The Cells of Ecosystem Functioning: towards a holistic vision of marine space

Ferdinando Boero

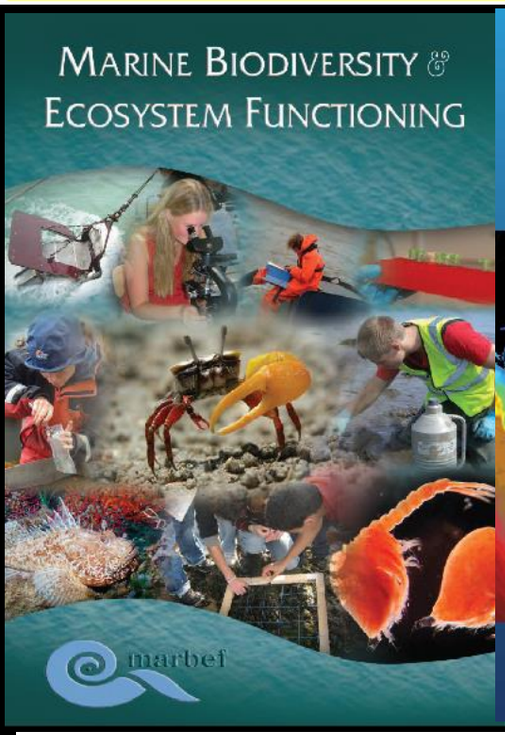
University of Naples Federico II - CoNISMa
CNR-IAS
Zoological Station Anton Dohrn

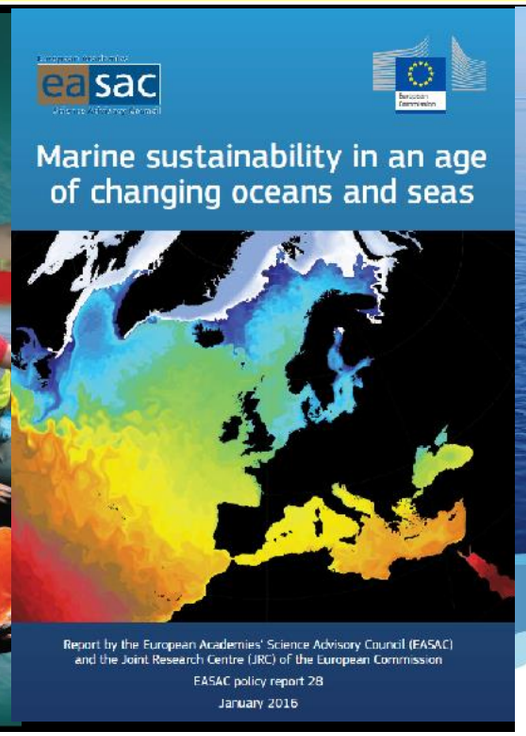
European Marine Board

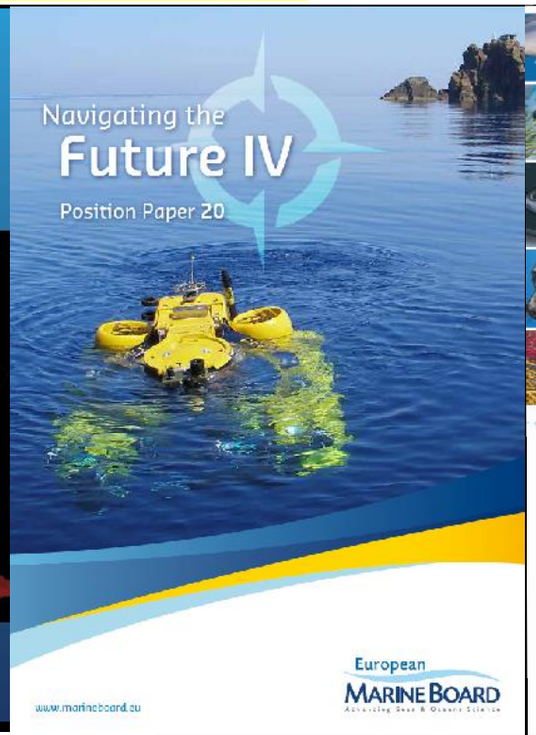
Reductionism must be upgraded

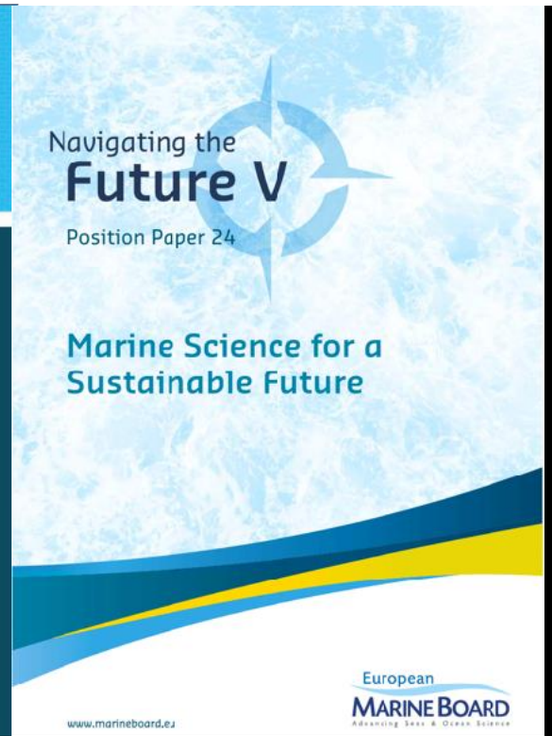
We need science! but…

To truly progress this knowledge, European scientists across a broad range of disciplines and domains must make a quantum leap towards holistic approaches and integrated research on a scale which will help us to much better understand, protect, manage and sustainably exploit the seas and oceans which surround us. This is a Grand Challenge; not just Europe, but for human society as a whole.



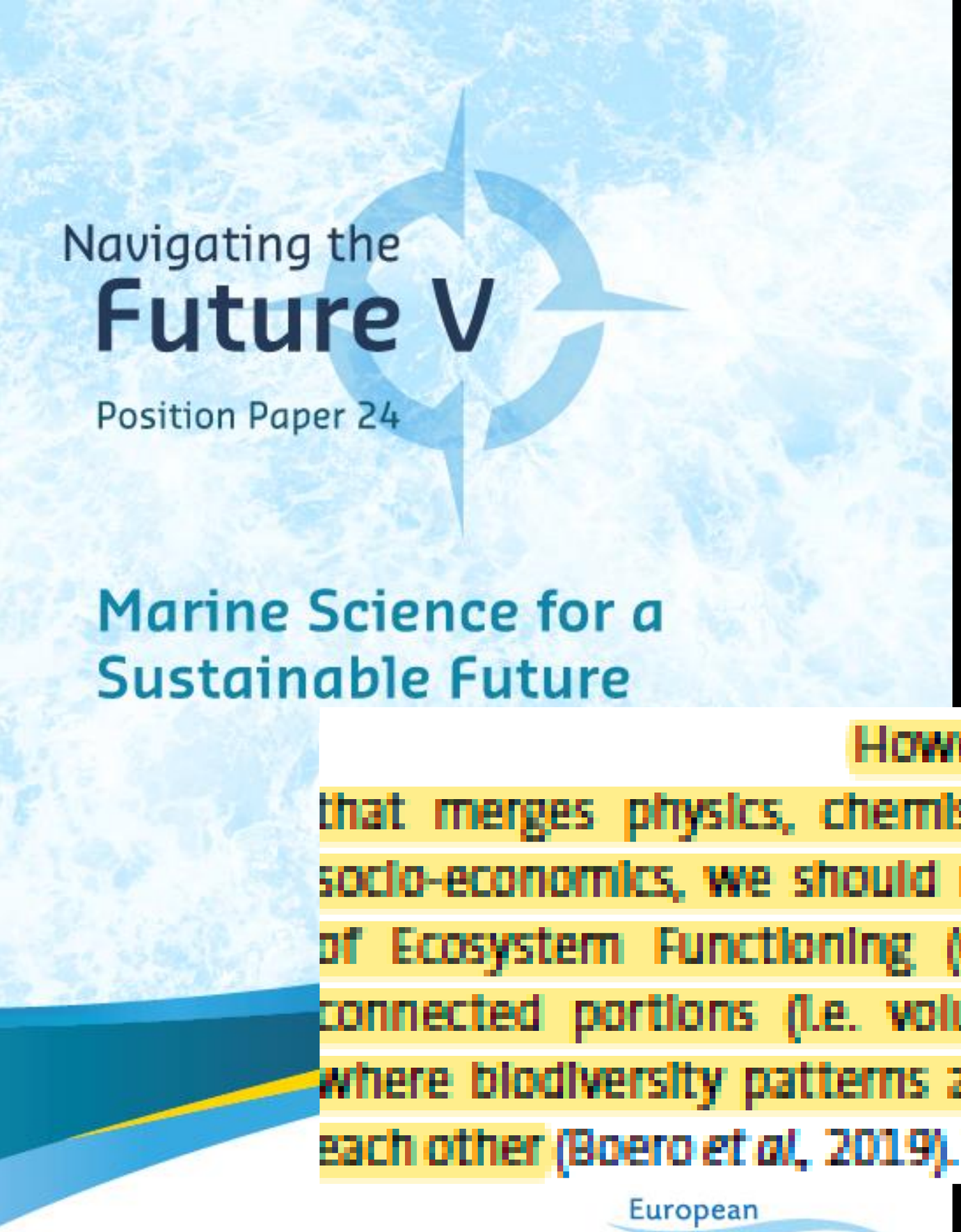






COHENET contract "Achieving coherent networks of marine protected areas: analysis of the situation in the Mediterranean Sea"
ENV.C.2/FRA/2016/0017

The scientific community has produced lots of data, analyses and recommendations, the directives are there!



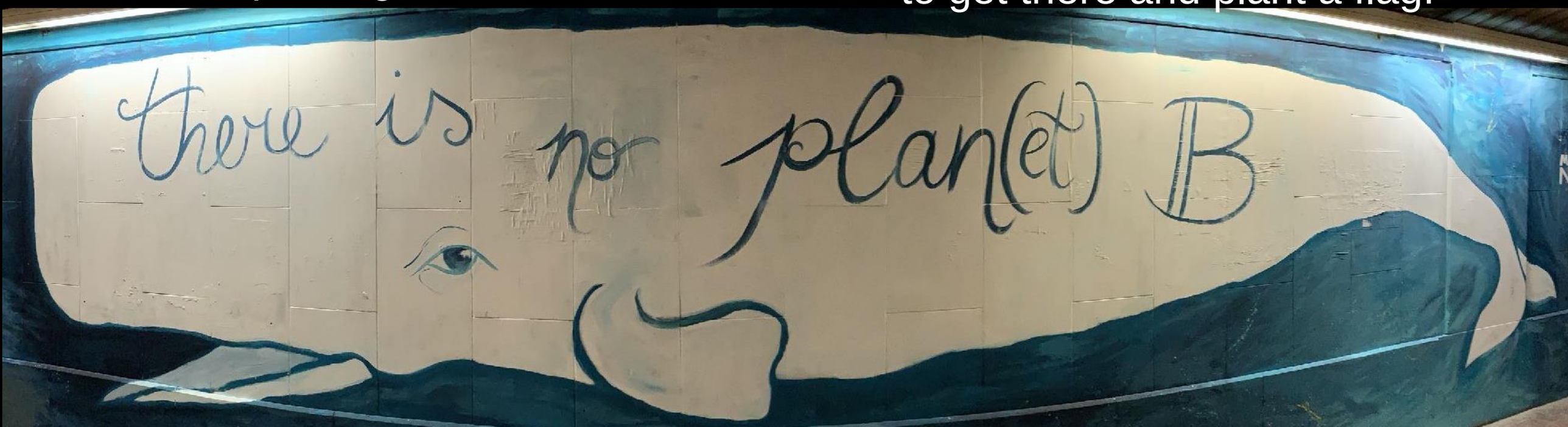
NF IV paved the way to the approach of NF V: Marine Sciences must evolve into Marine Science

However, to have a truly holistic approach that merges physics, chemistry, geology, biology, ecology and socio-economics, we should manage marine ecosystems in Cells of Ecosystem Functioning (CEFs). CEFs are the smallest fully connected portions (i.e. volumes) of the marine environment, where biodiversity patterns and ecosystem functions depend on each other (Boero *et al*, 2019).

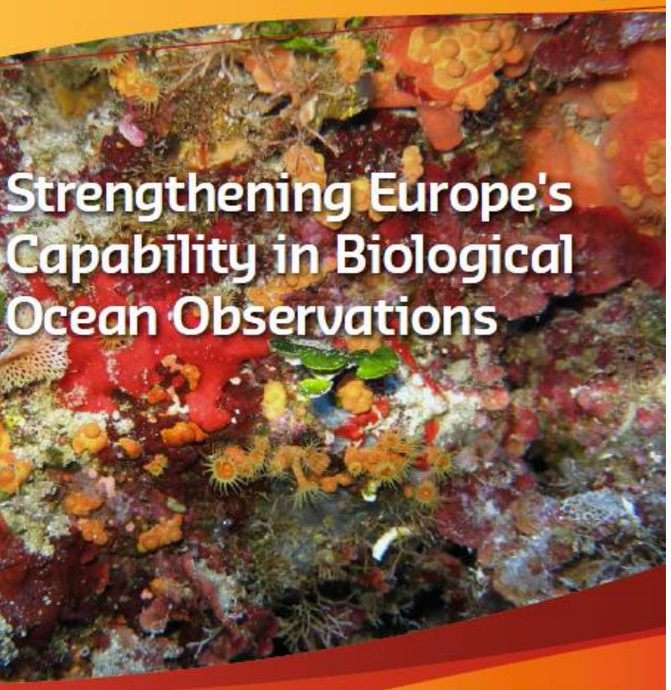
AND NOW: THE MISSIONS

"Man on the moon" is often taken as a paradigmatic "Mission"

But the Earth is much more complex than the Moon and the mission is not just to get there and plant a flag!



Future Science Brief Nº 3 July 2018

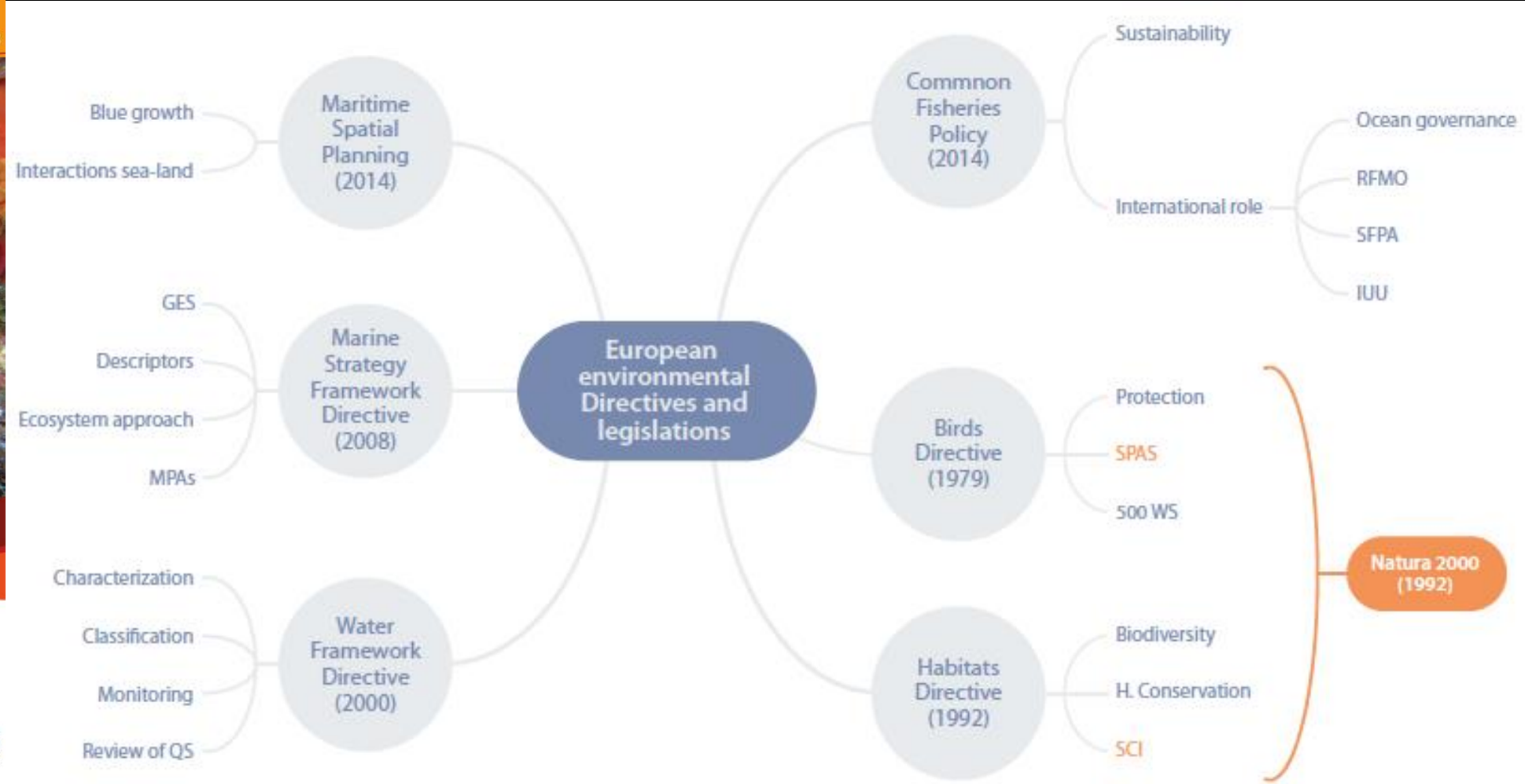


Strengthening Europe's Capability in Biological Ocean Observations

European MARINE BOARD Advancing Seas & Ocean Science

www.marineboard.eu

Benedetti-Cecchi, L., Crowe, T., Boehme, L., Boero, F., Christensen, A., Grémare, A., Hernandez, F., Kromkamp, J. C., Nogueira García, E., Petihakis, G., Robidart, J., Sousa Pinto, I. & Zingone, A. (2018) Strengthening Europe's Capability in Biological Ocean Observations. Muñiz Piniella, Á., Kellett, P., Larkin, K., Heymans, J. J. [Eds.] Future Science Brief 3 of the European Marine Board, Ostend, Belgium. 76 pp. ISBN: 9789492043559 ISSN: 2593-5232



The long and winding road of EU legislation towards sustainability. From Abiotic features, to Habitats and Species, to Biodiversity and Ecosystem Functioning, in a spatial framework

ework Directive calls for Good Environmental Status (Healthy Ocean

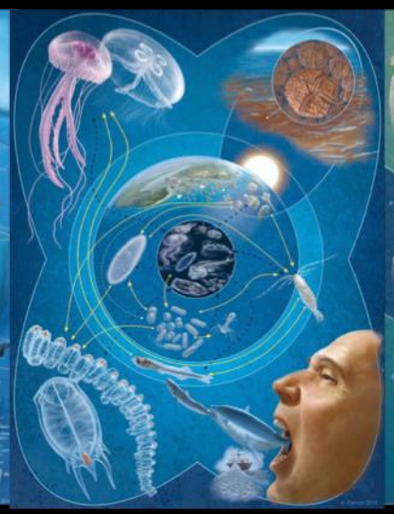
GES indicators

biodiversity

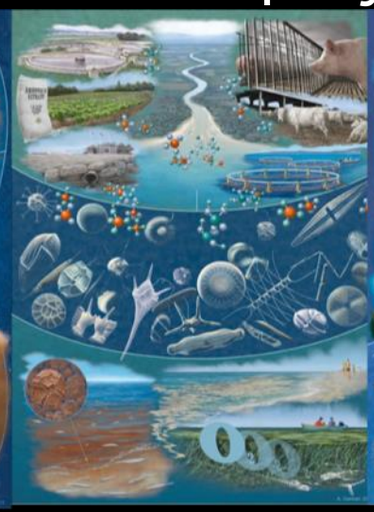
aliens

fish

networks

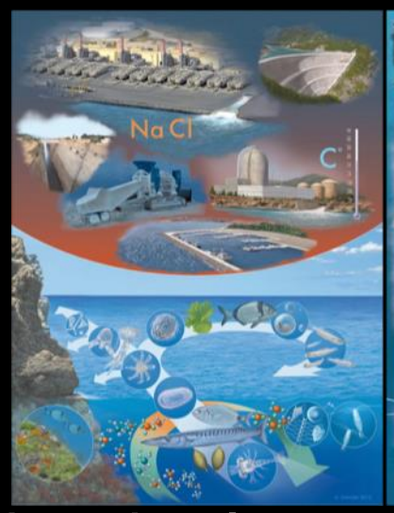


distrophy

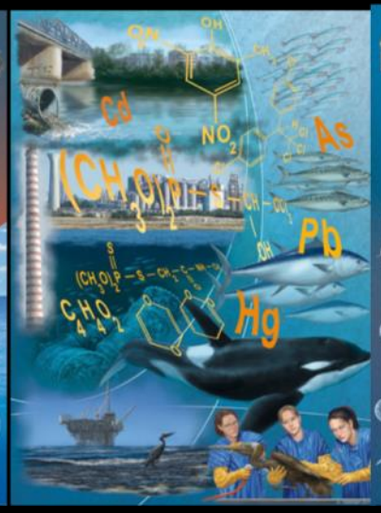


bottom

hydrology

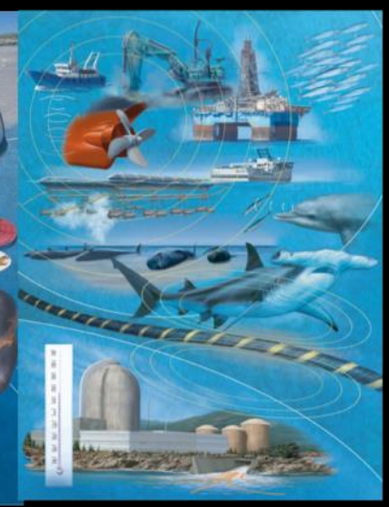


contaminants



litter

energy



MARINE BIODIVERSITY AND ECOSYSTEM FUNCTIONING: THE PILLARS OF GOOD ENVIRONMENTAL STATUS

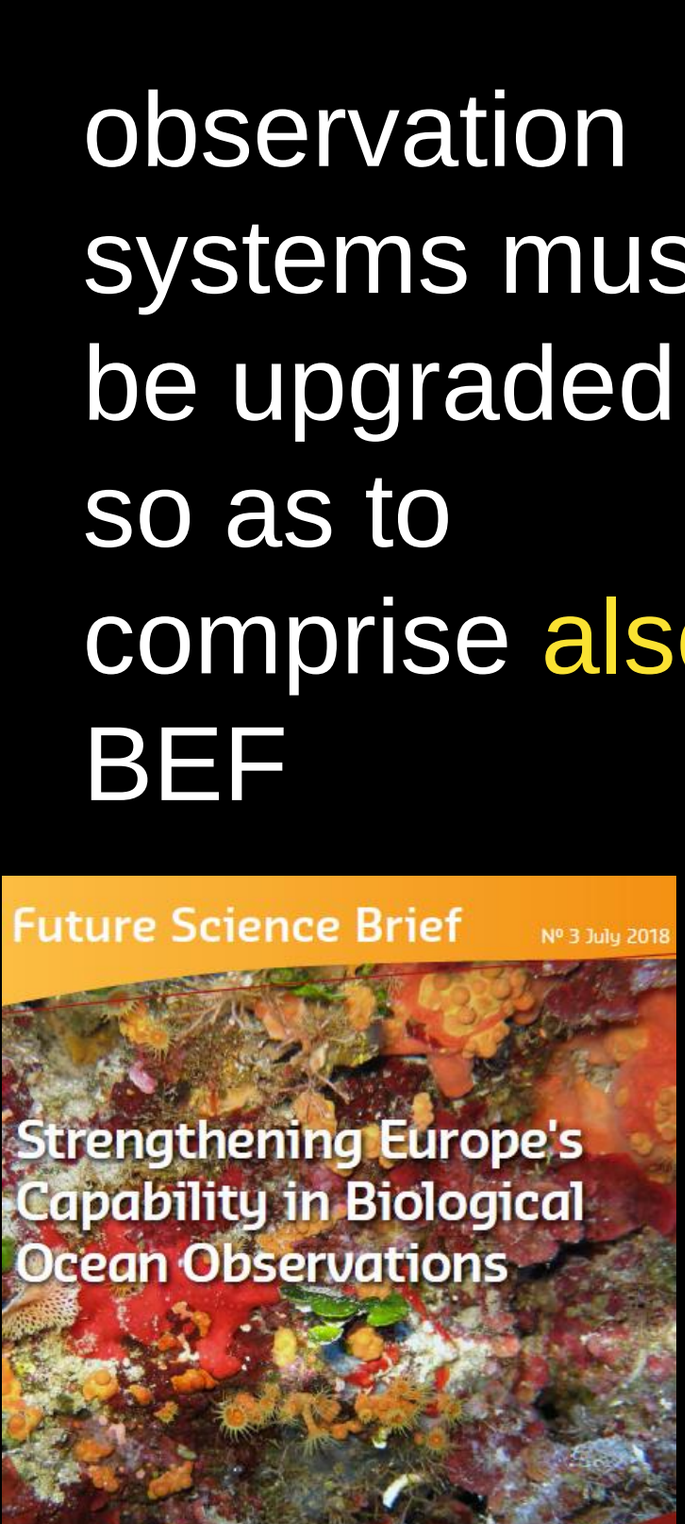
Biol. Mar. Mediterr. (2016), 23 (1): 50-57

F. Boero

In the light of all this, to protect and manage the environment we need to know BEF.

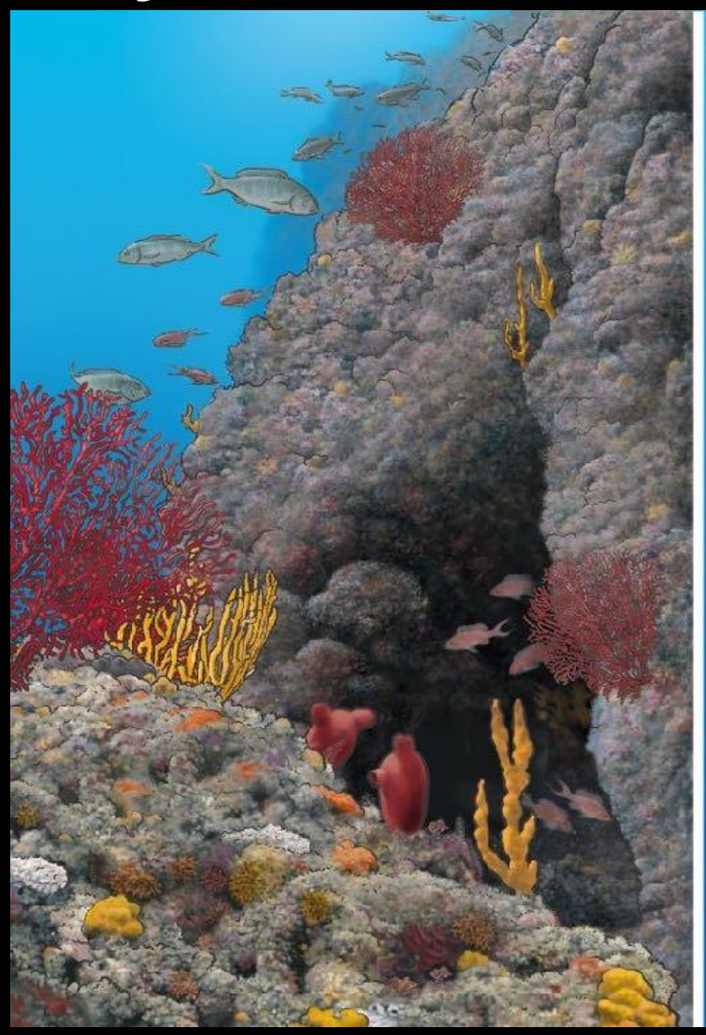
Oh oh: ocean observations mostly focus on biogeochemistry and physics!

observation systems must be upgraded so as to comprise also BEF



Descriptor 1 of GES prescribes that Biodiversity is maintained… but only charismatic expressions of biodiversity are covered

- Iconic habitats or species are not representative enough
- The protection of patterns of biodiversity distribution (hot spots) is not sufficient
- The processes that allow for the persistence of biodiversity hot spots must be considered
- We need to manage and protect both patterns and processes, i.e. BEF



Protected Areas are not enough

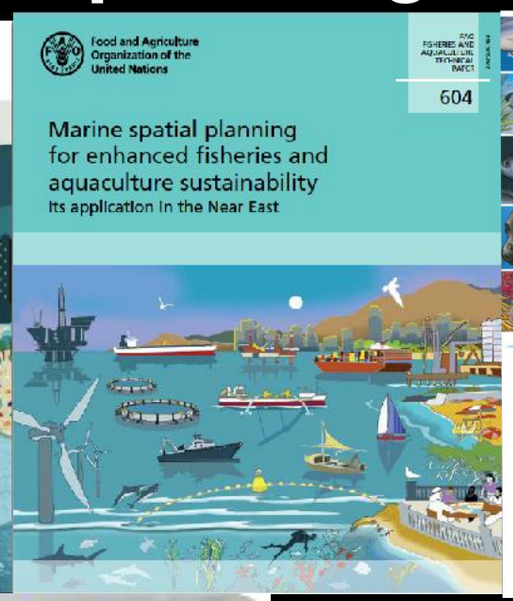
How to frame biodiversity and ecosystems into a spatial context and achieve GES in ALL waters?

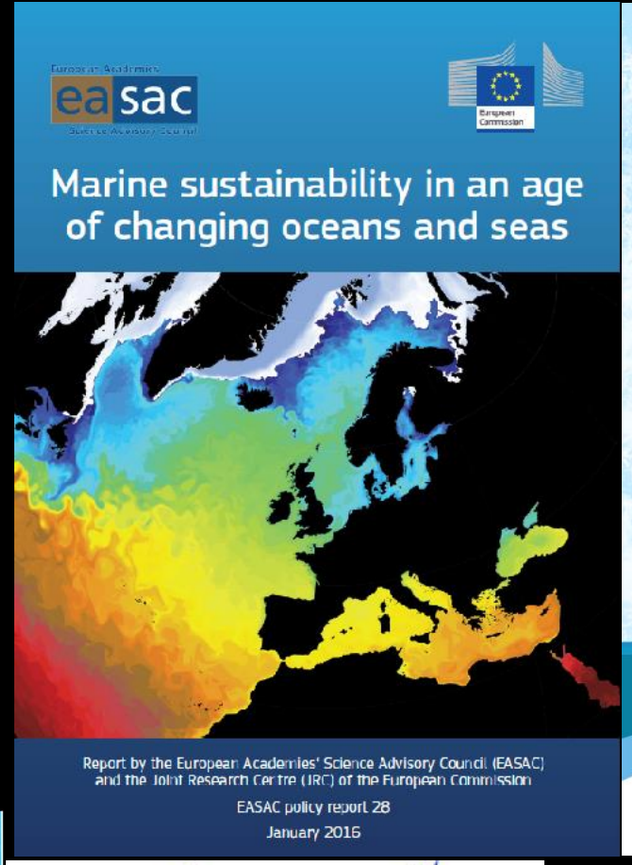
Sustainability is a must
Many different measures in the same space

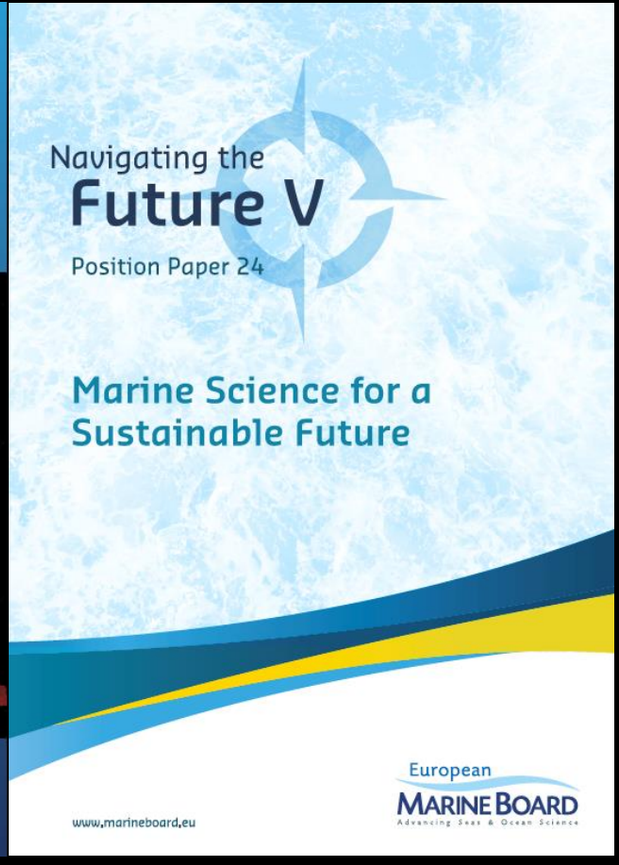
Maritime spatial planning

Marine spatial planning

MPA networks





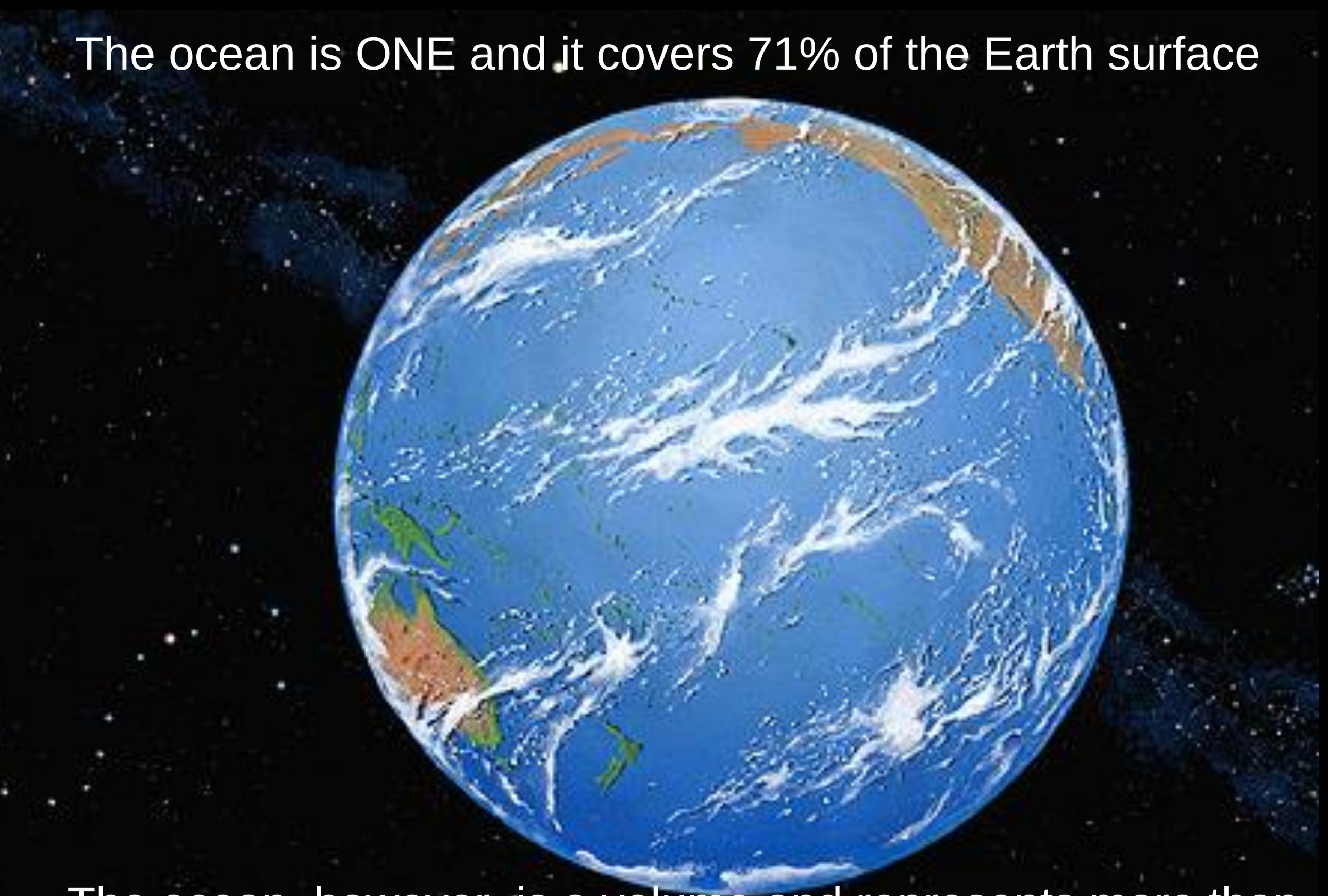


Sites of Community Importance

Integrated coastal zone management

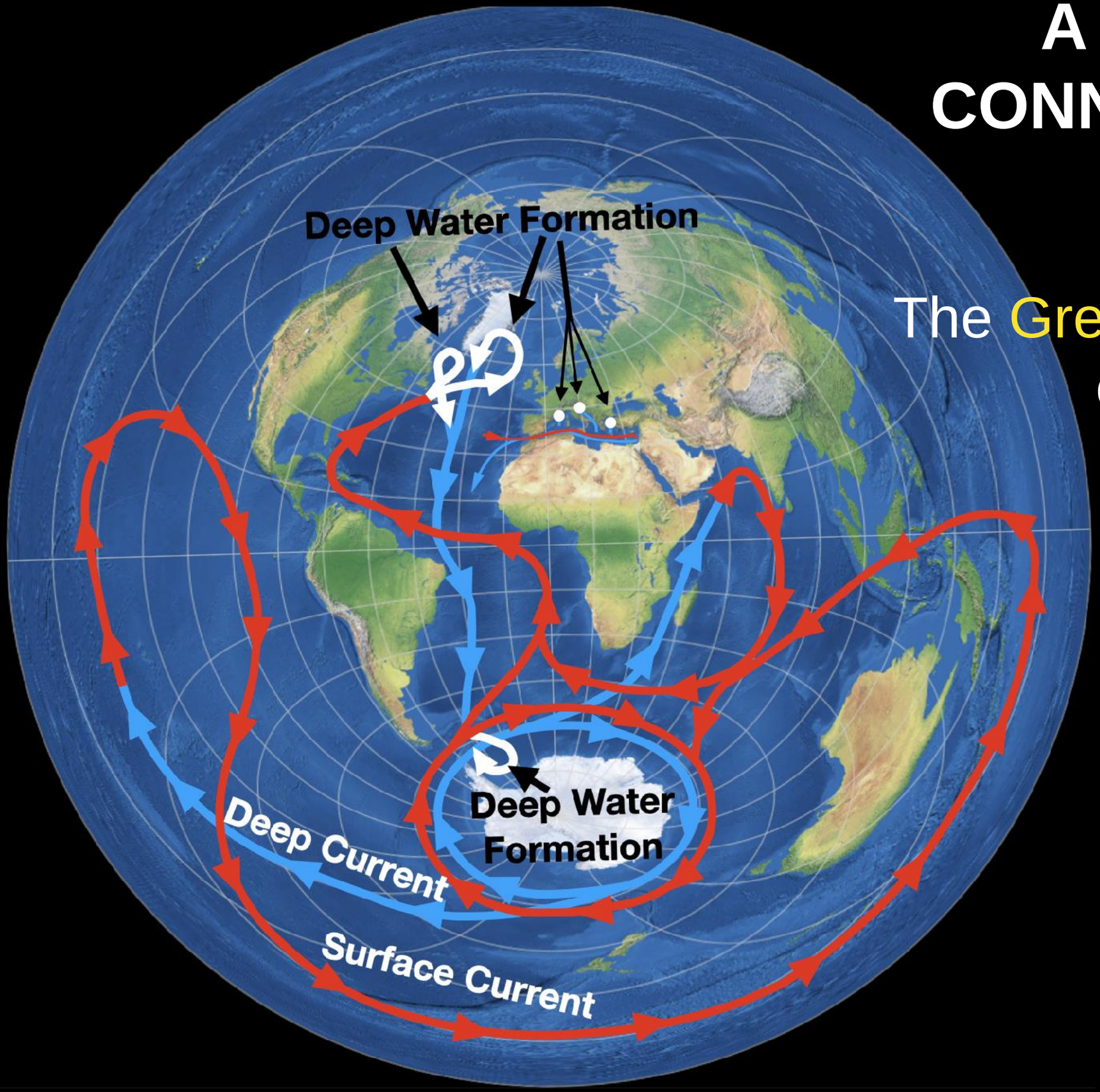
Other Effective Conservation Measures

The ocean is ONE and it covers 71% of the Earth surface



The ocean, however, is a volume and represents more than 90% of the life-inhabited space

A DYNAMIC AND CONNECTED SPACE



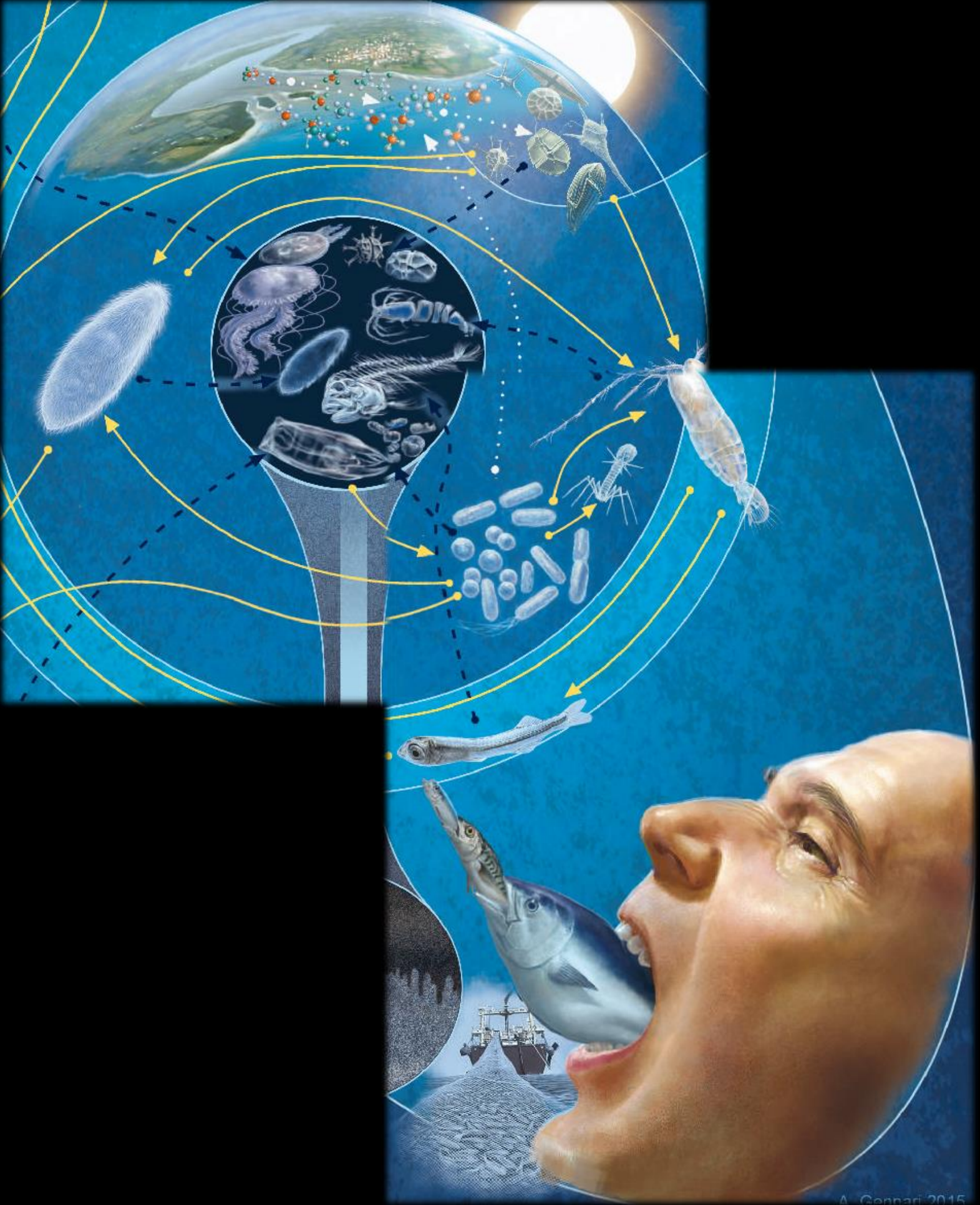
The Great Ocean Conveyor connects all oceans

The formation of sea ice produces dense waters that sink and come back to surface in a grand circulation system where the bulk of ecosystem processes takes place

Most ecosystem processes take place in the water column where matter flows along different pathways

the microbial pathway

for billions of years life functioned in this way



the microbes-crustacea-fish pathway

our favorite one

the herbivorous gelatinous plankton pathway

a rather neglected one

the carnivorous gelatinous plankton pathway

the most disliked one

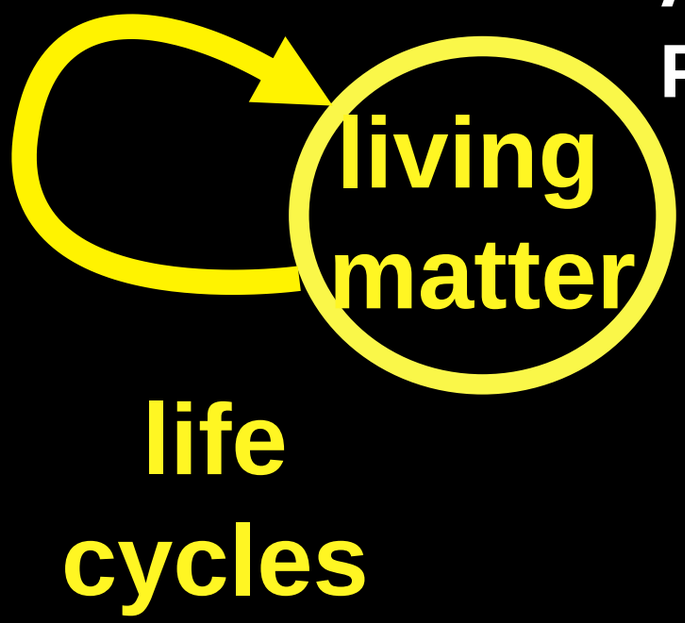
ALL TOGETHER NOW!

with carbon sequestration

The four pathways that lead to ecosystems functioning occur through a series of fluxes: the processes that link biodiversity structures

- life cycles: intra specific fluxes from one generation to the next
- trophic networks: inter specific fluxes from one species to another one
- biogeochemical cycles: extra specific fluxes from living to non living matter and from non living to living matter

intra-inter-extra-specific fluxes

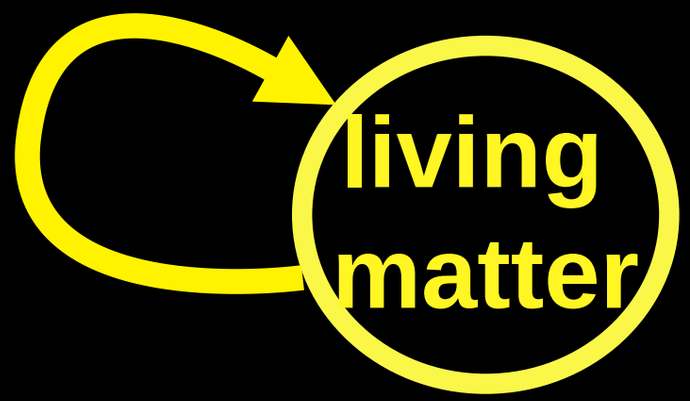


life
cycles

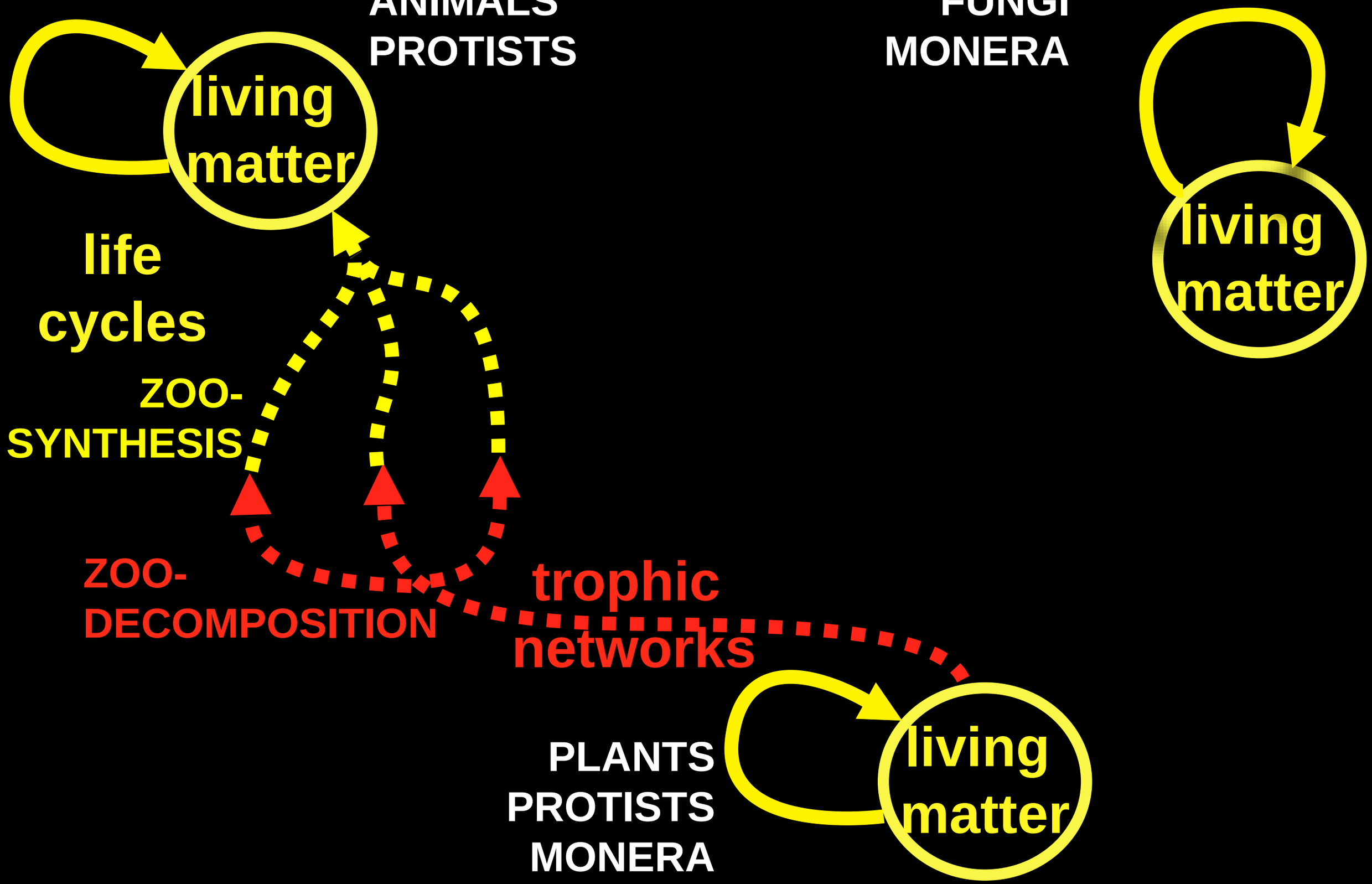
ANIMALS
PROTISTS

FUNGI
MONERA

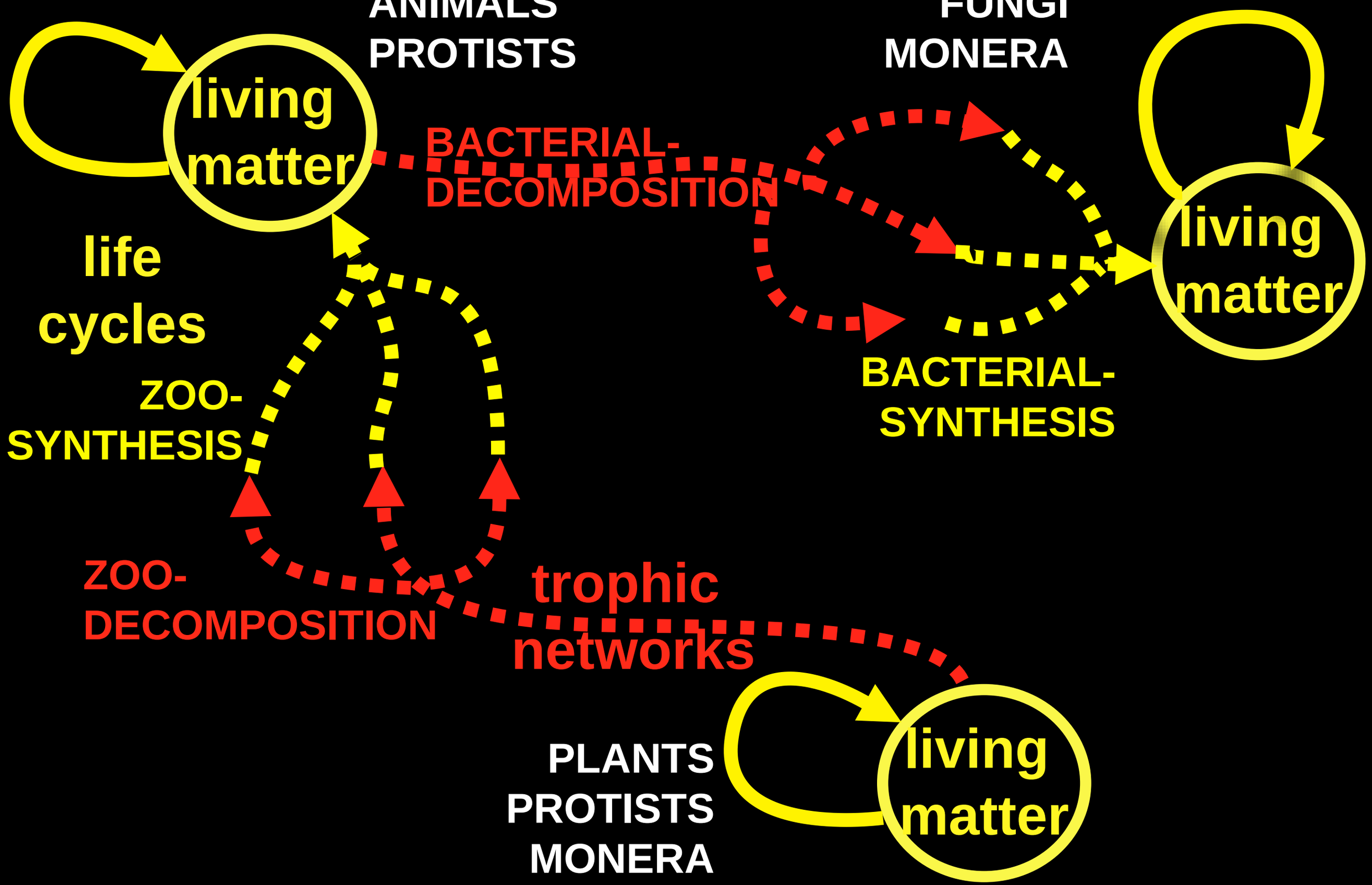
PLANTS
PROTISTS
MONERA



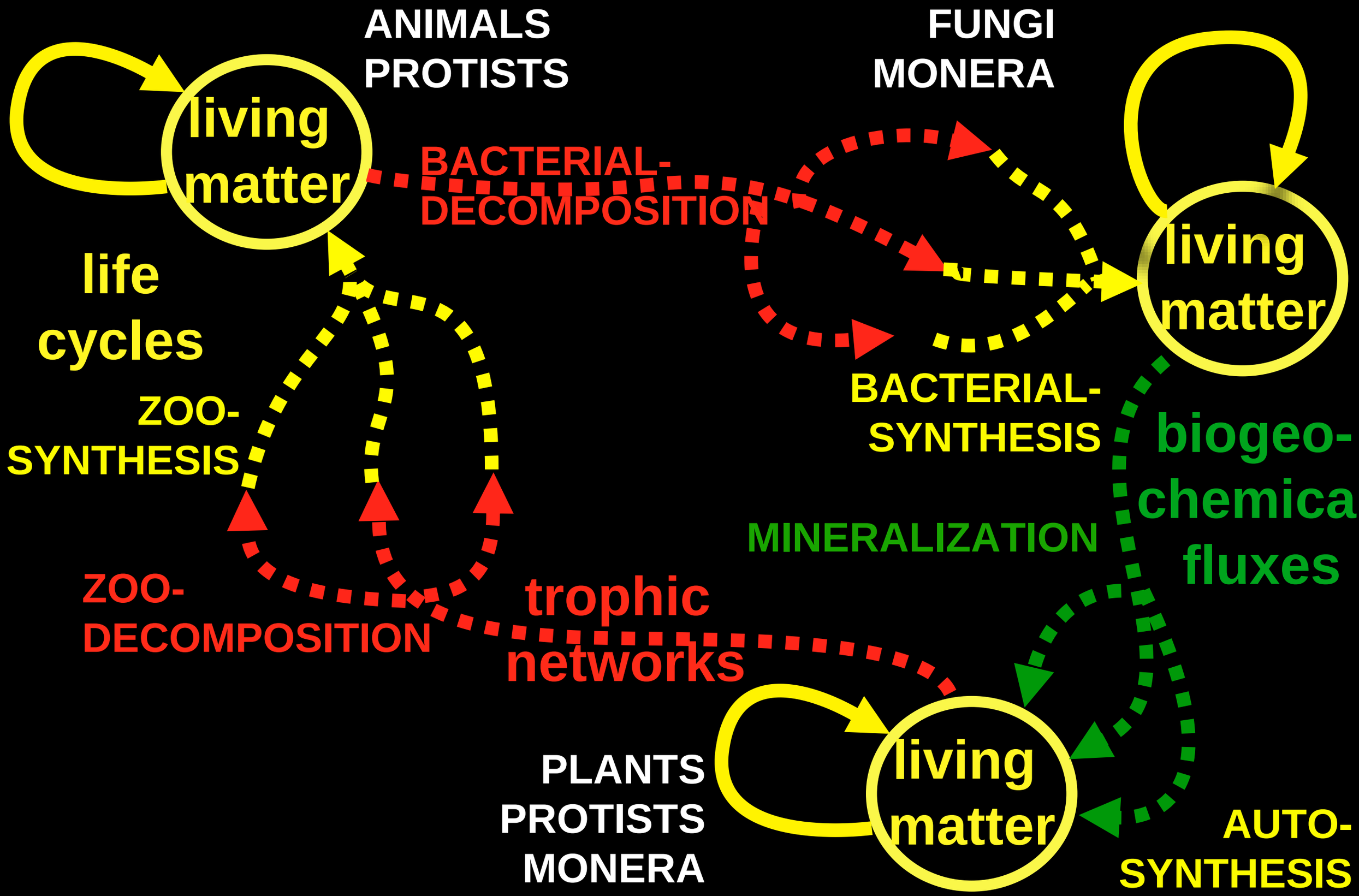
intra-inter-extra-specific fluxes



intra-inter-extra-specific fluxes



intra-inter-extra-specific fluxes



BGC = Biogeochemical cycles = Extra-specific Fluxes
LC = Life cycles = Intra-specific Fluxes
TN = Trophic Networks = Inter-specific Fluxes

BFD= Bacterial-Fungal Decomposition
ZD = ZooDecomposition
M = Mineralization

LC

Primary Producers

Photo-chemio synthesis

PLANTA
PROTISTA
MONERA

ZD

LC

Secondary Producers

Zoo-synthesis

ANIMALIA

LC

Higher Trophic Levels

Zoo-synthesis

ZD

ANIMALIA
PROTISTA

ZD

TN

Tertiary Producers

Zoo-synthesis

LC

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PROTISTA

BFD

ZD

FUNGI
MONERA

BFD

TN

BFD

Tertiary Producers
Zoo-synthesis

ZD

M
LC
Decomposers
Bacterial-fungal synthesis

LC

BFD

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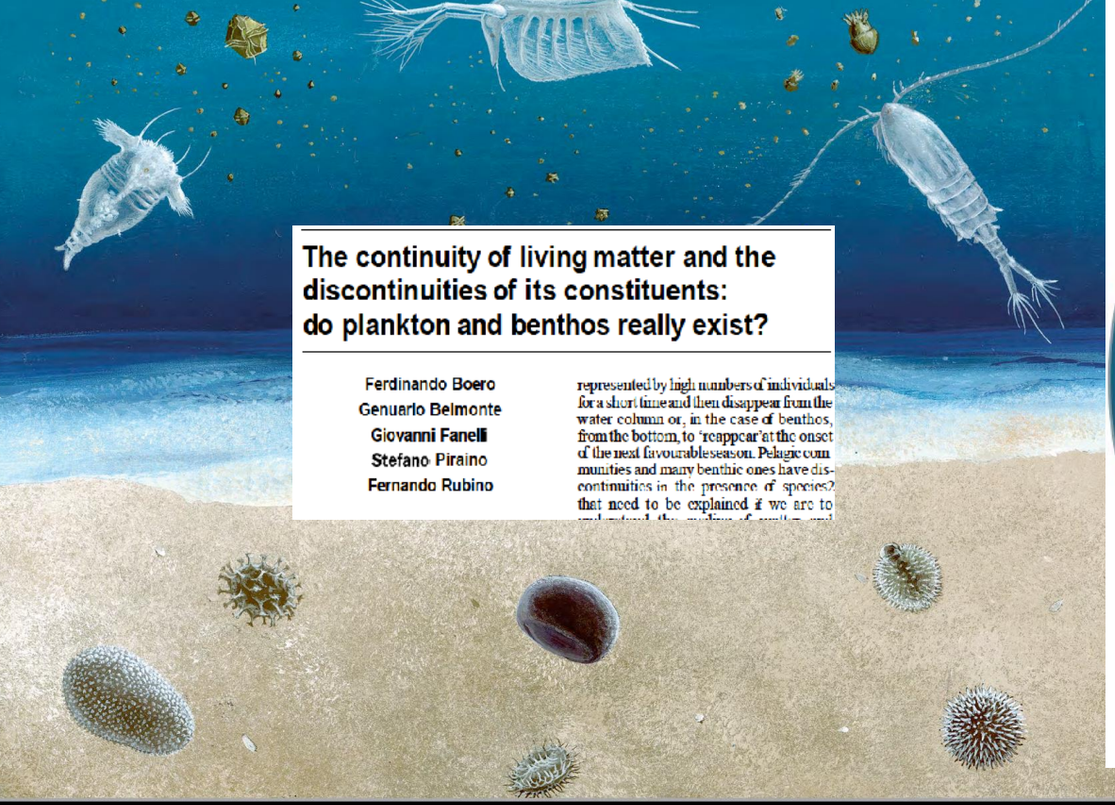


The continuity of living matter and the discontinuities of its constituents: do plankton and benthos really exist?

Ferdinando Boero
Genuario Belmonte
Giovanni Fanelli
Stefano Piraino
Fernando Rubino

represented by high numbers of individuals for a short time and then disappear from the water column or, in the case of benthos, from the bottom, to 'reappear' at the onset of the next favourable season. Pelagic communities and many benthic ones have discontinuities in the presence of species that need to be explained if we are to

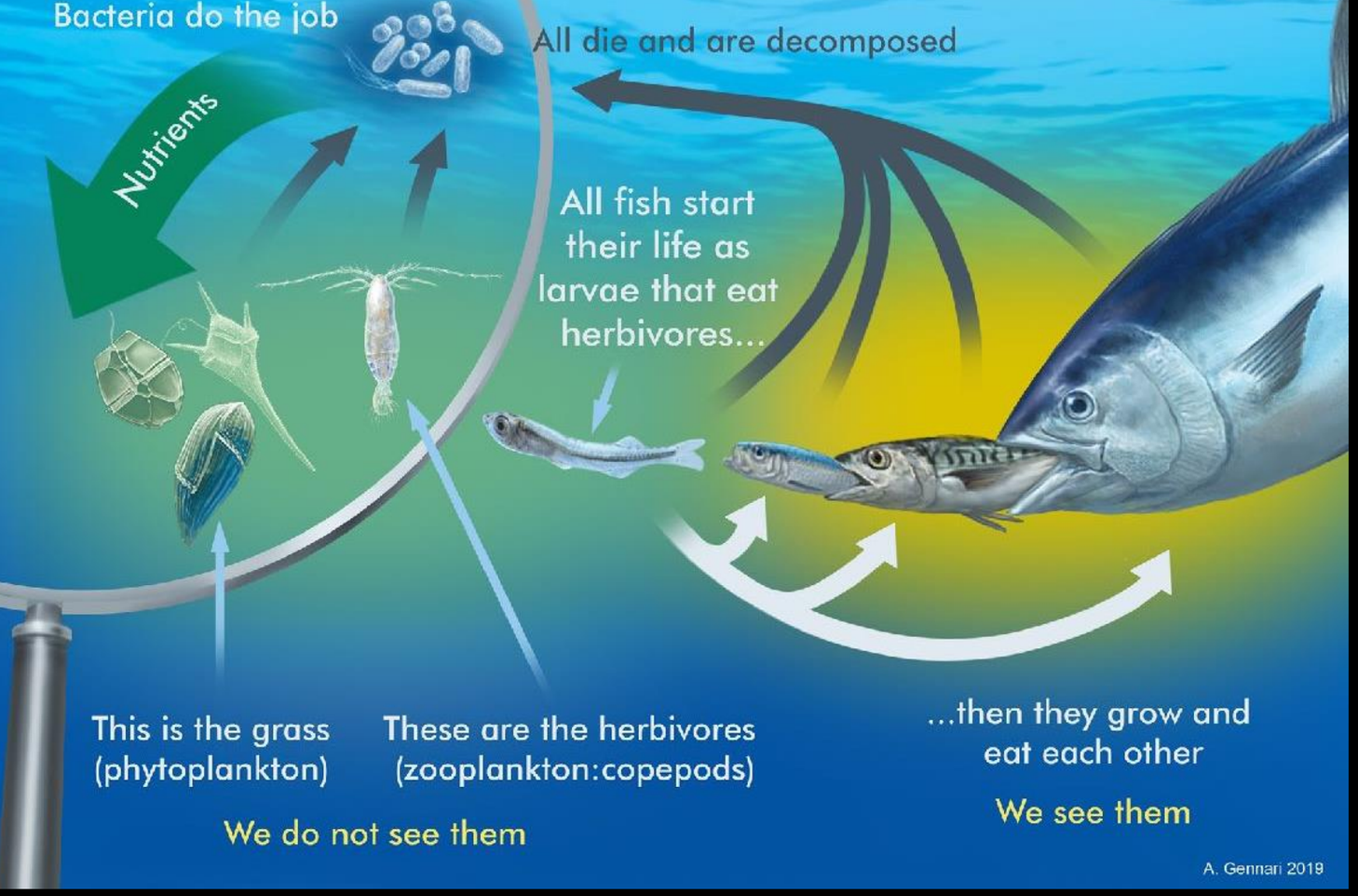
Vol. 356: 299–310, 2008
doi: 10.3354/meps07358
MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser
Published March 18

AS WE SEE IT*

Gelatinous plankton: irregularities rule the world (sometimes)

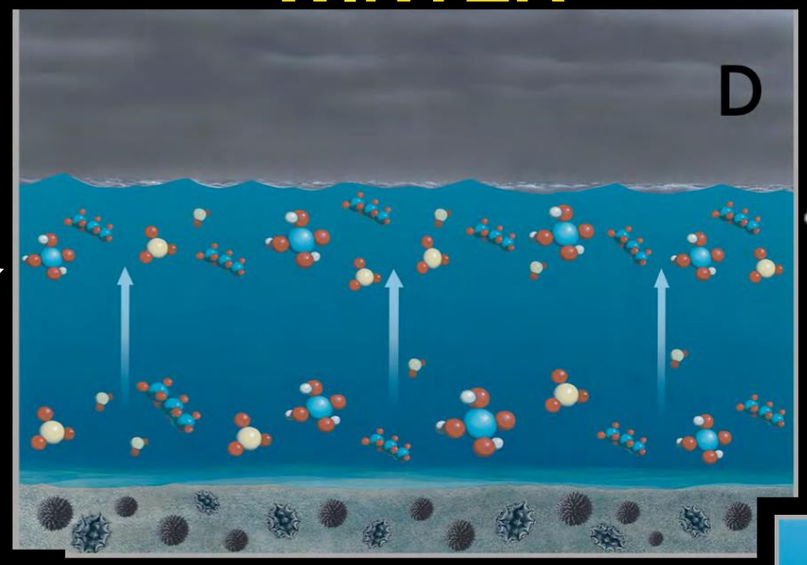
F. Boero[1,**,***], J. Bouillon[1], C. Gravili[1], M. P. Miglietta[2], T. Parsons[3], S. Piraino[1,***]

PLANKTON BENTHOS AND NEKTON?

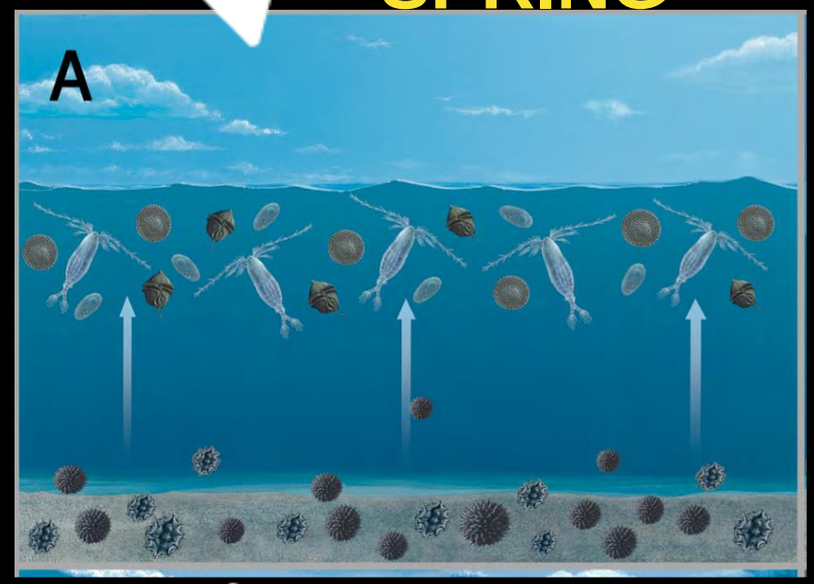


SEASONS SHUFFLE THE CARDS

WINTER

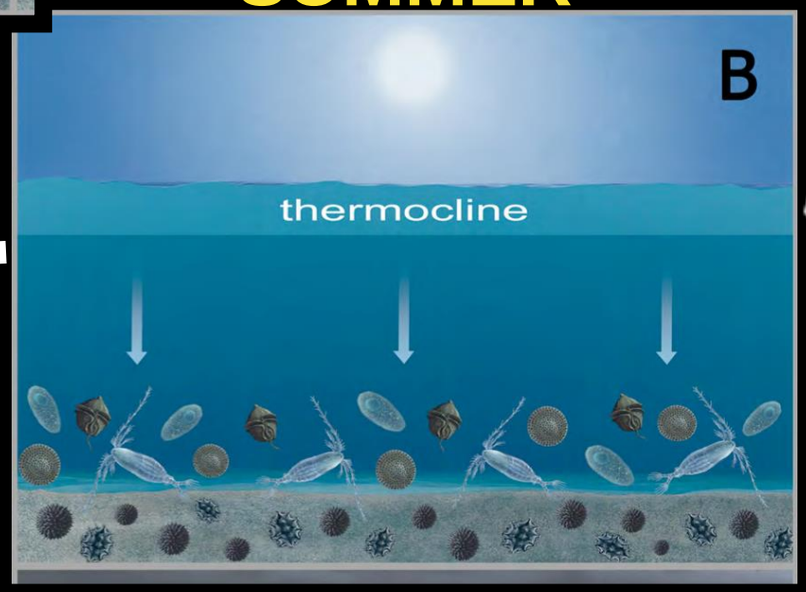


SPRING



FALL

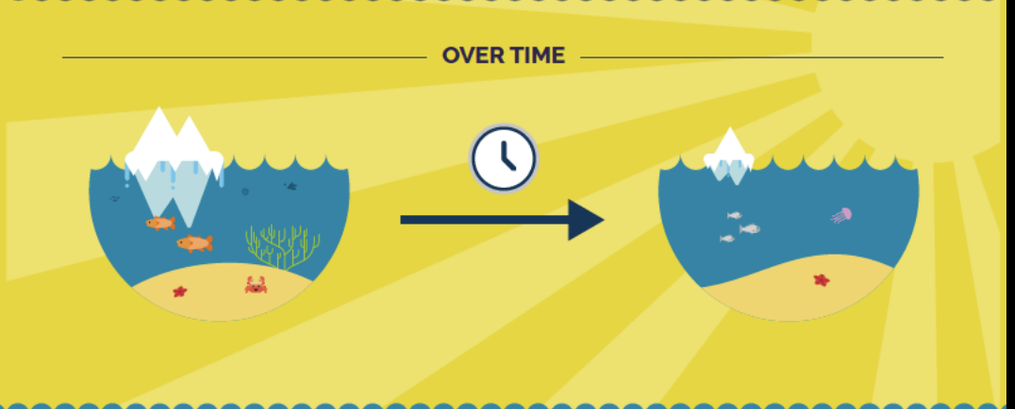
SUMMER

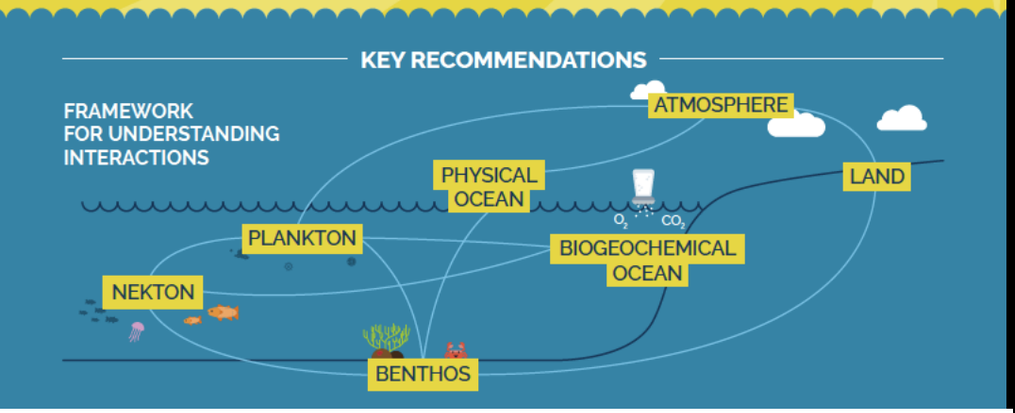


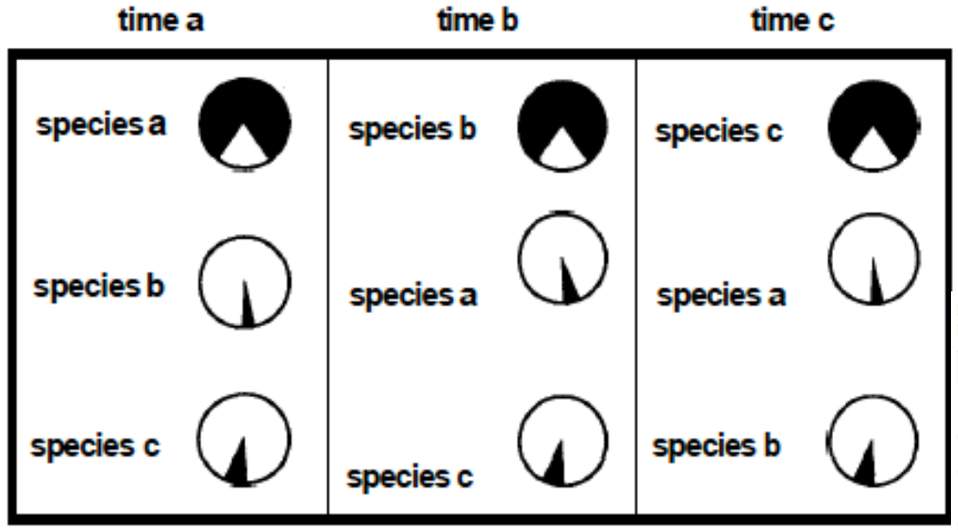
A 4D OCEAN

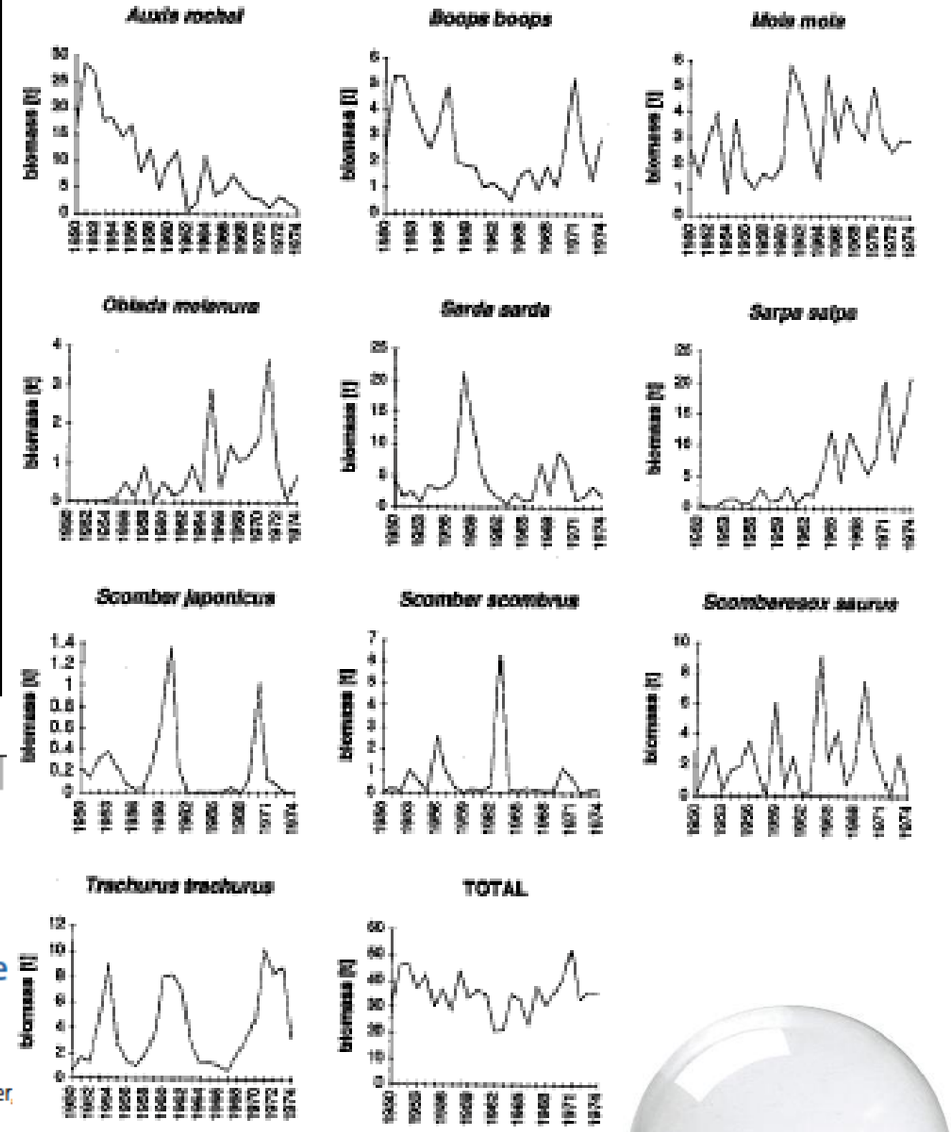
The ocean is not a surface: it is a volume! and it keeps changing

A 4th dimension (time) must be added to the 3 spatial dimensions









Rend. Fis. Acc. Lincei (2015) 26:3–12
DOI 10.1007/s12210-014-0340-y

SUSTAINABLE MANAGEMENT OF THE MEDITERRANEAN

The future of the Mediterranean Sea Ecosystem: towards a different tomorrow

Ferdinando Boero

P.S.Z.N.I: Marine Ecology, 15 (1): 3–25 (1994)
© 1994 Blackwell Wissenschafts-Verlag, Berlin
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TOPIC
Accepted: May 7, 1993

Fluctuations and Variations in Coastal Marine Environments

FERDINANDO BOERO

P.S.Z.N. I: Marine Ecology, 17 (1-3): 237–250 (1996)
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Accepted: January 30, 1995

Episodic Events: Their Relevance to Ecology and Evolution

FERDINANDO BOERO

Navigating the Future V: Marine Science for a Sustainable Future
European Marine Board – Position Paper 24
Coordinating authors
Ferdinando Boero, Valerie Cummins, Jeremy Gault, Geir Huse, Catharina J.M. Philippart, Ralph Schneider, Anne Marie Treguier

ECOLOGY LETTERS

Ecology Letters, (2014) 17: 1518–1525 doi: 10.1111/ele.12354

Gregory L. Britten,[1,2]* Michael Dowd,[2] Cóilín Minto,[3] Francesco Ferretti,[4] Ferdinando Boero[5] and Heike K. Lotze[1]

Predator decline leads to decreased stability in a coastal fish community

Contents lists available at ScienceDirect

Journal of Sea Research

journal homepage: www.elsevier.com/locate

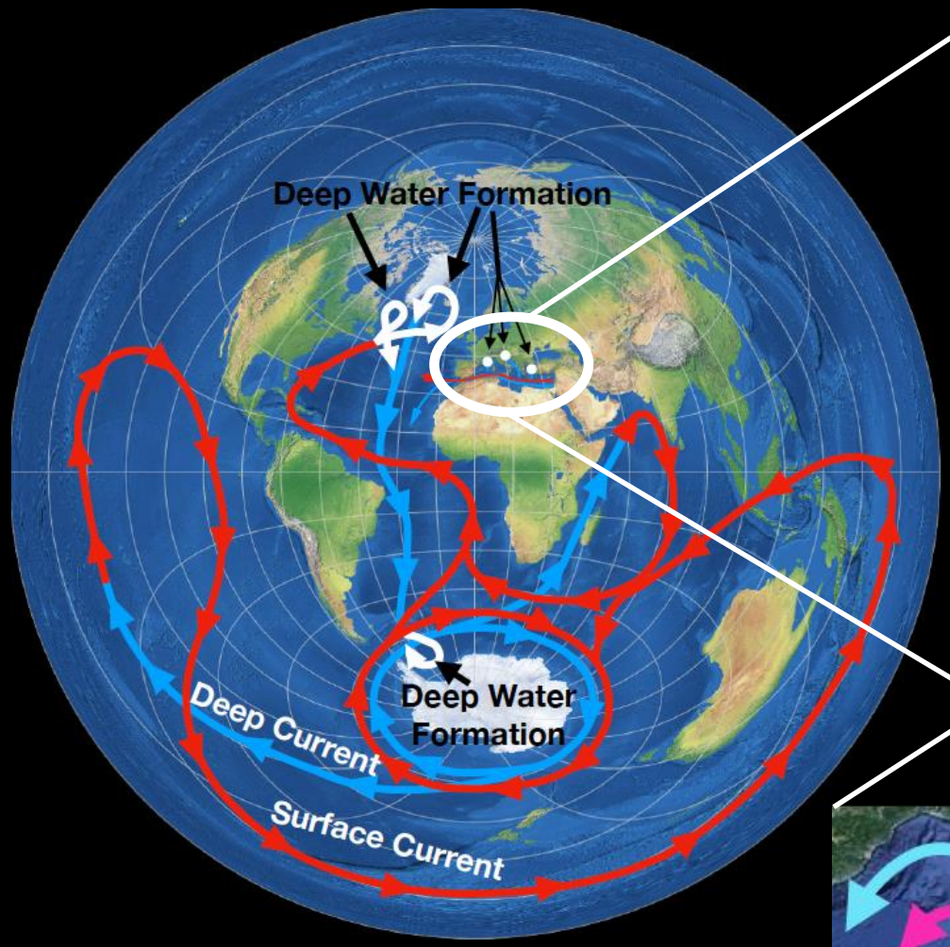
Time is an affliction: Why ecology cannot be as predictive as physics and why it needs time series

F. Boero [a,b], A.C. Kraberg [c,*], G. Krause [d], K.H. Wiltshire [c]

Predictive science eh?

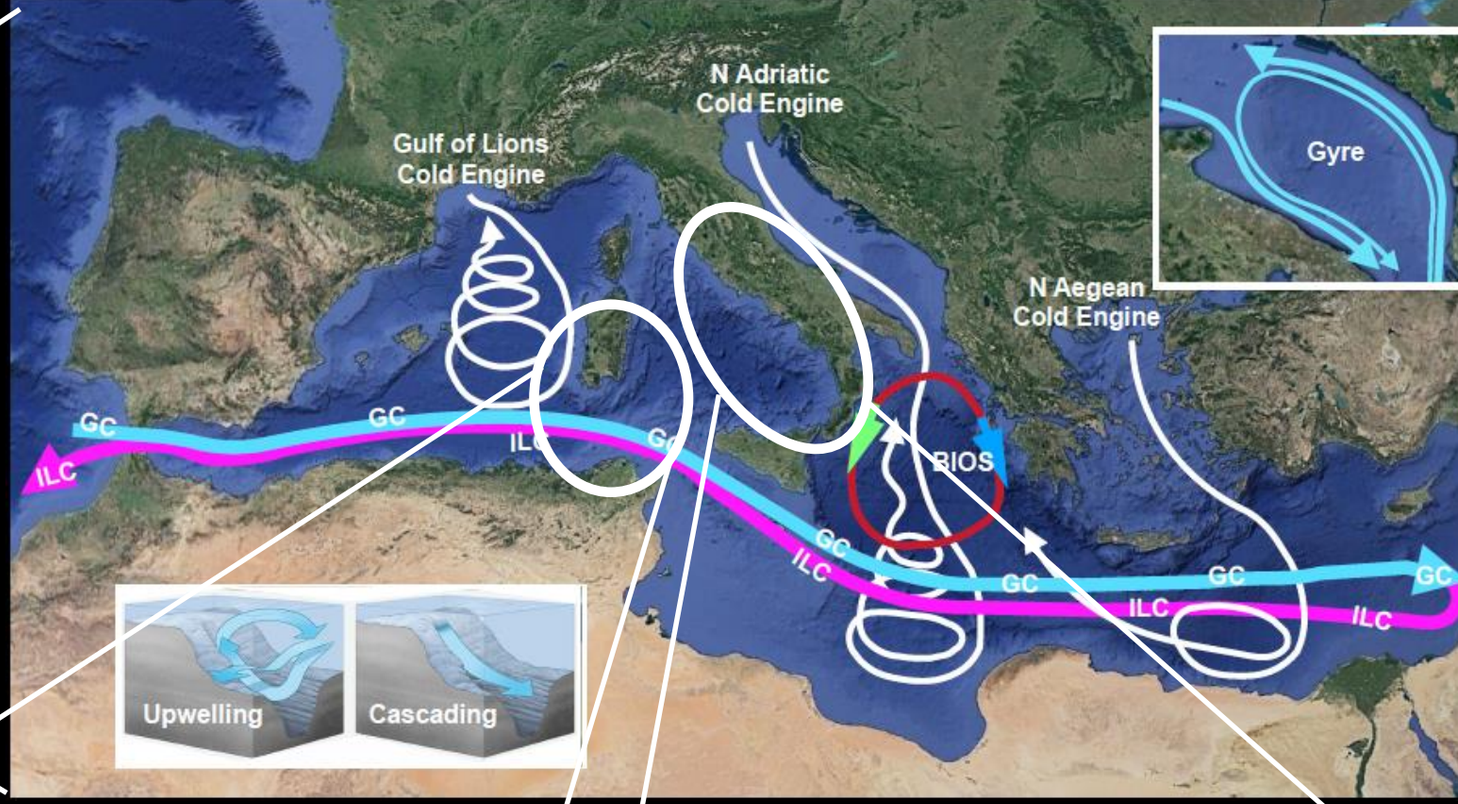
defining the spatial units of management and conservation

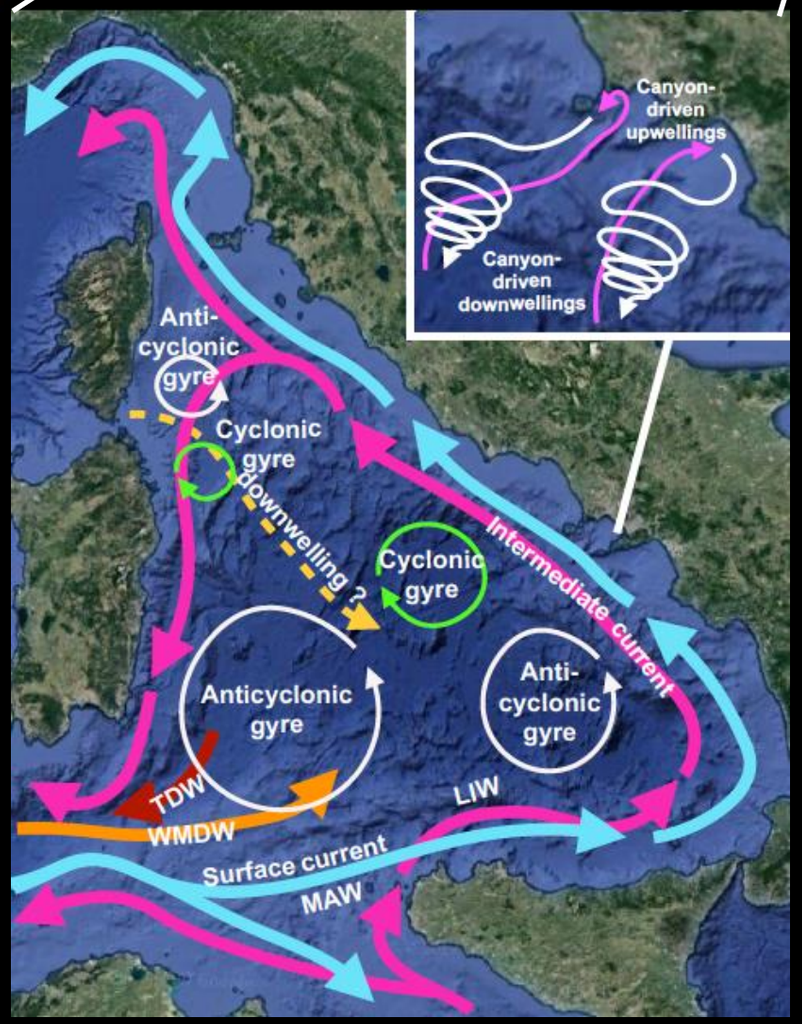
- They must be based on sound ecological grounds
- We cannot base the units based on our activities
- We must tailor our activities on the features of the environment
- Connectivity is crucial to define the spatial units of management and conservation



The world Ocean is highly connected, but it can be divided into volumes that are more connected within their boundaries than they are with neighboring ones

From physics to ecology: the Cells of Ecosystem Functioning

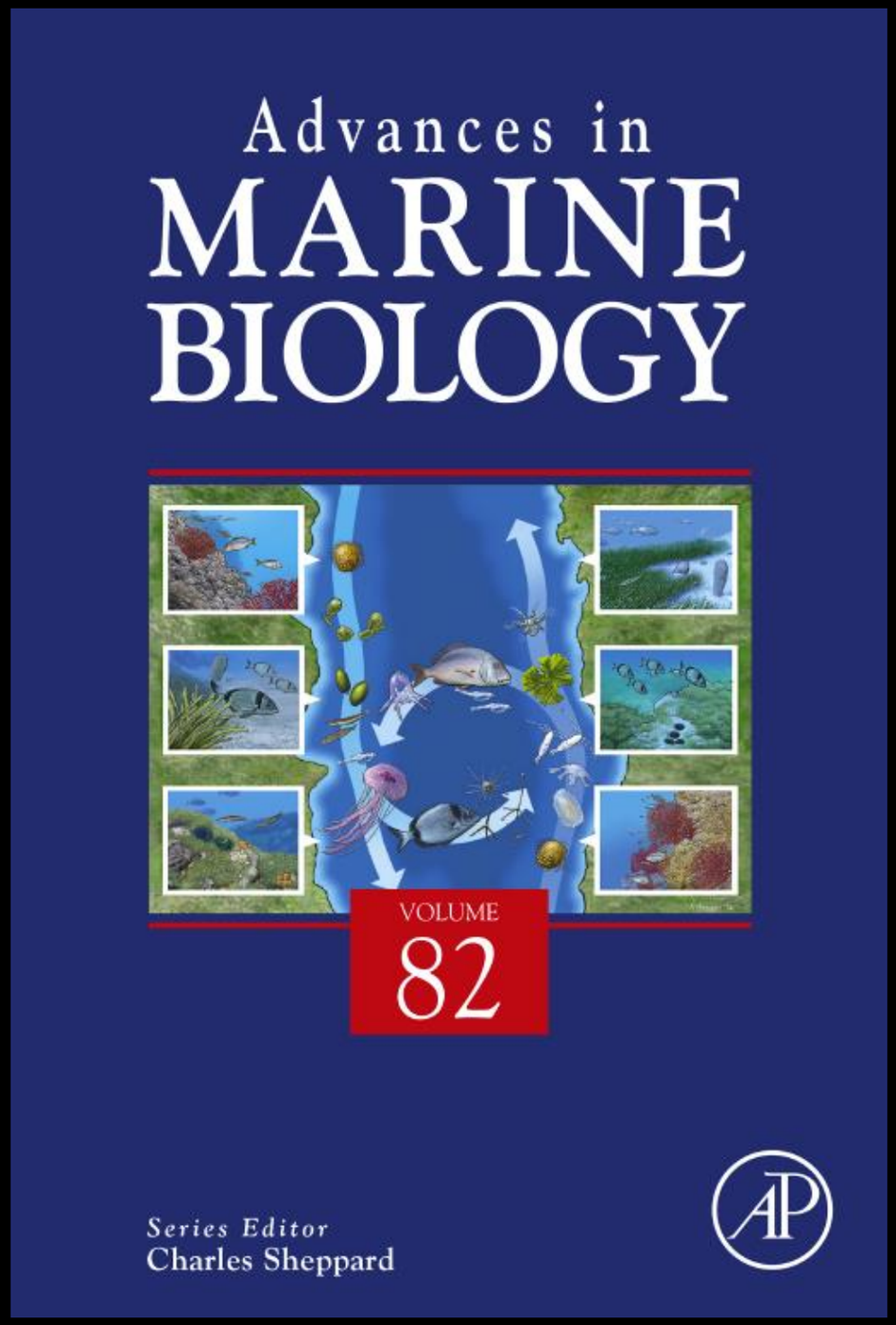


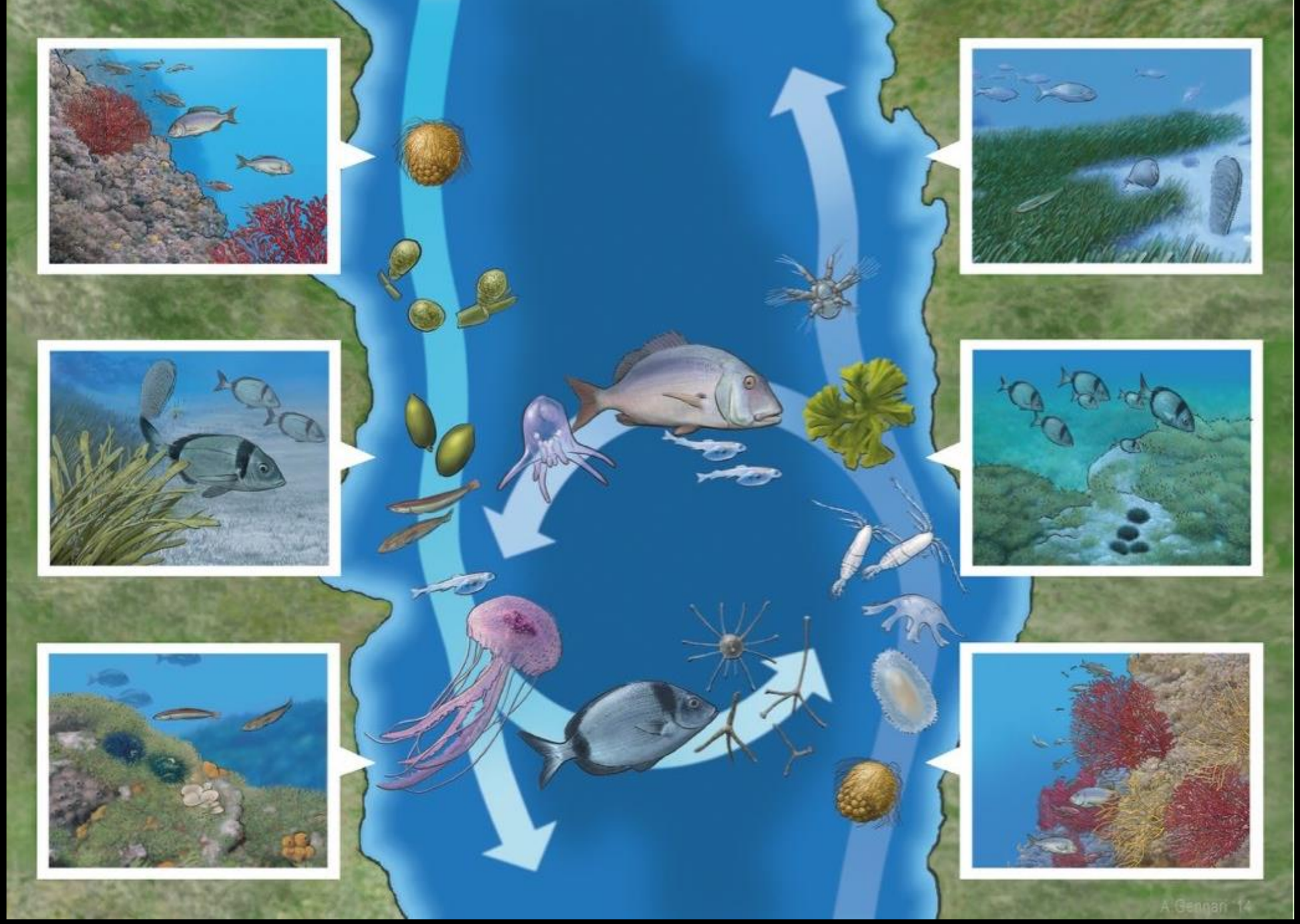


Connectivity can be assessed in many ways

- Currents determine a dynamic medium that “flows” but not all species respond in the same way to current regimes

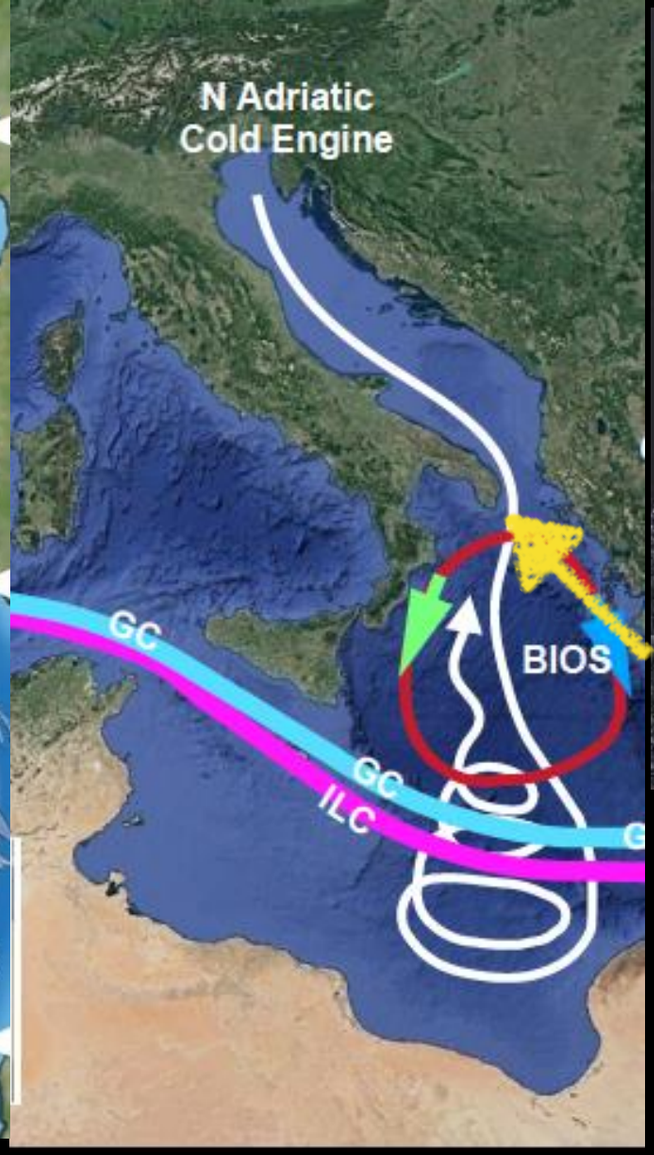
- Beta diversity
- Genetic fluxes
- Propagule fluxes
- Trophic fluxes

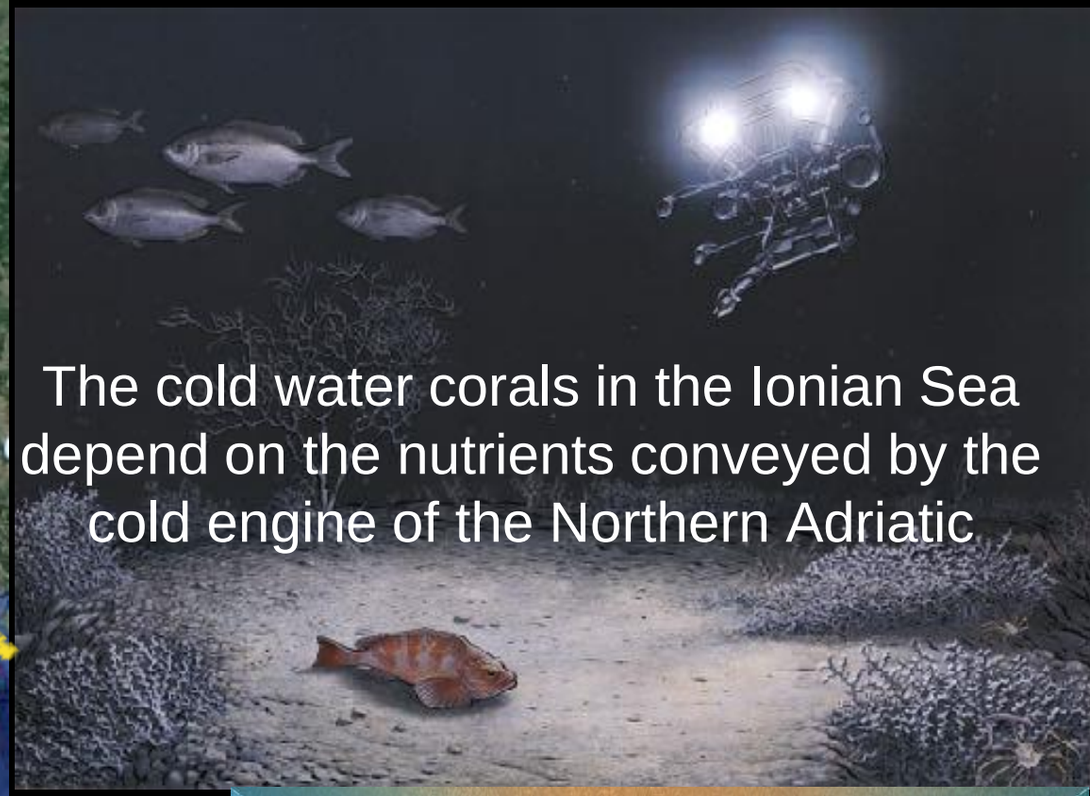




Currents disperse propagules, connecting similar habitat types where beta-diversity and gene flows are a measure of connectivity

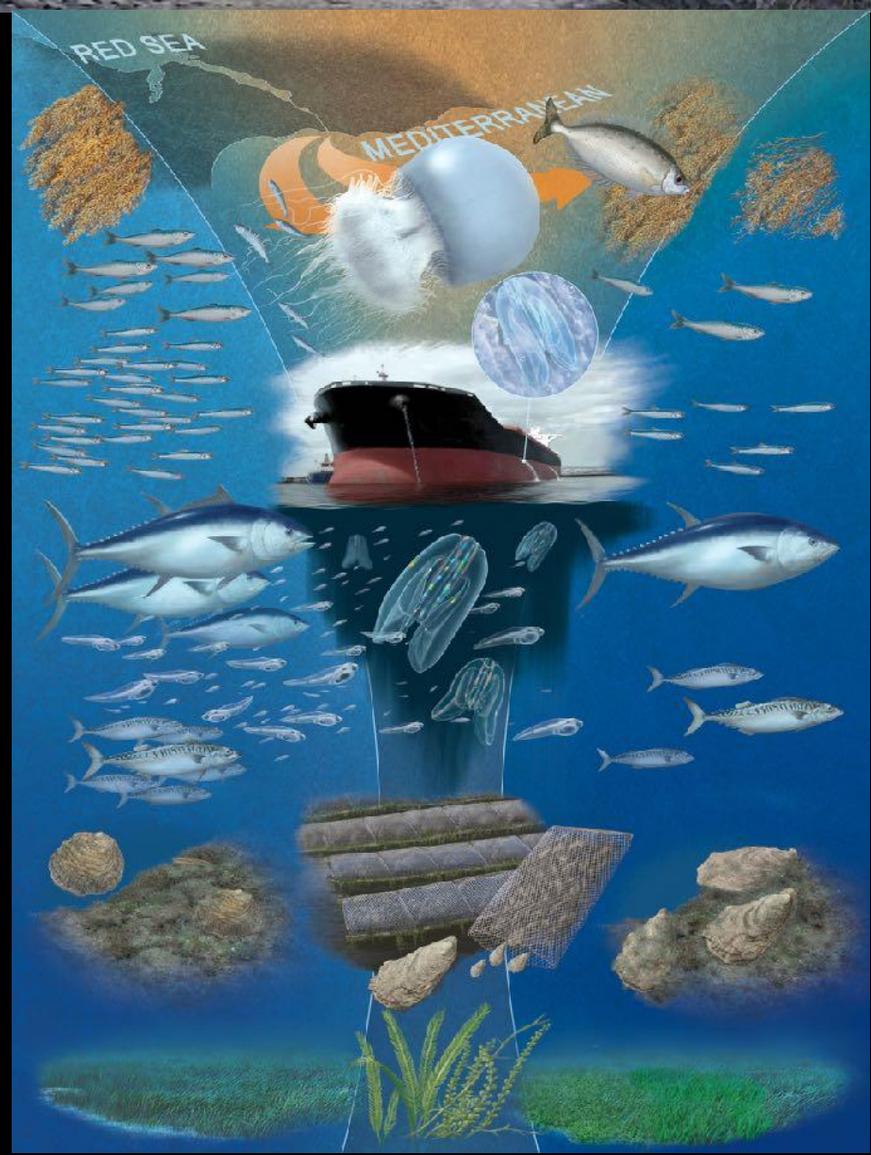
Biodiversity patterns are generated by ecosystem processes that are spatially defined





The cold water corals in the Ionian Sea depend on the nutrients conveyed by the cold engine of the Northern Adriatic

Connectivity occurs not only through propagule exchange but also through food webs and artificial transport



Ecosystem processes are carried out by millions of species

It is estimated that 8 million species inhabit the planet.

We named just 2 millions.

The knowledge of biodiversity is incomplete

The decade of biodiversity is ending

but biodiversity expertise is vanishing…

Sustainability is based on BEF!!!

United Nations Decade on Biodiversity

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

CONSISTENCY

- We cannot adopt several ways of protecting, managing and exploiting the same marine volumes (ICZM, MSP, MPAs, MPA networks, SCI Networks, Other Effective Conservation Measures)
- The MSFD is adopted in different fashions by different EU states
- Nature does not care about artificial boundaries
- CEFs are natural spatial units of management and conservation
- We must adapt our activities to nature, and not vice-versa!

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BIOLOGY

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CHAPTER FOUR

The Cells of Ecosystem Functioning: Towards a holistic vision of marine space

Ferdinando Boero[a,b,c,d,*], **Francesco De Leo**[c,e], **Simonetta Fraschetti**[a,c,d], **Gianmarco Ingrosso**[c,f]

[a]Department of Biology, University of Naples Federico II, Naples, Italy
[b]Consiglio Nazionale delle Ricerche, Istituto per lo Studio degli Impatti Antropici e sostenibilità in Ambiente Marino (CNR-IAS), Genoa, Italy
[c]Consorzio Nazionale Interuniversitario per le Scienze del Mare (CoNISMa), Rome, Italy
[d]Stazione Zoologica Anton Dohrn, Napoli, Italy
[e]Consiglio Nazionale delle Ricerche, Istituto di Scienze Marine (CNR-ISMAR), Bologna, Italy
[f]Dipartimento di Scienze e Tecnologie Biologiche ed Ambientali (DiSTeBA), University of Salento, Lecce, Italy
*Corresponding author: e-mail address: ferdinando.boero@unina.it

Contents

Abstract

Marine space is three dimensional, the turnover of life forms is rapid, defining a fourth dimension: time. The definition of ecologically significant spatial units calls for the spatio-temporal framing of significant ecological connections in terms of extra-specific (biogeochemical cycles), intra-specific (life cycles), and inter-specific (food webs) fluxes. The oceanic volume can be split in sub-systems that can be further divided into smaller sub-units where ecosystem processes are highly integrated. The volumes where

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The next grand challenge

Map the structure and the functions of the ocean
In 4 dimensions!!!
(as suggested in NFV) and…
explore biodiversity