Feeding guilds <end> & Bioturbation

Class 4: September 11, 2008

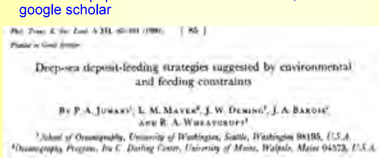
EEOS630

Slide 1 Feeding guilds <end> & Bioturbation

NOTES:

Old business

- WIMBA Session, Tonight, Thursday 9-9:45 pm
  - You'll need earphones/microphone
- Topics from last class
  - Guts as chemical reactors
    - 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


Deep-sea deposit-feeding strategies suggested by environmental and feeding constraints

By P. A. Jumars[1], L. M. Mayer[2], J. W. Deming[1], J. A. Baross[1] and R. A. Wheatcroft[1]

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Slide 2 Old business

NOTES:

Class schedule

- For Class 5, Tuesday 9/16/08
  - 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

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Slide 3 Class schedule

NOTES:

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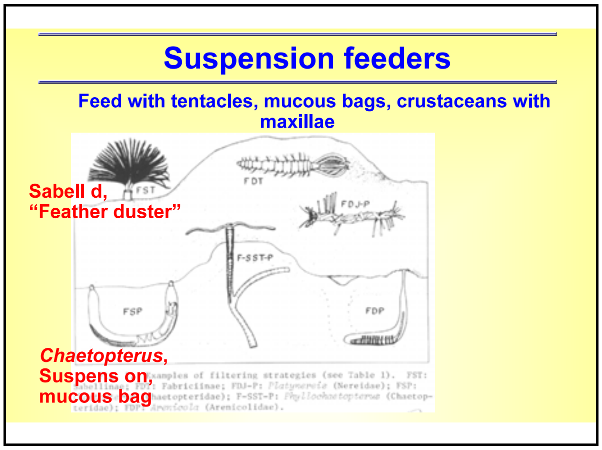

Slide 4 Suspension feeders

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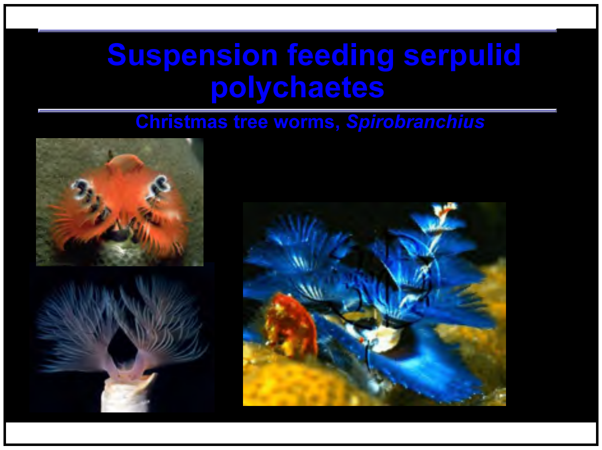

Slide 5 Suspension feeding serpulid polychaetes

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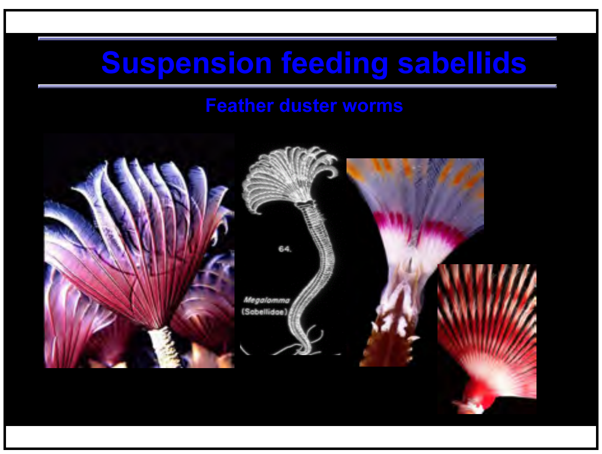

Slide 6 Suspension feeding sabellids

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Slide 7 Sabellaria reefs

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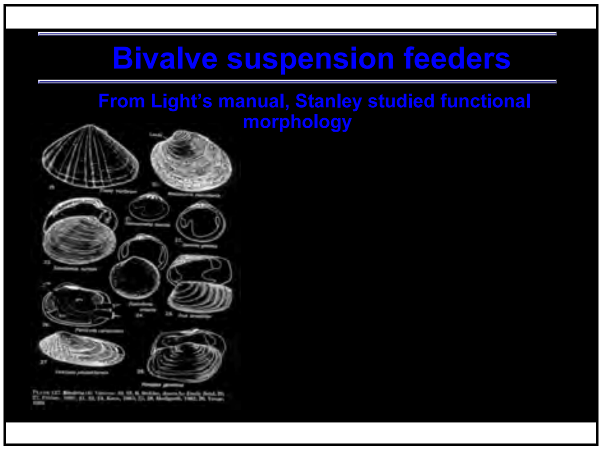

Slide 8 Bivalve suspension feeders

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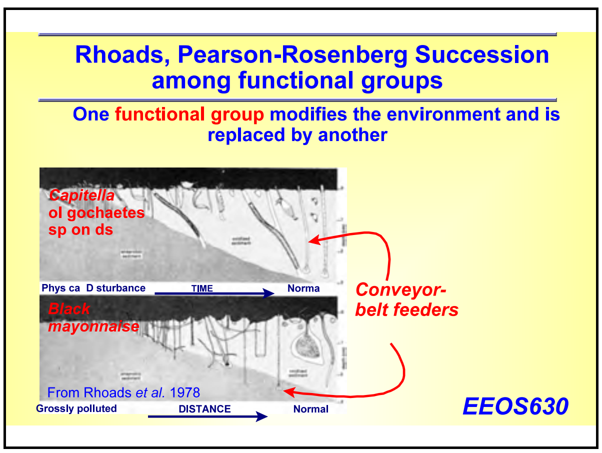

Slide 9 Rhoads, Pearson-Rosenberg Succession among functional groups

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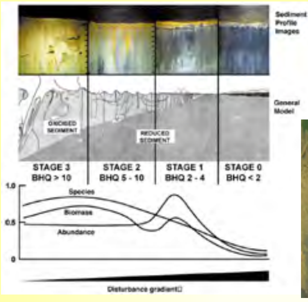
Pearson & Rosenberg model

And Rhoads et al. (1978)



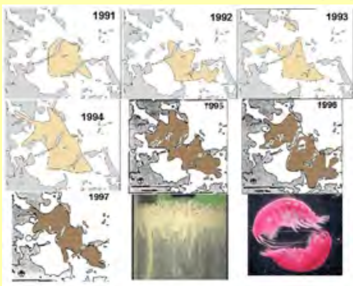
Ampelisca abdita mats in Boston Harbor: Stage 2

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)

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Slide 11 Ampelisca mats 1991-1997

NOTES:

Conveyor-belt feeders

Coined by Rhoads (1974). Some maldanids & *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

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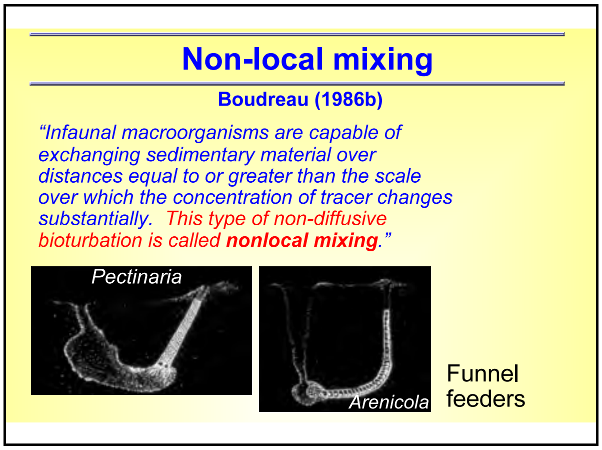
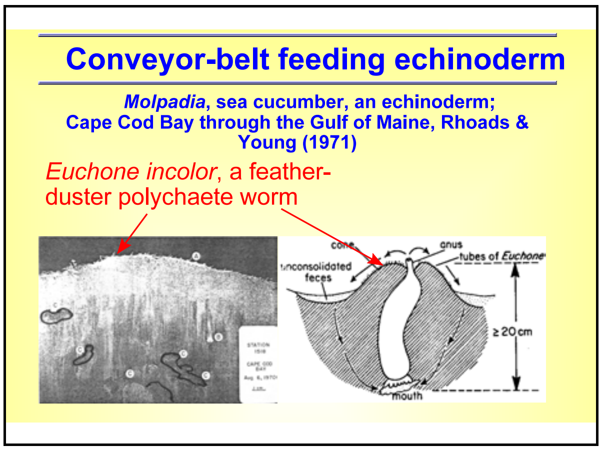


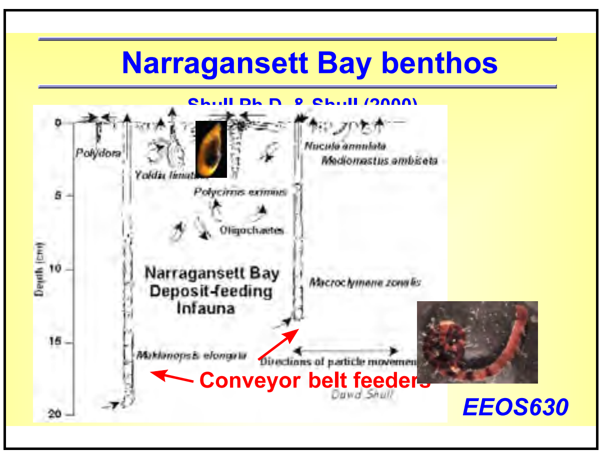
Slide 13 Non-local mixing

NOTES:



Slide 14 Conveyor-belt feeding echinoderm

NOTES:



Slide 15 Narragansett Bay benthos

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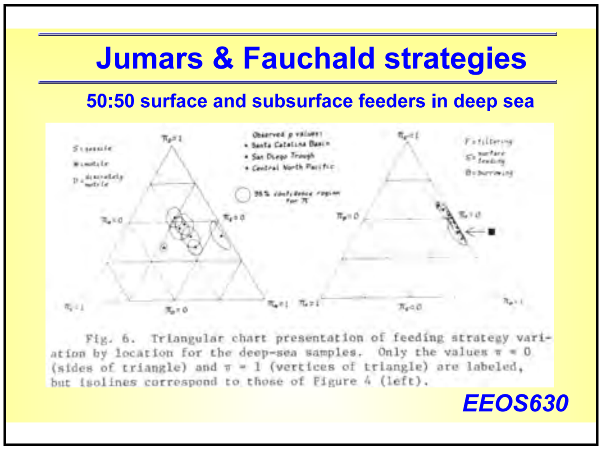
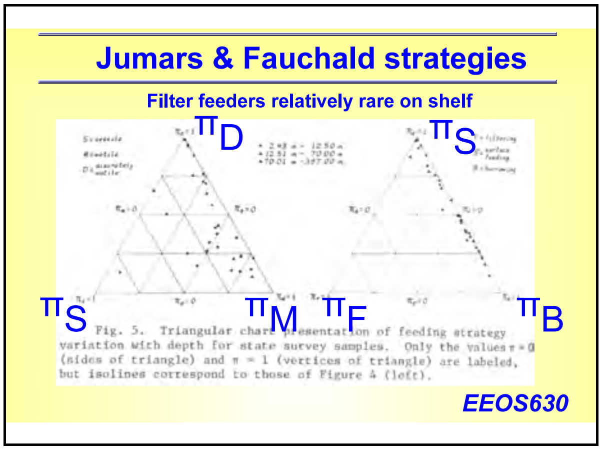


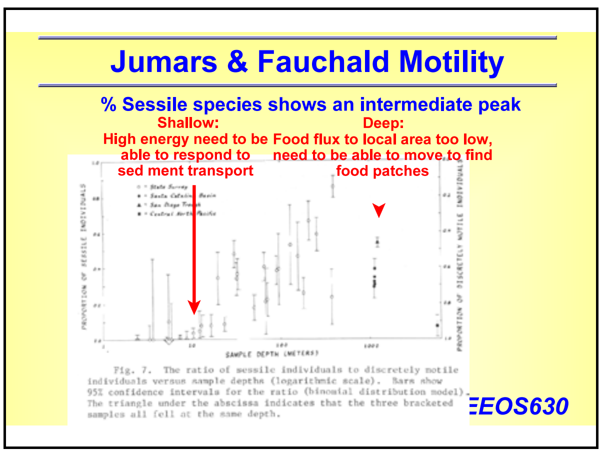
Slide 16 Jumars & Fauchald strategies

NOTES:



Slide 17 Jumars & Fauchald strategies

NOTES:



Slide 18 Jumars & Fauchald Motility

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Bioturbation

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Slide 19 Bioturbation

NOTES:

Darwin & bioturbation

The first model of bioturbation

"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."

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Slide 20 Darwin & bioturbation

NOTES:

Darwin's (1882) worm book

Describes the production of a lag layer

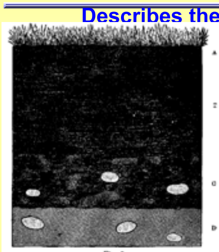

Fig. 5.

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, coal-cinders and quartz pebbles; D, sub-soil of black, peaty sand with quartz pebbles.

"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"

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Slide 21 Darwin's (1882) worm book

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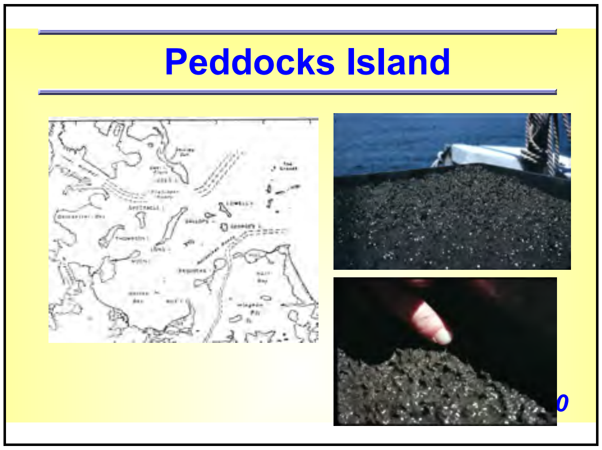
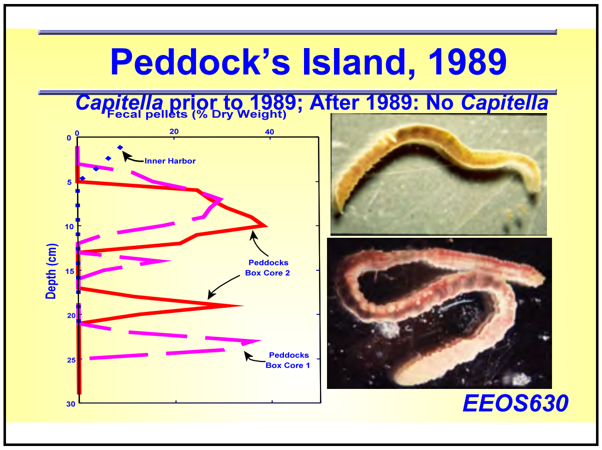


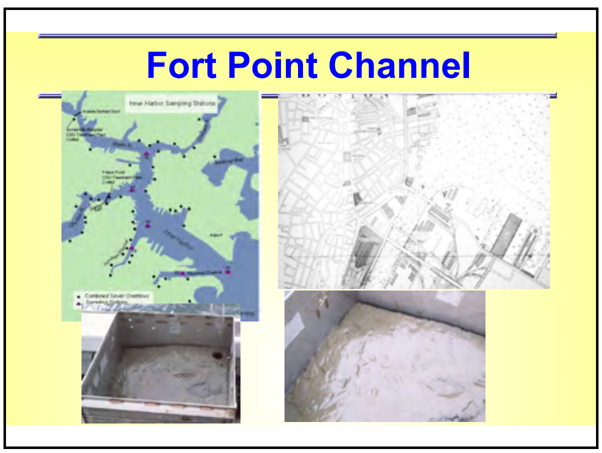
Slide 22 Peddocks Island

NOTES:



Slide 23 Peddock's Island, 1989

NOTES:



Slide 24 Fort Point Channel

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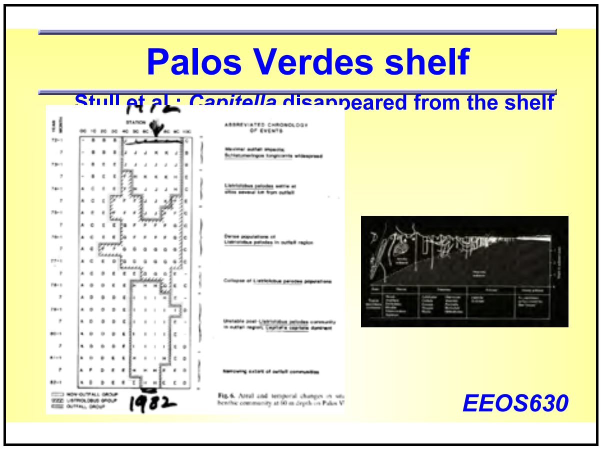
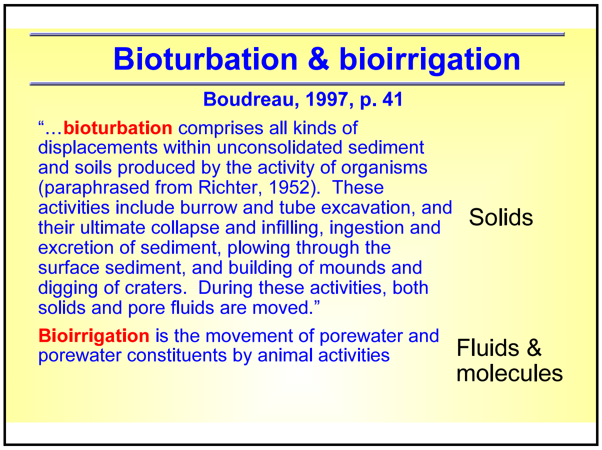


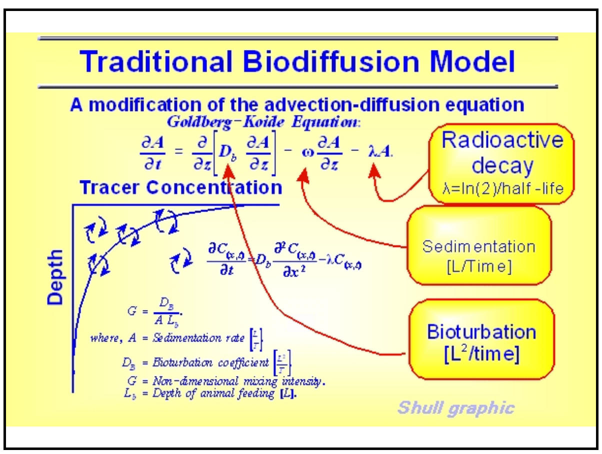
Slide 25 Palos Verdes shelf

NOTES:



Slide 26 Bioturbation & bioirrigation

NOTES:



Slide 27 Traditional Biodiffusion Model

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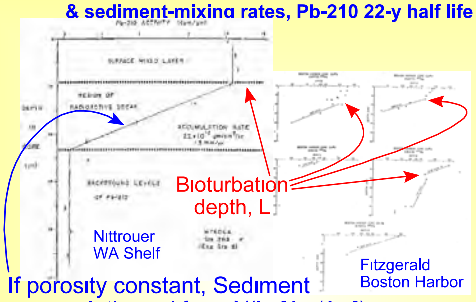
Estimating sedimentation rates

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



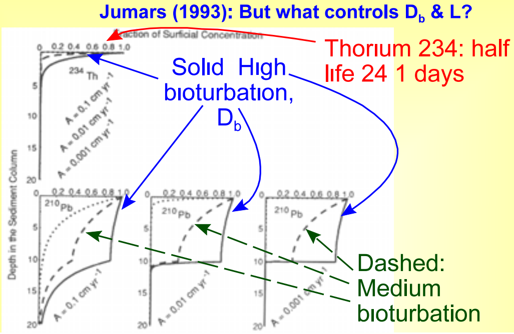
If porosity constant, Sediment accumulation = $\lambda\{z_2-z_1\}/(\ln [A_{z1}/A_{z2}])$

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

Slide 30 What are typical values for Db?

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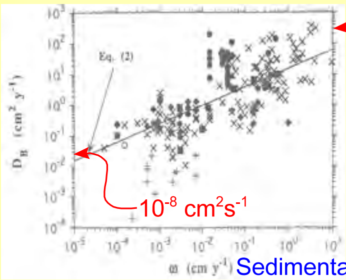
Bioturbation = f(Sedimentation)

Boudreau (1994): Bioturbation (D_b) & sedimentation (ω)

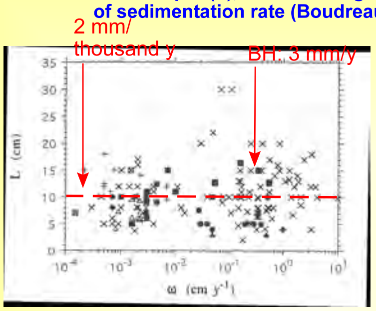


Slide 31 Bioturbation = f(Sedimentation)

NOTES:

Mixed Layer vs. Sedimentation

Bioturbation depth (L), 10-cm average, is not a function of sedimentation rate (Boudreau 1994)



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Slide 32 Mixed Layer vs. Sedimentation

NOTES:

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

Boudreau (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:

$$k = 3.0 w^{0.6}$$

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 Db increases with sedimentation, but so too does the rate at which organic matter degrades

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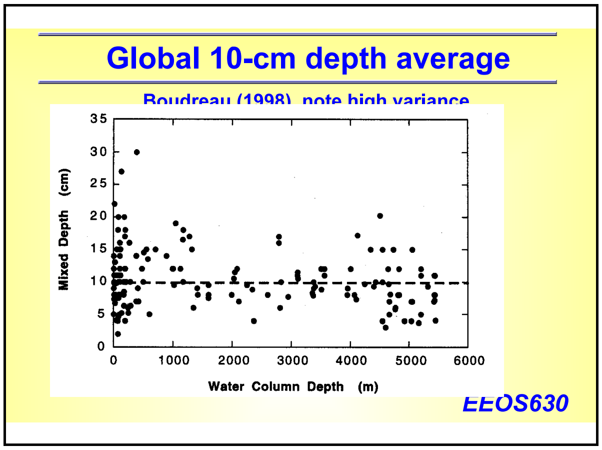
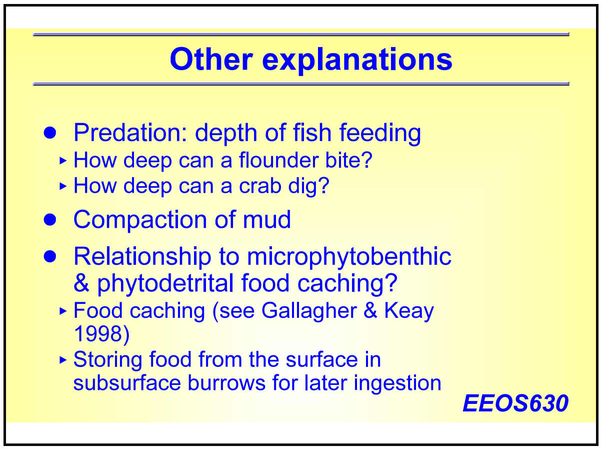


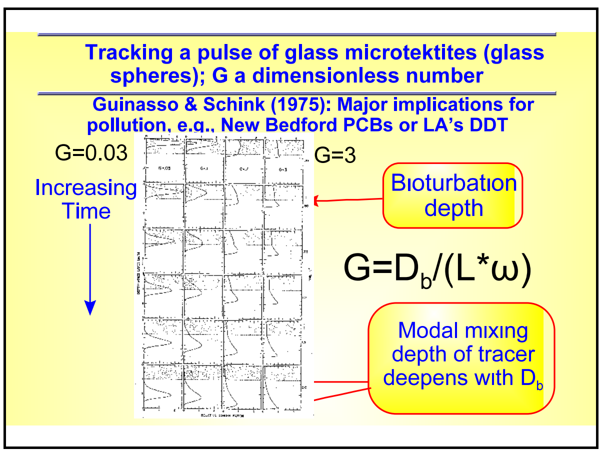
Slide 34 Global 10-cm depth average

NOTES:



Slide 35 Other explanations

NOTES:



Slide 36 Tracking a pulse of glass microtektites (glass spheres); G a dimensionless number

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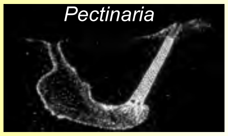
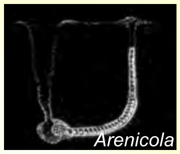
Modeling non-local mixing

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****."*





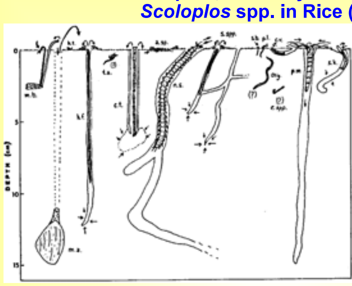
Funnel feeders

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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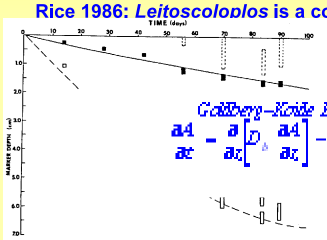
Slide 38 Lowes Cove Maine mudflat

NOTES:

Subduction of a chalk layer

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



Goldberg–Koide Equation:

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

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

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Slide 39 Subduction of a chalk layer

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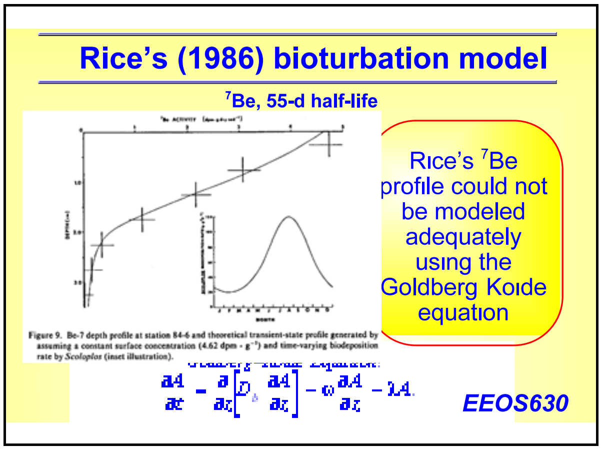
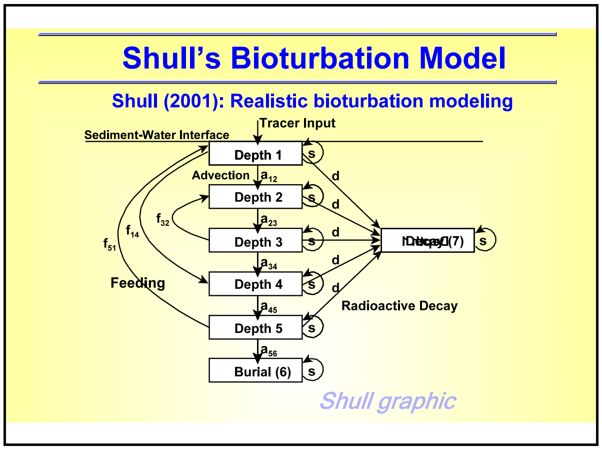


Slide 40 Rice's (1986) bioturbation model

NOTES:



Slide 41 Shull's Bioturbation Model

NOTES:

Bioturbation Transition Matrix

Shull's finite Markov chain, a single matrix

State at time t + 1 — To

State at time t (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

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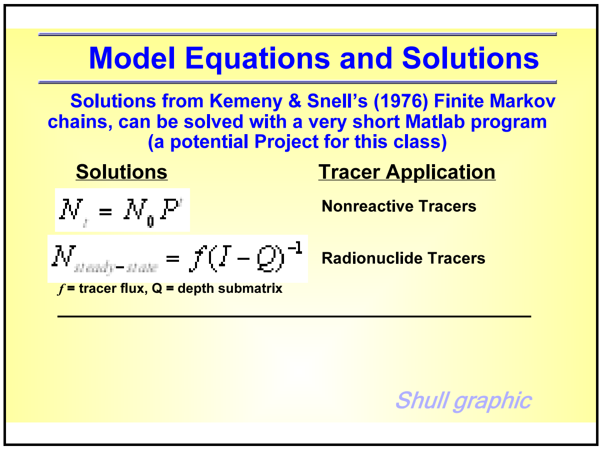
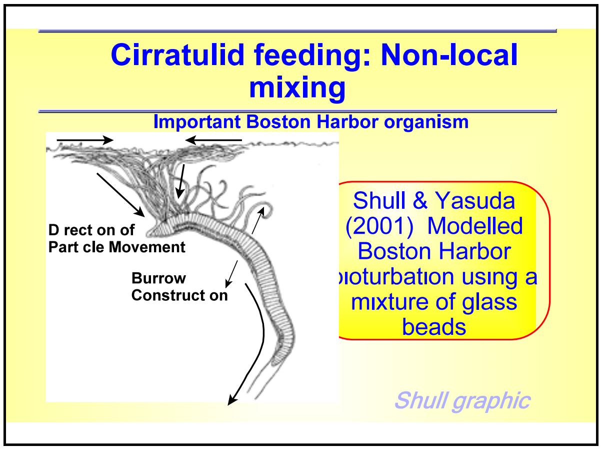


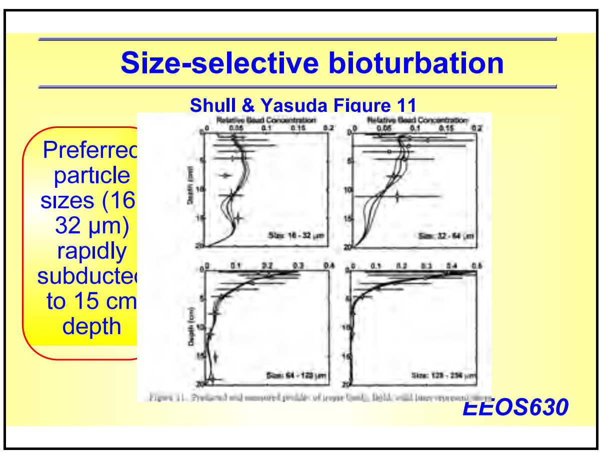
Slide 43 Model Equations and Solutions

NOTES:



Slide 44 Cirratulid feeding: Non-local mixing

NOTES:



Slide 45 Size-selective bioturbation

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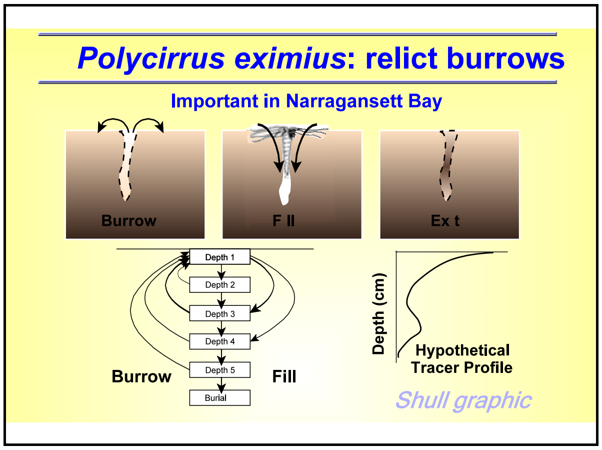
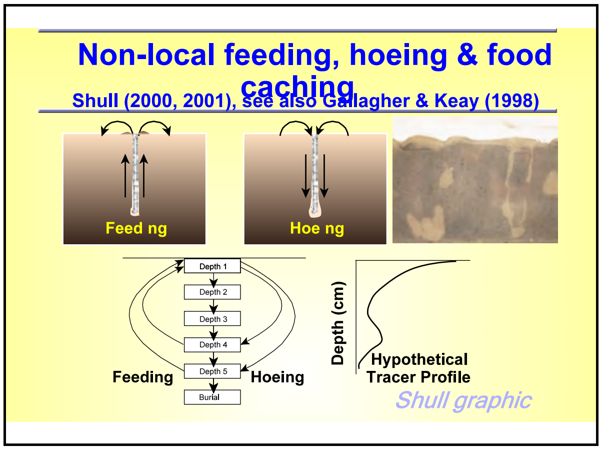


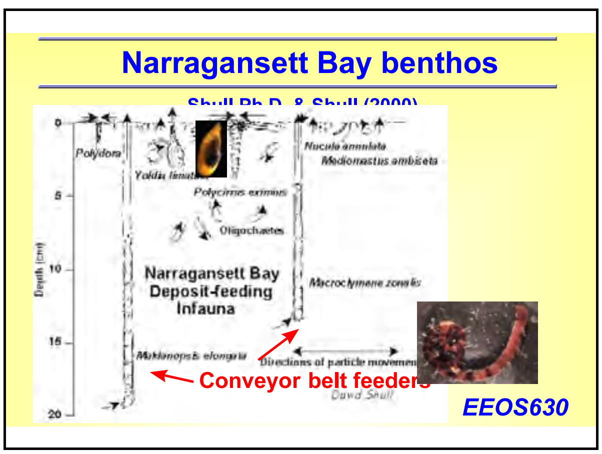
Slide 46 Polycirrus eximius: relict burrows

NOTES:



Slide 47 Non-local feeding, hoeing & food caching

NOTES:



Slide 48 Narragansett Bay benthos

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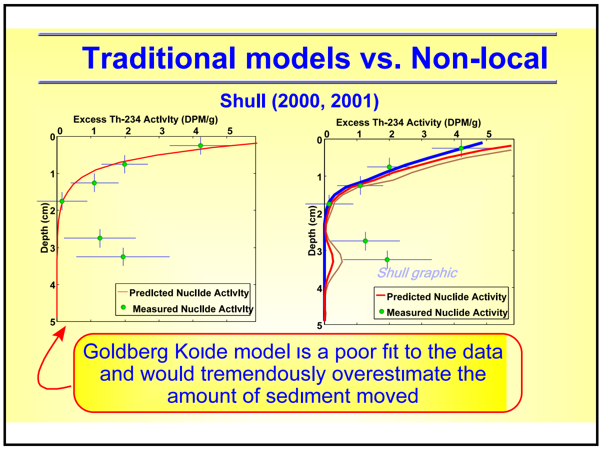
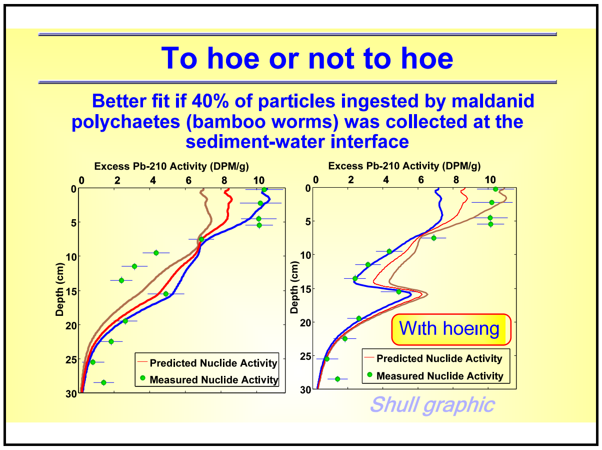


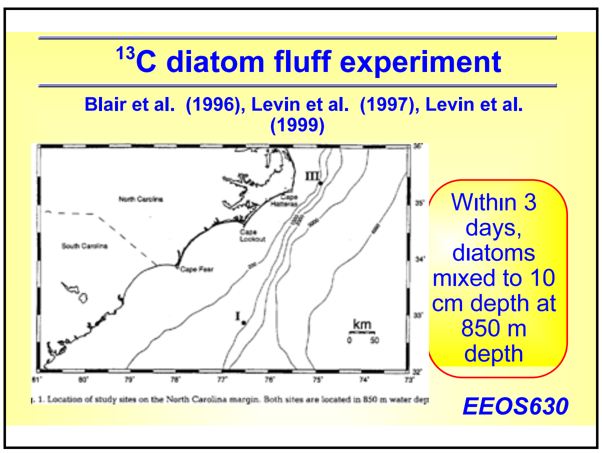
Slide 49 Traditional models vs. Non-local

NOTES:



Slide 50 To hoe or not to hoe

NOTES:



Slide 51 13C diatom fluff experiment

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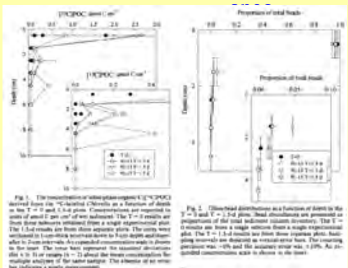
Blair et al. C-13 fluff experiment

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 Whitlach 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

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Benthic ecological issues

- 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

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Slide 55 Benthic ecological issues

NOTES:

What currency should be used?

- $$$$$$$$$$$$$$$$$$$$$$$$
  - Cost increases with
    - Thickness of cap
    - Transport distance
- Acute pollutant concentration in surface sediments
  - Minimizing vertical and lateral trophic transfer
    - Bioconcentration & bioaccumulation
  - Minimizing human health risk
- Changes in biodiversity
- Odds of meeting regulatory requirements

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Slide 56 What currency should be used?

NOTES:

Where to put CAD cells

Cost, ecological and human impact in conflict

- Cost
- Sediment transport & prop-wash
- Estuaries have low biodiversity, but
  - High human population density
  - Higher probability of human impacts, e.g., bottom-feeding fish
- Offshore sites
  - Higher species richness, more endemism (perhaps)

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Slide 57 Where to put CAD cells

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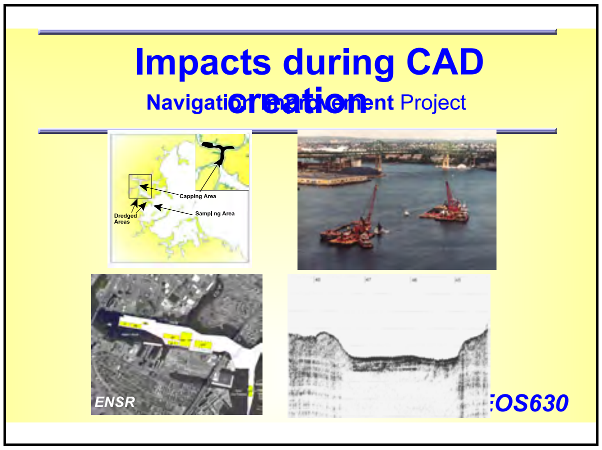

Slide 58 Impacts during CAD creation

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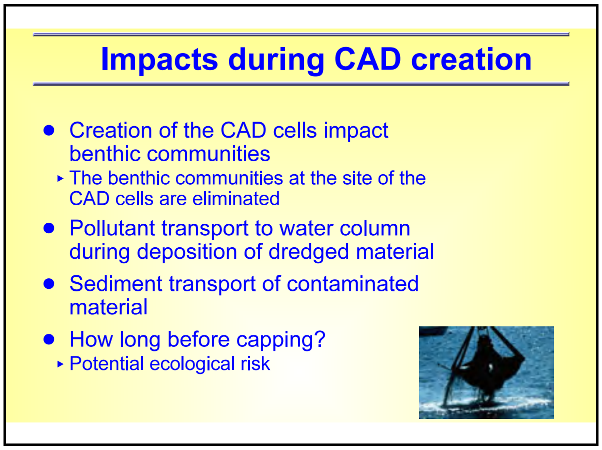

Slide 59 Impacts during CAD creation

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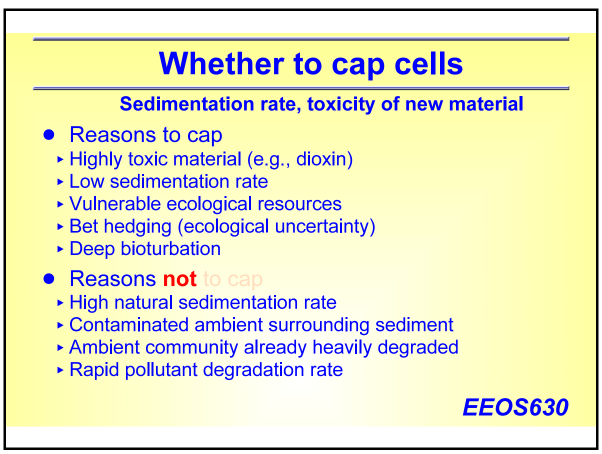

Slide 60 Whether to cap cells

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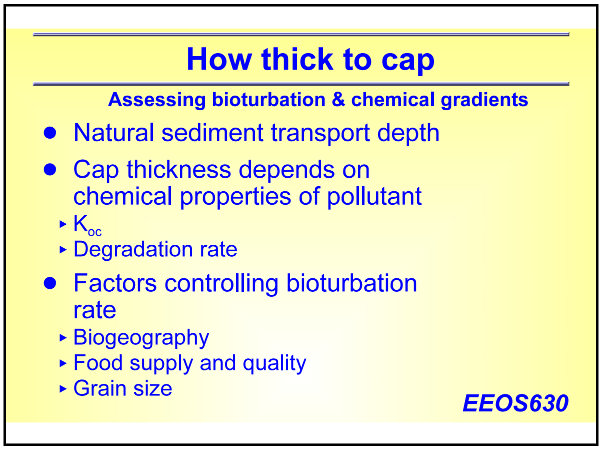

Slide 61 How thick to cap

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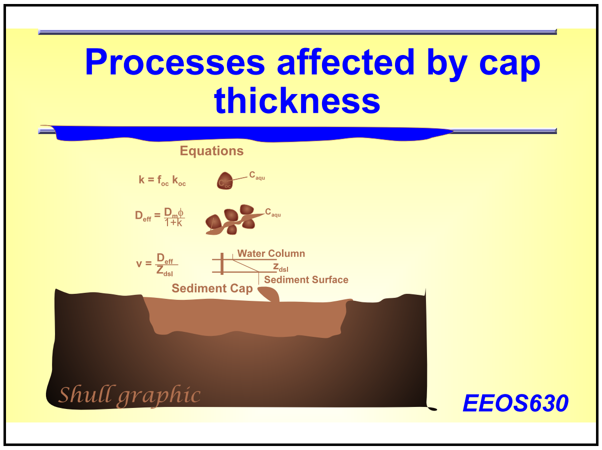

Slide 62 Processes affected by cap thickness

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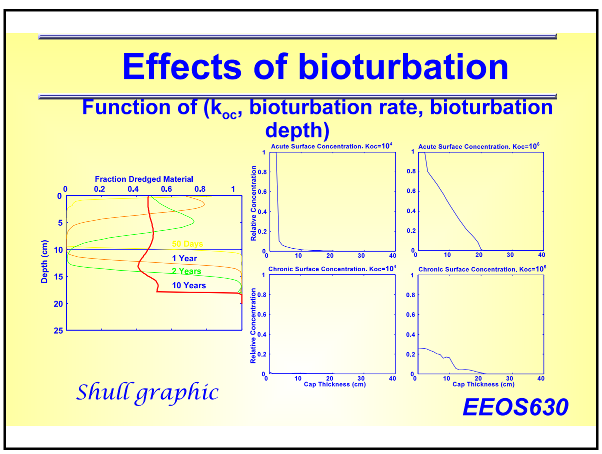

Slide 63 Effects of bioturbation

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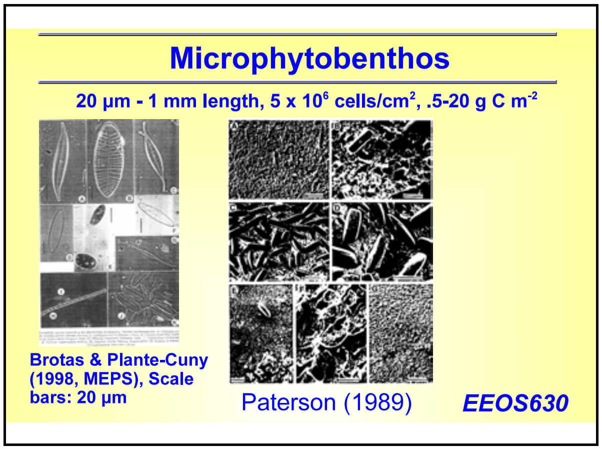

Slide 64 Microphytobenthos

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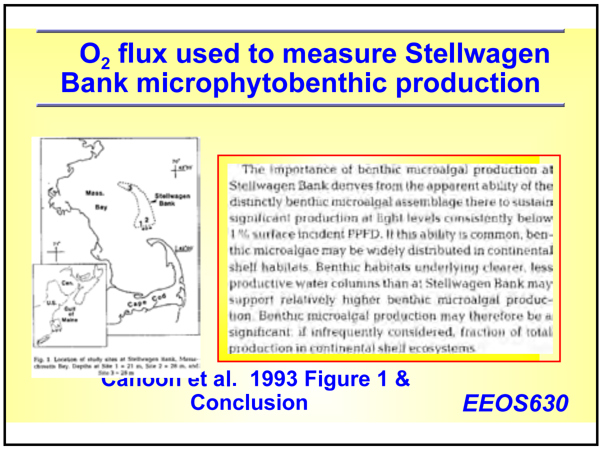

Slide 65 O2 flux used to measure Stellwagen Bank microphytobenthic production

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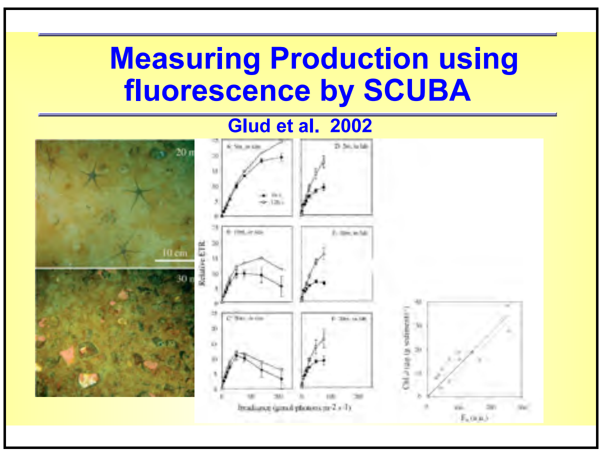

Slide 66 Measuring Production using fluorescence by SCUBA

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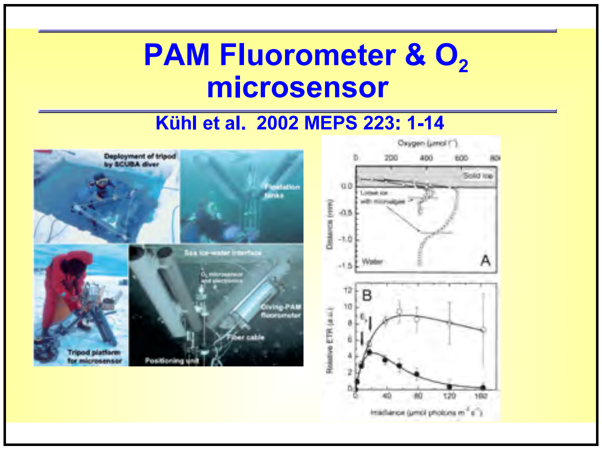

Slide 67 PAM Fluorometer & O_2 microsensor

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