Tidal Forests and coastal ecosystems

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What is a Mangrove?

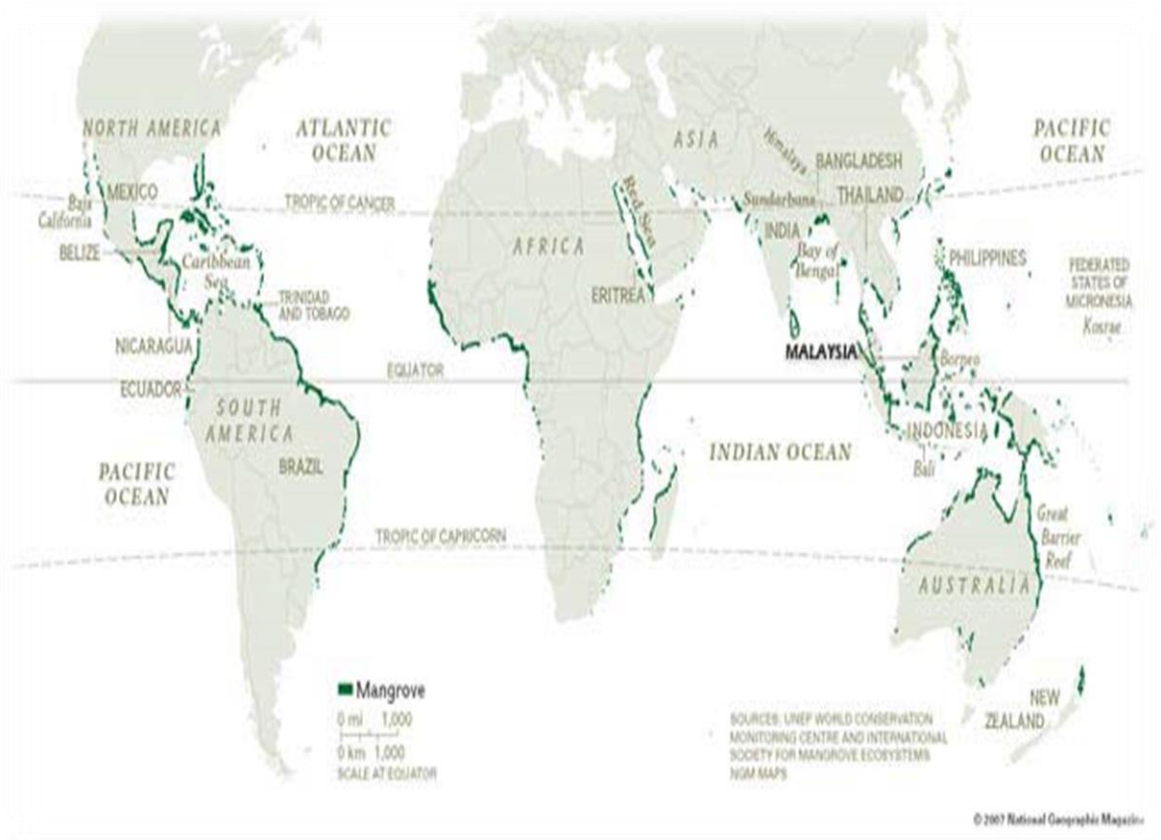
- Mangrove ecosystem is a peculiar habitat found at the **interface between land and sea.**
- Mangroves are various kinds of trees up to **medium height** and shrubs that grow in saline coastal sediment habitats in the **tropics and subtropics.**
- The mangrove biome, or **Mangal**, is a distinct saline woodland or shrubland habitat characterized by a depositional coastal environments, where fine sediments (often with high organic content) collect in areas protected from high-energy wave action

Where are Mangroves found?

- Found extensively in the **estuarine regions** where **mud-flats** are **wide** and **gently sloping.**
- Also inhabit the intertidal regions of **shallow bays and creeks.**
- Richest mangrove communities occur in **tropical and sub-tropical areas**
- Between **30°N** and **30°S latitudes**
- Where the water temperature is greater than **24ºC**
- Where the annual rainfall exceeds **1250mm**

Geographically…

- Found practically in almost all the continents, except Europe, the Arctic and Antarctic.
- Luxuriant patches of mangroves are found on all the other continents but **the best mangroves** are found in **Asia**, especially in **India and Bangladesh**
- The **Sunderbans** are the **largest mangrove forest** in the world both in size as well as biodiversity



- The total area of mangroves in India is about **6,740 sq. km**, which is about **7%** of the world's total area of mangroves

- Of the total mangroves **80%** are present along the **east coast**, mostly the Sunderbans, Bhitarkanika and the Andaman & Nicobar mangroves.

- The Gangetic **Sunderbans** is about **4,000 sq. km** , **Andaman & Nicobar** is about **700 sq km.**
- Large rivers like **Mahanadi, Krishna, Kaveri, Godavari** also harbor major mangroves in their estuarine regions.

- The remaining 20% mangroves are scattered on the west coast from **Kutch to Kerala.**

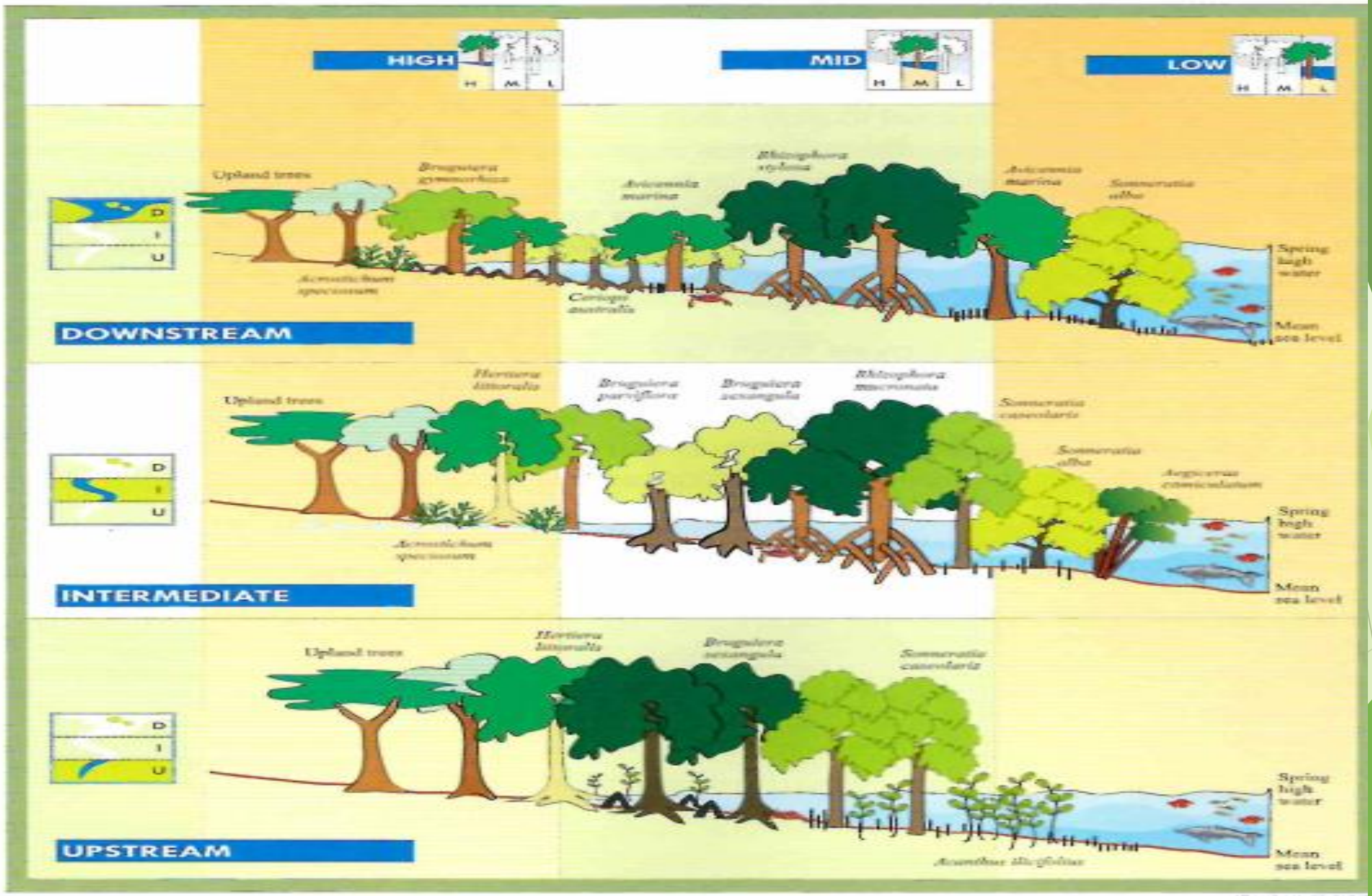
Zonation in Mangroves

- In India **Mangroves** zonation may be very distinctive (east coast of India) or merging (west coast of India). A very broad and general distinction would be:-

1. Proximal Zone (Front mangroves)
2. Middle Zones (Mid mangroves)
3. Distal Zone (Back mangroves)

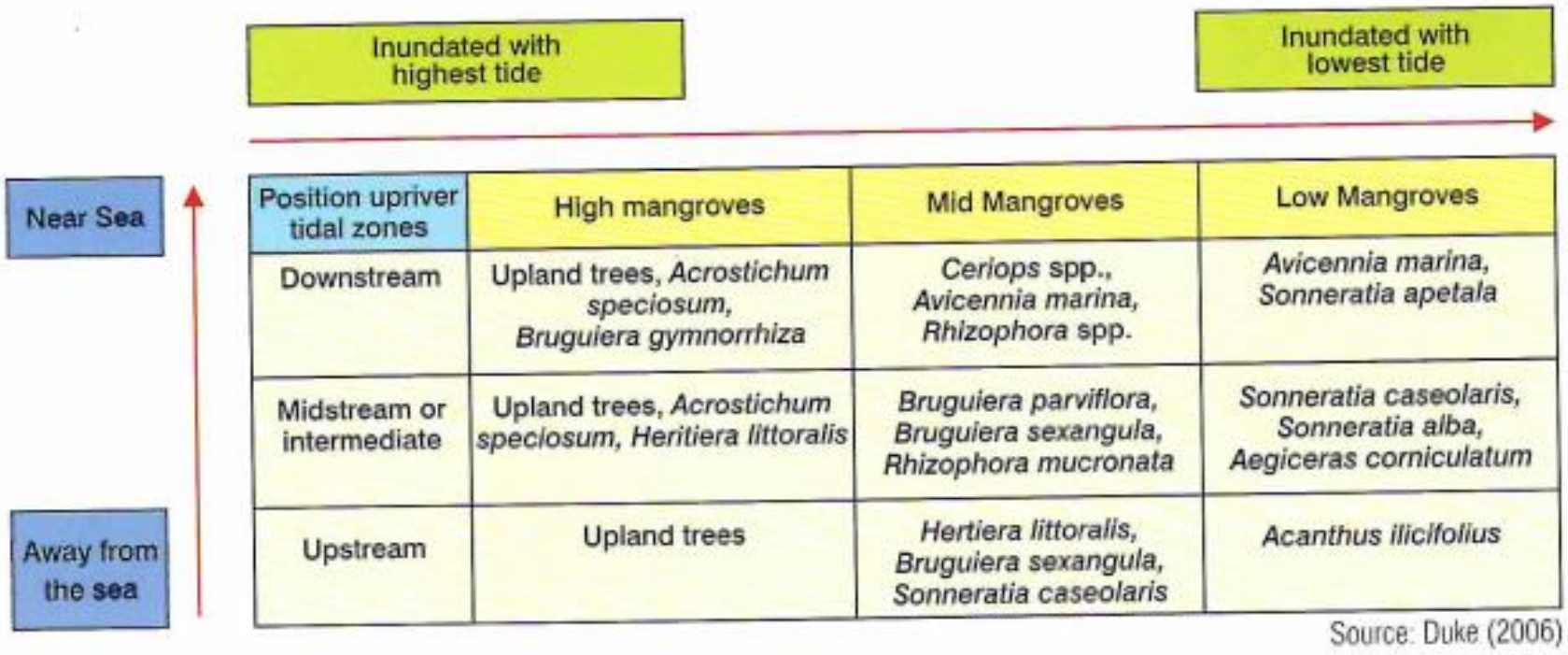
Tidal Zone

Position Upriver



Duke (2006

Zonation Pattern of Mangrove Species



Position upriver tidal zones	High mangroves	Mid Mangroves	Low Mangroves
Downstream	Upland trees, *Acrostichum speciosum*, *Bruguiera gymnorrhiza*	*Ceriops* spp., *Avicennia marina*, *Rhizophora* spp.	*Avicennia marina*, *Sonneratia apetala*
Midstream or intermediate	Upland trees, *Acrostichum speciosum*, *Heritiera littoralis*	*Bruguiera parviflora*, *Bruguiera sexangula*, *Rhizophora mucronata*	*Sonneratia caseolaris*, *Sonneratia alba*, *Aegiceras corniculatum*
Upstream	Upland trees	*Hertiera littoralis*, *Bruguiera sexangula*, *Sonneratia caseolaris*	*Acanthus ilicifolius*

Source: Duke (2006)

1. Proximal Zone (Front mangroves)

- They are found on the **Water front**
- Subject to **regular tidal effect** where intensity of soil accumulation and inundation is a continuous process.
- Mangrove species in this zone are specially adapted with stilt roots, prop roots for **stability and anchorage**.
- Rhizophora apiculata and Rhizophora mucronata are found.
- On rocky and coral reef substrata, Avicennia Spp, Sonneratia Caseolaris are also found.
- Both Avicennia and Sonneratia produce pneumatophores.

2. Middle Zones (Mid mangroves)

- Above the Rhizophora/ Avicennia line, luxuriant group of Bruguiera gymnorrhiza, Bruguiera Cylindrica, Lumnitzera racemosa, Lumnitzera littoralis, Ceriops tagal and Aegiceras corniculatum occur.
- Ceriops and Bruguiera develop **a strong hold fast** in the form of knee roots or bent roots as a special adoption for supporting the erect bole.

Knee roots are developed by Bruguiera species.

Knee roots emerge as a **root loop from the underground root system and allow the exchange of gases in oxygen-poor sediments.** Each underground horizontally growing root develops several knee roots at regular intervals.

3. Distal Zone (Back mangroves)

- Towards island area mangroves like Excoecaris agallocha, Heritiera littoralis and Xylocarnusspp occur.
- Both Heritiera and Xylocarpus produce buttresses.
- Generally the **salinity is on lower side** in this zone occurring towards hill sides where run off of fresh water is for a prolonged period.
- The duration of tidal submersion is **low** in this zone compared to front mangroves.

Heritiera littoralis

Biology

Plank roots of *Excoecarea agallocha*

Cable roots of *Avicennia*

Stilt roots of *Rhizophora*

Pneumatophores of *Avicennia*

The major types of aerial roots found in mangroves are as follows:

1. **Plank Roots**

   Like cable roots, they also runs horizontally remaining above the ground. This type of aerial roots (which resemble snakes) are found in *Excoecarea agallocha*. Many a times barnacles have also been reported on such aerial roots.

2. **Cable Roots**

   The cable roots run horizontally over a large area slightly below the ground. This type of roots are found in *Avicennia* spp. The pneumatophores develop on these cable roots. Due to soil erosion, the cable roots may also get exposed to air.

3. **Stilt Roots**

   These roots rise vertically above the ground, lifting the stem. A significant part of the root system remains exposed to air. In this case, the exposure to air is due to vertical spread of the root system above the ground. This type of aerial root is found in *Rhizophora* spp.

4. **Pneumatophores**

   These are finger-like aerial roots that protrude out of the mud for breathing. The roots radiate horizontally below the ground (cable root) and send out prop roots (pneumatophores) that emerge vertically out of the mud. The length of the propped out portions of these roots – called pneumatophores – may vary from 10 to 50 cm depending on the species and local conditions. This type of aerial root is found in *Avicennia* and *Sonneratia*.

Specialized Root System

Prop roots :

Description

- Red mangroves (Rhizophora Spp) have prop roots **descending from the trunk and branches.**
- provides a **stable support system**.
- Obtain stability with an extensive system of shallow, underground “cable roots” that radiate out from the central trunk for a considerable distance in all directions.
- Pneumatophores extend from these cable roots.

Breathing Roots (Pneumatophores)

- Special vertical roots, called pneumatophores, **form from lateral roots in the mud**
- Often projecting above soil **(height of 20-30 cms)** permitting some oxygen to reach the oxygen-starved submerged roots.
- The density, size and number of pneumatophores vary per tree.
- They are green and **contain chlorophyll**.

Stilt roots

- Main organs for **breathing** especially during the high tide.
- Extend **more than a meter** above the soil surface and contain **many small pores** (lenticels) which at low tide allow oxygen to diffuse into the plant.
- Aeration occurs also through **lenticels** in the bark of mangrove species, e.g., species of Rhizophora

Adaptations to Low Oxygen

- Red mangroves, which can survive in the most inundated areas, prop themselves above the water level **with stilt roots** and can then **absorb air through pores** in their bark **(lenticels).**

- Black mangroves live on higher ground and make many **pneumatophores** (specialised root-like structures which stick up out of the soil like straws for breathing) which are also covered in lenticels.

- These "breathing tubes" typically reach heights of up to **30 cms**, and in some species, **over 3 mts.**

Limiting Salt Intake

- Red mangroves exclude salt by having significantly **impermeable roots** which are highly suberised, **acting as an ultra-filtration** mechanism to exclude sodium salts from the rest of the plant.

- Analysis of water inside mangroves has shown **90% to 97%** of salt has been excluded at the **roots**. Salt which does accumulate in the shoot, concentrates in **old leaves** which the plant then sheds.

- Red mangroves can also store salt in **cell vacuoles**.

- White (or grey) mangroves can secrete salts directly; they have **two salt glands** at **each leaf base** (co-relating with their name—they are covered in white salt crystals).

1. **How do mangrove trees handle excess salts?**

Mangrove specie defend themselves against high salinity using the following mechanisms

(I) **Exclusion:** Species which have this mechanism are able to reject or exclude a large proportion of salts at the root level itself through a process called ultra-filteration. Thus, the roots are able to prevent most of the salts from entering the physiological system of the tree.

(ii) **Accumulation:** The species which employ this mechanism allow the salts to enter their physiological system but they are able to store these salts in leaves, barks and other parts which are regularly shed off.

(iii) **Secretion:** Under this mechanism, the trees allow the salts to enter the plant body but they are able to ooze out undesirable excess salts through the leaves.

Limiting Water Loss

- Because of the limited fresh water available in salty intertidal soils, mangroves **limit the amount of water they lose through their leaves- Reflection**

- They can **restrict the opening of their stomata** (pores on the leaf surfaces, which exchange carbon dioxide gas and water vapour during photosynthesis).

- They also vary **the orientation of their leaves** to avoid the harsh midday sun and so **reduce evaporation** from the leaves.

Nutrient Uptake

- **The biggest problem** that mangroves face is nutrient uptake.
- As the soil is perpetually waterlogged, there is **little free oxygen.**
- Anaerobic bacteria liberate nitrogen gas, soluble iron, inorganic phosphates, sulfides, and methane, which makes the soil **much less nutritious** and contributes to mangroves' **pungent odor**.
- **Pnuematophores (aerial roots)** allow mangroves to absorb gases directly from the atmosphere, and other nutrients such as iron, from the inhospitable soil which are **directly stored inside the roots**, processing them even when the roots are submerged during high tide.

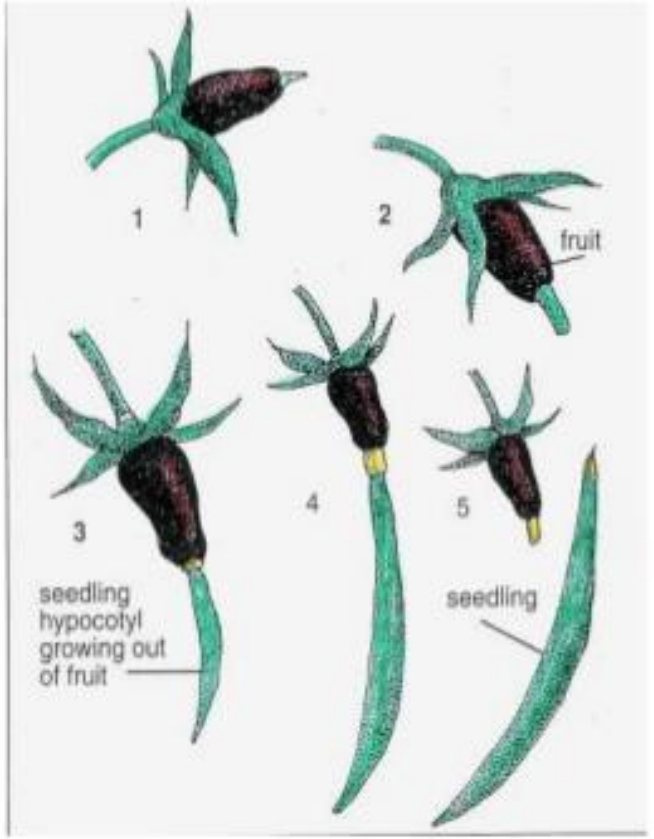
Reproductive Strategies

- All mangroves share two common reproductive strategies: **dispersal by means of water** and **vivipary**.

- Members of the Rhizophoraceae family have an intriguing viviparous method for successfully reproducing themselves.

- Vivipary means that the embryo develops continuously while attached to the parent tree and during dispersal.

Vivipary



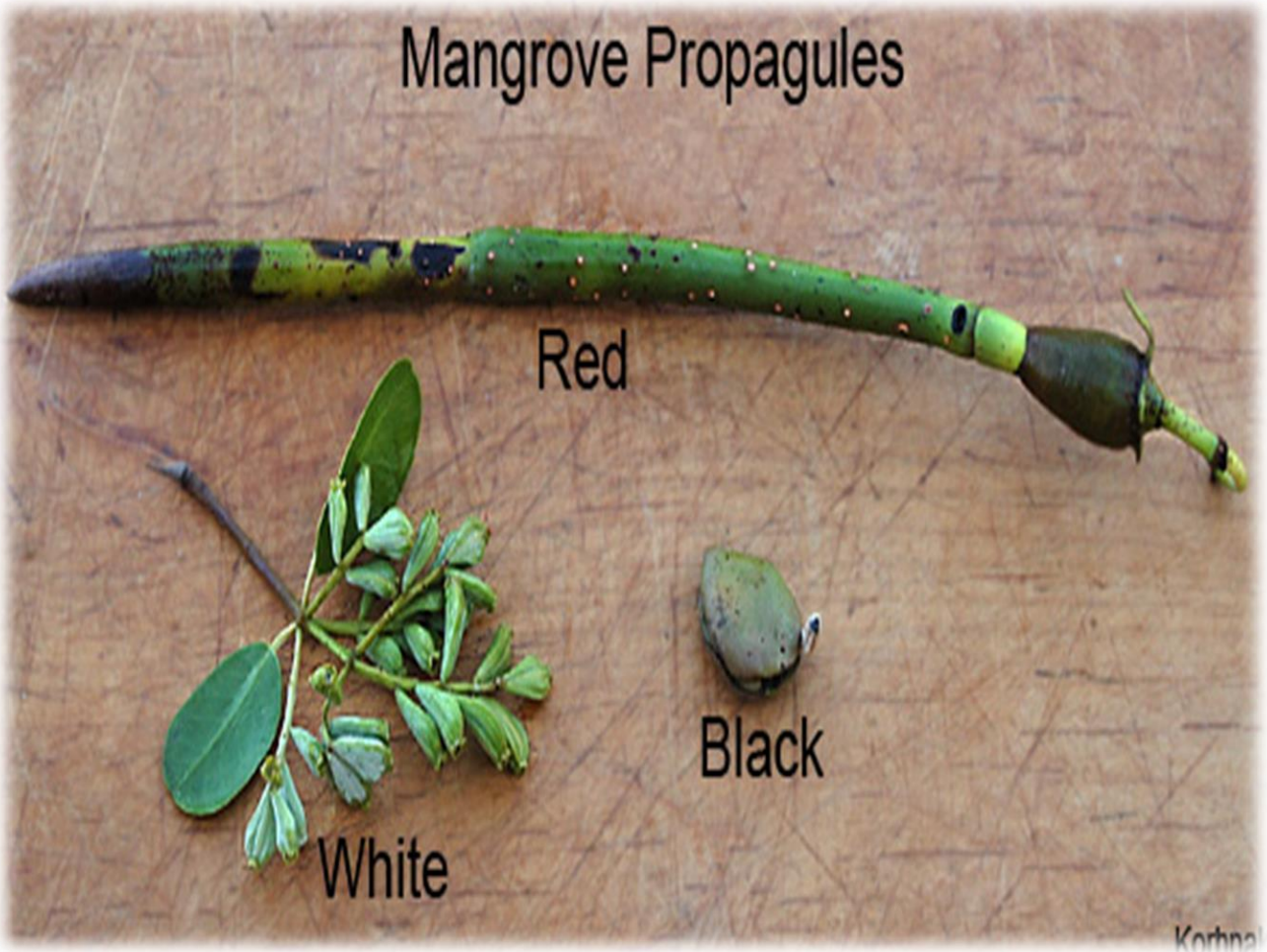
- They may grow in place**, attached to the parent tree**, for **one to three years,** reaching **lengths of up to one meter**, before breaking off from the parent and falling into the water.

- These seedlings then travel in an intriguing way.

- In buoyant sea water they **lie horizontally and move quickly.**

- **On reaching fresher water,** they **turn vertically**, roots down and lead buds up, making it easier for them to lodge in the mud.

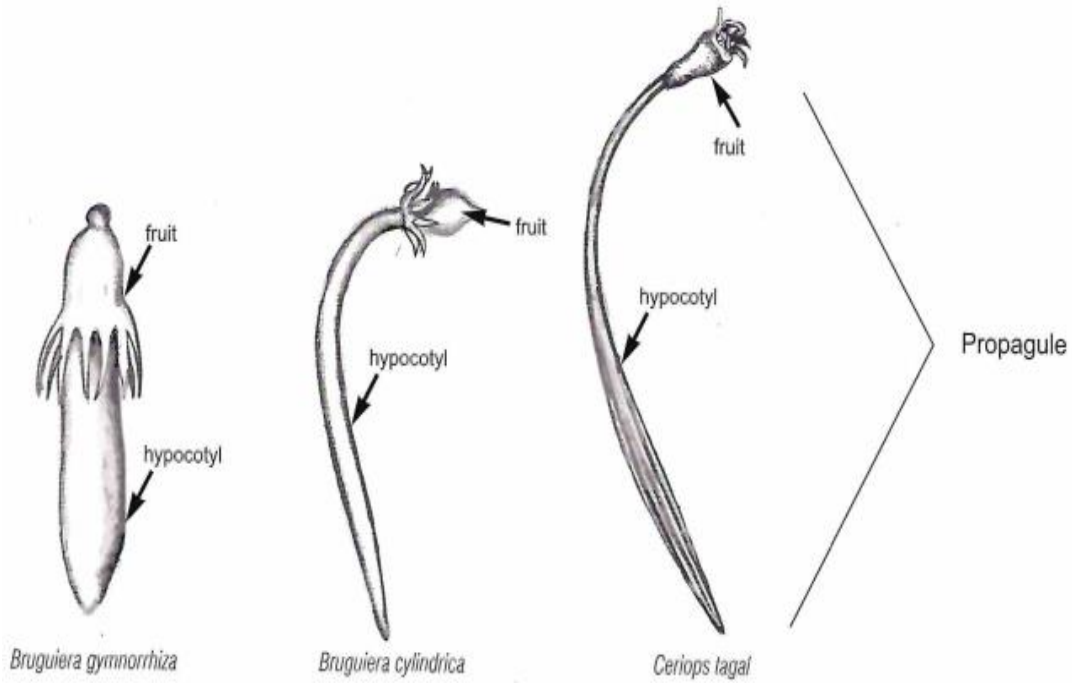
- Once lodged in the mud they quickly produce **additional roots and begin to grow.**



. What is the difference between a propagule and a fruit?

A fruit consists of seeds while a propagule does not have seeds because it is itself a seedling under continuous development.

Propagule (fruit and hypocotyl) **of Different Viviparous Mangrove Species**



Biodiversity of Mangroves

Flora

- The greatest biodiversity occurs in the mangal of **New Guinea, Indonesia and Malaysia.**

- Of the recognized 110 mangrove species, only about 54 species in 20 genera from 16 families constitute the "true mangroves", species that occur almost exclusively in mangrove habitats.

1. Rhizophora apiculata (Red Mangrove)

- This evergreen tree is a **front mangrove** species and grows well in sheltered areas rather than open seas exposed to the wave action.
- It generally grows upto **3-5 mts.**
- Leaves are about **10-20 cms** long and **2.5 - 7.5 cms** broad.
- Propagules are about **10-15 cm** long.

2. Ceriops tagal (Spur Mangrove)

- Shrubs or a tree, with a height of **3-5 mts.**
- leaves are **2.5-10 cms** long, **1.7-5** cms broad
- Propagules are thin, **10-15 cms** long.
- A widely distributed species with a **high tolerance for salinity.**

3. Bruguiera gymnorrhiza (Broad leaf orange mangrove)

- This evergreen tree grows upto **8-12 -mts** in height.
- Leaves are **9-12 cms** in length and **3.5-4.5 cms.** broad.
- Roots are characteristically thick, rope-like and **filled with air.**
- They are called **"cable roots".**

4. Bruguiera parviflora (Small leaf orange mangrove)

- Essentially a **back mangrove** species.
- It appears as a shrubby tree growing upto **3-5 mts**
- It is a useful tree for **commercial extraction of tannin.**
- The leaves are supposed to be used for **treating high blood pressure.**

5. Sonneratia Alba (Mangrove Apple)

- A large tree of upto **30 m** in height.
- It prefers **non swampy** intertidal zones.
- This is a **front mangrove species** and prefers open areas with some wave action.
- It has **thick, pointed and long pneumatophores.**
- The apple like fruits are edible and **used in pickles**.

6. Acanthus Ilicifolius (Shore Purslane)

7. Aegiceras Corniculatum (River mangrove)

8. Avicennia Marina

Fauna

- Mangroves form dense forests on the shore lines, creating a **secured habitat** for a variety of fauna.

- They give refuge to terrestrial, marine/brackish water as well as purely intertidal organisms, making itself a **richly diversed ecosystem.**

1. Zooplankton

- The zooplankton in the mangrove areas mostly includes **crustacean larvae**.
- Larvae of several species are found in large quantities.
- Food in the form of suspended solids is plenty, while shelter is sought in the complex root-systems of plants.

2. Insects

- In **W. Bengal and Orissa** honey collection is one of the major tribal activity.

- The common honey bees found here are **Apis dorsata (rock bee)** and **Apis mellifera (European bee).**

3. Butterflies and moths

- **Commonly found** in the mangrove ecosystem.
- Several species of butterflies and moths have been reported in mangrove areas.
- Salmona is a butterfly which is associated with the mangrove the most

4. Mangrove Crab (Scylla serrata)

- The large edible swimming crab, inhabits the muddy bottom of mangrove estuaries, as well as coastal brackish water.
- Due to its association with mangroves it is known as the Mangrove Crab or the Mud Crab.
- It is a **commercially important** crab and it is trapped in **special nets** throughout the country

5. Fiddler Crab

- Fiddler crab is probably one of the first animals one sees in a mangrove area.
- Charcteristised by the males which are armoured with a **single huge pincer** (claw) which is used as a **display tool** rather than for protection. The **other pincer is small** in the males and is used for feeding.
- Females have **two small pincers** of equal size.
- They are **semi-terrestrial**
- Their burrows are located in the **intertidal zone**, and at low tide the crabs come out for feeding and courting.
- There are **62 known species** of fiddler crabs in the world.

6. Fish

- Mangroves prove to be great **breeding and nursery grounds** for several species of fish.
- A total of **105 species** of fish are typical mangrove dwellers in India.
- Some common species are - scats, milk fish, mudskippers, mullets, cat fish, perches, etc.

Mud skippers

- These are one of the fish which live on the **mud flats** associated with mangroves shores
- They are seen **hopping along the mud** at the water's edge
- They are able to **change colour** to match their background.
- It respires under water like other fish but out of the water gulp air.
- When submerged it swims like a fish but on land proceeds by a series of skips.

7. REPTILES

Estuarine or Saltwater Crocodile (Crocodylusporosus)

- This is the **largest crocodile** found in India or in the world.
- Normally attains a size of **6 mtrs** and the largest record has been of a male over seven mtrs
- It is known to hunt fish and small animals
- Its main food is dead and decaying matter in the estuary and is a **major scavenger** of the estuaries

9. Mammals

Royal Bengal Tiger (Panthera tigris tigris) :

- Adaptation at the highest level in the animal kingdom and is one of the unique resident species of mangroves of the Sunderbans.
- There are about **250 tigers** now present in Sunderbans
- **Total protection** has been offered by including the area under **Project Tiger.**
- The tigers here hunt for spotted deer, wild boars and water monitor lizards.

Otters

- Otters are also visitors of mangroves and often frequent them in search of food and shelter.
- They are **elegant and swift swimmers.**
- Being hyperactive they are **constantly on the move.**
- Their favorite foods are sea urchin, crab, clam, mussels, squid, octopus and fish.
- The peculiar thing about sea otters is that, while most otters come ashore for breeding, the sea otters **breed in the water** itself.

Importance & Uses

Mangrove Uses	Mangrove Functions
A. Sustainable Production Uses	**B. Regulatory or carrier functions**
Timber; Firewood; Woodchips; Charcoal Fish, Crustaceans; Shellfish; Tannins; Nipa; Medicine; Honey; Traditional hunting; fishing and gathering; Genetic resources	Erosion prevention (shoreline and riverbanks); Storage and recycling of human waste and pollutants; Maintenance of biodiversity; Provision of migration habitat; Provision of nursery grounds, Nutrient Supply. Nutrient regeneration; Coral reef maintenance and protection; Habitat for indigenous people; Recreation sites
C. Conversion Uses	**D. Information Functions**
Industrial / urban land use; Aquaculture; Salt ponds; Rice fields; Plantations; Mining; Dam sites	Spiritual and religious information; Cultural and artistic inspiration; Educational, historical and scientific information; Potential information

Source: Modified after Reitenbeek (Adapted from Doherty 2004)

Components/ Functions/ Diversity/ Attributes	Economic Values		
	Direct	Indirect	Non-use
I. Components			
1. Forest Resources	XXX		
2. Wildlife Resources	X		
3. Fisheries	XX		
4. Forage Resources	X		
5. Agricultural Resources	XX		
6. Water Supply		XXX	
II. Functions/ Services			
1. Groundwater discharge		XX	
2. Flood and flow control		XXX	
3. Shoreline stabilization		XX	
4. Sediment retention		XXX	
5. Nutrient retention		XX	
6. Water quality maintenance		XXX	
7. Storm protection/ windbreak		XXX	
8. Micro climatic stabilization		XX	
9. Recreation/ tourism	XX		
10. Water transport	XXX		
III. Diversity/ Attributes			
1. Biological Diversity	X	X	X
2. Uniqueness to culture/ heritage			XX

Key: X – Low; XX – Medium; XXX - High

Source: Sathirathai, 1997

Threats

- The main culprit in the destruction of mangroves is **MAN.**
- Demographic pressure is exerting tremendous stress on the coastal environment.
- **Land reclamations** and **industrial effluents** are the major causes of mangroves degradation.
- Systematic dumping of all kinds of **waste and debris** in the mangrove areas destroys them.
- This waste/debris creates a barrier preventing the sea water from entering the mangroves and eventually kills the mangroves.
- **Deforestation** for fuel wood

RESTORATION
&
Conservation

Mangrove restoration

- Five key principles for successful mangrove restoration (after [**Understanding the individual species ecology at a potential restoration site;**
- Understanding **normal hydrological patterns** controlling seedling establishment and successful growth of mangrove species;
- Assessing **current environmental obstacles and modifications of the original mangrove habitat** that currently prevent establishment and succession;
- **Designing a restoration program** to restore appropriate hydrology and address conditions preventing natural colonisation of mangrove propagules and plant establishment;
- **Only planting propagules or seedlings after steps 1-4 have been taken and if natural recruitment** is not sufficient to provide the quantity of successfully established seedlings, the soil stabilization or rate of growth necessary for the project

https://www.globalnature.org/bausteine.net/f/8281/GNF_Mangrove_Handbook_2015.pdf%3Ffd%3D0

Mangrove nursery construction

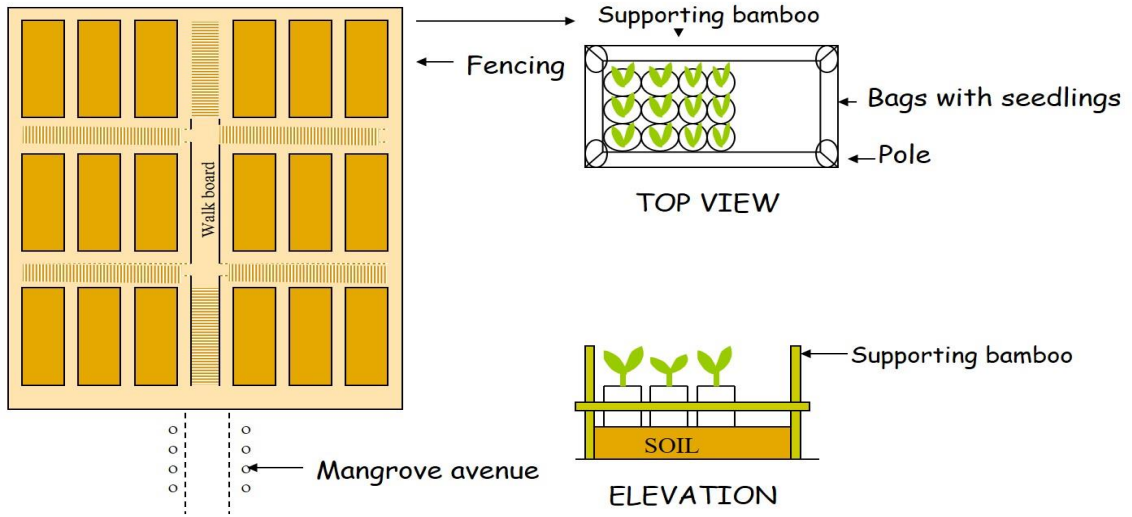
- The major components of a mangrove nursery are:

1. mechanisms to allow periodic inundation;
2. access to good quality salt and freshwater;
3. pumps for aeration and circulation of the water through the ponds;
4. power source;
5. shade regulation and good quality propagation stock.

Propagation methods

- NURSERY STOCK – seed stock
- Air layering
- Micro propagation
- Wildling pod collection

General Plan of Mangrove Nursery



(A) Diagrammatic sketch of Mangrove Nursery (B) Views of the beds in the Nursery

Restoration methods

Selection of site for afforestation

- Selection of suitable area
- Knowledge of climatology of the site
- Knowledge of Phenology
- Knowledge of natural zonation
- Knowledge of species succession.

Phenological observations on mangrove species

I. Time required from bud to mature fruit

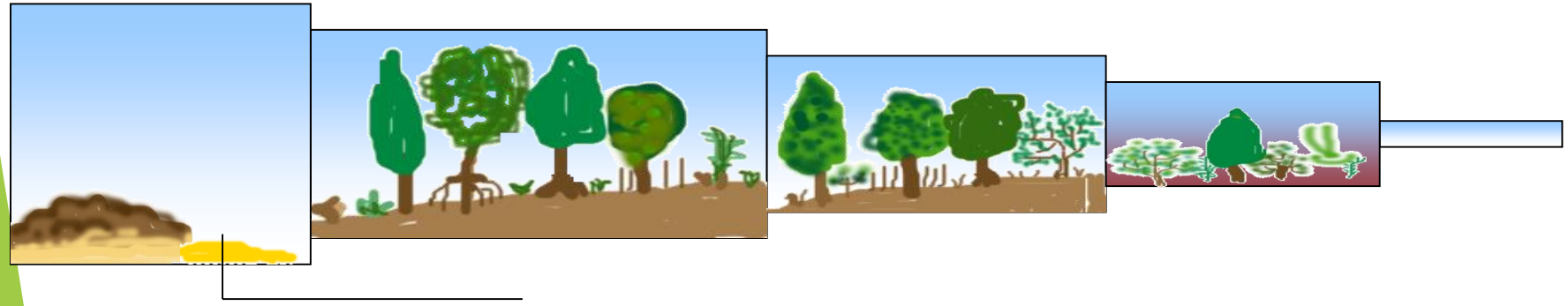
	Mangrove Species	Duration
a.	*Sonneratia alba*	3 months
b.	*Kandelia candel*	4 months
c.	*Ceriops tagal*	4 months
d.	*Rhizophora apiculata*	4 months
e.	*Rhizophora mucronata*	5 months
f.	*Avecennia officinalis*	5 months

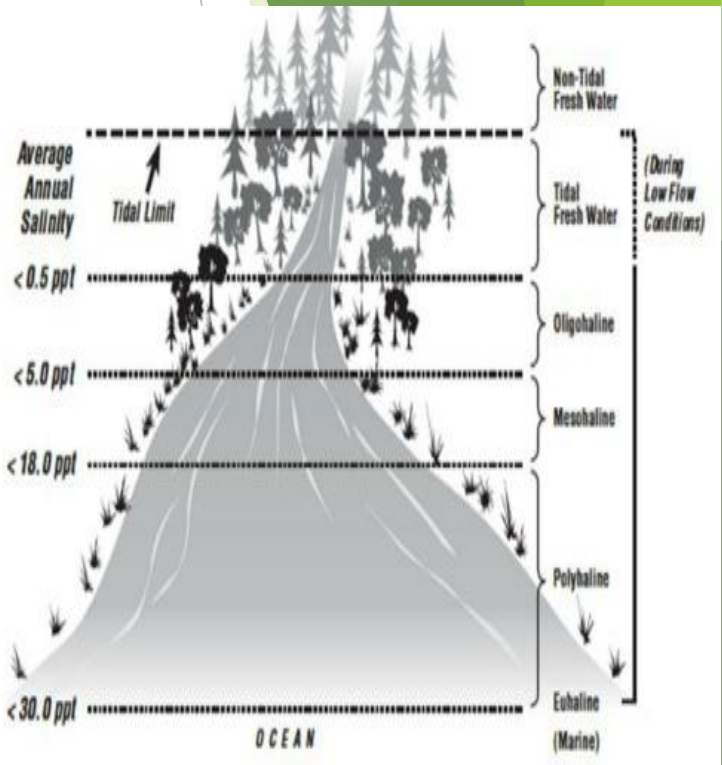
II. Development of buds to flowers and flowers to fruits (%)

	Mangrove Species	Buds to Flowers	Flowers to Fruits
a.	*Rhizophora apiculata*	44	14
b.	*Rhizophora mucronata*	55	6
c.	*Sonneratia caseolaris*	36	90
d.	*Avecennia officinalis*	79	66

Zonation of Mangroves on the bases of substatum & salinity

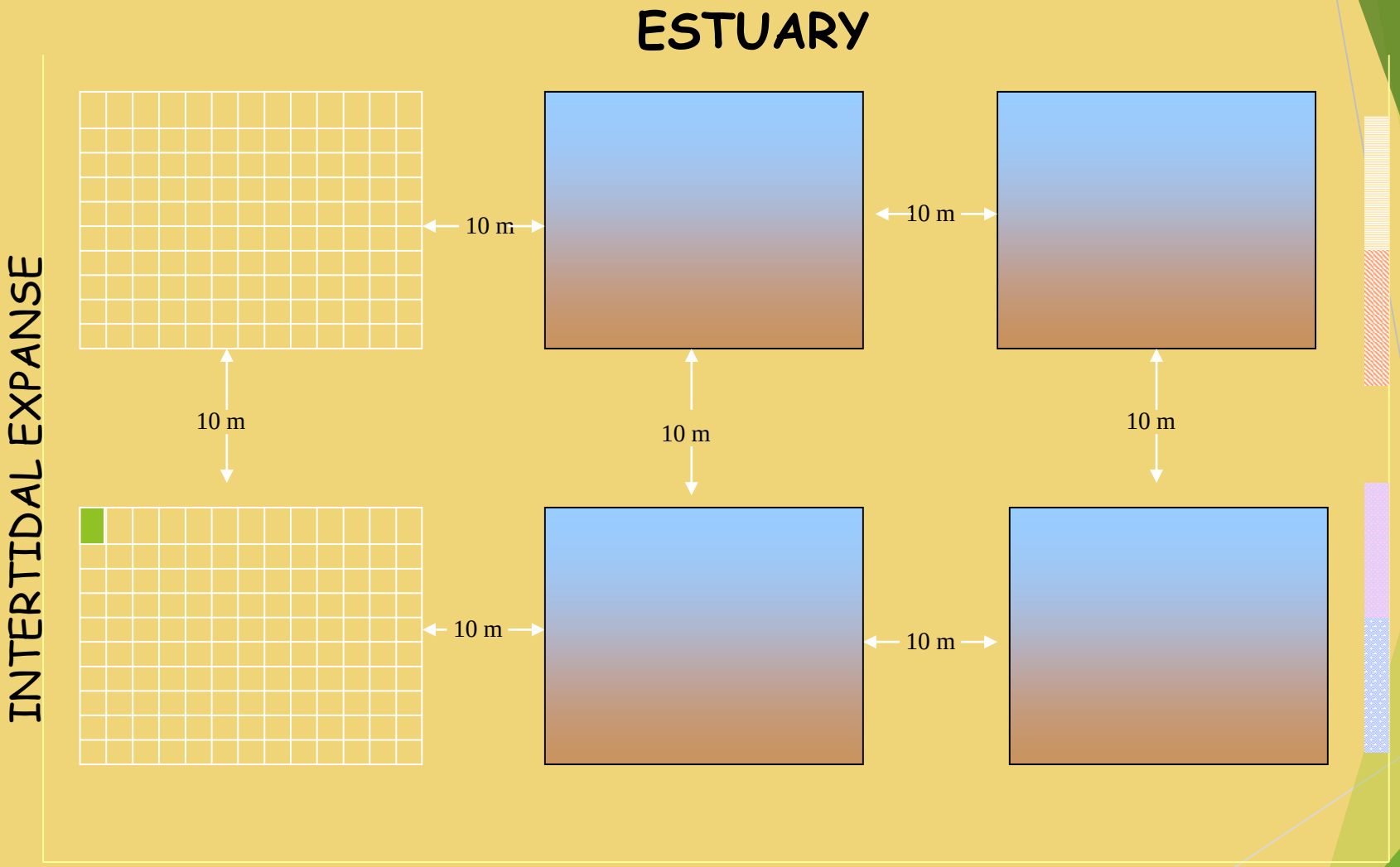
Rocky and sandy	Sandy Clay	Silty Clay	Silt	
	S. alba	K. candel	S. caseolaris	
	R. mucronata	A. officinalis	A. areum	
	A. marina	R. mucronata	Cypsreus	
	B. Gymnorhiza etc.	A. corniculatum		
		S. Alba		





Euhaline	Polyhaline	Mesohaline	Oligohaline	Limnotic
40 to 30 ‰	30 to 18 ‰	18 to 5 ‰	5 to 0.5 ‰	0.5 ‰

Plan of Afforestation



AFFORESTATION

Problems responsible for Mortality

- Barnacles & Oysters on young seedlings.
- Insect Suckers (monolepta orientalis).
- Insect borers on young Propagules.

Protection to the afforested area

i) Replace dead seedlings.

ii) Provision of wire fencing.

iii) Preventing cattle grazing or browsing.

iv) Proper pruning to maintain optimum space.

Species	Method Adopted	Survival Rate %
1. *Rhizophora mucronata*	a) direct sowing	75 to 80
	b) one-year old naked seedlings	20 to 25
	c) one-year old nursery raised seedlings in polybags	80 to 85
2. *Avicennia officinalis*	a) one-year-old naked seedlings	30 to 40
	b) one-year-old polybag seedlings	80 to 90
	c) broadcasting	20 to 30

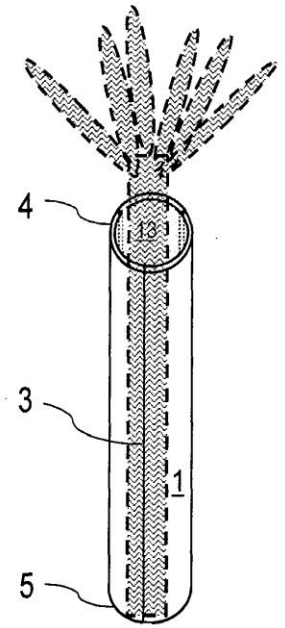
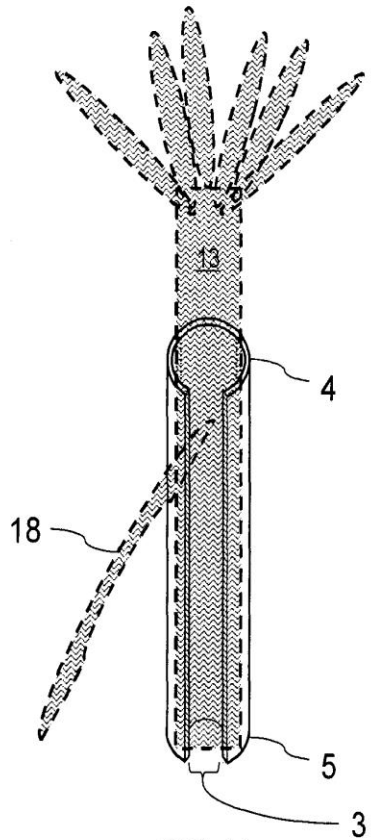


FIG. 10



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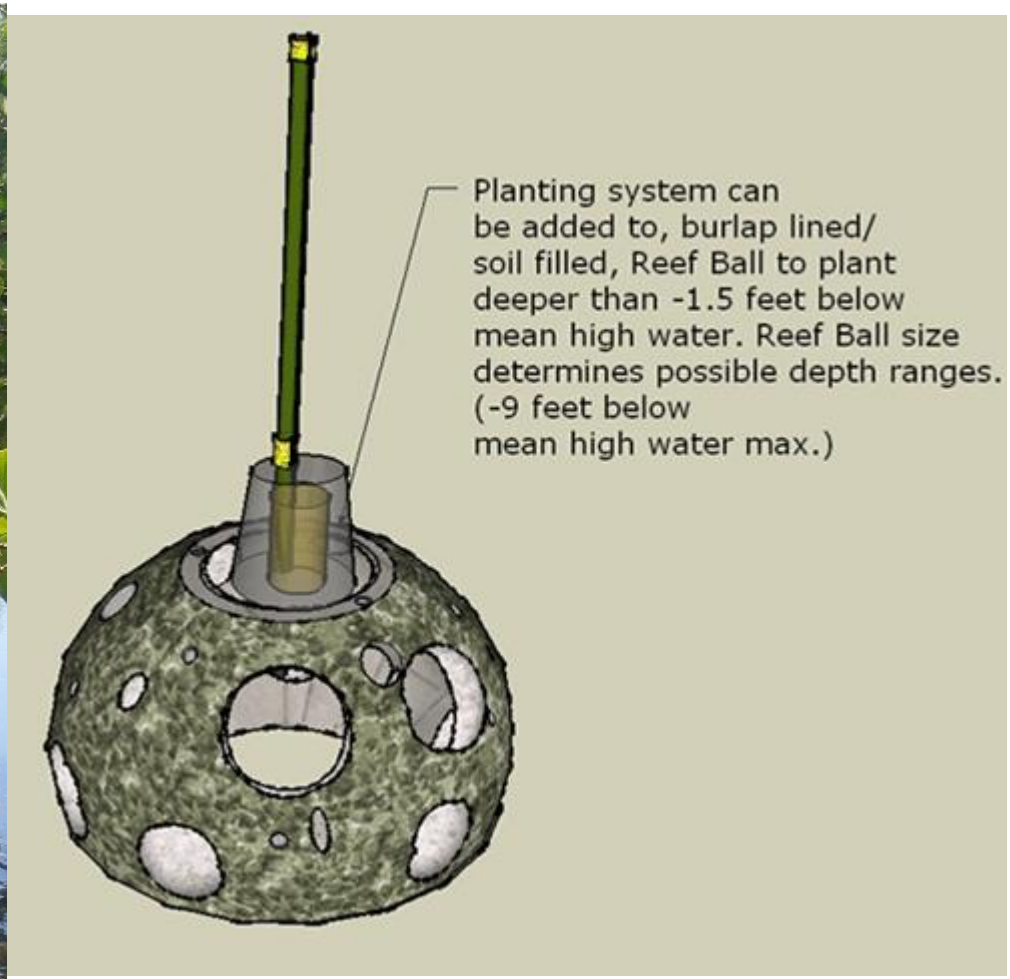
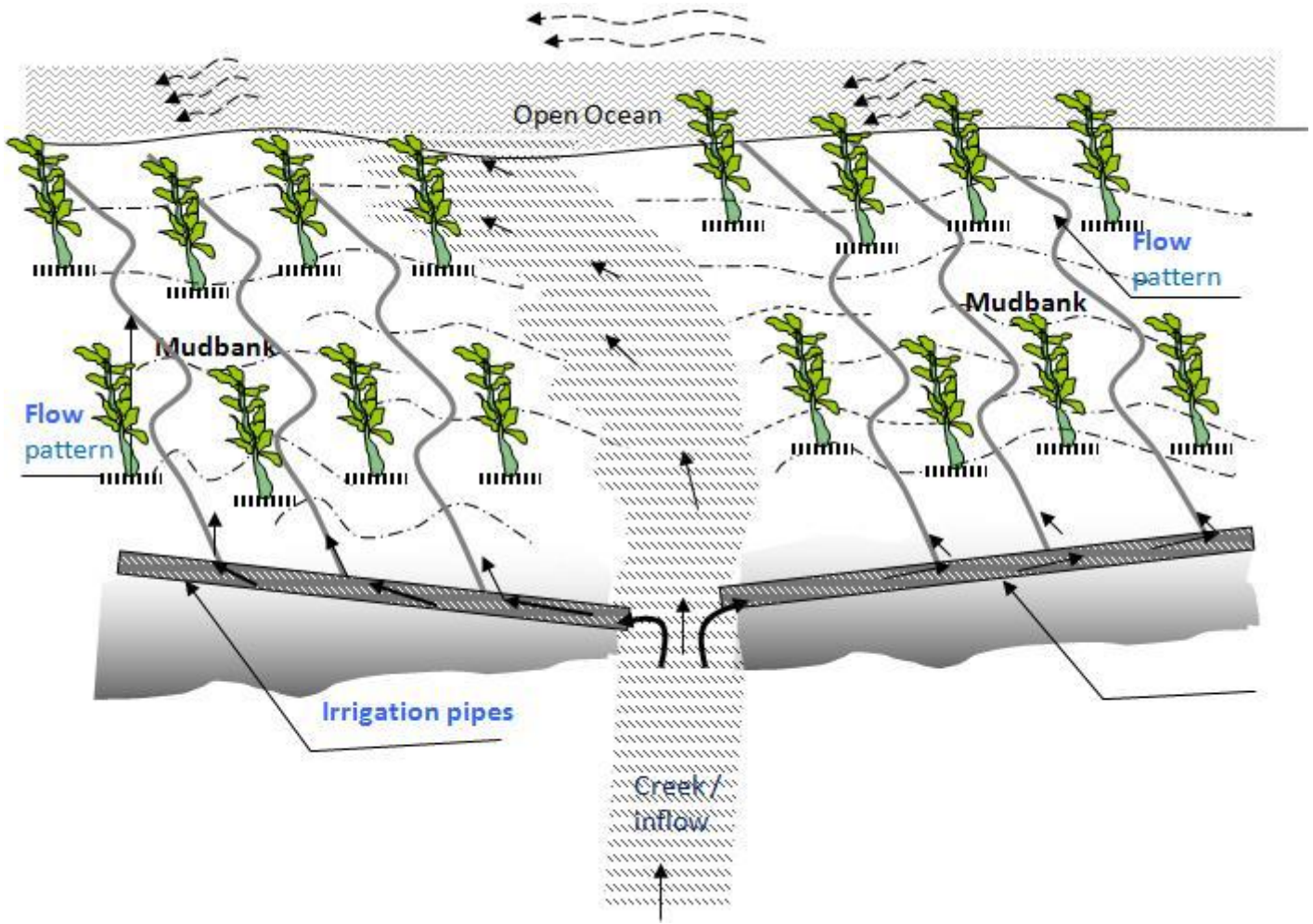
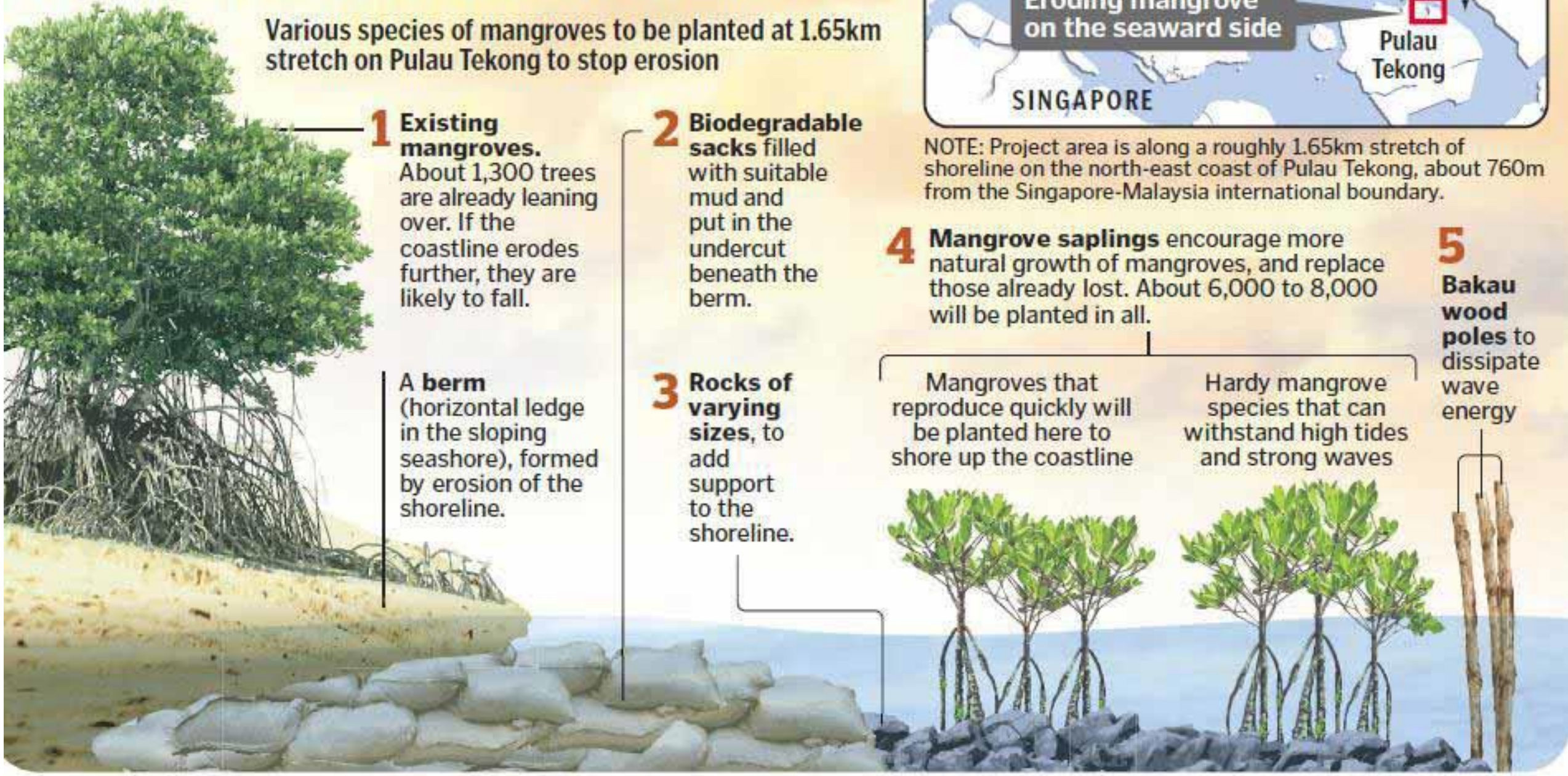


http://www.mangrovesolutions.com/product.php


Open Ocean
Flow
pattern
Mudbank
Mudbank
Flow
pattern
Irrigation pipes
Creek /
inflow

MANGROVE ENGINEERING

Various species of mangroves to be planted at 1.65km stretch on Pulau Tekong to stop erosion



NOTE: Project area is along a roughly 1.65km stretch of shoreline on the north-east coast of Pulau Tekong, about 760m from the Singapore-Malaysia international boundary.

TEXT: GRACE CHUA, GRAPHICS: LIM YONG

Tidal Forests & communities

Mussel Farming

Cage Culture of Fishes

Crab Farming

Oyster Farming

Ornamental Fish Culture

- Central Breeding Facility **being developed** at Airoli
- One-month old fishes to be supplied to 50 village level SHGs
- SHGs to rear them for 2 months

Community-led Village Ecotourism

- "**Swamini**"-Women's Self-Help Group in Vengurla (Sindhudurg Dt).
-
- Tourists can discover the mangrove habitat, its associated biodiversity and also familiarise themselves with the local traditions, culture and rituals.

http://www.geciczmp.com/data/sites/1/docs/socio-economic-benefits-of-mangroves.pdf

Thank you