Characteristics of the Deep-Sea environment II

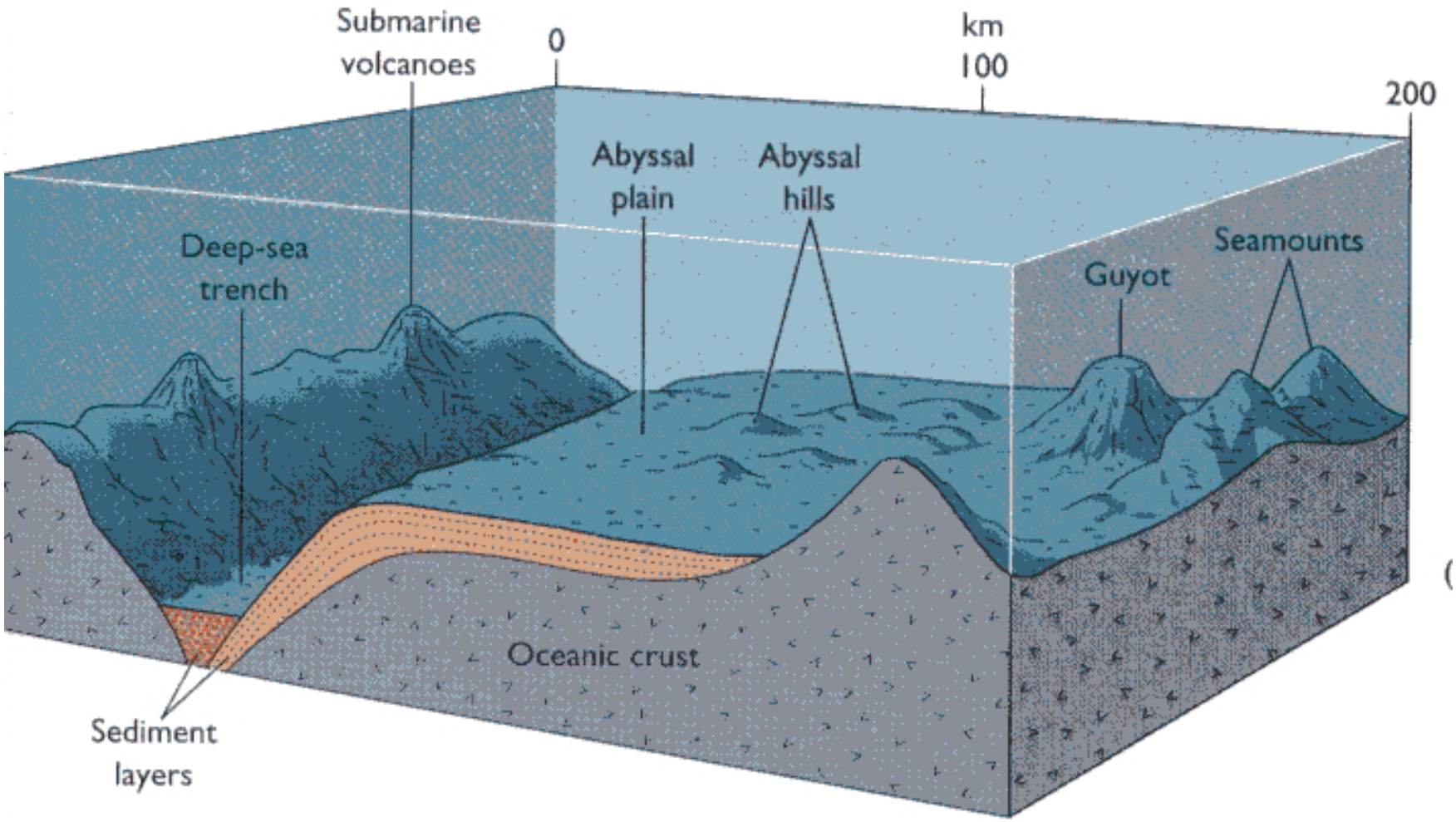
Malcolm Clark

SPC Secretariat of the Pacific Community

SPREP Secretariat of the Pacific Regional Environment Programme

4th Regional Training Workshop, Environmental Perspectives of Deep Sea Mineral Activities, Nadi, Fiji. December 2013

Bathyal and Abyssal regions-the habitats of deep sea resources



Vertical changes with depth

Physiological Parameters - Mainly affect top 1000 m

- **Light** - declines with depth
- **Temperature** - cooler with depth
- **Salinity** - polar/surface freshening
- **Oxygen** - midwater minima
- **Pressure** - increases 1 atm with 10 m depth
  (larvae have specific sensitivities as do adults)

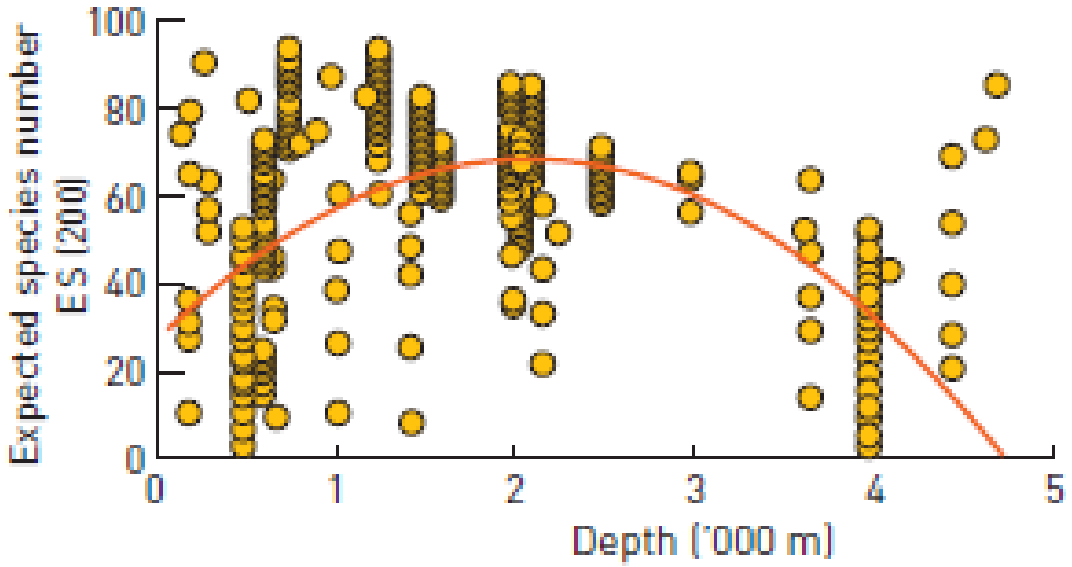
Depth-Related Features - usually act as gradients

- **Substrate Type** - grain size, grain composition
- **Organic matter source** (terrestrial vs marine)
- **Flow Regime** - accelerated near topography
- **Water Masses**- carry larvae

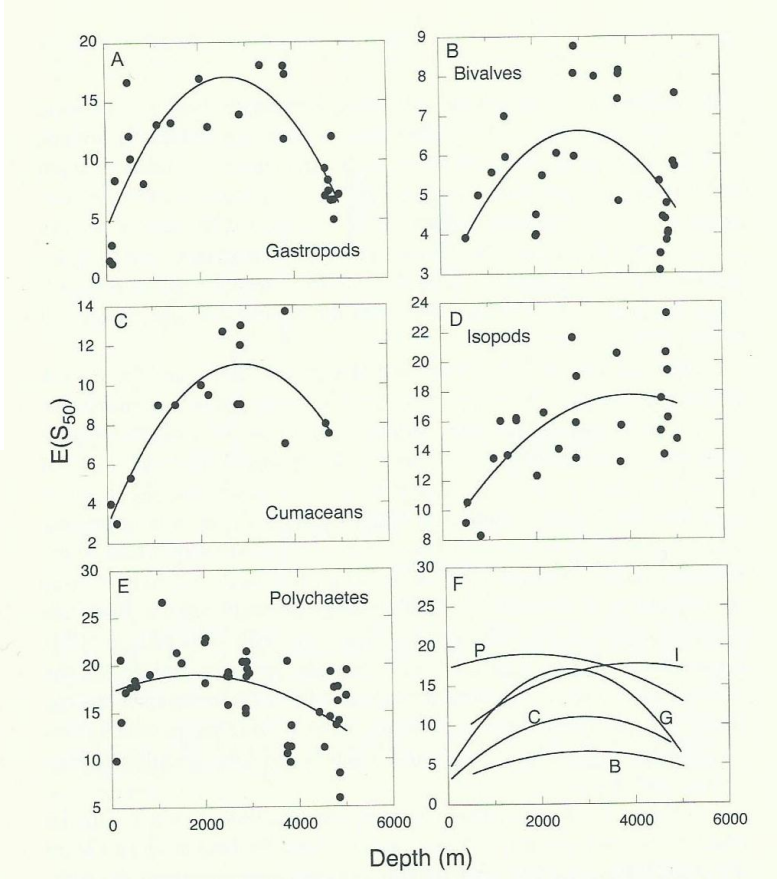
Changing Resources with Depth

- **Organic Matter Availability**- reflects surface production & horizontal advection
- **Habitat area/space**
  (least from 1000-3000 m, greatest from 4000-5000 m)

Depth-diversity

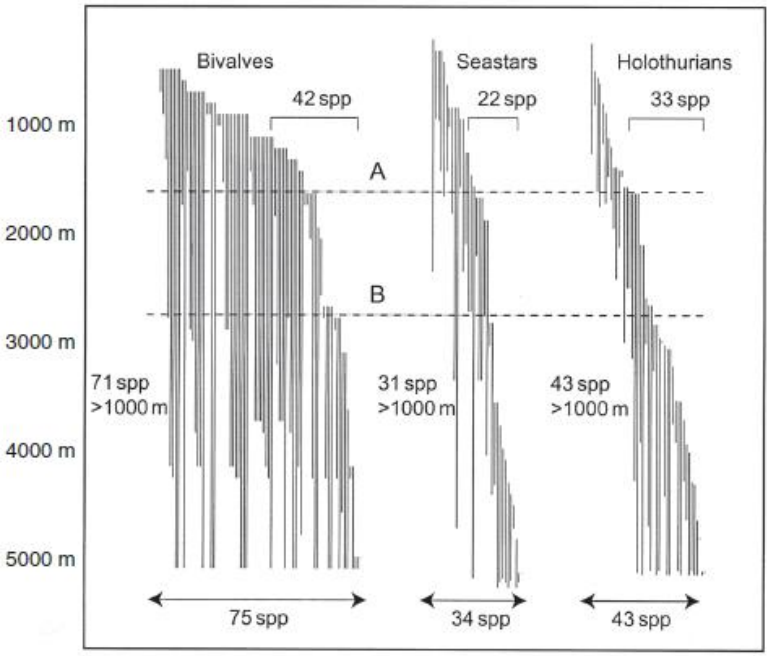


- As depth increases, initially there is an increase in diversity
- Peaks for many taxa at about 2000 m
- Then declines
- But still some taxa where diversity remains very high
- Especially infauna (more later)

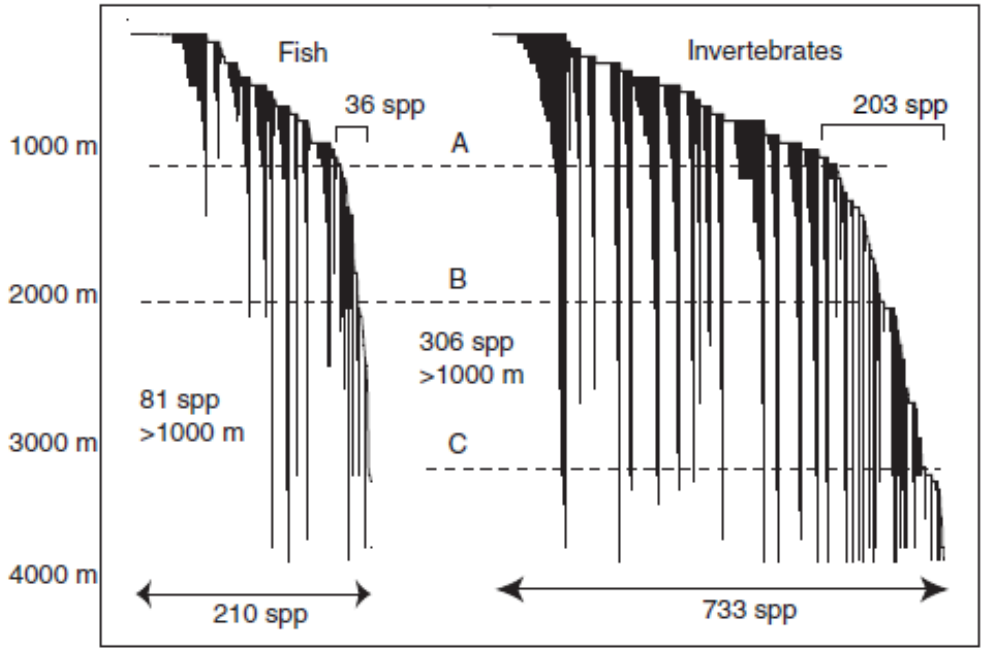


Rex & Etter 2010

Species ranges



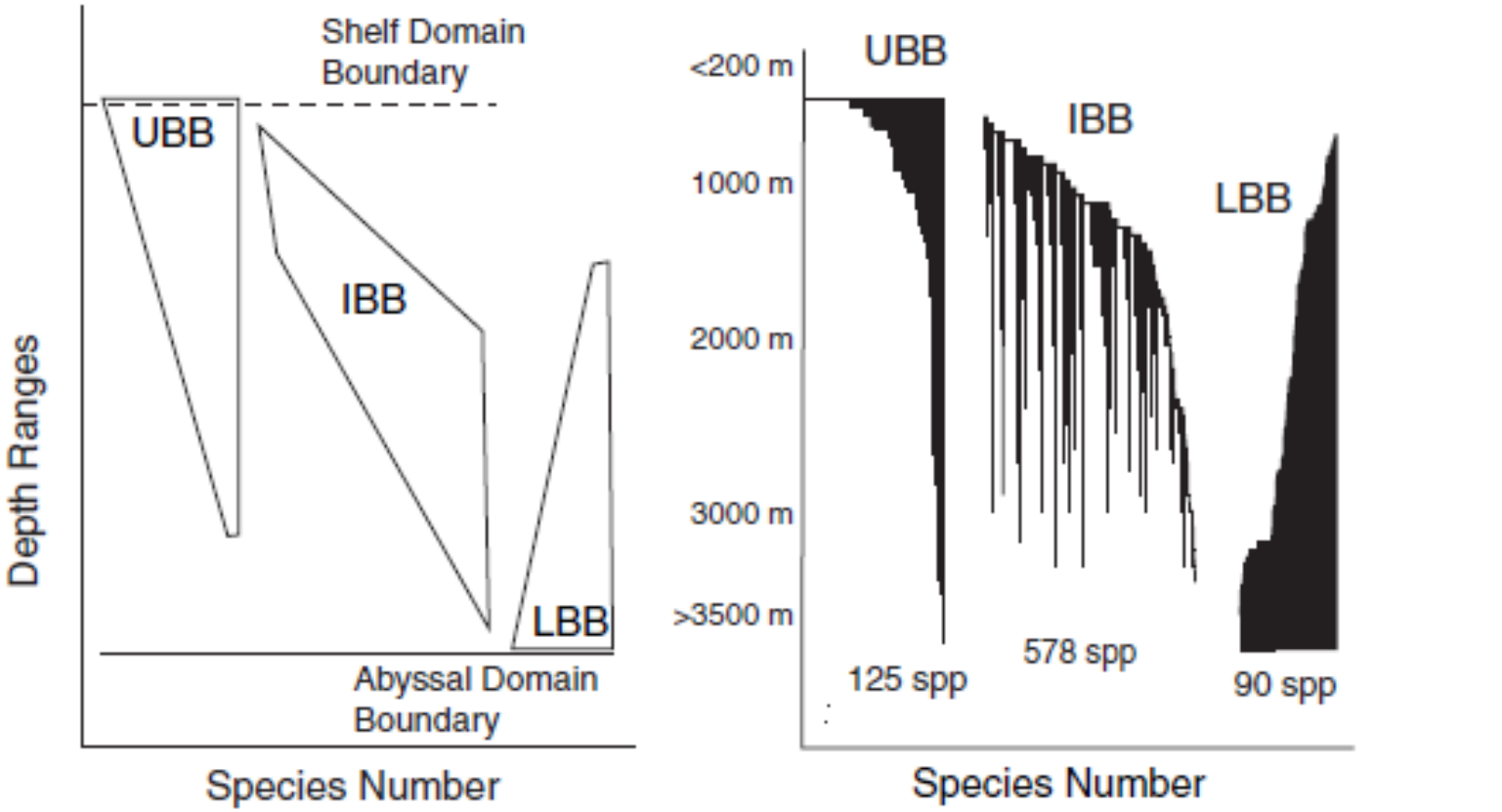
Porcupine Seabight area



Gulf of Mexico

- Often significant faunal change at mid-slope (A) and lower-slope (B) depths
- Fish diversity much less at depth than invertebrates

Species ranges (2)



Carney 2005

- Deep-sea faunal communities:
  - UBB: Upper Boundary Biota (mainly shallow)
  - IBB: Inter-Boundary Biota (intermediate)
  - LBB: Lower Boundary Biota (mainly deep)

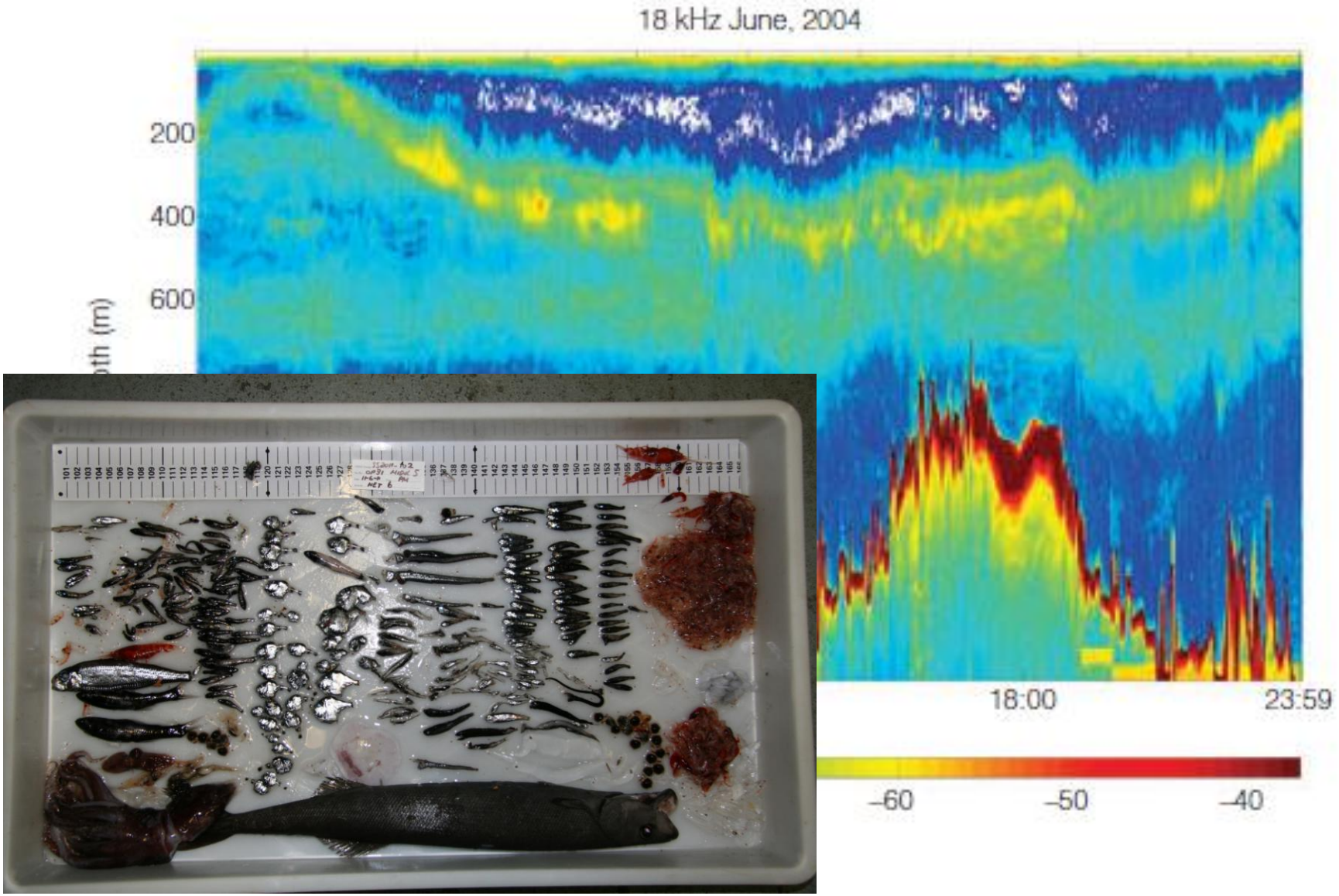
Summary of depth zonation

- Our knowledge is limited by sampling and taxonomy
  - Deep sea is poorly sampled and full of new species
  - There is a problem with “cryptic diversity”
- The reasons for depth zonation are not just depth (pressure), but also many related factors such as temperature, water masses, substrates, etc
- There are general trends in the types of animals present
  - More filter feeders shallow and more deposit feeders deep
  - The dominant groups of animals change with depth
- There are species that have very wide depth ranges and also others with very narrow depth ranges
- Many species are only found in the deep sea

What is there for dinner in the deep?

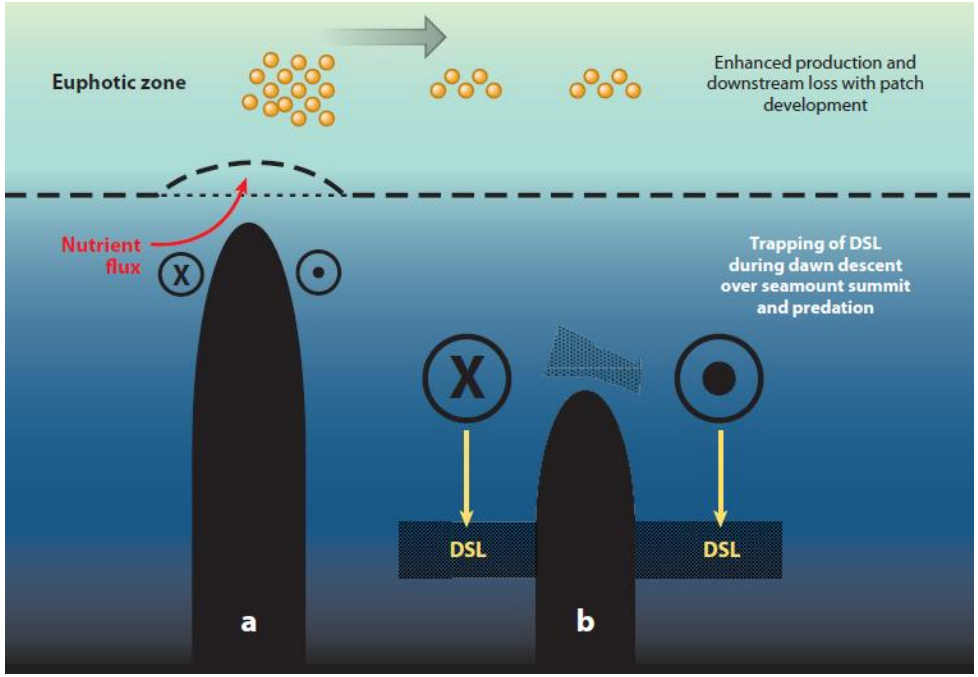
- Food is well recognised as a major limiting factor for animals living in the deep-sea
- Feeding mode with depth
  - Reduction in suspension feeders, increase in deposit feeders
  - Deeper still, mobile deposit feeders replace sessile deposit feeders
  - Omnivorous scavengers replace carnivores
  - Abyssal depths, 50:50 surface and subsurface feeders
- Most is derived from surface production (phytoplankton using the sunlight)
- Two main strategies
  - Migrate to the food (vertical migrations)
  - Wait for the food to come to you

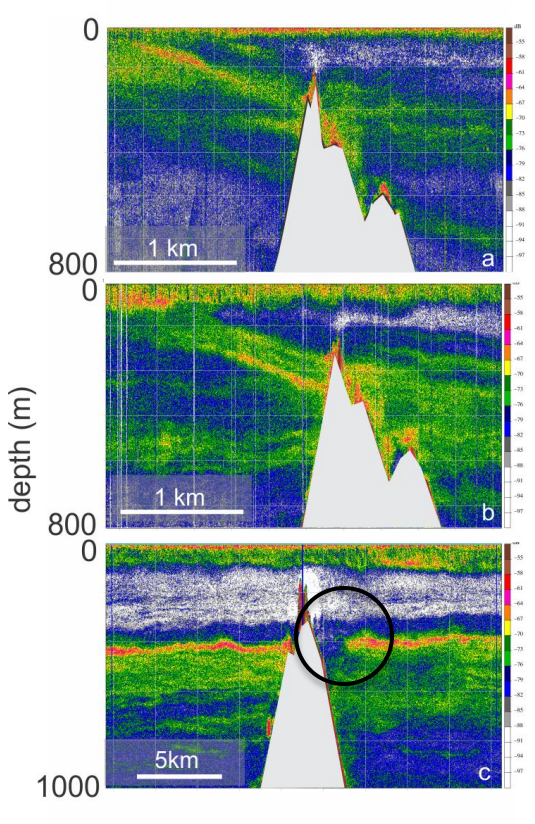
Vertical migrations



Seamount “effect”

- Vertical migrations can be blocked by the shallow summit of the seamount/guyot/ridge
- Seamount fishes feed on the plankton

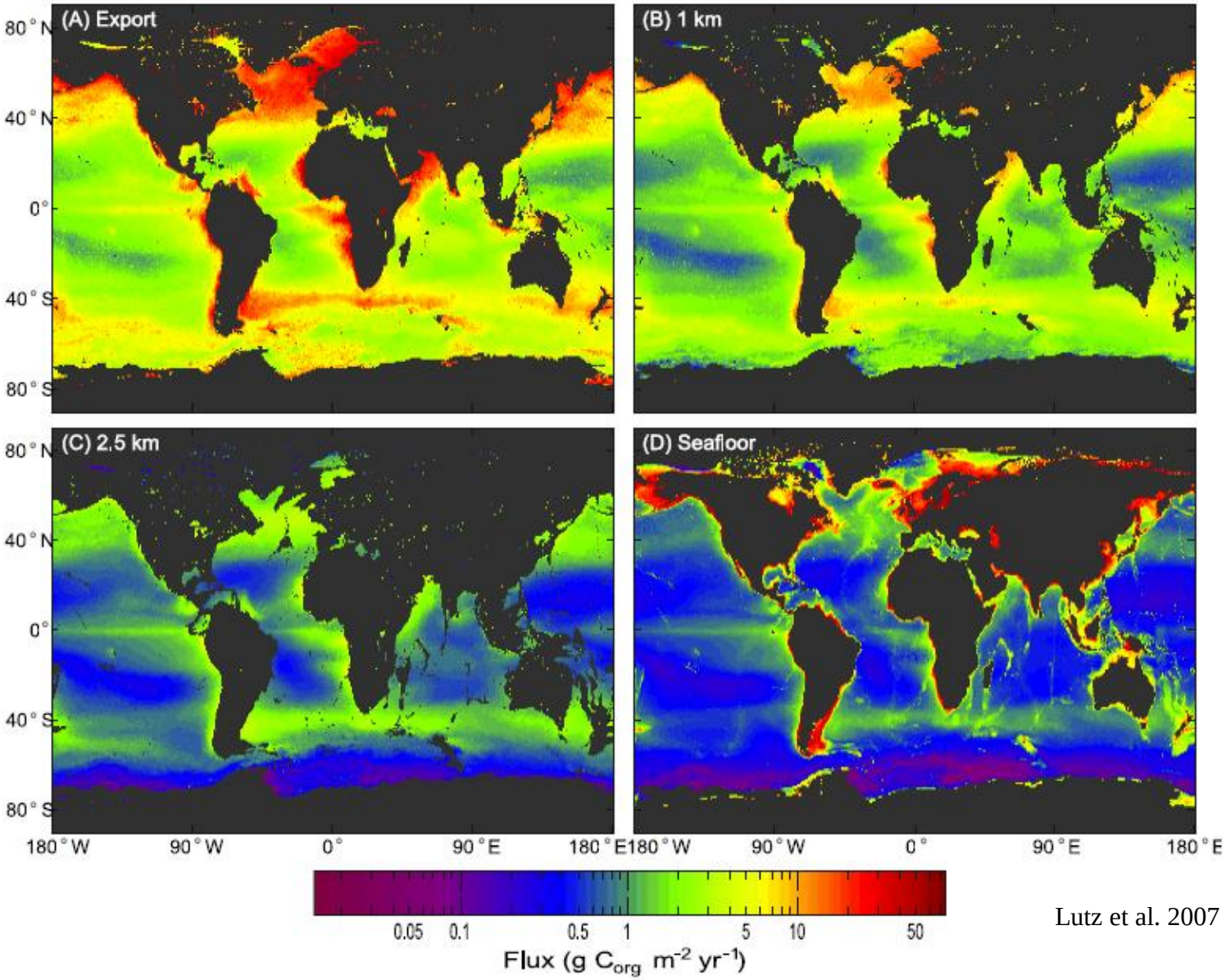




Organic matter to the deep

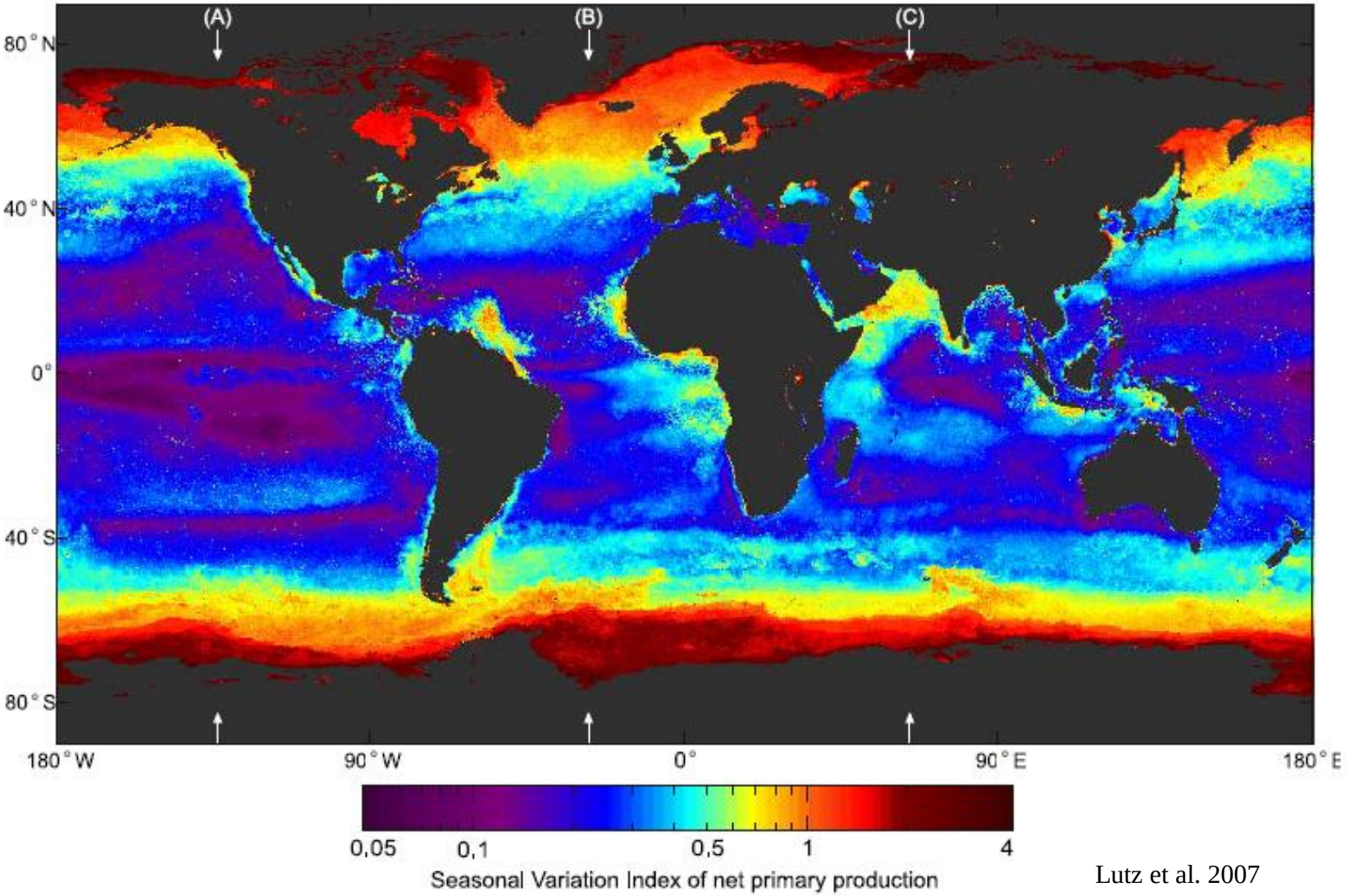
- Some from land-based sources
- Some large plant remains (e.g., Sargassum)
- MOST from small remains of plankton (faecal pellets, phytodetritus)
  - Animals die, and slowly sink
  - Much is eaten on the way down, but some makes it (as we will see shortly)
- SOME from large animal remains (whales, sharks, squids)

Production reduces with depth (flux)



Lutz et al. 2007

Surface production is variable



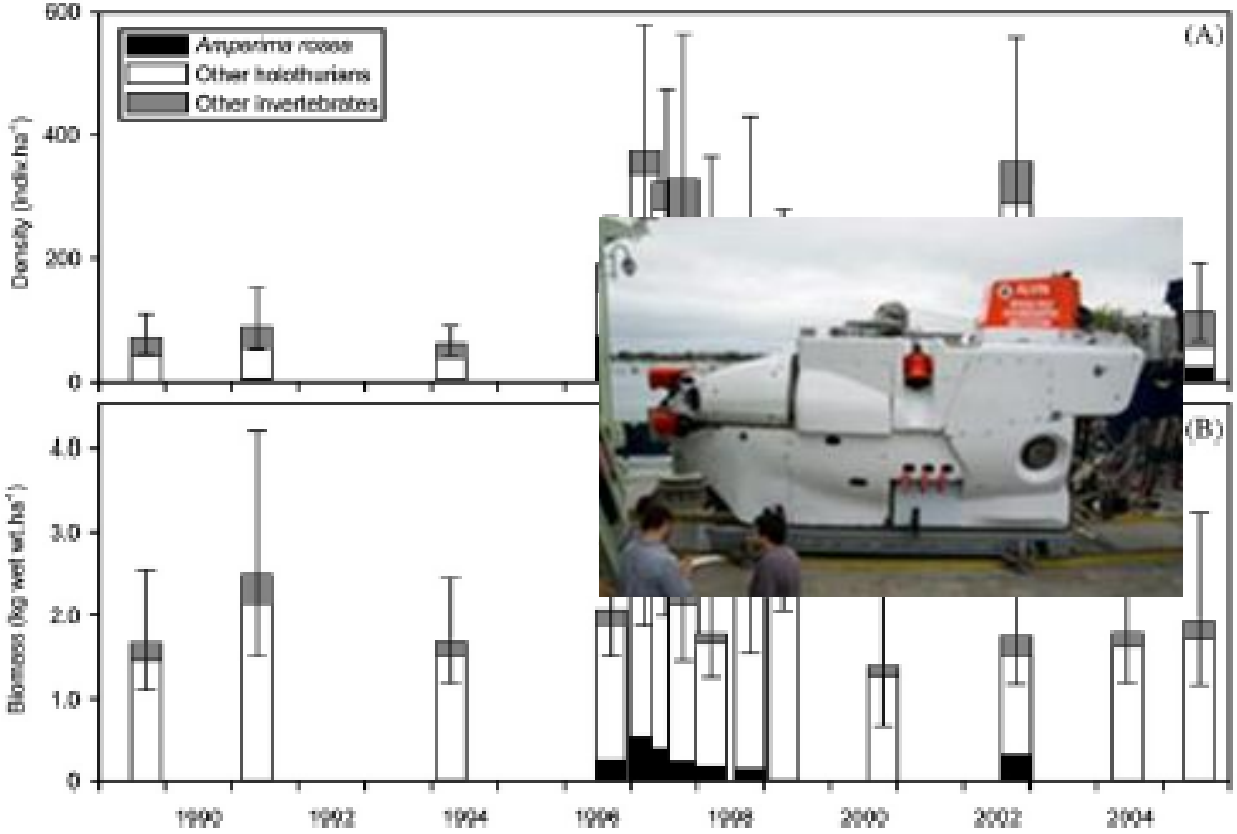
Lutz et al. 2007

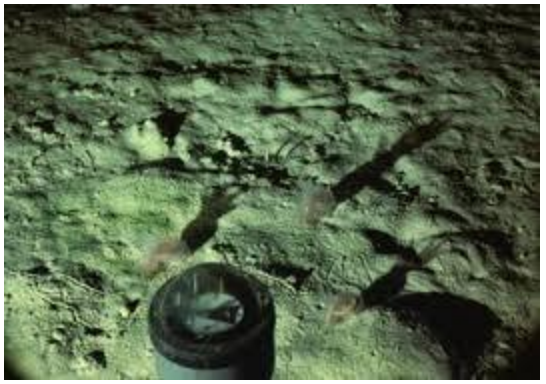
Porcupine Abyssal Plain

- West of the United Kingdom
- Strong seasonal falls of detritus
- Irregular “species explosions”
- Related to large-scale changes in flux of organic matter
- The Deep Sea is not necessarily a slow and stable environment, can be dynamic…

PAP, 4000 m, May-August 1982

Megafaunal response: *Amperima rosea*





Lag between phytodetritus and megafaunal abundances

Reproduction and growth

- Seasonality drives many shallow-water processes (where change in day length with season)
- Classic predictions
  - **No seasonal breeding time, year-round.**
  - **Low fecundity, little pelagic development**
  - **Slow growth rates because limited energy environment**
- But…
  - is some seasonal reproduction because of advantages of synchronised development
  - Planktotrophy does occur, but not common
  - Growth rates are slow, but there are exceptions
  - Seasonal food pulses are important

“Extreme” deep-sea environments

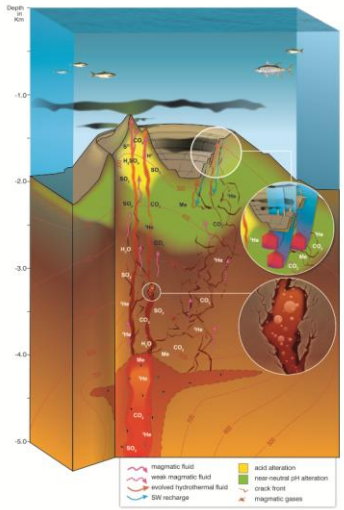
- Cindy has talked about the range of topography in the deep-sea
- **Most is sediment**
  - Abyssal plains are dominated by soft sediment (muds, oozes, sands)
- Hard bottom less extensive
  - Can be small rocks (Manganese nodules)
  - Mountains (seamounts) and escarpments
  - Hydrothermal vents
  - Cold seeps

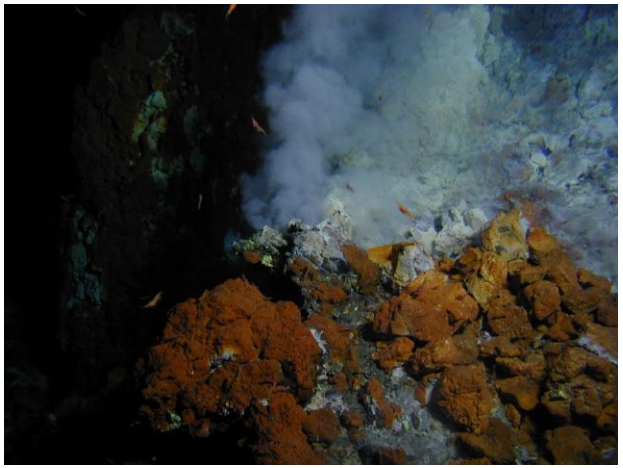
Deep-sea habitat diversity

- Expand more (briefly!) on:
  - Chemosynthetic environments
    - Hydrothermal vents
    - Methane-rich seeps
    - Whale falls
  - Unusual/severe environments
    - Oxygen Minimum Zones
    - Seamounts
    - Trenches/canyons

Hydrothermal vents

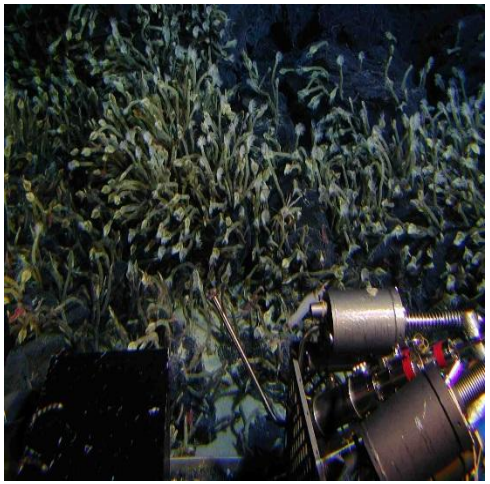
- Sites of active volcanic activity
- Mid-ocean ridges, tectonic plate margins (as in SW Pacific), magma hot-spots
- Geothermally heated gases and water plumes rich in minerals and chemicals
- Over 500 known active vent sites
- Very common in SW Pacific



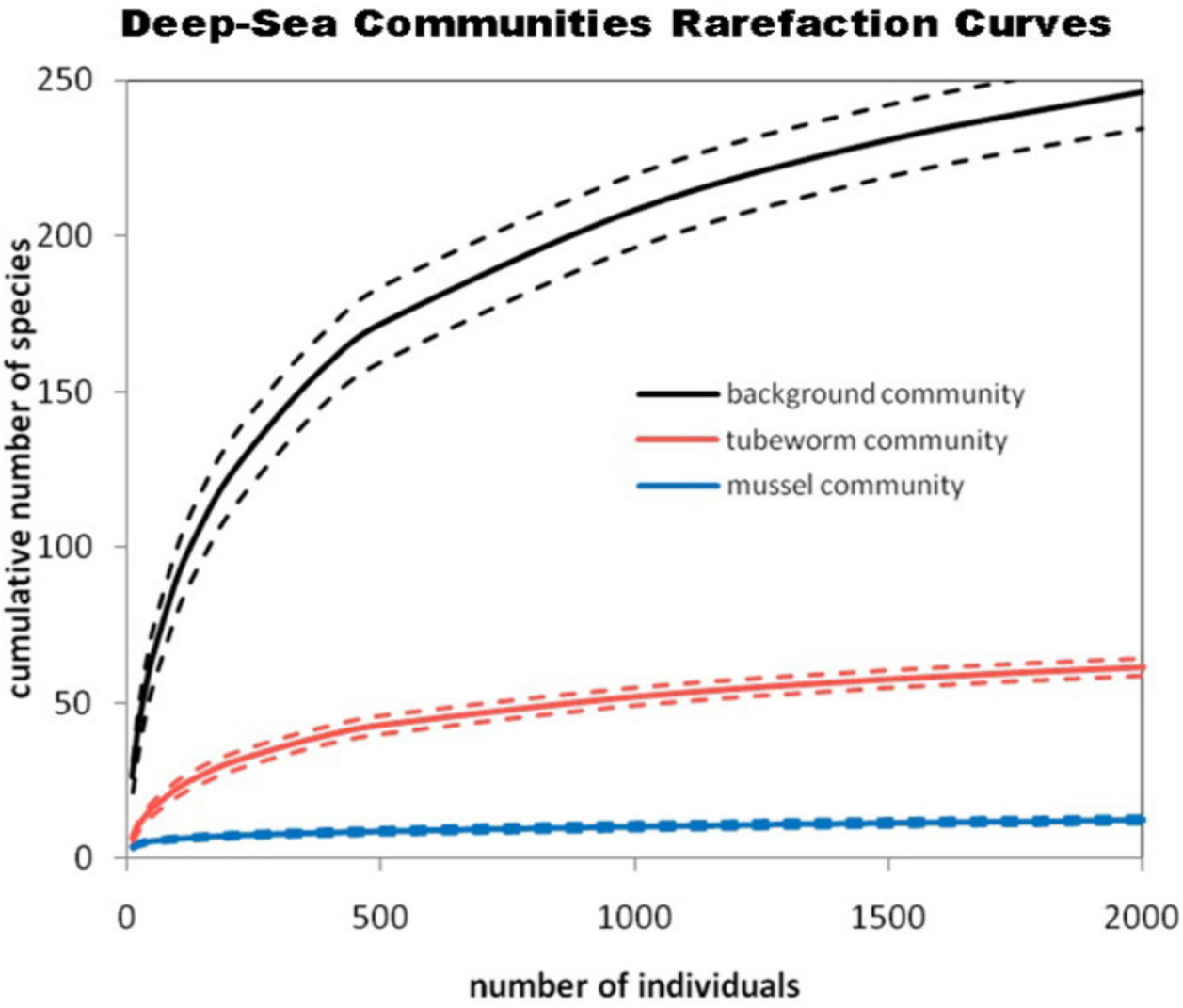


Hydrothermal vent communities

- Some animals can utilise hydrogen sulphide, or have chemosynthetic bacteria that convert S-rich fluids into energy (independent of sunlight-driven processes)
- Unique faunas: microbes and invertebrates, adapted to specific environmental conditions
- Typically not highly diverse
  - Tubeworms, mussels, snails, barnacles
- Very high biomass

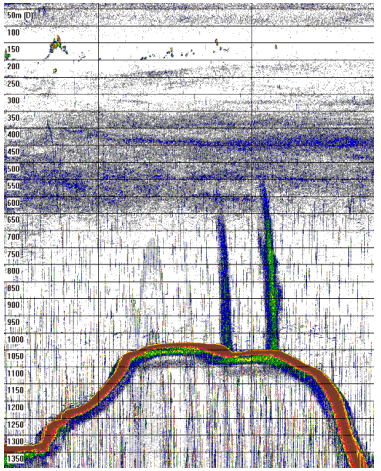


Vent faunal communities



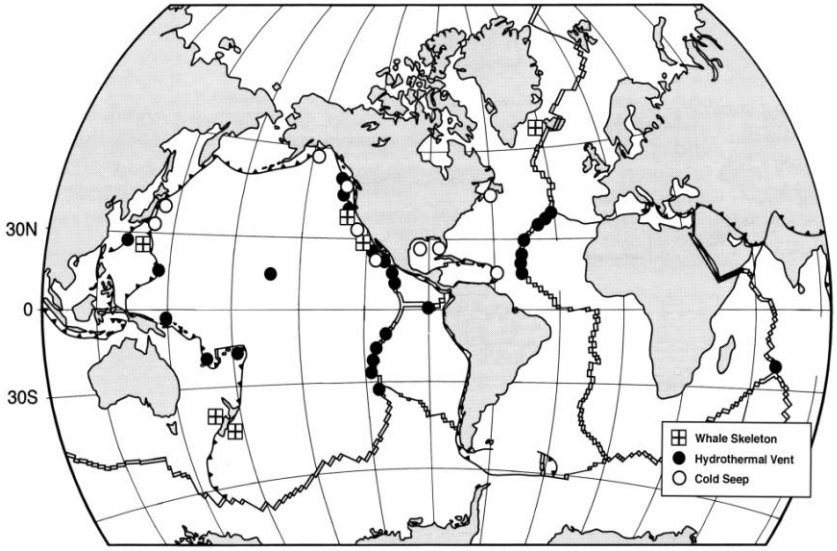
Cold seeps

- Seafloor areas where methane and other hydrocarbons seep through sediments
- Along continental margins
- Interest for their gas hydrate potential
- New Zealand, not PICTs
- Chemosynthetic processes
- Support distinctive seep communities
- Tubeworms, clams, mussels
- Polychaetes (in sediment)



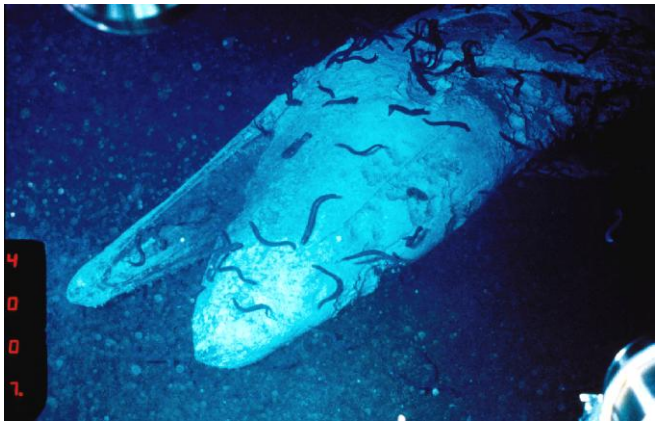
Whale falls

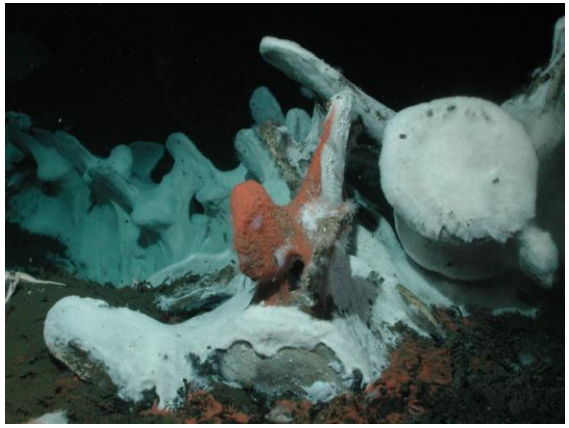
- Large animal carcasses are an important source of food in the deep-sea
- Whales die (e.g., 1000 grays in NE Pacific/yr)
- Large carcasses (30 t) slowly rotting…
- Provide abundant sulphide-rich habitat



Whale fall (2)

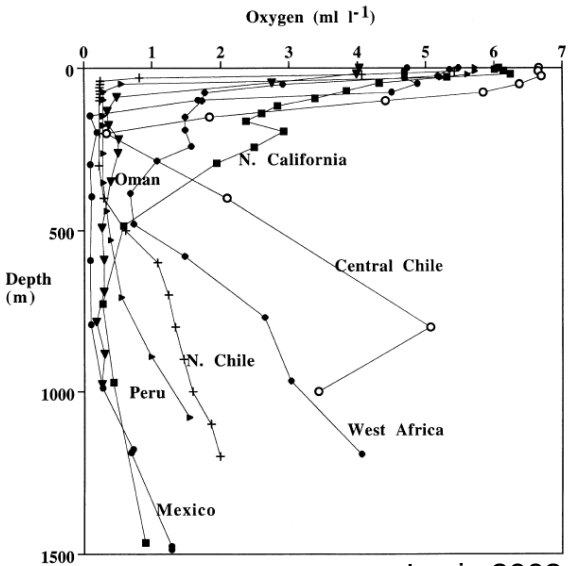
- Several colonisation stages
  - Mobile scavengers (hagfish, sharks, crabs)
  - Enrichment opportunists (worms)
  - Sulfophilic stage (chemo. Bacteria, clams, limpets)
- Unique species (e.g., carpet worms, snot worms)
- Habitat islands (chemosynthetics)
- Stepping stones for dispersal?





OMZ (Oxygen Minimum Zones)

- Ocean areas extremely low in oxygen
- Defined as < 0.5 ml/l concentration (usually 4-6 ml/l)
- Caused by strong upwelling, with high surface productivity, that then sinks and degrades, depleting oxygen in the water column
- Usually bathyal depths, 200 – 1000 m



Levin 2003

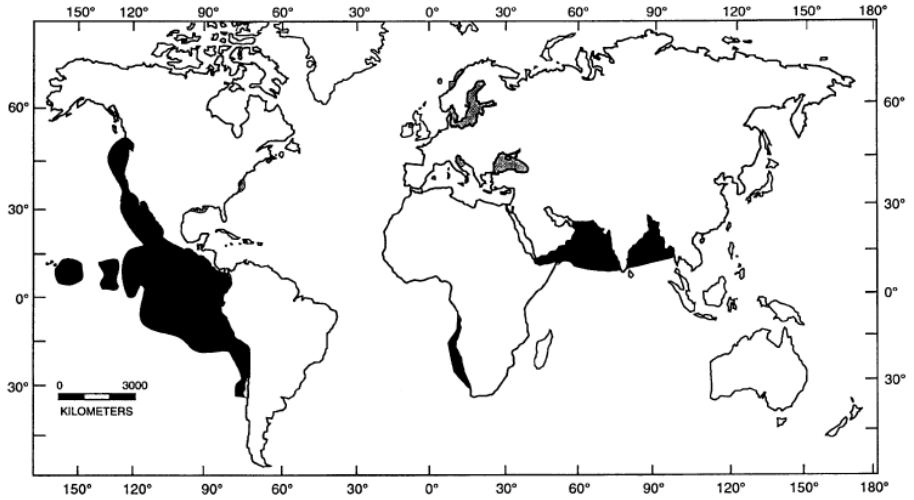


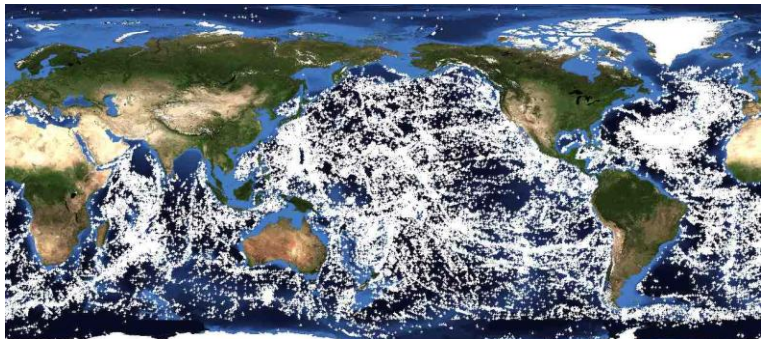
Figure 1 Distribution of the world oxygen minimum zones. Open water oxygen minima are shown in black, hypoxic enclosed seas and fjords are stippled. (Adapted from Diaz & Rosenberg 1995.)

OMZ (2)

- Protozoa can thrive in these conditions
- Organic-rich sediments host abundant sulphide-oxidising bacteria
- Foraminifera abundant, but low diversity
- Meiofauna also abundant, again low diversity
- Macrofauna and megafauna low densities. Some nematodes/polychaetes are tolerant, and have large respiratory organs, but generally stay away
- At very low oxygen levels, chemosynthesis important
- Endemism poorly known, but probably high.

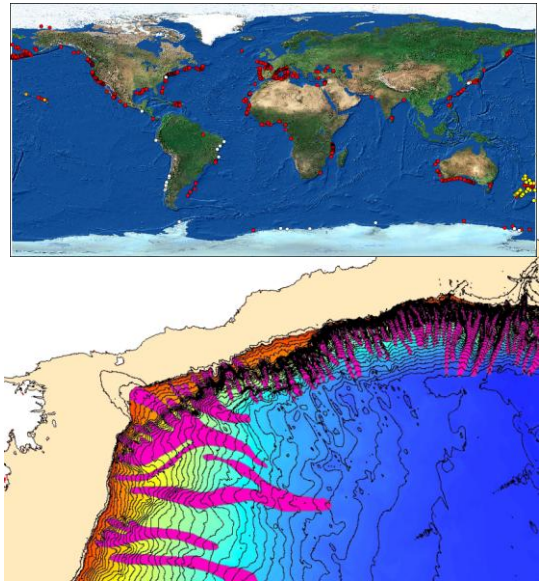
Seamounts

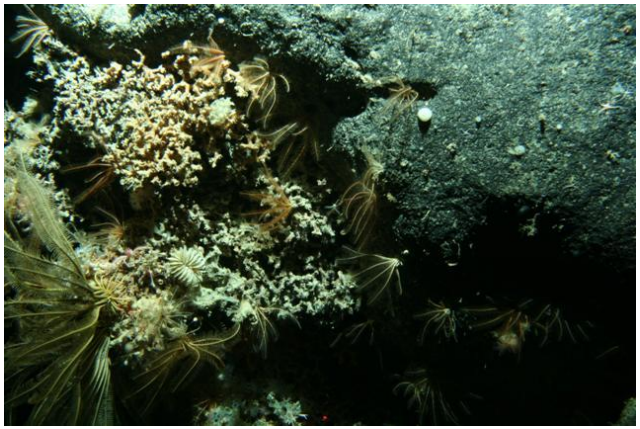
- Elevated seafloor topography, distinct feature
- Usually volcanic, commonly formed as “hotspots”
- Ecologically important
  - Provide hard substrate
  - Extend thousands of metres elevation
  - Localised oceanography can retain species
- Important for fisheries (more tomorrow)
- Very poorly sampled
- Can have high diversity and abundance
- Especially corals and sponges
- Important for SMS and CRC resources

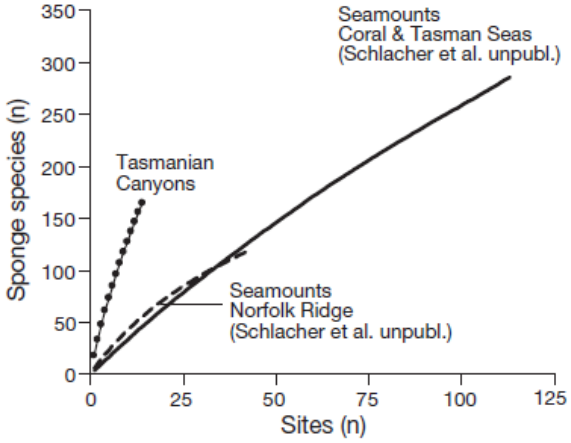


Canyons

- Form deep incisions in shelf and continental margins around the world
- Often high current flows, rocky flanks, soft sediment on canyon floor
- Diverse, abundant communities
- Sponge and corals on flanks, very dense infauna (nematodes in particular)

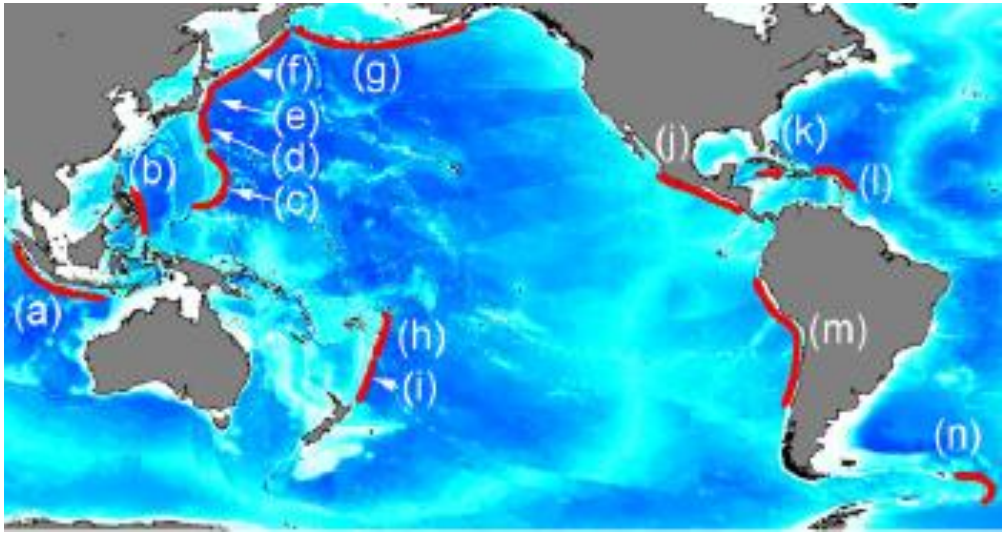


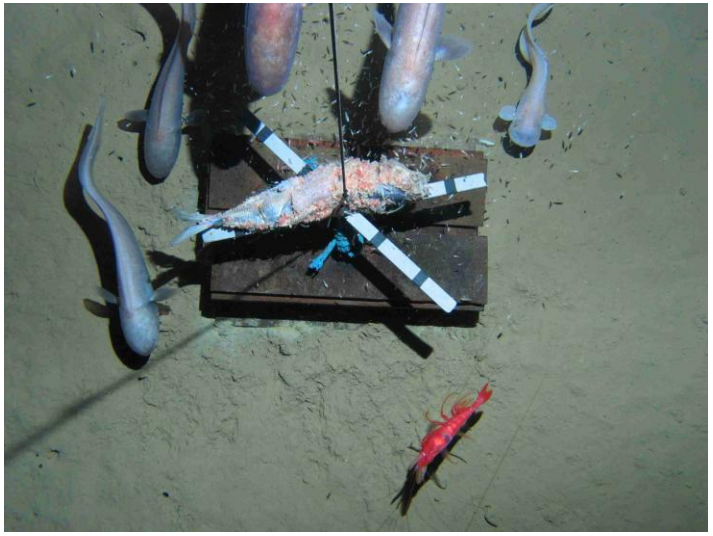




Trenches

- Defined as deeper than 6000 m
- Occur in areas of subduction of tectonic plates
- Western Pacific, Kermadec, Tonga, New Hebrides, Marianas, Japan etc
- Deepest fish (about 8000 m), dominated by scavenging amphipods. Low diversity, sometimes very abundant. Most animals small, giant ‘pod.





Ongoing scientific studies

- A talk in its own right….
- The deep sea is so large, diverse, that so too are the science programmes
- Some key elements
  - **Exploration**. Biodiversity, what is there?
  - **Structure**. Multiple habitats, “ecosystem” organisation.
  - **Dynamics**. How variable, over what spatial scale.
  - **Connectivity**. Linkages between habitats, depths, ocean basins
  - **Future** ocean structure and function-climate change
  - **Human impacts**. Fishing, mining, waste disposal, litter
- Refer INDEEP “Deep Sea Newsletters”

Deep-Sea Life

Issue 1, March 2013

Welcome from the Editor

Welcome to the first edition of Deep-Sea Life: a new informal publication for the deep-sea biology community. This newsletter aims to deliver current news regarding projects, new papers, meetings and workshops, cruises, student progress, jobs and training opportunities, opinion pieces and other useful information for the science community and all interested parties.

Deep-Sea Life was inspired by the original Deep-Sea Newsletter that many of us will remember fondly, which started in October 1978 and was tirelessly edited by Dr Torben Wolff (University of Copenhagen). The newsletter was intended to open regular communication between the European and, latterly, the international deep-sea community and was closely associated with the Deep-Sea Biology Symposia, which started in 1981. This publication was very well-received and much appreciated by the community. The entire back catalogue of the Deep-Sea Newsletter (1978-2005) is now available in scanned form via the INDEEP website (thanks to Gary Poore, Museum Victoria, Australia): www.indeep-project.org/news/deepsea-newsletter-archive-now-online

It is my sincere hope that Deep-Sea Life (currently hosted by INDEEP and published digitally twice per year) will be a useful read and will enhance our communication on an international level. I would very much appreciate any feedback regarding any aspect of the publication, so that it may be improved as we go forward. Please circulate to your colleagues and students who I have not reached as yet, and have them contact me if they wish to be placed on the mailing list for this publication.

I would like to thank the 61 contributors from 20 different countries that have led to this bumper first edition. Long may such enthusiasm to share your news and views continue! I would finally like to sincerely thank Dr Abigail Pattenden (University of Limerick, Ireland) and Dr Eva Ramirez-Llodra (ICM-CSIC, Spain) for their invaluable help with production.

Dr Maria Baker (Editor)

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This beautiful polynoid was captured by Deep-Sea Photographer, David Shale (now available for all your sea-going photography requirements. Contact: davidmshale@mac.com)

Issue Contents

Deep-Sea Life

Issue 2, October 2013

Welcome to issue 2

Welcome to the second edition of Deep-Sea Life: a new informal publication for the deep-sea biology community. I hope you enjoy browsing this latest information from your fellow colleagues concerning their current projects, new papers, meetings and workshops, cruises and so on.

In the next issue, we wish to start a new effort – as suggested by Yoshihiro Fujiwara (JAMSTEC, Japan) – called "Photo of the Issue"! The winning submission will adorn our front page. For this issue, Yoshi has provided us with a beautiful image to get the ball rolling. Thanks Yoshi!

Other notable changes for this issue are that the Student Profiles section has changed to the Scientist Profiles section (I hope for further staff submissions for this section next issue) and we now have a "Wanted" section on the final page.

I had wonderful (and extensive!) feedback following the publication of DSL issue 1 and it certainly gave me the impetus to continue with this venture. Thank you. I will always appreciate any feedback regarding any aspect of the publication, so that it may be improved as we go forward. Might I ask please that you send comments only to me – rather than bothering the wider community!

Please circulate this issue to your colleagues and students who I have not reached as yet, and have them contact me if they wish to be placed on the mailing list for this publication in future.

I would like to sincerely thank all those that have contributed to this second issue. And of course, thanks once again to Dr Abigail Pattenden (University of Limerick, Ireland) and Dr Eva Ramirez-Llodra (ICM-CSIC, Spain but on the move shortly - see page 43) for their invaluable help with production.

Dr Maria Baker (Editor)

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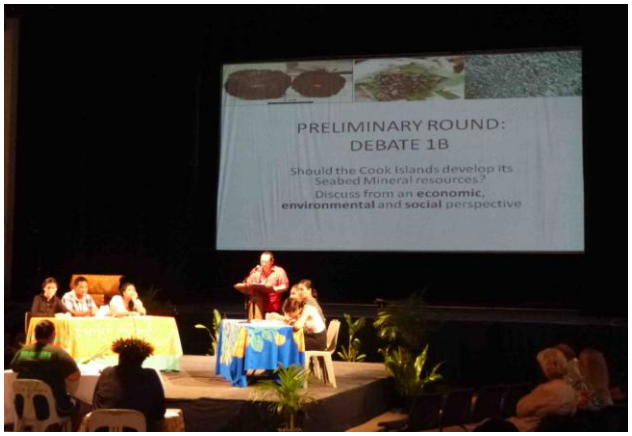
Anglerfish (Linophryne sp.- (tallx) lure prey with a luminescent lobe attached to a rod arising from the snout and hanging in front of the mouth. This robust individual is female, and a tiny male is attached to her side. Their blood circulatory systems will eventually fuse. This specimen was caught via plankton net in Sagami Bay in 2009. Courtesy of Yoshihiro Fujiwara/JAMSTEC

Issue Contents

Key Points

- Access to the deep sea has improved in recent decades, but understanding the ecology of the deep sea requires expensive ships and technologies. Most of the deep sea remains unexplored.
- The deep ocean is complex, with a number of dominant physiographic features well known and other features still to be discovered.
- A diverse fauna inhabits the deep sea, with many species undescribed or undiscovered; this fauna varies from one region to the other.
- The biological characteristics of deep-sea animals is not well known, but key issues for resilience to human impacts are slow growth rates and reproduction, and adaptations to food-poor conditions.



Vinaka

"I don't know why I don't care about the bottom of the ocean, but I don't."

New Yorker 1983