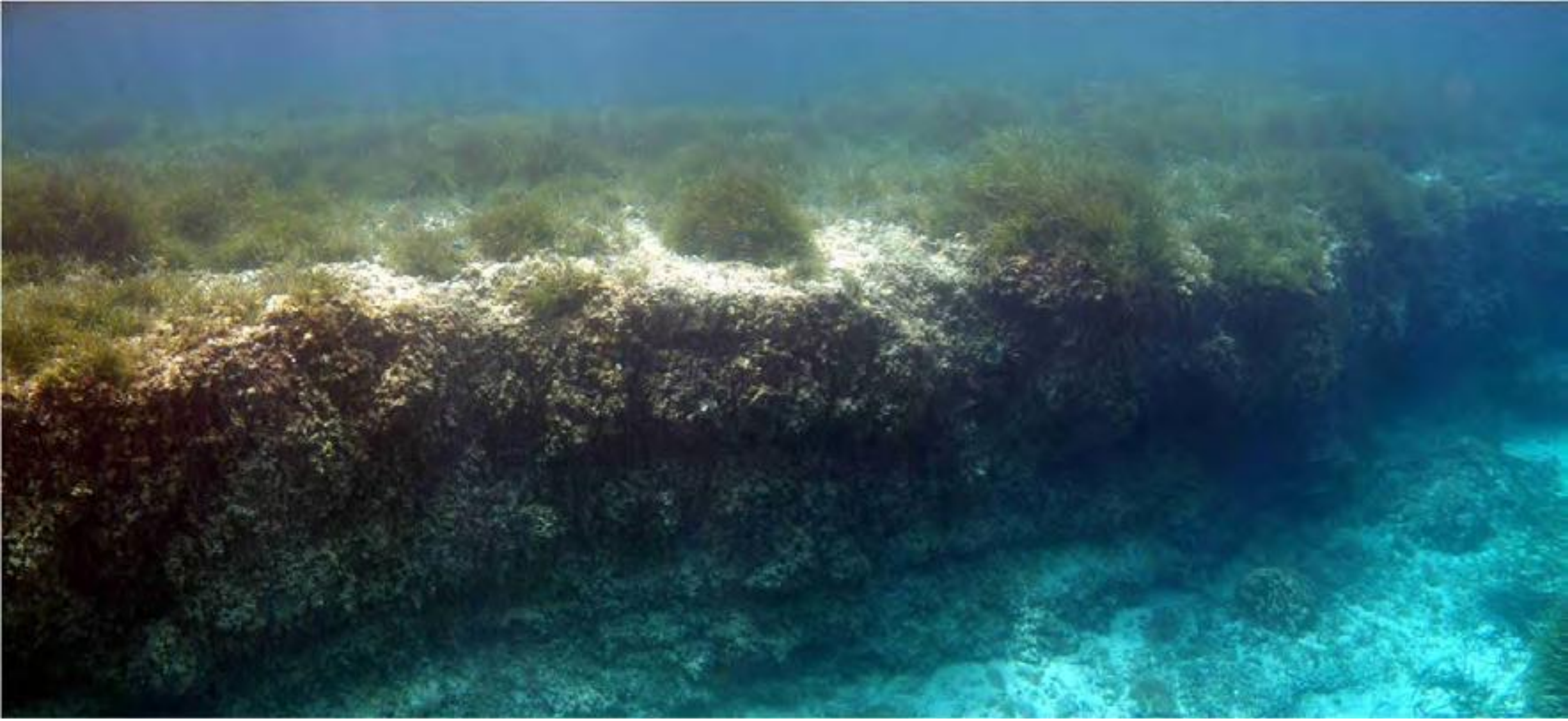


Blue Carbon stored in the seagrass beds of the world

James W. Fourqurean, Catherine Lovelock, Hilary A. Kennedy, Nuria Marbà, Miguel A. Mateo, Gary A. Kendrick and Carlos M. Duarte

International Blue Carbon Policy Working Group,
Guayaquil, Ecuador July 10-12, 2012


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

- **Tropical seagrass beds are among the most productive ecosystems, rivaling agricultural crops like corn and soybeans and coastal wetlands**

- **Valuable providers of ecological goods and services (most valuable ecosystem according to Constanza et al 1997)**

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

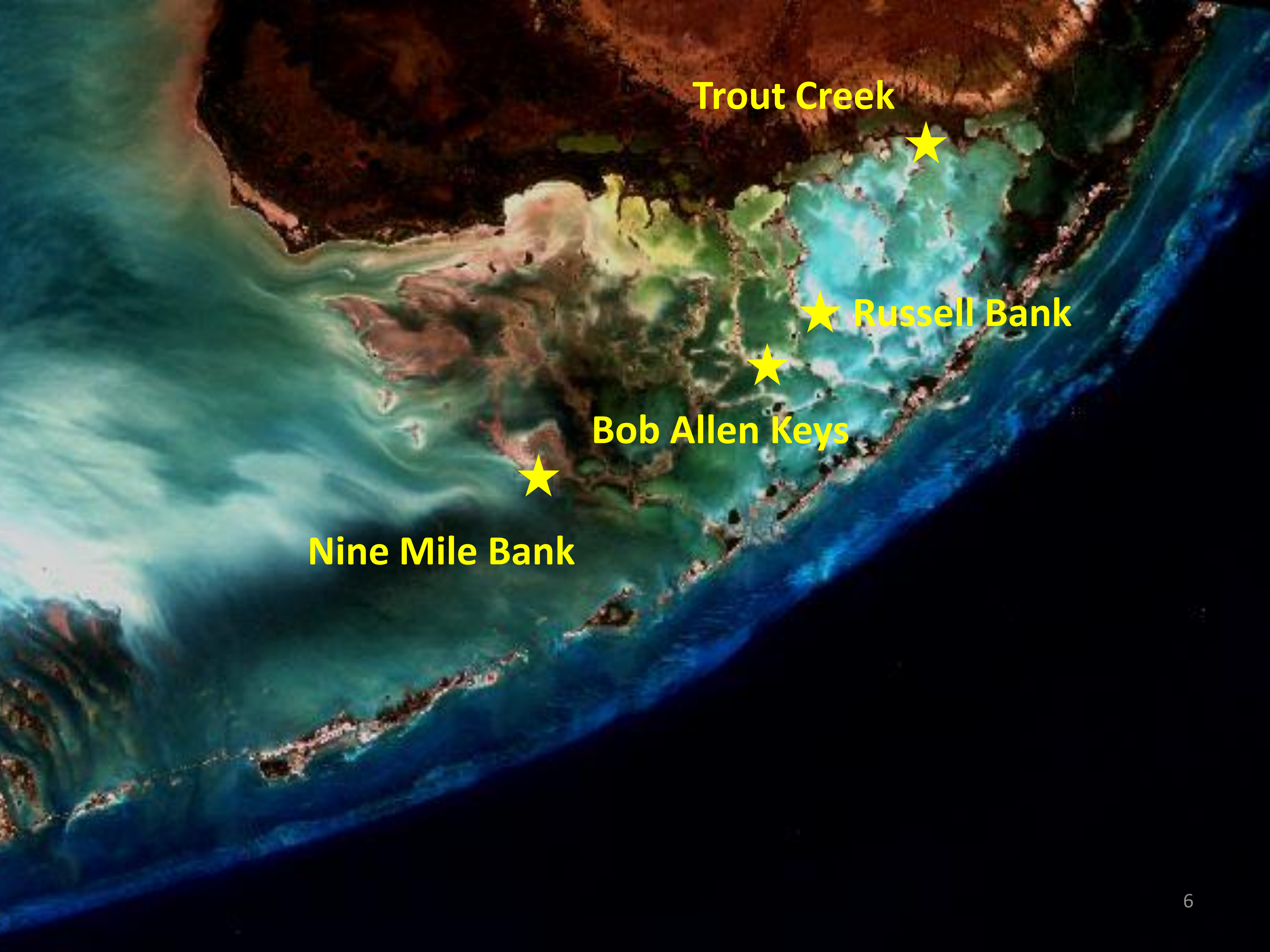
For comparison, mean NCP for:

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

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

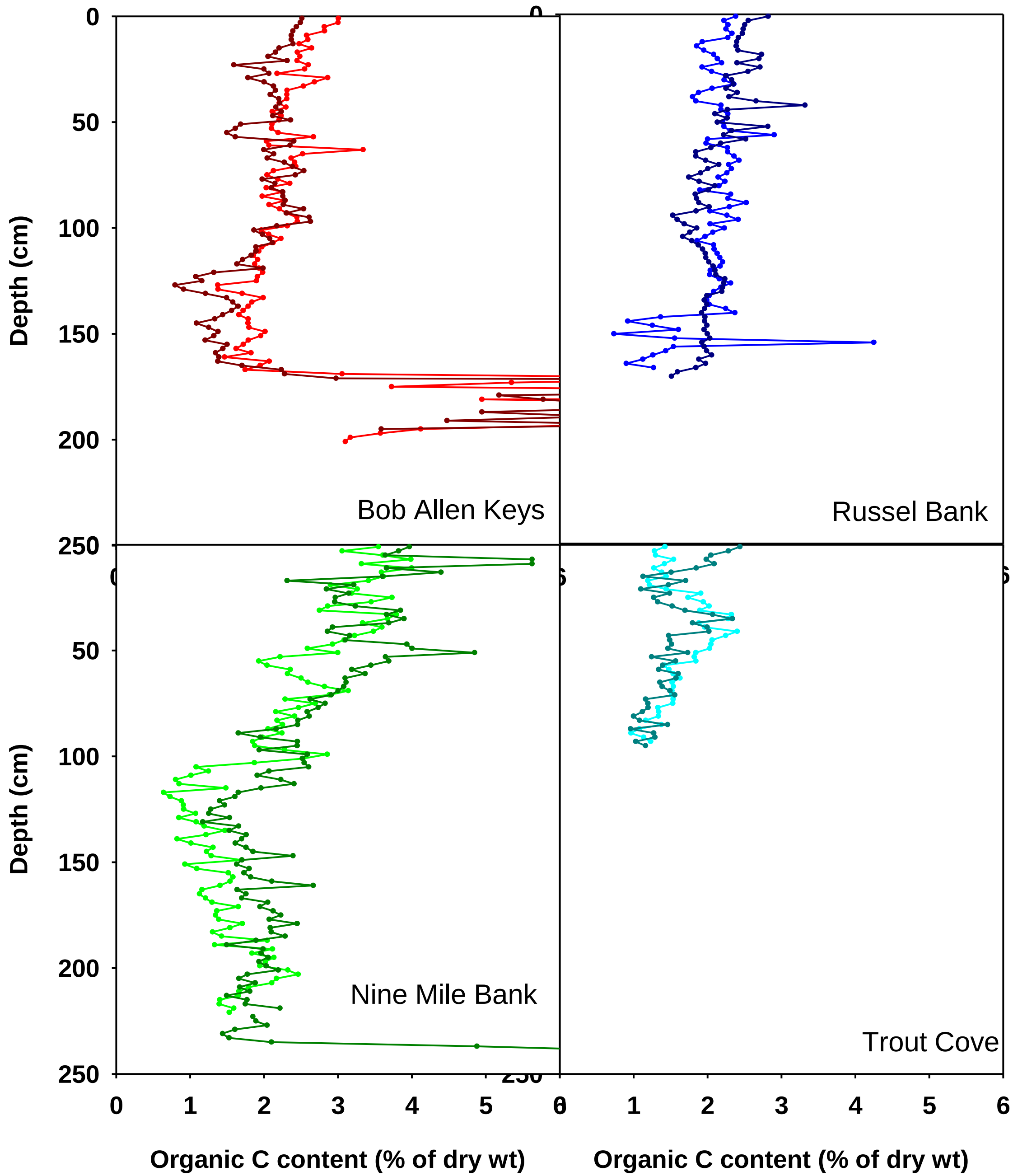
Duarte et al 2010 *Global Biogeochem. Cycles*

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

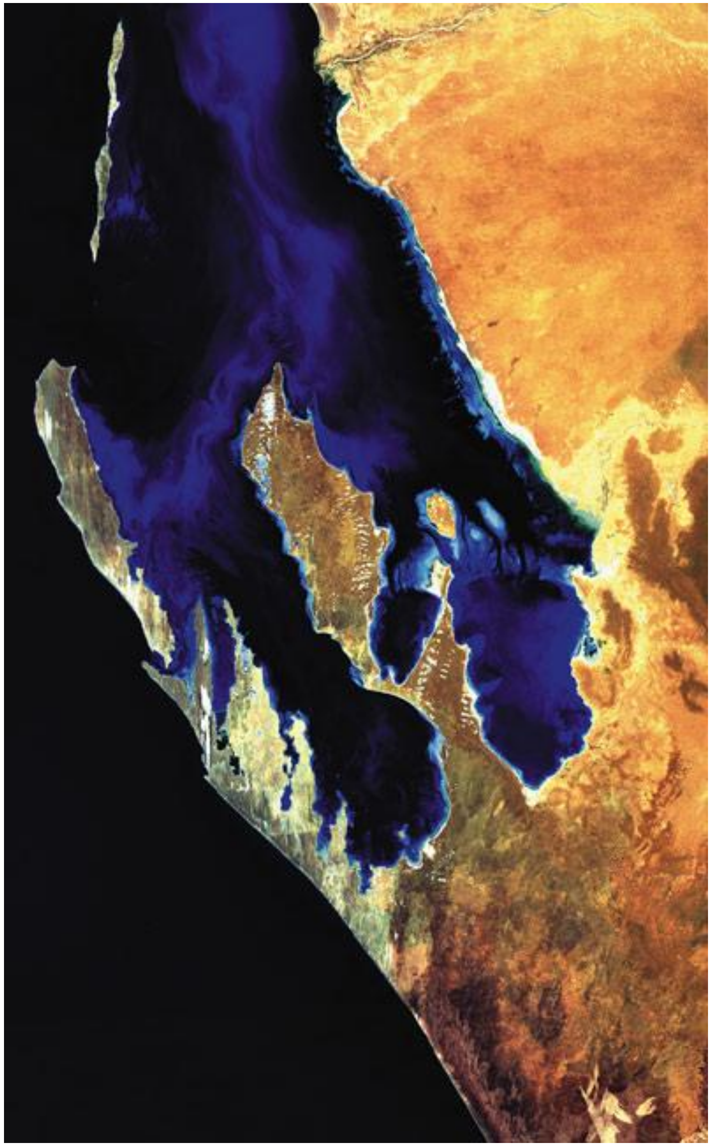

Trout Creek
Russell Bank
Bob Allen Keys
Nine Mile Bank

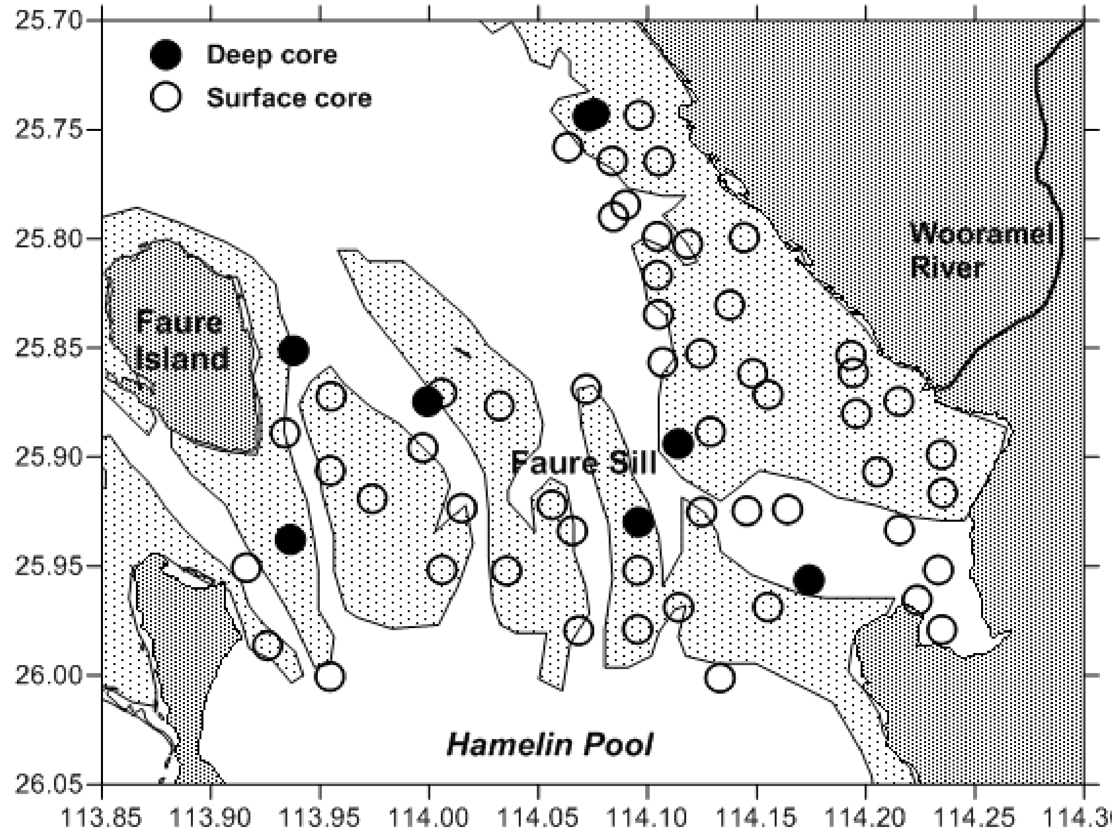
C_{org} generally decreases downcore in Florida Bay seagrass soils.

Buried peats have high C_{org}

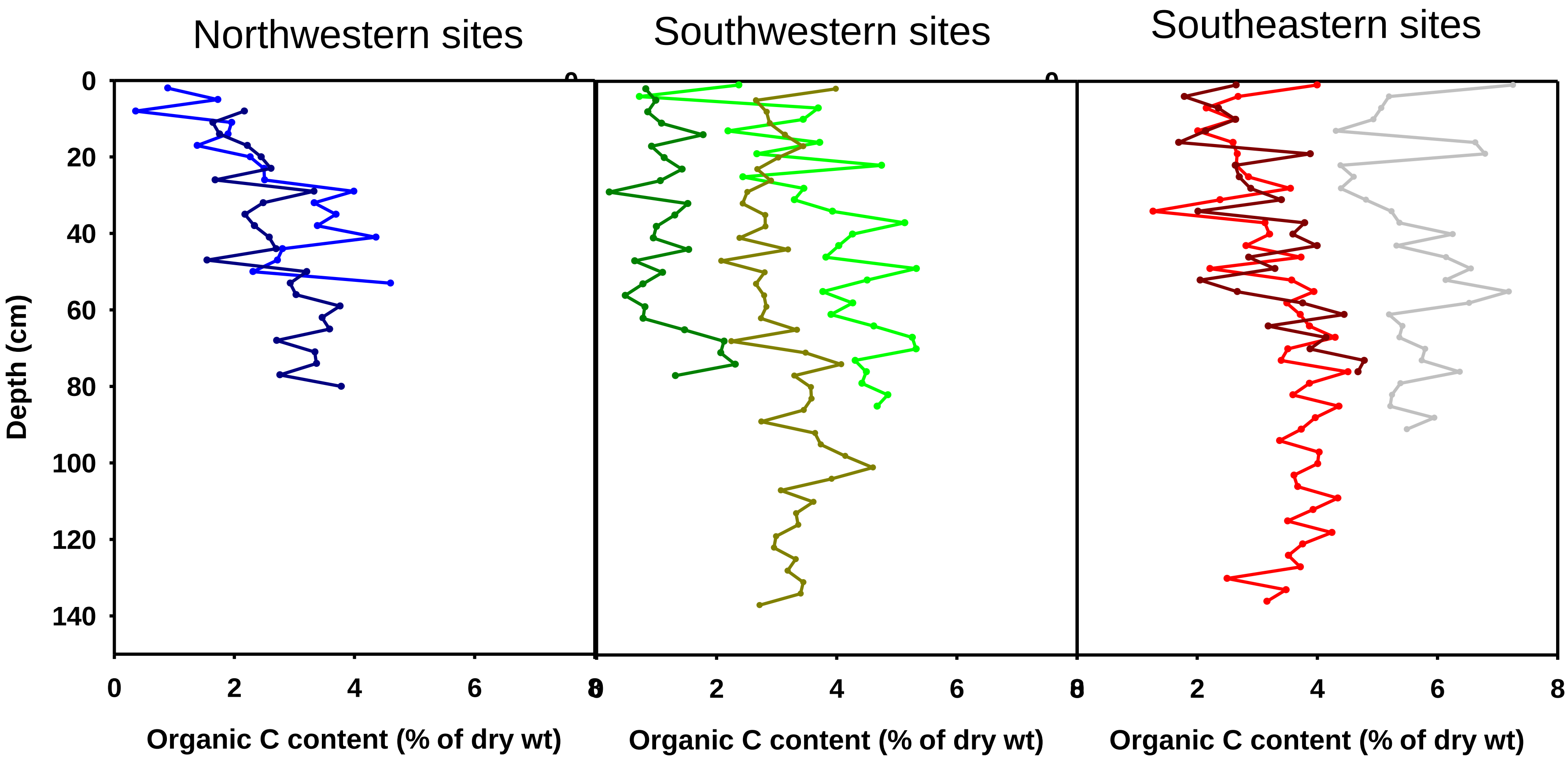


Fourqurean et al. In Press *MFR*



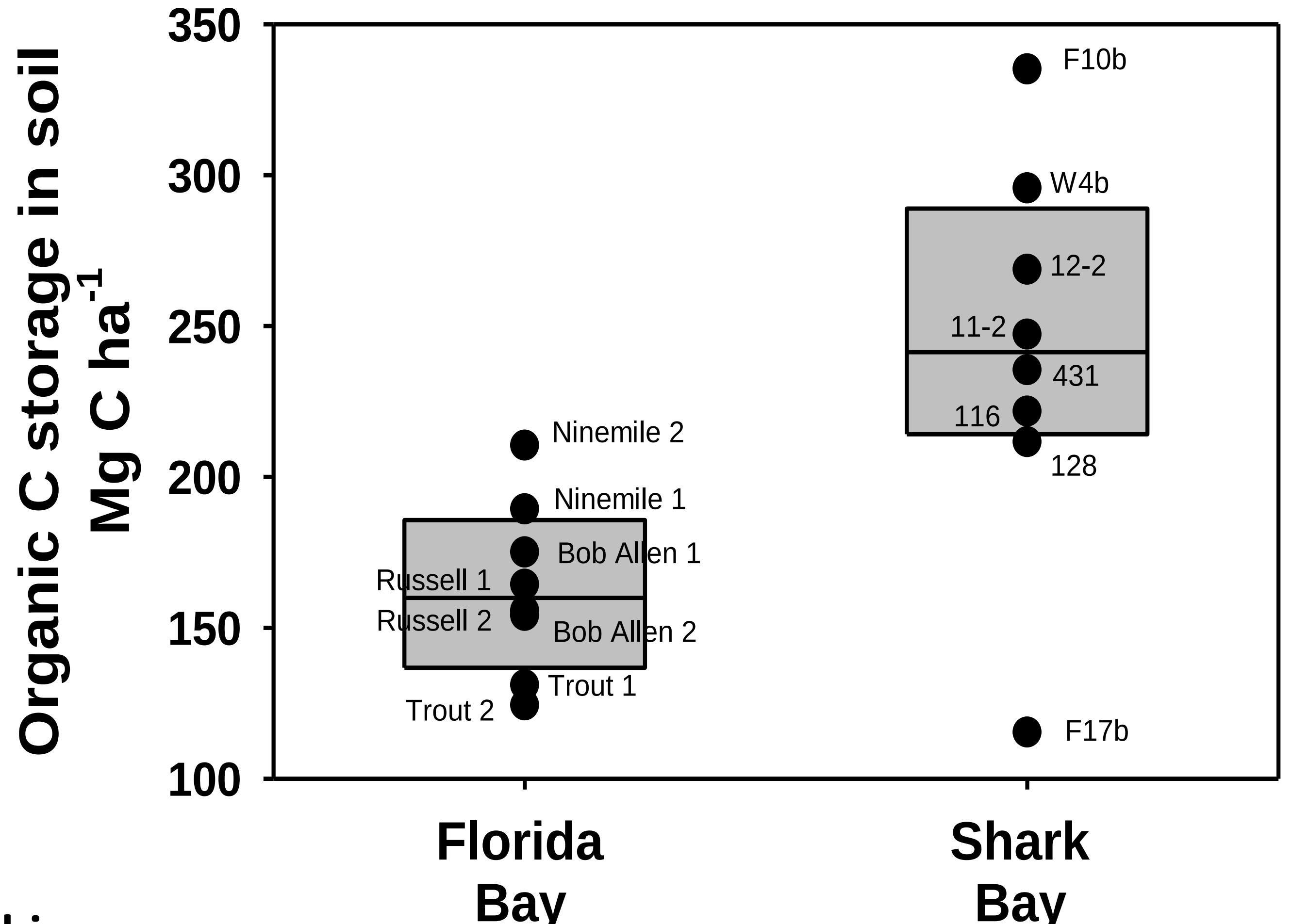

25.70
25.75
25.80
25.85
25.90
25.95
26.00
26.05
113.85
113.90
113.95
114.00
114.05
114.10
114.15
114.20
114.25
114.30
Deep core
Surface core
Faure Island
Faure Sill
Wooramel River
Hamelin Pool

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



Fourqurean et al. In Press *MFR*

C_{org} stocks in top m of seagrass beds



Seagrass biomass:

Florida Bay	**1.14 MgC ha^{-1}**
Shark Bay	**4.75 MgC ha^{-1}**

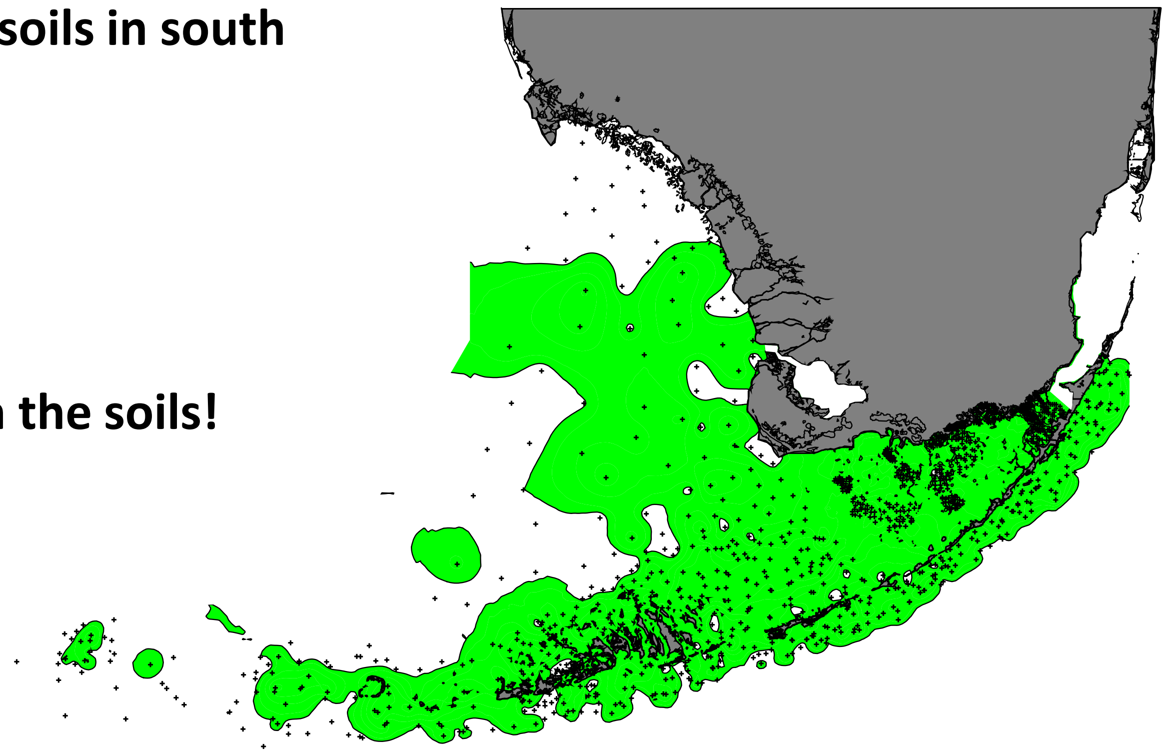
Fourqurean et al. In Press *MFR*

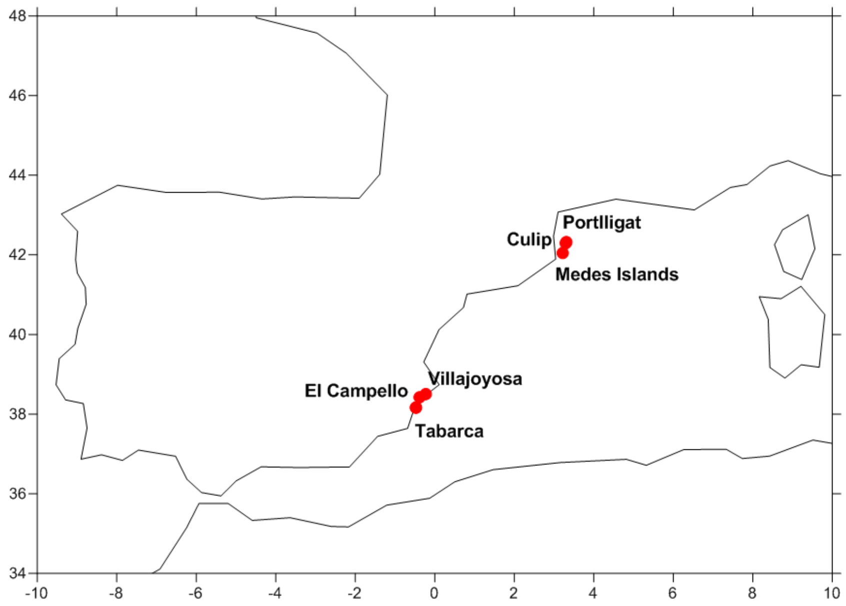
There are about 18,000 km^2 of seagrass beds in south Florida

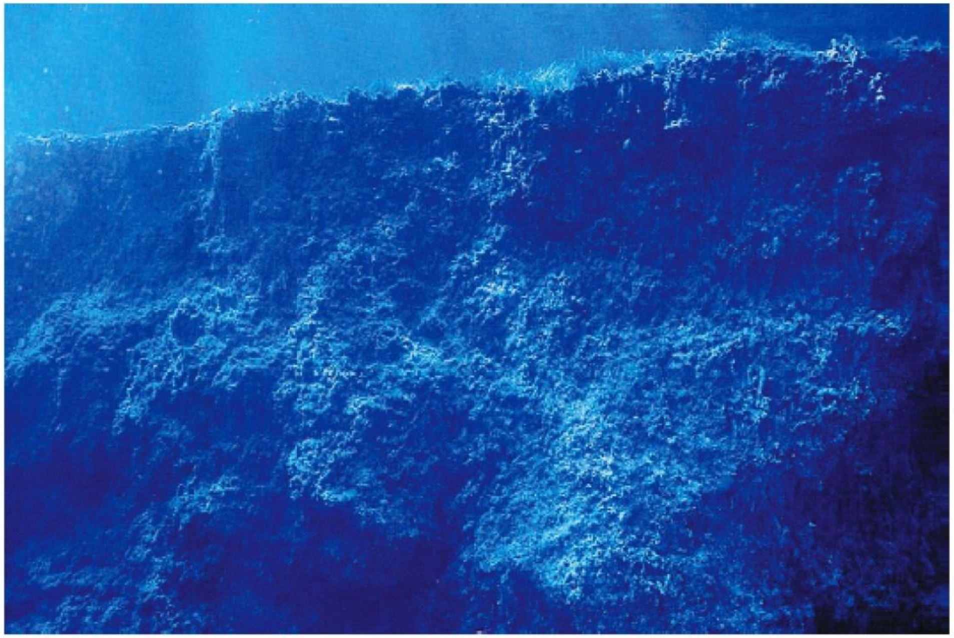
A very rough estimate of carbon stored in the top meter of seagrass soils in south Florida:

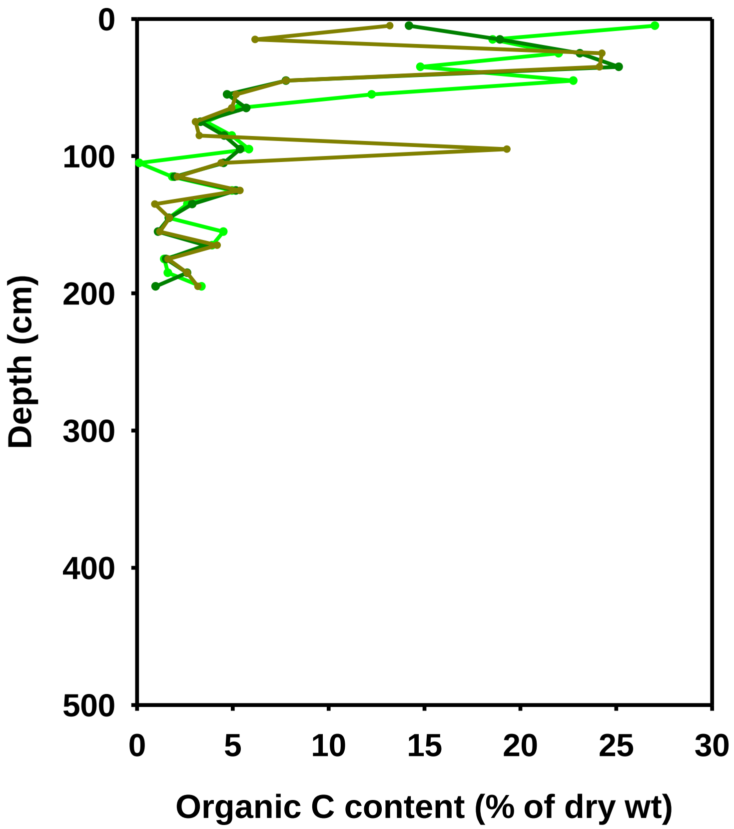
18,000 km^2 of seagrasses
594 tons CO_2e ha^{-1}

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



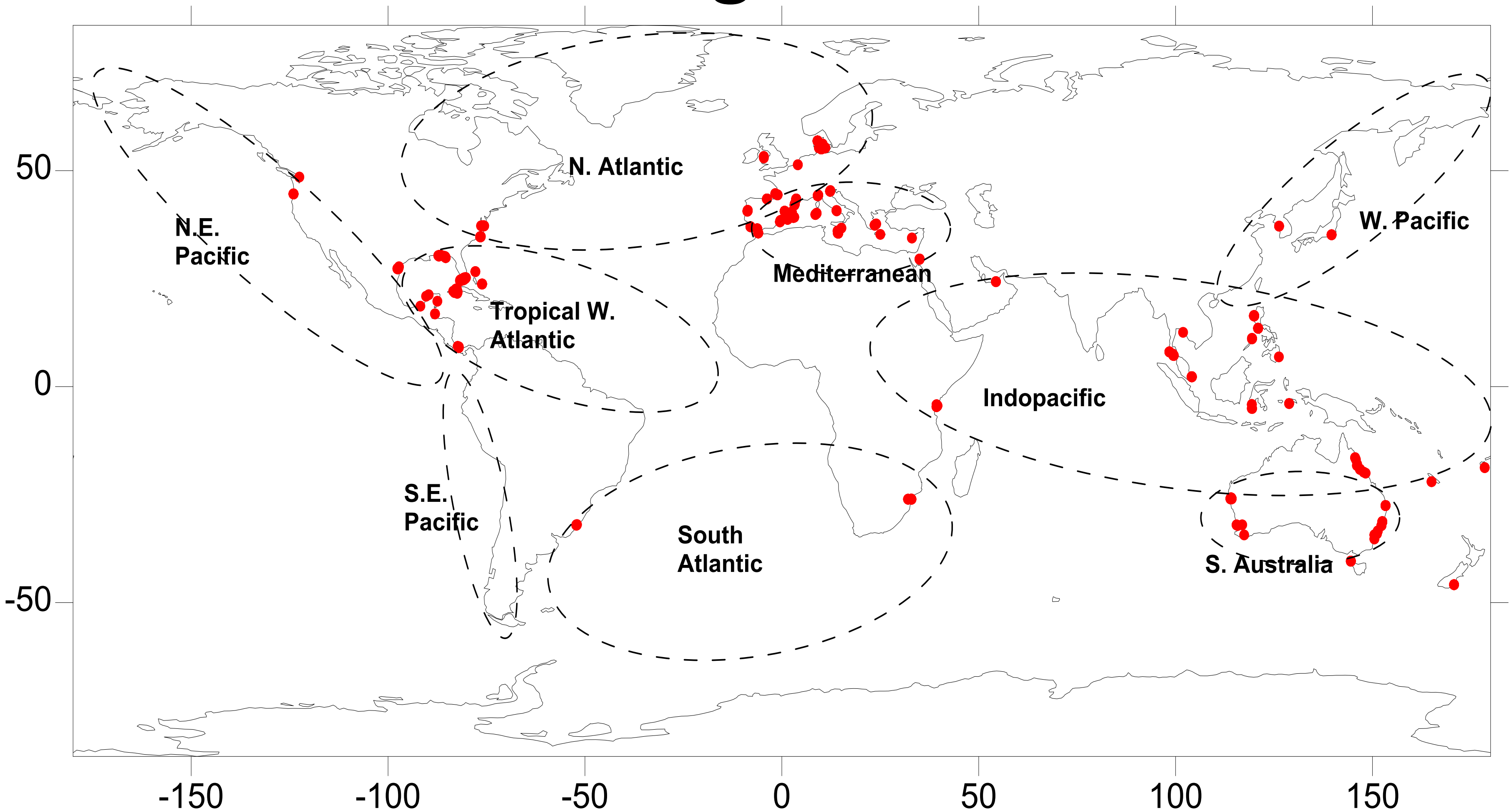






Mateo et al 1997 *ECSS*

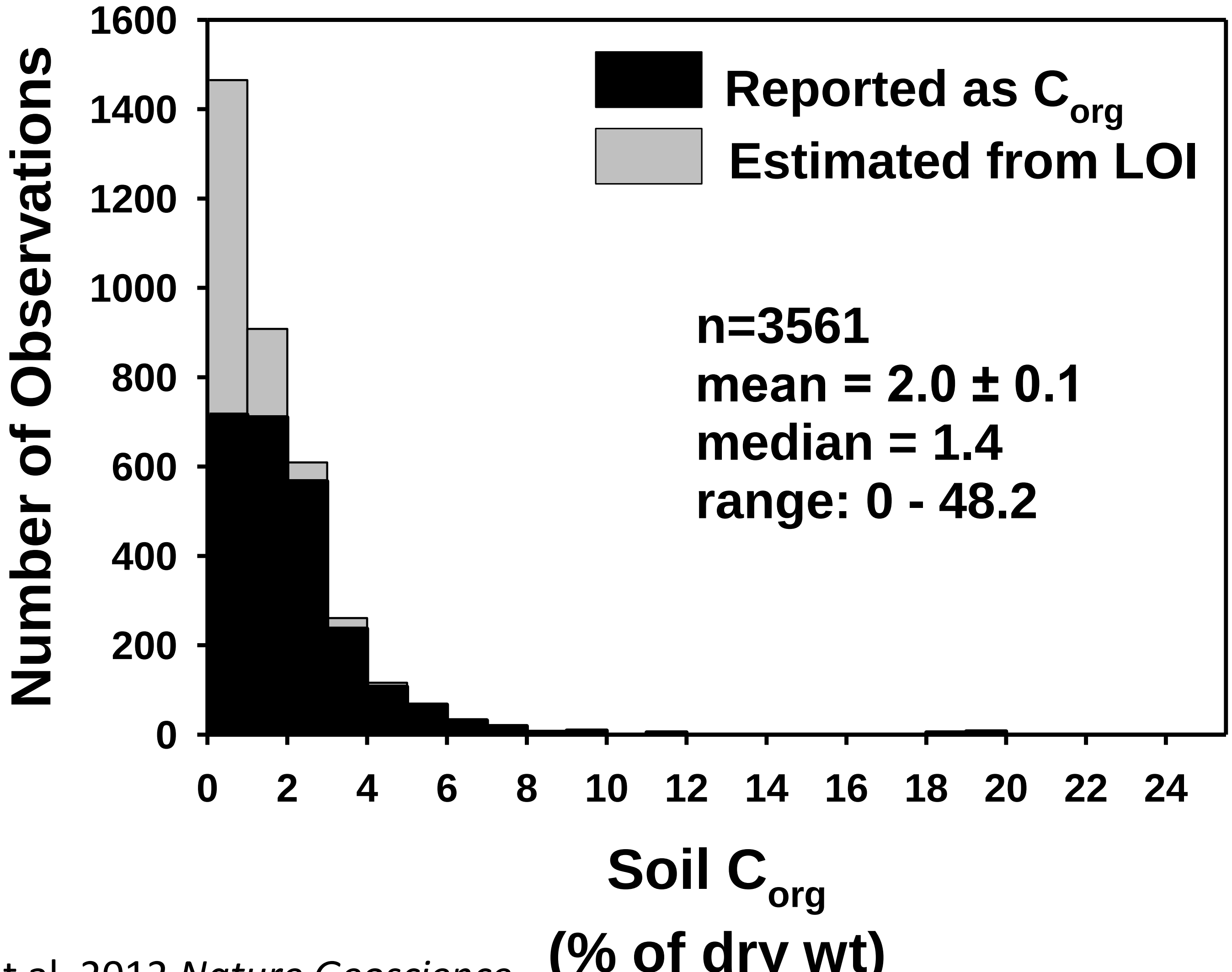
Distribution of seagrass C stock data



We compiled 3640 observations from 946 distinct locations

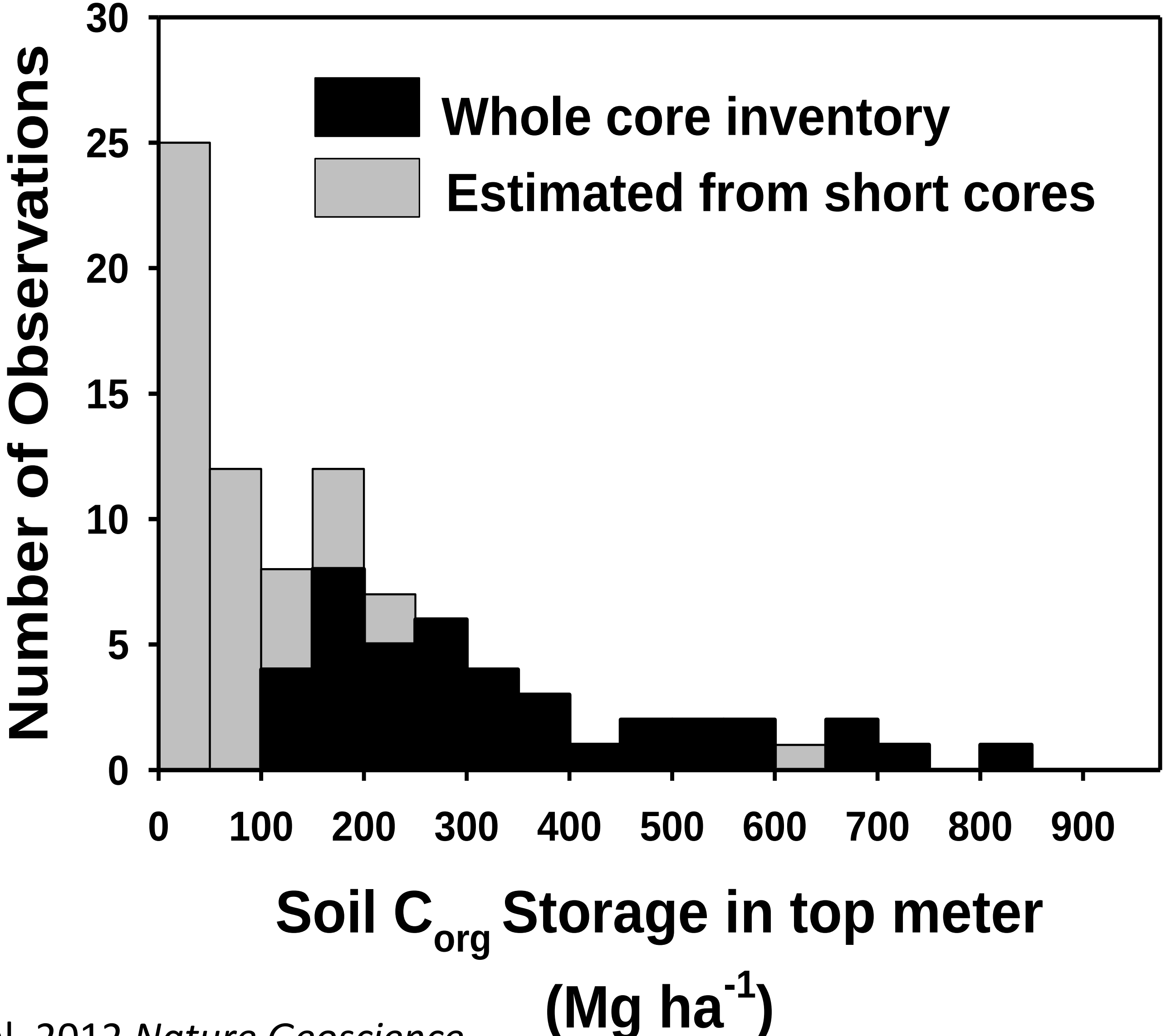
Fourqurean et al. 2012 *Nature Geoscience*

Global distribution of soil C_{org} in seagrass meadows



Fourqurean et al. 2012 *Nature Geoscience*

Global estimates of seagrass soil C_{org} stocks



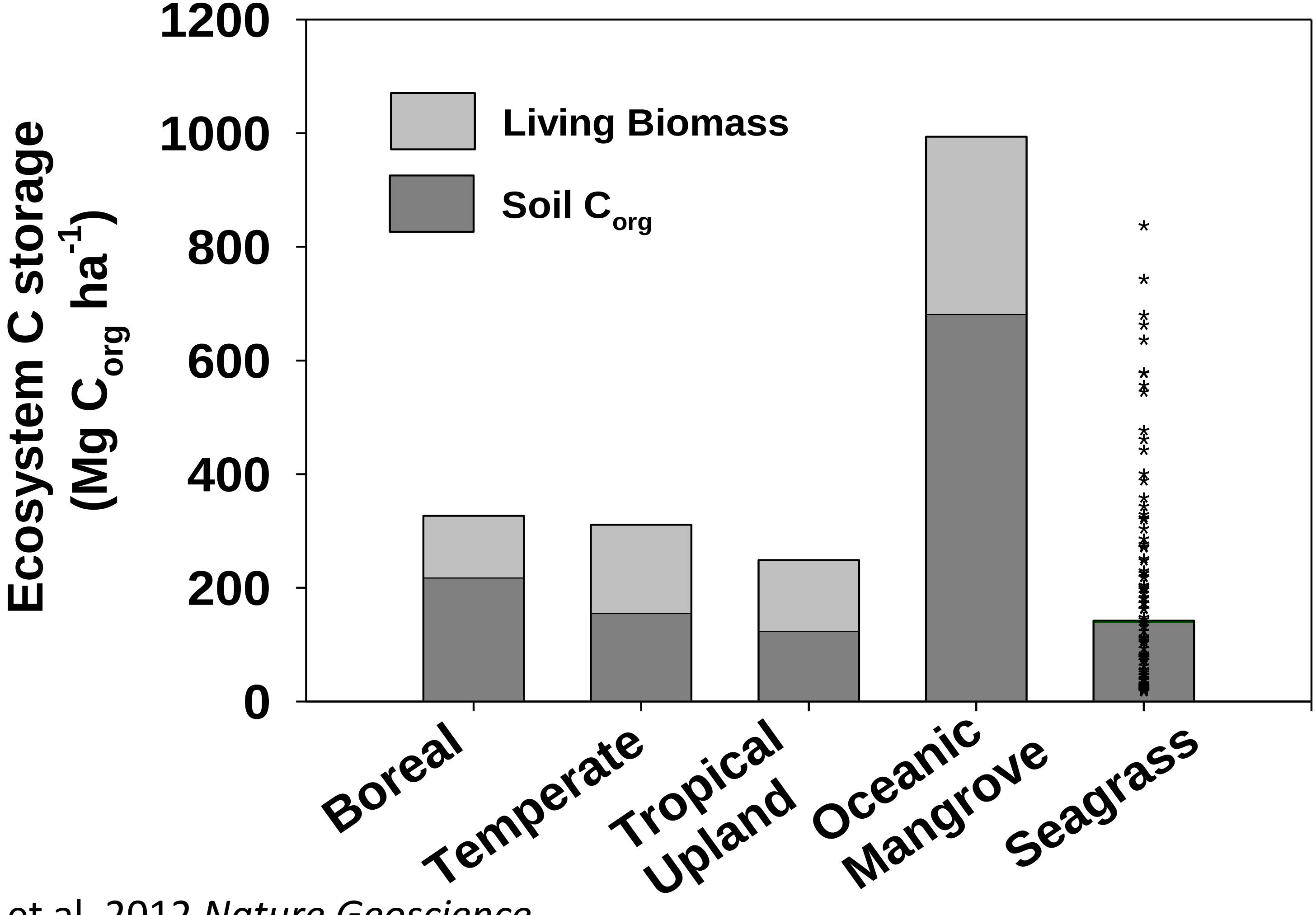
Fourqurean et al. 2012 *Nature Geoscience*

Regional estimates of Seagrass C_{org} stocks

Region	Living Seagrass Biomass MgC ha^{-1}			Soil C_{org} MgC ha^{-1}	
	n	Mean ± 95%CI		n	Mean ± 95%CI
Northeast Pacific	5	0.97 ± 1.02		1	64.4
Southeast Pacific	0	ND		0	ND
North Atlantic	50	0.85 ± 0.19		24	48.7 ± 14.5
Tropical Western Atlantic	44	0.84 ±0.17		13	150.9 ± 26.3
Mediterranean	57	7.29 ± 1.52		29	372.4 ± 74.5
South Atlantic	5	1.06 ± 0.51		5	137.0 ± 56.8
Indopacific	47	0.61 ± 0.26		8	23.6 ± 8.3
Western Pacific	0	ND		0	ND
South Australia	40	2.32 ± 0.63		9	268.3 ± 101.7
Global Average	251	2.51 ± 0.49		89	194.2 ± 20.2

Fourqurean et al. 2012 *Nature Geoscience*

Some seagrass beds rival C-rich terrestrial forests and mangroves



Fourqurean et al. 2012 *Nature Geoscience*

How big are Global Seagrass Blue Carbon stores?

- 300,000-600,000 km^2 of seagrasses
- Median estimate of seagrass biomass:

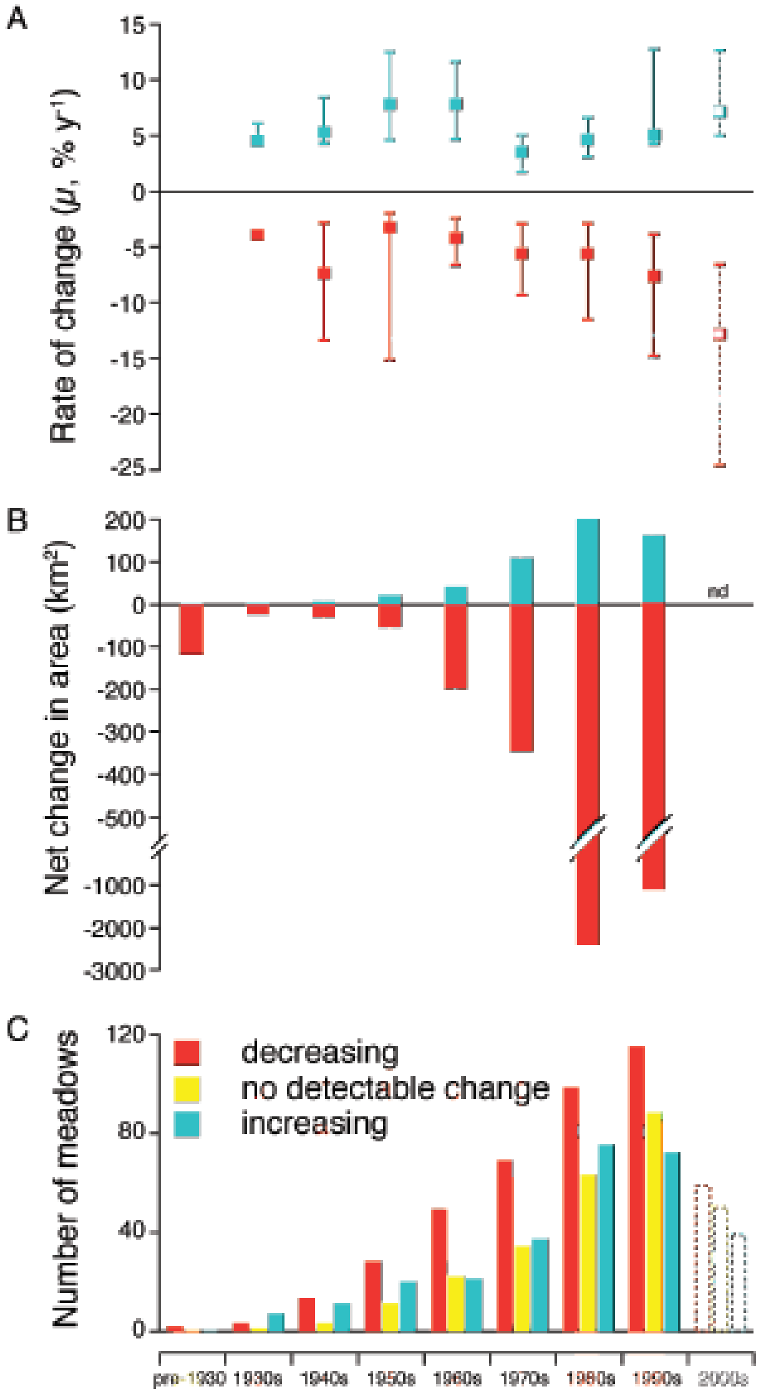
  2.5 Mg C_{org} ha^{-1}
- Median estimate of seagrass soil Corg (top meter)

  139.7 Mg C_{org} ha^{-1}
- Global seagrass biomass:

  75.5 and 151.0 Tg C
- Global seagrass Soil C_{org}:

  4.2 - 8.4 Pg C

  (earlier estimate of salt marshes and mangrove combined is 10 Pg C (Chmura et al 2003)



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

Waycott et al. 2009 *PNAS*

What are the consequences of seagrass loss to global C budget??

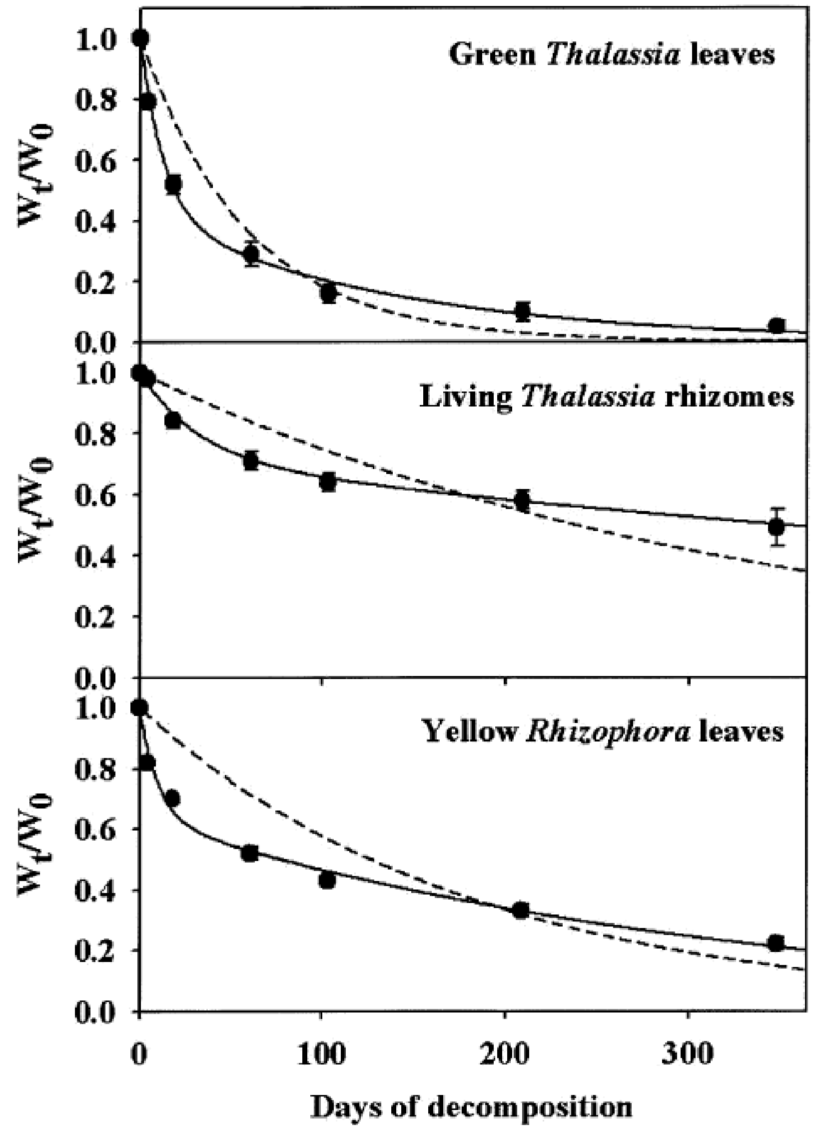
- Seagrass loss has averaged 1.5% y^{-1} since the beginning of the 20th century
- Resulting loss of seagrass biomass:

  11.3 – 22.7 Tg C y^{-1}
- Resulting loss of seagrass soil C_{org} (top meter)

  63 – 297 Tg C y^{-1}
- These rates are roughly 10% of total CO_2 fluxes attributable to land use change

What is the time course of CO_2 emissions from disturbed coastal ecosystems?

Most decomposition processes can be modeled as a simple exponential decay of one or more components. More labile pools are consumed more rapidly, and decomposition is generally faster in oxic environments.



Emissions model governing equations

$$TC_{org} = \sum_{i=1}^{n} C_{org(i)}$$

Where:

i = type of carbon (leaves, wood, stem, soil, etc)

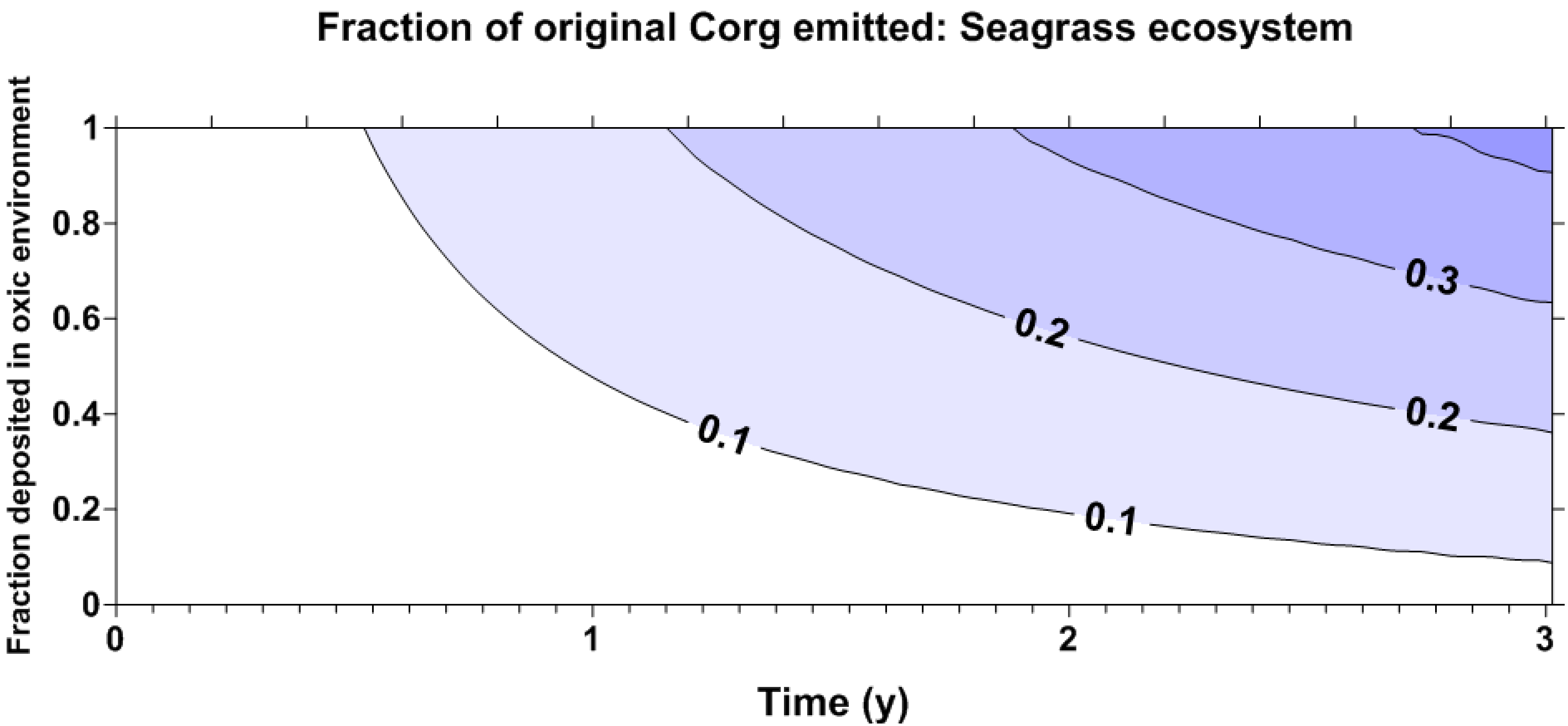
And:

$$C_{org(i)}(t) = \alpha C_{org(0)} e^{k_1 t} + (1-\alpha) C_{org(0)} e^{-k_2 t}$$

Where:

k_1 is decomposition rate in oxic environments, k_2 is decomposition in anoxic environments and α = fraction of C_{org} deposited in oxic environments

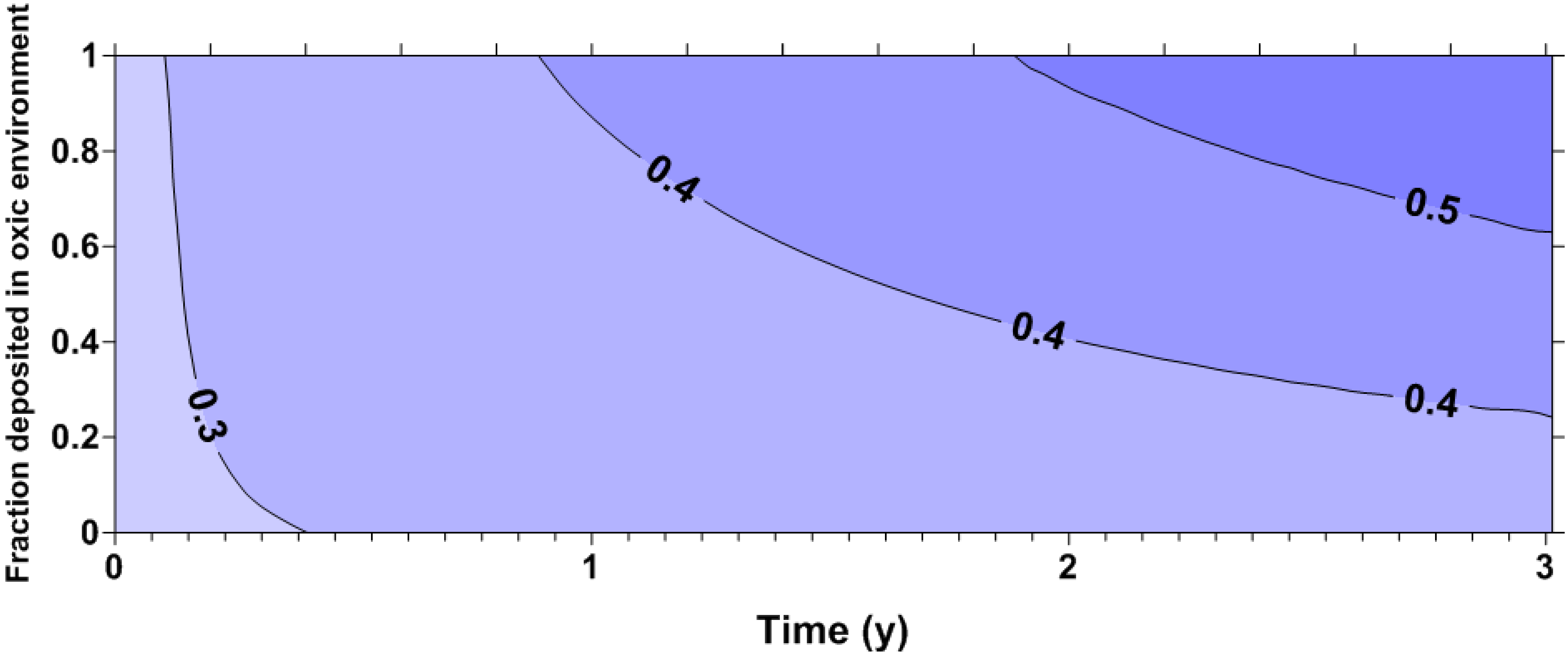
	Biomass component	Initial biomass ($Mg\ C\ ha^{-1}$)	k_{oxic} d^{-1}	k_{anoxic} d^{-1}
Seagrass				
	Aboveground biomass	**0.8**	**0.02**	**0.01**
	Belowground biomass	**1.8**	**0.0032**	**0.0016**
	Soil C_{org}	**139.7**	**0.0005**	**0.00005**
Tidal Marsh				
	Aboveground biomass	**0.8**	**0.02**	**0.01**
	Belowground biomass	**1.8**	**0.0032**	**0.0016**
	Soil C_{org}	**139.7**	**0.0005**	**0.00005**
Mangrove forest				
	Leaves	**20**	**0.03**	**0.03**
	Aboveground wood	**200**	**0.0007**	**0.0004**
	Coarse roots	**80**	**0.0007**	**0.0004**
	Fine roots	**20**	**0.0007**	**0.0004**
	Soil C_{org}	**700**	**0.0005**	**0.00005**



Fraction of original Corg emitted: Seagrass ecosystem
Fraction deposited in oxic environment
Time (y)
0
0.2
0.4
0.6
0.8
1
0
1
2
3
0.1
0.1
0.2
0.2
0.3

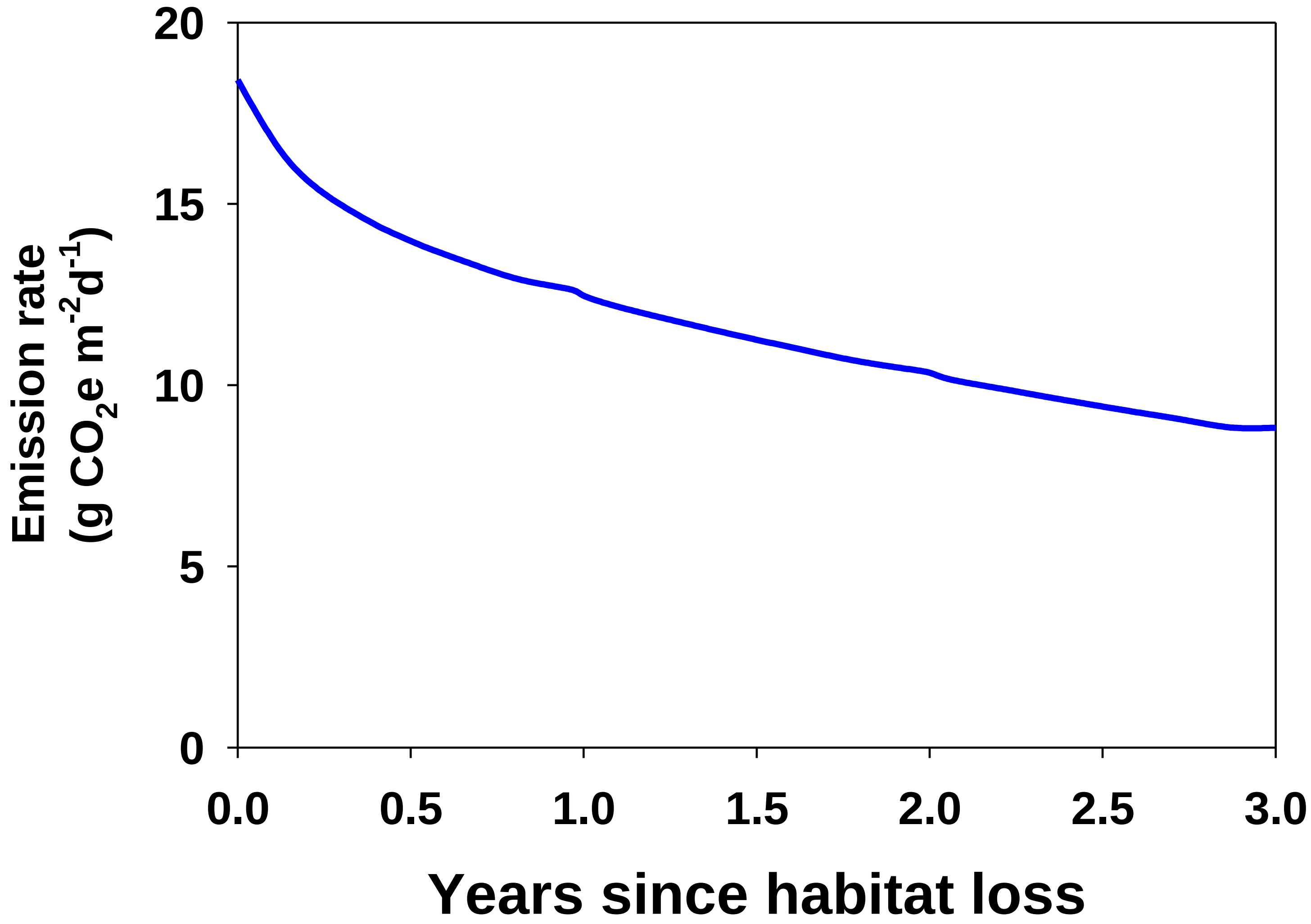
Fraction of C_{org} emitted from mangrove forest following loss

All wood burned



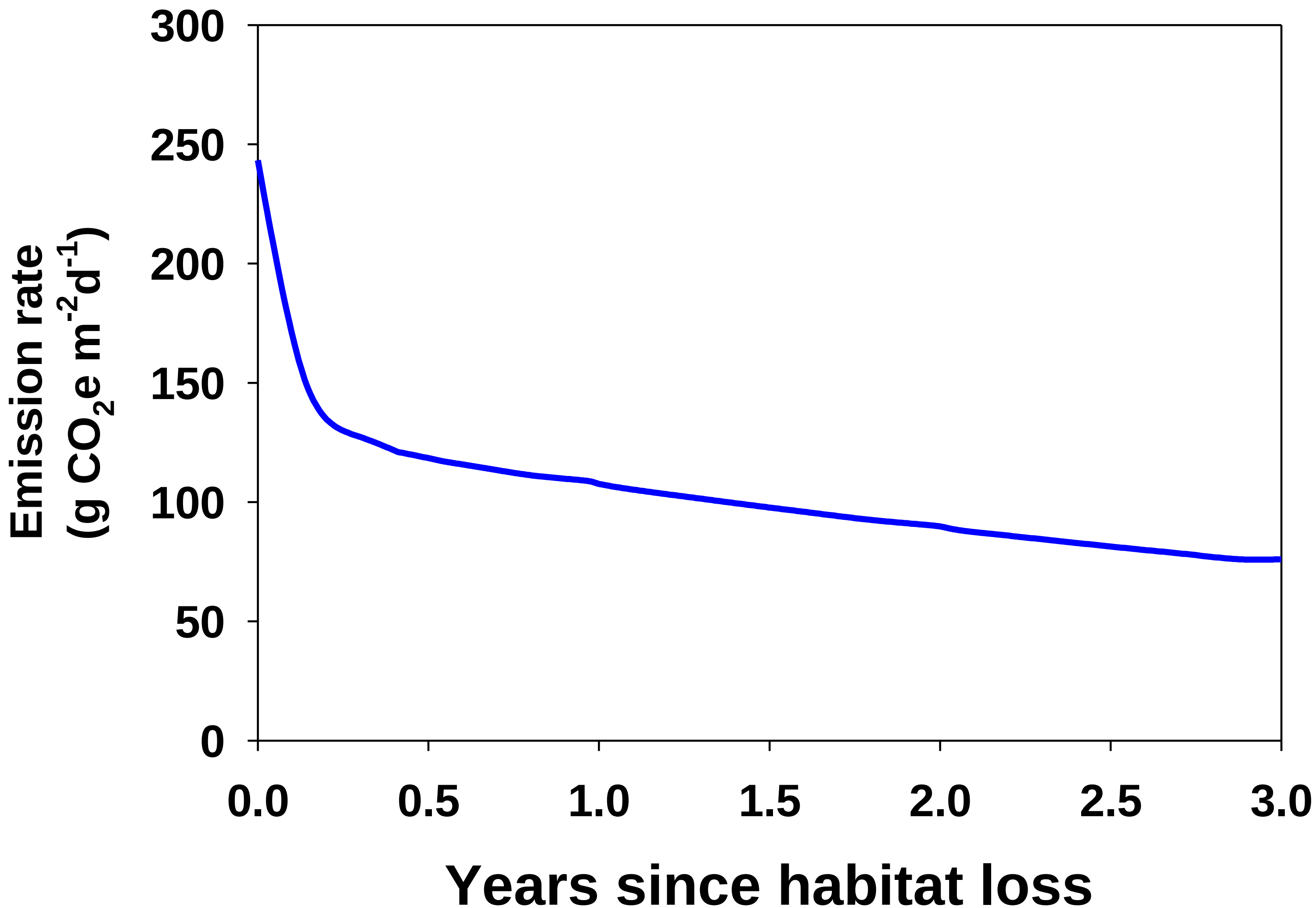
Time course of emissions from an average seagrass bed

(assuming median global stock estimate and 50% of C_{org} deposited in oxic environment)

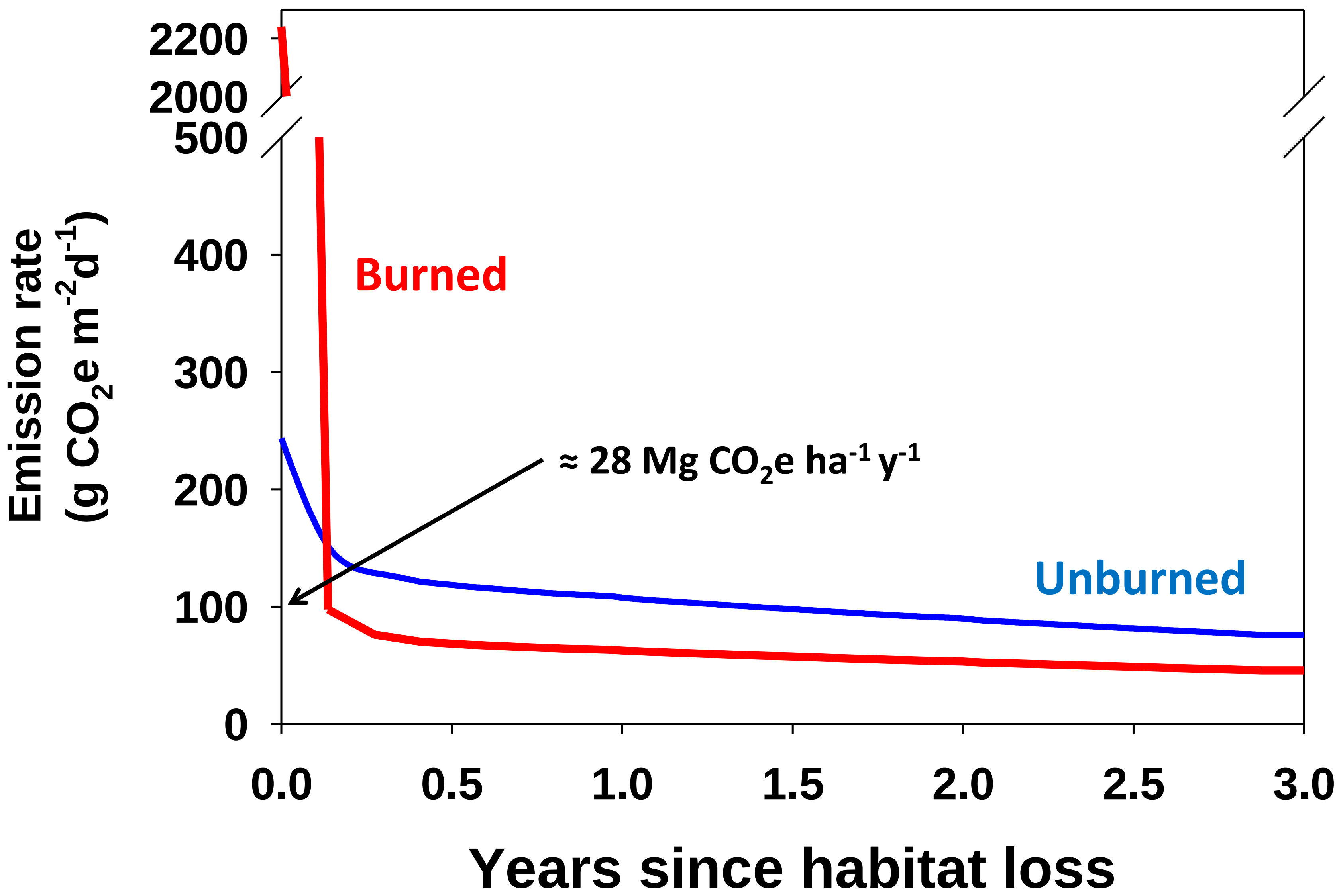


Time course of emissions from an average mangrove forest

(assuming median global stock estimate and 50% of C_{org} deposited in oxic environment, no burning)



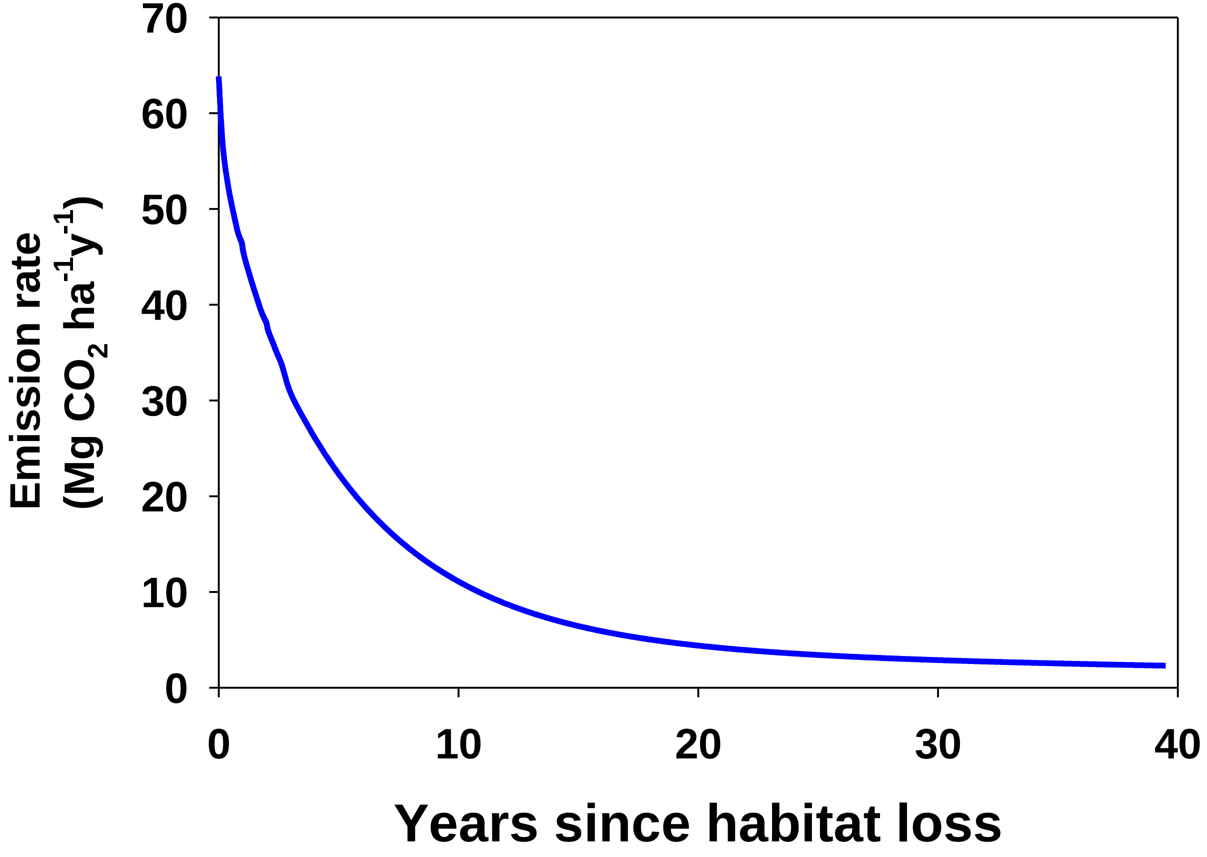
Effect of biomass burning on emissions trajectory, mangrove forest



Measured rates of CO_2e emissions from destroyed habitats

Habitat	Modification	CO_2 efflux Mg ha-1 year^{-1}	Method	Reference
Mangrove, Belize	Cleared	29	CO_2 efflux	Lovelock et al 2011
Mangrove, Honduras	Forest damaged by hurricane	15	Inferred from peat collapse	Cahoon et al. 2003
Mangrove, Australia	Shrimp pond	17.5 (22-50)	CO_2 efflux	Burford and Longmore 2001
Rainforest, Indonesia	Drained for agriculture	32	Inferred from peat collapse and measured as CO_2 efflux	Couwenburg et al. 2010 and references therein
Tundra, Alaska	Thawed (vegetation intact)	1.5-4.3	Net CO_2 exchange	Schuur et al. 2009

Long-term emissions from seagrass (assuming alpha = 0.5)



Seagrass Blue Carbon:

There is a lot of it stored, those stores are at risk, and there is a direct path to the atmosphere for the carbon