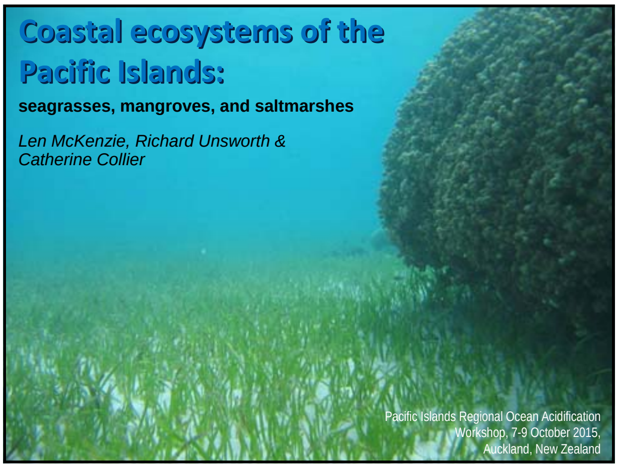


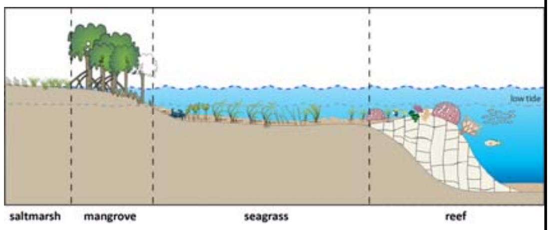
Coastal ecosystems of the Pacific Islands:

seagrasses, mangroves, and saltmarshes

Len McKenzie, Richard Unsworth & Catherine Collier

Pacific Islands Regional Ocean Acidification Workshop, 7-9 October 2015, Auckland, New Zealand

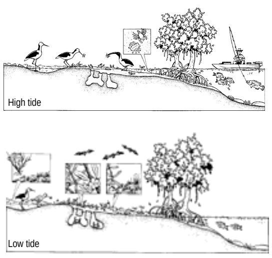
Coastal ecosystems



Saltmarshes

Tidal marine plants

- upper intertidal zone *(HAT to MSL)*
- typically landward of mangroves *(not dependent on co-existence)*
- may be bare *(microbial mats)* or vegetated
- plants <0.5m height
- plants generally low-formed, herbaceous or succulent
- annual rainfall <1500 mm

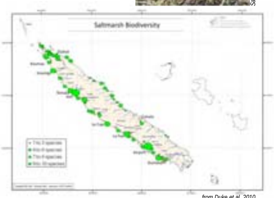


Saltmarshes

Pacific Islands

- at least 20 species
- total area unknown, lack of comprehensive surveys, but reported from larger high islands, *e.g. Papua New Guinea, Solomon Islands, New Caledonia & Fiji*

Sarcocornia quinqueflora from Duke et al. 2010

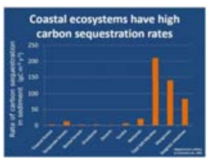


from Duke et al. 2010

Provide important ecosystem services

- **coastal protection**
- **erosion control**
- **nursery habitat for crabs and penaeid prawns**
- **water purification**
- **feeding area for fish & waterbirds** (incl. migratory)
- **carbon sequestration**

Voh River, New Caledonia, from Duke et al. 2010



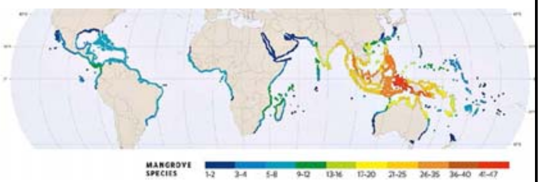
Mangroves

Tidal marine plants

- between high tide and MSL
- tree, shrub, palm or ground fern >0.5m in height
- salt tolerant
- breathing (pneumatophores) or stilt (lenticels) roots to compensate anoxic sediments
- commonly viviparous

Mangroves

Pacific Islands
- 31 species of mangroves & 5 hybrids
- PNG highest global mangrove diversity
- diversity declines west to east, reaching a limit at American Samoa.
- about 5,975 km^2 (3% global area)



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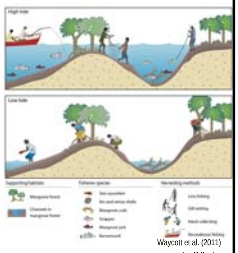
Provide important ecosystem services

- **raw materials** (e.g. timber)
- **coastal protection from waves & storm surges**
- **erosion control / sediment trapping**
- **regulate water quality & flow**
- **support coastal fisheries** (feeding & nursery area for fish, oyster, crab, prawns)
- **carbon sequestration**
- **cultural** (e.g. dye from bark used on tapa)



Waycott et al. (2011)

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Threats to saltmarshes & mangroves

Approx 50% of the global mangrove area lost since 1900 with 35% lost in the past few decades

- **land reclamation**
- **climate change** (e.g. sea level rise)
- **altered hydrologic regimes** (e.g. freshwater diversion**)**
- **forestry / logging**
- **salt ponds, agriculture & grazing**
- **herbicides & toxic chemicals** (e.g. oil)
- **pathogens**
- **runoff** (nutrients & sediments)

image courtesy ELAW

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Seagrasses

Tidal & subtidal marine plants
- MSL to 25m depth (to 80m)
- produce flowers, fruits and seeds while submerged
- have light sensitive leaves
- have a true root system
- have ability to uptake nutrients through roots and leaves
- have an internal vascular system

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Factors important for the persistence of healthy seagrass meadows

water depth
water quality
- *salinity – depends on species, tolerate from 4 to 65 parts per thousand (best growth 35ppt).*
- *clarity - 10-20% of surface irradiance on average (4.4% - 29% depending on species)*
- *temperature - thermal stress at 36-40ºC, >40°C inhibits photosystem II and plants die*

nutrients (C, N, P)
sediment quality
current and hydrodynamic processes
low/moderate disturbance
species interactions

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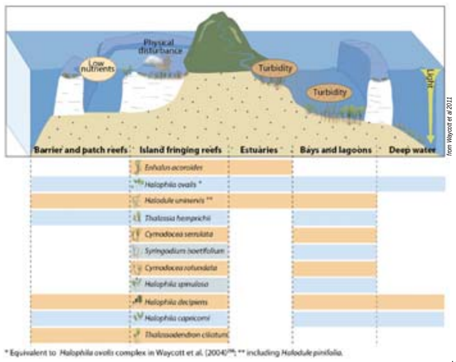
Five main habitats where seagrasses occur in the tropical Pacific



* Equivalent to *Halophila ovalis* complex in Waycott et al. (2004); ** including *Halodule pinifolia*.

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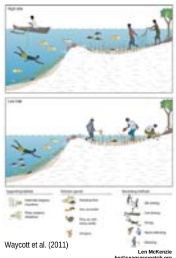
Food for animals protected or vulnerable to extinction

- a **dugong** can eat 28-40kg of seagrass in a day!
- a **green turtle** can eat 2kg of seagrass leaves in a day!

Provide important habitat

- **feeding place for shorebirds**
- **nursery for some fisheries** (commercial/ artisanal fish and prawns)
- **food & shelter for invertebrates** (subsistence fisheries)



Waycott et al. (2011)

Provide important ecosystem services

- **oxygen pumps** (1m² of seagrass can produce up to 10 litres of O_2 per day)
- **nutrient cycling** (1 ha of seagrass absorbs 1.2 kg of nutrients per year)
- **3 times more valuable than coral reefs** (based on ecosystem services)

Provide important ecosystem services

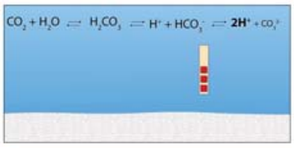
sequester carbon

- 12% of global carbon stored in ocean sediments
- Globally, seagrasses are as important as forests in storing CO_2 *(on an areal basis)* and can store carbon 35 times faster than rainforests
- The value of the C stored in seagrasses is ~USD12,000 ha^{-1}, *on par* with the annual value of other ecosystem services provided by seagrasses
- Australia's seagrasses, taking into account inter habitat variability, are worth about $3.5 billion if fixed carbon price of $25.40 $tonne^{-1}$

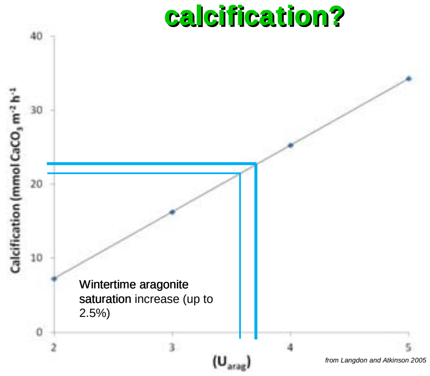
Lavery et al 2013 PLOSone 8(9), e73748

Provide important ecosystem services

locally offset ocean acidification

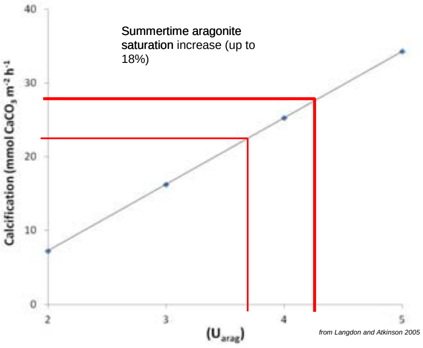


Could seagrass increase coral calcification?



from Langdon and Atkinson 2005

Could seagrass increase coral calcification?



from Langdon and Atkinson 2005

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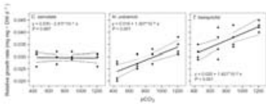
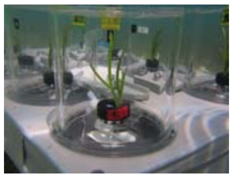
Seagrass & Ocean Acidification

Cellular response

Increasing pCO_2 levels

- increased maximum photosynthetic rates & efficiency
- increased net productivity
- overall responded positively, some species variation





Ow, Y.X., Collier, C.J., Uthicke, S. (2015) Responses of three tropical seagrass species to CO_2 enrichment, Marine Biology 162: 1005-1017.

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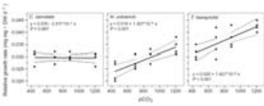
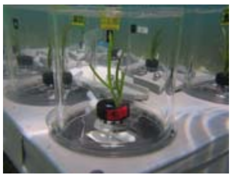
Seagrass & Ocean Acidification

Plant-scale response

Increasing pCO_2 levels

- leaf growth differed between species
  - increased *Halodule uninervis* & *Thalassia hemprichii*
  - no change *C. serrulata*
- *T. hemprichii* leaves larger
- *C. serrulata* rhizomes starch decreased





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Seagrass & Ocean Acidification

Long-term *in situ*

enriched pCO_2 levels

- higher cover / shoot density
- higher above- and below-ground biomass
- higher productivity
- lower size-specific growth
- altered species composition

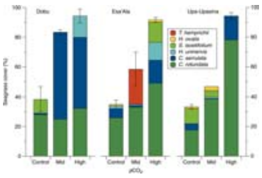

photo courtesy SeattleTimes.com

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Provide important ecosystem services

locally offset ocean acidification

- tropical seagrass meadows near or among coral reefs could offset local effects of ocean acidification, because they can increase the pH of surrounding water up to 0.38 units, making it much less acidic.
- effect depends on seagrass density, species composition, the water depth, the degree of mixing, and what the water turnover rate is (residence time).
- in shallow water reef environments, the ability of coral to be hardened or calcified can be **18% greater** downstream of seagrasses than without seagrasses.

from Unsworth et al. (2012) Environ. Res. Lett. 7: 1-9

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Adaptation to OA

adaptation consists of actions undertaken to reduce the adverse consequences, as well as to harness any beneficial opportunities. Adaptation actions aim to reduce the impacts of climate stresses on human and natural systems.

Primary considerations:

1. **What is the status and condition of the seagrass resource?**
2. **OA threat is not in isolation – we are dealing with cumulative threats?**
3. **Can the threats be managed?**
4. **Can we enhance seagrass resilience?**

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Seagrass extent poorly mapped in the Indo-Pacific

Globally mapped	**177,000 km²**
but estimated to be	**300,000 – 600,000 km²**
e.g. Pacific Islands	
Melanesia	*1,156 km²*
Micronesia	*162 km²*
Polynesia	*53 km²*
TOTAL	**1,371 km²**

high likelihood 4-5% shallow water areas of reef and continental slope <10 m below MSL would have at least sparse seagrass cover

Seagrass status in the Indo-Pacific?

unknown

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Global decline of seagrass meadows

Approximately 58% of seagrass meadows globally, have lost part of their distribution

According to reports, the documented losses in seagrass meadows globally since 1980 are equivalent to two football (soccer) fields per hour

Waycott et al (2009) *PNAS* 106(30): 12377–12381

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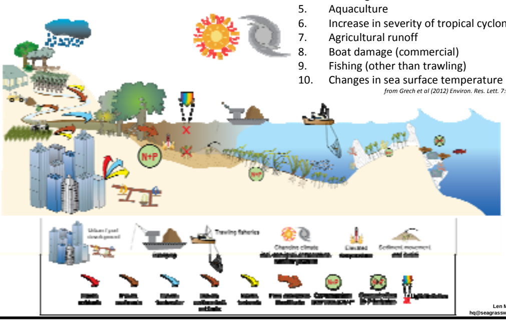
Threats to seagrass in Pacific Islands

Anthropogenic threats
(weighted-average vulnerability score):

1. **Urban/industrial runoff**
2. Urban/port infrastructure development
3. Dredging
4. Trawling
5. Aquaculture
6. Increase in severity of tropical cyclones
7. Agricultural runoff
8. Boat damage (commercial)
9. Fishing (other than trawling)
10. Changes in sea surface temperature

from Grech et al (2012) Environ. Res. Lett. 7:024006



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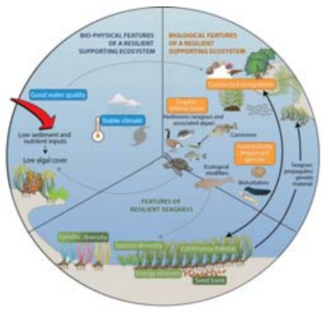
Seagrass Resilience

Conceptual framework demonstrates what resilience is within a seagrass ecosystem and how it operates. *Includes a series of bio-physical and biological features and modifiers which act as interacting influences upon seagrass ecosystem resilience.*

Keeping the features of a resilient seagrass ecosystem in mind will help focus adaptation actions.



Unsworth et al. (2015) Mar. Poll. Bull.

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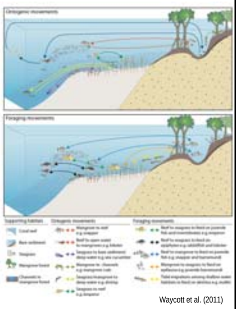
Connected ecosystems

A higher recognition of the level of connectivity among seagrasses and the coastal habitat mosaic *(coral reefs, mangroves, and saltmarshes)* also necessitates an over-riding priority for management to secure connectivity among all these habitats to enhance the resilience.



Waycott et al. (2011)

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Managing for resilience

Approaches

1. **non-prescriptive broad based approach** (ranging from planning processes to education)
2. **reactive approach** (stop small scale disturbances)
3. **prescriptive legal approach** (direct protection, MPAs, area or seasonal closures, mitigation and/or restoration)

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Non-prescriptive

Providing information/data for planning

Community outreach

basic education & awareness programs targeted for island schools, and communities to collectively manage and make decisions.

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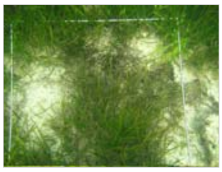
Reactive approach

Kabara

Data collected WWF Fiji

Marine baseline biological survey, Sep04

- villagers concerned about climate change and habitat destruction
- outboard motor owners relocate activity



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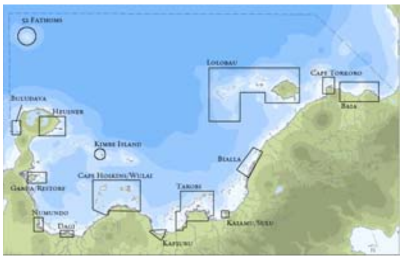
Prescriptive approach

Kimbe Bay (PNG)

Green et al 2007

- design process involved expert advice, targeted research and monitoring and an analytical design process
- identified 15 areas of interest that meet specific conservation goals
- seagrass was one of the conservation targets



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Mitigation and/or restoration

- Mangrove nurseries and planting becomming common across the Pacific Islands

- Coral farming also popular across the Pacific Islands – particularly in association with tourism

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Mitigation and/or restoration

- **Can we plant seagrass (transplanting)?**
  - success rates are poor
  - key issues:
    - **suitability of site**: *if the habitat is suitable for seagrass, then why isn't it there already?*
    - **availability** of donor stock
    - **limited experience**: *trials demonstrated that transplanting was possible but not practicable (transplants survived but didn't spread). Maybe better to use seeds. Research is urgently required.*
    - **scale**: *small scale is possible – scaling up to areas that would address OA issue is unlikely to be possible because of logistics*

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Enhancing & alternatives?

- **Can we fertilize seagrass on the reef and then 'mow' it for disposal on-land?"**
- **Can we have lines of seagrass hanging on a reef?**
- **Forget about seagrass and culture seaweed instead!**

  pros - *harvest provides subsistence income*

  cons - *loss of ecosystem services will be enormous*

Kappahycus alvarezii (Wagina Island, Choiseul, Solomon Islands)

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Managing for resilience

requires a hierarchy of on-ground management practices starting at the most general and large scale *(e.g., reduce sediment and nutrient runoff into coastal waters)* and cascading down to smaller meadow-scale issues *(e.g., prevention of anchor damage or meadow enhancement / restoration)*

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