GLOBAL CHANGE ECOLOGY AND SUSTAINABILITY
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Conservation and Management of Marine Ecosystems

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The role of disturbance in marine community dynamics

Definition(s)

Disturbance is…

Any discrete event able to determine killing / removal from the substratum of one or more individuals, with the consequence of providing direct or indirect opportunities to new individuals for settlement or development **Sousa 1984**

Before the event

(e.g., storm)

After the event

Disturbance

It refers to the damage itself, that is, the effect (impact) of some external agent or force.

Sousa 2001

Definition(s)

Disturbance is…

Any discrete event able to change the structure of ecosystems, communities, or populations, limiting resources, modifying the substrate or the environment.

Pickett & White 1985

Before the event

After the event

(e.g., storm)

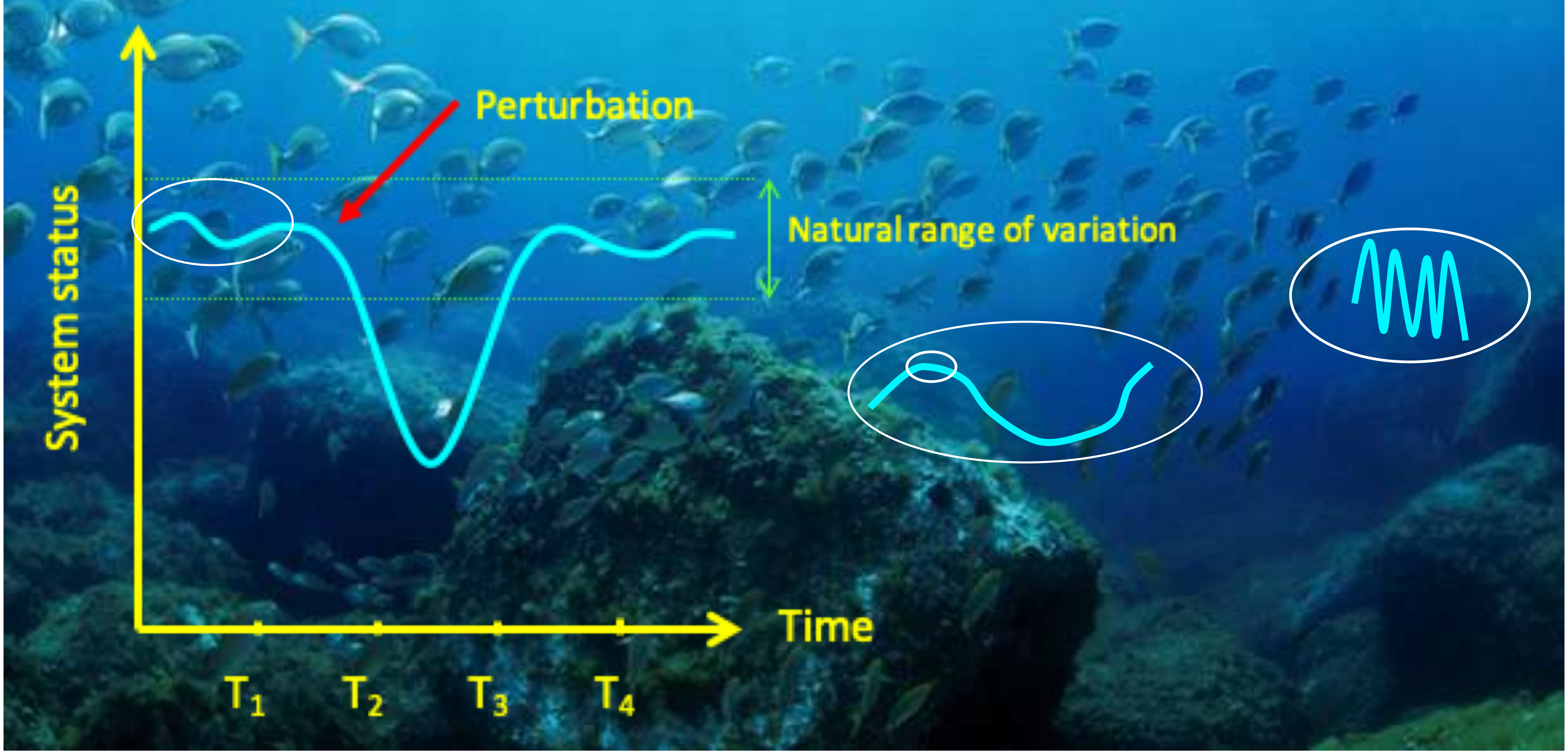
Disturbance

Disturbance is seen as a physical external force able to modify the system, for example removing organisms and opening patches. It refers to the physical agent that determine the biological consequences.

Impacts or perturbations

We intend **disturbance** as **any event**, which is **caused by** or originates from a physical, chemical or biological **agent**, able to produce directly or indirectly changes to the system or its components.

A perturbation (impact) is any interference with processes and structure characterizing a given system, or any event that change the state beyond its natural variation.



The nature of disturbance

Physical

Physical disturbance refers to physical agents. For instance, hydrodynamic forces from intense wave action.

Chemical

Disturbance is caused by chemical agents or alteration in chemistry of the environment. For instance, pollution

Biological

Biological disturbance is caused by organisms. For instance, the whiplash of large algae.

Others?

In a wider sense, even predation could be considered as a disturbance, since it is able to remove large number of individuals and opens free space available for other organisms. However, it is internal to the system and someone tends to exclude it from disturbance array. But take in mind that predation can be altered by external forces, and abnormal rates of predation may lead to consequences not so different from strong physical external disturbance

Types of disturbance

Abrasion, burial

Injuries, suffocation, death

Burning, burial

direct killing, death

Substrate modifications, physical action

Killing, displacement

Oxigen depletion, osmotic and metabolic stress

Killing, death

Abrasion

Killing, Injuries, death

Abrasion, burial

Killing, Injuries

Types of disturbance

Burial, displacement
Injuries, suffocation, death

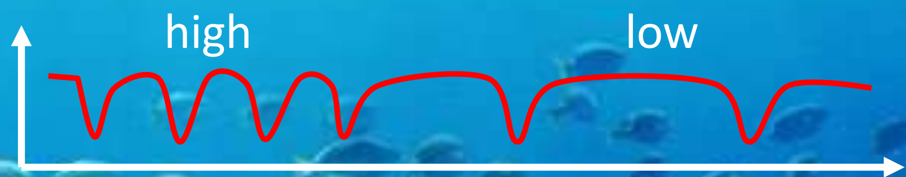
Abrasion, injuries
Killing, death

Shading, burial
Suffocation

Characteristics of disturbance

Intensity:
the strength of disturbance

Frequency:
the reoccurence of disturbance



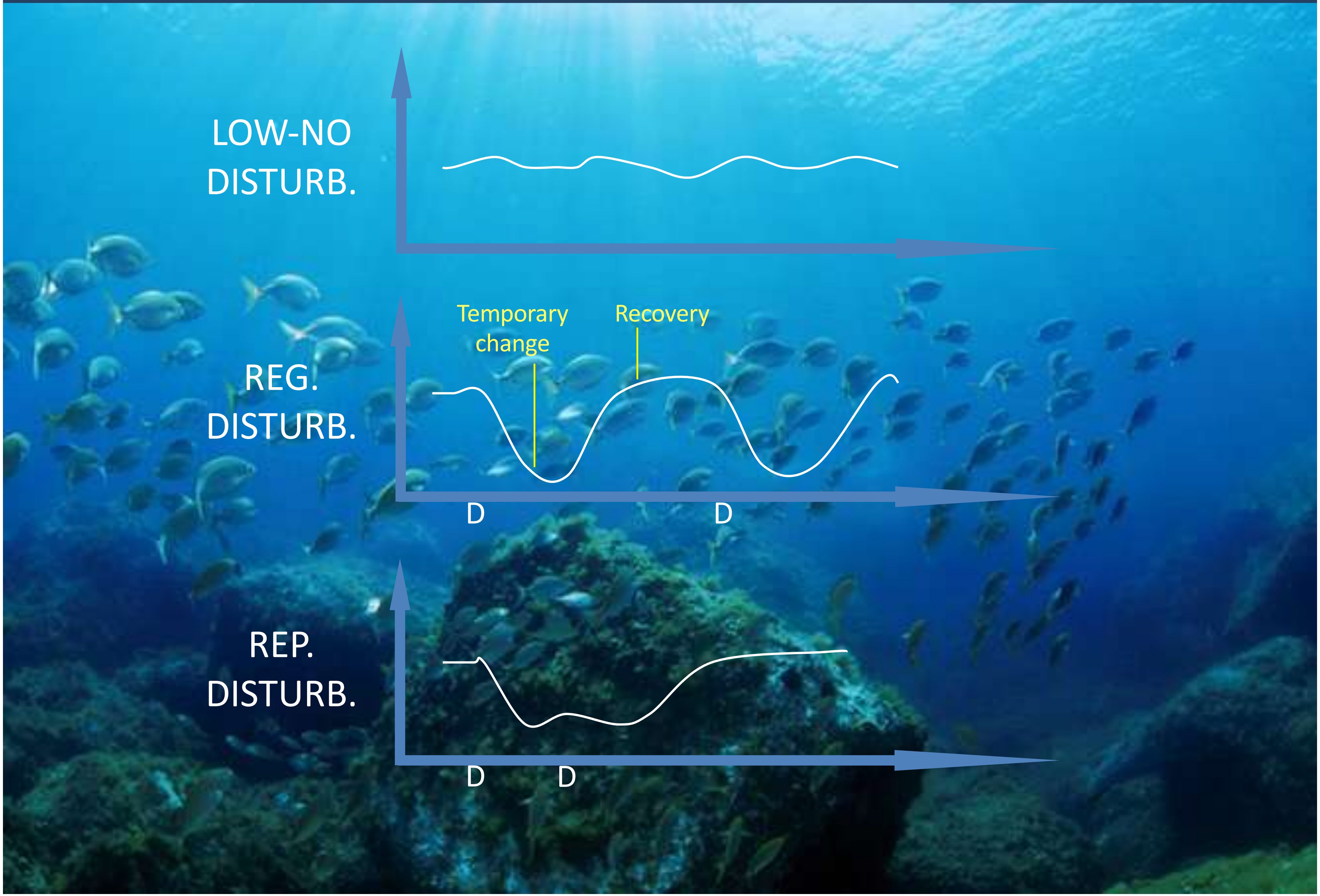
The importance of scale

Spatial variability:
Variations in the extent of areas affected and distribution of disturbance

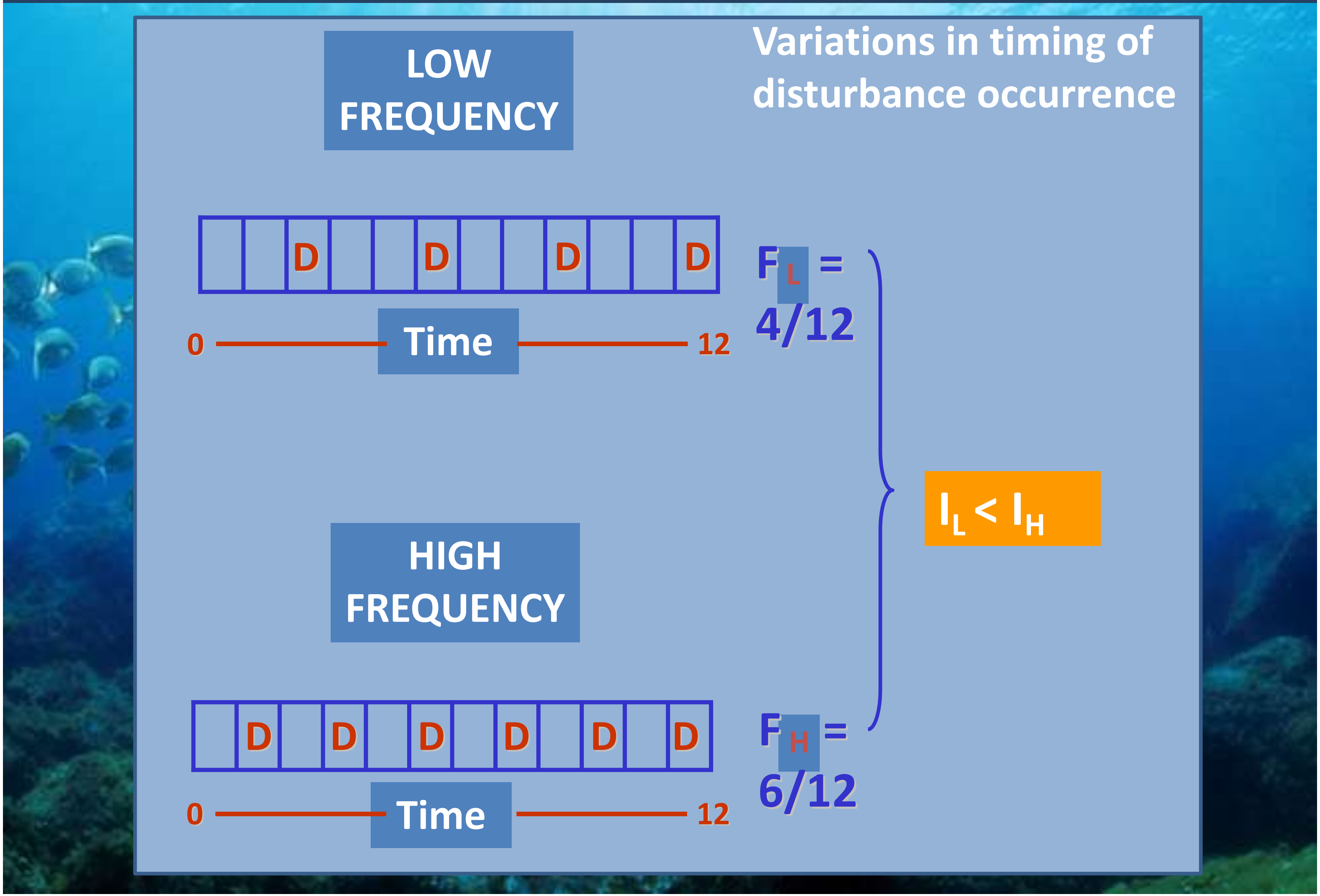
Ecological traits of organisms are important for the impact of disturbance and recovery potential

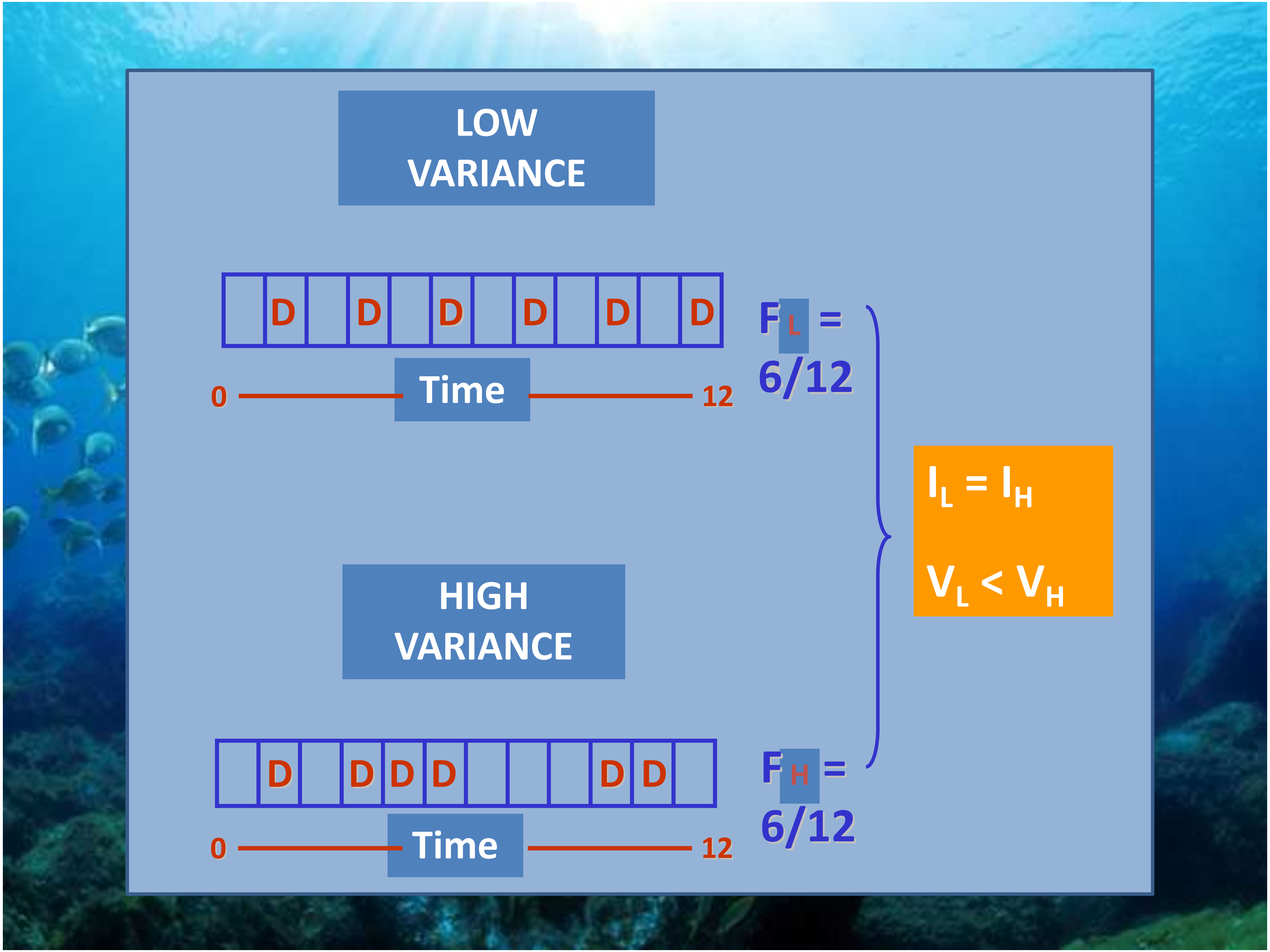
Regularity of disturbance – adaptation

Expected effects under different scenarios

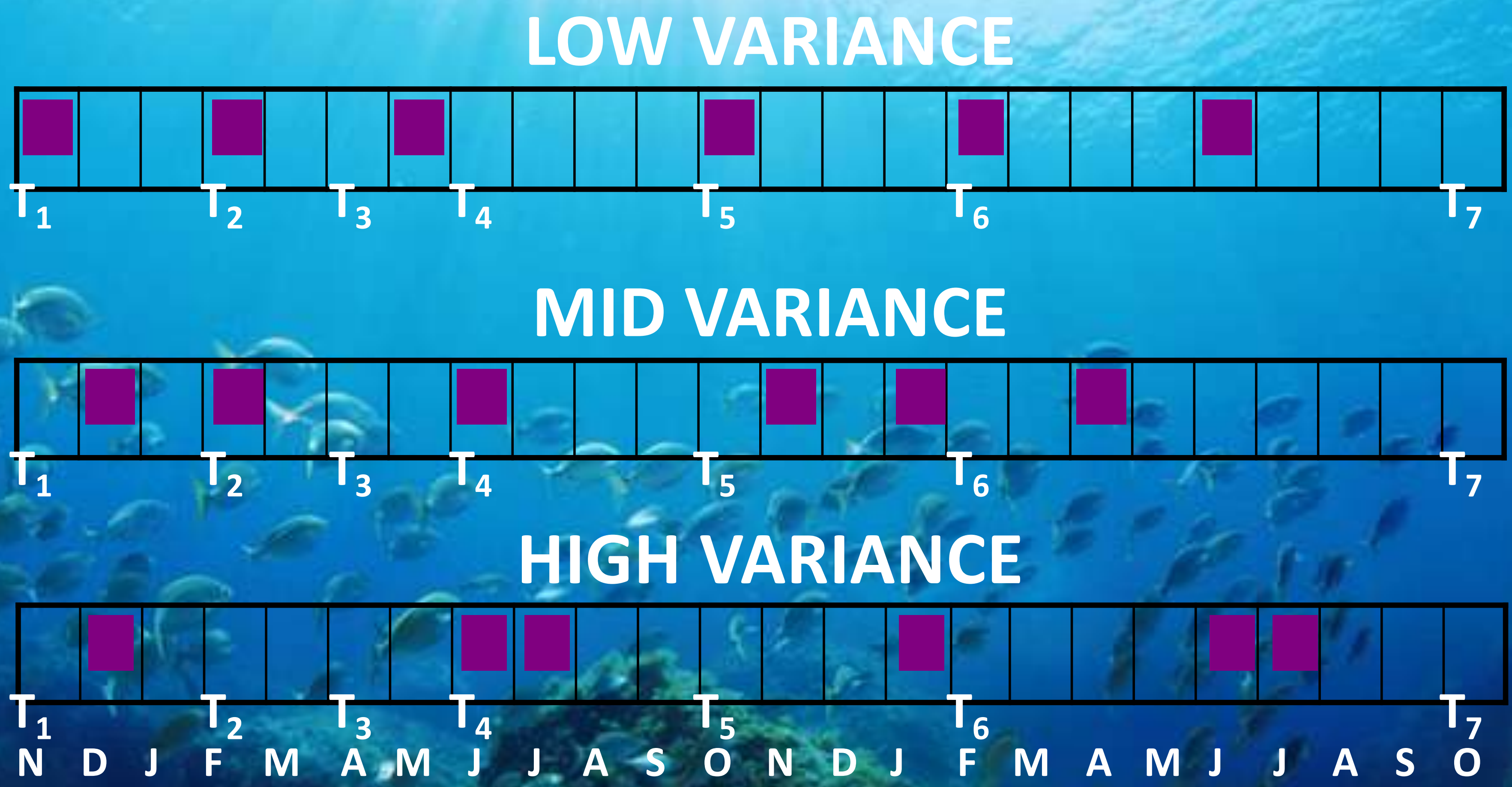


Temporal variability




LOW VARIANCE
D D D D D D
0 Time 12
F_L = 6/12
HIGH VARIANCE
D D D D D D
0 Time 12
F_H = 6/12
$I_L = I_H$
$V_L < V_H$

Effects of temporal variance...

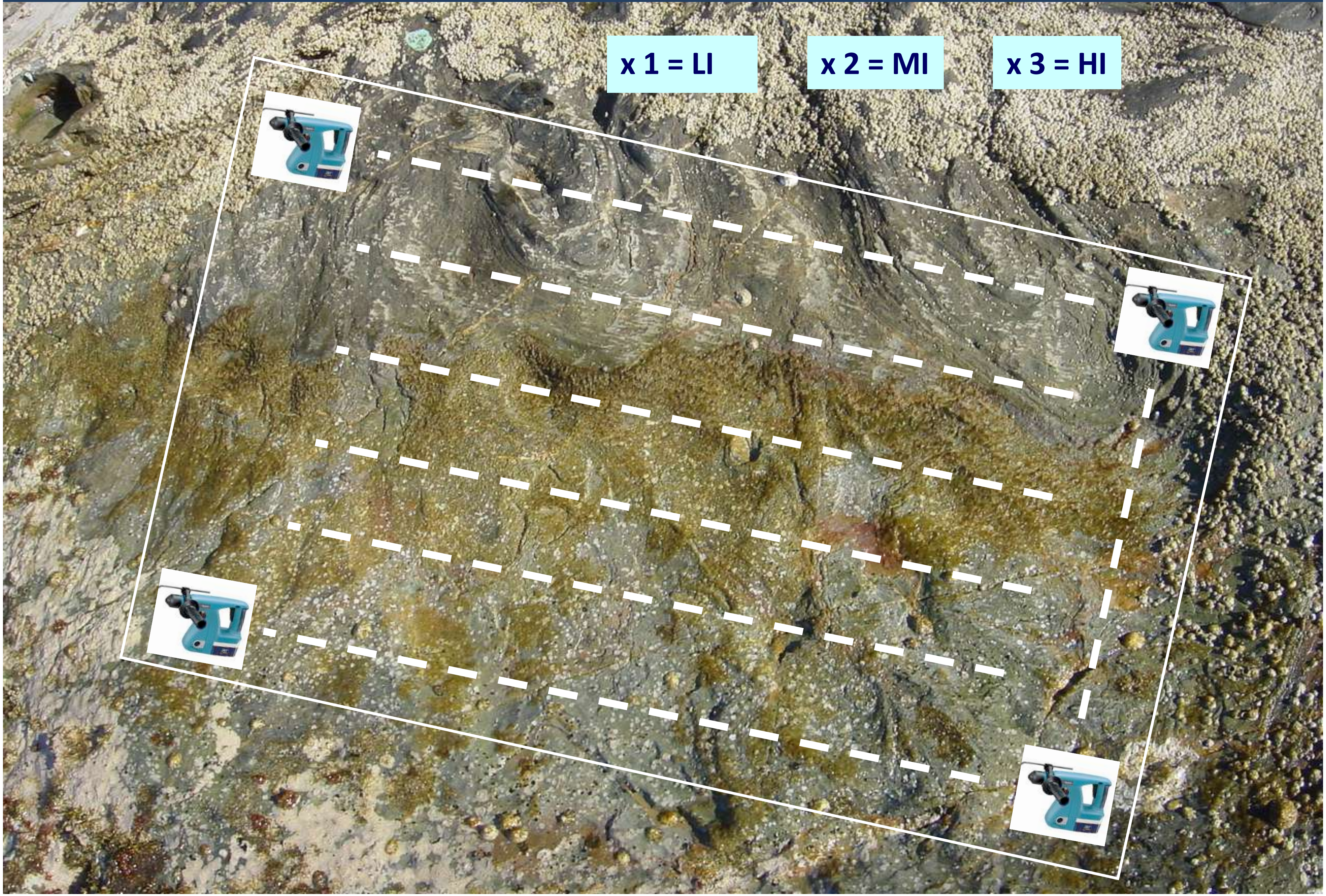


= DISTURBANCE (6 / 24 m)

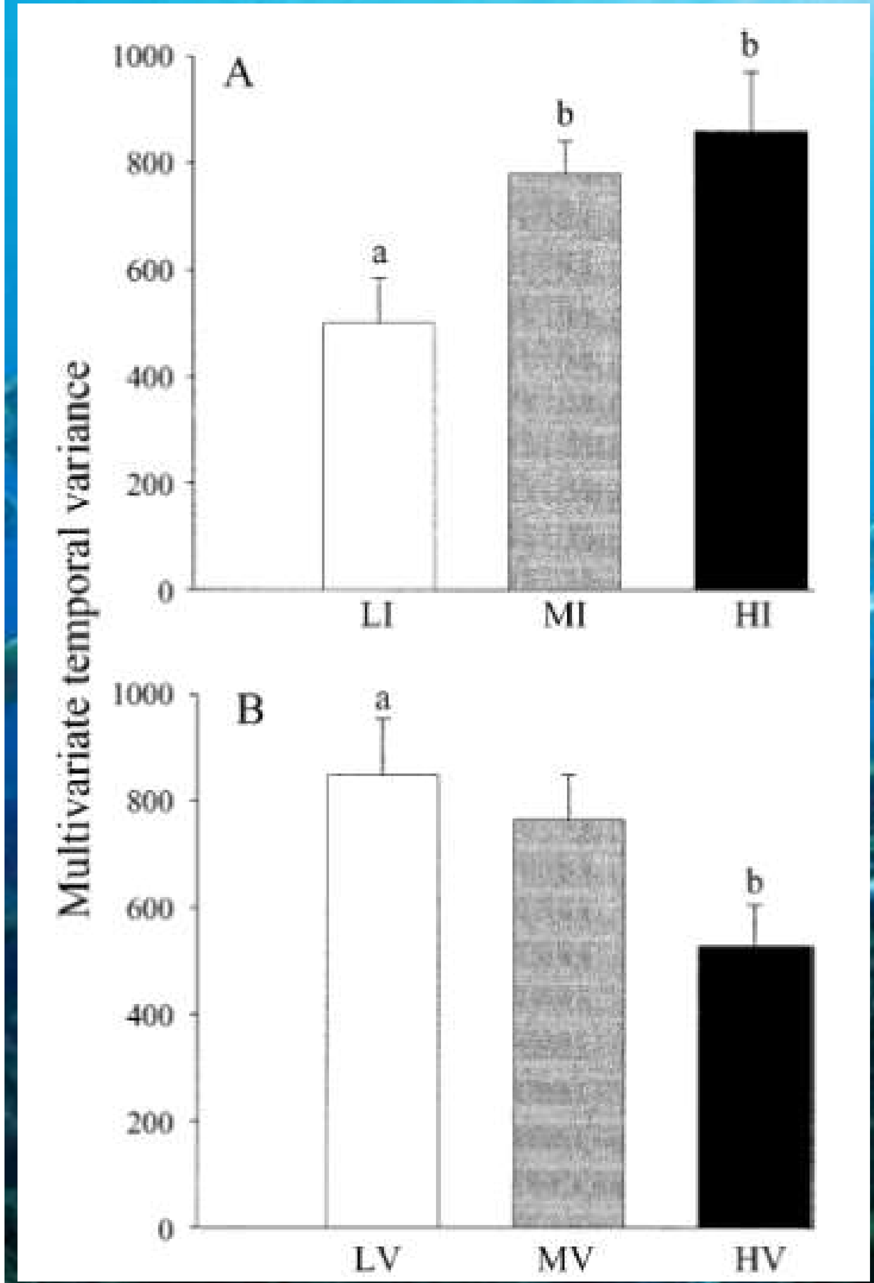
T_1-T_7 = Sampling dates (!)

Bertocci et al. 2006

...and intensity



Results

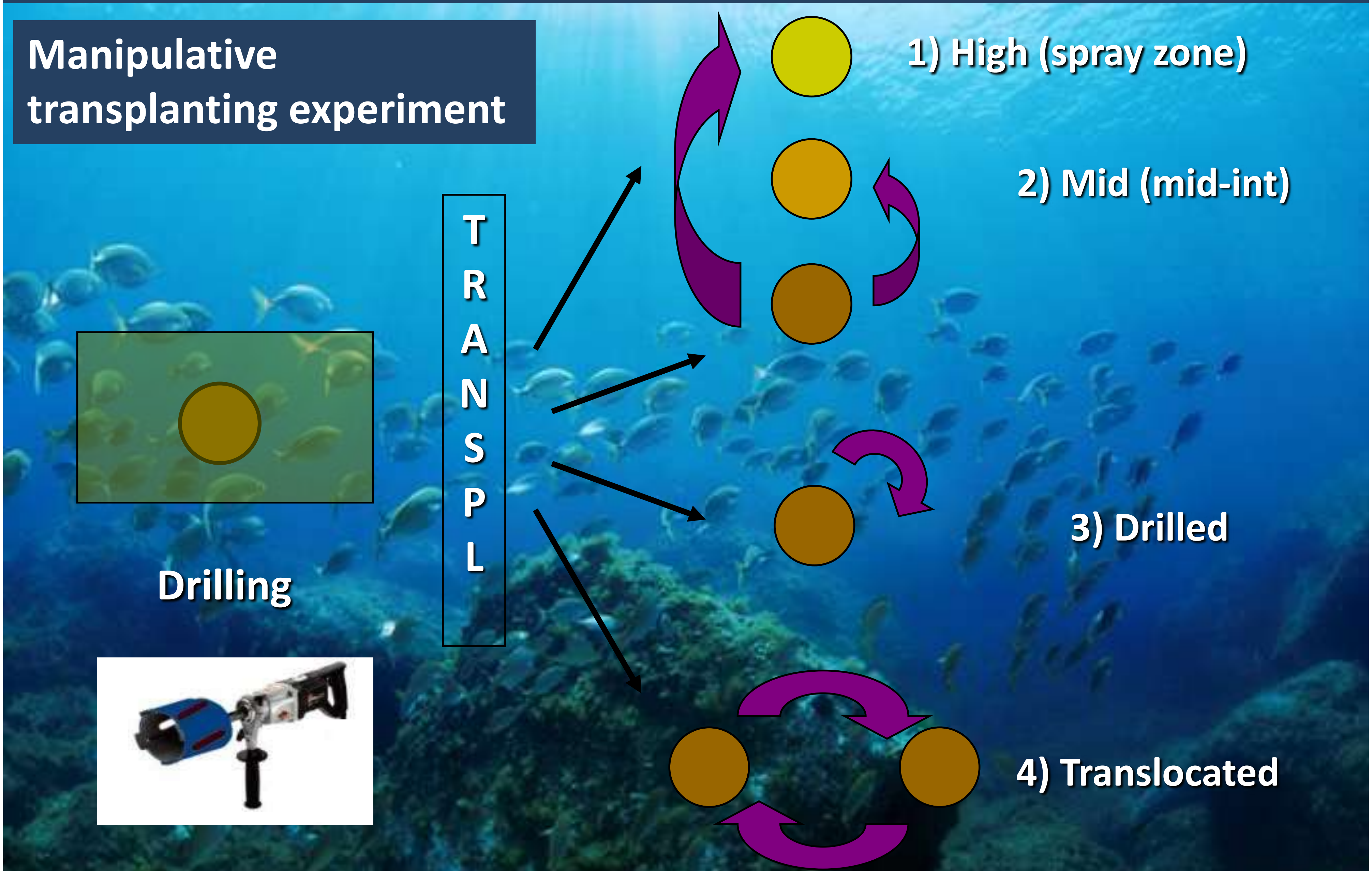


Changes in temporal variability

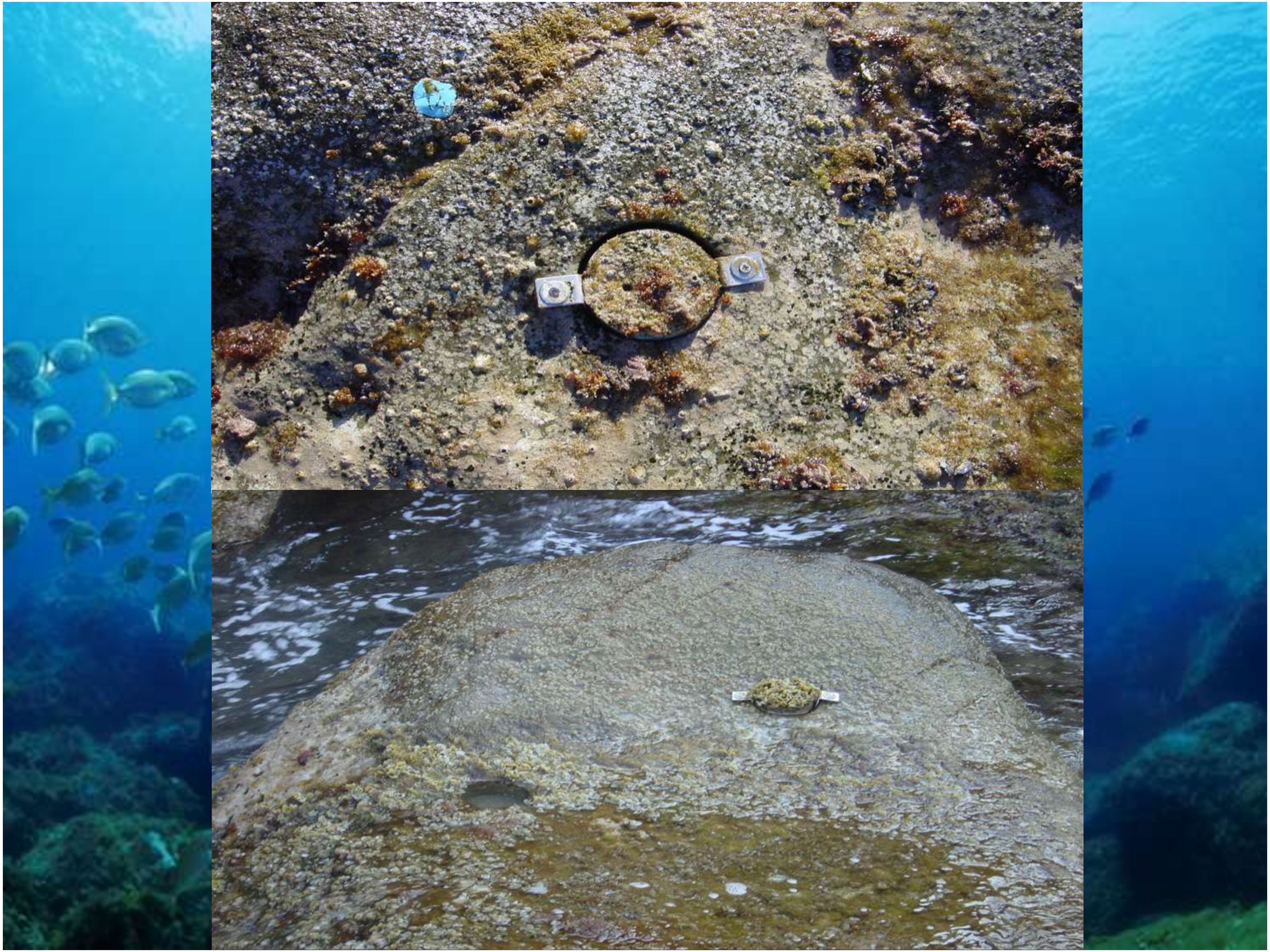
a) increasing intensity lead to increasing temporal variability in assemblage structure
b) Increasing variance in disturbance lead to decreasing temporal variability

Recovery dynamics are affected differently by intensity and variance

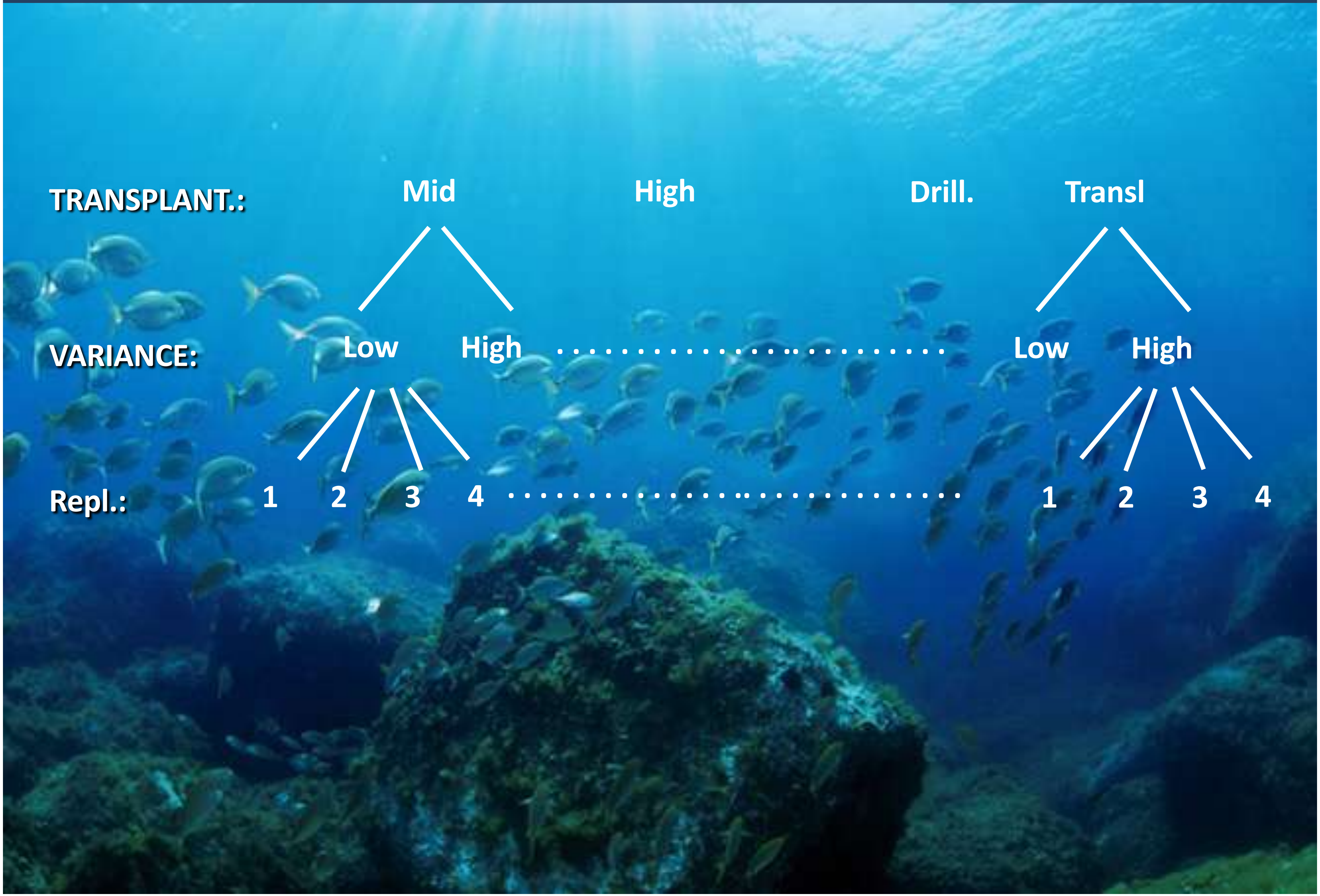
Effects of temporal variance and intensity



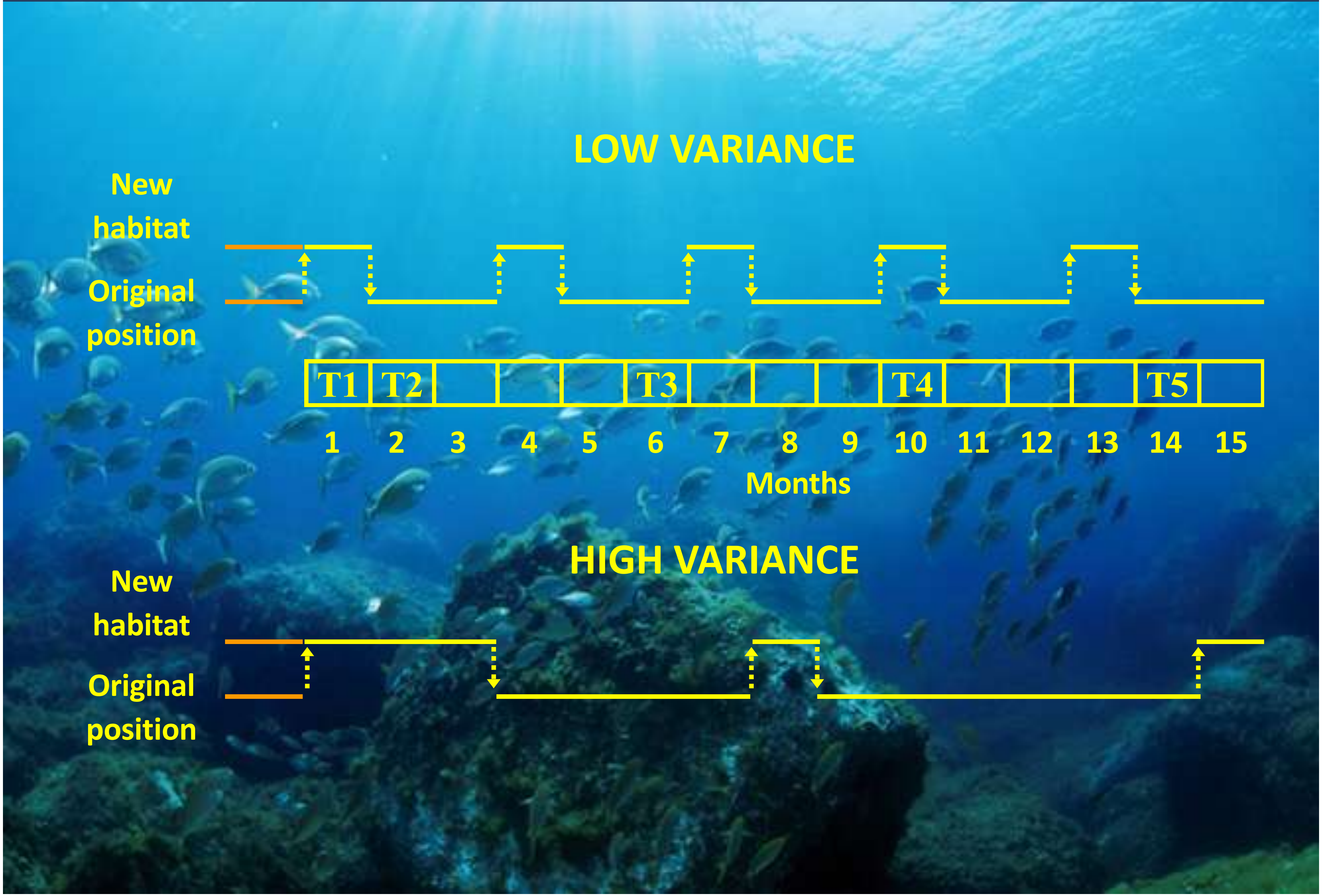
Benedetti-Cecchi et al. 2006



Experimental design



Timing of manipulation



Results

+ Aerial exposure
- Temp. variance
(+ variance)

+ barnacles + ECR
(drastically decrease)

Filamentous algae
C. branched algae

- Aerial exposure
- Temp. variance
(+ variance)

Reduced effects

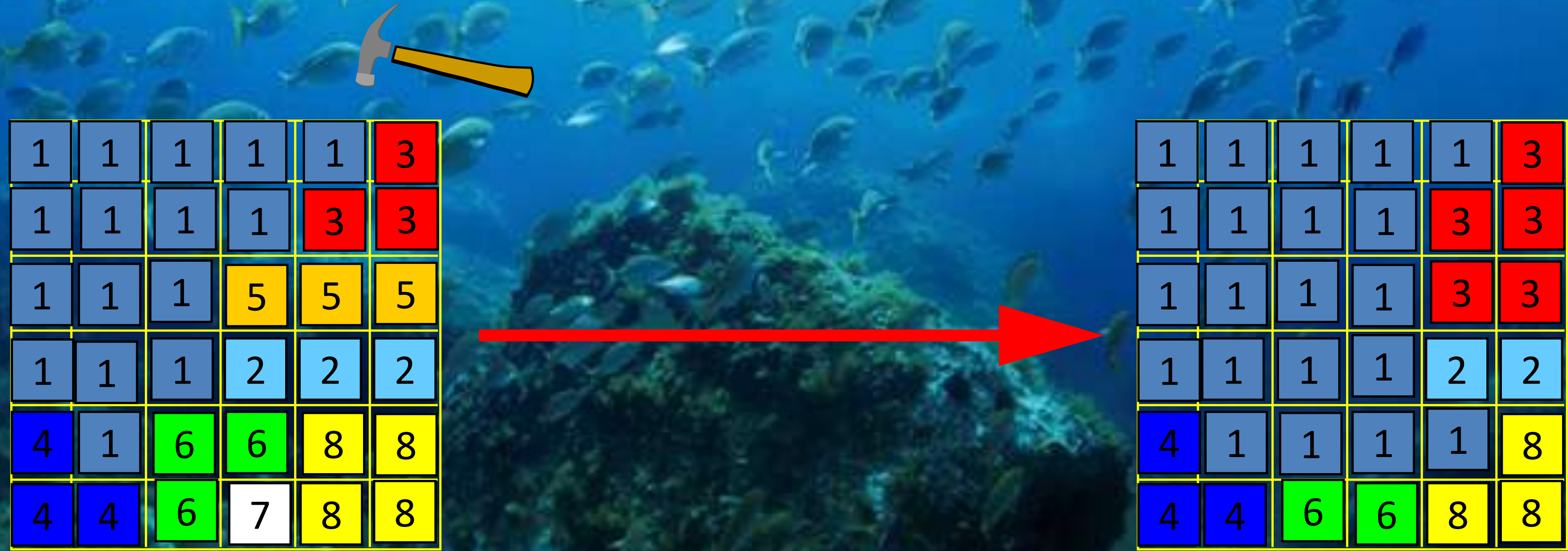
Enhanced by high variance
Irrespective of intensity, whereas regular disturbance decrease cover

Temporal variance may drastically change the effect of disturbance intensity

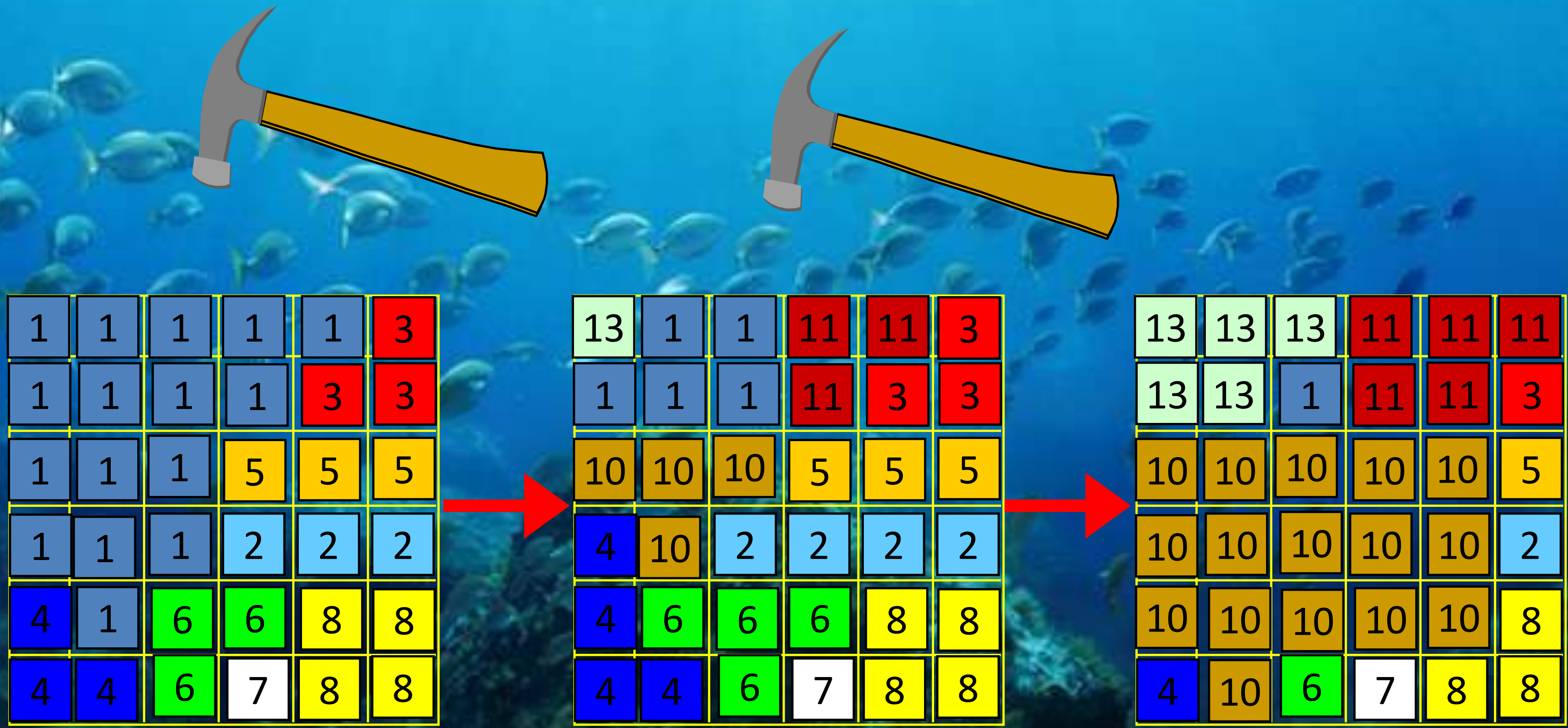
IDH

The intermediate disturbance hypothesis was formulated by S.J. Connell (1978) to explain the high diversity of rain forests and coral reefs.

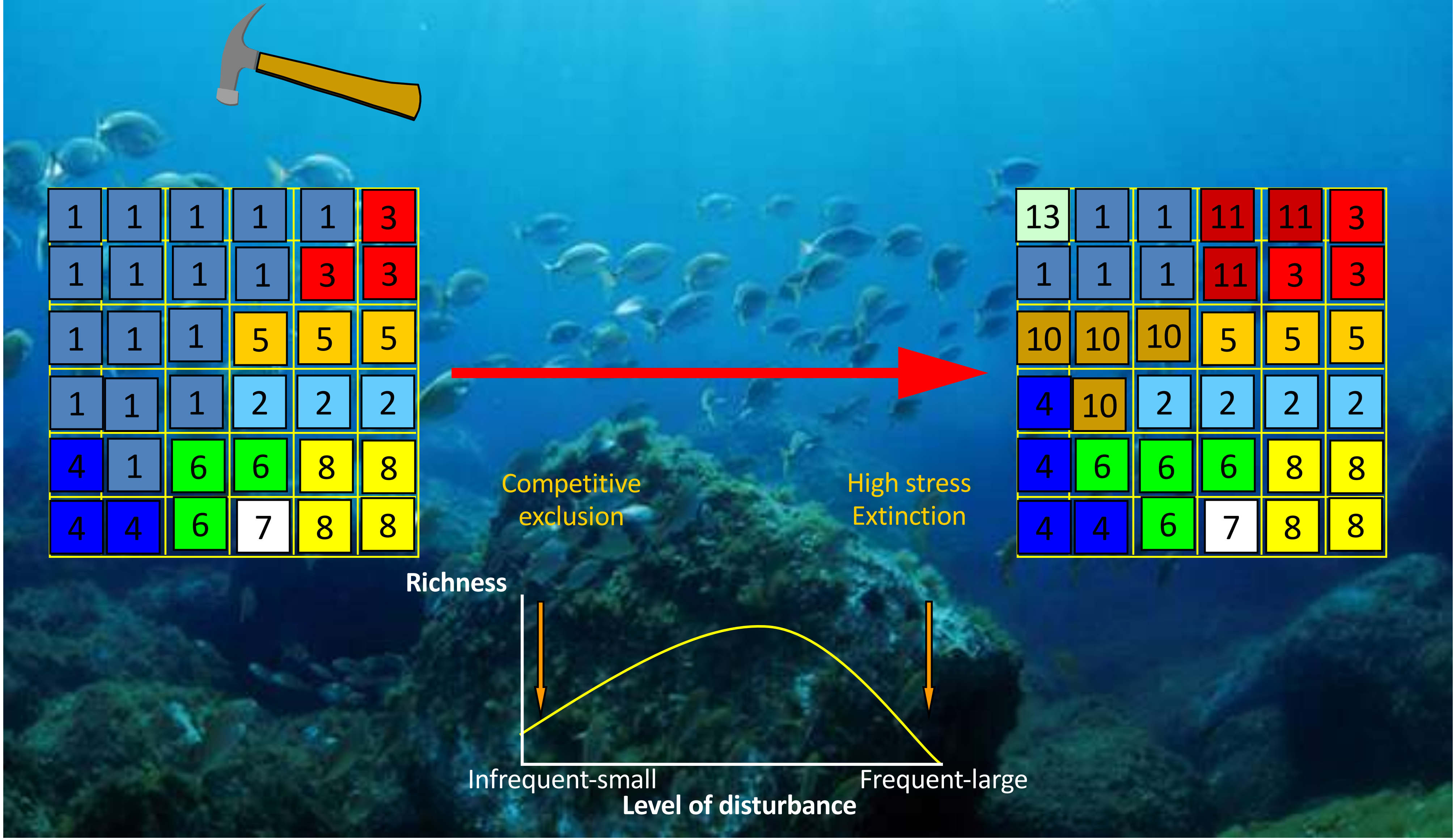
1 – when disturbance is rare (low frequency) and weak (low intensity), strong competitors win. Species richness is therefore reduced. (the assumption is that a hierarchy of competitors exists, and strong competitors occupy the space efficiently).



2 – when disturbance is very intense and frequent, strong competitors are reduced or excluded, and new settlers among weak competitors colonize the space. Species richenss is again reduced because some species lack, and only few species tolerate high level of disturbance

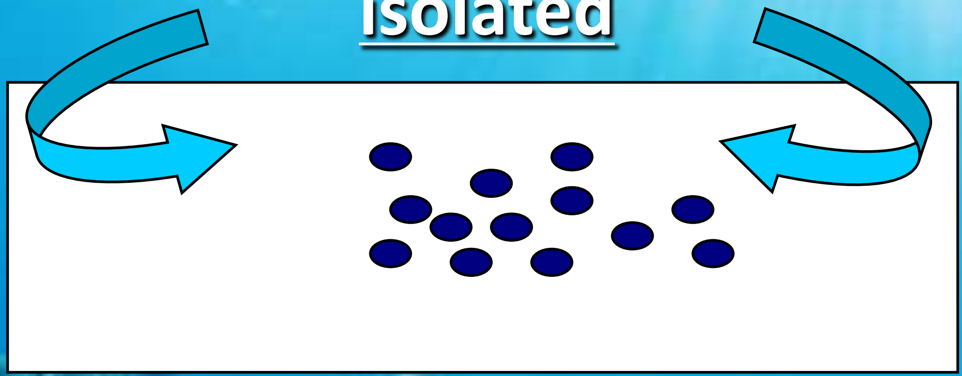


3 – finally, when disturbance regime has intermediate strength and frequency, strong and weak competitors coexist, since disturbance is not so high to cause the local extinction of the former, but sufficient to create patches available for the latter.

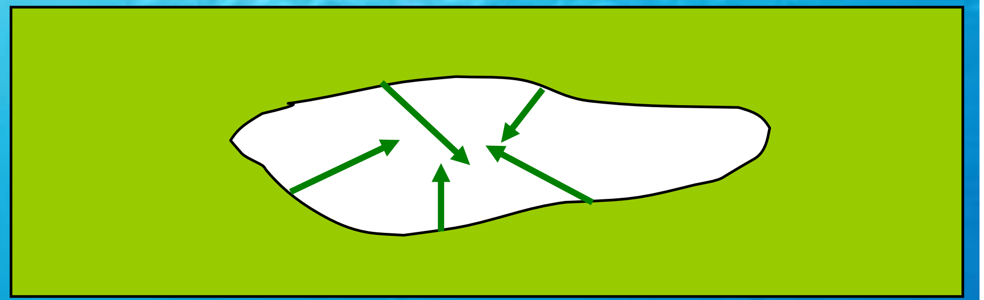


Patch dynamics

isolated



non-isolated



Recolonization: Arrival of drifting propagules from the water column

Recolonization: Vegetative growth from neighbours

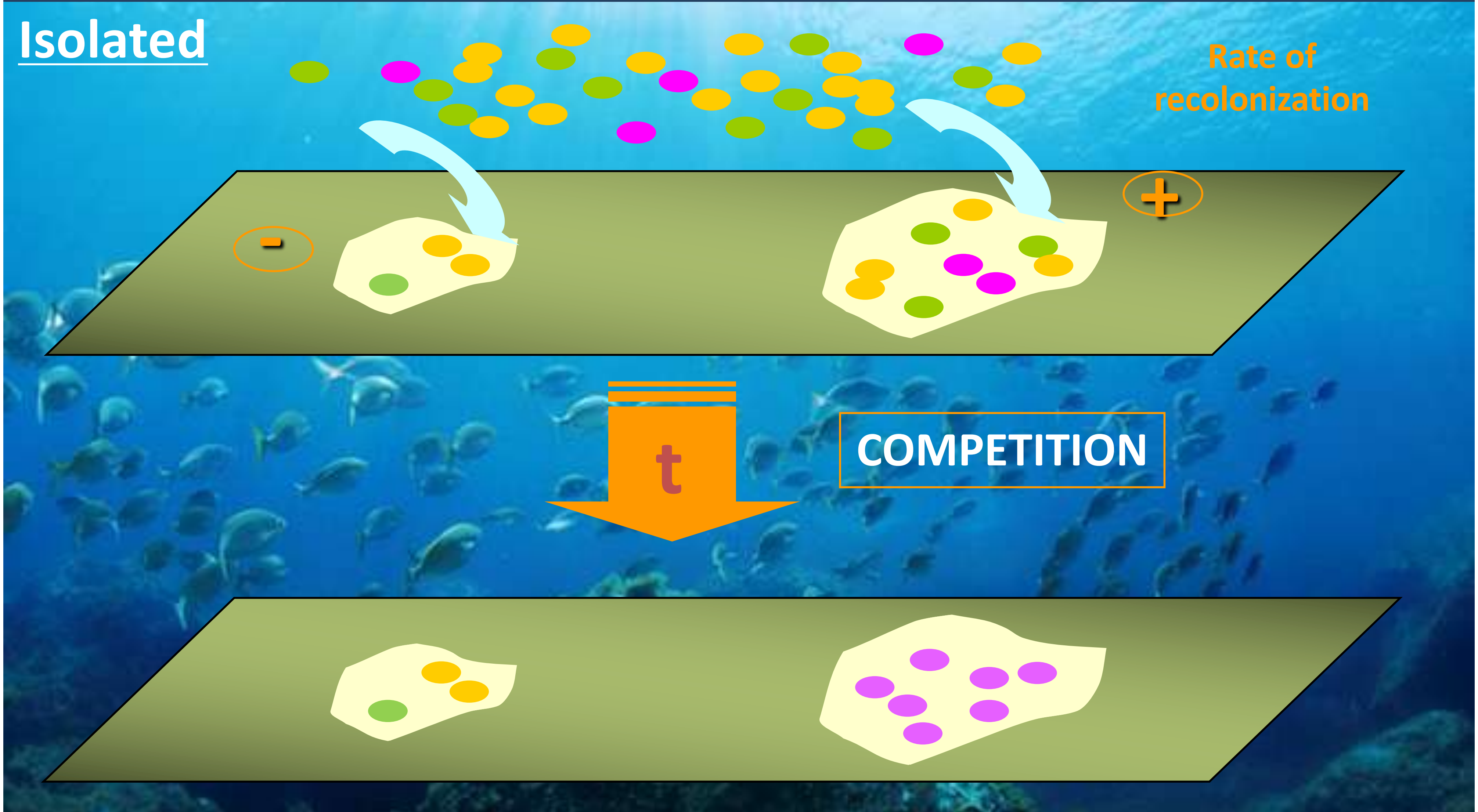
discrete pieces of substratum that were surrounded by water (isolated patches), and areas that were cleared within a background of other sessile organisms (nonisolated patches).

Non-isolated

Rate of ricolonization

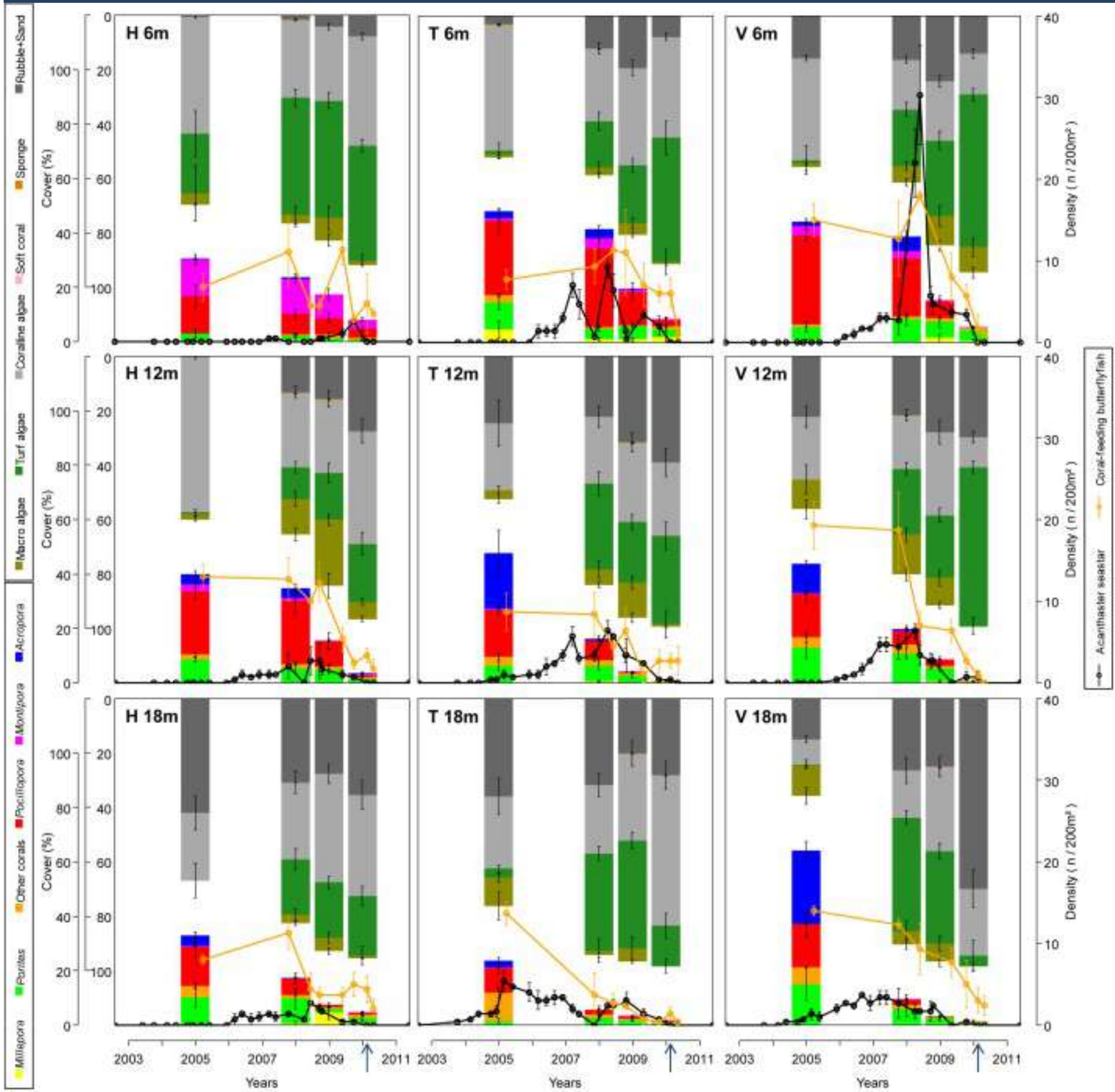
Keough 1984

Isolation and size



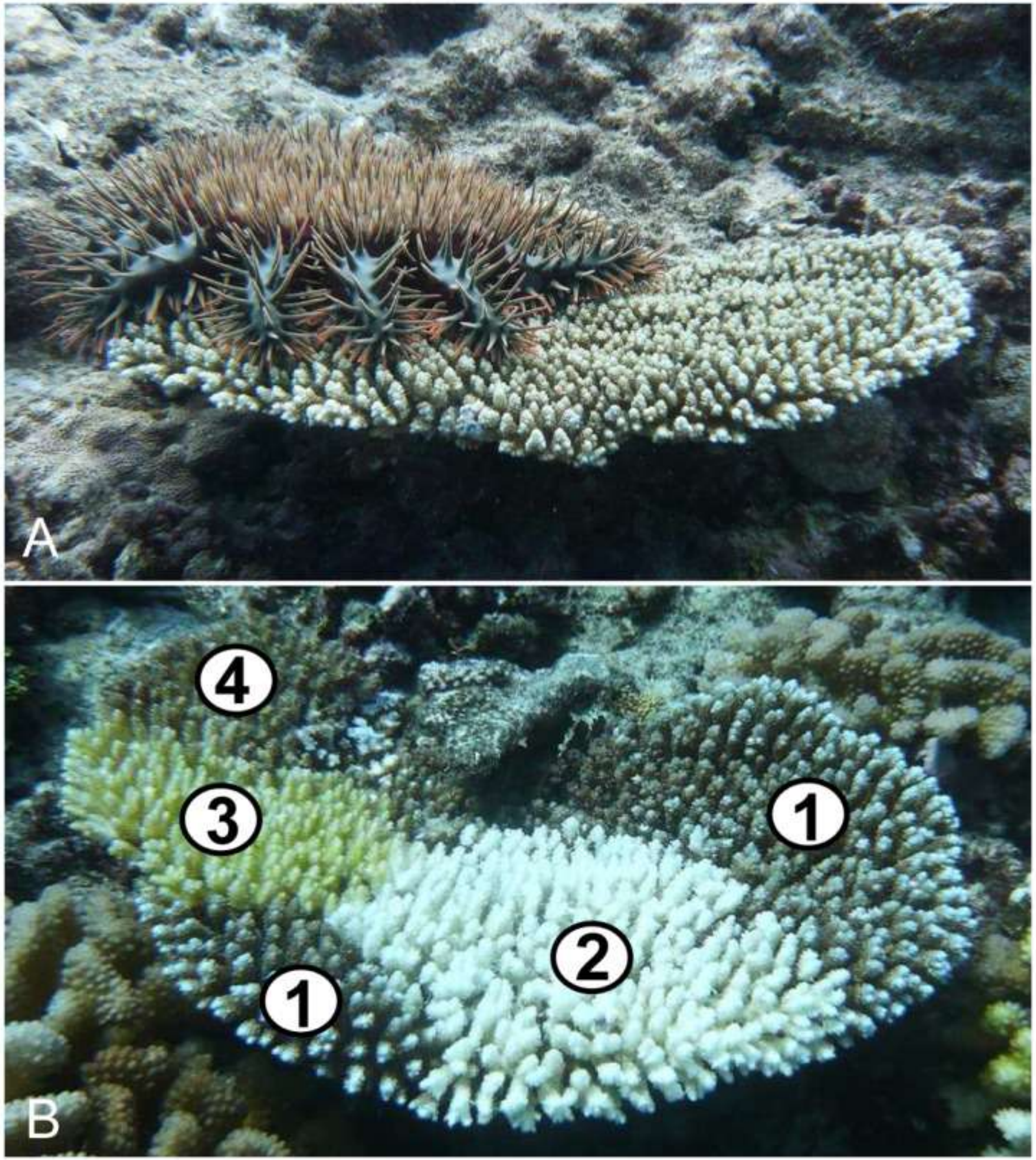
The interpaly among dispersal potential, competitive ability, and patch size affect colonization. In small patches dispersal and settlement are the most influential processes. In large patches, instead, it does not matter how good is your ability to reach the substrate and settle: strong competitors are favoured

Interactions with biological processes



Three sites × three water depths (6, 12, 18 m). Y-axes on the left indicate cover values (mean ± SE) of the sessile communities: reef-building corals and other benthic components. Y-axes on the right indicate densities (mean ± SE) of coral-predators: populations of the outbreaking seastar *Acanthaster* and butterfly fish assemblages. Arrows on the x-axes indicate the occurrence of the tropical cyclone Oli.

Kayal et al 2012



(A) An *Acanthaster planci* observed on a living tabular coral from the genus *Acropora*.

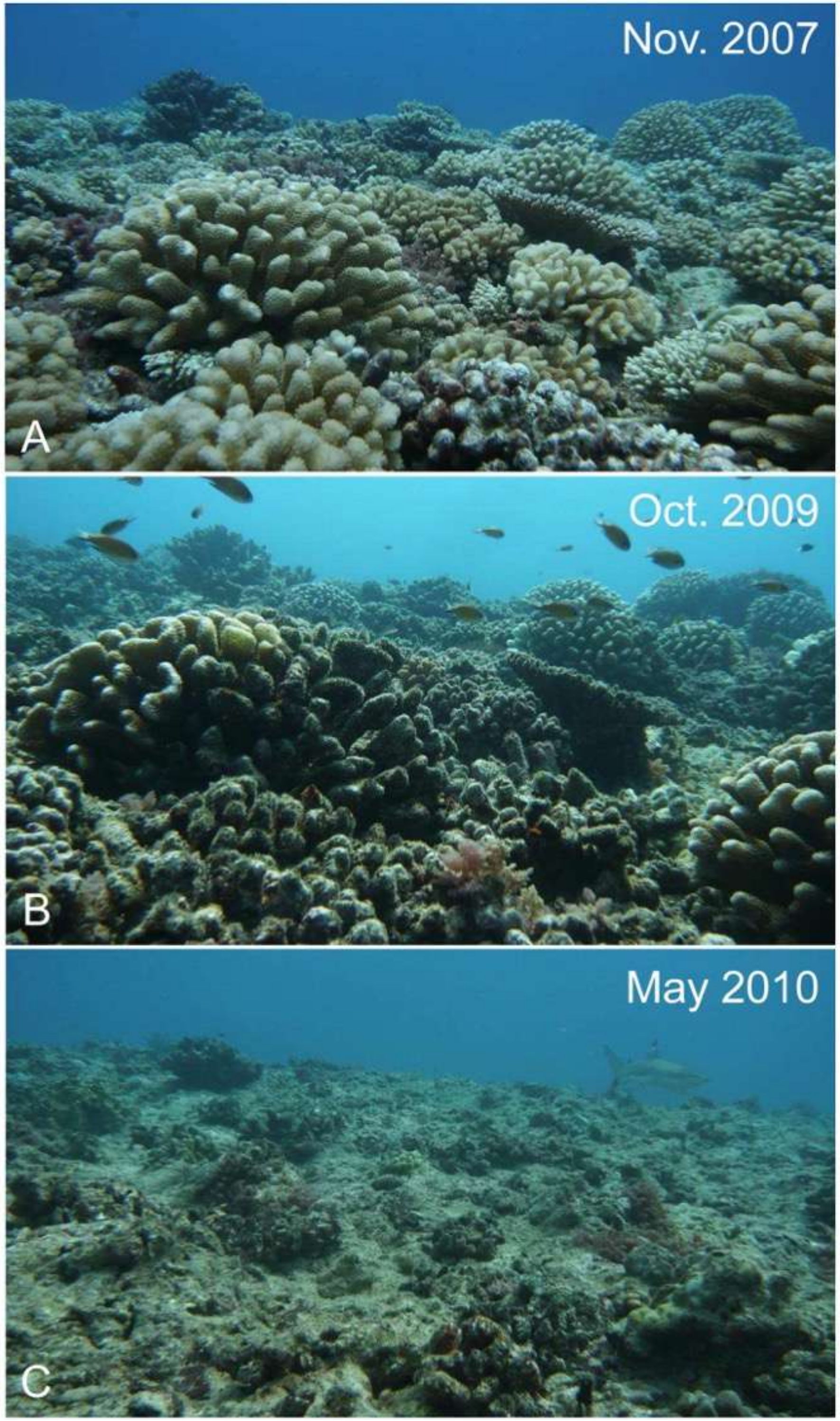
(B) A partially-killed coral from the genus *Acropora* bearing feeding-scars left by successive predation events by *Acanthaster*:

1) live portion of the colony bearing the pigmented coral tissue,

2) freshly killed portion of the colony deprived of its pigmented living tissue (<1 day post-predation),

3) recently killed portion of the colony covered by early colonizing algae and cyanobacteria (~10 days post-predation),

4) dead portion of the colony killed long ago and covered by turf algae (>3 weeks post-predation).

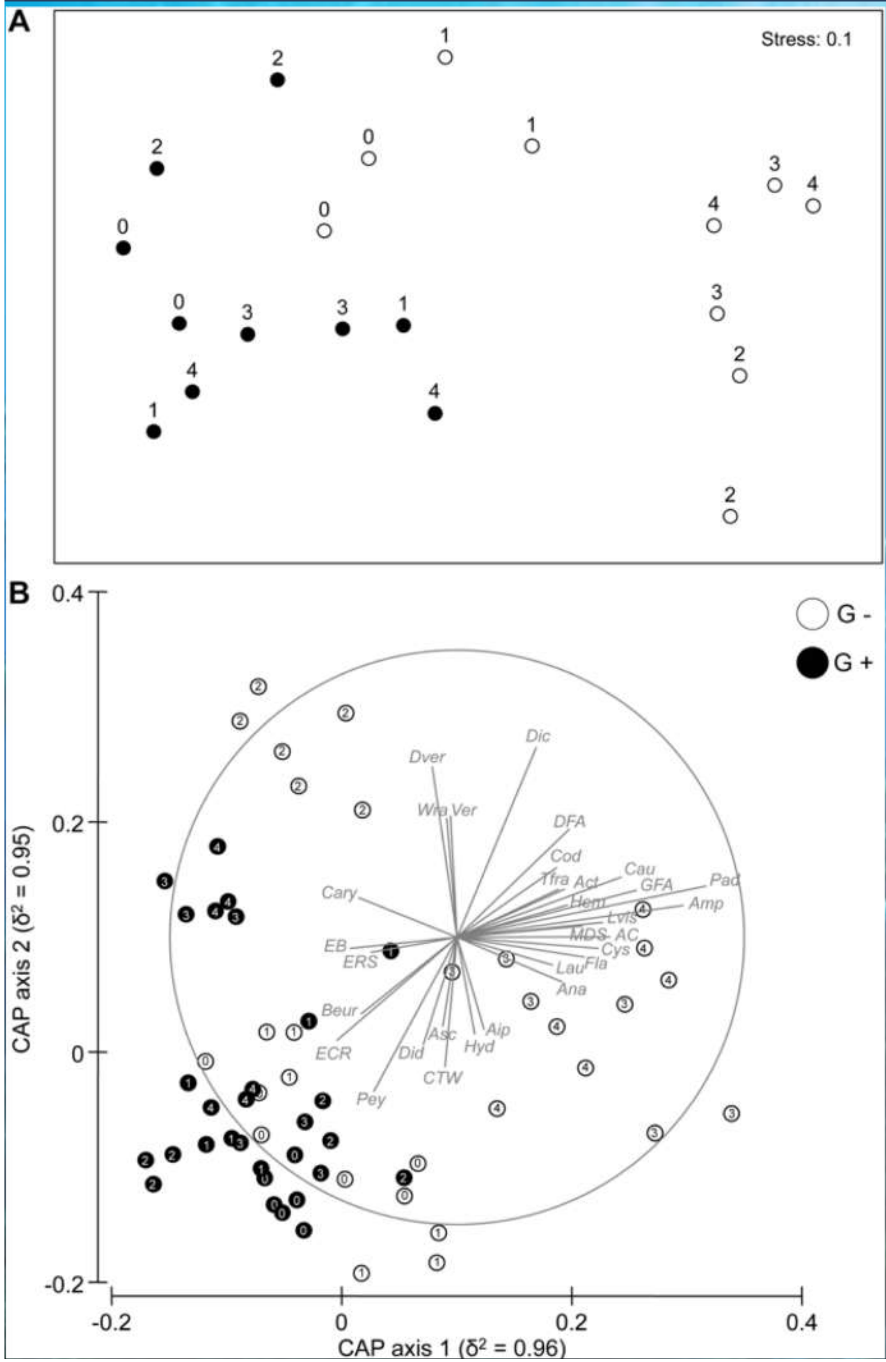


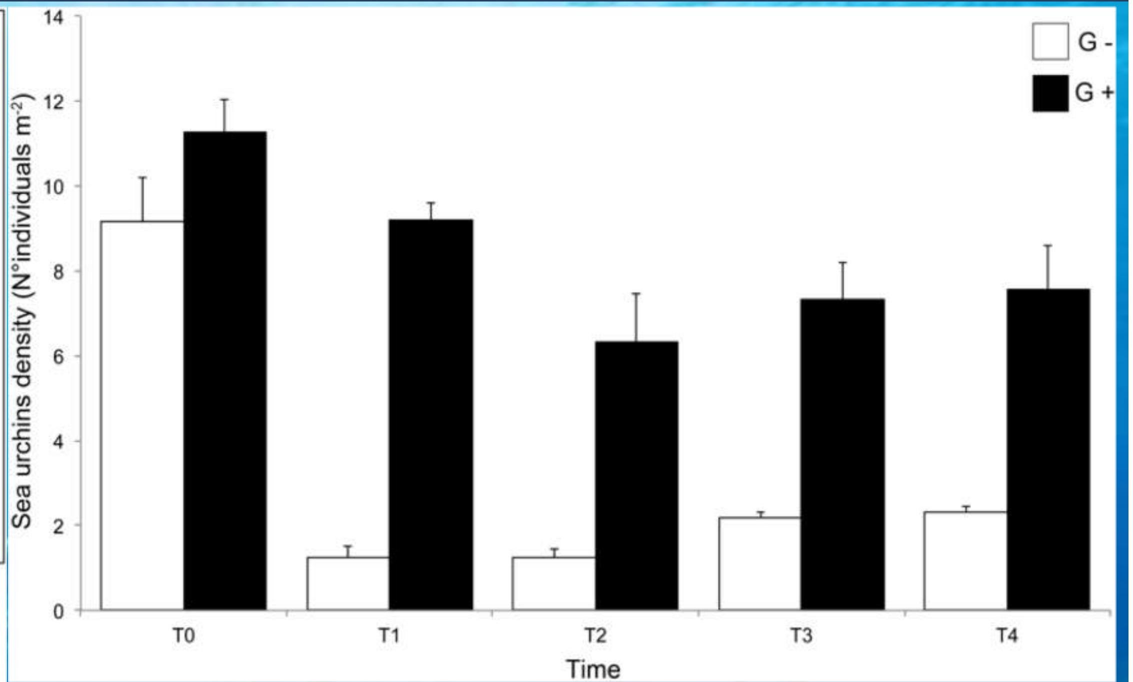
(A) Corals dominate the healthy reef (coral cover >40%).

(B) Algae have colonized dead coral skeletons following severe predation by the seastar *Acanthaster* (~10% coral cover).

(C) Mostly dead and weakened coral skeletons were swept away by a cyclone occurring at the end of the seastar outbreak and colonizing algae once again dominate the devastated reef (~5% coral cover).

Interactions with biological processes





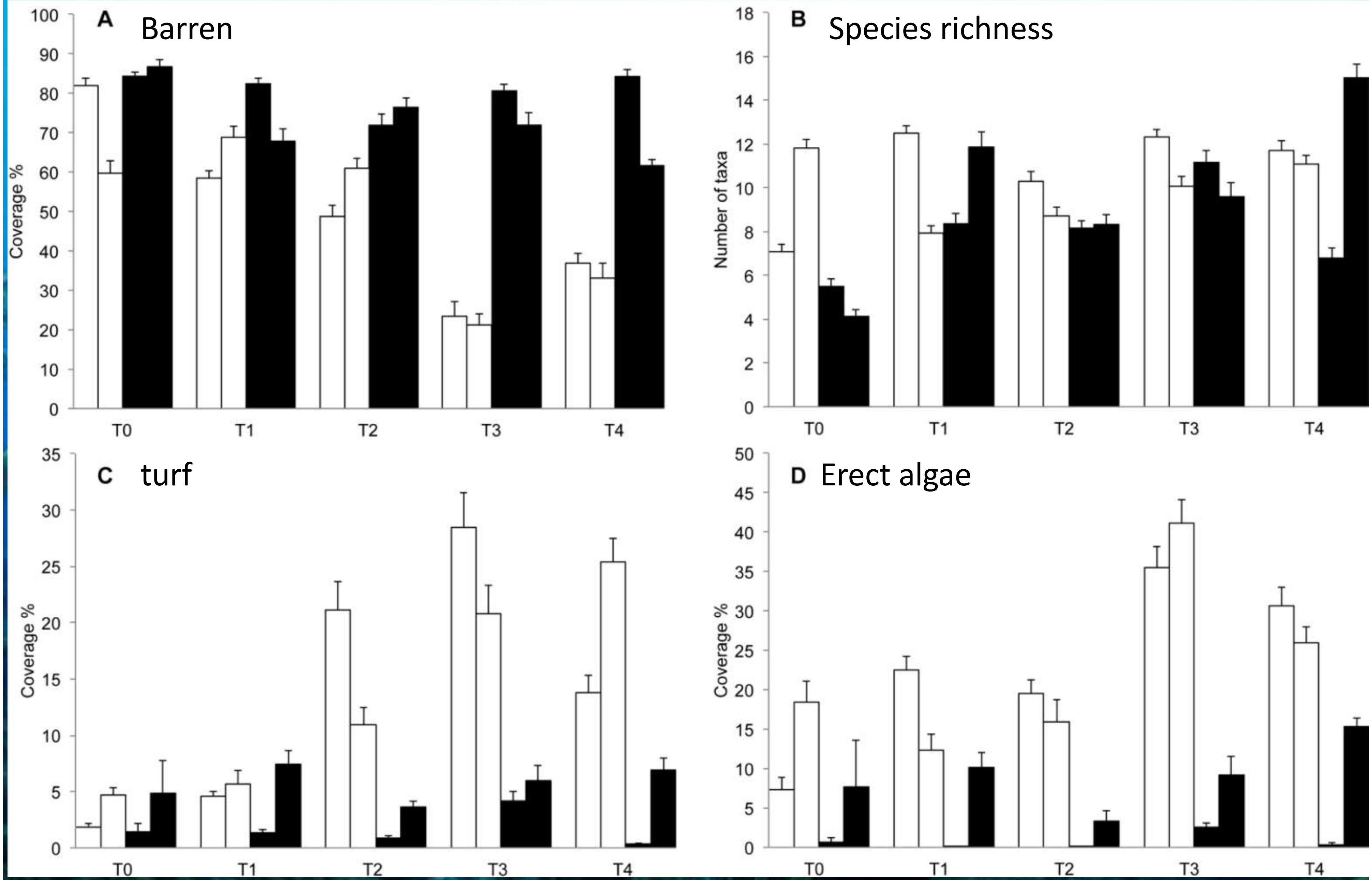
Two areas (200 m^2) with sea urchins in natural densities and two with removal.

Barren caused by date mussel fishery

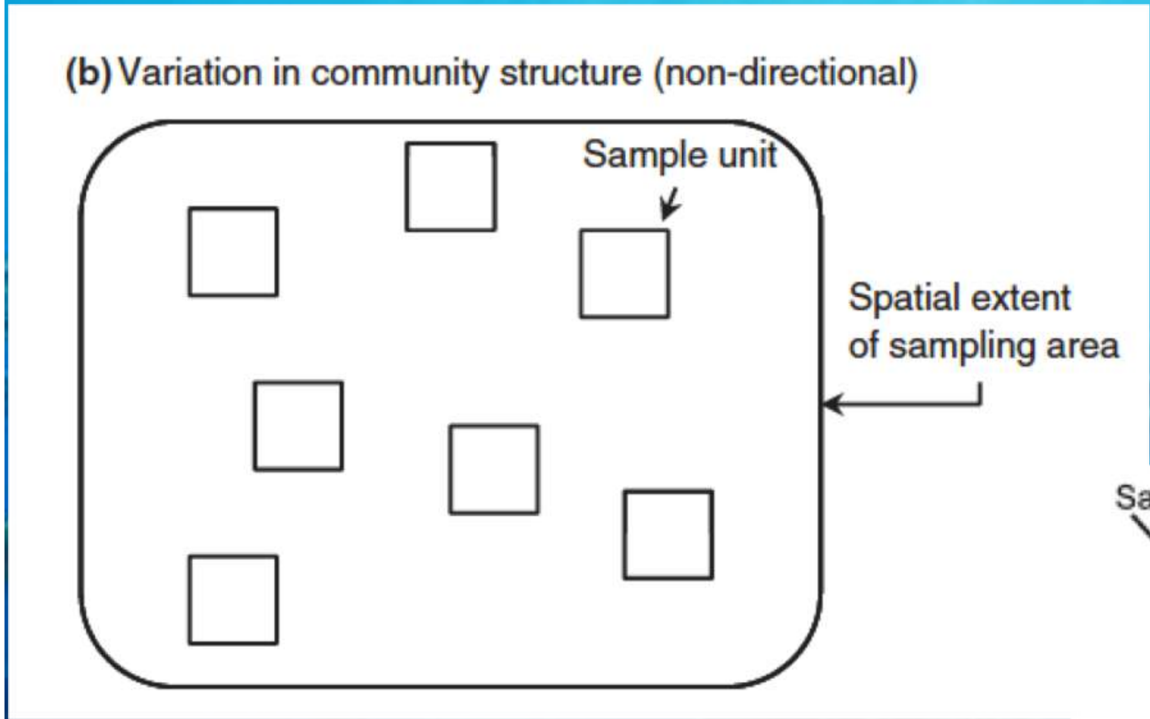
Recovery occurred after sea urchins removal

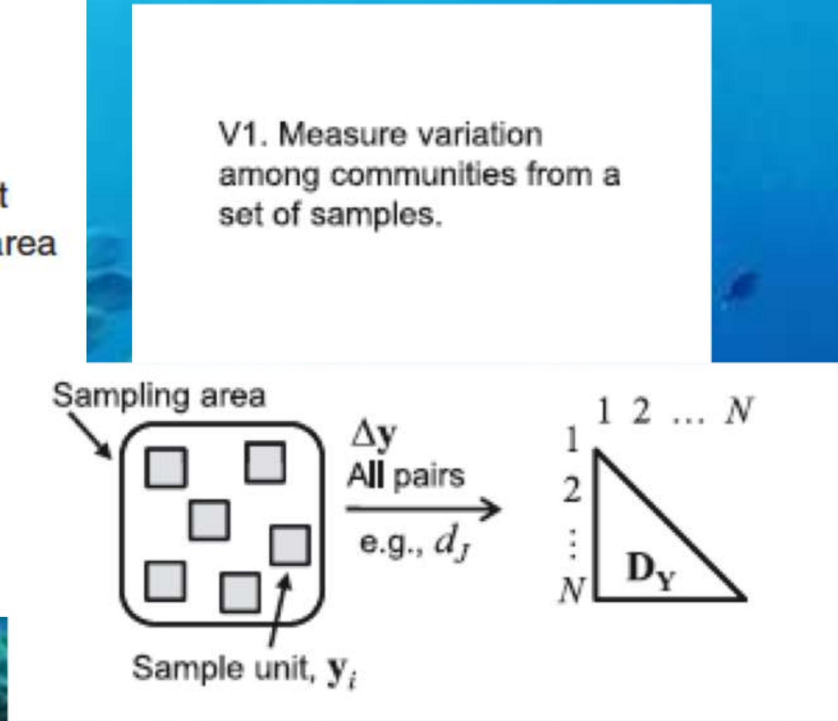
Guarnieri et al 2020

Interactions with biological processes



Disturbance effect on mean and variation

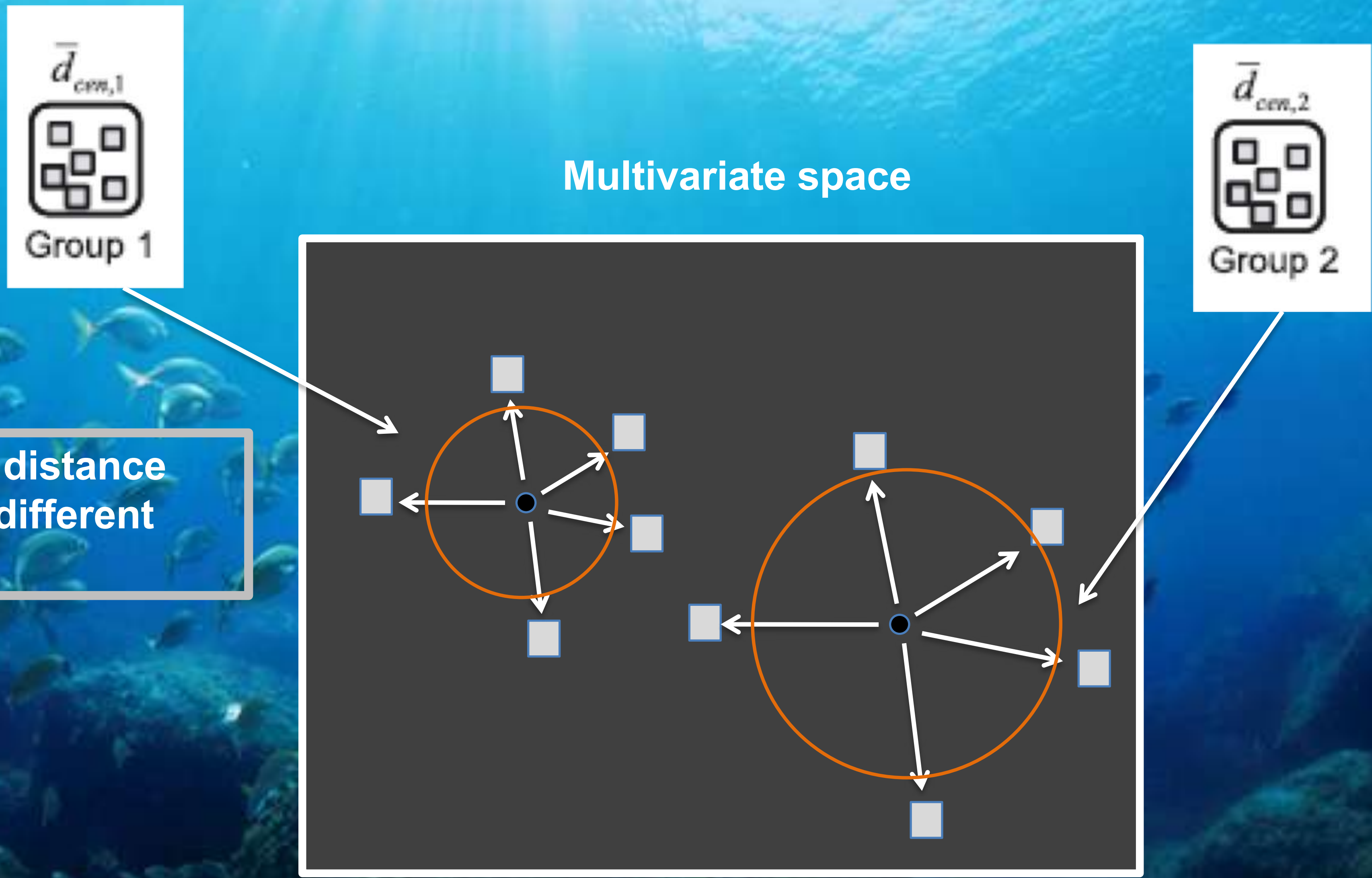




Changes occurring in community structure among a set of sample units within a given spatial, temporal, or environmental extent

From Anderson et al., 2011

Multivariate dispersion as a measure of heterogeneity

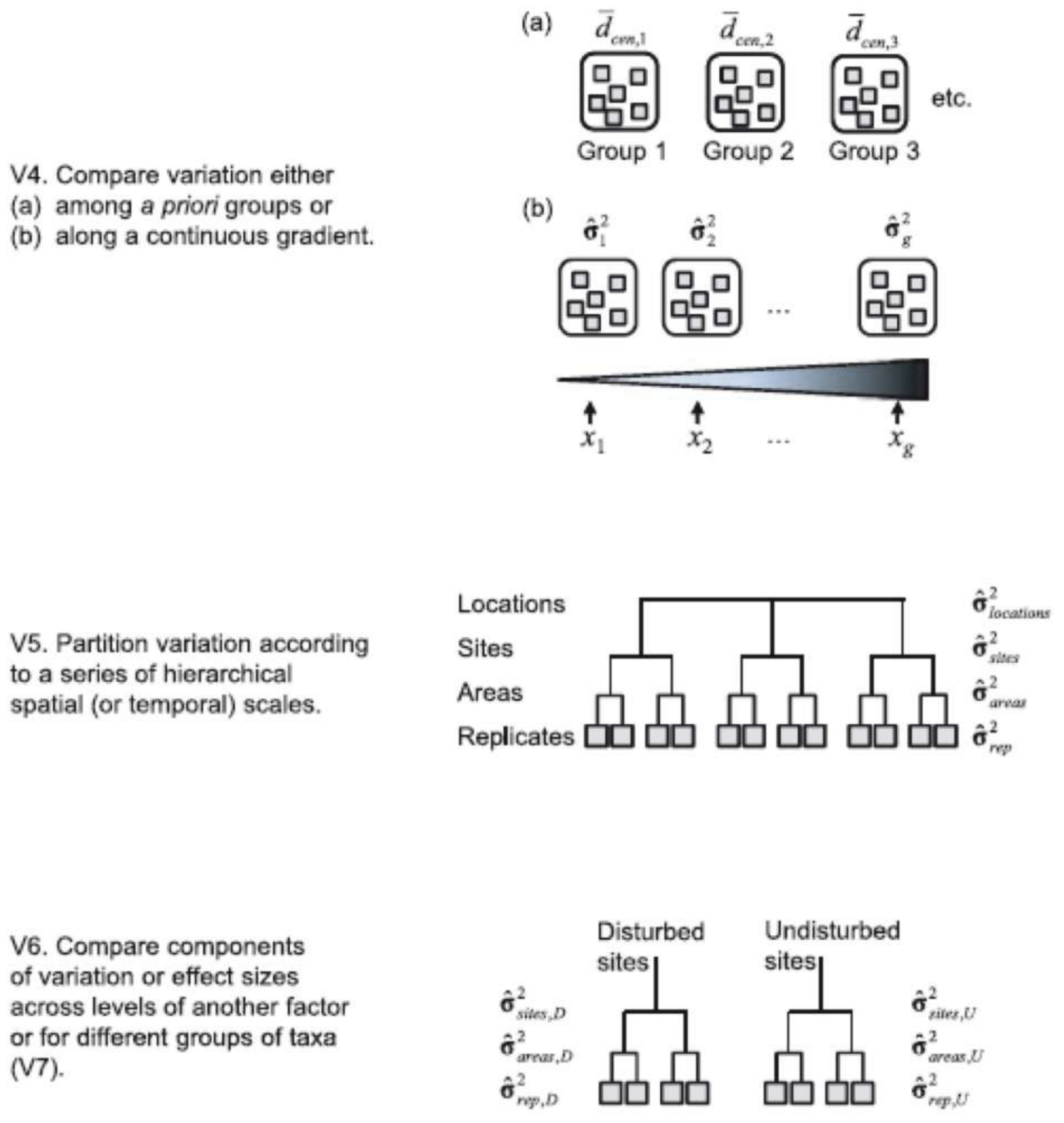


Average distance to centroids

Different distance metric = different meaning

From Anderson, 2006

Modelling β-diversity as variation

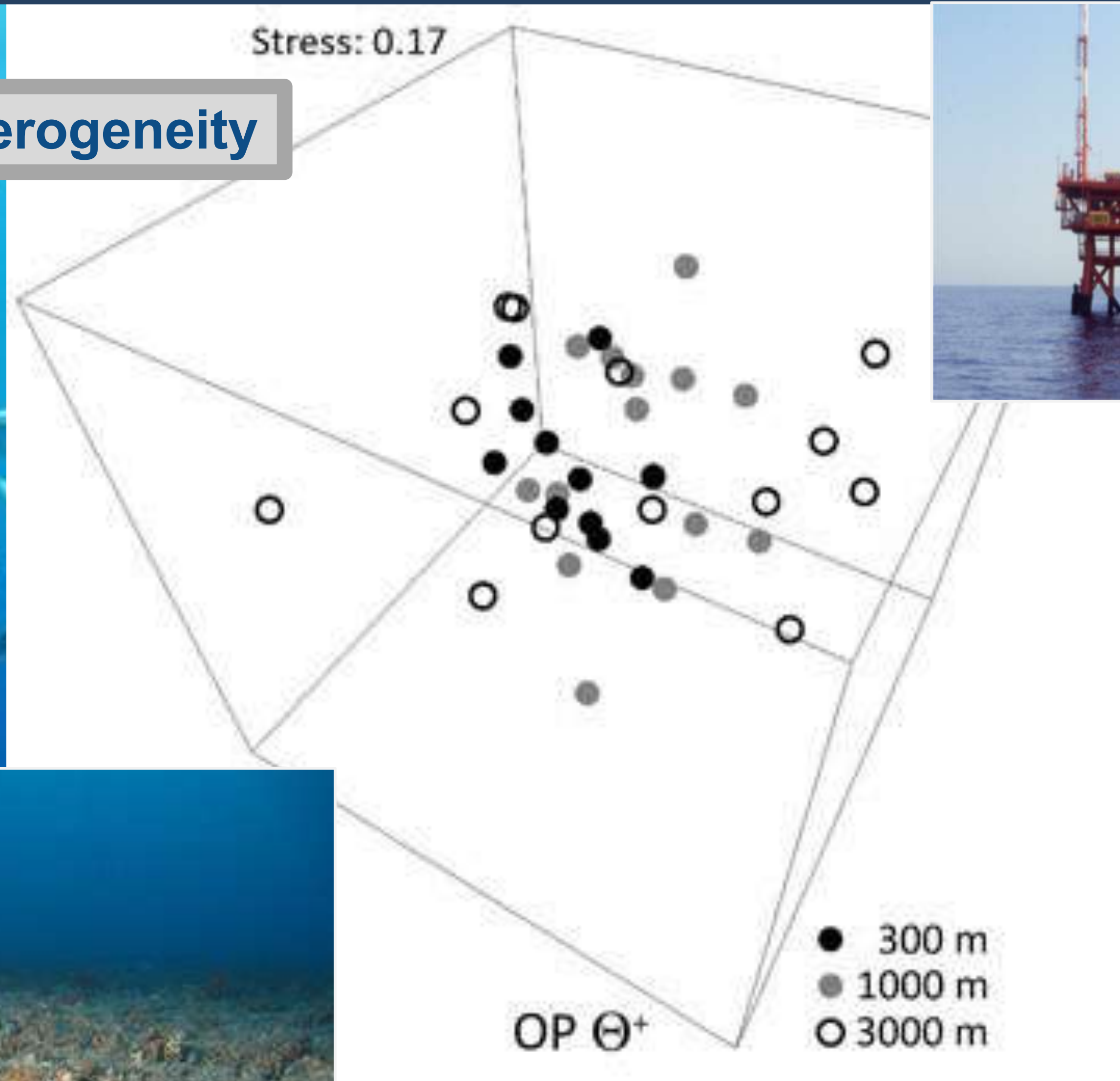


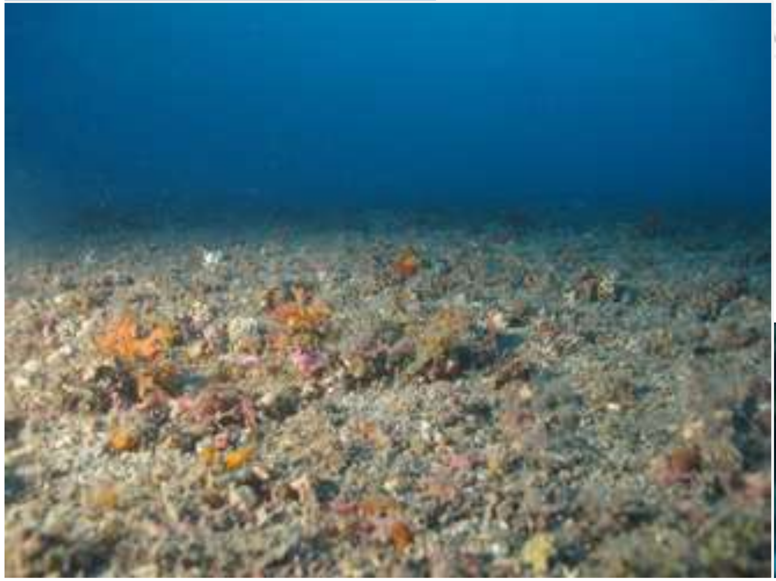
Comparing dispersion among communities, groups of communities, or according to spatial and temporal scales, or other factors.

From Anderson et al., 2011

Case studies on impacts and heterogeneity

Decreased heterogeneity



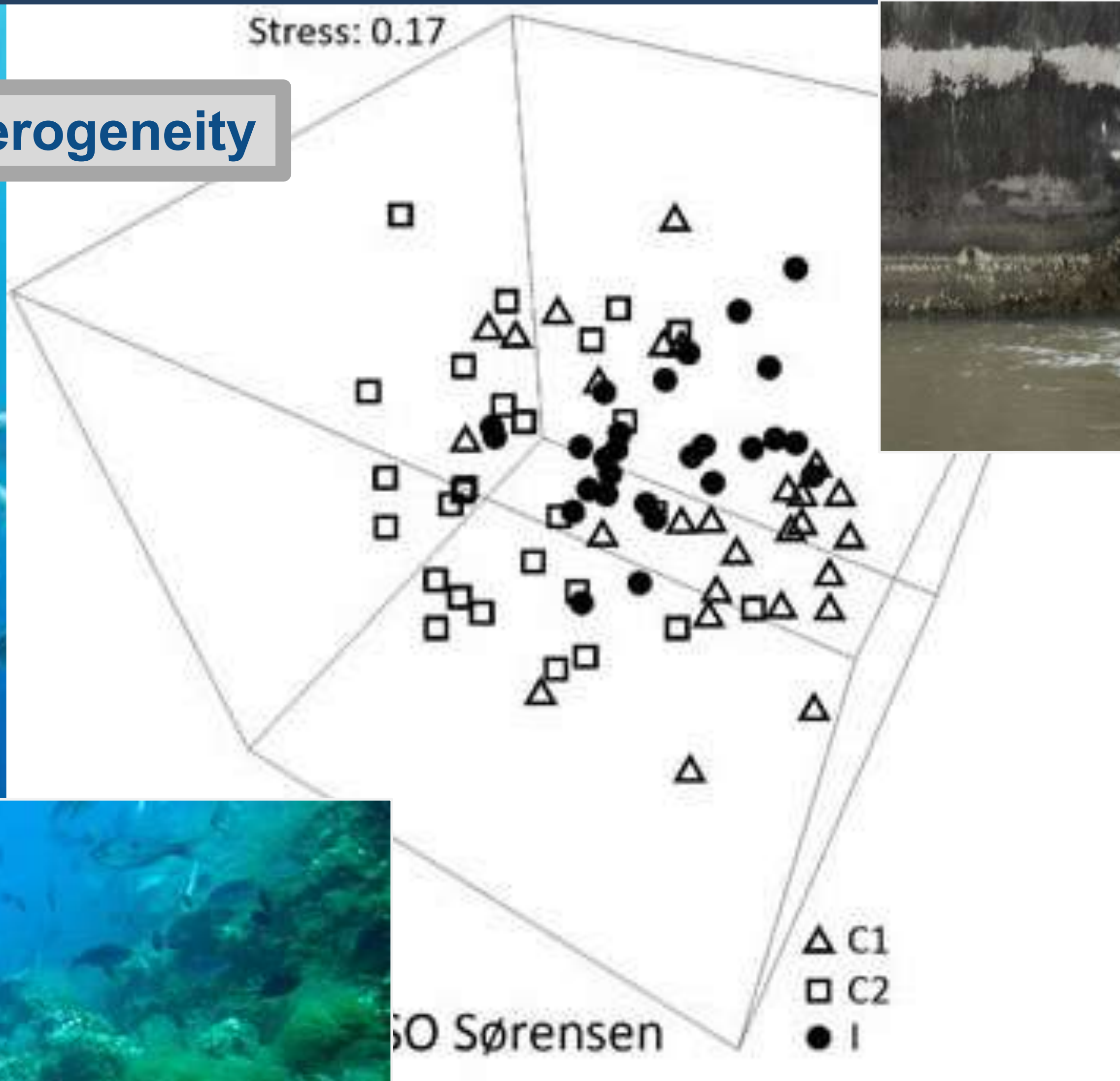


Comparable community structure
Comparable alfa diversity
Different beta-diversity (I<)

From Bevilacqua et al., 2012

Case studies on impacts and heterogeneity

Decreased heterogeneity

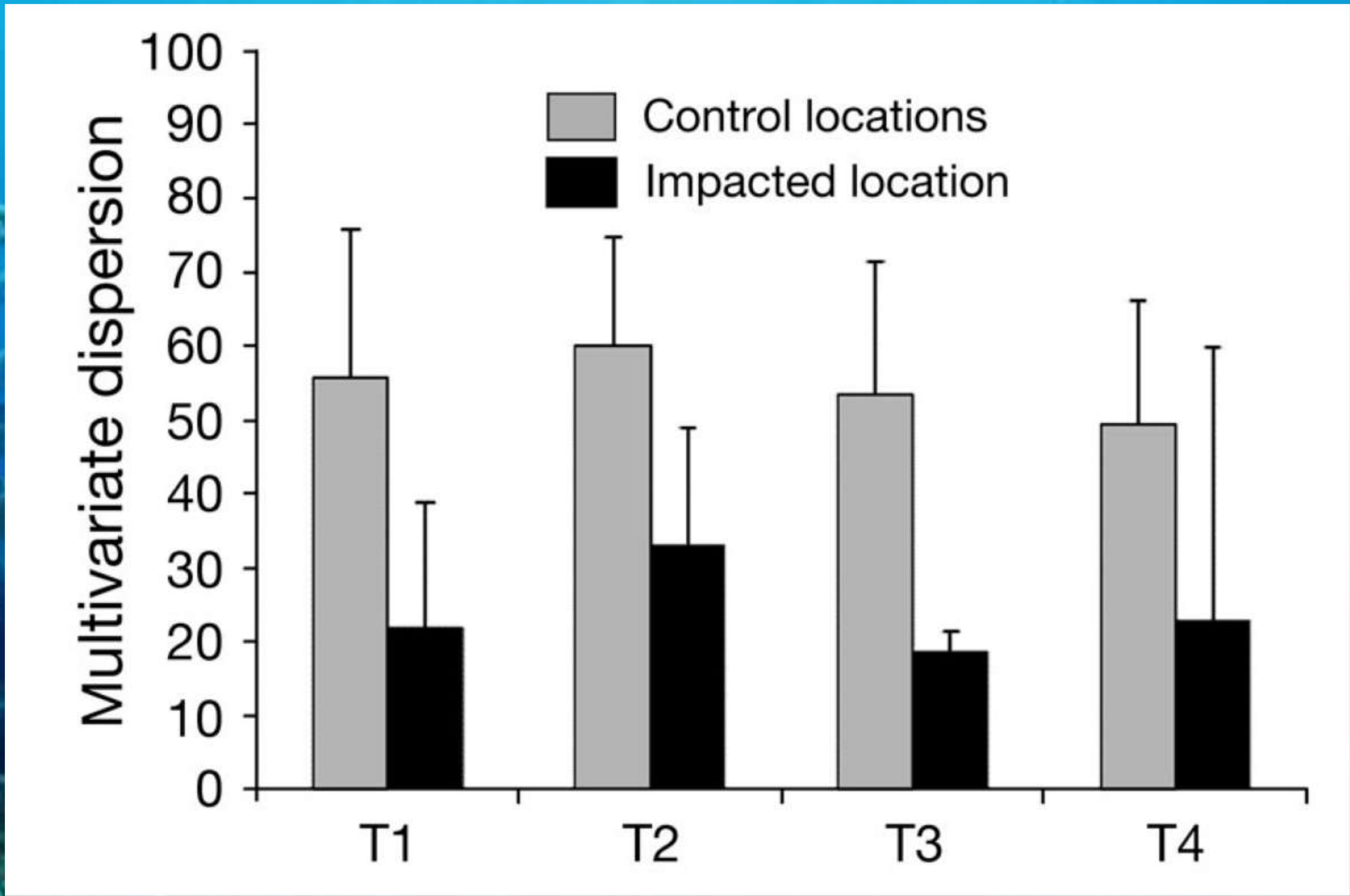


Different community structure
Different alfa diversity (I<)
Different beta (I<)

From Bevilacqua et al., 2012

Case studies on impacts and heterogeneity

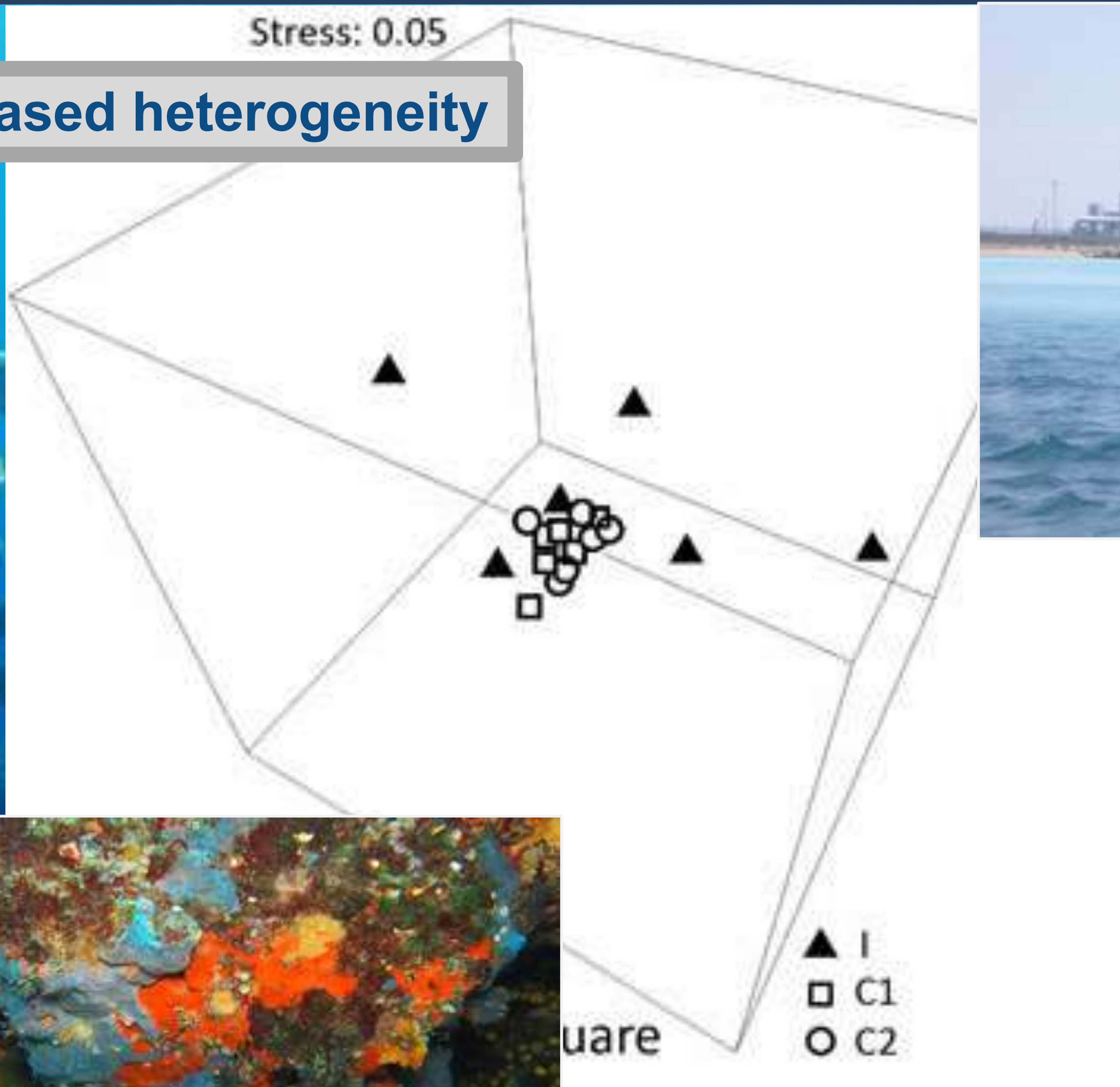
Decreased heterogeneity

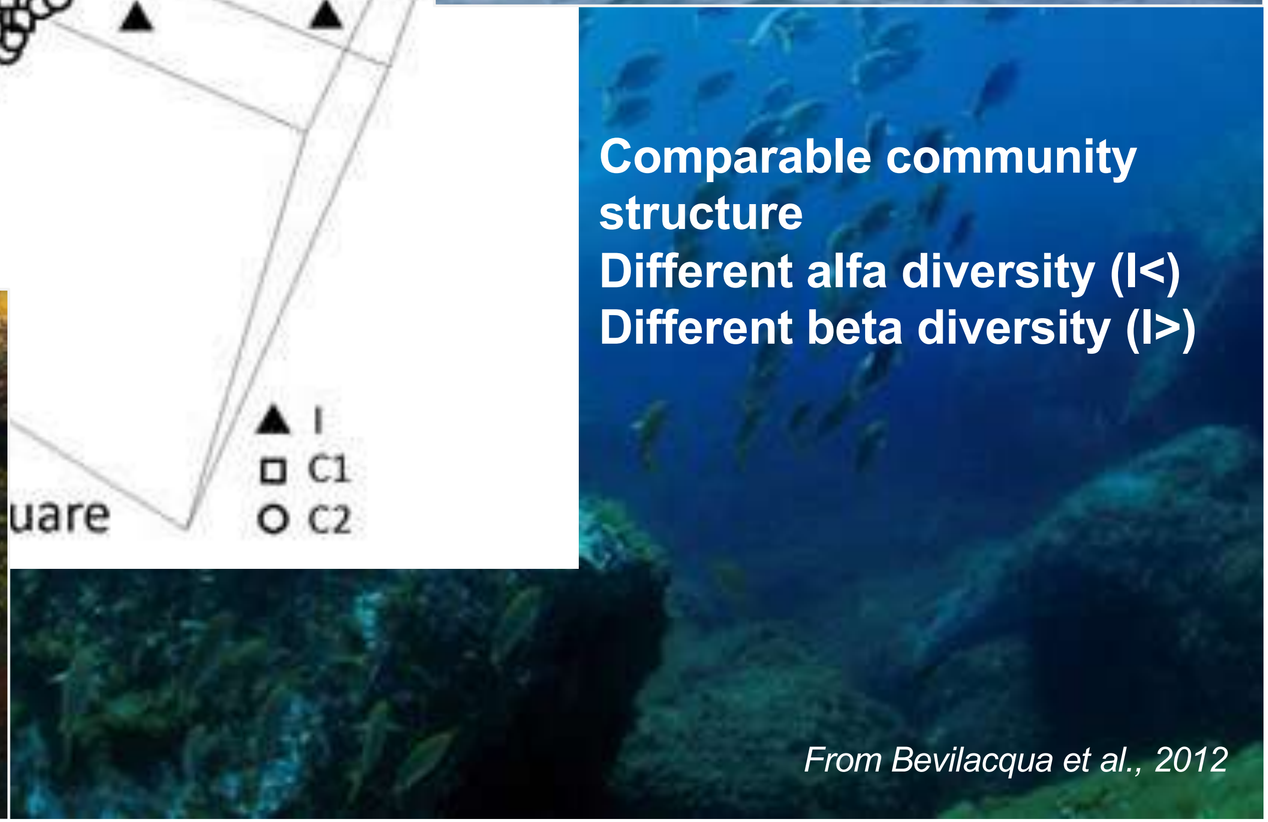


From Moreno-Valcarcel et al., 2016

Case studies on impacts and heterogeneity

Increased heterogeneity

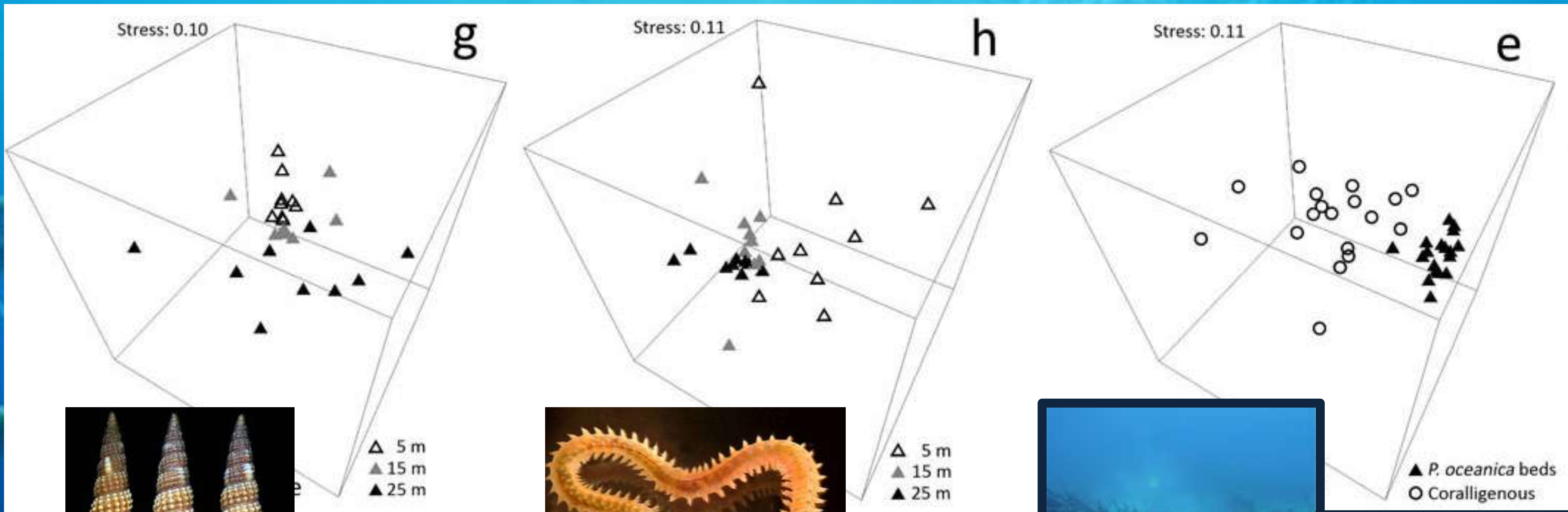


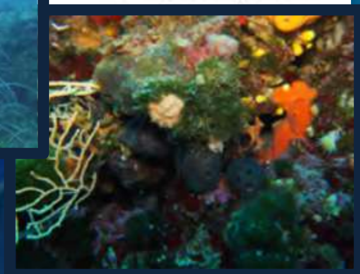


Comparable community structure
Different alfa diversity (I<)
Different beta diversity (I>)

From Bevilacqua et al., 2012

Changes in heterogeneity depends on habitats, geography and taxonomic group





Same gradient
Different groups
Opposite patterns of beta

Same group
Different habitat
Different beta

From Bevilacqua et al., 2012

Summary

- Disturbance is an important factor interacting with biological processes such as competition and predation in shaping marine community assembly
- Disturbance begets spatial, temporal and environmental heterogeneity, and this sustain biodiversity within certain levels
- Effects of disturbance depend on its features, such as intensity and frequency, but spatio-temporal variance of disturbance plays also a crucial role
- Recovery after disturbance, and sometimes the effect of disturbance itself, are strongly related with biological and ecological traits of species composing disturbed assemblages or the available diversity pool
- Biological processes, such as predation, though not being proper disturbance, act similarly and may interact with disturbance
- Recovery after disturbance is related to size of disturbed patches and the potential mechanisms of recolonization or reoccupation