" General overview of the environment and ecosystems of the Mid-Atlantic Ridge"

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2. LEEP-Ifremer

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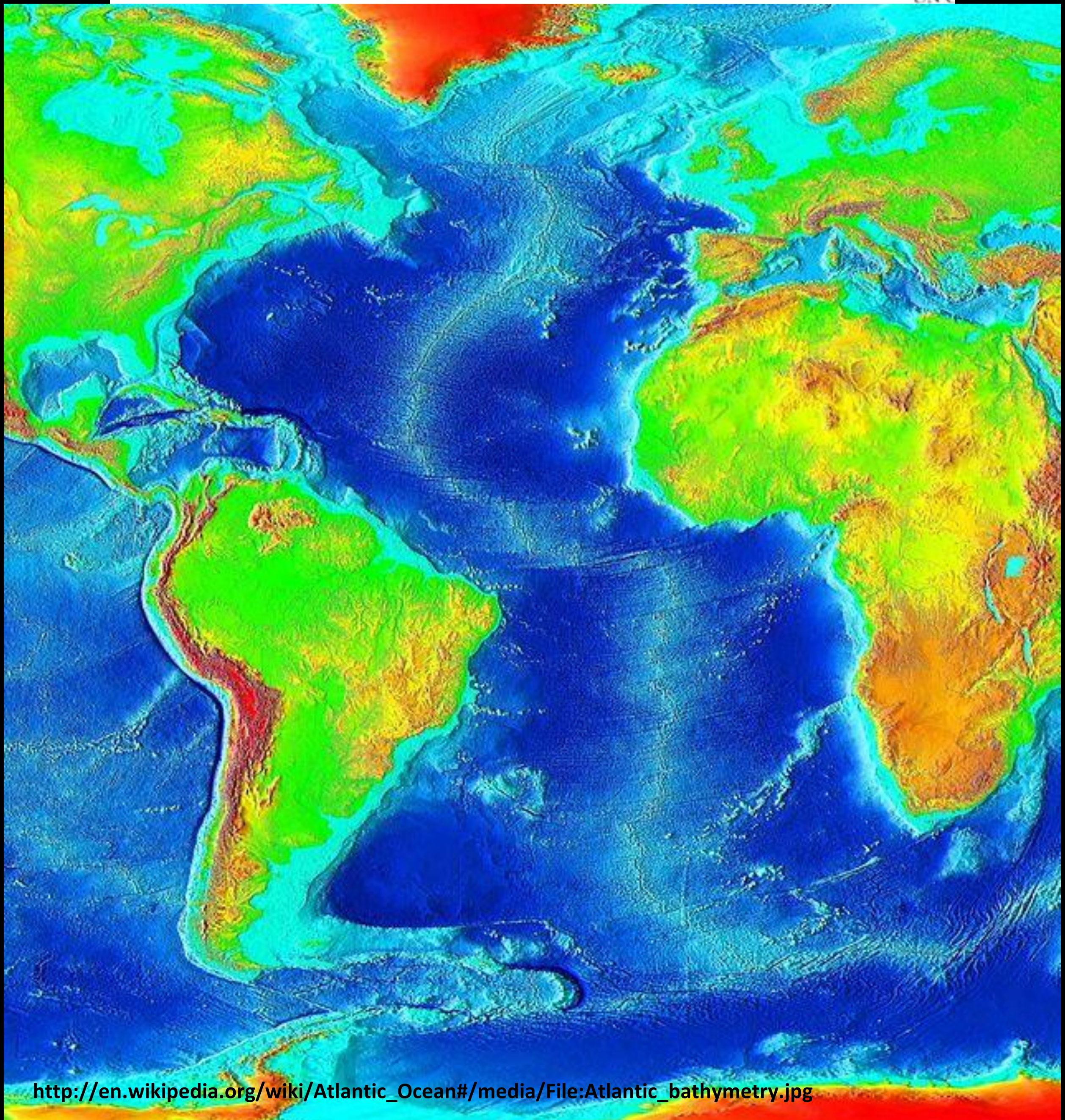
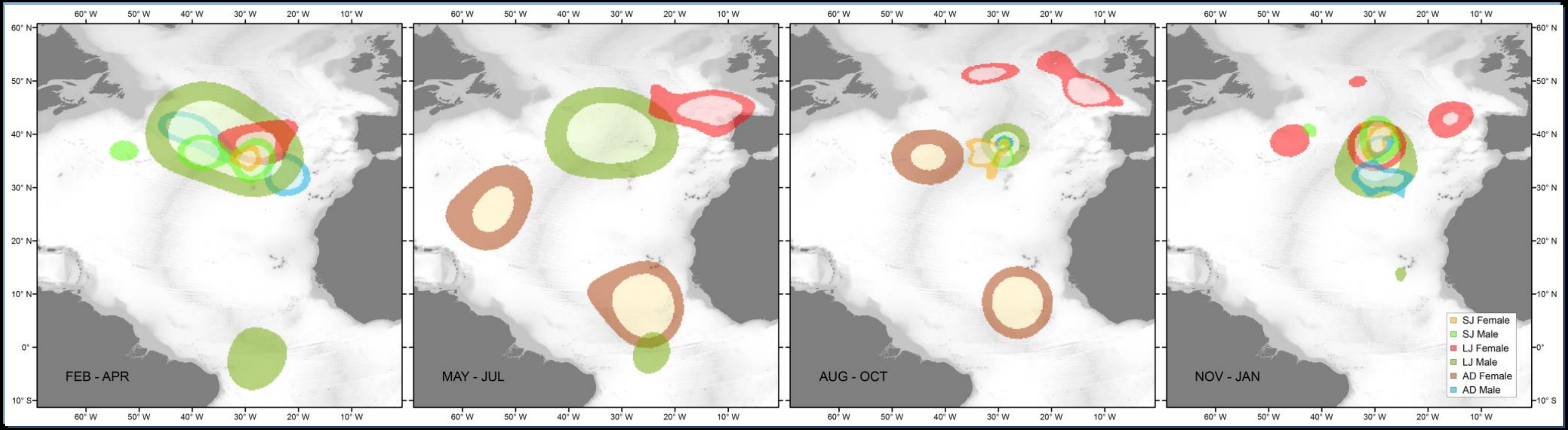
Towards the development of a strategic Environmental Management Plan for deep seabed mineral exploration and exploitation in the Atlantic basin (SEMPIA): 1-3 June 2015, Horta, Azores, Portugal



http://en.wikipedia.org/wiki/Atlantic_Ocean#/media/File:Atlantic_bathymetry.jpg

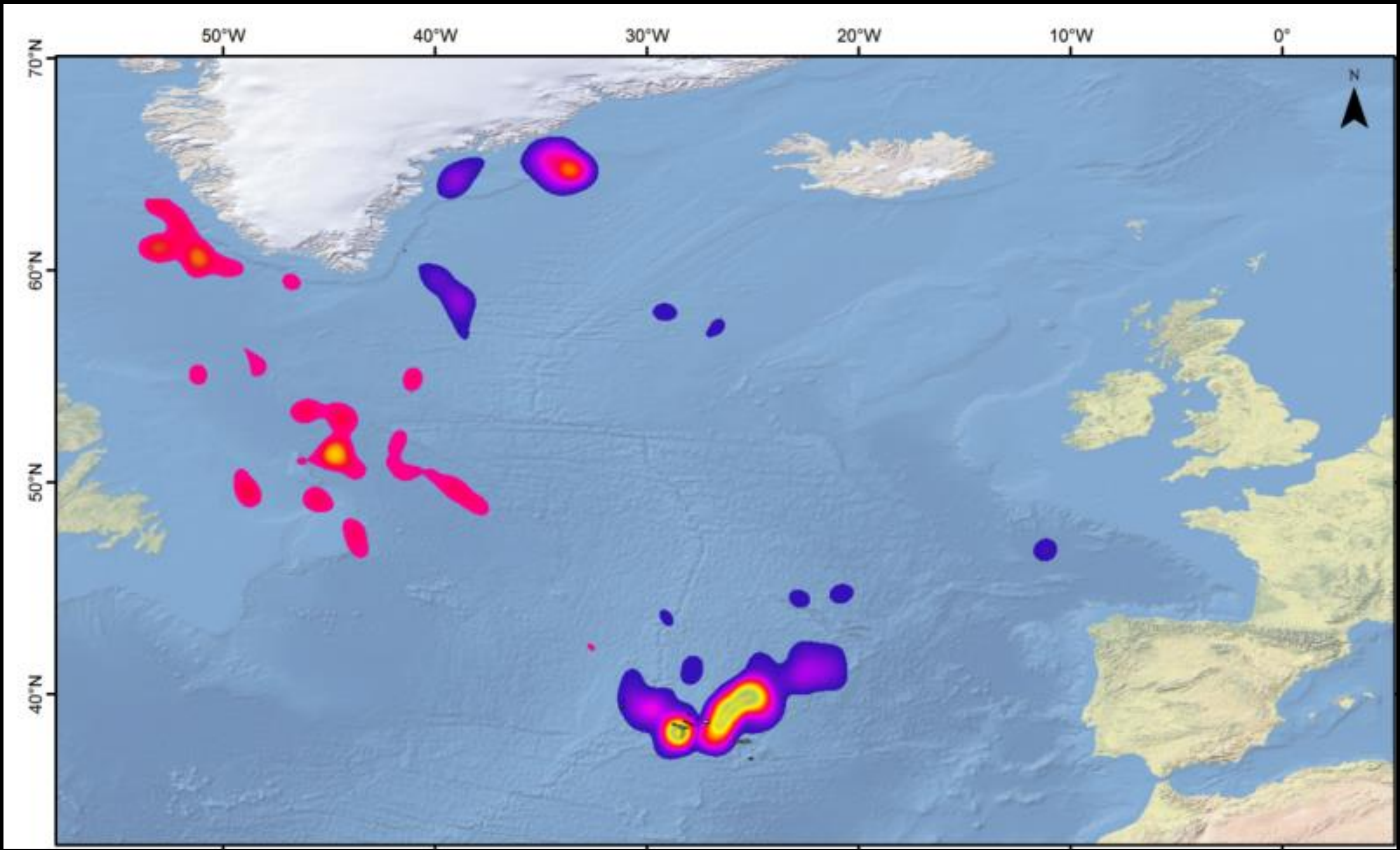
Charismatic species

Satellite telemetry: blue shark habitat preferences



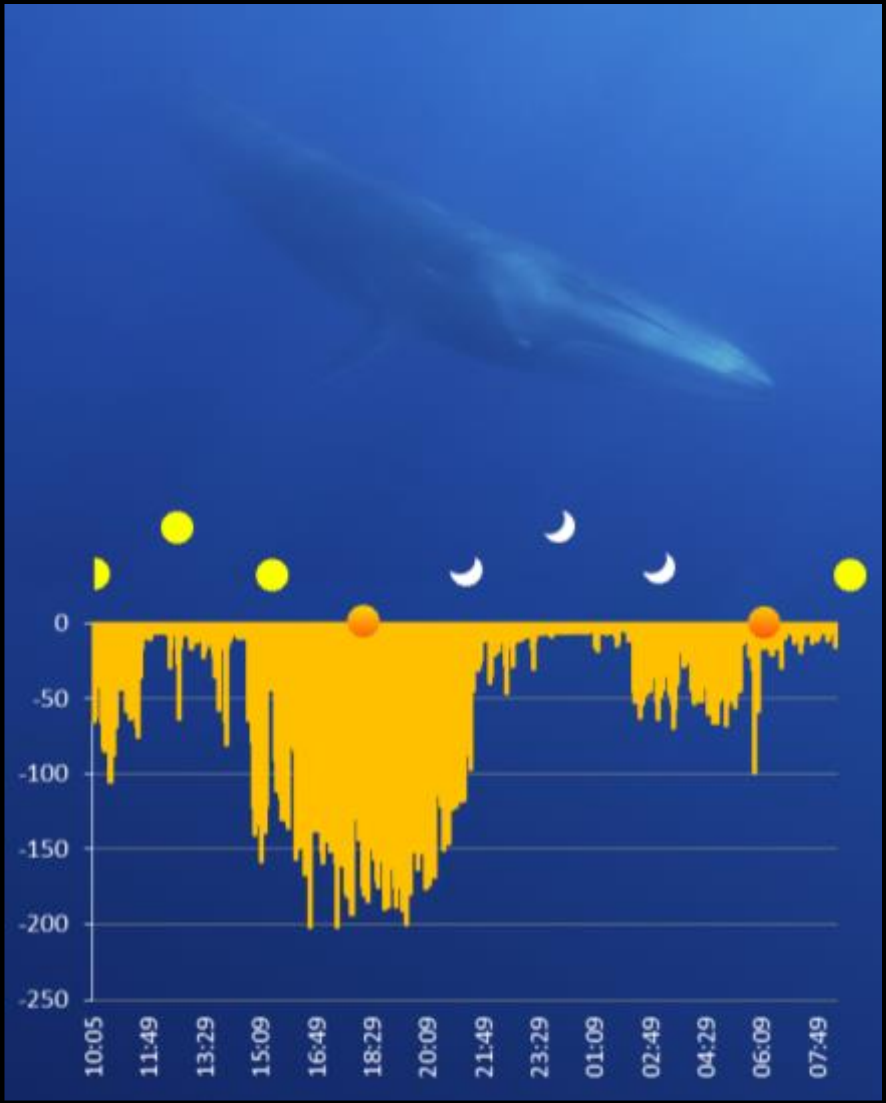
Vandeperre et al (2014) *PLoS ONE*

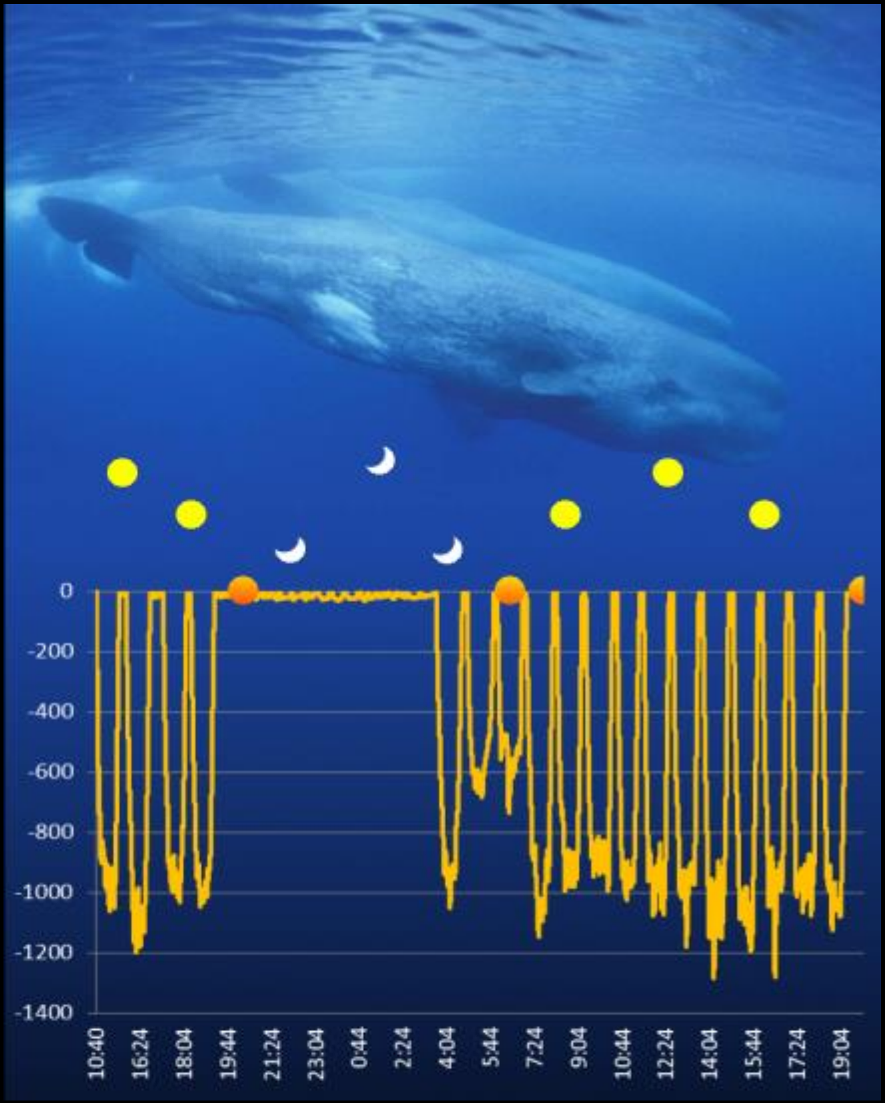
Satellite telemetry: whale migrations and habitat use



Silva et al (2013) *PLoS ONE*; Prieto et al (2014) *Endangered Species Research*.

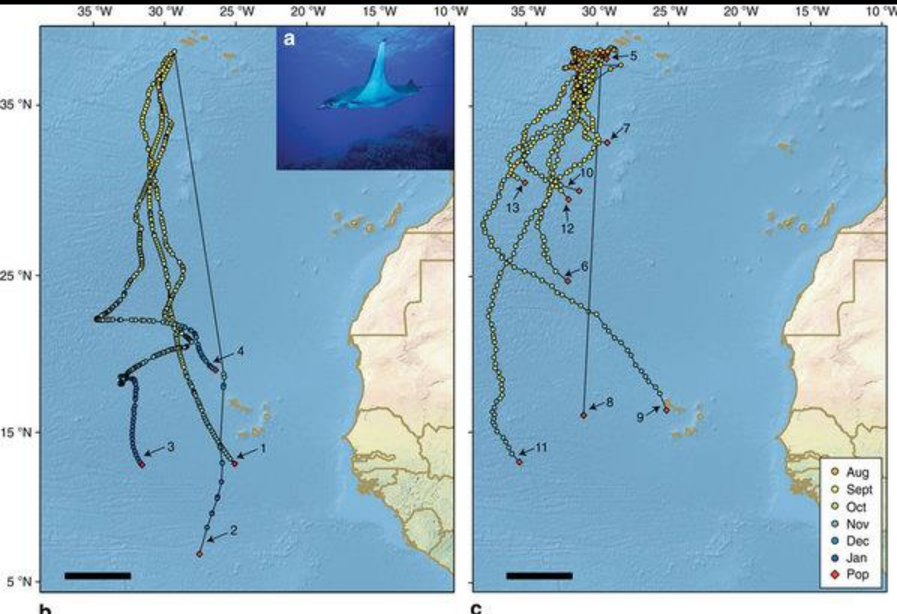
Whale diving and foraging behaviour

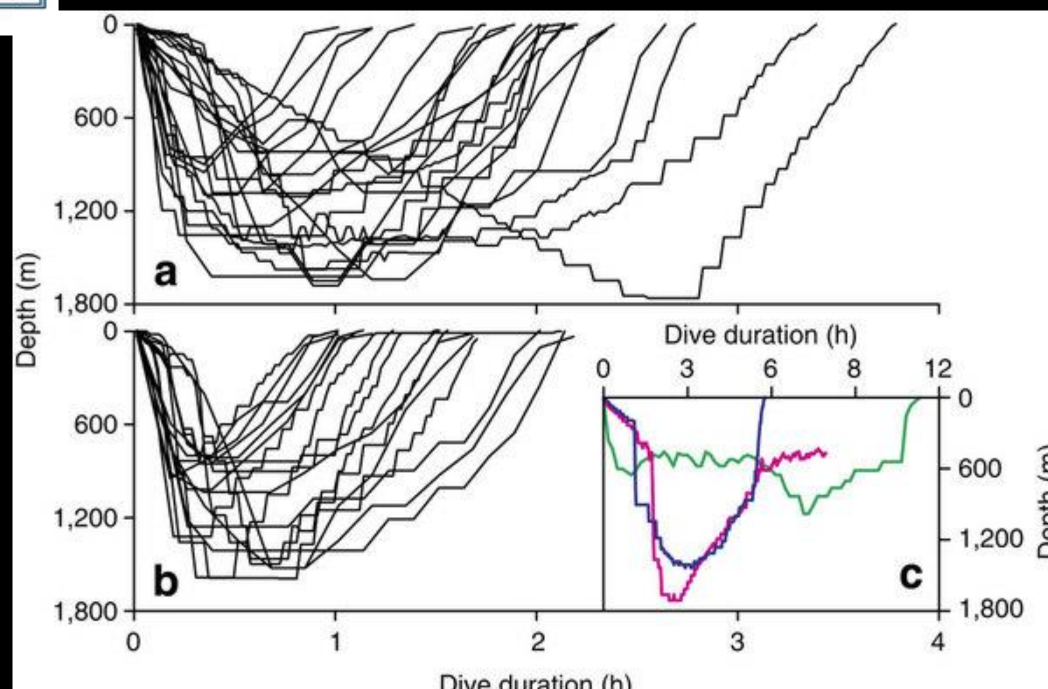




Silva et al, unpublished data

Extreme diving behaviour of devil rays

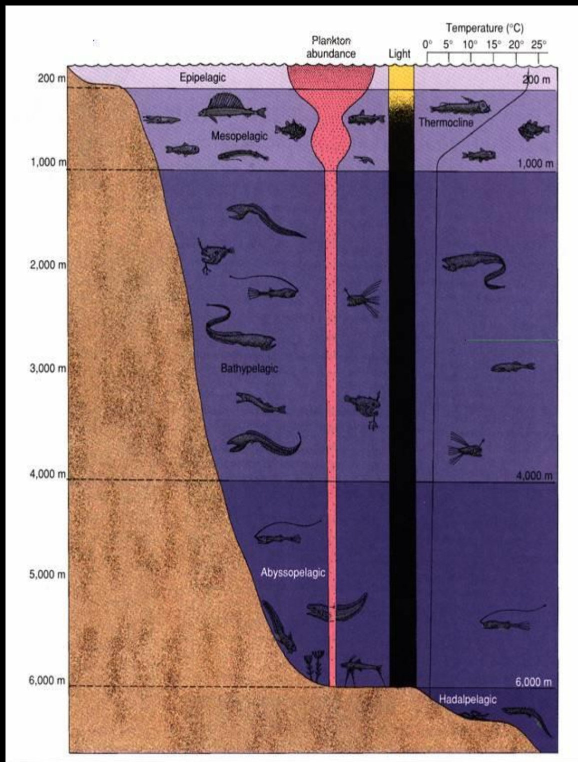


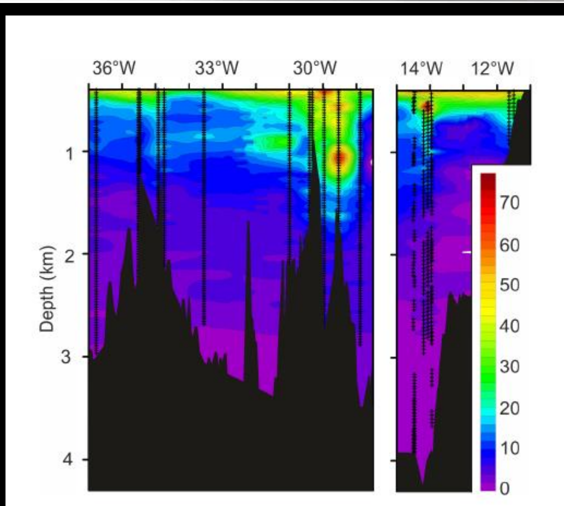


Thorrold et al, 2014

2. Between the shallow pink shelves that extend to a depth of about 200 meters around continents and the blue abyssal plains beneath the deep sea that average about 4,000 meters deep, the gray continental margins slope downward. Their gradient, exaggerated in this rendering, brings great and little-explored biodiversity. The margins also offer access to vast resources of petroleum and natural gas. In the view here, the world's longest mountain range, the Mid-Atlantic Ridge, traverses the ocean from north to south.
Image: Census of Marine Life Mapping and Visualization Team

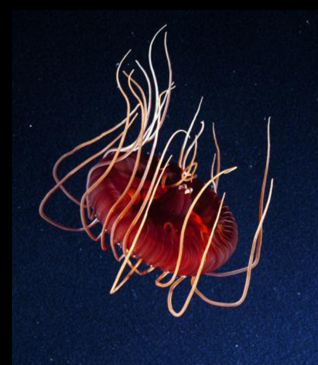
Meso/epipelagic 11 %; Mesopelagic 66 %; Meso/bathypelagic 24,1 %; Meso/epipelagic/bathypelagic 3,9 %











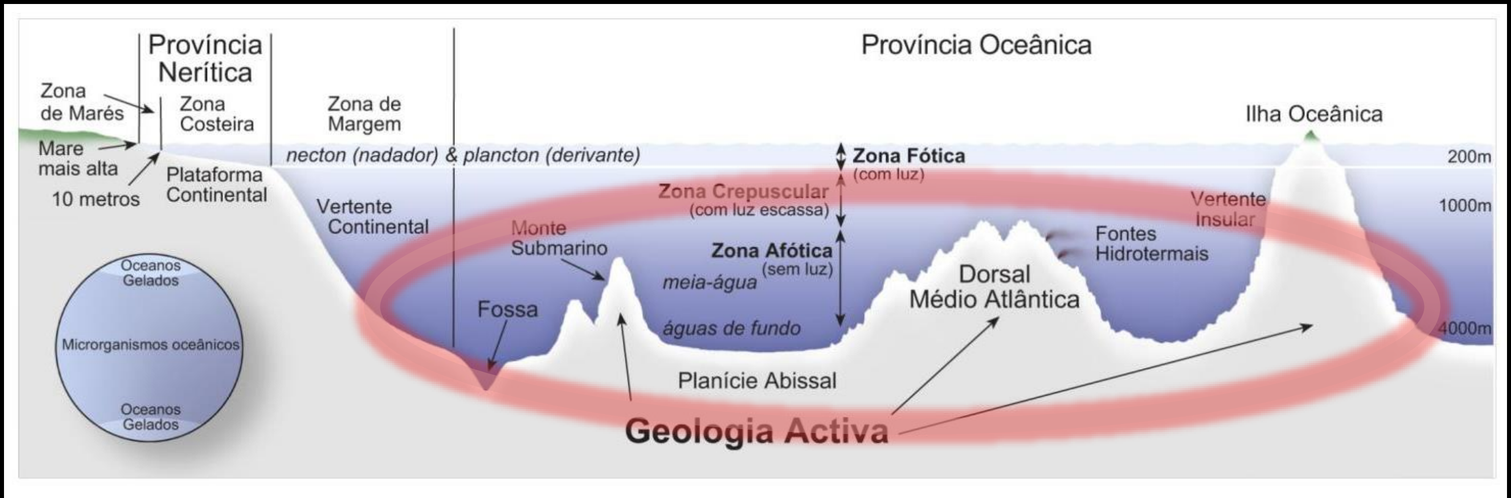


Deep sea Habitats

Les Galagher Fishpics

Habitat	Area (km^2)	% deep sea	% researched
Deep sea floor	326 000 000 km^2	100%	0,0001%
Abyssal plains	244 360 000 km^2	75%	< 1%
Ocean ridges	30 000 000 km^2 (ca. 50 000 km)	9,20%	10%
Seamounts	8 500 000 km^2	2,6%	0,25-0,28%
Coral reefs	280 000 km^2	0,08%	mínimo
Hydrothermal fields	Approx. 2000 (Unknown area)	Unknown	10% of the 200 hundred know fields
Cold seeps	10 000 km^2	0,003%	2%

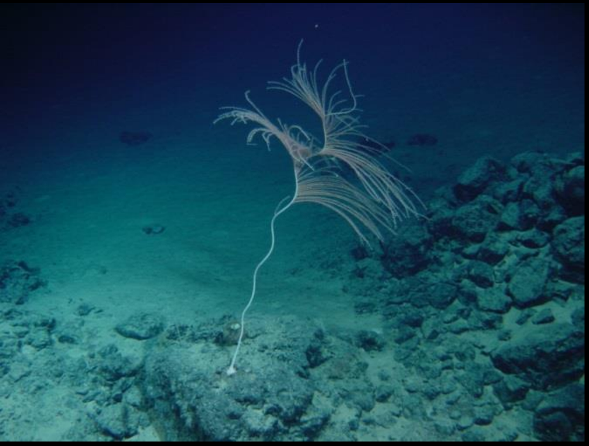
Ramirez-Llodra, et al. 2010.











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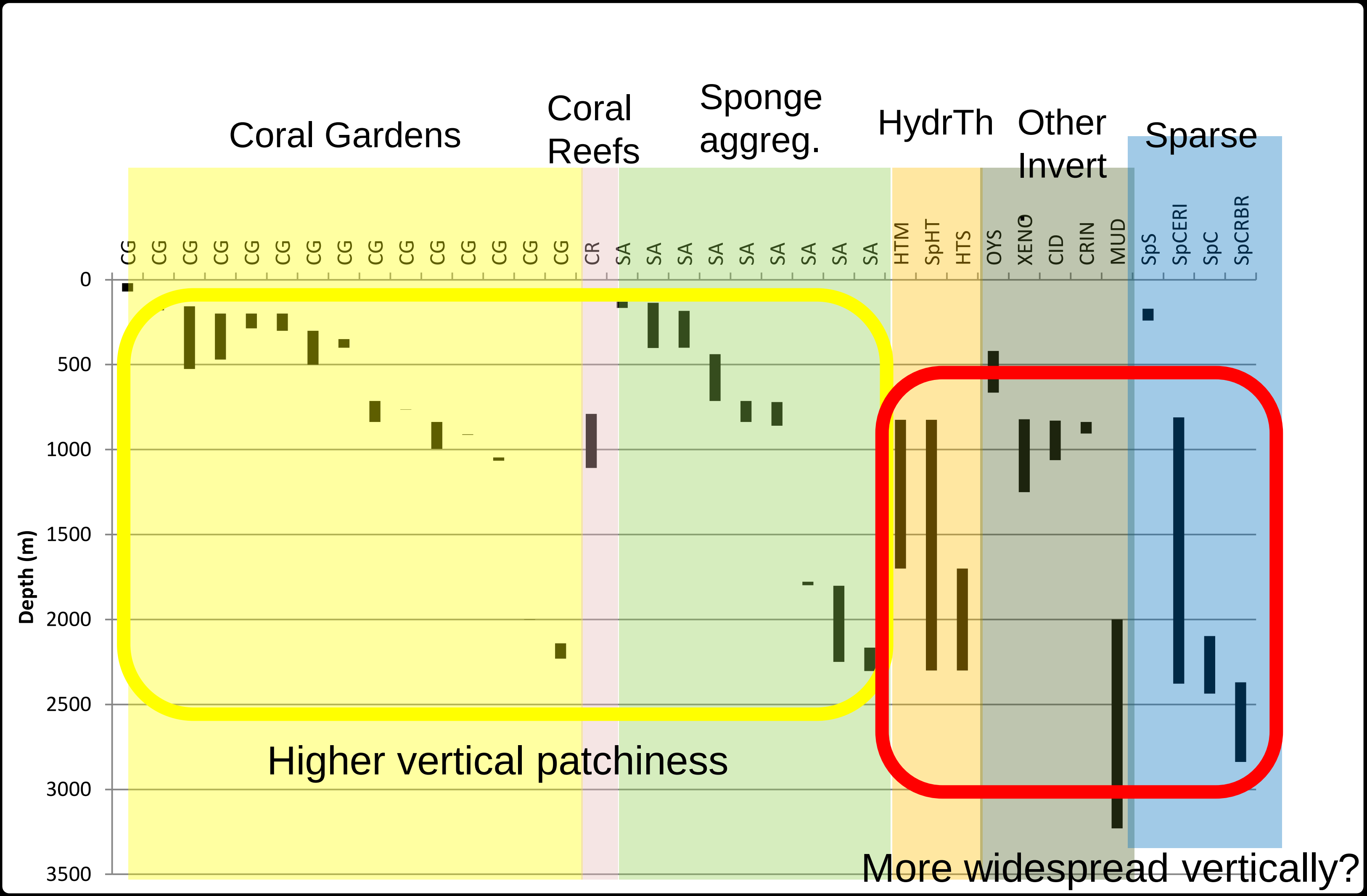
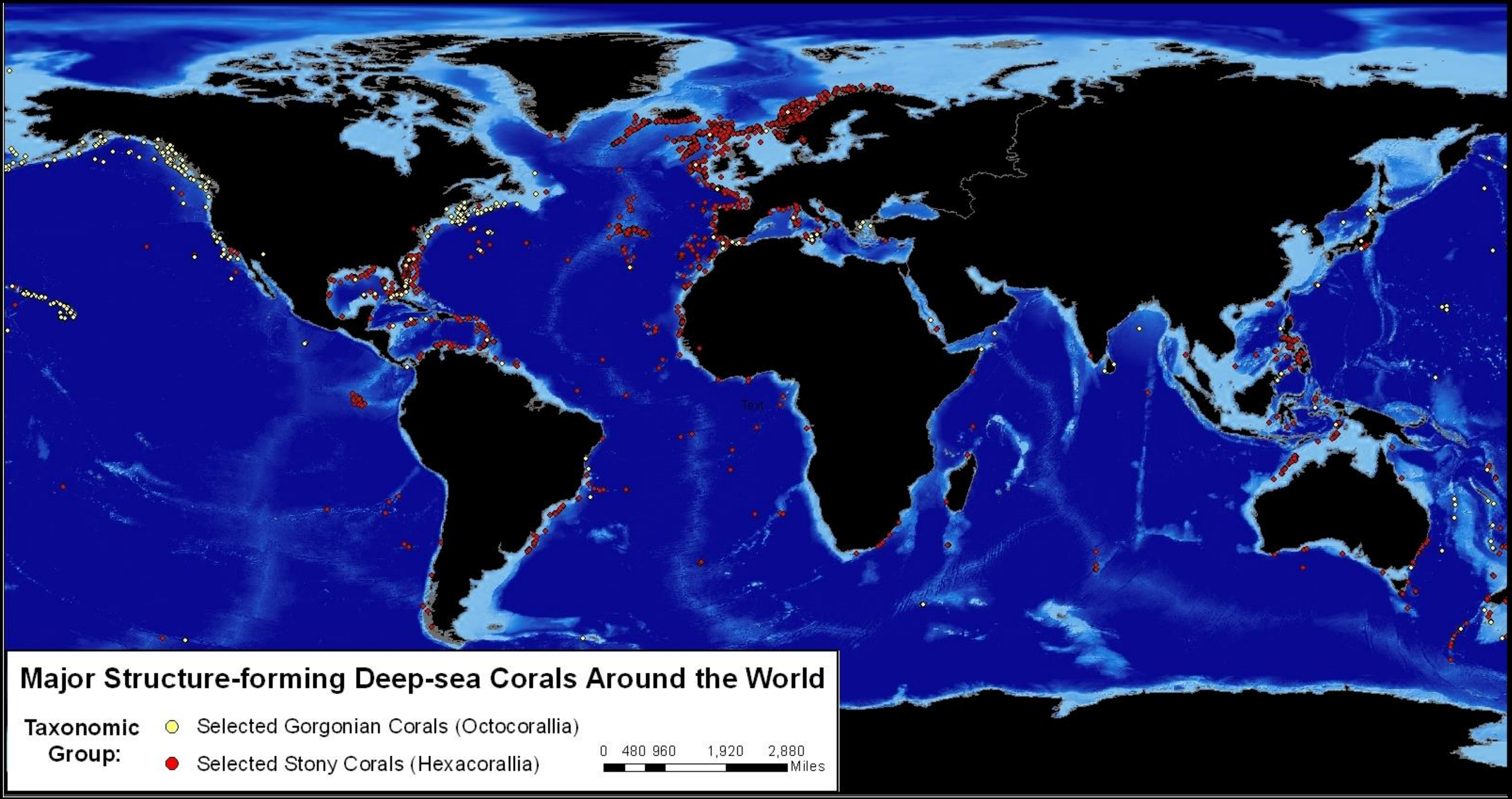
Deep-sea– Habitat and biotope diversity



About 40 different facies on the deep-sea but more to be described and discovered

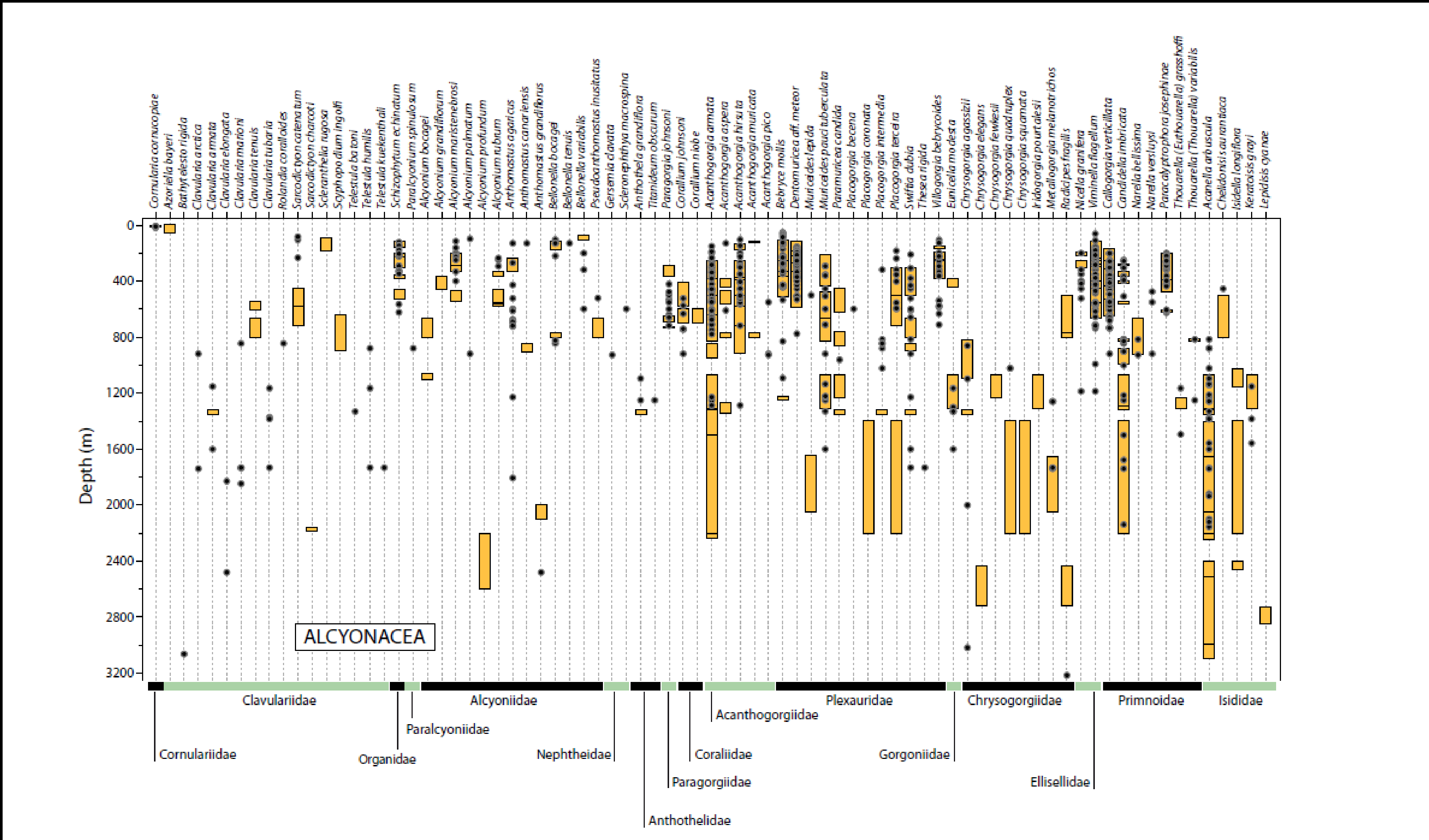
Credits: Fernando Tempera, DOP



NOAA Fisheries (map); Ocean Biogeographic Information System (OBIS), accessed February 9, 2011 (data)

Potential threats could include deep-sea bottom fishing, mining of cobalt-rich crusts on seamounts, deployment of submarine cables, and vessel discharges and anchoring.

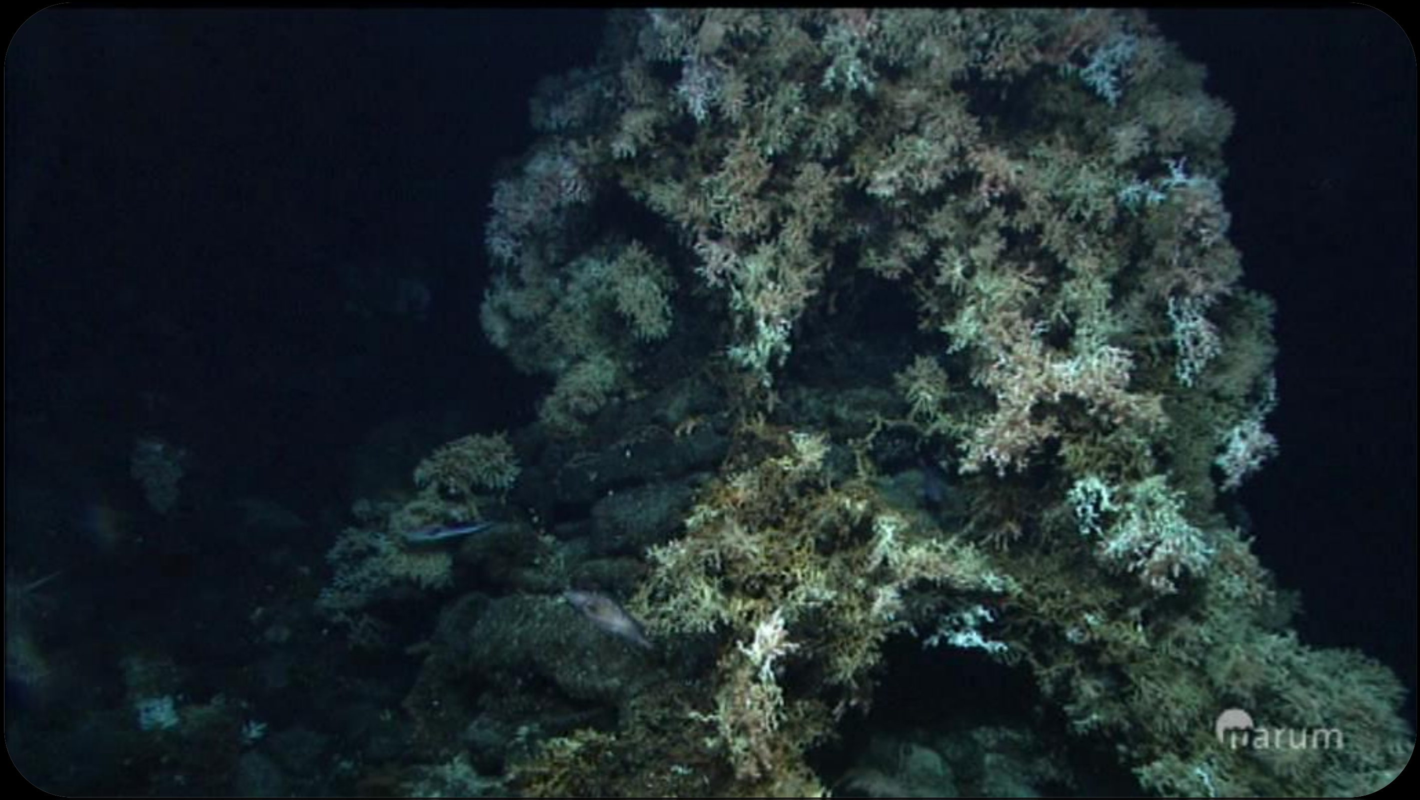
Species of cold water corals at the Azores



Braga Henriques et al, 2013 *Biogeosciences*

MenezMAR cruise, 2010

Live coral reef recorded in the vicinity of Menez Gwen hydrothermal field (~850m)



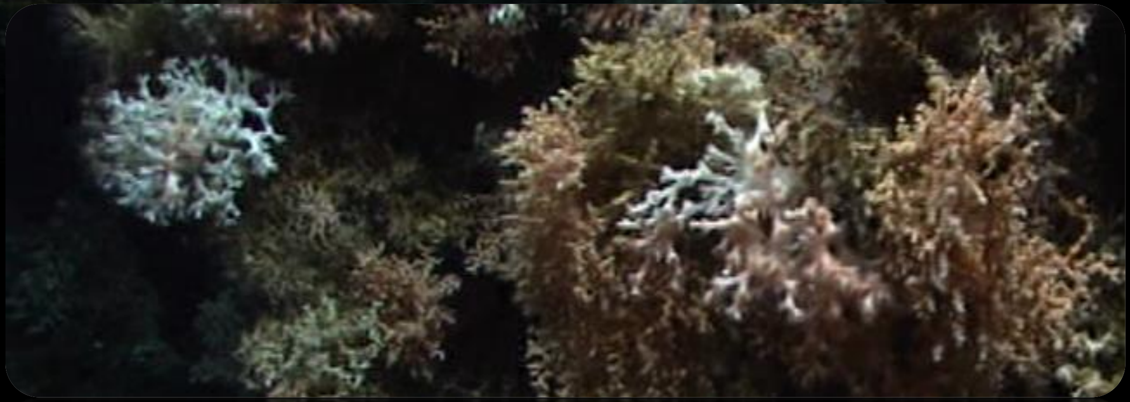


Image courtesy: MARUM

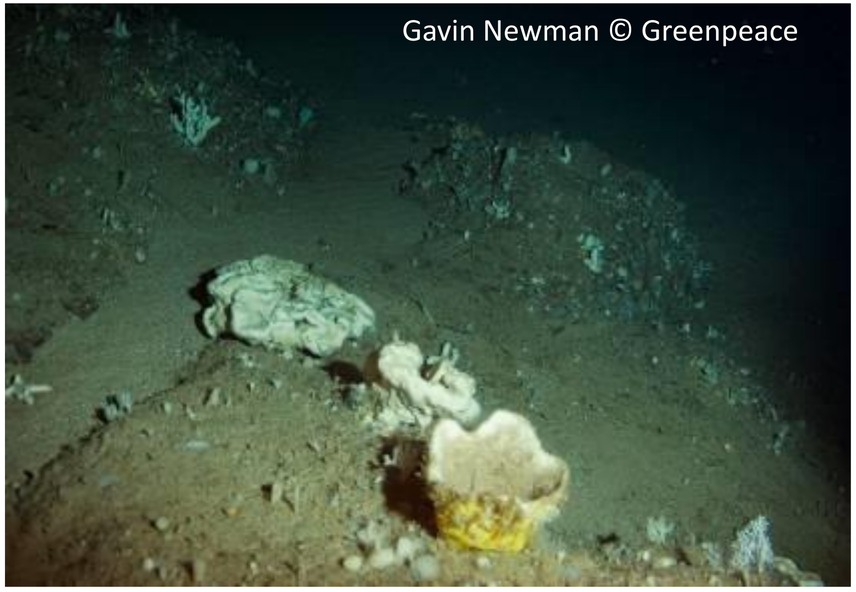
Deep-sea sponge aggregations:

Dense short sponges + sparse large-sized sponges and antipatharians

Species composition: lithistid sponges

Depth range: 438-714m

Locations known: Condor seamount, São Mateus bank, S. Jorge island slope



Deep-sea sponge aggregations:

Pheronema carpenteri on unconsolidated substrates

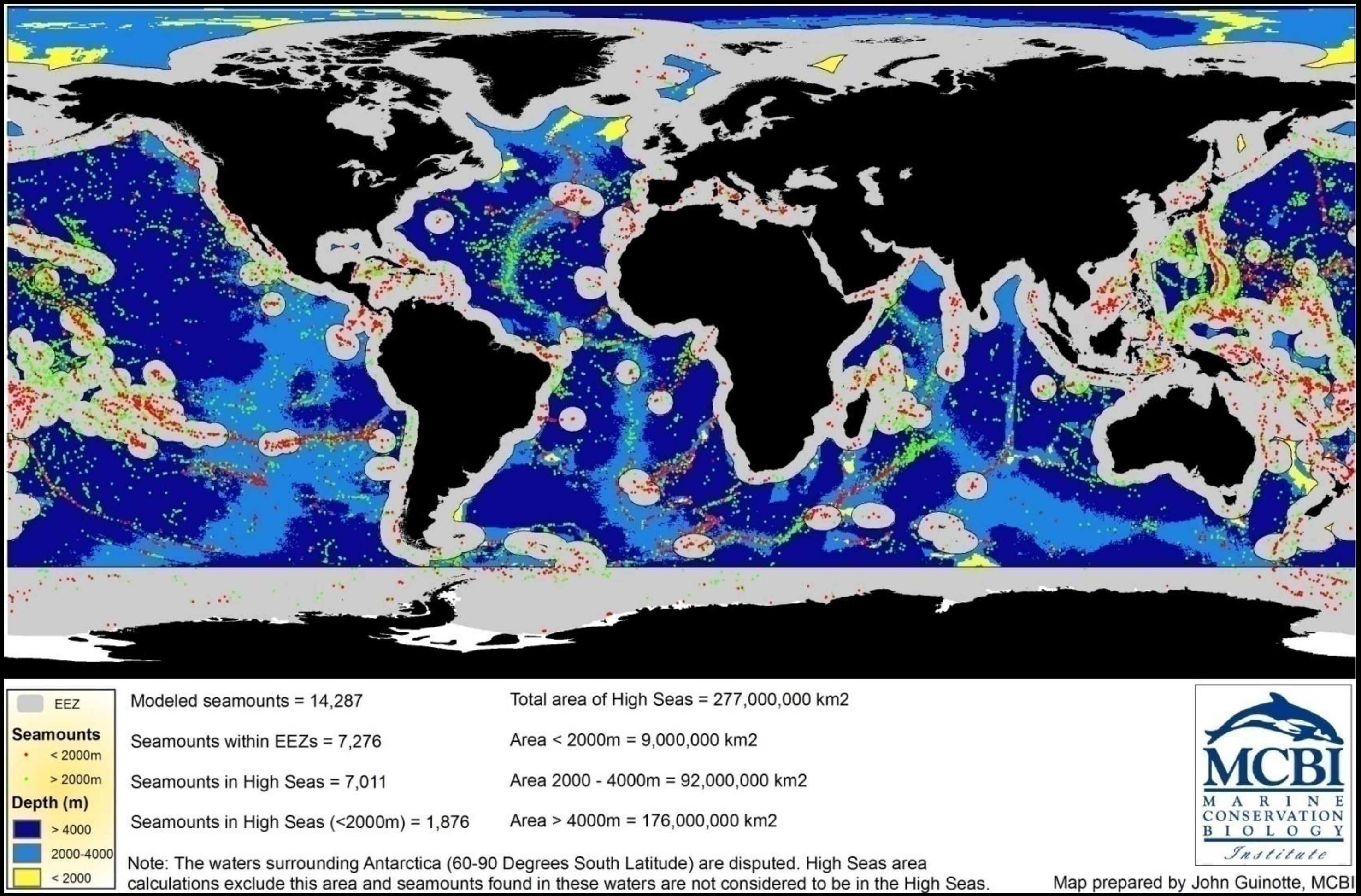
Species composition: *Pheronema carpenteri; Hyalonema cf. apertum*

Documented depth range: 720-860m

Locations known: Condor seamount, Açor Bank

Distribution of seamounts

50,000-100,000 (1000m elevation)



Kitchingman et al. 2007: *Ch. 2 How many seamounts are there and where are they located?*

Seamounts– What lives there?

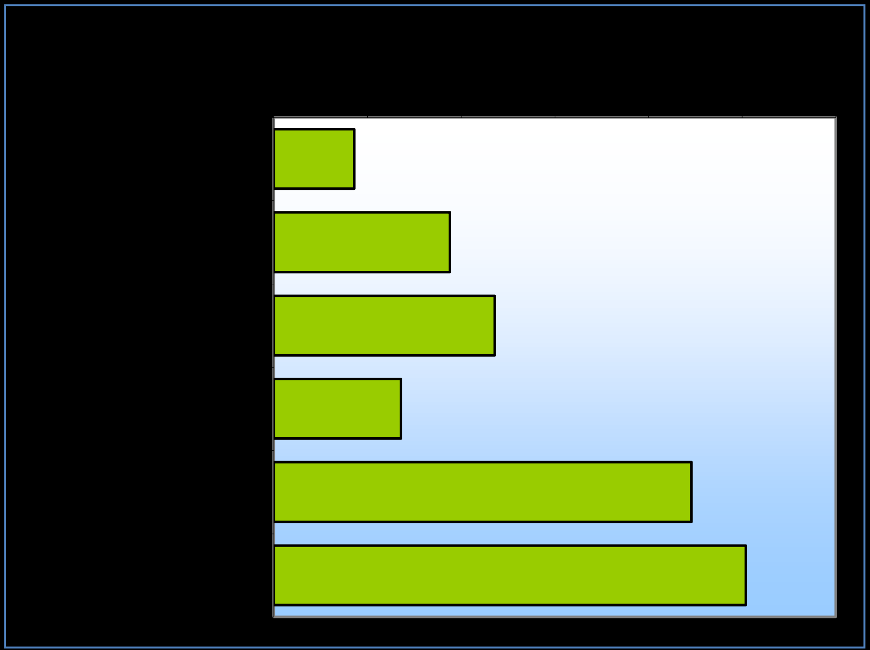
Enhanced currents and steep slopes expose the volcanic rocks and favour the growth of suspension feeders. Thus seamounts are often cover by rich communities dominated by suspensions feeders, e.g., gorgonians, corals, sponges at the summit and flanks. The base generally soft sediment organisms

Seamount Fish

- 800 fish species have been reported on seamounts (as for 2006)
- Over 20 species form large aggregations (seamount aggregating fish)
- about 50 spp. are commercially important
- about 10 spp. are mostly caught on seamounts

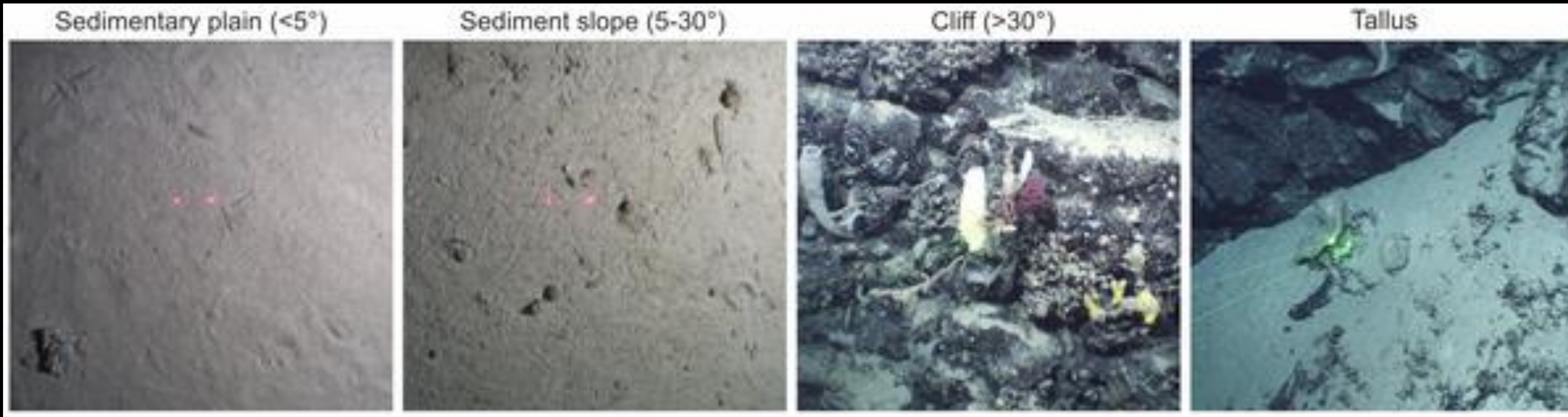
Alfonsino
Beryx decadactylus

Orange roughy
Hoplostethus atlanticus



Morato and Clark 2007: *Ch. 9 - Seamount fishes: ecology and life histories*

RIDGES



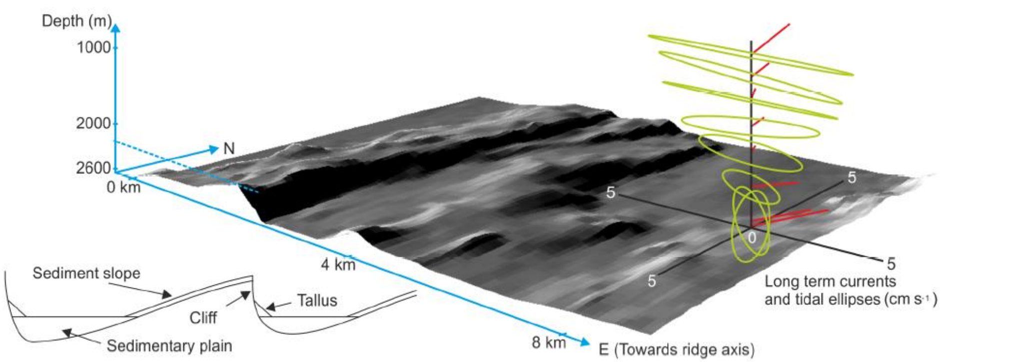


Figure 2. Sea floor topography and flow on the flanks of the MAR. (a) 3D projection from swath bathymetry surveys around the NW MAR station, vertical and horizontal scales the same. (b) Location of the NW mooring (base 2500 m depth) and flow at different heights above the sea floor. Red vectors - long term mean velocity. Green - ellipses of the dominant (M2) tidal constituent. (c) Diagrammatic cross section of a flank of the ridge showing the relationship between flat plains, gentle slopes and steep cliffs. The steep cliffs face towards the ridge axis.
doi:10.1371/journal.pone.0061550.g002

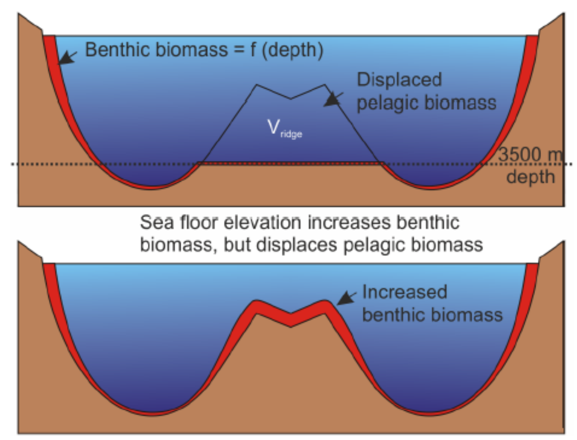


Figure 10. Effect of a ridge on mid-ocean biomass. Comparison of sections of a hypothetical ocean with the MAR truncated at the 3500 m depth horizon (upper panel) with the real ocean with a ridge present (lower panel). The thickness of the red section indicates the benthic biomass that decreases with depth. V_{ridge} is the volume of water, including pelagic biomass displaced by the ridge.
doi:10.1371/journal.pone.0061550.g010

Priede et al. 2013- No enhancement of biodiversity, between 10 to 20 % of endemecity. Higher biodiversity of abyssal fauna, and
Species generally exhibit depth fidelity e.g. 90.3% of trawled megafauna species common to the PSB and the MAR occurred at similar depth ranges.

MAR-ECO and ECOMAR projects	Nb Species	New species	MAR	N. Atltantic	Atlantic	Cosmopolitan
Amphipoda (scavenging)	39	15				
Polychaeta	34	1		14	6	1
Holoturoidea	32	3		10	2	8
Asteroidea	32	1		14	9	6
Hexactinellida	14	4	Affinities with Indian, Indo-West, W. & E. Atlantic			
Hydroida	21	2		7	4	3
Actiniaria	9		2	6		
Scleratiniaria	8				4	4
Antipatharia	1					1
Alcyonacea	7			6		1
Pennatulacea	8			2		6
Total	**205**	**26**	**2**	**59**	**25**	**30**
%		**13**	**20**	**42**	**18**	**21**

Ecology of benthic MAR ecosystems north of the Azores

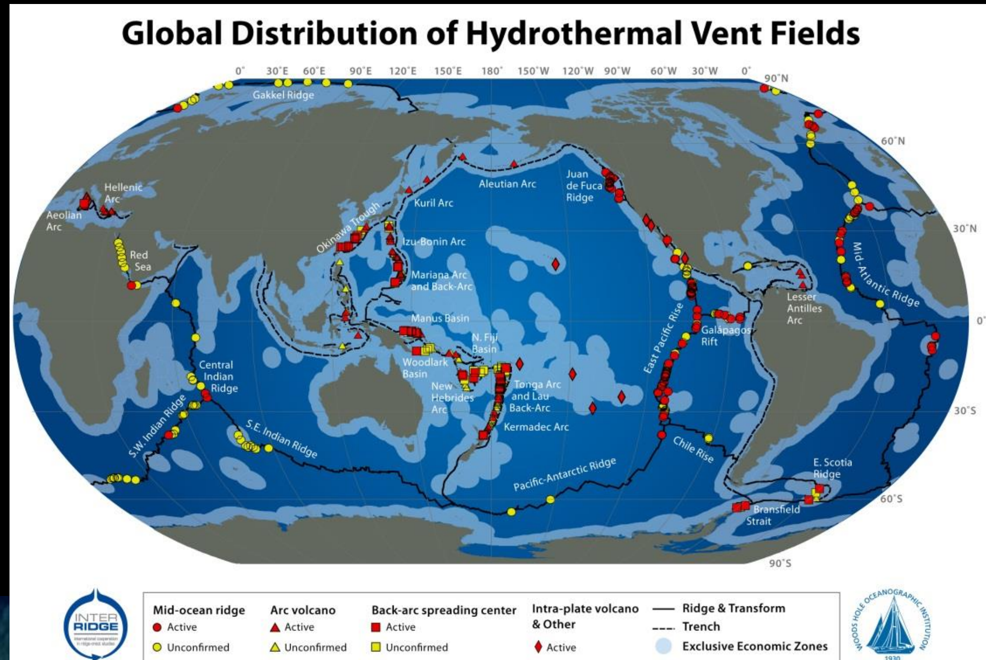
Copley et al., 1996 : Reykjanes Ridge, 225 -2600 m depth, 101 species, bathymetric zonation at 800 – 1000 m depth (water masses)

Alt et al., 2013 : 153 megafaunal taxa, shift in community composition between N and S CGFZ

Oceanic ridge with seamounts

- **The benthic communities are dominated by cold water corals and other organisms that feed on the suspended particles, and have resident and non resident fish populations, that not only have long living but also reproduce very late..**

Hydrothermal vents



German & Parson, 1998: One vent field every 110 km between 12 N and 26 N, and one vent field every 25–30 km along axis between 36 and 38N.

Cherkashov et al. 2010: one SMS deposit every 150 km from 12° N to 20° N


Missão SEHAMA, 2002 -FCT

IFREMER-ATOS

Missão SEHAMA, 2002 -FCT

IFREMER-ATOS

IFREMER-ATOS

Missão SEHAMA, 2002 -FCT

IFREMER-ATOS

Missão SEHAMA, 2002 -FCT

Missão SEHAMA, 2002 -FCT

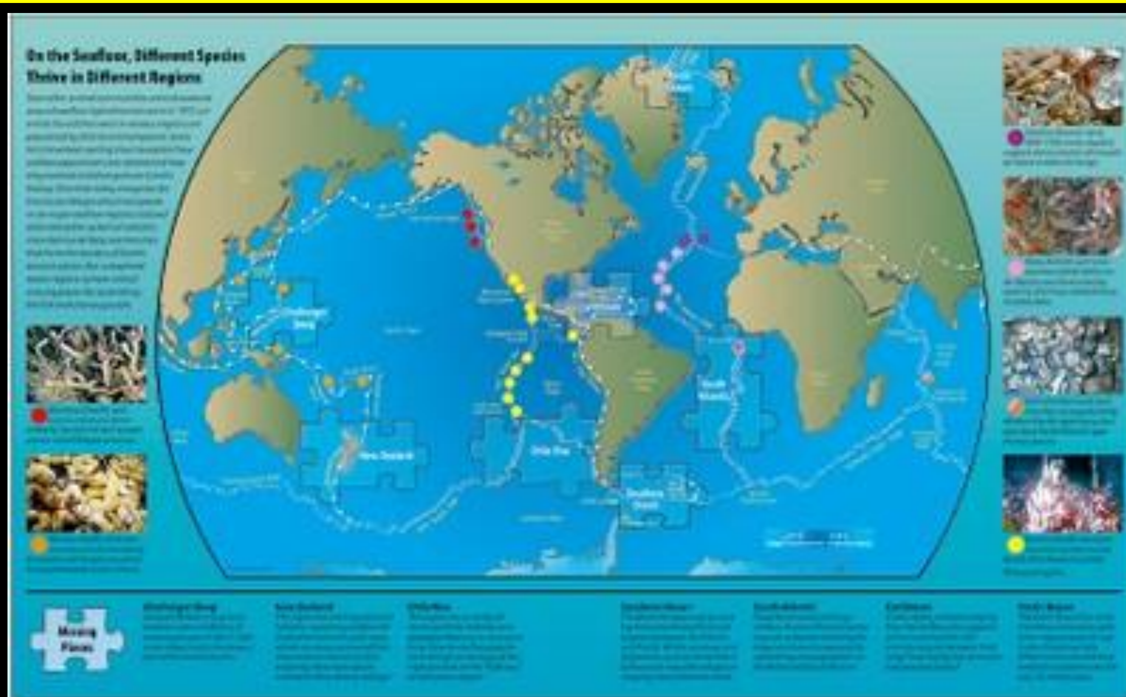


Table 1. Dominant fauna of main proposed biogeographical provinces.

Biogeographical Province and Depth	Dominating Fauna
Azores (shallow north Atlantic, 800-1700 m)	Bathymodiolid mussels, amphipods, and caridean shrimp
Mid-Atlantic Ridge between Azores Triple Junction and Equator (deep north Atlantic 2500-3650 m)	Caridean shrimp—mainly *Rimicaris exoculata*—and bathymodiolid mussels
South Mid-Atlantic Ridge	Caridean shrimp, bathymodiolid mussels, and clams
East Pacific Rise and Galápagos Rift	Vestimentiferan tubeworms—mainly *Riftia pachyptila*—and bathymodiolid mussels, vesicomyid clams, alvinellid polychaetes, amphipods, and crabs
Northeast Pacific	Vestimentiferan tubeworms excluding Riftiidae, polychaetes, and gastropods
Western Pacific	Barnacles, limpets, bathymodiolid mussels, “hairy” gastropod, vesicomyid clams, and shrimp
Central Indian Ridge	Caridean shrimp *Rimicaris kairei*, and mussels, “scaly” gastropods, and anemones

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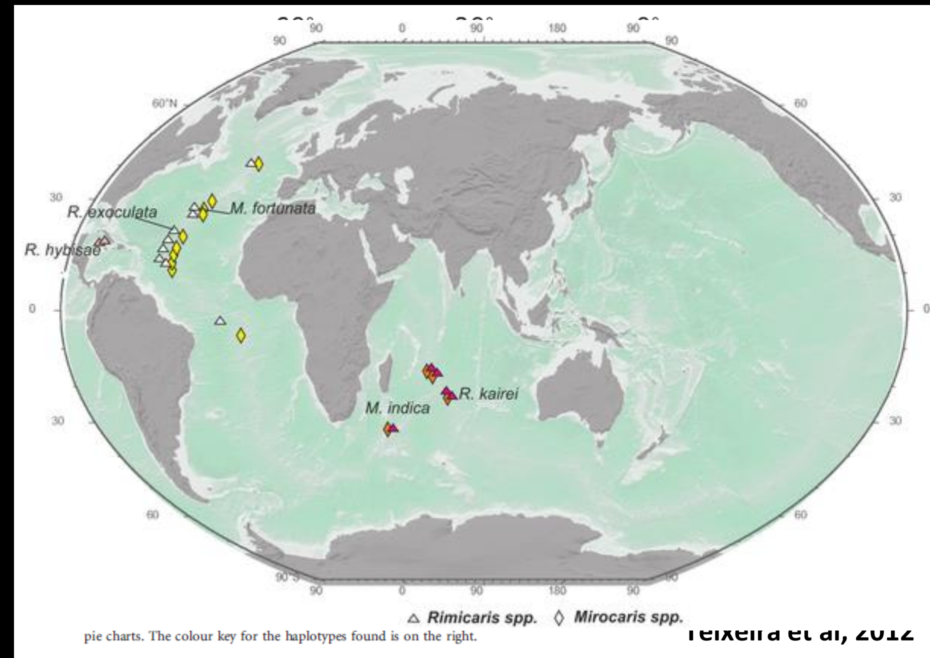
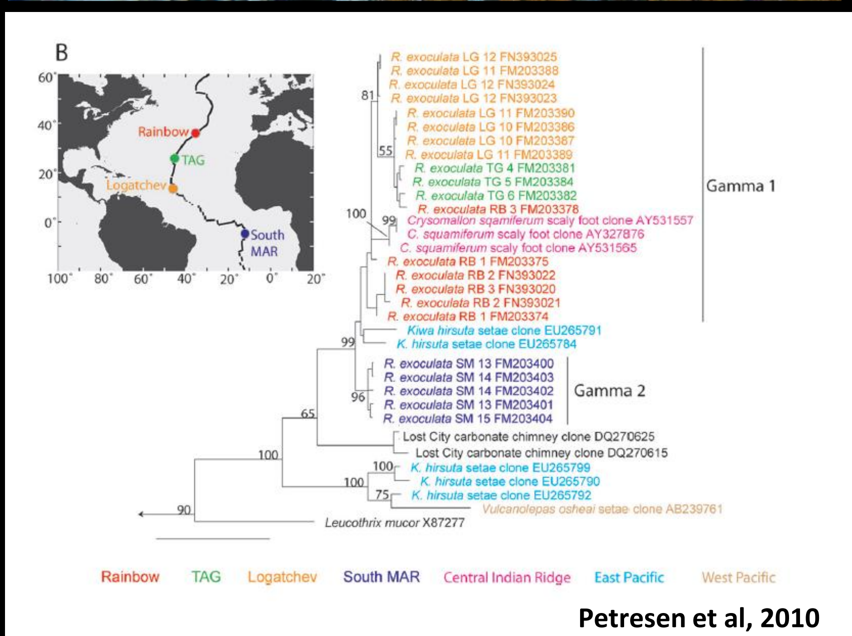
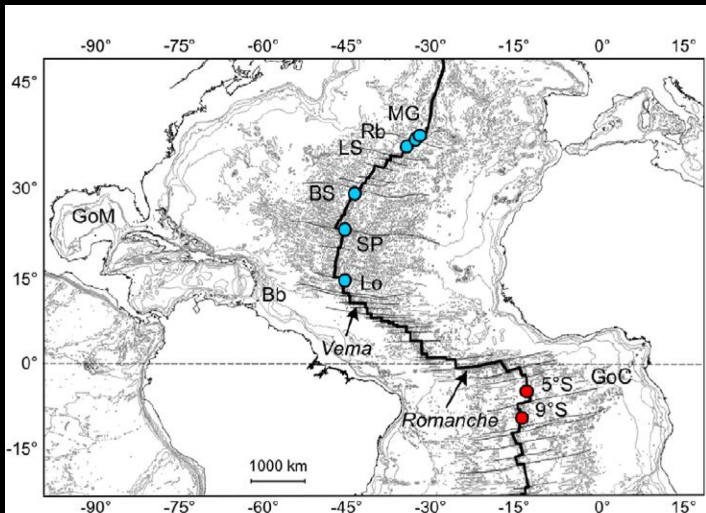
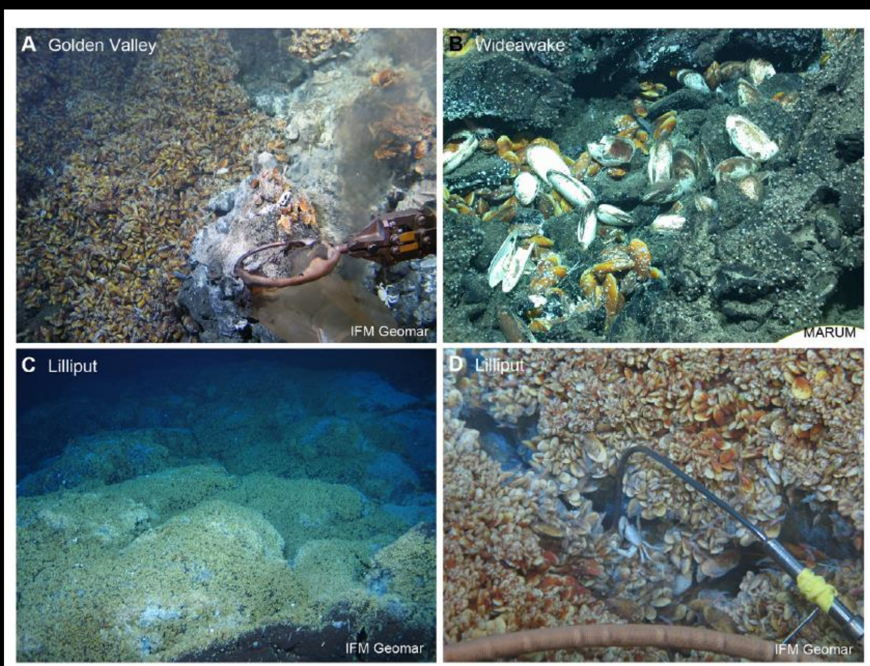
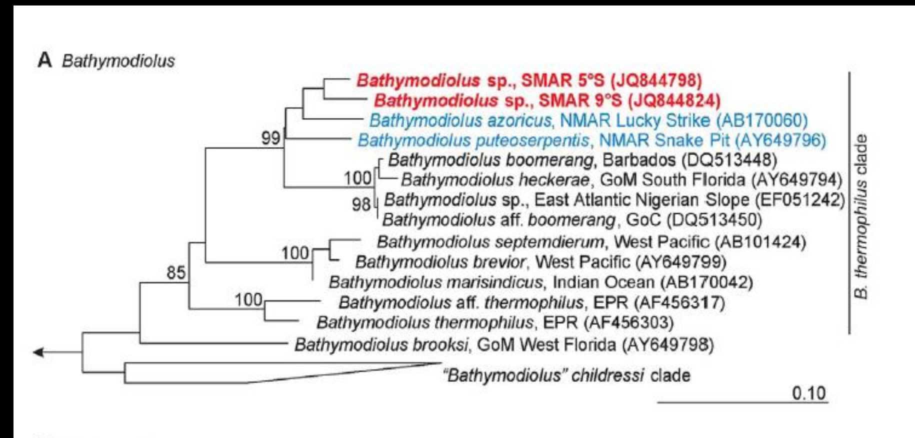

R. exoculata
R. hybisae
M. fortunata
M. indica
R. kairei
60°N
△ Rimicaris spp. ◊ Mirocaris spp.
pie charts. The colour key for the haplotypes found is on the right.
Teixeira et al, 2012

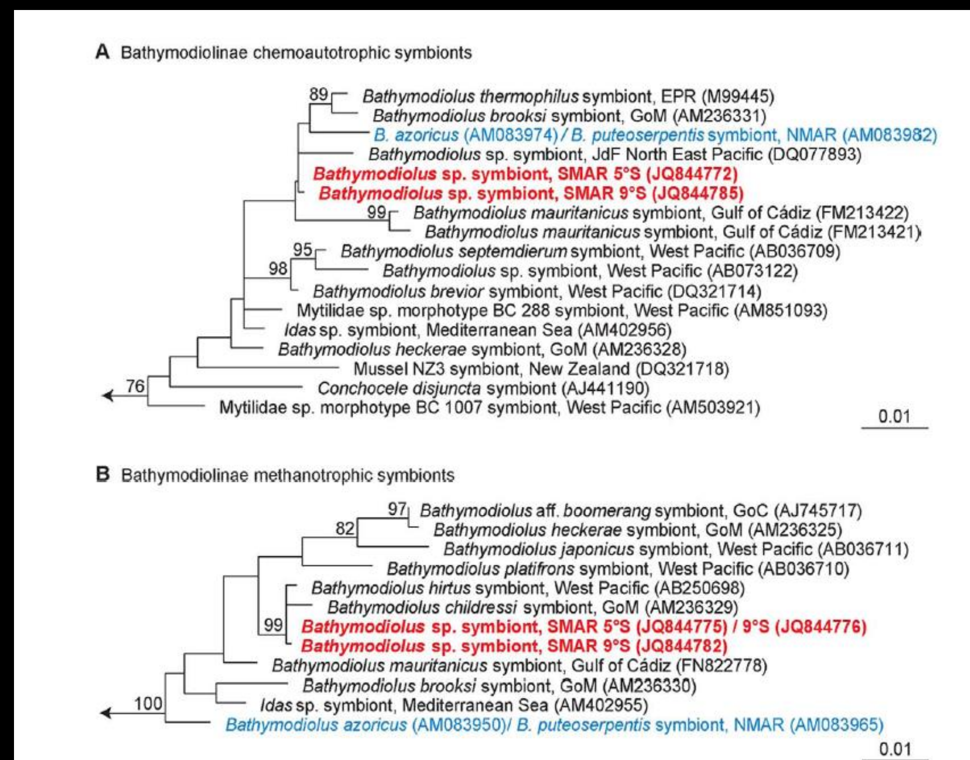

B
Rainbow
TAG
Logatchev
South MAR
R. exoculata LG 12 FN393025
R. exoculata LG 11 FM203388
R. exoculata LG 12 FN393024
R. exoculata LG 12 FN393023
R. exoculata LG 11 FM203390
R. exoculata LG 10 FM203386
R. exoculata LG 10 FM203387
R. exoculata LG 11 FM203389
R. exoculata TG 4 FM203381
R. exoculata TG 5 FM203384
R. exoculata TG 6 FM203382
R. exoculata RB 3 FM203378
Crysomallon sqamiferum scaly foot clone AY531557
C. squamiferum scaly foot clone AY327876
C. squamiferum scaly foot clone AY531565
R. exoculata RB 1 FM203375
R. exoculata RB 2 FN393022
R. exoculata RB 3 FN393020
R. exoculata RB 2 FN393021
R. exoculata RB 1 FM203374
Kiwa hirsuta setae clone EU265791
K. hirsuta setae clone EU265784
R. exoculata SM 13 FM203400
R. exoculata SM 14 FM203403
R. exoculata SM 14 FM203402
R. exoculata SM 13 FM203401
R. exoculata SM 15 FM203404
Gamma 1
Gamma 2
Lost City carbonate chimney clone DQ270625
Lost City carbonate chimney clone DQ270615
K. hirsuta setae clone EU265799
K. hirsuta setae clone EU265790
K. hirsuta setae clone EU265792
Vulcanolepas osheai setae clone AB239761
Leucothrix mucor X87277
Rainbow TAG Logatchev South MAR Central Indian Ridge East Pacific West Pacific
Petresen et al, 2010


Lunina & Vereshchaka 2014









van der Heijden et al, 2012

Table 2. Variation in Relative Abundances of Key Faunal Genera Present as "Abundant" in At Least One Vent Field in the North Atlantic or Arctic[a]

	Northern Mid-Atlantic Ridge (MAR) South of the Azores								MAR Azores to Iceland	Mid-Ocean Ridges North of Iceland	
Vent Field	Ashadze[b]	Logatchev[c]	Snake Pit[d]	TAG[e]	Broken Spur[f]	Rainbow[g]	Lucky Strike[g]	Menez Gwen[g]	Moytirra	Jan Mayen FZ area[i]	Loki's Castle[j]
Latitude (°N)	12.97	14.75	23.37	26.14	29.17	36.23	37.29	37.84	45.48	71.25–30	73.55
Depth (m)	4200	3050	3500	3670	3100	2320	1740	850	2095	500–750	2400
Cnidaria - Anthozoa											
Maractis	++++	–	+++	+++	++	–	+	–	–	–	–
Annelida - Polychaeta											
Nicomache	–	–	–	–	–	–	–	–	–	*	+++
Sclerolinum	–	–	–	–	–	–	–	–	–	–	++++
Mollusca - Bivalvia											
Bathymodiolus	–	+++	+	+	+	++	+++	+++	–	–	–
Mollusca - Gastropoda											
Peltospira	++	++	+	–	–	–	++	++	+++	–	–
Pseudosetia	–	–	–	–	–	–	–	–	–	+++	+++
Skenea	–	–	–	–	–	–	–	–	–	*	+++
Arthropoda -Crustacea											
Excitomelita	–	–	–	–	–	–	–	–	–	–	+++
Mirocaris	+++	+	+	+	+	+++	+++	++	+++	–	–
Rimicaris	+	+++	++++	++++	++	++	+	–	++	–	–

[a]Key to relative abundances of genera: – absent; * present but no relative abundance data reported; + rare; ++ common; +++ abundant;

Wheeler et al, 2013

Thurber et al, 2014

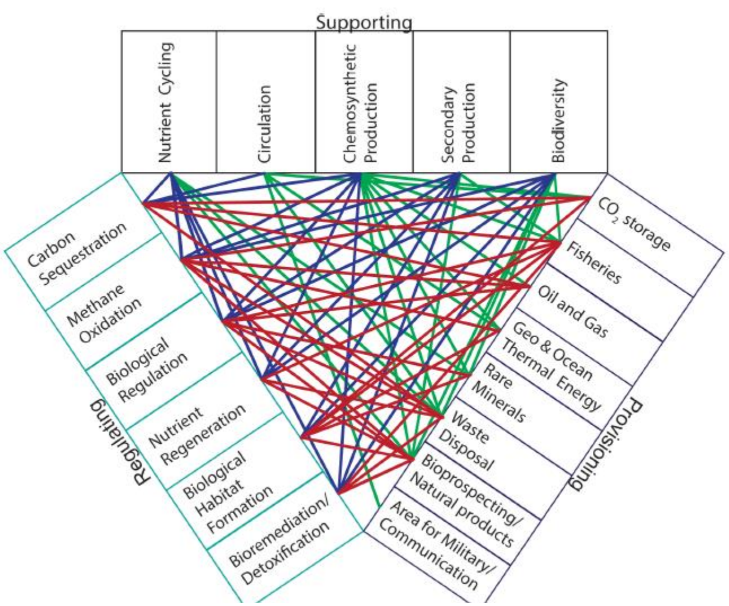
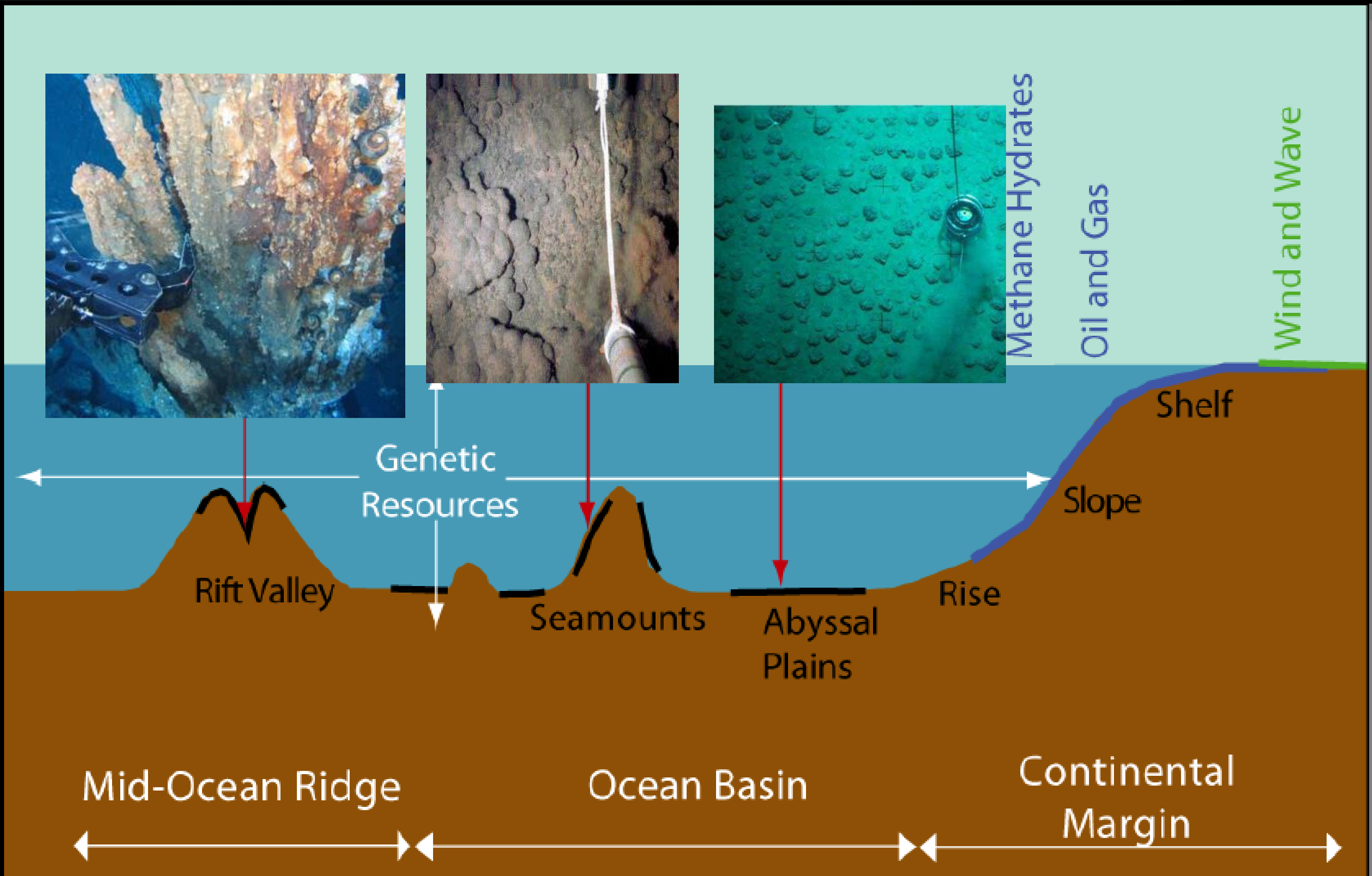


Table 1. The distribution of regulating and provisioning services among the habitats present in the deep sea. Blank = unknown or not present. P = present. W = widespread or abundant.

	Abyssal plains	Biogenic habitats	Canyons	Deep pelagic	Margins	Mid-ocean ridges	Seamounts	Trenches	Vents and seeps
Alternative energy sources			P	P	P	P	P		P
Bioprospecting	P	P	P	P	P	P	P	P	W
Carbon capture and disposal	P				W			P	
Communication cables	P		P		W	P		P	
Fisheries		W	W	P	W	W	W		
Metal-rich sediments	P								
Methane harvesting					W			P	P
Military			P		W	P	P		
Oil and gas extraction					W				
Phosphate mining					P				
Polymetallic crusts						W	W		P
Polymetallic nodules	W								
Rare Earth elements	P								
Seafloor massive sulfides						P	P		W
Waste disposal	W		W	P	W			P	

Potential future mining activities



De: Nuno Lourenço EMAM- Conferência On exploring and utilizing the resources of the sea, Câmara do Comércio e Indústria, Lisboa, 14 de Dezembro de 2011

Environmental – **crust vs sulphides**

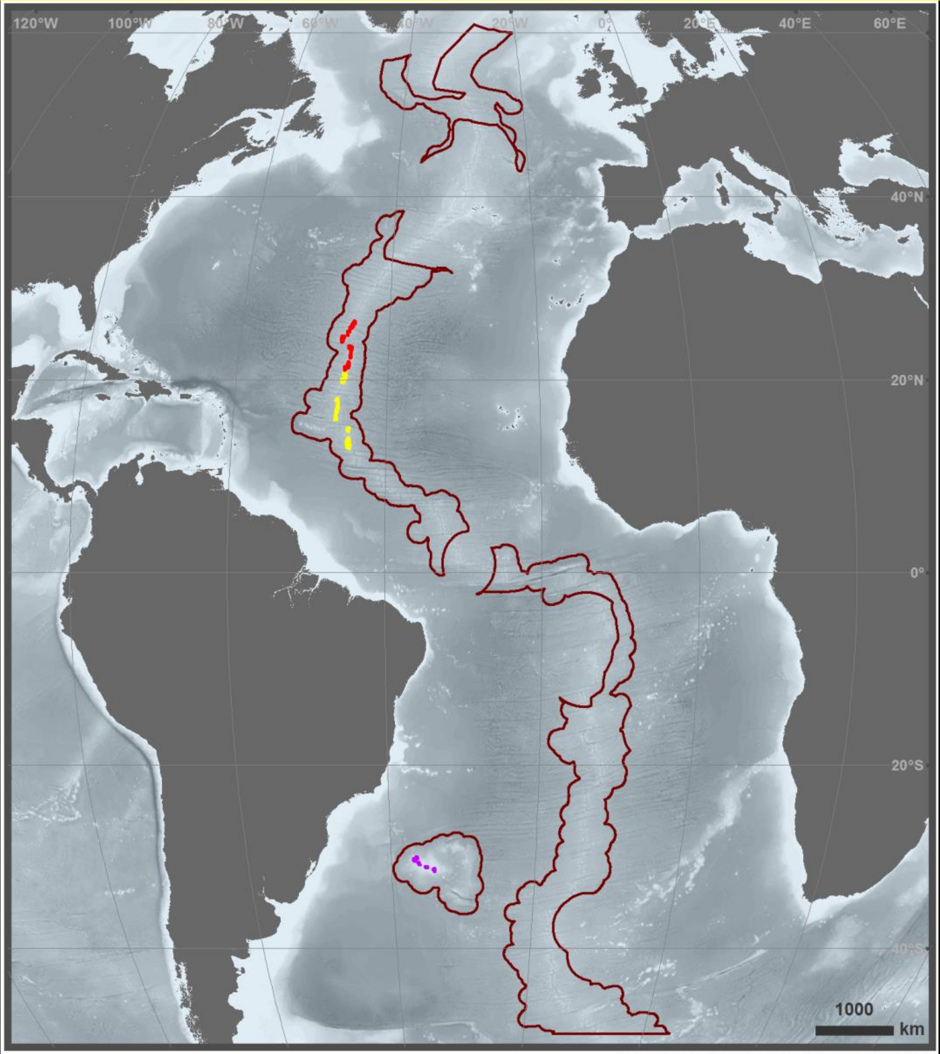
Comparison based on a 2 million ton per annum operation

	Nodule	Co Crust	Sulphide
Attribute	25 kg/m3	40mm	20m deep
Surface area	80 sq kilometres	16 sq kilometres	200m x 200m
Surface Environ	silt, mud abyssal plain	volcanic seamount	volcanic ridge
Depth	>4,000mbsl	>500mbsl	>1,000mbsl
Metal	Ni, Co, Cu	Co, Ni, Cu	Cu, Au, Zn, Ag

NAUTILUS Minerals Limited

Given the above differences it is clear that each resource requires different environmental regulations

Heydon, 2014



Exploration Areas

- ISA: France
- ISA: Russian Federation
- Brazil

Potential impacts

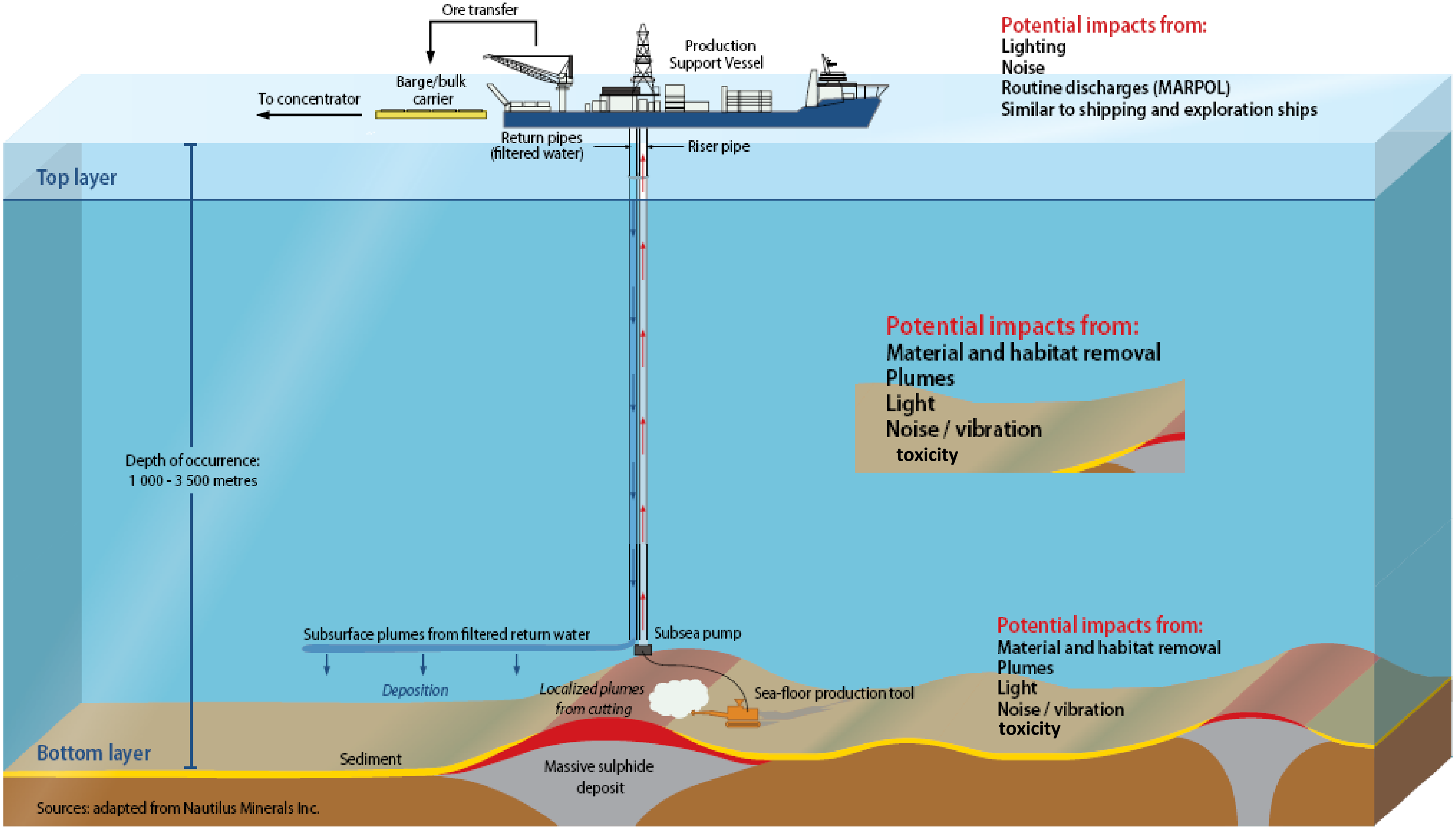
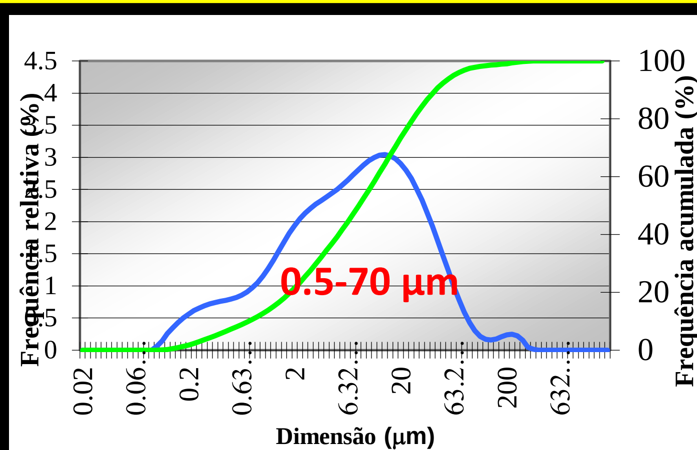


Figure 12. Example of a sea-floor massive sulphide mining system and related sources of potential environmental impact.

Baker, E., and Beaudoin,Y. 2013. (Eds.) Vol. 1A,



PollyMetalic sulphide particles were obtained by grinding hydrothermal chimney rocks collected at the **hydrothermal vent field Lucky Strike**

PMS **particle size** matched the range expected by Seafloor Mining Tools excavation and by dewatering processes, according to the IHC Mining B.V. (80% 0.5-10 um, and 80% between 10-70 um)

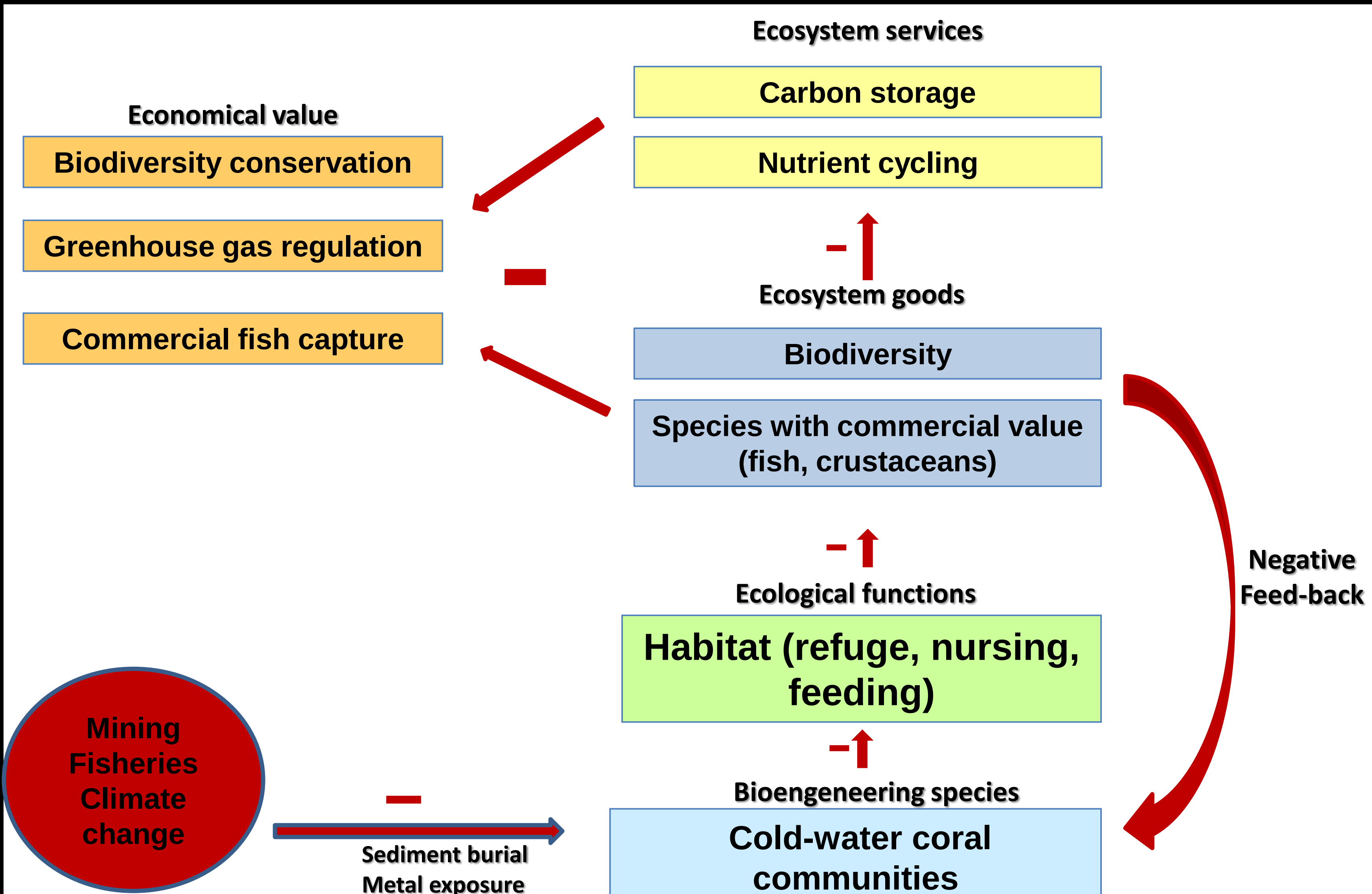
PMS PARTICLES | INERT PARTICLES | CONTROL

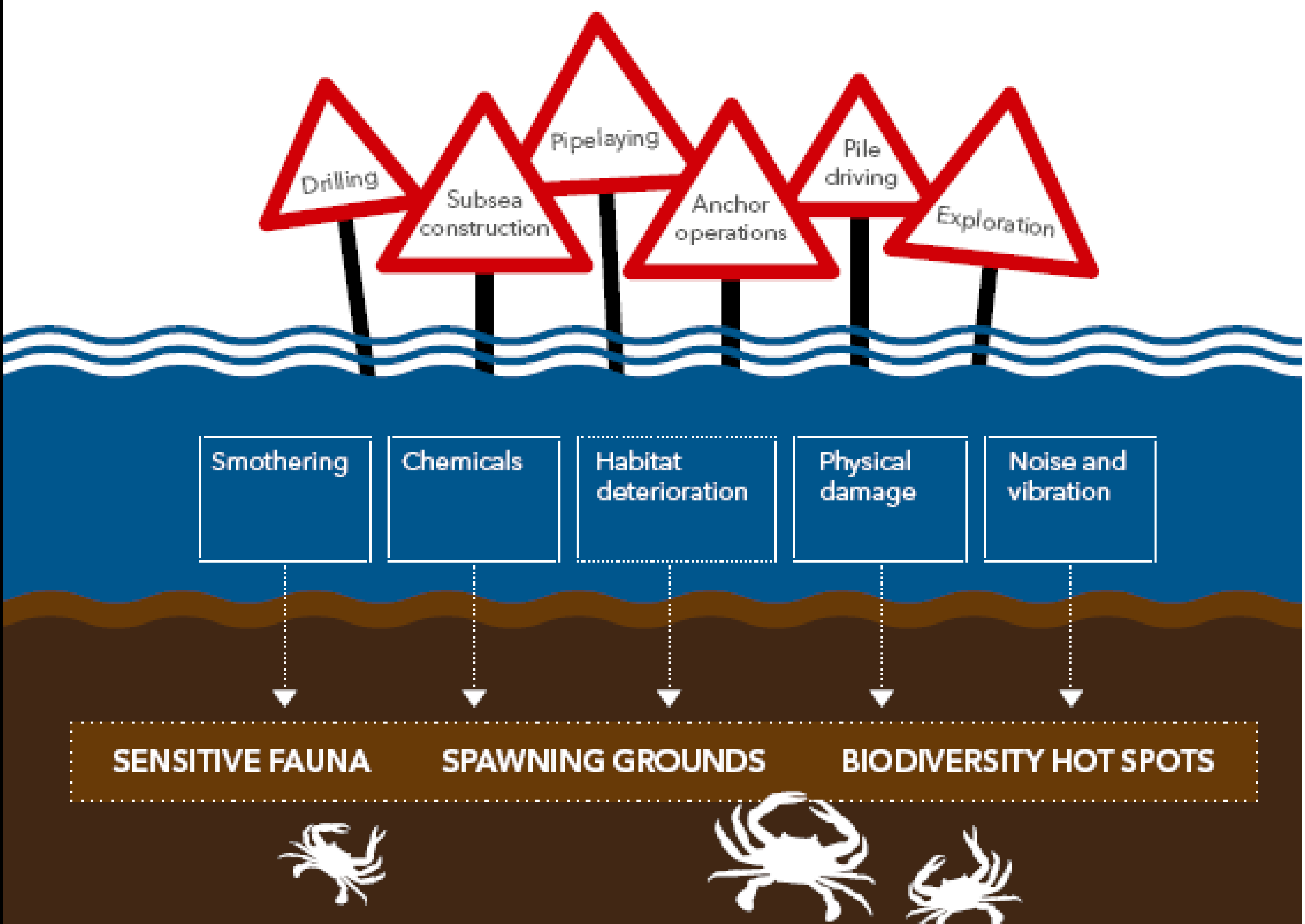
General decrease in tissue condition in both particle addition treatment but more accentuated in the PMS particle treatment

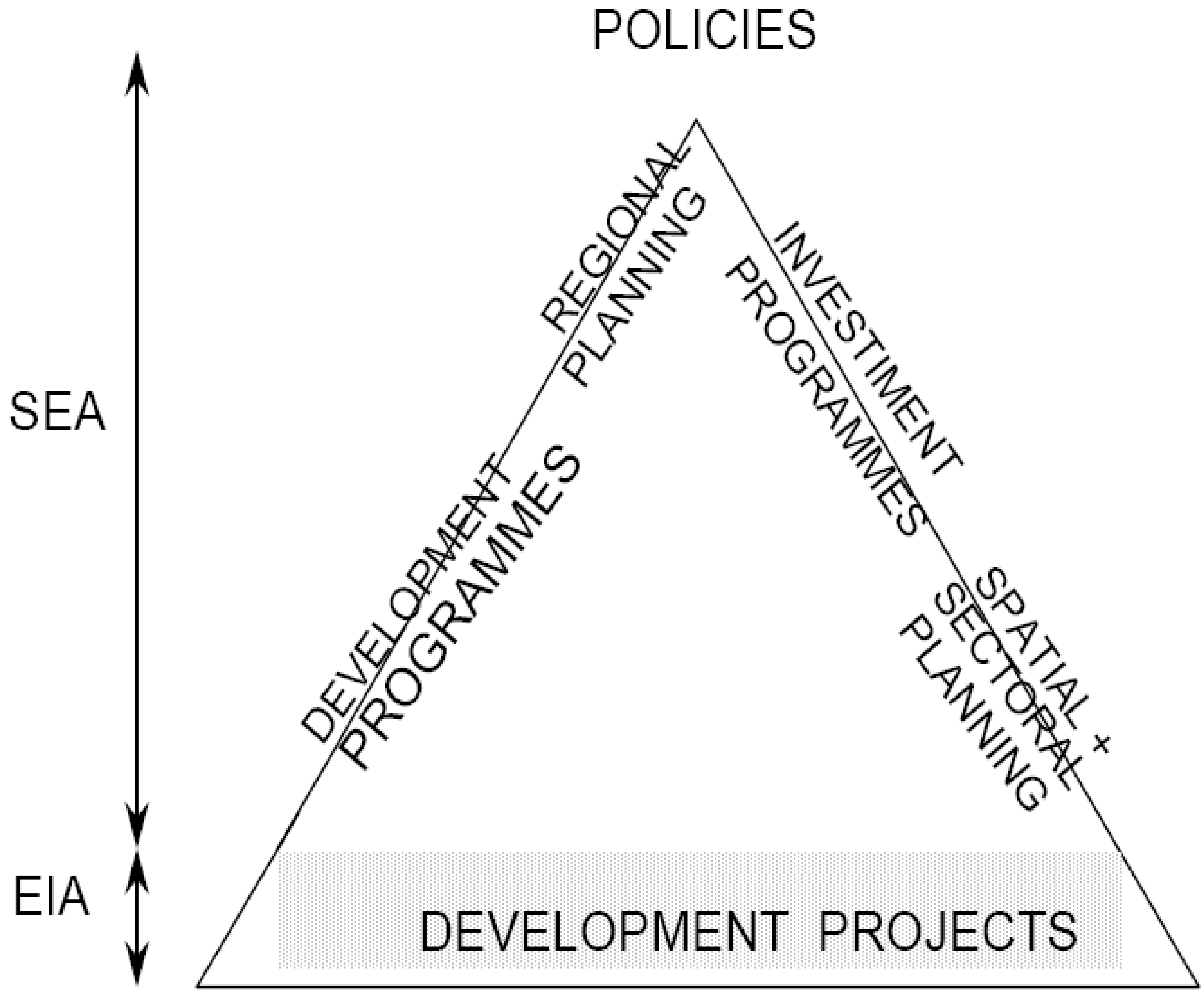
t=13

t=27

Cascading effects of CWC loss




Drilling
Subsea construction
Pipelaying
Anchor operations
Pile driving
Exploration
Smothering
Chemicals
Habitat deterioration
Physical damage
Noise and vibration
SENSITIVE FAUNA
SPAWNING GROUNDS
BIODIVERSITY HOT SPOTS


POLICIES
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EIA
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Thank you


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