Wave forces on marine organisms

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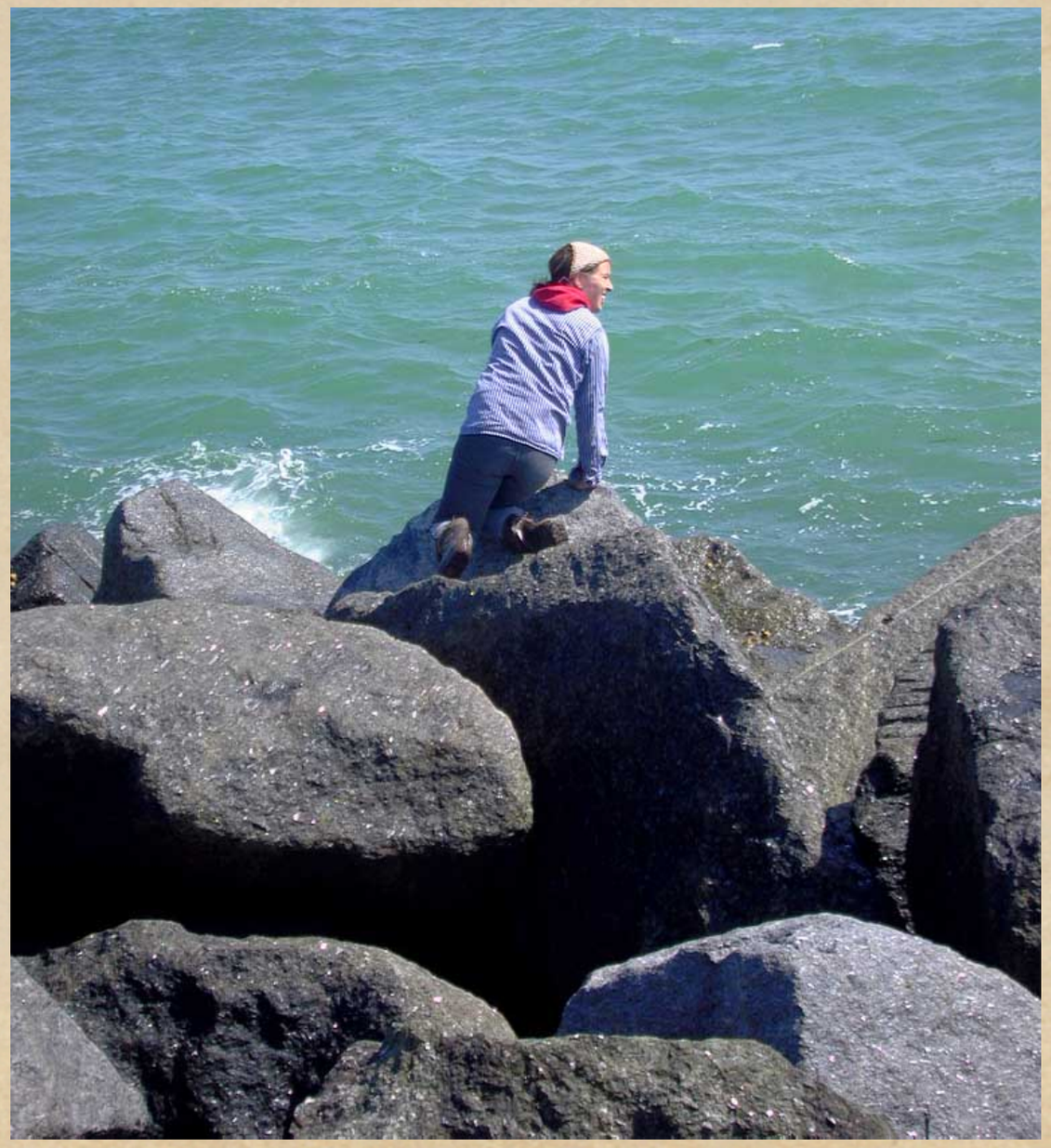
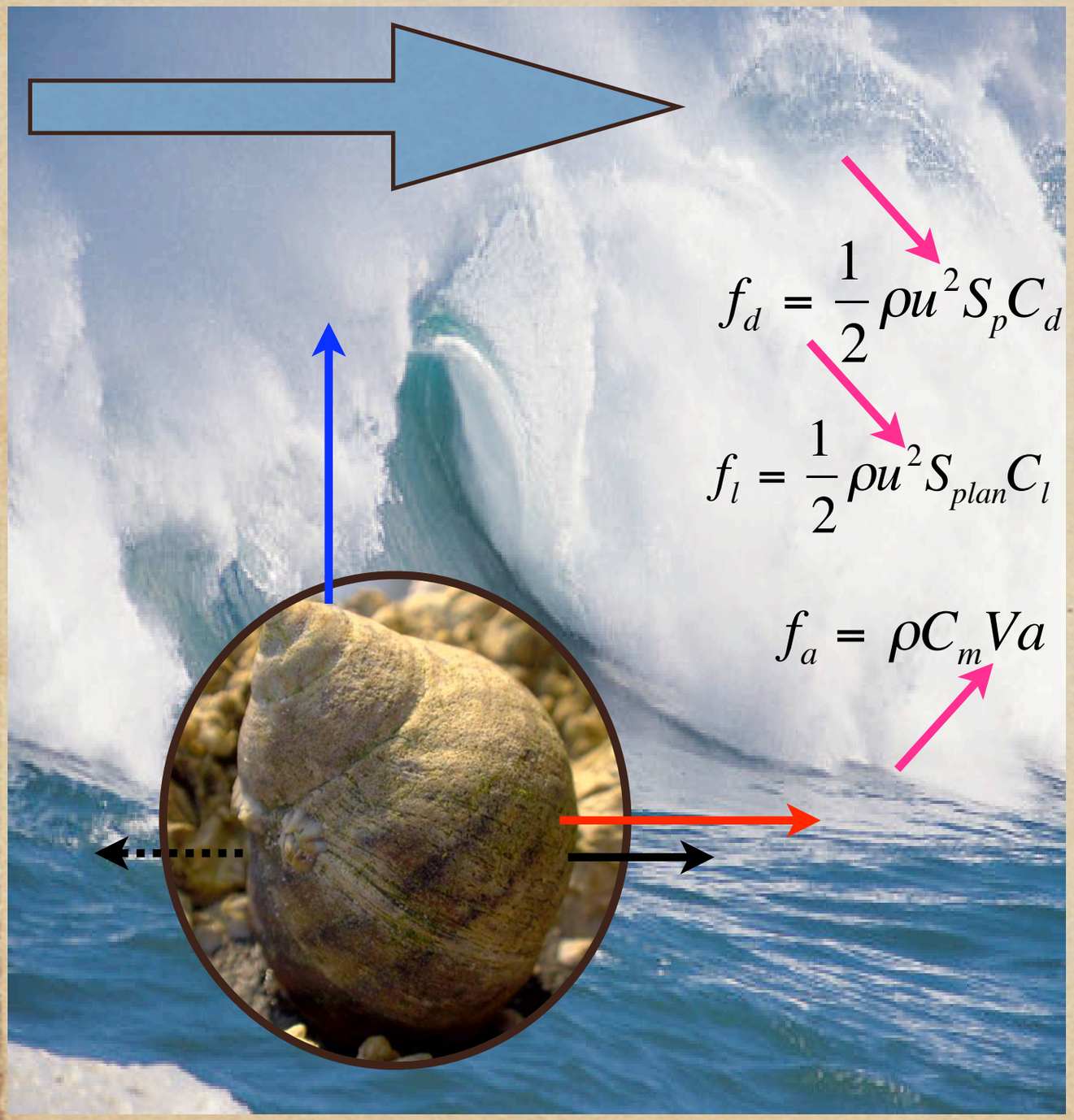
NMA course, Bergen 2005

Wave exposure on rocky shores



Hydrodynamic forces



$$f_d = \frac{1}{2}\rho u^2 S_p C_d$$ drag

$$f_l = \frac{1}{2}\rho u^2 S_{plan} C_l$$ lift

$$f_a = \rho C_m V a$$ acceleration reaction

Waves

shoaling

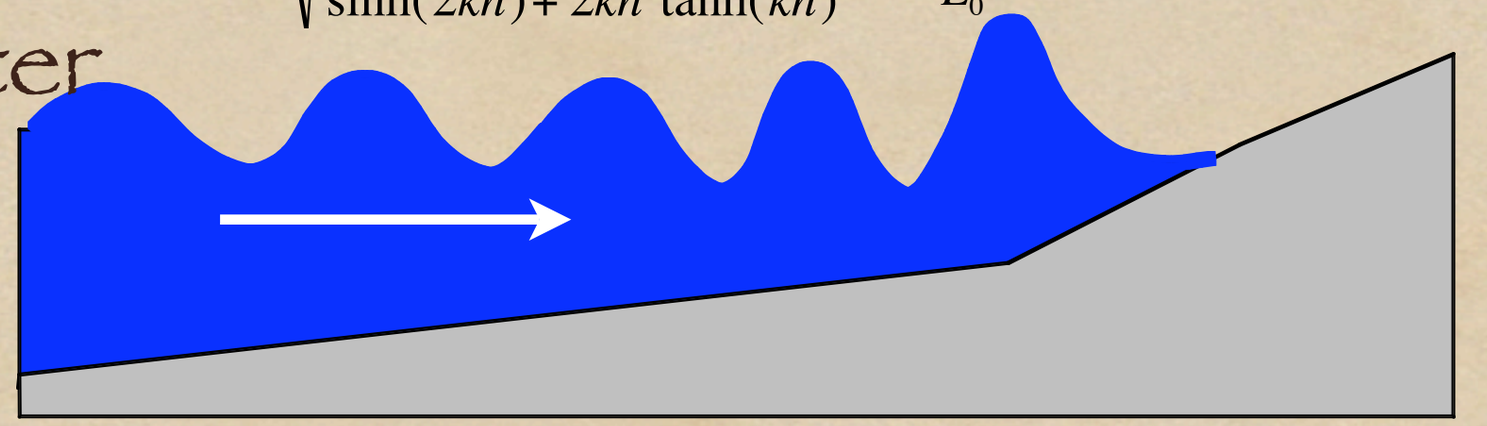
$$H = H_0 \sqrt{\frac{\sinh(2kh)}{\sinh(2kh)+2kh}\frac{1}{\tanh(kh)}} \qquad k = \frac{\pi}{L_0}$$

breaking waves

$$H_b = 0.18 L_0 \left(1 - \exp\left[-1.5\frac{\pi h}{L_0}\left(1+15\beta^{4/3}\right)\right]\right)$$

deep-water waves

(H_0, L_0)



Breaking wave flow speed

$$u_{\max} = 3.75 H_b^{0.57}$$

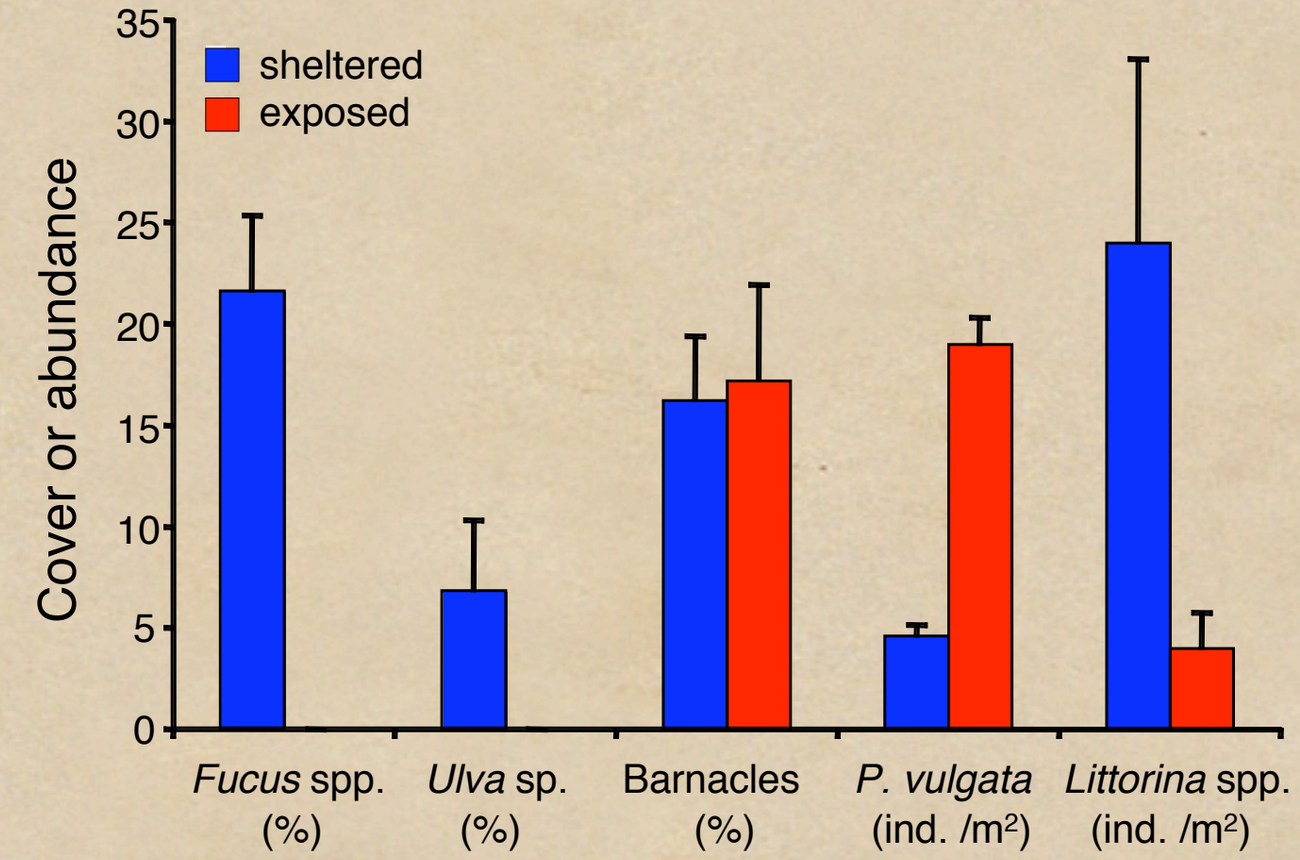
Does hydrodynamics control the distribution of shore organisms?

sheltered - exposed

Fucoid macro-algae

Limpets

Distributions of rocky-shore organisms

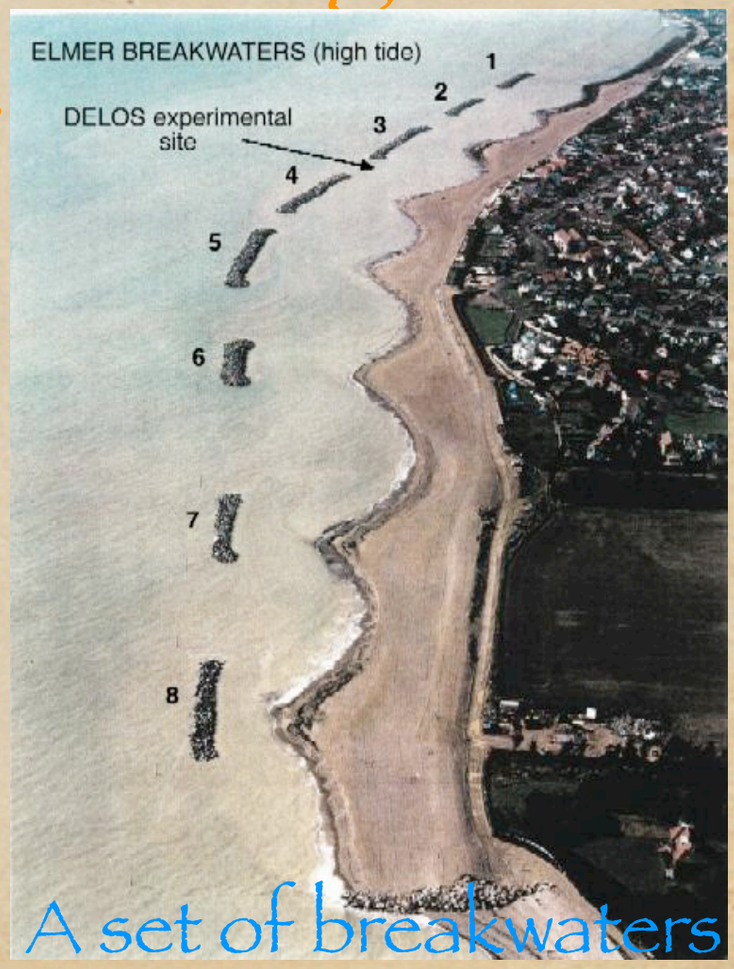


What factors cause observed patterns on rocky shores?

- Hydrodynamic forces caused by waves?
- Biological interactions, mainly predation?
- Other abiotic stress factors, e.g. heat & desiccation?

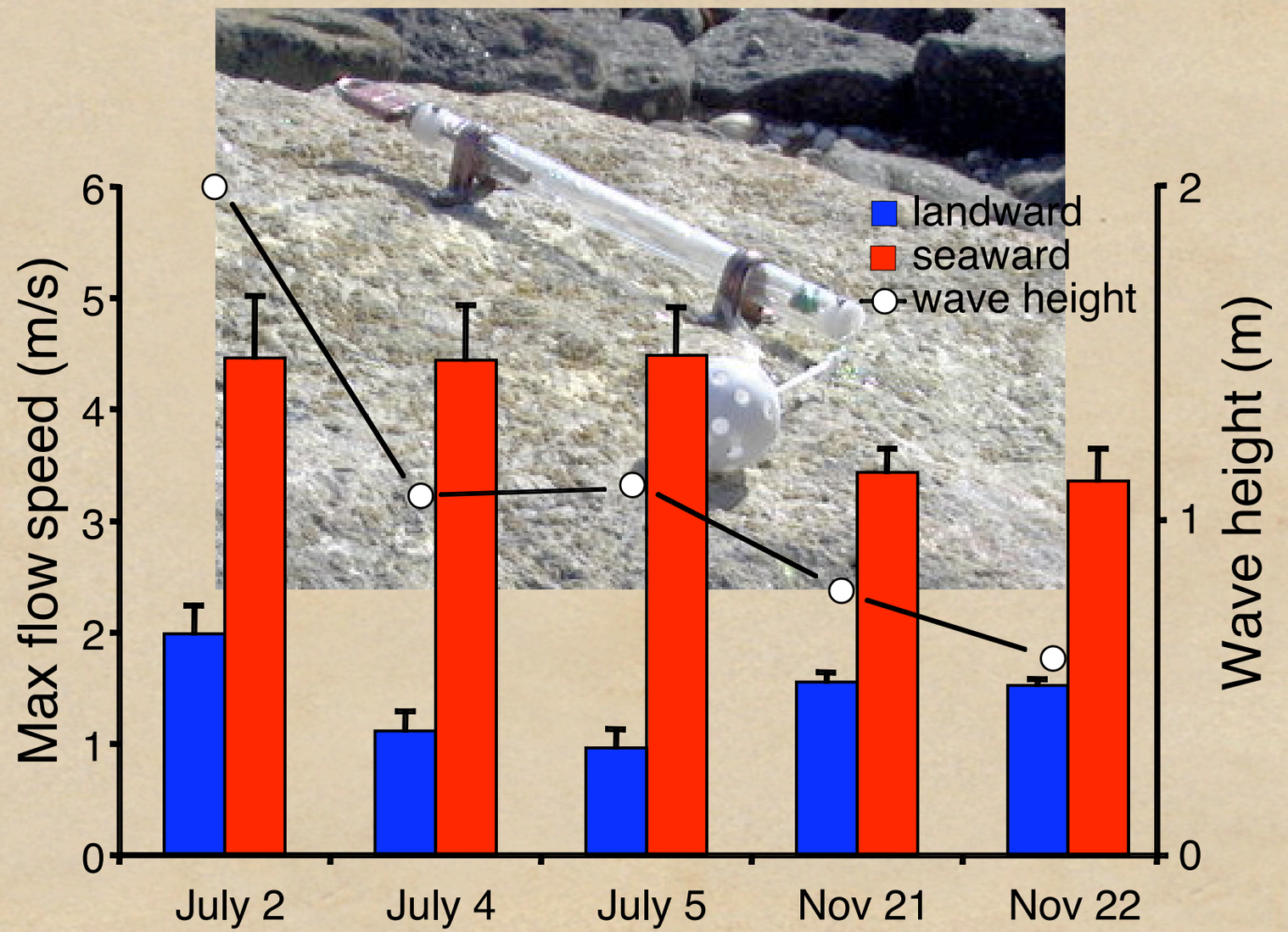
Physical modeling and experimental tests

- Do hydrodynamic forces limit macroalgae?
- Does grazing limit macroalgae?

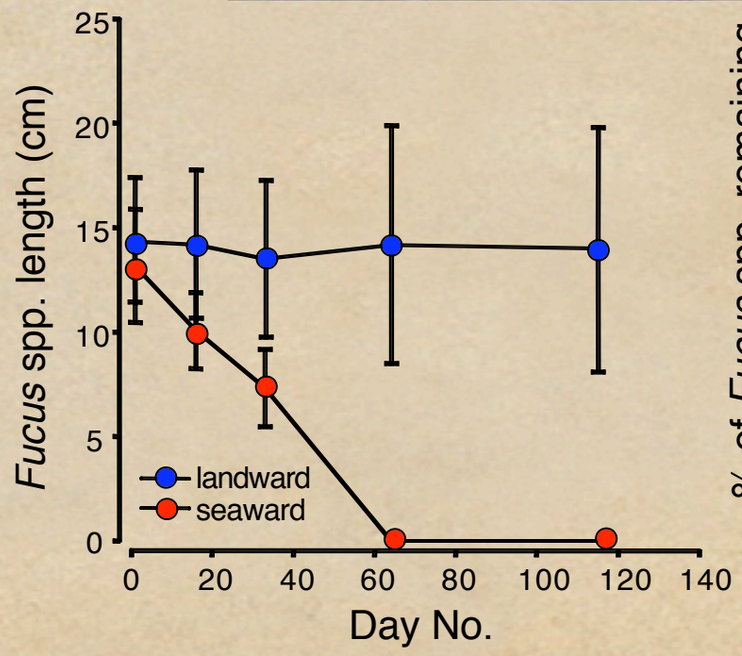


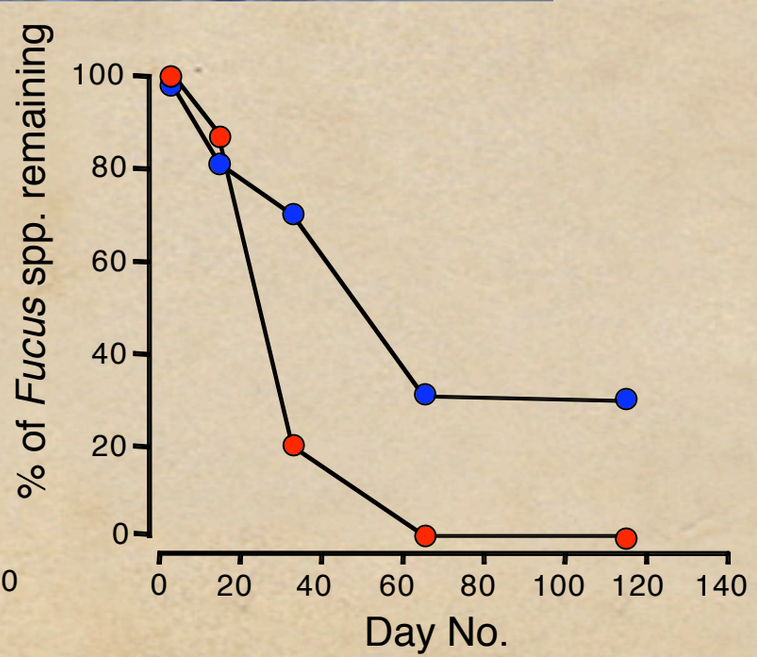
A set of breakwaters

Hydrodynamic forces



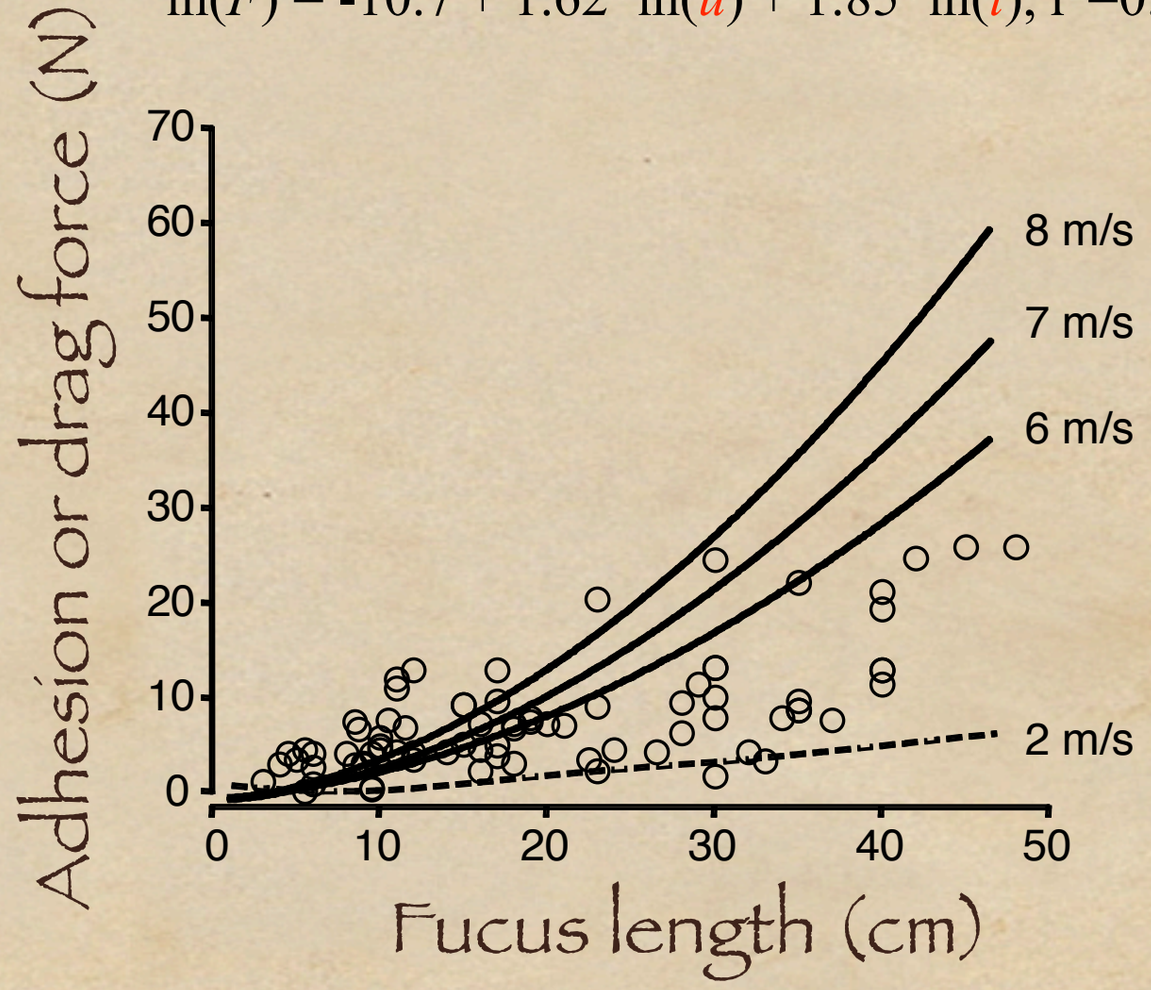
Transplantation experiment





Measurement of adhesion strength

$$\ln(F) = -10.7 + 1.62*\ln(u) + 1.85*\ln(l),\ r^2=0.97$$

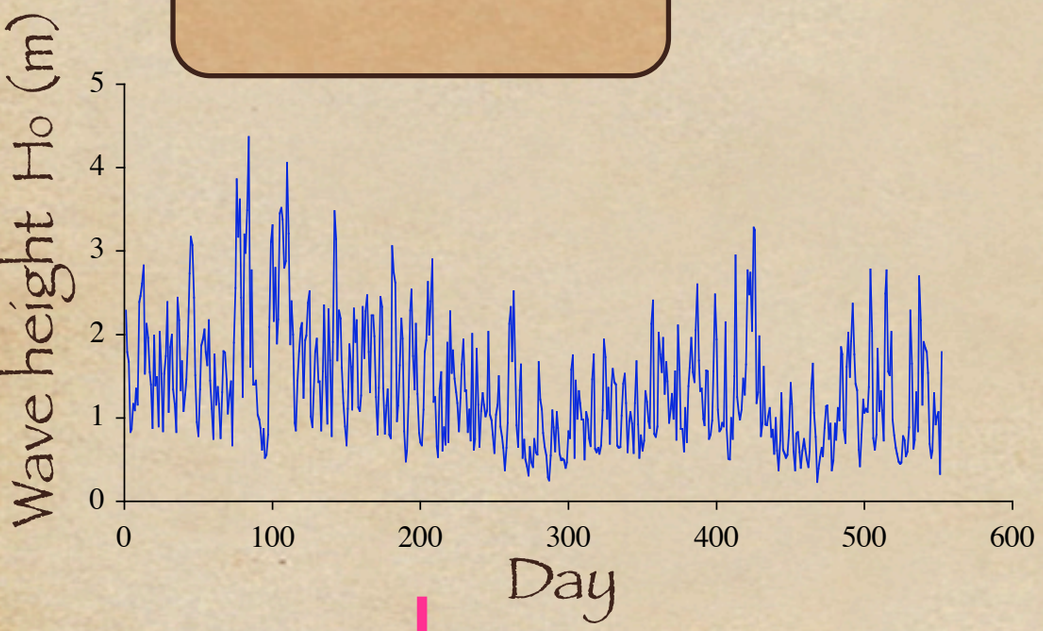


How to estimate relevant forces?

- Effects of waves may depend on maximum forces at rare events

Model of wave exposure

wave climate



extreme value analysis

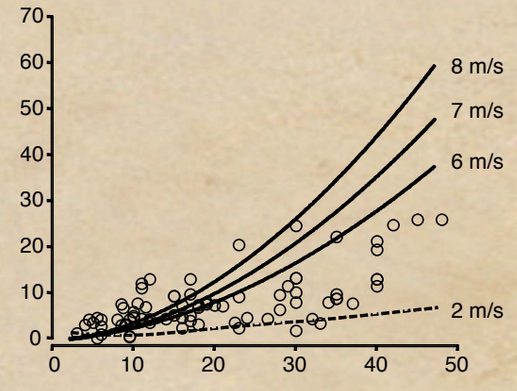
max wave height

shoaling

breaking

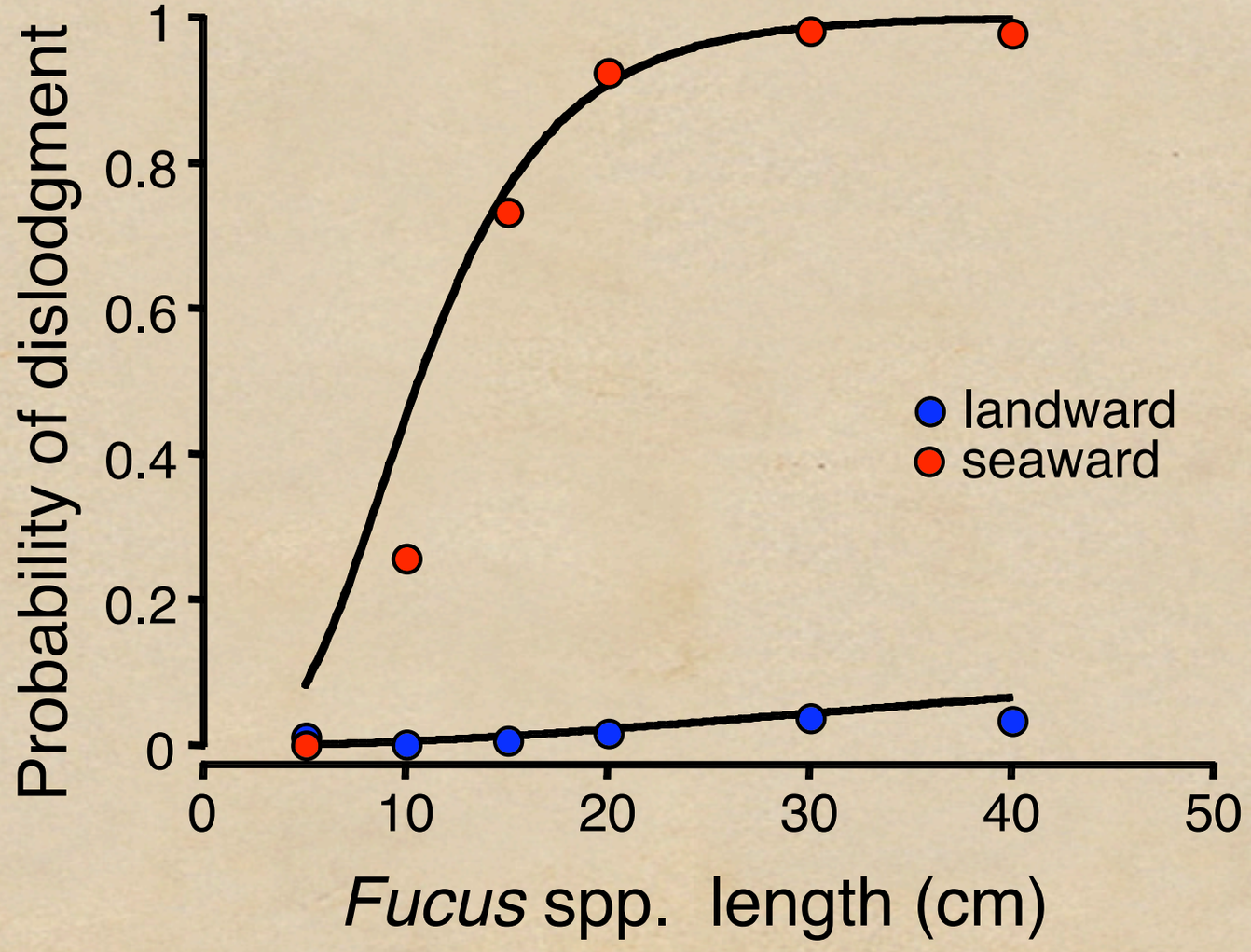
max flow speed

probability of dislodgment



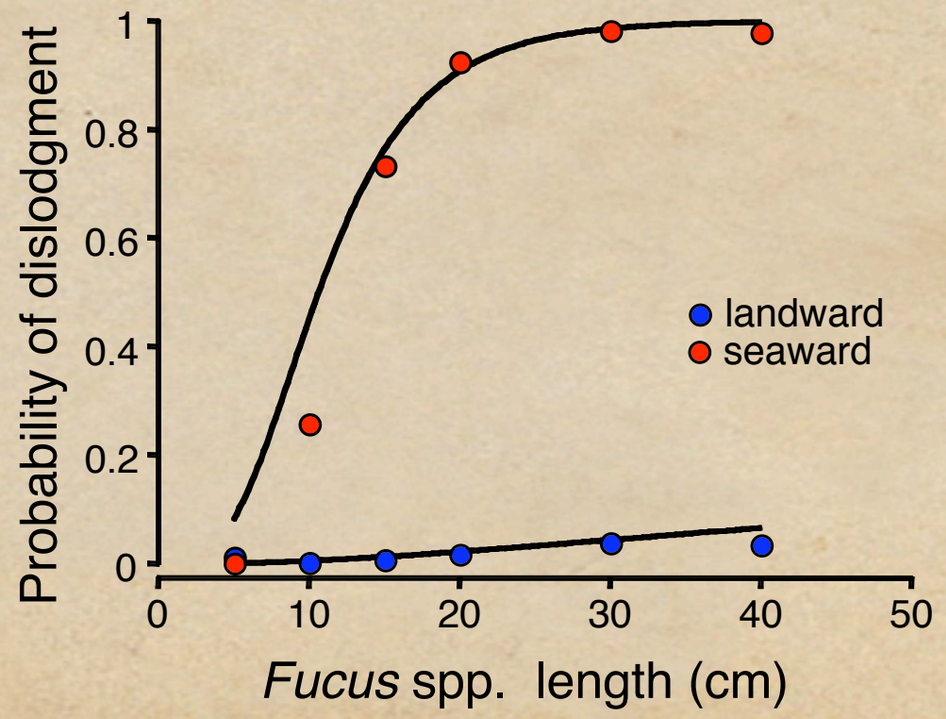
which results in..

Probability of dislodgment

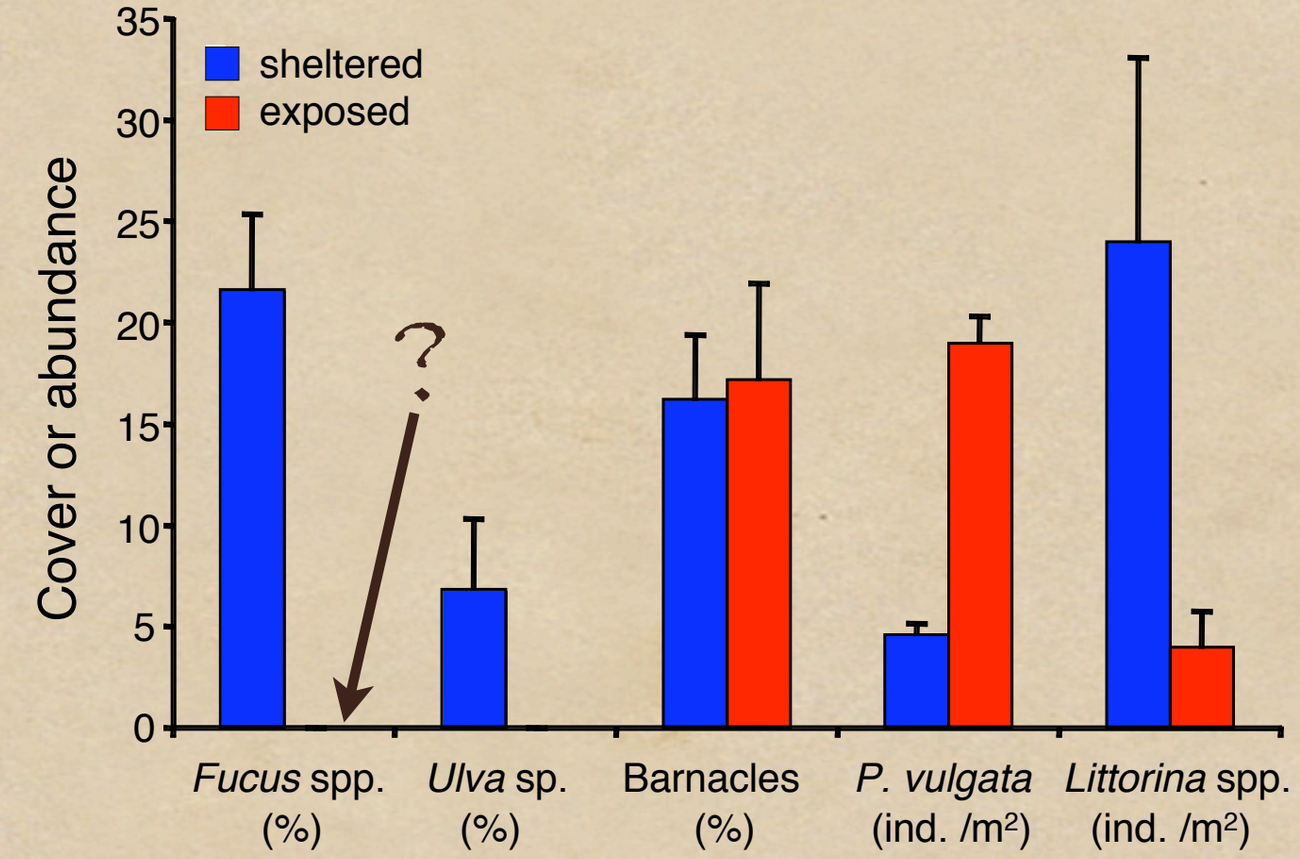


Conclusion from hydrodynamic analysis

- Macroalgae above ca 10 cm are expected to be detached or pruned on exposed shores



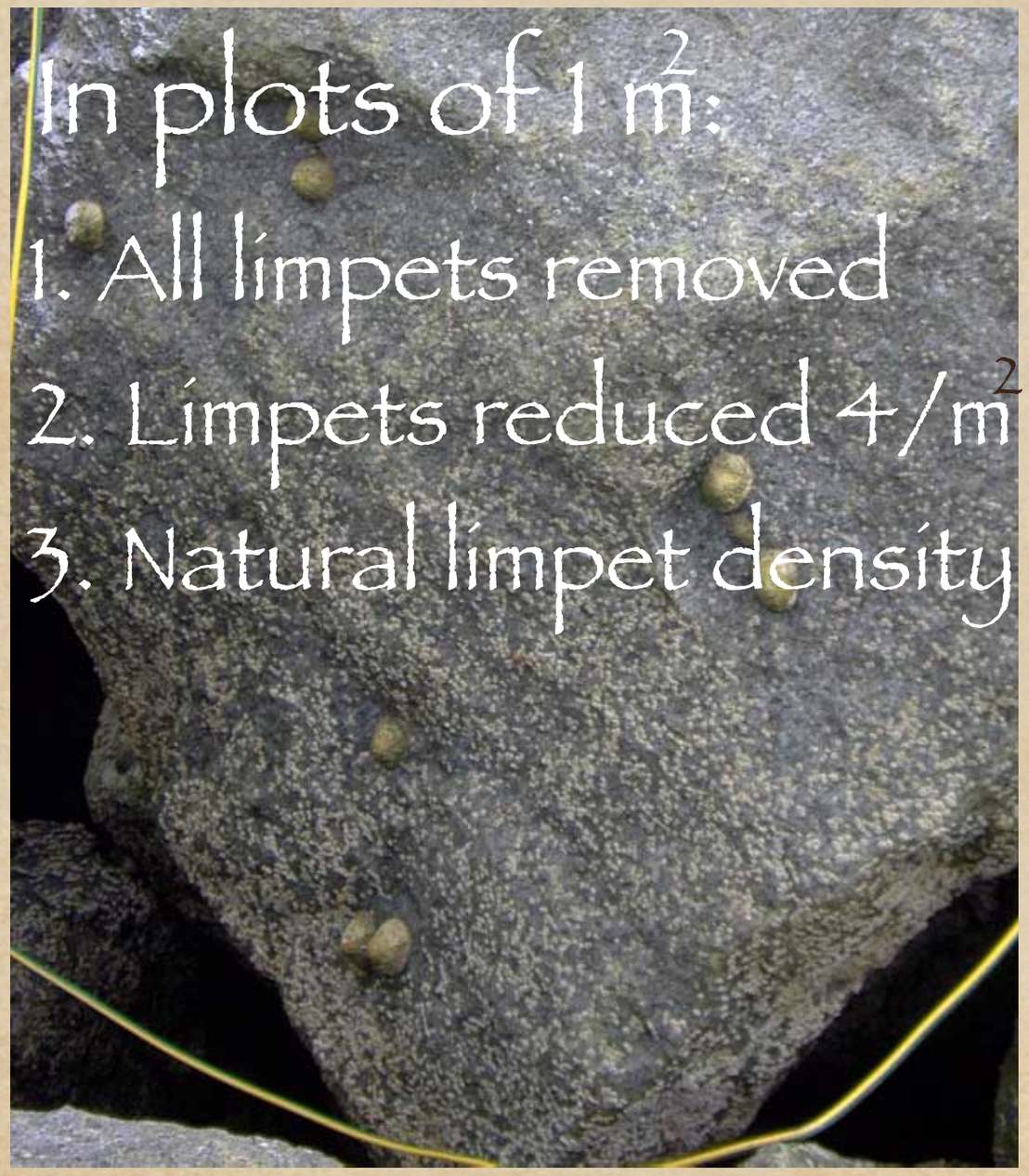
Where are all recruits on exposed shores?



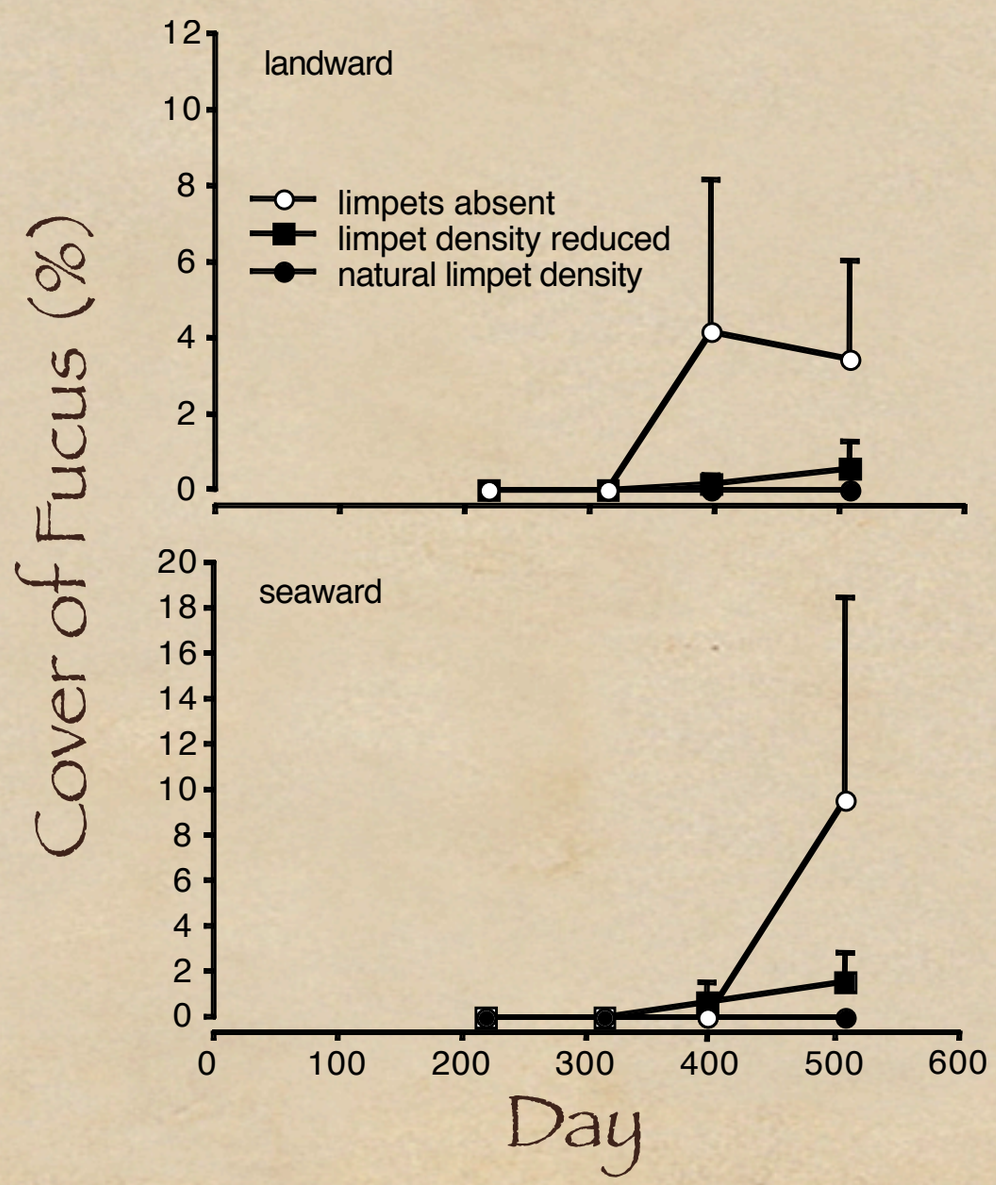
What about grazing?

Patella vulgata

Limpet removal experiment

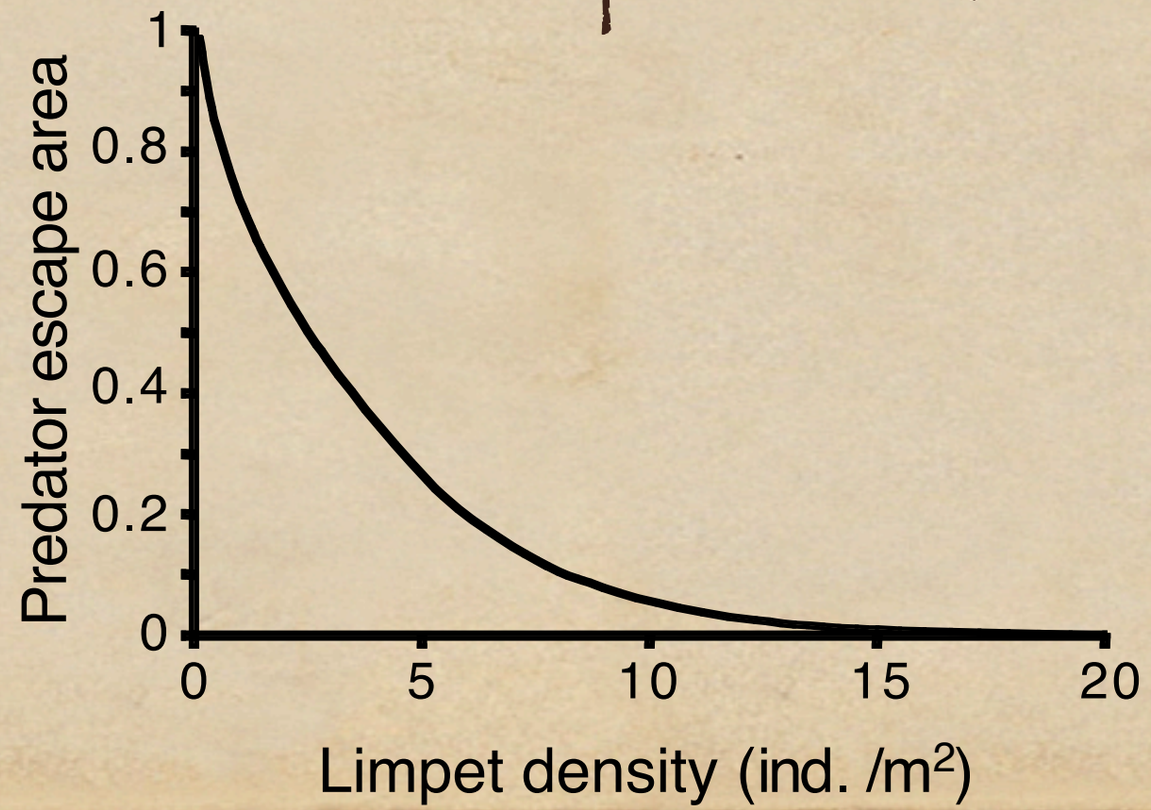


Limpet removal experiment

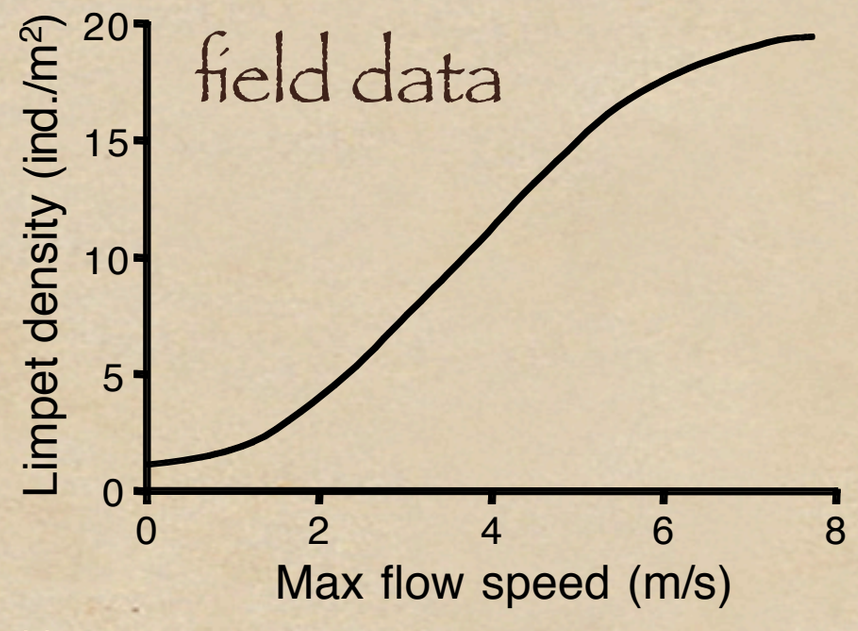


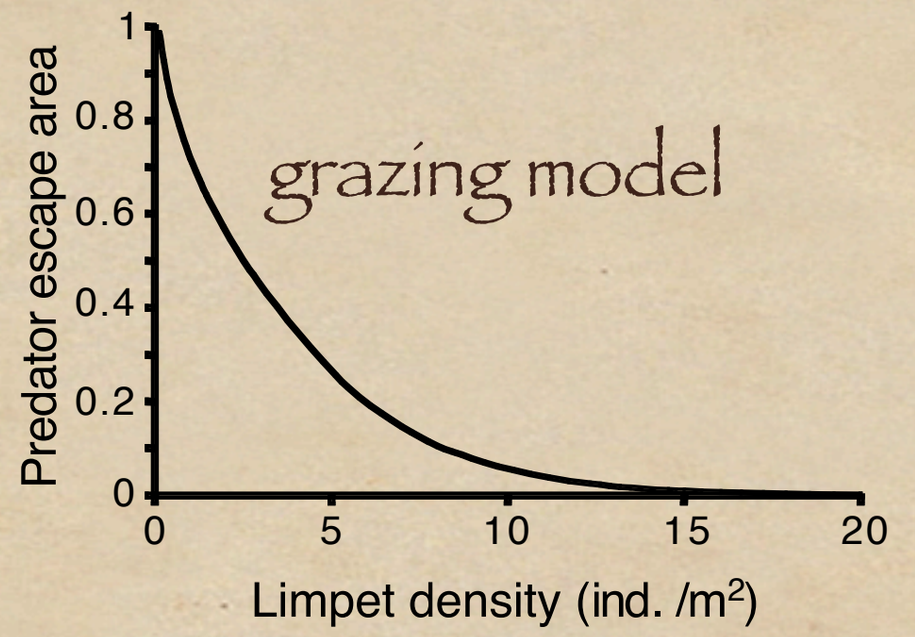
Model of limpet grazing

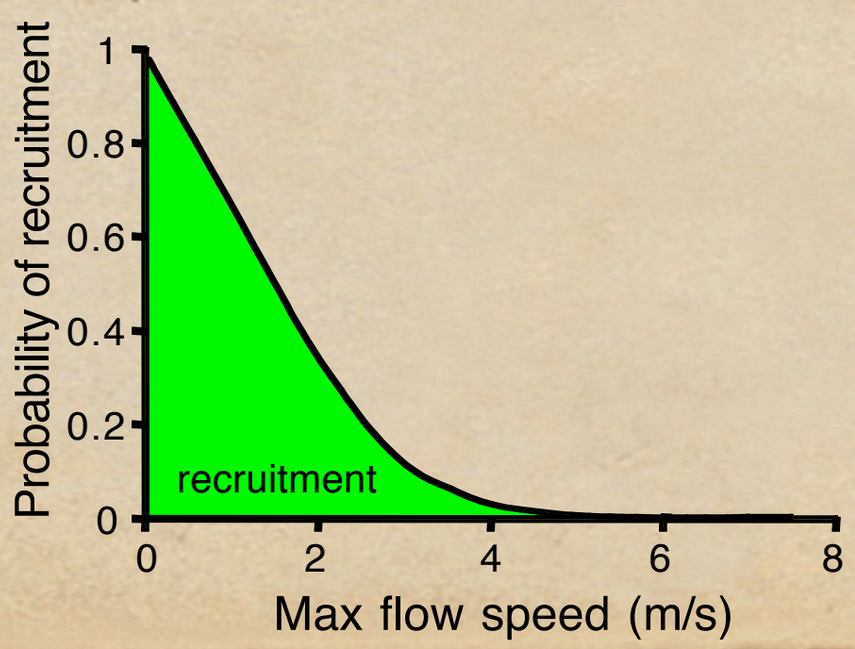
1. Correlated random walk
2. Activity and feeding rate
3. Model the % of non-grazed area until Fucus reaches escape size (3 cm)

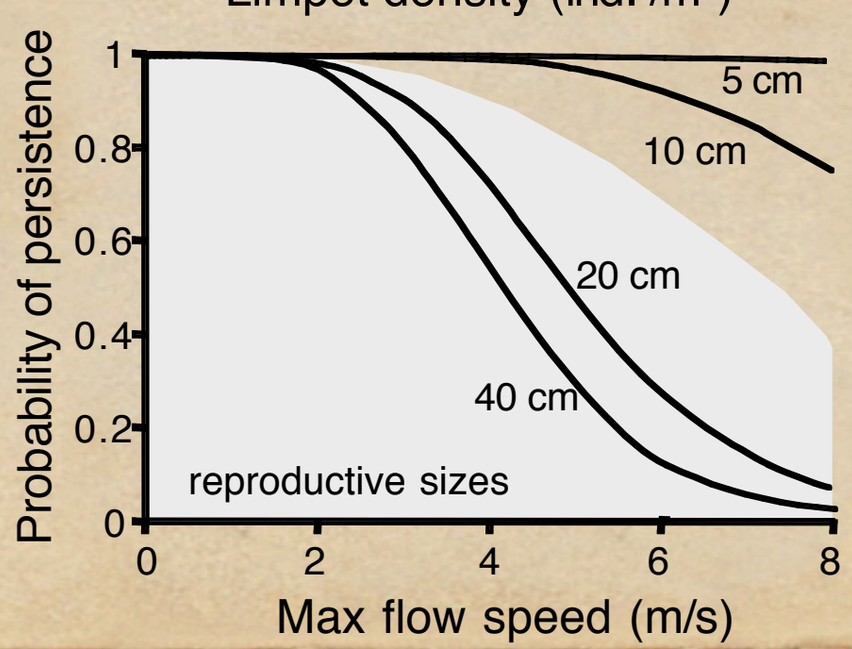


Conceptual model of regulation of Fucus









Overall conclusions

- Hydrodynamic exposure and grazing interact to control macroalgae
- In absence of grazing, algae will recruit but waves will prune or dislodge plants
- Recruitment is prevented if limpets exceed a critical density
- Limpets are favoured by wave exposure??

In collaboration with:

- Per Åberg, Göteborg University
- Richard Thompson, University of Plymouth
- Stephen Hawkins & Paula Moschella, Marine Biological Association

Thank you!