7 – MANGROVE FORESTS

- **Woody trees** or **shrubs that live** not completely submerged, but live **at the sea/land interface in sheltered tropical** and **subtropical coastal** and **estuarine regions** → haven't a cosmopolitan distribution
- Cannot tolerate continual and complete immersion in seawater, for this reason they live in the intertidal zone with the change of tide (float during the high tide, completely without water during the low tide), they are adapted to live partially immersed in saltwater (are called **halophytes: can tolerate also salt)**
- As seagrass they live in soft and fine sediments, not in rocky bottom
- Individual tree: **mangrove**
  Many mangroves create a **mangrove forest** called also **mangal**

CLASSIFICATION

- Polyphyletic group of **Angiosperms** (produce fruits and seeds) **dicotyledons** (VS seagrass that are monocotyledon) and belong to the class of Magnoliopsida
- *They have more than 1 common ancestor* → polyphyletic group
- The grouping is based on physiological and morphological attributes
- 16 families, 20 genera, 54 species: also the biodiversity is similar to the one of seagrasses

Only 2 main families dominated the major of the mangroves: are **BLACK MANGROVES** (*Avicenniaceae*) and **RED MANGROVES** (*Rhizophoraceae*), but there are other important families:

Major components [edit]

Family	Genus, number of species	Common name
Acanthaceae, **Avicenniaceae** or **Verbenaceae** (family allocation disputed)	*Avicennia*, 9	Black mangrove
Combretaceae	*Conocarpus*, 1; *Laguncularia*, 1; *Lumnitzera*, 3	Buttonwood, white mangrove
Arecaceae	*Nypa*, 1	Mangrove palm
Rhizophoraceae	*Bruguiera*, 7; *Ceriops*, 5; *Kandelia*, 2; *Rhizophora*, 8	Red mangrove
Lythraceae	*Sonneratia*, 5	Mangrove apple

The number close to the second column is the number of species that below to the correct family
Nypa is similar to a palm, there is only 1 species
The genera *Sonneratia* is the third most important genus of mangroves, with 5 species, is called **MANGROVE APPLE** because the leaves are very circular, like a fruit

Figura 1: Laguncularia sp. White mangrove

Figura 2: Avicennia sp. Black mangrove

Minor components [edit]

Family	Genus, number of species
Acanthaceae	*Acanthus*, 2; *Bravaisia*, 2
Bombacaceae	*Camptostemon*, 2
Cyperaceae	*Fimbristylis*, 1
Euphorbiaceae	*Excoecaria*, 2
Lecythidaceae	*Barringtonia*, 6
Lythraceae	*Pemphis*, 2
Meliaceae	*Xylocarpus*, 2
Myrtaceae	*Osbornia*, 1
Pellicieraceae	*Pelliciera*, 1
Plumbaginaceae	*Aegialitis*, 2
Primulaceae	*Aegiceras*, 2
Pteridaceae	*Acrostichum*, 3
Rubiaceae	*Scyphiphora*, 1
Sterculiaceae	*Heritiera*, 3

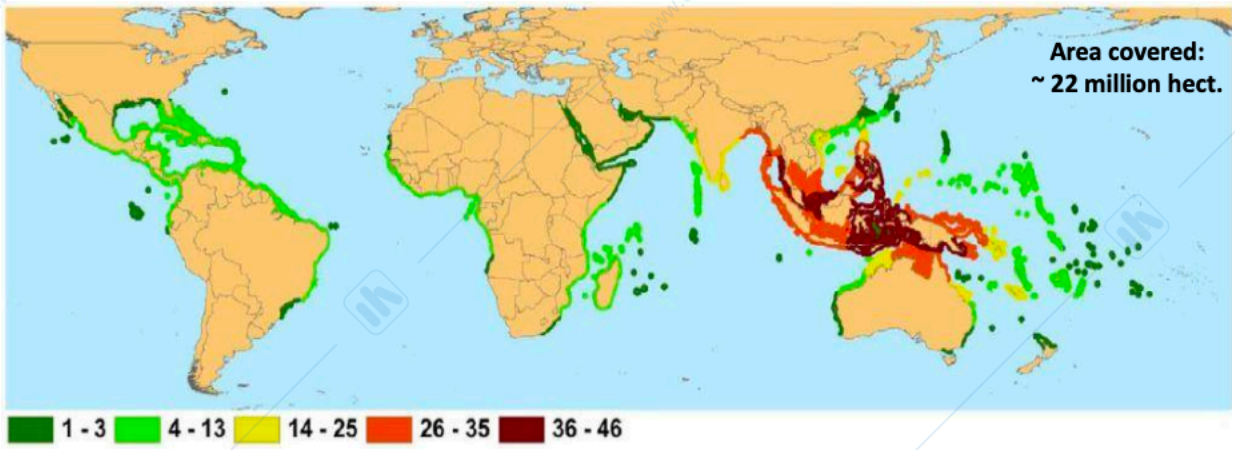
Figura 5: Nypa sp. Mangrove palm

Figura 4: Rhizophora sp. Red mangrove

Figura 3: Sonneratia sp. Mangrove apple

The red mangrove are very easy to recognize such as the black mangrove that have strange roots that go outside the sediments

7.0 - DISTRIBUTION



- Strictly tropical and subtropical distribution (difference in size and density if they are tropical or subtropical): higher and more density in the tropical ecosystem
- Coincides very closely with coral reefs distribution
- Distribution is confined in **water > 20°C** and not less than 16°C in the coldest month
- Highest diversity in Indo-West Pacific and **decline moving to the Caribbean/West Atlantic**, such as corals
- *Huge biodiversity in the coral triangle that is also the seagrass triangle and the MANGROVE TRIANGLE* (red part of the image below) it could represent the center of origin of both these 3 different organisms, corals, seagrasses, mangroves
- In the Amazonas region don't have coral, but mangroves
- In the west Africa, close to Senegal we can find mangroves and not coral

7.1 - MORPHOLOGICAL AND PHYSIOLOGICAL ADAPTATIONS

They must face 3 main problems:

1 - Waterlogged Sediment (aquitrinoso)

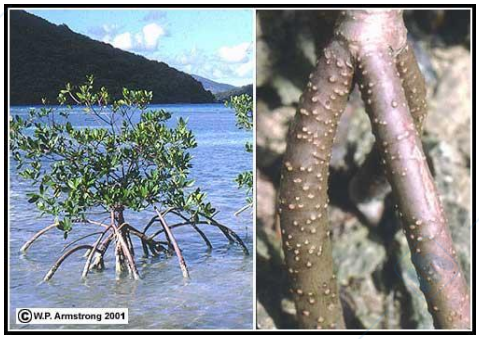
- Frequent flooding that reduce the gas exchange between roots and environment creating an anoxic sediment → without oxygen
- Anaerobic conditions that slows nutrient uptake and allows the accumulations of toxins such as hydrogen sulfide, methane, reducing metals… the mangroves have developed a **particular root system** with which can resolve this problem:

Mangroves developed a particular **root system**, used for:

1. exchange of water and nutrients
2. Exchange of gas
3. Oxygen retention (O2 cannot be found in the sediment because is anoxic, but with the root system they can uptake the O2 and use it for the respiration)

PARTICULAR ROOT SYSTEM with which

1. They show a **thickening of the root epidermis** (while in the seagrasses is less thick) which reduces the loss of O2 to the outside anoxic environment
2. Development of special **spongy aerenchyma** with the LACUNE (holes channel that allow the gas to move) for O2 transport along all the root
3. In the epidermis of the **roots** that **exit the sediment**, are OUTSIDE, that are provided by special little pores called **lenticels,** which favor the gas exchanges with the atmosphere keeping the section of root within the sediment supplied with O2, and thanks to the aerenchyma the O2 can go everywhere till the roots that are inside the sediment that is anoxic.



LENTICLES **are breathing pores for gas exchange, larger in size and smaller in number than stomata** (same function that have in the leaves)

E.g. Avicennia plants
The part of the roots that are not under the water or the sediment are provided by the lenticels to acquire the O2, it has transported down when the roots start to become branched to provide the function of anchoring the mangroves to the sediments.

Also the morphology of the roots can change:

- Some species have **roots that only partially fit into the sediment** avoiding the exposure to deeper- laying anoxic sediments. E.g. *Red mangroves* have roots that start early in the tree (are in the high part of the tree) because they increase the amount of area for the exchange of the oxygen. In that part outside they have a lot of lenticels to absorb O2 that than is transported down
- Other species have **Aerial roots/branch** (similar to branch, with lenticels) to aid oxygen uptake. E.g. *Red mangroves* have also these structures that are not branches but are roots, so roots that start from the top of the tree
- The *black mangroves*, *mangroves apple* and *white mangroves* have developed specific structures called: **Pneumatophores** → **are vertical roots that from the tree go down inside the sediment to anchorite and then go back outside the sediment to capture the oxygen.** Are root extensions that project into the air outside sediment to collect O2 and oxygenate the underground root parts.

E.g. A 2 m high *Avicennia* can have up to 10.000 pneumatophores

SUMMARY
1. *Rhizophora: r*oots which leave the tree up to 2 m from the ground to absorb O2 + most of them have also an aerial roots that start from the top, like branch
2. *Avicenna*: the roots system have pneumatophores emerging every 15-30 cm from the horizontal roots
3. *Bruguiera*: roots periodically break the soil surface during growth producing '**KNEES**' above sediment surface through which air is taken through lenticels

In the same plants, e.g. *Avicennia* have all of these 3 types of roots, Aerian roots, horizontal roots, vertical roots… to anchor to obtain nutrients and to obtain O2.

Figura 6: Avicenna

Figura 7: Rhizophora

Figura 8: Bruguiera

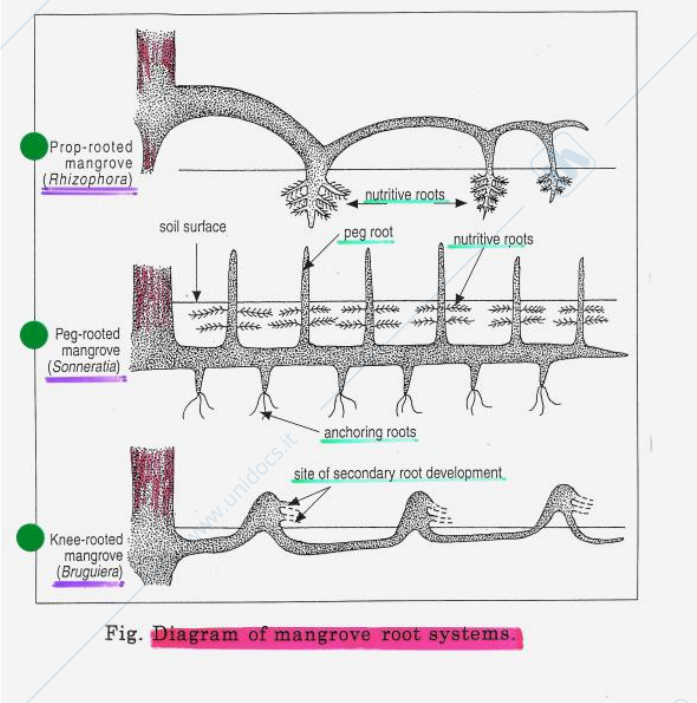


Fig. Diagram of mangrove root systems.

2 - Dealing with High Salt Levels (to exclude salt the mangroves…)

- Reducing of salt uptake by roots due to an **ultrafiltration system in roots** : in the roots they have a system that remove part of the salt present in the water
- **Salt glands** (in the surface below of the leaves) that secrete salt from the leaves
- **Translocation of the salt in the older leaves** that soon will fall down, they are able to cumulate the salt in the leaves that as soon as possible will be lost
- Develop special glands that can concentrate the salt solutions even 20-fold higher than the seawater
- **Accumulation of Na^+ in vacuoles**
- **Using the osmolyte to maintain osmotic and water potential**

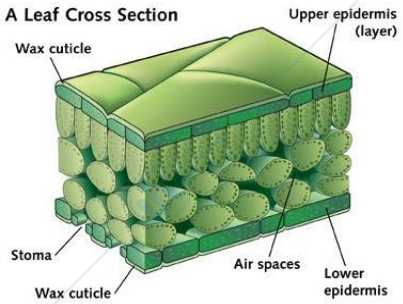
The habitat is anoxic and full of salt… Due to the osmotic difference, is difficult for mangroves to take up water, in general they take up water less easily than other terrestrial plants… Great salinity differences between root and sediment → Difficult in taking up water!! THEY HAVE TIO REDUCE THE OSMOTIC DIFFERENCES BETWEEN THE 2 COMPARTMENTS are able to this **increasing the root biomass** (usually a mangroves tree has more than 2-3 times the biomass of the whole plant). In fact there is a grater proportional **root biomass** compared with the rest of the plant to enable water uptake when salinity is high.

This ratio between above and below part of the plant increase, increasing the amount of the salinity of the sediment

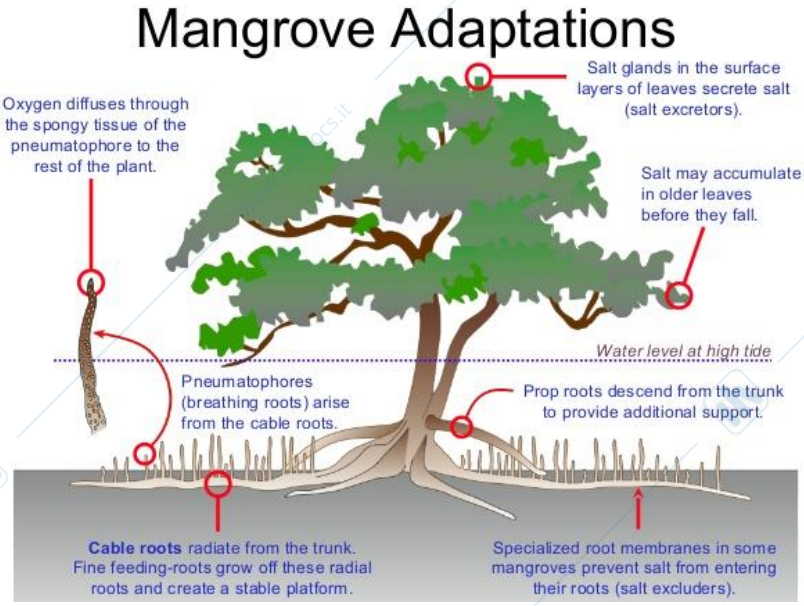
- > Salinity of the sediment, > will be the above: below ground ratio, so > biomass of the roots because they face difficult in the water due to the osmosis
- The additional growth of the roots restrict energy being put into vertical growth and reproduction, so they **are not so high as the terrestrial trees** because there is the problem of salinity and use the energy to increase the biomass of the roots, instead to became higher as the terrestrial trees do

3 – Water conservation (they must face the water loss due to the evaporation)

- Due to the high evaporation rate, they have adaptation to reduce the loss of water because they live in hot countries
- Thick and succulent leaves to accumulate water
- The epidermis is covered by a **thick cuticle** (the seagrass lost quite completely the cuticles)
- Stoma are sunken and usually confined to under face, in the internal part, they are not directly in the surface of the leaves (above surface), to avoid the loss of water
- Mangrove leaves are held at almost vertical orientations when exposed to full sunlight, 12:00 (up to 75° from horizontal), which corresponds to a projected area of 10 %. reduce the amount of light that can be absorbed by the laves.



All these morphological and physiological adaptations are summarized in this picture

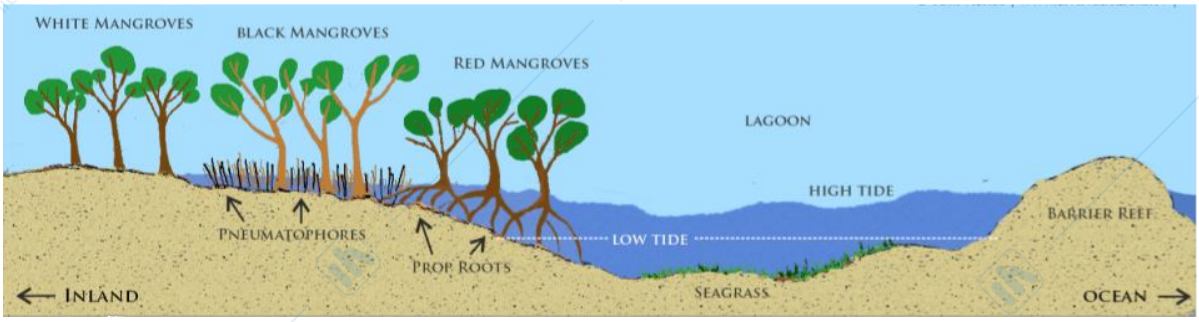


7.2 - ZONATION

There is a clear zonation withing the mangroves ecosystems
Mangroves forests can be divided into a series of **zones with different species dominating with increasing distance from shoreline:**

- Subtropical forests: may have only 1 mangrove species
- Tropical forests: many species zoned in abundance

1. **Red mangroves**: are also called the fringing mangroves, are the pioneer species: Rhizophora are founded in the **sea edge** because are the first that colonize the area. The roots system is huge, it can tolerate full-strength seawater and tidal inundation. They have the higher ability to anchorage the mangroves into the sediment, where there is a higher wave action, they can tolerate this condition. Also during the high tide the tree is elevated, they aren't completely submerged by the water because the root system is very high, so create a step, an elevation; → called **PROP ROOTS**
2. **Black mangroves**: Avicennia is the second species of mangroves that we can find, they have **PNEUMATOPHORES** and are located in the **mid swamp**, the roots can roots tolerate only occasional inundation (only during the high tide: if I put the black mangroves in the zone where there are the red mangroves, during the tide the pneumatophores will be completely submerged by the water and the plant will not be able to breath, so they move a little bit to the land).
3. **White mangroves**: they stay distant from the water, they are rarely inundated by water, are in **landward position** prefer sediment less waterlogged.

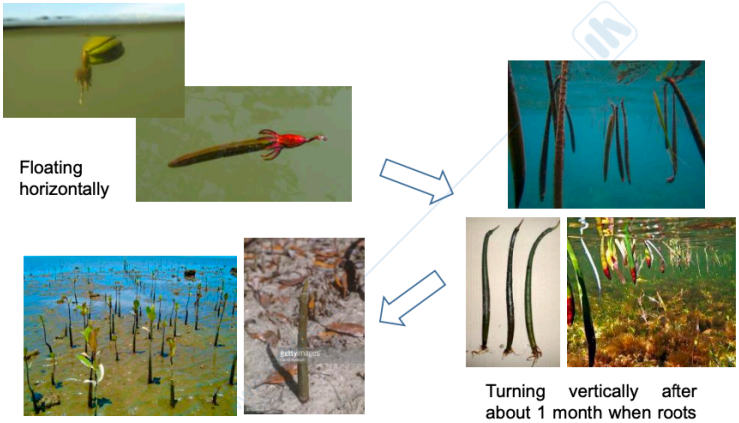


7.3 - REPRODUCTION

- All the mangroves species produce **flowers** and reproduce by **sexual reproduction (flowers, fruits, and seeds)**
- *THERE ISN'T THE ASEXUAL REPRODUTION, but only the sexual one*
- **Pollination mainly occur by animals (Bats** especially for the genera Sonneratia, **Birds, Butterfly, Bee**), is not a hydrophilic pollination (through the water such as the seagrass), but the normal pollination as in the territorial one.
- Some plants, Rhizophoraceae, can be impollinated by wind, not by the water or by the animals

Most of the mangroves demonstrate **VIVIPARY** (the seeds germinate when they are still attached to the mother plant instead to falling down and develop)
In the image there are all the stages of the development from the propagules to a new plant

- Following impollination the growing embryo remains on the parent plant for several months
- The young plant does not leave the adult as seed or fruit but as a fully developed seedling known as **propagule** (is the little plant), when it is ready, the propagule drops directly in the, FLOATING HORIZONTALLY, is carrying by the current and the wind, starts to develop when it find a suitable area, grow the roots, acquires a vertical position after about 1 month when roots start to develop, anchors the roots during the low tide and creates a new plant with the acquisition of a NEGATIVE BUOYANCY.



7.4 - ORGANISMS ASSOCIATED WITH MANGROVES – TERRESTRIAL

- One of the most important function of the mangrove forest is to provide habitat for other organisms, plants, animals… the plants are terrestrial, not aquatic (no other mangroves)
- **Non-woody plants**, no trees in the marine section of mangrove forest
- **Ephiphytic species** are common → they are mainly non woody, but live on the surface of plants
  - Bromeliads
  - Mistletoes
  - Orchid
- Many **insects** (ants, termites, mosquitoes, and caterpillars) that graze (eat) on the leaves of mangroves *reducing photosynthesis, growth, and reproduction* of the plans
  e.g. The beetle *Coccotrypes rhizophorae* is a key predator of new settling mangrove propagules of the genus *Rhizophora*
- **Reptiles** and **amphibian**, vertebrates terrestrial organisms that have developed exceptionally high tolerance to high salinity water, the frog *Fejervarya cancrivora* is eaten by crabs

- **Birds** use the mangrove for nesting, feeding and as a roost at high tide → there is a great variety of birds that live on the mangrove forest:
  - Kingfisher
  - Heron (widespread in all the mangals)
  - Storks
  - Ibis
  - Eagle
  - Cormorant

They use the mangrove for different proposes: **FOOD** (eat flowers, insect or little fish that live within the mangrove system: are called nectivores), **TO STAY IN A GOOD POSITION TO SEE THE PREDATORS**, so they have niche separation due to different trophic habits: nectarivores, insectivores, piscivores

7.5 - ORGANISMS ASSOCIATED WITH MANGROVES – MARINE

- **Sessile** fauna attached to submerged part of the roots (create a community called '**fouling community**'), the roots are very important, they provide a hard substrate for the attachment of the organisms in an area where there is only send (soft substratum).

The community is very rich:

- Particularly rich and diverse, mainly invertebrate and seaweeds
- Incredibly variable on composition over short periods (1-2 months) due to perturbations, due to the tides ***there is not a stable equilibrium among species*** (the climax is difficult to be reached, the things change very often)
- The community (that encrusts the lenticels) can impact the fitness of the mangrove → negative effect → due to smothering effect → stop gas exchange and the absorbance of the oxygen)

Sponges, ascidians, anemones, barnacles, sea squirt

- **Vagile** fauna that move **above** the water line, they are:

  - Mostly detritivores or grazers organisms
  - Move from leaf to roots, to sediment → they move vertically on the plants

E.g. *Snails* is one of the most abundant group that live in association with the mangroves:

Littoraria: (most abundant genera of snails), within this genera there are different species that show distinct niche separation → some species show daily vertical migrations in order to avoid being submerged, varying the diet as they encounter different habitats

Terebralia palustris: show ontogenetic change in diet (they change the diet during the different stage of life) → The young feed on detritus, whereas the adults graze directly on mangroves leaves once their radula has metamorphosed to be able to penetrate the leaf surface (the feeding apparatus change and metamorphosize according to the stage of the life)

- **Vagile** fauna inhabiting **burrows** within the mud:

  - They create and live the BURROW within the sediment (but can pass time out of the burrows)
  - There are 2 different categories of organisms: **MUDSKIPPERS FISHES**, **CRABS** (with the snail are the most abundant mangroves associated organisms)

1. Mudskippers (strange fish)

- They belong to the family of GOBIDI
- There are 3 different genera of mudskippers: *Periophthalmus, Boleophthalmus, Scartelaos*)
- They have strange eyes that allow them to have an excellent eyesight, for this reason they are called also *PERIOPHTHALMUS* (thalmus is something related to the eye)
- Are more active during the low tide, while during the high tide they stay in the burrows

- They have an **amphibious behaviour**; they are **tolerant to the exsiccation** (cutaneous air breathing → they acquire O2 also through diffusion) living in water-filled burrows that emerge as the tide drops. Can stay 2-3 days without oxygen because they are able to capture it by the skin, the cute, through diffusion. In addition of this behaviour they are also able to retain inside the mouth big bubbles of air, water, used to breath.
- They are also capable of **''walking''** across the mud surface using modify pelvic and pectoral fins
- Most are omnivores but some are specialized in term of diet

MUDSKIPPERS' BURROW is a clever structure

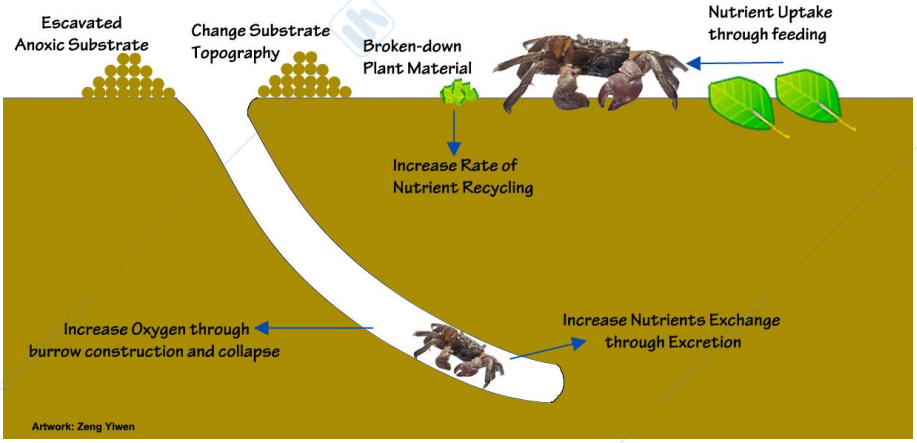
- In the upper part of the burrow there is a high amount of O2, then it starts to decrease going down
- In the **deeper breeding chamber there is no oxygen** (is less than 3%) → they release the eggs and lay them attached to the upper part of the breeding chamber, they can oxygenate the eggs because before entering the burrow, the fish fills its mouth cavity with air and transports this down the burrow, they release the air that go on the surface, but is stopped by the breeding chamber, so the eggs are oxygenated → *air released and trapped in the burrow provide an O2 reservoir for the fish and develop embryos that are laid on the roof of the chamber*
- There is a competition among the males of mudskippers for the female

2. Crabs (most abundant mangroves associated organism)

- The most important, abundant, and diverse group of mangrove fauna
- They have a major impact and influence on the whole functioning of the mangrove system, modifying, maintaining, and creating habitat **(ecosystem engineers in the mangrove ecosystem)** → they directly or indirectly are able to modulate the availability of the resources and habitat for other species
- In particular, they have major impact in sediment and detritus dynamics creating the burrows
- 2 main families of crabs are dominant in the mangrove ecosystem:
    - **Grapsidae** (genus: *Sesarma*) → have the most important role in terms of the functioning of the mangrove ecosystem. *Sesarma messa* feeding on mangrove leaf
    - **Ocypodidae** (genus: *Uca*) → *Uca lactea* feeding on a dead crab

2.1 Crabs – Grapsidae

- Sesarma crabs have the rare ability to utilize *mangrove leaf litter* as a prime food source despite its apparently unpalatability due to the presence of tannin in the mangroves leaves
- Some species (*S. messa*) are able to make daily vertical migration up mangrove to graze on live leaves
- Other species store leaves within burrows
- *Important burrowing activity* **(→ bioturbation)** which can influence the chemical make-up of the sediment and subsequent forest productivity → they create a lot of burrows → Crab activity is key to the healthy functioning of mangrove forests through **recycling of organic material**. With the bioturbation and the creation of the burrow, they allow the O2 to oxygenate the bottom part of the burrow where the oxygen is low, also increase the nutrients exchange through the excretion into the sediment → affecting chemical and physical characteristics, for this region they are ecosystem engineer



7.6 - MANGROVES FUNCTION AND SERVICES

They are important from an economical point of view

- They act as coastal protection system
- They host an incredible biodiversity
- They host a lot of fishes or palatable invertebrates (important for the fisheries)
- For tourism
- For wood (timber and fuel)
- For carbon storage (doing the photosynthesis)
- For the water purification

Physical functions

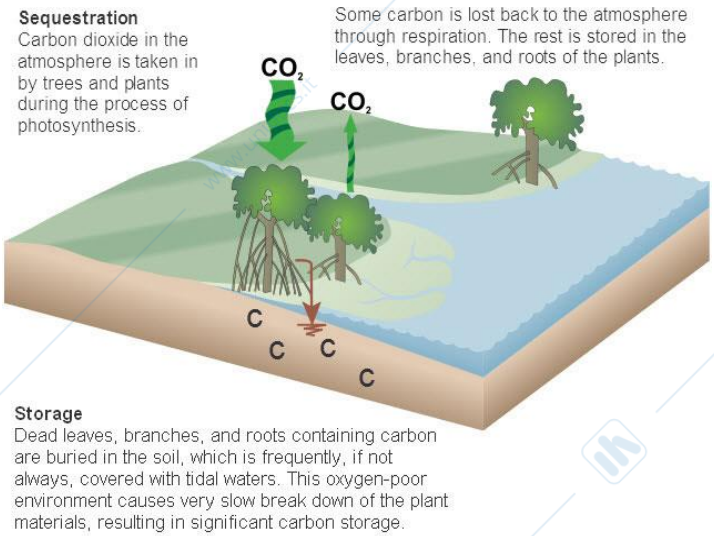
- They have **BUFFER FUNCTION**: protect inland areas from tides and major events: storms, hurricanes
- **BARRIER to coastal erosion** processes
- Reduce the amount of sediment washed into the coastal region **(decrease turbidity**) because they entrap the sediment into the roots
- Pollution control (**filter against pollution**), retaining dissolved nutrients (N and P) before reach ocean
- Article → *During the Tsunami of 2004*, India, the south east areas of India, where the mangroves has been removed due to human activities, suffered more damage than other areas where the mangroves still alive

Biological and Ecological functions

- Primary producers in complex systems where higher plants generally cannot live
- Provide shelter to many species → within the roots system, many species live
- Serve as nursery spots → some species tent to spend the first stage of the life among the roots to stay protected, than they move to the open ocean
- Provide recruits for coral reef systems → because the roots represent a hard substratum
- Increase the general biodiversity
- → they support an incredible **FOOD WEB/FOOD CHAIN**

Carbon sequestration and storage

- The Mangroves are **carbon sink**, thanks to the big roots apparatus
- Mangroves and their soils are the 2° largest repository of terrestrial sequestered C after tropical forests → ROOTS, DEATH LEAVES, BRANCHES contained carbon, **they contribute significantly to the global carb cycle**



Anthropogenic services (for people)

- Provide wood
- Provide food and medicine resources
- Recreation / Tourism

7.7 - IMPACTS OF MANGROVE FORESTS

In just the last decade, at least 35% of the world mangroves has been destroyed → the rate of loss exceeds the disappearance of tropical rainforest (**high lost rate**)

1 - Anthropogenic activities

- Dredging
- Coastal development
- Industrial activities

2 - Global warming and global climate change (mostly related to humans)

- Hurricane and storms
- Global warming (some papers suggest that mangroves produce a maximal shot density when the min T of the air doesn't exceed 30°C)
- Sea level rise (they live just in the intertidal zone, so are strongly affected by the change in tide)
- Reduction of precipitation in tropical area (→ increase of the salinity of the water and the sediment)
- Ocean acidification

3 - Shrimp farms (caused by the humans activities)→ the largest loss of mangroves is due to the establishment of shrimp farms. Hectares of mangroves are removed to create basins for the shrimp farms. This activity is mostly developed in Asian countries, (Thailand, China, India, Indonesia, Philippines).

Direct impacts: because we destroy the habitat

- Loss of mangrove habitat and coastal protection
- Loss of the associated biodiversity
- Loss of feeding areas, nursey area, shelter area, reproduction area

Indirect impacts:

- Change in hydrology and sedimentation rate of the habitat
- Saltwater intrusion that cause damages to adjacent, terrestrial areas (es. rice field)
- Diseases diffusion in the sea (bacteria, fungi…) due to the introduction of fertilizers
- High load of organic matter and fertilizers (N, P, BOD)
- High load of antibiotics then released to coastal waters

PROBLEM: The **shrimp farms** are efficient for few years, not for all the life in fact **after 10 years they can't be used anymore, they became abandoned** → the cost to replace, return to the original habitat is too high.

7.8 - MANGROVE RESTORATION

There are different groups and volunteers that are trying to restore mangroves. Usually we start with the **propagules or seeds**, as with the terrestrial plants, put them in a special structure and wait the recovery.