13 Benthic Life Habits

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

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• Last extra credit opportunity
• Friday April 23, 730 PM, Carl Safina, Marine Conservationist, “In the Same Net: Ocean Life, Ethics and the Human Spirit”, Wang Center Auditorium
Important benthic lifestyles

- Benthos
- Epibenthic
- Burrowers
- Borers
- Infaunal, Semi-infaunal
- Benthic swimmers
- Interstitial
Benthos - size classification

- Macrobenthos - shortest dimension > 0.5 mm
- 0.1 mm < Meiobenthos < 0.5 mm, greater
- Microbenthos < 0.1 mm
Feeding Classification

- Suspension feeders
- Deposit feeders
- Herbivores (macroalgae or microalgae)
- Carnivores
- Scavengers
Life in Mud and Sand

Mechanical measures of sediment grain size

**Particle size** - measure of current strength
Median, silt-clay percent (<62µm)

**Sorting** - variation of current strength, poor versus well sorted sediment
Life in Mud and Sand

Particle size - measures

**Median grain diameter** - measured usually by sieving and weighing size fractions

**Silt-clay fraction** - % of weight of sediment

$< 62 \mu m$
Sedimentary Structures

Can result from physical processes:
Ripple marks on an intertidal sand flat
Sedimentary structures

Can result from biogenic processes
Burrowing in sediment

- Burrowers use hydromechanical and mechanical digging mechanisms to move through the sediment.
- Watery sediments with high silt clay content have thixotropy - but burrowing also propagates cracks in muddy sediments with lower water content - particles coated with organic polymers stick together\(^1\).

Burrowing in sediment

- **Hydromechanical burrowing** - combines muscle contraction working against rigid, fluid filled chamber (skeleton)
- Form **penetration anchor** first to allow further extension of body into sediment
- Form **terminal anchor** to allow pulling of rest of body into the sediment
Burrowing in sediment - bivalve foot

PA = penetration anchor
TA = terminal anchor

Hydromechanical burrowing
Lugworm, *Arenicola marina*

- Longitudinal muscle contracting
- Circular muscle contracting
- Terminal anchor
- Eversion of pharynx
- Penetration anchor
Arenicola marina x section
Burrowing in sediment

Inarticulate brachiopod

Mechanical displacement
burrowing
Burrowing in sediment

Biogenic structures - burrowing and processing of sediment affects sedimentary structures

1. Burrowing in mud increases water content of sediment
2. Increases grain size (pellets)
3. Alters vertical and 3-D mechanical, chemical structure
Annelid ingests small particles at depth and deposits them on surface
Interstitial animals

• Live in the pore waters of sediment, usually sand grains
• Belong to many taxonomic groups
• All share elongate, wormlike form, in order to move through tight spaces
Interstitial animals 2

Harpacticoid copepod

Hydroid

Polychaete

Gastrotrich

Opisthobranch gastropod
Soft-sediment microzone

Burrowed, pelletized layer

Water content vs. depth graph
Soft-Sediment Microzone

- Strong vertical chemical gradients
- Gradients strongly affected by biological activity
Soft-Sediment Microzone

Sediment surface

O₂

mg/l

Light brown oxidized layer

Gray layer

RPD

H₂S

Reduced black layer

mg/l
Soft-Sediment Microzone

Aerobic bacteria (use oxygen to break down organic substrates)

Fermenting bacteria (break down organic cpds. --> alcohols, fatty acids)

Sulfate reducing bacteria (reduce SO\textsubscript{4} to H\textsubscript{2}S)

Methanogenic bacteria (break down organic cpds. --> methane)
Benthic Feeding Types
Deposit Feeders

• Feed upon sediment, within the sediment or at sediment surface

• **Head-down deposit feeders** feed within the sediment at depth, usually on fine particles, defecate at surface

• **Surface browsers** often feed on surface microorganisms such as diatoms
Deposit Feeders

- Surface tentacle feeding polychaete
- Tentacle feeding bivalve
- Surface siphonate feeding bivalve
- Deep feeding polychaete
- Surface feeding amphipod
- Deep feeding polychaete
Surface trace of burrow of the Lugworm, *Arenicola marina* (Anglesey, North Wales)
Arenicola marina burrow cross section
What is available?

Particulate organic matter: different
Ages and quality: phytoplankton sedimenting from water column (phytodetritus); old particles that are less digestible (oak leaves, marsh grass particles)

Microbial organisms: different digestibilities: bacteria, microalgae (different digestibility)
Deposit feeders 3

- **Microbial stripping hypothesis**: deposit feeders are most efficient at digesting and assimilating benthic microbes (diatoms, bacteria)

- **BUT**, In some sediments non-living organic matter is abundant, so even a low assimilation efficiency returns some nutrition for deposit feeders; microbes much less abundant
Deposit feeders

• At some times of years, fresh phytoplankton sinks and is added to the bottom: another source of non-living food for deposit feeders

• Detritus from seaweeds is probably more digestible than detritus from seagrasses and marsh grasses, which have much relatively indigestible cellulose
Deposit feeders

- Deposit feeders feed on sedimentary grains, microbial organisms living on particulate organic particles

- **Feeding activity accelerates microbial attack** - grazing stimulates microbial metabolism, results in tearing apart of organic particles

- Some deposit feeder guts - **surfactant activity** - emulsify particles

- Deposit feeders - **Optimal gut passage time**
Deposit feeders

Transport to surface of deep sediment

Microbial consumption

POM deposition
Free-burrowing bivalve

Sediment stirring

Metal, sulfur, dissolved organic carbon exchange

Stimulation of microbial growth
Tube

Metal, sulfur, dissolved organic carbon exchange

Ingestion of sediment

Egestion
Deposit Feeders - Main Points

- Ingest sediment including nonliving particulate organic matter (POM) and microbes.
- Microbes digested more efficiently than POM, but bacteria not abundant enough to support most macrobenthic deposit feeders.
- Some deposit feeders have surfactant digestive activity - loosen POM from sediment particles.
- POM often dominates total organic matter, so poor digestion can still bring a reward.
- Surface-feeders (better food) vs. deep head-down feeders (more refractory food).
- Spring deposition of POM from water column can bring a nutritious source of food in a pulse.
- Some environments (mangroves) have a continuous and nutritious source of organic matter.
Suspension Feeders

- Feed on small particles, low Reynolds number within a chamber (e.g. bivalves), higher Re outside
- Passive versus active suspension feeders
Suspension Feeders

Encounters of particles with fibers

- Sieving
- Direct interception
- Inertial impaction
- Motile particle deposition
- Gravitational deposition

= fiber
Suspension Feeders

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Suspension Feeders

Bivalve, x-section        Polychaete *Serpula*        Barnacle

Active suspension feeders
Active suspension feeders - issues

- Concentration of particles - saturation and even clogging
- Selection of high-quality particles
- Current velocity and ability to create current, and keep siphon erect
Acorn barnacle cirri - active suspension feeding
Mussel *Mytilus edulis*
Oyster gill lamella
Oyster, *Crassostrea virginica*
Measuring Selectivity

**Flow Cytometer:** Chlorophyll, Phycoerythrin, Particle Size, Index of refraction
Flow Cytometry Particle Discrimination
Bivalves are particle selective (on gills in case of oyster *Crassostrea gigas*)

Suspension Feeders

Sea squirt *Styela montereyensis*
Passive suspension feeding mechanism, combined with active ciliary pump
Suspension feeding of a basking shark

*Cetorhinus maximus*

6-8 m long (12 m)

Suspension feeding of a basking shark
Passive suspension feeders - issues

Orientation in current

Current velocity - pressure drag

Particle concentration - saturation of feeding structure (e.g., polyp processing)
Recap - Deposit Feeders and Suspension Feeders

- **Deposit Feeders** - process particles on bottom
- **Particles** range from inorganic (e.g., sand grains) to organic
- Organic range from indigestible (cellulose) to very digestible (living digestible bacteria, microalgae)
- Quantity important (e.g., bacteria not sufficient as food for most larger deposit feeders)
- Selectivity important, digestive strategies important (type of digestion, throughput), **recycling** of microalgae and **external supply** of particles important (e.g., deposition after spring phytoplankton bloom to bottom, deposition of seaweed detritus)
Recap continued

- **Suspension feeders** - gather particles either passively (protrude structure into current) or actively (suck water into siphon)
- Suspension feeders have access to different particle qualities - clay, non-living organic matter, microalgae of varying quality (some poisonous some indigestible)
- Gathering of particles important, but selectivity also important
- Digestive strategies and throughput also important issues
- Flow very important - causes change in form
Carnivores

- oystercatcher
- Bivalve *Cuspidaria*
- Polychaete *Glycera*
- Gastropod *Nucella*
- Crab *Callinectes sapidus*
Carnivore issues

- Low population size, movement to patches of prey
- Capture of prey
- Physiological limitations (depth of swimming, sensory biology, intertidal zone)
- Feeding, while avoiding predation by other species
Fish Feeding

• Three mechanisms in water column: biting, suction and ram feeding

• Many fish chew prey by means of teeth; some have specialized crushing teeth (puffer fish, some sculpins)

• Some species suspension feed, trap zooplankton, phytoplankton, or particulate organic matter on gill rakers
*Conus*, over 500 spp. Mainly in coral reefs

Poison: cysteine-rich peptides - attack ion channels
C. geographus  C. striatus
C. striatus  
C. geographus
Gene Family A

- Gene Duplication
- Amino Acid Sequence Evolution

Gene Family B

- Gene Duplication
- Amino Acid Sequence Evolution

Ancestral Gene

Gene Duplication

Time
**Herbivores**

- Polychaete *Nereis vexillosa*
- Chiton
- Parrot fish
- Urchins

**Radula**
areas of dotted lines indicate the main muscles that support the pharyngeal jaws

teeth; these may be formed for grasping, tearing, grinding, or combing, depending on prey type

premaxilla

outer teeth

lower pharyngeal jaw

lower jaw

pharyngeal jaw

eye socket

neurocranium
Herbivore issues

- Ability to mechanically attack plants
- Chemical defense of plants
- Feeding, while avoiding predation by other species
Cellulose feeder

Bivalve *Teredo*

Greatly elongated mantle

Obtains nitrogen with symbiotic nitrogen fixing bacteria

Impacts of chronic overfishing are evident in population depletions worldwide, yet indirect ecosystem effects induced by predator removal from oceanic food webs remain unpredictable. As abundances of all 11 great sharks that consume other elasmobranchs (rays, skates, and small sharks) fell over the past 35 years, 12 of 14 of these prey species increased in coastal northwest Atlantic ecosystems. Effects of this community restructuring have cascaded downward from the cownose ray, whose enhanced predation on its bay scallop prey was sufficient to terminate a century-long scallop fishery. Analogous top-down effects may be a predictable consequence of eliminating entire functional groups of predators.
The End