Foto: Martina Bleil

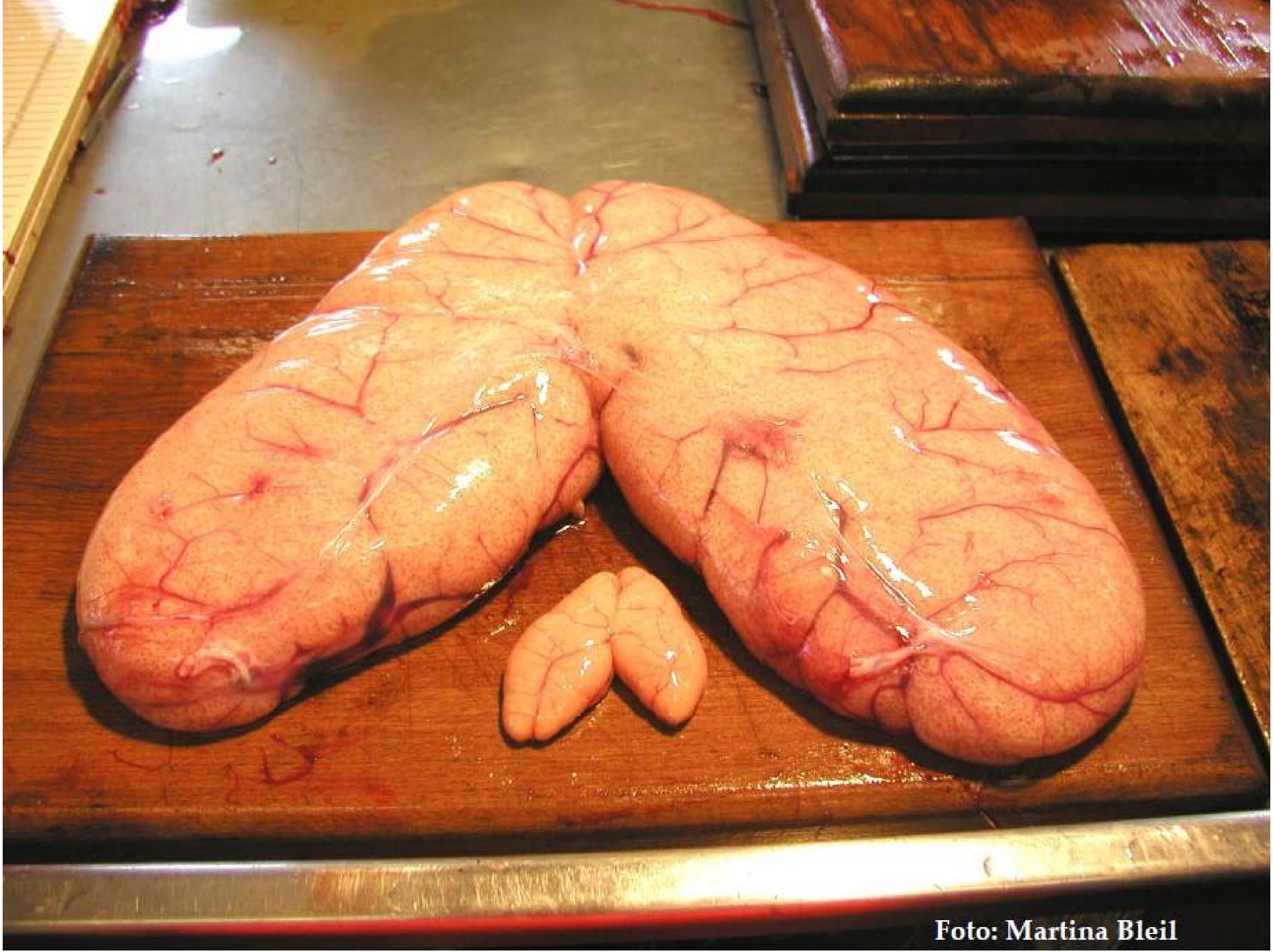
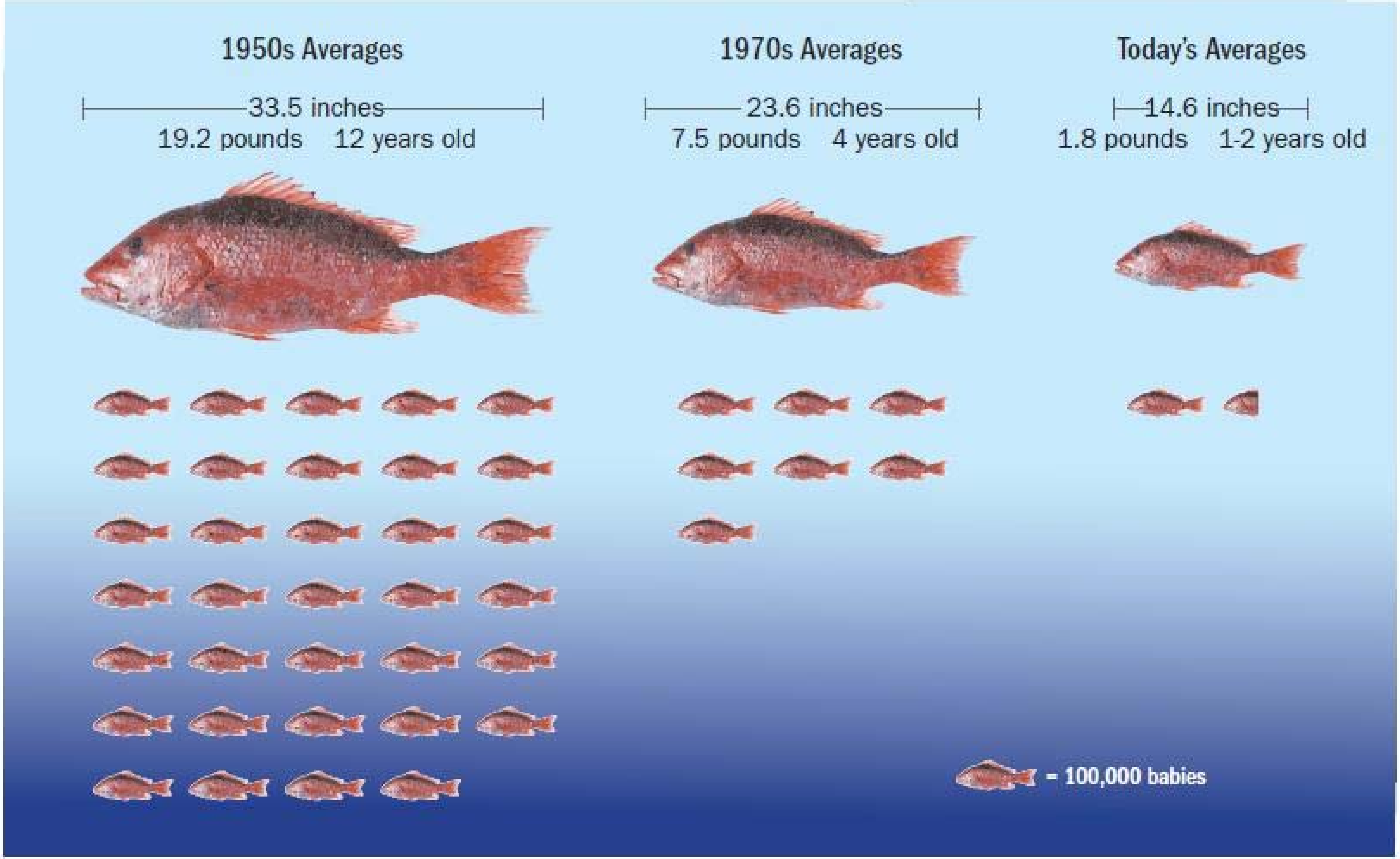


Foto: Martina Bleil

Figure 1. Red Snapper Overfishing: Smaller Fish, Fewer Babies

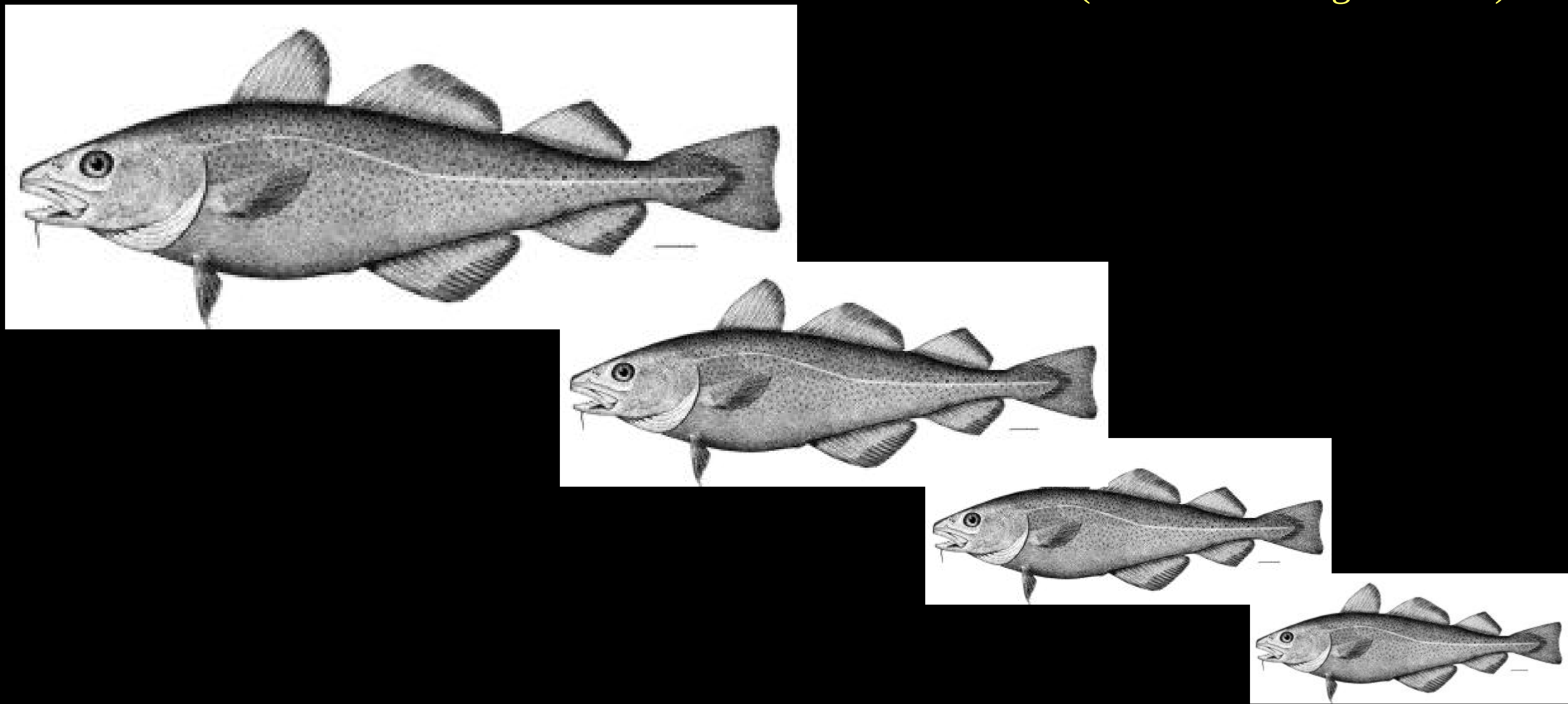


Source: Pew Environment Group

"Fifty years ago, a single cod was large enough to feed a family of four or five. Today it is barely enough for one"

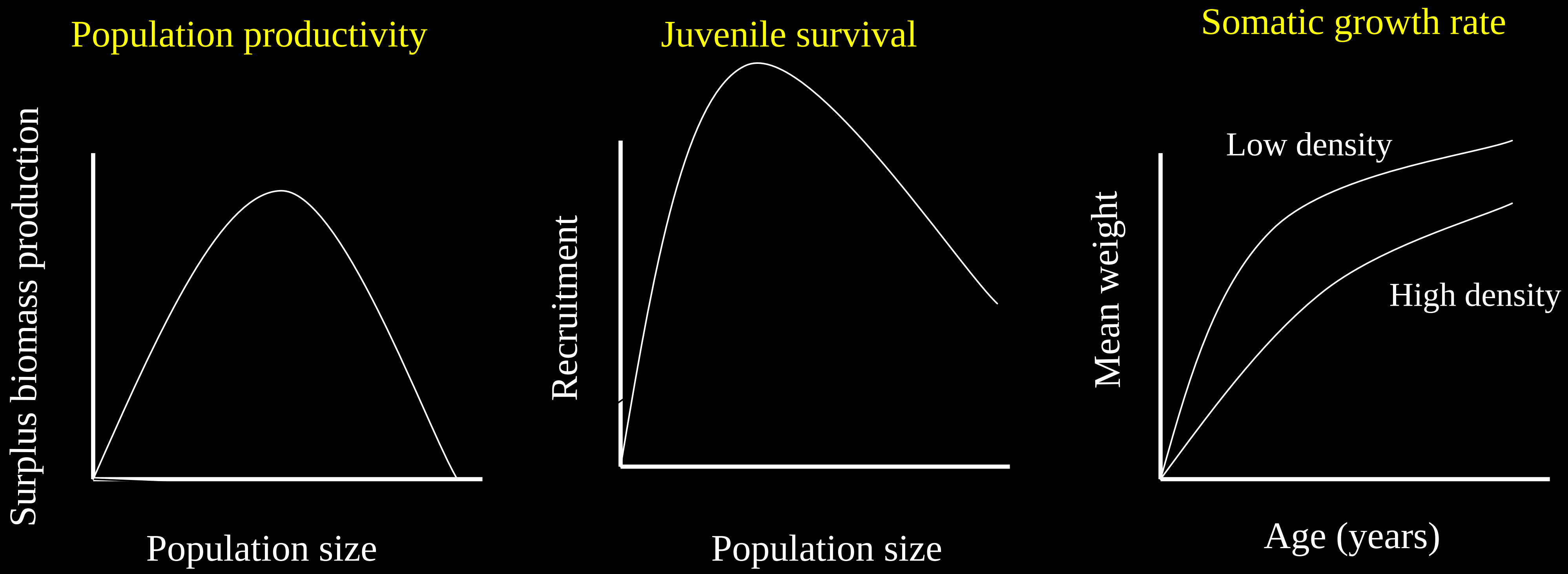
Lord Perry of Walton, UK House of Lords (1997)

(as cited in Stergiou 2002)




Minimum size limit:
Harvest larger sizes
Cohort biomass
Age or size

Density-dependent, ecological responses to harvest



Are fishery harvests purely a thinning process as in mowing a lawn?

or

Are fisheries a selective process the removes the more susceptible genotypes?

How do we disentangle environmental and genetic influences on phenotypic variation?

Approaches:

1. Analyze long term trends in field data and develop methods to account for environmental plasticity.

2. Conduct field experiments on model species.

3. Conduct experiments on model species under standardized environmental conditions (“common garden”).

Exploitation-induced evolution in the lab

David O. Conover
Marine Sciences Research Center
Stony Brook University
Stony Brook, NY, U.S.A.

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Outline of presentation

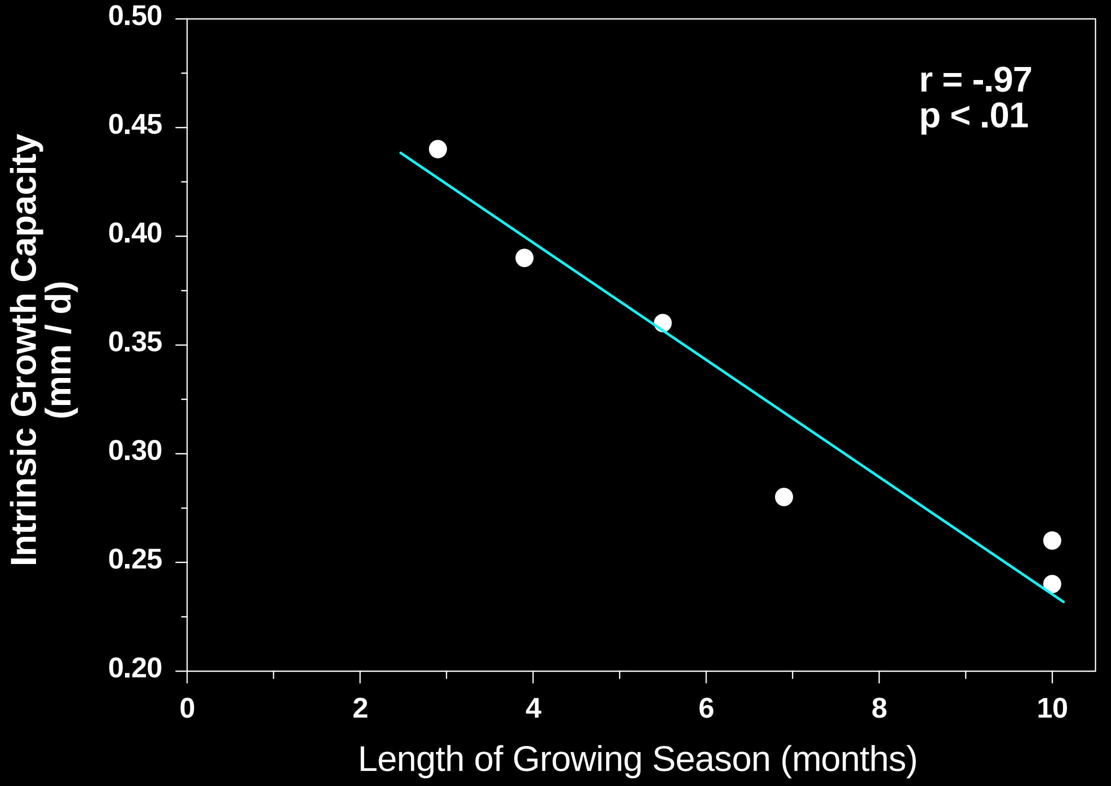
- Introduce model species, *Menidia menidia*
- Growth variation in nature: its physiological basis, and adaptive significance
- Size-selective harvest experiment
- Can we generalize from experiments on captive *Menidia*?

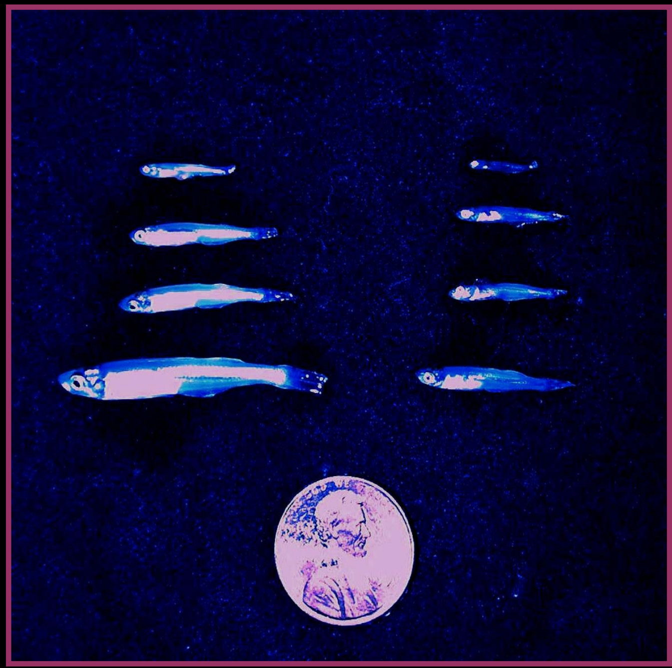
Ecology of *Menidia menidia*

- Distributed from Florida to Nova Scotia
- Typical life history:
  - mass spawner
  - high fecundity
  - 1 mm egg size
  - pelagic larvae
- Simple schooling behavior
- Annual life cycle
- Modest fishery harvest

Atlantic silverside

Capacity for growth is tightly correlated with latitude

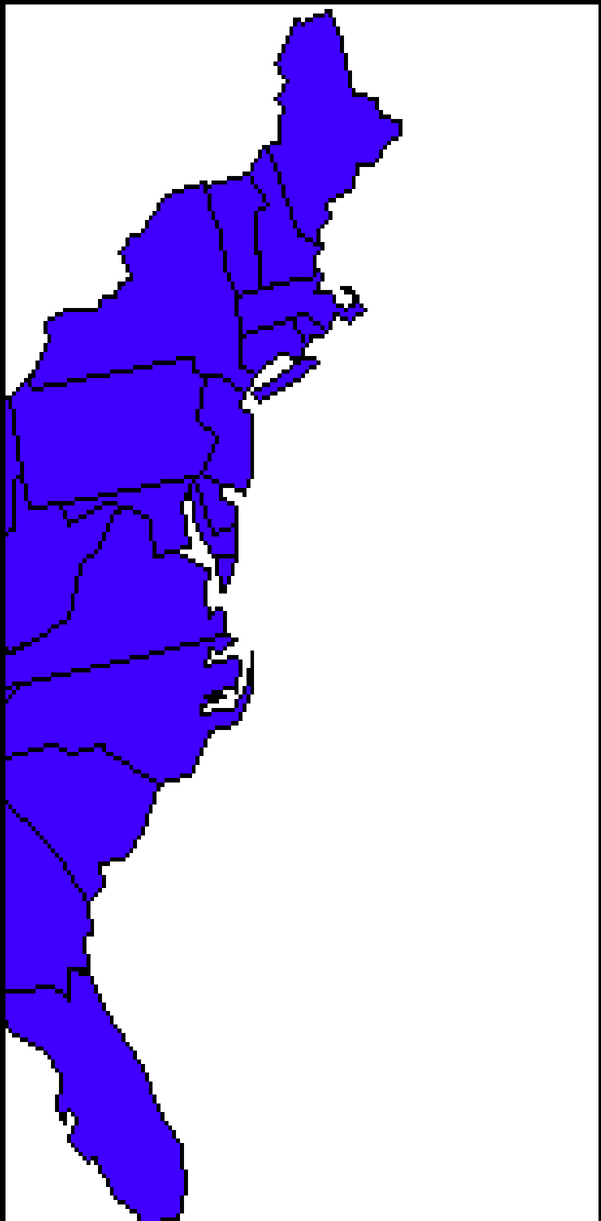




Correlated traits

Fast-growing northern fish have **higher**:

- Rates of energy consumption
- Metabolism
- Growth efficiency
- Lipid energy reserves
- Egg production rate
- Egg size
- Willingness to forage under threat of predation
- Number of vertebrae



Adaptive value of growth variation

Growing season	Winter duration	Size-selective winter mortality
short	long	intense
↓	↑	↑
long	short	minor

If the intrinsic rate of growth and correlated traits are capable of evolving in response to a natural gradient in size-selectivity (e.g., winter mortality), what about the response to size-selectivity imposed by harvest?

Can artificial selection on adult size lead to evolutionary changes like that observed in nature?

Design of fishing experiment

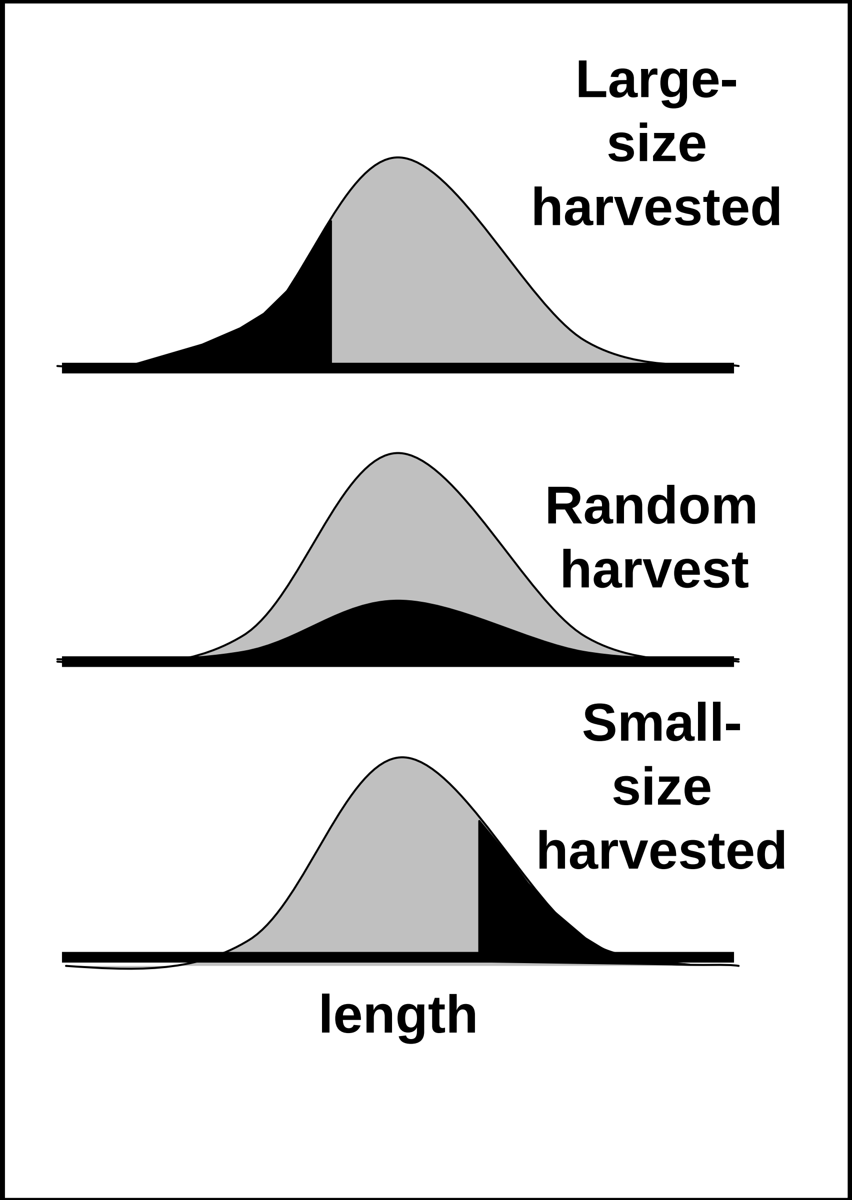
- Six populations founded from NY fish
- 90% harvest applied on day 190

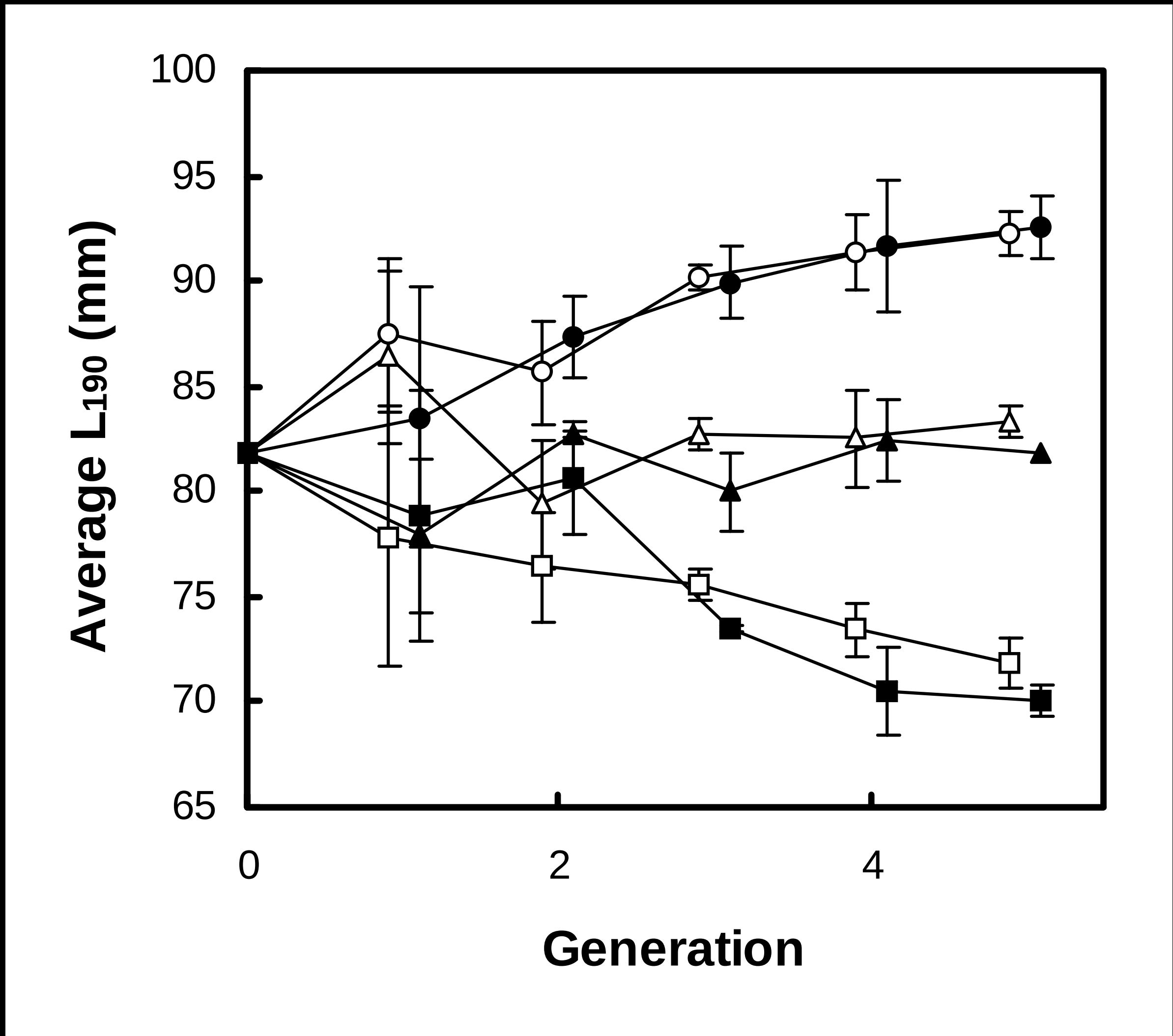
  n=2 large size harvested

  n=2 were small-size harvested

  n=2 harvested randomly

- *Prediction: somatic growth rate and population biomass will evolve in opposition to the size bias of the harvest regime*



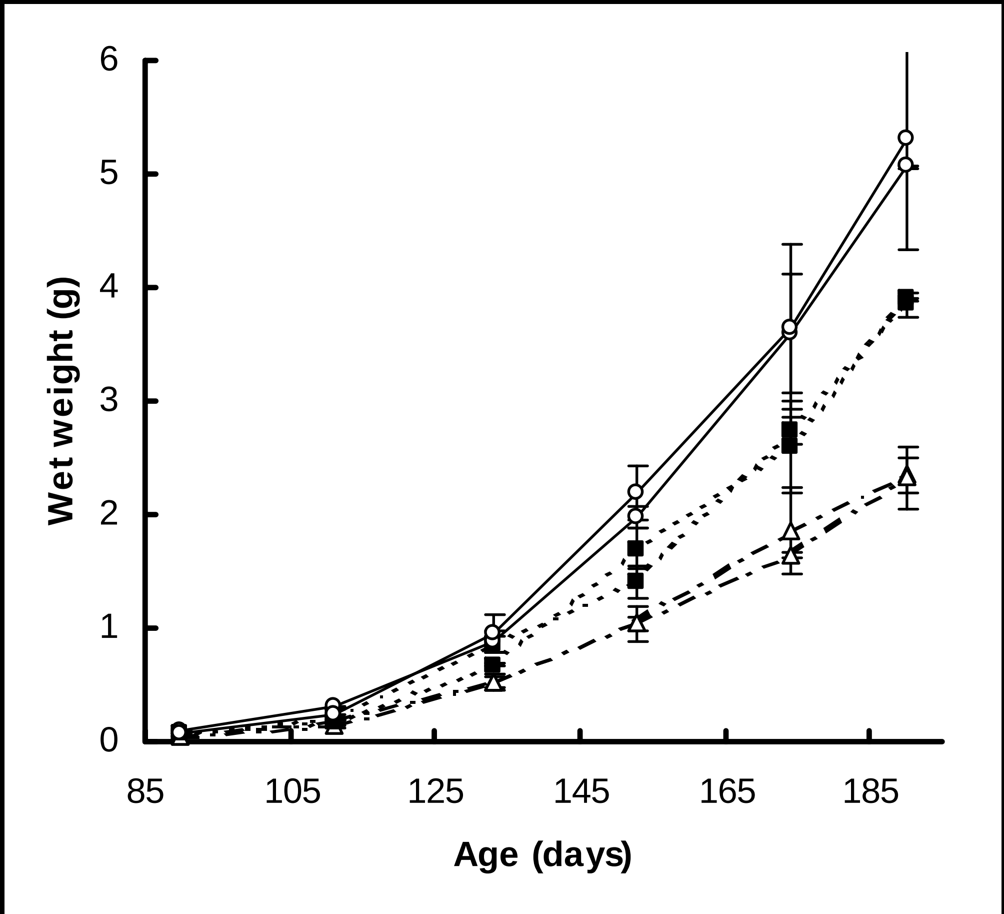


Small-size harvested

Randomly harvested

Large-size harvested

Growth trajectories after 4 generations

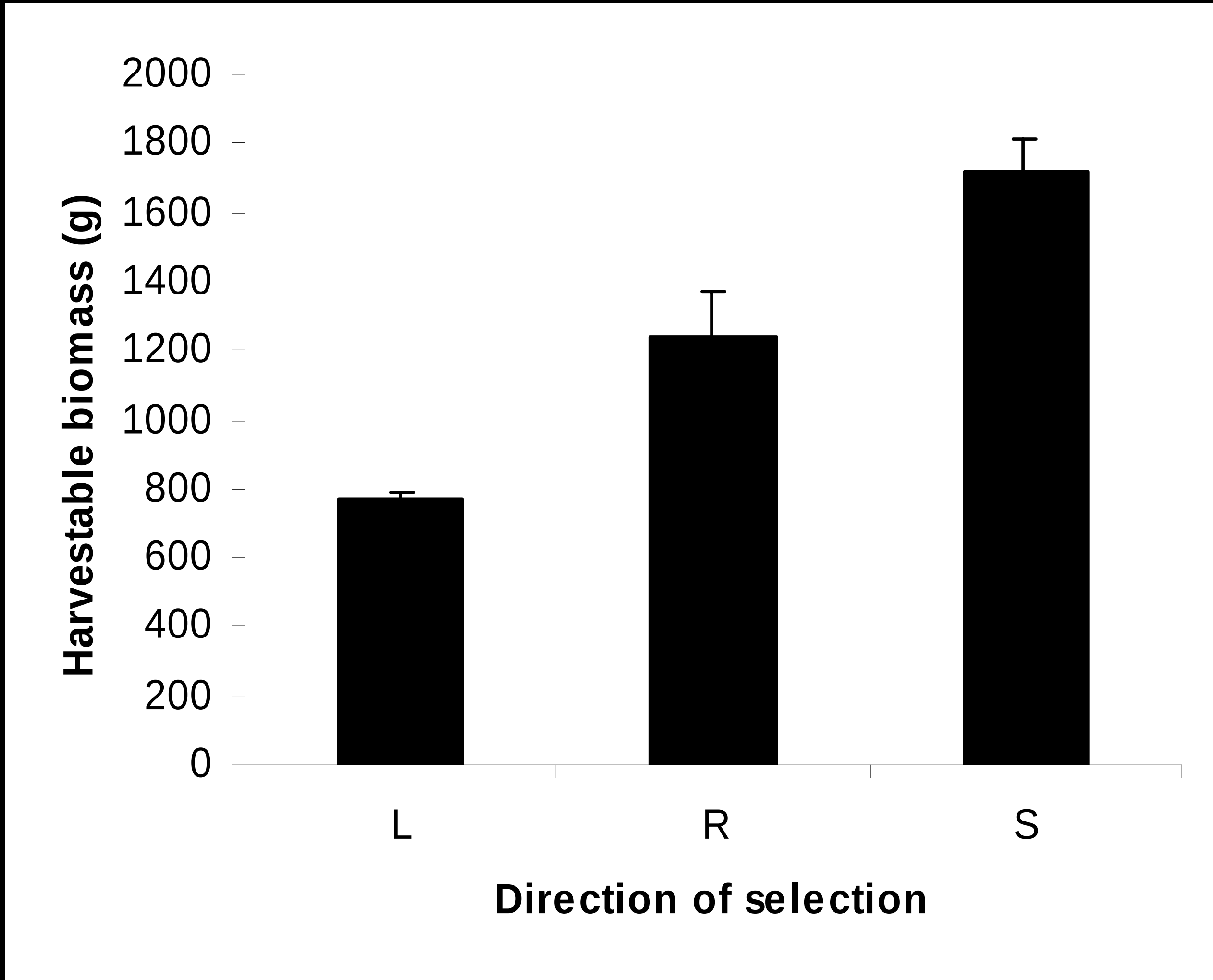


Small-size harvested

Randomly harvested

Large-size harvested

Harvested biomass



What about correlated changes in other traits?

Are the differences in physiology, behavior, and morphology of artificially size-selected fish similar to those in wild fish?

Summary of correlated changes in other traits

Reproductive traits

Egg size:	18% higher vol. in small-size harvested stocks
Length at hatch:	7% longer in small-size harvested stocks
Larval survival:	3-fold higher in small-size harvested lines
Larval growth rate:	20% higher in small-size harvested lines
Fecundity:	2-fold higher in small-size harvested stocks

Growth physiology:

Food consumption rate:	44% higher in small-size harvested stocks
Growth efficiency:	54% higher in small-size harvested stocks

Behavior:

Foraging	Small-size harvested fish are more risky foragers

Morphology

Vertebrae number	higher in small-size harvested stocks

Is *Menidia* a general model?

Heritability of 0.2 very common for life history traits

Genetic variation in growth with latitude now known to be widespread in numerous animals (molluscs, insects, amphibians, reptiles) and numerous fishes

Fishes with strong evidence of genetic variation in growth in the wild

Atlantic cod	*Gadus morhua*
Atlantic halibut	*Hippoglossus hippoglossus*
Atlantic salmon	*Salmo salar*
Atlantic silversides	*Menidia menidia*
Mummichog	*Fundulus heteroclitus*
Lake sturgeon	*Acipenser fulvescens*
Largemouth bass	*Micropterus salmoides*
Pumpkinseed sunfish	*Lepomis gibbosus*
Striped bass	*Morone saxatilis*
Turbot	*Scophthalmus maximus*

Should we expect similar evolutionary changes in wild harvested fish?

- Life history evolution occurs rapidly in the wild
  - Guppies (Reznick et al. 1990)
  - Salmon (Quinn et al. 2001; Hendry 2001)
  - Grayling (Haugen and Vollestad 2001)
- Fishing mortality rates are often 2-3x natural mortality
- Strongly size-selective
- Declines in size at age have frequently been observed in the wild harvested fish *(e.g., see Sinclair, Swain and Hanson 2002)*

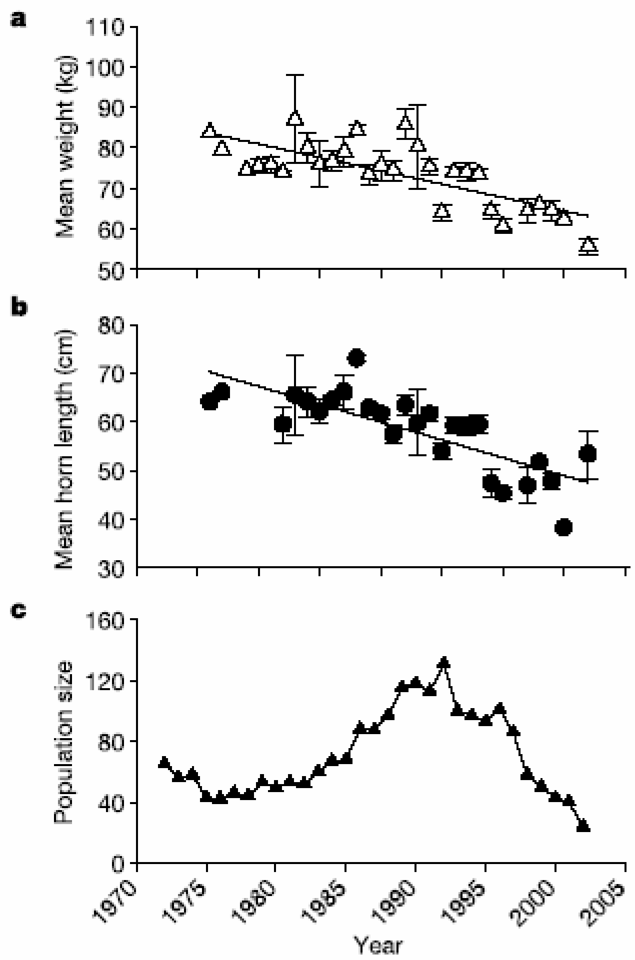


Figure 2 Observed changes in mean weight and horn length and in the population size from 1972 to 2002. **a**, Relationship between weight (mean ± s.e.m.) of 4-year-old rams and year ($N = 133$ rams). **b**, Relationship between horn length (mean ± s.e.m.) of 4-year-old rams and year ($N = 119$ rams). **c**, Changes in population size (taken as the number of ewes aged at least 2 years plus yearlings[17]) over time.

Alternatives

- Protect natural phenotypic variation:

e.g., use no-harvest reserves

- Consider protection of large fish by use of maximum size or slot limits

Conclusions

- Physiological rates and other life history traits vary genetically at the individual level and respond rapidly to selection
- By sorting genotypes according to their physiology, size-selective harvest may cause genetic changes in the productivity and yield of populations
- Fishery management theory must therefore predict and incorporate evolutionary changes due to harvest if population productivity is to be sustained