

Sequestration and storage ability and process of blue carbon in shallow coastal ecosystems

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CO₂ absorption, Sequestration?



CO2 absorption, Sequestration

An underwater photograph showing a dense, healthy seagrass bed. The seagrass is a vibrant green color and is growing in clear, blue water. The sunlight filters through the water, creating a shimmering effect on the sandy bottom. The seagrass is the central focus of the image, and it appears to be a large, continuous patch.

Seagrass bed

Ishigakijima Island, Okinawa, Japan

CO₂ absorption, Sequestration



Mangrove forest



Salt marsh



Sargassum forest



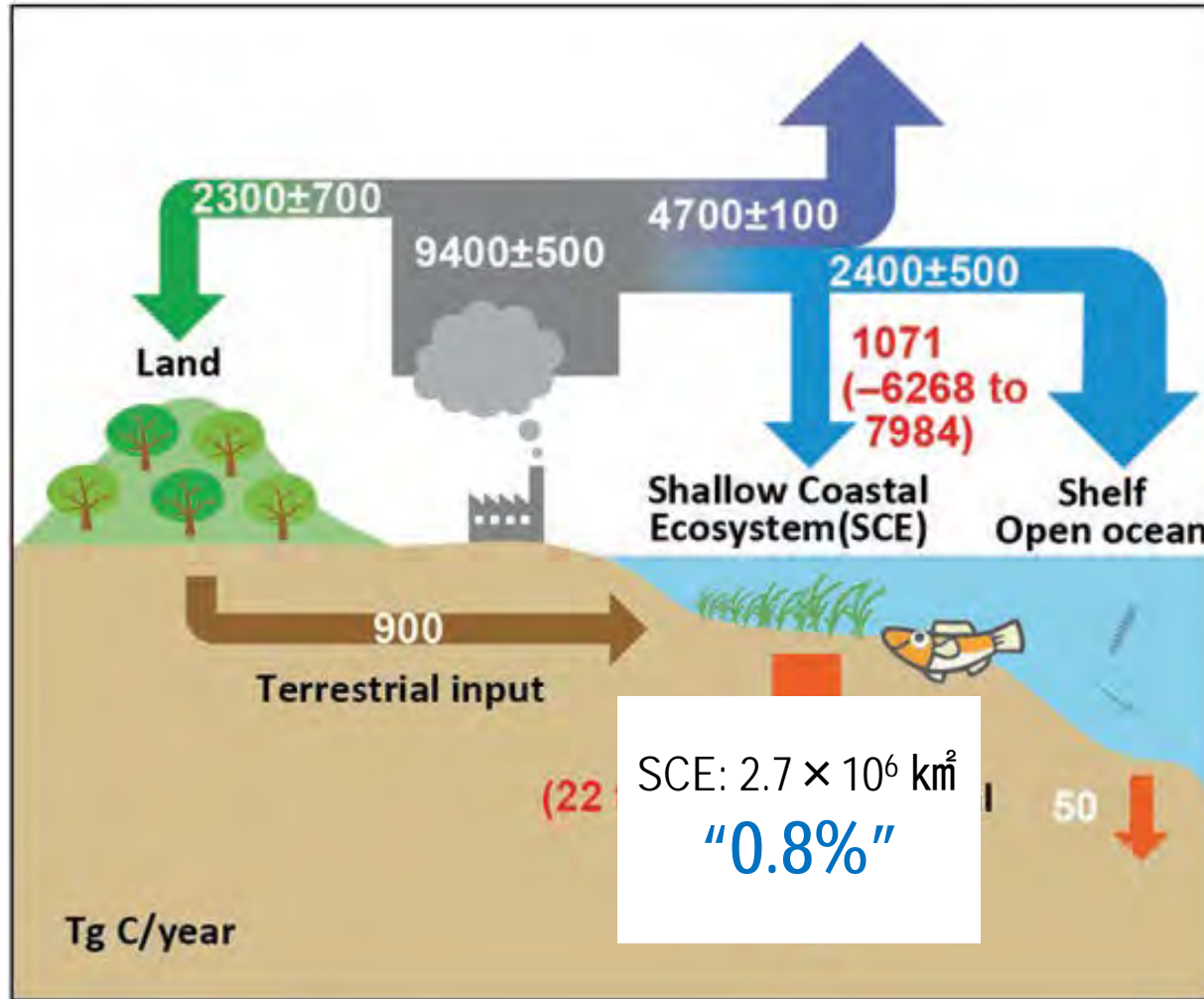
Kelp forest

Global carbon cycle

Land area
 $147 \times 10^6 \text{ km}^2$

Forest area
 $40 \times 10^6 \text{ km}^2$

Sea area
 $593 \times 10^6 \text{ km}^2$



Kuwaie and Hori (2018), LeQuere et al. (2018) for atmospheric data (mean \pm SD for 2007–2016), and IPCC (2013) for terrestrial input

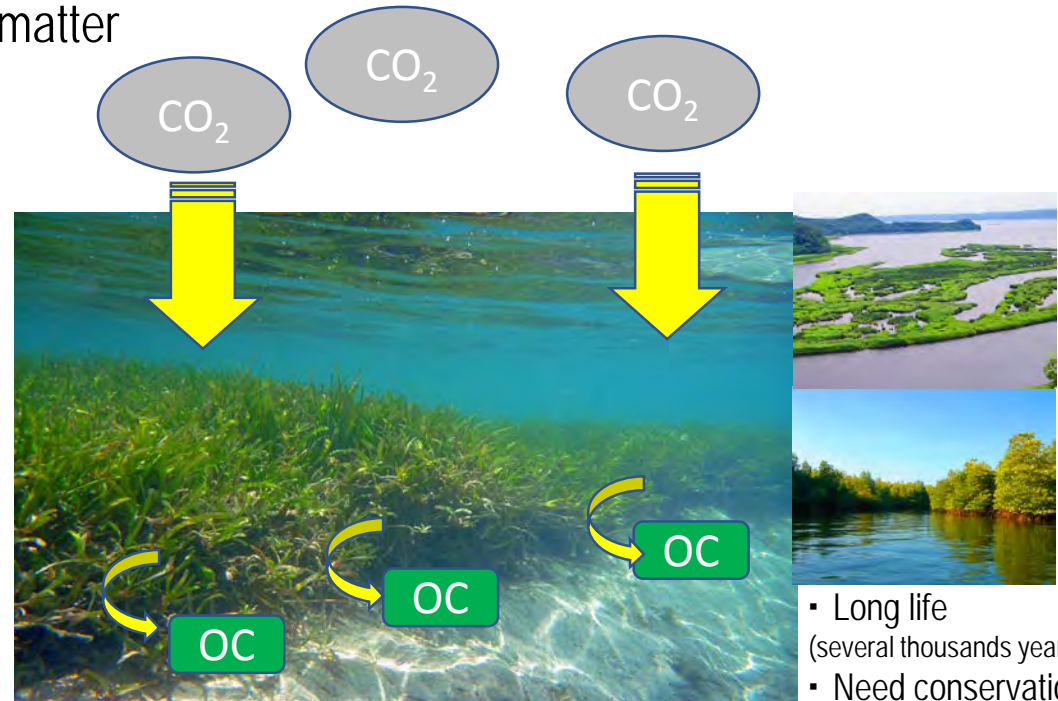
What is Blue Carbon?

“Blue carbon” is defined as marine green carbon

Green carbon is defined as carbon that plants have assimilated via photosynthesis and incorporated into organic matter



Nellemann *et al.* (2009) “Blue Carbon”

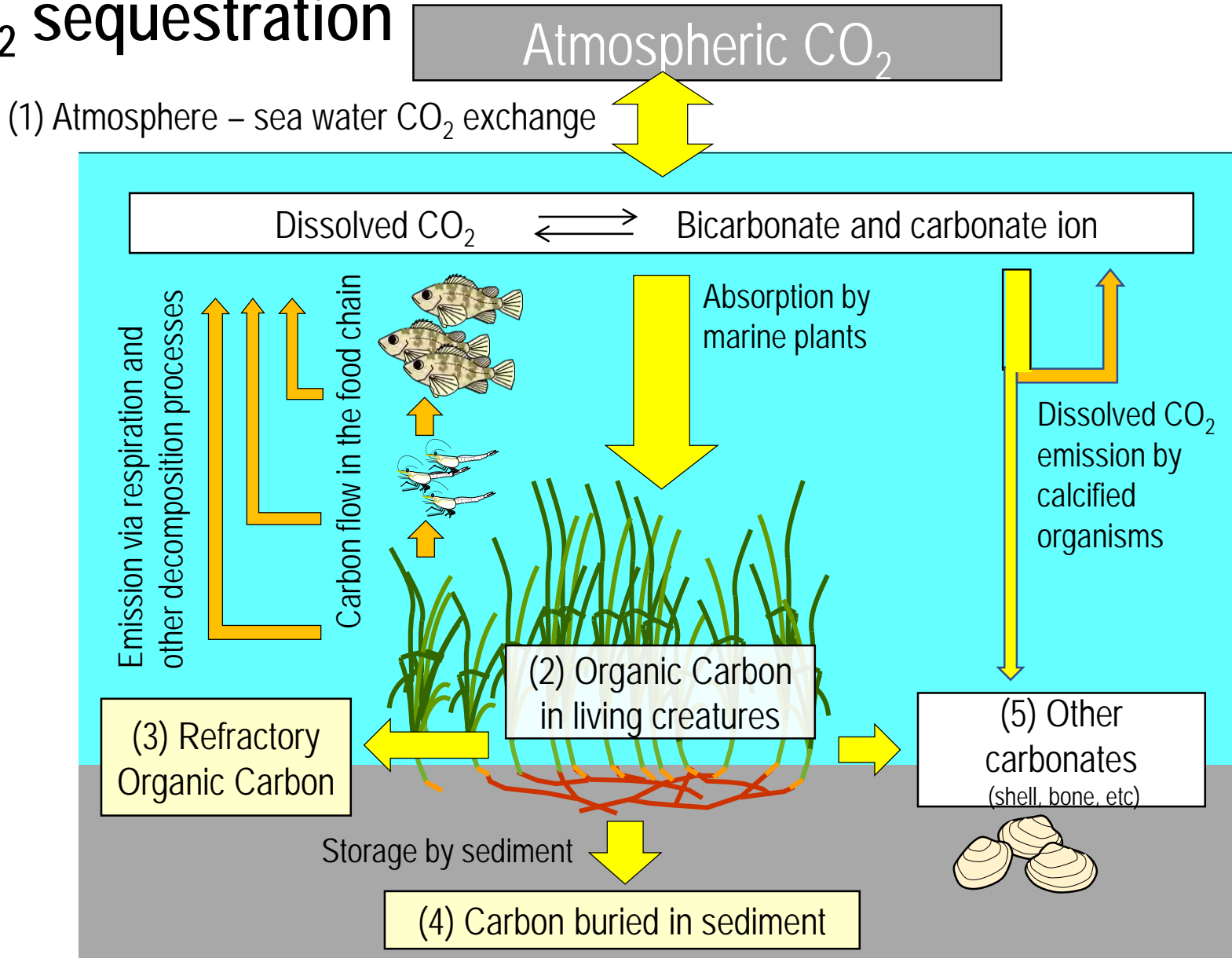


“Blue carbon ecosystems”

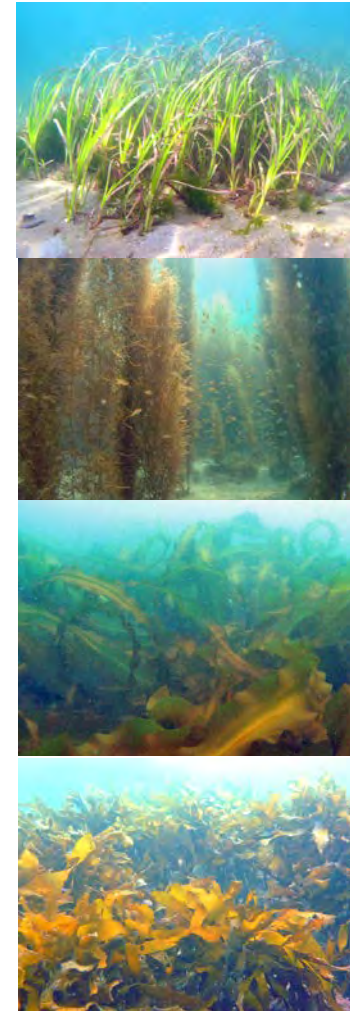
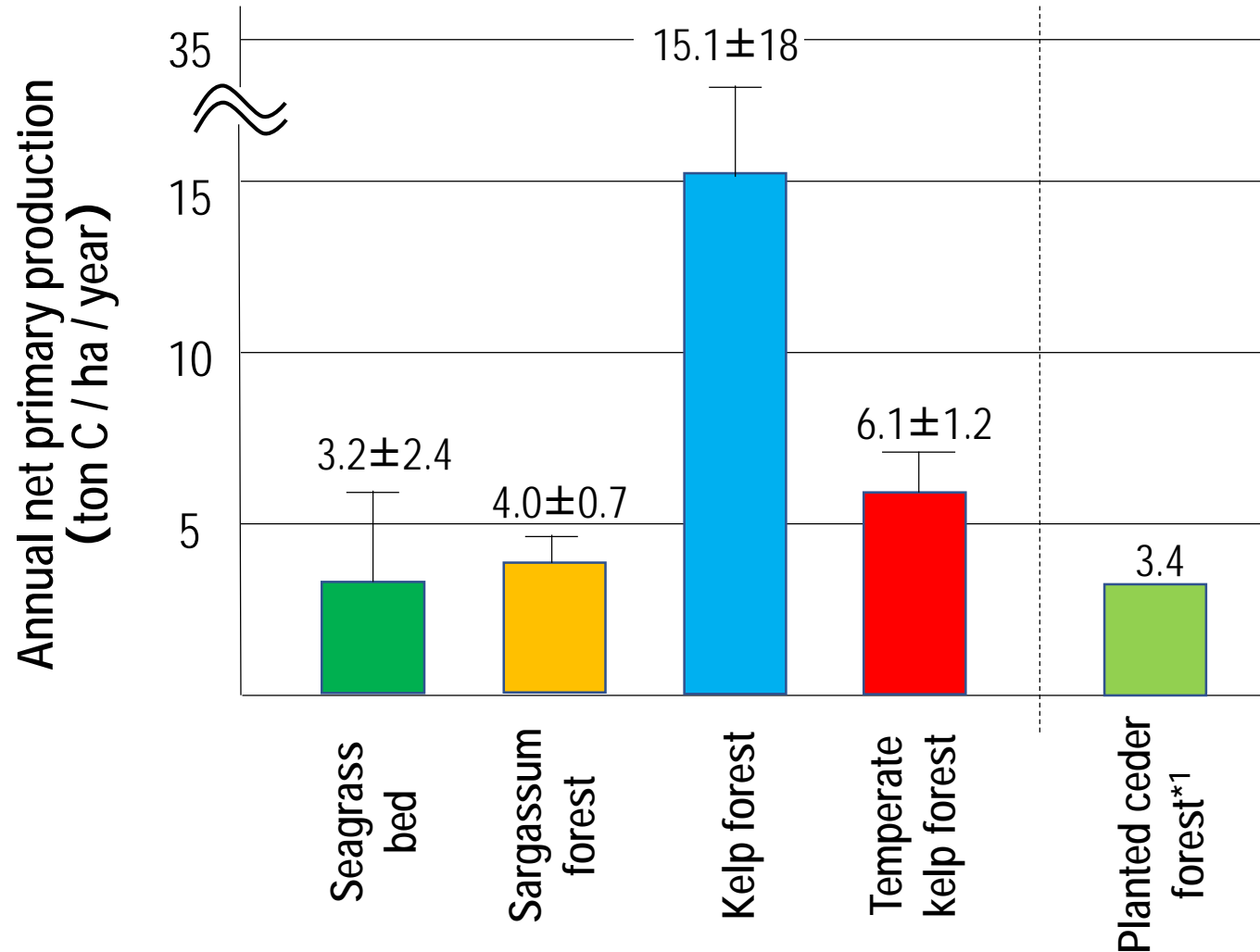
Seagrass beds, Salt marsh, Mangrove forest

Importance of blue carbon stocks in sediments of shallow coastal ecosystems

CO₂ sequestration



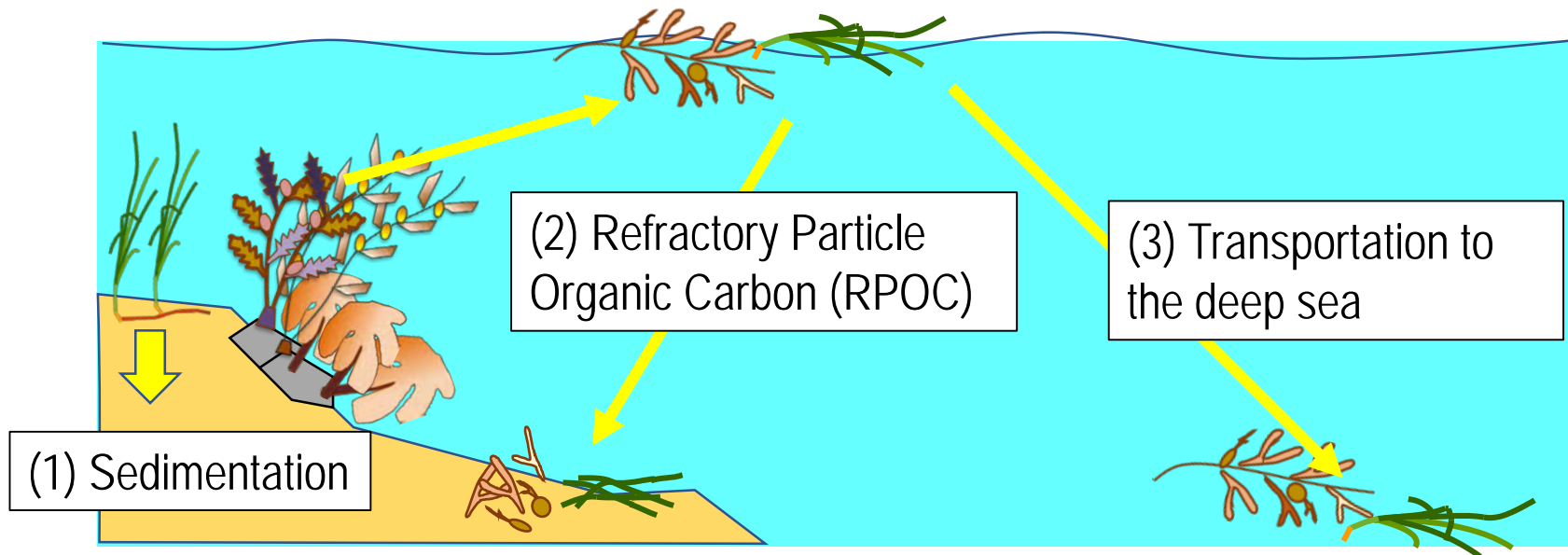
CO₂ sequestration as annual net primary production



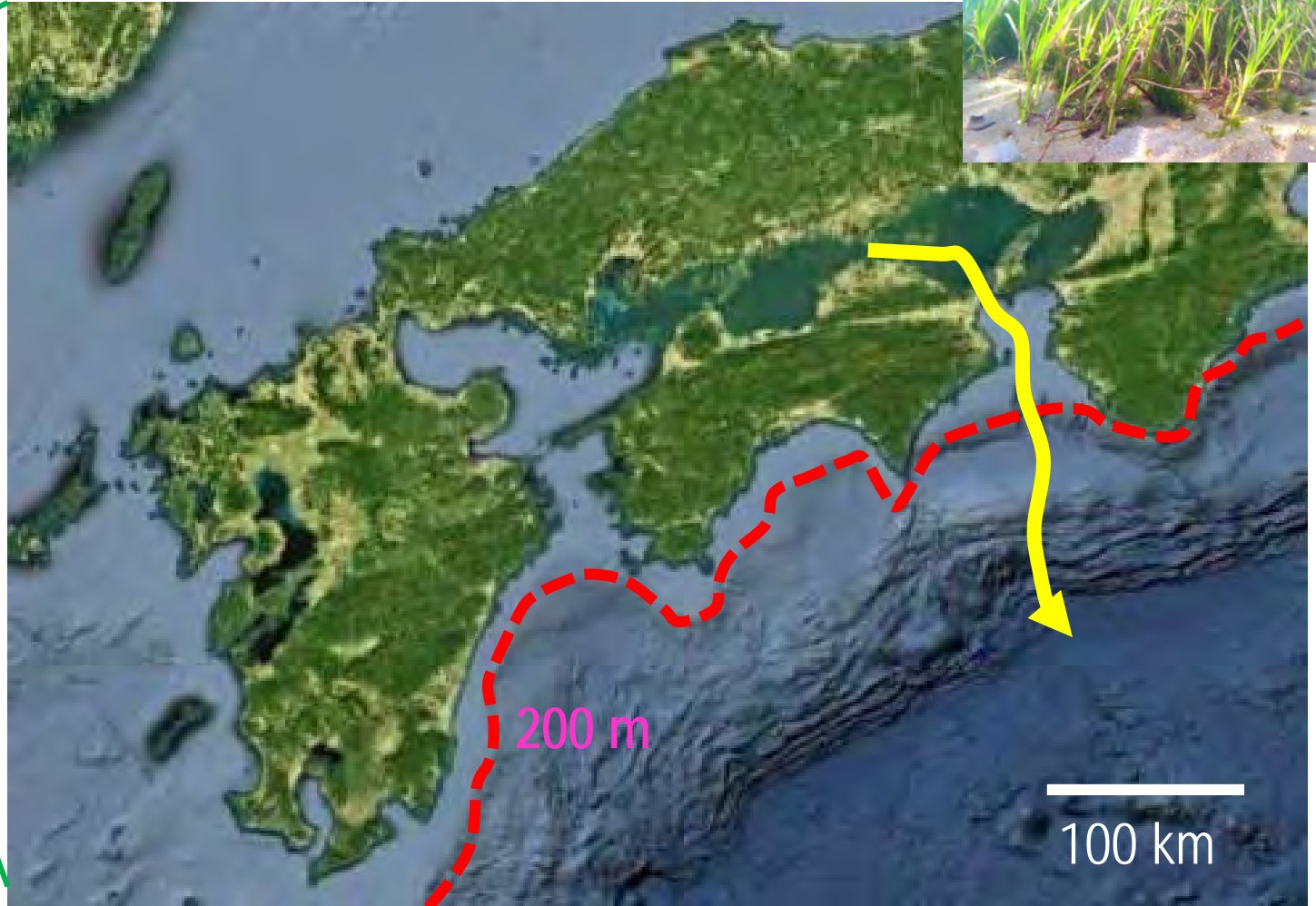
Modified from Yoshida *et al.* (2018)

*1: <http://www.rinya.maff.go.jp/kanto/iwaki/knowledge/breathing.html>

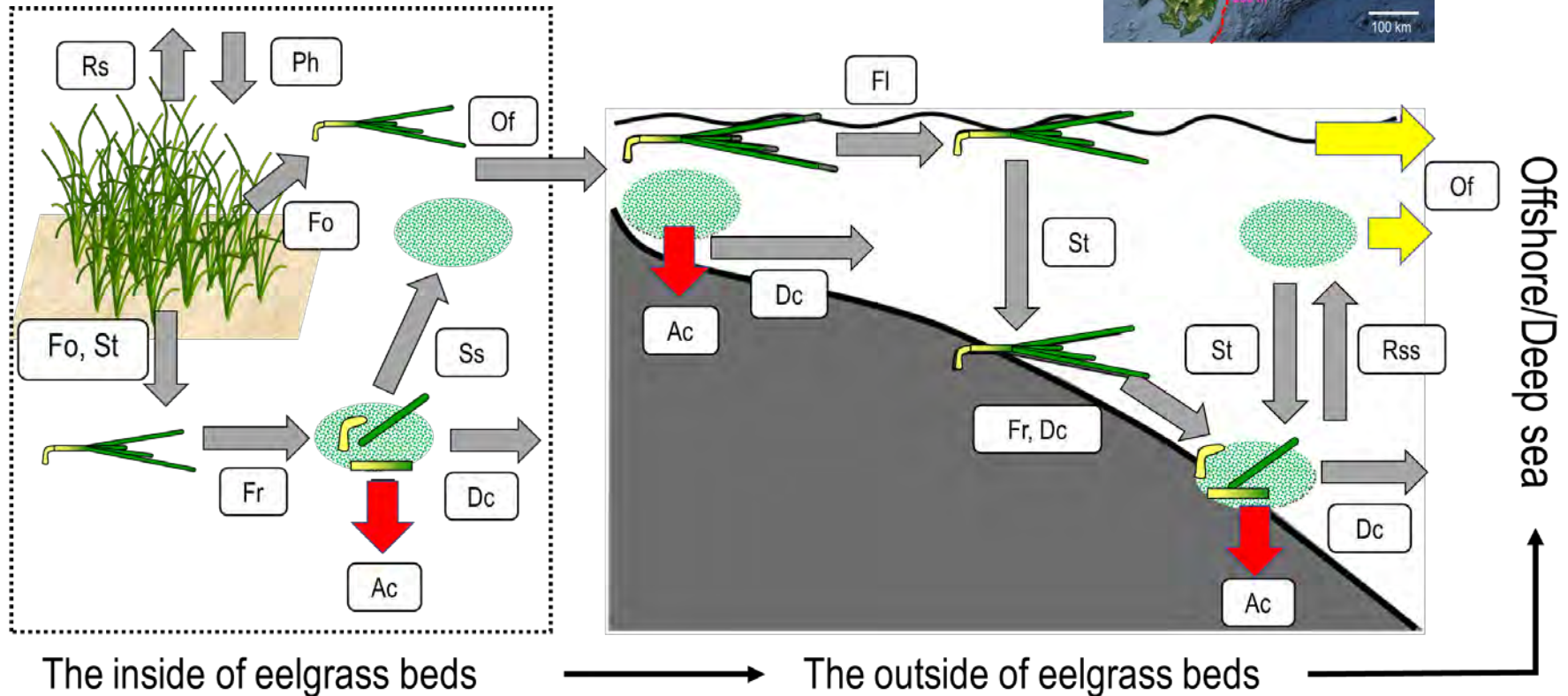
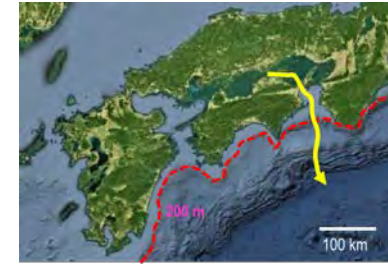
Storage processes



Practice: Seto Inland Sea, Japan

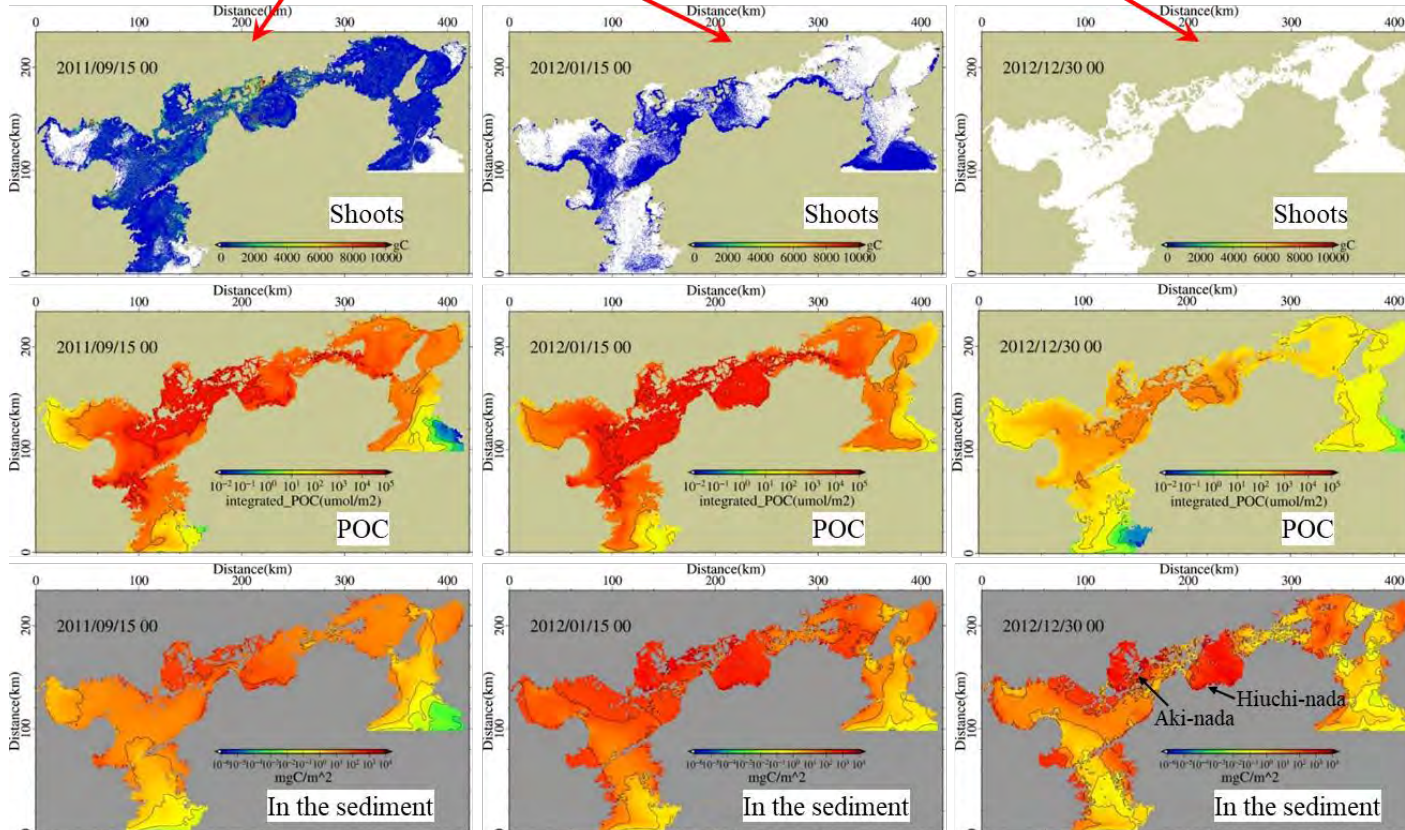
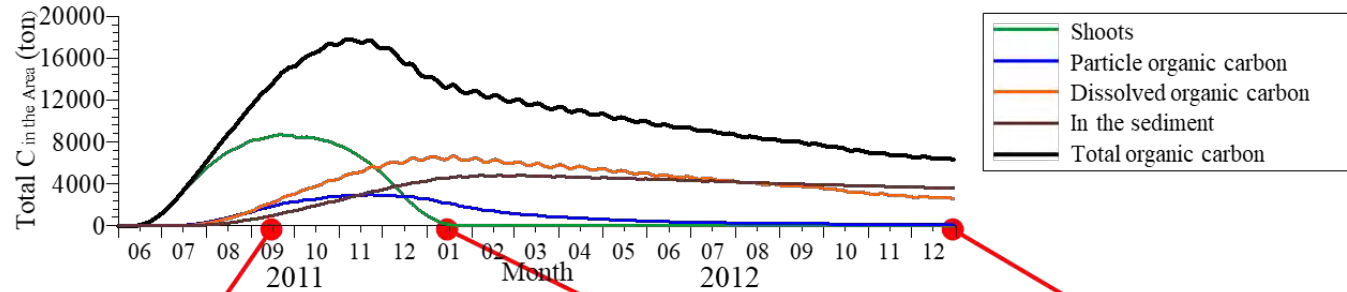


Practice: Seto Inland Sea, Japan

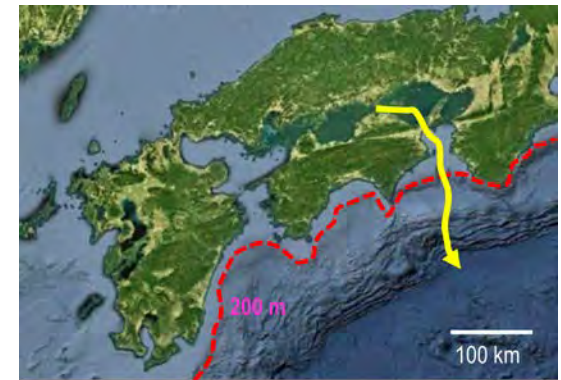
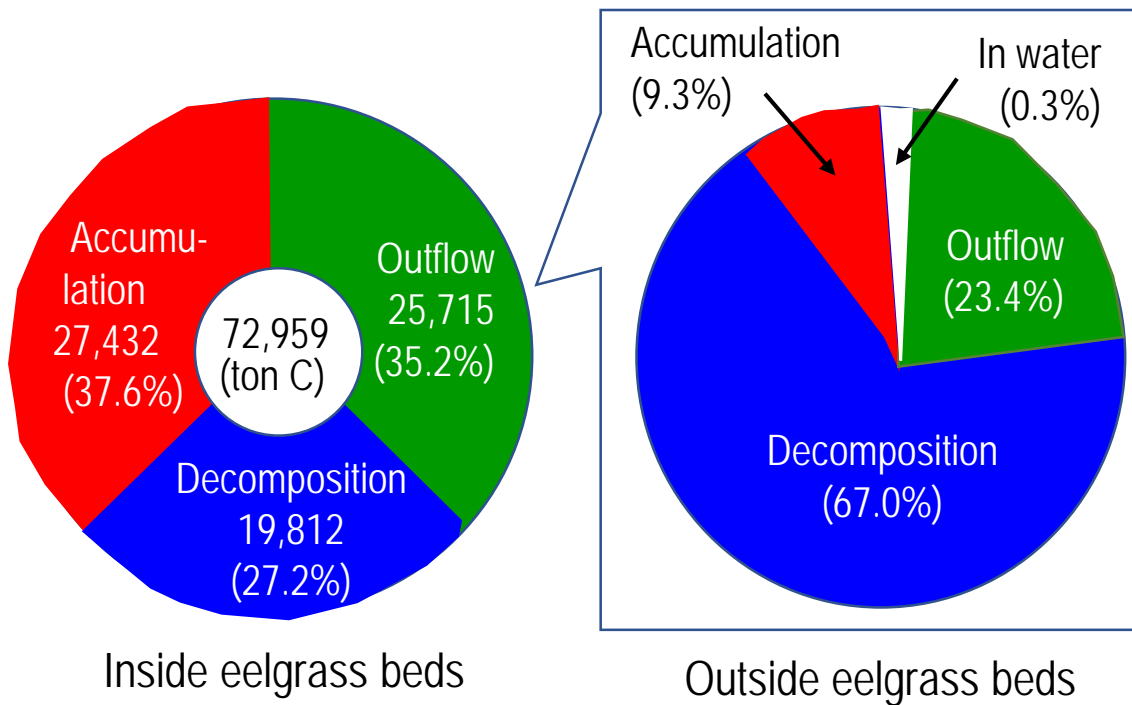


Rs: respiration, Ph: photosynthesis, Of: outflowing, Fo: falling off, St: settling, Fr: Fragmentation, Ss: suspension, Dc: decomposition, Ac: accumulation, Fl: floating, Rss: resuspension

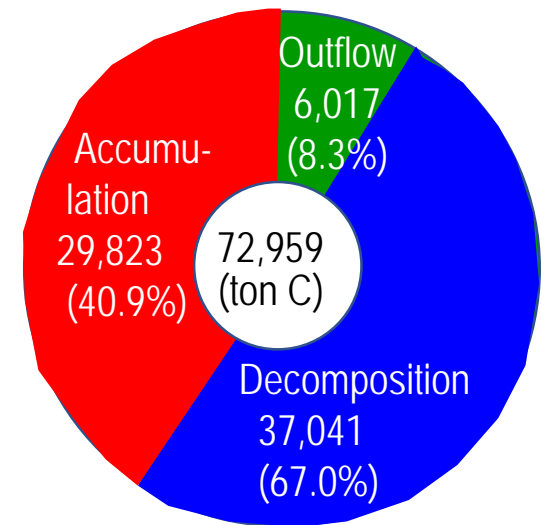
Practice: Seto Inland Sea, Japan



Practice: Seto Inland Sea, Japan



Transportation to the deep sea



Seto Inland Sea, Total

Contribution of macroalgal forests

nature
geoscience

PROGRESS ARTICLE

PUBLISHED ONLINE: 12 SEPTEMBER 2016 | DOI: 10.1038/NGEO2790

Substantial role of macroalgae in marine carbon sequestration

Dorte Krause-Jensen^{1,2*} and Carlos M. Duarte³

Vegetated coastal habitats have been identified as important carbon sinks. In contrast to angiosperm-based habitats such as seagrass meadows, salt marshes and mangroves, marine macroalgae have largely been excluded from discussions of marine carbon sinks. Macroalgae are the dominant primary producers in the coastal zone, but they typically do not grow in habitats that are considered to accumulate large stocks of organic carbon. However, the presence of macroalgal carbon in the deep sea and

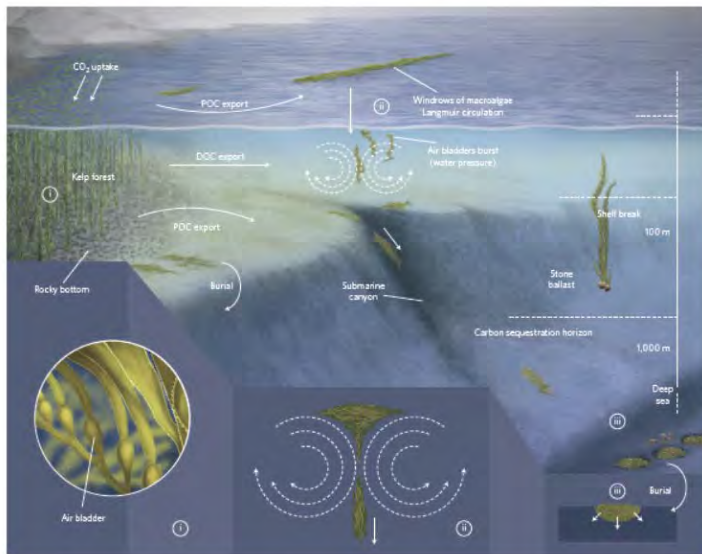
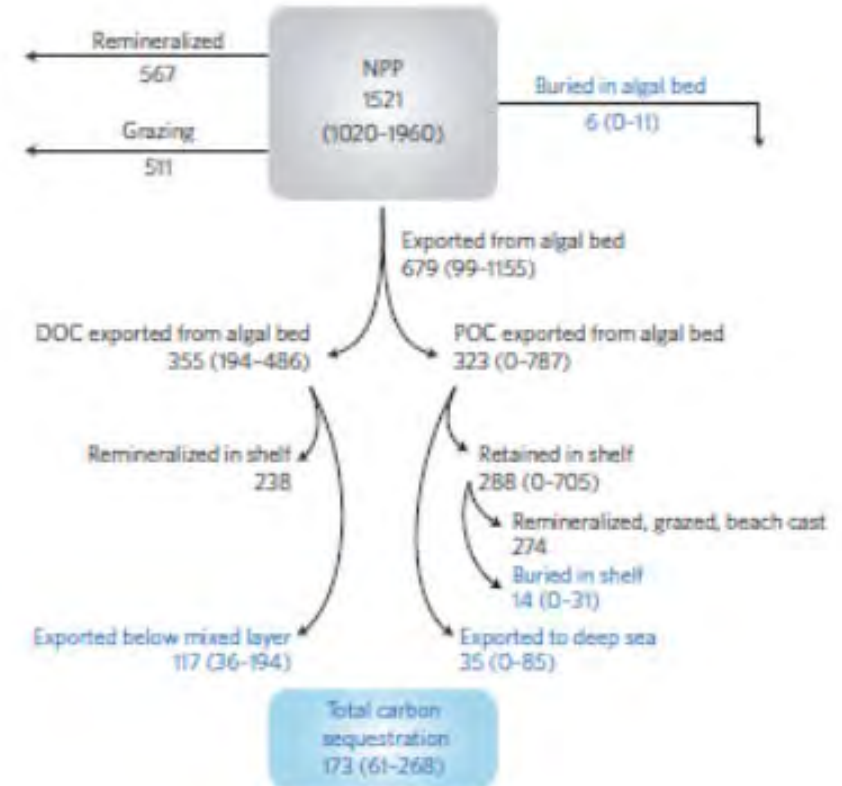
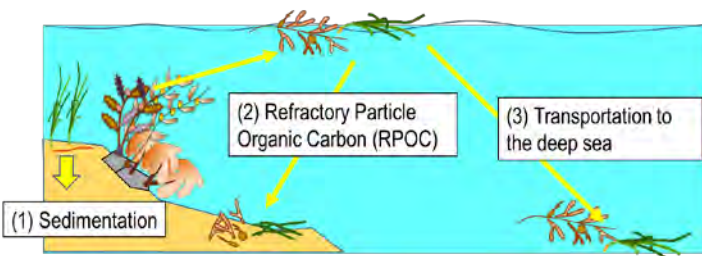


Figure 2 | Conceptual diagram of the pathways for export and sequestration of macroalgal carbon. Air bladders are common among brown algal taxa and facilitate their long-range transport (i). Langmuir circulation forms windows of macroalgae (ii) and can force the algae to depths where water pressure makes the air bladders burst and the algae then sink. Macroalgal carbon can be sequestered either via burial in the habitat or by transport to the deep sea where it is sequestered whether buried or not (iii).



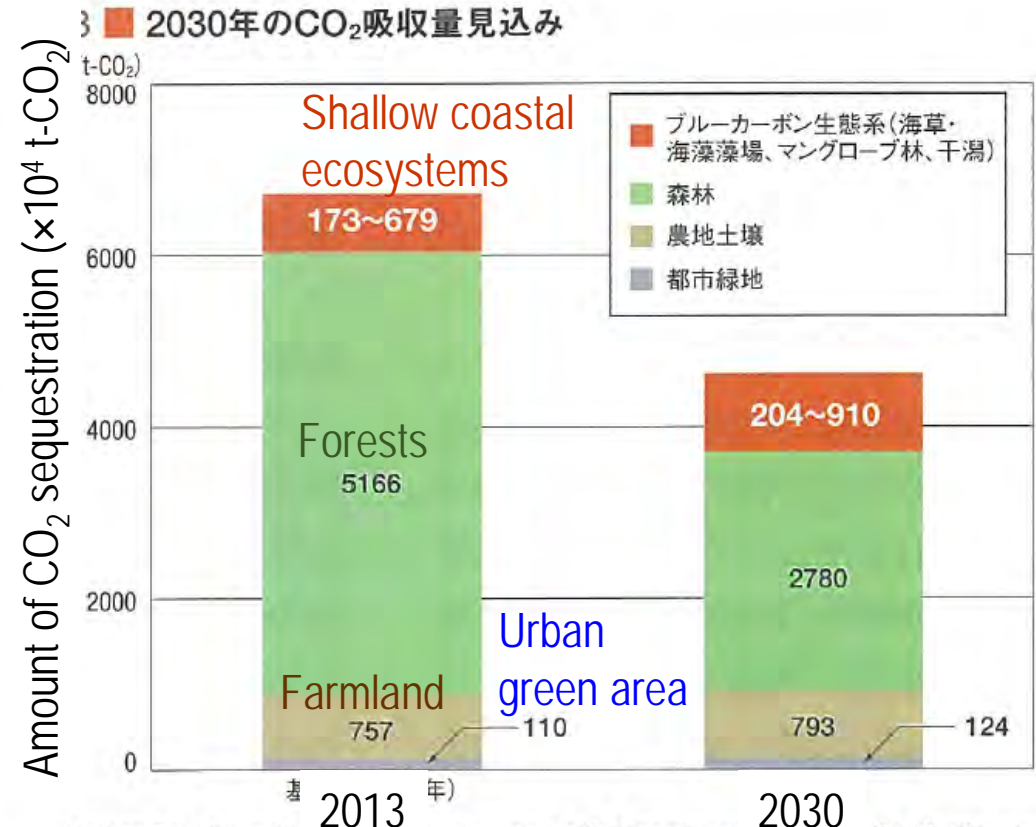
More than 10% of annual net production of sargassum species can be considered as blue carbon storage

Estimation of BC sequestration in a national scale



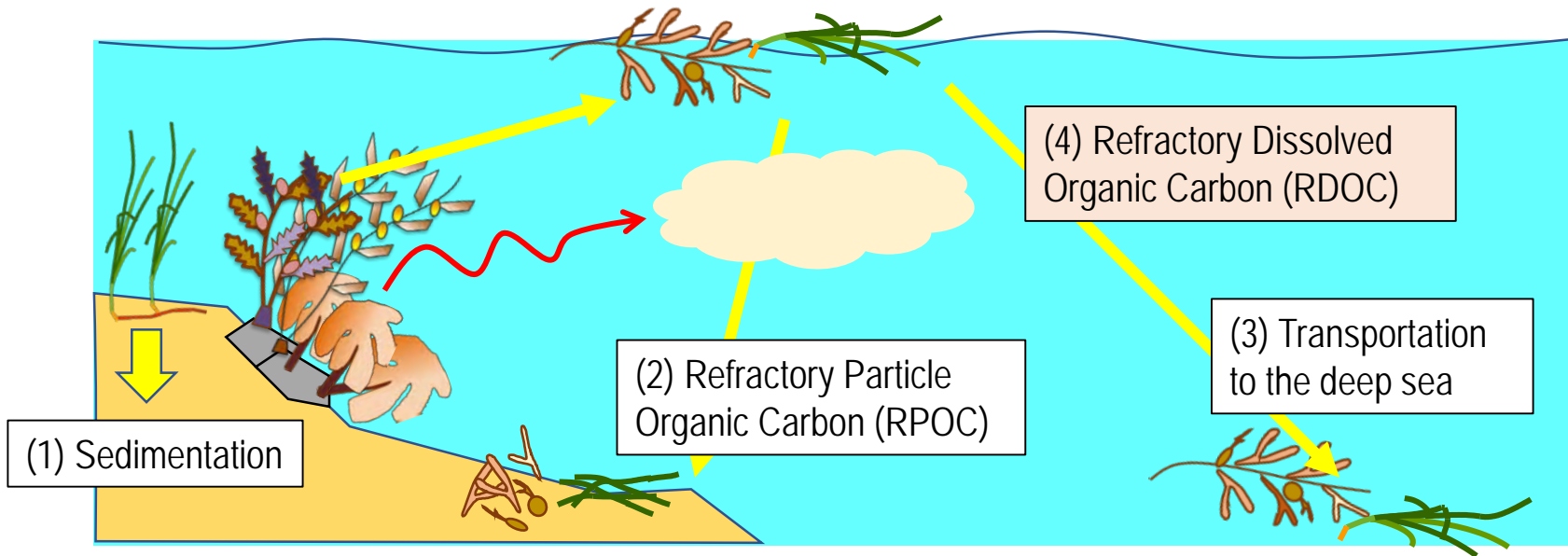
	Sequestration rate (t-CO ₂ / ha / year)	
	average	Maximum
Seagrass	5.8	33.4
<i>Sargassum</i>	2.7	5.1
<i>Saccharina</i>	10.3	36.0
<i>Ecklonia</i>	4.2	7.9
Mangrove	68.5	68.5
Tidal flat	2.6	2.6

Area total: 28.3×10^4 ha

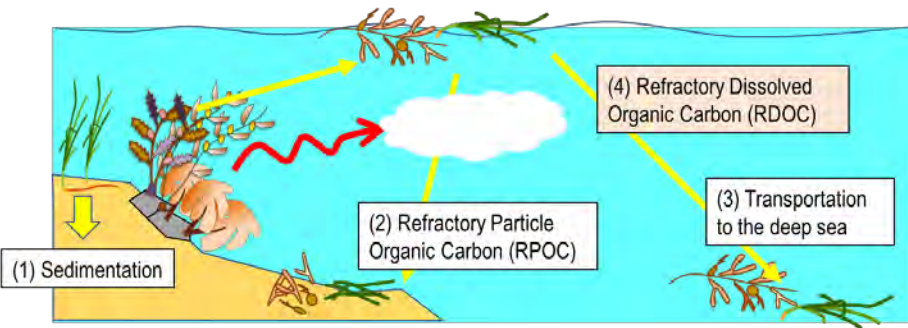


排出量を考慮した推定値。ブルーカーボン生態系のグラフは上記の値に基づき作成している。基準年の値については、森林・農地土壌・都市緑地は地球温暖化対策計画における2013年度の実績値、ブルーカーボン生態系は既存の知見（藻場面積2009～10年、マングローブ林・干潟面積は1996～98年）による推計値（資料：ブルーカーボン研究会）

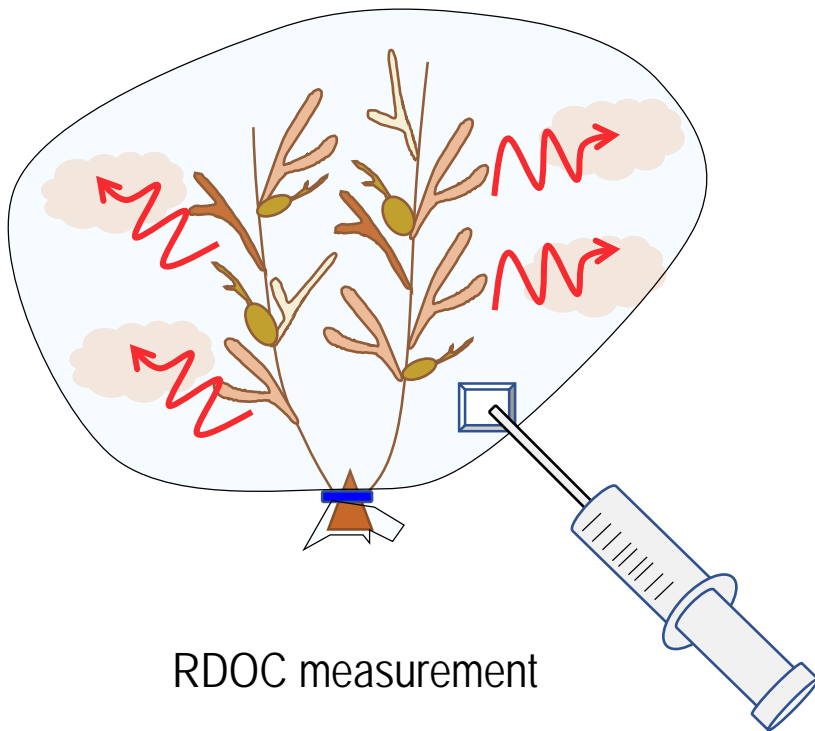
Newly unraveled storage processes



Newly unraveled storage processes



This process have never been included in any estimation of Blue Carbon storage!



Watanabe et al. (in prep)

Aquaculture can work as a climate change mitigation and adaptation measures: macroalgal (kelp, wakame, sargassum, nori laver, etc.) cultivation



RDOC released from growing algae contributes to blue carbon storage



Take-home message:

- The blue carbon contribution to atmospheric CO₂ sequestration is larger than terrestrial green carbon
- Approximately 50% of blue carbon sequestration is conducted in shallow coastal areas where is only 0.8% of the total ocean area
- Coastal marine vegetation can work not only as fishery grounds and fish nurseries but also as an effective CO₂ sink
- Macroalgal forests also function as CO₂ sink due to various organic carbon storage process
- Macroalgal aquaculture can also work as CO₂ sink by considering refractory dissolved organic carbon

Need conservation and restoration of coastal marine vegetation!