Lessons from Urban Wetlands

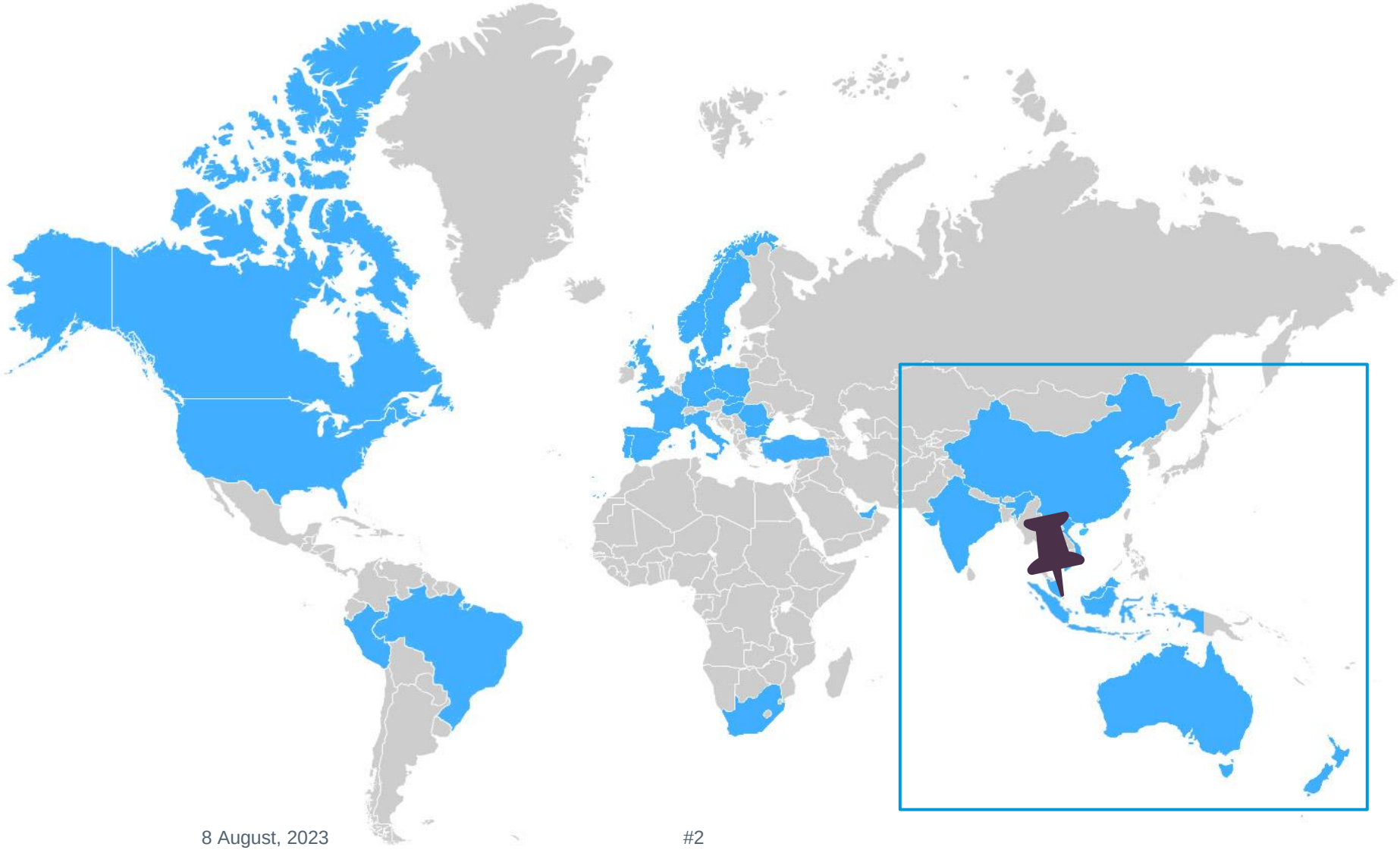
Mangroves in Freshwater and Carbon Sequestration

20 July 2023

Gardens by the Bay

DHI

DHI is global



APAC Region

Our Capabilities

Software Technology

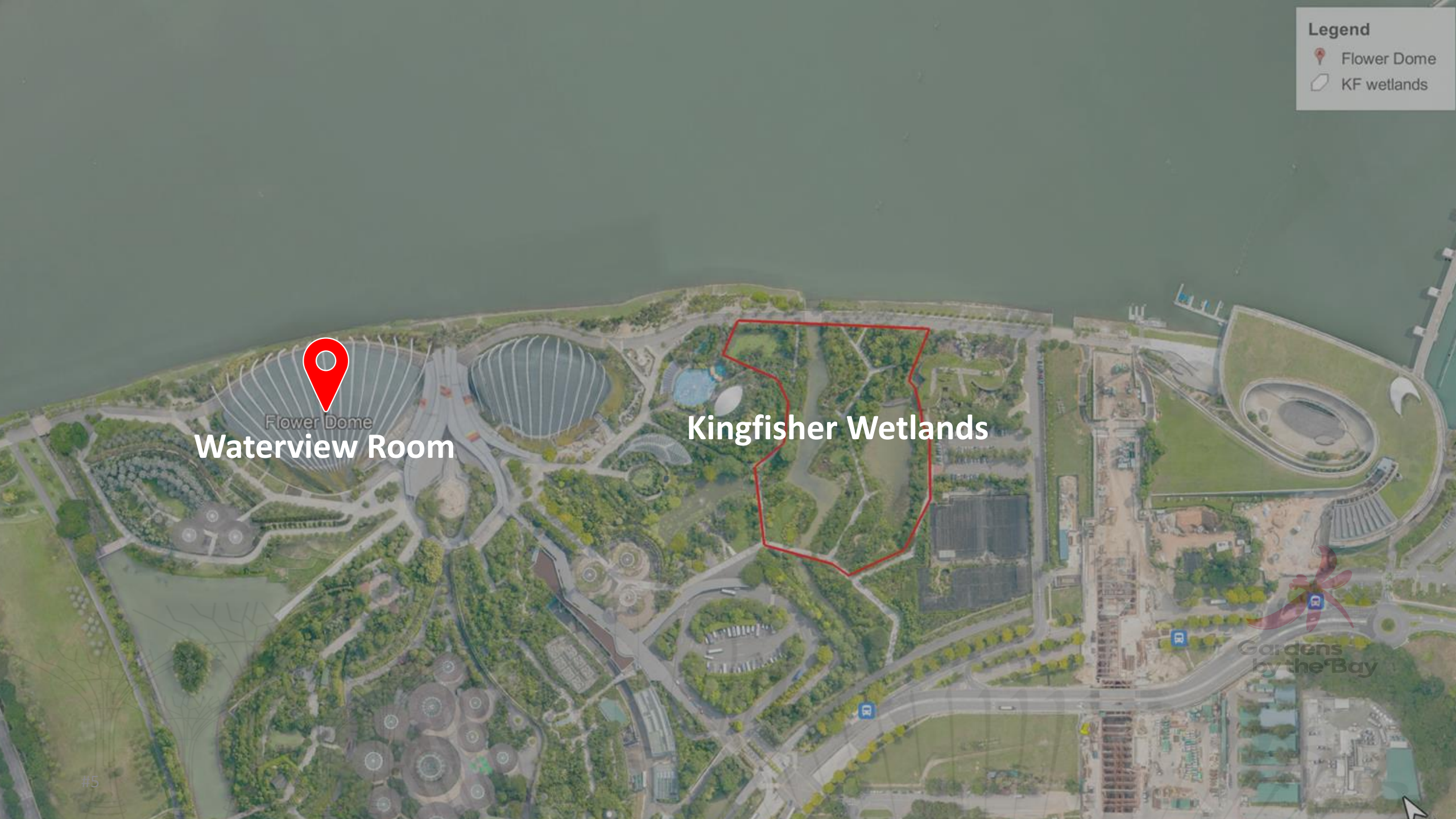
Numerical/Biogeochemical/Ecological Models

MIKE Powered by DHI

Consultancy Services

- Environmental Impact Assessment
- Environmental Management and Monitoring Plan
- Carbon Advisory
- Sustainability Advisory

Carbon Sequestration in Urban Wetlands


Legend
Flower Dome
KF wetlands
Flower Dome
Waterview Room
Kingfisher Wetlands
Gardens by the Bay

In 2021, Gardens by the Bay had the opportunity to develop the area now known as Kingfisher Wetlands into a central urban wetland.

- Popular birding site
- 15,000 sqm which contains 200 native true mangroves and mangrove associates
- Addition of cascades to promote biodiversity and water circulation

Pilot study on carbon sequestration in ponds

- Project Objective: Assess the potential of an urban wetland in carbon sequestration within a one-year timeframe
- Study Area : Frog and Lotus Pond

1. Isolated from public
2. Consists of mature mangroves
3. Dense tree cover

Frog Pond

Lotus Pond

1. Open, more foot traffic
2. Consists of mature and young mangroves
3. Larger than Frog Pond

Project Considerations

Novel Project

Short timeframe
~ 1 year

Resources

DHI's role

Role of Mangroves in Carbon Sequestration

Mangroves

- Trees, ferns, shrubs, palms located in the intertidal zone
- Distinct morphology i.e., roots, viviparous plants
- Provide ecosystem services e.g., carbon sequestration, coastal protection, support biodiversity

Intertidal zones

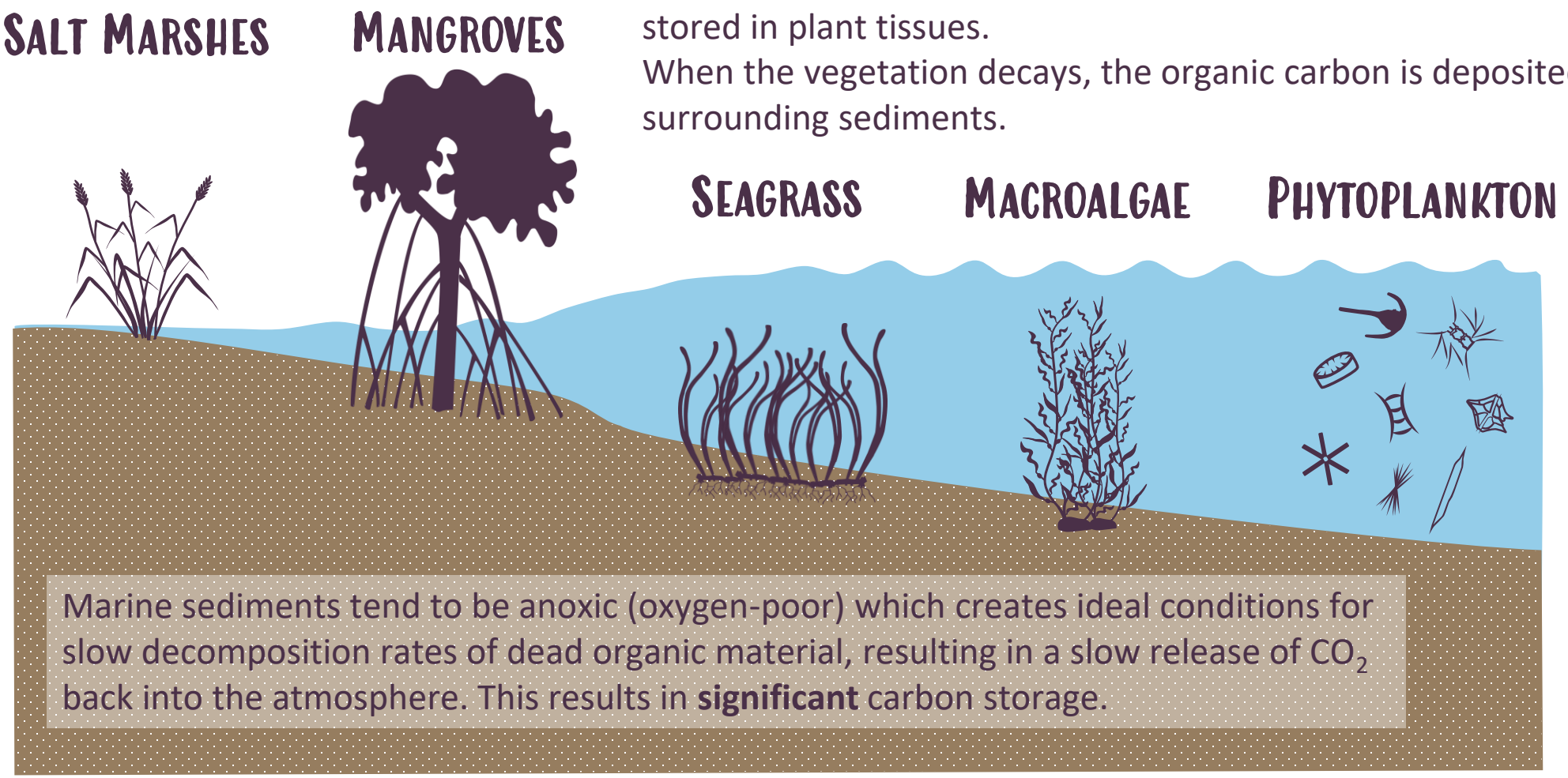
Mangrove Sapling

Rhizophora roots

Sonneratia roots

Blue Carbon Ecosystems

Blue carbon ecosystems comprise of vegetation which absorb carbon dioxide from the atmosphere via photosynthesis and convert it into organic carbon stored in plant tissues.
When the vegetation decays, the organic carbon is deposited into the surrounding sediments.



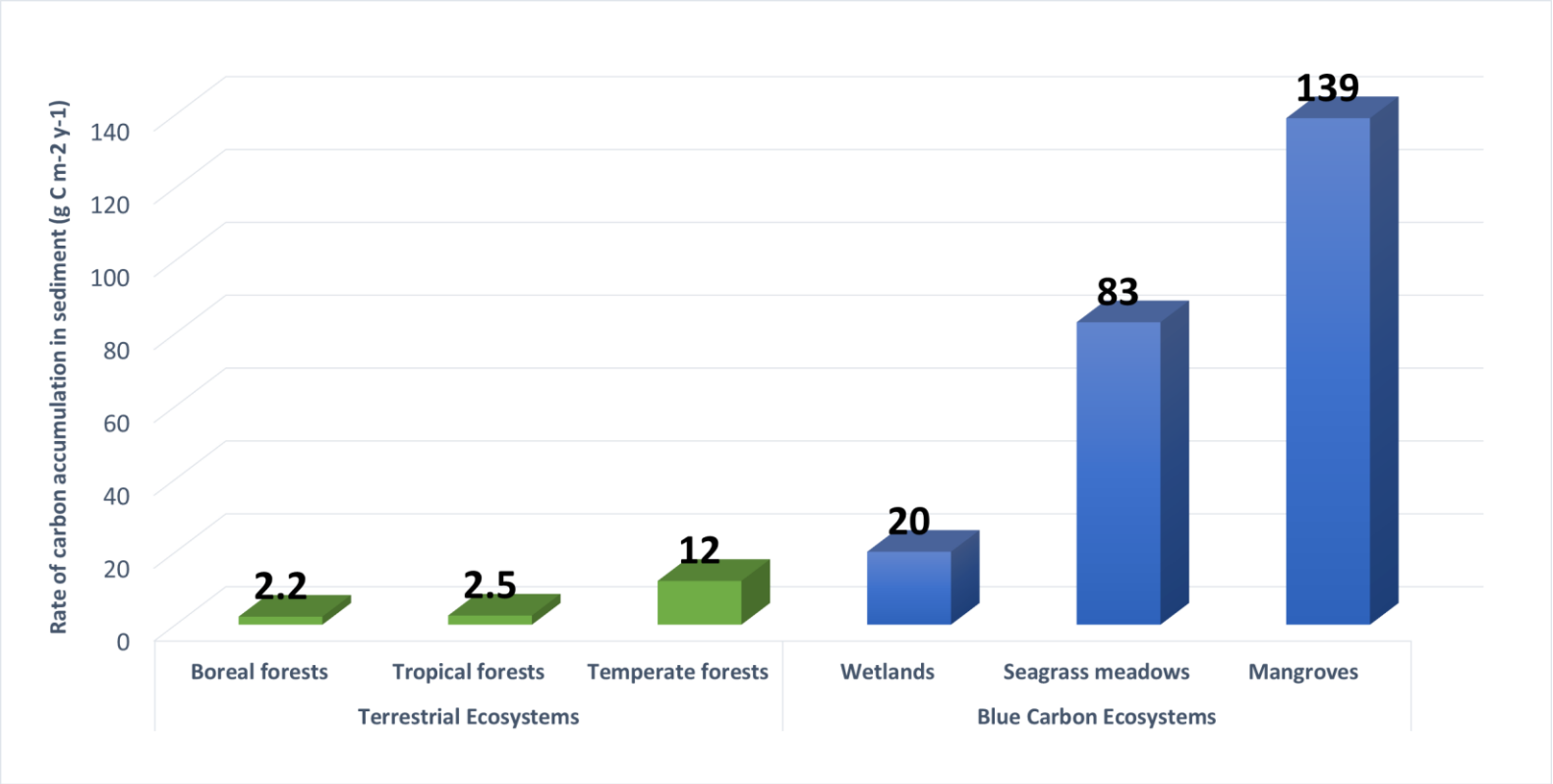
Marine sediments tend to be anoxic (oxygen-poor) which creates ideal conditions for slow decomposition rates of dead organic material, resulting in a slow release of CO_2 back into the atmosphere. This results in **significant** carbon storage.

In biotic elements…

… and in sediments

Comparison of carbon sequestration rates

Annual Sediment Carbon Sequestration Rate



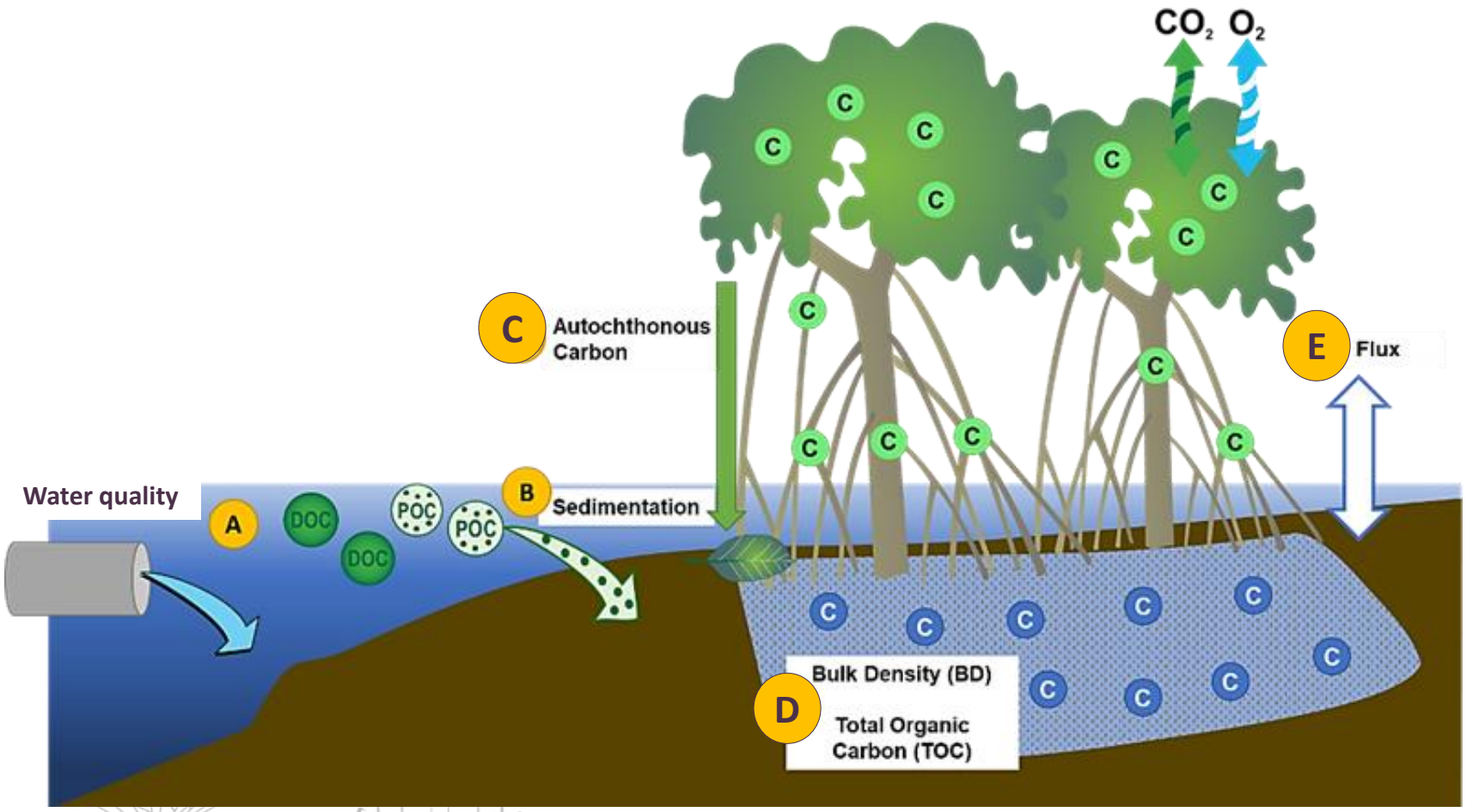
Adapted from Lafolley & Grimsditch (2009)

Marine habitats store more carbon annually compared to terrestrial ecosystems

Mangroves have one of the highest carbon sequestration rates relative to other blue carbon ecosystems

Blue Carbon Sources in Kingfisher Wetlands

Blue Carbon Cycle – Closing the Loop



Carbon Input

(A) Water quality (TOC, DOC, POC)

(B) Sedimentation Rate (Sediment carbon)

(C) Aquatic Flora and Aquatic Fauna

(C) Mangroves

- Survivability and health of transplants
- Carbon content from living biomass and leaf litter

Carbon Output

(D) Sediment Carbon Stock

Total organic carbon stock within the pond sediments

Carbon Pathways

(E) CO_2 gas flux

Measurement of CO_2 emitted from the sediments in the system

Input : Water quality

METHODS

- Three water quality samples collected in each pond
  - In-situ and ex-situ samples collected
  - Nine water quality parameters tested
    - Temperature
    - Dissolved Oxygen
    - pH
    - Turbidity
    - Salinity
    - Total Suspended Solids
    - Nutrients (NO_3, NO_2, TN, TP)
    - Organic Carbons (TOC, DOC, POC)
    - Chlorophyll-a

Input : Sedimentation Rate

METHODS

- Three sediment traps deployed in each pond for 7 days
  - Dry weight was analyzed and calculated for sedimentation rate

Input : Aquatic Flora

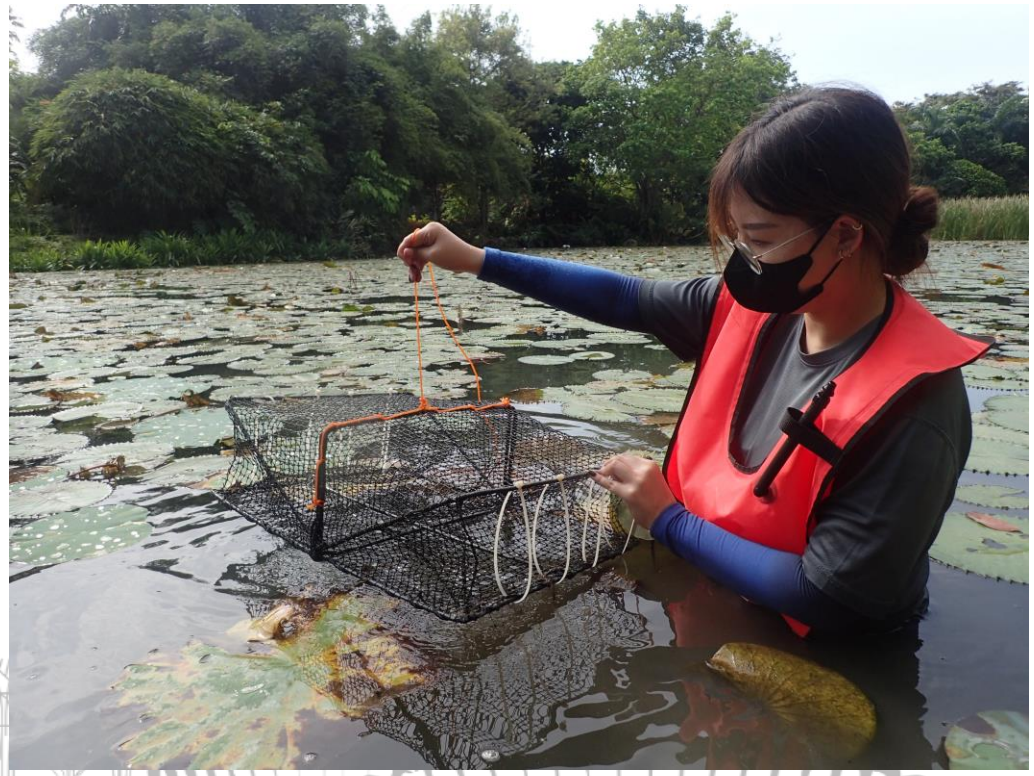
METHODS

- Visual estimate of flora cover using a 0.5m by 0.5m quadrat in each pond
- Samples were collected and analyzed for organic carbon content (%)

Input : Aquatic Fauna

METHODS

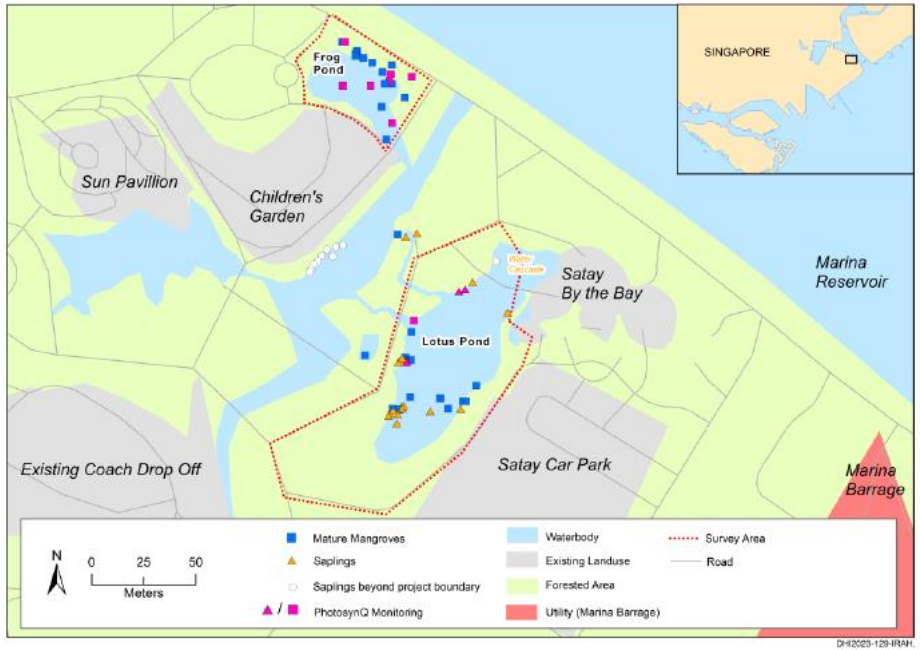
- Two fish traps and six minnow traps deployed in each pond for 24 hours
- Push and scoop netting conducted at 3 points in each pond

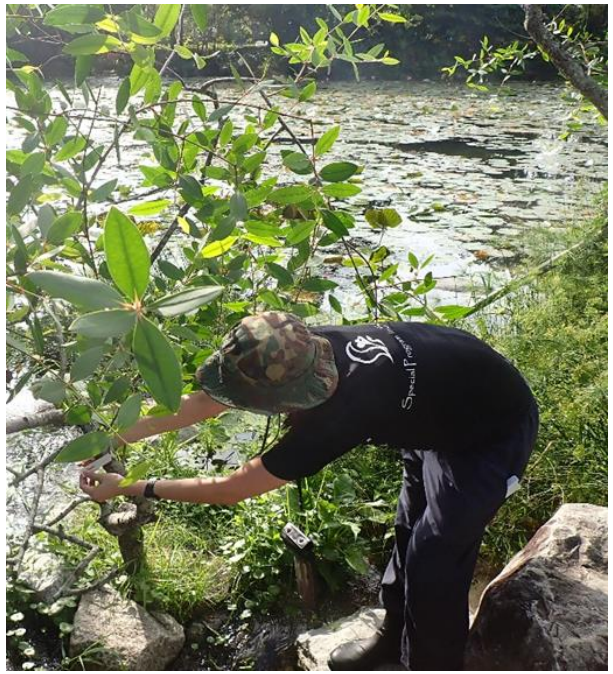


Input : Mangroves aboveground and belowground biomass

METHODS

- Mature and young mangroves monitored quarterly in Frog Pond and Lotus Pond
- Survival and health profiles were documented
- Total above-ground biomass and below-ground biomass estimated based on the diameter at breast height (DBH) of the trees and the species mean wood density





Input : Leaf Litter

METHODS

- Three leaf litter traps deployed for 72 hours close to the pond's edge
- Dry weight was analyzed and calculated for organic carbon content (%)

Output: Sediment Carbon Stock

METHODS

- Three sediment core samples collected in each pond
  - Cored to a depth of 15cm
  - Analyzed for particle size distribution, total organic carbon (TOC%), bulk density and sediment organic carbon

Carbon pathways

METHODS

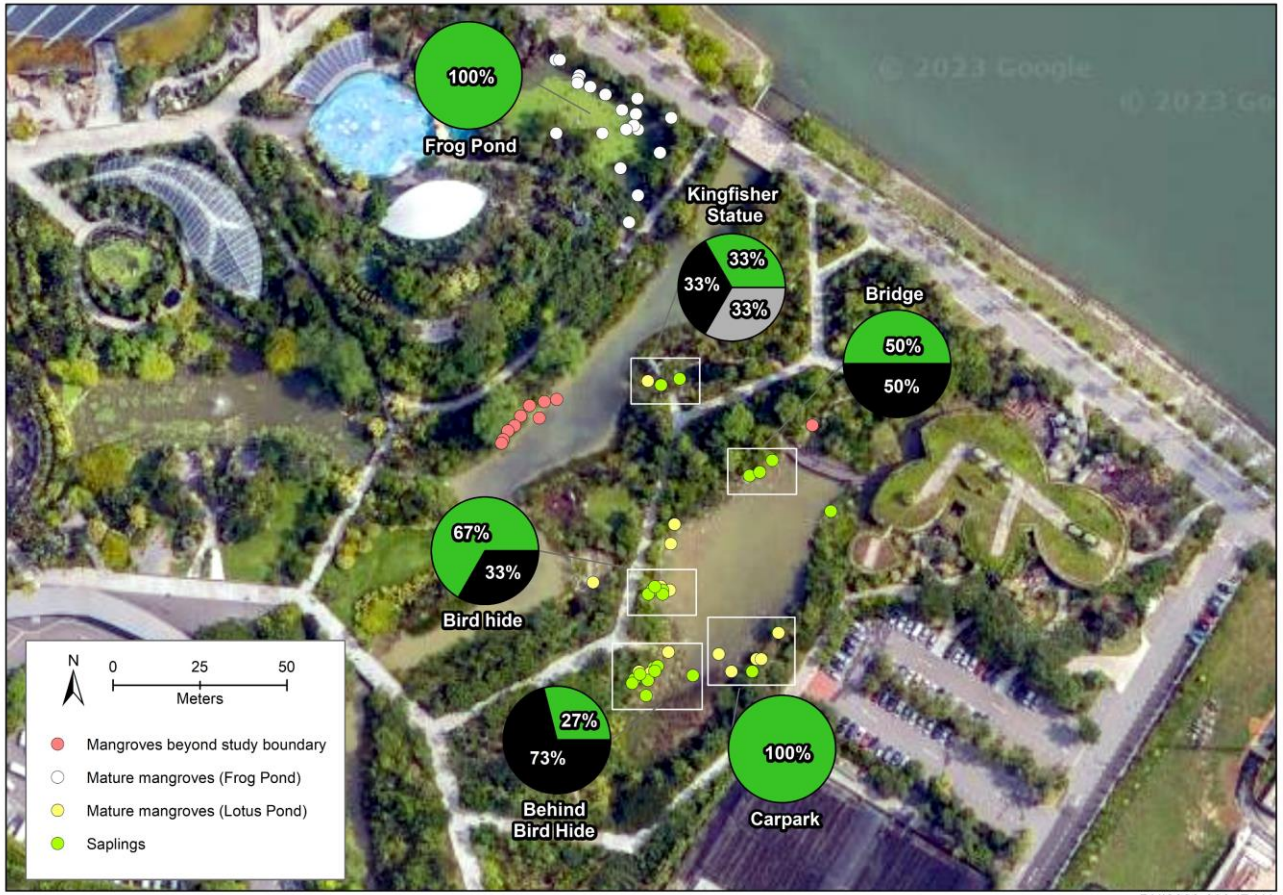
- CO_2 was measured close to the pond's edge
- The sampling interval was set to 10 min for a full 24-hour cycle to measure the CO2 efflux of the microbial layer in the topsoil

Key Takeaways

Health of the ecosystem

Mangrove survivorship

- In January 2023, 100% of mature transplants and 45% of saplings survived.
- Saplings with highest survivability was *Lumnitzera* sp., followed by *Bruguiera* sp.
- Areas with high sapling survivability: Carpark, Front of Bird Hide



Health of the ecosystem
Species Documentation

- 65 terrestrial species recorded
  - 9 species of reptiles
  - 2 mammals
  - > 30 species of birds, including migratory and C.S. species
- > 5 species of fish

Amphilophus citrinellus cf.
Midas cichlid

Ixobrychus sinensis
Yellow bittern

Chrysopelea paradisi
Paradise gliding snake

Carbon Stock

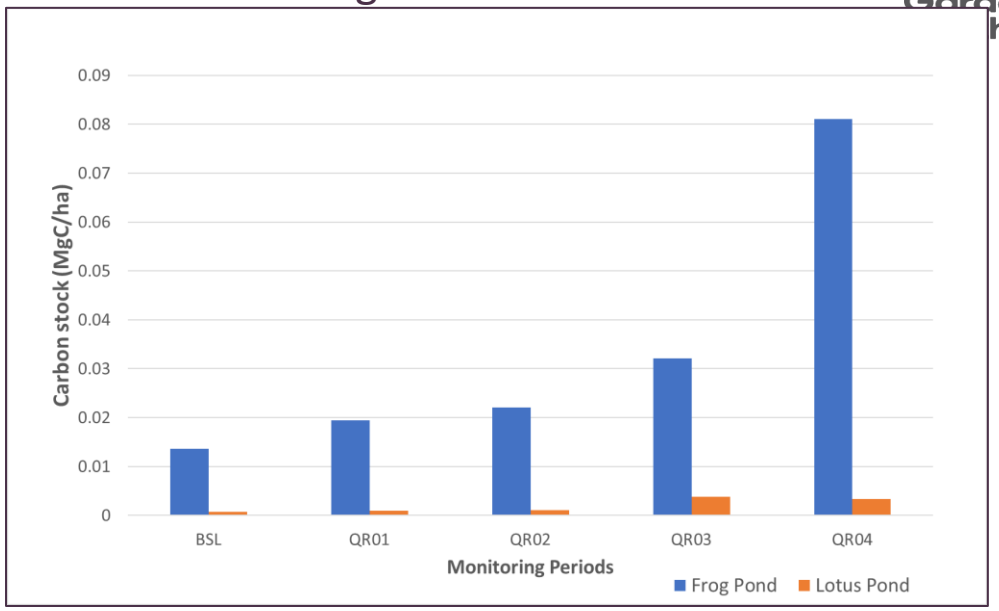
Mangrove and Sediment

Mangrove carbon stock increased from **Baseline** to **Last Monitoring Period.**

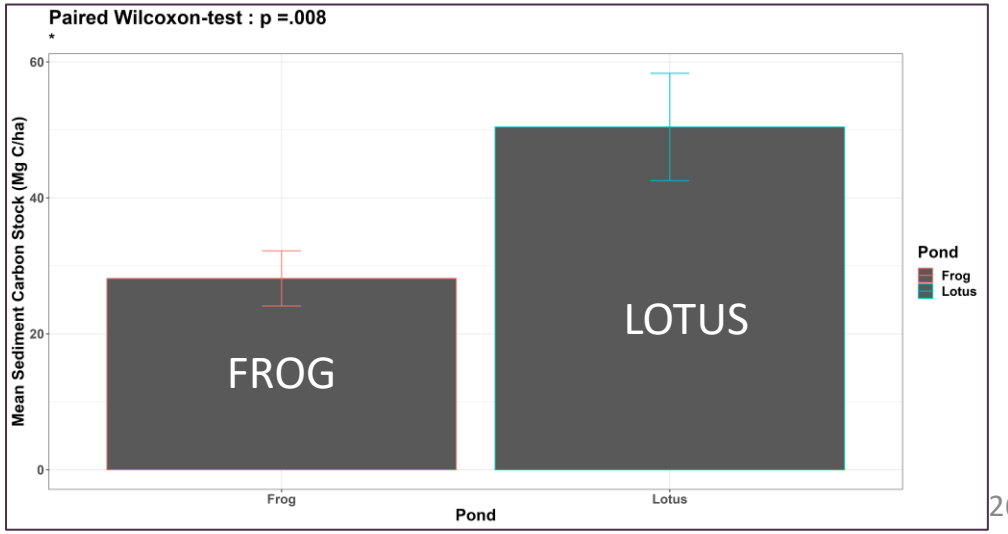
Mangrove carbon stock in Frog Pond : 0.0182 to 0.0810 MgC/ha is higher than in Lotus Pond: 0.000673 to 0.00338 MgC/ha

Mean sediment carbon stock in Lotus Pond (50.4±7.90 MgC/ha) is **significantly higher** than in Frog Pond (28.2±4.05 MgC/ha)

Mangrove carbon stock



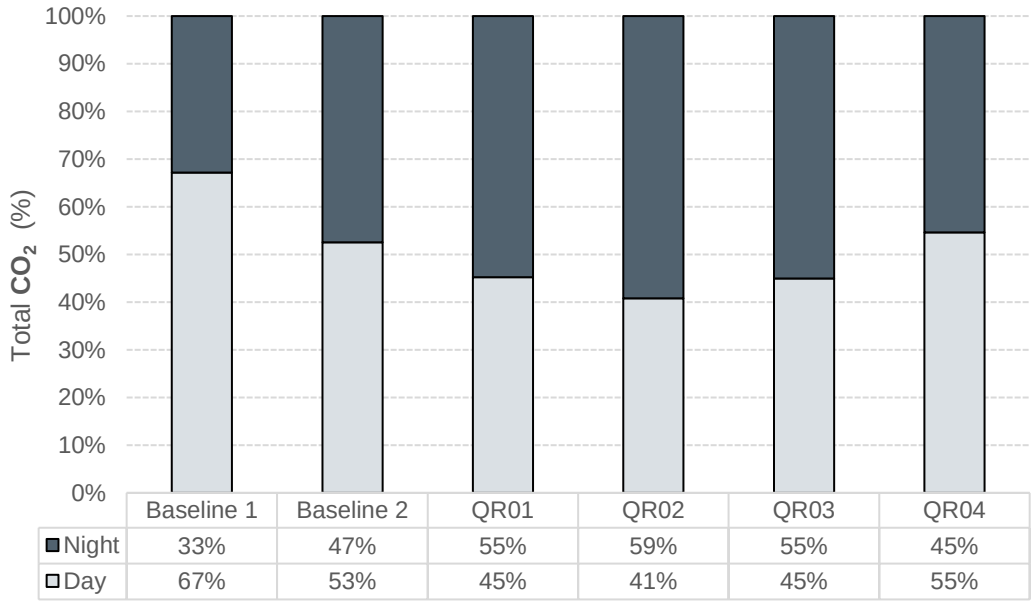
Sediment carbon stock



Carbon Flux

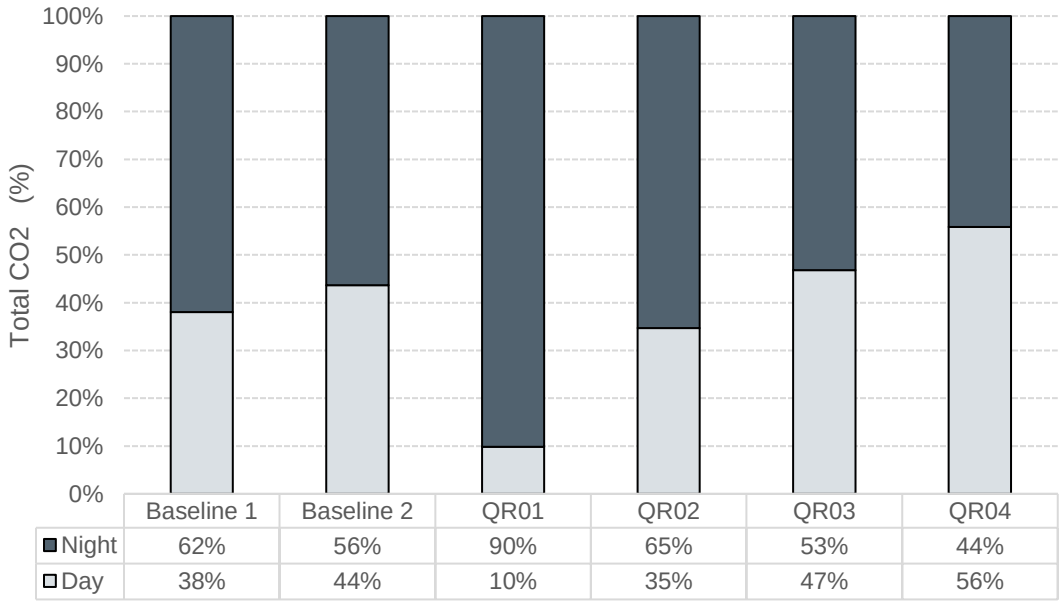
Overall, Night CO_2 (Respiration) > Day CO_2 (Photosynthesis)

Higher CO_2 variability in Lotus Pond as compared to Frog Pond



	Baseline 1	Baseline 2	QR01	QR02	QR03	QR04
Night	33%	47%	55%	59%	55%	45%
Day	67%	53%	45%	41%	45%	55%

Frog Pond



	Baseline 1	Baseline 2	QR01	QR02	QR03	QR04
Night	62%	56%	90%	65%	53%	44%
Day	38%	44%	10%	35%	47%	56%

Lotus Pond

Conclusions and Recommendations

Conclusions

- Some species of mangrove saplings (*Brugueira*, *Lumnitzera*) had higher survivability in these freshwater environments

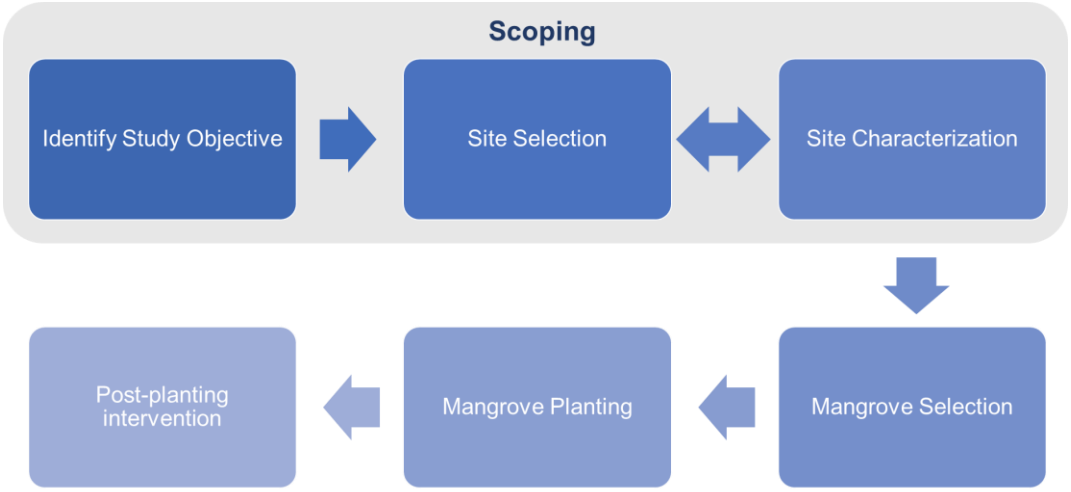
- Urban wetlands, such as Kingfisher Wetlands, were found to have higher sediment carbon stock as compared to local natural blue carbon ecosystems which make them feasible sites for urban carbon capture

- Urban wetlands play a role in climate change solutions by sequestering carbon, supporting biodiversity and providing recreational value

Recommendations

Conduct Scoping Assessment

- Numerical model can identify potential planting areas by simulating biogeochemical conditions of pond



Appropriate selection of mangroves (species, age) and post-planting care

Longer study period for comparable long-term results with natural blue carbon systems

Scaling efforts required to remove one metric tonne of CO_2 in order to be eligible for carbon crediting

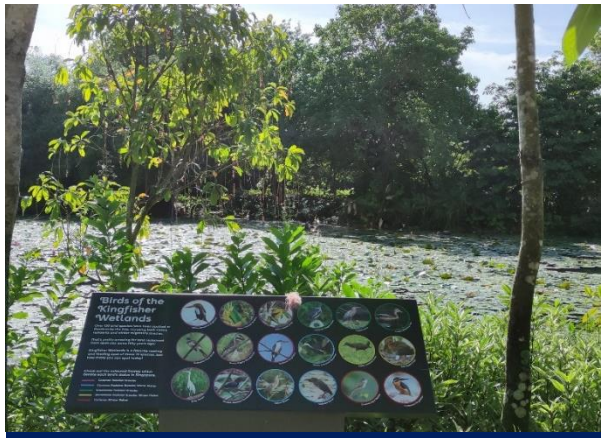
Bruguiera sp.

Lumnitzera sp.

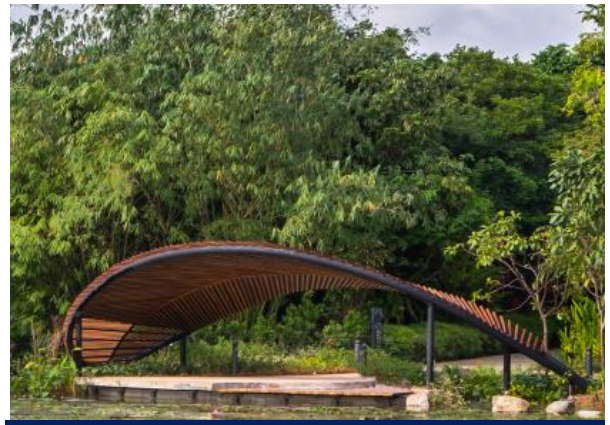
Beyond Carbon Sequestration

Community Engagement

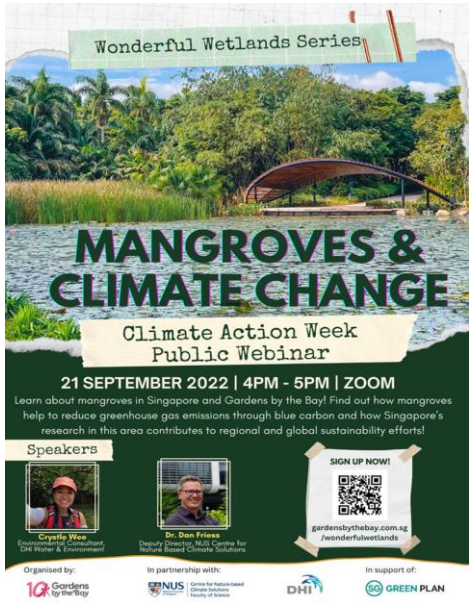
Since its launch in Nov 2021, Kingfisher Wetlands has attracted more than 510,000 visitors



Educational signboards



Bird hide



Public lectures

Community mangrove planting

Citizen science mangrove monitoring x 12

NUS National University of Singapore | Centre for Nature-based Climate Solutions | Faculty of Science

REPUBLIC POLYTECHNIC

GenZero

ITE Institute of Technical Education

SMU Singapore Management University

NIE National Institute of Education Singapore | An Institute of Nanyang Technological University Singapore

6 partners
17 activities

New

Gardens has also rolled out Urban Wetlands tour every Sat and Sun.
Over 630 participants have attended this tour since Dec 2022


Q&A