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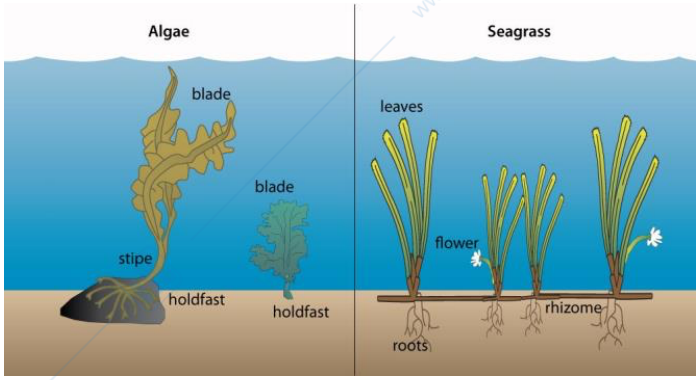
5.0 - SEAGRASS MEADOWS

All plants can be divided in vascular and not vascular plants (depending on the ability to have vascular tissues to transfer nutrients) with vascular tissue for the transporting of water and nutrients. The vascular plants are the majority plants on the earth, can be divided in 2 sub categories: vascular plants that don't produces seeds (= FERNS) and vascular plants that produces seeds (= ANGIOSPERMS if they produce flowers and fruits, GYMNOSPERMS, e.g. pine, don't have flowers of fruits, but the seeds are groped in structures, as the pine cone)

- **Marine angiosperms monocotyledon** (flowering plants), PLANTS fully submerged in the saline medium, they are able to produce FRUITS and FLOWERS. They are monocotyledon because when the embryo develop, from the embryo only one leaf exit from its (if are 2 or more, the plant belong to the dicotyledon)
- **Vascular plants** (contain structures with vascular tissues for transporting of water and nutrients)
- The only angiosperm fully adapted to live and complete the whole life cycle **entirely submerged in salt water**
- In the shallow coastal waters, lagoons, bays, and estuaries (but never in freshwater) and colonize soft sediments because they have roots (e.g. send). We cannot find them in great depth because do the photosynthesis, they need light
- They have a worldwide distribution; we can find them in different latitudes
- Seaweeds VS Seagrass



ALGAE VS **SEAGRASS**

Undifferentiated whole structure which performs the same functions (= thallus)	Differentiated tissues and organs that perform specific functions
Holdfast used only for anchorage, don't have roots	Complex system of roots for anchorage and extraction of nutrients and gas
Chloroplasts are present in the whole thallus	Chloroplasts are present only in the leaves
Acquisition of the minerals and nutrients by diffusion (from the water)	Acquire nutrients from the water, sediment, are able to transport nutrients and minerals by the vascular tissue (xylem, phloem)
Reproduction with spores	Reproduction sexually with flowers, fruits and seeds because they are angiosperms, mostly they reproduce asexually

5.1 - MORPHOLOGY OF THE SEAGRASSES PLANTS

- They are modular plant composed by several modules call **RAMETS**, they are all clone
- **All ramets are clones because they start from the same point called RHIZOME** → we have different plants linked by a unique rhizome, is a horizontal roots, under the sediment
- The entire plant is a unique and genetically identical clone (**GENET**) → is the whole plant, so different plants connected by the same big, longer rhizome, instead a single unit is the ramet
- The distance between two node along the rhizome is called **INTERNODE**, each **NODE** is the point from which the plant start to develop vertically (starting from the rhizome)

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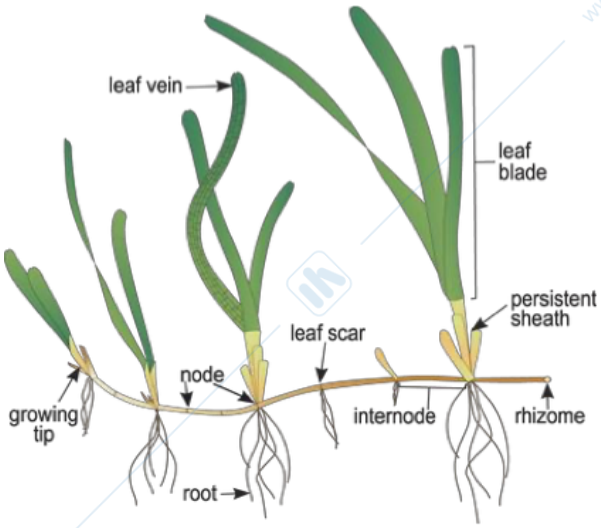
- The **LEAF BLADE** is the only thing that we can see swimming in the water, is the visible part of the seagrass
- Sometimes we can see the **PERSISTENCE SHEATH** → is a structure characterized by the oldest leaves, when the leaves die, they create a base, this sheath, 'guaina fogliare'
- They are characterized by **LEAF VEINS**, the vascular tissue



RHIZOME

- Is mainly horizontal, but can be also develop vertically
- **IS THE PERMANENT AND STABLE PART OF THE SEAGRASS**, REMAIN FOR DECADES ALSO IF THE PLANT DIES
- In general the rhizome is a very long structure
- It can remain intact burrowed inside the sediment even if the plant dies

Horizontal rhizome

- Is very robust, composed by wood and in same case can be herbaceous
- This part of the seagrass is used to anchorage the plant to the sediment and to favor the propagation of the colony, of the genet, so the rhizome is fundamental for the asexual growth of the plant → Horizontal growth creating extensive and dense underground networks allowing lateral spread (**seagrasses beds or meadows**)
- High biomass (60-80% of the total)
- The primary means through which the vegetative propagation occurs (asexual growth)

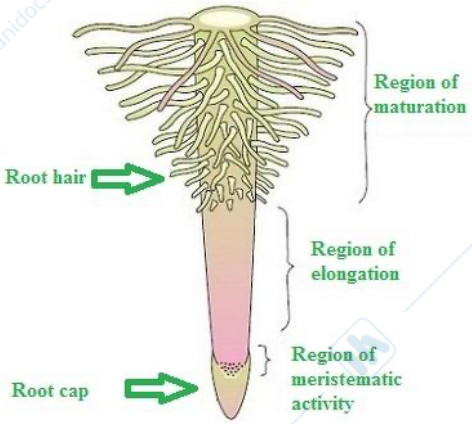
STEM (vertical rhizome) …

sometimes same species have a horizontal rhizome and a vertical one

- Is woody, but more flexible and adaptable to water movements, otherwise if can be broken by the waves
- Can allow the vertical growth, not only the horizontal one
- Prevents burial → the covering of seagrass by sedimentation
- Useful for the anchorage, for the asexual reproduction and in the gas exchange

ROOTS

- The roots grow from the bottom surface of the rhizomes or from the basal portion of each bud, of all each little plants
- Woody or threadlike and delicate, thinner than the rhizome
- Branched or simple
- Similar structure of the terrestrial plants roots, with **hair roots** (to increase the amount of nutrients absorbed, the surface area of the root) and **root cap** (called also CALIPTRA, is present also in the terrestrial plants and is useful for the gravity perception because contain particular cells, statocysts, protection, movement through soil and communication with microbiota, also to maintain the vertical structure of the root*). If we remove the root cap, it starts to grow not vertically, but randomly*. Is able to *secrete mucilaginous liquids* to allow the penetration of the roots inside the sediments



- The functions of the roots are: To anchoring the plants, to absorbed nutrients and mineral salts
- Some seagrasses have symbiotic nitrogen fixing bacteria in roots → is another important function of the roots
- Another important function of the roots: Gas exchange → usually they live in anoxic sediments, so the oxygen have to be transported from the leaves (where the photosynthesis occur) to the roots and allow the root respiration → the roots allow the OXYGEN RELEASE

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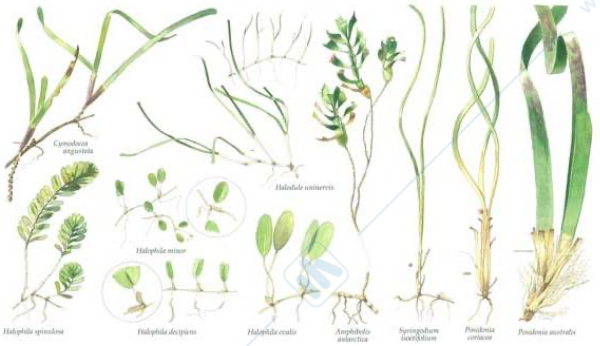
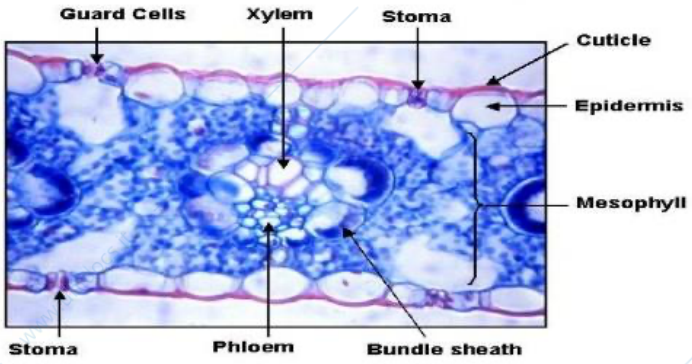
LEAVES

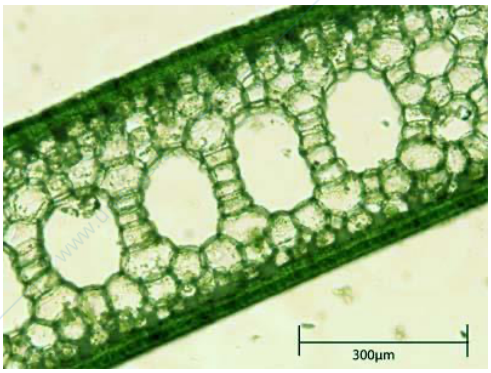


Zostera caulescens up to 5 m (Japan)

- Represent the part of the plant that can be affecting by the environmental conditions, are not persistence over all the time → **ARE NOT STABLE OR PERSISTENCE** VS rhizome… they can be replaced as the terrestrial leaves
- Different morphologies and sizes
- The top of the leaves can be different: Top rounded or pointed or cut off
- *The youngest leaves are internal and protected from older that are longer and bigger.*
- They are very flexible and resistance because they have to adapt to the currents and waves, mover they are full of little veins for the transportation of the nutrients and the O2 from the leaves to the roots
- Different species of seagrasses can be distinguish looking only one leaf and analyzing its → usually we use the leaves to classify the seagrass
- *Chloroplast are not present in all the structure, as the seaweeds, but they are located and confined in the leaves*, in fact the most important function of the leaves is the PHOTOSYNTHESIS: have photosynthetic function and absorption of nutrients by diffusion
- All the seagrasses (except *Halophila*) have **leaf sheaths** (IMAGE made by old leaves that when they die, they detach become woody) in order to protect the younger leaves.
- Many parallel veins, very thin and which does not lignify (are not like the veins of the terrestrial leaves)

DIFFERENCES BETWEEN A SECTION OF A TERRESTRIAL MONOCOTYLEDON AND A SEAGRASS (MARINE MONOCOTYLEDON)





- The leaf blade of the seagrass has lost or reduced the cutin layer, called **cuticle** (**thin cuticle**) to facilitate the diffusion of ions and carbon VS in the terrestrial monocotyledon the cuticle is made by wax (cera) and has protective function, in particular a hydrophobic function to minimize the water loss
- **No stoma and guard cells in the seagrass**, instead they are present in the terrestrial monocotyledon for the photosynthesis and allow the movement of the oxygen and the CO2 → the stoma are pores that allow the O2 to enter, the opening of the stoma are organized and regulated by cells called guard cells
- In the terrestrial monocotyledon the chloroplast are mainly located in the mesophyll → **No chloroplasts in the mesophyll in the seagrass,** they are located in the epidermis that is the principal site of the photosynthesis.
- The **epidermis** of the seagrass has a single layer of cells with chloroplasts, many mitochondria and a plasmalemma (cell membrane) invaginated to increase the exchange surface
- In the mesophyll of the seagrass is present a hole, in the middle of the image, is a sort of channel and is called **lacunae**. They create these specialized parenchyma (called **aerenchyma**), typical of the seagrass located below the epidermis, it is crossed by air channels (also with hole, lacunae) along the length of the leaf blade → in the seagrass the lacunae are useful for the gas transportation from the leaves till the roots. For this reason the leaves are vertical, and they don't fall down (are full of air). The aerenchyma with the lacunae is present in all

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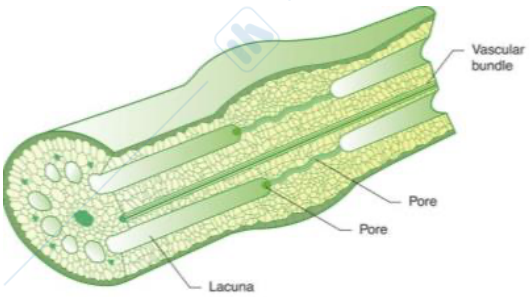
the structures of the seagrass, not only in the leaves, but also in the rhizome and in the roots. Is considered the most important adaptation of the seagrasses

ADAPTATIONS – ANATOMICAL AND PHYSIOLOGICAL

AERENCHYMA

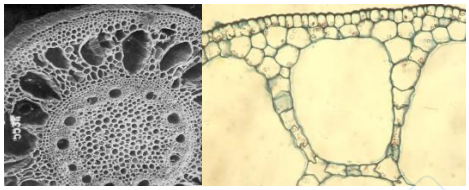


- Is the most important adaptation of the seagrass
- Is present in all the plants, is a *continue system of gas transport*, so no liquid are contained in the lacunae because they are full of air and block the water entry
- Aerenchyma in a cross section of a stem and rhizome. The large air spaces (**lacunae**) let oxygen down into the roots

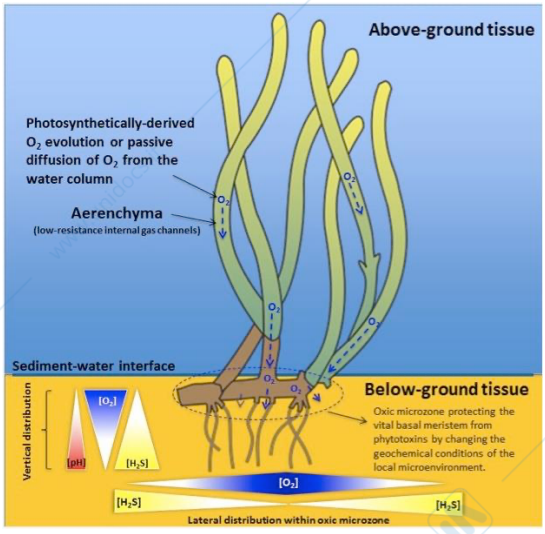
Is use for:

1. Gas transport (no liquids are contained in the lacunae)
2. Buoyancy
3. Block the water entry

If I put air inside the rhizome, it will go everywhere in the plants, is all connected in term of gas diffusion, not liquid diffusion



ADAPTATION TO ANOXIA



- The substrates where seagrasses are living are often **anoxic** due to the decomposition of organic matter inside the sediments, but thanks to the **aerenchyma**, this is a minor problem for the seagrasses
- the roots act as reserves of oxygen that comes from the leaves through the photosynthesis, where it is produced, and is transported through the rhizomes through the lacunae
- Oxygen accumulated in the roots and rhizomes is used in the plant metabolism or is important also for the microflora of the rhizosphere, the bacterial fauna that live within the roots and close to the rhizosphere, important to increase the nutrients uptake by the seagrass

→ the pH of the sediment change depending on the presence of seagrasses

ADAPTATIONS – REPRODUCTION AND GROWTH (both)

- **SEXUAL** → sometimes some species of seagrasses produce flowers, fruits, and seeds creating new genotype, new plants that will grow from which rhizome will produce again when seagrasses, however the sexual reproduction of the seagrass is very rare, not all the species do this and can change across the areas.
- **ASEXUAL** → called also **vegetative propagation** or **stolonization** (new ramet develops laterally from the pre-existing rhizome node), is the most widespread reproduction system which occur continuously, new ramets develop laterally from the preexisting rhizome node

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SEXUAL REPRODUCION OF THE SEAGRASS

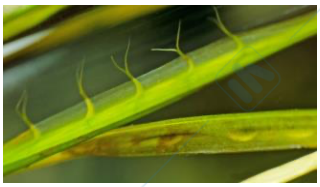
FLOWERS

- Dioecious → produce male and female flowers on different specimens, plants (70% of the species). These species require a partner for pollination, they are like gonochoristic species. E.g. *Enhalus acoroides*
- Monoecious → have both male and female flowers on the same specimen, plant, so they impollinated themselves. E.g. *Halophila decipiens*

- In general the flowers are originated from the nodes of rhizomes
- The flowers are usually small and white
- Stamens and pistils extend above the petals to encourage pollination, are very long, visible and easy to be reached by the pollens
- Flowers of some genera, e.g. *Posidonia* are showy and apical, lie on top of very elongated stems to make them very visible
- Flowers are produced seasonally (are not always present as the terrestrial plants) and is generally controlled by temperature, which facilitates simultaneous flowering of the same species across wide areas
- Different flowering period among species
- Great variability between years
- *Disturbance and stress enhance sexual reproduction* (intertidal > subtidal species), they represent an advantage for the sexual reproduction because they note that the intertidal species (subjected to high stress) have a higher sexual reproduction rate than subtidal species that are always submerged and don't have to face to stresses and disturbances
- Flowering is a relatively rare event in seagrass beds

STRANGE FLOWERS

Zostera marina; female flower styles, half covered by a sheath. A few developing seeds on a lower blade. Are more similar to appendix than flowers because are not colorful



5.2 - POLLINATION

Pollen grains:

- They have a considerable size (2 mm) more than the terrestrial ones
- they are water repellent and gelatinous
- they are filamentous and elongate
- they are specialized to stick to the appropriate target

Pollen release by sea grass, *Z. marina*

There are no organisms involved in the pollination

- **Hydrophilous pollination** → Pollen is released directly into the water column (not on the surface) where it is dispersed by currents and floats until encountering a receptive stigma (in the female flower), fertilizing female flowers (most common). This Hydrophilous pollination is the most common way for the reproduction in the water, but sometimes, some species use…

- **Surface and subaerial pollination** → Pollen is released and dispersed to the surface (e.g. *Enhalus acoroides*), the pollen is released in the water column but reach the surface, it moves and sink down to reach the female stigma. So this pollination is regulated by the tide cycles. *Enhalus acoroides* is a seagrass located mostly in the south east of the Pacific Ocean, can reach 1m high, has a long peduncle, the flower is located at the end of this peduncle that allow it to move to the surface of the sea, then it releases on the surface of the sea a lot of white pollen grains, they float, are transported to the currents creating this phenomena called seagrass snow.

Seagrass flowers could be pollinated by invertebrate animals??

There are evidence that suggest that some animals can transport the pollen to the seagrass flower but are not supported by scientific data.

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FRUITS AND SEEDS

Seeds depending on the dispersal ability, we can classify the fruits in 3 different types:

- **Achenes →** (e.g. fruit that *Zostera marina* has)
  - Dry fruit
  - Contain only 1 big seed that represents more or less the fruit → fruit and seed are the same structure
  - Seeds possess structures that enhance buoyancy to increase dispersion. These fruits show the greater dispersal ability, also can reach area far max 8m from the origin.

- *Enhalus acoroides* fruit **Globose Drupe →** is a fleshy fruit containing only 1 seed, VS for the achenes the seed is the fruit, in this case the seed in contained inside the fruit. This fruit has an intermedial dispersal ability

- *Halophila decipiens* **Globose fruit →** this fruit contain a lot of seeds, not only one, but multiple little with negative buoyancy seeds that are not able to be transported by the currents. Then they fall down and so have a low dispersal ability.

Other strategies of seeds releasing and dispersion:

- Only 2 genera (*Thalassodendron* and *Amphibolis*) are **viviparous**, Thalassodendron has also a vertical rhizome**, stem**
- Are Viviparus, so the seeds develop and germinate attached to the mother plant before leaving the mother plant and produce roots to anchorage

Other strategy

- *Posidonia oceanica* : sometimes shows **free floating fruits**: the fruit are detached from the mother colony, not the seeds, the fruit colonize new habitat travelling and releasing the seeds later
  The fruits, and not the seeds, colonize new habitat before releasing seeds
- *Posidonia oceanica* : other time shows **pseudo vivipary**: there is a meristem that normally developed into a flower, but in this case of pseudo vivipary the meristem create a vegetative bulb, plantlet, this bulb soon will detach from the parental plant, form the roots, anchoring into the soil and creating new plants. They don't produce flower, but bulb, like little propagules, plants. Are created by asexual reproduction. *Asexual propagules, such as bulbils or plantlets, replace sexual reproductive flower structures*. Then the bulbs create the rhizome and the root in order to anchorage themselves to the sediments.

The survival of both fruits and seeds is very low in the seagrasses, is less than 1% of the new hotspring, the sexual reproduction in seagrasses is very **inefficient**, in fact is very rare, **is not convenient to spent too much energy for this activity, since the survival rate is very low.**

ASEXUAL REPRODUCION OF THE SEAGRASS

ADAPTATIONS – VEGETATIVE REPRODUCTION AND GROWTH

- **Vegetative reproduction and clonal propagation is the major method of seagrass meadow survival and expansion**, is the widespread method → *starting from the same rhizome, new plants will grow laterally, new ramet will be created, are all clones,* the horizontal growth shows different rates depending on the species…
- **Horizontal growth rates** vary considerably between species and appear related to the rhizome diameter of the seagrass (the thickness of the horizontal rhizome) → there is a negative relationship between the rhizome diameter and the horizontal extinction rate occur. Species with small rhizome diameter can spread more rapidly compared to species with big diameter and bug rhizome, e.g. Halophil ovalis or Lalodule wrightii

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can spread more rapidly and they can grow horizontally up to 5m per year, they have a rapid, aggressive growth, so are used as pioneer species to recolonize damage areas as a restoration.

- **Leaf growth** depending on the season in temperate species, the tropical species are not affected because there is a seasonality. is highly seasonal in temperate species, relating to temperature and especially light level. **Leaf growth is directly related to production.** Seasonality in seagrass productivity in *Zostera marina* (during summer, the productivity of leaf growth is higher than in winter) . **Peak summer values, 6.5 greater than winter** … so there is seasonality in the leaf growth for the temperate species

  Leaves do not live particularly long (less than land plants) but leaf age varies considerably between species (up to a year for *Posidonia oceanica*) → they are often replaced and when are loss we can find beach completely full of seagrass leaves, as Posidonia:

Balls of fibrous material from its foliage, known as ***egagropili***, wash up to nearby shorelines. When the leaves are lost, they create this balls thanks to the waves, the winds…, is a normal events, change of leaves, as in autumn in the territorial plants. Are leaves with sediments created by the movements of the waves

ADAPTATIONS – GENETIC LEVEL

Changes in gene set respect terrestrial plants to adapt to marine lifestyle

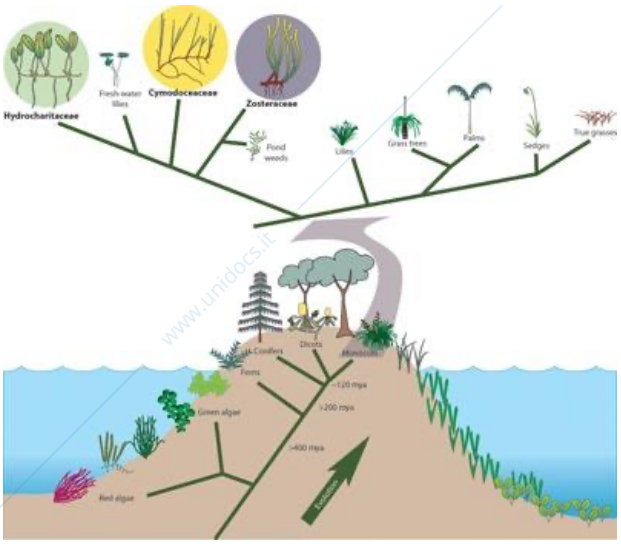
Why they can live completely submerged? There is an adaptation

In a big paper published in Nature in 2016, we can see that: the terrestrial plant becomes seagrasses losing some genes and acquiring other genes. There is a change in gene that involve light for the photosynthesis, a reduction of the genes involved in the defense against environmental stressors… seagrasses are adapted to live in this environment even because they have particular genes that aren't present in the terrestrial plants or because have modify genes.

TAXONOMY AND EVOLUTION

- Seagrasses first appeared in the marine environment around 100 million years ago (the oldest Cretaceous fossils include the genus *Posidonia*).
- **Uncertain ancestor** → There are 2 candidate ancestor, with 2 different hypothesis:

1. Derive from **Coastal plants** (saltmarshes, mangroves) because they:
   - Have lignified stems
   - Are mostly viviparous
2. Derive from **Freshwater plants** that live in freshwater, not salt, because also them have:
   - lacunae (= aerenchyma system as in the mesophyll of the leaves, in the roots and in the rhizome)



Den Hartog hypothesis (1970) propose this hypothesis:

The seagrasses have evolved from terrestrial halotolerant plants (can tolerate high concentration of salt) *that would adapt to the marine environment* → is the most acreditate hypothesis, so they **derive from coastal plants**.

- the seagrasses are **Polyphyletic group**: grouping of organisms with more than 1 evolutionary root form. They don't share only 1 common ancestor, but they have more than 1 evolutionary roots form
- seagrasses belong to the Phylum: *Magnoliophyte* (phylum of the angiosperms that produce flowers m/t)
- seagrasses belong to the Class: *Lilopsida* (includes all the monocotyledon plants with 1 leaf)
- seagrasses belong to the Order: *Alismatales*
- how many Families there are?? Since the develop of technology, scientists are classifying again the marine taxa

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*"Recent work establishes that there are ~ **50 seagrass species** in **4 families** and **12 genera**"*

- Fam. *Posidoniaceae* (include the genera *Posidonia*)
- Fam. *Zosteraceae* (include: *Zostera, Heterozostera, Phyllospadix*)
- Fam. *Hydrocharitaceae* (include the *Enhalus, Thalassia, Halophila*)
- Fam. *Cymodoceaceae* (include: *Syringodium, Halodule, Cymodocea, Amphibolis, Thalassodendron*)
- Some authors also include another family Fam. Ruppiaceae

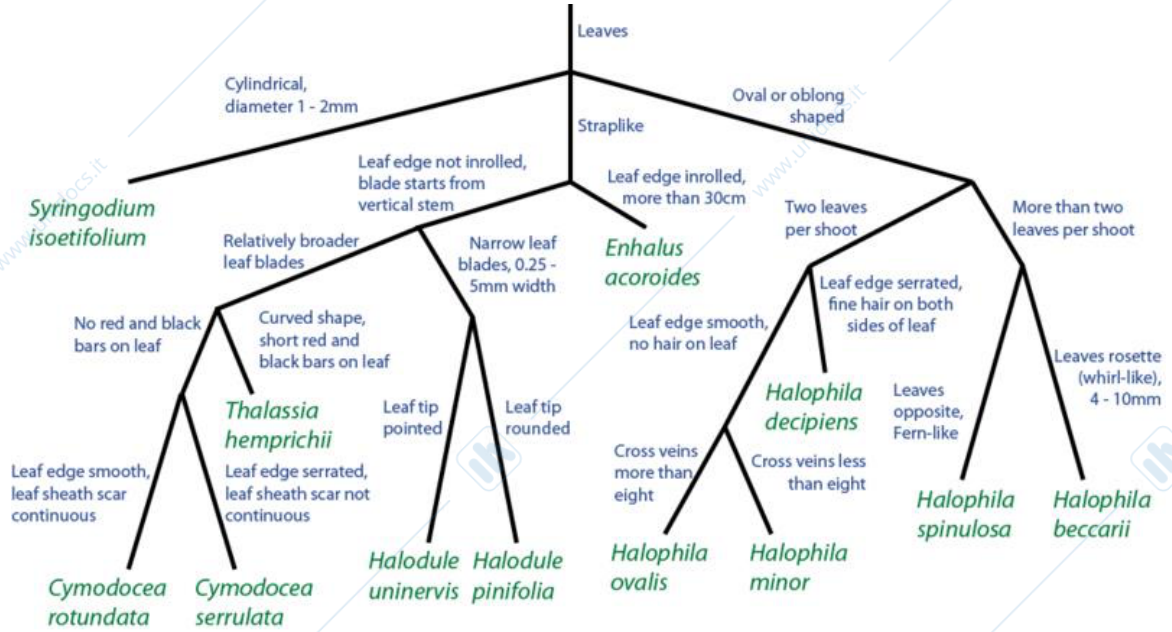
"There are some debate in the literature and between seagrass taxonomists on the details on the correct classification. Dr. Don Les (University of Connecticut) and Prof Waycott (James Cook University), establish this is the best: THEY THOUGHT THAT THERE ARE NOT ONLY 1 ORDER, BUT **2 DIFFERENT ORDERS** → the classification of seagrasses is not so clear

- ***Order**: Alismatales*
  Family: Hydrocharitaceae
- ***Order**: Potamogetonales*
  Family: Cymodoceaceae, Posidoniaceae, Potamogetonaceae, Ruppiaceae, Zannichelliaceae and Zosteraceae "

- The **diversity of seagrasses is very low (only ~ 50 species)**, probably due to the low rate of sexual reproduction and dispersal, they rarely reproduce sexually, so they cannot mix their genetic informations; also because they have seeds that aren't able to travel so much
- The majority of the species are contained in 3 of the oldest genera:
  Zostera** (medium high latitude)*, ***Posidonia** (temperate water, medium latitude)*, ***Halophila (tropical region)
- Seagrasses are exceptionally **plastic** even if are not so plastic as corals, sponges…
- High genetic diversity within meadows, the same patch

How many species of seagrass exist ???

CLASSIFICATION



- Generally the classification of the seagrasses is based on morphological features (shape of leaf margin), **especially on the morphological features of the leaves** (only part that go outside the sediments)
- DICHOTOMOUS KEYS are used to understand which plants we are looking. For each questions we have 2 different reply that will conduct as to the next step until understand which is the species.

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THE MOST COMMON TROPICAL SPECIES (higher biodiversity in the tropical sea), (in the Mediterranean Sea there is only one endemic specie, *Posidonia oceanica*)

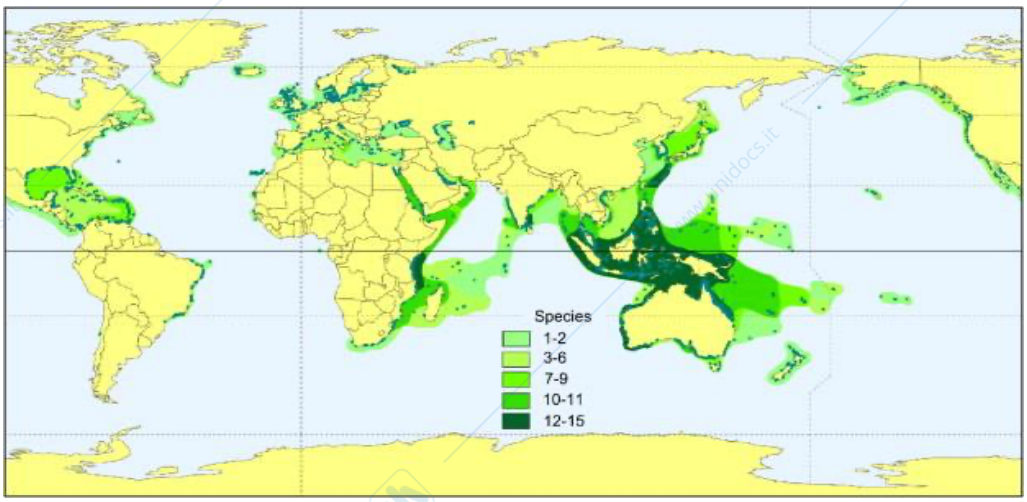
1. *Halodule uninervis*
2. *Halophila ovalis* → with little rhizome and grow very fast
3. *Halophila stipulacea* → similar to the *ovalis*
4. *Thalassia hemprichii* → only one that have cylindrical leaves
5. *Syringodium isoetifolium*
6. *Thalassodendron ciliatum* → have vertical rhizome
7. *Cymodocea rotundata*

Seagrass can form together patches that over the time can cover a lot of m of seabed, they create the MEADOWS, BEDS.

- The seagrasses can form small patches that can develop, forming extensive meadows covering large areas of seabed
  - Spencer Gulf Australia: Seagrass meadow up to 4000 Km2 of coverage, it contains up to 10.000 shoots/m2
- The beds can be:
  - Only 1 species: **Monospecific (only 1 species)**
  - More than 1 species: **Mixed** or **Multispecific (more than 1 species)**
- In sheltered inshore areas it is more common to find **mixed meadows** while, in area not so close to the coast, but at greater depths the meadows are generally **monospecific**
- When the condition are good, they are able to develop and create one of the most extended submarine habitat in the world

DISTRIBUTION

Darker is the color, higher is the biodiversity, the number of species



- **Cosmopolitan distribution** (we can find them both tropical, temperate, and cold regions, except Antarctica)
- Cover approximately *0.1 to 0.2% of the global ocean* (more or less as the coral reefs)
- Higher biodiversity in the Indo-Pacific and Queensland N-E (~30 sp. only in this area).
  Centre of origin for seagrasses?? SEAGRASS TRIANGLE and CORAL TRIANGLE (near Papua New Guinea, north of Australia, Thailand, Indonesia, Malaysia) is the place where there is the major quantity of reefs and seagrass. Higher biodiversity in term of corals, seagrass.
- Mainly in shallow and intertidal coastal areas (bays, estuaries, and lagune of the coral reef), protected by wave action and with clear waters, with a lot of light
- *Zostera* and *Posidonia are two genera that* have a **bipolar distribution** since their areal extend both north and south of the tropical zone (in both the hemisphere)

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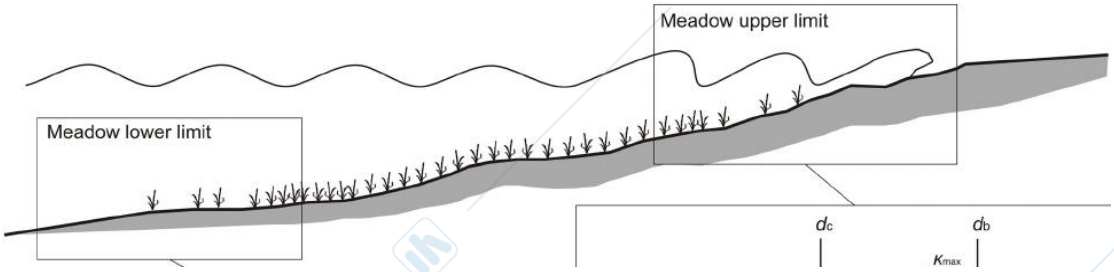
LIMITING FACTORS OF THE SEAGRASS GROWTH:

- **Depth range:** we find them only from 1 to 50-60 m (depending on the area, if there is a clear water, we can find it also at 50m)
- **Upper limit of the seagrass meadows:** shallower depth at which the meadows start to growth. Usually in the upper limit we have low density of seagrass because of the low tide because we have high light that can create damage, photoinhibition.
  Limiting factors that affect the upper limit are:
  - *slope of the seabed*
  - *hydrodinamism*
  - *light level*
- **Lower limit of the seagrass meadows:** maximum depth at which the meadows stop to growth. Also in the medium lower limit we have low density because of low light
  Limiting factors:
  - *light level*
  - *compensation point of the plant* (related to the light)
  - *transparency of the water* (depending on the clearness)

Following the graph below we encounter at first Low density (there is low light, they haven't the possibility to perform photosynthesis with a high efficiency), **then high density** (intermediate level) **and at the and low density** (the low tide exposes the seagrass to the atmosphere, there is too light that damages the photosynthetic system, the chloroplast)



FACTORS AFFECTING GROWTH – LIGHT

- **Light level** is the main factor that limit and influence the growth of the seagrasses
- High light level in order to:
  - Produce high [O2] that is used to transport in rhizomes and roots in anoxic environment
  - Compensate for the lack of some accessory photosynthetic pigments, that the algae or the photosynthetic organisms have and help to absorbed light and perform photosynthesis
- Too much light and UV, especially during low tides, can cause **photoinhibition**
- Related factors to the light are also:
  1. Water transparency
  2. level of pollution and turbidity (contribute to the pollution with the runoff)
  3. presence of rivers (contribute to increase the pollution and turbidity)
  4. human activities
- e.g. Burning seagrass leaves if there is too much light

FACTORS AFFECTING GROWTH – SUBSTRATE

- **seagrasses require SOFT substratum** (sand, mud) that will allow the penetration of the roots
- **No** highly mobile or exposed sediments, which result in burial of seagrasses
- **No** sediments with very high inputs of organic matter, which result too anoxic conditions

Phyllospadix is one of the few species of seagrasses able to live in rocky bottom, is the only genera that is able to grow on hard bottom

- Seagrass presence can increase the sediment organic content: The sediment should not contain high organic sediment because the sediment can be anoxic
- Seagrass presence can change the particle size distribution of the sediment, is called **BAFFLING EFFECT OF THE SEAGRASS**: they reduce the hydrodinamism and they also affect the particle size distribution of the sediment because they enounce the deposition of fine sediments particles on the sediment

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FACTORS AFFECTING GROWTH – SALINITY AND T°

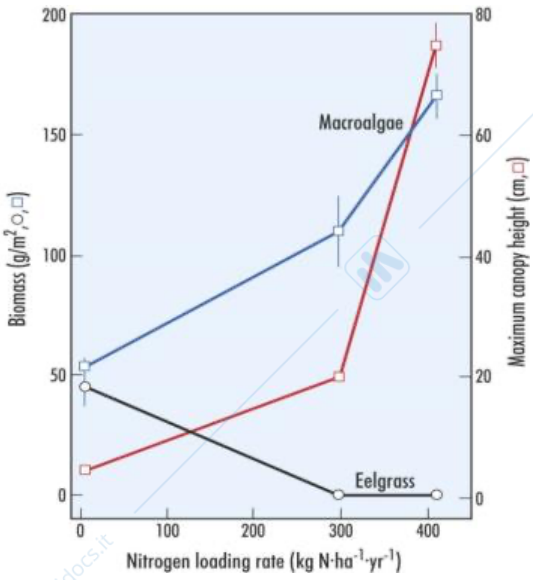
- **Salinity**
  - Optimum for growth and photosynthesis is 34-36 ppt even if:
  - Some seagrasses are **euryhaline** (*Zostera marina*): can tolerate a great range of salinity 4 - 65 ppt
  - Many tropical species are **stenohaline** (can't tolerate great range of salinity
  - Some species records leaves loss and decrease photosynthesis under 24 ppt
- **Temperature**
  - Influence the rate of growth and photosynthesis
  - *Above 35°C there is a reduction photosynthesis and stress which can affect the photosynthetic apparatus*
  - *Above 40°C begins the denaturation of many proteins of plants* (including the enzymes involved in the production of O2 in the PSII), and the block of electron chain → is very difficult to happen
  - *At extreme temperatures* (high even low) *starts the senescence of the leaves* → start to become black or brown because show a progressive aging with chlorophyll loss, the loss of the green coloration)

FACTORS AFFECTING GROWTH – PRESENCE OF EPIPHYTES

- In a biological factor → Presence of other organisms that live of the surface of the seagrasses
- Organisms growing on the surface of plants, which not deriving nutrition from them, don't use them as food, but as support, as space to grow. **Incrusting forms** that cover the seagrass, sometimes all the surface:
  1. Diatoms
  2. Corallinae algae
  3. Macro-and microalgae
  4. Benthic foraminifera
  5. Hydrozoan
  6. Tunicates
- In a seagrass bed the epiphytes biomass can range from 25% to 80% of the total biomass, this represent a PROBLEM:
  - Increase the load on the leaves, causing them to fall
  - Reduces the availability of direct light, nutrients, and CO2 diffusion, lowering their primary productivity
- Seagrasses and epiphytes compete for the light and the space
- *Their abundance is regulated by nutrients availability and other abiotic factors* BUT in term of ecosystem functionality, the presence of epiphytes **is not advantages for the seagrasses**, but create also **advantages for the ecosystem in general**: sometimes they are primary producers (sometimes they are algae) so they increase the level of the production of the ecosystem, increase the level of biodiversity of the system

FACTORS AFFECTING GROWTH – NUTRIENTS

- Growth of the seagrasses may be affected by **the levels of nutrients**, especially **nitrate** and **ammonium**
- Nutrients obtained mainly from the pore waters of the substratum, obtained by the roots
- Some seagrass obtain a portion of their nitrogen by means of *nitrogen-fixing bacteria on the rhizome*



Too high levels of nitrogen can influence the competitive balance between the seagrass productivity and that of algae associated by the meadow and also epiphytes → *with low concentration of nitrogen we have high growth of seagrass and low growth of seaweed* (they compete, so **is better if nutrients are present not in high concentration**), with a high concentration of nitrogen there is a shift in dominance, from the seagrass to the seaweed.

- *Zostera marina* showed a saturation-type response to increasing N level
- Macroalgae continue to grow and can reduce light available for seagrasses

→ Shift in dominance within the meadow (SEAGRASS → ALGAE)

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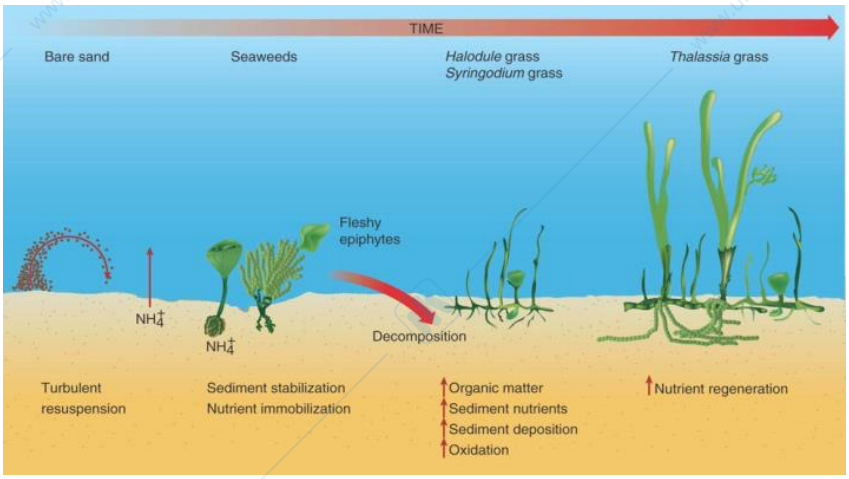
SEAGRASSES SUCCESSION

- A seagrass colonization of a new area after disturbances and succession *can start only if the sediment is already*:
  - physically stable
  - rich in dissolved nutrients
- because this can be accomplished by the presence of seaweeds → seaweeds firstly appear in empty soft bottom, stabilize the sediment with the thallus, and add nutrients in the form of ammonium, after their decomposition. Starting from a **BARE SEDIMENT** and a turbulent resuspension event, **SEAWEEDS** can appear, stabilize the sediment thanks to the thallus and start to immobilize the nutrients within the sediment increasing the amount of nutrients when they will die and decompose. Then after the seaweed the **FIRST SEAGRASS** start to grow, usually *Halodule* and *Syringodium* are the first species of seagrasses that colonize the area because grow faster than the other, are little and are called pioneer species. This species increase: organic matter, sediment nutrients, sediment deposition and oxidation of the sediment creating the field also for more developed and big seagrasses, as **THALASSIA GRASS**. The final stage is the **SEAGRASSES BEDS** in which one or more species coexist and they are able also to coexist with some seaweeds, such as *Corallin Halimeda*. The seaweeds or other corallin algae can represent a stimulus for increase the seagrass grow. E.g. This calcareous algae with produce carbon dioxide in the form of calcium carbonate represent a stimulus for increase the Thalassia growth.



Mature seagrass beds usually consist of coexisting seagrasses and seaweeds

Thalassia with *Halimeda*

SEAGRASS ECOLOGY AND FUNCITONS why we have to conserve seagrasses?

BIOLOGICAL → **Represent a habitat to a large variety of associated animal and algae species**, because they:

- *Provide environmental heterogeneity* (more ecological niche that can be used by the organisms, so more organisms)
- *Supports high biodiversity*
- *Nursery area for many species also important for economic value* (the baby grow, e.g. little fish)
- *Reproduction area for many species*
- *Shelter and protection from currents and predators for many species* (defensive function)
- *Provide food for turtles, dugongs*

Scallop *Argopecten irradians* has a planktonic larva that recruits to seagrass. The early juvenile stage remain attached to *Zostera* blades many months avoiding predation

4 MAIN CATEGORYS OF ORGANISMS THAT LIVE WITH THE SEAGRASSES

Infauna

- Protozoa and metazoan invertebrates that **burrow into the sediment** and **among the roots or the rhizomes**. They have some structures that exit from the sediment, they extrude *proboscides*
- They feed in the sediment, or filter the sediment or are suspension-feeders

Epifauna

- Organisms that live **on the sediment**
- Many invertebrates: sea stars, sea cucumbers, sea urchins, snails, bivalves, worms

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Ephiphytic

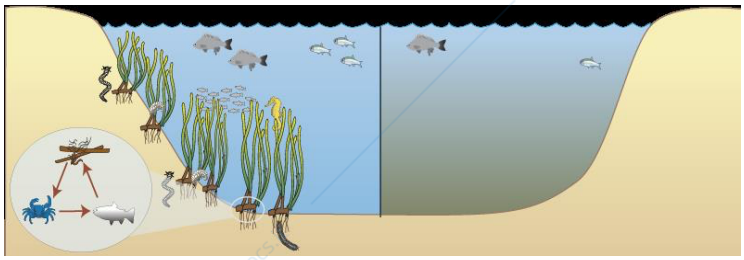
- Organisms that live **on the stems or leaves** of flowering plants, seagrasses
- Algae, bryozoans, polychaetes, small amphipods, hydroids

Necton

- Nektonic organisms visitors (foraging), as turtles, fish, they **swim** and live on the seagrass bed
- Vagile migrant fauna during the life cycle

the seagrass beds have a richer associated community than surrounding bare sediments

- Habitat amelioration for the infauna
- They are also **foundation species**, **ecosystem engineer** that facilitate the colonization of other species



In the image → there is the same bottom, that is colonized or not by seagrass, if the biodiversity change, also the amount of organisms that live in a specific area can change.

Seagrasses have significant effect on the composition and abundance of the associated fauna, providing new habitat for organisms

Some studies suggest that there is a direct relationship between:

- the complexity of a meadows
- the diversity and abundance of associated organisms

In general, the relationship between these 2 factors is explain as: **Habitat more architecturally complex → more niches available → more n° of species**

A paper demonstrate that there is a positive relationship between the shoot density (is a measure of the complexity of the meadows) and the associate organisms invertebrates, higher is the density of the shoot of the seagrass, higher is the diversity of the associated invertebrate

Another article shows that **Complexity = Density or also seagrass biomass**

PREDATION

Since the seagrass beds have an important role as nursery ground, are represent a shelter for the predation, they represent also a hypothetical food supply and can attract large predator, **so the PREDATION PRESSURE is the major force structuring the assemblages found within seagrass beds.** This predation pressure creates the:

Edge Effect:

- The distance of a prey from the edge of a bed is an important factor that regulate the predation pressure
- The density of the blades and rhizome systems, which increase moving in the middle of the meadow, tends to deter large predators from entering in the bed→ *large predator rarely enter in the center of the seagrasses meadows due to the higher density of the rhizome*, so the central denser part provide more shelter for smaller animals
- **Predators are much more successful at the edge where the predation pressure is higher**

Agropectinen irradians, Mercenaria mercenaria: these two scallops (mollusk bivalves) don't live in the center of the meadows, but laterally, they suffer high predation, due to the edge effect, but they seems to grow faster when stay laterally than in the middle of the seagrass meadows → is an adaptation

At the edge more predation that stimulate more and faster growth to reduce the possibility to be preying

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Habitat Fragmentation

Another important factor that influence the diversity and the structure of the communities is the habitat fragmentation

- Fragmentation of the seagrass bed in **many smaller patches** due to the human activity, anthropogenic pressure, or due to natural events.
- Is another factor that affect the assemblage of the organisms with the seagrass

Consequences:

- The overall area is reduced, which may impact big species required large area
- Small patches can form islands separated by bare dangerous sediment, potentially isolating organisms from the main population → **ISOLATION**
- Increase the edge effect, increasing overall predation pressure
- Change water flow and sediment deposition

DIFFERENT HYPOTHESIS ABOUT THE HABITAT FRAGMENTATION:

On the land, in the forest the negative impacts of habitat fragmentation is well accepted, evidence on seagrass beds is equivocal:

1. Bowden et al (2001) demonstrated **higher diversity** of sediment- dwelling invertebrates **in large *Zostera marina* patches** than in several small patches → is better to have 1 big patch.
2. McNeill and Fairweather (1993) found that **several small patches had a higher overall diversity** than continuous patches of the same area → there are some evidences that suggest that the biodiversity is increase in a lot of little patches than 1 single big patch

Seagrass beds have exceptionally high biomass and productivity (they are photosynthetic organisms)

1. **Seagrass bed: 1012 g dry weight/m2/year** (is the most productive habitat in the marine environment)
2. Macroalgae: 365 g/m2/year
3. Phytoplankton: 128 g/m2/year
4. Savannah: 900 g/m2/year
5. Boreal forest: 800 g/m2/year
6. Lakes and streams: 250 g/m2/year
7. Rainforest: 2200 g/m2/year

- Seagrass beds provide large amounts of C for input into coastal systems
- The high leaf biomass produced by seagrass is also harvested by humans for a range of use, such as packing material, fibre for use in mat weaving, storage box and seagrass furniture, also for FOOD, but not only…

ECONOMICAL IMPORTANCE OF THE SEAGRASS

- Production of the paper
- Fertilizer for agriculture
- Thermal and sound housing insulation
- Human food in several countries
- Carpets, hats, baskets, and others

→ these are economic and social functions of the seagrasses

17/11/2022

From a physical point of view:

Seagrass beds are stabilizing features within the coastal landscape providing a natural form of coastal protection from the wave actions

- Root-rhizome system: enhances sediment stabilization and thus prevent erosion (permanent part of seagrass)
- Foliage: leave slows water currents through their baffling effect, encouraging sediment to settle down and preventing resuspension, so they have an important function to maintain the water clear, low turbidity. The waves action is reduced, also the particles of sediment are settled down (prevented the turbidity) thanks to the baffling effect of the seagrass
- The density of the meadow: if there is high density, this physical action is high and more effective

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In the tropical area, **seagrasses** are connected with the **corals reefs** and the **mangrove** ecosystem: they create LAGUNES (sand bottom, clear water) that allow the light to penetrate, so is a good habitat for the seagrasses. Also is reduce the hydrodinamism in land where the mangroves live→ protection of the shore and related habitats thanks to the presence of these ecosystems. The role of these 3 ecosystems are strictly related, e.g. the seagrass reduce the turbidity allowing the developing of corals...

Water purification and nutrient cycling since they are photosynthetic organisms…

- They oxygenate the water and remove the carbon from the environment, in particular the CO2 by the atmosphere
- Water oxygenation and carbon dioxide uptake from the atmosphere to do the photosynthesis
- Sediments oxygenation thanks to the aerenchyma
- Removal nutrients from the water column and sediment
- They are filter for organic pollutants

They are INDEX of environmental QUALITY

Unfortunately *Posidonia oceanica meadow* in many Mediterranean coastal regions is reduced due to the different impacts factors, so many beaches of Ligurian sea are eroded, and every year have to put additional sands

OTHER FUNCTIONS OF SEAGRASS:

1. Mangroves can contribute to the climate change mitigation, they absorb carbon dioxide, that is stock in the rhizome system and roots system, so remove carbon from the atmosphere, mitigating the CC. The rhizome system of the *Posidonia oceanica* can persist in the sediments for hundreds of years, creating a structure called **MATTE** that continue to store carbon, even if the seagrass die.
2. They also contribute to control and mitigate the ocean acidification, control the pH of the water, and provide benefit for the coral reef ecosystems that is the most affected by the acidification. Has been demonstrated that coral reefs that live close to the seagrass can suffer less the acidification compared to the coral reef that don't live surrounded by seagrass.

HOW EAT SEGRASSES? SEGRASS GRAZERS

SEAGRASS GRAZING – INVERTEBRATES

- Small grazers (gastropods, amphipods) generally feed on *epiphytic algae*, (DON'T FEED DIRECTLY ON THE SEAGRASSES, BUT ON THE EPIPHYTIC ALGAE THAT LIVE ON THE SEAGRASSES, BUT CAN ALSO FEED ON THE SEAGRASSES BAD) thus preventing overgrowth of the seagrasses, provide an advantage to the seagrass. E.g. little snails
- **Sea urchins** are the only invertebrates that have a major grazing impact on seagrasses, in particular 2 species:
    - *Lytechinus variegatus* can occur in large number (up to 360/m2) within seagrass of NE America grazing 0.8 km2 of meadow in 8 months
    - *Diadema antillarum* responsible of the creation of patch coral reefs in the middle of seagrass meadows (create structures called **halos**). During the day urchins hide in the crevices on the patch reef but on the night, they move out to consume seagrasses

SEAGRASS GRAZING – VERTEBRATES

Green Turtle (*Chelonia mydas*)

- Grazes primarily on *Thalassia testudinum* particularly in the Caribbean
- *The young turtles are pelagic omnivores but once they reach 20-30 cm* (start to be juveniles), *they begin benthic grazers* (they eat algae when seagrasses are not available), became obligate seagrass grazers, change the diet.
- In **high-density areas** of meadows they are selective consuming the younger leaves which contain high nutrients and low lignin (there is a lot of food, so they eat what they want)
- In **low-density areas** they are less selective because the food is less and can't be selective
- They do not overgraze their areas allowing the seagrass regrowth
- They eat only the leaf tip
- An adult can eat up to 2Kg per day (huge amount)

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Dugong (*Dugong dugong*)

- Grazes primarily on *Halodule ovalis* and *Halophila* (particularly in the Indo-Pacific) as they have high N content, low fibre and grow rapidly in order to quickly re-colonize the habitat
- A similar animal close to the dugong (that lives only in the indo-Pacific Ocean), Manatees, that live in the Atlantic Ocean, eat the seagrasses, but live in a separate habitat due to the different shape of tale (dugong has a rounded tale, the Manati has a tale compose by 2 lobos)
- Eat the whole plant leaving distinctive feeding trails, not as the turtles that eat only the leaf tip
- Often eat in groups (herds)
- In 35 m of the intestine there are the microorganisms relevant for the digestion of cellulose
- An adult can eat from 30 to 40 kg of seagrass /day, more than the sea turtles

SEAGRASSES SUPPORT A COMPLEX FOOD CHAIN, they are a base for not only the organisms that live directly on them, or the infaunal, nektonic organisms, Ephiphytic… but they also support the microbial food chain, in fact when the leaf die and fall down in the sediment, a lot of organisms will decompose it **SUPPORTING A COMPLEX DETRITUS-BASED FOOD CHAIN** → Decomposing seagrasses leaves, and rhizomes provide food for benthic aquatic life. The decaying leaves are broken by fungi and bacteria which provide food for other microorganisms such as flagellates and plankton

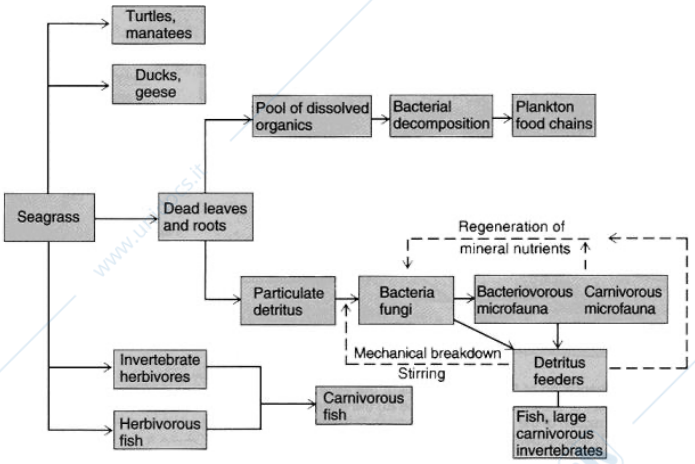

FIGURE 5.32 The pathway for the channeling of eelgrass into the food web. (Modified from *Seagrass Ecosystems*, C. P. McRoy & C. Helfferich, eds., 1977, Marcel Dekker.)

DECLINE OF SEAGRASSES

Human Damage - Direct effects

- Bottom trawling: use of some fishing strategies that affect the seagrass abundance, this technique destroy everything
- Boat propeller scars and anchors: they can affect the seagrasses beds
- Direct destruction for coastal development: in Maldives they are covering all the seagrasses meadows with send in order to increase the dimension of the island due to the land reclamation
- Pollution
- Construction of the coastline, with changes in coastal currents and in sedimentary regimes: e.g. in Dubai they built a lot of artificial structures on the seagrass bed, e.g. Pier and jetty construction

Human Damage – Indirect effects

- Coastal runoff: discharges and waste water of industries, aquaculture and river inputs, seagrasses are overgrown and suffocated by algae due to the nutrients that arrived thank to the coastal runoff
- Overfishing of **herbivores** that consume seaweeds and epiphytes (creating a trophic cascade): input of new species can affect the equilibrium of the seagrass, and go the total equilibrium of the ecosystem
- Overfishing of **carnivores** that consume the herbivores (creating a trophic cascade): input of new species can affect the equilibrium of the seagrass, and go the total equilibrium of the ecosystem
- Reduction of **suspension feeders** cause increase in phytoplankton which might shade them out and favor seaweeds: in the Mediterranean Sea, the most important claim suspension feeders is the *Pinna nobilis*, live in a vertical position inside the seaweeds. The removal cause an increase in phytoplankton. Nowadays Pinna nobilis was affected by global disease due to bacteria or other organisms but we don't know precisely who they are, these events cause the death of 90% of all the Pinna nobilis in the Mediterranean Sea, now the population is increasing again, but had important effects in the seagrass meadows.

Invasive species: species that are introduced in a habitat by direct or indirect human activity, are exotic species

e.g. *Caulerpa taxifolia*

- Introduced accidentally into Mediterranean in 1984 from the Oceanographic Museum in Monaco
- By 2000 it had colonized a huge area, 131 km2 of seabed at 103 locations along 191 km of coast (in less than 20 years)

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- It Grows exceptionally fast and is able to cover 100% of the seabed smothering all native sessile invertebrates, algae and in particular the Mediterranean seagrass *Posidonia oceanica*. They overgrow completely the Posidonia oceanica because no fish feed on them because is not endemic.
- Invasion of seagrass beds seems particularly successful when seagrass has already experienced some decline due to other pressures
- *C. taxifolia* replaced *Posidonia* across Mediterranean where it can invade damaged beds, reducing native species diversity and fish habitats
- In addition to grow very fast and has a great colonization rate, this algae is also TOXIC, it produces toxic substances (called **caulerpenynes**)
- Recently has been documented in California and Sydney
- *C. racemosa* is a similar species, it has been recently (1990) introduced in Mediterranean from Australia

Natural disturbances:

- Not human disturbances, but is very difficult to distinguish them
- Climate Change: **high temperature** → damage to the photosynthetic apparatus, the leaves loss the chlorophyll and can die
- **Storms** and **hurricanes**
- **Wasting disease** affect mainly Zosterae marina species
- A healthy *Amphibolis antarctica* meadow (left) and a defoliated meadow in Shark Bay (right). We believe a combination of low light availability and elevated temperatures has led to this loss of leaf material.

Wasting disease:

- Is a kind of disease that affect especially the *Zostera marina*
- Great epidemic event in 1930 in the American and European Atlantic coasts (90% of seagrass lost)
- Decline in seagrass cover and in abundance of all related benthic species
- Increase in coast erosion
- Pathogen: fungus ***Labyrinthula zosterae;*** The pathogen is less active at low salinity (~20 ppt)
- Wasting disease spreads through direct leaf to leaf contact and can be identified by black-brown dots or streaks on the leaves
- Infection moves rapidly through tissues, initiating enzymatic degradation of eelgrass cells and destroying cell cytoplasm
- Photosynthetic activity is reduced, creating a negative carbon balance which ultimately leads to mortality
- **Eelgrass wasting disease index key** in order to understand the amount of the incidence of this disease. Volunteer monitors can use this key to estimate the disease's presence on the leaves.

SEAGRASSES RESORATION

- As the coral reef restoration, there is also the seagrass and mangrove restoration
- There are different methods and different research groups: e.g. Seagrass seedlings growing underwater in the Centre for Sustainable Aquatic Research at Swansea University

1. *Posidonia australis* were harvested from donor material and each **sprig** (piece of plant) tied to a purpose-designed degradable wire staples (30 cm in length) and planted and secured into a bare sandy area at 50 cm shoot spacing
2. Divers at Swansea University collected **seeds** of the seagrass *Zostera marina* at Helford River (Cornwall). The seeds were then separated once dropped and have now begun to germinate in aquaria facilities. Seagrass scientists are now developing a means of growing the hundreds of germinating seedlings into seagrass mats that can be readily deployed into the marine environment for habitat restoration.
3. The restoration can also be done from the **whole plants**, also the rhizome and the roots tied to a mesh frame

A lot of people try to develop new technology, like this:

1. "To restore areas of seagrass that have been damaged by propeller scars and blowouts, the restoration contractor employs its **Sediment Tube technology** to replace sediment into damaged areas while minimizing the turbidity of the water. The Sediment Tube is made of specialized cotton that biodegrades fully over a period of 3 – 5 months and is filled with native sediment to provide a viable growing medium. After approximately three to five months, seagrass planting units are inserted into the partially degraded Sediment Tubes. Based upon our experience, complete seagrass restoration is achieved 18 to 24 months after the Sediment Tubes are initially placed into the propeller scar or blowout area".
2. For the restoration can be used also the **fecal pellets of the birds**

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