


Blue Carbon in seagrass ecosystems: how much is there and what's it worth?

The Seagrass Blue Carbon task force:

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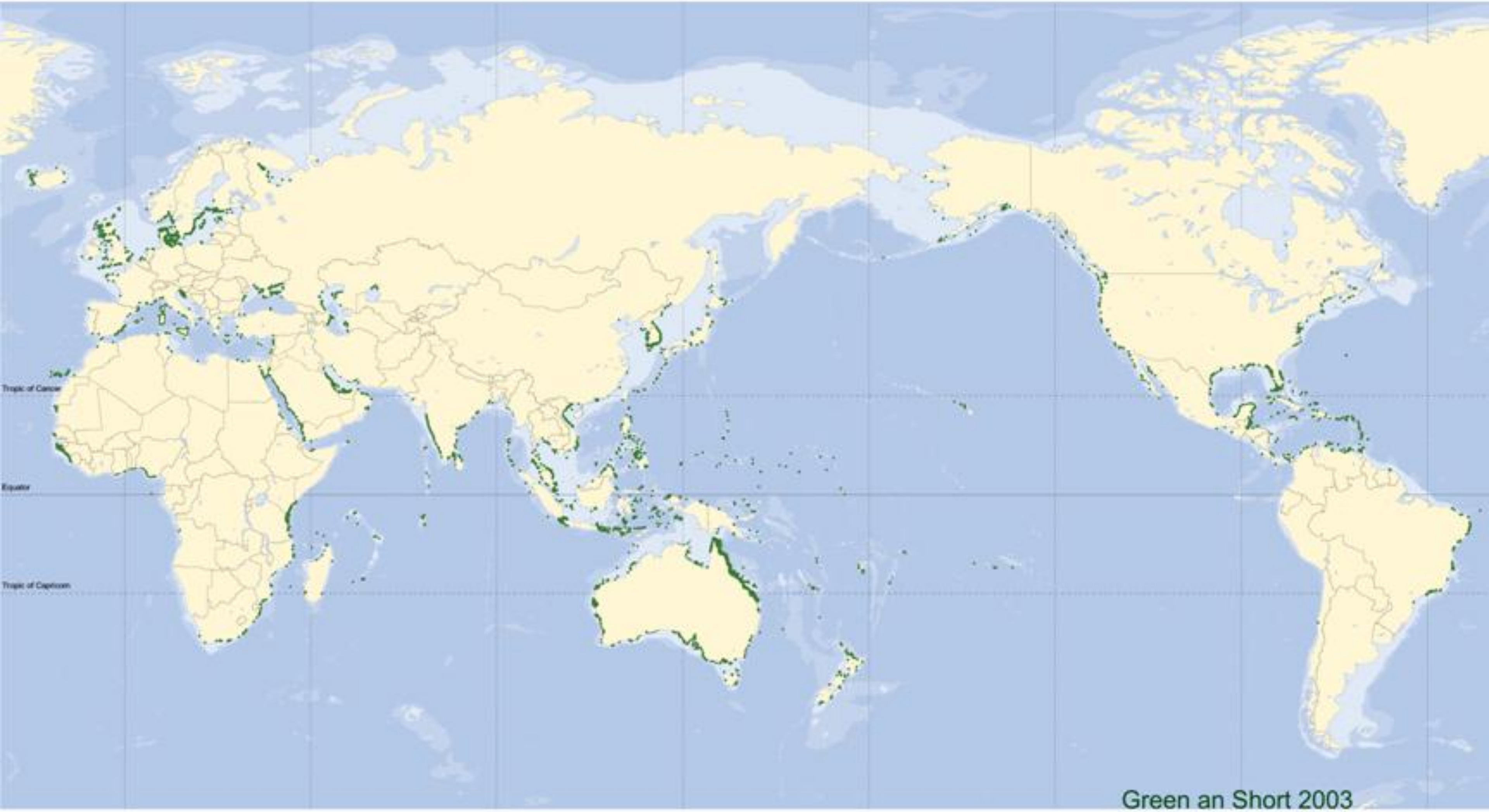
Blue Carbon Science Working Group meeting,
Bali, Indonesia 26 July 2011


Seagrasses are flowering plants that live submerged in the sea
(c) Kim Holzer 2005

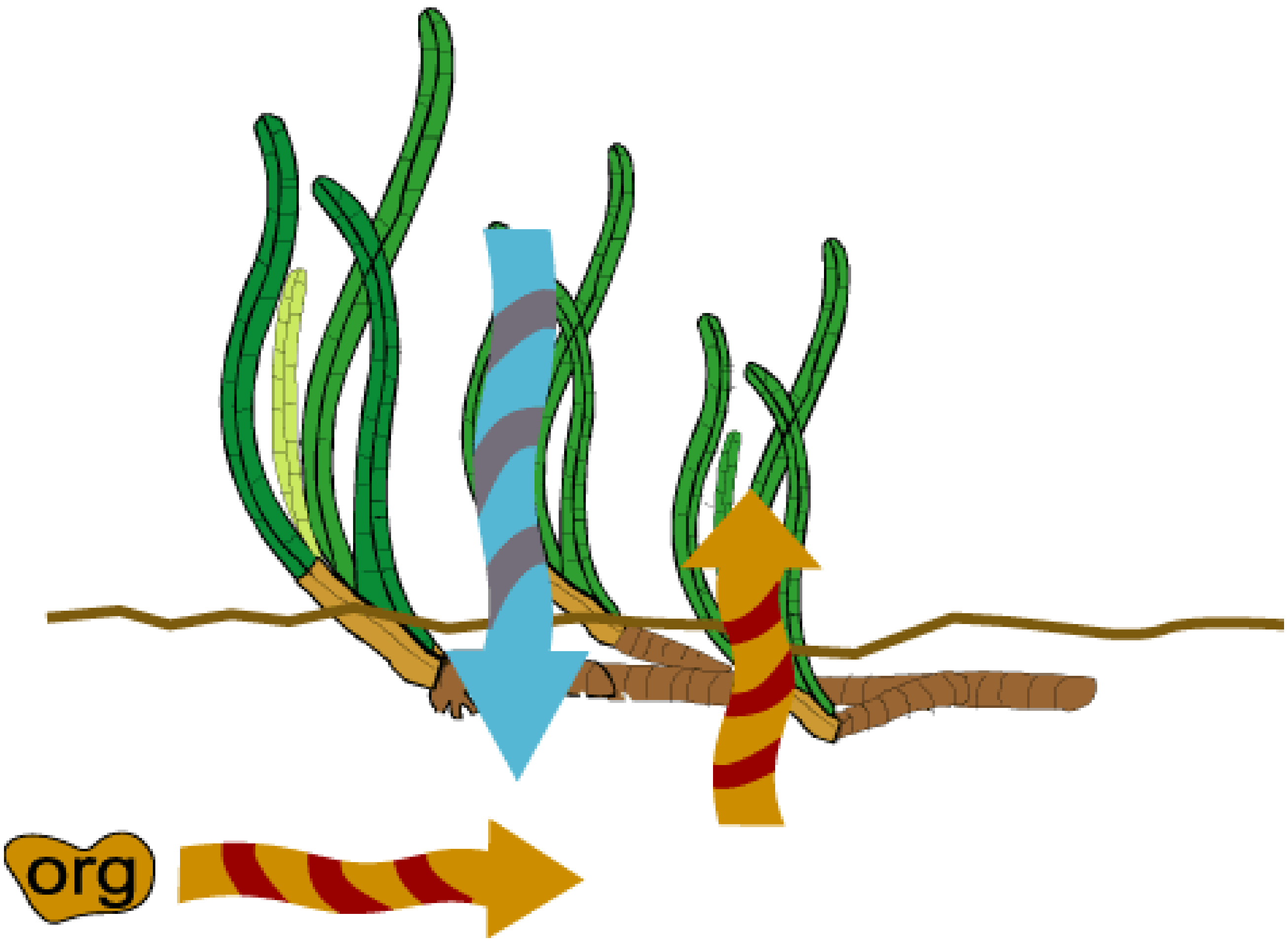
Seagrasses have a broad global distribution



Primary producers: tropical seagrass beds are among the most productive ecosystems, rivaling agricultural crops like corn and soybeans

Sediment stabilizers: seagrasses efficiently hold sediments in place, preventing resuspension and movement of sediment deposits

Nutrient processors: Seagrass beds absorb and transform nutrients in the marine environment



Seagrass provides critical food source in tropical regions

Manatee (Trichechus)
In Thalassia meadow,
Puerto Rico

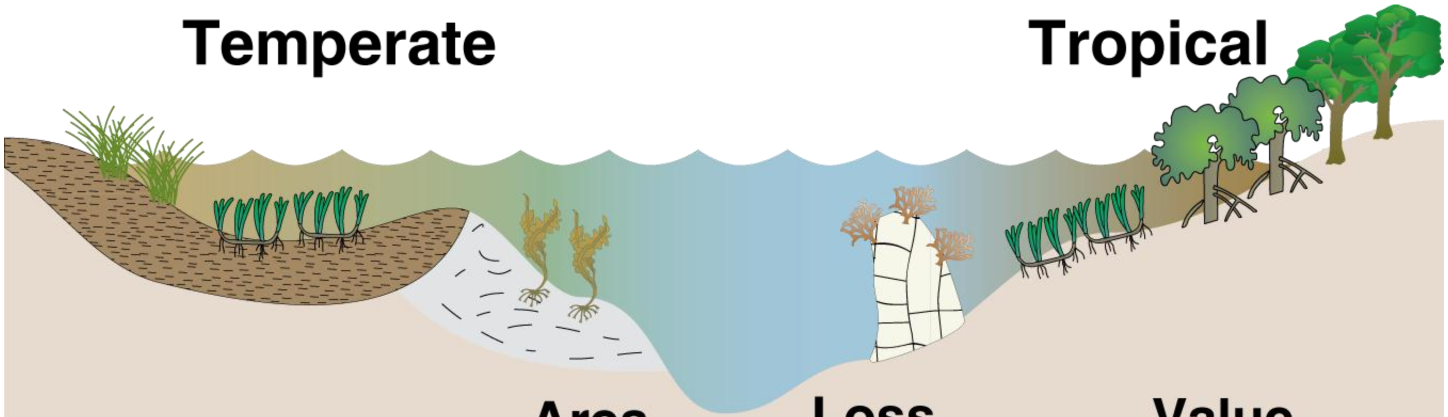
Green Sea Turtle (Chelonia)
In Thalassia and Syringodium meadow,
Yucatan, Mexico

Seagrass provides critical habitat in temperate and tropical regions

Seahorse (Hippocampus)
In Cymodocea meadow,
Mediterranian Sea

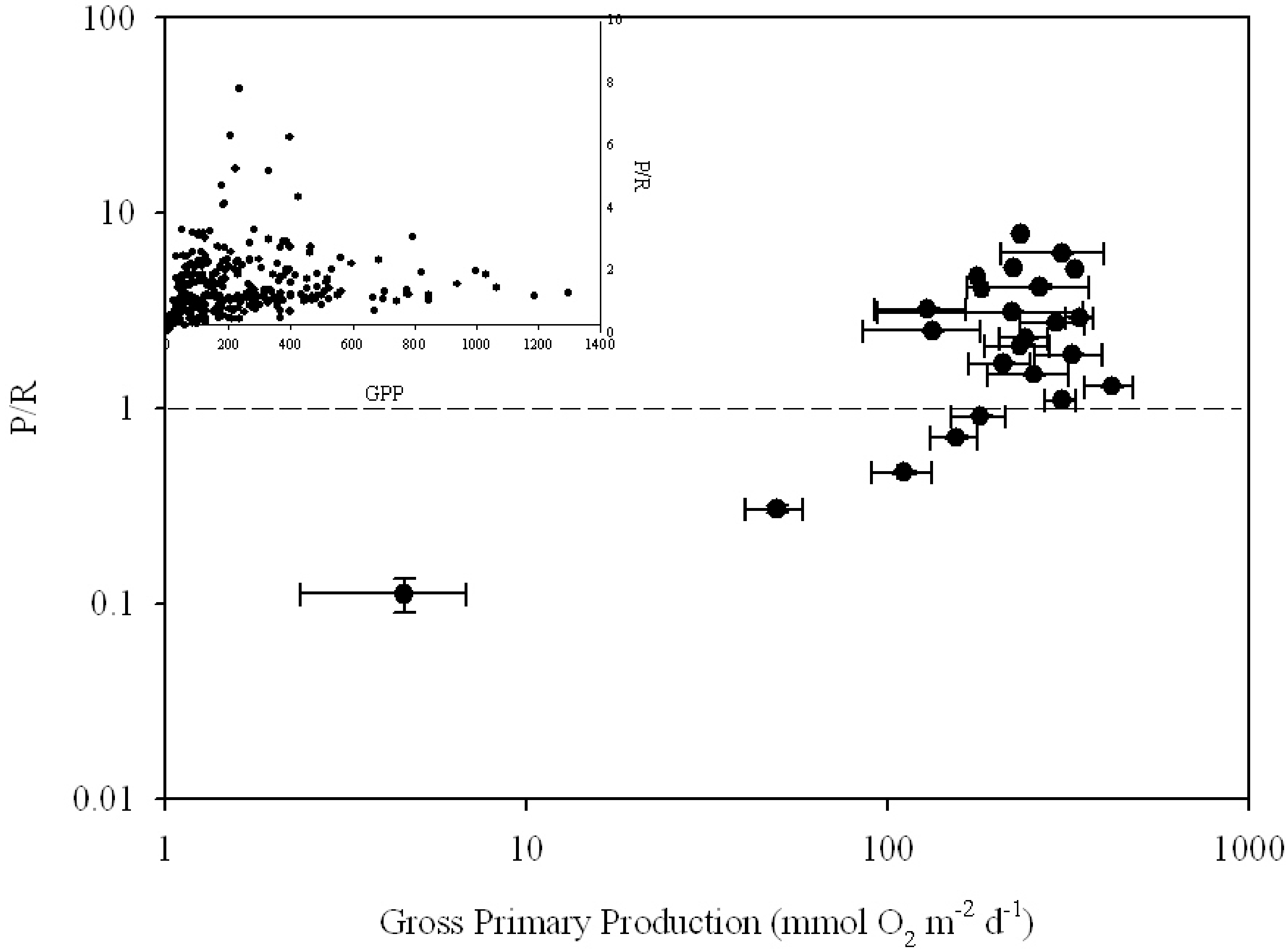
Zebra fish (Girella)
In Posidonia meadow,
Perth, Western Australia

Seagrasses are valuable and threatened compared to other major marine habitats



Ecosystem	Area (10^6 ha)	Loss (% $year^{-1}$)	Value (US\$ ha^{-1} $year^{-1}$)
Seagrass	18	2–5	19 004
Salt marsh	140	1–2	9 990
Mangrove	15	1–3	9 990
Coral	62	4–9	6 075
Tropical forest	1 900	0.5	2 007

A new realization: seagrasses are important in the global carbon balance -
Dense seagrass beds fix more CO_2 than they consume



Duarte et al. 2010 GBC

Estimates of global CO_2 flux in seagrass beds

	NCP	low estimate of global extent	Integrated NCP	high estimate of global extent	Integrated NCP
	tons CO_2e $ha^{-1}y^{-1}$	km^2	Tg CO_2e y^{-1}	km^2	Tg CO_2e y^{-1}
Mean	4.4	300000	130.7	600000	261.4
Upper 95th cl of mean	6.2	300000	185.5	600000	371.1
Lower 95th cl of mean	2.5	300000	75.9	600000	151.8
maximum	85.4	300000	739.2	600000	1478.3

At $20/ton, the NCP value of seagrasses is about $88 $ha^{-1}y^{-1}$, small compared to the $19k for nutrient processing or $3k of fisheries yield

For comparison, mean NCP for:

wetlands = 0.6 tons CO_2e $ha^{-1}y^{-1}$

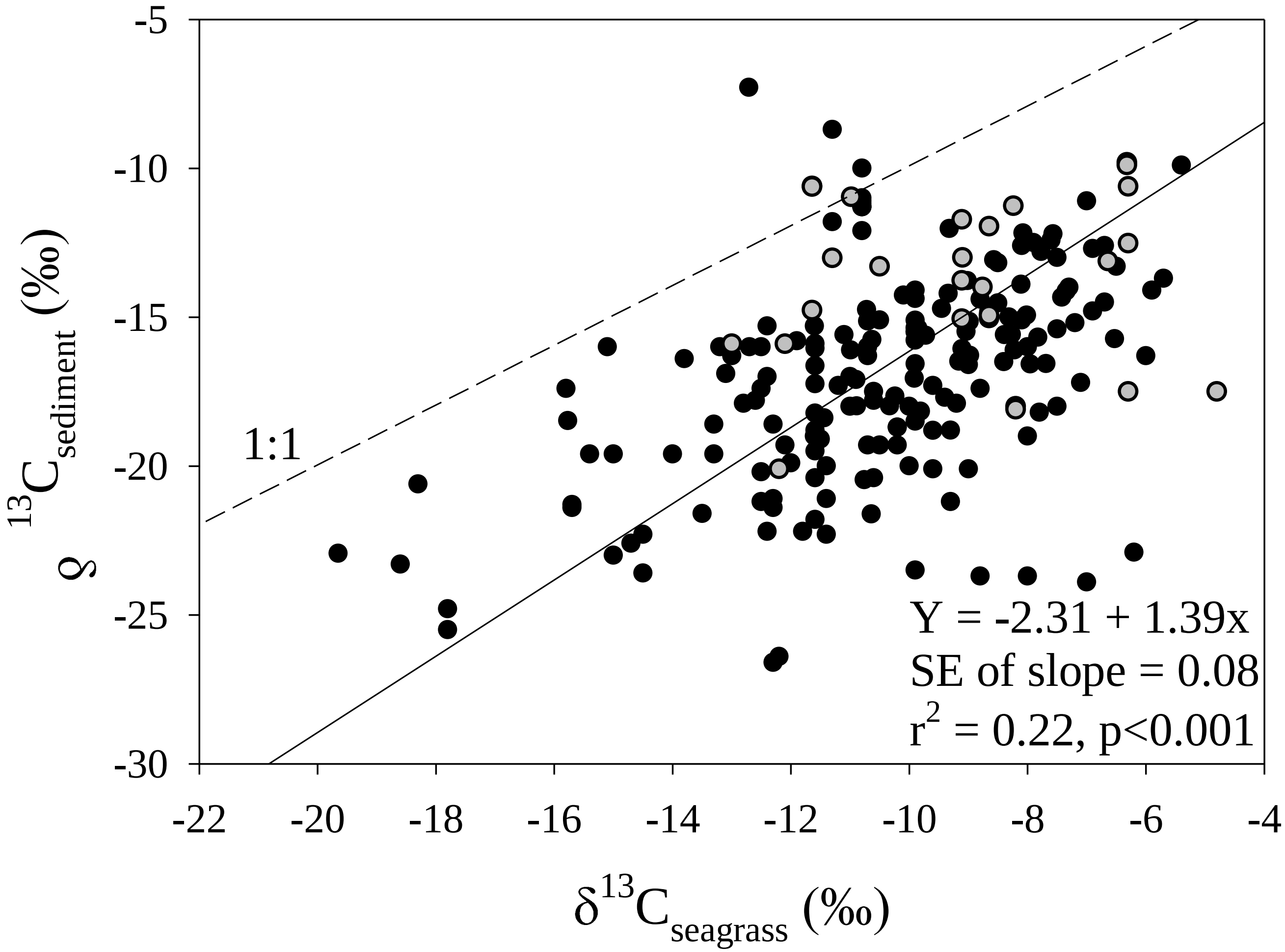
Amazon rainforest: 3.7 tons CO_2e $ha^{-1}y^{-1}$

Duarte et al 2010 GBC

But what about the value of the Blue Carbon stored in the system?

Carbon fixed in seagrass beds does not all stay in the seagrass beds

Only about half of the C buried in seagrass beds is derived from seagrass



Kennedy et al 2010 GBC

So, how much C is stored in seagrass ecosystems?

- Measuring C storage in some Seagrass ecosystems:
  - Florida Bay
  - Shark Bay
  - Western Mediterranean
- Literature review of C stores in seagrasses
- Back-of-the-envelope estimates of the sizes of stocks and potential value of those stocks in a global CO_2 market

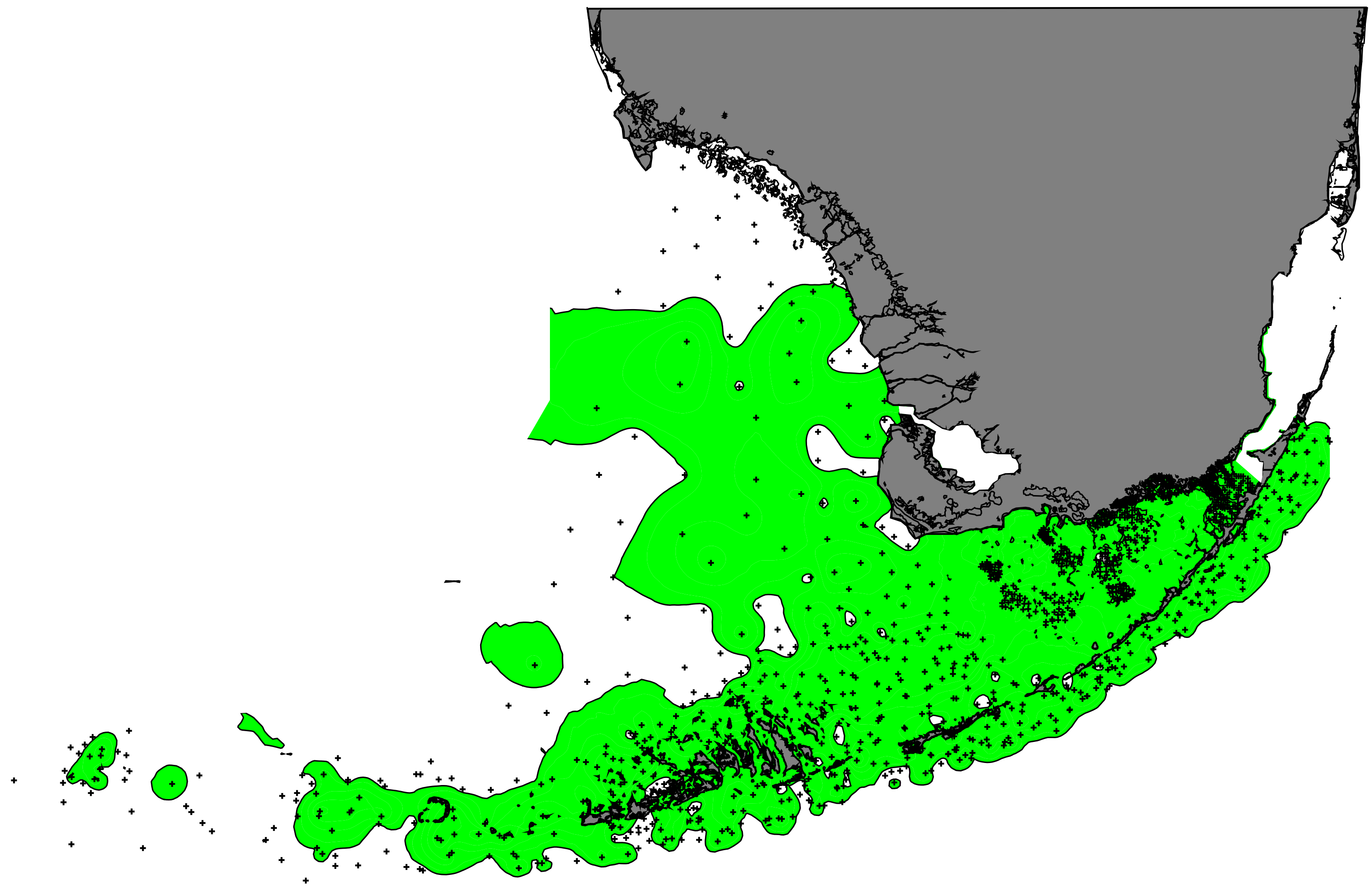
Measuring C stored in living biomass

Measuring C stored in seagrass soils: Piston corer to collect uncompressed cores

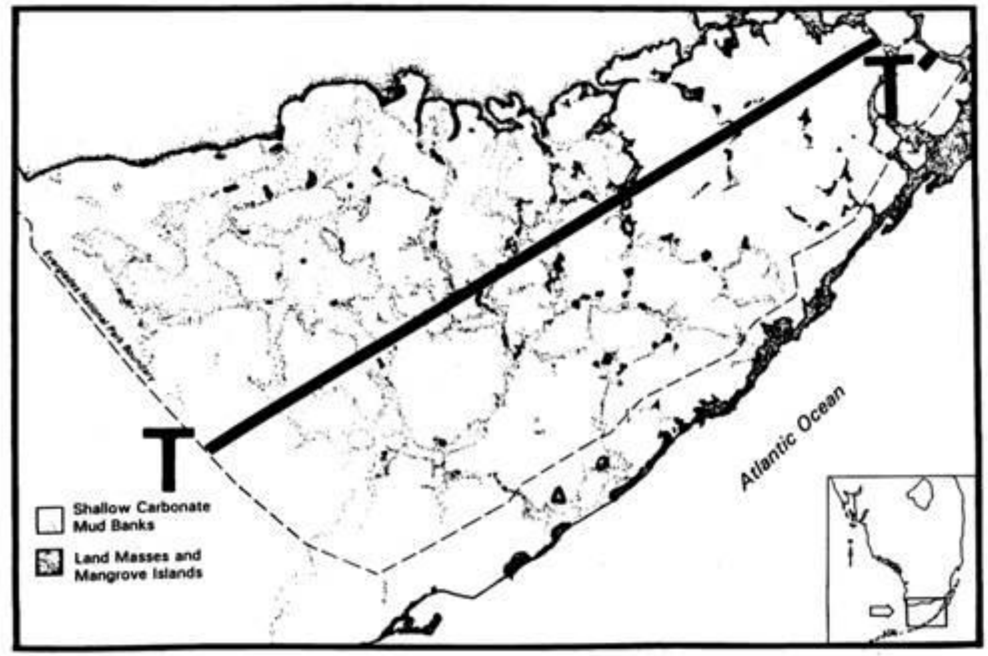
Need:

- volumetric measures of Dry Bulk Density (mass of soil per volume)
- Carbon content of soil (as a fraction of mass)
  - Organic matter, or Loss on Ignition (LOI)
  - C_{org}

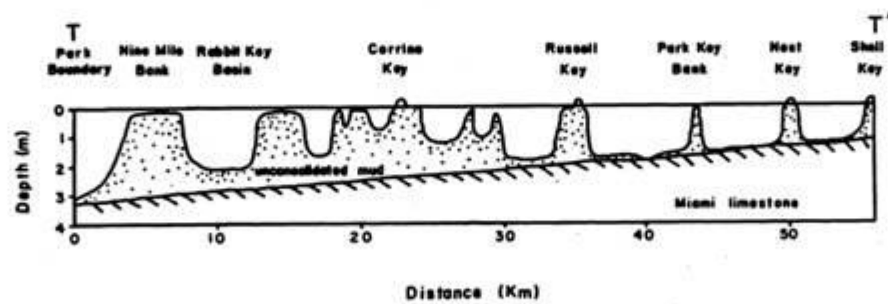
There are about 18,000 km^2 of seagrass beds in south Florida

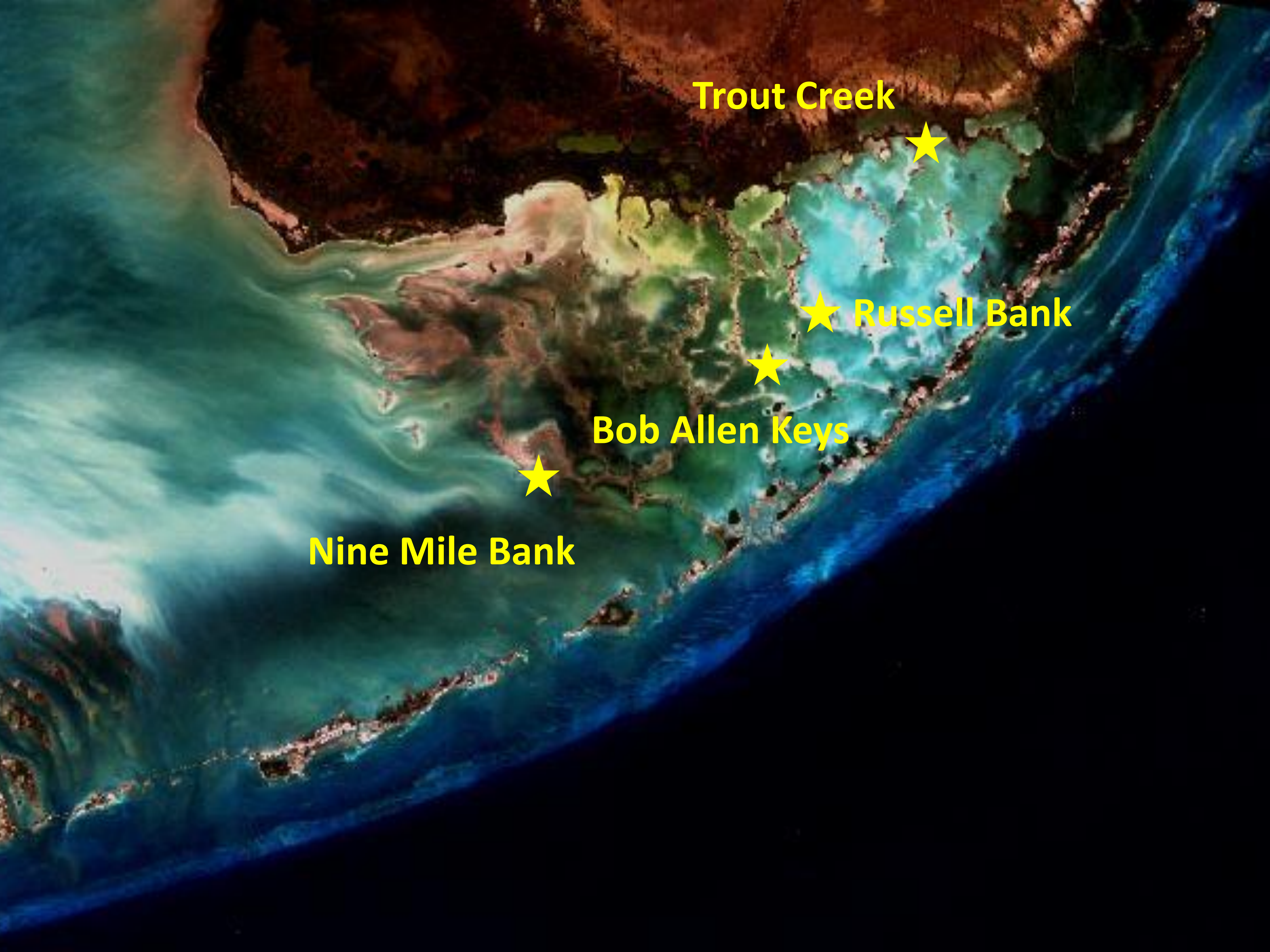


Florida Bay is broken into many basins by mud banks
that are often exposed at low tides.
These mud banks restrict water circulation and tidal effects in the Bay



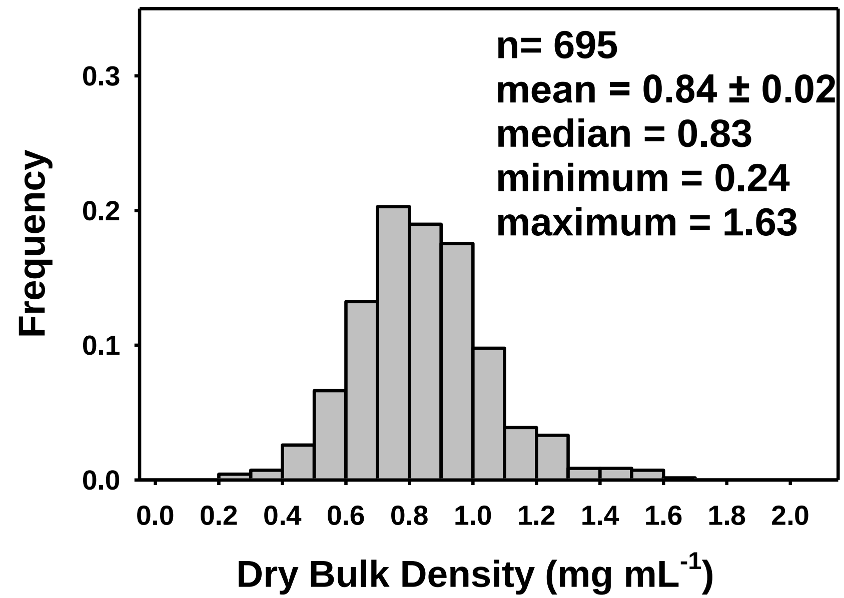
The mud banks increase in thickness towards the southeast part of the Bay



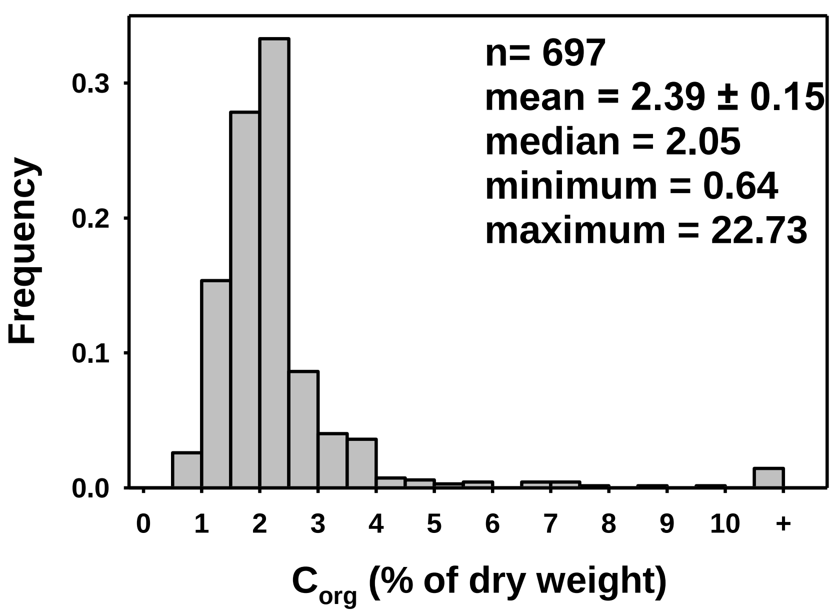


Trout Creek
Russell Bank
Bob Allen Keys
Nine Mile Bank

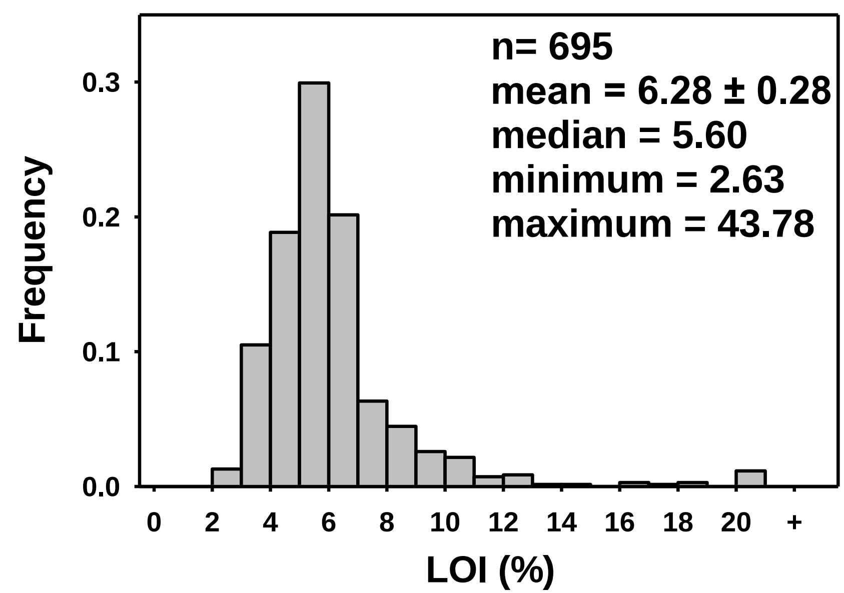
25
mL
20
15
10
5



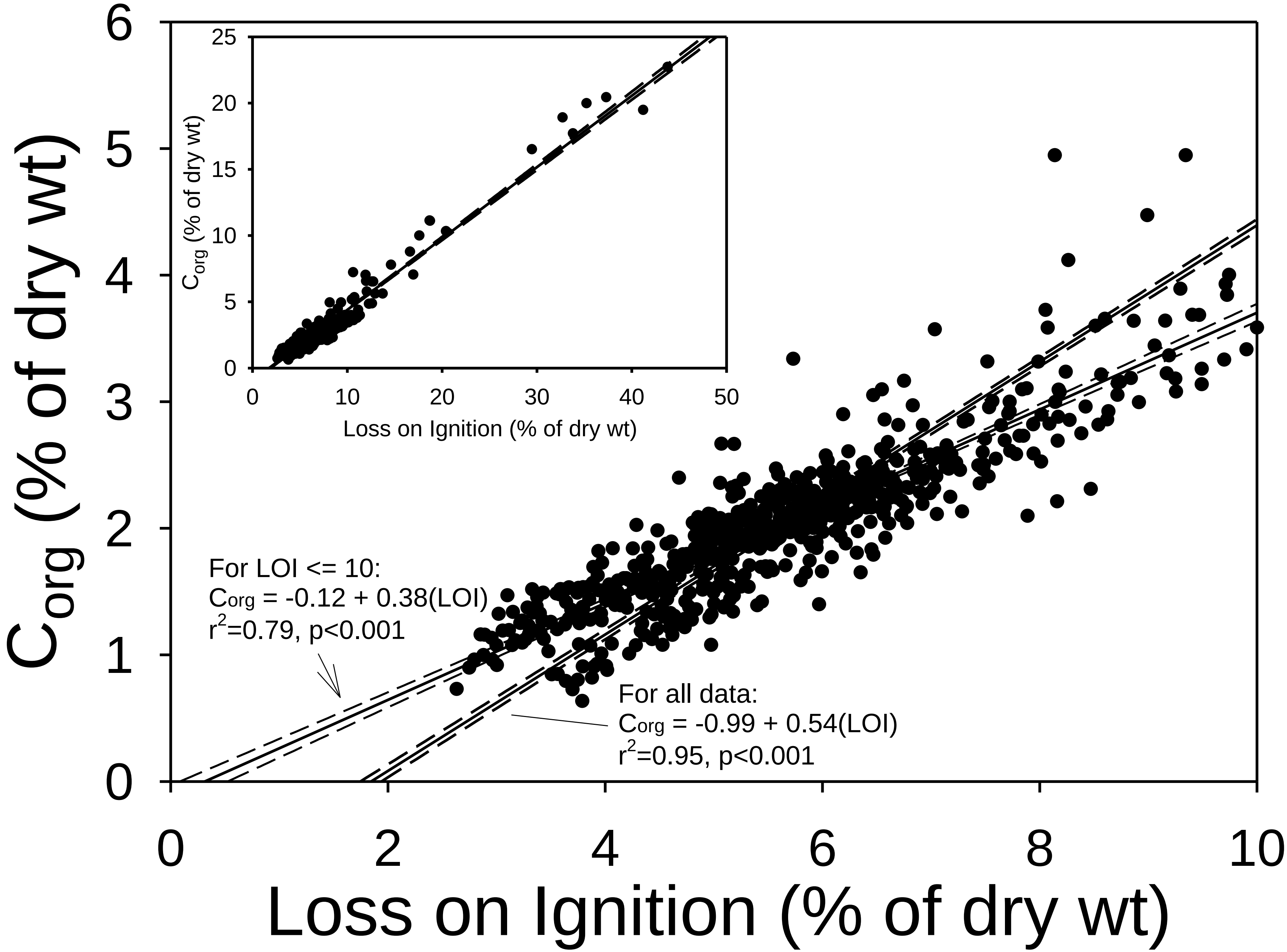
n= 695
mean = 0.84 ± 0.02
median = 0.83
minimum = 0.24
maximum = 1.63
Frequency
0.0
0.1
0.2
0.3
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
Dry Bulk Density (mg mL^{-1})



n= 697
mean = 2.39 ± 0.15
median = 2.05
minimum = 0.64
maximum = 22.73
Frequency
0.0
0.1
0.2
0.3
0 1 2 3 4 5 6 7 8 9 10 +
C_{org} (% of dry weight)



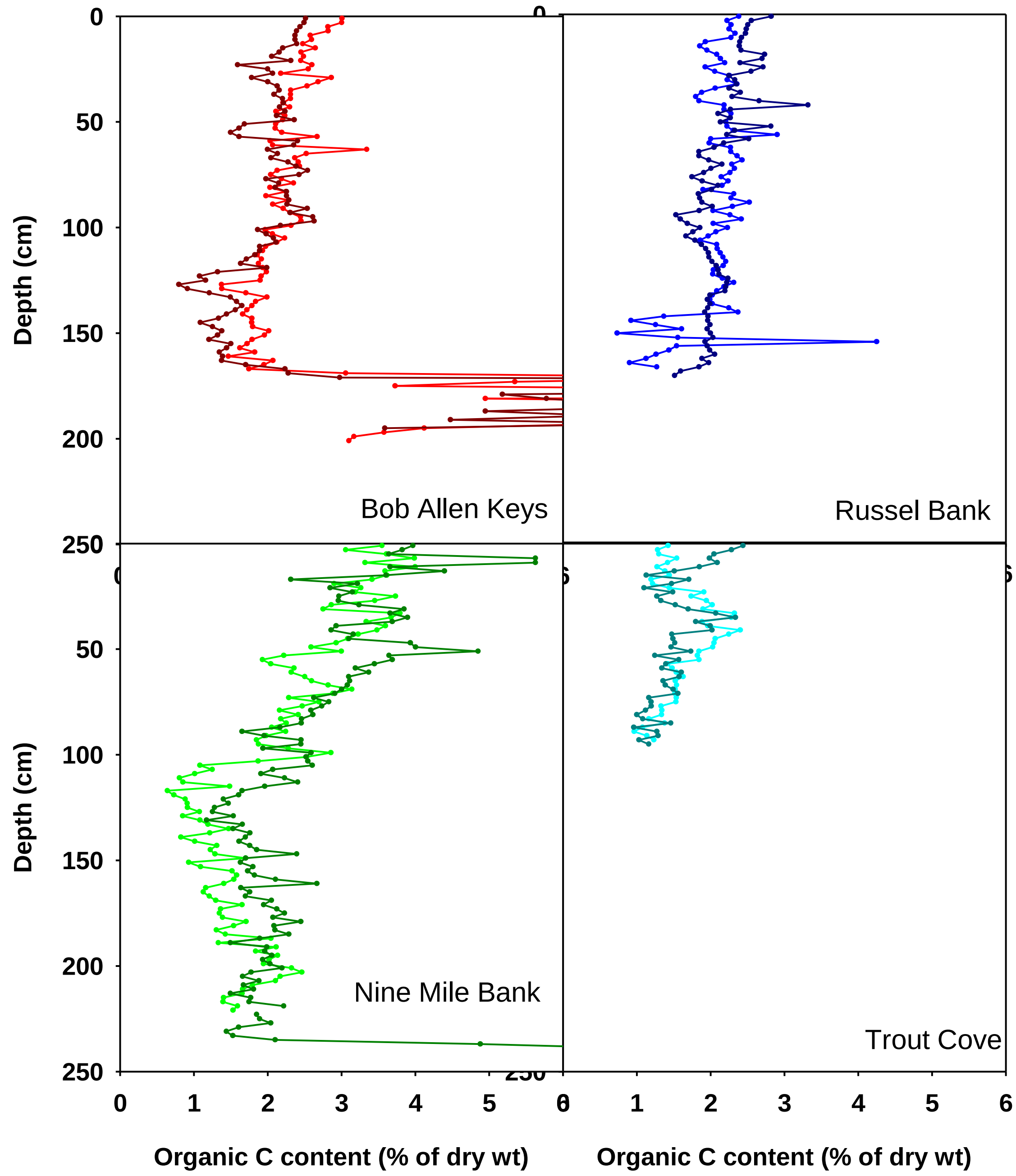
n= 695
mean = 6.28 ± 0.28
median = 5.60
minimum = 2.63
maximum = 43.78
Frequency
0.0
0.1
0.2
0.3
0 2 4 6 8 10 12 14 16 18 20 +
LOI (%)



6
5
4
3
2
1
0
0
2
4
6
8
10
C_{org} (% of dry wt)
Loss on Ignition (% of dry wt)
25
20
15
10
5
0
0
10
20
30
40
50
C_{org} (% of dry wt)
Loss on Ignition (% of dry wt)
For LOI <= 10:
C_{org} = -0.12 + 0.38(LOI)
r^2=0.79, p<0.001
For all data:
C_{org} = -0.99 + 0.54(LOI)
r^2=0.95, p<0.001

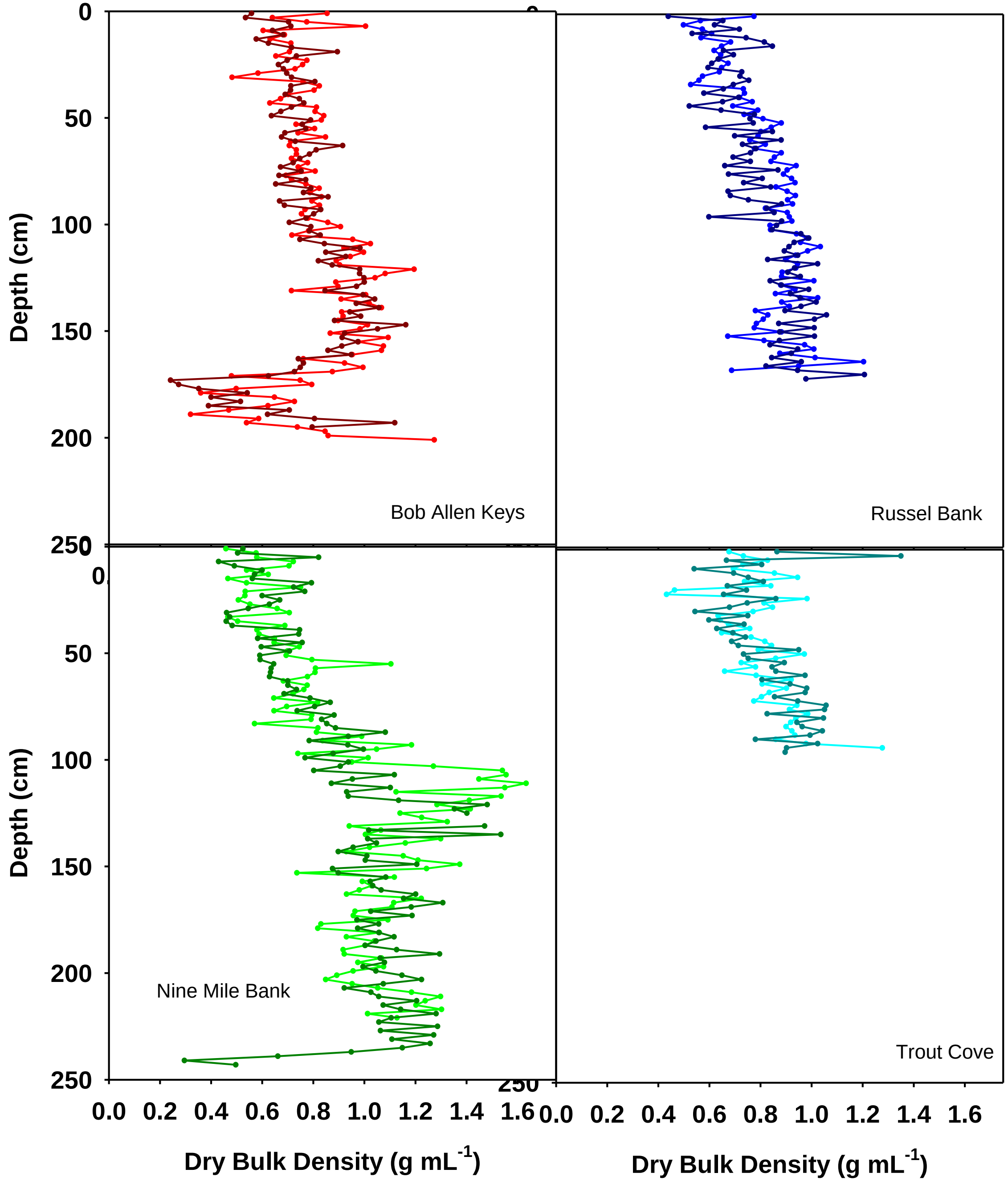
C_{org} generally decreases downcore in Florida Bay seagrass soils.

Buried peats have high C_{org}



DBD generally increases downcore in Florida Bay seagrass soils.

Buried peats have low DBD



Florida Bay soil C stocks (integrating over the top meter)

Core ID	kg CO_2e m^{-2}	tons CO_2e ha^{-1}
Bob Allen1	65.6	656
Bob Allen 2	57.6	576
Russell Bank 1	61.5	615
Russell Bank 2	58.1	581
Nine Mile Bank 1	71.5	715
Nine Mile Bank 2	78.6	786
Trout Cove 1	44.6	446
Trout Cove 2	38.1	381
mean	59.5	594.5
sd	13.3	132.9
95% CI	9.2	92.1

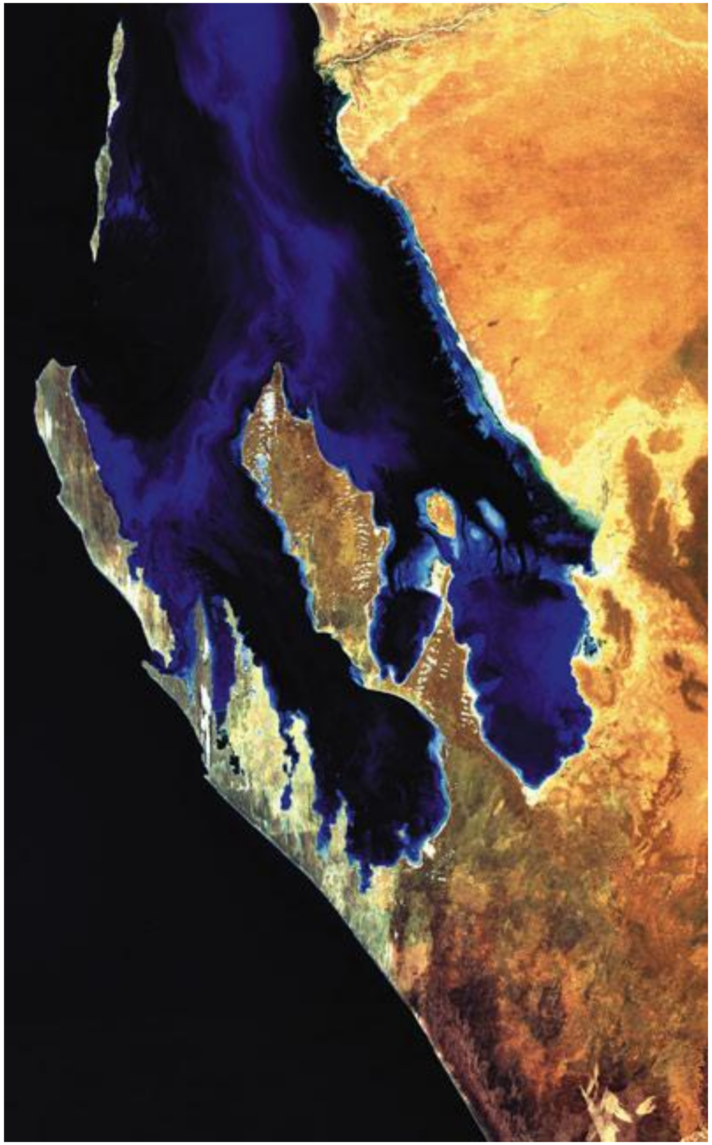
Estimate of seagrass biomass C: 4.4 – 18.3 tons CO_2e ha^{-1}

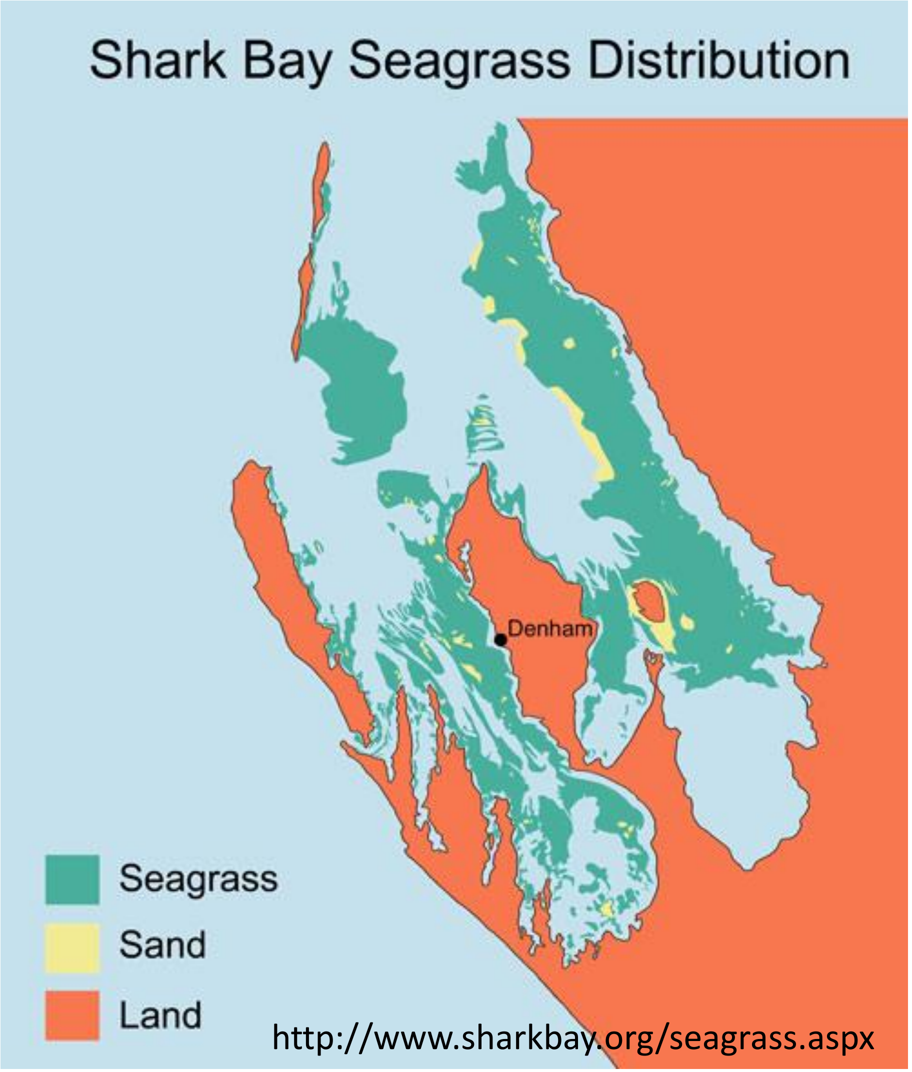
A very rough estimate of carbon stored in the top meter of seagrass soils in south Florida:

18,000 km^2 of seagrasses
594 tons CO_2e ha^{-1}

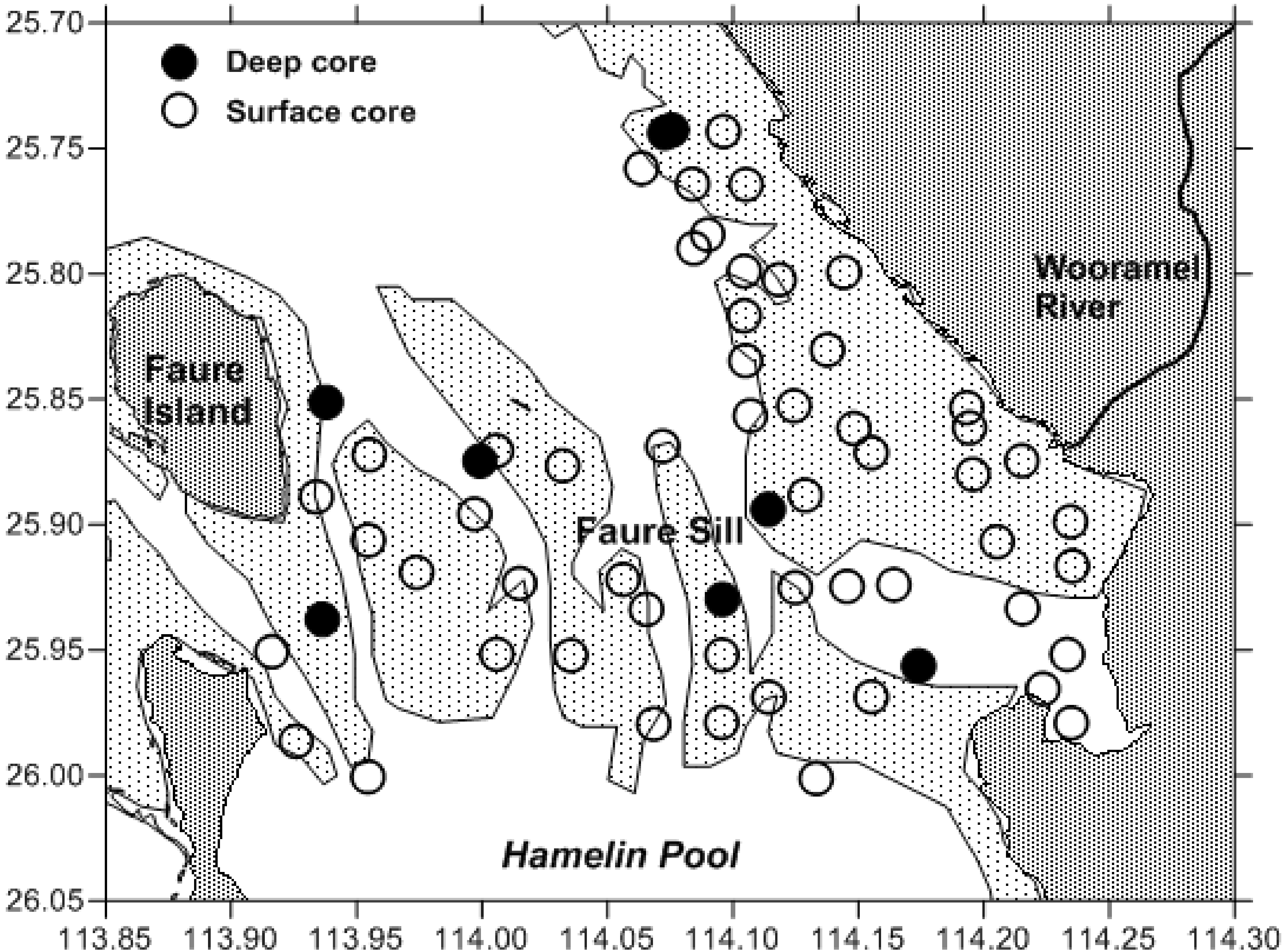
1 x 10^9 tons CO_2e stored in the soils!

Anthropogenic CO_2e flux is about 29 x 10^9 tons y^{-1}





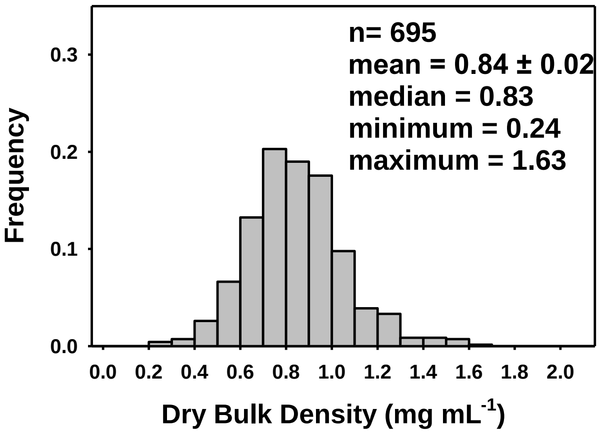
http://www.sharkbay.org/seagrass.aspx

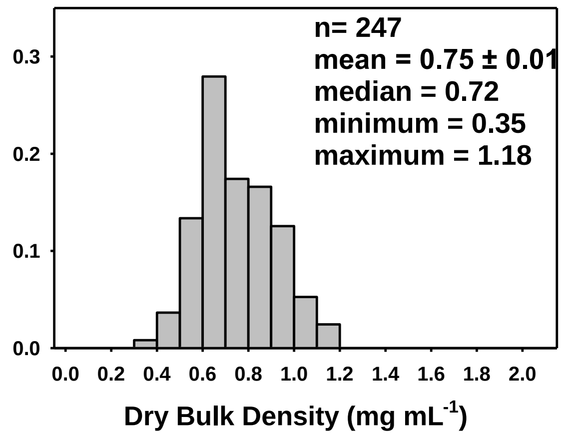


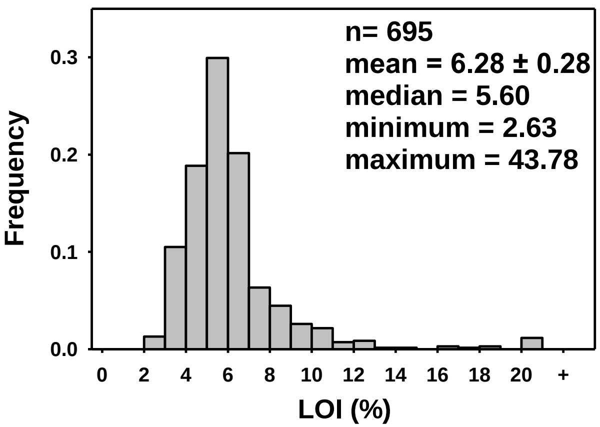
Deep core
Surface core
Faure Island
Wooramel River
Faure Sill
Hamelin Pool
25.70
25.75
25.80
25.85
25.90
25.95
26.00
26.05
113.85
113.90
113.95
114.00
114.05
114.10
114.15
114.20
114.25
114.30

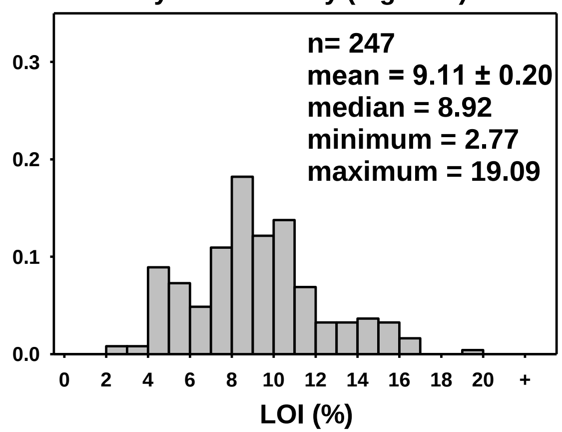
Florida Bay

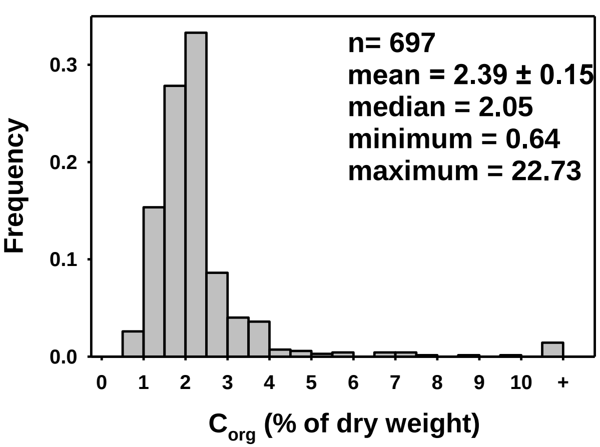
Shark Bay

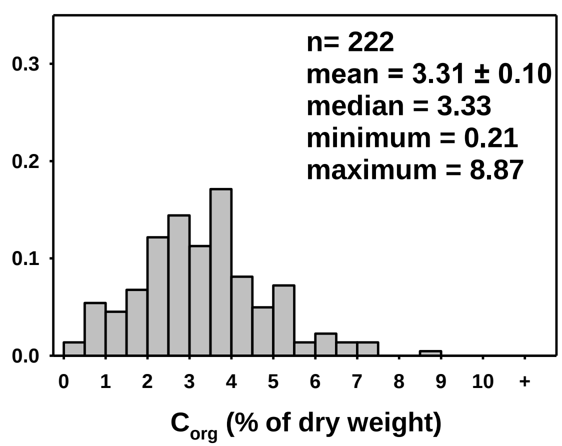


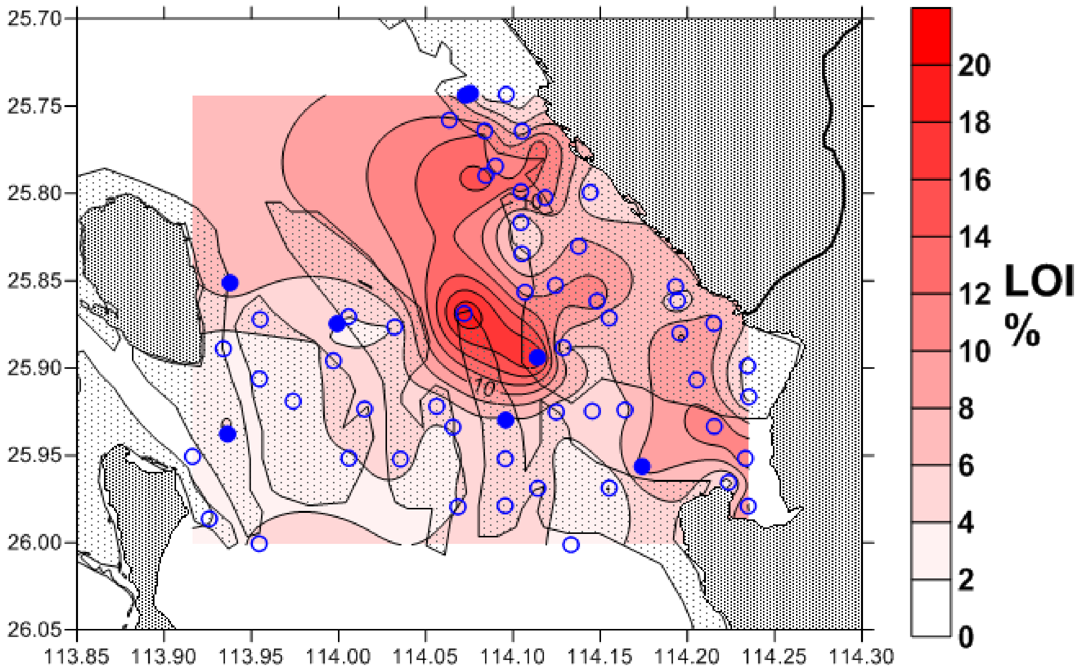


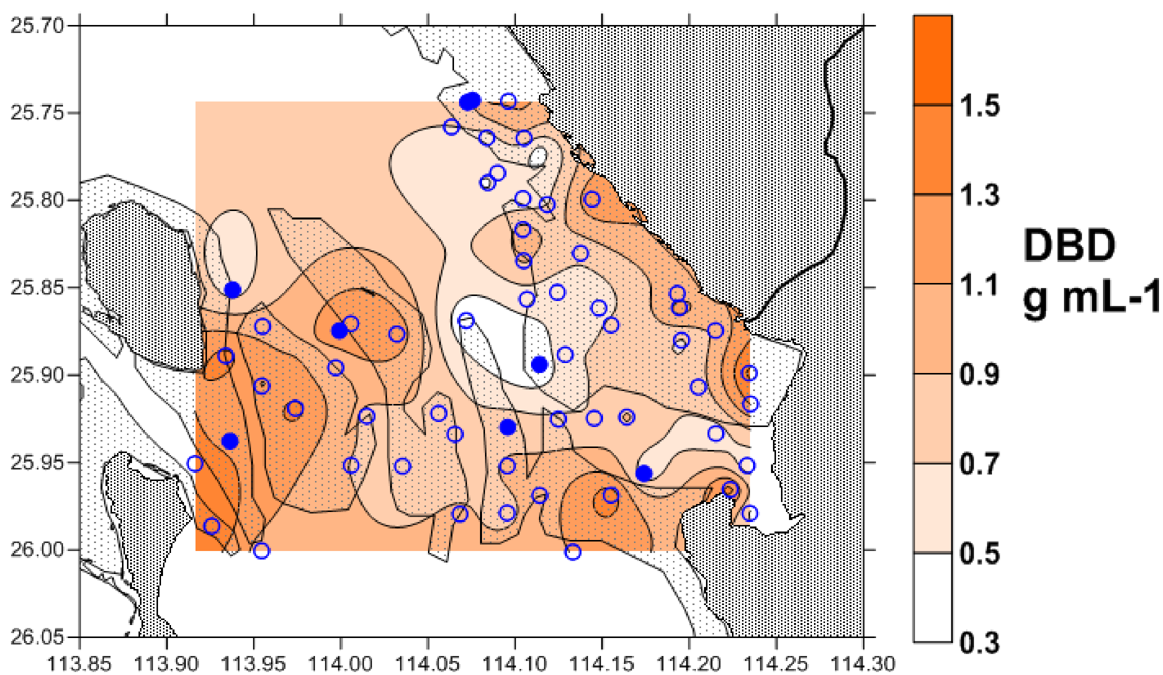






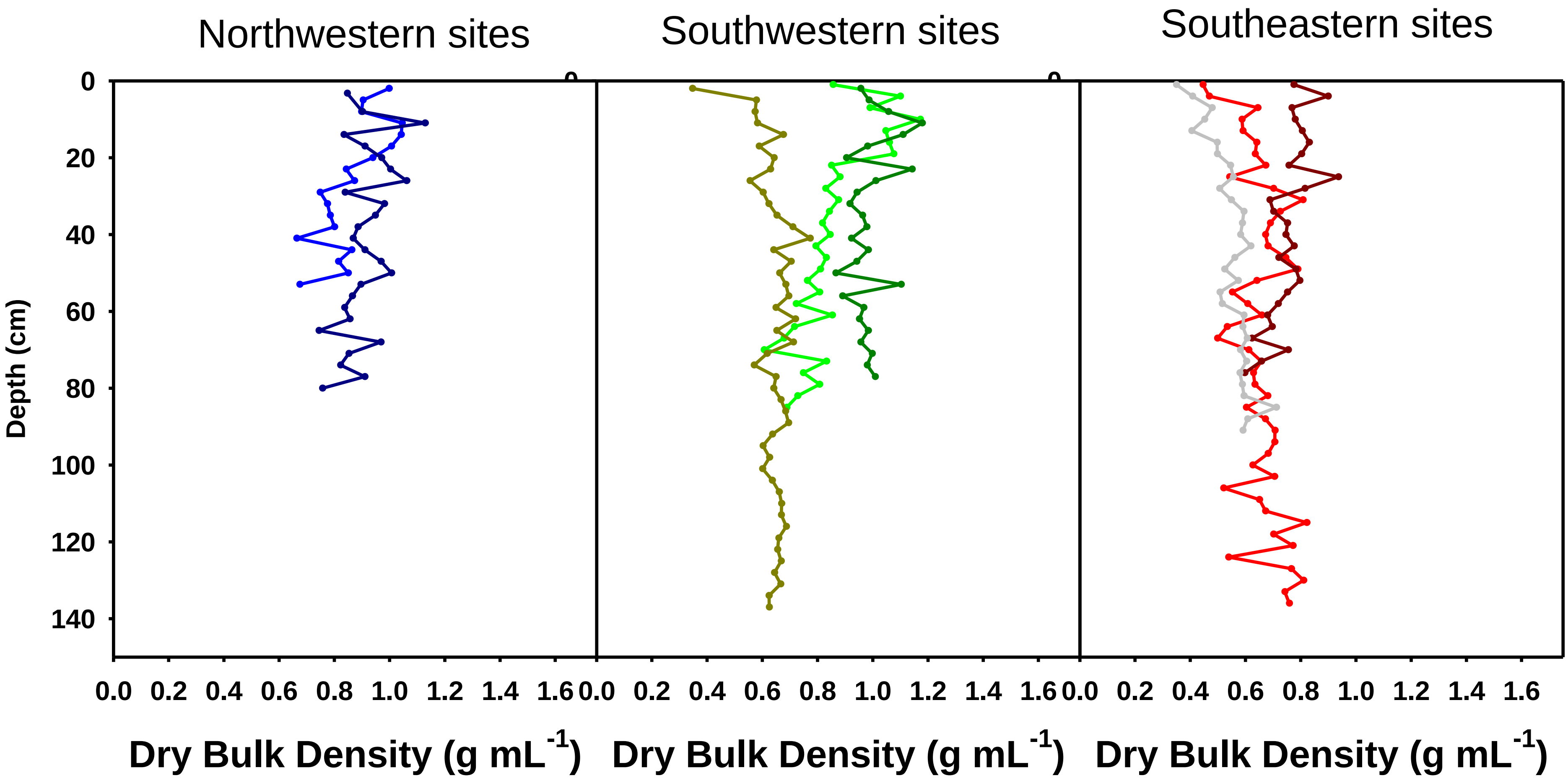




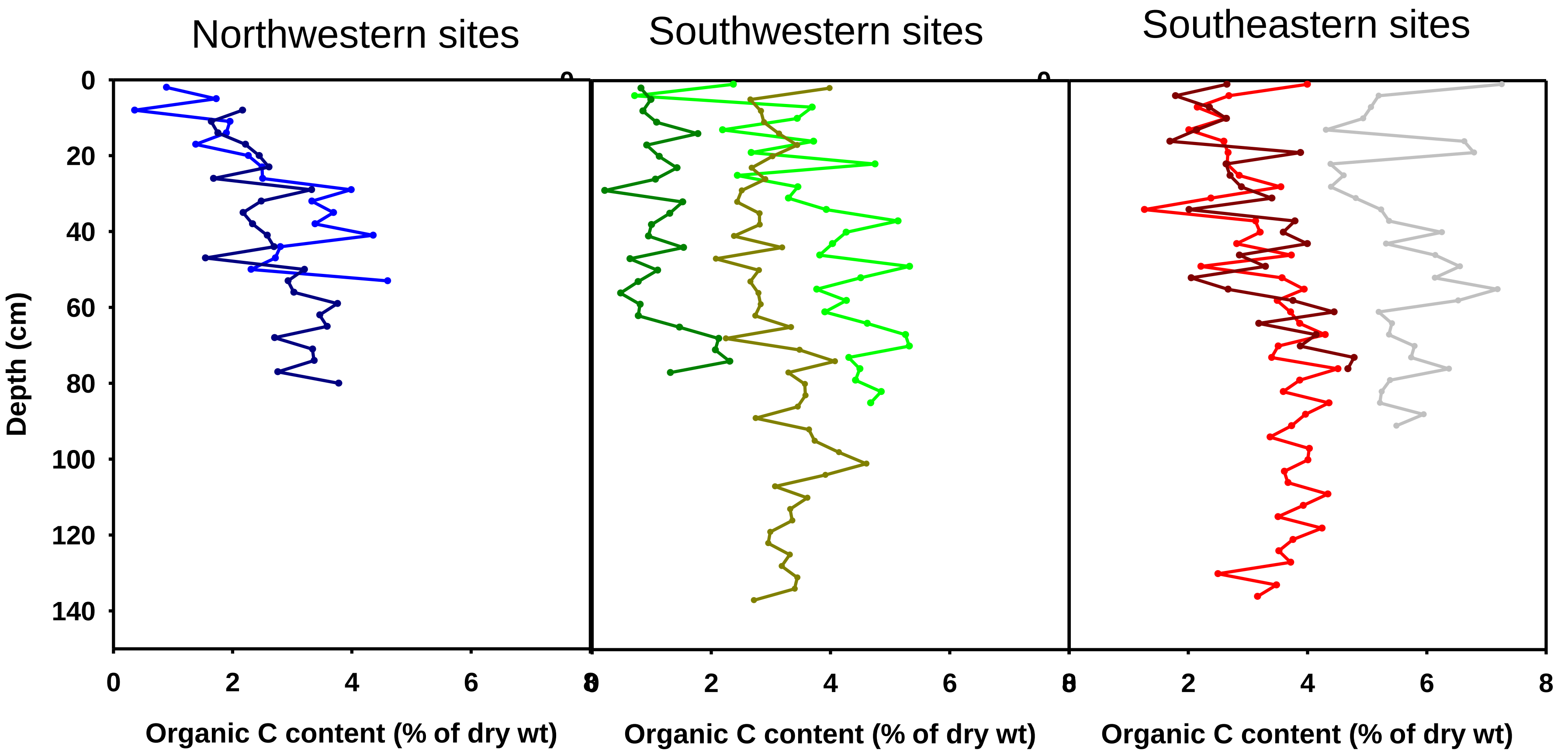


- **Soil properties vary in space across the study area**

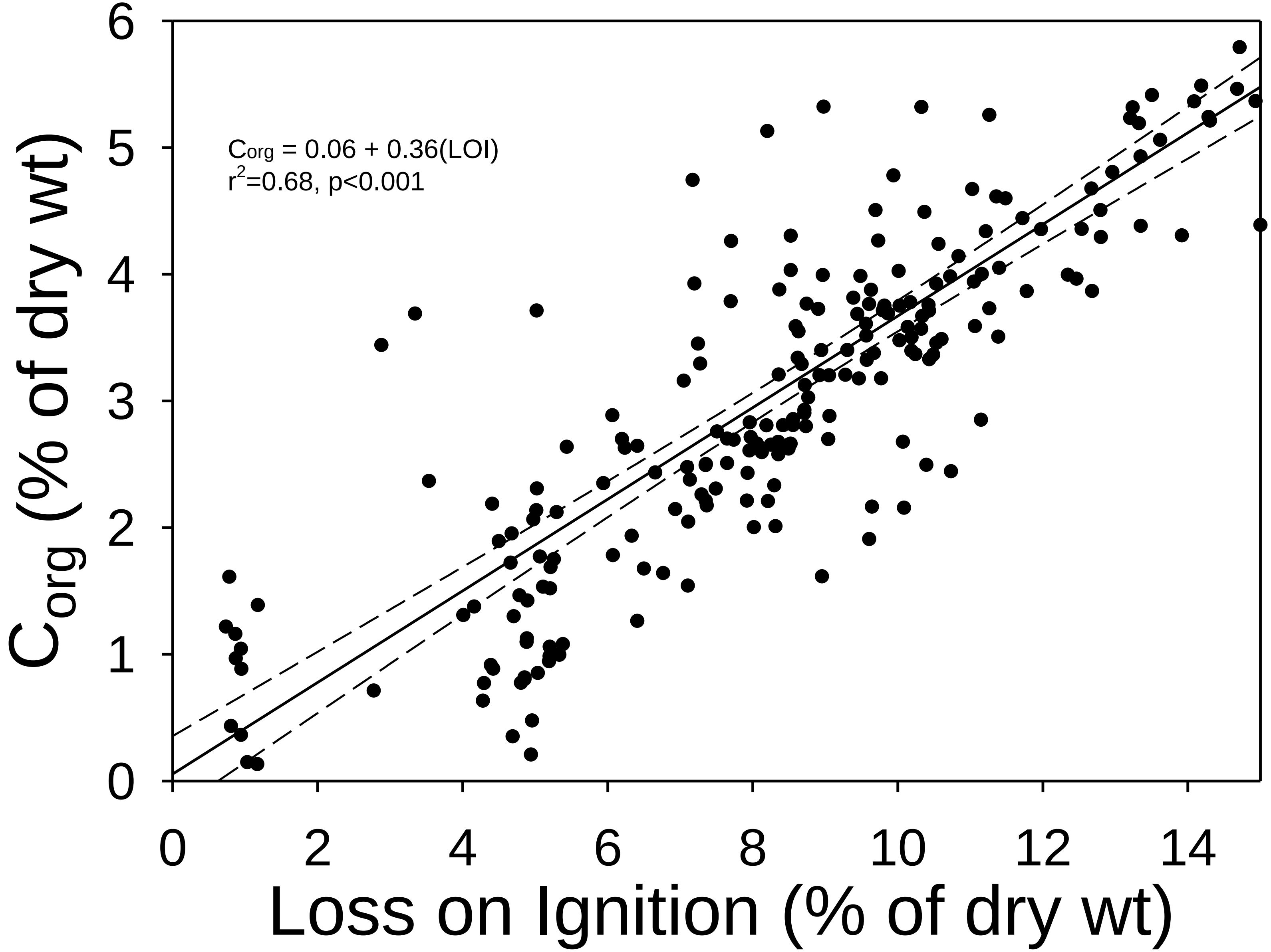
Little evidence of compaction down-core in Shark Bay



C_{org} is constant or increases down-core in Shark Bay



Shark Bay relationship between LOI and Corg is similar to that found in Florida Bay



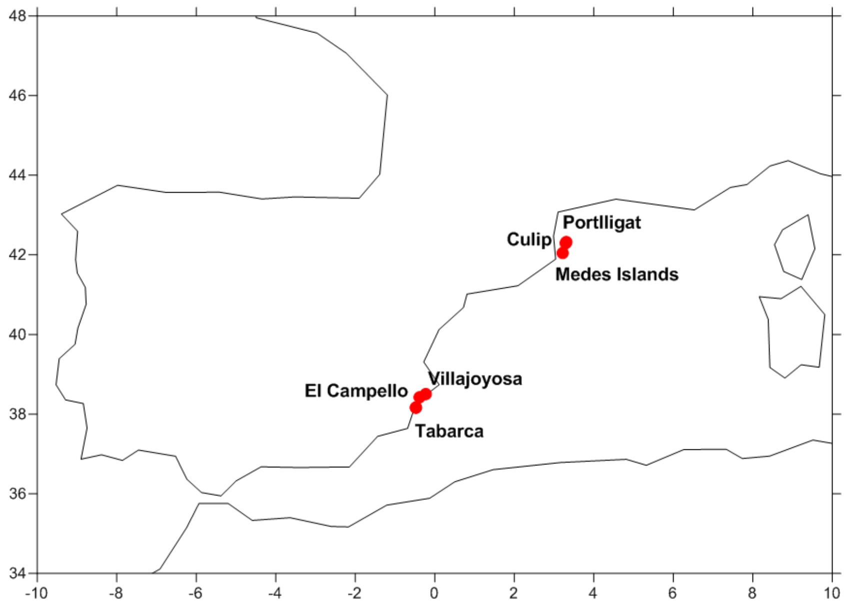
Shark Bay soil C stocks (integrating over the top meter)

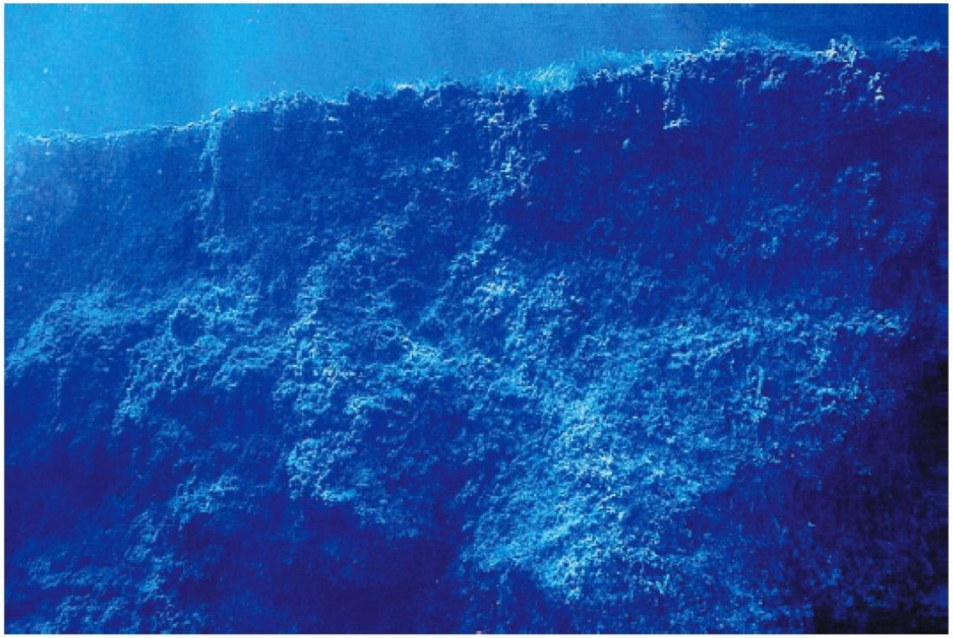
Core ID	kg $CO_2e\ m^{-2}$	tons $CO_2e\ ha^{-1}$
Northeastern sites		
W11-2	**90.6**	**906**
W12-2	**98.5**	**985**
Southwestern sites		
F17b	**42.3**	**423**
116	**81.3**	**813**
F10b	**122.9**	**1229**
Southeastern sites		
W4b	**108.4**	**1084**
431	**86.3**	**863**
128	**77.6**	**776**
mean	**88.5**	**884.8**
sd	**23.9**	**238.8**
95% CI	**16.5**	**165.5**

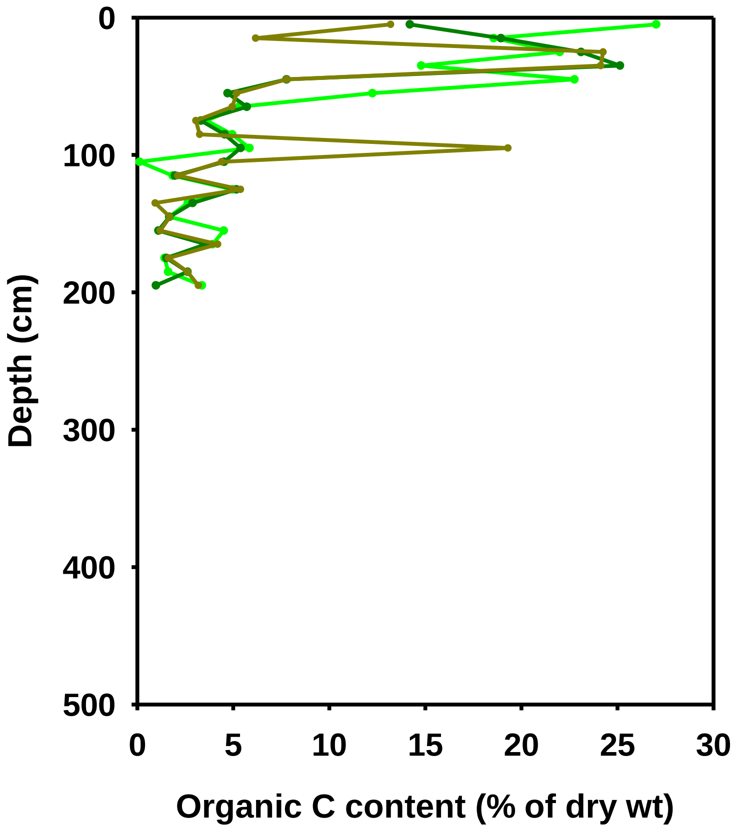
A very rough estimate of carbon stored in the top meter of seagrass soils in Shark Bay:

4,000 km^2 of seagrasses
900 tons CO_2e ha^{-1}

0.4 x 10^9 tons CO_2e stored in the soils!


Portlligat
Culip
Medes Islands
Villajoyosa
El Campello
Tabarca




Depth (cm)
Organic C content (% of dry wt)

Western Mediterranean *Posidonia* soil C stocks (top meter)

Core ID	kg $CO_2e\ m^{-2}$	tons $CO_2e\ ha^{-1}$
Villajoyosa	139.4	1394.4
Villajoyosa	117.6	1176.3
Villajoyosa	114.5	1144.6
Tabarca	239.9	2398.6
Tabarca	84.6	846.2
Tabarca	304.0	3040.3
Tabarca	96.9	969.4
El Campello	246.2	2462.3
El Campello	115.6	1156.2
Portlligat	171.4	1714.1
Portlligat	96.6	966.1
Portlligat	190.0	1900.0
Portlligat	70.8	708.1
Portlligat	71.7	717.3
Culip	210.6	2106.0
Medes Island	166.1	1661.2

***Posidonia* biomass:**

1.3-85.7 tons $CO_2e\ ha^{-1}$
33.4 +/- 3.2 (95% CI)

Soil C stocks:

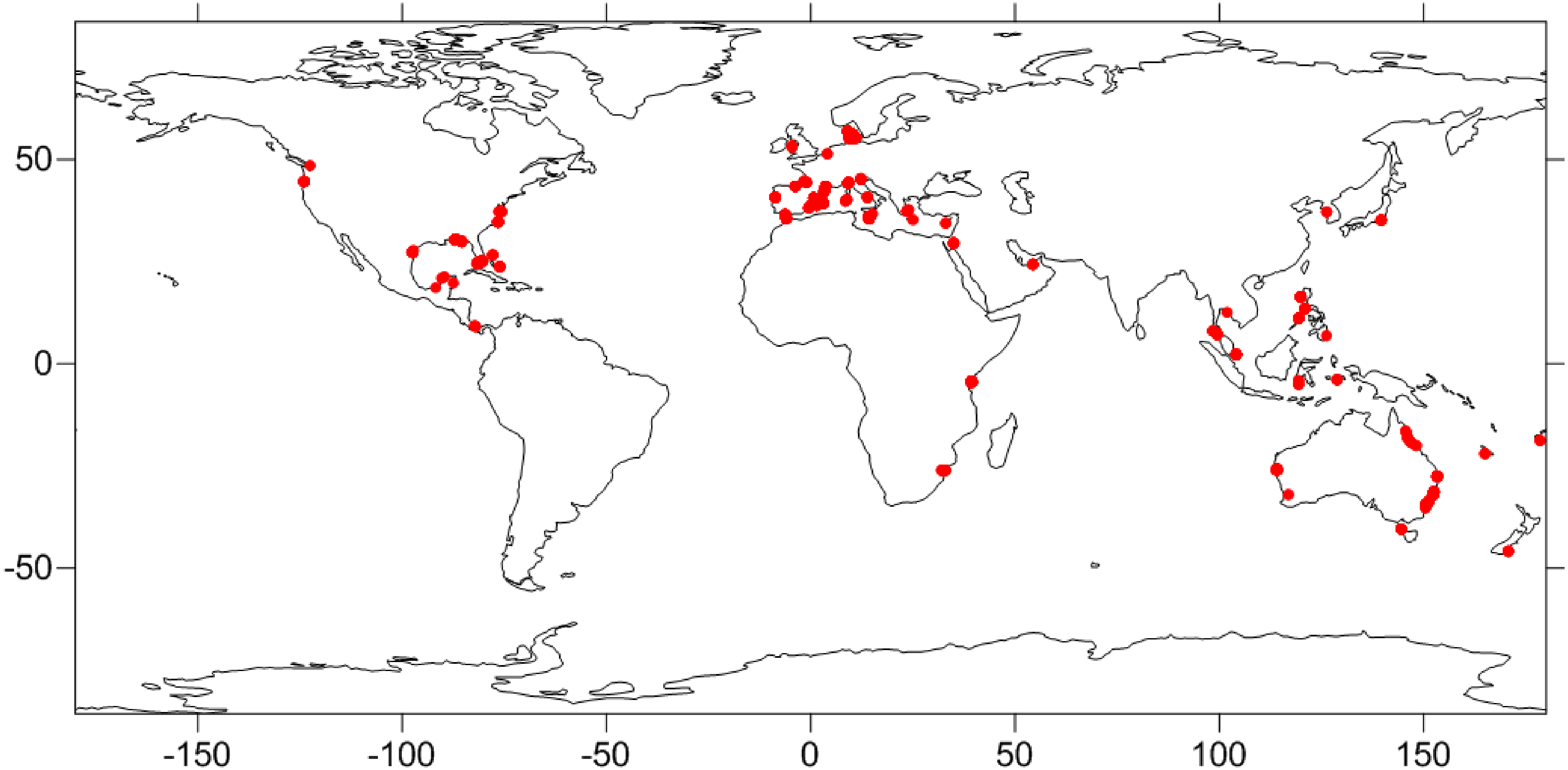
708.1- 3040.3 tons $CO_2e\ ha^{-1}$
1552.6 +/- 341.6 (95% CI)

A very rough estimate of carbon stored in the top meter of *Posidonia oceanica* soils in Western Mediterranean:

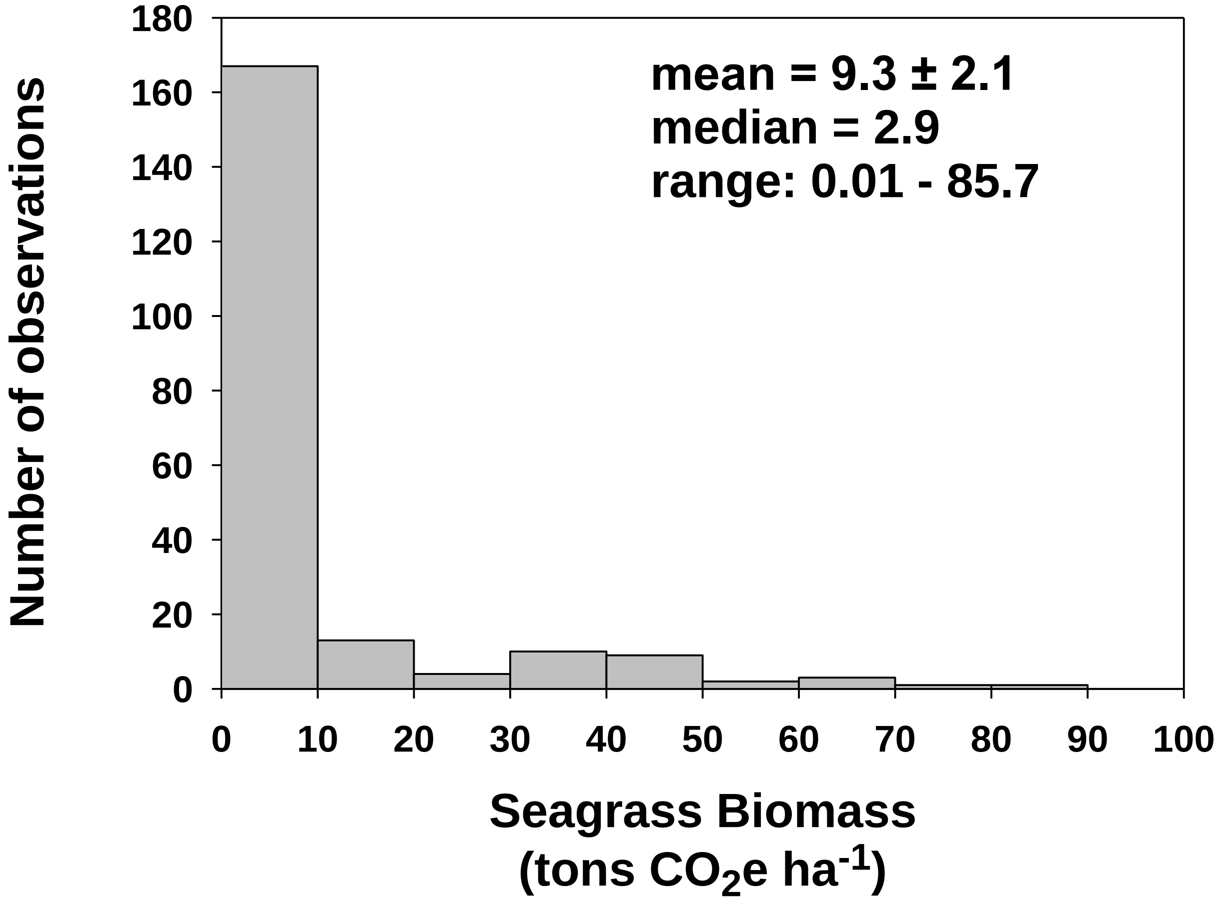
40,000 km^2 of seagrasses
1553 tons CO_2e ha^{-1}

6.2 x 10^9 tons CO_2e stored in the soils

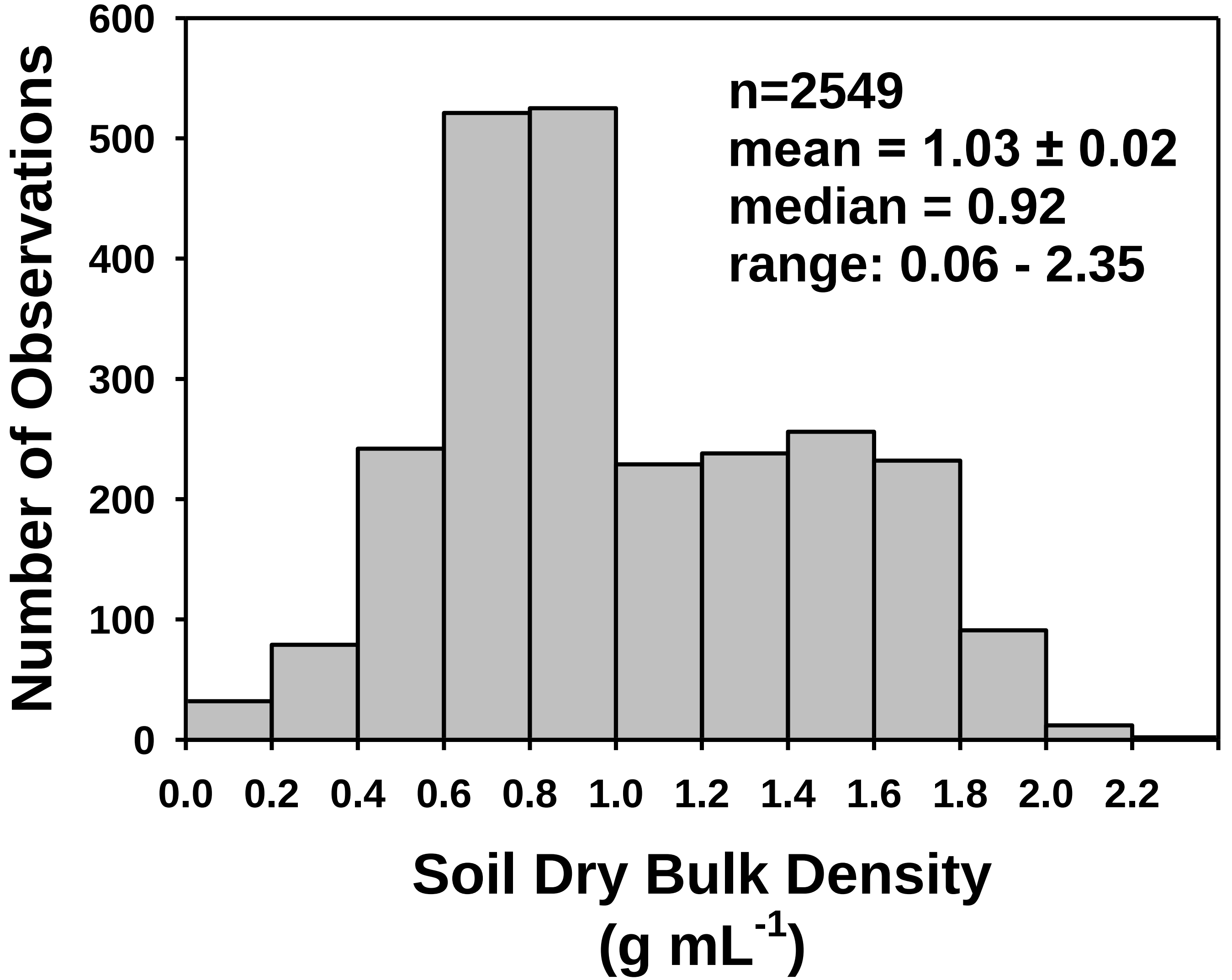
Towards an estimate of global Seagrass Blue carbon stocks

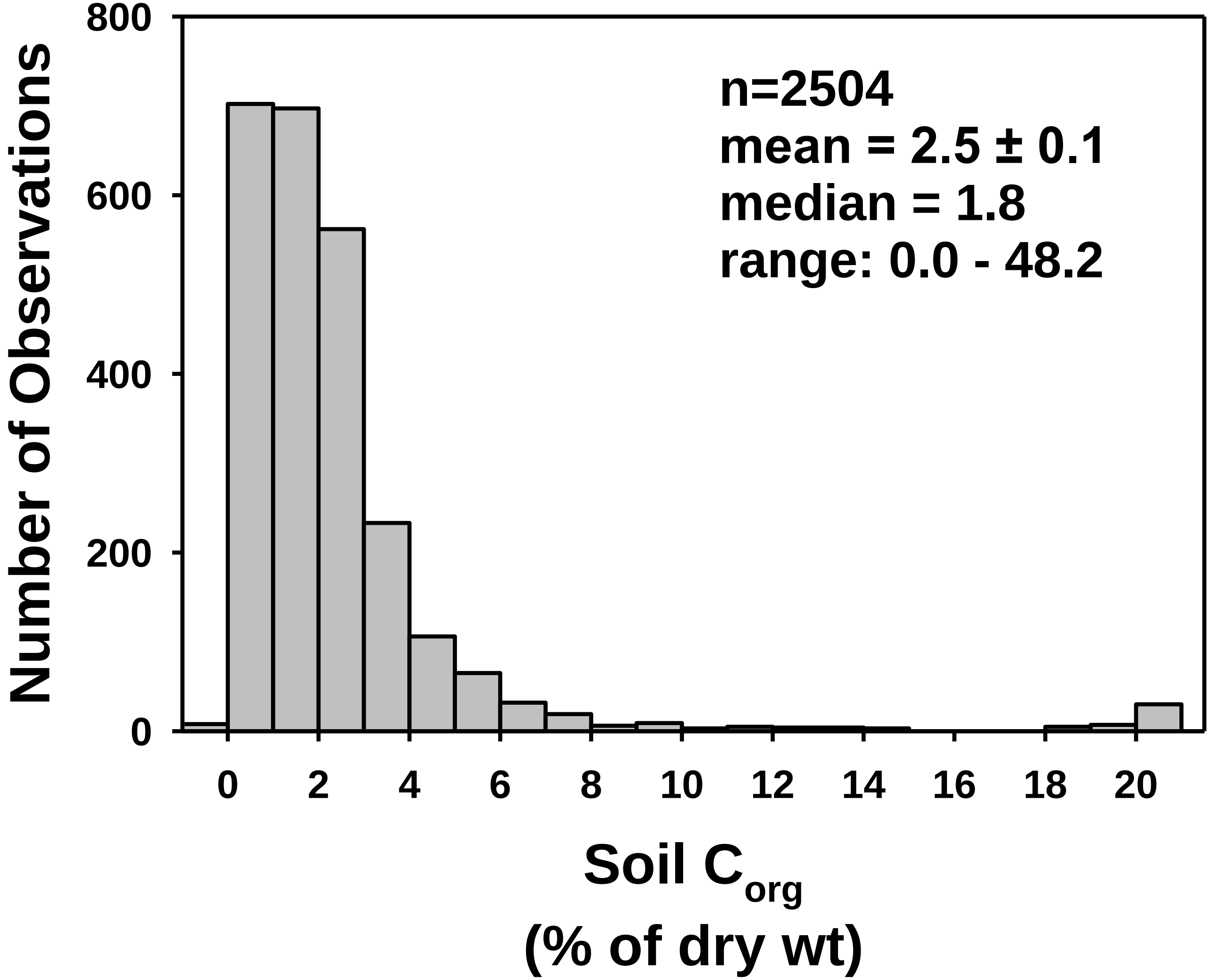


3576 data points from 882 discrete sample locations

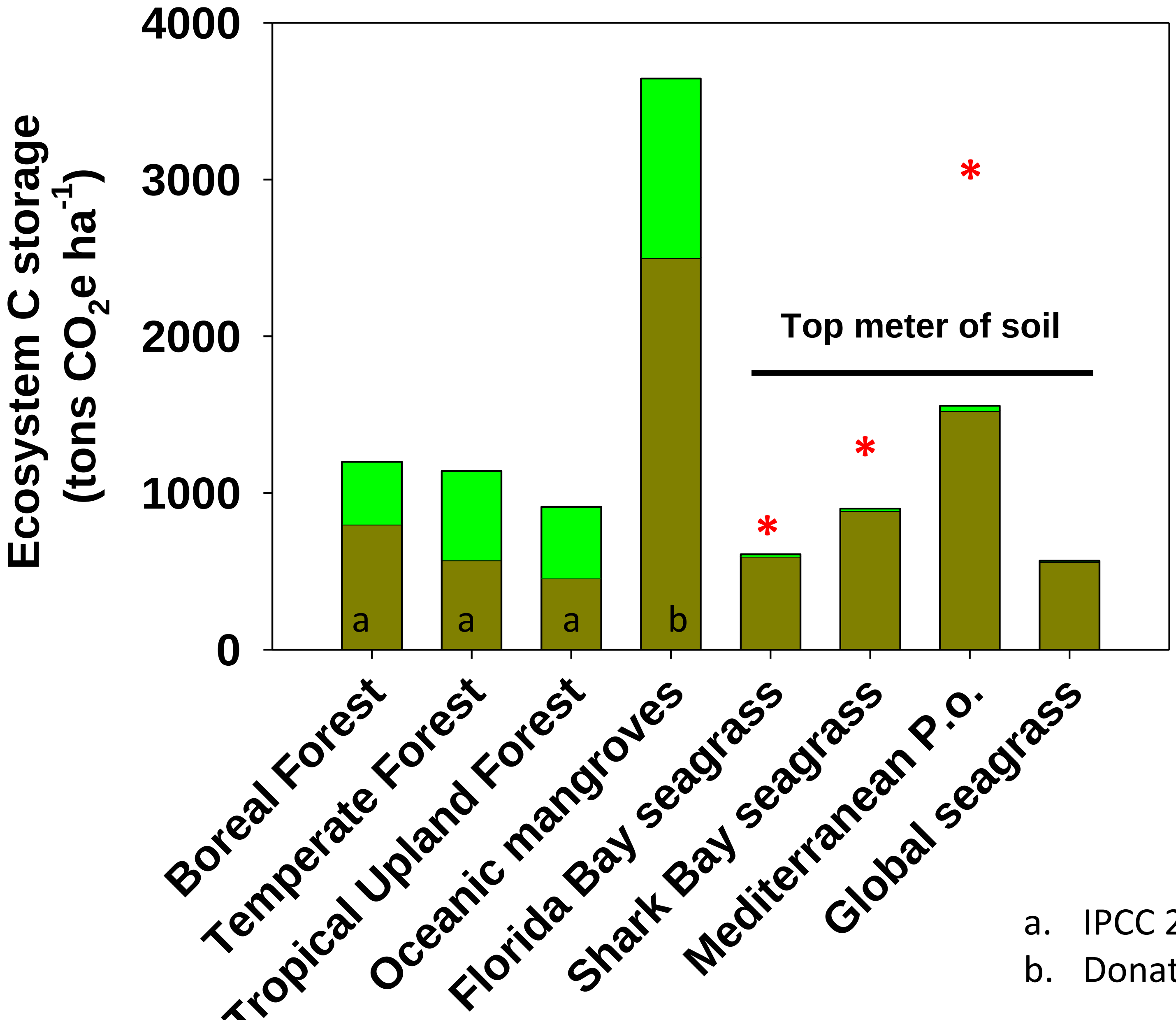


mean = 9.3 ± 2.1
median = 2.9
range: 0.01 - 85.7
Number of observations
0
20
40
60
80
100
120
140
160
180
0
10
20
30
40
50
60
70
80
90
100
Seagrass Biomass
(tons CO_2e ha^{-1})


n=2549
mean = 1.03 ± 0.02
median = 0.92
range: 0.06 - 2.35
Number of Observations
0
100
200
300
400
500
600
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
Soil Dry Bulk Density
(g mL-1)



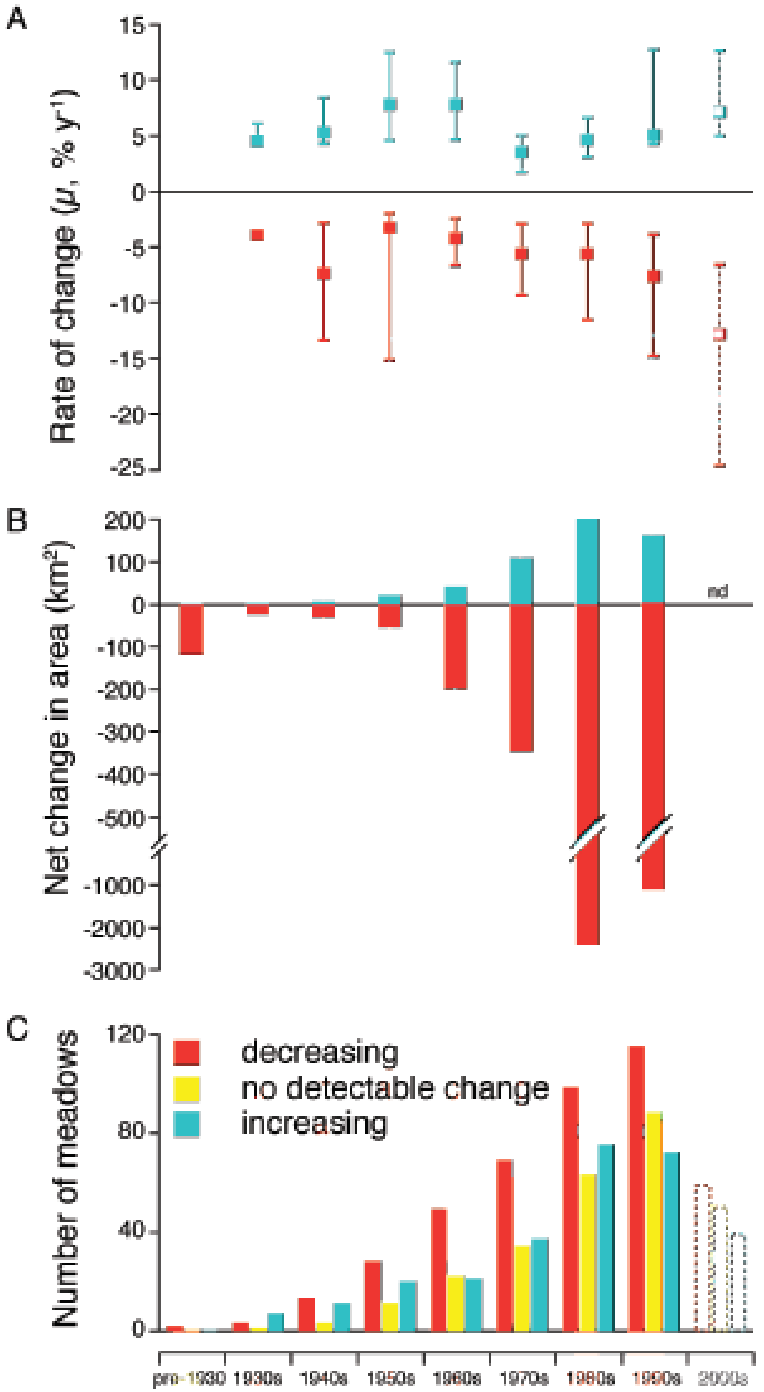
n=2504
mean = 2.5 ± 0.1
median = 1.8
range: 0.0 - 48.2
Number of Observations
800
600
400
200
0
0
2
4
6
8
10
12
14
16
18
20
Soil C_{org}
(% of dry wt)



a. IPCC 2007
b. Donato et al 2011

Global averages carbon sequestration rates and global ranges for the main carbon pools, by habitat type

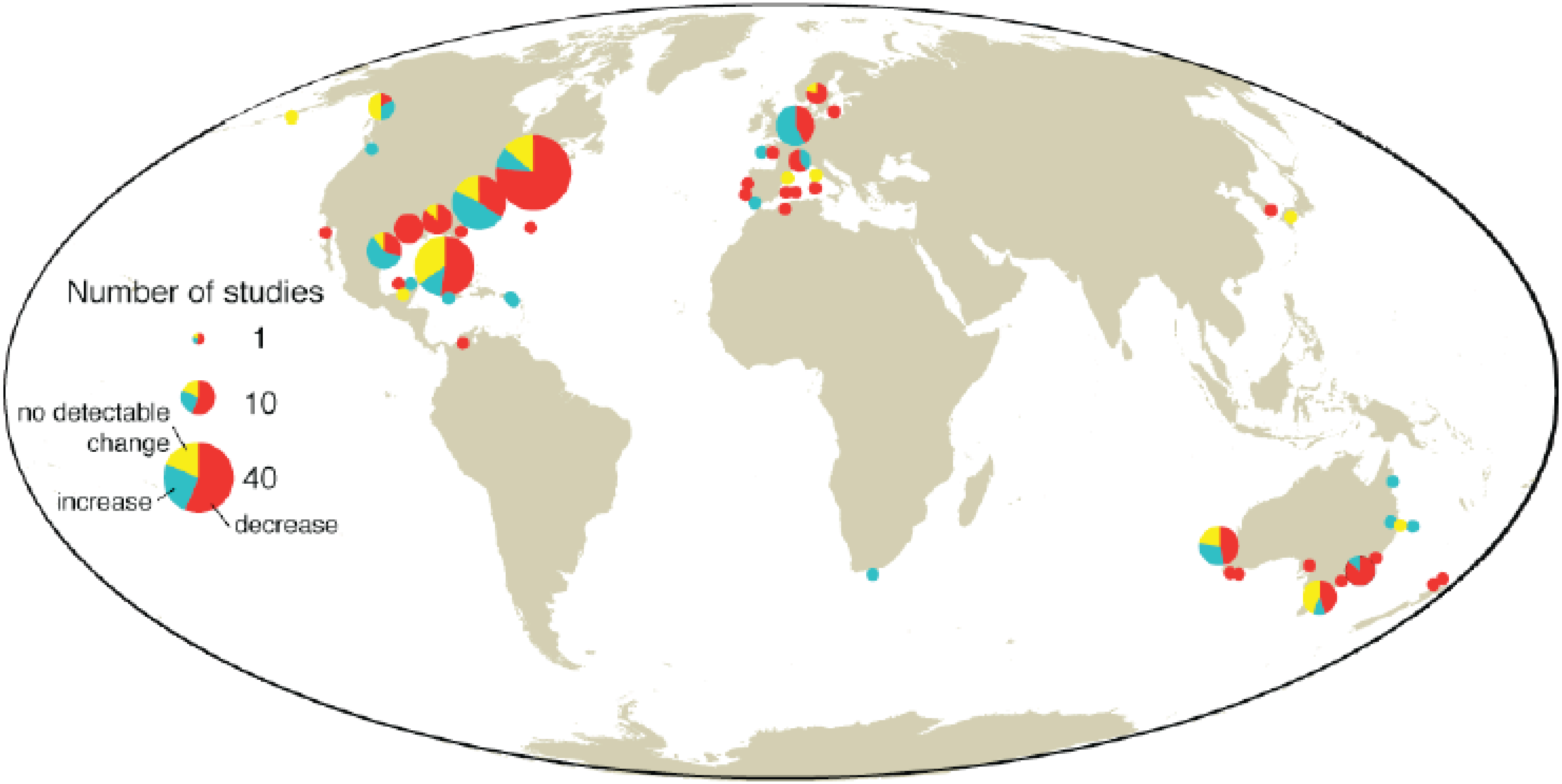
Habitat Type	Annual Carbon Sequestration Rate ($tCO_2e/ha/yr$)	Living biomass (tCO_2e/ha)	Soil organic carbon (tCO_2e/ha)
Seagrass	4.4 ± 0.95[a]	0.4–100[b]	66–3040[c]
Tidal Marsh	7.97 ± 8.52[d]	12–60[e]	330–1,980[f]
Estuarine Mangroves	6.32 ± 4.8[g]	237–563[h]	1,060[h]
Oceanic Mangroves	6.32 ± 4.8[g]	237–563[h]	1,690–2,020[h]



Reports of seagrass losses and the rates of decline are increasing dramatically

Waycott et al. 2009 *PNAS*

Seagrass ecosystems are declining globally



Waycott et al. 2009 *PNAS*

Table 1. Estimates of total carbon (C) at risk of release, including biomass carbon and soil organic carbon in the top meter of soil beneath coastal habitats.

Habitats	Soil Organic Carbon at risk (top meter, $tCO_2e\ ha^{-1}$)	Total Carbon at risk including biomass ($tCO_2e\ ha^{-1}$)	Current Habitat Extent (Mha)	Total Carbon in Habitat (BtCO2e)	C loss from annual habitat conversion - 0.7% rate ($BtCO_2e\ yr^{-1}$)	C loss from annual habitat conversion - 2% rate ($BtCO_2e\ yr^{-1}$)	Economic costs of habitat loss - 0.7% rate (Billion US\$ yr^{-1})	Economic costs of habitat loss - 2% rate (Billion US\$ yr^{-1})
Salt Marsh	917	949	5.1	4.8	0.03	0.10	1.4	4.0
Mangroves	1298	1762	13.8	24.3	0.17	0.49	7.0	19.9
Seagrass	500	511	30	15.3	0.11	0.31	4.4	12.6
Total			48.9	44.5	0.31	0.89	12.8	36.5

Note: Carbon loss estimates with conversion assume complete loss of carbon in biomass and the top meter of soil; these estimates are nevertheless conservative since most areas contain deeper soils up to several meters which may also be affected by habitat conversion, though there is less scientific certainty on the fate of deeper soil layers.

Pendelton et al. in review

Points to remember:

1. **Seagrasses play a significant part in the global C cycle**
2. **Shark Bay, Florida Bay and the Mediterranean have huge C stocks**
3. **Globally, seagrasses are as important as forests in storing CO_2 (on an areal basis)**
4. **The value of the C stored in seagrasses is around \$12,000 ha^{-1}, on par with the annual value of other ecosystem services provided by seagrasses**
5. **Seagrasses are declining at a fast rate, potentially releasing 0.1 – 0.3 Gton CO_2e y^{-1} (worth ca. \$4-12 B y^{-1} at current market values)**
6. **Can seagrasses be included in a REDD+-like scheme? Who would get the payments?**
7. **Big job ahead: predicting the fate of stored C when seagrasses are destroyed**