THE ECOSYSTEM SERVICES OF THE OCEAN'S TWILIGHT ZONE (OTZ)

Porter Hoagland

Marine Policy Center
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

*https://twilightzone.whoi.edu/

January 30,2019

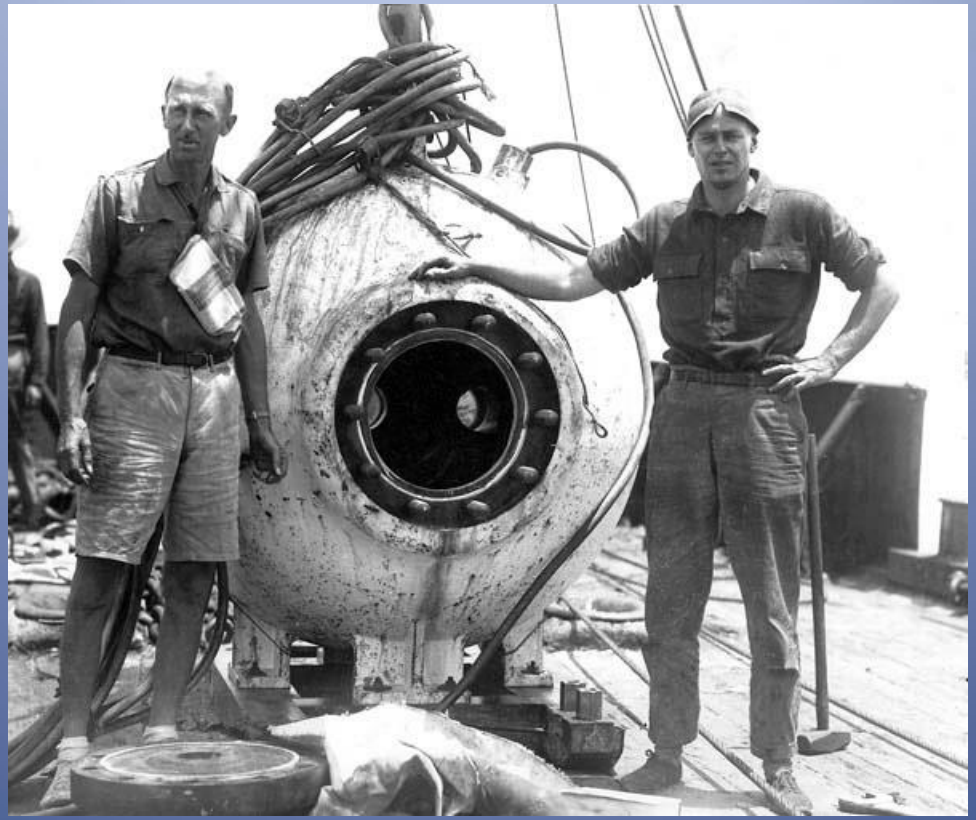
University of Connecticut at Avery Point

***Acknowledgements: Di Jin, Ankur Shah, other WHOI/OTZ principals**

Outline

- Goal of sustainable conservation
- Physical environment
- Law of the Sea jurisdictions
- MA 2005 Framework (ecosystem services)
- Important services
- Some analytical directions
- Policy relevance

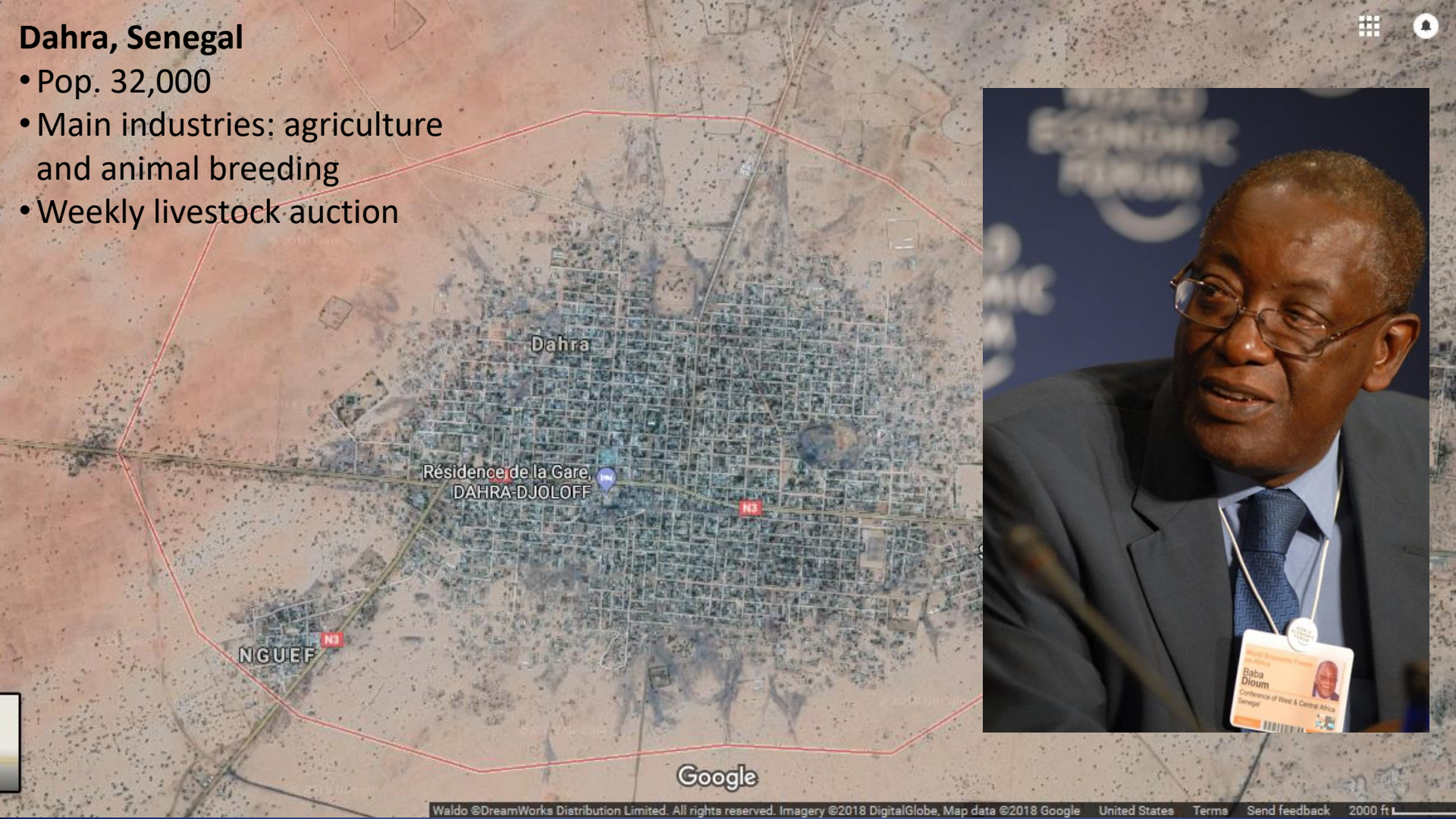
“Few have heard of the mesopelagic. It is a layer of the ocean, a few hundred metres below the surface, where little light penetrates, so algae do not live. But it is home to animals in abundance. .. [*The Economist*, April 15, 2017]



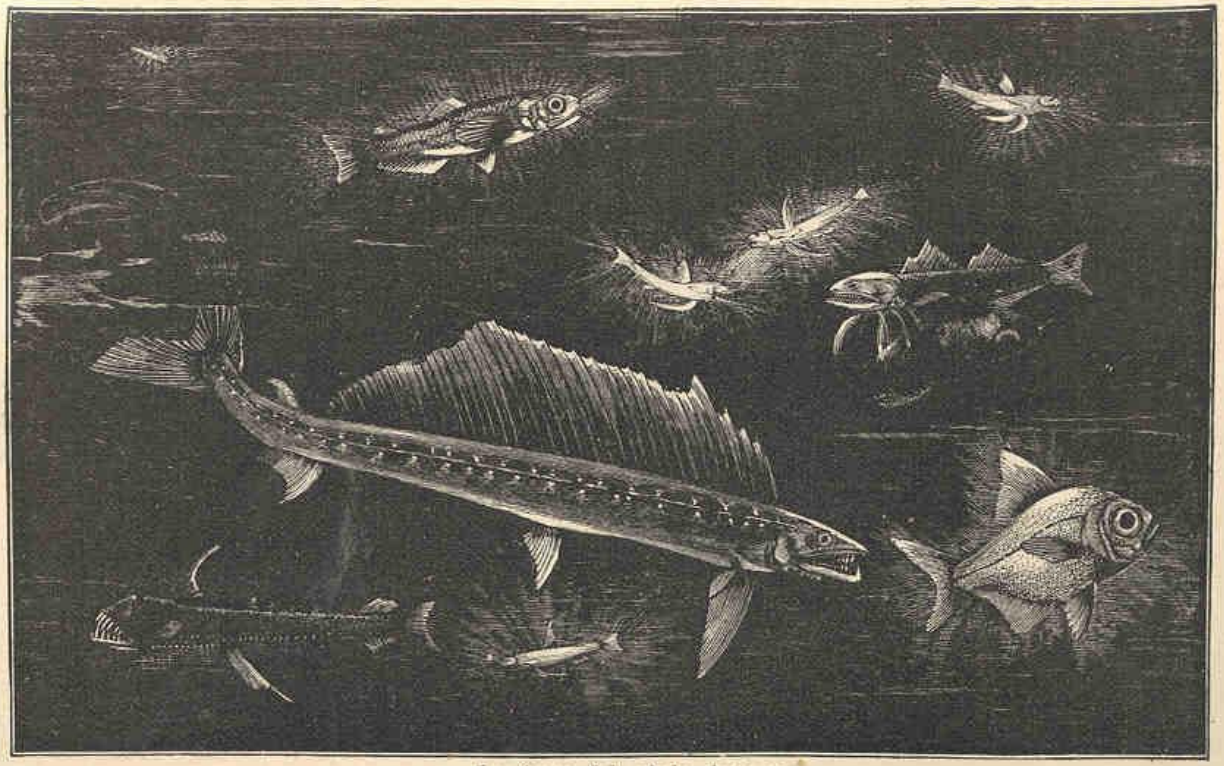
These descents of mine beneath the sea seemed to partake of a real cosmic character…there was the complete and utter loneliness and isolation, a feeling wholly unlike the isolation felt when removed from fellow men by mere distance … [William Beebe, *Half Mile Down* (1951)]

Dahra, Senegal

- Pop. 32,000
- Main industries: agriculture and animal breeding
- Weekly livestock auction



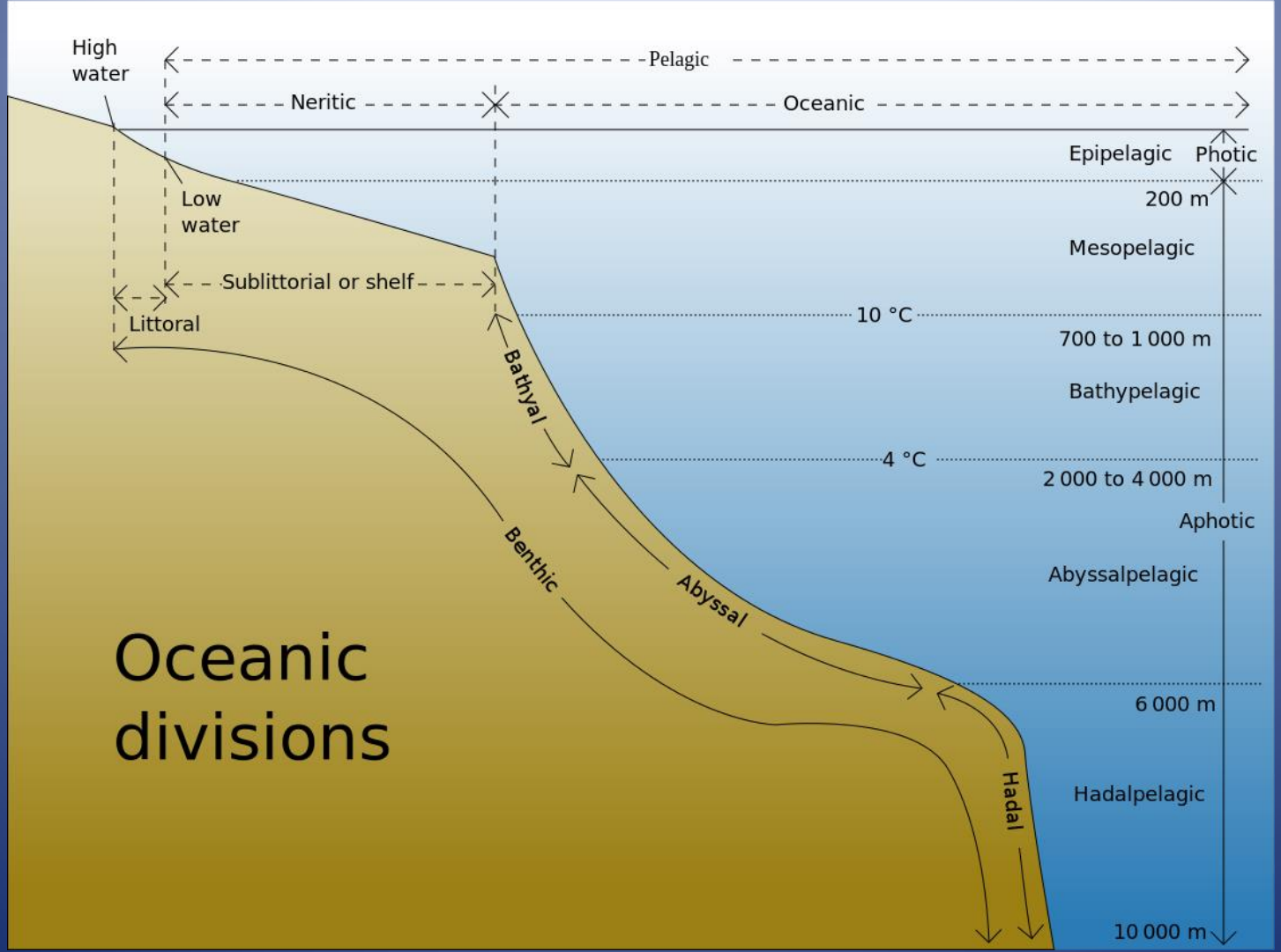
SEA/MBC C-279 (2018)

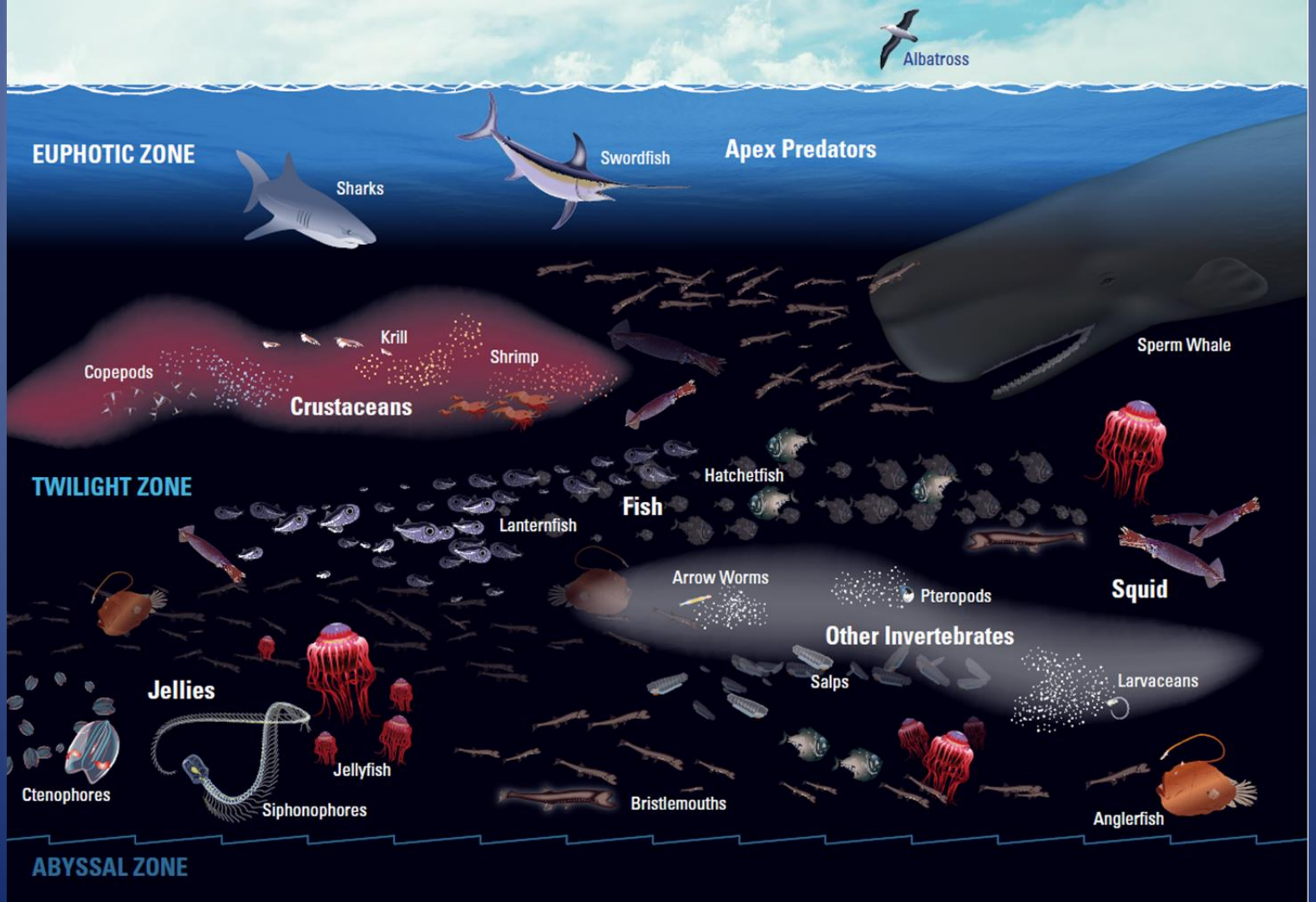


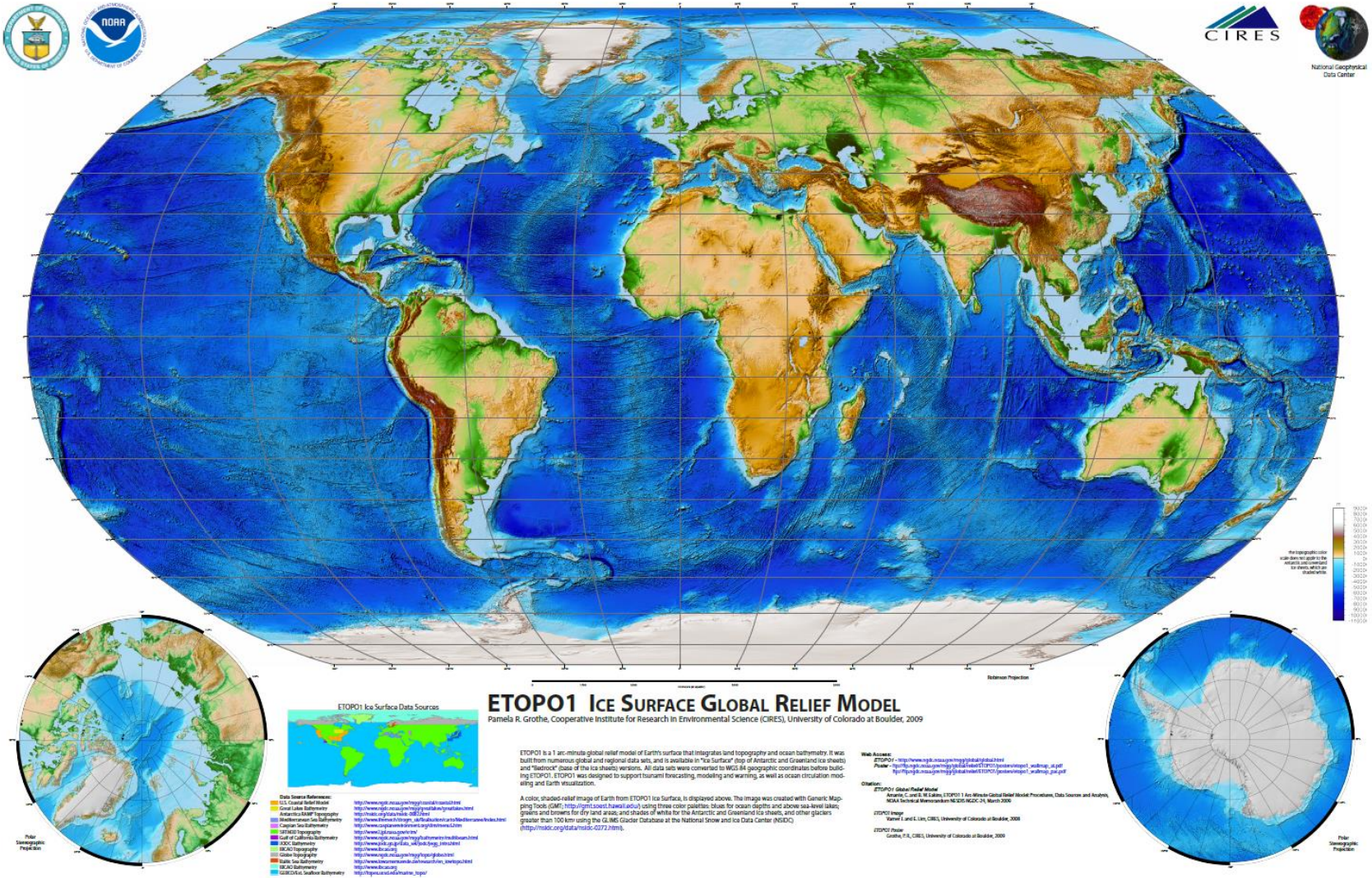
Luminous fish of the deep sea.

"Now boys…hold the net steady and remember our rule—not to kill more than we can actually use…"

[Charles Frederick Holder (1892) *Along the Florida Reef*]


High water
Pelagic
Neritic
Oceanic
Epipelagic
Photic
Low water
200 m
Mesopelagic
Sublittorial or shelf
Littoral
10 °C
700 to 1 000 m
Bathypelagic
Bathyal
4 °C
2 000 to 4 000 m
Aphotic
Benthic
Abyssal
Abyssalpelagic
Oceanic divisions
6 000 m
Hadal
Hadalpelagic
10 000 m


Albatross
EUPHOTIC ZONE
Sharks
Swordfish
Apex Predators
Sperm Whale
Krill
Shrimp
Copepods
Crustaceans
TWILIGHT ZONE
Hatchetfish
Fish
Lanternfish
Arrow Worms
Pteropods
Squid
Other Invertebrates
Salps
Larvaceans
Jellies
Jellyfish
Ctenophores
Siphonophores
Bristlemouths
Anglerfish
ABYSSAL ZONE



ETOPO1 Ice Surface Global Relief Model

Pamela R. Grothe, Cooperative Institute for Research in Environmental Science (CIRES), University of Colorado at Boulder, 2009

ETOPO1 is a 1 arc-minute global relief model of Earth's surface that integrates land topography and ocean bathymetry. It was built from numerous global and regional data sets, and is available in "Ice Surface" (top of Antarctic and Greenland ice sheets) and "Bedrock" (base of the ice sheets) versions. All data sets were converted to WGS 84 geographic coordinates before building ETOPO1. ETOPO1 was designed to support tsunami forecasting, modeling and warning, as well as ocean circulation modeling and Earth visualization.

A color, shaded-relief image of Earth from ETOPO1 Ice Surface, is displayed above. The image was created with Generic Mapping Tools (GMT; http://gmt.soest.hawaii.edu/) using three color palettes: blues for ocean depths and above sea-level lakes; greens and browns for dry land areas; and shades of white for the Antarctic and Greenland ice sheets, and other glaciers greater than 100 km² using the GLIMS Glacier Database at the National Snow and Ice Data Center (NSIDC) (http://nsidc.org/data/nsidc-0272.html).

Web Access:

ETOPO1 - http://www.ngdc.noaa.gov/mgg/global/global.html

Poster - ftp://ftp.ngdc.noaa.gov/mgg/global/relief/ETOPO1/posters/etopo1_wallmap_a4.pdf
ftp://ftp.ngdc.noaa.gov/mgg/global/relief/ETOPO1/posters/etopo1_wallmap_gar.pdf

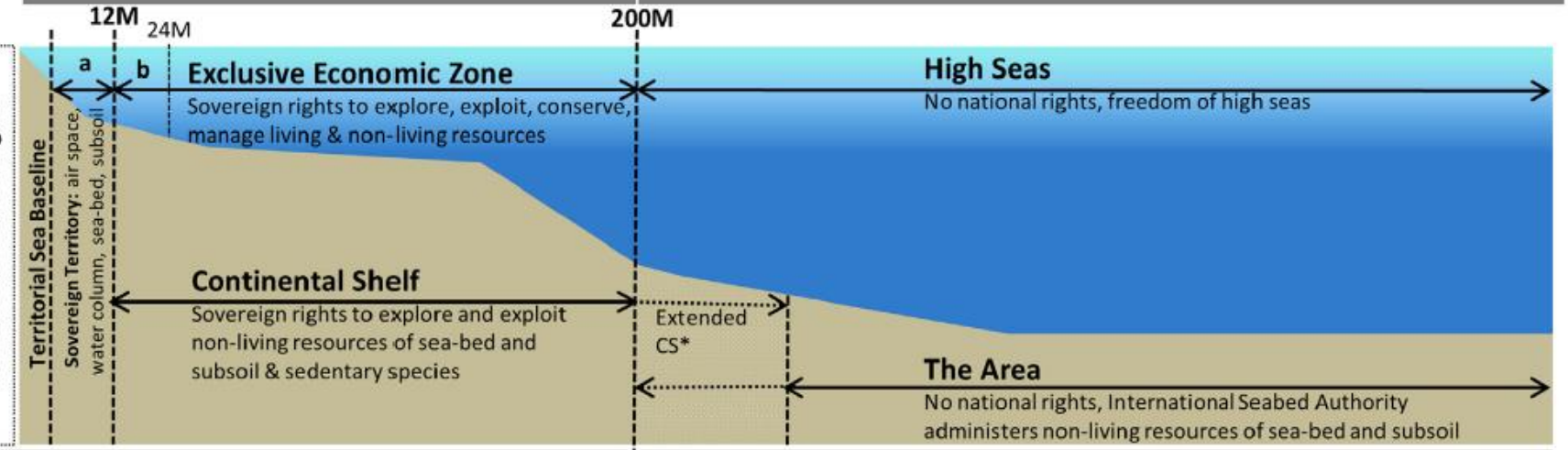
Citation:

ETOPO1 Global Relief Model
Amante, C. and B. W. Eakins, ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis, NOAA Technical Memorandum NESDIS NGDC-24, March 2009

ETOPO1 Image
Varner J. and E. Lim, CIRES, University of Colorado at Boulder, 2008

ETOPO1 Poster
Grothe, P.R., CIRES, University of Colorado at Boulder, 2009

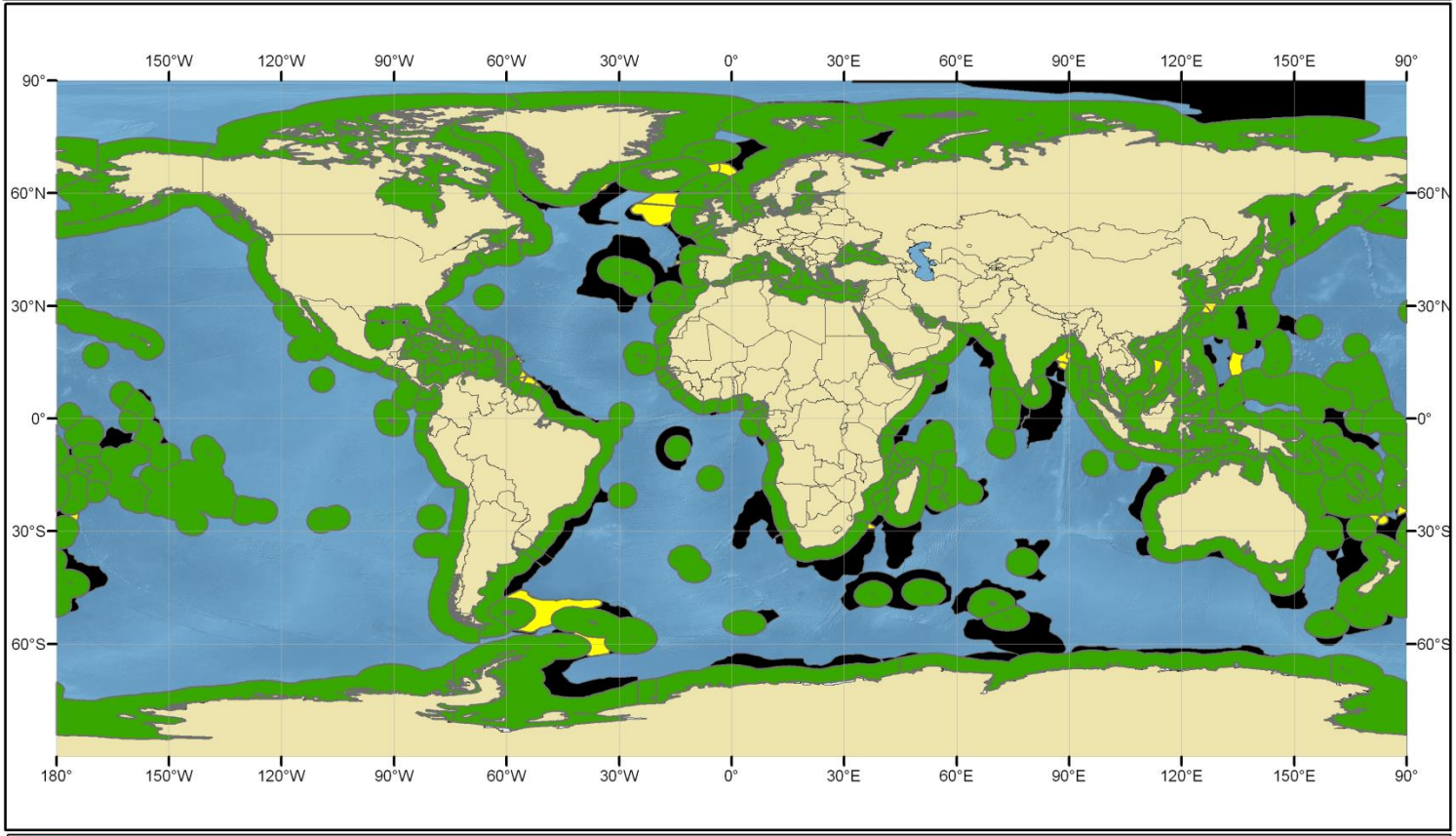
MARINE AREAS WITHIN NATIONAL JURISDICTION Internal Waters; Archipelagic Waters; Territorial Sea (a); Contiguous Zone (b); Exclusive Economic Zone (EEZ); Continental Shelf (CS)	MARINE AREAS BEYOND NATIONAL JURISDICTION (ABNJ) High Seas (water column) The Area (sea-bed, subsoil)



UNCLOS Maritime zones & associated resources rights		
International law re: MGR	UNCLOS: coastal state right to grant or withhold consent for marine scientific research (XIII)	UNCLOS: freedom of marine scientific research in the high seas (VII); marine scientific research for benefit of mankind in the Area (XI).
	CBD Nagoya Protocol: facilitate access and share benefits from genetic resources	No applicable access and benefit-sharing regime for genetic resources
	UNCLOS: principles for conduct of marine scientific research; duty to publish and share results and information (XIII), develop and transfer marine technology (XIV); duty to protect and preserve marine environment (XII).	

*Maximum extent of extended continental shelf: "shall not exceed 350 nautical miles from the territorial sea baselines or it shall not exceed 100 nautical miles from the 2500 metre isobath which is a line connecting the depth of 2500 metres" (UNCLOS art. 76(5)). Submission required to Commission on the Limits of the Continental Shelf to confirm rights over extended continental shelf.

ECS - EEZ WORLD



Exclusive economic zone

Extended continental shelf

Extended continental shelf (overlapped)

GEOMAR MARINE PLAN

GEOMAR
University of Seville. Department of Human Geography

Source: Author based on VLIZ / DOALOS

Ecosystem Service Typology

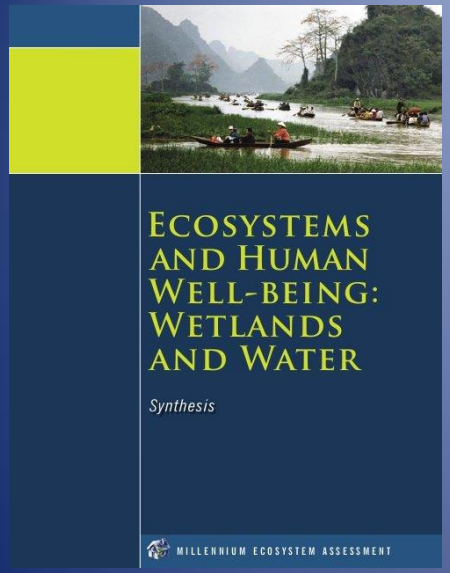
Provisioning	seafood, genetic resources
Regulating	C-sequestration, waste assimilation
Cultural	science, education, “sense-of-place”
Supporting	1° productivity, lower trophic levels

Ecosystem Service Typology

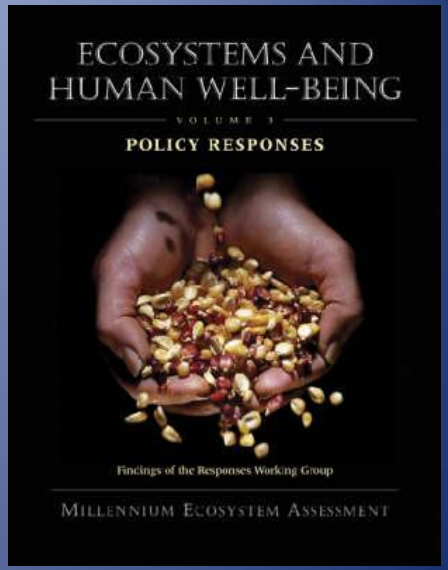
Supporting

- Provisioning
- Regulating
- Cultural

Millennium Ecosystem Assessment (2005)



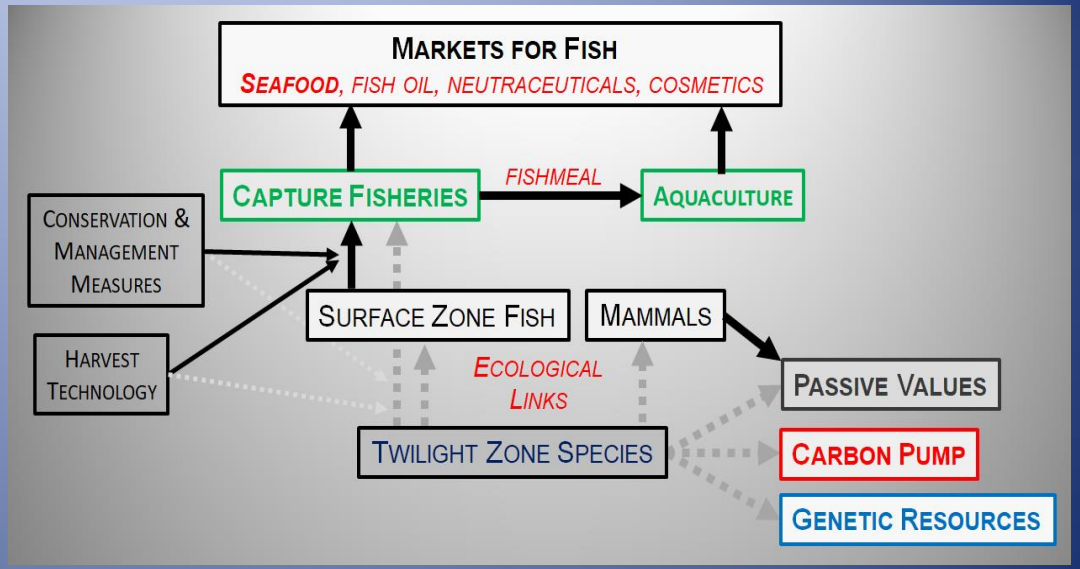
Category	Ecosystem service	Explanation
Provisioning services	Food	Food products derived from plants, animals, and microbes.
	Fibre and fuel	Materials including wood, jute, cotton, hemp, silk, and wool. Biological materials providing sources of energy e.g. wood, dung.
	Genetic resources	Genes and genetic information used for animal and plant breeding and biotechnology.
	Biochemical / natural medicines	Medicines, biocides, food additives such as alginates.
	Ornamental resources	Animal and plant products (e.g. skins, shells, and flowers) are used as ornaments. Whole plants used for landscaping and ornaments.
	Fresh water	People obtain fresh water from ecosystems. Fresh water in rivers is also a source of energy.
Regulatory services	Pollination	Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
	Pest and disease regulation	Ecosystem changes affect the abundance of human pathogens and disease vectors and the prevalence of crop / livestock pests and diseases.
	Climate regulation	Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
	Air quality regulation	Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
	Water regulation	The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover.
	Erosion regulation	Vegetative cover plays an important role in soil retention and the prevention of landslides.
	Natural hazard regulation	The presence of coastal ecosystems (e.g. mangroves and coral reefs) can reduce the damage caused by hurricanes or large waves.
	Water purification / soil remediation / waste treatment	Ecosystems can be a source of impurities but also can help filter out and decompose organic wastes introduced into ecosystems. They can also assimilate and detoxify compounds through biological processes.
Cultural services	Spiritual and religious values	Many religions attach spiritual and religious values to ecosystems or their components.
	Education and inspiration	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
	Recreation and ecotourism	People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes.
	Cultural diversity and heritage	The diversity of ecosystems is one factor influencing the diversity of cultures. Many societies place high value on the maintenance of either historically important landscapes ('cultural landscapes') or culturally significant species.
	Aesthetic values	Many people find beauty or aesthetic value in various aspects of ecosystems.
	Sense of place	Many people value the 'sense of place' that is associated with features of their environment, including aspects of the ecosystem.
Supporting services	Primary production, photosynthesis	Primary production is the assimilation of energy and nutrients by biota. Photosynthesis produces oxygen required by most living organisms.
	Soil formation and retention	Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.
	Nutrient cycling	Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems.



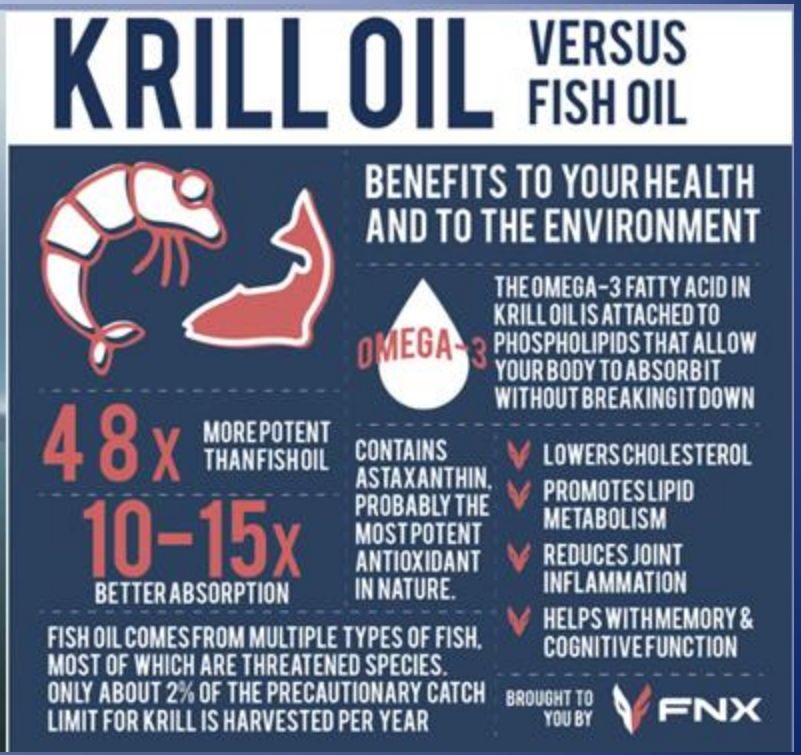
A typology for organizing our thinking about tradeoffs.

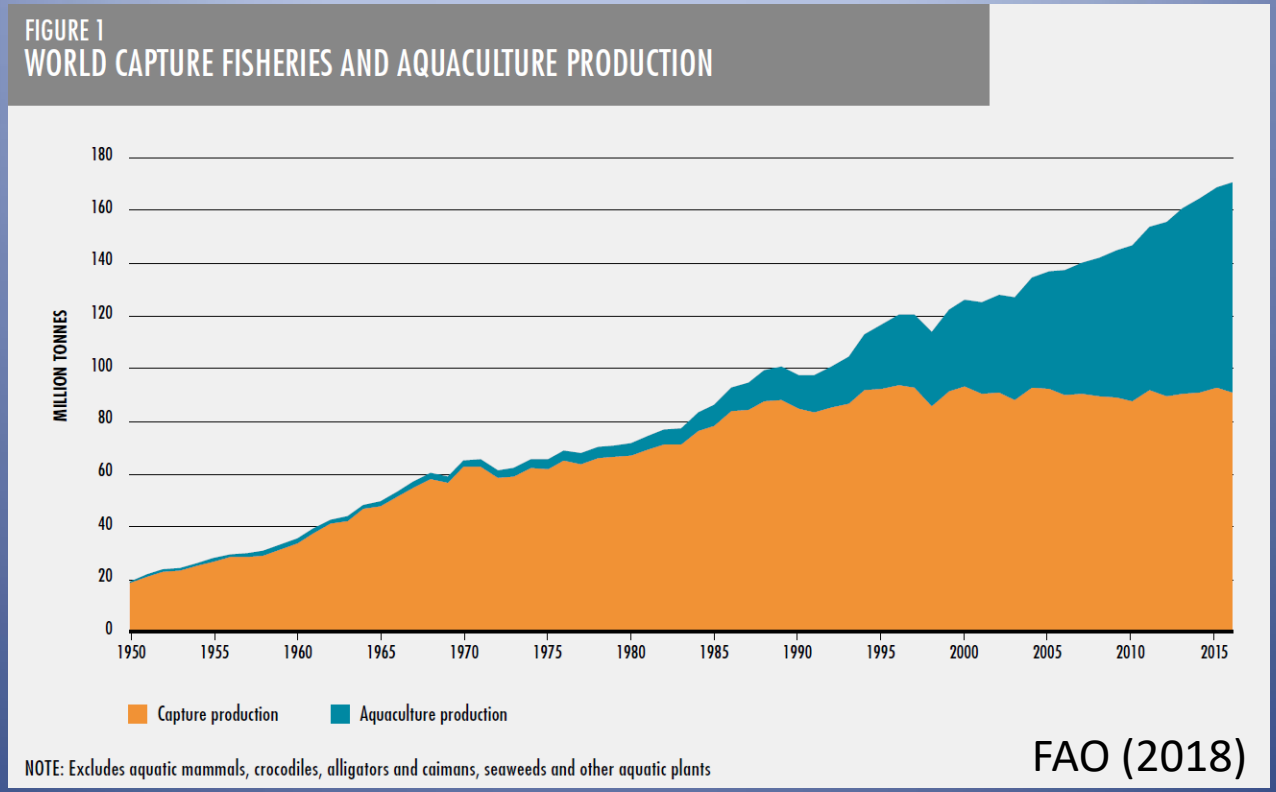
OTZ Ecosystem Services

- A WHOI/OTZ **Program Goal** is the development of scientific knowledge for the **sustainable use and conservation** of the OTZ (across generations)
- Identifying and characterizing the ecosystem services (ESs) of the OTZ provides an **organizing framework for conceptualizing sustainability**
- Understanding the OTZ's economic benefits is critical for gauging the **opportunity costs** of activities that could diminish those benefits
- **International MA Framework**: Provisioning, Regulating, Cultural, and Supporting ecosystem services



Provisioning Services

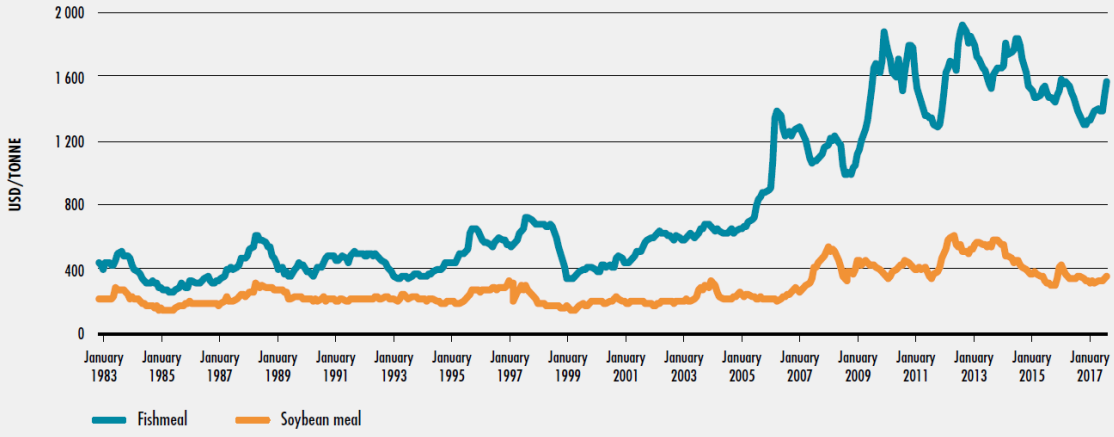




FAO (2018)

"Despite a slowdown in its annual growth rate, aquaculture will be the main driver of [future] growth in seafood production. [OECD (2016)]

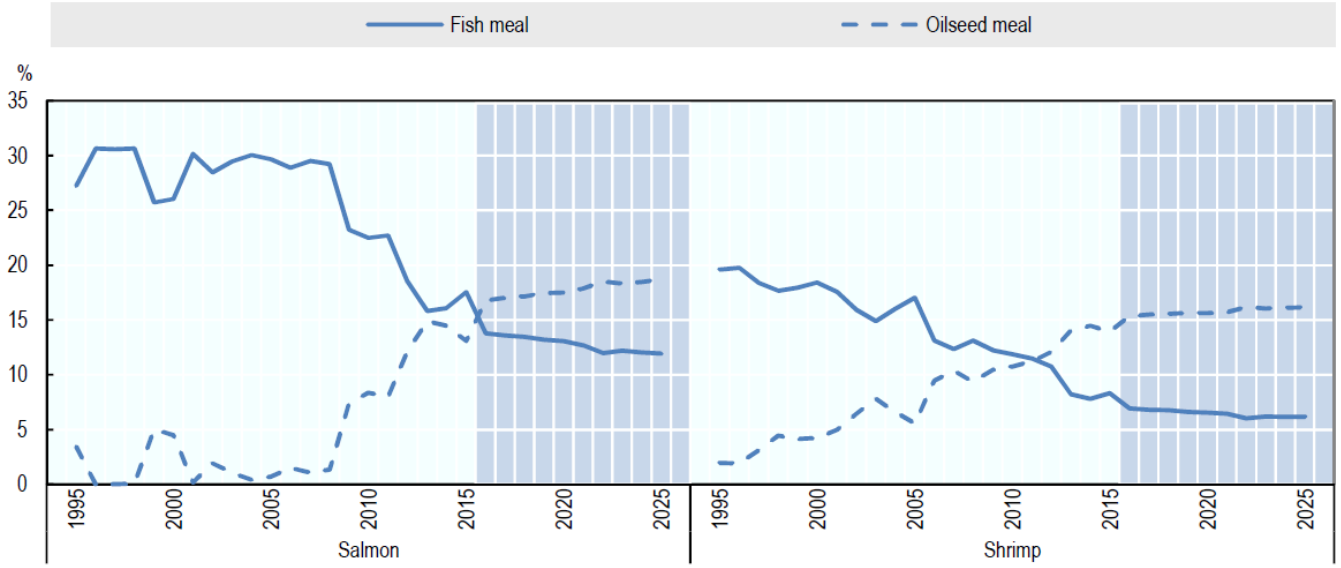
FIGURE 27
FISHMEAL AND SOYBEAN MEAL PRICES IN GERMANY AND THE NETHERLANDS



NOTES: Data refer to CIF (cost, insurance and freight) prices. Fishmeal: all origins, 64–65 percent, Hamburg, Germany. Soybean meal: 44 percent, Rotterdam, the Netherlands.
SOURCE: Data from Oil World and FAO's GLOBEFISH project

"…the continued high costs of fishmeal, fish oil and other related feeds will serve as a drag on growth as they are a crucial component of production for many species, in particular carnivorous ones…." [OECD (2016)]

Figure 3.6.5. Share of fishmeal consumption by type of aquaculture



Source: OECD/FAO (2016), "OECD-FAO Agricultural Outlook", *OECD Agriculture statistics* (database), http://dx.doi.org/10.1787/agr-outl-data-en.

"The amount of fishmeal and fish oil in aquaculture feeds are expected to continue their downward trend due to high prices and major innovation efforts, and fishmeal and fish oil will be more frequently used as strategic ingredients to enhance growth at specific stages of fish production." [OECD (2016)]

EVALUATION OF LANTERN FISH (*BENTHOSEMA PTEROTUM*) AS MARINE SOURCE IN FISH FEEDS: NUTRIENT COMPOSITION AND CONTAMINANTS ASSESSMENT

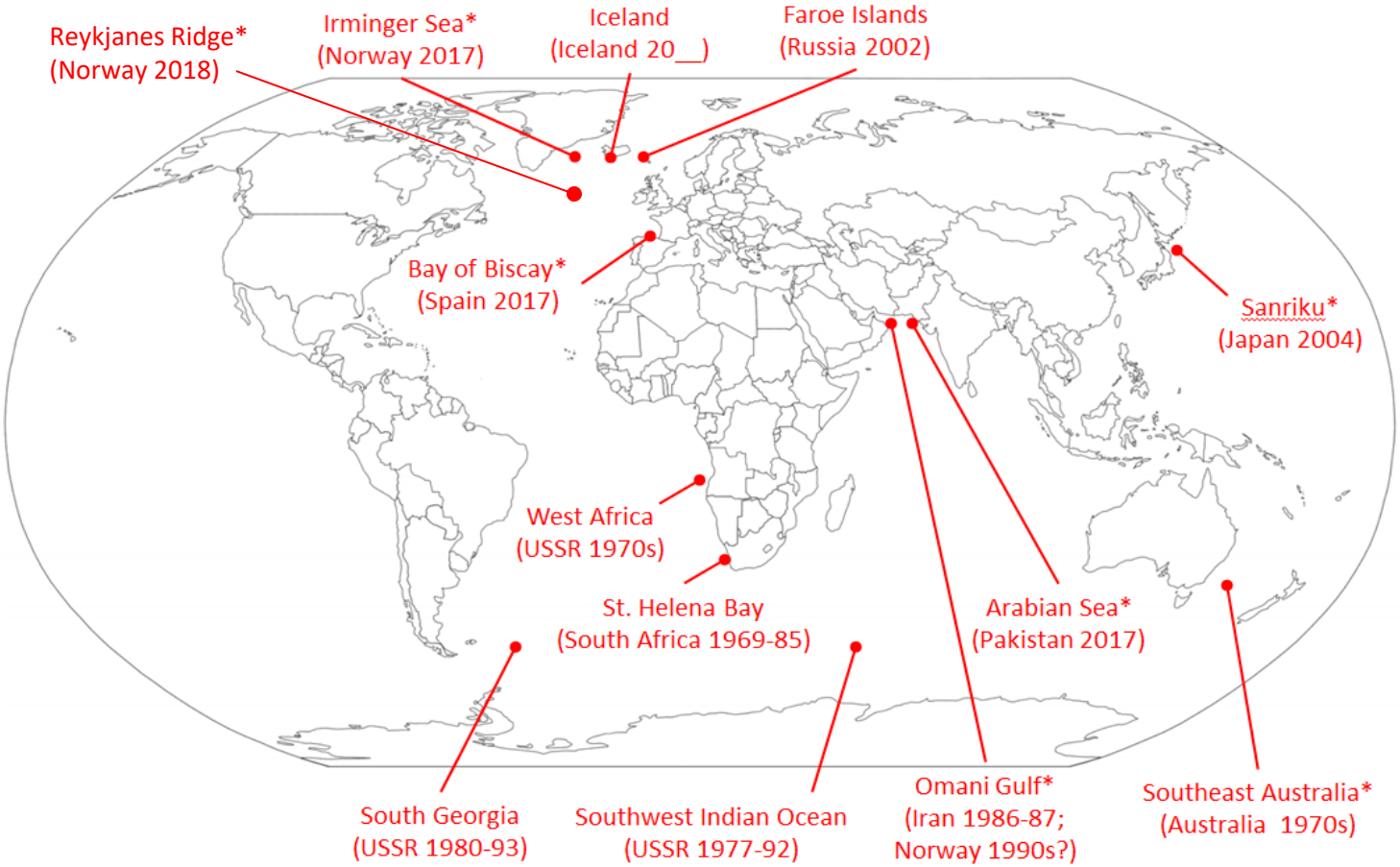
El-Mowafi A., Dominic Nanton and *Marc Berntssen
EWOS Innovation AS, 4335 Dirdal, Norway
*** Current address: NIFES, PO Box 2029 Nordnes, N-5817 Bergen, Norway**

ABSTRACT

Freeze dried samples of Lantern fish (*Benthosema pterotum*) from Gulf of Oman were supplied by the Department of Marine Science and Fisheries, Sultan Qaboos University, Muscat, Oman for nutrient and contaminant assessment.

Proximate and amino acid analysis showed that fish meal made of lantern fish is similar to South American fish meal with the exception of slightly lower protein content (65.1%), higher ash content (13.4%) and lower histidine content (14.4 g/kg).

In conclusion, analytical data on freeze dried samples from lantern fish indicate that it can be utilized as a source of fishmeal and fish oil in salmonid diets. Nevertheless, it is recommended that further first feeding screening trials in Atlantic salmon need to be done to compare to reference fish meals. More research is still required in particular on Lantern fish composition by location and by season.

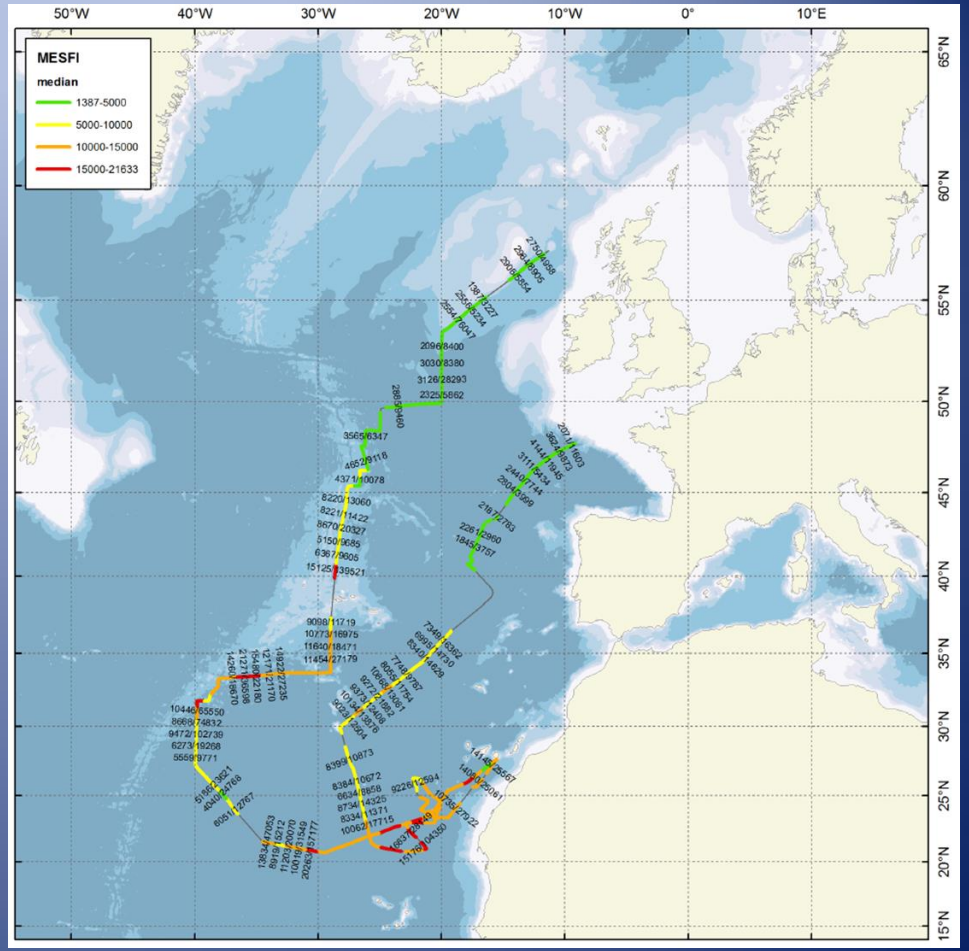

Reykjanes Ridge*
(Norway 2018)
Irminger Sea*
(Norway 2017)
Iceland
(Iceland 20__)
Faroe Islands
(Russia 2002)
Bay of Biscay*
(Spain 2017)
Sanriku*
(Japan 2004)
West Africa
(USSR 1970s)
St. Helena Bay
(South Africa 1969-85)
Arabian Sea*
(Pakistan 2017)
South Georgia
(USSR 1980-93)
Southwest Indian Ocean
(USSR 1977-92)
Omani Gulf*
(Iran 1986-87;
Norway 1990s?)
Southeast Australia*
(Australia 1970s)

EXPERIMENTAL FISHERY AND UTILIZATION OF MESOPELAGIC SPECIES IN THE NORTH EAST ATLANTIC – NEAFC RA 1 REYKJANES RIDGE AREA

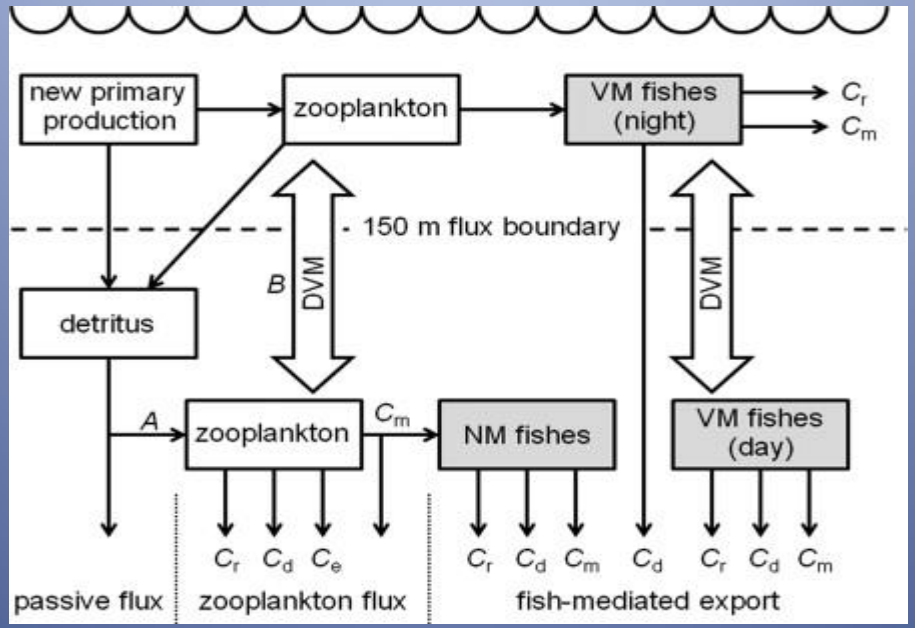
Grimaldo *et al*. (2018) ICES/ASC

[Norwegian Fishing Industry Project]

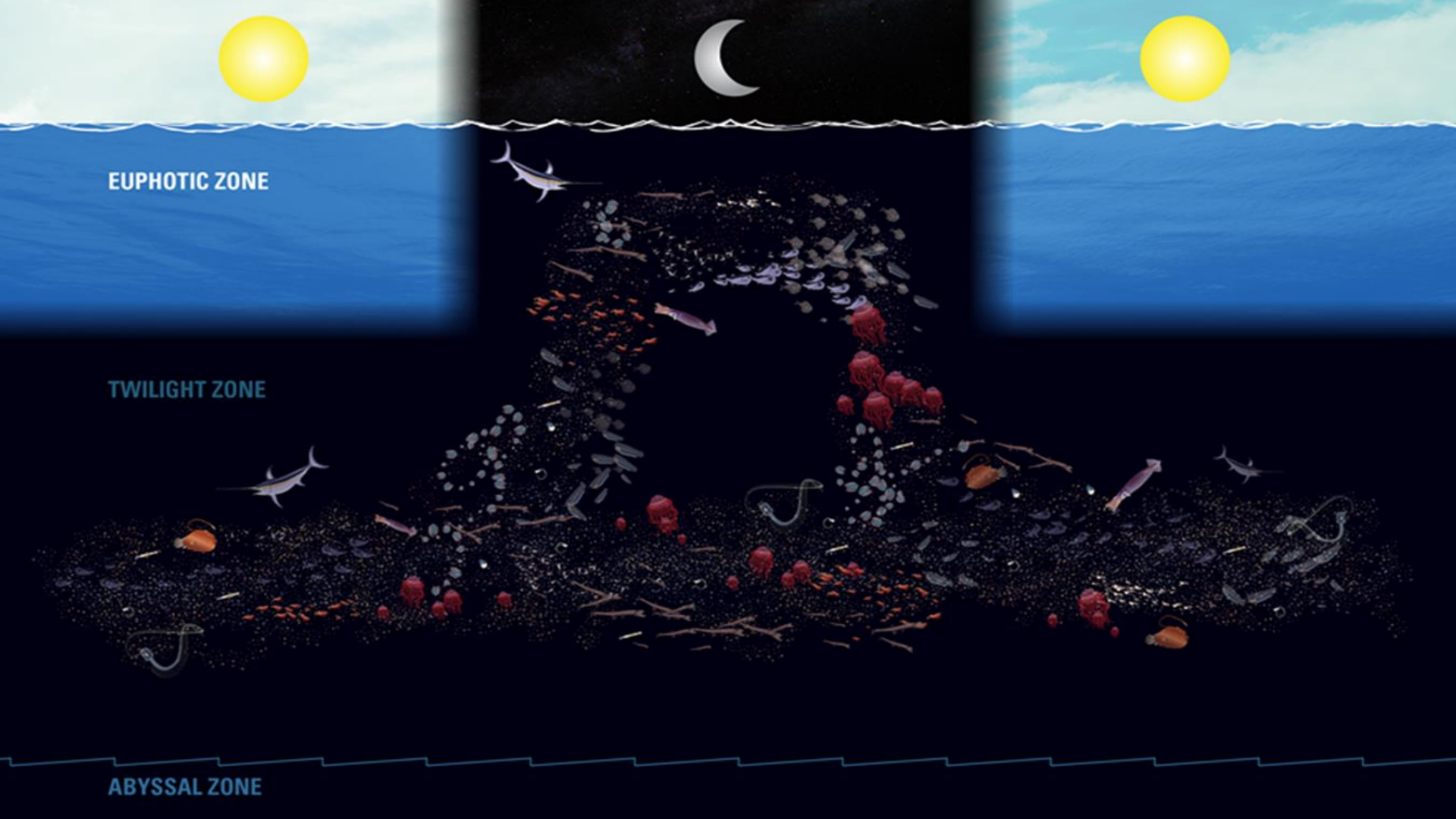
Bristlemouths (Maurolicus spp.)



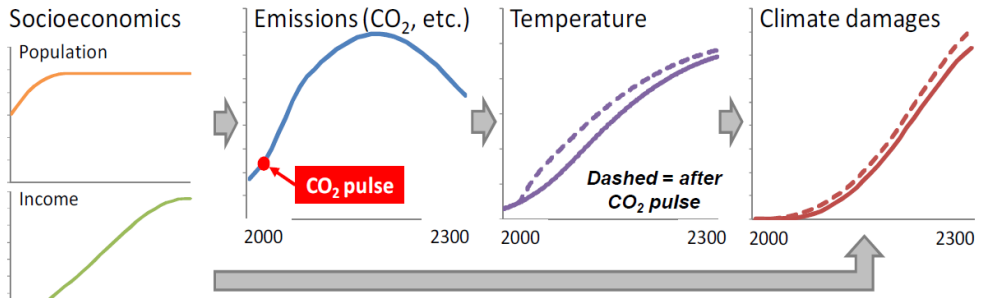
Regulating Services



Davison *et al*. (2013)


EUPHOTIC ZONE
TWILIGHT ZONE
ABYSSAL ZONE

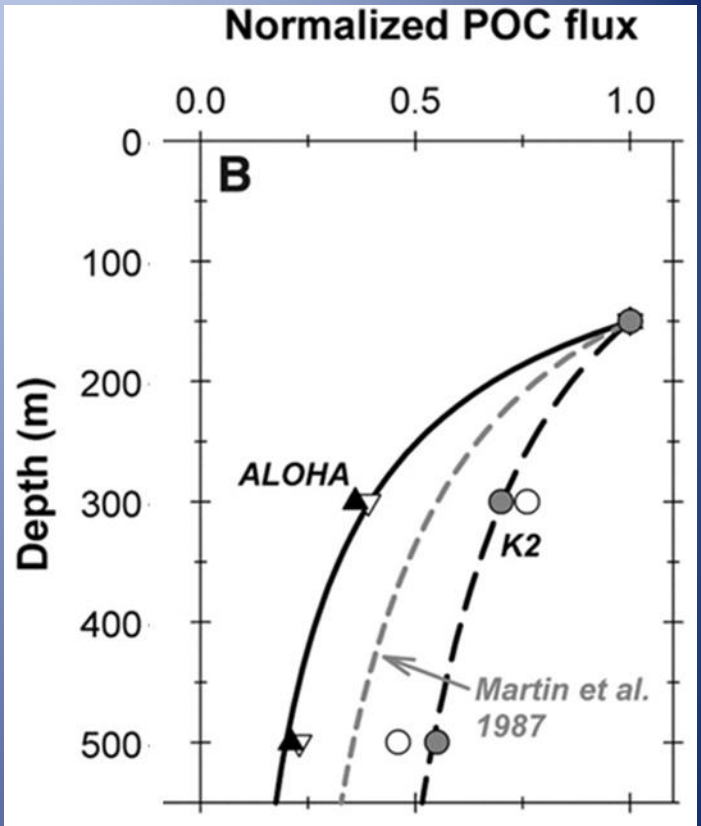
Definition: The net present value of global climate change impacts from one additional net global tonne of carbon dioxide emitted to the atmosphere at a particular point in time



SCC in 2020 is the discounted value of the additional impacts from the marginal emissions increase in 2020

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Source: Rose (2014)



Source: Buesseler *et al*. (2007)

- Jin *et al*. (in progress): value of information approach
- Potential impacts of climate change, midwater fisheries?

Cultural Services

DR. BEEBE DESCENDS 2,200 FEET INTO SEA

Continued from Page One.

from the world of humanity." The explorer of oceanic depths found it exceedingly difficult to describe the weird coloring that appeared to filter through the windows of the underwater globe, but which seemed not to be born of light from the sun because his spectroscope registered no reading.

"Let's go down some more," said Dr. Beebe with the enthusiasm of the true explorer approaching the unknown, as he reached and passed the depth of his former record. At times he seemed totally at a loss to name or even describe some of the wonders he saw. At one moment the sea was "as black as Hades." The next instant he told of it being "brilliant" with iridescence of passing schools of fish, which gave off light from their gleaming sides. He said the fish were not more than two feet from his eyes.

"It is absolutely black," he continued, as the 1,700-foot depth was being approached. "Now there are fish two or three feet away. I can make out their forms from their own light. There are a great many of them. They seem to be double. I think the double ones are fish coming head on. It is the most amazing thing now; the amount of light down here."

Miss Hollister asked Dr. Beebe over the telephone if he could describe the light from the fish. He said it varied from pale blue to pale green—no deep tones.

"It must be from the normal luminescence of the creature," he said, sending a request to those above to be "lowered down further." At 1,750 feet there were dozens of lights all about the bathysphere; at 1,900 feet he reported it was "very brilliant—everything lit up."

At 2,000 feet radio listeners heard an order to stop the bathysphere. The adventurers took picture after picture of the strange denizens that flashed and flickered through depths that resemble a clear sky at night. The grinding of the camera as the explorers took their pictures was plainly heard over the radio and wire circuit linking the bathysphere with New York networks. Near the 2,000-foot depth Dr. Beebe told of seeing "loads of little—I don't know

Times Wide World Photo.

The Bathysphere Being Lowered Into the Sea in a Test.

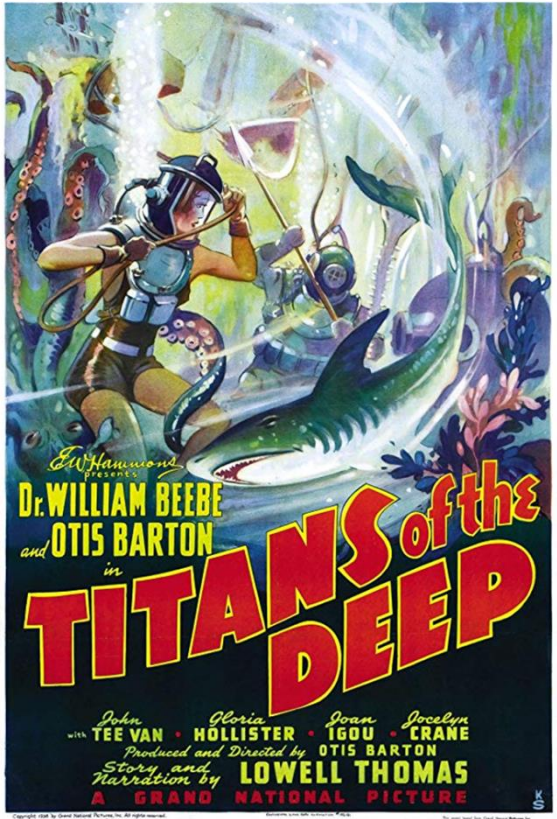
what they are—I never saw anything like them."

The identities of the "little" things seen by the deep-sea adventurers are expected to remain unsolved until the plates are developed and studied. The explorers at times apparently were called upon to work under difficulties. Miss Hollister reported that the sea was causing the craft from which the bathysphere was suspended to roll considerably.

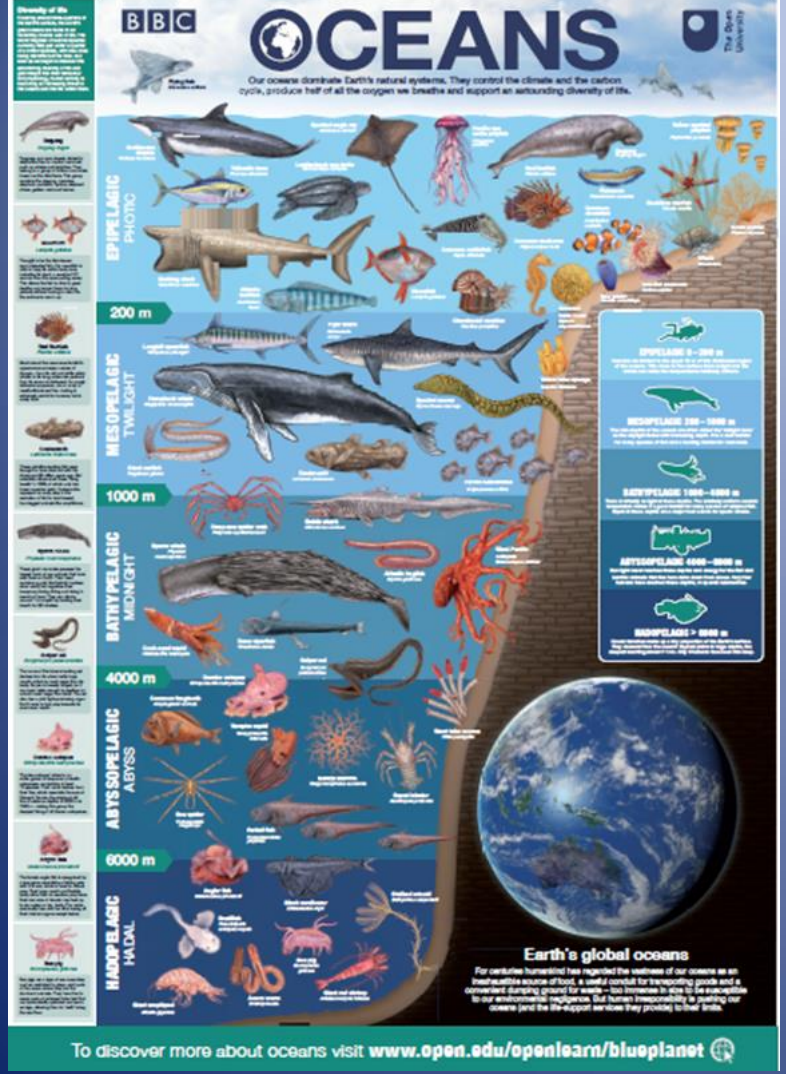
"Yes, I feel it rolling," said Dr. Beebe, "but it isn't a roll down here. We are just going up and down."

Once he reported seeing large fish. One was like a barracuda that whisked through the green water and was off before a good description of it could be broadcast. At numerous depths Miss Hollister asked the scientist to report the condition of the "stuffing box," which is the water-tight mechanism around the door through which the men enter or leave the sphere. Dr. Beebe generally reported promptly on most occasions, as failure of the stuffing box on a recent test lowering of the bathysphere allowed the sphere to fill with sea water. Temperatures were also taken frequently, registering around 70 degrees, Fahrenheit.

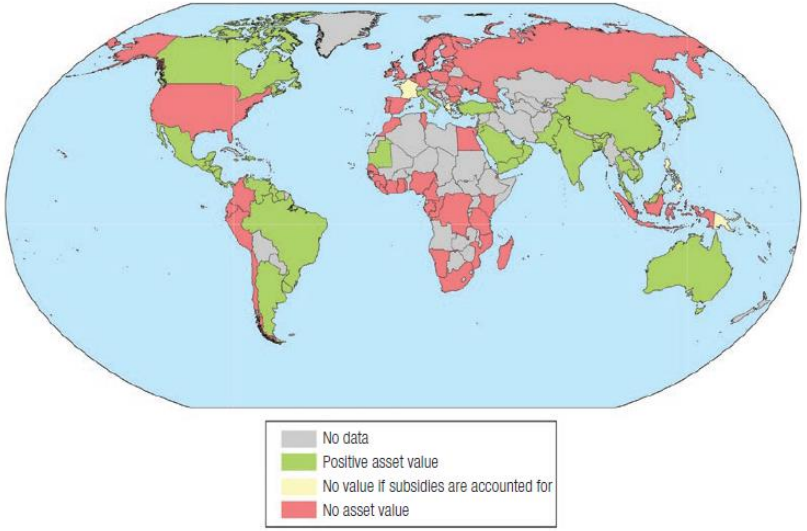
"Let's go down some more," Dr. Beebe repeated as the bathysphere neared the level where the broadcast ended. "You're on your way," said Miss Hollister as the creaking windlass on the vessel told of wheels turning to let out more cable.




BLUE PLANET II
Take a deep breath


BBC
OCEANS
The Open University
Our oceans dominate Earth's natural systems. They control the climate and the carbon cycle, produce half of all the oxygen we breathe and support an astounding diversity of life.
EPIPELAGIC
PHOTIC
200 m
MESOPELAGIC
TWILIGHT
1000 m
BATHYPELAGIC
MIDNIGHT
4000 m
ABYSSOPELAGIC
ABYSS
6000 m
HADOPELAGIC
HADAL
Earth's global oceans
For centuries humankind has regarded the vastness of our oceans as an inexhaustible source of food, a useful conduit for transporting goods and a convenient dumping ground for waste – too immense to seem to be susceptible to our environmental negligence. But human irresponsibility is painting our oceans (and the life-support services they provide) to their limits.
To discover more about oceans visit www.open.edu/openlearn/blueplanet

Supporting Services



Source: World Bank calculations based on Pauly and Zeller 2016; Sumaila et al. 2012; and Tai et al. 2017.

- Overexploitation of surface water fisheries…
- …implies supporting services (prey, other components of the ecosystem) are undervalued
- What are the ecological links between the surface and the midwater?

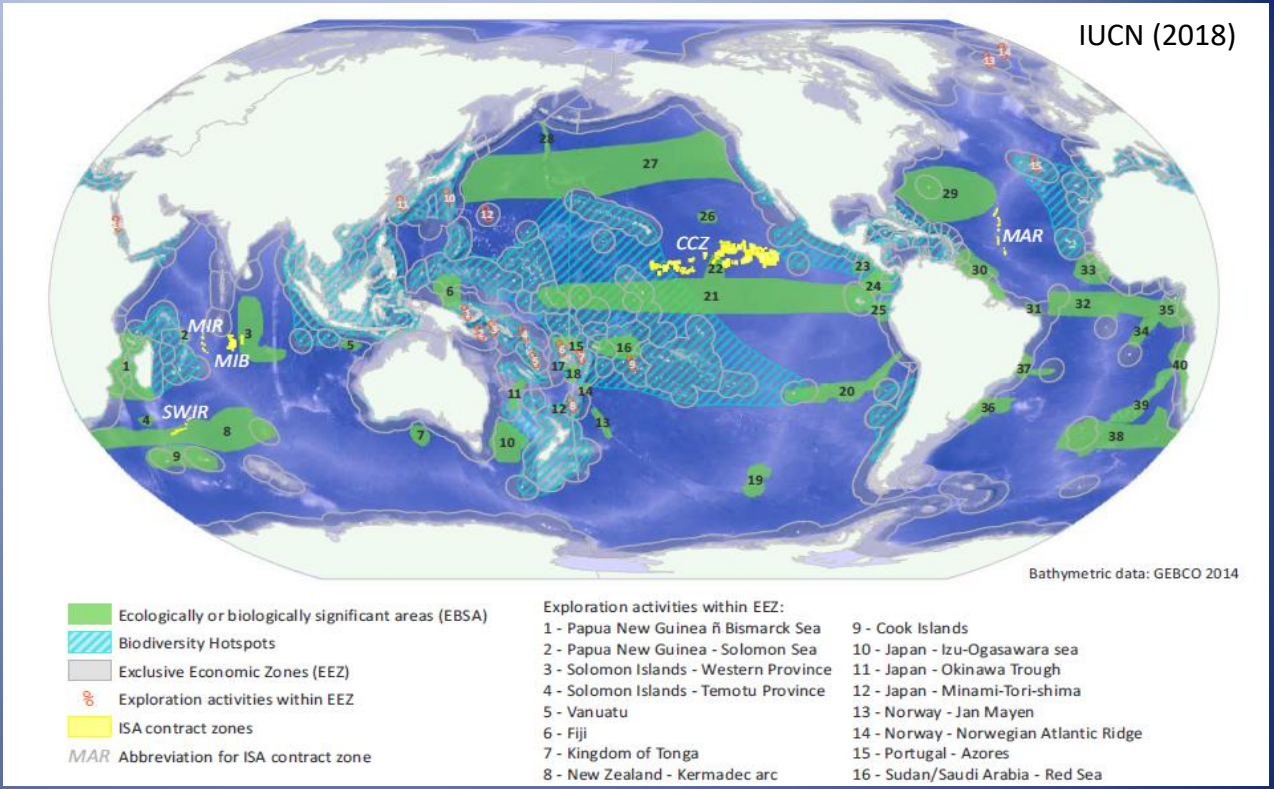
World fisheries are heavily subsidized, and, in many countries, resource rents from fisheries are negative—meaning that revenues do not fully cover the costs of fishing. At the global level, the data show that, overall, **$83b of resource rent was foregone** in global fisheries in 2012. [DeFontaubert *et al*. (2018)]

BBNJ

- Extends UNCLOS III to high seas governance
- Area-based conservation (high seas MPAs)
- Environmental impact assessments (EIAs)
- Access to marine genetic resources [MGRs] and allocation of benefits
- Science and technology transfers to LMICs

MPAs

- EBSAs identified mainly on the basis of surface water observations
- Links to mesopelagic may be important
- Focus of the BBNJ has been on surface waters and the deep seabed



"The simple truth is that [the greatest assemblage of animal species on the planet live in an immense and inaccessible habitat that is difficult to sample and even harder to visualize." [Robison (2009)]

MGRs

- No single sovereign “owner” of the high seas
- Freedom of marine scientific research
- Variable IP laws: US, AUS: cannot patent a natural genetic sequence: EUR, JAP: possible
- Concentration in marine IP holdings (BASF 40%)
- Push to transfer benefits, technologies to LDCs

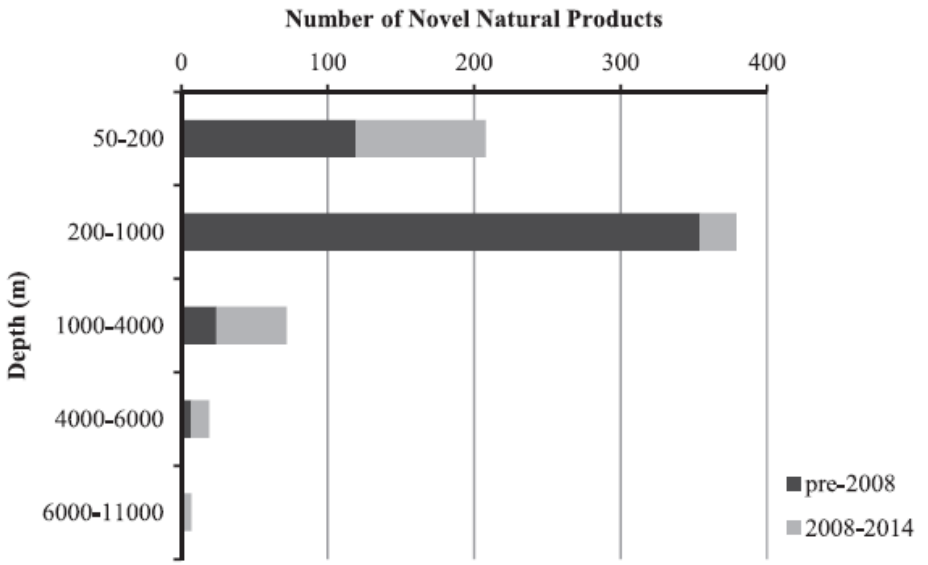


Fig. 1. Number and depth profile of novel natural products isolated from deep-sea sources (pre-2008 and 2008–2014). Data sources: Skropeta and Wei (2014) and Skropeta (2008). Depth profile provided in pelagic zones: 0–200 m (epipelagic); 200–1000 m (mesopelagic); 1000–4000 m (bathypelagic); 4000–6000 m (abyssopelagic); 6000 m+ (hadal zone). Note: epipelagic zone divided into 0–50 m and 50–200 m in line with Skropeta and Wei (2014) and Skropeta (2008).

Source: Harden-Davies (2017)

Summary

- Ecosystem service framework provides a way of organizing our thinking about the ocean's twilight zone
- Its services are already highly beneficial, but they're out of sight
- Need to think about tradeoffs: what do we gain and what do we lose from future actions that could affect OTZ ecosystem services?
- Helpful to compare apples with apples
- Can we use it sustainably?