DEPARTMENT OF ZOOLOGY
UNIVERSITY OF OXFORD,
TINBERGEN BUILDING,
SOUTH PARKS ROAD,
OXFORD,
OX1 3PS

SOMERVILLE COLLEGE,
WOODSTOCK ROAD,
OXFORD,
OX2 6HD

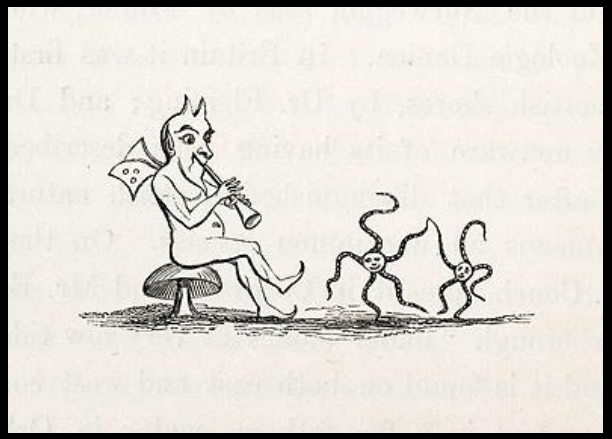
Blue growth in the deep sea: balancing economic and environmental considerations

Prof. Alex David Rogers,

Email: alex.rogers@zoo.ox.ac.uk

May 5, 2015

Forbes and the Azoic theory



Edward Forbes
HMS Beacon,
Aegean Sea

Below 300 fathoms
the deep sea is barren
and lifeless

Hurrah for the dredge, with its iron edge,
And its mystical triangle,
And its hided net with meshes set,
Odd fishes to entangle!
The ship may move thro' the waves above,
'Mid scenes exciting wonder,
But braver sights the dredge delights,
As it roves the waters under…..

The deep sea is different!

Deep ocean is all areas beyond the continental
shelf (generally >200m depth)

Ocean volume is >1.3 billion km^3 (70% High seas), >99% is deep sea

Largest ecosystem on Earth

Average depth of ~ 4.2km

Area of deep seabed >434 million km^2

Average temperatures <4^oC, pressure ~400atm, near total darkness

Little photosynthetic primary production >200m depth

Food limited environment….but there is life

Horizon 2020 and the Blue Economy

- All economic activities related to the oceans, seas and coasts.
- This includes the closest direct and indirect supporting activities necessary for the functioning of these economic sectors
- Can be located anywhere, including in landlocked countries
- Current blue economy employs 5.4 million people and a gross added value of just under €500 billion per annum (~4-5% EU GDP)

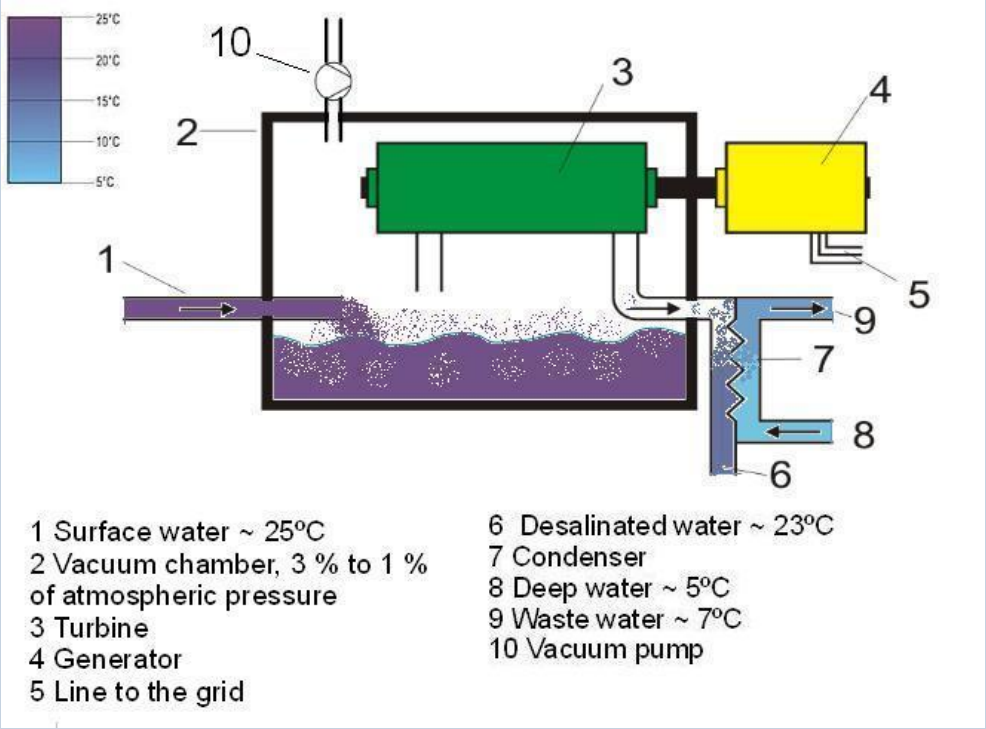
Focus - Blue Energy

Emphasis is on renewables

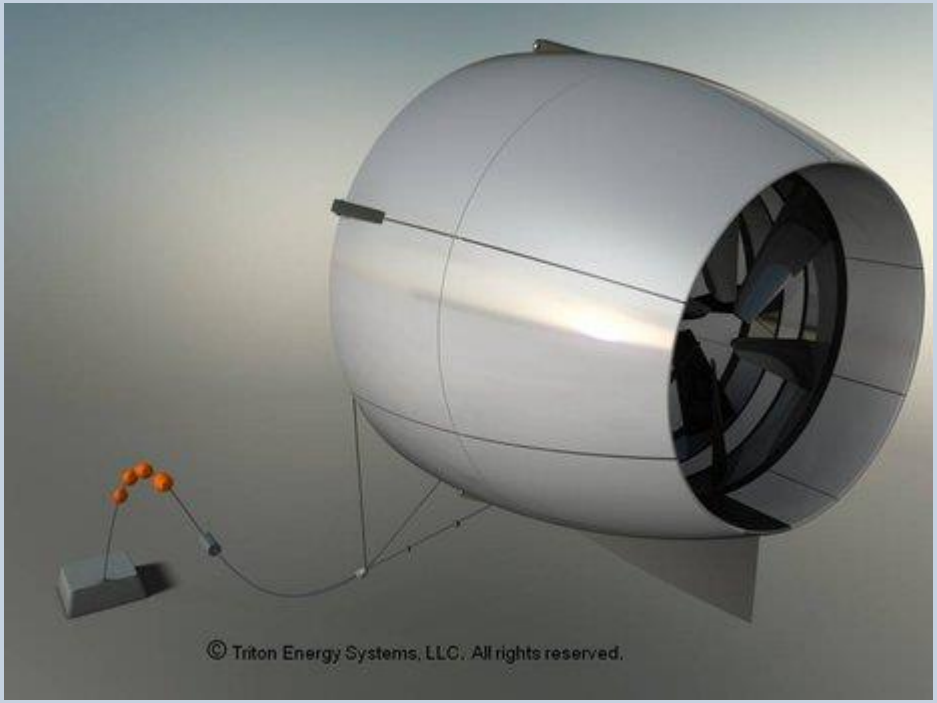
A deep-water example is Ocean Thermal Energy Conversion (OTEC)

Example shown is an open-cycle OTEC plant

- Warm seawater is vapourised under low pressure
- Vapour drives a turbine
- Water is condensed using cold deep-sea water
- By-products: freshwater; nutrient-rich seawater



Blue energy



IEEE Spectrum, October 2012

Aim is to take advantage of steadily flowing deep-water currents

Demonstration project between Eaton Technologies and Triton (subs)

1MW plant 30-150m deep

Aim is to build systems for 300-500m depth

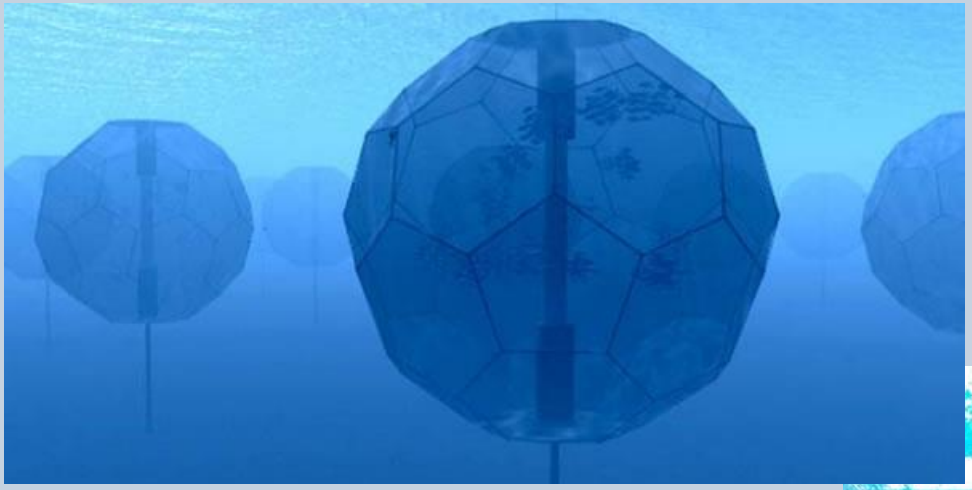
Greener technologies for maritime industries

Seaborne transport accounts for ~ 3% of greenhouse gas emissions

Room for considerable improvement in efficiency

Other areas to look at (dumping at sea; noise etc.)

Focus - Aquaculture



FAO 2010

"Most members thought it inevitable that aquaculture will move further offshore if the world is to meet its growing demand for seafood"

Area of active research with the aim of developing autonomous, untethered submerged culture/ ranching cages

Example: Hawaii Oceanic Technology

Focus – Tourism

Yachting €183 Billion

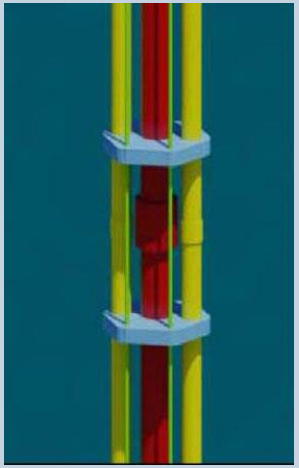
Game fishing Total

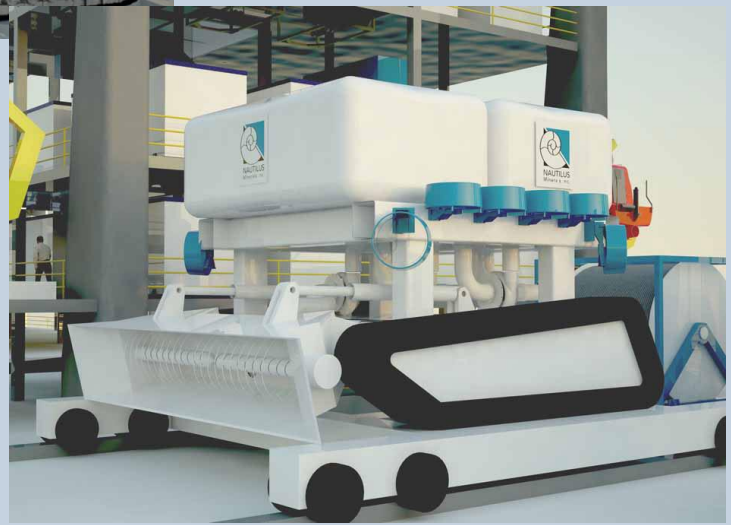
Cruise industry

Submarine tourism

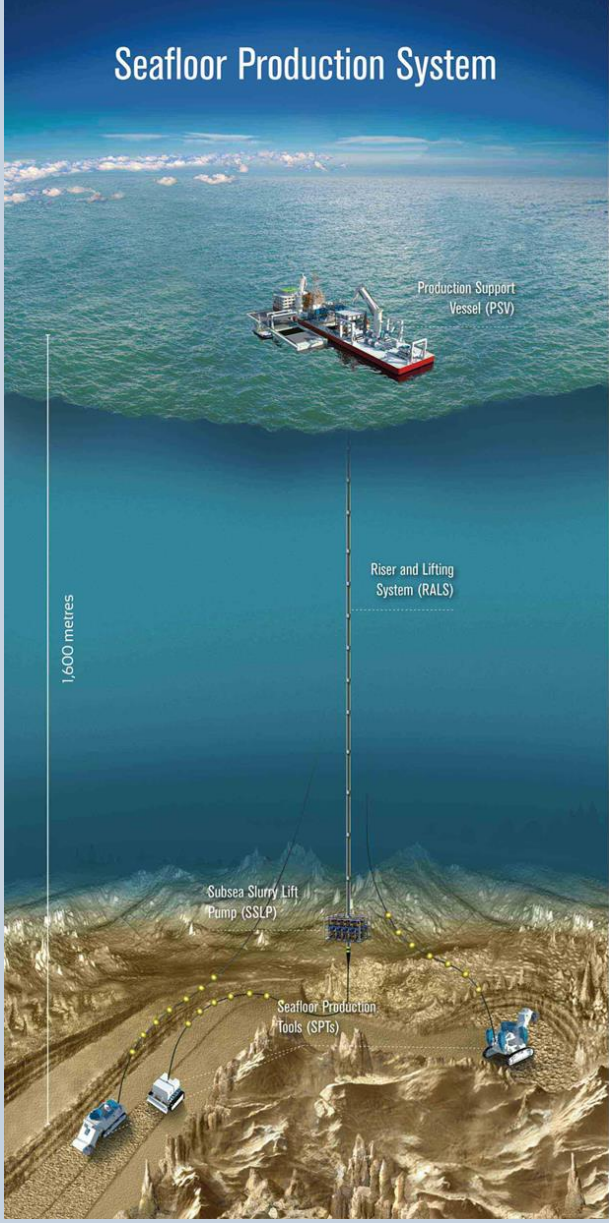
The need for a healthy ocean

Focus – Deep-Sea Mining



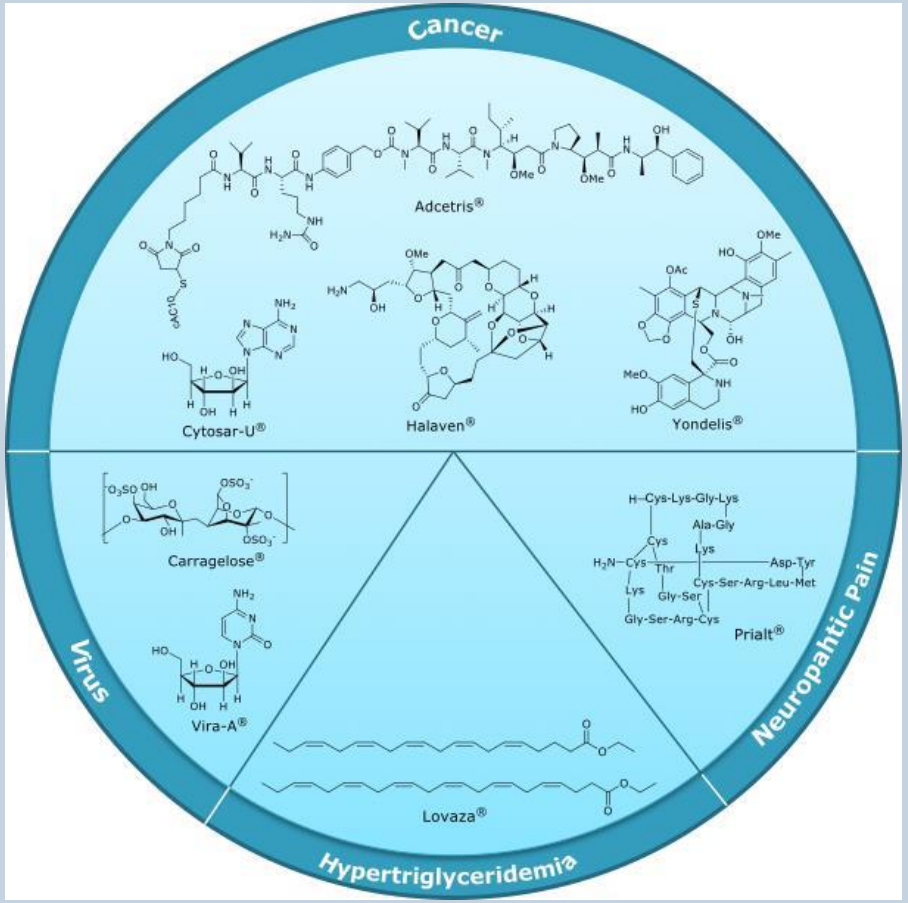


Marine mining (Nautilus Minerals PNG)



Focus - Biotechnology

- Sector employs 160,000 people in EU, USA, Canada, Australia.
- Revenues 2011-2012 were $89.9 billion (8% increase)
- Marine biotechnology products in 2012 worth ~$3.75 billion; increase from 2007 ($1.82 billion)
- EU currently industry has an added value of €0.8 billion - high potential for growth
- Increasing focus on novel metabolites rather than novel organisms



Chemical structure of marine drugs on market divided by therapeutic area

Goods and services provided by the deep oceans (Armstrong et al. 2012)

- Nutrient cycling
- Habitat
- Biodiversity
- Water circulation and exchange
- Carbon capture and storage
- Food (e.g. fish)
- Fuel/energy/minerals
- Chemical compounds (pharmaceutical / industrial)
- Waste disposal sites
- Gas & climate regulation
- Waste adsorption & detoxification
- Biological regulation
- Education
- Science
- Aesthetic / existence / bequest

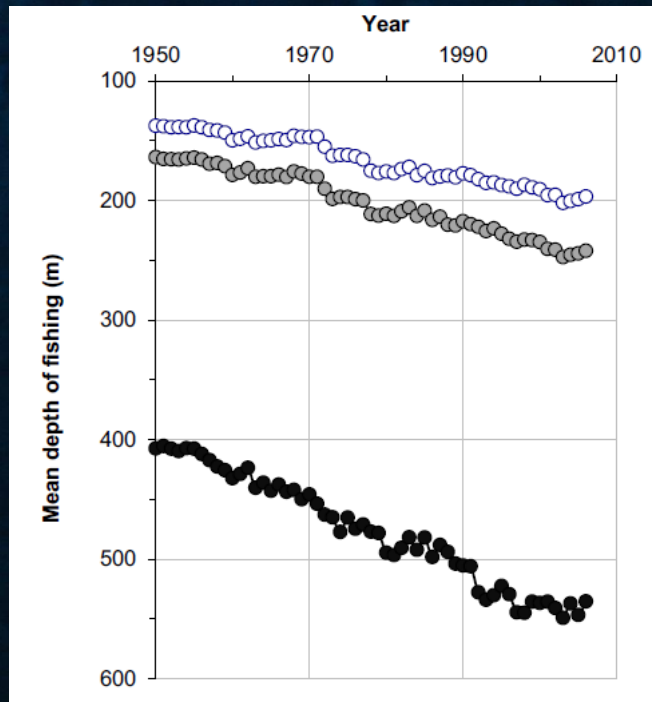
The mistakes of the past…..

Slow to mature (30-40 years)

High longevity (150 yrs+)

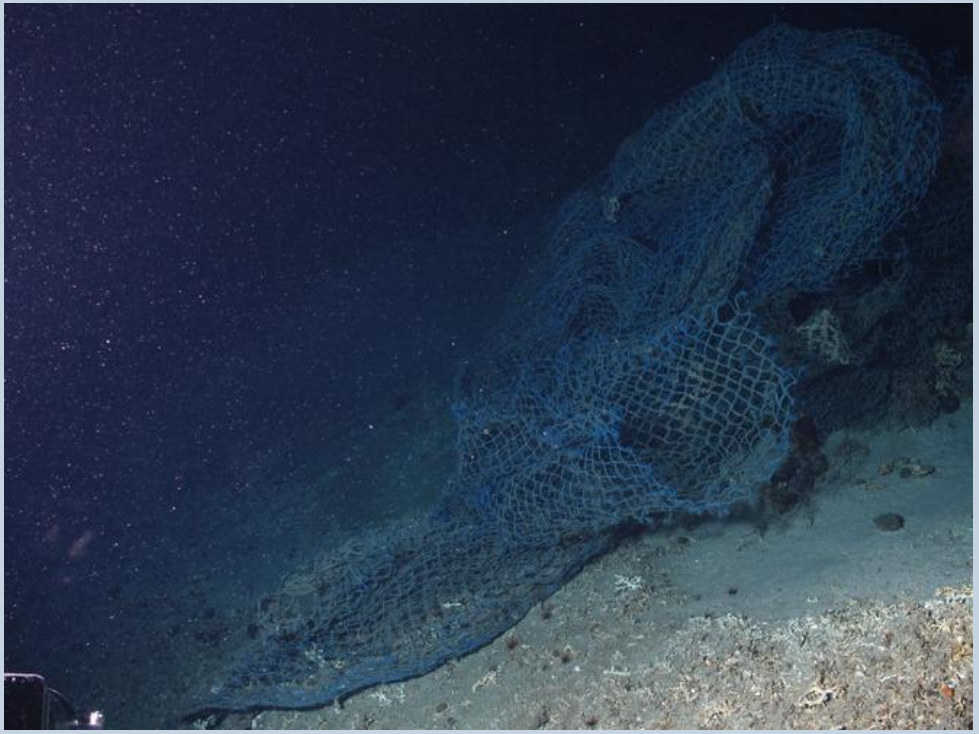
Sporadic reproduction

Aggregates to spawn

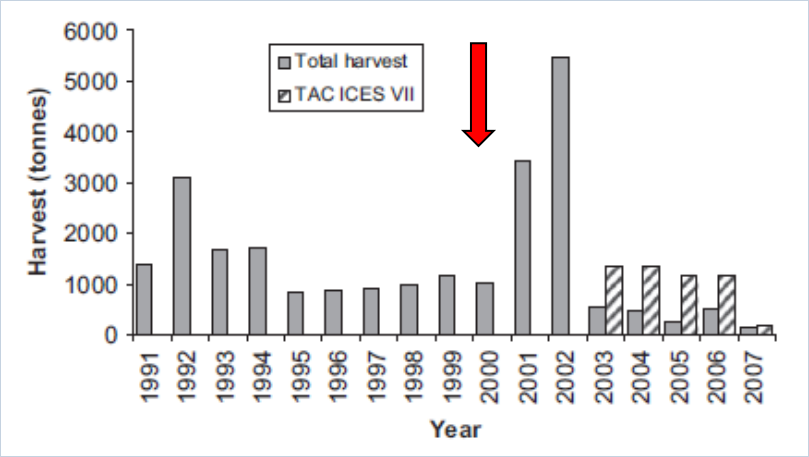


Trends in mean depth of catches of the EU fleet (blue = pelagic; grey = bottom fish; black = deep-sea species)
(Villasante et al 2012)

Overexploitation, by-catch, habitat damage



Sophie Arnaud-Haond IFREMER



Orange roughy catch ICES Area 7 1991 – 2007 (Foley et al. 2011)

Evidence of bottom trawl damage to vulnerable marine ecosystems (e.g. coral habitats) wide-spread. Also evidence of damage to biodiversity and ecosystem function of sedimented habitats (Pusceddu et al., 2014)

Role of deep-demersal fish in carbon cycling

(Trueman et al 2014)

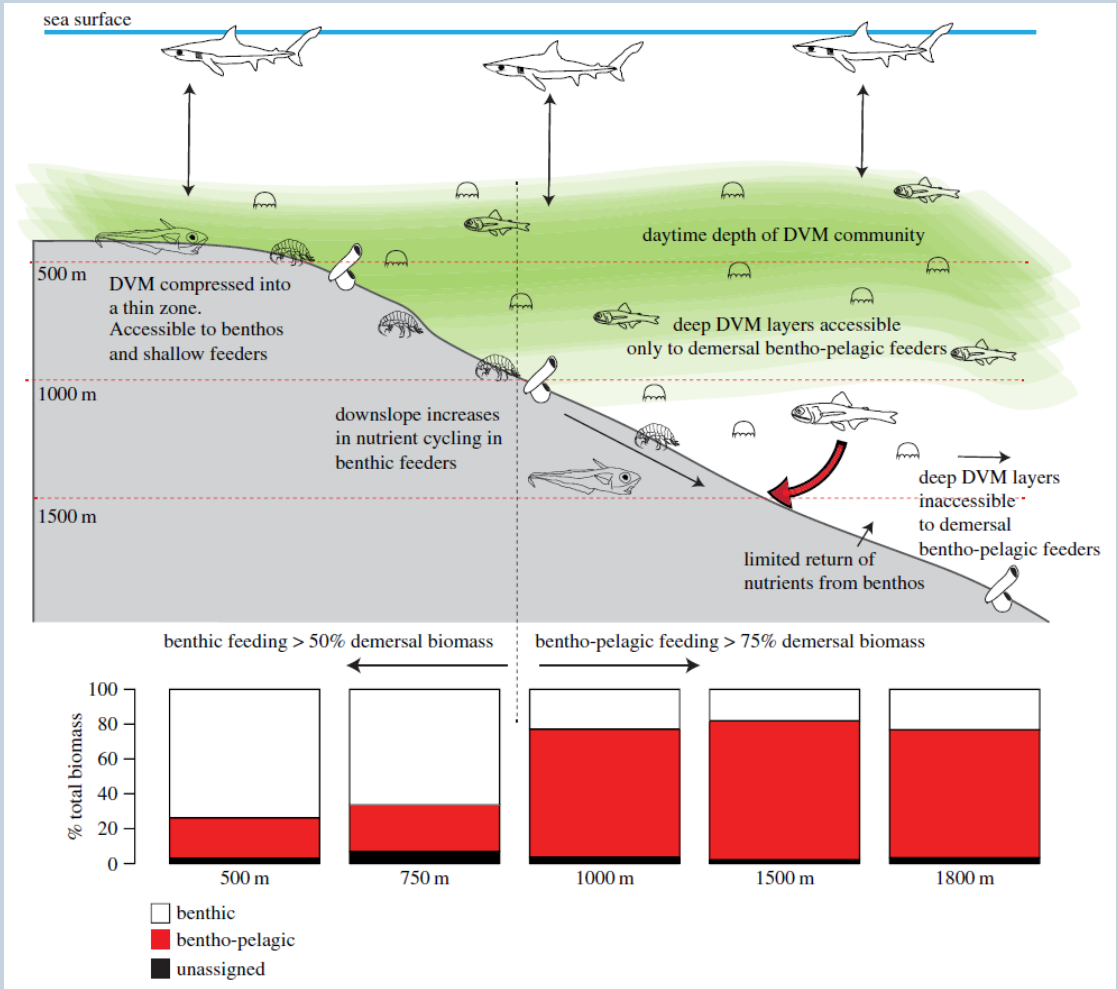
Schematic of nutrient cycling on the EU continental slope

Deep demersal fish capture carbon in the form of DVM plankton & micronekton and transport it below the remineralisation zone

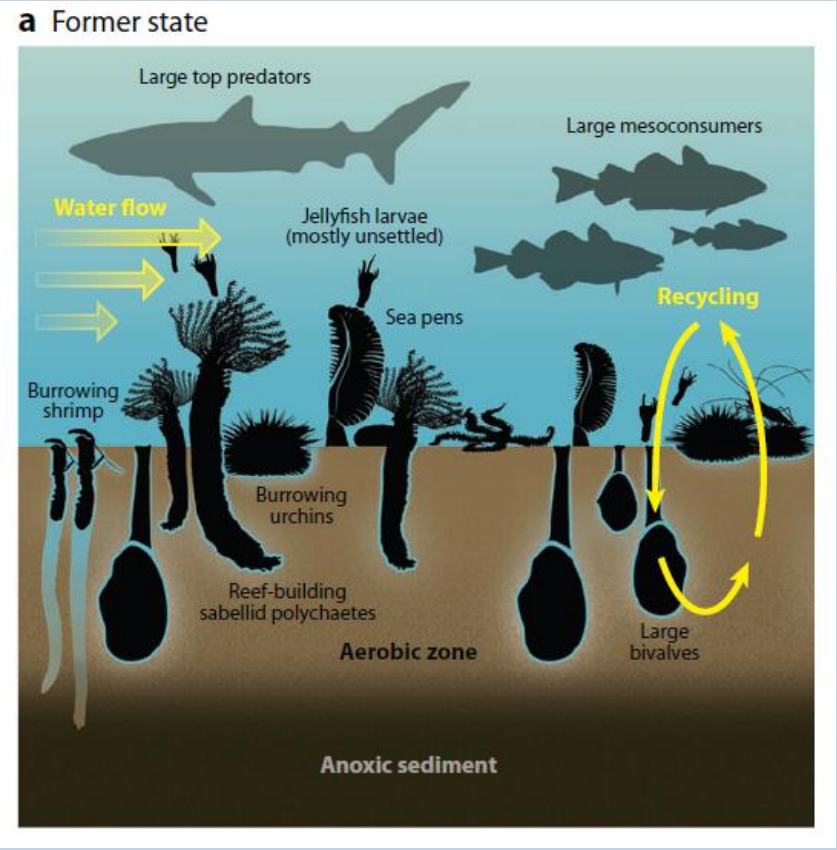
Value in terms of CO_2 capture
Trueman UK / Irish continental slope
= €8-14million (€6 t^{-1})

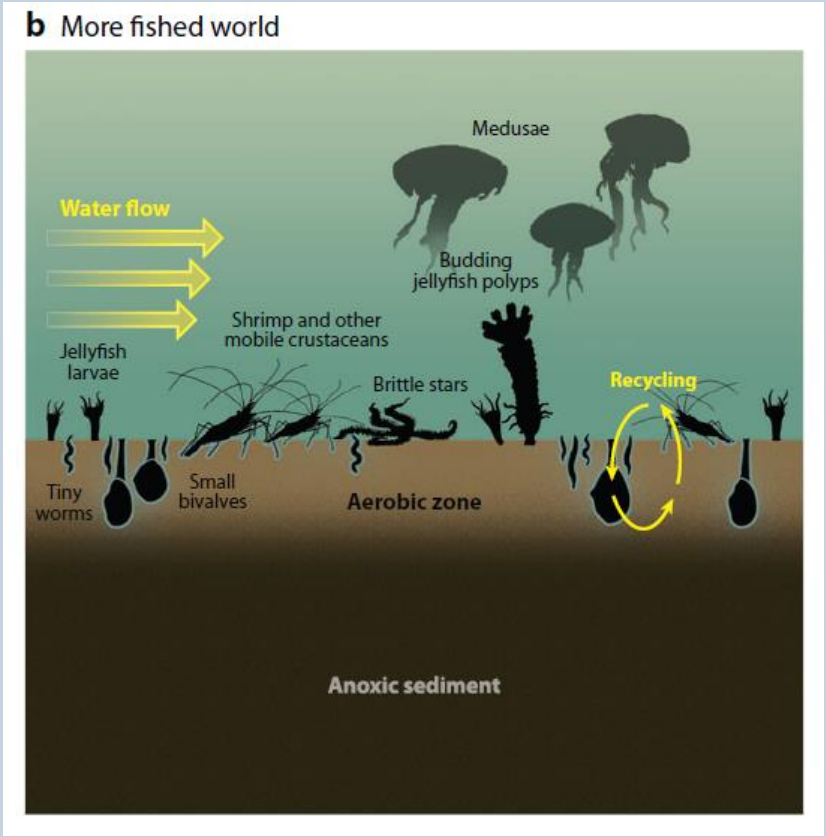
Highest SCC value (€101 t^{-1})
= €130-231 million

Value of all NE Atlantic DS Fisheries = €101



The production of some ecosystem services rely on ecosystem health



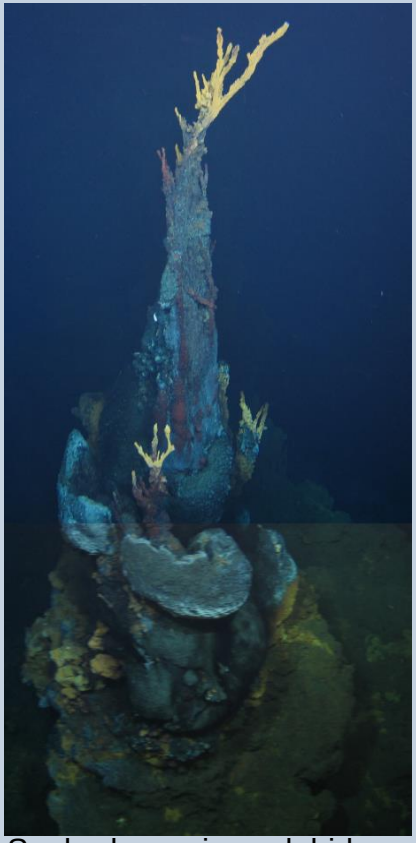


Goal: maintain an ecosystem in a healthy, productive and resilient condition so that it can provide <u>all</u> the services we need

Benefits - deep-sea mining

Marine phosphates (Namibia Phosphate)

Seamount cobalt crusts (BGR)

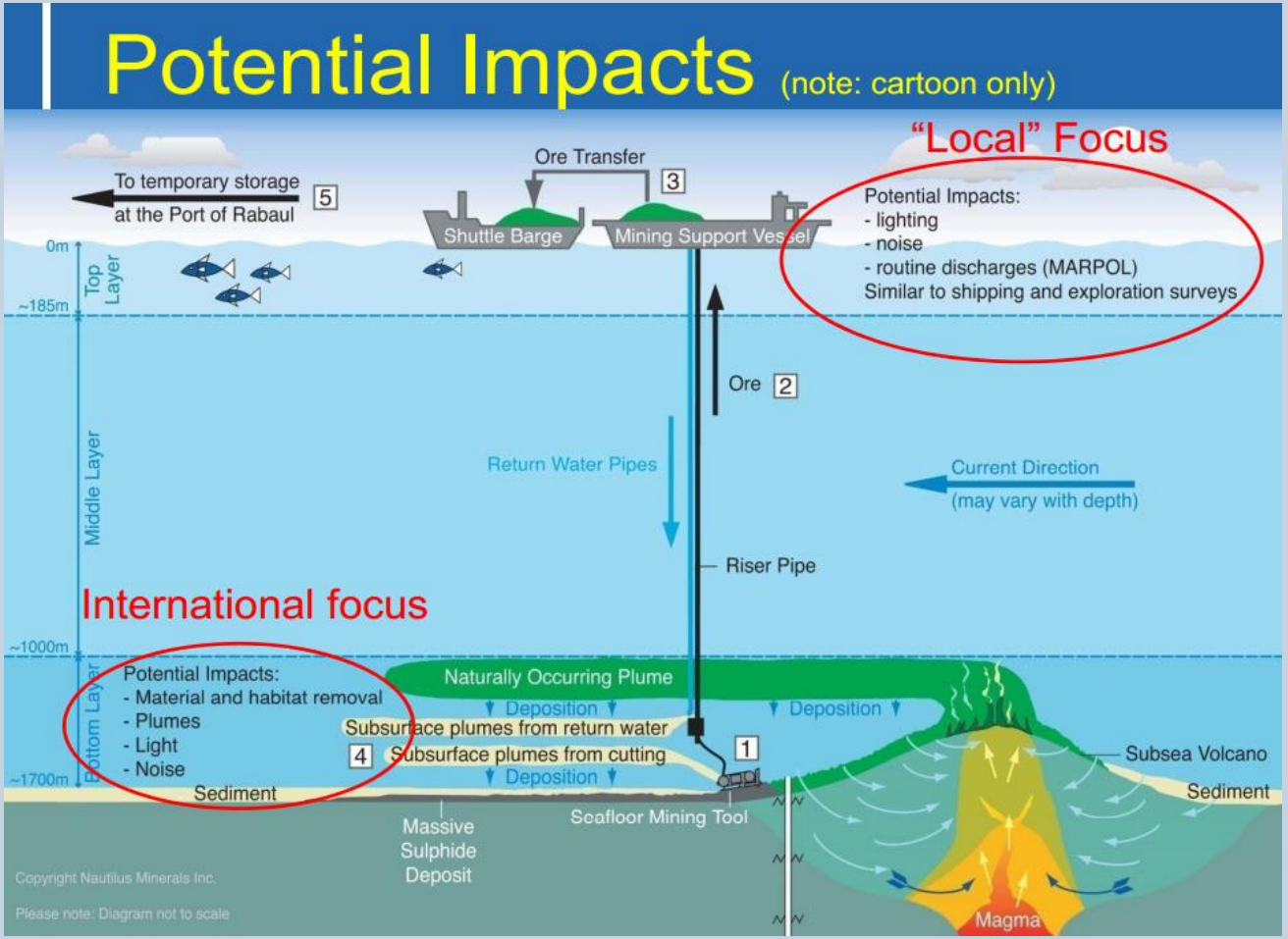


Seabed massive sulphides (Dragon vent field – NERC)

By 2030 10% of the world's mineral resources taken from the ocean with an annual turnover of €10 billion….
Includes copper, cobalt, zinc.
Importance of strategic supply.

Manganese nodules (Census of Marine Life / Aker Wirth)

Risks – potential impacts on the environment and ecosystem services



Nautilus Minerals

Rare Earth Elements – mine them from the deep sea or recycle?

What are the alternatives?

A good example is REEs. Is it sensible to try and extract them from the deep-sea or would a better EU investment be in developing technologies that do not depend on REEs or which recycle them?

Informing policy makers of benefits, risks and options

(Image: CNN Money Nov. 18th, 2011)

Objectives of the Deep-Sea WG

- Enhancing cross-sector collaboration (science, industry, social science, economics)
- 360º Review; achievements to date in deep-sea research; EU infrastructure; gap analysis (science leading on to capability)
- Define societal opportunities (extraction of biotic and abiotic resources; biotechnology; CO_2 sequestration etc).
- Key recommendations for future EU deep-sea research to address societal challenges (Horizon 2020 emphasis on blue economy)
- Mechanisms for how deep-sea sea research can contribute to sustainable management and governance of the ocean

EMB survey: priorities given to different areas of deep-sea research in blue growth context – scientists and science funders

Area of research	Low Priority				High priority
	1	2	3	4	5
Increasing knowledge	0	0	2	3	7
Seafloor mapping	2	1	4	1	2
Seafloor surveying	3	1	2	2	1
Anthropogenic impacts	2	0	5	4	1
Environmental impacts	2	0	4	3	3
Valuing goods and services	2	2	4	1	0
Ecosystem interactions	1	1	2	2	3
Physical oceanography	1	3	4	1	0
Biogeochemical cycles	5	1	1	1	3
Technology development	4	3	1	0	4
Policy and legal issues	4	2	2	0	0
Long term monitoring	1	2	4	2	2
Other	0	0	0	0	5

Largest priority was increasing basic knowledge, understanding human impacts, environmental impact (EIA), valuing good and services and seafloor mapping.

EMB survey: priorities given to different areas of deep-sea research in blue growth context - industry

Area of research	Low Priority				High priority
	1	2	3	4	5
Increasing knowledge	3	2	0	4	1
Seafloor mapping	3	0	3	1	2
Seafloor surveying	3	0	2	2	2
Anthropogenic impacts	1	1	2	2	2
Environmental impacts	2	2	1	1	0
Valuing goods and services	3	1	2	2	0
Ecosystem interactions	3	0	1	2	1
Physical oceanography	1	3	4	1	0
Biogeochemical cycles	3	5	0	1	0
Technology development	3	0	1	2	2
Policy and legal issues	1	0	0	4	3
Long term monitoring	2	0	3	4	0
Other	0	0	0	0	0

High priority for increasing basic knowledge but also policy and legal issues and long-term monitoring.

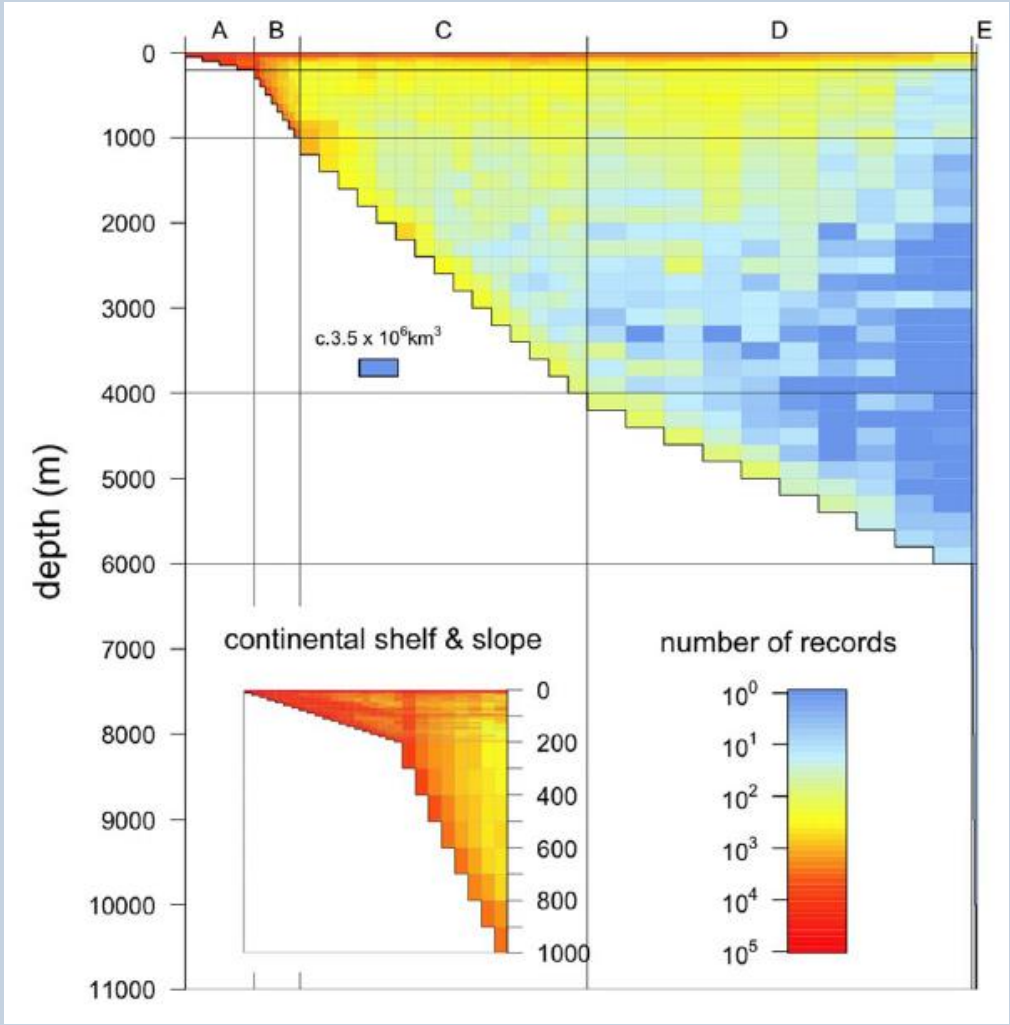
Number of records per unit ocean volume

Deep ocean is poorly sampled

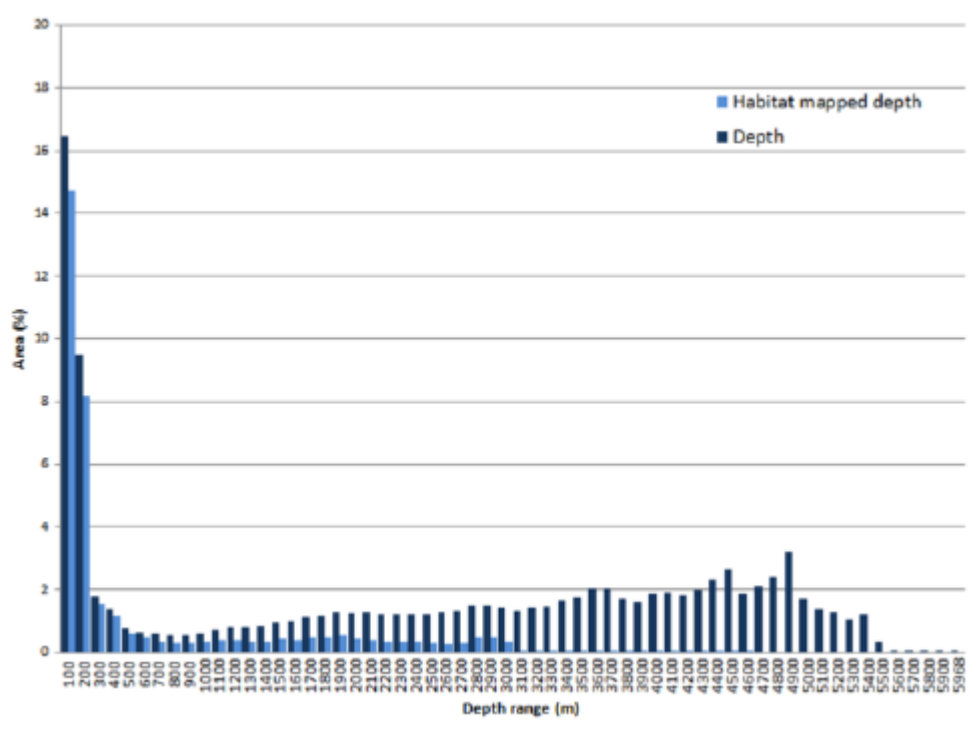
Deep pelagic zone is the most poorly sampled (many depth zones over abyssal plains not sampled)

A = continental shelf; B = continental shelf / mesopelagic;
C = continental shelf / bathypelagic; D = abyssal plain;
E = hadal zone

Webb et al. 2010



Lack of understanding of spatial and temporal variation in biodiversity



Depth distribution of EEZ of EU (dark blue) and depth distribution of mapped habitat (light blue) Galparsoro et al (2014)

Proportion of deep-sea habitats Investigated (Ramirez-Llodra et al. 2010)

Deep pelagic	<<0.00001%
Deep seafloor	0.00001%
Abyssal plains	<1%
Continental slope	Minimal
Ridges	10%
Seamounts	0.25-0.28%
Hadal zone	Minimal
Canyons	Minimal
Benthic eOMZ	<1%
Hydrothermal vents	~10%
Cold seeps	~2%
Whale falls	~0.05%

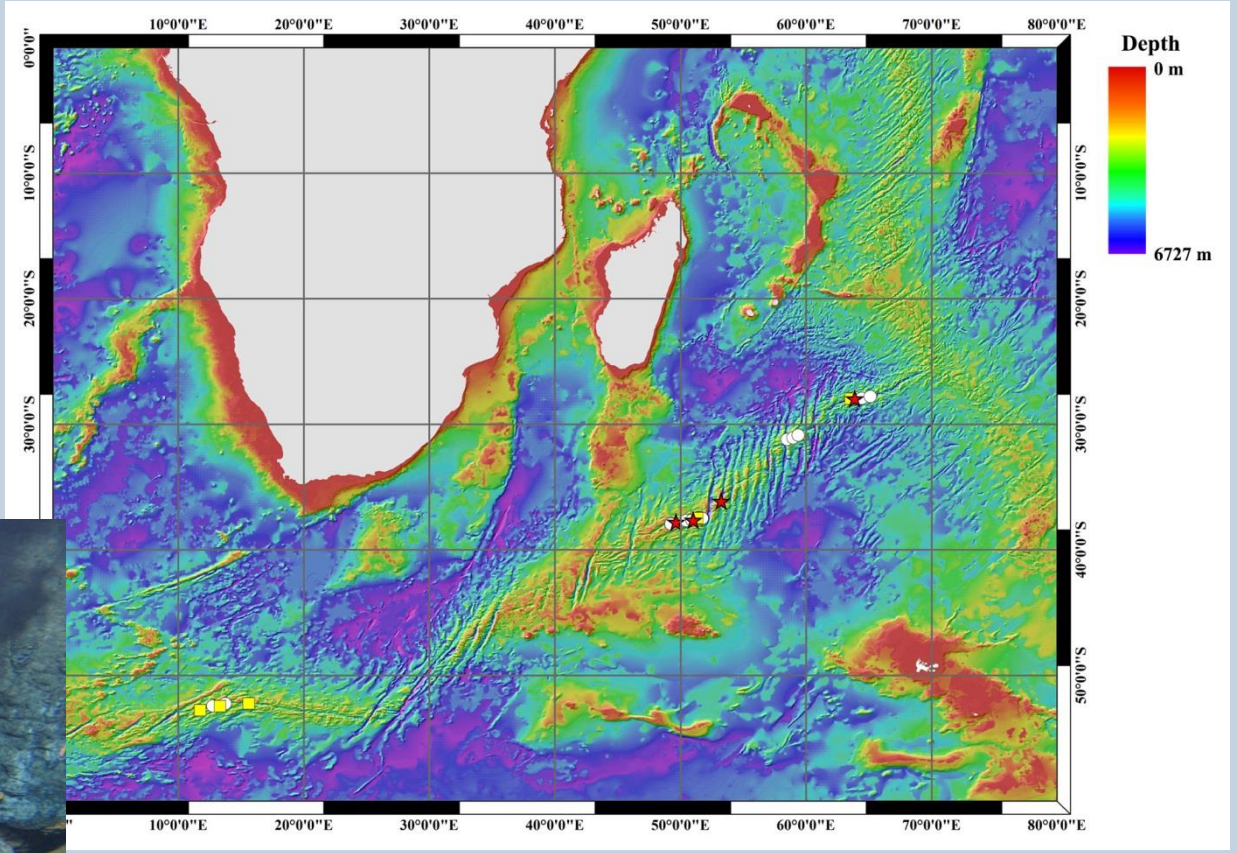
Environmental impact assessment: what's the point with no context?

South West Indian Ridge

EIA required by ISA

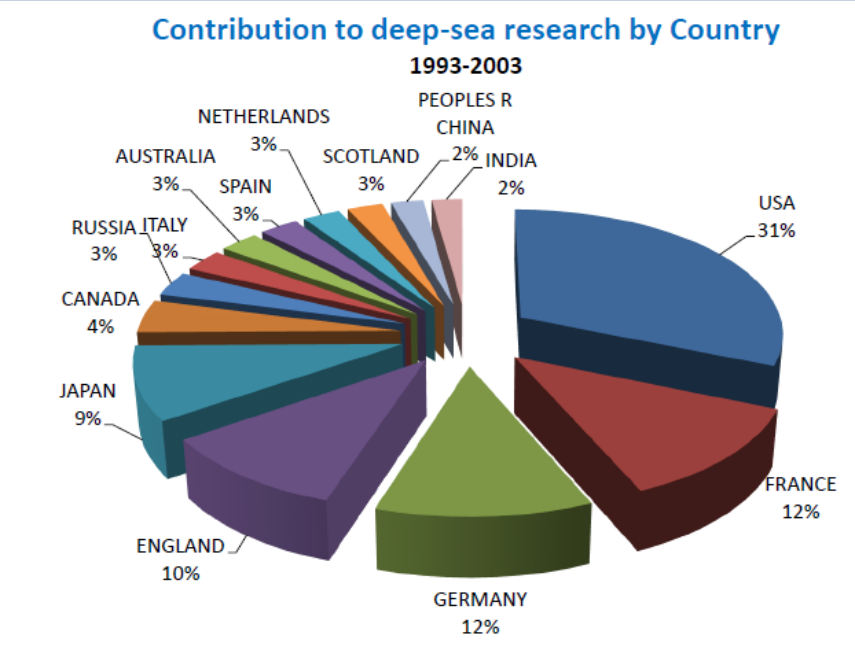
Most work on Dragon (Longqui) vent field

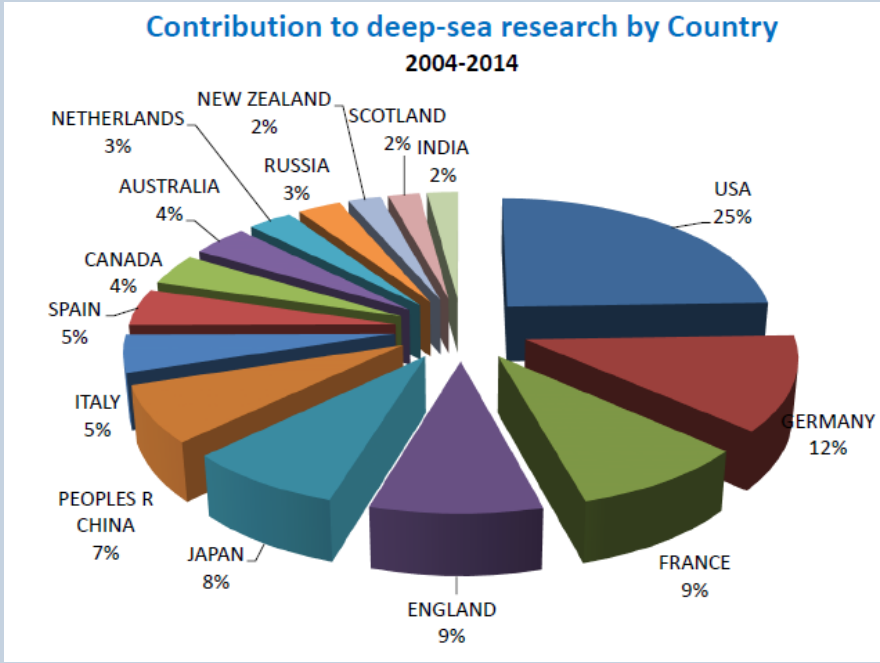
Little work elsewhere



Stars = known fields; Yellow boxes = well constrained fields; White spots = poorly constrained fields

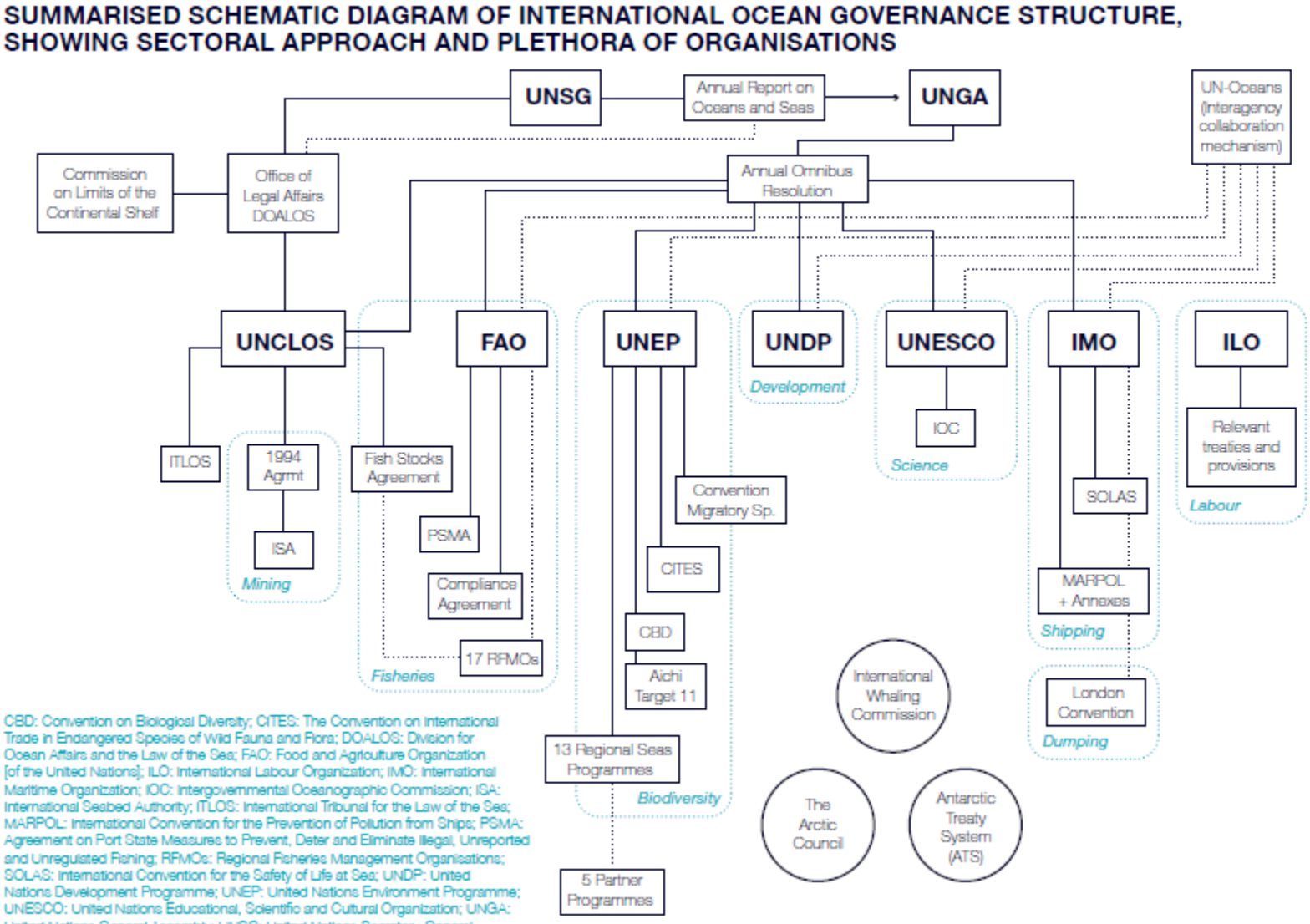
Europe's contribution to deep-sea science (Danavaro In prep)





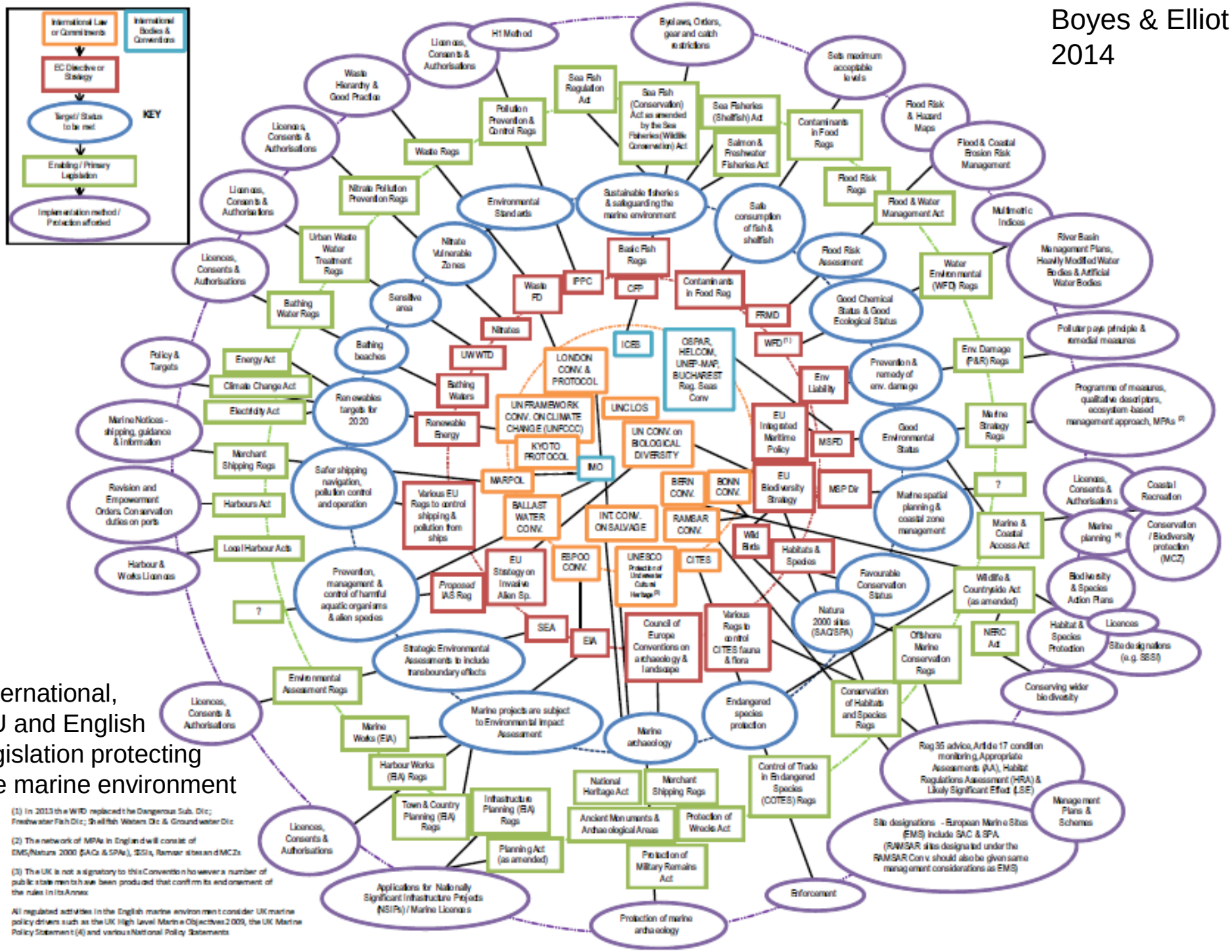
EU is by far largest contributor to deep-sea science according to ISI Web of Science database…….but issues of resources and infrastructure.

Divided governance infrastructure



GOC, 2014

Boyes & Elliot 2014



International, EU and English legislation protecting the marine environment

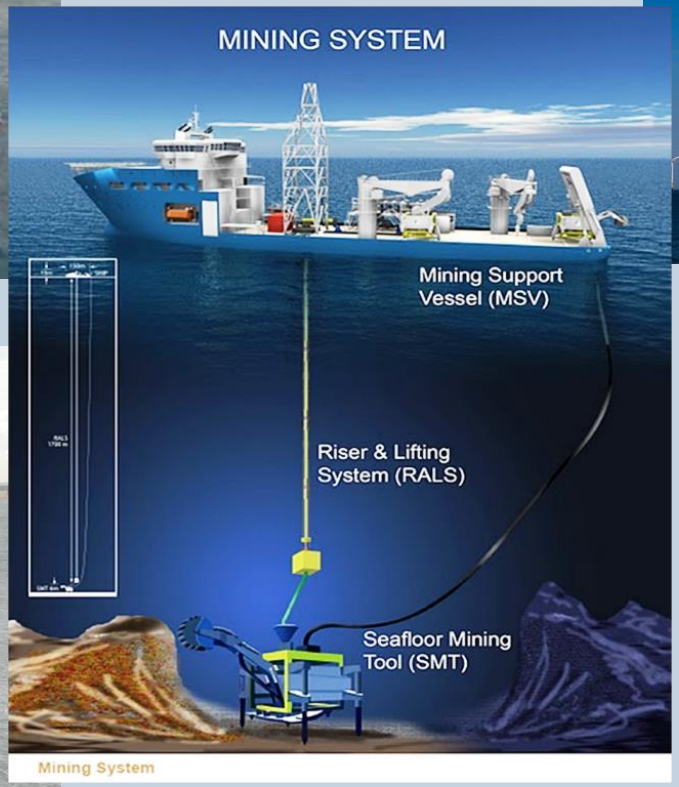
(1) In 2013 the WFD replaced the Dangerous Sub. Dirs; Freshwater Fish Dirs; Shellfish Waters Dirs & Groundwater Dirs

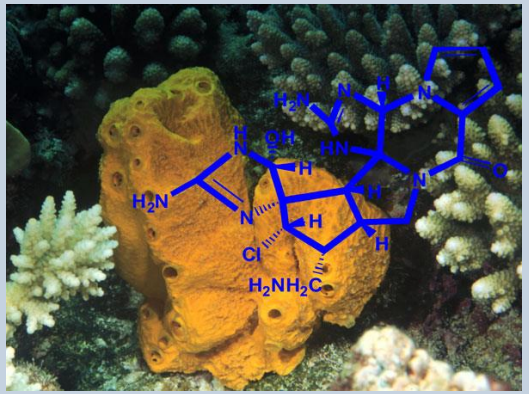
(2) The network of MPAs in England will consist of EMS/Natura 2000 (SACs & SPAs), SSSIs, Ramsar sites and MCZs

(3) The UK is not a signatory to this Convention however a number of public statements have been produced that confirm its endorsement of the rules in its Annex

All regulated activities in the English marine environment consider UK marine policy drivers such as the UK High Level Marine Objectives 2009, the UK Marine Policy Statement (4) and various National Policy Statements

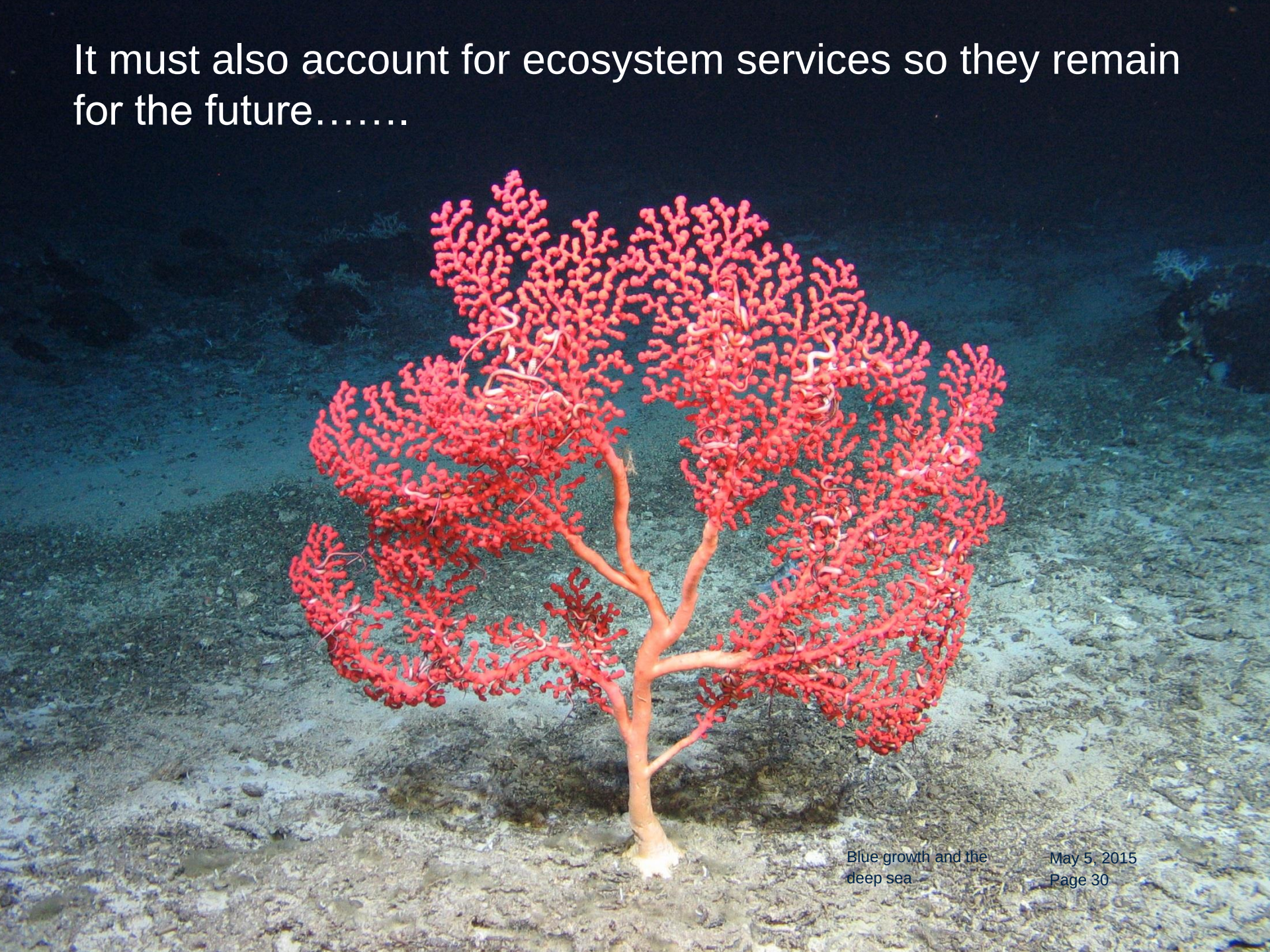
Management must be cross-sectoral, ecosystem-based and driven by knowledge





Marine spatial planning in the ocean

It must also account for ecosystem services so they remain for the future…….



Summary

- The deep sea is different from shallow-water ecosystems
- The deep sea has an important role to play in blue growth
- It is important to avoid the mistakes of the past
- Sustainable blue growth requires a complete understanding
- of the benefits and risks of new (and old) industries
- There is a strong need for more knowledge (biodiversity etc)
- Need for new approaches to ocean management and governance