

# Food-dependent growth and life history evolution in (exploited) fish populations

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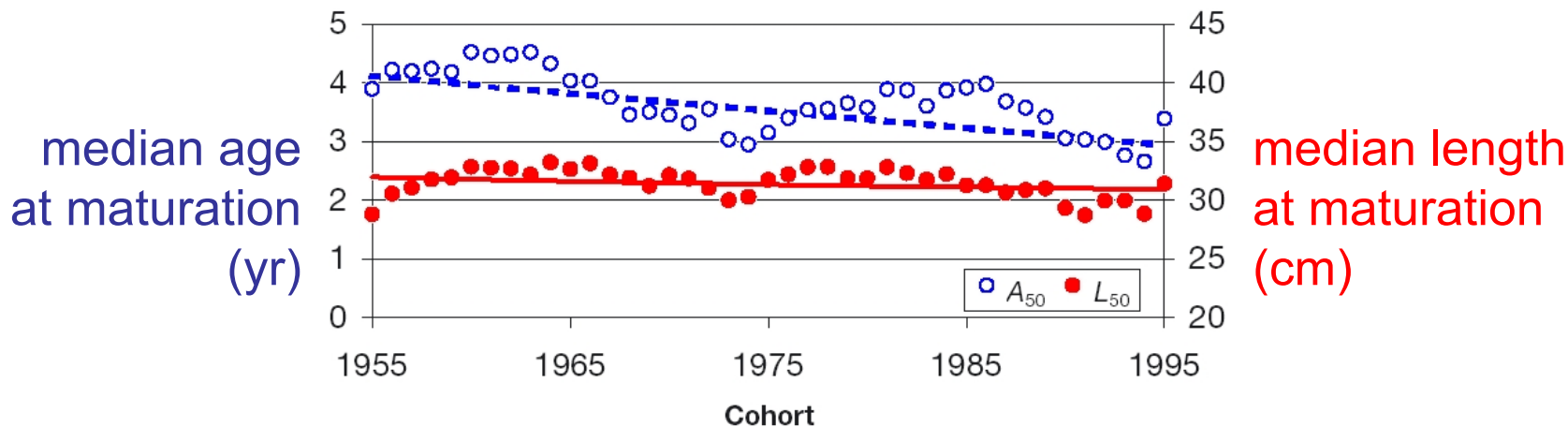
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André de Roos (Amsterdam)

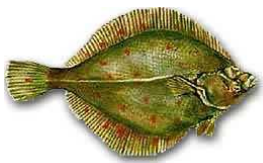
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# Size and age at first reproduction in North Sea plaice

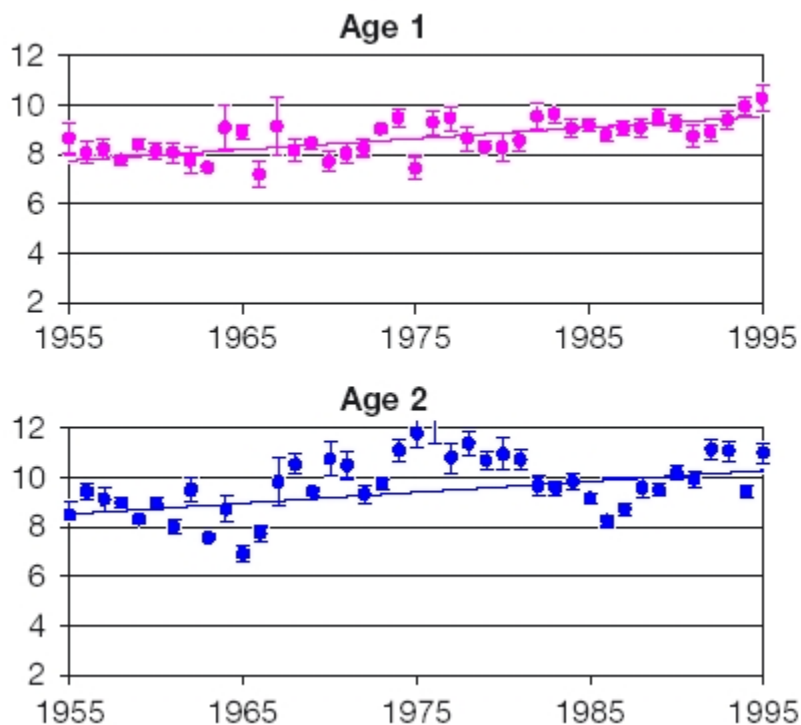


- North Sea plaice start reproducing at earlier age and smaller size
- Claimed to be an evolutionary response to harvesting: due to genetic change in the population
- Presumed: it reduces risk of being harvested before reproduction

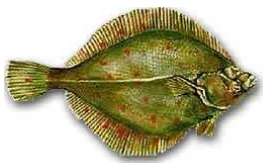


...But may be an ecological response

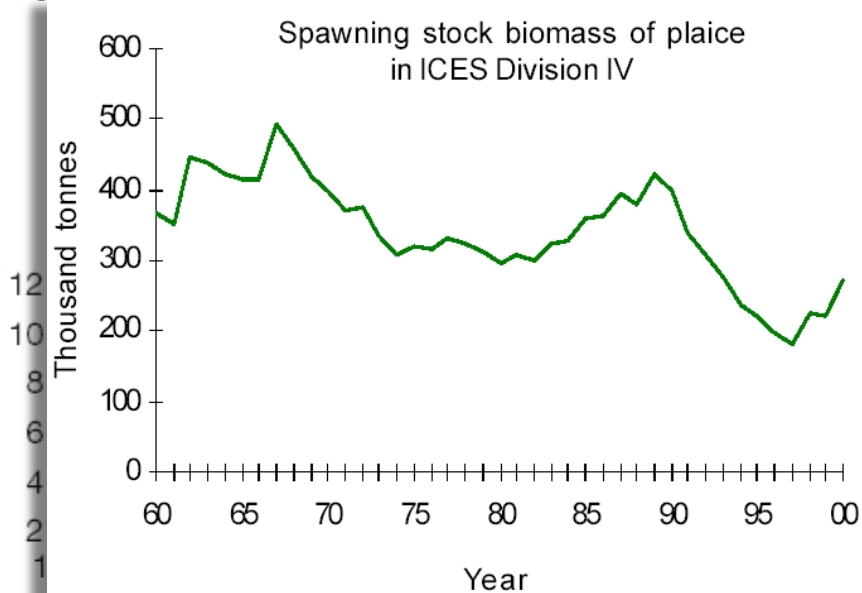
growth  
rate  
(cm/yr)



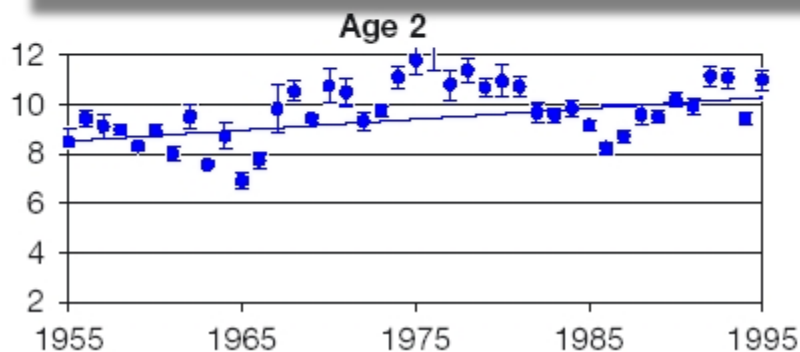
growth rates have  
increased



# ...But may be an ecological response



growth  
rate  
(cm/yr)



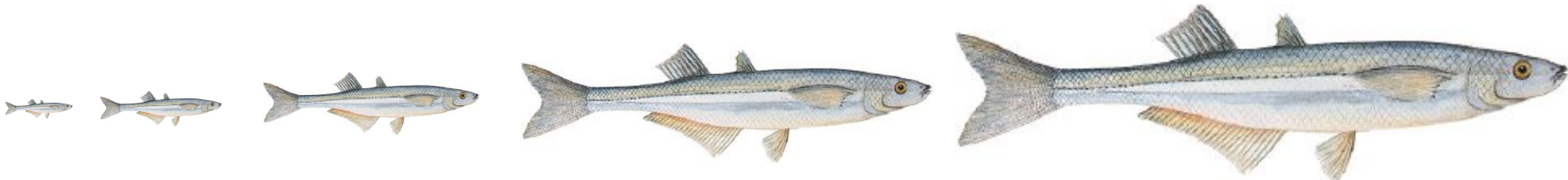
growth rates have  
increased,  
in response to  
reduced  
population size

# Question: to unravel

- Ecological response to harvesting
  - population size
  - individual growth rates
- Evolutionary response to harvesting
  - genetic changes due to size-selectivity

# The importance of body size

- Harvesting is size-selective
  - Individual growth is important
  - Ecological role (‘function’ in ecosystem) depends on body size
- size-structured population models appropriate to represent this system



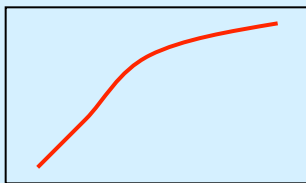
# Two theoretical tools

- Ecological response
  - Physiologically structured population models
- Evolutionary response
  - Models of adaptive dynamics

# The essence of the tools

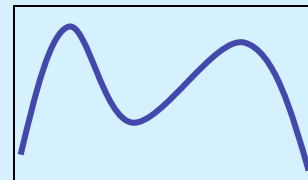
- Physiologically structured population models
  - Account for individual life history and its dependence on the population / environment

*length*



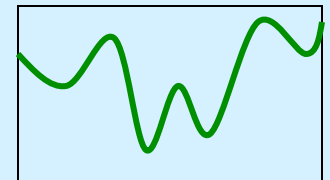
*age*

*number of individuals*



*length*

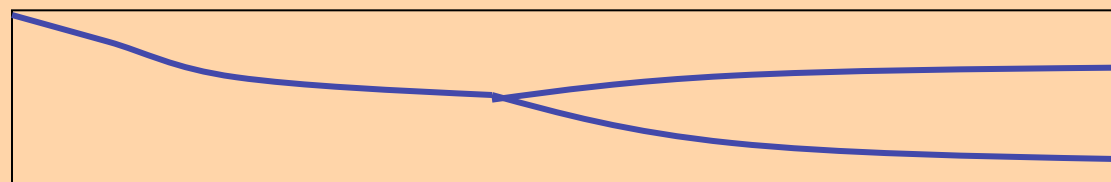
*food*



*time*

- Models of adaptive dynamics
  - Predict the course and endpoint of evolution, given the context set by an ecological model

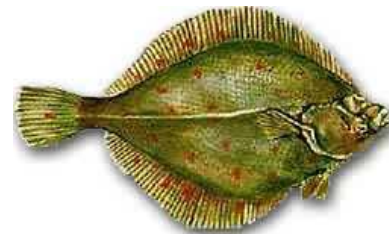
*maturation length*



*time*



# Evolution of size at maturation: the role of resource level



# Evolution of maturation size

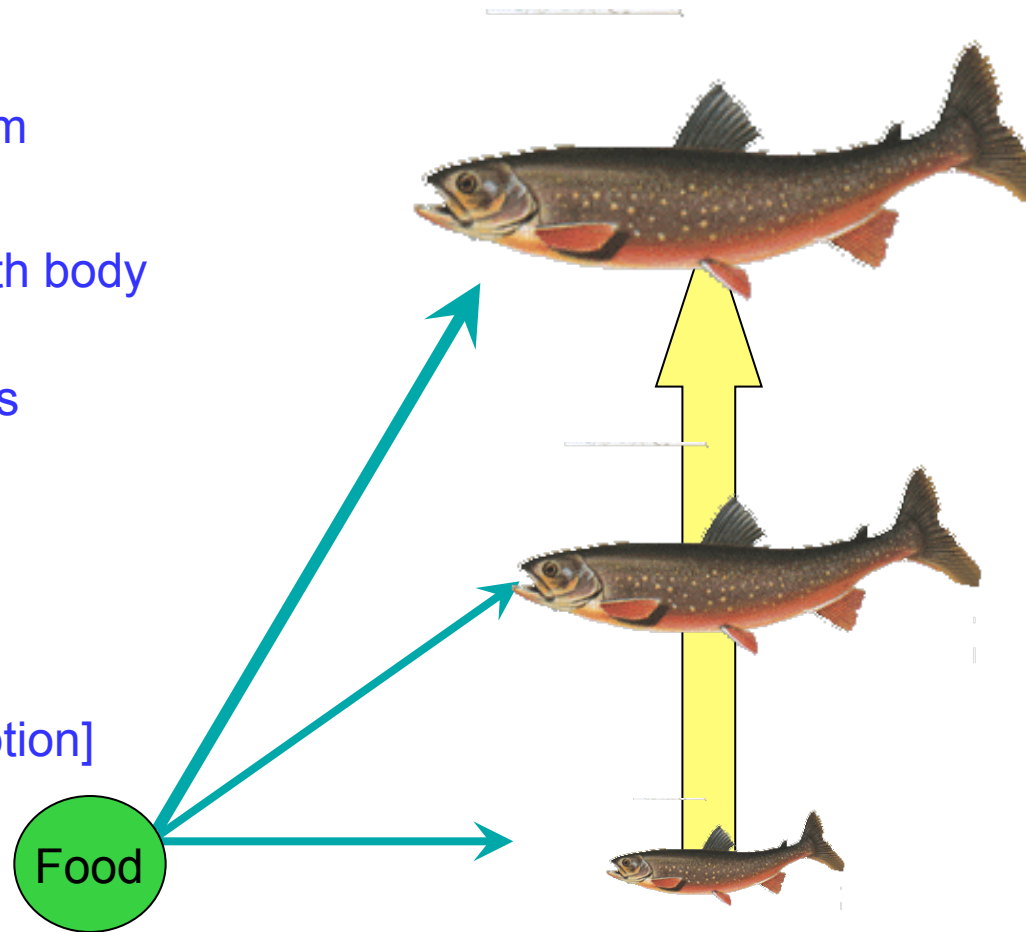
- Classical life history theory predicts:
  - Evolutionarily stable (ESS) size at maturation decreases when mortality increases
- Derek Roff's *fish model* (Roff 2002) :
  - Fecundity =  $a L^b$
  - von Bertalanffy growth
- Predictions:
  - optimal age,  $\alpha$ , at first reproduction
  - optimal size,  $L(\alpha)$ , at first reproduction
  - ... both decrease with mortality  $M$

$$\alpha = \frac{1}{k} \log \left( \frac{bk}{M} + 1 \right)$$

$$L(\alpha) = L_{\infty} \left( \frac{bk}{bk + M} \right)$$

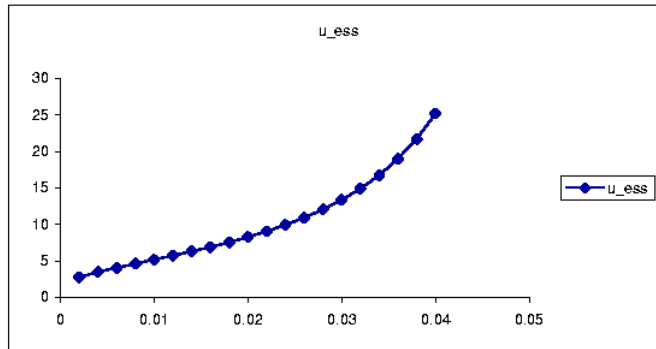
# The size-structured model

- Dynamic Energy Budget model
  - $\text{Growth} = \text{Assimilation} - \text{Metabolism}$
- Individual biology:
  - Consumption rate increases with body size
  - After maturation, 80% of surplus energy invested in reproduction
  - Size-independent mortality
  - Size-dependent harvesting
- Resource dynamics
  - $dR/dt = [\text{renewal}] - [\text{total consumption}]$
- Size at maturation evolves

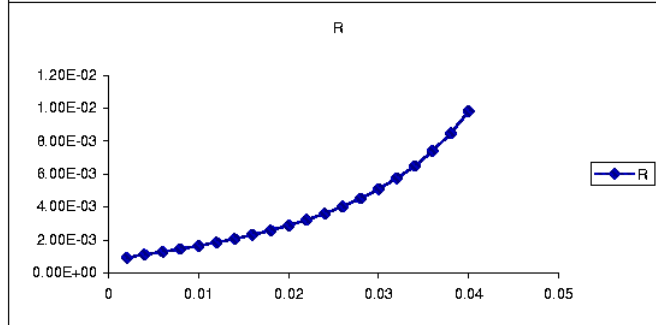


# Effect of mortality

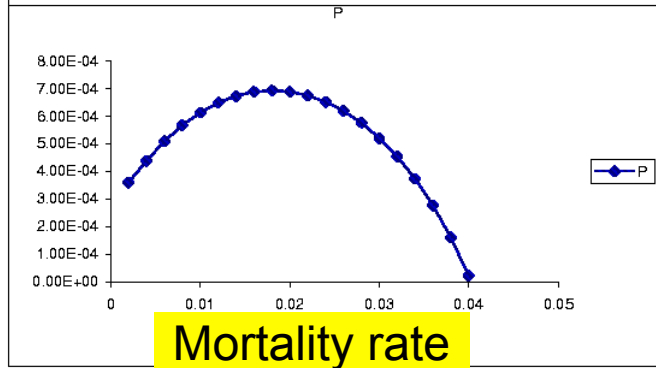
Size at maturation



Resource level



Population density



Mortality rate

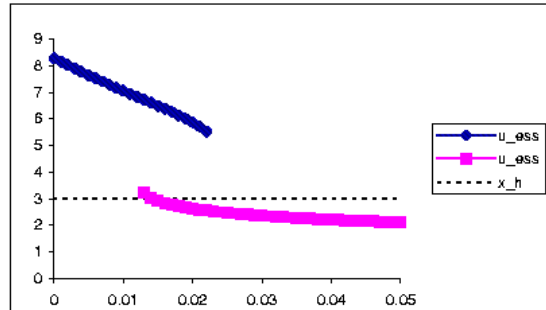
Evolutionary stable maturation size **increases** with mortality

Resource level increases with mortality

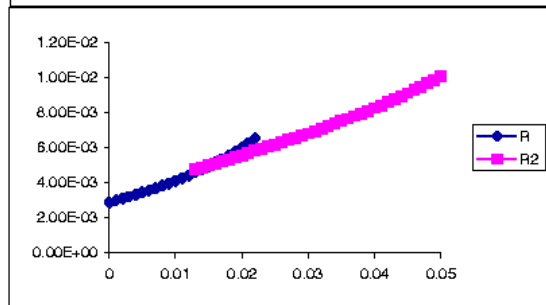
Faster growth; shorter juvenile period; higher survival until maturation

# Size-dependent harvesting

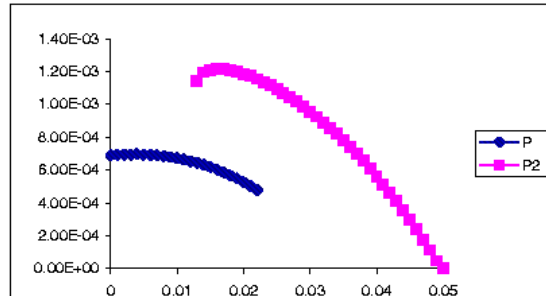
Size at maturation



Resource level



Population density



Harvesting rate

Evolutionary stable maturation size decreases with harvesting mortality

Resource level increases with harvesting

Multiple evolutionary stable states:

1. Minimise harvesting (early maturation)
2. Maximise reproduction (late maturation size)

# Conclusions (of this part)

- This (preliminary) study suggests that if
  - body growth depends on food intake
  - food intake depends on population size
- ESS maturation size may increase with mortality
  - cf. increase  $k$  in Roff's (2002) model
- Selective harvesting on large individuals selects for smaller maturation size
- But there can be multiple ESS life histories:
  - Gradual increase in harvesting can have catastrophic effect
  - Abrupt jump to small optimal maturation size
  - Reversal requires very large reduction in harvesting
- NB pulsed reproduction changes predictions! (D. Boukal)