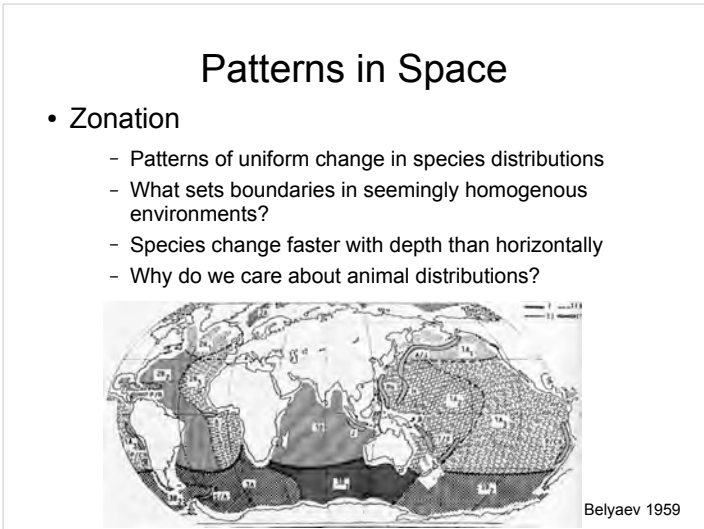
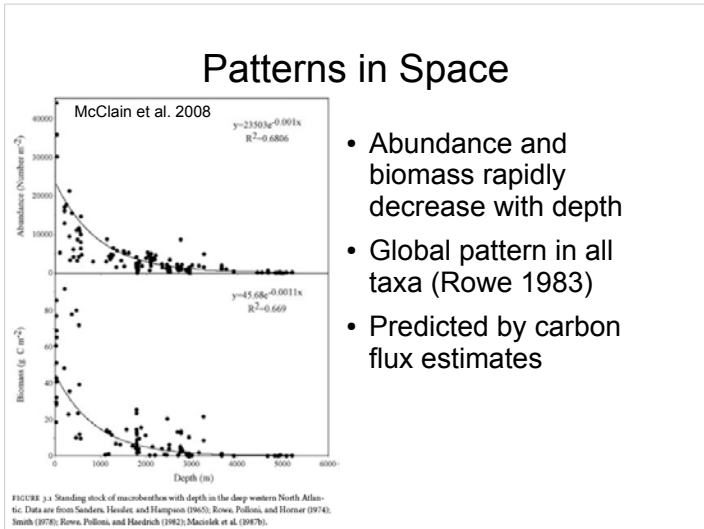


- ## We've come a long way!
- We've studied:
    1. History of deep-sea exploration
    2. General features of the seafloor and seawater
    3. Carbon cycling in the ocean
    4. Deep sea fauna
    5. Adaptations to living in the deep
    6. Feeding and reproduction of deep sea fauna

- ## The BIG Picture
- Are there patterns to animal distributions around the world? (across ocean basins, with depth)
  - How do deep-sea communities respond to perturbations in their environment?
  - What characteristics specific to the deep-sea fauna explain its high diversity in the face of low productivity and low environmental variety?

- ## Patterns in Space
- *Macroecology* – study of relationships between organisms and their environment that involves characterizing and explaining statistical patterns of abundance, distribution, and diversity
    - Centers on large-scale phenomena
    - Quantitative sampling
  - Standing stock – Abundance and biomass of fauna → What is this drive by?



## Patterns in Space

- Zonation may be forced by physiography of the ocean floor

### Shelf Break

- The "mud line" from *Challenger* Expeditions (Murray 1895): boundary between shelf and deep-sea fauna
- May occur at 200m (W. Europe), 500m (Antarctic) or a few m (fjords)

### Sediment Type (Ekman 1953)

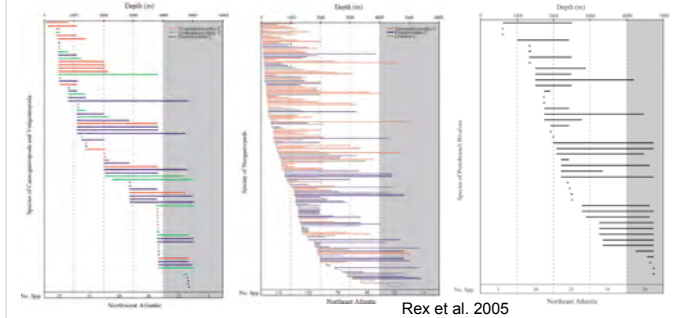
- Break between hemipelagic and pelagic sediments

### Antarctic

- Little difference between shelf and deep-sea fauna
- Why do you think there is greater continuity and high latitudes?

## Patterns in Space

- Bathyal (1-4km) vs Abyssal (4-6km) zonation
  - Bathyal contains mixture of fauna from shallow and deep
  - Abyssal contains true deep-sea (=endemic) faunas, though most have ranges into the bathyal region



## Patterns in Space

- How do we measure zonal breaks?
- How does biodiversity change over depth and latitude?
- Is biomass distributed similarly over space?
- Why is the giant isopod so... GIANT?

Next class!

## Patterns in Space

- Individual Species Patterns: Aggregation
  - When do species aggregate?
    - Filter-feeders?
    - Mobile macrofauna?
  - How do we measure density?



## Aerial Surveys

Podowski et al. 2010

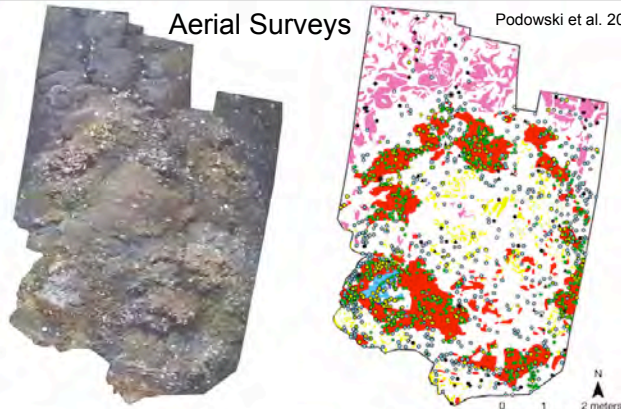


Fig. 2. KM2 mosaic and digitized fauna. *Ln.*: *Iremenia nauzelei*, *WH Ln.*: white *I. nauzelei*, *B.b.*: *Bathymodiolus brevior*, *A.a.*: *Austinograea alypsosa*, *A.w.*: *Austinograea williamsi*, *A.spp.*: *Austinograea* spp., *M.l.*: *Munidopsis leuensis*, *Ph.*: *Paralomis hirtella*, *A.k.*: *Abitocris komati*, *Os.*: 'other' shrimp, *E.d.*: *Eosipho destroyeri*, *Aa.*: *Actinostolidia* spp., *Anth.*: *Anthosactis* sp., *Oa.*: 'other' anemones, *Cs.*: cladorhizid sponge, and *C.h.*: *Charadria hydrothermica*



## Sampling the Deep

- Aerial surveys work for megafauna, what about smaller stuff?
  - Destructive sampling:
    - From a submersible: claw/device/suction/coring



## Sampling the Deep

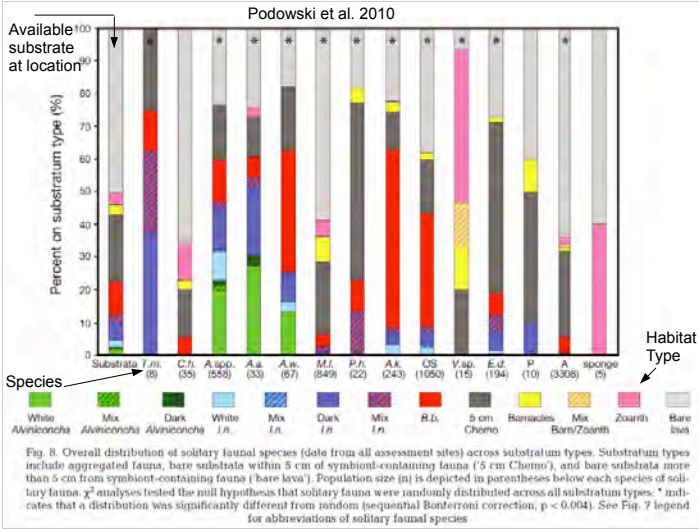
- Aerial surveys work for megafauna, what about smaller stuff?

- Destructive sampling:
  - From a ship: dredge/rawl/piston core/box core



## Sampling the Deep

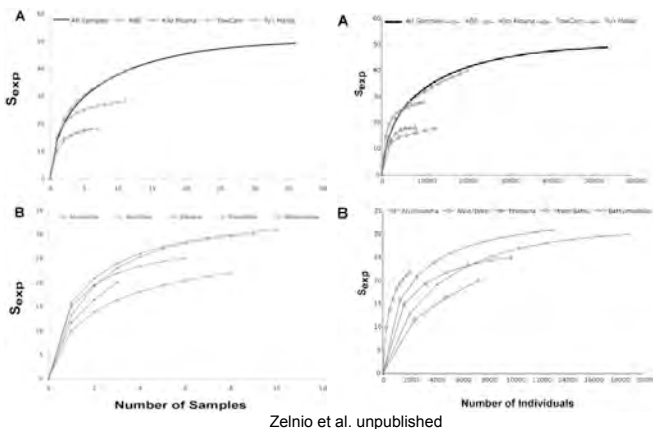
- Getting density: # ind or mass per spp per area or volume
  - Can use quadrat for suction/scrape sampling
- Equipment has standardized area or volume
- Purpose: find correlations among animals distributions or between animal distributions and habitat type/conditions



## Sampling the Deep

- Species-Accumulation curves/Rarefaction
  - Problem:** Samples taken with different methods or of different sizes are not directly comparable.
    - The larger the sample size, the more species you expect to find
  - Solution:** Plot cumulative species richness curves per sample (sampling effort) or per # individuals (diversity)

## Sampling the Deep



## Patterns in Space

- Abundance or biomass?
- Rowe 1983: for quantification of deep-sea life, biomass is more meaningful (although both patterns tend to follow the same trends)
  - Disadvantages to using biomass?

## Patterns in Space

- Abundance or biomass?
- Rowe 1983: for quantification of deep-sea life, biomass is more meaningful (although both patterns tend to follow the same trends)
- Biomass provides an estimate of production
- Disadvantages to using biomass?
  - Weigh wet, dry or preserved?
  - With shells or no shells?
  - How to remove sediment particles?
  - For small organisms, stored waste mass may be large
  - Seasonal pulses?
  - Susceptible to high variance (i.e. 1 large individual)

## Patterns in Space

- What is the reality of our sampling generalizations?
  - <1000 quantitative samples (up to 1983)
  - 100,000s of seafloor photographs
  - ex. 80,000 photographs of a Manganese Nodule province, but biological community only characterized by 15 box cores!

## Patterns in Space

- What leads to spatial variation in biomass?
  - Primary production at the surface
  - Depth & distance from land (correlated to primary production at the surface)
  - Slope upwelling
  - Submarine canyons & trenches

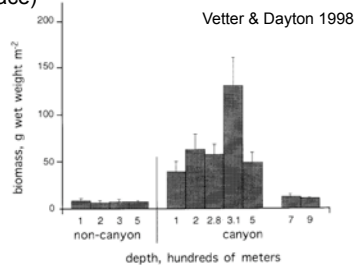
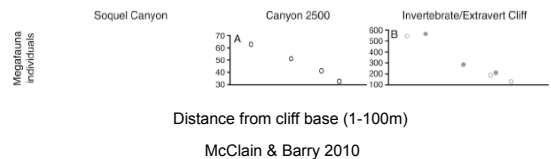


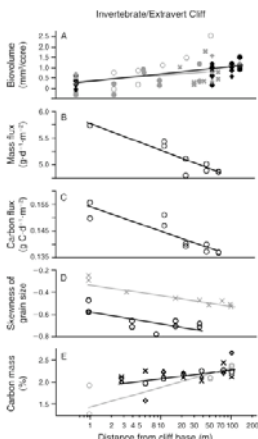
Fig. 4. Mean macrofaunal biomass (wet, ethanol preserved) in Scripps Canyon from 100 to 280 m, La Jolla Canyon from 300 to 900 m, and outside the canyons from 100 to 200 m. Bars = 1 standard error.

## Patterns in Space

- Submarine canyons
  - While a funnel for organic matter, also a haven for predators:
    - If organic matter is funneling from the canyon walls, then we should expect high biomass at the base of the wall and decay further away from wall
    - Predator biomass was highest near cliff walls



## Patterns in Space



Though more productive near canyon walls, fewer animals in sediment cores, correlated to more megafauna nearer the walls in photo transects = predators attenuated funneling effect of canyon in primary production!

FIG. 5. Biological and environmental attributes at Invertebrate/Extravert Cliff in relation to distance from the cliff base, plotted on a log scale. Invertebrate Cliff is denoted by gray symbols, and Extravert Cliff by black with varying symbol type denoting different seasons and ROV dives. Regression statistics are given in Table 2. (A) Average biovolume across all species per core, (B) mass flux in sediment traps deployed 15 m off the bottom, (C) carbon flux in sediment traps deployed 15 m off the bottom, (D) skewness of sediment grain size distribution from cores, and (E) percentage of the total mass of carbon in the sediment from cores.

McClain & Barry 2010

## Patterns in Space

- Did they sample well?

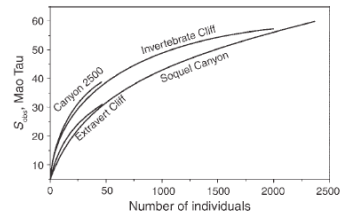


FIG. 3. Species accumulation curves (measured as Mao's Tau) for all four sampling sites.

McClain & Barry 2010