

Sensitivity of marine systems to climate and fishing: concepts, issues and management responses

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Photo: J. Alheit



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Effects of climate and fishing on marine systems often assumed to be “additive” i.e. not interacting

- implications:

- it should be possible to separate climate and fishing effects
- populations that have recovered to substantial biomass levels should respond to climate variability in a similar way as in the past

- *“the separation of the effects of environmental variability from the impacts of fishing ... is essential for sound fisheries management”* (Nature 2006)



Hypothesis:

Effects of climate and fishing on marine systems are
“multiplicative” i.e. interacting

- not climate OR fishing, but climate AND fishing

How does fishing modify the responses of :

- individual fish and invertebrates
- populations of fish and invertebrates
- communities of fish
- marine ecosystems

to climate variability and climate change (trend)?

Does fishing increase sensitivity to climate forcing?



Does fishing increase the sensitivity of individuals to climate forcing?

Fishing:

- operates on individuals, but
- consequences are observed in changes in population, community, ecosystem characteristics

Fishing is unlikely to have strong influences on responses of individuals to climate forcing

- removes individuals with certain characteristics from the gene pool
- this changes genetic make-up of the population and its responses to climate forcing

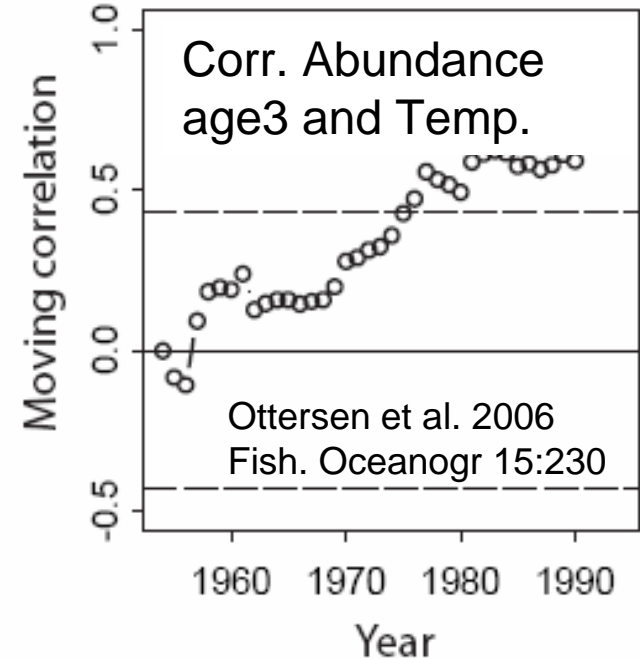
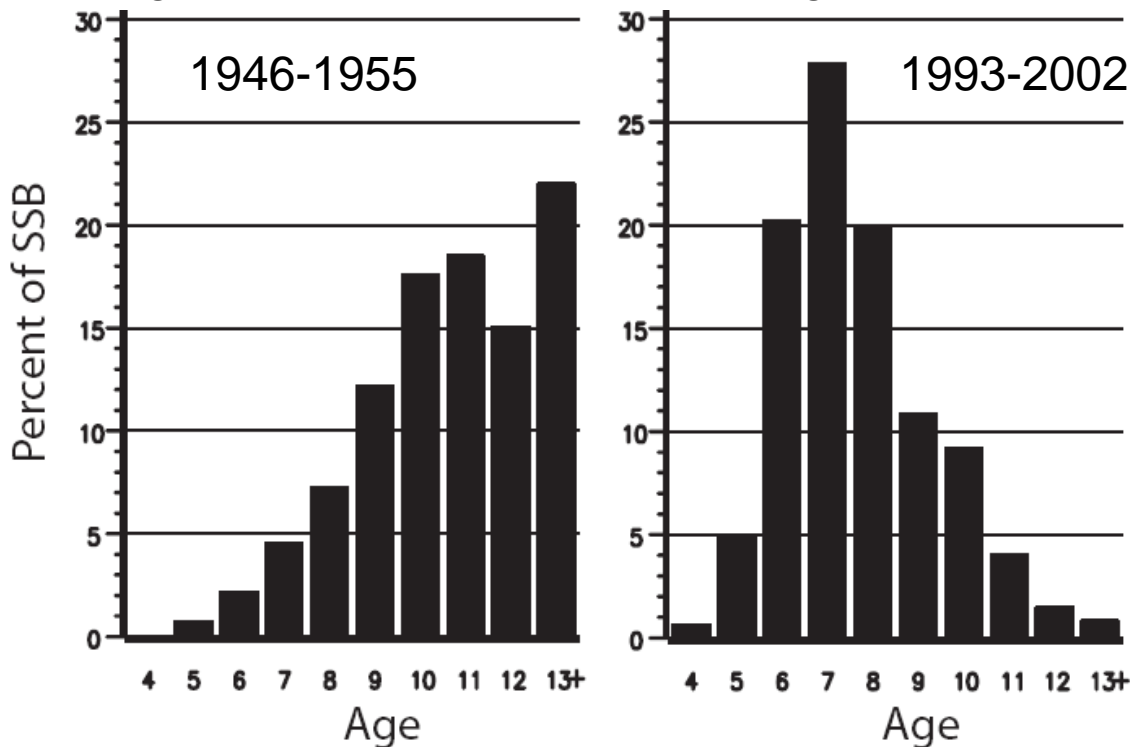


Does fishing increase the sensitivity of populations to climate forcing?

Alteration of Demographic Structure and Life History Traits

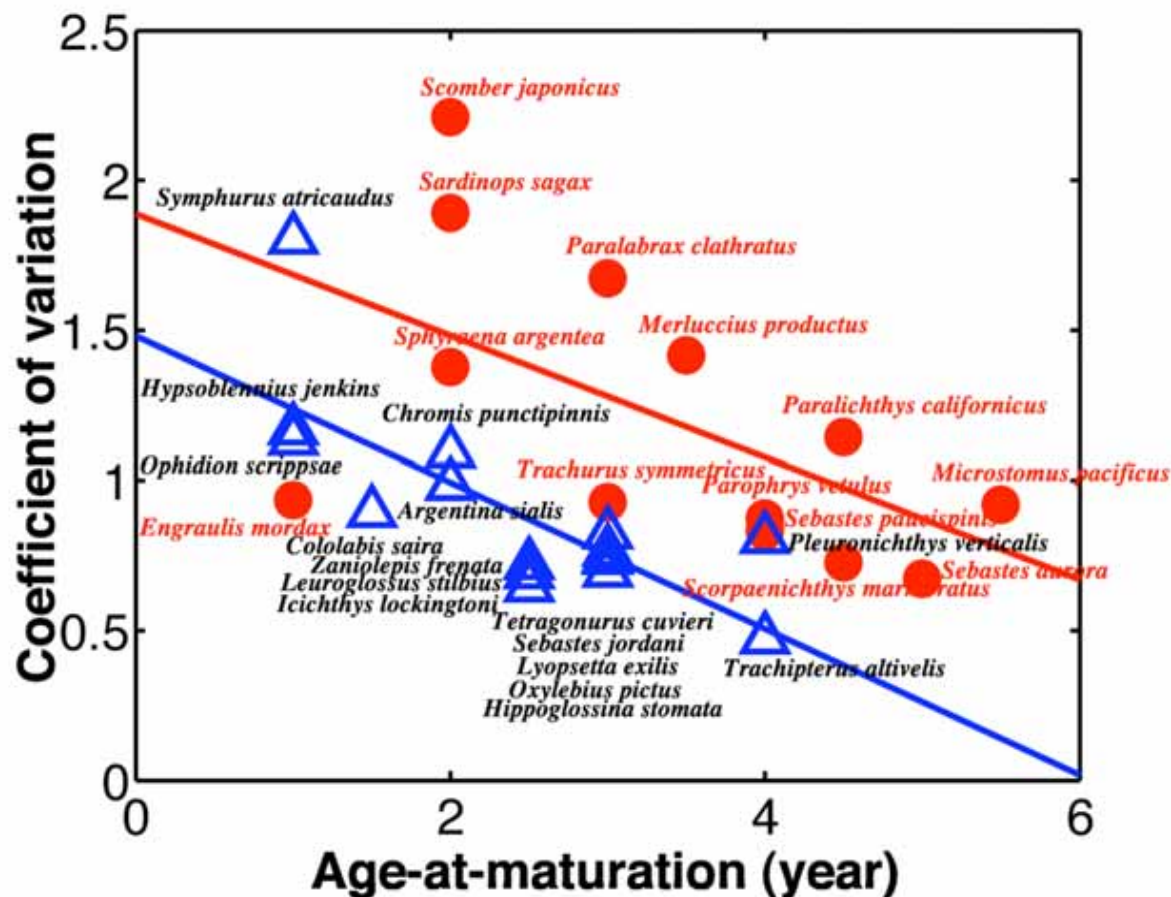
- fishing removes larger (older) individuals – increases correlation with climate (e.g. temperature)

Age composition of Arcto-Norwegian cod spawning stock biomass



Does fishing increase the sensitivity of populations to climate forcing?

Alteration of Demographic Structure and Life History Traits



– increases variability

Abundances of **Exploited** populations are more variable than those of **Unexploited** populations for the same age-at-maturity

because of decreased age classes and decreased buffering capabilities

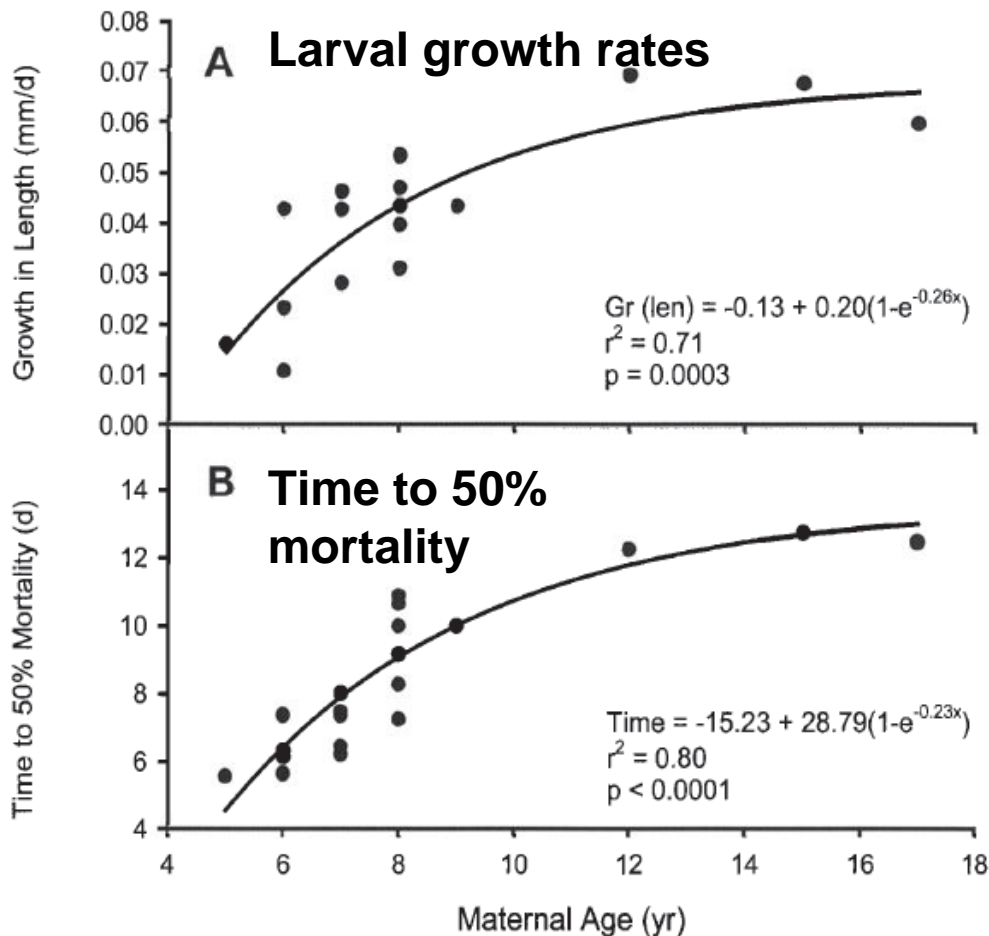
California Current System:

Hsieh et al. 2006. Nature 443:723.



Does fishing increase the sensitivity of populations to climate forcing?

Alteration of Demographic Structure and Life History Traits



– changes in spawning dynamics

Larval growth rates on same diet (A) and median time to 50% starvation mortality (B) of larval **black rockfish** are related to age of spawning fish

Berkeley et al. 2004. *Fisheries* 29(8):23.

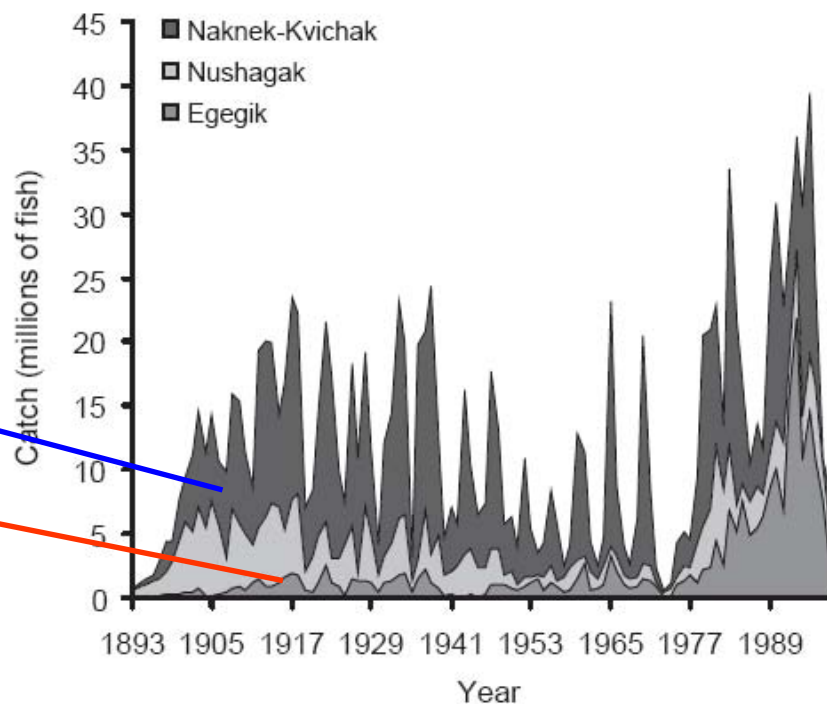
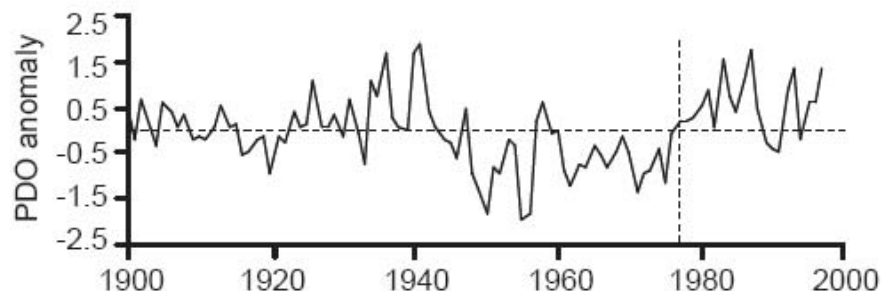
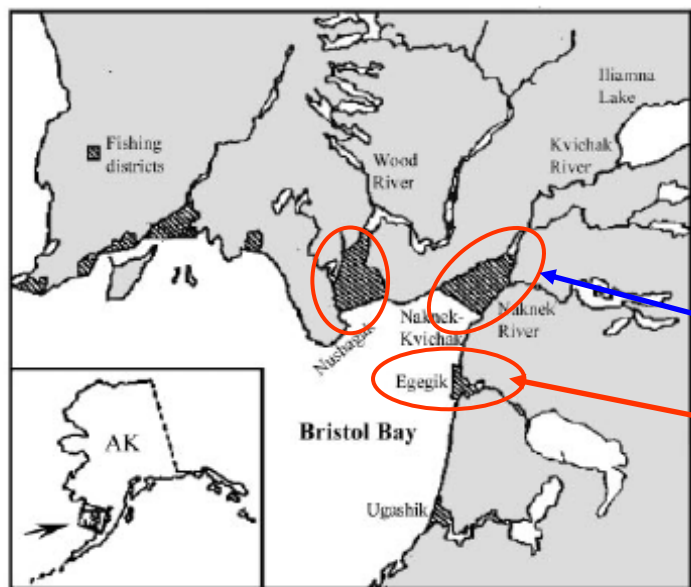


Does fishing increase the sensitivity of populations to climate forcing?

Alteration of Spatial Structure

Alaska sockeye salmon: stock complex productivity sustained by different stocks during different climate regimes

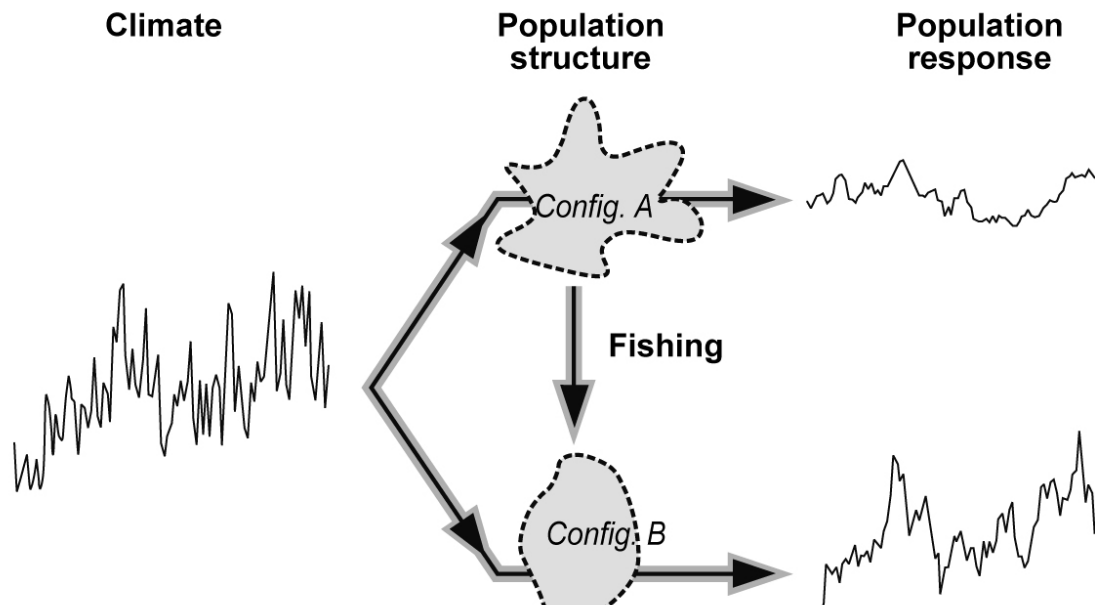
Hilborn et al. 2003 PNAS 100:6564



Does fishing increase the sensitivity of populations to climate forcing?

Fishing acts on individuals to alter population characteristics and how populations respond to climate forcing

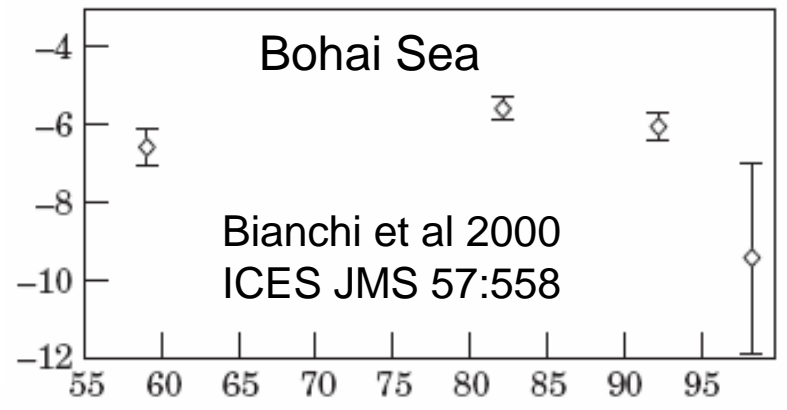
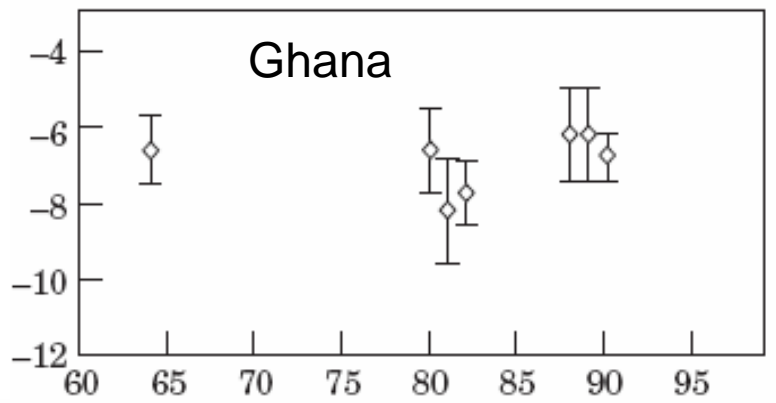
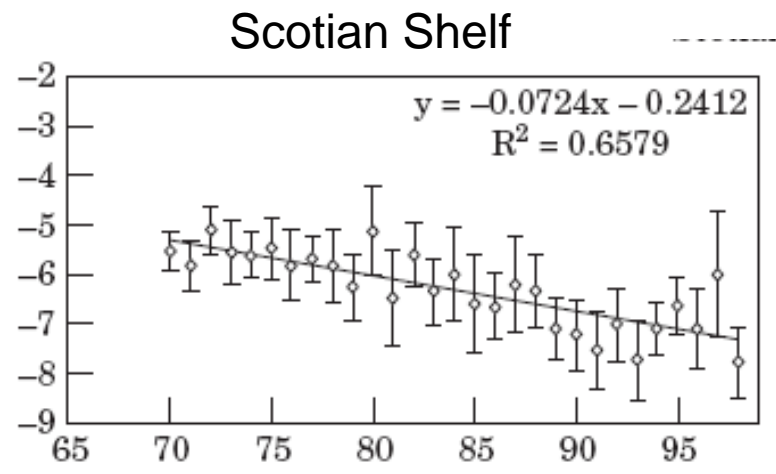
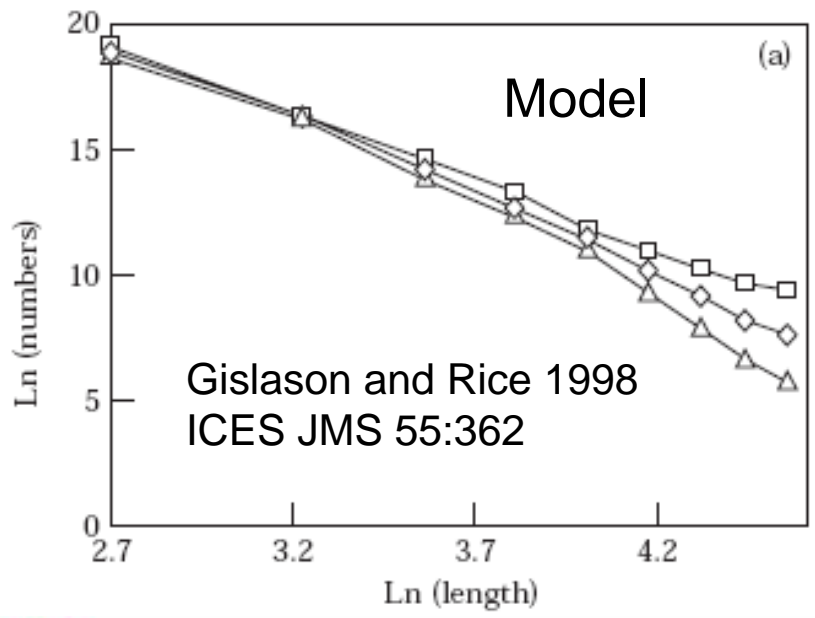
- fishing “simplifies” characteristics of marine populations
 - demographic, temporal, spatial features
- populations become more “sensitive” to climate forcing



Does fishing increase the sensitivity of communities to climate forcing?

Slope of size spectrum bends down due to removals of larger fish

- More evident at high latitudes
- Less evident in tropics – higher growth rates make slope less sensitive to changes due to fishing



Does fishing increase the sensitivity of communities to climate forcing?

Changes in size spectra (decrease of larger fish) imply:

- increase in mean turn-over time of community (more small fish)
- more energy allocated to reproduction
- community tracks more closely the short-term variability in production due to variability in climate

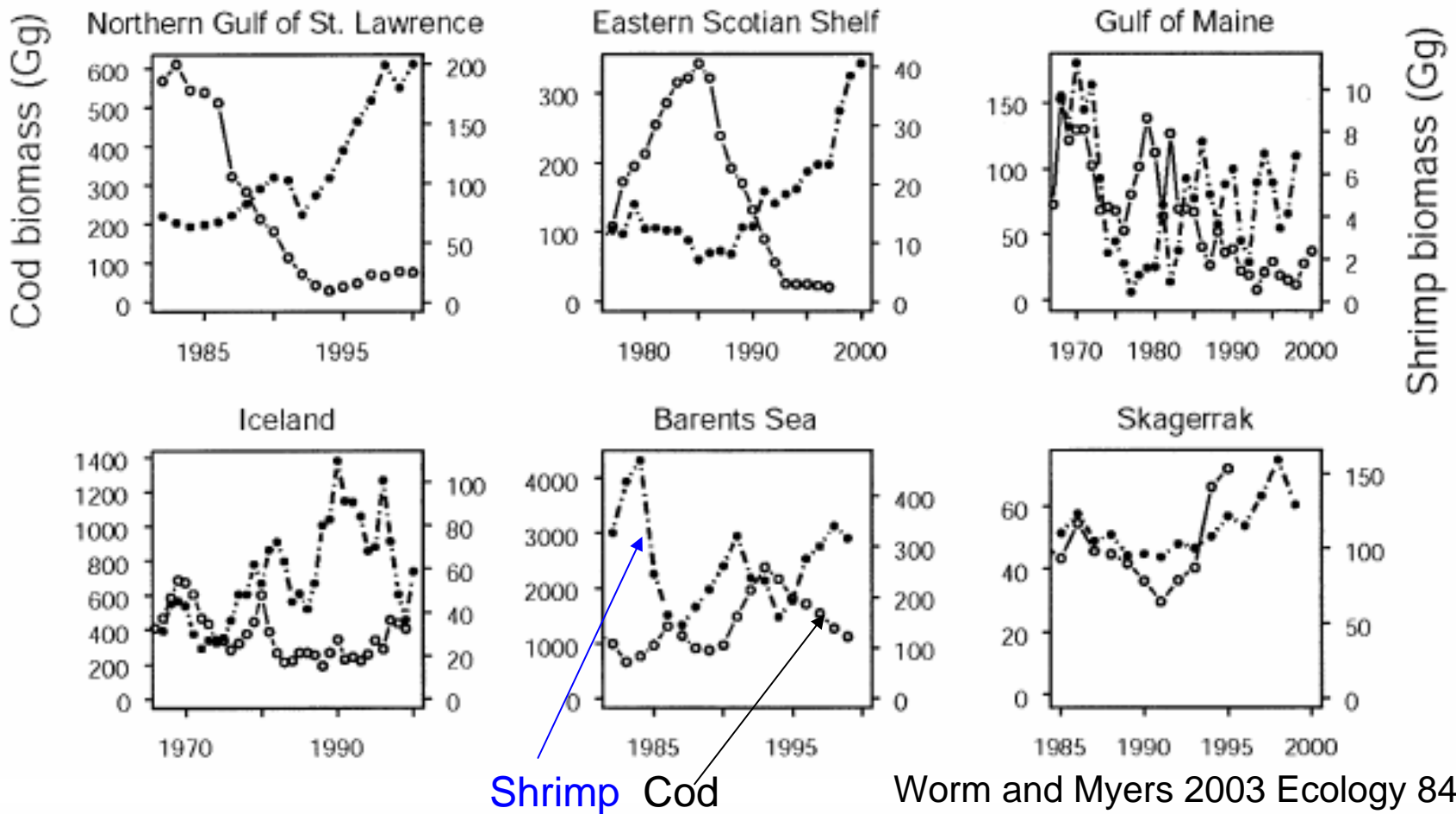
Changes in species richness less clear

- studies within and outside MPAs suggest species richness declines as fishing intensity increases
- studies on Georges Bank suggest when functional redundancy is high, marked changes in species composition may produce less change in community properties



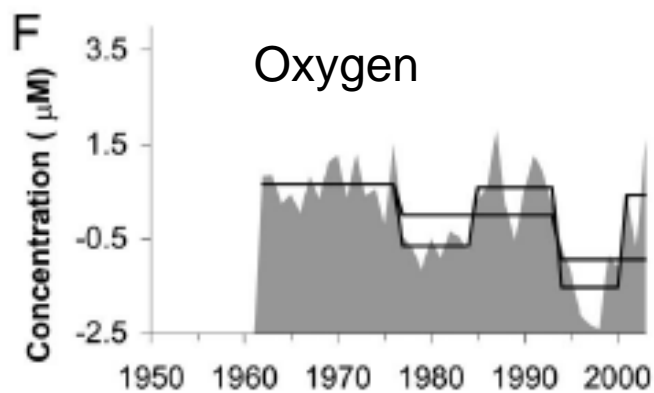
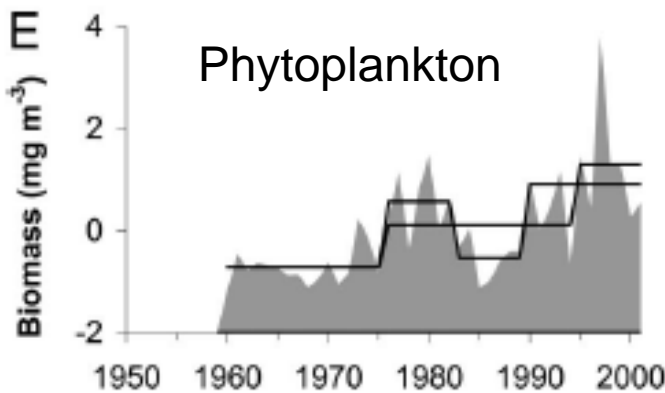
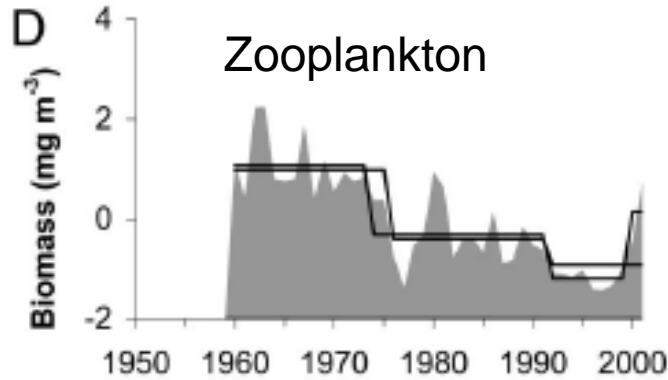
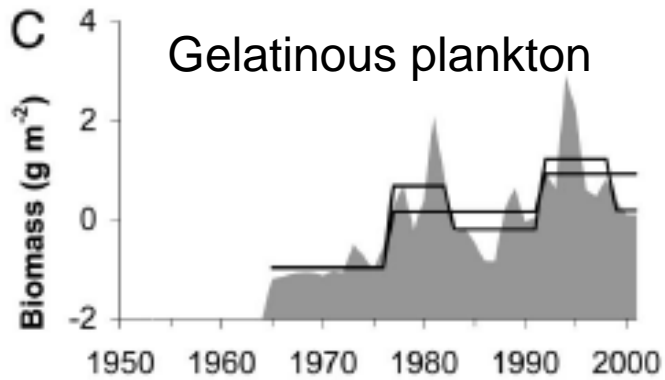
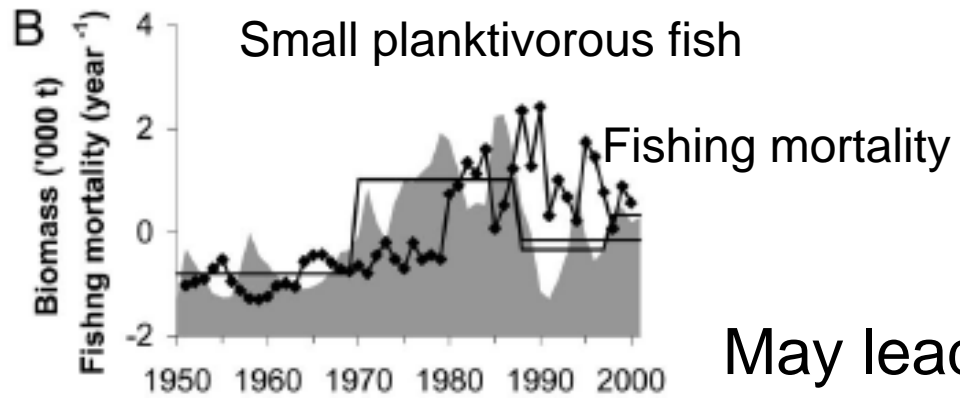
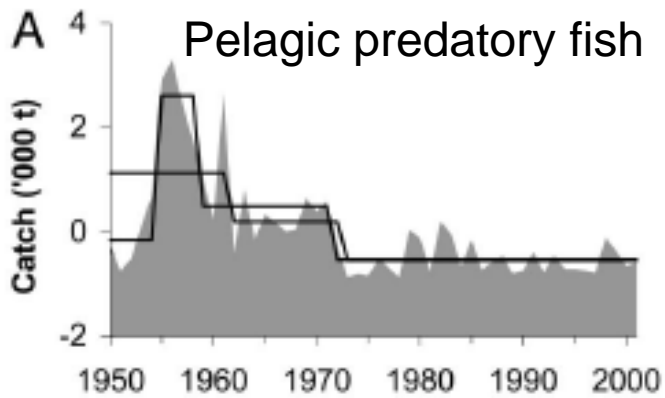
Does fishing increase the sensitivity of ecosystems to climate forcing?

Removal of top predators enhances biomass and productivity of lower trophic levels – e.g. cod and shrimp in N. Atlantic



Worm and Myers 2003 Ecology 84:162.





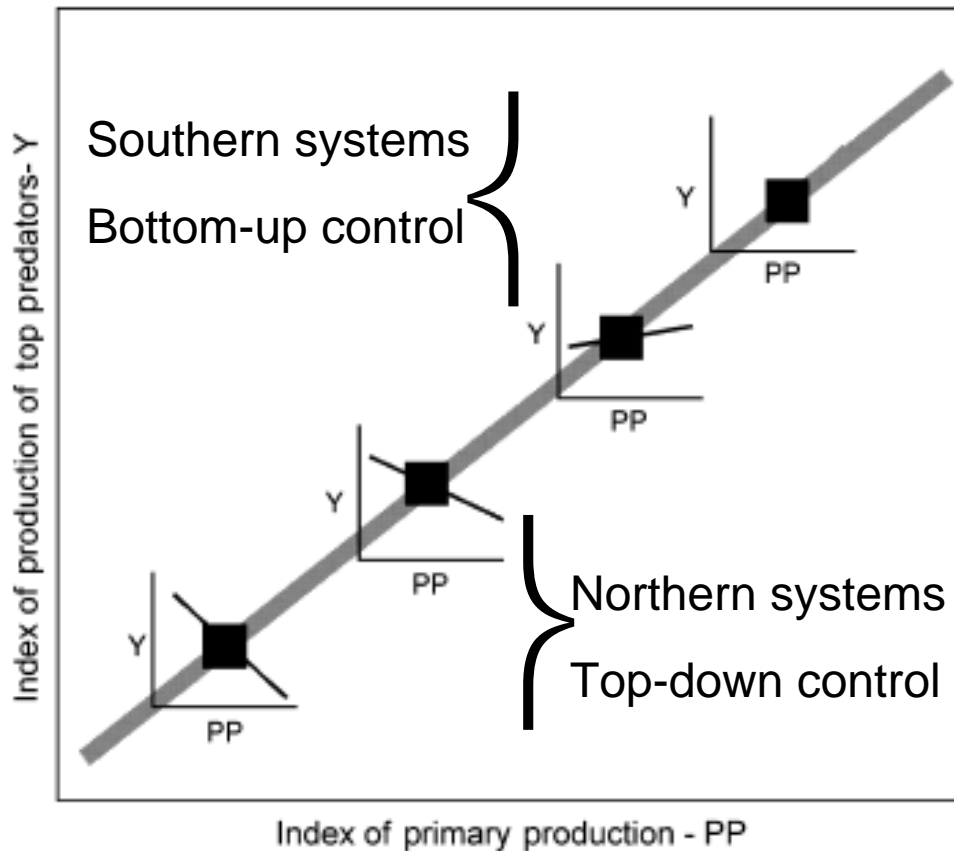
May lead to cascading effects through several trophic levels

e.g. **Black Sea**

Daskalov et al. 2007
PNAS 104:10518



Does fishing increase the sensitivity of ecosystems to climate forcing?



NW Atlantic ecosystems:

Bottom-up control predominates in higher productivity, warmer and more species-rich systems

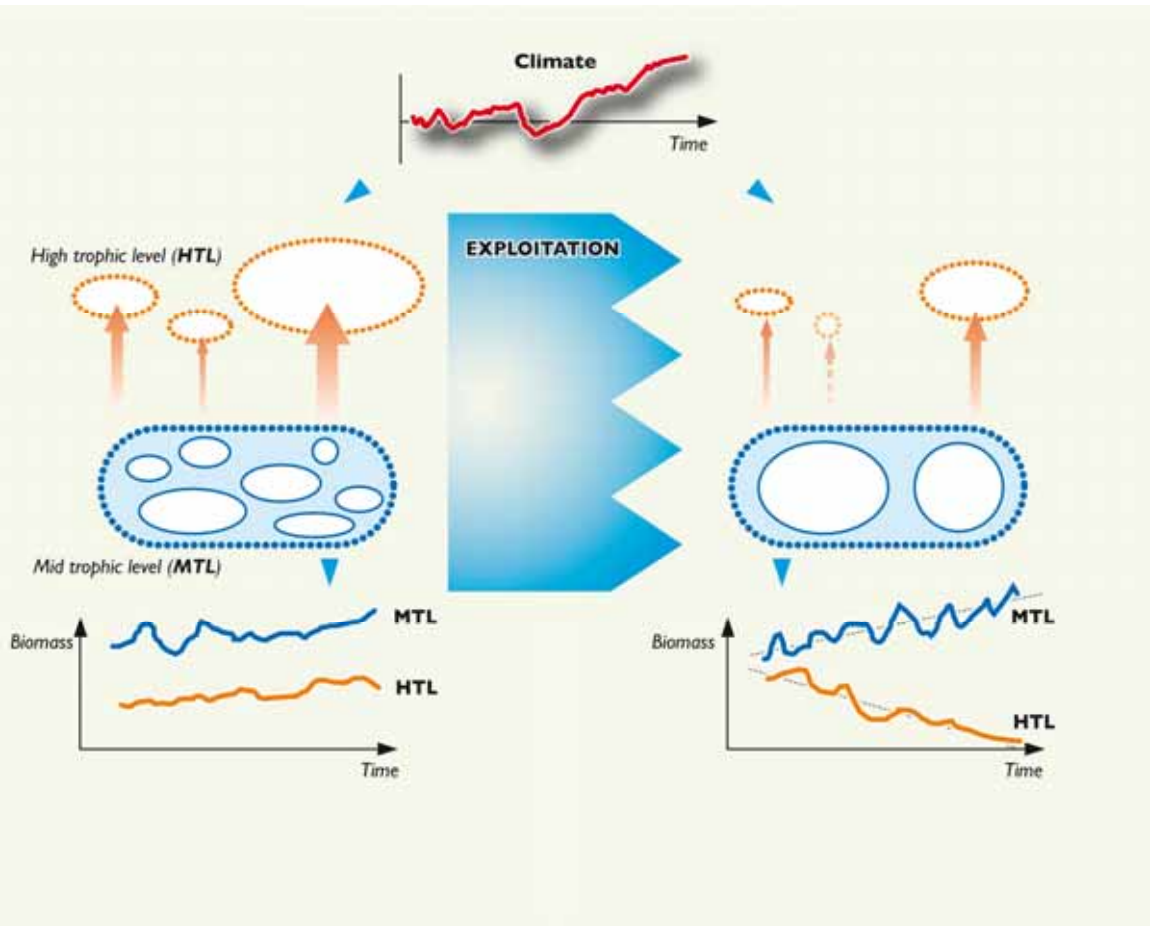
Top-down control predominates in lower productivity, colder, species-poor systems

“among heavily exploited areas, those with higher primary production and greater species diversity are more resistant to top-down effects”

Frank et al. 2006 Ecol. Letters 9:1096



Does fishing increase the sensitivity of ecosystems to climate forcing?



Ecosystems under intense exploitation evolve towards simpler systems:

- decreased stock sizes of top predators
- increases in smaller mid-trophic level species with faster turn-over rates

Resulting in stronger bottom-up control and greater sensitivity to climate forcing



Management implications

- maintain natural resilience of individuals, populations, communities, ecosystems to combined effects of climate and fishing
 - don't focus on biomass alone; keep "the big ones"; spatial patterns

Fisheries management, commercial, artisanal fisheries prefer increased predictability:

3 perspectives on predictability:

1. fishers – stable catches year after year
 2. fishery scientist – forecast catches a few years ahead because most biomass and yield already recruited
- achieve these by reducing fishing impacts on the system
3. scientist assessing climate effects on marine systems
 - if response of system tracks climate signal, system can be predicted from climate
 - this type of predictability may increase with fishing



Conclusions (1)

Fishing:

- is unlikely to alter sensitivities of individual fish to climate forcing
 - removal of individuals with particular characteristics affects structure / function of higher levels
- makes populations more sensitive to climate variability by removing:
 - older age classes; spatial sub-units; changing life-history traits
- makes communities track climate variability more closely by:
 - decreasing mean size and trophic level and increasing turnover rates
- makes ecosystems more sensitive to climate forcing by:
 - evolving towards stronger bottom-up control



Conclusions (2)

Because climate change occurs slowly relative to climate variability

- effects of **climate change** likely **not** have immediate impacts on marine systems
- instead, will appear as accumulation of interactions between fishing and **climate variability**
 - **unless threshold limits** are exceeded

Fisheries management needs to maintain natural resilience of individuals, populations, communities, ecosystems to combined effects of climate and fishing

Populations that have recovered to substantial **biomass** levels may not respond to climate variability in a similar way as in the past, and may be more sensitive to climate forcing

