

# The bio-economic consequences of fishing-induced evolution

## Modelling the quantitative impact



AARES annual conference 2011

11.02.2011

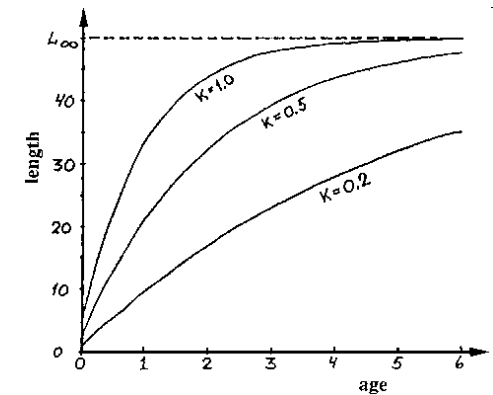
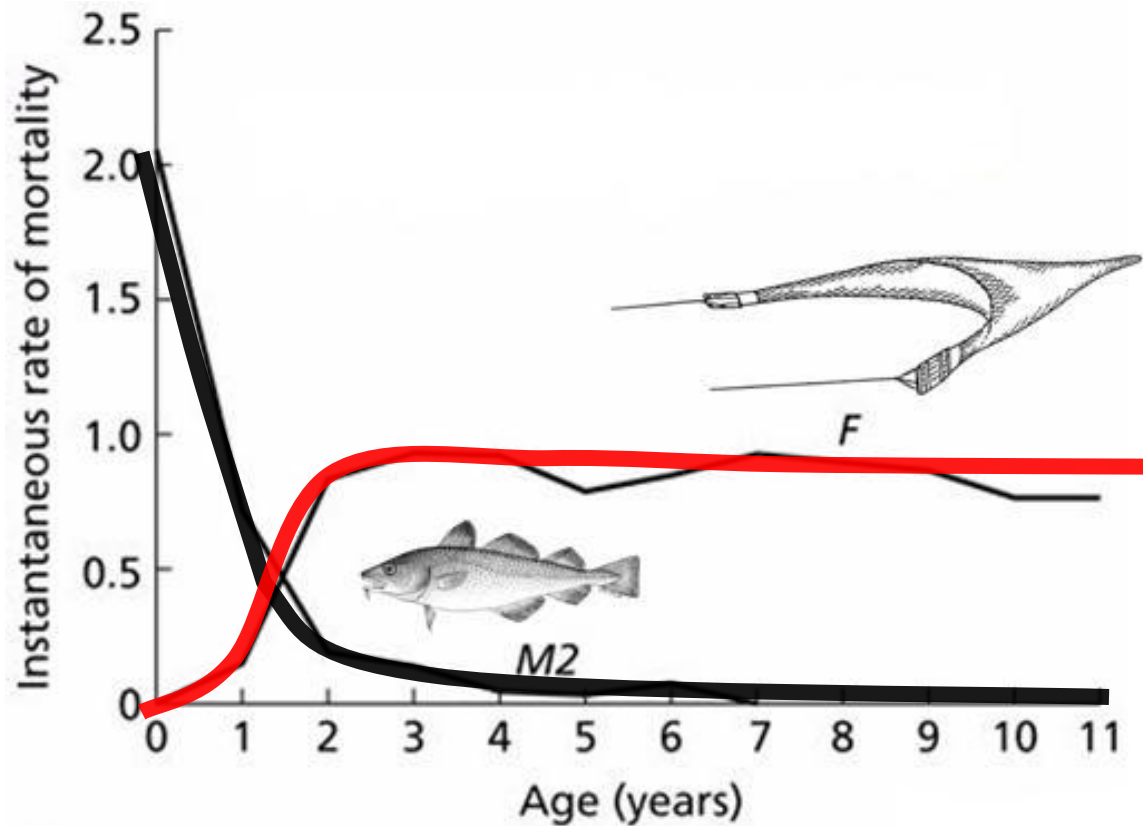
Fabian Zimmermann and Christian Jørgensen



UNIVERSITY OF BERGEN

# Mortality

Natural mortality vs. **fishing mortality**

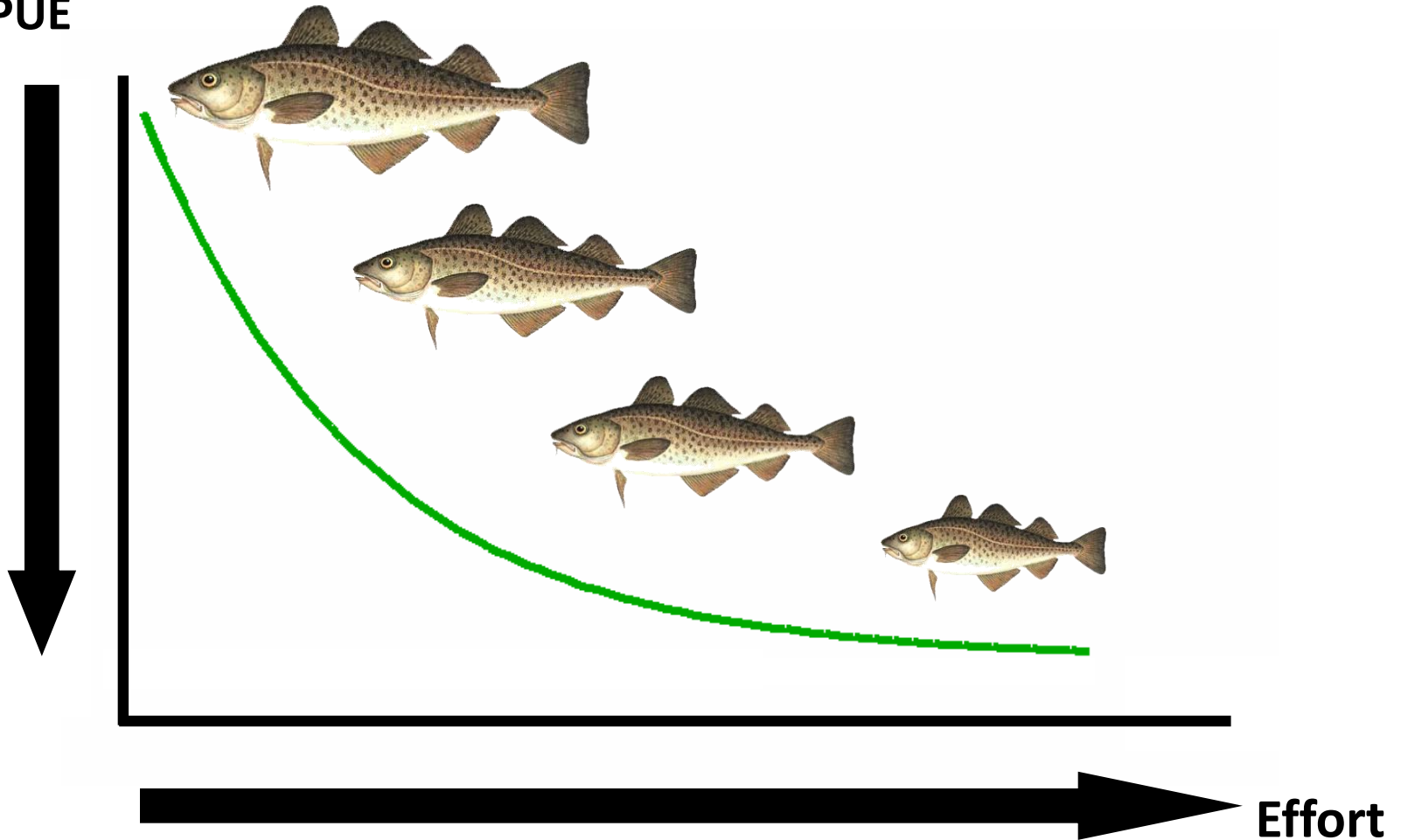


≈ Size (e.g. Von Bertalanffy Growth Function)



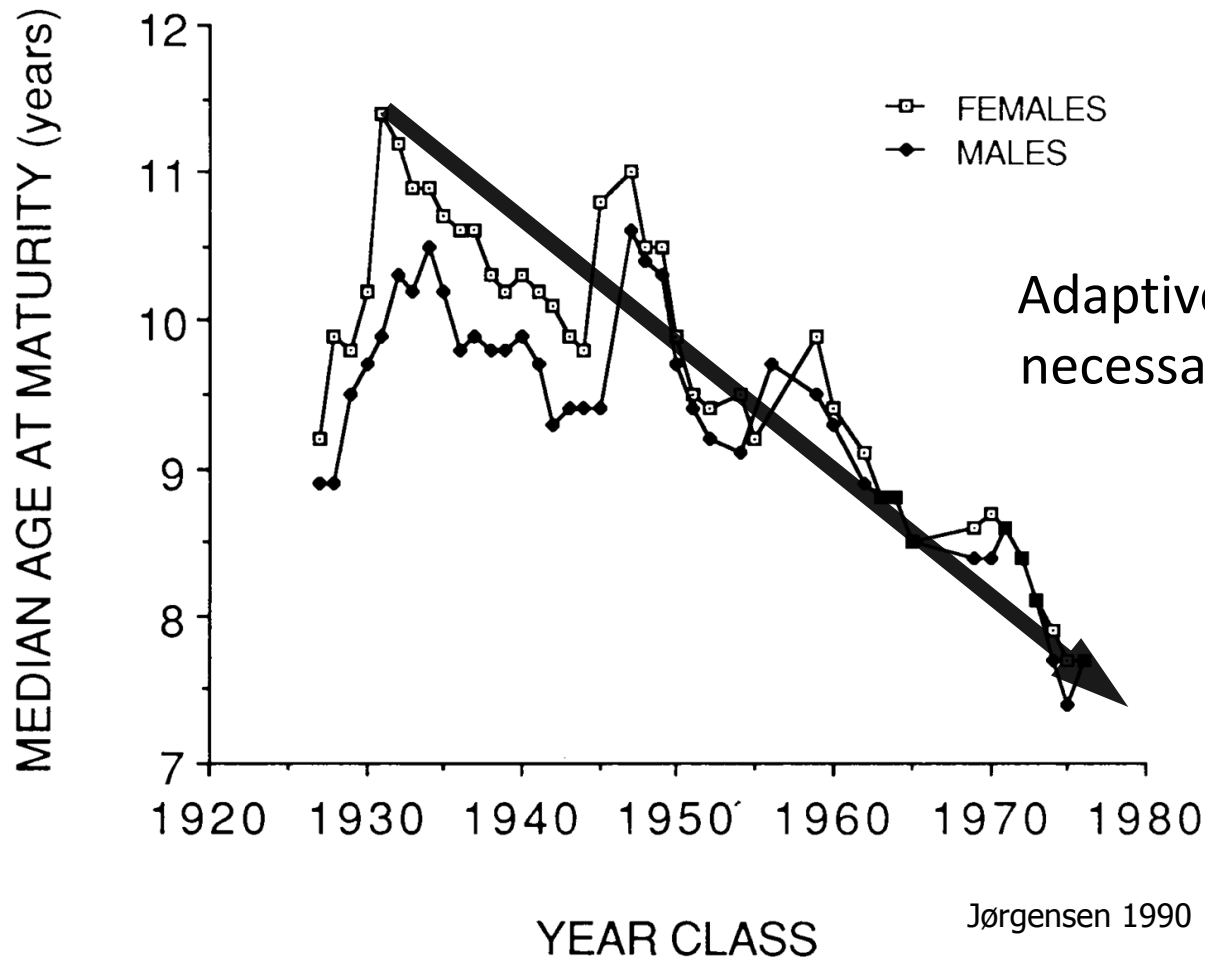
# Catch weight

CPUE



# Maturation age

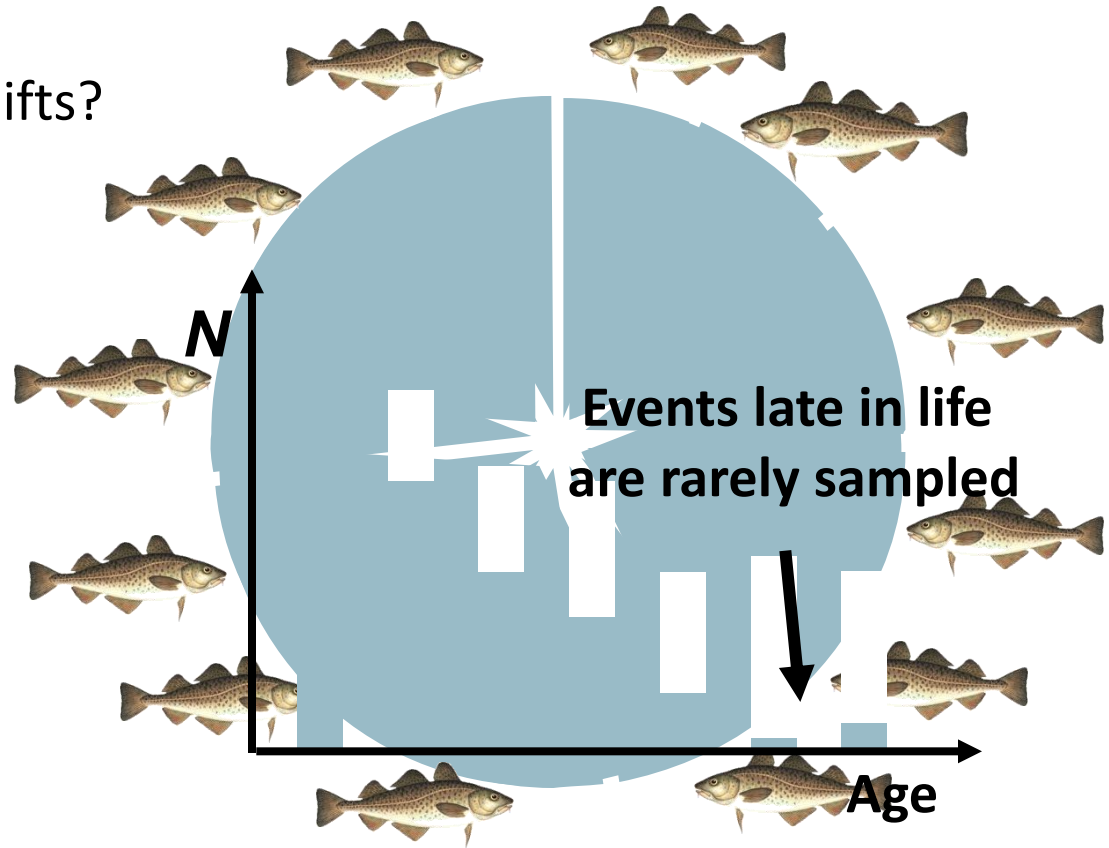
Age at maturity in Northeast Arctic Cod



# Fisheries induced evolution

How to explain trait shifts?

- Demographic response
- Released density dependence and phenotypic plasticity
- Evolutionary response



C. Jørgensen 2009



# Evidence for fishing-induced evolution

- time-series analysis of fisheries data  
(Ricker 1981, Heino et al. 2002, Swain et al. 2007)
- evidence of reduced homozygosity in harvested populations  
(Smith et al. 1991)
- experimental evolution under controlled conditions  
(Silliman 1975, Reznick and Ghalambor 2005, Conover et al. 2009)
- modeling and theoretical work  
(e.g. Dunlop et al. (2009))

C. Jørgensen et al. 2007

Harvest-induced evolutionary changes in marine and freshwater fish.

Evolutionary change	No. of species	No. of studies	Change % (n)
Maturation at lower age	6	10	23–24 (1)
Maturation at smaller size	7	13	20–33 (3)
Lower PMRN midpoint	5	10	3–49 (13)
Reduced annual growth	6	6	15–33 (3)
Increased fecundity	3	4	5–100 (3)
Loss of genetic diversity	3	3	21–22 (2)

# Impact on fisheries

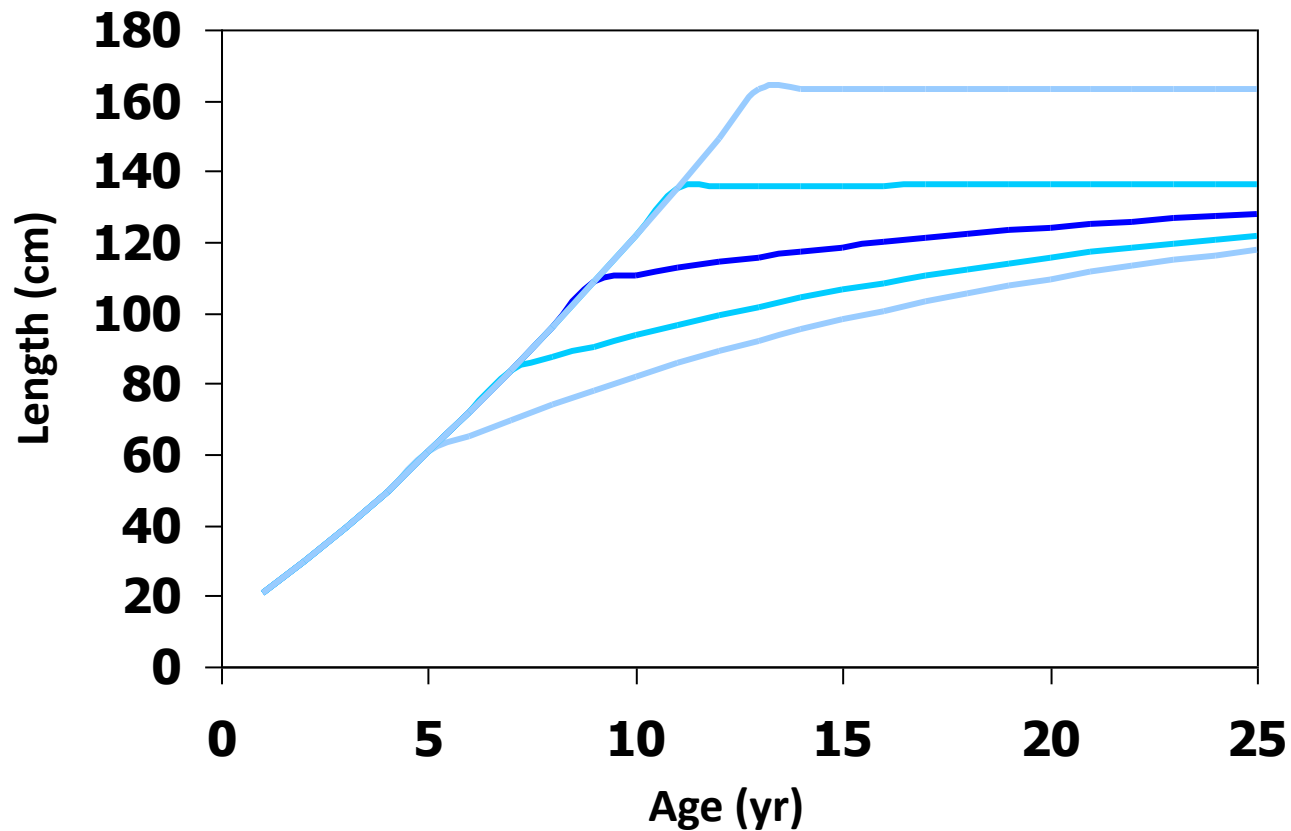
Increasing calls for management consideration:

(Heino 1998, Conover and Munch 2002, Ashely et al. 2003, Jørgensen et al. 2004, Dunlop et al. 2009, ICES working group)

But what about economics?

- Quantification of impact through comparison of a cod-like fishery with and without “evolution”
- Focus on age at maturation as one evolving quantitative trait
- Long-term assessment with management based on constant input control (fishing mortality and size selectivity)

# Model – Growth trajectories



$$L(a, a_{mat}) = \frac{L_{\infty} - 1, a_{mat}^{b_1 b_2} + b_2 G(a - 1, a_{mat}) a_1^{-b_2}}{1 + b_2 GSI(a)}$$

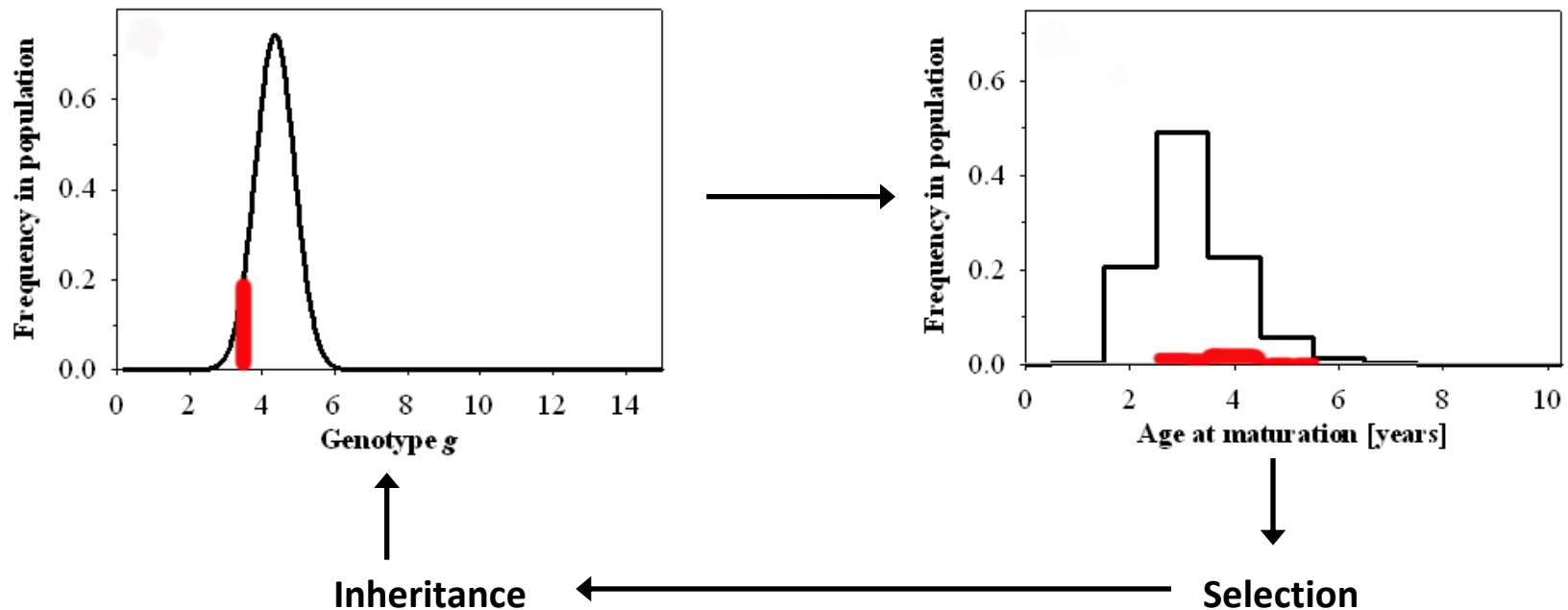
(Enberg et al. 2009)

(Quince et al. 2008)

# Model – Evolutionary cycle

One evolving quantitative trait: Age at maturation

$$a_{mat} = g_{cat} + \delta_{D+E}$$

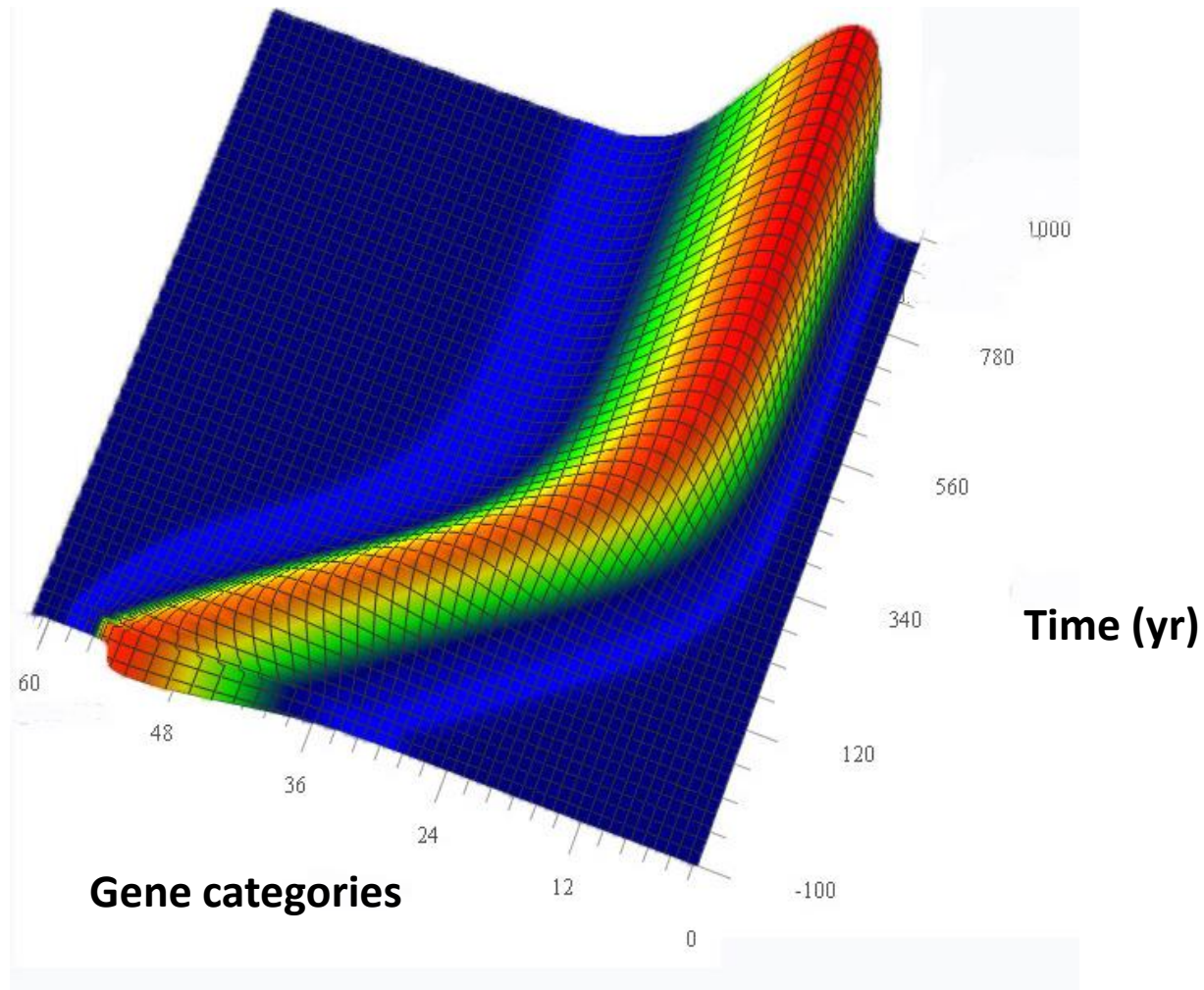


(Jørgensen et al. 2010)

Maturation age defines the trajectories for growth/fecundity/survival

# Model – Genotypic distribution

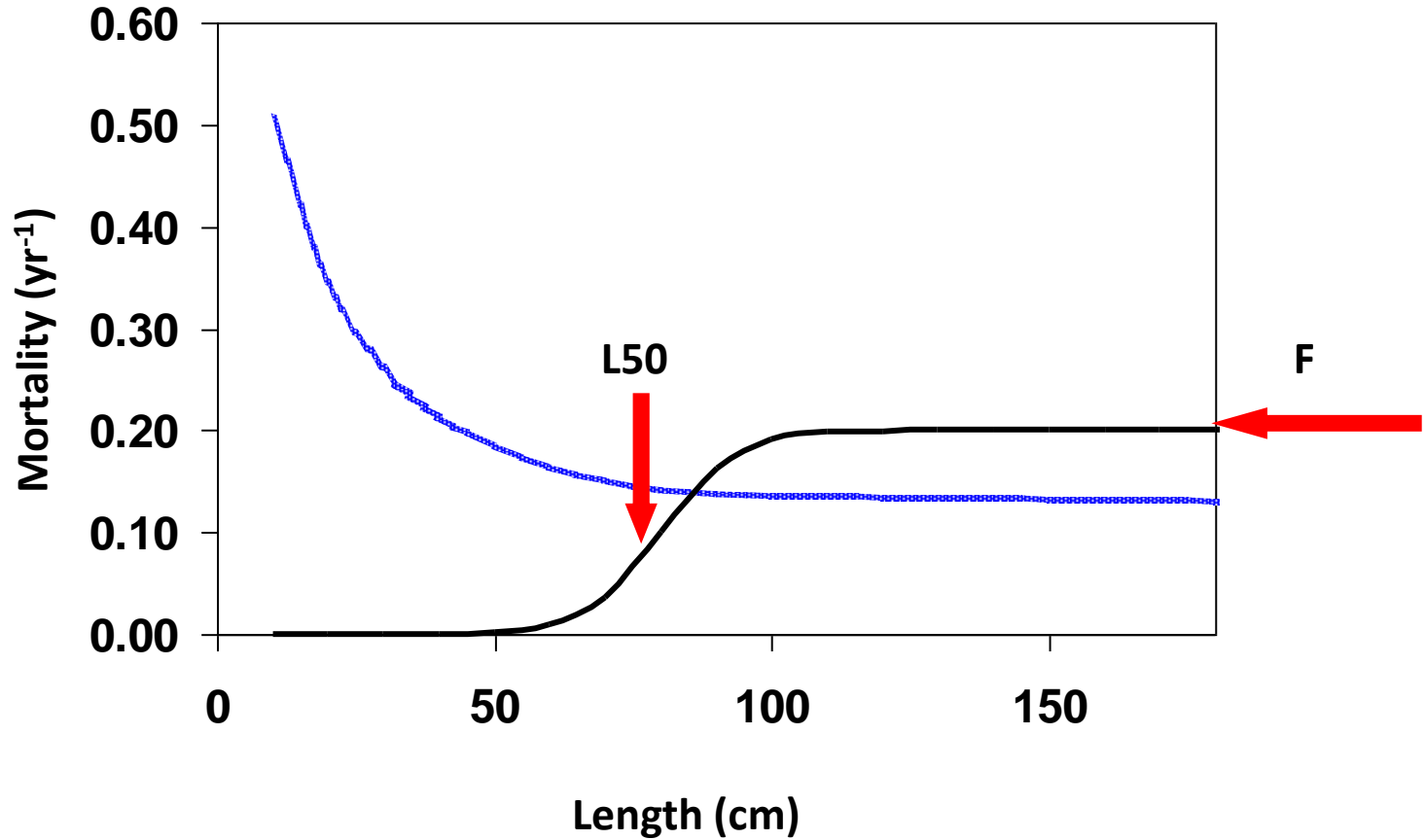
Changes in distribution for specific fishing pattern



# Model – Fishing selectivity

Natural mortality (Gislason et al. 2010)

Fishing mortality



# Model

## Economics

- Constant price
- Output-regulated variable unit cost on fleet level:

$$\frac{C}{Y} = \alpha Y(t)^{-\beta_1} X(t)^{-\beta_2} \quad (\text{Sandberg 2008})$$

Cost coefficient

Yield elasticity

Stock elasticity

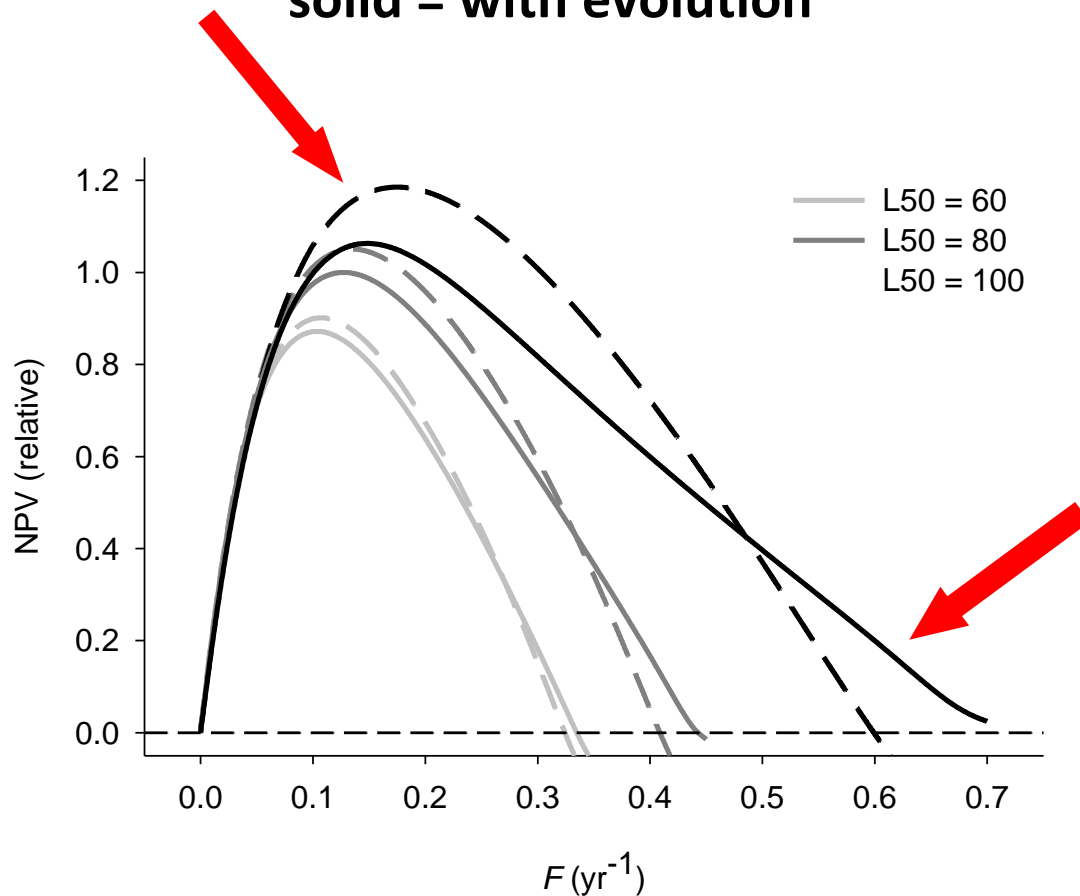
- Parameters estimated from Norwegian cod fisheries

## Simulation

- 300 years for equilibration of population size and demography
- 1000 years of fishing
- Control variables (F and L50) assumed constant over the whole period

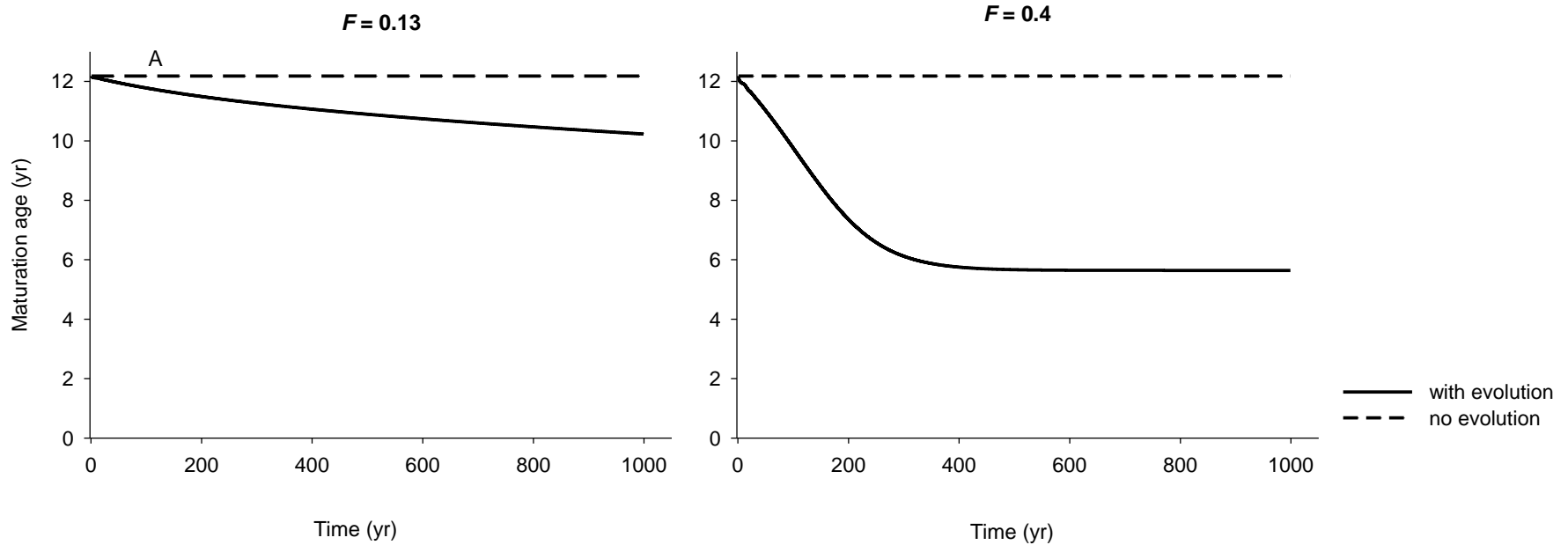
# Results

Net present value ( $d=0.01$ )  
dashed = assuming no evolution  
solid = with evolution



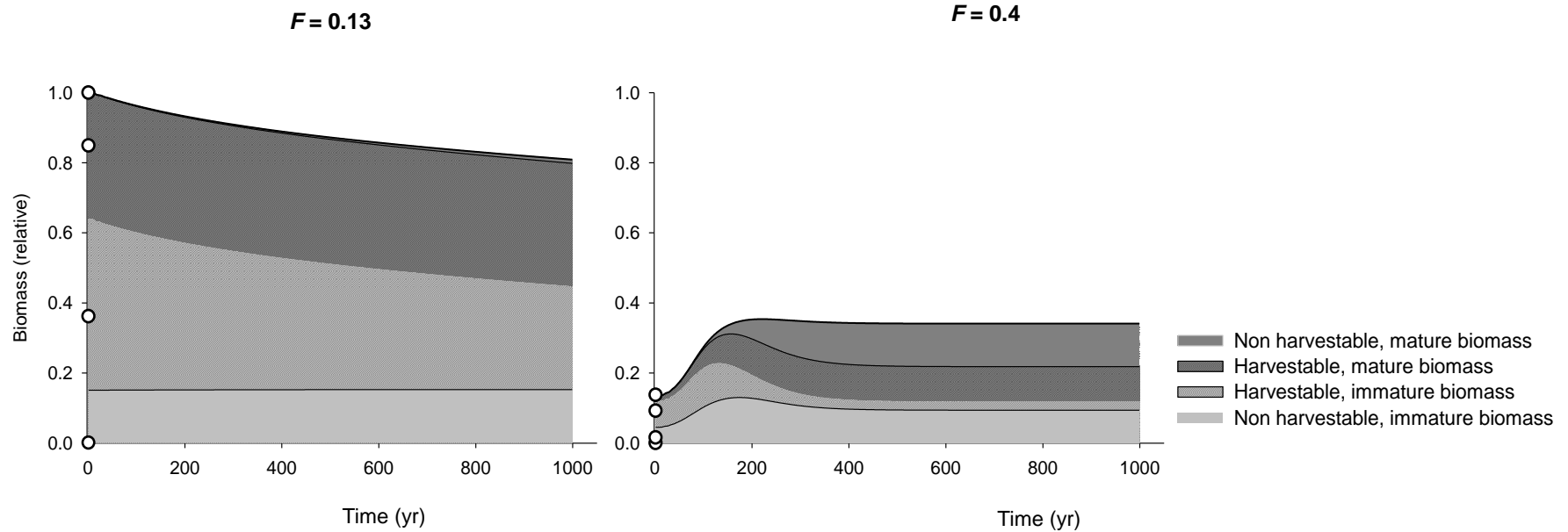
# Dynamic under low and high fishing

**L50 = 80cm**  
**Age at maturation**



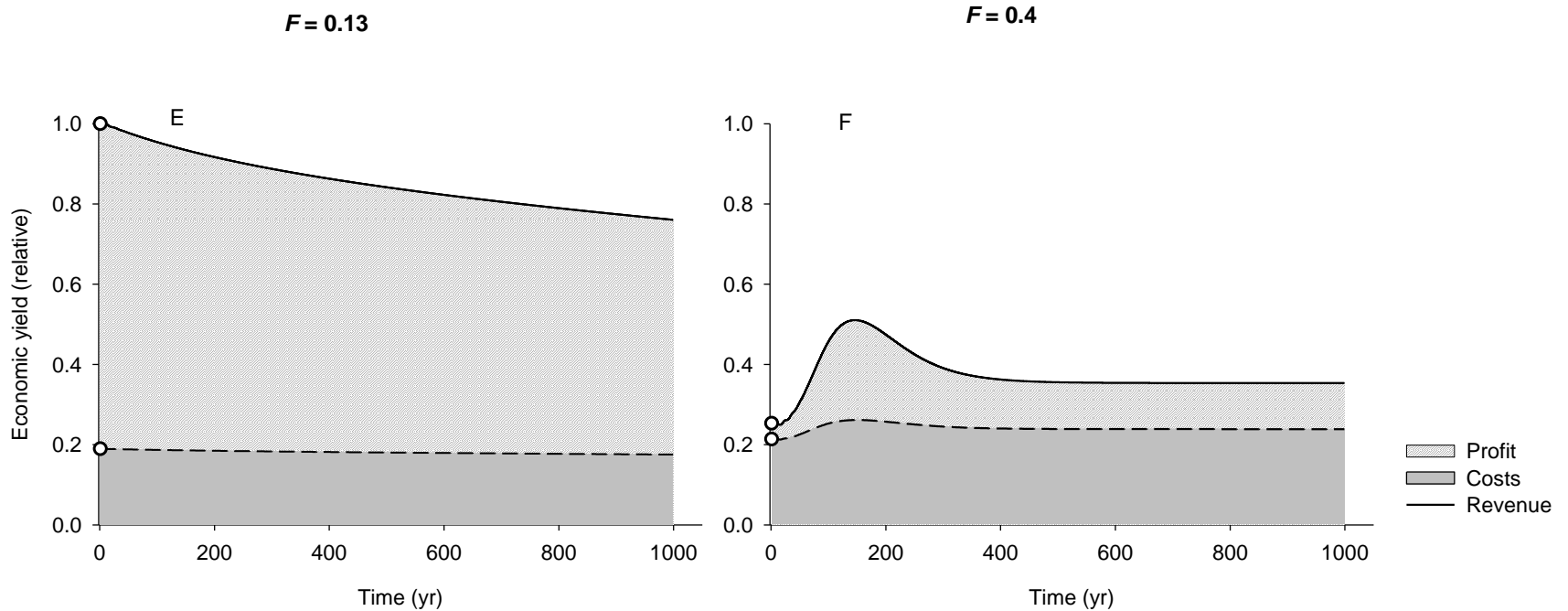
# Dynamic under low and high fishing

## Stock biomass



# Dynamic under low and high fishing

## Revenue/Costs

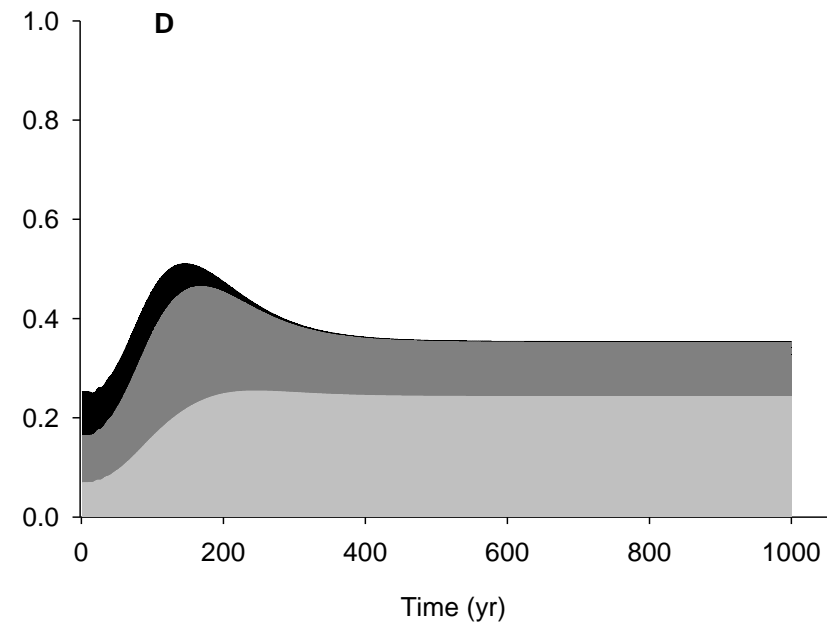
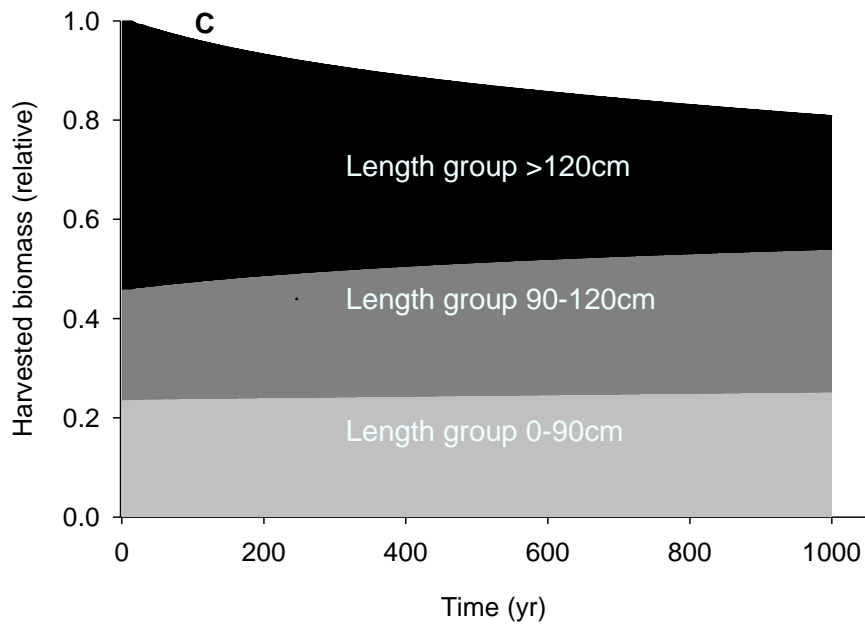


# Dynamic under low and high fishing

## Length distribution in harvested biomass

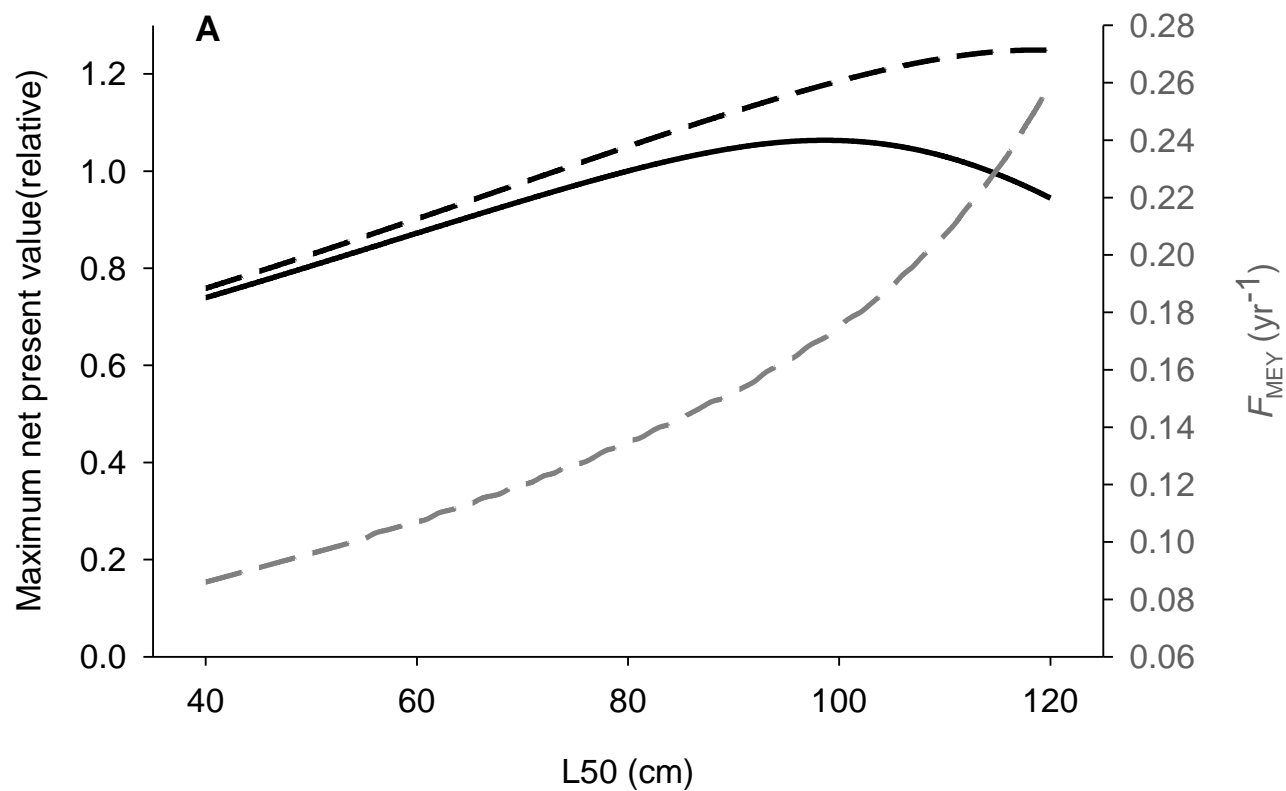
$F = 0.13$

$F = 0.4$



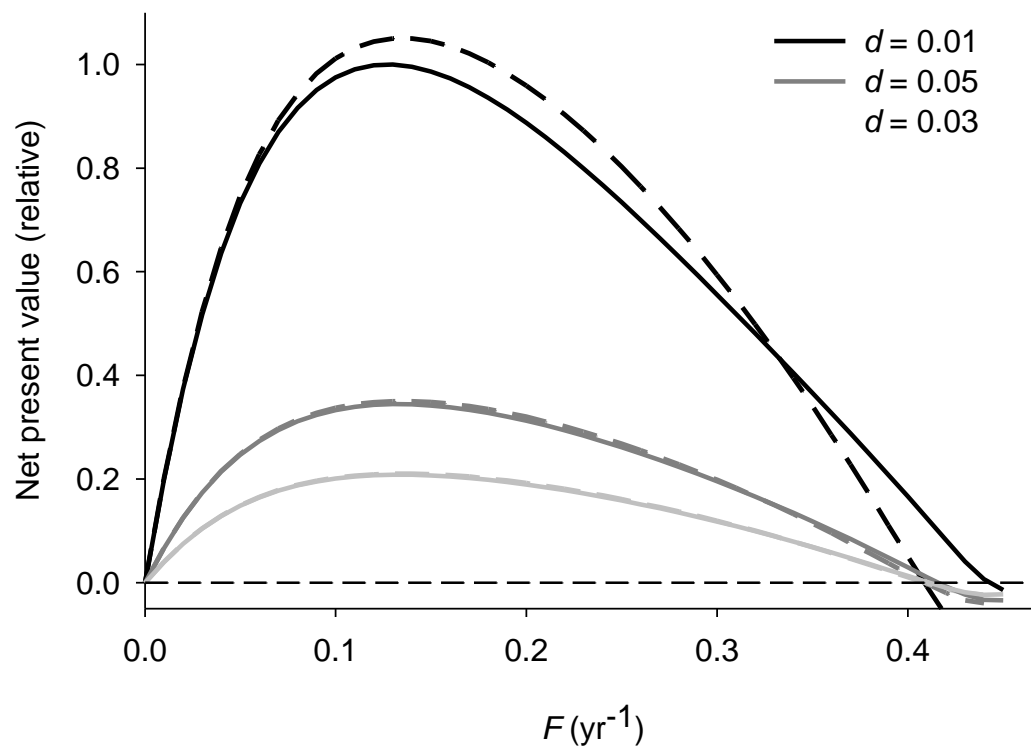
# Results

## Influence of size selectivity



# Results

## Sensitivity to discount rate



# Conclusions

- Economic long-term consequences of FIE ambivalent
  - Evolutionary cost for optimal/intermediate F
  - FIE beneficial for higher levels of F (however, effect driven by a boost early on)
- Relevance of FIE depends on size-selectivity
  - Fishing selectivity defines the evolutionary potential
- Economic relevance of FIE sensitive to discounting
  - Significant differences even for small changes on low discount rates

**Thank you for your attention..**

