

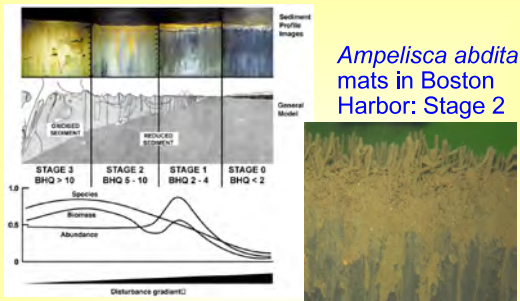
<div data-bbox="319 226 747 306" data-label="Section-Header"> <h2>Feeding guilds <end> & Bioturbation</h2> </div> <div data-bbox="354 323 654 354" data-label="Text"> <p>Class 4: September 11, 2008</p> </div> <div data-bbox="654 514 771 541" data-label="Text"> <p>EEOS630</p> </div>	<div data-bbox="816 134 1271 207" data-label="Section-Header"> <h3>Slide 1 Feeding guilds <end> & Bioturbation</h3> </div> <div data-bbox="816 294 940 327" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="404 693 609 728" data-label="Section-Header"> <h2>Old business</h2> </div> <div data-bbox="233 753 654 926" data-label="List-Group"> <ul style="list-style-type: none"> • WIMBA Session, Tonight, Thursday 9-9:45 pm <ul style="list-style-type: none"> ▸ You'll need earphones/microphone • Topics from last class <ul style="list-style-type: none"> ▸ Guts as chemical reactors <ul style="list-style-type: none"> ▪ See Penry & Jumars papers and text on feeding guild chapter. ▪ Http://www.jstor.org/pss/53655 ▪ All Jumars papers are on his Maine website, check out google scholar </div> <div data-bbox="258 928 631 1062" data-label="Image"> <p>FIG. 1. Deep-sea deposit-feeding strategies suggested by environmental and feeding constraints.</p> <p>By P. A. JUMARS¹, L. M. MAYER², J. W. DEMING², J. A. BAROIS², AND R. A. WHITNEY¹</p> <p>¹School of Oceanography, University of Washington, Seattle, Washington 98195, U.S.A. ²Oceanography Program, Box C, Darling Center, University of Maine, Walpole, Maine 04572, U.S.A.</p> </div> <div data-bbox="654 1039 771 1066" data-label="Text"> <p>EEOS630</p> </div>	<div data-bbox="816 659 1115 695" data-label="Section-Header"> <h3>Slide 2 Old business</h3> </div> <div data-bbox="816 781 940 816" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="388 1180 625 1218" data-label="Section-Header"> <h2>Class schedule</h2> </div> <div data-bbox="233 1255 660 1554" data-label="List-Group"> <ul style="list-style-type: none"> • For Class 5, Tuesday 9/16/08 <ul style="list-style-type: none"> ▸ Chapter 3 Microphytobenthic Production & Carbon Limitation ▸ Microphytobenthos. Read ▸ Chapter 3. Microphytobenthos ▸ Gould, D. G. and E. D. Gallagher. 1990. Field measurement of specific growth rate, biomass and primary production of benthic diatoms of Savin Hill Cove, Boston. Limnol. Oceanogr. 35: 1757-1770. • For Class 6, Thus 9/18/08. Chapter 4 on Benthic Population Processes and Gallagher et al. 1990 </div> <div data-bbox="654 1526 771 1554" data-label="Text"> <p>EEOS630</p> </div>	<div data-bbox="816 1148 1141 1182" data-label="Section-Header"> <h3>Slide 3 Class schedule</h3> </div> <div data-bbox="816 1268 940 1304" data-label="Text"> <p>NOTES:</p> </div>

<div data-bbox="240 163 760 205" data-label="Section-Header"> <h3>Suspension feeders</h3> </div> <div data-bbox="276 216 751 262" data-label="Text"> <p>Feed with tentacles, mucous bags, crustaceans with maxillae</p> </div> <div data-bbox="227 262 633 541" data-label="Image"> <p>The diagram shows four different feeding structures labeled with abbreviations: FDT (Feather duster tentacles), FDI-P (Feather duster with pharyngeal teeth), F-SST-P (Feather duster with specialized tentacles and pharyngeal teeth), and FSP (Feather duster with specialized pharyngeal teeth). Below the diagram, text identifies 'Sabellid, "Feather duster"' and 'Chaetopterus, Suspens on, mucous bag'.</p> </div>	<div data-bbox="824 132 1201 174" data-label="Section-Header"> <h3>Slide 4 Suspension feeders</h3> </div> <div data-bbox="824 315 938 352" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="305 653 722 722" data-label="Section-Header"> <h3>Suspension feeding serpulid polychaetes</h3> </div> <div data-bbox="332 724 686 751" data-label="Text"> <p>Christmas tree worms, <i>Spirobranchius</i></p> </div> <div data-bbox="235 751 706 1024" data-label="Image"> <p>Two photographs are shown. The left one shows a red and white Christmas tree worm (Serpulid polychaete) with its feathery tentacles extended. The right one shows a blue Christmas tree worm (Serpulid polychaete) with its feathery tentacles extended.</p> </div>	<div data-bbox="824 621 1323 699" data-label="Section-Header"> <h3>Slide 5 Suspension feeding serpulid polychaetes</h3> </div> <div data-bbox="824 779 938 816" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="300 1178 730 1220" data-label="Section-Header"> <h3>Suspension feeding sabellids</h3> </div> <div data-bbox="402 1228 605 1255" data-label="Text"> <p>Feather duster worms</p> </div> <div data-bbox="235 1255 738 1554" data-label="Image"> <p>Three photographs and one diagram are shown. The left photograph shows a purple and white feather duster worm. The middle photograph shows a white feather duster worm. The right photograph shows a red and white feather duster worm. The diagram in the center shows a cross-section of a sabellid worm with its pharynx and tentacles.</p> </div>	<div data-bbox="824 1146 1328 1188" data-label="Section-Header"> <h3>Slide 6 Suspension feeding sabellids</h3> </div> <div data-bbox="824 1268 938 1306" data-label="Text"> <p>NOTES:</p> </div>

<p>Sabellaria reefs</p> <p><i>Sabellaria alveolata</i> studied by D. P. Wilson</p>  <p>EEOS630</p>	<p>Slide 7 Sabellaria reefs</p> <p>NOTES:</p>
<p>Bivalve suspension feeders</p> <p>From Light's manual, Stanley studied functional morphology</p> 	<p>Slide 8 Bivalve suspension feeders</p> <p>NOTES:</p>
<p>Rhoads, Pearson-Rosenberg Succession among functional groups</p> <p>One functional group modifies the environment and is replaced by another</p>  <p>From Rhoads et al. 1978</p> <p>EEOS630</p>	<p>Slide 9 Rhoads, Pearson-Rosenberg Succession among functional groups</p> <p>NOTES:</p>

Pearson & Rosenberg model

And Rhoads et al. (1978)



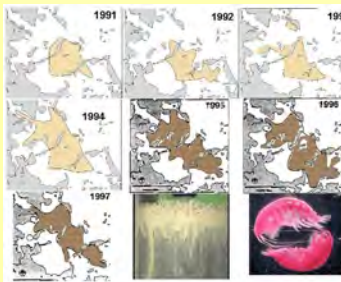
Ampelisca abdita
mats in Boston
Harbor: Stage 2

Slide 10 Pearson & Rosenberg model

NOTES:

Ampelisca mats 1991-1997

Oligochaete-spionid-*Capitella* → *Ampelisca*-*Polydora* →
Corophiids & other amphipods



Ampelisca are
'structure makers'
in Goodall's
terminology. The
control local
microclimate.

Data from
MWRA & ENSR
(Bob Diaz)

EEOS630

Slide 11 Ampelisca mats 1991-1997

NOTES:

Conveyor-belt feeders

Coined by Rhoads (1974). Some malpadianids & *Molpadia*
are the classic conveyor-belt feeders.

Don Rhoads' (1974) descriptive phrase for
a subsurface deposit feeder that feeds at
depth and defecates at the sediment
surface.

The less common **reverse conveyor-belt
feeders** feed at the surface and defecate
at depth. Both feeding modes are called
non-local mixing because the movement of
particles doesn't fit the commonly used
diffusion analogy

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Slide 12 Conveyor-belt feeders

NOTES:

Non-local mixing

Boudreau (1986b)

"Infaunal macroorganisms are capable of exchanging sedimentary material over distances equal to or greater than the scale over which the concentration of tracer changes substantially. This type of non-diffusive bioturbation is called **nonlocal mixing**."



Funnel feeders

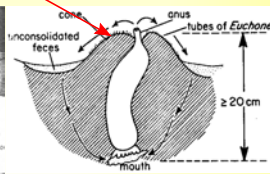
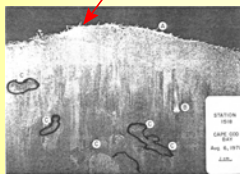
Slide 13 Non-local mixing

NOTES:

Conveyor-belt feeding echinoderm

Molpadia, sea cucumber, an echinoderm;
Cape Cod Bay through the Gulf of Maine, Rhoads & Young (1971)

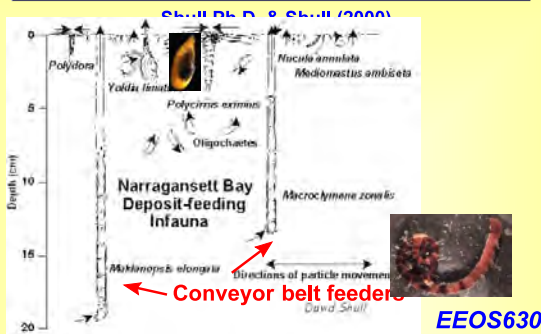
Euchone incolor, a feather-duster polychaete worm



Slide 14 Conveyor-belt feeding echinoderm

NOTES:

Narragansett Bay benthos

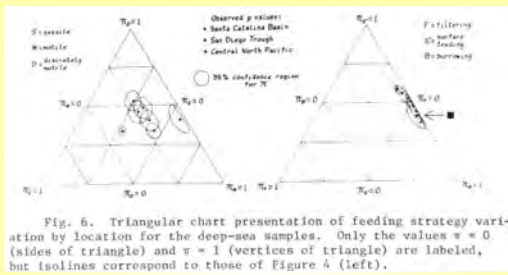


Slide 15 Narragansett Bay benthos

NOTES:

Jumars & Fauchald strategies

50:50 surface and subsurface feeders in deep sea



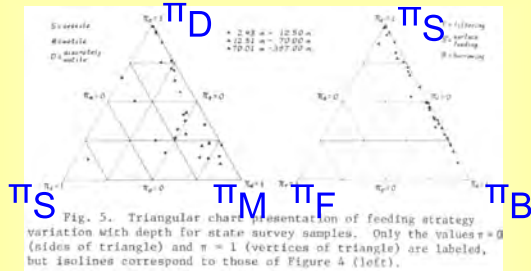
EEOS630

Slide 16 Jumars & Fauchald strategies

NOTES:

Jumars & Fauchald strategies

Filter feeders relatively rare on shelf



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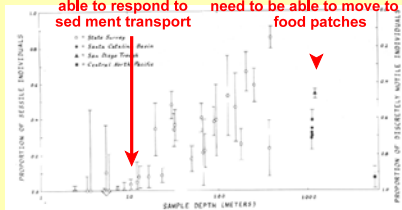
Slide 17 Jumars & Fauchald strategies

NOTES:

Jumars & Fauchald Motility

% Sessile species shows an intermediate peak

Shallow: High energy need to be able to respond to sediment transport
Deep: High energy need to be able to move to find food patches



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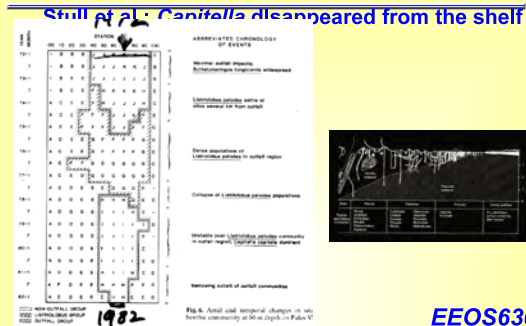
Slide 18 Jumars & Fauchald Motility

NOTES:

<div data-bbox="393 273 623 310" data-label="Section-Header"> <h2>Bioturbation</h2> </div> <div data-bbox="654 514 771 541" data-label="Text"> <p>EEOS630</p> </div>	<div data-bbox="816 134 1135 170" data-label="Section-Header"> <h3>Slide 19 Bioturbation</h3> </div> <div data-bbox="816 258 940 291" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="341 655 677 690" data-label="Section-Header"> <h2>Darwin & bioturbation</h2> </div> <div data-bbox="362 701 654 728" data-label="Section-Header"> <h3>The first model of bioturbation</h3> </div> <div data-bbox="233 732 660 980" data-label="Text"> <p><i>"A quantity of broken chalk was spread, on December 20, 1842, over a part of a field near my house, which had existed as pasture certainly for 30, probably for twice or thrice as many years. The chalk was laid on the land for the sake of observing at some future period to what depth it would become buried. At the end of November 1871, that is after an interval of 29 years, a trench was dug across this part of the field; and a line of white nodules could be traced on both sides of the trench, at a depth of 7 inches from the surface. The mould, therefore, (excluding the turf) had here been thrown up at an average rate of .22 inches per year."</i></p> </div> <div data-bbox="654 1001 771 1029" data-label="Text"> <p>EEOS630</p> </div>	<div data-bbox="816 623 1278 657" data-label="Section-Header"> <h3>Slide 20 Darwin & bioturbation</h3> </div> <div data-bbox="816 743 940 777" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="271 1144 753 1186" data-label="Section-Header"> <h2>Darwin's (1882) worm book</h2> </div> <div data-bbox="310 1190 711 1220" data-label="Section-Header"> <h3>Describes the production of a lag layer</h3> </div> <div data-bbox="243 1220 440 1444" data-label="Image"> </div> <div data-bbox="233 1446 461 1507" data-label="Caption"> <p>Fig. A. Section, reduced to half the natural scale, of the vegetable mould in a field, drained and reclaimed fifteen years previously; A, turf; B, vegetable mould without any stones; C, mould with fragments of burnt marl, sand-silica and quartz pebbles; D, subsoil of black, peaty mud with quartz pebbles.</p> </div> <div data-bbox="440 1220 771 1491" data-label="Text"> <p>"A piece of waste, swampy land was enclosed, drained, ploughed, harrowed and thickly ocered in the year 1822 with burnt marl and cinders ...Holes were dug in this field in 1837, or 15 years after its reclamation, and we see in the accompanying diagram ...the fragments of burnt marl and cinders had been covered ... by a layer of fine vegetable mould"</p> </div> <div data-bbox="654 1488 771 1516" data-label="Text"> <p>EEOS630</p> </div>	<div data-bbox="816 1110 1344 1146" data-label="Section-Header"> <h3>Slide 21 Darwin's (1882) worm book</h3> </div> <div data-bbox="816 1232 940 1266" data-label="Text"> <p>NOTES:</p> </div>

<div data-bbox="357 168 654 210" data-label="Section-Header"> <h2>Peddocks Island</h2> </div> <div data-bbox="248 243 769 554" data-label="Image"> <p>The slide features a map of Peddocks Island on the left. To the right are two photographs: the top one shows a dark, silty sediment surface from a boat, and the bottom one is a close-up of a hand holding a sample of dark, granular sediment.</p> </div>	<div data-bbox="815 132 1183 170" data-label="Section-Header"> <h3>Slide 22 Peddocks Island</h3> </div> <div data-bbox="815 256 941 294" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="303 655 711 699" data-label="Section-Header"> <h2>Peddock's Island, 1989</h2> </div> <div data-bbox="235 701 769 1029" data-label="Figure"> <p><i>Capitella</i> prior to 1989; After 1989: No <i>Capitella</i> Fecal pellets (% Dry Weight)</p> <p>The figure includes a line graph with 'Depth (cm)' on the y-axis (0 to 30) and 'Fecal pellets (% Dry Weight)' on the x-axis (0 to 40). Two data series are plotted: 'Peddocks Box Core 1' (dashed line) and 'Peddocks Box Core 2' (solid line). Both show peaks between 5 and 15 cm depth. Annotations include 'Inner Harbor' with an arrow pointing to the 0-5 cm range and 'EEOS630' at the bottom right. To the right of the graph are two photographs of yellowish, segmented <i>Capitella</i> worms.</p> </div>	<div data-bbox="815 621 1274 659" data-label="Section-Header"> <h3>Slide 23 Peddock's Island, 1989</h3> </div> <div data-bbox="815 804 941 840" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="339 1144 675 1186" data-label="Section-Header"> <h2>Fort Point Channel</h2> </div> <div data-bbox="261 1188 750 1522" data-label="Image"> <p>The slide contains a map of the Fort Point Channel area on the left. To the right is an aerial photograph of the channel. Below the map and aerial photo are two photographs of sediment: one in a metal tray showing a light-colored, silty surface, and another showing a similar sediment sample in a different container.</p> </div>	<div data-bbox="815 1110 1226 1148" data-label="Section-Header"> <h3>Slide 24 Fort Point Channel</h3> </div> <div data-bbox="815 1232 941 1268" data-label="Text"> <p>NOTES:</p> </div>

Palos Verdes shelf



Slide 25 Palos Verdes shelf

NOTES:

Bioturbation & bioirrigation

Boudreau, 1997, p. 41

"...**bioturbation** comprises all kinds of displacements within unconsolidated sediment and soils produced by the activity of organisms (paraphrased from Richter, 1952). These activities include burrow and tube excavation, and their ultimate collapse and infilling, ingestion and excretion of sediment, plowing through the surface sediment, and building of mounds and digging of craters. During these activities, both solids and pore fluids are moved."

Solids

Bioirrigation is the movement of porewater and porewater constituents by animal activities

Fluids & molecules

Slide 26 Bioturbation & bioirrigation

NOTES:

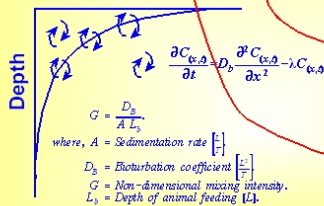
Traditional Biodiffusion Model

A modification of the advection-diffusion equation

Goldberg-Koide Equation:

$$\frac{\partial A}{\partial t} = \frac{\partial}{\partial z} \left[D_b \frac{\partial A}{\partial z} \right] - \omega \frac{\partial A}{\partial z} - \lambda A$$

Tracer Concentration



Radioactive decay
 $\lambda = \ln(2)/\text{half-life}$

Sedimentation
[L/Time]

Bioturbation
[L²/time]

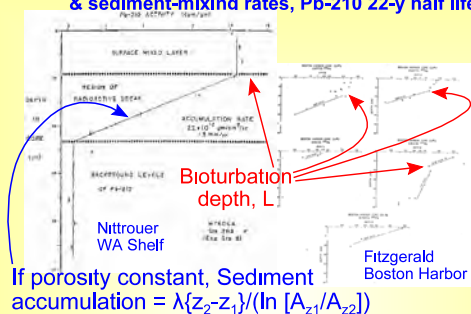
Shull graphic

Slide 27 Traditional Biodiffusion Model

NOTES:

Estimating sedimentation rates

& sediment-mixing rates, Pb-210 22-y half life

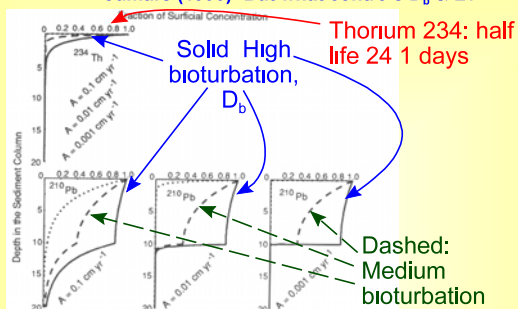


Slide 28 Estimating sedimentation rates

NOTES:

Typical bioturbation profiles

Jumars (1993): But what controls D_b & L ?



Slide 29 Typical bioturbation profiles

NOTES:

What are typical values for D_b ?

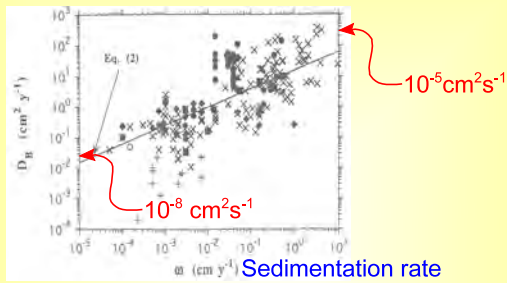
Goldberg-Koide Equation:

$$\frac{\partial A}{\partial t} = \frac{\partial}{\partial z} \left[D_b \frac{\partial A}{\partial z} \right] - \omega \frac{\partial A}{\partial z} - \lambda A$$

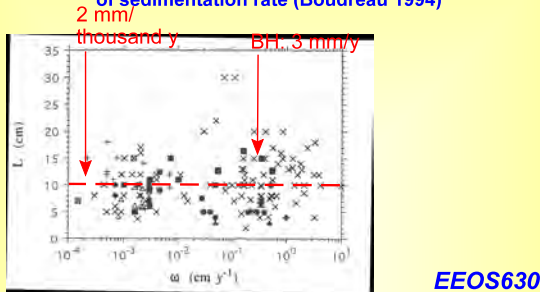
- Deep-sea and nearly azoic polluted sediments: $10^{-8} \text{ cm}^2 \text{ s}^{-1}$
- Exceptionally high rates of bioturbation in coastal zones with conveyor-belt feeders: $2 \times 10^{-5} \text{ cm}^2 \text{ s}^{-1}$
- By comparison
 - Horizontal eddy diffusion $K_x > 10^6 \text{ cm}^2 \text{ s}^{-1}$
 - Vertical eddy diffusion, K_z : $0.05 - 4 \text{ cm}^2 \text{ s}^{-1}$
 - Molecular diffusion coefficients for O_2 & CO_2 $\approx 2 \times 10^{-5} \text{ cm}^2 \text{ s}^{-1}$

Slide 30 What are typical values for D_b ?

NOTES:

Bioturbation = f(Sedimentation)Boudreau (1994): Bioturbation (D_b) & sedimentation (ω)**Slide 31 Bioturbation = f(Sedimentation)**

NOTES:

Mixed Layer vs. SedimentationBioturbation depth (L), 10-cm average, is **not** a function of sedimentation rate (Boudreau 1994)**Slide 32 Mixed Layer vs. Sedimentation**

NOTES:

 D_b increases with sedimentation, but so too does the rate at which organic matter degradesBoudreau (1994): the relationship between bioturbation rate, D_b , and sedimentation rate, w :

$$D_b = 15.7 w^{0.6}$$

Tromp et al. (1994): the relationship between the rate of degradation of organic matter with reaction rate k and sedimentation rate, w :

$$T_0 = 30 w^{0.6}$$

The 0.6 exponents cancel out when inserted in a model to predict mixed layer depth (Boudreau 1998, equations (5) & (6)). So, at shallower depths there is more organic matter input, but this higher organic matter input is associated with higher degradation and bioturbation rates producing similar mixed layer depths

Slide 33 D_b increases with sedimentation, but so too does the rate at which organic matter degrades

NOTES:

<div data-bbox="302 168 714 207" data-label="Section-Header"> <h3>Global 10-cm depth average</h3> </div> <div data-bbox="248 216 769 541" data-label="Figure"> <p>Roudeanu (1998) note high variance</p> </div>	<div data-bbox="816 134 1346 174" data-label="Section-Header"> <h3>Slide 34 Global 10-cm depth average</h3> </div> <div data-bbox="816 258 940 294" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="363 655 656 695" data-label="Section-Header"> <h3>Other explanations</h3> </div> <div data-bbox="238 730 656 1012" data-label="List-Group"> <ul style="list-style-type: none"> • Predation: depth of fish feeding <ul style="list-style-type: none"> ▸ How deep can a flounder bite? ▸ How deep can a crab dig? • Compaction of mud • Relationship to microphytobenthic & phytodetrital food caching? <ul style="list-style-type: none"> ▸ Food caching (see Gallagher & Keay 1998) ▸ Storing food from the surface in subsurface burrows for later ingestion </div> <div data-bbox="656 1001 769 1029" data-label="Text"> <p>EOS630</p> </div>	<div data-bbox="816 623 1222 661" data-label="Section-Header"> <h3>Slide 35 Other explanations</h3> </div> <div data-bbox="816 743 940 779" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="280 1138 747 1190" data-label="Section-Header"> <h3>Tracking a pulse of glass microtektites (glass spheres); G a dimensionless number</h3> </div> <div data-bbox="280 1190 737 1239" data-label="Text"> <p>Guinasso & Schink (1975): Major implications for pollution, e.g., New Bedford PCBs or LA's DDT</p> </div> <div data-bbox="230 1239 747 1518" data-label="Figure"> <p>G=0.03</p> <p>Increasing Time</p> <p>G=3</p> <p>Bioturbation depth</p> <p>$G = D_b / (L * \omega)$</p> <p>Modal mixing depth of tracer deepens with D_b</p> </div>	<div data-bbox="816 1110 1299 1222" data-label="Section-Header"> <h3>Slide 36 Tracking a pulse of glass microtektites (glass spheres); G a dimensionless number</h3> </div> <div data-bbox="816 1306 940 1341" data-label="Text"> <p>NOTES:</p> </div>

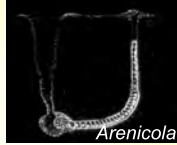
Modeling non-local mixing

Boudreau (1986b)

"Infaunal macroorganisms are capable of exchanging sedimentary material over distances equal to or greater than the scale over which the concentration of tracer changes substantially. This type of non-diffusive bioturbation is called **nonlocal mixing**."



Pectinaria



Arenicola

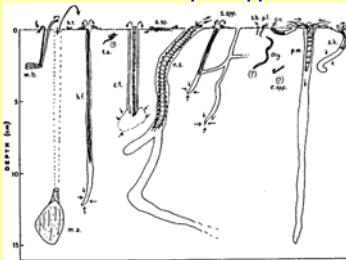
Funnel
feeders

Slide 37 Modeling non-local mixing

NOTES:

Lowes Cove Maine mudflat

Leitoscoloplos, a conveyor belt feeder, called *Scoloplos* spp. in Rice (1986)



Rice (1986)
JMR
Modelled
bioturbation as
if only 1
species,
Leitoscoloplos
was
responsible

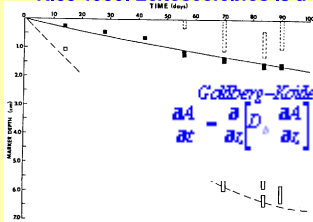
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Slide 38 Lowes Cove Maine mudflat

NOTES:

Subduction of a chalk layer

Rice 1986: *Leitoscoloplos* is a conveyor-belt feeder



$$\frac{a_1}{a_2} = \frac{a}{a_2} \left[\frac{a_1}{a_2} \right] - \frac{a_1}{a_2} - 1$$

Rice (1986) modeled
bioturbation with an advection
term, bioadvection, not D_b
bio diffusion

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Slide 39 Subduction of a chalk layer

NOTES:

Rice's (1986) bioturbation model

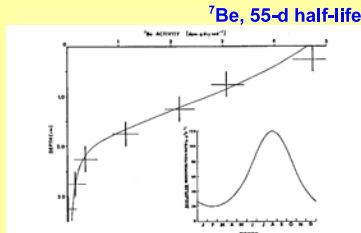


Figure 9. Be-7 depth profile at station B4-6 and theoretical transient-state profile generated by assuming a constant surface concentration (4.62 dpm · g⁻¹) and time-varying biodeposition rate by Scoloplos (inset illustration).

Rice's ⁷Be profile could not be modeled adequately using the Goldberg Koide equation

$$\frac{\partial A}{\partial t} = \frac{\partial}{\partial z} \left[D \frac{\partial A}{\partial z} \right] - \omega \frac{\partial A}{\partial z} - \lambda A$$

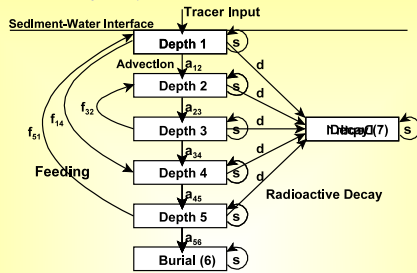
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Slide 40 Rice's (1986) bioturbation model

NOTES:

Shull's Bioturbation Model

Shull (2001): Realistic bioturbation modeling



Slide 41 Shull's Bioturbation Model

NOTES:

Bioturbation Transition Matrix

Shull's finite Markov chain, a single matrix

State at time t	State at time t + 1 To						
From	1	2	3	4	5	Burial	Decay
1	s	a ₁₂ (1-d)	0	f ₁₄ (1-d)	0	0	d
2	0	s	a ₂₃ (1-d)	0	0	0	d
3	0	f ₃₂ (1-d)	s	a ₃₄ (1-d)	0	0	d
4	0	0	0	s	a ₄₅ (1-d)	0	d
5	f ₅₁ (1-d)	0	0	0	s	a ₅₆ (1-d)	d
Burial	0	0	0	0	0	1	0
Decay	0	0	0	0	0	0	1

Shull graphic

Slide 42 Bioturbation Transition Matrix

NOTES:

Model Equations and Solutions

Solutions from Kemeny & Snell's (1976) Finite Markov chains, can be solved with a very short Matlab program (a potential Project for this class)

Solutions

$$N_i = N_0 P^i$$

$$N_{steady-state} = f(I - Q)^{-1}$$

f = tracer flux, Q = depth submatrix

Tracer Application

Nonreactive Tracers

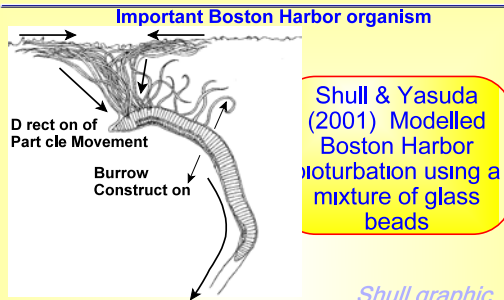
Radionuclide Tracers

Shull graphic

Slide 43 Model Equations and Solutions

NOTES:

Cirratulid feeding: Non-local mixing



Slide 44 Cirratulid feeding: Non-local mixing

NOTES:

Size-selective bioturbation

Shull & Yasuda Figure 11

Preferred particle sizes (16-32 μm) rapidly subducted to 15 cm depth

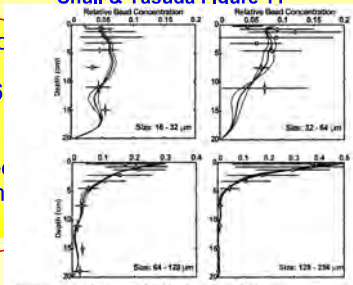
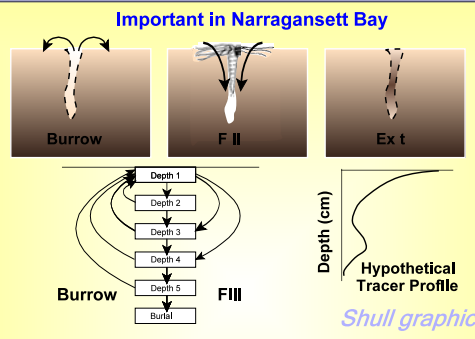
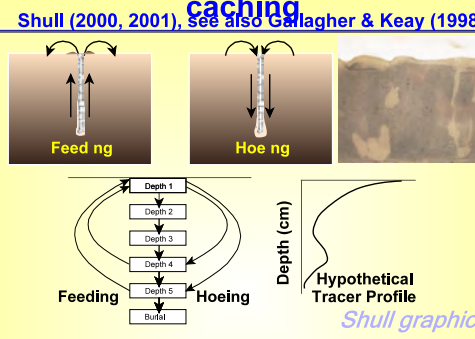
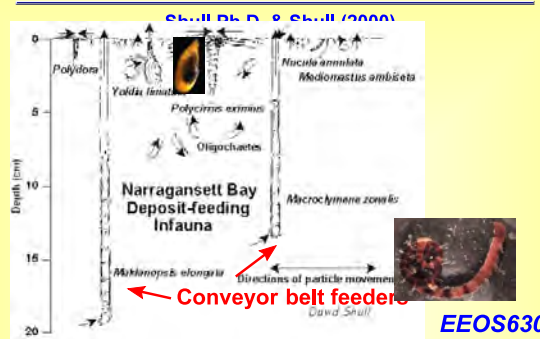


Figure 11. Preferred and rejected particle sizes of caprellid amphipods.

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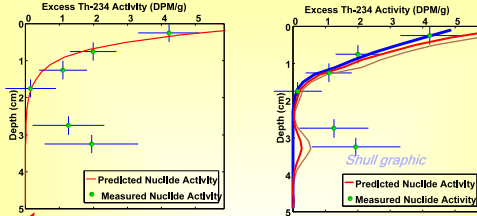
Slide 45 Size-selective bioturbation

NOTES:

<p>Polycirrus eximius: relict burrows</p> <p>Important in Narragansett Bay</p>  <p>Shull graphic</p>	<p>Slide 46 Polycirrus eximius: relict burrows</p> <p>NOTES:</p>
<p>Non-local feeding, hoeing & food caching</p> <p>Shull (2000, 2001), see also Gallagher & Keay (1998)</p>  <p>Shull graphic</p>	<p>Slide 47 Non-local feeding, hoeing & food caching</p> <p>NOTES:</p>
<p>Narragansett Bay benthos</p>  <p>EEOS630</p>	<p>Slide 48 Narragansett Bay benthos</p> <p>NOTES:</p>

Traditional models vs. Non-local

Shull (2000, 2001)



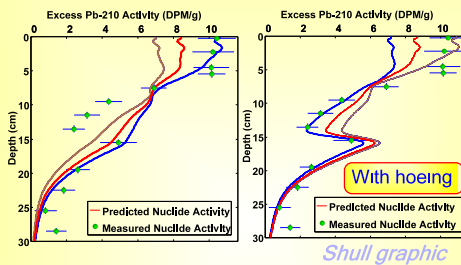
Goldberg Koide model is a poor fit to the data and would tremendously overestimate the amount of sediment moved

Slide 49 Traditional models vs. Non-local

NOTES:

To hoe or not to hoe

Better fit if 40% of particles ingested by maldanid polychaetes (bamboo worms) was collected at the sediment-water interface

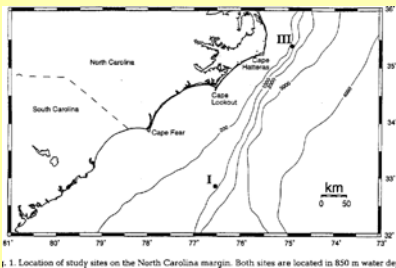


Slide 50 To hoe or not to hoe

NOTES:

¹³C diatom fluff experiment

Blair et al. (1996), Levin et al. (1997), Levin et al. (1999)



Within 3 days, diatoms mixed to 10 cm depth at 850 m depth

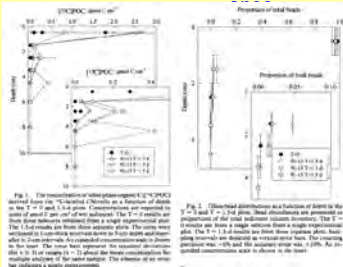
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Slide 51 ¹³C diatom fluff experiment

NOTES:

Blair et al. C-13 fluff experiment

Note C-13 is a stable isotope, measured with Mass



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Slide 52 Blair et al. C-13 fluff experiment

NOTES:

Non-local transport modes for fresh organic matter

From Blair et al. (1996), Levin et al. 1997 & 1999

- Smith *et al.* 1986-1987 invoked subsurface defecation to explain naturally occurring 239-240-Pu profiles in NW Atlantic sediments
- Graf (1989) explained subsurface Chl *a* peaks in the deep sea
- Wheatcroft (1992) Santa Catalina basin beads
 - Possibly sediment-tagged Nobel metals in MA Bay
- "Alternatively, subsurface defecation may be a means of caching material for later use (Jumars *et al.* 1990, Smith 1994)"
- Scraping or hoeing surficial material into burrows, as has been observed in shallow water (Dobbs and Whittlatch 1992) may be another means of rapid transport

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Slide 53 Non-local transport modes for fresh organic matter

NOTES:

Benthic ecology & capping




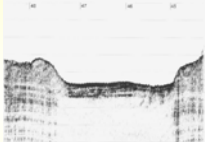

Gallagher & Shull MIT capping workshop

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Slide 54 Benthic ecology & capping

NOTES:

<div data-bbox="235 163 771 214" data-label="Section-Header"> <h3>Benthic ecological issues</h3> </div> <div data-bbox="235 241 771 493" data-label="List-Group"> <ul style="list-style-type: none"> • What currency should be used? • Where should the CAD cells be placed? • Impacts during CAD creation • Whether to cap • How thick to cap • How to monitor </div> <div data-bbox="654 514 771 541" data-label="Text"> <p>EEOS630</p> </div>	<div data-bbox="816 132 1412 174" data-label="Section-Header"> <h3>Slide 55 Benthic ecological issues</h3> </div> <div data-bbox="816 258 1412 300" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="235 657 771 707" data-label="Section-Header"> <h3>What currency should be used?</h3> </div> <div data-bbox="235 720 771 1014" data-label="List-Group"> <ul style="list-style-type: none"> • Cost increases with <ul style="list-style-type: none"> ▫ Thickness of cap ▫ Transport distance • Acute pollutant concentration in surface sediments <ul style="list-style-type: none"> ▫ Minimizing vertical and lateral trophic transfer ▫ Bioconcentration & bioaccumulation ▫ Minimizing human health risk • Changes in biodiversity • Odds of meeting regulatory requirements </div> <div data-bbox="654 1003 771 1031" data-label="Text"> <p>EEOS630</p> </div>	<div data-bbox="816 625 1412 667" data-label="Section-Header"> <h3>Slide 56 What currency should be used?</h3> </div> <div data-bbox="816 741 1412 783" data-label="Text"> <p>NOTES:</p> </div>
<div data-bbox="235 1140 771 1190" data-label="Section-Header"> <h3>Where to put CAD cells</h3> </div> <div data-bbox="235 1190 771 1518" data-label="List-Group"> <p>Cost, ecological and human impact in conflict</p> <ul style="list-style-type: none"> • Cost • Sediment transport & prop-wash • Estuaries have low biodiversity, but <ul style="list-style-type: none"> ▫ High human population density ▫ Higher probability of human impacts, e.g., bottom-feeding fish • Offshore sites <ul style="list-style-type: none"> ▫ Higher species richness, more endemism (perhaps) </div> <div data-bbox="654 1491 771 1518" data-label="Text"> <p>EEOS630</p> </div>	<div data-bbox="816 1113 1412 1155" data-label="Section-Header"> <h3>Slide 57 Where to put CAD cells</h3> </div> <div data-bbox="816 1228 1412 1270" data-label="Text"> <p>NOTES:</p> </div>

<div data-bbox="207 132 782 569"> <h2>Impacts during CAD creation</h2> <p>Navigation and Environment Project</p>     <p>ENSR</p> <p>OS630</p> </div>	<div data-bbox="824 132 1401 170"> <h3>Slide 58 Impacts during CAD creation</h3> </div> <div data-bbox="824 258 938 289"> <p>NOTES:</p> </div>
<div data-bbox="207 617 782 1056"> <h2>Impacts during CAD creation</h2> <ul style="list-style-type: none"> Creation of the CAD cells impact benthic communities <ul style="list-style-type: none"> The benthic communities at the site of the CAD cells are eliminated Pollutant transport to water column during deposition of dredged material Sediment transport of contaminated material How long before capping? <ul style="list-style-type: none"> Potential ecological risk  </div>	<div data-bbox="824 617 1401 655"> <h3>Slide 59 Impacts during CAD creation</h3> </div> <div data-bbox="824 743 938 774"> <p>NOTES:</p> </div>
<div data-bbox="207 1102 782 1541"> <h2>Whether to cap cells</h2> <p>Sedimentation rate, toxicity of new material</p> <ul style="list-style-type: none"> Reasons to cap <ul style="list-style-type: none"> Highly toxic material (e.g., dioxin) Low sedimentation rate Vulnerable ecological resources Bet hedging (ecological uncertainty) Deep bioturbation Reasons not to cap <ul style="list-style-type: none"> High natural sedimentation rate Contaminated ambient surrounding sediment Ambient community already heavily degraded Rapid pollutant degradation rate <p>EEOS630</p> </div>	<div data-bbox="824 1102 1401 1140"> <h3>Slide 60 Whether to cap cells</h3> </div> <div data-bbox="824 1228 938 1260"> <p>NOTES:</p> </div>

How thick to cap

Assessing bioturbation & chemical gradients

- Natural sediment transport depth
- Cap thickness depends on chemical properties of pollutant
 - K_{oc}
 - Degradation rate
- Factors controlling bioturbation rate
 - Biogeography
 - Food supply and quality
 - Grain size

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Slide 61 How thick to cap

NOTES:

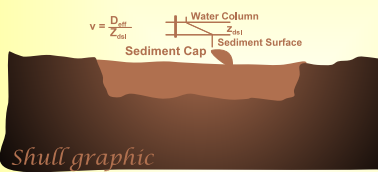
Processes affected by cap thickness

Equations

$$k = f_{oc} K_{oc}$$

$$D_{eff} = \frac{D_{oc}}{1 + \frac{k}{v}}$$

$$v = \frac{D_{eff}}{Z_{sed}}$$



Shull graphic

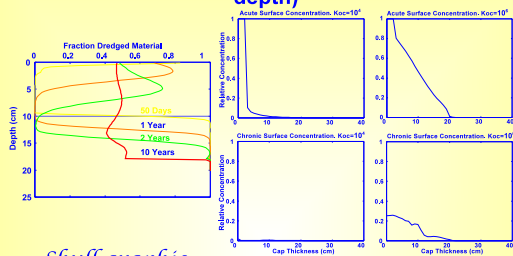
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Slide 62 Processes affected by cap thickness

NOTES:

Effects of bioturbation

Function of (k_{oc} , bioturbation rate, bioturbation depth)

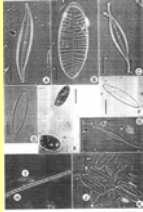
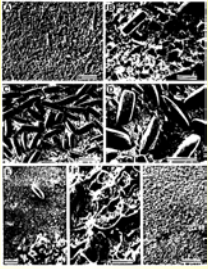
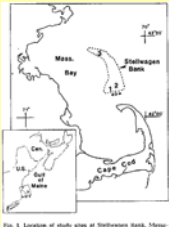
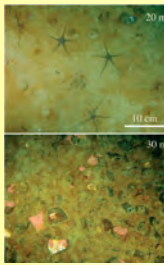
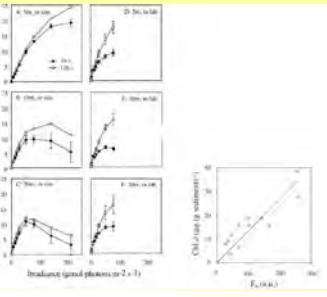


Shull graphic

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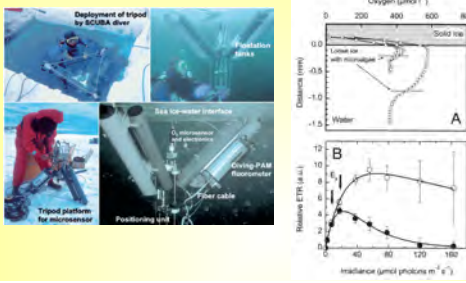
Slide 63 Effects of bioturbation

NOTES:

<p style="text-align: center;">Microphytobenthos</p> <p style="text-align: center;">$20\ \mu\text{m} - 1\ \text{mm}\ \text{length}, 5 \times 10^6\ \text{cells}/\text{cm}^2, .5\text{-}20\ \text{g C m}^{-2}$</p> <div style="display: flex; justify-content: space-around;">   </div> <p>Brotas & Plante-Cuny (1998, MEPS), Scale bars: 20 μm</p> <p>Paterson (1989) EEOS630</p>	<p>Slide 64 Microphytobenthos</p> <p>NOTES:</p>
<p style="text-align: center;">O₂ flux used to measure Stellwagen Bank microphytobenthic production</p> <div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> <p>The importance of benthic microalgal production at Stellwagen Bank derives from the apparent ability of the distinctly benthic microalgal assemblage there to sustain significant production at light levels consistently below 1% surface incident PPFD. If this ability is common, benthic microalgae may be widely distributed in continental shelf habitats. Benthic habitats underlying clearer, less productive water columns than at Stellwagen Bank may support relatively higher benthic microalgal production. Benthic microalgal production may therefore be a significant, if infrequently considered, fraction of total production in continental shelf ecosystems.</p> </div> </div> <p>Caron et al. 1993 Figure 1 & Conclusion EEOS630</p>	<p>Slide 65 O₂ flux used to measure Stellwagen Bank microphytobenthic production</p> <p>NOTES:</p>
<p style="text-align: center;">Measuring Production using fluorescence by SCUBA</p> <p style="text-align: center;">Glud et al. 2002</p> <div style="display: flex;">  <div style="margin-left: 20px;">  </div> </div>	<p>Slide 66 Measuring Production using fluorescence by SCUBA</p> <p>NOTES:</p>

PAM Fluorometer & O₂ microsensor

Kühl et al. 2002 MEPS 223: 1-14



Slide 67 PAM Fluorometer & O₂ microsensor

NOTES: