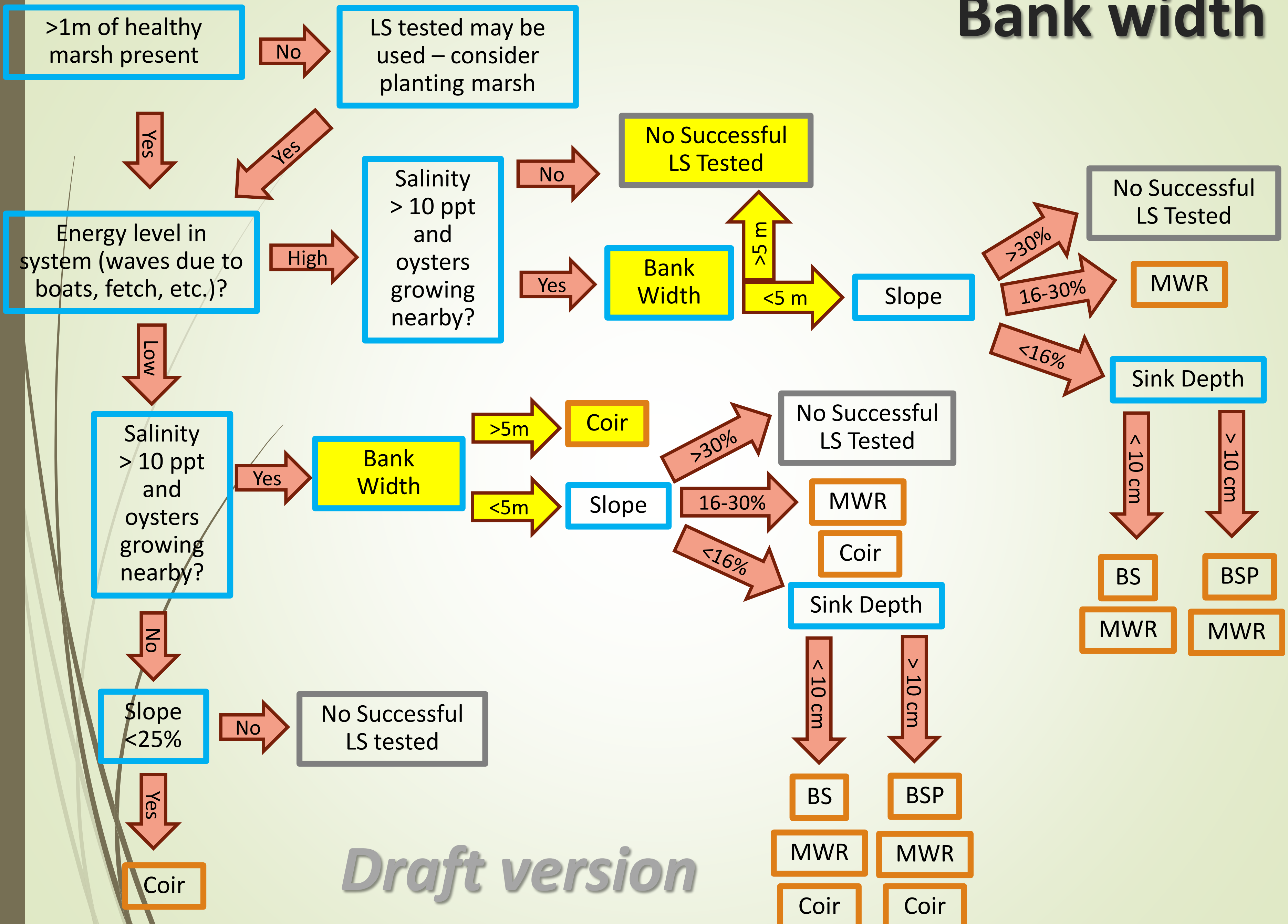
- Coir logs did not perform well at high energy sites (dredged/ICW, outside bend, open bay)
  - 71% failure rate
- High energy sites also tended to be higher salinity sites
- Recommend extra staking for bagged shell or MWR treatments in high energy areas
- Some treatments exhibited reduced sediment accumulation in high energy areas


Salinity
>1m of healthy marsh present
No
LS tested may be used – consider planting marsh
Yes
Yes
Energy level in system (waves due to boats, fetch, etc.)?
High
Salinity > 10 ppt and oysters growing nearby?
No
No Successful LS Tested
Yes
Bank Width
>5 m
No Successful LS Tested
<5 m
Slope
>30%
No Successful LS Tested
16-30%
MWR
<16%
Sink Depth
< 10 cm
> 10 cm
BS
MWR
BSP
MWR
Low
Salinity > 10 ppt and oysters growing nearby?
Yes
Bank Width
>5m
Coir
<5m
Slope
>30%
No Successful LS Tested
16-30%
MWR
Coir
<16%
Sink Depth
< 10 cm
> 10 cm
BS
MWR
Coir
BSP
MWR
Coir
No
Slope <25%
No
No Successful LS tested
Yes
Coir
Draft version

Salinity

- Low salinity options tested included coir logs and Curlex Bloc
- Curlex Bloc failed in 100% of deployments
- Coir log was often successful in low energy high salinity areas along with oyster-based methods
- Recommend checking adjacent shoreline for oysters. Lowest salinity tested here ~18 ppt
- May work as low as 10-15 ppt

Bank width



>1m of healthy marsh present
No
LS tested may be used – consider planting marsh
Yes
Yes
Energy level in system (waves due to boats, fetch, etc.)?
High
Salinity > 10 ppt and oysters growing nearby?
No
No Successful LS Tested
Yes
Bank Width
>5 m
<5 m
Slope
>30%
No Successful LS Tested
16-30%
MWR
<16%
Sink Depth
< 10 cm
> 10 cm
BS
MWR
BSP
MWR
Low
Salinity > 10 ppt and oysters growing nearby?
Yes
Bank Width
>5m
Coir
<5m
Slope
>30%
No Successful LS Tested
16-30%
MWR
Coir
<16%
Sink Depth
< 10 cm
> 10 cm
BS
MWR
Coir
BSP
MWR
Coir
No
Slope <25%
No
No Successful LS tested
Yes
Coir

Bank width

- Most sites exhibited bank widths < 8 m, but a few very wide banks tested (15+ m)
- Bank widths < 5 m exhibited:
  - Greater silt/clay change (all)
  - Greater sediment accumulation (all)
  - Greatest potential for marsh protection (BS)
  - Greatest oyster coverage after 2 yr (BS/MWR)
  - Consider placement higher in tidal frame/closer to marsh in wide areas

Slope

>1m of healthy marsh present
No
LS tested may be used – consider planting marsh
Yes
Yes
Energy level in system (waves due to boats, fetch, etc.)?
High
Salinity > 10 ppt and oysters growing nearby?
No
No Successful LS Tested
Yes
Bank Width
>5 m
<5 m
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BS
MWR
BSP
MWR
Low
Salinity > 10 ppt and oysters growing nearby?
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Bank Width
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16-30%
MWR
Coir
<16%
Sink Depth
< 10 cm
> 10 cm
BS
MWR
Coir
BSP
MWR
Coir
No
Slope <25%
No
No Successful LS tested
Yes
Coir
Draft version

Bank slope

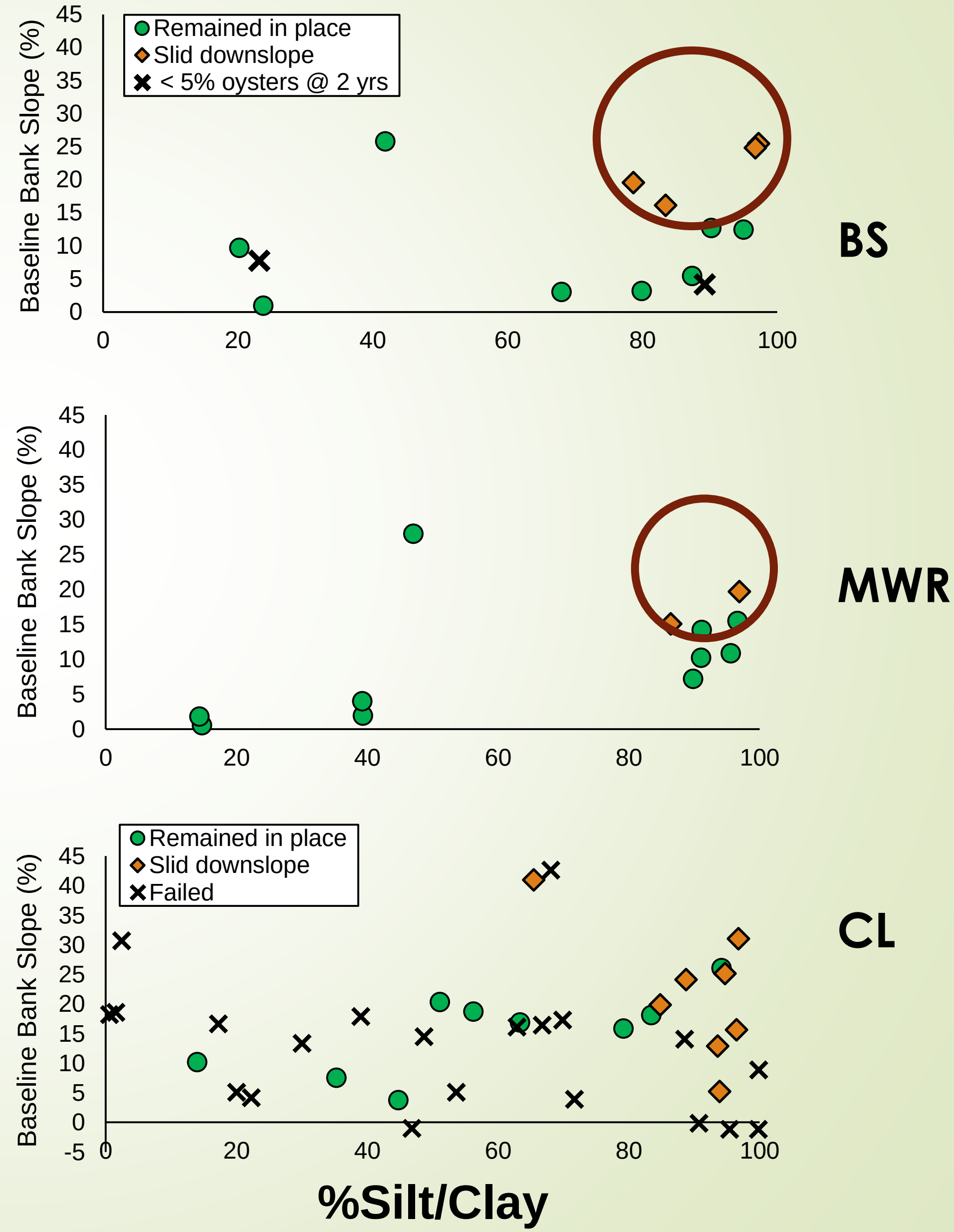
- Treatment sliding is a concern in soft substrates, recommend extra staking at higher slopes
  - MWR is a lightweight option, easy to adjust
- Higher slopes exhibited greatest elevation gains and shift to fine sediments (BS/coir)
  - Especially with lower placement of treatment in tidal frame
- Higher placement may provide better marsh protection but less oyster growth

Bank slope

For bagged shell and manufactured wire reefs, movement appears to be a function of slope **and** substrate type

Coir logs exhibited failure in many cases and did not fit this trend.

71% of failures were at high energy sites



Sink depth

>1m of healthy marsh present
No
LS tested may be used – consider planting marsh
Yes
Yes
Energy level in system (waves due to boats, fetch, etc.)?
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Salinity > 10 ppt and oysters growing nearby?
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16-30%
MWR
Coir
<16%
Sink Depth
< 10 cm
> 10 cm
BS
MWR
Coir
BSP
MWR
Coir
No
Slope <25%
No
No Successful LS tested
Yes
Coir

Sink depth

- SCORE program typically uses pallets at softer (pluffy) sites (<~10 cm sink depth)
- Provides firm base, solid structure to stake down
- Recommend extra staking
- High potential for sediment accumulation

Results: treatment failure

INTEGRITY FAIL	No	Yes (%)
Bagged Shell	13	1 (7)
Coir Logs	17	21 (55)
MWRs	12*	
Curlex Bloc		14 (100)

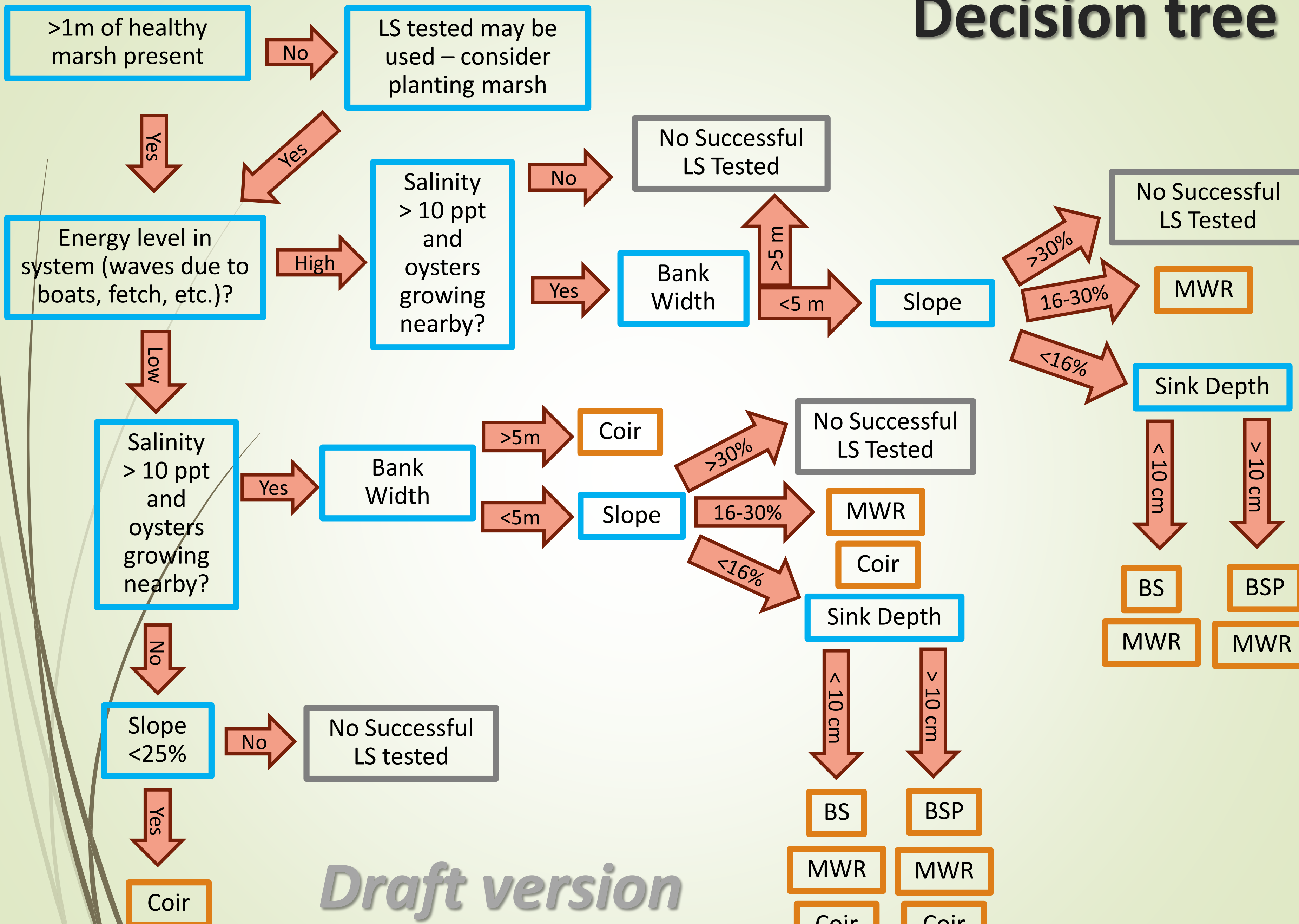
Coosaw Cut (after two successive failures)

Results: treatment movement

TREATMENT MOVEMENT	No	Yes (%)
Bagged Shell	9	4 (31)
Coir Logs	9	8 (47)
MWRs	10	2 (17)
Curlex Bloc	n.a	n.a.

Abbapoola bagged shell movement

Decision tree



Draft version

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Holly Kight
Greg Sorg
Holly Hillman
Zach Bjur
And others