From the Continental Shelf to the Deep Sea

Notes for *Marine Biology: Function, Biodiversity, Ecology*

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**Sampling the Subtidal Benthos**

Types of bottom samplers:

- **Dredges**, heavy metal frames with cutting edges that dig into sediment
- **Sleds**, dredges with ski-like runners that allow only shallow sampling of sediment
- **Grabs**, samplers that sample only a defined area at a time
- **Corers**, small tubes that are dropped into sediment (useful for microbiota, sediment samples)
Anchor dredge: digs to a specified depth

Peterson Grab

Box Corer
Sampling the Subtidal Soft-Bottom Benthos

A good sampler should:

• Sample a large area of bottom
• Sample a defined area and uniform depth below the sediment-water interface
• Sample uniformly in differing bottom substrata
• Have a closing device to prevent washout of specimens as sampler is brought to the surface
Sampling the Subtidal Benthos

• Visual observation is crucial
• Observations and sampling can be done by submersibles, manned and unmanned
Alvin from WHOI
The Ventana, MBARI
Johnson Sea-Link, Harbor Branch Inst., Florida
The Shelf-Deep Sea Gradient

• Supply of nutrient-rich particulates to deep sea is low:
  Distance from shore
  Depth and time of travel of material from surface to bottom (decomposition)
  Low primary production over remote deep sea bottoms
Input of Organic Matter

- Input of organic matter from water column declines with depth and distance from shore: continental shelf sediment organic matter = 2-5%, open ocean sediment organic matter = 0.5 - 1.5%, open ocean abyssal bottoms beneath gyre centers < 0.25%
Microbial Activity on Seabed

• Sinking of the Alvin and lunch.
• Mechanism - not so clear; high pressure effect on decomposition (depth over 1000m) or perhaps low rates of microbial activity in deep sea
Microbial Activity on Seabed

- Deep-sea bottom oxygen consumption 100-fold less than at shelf depths
- Bacterial substrates such as agar labeled with radioactive carbon are taken up by bacteria at a rate of 2% of uptake rate on shelf bottoms
- Animal activity is more complex; deep-sea benthic biomass is very low, some benthic fishes are poor in muscle mass, others are efficient predators and attack bait presented experimentally in bait buckets; also some special environments with high nutrients (more later)
Deep-Sea Bacteria

• Known to be barophilic (Yayanos 1986 Proc. Nat. Acad. Sci.)

• Have reduced respiration rates and reduced conversions of substrates in heterotrophy (Schwarz and Colwell 1975 Applied Microbiology)

• Genetically different from shallow water strains
IS THE DEEP SEA IN SLOMO?
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Yes, but there are islands of high-speed!
Hot Vents - Deep Sea Trophic Islands

- Hot Vents - sites usually on oceanic ridges where hot water emerges from vents, associated with volcanic activity
- **Sulfide** emerges from vents, which supports large numbers of sulfide-oxidizing bacteria, which in turn support large scale animal community; most animals live in cooler water just adjacent to hot vent source
- Sulfide bacteria can be free living or symbionts within vent organisms
Galatheid crabs around vent
Smoky plume from vent
Sulfide bacteria coming from vent
Hot Vents - Deep Sea Trophic Islands

- Hot Vents - Animals near hot vents are uncharacteristically large and fast growing for deep sea
- Bivalves, also members of tube-worm group Vestimentifera, have symbiotic sulfide bacteria, which are used as a food source
• Vestimentifera - closely related to phylum Pogonophora, both have no gut

• Has red plume, which takes up water and sulfide, and trophosome, which contains symbiotic bacteria

• Symbiotic bacteria take up sulfide, derive energy

• Worms get nutrients from bacteria

Vestimentifera tube worms at a hot vent
Population of hot-vent bivalve *Calyptogena magnifica*, which has sulfide bacteria in gills
Yeti Crab, *Kiwa hirsuta*, squat lobster
- galatheid crab
Cold Seeps - Other Deep Sea Trophic Islands

• Deep sea escarpments (e.g., Gulf of Mexico) may be sites for leaking of high concentrations of hydrocarbons or sulfides

• These sites also have sulfide-based trophic system with other bivalve and vestimentiferan species that depend upon sulfur bacterial symbionts
Deep-Water Coral Mounds

- Coral mounds are found in depths of > 1000m
- Coral mounds are associated with bottoms often with glacial rock deposits, upon which mounds form
- Mounds are dominated by calcareous corals but coral whips and sea fans also common, along with hundreds of invertebrate species or more
- Mounds also attract fish and are in danger from deep-sea trawlers
Deep-water coral *Lophelia pertusa* with squat lobster and sea urchin.
Whale carcass falls --> Islands

1. Mobile scavenger stage
2. Enrichment opportunist stage - polychaetes, gastropods
3. Sulfophilic-chemoautotrophic stage - mussels, Osedax
   (see Rouse et al. 2004 Science 305:668-671)

Osedax frankpressi Dwarf males

Experimental whale carcass - C. Smith
Deep-Sea Biodiversity Changes

• Problem with sampling, great depths make it difficult to recover benthic samples
• Sanders and Hessler established transect from Gay Head (Martha’s Vineyard, an island, near Cape Cod) to Bermuda
• Used bottom sampler with closing device
• Population density was very low, BUT...
• Muddy sea floor biodiversity was very high, in contrast to previous idea of low species numbers
• Concluded that deep sea is very diverse
Deep-Sea Biodiversity Changes

- Problem with sampling:
  
  Correction for sample size - Rarefaction

  Data usually reported as estimated specied number for sample size of 50 animals
Deep-sea Biodiversity Changes

• Results: Number of species in deep sea soft bottoms increases to maximum at 1500 - 2000 m depth, then increases with increasing depth to 4000m on abyssal bottoms

• In abyssal bottoms, carnivorous animals are conspicuously less frequent (low population sizes of potential prey species)
Deep-Sea Biodiversity Changes

- **Gastropoda**
  - Expected number of species vs. depth
  - Maximum diversity at around 2000 m

- **Polychaeta**
  - Similar pattern to Gastropoda
  - Maximum diversity at around 2000 m

- **Protobranch bivalves**
  - Maximum diversity at around 2000 m

- **Invertebrate megafauna**
  - Maximum diversity at around 2000 m

- **Fish megafauna**
  - Maximum diversity at around 2000 m

- **Cumacea**
  - Maximum diversity at around 2000 m
Deep-Sea Biodiversity Changes. Why?

- Environmental stability hypothesis -
- Population size effect - explains decline in abyss - carnivores? Does *not* explain lower diversity on continental shelf
- Possible greater age of the deep sea, species accumulate over longer time
- Particle size diversity greater at depths of ca. 1500m
Environmental Stability in the Deep Sea

Shelf waters more physically constant than deep waters

Seasonal variation in bottom-water temperature at different depths
Diversity Gradients

• Latitudinal Diversity Gradient - one of the most pervasive gradients. Number of species increases towards the equator
• Gradient tends to apply to many taxonomic levels (species, genus, etc.)
FIG. 17.8 The relationship of bivalve mollusk taxon diversity and latitude. Points are average number of species, genera, and taxonomic families. (After Stehli et al., 1967, courtesy of the Geological Society of America.)
Other Diversity Differences

• **Between-ocean differences.** Pacific biodiversity appears to be greater than Atlantic, although the specifics are complex.

• **Within-ocean differences.** From a central high of biodiversity in the SW Pacific, diversity declines with increasing latitude and less so with increasing longitude, away from the center.

• **Inshore-estuarine habitats** tend to be lower in diversity than open marine habitats.

• **Deep-sea diversity increases,** relative to comparable shelf habitats, then decreases to abyssal depths.
Explanations of Diversity Differences

- **Short-term ecological interactions** - presence of predators might enhance coexistence of more competing species, competitor might drive inferior species to a local extinction

- **Longer term mechanisms** - must involve speciation and extinction
Explanations of Diversity Differences

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• Short-term ecological interactions - presence of predators might enhance coexistence of more competing species, competitor might drive inferior species to a local extinction

• Greater speciation rate - might explain higher diversity in tropics; Center of Origin Theory argues that tropics are source of most new species; some of which may migrate to higher latitudes

• Lower extinction rate in high diversity areas - might also explain major diversity gradients

• Area - greater area might result in origin of more species, but also lower extinction rate of species living over greater geographic ranges (having higher population sizes)
Explanations of Diversity Differences

- **Habitat stability** - A stable habitat may reduce the rate of extinction, because species could persist at smaller population sizes.

- **Sea-level fluctuations** - Sea level fluctuations, such as during the Pleistocene, might have created barriers during low stands of sea level, leading to isolation and speciation. This mechanism has been suggested as increasing the number of species in the SW Pacific in coral reef areas.
Value of Biodiversity

• Complementarity – more species results in more exploitation of difference resources, more productivity, provision of more interactions with other species

• Redundancy – drive one species to extinction and another with similar ecology can take its place
The End