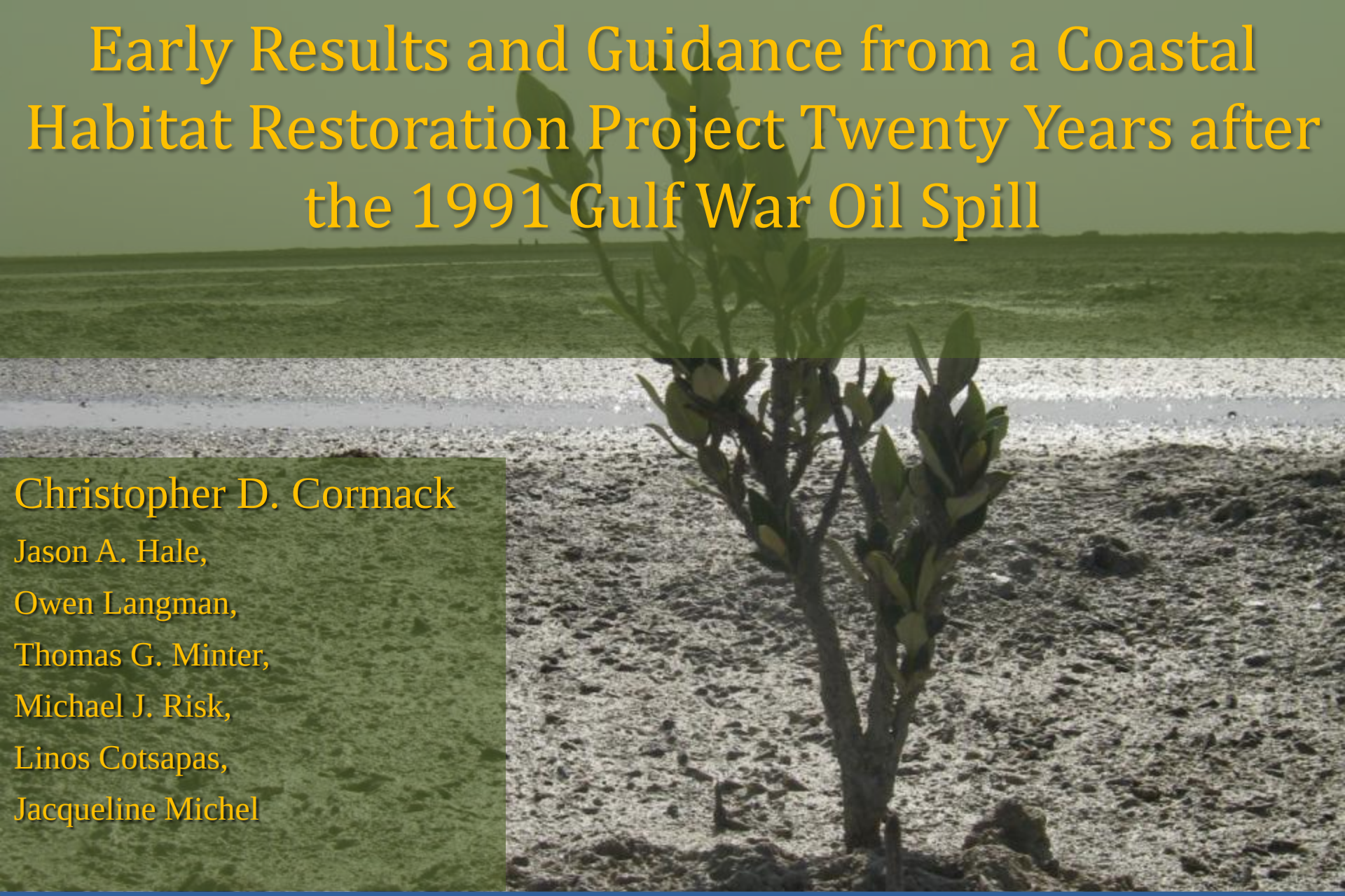
Early Results and Guidance from a Coastal Habitat Restoration Project Twenty Years after the 1991 Gulf War Oil Spill



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Overview

- Background - 1991 Gulf Spill
- Principles - UNCC Restoration Program
- Actions - What are we doing, and why?
  - Channelization
  - Tilling
  - Planting
- Guidance – Lessons learned

Oil Spill

1991 Gulf War

- 10 M barrels
- 800 km KSA shoreline

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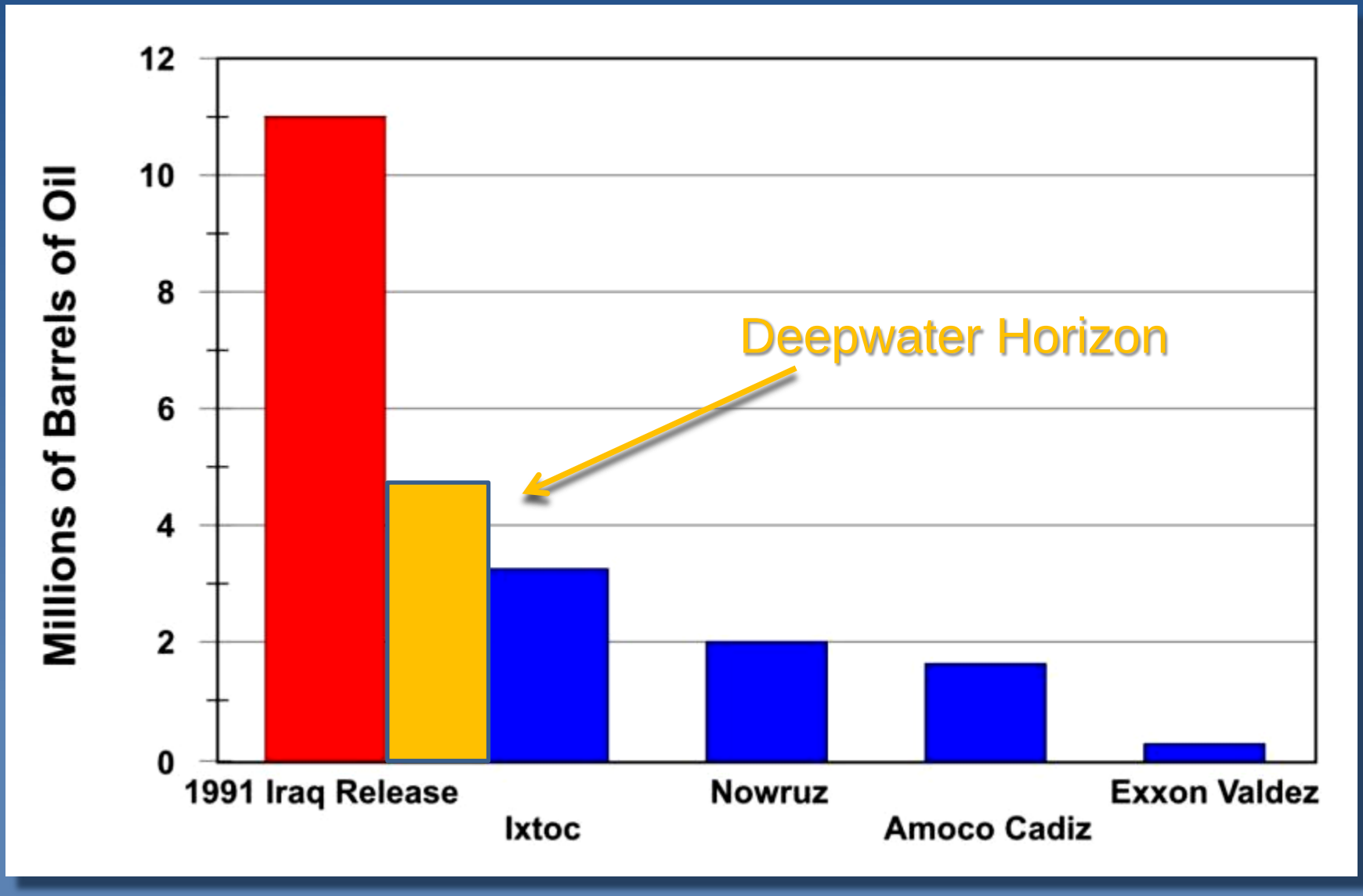
Millions of Barrels of Oil
12
10
8
6
4
2
0
Deepwater Horizon
1991 Iraq Release
Ixtoc
Nowruz
Amoco Cadiz
Exxon Valdez

The Consequences

- 20 years later: Little natural recovery
  - Heavy oil loading (physical + toxicity effects)
  - Low energy setting
  - Deep penetration into burrows
  - Physical alterations to habitat (disrupted hydrology by algal mats)

Heavily Impacted Marsh

Healthy Marsh

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How do we go from…..to…..

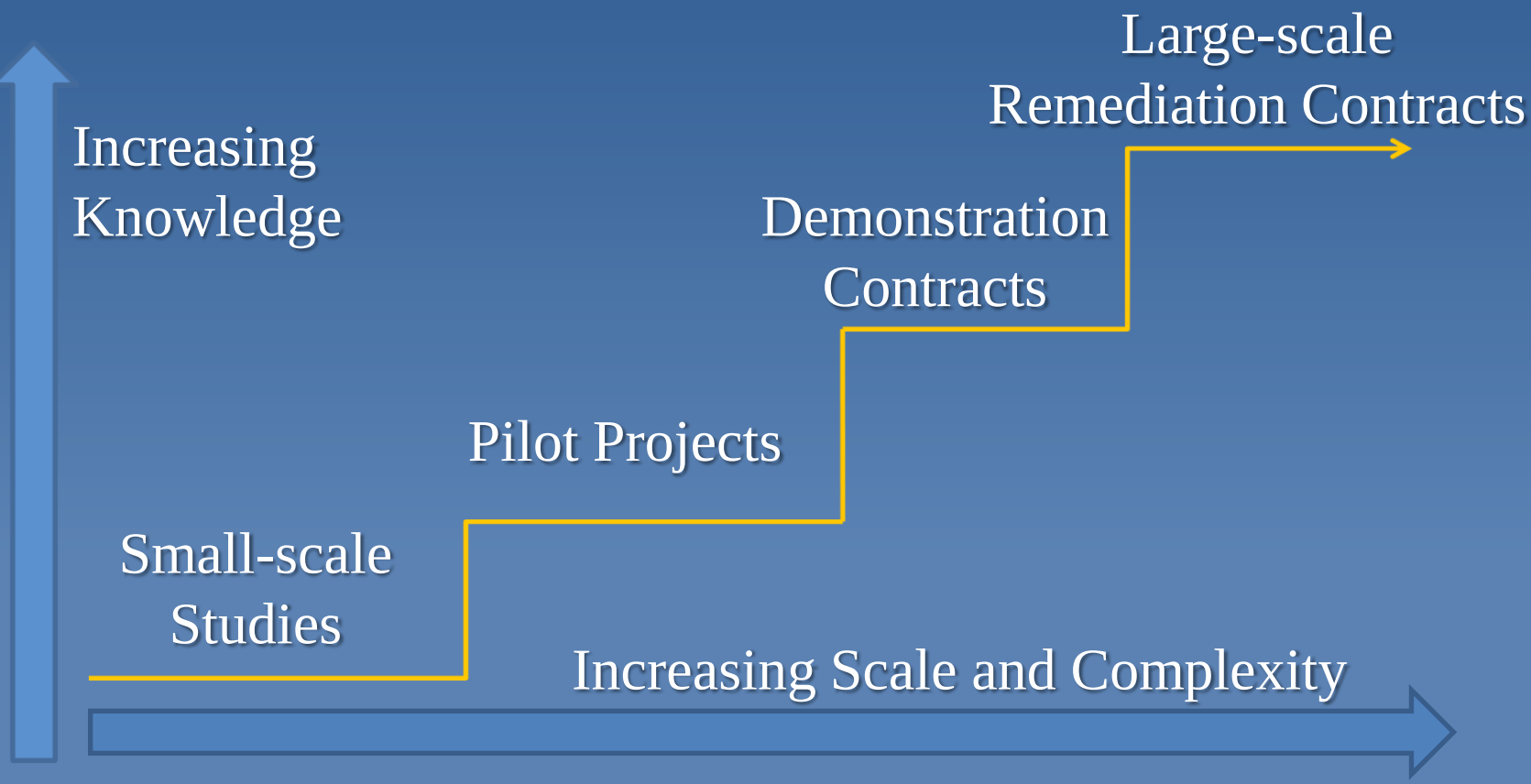
Guiding Principles

- Adhering to Decision 258 and F4 panel principles; remediation activities aim to:
  - avoid techniques that pose unacceptable risks
  - result in more positive than negative results
  - facilitate natural recovery to the extent possible
  - rely on proven techniques
  - utilize adaptive management
  - be cost effective
  - consider short- and long-term effects and landscape connectivity

Approach

- Target “Ecological Restoration”
- Methods must include:
  - Adaptively managed
  - Understand and characterize conditions and site
  - Identify stressors
  - Design appropriate remediation activities
  - Test and monitor effects of remediation activities

Adaptive Management



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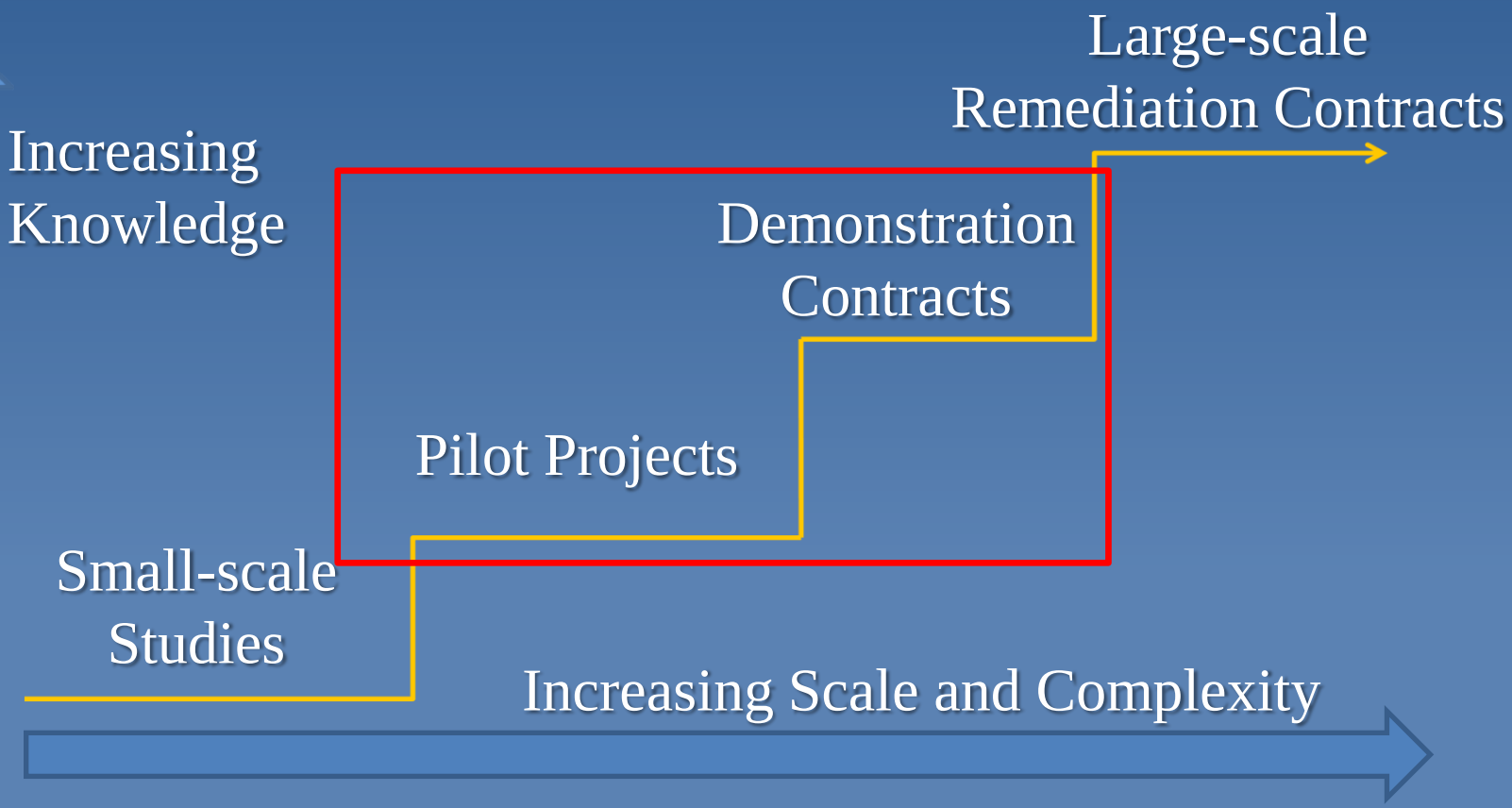
Adaptive Management



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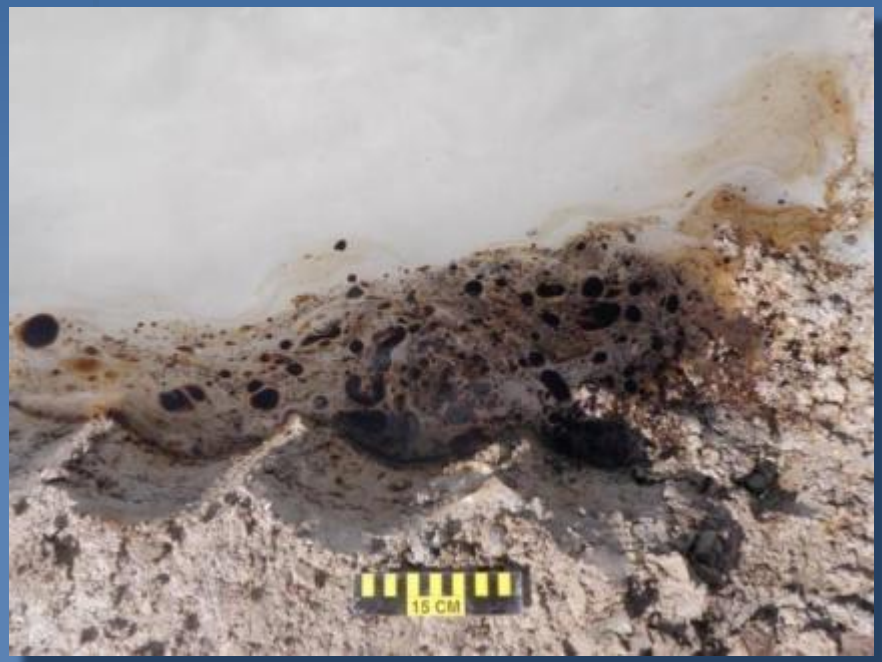
Progression of Stress Part 1: Oil



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Progression of Stress Part 2: Algal Mat

Progression of Stress Part 2: Algal Mat

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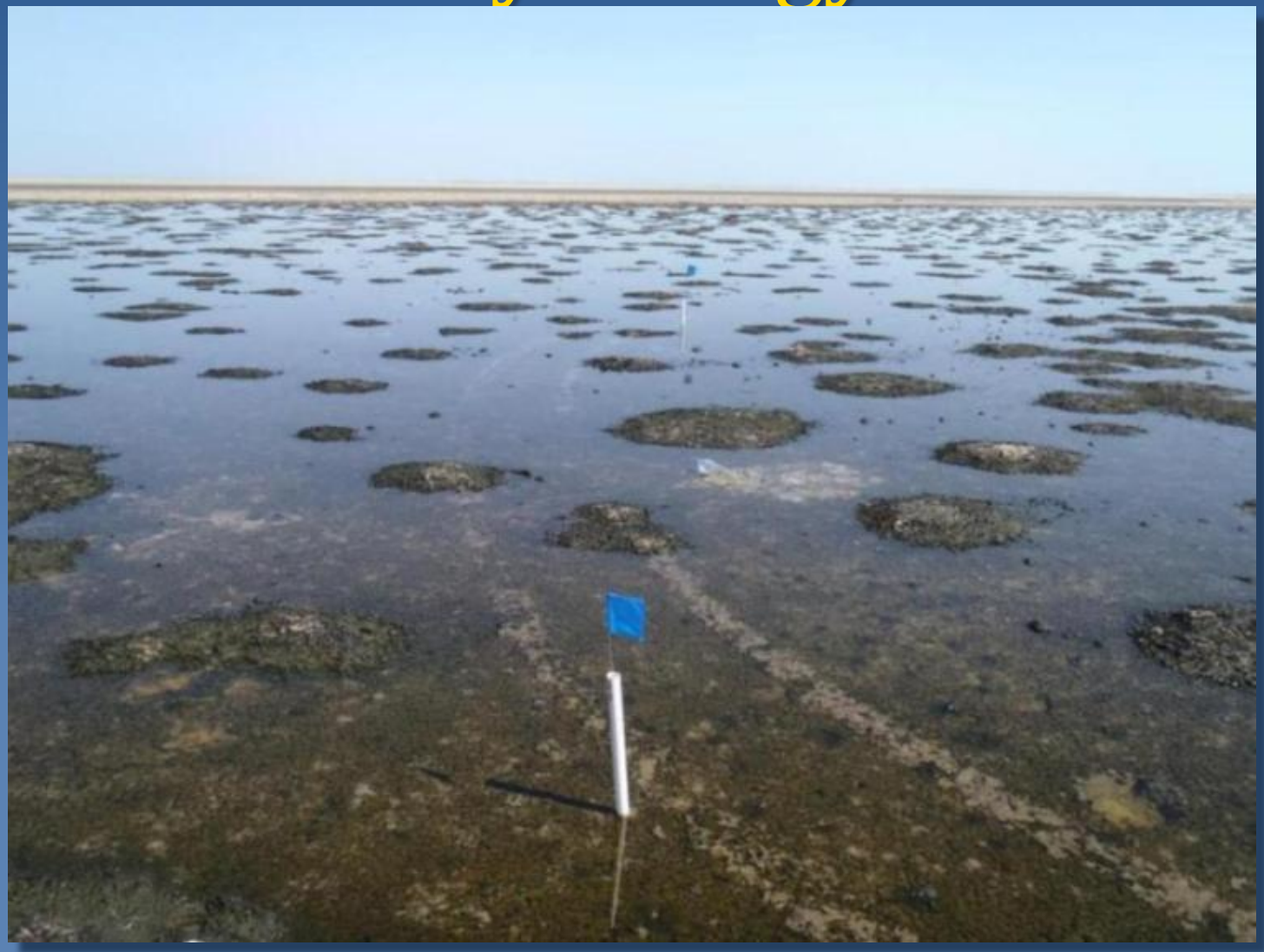
What's wrong with this picture…? Algal mat as a barrier…

Progression of Stress Part 3: Hydrology



Progression of Stress Part 3: Hydrology

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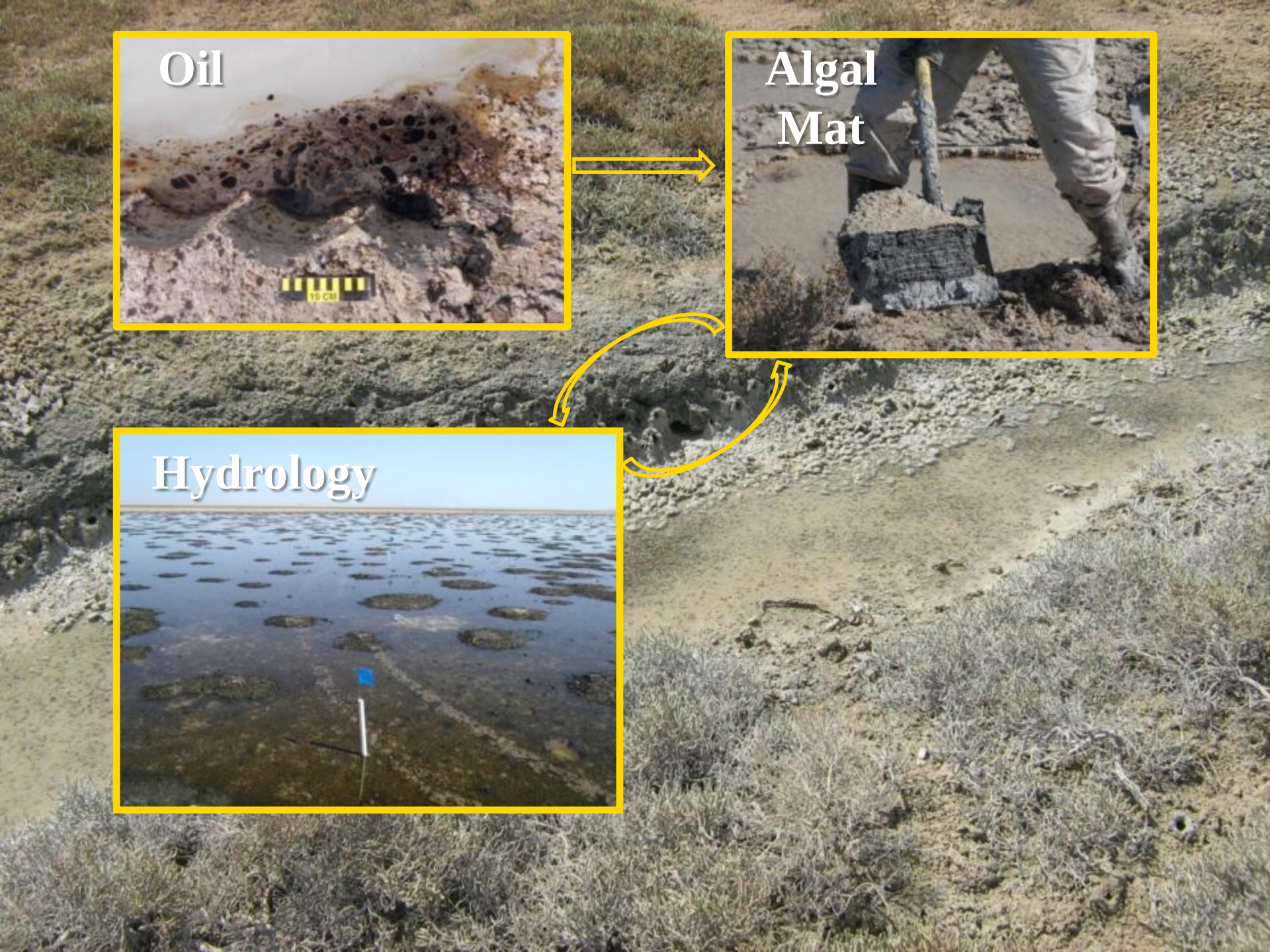
What's wrong with this picture…?


Oil
Algal Mat
Hydrology

How to Restore Salt Marsh Habitat?

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Choosing Remediation Activities

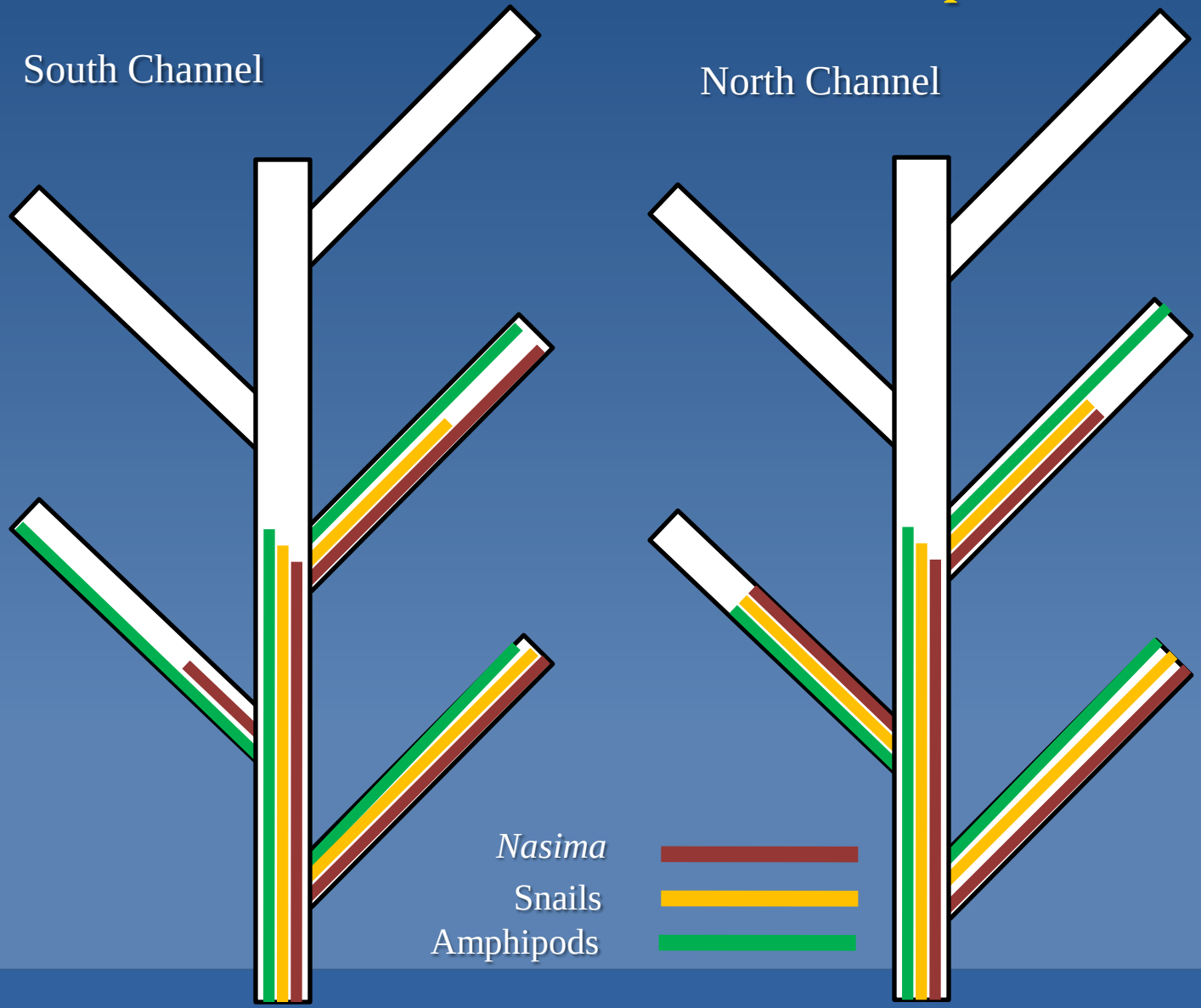
- EXCAVATE - Refresh (existing) and/or excavate (new) tidal channels
- TILL – Remove algal mats/De-compact and aerate substrate in marsh and tidal flat habitats
- PLANT - Transplantation of mangroves/halophytes to rapidly increase the populations

Channel Excavation

What's wrong with this picture…?

better…?

CRC1 Colonization – Two months post excavation



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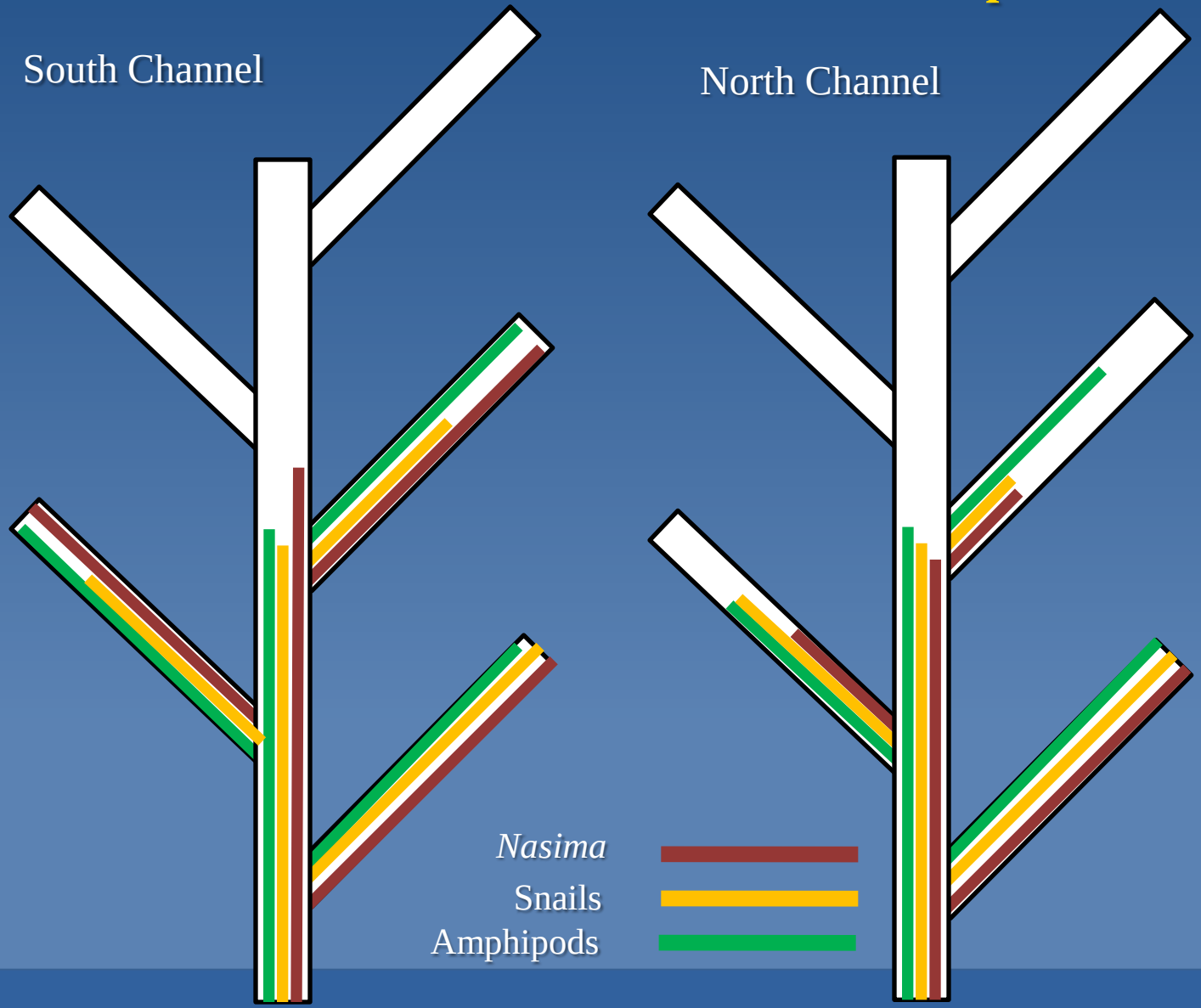
CRC1 Colonization – Three months post excavation



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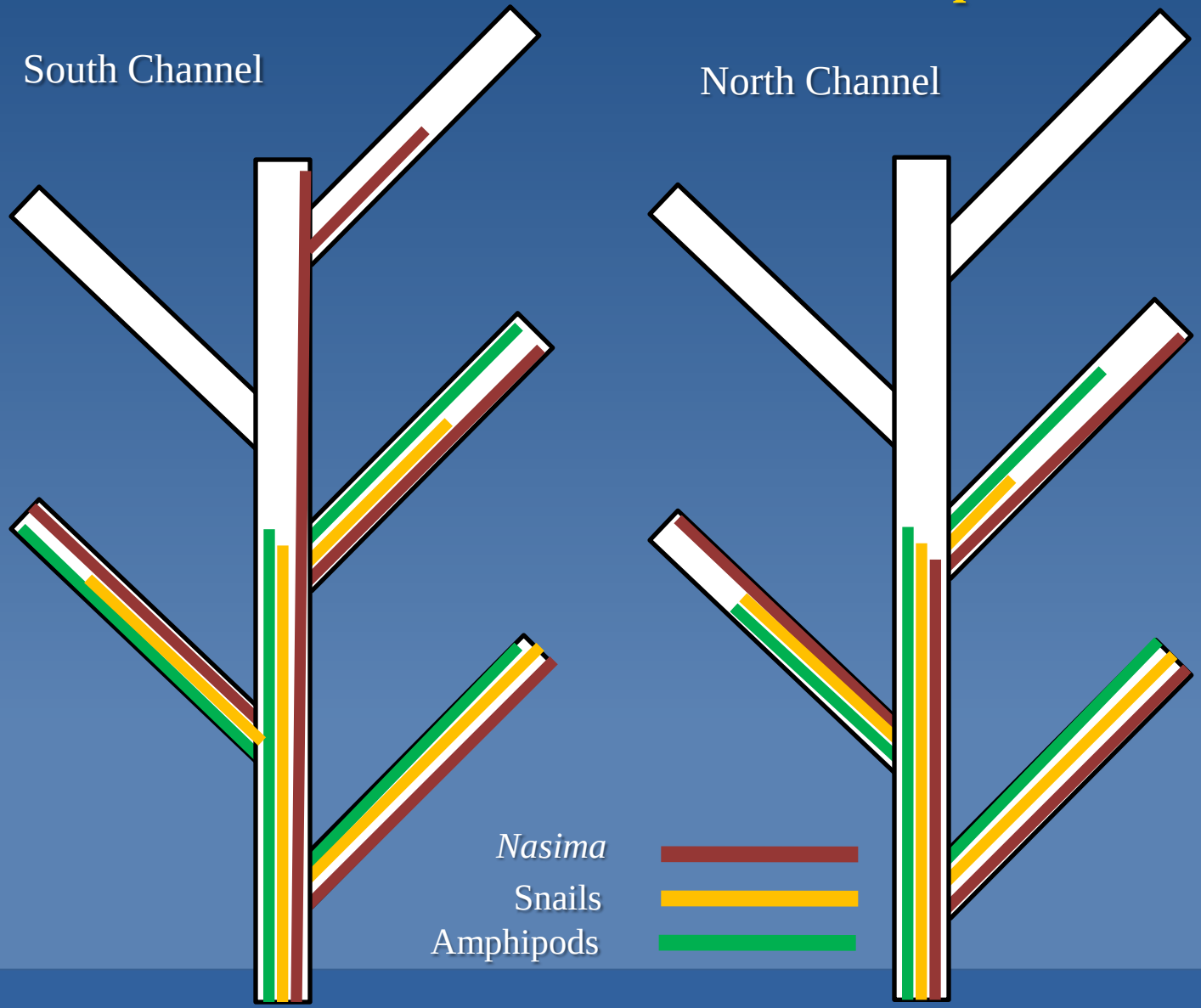
CRC1 Colonization – Four months post excavation



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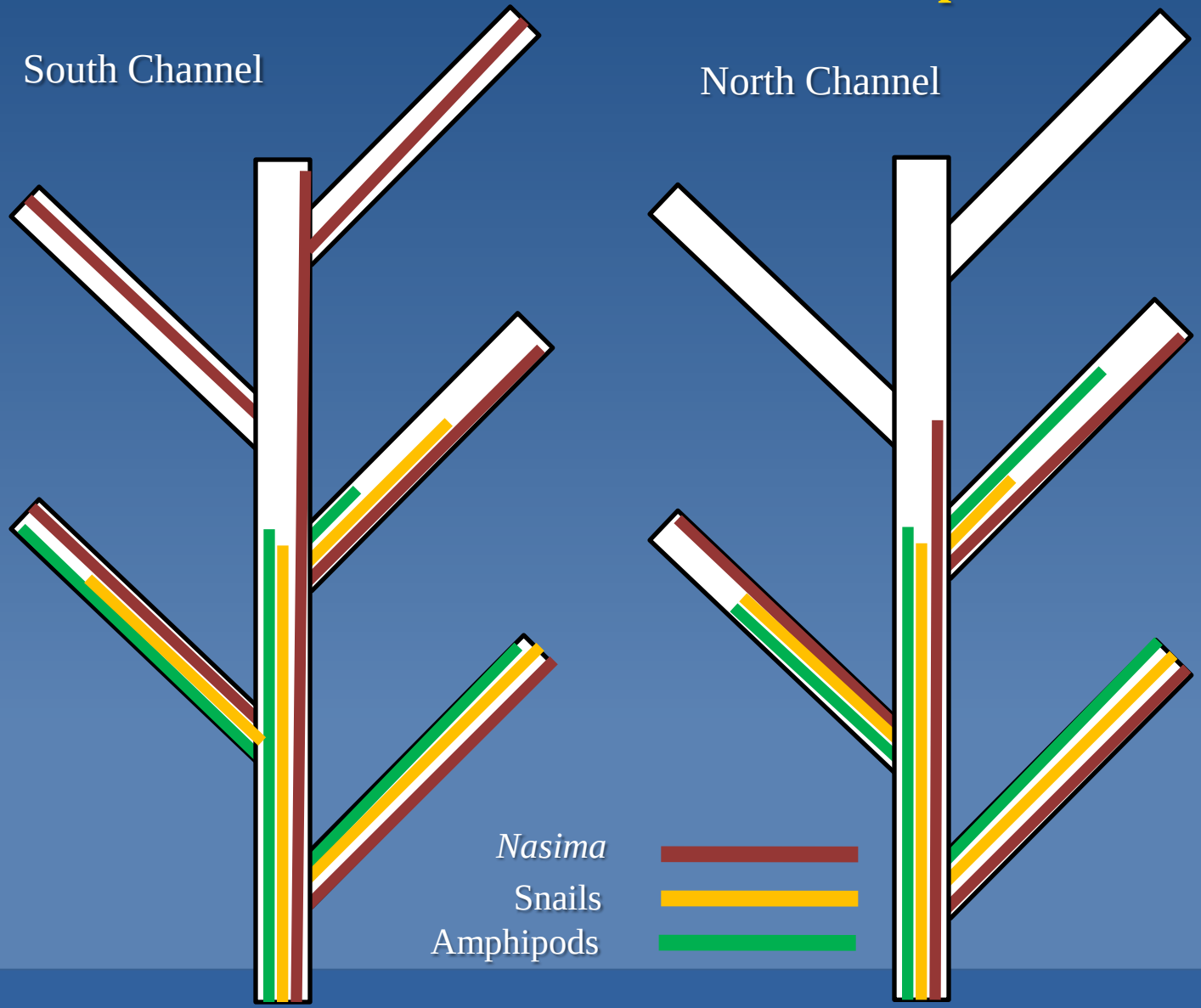
CRC1 Colonization – Five months post excavation



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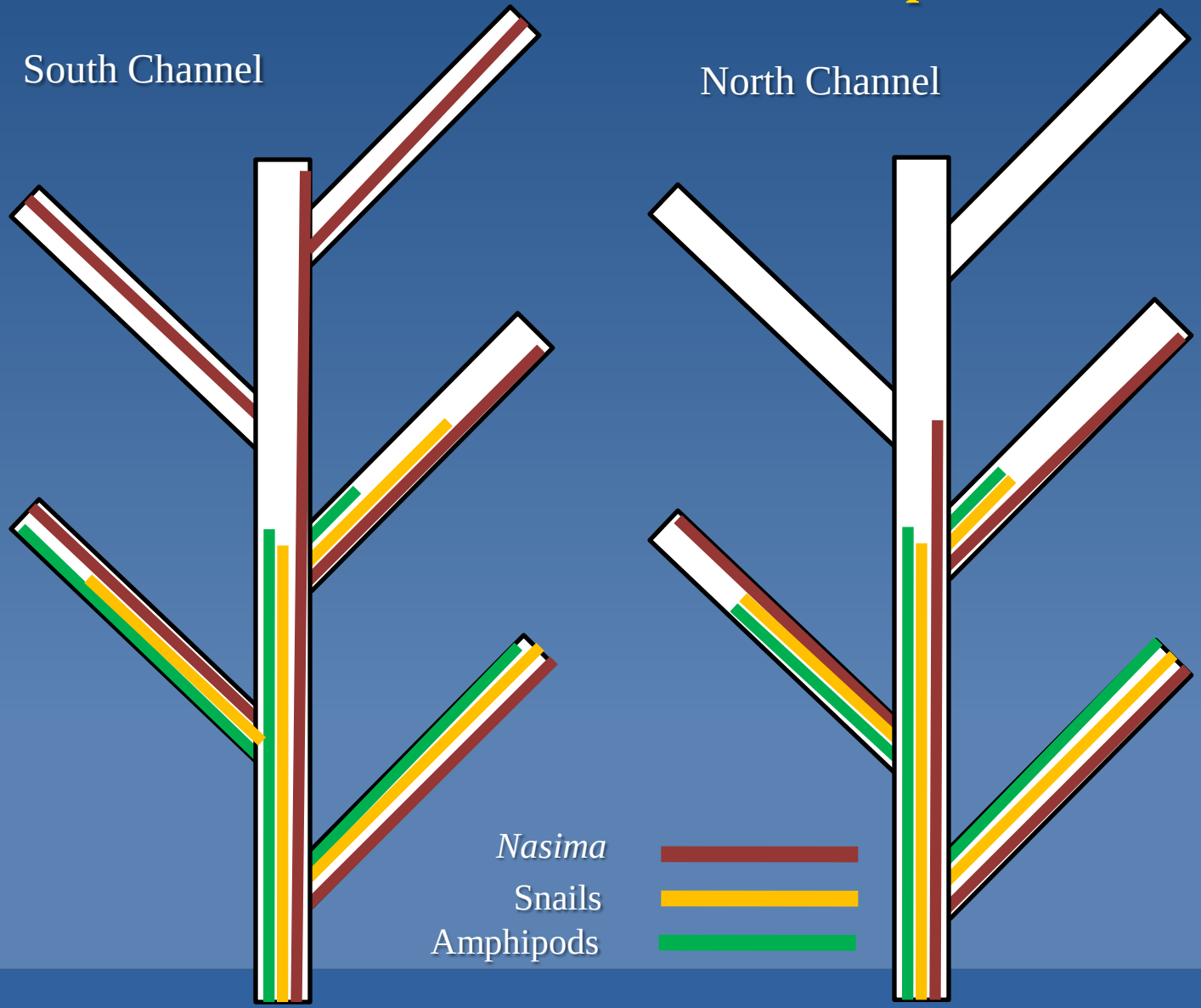
CRC1 Colonization – Six months post excavation



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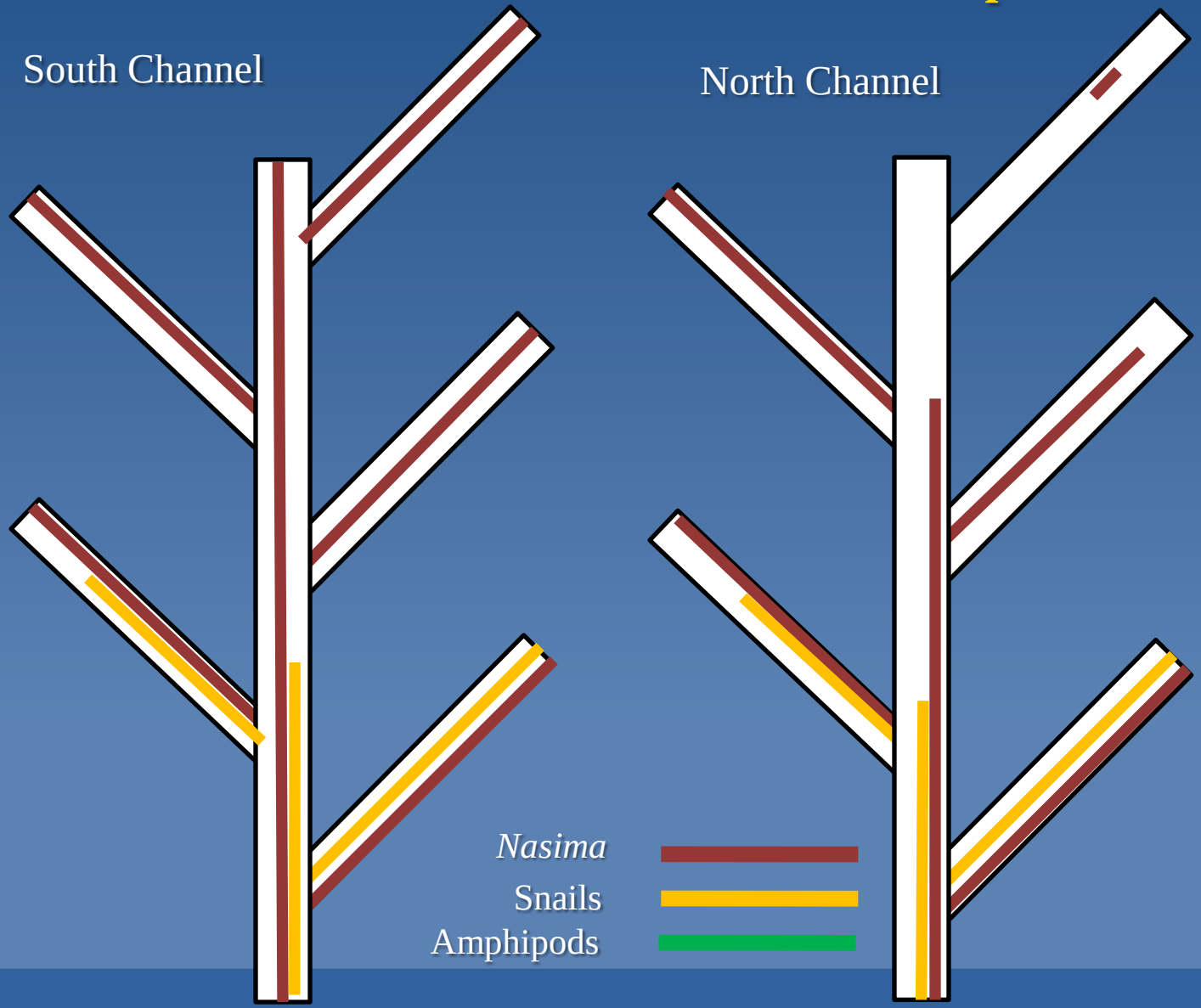
CRC1 Colonization – Seven months post excavation



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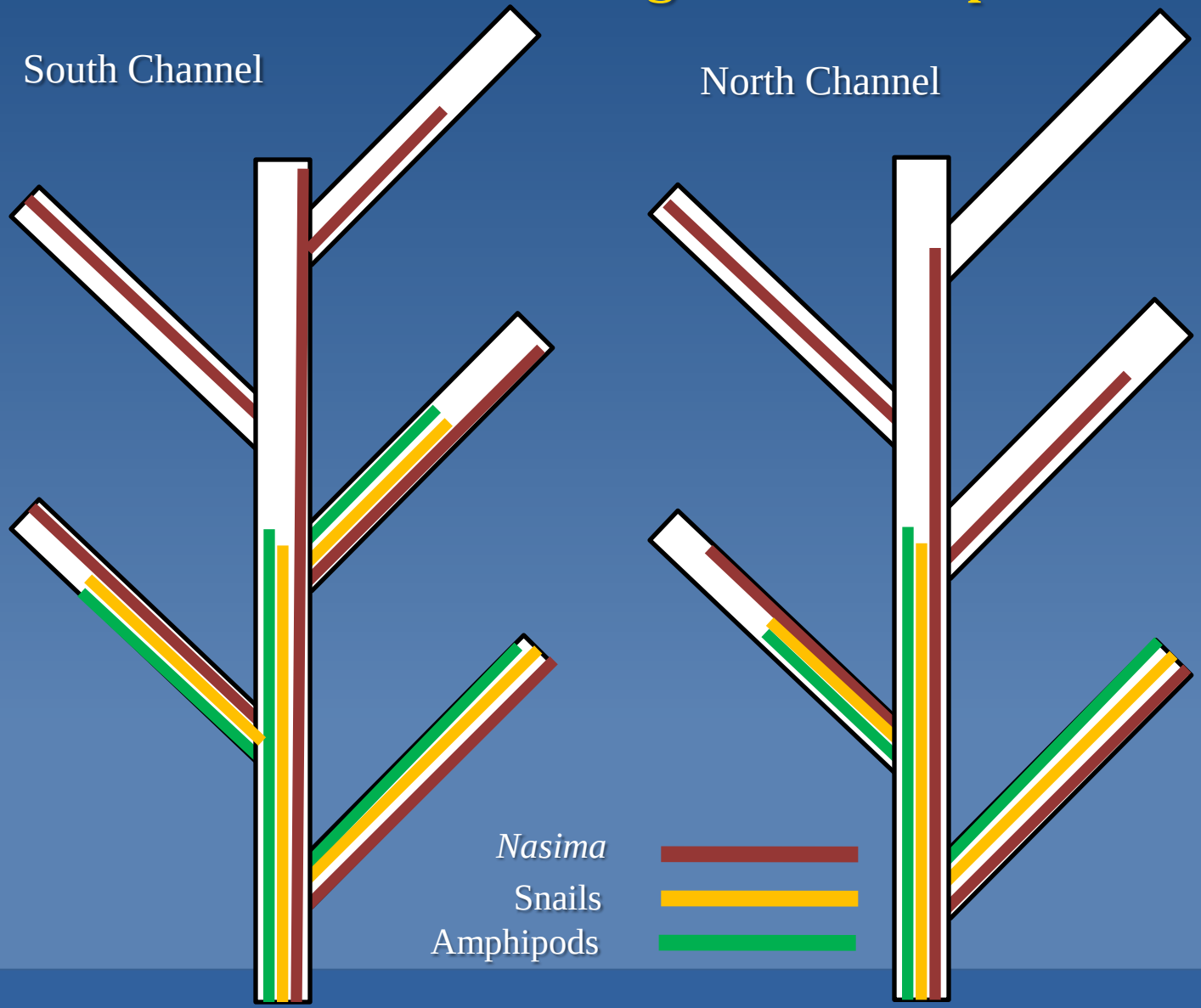
CRC1 Colonization – Eight months post excavation



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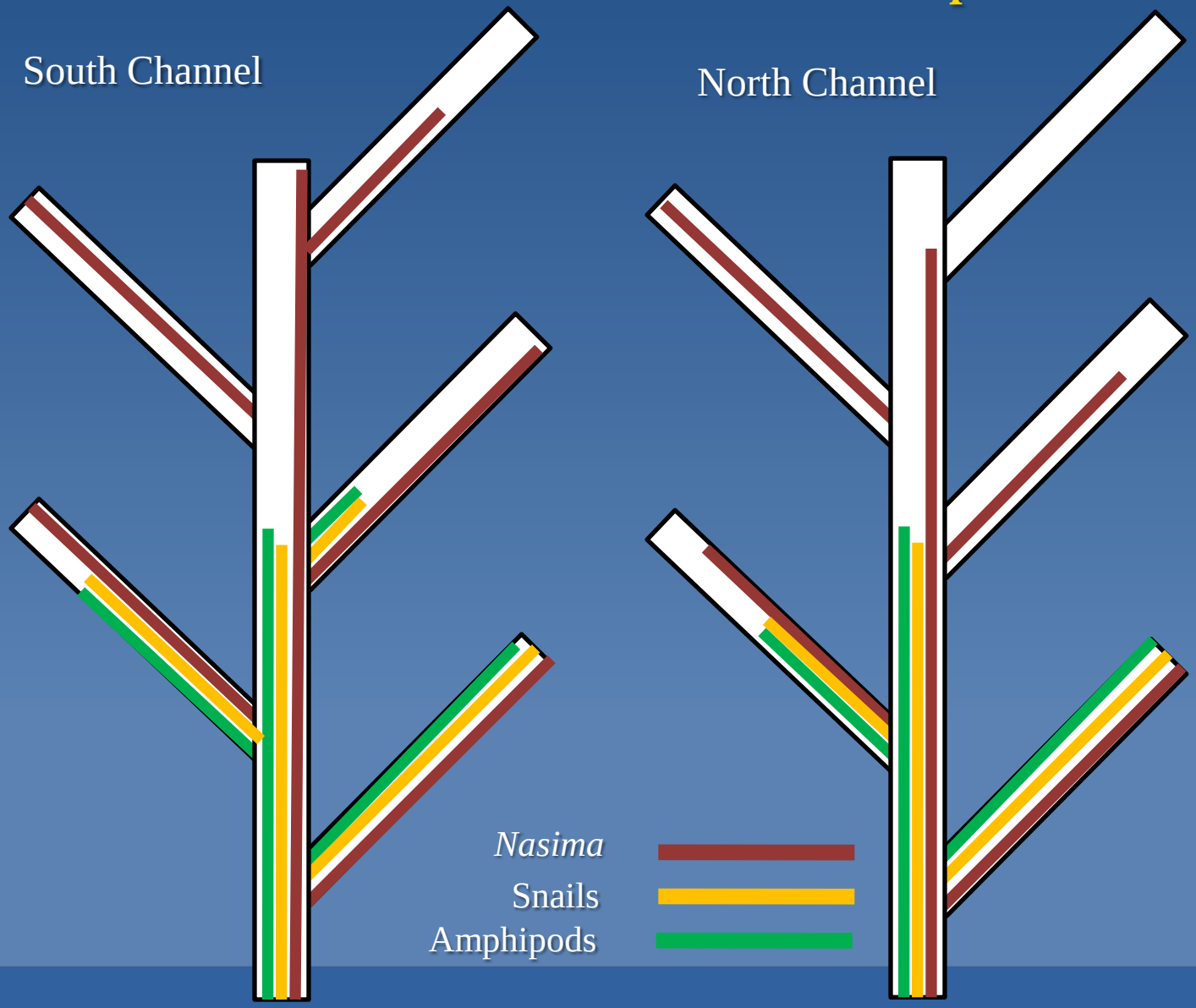
CRC1 Colonization – Nine months post excavation



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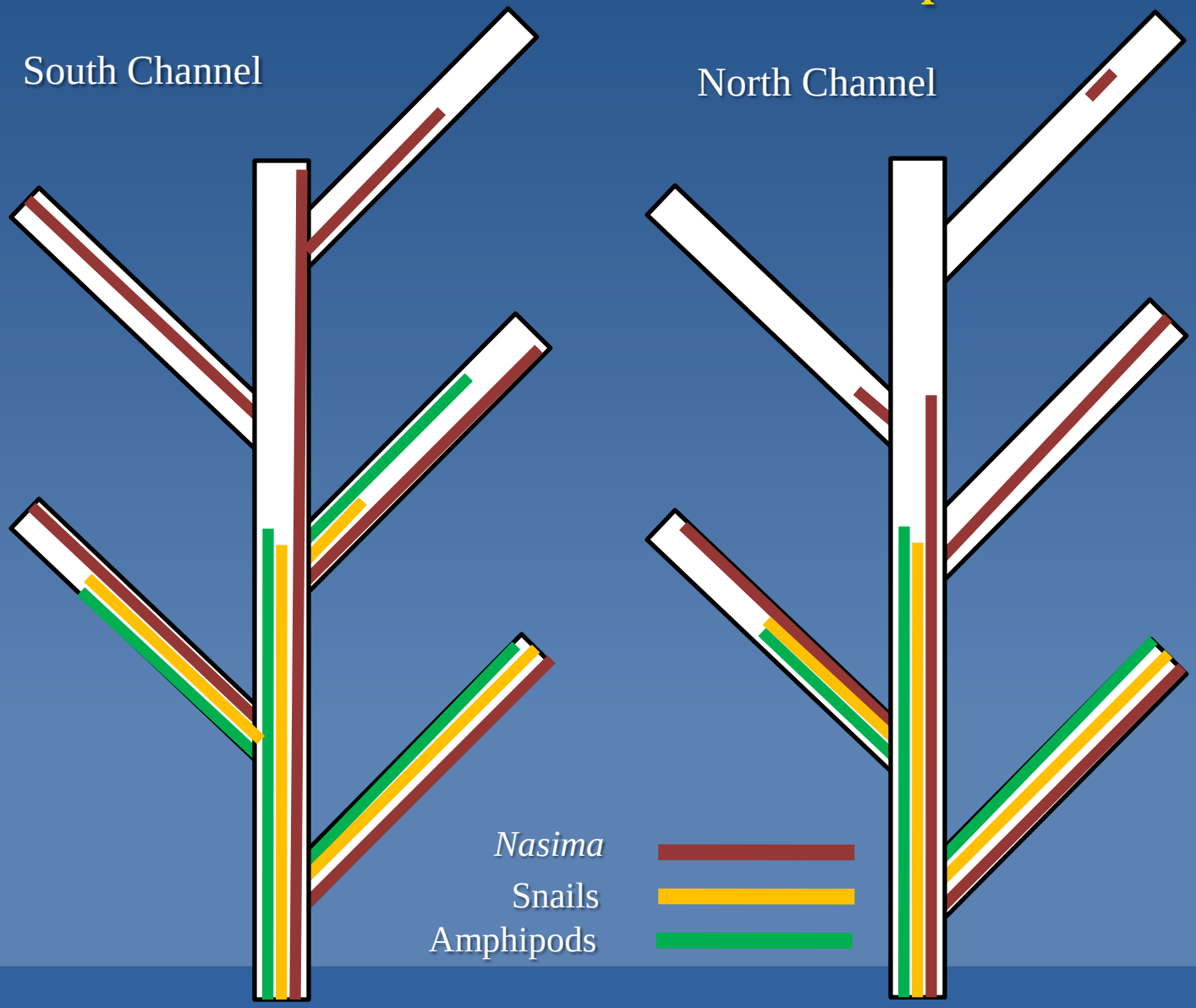
CRC1 Colonization – Ten months post excavation



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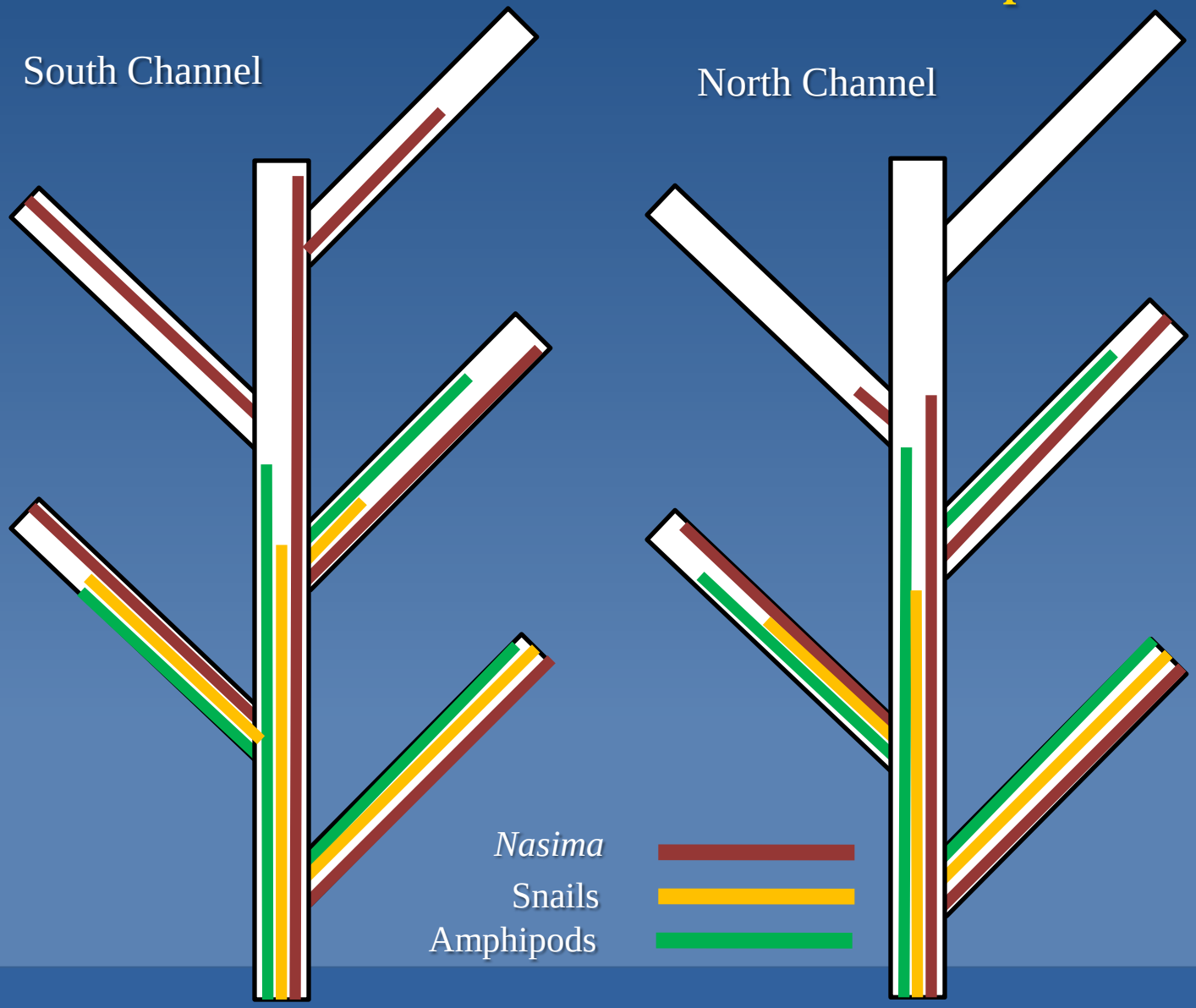
CRC1 Colonization – Eleven months post excavation



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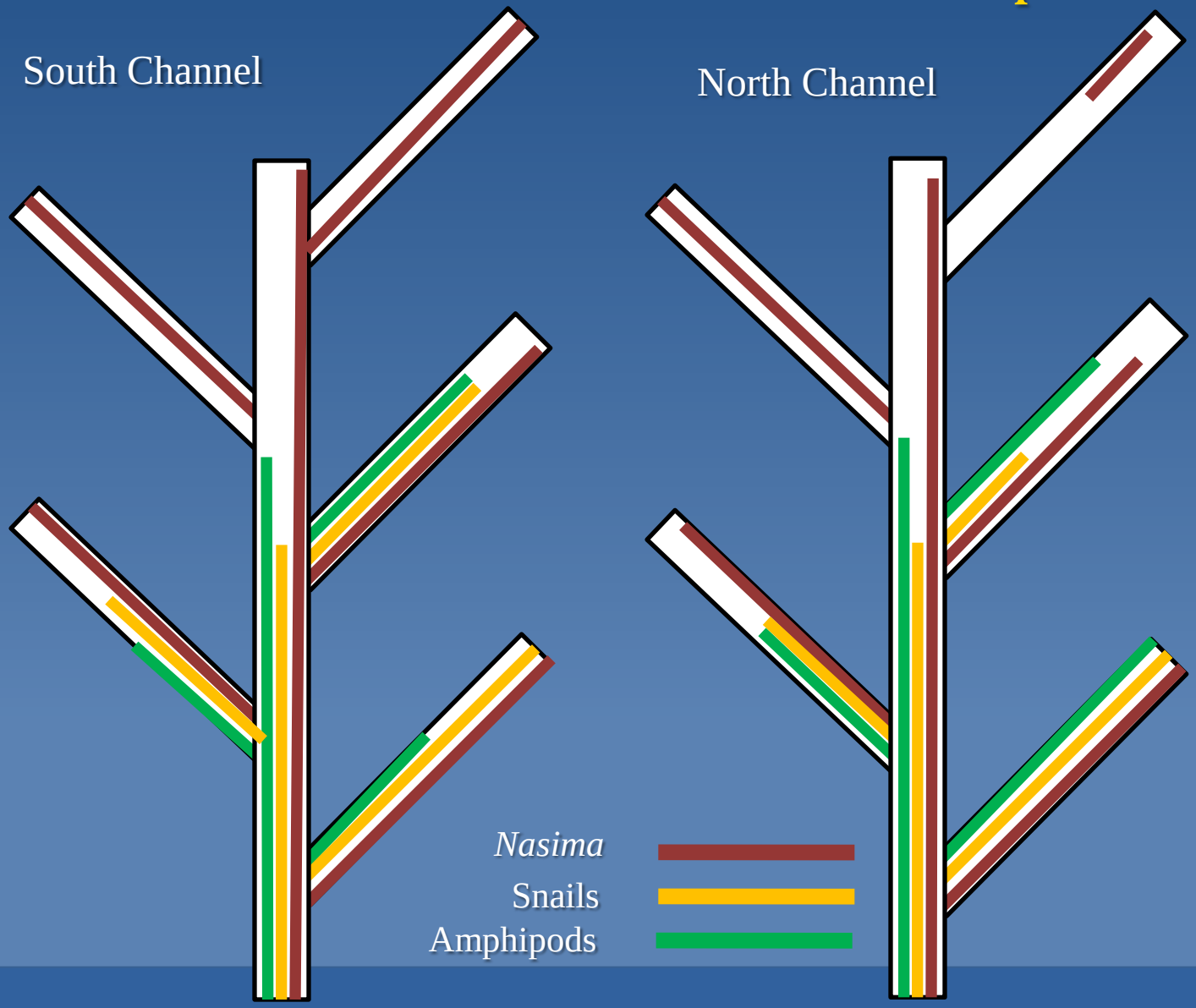
CRC1 Colonization – Twelve months post excavation



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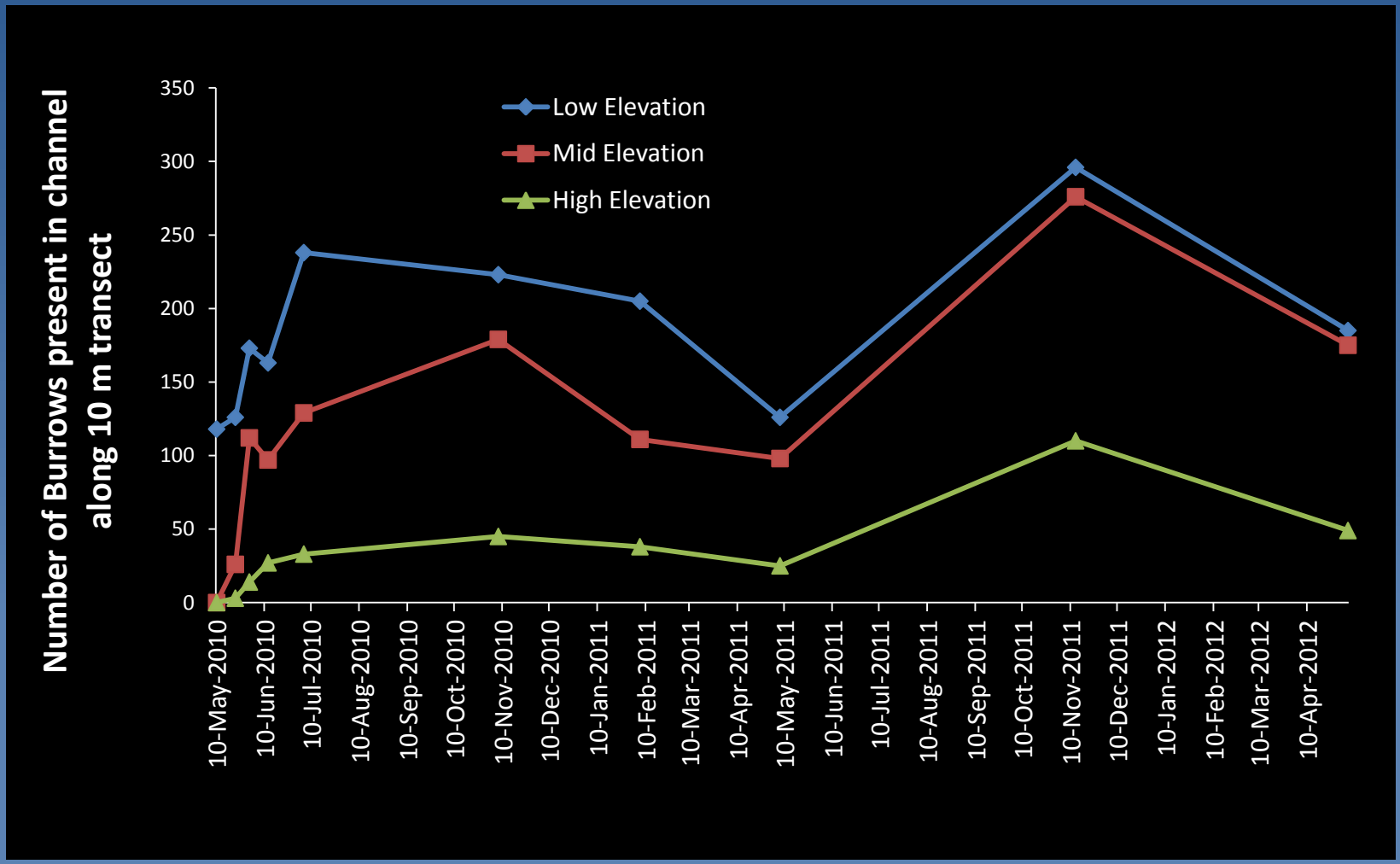
Excavation of Tidal Channels

Monitoring Results To Date



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Natural Channel Development

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Natural Channel Development

Natural Channel Development

Natural Channel Development

Natural Channel Development

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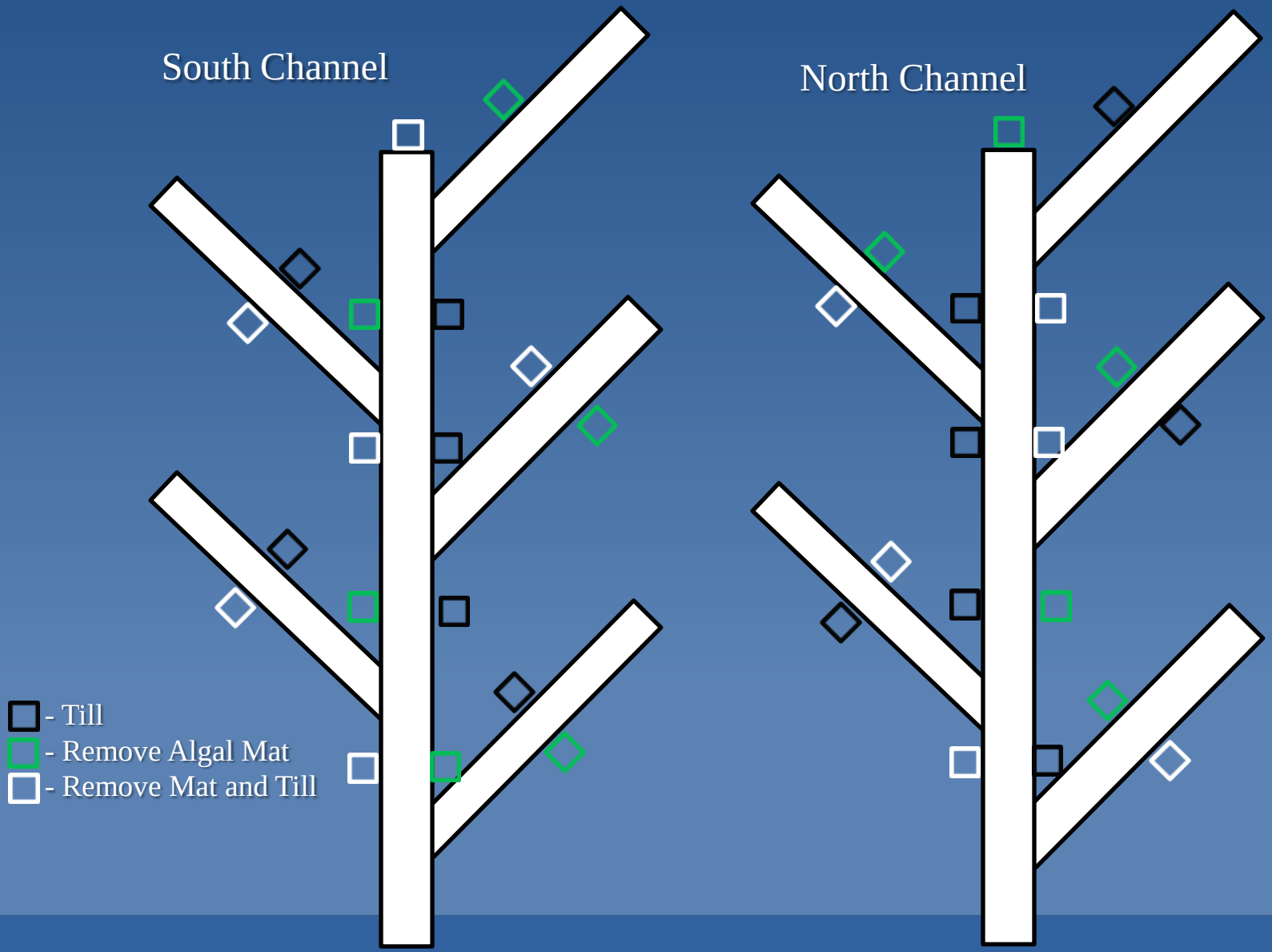
Tilling

- Three alternative marsh surface treatments:
  - Tilling
  - Algal mat removal
  - Algal mat removal followed by tilling
- Treatment directly adjacent to channel excavation in 5 x 5 m plots

CRC1 Alternative Treatment Plots - 0 Months



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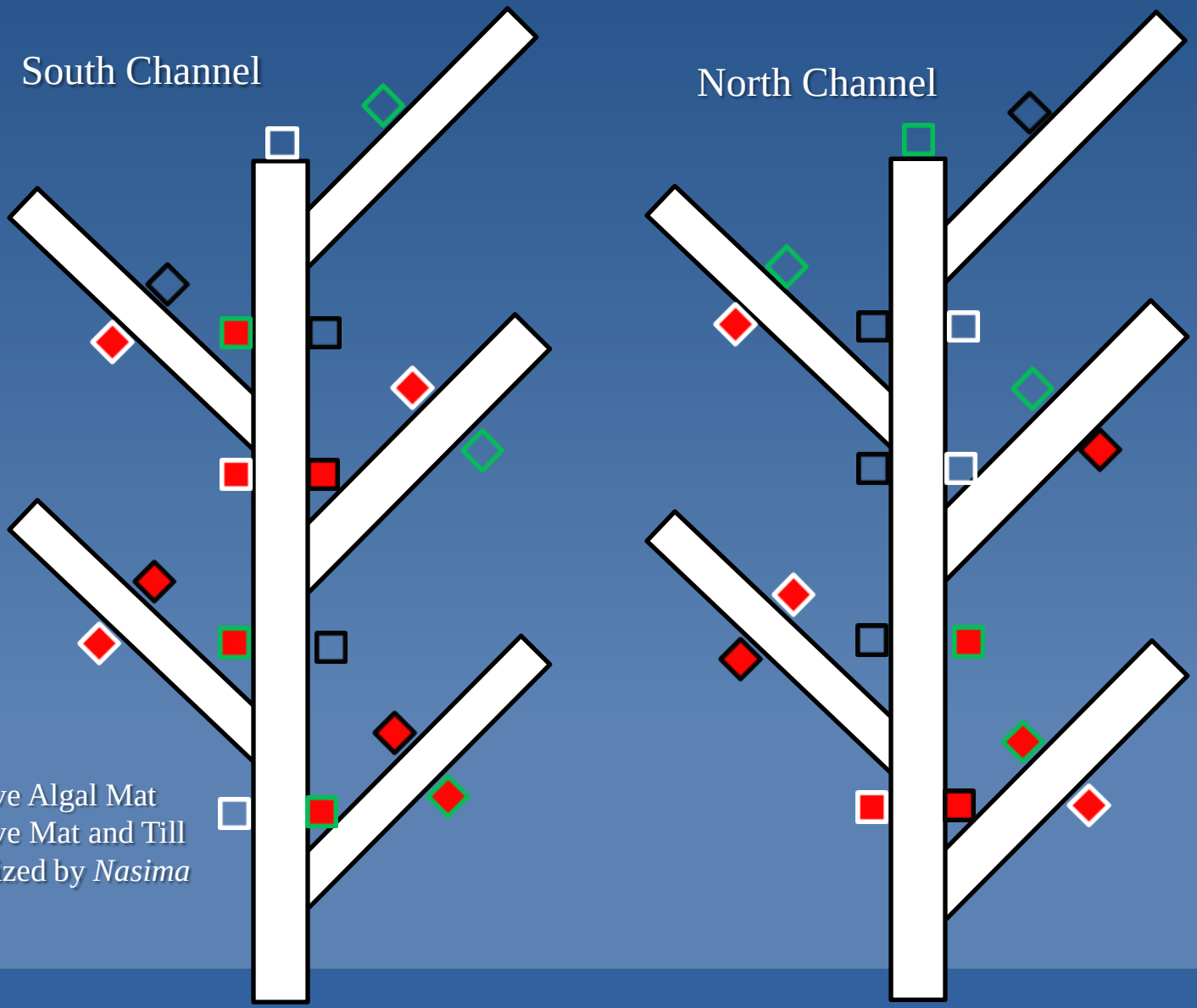
CRC1 Alternative Treatment Plots – 3 Months



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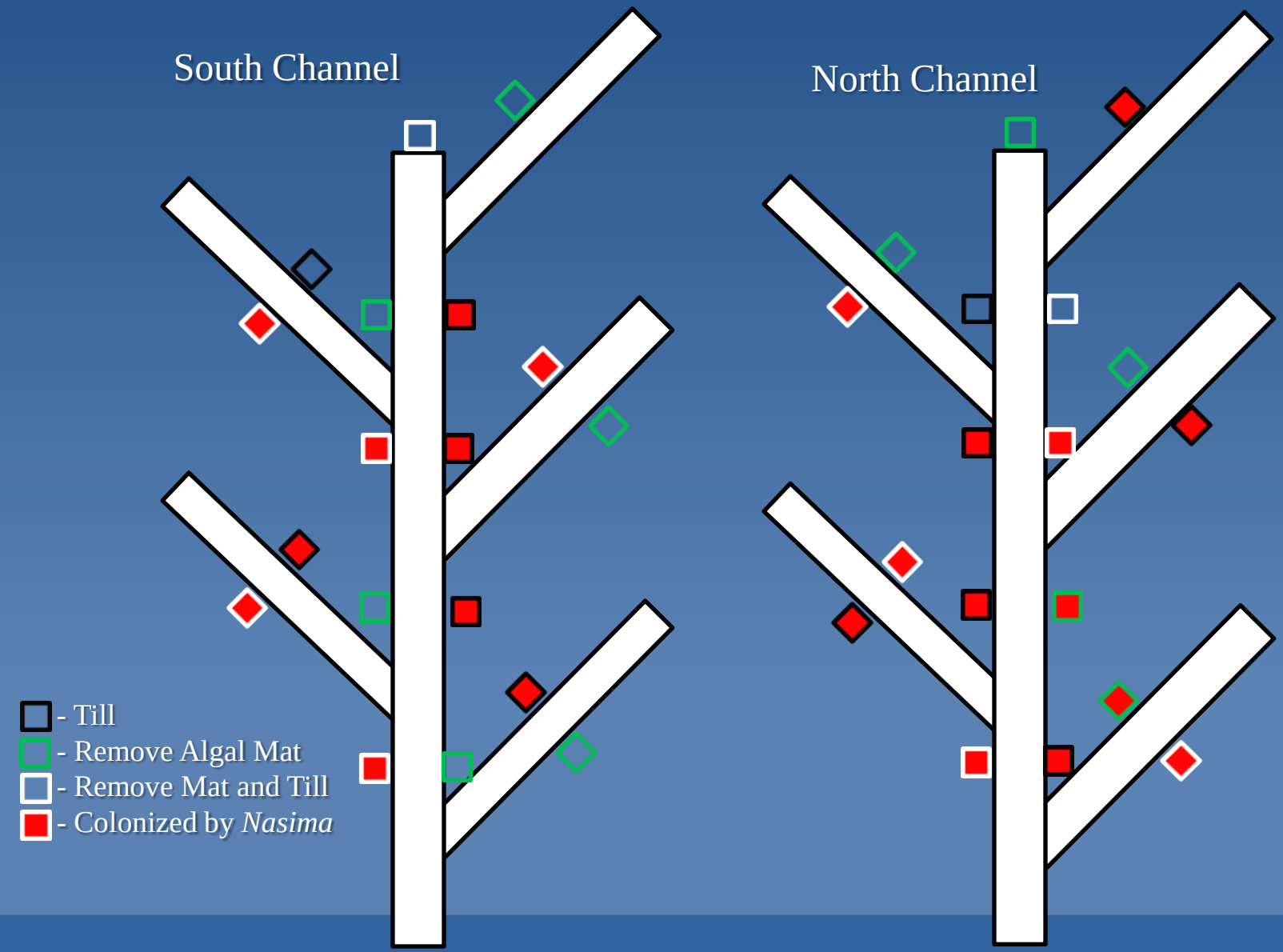
CRC1 Alternative Treatment Plots – 6 Months



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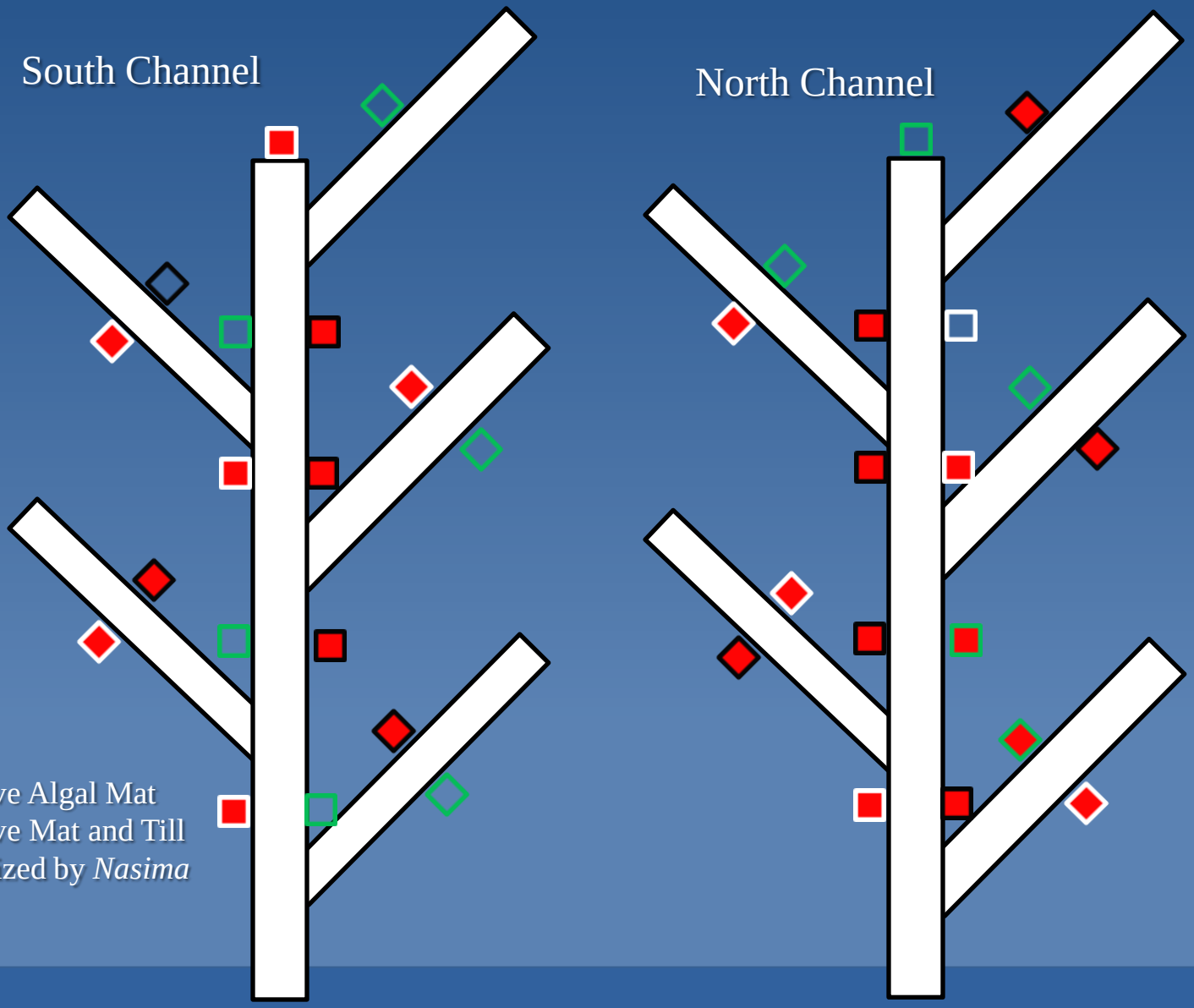
CRC1 Alternative Treatment Plots – 9 Months



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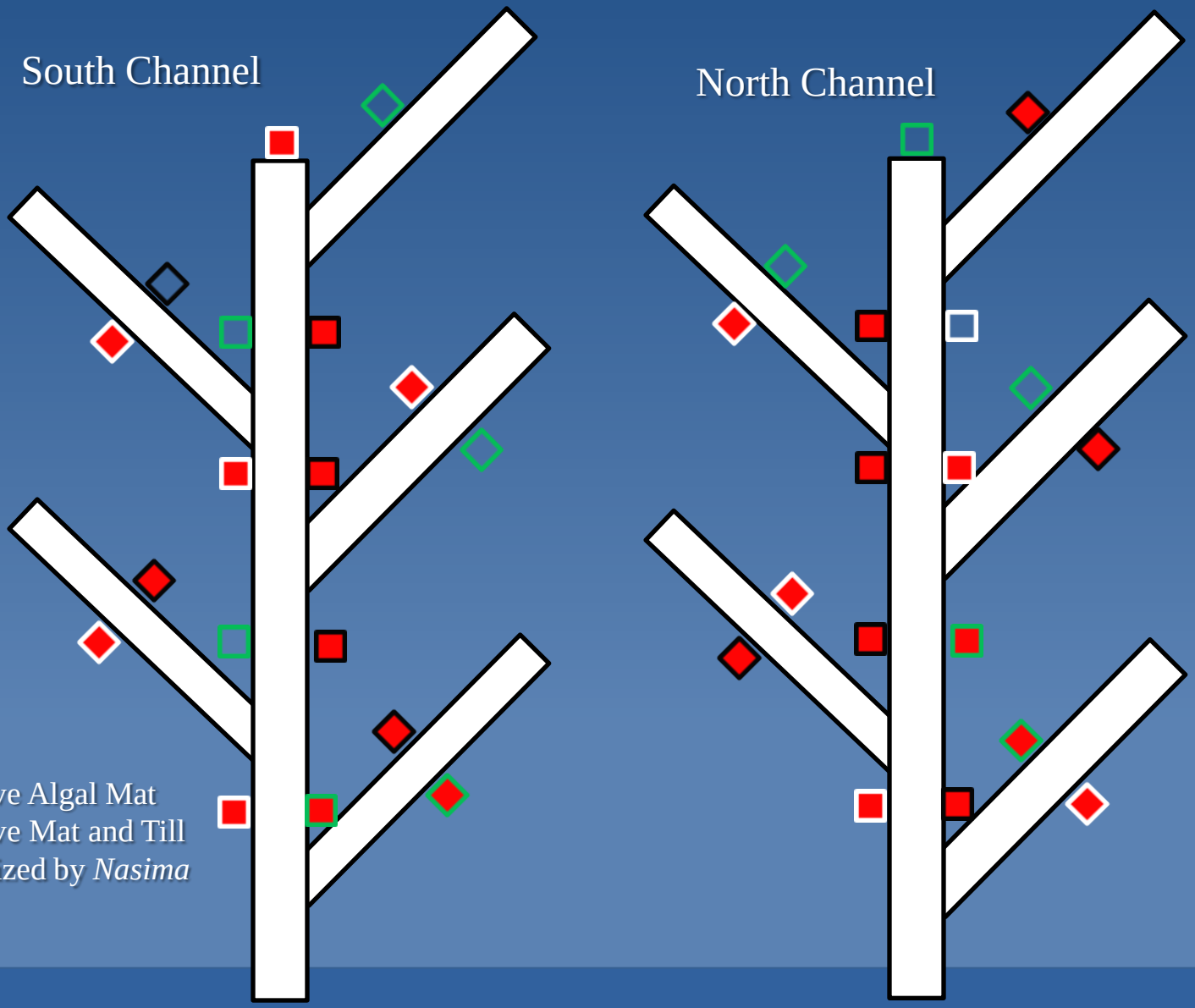
CRC1 Alternative Treatment Plots – 15 Months



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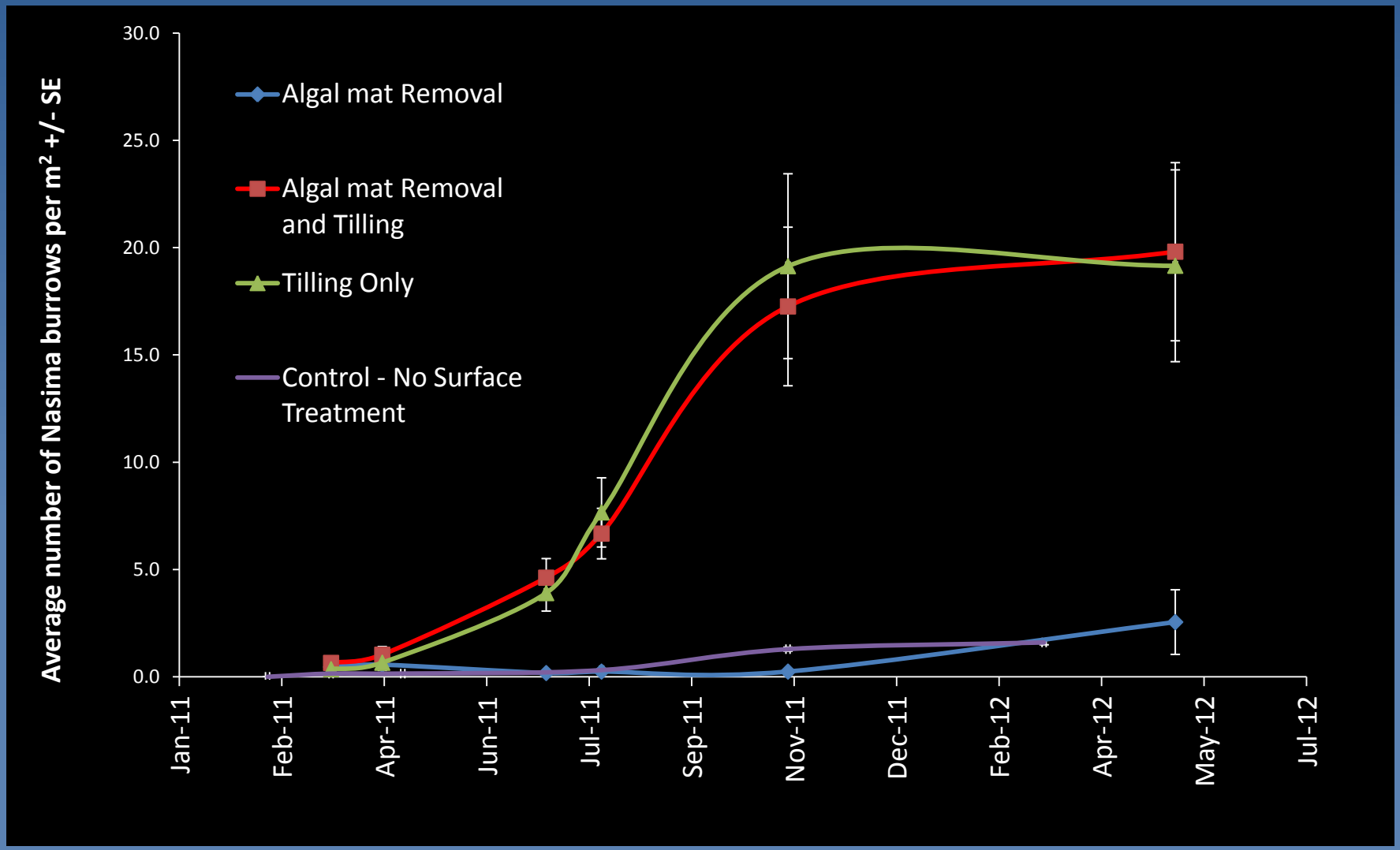
Tilling/Algal Mat Removal



Planting

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Planting

- Mangroves
  - *Avicennia marina*
- Perennial Halophytes
  - *Halocnemum strobilaceum*
  - *Arthrocnemum macrostachyum*

Mangroves

Observable changes (same plant)

after 2 months

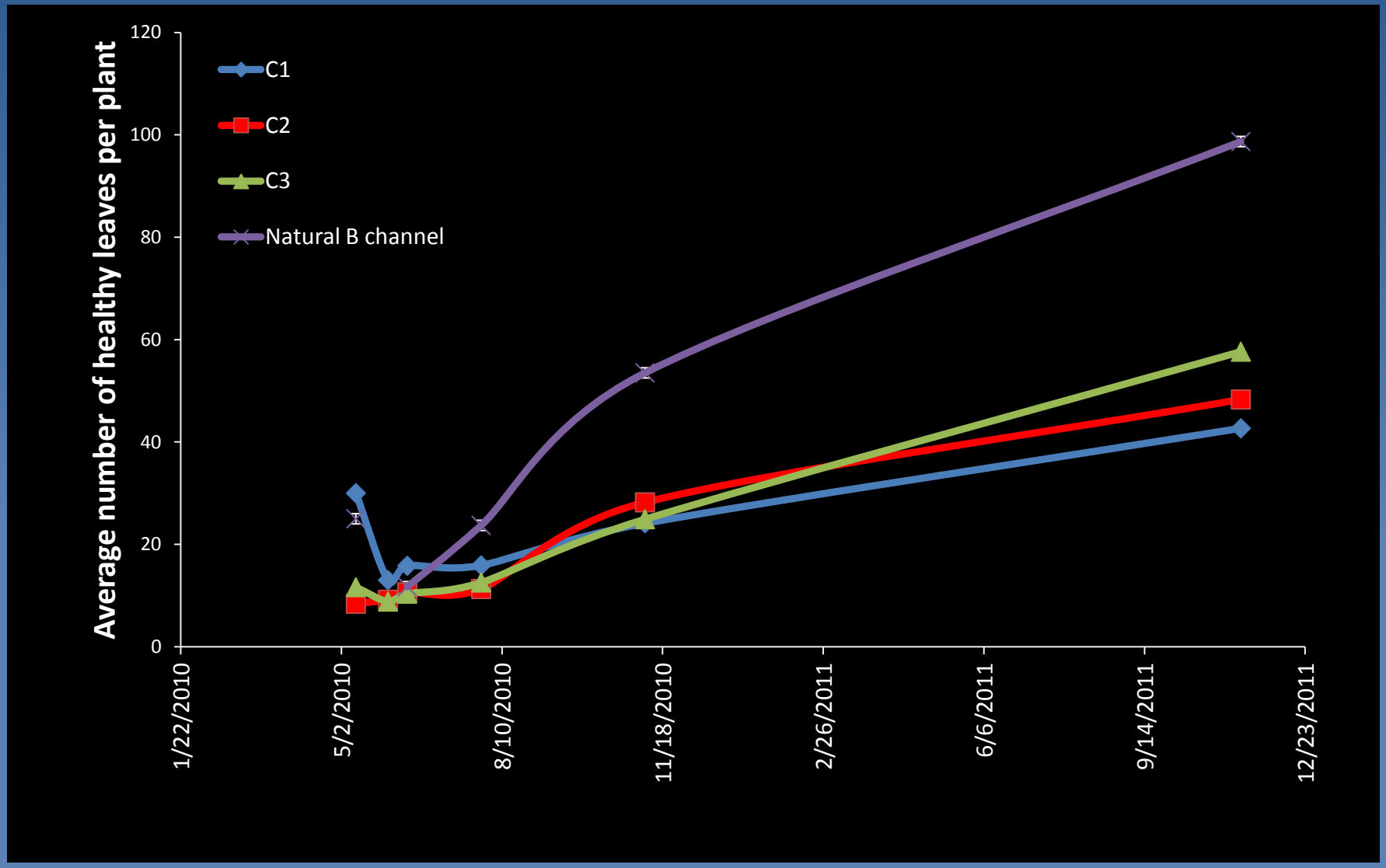
after 6 months

after 1 year

Mangroves

- Observations:
  - Majority of previously surviving plants continue to grow
  - Overall plant height has not increased, however, branch density and leaf count is increasing

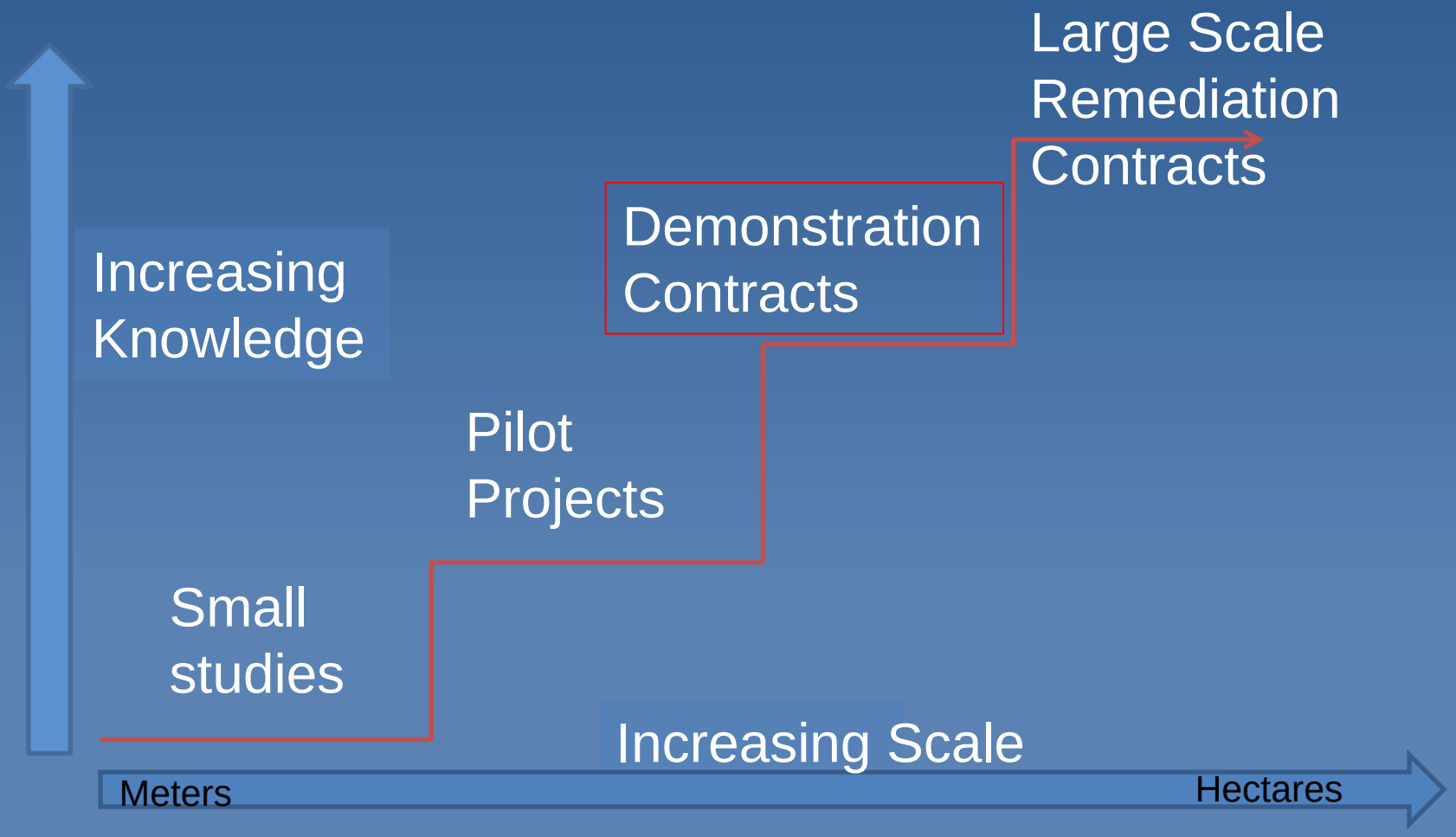
Monitoring Results To Date



Mangroves

- Transplanting mangroves in oiled sediments can be successful
- Poor survival in areas lacking drainage, having high oil concentration, and high algal mat cover
- Highest survival on banks of newly excavated channels. Linkage between excavation and planting

Adaptive Restoration Process



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Lessons Learned

- Rapid increases in colonization can occur in areas of remediation until balanced state is achieved
- Abundance of organisms colonizing areas may follow seasonal trends
- Channels not expected to fill or slump
- Planting success is species dependant

Guidance – Lessons Learned

Channel Excavation

- Efficient method in low energy environment to increase tidal flushing and promote recolonization.

Guidance – Lessons Learned

Channel Excavation

- Efficient method in low energy environment to increase tidal flushing and promote recolonization.
- Channels will continue to be the primary method of remediation of the salt marsh habitats

Guidance – Lessons Learned

Tilling

- Effective at reducing oil residues and de-compact areas covered by barrier increasing potential for recolonization

Guidance – Lessons Learned

Tilling

- Effective at reducing oil residues and de-compact areas covered by barrier increasing potential for recolonization
- Increased areas of tilling have been incorporated into future contracts

Guidance – Lessons Learned

Planting

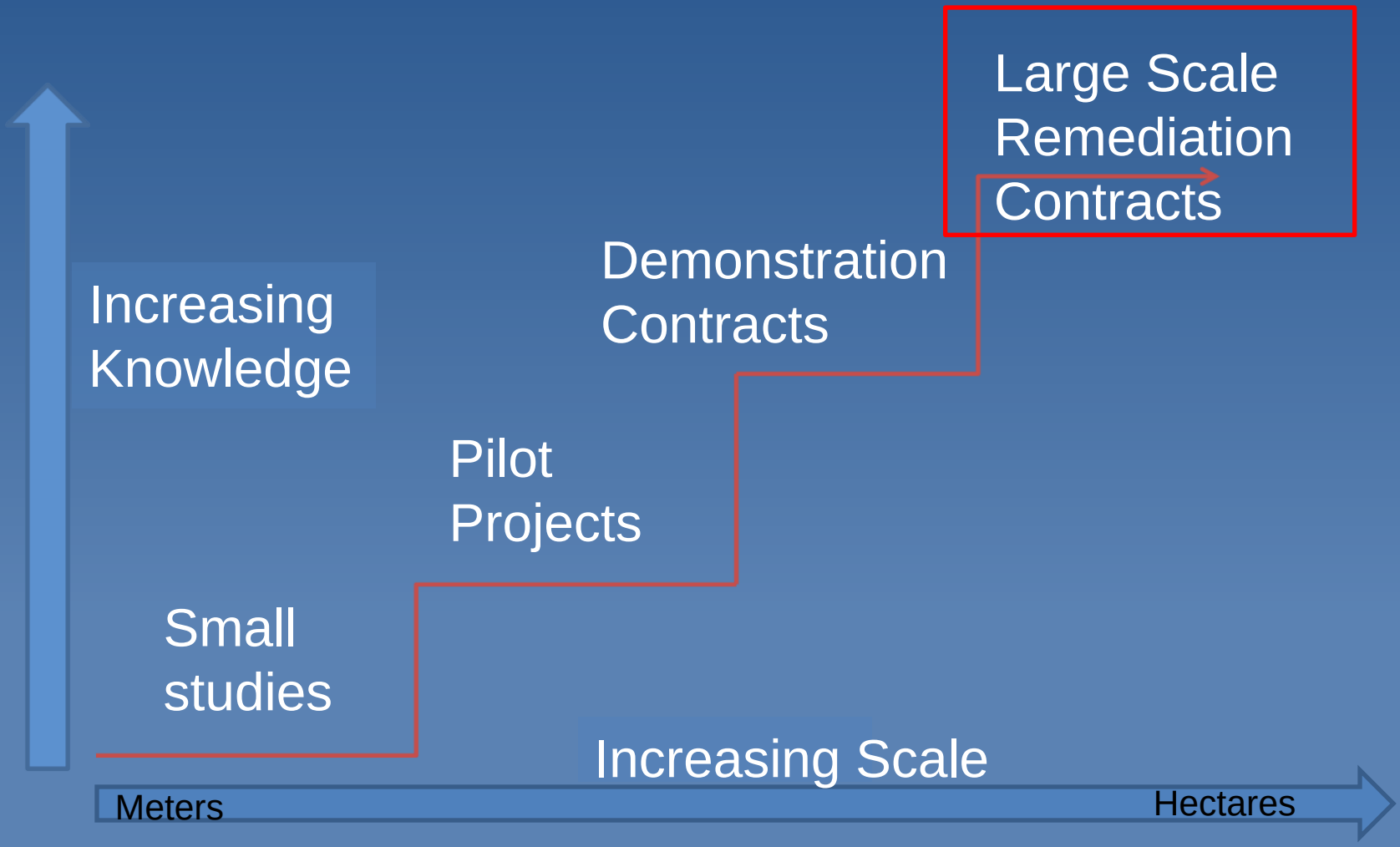
- Recommended for species that are slow to recruit and grow but also able to survive and establish following transplanting

Guidance – Lessons Learned

Planting

- Recommended for species that are slow to recruit and grow but also able to survive and establish following transplanting
  - Mangroves are to be included along the banks of the channels in all future contracts
  - Other halophytes remain limited to small scale/demonstration tests until successful methods can be determined

Adaptive Restoration Process



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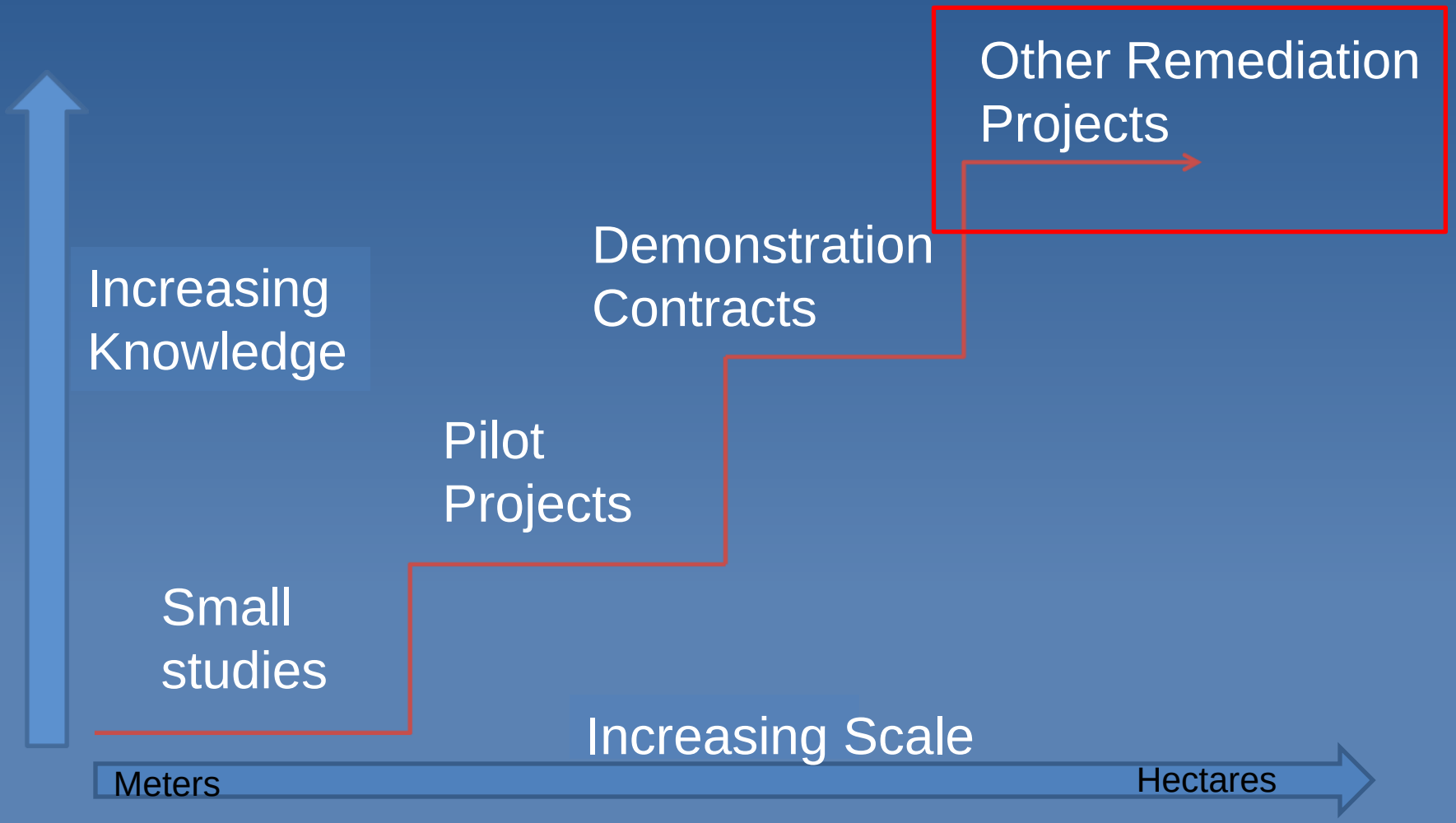
Adaptive Restoration Process



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Thank You

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