Sexing up Seagrass to avert irreversible climate change.

On the catwalk of the world's most beautiful endangered eco-systems, seagrass isn't in the limelight beside coral reefs, rainforests or mangroves.

However we ignore seagrass at our peril. The under-water meadows absorb up to 35% more atmospheric CO2 per hectare than tropical rainforests (Macreadie *et al.*, 2015). They're also disappearing faster (Waycott *et al.*, 2009), yet provide vital life-support functions to coral reefs and mangroves, among their many ecosystem services.

Scientists consistently identify media exposure and public awareness (Hind-Ozan and Jones, 2018) as priorities in the battle to save these ancient, flowering, submarine plants on which our oceans and planet depend (Orth *et al.*, 2006) (Duarte *et al.*, 2008).

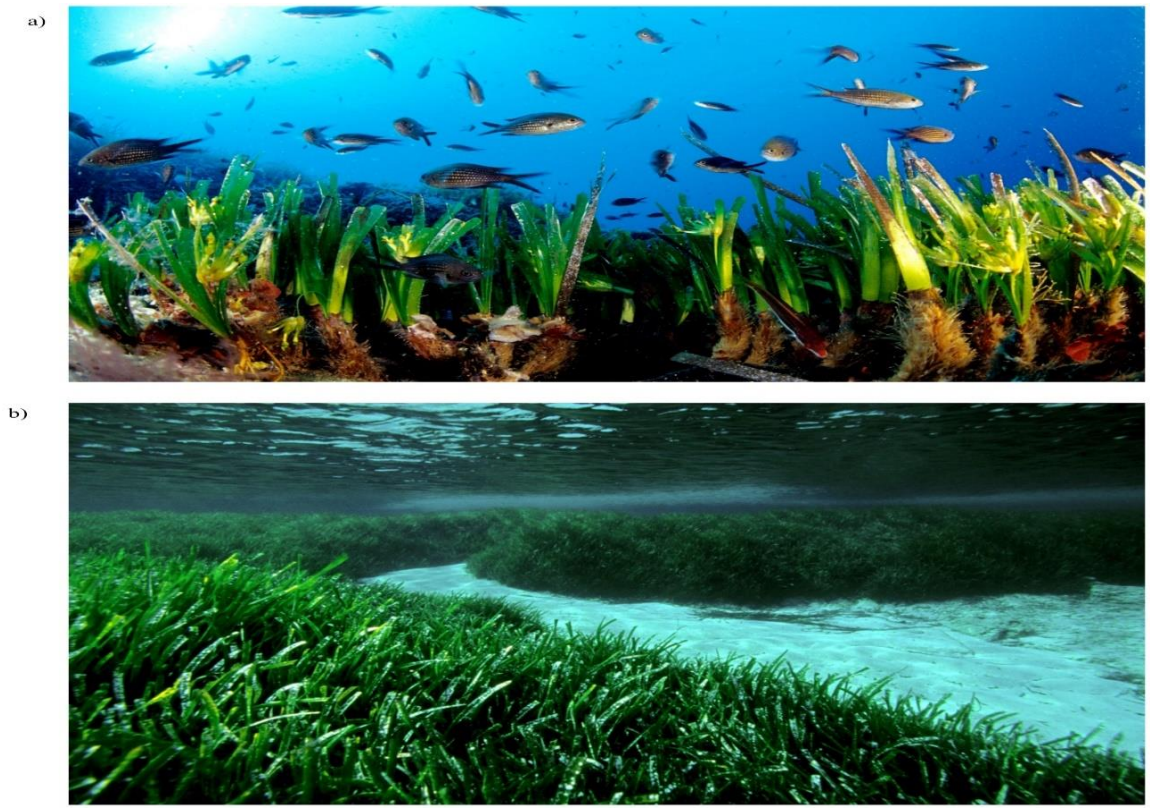

Fig 1) Pictures (a) illustrating the individual shoots (ramets), (b) hosting the largest (15 km) clones detected in this study. (Arnaud-Haond *et al.*, 2012) Photograph by M. San Félix. https://doi.org/10.1371/journal.pone.0030454.g002

The beauty of Seagrass

Seagrasses, as the only underwater flowering plants in our oceans, are absolutely unique. The males flower to release their pollen, which is carried on water currents to the female flowers, or transported by submarine pollinators. The beauty of seagrass flowering is caught in this extraordinary video.

The Ancient History & lineage of Seagrass:

Seagrass is a submarine flowering angiosperm/plant.

72 seagrass species vs over 250,000 terrestrial angiosperms.

3 main lineages: *Zosteraceae, Hydrocharitaceae*, and *Cymodoceaceae complex.*

Single land-based predecessor 70-100 million years ago, which migrated into the oceans in the age of the dinosaurs. Thought to be the most extreme habitat shift by any plant.

Seagrasses thus survived the greatest extinction to date, 66 million years ago.

Since spread to coastlines of every continent except Antarctica.

DNA dating of the Mediterranean's dominant *Posidonia oceanica found* it could well be the world's oldest living organism.

Seagrass eco-system services

Best known for woven fibre matting and floor-coverings, seagrasses provide many vital eco-system services. Research demonstrates seagrass is fundamental to global fisheries, with serious implications for world food security (Unsworth, Nordlund and Cullen-Unsworth, 2018).

They're also prime habitat for megaherbivores including the endangered dugong and green turtle, and their services to marine eco-systems and life on Earth are literally priceless.

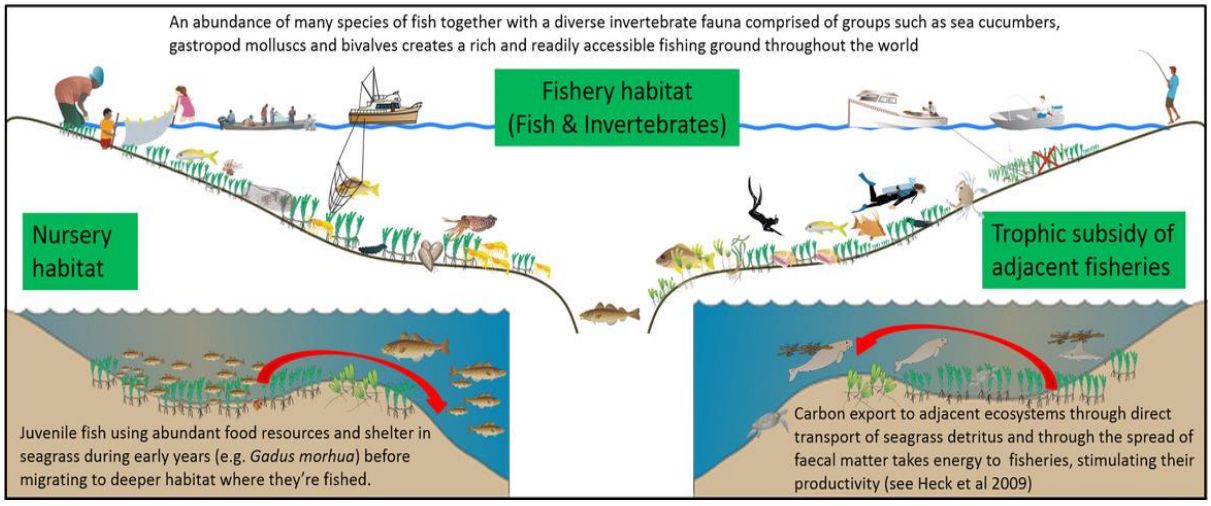

Fig 2) Seagrass meadows support global food security by (1) providing nursery habitat for fish stocks in adjacent and deep water habitats, (2) creating expansive fishery habitat rich in fauna, and (3) by providing trophic support to adjacent fisheries. They also provide support by promoting the health of fisheries associated to connected habitats (e.g., coral reefs). (Unsworth *et a*l, 2018) https://onlinelibrary.wiley.com/doi/pdf/10.1111/conl.12566

Seagrasses' most vital and valuable services, though, are as carbon sinks (Fourqurean *et al.*, 2012).

Rainforests are among the most efficient carbon sinks on land, but beneath the waves seagrass far outperforms them. Covering only **0.1%** of the seabed globally, but capturing **20%** of atmospheric Co2, they sequester carbon at a rate of 14.8 ton CO2/yr, per hectare (Duarte *et al.*, 2013).

Furthermore, seagrass locks down carbon for thousands of years, compared to hundreds of years at best in trees (Duarte *et al.*, 2013).

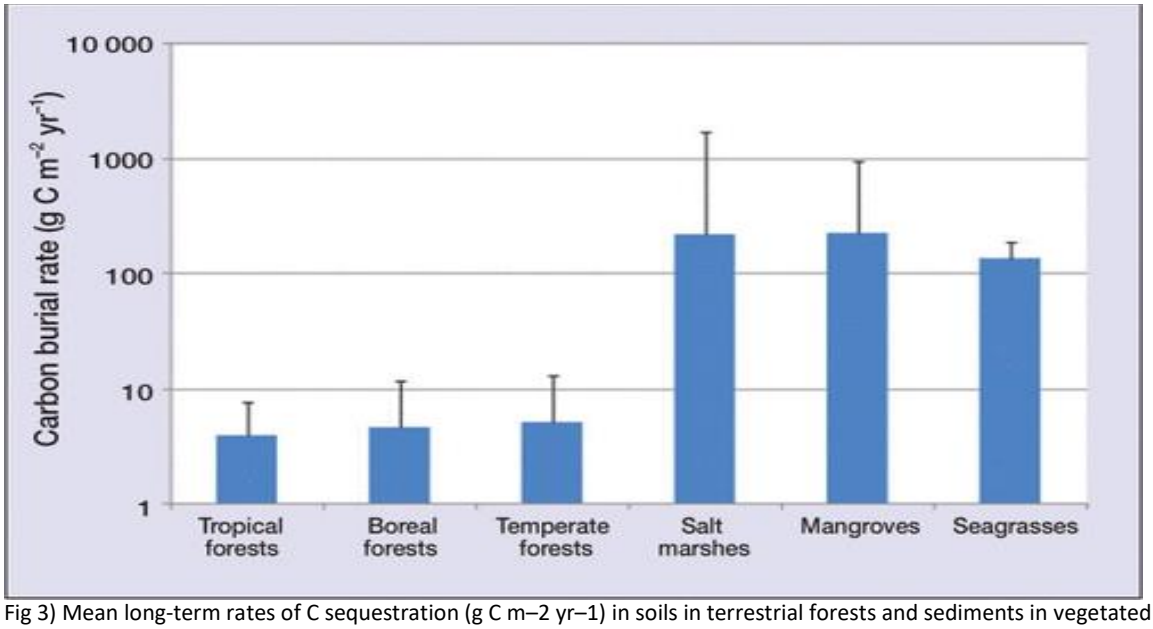

Fig 3) Mean long-term rates of C sequestration (g C m–2 yr–1) in soils in terrestrial forests and sediments in vegetated coastal ecosystems. Error bars indicate maximum rates of accumulation. Note the logarithmic scale of the y axis. (Duarte *et al.*, 2013) https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/110004

Threats to seagrass meadows

Seagrass habitats worldwide are suffering the top 5 most serious threats to marine biodiversity : over exploitation, physical modification, nutrient and sediment pollution, introduction of non-native species, and climate change (Waycott et al 2009).

Man's activities on sea and land directly contribute to their die-off, including: dredging, industrial fishing activities, recreational boating, run-off, that muddy coastal waters and deprive seagrass of clear light for respiration (Short and Wyllie-Echeverria, 1996) (Zimmerman *et al.*, 1997).

Research shows that seagrass meadows are disappearing at a rate of 100km2/year since 1980, with a total loss of 29% since 1879, when seagrass meadows were first recorded (Waycott *et al.*, 2009).

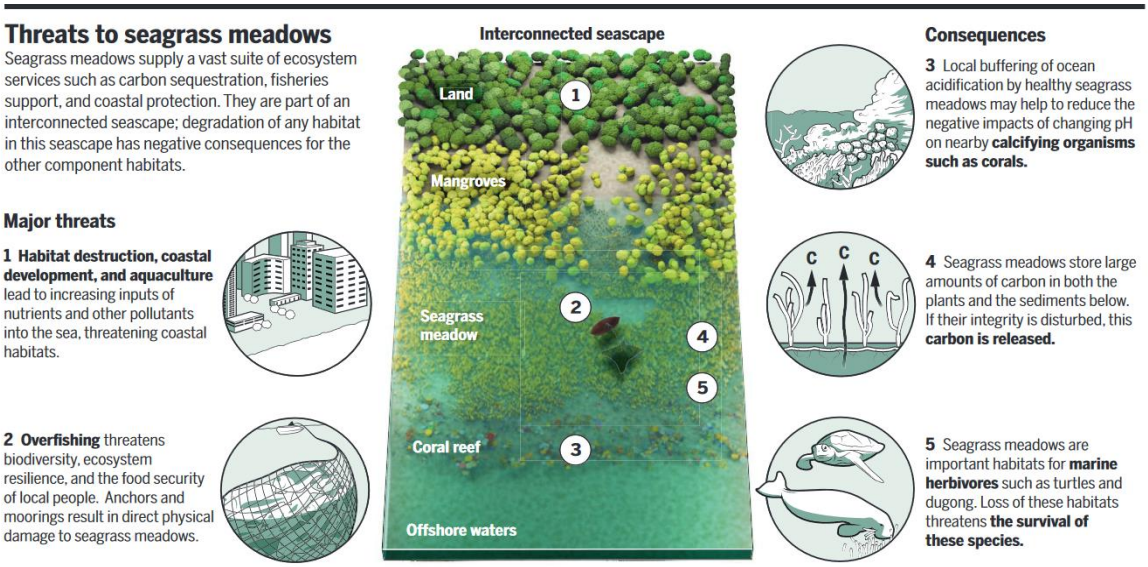

Fig 4) Ecosystem inter-connectedness of mangroves, seagrass meadows & coral reefs, threats and consequences(Cullen-Unsworth and Unsworth, 2018) [." http://fishersisland.net/wp-content/uploads/2018/09/2018-Science-A-call-for-seagrass-protection.pdf](http://fishersisland.net/wp-content/uploads/2018/09/2018-Science-A-call-for-seagrass-protection.pdf)

Ocean warming presents the biggest single threat to these life-support systems worldwide. In 2011, an unprecedented marine heat wave in Western Australia raised water temperatures 2-4°C above average for over 8 weeks, leading to the devastation of the dominant seagrass species [*Amphibolis Antarctica*] of the Shark Bay World Heritage Site.

The result was a calculated loss of 36%, equivalent to 1000km2, of the world's largest area of seagrass meadows over the 2002 baseline (Arias-Ortiz *et al.*, 2018).

Fig 4) Shark Bay seagrass example before 2011 heat wave (L) and study site in 2013 (R).
(Arias-Ortiz *et al.*, 2018) *Credit: Shark Bay Ecosystem Research Project.*

Australia's Shark Bay die-off led to release of up to 9 million metric tons of CO2, or roughly the equivalent to the annual CO_2 output of 800,000 homes, or two average coal-fired power plants.

Restoration efforts have been "disappointing". Seagrasses grow, or colonise very slowly. Studies show Posidonia oceanica patches having the slowest lateral growth (2 cm/year) and Cymodocea nodosa showing the fastest growth (200 cm/year) (Borum *et al.*, 2004).

Positive Feedback Cycle

Through the bio-sequestration process seagrasses draw organic carbon and atmospheric CO2 down through the water column, securing it in sedimentary banks between their roots, in much the same way fossil fuels were formed (Mcleod *et al.*, 2011). These sediments deepen over time, locking down millennia's worth of carbon (Macreadie *et al.*, 2014) (Arnaud-Haond *et al*, 2012).

Seagrasses are in decline globally, (Short *et al.*, 2011) and when they are degraded or die-off, those carbon reserves are released back into the atmosphere, potentially creating a feedback cycle that accelerates CO2 emissions, climate change, and ocean warming. In the Mediterranean, warming threatens the ancient beds of *Posidonia oceanica* with extinction mid-century. *Posidonia oceanica* absorbs approximately 10x more carbon than other species (Telesca *et al.*, 2015).

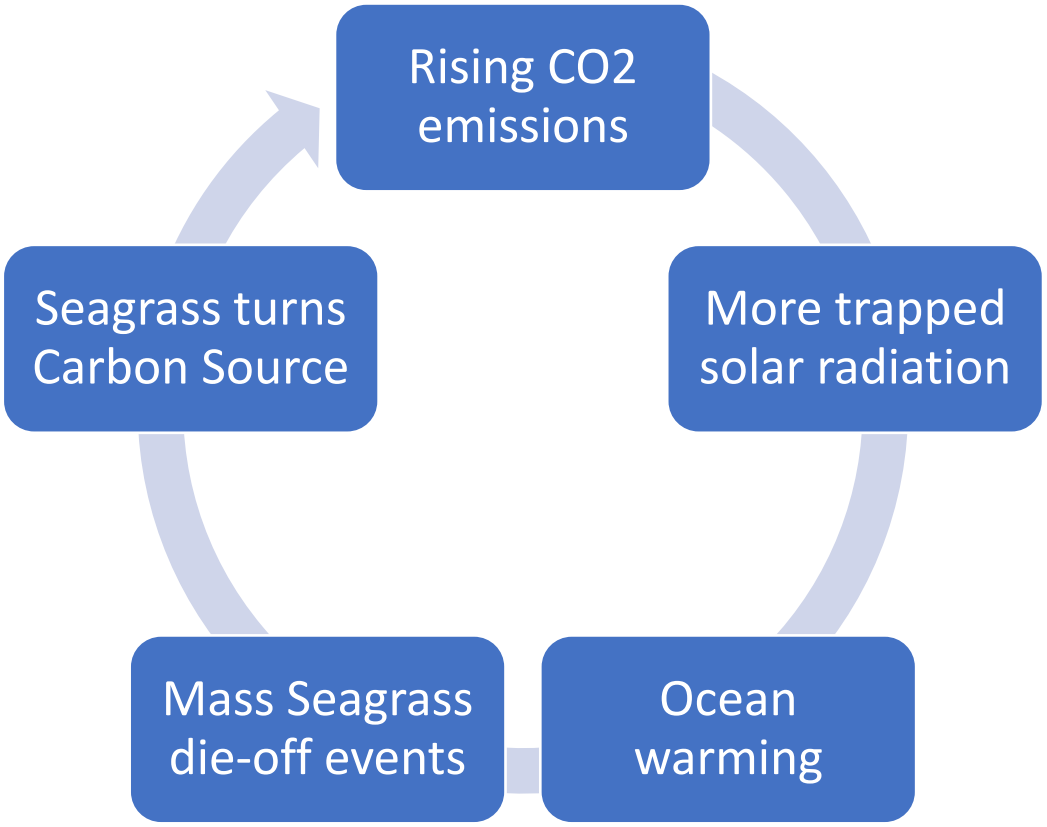

Fig 5) Positive feedback loop of seagrass as a carbon source. C.Fielding

Research from 946 seagrass meadows globally found that seagrass captures approximately 27.4 million tonnes of carbon a year. Total carbon storage of global seagrass meadows is calculated at 19.9 billion tonnes. (Fourqurean *et al.*, 2012) These ancient carbon stores are predicted to turn from carbon sink to carbon source as the oceans absorb unprecedented levels of heat.

Conclusion

Recent studies demonstrate ocean warming increased for the last 5 consecutive years, with 2018 the hottest on record (Resplandy *et al.*, 2018) (Cheng, Zhu, *et al.*, 2019) (Smale *et al.*, 2019).

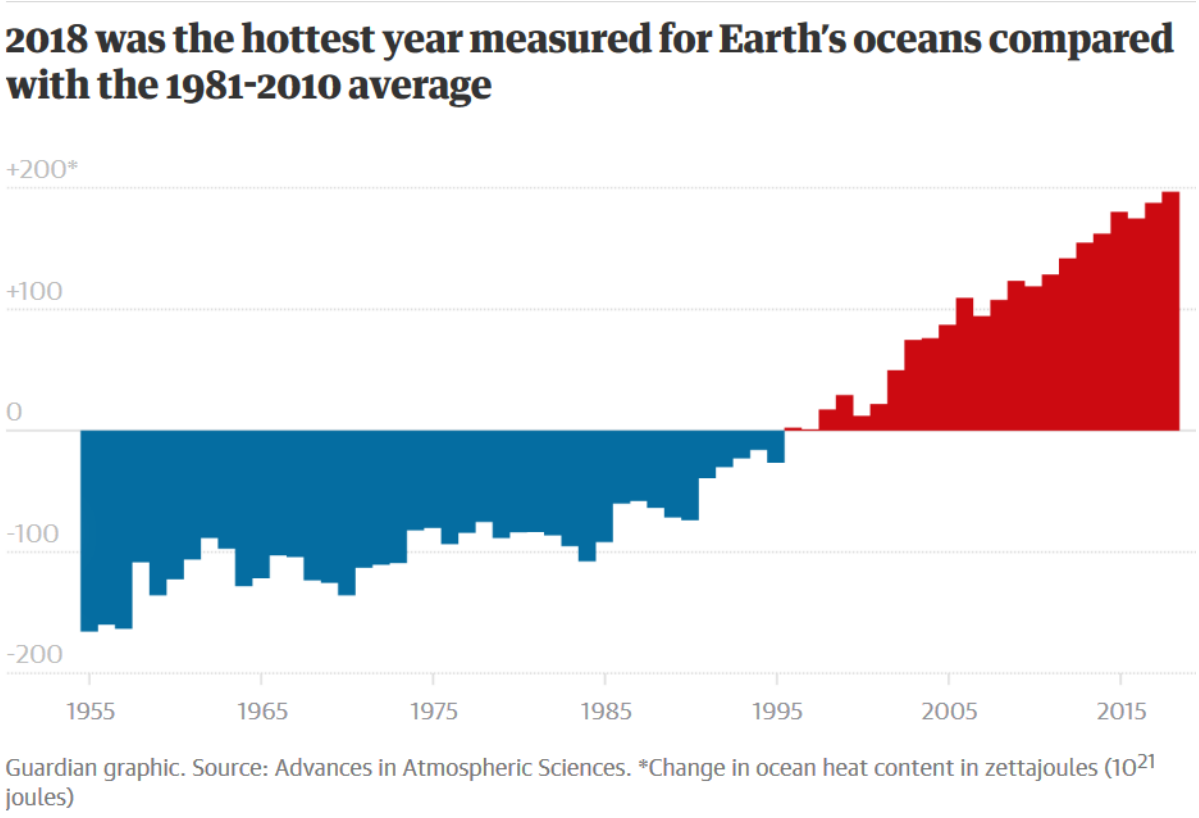

Fig 6) Ocean heat content.

The figures are astronomical. The heat increase in 2018 relative to 2017 is ~388 times more than the total electricity generation by China in 2017, according to a co-author of one report (Cheng, Abraham, *et al.*, 2019).

Australia is currently experiencing another unprecedented heatwave, likely to exceed the 2012 Shark Bay impacts, with alarming implications (Smale *et al.*, 2019).

Marine heatwaves now directly pose the biggest single threat to seagrass meadows, suggesting we're fast approaching a tipping point for marine ecosystems (deYoung *et al.*, 2008). The news isn't all bad however. Recent research shows seagrasses to be expanding in cooler waters (Marbà *et al.*, 2018), and there's extensive policy advice for protecting seagrass (Björk *et al.*, 2008).

The future of seagrass as a foundation marine ecosystem and key carbon sink is critical (Cullen-Unsworth *et al.*, 2014), and it's in our hands. The science is expanding rapidly and public awareness growing fast, with community protection and restoration campaigns worldwide.

In Wales, Project Seagrass is very active, and has even introduced a "Seagrass Spotter" phone app so we can all get involved and learn about seagrass.

So download the app, head to the coast this summer and see if you find this beauty below the waves, and if you're a boater, check where you cast your anchor!

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