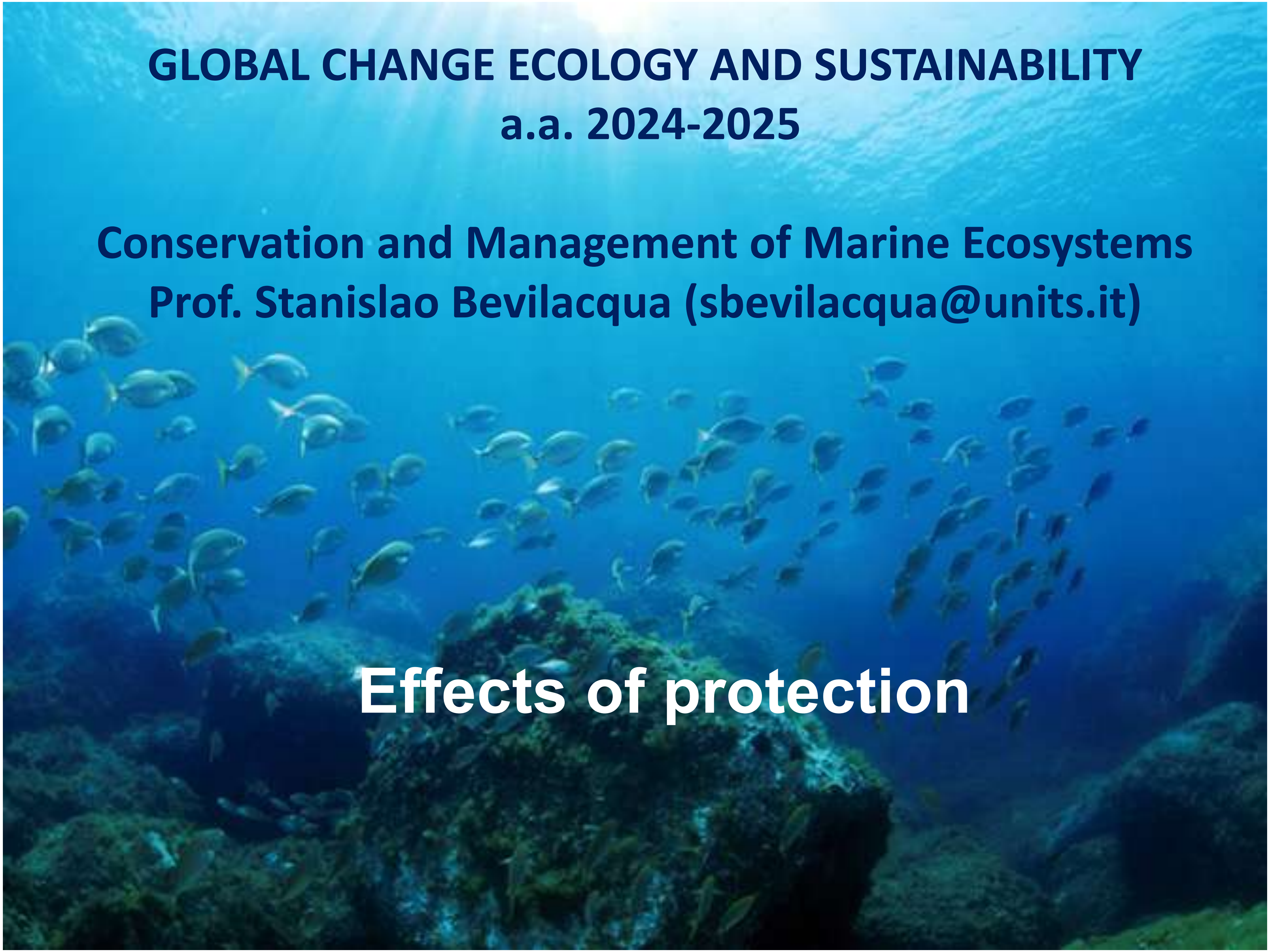


GLOBAL CHANGE ECOLOGY AND SUSTAINABILITY
a.a. 2024-2025

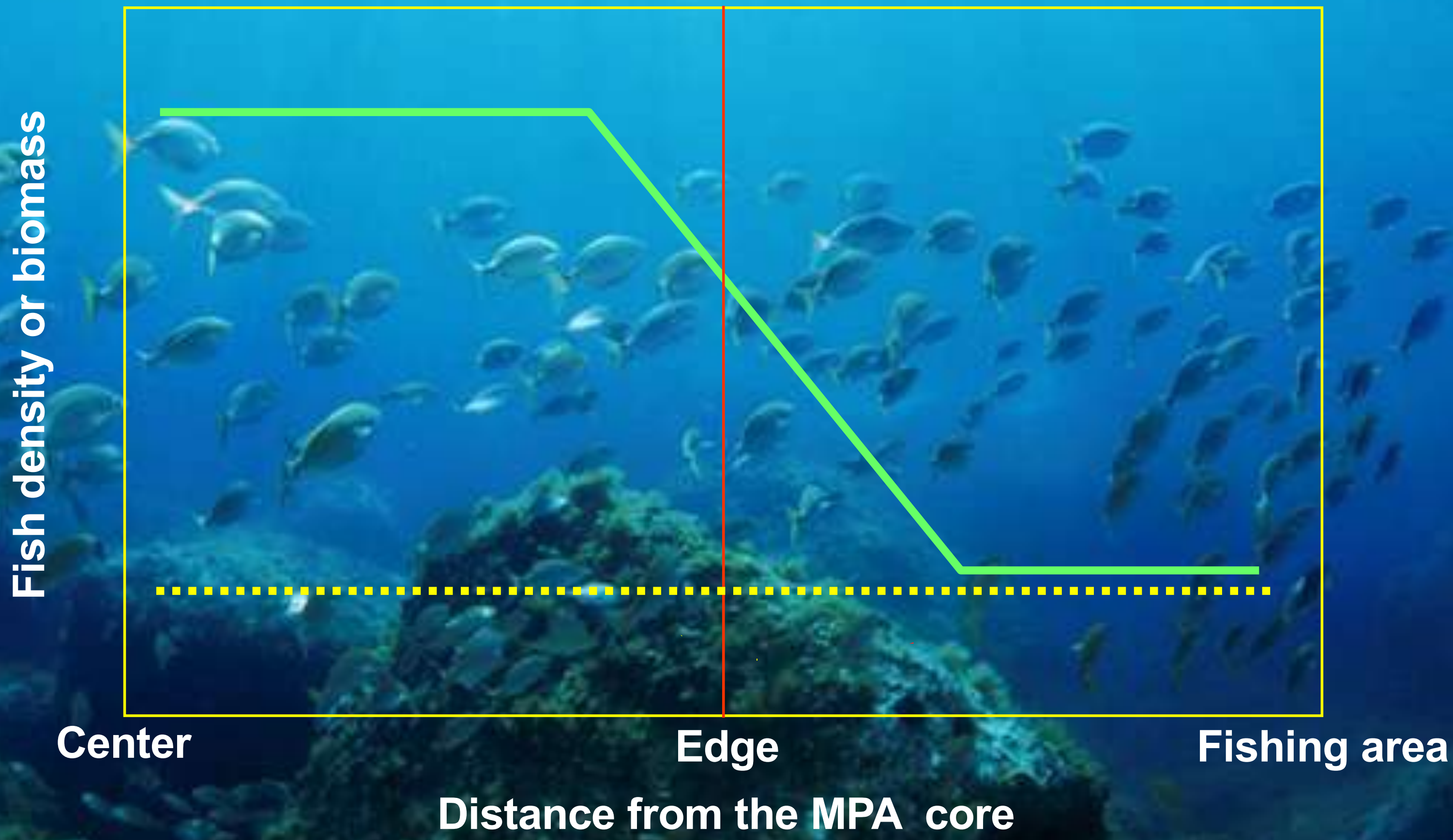
Conservation and Management of Marine Ecosystems

Prof. Stanislao Bevilacqua (sbevilacqua@units.it)

Effects of protection

Sheltering

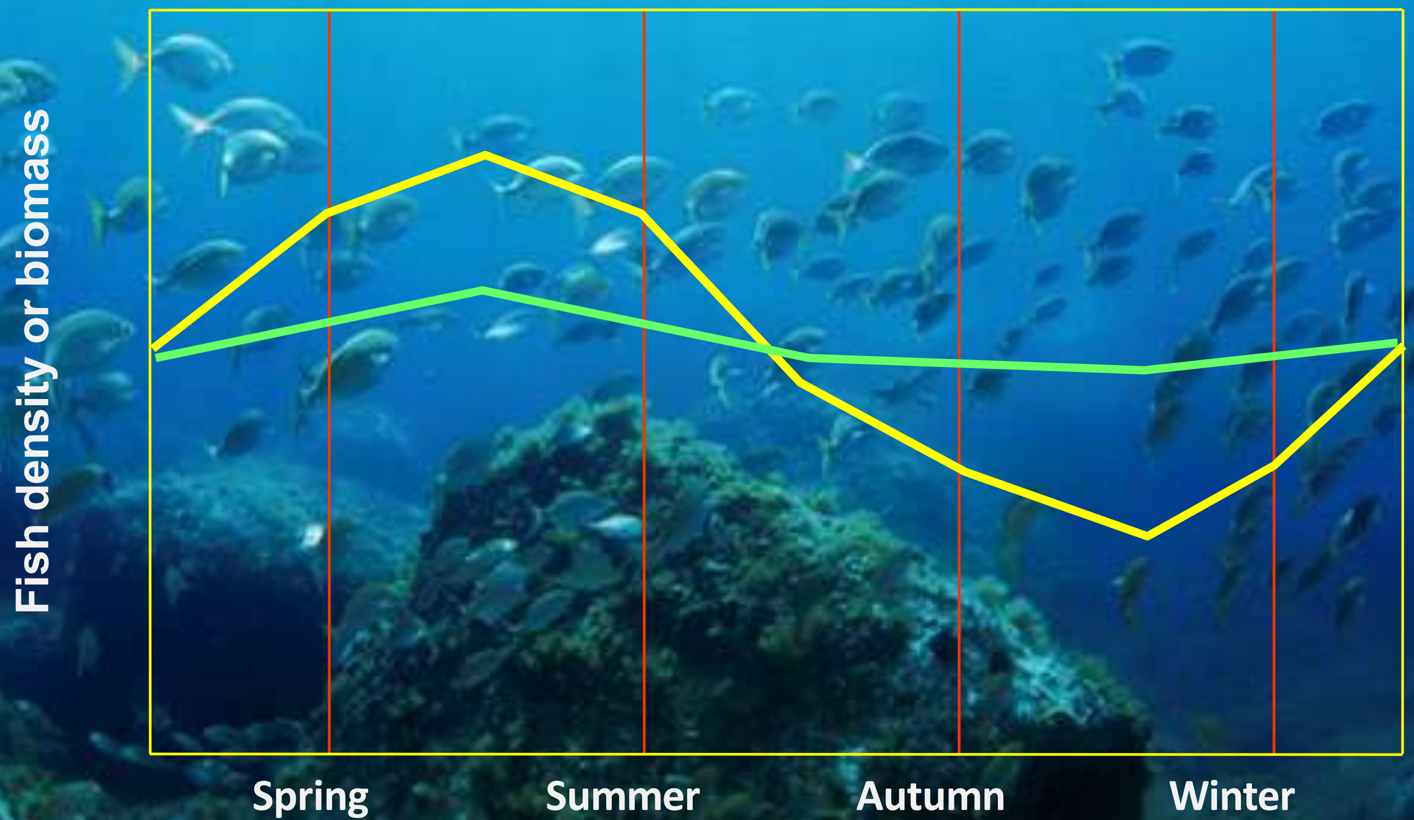
This occurs when one or more target species increase their abundance, size or biomass within the protected areas with respect to fished areas.



Spillover

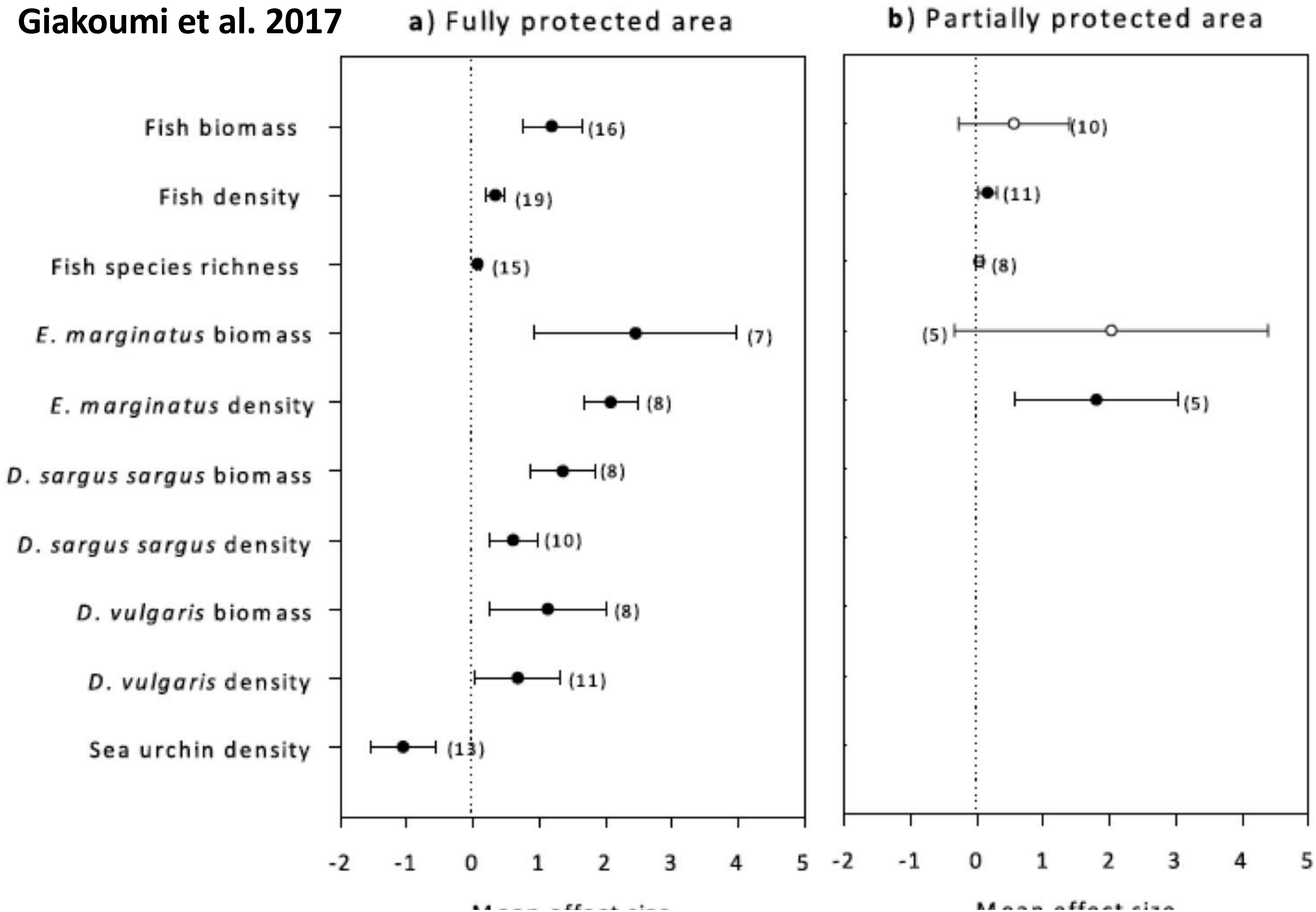
Buffering

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)

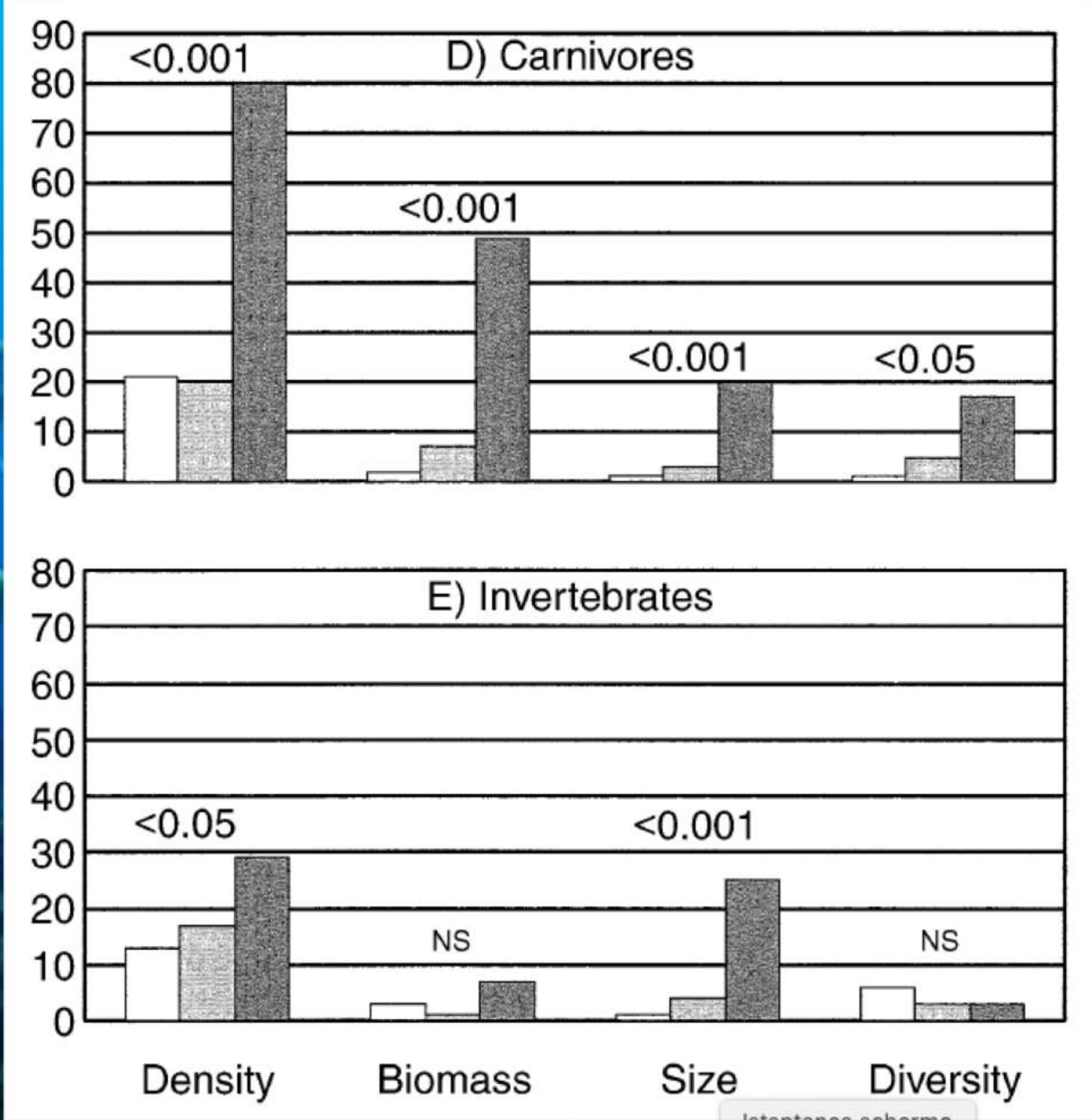


Effects on fish fauna

Giakoumi et al. 2017



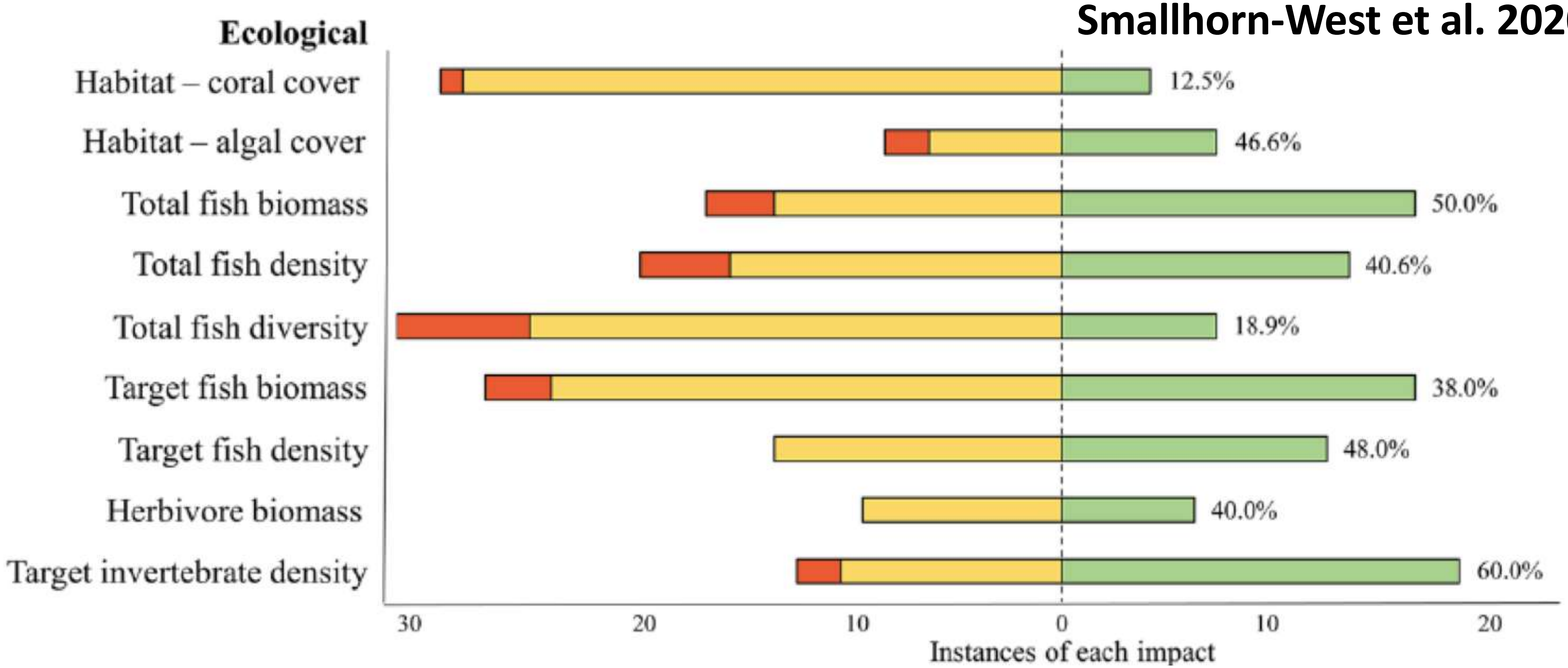
Comparing effects between fish and invertebrates

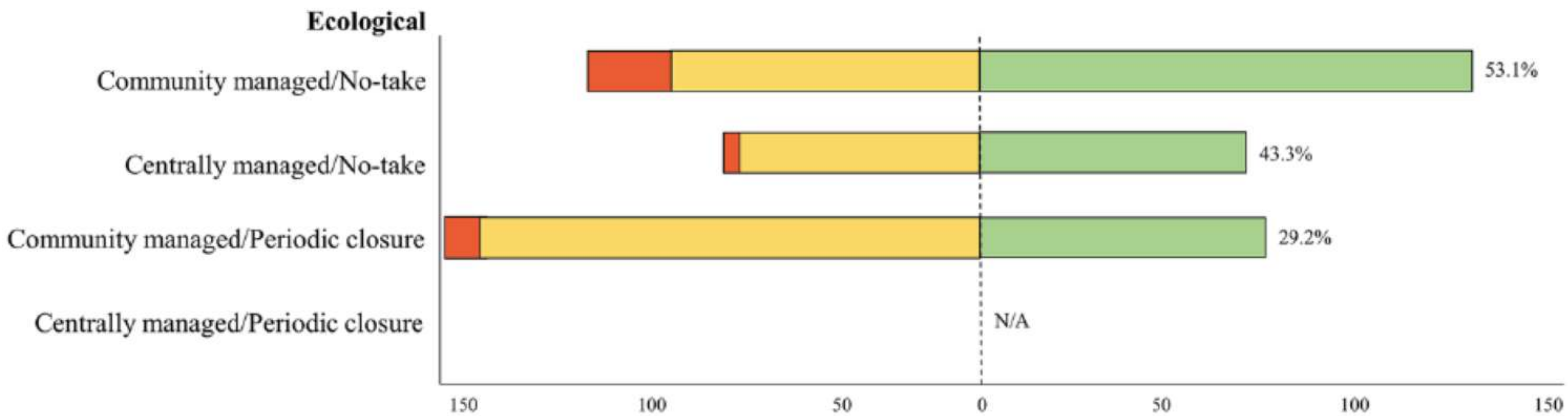


Halpern, 2003
89 MPAs.
Density, size, biomass and diversity of fish fauna were signifcantly higher within than outside the reserve. Benthic invertebrates, however, showed significant difference only for density and size

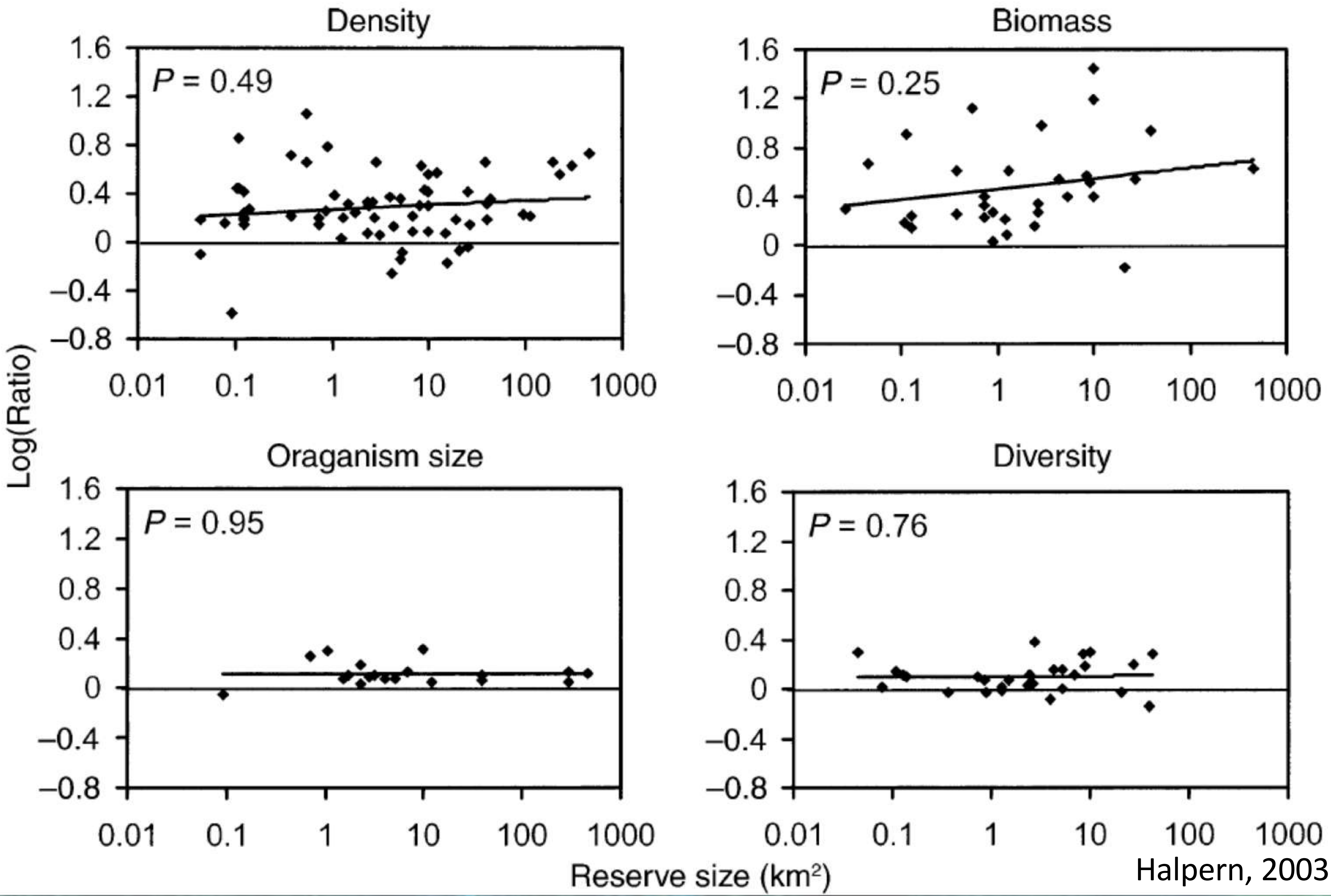
Effects on different ecological compartments

Smallhorn-West et al. 2020



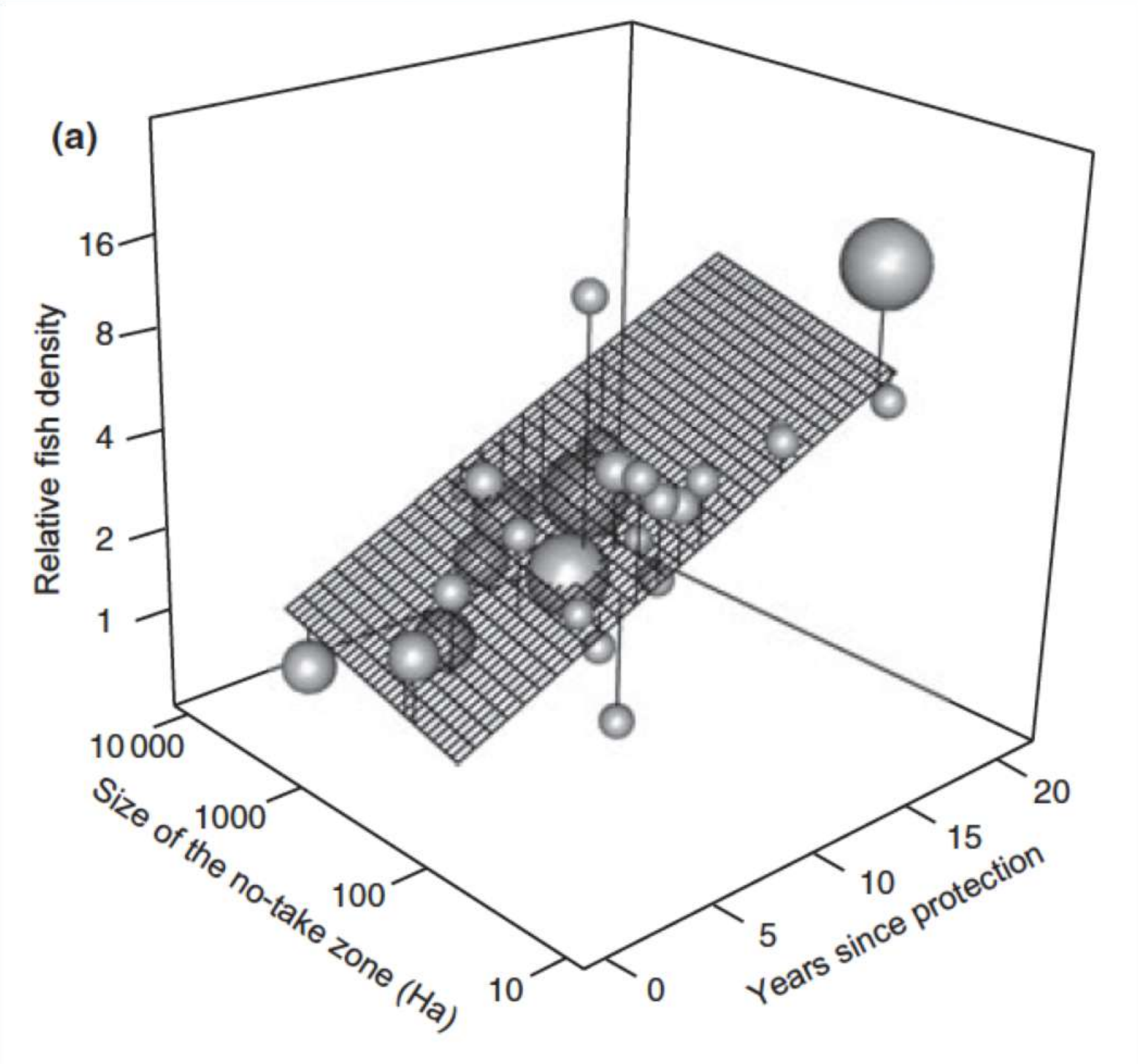


Relationship with reserve size



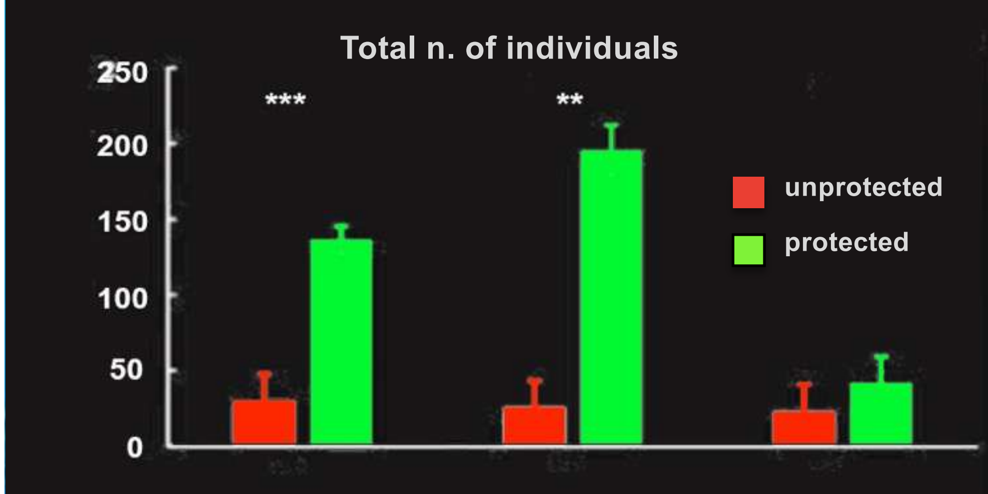
Halpern, 2003

Size again…

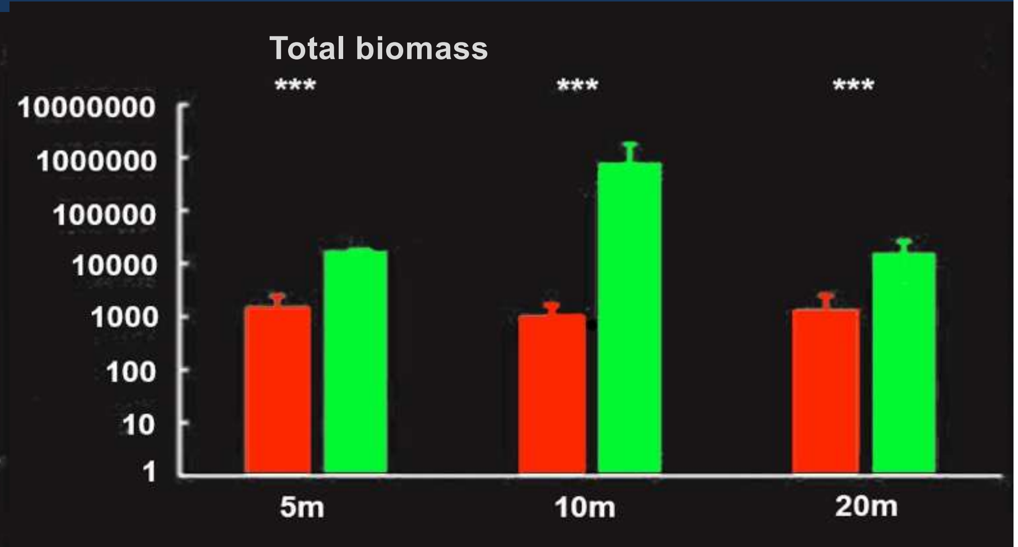


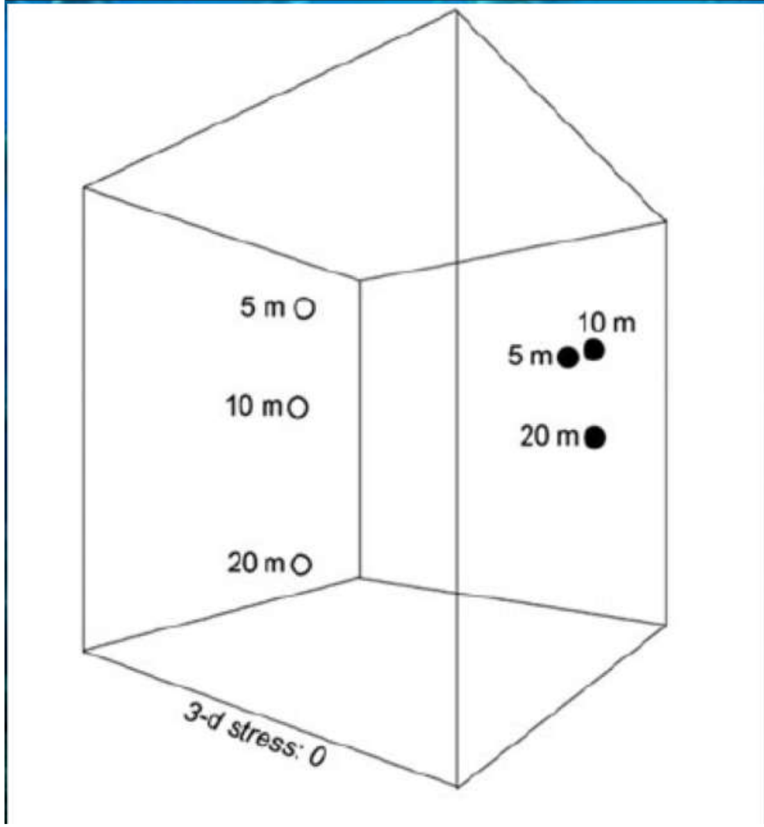
Using 58 datasets from 19 European marine reserves, they showed that reserve size and age do matter: Increasing the size of the no-take zone increases the density of commercial fishes within the reserve compared with outside. Moreover, positive effects of marine reserve on commercial fish species and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

Effects on target species

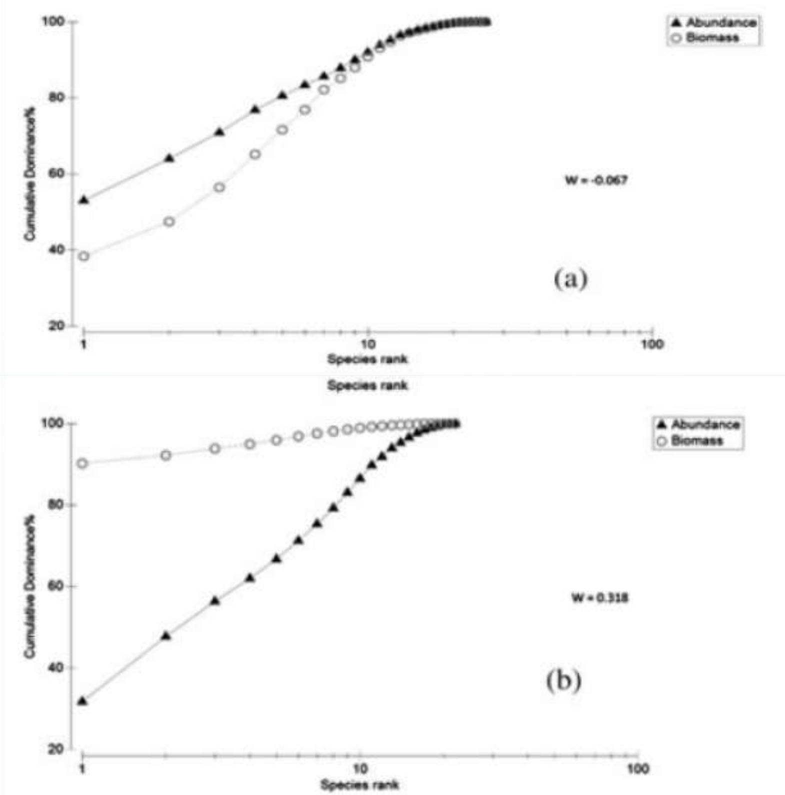


Appolloni et al., 2017.



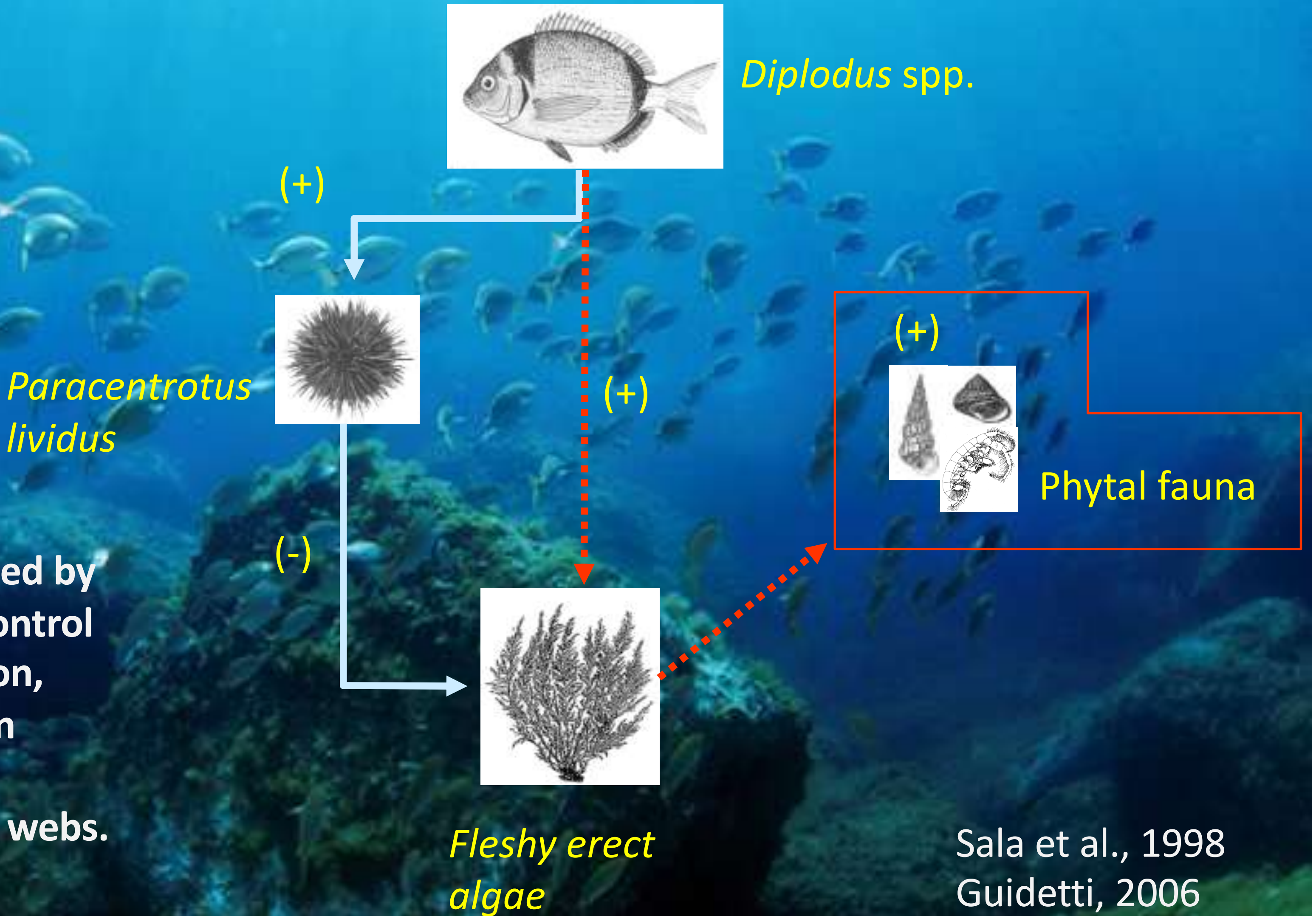


Maintainance of depth structure in fish assemblages. Abundance-biomass patterns typical of healthy conditions



Cascading effects

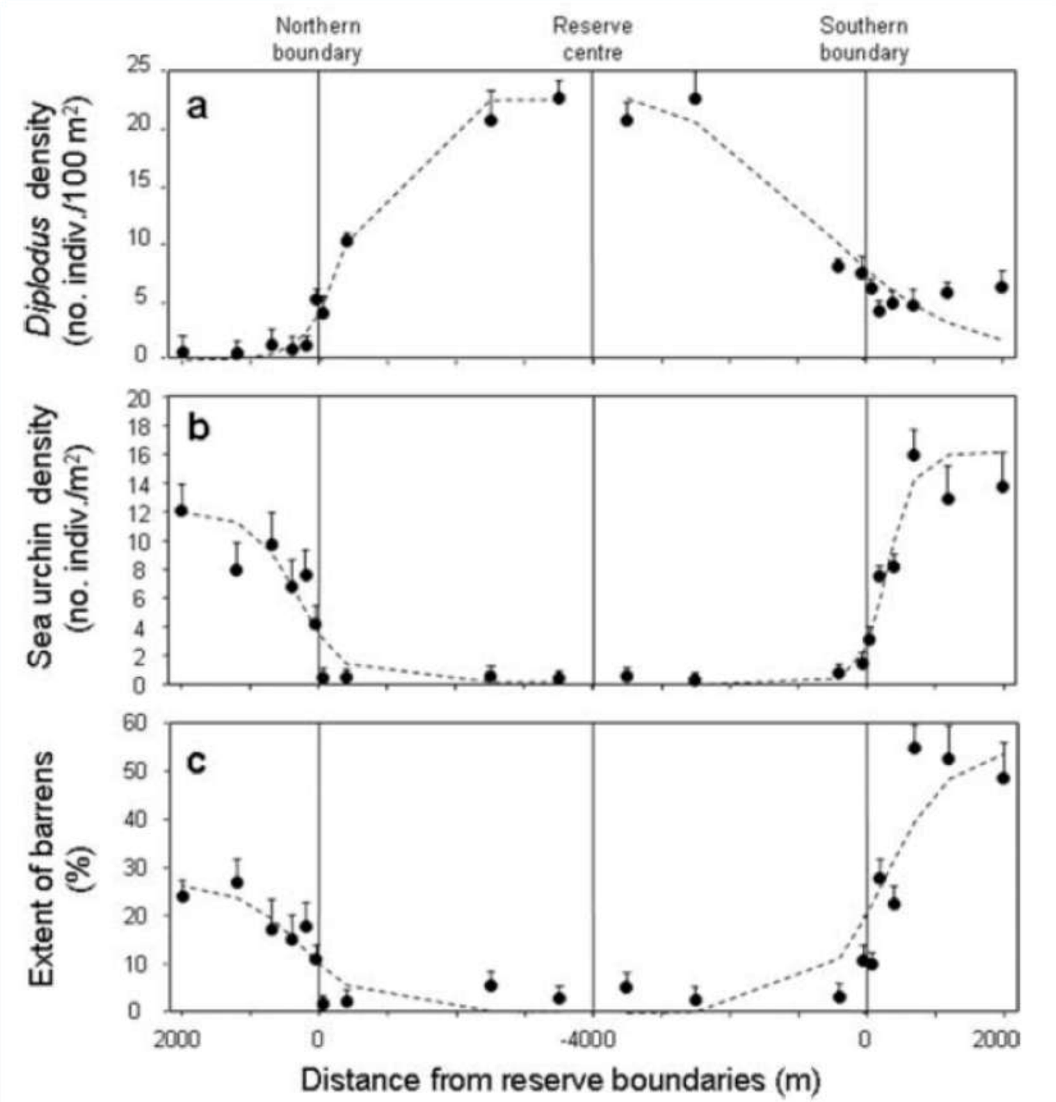
This occur when one or more target species have specific ecological role in stucturing marine communities. Protection, by increasing the abundance of this species allow them maintaning their role in controlling lower trophic levels, triggering cascading effects.

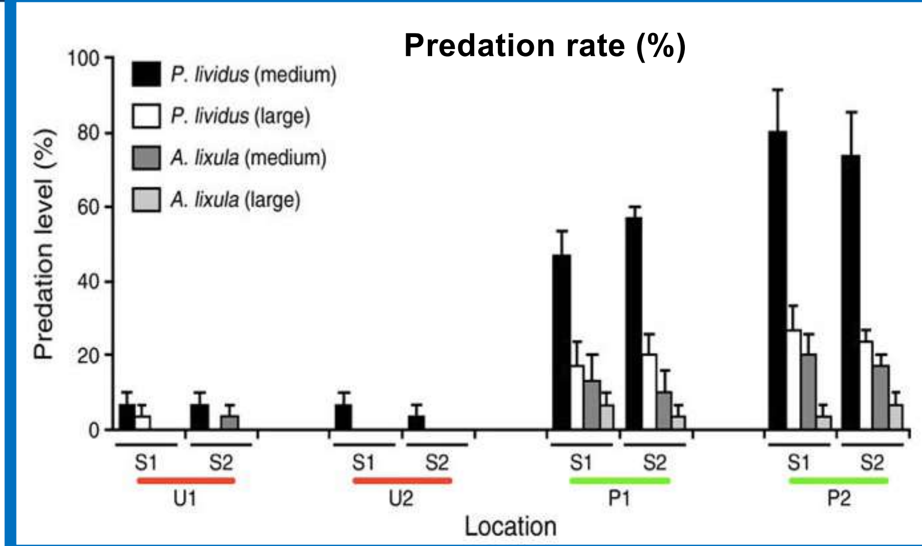


So, a predator population, enhanced by protection, could control their prey population, which in turn has an effect on basal component of food webs.

Sala et al., 1998
Guidetti, 2006

Trophic cascades



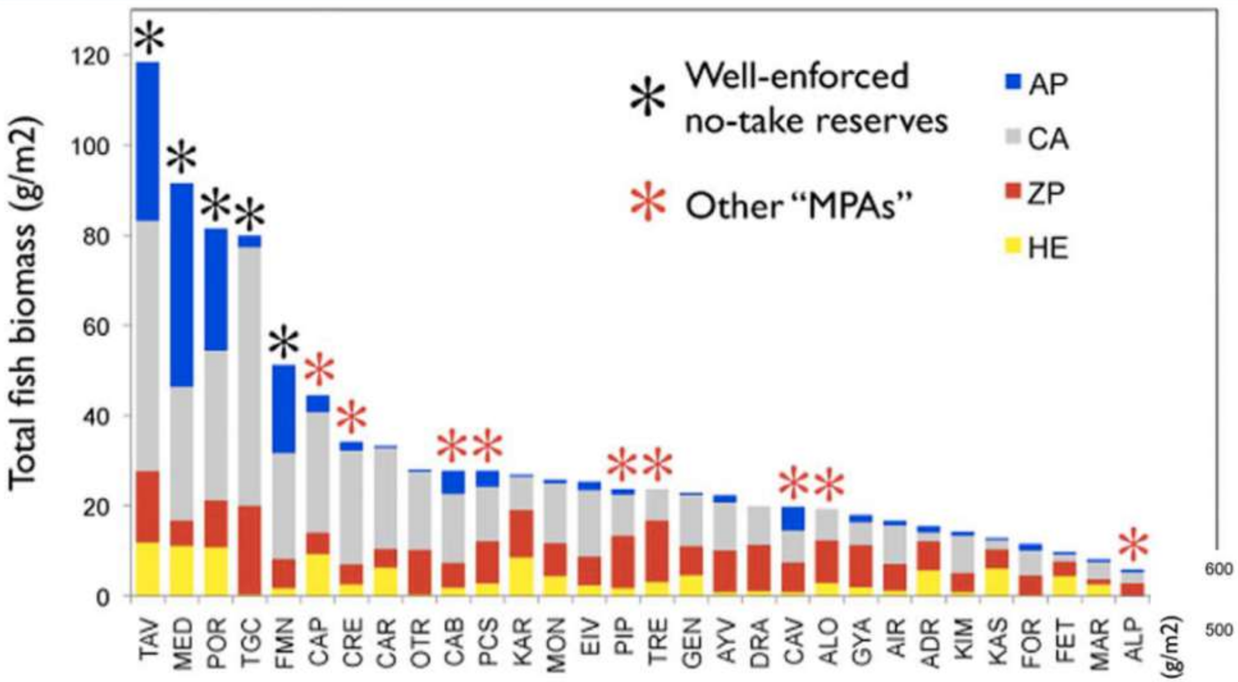


Guidetti, 2006. Ecol Appl

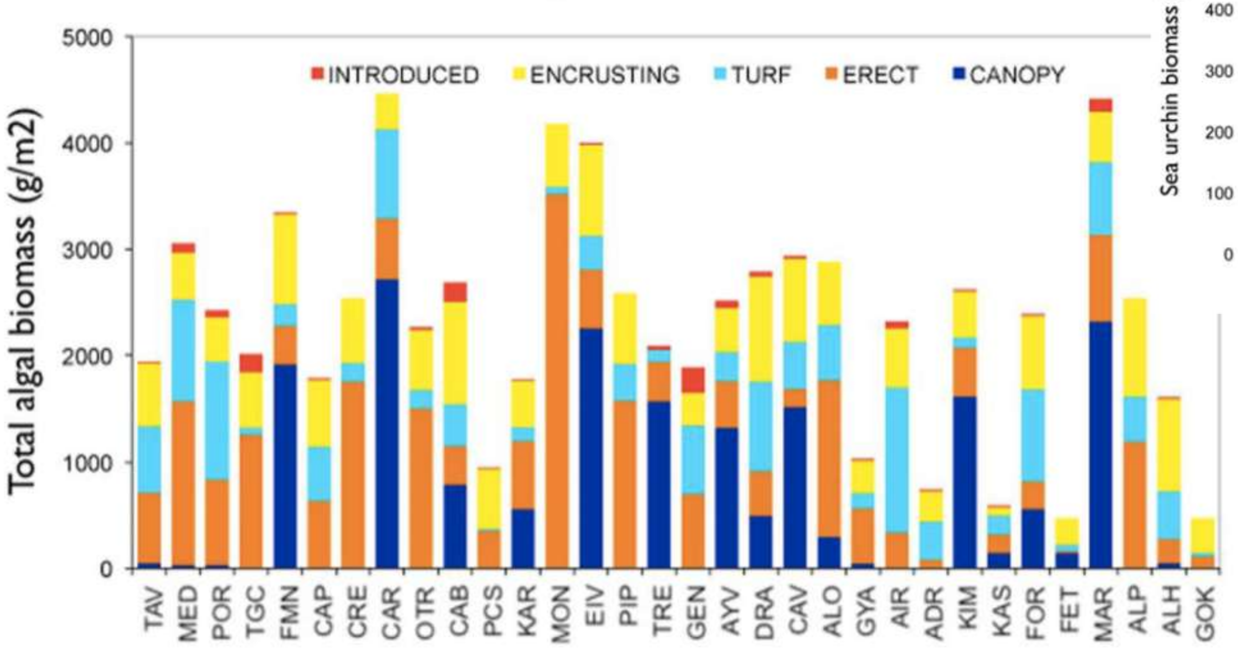
Predation rates within reserves can be much more intense than outside

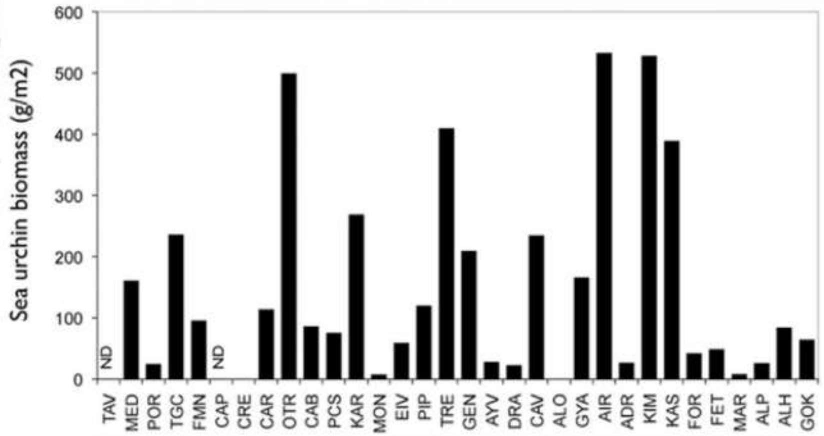
Increase of sea urchin predators due to protection reflects in decrease of sea urchins population within reserve boundaries, and the ensuing decrease of overgrazed substrates (Guidetti et al. 2008)

Mediterranean MPAs – subtidal rocky reefs



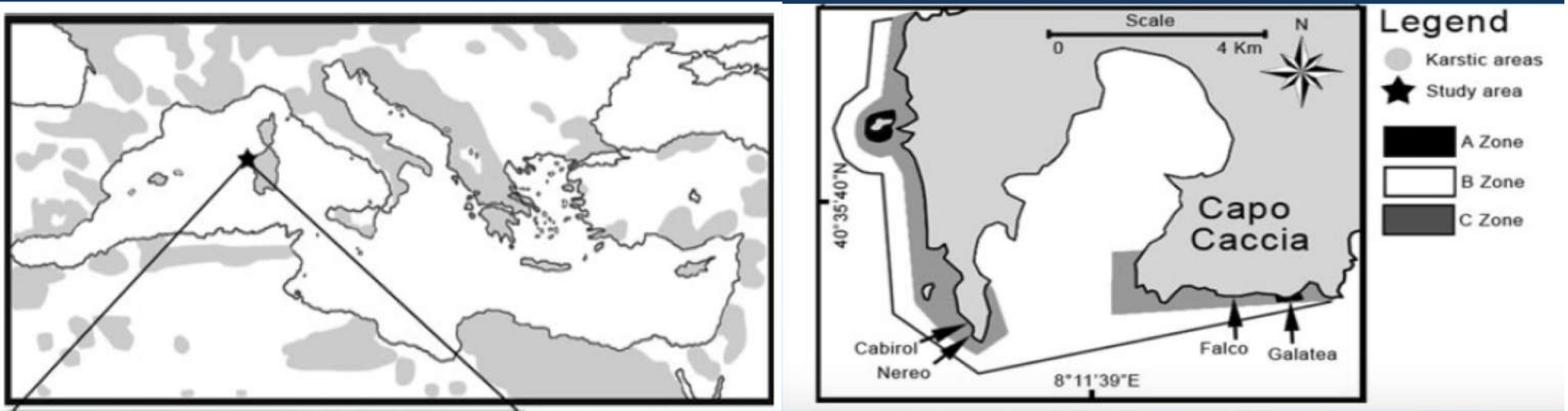
Fish biomass is significantly higher in well-enforced MPAs. Also, macroalgal stands (erect and canopy-forming species strongly varied, but were not related to protection. (Sala et al., 2012)

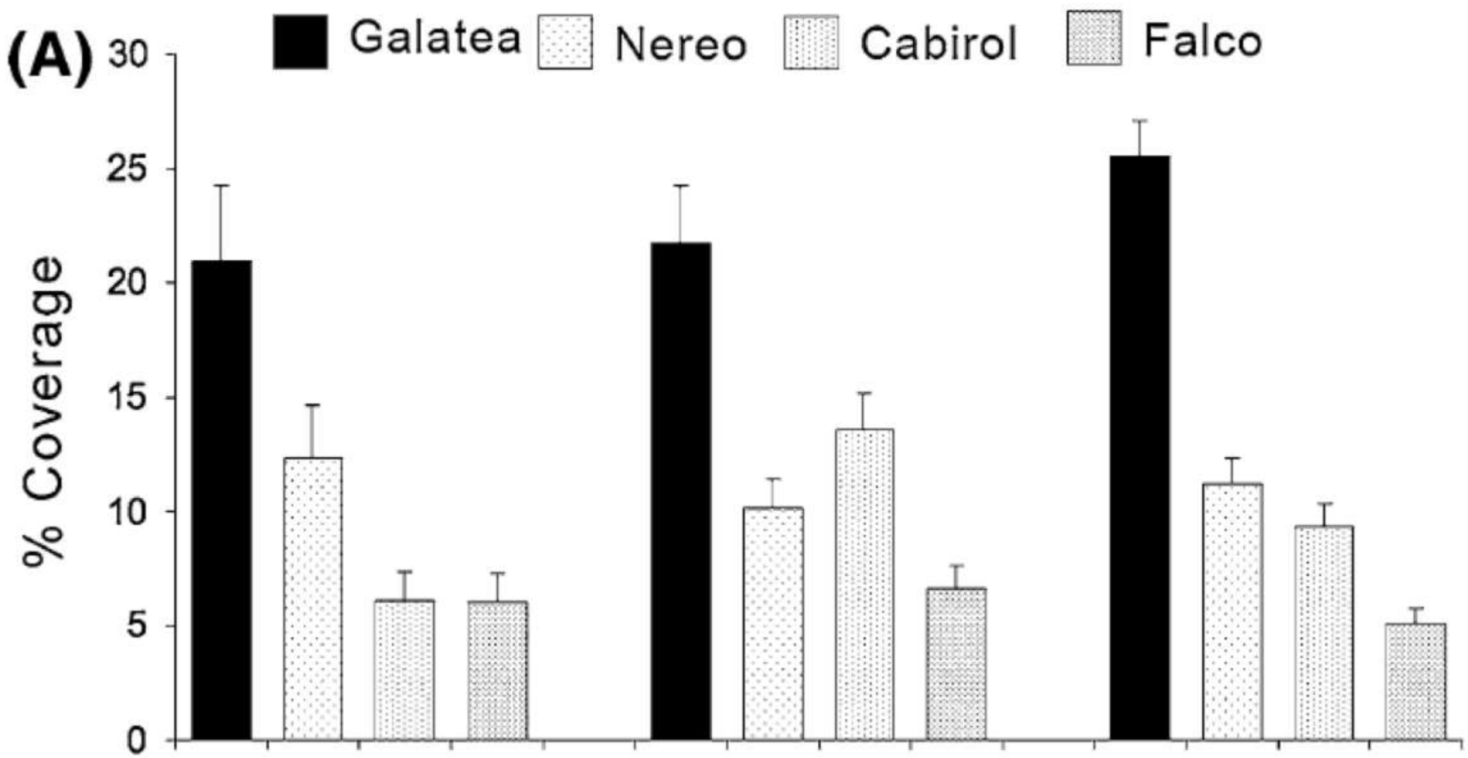




However, macroalgal stands were associaoted to low herbivore (sea urchins) pressure.

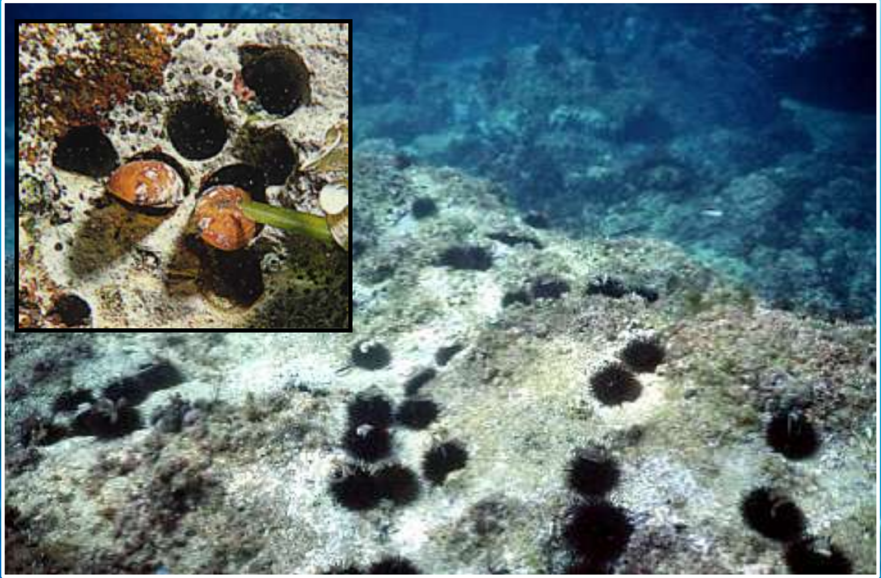
Effects on fragile organisms





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

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

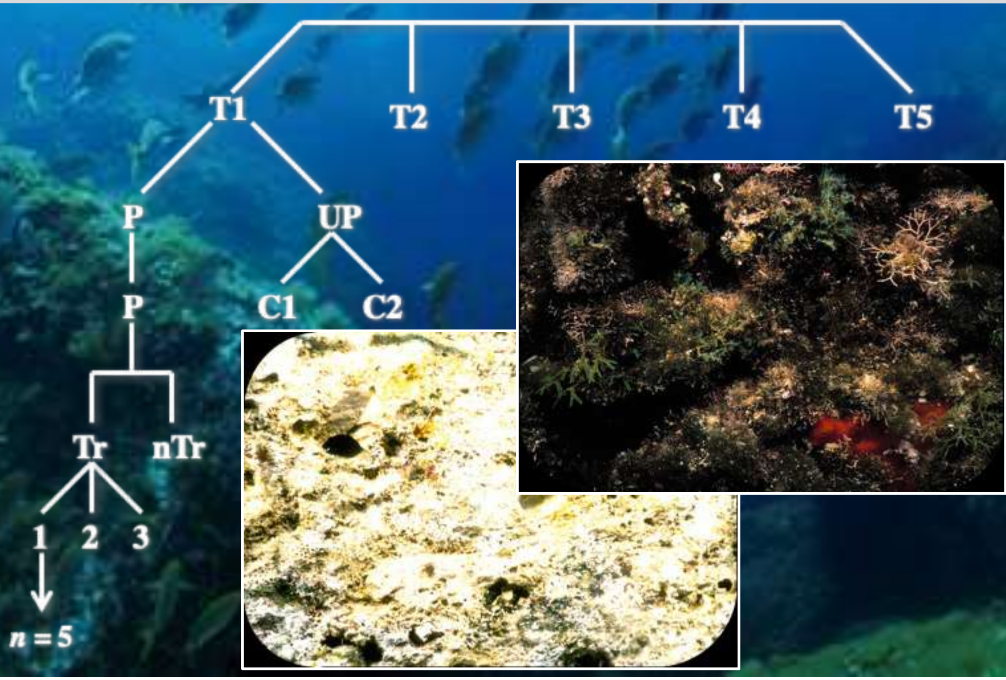
Full protection →

Unprotected →

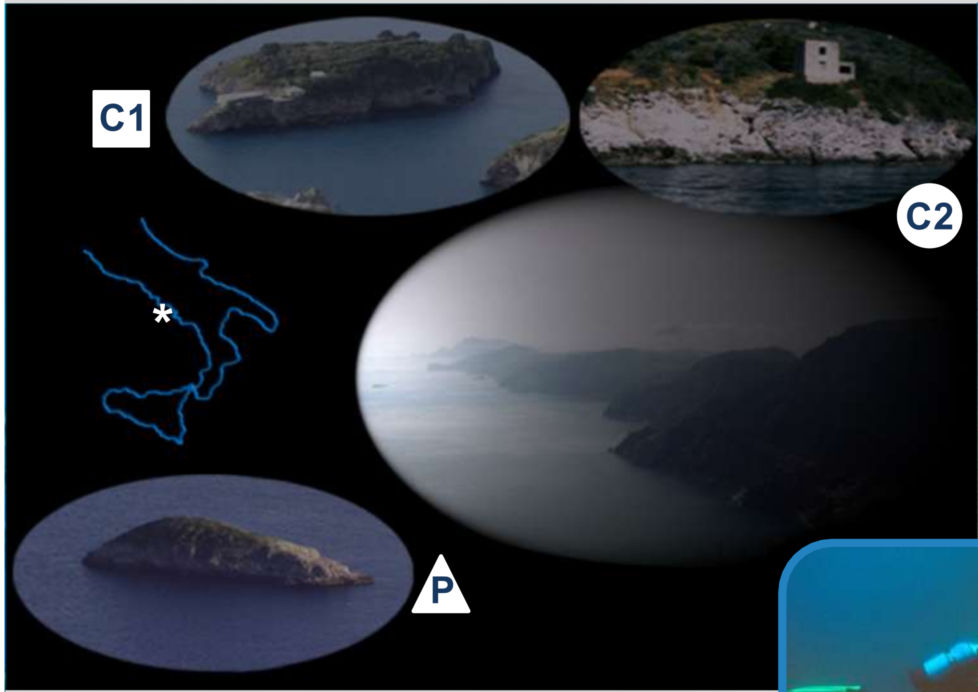
Simulating disturbance

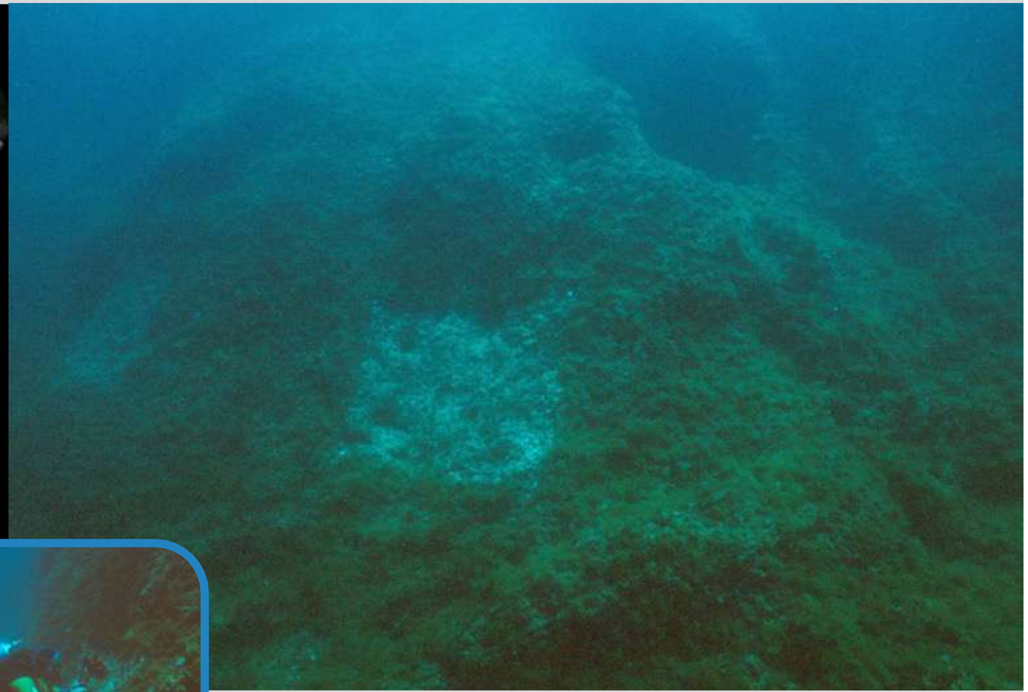
→ **Comparing trends in recovery**

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



Temporal patterns of recovery



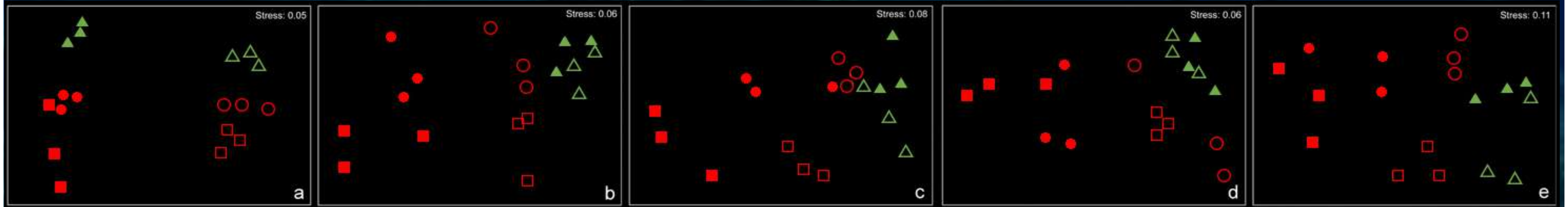


Human impact (date-mussel fishery) simulated within a no-take zone and 2 control areas (NW Mediterranean)

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



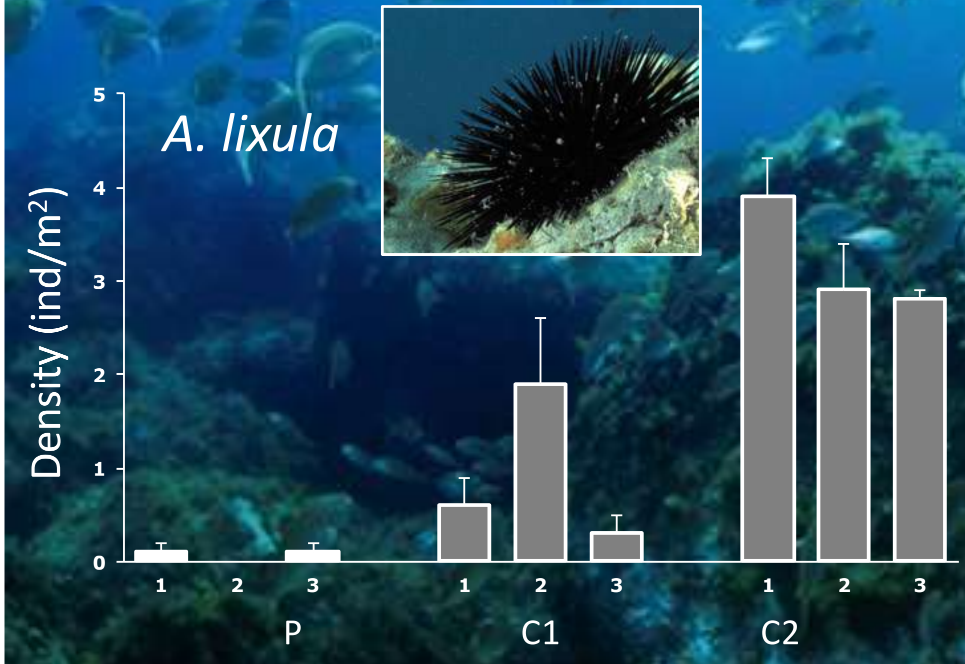
0 months | 3 months | 9 months | 12 months | 20 months

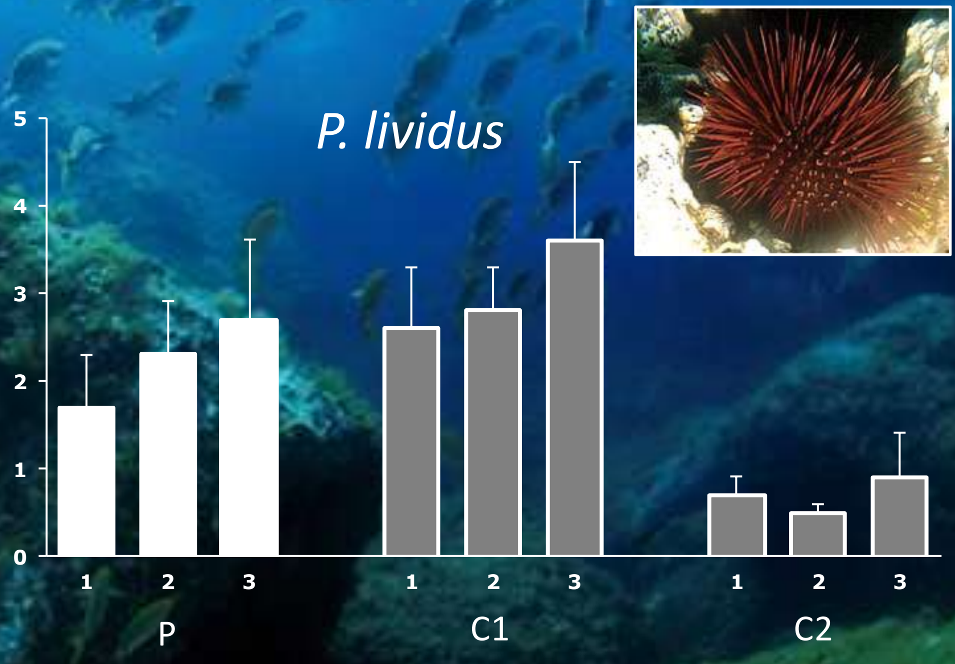
Recovery at the no-take zone was faster than at the unprotected control areas

Sea urchins

ANOVA

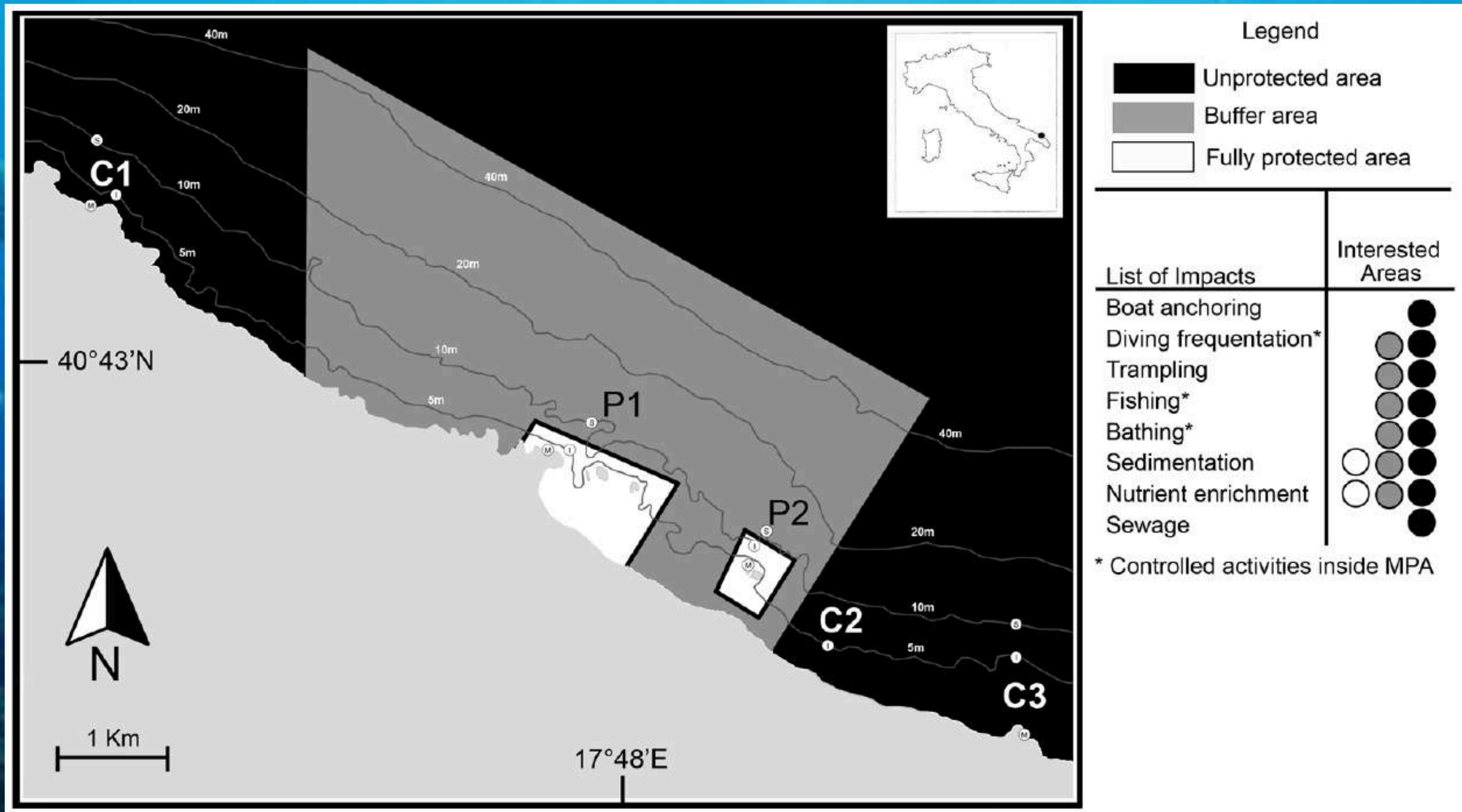
Source of variation	df	SS	MS	F	F versus
Time = Ti	2	0.08	0.04		
Location = Lo	2	1402	7.01	12086*	Ti × Lo
Controls = *Cs*	1	0.85	0.85	0.988ns	Ti × *Cs*
P-v-Cs	1	1317	1317	22706***	Residual
Ti x Lo	4	2.33	0.58	1.289ns	Residual
Ti × *Cs*	2	1.71	0.86	2.263ns	Res *Cs*
Ti × *P-v-Cs*	2	0.62	0.31	0.689ns	Residual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





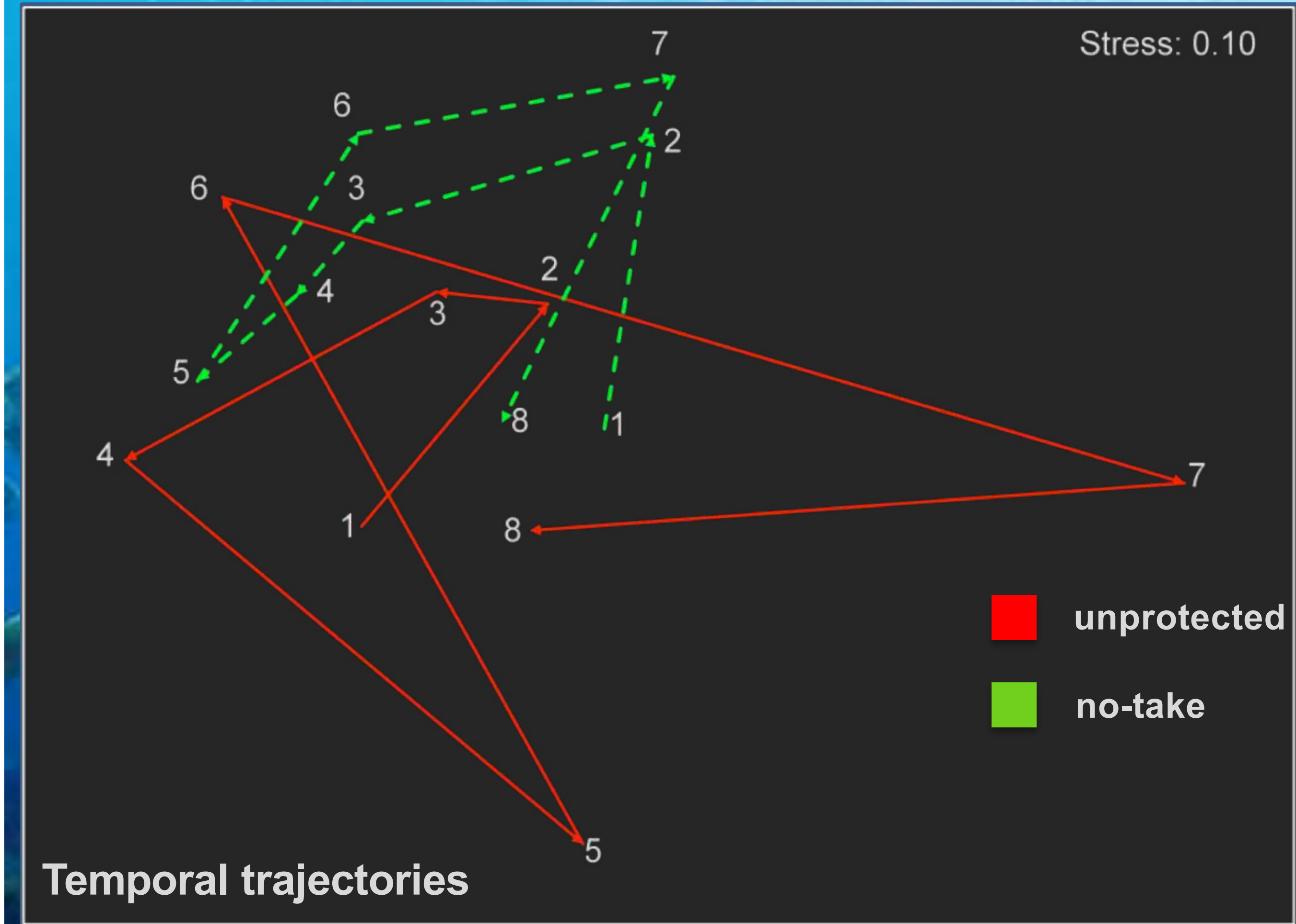
Does protection beget stability?

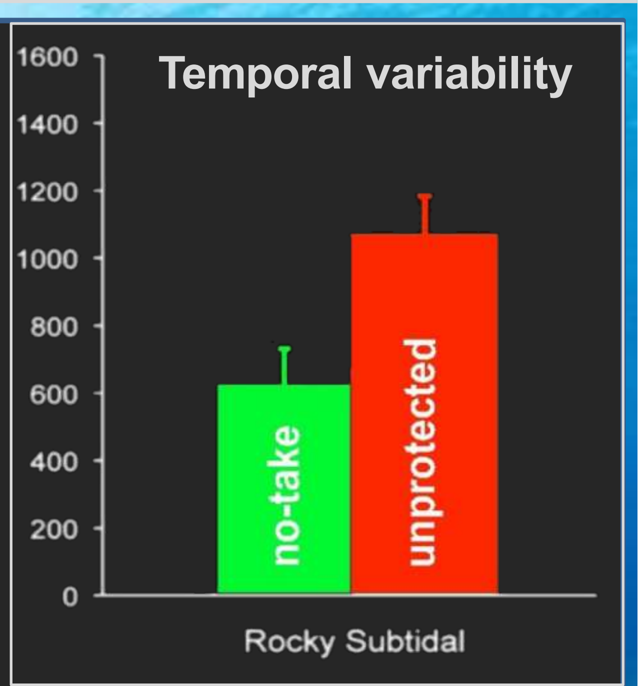
The MPA of Torre Guaceto (SE Adriatic Sea), instituted in 1991 and embedded into a human-dominated landscape, is a rare example of well-managed MPA where an adequate enforcement determined target fish recovery

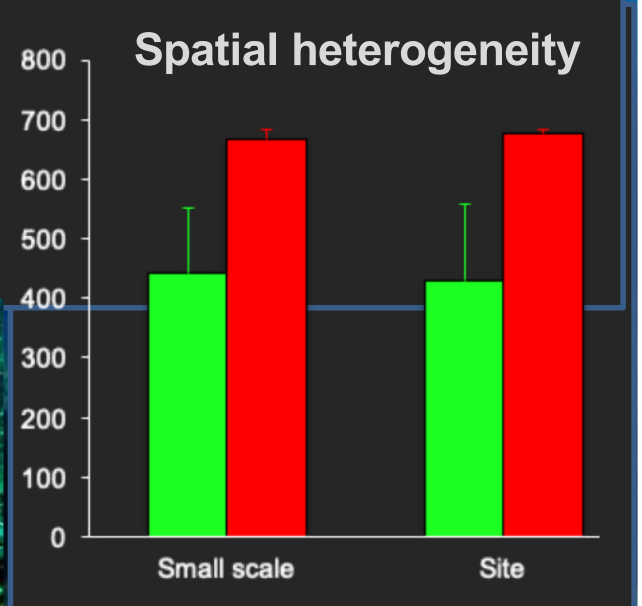


This MPA provided the opportunity to follow the effects of protection on the stability of subtidal benthic assemblages, through the comparison of protected and unprotected locations, from 2002 to 2008

Protection, stability, and heterogeneity





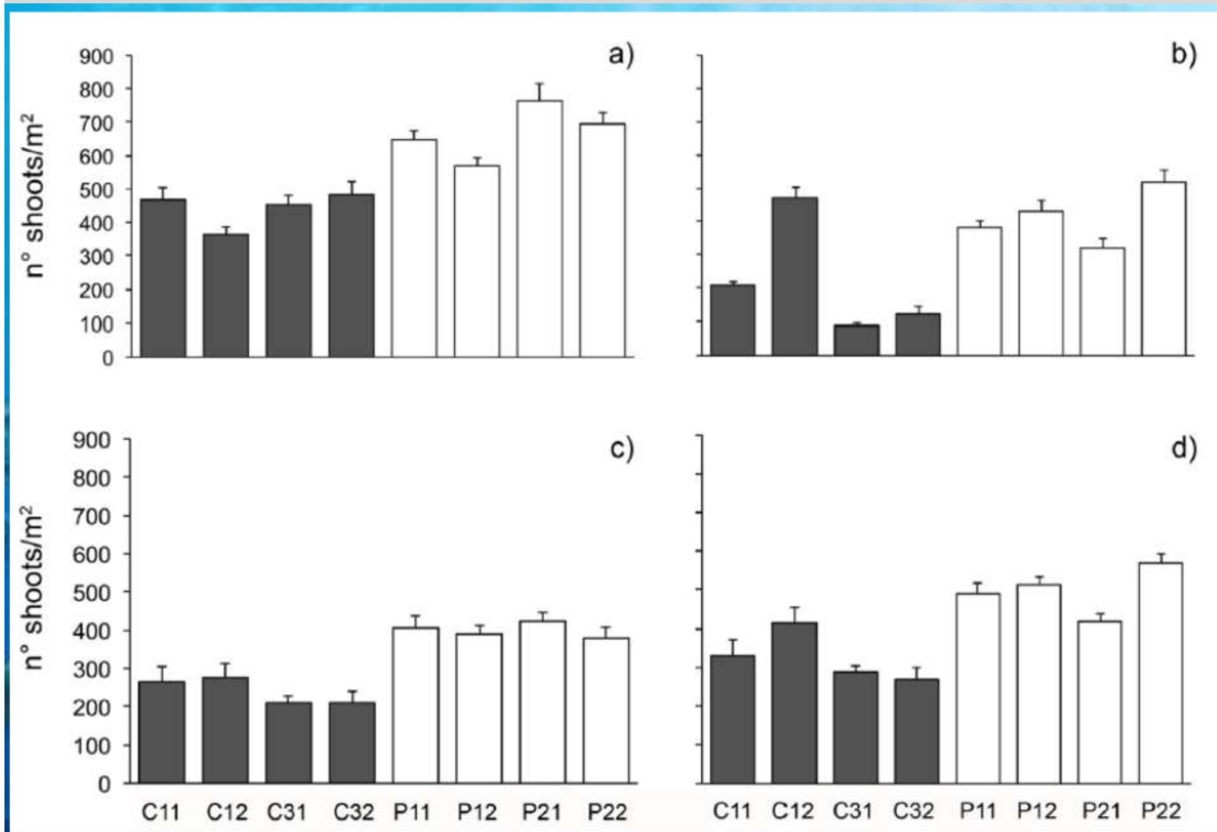


Fraschetti et al., 2013. PLoS One

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

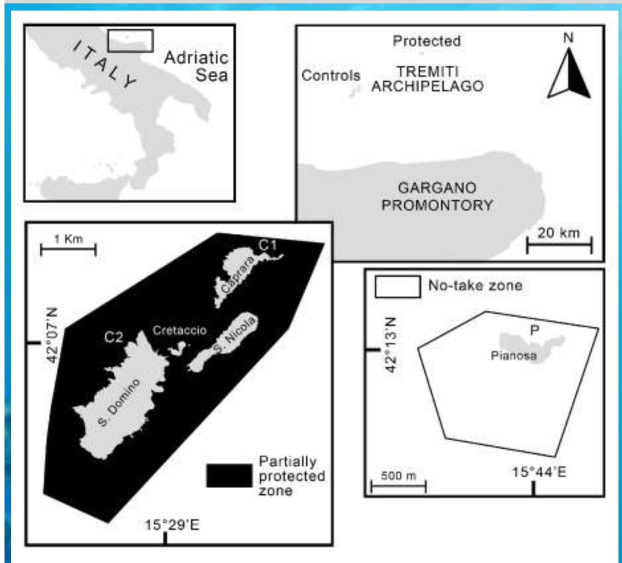


Seagrass beds under reduction in the area due to general increase in sedimentation rates and turbidity. However, the decline is less steep within the no-take areas, where additional direct human impacts (e.g., anchoring) are alleviated or excluded.

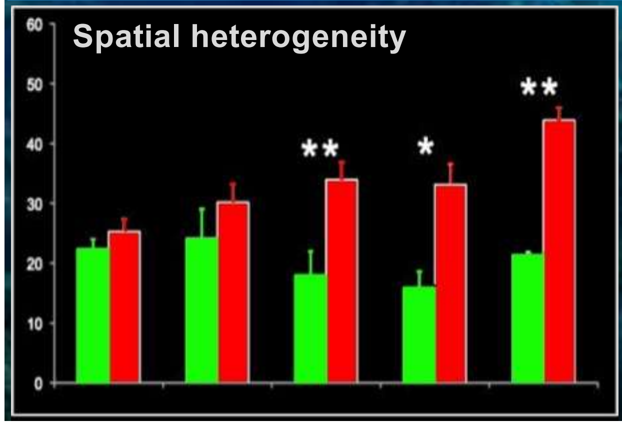
Table 6. Classification of the status of *P. oceanica* beds based on shoot density following Pergent et al. [54].

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



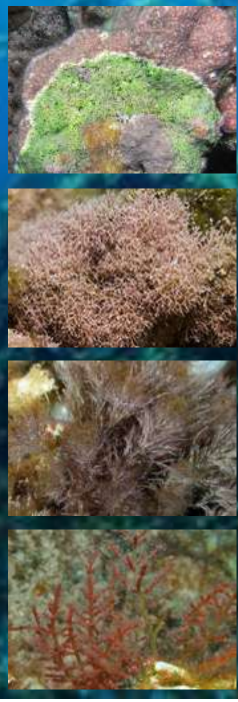
ROCKY INTERTIDAL



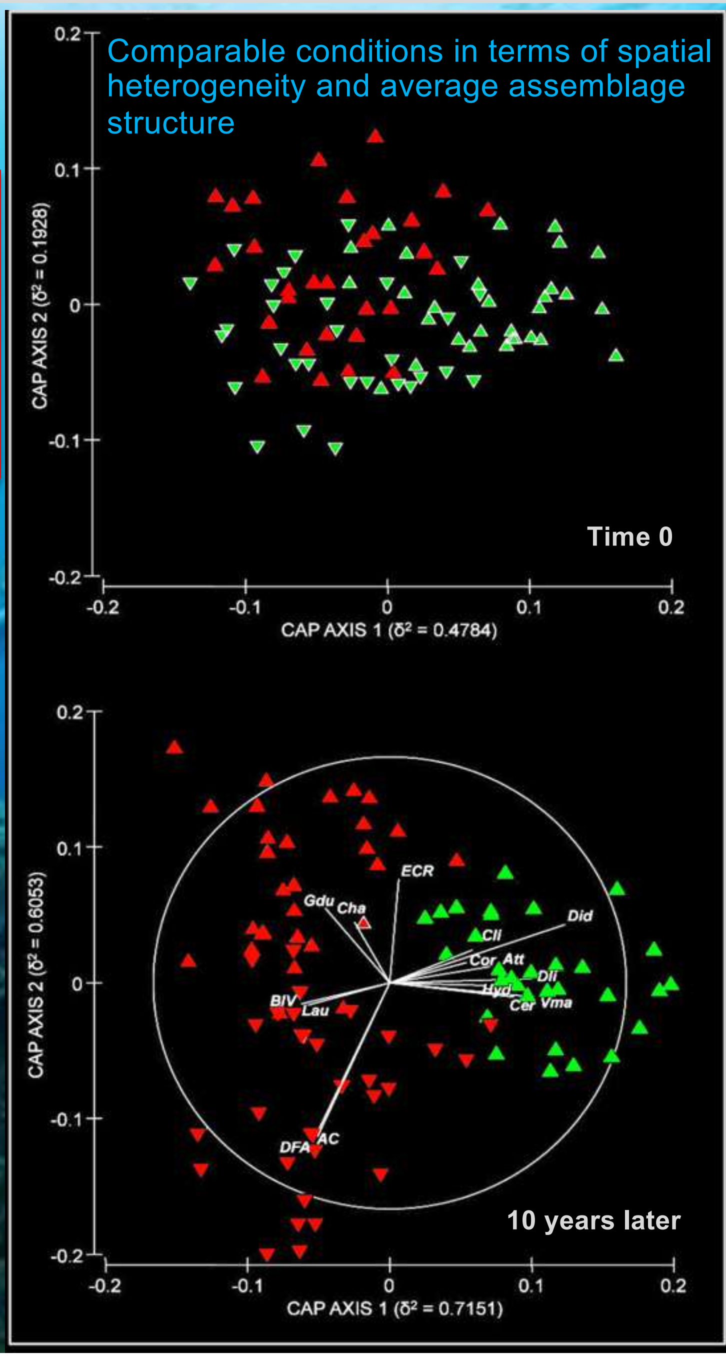
Fraschetti et al., 2012. Mar Ecol Progr Ser

unprotected

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



Comparable conditions in terms of spatial heterogeneity and average assemblage structure



protected

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

Fraschetti et al., 2012. Mar Ecol Progr Ser

Factors limiting protection effectiveness

Environmental

Poor recruitment from El Nino (Preuss et al. 2009; Ferraris et al. 2005)

Environmental fluctuations (Preuss et al. 2009; Powel et al. 2016)

Eutrophication (Moore et al. 2013)

Confounding habitat effects (Dumas et al. 2010)

Discharge from river mouth (Jupiter and Egli 2011)

Cyclone (Thiault et al. 2019)

Study design

Spillover into control sites minimizing impact (Berdach 2003; Ferraris et al. 2005; Preuss et al. 2009)

Habitat differences between control and MPA sites (Wantiez et al. 1997; Jupiter et al. 2012)

Incorrect technique for question (Jupiter et al. 2013)

Biological

Larval dispersal (Preuss et al. 2009)

Density dependent recruitment (Dumas et al. 2012)

High natural variability (Kulbicki et al. 2007)

Increased coral abundance attracts Crown of thorns starfish (Clements and Hay 2017)

Crown of thorns outbreak (Thiault et al. 2019)

Low overall abundance of target organisms (Dumas et al. 2010)

Complex life histories (Dumas et al. 2010)

Changing predator dynamics (Goetz and Fullwood 2013; Dell et al. 2015; Powel et al. 2016))

Social

Insurmountable social barriers (Bartlett et al. 2009b)

Poacher aggression (Lalavanua et al. 2014)

Low overall fishing pressure (Berdach 2003; Carassou et al. 2013)

Reserve design

Small reserve size (Preuss et al. 2009; Dumas et al. 2010; Jupiter and Egli 2011)

Proximity to human populations (Preuss et al. 2009; D'agata et al. 2016)

Insufficient time (Dumas et al. 2010)

Unproductive habitat (Preuss et al. 2009)

Poor visibility from village (Jupiter and Egli 2011)

Smallhorn-West et al. 2020

Management

Poaching/lack of compliance (Bartlett et al. 2009b; Jupiter and Egli 2011; Moore et al. 2013; Lalavanua et al. 2014; Albert et al. 2016; Peters 2017; Thiault et al. 2019)

Overharvest of periodic closures (Goetz et al. 2017)

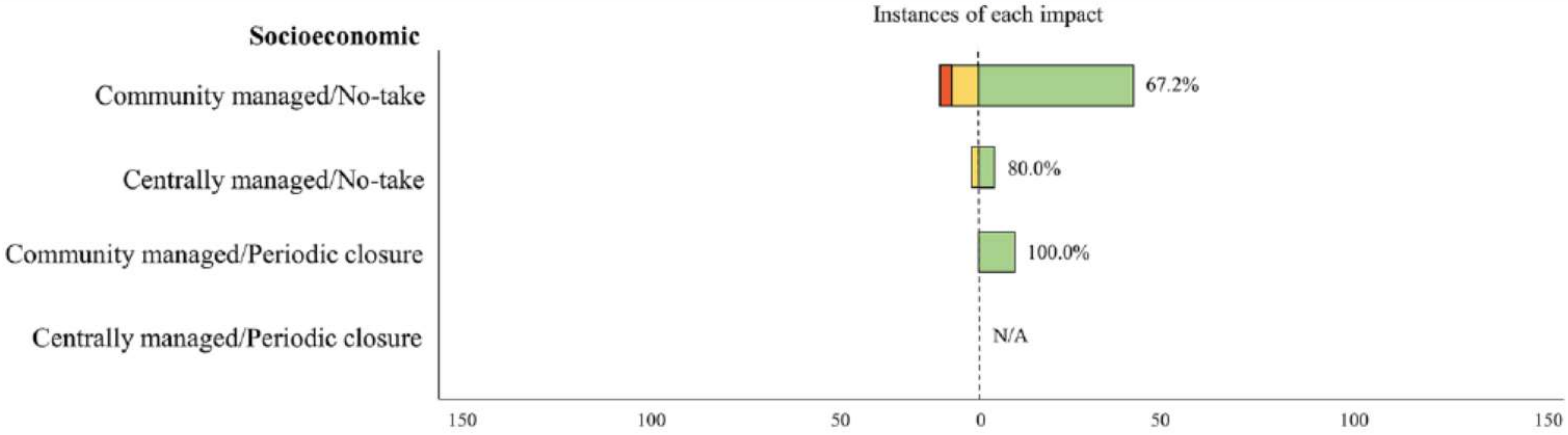
Short periodic closure recovery time (Jupiter et al. 2012; Goetz et al. 2015; Goetz et al. 2016)

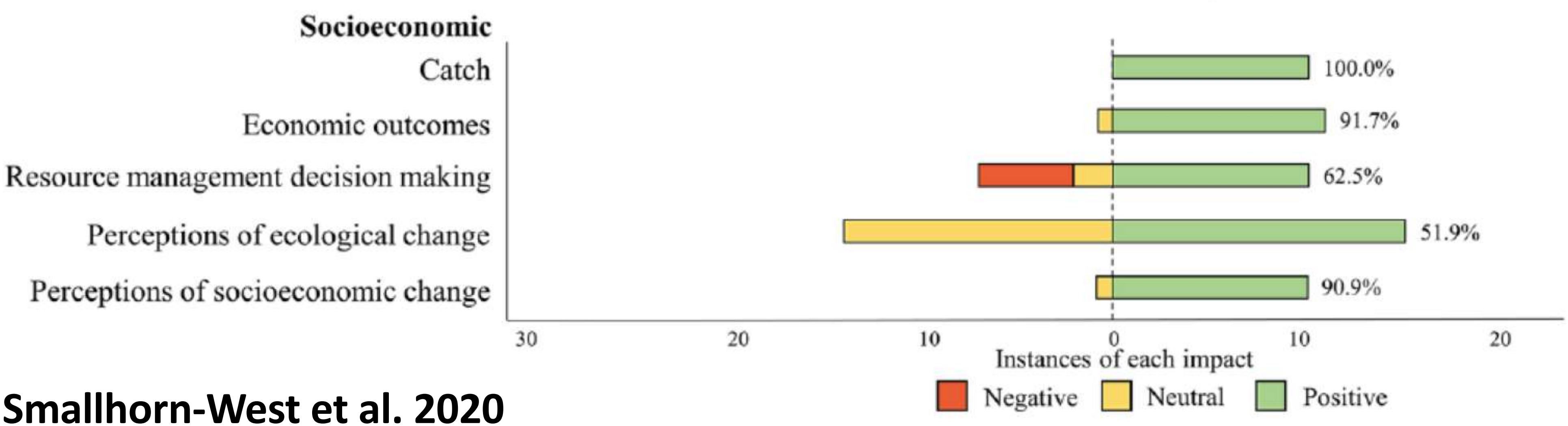
Impact on socio-economy

Type of Activity	Sub-type of Activities	Potential Positive Impacts on Users	Potential Negative Impacts on Users
Fisheries	Artisanal fisheries / small scale	Improved catch mix. Income and job increase, for professional and pleasure fisheries and for diving Exclusive access (less competence)	Closure of areas to fisheries If retention rates inside the MPA are high (dispersal ability is low comparing to MPA size) there might be no benefit for nearby fisheries
	Commercial fisheries / large scale	Improved catch mix Increased catch ("spillover effect" and also by the "recruitment effect") Income and job increase, for professional and pleasure fisheries and for diving Increased biomass (reserve effect) Increased fish size (reserve effect)	Closure of areas to fisheries If retention rates inside the MPA are high (dispersal ability is low comparing to MPA size) there might be no benefit for nearby fisheries
	Recreational fisheries	Income and job increase, for professional and pleasure fisheries and for diving	Closure of areas to visitors If retention rates inside the MPA are high (dispersal ability is low comparing to MPA size) there might be no benefit for nearby fisheries

Navigation and Communications	Commercial shipping	NA	Effect on shipping lanes Increase transport time by reducing speed limits
	Ports & harbour service area	NA	Negative effects of anchoring on seabed (e.g. seagrass)
	Communication cables	NA	Limitation of allocation
Mineral, Water and Energy Resources	Offshore oil/gas platforms, resources extraction, pipelines and cables	NA	Limitation of extraction and allocation
	Offshore wind-farms	NA	Limitation of allocation
	Sailing	Increase sailing visitation; increase in tourism demand	Damage to ecosystem from tourist congestion (e.g. anchoring)
	Marine cruising	Increase in marine cruises relating to cetaceans or seabirds sightseeing	Negative effects of anchoring on seabed (e.g. Seagrass)
	Diving, snorkelling, nautical activities	Increase in divers' visitation. Income and job increase, for professional and pleasure fisheries and for diving	Damage to ecosystem from tourist congestion Negative non-consumptive divers impacts on the natural environment Closure of areas
	Cetacean and seabird watching	Increase in demand	Negative effects on cetaceans
Management	MPA management	Economic benefits to scientists and biologists (budget for their research, projects, etc.)	Economic cost for public finances of administration, supervision, monitoring, scientific information policies, prohibitions with financial compensation

Effects on socio-economy

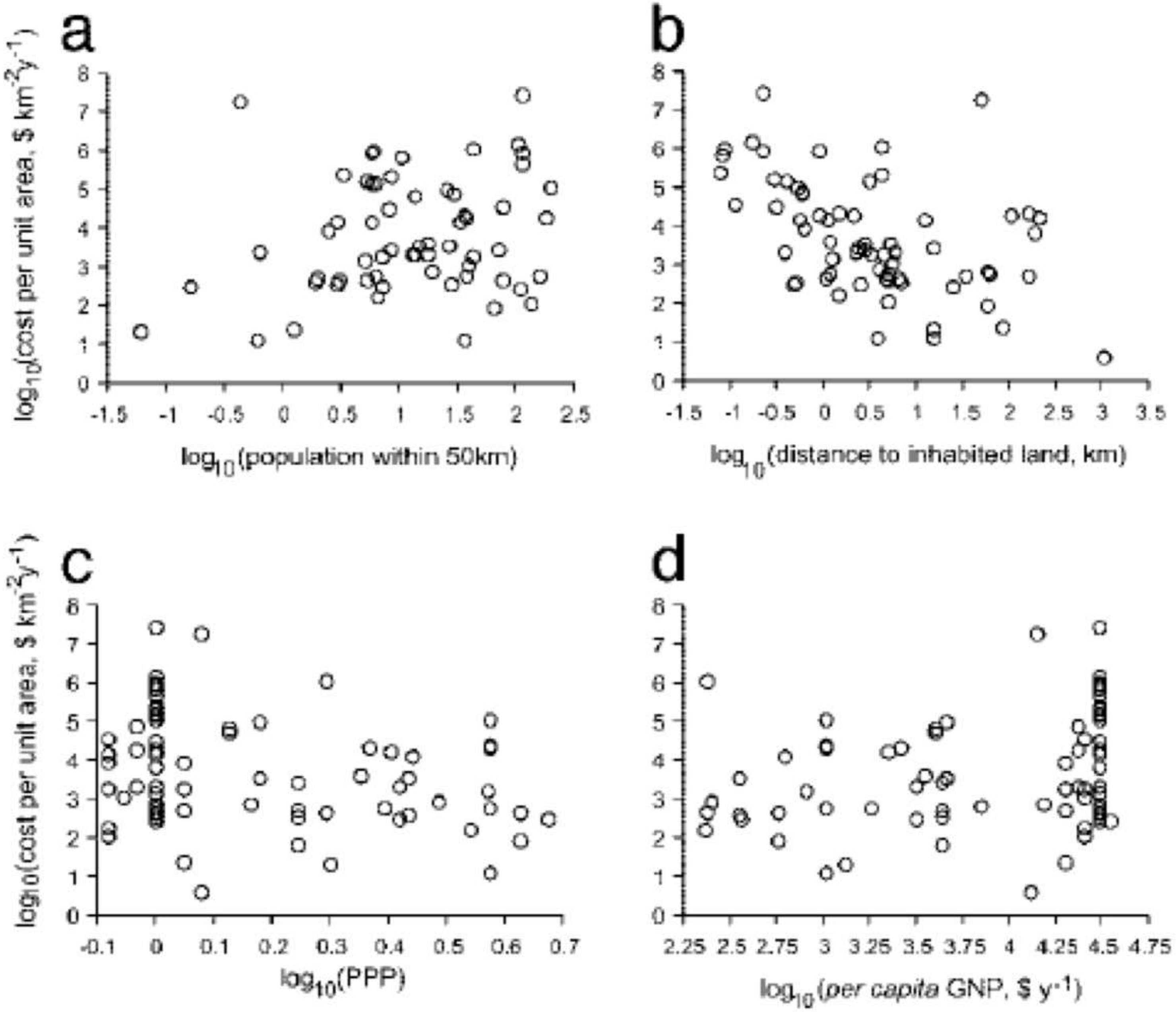




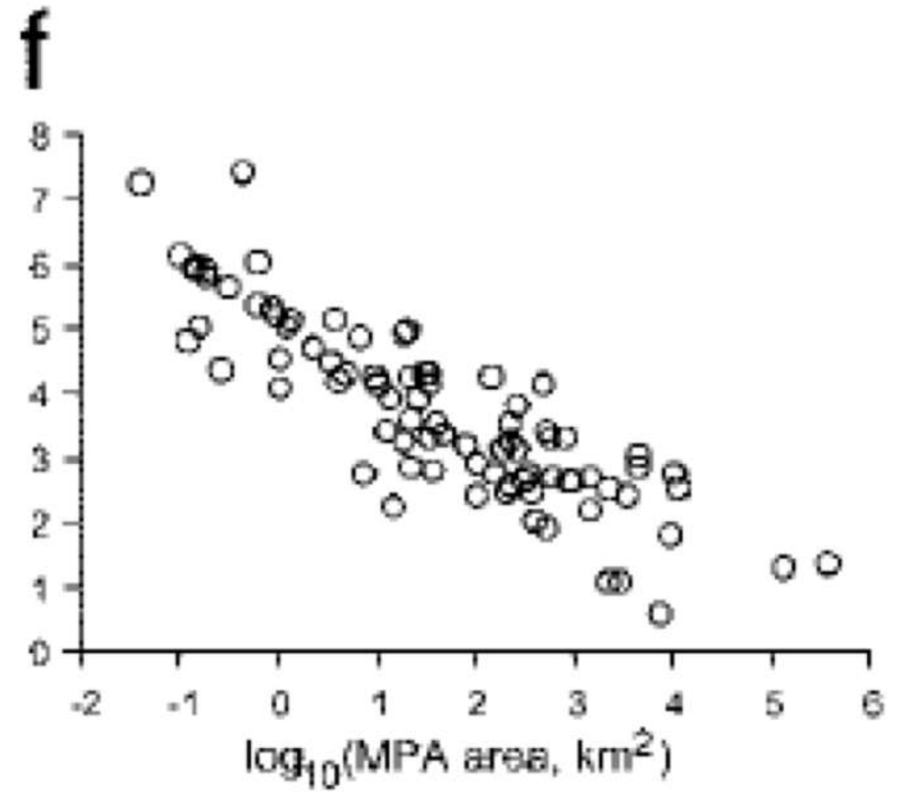
Smallhorn-West et al. 2020

How much does conservation cost?

Balmford et al. 2004



How much does conservation cost?

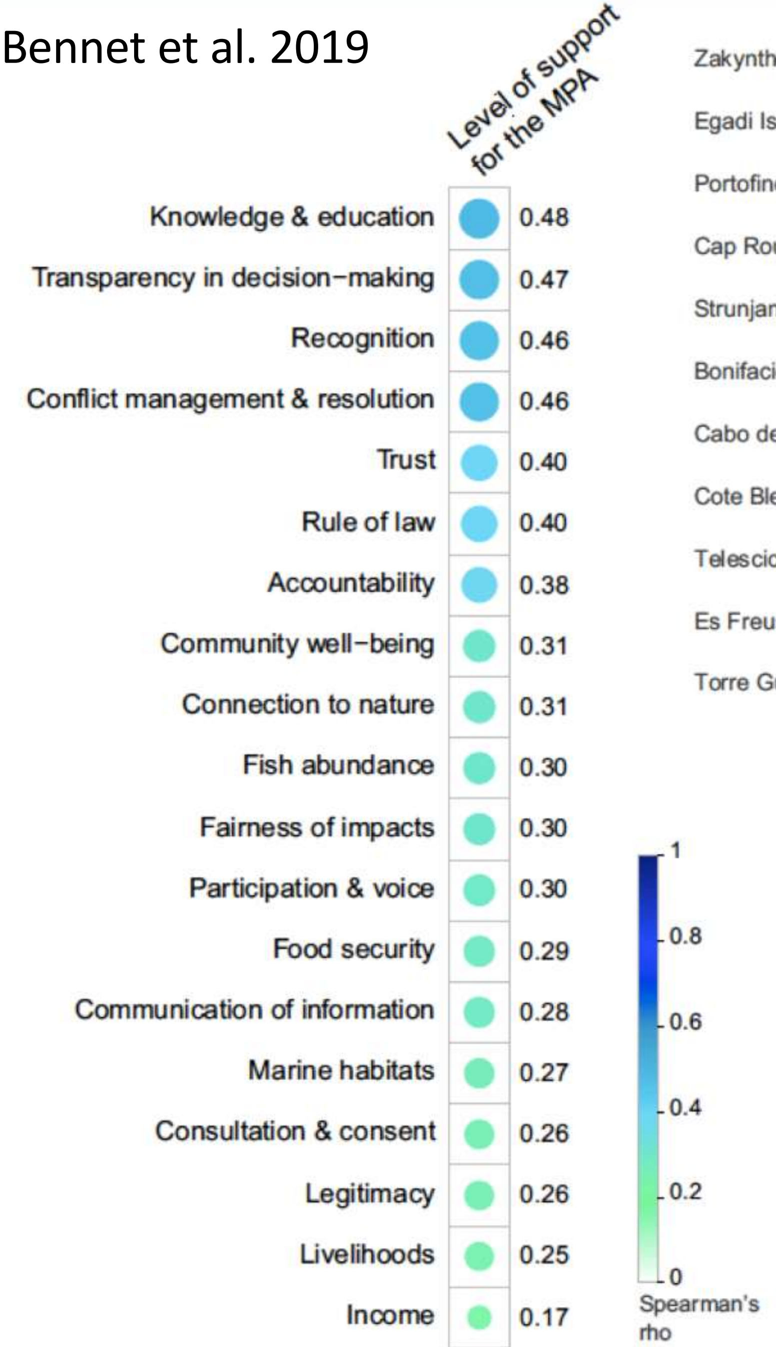


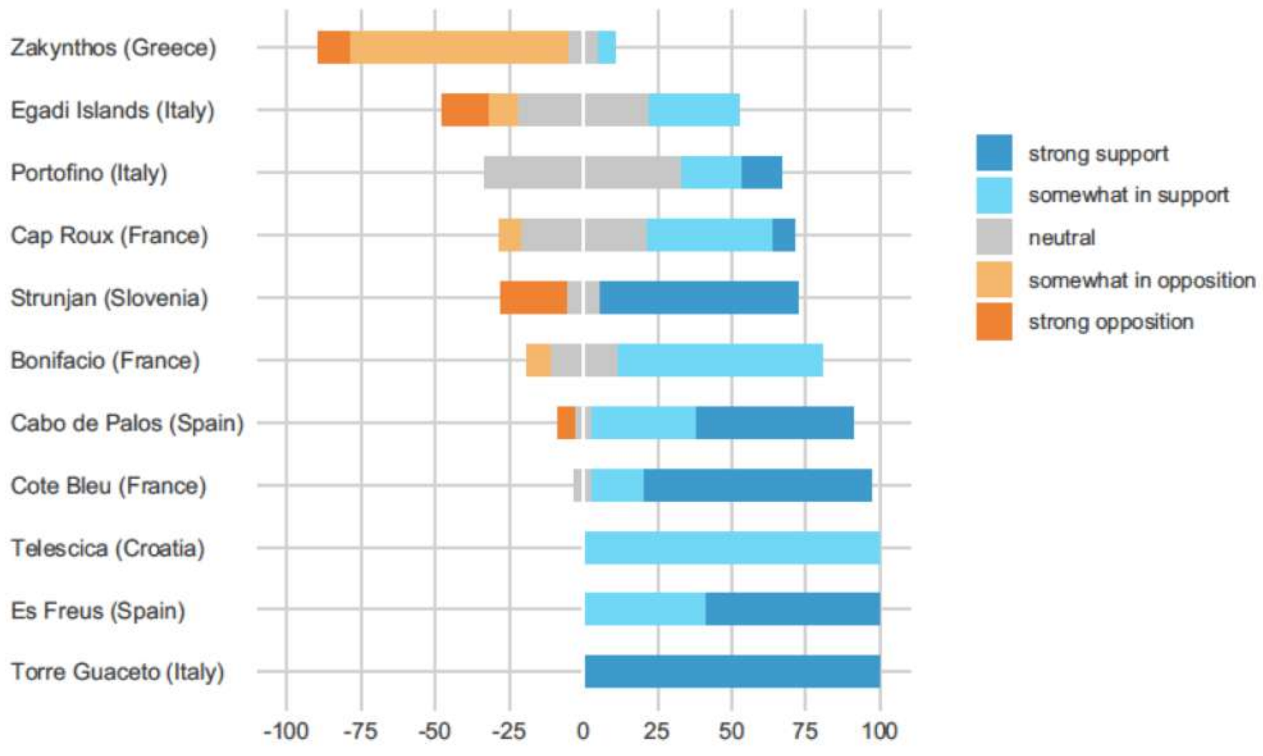
Balmford et al. 2004

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





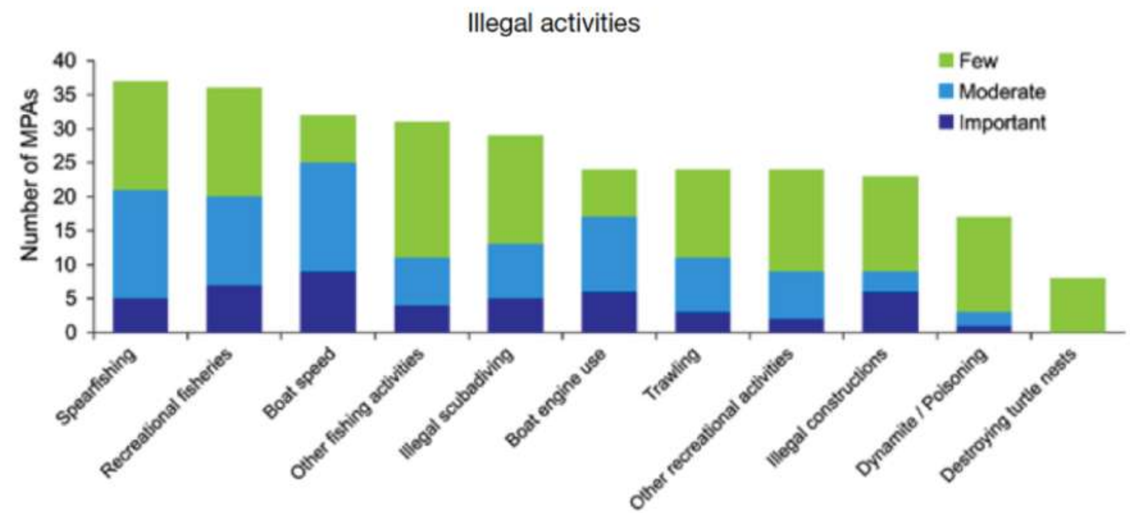
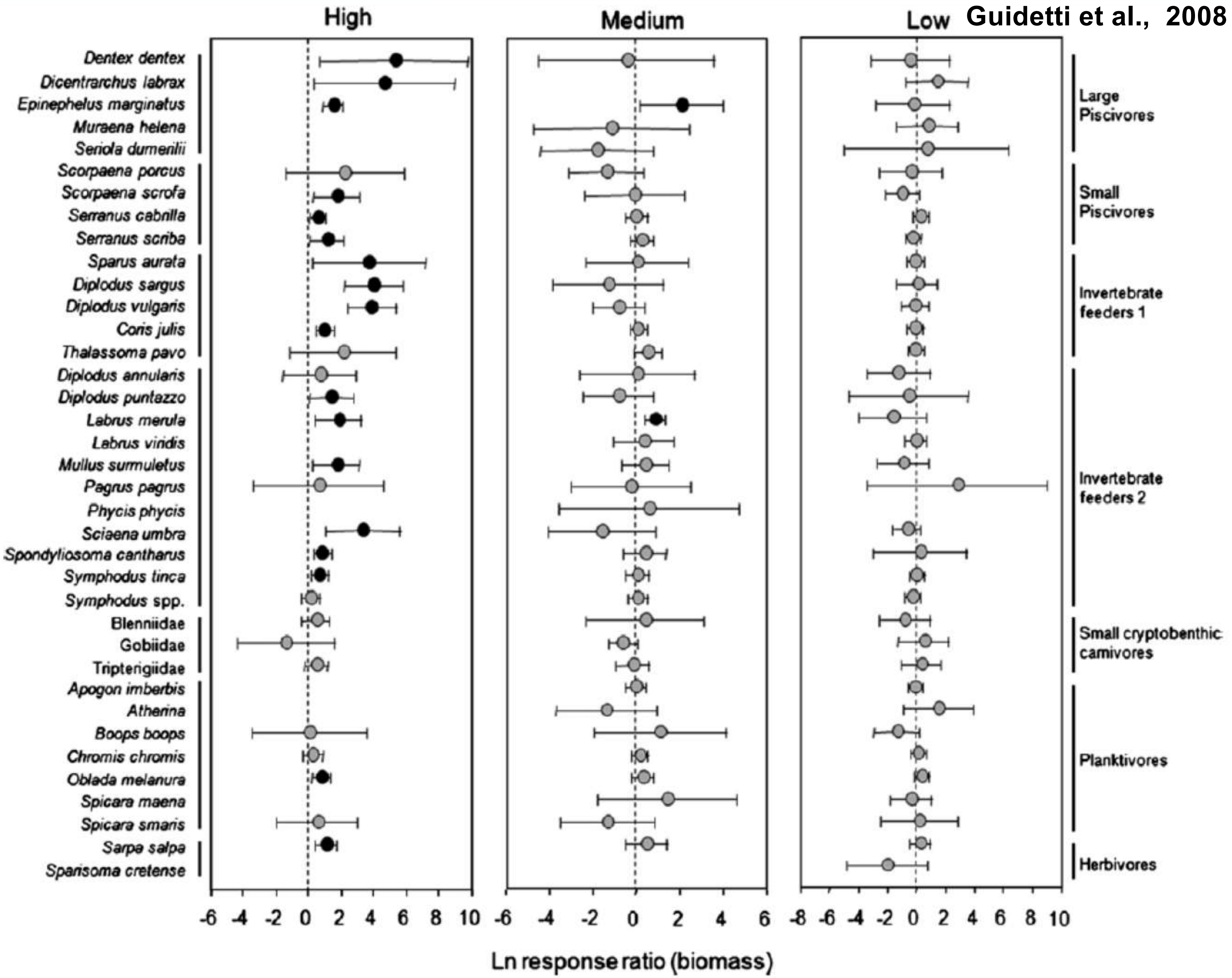


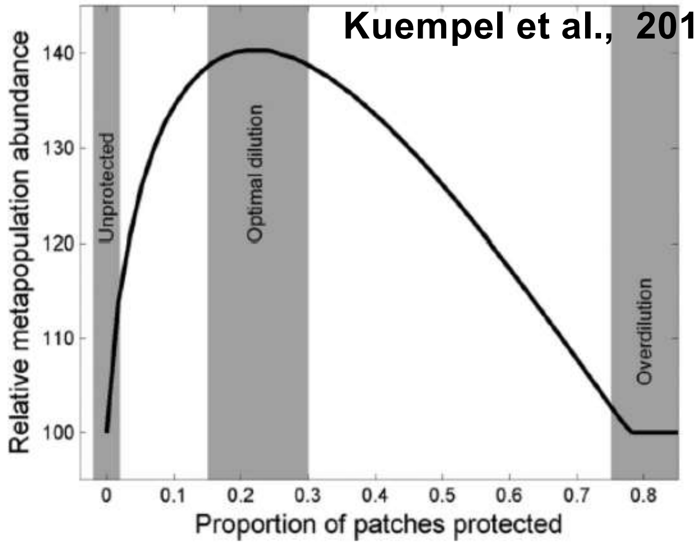
Figure 12. Illegal activities reported to occur in Mediterranean MPAs (n = 45).

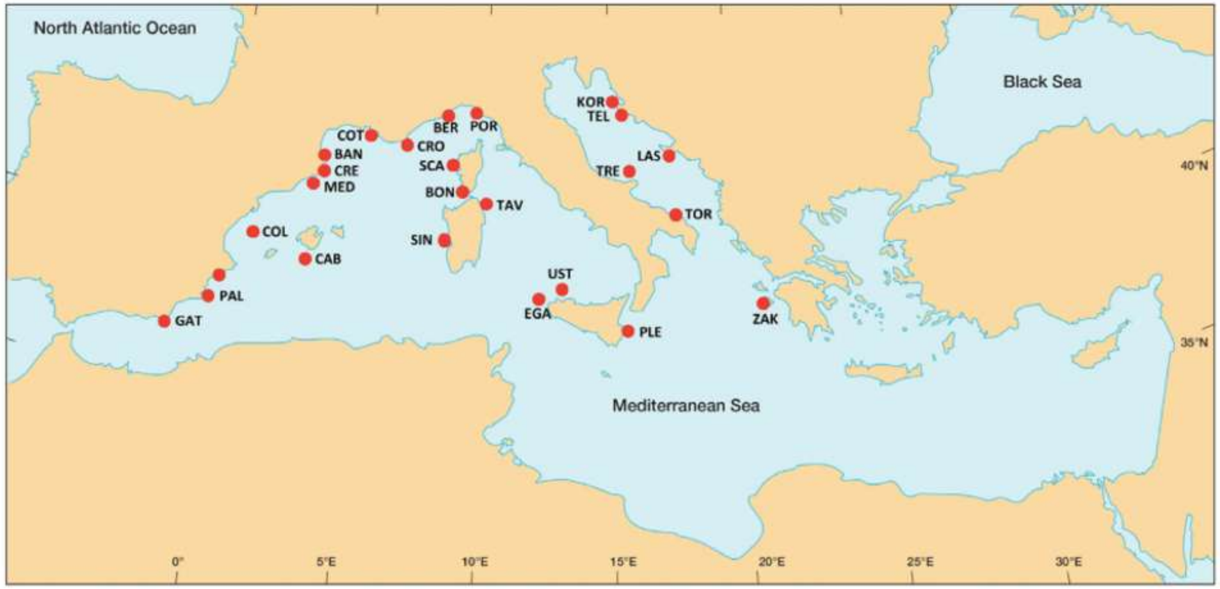
The role of enforcement



Key factors in MPA effectiveness

Kuempel et al., 2017





Di Franco et al., 2016