Connectivity issues in marine environments: beyond biotic exchange

T.J. Bouma, J. van de Koppel, L. Gwen Gillis, T. van der Heide, M. van Katwijk, H. Olff, P. Herman

connectivity → focus on biotic exchange

- Landscape connectivity is crucial for:
  - dispersal
  - gene flow
  - demographic rescue
  - movement in response to climate change
- Management efforts → map and conserve areas that facilitate movement to maintain population connectivity & promote climate adaptation

McRae et al. (2012) Where to Restore Ecological Connectivity? Detecting Barriers and Quantifying Restoration Benefits. PLoS ONE 7(12): e52604.

Novel opportunities → physical models

→ Modeling biotic exchange

Biogeosciences, 10, 5095–5113, 2013
www.biogeosciences.net/10/5095/2013/
doi:10.5194/bg-10-5095-2013

Biogeosciences Open Access

Modelling drivers of mangrove propagule dispersal and restoration of abandoned shrimp farms

D. Di Nitto[1], P. L. A. Erftemeijer[2,3], J. K. L. van Beek[4], F. Dahdouh-Guebas[1,5], L. Higazi[1], K. Quisthoudt[1], L. P. Jayatissa[6], and N. Koedam[1]

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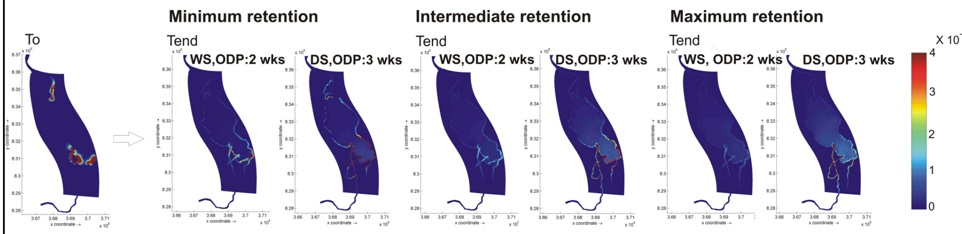
➔ Modeling biotic exchange

Scenario 1: 'What is the effect of species-specific buoyancy characteristics on propagule dispersal?'

A) Avicennia officinalis



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predictions = f (bio & physical inputs) !!

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Biogeosciences, 10, 3635–3647, 2013
www.biogeosciences.net/10/3635/2013/
doi:10.5194/bg-10-3635-2013

Open Access

The role of wind in hydrochorous mangrove propagule dispersal

T. Van der Stocken[1,2,*], D. J. R. De Ryck[1,2,*], T. Balke[3], T. J. Bouma[3,4], F. Dahdouh-Guebas[1,2], and N. Koedam[1]

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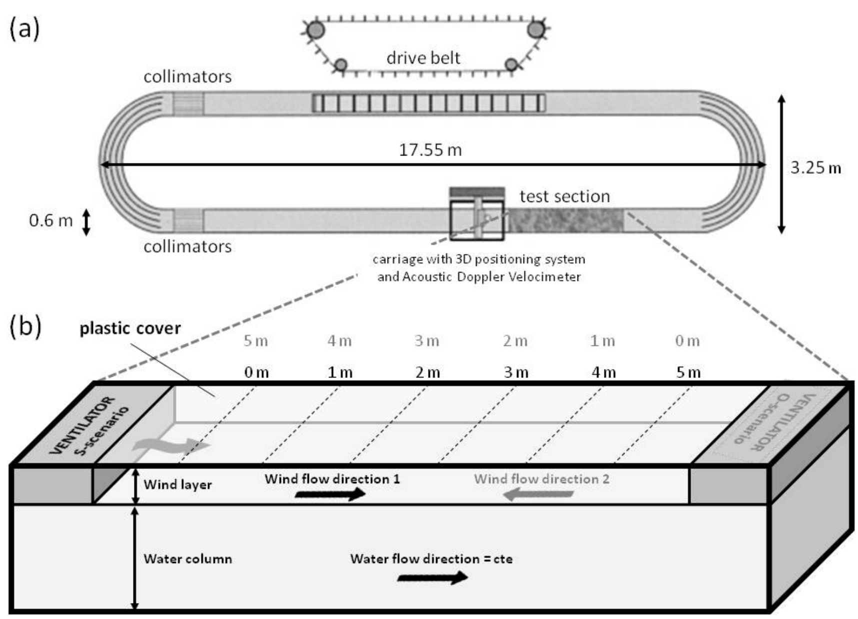
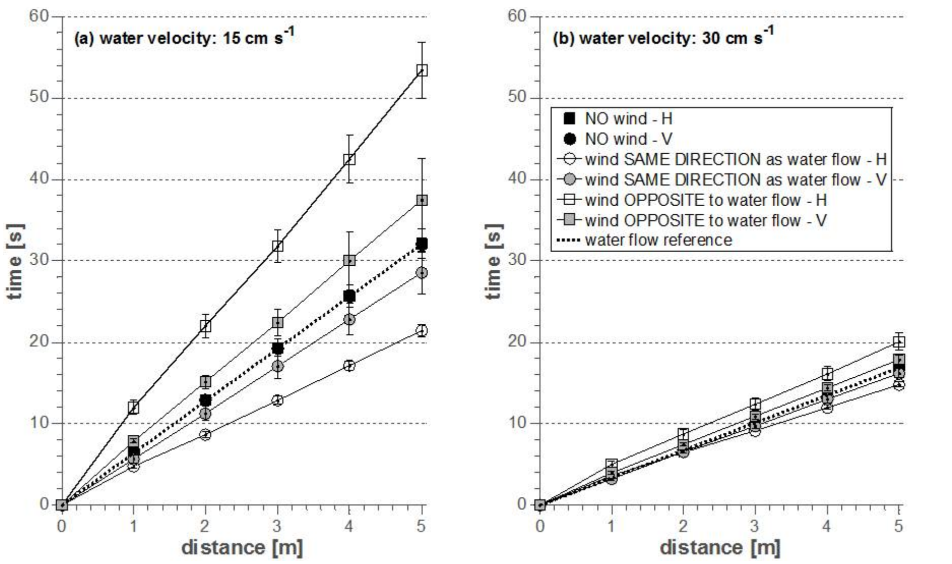
Contrasting propagule types

https://wiki.trin.org.au/Mangroves/PropoguleType

Physical approach to biotic exchange



Inputs for modeling biotic exchange ⇔ large-scale connectivity



Connectivity beyond biotic exchange?

Connectivity beyond biotic exchange?

- The importance of spatial extended ecosystem engineering
  - eco. eng. / facilitation concept / max. scale
- Ecosystem connectivity at landscape-scale
  - temperate & tropical example
- Management implications
  - protection & restoration
- Coastal defense cascades
  - Application in the future

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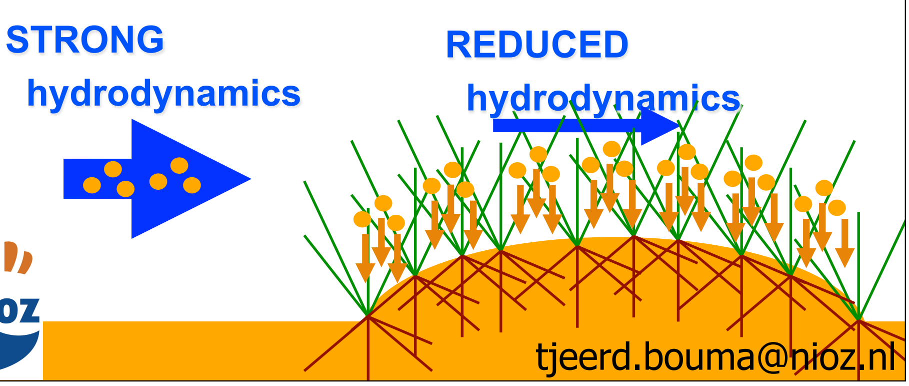
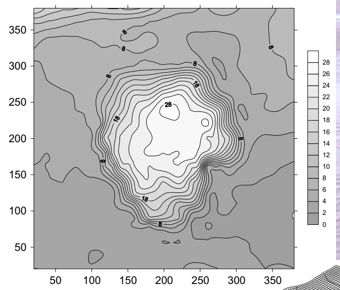
ecosystem engineering:

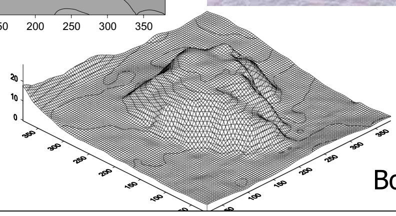
EE = modification of the abiotic environment by biological activity (Jones 1994)



tjeerd.bouma@nioz.nl

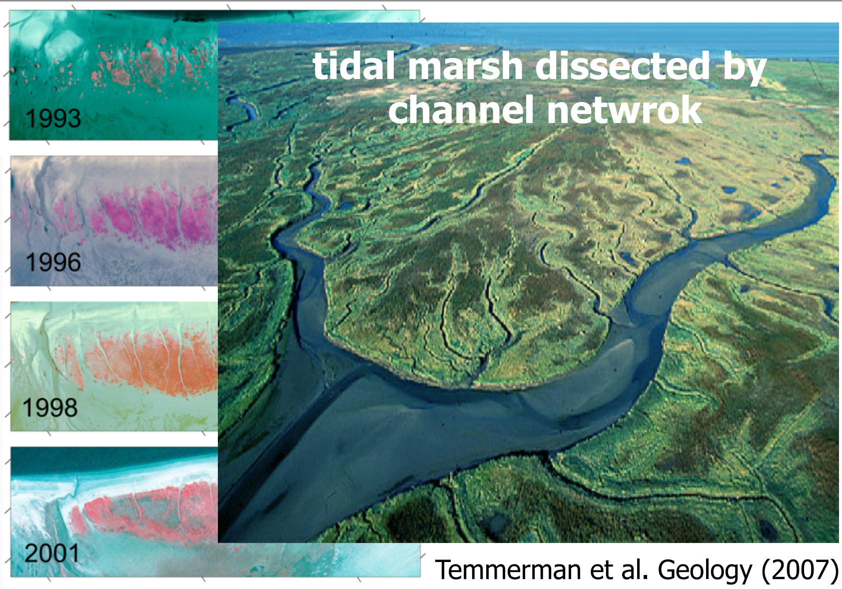
ecosystem engineering: modifying your own environment





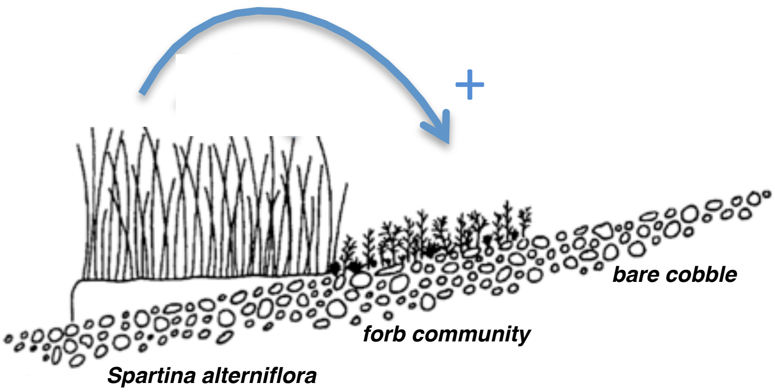
Bouma et al. Cont Shelf Res (2007)

ecosystem engineering: potential to build landscapes



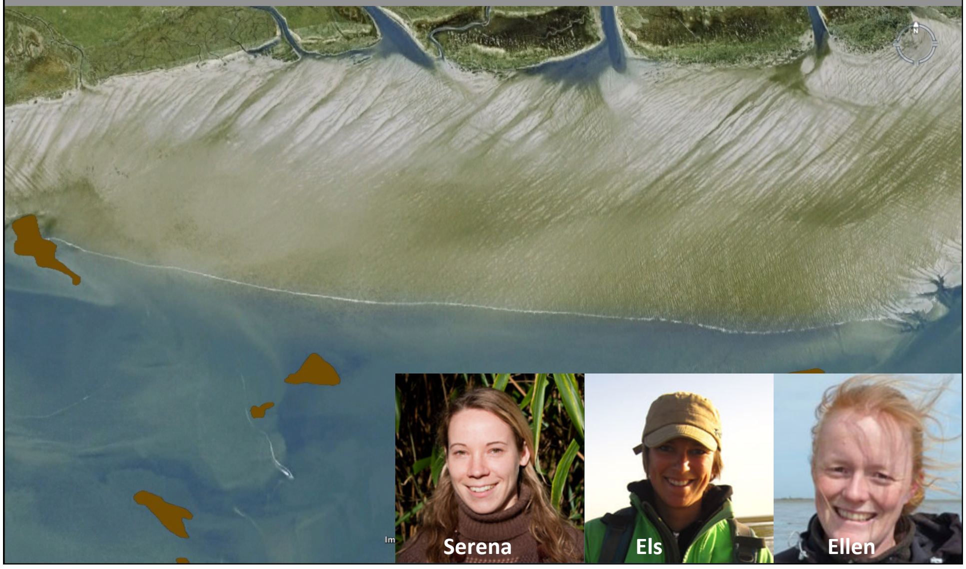
Temmerman et al. Geology (2007)

EE → may facilitate neighbors

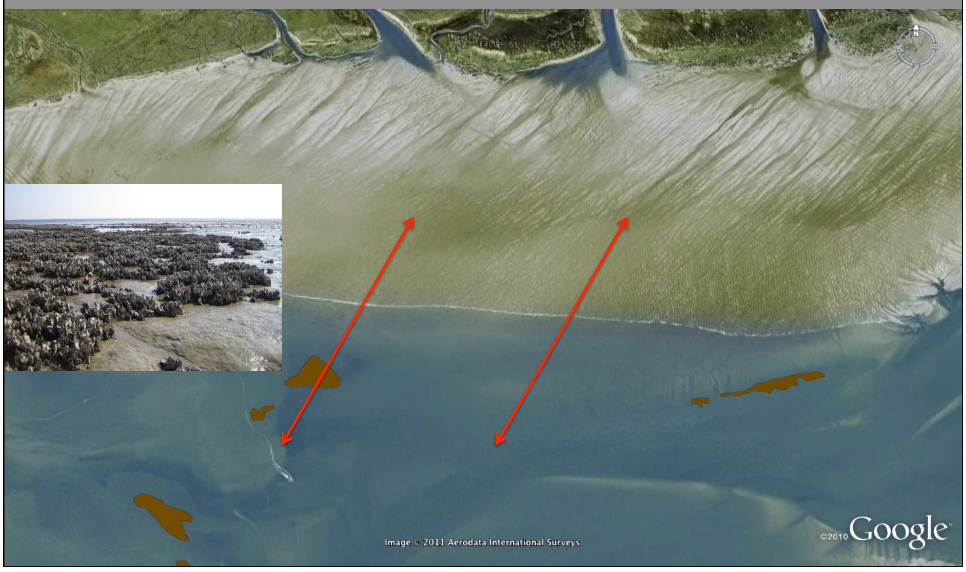


Van de Koppel et al. Ecol. Letters (2006)

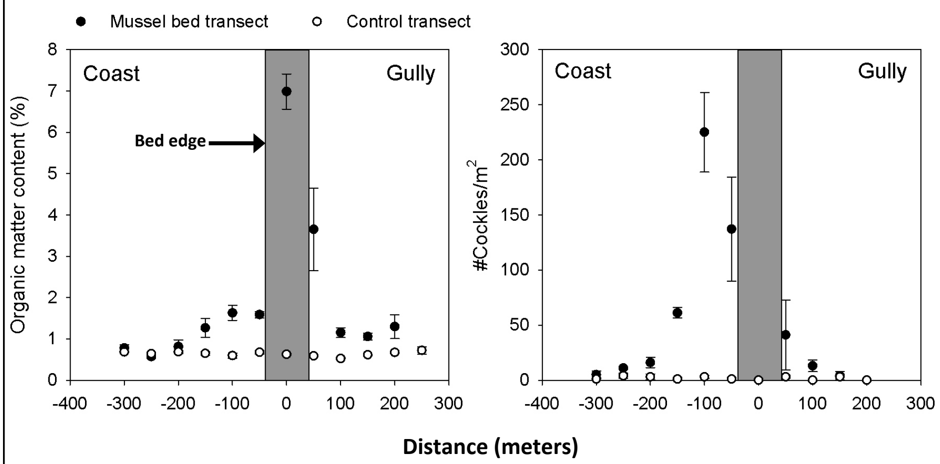
How far can EE-effects extend?



How far can EE-effects extend?

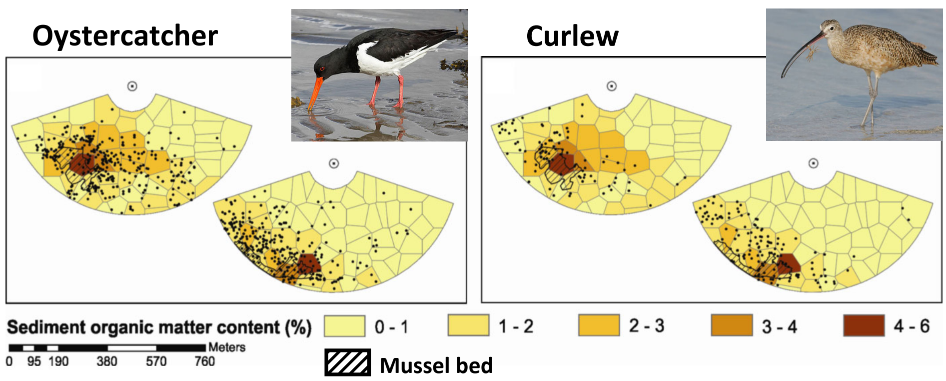


Evidence for extended EE-effects



Donadi *et al.*, Ecology (2013); Ecosystems (2013)

Evidence for extended EE-effects



Van der Zee *et al.*, Ecosystems (2012)

Connectivity beyond biotic exchange?

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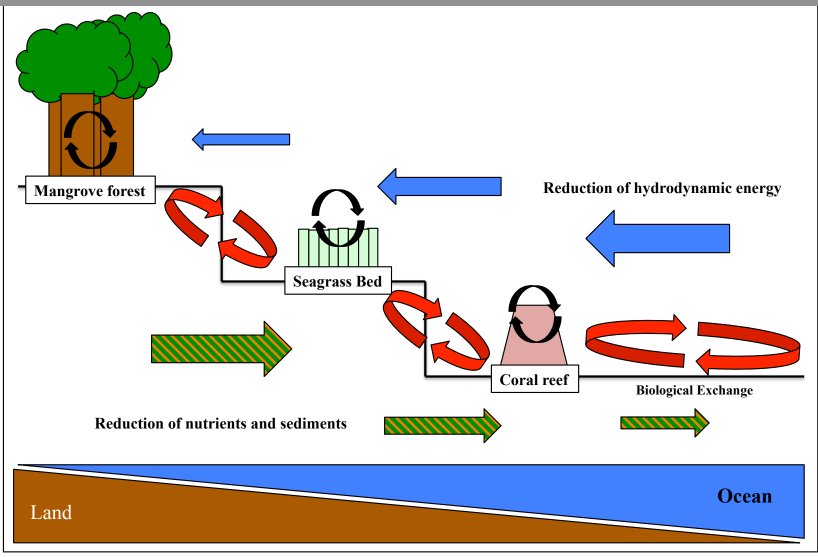
Landscape-scale facilitation between connected tropical ecosystems



Gillis et al. MEPS 2014

Landscape-scale facilitation between connected tropical ecosystems

Vol. ■ ■ doi: 10.3354/meps10716	MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser	Published ■ ■

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REVIEW

Potential for landscape-scale positive interactions among tropical marine ecosystems

L. G. Gillis[1,*], T. J. Bouma[1], C. G. Jones[2], M. M. van. Katwijk[3], I. Nagelkerken[4], C. J. L. Jeuken[5], P. M. J. Herman[1], A. D. Ziegler[6]

Landscape-scale facilitation based on:

- differences in threshold values
- EE reducing physical stressors

Landscape-scale facilitation based on:
- differences in threshold values
- EE reducing physical stressors

Threshold variables	Mangrove forests	Seagrass beds	Coral reefs	Facilitation potential
Wave height (m)	0.5	0.4	0.9	CR→SB→MF
Total suspended sediment ($g^{-1}\ m^{-2}\ d^{-1}$)	82	161	11.2	MF→SB→CR
Water column nitrogen ($g\ N\ m^{-2}\ d^{-1}$)	0.07	0.04	0.009	MF→SB→CR
Water column phosphorous ($g\ P\ m^{-2}\ d^{-1}$)	0.04	0.002	0.0002	MF→SB→CR

Landscape-scale facilitation based on:
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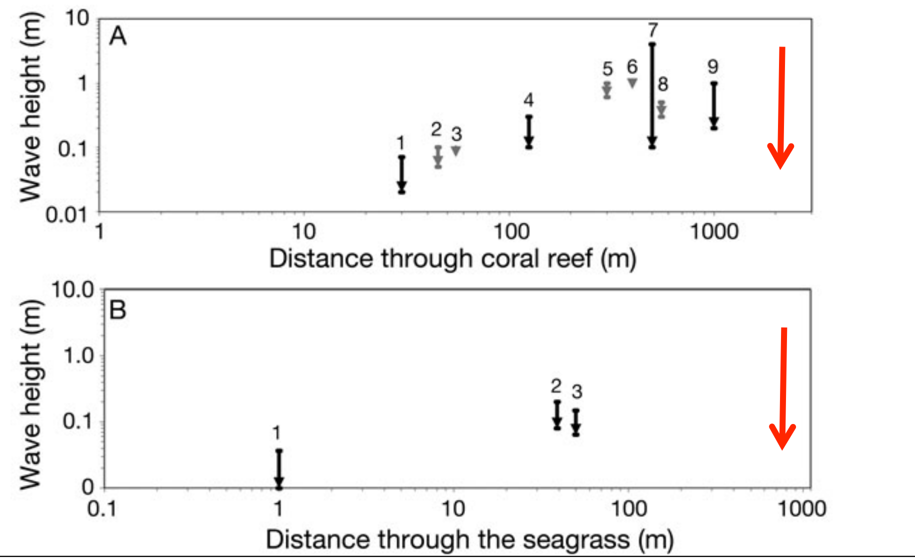

Landscape-scale facilitation based on:
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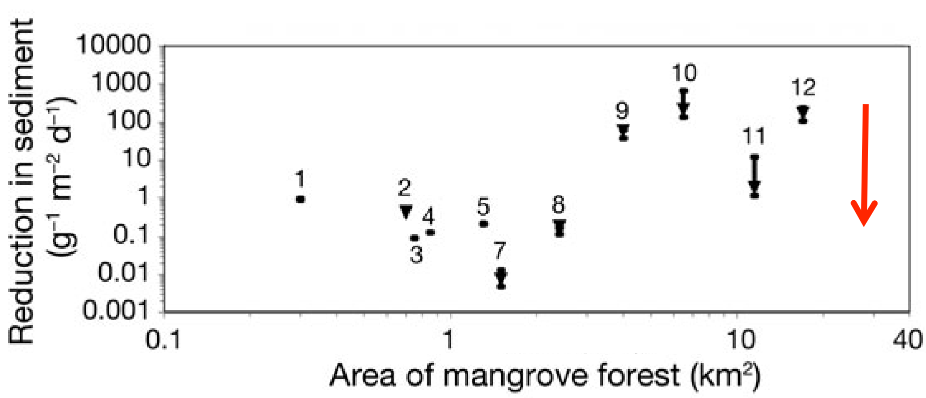

Landscape-scale facilitation based on:
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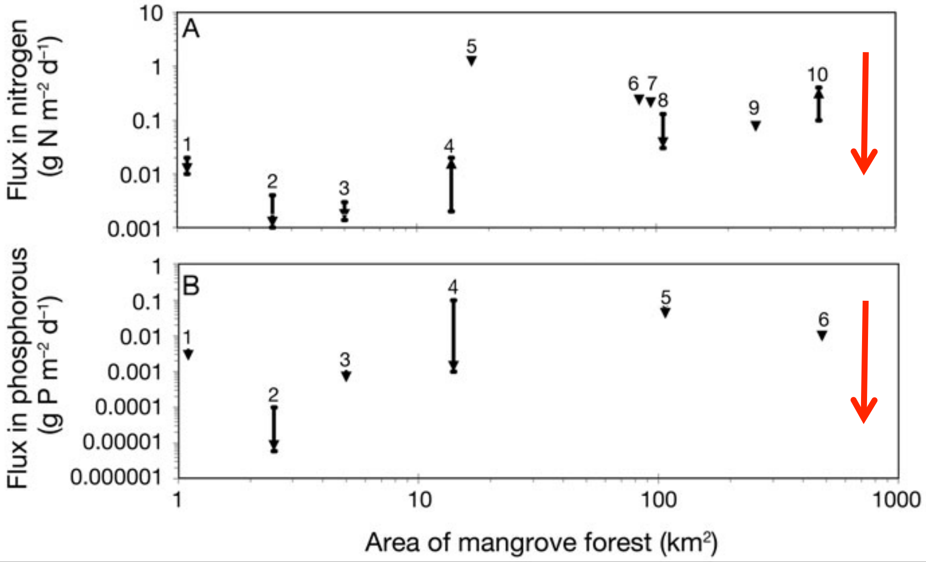

Landscape-scale facilitation based on:
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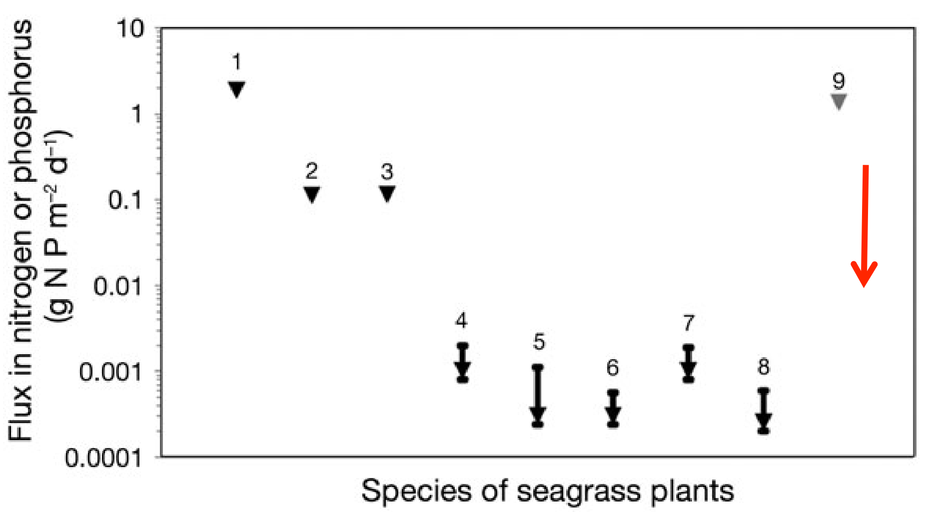
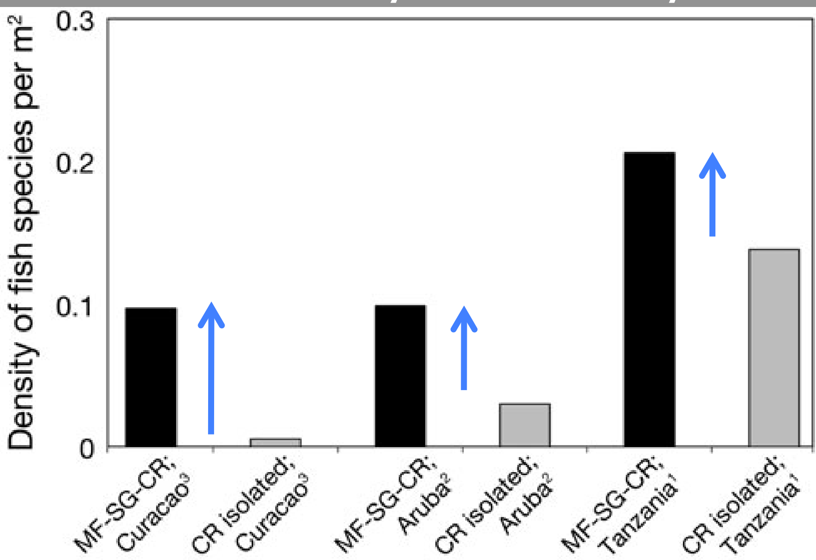
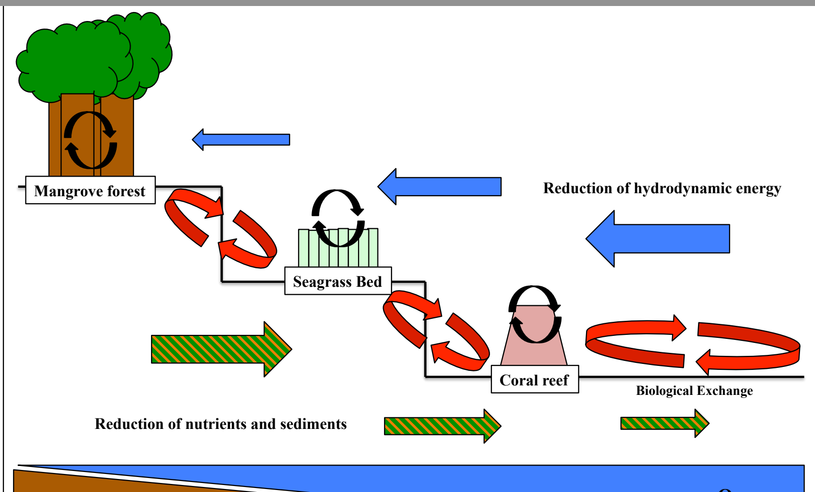


Landscape-scale facilitation:
- enhances diversity
- enhances ecosystem stability



Landscape-scale facilitation between connected tropical ecosystems



what does not co-occur now, may have in the past!

Gillis et al. MEPS 2014

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- **Management implications**
  - protection & restoration
- Coastal defense cascades
  - Application in the future

Management implications → restoration

Ecosystem Engineering across Environmental Gradients: Implications for Conservation and Management

CAITLIN MULLAN CRAIN AND MARK D. BERTNESS

Ecosystem engineers are organisms whose presence or activity alters their physical surroundings or changes the flow of resources, thereby creating or modifying habitats. Because ecosystem engineers affect communities through environmentally mediated interactions, their impact and importance are likely to shift across environmental stress gradients. We hypothesize that in extreme physical environments, ecosystem engineers that ameliorate physical stress are essential for ecosystem function, whereas in physically benign environments where competitor and consumer pressure is typically high, engineers support ecosystem processes by providing competitor- or predator-free space. Important ecosystem engineers alleviate limiting abiotic and biotic stresses, expanding distributional limits for numerous species, and often form the foundation for community development. Because managing important engineers can protect numerous associated species and functions, we advocate using these organisms as conservation targets, harnessing the benefits of ecosystem engineers in various environments. Developing a predictive understanding of engineering across environmental gradients is important for furthering our conceptual understanding of ecosystem structure and function, and could aid in directing limited management resources to critical ecosystem engineers.

Keywords: stress gradients, ecosystem engineers, conservation, associational defenses, environmental stress model

Management implications → restoration

Vol. 336: 121–129, 2007 | MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser | Published April 27

Planting density, hydrodynamic exposure and mussel beds affect survival of transplanted intertidal eelgrass

Arthur R. Bos[1,2,*], Marieke M. van Katwijk[1]

Management implications → restoration

Management implications → restoration

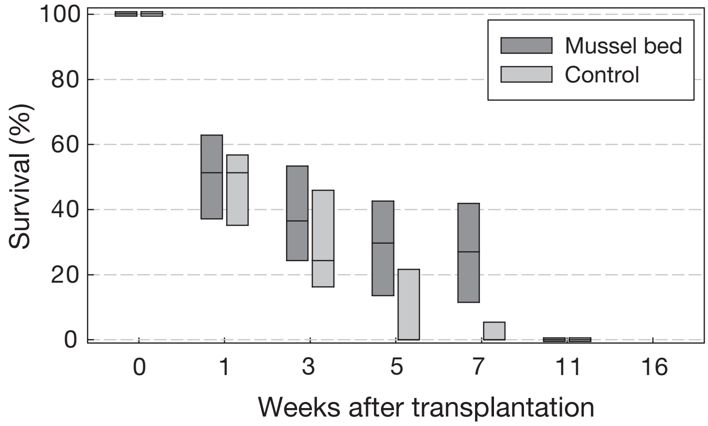


Fig. 4. *Zostera marina* and *Mytilus edulis.* Survival of eelgrass transplants (median, upper and lower quartiles) at Location B3 within a mussel bed and at a control location without mussels

BUT EE→ can have negative interactions

Ecological Applications, 22(4), 2012, pp. 1224–1231

Suppressing antagonistic bioengineering feedbacks doubles restoration success

Wouter Suykerbuyk,[1,2,6] Tjeerd J. Bouma,[2] Tjisse van der Heide,[3] Cornelia Faust,[2] Laura L. Govers
Wim B. J. T. Giesen,[1,4] Dick J. de Jong,[5] and Marieke M. van Katwijk[1]

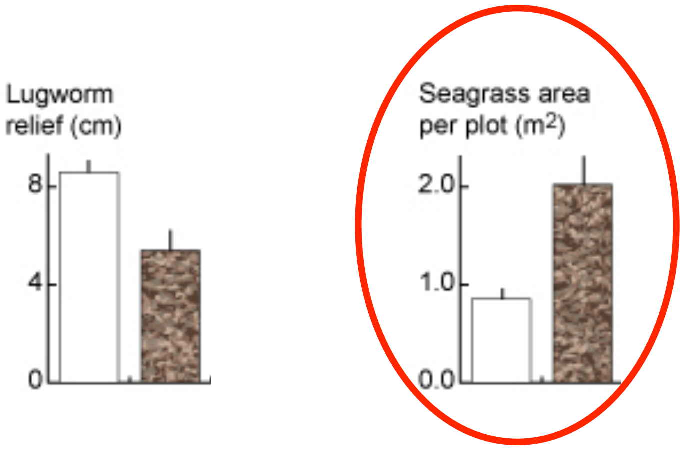
Seagrass mitigation → effect of excluding lugworms …

Zeeweringen

NIOZ

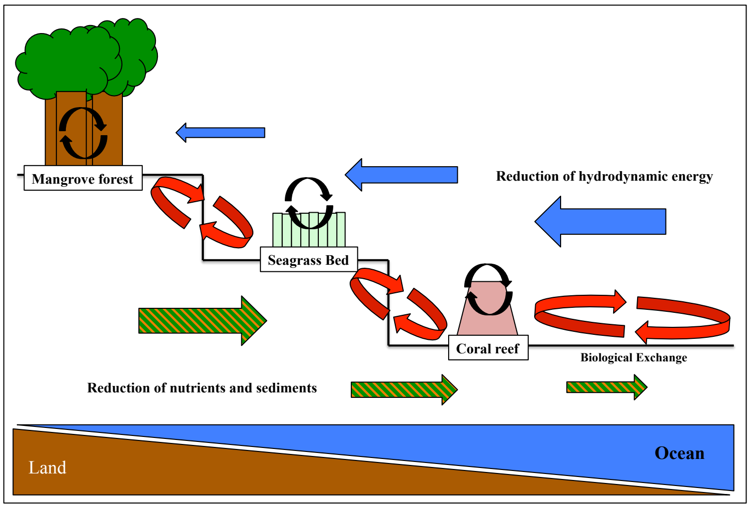
Seagrass mitigation → effect of excluding lugworms …

excluding lugworms → double success !



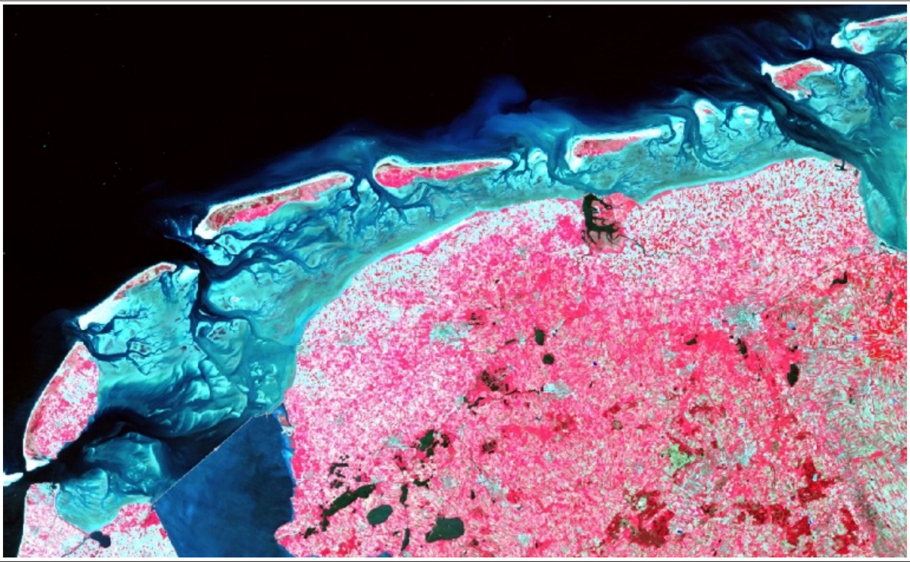
Suykerbuyk et al et al. – Ecol. Application 2012

Management implications – landscape scale
→ maintain all components
→ restore missing links



Gillis et al. MEPS 2014

Management implications – landscape scale
→ do we need to make choices?
→ better to protect 1 complete than 2 half?



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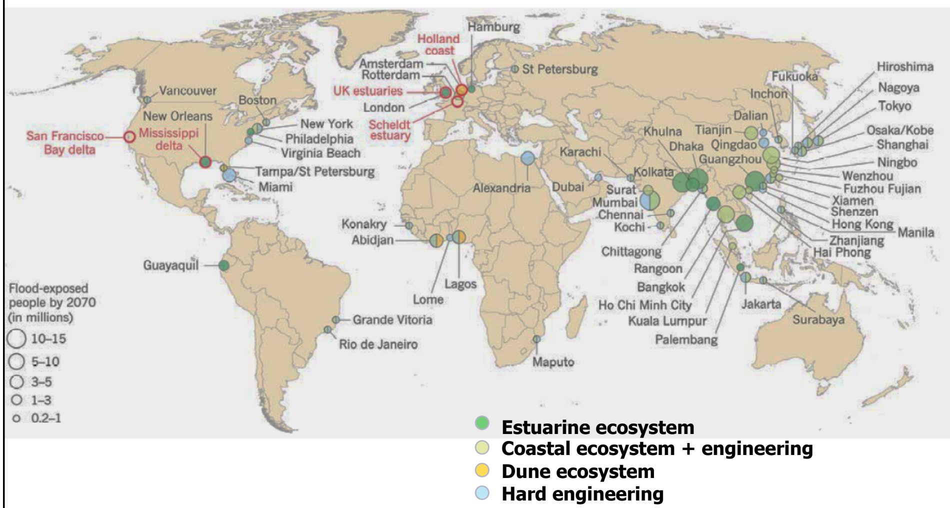
- **Coastal defense cascades**
  - Application in the future

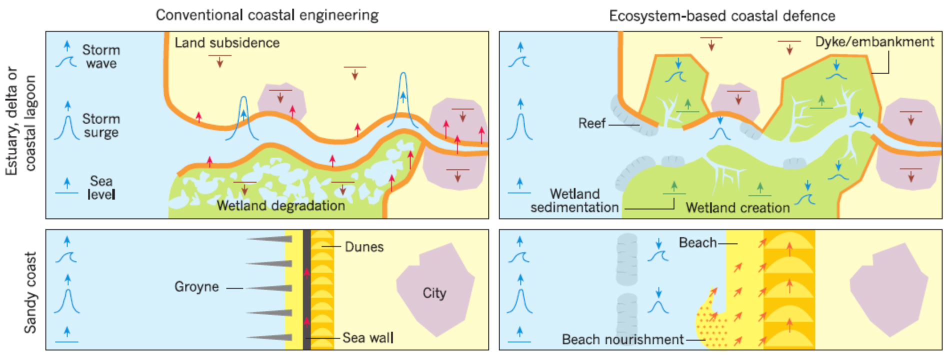
Mega cities endangered by drowning in 2070
→ Need for new cost effective coastal defense

Stijn Temmerman[1], Patrick Meire[1], Tjeerd J. Bouma[2], Peter M. J. Herman[2], Tom Ysebaert[2,3] & Huib J. De Vriend[4]



Temmerman et al. 2013, *Nature*

Towards a new coast ?



- Which ecosystems to use?
- When can they be applied?

Temmerman et al. 2013, *Nature*

Which ecosystems are (most) suitable?

‘structure building’ organisms → attenuate waves
→ ecosystem engineers ⇔ biobouwers

Bouma et al. 2014, *Coastal Engineering*

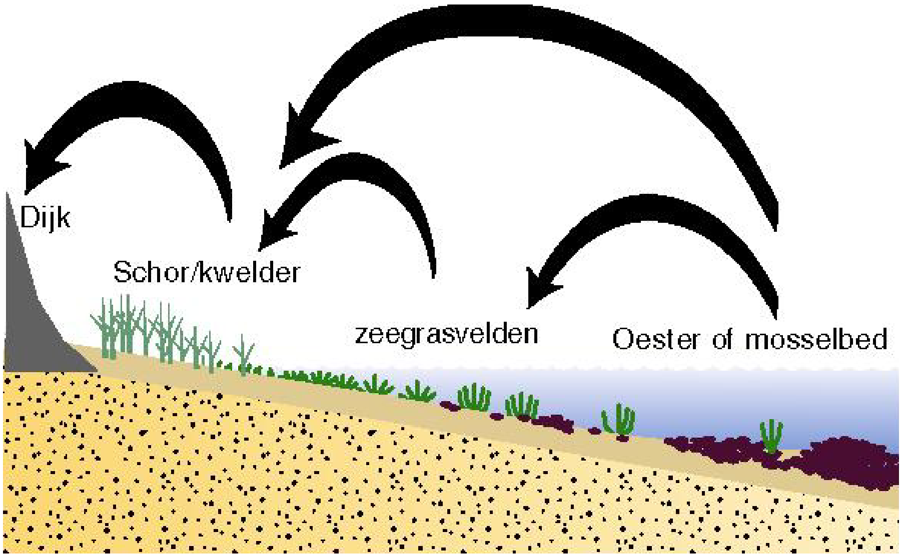
Which ecosystems are (most) suitable?

Intertidal Ecosystems	Habitat characteristics		Coastal protection service			
			Sediment stabilization	Wave attenuation		
	Wave exposure	Height in intertidal frame as submersion period (typical % [range %])		Wave decay coefficient ($k_{habitat}$; m^{-1})	Does seasonality affects wave attenuation?	Maximum Tidal range (m) reducing 50% wave height over 50 ($MT_{50/50}$) and 100 ($MT_{50/100}$) m ecosyst
 Salt marshes	Sheltered	5% [<30%]	Binding by roots & rhyzomes[c]; Reduction of currents	0.01-0.05[j,l,m]	Yes, due to loss of aboveground biomass in winter[i]	marshes are always effective for any realistic tidal range (i.e. $MT_{50/50}$ = 22.6; $MT_{50/100}$ = 33.2)
 Seagrass meadows	Moderate exposed	45% [>30%]	Binding by roots & rhyzomes[b,d]; Reduction of currents[h]	0.001-0.01[f,k]	Yes, due to loss of aboveground biomass in winter[i]	$MT_{50/50}$ ~ 0 $MT_{50/100}$ = 0.7
 Mussel beds	Moderate exposed	63% [>45%]	Sediment covering; Reduction of currents	0.05-0.15[b,e]	No	$MT_{50/50}$ = 1.8-3.2 $MT_{50/100}$ = 2.7-4.2
 Oyster reefs	Exposed	75% [>55%]	Reduction of currents[i]	0.15-0.30[b]	No	$MT_{50/50}$ = 2.8-3.5 $MT_{50/100}$ = 3.5-4.3
 Sabellaria reefs	Exposed	95% [>75%]	Sediment binding[g]; Reduction of currents[g]	no data	No	unknown

higher in intertidal ➔ stronger wave attenuation
➔ intertidal (marsh) vegetation most suitable EE

Bouma et al. 2014, *Coastal Engineering*

Lower ecosystems also important: stabilizing the cascade!



Van Katwijk et al. (2007)

Thank you for your attention ☺

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