University of Trieste: GLOBAL CHANGE ECOLOGY a.a. 2019-2020

BIODIVERSITY AND ECOSYSTEM FUNCTIONING

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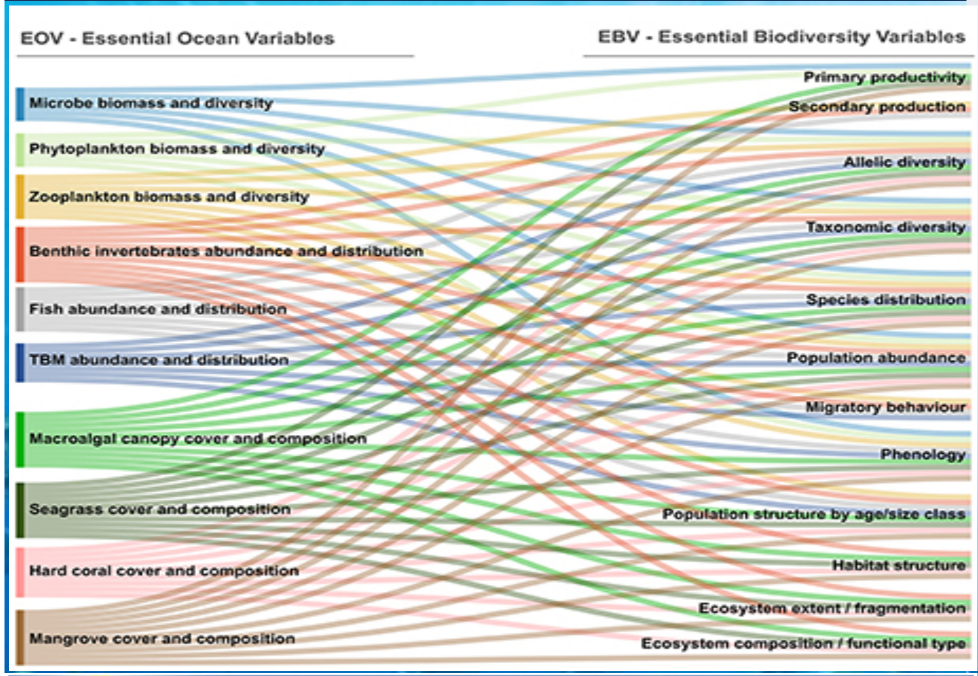
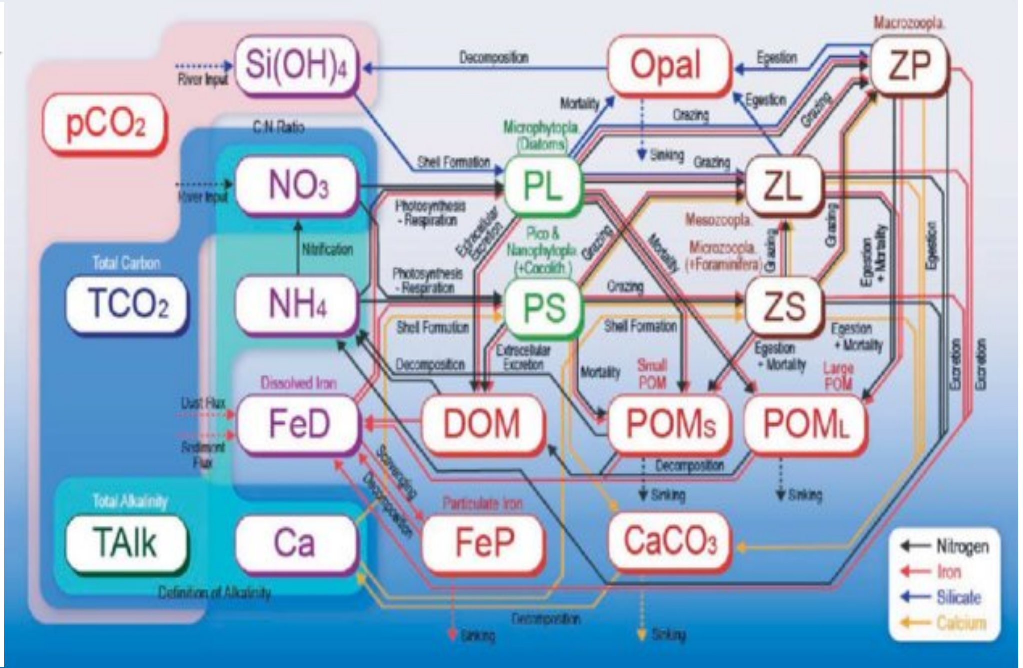
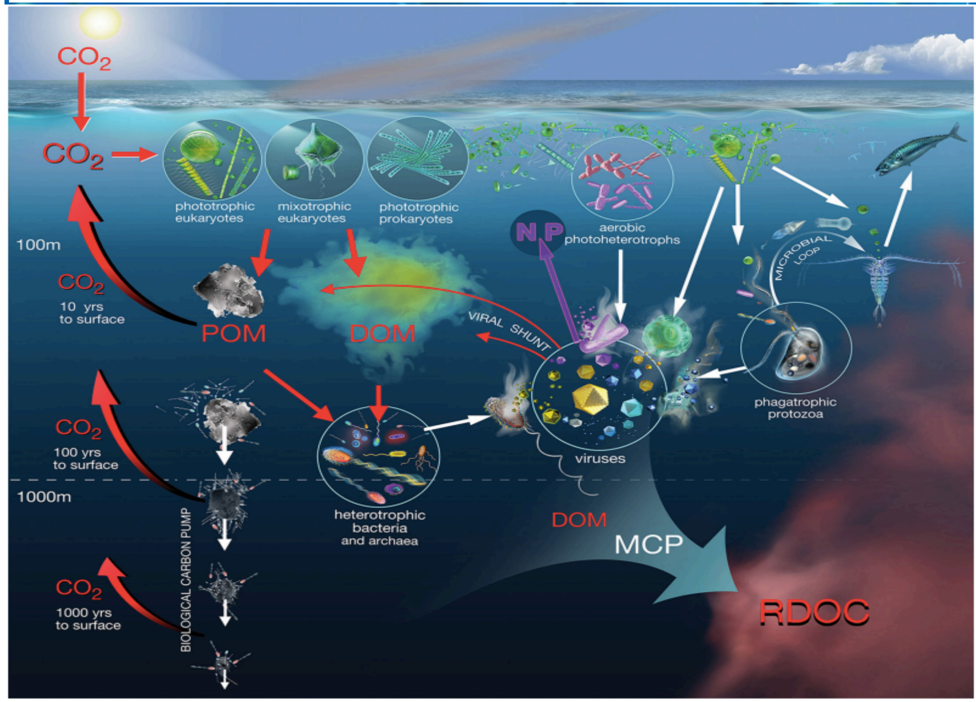
Marine ecosystem dynamics

Ecosystem complexity

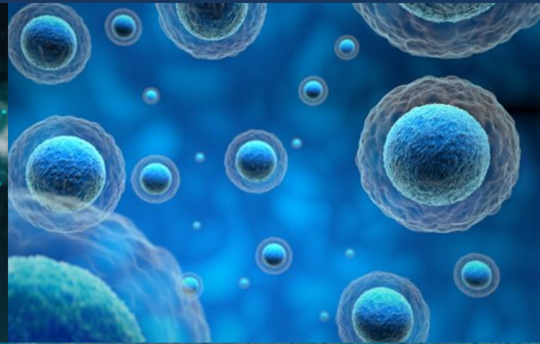




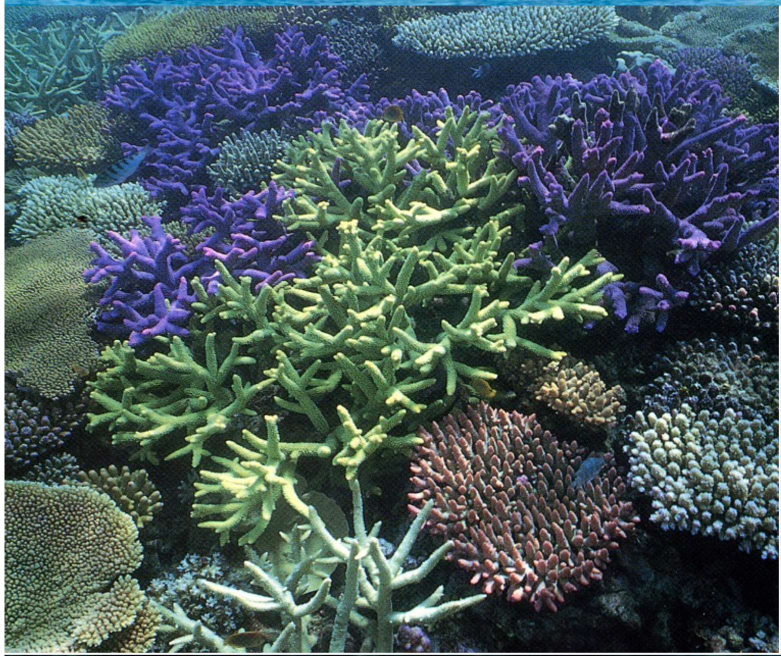


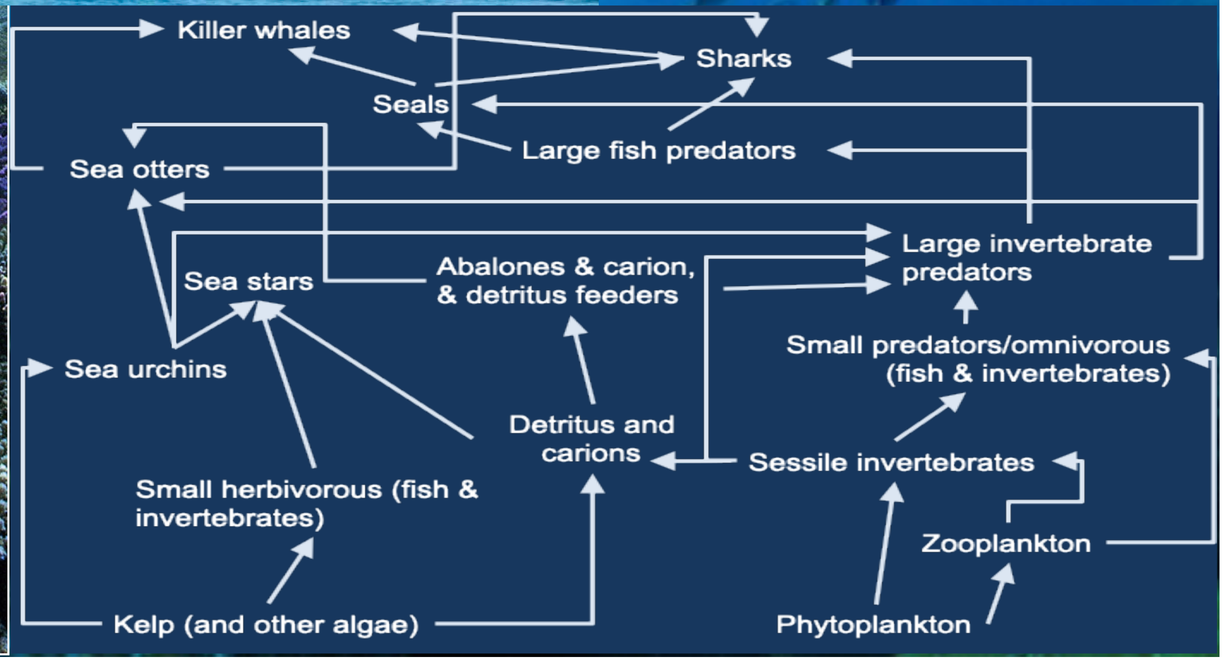
Ecosystems are complex. This stems from the huge number of components (abiotic and biological) and their respective interactions (predation, competition, parasitism, trophic relations, cycling of organic and inorganic matter, decomposition, and many others). Complexity is so high that generate emergent properties. These properties allow ecosystems to self-sustaining, self regulating, and self-repairing.

Emergent properties



The whole is more than the sum of components



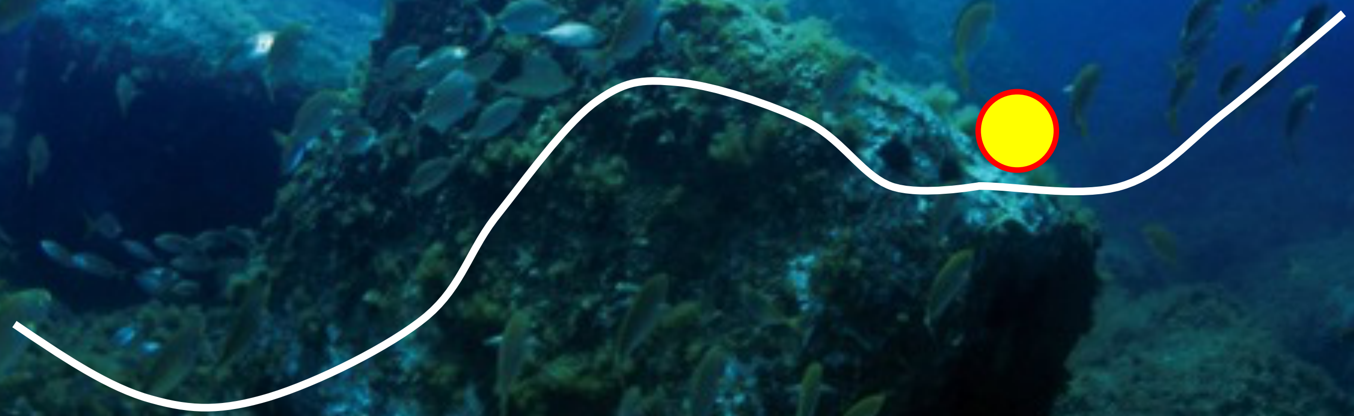


Ecosystem state(s)

Attractor—The dynamic regime to which a system converges under constant environmental condition.

Alternative stable states—The different attractors to which a system may converge. Also known as alternative dynamic regimes or alternative attractors.

Critical threshold—The point at which the qualitative behaviour of a system changes. It is usually associated with the shift between two alternative dynamic regimes. Also known as tipping point or bifurcation.



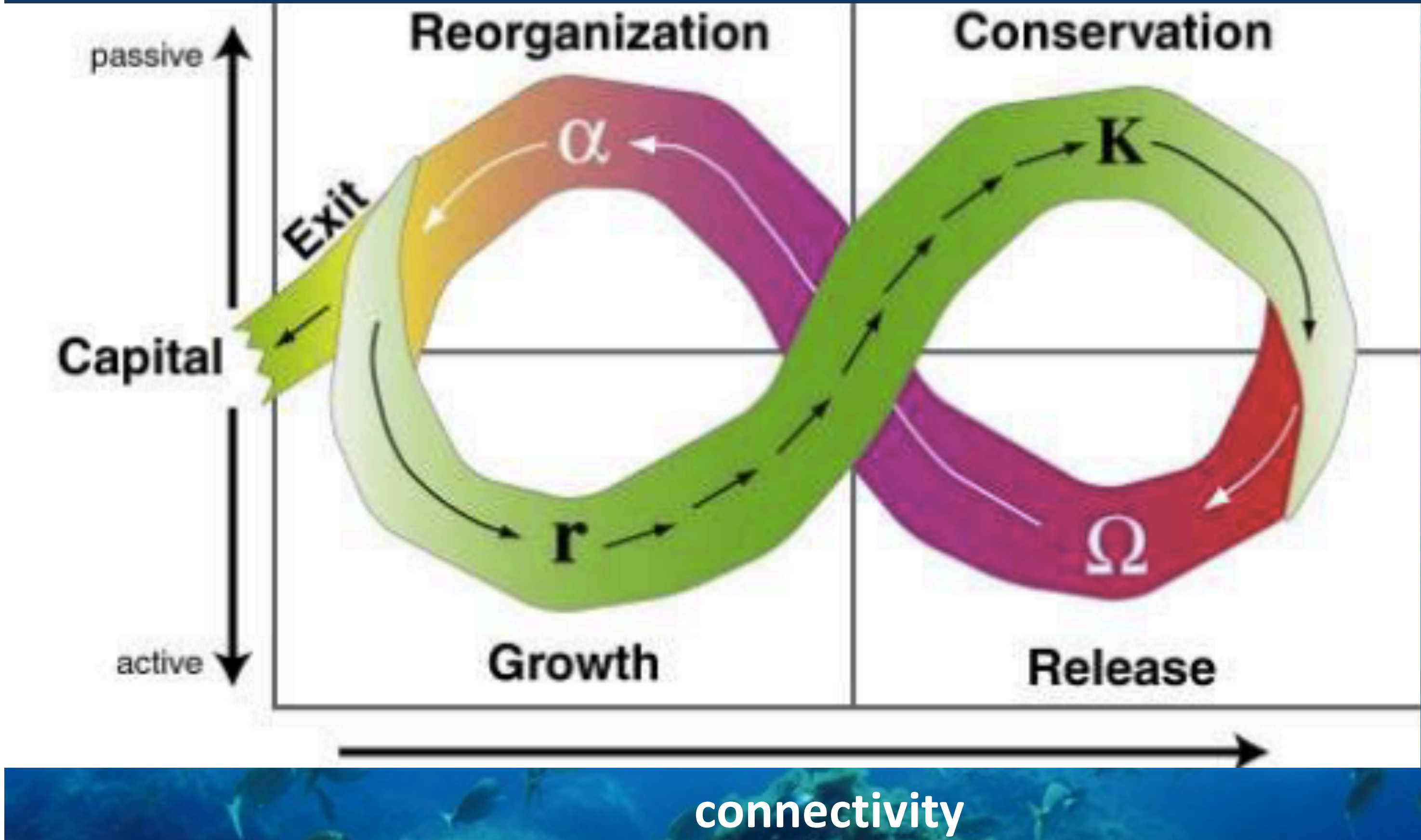
Resilience, resistance, persistence

RESISTANCE: One of the components of resilience—a measure of difficulty in moving a system within a basin of attraction (Walker et al. 2004); 'the ability of an ecosystem to resist displacement from its reference state during a perturbation stress'

RESILIENCE: The capacity of a system to absorb disturbance and reorganize while undergoing change so as to maintain essentially the same functions, structure, identity and feedbacks

PERSISTENCE: the capacity of a system to maintain its integrity, that is its distinctiveness in terms of structure, processes and functions

Cycle of Holling

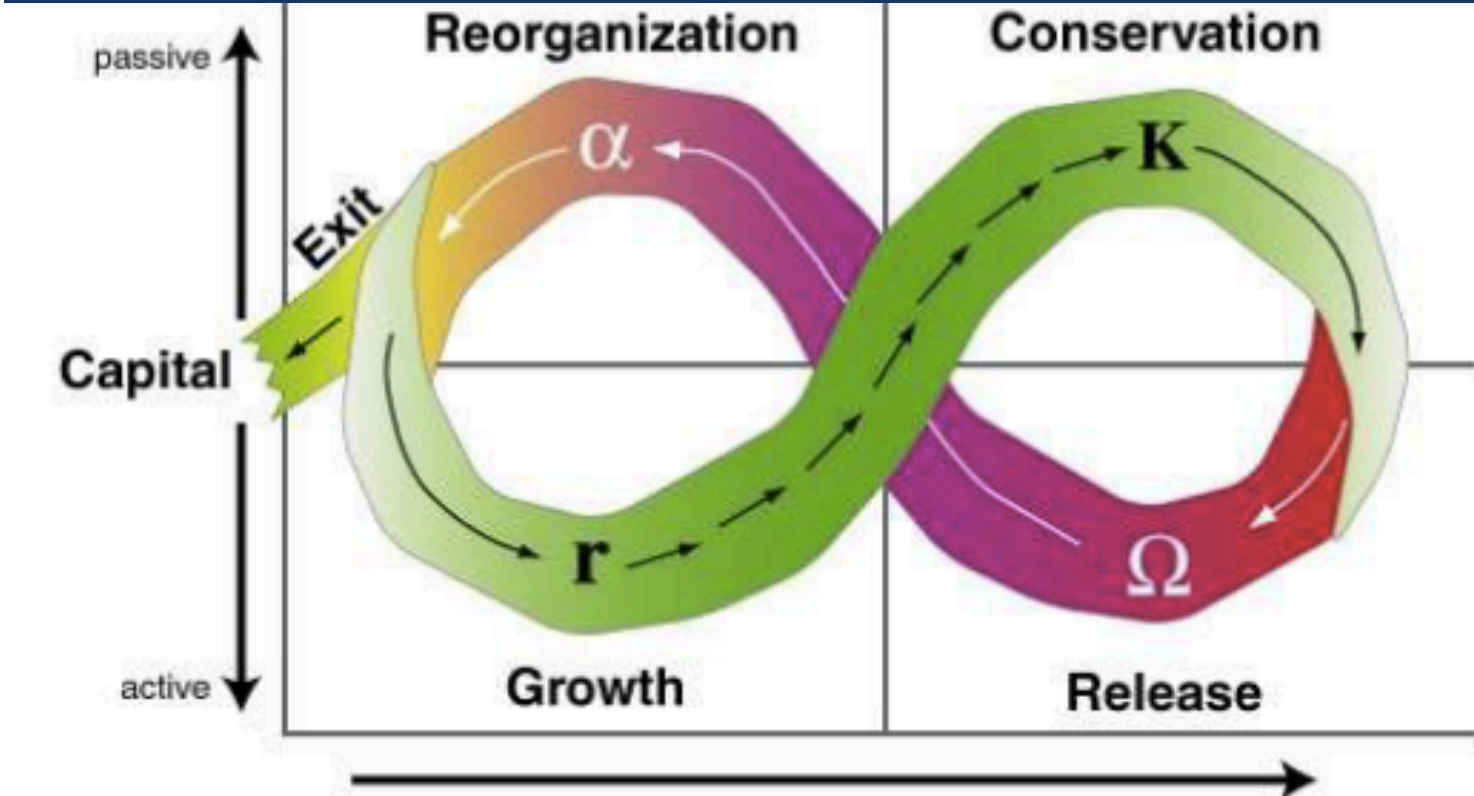


Gunderson e Holling, 2002

Adaptative cycle within the stability domain (basin of attaction) of a given system

1. **Growth phase**
2. **Conservation phase**
3. **Release phase**
4. **Reorganization phase**

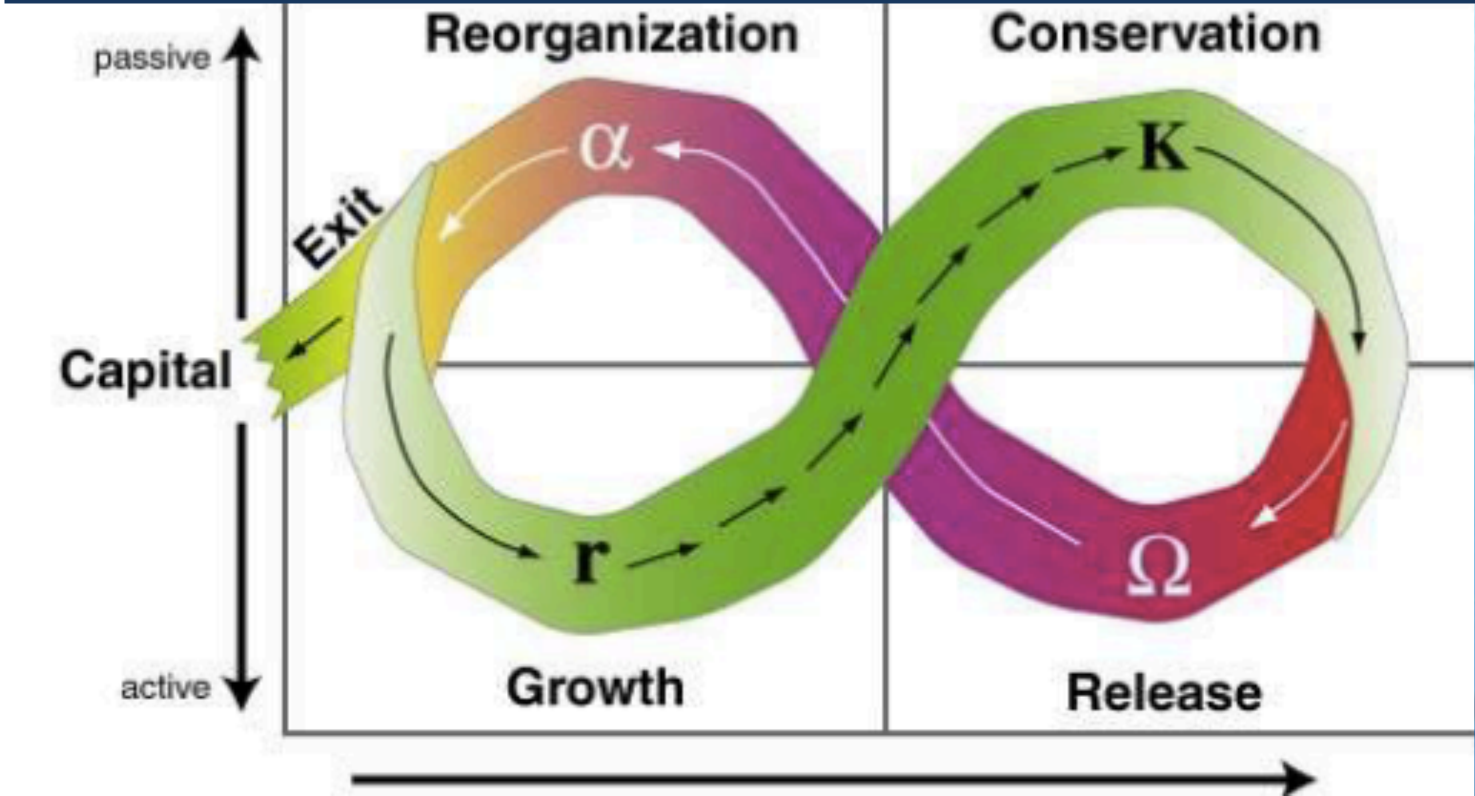
Growth



connectivity

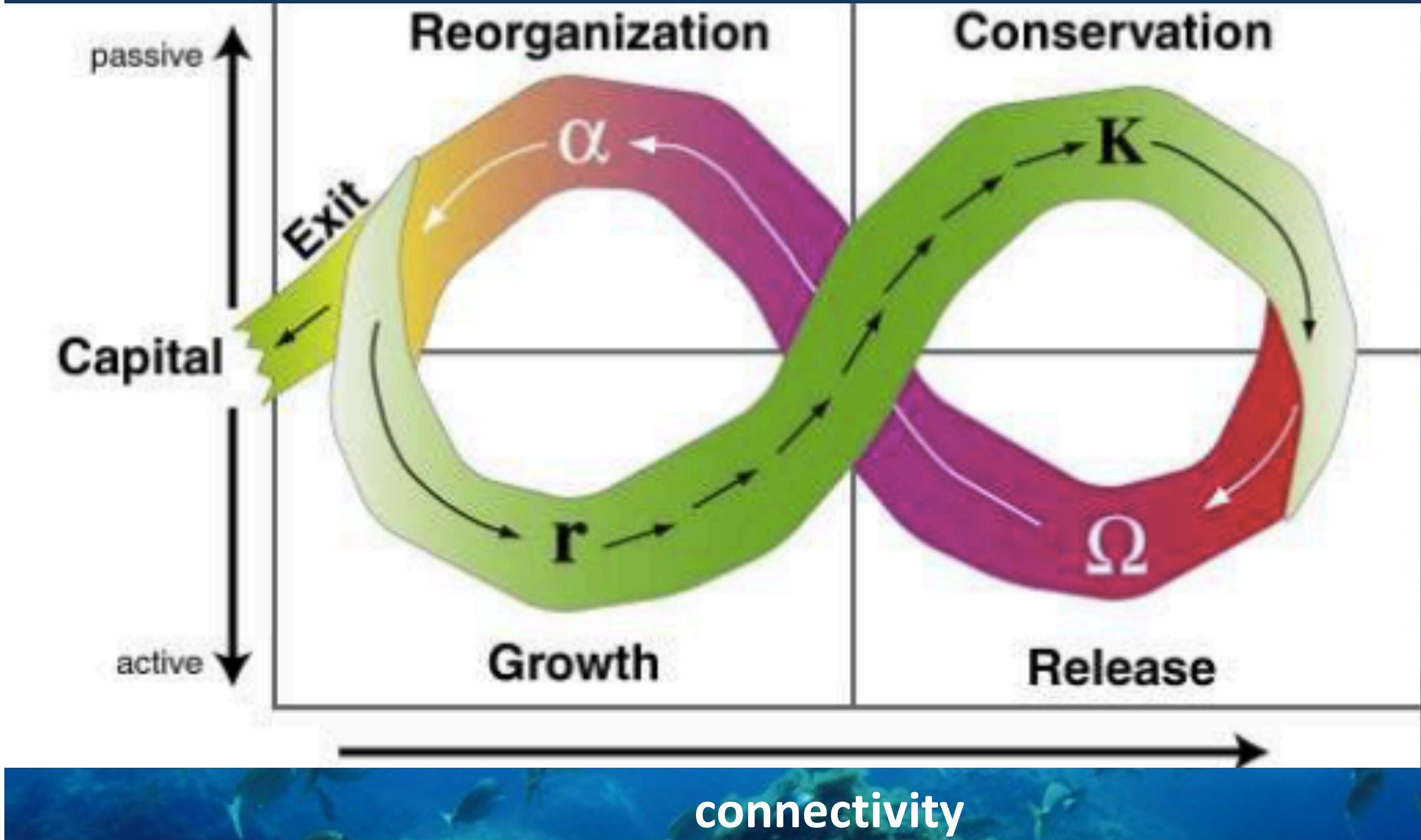
Rapid growth with r species, resources are available and not capitalized. Connection among species are limited. This is the phase in which the system is forming and structuring.

Conservation



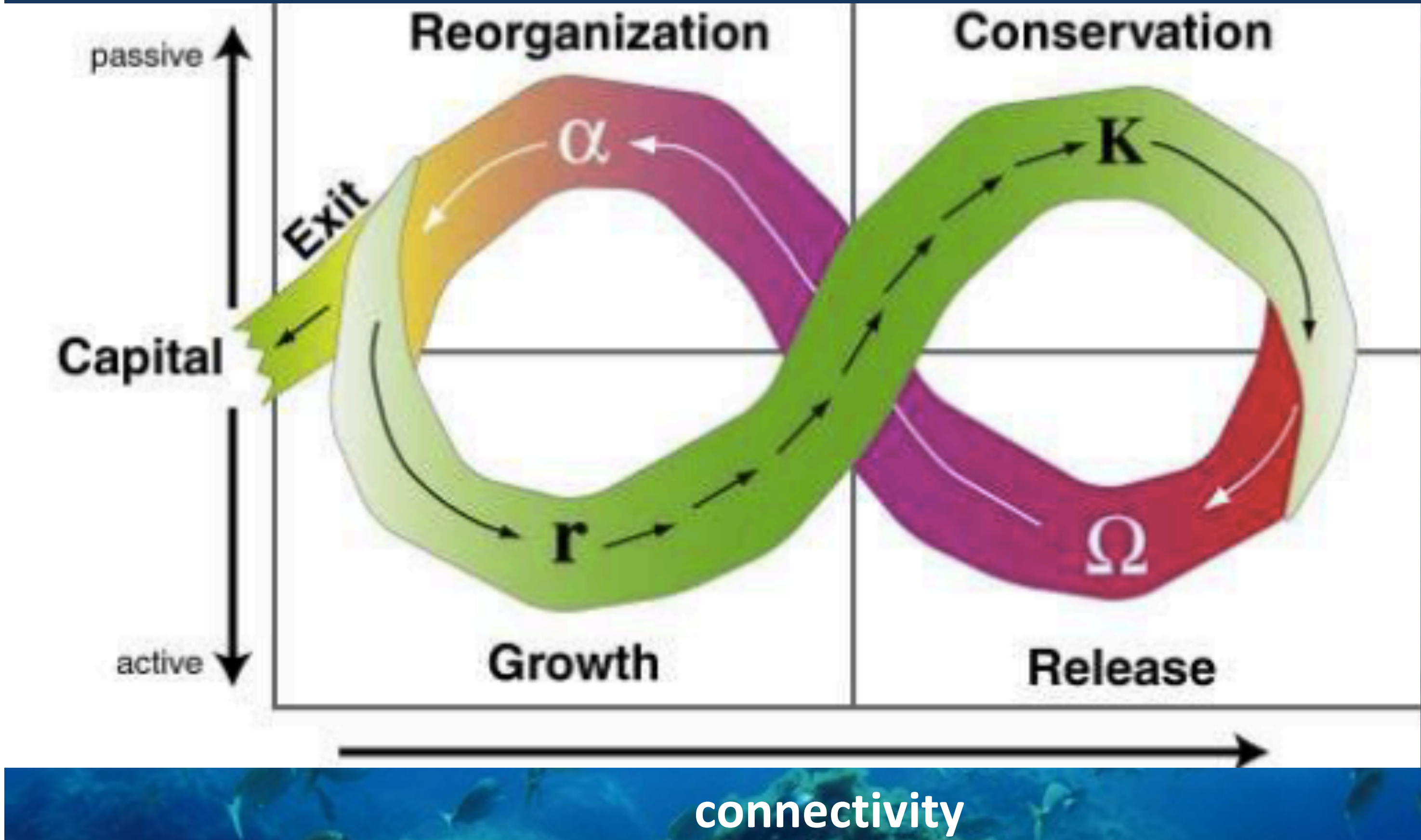
Period of conservative status, with k species. Resources are capitalized, and connections among species are strong and structured. Specialization and conservation of functions.

Release



Following a perturbation the system is destabilized, resources are released and available. Connections start to break eventually

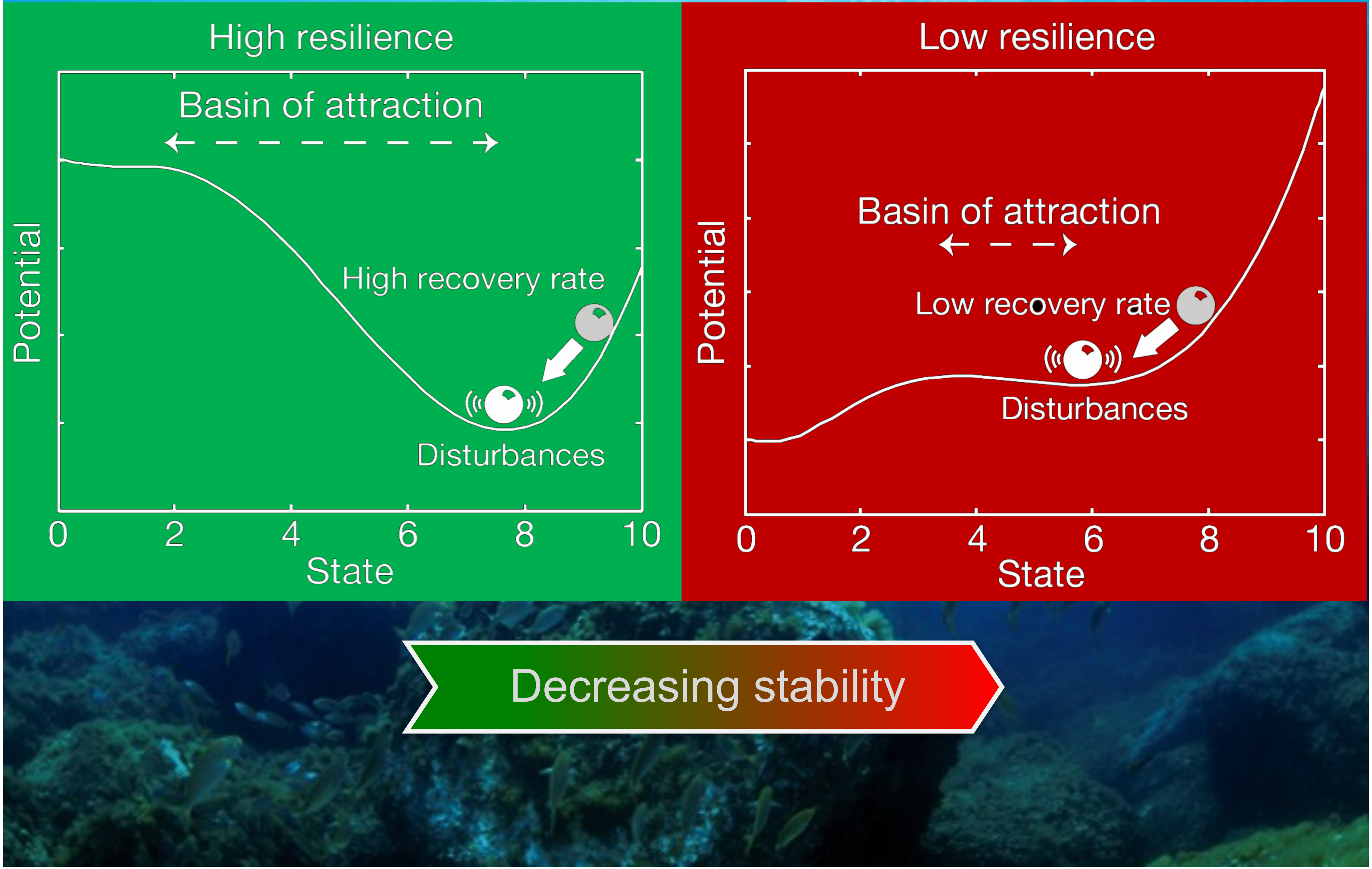
Reorganization



Resources are available for reorganizing the system, to restablish the original structure and connections passing by a new growth phase…or shifitng towards a different regime

Ecosystem stability

Modified from Scheffer et al., 2009



Phase shifts

Box 1. Definitions

Ecological regime shift—Dramatic, abrupt changes in the community structure, encompassing multiple variables, and including key structural species (*definition from this Theme Issue*) (figure 1). Note that the term *regime shift* is synonymous with *phase shift*, the former being used prevalently in open ocean systems, the latter in spatially fixed systems such as reefs. Also termed *state shifts* or *ecosystem reorganizations*. Regime shifts that involve the crossing of a tipping point and pertain to systems with alternative states are also called *critical transitions*.

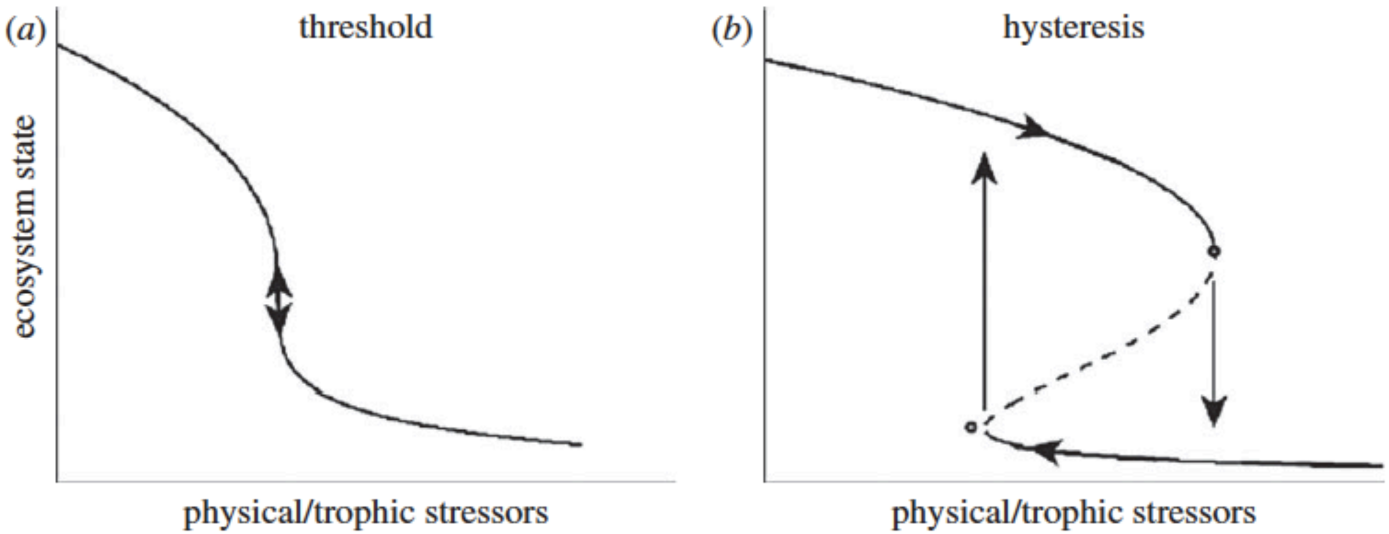
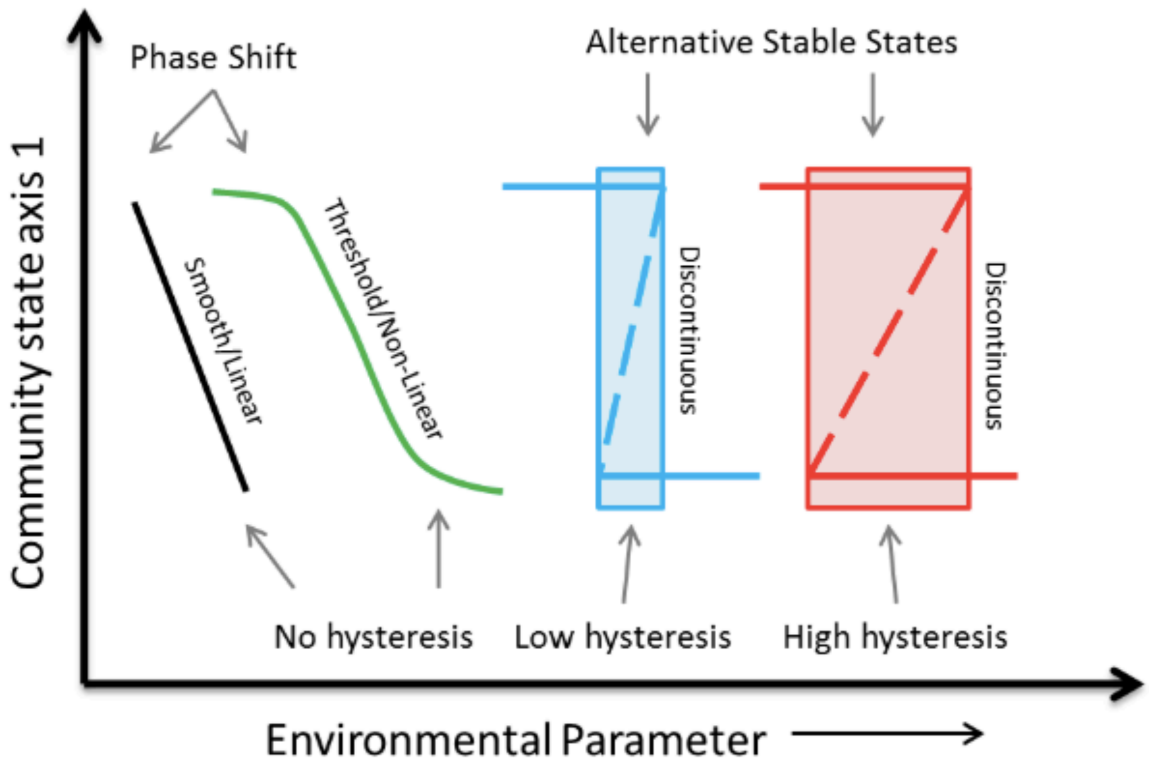


Figure 1. Examples of regime shift. Two different responses are shown, one without (*a*), and the other with hysteresis (*b*), both of which are encompassed by our working definition of regime shifts (adapted from [5]).

Regime and phase shifts – tipping point/bifurcations/critical transitions

Phase shifts

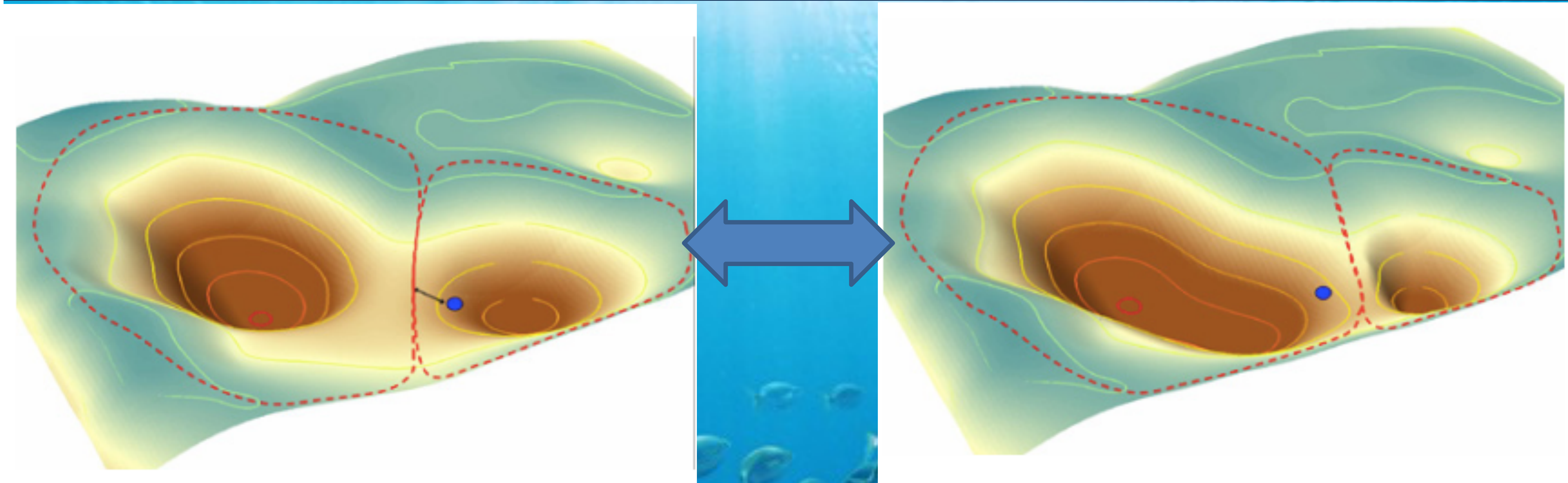


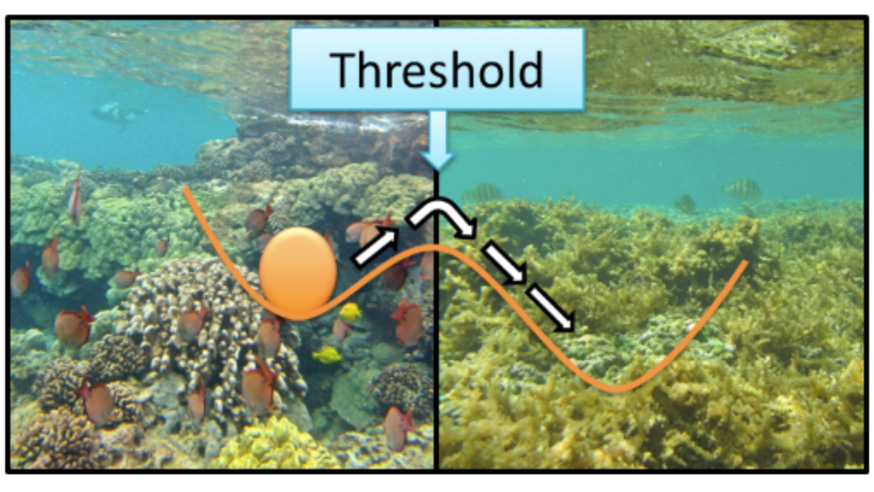
Smooth or Linear- characterized by a linear or nearly linear relationship between the stressor (e.g. fishing effort) and the ecosystem state (e.g. fish abundance) variables

Non-linear- characterized by a non-linear relationship between conditions and the ecosystem state variables. The rate of change in ecosystem state speeds up when crossing the threshold between regimes

Hysteretic or Discontinuous- characterized by a non-linear relationship with hysteresis – in which the path from state A to B (degradation) is different from the path from B to A (recovery) and may be very hard to reverse

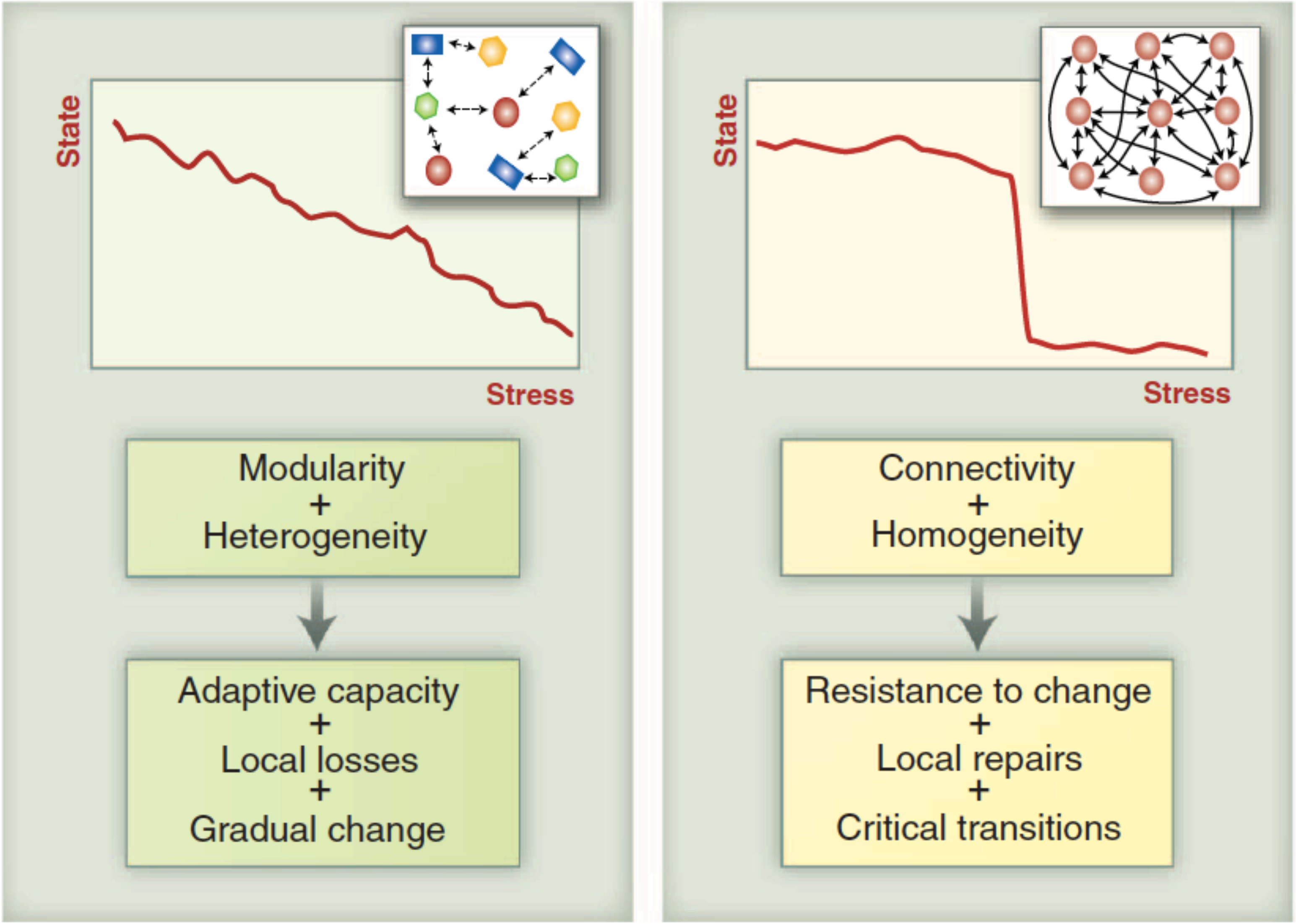
Phase shifts





Changes in landscape of conditions and basins of attraction (enlargement, reduction) as a consequence of resilience erosion, smoothing thresholds

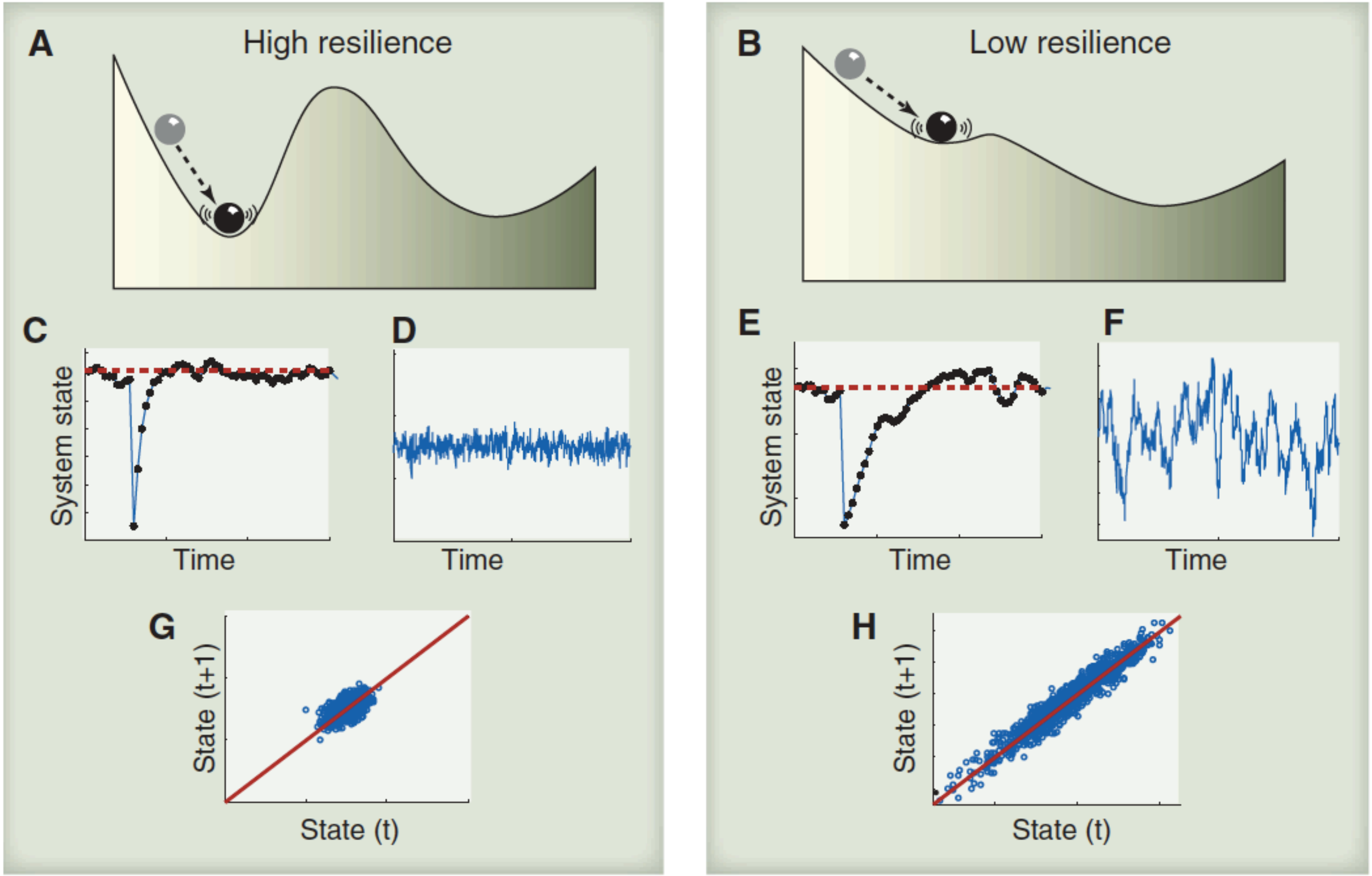
Architecture of fragility



The connectivity and homogeneity of the units affect the way in which distributed systems with local alternative states respond to changing conditions. Networks in which the components differ (are heterogeneous) and where incomplete connectivity causes modularity tend to have adaptive capacity in that they adjust gradually to change.

By contrast, in highly connected networks, local losses tend to be “repaired” by subsidiary inputs from linked units until at a critical stress level the system collapses.

Signals of potential transition



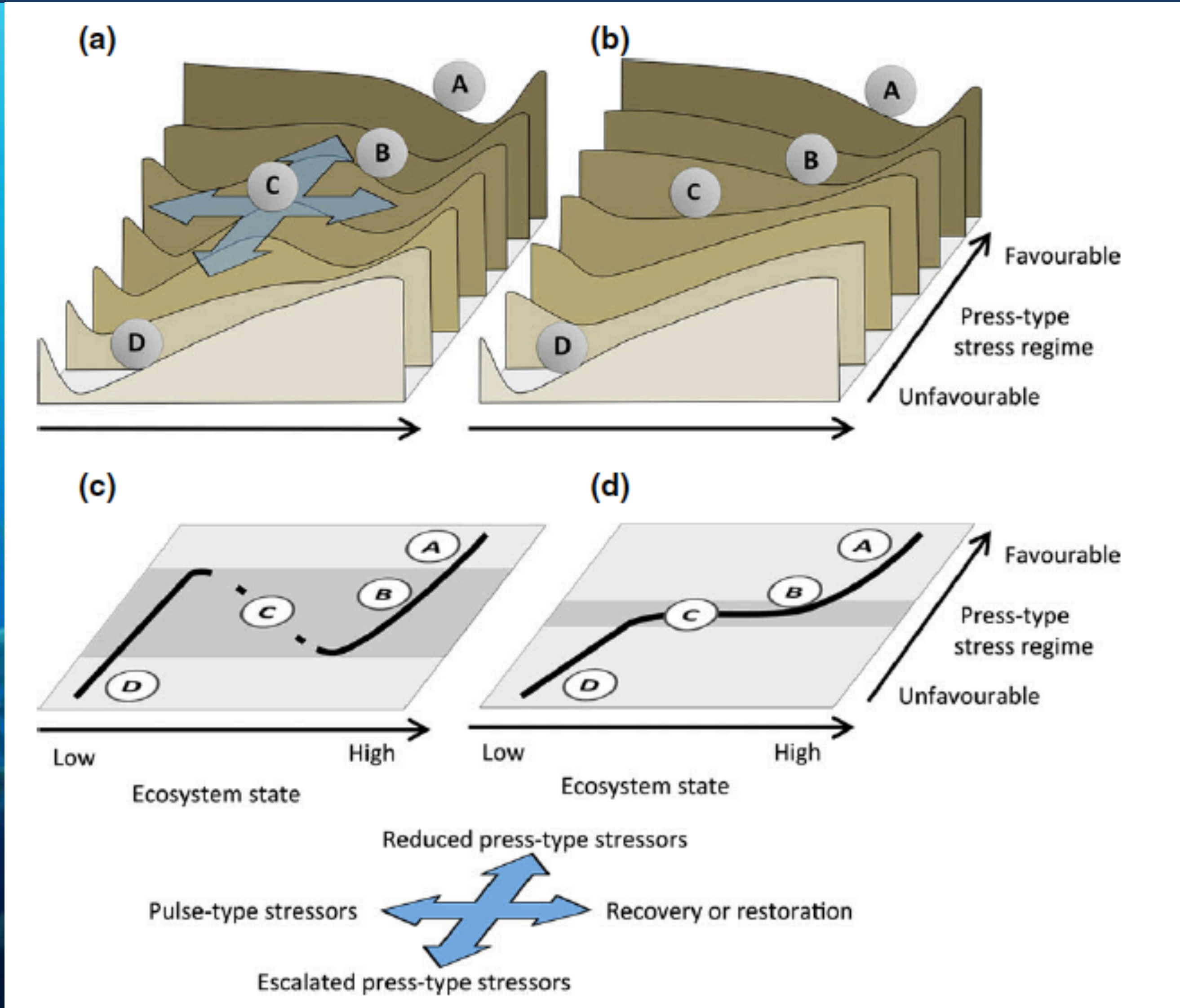
Scheffer et al 2012

Slowing down recovery **Autocorrelation** **Increased variance**

Flickering between alternative states

Ecosystem phase shifts: a conceptual model

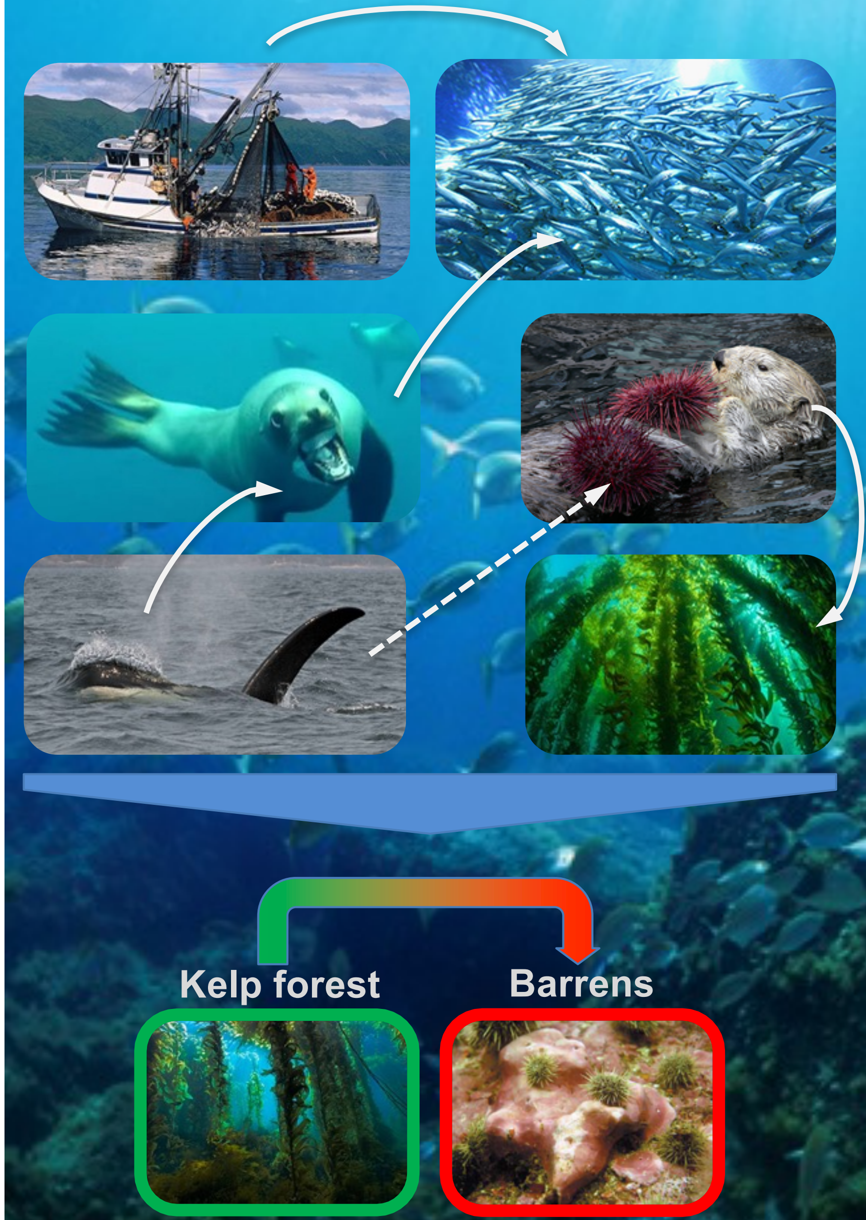
Two stable states are possible. Normally, the 'good state' is A. Increasing deterioration leads to fragile equilibrium where even a relative minor perturbation could cause a shift



As the case on the left. However, no bifurcation. The system gradually change from A to the worse state

Anthony et al., 2015

Regime shifts: Aleutian Archipelago



Potential effects of warming period at the end of 70s. Decrease in phytoplankton and consequently of zooplankton. Bottom up effects on herrings and planktivore fish, reduction of marine mammals. Increase in salmon, attracting sharks.

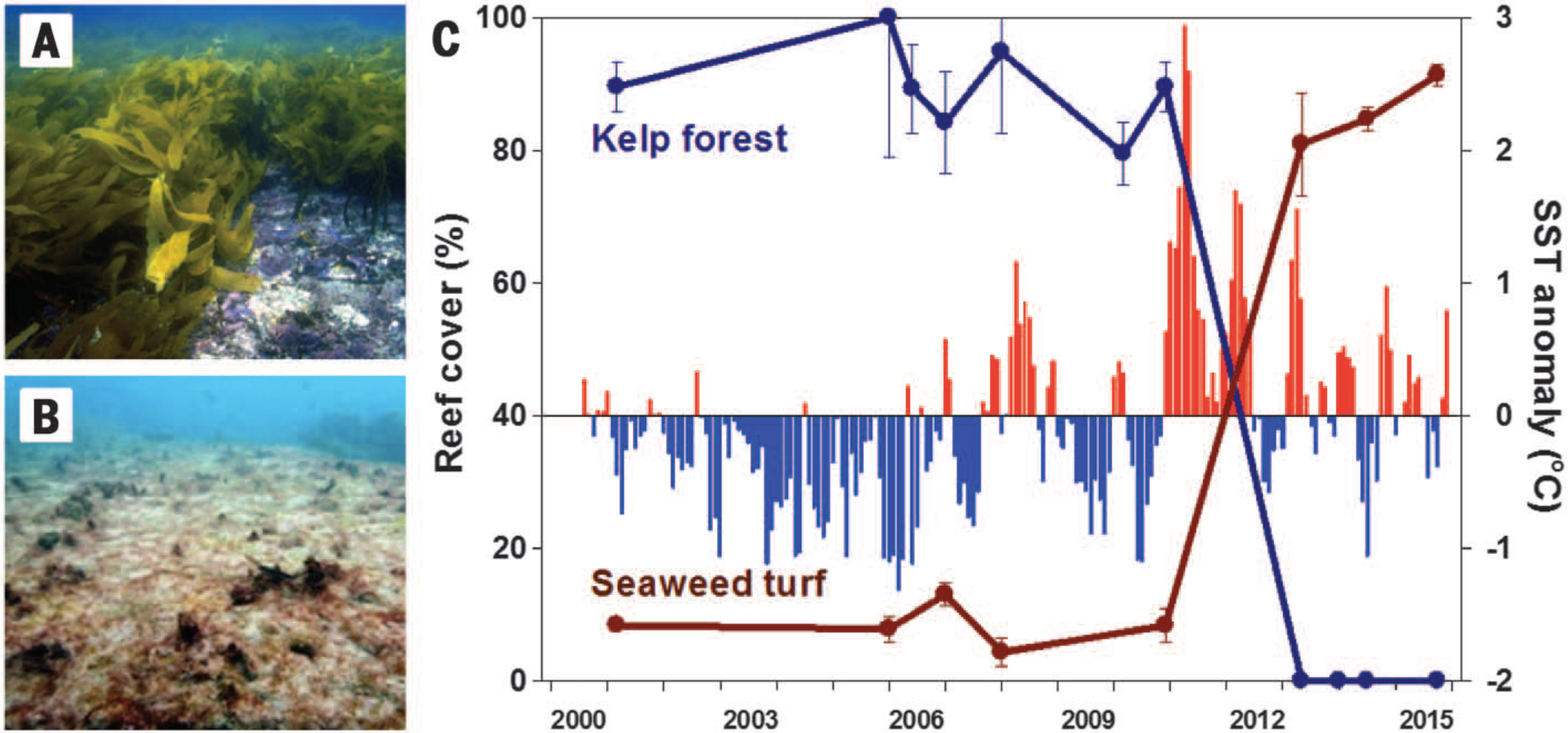
This copupled with overfishing, and reduction of marine mammals. Attracting orcas towards otters. Predation release on sea urchins that increased their population. Grazing pressure increased with consequent collapse of kelp forests

Regime shifts: Caribbean reefs

Caribbean Sea, from the 70s until now. Again, overfishing and exploitation of corals damaged the reef. Herbivore fish were exploited as commercial targets. These species controls turf algae on the reefs avoiding excessive proliferation of these competitors of corals. Fortunately, reduction of fish population and their herbivory was compensated by sea urchins, which allowed to maintain low abundance of turf forming algal species. However, extreme atmospheric events further damaged the reefs, and also nutrient enrichment from human discharge stimulate algal production. Finally, a disease drastically reduced sea urchin populations and algal blooms were out of control.

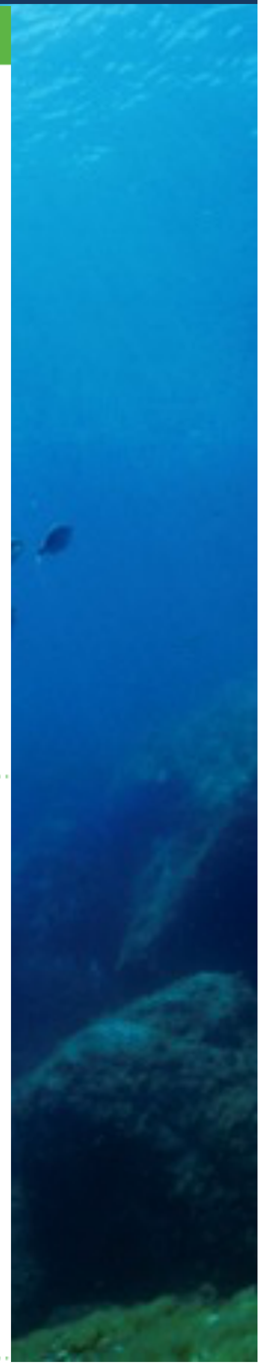
Regime shifts: SW Australia kelp

Extreme marine heat waves forced a 100-kilometer range contraction of extensive kelp forests and saw temperate species replaced by seaweeds, invertebrates, corals, and fishes characteristic of subtropical and tropical waters.
Wernberg et al. 2016



Shifts and drivers

regime shift name	key drivers	ecosystem services impacted
Arctic salt marshes	fishing	soil formation
	global warming	primary production
	invasive species	nutrient cycling
	nutrient inputs	biodiversity
	sea-level rise	fisheries
	sediments	feed, fuel and fibre crops
		climate regulation
		water purification
		regulation of soil erosion
		natural hazard regulation
		recreation
		aesthetic values
Arctic sea ice	atmospheric CO_2	water cycling
	global warming	biodiversity
	greenhouse gases	fisheries
	temperature	wild animal and plant foods
		climate regulation
		water purification
		water regulation
		aesthetic values
		knowledge and educational values
		spiritual and religious



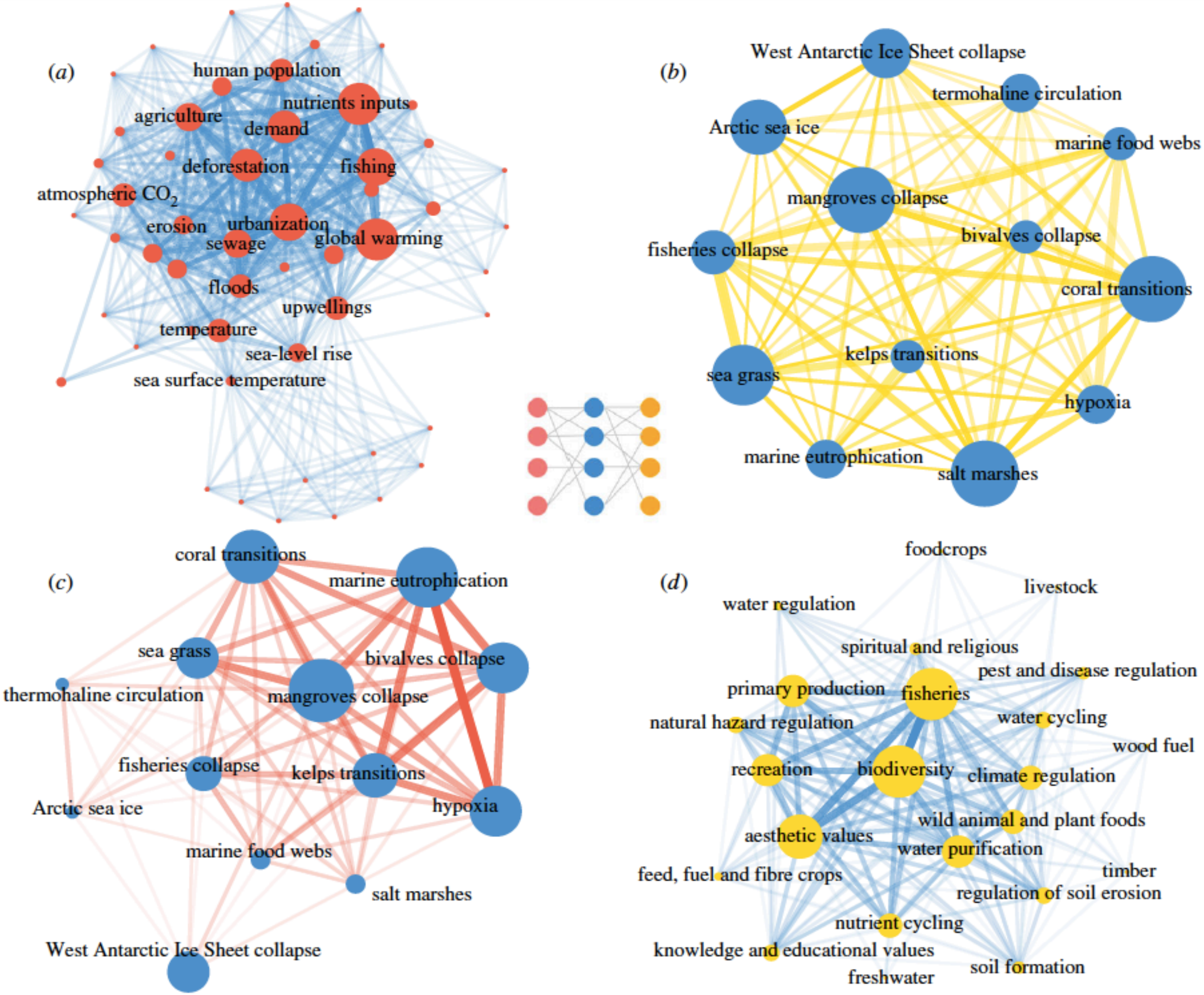
Rocha et al. 2015

Shifts and drivers

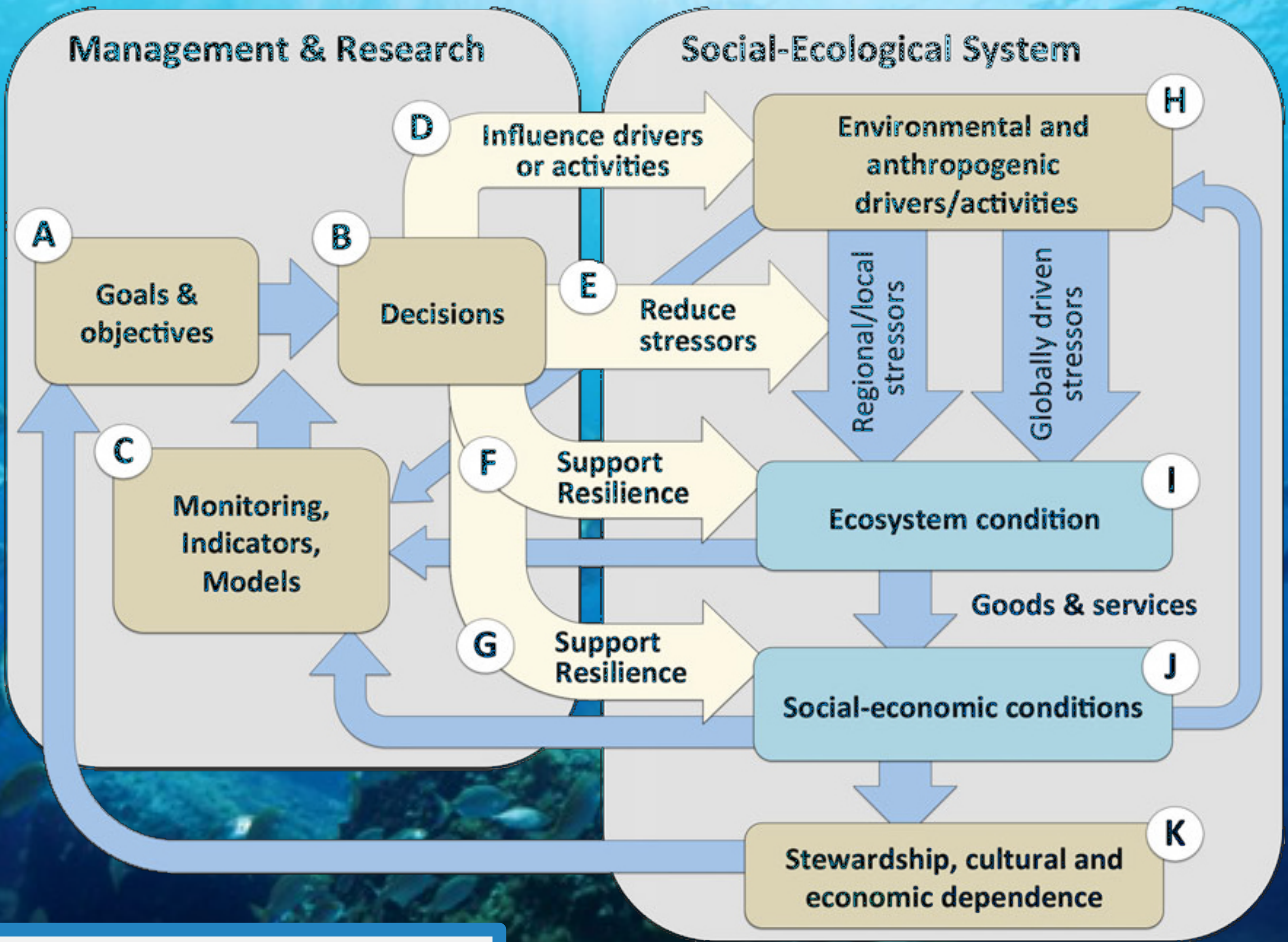
regime shift name	key drivers	ecosystem services impacted
mangroves transitions	agriculture	soil formation
	aquaculture	water cycling
	atmospheric CO_2	biodiversity
	deforestation	fisheries
	droughts	wild animal and plant foods
	erosion	timber
	floods	wood fuel
	global warming	climate regulation
	hurricanes	water purification
	infrastructure development	regulation of soil erosion
	irrigation infrastructure	natural hazard regulation
	landscape fragmentation	aesthetic values
	ocean acidification	
	rainfall variability	
	sea-level rise	
	sea surface temperature	
	sediments	
	sewage	
	temperature	
	urbanization	

Shifts and drivers

regime shift name	key drivers	ecosystem services impacted
sea grass collapse	atmospheric CO_2	primary production
	deforestation	nutrient cycling
	disease	biodiversity
	fishing	fisheries
	infrastructure development	wild animal and plant foods
	nutrient input	climate regulation
	rainfall variability	water purification
	sea-level rise	regulation of soil erosion
	sediments	natural hazard regulation
	sewage	recreation
	temperature	aesthetic values
	urbanization	


(a)
human population
nutrients inputs
agriculture
demand
deforestation
fishing
atmospheric CO_2
erosion
urbanization
sewage
global warming
floods
upwellings
temperature
sea-level rise
sea surface temperature
(b)
West Antarctic Ice Sheet collapse
termohaline circulation
Arctic sea ice
marine food webs
mangroves collapse
bivalves collapse
fisheries collapse
coral transitions
kelps transitions
sea grass
hypoxia
marine eutrophication
salt marshes
(c)
coral transitions
marine eutrophication
sea grass
bivalves collapse
thermohaline circulation
mangroves collapse
fisheries collapse
kelps transitions
hypoxia
Arctic sea ice
marine food webs
salt marshes
West Antarctic Ice Sheet collapse
(d)
foodcrops
livestock
water regulation
spiritual and religious
pest and disease regulation
primary production
fisheries
natural hazard regulation
water cycling
wood fuel
recreation
biodiversity
climate regulation
wild animal and plant foods
aesthetic values
water purification
feed, fuel and fibre crops
timber
regulation of soil erosion
nutrient cycling
knowledge and educational values
soil formation
freshwater

Management



Reduce anthropogenic stressors

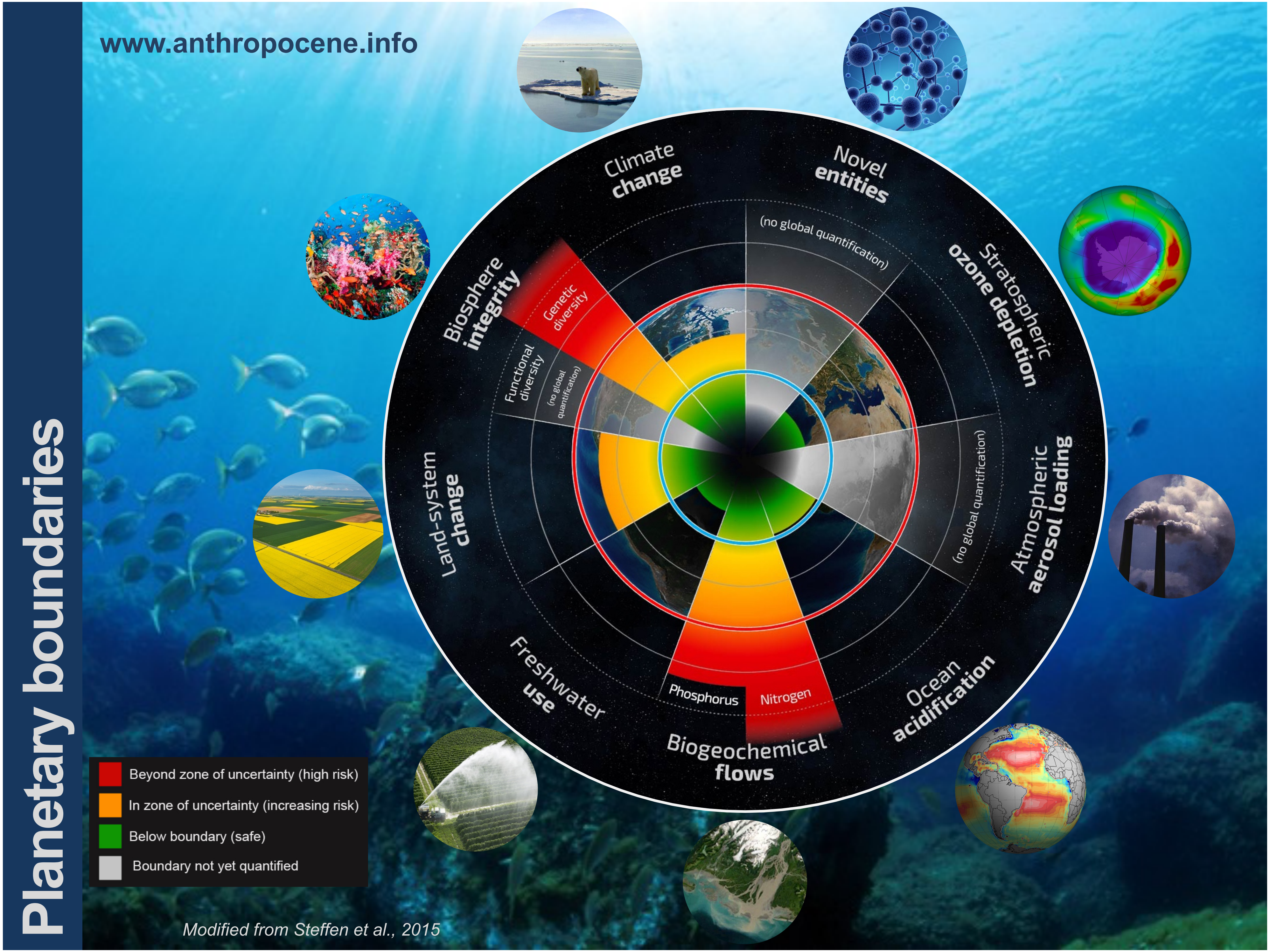
Support system's resilience

Monitoring the state of systems

Anthony et al., 2015

Management

	Management levers			
Example	D: Influence drivers and/or activities	E: Reduce stressors	F: Support ecosystem resilience	G: Support social-economic resilience
Great Barrier Reef	Influence national emissions policies through education and awareness-raising around climate change and linkages between land use and run-off	Improve land-use management to reduce pollution in receiving waters; maintained fisheries management	Networks of no-take areas (spatial planning for connectivity and population viability of key species); control CoTS at local scales	Work with fishers and tourism operators to help build resilience in their industries
Coral Triangle	Education of local communities and regional government bodies	Reduce fishing of herbivores; stop destructive fishing practices; reduce pollution	Networks of no-take areas (spatial planning for connectivity and population viability)	Capacity-building of local communities and regional government bodies, support alternative livelihoods
Florida Reef System	Education and awareness-raising around climate change and linkages between land use and land run-off	Reduce nutrient and sediment loads; reduce fishing pressure; manage pressures from recreational use	Coral and reef habitat restoration in combination with networks of no-take areas	Work with local communities and the tourism industry to develop adaptation strategies including livelihood transitioning


Planetary boundaries
www.anthropocene.info
Climate change
Novel entities
(no global quantification)
Stratospheric ozone depletion
Atmospheric aerosol loading
(no global quantification)
Ocean acidification
Biogeochemical flows
Phosphorus
Nitrogen
Freshwater use
Land-system change
Biosphere integrity
Genetic diversity
Functional diversity
(no global quantification)
Beyond zone of uncertainty (high risk)
In zone of uncertainty (increasing risk)
Below boundary (safe)
Boundary not yet quantified
Modified from Steffen et al., 2015

Final remarks

Complex systems are difficult to understand, and even more difficult to project. Previsions are largely uncertain.
Ecosystem can be assumed as chaotic systems, so their dynamics are extremely sensitive to initial conditions and unpredictable on the long run. There are too many variables… (Theory of chaos)

Could we manage to predict trajectories of ecosystems? Or it could be easier to reduce our pressure?