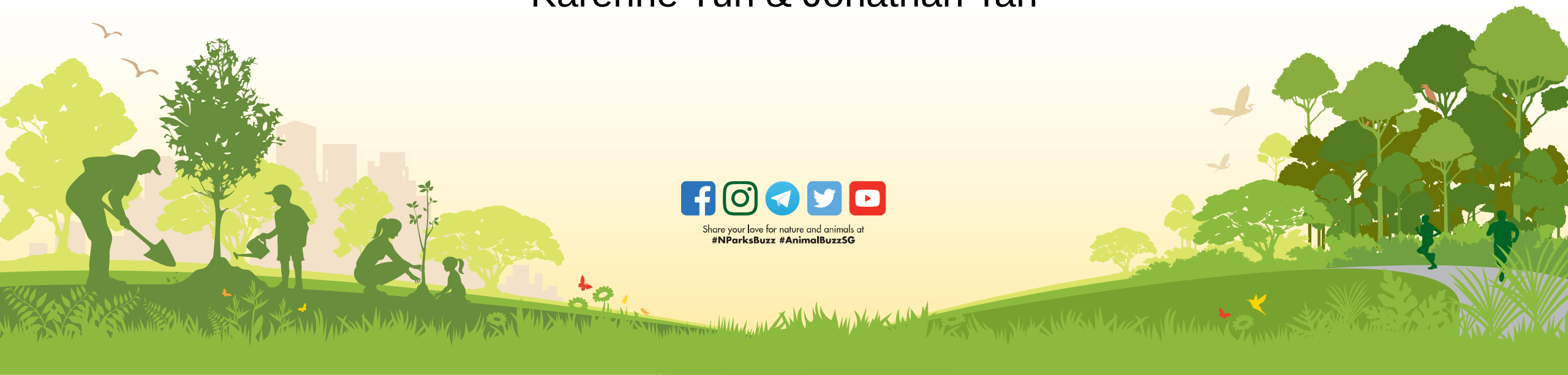
NATIONAL PARKS
LET'S MAKE SINGAPORE OUR CITY IN NATURE

Coastal Protection: Harnessing Nature's Typologies in Singapore

Karenne Tun & Jonathan Tan



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Outline

- What do we need to protect?
- What are Nature-based Solutions?
- Coastal Nature-based Solutions in Singapore
- Future Research
  - Knowledge Gaps
  - MCCS

Impacts of climate change on Singapore

Photo Credit: AsiaOne

Photo Credit: AsiaOne

Photo Credit: The Straits Times

Rising temperatures
Urban Heat Island effect

- Max daily temp could reach 35 – 37^{o}C by 2100

Extreme weather

- Increased intensity and frequency of heavy rainfall events

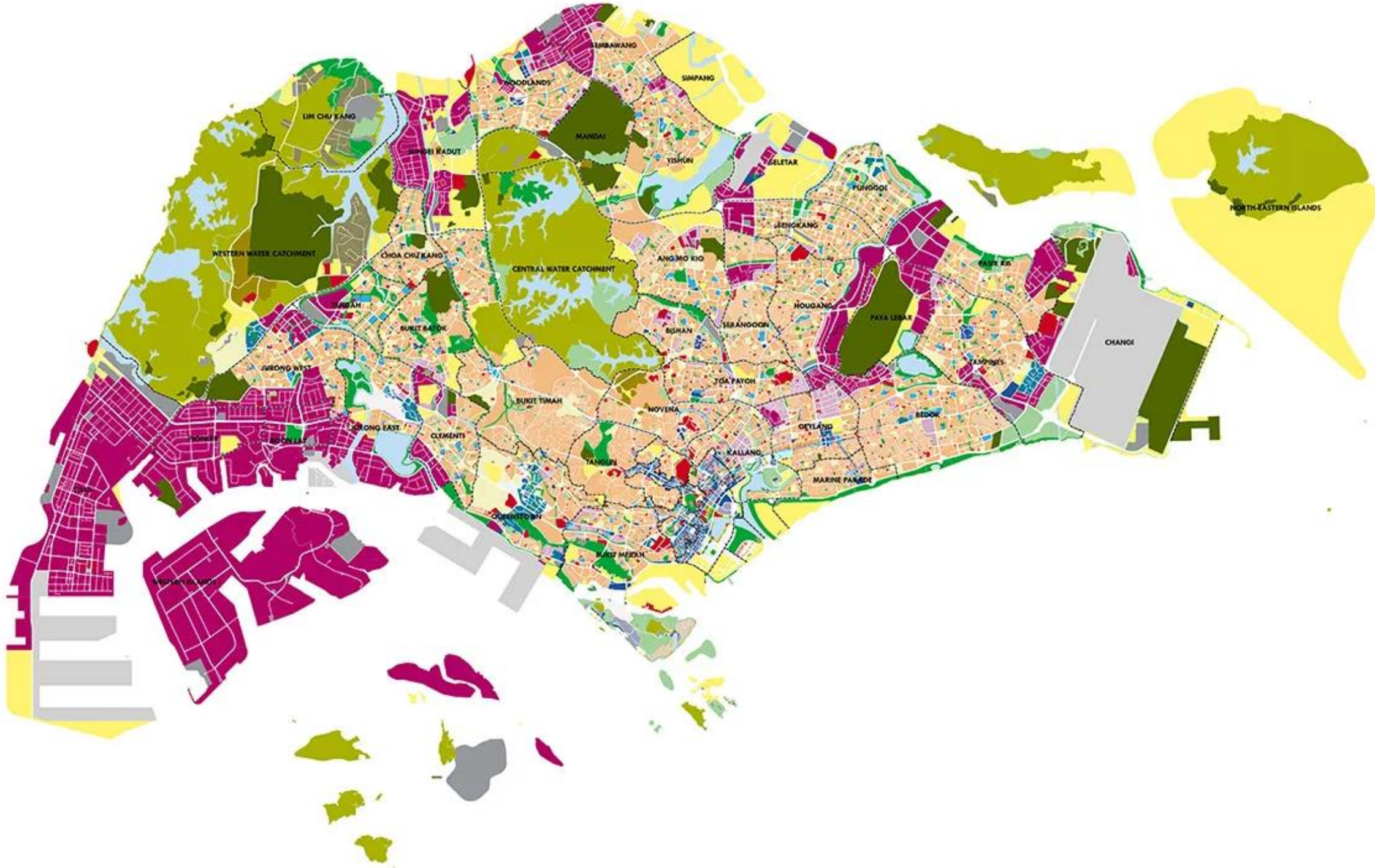
Rising sea levels

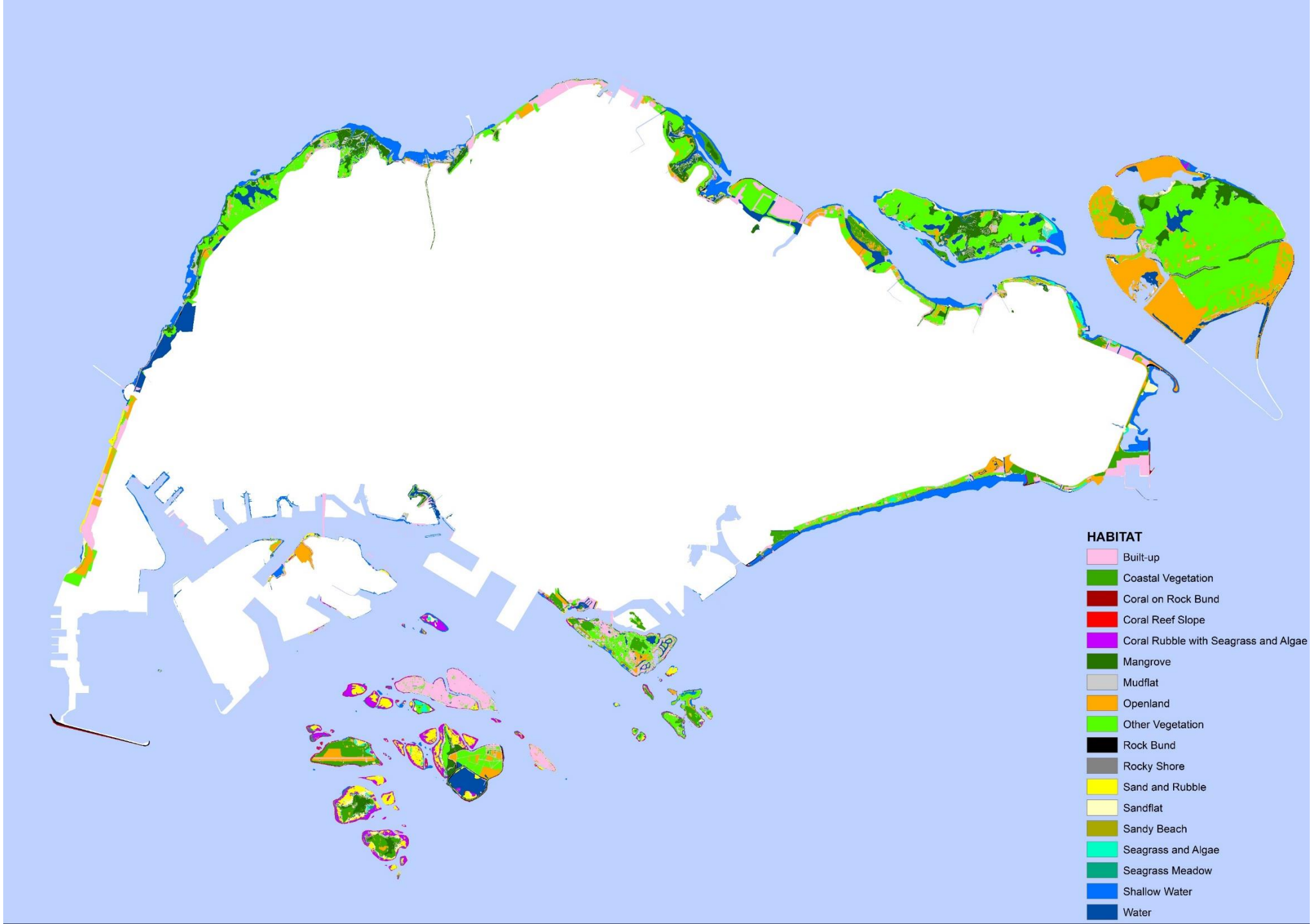
- Average sea level around Singapore 14 cm above pre-1970s levels
- 1 m rise by 2100

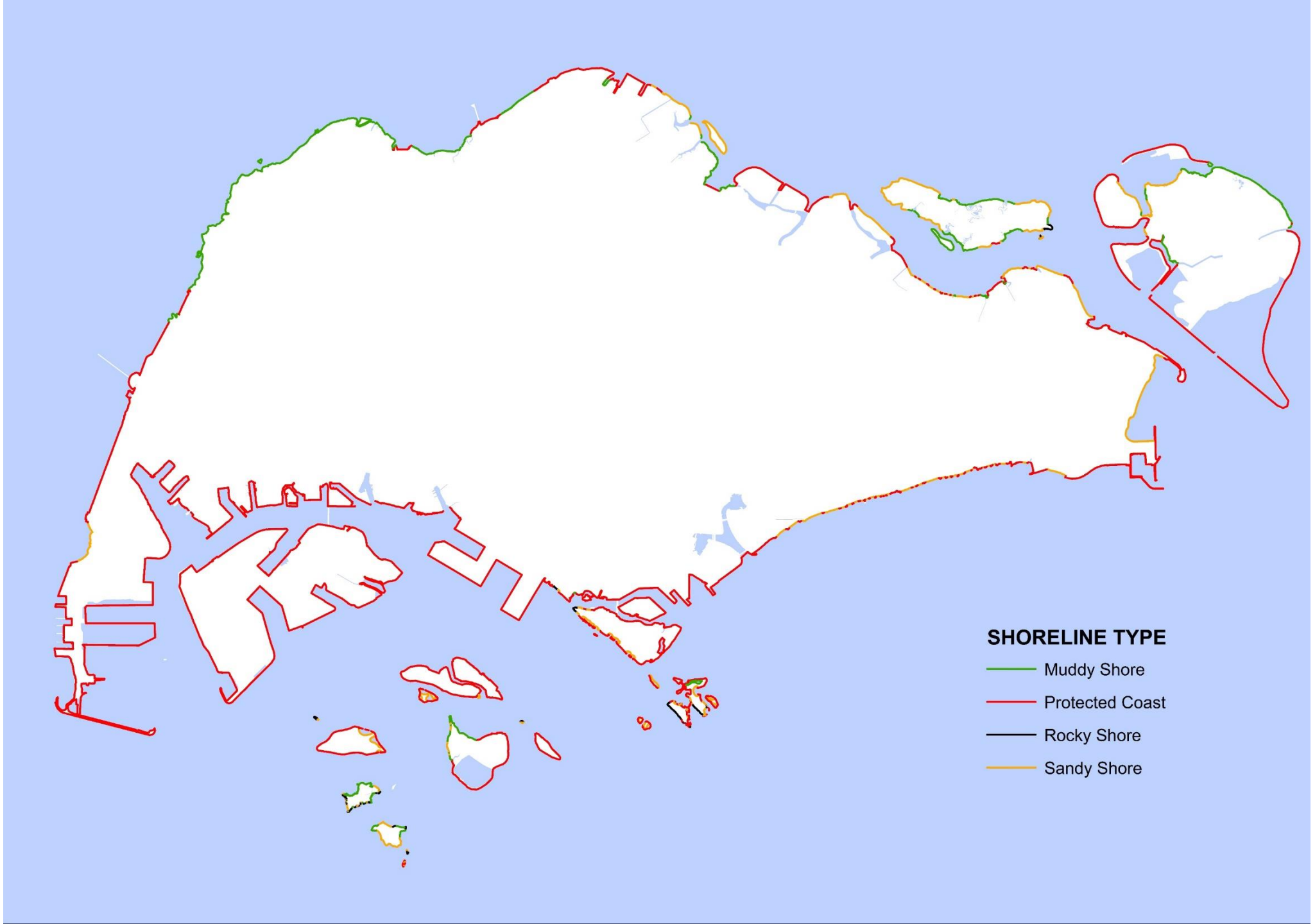
East Coast; (Chensiyuan, Creative Commons)

What do we need to protect?

Mandai Mangrove and Mudflat (Gov.sg)

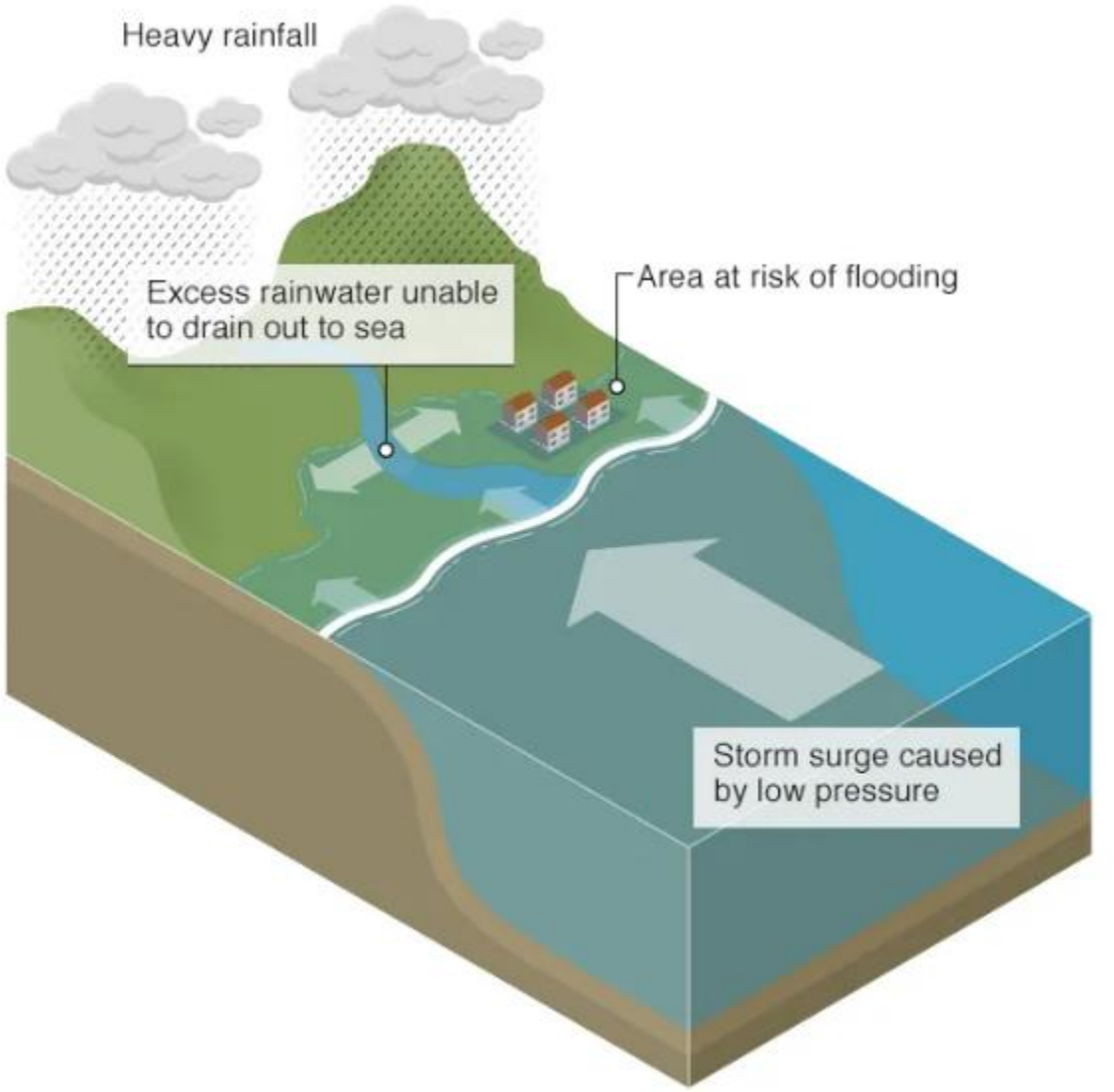

SEMBAWANG
WOODLANDS
SIMPANG
LIM CHU KANG
MANDAI
SEMBAWANG
YISHUN
SELETAR
PUNGGOL
NORTH-EASTERN ISLANDS
SENGKANG
WESTERN WATER CATCHMENT
CHOA CHU KANG
ANG MO KIO
CENTRAL WATER CATCHMENT
PASIR RIS
HOUGANG
PAYA LEBAR
BISHAN
SERANGOON
CHANGI
BUKIT BATOK
JURONG WEST
TOA PAYOH
BUKIT TIMAH
NOVENA
BEDOK
JURONG EAST
CLEMENTI
GEYLANG
KALLANG
TANGLIN
MARINE PARADE
QUEENSTOWN
BUKIT MERAH
WESTERN ISLANDS

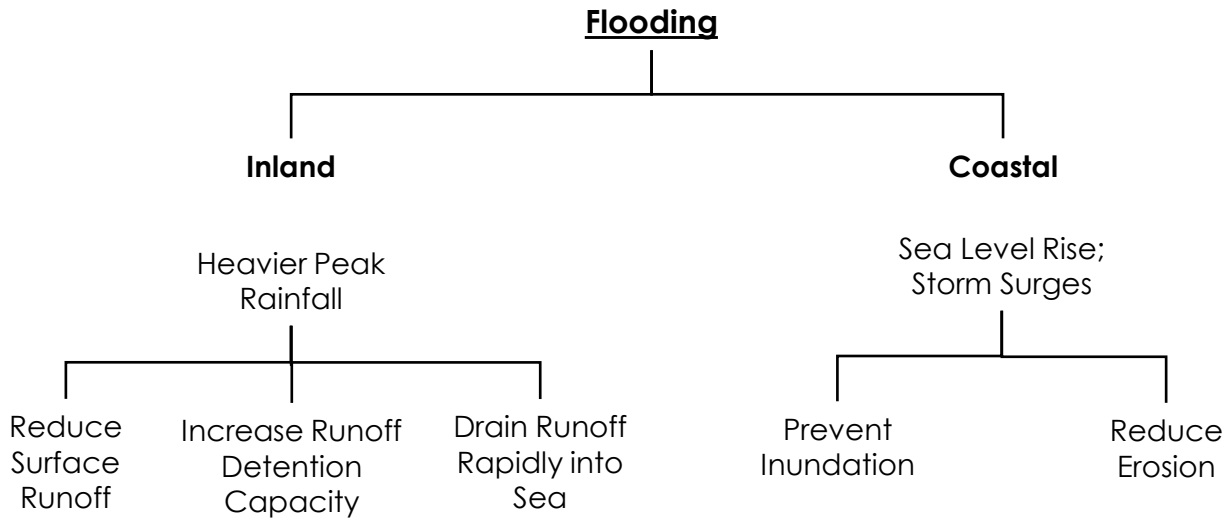

HABITAT
Built-up
Coastal Vegetation
Coral on Rock Bund
Coral Reef Slope
Coral Rubble with Seagrass and Algae
Mangrove
Mudflat
Openland
Other Vegetation
Rock Bund
Rocky Shore
Sand and Rubble
Sandflat
Sandy Beach
Seagrass and Algae
Seagrass Meadow
Shallow Water
Water


SHORELINE TYPE
Muddy Shore
Protected Coast
Rocky Shore
Sandy Shore

National Day Rally 2019 (for illustrative purposes only)

Flooding and Climate Change



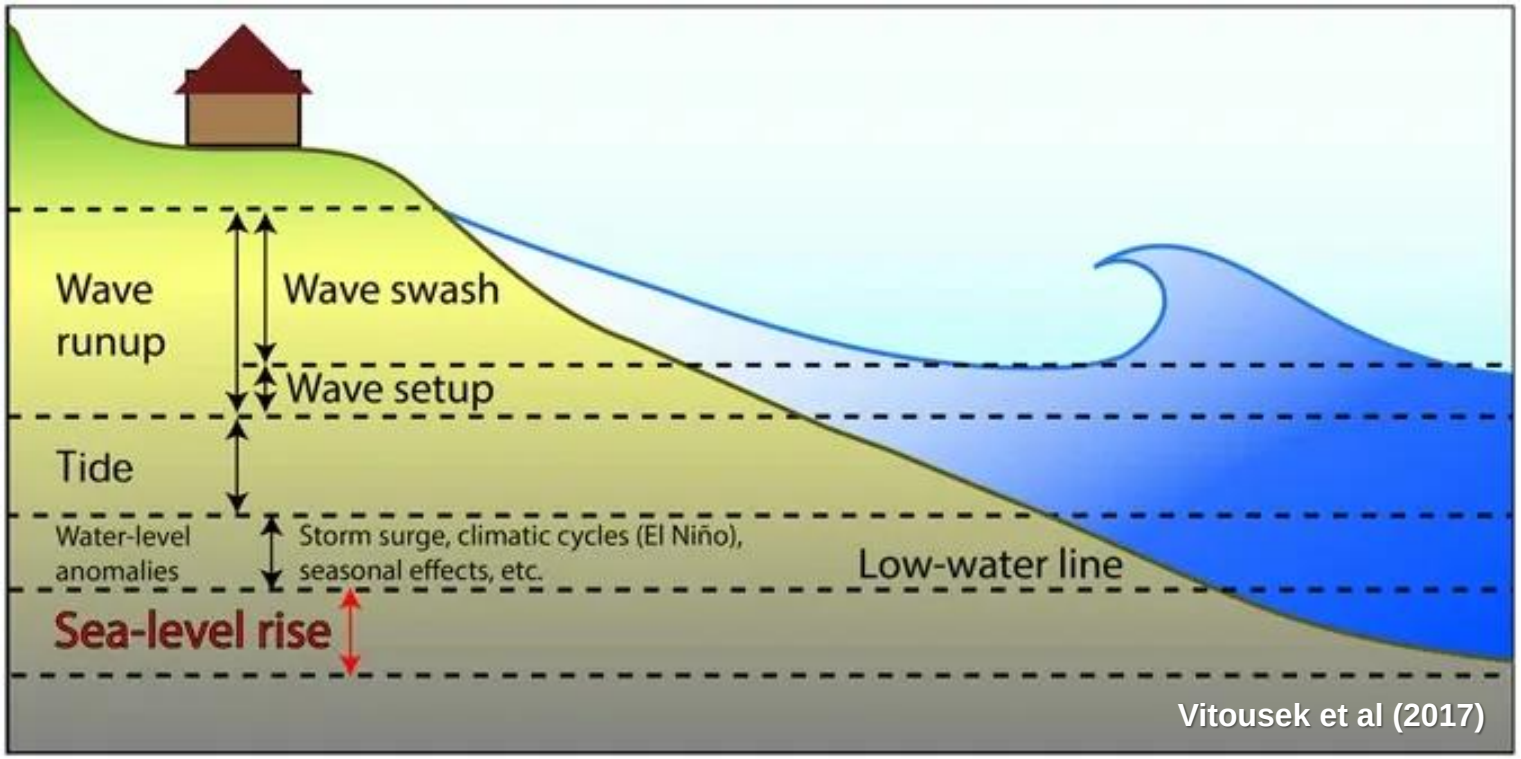


Flooding has both Inland and Coastal components

-> Need to deal with this as an integrated system

Coastal Protection deals with **Inundation** and **Erosion**

Inundation and Erosion



Inundation is driven by

- Sea levels (rising)
- Storm surges (stronger/more frequent)
- High spring tides (monthly, annual, and 18.6 yr lunar nodal cycles)

Erosion is driven by

- Wave action (exacerbated by sea-level rise)
- Storms (stronger/more frequent)
- Ship wakes (shipping lanes)

Nature-based Solutions

Mangrove revetment @ Pulau Tekong

Launched in Feb 2021

City in Nature as one of the 5 pillars of SGP 2030:
Green, Liveable and Sustainable Home for Singaporeans

SG GREEN PLAN

City in Nature

Enhancing and extending our natural capital across our island

- Plant 1 million more trees, and have every household within a 10-min walk from a park by 2030
- Add over 130 ha of new parks, and enhance around 200 ha of existing parks with more lush vegetation and natural landscapes by end-2026
- Add 1,000 ha of green spaces by 2035
- **City in Nature for Climate Resilience:** Addressing climate change impacts using **nature-based solutions**


Marina Barrage (PUB)


Jurong Island (JTC)

Traditional Coastal Protection

- Relies exclusively on hard infrastructure
- Effective in coastal protection
- Limited or no biodiversity value
  - Can have some recreational value e.g. Marina Barrage
- Not able to self-repair or grow with sea level rise

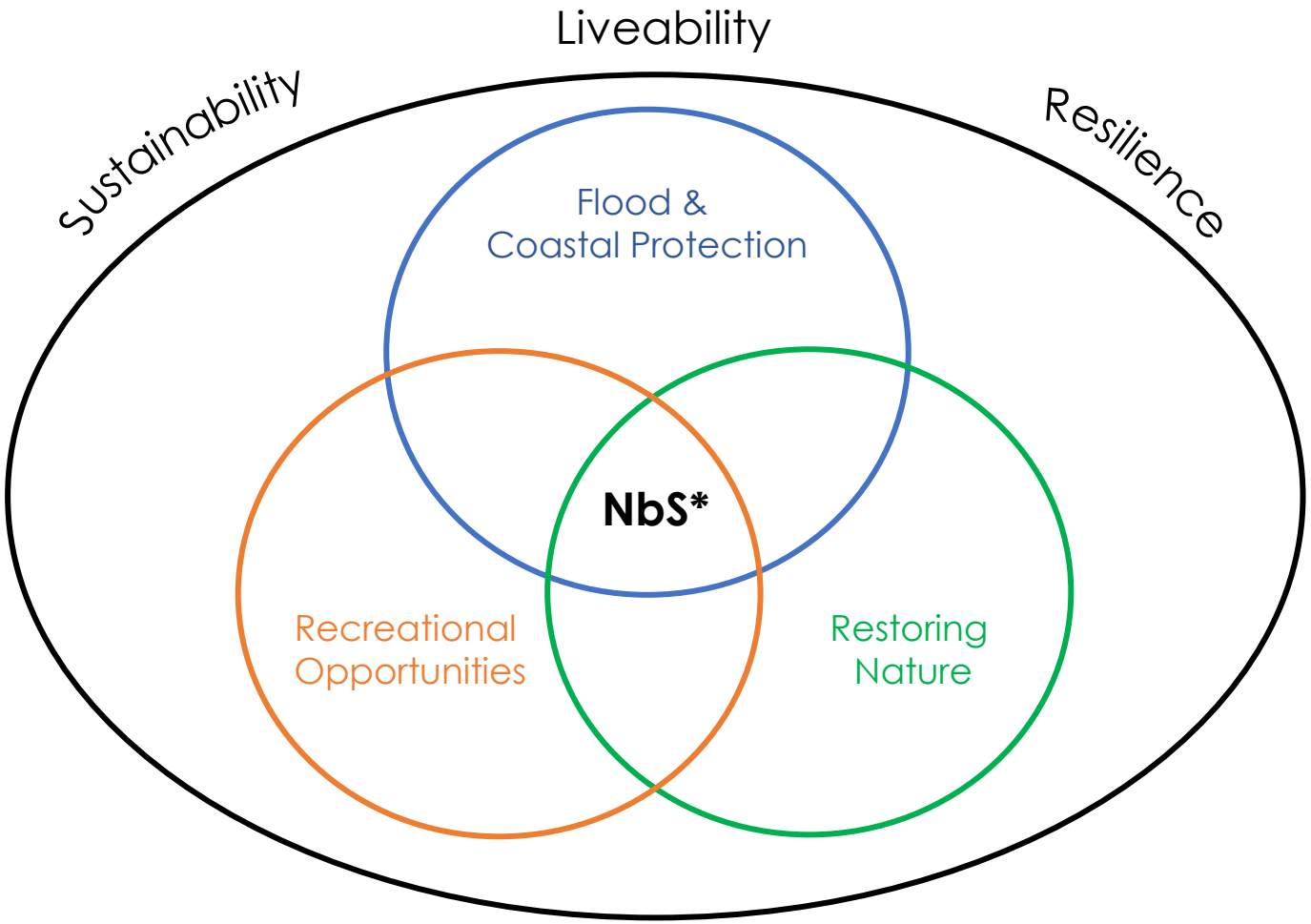
Nature-based Solutions (NbS)

What are NbS?

- Solutions that tap on natural systems to address societal challenges effectively and adaptively
- These solutions should also provide human well-being and biodiversity co-benefits
- Where possible, protect, sustainably manage, and restore natural or modified ecosystems
- Where hard engineering solutions are needed, soften up for recreation and biodiversity

IUCN

Nature-based Solutions (NbS)



Why NbS?

Solve multiple problems:

- Coastal Protection
- Social/Recreational Spaces
- Ecological Resilience

Economic Case:

- Potentially cheaper to build/maintain
- Can have better cost-benefit returns due to multiple uses
- Bishan-AMK Park: cost less, and higher returns

Potential to grow with/adapt to sea-level rise

- Mangroves
- Coral Reefs
- Seagrass Meadows

What kind of NbS for Singapore?


Sungei Api-Api (Nathaniel Soon)

- Singapore has limited land and sea space; little room to advance or retreat
- Soft NbS to prevent coastal inundation (e.g. sand dunes) not feasible due to high land-take required
- Most NbS for protection against inundation will be **hard or hybrid eco-engineering**
  - Seawalls where there are critical assets or minimal land availability, and softening to add recreational and ecological value
  - Hybrid systems for recreational areas e.g. beach berms with seagrass lagoons and offshore artificial reefs
- Soft NbS (e.g. mangroves) can still mitigate erosion, with hard edge inland to prevent inundation

Possible Coastal NbS for Singapore

Intertidal Terrace and Pools

Changi Beach Park

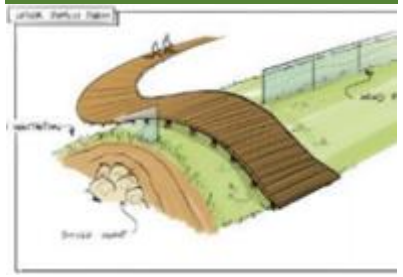
Biodiversity Tiles

Changi Bay

Floating Reefs

Keppel Marina

Upper Beach Berm



(Not trialled in SG)

Artificial Reefs

Sisters' Islands

Intertidal Seawall Reefs

Tanah Merah

Subtidal Seawall Reefs

Southern Islands

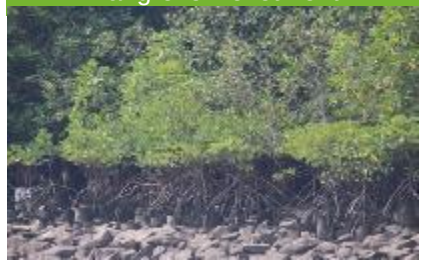
Reclaimed Lagoons

Sisters' Islands

Perched Beach

Marina East

Mangrove Revetment



Pulau Tekong

Mangrove Restoration

Pulau Semakau

Intertidal Bays

East Coast Park

Outlet Drain Intertidal Flats

Tanah Merah

Hard (Artificial) — **Hybrid** — **Soft (Natural)**

Image credits: MSE, NUS-Deltares, The Straits Times, Loh Kok Sheng, Lynette Loke, Jonathan Tan, Kikuzawa Yuichi, Nathaniel Soon, Ria Tan

Existing Coastal NbS in Singapore

Mangrove revetment @ Pulau Tekong

Seawall Enhancement (Hard eco-engineering)

- Artificial tidal pools or biodiversity enhancement tiles can be added onto seawalls
- Create microhabitats for marine life e.g. algae, molluscs, crabs
- Placed at higher shore, more accessible/visible to people
- Largely experimental or pilot projects

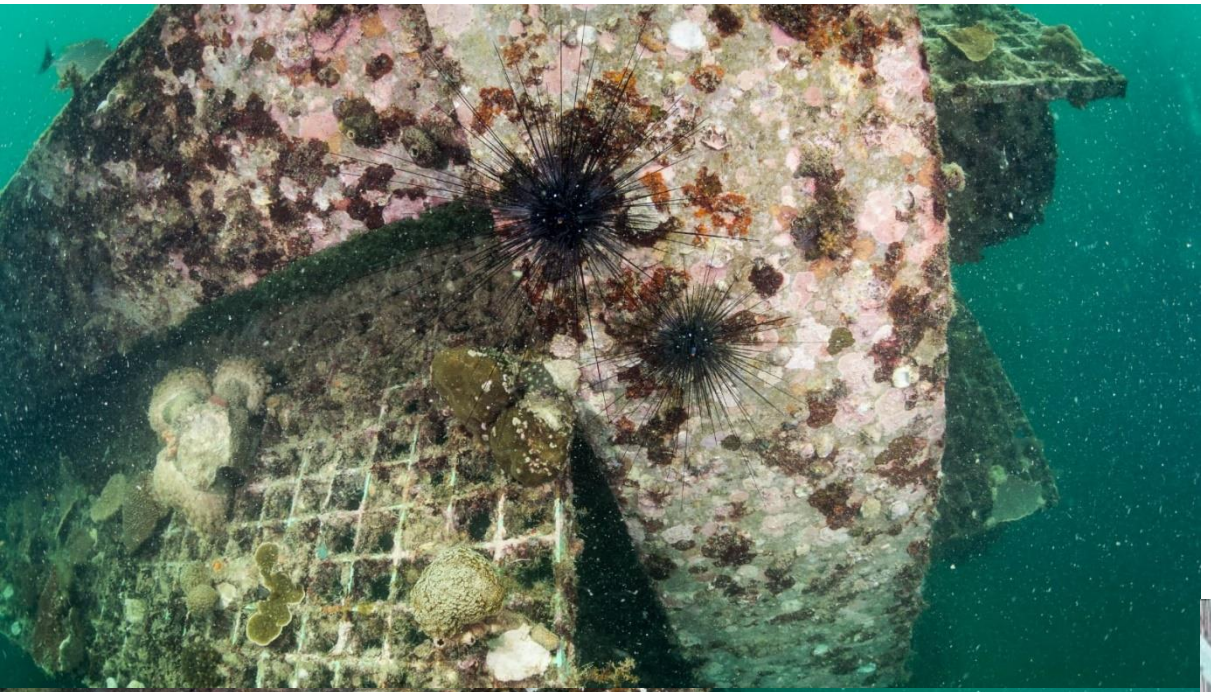
Tidal Pool units at Changi Beach Park

BioBOSS tiles (Lynette Loke)

Floating Reefs: Marina at Keppel Bay

- Built to allow currents to freely flow through, bring nutrients and larvae
- Strict controls on boat wakes, use of biodegradable detergents
- Rich variety of corals grow on the floating pontoons
- Marine life includes seahorses, sea turtles, clownfish etc.
- Increases biodiversity and recreation value of adjacent vertical seawalls

Artificial Reefs: Sisters' Islands

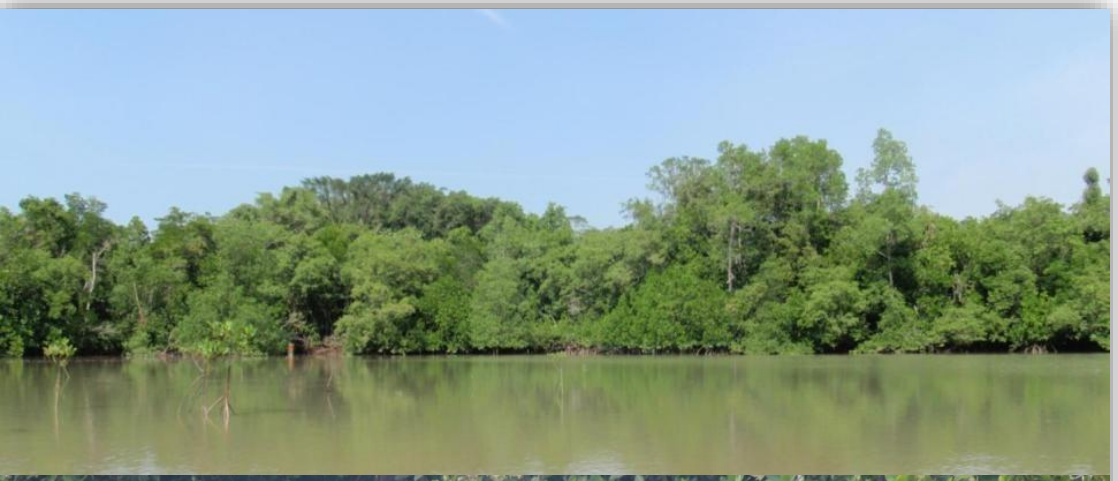


Photos by DHI

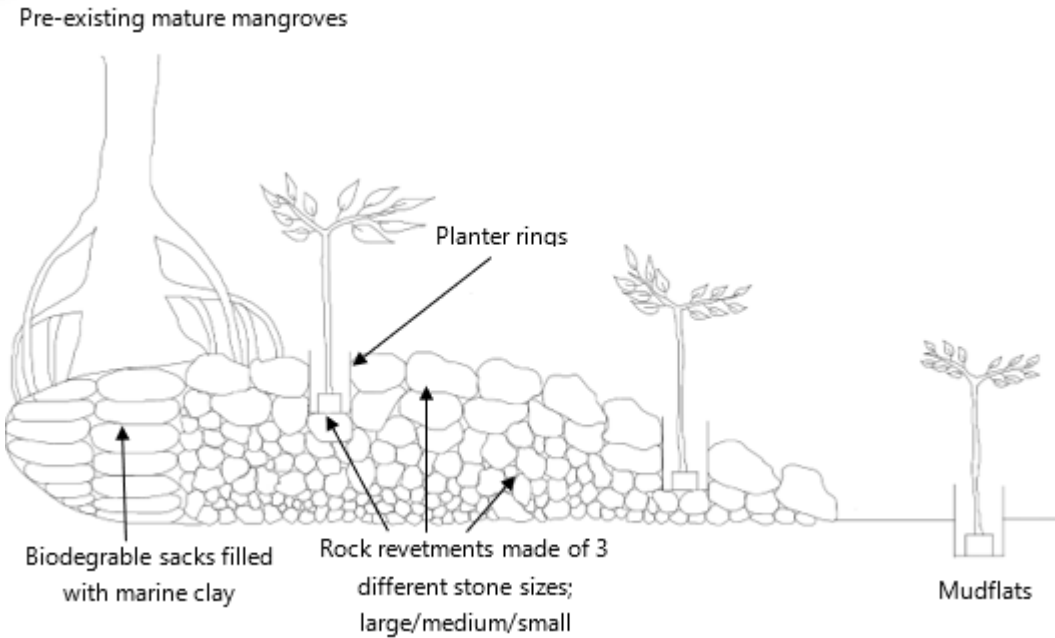
- In 2018, JTC installed 8 multi-storey artificial reefs at Sisters' Islands Marine Park
- Quickly overgrown with algae, sponges, shellfish etc.
- Within a few months, large numbers of fish appeared
- Within a year, new corals recruited onto the reef
- Mature corals have also been transplanted there
- Deliberately minimised hydrodynamic impact; future units could be modified to break waves instead

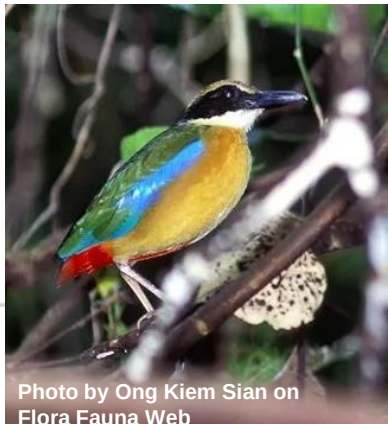
Photo by The Straits Times

Mangrove Revetment: Pulau Tekong



- Northeast Pulau Tekong (92 ha) – largest pristine mangrove in Singapore
- Suffering from severe erosion
- Hybrid rock-mangrove revetment built 2011
- Erosion successfully arrested. Mix of planted saplings and naturally recruited saplings now grow amongst the rocks

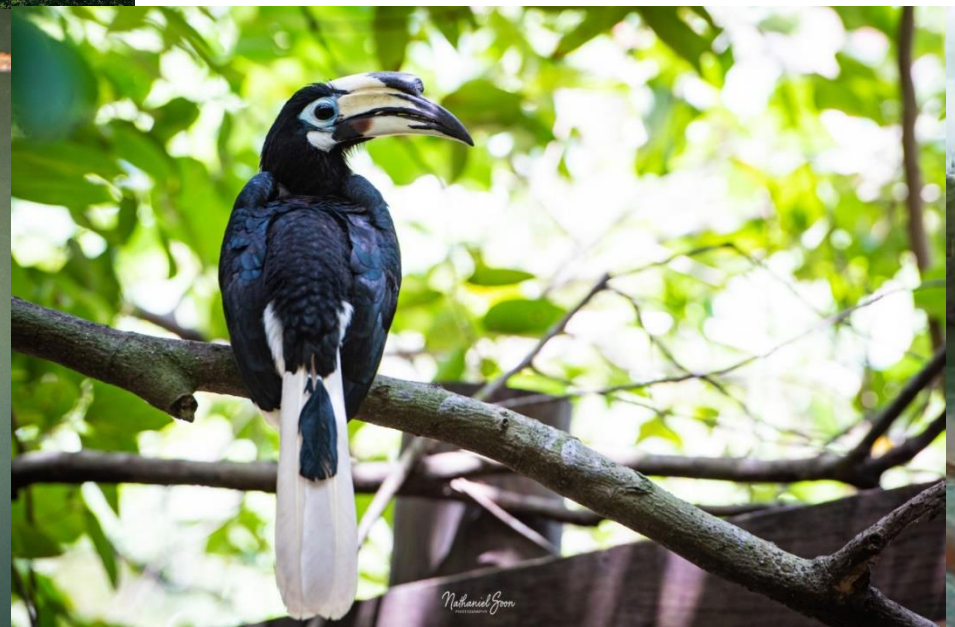




Mangrove River Naturalisation

- Many mangrove rivers have been linearised and cleared
- Some of these have regenerated on their own: Berlayer Creek, Sg Pang Sua
- Sungei Api-Api: joint project between HDB and PUB 1980s
  - Banks high enough to avoid flooding
  - Channel wide enough to allow stormwater to drain quickly

Sg Api-Api; Nathaniel Soon



Berlayer Creek

Mangrove Planting


Pulau Semakau; NEA

- Construction of Semakau Landfill (1999) caused mangrove loss
- As compensation, the seabed was raised to create two new mudflat plots bounded by a rock bund
- 400,000 mangrove saplings (mostly Bakau i.e. *Rhizophora* spp.) were planted by NEA
- Wall of Bakau roots likely an effective erosion barrier; more study needed
- Mangrove planting also ongoing in Sungei Buloh


Sungei Buloh; Mendis Tan


Sungei Buloh; The Straits Times


Pulau Semakau; Ria Tan


Pulau Semakau

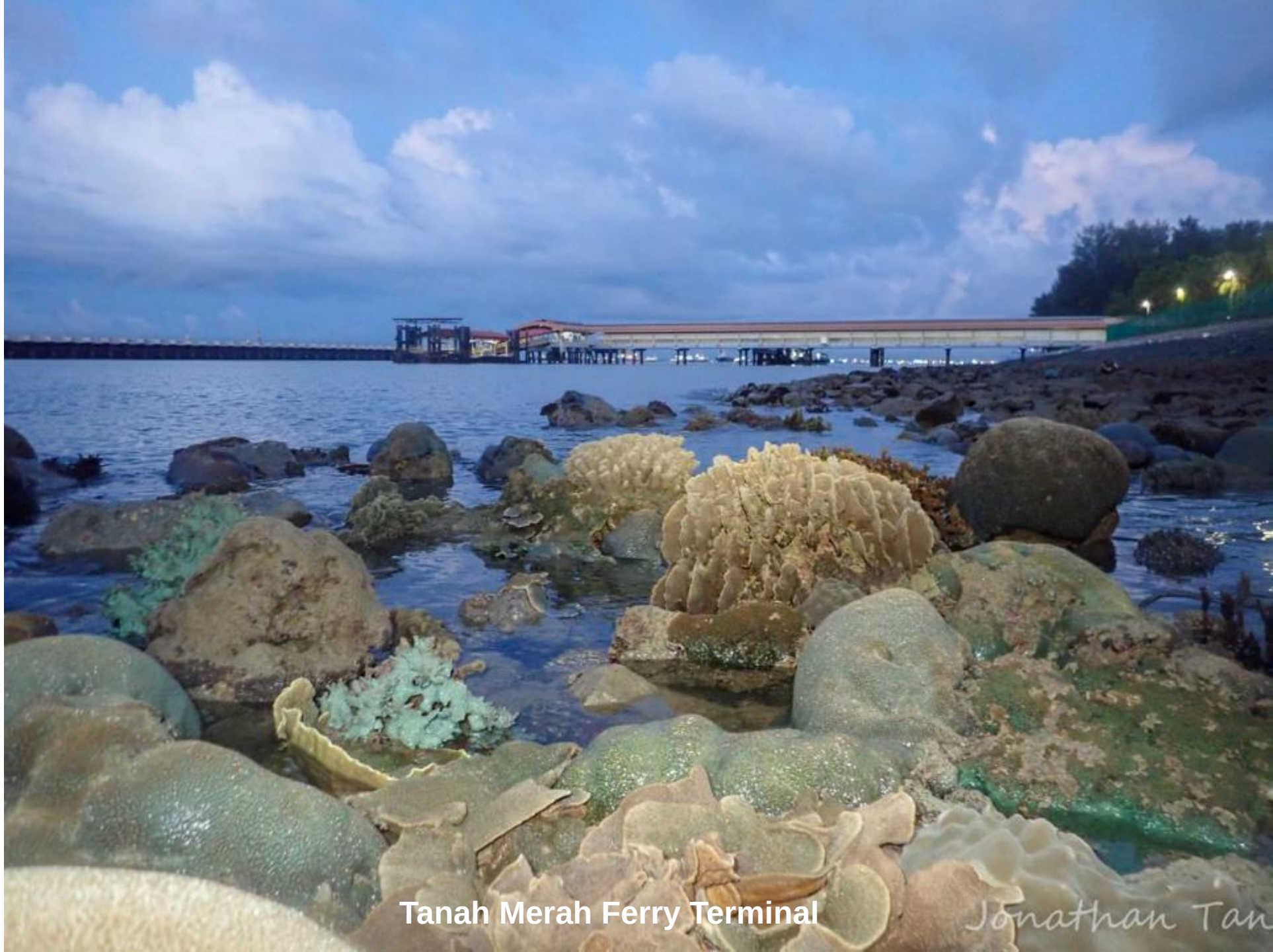
Ecological Mangrove Restoration

Mangrove restoration at Pasir Ris Park

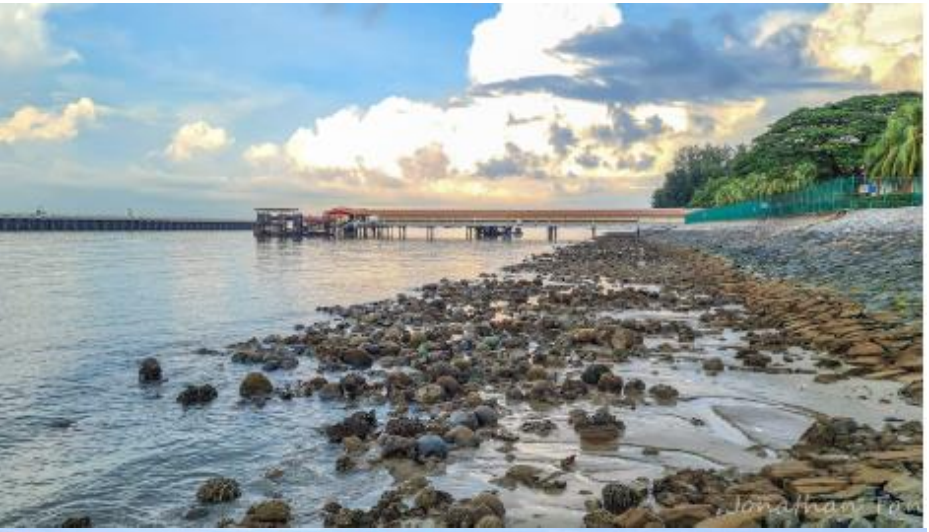
- 1989: Pasir Ris mangroves impacted by reclamation
- 5 ha patch retained and connected with Sg Tampines.
- 1 ha of levelled ground allowed to be tidally inundated. Colonised by mangroves within 3 months
- New areas continue to be restored to mangrove by lowering platform levels
- Restore Ubin Mangroves (RUM): Community effort to modify hydrology in former prawn ponds and allow mangrove regeneration

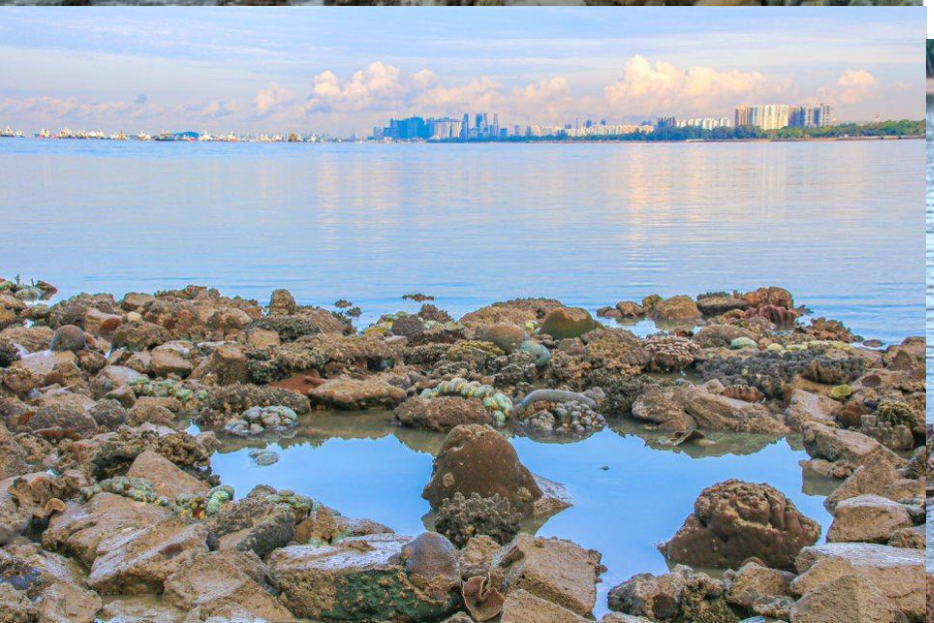
Surveying works for Restore Ubin Mangroves; Ria Tan

“Accidental” Coastal NbS



Seawall Reefs

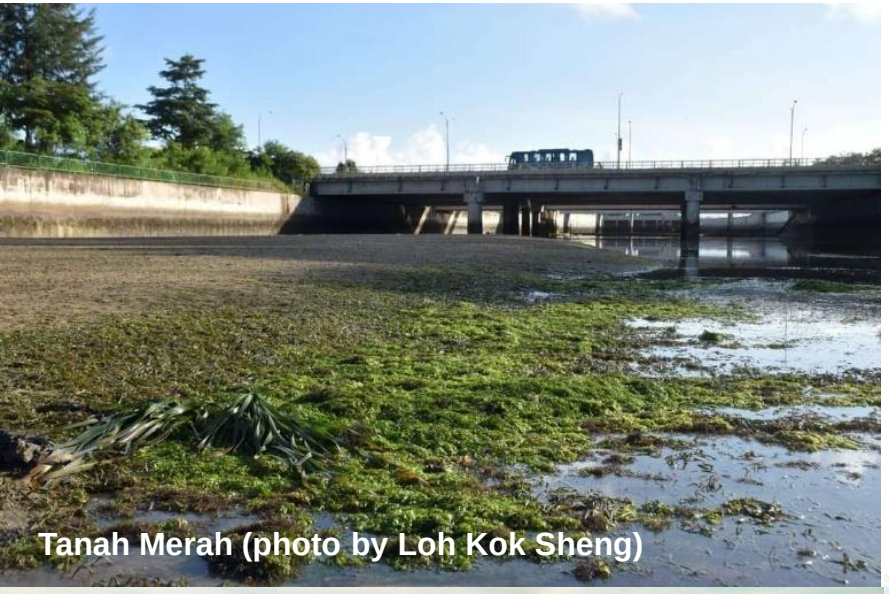




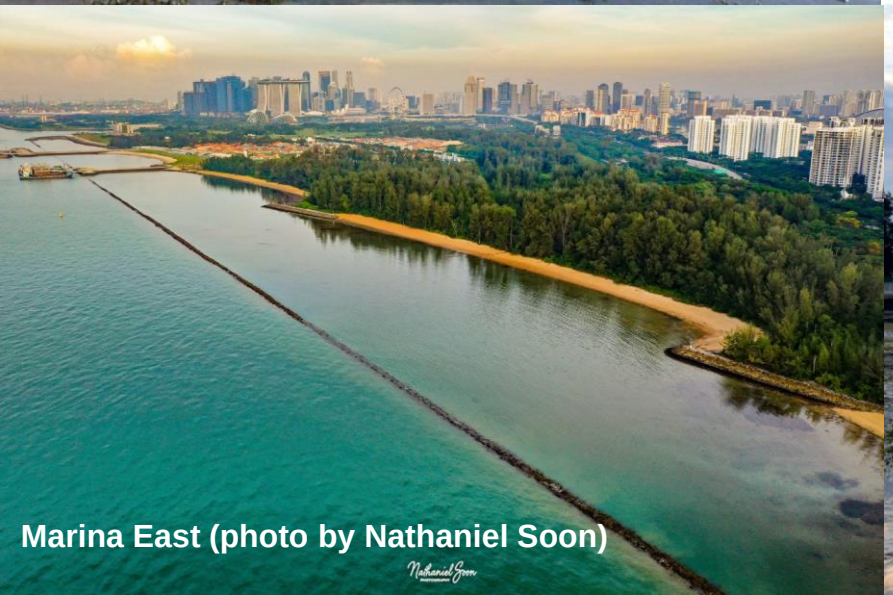
- Some seawalls and revetments have been naturally settled by hard corals (Tanah Merah, Marina East, Tuas, Southern Islands)
- Coral density and diversity can exceed some natural reefs due to the stable substrate (granite boulders)
- Principles to learn:
  - Coral reefs can regenerate naturally on seawalls with right conditions
  - Gentler inclines support more coral
  - Highest coral densities from 0.0 to -3.0 m CD; maximise surface area at these depths e.g. plateaus, gentler slopes
- Potential to attenuate wave action, further protecting the coast

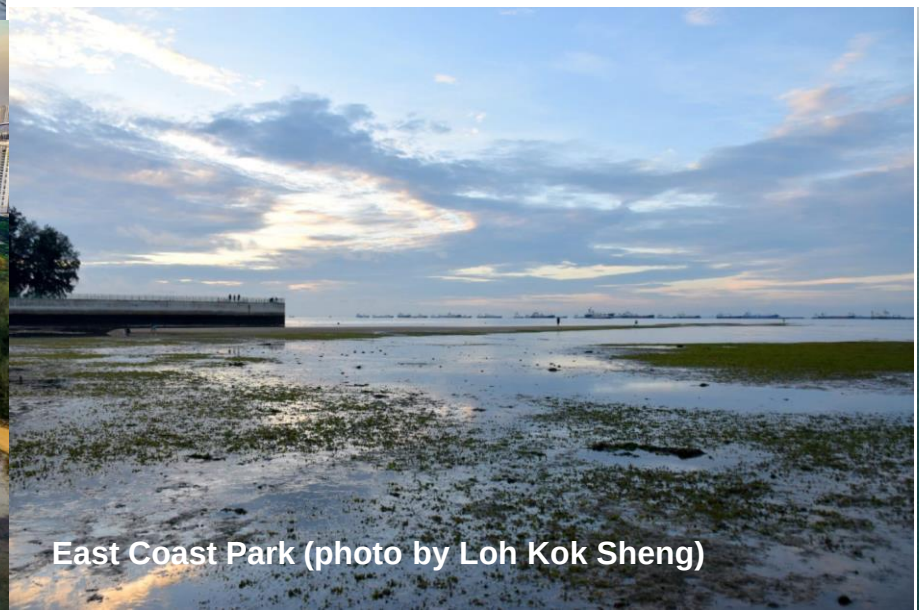
P. Semakau (Kikuzawa Yuichi)

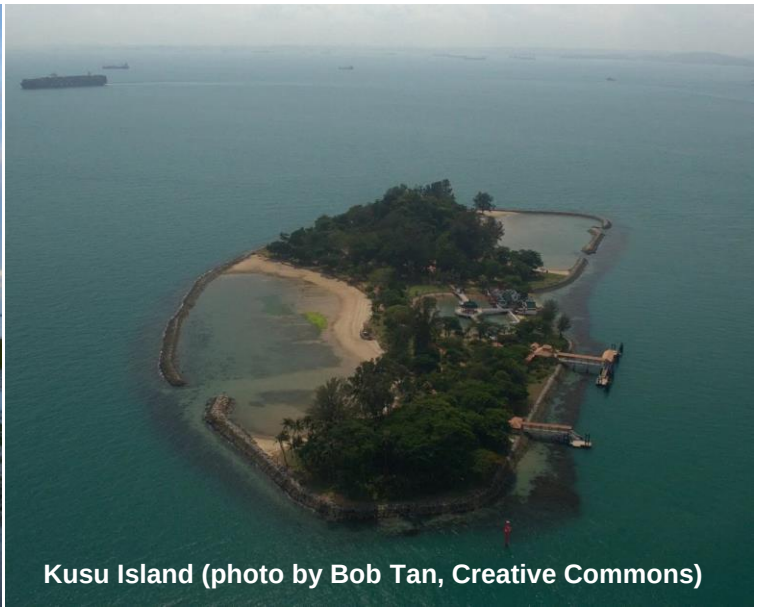
Perched Beaches, Reclaimed Lagoons, Outlet Drain Tidal Flats


Tanah Merah (photo by Loh Kok Sheng)

- Sandy beach or outlet drain protected by revetments e.g. East Coast, Southern Islands
- Seagrasses and corals colonise sheltered zone; revetments colonised by coral
- Recreational potential for lagoons: beach activities, sea sports, intertidal walks
- Principles to learn:
  - Right bathymetry essential - Intertidal life richest below 0.4 m CD, but if too low (below 0.0 m CD) then not accessible to public.
  - Aim for sheltered, gently sloping or flat lagoons


Marina East (photo by Nathaniel Soon)


East Coast Park (photo by Loh Kok Sheng)


Kusu Island (photo by Bob Tan, Creative Commons)

Perched Beaches, Reclaimed Lagoons, and Outlet Drain Tidal Flats

Marina East

East Coast Park and Tanah Merah
(Photos by Loh Kok Sheng)

We want to hear from you!

Gaps in Knowledge

Mangroves growing on rock revetment; Pulau Hantu (photo by Ria Tan)

Past NbS in Singapore were not designed to deal with climate change; questions remain:

- How much erosion protection can mangroves, coral reefs, or intertidal flats provide?
- How well can natural ecosystems keep pace with rising sea levels?
- If natural ecosystems cannot stop inundation, how do we integrate them with hard engineering solutions that can?
- How can we integrate coastal protection NbS with inland flood control NbS?
- NParks and other agencies will work to address such questions through research
  - **Marine Climate Change Science** Programme (MCCS)
  - **City in Nature pillar of Cities of Tomorrow** R&D Programme (CoT)

Send in your ideas to info@urbansustainability.sg

Key Takeaways

- Nature-based solutions offer **multiple co-benefits** over traditional solutions
- Most nature-based solutions in Singapore will be hybrid or hard eco-engineering
- Hard barriers (walls, earth mounds, tidal gates etc.) still essential to prevent inundation, but can be softened with natural elements
- **Build it right and biodiversity will come** on its own for free, for all to enjoy
- **R&D is needed** to help build the knowledge we need to deploy NbS effectively

Find out more about our work

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