Overfishing affects more than fish populations

Regime shifts, Trophic cascade, Biological invasions, Overfishing and their effects on Ecosystem Functioning and Fisheries

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In the spring the mackerels and bonitos move to the Pont (Euxin) where they stay during the summer like all the other fishes swimming in schools. ***And they are very numerous ...****They go to the Pont for food, because there the food is better and more abundant because of the fresh water...So they go to the Pont for food and spawn there because there are many suitable places and the fresh water is good for feeding of their larvae...*

ARISTOTLE (384-322 BC)

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Studying "Natural large-scale ecosystem experiments"

Strong disturbances due to forcing factors like climate, overfishing, eutrophication, alien invasion, allow to explore system's response in terms of resistance/resilience, shift between alternative states, and recovery

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The Idea: Fishing can trigger ecosystem scale regime shifts

- Marine ecosystems exist in internally consistent dynamic states, or regimes. Switches between alternative regimes are called regime shifts and can be driven by both external forcing (climate change, alien invasions, cultural eutrophication, overfishing) and internal perturbations.
- Mechanisms of top-down driven regime shift: hierarchy concept of ecosystem, alternating consumer/donor controls, trophic cascade, fishing down marine food webs
- Overfishing, fish stock collapse and recovery: multispecies and ecosystem implications

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Historical overview of main trends and events: shift from health to pathology?

1950 1966	Decimating the dolphin population
~1970	Collapse of bonito and bluefish and disappearance of the macker
1970s	Intensive bottom trawling and silt disposal the NW Black Sea
1975-1985	Increase in the small pelagics fish that become a base of industrial fishery
1975-1990	Increase in the nutrient loadings, cultural eutrophication and rela effects of bottom hypoxia and hydrogen sulphide production
1975-1985	Increased biomass of *A. aurita* peaked about 1980
1975-1980	Collapse of the *Phyllopora* and black mussel in the NW Black Sea
~1985	Collapse of the turbot stock
Late 1980s-90s	Unintentional introduction and outburst of *Mnemiopsis leidyi*
~ 1990	Collapses of most of the commercially exploited fish stocks
Late 1990s	Partial recovery of sprat and anchovy
1997	Unintentional introduction of *Beroe ovata*
Early 2000	Relative decrease of the nutrient loading
Early 2000	Relative decrease in *M. leidyi*

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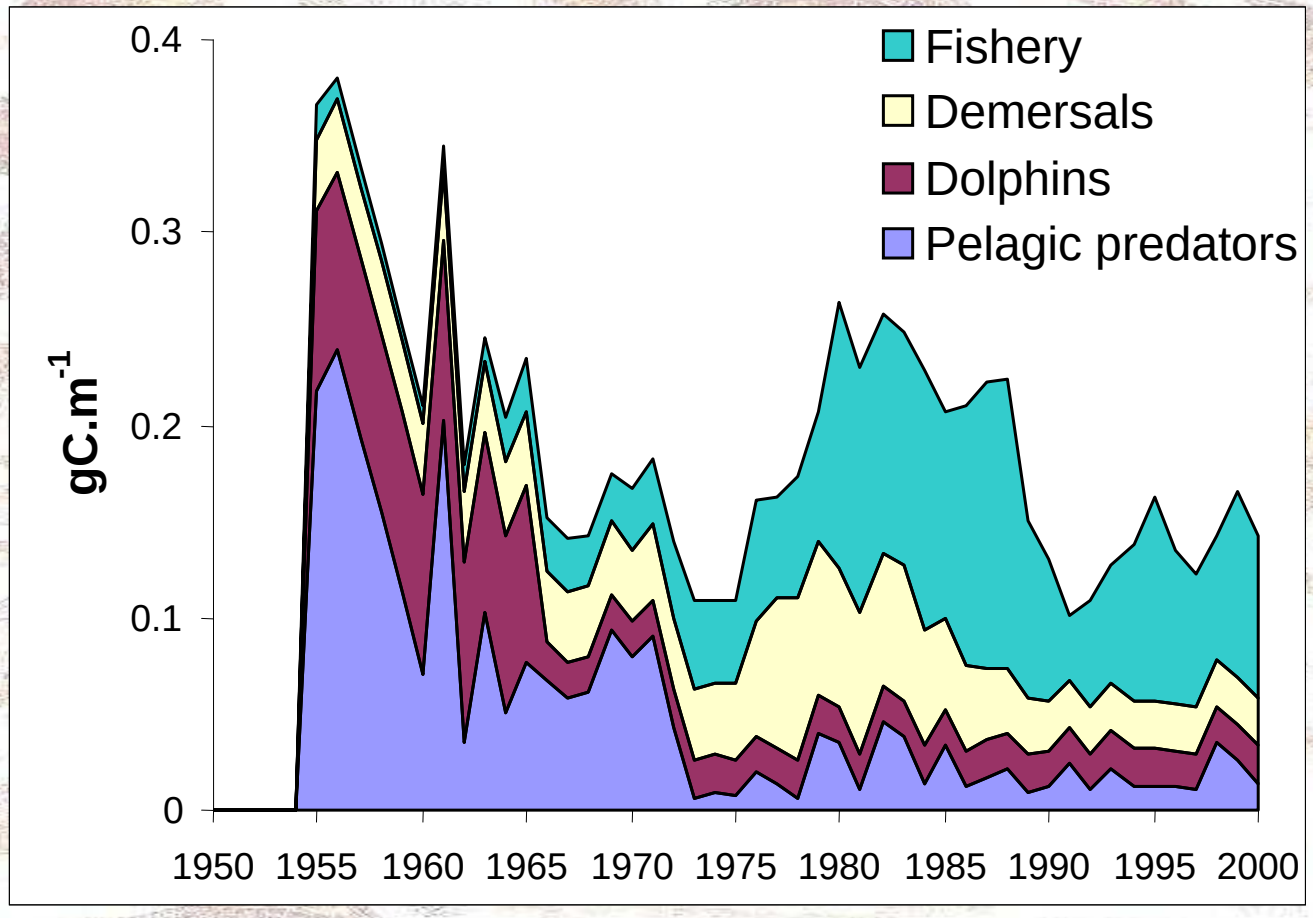
FISH BIOMASS CONSUMED BY PREDATORS AND FISHED



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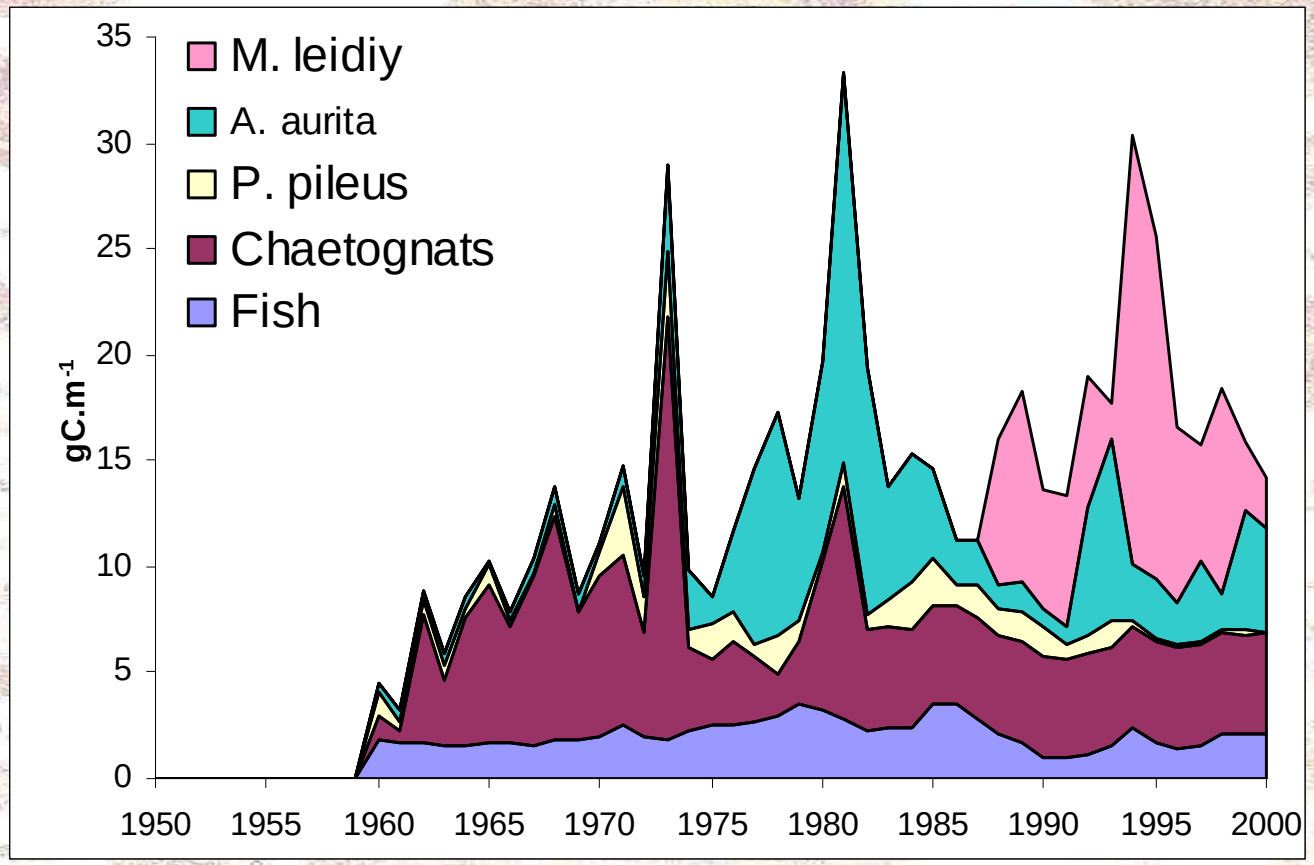
MIDDLE TROPHIC LEVELS: BIOMASS CONSUMED BY ZOOPLANKTON EATERS



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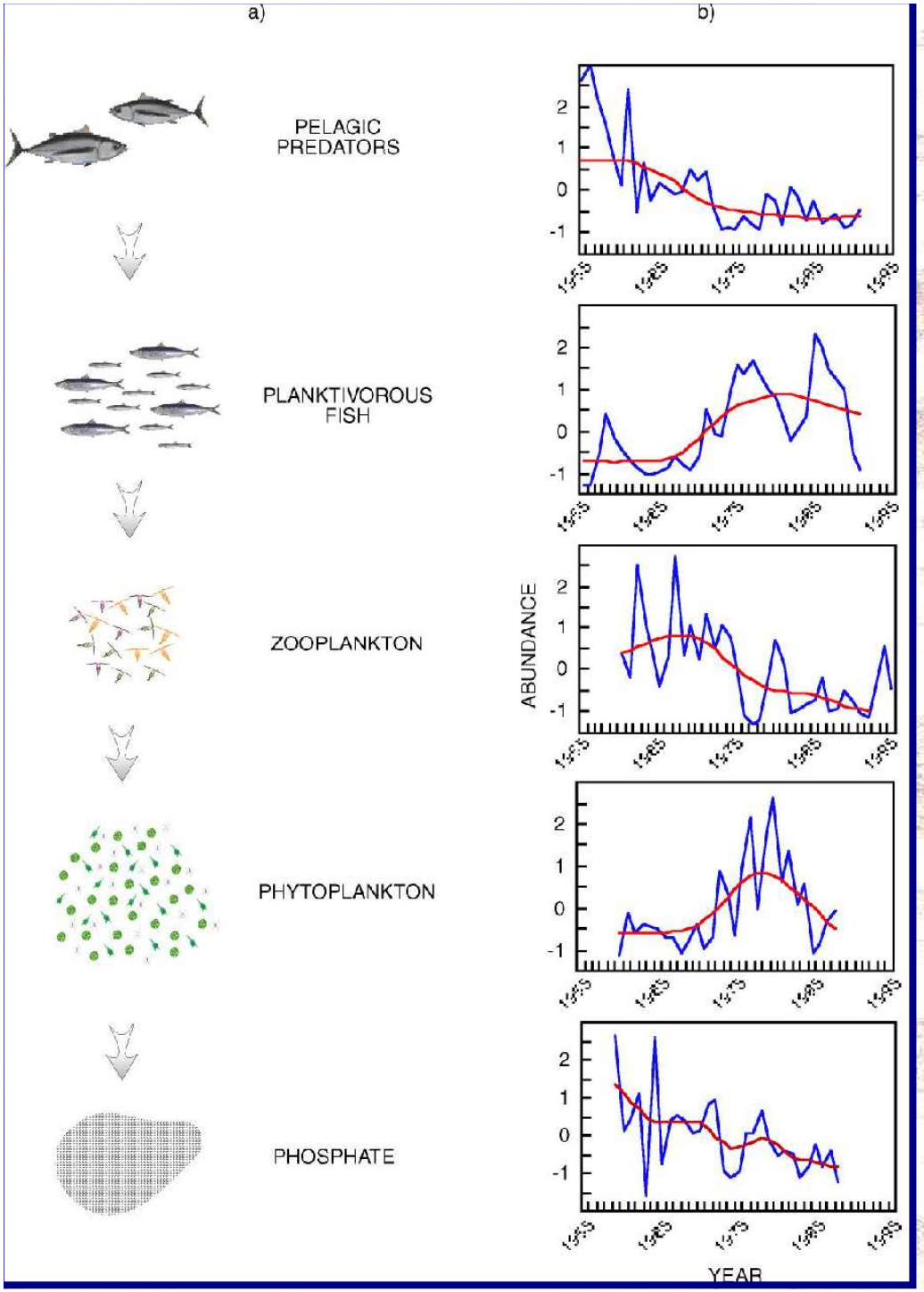

INTEGRATED ECOSYSTEM EFFECTS:

TROPHIC CASCADE CAUSED BY OVERFISHING

(Daskalov, MEPS, 2002)

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UNINTENTIONAL INTRODUCTION OF THE CTENOPHORE *MNEMIOPSIS LEIDYI* FOLLOWED BY ITS MASS EXPANSION

- **Pronounced changes in zooplankton community and biomass**
- **Collapse of fish stocks and associated fisheries**
- **Overfishing may have preceded population explosion of *M. leydyi***

RECENTLY ANOTHER EXOTIC CTENOPHORE *BEROE OVATA* FEEDING ON *MNEMIOPSIS* DEVELOPED

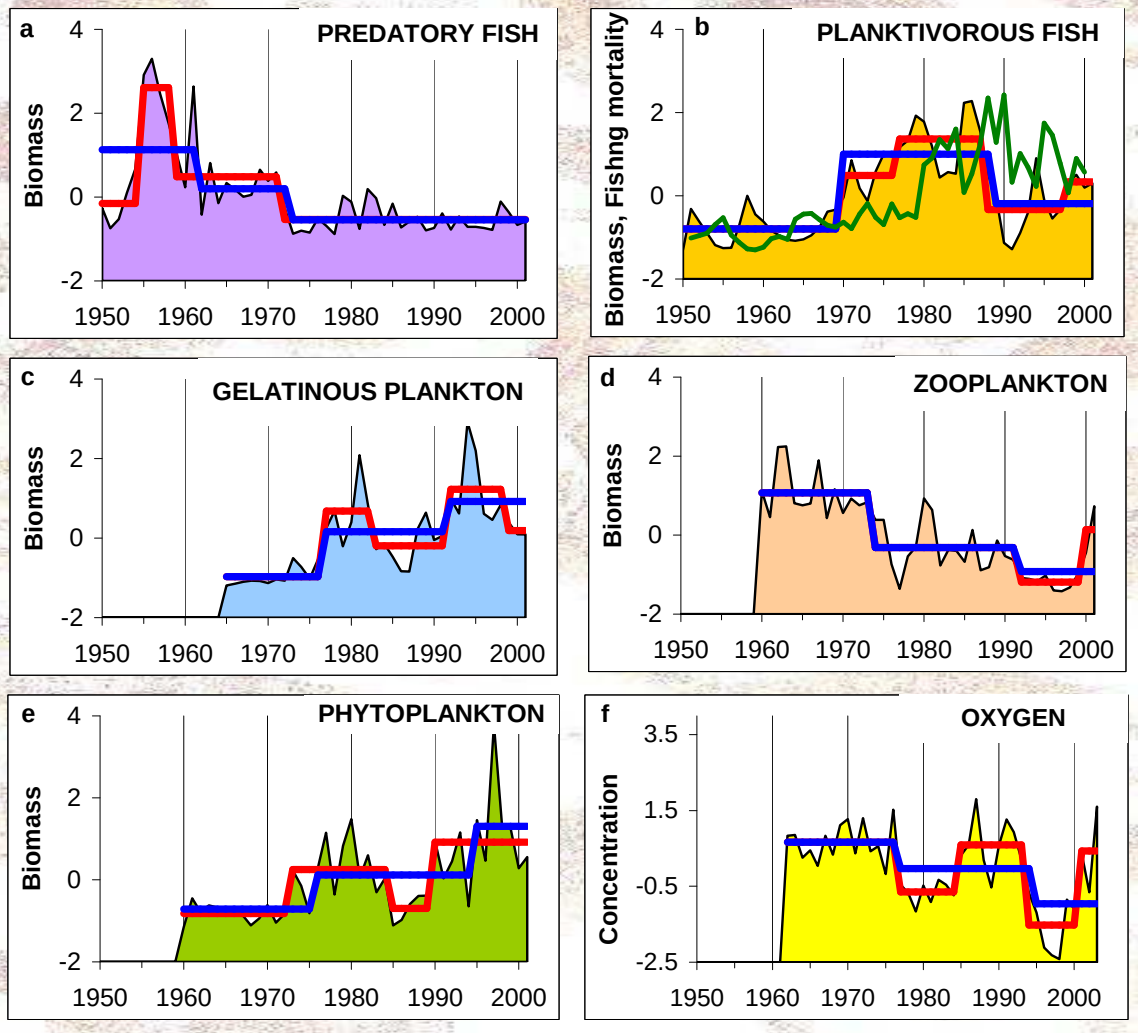
- Partial recovery of small pelagic fish stocks in presence of *Mnemiopsis*

- Signs of recovery of the previous structure and abundance of zooplankton

- No evidence of system wide control of *B. ovata* over *M. leidyi* population

Regime shifts in the Black Sea

(Daskalov et al., PNAS, 2007)



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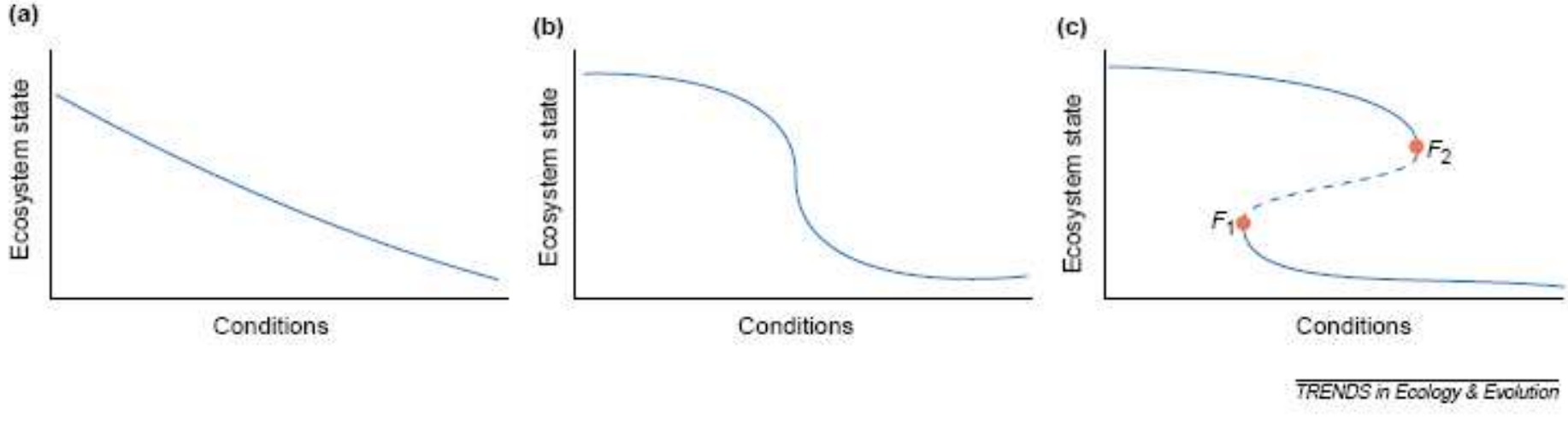
Smooth (a), abrupt (b) and discontinuous (c) shifts (Scheffer & Carpenter, TREE, 2003)

Some shifts are triggered by disproportionately small forces until a critical threshold is passed, then the system would require substantially stronger driving force to recover at the initial state, a process referred to as hysteresis.



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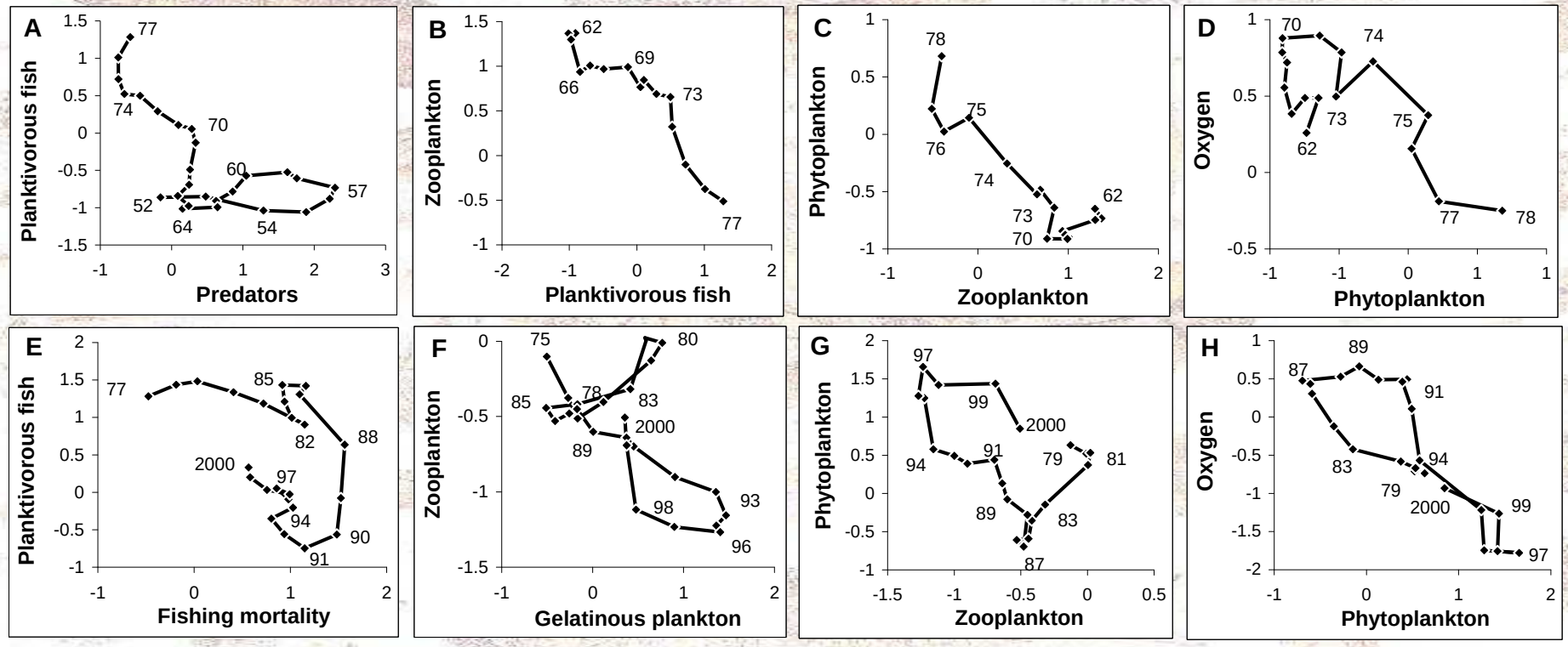
Phase space plots of consumer (driver) against resource (response), illustrating the ecosystem regime shifts of the 1970s (A–D) and 1990s (E–H)

Daskalov et al. PNAS, 2007



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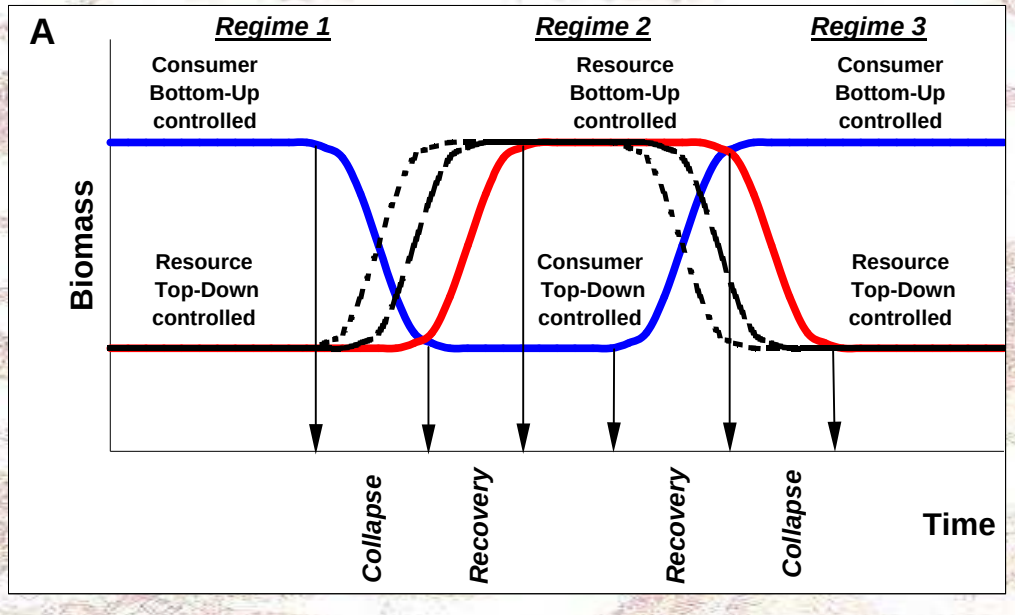

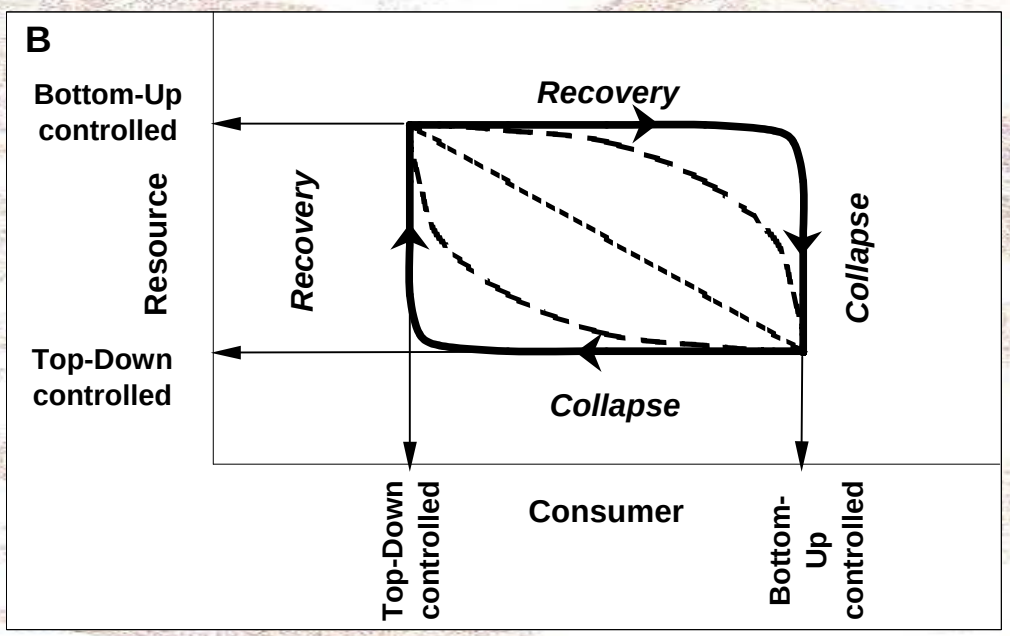

Conceptual model of top-down driven regime shift

(Daskalov et al., PNAS, 2007)

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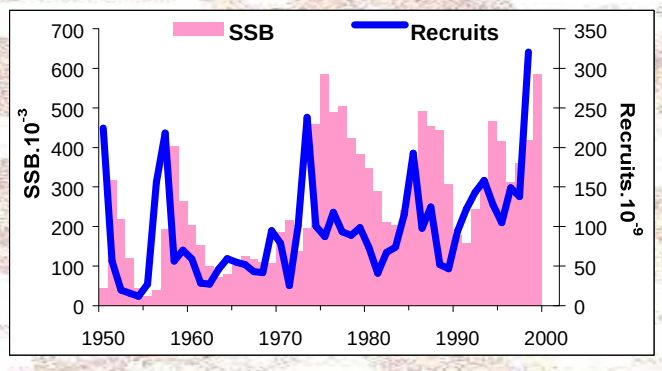
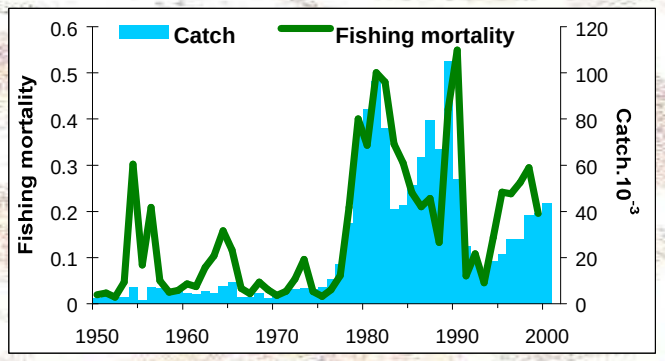
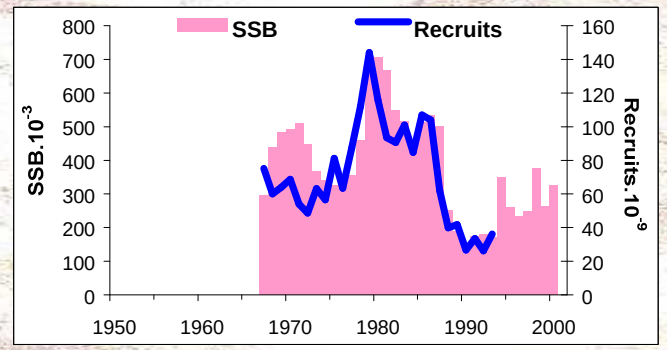
MIDDLE TROPHIC LEVEL: INCREASE, COLLAPSE AND RECOVERY OF SMALL PLANKTIVOROUS FISH (Daskalov et al. 2007)

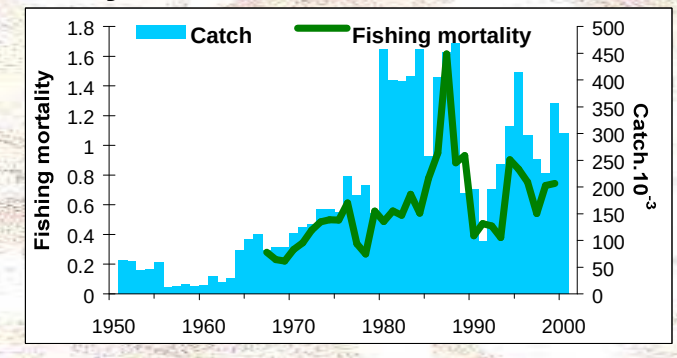
Sprat



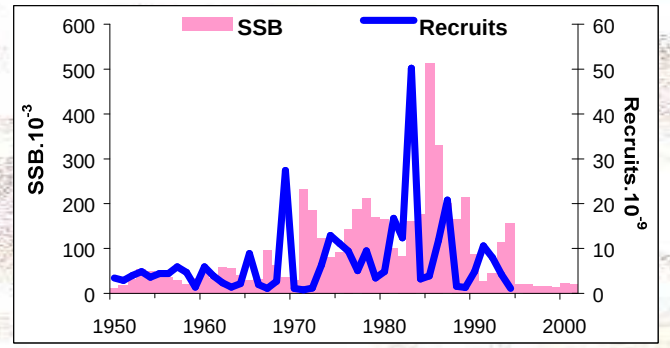


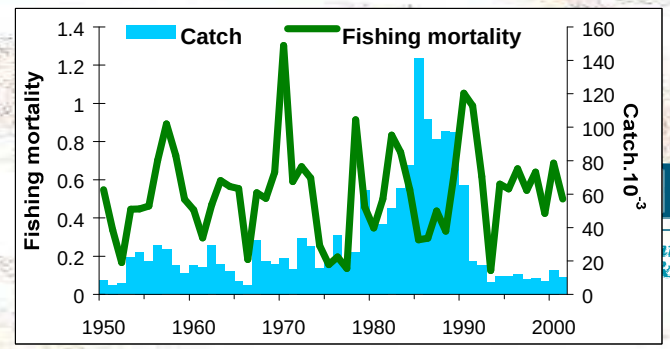
Anchovy





Horse mackerel





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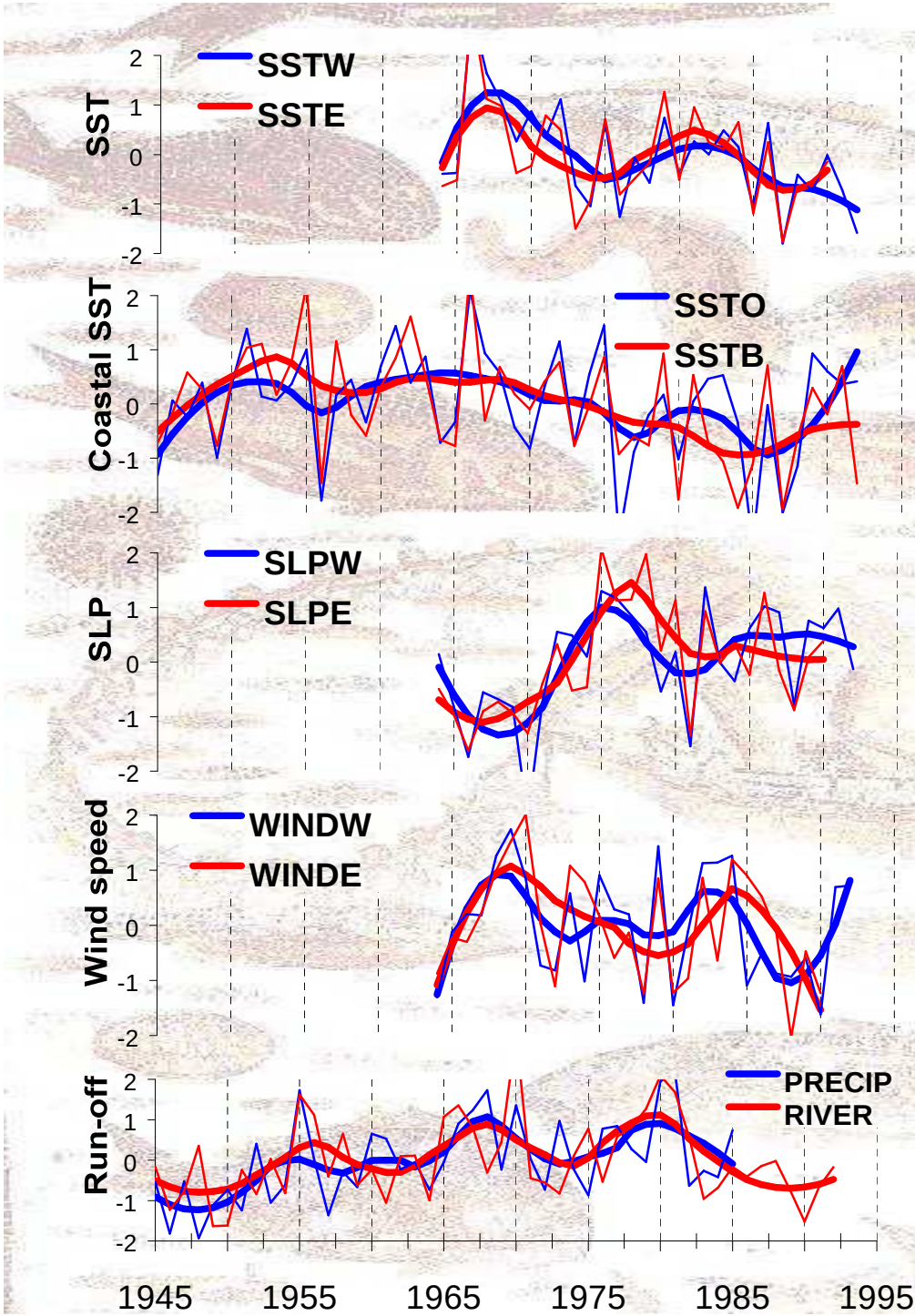

BOTTOM-UP INFLUENCES

NATURAL VARIABILITY CAPTURED BY HYDROCLIMATIC SERIES

(Daskalov, 2003)

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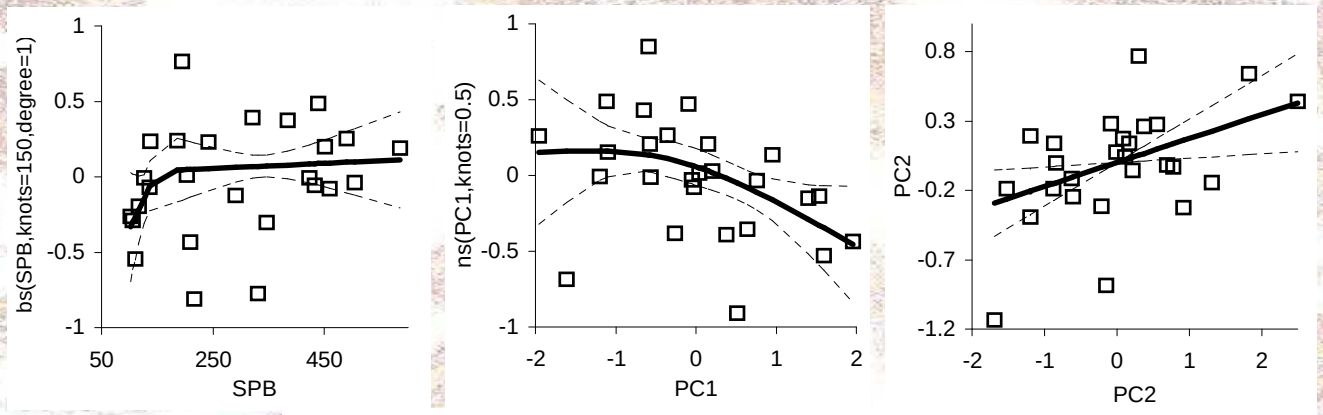
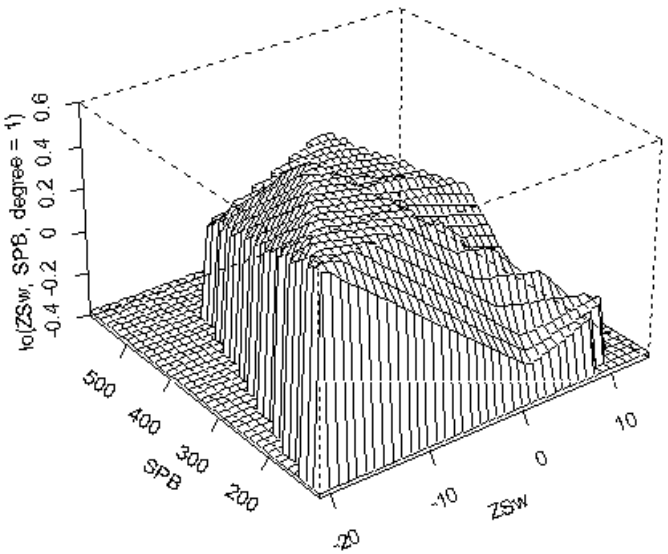
Stock dynamics depends on environment (Daskalov, 1999)





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Mechanisms of overfishing and stock collapse

- Natural decrease in fish biomass and production (recruitment, growth, egg production) related to fluctuating environment, biological interactions
- Sustained or growing heavy fishing pressure: building fishing capacity and improvement in technology
- Lack of adaptive management that is expected to adjust to the stock changes

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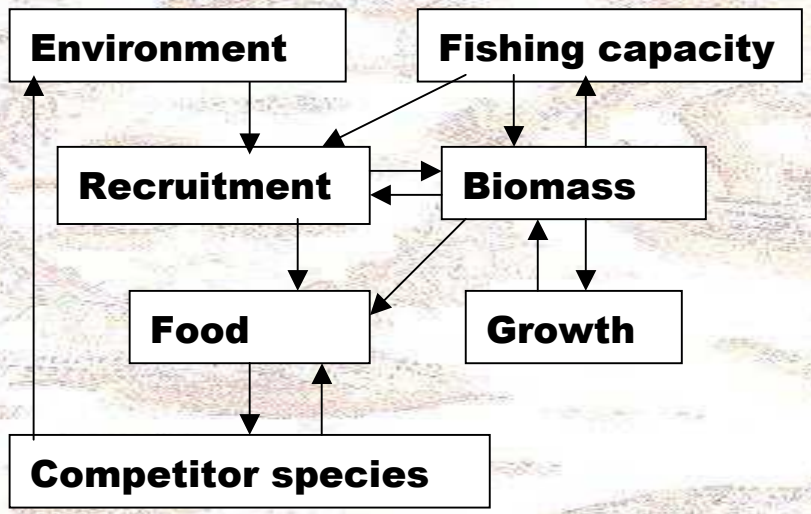
HYPOTHETICAL MECHANISM OF STOCK COLLAPSE AND RECOVERY

STOCK COLLAPSE

1. Decrease in Recruitment and Biomass
2. Increased fishing effort due to previously built overcapacity
3. Interspecies effects: increase of competitors, decrease of food,
4. Cascade effect and environment deterioration



STOCK RECOVERY

1. Reduce capacity and fishing effort
2. Increase in Recruitment and Biomass
3. Normalise Interspecies effects: moderate and divers competitors, increase of food,
4. Buffer cascade effects and improve Environment

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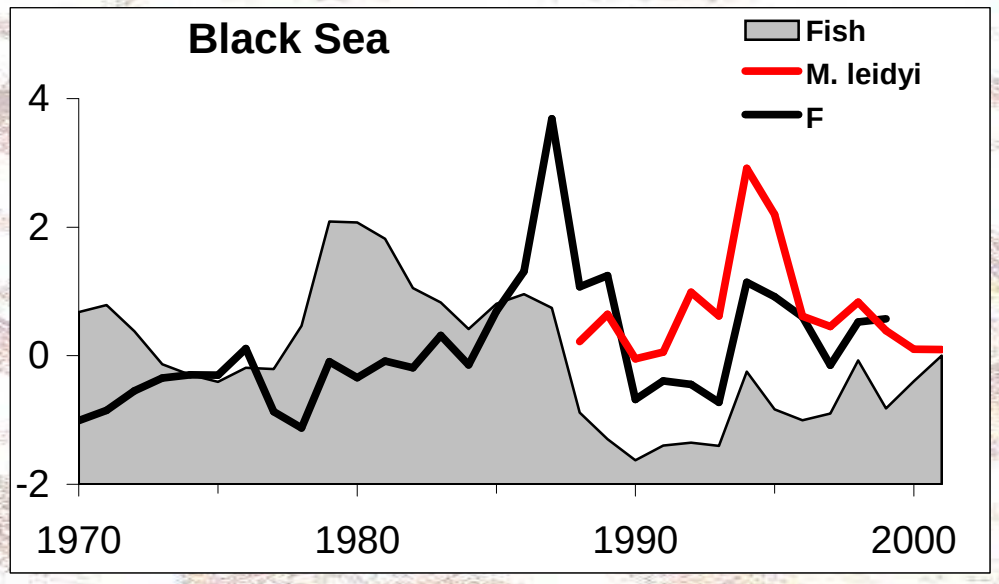

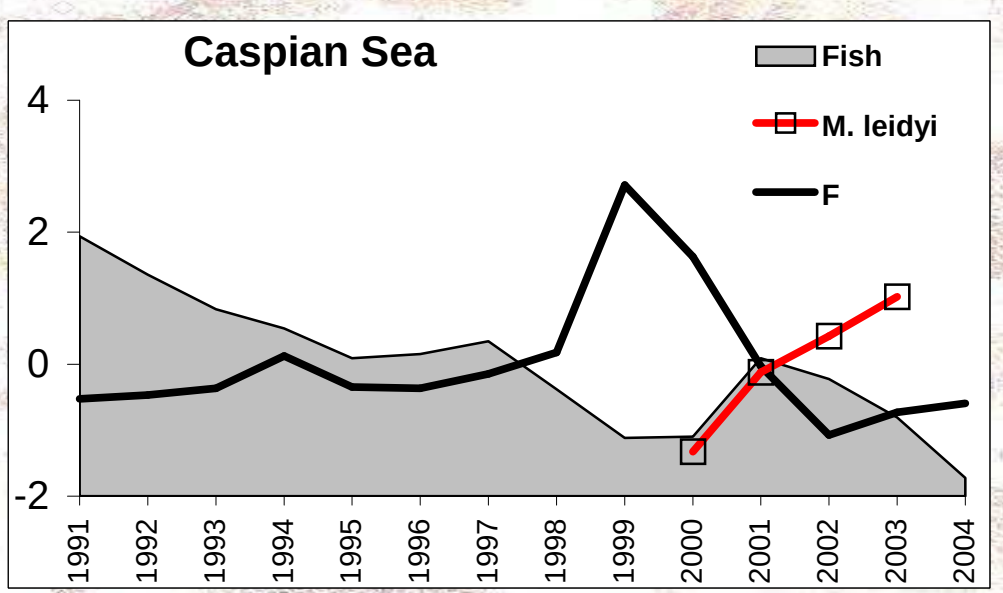

Overfishing, Invasives & fish stock collapse in the Black & Caspian Seas

(Daskalov et al., AFS, 2007; Daskalov & Mamedov, ICES JMS, 2007,)

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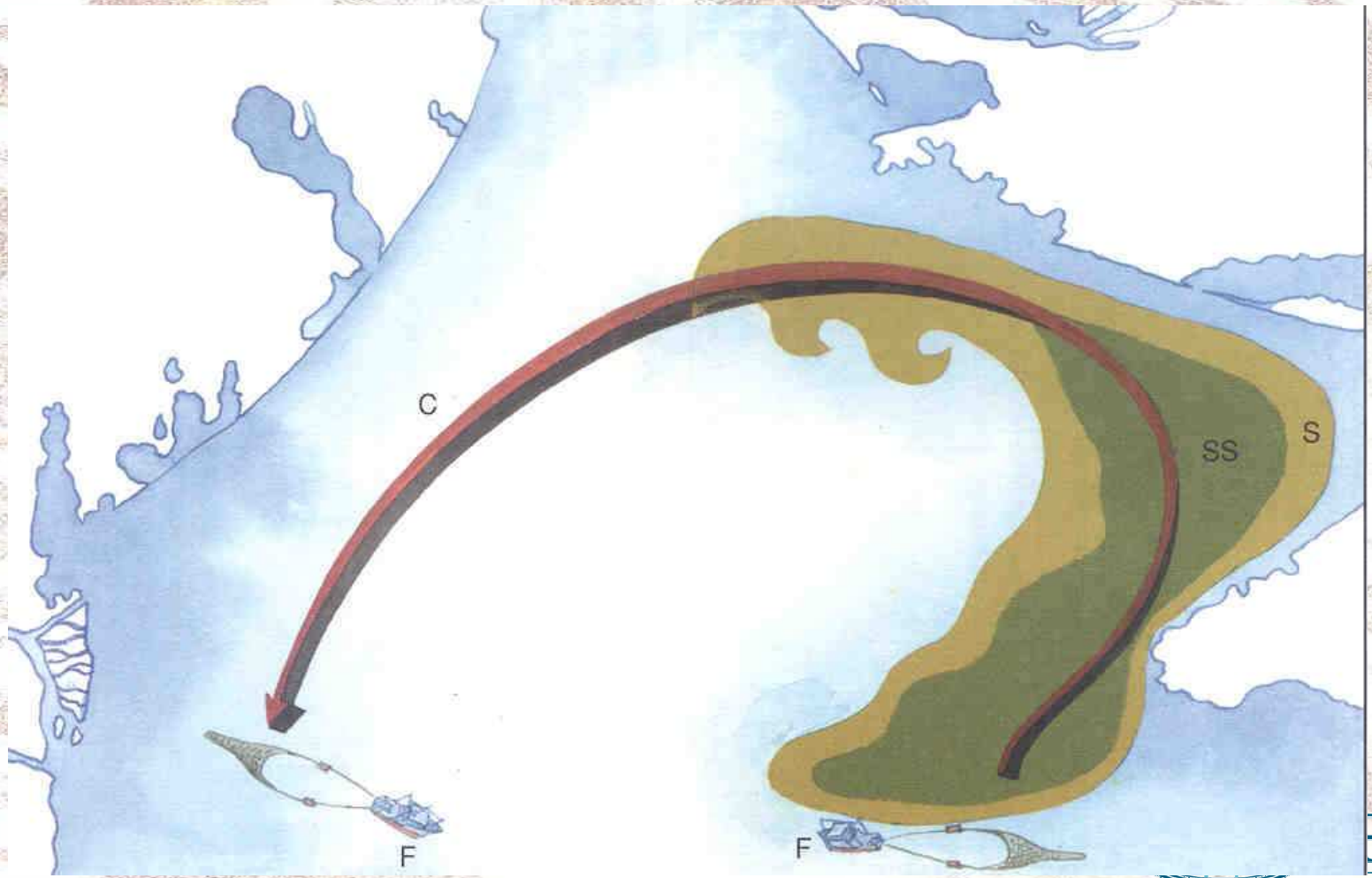
BOTTOM TRAWLING IN THE NORTH-WEST SHELF ECOSYSTEM:

RESUSPENTION OF SEDIMENT AND SILT DISPOSAL



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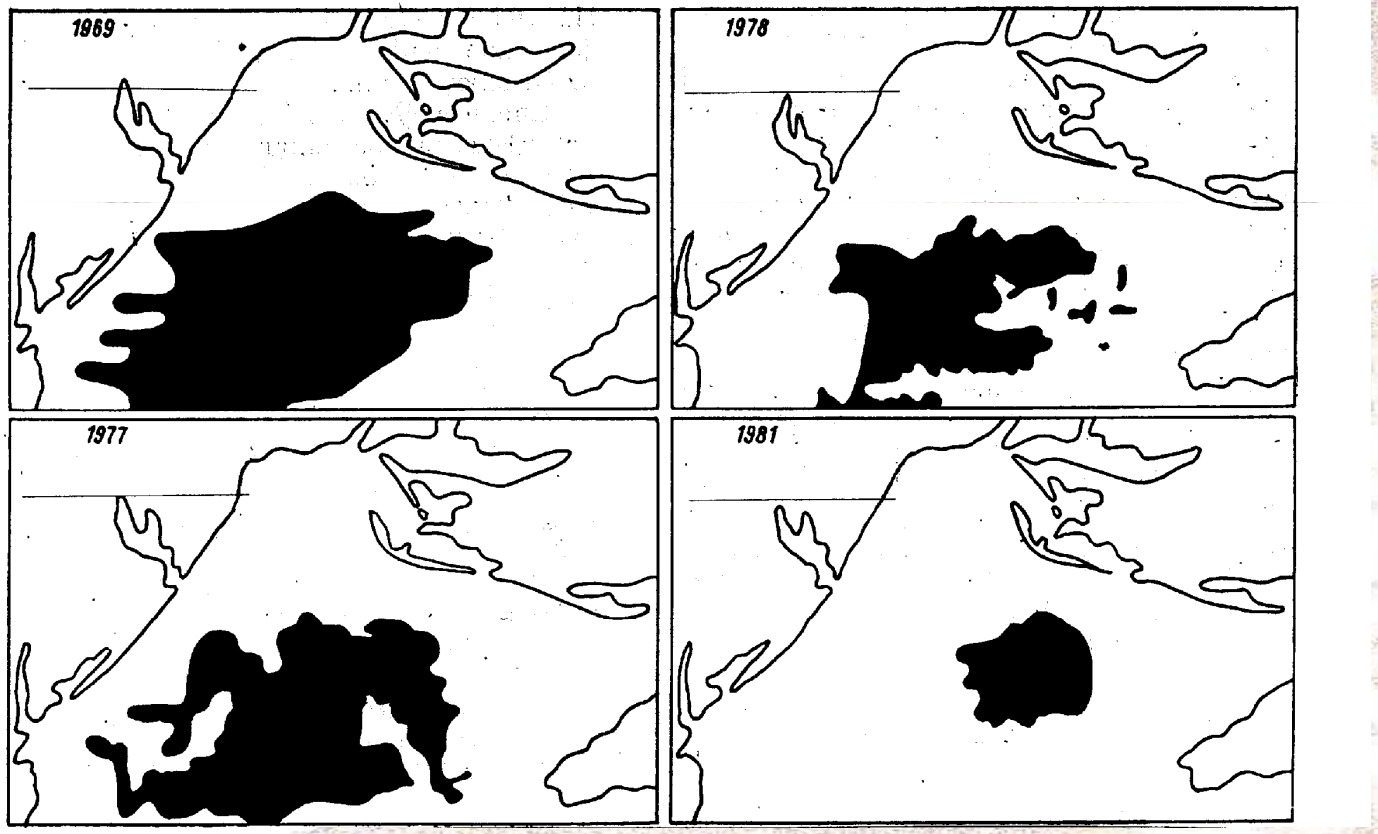
INCREASE IN TURBIDITY ->
COLLAPSE OF THE BENTHIC RED ALGAE *PHYLLOPHORA*



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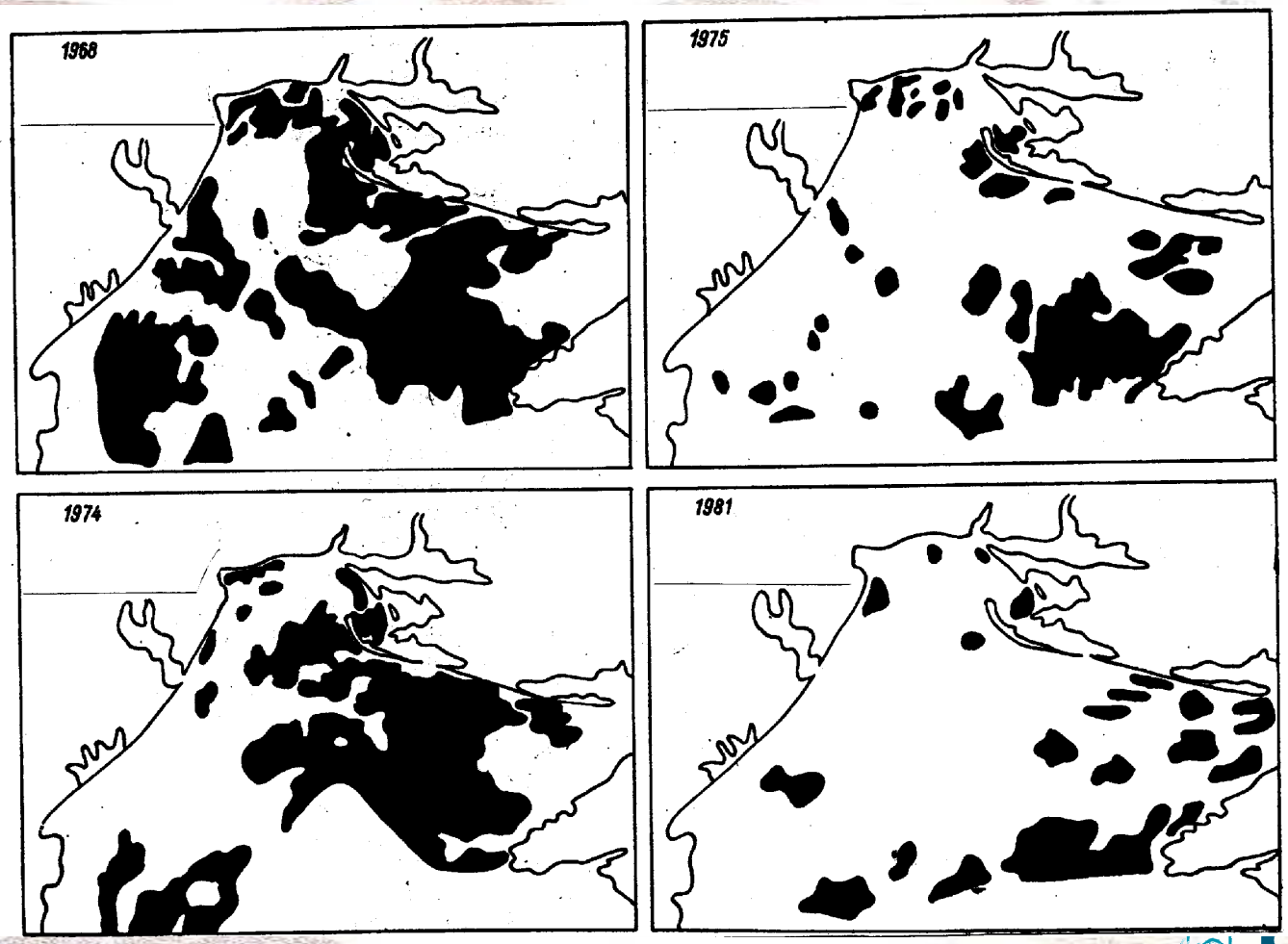
DECREASE OF THE BLACK MUSSEL
M. GALLOPROVINCIALIS



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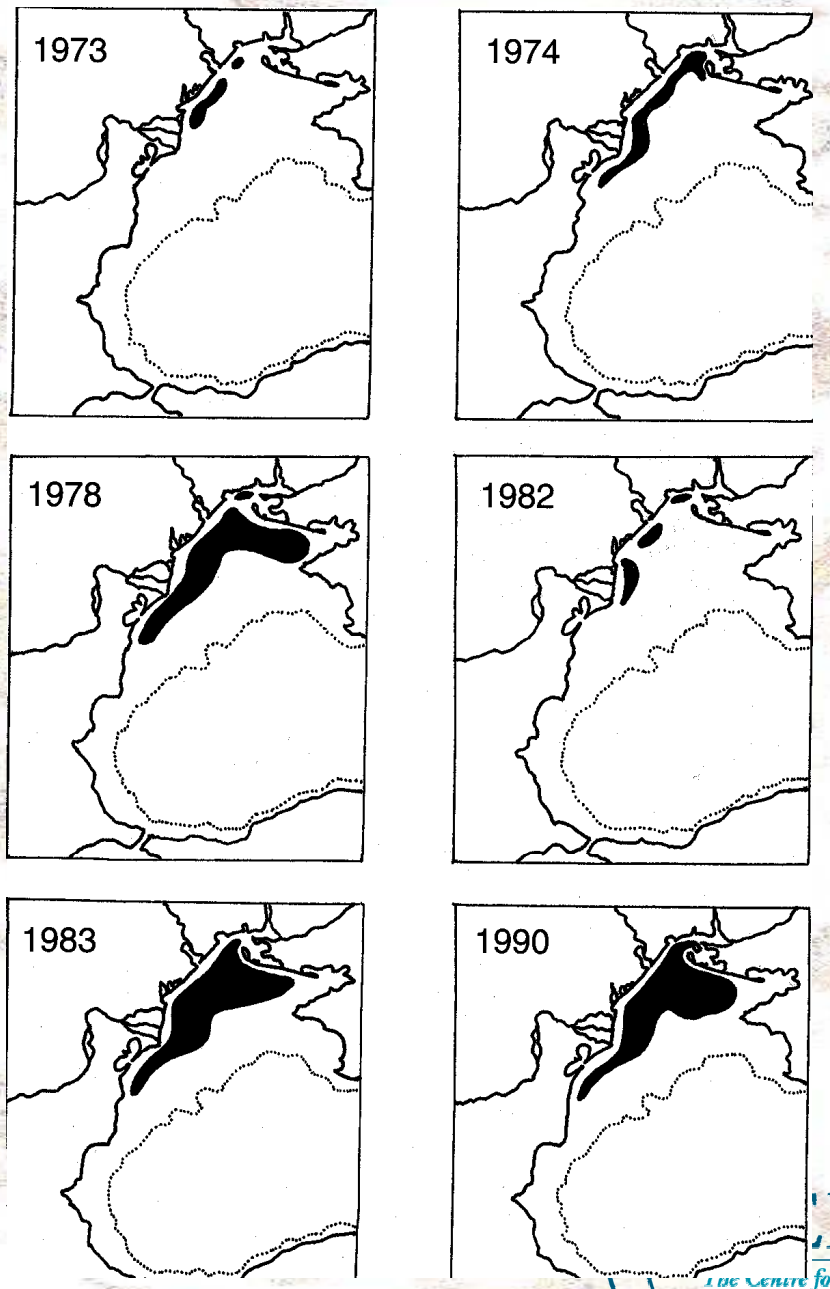
INCREASED BOTTOM HYPOXIA



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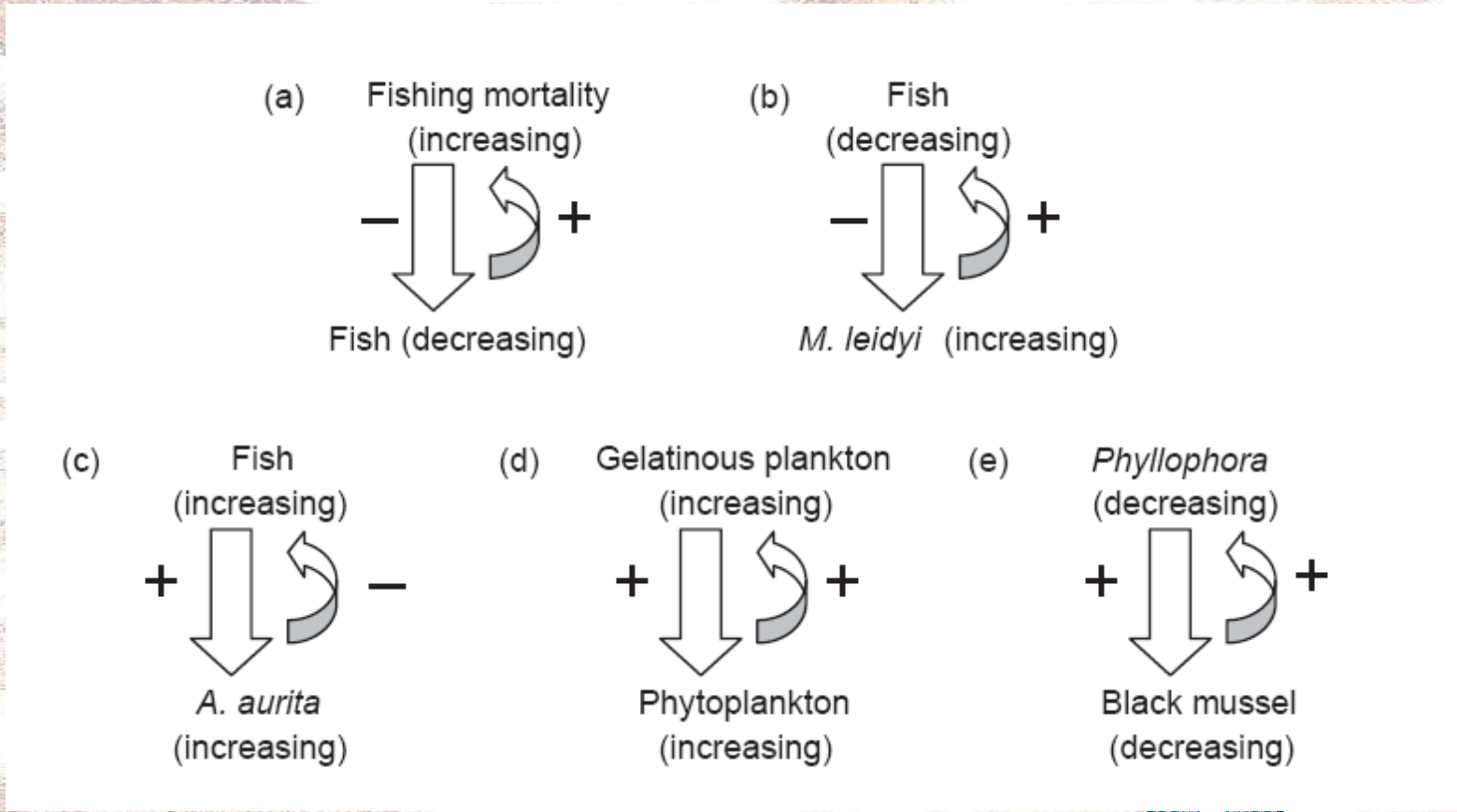
UNINTENTIONAL INTRODUCTION OF THE PREDATORY GASTROPOD *Rapana thomasiana*

- Collapse of the natural oyster and mussel stocks
- Rapana becomes one of the most important fisheries resources

Feedback mechanisms in the Black Sea

Feedback effects are positive when leading to amplification of the existing direct effects, and negative when reducing the strength of direct effects, or can even invert them, (Daskalov, Blackwell, 2008)



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Conclusions and lessons for the EAF

- **Ecosystem regime shifts associated with trophic cascade are detected from analysis of "natural experiments" – top-predator extinction and *Mnemopsis* invasion**
- **Overfishing is recognised as a main driving factor though associated with other factors as climate, eutrophication, and alien invasion**
- **Fishing is a structuring factor affecting not only fish stocks, but the whole ecosystem and can be responsible for a system shift to pathological states**
- **Recovery of a resilient ecosystem should mean restoring all important components into a new desirable state: reducing the anthropogenic impact, normalizing species interactions, buffering trophic cascades, increasing biodiversity, and improving environmental quality.**
- **Fisheries are subject to regulation and management that must target recovery of damaged ecosystems into a healthy and resilient state. Partial recovery of only some components is not stable and may drag the system back into an undesirable state**

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