


T4. Coastal carbon sinks


UIMP Universidad Internacional Menéndez Pelayo

CSIC Consejo Superior de Investigaciones Científicas

Máster Universitario en Cambio Global
Doctorado
Programa Oficial de Posgrado adaptado al EEES

Coastal carbon sinks
Who are they?

Blue Carbon

- Tidal salt marshes
- Mangroves
- Kelp forests ?
- Seagrass meadows
- Coastal Sediments
- Coral reefs ?

Ecosystem type	Standing carbon stock (gC m^{-2})		Total global area ($*10^{12}$ m^2)	Global carbon stocks (PgC)		Longterm rate of carbon accumulation in sediment (gC m^{-2} yr^{-1})
	Plants	Soil		Plants	Soil	
Tidal Salt Marshes			Unknown (0.22 reported)		0.4*	210
Mangroves	7990		0.157	1.2		139
Seagrass meadows	184	7000	0.3	0.06	2.1	83
Kelp Forests	120-720	na	0.02-0.4	0.009-0.02	na	na

*Estimate by Chmura et al. 2003 for the upper 50cm of tsm.

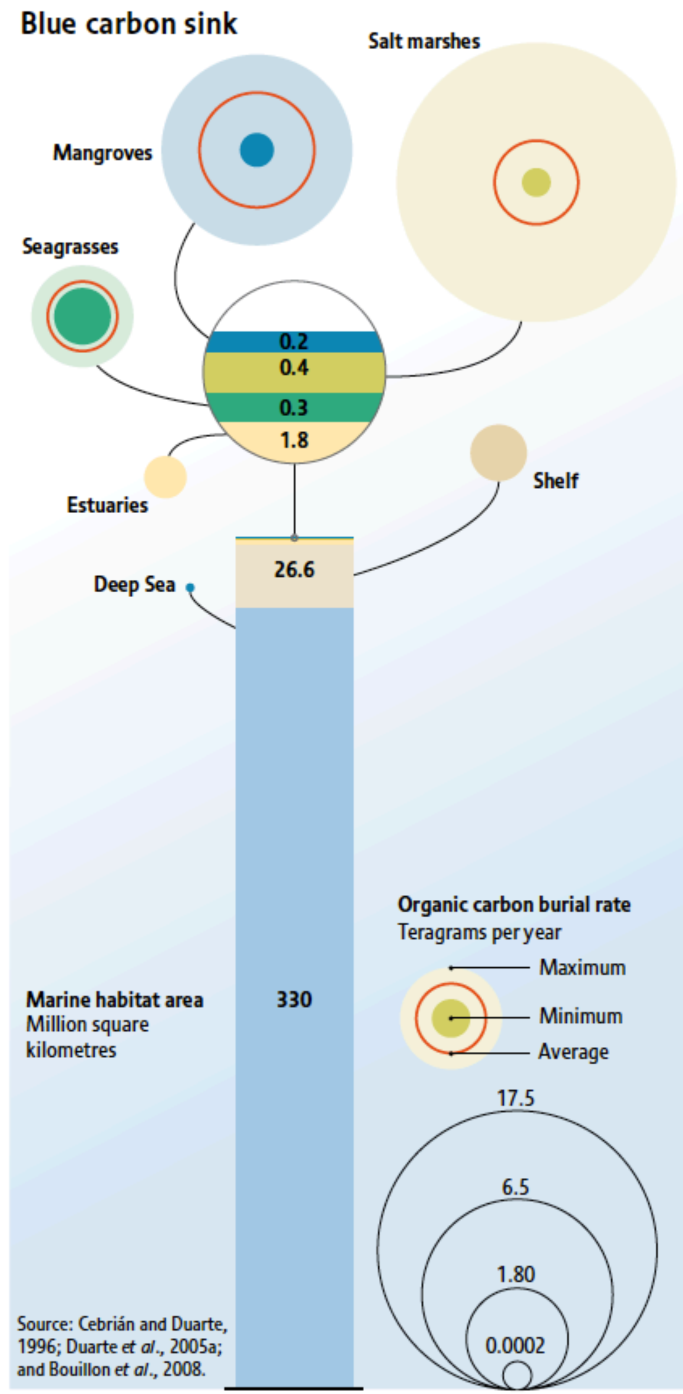

Figure 17: Blue carbon sinks.

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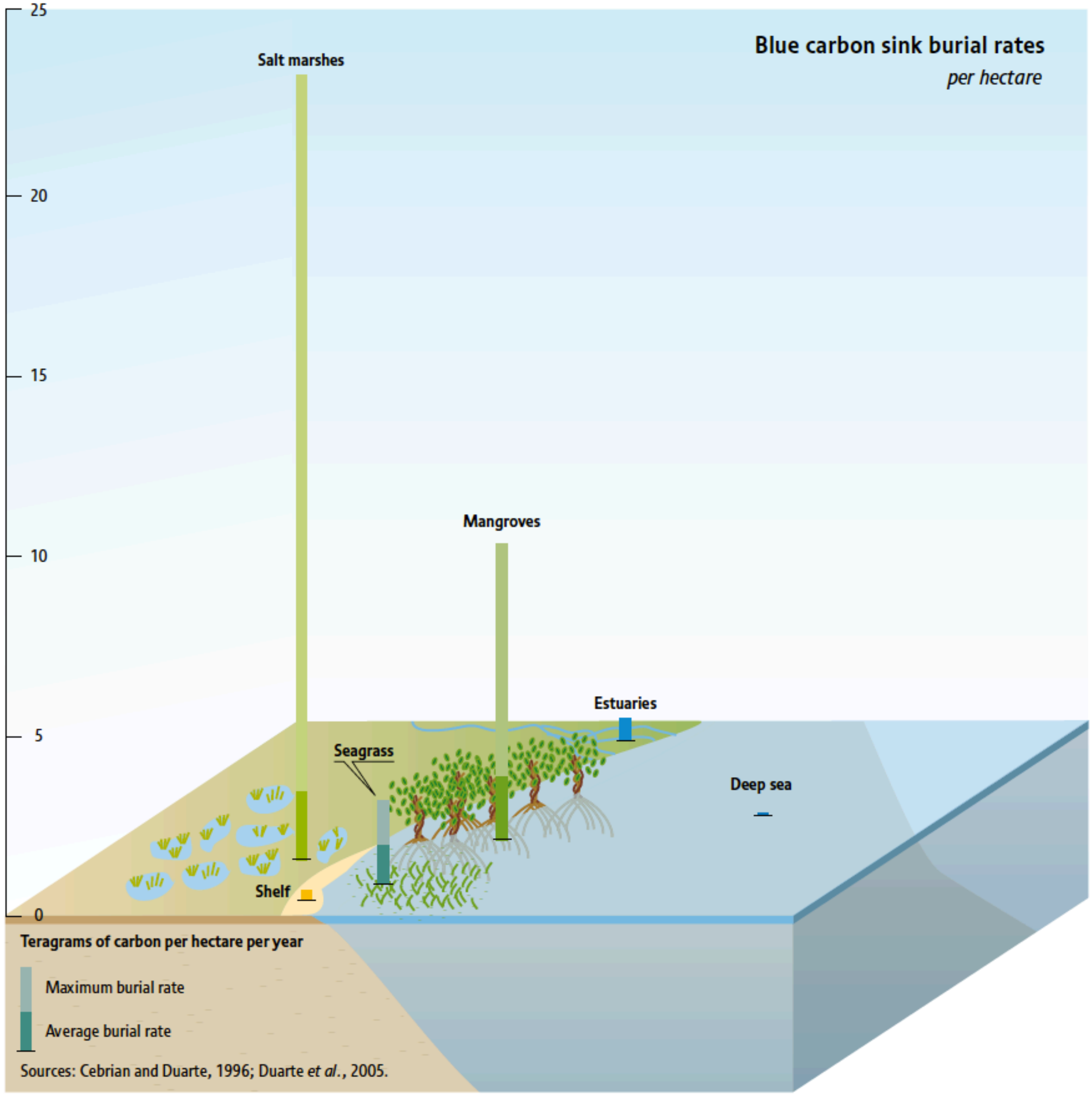

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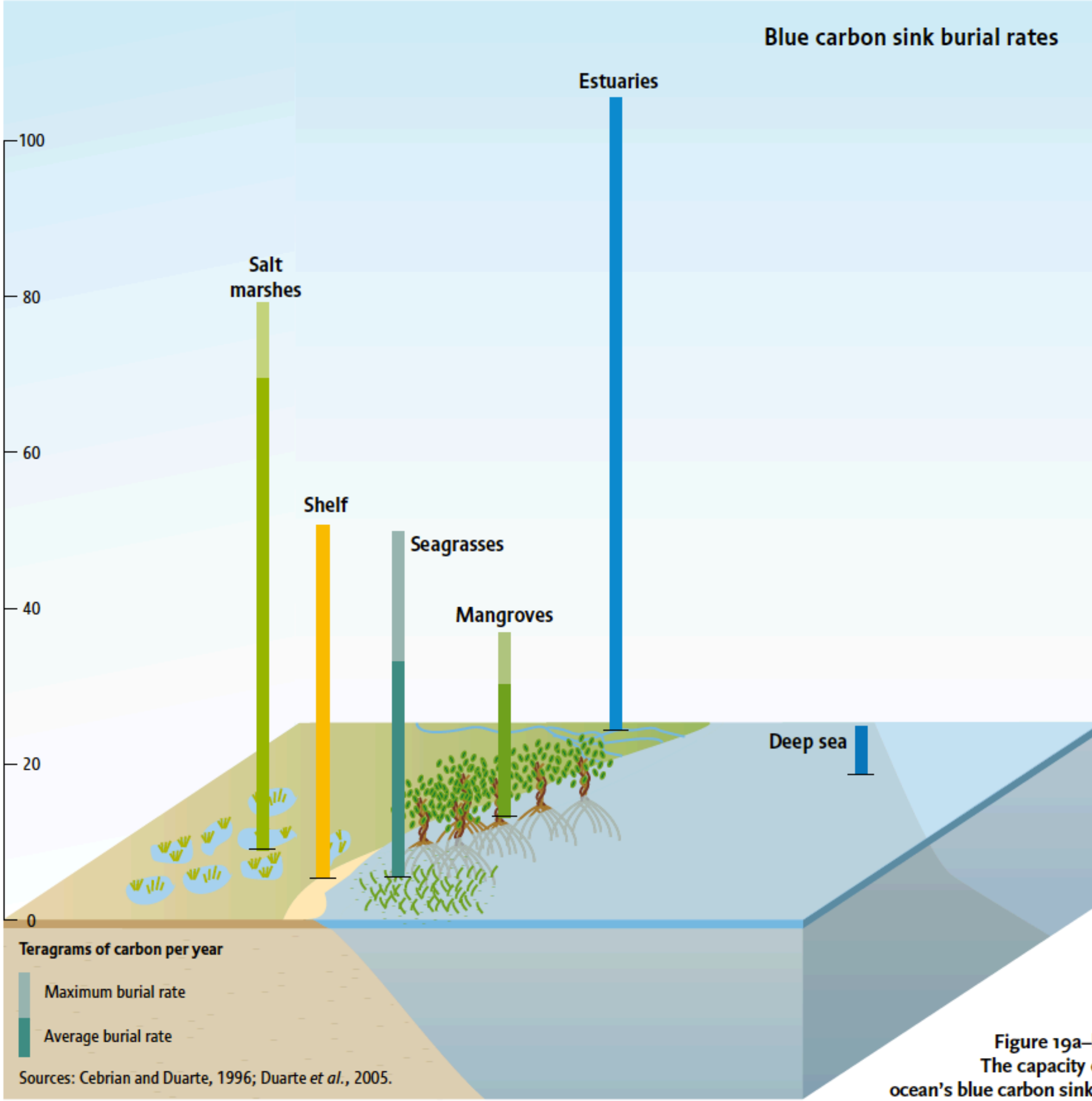

Figure 19a–b: The capacity of ocean's blue carbon sinks.

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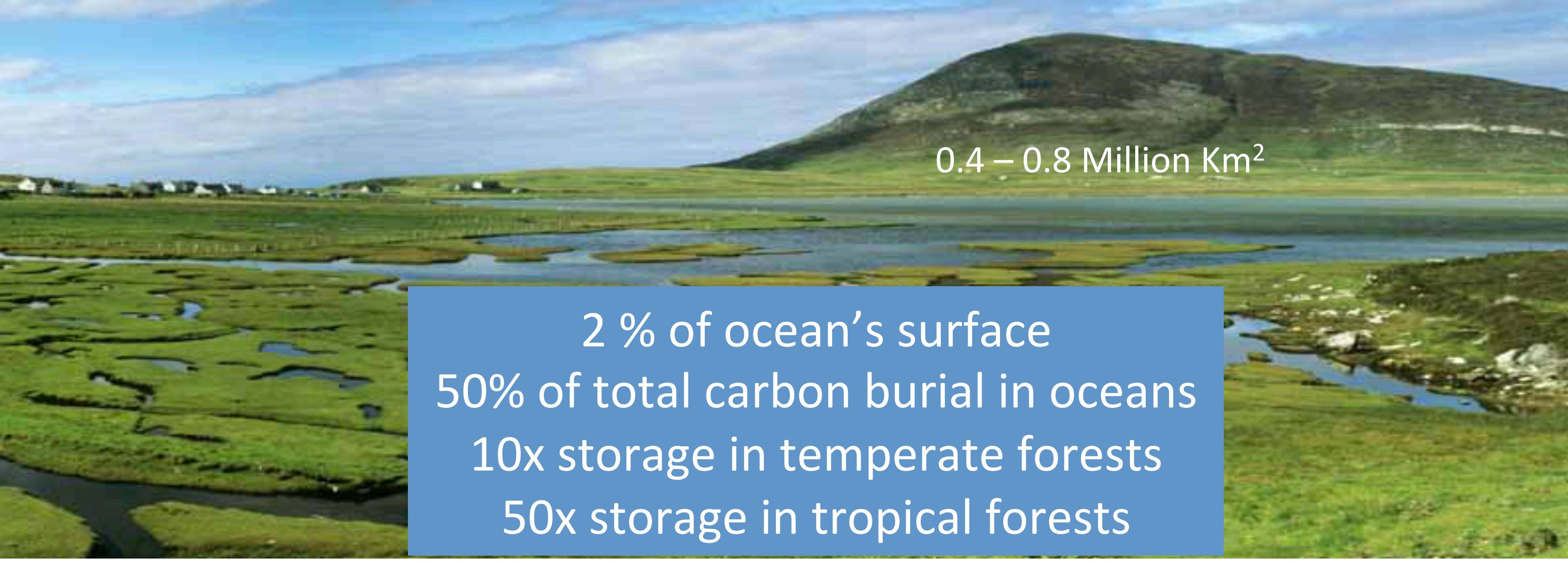

2 % of ocean's surface
50% of total carbon burial in oceans
10x storage in temperate forests
50x storage in tropical forests

Coastal carbon sinks
Area covered and global burial rates

Nelleman et al. 2009

Component	Area Million km^2	Organic Carbon burial Ton C ha^{-1} y^{-1}	Organic Carbon burial Tg C y^{-1}
Vegetated habitats			
Mangroves	0.17 (0.3)	1.39, 0.20 – 6.54 (1.89)	17 – 23.6 (57)
Salt Marsh	0.4 (0.8)	1.51, 0.18 – 17.3 (2.37)	60.4 – 70 (190)
Seagrass	0.33 (0.6)	0.83, 0.56 – 1.82 (1.37)	27.4 – 44 (82)
Total vegetated habitats	0.9 (1.7)	1.23, 0.18 – 17.3 (1.93)	114 – 131 (329)
Depositional areas			
Estuaries	1.8	0.5	81.0
Shelf	26.6	0.2	45.2
Total depositional areas			126.2
Total coastal burial			237.6 (454)
% vegetated habitats			46.89 (0.72)
Deep sea burial	330.0	0.00018	6.0
Total oceanic burial			243.62 (460)
% vegetated habitats			45.73 (0.71)

Coastal carbon sinks
Input process

- **Photosynthesis** captures carbon from the atmosphere or from the water.
- This organic carbon joins ‘circular routes’ of various ‘diameters’ or **residence times**.
- In coastal carbon sinks residence times can vary **from hours** (dissolved organic carbon – DOM) **to millennia** (refractory detrital carbon).
- The way in of carbon into coastal carbon sinks is known as ‘**burial**’.

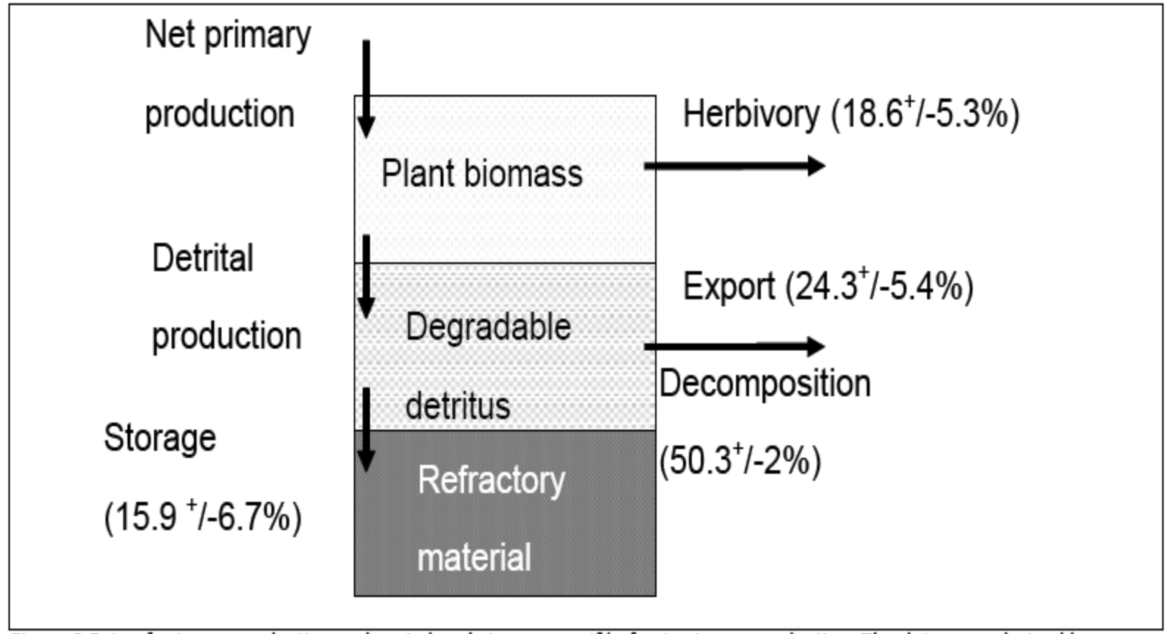

Figure 2 Fate of primary production, values in brackets represent% of net primary production. The data were derived by averagingindependent estimates from a range of seagrass species (adapted from Cebrian 1999 & Duarte & Cebrian 1996)

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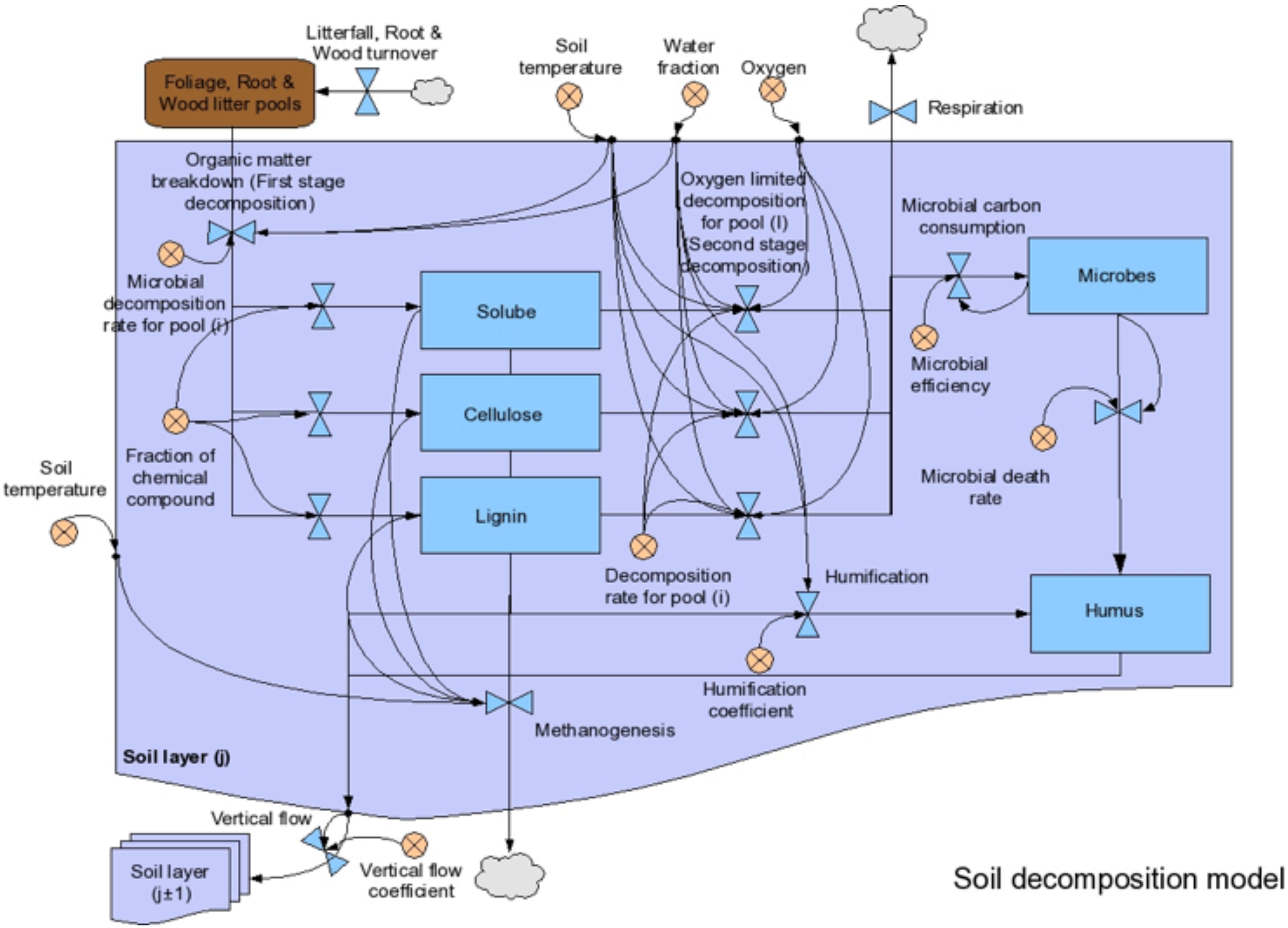
Coastal carbon sinks
Output process



Soil decomposition model

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Coastal carbon sinks Global Stocks and specific acc. rates

- **CCS are largely unexplored**. Global area, aboveground and specially belowground standing stocks, lack accurate estimates.
- Estimates of refractory accumulation in CCS show **efficiencies order of magnitud (1-2) higher** than in any other ecosystem type.
- Kelp forests and coral reefs??

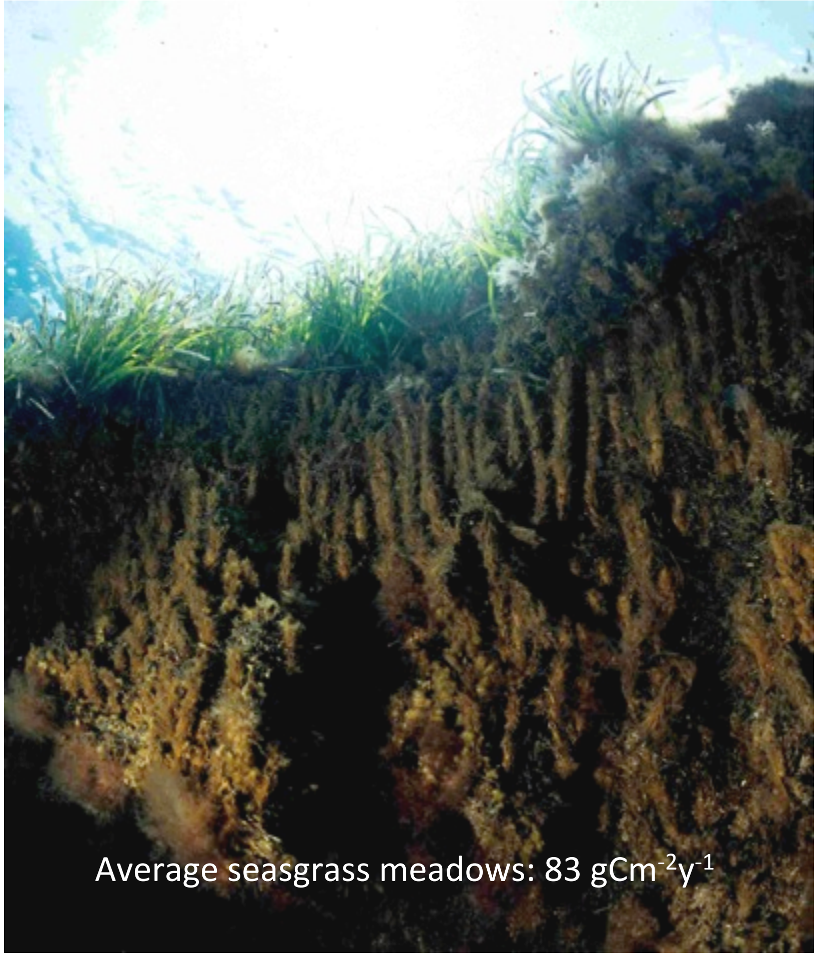
Ecosystem type	Standing carbon stock ($gC\ m^{-2}$) Plants	Standing carbon stock ($gC\ m^{-2}$) Soil	Total global area ($*10^{12}\ m^2$)	Global carbon stocks ($*10^{15}\ gC$) Plants	Global carbon stocks ($*10^{15}\ gC$) Soil	Longterm rate of carbon accumulation in sediment ($gC\ m^{-2}\ y^{-1}$)
Tropical forests	12045	12273	17.6	212	216	2.3-2.5
Temperate forests	5673	9615	10.4	59	100	1.4 – 12.0
Boreal forests	6423	34380	13.7	88	471	0.8 – 2.2
Tropical savannas and grasslands	2933	11733	22.5	66	264	
Temperate grasslands and shrublands	720	23600	12.5	9	295	2.2
Deserts and semi-deserts	176	4198	45.5	8	191	0.8
Tundra	632	12737	9.5	6	121	0.2 – 5.7
Croplands	188	8000	16	3	128	
Wetlands	4286	72857	3.5	15	225	20
Tidal Salt Marshes			Unknown (0.22 reported)			210
Mangroves	7990		0.152	1.2		139
Seagrass meadows	184	7000	0.3	0.06	2.1	83
Kelp Forests	120-720	na	0.02- 0.4	0.009-0.02	na	na

Table 1 Comparison of carbon stocks and longterm accumulation of carbon in soils in key terrestrial and coastal marine ecosystems. (Terrestrial ecosystems (Kennedy & Bjork 2009), seagrass meadows (Duarte & Cebrian 1996, Duarte & Chiscano 1999, Duarte et al. 2005, Kennedy & Bjork 2009), Tidal Salt marshes (Chmura et al. 2003), Mangroves (Alongi 2002, Cebrian 2002, Duarte et al. 2005, FAO 2007), Kelp (Reed & Brzezinski 2009))

Long/short-term accumulation
A key gap of knowledge

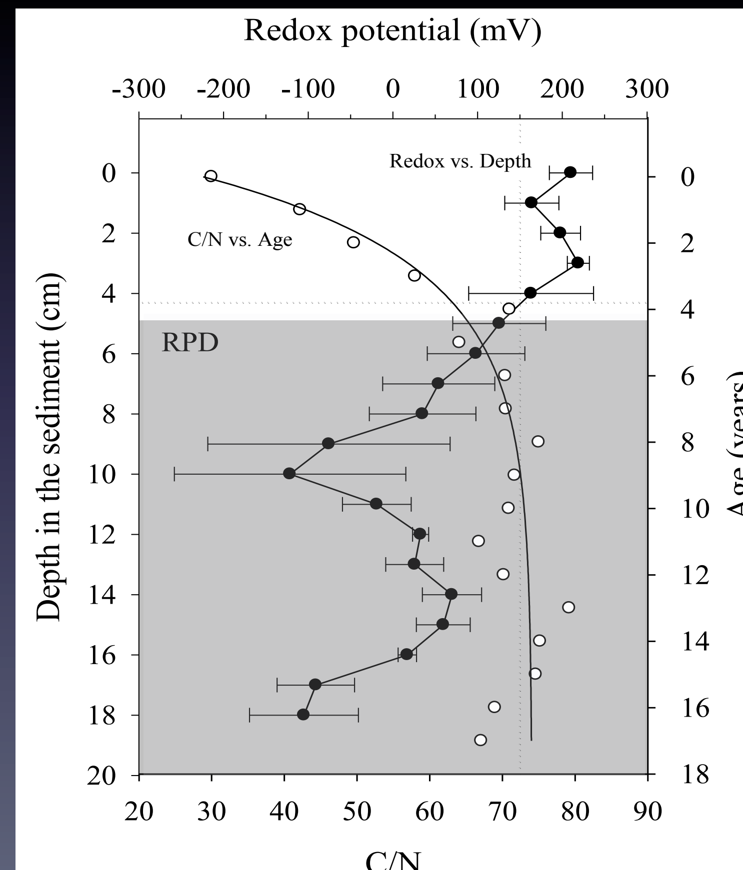
Ecosystem type	Long-term rate of accumulation ($gC\ m^{-2}\ a^{-1}$)
Tropical forests	2.3-2.5
Temperate forests	1.4 – 12.0
Boreal forests	0.8 – 2.2
Temperate grasslands	2.2
Temperate deserts	0.8
Tundra	0.2 – 5.7
Wetlands	20
Posidonia oceanica meadows	9 – 112

Table 2 Long-term carbon accumulation rates in Holocene (<10,000yr old) soils and wetlands (Schlesinger 1990, Armentano & Menges1986) and Posidonia oceanica *(6,000 yr old) as one of the few species of seagrass that accumulate refractory organic matter in below-ground deposits termed mattes (Romero et al., 1994, Mateo et al., 1997, 2006).*



What is burial?

- Organic carbon pool remaining after 1 plant annual cycle
- Typically found in the sediments
- We proposed short- vs long-term as:
    - Short-term: >1 year; <4-6 years
    - Long-term: >4-6 years (millennia)



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Burial ≠ Long-term sink

- Published global estimates are mostly indirect estimates or use *shallow sink* samples
- Published estimates do not specify turnover, nor carbon fraction considered; usually include potential leave-derived refractory carbon
- They may refer to the *Potential sink* (short + long-term sinks)
- Short-term sinks are very small, hardly significant for carbon storage
- We look for sinks with a *residence time* of >100 years or so, therefore …
  - We need direct estimates of the long-term sink or, even better, *competent* accumulation models

Mateo et al 2010; Serrano 2011; Serrano et al, submitted; Mateo, in prep.

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Direct estimates

- Plant primary production estimate
- 5m sediment cores, 4000-6000 years old
- Direct measurement of organic and inorganic carbon

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Algal 'forests'

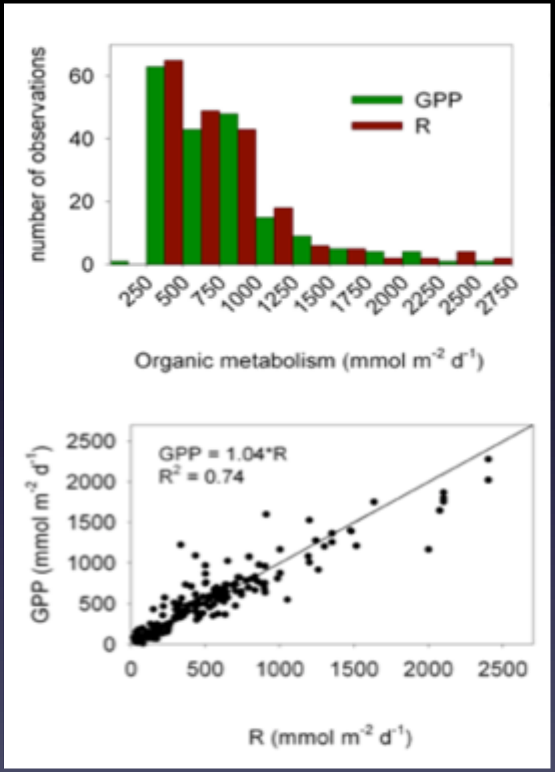
$P \approx R$

Coral reefs

Global C emitters

The coral reef theory and the *rule of the 0.6*

(e.g., Ware et al. 1992, Smith and Gatusso 2009)



$$Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 \uparrow + H_2O$$

Role of *Blue Carbon* Justification

Organic Carbon Influx

Blue Carbon Sinks	*Oceanic Carbon Sinks*
120 $TgC\ y^{-1}$ (Up to 329 $TgC\ y^{-1}$)	243.6 $TgC\ y^{-1}$

BCS ≈ 50 – 71% of OCS

Up to 15% of the *Missing Sink**

*Residual 'terrestrial' carbon

Role of *Blue Carbon* Target

Atmosphere carbon increase: 3.3 Pg y^{-1}

IPCC'2007 target: stabilize CO_2 at 445 – 490 ppm by Reducing emissions and Enhancing sinks

Conservation, Promotion and Restoration of BCS

Prevent of annual loss of 10% of reductions needed (20-25% including *Green Carbon* REDD)

Nelleman et al. 2009

Coastal carbon sinks
Future Evolution and accumulation efficiency (comparison)

	Mangroves	Seagrasses
Annual average global loss (km^2/year)	118	110
Equivalent tropical forest loss (km^2/year)	6600	3600
Equivalent temperate forest loss (km^2/year)	1400	770
Total estimated global loss (km^2)	36,000	51,000
Equivalent tropical forest loss (km^2)	2,000,000	1,700,000
Equivalent temperate forest loss (km^2)	430,000	350,000

Table 2: Annual and total loss of mangrove and Seagrass habitat (FAO 2007, Waycott et al. 2009) and the equivalent areas of tropical and temperate terrestrial forest needed for longterm carbon sequestration in sediments (calculated from longterm rate of carbon accumulation in soils in Table 1).

Seagrasses

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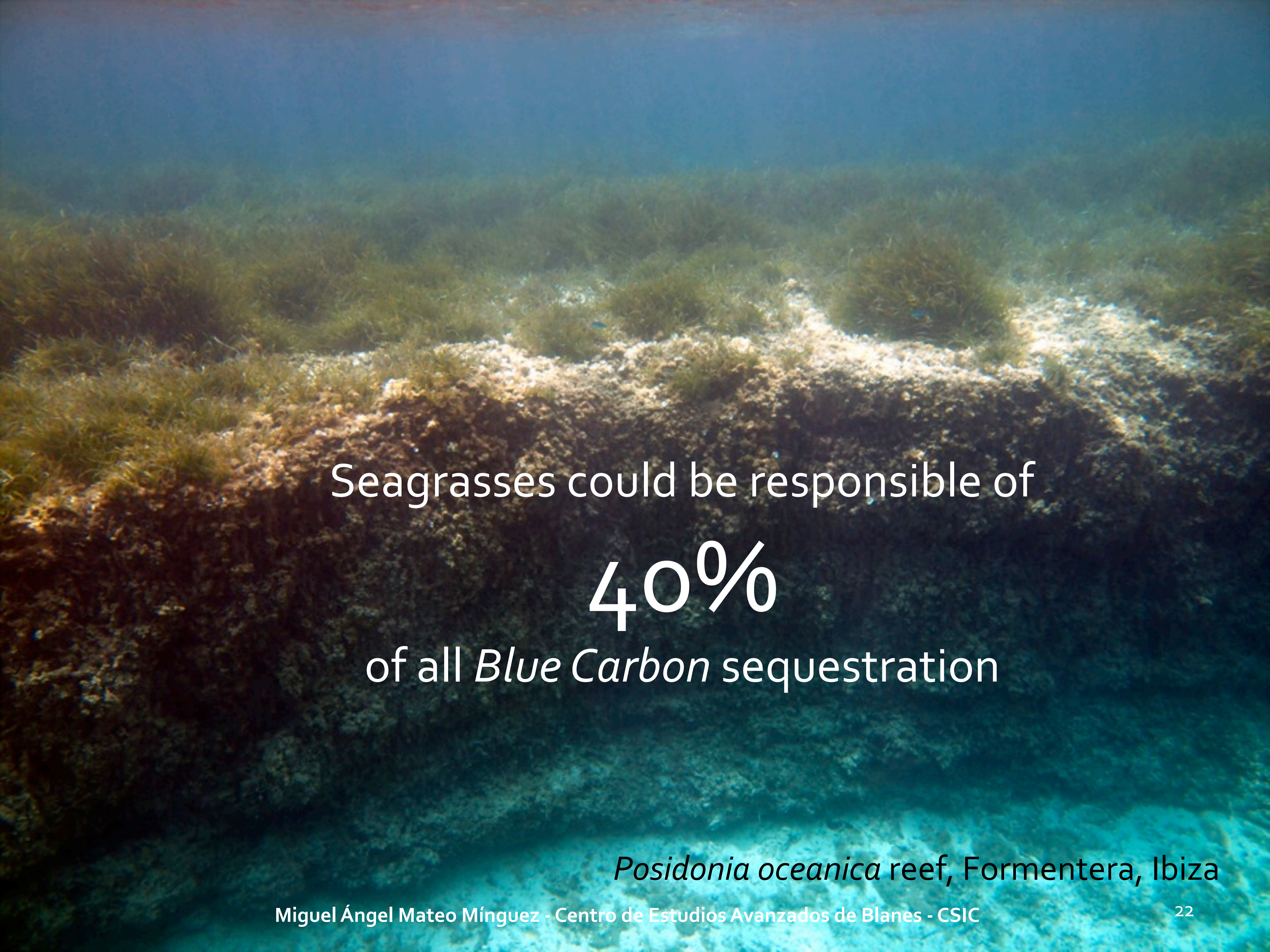


Posidonia oceanica reef, Formentera, Ibiza

Sinks need sources

Seagrass meadows: hihgly productive ecosystems

(maybe the highest after wetlands)

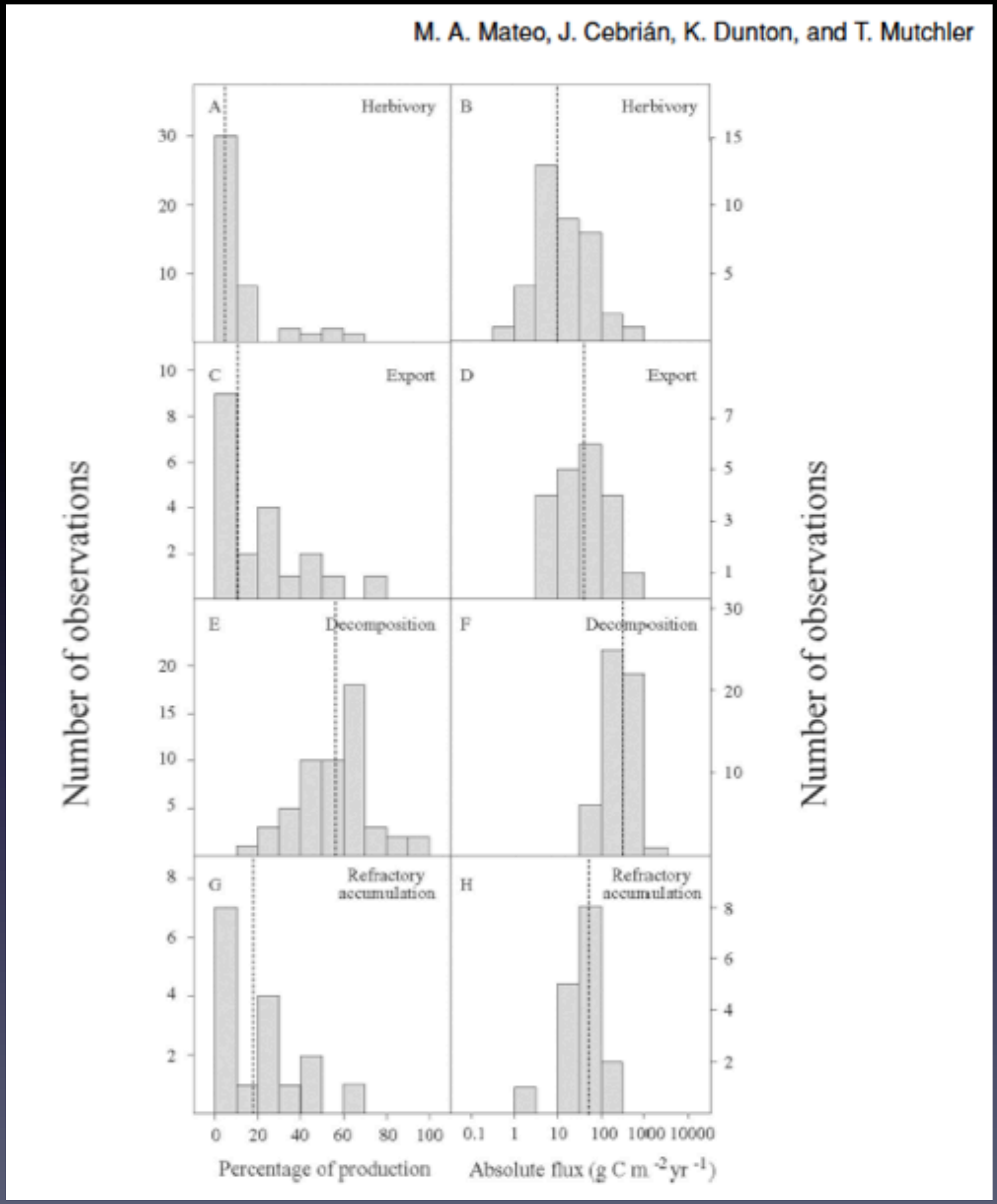
300 - 1500 gC m^{-2} y^{-1} Mateo et al 2006

700 - 1700 gC m^{-2} y^{-1} Duarte et al 2010

P/R ratio = 1.55 ± 0.13

(community metabolic approach)

Kennedy et al 2010



Mateo et al. 2006

For all seagrasses

Grazing
8%

Export
12%

Detrital pathway
60%

Burial
20%

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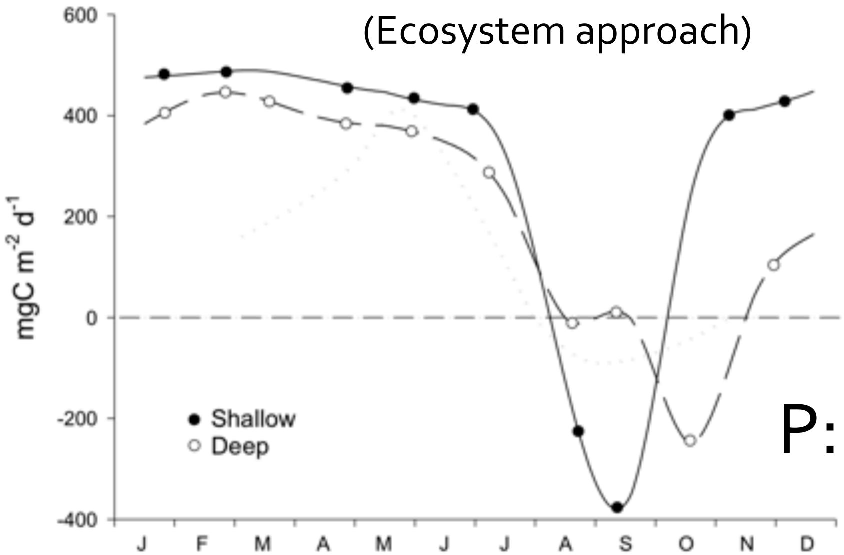
Mateo et al. 2006

Production vs Respiration

(Ecosystem approach)



P:R ≈ 3

For *P. oceanica*

Productivity

60 to 705 gC m^{-2} y^{-1}

Burial

11-47%

	MEDES (5–13 m)	CALVI (1–30 m)	ISCHIA (5–20 m)
Production	153.5 (100)	155 (100)	96.9 (100)
Remineralization	61.3 (39.9)	68.7 (44.3)	23.2 (23.9)
Budget	92.3 (60.1)	86.3 (55.7)	73.7 (76.1)
Export	9.8 (6.4)	38.8 (25.0)	47.9 (49.5)
Grazing	10.0 (6.5)	31.0 (20.0)	6.3 (6.5)
Known fate	81.0 (52.8)	138.5 (89.3)	77.4 (79.9)
Potential sink	72.5 (47.2)	16.6 (10.7)	19.5 (20.1)
P:R	2.5	2.3	4.2

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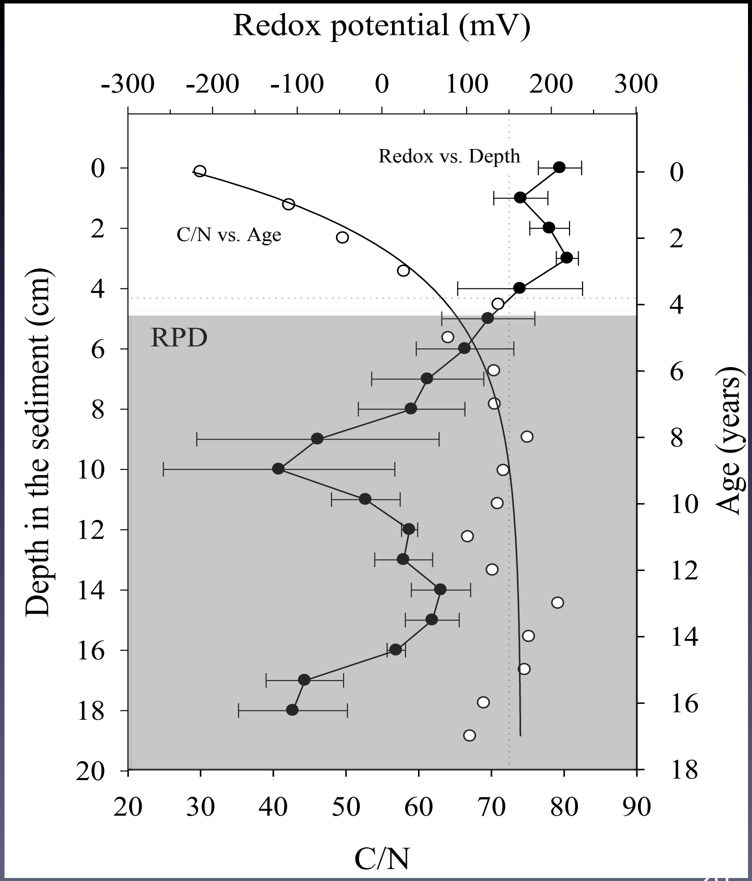

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  - We need direct estimates of the long-term sink or, even better, *competent* accumulation models

Mateo et al 2010; Serrano 2011; Serrano et al, submitted; Mateo, in prep.

Direct estimates

- Plant primary production estimate
- 5m sediment cores, 4000-6000 years old
- Direct measurement of organic and inorganic carbon

Total plant NPP: 234 gC m^{-2} y^{-1}
(at 3-6 m depth)

Sink	gC m^{-2} y^{-1}	% NPP
***P. oceanica*-derived carbon**		
Potential (s-t + l-t)[1]	7 - 331	11 - 47
Short-term[2]	4 - 296	6 - 42
Long-term[3]	**3 - 88**	**5 - 12**
All carbon sources		
Potential (s-t + l-t)	14 - 662	22 - 94
Short-term	8 - 487	13 - 70
Long-term	**6 - 175**	**10 - 25**

Portlligat Bay, NW Mediterranean

Mateo and Serrano (2011) IUCN, in press

The coral reef theory and the *rule of the 0.6*

(e.g., Ware et al. 1992, Smith and Gatusso 2009)

$$Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3 + CO_2\uparrow + H_2O$$

High $CaCO_3$ production

(of *P. oceanica* calcifying organisms community)

Posidonia

47-138 g C_{carb} m^{-2} yr^{-1}

Coral reefs

144 gC_{carb} m^{-2} yr^{-1}

P. oceanica source

28 - 83 g C_{carb} m^{-2} yr^{-1}

This work and Smith and Gattuso 2009

Some global estimates
Fluxes

	Specific	Mediterranean[1]
	gC m^{-2} y^{-1}	TgC y^{-1}
Organic sink[2]	6 to 175	0.15 to 8.75
Inorganic source[3]	28 to 83	0.7 to 4.2
Balance	-147 to +77	-8.1 to +4.1

Mateo and Serrano 2011

All seagrasses ≈ -50 TgC y^{-1}

-27 to -44 and up to -82 TgC y^{-1}

Nelleman et al. 2009

Some global estimates
Stocks

Mateo and Serrano 2011

	Compartment	Specific $gC\ m^{-2}$	Mediterranean Pg C
Living	Above	270	0.007 - 0.014
	Below	970	0.024 -0.048
Dead	Above	25	0.0006 - 0.0013
	$Below_{coarse}$	$4 - 16 \times 10^4$	1.0 - 8.0
	$Below_{fine}$	$6 - 25 \times 10^4$	1.5 - 12.5
	$Below_{total}$	$10 - 41 \times 10^4$	2.5 - 20.5
C_{carb}		$4.7 – 55.2 \times 10^4$	1.2 - 27.6
Total		$14.8 – 96.3 \times 10^4$	3.7 - 48.2

2.1 PgC for all seagrasses*

2.5 – 20.5 PgC for *P. oceanica***

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P. oceanica in the BC context

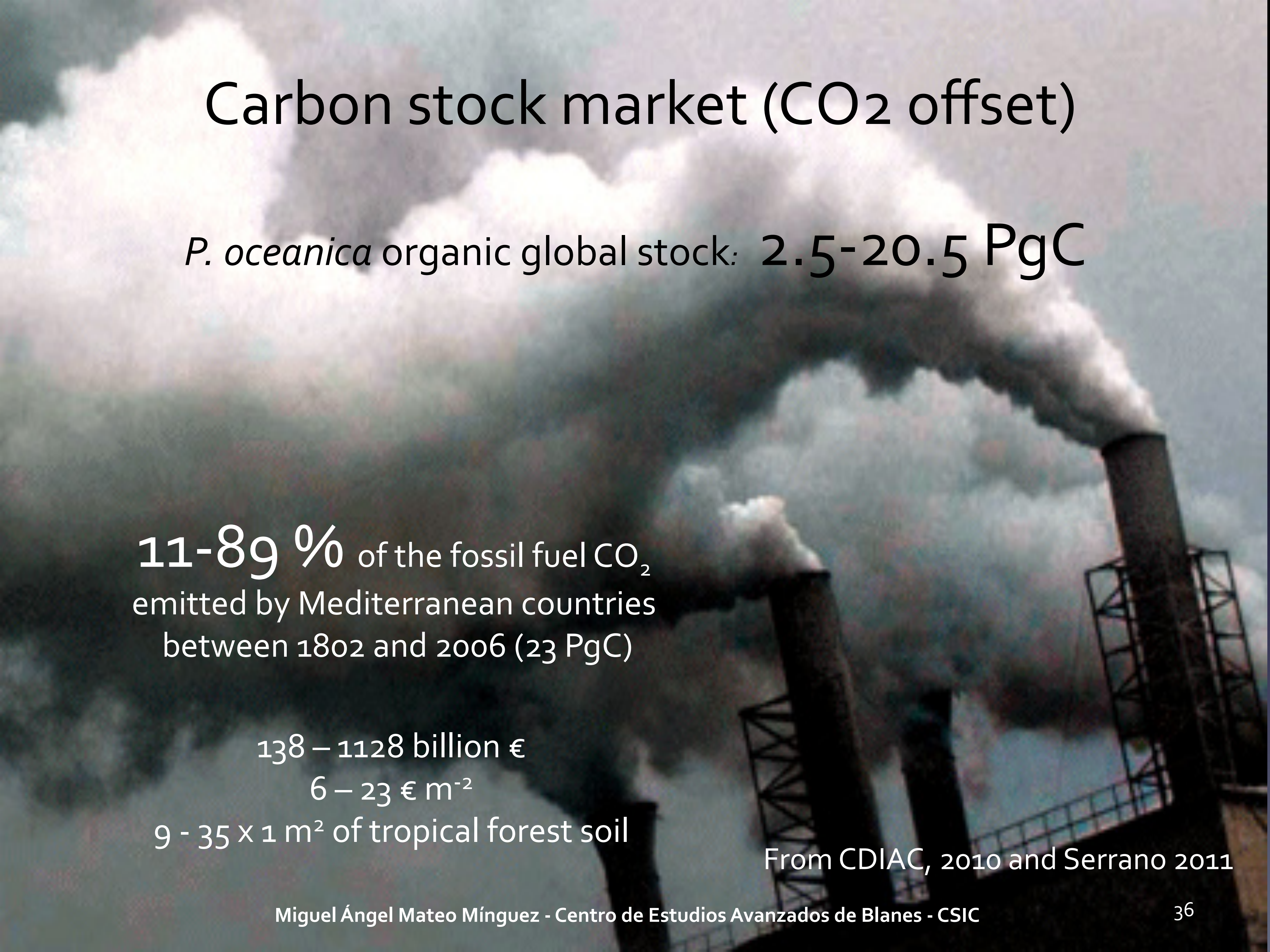
Component	Area	Organic Carbon burial	
	Million km^2	Ton C ha^{-1} y^{-1}	Tg C y^{-1}
Vegetated habitats			
Mangroves	0.17 (0.3)	1.39, 0.20 – 6.54 (1.89)	17 – 23.6 (57)
Salt Marsh	0.4 (0.8)	1.51, 0.18 – 17.3 (2.37)	60.4 – 70 (190)
Seagrass	0.33 (0.6)	0.83, 0.56 – 1.82 (1.37)	27.4 – 44 (82)
Total vegetated habitats	0.9 (1.7)	1.23, 0.18 – 17.3 (1.93)	114 – 131 (329)
Posidonia oceanica	0.035 (0.050)	0.06 – 1.75	0.15 – 8.75

The values for *P. oceanica* refer to the long-term burial

Carbon content of Australian seagrasses sediments (upper 24 cm) Comparison to *Posidonia oceanica*

Species	Climate	N	% OM (bulk) Means	SD	% C (bulk) Means	SD	mgC cm^{-3} Means	SD	gC m^{-2} Means	SD
Halophila ovalis	tropical	15	6.21	3.45	1.18	0.38	8.64	2.86	2072.77	685.41
Zostera capricorni	tropical	15	4.48	1.30	1.33	0.83	8.06	3.38	1933.85	810.48
Cymodocea serrulata	tropical	15	3.02	0.88	0.68	0.19	6.32	1.74	1516.70	417.02
Posidonia australis	subtropical	29	6.78	4.43	0.79	0.50	6.01	1.98	1442.76	474.36
Halodule uninervis	tropical	27	5.87	2.51	0.69	0.36	5.19	2.55	1244.96	610.93
Amphibolis antarctica	subtropical	30	3.32	2.74	0.39	0.26	3.82	1.74	917.49	417.14
Amphibolis antarctica	temperate	29	1.51	1.59	0.33	0.38	2.82	2.64	677.12	633.55
C. rotundata/S. isoetifolium	tropical	15	3.08	0.39	0.32	0.11	2.67	0.85	640.15	204.87
Posidonia sinuosa	temperate	44	1.72	1.70	0.28	0.31	2.44	2.01	585.35	482.62
C. rotundata/H. uninervis	tropical	28	2.55	2.89	0.28	0.10	2.43	0.85	582.33	203.38
T. hemprichii/C. rotundata	tropical	15	2.94	2.36	0.30	0.10	2.38	0.85	571.82	204.72
All spp (Australia)		262	**3.59**	3.10	**0.54**	0.48	**4.23**	2.88	**1015.78**	691.59
Posidonia oceanica	temperate	7	**42.99**	12.09	**17.85**	6.08	**20.16**	9.49	**4837.42**	2276.62
P. oceanica/Aus. Spp			12x		33x		5x		5x	

Mateo and Lavery (in prep).



Carbon stock market (CO_2 offset)

P. oceanica organic global stock: 2.5-20.5 PgC

11-89 % of the fossil fuel CO_2 emitted by Mediterranean countries between 1802 and 2006 (23 PgC)

138 – 1128 billion €
6 – 23 € m^{-2}
9 - 35 x 1 m^2 of tropical forest soil

From CDIAC, 2010 and Serrano 2011

Last thoughts
Limitations

- The lack of knowledge of production and stocks in seagrasses, most especially regarding belowground organs
- The lack of knowledge of the terms of the carbon ecosystem balance (decay, export, grazing/assimilation, carbonates-carbon source)
- The lack of knowledge of the area covered by seagrasses
- The lack of unifying concepts, definitions and methods (sink, short- / long-term, direct-indirect-modelled, compartments and carbon fractions considered)

Last thoughts
Uncertainties

- Sink distribution and long-term dynamics
  (Pre-Holocene deposits? Sink limits (Max. Stor. Capacity?)
- Magnitude of the tidal coastal pump?
  (seagass-derived carbon stored *ex-situ*; *Jahnke 2008*)
- Sink behaviour in a warming setting (carbon accretion vs respiration; *Ostergaard et al, accepted*)
- Seagrass decline rate (5% Marbà et al. 1996; 0.1% Boudouresque et al. 2009)
- Are the *Rapid Assessment Reports* … too rapid?
- Results presented here at our best, but will change…

Last thoughts
Facts

- The role of seagrasses as a carbon sink needs much, much futher research
- Seagrass ecosystems with high herbivory and/or calcifying rates, seagrass meadows might act as carbon sources
- Seagrasses hold vast stocks of organic carbon stocks in the sediments accumulated during centuries or millennia
- From above, it could be inferred that the real important role of seagrasses in the carbon global cycle is their global stock, and not the annual sequestration rate (analogy to oil reserves)

3 ideas to take home

1. *Posidonia oceanica*: efficient in carbon sequestration but quantitatively discrete. Responsible of emissions following calcification (could be a source?). Its value is the stock.
2. Same would apply to salt-marshes and mangroves.
3. Coastal vegetation without a well developed refractory belowground organic compartment, may not be relevant from the carbon sequestration/storage point of view.

Seagrass ecosystems as a significant global carbon stock

Nature Geosciences 2012

James W. Fourqurean, Eugenia Apostolaki, Carlos M. Duarte, Núria Marbà, Marianne Holmer, Gary A. Kendrick, Hilary Kennedy, Dorte Krause-Jensen, Miguel Ángel Mateo, Karen McGlathery, Oscar Serrano


Mangroves
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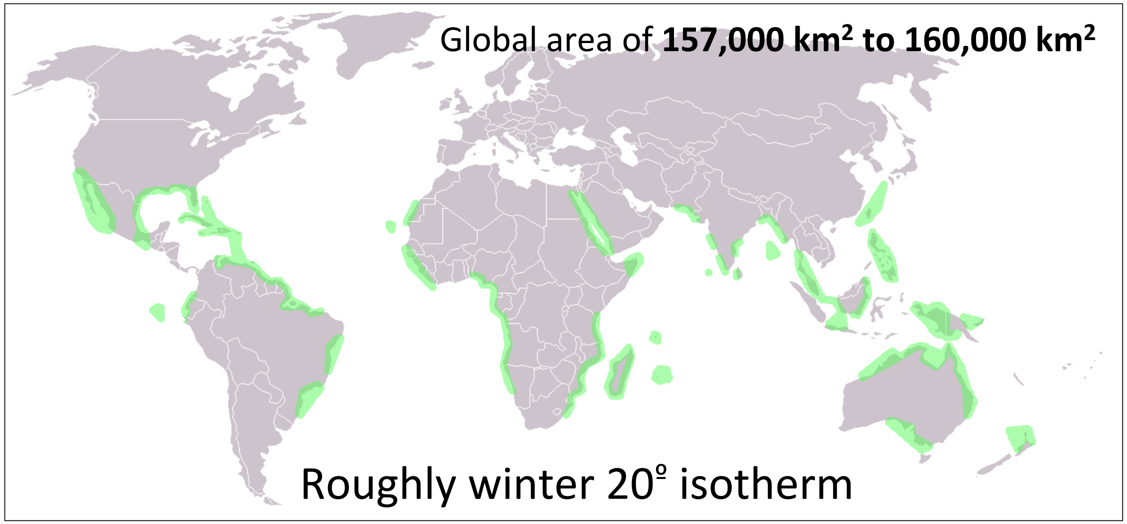
Coastal carbon sinks
Mangroves

- Salt-tolerant, mainly arboreal, flowering plants growing in **the intertidal zone of tropical and sub-tropical shores**.
- Global area of **157,000 km^2 to 160,000 km^2**.
- Global carbon burial of approximately **18.4 Tg C yr^{-1}** .
- Mangrove forests are estimated to have occupied **75% of the tropical coasts worldwide**. Now, less than 50% of the original total cover.
- **Causes for regression**: timber and fuel-wood production, reclamation for aquaculture and saltpond construction, mining, oil spills, pollution and damming of rivers that alter water salinity levels.
- **Rehabilitation/restoration needed** based on ecological or socio-economical considerations, and potentialas efficient sink of CO2.

Mangroves
Distribution of the sink

Mangroves:
The word 'Mangroves'' refers to a diverse group of unrelated plants that share a common ability to live in waterlogged **saline soils** subjected to regular flooding. They are highly specialised and adapted plants in order to survive in unstable conditions.

Global Mangrove distribution:
Mangroves are distributed **circumtropically**, and are largely restricted to latitudes between 30° N and 30° S. Total mangrove coverage is **18 million hectares**, which represents only 0.45% of world forests & woodland.



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Mangroves
Mangrove types

Of the **80 different species** most common are:


Red Mangrove (*Rhizophora mangle*)

It usually grows near the shore of the water, has red roots that raise over the water.


Black Mangrove (*Avicennia germinans*)

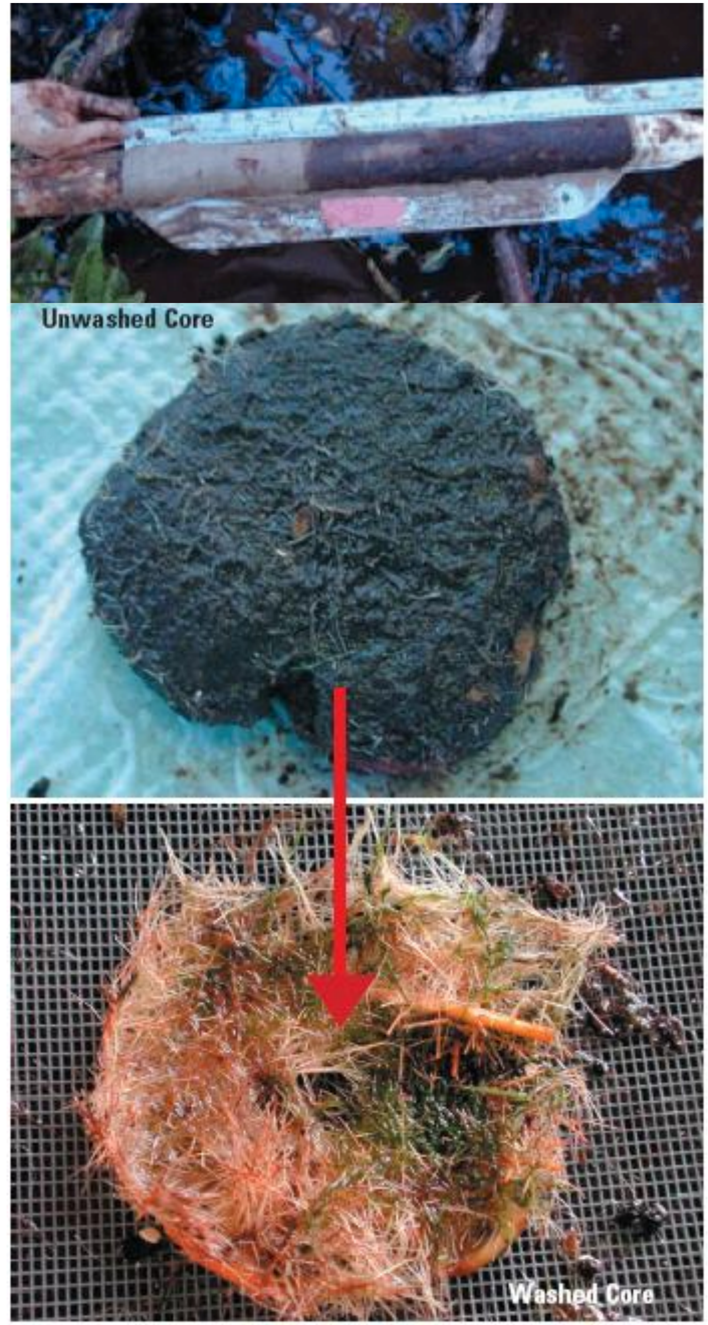
It grows in higher areas than the red mangrove and its roots spread near the trunk in shapes of fingers.


White Mangrove (*Avicennia marina*)

It grows in higher areas than the black mangrove and the roots are not visible.

Mangroves
Structure, formation, dynamics

- Mangrove soils develop through a combination of mineral sediment deposition and **organic matter accumulation**.
- The mangrove peat is composed primarily of **refractory roots**.
- Because mangrove soils are waterlogged and nutrient availability is low, **decomposition** of mangrove roots and other plant tissues **is extremely** slow.



Miguel Ángel Mateo Mínguez
Centro de Estudios Avanzados de Blanes - CSIC

Mangroves
Carbon storage

Quantification of whole-ecosystem carbon storage:

Measured:

- tree and dead wood biomass
- soil carbon content
- soil depth

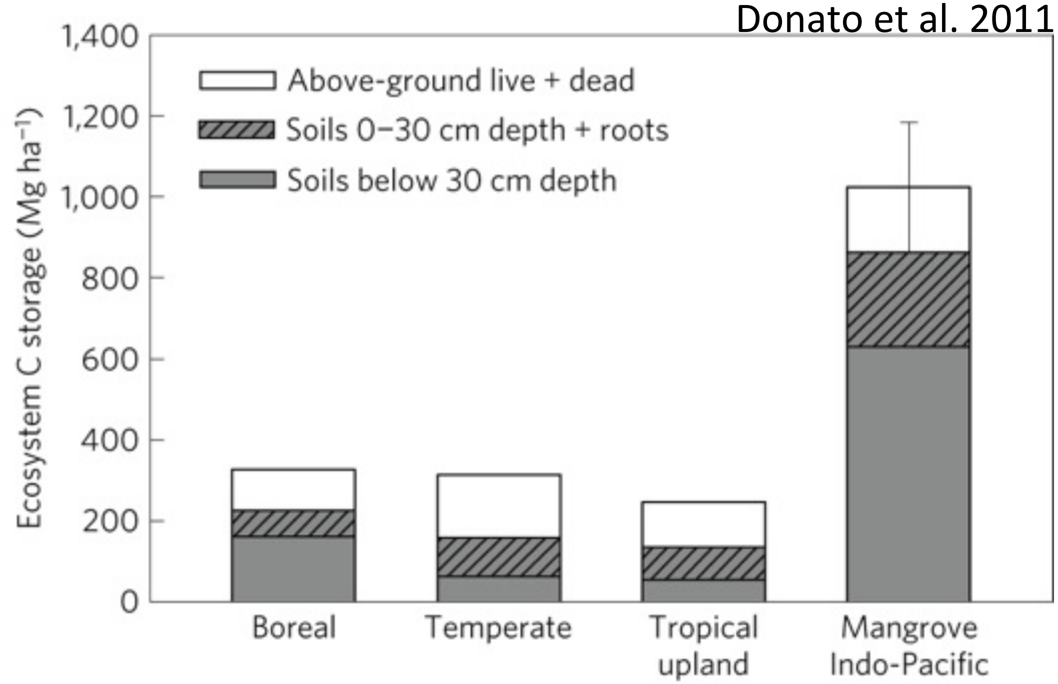
in 25 mangrove forests in the Indo-Pacific region

Mangroves are among the most carbon-rich forests in the tropics, containing on average **1,023 Mg carbon/ha**.

Organic-rich soils accounted for **49–98% of carbon storage** in these systems.

Mangrove deforestation generates about **10 %** of emissions from deforestation globally.

Donato et al. 2011



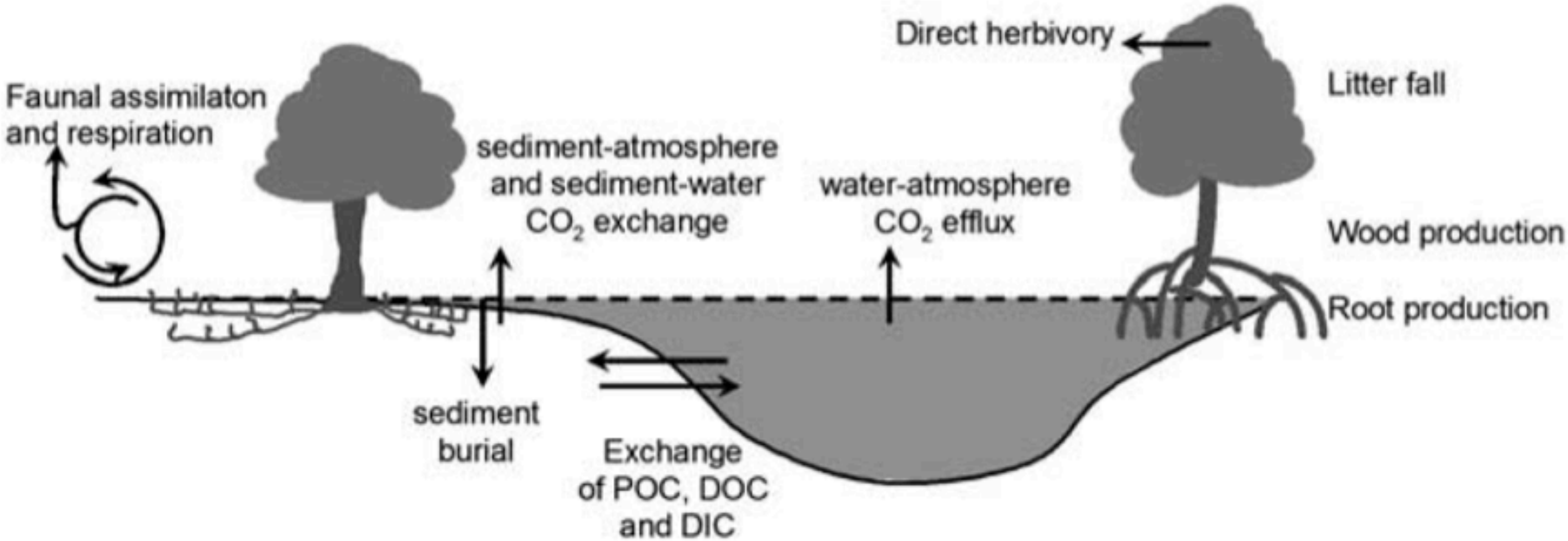


Table 1. Summary of Literature Estimates of Various Components in the Global Mangrove C Budget[a]

	Data Sources				
	Twilley et al. [1992]	*Jennerjahn and Ittekkot* [2002]	*Duarte et al.* [2005]	*Dittmar et al.* [2006]	*Duarte and Cebrián* [1996]
Area, km^2	240,000	200,000	200,000	180,000	110,000
Net Primary Production	280 (litter + wood)	92 (litter)			
Herbivory					9.1 ± 2.4%
Mineralization					40.1 ± 6.5%
Burial	20	23	23.6		10.4 ± 3.6%
Organic carbon export	30–50 (POC + DOC)	46 (POC + DOC)		26.4 (as DOC)	29.5 ± 9.4%

[a]Fluxes are expressed in Tg C a^{-1}, except for the estimates by *Duarte and Cebrián* [1996] which are in percent of the overall net primary production. Note that the areal extent of mangroves (in km^2) differs between some of the data sources.

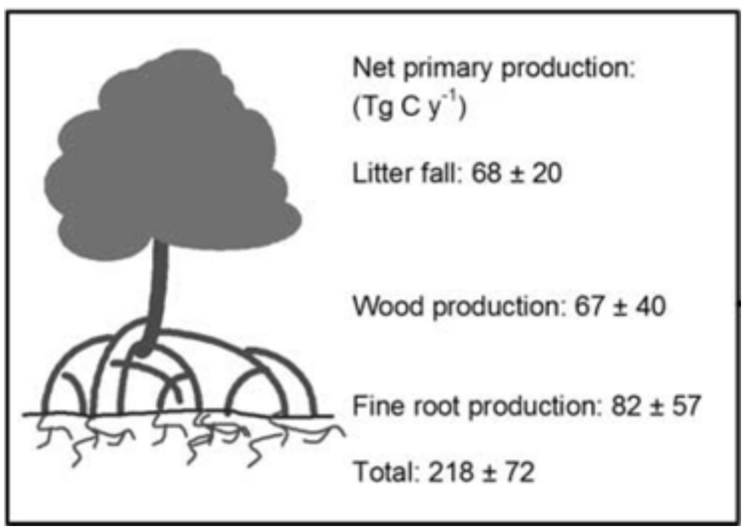
Bouillon et al 2008

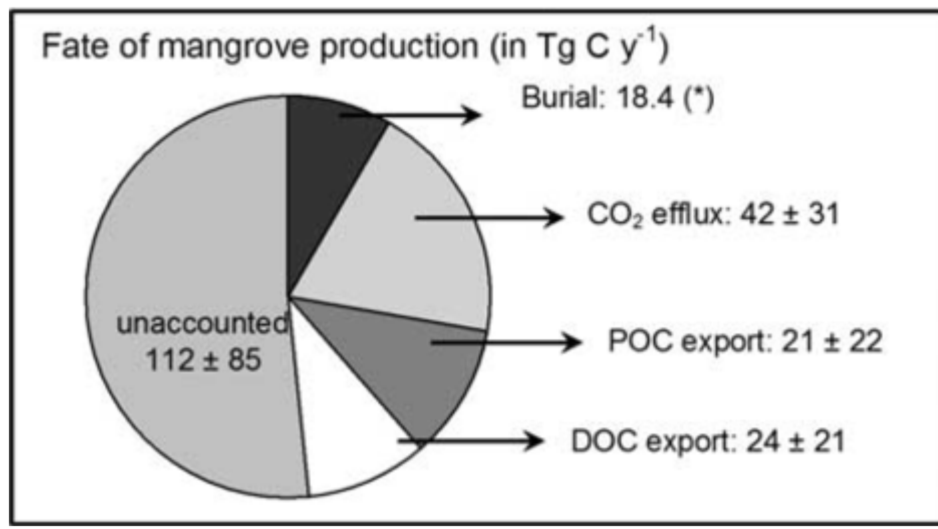
Estimating mangroves sink

- No direct measurements so far!!
- No error estimates so far!!
- Indirect estimates:

  Burial = production – decomposed – exported

  Global community mass balance
- The right way to do it: accumulation models based in long cores (P2).





Bouillon et al 2008

Mangroves: role as carbon sink

Ecosystem type	Standing carbon stock (gC m^{-2})		Total global area (*10^{12} m^2)	Global carbon stocks (PgC)		Longterm rate of carbon accumulation in sediment (gC m^{-2} yr^{-1})
	Plants	Soil		Plants	Soil	
Tidal Salt Marshes			Unknown (0.22 reported)		0.4*	210
Mangroves	7990	?	0.157	1.2	?	139
Seagrass meadows	184	7000	0.3	0.06	2.1	83
Kelp Forests	120-720	na	0.02-0.4	0.009-0.02	na	na

*Estimate by Chmura et al. 2003 for the upper 50cm of tsm.

- The actual size of the sink is likely to be **substantially greater**, for two reasons:
  - First, soils of many salt marshes obtain depths of meters and amounts of salt marsh carbon **do not significantly decline with depth**.
  - Second, the **aerial extent of salt marshes is not well documented** for many regions of the world.

Mangroves: production and fate

Nelleman et al. 2009

Component	Area Million km²	Organic Carbon burial Ton C ha^{-1} y^{-1}		Organic Carbon burial Tg C y^{-1}
Vegetated habitats				
Mangroves	0.17 (0.3)	1.39	0.20 – 6.54 (1.89)	17 – 23.6 (57)
Salt Marsh	0.4 (0.8)	1.51	0.18 – 17.3 (2.37)	60.4 – 70 (190)
Seagrass	0.33 (0.6)	0.83	0.56 – 1.82 (1.37)	27.4 – 44 (82)
Total vegetated habitats	0.9 (1.7)	1.23	0.18 – 17.3 (1.93)	114 – 131 (329)

Net primary production	**218 ± 72**
Litter fall	68 ± 20
Wood production	67 ± 40
Root production	82 ± 57
Fate of mangrove production	
CO_2 efflux	42 ± 31
Export as POC and DOC	45 ± 31
Burial	18.4
Unaccounted	**112 ± 85**

Table 1: Overview of current global estimates of net primary production and carbon sinks in mangrove systems (from Bouillon et al. 2008). All rates reported are in Tg C yr^{-1}.

http://www.youtube.com/watch?v=1o4nz0hbR8U&feature=youtube_gdata

Blue carbon: the three most relevant components

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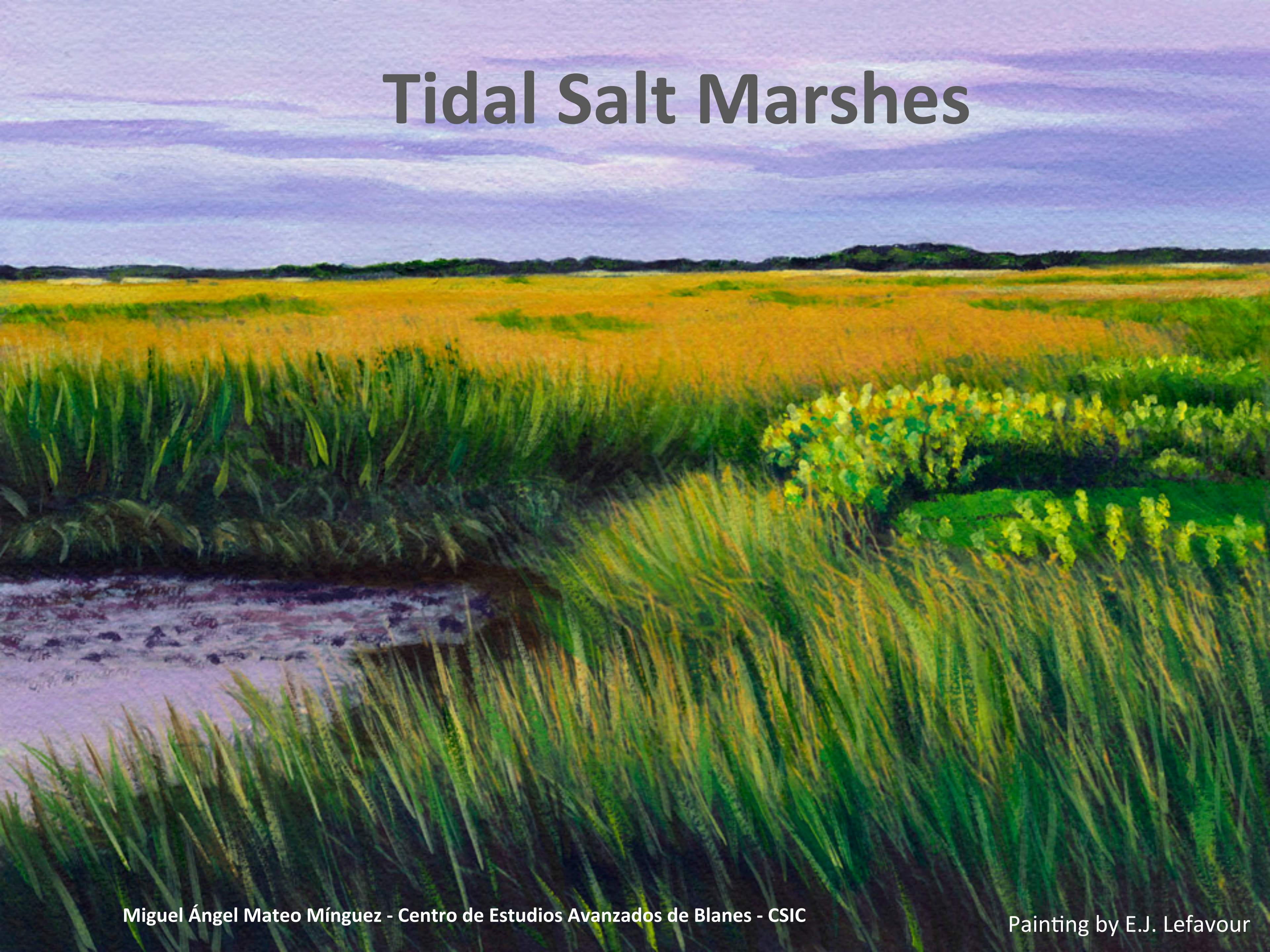
Tidal Salt Marshes



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Painting by E.J. Lefavour

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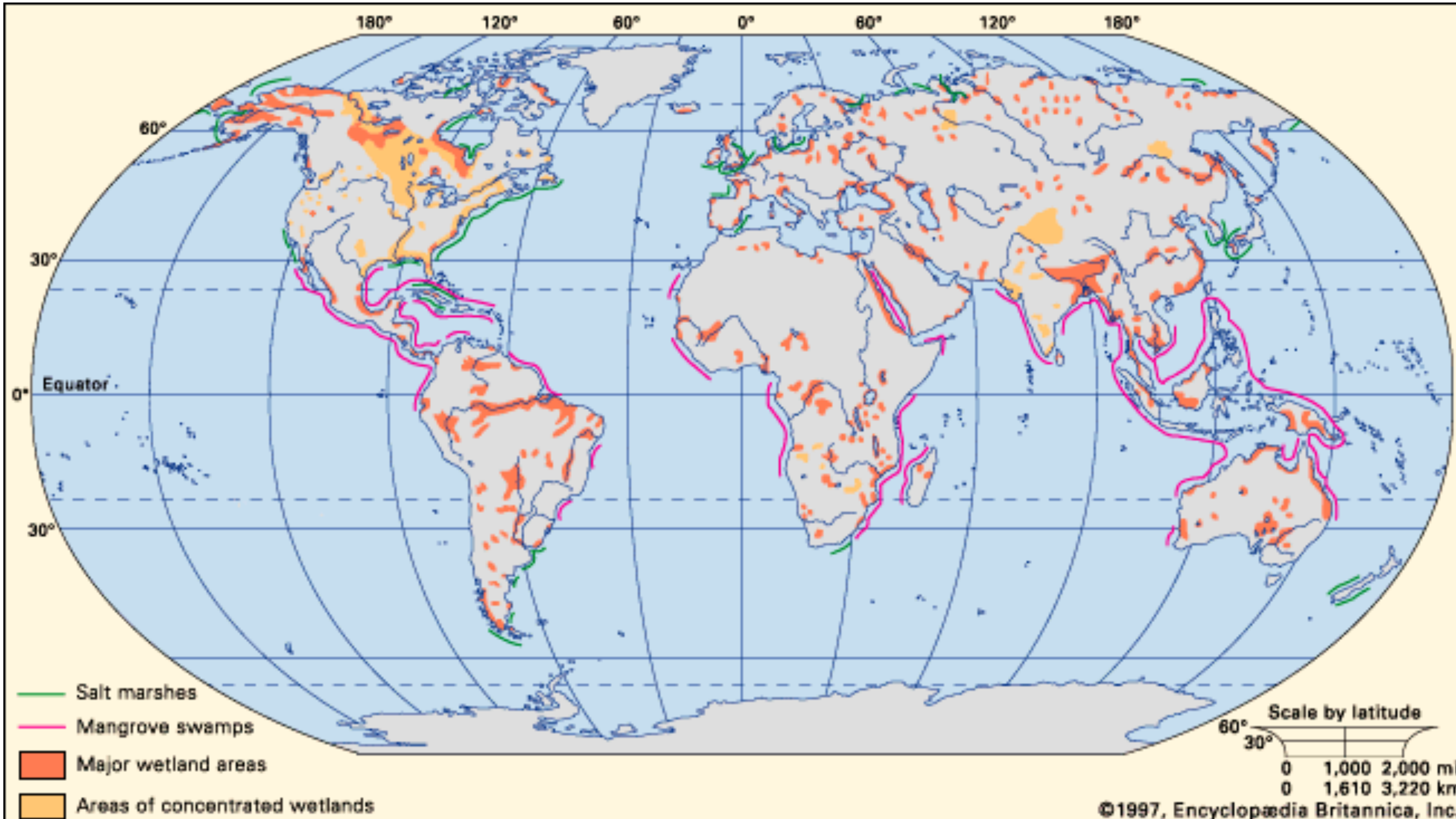
Coastal carbon sinks
Tidal salt marshes

- Intertidal ecosystems dominated by vascular plants.
- Occur on sheltered marine and estuarine coastlines from the sub-arctic to the tropics, but most extensive in temperate climates.
- Their soils store 210 g C m-2yr-1.
- Special capture efficiency and value. Little methane production in salt water wetlands.
- Extensive marsh areas have been lost from dredging, filling, draining, construction of roads and are now threatened by sea level rise.
- Sustainability of marshes with accelerating sea level rise requires that they be allowed to migrate inland. Development immediately inland to marshes should be regulated through establishment of buffer zones. Buffer zones also help to reduce nutrient enrichment of salt marshes, another threat to this carbon sink


Source: UNEP-WCMC, 2009;
Duarte et al., 2008.
Salt Marshes
30%
25%
20%
15%
10%
5%
0%
Habitat lost
since 1940s
Habitat loss
rate per year
in recent times

Tidal salt marshes Distribution

Tidal salt marshes occur on **sheltered marine and estuarine coastline**s in a range of climatic conditions, **from sub-arctic to tropical**, but are **most extensive in temperature climates**



Tidal salt marshes
Species

- Tipically perennial gasses and suculent plants resistant to hypersaline environments.
- ***Spartina alterniflora (1)*** and ***Spartina patens (2)*** (cord grasses) are dominant along much of the Atlantic coast of North and South America.
- In some other regions perennial broad-leaved herbaceous plants dominate, such as ***Atriplex portuloides (3)*** along portions of Europe's coast. Perennial succulents such as the related ***Salicornia, Sarcocornia (4,6)*** or ***Arthrocnemum (5)*** species that grow to shrub size tend to dominate coastlines of Mediterranean climates.

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Tidal salt marshes
Species productivity

- The high value of tsm species as carbon sinks is their high belowground productivity.
- *Spartina alterniflora*, and all the genus *Spartina* in general, show outstanding belowground productivity.
- Abundant and thick rhizomes and roots account for the massive stock that tsm accumulate.

Plantago maritima contributes to 'tsm' from temperate to arctic regions

Species		Below ---g m^{-2} yr^{-1}---	Above	Region	Reference
Chenopodieaceae					
Arthrocnemum	*macrostachyum*	1260	683	Po Delta	Ibañez et al. 2000
Arthrocnemum	*macrostachyum*	50	190	Ebre Delta	Ibañez et al. 2000
Arthrocnemum	*macrostachyum*	340	840	Ebre Delta	Ibañez et al. 2000
Salicornia	*fructosia*	950	580	Ebre Delta	Ibañez et al. 2000
Atriplex	*portulacoides*	1601	598	Guadiana River	Neves et al. 2007
Plantaginaceae					
Plantago	*maritima*	648	296	Bay of Fundy	Connor 1995
Poaceae					
Spartina	*patens*	1113	500	Bay of Fundy	Connor 1995
Spartina	*patens*	3300	785	Delaware Bay	Roman & Daiber 1984
Spartina	*alterniflora*	1575	718	Bay of Fundy	Connor 1995
Spartina	*alterniflora*	6500	1487	Delaware Bay	Roman & Daiber 1984

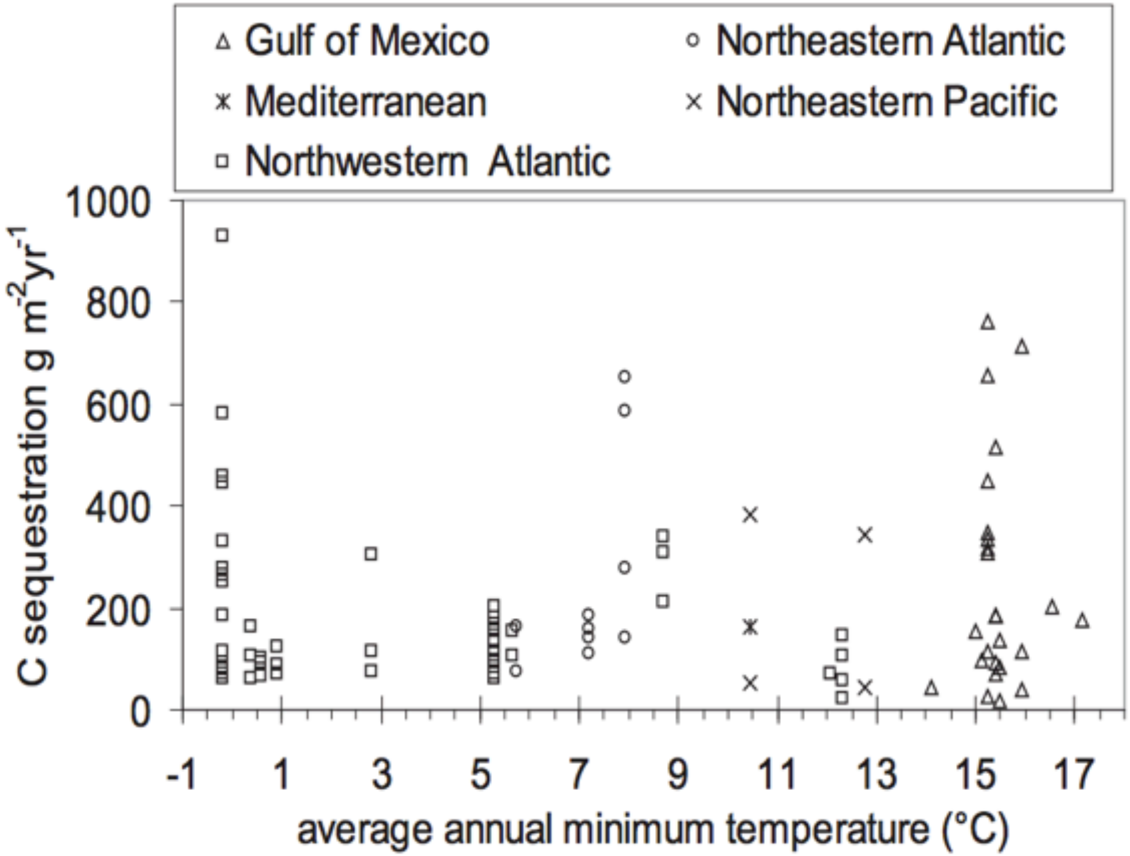
Table 1. Rates of above and below ground production of selected tidal salt marsh species from three different plant families in North America and Europe demonstrate the importance of below ground production with varied plant forms.

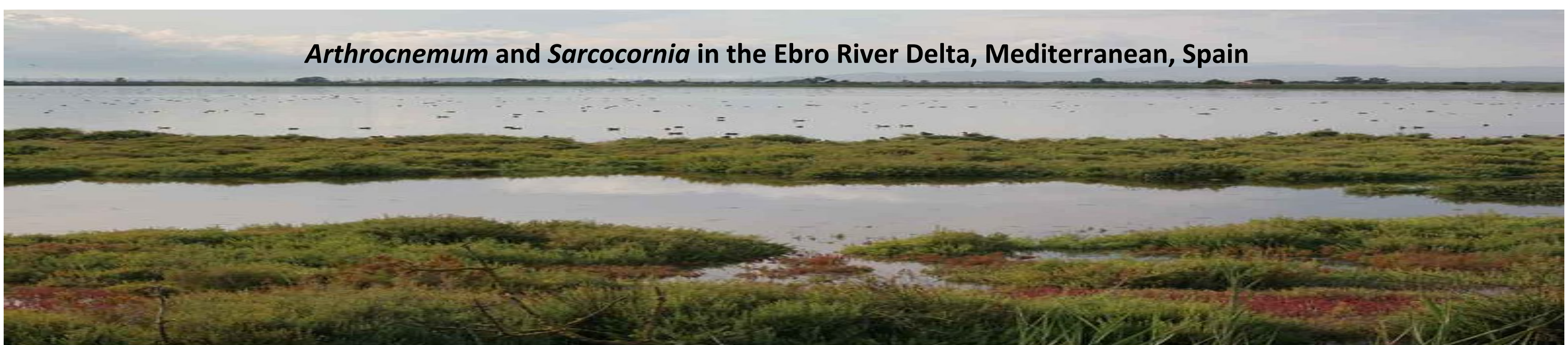
Delaware Bay, Baltimore

Laffoley and Grimsditch 2009

Tidal salt marshes
Species productivity

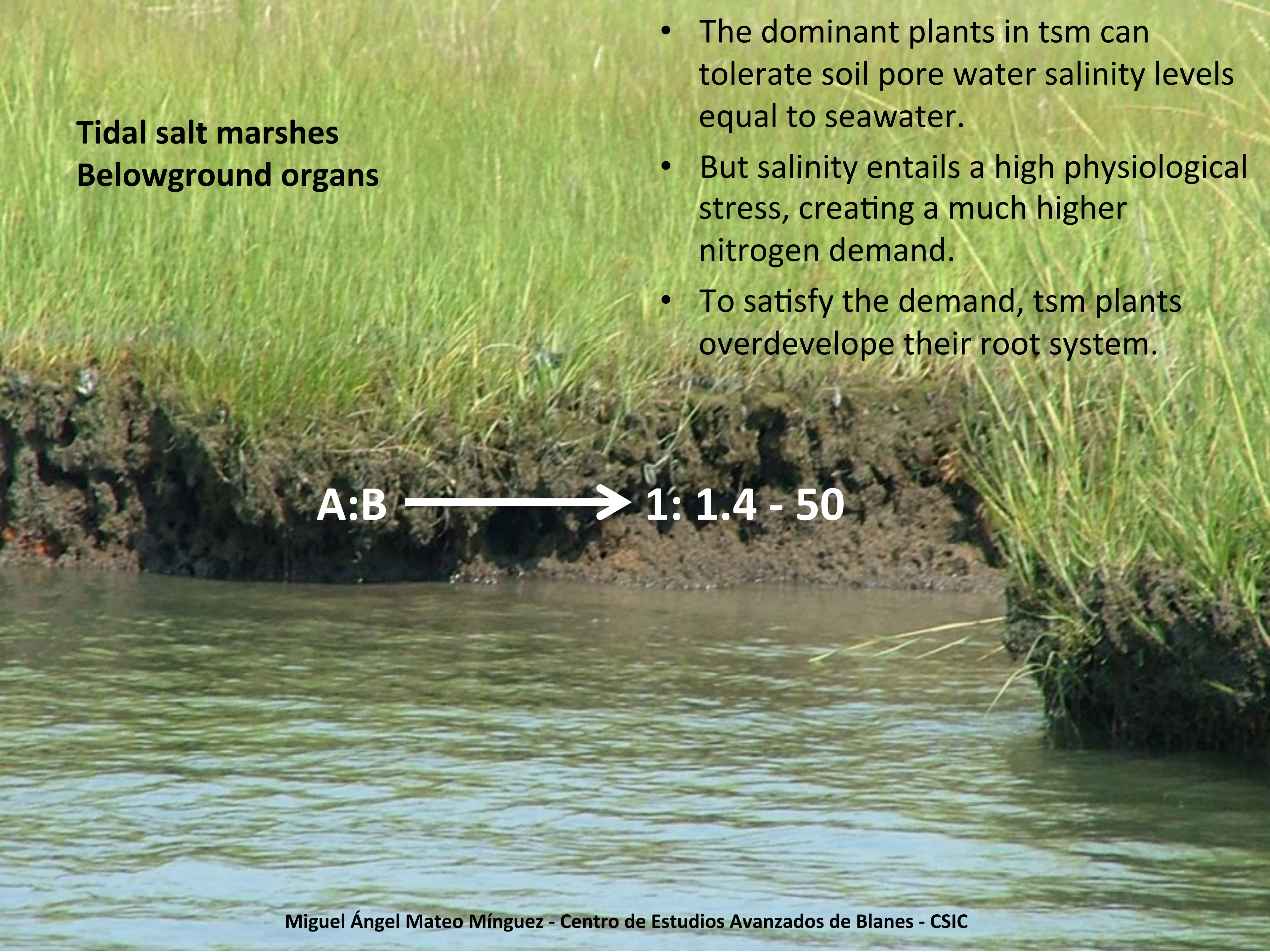
- It is difficult to establish productivity patterns. It can vary the same widely within a location than with latitude.
- Although not very well established yet, temperature seems to enhance tsm plants productivity.
- Most productivity studies have been limited to biomass produced by vascular plants aboveground, missing two critical components: below-ground vascular plant production and non-vascular plant production.





Tidal salt marshes
Belowground organs

- The dominant plants in tsm can tolerate soil pore water salinity levels equal to seawater.
- But salinity entails a high physiological stress, creating a much higher nitrogen demand.
- To satisfy the demand, tsm plants overdevelope their root system.



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Coastal carbon sinks
Literature and web sites

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- http://www.nt.gov.au/nreta/wildlife/nature/pdf/mangroves/2_mangrove_ecosystem.pdf (mangroves general)
- http://www.nwrc.usgs.gov/factshts/2004-3126/2004-3126.htm (belowground dynamics in mangrove ecosystems)
- Video:http://www.youtube.com/watch?v=1o4nz0hbR8U&feature=youtube_gdata (mangroves core sampling in Belize)