Modeling the potential impacts of aquaculture expansion and climate fluctuations on marine ecosystems

Gorka Merino, Manuel Barange, Christian Mullon and Lynda Rodwell

"Integrated modelling approaches for the management of marine resources"

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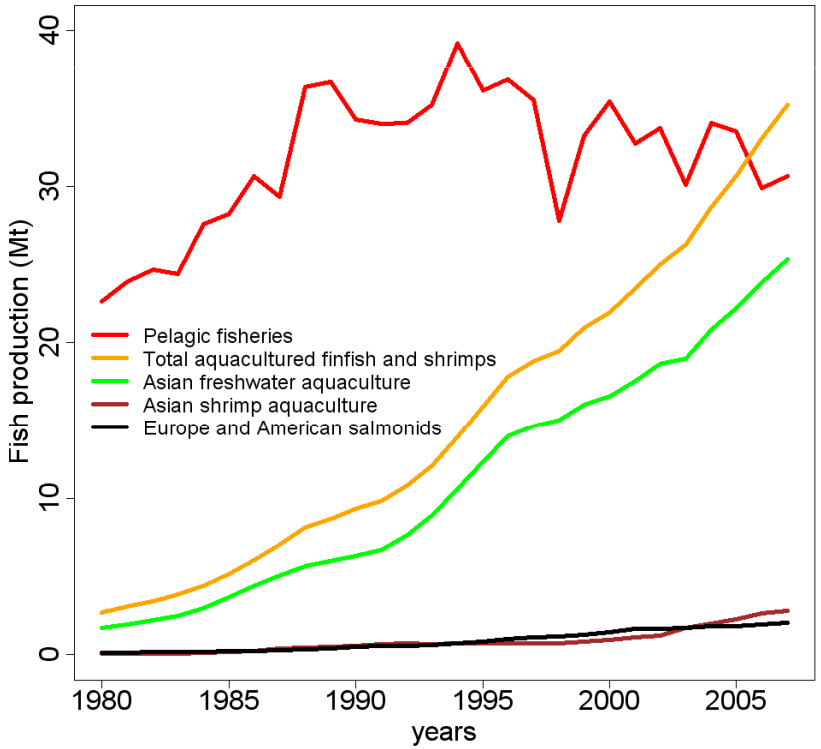
Plymouth Marine Laboratory

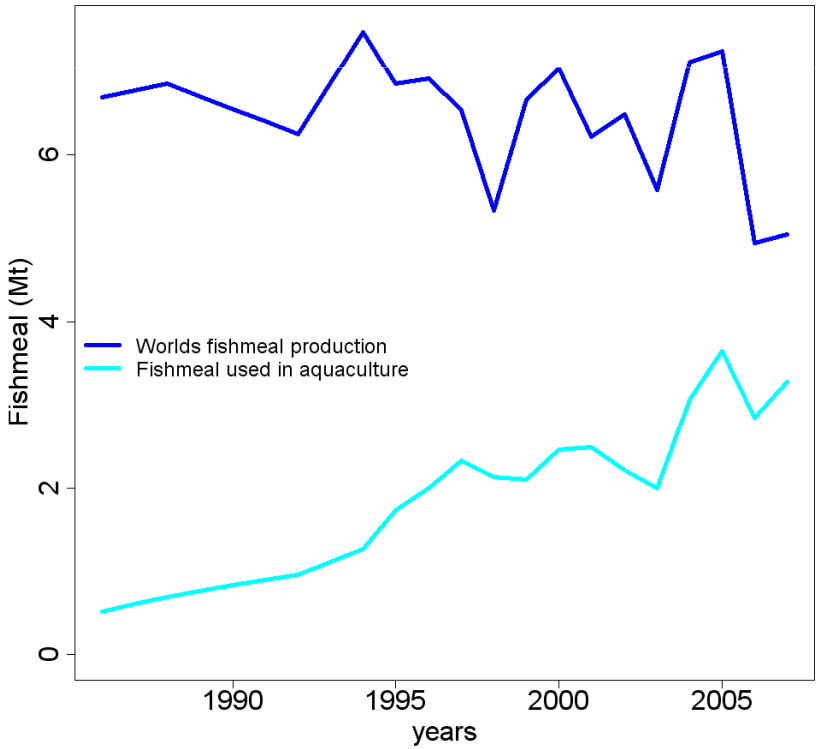
IRD Institut de recherche pour le développement

The University of Plymouth

Introduction

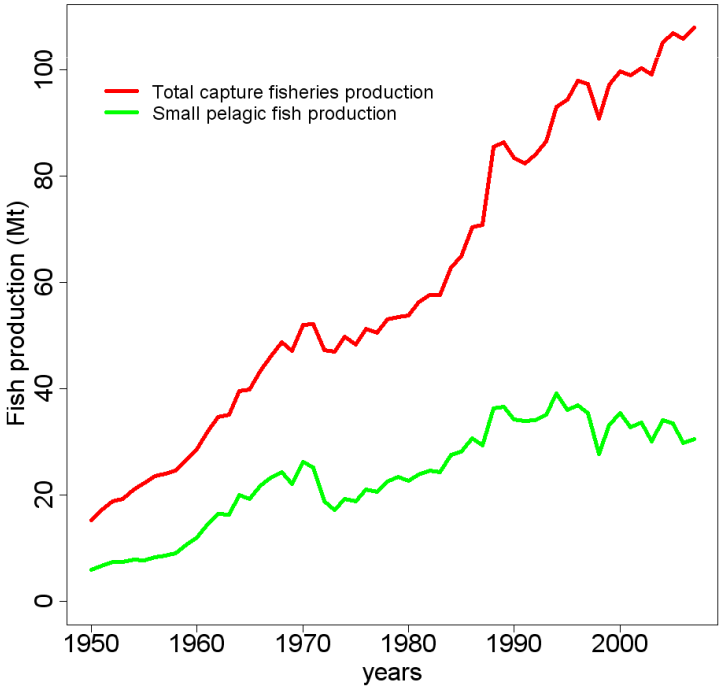
- Global fish consumption has increased from 9 kg per capita and year in 1961 to 16.5 kg in 2003, and is expected to rise to 17.0 kg by 2020 (Delgado et al., 2003).
- The increase in fish supply has been supported by aquaculture.
- Such growth in global aquaculture has raised some concern on the fate of the fish species

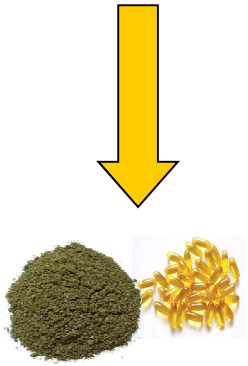




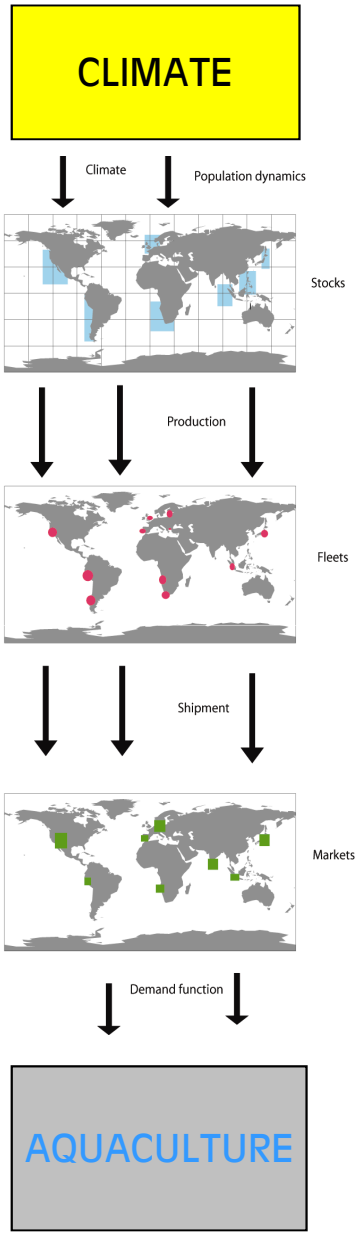
Introduction

- Small pelagic fish (sardine, anchovies, sandeel…) represent nearly 30% of the total marine fisheries.
- Production highly related to environmental fluctuations (El Niño in Humboldt, NAO index in the North sea, temperature related in Japanese anchovy…).
- Almost entirely used to produce fishmeal, a powder of high protein content used in aquaculture and others…





6Mt Fishmeal + 1.2 Mt Fish oil

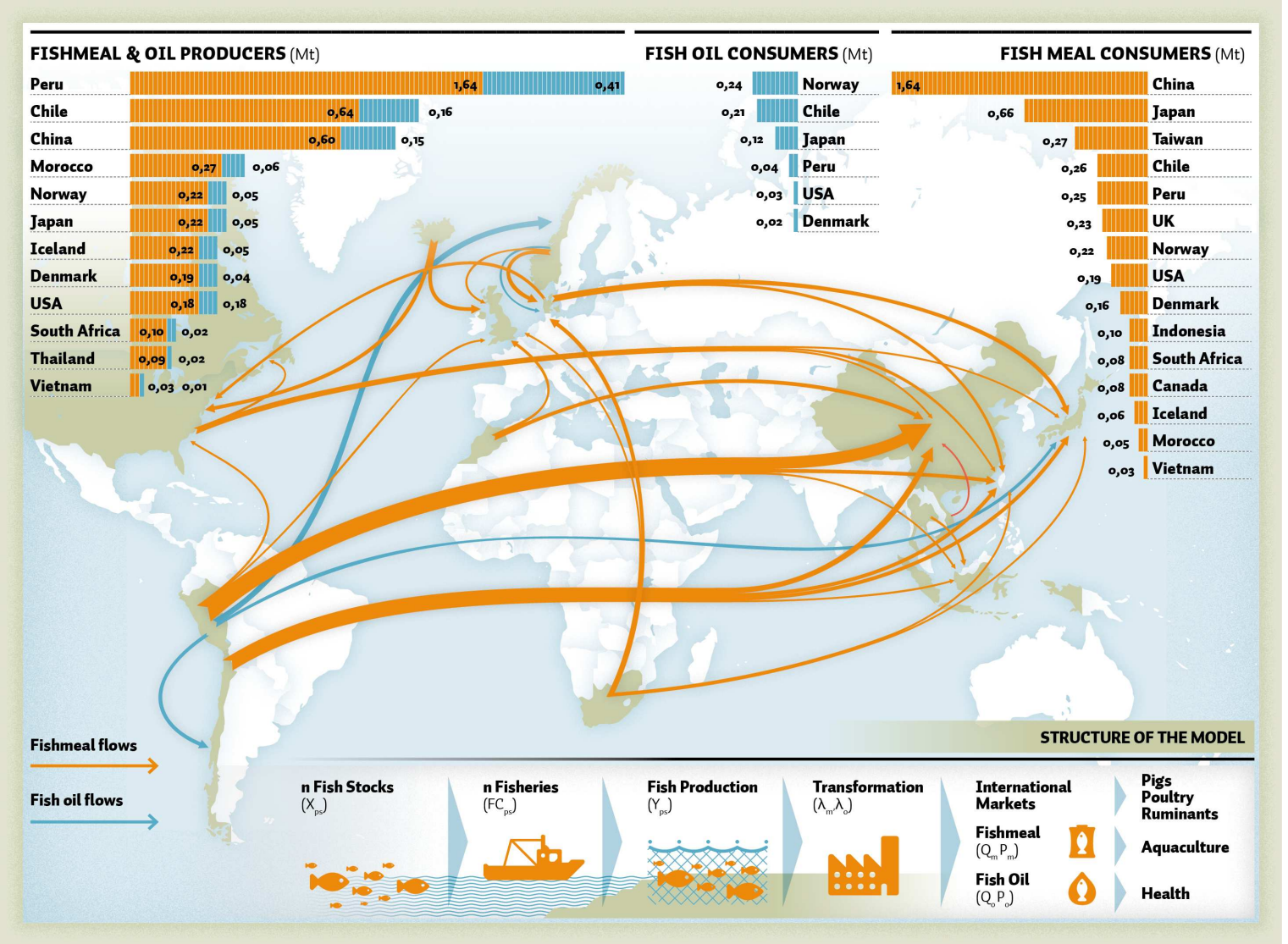


Objectives

- Modelling the climate-ecosystems-fisheries-aquaculture and markets system.
- Evaluate the potential of regional climate and global market perturbations to alter a global bio-economic equilibrium.
- Will aquaculture expansion relieve pressure on wild stocks or will it reduce the overall available protein for human consumption?

The data

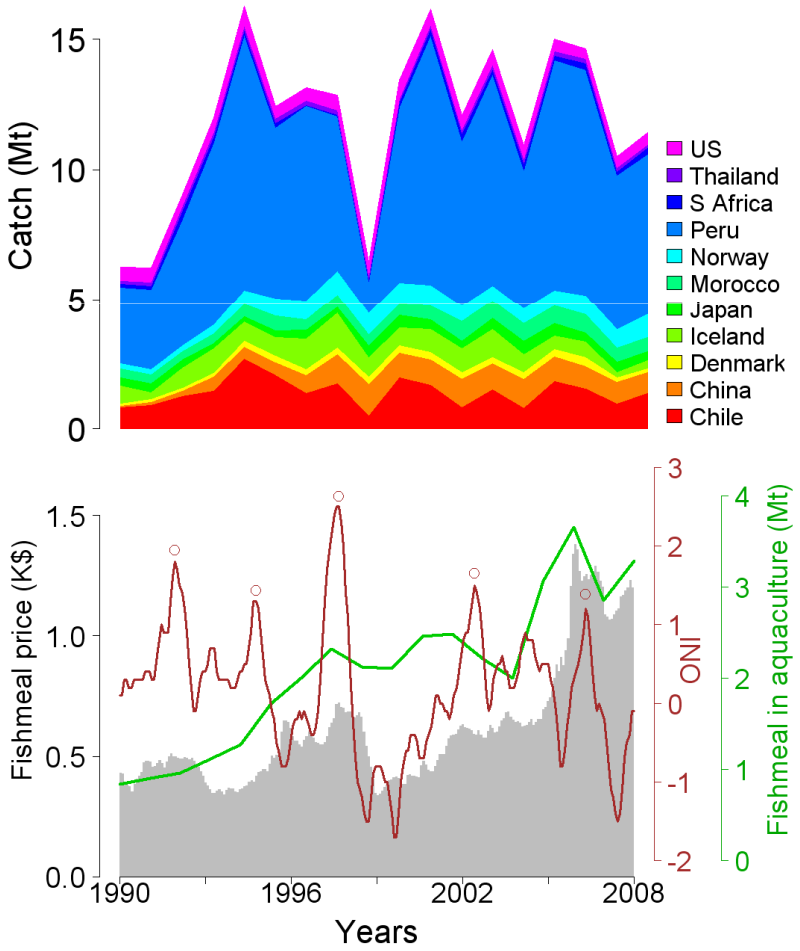
- 1) 1997-2004 International Fishmeal and Fish Oil Organization import and exports. The model captures ca. 85% of the global fishmeal trade.



The data

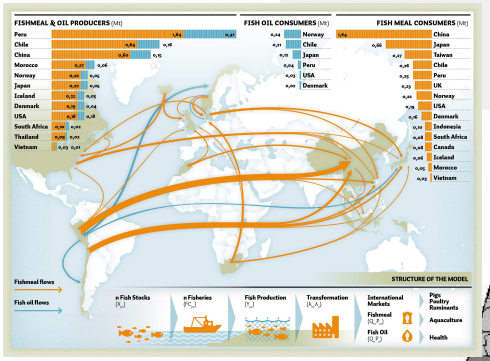
- 1) 1997-2004 International Fishmeal and Fish Oil Organization import and exports. The model captures ca. 85% of the global fishmeal trade.

- 2) Independent climate indicator (Oceanic Niño Index, NOAA), commodity price database (World Bank) and commercial fisheries data (FAO).

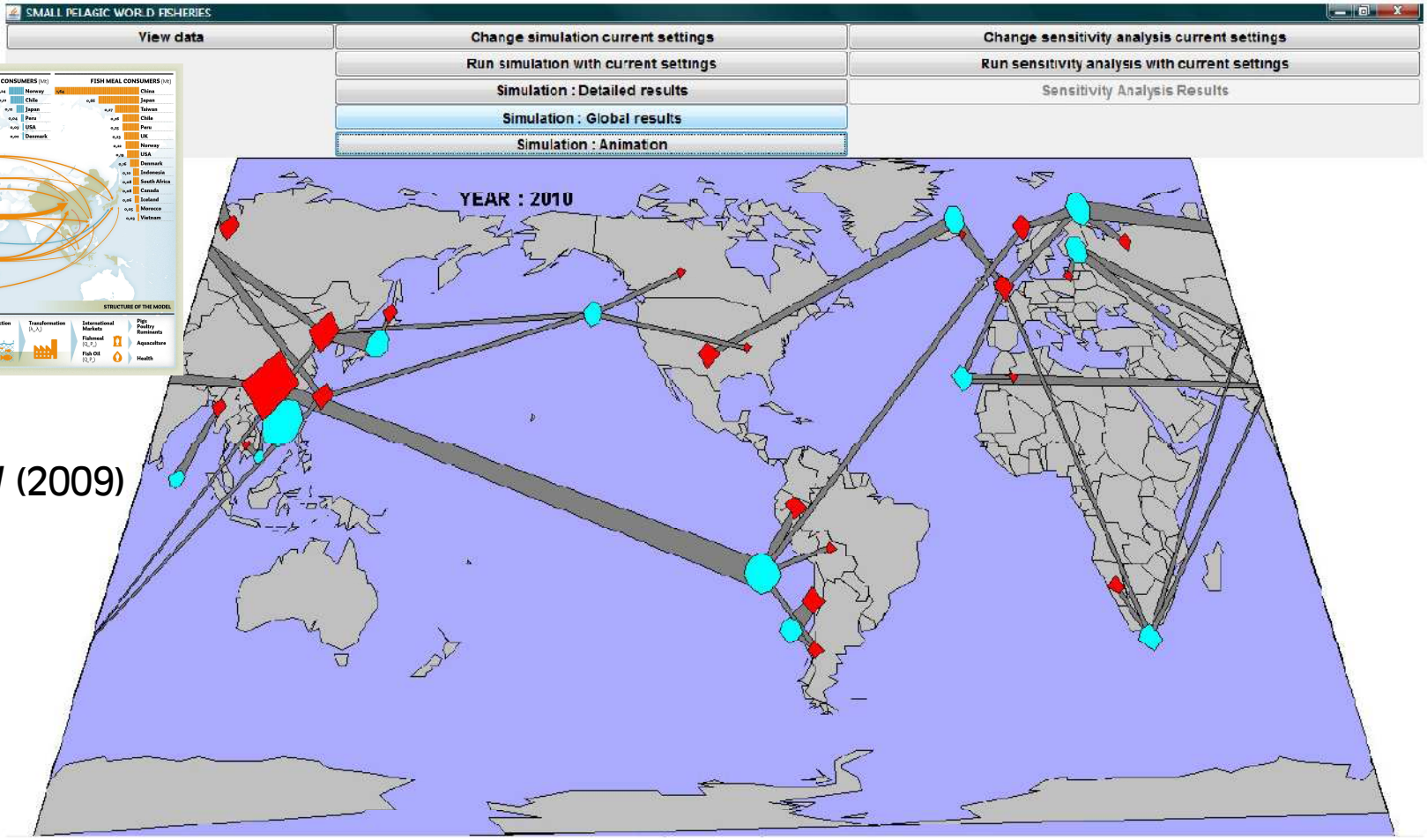


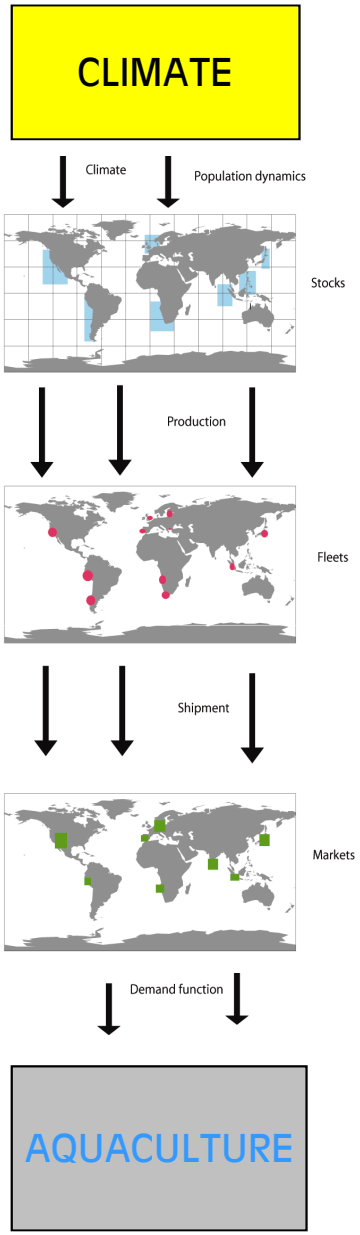
The model :

- Natural resources: 12 Surplus production and fisheries investment models.
- 15 fishmeal and 6 fish oil paths from producers to consumers.
- *Exogenous fluctuations on stocks and price equations.*

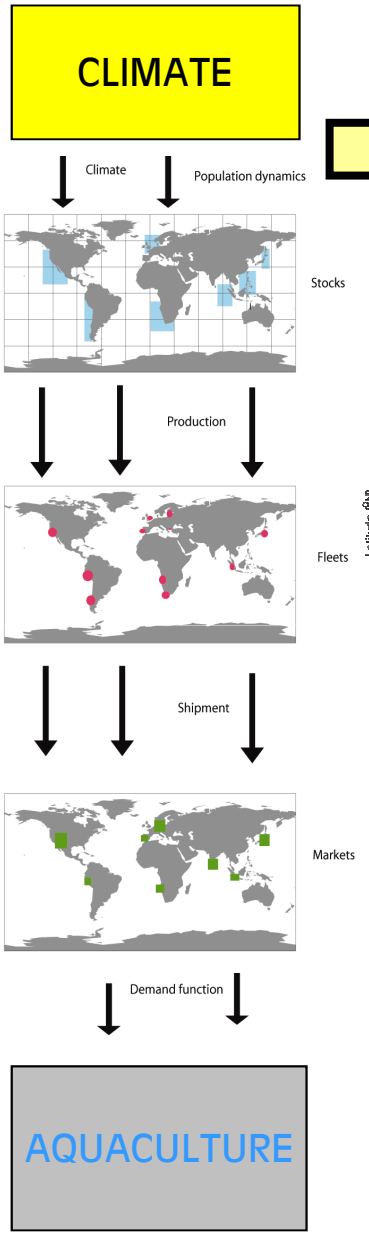


Mullon *et al* (2009)



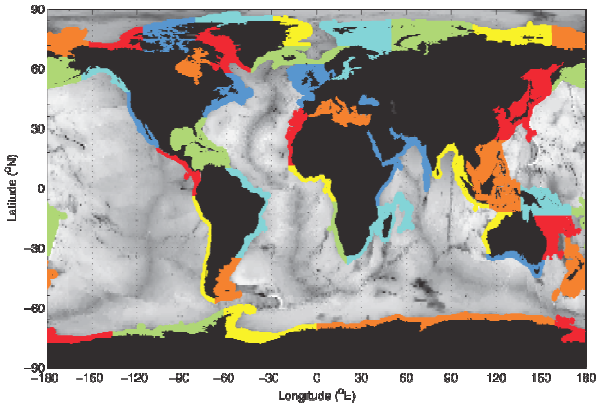


THE SIMULATION



1) 50% mortality produced due to El Niño on the 4th year of the simulation in the Chilean and Peruvian anchoveta.

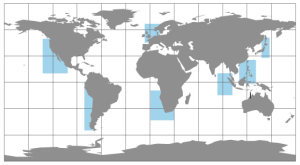
2) 30% random variability on the recruitment of all the stocks modelled.



CLIMATE

Climate

Population dynamics

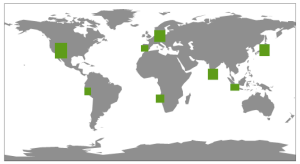


Stocks

Production

Fleets

Shipment



Markets

Demand function

AQUACULTURE

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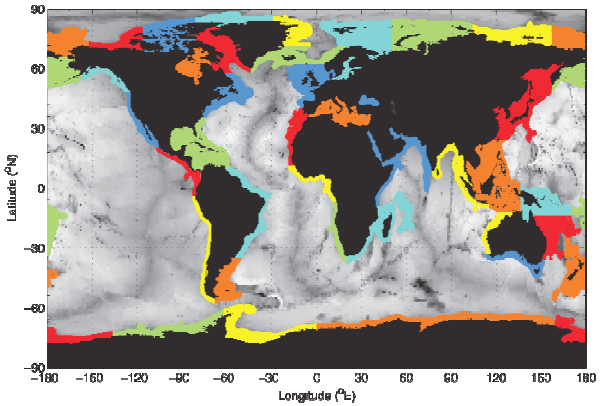
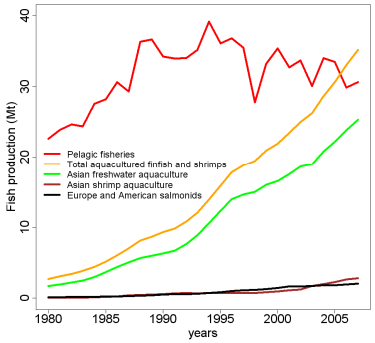
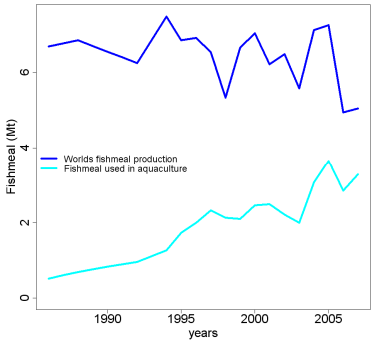






SCENARIOS

(a) Fishmeal substitution allows market stabilization.

(b) Market demand expands at aquaculture expansion rate.

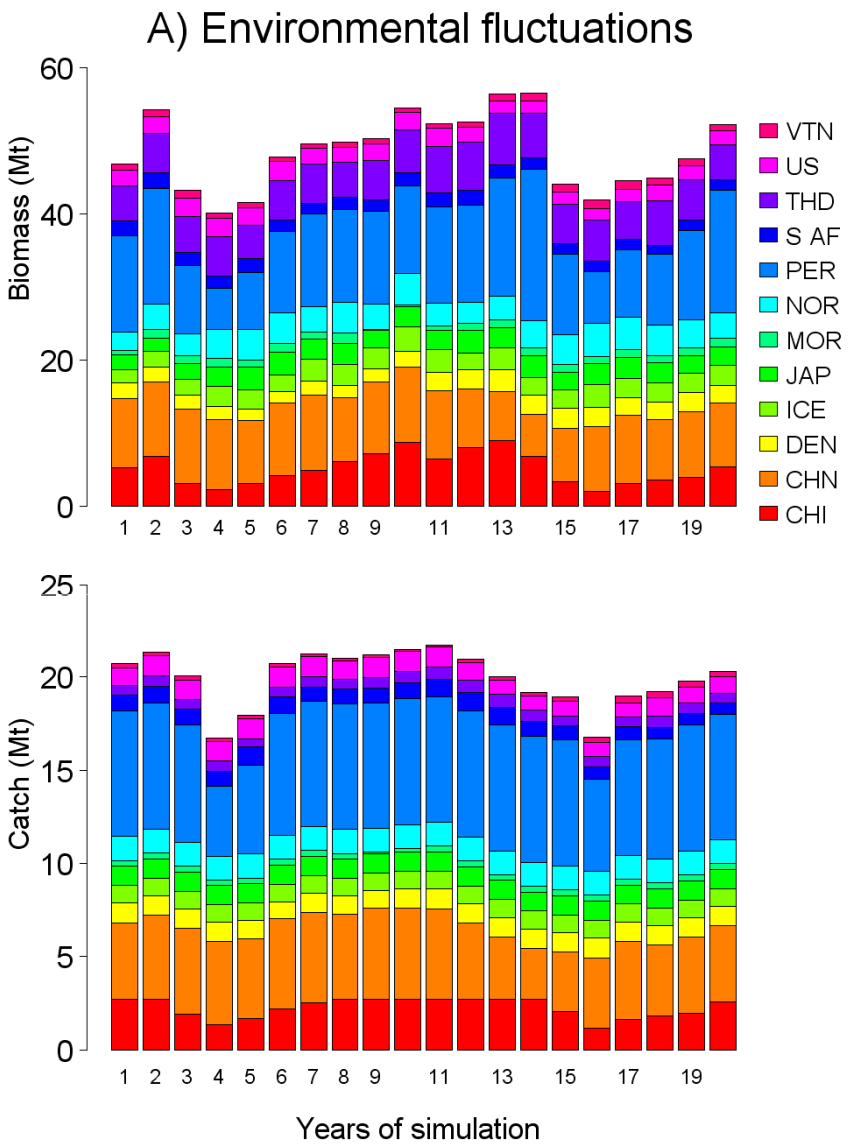
Results

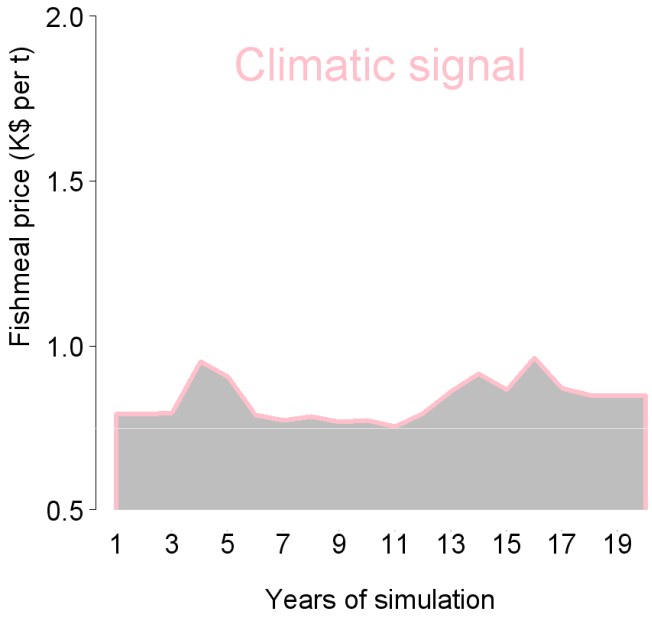
Fish stocks, catch and price

SCENARIOS

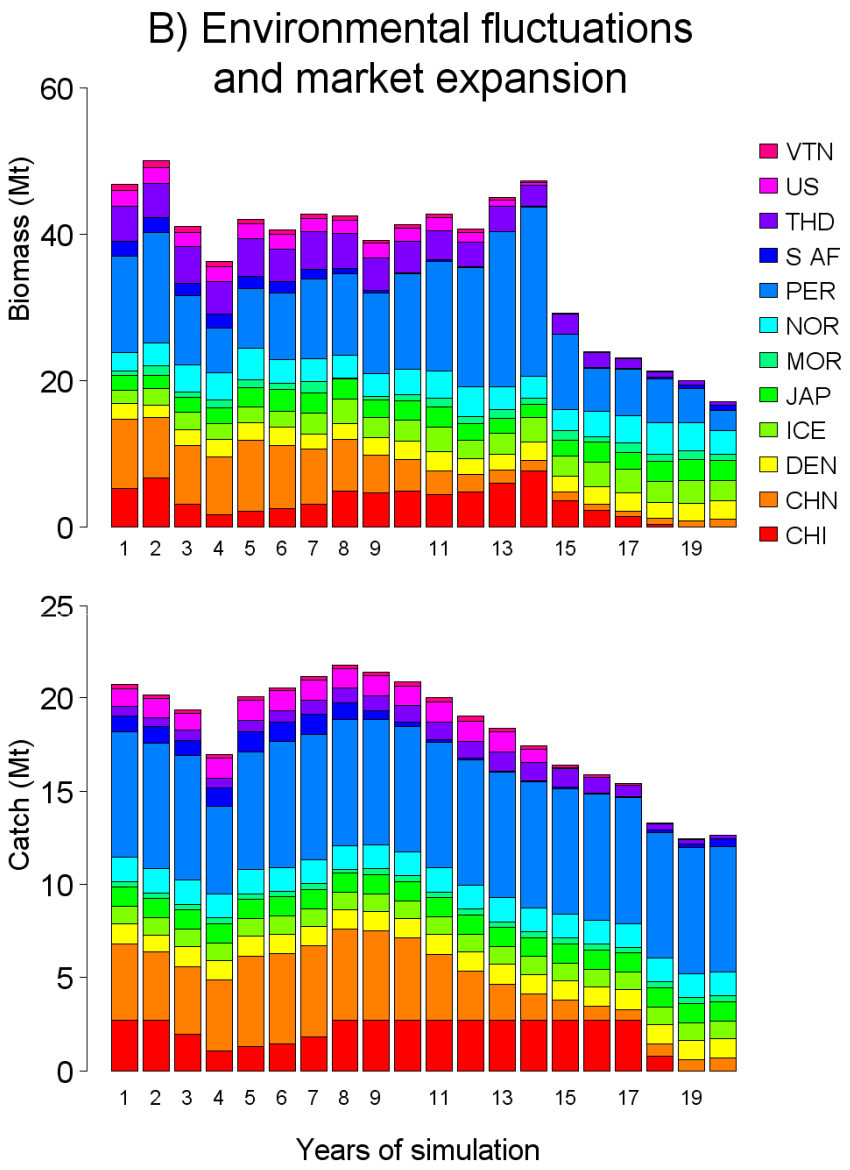
(a) Fishmeal substitution allows market stabilization.

(b) Market demand expands at aquaculture expansion rate.





Price dynamics respond to supply fluctuations and stocks recovery.

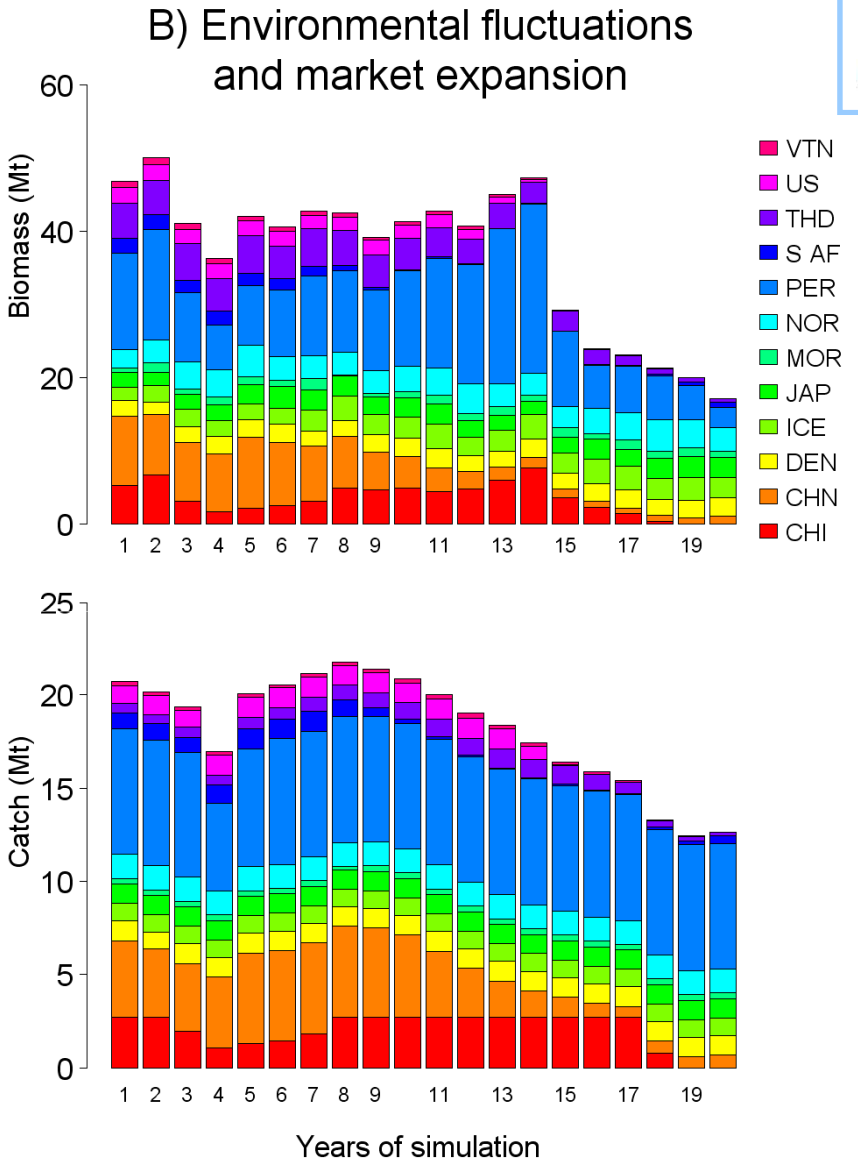


Price increases enough to increase the FC and mortality to supply the markets in the short term, no recovery. A higher fraction of the declining stock is removed without exceeding quotas.

Double exposure: assessing the impacts of climate change within the context of economic globalization

Karen L. O'Brien[a,*], Robin M. Leichenko[b]

K.L. O'Brien, R.M. Leichenko / Global Environmental Change 10 (2000) 221–232



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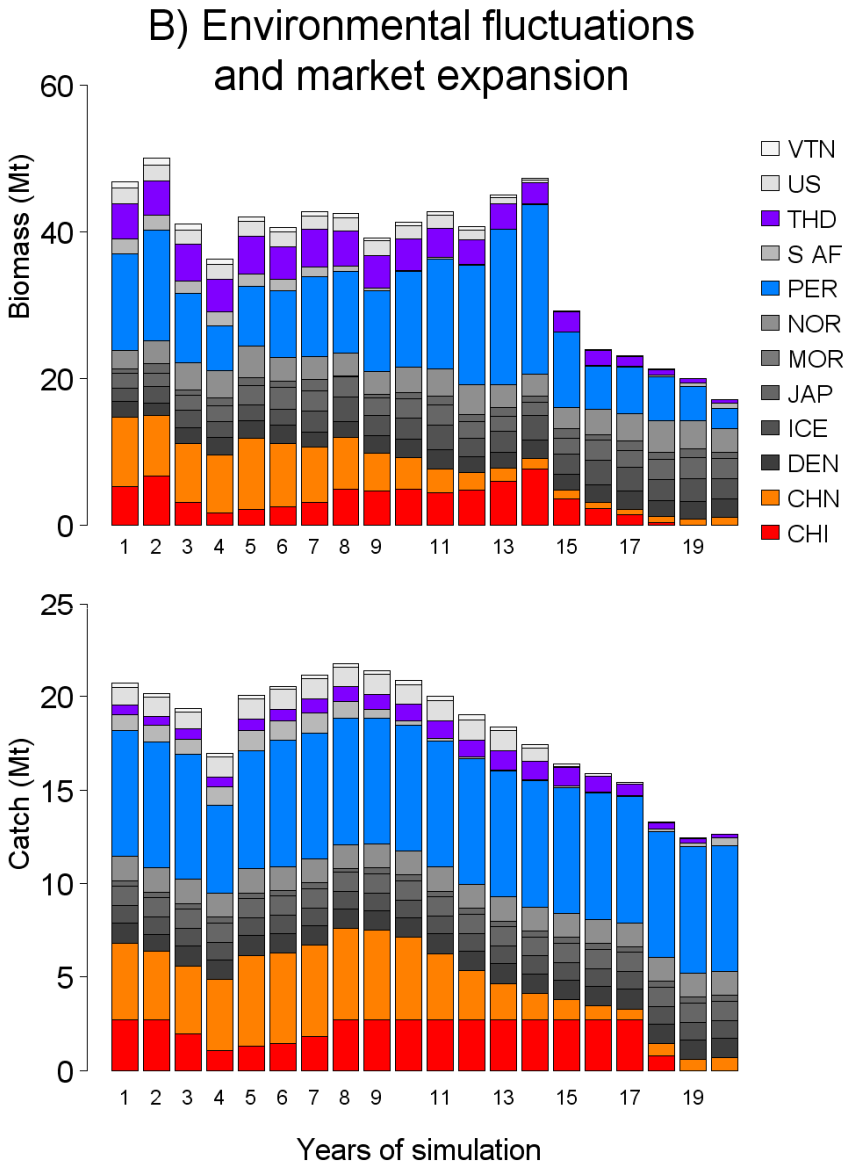

"Globalization, roving bandits and marine resources"

F. Berkes,[1*] T. P. Hughes,[2] R. S. Steneck,[3] J. A. Wilson,[4] D. R. Bellwood,[2] B. Crona,[5,6] C. Folke,[5,6] L. H. Gunderson,[7] H. M. Leslie,[8] J. Norberg,[6] M. Nyström,[5,6] P. Olsson,[5] H. Österblom,[6] M. Scheffer,[9] B. Worm[10]

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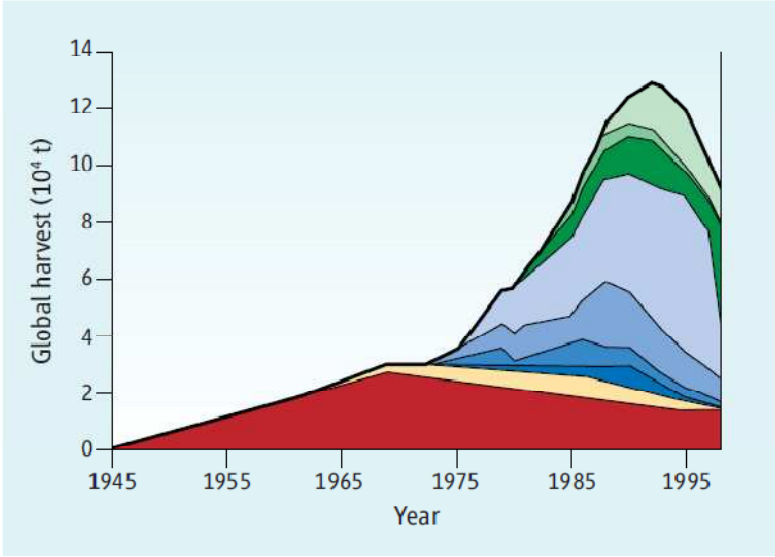
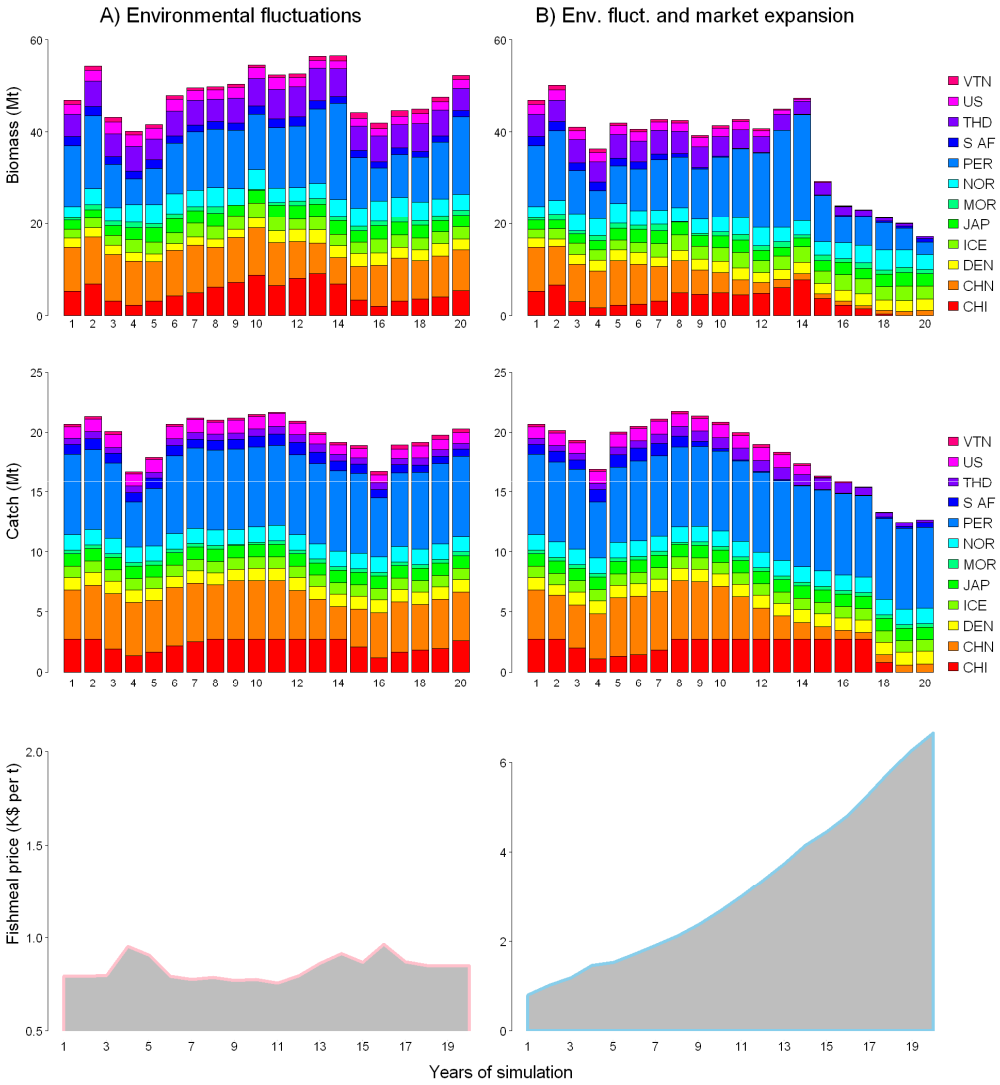
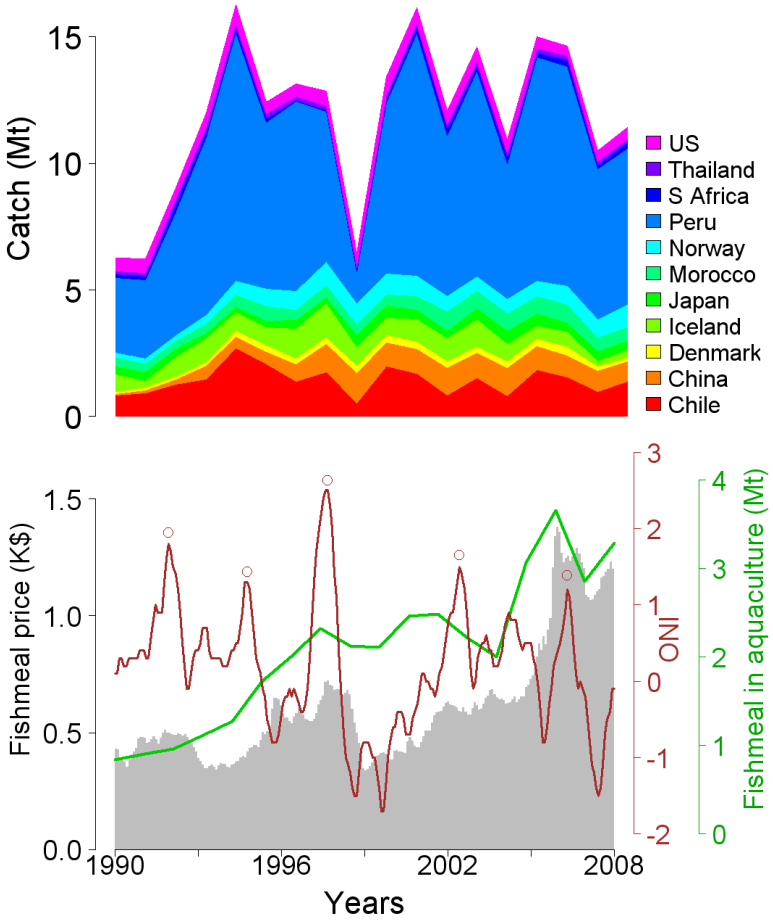


Global sea urchin harvests over time. Color coded by region, in chronological ascending order: Japan; Korea; Washington and Oregon; Baja, Mexico; California; Chile; NE Pacific (Alaska and British Columbia); Russia; NW Atlantic (Maine, Nova Scotia, New Brunswick).

Simulation vs Observations





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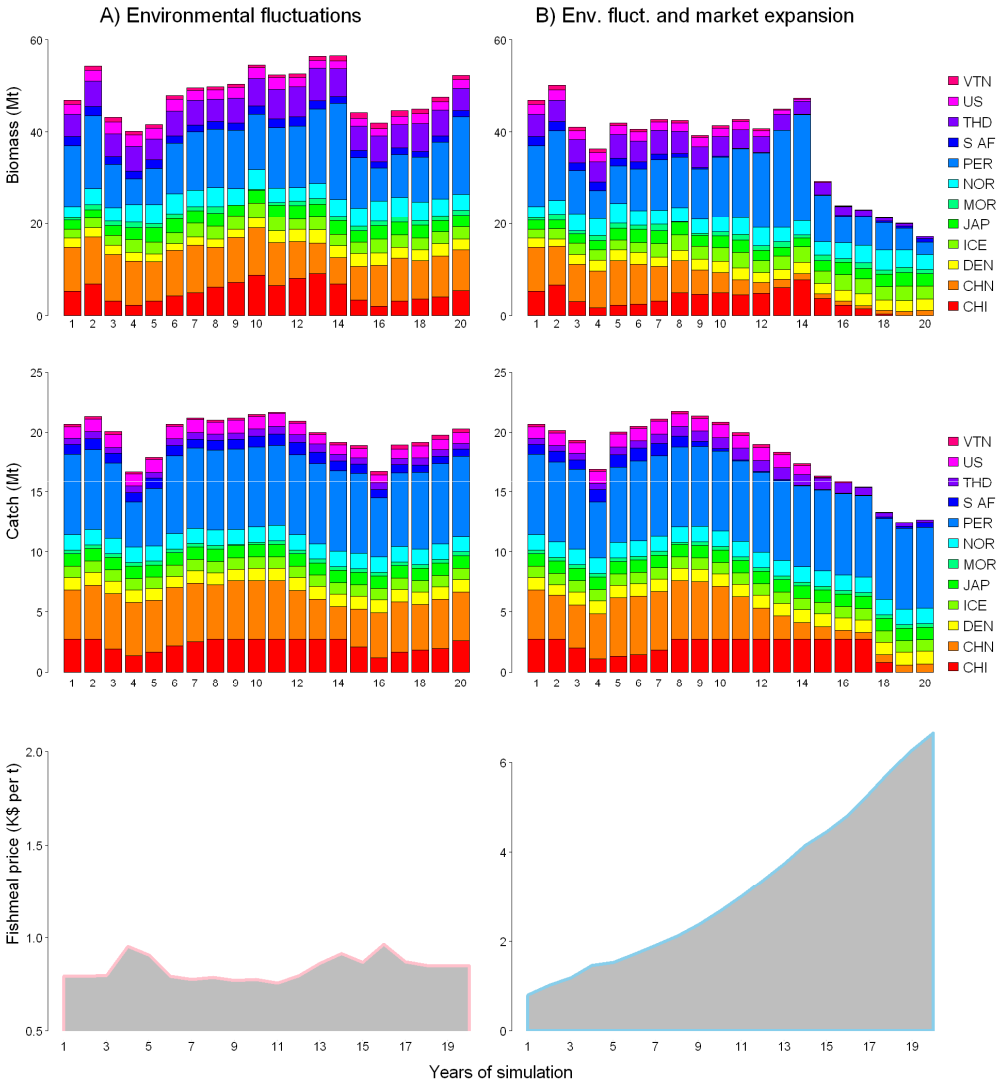

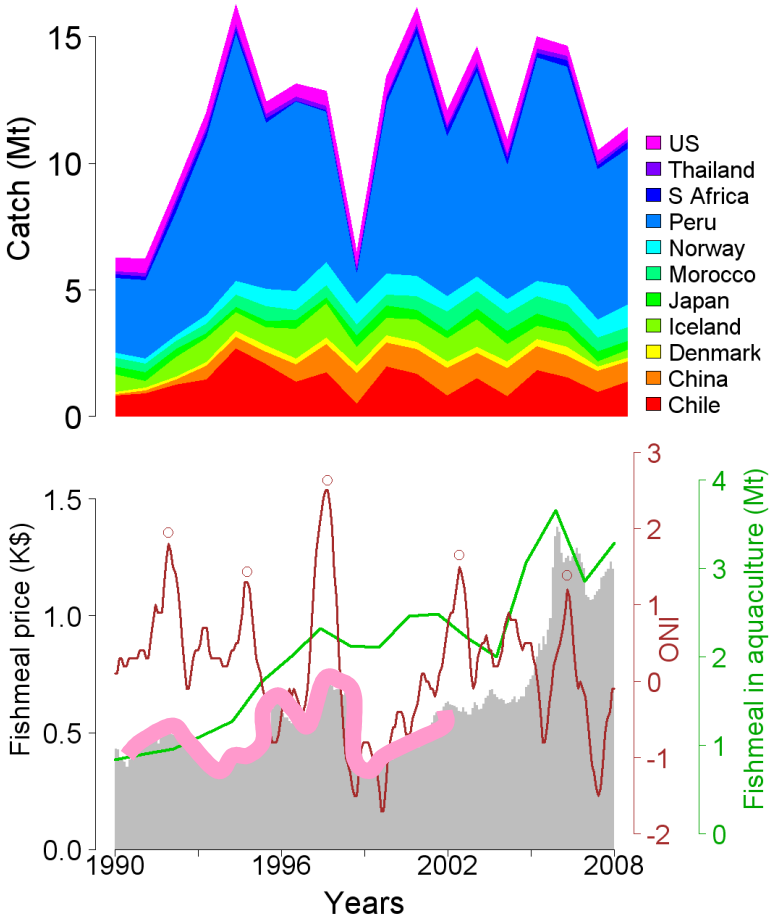

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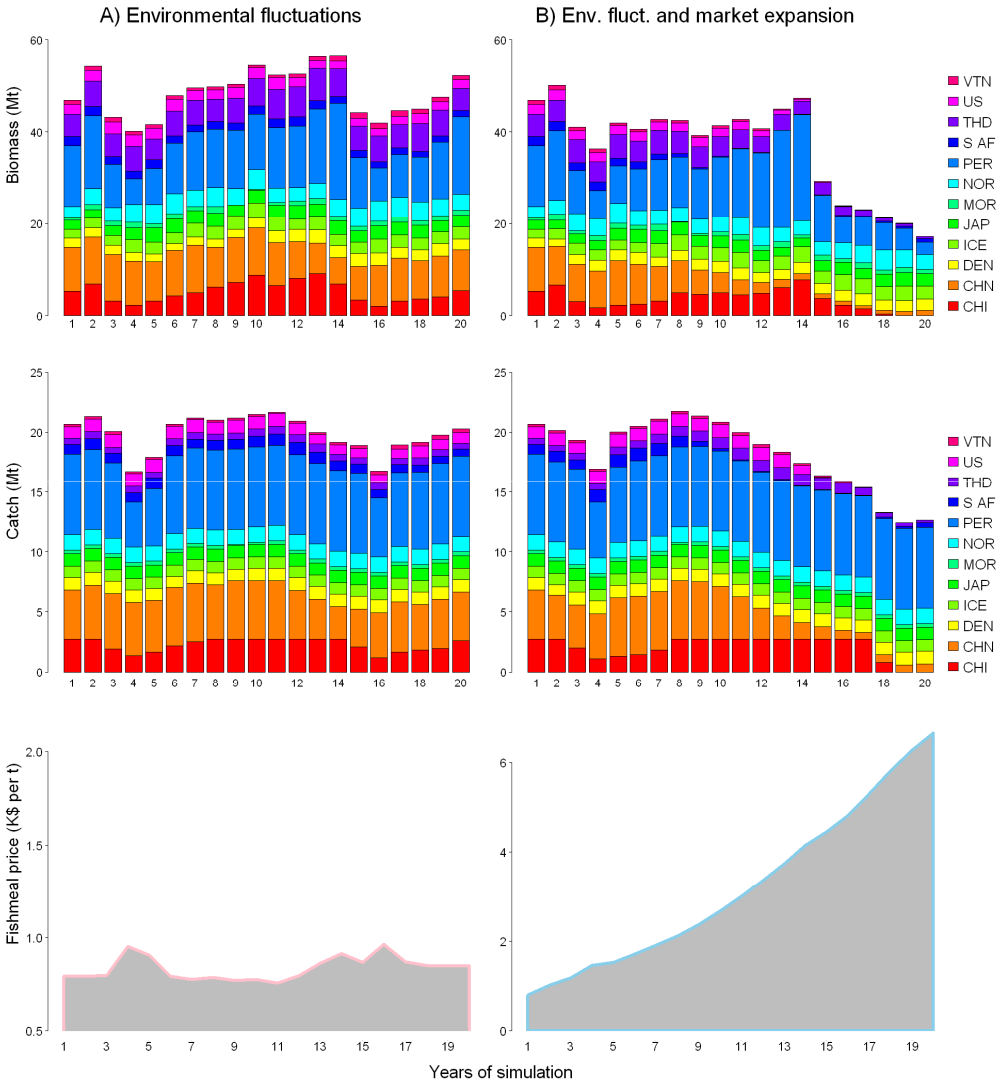

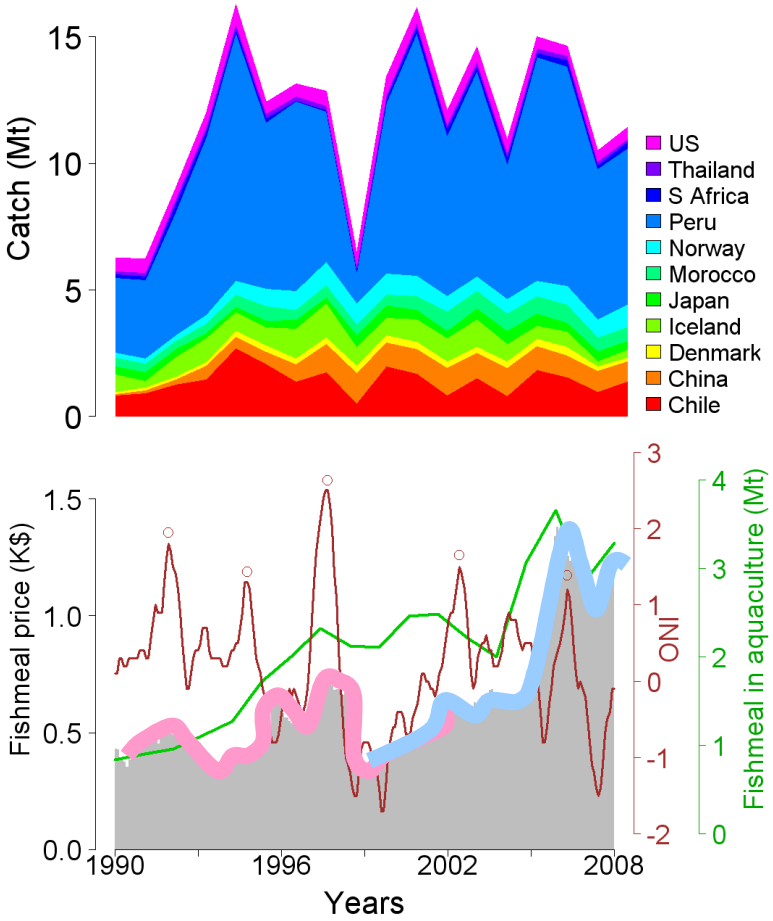

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Discussion

Some of the conditions that trigger global resources collapse in our simulations are identified in recent observations:

1) **Strong environmental impact**: The intensity and frequency of El Niño may increase as a result of climate change (Hansen, et al., 2006).

2) **Management:** Small pelagic fisheries are nationally managed with quotas and described as regulated open access (Asche and Tveterås, 2004).

3) **Aquaculture:** Constant increase of fishmeal utilization suggests that it is influencing meal price. Whilst aquaculture expansion was not an immediate threat to fisheries when it used 35% of the total fishmeal production (Asche and Tveterås, 2004), the current rate of 65%...

4) **Economic globalization:** A well established globalized economic network allowing overall price responses to supply reductions or demand increases.

Acknowledgements

CLIMATE → ECOSYSTEMS → FISH → PEOPLE

QUEST-Fish

Funding for this study has been provided by the Natural Environment Research Council of the UK as a contribution to the QUEST-Fish project (http://web.pml.ac.uk/quest-fish).

"… to obtain probabilistic projections of how climate change will affect global fish production and estimate the socio-economic impacts"

Thanks for your attention