Overview of Biological Studies

Outline
- A brief history of deep sea biology research
- Methods for deep sea biology research
  - Tools: Nets, dredges, cameras, subs, ROVs, AUVs and hybrids
  - Research approaches: Photo surveys, Physical Collections, In situ measurements and assessments, In situ experiments
- Intro to the biology of the deep sea
  - Zones and depth zonation
  - Life in the deep sea
    - Is it an extreme environment for life?
    - What kinds of animals live in the deep sea?
  - Deep sea habitats
  - Biogeography

Special thanks to Drs Lisa Levin, Craig Smith, Anna Metaxis, and Pete Girguis for sharing pictures and lecture material

A brief History of Deep Sea Biology Research

Socrates (600 BC): *The beginning of wisdom is to know that one knows nothing*

Pliny (50 BC): *The deep sea is an inferior world. All we know of it is all there is to be known.*

Early to mid 1800's*: Early dredging to moderate depths led to*

Azoic hypothesis (1859): *Since the deep sea is dark, cold, with such high pressure it is stagnant and anoxic and cannot support life.*

Over the next ten years: *Lots of data slowly accumulated from dredging and recovery of deep telegraph lines found life at depths, and several scientists argued against the Azoic hypothesis. But still the general idea of not much life in the deep sea persisted.*

H.M.S. Porcupine (1869-70)

First ship specifically equipped for oceanographic studies in deep water (first fully organized oceanographic expedition)

Carpenter and Thomson - chief scientists
- West of Ireland - dredged to 2700 m
- South of England/France - 4450 m
- Mediterranean Sea w of Spain

Recovered all major animal groups (mollusks, crustaceans, echinoderms, sponges, stalked crinoids, banks of the coral *Lophelia pertusa)*

W. Thompson

Challenger Expedition (1872 – 1876)

Beginning of modern oceanography
(Institutional, collaborative, multidisciplinary)

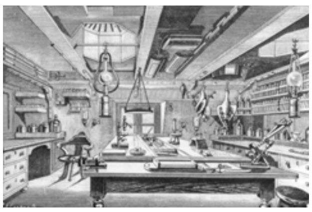
C. Wyville Thomson – Expedition leader

- 3.5 years
- 68,890 nautical miles
- 362 stations
- 40% time spent in ports

19th century equivalent of the US space program in 20th century

H.M.S. Challenger
(226 ft corvette)

Dredging equipment
- Winch
- Beam trawl



Natural History Laboratory

Some of the Challenger Expedition Results

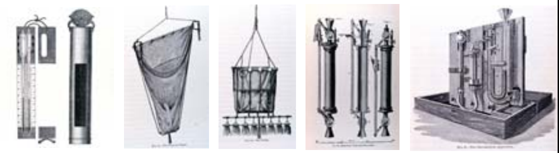
1. Animals collected to 5500 m depth
2. High species diversity in the deep sea
3. Different taxa in deep than shallow water (zonation)
4. Many taxa are endemic to the deep sea
5. Deep-sea environment is stable (temperature, chemical composition, lack of seasonal changes)
6. Deep-sea sediments (calcareous, siliceous oozes) of pelagic origin (foraminifera, radiolarians, coccolithophores, pteropods, diatoms, etc)
7. Dredged seamounts
8. Discovered manganese nodules in central oceans
9. Discovered the Mid-Atlantic Ridge

Scientific results were published in 50 volumes of 29,500 pages with 3,000 plates

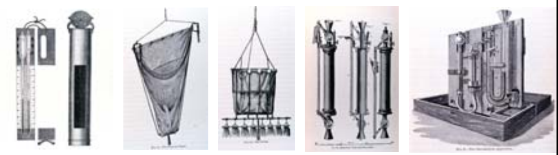
Post-Challenger Expeditions

- Alexander Agassiz (1877- 1888) USA
- Italian expedition on the Vetter Pisani (1882-1885)
- French Travailleur – (1880) and Talisman expeditions– (1888-1927)
- German Valdivia expedition (1898-1899)
- Prince Albert of Monico conducted a series of expeditions between 1885 and 1914.
- John Murray (Great Britain) and Johan Hjort (Norway) collaborate on the Michael Sars expedition in 1910
- Then, not much deep sea research from WWI to WWII
- Through the 40's, 50's and most of the 60's and 70's deep sea research was still dominated by trawling and dredging, with some large and well funded national efforts after WWII

Scientific gear on board the HMS Challenger



The legacy of Challenger



Visiting the deep sea floor

1960: Bathyscape Triest dives to the Bottom of the Challenger Deep with 2 passengers.
4 hours each way, 20 minutes on the bottom at about 10,900m

1965: Alvin does it's first science dive to the deep sea
1977: Alvin makes first dives to hydrothermal vents and discovers the hydrothermal vent communities

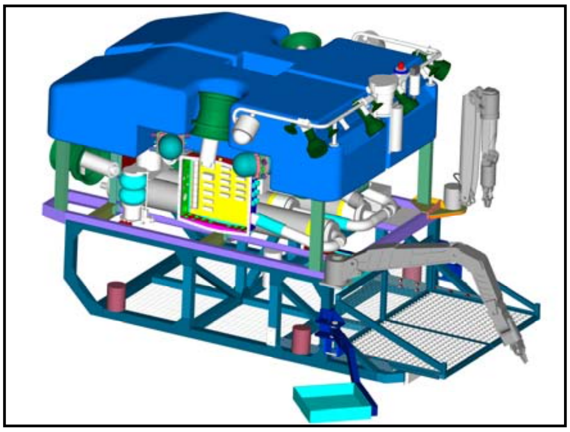
Deep sea Biology Research in 2012

- Much can be and still is done with trawling and dredging, multicoring, and remote sensing
- Similarly, survey and discovery work can often be accomplished by remote sensing coupled with Photo sleds and Drift cameras
- The above types of techniques are very powerful for characterizing large and more uniform habitats, like Manganese Nodule Provinces, and to some extent over seamounts.
- But the modern workhorses for addressing the still unanswered questions about deep sea biology, particularly over hardgrounds, and especially at hydrothermal vents are ROVs, AUVs and Submarines
- For long term observations; landers, remote instruments, time lapse cameras, and cabled observatories are fast coming of age.

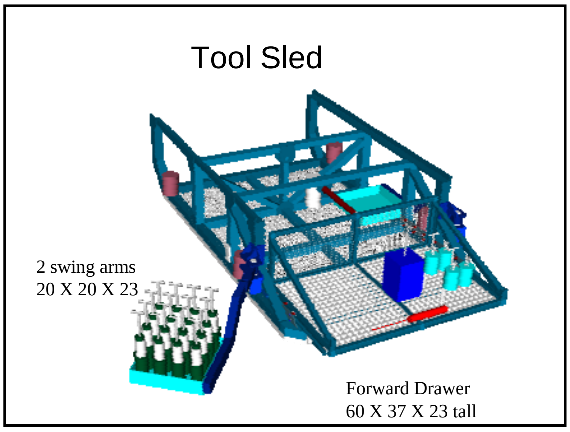
AUVs for survey, discovery and site mapping

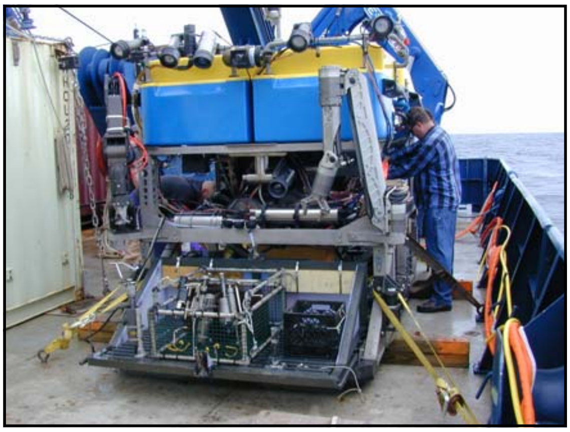
- Example, AUV Sentry from WHOI, USA

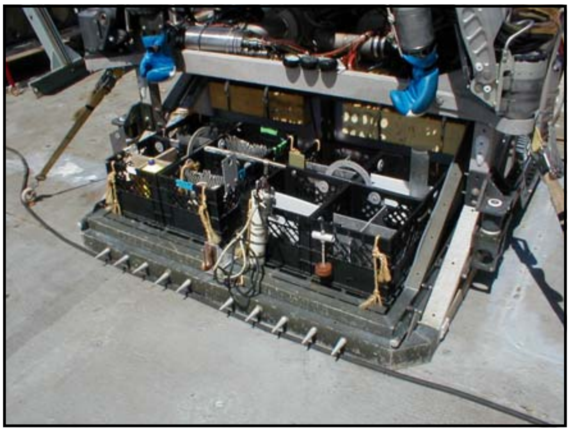

ROVs for:
Sampling
Close up imaging
Experiments
Equipment deployments
Jason II ROV
Thanks to Matt Heintz



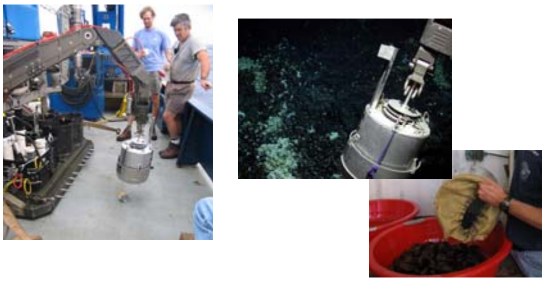

NOAA
ONR

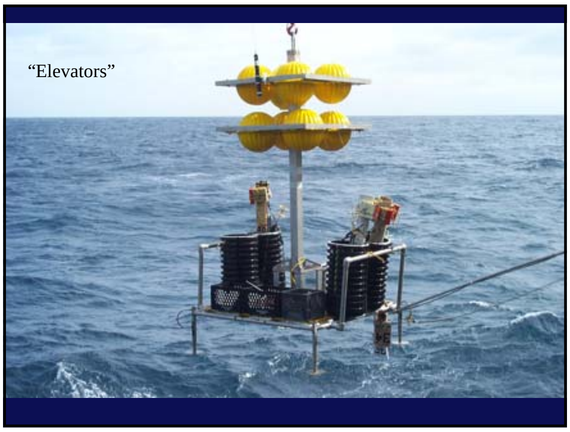

Tool Sled
2 swing arms
20 X 20 X 23
Forward Drawer
60 X 37 X 23 tall

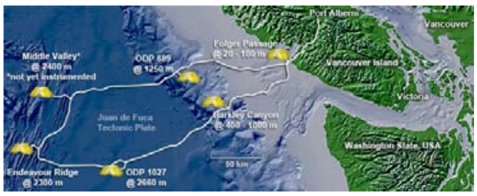




Quantitative collections: Mussel/Snail Pots







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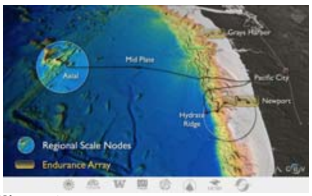
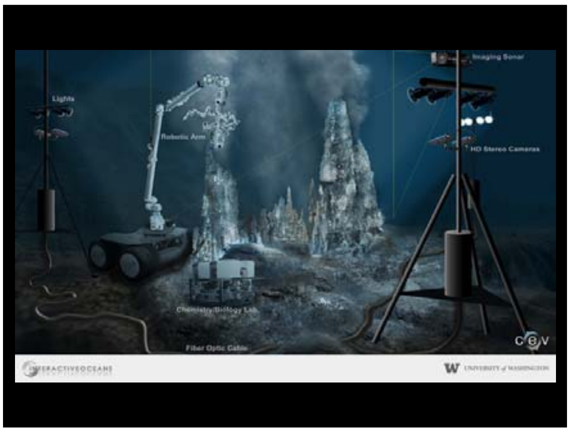


US Cabled Observatory
Coming soon:
http://www.ooi.washington.edu/story/Observatories



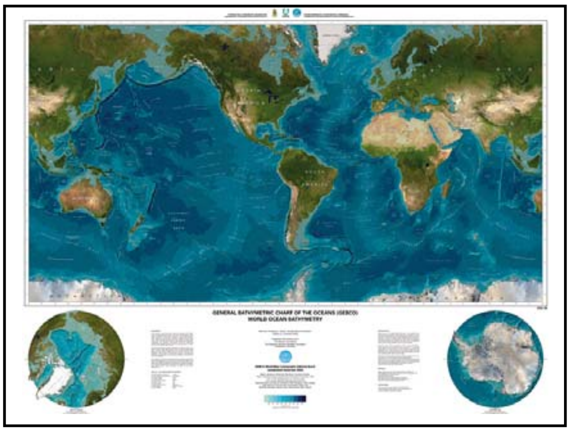
Use different tools for different tasks:

- Characterize and map the biology at a large scale:
  - AUVs, ROVs, camera sleds, multicorers, dredges and nets in some cases
- Characterize the physical/chemical oceanography
  - CTDs, current meters etc.
- Sample biology for inventory and study
  - ROVs with special tools and high quality cameras, plus multicorers for nodule provinces, perhaps dredges for nodules and crusts
- Study population connectivity, bioprospecting, physiology, etc
  - Lab work on samples
- Experiments to understand processes (ie succession, competition)
  - ROV insitu work
- Understand natural and induced changes over time
  - Long term observations and sampling with ROVs and remote instruments

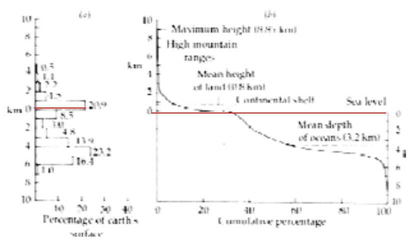
What is known and what is not known.

Life in the deep sea has only been acknowledged for 150 years
There is a high diversity of life in the deep sea
We now have an abundance of tools to study patterns and processes in the deep sea.
We have learned a lot and new tools and techniques will help us to learn a lot more, relatively quickly

However, the deep sea is still very poorly known:
- Do not know the biodiversity. (thousands of unknown species)
- Rarely know species life histories
- Often do not know their reproductive and larval biology
- Rarely know a species population connectivity
- Rarely understand competitive or cooperative interactions
- Food webs are poorly constrained



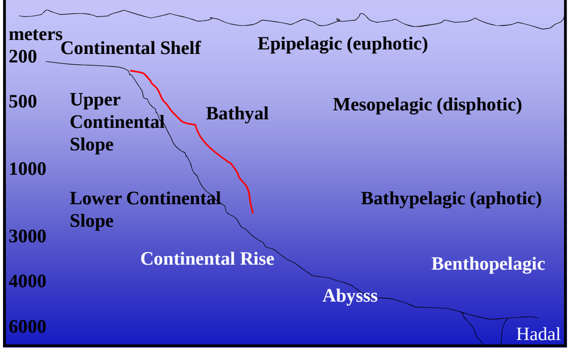
Most of the Earth is Ocean and most of that is Deep Sea



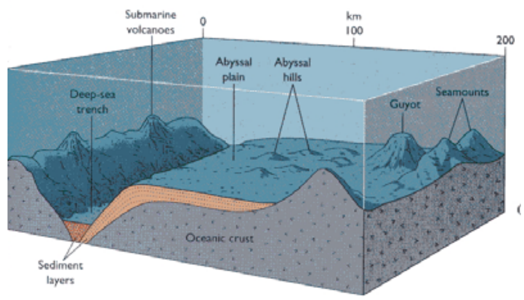
Percent distribution of earth's surface assessed in vertical relief.

Hypsographic curve

Zonation Terminology



Abyss



Features Affecting Vertical Zonation

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)

Zonation of Feeding Mode

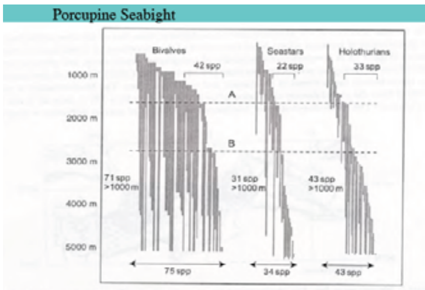
- Reduction in suspension feeding & increase in deposit feeding with depth
- Replacement of sedentary deposit feeders with mobile deposit feeders at deeper depths. (Fauchald and Jumars 1979)
- 50:50 surface and subsurface-deposit feeders at depth.

Compositional Zonation

MACROBENTHOS
Shallower Taxa -
Amphipods, molluscs, polychaetes

•Increasing in deep water -
-tanaid and isopod (peracarid) crustaceans
-aplacophorans (mollusca)
-sipunculans, priapulids

Porcupine Seabight



zonal breaks are those where greater number of upper and lower depth limits occur

Figure 6 Porcupine Seabight zonation. Seastars, holothurians, and bivalve molluscs all show a progressive change with depth with some similar regions of greater faunal change at mid-slope (line A) and lower slope (line B) depths. Graphs are based on the data tables, with selected omissions, in Billett (1991), Howell et al (2002), and Olabarria (2005).

Cascadia Basin

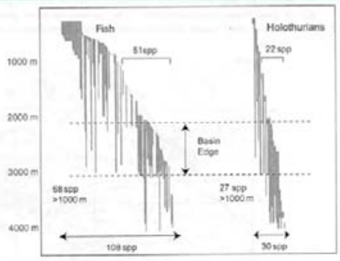


Figure 12 Cascadia Basin faunal zonation. Fish and holothurians are taxa that are most species rich on the upper and lower slope respectively. On the continental slope, Cascadia Basin, and Tufts Plain the taxa show a similar marked increase in species at the junction of the basin and plain. Graphs are based on the author's datasets reported in Pearcy et al. (1982) and Carney & Carey (1982).

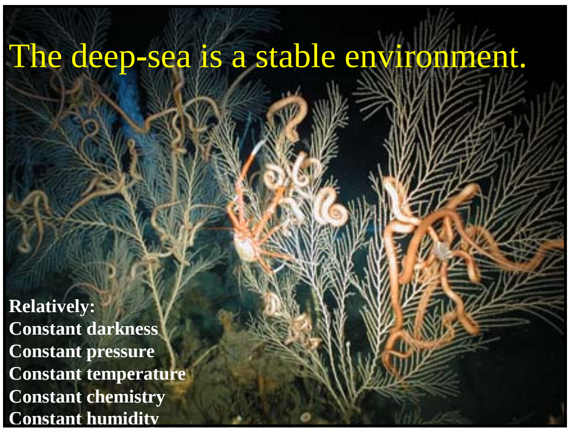
Some take home messages about depth zonation:

- 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”
    - Different species can look alike
- 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 (taxa) 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

Is the Deep Sea an extreme environment?

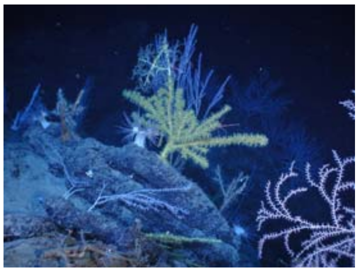
Very Little Light | Very High Pressure
Very Limited Food | Low Temperature

Adapting to high pressure and low temperature.



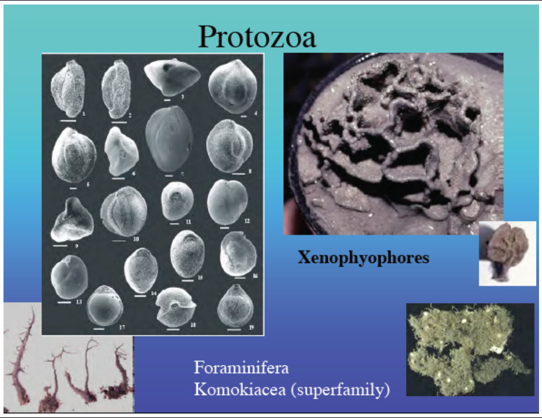
Is the Deep Sea an extreme environment?

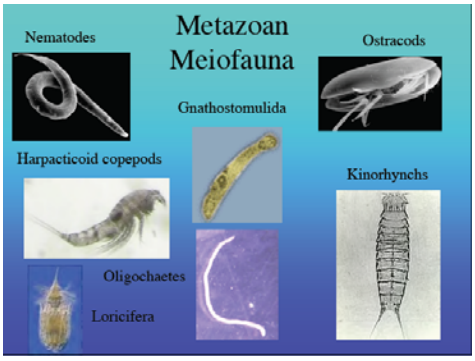
Not really, it is a large stable environment that 100’s (perhaps 1000’s) of groups of animals have <u>independently</u> evolved to inhabit

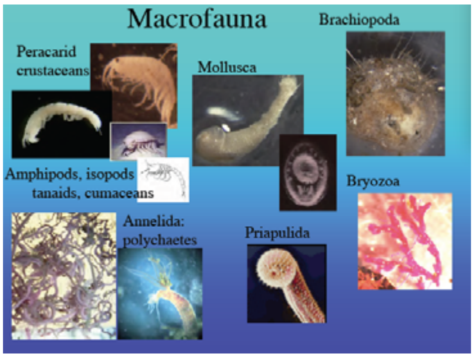


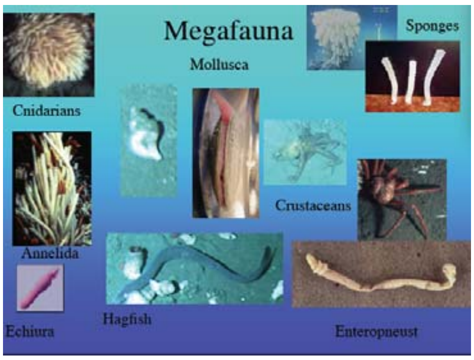
Who Lives in the Deep Sea?

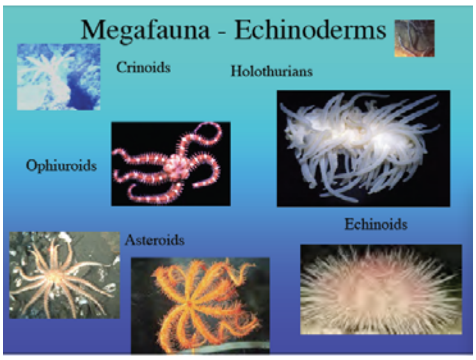
- Bacteria/Archaea
- Protozoa
- Meiofauna (42-500 μm)
- Macrofauna (>300 μm)
- Megafauna (visible, >1 cm)
- Giants

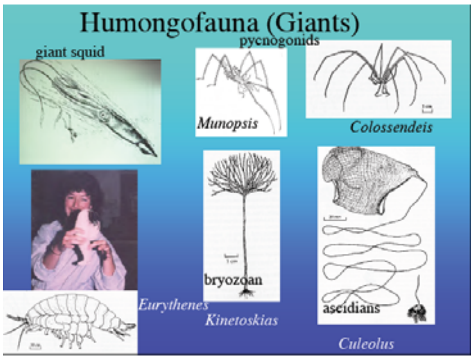












Deep Sea habitats

- Most is sediment
  - Different types of sediment and different sizes of grains host different biology
  - Faunal groups change with depth
  - Fauna changes with food input
- Hard bottom
  - Can be small rocks (Manganese nodules)
  - Mountains (seamounts) and escarpments
  - Hydrothermal vents
  - Cold seeps

Biogeography

- A type of "vertical zonation"
- Occurs when groups of populations are isolated for long periods of evolutionary time (ie Australian vs African fauna)
- In the ocean separation can be physical or oceanographic barriers
- Other important causes of vertical zonation in the deep sea include influence of water masses and food supply

Some general Take Home messages

- The fauna of the deep sea is very diverse, but relatively poorly known
- Different communities are found in different habitats
- Different communities are found at different depths
- Different communities are found in different parts of the world's oceans