Benthic Habitats and Organisms

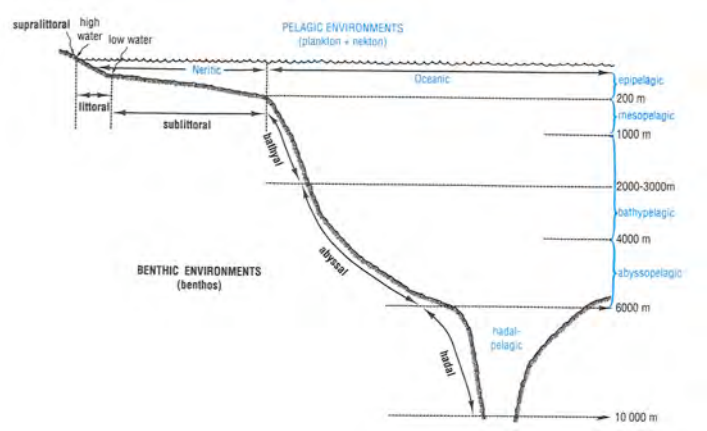
EBS 566

Reading

- Assigned
  - Chapter 12, 14, Miller
  - Discussion paper:
    - Wishner et al. Involvement of the oxygen minimum in benthic zonation on a deep seamount. Nature (1990) pp. 57-59
- Supplementary
  - Chapter 13, Miller
  - Ruhl and Smith. Shifts in deep-sea community structure linked to climate and food supply. Science (2004) vol. 305 (5683) pp. 513
  - Smith et al. Climate, carbon cycling, and deep-ocean ecosystems. Proceedings of the National Academy of Sciences (2009) vol. 106 (46) pp. 19211-19218

If you weren't in class I suggest you read at least one of the supplementary articles

Marine Habitats



Lalli & Parsons, 1997

F. Azam

Benthic habitats

- Benthic refers to the solid earth under the water column
- Factors influencing benthic habitats
  - Substrate: sediment or rocky
  - Depth
  - Temperature
  - Oxygen, constant and high in most areas, except where intersects oxygen minimum
  - Food supply
  - Wave energy (in shallow areas)

Challenger expedition of 1872–76

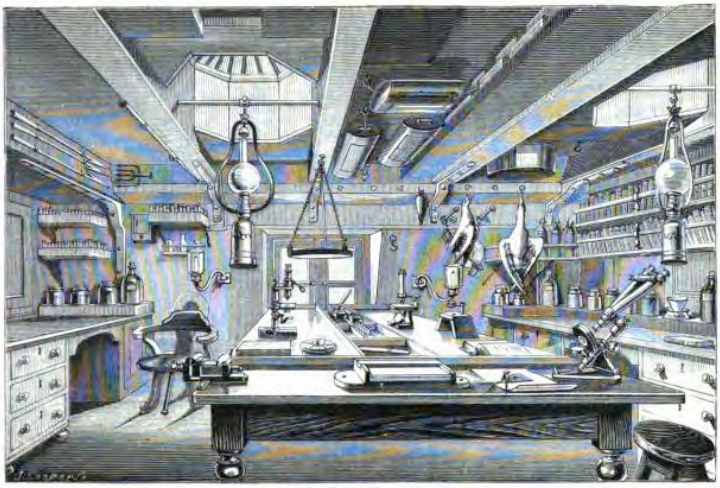


Fig. 1.—The Natural History Work-room.

Looks a lot like a shipboard laboratory today!

Challenger Reports

- More than 90 volumes, > 30,000 pages
- Full set in the library of the University of Oregon's Oregon Institute of Marine Biology in Charleston
- Searchable pdfs online
  - http://19thcenturyscience.org/#H.M.S._Challenger_Library
- Also in Google Books
- Demonstrated for the first time that life existed at great depths

Abyssal plain

- Largest benthic habitat: 60% of ocean area
- Food availability much higher than overlying water column
- Food supply: 1-2% of the productivity of the overlying water
- Substrate is fine sediment

Abyssal habitat

- Relatively constant
  - Temperature less than 3 degrees C
  - Salinity constant
  - Oxygen high, constant in overlying water
  - Pressure constant at any site, gradually changing with distance
  - Complete darkness
- Paradoxically, very high faunal diversity

Abyssal habitat

- Variability
  - Food supply is highly episodic
    - Larger animals falling to the bottom
    - Collapsing phytoplankton blooms
- Food supply variability may support high diversity
- Metabolic activity of benthic biota influences CO_2 production and carbon burial, and hence climate

Abyssal organism categories

- Location
  - Epifauna
    - Mobile, on the surface
  - Infauna
    - Buried in sediment
- Size: Classified by sieving
    - Microfauna <0.1 mm
      - Bacteria, archaea, protozoa, responsible for most metabolism
    - Meiofauna 0.1-1mm
      - Nematodes, harpacticoid copepods, heterotrophic diatoms
    - Macrofauna >1 mm
      - Annelids, crustaceans, molluscs
    - Megafauna >> 1 mm
      - Fish, echinoderms, mollusks

Long term dataset: Station M

- Ken Smith, Scripps Institution of Oceanography
- 18 years of data collection
  - Time lapse photography
  - Sediment respiration
  - Sediment traps

Smith K L et al. PNAS 2009;106:19211-19218

Ken Smith and Roberta Baldwin

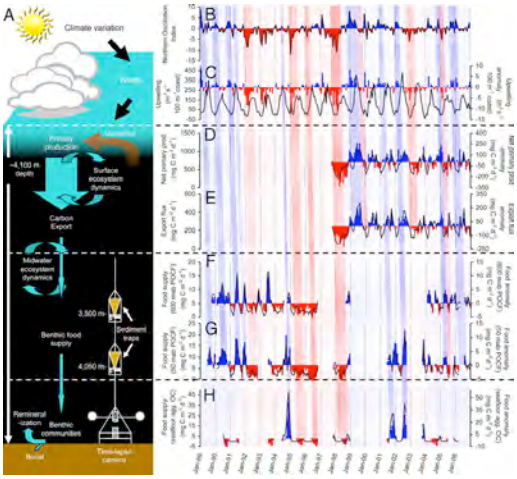
http://legacy.signonsandiego.com/news/obituaries/20060214-9999-1m14baldmin1.html

PNAS

Locations of Station M (Sta. M) at ≈4,100 depth in the Northeast Pacific Ocean and PAP at ≈4,850-m depth in the Northeast Atlantic Ocean. Map was produced by using Google Maps.

Roberta Baldwin was Ken Smith's head technician and collaborator. They worked together for 30 years until her death from brain cancer in 2004. She was a mother of four who went back to school after raising her kids to get a B.S. She began volunteering in Smith's lab, and gradually became his right hand, co-authoring articles and acting as chief scientist on research cruises.

Schematic of processes and 18-year time series analyses (1989–2007) through the oceanic water column to the sea floor at the Northeast Pacific study site (Station M)

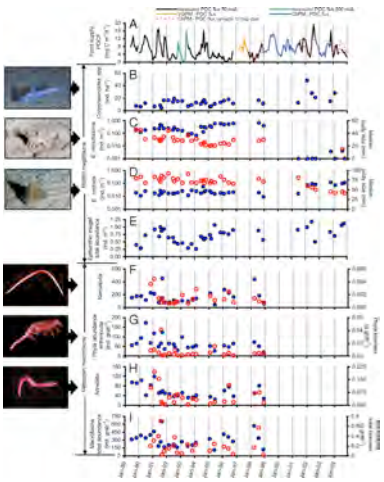


Smith K L et al. PNAS 2009;106:19211-19218

PNAS

Schematic of processes and 18-year time series analyses (1989–2007) through the oceanic water column to the sea floor at the Northeast Pacific study site (Station M). (A) Schematic illustrating the simplified process by which climate can influence deep-sea ecology and biogeochemistry. (B) NOI (www.pfeg.noaa.gov/products/PFEL/modeled/indices/NOIX/noix.html), an indicator of El Niño-Southern Oscillation (ENSO) variation in the Northeast Pacific (70), is shown. Monthly data (black lines) and anomalies (positive in blue bars and negative in red bars) are from the Northeast Pacific. (C) Upwelling Index (71) for the California coastline in the vicinity of the Northeast Pacific study site (Station M). (D) Net primary production computed by using the carbon-based production model (72) applied to satellite data collected over monthly periods at a radius of 50 km around the study site. (E) Export flux calculated from net primary production and sea-surface temperature (73). (F and G) POCF to 600 m above bottom (mab) (3,500-m depth) (F) and 50 mab (4,050-m depth) (G). (H) Visibly detectable aggregate fluxes to the seafloor measured by using empirically calibrated time-lapse photography (21). Overlying the time series plots are light blue and light pink shading indicating time periods dominated by positive and negative NOI conditions, respectively. La Niña conditions are associated with the higher peaks in the NOI, as in early 1997 and late 1998, whereas El Niño conditions are associated with lower values of the NOI, as in early 1995 and early 1998. These conditions are then ultimately related to either higher than (light blue) or lower than average (light pink) food supplies. Darker blue and pink bars indicate similar associations on monthly time scales. The slant of the bars from the top to bottom panels is indicative of the time lags linking

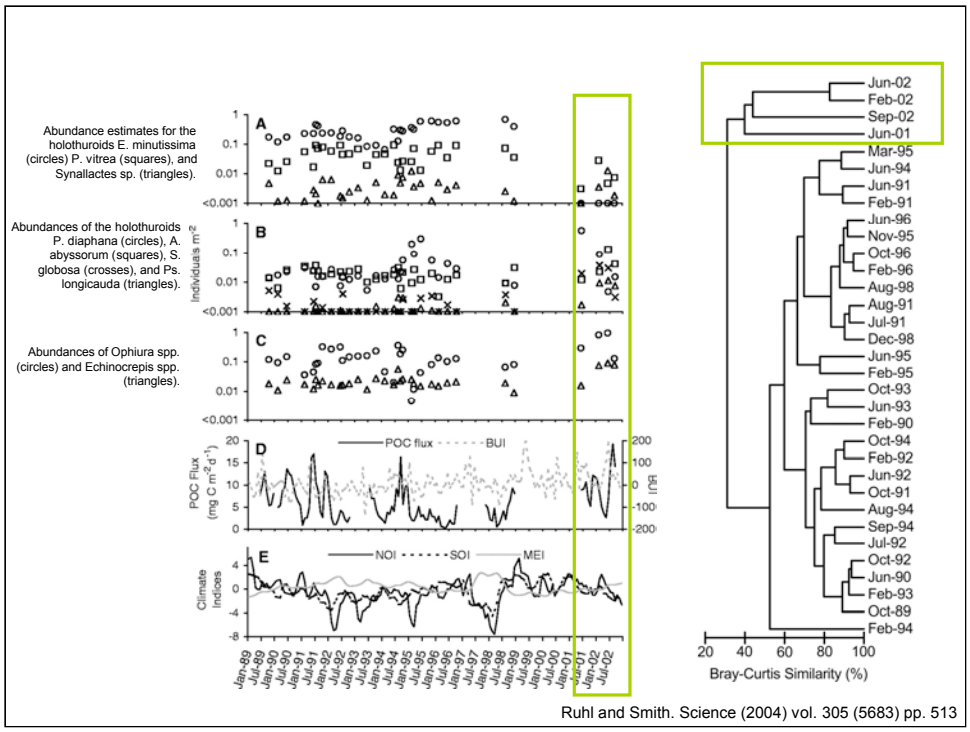
Food supply and benthic community components in the Northeast Pacific



Smith K L et al. PNAS 2009;106:19211-19218

PNAS

Food supply and benthic community components in the Northeast Pacific. (A) Black, green, orange, and blue time-series lines representing a composite of POCF estimates from 50 mab (black) and 600 mab (green) sediment traps and model-estimated flux using the vertically generalized production model (74) (orange) and the carbon-based production model (72) (blue) where possible. The red dashed line is unincorporated model data (16). The difference between the red dashed line and the black line indicates how well the model estimates correspond to measured POC flux values at 50 mab. (B) Density of Coryphaenoides spp. fishes (blue circles). (C and D) Density (blue circles) and median body size (red open circles) for E. minutissima (C) and E. rostrata (D). (E) Total mobile epibenthic megafauna density (blue circles). (F–H) Monthly density (blue circles) and biomass (open red circles) for Nematoda (F), Arthropoda (G), and Annelida (H). (I) Total metazoan macrofauna abundance (blue circles) and biomass (red open circles).

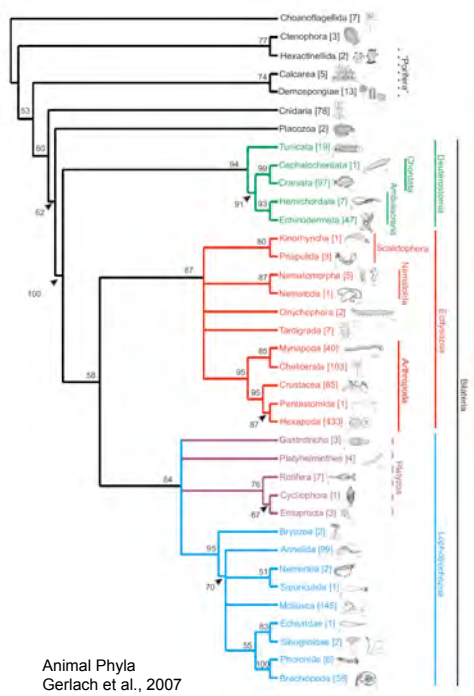


Ruhl and Smith. Science (2004) vol. 305 (5683) pp. 513

Fig. 1. (A) Abundance estimates for the holothuroids E. minutissima (circles) P. vitrea (squares), and Synallactes sp. (triangles). (B) Abundances of the holothuroids P. diaphana (circles), A. abyssorum (squares), S. globosa (crosses), and Ps. longicauda (triangles). (C) Abundances of Ophiura spp. (circles) and Echinocrepis spp. (triangles). (D) Monthly POC flux (mg of C per m2 per day) at 50 m above bottom (4050-m depth) at Station M, representing food supply to the sea floor, and upwelling index (m3 per s per 100 m of shoreline) [monthly Bakun Upwelling Index (BUI) anomaly for 36°N 122°W]. (E) Three-month centered running means for the NOI, SOI, and MEI climate indices.

Microbial communities

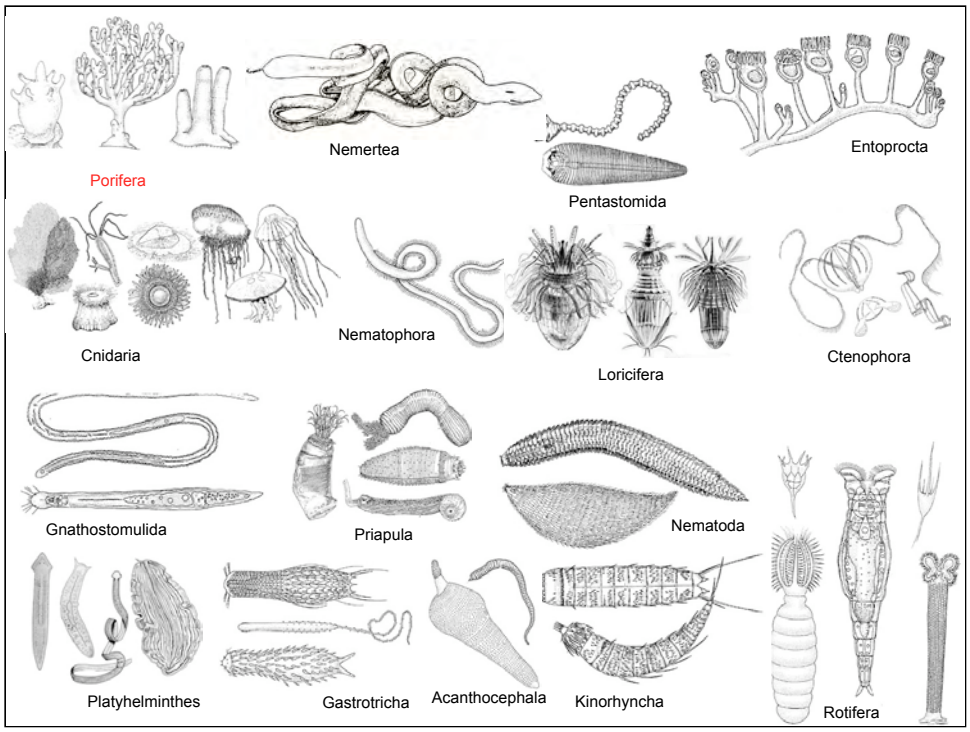
- Relatively little cultivation independent work done on deep sea sediments
  - Generally, more gamma proteobacteria and actinobacteria are seen.
  - Unlike *P. ubique*, deep sea microbes are likely to be copiotrophs adapted to rapid response to nutrient pulses
- Mostly studied by *in situ* bulk measurements such as oxygen consumption



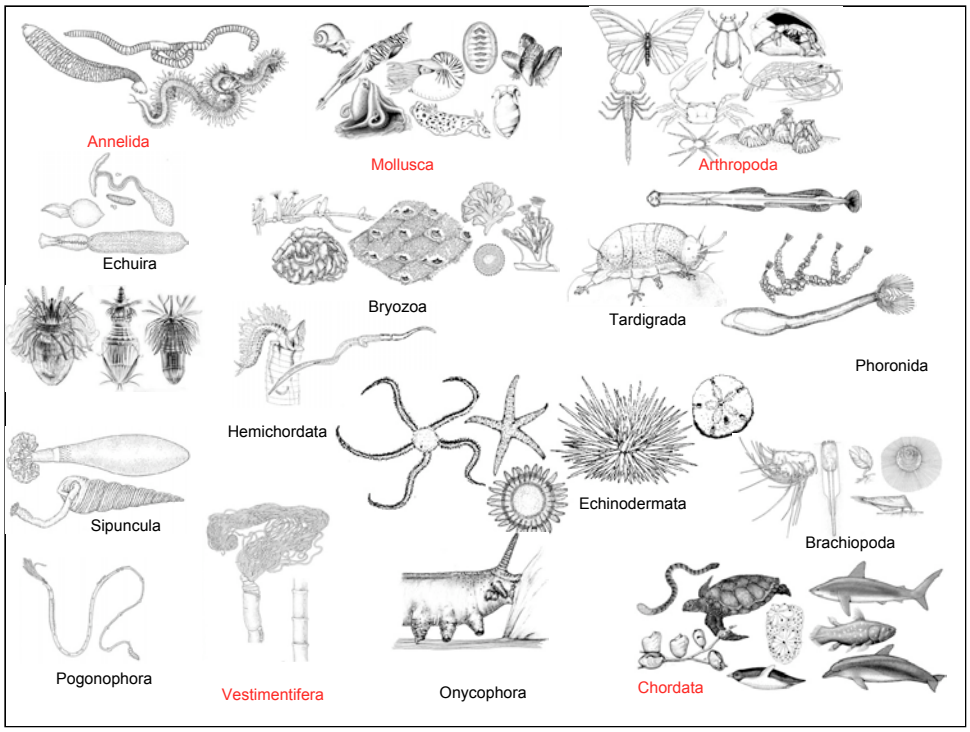
Animal Phyla
Gerlach et al., 2007

Animal Phyla

- Most are invertebrates
- Most are marine
- Most are tiny



Morphological diversity in animal phyla


Annelida
Mollusca
Arthropoda
Echuira
Bryozoa
Tardigrada
Phoronida
Hemichordata
Echinodermata
Sipuncula
Brachiopoda
Pogonophora
Vestimentifera
Onycophora
Chordata

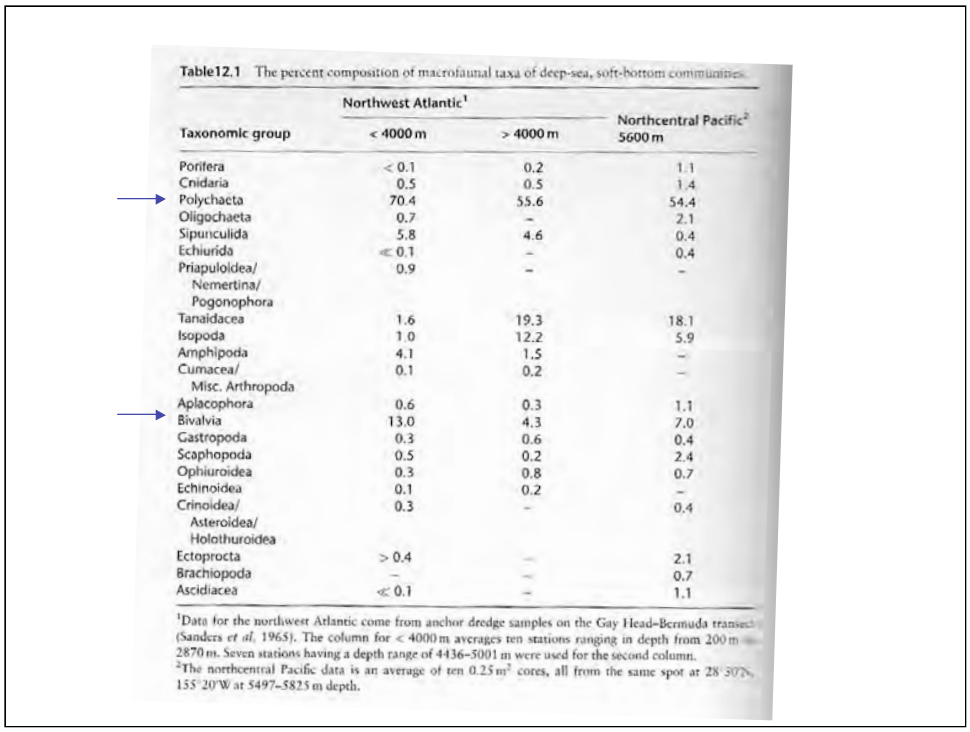


Table 12.1 The percent composition of macrofaunal taxa of deep-sea, soft-bottom communities.

Taxonomic group	Northwest Atlantic[1] < 4000 m	Northwest Atlantic[1] > 4000 m	Northcentral Pacific[2] 5600 m
Porifera	< 0.1	0.2	1.1
Cnidaria	0.5	0.5	1.4
Polychaeta	70.4	55.6	54.4
Oligochaeta	0.7	–	2.1
Sipunculida	5.8	4.6	0.4
Echiurida	≪ 0.1	–	0.4
Priapuloidea/ Nemertina/ Pogonophora	0.9	–	–
Tanaidacea	1.6	19.3	18.1
Isopoda	1.0	12.2	5.9
Amphipoda	4.1	1.5	–
Cumacea/ Misc. Arthropoda	0.1	0.2	–
Aplacophora	0.6	0.3	1.1
Bivalvia	13.0	4.3	7.0
Gastropoda	0.3	0.6	0.4
Scaphopoda	0.5	0.2	2.4
Ophiuroidea	0.3	0.8	0.7
Echinoidea	0.1	0.2	–
Crinoidea/ Asteroidea/ Holothuroidea	0.3	–	0.4
Ectoprocta	> 0.4	–	2.1
Brachiopoda	–	–	0.7
Ascidiacea	≪ 0.1	–	1.1

[1]Data for the northwest Atlantic come from anchor dredge samples on the Gay Head–Bermuda transect (Sanders *et al.* 1965). The column for < 4000 m averages ten stations ranging in depth from 200 m to 2870 m. Seven stations having a depth range of 4436–5001 m were used for the second column.
[2]The northcentral Pacific data is an average of ten 0.25 m^2 cores, all from the same spot at 28°30'N, 155°20'W at 5497–5825 m depth.

In soft bottom communities, polychaete worms, several groups of crustaceans and bivalve mollusks dominate

Abyssal Invertebrates

- Echinoderms
  - Ophiuroids (brittle stars
    - Ophiura rouchi
  - Holothurians (sea cucumbers)
    - Abyssocucumis abyssorum
  - Echinoids (sea urchins and sand dollars)
    - Echinocrepis

Encyclopedia of Life
http://www.eol.org/

Abyssal invertebrates

- Annellids (worms)
  - Polychaeta most abundant
    - Capitella capitata
- Crustaceans
  - Tanaids
    - Tanaissus lilljeborgi
  - Amphipods
    - Ampelisca richardsoni
  - Isopods

http://oceanexplorer.noaa.gov/explorations/02mexico/logs/oct13/media/isopod.html

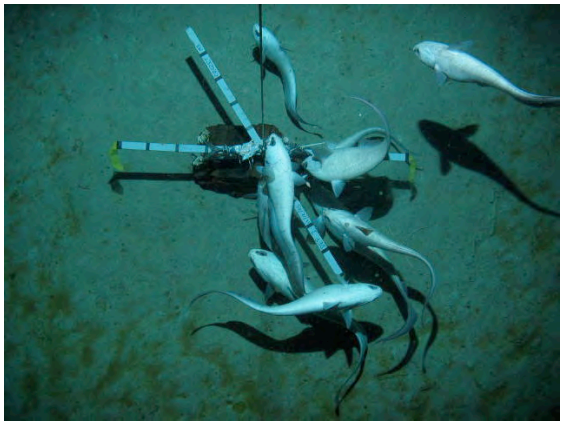
Abyssal invertebrates

- Mollusca
  - Bivalves
- Sipunculids

Tindaria kennerlyi, http://www.mbari.org/benthic/bivalves.html

Vertebrates

- Coryphaenoides



pcwww.liv.ac.uk/earth/crozet/131205.htm

Hard substrates

- Bryozoa
- Tunicata

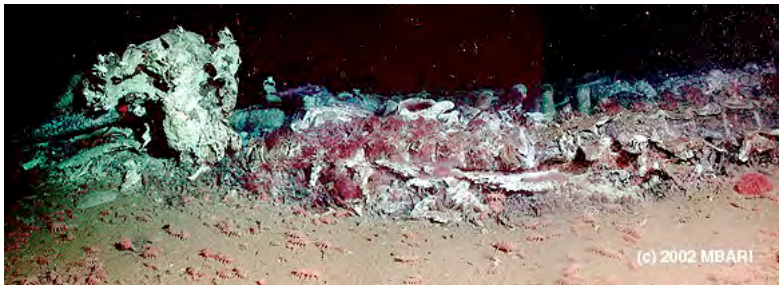
Megalodicopia hians
http://www.mbari.org/data/images_video/animals2.htm

- Echinodermata
- Cnidaria
- Porifera

More on these next year

Whale falls

- http://www.mbari.org/twenty/osedax.htm



Osedax (fluffy red on the bones) is a worm (annellid) that specifically colonizes whale bones, which contain a lot of lipids. They have bacterial symbionts that help them metabolize the oil, tiny males live inside the tubes of the females.

Resources

- There is a movement underway in biodiversity research to develop web-based bioinformatic tools that can link together and interchange information, and make up-to-date, curated information available on taxonomy, biogeography, etc, using a team approach. None of the resources are anything like complete, but this seems to be the wave of the future.
  - Encyclopedia of Life: http://www.eol.org/
  - Ocean Biogeographic Information System, OBIS: http://www.iobis.org/
  - World Register of Marine Species, WoRMs: http://www.marinespecies.org/
  - Integrated Taxonomic Information System, IT IS: http://www.itis.gov/
  - Discover Life, hosts interactive keys to aid non-experts in identifying organisms. This link is to a key for Indo-Pacific marine mollusks my group is working on. http://www.discoverlife.org/mp/20q?guide=Turridae_Indo_Pacific
- Census of Marine Life: http://www.coml.org/
  - An umbrella for a variety of projects on marine organisms