

Restoration of mangroves using traditional and innovative techniques



& the long-term monitoring of rehabilitation success
in Darwin Harbour

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Kristin Metcalfe ^{1, 2}
Adam J Bourke ¹
Shaun Levick ³

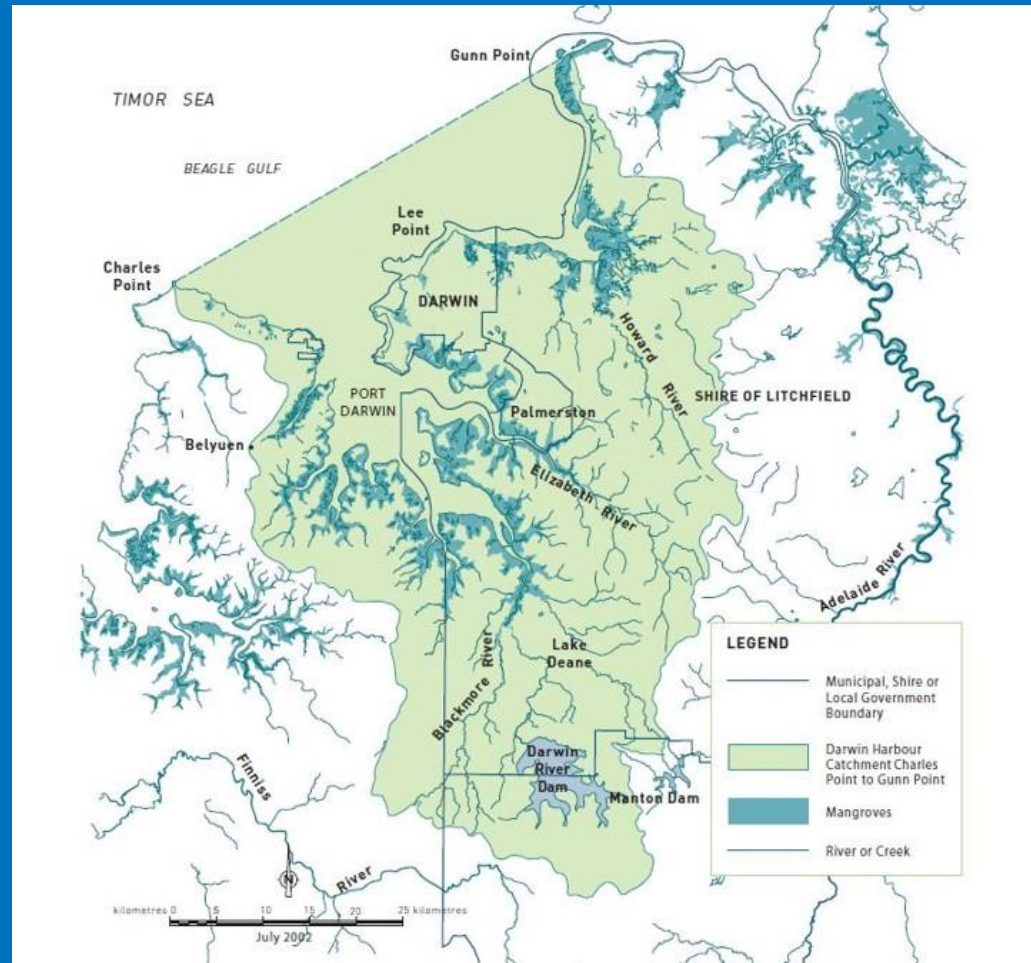
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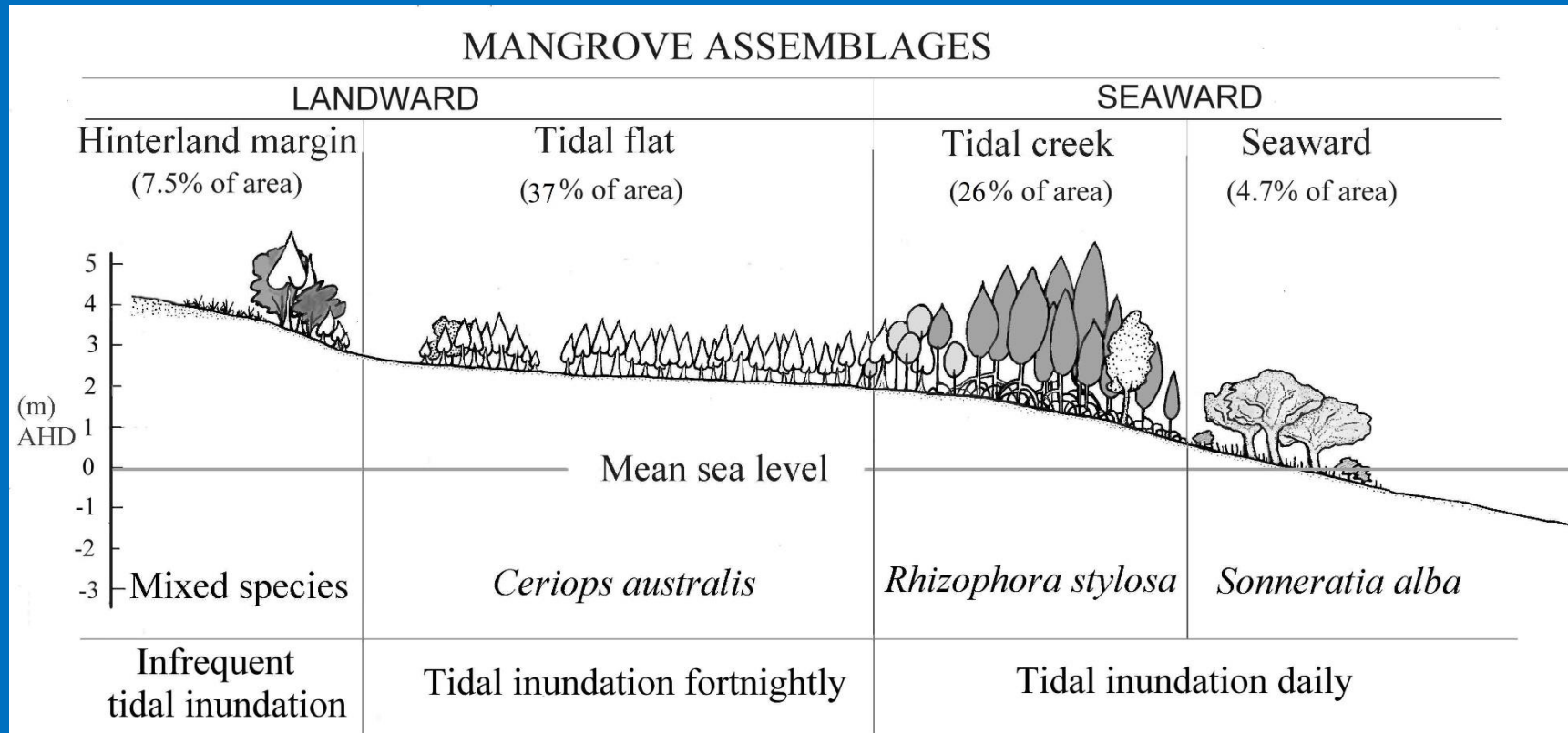


Darwin Harbour – very extensive estuary, macro-tidal, monsoonal climate
20,000 ha of relatively undisturbed mangroves



Darwin Harbour – typical pattern of zonation

- Four main mangrove assemblages (75% of area)



- Successful restoration requires different strategies for each assemblage

➔ Delayed recovery after complete deforestation

e.g. tracks bulldozed through mangroves in 1992



➔ Delayed recovery after complete deforestation

e.g. tracks bulldozed through mangroves in 1992



➔ Delayed recovery after severe natural disturbance
e.g. damage by Cyclone Tracey in 1974



Reasons for delayed reforestation?



Repeated grazing by Green sea turtles in low intertidal zone



Rhizophora stylosa seedling
damaged by
Green sea turtle



Stomach contents of Green turtle (*Chelonia mydas*)

Green turtles graze on *Rhizophora stylosa* seedlings in mangrove habitats at high tide



Long recovery times + big tides + extreme seasonal variation +
turtle grazing = challenges for mangrove restoration

Small scale rehabilitation trials using traditional techniques found:

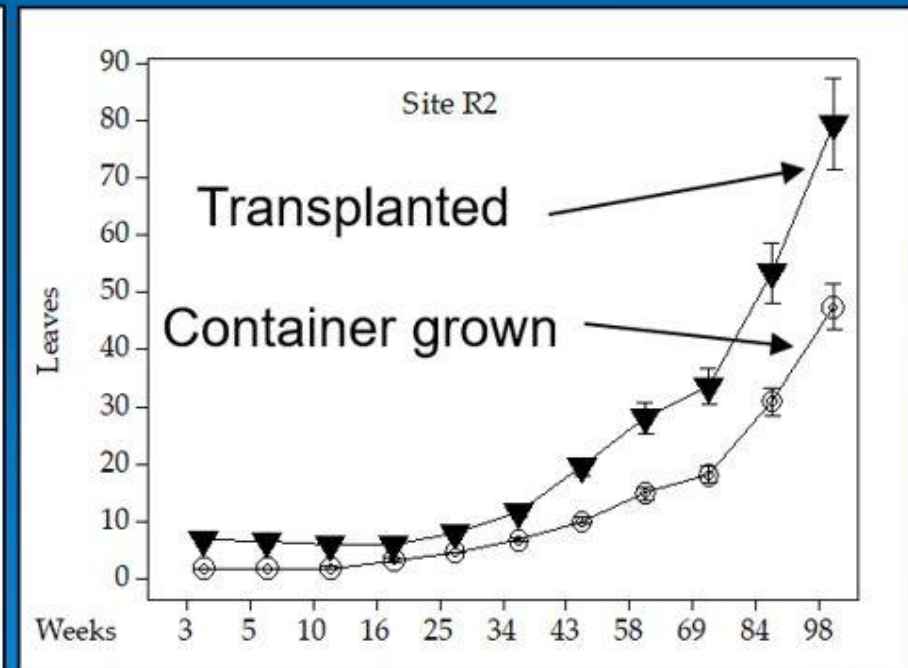
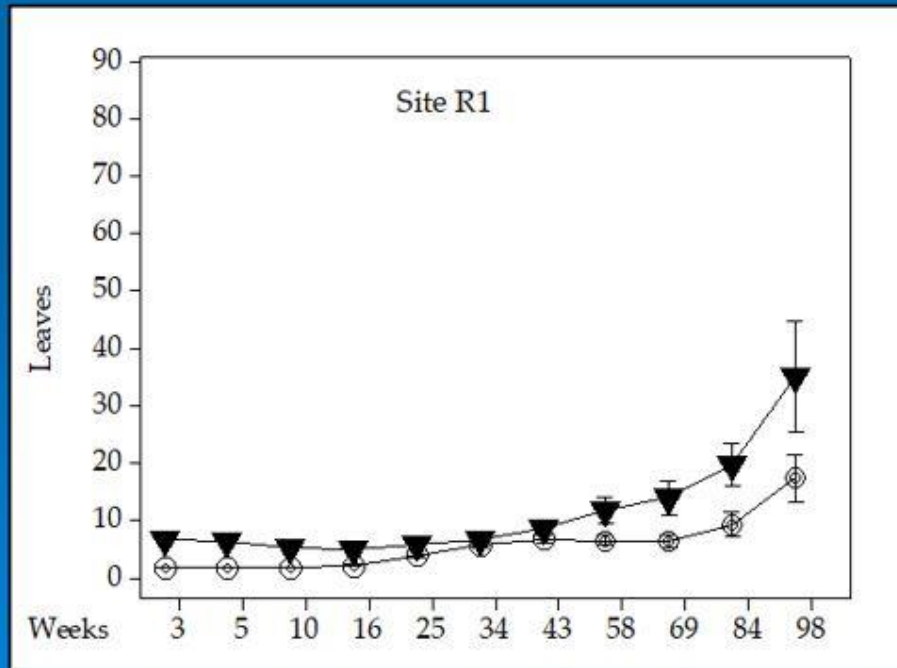
- High survival of **nursery-cultivated seedlings** (>40%)



Aegialitis annulata *Avicennia marina* *Ceriops australis* *Rhizophora stylosa*

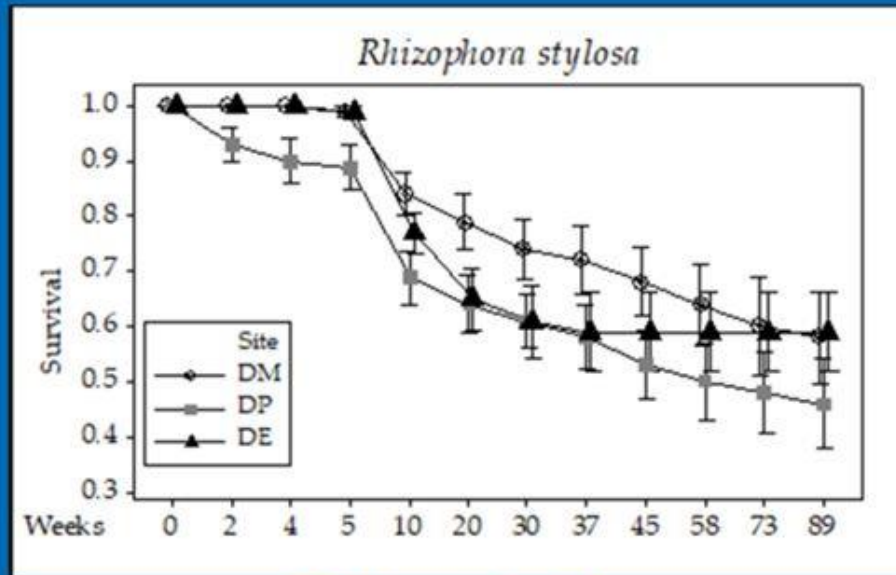
Small scale rehabilitation trials using traditional techniques found:

- High survival of nursery-cultivated *seedlings* (>40%)
 - High survival of **transplanted** seedlings

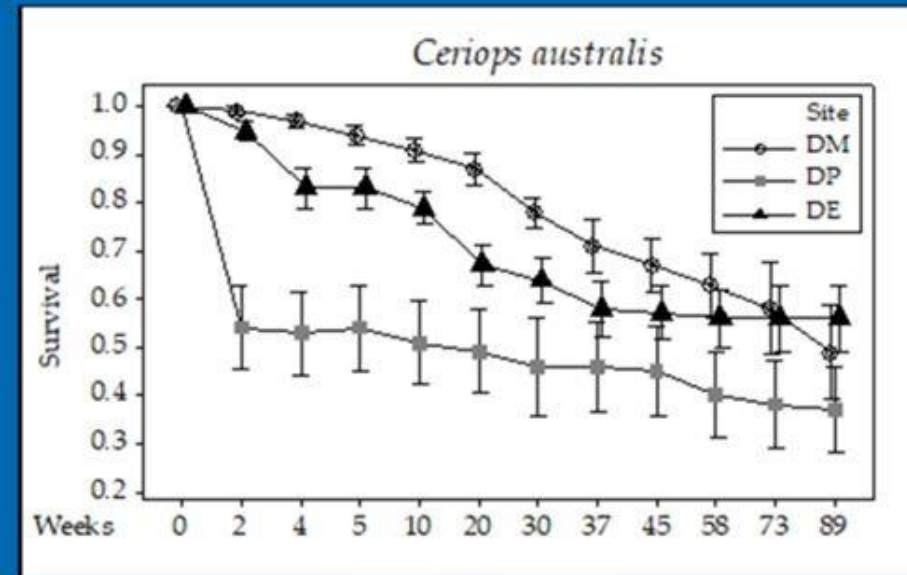


Small scale rehabilitation trials using traditional techniques found:

- High survival of **nursery-cultivated seedlings** (>40%)
 - High survival of **transplanted seedlings**
- **Direct sowing** of propagules successful (47- 54% survival)



54% survival



47% survival

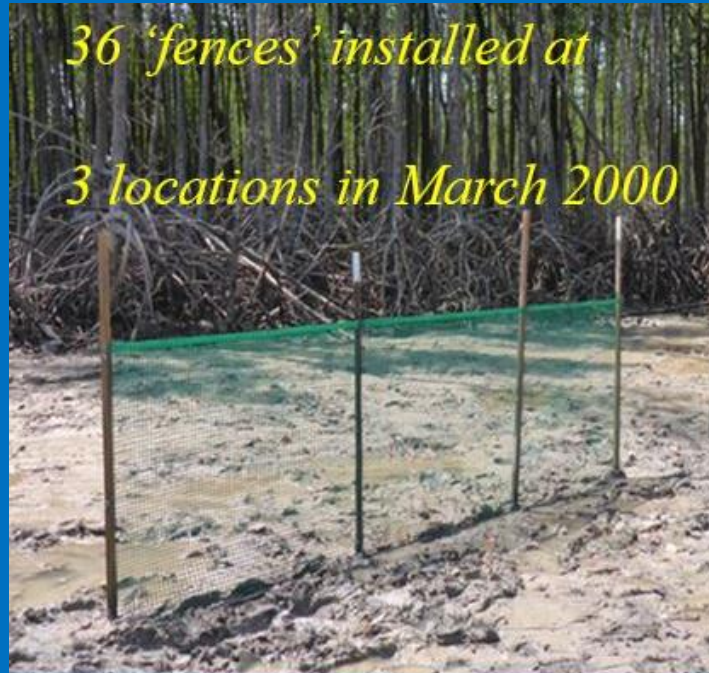
Incidental observation:

Natural seedling recruitment occurs in refuges created by wire netting exclosures

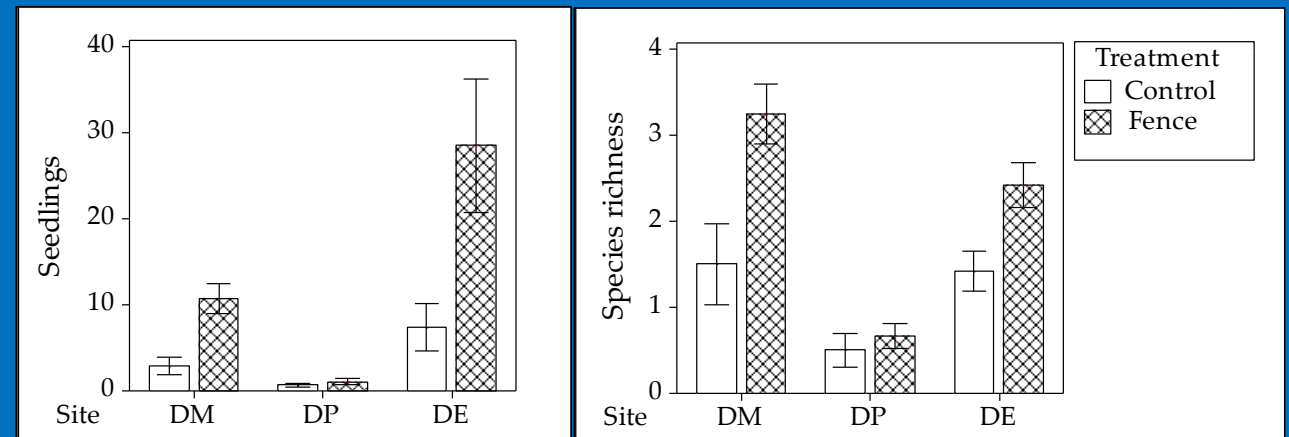


- Wire slows strong tidal currents
- Seeds and propagules get stranded
- Assists seedling establishment

... the inspiration for innovative "recruitment fences"



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- Seeds and propagules get stranded
 - Assists seedling establishment



Significantly higher recruitment at fences after 18 months

- Useful technique for future mangrove restoration?

INPEX – operated Gas Export Pipeline project

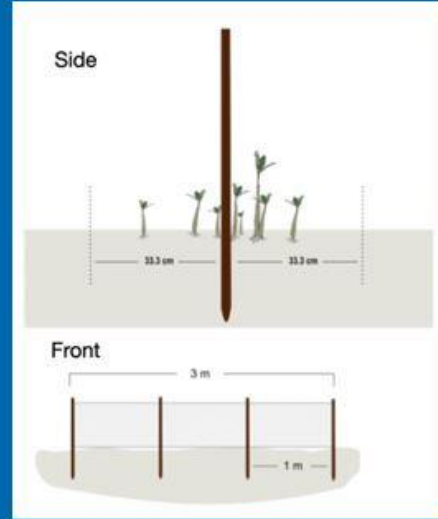
- In 2013, a 900 m pipeline corridor was constructed through mangrove & salt flat
- Approx. 1.6 ha mangrove forest was cleared



INPEX – operated Gas Export Pipeline project

- In 2013, a 900 m pipeline corridor was constructed through mangrove & salt flat
- Approx. 1.6 ha mangrove forest was cleared
- EIS requirement – mangroves must be rehabilitated & success of reforestation monitored





NEW TECHNIQUE - FENCES TO ASSIST NATURAL RECRUITMENT

- Installed 143 recruitment fences
- 10 monitoring fences compared with 10 controls in each assemblage





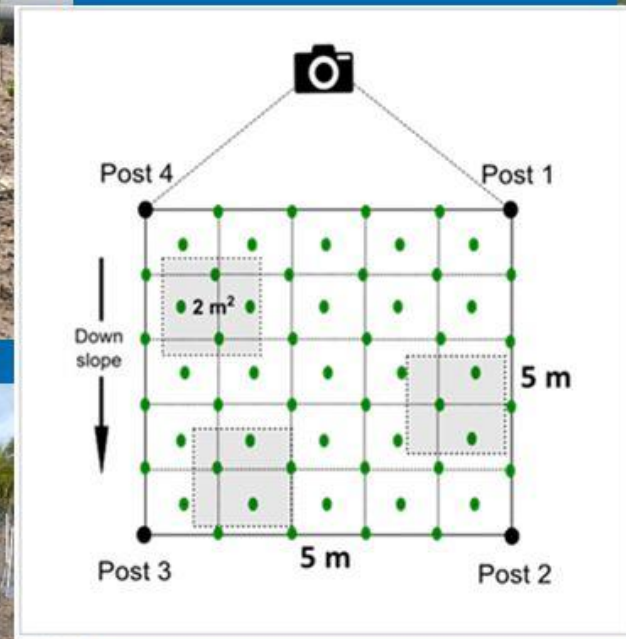
TRADITIONAL TECHNIQUES

- Nursery cultivation & planting - 2 species
- Direct implanting of propagules
- Planted at mean density of 2.3 plants / m²

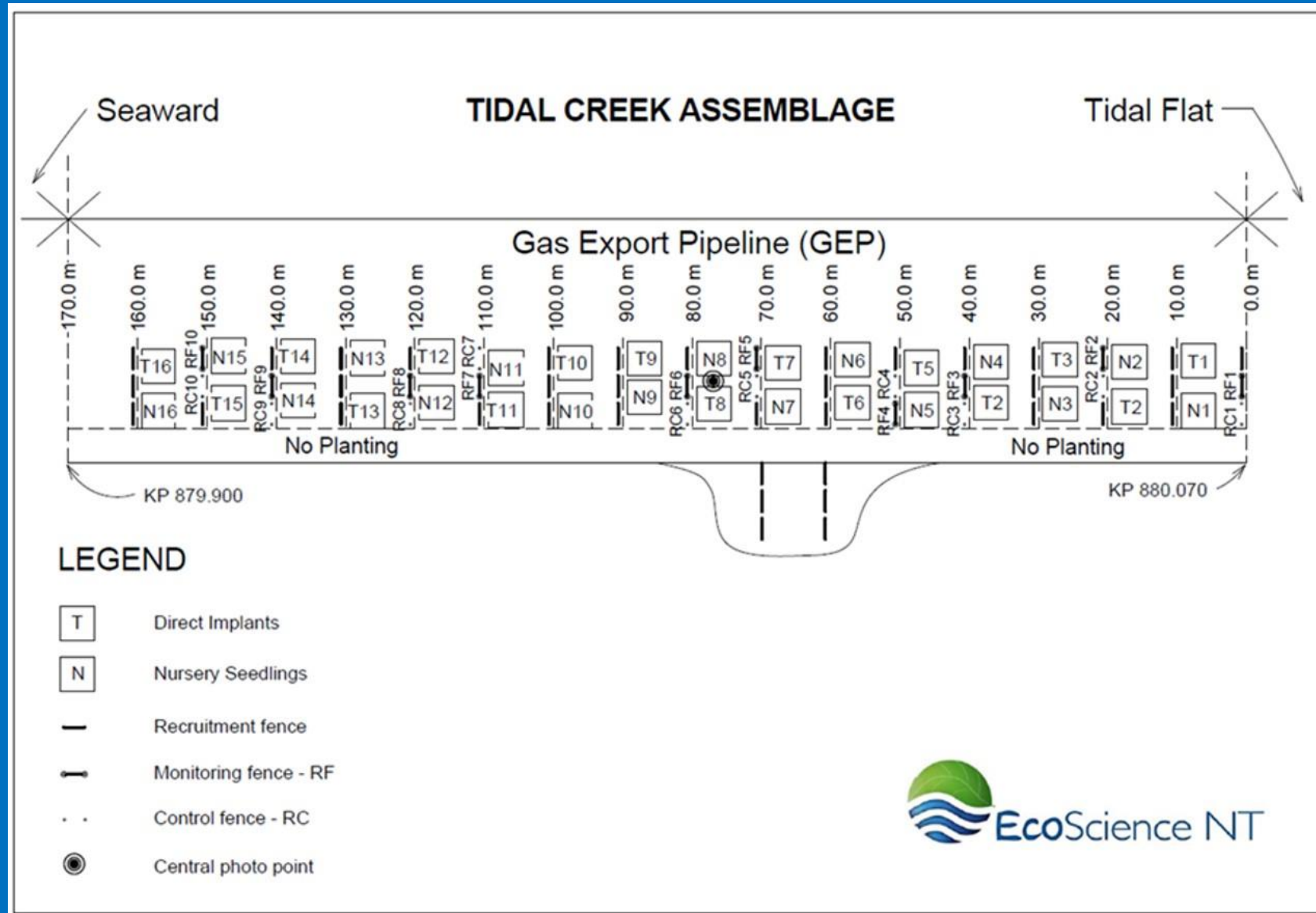


Long-term monitoring of rehabilitation success-

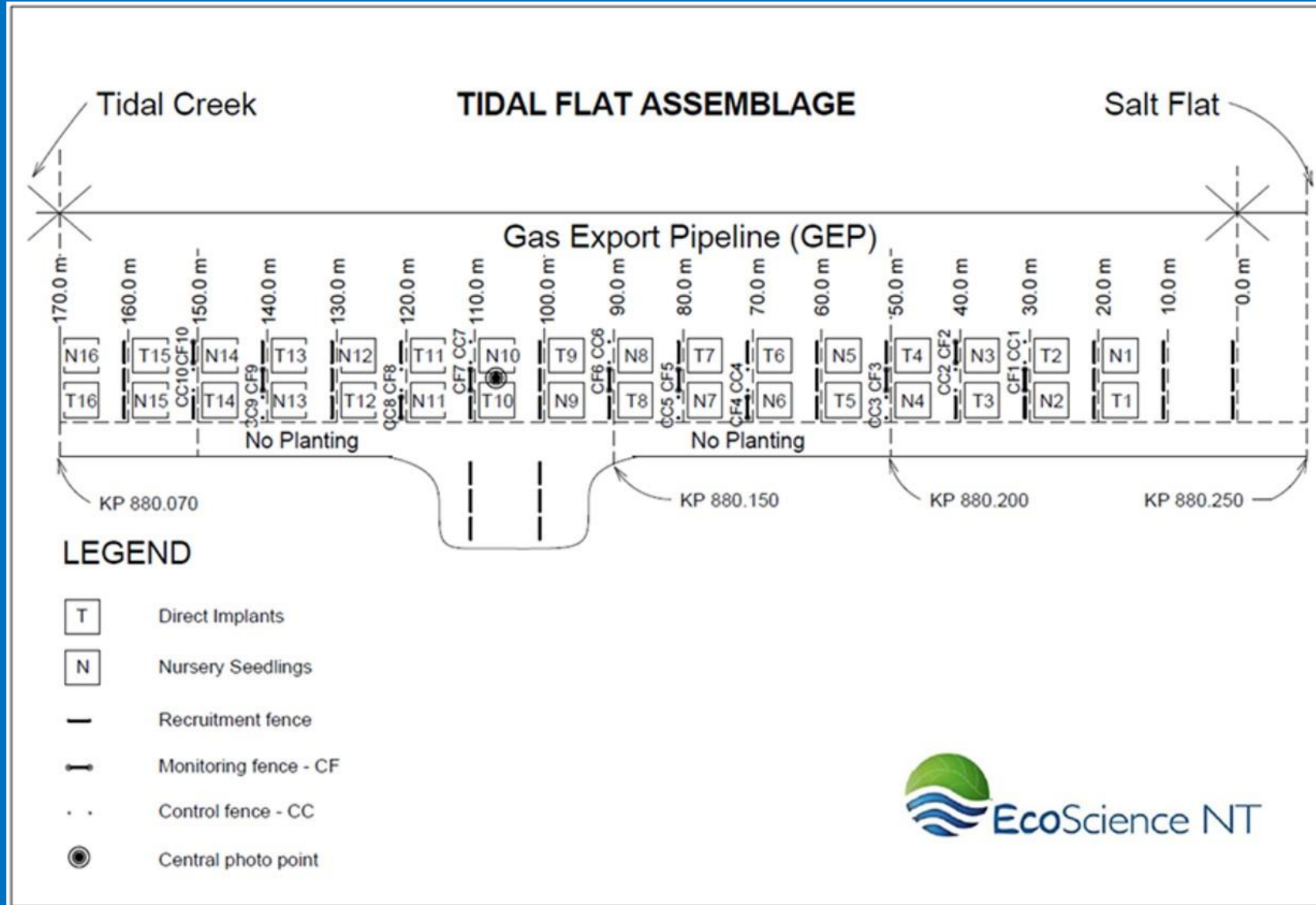
- Planting and implanting within 5 m x 5m permanent monitoring plots
- Design allowed natural recruitment to be monitored within plots



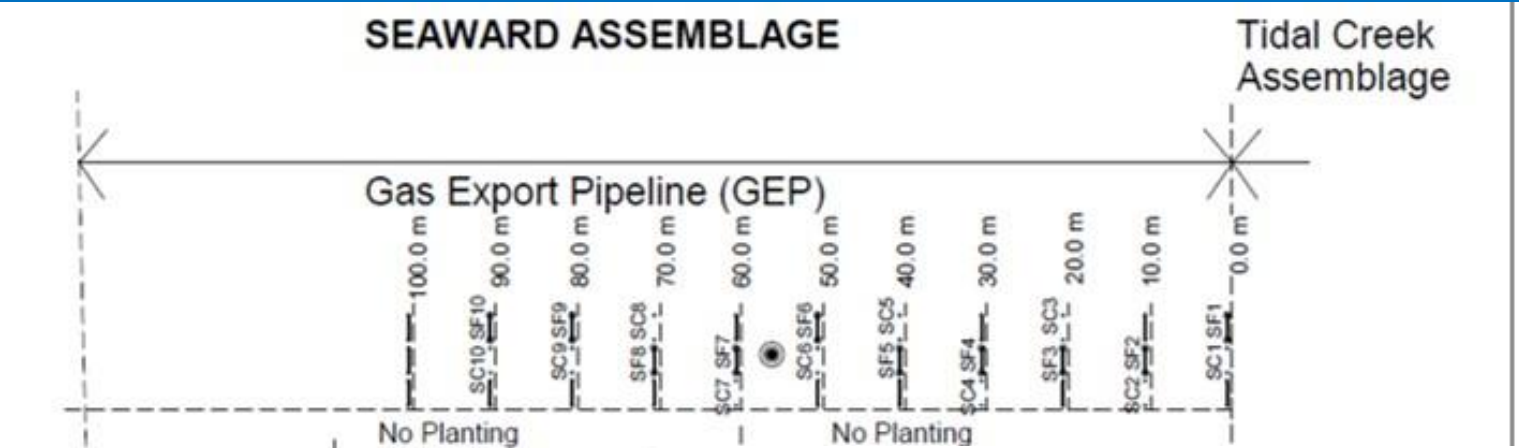
Long-term monitoring of rehabilitation success -



Long-term monitoring of rehabilitation success -



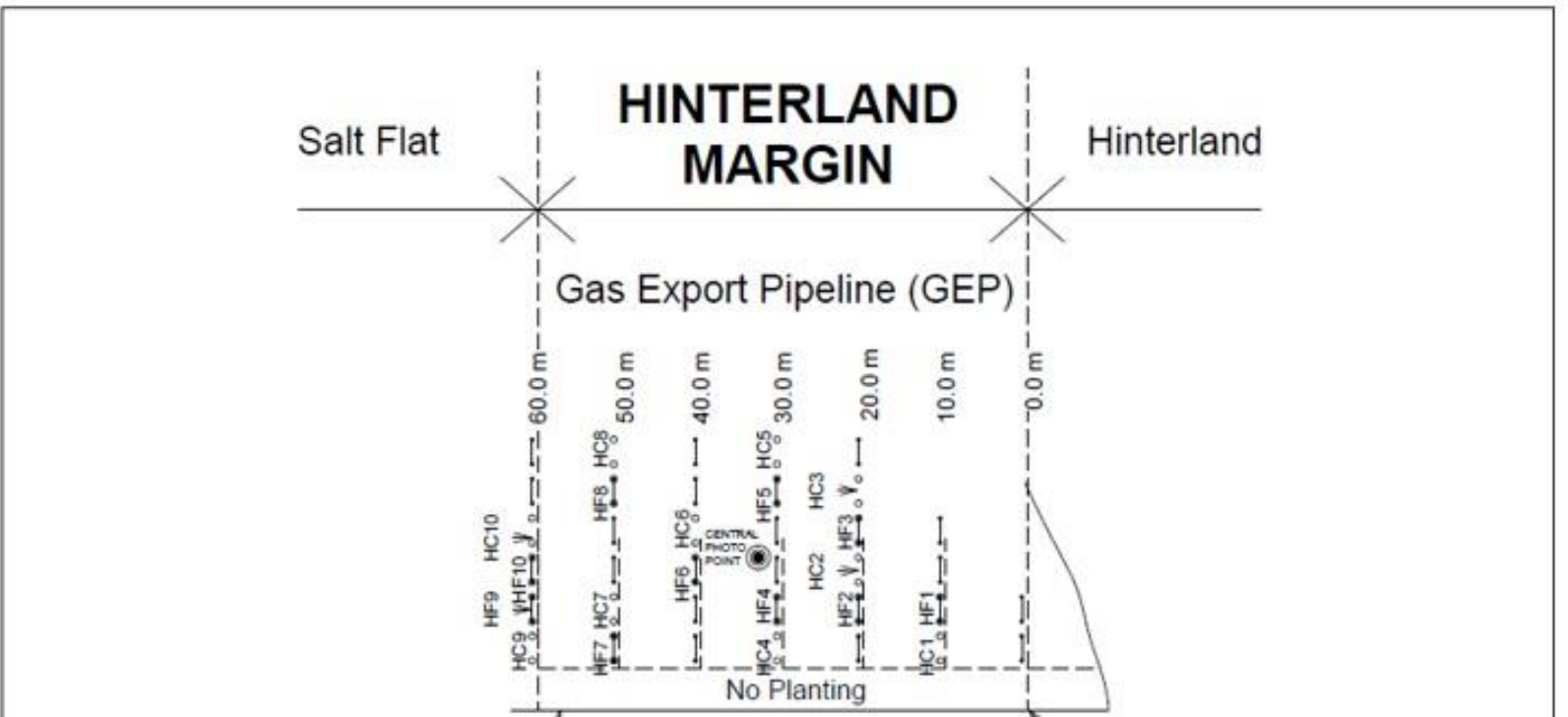
Long-term monitoring of rehabilitation success-



Survival and growth -within plots, at fences & from natural recruitment - was measured regularly for the first 2 years

LEGEND

- Recruitment fence
- Monitoring fence - SF
- · Control fence - SC
- Central photo point



In 2016, after only 2 years, the client ceased all monitoring
EcoScience continued monitoring as voluntary research project (2017, 2019, 2020)



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EcoScience continued monitoring as voluntary research project (2017, 2019, 2020)



Remote sensing options:

- Preliminary trial using drone - 2016
- Terrestrial laser scanning (TLS) trials - 2017 to 2020
- Multi-spectral drone (NDVI) trial - 2023



Trial of time-series Terrestrial LiDAR Scanning (TLS)

Objective: to monitor mangrove rehabilitation progress 2017- 2020 *



2017

– scanning with the light-weight
Leica BLK360



2019 & 2020

- scanning with the long-
range Riegl VZ-2000i

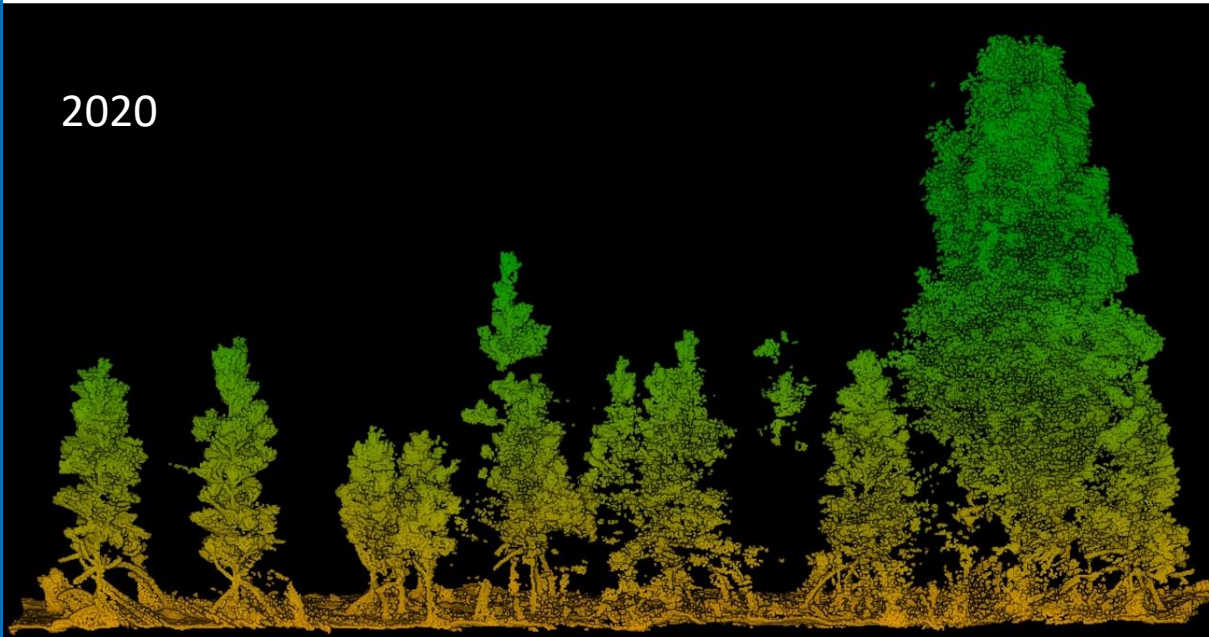
* A joint EcoScience NT and CSIRO Kickstart Project

Terrestrial LiDAR Scanning (TLS)

2017

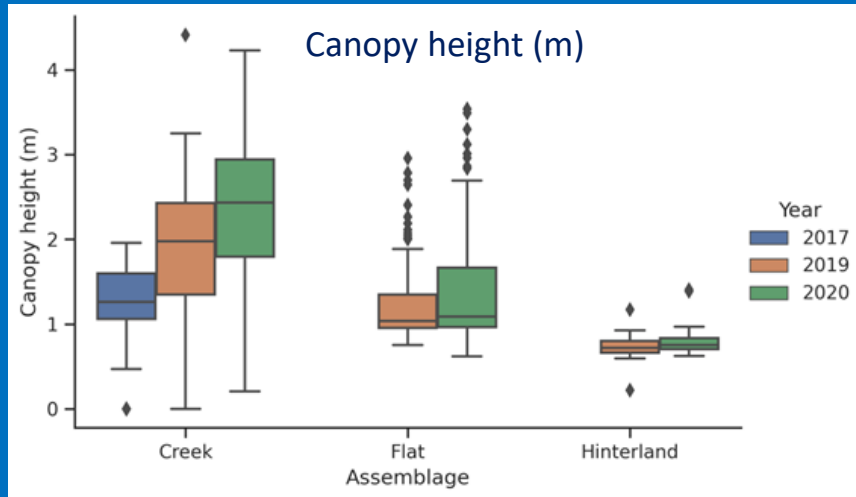


2020



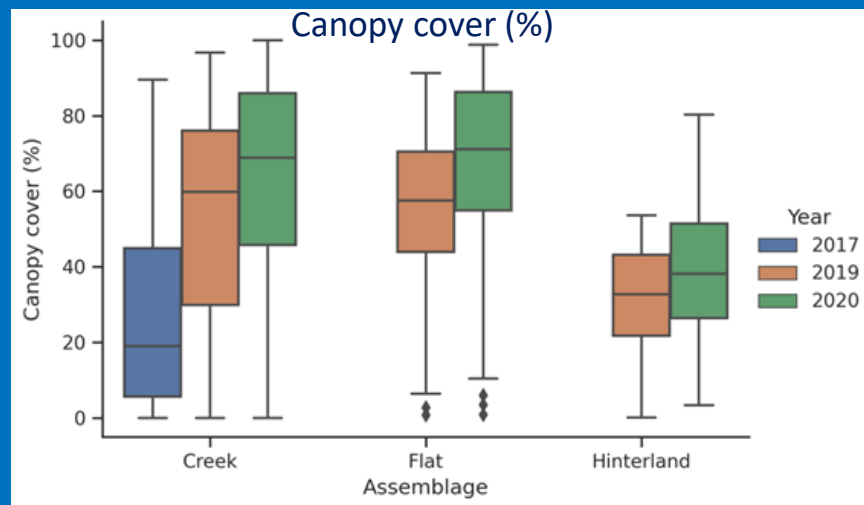
LiDAR captured the 3D structure of regrowth in high resolution detail

Terrestrial LiDAR Scanning (TLS) of monitoring plots



Tidal creek - 2020 results (after 6 years)

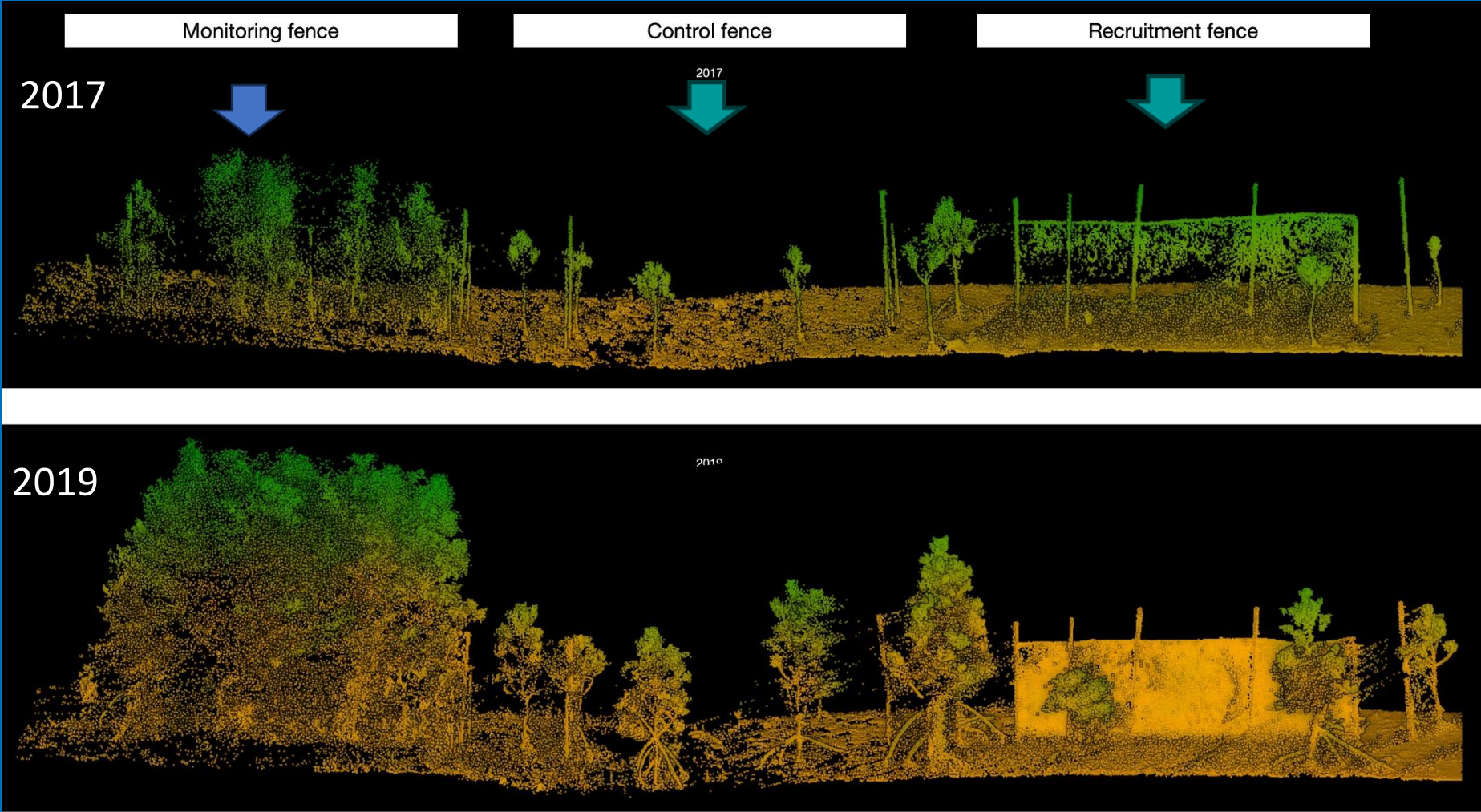
- median height of 2.5 m and
- 57% canopy cover



Tidal flat -2020 results (after 6 years)

- median height of 1 m and
- 68% canopy cover

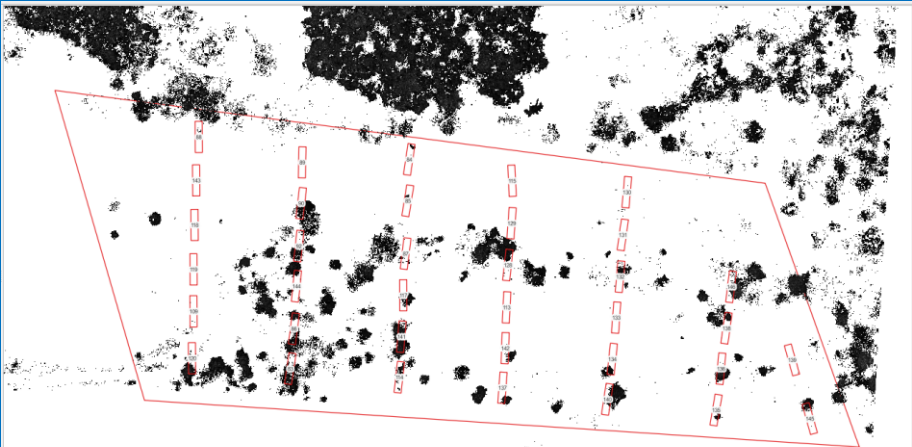
Terrestrial LiDAR Scanning (TLS)



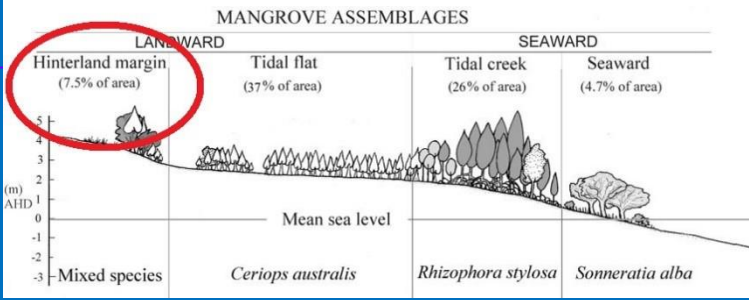
Side view of terrestrial laser scanning data collected across monitoring, control and recruitment fences

Hinterland margin zone

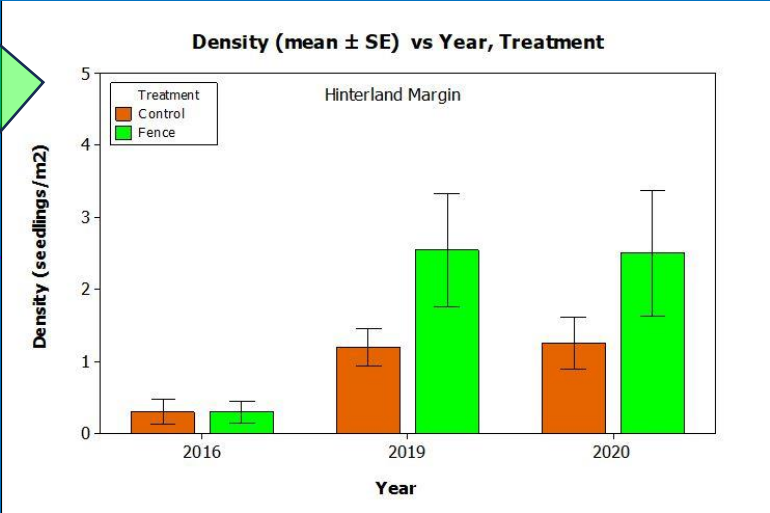
2023
(9 years)



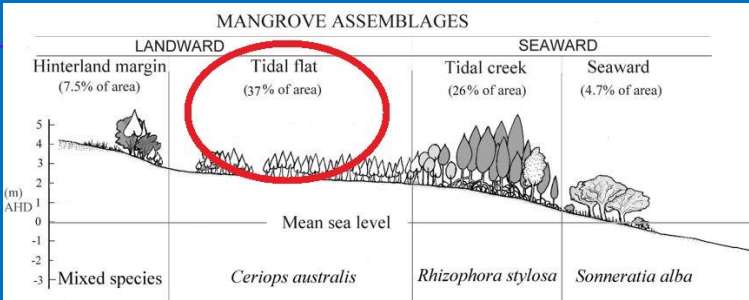
2023 drone survey – green cover



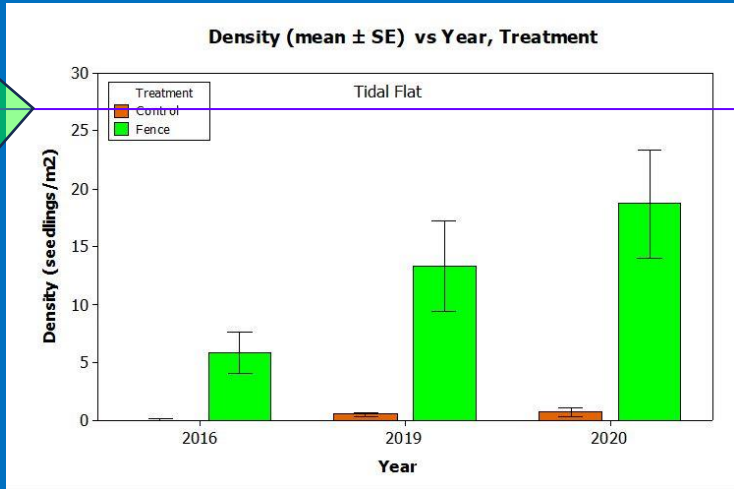
- Hinterland margin – 2023 results
- Canopy cover $\approx 7\%$
- Fences - significantly higher recruitment
- Natural recruitment - patchy
- Substrate variability – poor reinstatement



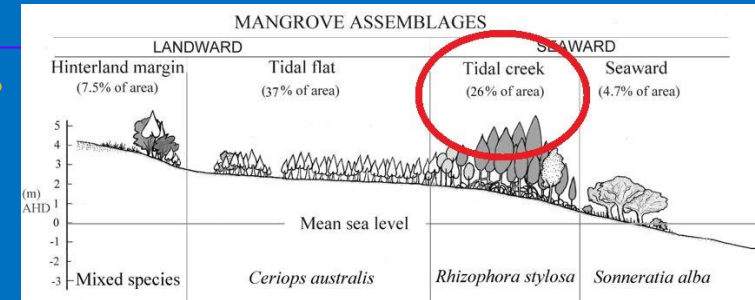
Tidal Flat (Ceriops) zone



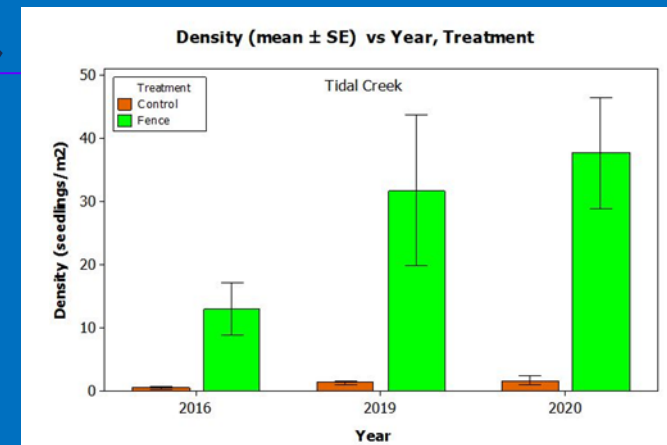
- Tidal flat – 2023 results
- Canopy cover - 20 %
- Fences – significantly higher recruitment
- High natural recruitment



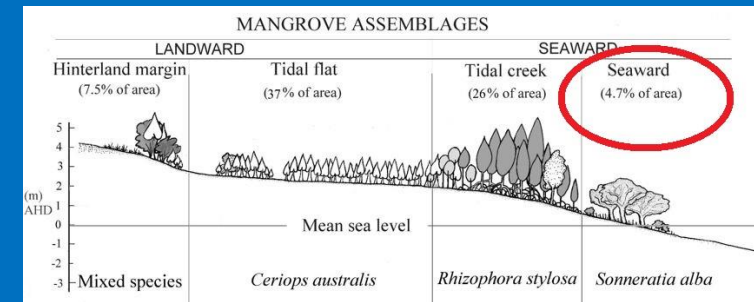
Tidal Creek (Rhizophora) zone



- Tidal creek – 2023 results
- Canopy cover - 45 %
- Fences – significantly higher recruitment
- Highest natural recruitment
- Turtle damage – extreme in lower intertidal (16% cover)



Seaward zone



Seaward zone – 2023 results

- Patchy recovery
- Canopy cover $\approx 4\%$
- Fences failed - damaged
- Substrate instability

SUMMARY

Fences

- Successful in fast-tracking restoration in 3 assemblages
 - Still functional 9 years after installation

Survival & growth

- Over 20% - planted & implanted seedlings
- No long-term advantage from nursery culture

Natural recruitment

- Surpassed density of planted seedlings after 2 years (in tidal creek)
 - In general, increased markedly after 5 years



2023 RPAS survey



Forest regrowth 10 years after clearing, nearly 9 years since rehabilitation works

2023 RPAS survey



Good reforestation in Tidal flat assemblage – high natural recruitment of *Avicennia marina*

2023 RPAS survey



Dense reforestation in Tidal creek assemblage

2023 RPAS survey



Delayed recovery in turtle grazing zone – but continues to be a feeding ground for Endangered Green turtles

Questions?

