

An underwater photograph showing a large school of small, silvery fish swimming in clear blue water. In the foreground, there are dark, rocky structures covered in green seagrasses. Sunlight rays are visible at the top of the frame, creating a bright, shimmering effect on the water's surface.

**Scienze per l'Ambiente Marino e Costiero**

**a.a. 2025-2026**

**GESTIONE E CONSERVAZIONE ECOSISTEMI MARINI -  
IMPATTI ANTROPICI E CONSERVAZIONE DELLA FAUNA  
MARINA**

**Prof. Stanislao Bevilacqua ([sbevilacqua@units.it](mailto:sbevilacqua@units.it))**

**Seagrasses**

# Seagrass

- Spermatophyta (angiosperms, phanerogams, Magnoliophyta - flowering plants)
- 160 Mya, spread during the Cretaceous (120-60 Mya)
- Flowers, fruits, seeds, roots, rhizomes (modified plant stem), leaves
- Substitute anemophilous pollination with hydrophilous pollination

## Features:

1. Adaptation to live in sea waters
2. No stomas
3. Tissues with aerenchyma

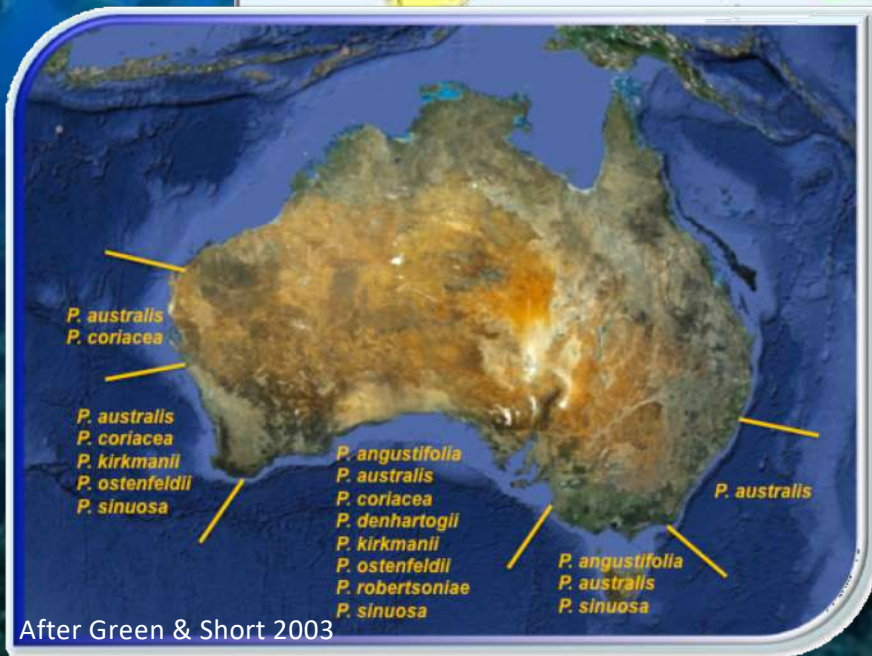
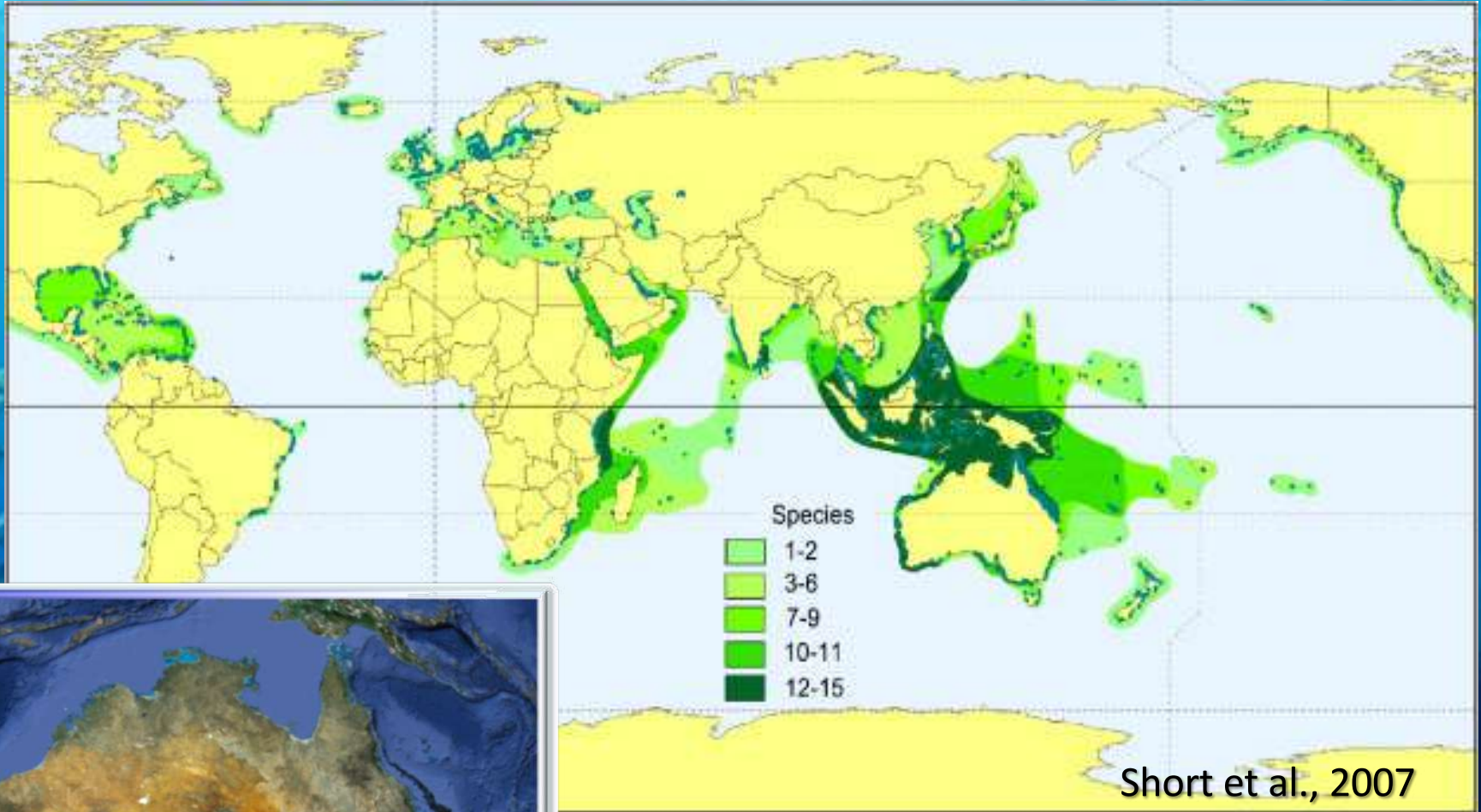
30 Mya *P. parisiensis*



After the **Messinian Crisis**

Only species that tolerate high salinity

# Distribution



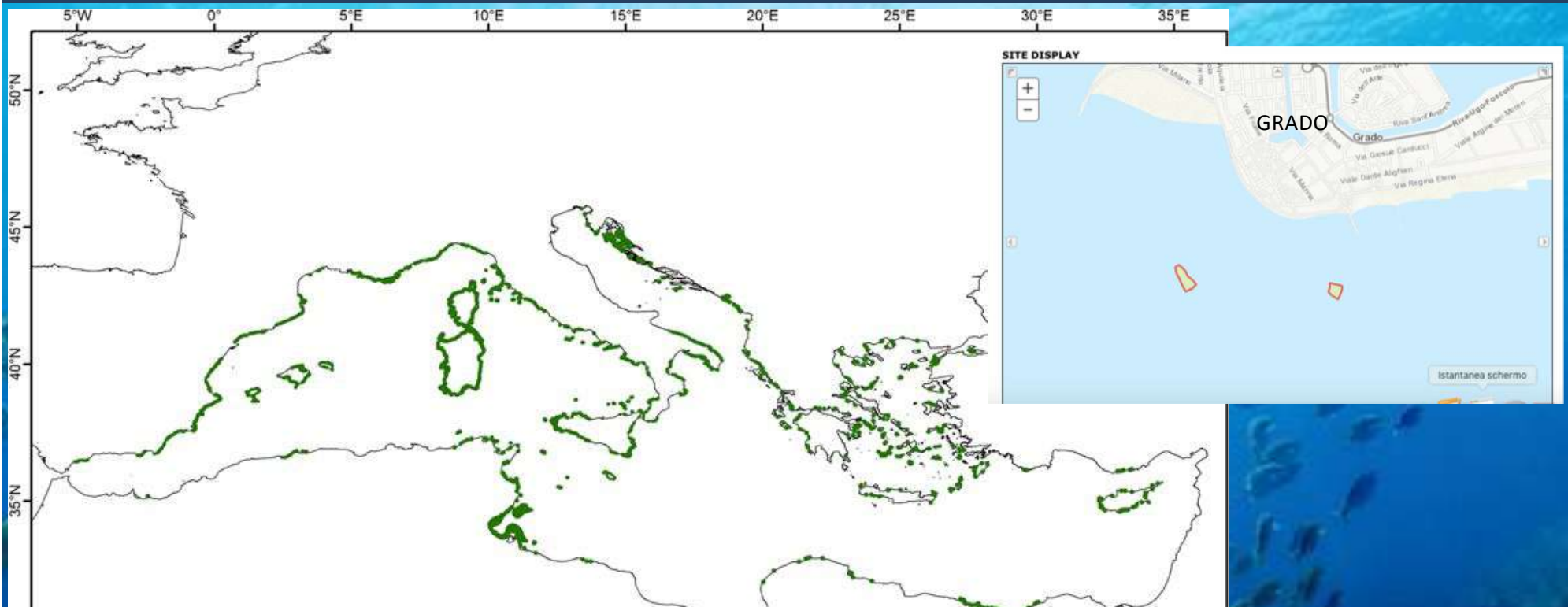
About 70 species

# In the Mediterranean Sea

1. *Posidonia oceanica* **endemic** of the Mediterranean Sea
2. *Cymodocea nodosa* widespread from 1-25 m on sand-mud, low hydrodinamism
3. *Nanozostera noltii*, until 5 m depth, often associated to *C. nodosa*
4. *Nanozostera marina* typical of coastal lagoons
5. *Ruppia* spp.
6. *Halophila stipulacea*, introduced from Red Sea (**lessepsian**)

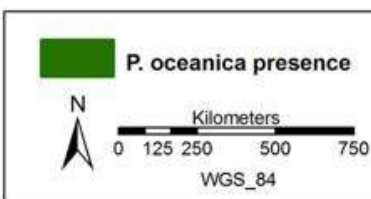


# *P. oceanica* distribution



Telesca et al. 2015

	Mediterranean Sea	Western basin		Eastern basin	
Coastline length (km)	46,000	11,621	25%	34,379	75%
Coastline length with <i>P. oceanica</i> (km)	11,907	6,201	14%	5,706	12%
Coastline length without <i>P. oceanica</i> (km)	12,622	3,925	9%	8,697	19%
Coastline length without data (km)	21,471	1,494	3%	19,977	43%
Total area of <i>P. oceanica</i> (ha)	1,224,707	510,715	41.7%	713,992	58.3%



# Growth

Basal growth

Rhizomes **Plagiotropic, Orthotropic**

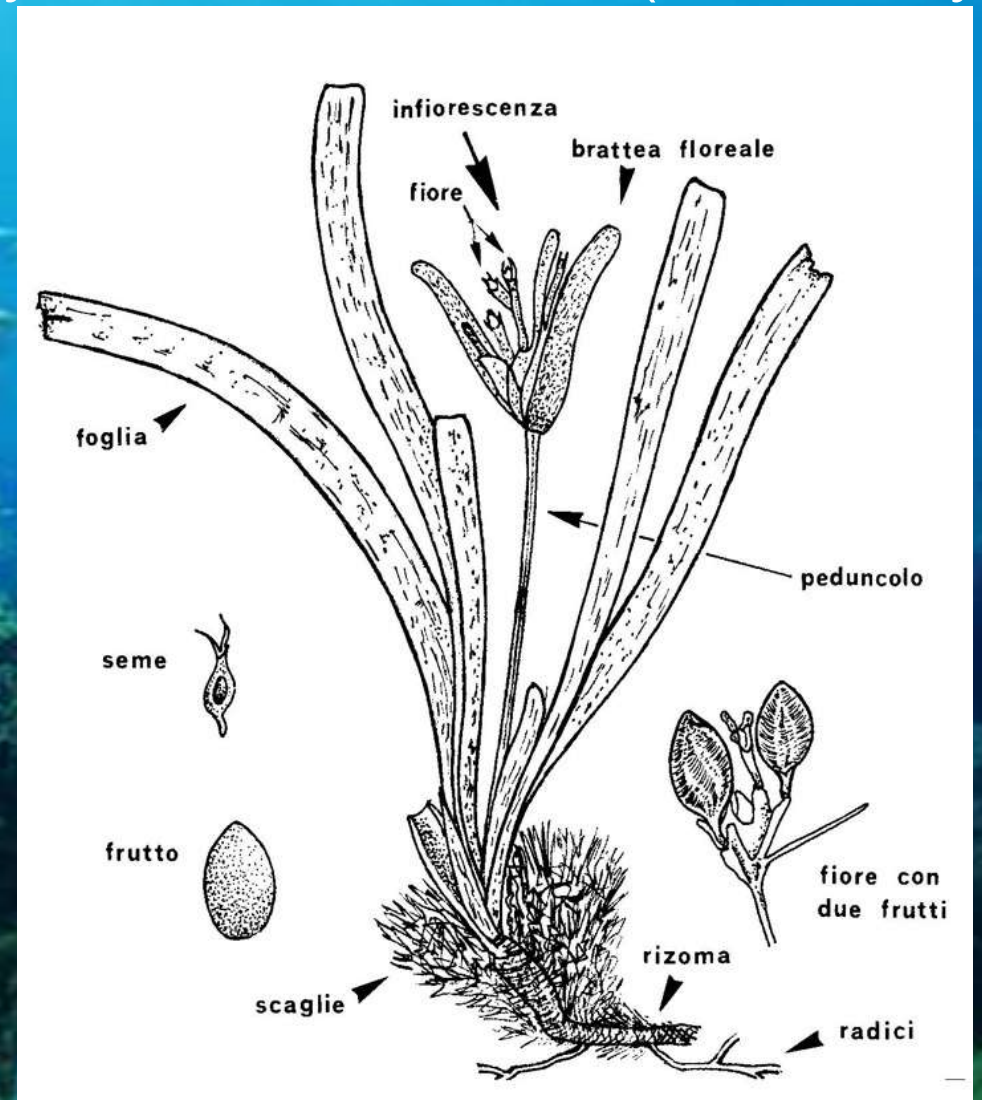
**Matte** = intricate structure built by roots and rhizomes (1 m x 100y)

Growth rates higher in spring

100-700 shoots m<sup>-2</sup>

Reduced when < 50 shoots m<sup>-2</sup>

Depending on depth



# Morphology and reproduction

Sexual reproduction: hermaphroditic flowers (autumn)

Asexual reproduction (stolons)

Shoots 6-7 leaves, length until 1 m

Nutrient uptake from sediments, but also through the leaves

Fruits: sea olives, floating to increase dispersion

In autumn: flowers



Dispersion of fruits



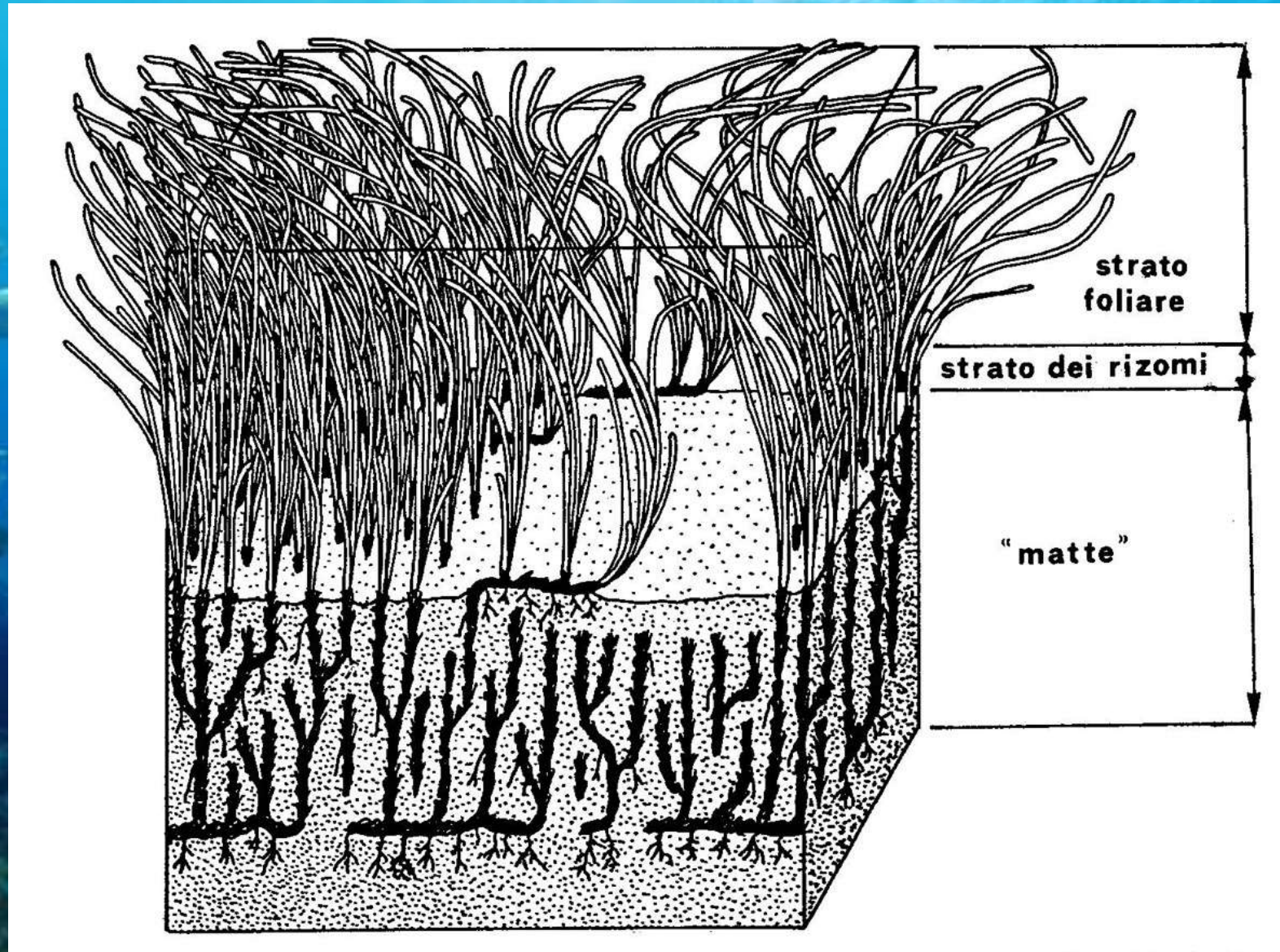
Plantules



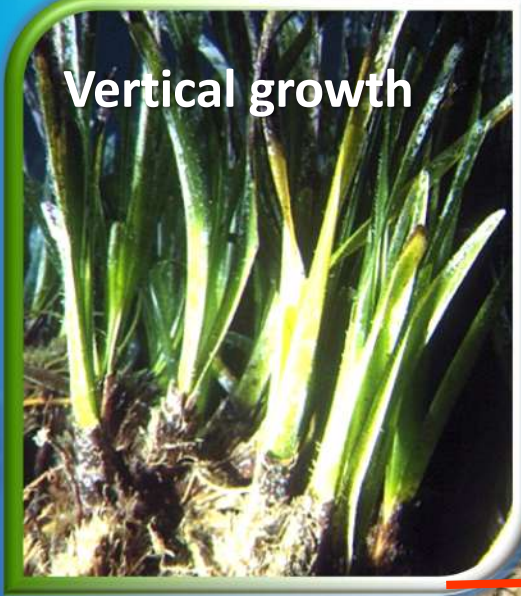
In spring: fruits



# Structure and layers



# Structure and layers



# Factors influencing distribution

Transparency - Type of seabed - Anthropogenic factors



# Morphotypes



© Google Earth



© M. Foulquier

© GP



© G. Cancemi



© J.G. Harmelin

# Ecological role and functioning

1. **Protect** coastline and seabed from **erosion** with their **stabilizing effect** on sediment and reduction of wave action
2. **Reduce sedimentation** and water turbidity by trapping sediments in their mat
3. Significantly contribute to **primary production** of coastal systems, oxygenation
4. **Carbon sequestration**
5. Provide **nursery** areas and **food** for many marine organisms
6. Represent **secondary substrate** and host high biodiversity

# Protection and Production

Biomass production (mean dry weight): 5 to 13 t/ha/y

Associated fauna biomass (mean dry weight): up to 2 t/ha

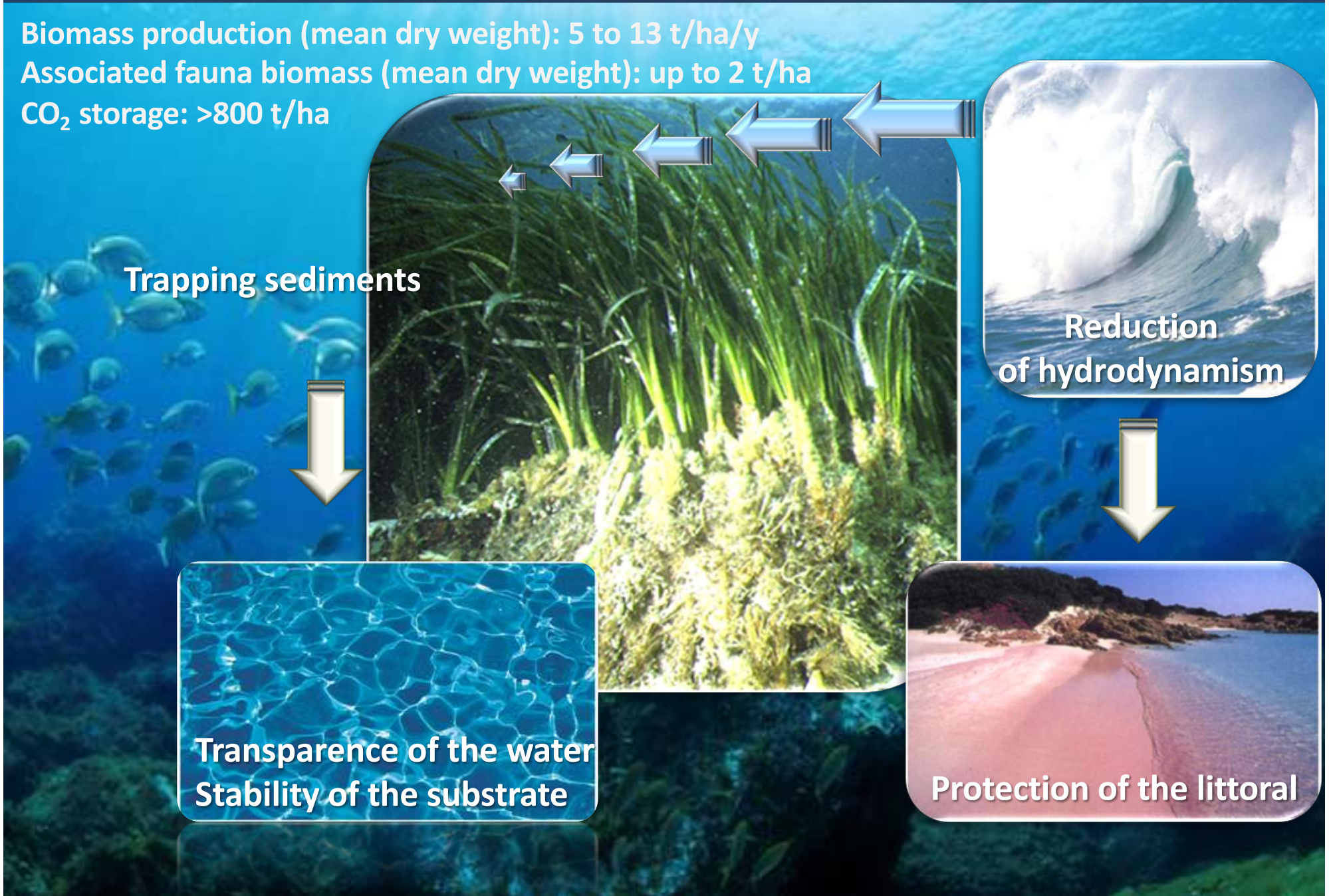
CO<sub>2</sub> storage: >800 t/ha

Trapping sediments

Reduction  
of hydrodynamism

Transparence of the water  
Stability of the substrate

Protection of the littoral



# Protection and Production

**Accumulation of leaves**



**Protection of the coastline**



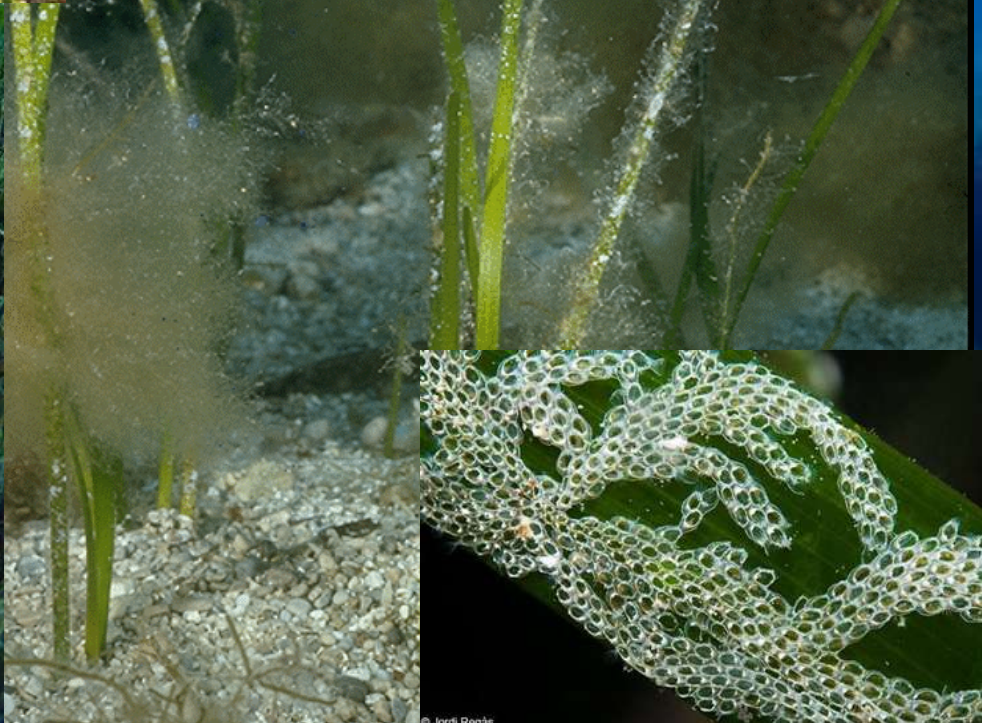
It has been estimated that the destruction of 1 m in thickness of "*matte*" drives the erosion that in sandy shores can lead to a retraction of the coast line of 20 meters.

**Nesting areas for seabirds**

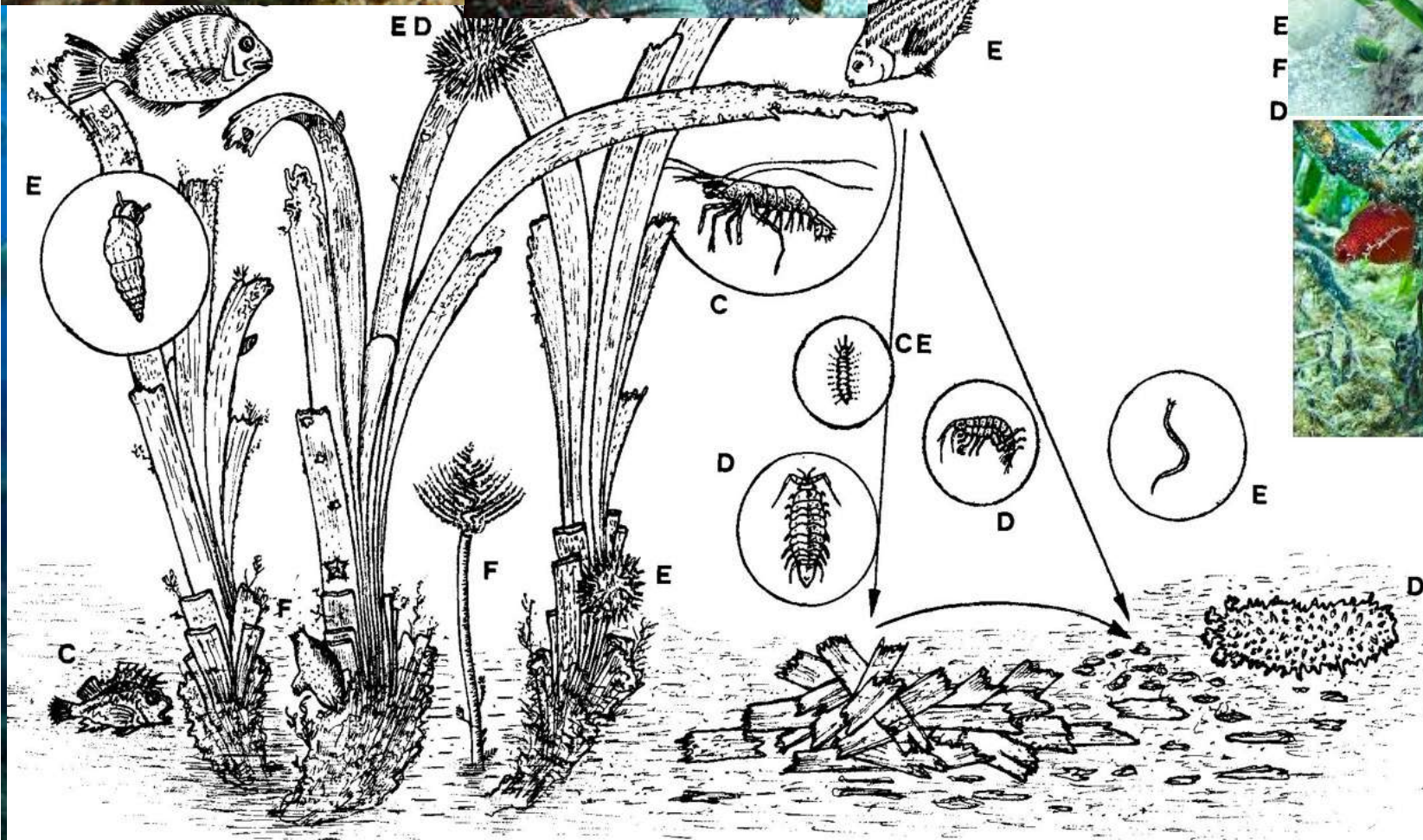


# Biodiversity

- a. Vagile and sessile organisms on leaves
- b. Vagile organisms among leaves and in the water column
- c. Vagile and sessile organisms on rhizomes
- d. Infauna within matte and sediments

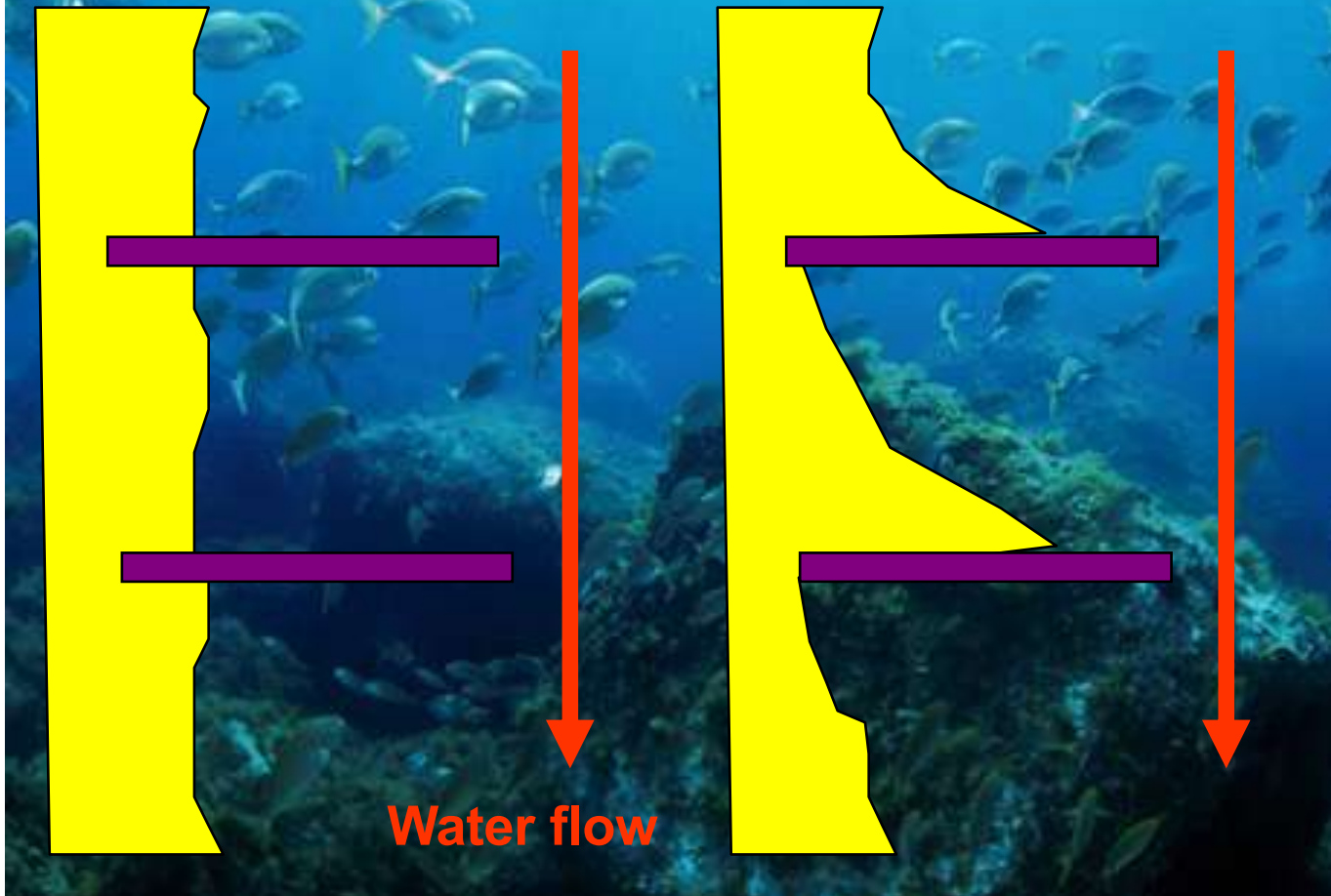


# Trophic relationships



# Human impacts

Alteration of sedimentation rates due to coastal engineering



# Sedimentation



Erftemeijer and Lewis, 2006

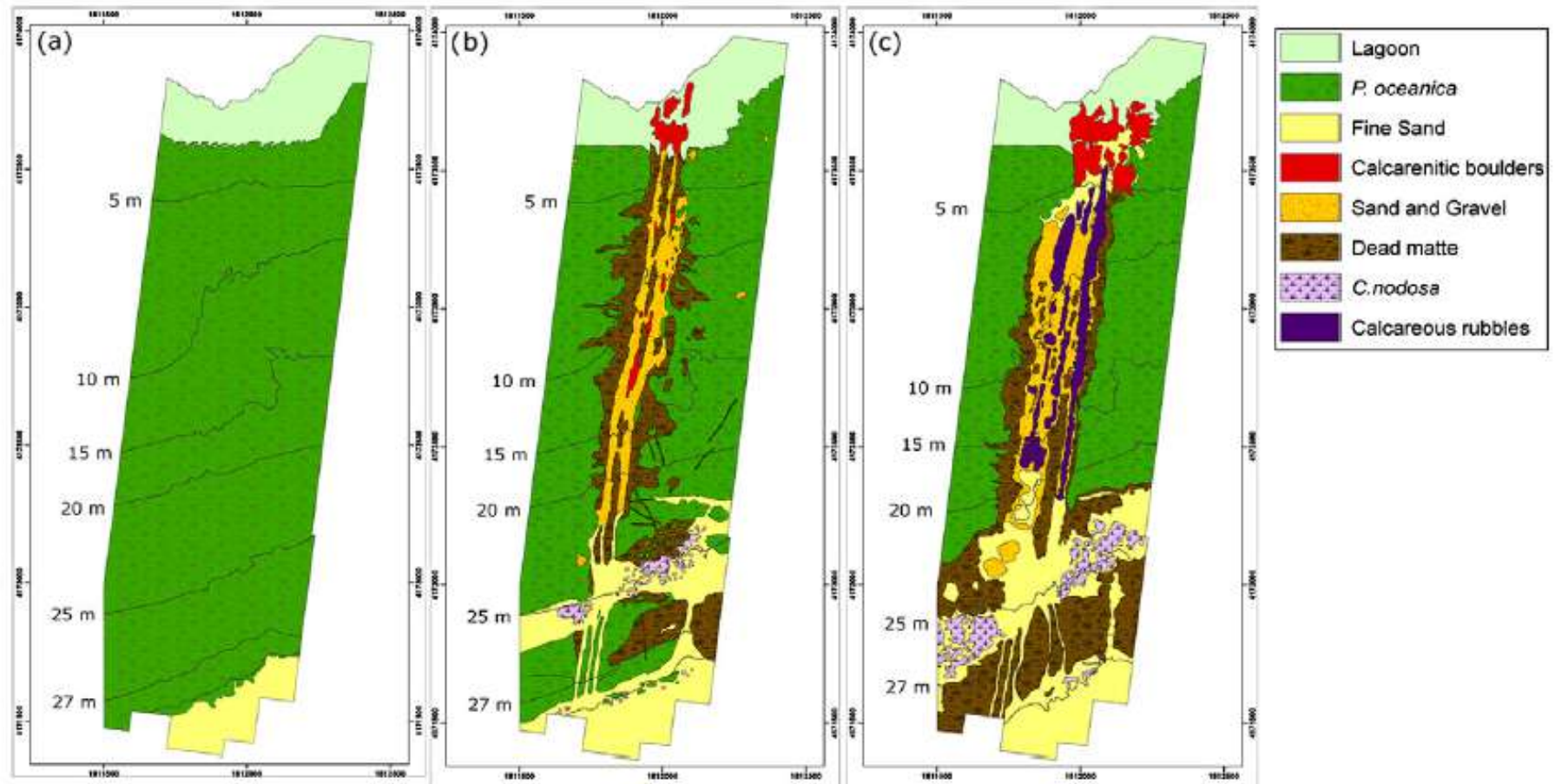
Table 3  
Critical thresholds of seagrasses for sedimentation (cm/year)

Species	Location	Sedimentation (cm/yr)	Reference
<i>Cymodocea nodosa</i>	Mediterranean (Spain)	5	Marba and Duarte (1994)
<i>Cymodocea rotundata</i>	Philippines	1.5	Vermaat et al. (1997)
<i>Cymodocea serrulata</i>	Philippines	13	Vermaat et al. (1997)
<i>Enhalus acoroides</i>	Philippines	10	Vermaat et al. (1997)
<i>Halophila ovalis</i>	Philippines	2	Vermaat et al. (1997)
<i>Posidonia oceanica</i>	Mediterranean (Spain)	5	Manzanera et al. (1995)
<i>Zostera noltii</i>	Mediterranean (Spain)	2	Vermaat et al. (1997)

# Anchoring, harbouring, fishing nets



# Pipelines, cables



*Badalamenti et al. 2011*

Fig. 2. Maps of substrate distributions in the study area: (a) in 1979, before trenches excavation; (b) in 1993, after the first trench excavation; and (c) in 1995, after the second trench excavation.



# Status of beds – tables based on shoot density

Depth (m)	High	Good	Moderate	Poor	Bad
1	> 1133	1133 to 930	930 to 727	727 to 524	< 524
2	> 1067	1067 to 863	863 to 659	659 to 456	< 456
3	> 1005	1005 to 808	808 to 612	612 to 415	< 415
4	> 947	947 to 757	757 to 567	567 to 377	< 377
5	> 892	892 to 709	709 to 526	526 to 343	< 343
6	> 841	841 to 665	665 to 489	489 to 312	< 312
7	> 792	792 to 623	623 to 454	454 to 284	< 284
8	> 746	746 to 584	584 to 421	421 to 259	< 259
9	> 703	703 to 547	547 to 391	391 to 235	< 235
10	> 662	662 to 513	513 to 364	364 to 214	< 214
11	> 624	624 to 481	481 to 338	338 to 195	< 195
12	> 588	588 to 451	451 to 314	314 to 177	< 177
13	> 554	554 to 423	423 to 292	292 to 161	< 161
14	> 522	522 to 397	397 to 272	272 to 147	< 147
15	> 492	492 to 372	372 to 253	253 to 134	< 134
16	> 463	463 to 349	349 to 236	236 to 122	< 122
17	> 436	436 to 328	328 to 219	219 to 111	< 111
18	> 411	411 to 308	308 to 204	204 to 101	< 101
19	> 387	387 to 289	289 to 190	190 to 92	< 92
20	> 365	365 to 271	271 to 177	177 to 83	< 83
21	> 344	344 to 255	255 to 165	165 to 76	< 76
22	> 324	324 to 239	239 to 154	154 to 69	< 69
23	> 305	305 to 224	224 to 144	144 to 63	< 63
24	> 288	288 to 211	211 to 134	134 to 57	< 57
25	> 271	271 to 198	198 to 125	125 to 52	< 52
26	> 255	255 to 186	186 to 117	117 to 47	< 47
27	> 240	240 to 175	175 to 109	109 to 43	< 43
28	> 227	227 to 164	164 to 102	102 to 39	< 39
29	> 213	213 to 154	154 to 95	95 to 36	< 36
30	> 201	201 to 145	145 to 89	89 to 32	< 32

Pergent et al. 1995, UNEP-RAC/SPA 2011



sella baldacconi

**Replacement with  
invasive species**

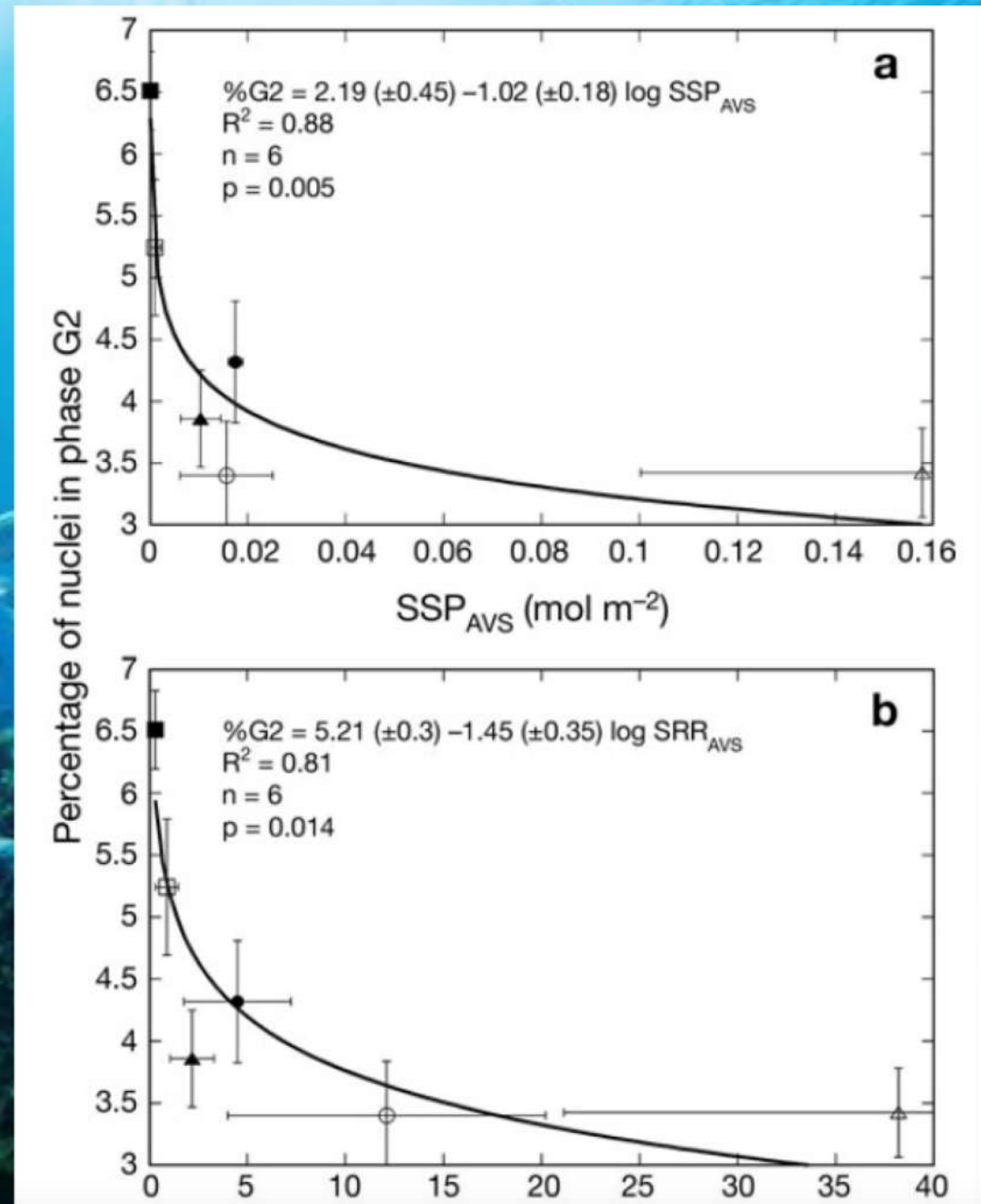
**Shifts  $\Rightarrow$ . Dead matte  $\Rightarrow$ . Turf algae**



# Potential mechanisms

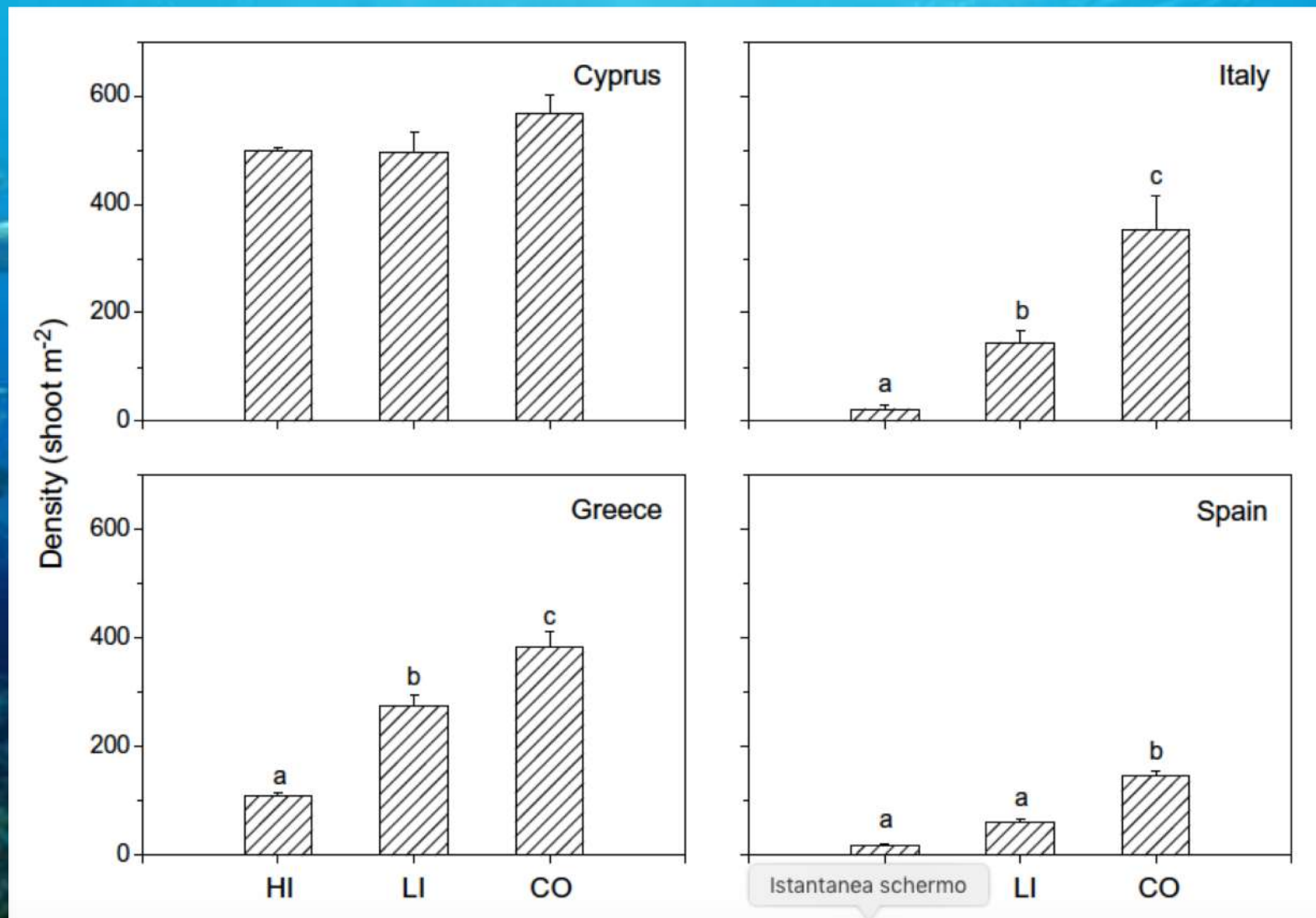
*Caulerpa* spp. affect the sediment biogeochemical conditions by increasing sulfide concentration and sulfate reduction rates (Holmer et al 2009).

Increase in sulfides in sediment could have a detrimental effect on meristematic activity in *P. oceanica*, reducing growth and contributing to the decline of beds



# Case study: effects of fish farming

Four locations, each of them with an aquaculture plant (cages). The number of shoots was significantly lower in stations near to the cages than far from them



# Climate change

SST increase and MHWs: tolerance limit inducing thermal stress  $28^{\circ}\text{C}$

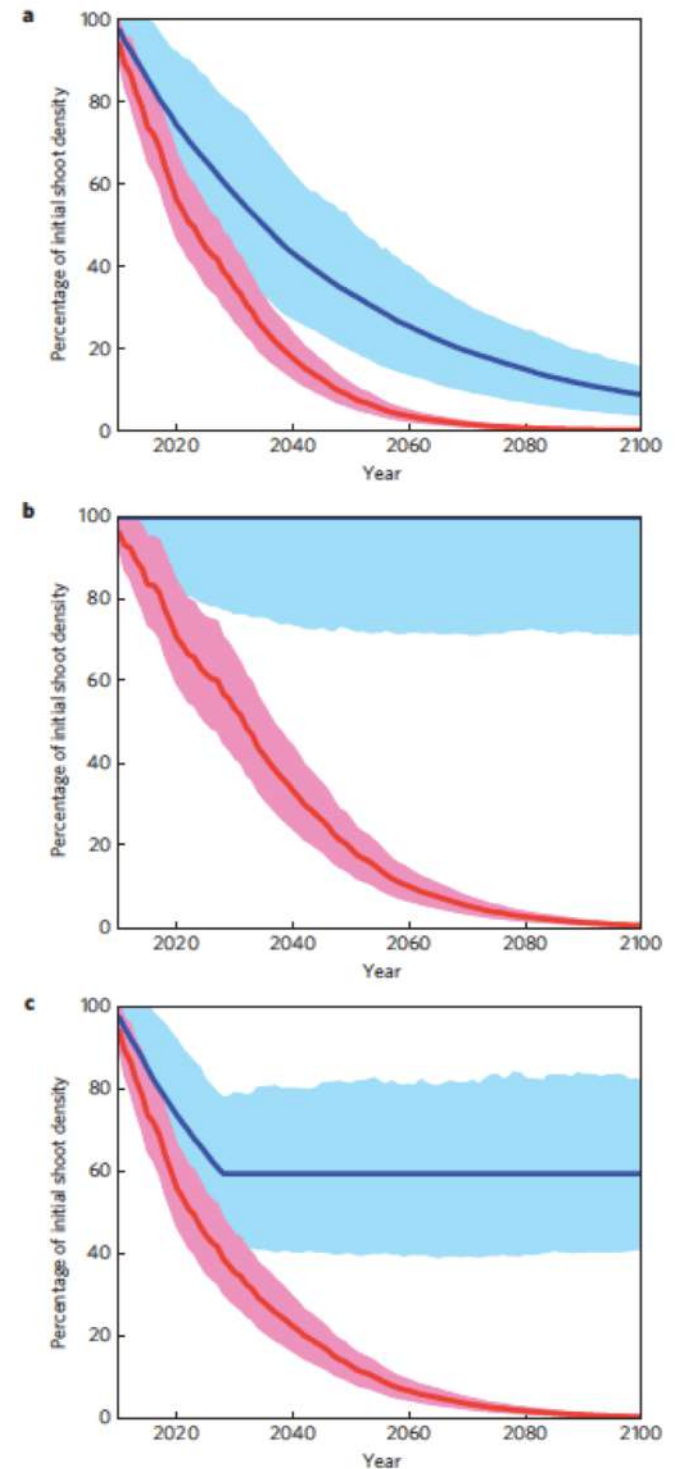
This could lead seagrass to regress (respiration instead of production)

However, do not account effects on reproduction (shift towards sexual reproduction, increasing genetic variability and epigenetic fixation of adaptation to SST increase), and thermal tolerance is greater if carbon is not limiting.

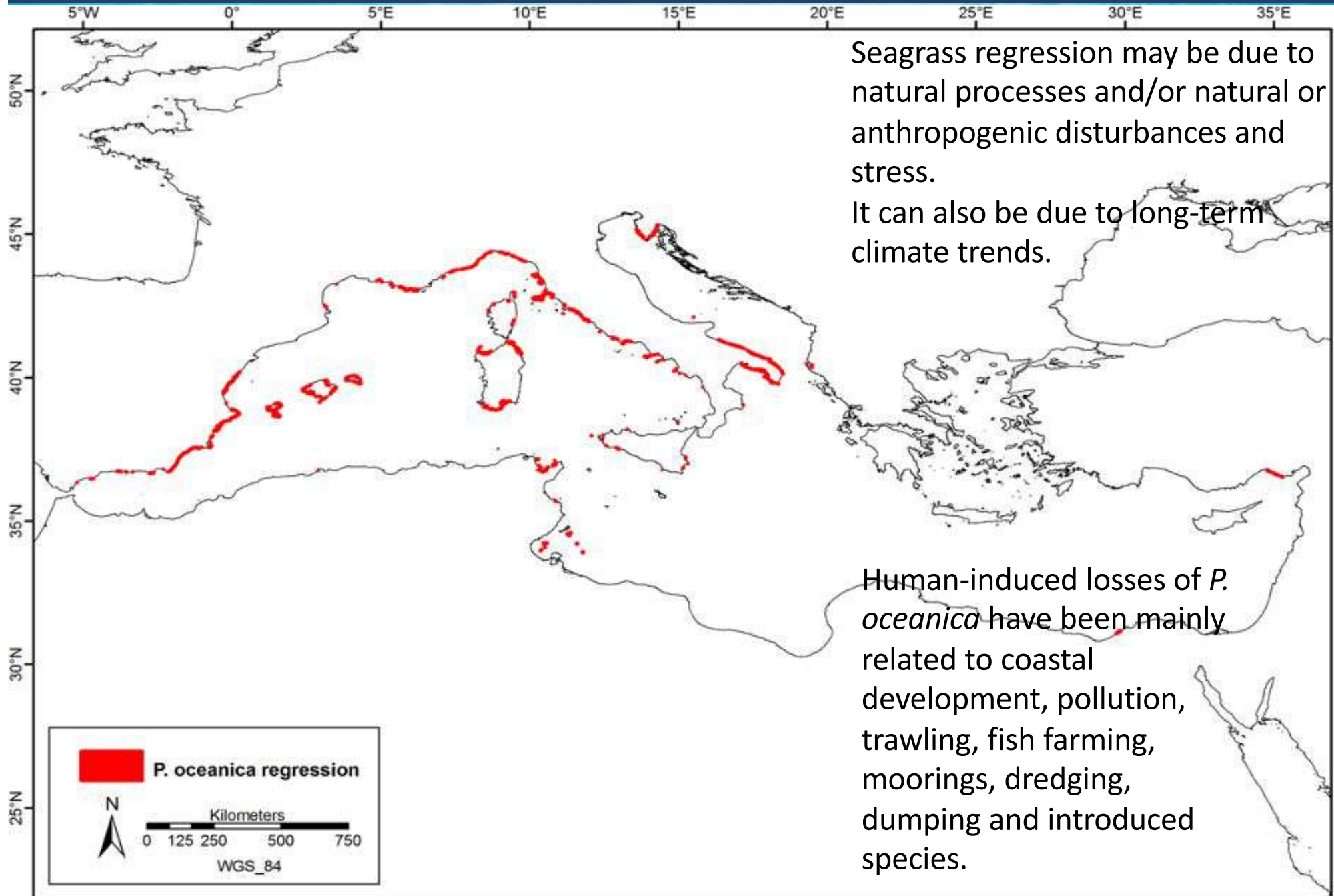
It is one of the few plants able to exploit bicarbonate ions for photosynthesis, thus favoured in acidification scenarios with respect to thermophilic algae

Sea level rise and extreme weather events could cause regression because of limiting light (increased turbidity, increasing depth, phytoplankton blooms, etc.)

Jorda et al. 2012

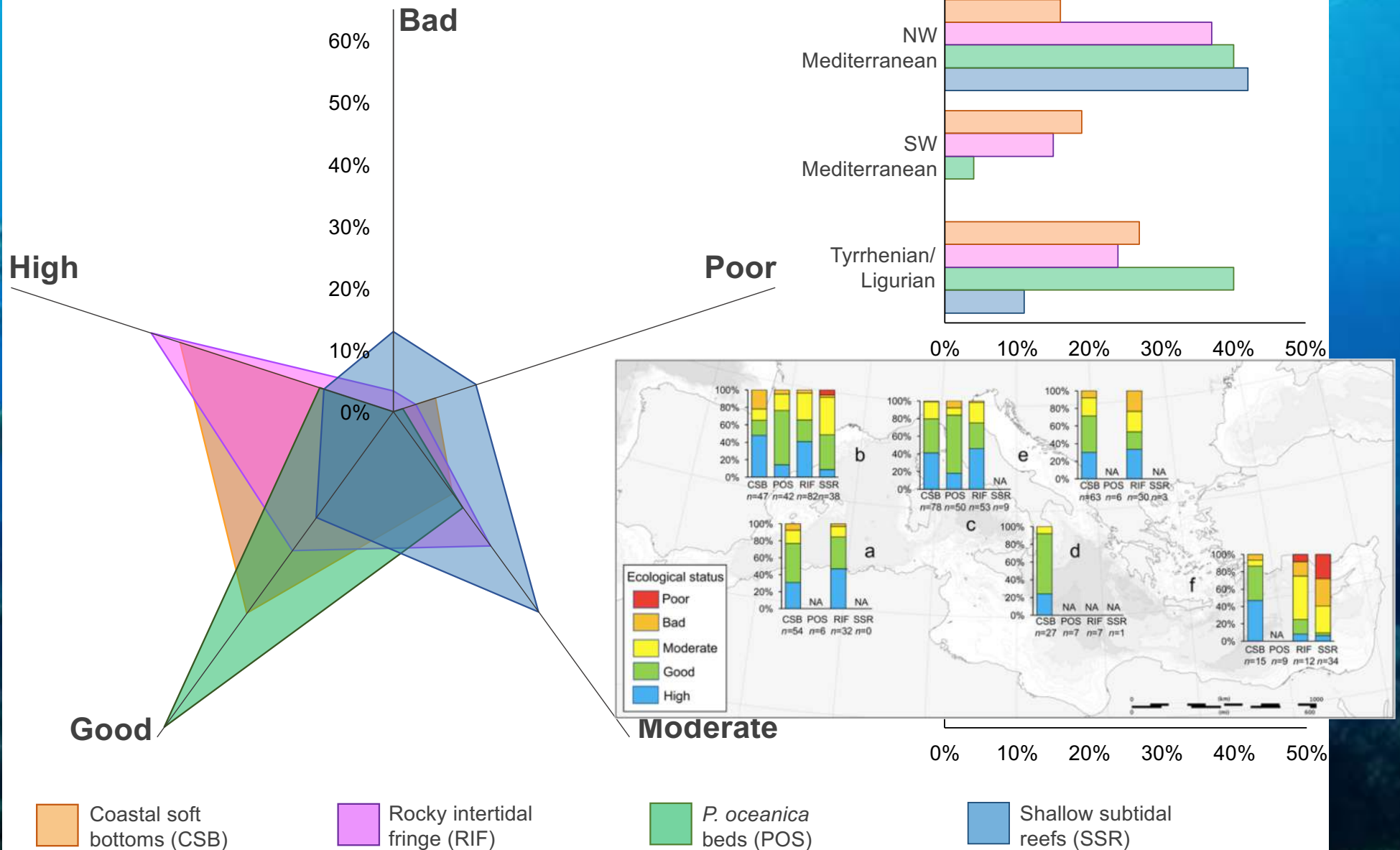


# Current status

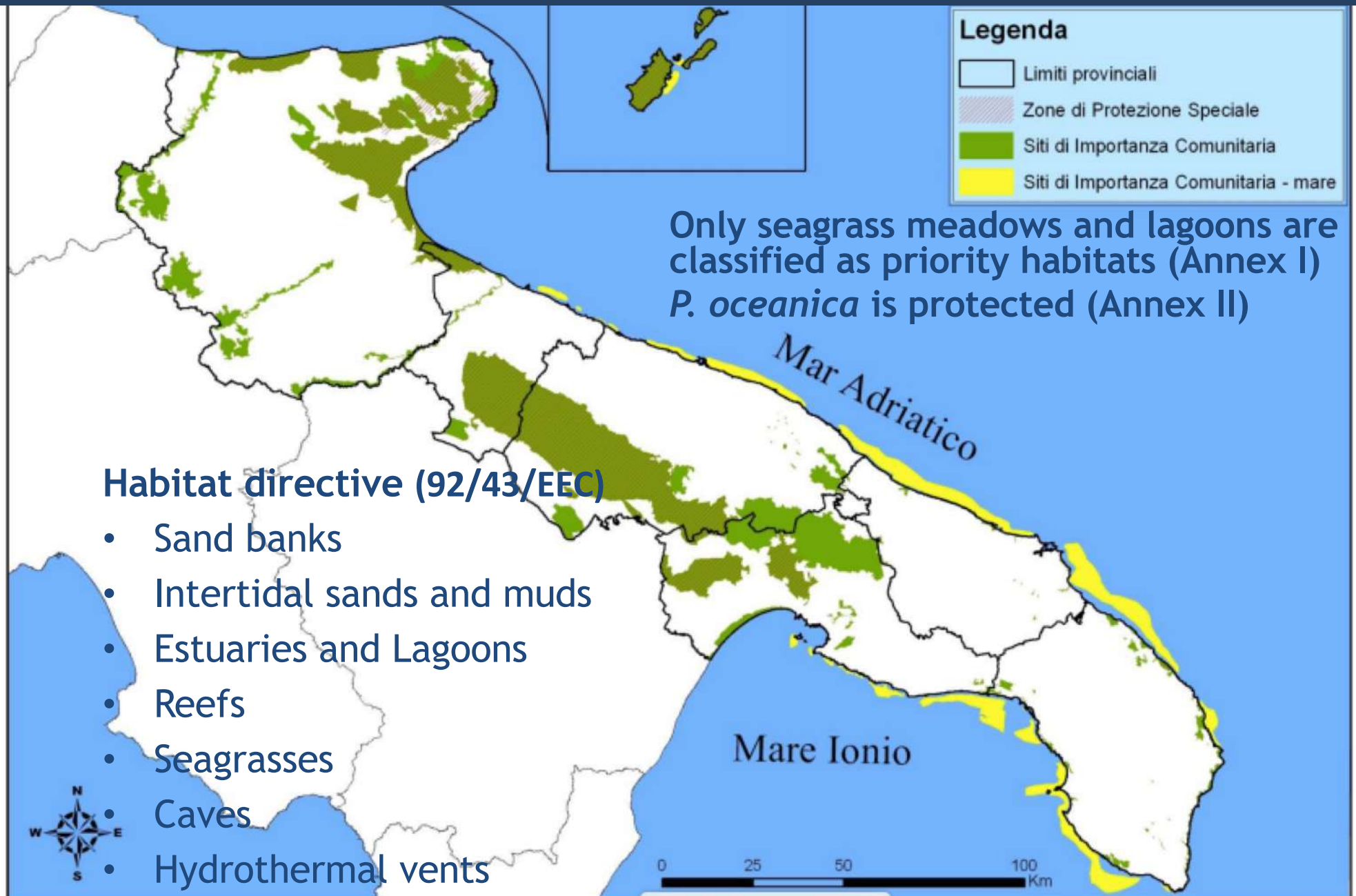


# Ecological status

Bevilacqua et al., 2020



# Environmental management





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**Mangroves**

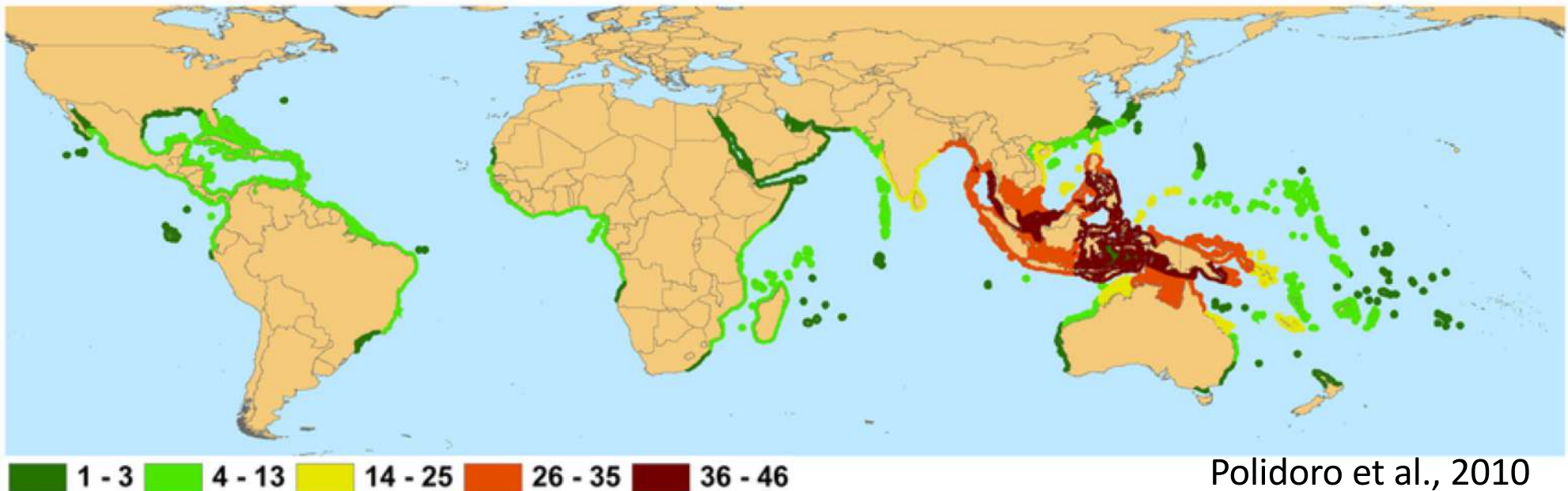
# Mangroves

- Spermatophyta (Angiosperms, Phanerogams, Magnoliophyta - flowering plants)
- Flowers, fruits, seeds, roots, stems, leaves
- Halophytes (tolerate high salt concentration)
- Evergreen



# Distribution

Typical of tropical and subtropical tidal and estuarine areas  
Do not tolerate freeze temperature. Generally, optimum is an average temperature of 20° C



Typical of sheltered areas and low hydrodynamism – roots are sensitive to strong wave movement (damage and sediment removal), and plant recruitment is also affected  
There are about 80 mangrove species

# Mangrove types

## Red mangroves (*Rhizophora*)

About 25 m in height and 40 cm in diameter.  
Generally, typical of submerged areas.  
Intricate aerial root system stabilizing the tree



## Black mangroves (*Avicennia*)

Same size of red mangroves. Typical of high tide areas. Pneumatophores.



## White mangroves (*Laguncularia*)

Smaller than the others, up to 5-6 m in height and 30 cm diameter. Generally found in the back areas of mangroves, apart from the inundated area



# Adaptations

## Roots

Mangroves develop impressive root systems, allowing plants to have a stable anchoring to the soft substrate. Since they grow on anoxic soils, these aerial roots permit oxygenation of roots beneath the sediments and water.

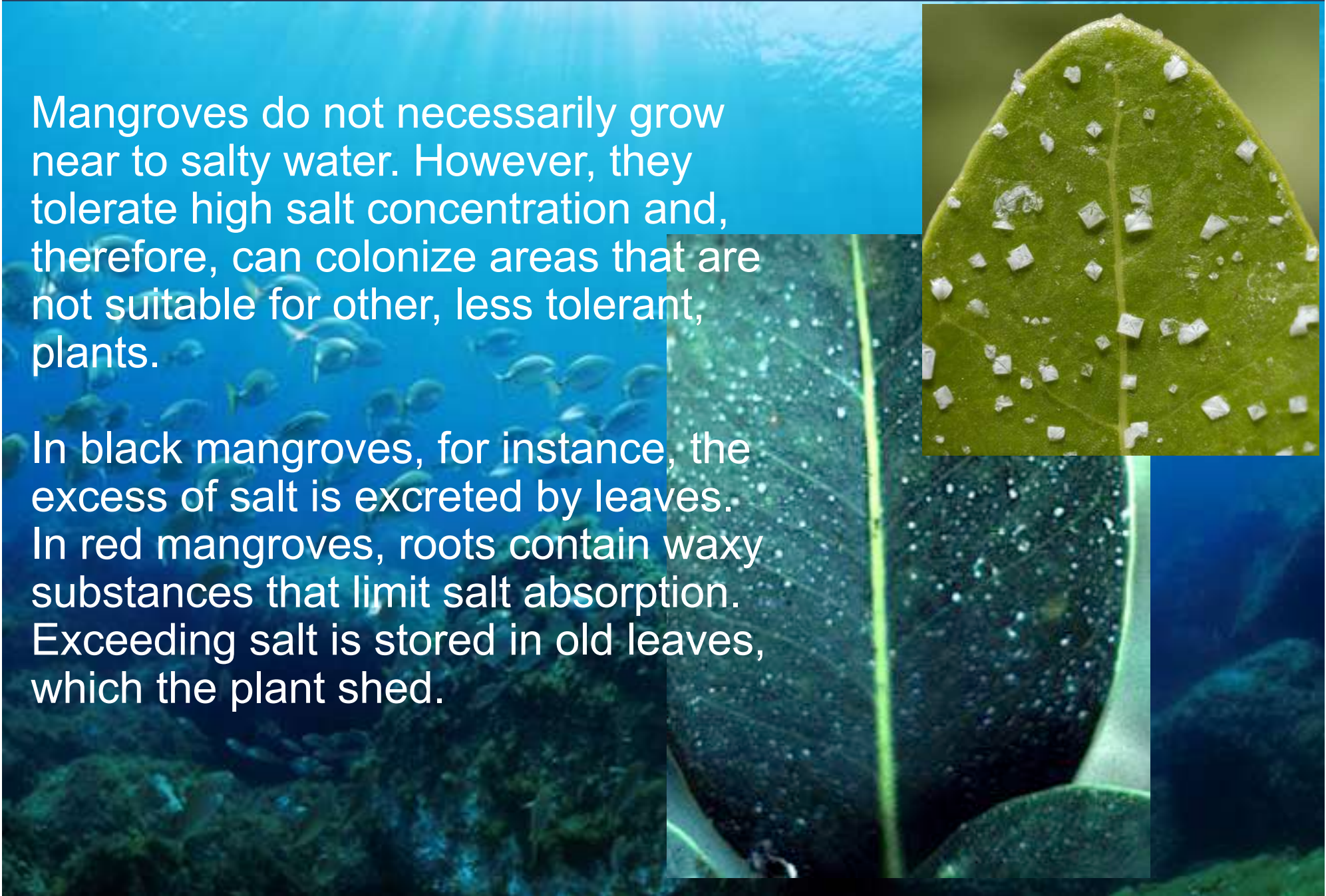
A particular type of structure is represented by pneumatophores: specialized root structures that growth out from water and allow oxygenation of submerged roots



# Adaptations

Mangroves do not necessarily grow near to salty water. However, they tolerate high salt concentration and, therefore, can colonize areas that are not suitable for other, less tolerant, plants.

In black mangroves, for instance, the excess of salt is excreted by leaves. In red mangroves, roots contain waxy substances that limit salt absorption. Exceeding salt is stored in old leaves, which the plant shed.



# Adaptations

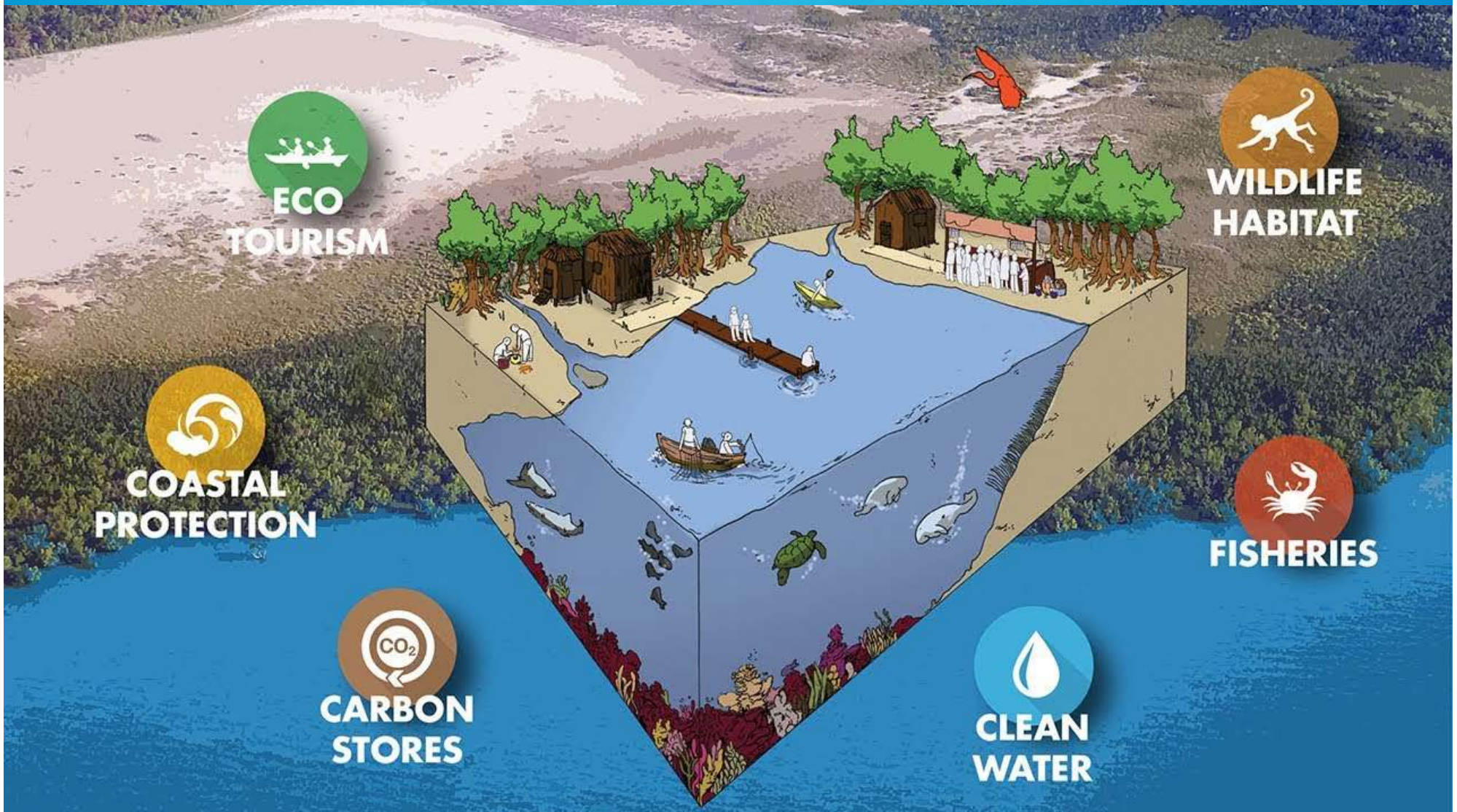
Mangroves rely on different pollination systems: anemophilous, entomophilous and zoophilous.

However, with respect to other plants, they have a peculiarity: seeds germinate when they are still on the parent plant (viviparous)

This allows seeds to disperse exploiting suitable areas in few days



# Ecological role and functioning



# Carbon storing and feeding grounds

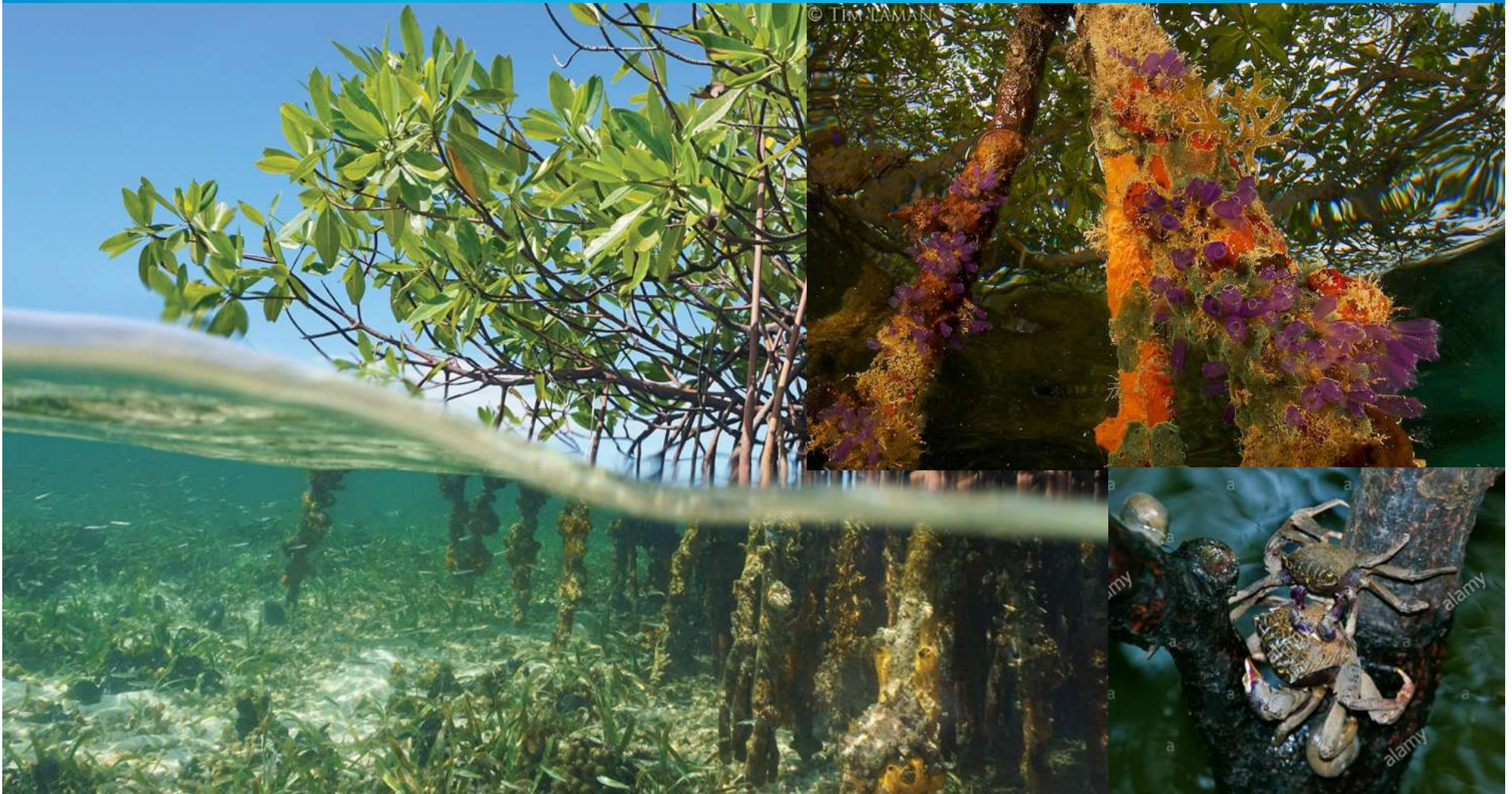
Mangroves are unique ecosystems at the boundary between sea and land. They are among the most productive coastal ecosystems (10-12 t C/ha  $y^{-1}$ , Pongpan et al., 2012)

Mangroves are essential for coastal trophic nets in tropical waters. Biomass from leaves is decomposed, releasing nutrients that sustain high planktonic productivity. This, in turn, fuels zooplanktonic herbivores, benthic communities, invertebrate and vertebrate secondary consumers (crabs, fish, birds, reptiles), representing essential feeding grounds for many species



# Habitat provision for marine...

The intricate and large complex of mangrove roots provides secondary substrate for many marine sessile invertebrates and algae. Moreover, it also provide shelter for vagile fauna.



# ...and terrestrial organisms

...which exploit the mangrove canopy to live and thrive



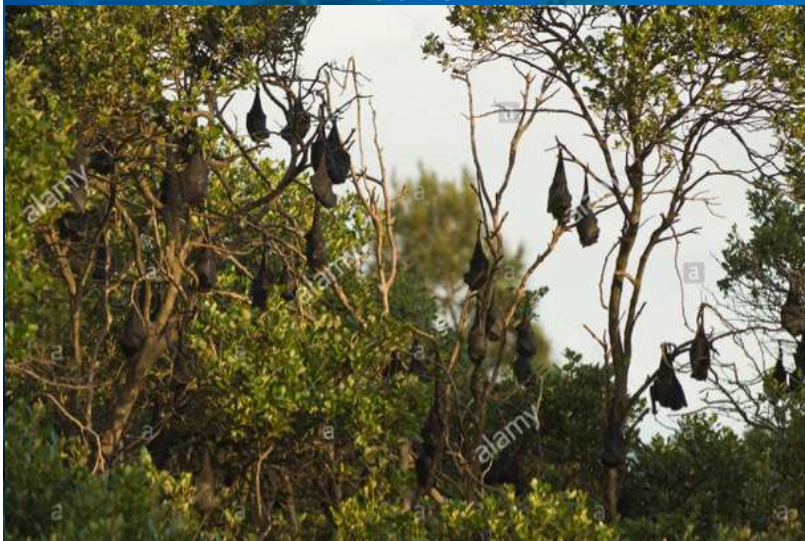
birds  
bats



monkeys  
snakes



frogs



# Breeding grounds and nursery



Mangroves serve as a nursery and breeding areas to many vertebrates and invertebrates



# Biodiversity



PATRICIO ROBLES GIL / MINDEN PICTURES



Korhnek



Korhnek



# Coastal protection

Act as a **buffer** against the high winds and eroding waves of storms. The mangroves trap sediments and prevent them from building up further out to sea, which can damage other ecosystems like coral reefs and seagrasses.

**Filter** out pollutants (nitrates, phosphates and petroleum based products) from run-off, which are then degraded by the microbes in the sediment



# Sustain local fisheries and tourism

Mangroves contribute to economy, having a huge impact on fisheries because many commercial species breed or develop in mangrove systems.



*Scylla serrata*



Service	Obs.	Mean	Min	Max
Fisheries	51	23,613	10.05	555,168
Forestry	35	38,115	18.00	1,287,701
Coastal protection	29	3,116	10.45	8,044
Recreation & tourism	14	37,927	1.74	507,368
Nutrient retention	1	44	-	-
Carbon sequestration	7	967	39.89	4,265
Nonuse	6	17,373	3.77	50,737
Biodiversity	1	52	-	-
Water and air purification/ waste assimilation	4	4,748	12.43	7,379
Traditional uses	1	114	-	-
Total	149			

Salem & Mercer, 2012



Fig. 1. The Gulf of California and the 13 fishing regions (red dashed perimeters) considered in this study, based on mangrove distribution and affinity in the composition of landings. These regions represent physical hydrogeomorphic landscape units, distinctive from adjacent landscapes. Green areas represent mangroves; black dots indicate the location of the local offices of the Mexican National Fisheries and Aquaculture Commission (CONAPESCA).

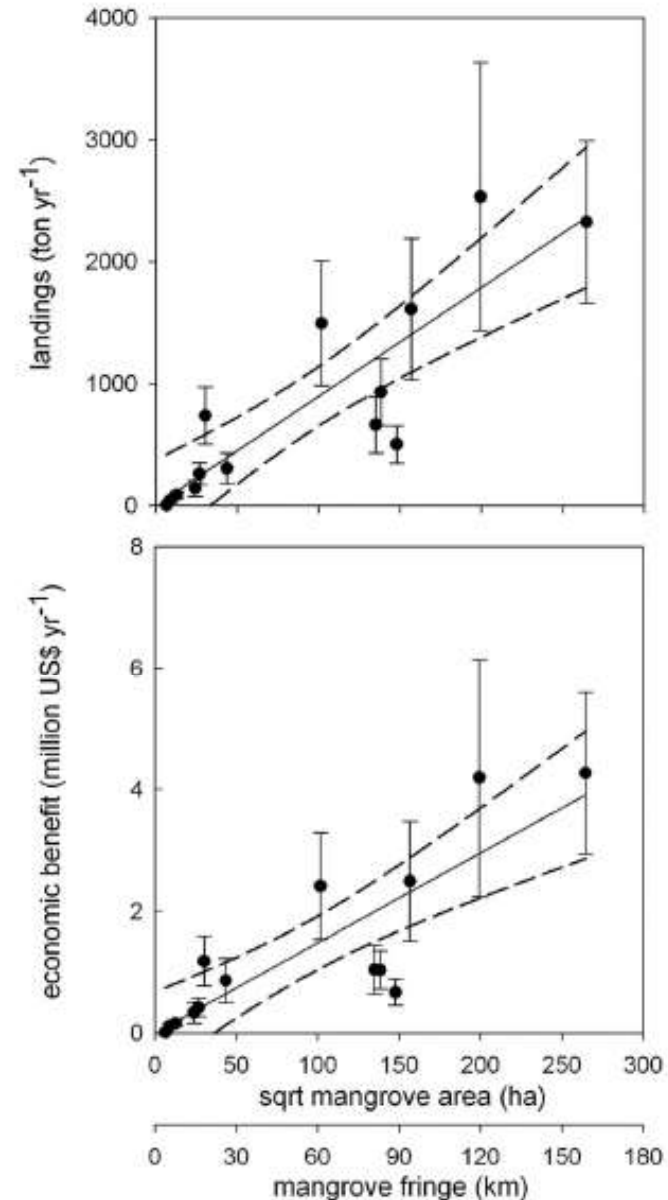


Fig. 2. Relationship between landings (fish and blue crab) and economic value (price paid to fishermen by local fishing cooperatives) against the area of mangrove fringe in the Gulf of California. Data are average  $\pm$  SE (2001–2005; solid line, model; dashed line, 95% confidence intervals).

# Human impacts

Coastal development physically destroys mangroves, or cause changes in coastal hydrodynamism and sedimentation rates

Dredging, floods. This submerges their air breathing roots and they can not get enough oxygen and nutrients

Although mangroves filter some pollutants, they can be irreparably damaged by oil spills and herbicide



# Climate changes

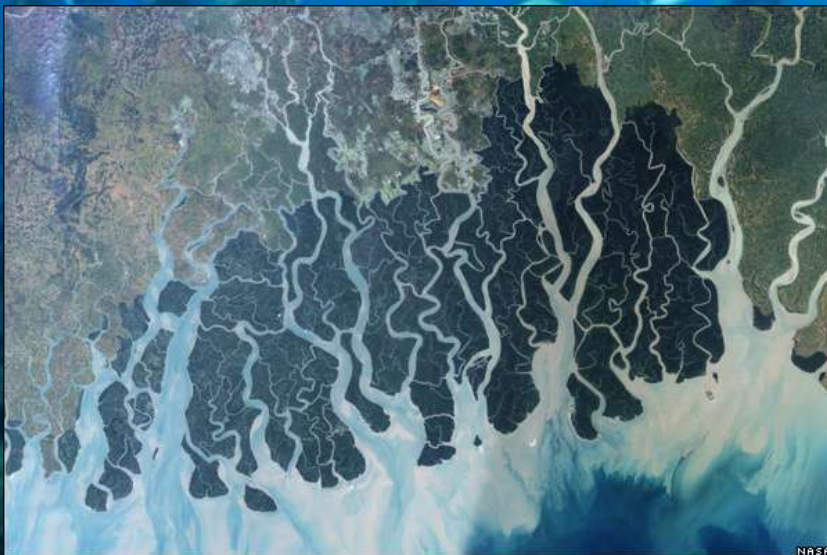
Hurricanes have a profound impact on Mangrove communities. Erosion and wind damage can restrict growth. In severe cases, areas of mangroves can be destroyed. The picture shows damage to Florida mangroves by Hurricane Charley (2004)



# Consequences

Loss of biodiversity due to habitat destruction. Moreover, without a barrier of mangroves low lying countries (e.g. Bangladesh) are more susceptible to flooding and devastation by cyclones. Loss of mangroves could severely impact economies that rely on tourism and fisheries.

Mangrove forests was estimated at 137,760 km<sup>2</sup> in the year 2000, marking an approximate decrease of 35% from 1980 estimates (Giri et al. 2011). Moreover, the rate of decrease of global mangrove forests was larger than or equal to the rates measured for coral reefs or tropical rainforests (Duke et al. 2007).



# A sad story

Indonesia's mangrove area shrank from about 41,000 km<sup>2</sup> in 1800 to 31,000 km<sup>2</sup> today, mostly because of shrimp aquaculture (Joffre et al. 2015)



How unsustainable economy turns into ecological disaster and social deprivation