

Sustainable exploitation of small pelagic fish stocks challenged by environment and ecosystem changes



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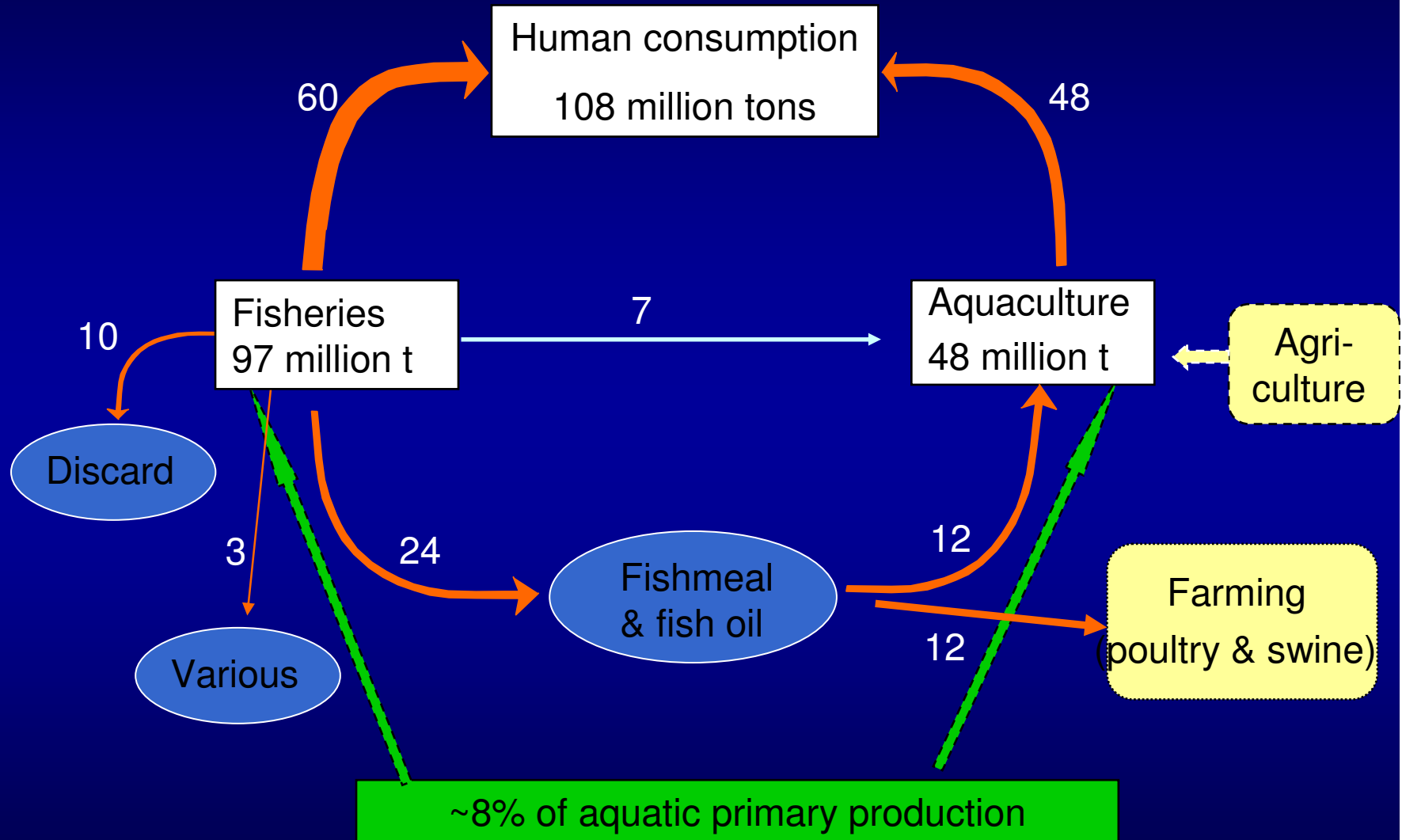
Introduction

1. Why small pelagic fish and fisheries are so “special”
2. Small pelagic fish and their physical environment
- ~~3. Pelagic fish within the trophic web~~
4. Sustainable management of small pelagic fisheries

Conclusion

Fish consumption 2005 (million t)

INTRODUCTION

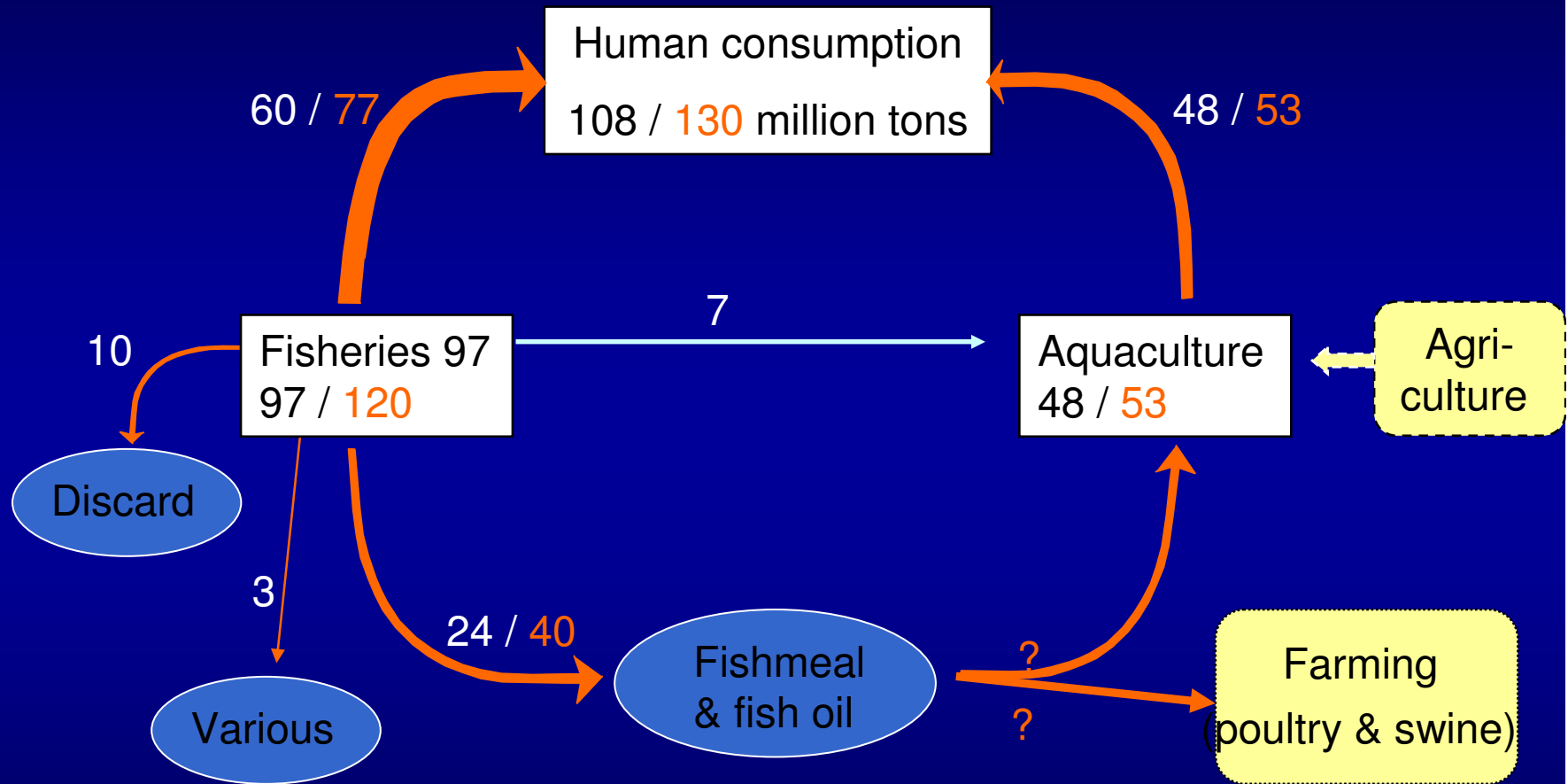


Sources: Naylor et al. 2000. Nature 405, 1017 – 1024; FAO report 2006; Ph. Gros Ifremer.

Fréon et al. IRD, France/SA

Fish consumption 2005 & 2020 (million t)

INTRODUCTION

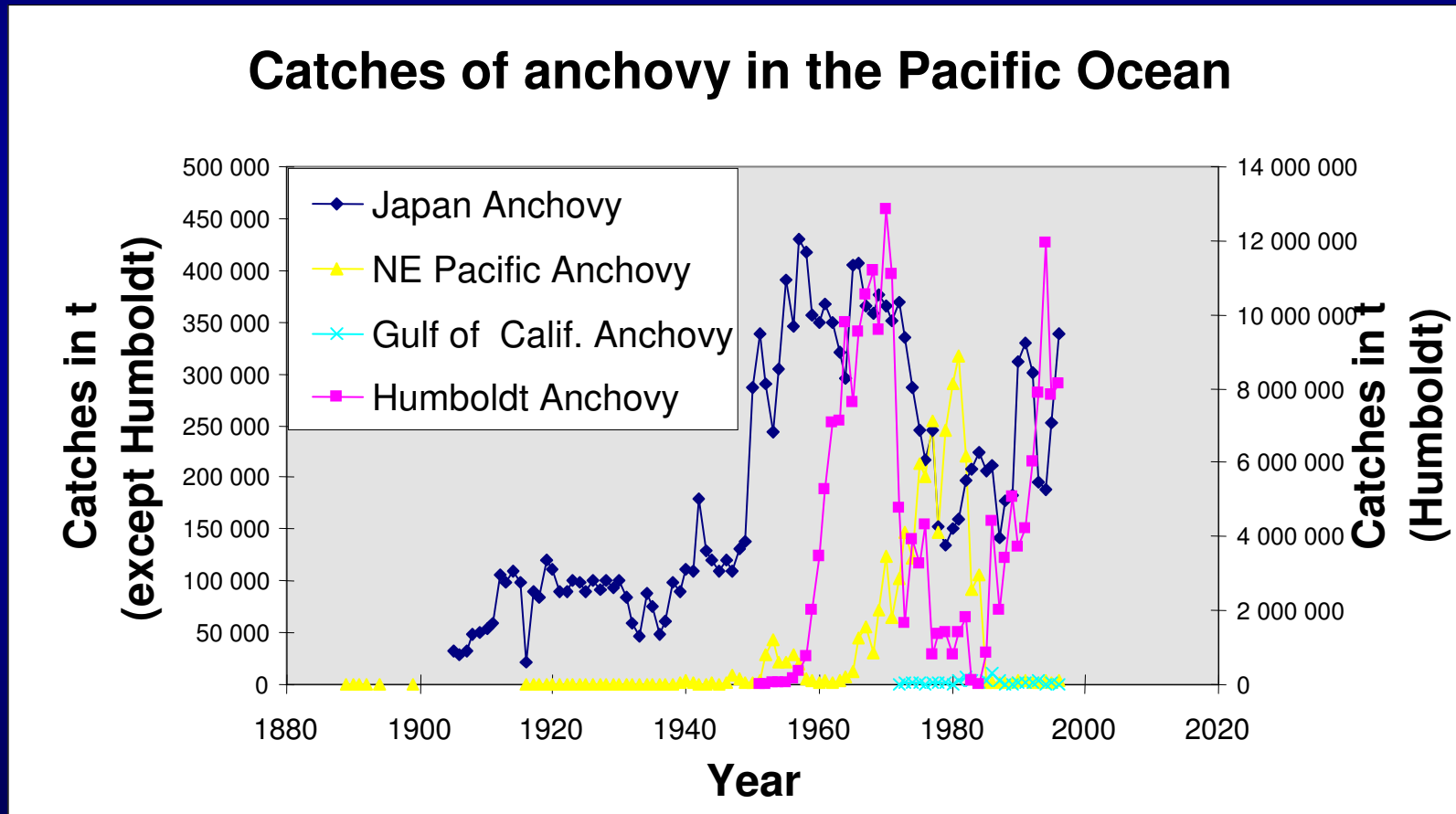


Sources: Delgado et al. 2003; Ph. Gros Ifremer.

Fréon et al. IRD, France/SA

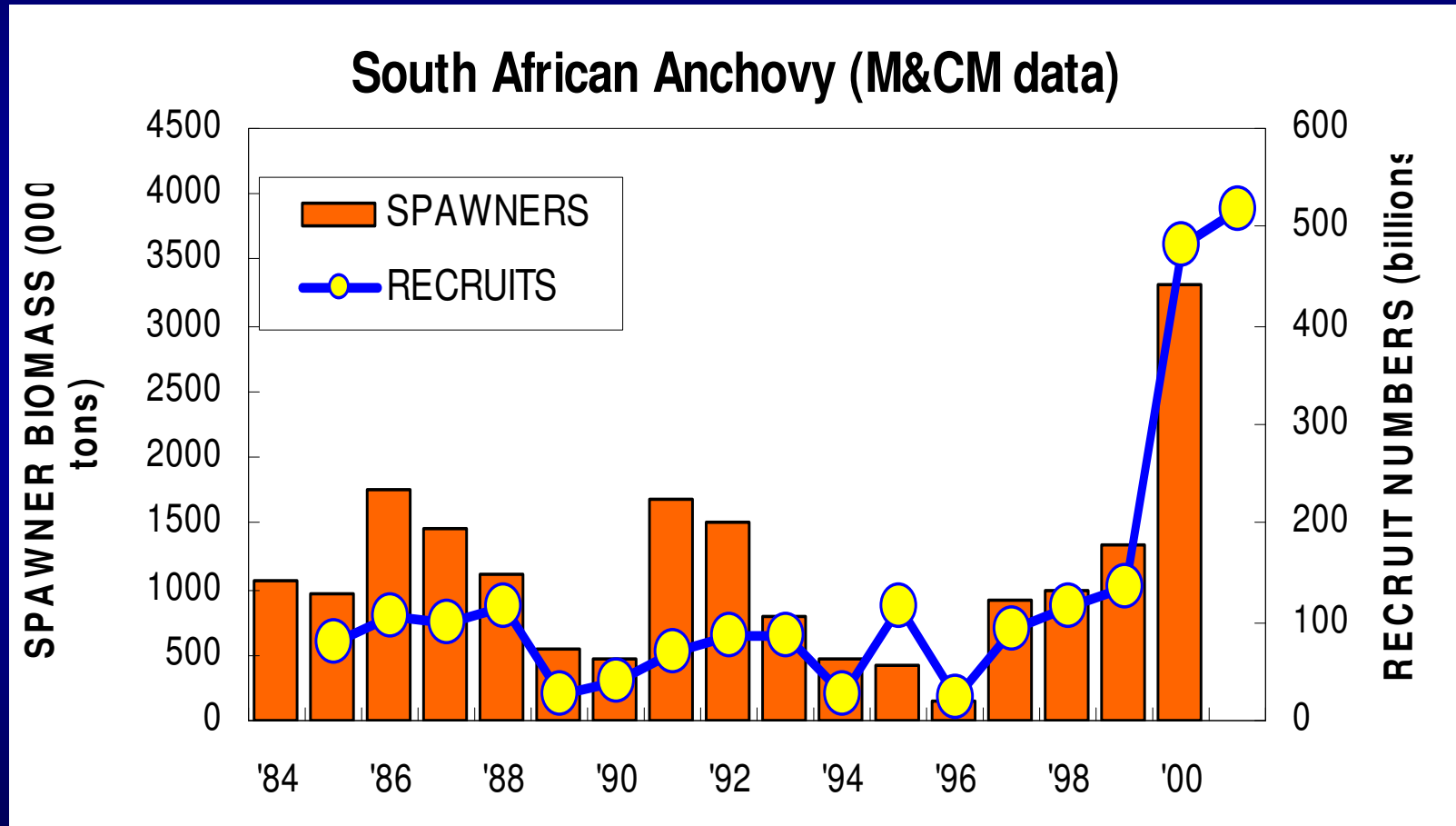
Large interannual and interdecadal variability

INTRODUCTION

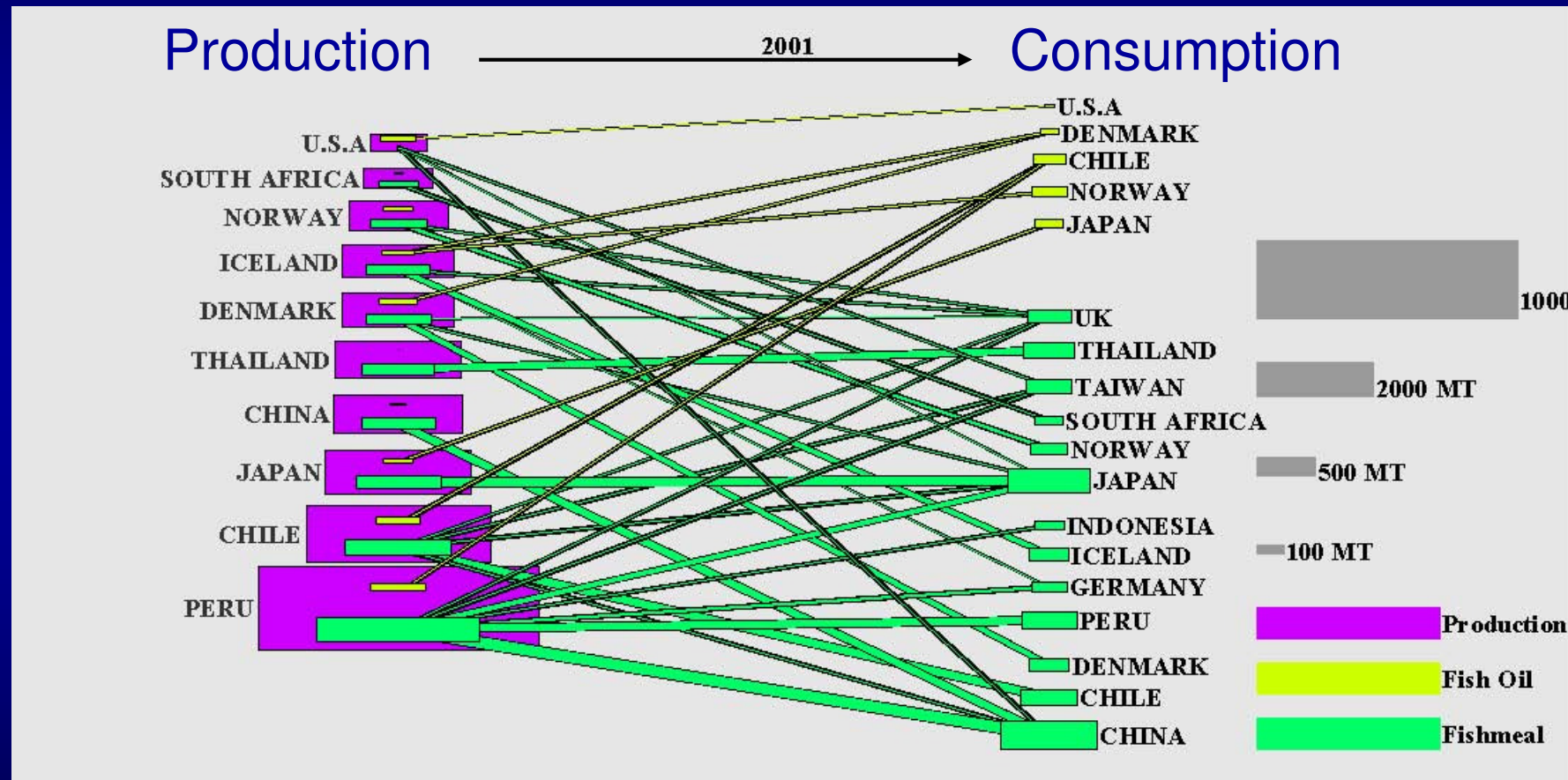


Large interannual and interdecadal variability

INTRODUCTION



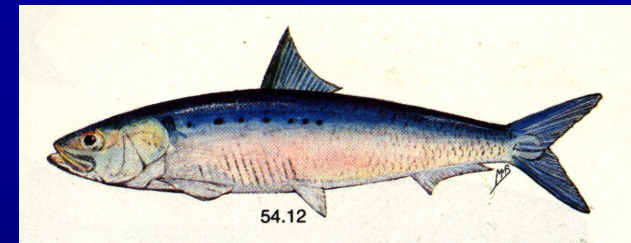
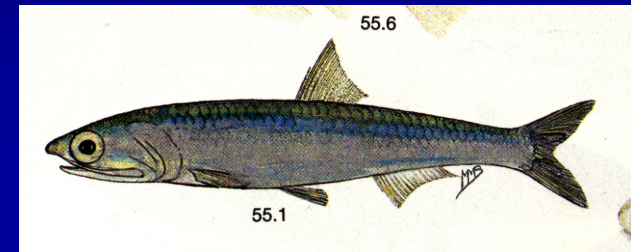
International market



Mullon et al. In prep.

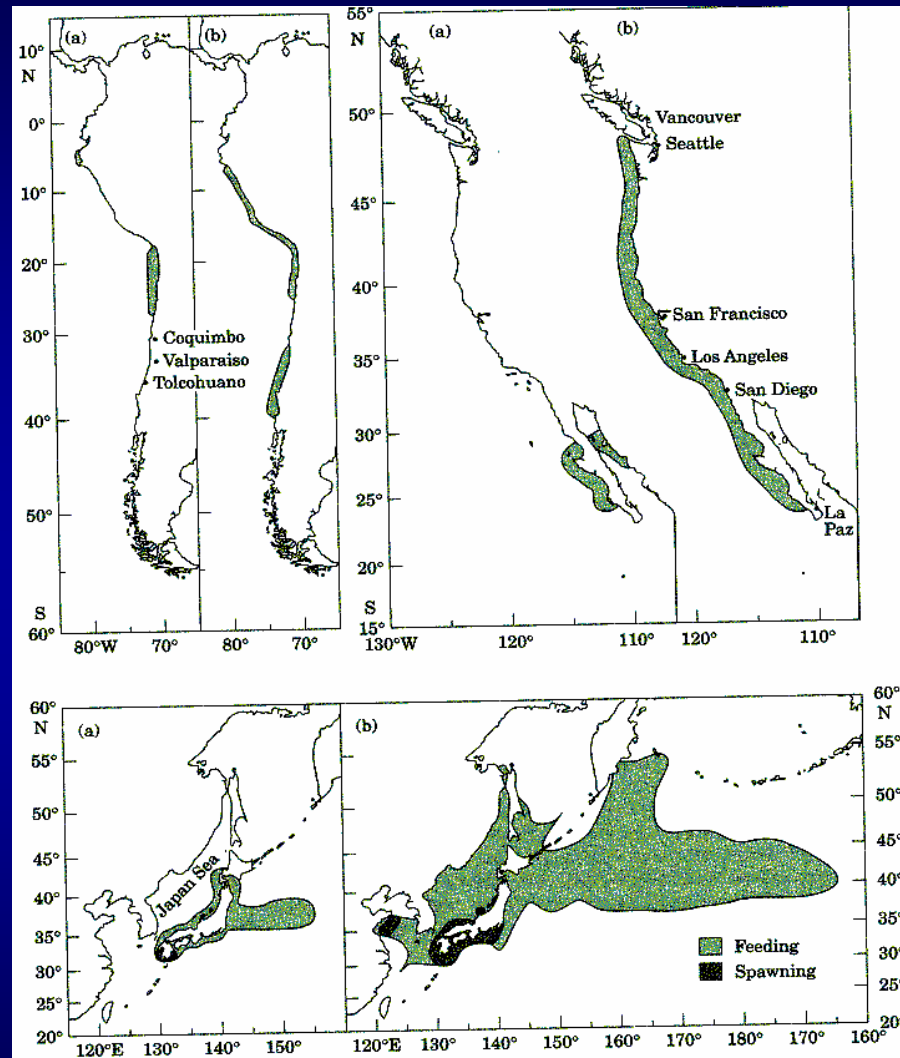
1. WHY SMALL PELAGIC FISH ARE SO « SPECIAL »

- International market
- Life history traits (lifespan, fecundity, mortality)
- Highly migratory
- Position in the ecosystem (wasp-waist)
- Spatial behavior (gregarious, fractal)
- Density dependence



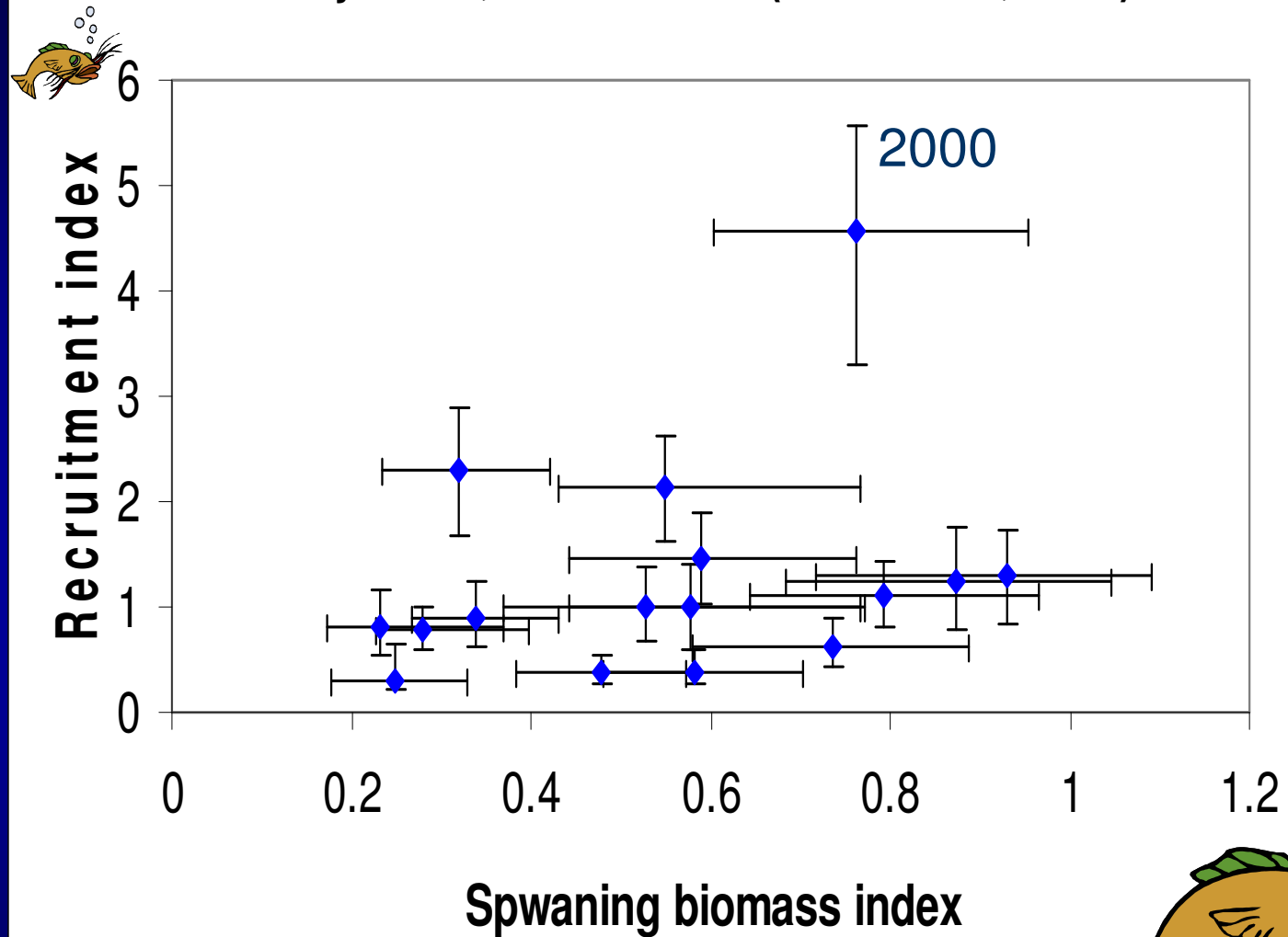
Distribution area and abundance

FISH AND ENVIRONMENT



Distribution of 3 pelagic stocks during low (left) and high (right) abundance periods

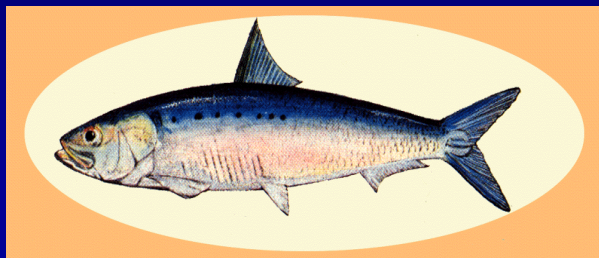
Anchovy stock, South Africa (De Oliveira, 2001)



See also Sheperd & Cushing 1990: « It is indeed plausible that the only process operating for fish population is a stochastic one: increased (and non-normal) variability at low stock size ».

Density dependence: condition & gonado-somatic index

WHY SUCH SPECIAL FISH



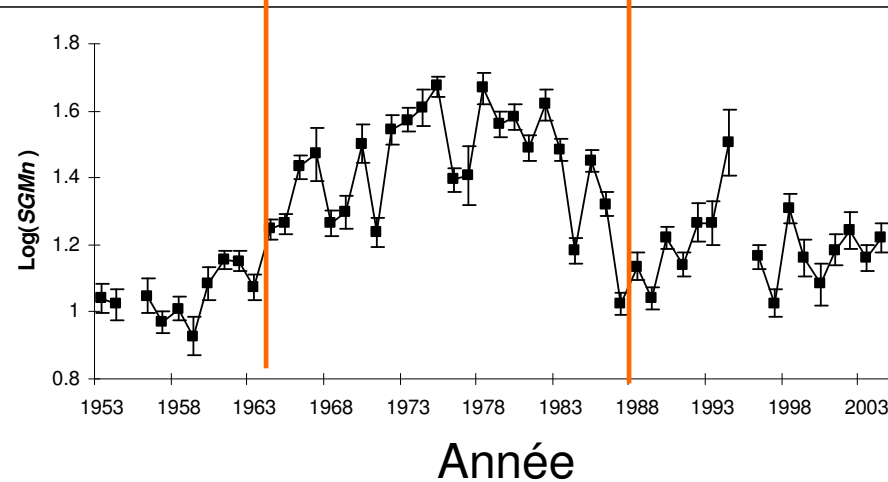
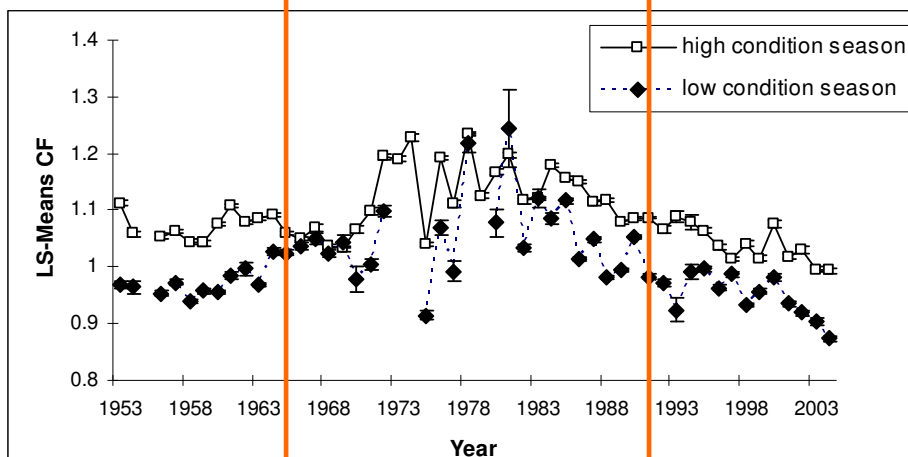
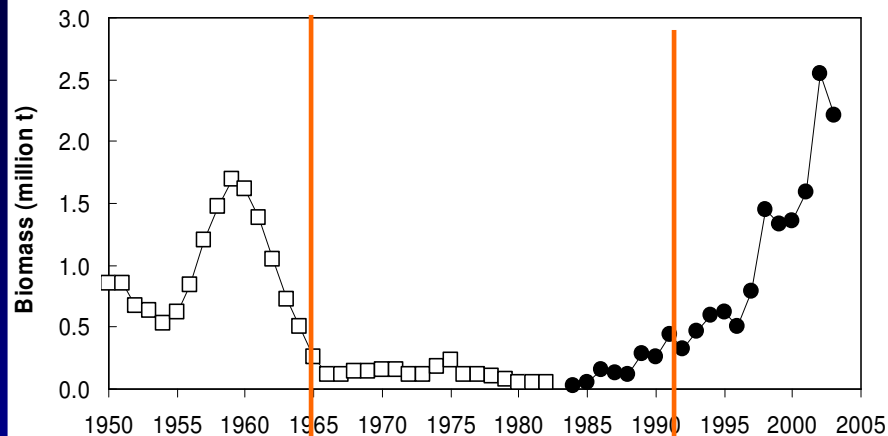
Biomass

Condition
facteur
(2 seasons)

Gonado-
Somatic
index

Van der Lingen et al. 2005

Fréon et al. IF



Année

2. PELAGIC FISH AND THEIR PHYSICAL ENVIRONMENT

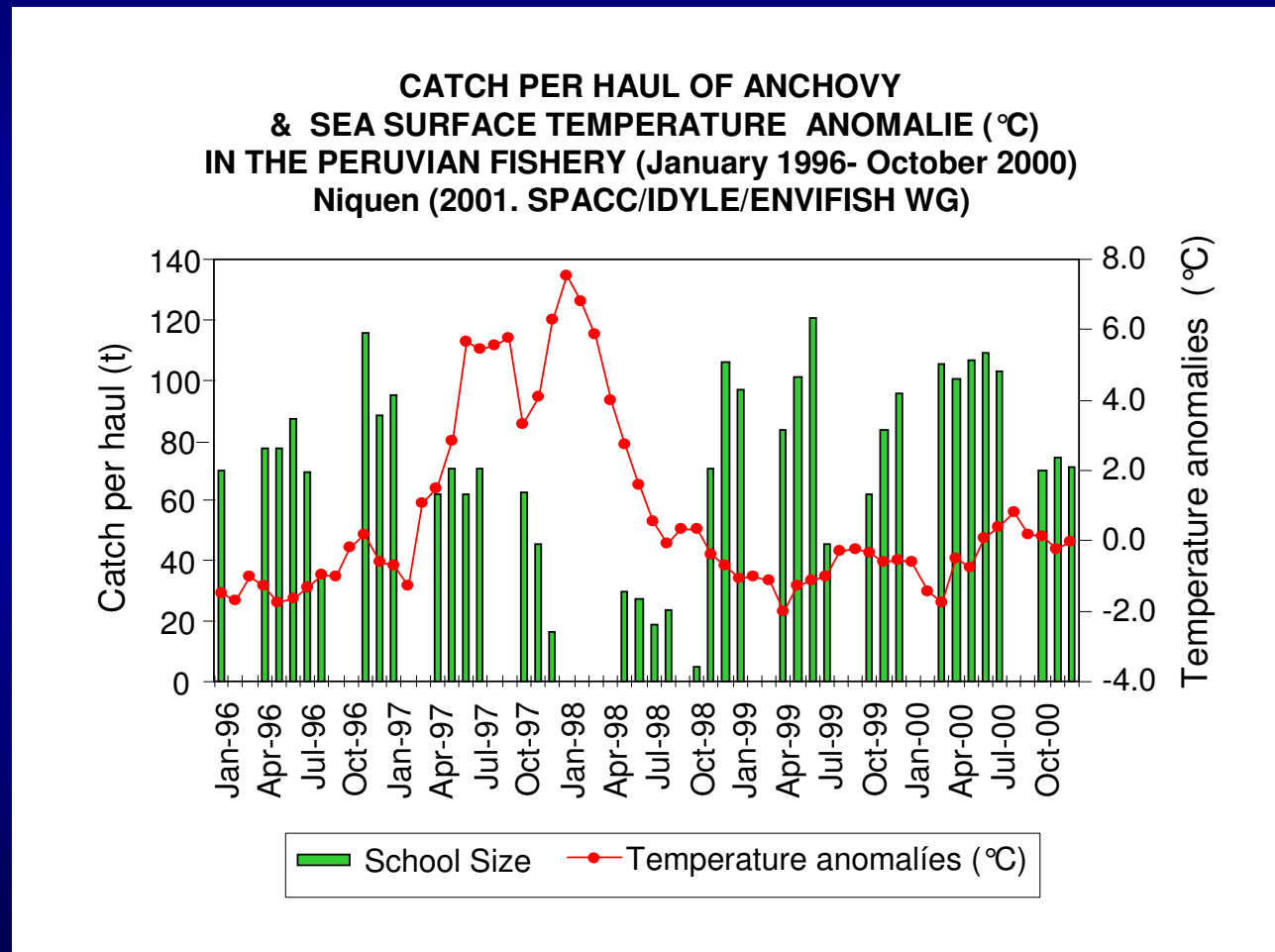
- Short term effects (on catchability)
- Medium term effects (on stock abundance)
- Long term effects (ecosystem changes)
- Relationship between distribution area and abundance

Short term effects (on catchability)

On the short term, many physical factors influence catchability, which makes it difficult to control fisheries by fishing effort regulation only.

FISH AND ENVIRONMENT

Example: effect of El Niño on the school size of anchovy in the Peruvian fishery.



Medium term effects (on stock abundance)

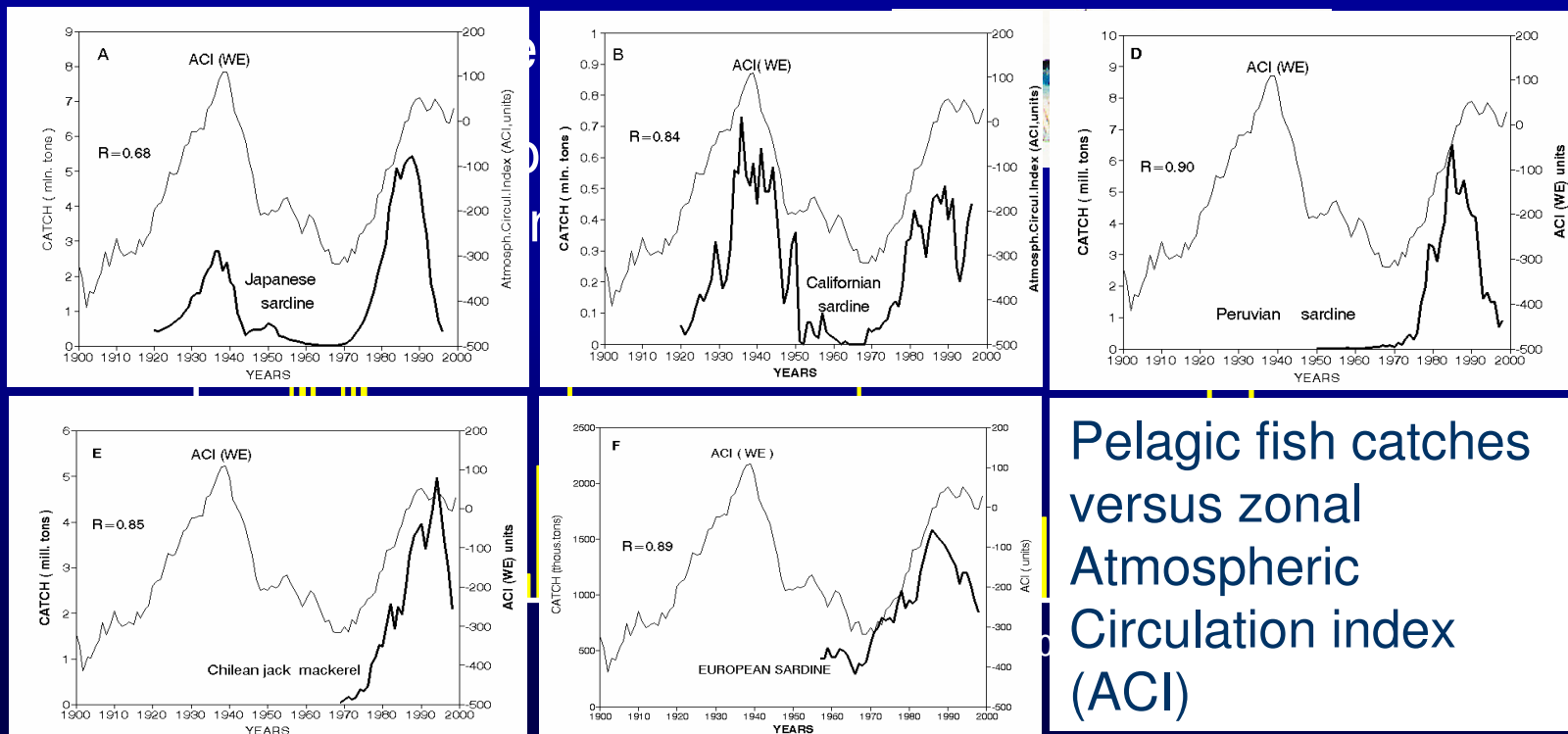
FISH AND ENVIRONMENT

- Hjort “critical period” (1913): The Oceanographic environment affects larvae survival and has an important effect on recruitment success.
- Cushing “match-mismatch” hypothesis (1969): The production of fish larvae matches or mismatches the production of their food.
- Lasker “stability” hypothesis (1975, 1978): A stable environment is needed to allow successful feeding for larvae.
- Parrish *et al.* “transport” hypothesis (1981) : Larvae transported by currents offshore are lost for the recruitment.
- Sinclair “member/vagrant” hypothesis (1988): constraints imposed by mesoscale oceanographic events on the life cycle.
- Rothschild and Osborn/MacKensie “turbulence” hypothesis (1988): micro turbulences increase the encounter rates between larvae and their food.
- Cury & Roy Environmental windows hypothesis (1989).
- Bakun “triad” hypothesis (1993): Retention, Production Concentration processes important to recruitment success. Leads to the OEW hypothesis (Cury and Roy).

Long term effects (ecosystem changes)

- Large inter-decadal variability of pelagic fish stock abundance (“regime shift”) often **claimed to be environmentally driven**, although **alternative hypotheses** proposed: interspecies dynamics; diseases (virus, parasites...).
- No clear long term periodicity but rather a **pseudo-periodicity** with a period of around 40-60 years (Baumgartner et al. 1992; Klyashtorin, 2000).
- Proposed **global climatic indices** also have pseudo-cycle lengths close to 60 years related to fish catch variations (Klyashtorin, 2000).

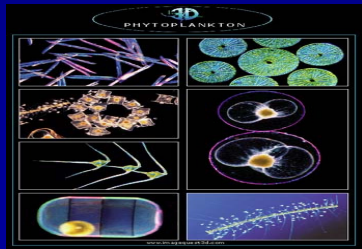
FISH AND ENVIRONMENT



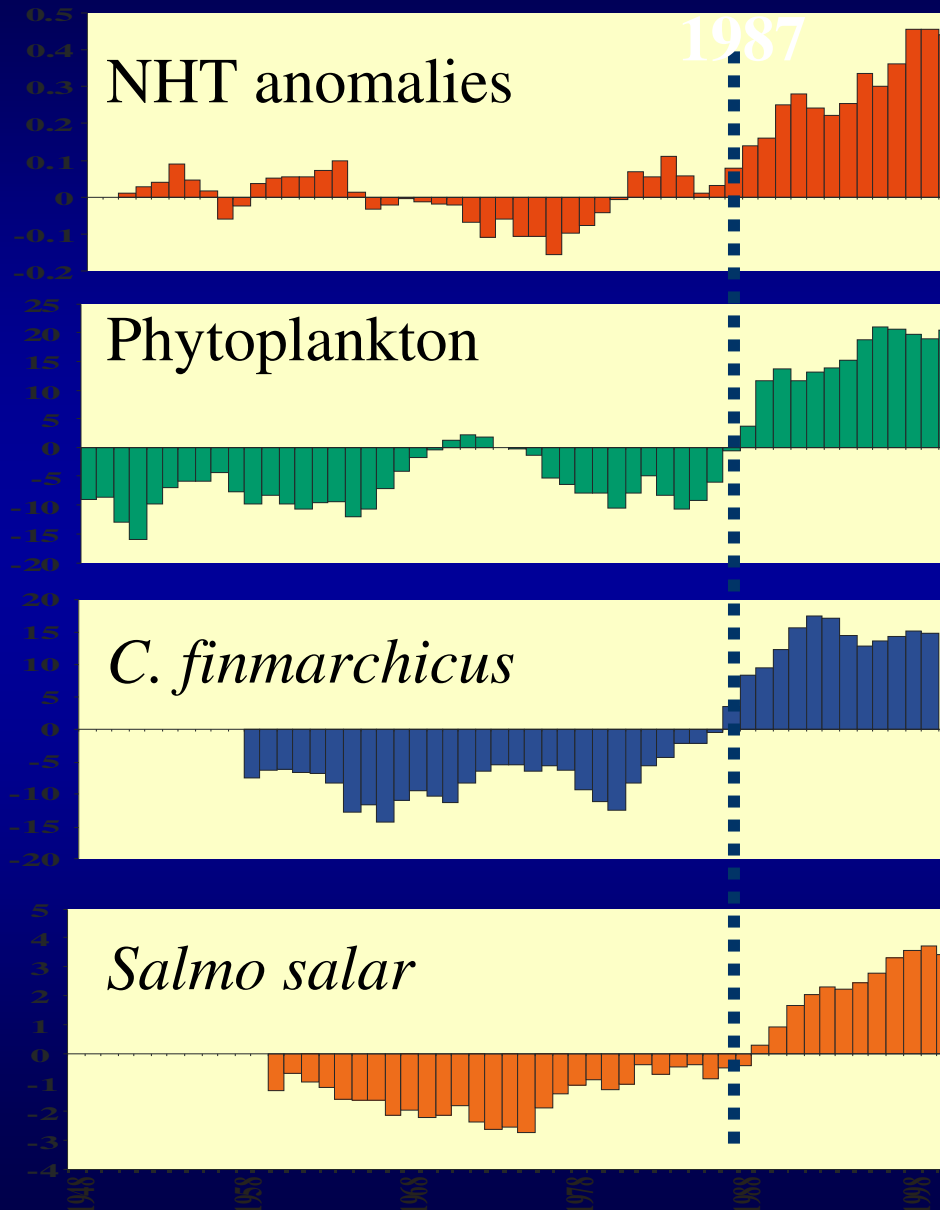
Pelagic fish catches
versus zonal
Atmospheric
Circulation index
(ACI)

Climate, plankton & salmon in NE Atlantic

FISH AND ENVIRONMENT

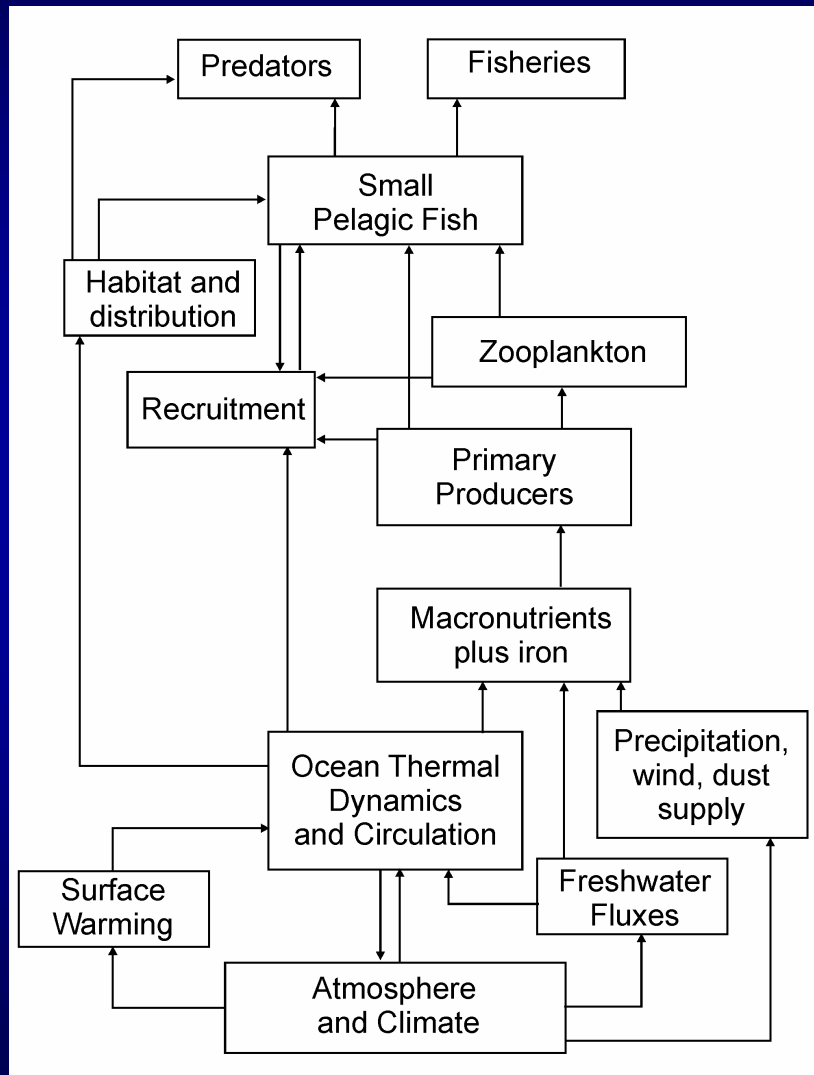


Beaugrand & Reid Global Change Biology (2003);



Fréon et al. IRD, France/SA

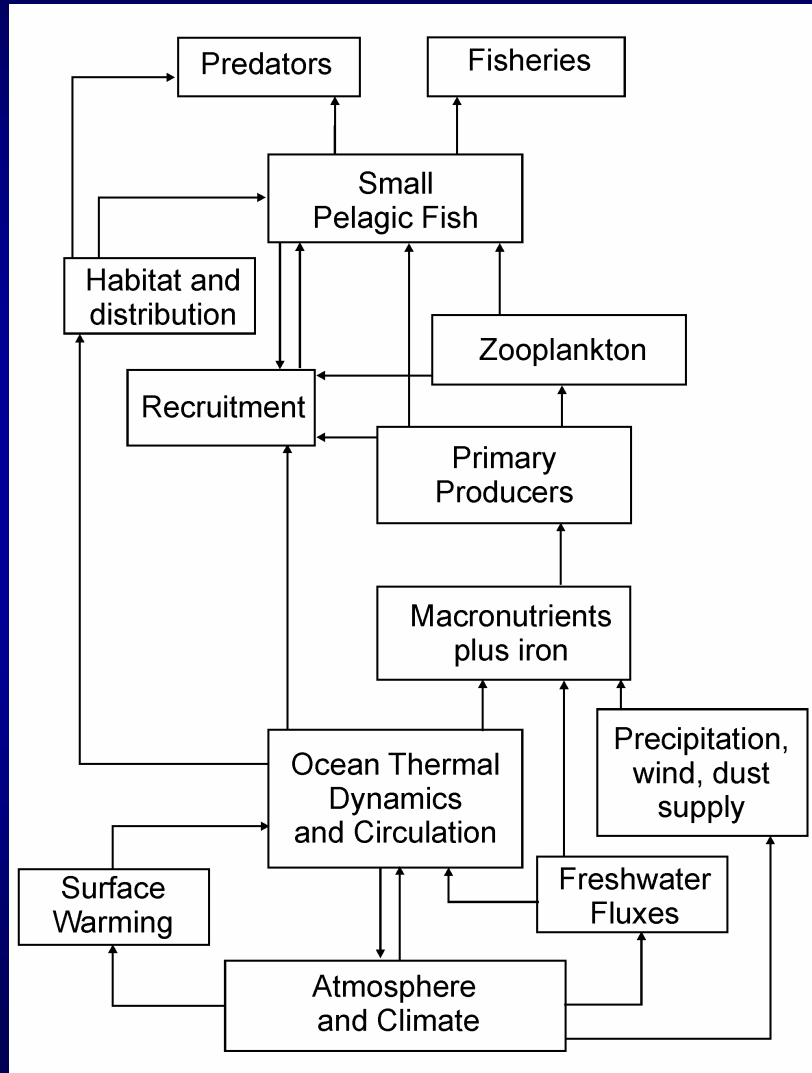
Effects of climate change



Fréon, Werner & Chavez in press

- An increase in biological productivity near shore in eastern boundary upwelling systems in response to increased winds.
- Sardine populations might be favoured, with anchovy maintaining populations in enhanced upwelling regions near shore.
- Japanese anchovy favoured (batch fecundity and larval growth) over Japanese sardine.
- Offshore and at high latitudes lower overall biological productivity
- Except when input of fresh water stabilize the water column;

Effects of climate change (cont.)



- Change in delivery of micro-nutrients (e.g. iron) by atmospheric dust deposition could affect productivity and phytoplankton composition
- Expected changes in upwelling seasonality, and phenological impacts on plankton and fish
- Species ranges to shift toward the poles, with species of shorter life cycles and smaller body sizes adapting more quickly
- Populations located along the latitudinal boundaries of a species range more likely to be affected than those found at the centre of the distribution
- Exploitation will reduce resilience of populations and make them more susceptible to future climate variability and change.

3. SUSTAINABLE MANAGEMENT OF SMALL PELAGIC FISHERIES

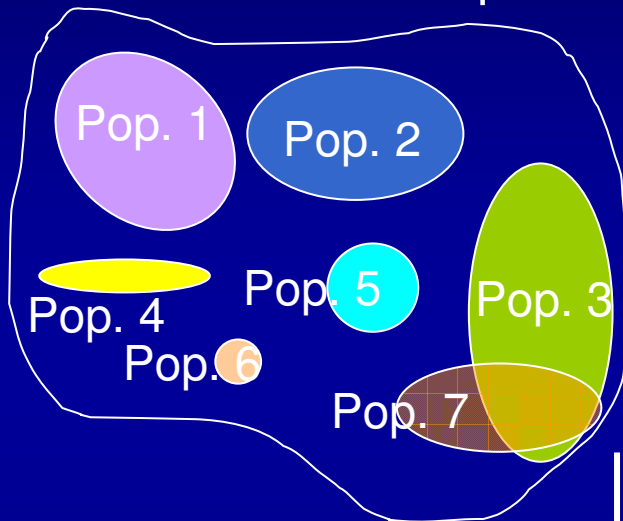
- Stock structure and resilience to exploitation
- Overcapacity and interdecadal variability of abundance
- Different management options
- Different Regulatory mechanisms
- Proposal for a two-level management strategy



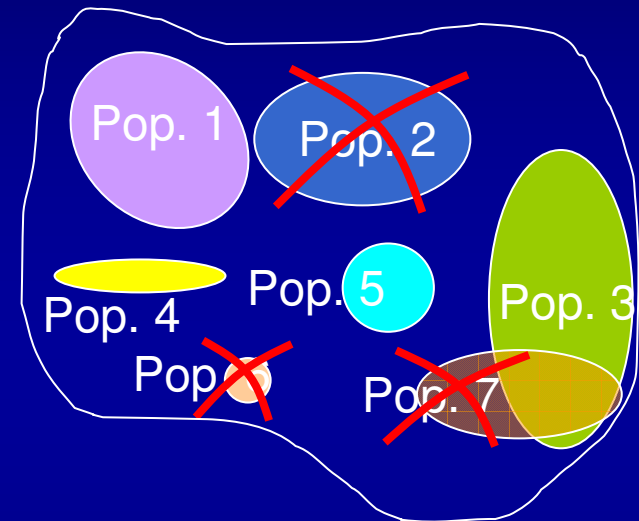
Stock structure and resilience to exploitation

The question mark of stock structure (stock as a single unit versus meta populations, sub-stocks linked to refuge areas) and resilience to exploitation.

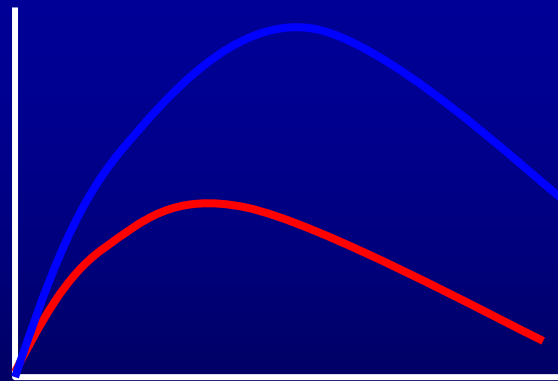
SUSTAINABLE MANAGEMENT



Fishing out biodiversity



Catch



Collapse of 3 populations

Fishing effort

Overcapacity and interdecadal variability of abundance

SUSTAINABLE MANAGEMENT

Why don't they move?



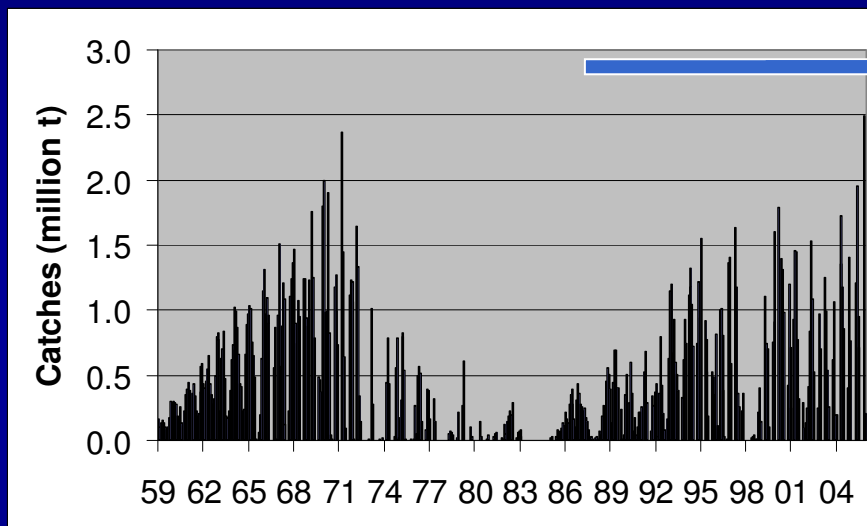
S. Bertrand



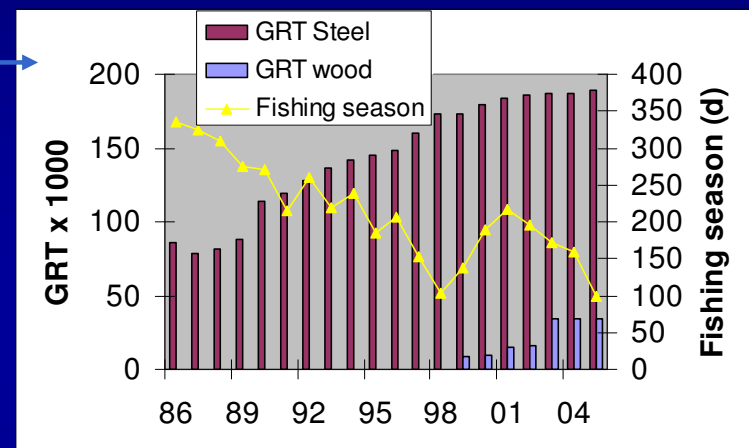
Evidences of overcapacity

Anchovy in the peruvian north-central area

SUSTAINABLE MANAGEMENT



Monthly landings of anchovy from 1959 to 2005.

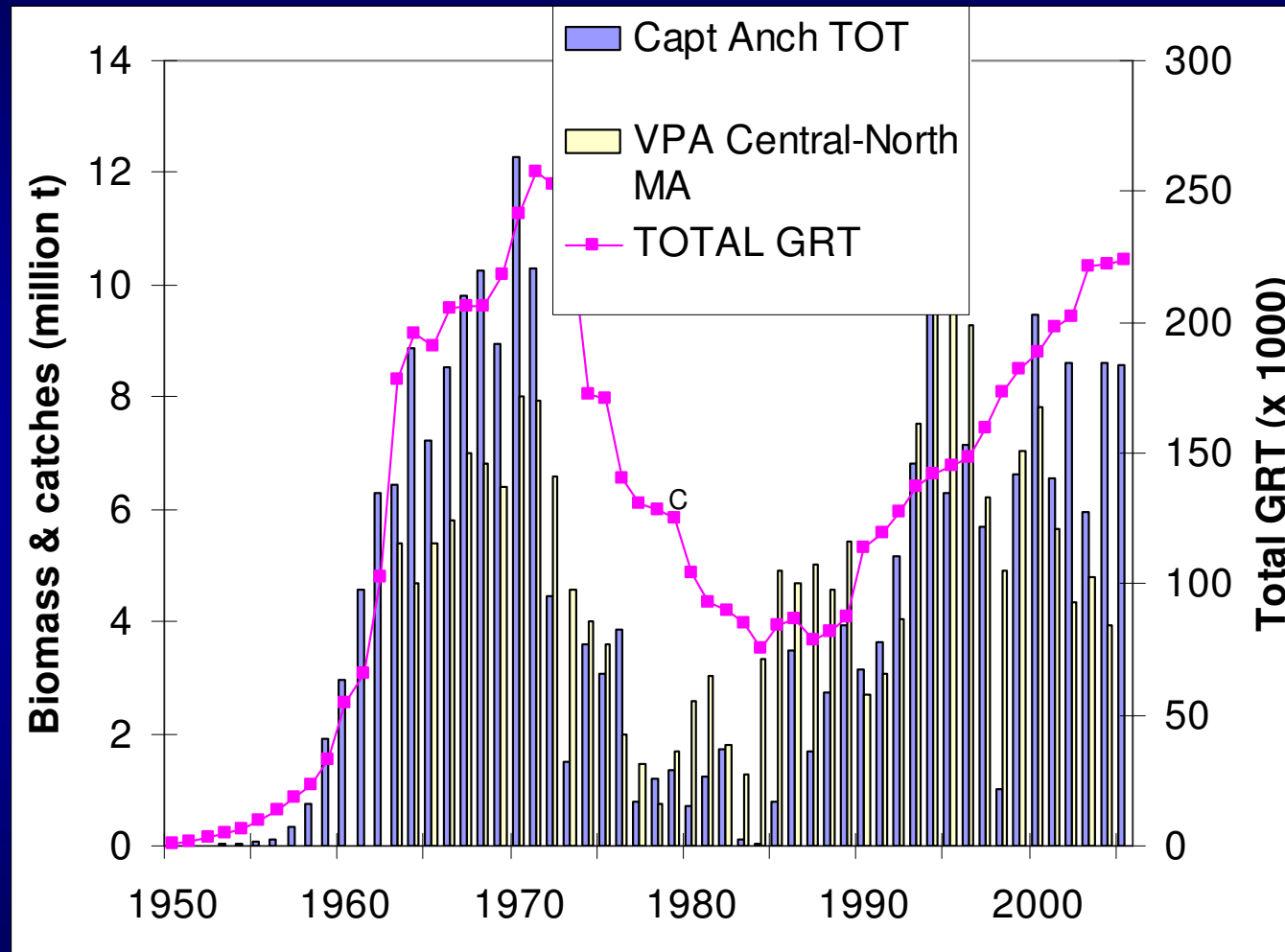


GRT and duration of the fishing season (1986-2005)

Niquen & Fréon 2006
Fréon et al. In press

Stock dynamics versus fleet dynamics

SUSTAINABLE MANAGEMENT


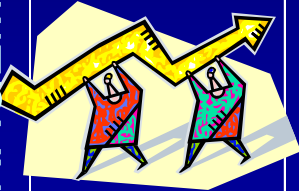





Lag between investment and disinvestment







Fréon et al. In press

Different management options

SUSTAINABLE MANAGEMENT

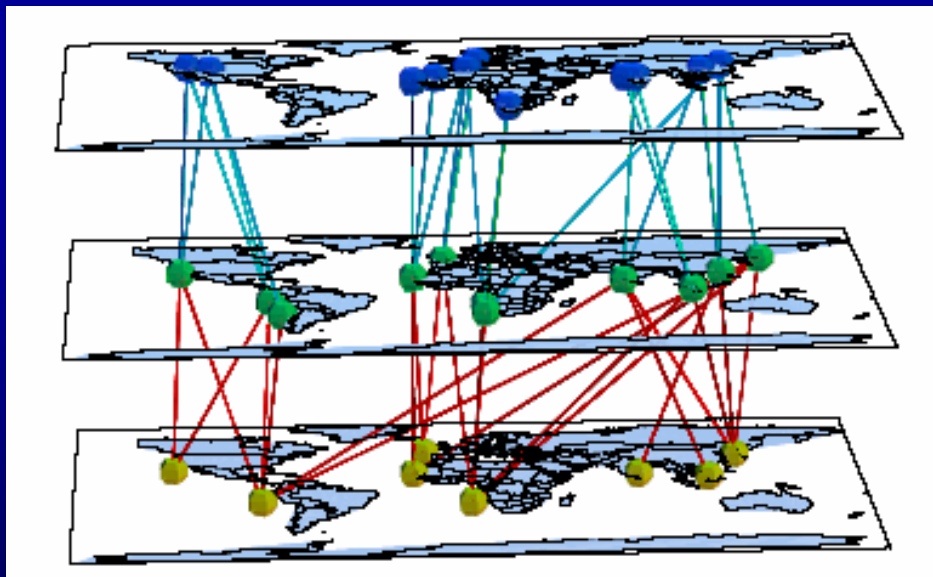
METHOD	PROS	CONS
Steady state 	Easy to implement. Availability of reference points.	Not adapted to highly variable resources. Ignore ecosystem effects. Imposes conservative options to limit risks.
Adaptive 	Flexibility in time. Decreases risks of collapses by taking into account major uncertainties. Makes use of good fishing opportunities.	Requires good annual stock assessment and fast data processing. Permanent uncertainty for fishing industry (investment, employment). If resource abundance too variable in time, fishing allowance might not fit fleet capacity.
Predictive 	Anticipation of future events (investment, employment). Makes use of good fishing opportunities.	Risk of over/under exploitation if poor abundance forecast. Ecological processes not well enough understood to allow reliable predictions. Environmental prediction required if short delay between environmental forcing and change in abundance.
Manag. procedure 	Combines above methods. Dampers interannual variab.	As above but minimized.
Ecosystem 	Global approach. Can resolve conflicting objectives. Explores different options.	Difficulties of trade-off. Few tools, lack of experience and scientifically accepted marine ecosystem indicators.

Different Regulatory mechanisms

MECHANISM	PROS	CONS
 <p>Quota (TAC)</p>	<p>Relatively easy to implement and enforce. Full control of total mortality. Flexibility in time.</p>	<p>Variable TACs might not fit fleet capacity. Problem of mixed-species schools (encourages dumping).</p>
 <p>Control of overall fleet capacity</p>	<p>Easy to enforce. Limits risks of ecosystem overexploitation. Reduces costs and limits socio-economical problems.</p>	<p>Not species specific. Risk of overexploitation if increase in catchability and vice versa. Risk of overcapacity due to increasing efficiency (technology, learning, etc).</p>
 <p>Control of standardized effort</p>	<p>Might be species-specific in some cases. Limits fish dumping.</p>	<p>Difficult to calibrate effort by several fleets. Uncontrolled changes in F if changes in q. Difficult to implement and enforce. No reduction of overhead costs. Might create socio-economical difficulties.</p>
 <p>Time/area closure (seasonal or <i>ad hoc</i> base)</p>	<p>Allows protection of some developmental stages. Easier to enforce. Limits fish dumping.</p>	<p>Not protective enough if not on an <i>ad hoc</i> base. Difficult to decide on the optimal season. No reduction of overhead costs.</p>
 <p>Area Closure and MPA</p>	<p>As above. Protect the ecosystem.</p>	<p>Not protective enough for pelagic species. Optimal size, number and location of MPAs?</p>
 <p>Fish size control</p>	<p>Allows protection of some developmental stages (e.g. pre recruits or old fish).</p>	<p>Not always easy to implement without avoiding fish dumping (poor gear selectivity). Genetic manipulation (max. size).</p>

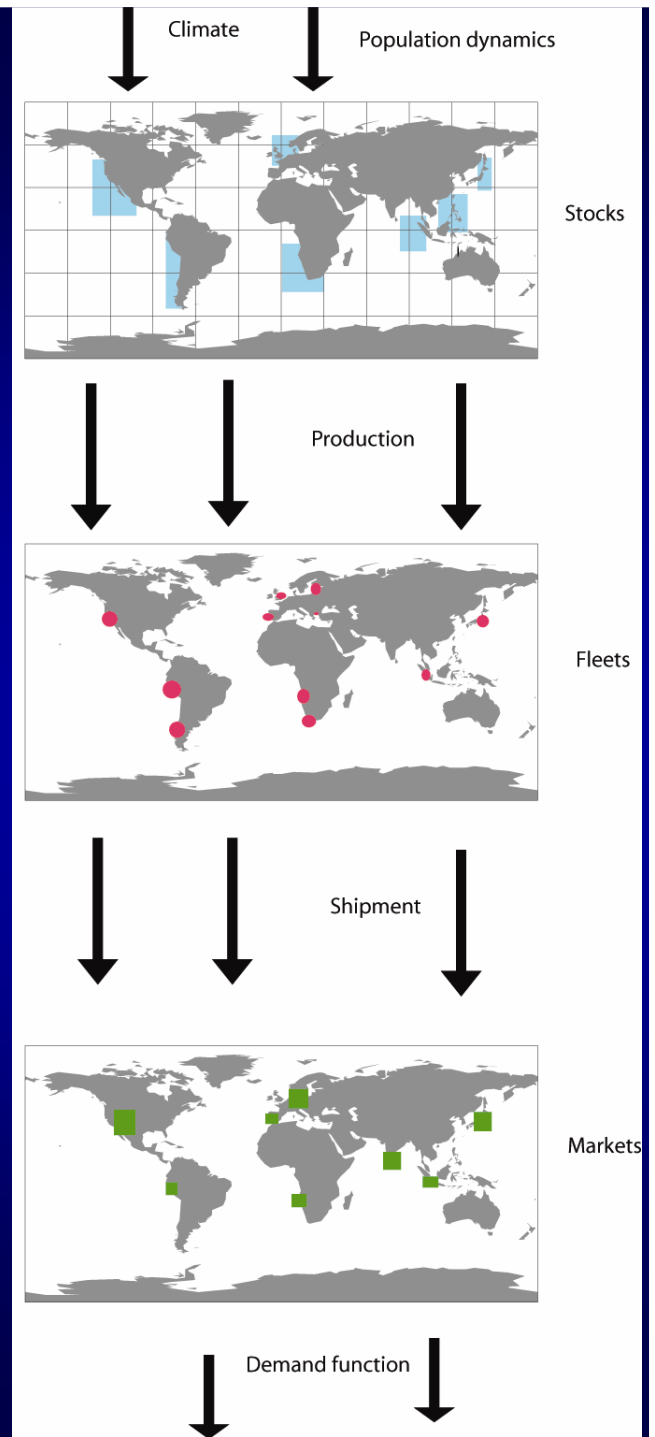
Bioeconomical models & role-playing game sessions

SUSTAINABLE MANAGEMENT



Mullon & Fréon 2005

Fréon et al. IRD, France/SA

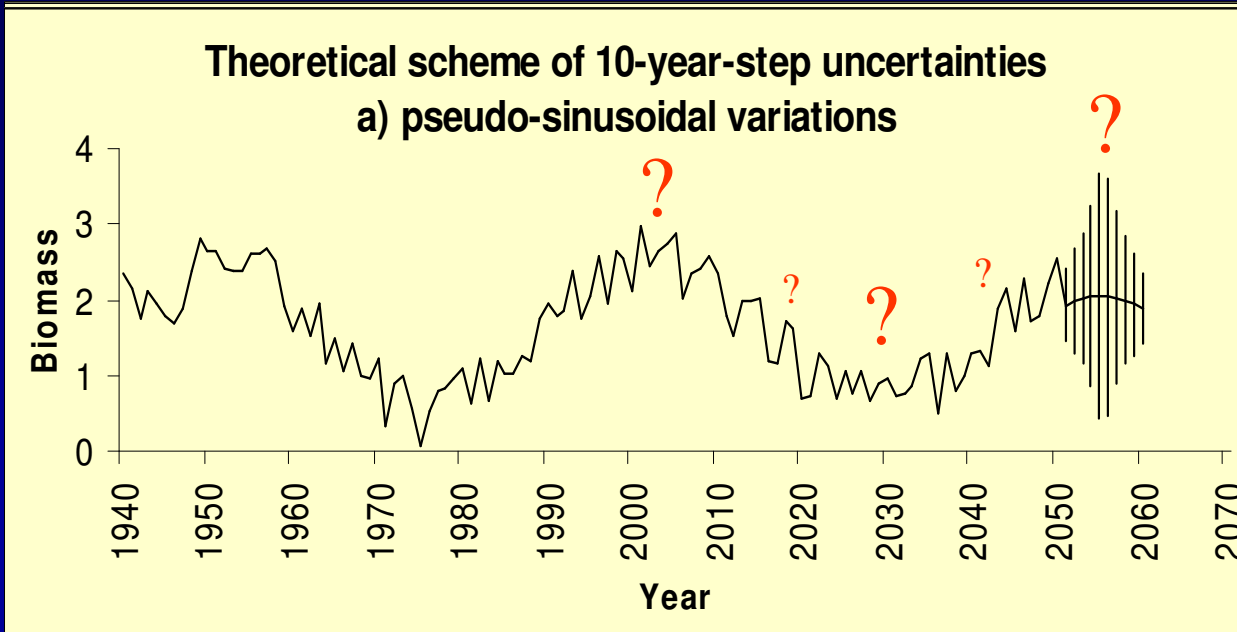


Proposal for a two-level management strategy

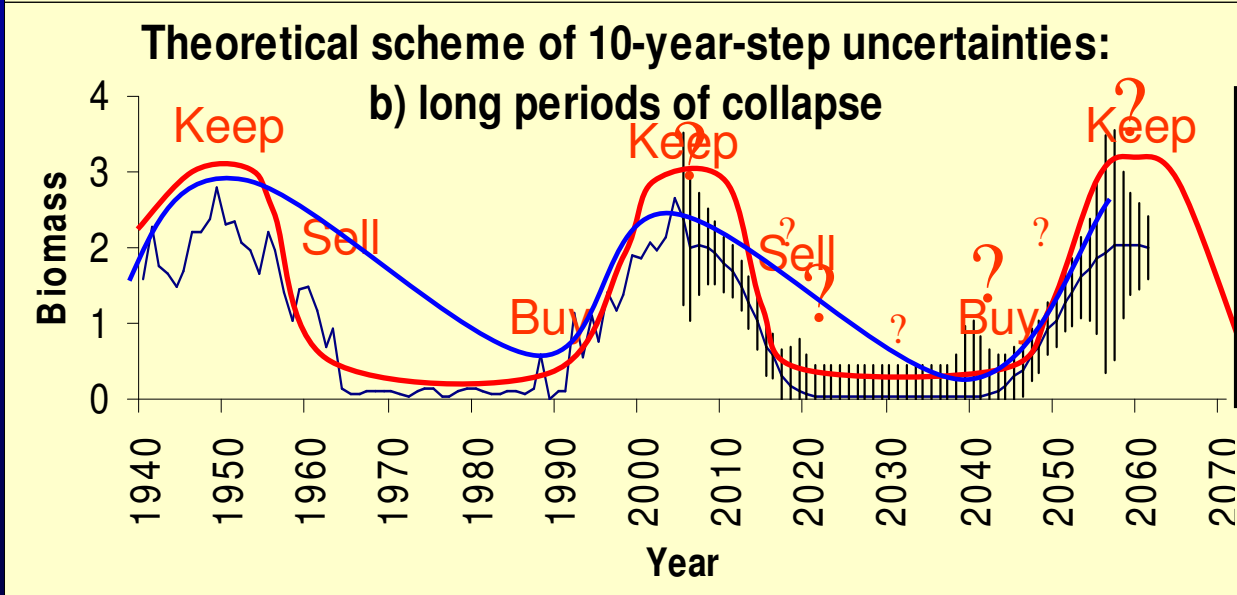
SUSTAINABLE MANAGEMENT

- 1) Short term adaptive management** (example MP based TAC) using new ecosystem-based indicators as far as possible.
- 2) Long term fleet capacity control** based on long-term autocorrelation and pseudo-periodicity of pelagic fish stock abundance. Make use of versatile national fleet or distant-water foreign fleets when necessary.

Proposal for a two-level management strategy



The difference between a) and b) is likely to be due to exploitation, resulting in accelerated decrease in abundance and extended periods of collapse.



Investment strategy:

- Present
- Optimal

CONCLUSION

- Small pelagic fish share many common specific traits (life history, etc.).
- The majority of small pelagic exploited stocks are threatened by exploitation often out of phase with environmental impacts (short and long term) and the demand will keep growing, but they are resilient
- Environmental changes can affect the fisheries either at different levels: catchability, distribution & abundance of the resource
- Despite decades of research, lack of understanding of processes still limits short term forecast of abundance. Process-oriented studies (bio-energetics, IBM, experiments, etc.) requested
- Stock structure must be better understood (genetics on DNA)
- Assessment and management of small pelagic fish stocks is difficult due to their specific traits & rapid response to climate and environmental signals
- As a result they are less tractable through traditional population dynamic models and assumptions
- Need to improve the accuracy of direct and modern methods of stock assessment (acoustic, LIDAR, visual, ichthyoplankton via CUFES, etc.) on recruits & adults abundance
- Should try to combine adaptive management (short term), fleet capacity control (long term) and ecosystem consideration, with participative management
- Lot of unknowns but innovative field of research that generated several original hypothesis in the recent years.