Size specific energetic effects on growth and reproduction in sea urchin barrens

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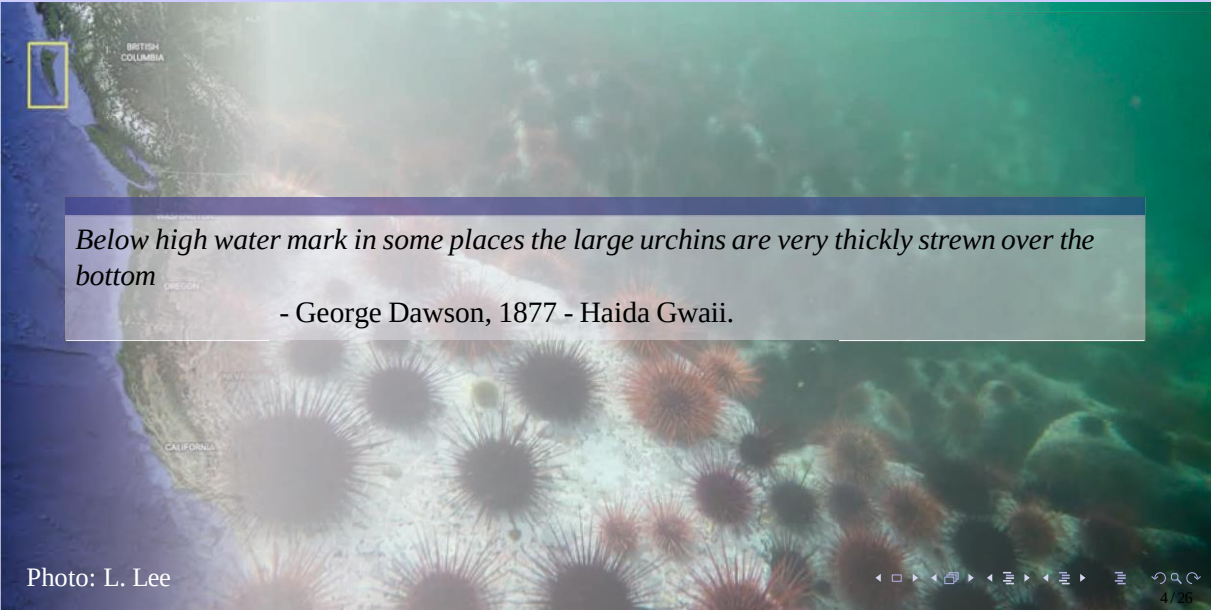
- Hakai Institute
- Gary Saunders
- Parks Canada Gwaii Haanas

Funding




How do urchins persist in barrens for decades or even centuries?

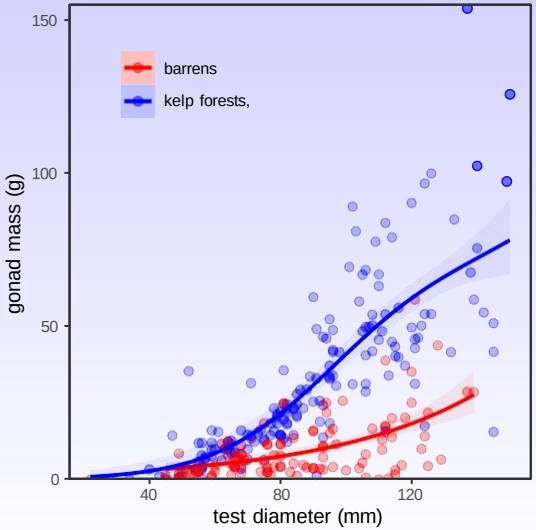


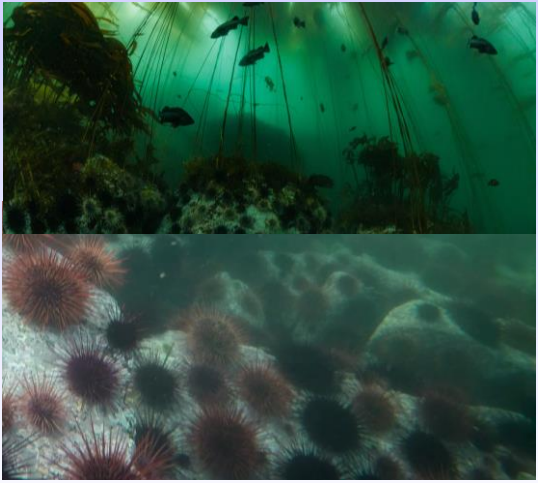
Below high water mark in some places the large urchins are very thickly strewn over the bottom

- George Dawson, 1877 - Haida Gwaii.

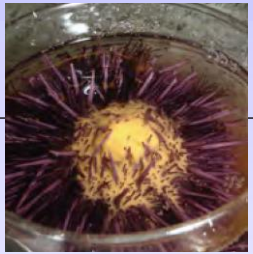
Photo: L. Lee

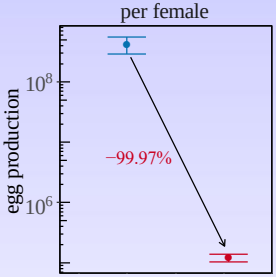
Reduced red urchin gonad mass in barrens (unmarketable)





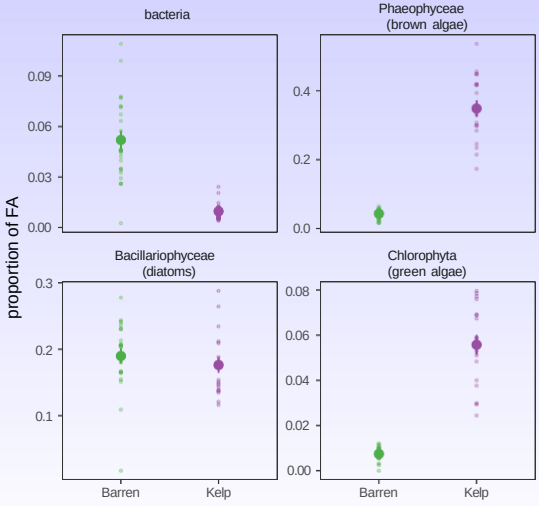
Purple urchin barrens are reproductive sinks

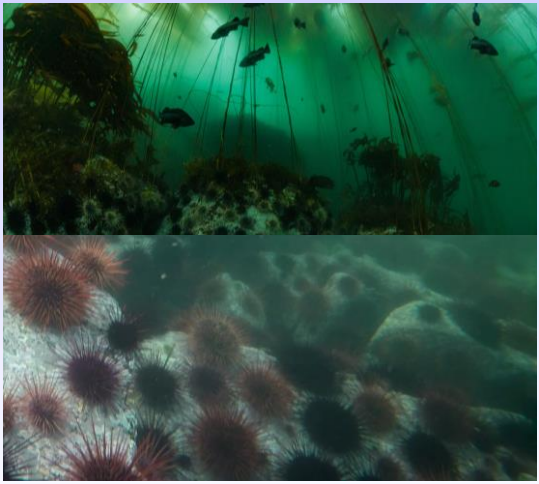




Okamoto & Reed (in prep)

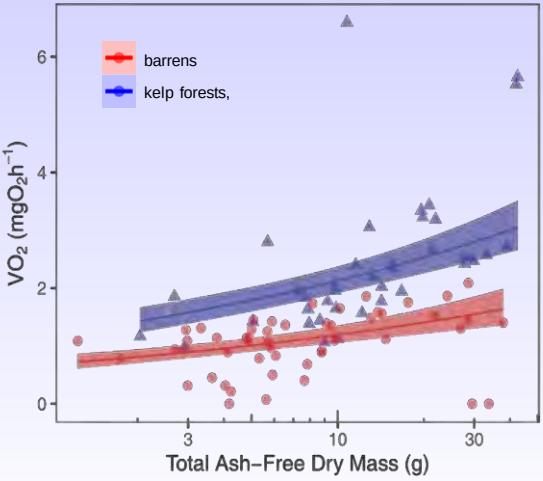
Not only food quantity, but dietary sources differ in barrens





Spindel, Okamoto, Lee, Galloway et al. In Prep

Size specific metabolic rate ↓ in barrens



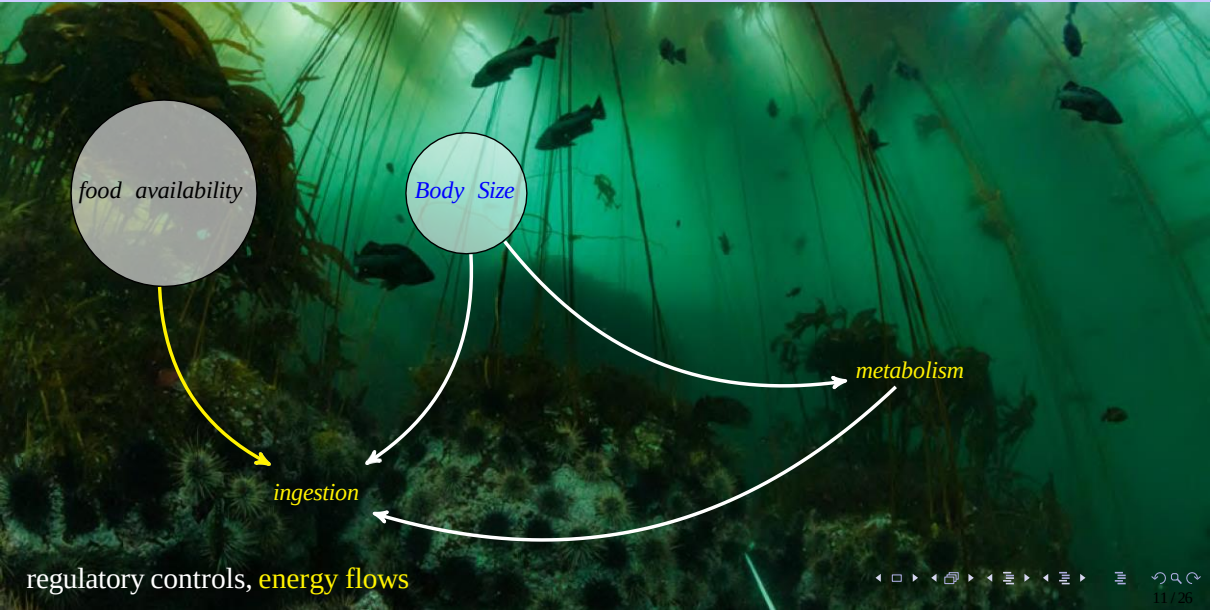
Spindel, Lee, & Okamoto. *2021* Ecology

How do animals alter energetic strategies (metabolism, growth & reproduction) to cope with nutritional stress?

- process-based models help understand & forecast responses to food limitation, climate change, harvest
- classic (DEB/LVB) models: rigid allocation assumptions & poor fit to marine inverts

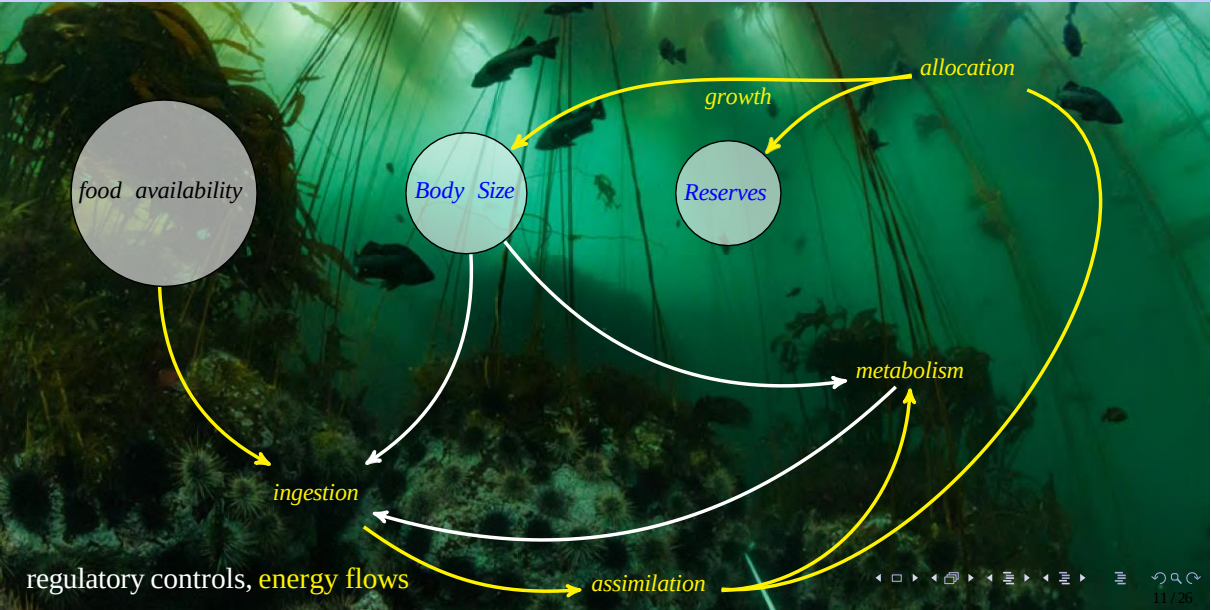
Objective: combine laboratory measurements, field experimental data, and modified energy budget models to quantify shifts in energy strategies inside and outside of barrens

A simplified dynamic energy budget framework



regulatory controls, energy flows

A simplified dynamic energy budget framework



regulatory controls, energy flows

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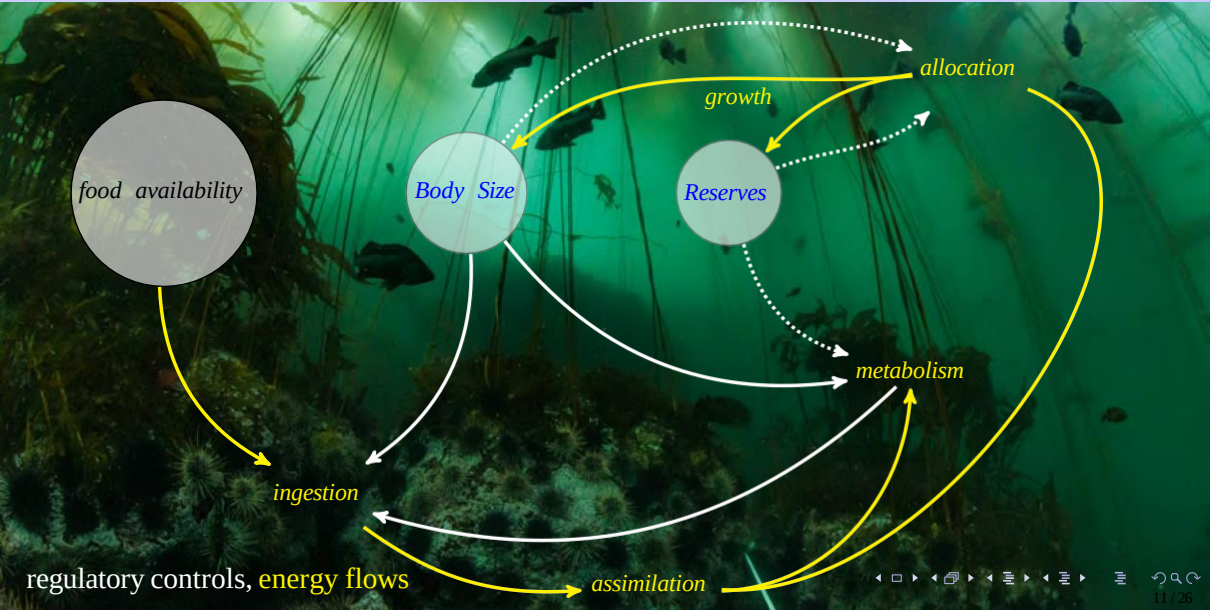

regulatory controls, energy flows

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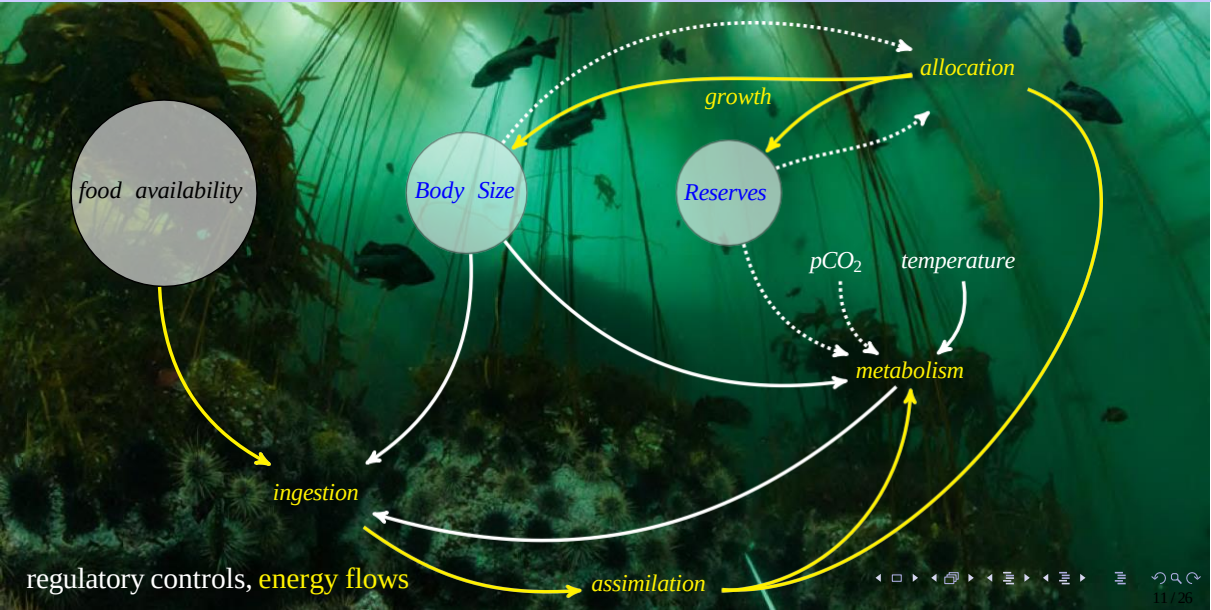


regulatory controls, energy flows

measureable rules by body size (l)

- metabolic demands: $e_{maint} = \beta s^{\gamma}$
- max consumption: $f_{max} = \theta s^{\psi}$
- energy intake func. response: $e_{gain} = \delta \frac{\alpha f}{1 + \frac{1}{f_{max}} \alpha f}$
- c_r = energetic cost of building reserve
- f = food availability

Balance growth vs. reproduction by body size (l)

- $\frac{dS}{dt} = c_s(1 - \lambda)(e_{gain} - e_{maint})$ (Structral Allocation)
- $\frac{dR}{dt} = c_r\lambda(e_{gain} - e_{maint})$ (Reproductive Allocation)
- c_s = energetic cost of building structure
- λ = energy allocation to reproduction after maintenance is paid

A field test of food & body size on energetic performance

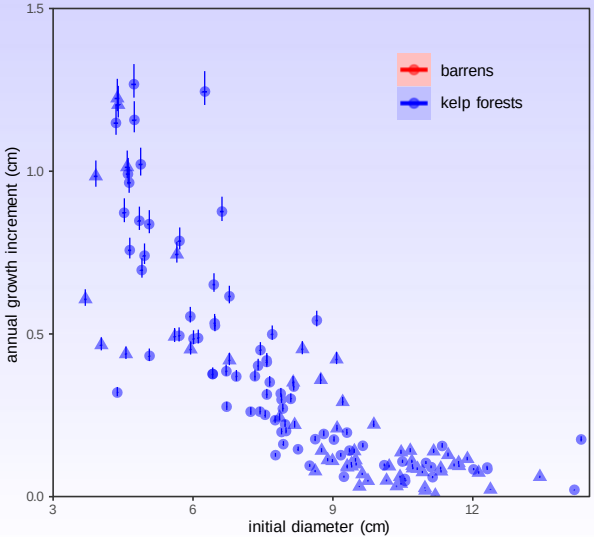
An “inverse problem”

Estimating the partially resolved model

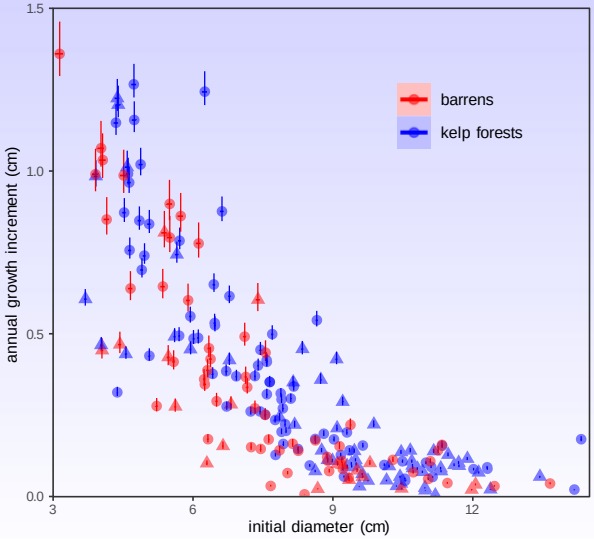
- **mark recapture** of animals inside/outside of barrens
- **measure** growth, gonad production, metabolic rate, food
- **integrate lab measurables** (caloric dens., assimilation efficiency, feeding rates, etc.)
- **estimate energetic allocation strategies** in a DEB framework using Bayesian integrated analysis

Indeterminate and non-asymptotic growth rates

Estimated growth ↓ w size, but growth is positive even at large size classes



↓ in estimated growth only apparent at medium sizes in barrens



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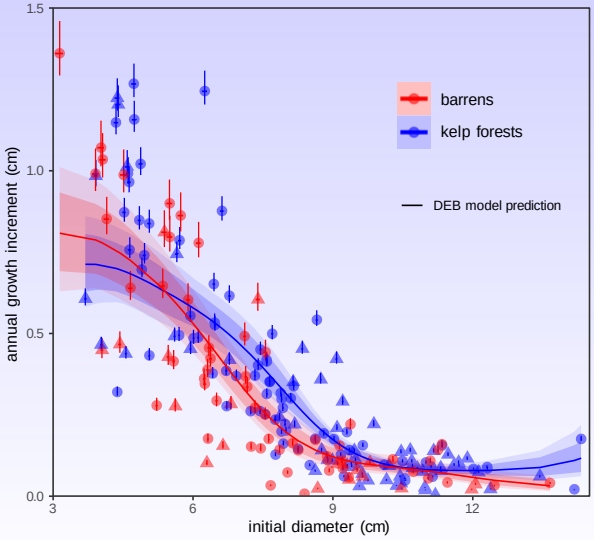
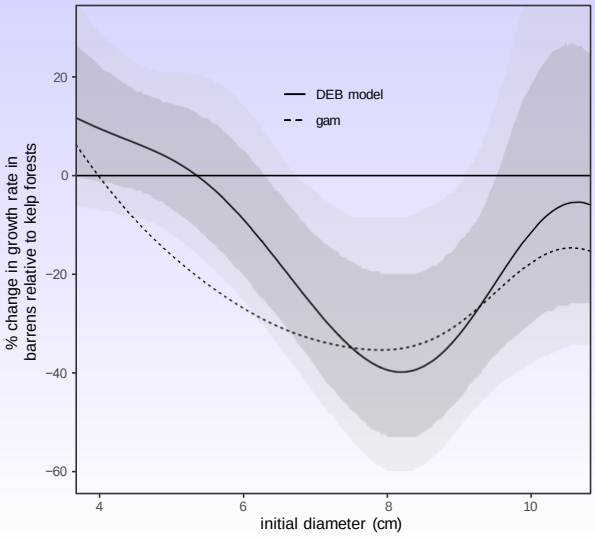


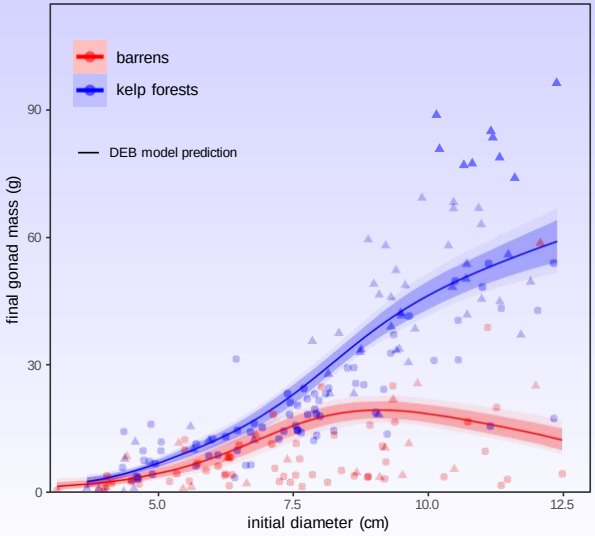
curves significantly different in both DEB and empirical models

40 % decline in growth for mid-sized urchins

little to no change at smallest/largest size-classes!



↓ in reproduction most pronounced for large urchins



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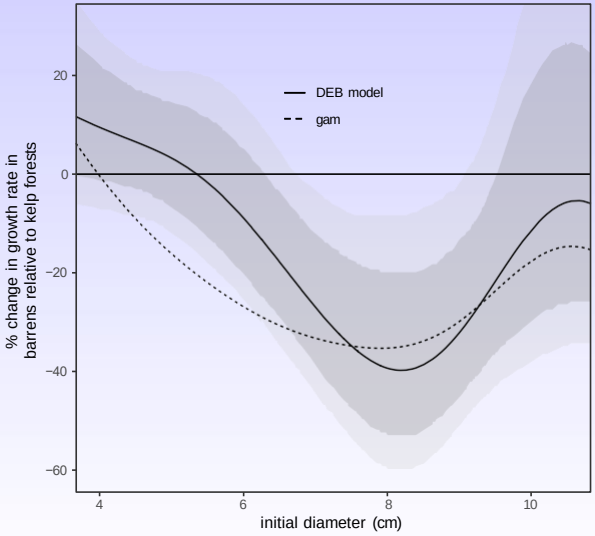
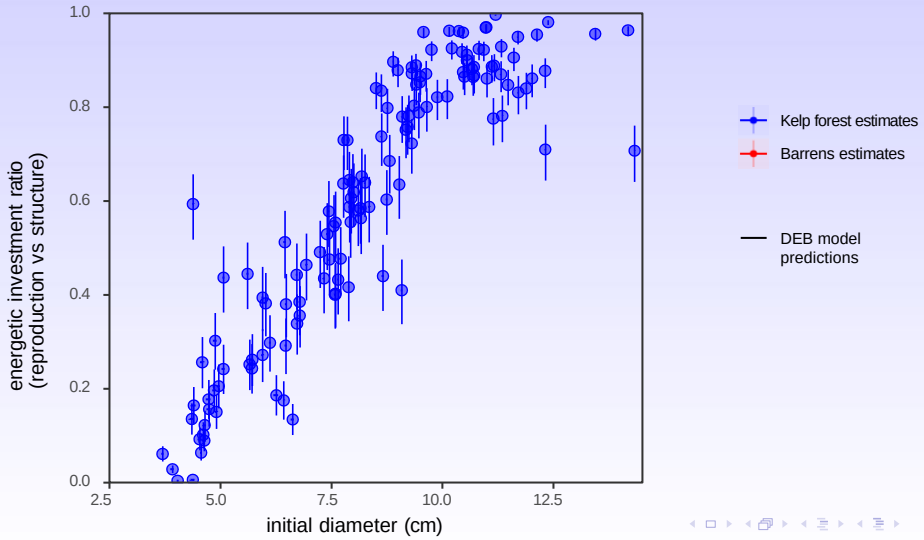
Why does growth appear most limited at medium sizes?



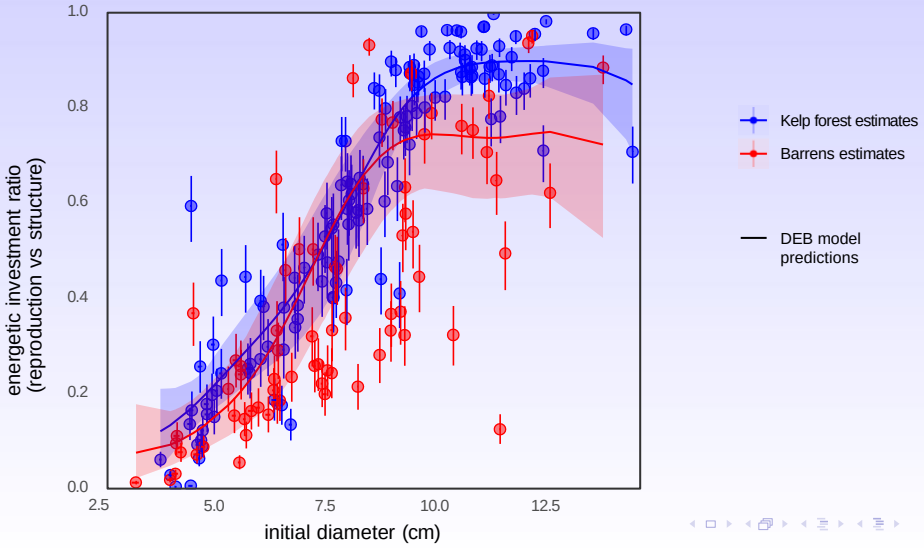
Why does growth appear most limited at medium sizes

Estimated allocation shifts from growth → reproduction as size ↑



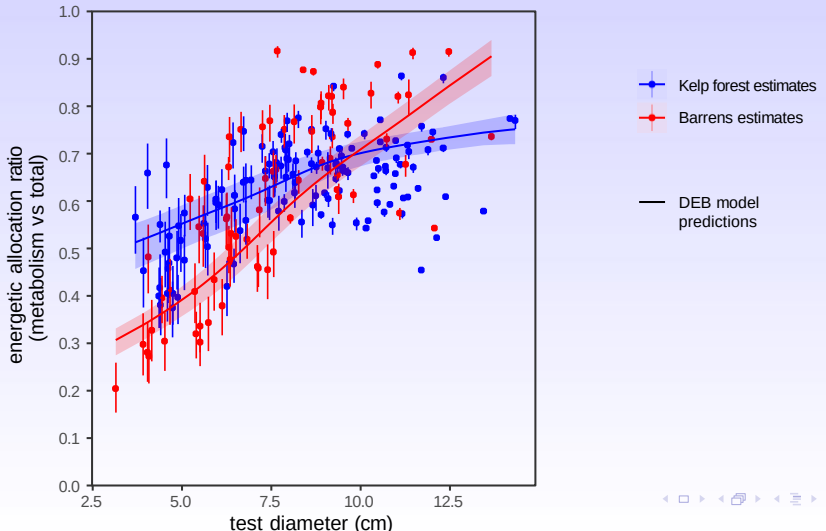
Why does growth appear most limited at medium sizes?

... but larger animals in barrens prioritize growth over reproduction



Why does growth appear most limited at medium sizes?

... and smaller animals estimated to have lower metabolic overhead relative to intake



Conclusions

- **Energy allocation shifts from growth to reproduction with size**
- **Smaller animals are more energetically efficient esp. in barrens**

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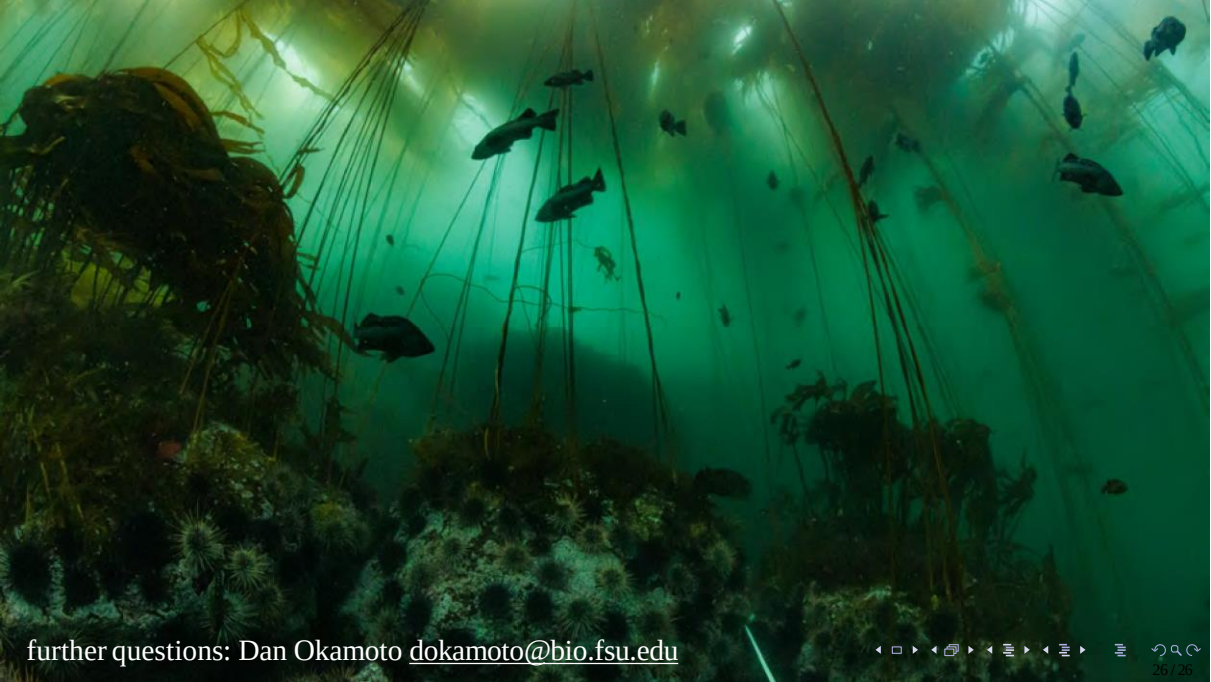
- **Reproductive cost of living in barrens ↑ with body size**
- **Growth cost of living in barrens only ↑ at medium sizes**

Conclusions

- **Energy allocation shifts from growth to reproduction with size**
- **Smaller animals are more energetically efficient esp. in barrens**
- **Reproductive cost of living in barrens ↑ with body size**
- **Growth cost of living in barrens only ↑ at medium sizes**
- **Modified DEB model can explain shifts in energetic allocation patterns in barrens**



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