



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

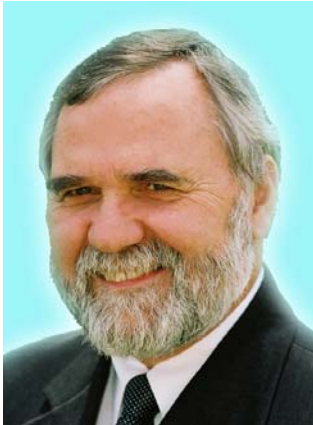
*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Impacts on Capture Fisheries and Aquaculture

Rob Lewis
Affiliate Professor
SARDI

Paper prepared for presentation at the “Agriculture in A Changing Climate: The New International Research Frontier” conference conducted by the Crawford Fund for International Agricultural Research, Parliament House, Canberra, Australia, September 3, 2008

Copyright 2008 by Rob Lewis. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.



Impacts on Capture Fisheries and Aquaculture

ROB LEWIS

SARDI

GPO Box 397, Adelaide, SA 5001

Email: lewis.rob@saugov.sa.gov.au

Over the last two hundred years the impact of industrial-scale fishing on fish stocks and their sustainability has been recognised and sought to be addressed or managed. This impact has resulted in some stocks collapsing, many being exploited at maximum or non-sustainable levels, with a subsequent increased focus on aquaculture as a source of fish protein to meet the demands of growing populations and economies.

It is now recognised that these enterprises are also subject to the additional influences of climate change. Due to the coastal and high seas nature of our fisheries, the complexity and diversity of riparian, coastal and oceanic systems, habitats and populations, the perceived impacts from climate change on fisheries and aquaculture are less defined than in other industrial and community areas.

Climate change induced impacts are anticipated to deliver both adverse and in some cases positive effects on fisheries and aquaculture. Potential adverse impacts include detrimental changes in oceanic physio-chemical characteristics (e.g. O₂, temperature, salinity, total inorganic carbon content and acidification) and

key oceanic circulation systems, declines in production potential of traditional species, abundance changes and altered trophic/ecosystem relationships, disturbance of reproductive patterns and migratory routes, increased vulnerability to diseases and pests, increased extreme weather events (e.g. storm surges and cyclones) and the provision of a competitive advantage for lower-valued and invasive species. Adverse impacts also include decreased community (industrial and artisan) economic benefit, the additional cost of relocation and relocation of production system and coastal infrastructure, and the recognised vulnerability of coastal and low-lying island nations to rising sea levels.

Positive impacts include the potential for increased coastal nutrients and productivity from more intense upwelling systems, increased growth rates and extended growing seasons, increased competitiveness of high-valued less abundant and new profitable species, and climate change driven improvements in production systems, infrastructure and resource management strategies.

The critical challenge for the world's fisheries and aquaculture is to ensure they effectively contribute to the global response to address the causes of climate change, whilst embracing and adapting to opportunities that future change delivers.

AFFILIATE PROFESSOR LEWIS is currently Executive Director of the South Australian Research and Development Institute (SARDI) and South Australia's Interim Commissioner for Water Security. Rob has a research and research management background, initially in marine sciences, and has been awarded BSc (Hon) from Adelaide University and an honorary DSc from Flinders University, and is an Affiliate Professor with Adelaide University. He is a Fellow of the Australian Academy of Technological Sciences and Engineering and Chair of the SA Division. He has directorships on the boards of a significant number of research associations and commercial companies, including the committee of the South Australian program of the Crawford Fund.

Introduction

'... all the great sea fisheries are inexhaustible: that is to say that nothing we do seriously affects the numbers of fish. Any attempts to regulate fisheries seems useless'

(T.H. Huxley at the International Fisheries Exhibition London, 1883)

'The supply of fish in the ocean may be considered to be practically inexhaustible'

(Introductory line of the chapter on seafood in Mrs Beeton's *Book of Household Management*, 1880)

I thank the Crawford Fund for this opportunity to present on the aquatic-industry-based sectors, complementary to the traditional land-based agricultural focus.

The foregoing quotations represent the status of the knowledge of fisheries at the time. We now know that globally fisheries have been challenged by a range of factors including recruitment and economic over-exploitation, natural variation in species stock dynamics, and habitat and ecosystem destruction by damaging fishing practices and or anthropogenic pollution. It is also now evident that the challenges from climate change need to be accommodated.

Fishing is a hunting/harvesting operation, aquaculture a farming/husbandry operation. Modern fisheries seek the sustainable exploitation of biologically renewable resources, delivering economic and social benefits to current and future generations. They embrace the interactions of complex biological, technological, economic, social and cultural, geo-political, regulatory and compliance factors.

The demand for fish products continues to increase as a consequence of increased population as well as to cater for the increasing recognition of their health benefits. Increased demand for fish products has also been driven by the global need for feedstock (fishmeal and fishoil) for aquaculture and other intensive animal industries emerging over the last forty years.

Current global capture fisheries production exceeds 90 million tonnes annually, with aquaculture production over 40 million tonnes (FAO 2004). Capture fisheries production grew at 1.2% annually after 1970 but it has stabilised over the last decade; aquaculture production has increased at an average rate since 1970 of 8.9% per annum (FAO ongoing). In 1970 aquaculture contributed 3.9% by weight; in 2002 it was 29% by weight. Estimates predict that by 2020 wild capture production will remain in the 90–100 million tonne range, with aquaculture possibly surpassing 70 million tonnes (FAO 2004). Seventy percent of the worlds aquaculture production is from China (FAO ongoing).

It is now recognised that the major stressors of large-scale marine stocks are over-fishing, habitat destruction and climate change (Handisyde *et al.* undated).

Climate change

When considering the impacts of climate change on fisheries and aquaculture it is convenient to group them in three categories:

- physio-chemical
- biological
- societal.

The impacts of climate change on fisheries and aquaculture are many and varied. The aquatic environment will respond to climate change in ways that are equally significant as the responses in terrestrial and atmospheric environments. The changes may be more gradual and less apparent than those taking place terrestrially, because of the ability of oceans to absorb and distribute heat (2WE Associates 2000).

Consideration of climate change impacts on fish stocks needs to recognise underlying short- and long-term fluctuations in populations. Examples of these are the persistent cyclic nature of stocks of Californian sardines and anchovy, where analysis of fish scales from offshore sediment cores covering 1700 years has identified cyclic time scales of abundance indices with periods of 54 to 57 and 223 to 273 years. These cycles have been correlated to air temperature as measured from fossil ice cores. Shorter-term fluctuations in the Peruvian anchovy stocks are closely correlated with strong El Nino events.

Physio-chemical impacts

Oceans, like terrestrial systems, are experiencing change in core parameters, albeit reflecting the nature of the medium. The Intergovernmental Panel on Climate Change (IPCC 2001) reports that over the period 1961 to 2003 global ocean temperatures increased 0.1°C in the region from the surface to 700 m depth. The global ocean heat content in the region from 0 to 3000 m increased over the same period, absorbing energy at a rate of $0.12 \pm 0.04 \text{ Wm}^2$ globally averaged, with the top 700 m absorbing two-thirds of this input.

In the case of salinity, over the period 1955–1998 global freshening has been observed in sub-polar latitudes (Pacific), with salination occurring in the shallower parts of the tropical and sub-tropical oceans (Atlantic and Indian Oceans).

Acidification of the oceans is recognised to be a direct consequence of global warming. Uptake of anthropogenic carbon has resulted in the ocean

becoming more acidic. The IPCC has estimated the total inorganic carbon content of the oceans has increased by 118 ± 19 Gt C from the pre-industrial period (1750). The IPCC estimates the likely fraction of emitted CO₂ taken up by the oceans has decreased from $42 \pm 7\%$ during the period 1750–1994 to $37 \pm 7\%$ over the period 1980–2005 (it should be noted there is uncertainty around these data). The increase in total carbon results in a decrease in the depth at which calcium carbonate dissolves as well as a decrease in surface pH. The IPCC estimates an average decrease of 0.1 pH units since 1750, although for more recent times (over the last 20 years) an indicative rate of decrease of 0.02 pH units per decade has been suggested to be occurring.

Although much more investigation is required, the predicted impact of this acidification is a reduction in bio-calcification in marine organisms. The most obvious potential impact is a threat to coral reef communities and their structural integrity, as well as marine food chains based on carbonate plankton and organisms with aragonite calcareous skeletons and shells (e.g. crustaceans, molluscs).

The earliest impact of ocean acidification is expected to occur in deeper and polar waters. It is predicted that tropical areas will remain saturated but experience a significant drop in the aragonite availability to marginal levels in 2100.

Oceanic circulation and sea level rise

The best-known impact of climate change in the aquatic environment is the predicted rise in sea level. For aquaculture this means having to cope with changes in tidal amplitude and strength. It is well recognised that rising sea levels will particularly affect coastal areas and low-lying island nations. The main factors contributing to increasing sea level are:

- thermal expansion
- glacial contributions.

The contribution of thermal expansion to sea level rises (1961–2003) has been estimated to be 0.4 ± 0.1 mm per annum.

The IPCC estimates that sea levels have risen over the period 1961–2002 at 1.8 mm per annum, although this is spatially non-uniform.

The major impacts of sea level rise will include:

- increased inundation of coastal wetlands and lowlands
- loss of estuarine, coastal species and communities
- increased intrusion of salt-water vegetation into freshwater ecosystems in coastal areas
- contamination of coastal quality water aquifers
- changes in the structure of coastal marine communities, including coral reefs
- loss of low-lying island states and coastal regions with consequential economic loss and social disruption.

With regard to mass transport distribution, there has not been any clear evidence for oceanic circulation changes, although changes in the contributing water body characteristics have been observed.

Ocean thermohaline circulation and continental shelf ‘flushing and cleaning’ mechanisms are crucial to coastal water quality and nutrient cycling and the global heat budget. Most climate change models indicate a weakening of the thermocline circulation (THC) in the northern hemisphere, although the extent with which this overall circulation is threatened is still uncertain.

There is an emerging literature that reinforces the concerns from the wholesale physical changes predicted. CSIRO has observed changes to ocean circulation in the western Pacific Ocean and Timor Sea, and an upward trend in water temperature has led to environmental modification in SE Australia as the East Australia Current pushes further south, carrying sub-tropical species into temperate waters (Hobday *et al.* 2006).

Extreme weather

Fishers and aquaculturalists derive their living from the sea; consequently they live and operate at the sea–land interface, and are therefore vulnerable to climate change induced impacts at this interface. Extreme weather events are intrinsically linked to the climate change regimes and influences. The warming and consequential increase in ocean heat content, thermal expansion and reduction in land-based ice are seen as contributory factors driving these phenomena. Extreme events include intensified precipitation and droughts; monsoonal, cyclonic and hurricane activity; storm surges and flooding; as well as temperature shocks. Extreme events can manifest

themselves through both increased frequency and or severity. Extreme events occur on a global scale as seen from cyclonic events, or on a local scale as the Australian southern bluefin tuna farming industry experienced in 1996 when more than 95% of the standing production was wiped out by a localised high-intensity event.

One of the most intensively monitored phenomena has been the long-term observed changes in the El Nino Southern Oscillation (ENSO), with well-recognised effects on southern Australia in particular.

An area that has yet to receive significant attention with regard to climate change impacts is upwelling. Upwellings of deep ocean waters onto continental shelf margins are a major source of cold nutrient-rich waters that traditionally enhance regional productivity. Upwelling is induced by seasonal intensification of wind blowing parallel to the coastline (N–S alignment), usually resulting from intensified temperature differentials between the adjacent land mass and the ocean and consequent latitudinal shifts in inter-continental high-pressure systems. Under the influence of the Coriolis effect, surface water is transported offshore and is replaced by upwelled sub-surface water. The significance of upwelling events is reflected in the fact that upwelling areas account for 1% of the ocean surface but support 50% of the world's fisheries (Nellman *et al.* 2008).

Climate change has the potential to strengthen upwelling events, enhancing nutrient input to receiving regions. This is predicted to have both adverse and positive effects. Adverse effects include disruption of the bio-rhythms and processes of key species, whilst pluses are predicted to include increased regional productivity from the additional nutrient inputs.

Abundance and trophic/ecosystems relationships

Physico-chemical and circulation modification are manifested through physio-biological changes in the aquatic biota and ecosystems.

Aquatic systems are expected to be less tolerant than terrestrial systems, changing the adaptive capacity of species. This includes:

- increased competitive advantage for lower-valued and invasive species
- declining stocks and unstable fisheries

- species shift to those more tolerant of warmer and perhaps less oxygenated waters.

Changed physical environment, induced upwelling strengths, and shifts in oxygen and temperature can also result in more frequent algal blooms in coastal areas and increased incidence of fish kills resulting from toxic algae.

Phenology, migratory routes and reproduction

As with land-based plants and animals, there are expected to be climate-based changes in the phenology of seasonal and life-cycle movements in aquatic organisms. These can include changes in timing and location of annual peak abundance and movements for reproductive purposes.

Changes in those latitudes expected to experience elevated water and air temperatures are likely to be:

- longer growing seasons
 - lower natural mortality (M) rates
 - faster growth in higher latitudes,
- with consequential beneficial impacts on growth rates and feed conversion ratios. These have particular interest to aquaculture and provide an opportunity to enhance this sector of the industry.

A literature search identified little solid empirical documentation for these phenomena. UK studies on the flounder (*Platichthys flesus*) and squid (*Loligo forbesii*) have documented shifts for these species in time of arrival on spawning grounds related to temperature, concluding that for these species migration phenology is 'driven by short term, climate induced change in the thermal resources of their habitats' related to the North Atlantic Oscillation (NOA) (Sims *et al.* 2004).

In Australia CSIRO (Thresher 2007) has reported that growth rates of coastal species such as juvenile morwong in the 1990s were 28.5% greater than recorded in the 1950s. Conversely he found that species at depth (1000 m), such as juvenile oreos, had growth rates 27.9% less than those extrapolated for the 1860s. Thresher has linked these observations to factors such as higher mortalities, reduced food availability and reductions in the size of sexual maturity. He observed that this also coincides with sea surface temperature rises in the south-west Pacific east of Tasmania of the order of 2°C, coinciding with the strengthening of the warmer southerly-moving East Australia Current.

Increased temperature of coastal waters provides the opportunity for increased production in aquaculture by expanding species ranges. This includes responses to reductions in sea ice resulting in an increased geographic range becoming available for aquaculture (IPCC 2001).

Diseases and pests/biotechnology

Changes in physical parameters impact on the adaptability and competitiveness of pests and diseases, resulting in an increased incidence of infections. A portent of the future could be the herpes virus that decimated southern Australia's southern bluefin tuna stocks in the 1990s, and the global spread of the toxic green alga *Caulerpa taxifolia* to locations including a number of sites in Australia.

With regard to aquaculture, there is a recognised increased occurrence and intensity of disease and vulnerability to pests due to factors such as stress induced by shifts in temperature and oxygen levels.

There is future potential for accelerated breeding programs, including the use of molecular biotechnologies, to deliver benefits (growth, abiotic and biotic resistance) while having to address wider community demands, and in some quarters opposition to the use of such technologies.

With an understanding of the physical and biological changes from climate change, the application of this knowledge is how society responds. Most the global consideration is focussed on the disruptive impacts from weakened biological systems, severe infrastructure and coastal degradation, economic loss, fragmentation of societal cohesion and lifestyle disruption to post extreme event health and nutrition challenges in artisanal communities.

Societal impacts

Opportunities for aquatic-resource-supported societies include the development of possible new profitable species and enterprises, biological enhancement of current stocks, drivers for industry and infrastructure planning and renewal, along with new management approaches and more efficient industries and communities driven through adaptive necessity. It is hoped that this would also result in greater recognition of the risks and opportunities, as well as support for greater knowledge of the systems and the uncertainty around the models to better enable science-based management.

Whilst research on climate-change-related aquatic systems (physical and biological) has contributed to the overall understanding of systems and their future landscapes, significantly less research has been directed at the impacts on fisheries and aquaculture.

The IPCC's general conclusion is also relevant to fisheries and aquaculture: that both mitigation (in the form of the industries' contributions to emission reductions) and adaptation must be embraced.

This will allow both industrial and artisanal industries and communities to address the impacts as well as to pursue the opportunities that climate change will inevitably present.

Summary

Responding to climate change in the aquatic environment requires both short- and long-term solutions. Near-term adaptation strategies include reinforcing coastline infrastructure, restoring wetlands to protect coasts and if necessary reconfiguring ports and coastal facilities to resist extreme weather events. In addition, jurisdictions need to plan for such events to enable adequate responses to protect and assist their citizens, whether it be to meet a consequential health risk in flooded areas (e.g. cholera), provide emergency shelter and sustenance, or rebuild destroyed infrastructure.

In the longer term, the critical challenge for the world's fisheries and aquaculture is to ensure they effectively contribute to the global response to address the causes of climate change, whilst embracing and adapting to opportunities that future change delivers. This involves adopting appropriate technologies and practices across the whole value and delivery chain to:

- reduce climate risks
- ensure continued investment in the large-scale research programs required to reduce uncertainty around future projections
- ensure that the outcomes of this investment are disseminated to assist governments and society to better interpret and understand the threat, balance the uncertainties and strategically plan to effectively adapt.

Climate change impacts in fisheries and aquaculture provide both risks and opportunities.

References

- FAO (2004) *The State of World Fisheries and Aquaculture 2004*. FAO, Rome.
<ftp://ftp.fao.org/docrep/fao/007/y5600e/y5600e00.pdf>
- FAO (ongoing) *FishStat Plus*. FAO, Rome.
<http://www.fao.org/fishery/statistics/software/fishstat>
- Intergovernmental Panel on Climate Change (IPCC) Houghton, J.T. *et al.* (2001). *Climate Change 2001: The Scientific Basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge.
- Handisyde, N.T., Ross, L.G., Badjeck, M-C. and Allison, E.H. (undated) *The Effects of Climate Change on World Aquaculture: A Global Perspective*. Department for International Development, UK.
<http://www.ecasa.org.uk/Documents/Handisydeetal.pdf>
- Hobday, A.J. *et al.* (eds) (2006) *Impacts of Climate Change on Australian Marine Life*. Australian Greenhouse Office, Canberra.
<http://www.greenhouse.gov.au/impacts/publications/>
- Nellman, C., Hain, S. and Adler, J. (eds) (2008) *In Dead Water — Merging of Climate Change with Pollution, Over-Harvest, and Infestations in the World's Fishing Grounds*. United Nations Environment Program, GRID-Arendal, Norway.
www.unep.org/pdf/InDeadWater_LR.pdf
- Sims, D.W., Wearmouth, V.J., Genner, M.J., Southward, A.J. and Hawkins, S.J. (2004) Low-temperature-driven early spawning migration of a temperate marine fish. *Journal of Animal Ecology* **73**, 333–341.
- Thresher, R.E., Koslow, J.A., Morison, A.K. and Smith, D.C. (2007). Depth-mediated reversal of the effects of climate change on long-term growth rates of exploited fish. *Proceedings of the National Academy of Sciences USA* **104**, 7461–7465.
- 2WE Associates (2000). Aquaculture and climate change in Canada: A discussion paper. In: *Seafood Sustainability in a Changing Climate: A Participatory Workshop to Develop Solutions for the Northeast Pacific Ocean and Coastal Zones*. 25–26 May, University of Victoria, Victoria, BC. Canadian Institute for Climate Studies (CICS).
<http://www.cics.uvic.ca/workshop/>