University of Trieste: GLOBAL CHANGE ECOLOGY a.a. 2021-2022

Conservation & Management in Marine Protected Areas

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Ecological principles underlying marine conservation

Implications for differences in conservation strategies and reserve networks

Feature	Terrestrial ecosystems	Marine ecosystems
Reserve objectives		
Spatial focus for protection	within reserves	within and outside reserves
Emphasis on propagule export	little	great
State of knowledge		
Taxonomic identification	good	poor
Patterns of species distribution and abundance	good	poor to moderate
Geographic patterns of marine ecosystem diversity	good	poor
Design criteria		
Movement (connectivity) corridors		
Importance of connectivity	less	greater
Type	primarily habitat based	primarily current based
Importance of habitat corridors	greater	lower
Human managed	great	little
Constancy/predictability	high	low
Protection of nonreserve populations	less critical	very critical
Reserve size		
Sufficient for local replenishment (single reserve)	smaller	larger
Habitat diversity necessary for resource requirements	smaller	larger
Reserve location		
Sensitivity to biogeographic transitions	less	greater
Importance of import–export processes (i.e., winds, currents)	less	great

(Carr et al., 2003)

Contribution of ecological theories to marine conservation

Theory of island biogeography

(MPAs can be seen as 'islands' of reduced human influence within a 'sea' subject to several human pressures; the larger the more speciose, high isolation - low diversity)

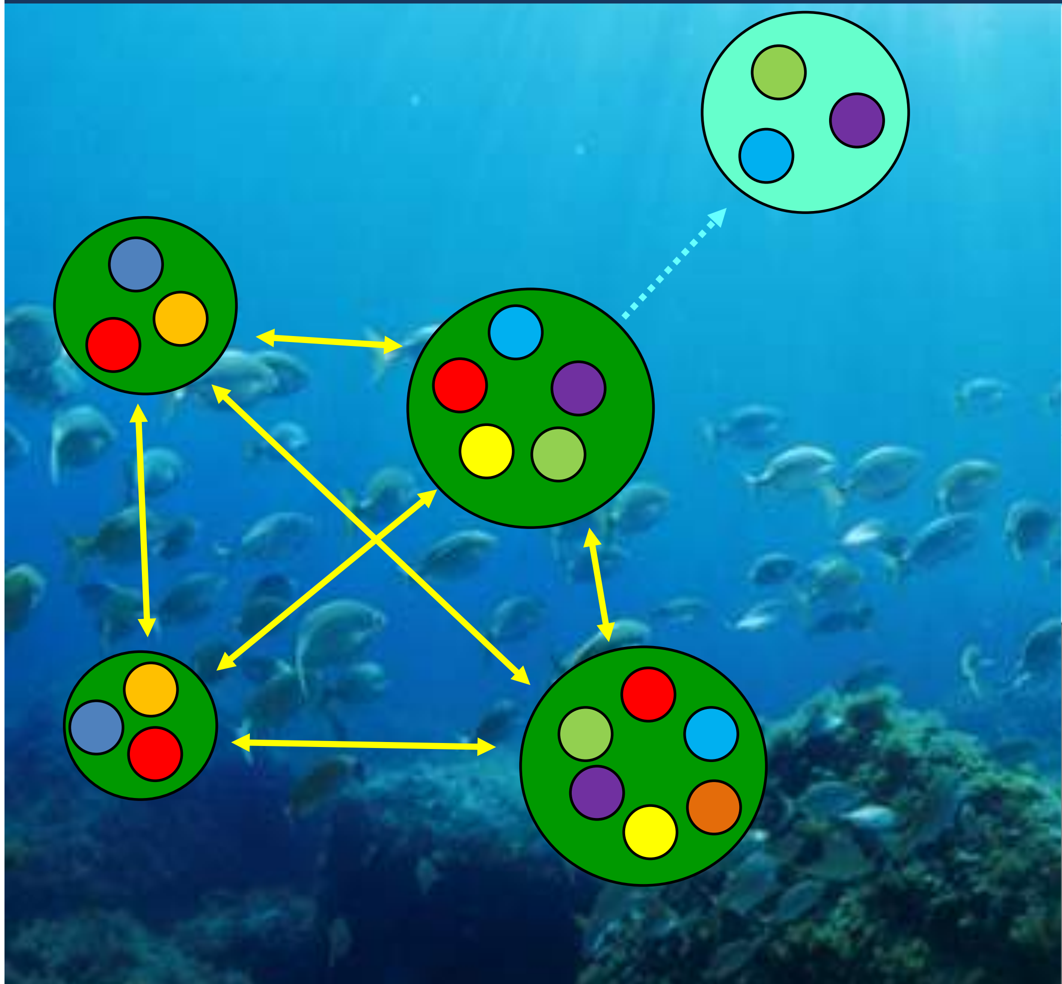
Supply side ecology

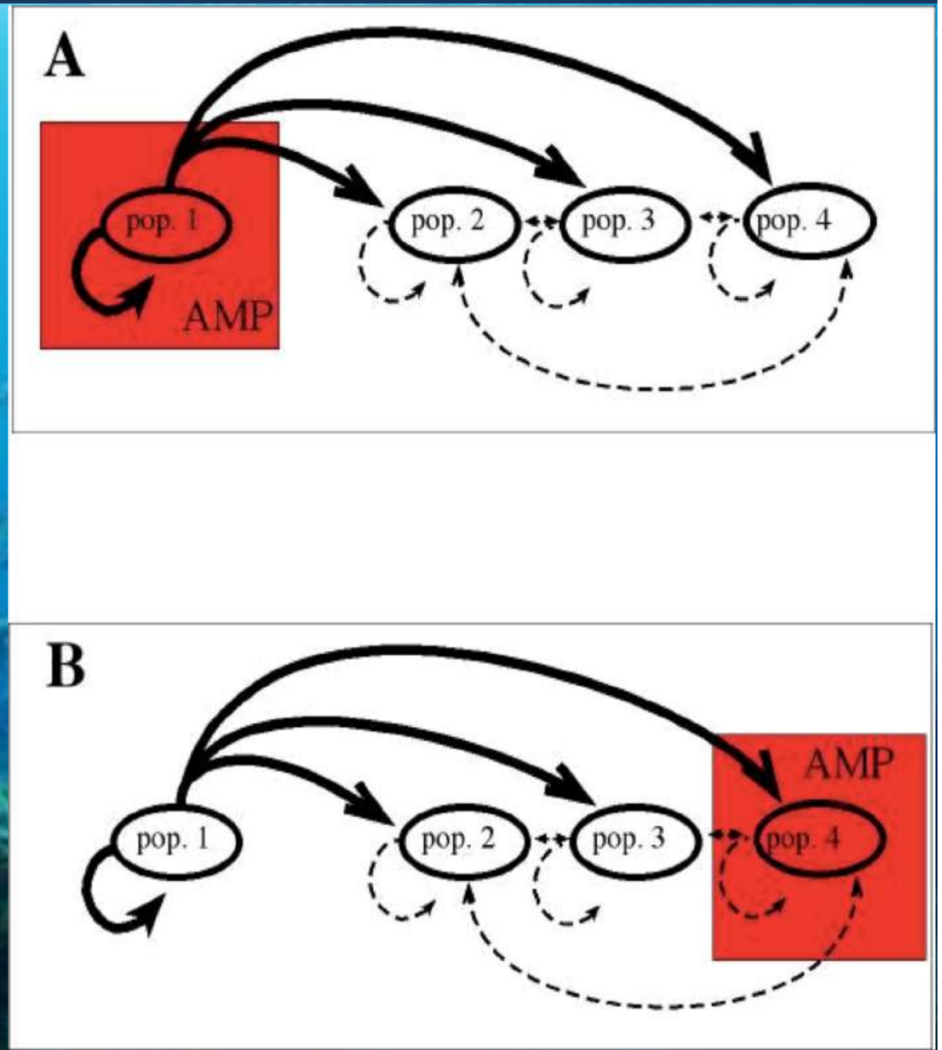
Metapopulation theory

Patch dynamic

Great contribution of experimental marine biology and ecology

Supply side ecology, metapopulations, and metacommunities





Sinks and sources

The importance of life cycles and life histories

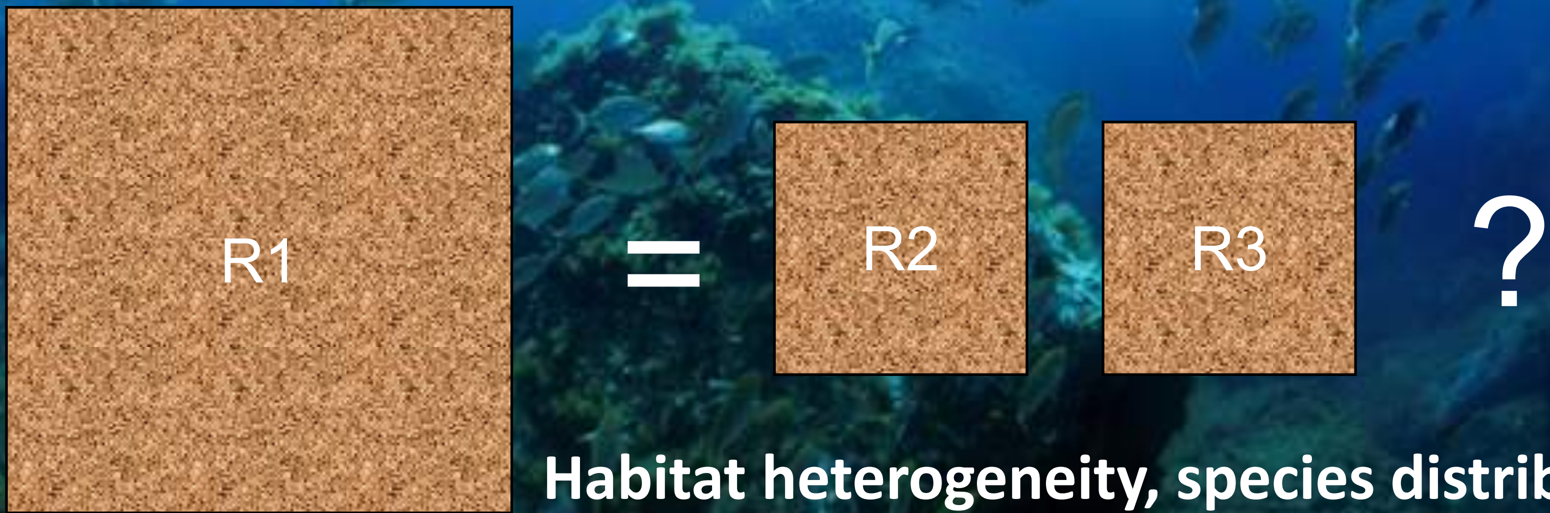
Inter-habitat harmonization

SLOSS controversy

IBT raised concerns about the opportunity to implement single large or several small reserves

Large areas allow protecting more species than smaller ones.
However…Large areas are more difficult to manage and control.
They are politically difficult to propose and sustain.
Large areas have higher probability to create social and economic conflicts. **They are also more difficult to monitor**
Uncertainty on the result of conservation in terms of amount of species protected…

$$S_{R1} \leq (S_{R2}+S_{R3})$$



Habitat heterogeneity, species distribution

A question of size

Pelagos Sanctuary (SPAMI)
Year of institution: 1999
Surface: about 90,000 km^2
Countries: Italy, France, Monaco

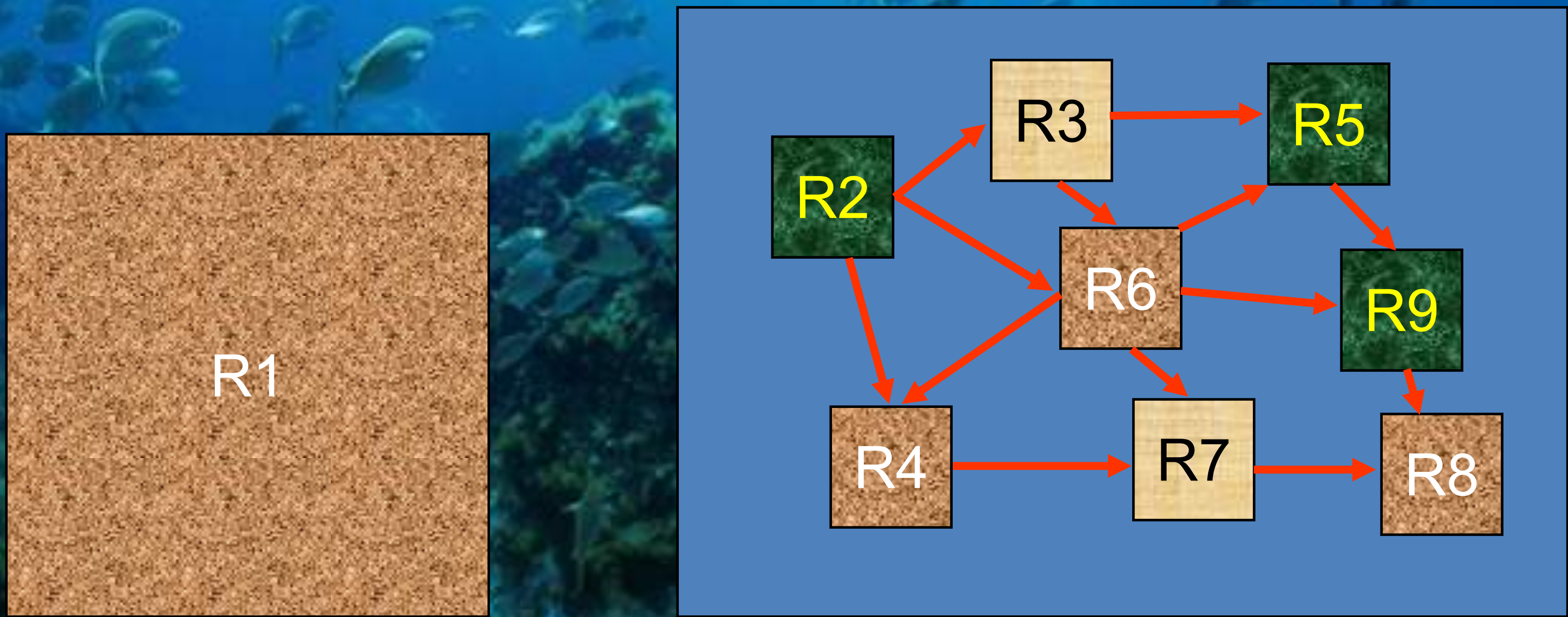
Large reserve for large animals or animals requiring a large surface for movements and foraging

A question of size: distribution

The largest marine park in the Mediterranean Sea is the National Marine Park of Sporadi, in the Aegean Sea. Created in 1992, it is devoted to protection of *Monachus monachus*, the Mediterranean monk seal

Small reserves could increase chance in the face of perturbations

Several small interspersed reserves could provide insurance against perturbations (e.g., catastrophic disturbance or demographic events), with recolonization provided by undisturbed sites, or including higher habitat diversification with respect to larger ones and therefore more species



Notwithstanding, large reserves…

Should….

1 – decrease competition and predation pressure from neighbouring species, with border populations more exposed than those in the centre of the reserve;

2 – provide a better spatial match with the *home-range* of large carnivorous species;

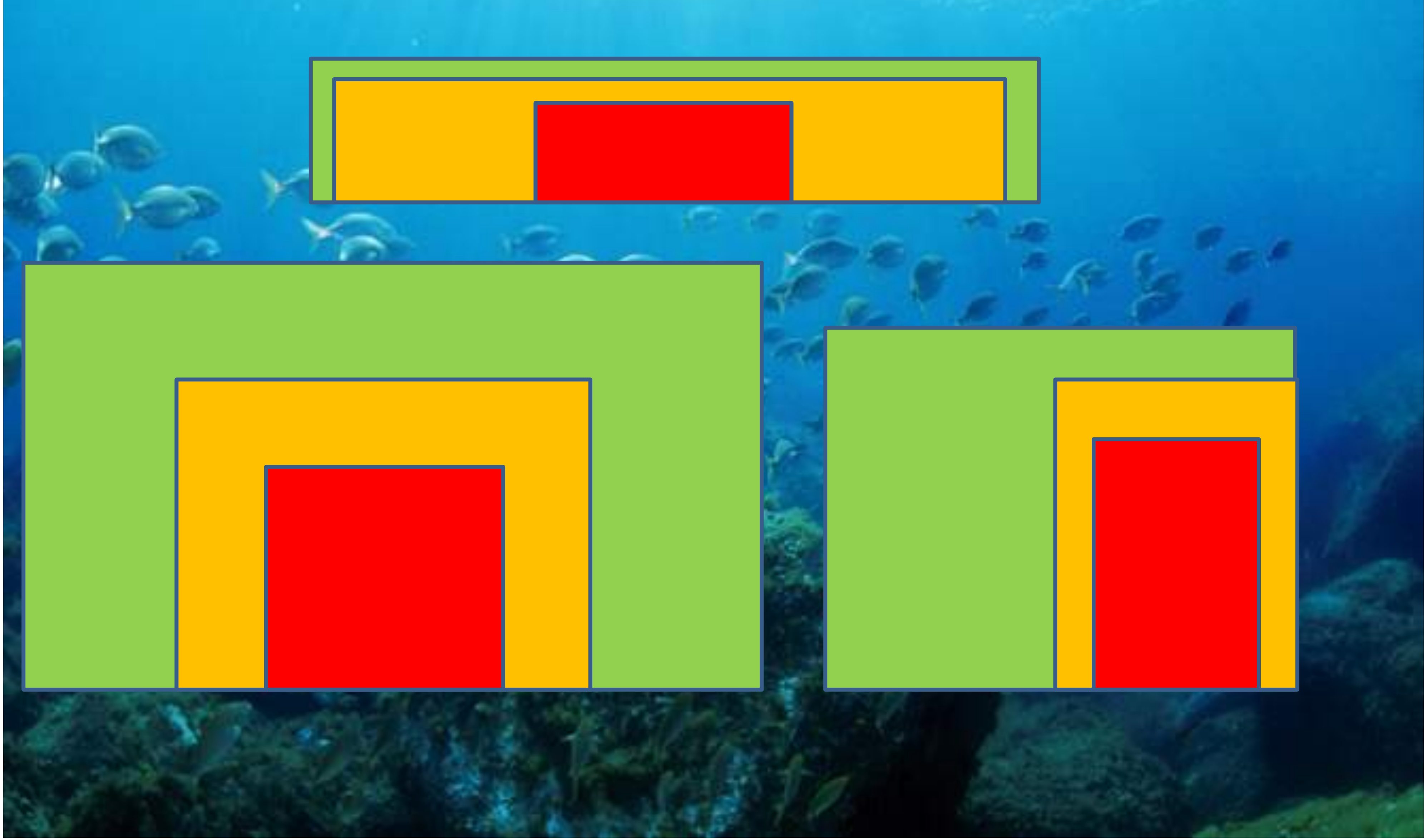
3 – include a larger range of environments to allow persistence of different species populations in the long term;

4 – include different subpopulations and, as a consequence, higher intra-specific genetic diversity;

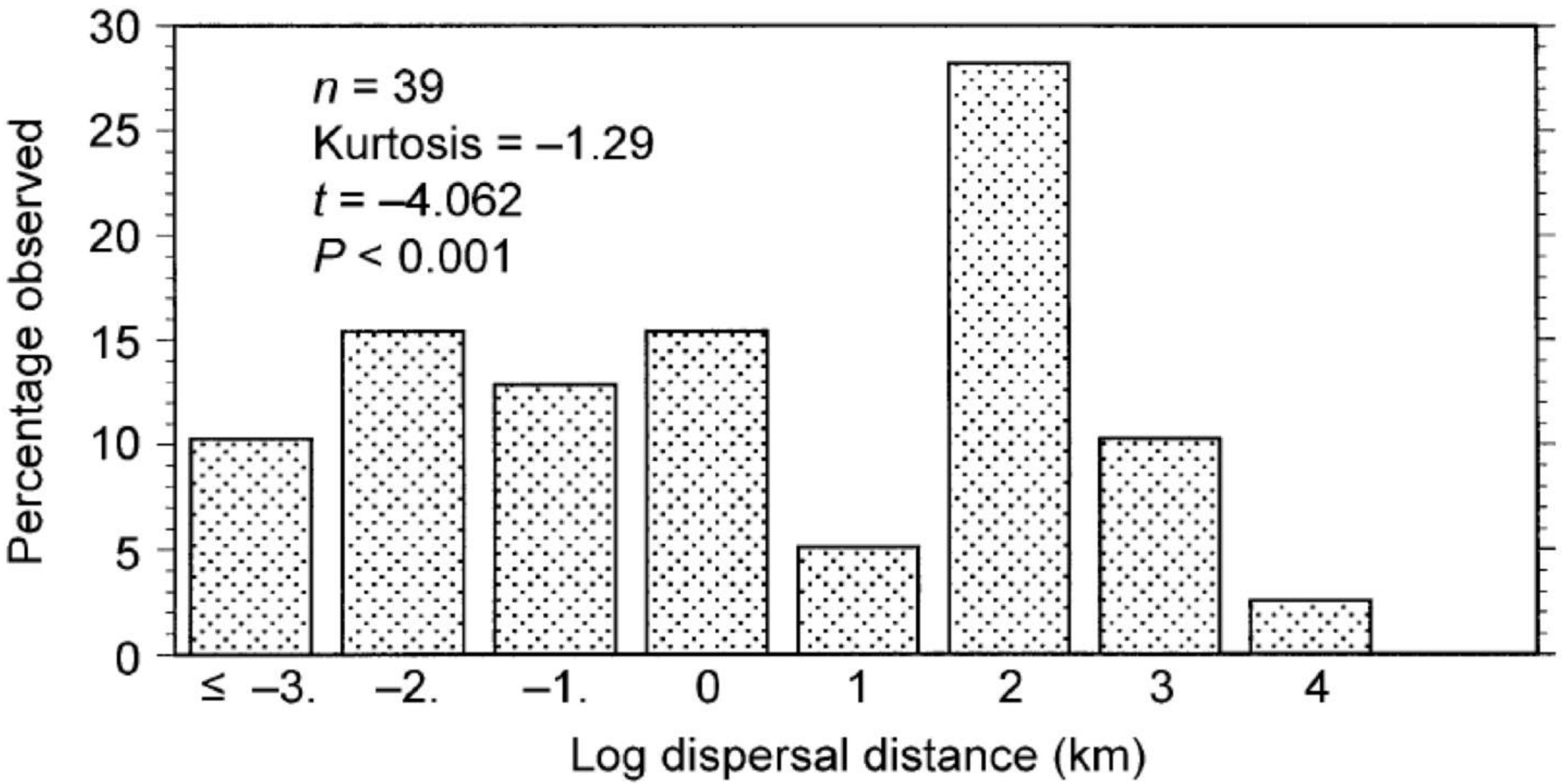
5 – better respond to external disturbace through a buffer effect

Shape

Low area/perimeter ratio could increase exposure of central populations to external influence



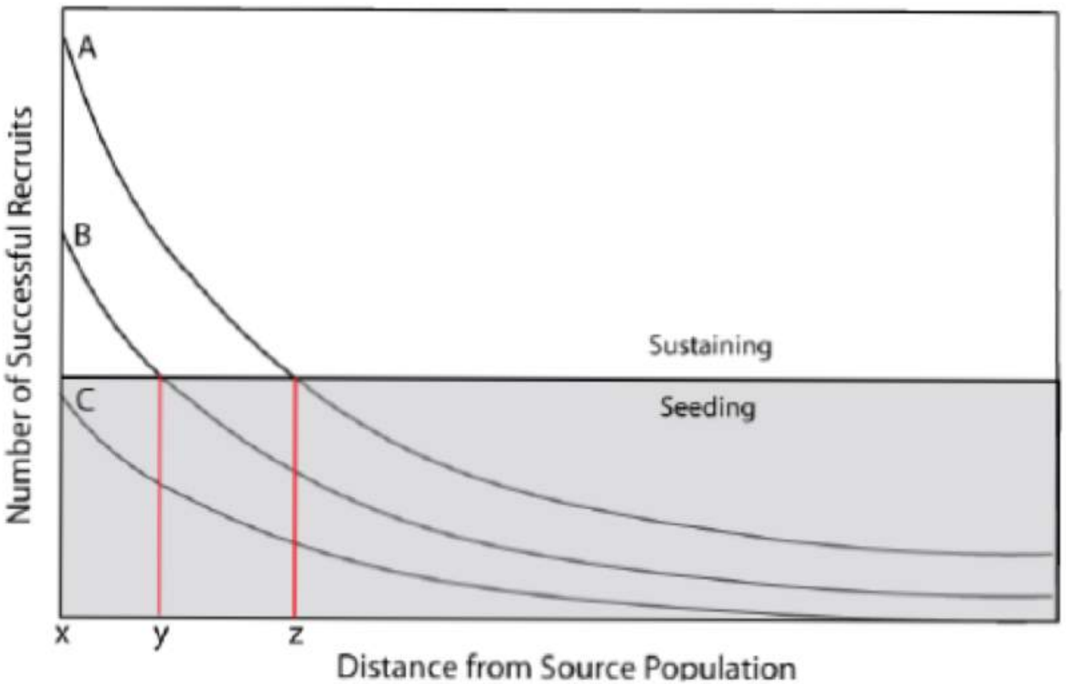
Spacing

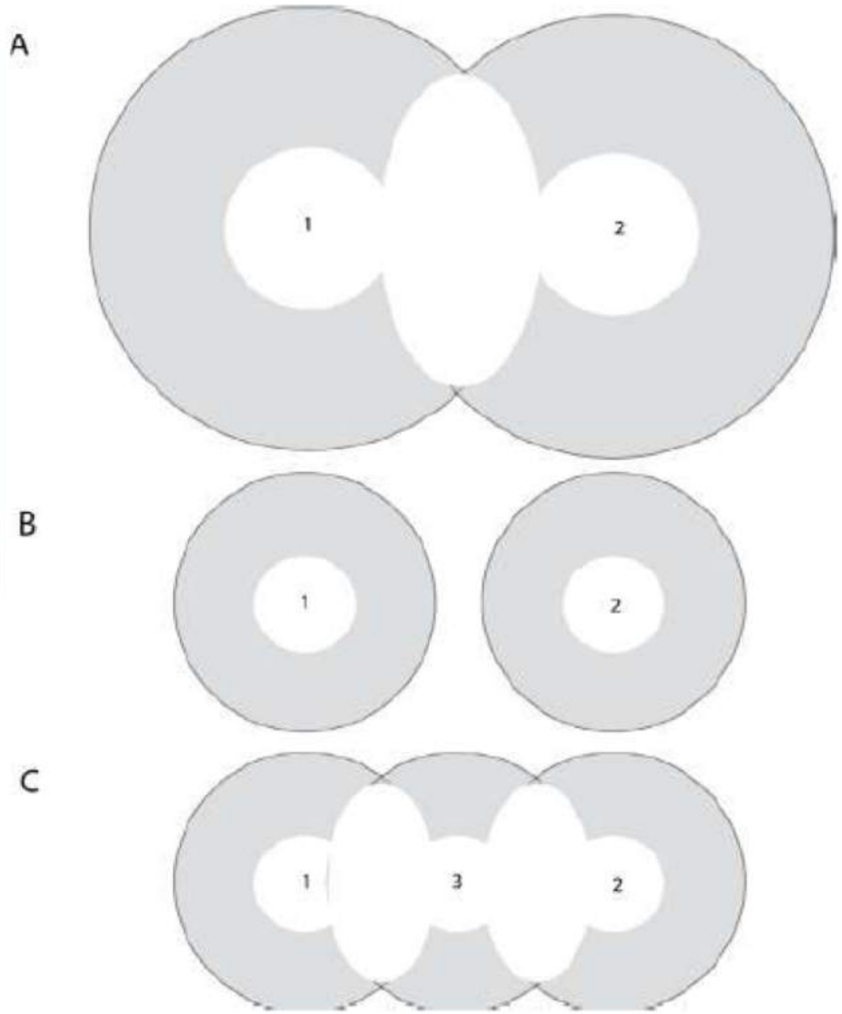


1) Bimodal trend in dispersal strategies, one short distance and long distance.
2) Reserves with diameter of 4-5 km, 10-20 km apart are wide enough to retain propagules of short-distance dispersers and far enough to allow long-distance dispersers to be captured. However, limited range of organisms.
Shank et al., 2003

Spacing

To understand the effects of dispersal on population replenishment and resilience, it is important to differentiate between (1) "sustaining" dispersal: ecologically/ demographically important in maintaining or increasing a local population and (2) "seeding" dispersal: evolutionarily important in maintaining gene flow and decreasing the long-term probability of local extinction. Sustaining dispersal occurs over small spatial scales whereas seeding dispersal occurs over large spatial scales.

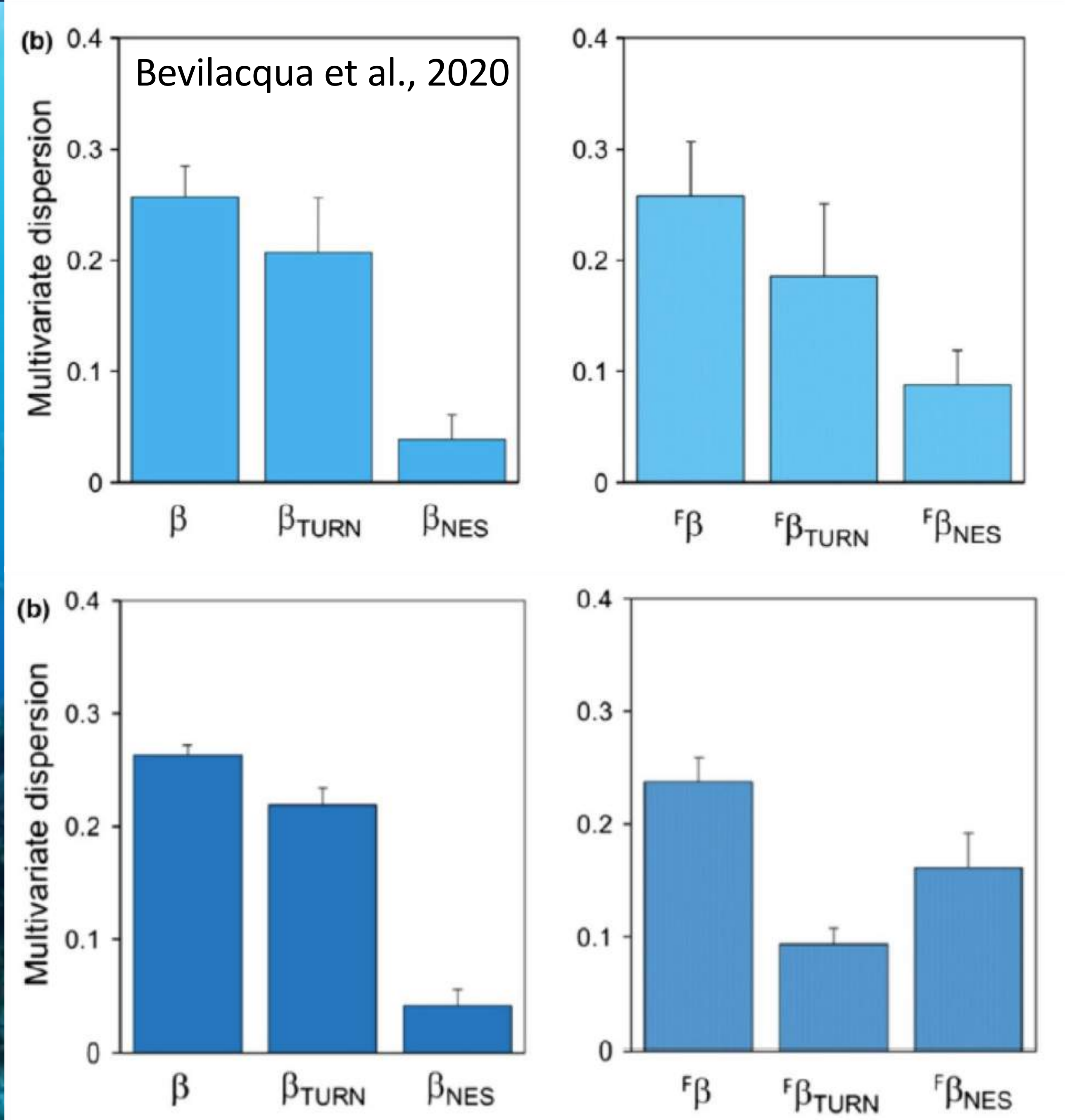




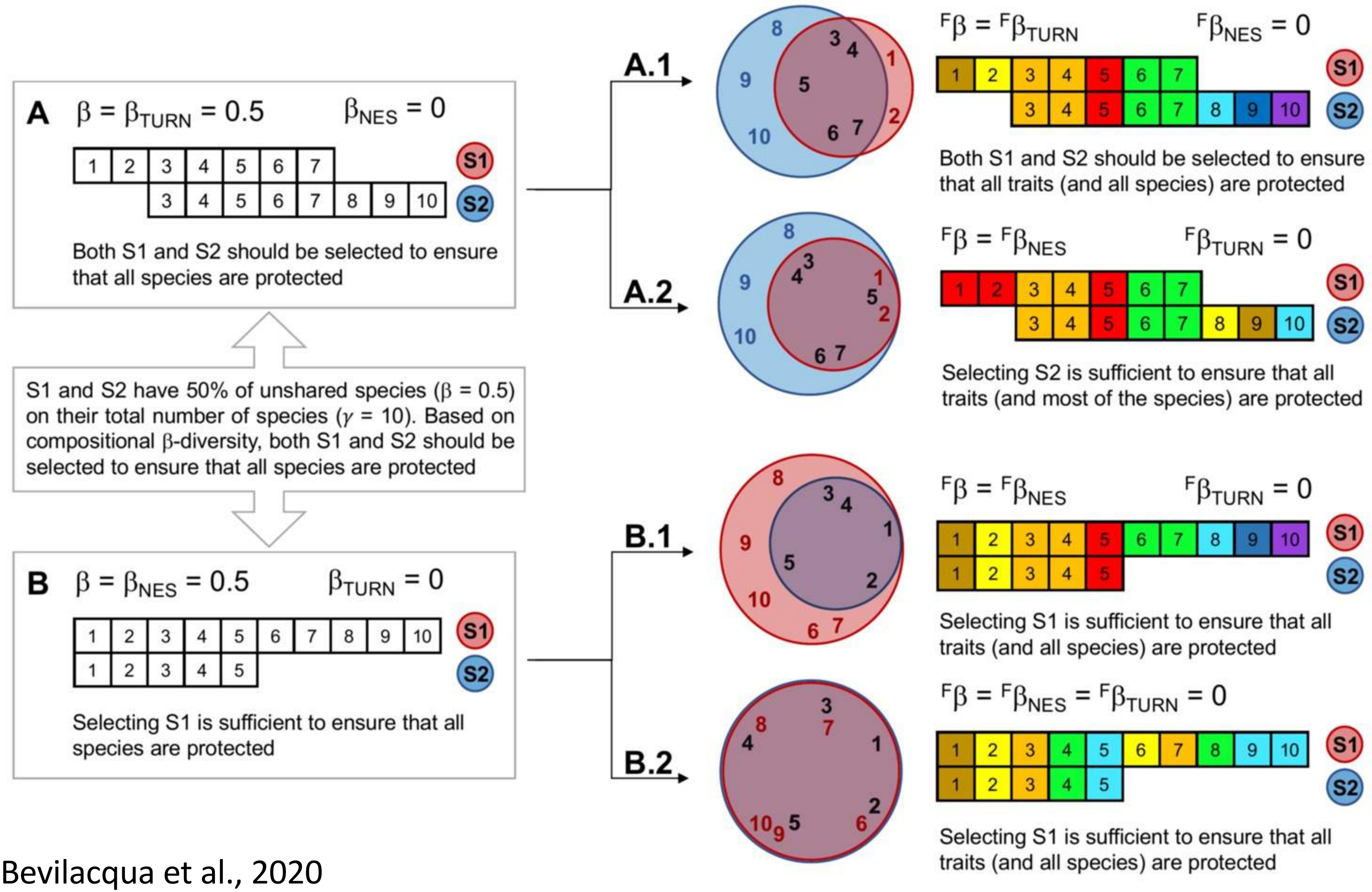
Small populations produce fewer propagules than large populations. Thus, as size decrease distance of seeding and sustaining decrease.

Biological heterogeneity

Siting and spacing are strictly related to connectivity. Current transport of propagules, and heterogeneity in distribution of species are main factors to account for ecologically coherent network. Often, the analysis of beta-diverity patterns focuses on taxonomic diversity. However, other aspects of diversity should be considered to implement networks that, beyond representative of species diversity also allow to conserve functional diversity.

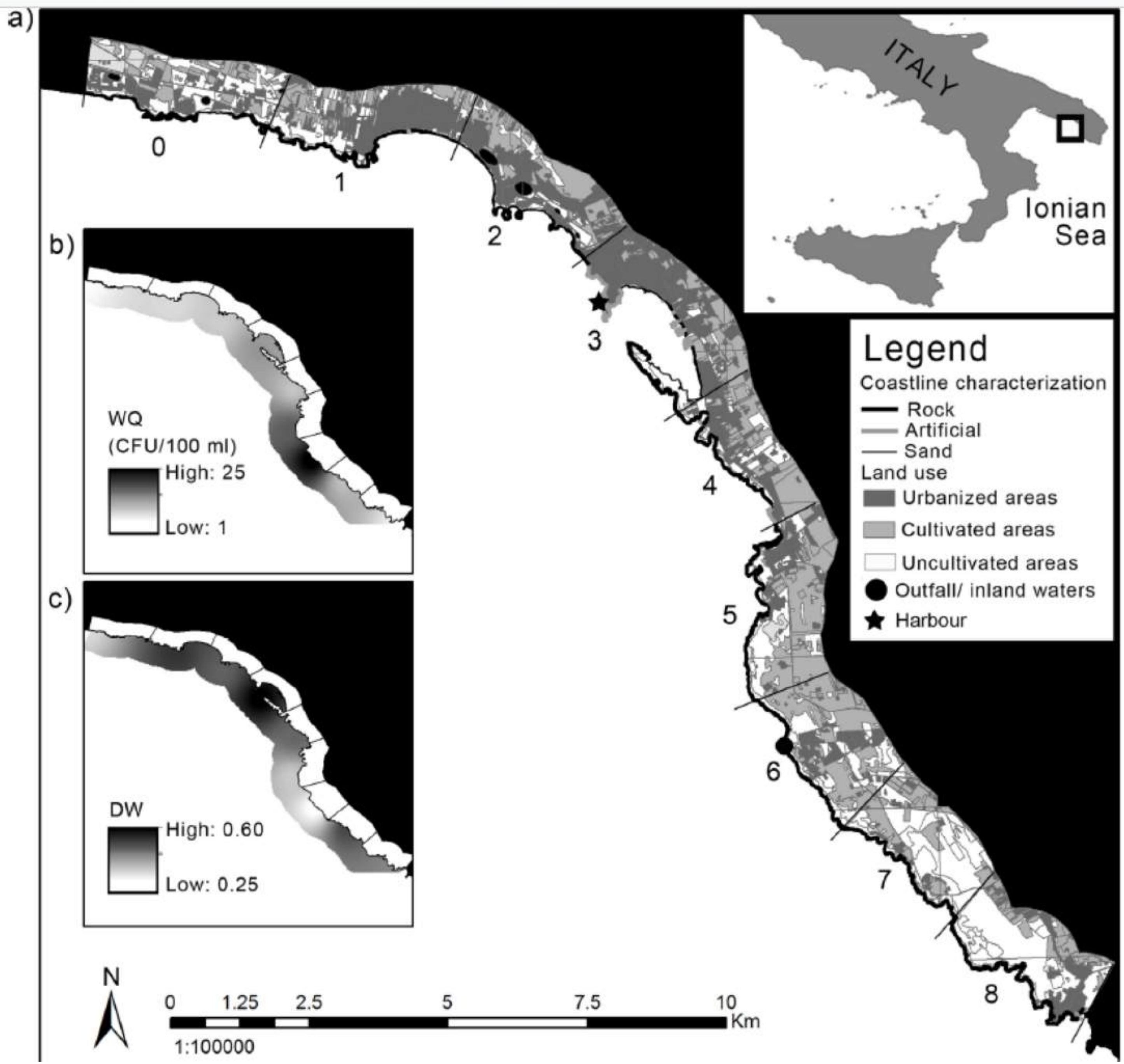


Implication for siting and spacing



Bevilacqua et al., 2020

Environmental context: human threats



Guarnieri et al., 2016

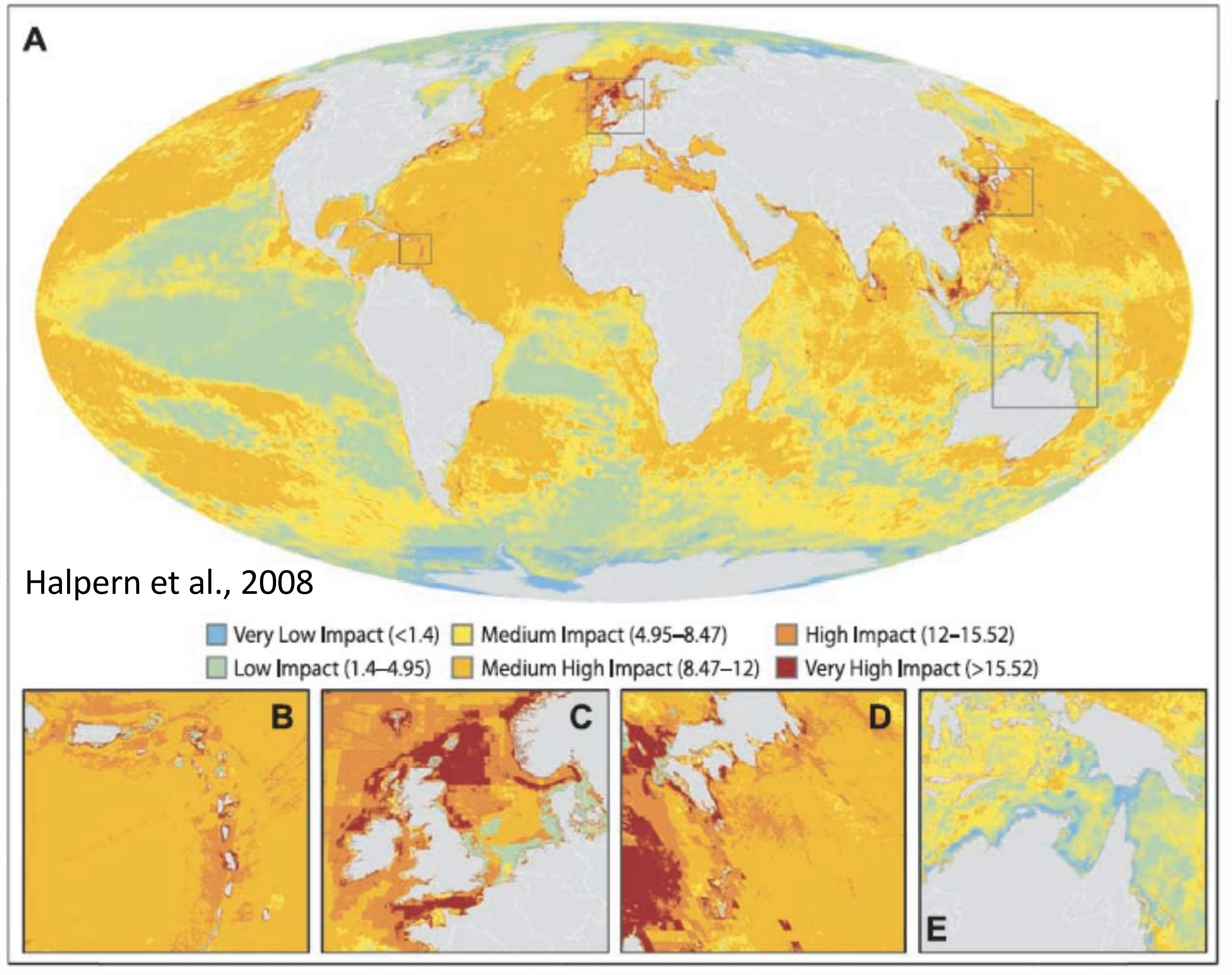
High level of anthropization could increase exposure of protected populations and communities to human pressures or impacts

Should We Protect the Strong or the Weak?

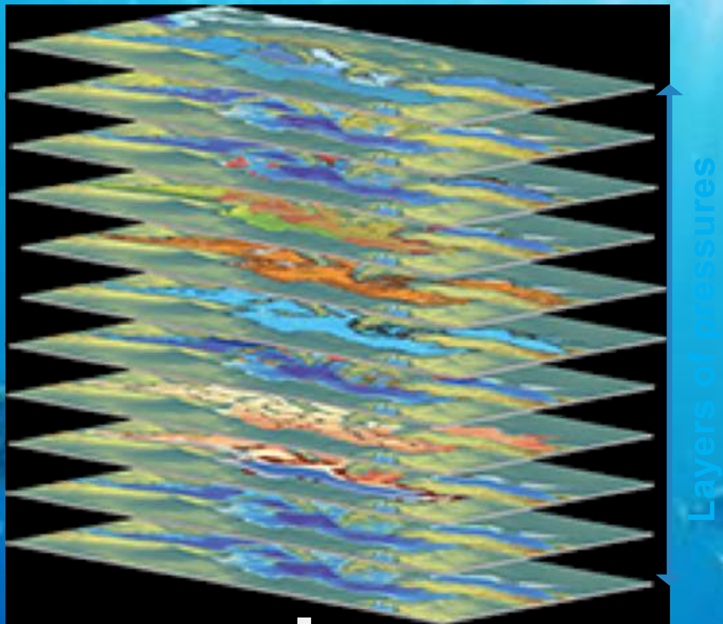
If the conservation objective was to maximize the chance of having at least 1 healthy site, then the best strategy was protection of the site at lowest risk. On the other hand, if the goal was to maximize the expected number of healthy sites, the optimal strategy was more complex. If protected sites are likely to spend a significant amount of time in a degraded state, then it is better to protect low-risk sites. Alternatively, if most areas are generally healthy then it is better to protect sites at higher risk. (Game et al., 2008)

Alternative strategies have been proposed, for instance, to protect areas proportional to the risk of pertubation event to increase insurance that catastrophic events will not affect the core of reserves. (Allison et al., 2003)

Estimating cumulative impacts



The additive formula



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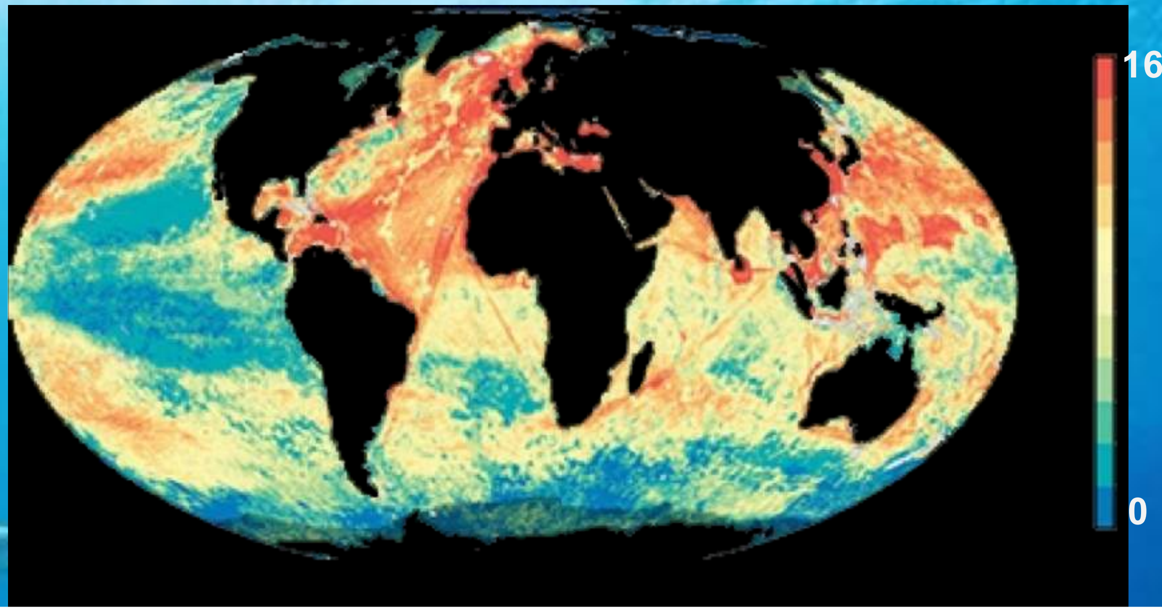
Sensitivity weights by expert opinion

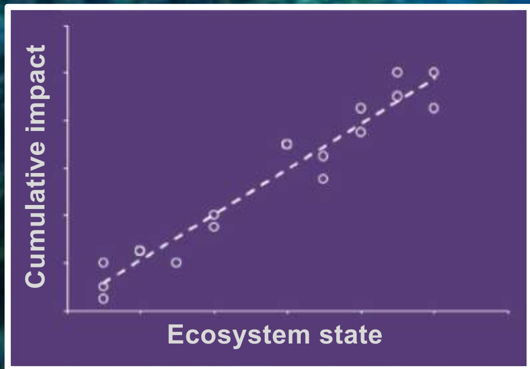
Computing geo-referred impact score

$$I_c = \sum P_i w_i E_j$$



Map of cumulative impact

Cumulative impact score versus ecosystem state

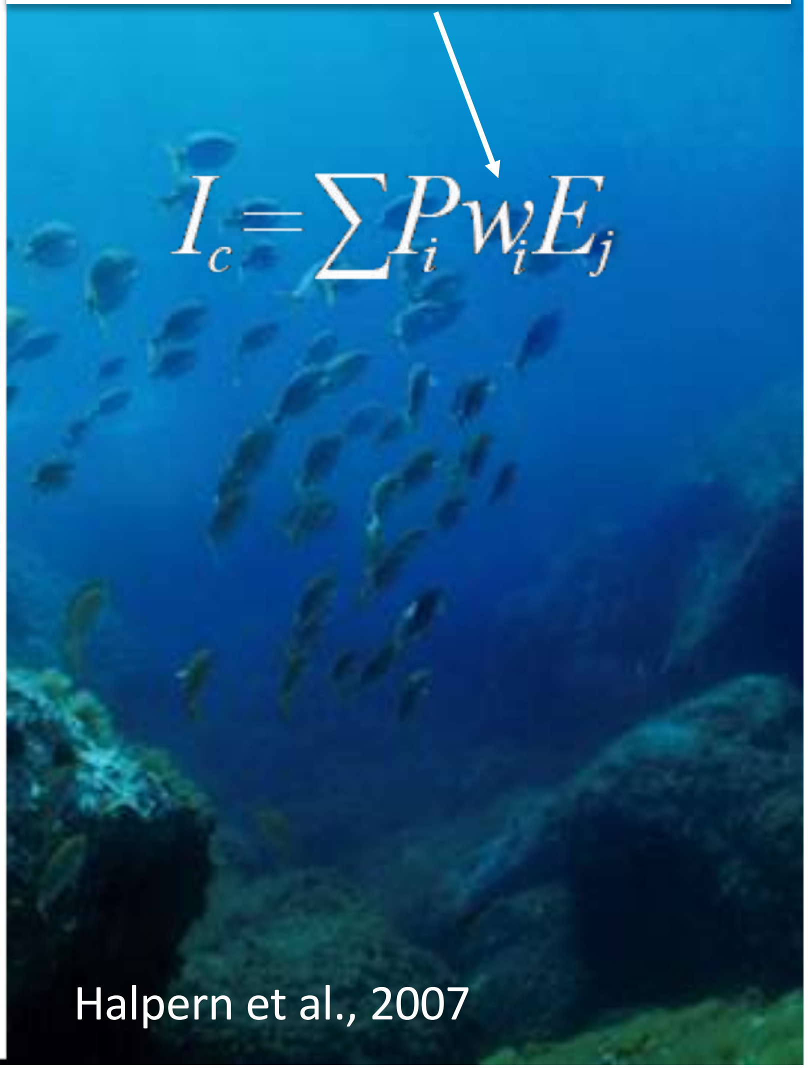


- Linear response to pressure
- Additivity of impacts
- Expert-based sensitivity
- Resolution and downscaling

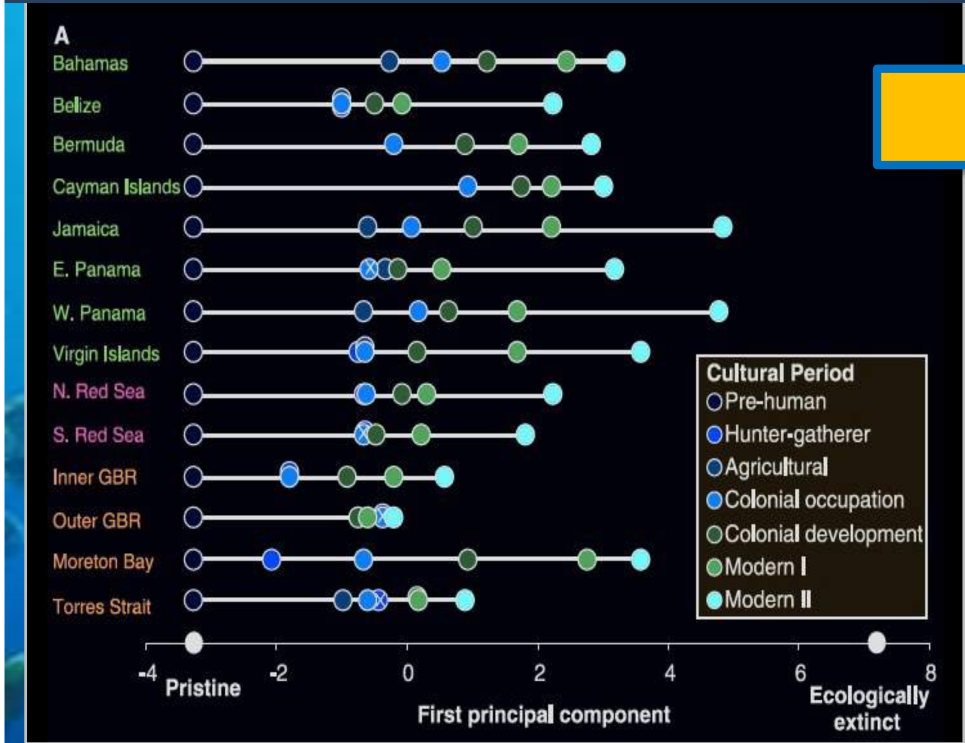
Scores

	Intertidal					*Coastal*				
	Rocky intertidal	*Intertidal mud*	*Beach*	*Mangrove*	*Salt marsh*	*Coral reef*	*Seagrass*	*Kelp forest*	*Rocky reef*	*Suspension-feeder reef*[c]
Threat[b]	13	5	7	7	14	24	6	7	9	5
Freshwater input										
increase	1.6	1.3	0.3	1.8	1.9	1.5	1.6	0.0	1.5	1.7
decrease	1.1	1.1	0.0	2.6	1.9	0.4	1.4	0.0	0.6	1.2
Sediment input										
increase	2.4	2.0	1.1	2.2	2.2	2.8	2.9	1.2	2.0	2.2
decrease	0.6	1.6	0.7	1.3	1.7	0.4	0.5	0.0	0.0	1.5
Nutrient input[d]										
into oligotrophic water	1.8	1.1	0.2	1.4	1.4	2.4	2.1	0.0	1.7	0.0
into eutrophic water	1.3	2.1	0.6	2.1	2.3	1.1	2.0	0.8	1.5	2.8
Pollutant input										
atmospheric	0.8	0.7	0.0	0.9	1.6	0.9	0.6	0.0	0.5	1.8
point, organic	2.4	2.1	1.9	2.0	1.5	2.2	1.9	0.8	2.1	2.4
point, nonorganic	2.2	1.7	0.8	1.1	2.0	1.9	0.4	0.2	1.6	2.4
nonpoint, organic	2.1	2.8	0.1	1.4	1.7	1.2	1.0	1.0	2.2	2.8
nonpoint, nonorganic	2.1	1.6	0.6	0.5	2.0	0.7	0.8	0.0	2.2	2.7
Coastal engineering	2.7	2.1	2.8	3.1	2.3	2.3	2.4	0.0	1.9	3.0
Coastal development	2.7	2.9	3.2	3.4	2.8	2.9	3.3	1.2	2.5	3.2
Direct human	2.8	2.2	2.7	3.3	1.6	2.3	2.5	1.6	2.5	3.0
Aquaculture	2.0	2.0	0.1	3.1	1.7	1.8	2.1	0.0	1.9	1.5
Fishing										
demersal, destructive	1.2	1.4	0.2	0.0	1.0	1.2	0.2	1.5	2.7	3.1
demersal, nondestructive	0.8	1.9	0.9	0.9	1.0	1.6	1.1	2.1	2.9	0.7
pelagic, high bycatch	0.9	0.0	0.1	0.0	0.5	0.5	0.0	0.0	2.6	0.0
pelagic, low bycatch	0.0	0.0	0.0	0.0	0.4	0.7	0.0	0.0	2.6	0.0
aquarium	1.4	0.0	0.0	0.7	0.5	1.6	0.4	0.0	1.8	0.0
illegal/unregulated/unreported	1.2	0.0	0.7	0.0	0.4	1.0	0.6	0.0	1.2	0.0
artisanal, destructive	1.1	0.5	0.8	1.2	0.5	2.0	0.0	1.5	2.3	1.2
artisanal, nondestructive	1.4	0.3	0.5	2.2	0.6	2.5	0.6	0.0	2.1	0.7
recreational	2.0	1.7	0.4	2.1	0.5	2.1	2.2	2.3	2.6	1.3
Climate change										
sea level	2.5	1.9	2.1	3.0	3.1	2.4	2.6	1.6	1.5	1.8
sea temperature	2.8	1.4	0.6	2.4	1.4	2.8	2.1	2.0	1.9	0.8
ocean acidification	0.9	1.0	0.0	1.2	1.3	1.1	1.4	0.0	1.1	0.7
ozone/UV	0.9	1.3	0.0	0.2	1.1	0.8	0.5	0.1	0.7	0.0
Species invasion	2.8	2.9	0.9	1.0	2.8	1.5	1.2	1.3	2.5	2.6
Disease	1.3	1.8	0.0	1.7	1.1	2.2	1.0	0.7	1.8	2.1
Harmful algal blooms	1.9	2.2	0.9	1.6	2.0	1.8	2.3	0.4	1.7	2.5
Hypoxia	1.2	2.1	0.6	0.6	1.9	0.8	1.3	1.0	1.6	2.9
Ocean-based pollution	1.3	0.8	0.5	1.2	1.2	1.2	0.5	0.1	1.7	0.0
Commercial activity	0.3	1.9	1.9	2.0	1.4	1.5	1.9	0.0	1.4	0.0
Ocean mining	0.9	0.0	0.3	0.0	1.1	0.8	0.4	0.0	1.3	0.0
Offshore development	0.7	0.0	0.4	0.0	0.7	0.2	0.0	0.5	0.7	0.0
Benthic structures	1.0	0.9	0.8	1.3	0.9	0.5	1.6	0.0	1.7	0.4
Ecotourism	1.6	0.0	1.0	2.3	1.3	1.8	1.5	0.8	1.7	0.3
Summed threat	58.9	51.4	28.4	55.7	54.9	57.2	48.9	22.4	66.6	53.2
Average threat	1.5	1.4	0.7	1.5	1.4	1.5	1.3	0.6	1.8	1.4

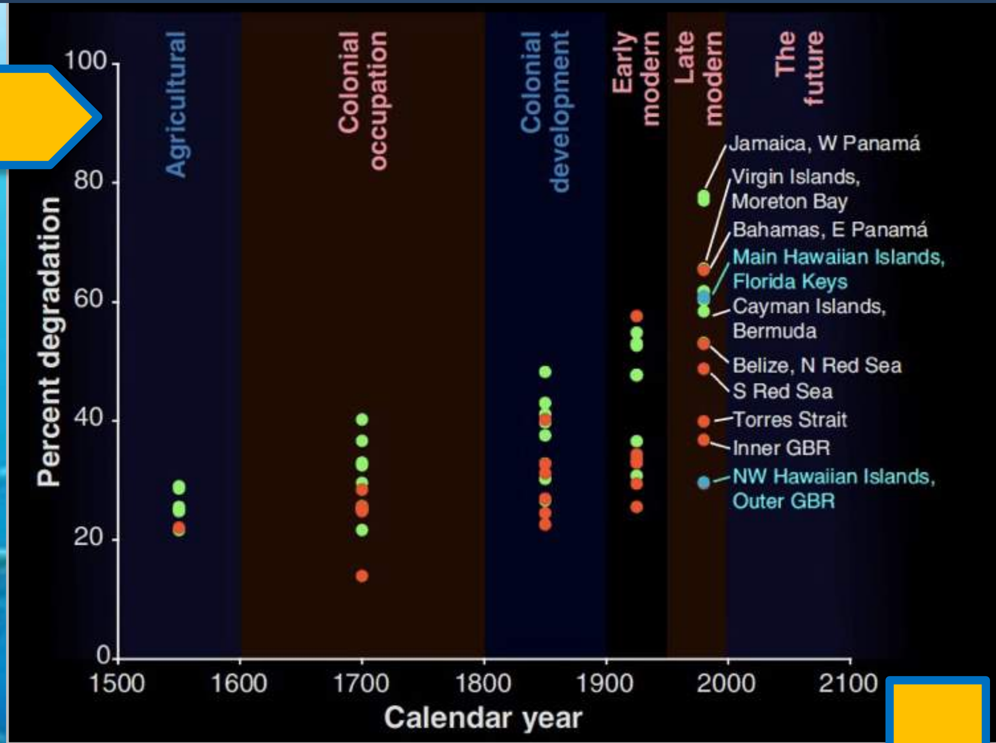
Score from expert opinion. For each ecosystem and each threat a sensitivity score has been assigned



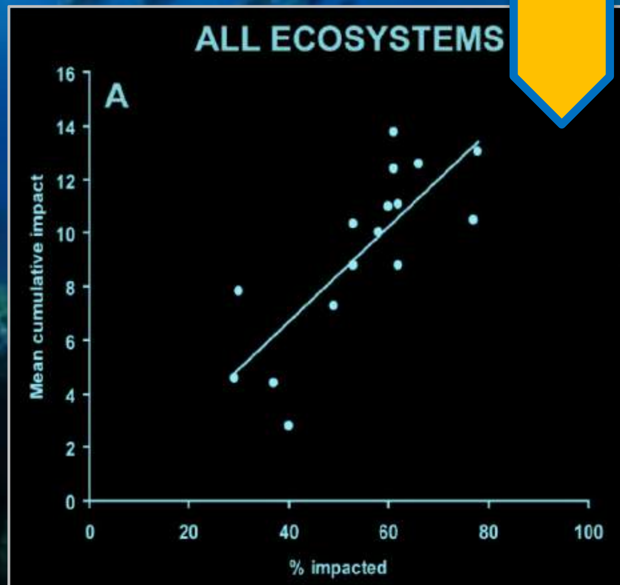
Pressure response relationship



Pandolfi et al., 2003. Science



Pandolfi et al., 2005. Science



I_c = 0.1762 × [level of system degradation] – 0.3381

Halpern et al., 2008. Science

<10%	very low (<1.4)		50-70%	medium-high (8.47-12)
10-30%	low (1.45-4.95)		70-90%	high (12-15.52)
30-50%	medium (4.95-8.47)		>90%	very high (>15.52)