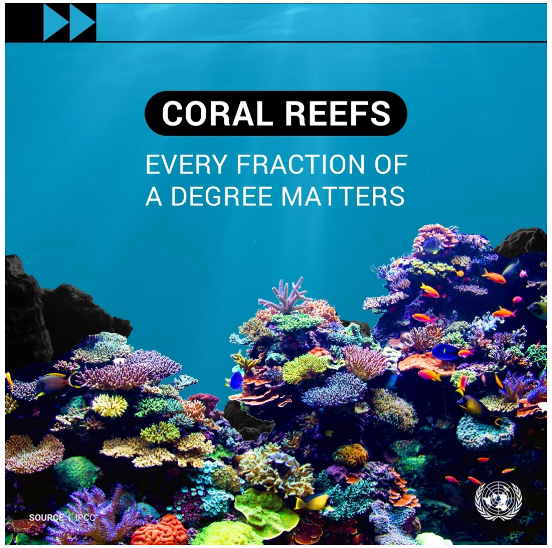
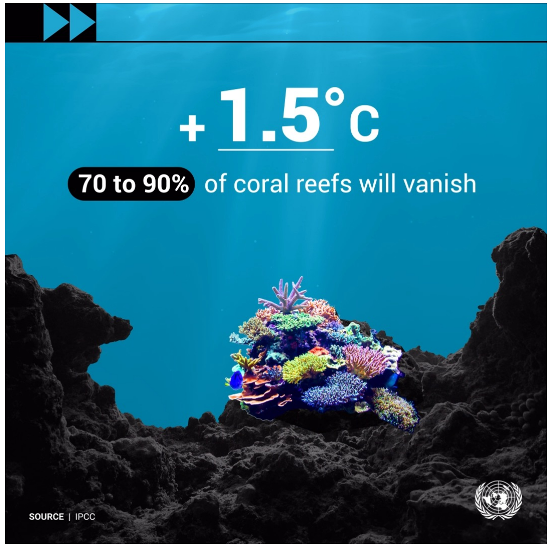
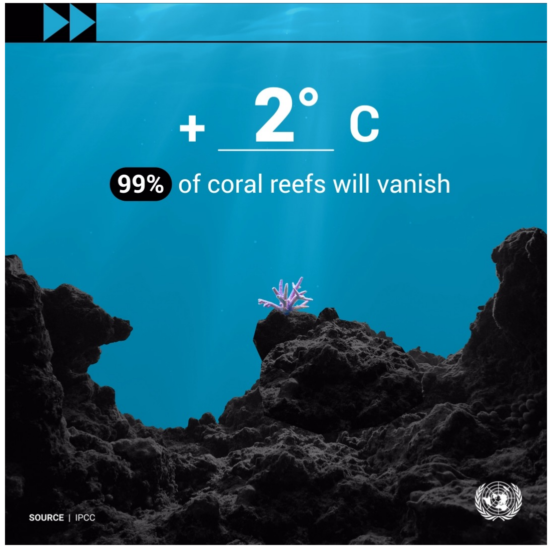
Climate change impacts and mitigation in coastal ecosystems: from tipping points to blue carbon and reserve networks

Frederic Guichard

McGill University





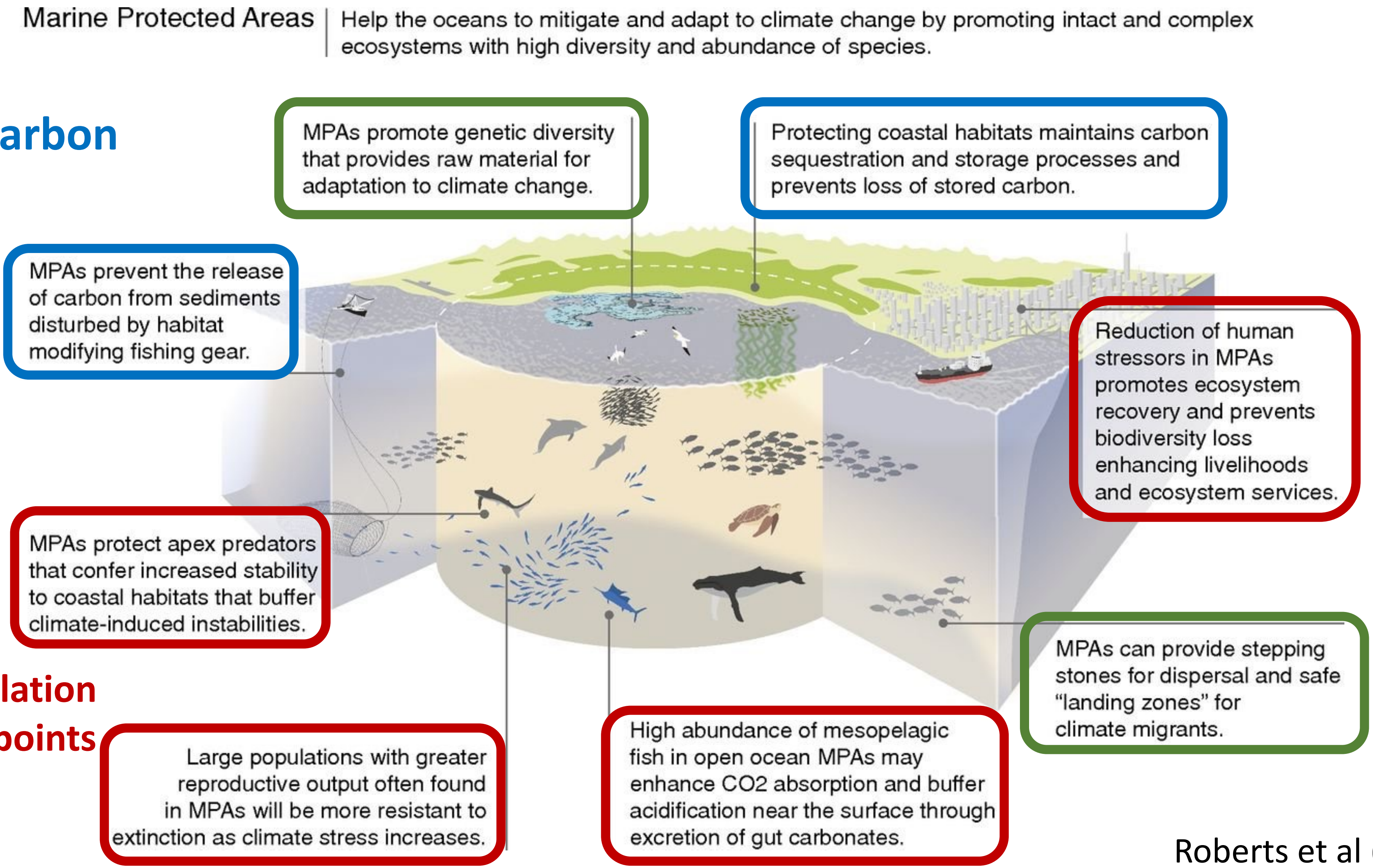


McGill

CAMBAM

Marine protected areas as dynamic networks

Blue carbon

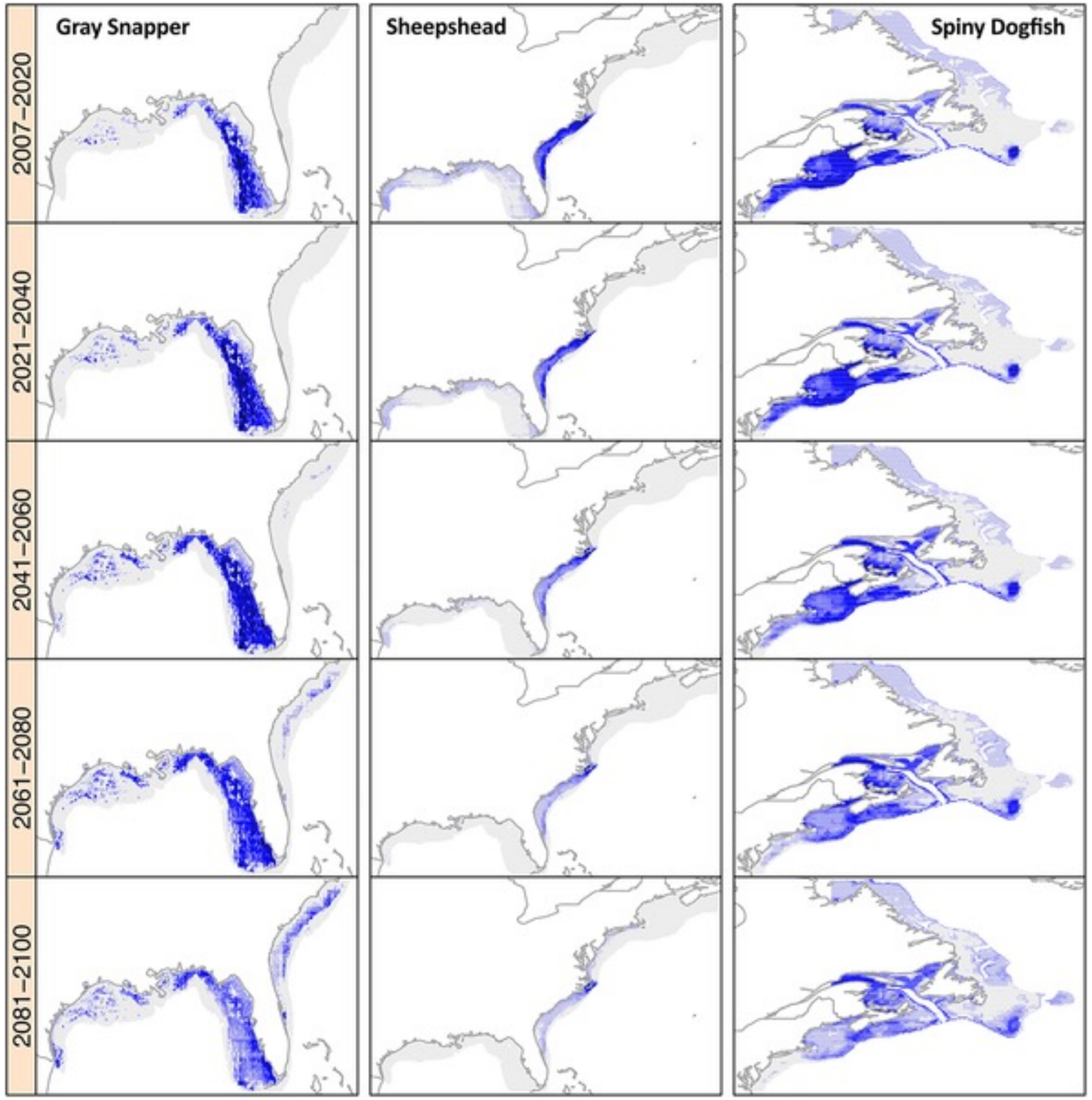


Connectivity & adaptation

Trophic regulation and tipping points

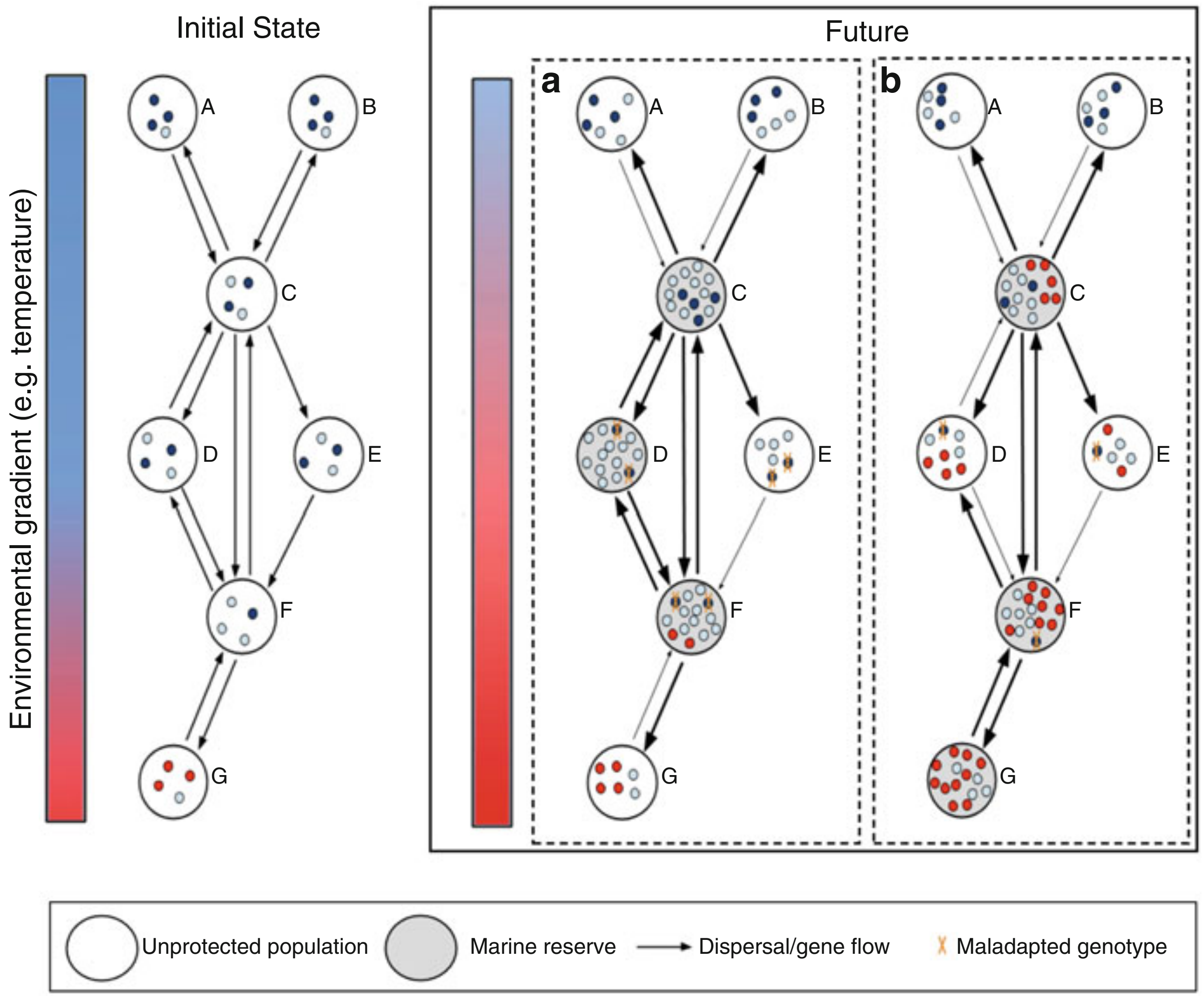
Roberts et al (2017, PNAS)

Dynamics of climate change: range shifts



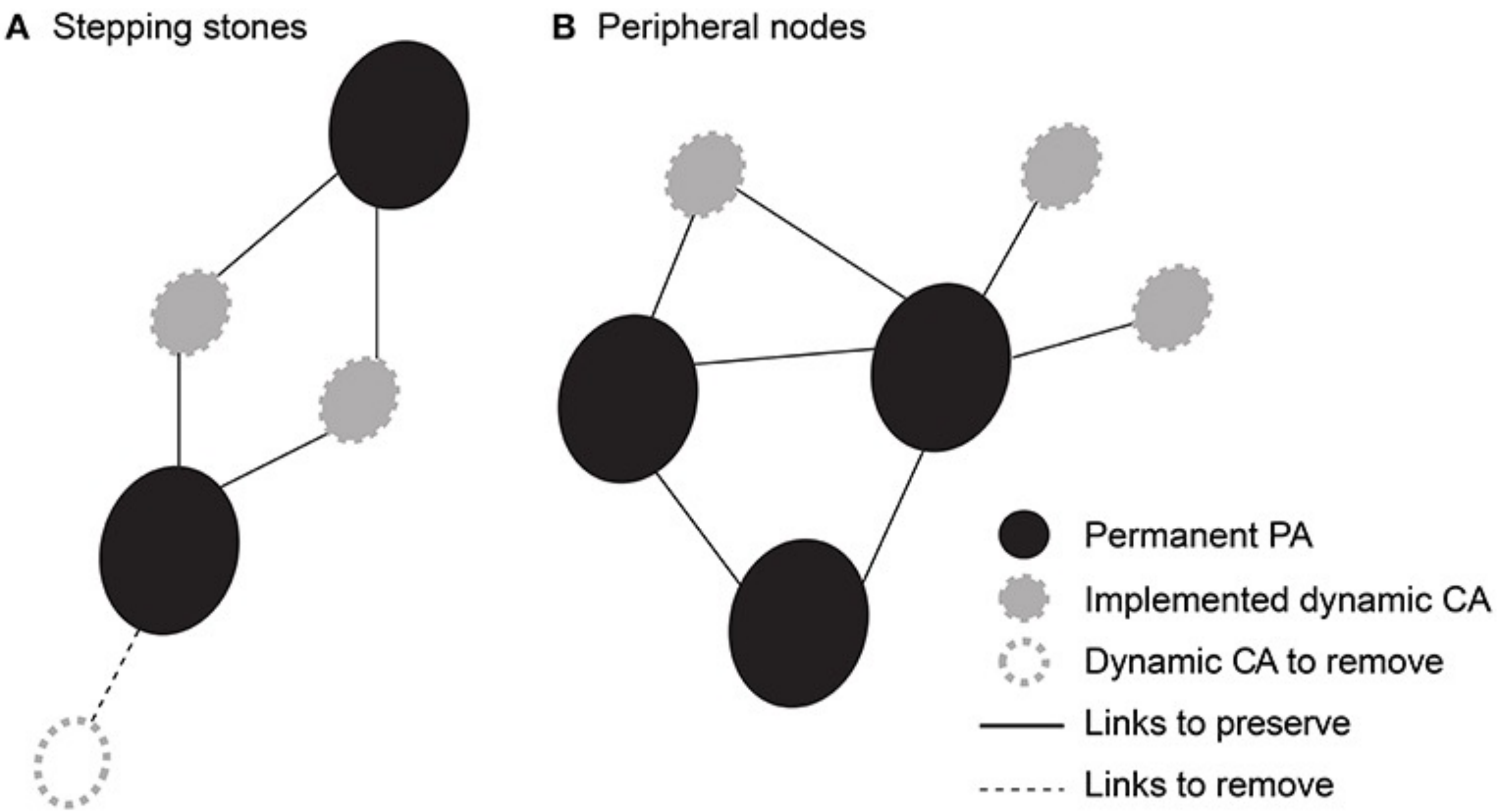
Morley JW, Selden RL, Latour RJ, Frölicher TL, Seagraves RJ, et al. (2018) Projecting shifts in thermal habitat for 686 species on the North American continental shelf. PLOS ONE 13(5): e0196127

Networks of protected areas: connectivity and adaptation



Xuereb A et al. (2018)

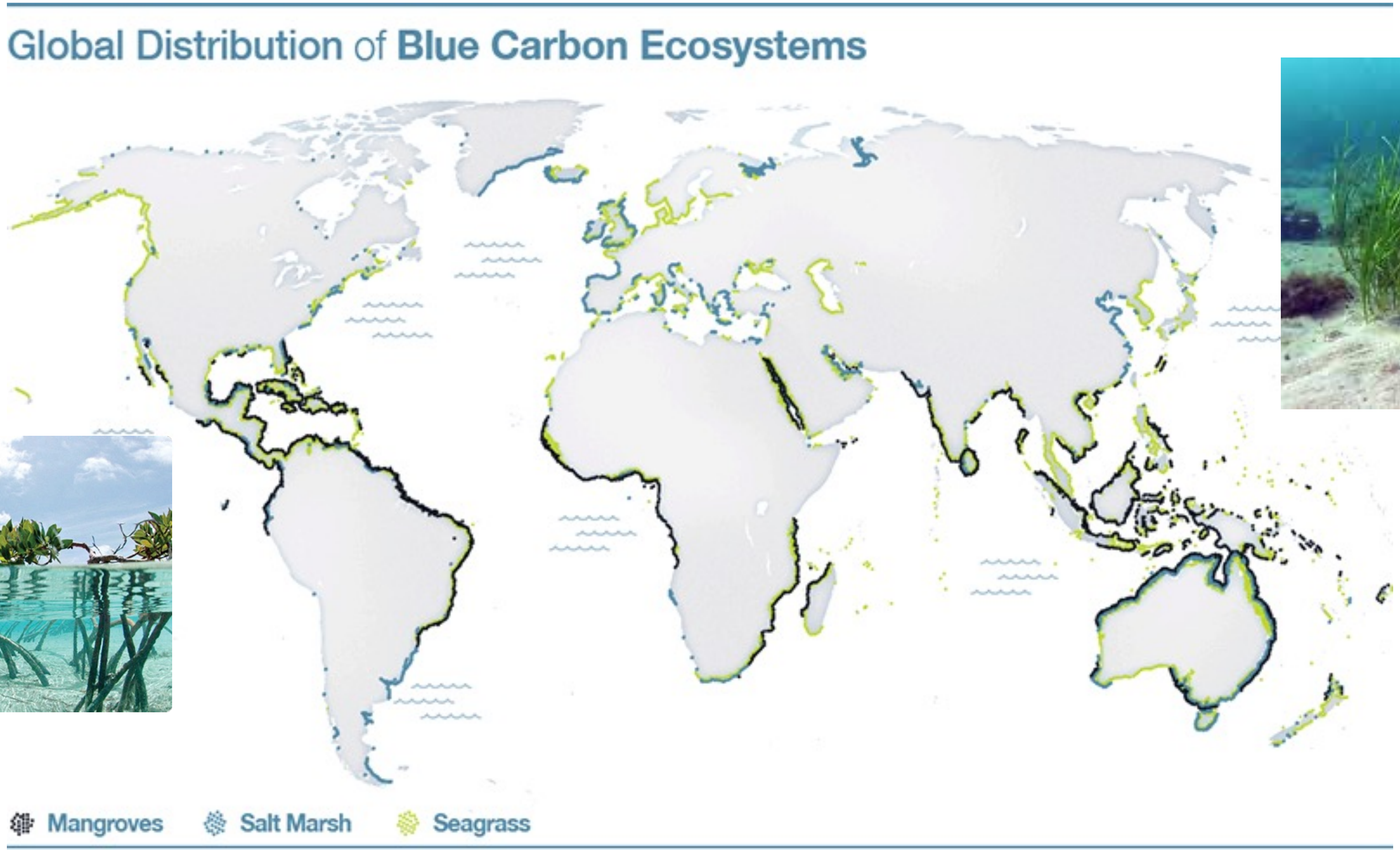
Integration of permanent and dynamic conservation areas



D'Aloia et al. 2019

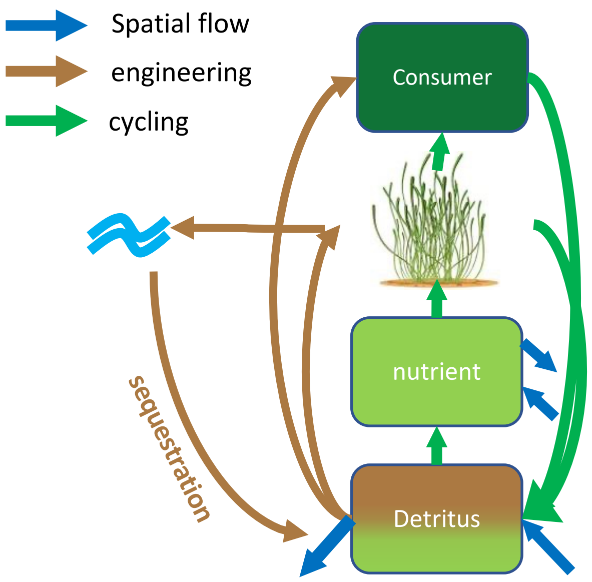
Blue carbon: carbon stored in coastal and marine ecosystems

'Ecosystem engineers' contribute to carbon sequestration

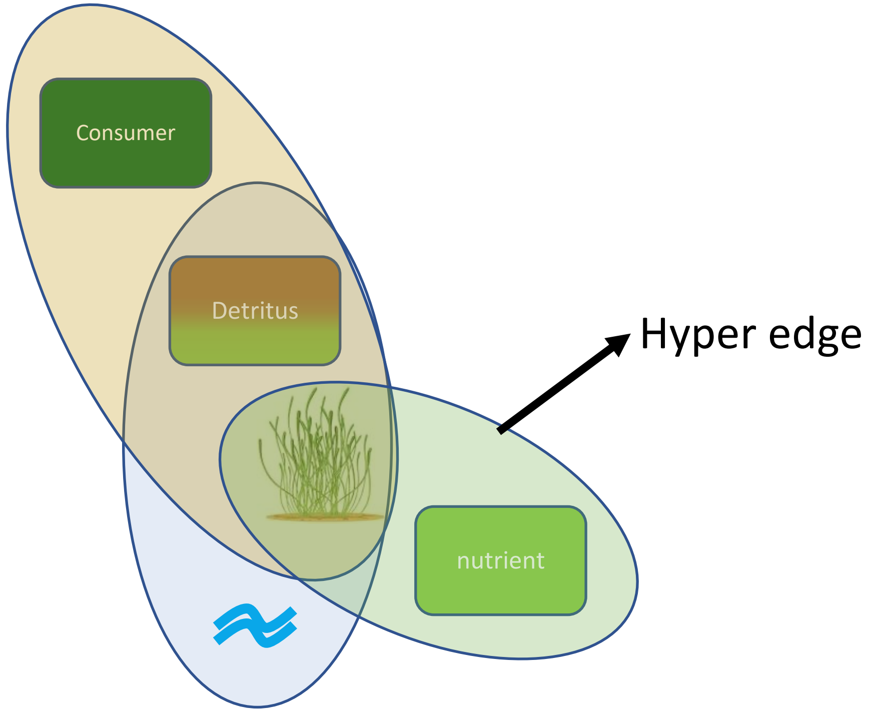


https://www.thebluecarboninitiative.org/

Ecosystem engineering: higher-order interactions and hypergraphs

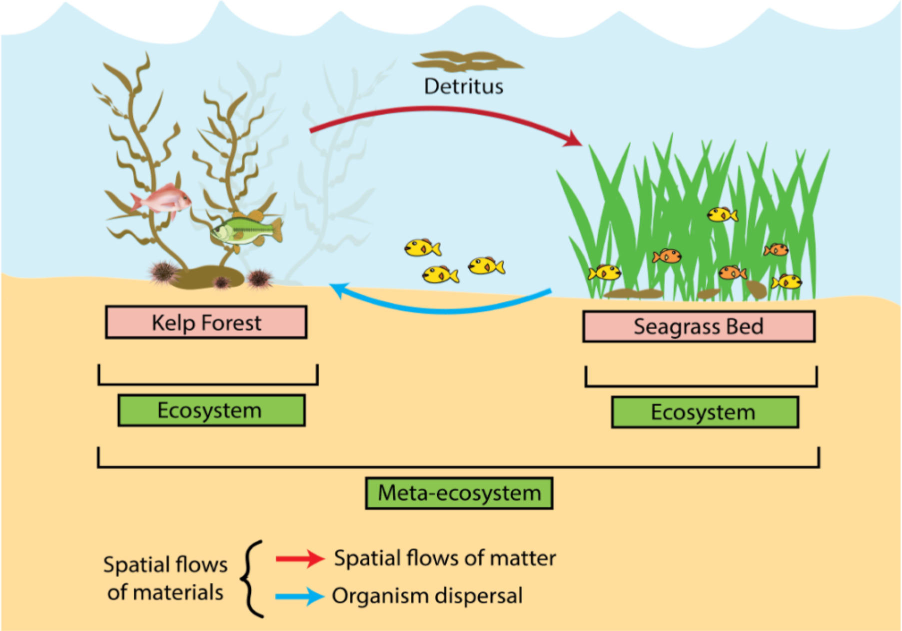


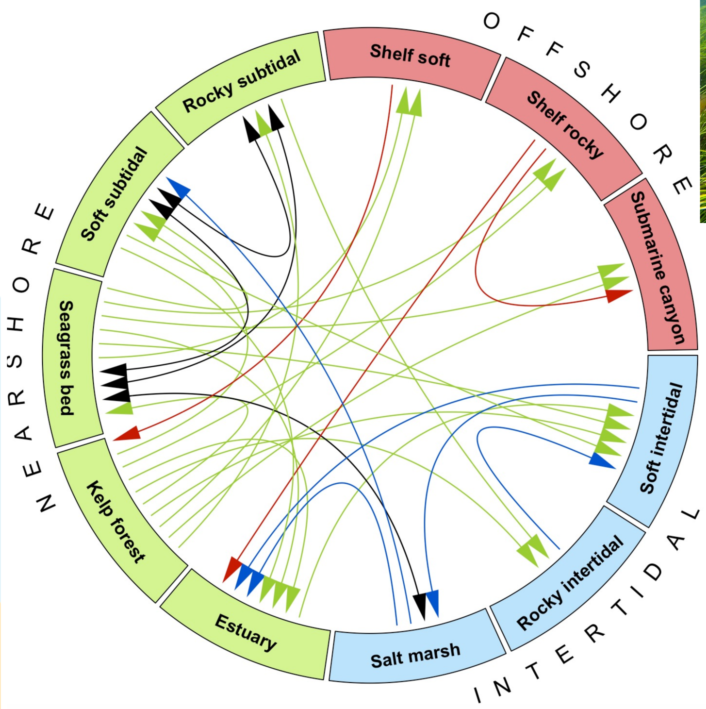
non-trophic (higher-order) interactions

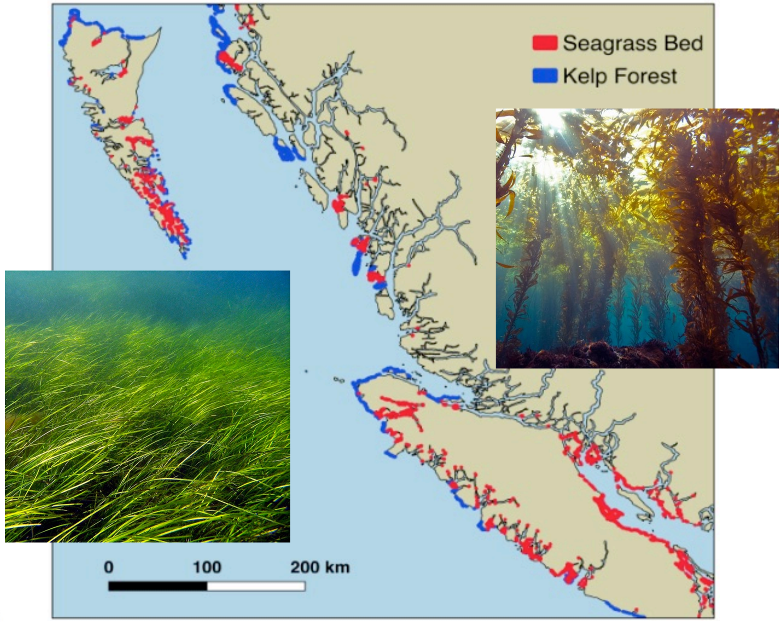


(annotated) Hypergraph representation

Meta-ecosystem engineering: spatial subsidies (detritus) in coastal ecosystems

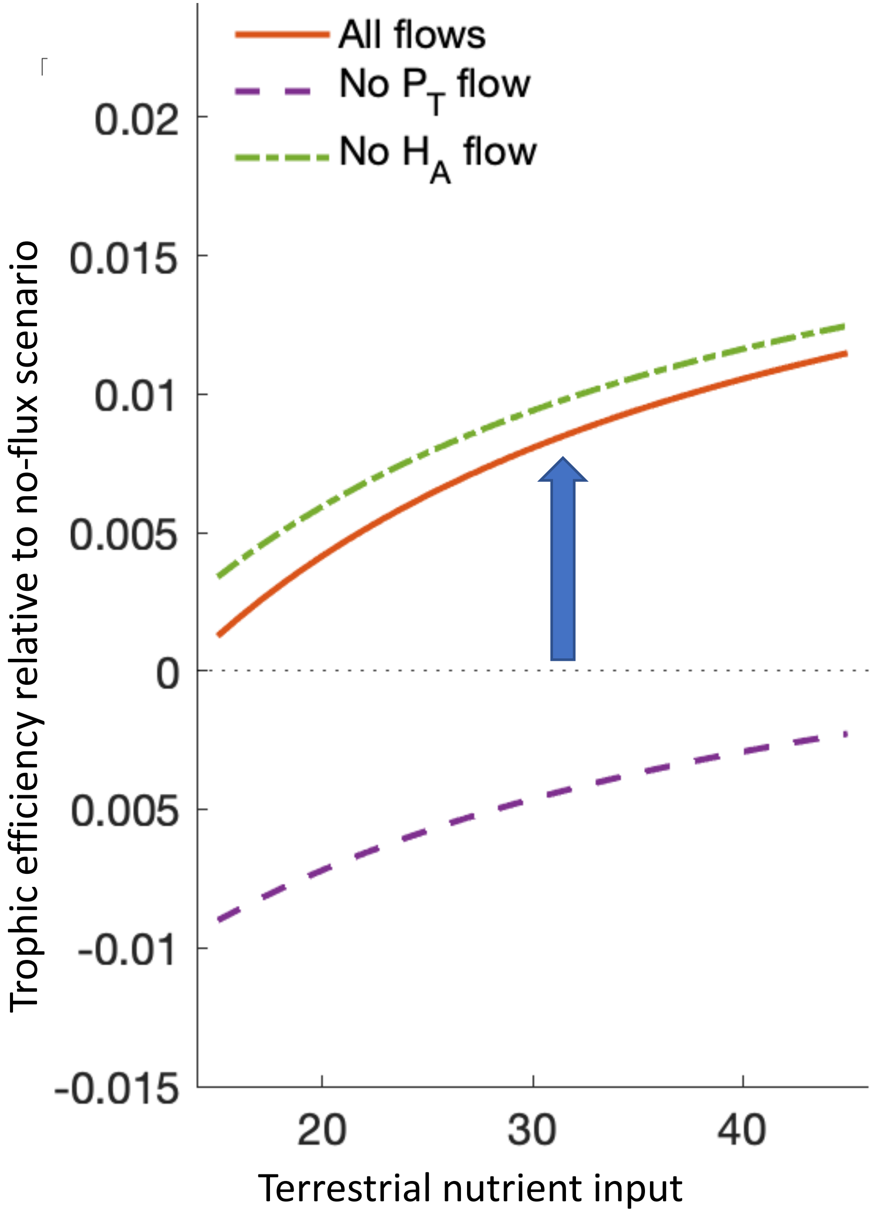


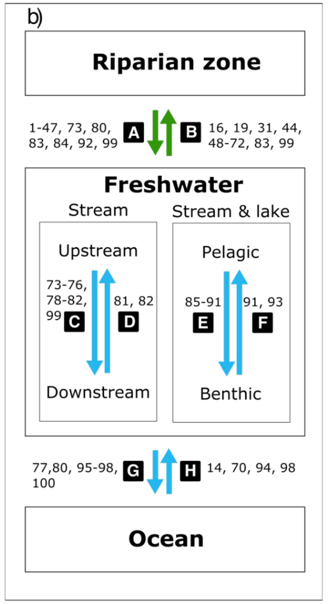




Peller et al. (2019)

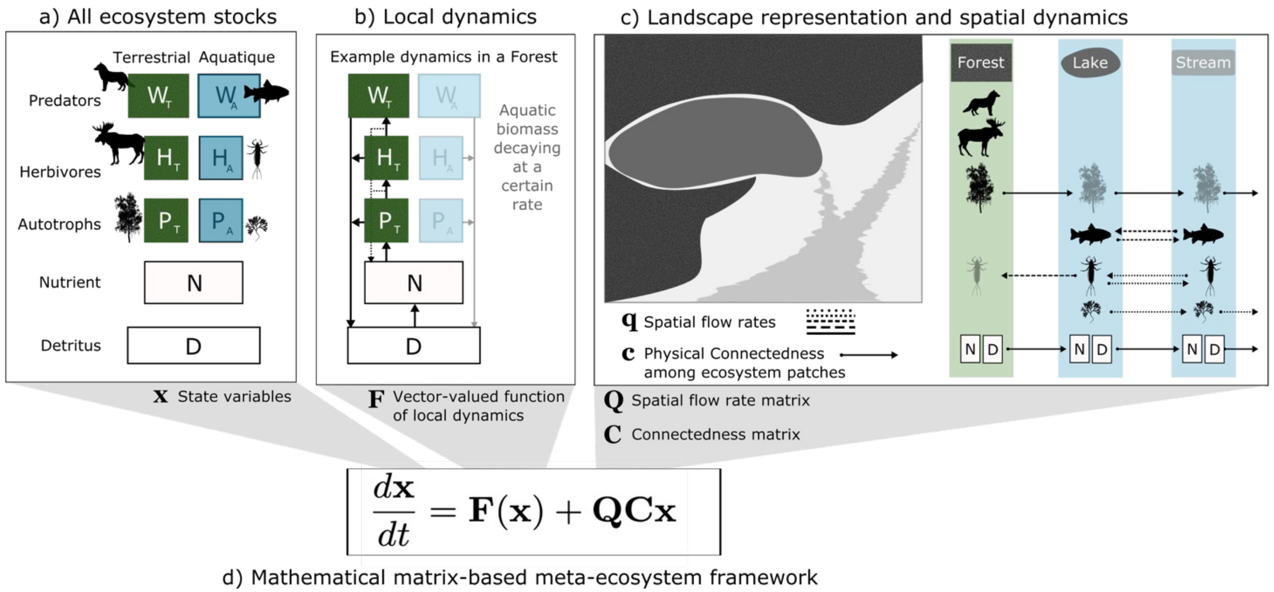
Cross-ecosystem fluxes increase meta-ecosystem efficiency





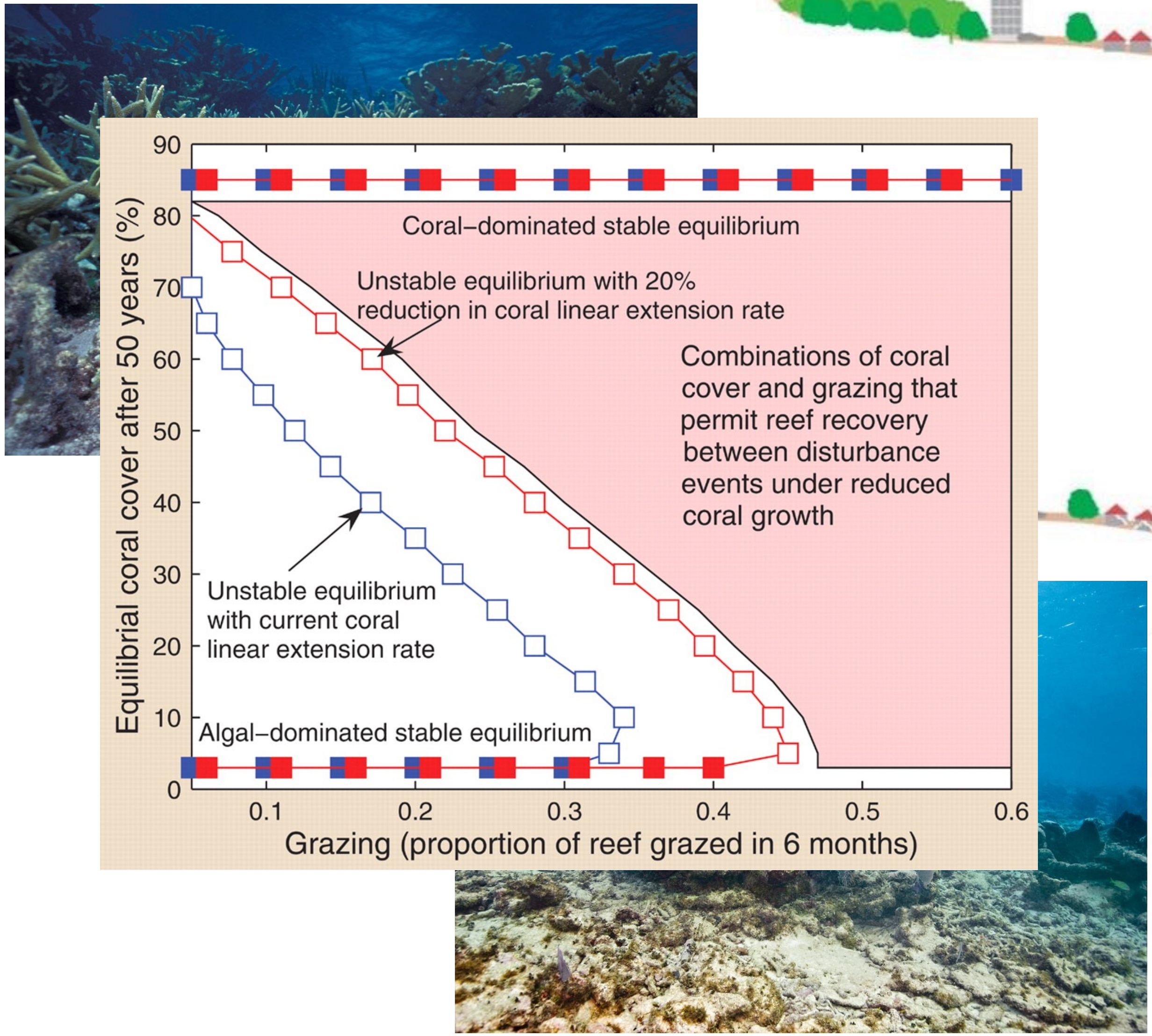
$$\mathbf{C} = \bigoplus_{k=1}^{m} (\mathbf{C}_k)^T = \begin{pmatrix} (\mathbf{C}_1)^T & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & (\mathbf{C}_2)^T & \cdots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & (\mathbf{C}_m)^T \end{pmatrix}$$

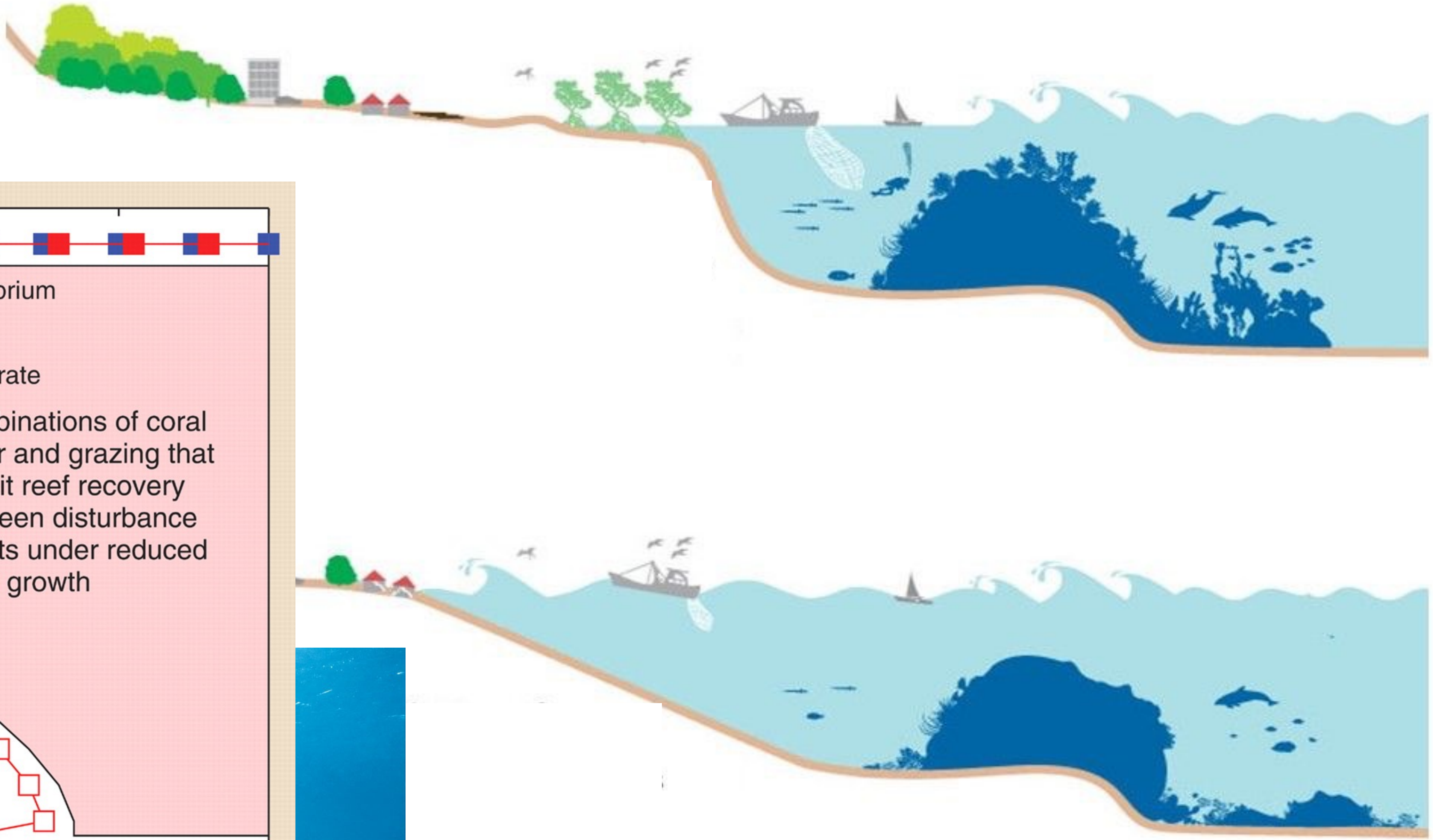
$$\mathbf{Q} = \mathbf{Q}' \otimes \mathbf{I}_{(n,n)} = \begin{pmatrix} q_1 \mathbf{I}_{(n,n)} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & q_2 \mathbf{I}_{(n,n)} & \cdots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & q_m \mathbf{I}_{(n,n)} \end{pmatrix}$$



Tipping points: coral reef ecosystems

1980

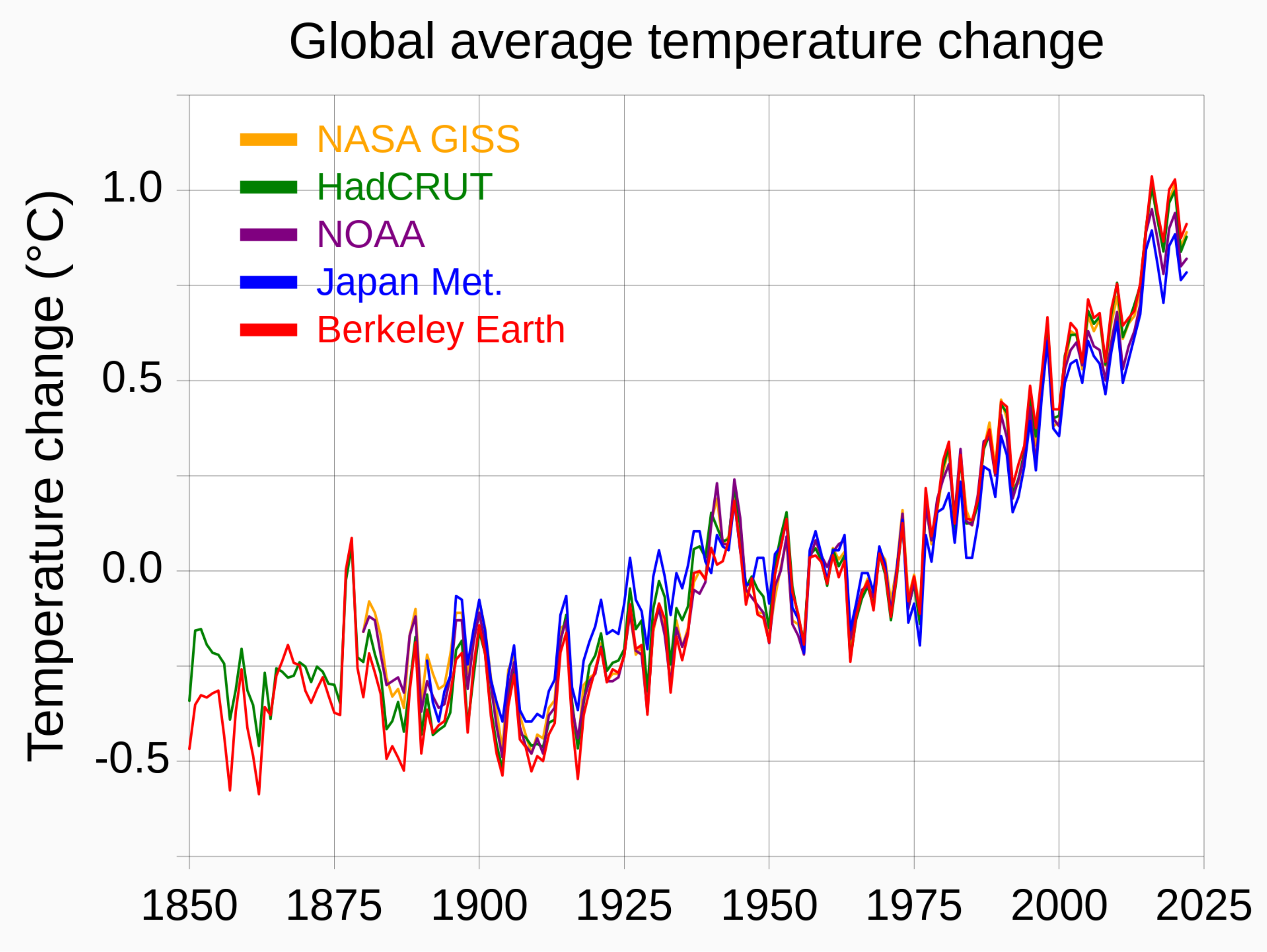




Hoegh-Guldberg et al. (2008, Science)

Images: David Arnold,www.doublexposure.net

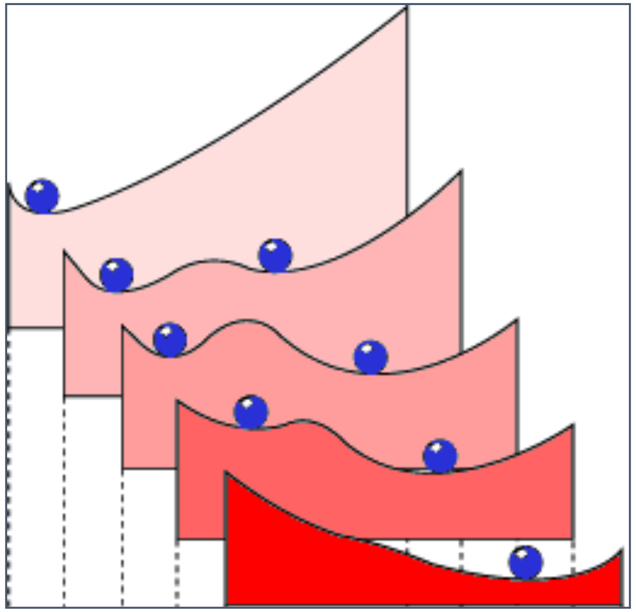
Dynamics of climate change: rate-dependent impacts



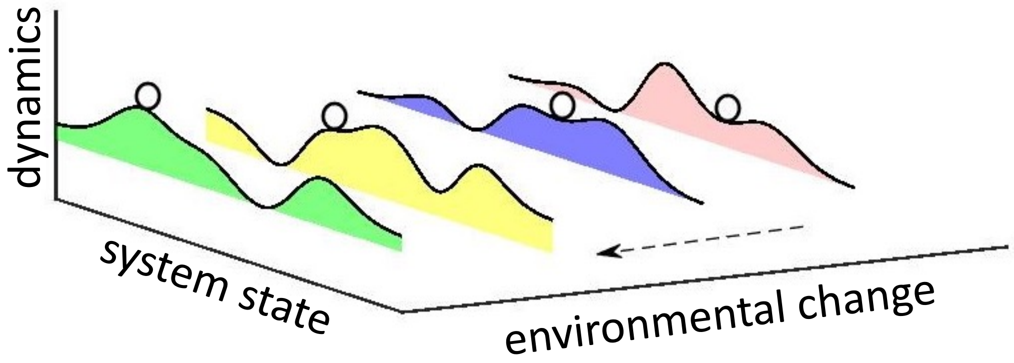
NASA-GISS HadCrut NOAA (Wikipedia)

The rate of environmental change can drive ecological response

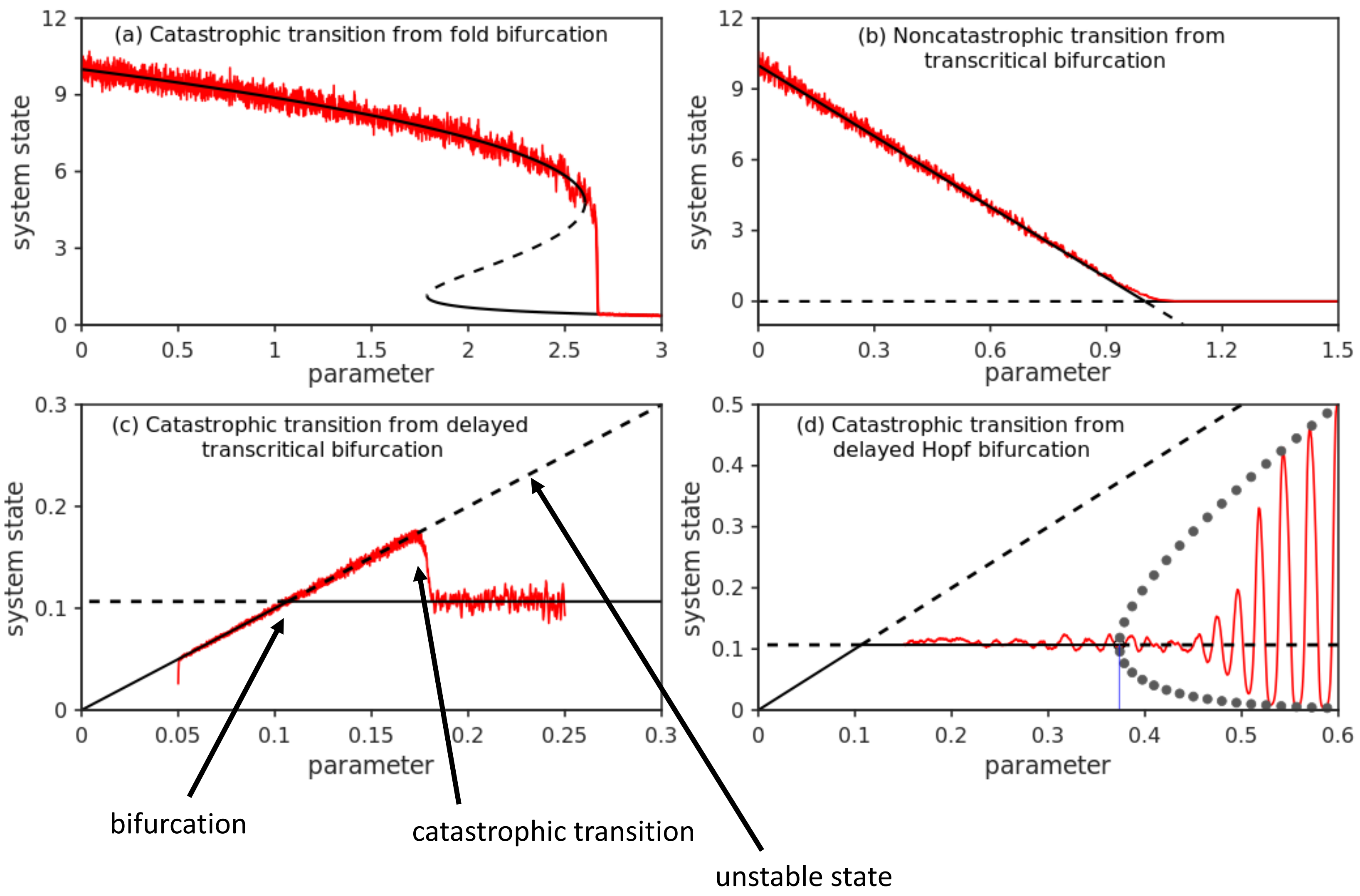
Stability landscape at equilibrium



Non-equilibrium: the ecological states is under a shifting stability ‘landscape’



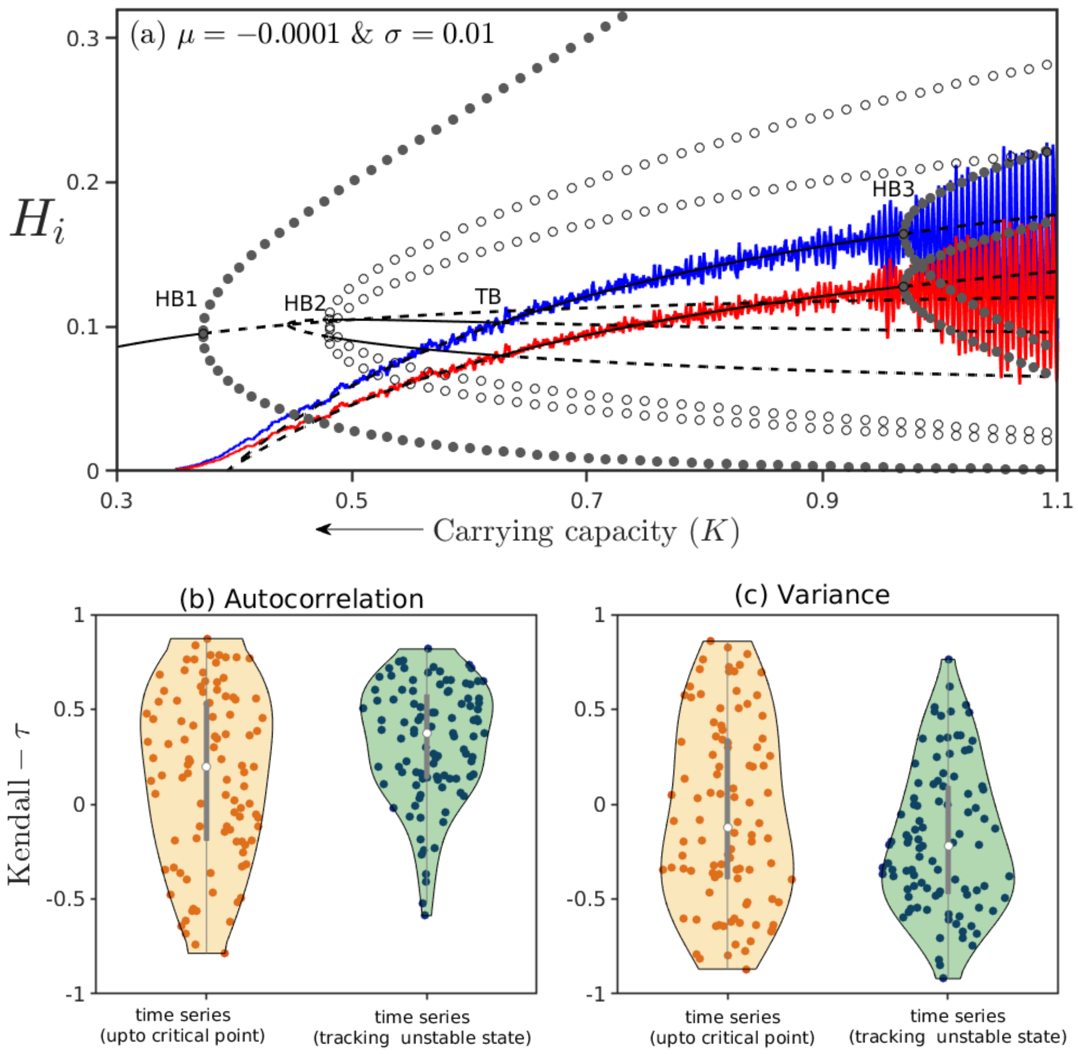
The rate of environmental change can decouple bifurcation and transitions



Arumugam et al. (2020, 2021, in rev)

Early-warning signals of bifurcations vs transitions

- Non-catastrophic transcritical bifurcation leads to extinction

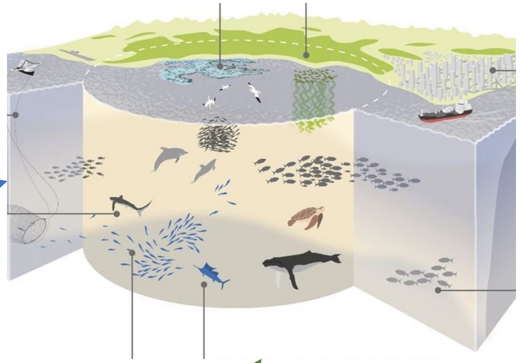


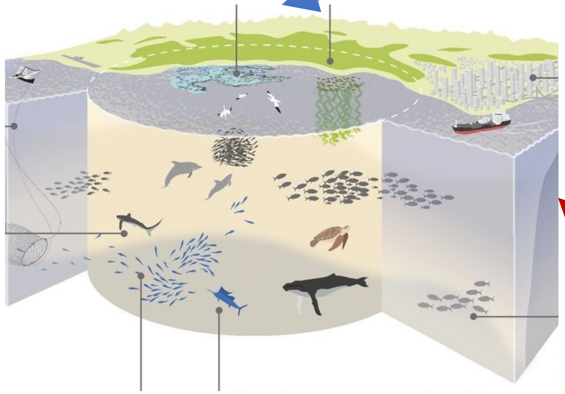
- Variance: false-negative prediction of catastrophic transition
- Transition predicted by autocorrelation but not the bifurcation

Conclusions

Blue carbon:

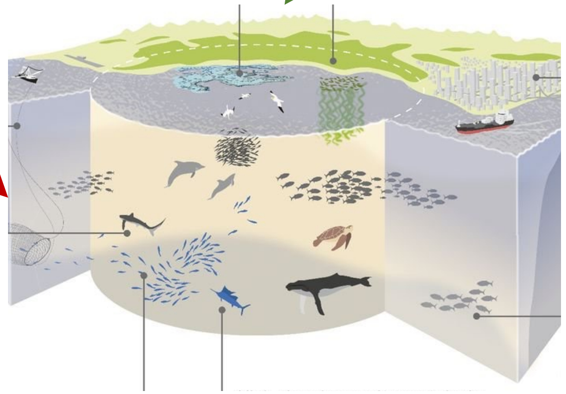
- Cross system fluxes and non-trophic interactions





Connectivity & adaptation:

- Eco-evolutionary dynamics on networks
- Network rewiring
- Dynamic MPA networks



Trophic regulation and tipping points:

- Rate-dependent tipping