Conservation on land

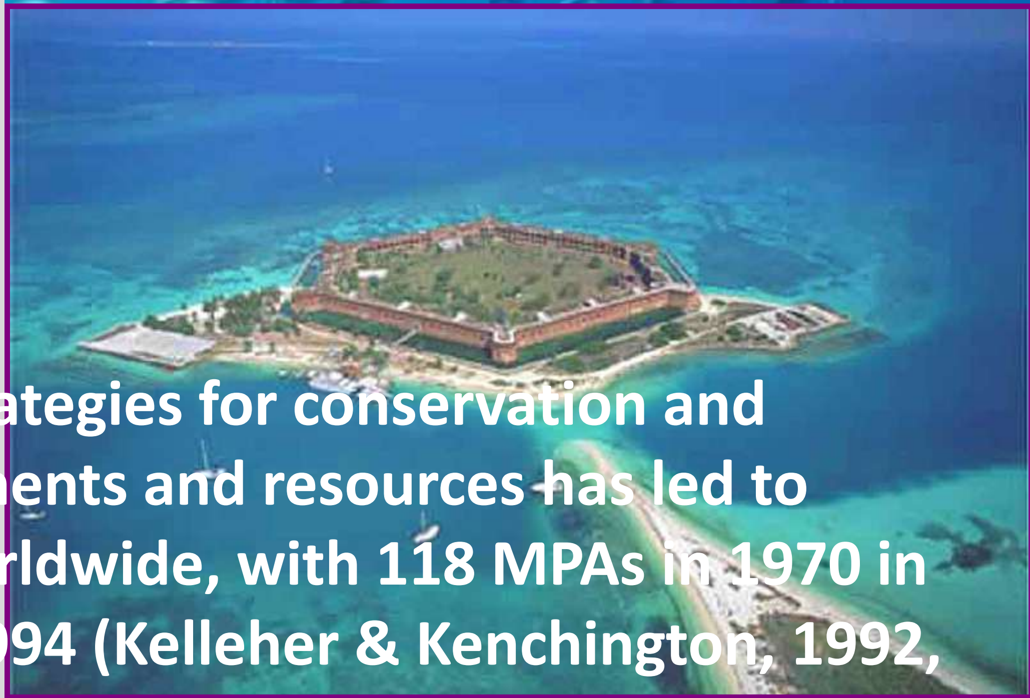
First protected forests in India more than 2000 years ago (Talbot, 1984);

In Europe (England, Italy, etc.) between XVII and XIX centuries several protected areas were established with the aim of protecting natural resources, but indeed they were hunting reserve only for rich people;

In 1872, the Yellowstone National Park was established as a “place where natural beauty is preserved for the whole society” (Wright, 1996).

Marine conservation

The implementation of Marine Protected Areas (MPAs) is relatively recent: the first MPA was probably the Fort Jefferson National Monument created in Florida in 1935 (Gubbay, 1995).



In 1950s the need for suitable strategies for conservation and management of marine environments and resources has led to increase the number of MPAs worldwide, with 118 MPAs in 1970 in 27 countries and 1306 MPAs in 1994 (Kelleher & Kenchington, 1992, Kelleher *et al.*, 1995)

Historical evolution of conservation purposes

Rough timeline	Framing of conservation	Key ideas	Science underpinning
1960 1970	**Nature for itself** 	Species Wilderness Protected areas	Species, habitats and wildlife ecology
1980 1990	**Nature despite people** 	Extinction, threats and threatened species Habitat loss Pollution Overexploitation	Population biology, natural resource management
2000 2005	**Nature for people** 	Ecosystems Ecosystem approach Ecosystem services Economic values	Ecosystem functions, environmental economics
2010	**People and nature** 	Environmental change Resilience Adaptability Socioecological systems	Interdisciplinary, social and ecological sciences

Modified from Mace, 2014

Key differences between terrestrial and marine ecosystems (1)

Feature	Terrestrial ecosystems	Marine ecosystems
Environmental		
Prevalence of aquatic medium	less	greater
Dimensions of species distribution	two-dimensional	three-dimensional
Scale of chemical and material transport	smaller	greater
"Openness" of local environment (i.e., rates of import and export)	less	greater
Ecological		
Phyletic diversity (α and β)	less	greater
Life-history traits		
Per capita fecundity of invertebrates and small vertebrates	lower	higher
Per capita fecundity of mammals	low	low
Difference in dispersal between life stages	less	greater
Importance of pollination syndromes	great	minimal
Rate of response to environmental variability	lower	faster
Sensitivity to large-scale environmental variability	lower	higher
Population structure		
Spatial scale of propagule transport	smaller	greater
Spatial structure of populations	less open	more open
Reliance on external sources of recruitment	lower	higher
Likelihood of local self replenishment	high	low
Sensitivity to habitat fragmentation	greater	less
Sensitivity to smaller scale perturbations	greater	less
Temporal response to large-scale events	slower (centuries)	higher (decades)

(Carr et al., 2003)

Key differences between terrestrial and marine environments (2)

Trophic		
Lateral transport of energy	low (few planktivores)	high (many planktivores)
Turnover of primary producers	slow (many perennials)	high (few perennials)
Reliance of carnivores on external input of prey	lower	higher
Prey populations influenced by external input of predators	lower	higher
Pronounced ontogenetic shifts of vertebrates	rare	very common
Genetic		
Effective population size	smaller	larger
Spatial scale of gene flow	smaller	larger
Interpopulation genetic diversity	higher	lower
Types and relative importance of contemporary human threats		
Habitat destruction	widespread	spatially focused (e.g., estuaries, coral reefs)
Loss of biogenic habitat structure	widespread (e.g., deforestation)	spatially focused (e.g., estuaries, coral reefs)
Trophic levels threatened or exploited	lower (primary producers)	higher (predators)
Degree of domestication	higher	lower

(Carr et al., 2003)

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)

Conservation purposes

→ Increase or maintain species diversity

→ Protect vulnerable species

→ Protect areas of high endemism or biodiversity hotspots

→ Protect biological uniqueness

→ Protect commercial species (nursery areas, shelter areas, genetic diversity), increasing their abundance (and/or biomass)

→ Protect priority habitats

→ Education, research, aesthetic and cultural

Often multipurpose MPAs

Networks to increase complementarity, or connectivity

Restoration purposes

Contribution of ecological theories to marine conservation

Theory of island's 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)

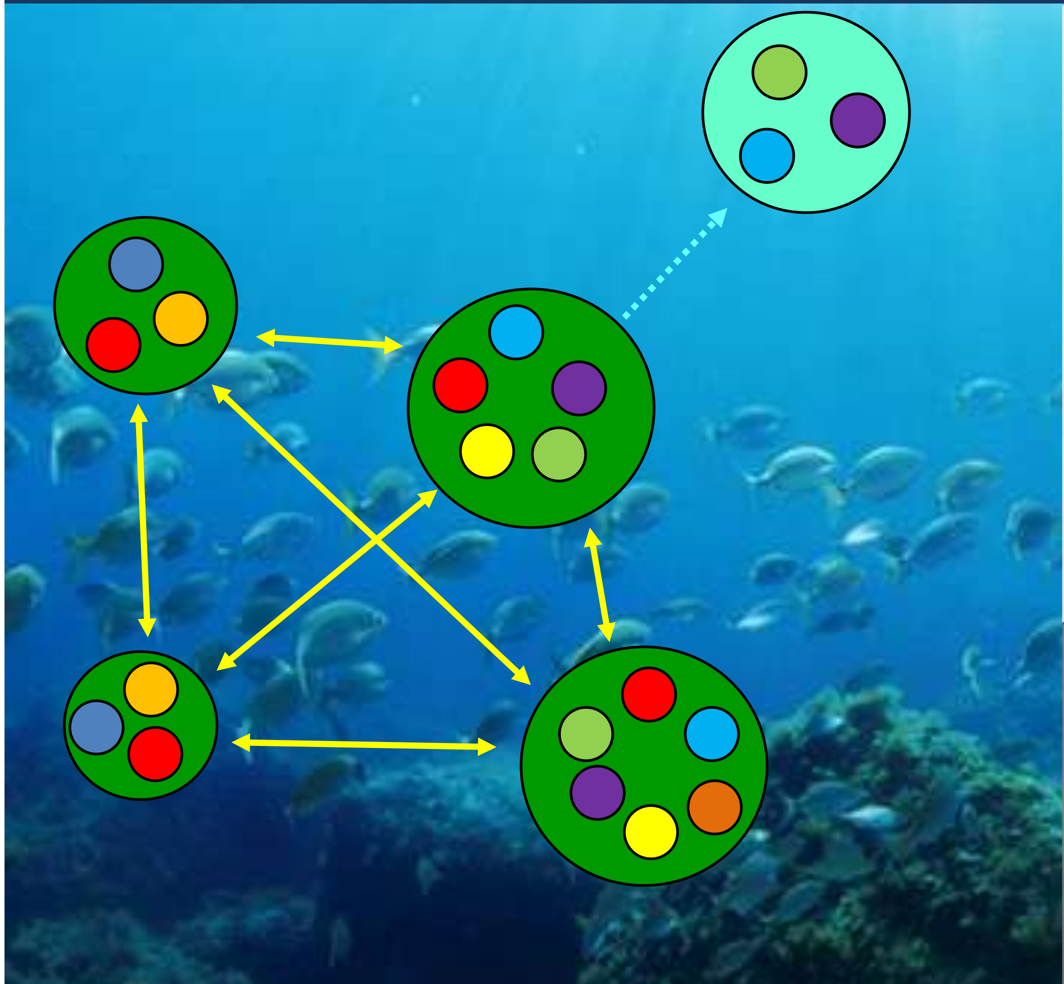
Supply side ecology

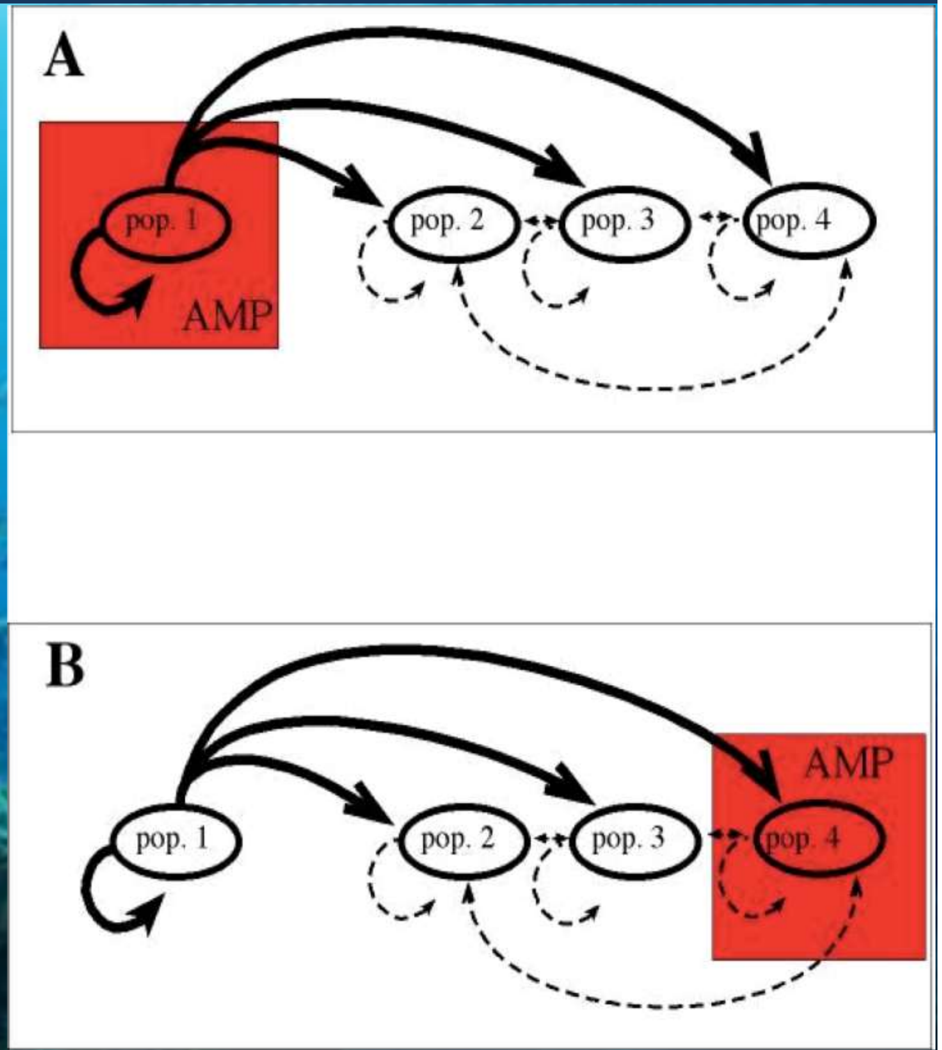
Metapopulation theory

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

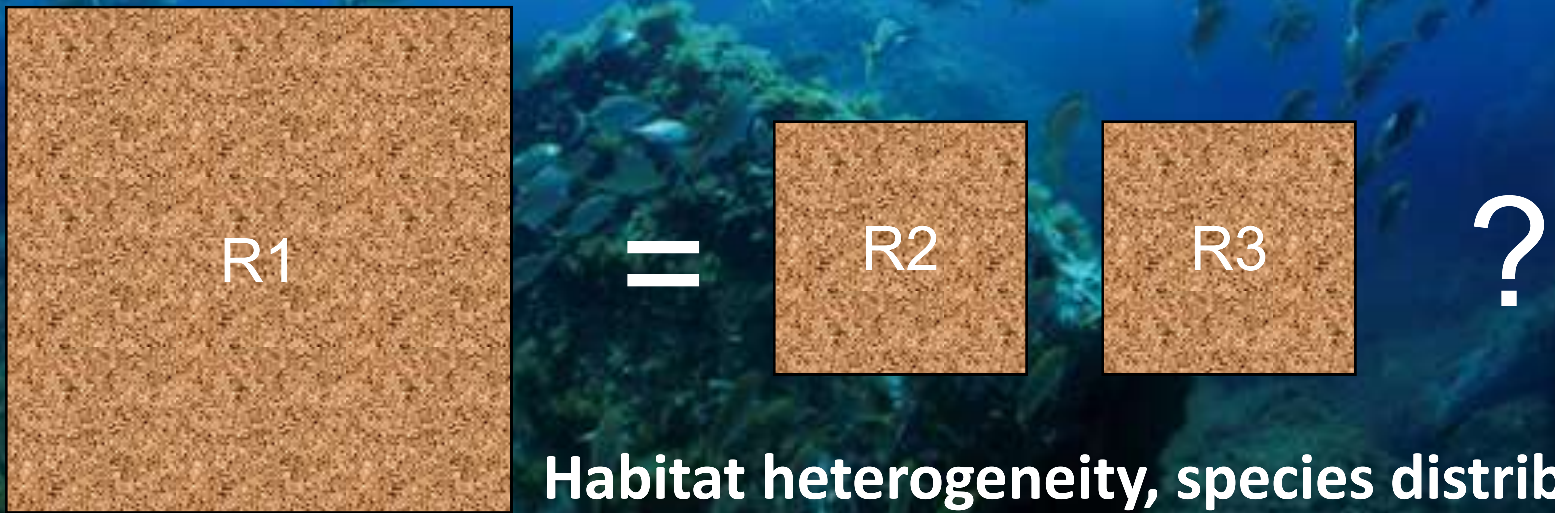
IBT raised concerns about the opportunity to implement single large or several small reserves

Large areas allow protecting more species than smaller ones. However…Large areas are expensive in terms of management and enforcement. 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

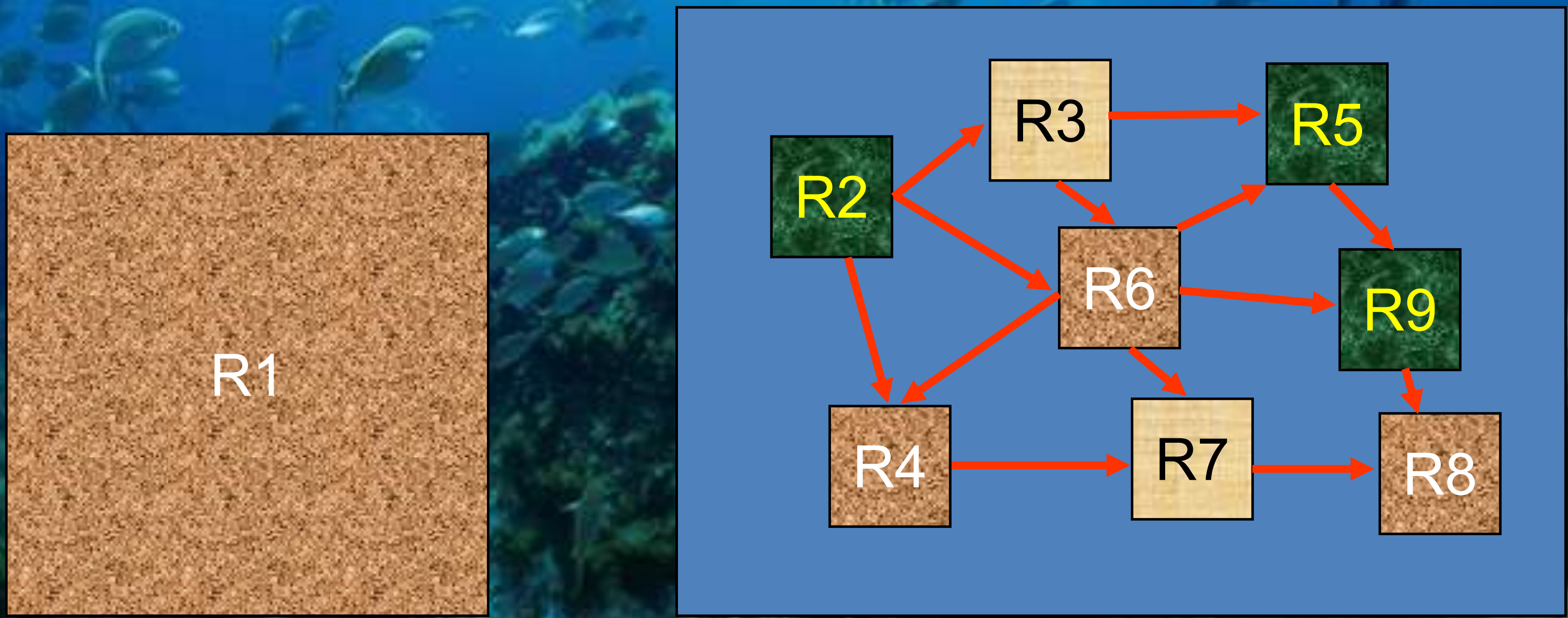
Large reserve for large animals or animals requiring a large surface for movements and foraging

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;

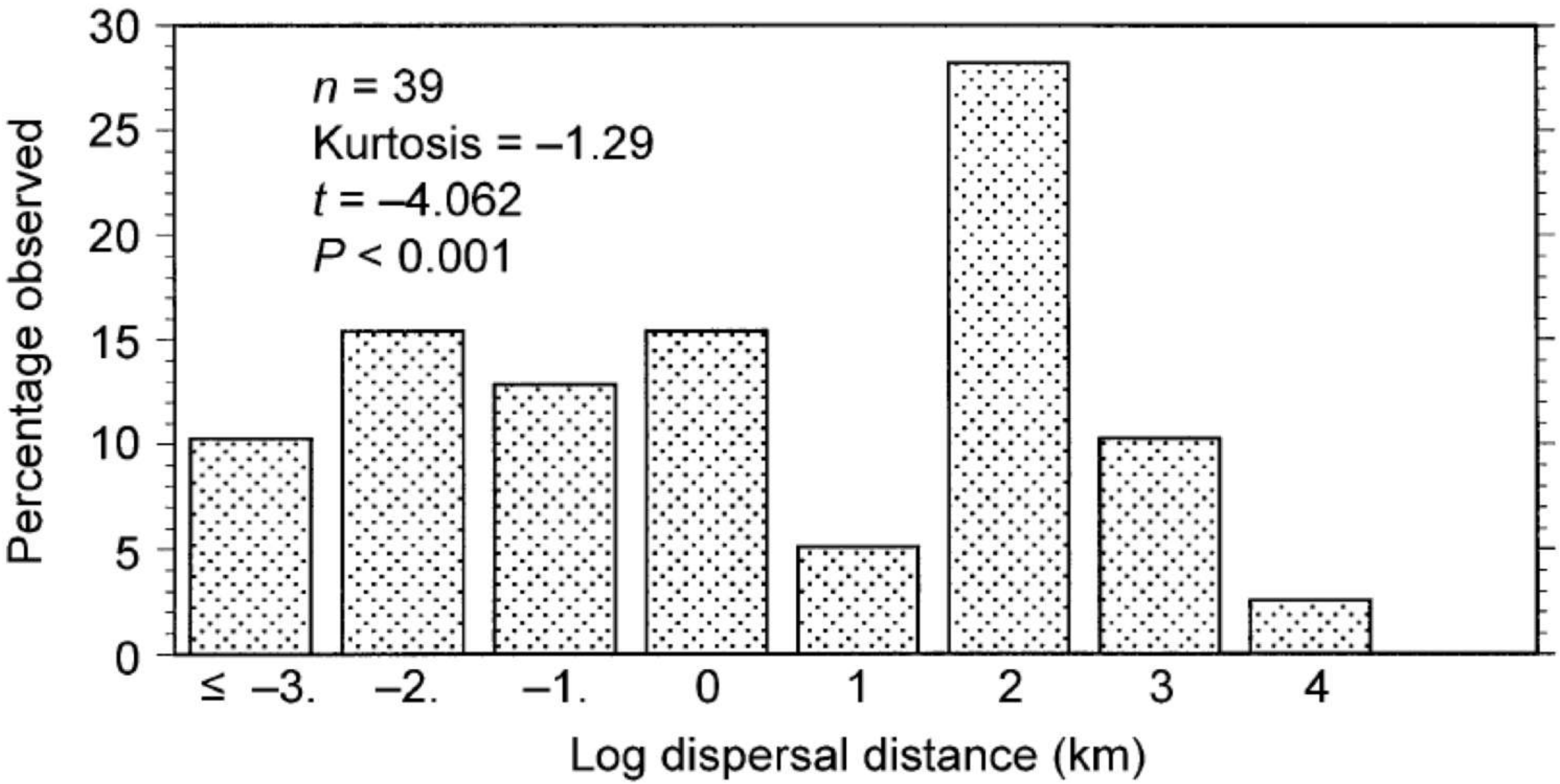
5 – better respond to external disturbace through a buffer effect

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 events to increase ensurance that catastrophic events will not affect the core of reserves. (Allison et al., 2003)

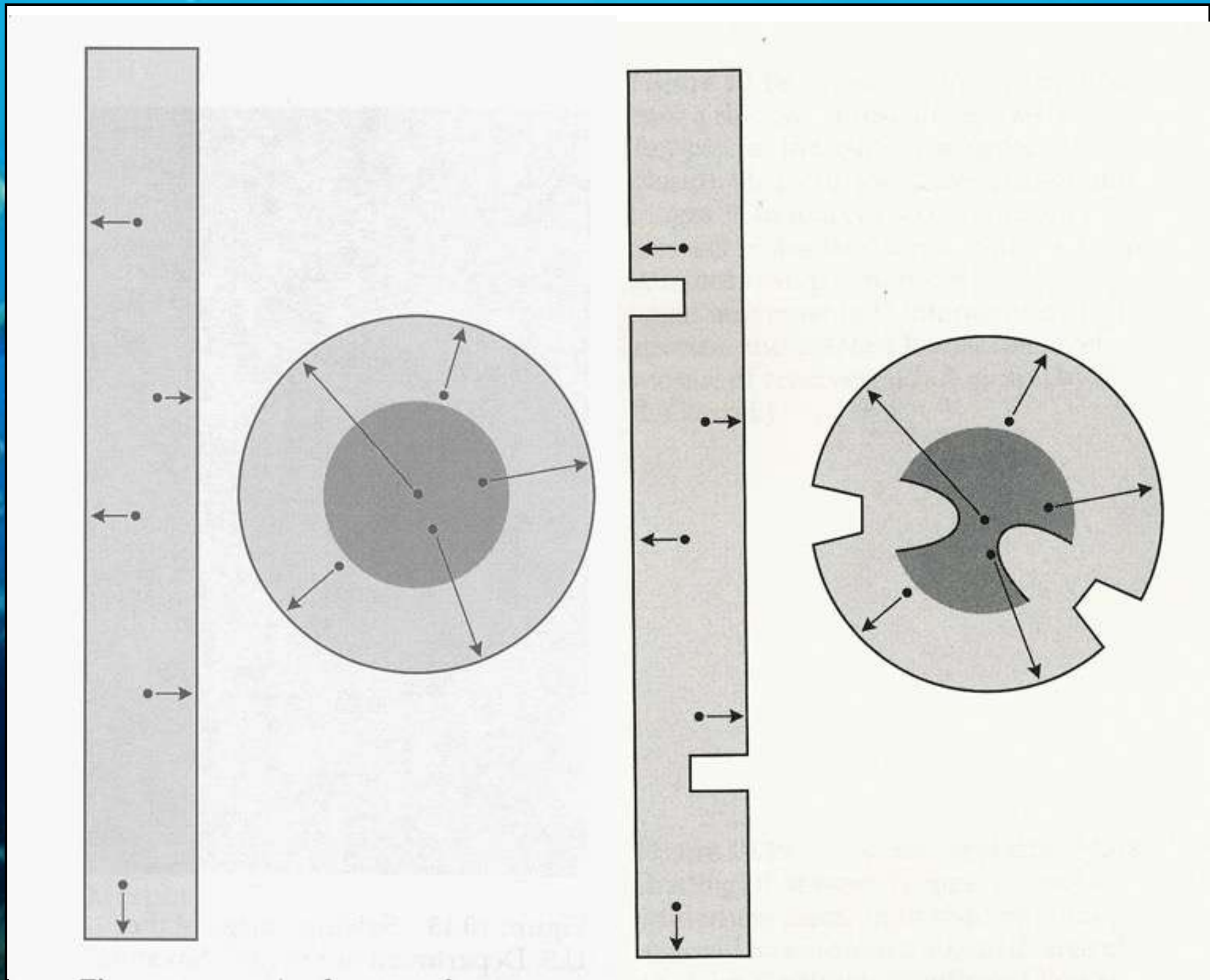
Environmental context: spacing



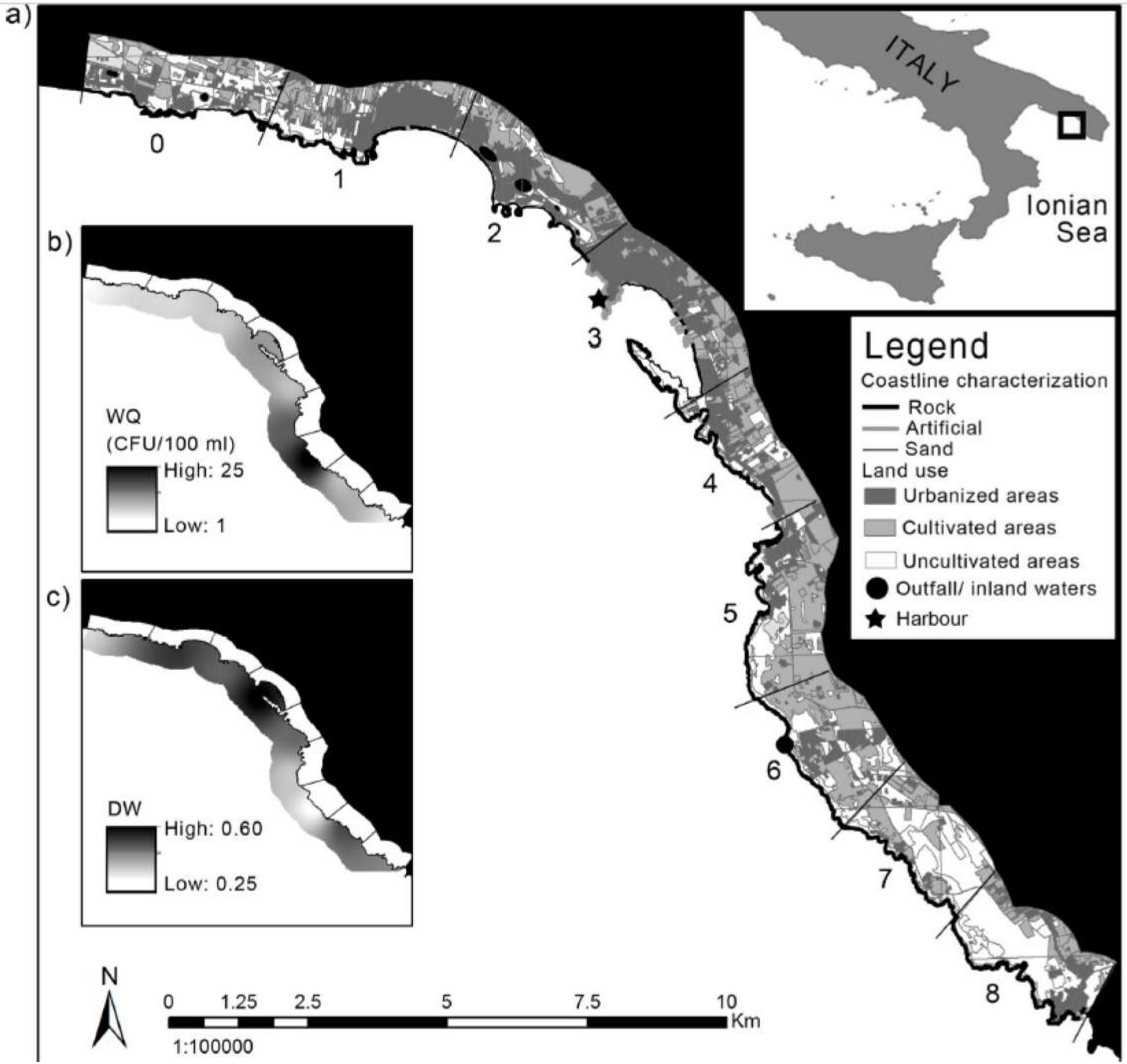
1) Bimodal trend in dispersal strategies, one short distance and long distance.
2) Reserves with diameter of 4-5 km, 10-20 km apart are wide enough to retain propagules of short-distance dispersers and far enough to allow long-distance dispersers to be captured. However, limited range of organisms. Habitat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

Environmental context

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



Environmental context

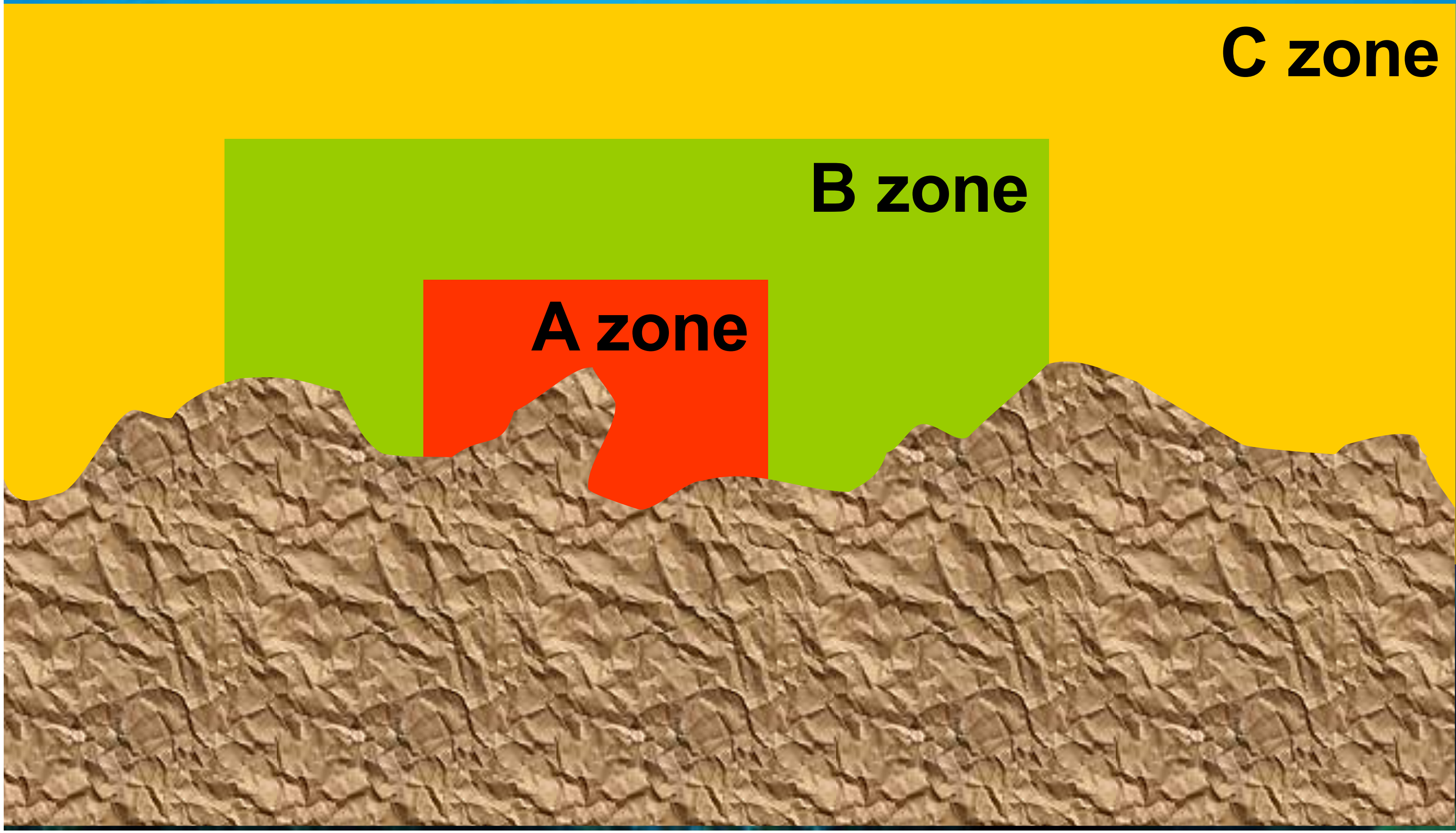


Guarnieri et al., 2016

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

Zonation

Management of MPAs relies, as first, on zonation. This allow to delimit different areas at different protection regimes in order to fulfil conservation purposes and reduce conflicts with neighbouring human populations and influence of human activities



Zonation

A Zone (*no-take, no access*): full protection.
The core of the MPA, all human activities are forbidden, except those authorized concerning scientific research and control.

B Zone (*general protecton*)
Local fishery with not-impacting gears (selective fishing) could be authorized. Bathing, SCUBA diving frequentation (limited or controlled), entrance, and authorized boating can be allowed.

C Zona (*buffer area*): general protection
Same as B zone, plus anchoring (but within limited specific areas), recreational fishing (but not spearfishing) could be allowed

Summary: factors to take into account

Protection purpose(s) (seascape, communities/ecosystems, target species)

Geographic position, size, shape

Connectivity of protected species or communities (network)

Size of protected populations

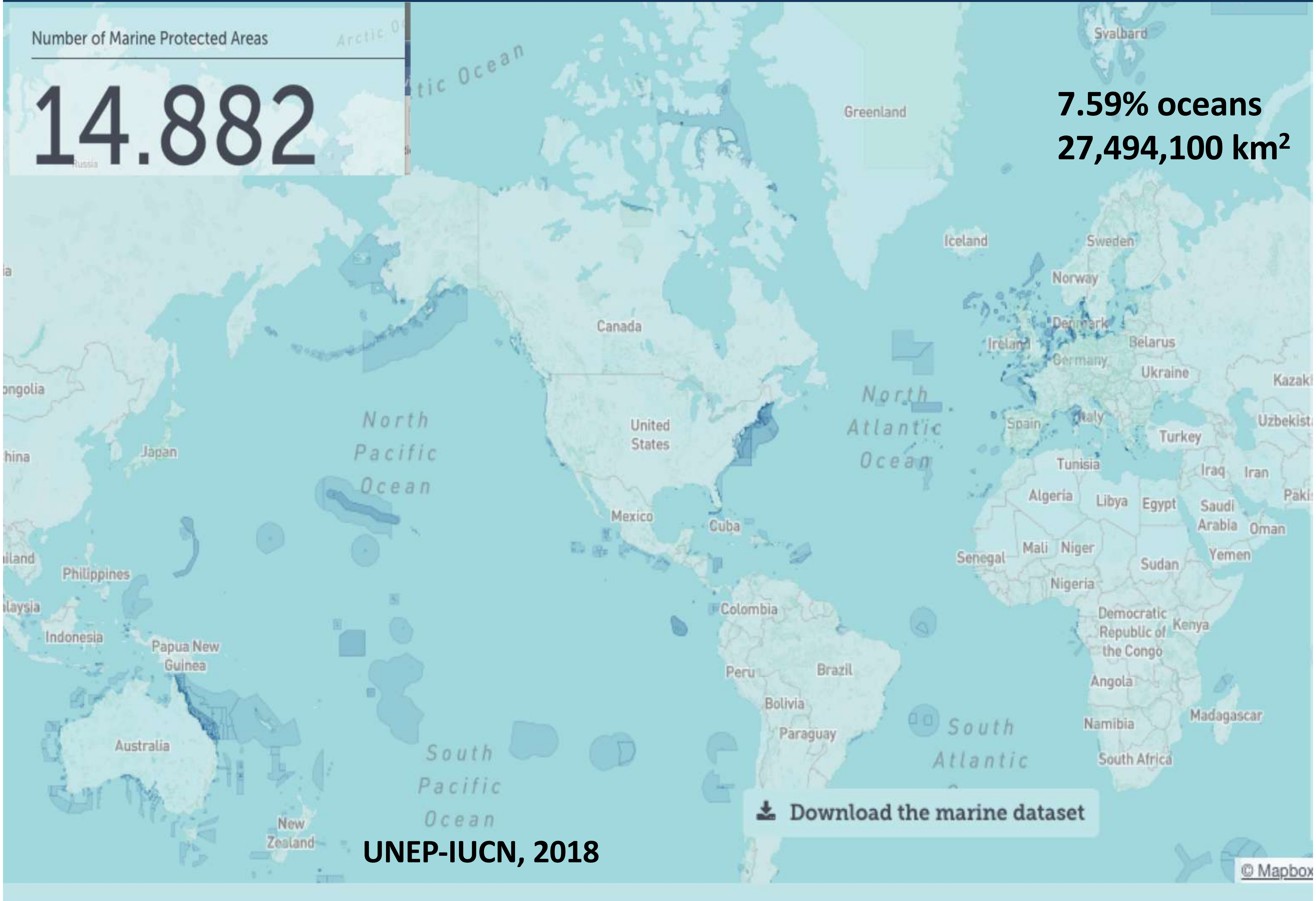
Ecological process with the MPA

Human threats from neighbouring areas

Socio-economic and cultural context (reduce conflicts and increasing compliance)

Governance and environmental policy

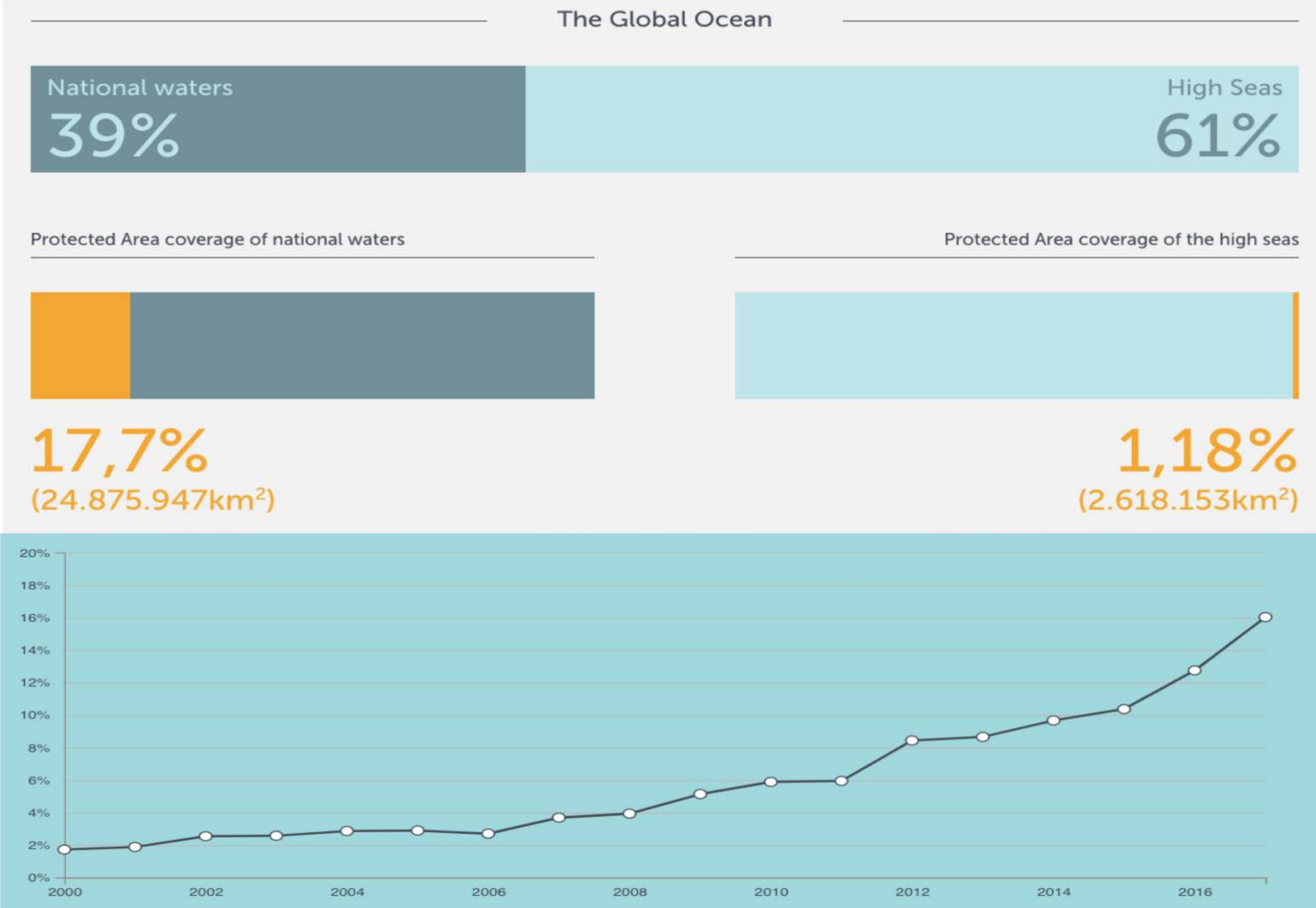
Marine conservation at global scale



7.59% oceans
27,494,100 km^2

UNEP-IUCN, 2018

Marine conservation at global scale

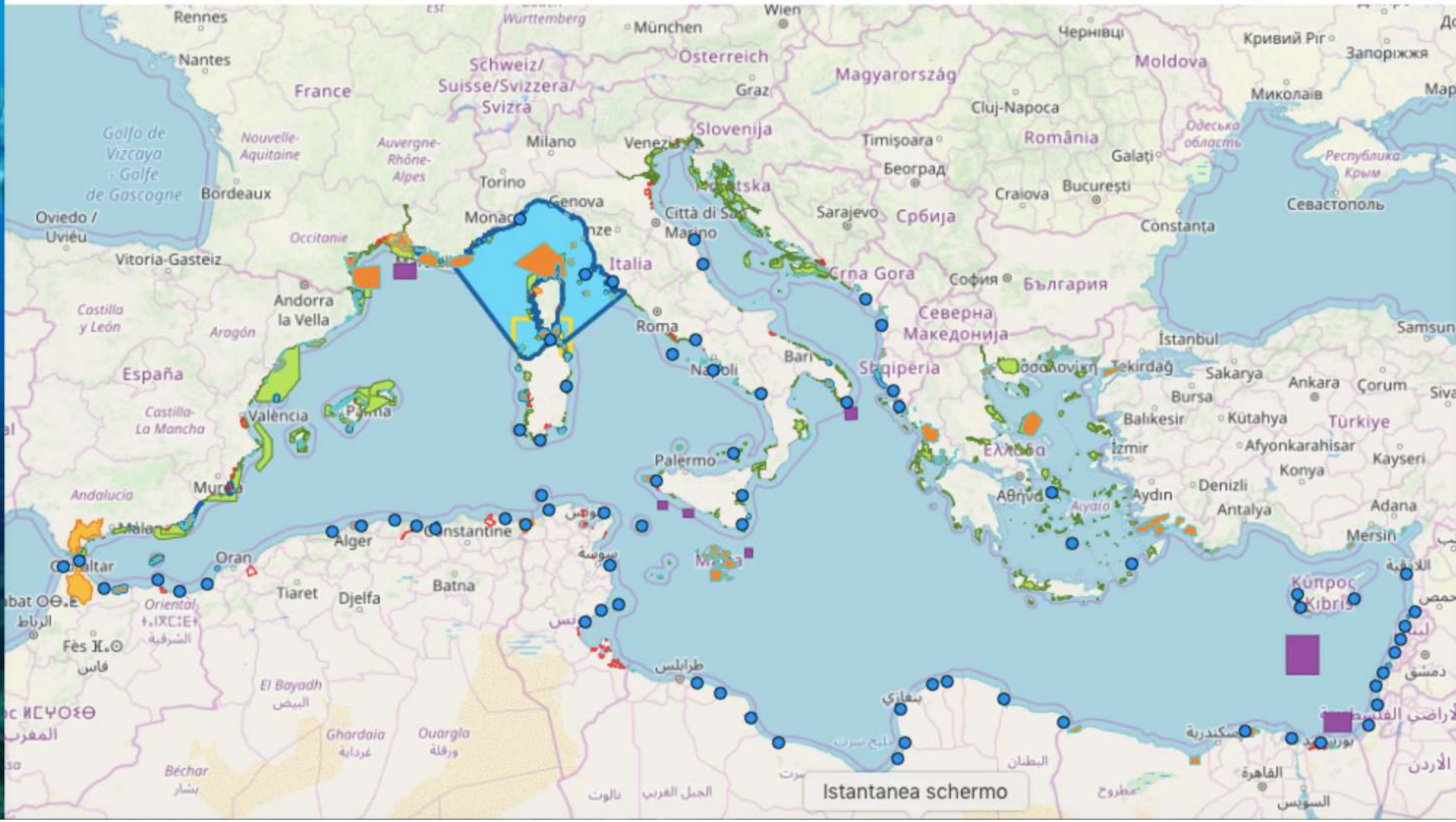


The Mediterranean Sea

MAPAMED

MedPAN UN environment SPA/RAC

This is a simple visualisation of MAPAMED, a more advanced visualisation will be part of our new web site soon.
Be patient, it is a bit long to download the first time.
Nov. 2017 release - If you need access to the dataset please contact reda.neveu@medpan.org



The Mediterranean Sea

There are 1,231 MPAs and OECMs in the Mediterranean covering 179,798 km^2 which places a surface of 7.14% under a legal designation

Over 72.77% of the surface covered is located in the Western Mediterranean, 90.05% of the total surface covered by MPAs and OECMs are found in EU waters.

9.79% of European waters are covered mostly due to the Natura 2000 at sea network which rarely affords strict restrictive measures.

Mostly shallow waters

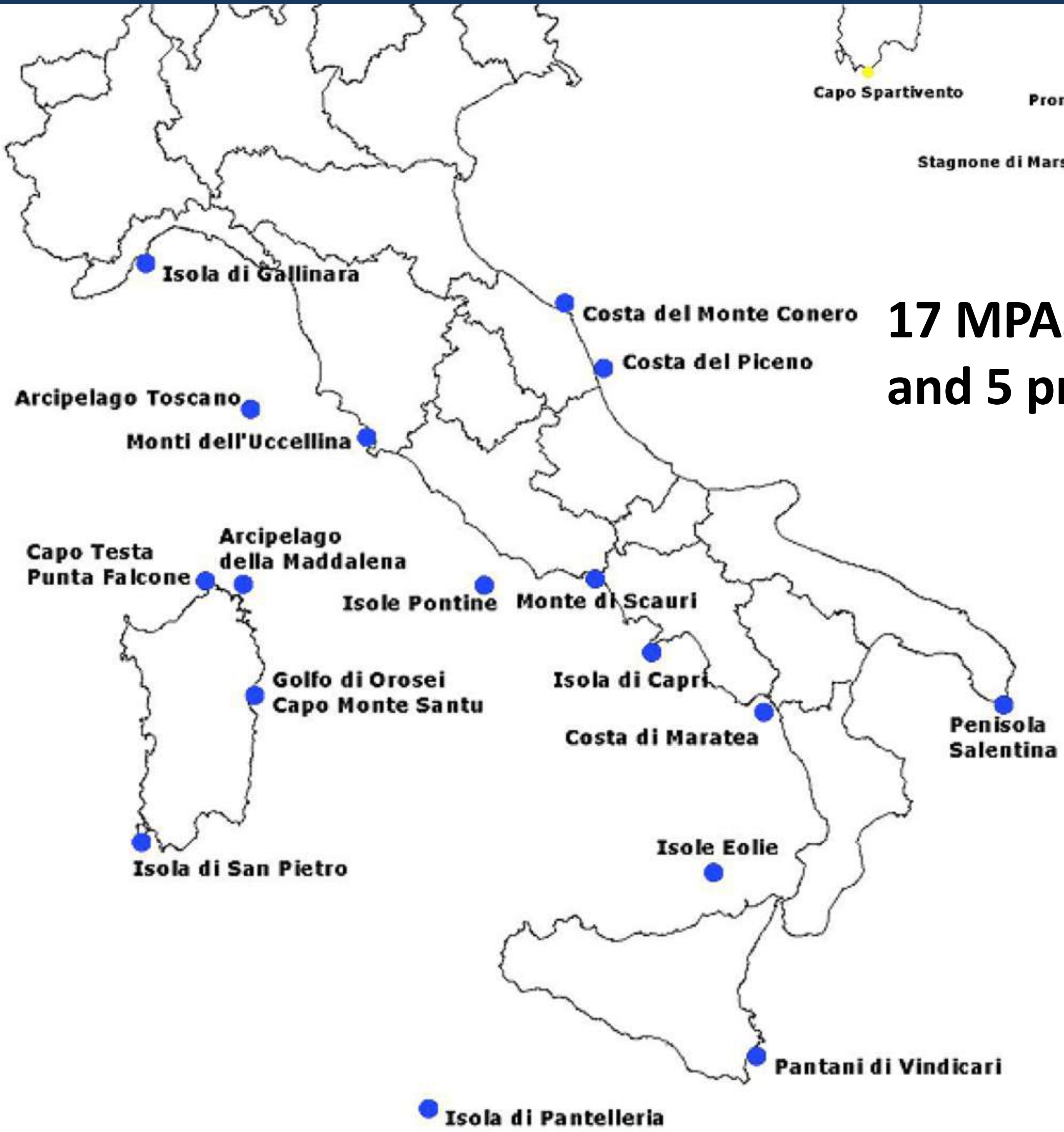
39.77% of *Posidonia* meadows and 32.78% of Mediterranean coralligenous communities are covered.

65.05% of MPAs of national designations have a marine surface of less than 50 km^2 (77.17% of all MPAs and OECMs), 69 nationally designated sites have a marine area smaller than 10 km^2 and 46 are larger than 100 km^2.

78% of nationally designated MPAs are over 10 years old, which is considered the minimum age for an MPA to reach a certain maturity (even though the time required for an MPA to be effective varies greatly from one area to another) and 46 sites are over 20 years old.

The Italian coasts: implemented

The Italian coasts: next designation



17 MPAs for next designation and 5 projected

Designation and implementation

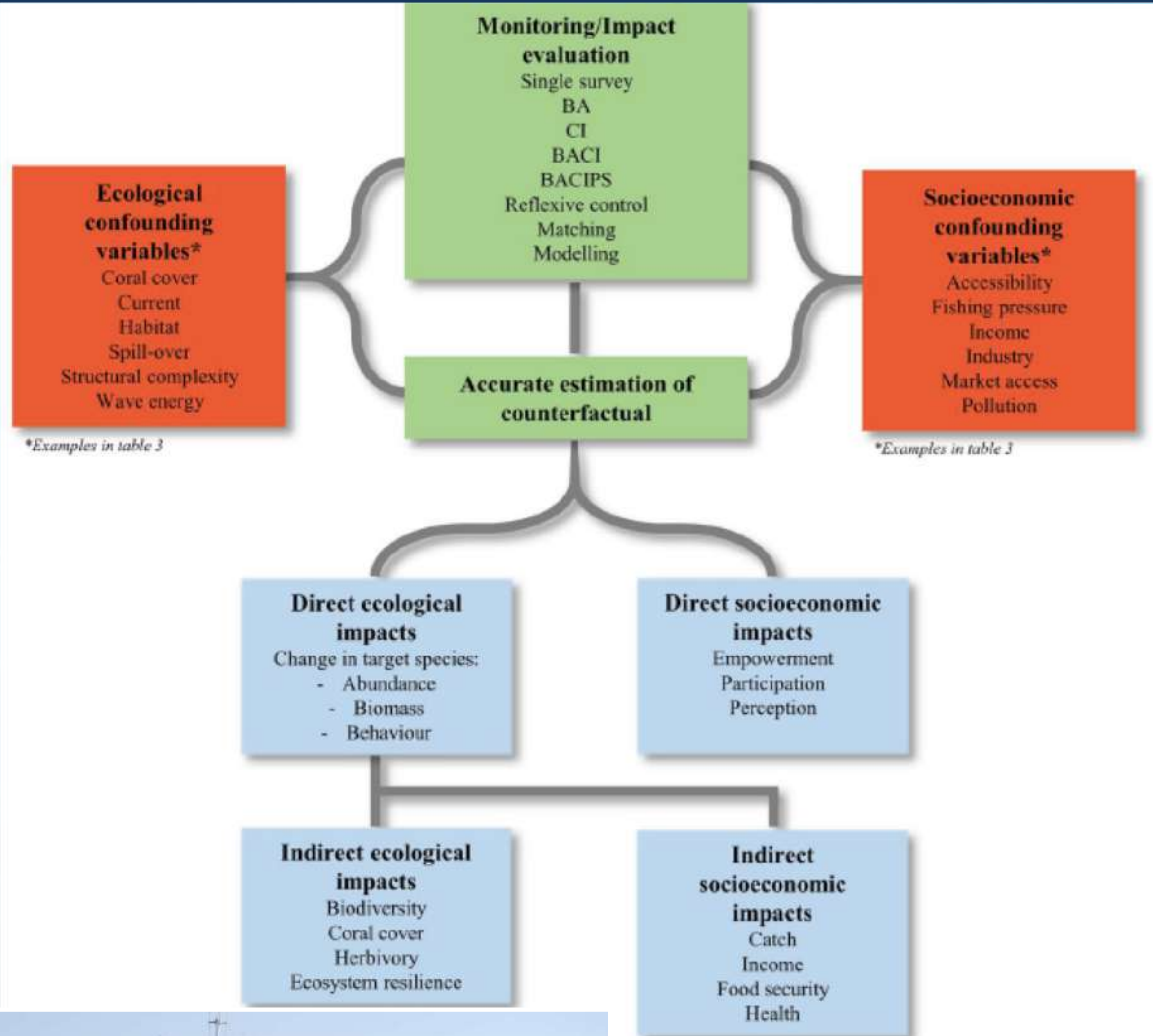
As first, in order to implement a Marine Protected Area, a given site have to be designated by law as a potential marine area for protection. Prior to institution, a comprehensive baseline knowledge of the natural environment, habitats, biodiversity, and socio-economic issues must be acquired.

Once the legal procedure is started, the area is recognized as an MPA of forthcoming institution. MPAs are instituted by a a decree of the Ministry of the Environment, which identify the name of the MPA and dictates its boundaries, objectives of conservation, and regulation.

MPA are managed by governmental bodies, scientific institutes, or recognized NGOs, or consortia of several such organizations, after a formal engagement by the Ministry in agreement with local and regional institutions.

Monitoring what and how

A number of monitoring strategies exists depending on the aspect of conservation under study.
Monitoring is not only related to bio-physical effects, but also to socio-economic consequences of protection and governance effectiveness



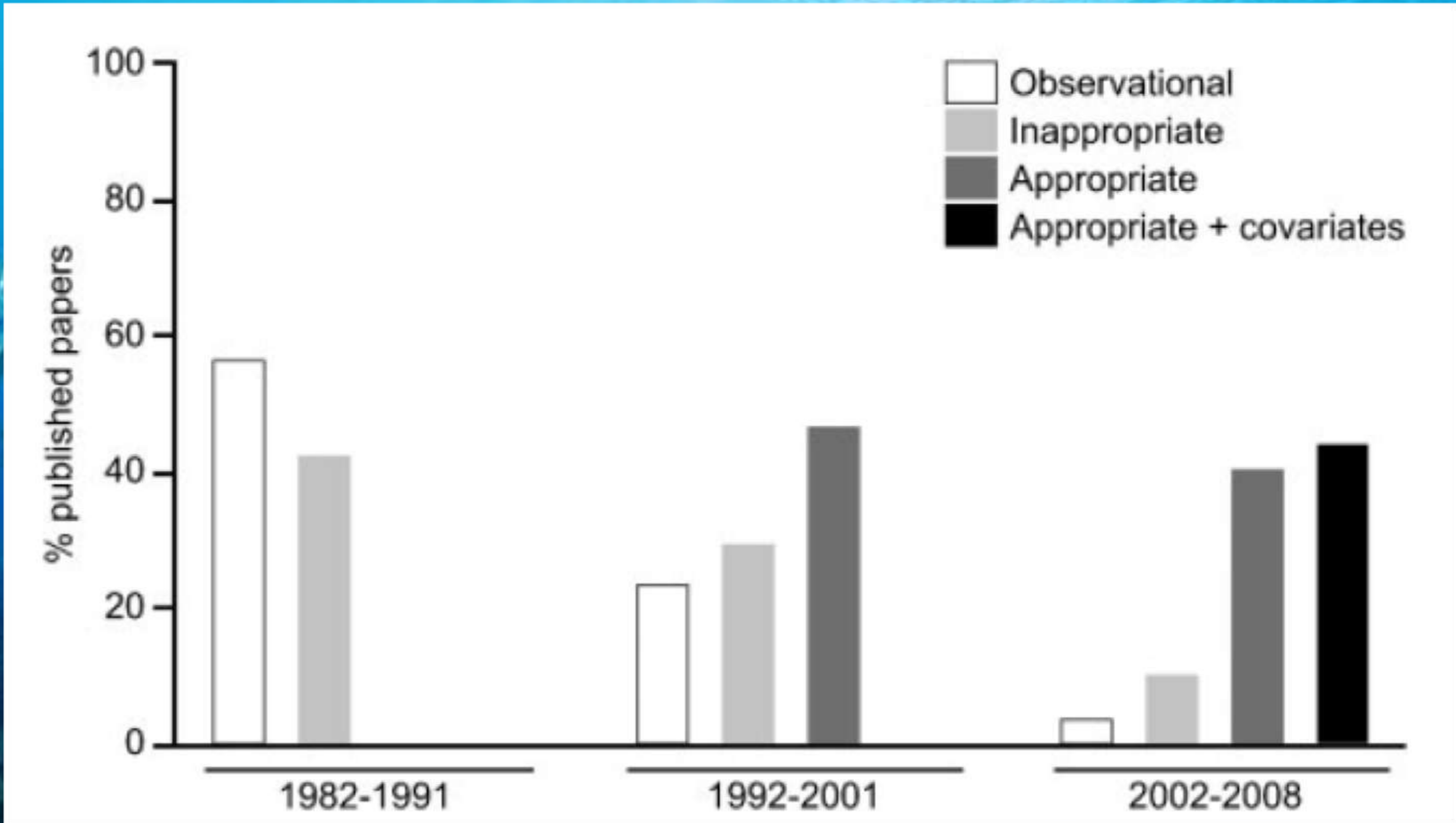
Potential confounding effects

Potential confounders	Examples of how poorly chosen control sites can lead to over- or under-estimation of impact
Coral cover and structural complexity	Greater coral cover and complexity increases the carrying capacity of an ecosystem. An MPA is configured to protect areas with exceptional coral cover. Subsequent control-intervention studies that fail to account for high coral cover will overestimate impact
Displaced fishing effort	An MPA displaces current fishing activity to a nearby reef, which is subsequently used as a control site. Displaced fishing effort from the MPA will result in variables of interest declining in nearby areas, with overestimation of impact, even though the net stock remains the same
Education	Education about ecological recovery is introduced by an NGO along with an MPA. Perceptions of ecosystem health in the MPA community therefore increase. At the same time they also conduct educational outreach in a nearby control village with no MPA, thereby increasing their understanding of the damage fishing is causing. Impact is overestimated because the difference in perceived change between MPA and control villages is the result of additional educational programs and not the implementation of the MPA
Fishing pressure	Control sites are selected in areas with higher fishing pressure than would have occurred in MPAs, overestimating impact. Sites with high fishing pressure do not represent an accurate counterfactual unless the MPA sites would also have had equally high fishing pressure in the absence of management. (e.g. Wantiez et al. 1997; Goetze et al. 2011, 2015; Goetze and Fullwood 2013)
Habitat quality	High/Low-quality habitats are selected for protection by MPAs, which have a higher/lower carrying capacity of target species than control sites. Subsequent control-intervention studies over/under-estimate impact. (e.g. Jupiter et al. 2012)
Income	A village with high average income is used as a control for an MPA village with low income. Fishing in the high-income village is conducted with new equipment and faster boats than the MPA village. Economic impact is underestimated because of failure to account for difference in fishing efficiency

Potential confounding effects

Industry	A tuna canning factory is introduced near a village heavily reliant on fishing. The factory employs people from a nearby village with an MPA but not from the village acting as the control. Dependence on fishing decreases in the MPA village but remains stable in the control village. Income rises in the MPA village. The biological impact of the MPA is overestimated because the number of people fishing in the MPA village has decreased. The economic impact of the MPA is overestimated because increased income stems from employment in the factory
Market access	A non-MPA village has excellent access to a large market in the capital city. A nearby MPA village has greater catch rates, but economic impact is underestimated because they receive less income for their catch due to unequal market connection
Politics	A recent election has empowered many community members in an MPA village to participate in village affairs. Social impact of the MPA is overestimated because empowerment was not the result of the MPA, but of the recent election
Pollution	Sedimentation from a nearby agricultural enterprise has increased algal proliferation on an MPA reef. Impact is underestimated compared to a healthy control site
Spillover from adjacent MPA	Control sites are located too close to MPA, within the radius of target species spillover. Surveys record a smaller difference between control and MPA sites and ultimately underestimate impact
Wave energy and current	High-current environments (e.g. lagoon entrances) can have greater abundances of fish than surrounding areas. An MPA is in the middle of a reef but the lagoon entrance is used as a control site. Greater species abundance at the lagoon entrance results in an underestimation of impact

Appropriateness of MPA studies



Guidetti & Claudet 2010

Guidelines for improving biological monitoring

1) The social factors are seldom explicitly considered or quantitatively evaluated. When protection was not enforced and fishing continued to occur within the MPA, an MPA is just a paper park and no protection effects should be expected. Actual enforcement and compliance, and not the formal MPA establishment, must be considered as the true starting point of protection.

2) The choice of the indicators should be clearly linked to the MPA goal(s), the hypothesis tested and the pre-existing knowledge. For example, species richness, which seldom responds to protection, should be used only when the specific MPA goal is to enhance biodiversity. On the other hand, indicators that perform well in responding to cessation of fishing (e.g. density and size of commercial fish) should only be used when the specific MPA goal is the recovery of target populations.

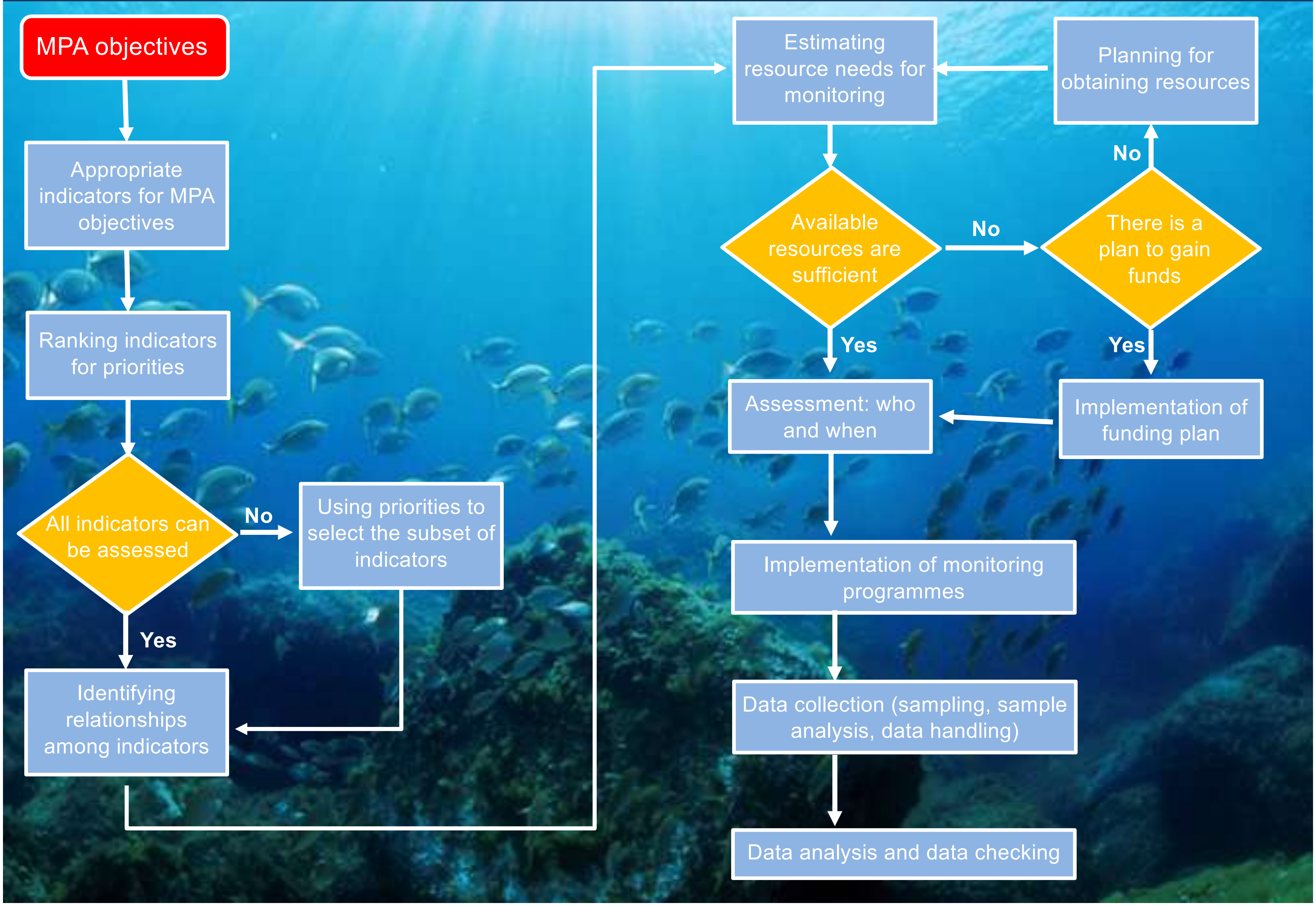
3) Habitat structure (both heterogeneity and complexity) affects indicators of the response to protection. Since MPAs are often established in complex and heterogeneous habitats, we need to distill the effects of protection from those attributable to habitat features.

4) MPA size and age may exert a strong influence on the response to protection of fish, invertebrates and the whole marine community

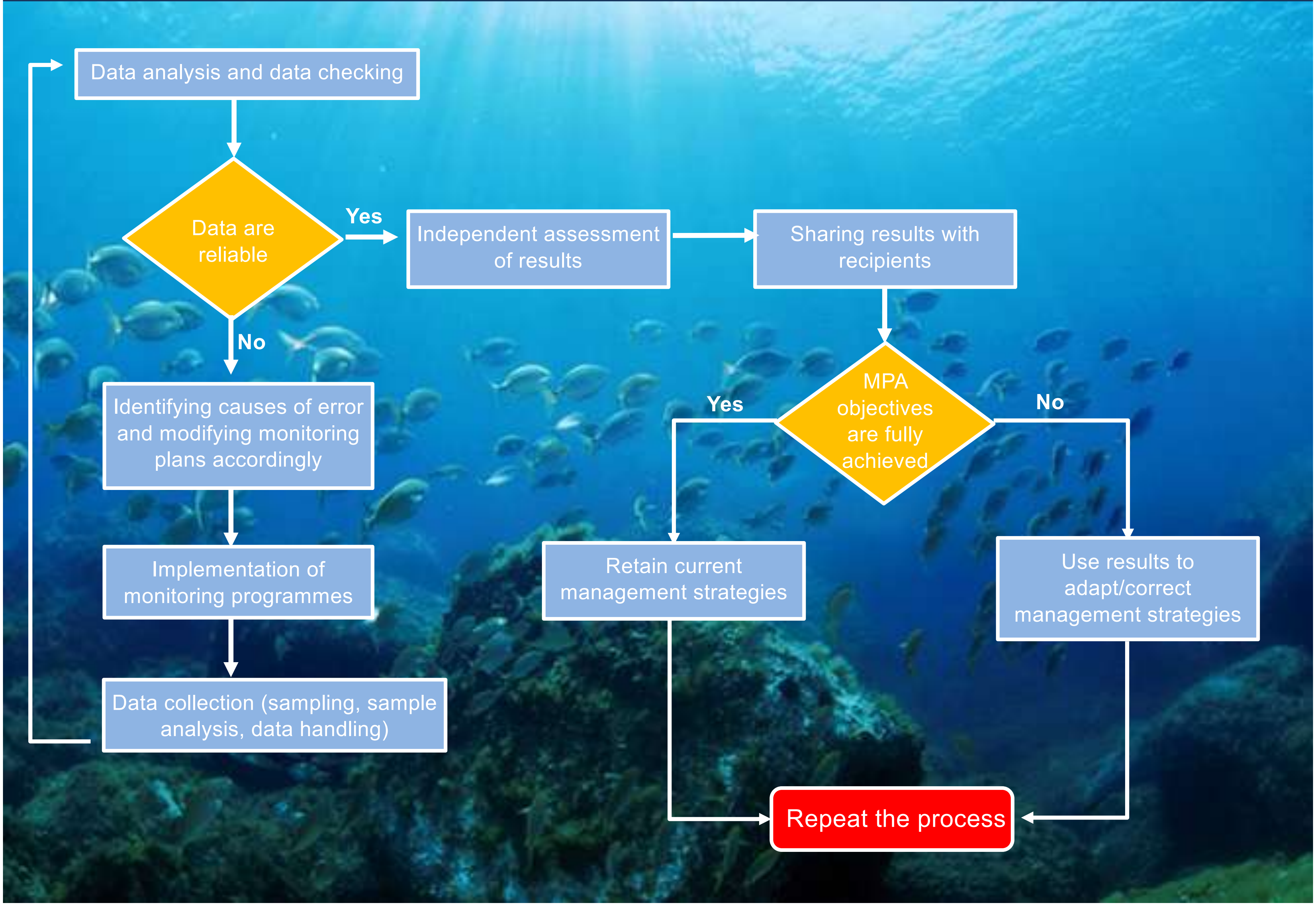
5) Quantifying the actual fishing pressure occurring outside a MPA, the potential spillover across MPA boundaries, as well as human behaviour in control areas (e.g. displacement effects) is essential for an appropriate assessment of MPA effectiveness

Guidetti & Claudet 2010

Work flow for monitoring plan

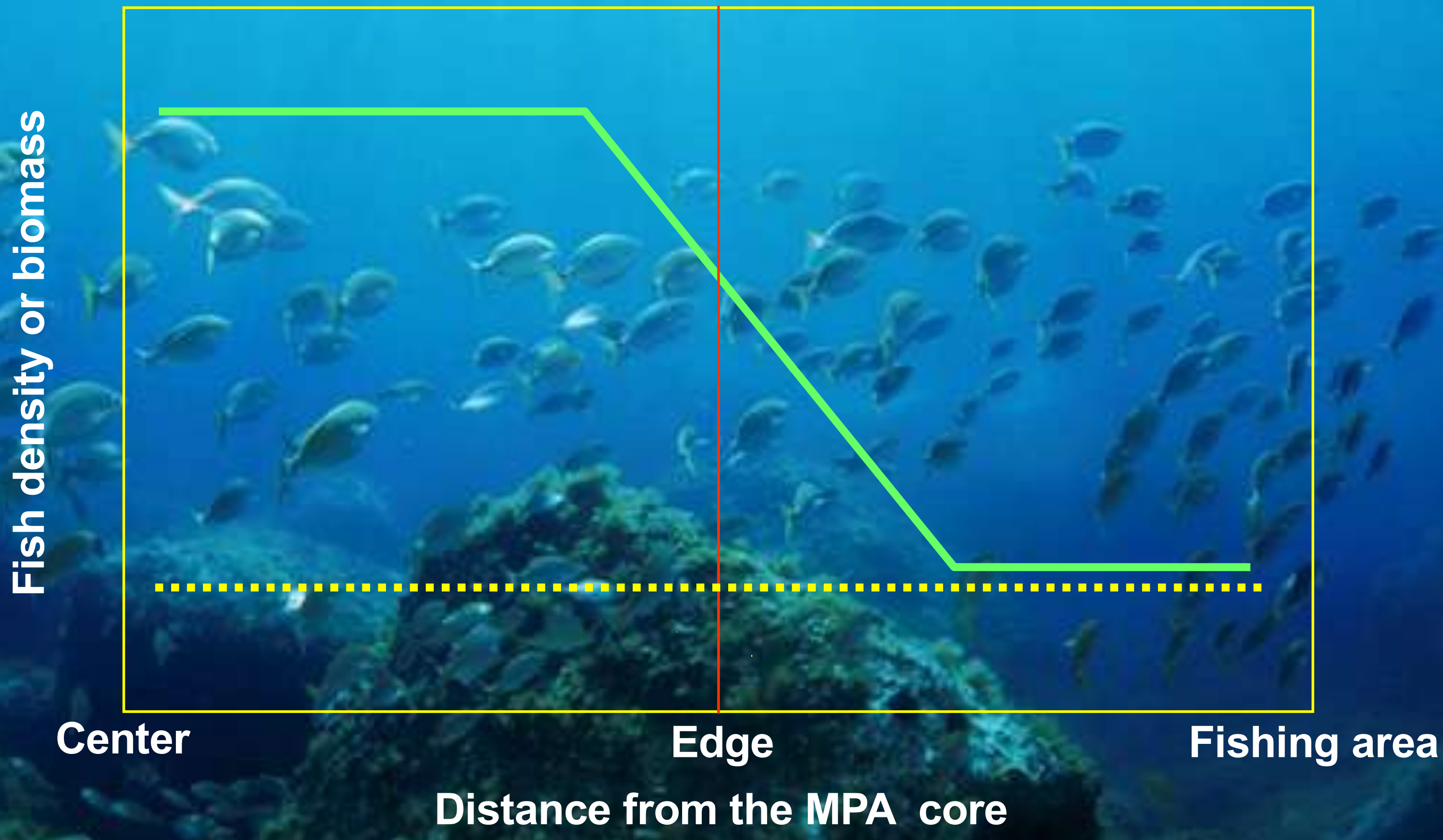


Work flow for monitoring plan



Sheltering

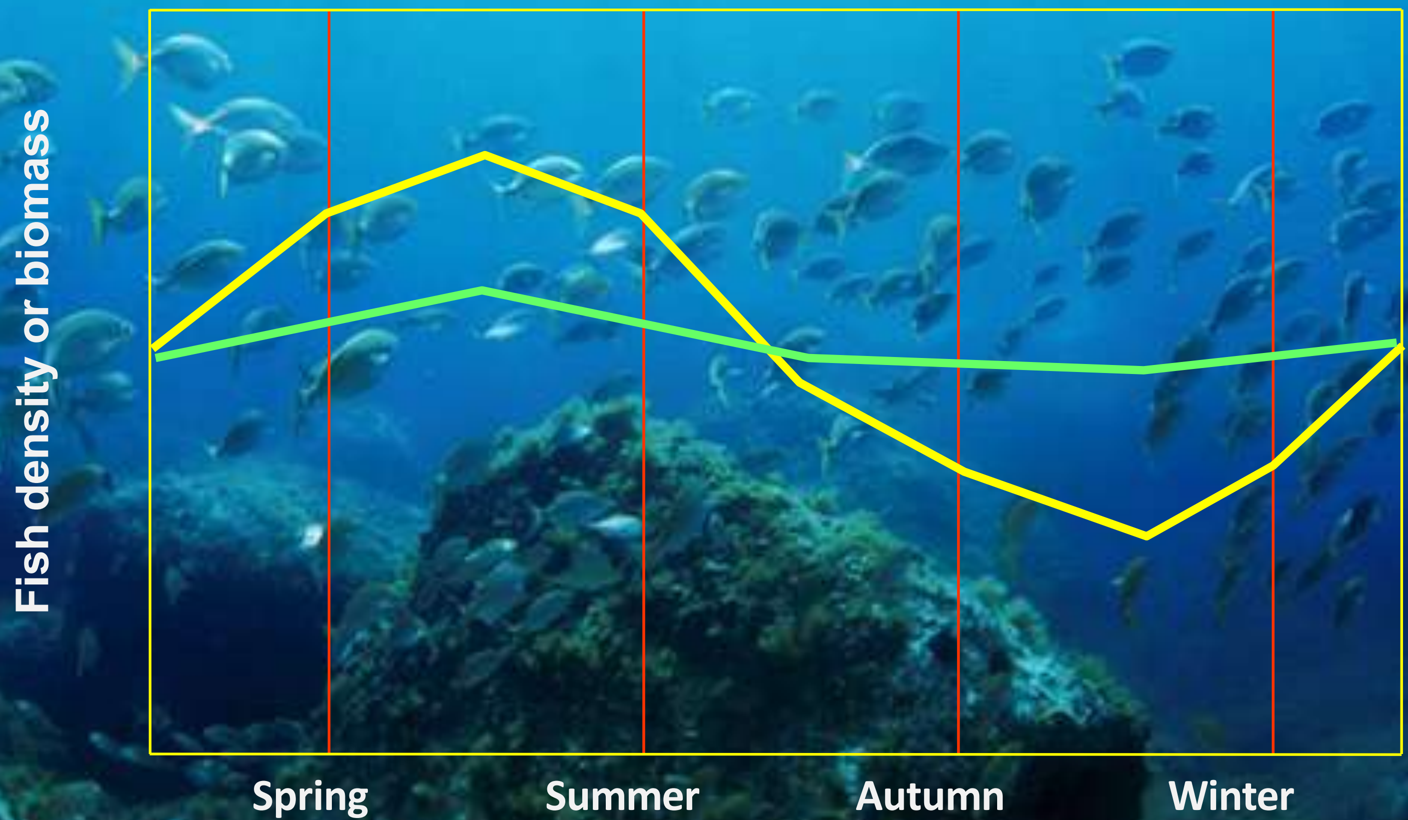
This occurs when one or more target species increase their abundance, size or biomass within the protected areas with respect to fished areas.



Spillover

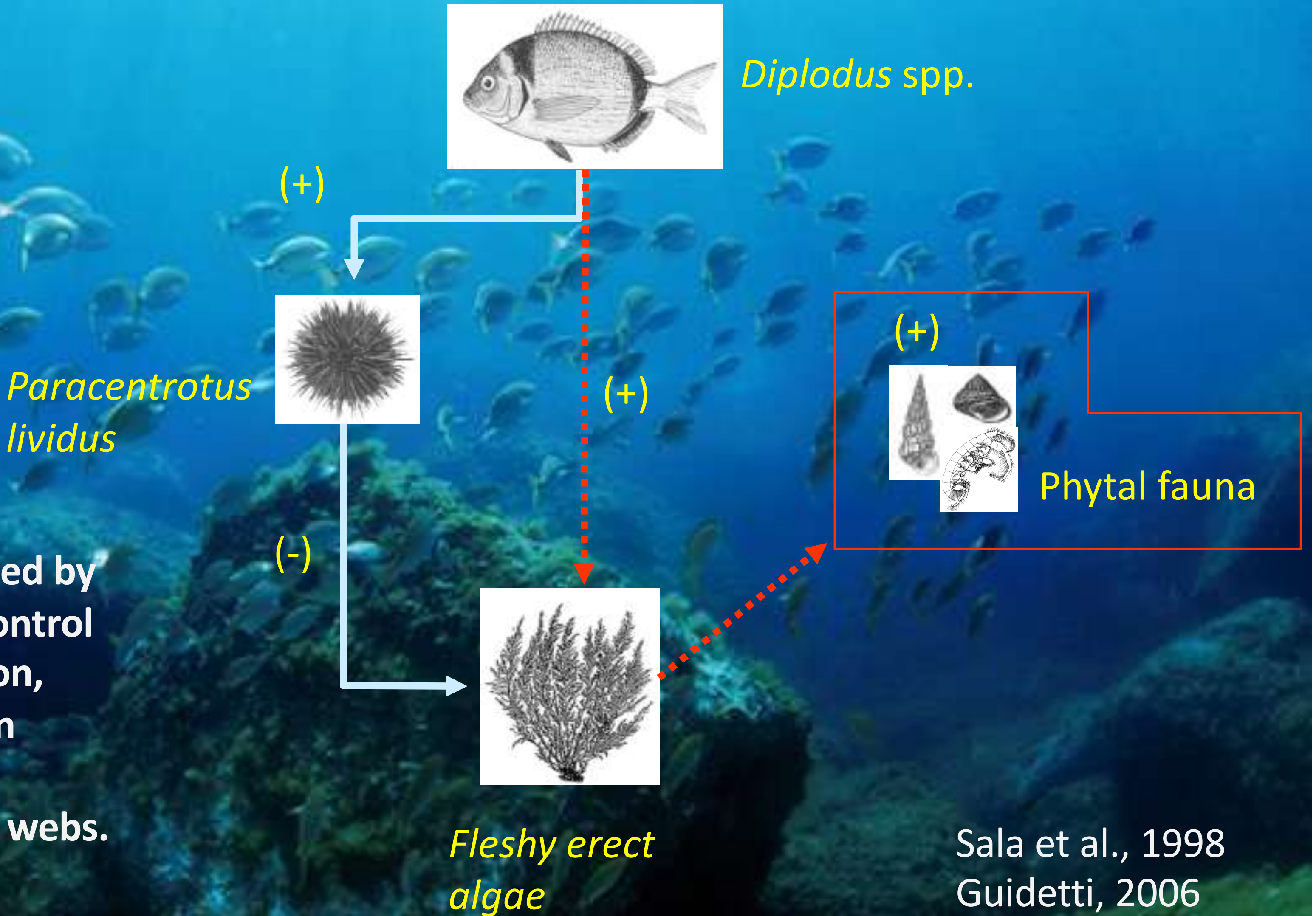
Buffering

This occurs when one or more target species exibit less steep seasonal and/or interannual fluctuations within the protected area. Complex causes…reduction of post-recruitment mortality, increase of larval mortality (high density of predators)



Cascading effects

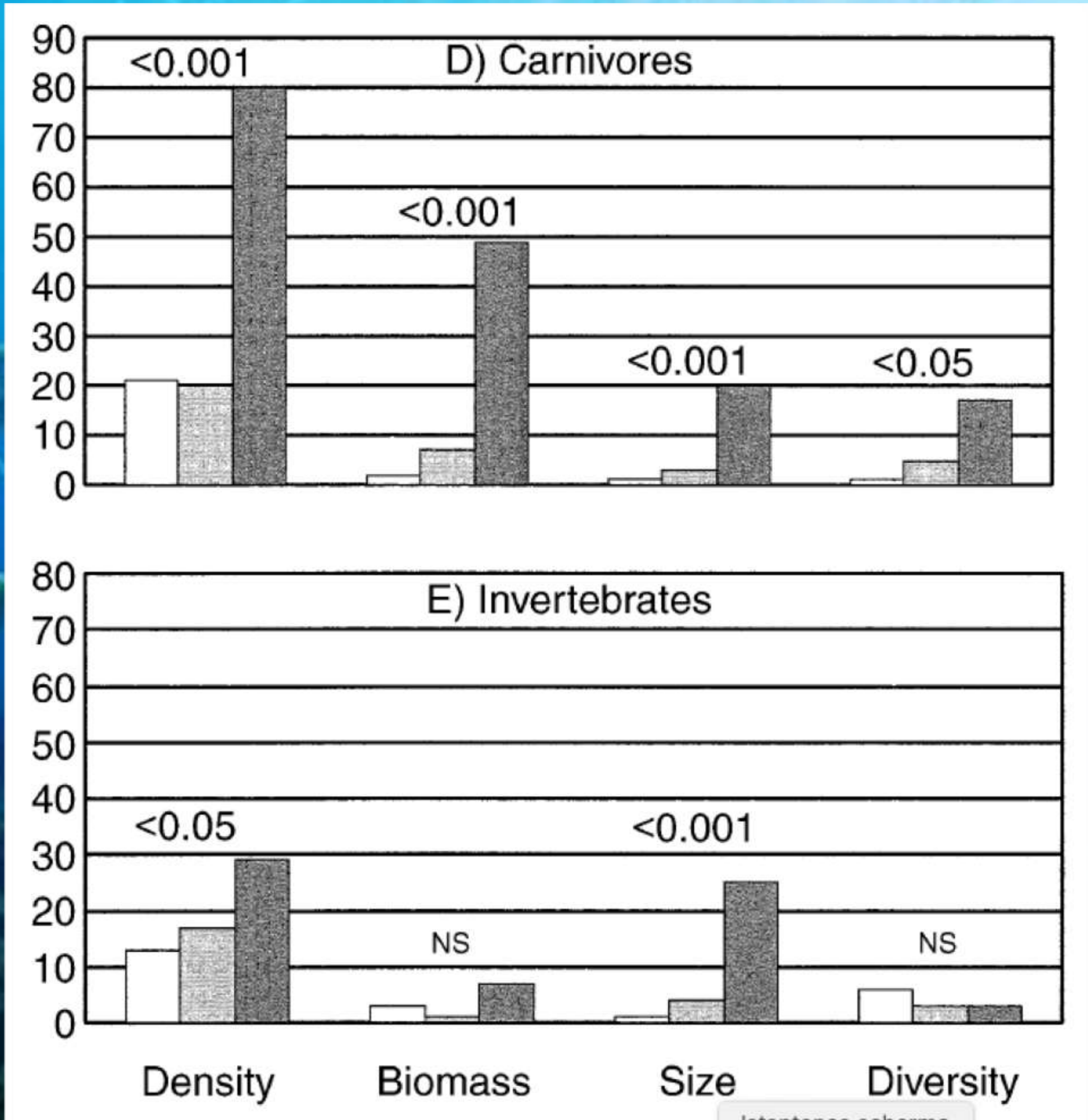
This occur when one or more target species have specific ecological role in stucturing marine communities. Protection, by increasing the abundance of this species allow them maintaning their role in controlling lower trophic levels, triggering cascading effects.



So, a predator population, enhanced by protection, could control their prey population, which in turn has an effect on basal component of food webs.

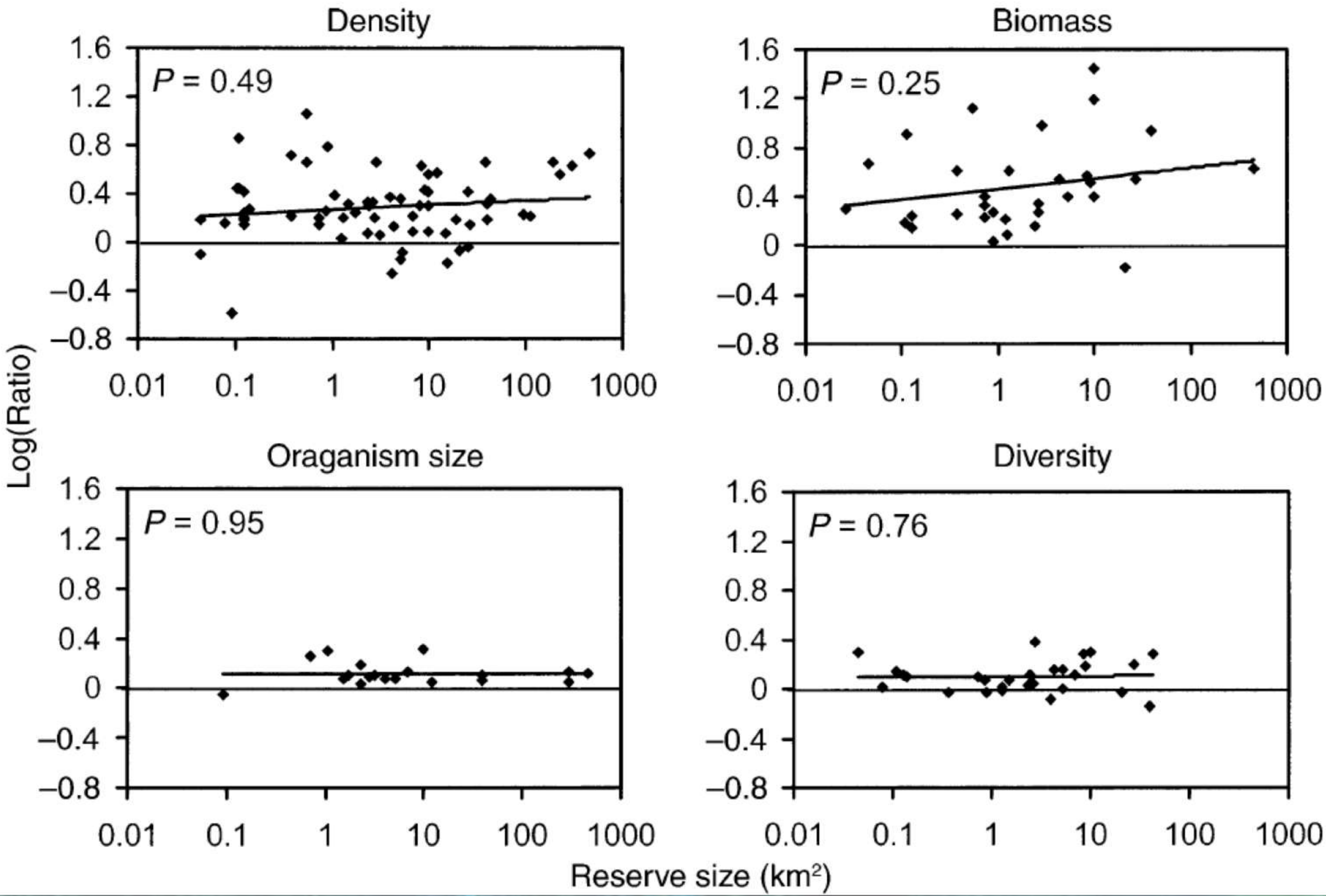
Sala et al., 1998
Guidetti, 2006

Comparing effects between fish and invertebrates

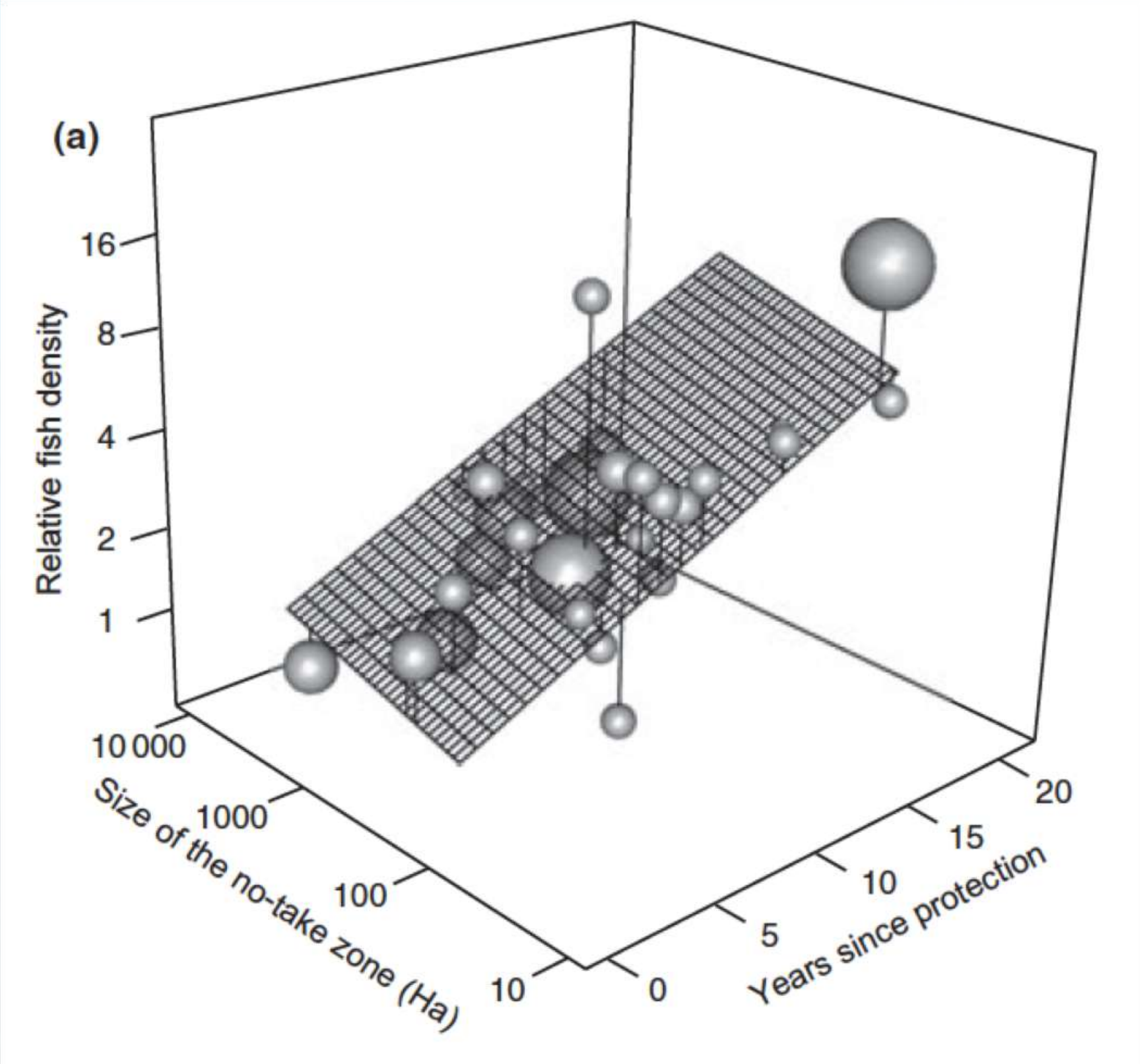


Halpern, 2003
89 MPAs.
Density, size, biomass and diversity of fish fauna were signifcantly higher within than outside the reserve. Benthic invertebrates, however, showed significant difference only for density and size

Relationship with reserve size

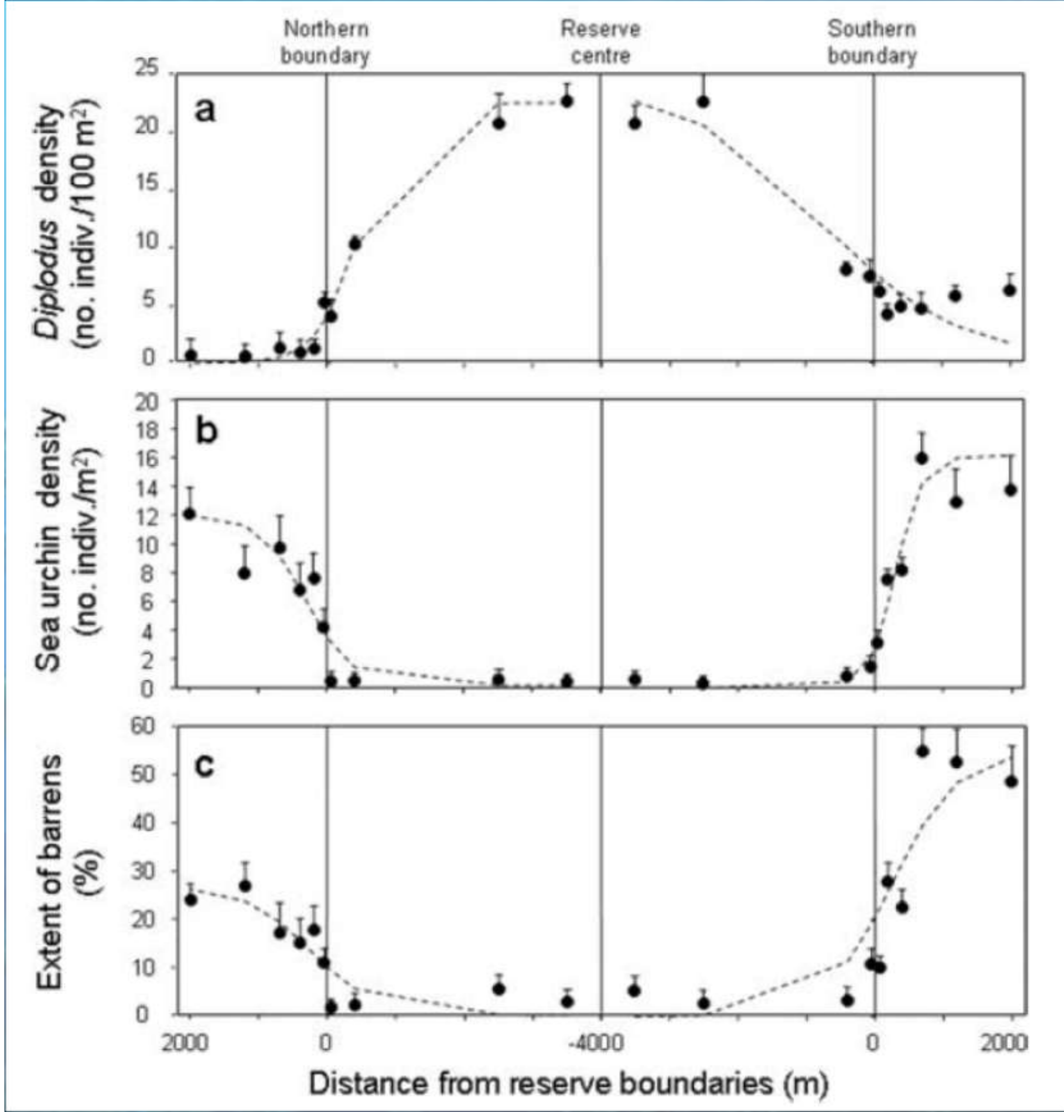


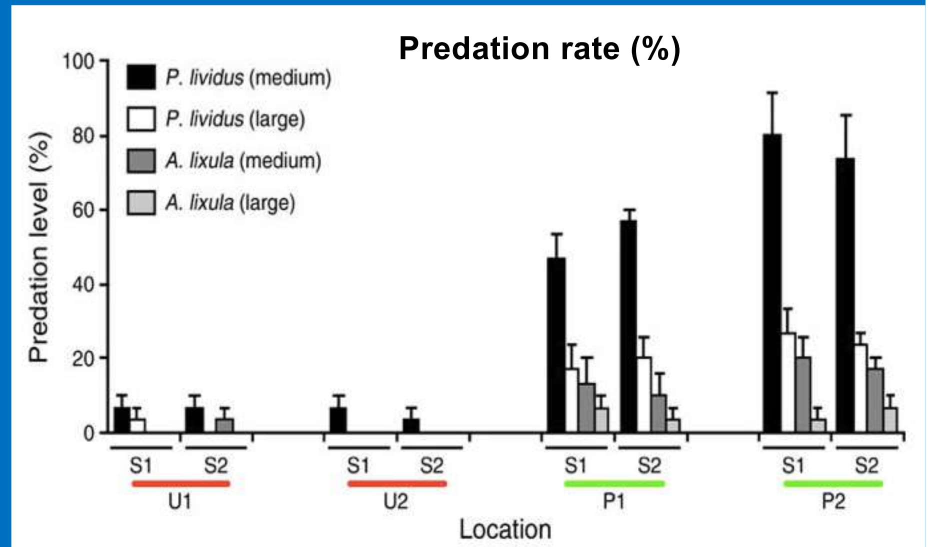
Size again…



Using 58 datasets from 19 European marine reserves, they showed that reserve size and age do matter: Increasing the size of the no-take zone increases the density of commercial fishes within the reserve compared with outside. Moreover, positive effects of marine reserve on commercial fish species and species richness are linked to the time elapsed since the establishment of the protection scheme. (Claudet et al, 2008)

Trophic cascades



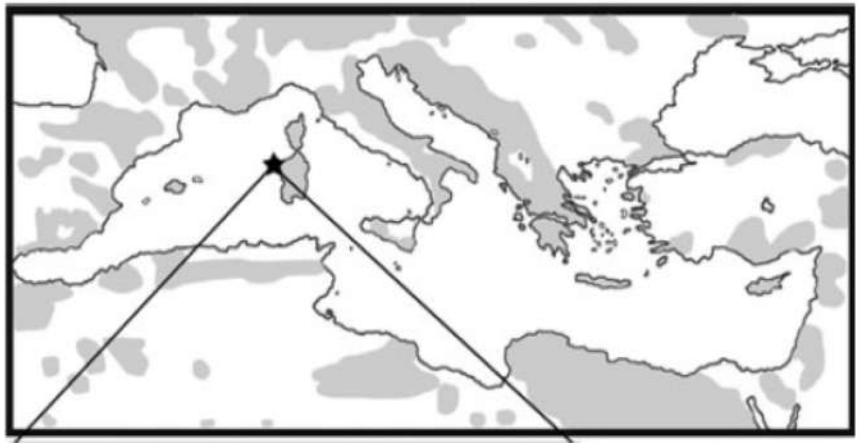


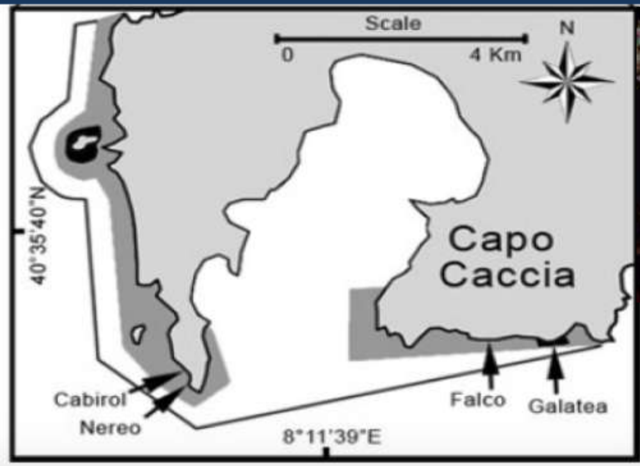
Guidetti, 2006. Ecol Appl

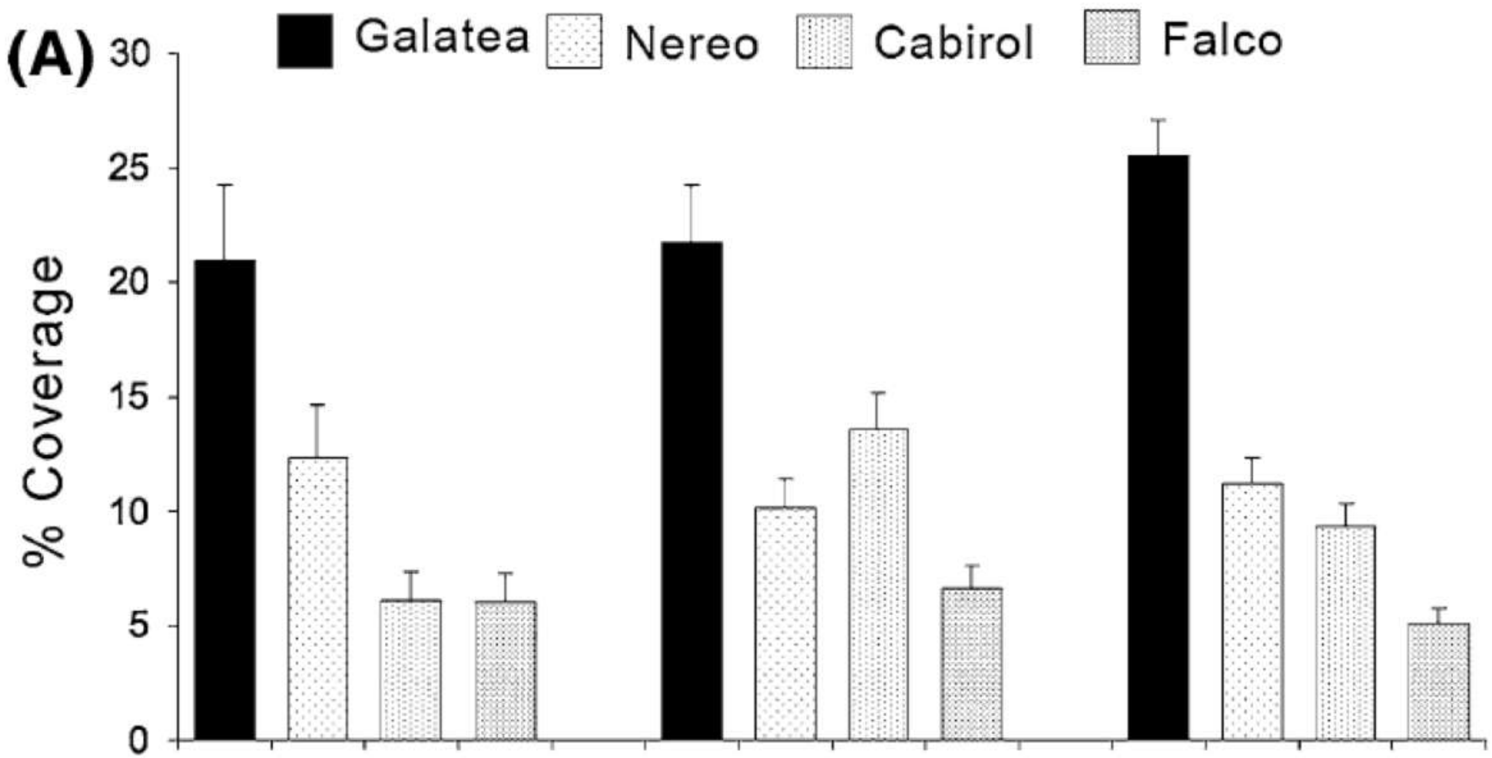
Predation rates within reserves can be much more intense than outside

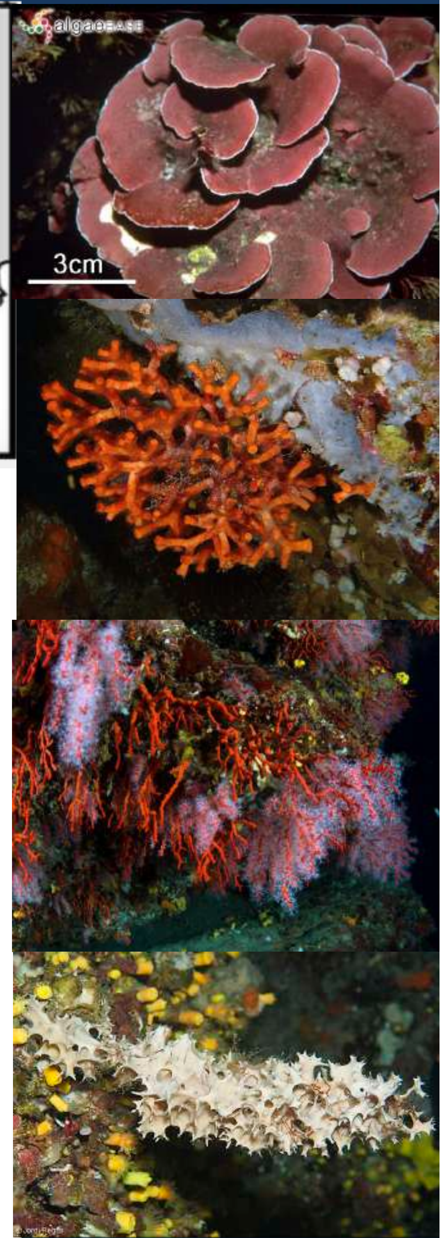
Increase of sea urchin predators due to protection reflects in decrease of sea urchins population within reserve boundaries, and the ensuing decrease of overgrazed substrates (Guidetti et al. 2008)

Effects on fragile organisms



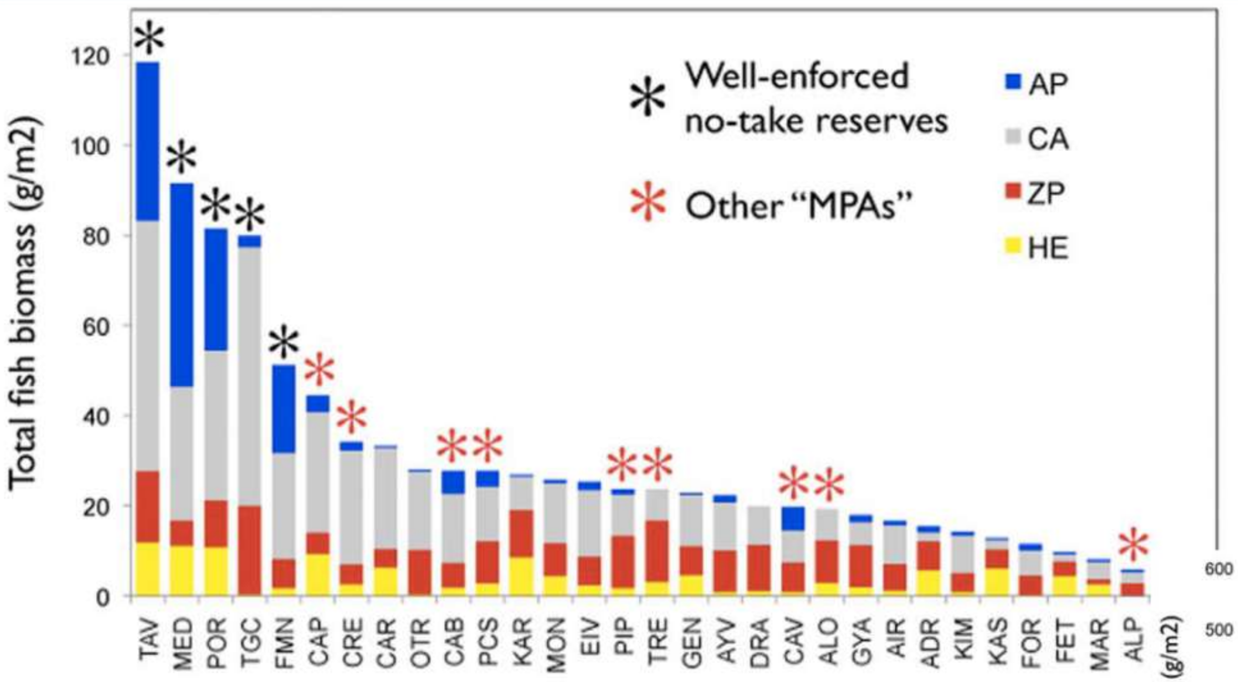


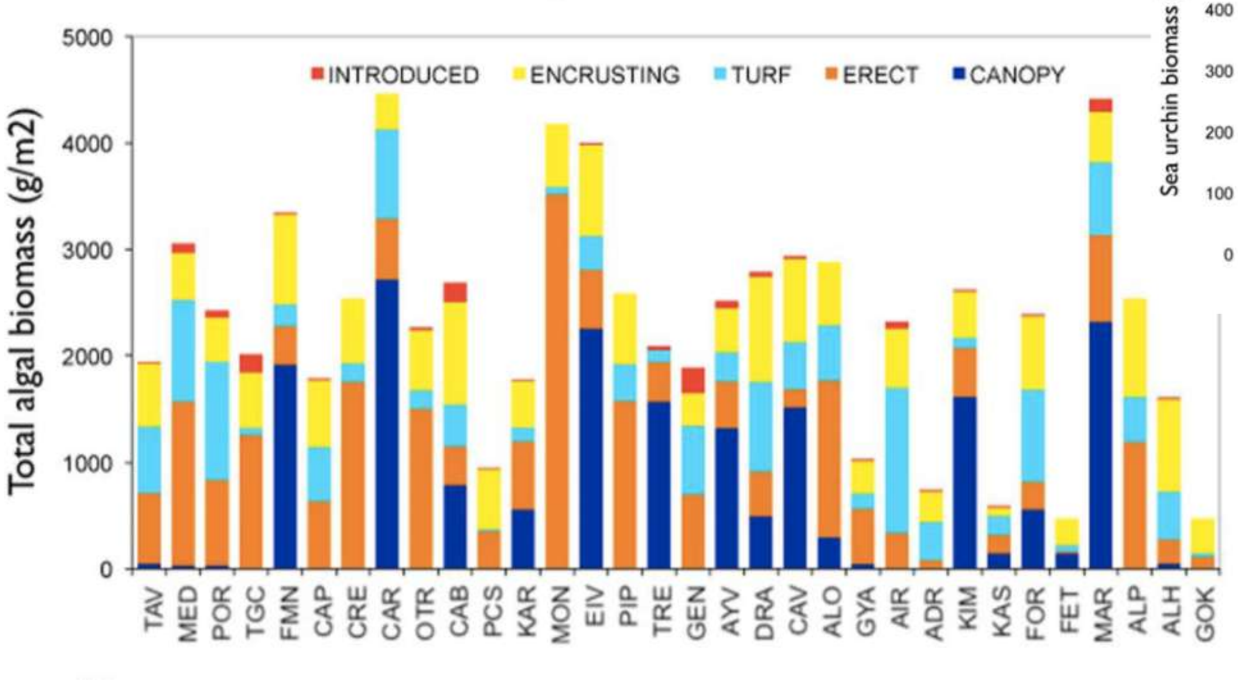




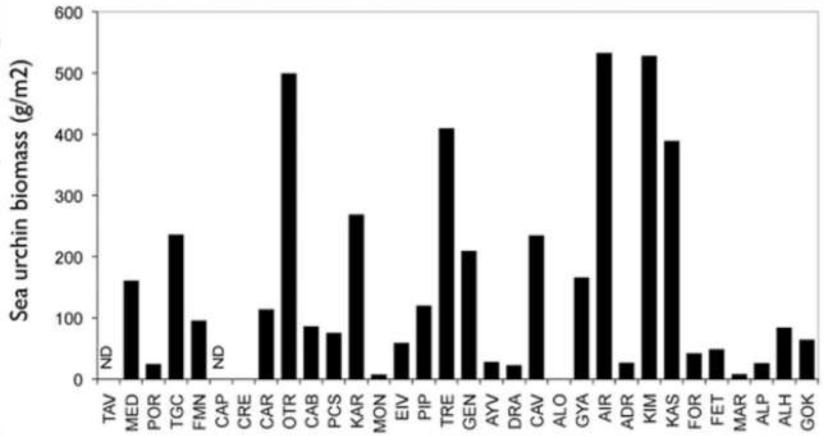
Diving frequentation in submarine caves. Effects on benthic invertebrates (Guarnieri et al., 2012)

Mediterranean MPAs – subtidal rocky reefs



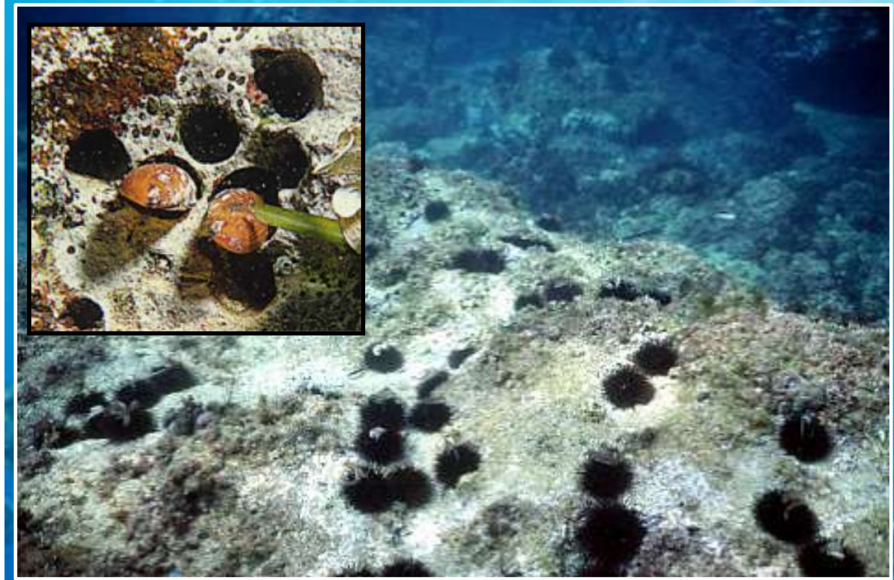


Fish biomass is significantly higher in well-enforced MPAs. Also, macroalgal stands (erect and canopy-forming species strongly varied, but were not related to protection. (Sala et al., 2012)



However, macroalgal stands were not associated to low herbivore (sea urchins) pressure.

MPAs and resilience: a manipulative experiment

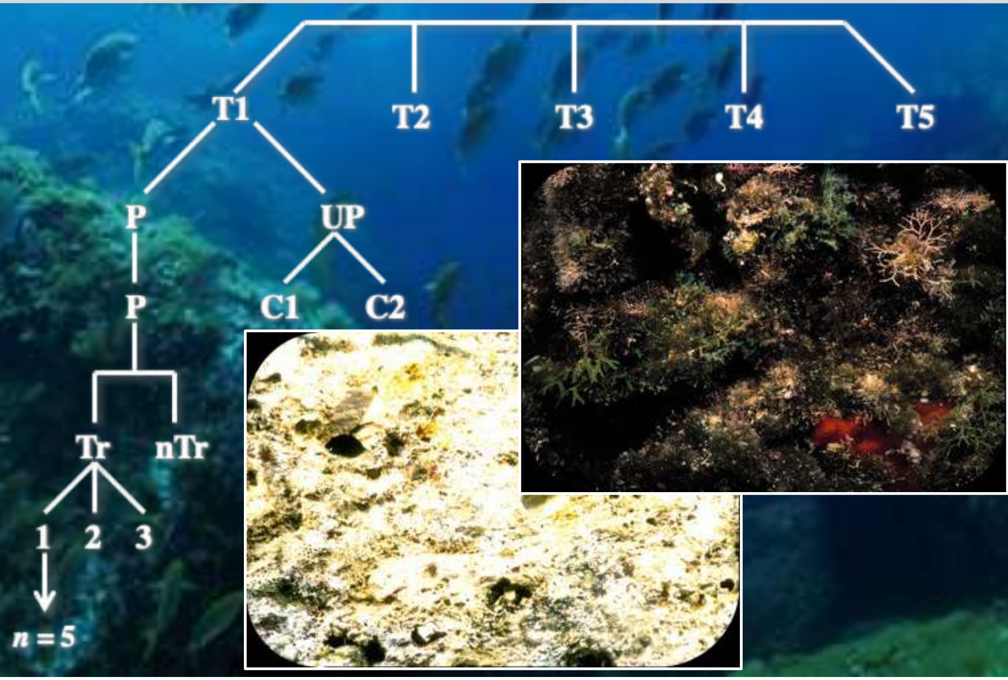


Date mussel (*Lithophaga lithophaga*) fishery

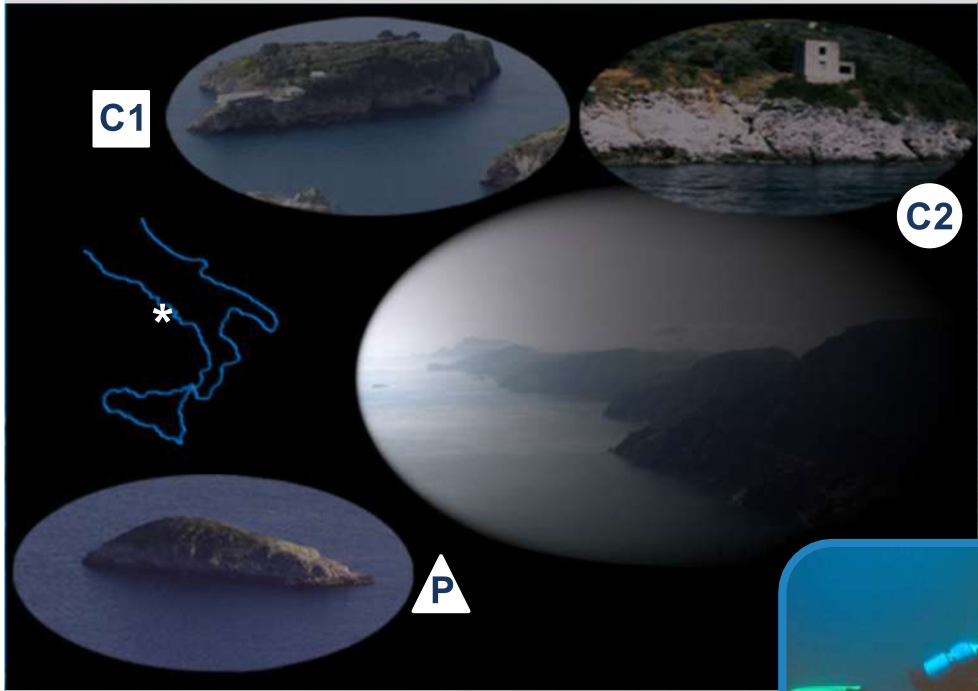
Banned in 1998 in Italy and in 2006 in EU
Caused the destruction of tens of km^2 or rocky bottoms in the Mediterranean, and especially in Italy, Croatia, Albania, Greece
Fishermen destroy the rocky surface, and everything living on the substrate, to reach the endolithic bivalve for collection
Still practiced, although illegal; costs of date mussels on the black market can range between 60-80 euros per Kg

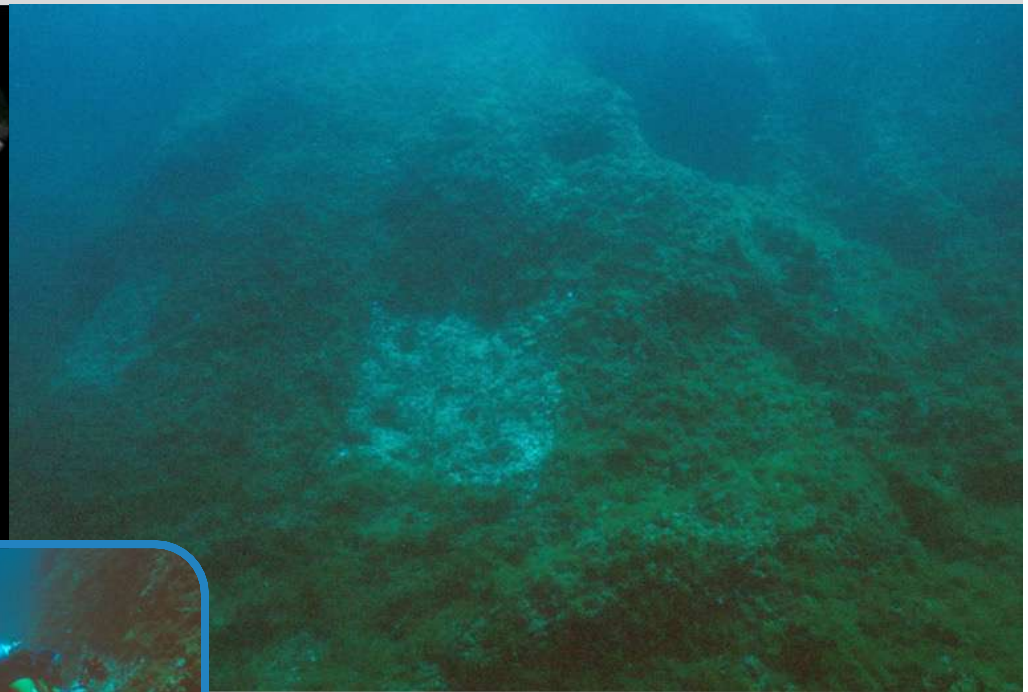
Full protection →
Unprotected →
Simulating disturbance
→ **Comparing trends in recovery**

H_0: no difference in recovery between the no-take zone and controls



Temporal patterns of recovery



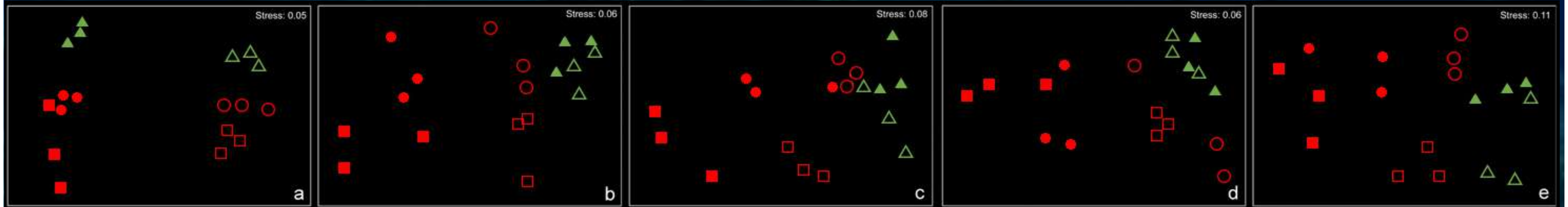


Human impact (date-mussel fishery) simulated within a no-take zone and 2 control areas (NW Mediterranean)

Recovery of macrobenthic assemblages followed during 20 months (5 times of sampling) in disturbed plots

Filled symbols = disturbed plots; empty symbols = undisturbed plots

Bevilacqua et al., 2006. J Animal Ecol



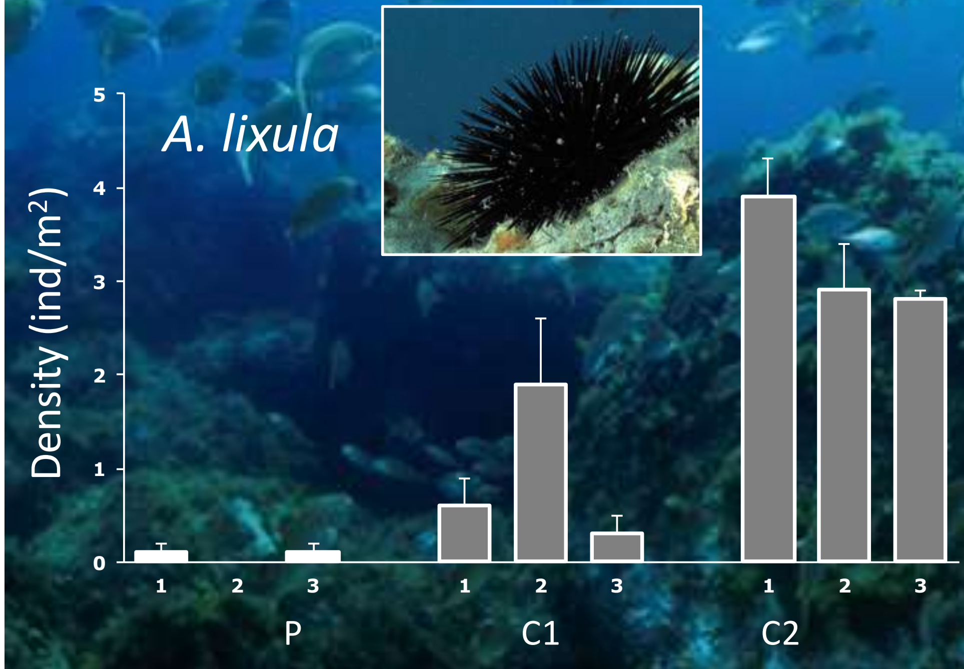
0 months | 3 months | 9 months | 12 months | 20 months

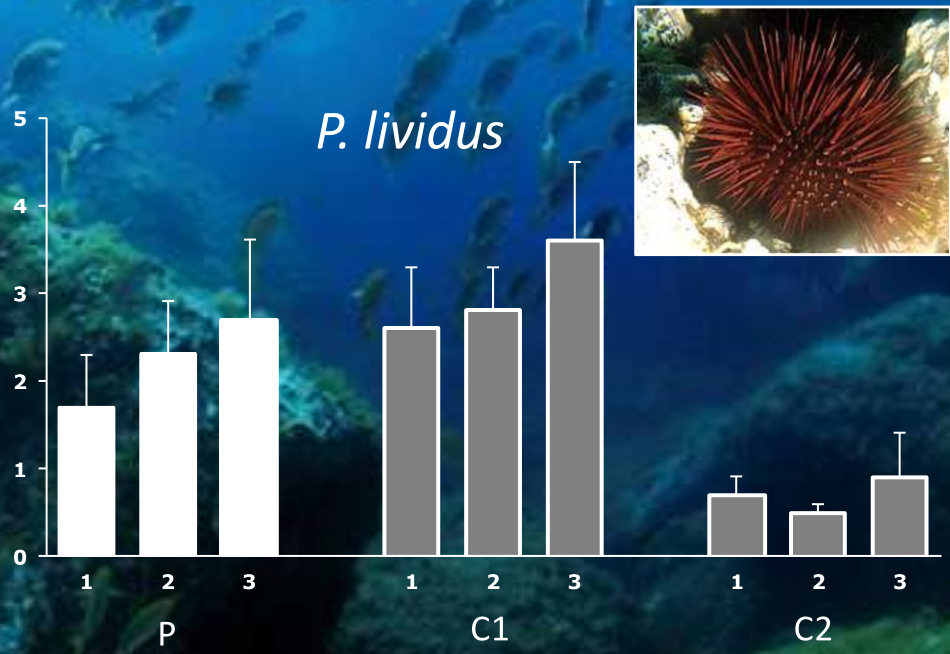
Recovery at the no-take zone was faster than at the unprotected control areas

Sea urchins

ANOVA

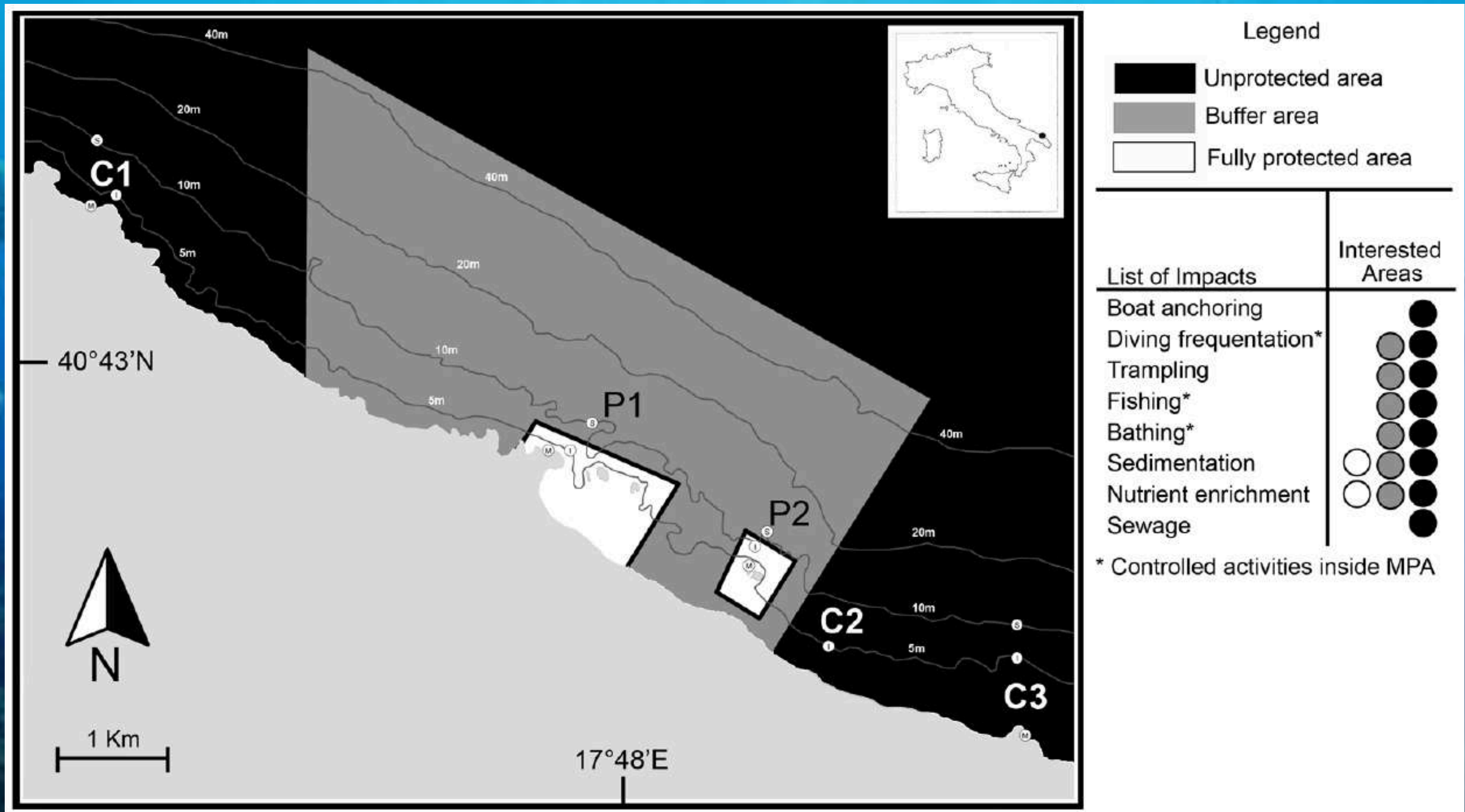
Source of variation	df	SS	MS	F	F versus
Time = Ti	2	0.08	0.04		
Location = Lo	2	1402	7.01	12086*	Ti × Lo
Controls = *Cs*	1	0.85	0.85	0.988ns	Ti × *Cs*
P-v-Cs	1	1317	1317	22706***	Residual
Ti x Lo	4	2.33	0.58	1.289ns	Residual
Ti × *Cs*	2	1.71	0.86	2.263ns	Res *Cs*
Ti × *P-v-Cs*	2	0.62	0.31	0.689ns	Residual
Residual	171	7697	0.45		
Res *Cs*	114	4349	0.38		
Res *P*	57	3348	0.59		





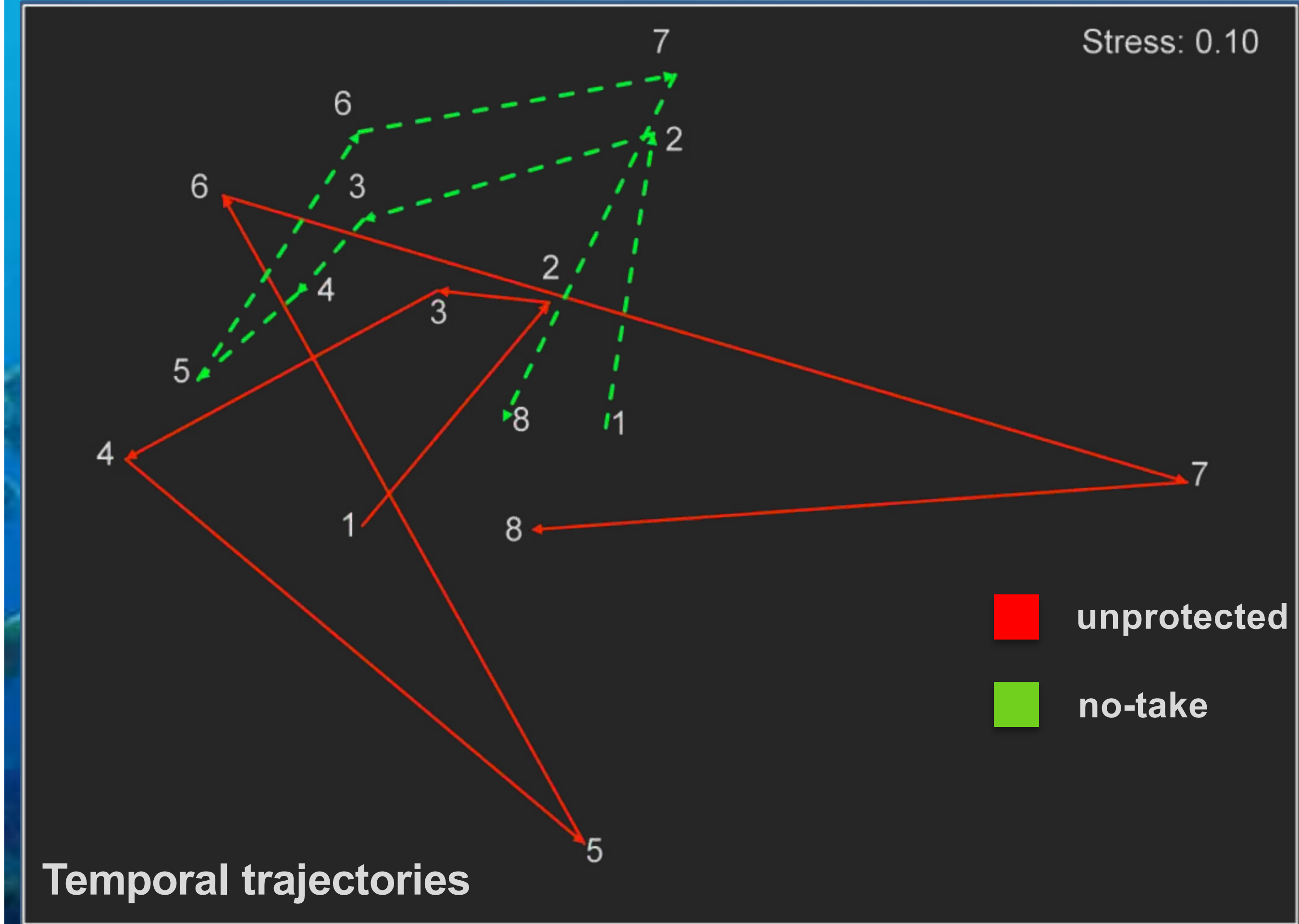
Does protection beget stability?

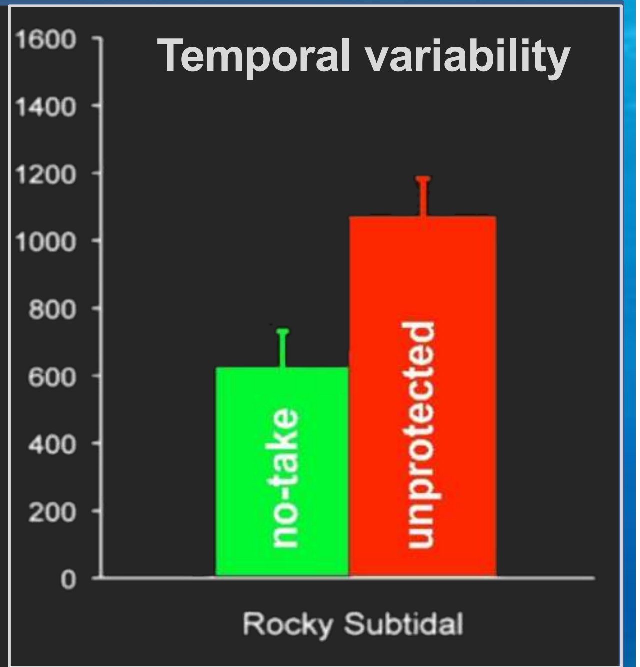
The MPA of Torre Guaceto (SE Adriatic Sea), instituted in 1991 and embedded into a human-dominated landscape, is a rare example of well-managed MPA where an adequate enforcement determined target fish recovery

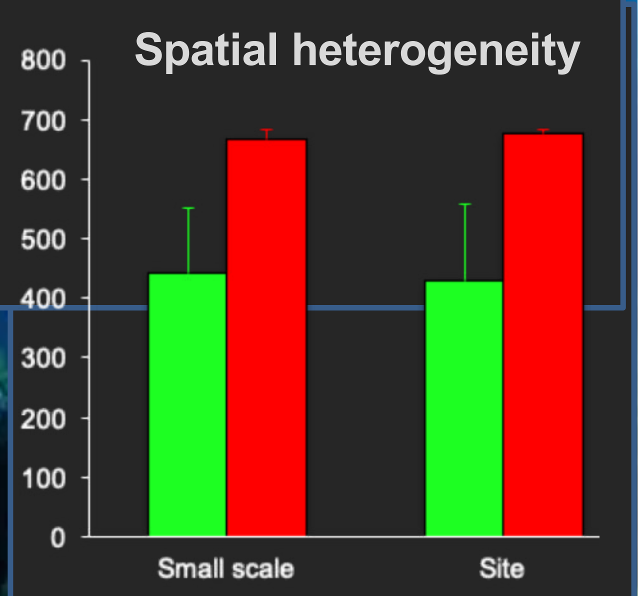


This MPA provided the opportunity to follow the effects of protection on the stability of subtidal benthic assemblages, through the comparison of protected and unprotected locations, from 2002 to 2008

Protection, stability, and heterogeneity





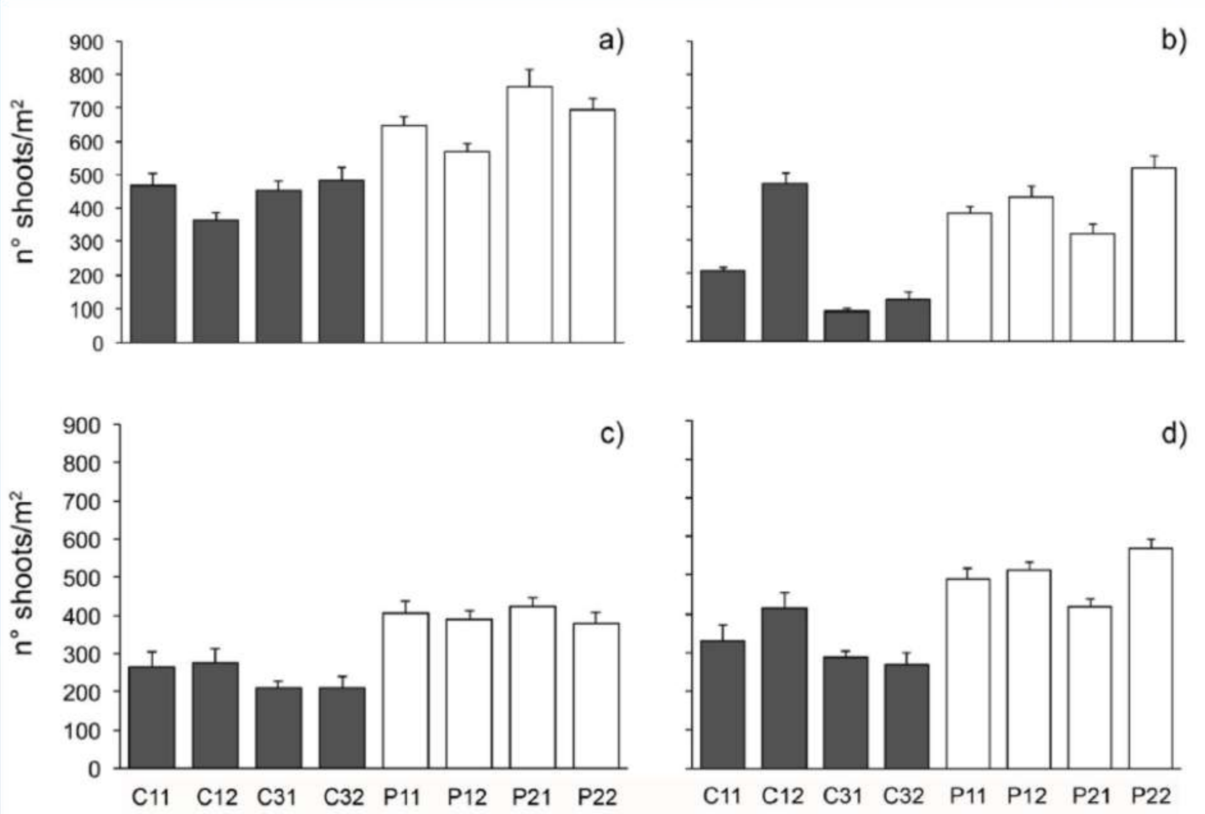


Fraschetti et al., 2013. PLoS One

SUBTIDAL ROCKY REEFS

The structure of subtidal sessile assemblages showed larger fluctuations outside the marine protected area than within the no-take zone where, in contrast, assemblage structure showed high temporal homogeneity.

Buffering effects on seagrass decline

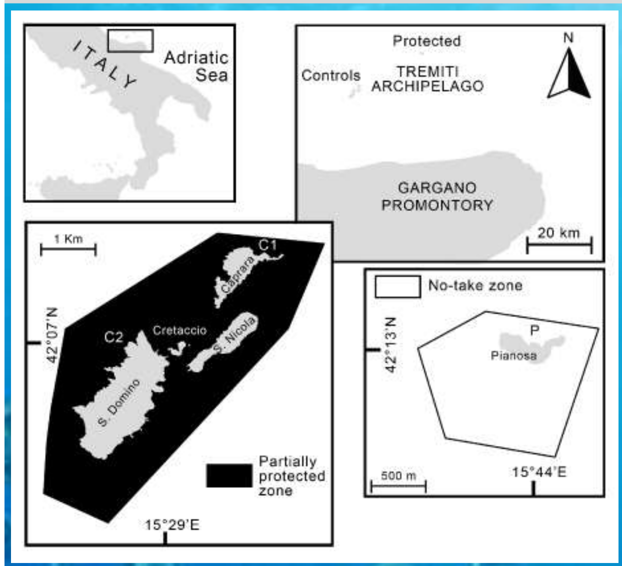


Seagrass beds under reduction in the area due to general increase in sedimentation rates and turbidity. However, the decline is less steep within the no-take areas, where additional direct human impacts (e.g., anchoring) are alleviated or excluded.

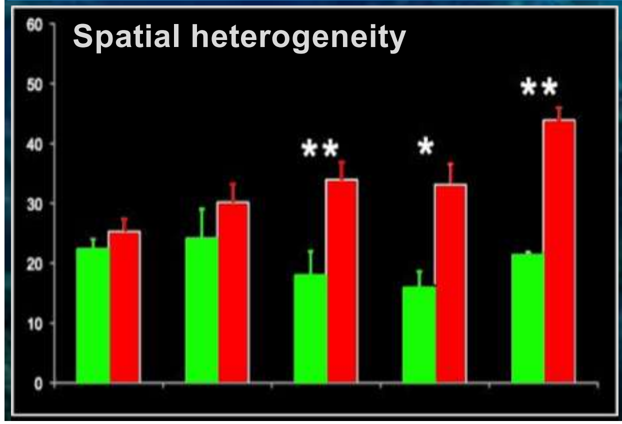
Table 6. Classification of the status of *P. oceanica* beds based on shoot density following Pergent et al. [54].

Location	Patch	2006	2007	2008	2009
P1	1	undisturbed	disturbed	Undisturbed	undisturbed
P1	2	undisturbed	undisturbed	Undisturbed	undisturbed
P2	1	undisturbed	disturbed	Undisturbed	undisturbed
P2	2	undisturbed	undisturbed	Undisturbed	undisturbed
C1	1	undisturbed	very disturbed	very disturbed	disturbed
C1	2	undisturbed	very disturbed	very disturbed	undisturbed
C3	1	disturbed	undisturbed	Disturbed	Disturbed
C3	2	undisturbed	very disturbed	very disturbed	Disturbed

Further evidence

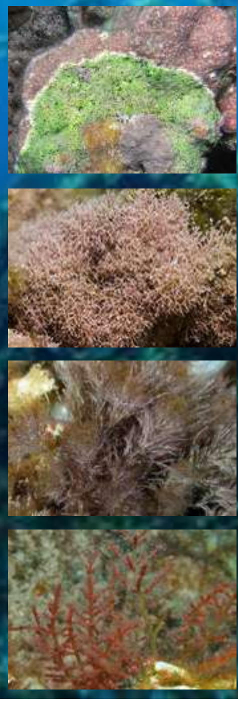


ROCKY INTERTIDAL

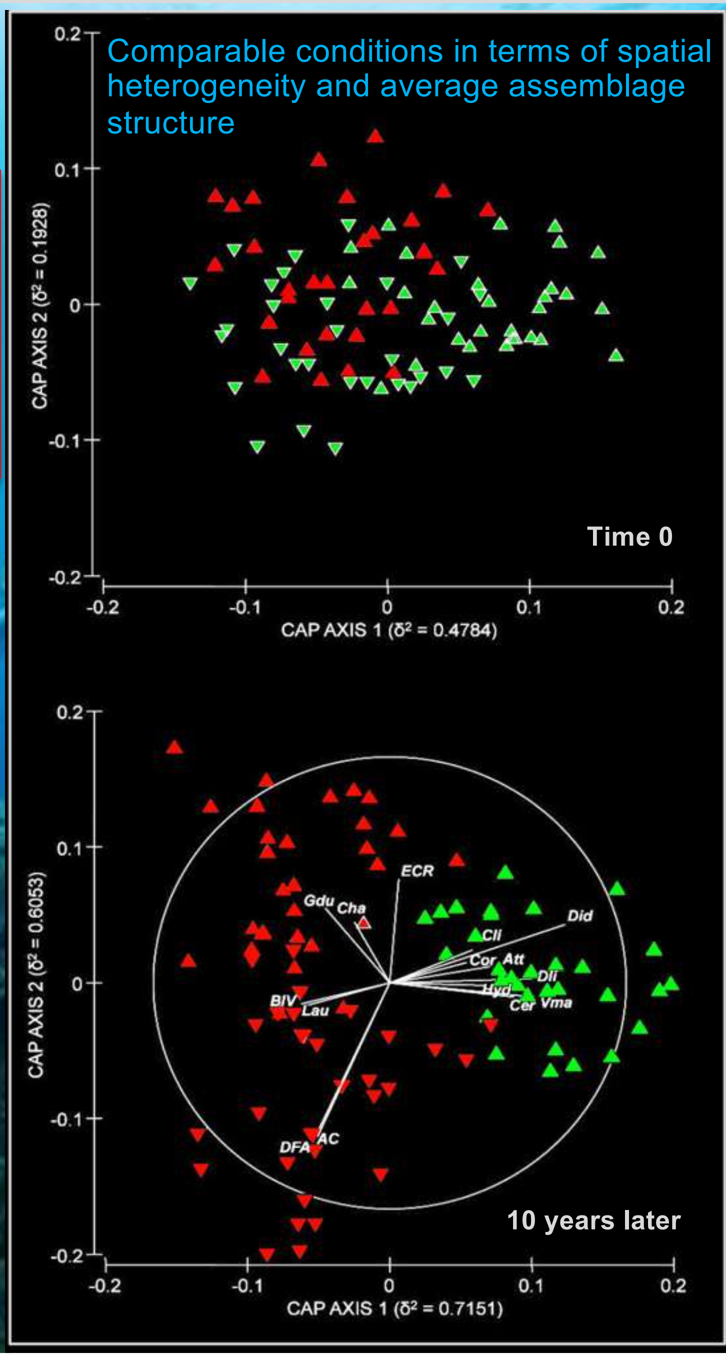


unprotected

Higher spatial heterogeneity, high temporal variability, decrease in canopy cover



Fraschetti et al., 2012. Mar Ecol Progr Ser

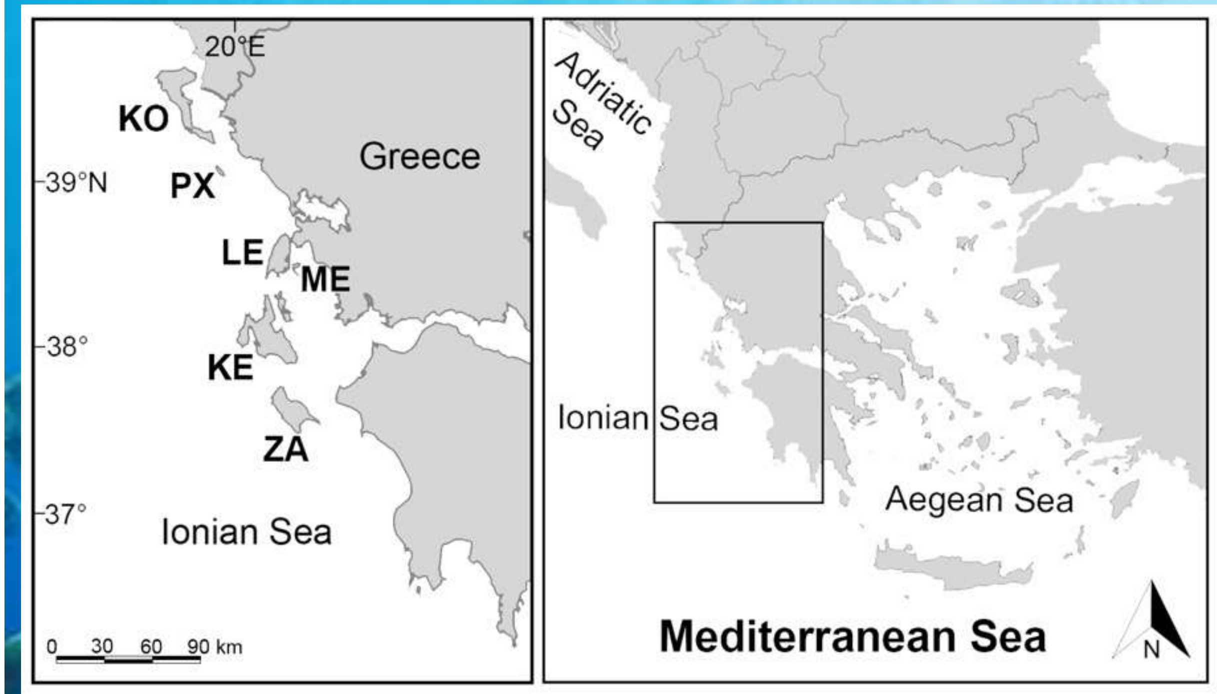


protected

Low spatial heterogeneity, high stability in canopy cover and associated understorey assemblages

Fraschetti et al., 2012. Mar Ecol Progr Ser

Diversity patterns and conservation



Six islands, four sites in each islands. Sessile assembalges on subtidal reefs at 5 and 15 m depth. Photographic samples with 10 replicates in each sites. Identification of taxa at species level (genus or morphological groups in case of difficult organisms). Identification of funtional traits (48)

Traits related to functional aspects of organisms (shape, reproduction, dispersal, interaction with the environments, energy flow. Construction of multidimensional functional space for each assemblage in each islands and depth

Functional traits: an example

Category	Trait	Description
Morphology	*Body complexity*	Body shape and three-dimensional structure
	Body size	Dimension of the body/colony (cm)
	Flexibility	Quality of bending without breaking (angle)
	Fragility	Likelihood to break as a result of physical impact
Life cycle and growth	*Growth form*	Individual or modular life form
	Life cycle	Type of life cycle: haplontic (multicellular haploid stage, unicellular diploid stage), diplontic (the opposite of haplontic), or haplo-diplontic (presence of multicellular haploid and diploid stages)
	Developmental mechanism	Development of the organism through spores, planktotrophic larvae, or lecitotrophic larvae
	Growth rate	Rate of increasing in size (mm mo^{-1})
	Life span	Approximate duration of life (years)
Reproduction	*Reproductive type (sexual)*	Type of sexual reproduction
	Gamete type	Morphology of male and female gametes
	Reproductive season	Range of months or season(s) for reproduction
	Reproductive strategy	Type of life strategy encompassing a single (semelparous) or multiple (iteroparous) reproductive events during life
	Generation time	Time between two generations (years)
	Time to maturity	Time to sexual maturity (years)
	Fecundity-Egg size	Size of eggs
	Fecundity-Number of eggs	Number of eggs
	Fertilization type	External or internal fertilization

Functional traits: an example

Interactions with the environment	*Living habit/environmental position*	Position with respect to the substrate
	Strength of attachment to substrate	Difficulty of being detached from the substrate
	Min depth	Approximate upper limit of depth distribution range (m)
	Max depth	Approximate lower limit of depth distribution range (m)
	Min salinity	Approximate lower limit of the salinity range
	Max temperature	Approximate upper limit of temperature range
	Max N	Approximate upper limit of nitrogen range
	Max P	Approximate upper limit of phosphorous range
	Min O% saturation	Approximate lower limit of oxygen saturation range
	Degree of attachment to substrate	Quality of being permanently or temporary attached to the substrate
	Substratum preferences	Type of typical substrate

Functional traits: an example

Dispersal and colonization	*Spatial distribution*	Distribution range at basin scale (Mediterranean Sea)
	Duration of larval stage (pelagic)	Time spent by larval stages in the water column before settelment (days)
	Asexual reproduction	Presence or absence of any type of asexual reproduction
	Recruitment success	Rate of post-settlement survival
	Migration	Capacity to migrate
	Mobility	Movement features
	Regeneration potential	Potential to survive to injury or damage through regenaration of lost tissues
	Dispersal potential (larval)	Distance of larval dispersal
	Dispersal potential (adult)	Distance of adult dispersal

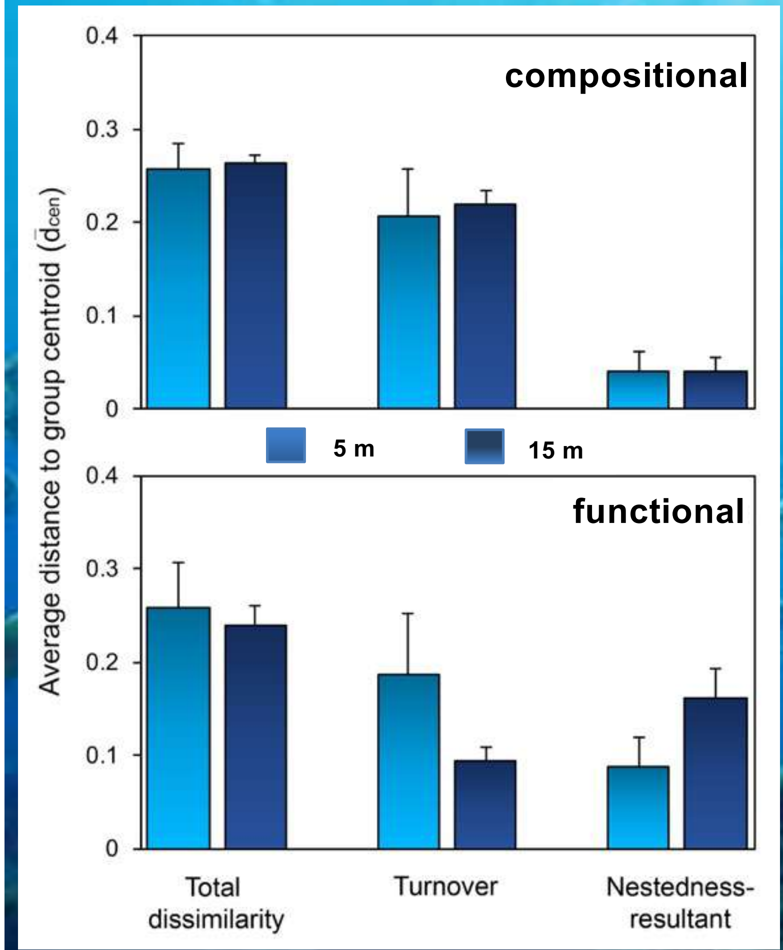
Matter and energy flow	*Biomass*	Biomass
	Caloric content	Energy content of tissues
	$CaCO_3$ content	Amount $CaCO_3$ in tissues (% per g dry weight)

Functional traits: an example

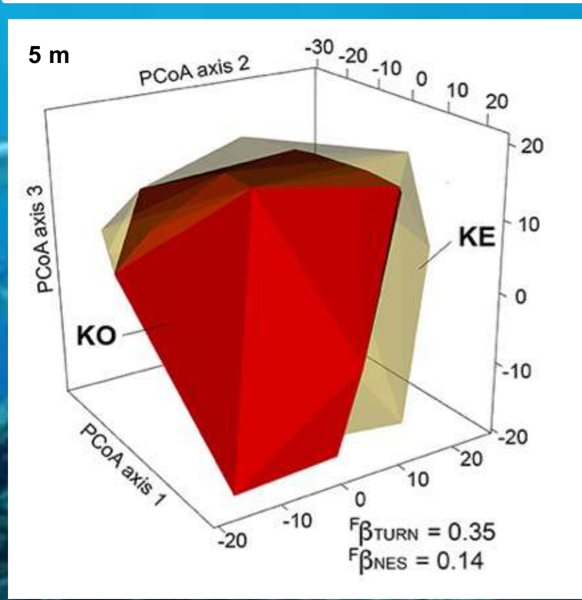
Biological interactions	*Sociability*	Aptitude to live with conspecific or to form colonies
	Defence	Presence of defence against predators, competitors
	Biogenic habitat provision	Quality of providing shelter or secondary substrate for other organisms
	Scale of habitat provision	Persistence in providing shelter, secondary substrate or forming biogenic habitat
	Food type/diet	Type of food ingested
	Dependency	Presence of symbiotic interactions

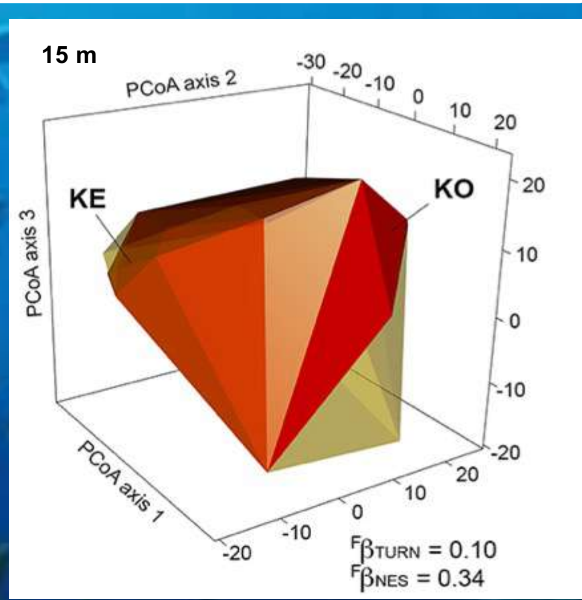
Matter and energy flow	*Feeding habit*	Strategy employed for food collection/production
	Biomass	Biomass
	Caloric content	Energy content of tissues
	$CaCO_3$ content	Amount $CaCO_3$ in tissues (% per g dry weight)

Results



Compositional beta-diversity of assemblages at both depths was mainly due to species turnover (replacement), whereas nestedness component was negligible.
However:
5 m: species turnover ⟹ functional turnover
15 m: species turnover ⟹ functional nestedness
This means that at 15 m there were islands representing hotspots of functional diversity, and islands that were functional subsets of these hotspots.

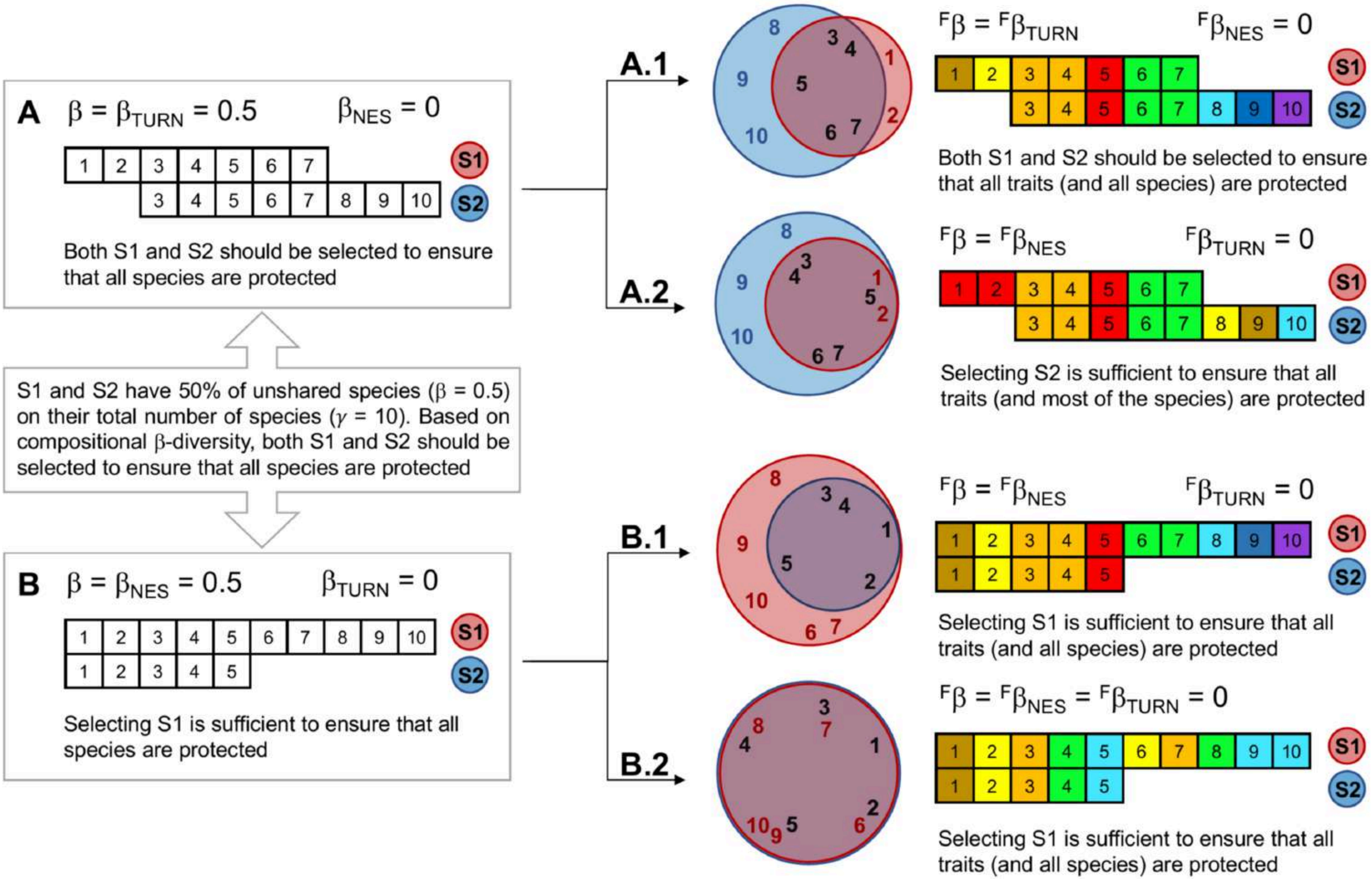




Partitioning nestedness and turnover unveils contrasting relationships between compositional and functional beta-diversity in subtidal rocky reef assemblages at varying depth.

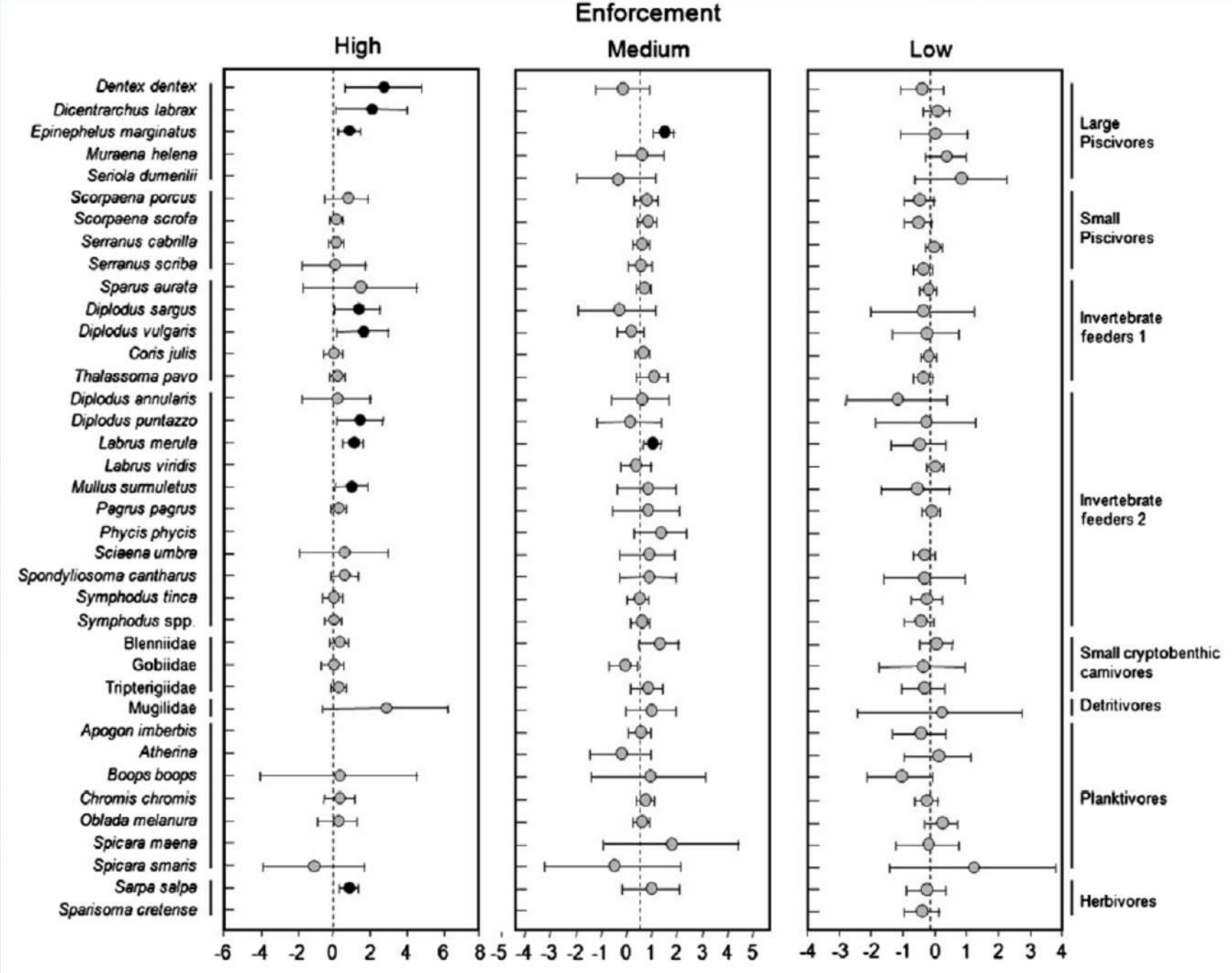
Understanding whether compositional diversity underlies functional diversity is crucial for conservation strategies.
Reserve networks based on taxonomic beta-diversity, although maximizing protection of species richness, do not necessarily ensure preserving functional representativeness.

Results

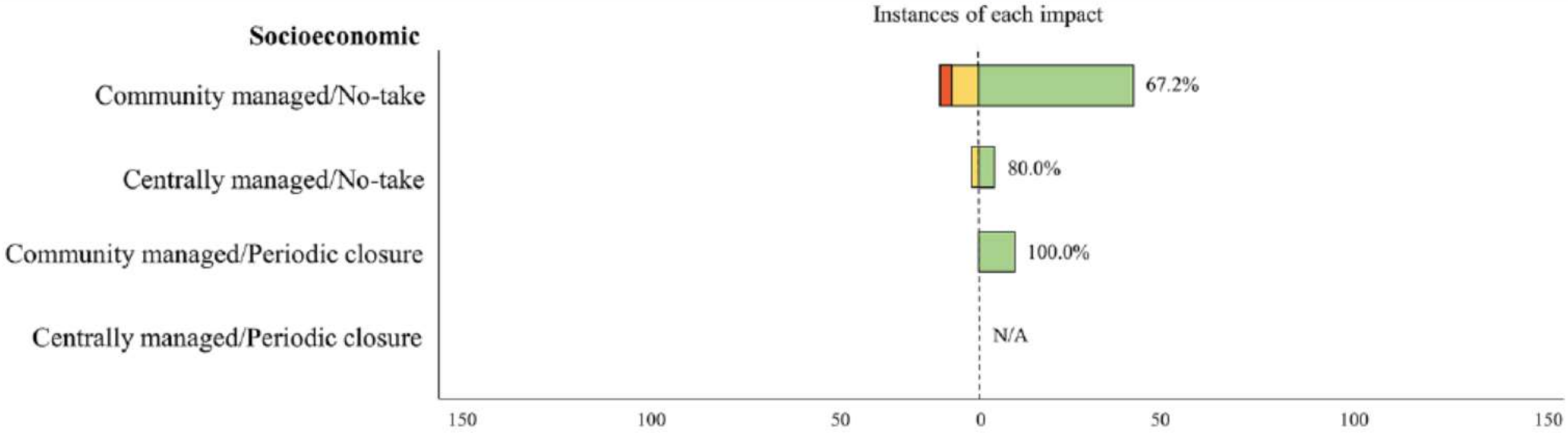


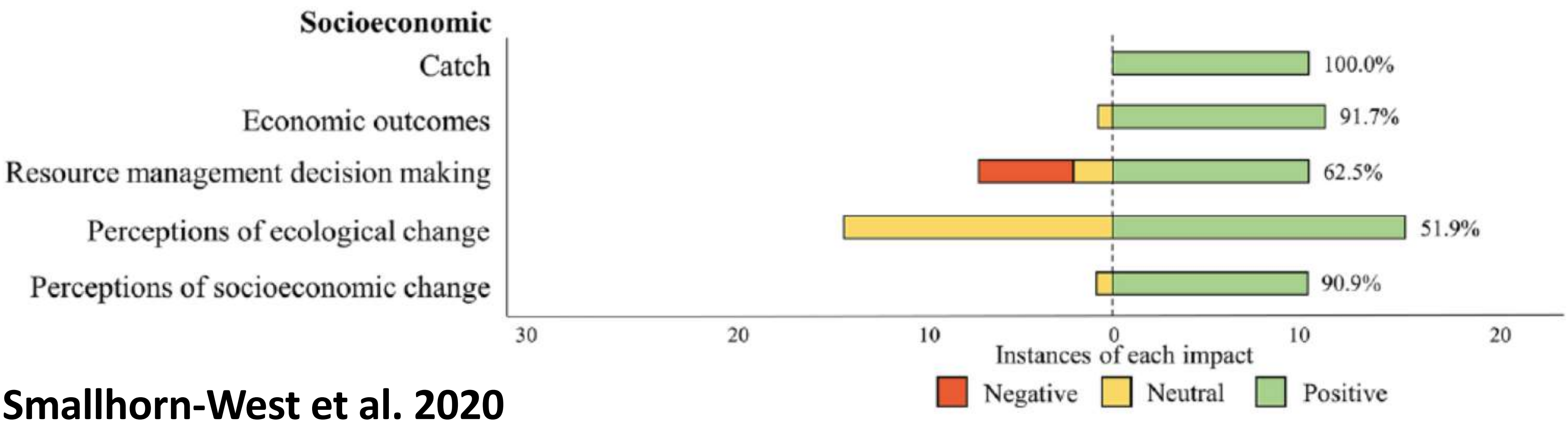
A β = βTURN = 0.5 βNES = 0
1 2 3 4 5 6 7
3 4 5 6 7 8 9 10
S1
S2
Both S1 and S2 should be selected to ensure that all species are protected
S1 and S2 have 50% of unshared species (β = 0.5) on their total number of species (γ = 10). Based on compositional β-diversity, both S1 and S2 should be selected to ensure that all species are protected
B β = βNES = 0.5 βTURN = 0
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5
Selecting S1 is sufficient to ensure that all species are protected
A.1
A.2
B.1
B.2
Fβ = FβTURN FβNES = 0
Both S1 and S2 should be selected to ensure that all traits (and all species) are protected
Fβ = FβNES FβTURN = 0
Selecting S2 is sufficient to ensure that all traits (and most of the species) are protected
Fβ = FβNES FβTURN = 0
Selecting S1 is sufficient to ensure that all traits (and all species) are protected
Fβ = FβNES = FβTURN = 0
Selecting S1 is sufficient to ensure that all traits (and all species) are protected

The role of enforcement



Effects on socio-economy

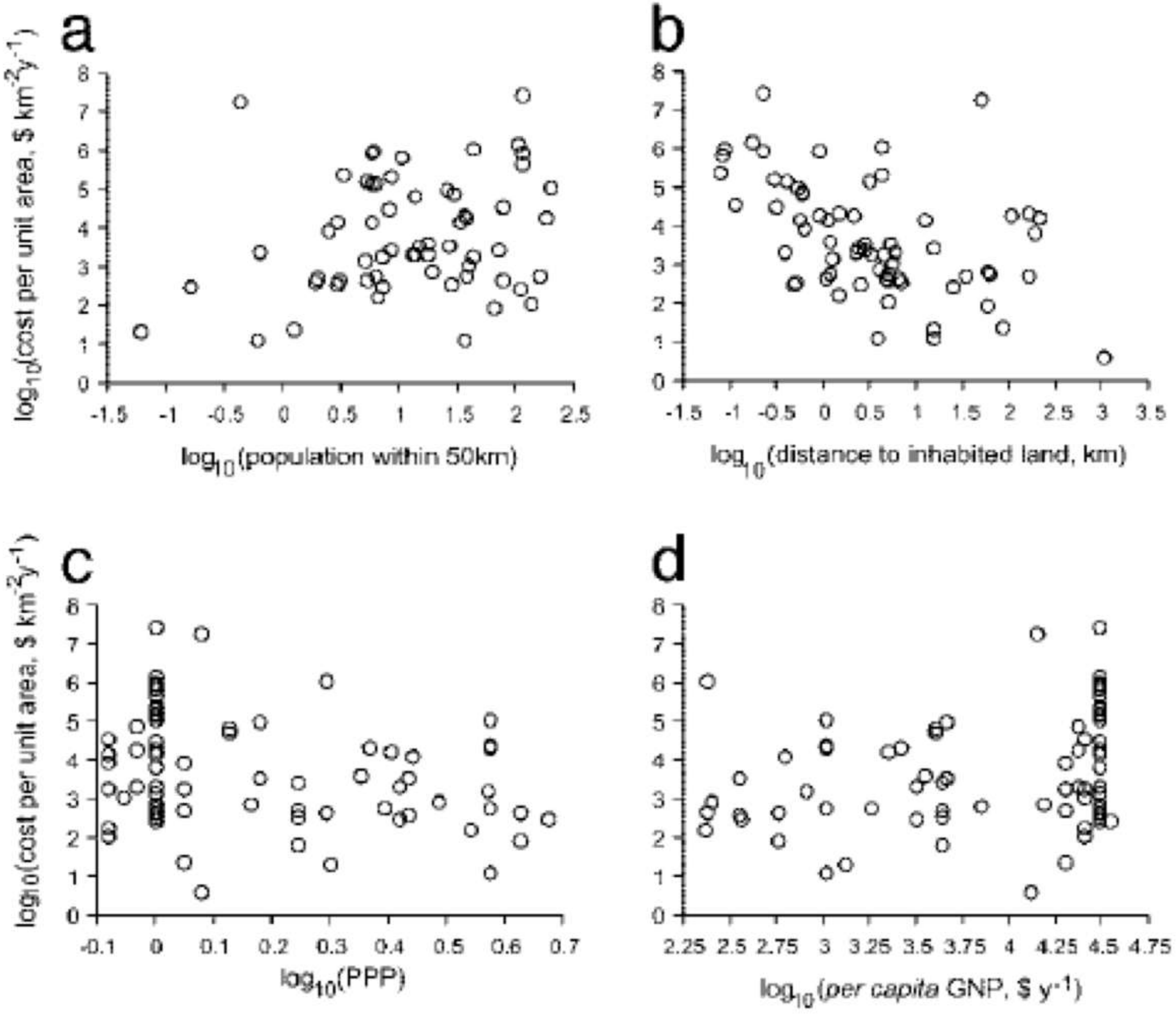




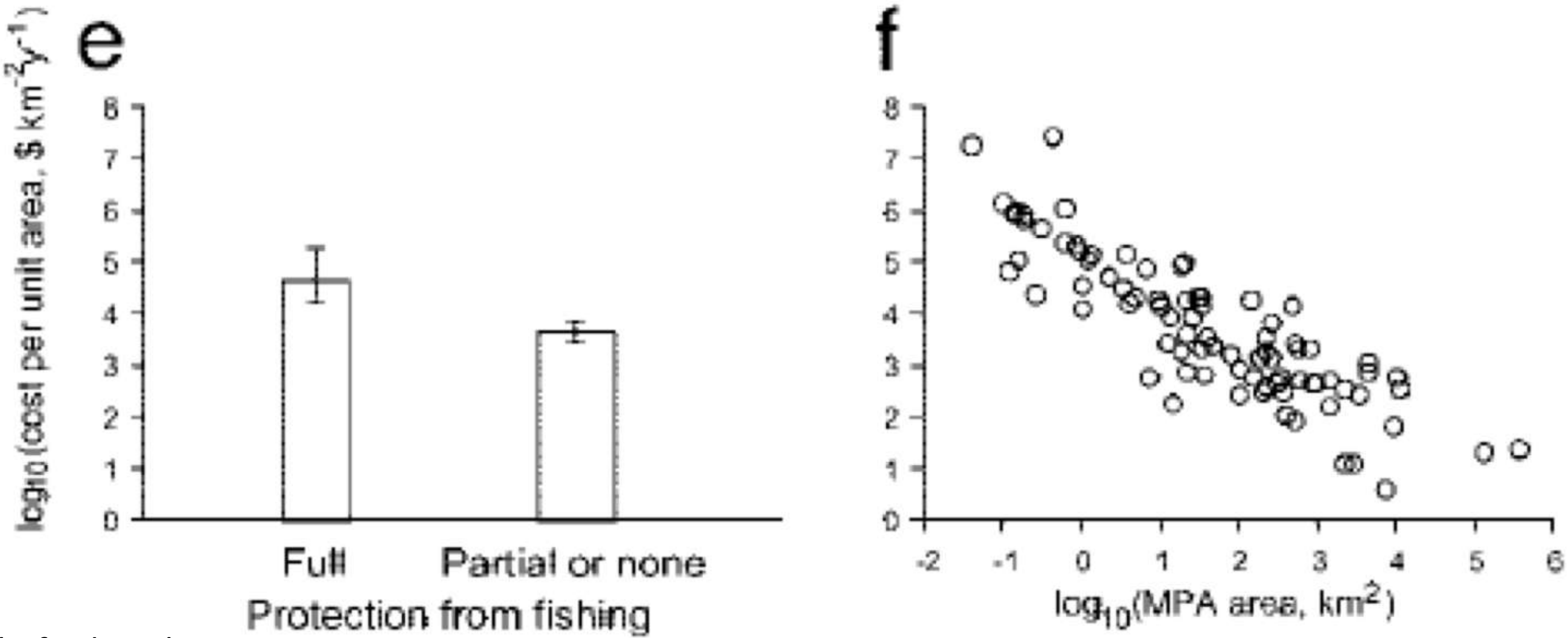
Smallhorn-West et al. 2020

How much does conservation cost?

Balmford et al. 2004



How much does conservation cost?

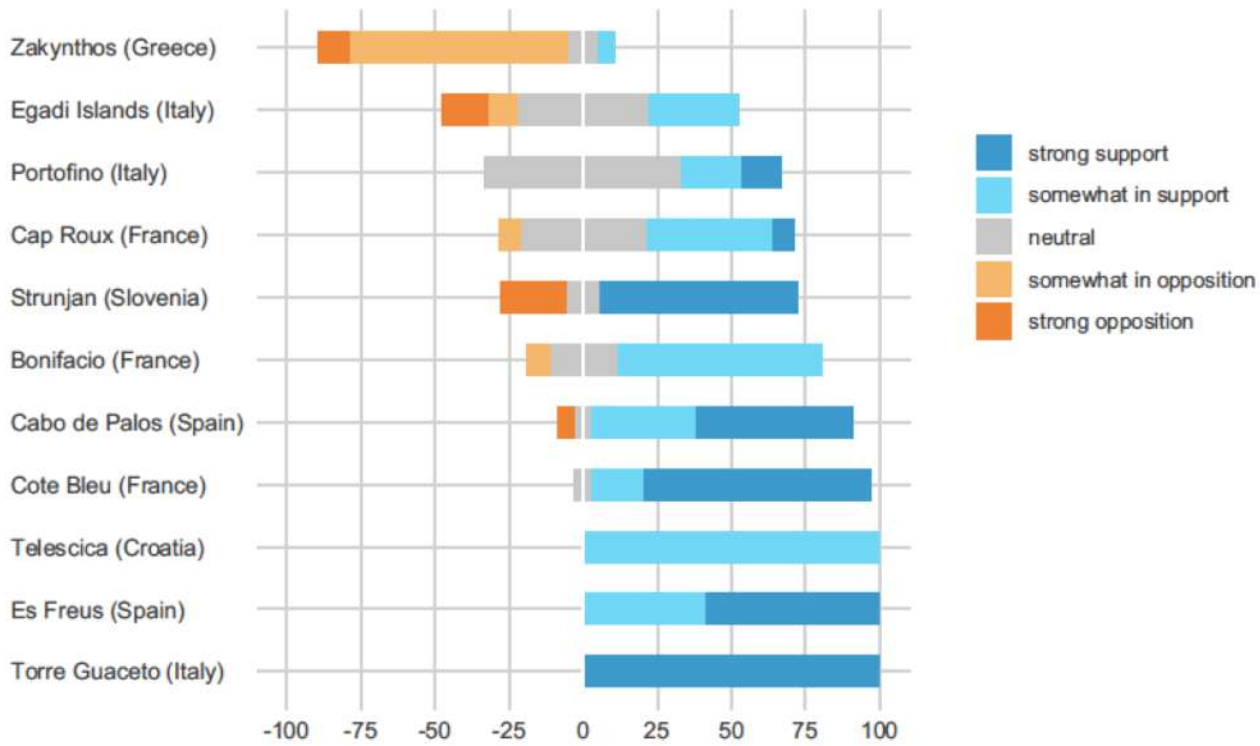


Balmford et al. 2004

Cost ranges between 0 and about 30 millions US dollars per square km year , depending significantly on the size of the MPA and the level of anthropization (population and urbanization)

Compliance

Bennet et al. 2019



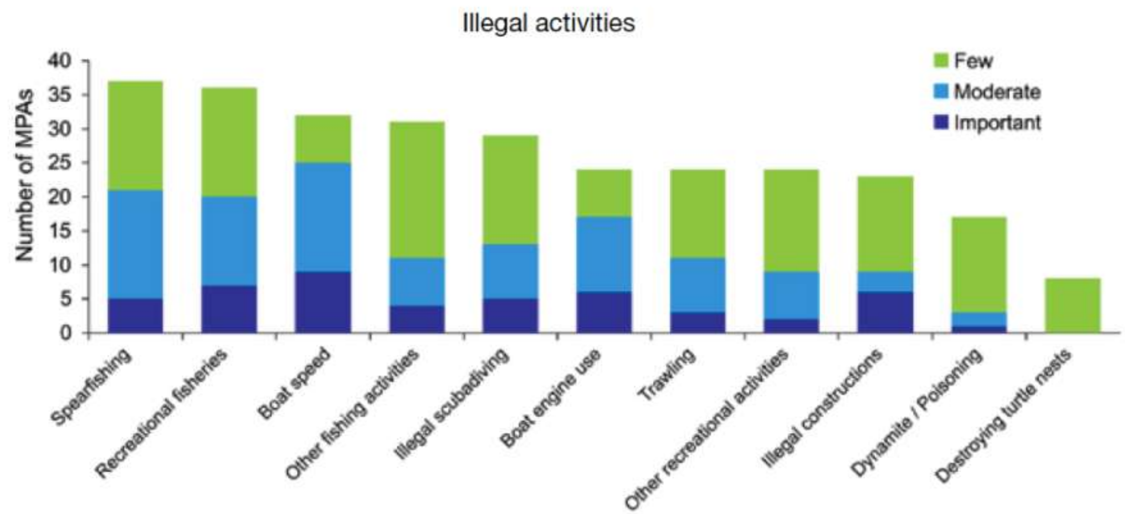
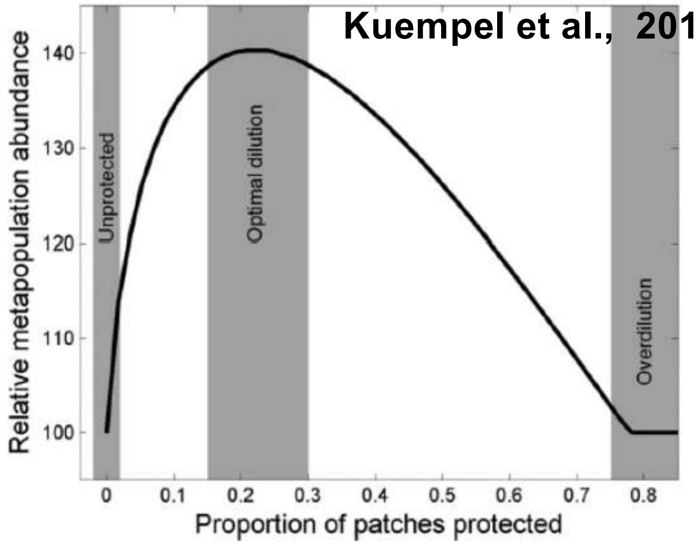
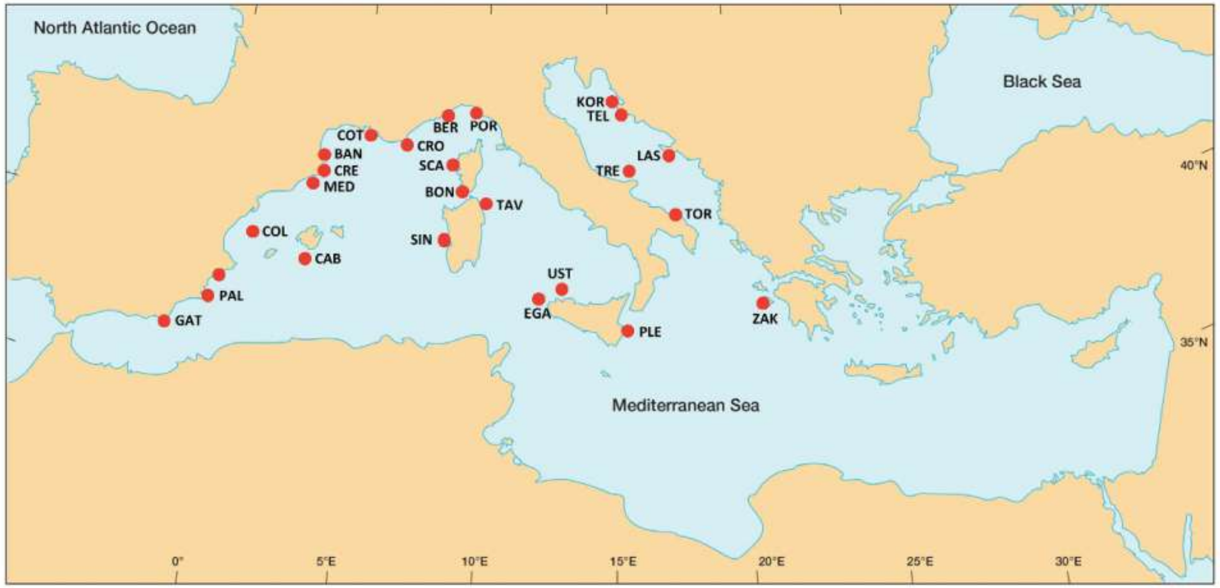


Figure 12. Illegal activities reported to occur in Mediterranean MPAs (n = 45).

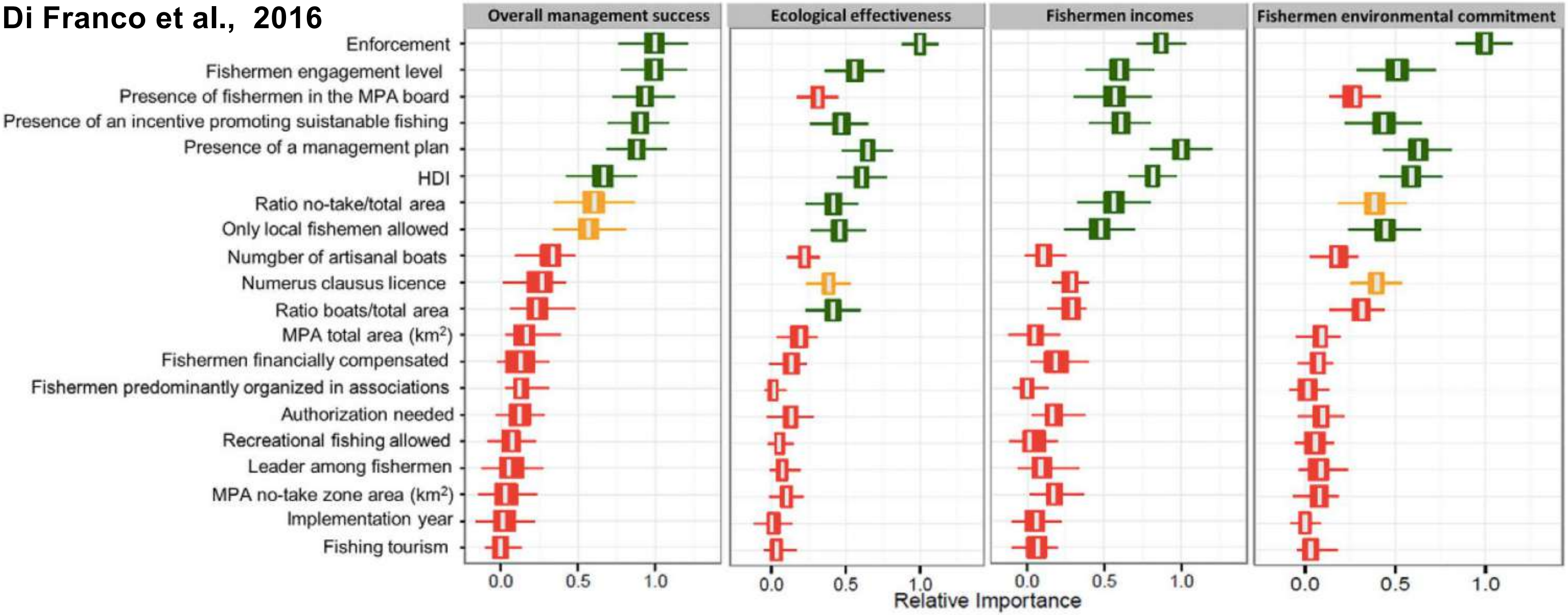
Key factors in MPA effectiveness

Kuempel et al., 2017





Di Franco et al., 2016



Issues

Effective protection require three main points:

1) as first, MPAs should be sited to fulfil well-defined conservation purposes. This in turn will guide positioning and subsequent conservation strategies. The aims of MPAs should take into account connectivity, population dynamics, diversity distribution and, last but not least, the context to reduce socio-economic conflicts and external human pressures.

2) effective protection cannot fall outside considerations of geopolitical and large scale governance constraints, resources availability to maintain governace of reserves, and therefore enforcement, to avoid creation of ‘paper reserves’

3) adaptive management is unavoidable; habitats distribution could change, zonation could require refinements, and monitoring is mandatory to detect changes and implement actions, modifying strategies, or simple to insure that conservation target are being achieved

(Airamè et al., 2003)

Necessary but not sufficient…

Research is demonstrating that marine reserves are powerful management and conservation tools, but they are not a panacea;

They cannot alleviate all problems, such as pollution, climate change, or overfishing, that originate outside reserve boundaries. Marine reserves are thus emerging as a powerful tool, but one that should be complemented by other approaches.

The answer to the question, ‘‘how much is enough’’ is the holy grail of conservation in both marine and terrestrial ecosystems. The goal of marine reserves is to ensure the persistence of the full range of marine biodiversity—from gene pools to populations, to species and whole ecosystems—and the full functioning of the ecosystem in providing goods and services for present and future generations. Because there will always be opportunity costs to conservation, there is a limit to how much we can conserve.

(Lubchenco, 2003)